



Expanding the Dialogue on Climate Change & Water Management in the Okanagan Basin, British Columbia

INTERIM REPORT

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Cover photo by Wendy Merritt: irrigation canal south of Oliver, BC.

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Notice to Readers

The results presented in this interim report were obtained using data available from published sources and standard monitoring techniques, and methods developed or modified by the study team consistent with peer-reviewed literature. However, this report describes a work in progress which has not been peer reviewed outside of the study team. Readers are advised to be aware of the uncertainties and limitations of this research. Details are provided for the various study components in this report.

Simulations of future changes in hydrology and crop water demand are based on scenarios of climate change obtained through the Canadian Climate Impact Scenarios project (<http://www.cics.uvic.ca/>). The results presented herein are for the purposes of research, and are not to be used for commercial exploitation. Although care has been taken in the preparation of these scenarios, and in their use by the project team, no liability is accepted by the project team for errors or omissions, and no warranty is given as to the suitability of these scenarios.

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EXECUTIVE SUMMARY

The research activity described in this report aims to be a comprehensive regional assessment of the impacts of climate change on water resources and options for adaptation in the Okanagan Basin. The assessment is a collaborative, interdisciplinary effort involving researchers from Environment Canada, Agriculture and Agri-Food Canada, the University of British Columbia, the BC Ministry of Water, Land and Air Protection and the City of Summerland.

The ultimate goal of the project is to develop integrated climate change and water resource scenarios in order to stimulate a multi-stakeholder discussion on the implications of climate change for water management in the region. The study team hopes to achieve two main objectives: a) providing a set of research products that will be of relevance to regional interests in the Okanagan, and b) establishing a methodology for participatory integrated assessment of regional climate change impacts and adaptation that could be applied to climate-related concerns in Canada and other countries.

The study comprises five key components:

1. **Climate change scenarios:** downscaling global climate change scenarios to the regional level;
2. **Hydrological scenarios:** determining impacts of climate change on basin hydrology;
3. **Water demand scenarios:** developing future demand scenarios particularly for municipalities and irrigated agriculture, factoring in socio-economic trends;
4. **Land-use change scenarios:** researching crop suitability under changing climatic conditions, and;
5. **Adaptation options:** exploring feasible management approaches for augmenting water supply and/or reducing water consumption.

Climate

Many crops in the Okanagan Basin rely on various microclimates created by the complex topography. Microscale topographic variations in slope, aspect and elevation, and the different crop types give rise to an assortment of microclimates that have yet to be studied in detail. This project uses a network of Hobo computerized temperature loggers to collect temperature data so that the microscale variations in climate can be mapped to aid the understanding of crop water demand and crop suitability. Preliminary results for the growing season of 2002 have indicated that there is a considerable range in daily maximum and minimum temperatures within the study area. Over a three-month period (Aug 1st- Oct 31st), differences amongst sites for max. daily temperature ranged from 2-7°C and for min daily temperature from 2-8°C.

Climate change scenarios were developed from three different climate models (CGCM2-Canada, HadCM3-UK, CSIROm2-Australia), and two scenarios of global greenhouse gas emissions from the Intergovernmental Panel on Climate Change's SRES series. For the 2050s, increases in winter temperature relative to the 1961-90 baseline lie in the range 1½ to 4 degrees Celsius with winter precipitation increases on the order of 5 to 25 percent. For summer, all models show a warming of roughly 2 to 4 degrees Celsius and precipitation changes ranging from almost no change to a 35 percent decrease in precipitation compared to the 1961-90 baseline. The greatest change in winter conditions are reflected by the Australian model (CSIROM2) while the UK Hadley Centre model (HadCM3) shows the greatest change in summer climate.

Hydrology

The UBC Watershed Model has been chosen to model precipitation-runoff processes. The model has been used extensively in British Columbia, and has been shown to adequately reproduce the hydrologic response of watersheds, and has previously been used in climate change studies.

Overall, the UBC Watershed model has been shown to be a suitable model for application to a region such as the Okanagan Basin. The arid climate of the basin and the deficiencies in the meteorological network make successful calibration of the model more difficult than in humid watersheds that exhibit less variability in precipitation across the watershed. Despite problems with representativeness of available climate data, the model was generally shown to perform adequately when the average parameter set and estimated precipitation parameters were used to drive the model. Likewise, model performance over the verification period indicates that the model is capable of predicting hydrologic response over different climatic periods.

All scenarios have been run for the model watersheds and analyses of the scenario outputs are currently being undertaken. The preliminary results presented in this report provide an idea of the range in hydrological response to the climate scenarios. All scenarios consistently predicted an early onset of the freshet, a tendency towards a more rain dominated hydrograph and considerable reductions in annual and freshet flow volumes. The Hadley and CSIRO climate scenarios provide two quite different, although plausible, outlooks for the future hydrology of watersheds of the Okanagan Basin. With the Hadley climate model, the hydrograph is peaky and quite confined in the period of elevated flows. Such a scenario would pose difficulties with water managers who would have to cope with the majority of water entering their reservoirs in a very short time frame. They would have to manage water levels in the reservoir(s) keeping in mind the prolonged shortage of flows in the dry season downstream of the reservoir. In contrast, the CSIRO scenarios produce flatter hydrographs that distribute water more evenly through the season, in this sense making the job of managers easier. However, this would be offset by the extreme reduction in flows predicted by the climate model.

Agriculture

An agricultural land use database for the Okanagan basin has now been compiled and incorporated into a GIS using ArcInfo™. These data are now ready to be incorporated into a valley wide model for crop water demand estimates.

We examined the relationships between growing degree day (GDD) accumulations and bloom date in a complete and well recorded, set of data collected between 1937 and 1964 at the Summerland Research Centre. Regression analysis indicated that the relationship between the bloom dates of apple and start of accumulation of GDD10 (10 °C base) was better than that of all other species with either GDD5 or GGD10. Regression analysis also indicated that there were strong relationships between the date of apple bloom and the date of bloom for other species, although this was less well established for apricot and peach than for pear, cherry and plum. Consequently, a combination of the equation for GGD10 and apple bloom, and the relationships derived for apple and other species, will be used for assessing the start of the growing season for each crop.

The approach to estimating crop water demand remains similar to that used in previous studies, but now using the six climate change scenarios generated in this study. Using the historical record of climate data from Summerland-CDA, the variation in annual crop water demand was calculated for a hypothetical hectare of apple. Between 1916 and 2002, the water demand ranged from 900 to 1180mm, with an average of 1026mm. Using estimates for 1961-1990 climate normals and climate scenario data from CGCM_2 output for 2020, 2050

and 2080 time-slices, the average estimated crop water use was 872, 1015, 1119 and 1239 mm respectively. It should be noted that the average for the 1961-1990 normal data was considerably lower than the average calculated for 1916-2002 daily data. These estimates indicate that, within the next 100 years, 'average' water demand, estimated from 'adjusted normals' data is likely to exceed the most extreme demand experienced in the historical record. If the variation in climate continues to follow a distribution similar to that observed between 1916-2002, the highest crop water demand (1180mm) exceeded 1% of the time in the historical record, would potentially be exceeded 27% of the time by the 2050's.

Calculations for the Summerland CDA station data, perturbed by GCM-output will be available shortly. It is anticipated that some estimate of inter-annual variability will be included in estimates of crop water demand for the detailed case studies for the Trout Creek, Ellis Creek and Penticton Creek watersheds based on this information and/or weather generator modeling.

Water Management

There are three primary features of the Okanagan watershed which emphasise the complex, convoluted and multi-scale structure of interacting organisations and institutions involved in water management decisions:

- The water system crosses an international border
- Multiple levels of government
- Multiple in-stream and out-of-stream water uses meaning many advocacy organisations at different scales

Water management is shared by various levels of government (federal, provincial, local), as well as by regional bodies established to focus on particular issues. The latter include the Okanagan Basin Water Board that has recently worked on liquid waste disposal and Eurasian water milfoil, and the Okanagan Technical Working Group that identifies and steers initiatives to rebuild fish stocks.

The Okanagan Basin also presents an interesting forum for exploring water allocation and licensing given its semi-arid climate, its growing population and the importance of irrigation to the regional economy. As of July 2002, there were approximately 4130 active water licenses in the Okanagan Basin listed in the Water License Query database maintained by Land and Water BC. These licenses represent approximately 1.05 billion cubic meters of allocated water on 980 streams for both consumptive and in stream uses. Sixty-six water license applications were also listed requesting a further 209 million cubic meters. Of the 1.05 billion m³ of water allocated in the Okanagan, 476.8 million m³ is allocated for consumptive purposes, where water is removed from the source. Around ²/₃ is used for irrigation.

In the context of adaptation to climate change in the Okanagan, British Columbia's regulatory system provides several challenges. Rising water demands due to population growth and changes in water supply and demand resulting from climate change may result in increased activation of the prior appropriation principle, resulting in increased conflict. Even though conflict is often resolved in the field through more fair methods, increased water stress makes the situation more vulnerable. Under the same conditions, the beneficial use principle could become a more significant requirement in divvying out licenses as water sources become saturated. The perpetual nature of water licenses and the limited ability of managers to modify water rights e.g. transferability and conditionalities, may become restrictive in the face of increasing demands to manage water for multiple objectives (which may or may not be subject to water licensing). Balancing in-stream e.g. fish, and out-of-stream uses e.g.

domestic, could become an increasingly difficult under a climate change scenario. The failure to proclaim the Fisheries Protection Act and to define acceptable minimum fish flows adds to this difficulty.

Adaptation Case Studies

Four case studies were carried out in order to gain an appreciation for the circumstances influencing decisions about adopting demand side management approaches. The early adopter study explored the actual ‘adaptation process’ in the four cases: Kelowna (domestic metering), Vernon (water reclamation), Greater Vernon Water Utility (GVWU) (regionalisation) and Southeast Kelowna Irrigation District (SEKID) (metering irrigation). It explored how and why decisions were made and what factors influenced or limited ‘adaptation’ – or change – to take place, specifically changes in practises and structures of systems at a local level with respect to water management. The reasoning was that climate change impacts on water resources would likely be experienced and viewed as a water management problem, not a climate change problem. A key challenge for the near term (i.e. the next decade) is identifying adaptation options that represent appropriate adjustments to anticipated climate changes, but which also make good water management sense on their own i.e. ‘no regrets’ measures.

There are some clear lessons learned from these case studies that are important in answering the question - how to adapt to climate change in the Okanagan? The fear of change - the challenge of transition - runs throughout. Many factors either exacerbate the difficulty of change or smooth out the process. Three common problematic areas were identified:

- Financial - the initial substantial capital outlay;
- Political - political will, leadership, manipulation and acceptability;
- Attitudinal - public perceptions and values.

While adaptation is the act of adapting (the decisions that are made, its evolution from initiation to implementation), adaptive capacity defines the conditions that allow (or prevent) adaptation to occur. In the context of climate change, the IPCC defines adaptive capacity as: “ability of a system to adjust to climate change. General adaptive capacity for example, can be seen as a function of wealth; population characteristics, such as demographic structure, education and health; organisational arrangements and institutions; and access to technology, and equity.” The case studies indicate that adaptive capacity is more than such ‘objective’ characteristics. While access to funds is primary for change to occur, equally important is the desire to act (e.g. Kelowna), being pro-active (e.g. Vernon), or simply having a perception that it needs to be done (e.g. SEKID).

Costs of Adaptation Options

A number of adaptation options are available that can help meet possible shortages due to climate change and other factors such as population growth. These options include both demand side measures and supply side measures. Demand side options include water conservation alternatives such as irrigation scheduling, public education, metering and adoption of efficient micro irrigation technologies. Supply side options include increasing upstream storage and switching to the mainstem lakes or rivers as a supply source, thereby relying on the large storage capacity of Okanagan lake.

The costs of both demand and supply side options will vary greatly depending on various features of the individual water supply systems and the type of demands served. In summary, there is no one least cost adaptation option for all water systems since costs will vary significantly from system to system. The lowest cost option in one area may turn out to be a

higher cost option in other areas. Other factors, such as water quality and treatment options will also enter into the decision. Often a combination of options will be necessary in order to achieve full insurance against future water shortages and demand increases.

For future budgeting purposes, it appears that systems that are already near capacity would have to consider costs of at least \$1000 per acre-foot to conserve or develop supplies of water to adapt to climate change. If projections indicate that large amounts of water must be conserved or supplied then probably \$2000 per acre-foot would be a reasonable figure to consider in future budgets. Site-specific engineering studies would have to follow to obtain more accurate figures.

Water Supply and Demand Scenarios

Research for this component, which will take place in year two of the project, will examine the vulnerability of water resource systems in the Okanagan Basin, British Columbia to the impacts of climate change on water supply and demand. The role that various adaptation options can play in reducing vulnerability will also be examined. This study will use results generated from other components of the regional assessment as well as projections of future development in the region to create scenarios of future water supply and demand. These scenarios will be presented to stakeholders in the region during dialogue sessions focusing on the implications of climate change for water management in the Okanagan.

The scenarios approach will aim to create “plausible futures”, or depictions of future water supply and demand that are plausible given the range of development, climate change and water management trends that could occur in the future. Scenarios will address the questions of how regional development and climate change will shape future water supply and demand in the Okanagan Basin and how changes in water management practices can reduce vulnerability.

Dialogue with Stakeholders

This dialogue with stakeholders will be used to examine whether the scope of the research program on climate change and climate impact scenarios, complemented by studies of regional water management frameworks, institutions, and adaptation options, is appropriate for bringing global scale climate concerns to the regional scale. Stakeholders will participate in the evaluation of potential adaptation options according to their specific water use interests. An adaptation evaluation exercise will give stakeholders the opportunity to identify evaluation criteria, indicators for measuring criteria, and other aspects of the evaluation exercise using some level of consensus-based decision-making. While illustrating the effectiveness of such an exercise to stakeholders, the evaluation will also help identify barriers and/or other aspects of adaptation not considered in the review of water management frameworks and the synthesis of adaptation case studies.

At this time, the research team is planning to build on the interviews and surveys undertaken for the water management and adaptation case study components to organize a series of focus group sessions on identifying preferred adaptation options and processes for their implementation. Rather than seeking consensus on the “best” option or process, the focus groups will be asked to consider available options as part of a portfolio that could address both supply side and demand side aspects of water resources management in the Okanagan. It is anticipated that this would happen in two stages: a) homogeneous groups (e.g. irrigators, municipal, fisheries) expressing their preferences for an adaptation portfolio and associated implementation processes, based on their management objectives, and b) heterogeneous groups (whole region or possibly based on subregions, e.g. north, central, south) considering tradeoffs between various sets of management objectives, and expressed preferences of homogeneous groups.

Chapter 1. Background and Objectives

Stewart Cohen and Denise Neilsen

This is the Interim Report of the study on Okanagan water management and climate change, Climate Change Action Fund (CCAF) Project A463/433. This is being offered at the mid-point of this collaborative research effort, both to fulfill reporting requirements of CCAF, but also as a record for the research team, its partners, and interested parties in the Okanagan and elsewhere.

1.1 Introduction

Water resources, their management and use, are known to be sensitive to variations in climate, and will be influenced by climatic change. Hydrologic studies of various watersheds throughout the world (Schriner and Street, 1988; Arnell *et al.*, 2001) suggest changes in total annual flows, seasonal aspects of water supply and demand, implications for ecosystems, and challenges for managers in meeting multiple objectives (energy, irrigation, navigation, flood control, etc.).

The Columbia Basin has been the subject of some detailed case studies (Mote *et al.*, 1999; Hamlet and Lettenmaier, 1999; Miles *et al.*, 2000), and there has been an initial attempt to bring in transboundary perspectives (Cohen *et al.*, 2000). This work suggests that a warmer climate would lead to changes in hydrology, including reduced snow pack and earlier snowmelt peaks, with subsequent implications for regional water supplies and fisheries. The earlier peak would lead to increased flow during winter months and an earlier flood season. Less water would be flowing during the summer months when irrigation demand is highest. Low summer flows would also affect hydroelectricity production and salmon habitat.

These findings have contributed to a growing dialogue on water management and climate change on the American side of the Columbia Basin. This needs to be matched by a similar dialogue in Canada, and ultimately, a bi-national one. Although basin-wide hydrologic assessments have been done, detailed hydrologic studies on the Canadian side were not part of this. The Okanagan region is one such area needing attention. The Okanagan is already experiencing rapid population growth and land use changes, with associated stresses on its water resource systems.

Another important aspect is the need to broaden the dialogue on adaptation (Smit *et al.*, 2001). Changes in climate parameters may change opportunities and risks, but climate represents only one of many issues to be considered in resource management and use. In principle, there are many technical and institutional options available, but the implications of selecting any particular options have not been explored in a long-term planning and climate change scenario context. Certain options, such as new water pricing regimes or water banks (Bruce *et al.*, 2000; Miller, 2000) are being considered and tested in areas facing water shortages now (e.g. California). However, it is not clear how these or other options would perform under a particular scenario of regional development (e.g. conversion of pasture to high intensity horticulture, urban growth, tourism growth, demands from the Columbia system) or a different climatic and hydrologic regime (e.g. longer warmer growing season, higher summer demand for electricity, changing winter/spring flood regime, changing fire and disease risks).

Coupled with the impacts and adaptation challenges being faced by the Okanagan and Columbia watersheds, there is also an important methodological concern - bringing regional aspects of climate change into a global-scale research and policy environment. Analyses within natural and social sciences have long been faced with the trade-off of choosing

between the difficulties of accounting for complex regional detail, and the ease of simpler aggregation accompanied by unrealistic assumptions about natural processes and human behaviour. National and global model-based impacts studies are, by necessity, highly aggregated. These incorporate assumptions about adaptation choices, and their acceptance into practice. Damage costs and adaptation costs and benefits have been estimated for the U.S. using these kinds of assumptions (Mendelsohn and Neumann, 1999). Results can be quite sensitive to what is assumed about levels of shoreline protection, choice of tree species for planting, etc., and how widespread these practices would become during the scenario time period.

If we're going to estimate the costs of climate change impacts, and the value of any adaptation investments, there needs to be more attention given to the development of adaptation scenarios that could reflect regional opportunities and constraints associated with any options that might be considered. Just because a growing season may become longer doesn't mean that all decision makers will be able to adjust to this in the same way or at the same pace. What would stakeholders really do in the face of such changes? How would governments, communities and the private sector incorporate uncertain scenarios of climatic change into their planning? This suggests that dialogue with stakeholders needs to be an explicit part of the process of framing research questions and carrying out impact and adaptation assessments.

1.2 Previous Work, 2000-01

This study of Okanagan water resources and climate change implications builds on two studies conducted during 2000-01. One of these focused on hydrologic aspects while the other was oriented towards irrigated agriculture, the largest consumer of water in the region. The hydrologic study (Cohen and Kulkarni, 2001) had two main goals:

1. To identify climate change impacts on regional hydrology, and possible adaptation strategies for the Okanagan region, and
2. To test an approach for engaging resource managers and regional stakeholders as collaborators in research and dialogue on climate change impacts and adaptation.

Figure 1.2.1 illustrates how the 2001 study was organized. The relatively short duration of available time for this study (one year) precluded consideration of a major effort at modeling all natural and human processes relevant to climate and water. Rather than developing an all-inclusive model of water resources, in which the connections to climate and management decisions are mathematically expressed, the approach here was to use dialogue to complement mathematical models. This enables the inclusion of issues that may be difficult to model in such terms. Mathematical models were used strategically to generate information on known environmental indicators and processes (temperature, precipitation, snow pack, runoff, streamflow). Dialogue was used for those indicators and processes that include a human component (irrigation, land use, forestry, fisheries, and institutional arrangements).

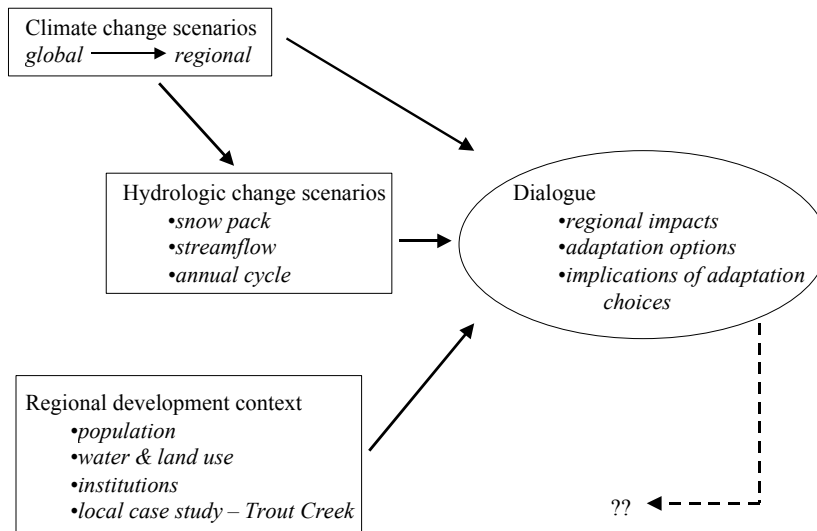


Figure 1.2.1: Okanagan Climate and Water Resource Impacts Study Framework (Cohen and Kulkarni, 2001).

Climatic change scenarios, obtained from simulations from three climate models, indicated a temperature increase of 1.0-2.5°C from the 1961-1990 base period to the 2020s, and 3-5°C by the 2080s. Higher precipitation was projected for winter, but the climate model simulations did not agree on the direction of change for summer. Results for the climate scenarios for six unregulated creeks within the Okanagan Basin indicated earlier onset of spring peak flows, by as much as 4-6 weeks. The peak was generally lower than current peak flows. All areas showed loss of snowpack, with the highest elevation creeks showing the smallest loss. Winter flow would increase, while summer flow would decrease. There was no consensus on scenario changes to total annual flow.

The above analyses were followed by a dialogue process consisting of focus group exercises designed to elicit views on impacts, adaptation, and implications of adaptation choices. Participants identified impacts for forestry, agriculture, fisheries, infrastructure, health and ecosystems. Subsequent consideration of adaptation options resulted in a preference for structural measures, particularly intervention to prevent impacts (e.g. snow making, dams at high elevations, controls on land use and irrigation). Other popular alternatives were developing alternative uses for resources (e.g. alternative energy, grey water) and changing land use plans (e.g. densification of urban land). Participants were then asked to consider implications of adaptation choices. Considerable attention was given to water licensing, flow regulation through dams, and potential restrictions on development. Many comments indicated a need for additional research and outreach activities or changes in consultative processes associated with a particular option.

The study on irrigated agriculture (Neilsen et al., 2001) addressed potential impacts on crop water use under climate change scenarios during the next 100 years. The objectives of the study were to develop methodology to determine crop water requirements under current climate and climate change scenarios and to compare predicted demand with reported current water use and water supply. Methods were developed to integrate crop water use data with spatial climate and land use data. For various crops, equations for estimating crop water use were derived from measured water balances and relationships between daily maximum

temperature and estimated potential evapotranspiration. Land use data were acquired from a variety of sources and incorporated into a GIS. The complex terrain in the Okanagan basin and its potential effect on daily temperature regimes and hence crop water use, required the use of techniques to downscale climate data spatially through PRISM (Parameter-elevation Regressions on Independent Slopes Model) to a 4km x 4km grid (Daly et al. 1994). This grid was overlain on the land use data in the GIS to create unique polygons. Calculations of crop water demand were performed for each polygon in a database program. Boundaries of areas supplied by the major water purveyors in the basin (Irrigation Districts) were digitized and added to the GIS. Crop water demand was then totalled on a region and Irrigation District basis,

Overall average predicted water use for present day conditions was compared with values of expected water use provided by B.C. Ministry of Agriculture Fisheries and Food for sites within the region in order to test the crop water demand model. Predicted values were slightly lower than the BCMAFF values (745 mm/year vs. 820-1000 mm/year), which was likely the result of under-estimation of temperatures by PRISM. This was attributed to the coarseness of the PRISM grid, which resulted in large elevation changes within cells. Total annual water consumption for the period 1996-1999, reported by the major Irrigation Districts within the region, was reasonably similar to that predicted by the model (46.9 m³x 10⁶ vs 51.8 m³x 10⁶). Thus the model was considered adequate for assessing effects of climate change. For the region as a whole, estimated crop water demand increased by 37%, from 745 to 1021 mm/year (80 to 110 m³x 10⁶) between the present day and a 2070-2099 scenario. Analysis of water allocations to the 10 major Irrigation Districts indicated that those drawing water from the main channel and lake system would likely have sufficient water to meet increased demand, but some districts using tributary water may not. A major limitation in this study was the availability of data from only one GCM scenario downscaled through PRISM. In the current study, data from a range of models and scenarios will be used to capture the uncertainty associated with GCM experiments.

1.3 Study Objectives

The research activity described in this report aims to be a comprehensive regional assessment of the impacts of climate change on water resources and options for adaptation in the Okanagan Basin. The assessment is a collaborative, interdisciplinary effort involving researchers from Environment Canada, Agriculture and Agri-Food Canada, the University of British Columbia, the BC Ministry of Water, Land and Air Protection and the City of Summerland.

The ultimate goal of the project is to develop integrated climate change and water resource scenarios in order to stimulate a multi-stakeholder discussion on the implications of climate change for water management in the region. The study team hopes to achieve two main objectives: a) providing a set of research products that will be of interest to regional interests in the Okanagan, and b) establishing a methodology for participatory integrated assessment of regional climate change impacts and adaptation that could be applied to climate-related concerns in Canada and other countries.

1.4 Study Framework

The study comprises five key components:

1. **Climate change scenarios:** downscaling global climate change scenarios to the regional level;
2. **Hydrological scenarios:** determining impacts of climate change on basin hydrology;

3. **Water demand scenarios:** developing future demand scenarios particularly for municipalities and irrigated agriculture, factoring in socio-economic trends;
4. **Land-use change scenarios:** researching crop suitability under changing climatic conditions, and;
5. **Adaptation options:** exploring feasible management approaches for augmenting water supply and/or reducing water consumption.

Figure 1.4.1 illustrates the main components of the project. Climate and hydrologic scenarios provide inputs to the other components, and help to establish the “what if” context for this exercise. The primary research method chosen for the Okanagan project is a participatory approach to integrated assessment of climate change impacts and adaptation. Rotmans and van Asselt (1996, 2002) have described integrated assessment as a process that can promote active dialogue and knowledge sharing between scientists, in the form of interdisciplinary research, and local knowledge holders, who use their experiences and judgements to help frame research questions and express response options that satisfy the region’s interests. A participatory approach can complement research produced through quantitative models and fieldwork. In the Okanagan study, local knowledge from water managers, user groups and other stakeholders are integral parts of the water demand, land use change and adaptation components. Note that the adaptation component consists of several elements: institutions, adaptation options and their costs, and dialogue. The team approach and local partnerships build on previous work in the region (Cohen et al., 2000; Cohen and Kulkarni, 2001; Neilsen et al., 2001).

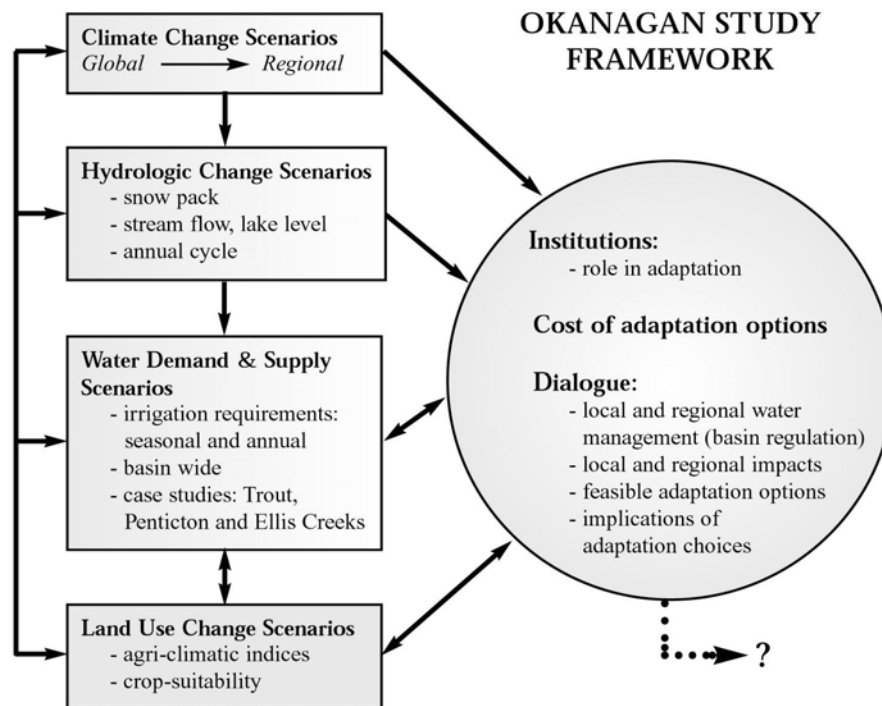


Figure 1.4.1: Framework for study on climate change and water management in the Okanagan region.

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Chapter 2. Climate Analysis and Scenarios

Bill Taylor, Mark Barton and Denise Neilsen

2.1 Climate trends and variability

In our CCAF project proposal, we identified five deliverables under this section related to furthering our knowledge of the climate of the Okanagan basin. These include: trends and patterns in the snow pack, drought frequency, extreme minimum temperatures, basin-wide precipitation trends, and natural climate variability (ENSO and PDO effects). Owing to an immediate requirement in Year 1 to set-up a fine-scale climate monitoring network and to prepare climate change scenarios, there is no progress to report on those five deliverables. These studies will be deferred to Year 2

2.2 Monitoring fine-scale climate

Okanagan climate variables have been measured by Environment Canada, for widely varying periods, at about thirty locations within the Okanagan basin. Of these, only two weather stations, Summerland CDA and Vernon Cold Stream Ranch, are well suited to long-term trend analysis because of their long and continuous records. Temperature and precipitation have been recorded at Vernon since 1900 and at Summerland since 1907. Daily data for these stations have been homogenized and corrected for non-climate related jumps caused by instrumentation changes and station relocations (Vincent & Gullett, 1999; Mekis & Hogg, 1999). Homogenized data are specifically intended for climate trend analyses.

Many crops in the Okanagan Basin rely on various microclimates created by the complex topography. Current Environment Canada weather stations are too widely spaced to monitor microclimates. Therefore, a network of 42 temperature sensors was deployed in orchards and vineyards in Summerland and Naramata for the analysis of microclimate variations that affect the agricultural land, which is concentrated in valley bottom and low and middle elevation bench areas. Microscale topographic variations in slope, aspect and elevation, and the different crop types give rise to an assortment of microclimates that have yet to be studied in detail. This project uses a network of Hobo computerized temperature loggers to collect temperature data so that the microscale variations in climate can be mapped to aid the understanding of crop water demand and crop suitability. Collection of data will likely continue for five years. This period allows a range of seasonal climate effects to be studied.

When setting up the climate monitoring network, a key consideration was that the data should be representative of the climate of the areas of interest. The instruments were carefully located so that they accurately measure the 'screen level' temperature. For air temperature measurement this requires installation at a particular height, screen height (~1.4m), so that measured temperatures are comparable with those measured in Summerland and at other weather stations in the study area. Another consideration was the degree to which measured temperatures are representative of a particular crop area such as an orchard or vineyard. This is achieved by locating the logger in the middle of large crop areas so that recorded temperatures are reflective of a particular crop with a particular slope, aspect and elevation.

Regular data collection commenced in late July 2002 at most of the 22 Summerland sites and 18 Naramata sites, where temperatures were recorded at hourly intervals. Collection at two minute intervals was introduced later in the summer when the need to identify periods of crop irrigation from temperature changes became apparent. Furthermore, two loggers were attached to Environment Canada thermometer screens, one in Summerland and one at Penticton airport. This permits a long-term comparison of the low cost Hobo loggers that are used in this study with the more expensive Campbell Scientific equipment at the regular

weather stations. Short-term field measurements in Summerland sites and Naramata sites will be compared with their respective long-term weather station records so that drought and frost risk can be assessed.

The locations of the Hobo loggers, with reference to topography, are indicated in Figure 2.2.1 and Figure 2.2.2. The elevation range in the study area on the W. side of the valley is 330-605m and on the E. side 381-481m. The complexity of the terrain is evident from the location map on the E. side of the valley (Figure 2.2.1). Slopes range from 0-20% (Figure 2.2.2) and a full range of aspects was sampled, although, location on the E or W side of the valley determined the dominant aspect categories. Preliminary results for the growing season of 2002 have indicated that there is a considerable range in daily maximum and minimum temperatures within the study area. Over a three month period (Aug 1st- Oct 31st), differences amongst sites for max. daily temperature ranged from 2-7°C and for min daily temperature from 2-8°C (Figure 2.2.3). Lapse rates have not yet been calculated as highest and lowest daily max. or daily min. temperatures may have occurred at different times in the day. Preliminary classification of topography will be undertaken shortly. Relationships will be derived between Hobo data, topography and climate data from the Environment Canada weather stations at Summerland-CDA and Penticton Airport to determine the modifying effect of landscape position on daily temperatures. A variety of statistical techniques will be used including regression and neural network analysis.

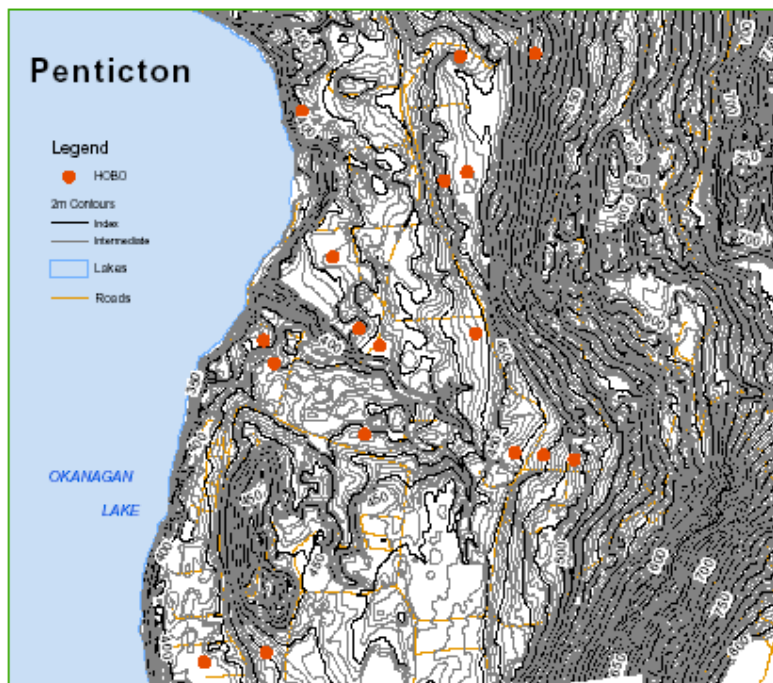


Figure 2.2.1: Topography and HOBO locations on the E. side of the Okanagan Valley within the Penticton water Purveyor District.

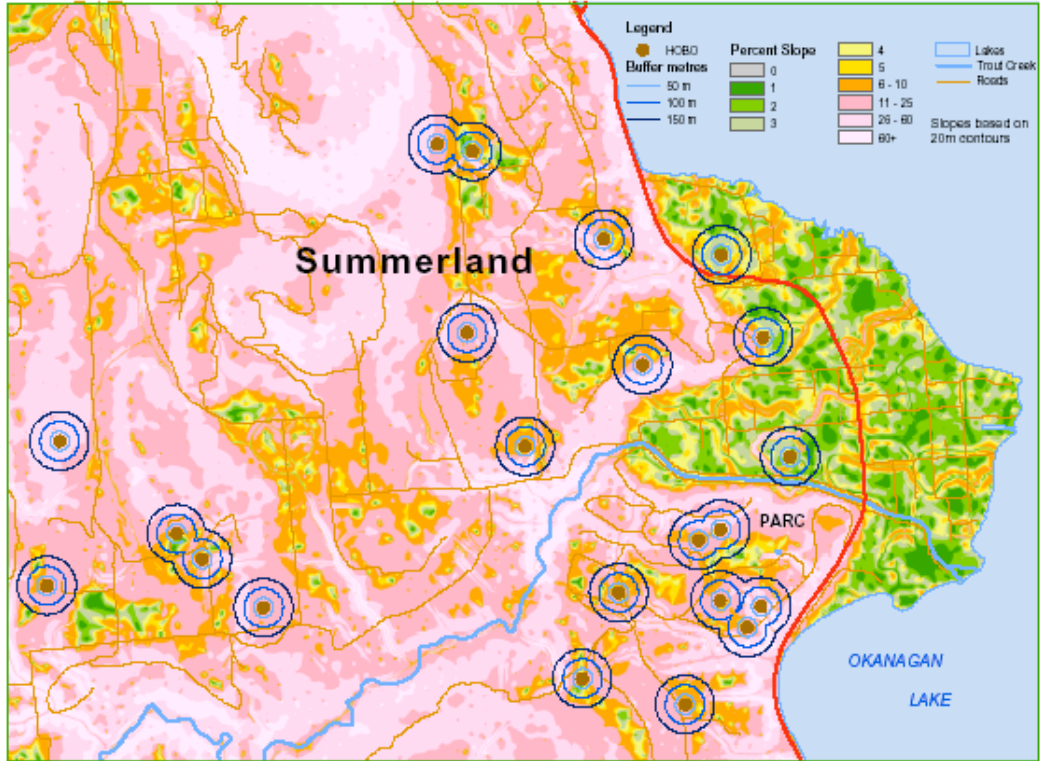


Figure 2.2.2: Slope classification and HOB0 sites on the W. side of the Okanagan Valley in the Summerland Water Purveyor District

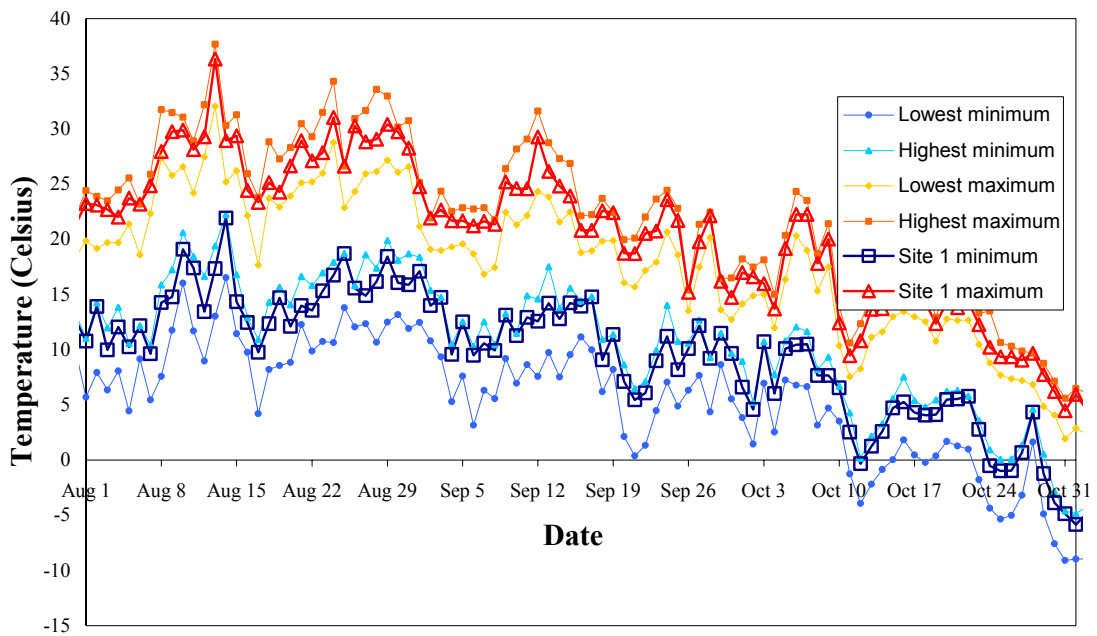


Figure 2.2.3: Daily maximum and minimum temperature ranges in the Summerland - Penticton area in 2002 compared with temperatures of a selected site

2.3 Climate Change Scenarios

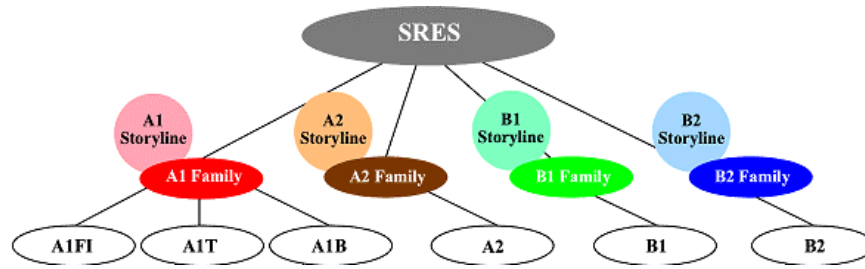
Year 1 deliverables include a suite of high-resolution climate change scenarios which draw on a variety of different GCMs, use appropriate downscaling techniques, incorporate SRES emissions scenarios, and are suitable for use in hydrologic modeling. Completing this part of the project during Year 1 was essential because the climate change scenarios are a foundation piece for the hydrologic modeling and the agricultural modeling.

2.3.1 Choosing a Global Climate Model

Despite their inherent uncertainties, global climate models (GCMs) are regarded as the only credible way to explore the complexity of the climate system and to provide quantitative estimates of future climate changes (IPCC, 2001). Climate models are under development at major scientific research centres throughout the world, so there are many different models from which to choose. Since the future climate cannot be known with any degree of certainty, climate change projections should be expressed in terms of a range of possible future climates. Accordingly, the IPCC (1994) recommends that the results from more than one global climate change model be considered in conducting climate change impacts work.

Estimating future global greenhouse gas emissions represents one source of uncertainty in the climate change projections. In its Third Assessment Report, the IPCC (2001) bases its global temperature projections on six SRES emissions scenarios (Special Report on Emissions Scenarios), which in turn are based on a range of global population projections and assumptions about economic growth and technological change. These SRES scenarios are named A1, A2, B1, and B2 depending on which growth assumptions are used. In addition, there are three variants of A1 (A1B, A1FI, and A1T).

Our choice of GCM models and SRES scenarios was largely influenced by the accessibility of the data from the Canadian Climate Impacts Scenarios (CCIS) website. <http://www.cics.uvic.ca/scenarios/index.cgi>. Data from the SRES model runs are available from CCIS for three different GCMs: the Canadian global coupled model (CGCM2), the UK's Hadley Centre model (HadCM3), and the Australian model from the Commonwealth Scientific and Industrial Research Organization (CSIROMk2). It is common for a modeling centre to produce an ensemble of model runs using the same climate forcing but different initial conditions. The Hadley model (HadCM3) and the Canadian model (CGCM2) include ensembles of data from two or three such runs. The data available from CCIS for the three models are shown in Figure 2.3.1. Numerals inside the table cells refer to ensemble members.



CGCM2				1, 2, 3		1, 2, 3
CSIROMk2			1	1	1	1
HadCM3	1			1, 2, 3	1	1, 2

Figure 2.3.1: SRES model runs available from the Canadian Climate Impacts Scenarios website in 2002. Numerals inside table cells refer to ensemble members.

In deciding on an appropriate number of scenarios for the study, we also considered the computational requirements of the hydrological model and the agricultural model. We thought it prudent to select scenarios representing all three GCMs and to incorporate the results from both a high emissions scenario and a low emissions scenario. Based on these criteria, we selected one ensemble member from A2 (high emissions) and one from B2 (low emissions) from each of the Canadian, Australian, and UK global climate models for a total of six scenarios.

2.3.2 Downscaling Methods

Global climate model projections refer to climate changes for very large areas (grid cells of about 100,000 km²). Also, global climate models do not have the ability to resolve small-scale weather phenomena or the effects of topography. Thus there is a mismatch between the scale of the GCM and the environmental impact being modeled. Therefore a method is required to downscale GCM output to the individual weather station scale. SDSM (Statistical Downscaling Model) allows the construction of climate change scenarios for individual sites at the daily timescale (Wilby et al, 2002). This approach to downscaling is based on the relationship between a surface weather variable and large area and/or large scale circulation variables which are reasonably well simulated by the GCM. SDSM generates a multiple linear regression statistical relationship between GCM output climate variables (predictors) and a local surface weather station variable (predictand) based on the historical record. Once generated, relationships are assumed to hold for the future time periods, thereby allowing future climates to be estimated from GCM output.

Initial work shows a far better performance in generating temperature scenarios than in generating precipitation scenarios. Correlation coefficients in the range of 0.3 to 0.7 were obtained for daily maximum temperature using modeled monthly mean temperature, warm season 500 hPa heights, and cold season near-surface humidity as predictors. However, only very weak correlations were found between surface precipitation and a number of predictor variables. Precipitation is inherently difficult to model using atmospheric predictor variables due to the great local topographic control of precipitation occurrence. The problem of downscaling precipitation is common to all regression-based downscaling methods. A number of suggestions have been made to try to improve the performance of SDSM for precipitation which remain to be tested. These include forward lagging the predictors to account for time

differences between the surface observations and the model output, and using predictor variables in the grid cell to the west of the climate station (R. Wilby, pers comm.).

Another shortcoming of SDSM is that, at the present time, it is set up to operate only with model output from CGCM1, and thus provides only a single climate change scenario.

An alternative approach to downscaling is to apply the proportional changes predicted by selected GCMs directly to temperature and precipitation using the LARS-WG weather generator software. LARS-WG (Semenov & Barrow, 1997) generates future daily time series of temperature, precipitation and solar radiation from a current climate record by adjusting the record with the amount suggested by the respective GCM output for the future time-period and chosen emissions scenario. This approach is widely used and is readily applied for several models and emission scenarios. LARS-WG will be applied in areas where station data is short or sparse to supplement existing climate records. Distributions of possible future climates can also be generated from hundreds of synthetic time-series produced by the weather generator.

2.4 Climate Change Scenarios Results

The selection of GCM grid cells was influenced by the fact that the Okanagan basin is easily contained within the respective grid cell of each of the three GCMs. Since each GCM has unique grid spacing, the location of the centre and the dimensions of each grid cell are different. Some impacts researchers take an average of several grid squares encompassing their region of interest, while others use just one grid cell. The use of surrounding grid cells poses some difficulties when neighbouring cells border on different environments at, say, the ocean/land interface. In consultations with the CCIS principal investigator (Elaine Barrow, pers. comm.) we decided it would be acceptable to use just a single grid cell from each of the three models.

At the grid cell scale, six climate change scenarios display considerable variability in temperature and precipitation projections. Scatterplots showing the range of temperature and precipitation projections for summer and winter for each of the six scenarios for the 2050s time slice are shown in Figure 2.4.1. The full set of winter, summer and annual projections for each of the six scenarios for the 2020s 2050s and 2080s time slices are given in Appendix A.

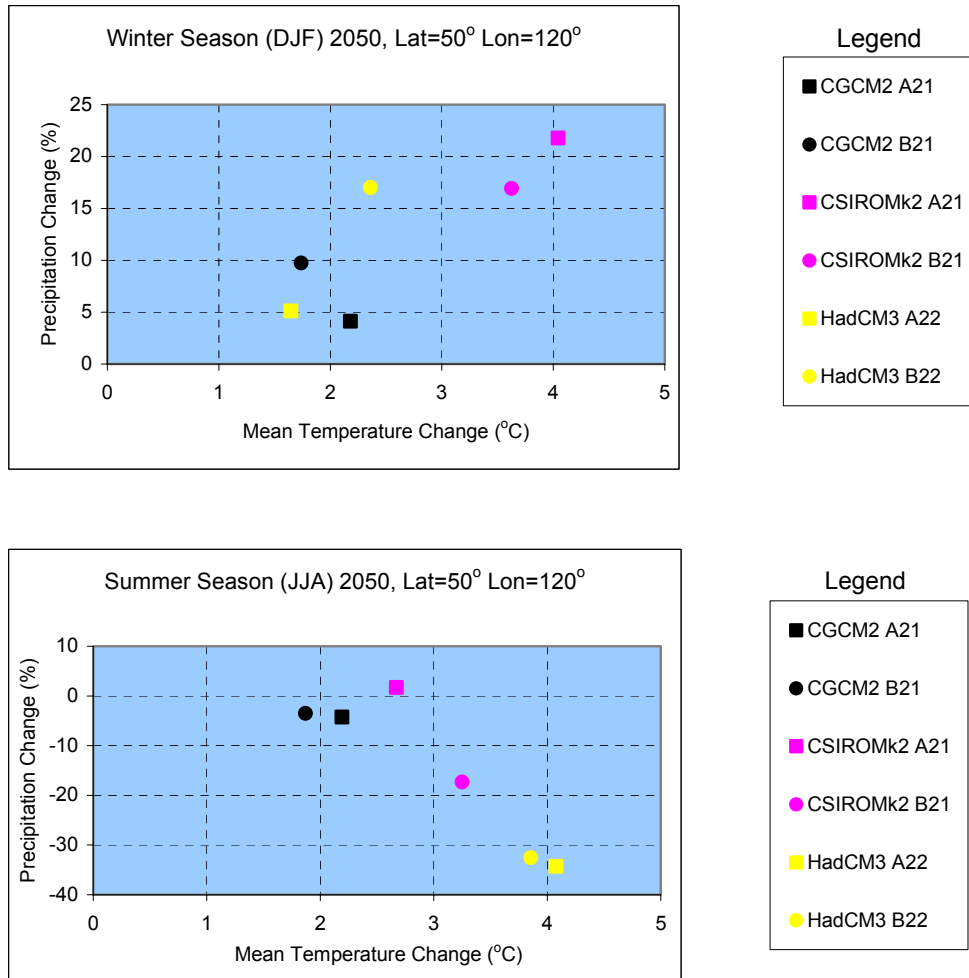
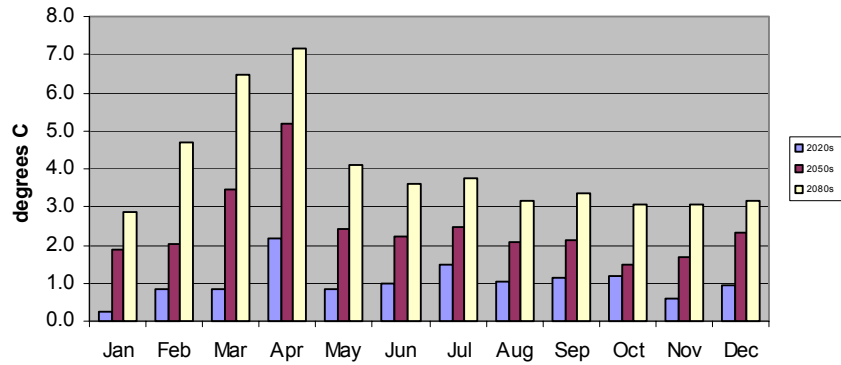


Figure 2.4.1: Scatterplots of projected changes in average daily temperature (degrees C) and precipitation (percent) for the 2050s relative to 1961-90 for winter (top) and summer (bottom) for three GCMs and two SRES scenarios.

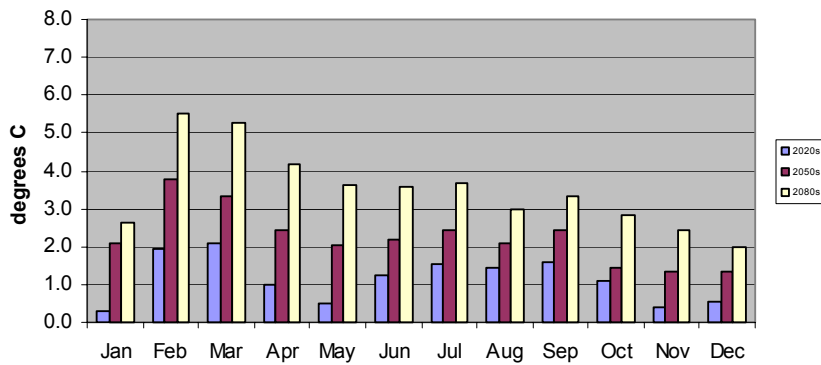
These plots show that for the 2050s, changes in winter temperature relative to the 1961-90 baseline lie in the range 1½ to 4 degrees Celsius with precipitation increases on the order of 5 to 25 percent. For summer, all models show a warming of roughly 2 to 4 degrees Celsius and precipitation changes ranging from almost no change to a 35 percent decrease in precipitation compared to the 1961-90 baseline. The greatest change in winter conditions are reflected by the Australian model (CSIROMk2) while the Hadley Centre model (HadCM3) shows the greatest change in summer climate.

Climate change scenario data are typically provided as monthly changes in daily maximum and minimum temperatures in degrees Celsius and changes in daily precipitation expressed as percent. The changes in these climate variables for one such scenario, CGCM2 A21, are shown in Figure 2.4.2.

CGCM2 Tmax changes SRES A2 - 1



CGCM2 Tmin changes SRES A2 - 1



CGCM2 Precip changes SRES A2 - 1

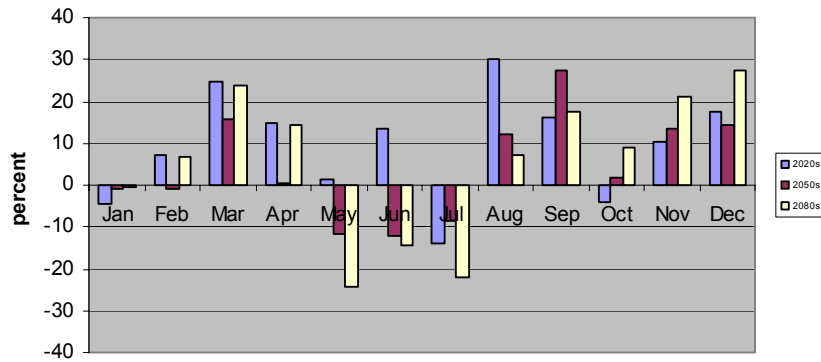


Figure 2.4.2: Projected monthly changes in daily maximum temperature (Tmax) and daily minimum temperature (Tmin) in degrees Celsius and Precipitation (Precip) in percent for three time slices 2020s, 2050s and 2080s, based on ensemble member 1, CGCM2, using SRES emissions scenario A2.

It is worth emphasizing that the plots shown in Figure 2.4.2 are the results of one ensemble member from one GCM based on the results of one SRES emission scenario. It is not a best guess of the future climate - all six scenarios are regarded as equally likely. Plots of all six climate change scenarios used in this study are attached in Appendix A.

While GCMs produce monthly outputs, the hydrological and agricultural models for this study require daily climate data to produce realistic results of stream discharge and crop water demand, respectively. It is generally accepted that climate data from the GCMs are at too coarse a scale to be used directly in regional climate change studies, and as noted previously, downscaling may be employed to obtain a time series of daily data. In the absence of downscaling, an acceptable alternative is to use the “delta” method of applying GCM changes to local station data.

The delta method adds projected monthly changes in temperature from the GCM to the station daily time series, while daily precipitation observations are adjusted by a percentage. This method has an effect on the statistical properties of the original climate observations. In the case of temperature, the addition of a constant results in a scalar change in the mean, but it does not change the variance of the temperature distribution. However, because daily precipitation is not normally distributed, the percentage adjustment results in a change in both the mean and the variance that favours disproportionately greater changes in heavy precipitation. In the case of projected increases in precipitation, the percent adjustment results in only a small increase in the lower end of the distribution, and a larger increase in precipitation extremes. For projected decreases in precipitation, the effect is the same but in the opposite direction, i.e. disproportionately greater decreases in heavy precipitation events.

One of the computational issues associated with the delta method is that the perturbation of daily data using monthly means can result in large discontinuities at the monthly boundaries. This occurs because there may be large differences in the deltas from one month to the next. Note, for example, the large difference between the projected changes in daily maximum temperature for April (5.2 degrees C) compared to May (2.4 degrees C) in the 2050s in Figure 2.4.2. A smoothing algorithm is necessary to reduce abrupt changes at the monthly boundaries, which may result in an unrealistic climate simulation. We used a heuristic approach described by Morrison (2002), which redistributes the discontinuity throughout the entire month in such a way that produces smooth transitions from month to month and also preserves the GCM-predicted change in the monthly mean (Figure 2.4.3).

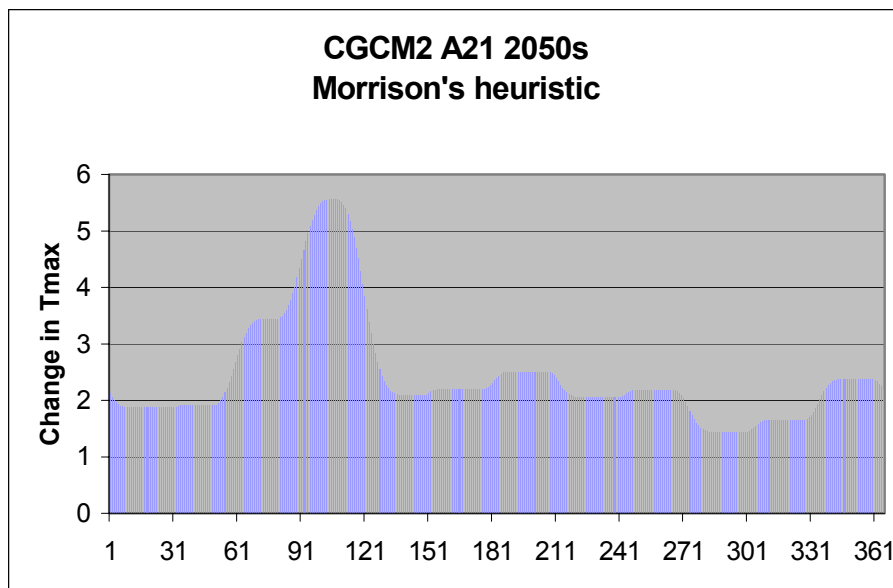
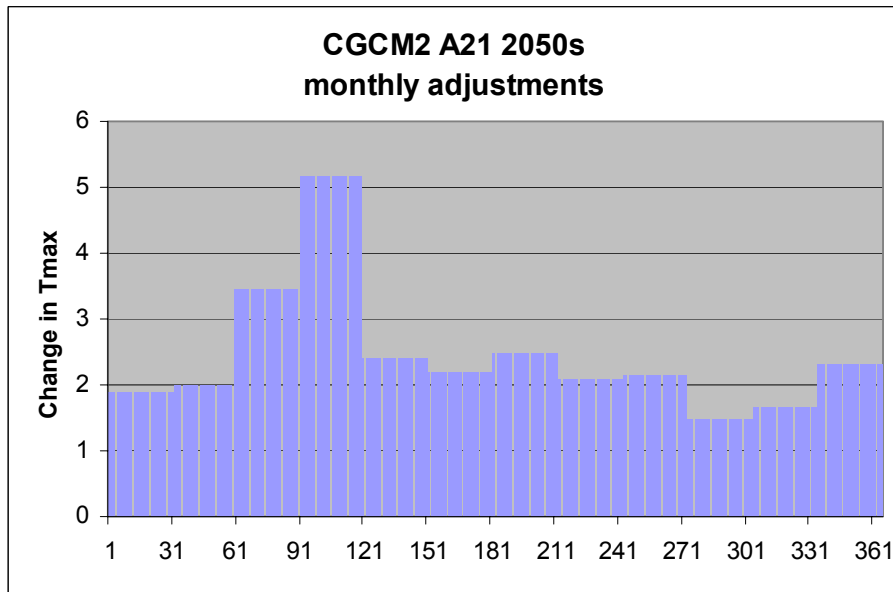


Figure 2.4.3: Effect of applying Morrison's smoothing technique to monthly GCM adjustments. The top figure shows the Canadian model CGCM2 A2 monthly adjustments for the 2050s. The abrupt changes at the monthly boundaries are removed at the bottom after applying the smoother.

The preparation of the climate change scenarios has just been completed at the end of Year 1 of the project. Scenario files are being provided to the hydrology and agriculture components of the project during March 2003. We anticipate playing a supporting role to these project components over Year 2 while we undertake the studies outlined in Section 2.1.

2.5 Acknowledgements

Temperature monitoring sites were selected by Denise Neilsen and Scott Smith based on local knowledge and an understanding of microclimate science. Temperature measuring equipment was installed and recorded data downloaded and entered into a database by Istvan Losso. Grace Frank surveyed sites with a GPS and mapped them with ArcInfo GIS.

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Chapter 3. Hydrology

Wendy Merritt and Younes Alila

3.1 Introduction

The hydrology of the Okanagan Basin is largely snow dominated with much of the water that enters the main-stem lakes and Okanagan River originating from high elevation regions.

Recent trends suggest that the basin is getting warmer and wetter, with minimum temperatures increasing at a rate greater than maximum temperatures, and frost-free days having increased by approximately 3.1 days per decade during the 20th century (Cohen and Kulkarni, 2001). In spite of increased water usage in the Okanagan basin, net inflow or streamflow has increased over the last 50-100 years by 0.3% to 0.5% per year, due largely to the increase in precipitation (cited in Obedkoff, 1994).

3.1.1 Previous Hydrologic Modeling Applications in Okanagan Basin

Hydrological modeling applications in the Okanagan Basin have generally been undertaken in selected subwatersheds (e.g. Cohen and Kulkarni, 2001) or as part of broad scale modeling of the Columbia River Basin (e.g. Hamlet and Lettenmeier, 1999). The notable exception to this is the work undertaken by Obedkoff (1973) for the Okanagan Study Committee, where an approach based on a 5 km² grid resolution was used to estimate mean monthly runoff for the extent of the Okanagan Basin. The work of Hamlet and Lettermeier (1999) explored the effects of climate change on the hydrology and water resources in the Columbia River basin. However, the spatial resolution of the modeling (pixel size was set to 1/8th of a degree) means that the model outputs are not provided at a scale that is of use to adaptation studies in the basin.

In a previous project, funded by the Climate Change Action Fund (CCAF), that explored issues of water management and climate change in the Okanagan Basin (Cohen and Kulkarni, 2001), analogue and process based modeling approaches were applied to six watersheds of the basin. Results from this work suggested an earlier onset of spring peak flows will occur under climate change, with these peaks having less volume than current peak flows (Cohen and Kulkarni, 2001). However, the degree of predicted response to climate change scenarios varied between the watersheds. This variation was considered to be controlled predominantly by basin hypsometry, although other characteristics such as aspect and the latitude of the watershed contribute to the differences in the simulated hydrological response to climate change.

3.1.2 Model Selection

The first stage of the hydrology component was to undertake a review of available models to ascertain the model most suited for application to the Okanagan Basin.

Two main options existed for the climate change modelling exercise; namely application of a grid-based fully distributed model or the use of lumped or semi-distributed conceptual models of the watersheds of the Okanagan Basin. Fully distributed models tend to discretise the study area into a grid, with computations made for all cells in the grid. Outputs from the cells are routed through a flow network to produce estimates of hydrologic indicators at points in the basin. Lumped conceptual models, on the other hand, often break the basin into watersheds and are a conceptually simpler way of representing the basin. Semi-distributed conceptual models tend to model the watershed as a set of pre-defined regions, usually elevation bands,

and aggregate model outputs for these regions up to the watershed outlet. For both lumped and semi-distributed models, homogenous regions, within a watershed or elevation band, are often defined based on watershed characteristics (e.g. topography, land use, climate, geology). Model computations are performed for each region type, assuming that all incidences of a region behave in a hydrologically similar manner. Model outputs are provided at the outlet of the watershed and can be linked (in series or parallel) with the outputs from other watersheds to provide estimates at the basin outlet or other points of interest. The major advantages and constraints of fully versus semi-distributed models are discussed in Table 3.1.1. Examples of fully distributed and semi-distributed models are provided in Table 3.2.1 and Table 3.2.2 respectively.

Distributed hydrologic models largely fit into the categories of either large-scale models that are routinely linked with Global Climate Models (GCM) and tend to be applied at coarse resolutions (e.g. Variable Infiltration Capacity [VIC] – Liang et al., 1994), or models developed for application at finer resolutions. Initial reviews suggested that VIC would be applicable. However, the finest cell resolution used in the literature is 1/8th degree, a resolution that would lump a number of tributaries in the Okanagan Basin together and fail to distinguish between the eastern and western sides of Okanagan Lake. Discussions with the model developer at the University of Washington raised questions regarding the validity of model assumptions at a resolution finer than 1/8th of a degree, particularly the assumption of no transfer of soil moisture between cells other than through the channel (D. Lettenmaier – pers. comm.). On the other hand, a model such as the Distributed Hydrology Soil Vegetation Model (DHSVM – Wigmosta et al., 1994) was designed for application to small watersheds in which the watershed is discretized into grid cells of less than 150 m × 150 m in size. These models typically have large requirements for spatial data and often require sub-daily meteorological inputs. The available data and the scale at which model outputs are required for this study do not justify their use.

	<i>Fully distributed (grid-based)</i>	<i>Semi-distributed</i>
Advantages	provides outputs spatially in addition to channel outlets often explicitly represent topography	less input data and less computationally demanding
Constraints	computationally demanding	outputs tend to be provided only at the watershed outlet simplification of processes (e.g. topography often represented through elevation bands)
Incorporation of GIS data	GIS data is increasingly used to drive the model	GIS not explicitly included in modeling, rather is used to generate inputs prior to modeling
Main work to apply to the Okanagan Basin	generating spatial estimates of driving climate, soils, geological (etc) variables calibration / testing	calibration / testing regionalisation of model parameters to ungauged tributaries

Table 3.1.1: Features of fully distributed grid-based models and semi-distributed models and the main work required for their application to the Okanagan Basin.

A more suitable option is the use of semi-distributed conceptual models in conjunction with routing and reservoir models. Two examples are the UBC Watershed Model (Quick, 1995) and the HBV model (Bergstrom, 1995). The two models are similar in terms of their input requirements and the outputs that are simulated. HBV was used in the previous study (Cohen

and Kulkarni, 2001) in several unregulated creeks. The longer history of application of the UBC watershed model in British Columbia compared with HBV, combined with the work done by Micovic and Quick (1999) to develop standard parameter sets, made it the more appropriate choice for this application.

Our study extends the hydrologic modeling work detailed in Cohen and Kulkarni (2001) to provide basin wide estimates of the impacts of climate change scenarios on the discharge of tributaries entering the Okanagan River and the main-stem lakes. The application involves the calibration and testing of the UBC Watershed Model on unregulated and gauged tributaries in the Okanagan Basin. The model is then applied to ungauged tributaries that enter the Okanagan lakes and main-stem river. The hydrologic modeling concentrates on predicting natural (or unregulated) flows. While most of the tributaries of the Okanagan River are regulated to some degree, the extent and timing of these abstractions are not well documented. As the Okanagan River and main-stem lakes are heavily regulated, we do not attempt to route these flows through to the outlet of the Okanagan Basin. Current management practices pertaining to the release of water from the major dams, and the flow targets that shape these management practices, may change.

3.2 Precipitation-Runoff Modeling

3.2.1 UBC Watershed Model

The UBC Watershed Model (Quick, 1995) is to be used to model precipitation-runoff processes. The model has been used extensively in British Columbia, and has been shown to adequately reproduce the hydrologic response of watersheds, and has previously been used in climate change studies (e.g. Loukas et al., 2002; Morrison et al., 2002; Whitfield et al., 2002). The model conceptualizes a watershed as a series of elevation bands. Meteorological data is distributed with elevation to each band, with the precipitation form at each elevation band estimated based on temperature. Snowpack accumulation is estimated based on temperature and elevation, whilst snow melt is modeled using a simplified energy balance approach. Snowmelt and rain distribution between the runoff response components (very slow, slow, medium, and fast) is controlled by the soil moisture model. The water allocated to each runoff component is subject to a routing procedure based on the linear storage reservoir concept. The quick and medium components use a set of reservoirs, while the slower components are represented by a single reservoir. Each component runoff is summed to produce runoff for each band, and for the watershed at each time step. The model structure is illustrated in Figure 3.2.1. Quick (1995) provides a detailed model description.

The UBC Watershed Model has relatively modest input data requirements, with the minimum dataset needed to drive the model consisting of maximum and minimum air temperature, the watershed area, reservoir or lake area, the impermeable area of watershed, elevation of meteorological stations, and discharge data for calibration and verification purposes.

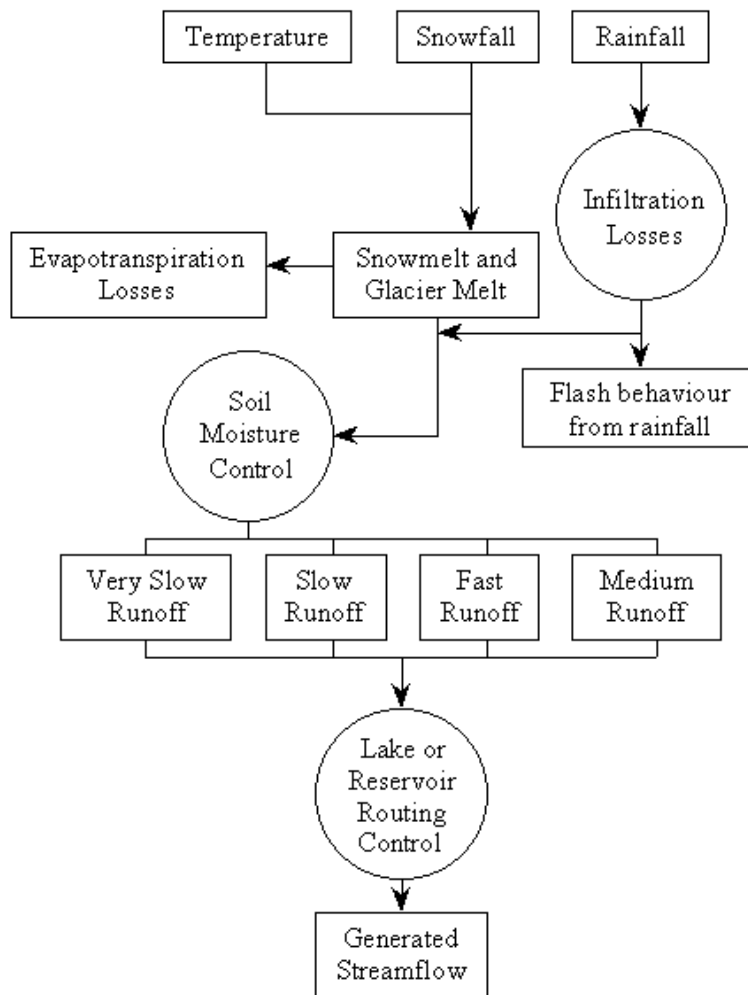


Figure 3.2.1: Structure of the UBC Watershed Model (Quick, 1995)

3.2.2 Data Processing

Daily time series of maximum air temperature, minimum air temperature, and precipitation are required to drive the model. Stations used in calibration and testing the UBC watershed model are detailed in Table 3.2.3 and Figure 3.2.2.

<i>Model</i>	<i>Inputs/Outputs</i>	<i>Spatial Resolution</i>	<i>Temporal resolution</i>	<i>Comments</i>
DHSVM University of Washington	Inputs Detailed vegetation, soil, topographic and climate data Outputs Soil moisture, snow cover, evapotranspiration, and runoff	Typically 30-100 metres (maximum advisable scale is 150m pixels – pers. comm. D. Lettenmeier)	Hourly – relatively poor performance at time steps coarser than sub-daily	Designed to estimate the spatial distribution of surface moisture, energy fluxes, and runoff generation at the watershed scale. Explicitly represents topography, hence the need for a relatively high resolution.
VIC University of Washington	The model can be operated in two modes: a full energy and water balance model driven by precipitation, radiation, air temperature, humidity and wind data to predict land surface water and energy fluxes a water balance mode driven by precipitation and temperature data that predicts evaporation, surface runoff, subsurface runoff	1/8 degree (minimum advisable pixel size – pers. comm. D. Lettenmeier)	Daily or sub-daily	Designed for coupling with GCM. Topography is represented through elevation bands, similar to many semi-distributed models. Transfers between grid cells (other than by channel network) are ignored, limiting the resolution of grid cell size to coarse resolutions.
WATFLOOD University of Waterloo	Inputs Land use, elevations, drainage directions, radar rainfall amounts, streamflow, and air temperatures Outputs Water balance (vertical, horizontal), streamflow	Has been applied on 2×2 km (and larger) grid cell size	Daily or sub-daily	Uses a Grouped Response Unit (GRU) method, where all similarly vegetated within a subwatershed or element are grouped as one response unit and called a GRU. The hydrological responses from all GRU's in an element are summed. WATFLOOD is commonly linked with the SVAT model CLASS. Models the processes of interception, infiltration, baseflow, interflow, overland flow, and channel routing.

Table 3.2.1: Examples of fully-distributed (grid-based) models

<i>Model</i>	<i>Inputs/Outputs</i>	<i>Spatial Resolution</i>	<i>Temporal resolution</i>	<i>Comments</i>
UBC Watershed model University of British Columbia	<i>Input</i> Daily maximum and minimum temperature, precipitation <i>Outputs</i> Streamflow (snowmelt, glacier, rainfall contributions), snow cover area	Watershed is split into elevation bands to which model algorithms are applied.	Daily, continuous	Conceptual model developed for mountainous watersheds. Models the processes of soil moisture, snowmelt, glacier melt, rainfall-runoff, groundwater, and evaporation. Has been applied to watershed ranging in size from 10's to 1000's of square kilometres
HBV Swedish Meteorological and Hydrological Institute	<i>Inputs</i> Temperature, precipitation, elevation <i>Outputs</i> Snow cover, runoff	Snowmelt is computed for each of several elevation zones.	Daily (or sub-daily)	Conceptual model developed initially in Sweden and modified by staff at Environment Canada for application in Canada (HBV-EC). Estimates the growth and decay of a snow pack, runoff production, ET, and percolation
SLURP National Hydrology Research Institute	<i>Inputs</i> Land cover, soils, climate data <i>Outputs</i> Horizontal and vertical water budgets	Algorithms applied on aggregated simulation areas (hydrologically uniform areas with known elevations and land cover distributions).	Daily	Semi-distributed conceptual model developed for use in Canadian meso-scale watersheds. Has been applied on watersheds from 250 km ² to 1.6 million km ² . Models the processes of precipitation, canopy interception, snowmelt, infiltration, surface runoff, and groundwater outflow.
PRMS USGS	<i>Inputs</i> Daily precipitation, minimum and maximum [daily short-wave radiation data recommended for snow melt computations] temperature, soil, topography, vegetation <i>Outputs</i> Water balance, flow regimes, flood peaks and volumes, soil-water relationships, sediment yields, and groundwater recharge.	Hydrological Response Units – subunits developed based on characteristics such as slope, aspect, elevation, land use, soil type, vegetation type, and precipitation distribution.	Daily	Deterministic modeling system developed to evaluate the impacts of various combinations of precipitation, climate and land use on streamflow sediment yields and general basin hydrology. Models soil moisture, snow cover, runoff production, water quality (sediment), recharge

Table 3.2.2: Examples of semi-distributed models

	<i>ID</i>	<i>Station</i>	<i>Elevation (m)</i>	<i>Record Used</i>
1	1120633	Bankier Chain Lake	1020	1974-1988
2	1123360	Hedley	517	1970-2001
3	1123750	Joe Rich Creek	875	1970-1993
4	1123970	Kelowna A	430	1968-2001
5	1123984	Kelowna East	491	1980-1997
6	1123992	Kelowna PC Burnetts	350	1970-1992
7	1124112	Keremeos 2	435	1979-1994
8	1124980	McCulloch	1250	1987-1996
9	1125223	Mt Kobau Observatory	1862	1966-1980
10	1125865	Osoyoos West	297	1970-2001
11	1126077	Peachland Brenda Mines	1520	1970-1990
12	1126150	Penticton A	354	1960-2001
13	1127800	Summerland CDA	455	1960-1995
14	1128551	Vernon	556	1971-1994
15	1128580	Vernon Coldstream Ranch	482	1970-1997
16	1128958	Winfield	503	1974-2001
17	1126784	Falkland Spanish Lake	823	1959-1981
18	1126785	Falkland Salmon Valley	635	1975-1984

Table 3.2.3: Meteorological time series data used in the hydrology modeling

For calibration purposes, daily discharge data is also required. Nine stations in the basin have a sufficient length of record of unregulated streamflow, and are of sufficient quality, to test the UBC watershed model (Figure 3.2.2 and Table 3.2.4). These gauged watersheds are largely confined to the mid-to-high elevation regions of the basin. The watersheds are located throughout the basin, from the high elevation tributaries of Mission Ck (e.g. 08NM172) to the more arid watersheds discharging to Okanagan River and main-stem lakes near Osoyoos (e.g. 08NM015 and 08NM171). All watersheds are largely forested although have had varying degrees of logging within their watershed boundaries.

	Watershed	Area (km ²)	Elevation (m)			Forest Area (%)	Mean Flow (m ³ /s)
			Min.	Ave.	Max.		
a	08NM015 Vaseaux Creek above Dutton Ck	255	570	1580	2300	75	1.44
b	08NM035 Bellevue Ck	73.3	590	1500	2140	85	0.51
c	08NM134 Camp Ck	33.9	1040	1460	1920	64	0.15
d	08NM137 Dave's Creek	31.1	850	1310	1670	46	0.11
e	08NM138 Terrace Creek near Kelowna	31.3	1330	1480	1810	48	--
f	08NM139 Esperon Creek near Kelowna	13	1380	1530	1730	53	--
g	08NM146 Clark Creek	15.3	990	1330	1540	51	0.08
h	08NM171 Vaseaux Creek above Solco Ck	112	1180	1700	2300	77	0.88
i	08NM172 Pearson Ck	73.6	920	1550	2030	82	0.95
j	08NM174 Whiteman Ck	112	610	1400	2030	89	0.63
k	08NM176 Ewer Ck	52.8	640	1380	1760	76	0.40

Table 3.2.4: Unregulated gauged watersheds in the Okanagan Basin used in the calibration and testing of the UBC Watershed Model. The location of these watersheds are shown in Figure 3.2.2 and are identified by column 1.

Each elevation band in a watershed is described by the mid-elevation point (in metres) of the band, the area of the band (km²), the forested fraction of the band, density of the forest canopy (%), the orientation index (0 = North, 1 = South), the fraction of impermeable area, the precipitation adjustment factor, and the climate station indices for temperature, precipitation, and evapotranspiration.

The band area, mid-point elevation and orientation index for each band was determined from TRIM data.

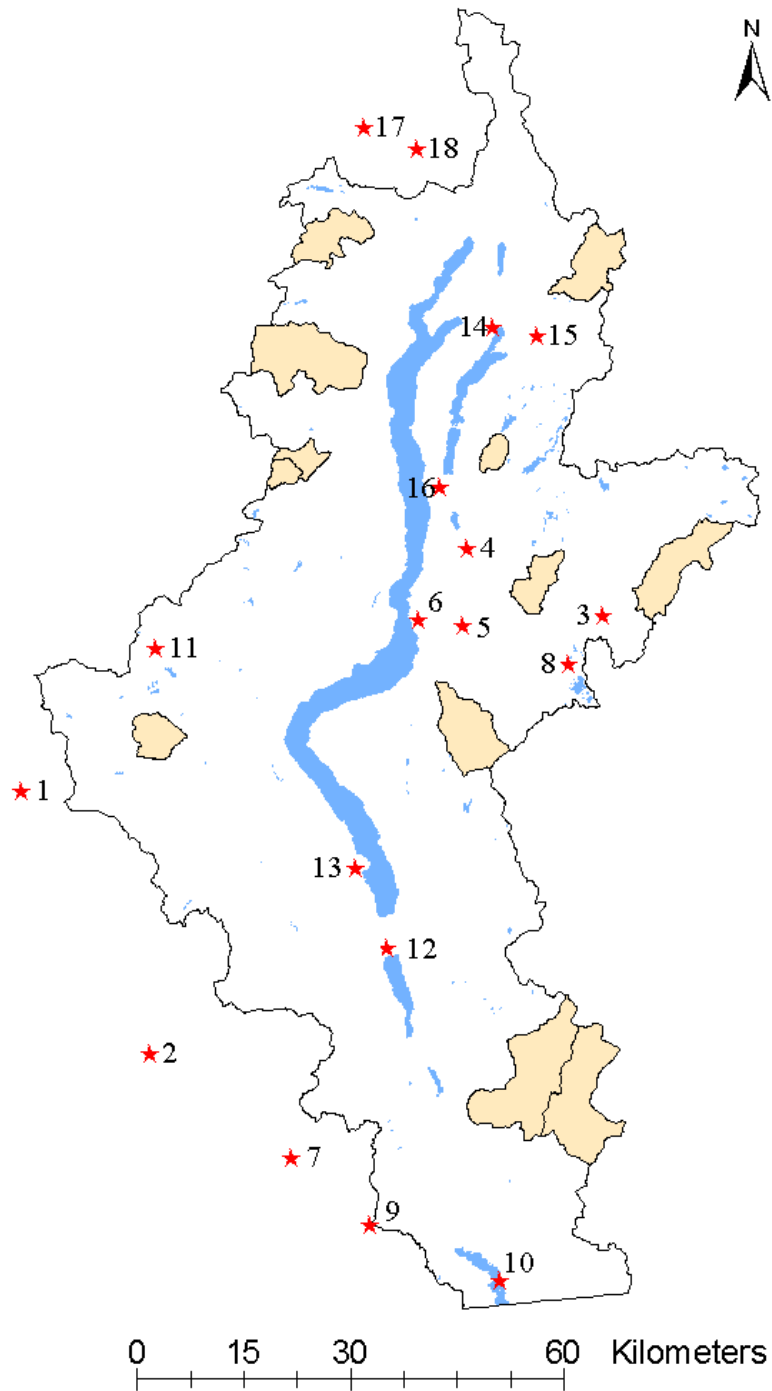


Figure 3.2.2: Meteorological stations and unregulated watersheds used in calibration and testing of the UBC Watershed Model.

The forested area of each band was estimated from Baseline Thematic Mapping [BTM] data (Source: Decision Support Services, Ministry of Sustainable Resource Management).

The Ministry of Forestry forest cover GIS dataset includes maps of the percentage canopy cover at a resolution of 1:20000 for crown land in the Okanagan Basin. This dataset was used to provide estimates of the density of the forest cover.

The impermeable area of each band, the parameters that largely defines the surface (very quick) runoff component of the streamflow in a band and at the watershed outlet, was determined using the BTM data and Aggregate Resource Potential dataset developed by the British Columbia Ministry of Energy and Mines (Bobrowsky *et al.*, 1998). The Aggregate Resource Potential dataset covers much of the Okanagan Basin, although the upper reaches of the Trout Creek and Mission Creek tributaries are not covered by the dataset. Here the impervious area is set to the area of each band not covered by vegetation. Alternatively, the impervious area can be calibrated, although if acceptable calibrations can be obtained without having to calibrate this parameter, the transfer of model parameters to ungauged watersheds is more valid. From the BTM dataset, the land use classifications of urban, fresh water, wetlands and the barren surfaces (unless morainal deposits are the primary geology) add to the impermeable area. When bedrock, glaciolacustrine, and organic deposits are the primary geology these areas add to the impermeable area of the band. Classifications were based on those of other applications of the UBC Watershed Model in British Columbia (Micovic and Quick, 1999; Loukas *et al.*, 2002; Morrison *et al.*, 2002). Areas are also considered impermeable if the primary geology is colluvial and the secondary geology is bedrock. The assumption here is that these are the shallow colluvial deposits over bedrock referred to by Wittneben (1986). This last category was included to further increase the fraction of the impermeable area and increase the proportion of water that is partitioned in to quick flow. Improved calibrations were obtained using this classification.

Daily time series data for the Okanagan Basin was provided by Environment Canada.

3.2.3 Calibration

As the model will be applied to explore climate scenarios, and will be applied on ungauged tributaries, we need to verify as much as possible that the model performs adequately under different climate regimes and between different subwatersheds. To establish model validity, model calibration will be split into two components, as suggested by Xu (1999). To verify that the model has general validity under different climatic periods in the existing records, a *split-sample test* was undertaken, whereby the discharge record is split into different climatic regimes on which the model is calibrated and tested. A *proxy-basin test* was used to test the geographic transferability of the model. In this test, the model is calibrated on watershed *A* and validated on watershed *B* (and *vice versa*).

The Nash and Sutcliffe (1970) coefficient of model efficiency (E) and the coefficient of determination (D) are used to measure the quality of the model calibration. The model efficiency describes how well the volume and timing of the calibrated hydrograph compares to the observed hydrograph and is calculated as

$$E = 1 - \frac{\sum_{i=1}^n (Q_{obs}^i - Q_{cal}^i)^2}{\sum_{i=1}^n (Q_{obs}^i - \bar{Q}_{obs})^2} \quad (1)$$

where,

$$\bar{Q}_{obs} = \frac{\sum_{i=1}^n Q_{obs}^i}{n}, \quad (2)$$

n is the number of time-steps, Q_{obs}^i is the observed flow at time step i , and Q_{cal}^i is the modeled flow at time step i . The coefficient of determination, D , measures how well the shape of the model hydrograph reflects the observed hydrograph and depends solely on the timing of changes in the hydrograph. The closer the values of E and D are to 1, the more successful the model calibration.

While the UBC Watershed Model has a large number of parameters, previous work has illustrated that most parameters can take a standard value. The semi-automatic calibration scheme allows the optimization of the key variables. Initial parameter ranges that were used based on Micovic and Quick (1999) and discussions with the developer of the model.

3.2.3.1 Climate Transferability

The period of record for each gauged watershed was split into two time periods, one of which was used to calibrate the UBC Watershed Model. The parameters calibrated for this time period were then used to simulate streamflow over the second time period. The performance statistics over the calibration and verification periods are shown in Table 3.2.5. Model performance over the verification period is generally acceptable although the Dave's Creek watershed showed considerable reduction in the model performance statistics.

Watershed	Date	Q (m ³ /s)	E	D
<i>Calibration Period</i>				
08NM015	01/01/1971 to 31/12/1975	596.6	0.77	0.77
08NM035	01/01/1971 to 31/12/1976	139	0.74	0.75
08NM134	01/10/1975 to 31/12/1981	46.7	0.84	0.85
08NM137	01/01/1971 to 31/12/1976	42.5	0.74	0.74
08NM146	01/01/1975 to 31/12/1978	26.8	0.70	0.70
08NM171	01/10/1980 to 30/09/1987	362.8	0.75	0.76
08NM172	01/10/1970 to 30/09/1975	342.3	0.89	0.89
08NM174	01/01/1972 to 31/12/1982	251.4	0.80	0.80
08NM176	01/01/1975 to 31/12/1979	113.9	0.72	0.72
<i>Verification Period</i>				
08NM015	01/01/1976 to 31/12/1982	468.5	0.72	0.74
08NM035	01/01/1977 to 31/12/1983	135	0.75	0.78
08NM134	01/01/1982 to 31/12/1988	51.6	0.74	0.74
08NM137	01/01/1977 to 31/01/1983	46.0	0.44	0.48
08NM146	01/01/1979 to 31/12/1982	30.0	0.66	0.76
08NM171	01/10/1987 to 30/11/1994	295.7	0.63	0.65
08NM172	01/10/1976 to 31/01/1983	367.8	0.59	0.68
08NM174	01/01/1983 to 31/12/1993	213.2	0.71	0.71
08NM176	01/01/1980 to 31/03/1984	124.6	0.85	0.86

Table 3.2.5: Performance statistics for the split-sample test of climate transferability (mean annual discharge is provided for the calibration and verification periods).

3.2.3.2 Geographic Transferability

Micovic and Quick (1999) used the UBC watershed model to develop regional parameter sets to predict streamflow in ungauged watersheds. Data from a number of basins in British Columbia was used to develop the parameter sets and test model performance using these parameters. The authors demonstrated that, as long as the precipitation inputs are sufficient and that the impermeable fraction of the watershed can be determined, the standard parameter set could be used to obtain reasonable model results for watersheds that were not used to generate the parameter sets. To test the geographic transferability of the calibrated parameters throughout the Okanagan Basin, an average parameter set, derived from the watershed calibrations conducted over the entire period of record (Table 3.2.6), were transferred to the

test watersheds and used to simulate streamflow. The average parameter set, and the parameters calibrated for the 9 watersheds are listed in Table 3.2.7. Two additional gauged watersheds that had limited records of unregulated flows, and therefore were not considered in the calibration process, were used to test the transferability of model parameters. All model parameters were transferred, other than those parameters that describe the distribution of precipitation from point data to the bands and that describing the impermeable area of each band in a watershed.

Watershed	Climate Station(s)	E	D	Calibration Period
08NM015	1126150	0.80	0.81	1st Dec 1974 to 31st Dec 1982
08NM035	1123970	0.76	0.76	1st Dec 1970 to 30th June 1986
08NM134	1120633 1126077	0.79	0.82	1st Jan 1975 to 30th Sep 1988
08NM137	1123750	0.65	0.66	1st Jan 1975 to 30th Sep 1988
08NM146	1128958 1123750	0.76	0.76	1st Jan 1984 to 31st July 1990
08NM171	1126150	0.79	0.80	1st Jan 1972 to 31st July 1986
08NM172	1123750	0.79	0.79	1st Jan 1972 to 31st July 1986
08NM174	1128580	0.80	0.80	1st Jan 1972 to 31st July 1986
08NM176	1128551 1162785	0.79	0.79	1st Jan 1972 to 31st July 1986

Table 3.2.6: Calibration performance statistics over the period of hydrologic record

The precipitation parameters were estimated for each watershed, according to the methodology used by Micovic and Quick (1999), from existing meteorological data where available. The precipitation gradients (P0GRADL, P0GRADM and P0GRADU) were determined by matching the estimated snow water equivalence with existing snow course data measurements. Where snow course data did not exist for the watershed, the precipitation gradients were estimated for nearby watersheds and transferred to the test watershed.

Micovic and Quick (1999) assigned the parameters defining the threshold elevations, at which the precipitation gradients are applied, based on the elevations of the meteorological stations used as input to the model. For their application, the authors used two meteorological stations for each watershed and two precipitation gradients (P0GRADL and P0GRADM). P0GRADL was applied up to the maximum elevation of the highest elevation band that used the lower elevation climate station (E0LMID). At elevations greater than E0LMID, precipitation is assumed to increase at the rate of P0GRADM. In most of the watersheds used in this study, there were insufficient meteorological records to use multiple climate stations at various elevations through the watershed. P0GRADL, P0GRADM and P0GRADU were thus estimated from the climate subzones in the Biogeoclimatic Ecosystem Mapping dataset, developed by the Ministry of Sustainable Resource Management.

The POSREP and PORREP parameters are used to adjust precipitation, snowfall and rainfall respectively, for each station to match precipitation in the watershed. If the station records are representative of the watershed precipitation, both parameter values are set to zero. In the

regionalization methodology implemented by Micovic and Quick (1999), the authors assumed that the station records were representative of the watershed and were able to obtain reasonable results when transferring model parameters to watersheds that were not used to develop the parameters. In the Okanagan Basin, however, this assumption is not valid for most of the gauged watersheds calibrated. The calibrated POSREP and PORREP parameters listed for each watershed in Table 3.2.8 illustrate this. Using station 08NM171 as an example, snow fall is increased by 14% and rainfall is reduced by 40% from the reference meteorological station (1126150). Assuming the climate stations are representative leads to significant errors in the volume of precipitation, and hence discharge, in the watershed. As the majority of the unregulated subwatersheds have their outlets in mid-to-high elevations, much of the existing meteorological network is not representative of these subwatersheds. For this study, the value of POSREP and PORREP were estimated for each watershed based on the meteorological station(s) used and the value of the parameters for nearby watersheds. The parameter values calibrated for the gauged watersheds were used in the results presented in Table 3.2.9. The POSREP and PORREP parameters for the additional test stations (08NM138 and 08NM139) were taken from calibration of the Whiteman Ck watershed (08NM174) using the climate station 1123970. The results are promising with acceptable reproduction of streamflow in most watersheds with the exception of Daves Creek (08NM137). The relatively low elevation of this watershed compare to the other test watersheds may partially account for this difference, although it should be noted that the calibration of this watershed was not as successful as for other watersheds, perhaps due to the quality of the data for this watershed.

The transfer of the POSREP and PORREP parameters between watersheds was tested for two pairs of watersheds that are in close proximity to one another (Table 3.2.10). Calibrated values of the POSREP and PORREP parameters for one watershed were substituted with parameters calibrated for the other watershed in the pair and used to simulate discharge over the period of record. As would be expected, this mostly results in a drop in both of the performance statistics. The model statistics are in most cases acceptable, indicating that the transfer of the POSREP and PORREP model parameters between similar watersheds in close proximity to each other can be used to produce reasonable simulations. In regions such as the western side of the Okanagan River near Osoyoos, where there is no nearby gauged watershed and little climate data, the transfer of these two parameters from gauged to ungauged watersheds is more uncertain. However, the coverage of both the meteorological and hydrometric data is best in the central and north regions of the Okanagan. As these regions contribute dominantly to the overall basin runoff it is more important from a regional perspective that the method for transferring precipitation parameters is valid for these regions. The tests undertaken indicate that this is so although more rigorous and improved simulations may be achieved if a denser network of climate and ungauged discharge data was established to further test this approach.

The impermeable area was determined from land use and geology GIS, as described in Section 3.2.2. Calibrations for the majority of watersheds did not indicate a significant improvement in the performance of the optimized model parameters to describe discharge at the outlet watershed.

3.2.3.3 Calibration Summary

Overall, the UBC Watershed model has been shown to be a suitable model for application to a region such as the Okanagan Basin. The arid climate of the basin and the deficiencies in the meteorological network (see Box 3-1) make successful calibration of the model more difficult than in humid watersheds that exhibit less variability in precipitation across the watershed.

For most watersheds, calibrating the parameters that describe the impermeable area did not greatly improve performance statistics from model calibrations where the impermeable area was estimated from GIS using the procedure described in Section 3.2.2. Despite problems with how representative much of the climate data is, the model was generally shown to perform adequately when the average parameter set and estimated precipitation parameters were used to drive the model. Likewise, model performance over the verification period indicates that the model is capable of predicting hydrologic response over different climatic periods.

Box 3-1: The Importance of Maintaining and Improving Basin-Wide Climate Monitoring Networks

Over recent years, there has been a Canada wide trend to reduce the number of monitoring sites. The rationale behind this has been largely related to the cost of implementation and maintenance of meteorological networks and perhaps due to the belief that other technologies, such as remote sensing, would become a cost effective and reliable means of measuring precipitation and other variables. Aspects of the hydrology modelling exercise have highlighted key deficiencies in the existing meteorological network in the Okanagan River Basin. The monitoring of climate variables in the Okanagan is predominantly from the following four sources:

- | | |
|-----------------------------------|---|
| Environment Canada | <ul style="list-style-type: none"> • ~ 30 stations basin wide • year round measurements taken at a daily or sub-daily time step • a low density of climate records at high elevations in the basin • only one higher elevation station has records over the entire 1961-1990 baseline period routinely used in climate change studies |
| Ministry of Forestry | <ul style="list-style-type: none"> • 5 stations basin-wide (3 at elevations above 1000 m) • daily recordings for the snow-free periods (usually May to October) • established from 1982 onwards |
| Ministry of Transportation | <ul style="list-style-type: none"> • 8 stations with daily to sub-daily observations (3 at high elevation) • 5 automated stations of 2-7 years, 3 manual stations • operationally maintained for during the winter months only |
| River Forecast Centre | <ul style="list-style-type: none"> • 24 snow course and 2 snow pillow monitoring sites of varying records in length and at elevations greater than 600 m • monthly to twice-monthly measurements of snow depth and snow water equivalence between January and June |

If improvements in the modelling of the hydrology at the basin scale are to be made then considerable effort is required to maintain and further improve the monitoring network in the basin. The hydrology of the Okanagan Basin is largely controlled by the development and recession of the snowpack. For this reason, it is essential that a modelling application is capable of accurately capturing the snow accumulation and melt processes. Without high elevation stations, modellers are forced to rely on lower elevation stations and make assumptions with respect to how precipitation and temperature change with elevation. Precipitation, in particular, is extremely variable and is more difficult to predict and extrapolate between sites than temperature. A low density of stations can therefore introduce potentially large errors into the modelling exercise.

Ideally, improvements to any hydrological models of the basin could be made by establishing a number of long-term climate gauges at high elevation. This would provide invaluable data for future studies in the Okanagan Basin. However, key improvements to the hydrological modelling in this project could be achieved by instigating detailed studies to investigate the relationship between elevation and precipitation (both amount and form) in the basin. The study site(s) could be selected to complement existing networks, such as the active snow survey sites in Trout Creek or Trepanier Creek. Information from these studies may allow improved extrapolation of precipitation from the existing network to higher elevation zones as well as guide the estimation of precipitation parameters for the UBC Watershed Model.

Parameter		Watershed (08NMXXX)									Mean
Name	Description	015	035	134	137	146	171	172	174	176	
P0AGEN	Impermeable area modification factor	176	29	92	50	151	188	142	144	73	116
P0PERC	Groundwater percolation (mm/day)	12.8	43.0	46.4	12.4	48.6	7.7	14.4	4.8	16.3	23
P0DZSH	Fraction of groundwater in deep zone	0.25	0.36	0.43	0.44	0.48	0.22	0.26	0.50	0.43	0.37
V0FLAS	Flash flood threshold	80	85	53	90	82	56	77	100	60	76
P0FRTK	Fast runoff time constant for rain (days)	1.39	1.50	0.35	0.75	0.58	0.004	1.52	1.14	0.58	0.87
P0FSTK	Fast runoff time constant for snow (days)	0.10	0.74	0.45	0.37	0.10	0.20	0.85	1.11	1.00	0.55
P0IRTK	Interflow time constant for rain (days)	5.8	4.8	6.3	6.4	4.1	6.1	6.6	7.2	4.0	5.7
P0ISTK	Interflow time constant for snow (days)	2.0	9.6	9.0	5.7	7.3	1.6	4.5	5.4	6.8	5.7
P0UGTK	Time constant for upper groundwater runoff (days)	17.9	10.2	10.9	18.2	13.8	22.9	17.6	17.5	39.8	19
P0DZTK	Time constant for deep groundwater runoff (days)	201	226	246	246	246	248	243	207	247	243

Table 3.2.7: Calibrated parameters used to derive an average parameter set for application of the UBC Watershed Model to ungauged watersheds in the Okanagan Basin

Parameter	08NM015	08NM035	08NM134	08NM137	08NM146	08NM171	08NM172	08NM174	08NM176
P0SREP1	0.908	-0.103	-0.523	-0.267	-0.443	0.141	0.598	0.821	-0.749
P0SREP2	--	-0.045	-0.197	--	-0.236	--	--	0.17	0.236
P0RREP2	-0.977	-0.169	0.013	-0.267	0.942	-0.395	-0.159	-0.901	0.96
P0RREP2	--	-0.572	-0.796	--	-0.138	--	--	-0.742	-0.873

Table 3.2.8: Calibrated precipitation parameters POSREP and PORREP

	Coefficient of Efficiency		Coefficient of Determination	
	Calibrated	Average	Calibrated	Average
08NM035	0.76	0.53	0.76	0.72
08NM134	0.79	0.61	0.82	0.73
08NM137	0.65	0.16	0.66	0.72
08NM138	--	0.7	--	0.74
08NM139	--	0.51	--	0.57
08NM146	0.76	0.6	0.76	0.71
08NM172	0.79	0.76	0.8	0.77
08NM174	0.8	0.74	0.8	0.82
08NM176	0.79	0.77	0.79	0.8

Table 3.2.9: Proxy-basin test of geographic transferability.

	Pair 1		Pair 2a		Pair 2b	
	08NM035	08NM137	08NM174	08NM176	08NM174	08NM176
Climate station	1123750	1123750	1128551	1128551	1128580	1128580
<i>Calibration</i>						
POSREP	-0.143	-0.267	0.308	0.552	0.1	-0.208
PORREP	-0.4	-0.267	-0.08	-0.4	-0.8	-0.8
E	0.74	0.65	0.79	0.75	0.80	0.71
D	0.74	0.65	0.79	0.75	0.80	0.72
<i>Test</i>						
POSREP	-0.267	-0.143	0.552	0.308	-0.208	0.1
PORREP	-0.267	-0.432	-0.362	-0.77	-0.823	-0.795
E	0.72	0.58	0.67	0.47	0.65	0.42
D	0.72	0.62	0.76	0.74	0.82	0.81
<i>Change in model performance</i>						
ΔE	0.02	0.07	0.12	0.28	0.15	0.29
ΔD	0.02	0.03	0.03	0.01	-0.02	-0.09

Table 3.2.10: Testing the validity of transferring POSREP and PORREP between model watersheds.

3.2.4 Regionalization of Model Parameters to Ungauged Tributaries

The objective of the hydrology modeling component of this project was to develop a basin scale model of the Okanagan Basin. This requires the model to be run on the ungauged tributaries of the basin and so a methodology is required to assign model parameters to the ungauged basin. Regionalisation of model parameters from gauged to ungauged watersheds is not a trivial task and previous attempts to regionalise parameters of models similar to the UBC Watershed Model have shown mixed results. Complicating this process further is that much of the climate data used in this study is located at low elevations and is not representative of the higher elevation regions of the watershed. Regionalisation studies have generally involved developing relationships between catchment characteristics and model parameters using, for example, multiple regression techniques (e.g. Abdulla and Lettenmeier, 1997). In the Okanagan Basin there are insufficient unregulated watersheds with which to develop such relationships. However, the results presented in Section 3.2.3.2 indicate that estimating the precipitation parameters using supporting meteorological data and using a standard set of the other parameters provides a simple procedure for predicting discharge in the ungauged watersheds that performs relatively well. It is important to note, however, that the level of uncertainty regarding the quality of predictions in ungauged watersheds is considerably greater than for the calibrated watersheds. Extra care should be taken in interpreting hydrologic response to the climate scenarios in the ungauged watersheds. The methodology described in Section 3.2.3.2 to test the model was used to develop parameter files for the ungauged watershed in the Okanagan Basin.

The Okanagan Basin is split into a number of watersheds to which the UBC Watershed Model is applied, as illustrated into Figure 3.3.1. Large tributaries such as Trout Creek and Mission Creek tributaries (indicated by 24 and 57 in Figure 3.3.1), or those tributaries that have significant water storage reservoirs, are split into subwatershed to provide estimates of discharge at specific location such as above the reservoir. Natural flow for smaller tributaries are modeled as a whole system (e.g. the Equesis Creek watershed, marked 4 in Figure 3.3.1). The details of the model watershed are tabled in Appendix B.

3.3 Lake Evaporation

The main features of the basin are Okanagan Lake, with a surface area of 350 km², and five smaller main stem lakes along the Okanagan River with a combined surface area of roughly 87 km². These lakes greatly impact the basin hydrology through evaporation from the lake and interactions between surface and groundwater systems. These lakes are heavily regulated with dams at the outlets of five of the six lakes. While our efforts have been largely focused on the calibration and testing of the precipitation-runoff model, and the extension to the ungauged watersheds, an important aspect of the hydrology of the Okanagan Basin is evaporation from the lake's surface. Under conditions of climate change, changes in the levels of evaporation from the lakes may be extreme. Lake evaporation is estimated using a simple radiation-based approach, based on the Priestly-Taylor equation. Whilst more detailed and process-based methods exist for estimating evaporation from open surfaces lack of detailed meteorological data such as global radiation, at least outside of the Summerland Research Station, prohibits the use of these techniques.

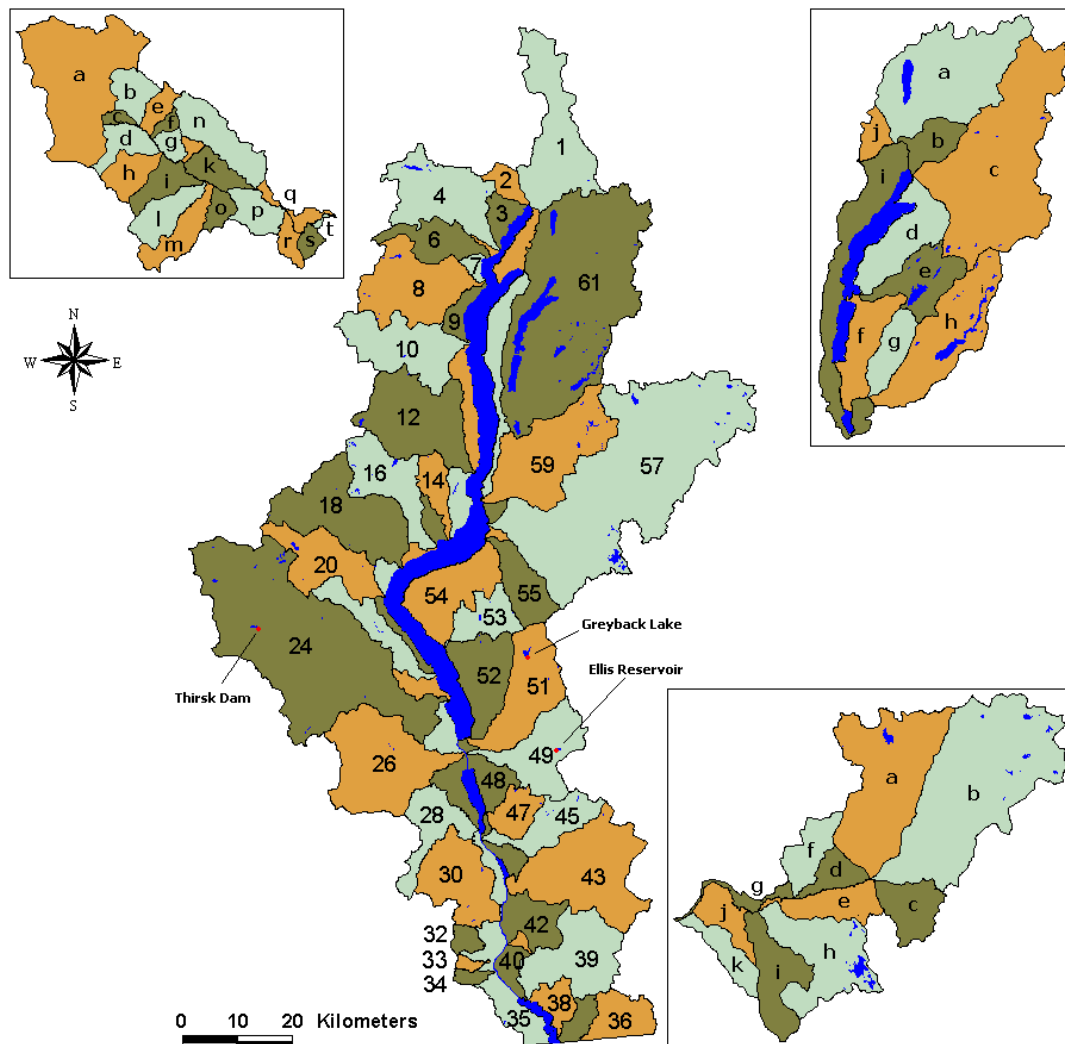


Figure 3.3.1: Delineation of model watersheds in the Okanagan Basin

3.4 Application of Climate Change Scenarios

3.4.1 Generation of Meteorological Inputs

Meteorological inputs for each of the climate scenarios are derived from observed time series data, although modified using the GCM results described in Chapter 2. Monthly adjustments to the minimum and maximum temperature and precipitation are converted into daily adjustments using a process that minimizes daily changes while preserving the change in the monthly mean that is predicted by the GCM. The code for this process was provided by John Morrison from the Institute of Ocean Sciences, Fisheries and Oceans Canada. These daily adjustments are then applied to the historical time series data used in the base hydrology scenario to generate the input climate file for the climate scenario.

3.4.2 Hydrologic Scenarios

Using the scenario meteorological time series detailed above as input, and the procedure detailed in section 3.2, the UBC Watershed Model was applied to tributaries entering the main stem lakes and Okanagan River. In addition, scenarios were applied to the gauged watersheds on which the UBC Watershed Model was tested as well as selected watershed areas upstream of significant reservoirs. All hydrological scenarios (three GCMs and two emission scenarios) have been run for the model watersheds. Some preliminary analysis is presented below.

The scenarios produce a wide range of changes in the hydrological regime of in the model watersheds. All combinations of GCM and emissions indicate an earlier onset of the spring freshet and peak flows compared to the base scenario. However, there is a large degree of variation between predicted annual and seasonal flow volumes and the scale of the timing shift.

3.4.2.1 Precipitation Form

Much of the change reflected in the streamflow hydrograph under scenarios of climate change is due to an overall increase in temperature under the various climate scenarios and how this affects the partitioning of precipitation form in the UBC Watershed model. Within the UBC Watershed Model, total precipitation is partitioned as snowfall when the daily minimum temperature is less than or equal to 0°C and as rainfall when the minimum temperature exceeds a threshold of 2°C. For daily minimum temperatures between these thresholds, the proportion of the precipitation that occurs as rainfall is set equal to the ratio of the minimum temperature and the rainfall threshold (2°C). Over the 30 years of record, the proportion of days with minimum temperatures less than 2°C is substantially lower across all scenarios compared to the base scenario. Table 3.4.1 illustrates this point for the Summerland Research climate station (1127800). In Table 3.4.1 the proportional changes are over the whole period of record.

In terms of the hydrology, it could be expected that the most sensitive period controlling changes in the timing and volume of peak flow under scenarios of climate change would be the transition months between seasons where daily minimum temperatures are close to the thresholds defined in the UBC Watershed Model. In these months, temperature increases will greatly impact the development and recession of snowpacks. Section B-2 of Appendix B shows plots of the average monthly snowfall, as a proportion of total precipitation, for January, April, July and October. In January, the precipitation is partitioned almost entirely as snowfall across all scenarios. Similarly, in summer months like July, the proportion of snowfall is negligible for all scenarios. However, in both April and October, considerably more precipitation is allocated to rainfall under scenarios of climate change. This is consistent across all GCM and emission scenarios. Generally, this trend of increased rainfall and decreased snowfall is stronger in the latter time slices. Again, the exception to this is the B2 emission scenarios generated using the CSIRO climate model. A slight increase in the proportion of snowfall occurs between the 2020's and 2050's followed by a decrease in the 2080's. Whether this is due to the impact of using a single grid cell to downscale climate scenarios or is the result of a change in the climate as predicted by the CSIRO GCM needs to be examined.

	<i>1961 to 1990</i>		
	<i><0 °C</i>	<i>0 to 2 °C</i>	<i>>2 °C</i>
Base	0.28	0.13	0.59
<i>CGCM2 [A2]</i>			
2020	0.24	0.11	0.66
2050	0.18	0.10	0.72
2080	0.15	0.07	0.78
<i>CGCM2 [B2]</i>			
2020	0.23	0.11	0.66
2050	0.20	0.10	0.70
2080	0.18	0.09	0.73
<i>CSIRO [A2]</i>			
2020	0.22	0.10	0.68
2050	0.11	0.08	0.81
2080	0.06	0.03	0.91
<i>CSIRO [B2]</i>			
2020	0.13	0.09	0.78
2050	0.20	0.10	0.70
2080	0.08	0.06	0.86
<i>HADLEY [A2]</i>			
2020	0.21	0.10	0.69
2050	0.18	0.09	0.73
2080	0.11	0.06	0.83
<i>HADLEY [B2]</i>			
2020	0.22	0.11	0.67
2050	0.17	0.09	0.74
2080	0.14	0.08	0.78

Table 3.4.1: Proportion of daily minimum temperatures less than 0°C, between 0°C and 2°C, and greater than 2°C over the 30-year period of record for the Summerland Research Station (1127800).

3.4.2.2 Timing and Volume of the Peak Flows

As mentioned previously, all scenarios predict a shift of the simulated hydrograph to earlier in the year. This is consistent across all modelled watersheds. Generally the trend of earlier peaks continues through all time slices (2020's, 2050's, and 2080's) and a similar pattern is seen between emission scenarios. Examples of the mean annual hydrograph (for all scenarios) in some of the modelled watersheds in the Okanagan Basin are provided in section B-4 of Appendix B, showing the general earlier onset of the freshet period. However, a considerable degree of inter-annual variability in the timing shifts exists. This is illustrated in

Figure 3.4.1 for the Ewer Creek subwatershed. The plot shows, in days, the maximum and minimum shifts in the peak flow and the 1st and 3rd quartiles for the CGCM2, Hadley and CSIRO climate models. The value of the mean early onset (in days) is indicated on the plots. The low emission (B2) scenarios from the CSIRO climate model do not show that same pattern of increasingly earlier maximum peak flows from the 2020's through to the 2080's that was observed for all other scenarios. Not only does the mean shift decrease over the time periods but

the inter-annual variability also decreases. Further analyses are being undertaken in order to ascertain an explanation of these results

The magnitude of peak flows under climate change varies considerably between GCMs and emission scenarios. Using the Hadley climate model, peak flows, while occurring earlier, generally exceed the base scenario in the 2020's and 2050's. By the 2080's, the snowpack development is predicted to be insufficient to provide the volume required to maintain peak flows. Under the CSIRO climate model, a decrease in the magnitude of peak flow is evident in the 2020's and progressively decreases in the 2050's and 2080's.

There is considerable inter-annual variability in the magnitude of the maximum peak flows under the different climate change scenarios. Using the Ewer Ck gauged watershed as an example, the maximum peak flows for each simulation year were ranked from highest to lowest for each climate change scenario (Figure 3.4.2). In the 2020's, there is little difference in the magnitude of the hydrographs peak for both emission scenarios obtained from the CGCM2 climate model. Similarly, the A2 scenario from the CSIRO climate model produced similar magnitudes to the base scenario, although the B2 scenario showed significantly reduced peak flows, contrary to what would be expected under a low emission scenario. The adjustments made to the historical time series for the CSIRO A2 and B2 scenarios are shown in Figure 3.4.3. Of crucial significance, in terms of the hydrological model, is the predicted increase in minimum temperatures under the B2 scenario during the winter months. Despite the increase in precipitation over this period, this significantly reduces the modelled snowpack development and, therefore, the magnitude of peak flows during the freshet. In the 2020's, the Hadley climate model scenarios predominantly exceed the magnitude of the base scenario peak flows, raising the possibility of a heightened risk of flooding which managers of the lakes and reservoirs in the basin may have to plan for. For the 2050's, the increase in temperature predicted by both the CGCM2 and CSIRO climate model results in lower peak flow magnitudes than predicted for the base scenario. The low emissions scenario, for both models, has a less severe reduction than that simulated under the A2 scenario. The Hadley model, in contrast to the other climate models, still predicts increased peak flows for both emission scenarios although by the 2080's the warming is sufficient to reduce peaks, for most years, to below that of the base scenario. The CSIRO low emission scenario in the 2080's predicts increased peak flow magnitudes over the mid-to-high flow years compared with the base scenario. The adjustments made to the historical time series for the CSIRO A2 and B2 2080's scenarios are shown in Figure 3.4.4. With the exception to the month of February, the adjustments applied to the historical minimum temperature data series are considerably smaller for the B2 scenario than for the A2 scenario. In the UBC Watershed Model, more precipitation is partitioned into snowfall in the B2 scenario than in the A2, and this, combined with lower maximum temperatures and therefore lower potential evapotranspiration, increases the volume of water that contribute to runoff as well as the magnitude of maximum peak flows.

3.4.2.3 Seasonal and Annual Volumes

A key issue for managers of the reservoirs and lakes in the Okanagan Basin is not only the possible changes to annual flow volumes under climate change but also how seasonal flow volumes may change.

For the 2020's scenarios, annual flow volumes contributing to the Ellis Creek reservoir were predicted to change between -26% [CSIRO, B2] and +2% [Hadley, B2]. Apart from the CSIRO B2 scenario, changes in annual volumes are less than 5%. However, while keeping in mind the additional uncertainties with longer term predictions, all models suggest a significant decrease in

annual volumes in both the 2020's and 2050's (Table 3.4.2). At these later time slices, the differences between the high and low emission scenarios generally become more apparent.

Table 3.4.2: Mean annual flow volumes (as a proportion of the base scenarios) under the climate change scenarios for Ellis Reservoir and Greyback Lake.

	<i>Ellis Reservoir</i>			<i>Greyback Lake</i>		
	<i>2020's</i>	<i>2050's</i>	<i>2080's</i>	<i>2020's</i>	<i>2050's</i>	<i>2080's</i>
<i>High Emission [A2]</i>						
CGCM2 [A2]	0.96	0.65	0.51	0.96	0.66	0.54
Hadley [A2]	0.95	0.72	0.51	0.94	0.78	0.66
CSIRO [A2]	0.95	0.67	0.34	0.94	0.74	0.58
<i>Low Emission [B2]</i>						
CGCM2 [B2]	0.95	0.78	0.65	1.00	0.83	0.74
Hadley [B2]	1.02	0.82	0.72	0.97	0.79	0.46
CSIRO [B2]	0.74	0.74	0.40	0.83	0.78	0.52

For all scenarios, the greatest change in flow volumes is for the months of April through to June. However, significant proportional changes occur in other seasons. For example, the decrease in flow volumes in the July to August period under the Hadley high emission climate scenario is of the order of 80% of the base scenario volumes in the 2080's (Figure 3.4.5). Although an extreme scenario in terms of emissions and the high uncertainty of simulating future climates, if such a scenario eventuates then the managers of reservoirs have an increasingly difficult task in managing water resources throughout the year. The smaller freshet volumes may potentially make it difficult for managers to store sufficient volumes of water to maintain downstream flow requirements.

Table 3.4.2 and Figure 3.4.5 focussed on changes to the mean annual and seasonal volumes. However, the variability between years is crucial to consider. Plots showing the probability of exceeding annual and seasonal flow volumes are provided in B-4 of Appendix B. These plots illustrate the variability in volumes for the scenarios over the 30-year period of simulation.

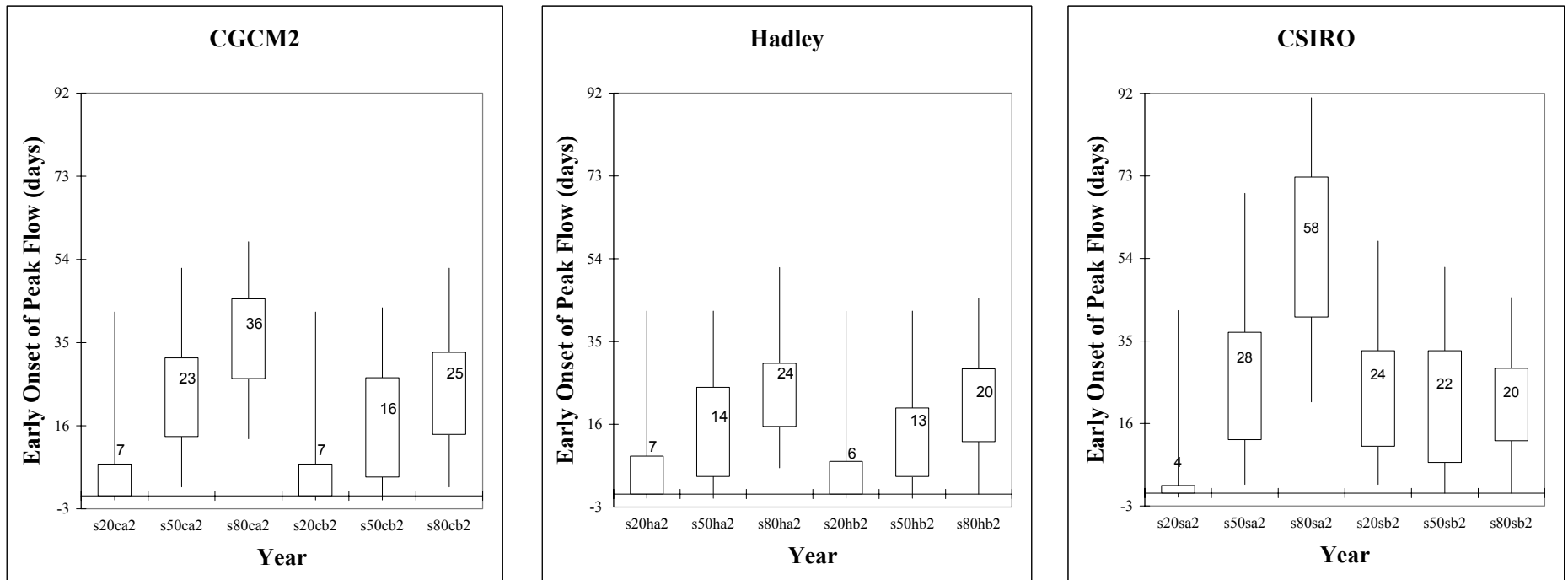


Figure 3.4.1: Timing of maximum peak flow for the Ewer Creek watershed under (a) CGCM2, (b) Hadley, and (c) CSIRO climate scenarios. From left to right, the scenarios are the A2 [high emission] scenarios (2020's, 2050's, 2080's) followed by the B2 [low emission] scenarios (2020's, 2050s, and 2080's)

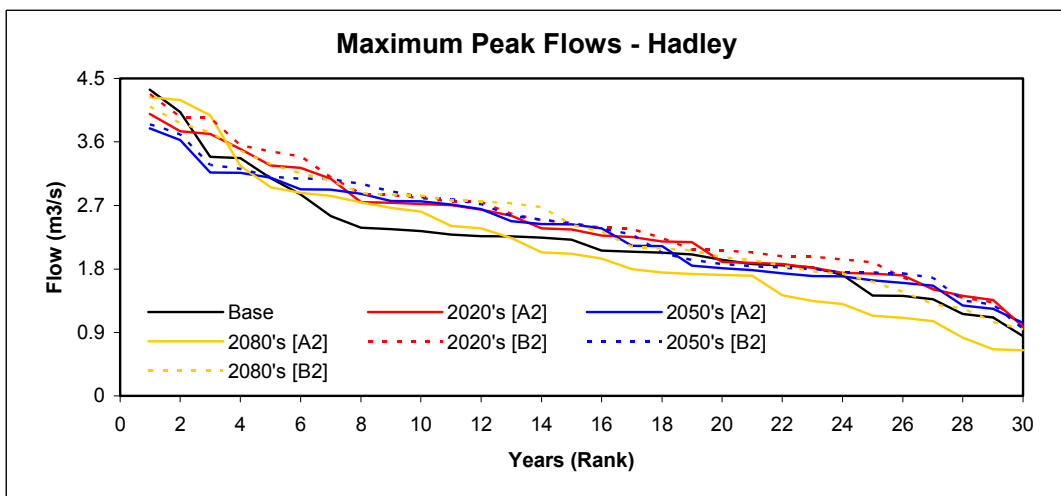
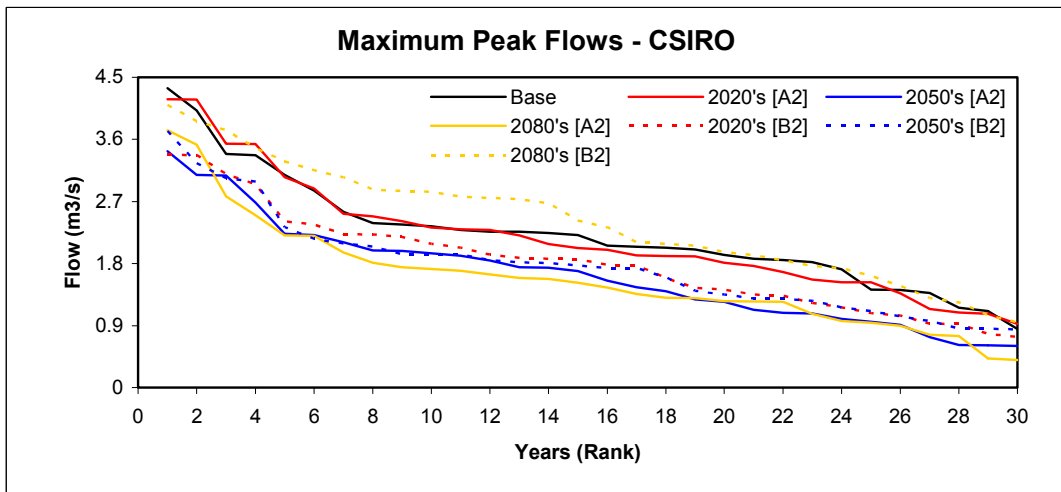
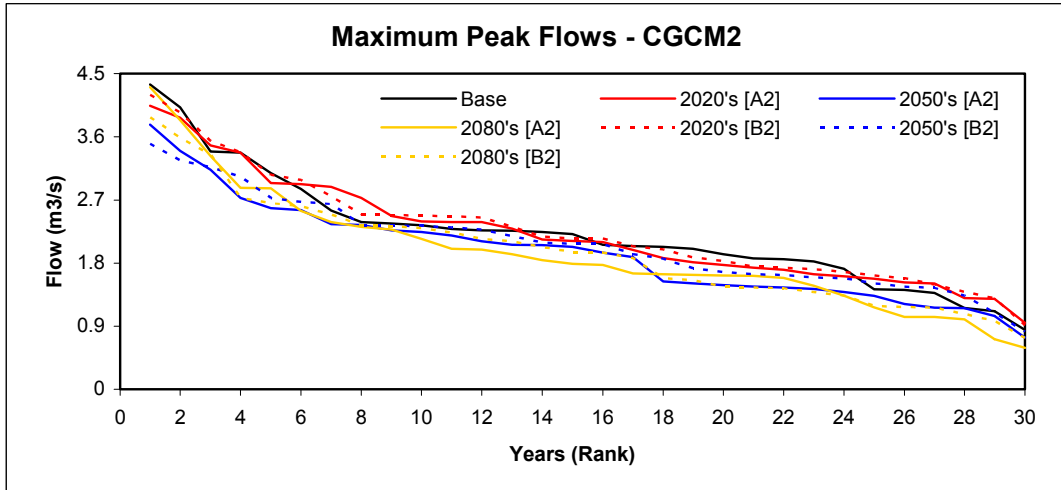


Figure 3.4.2: Maximum peak flows over the 30 year simulation period for the Ewer Creek subwatershed.

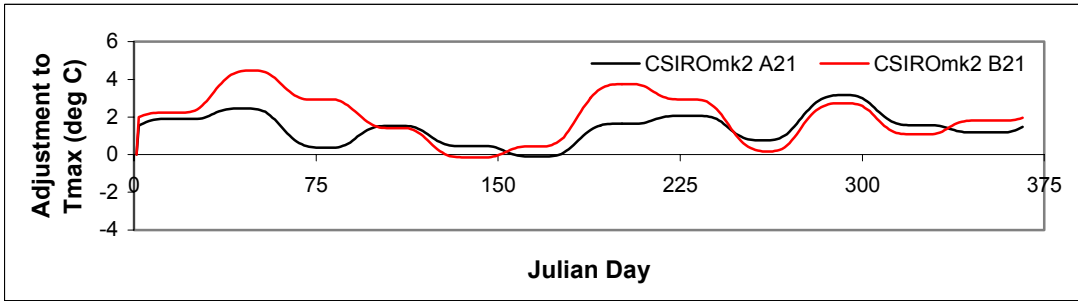
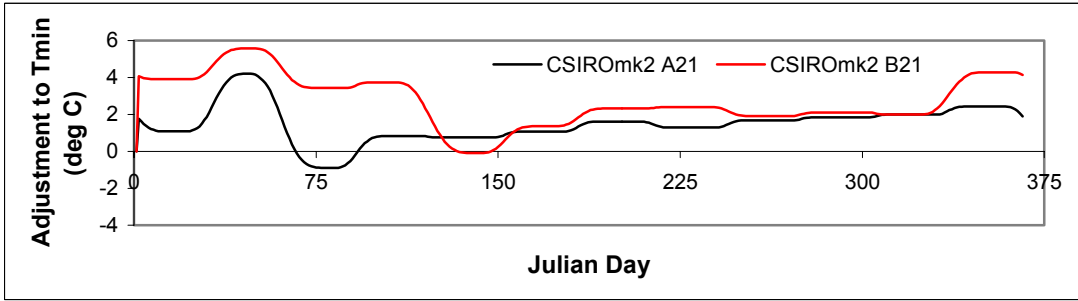
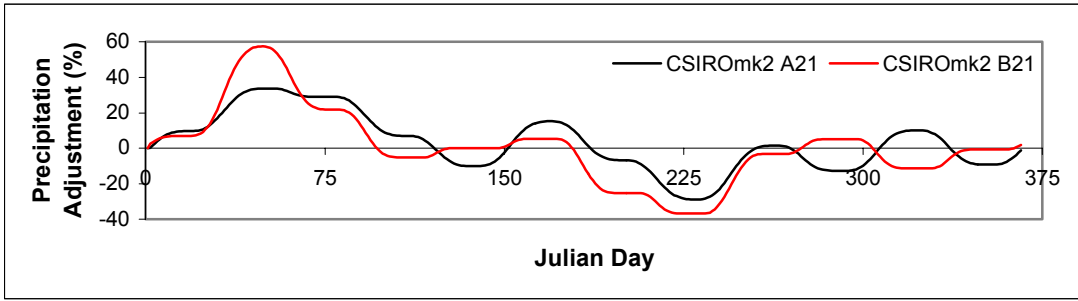


Figure 3.4.3: Daily adjustments to precipitation, minimum temperature, and maximum temperature for the CSIRO A2 and B2 emissions scenarios for the 2020's.

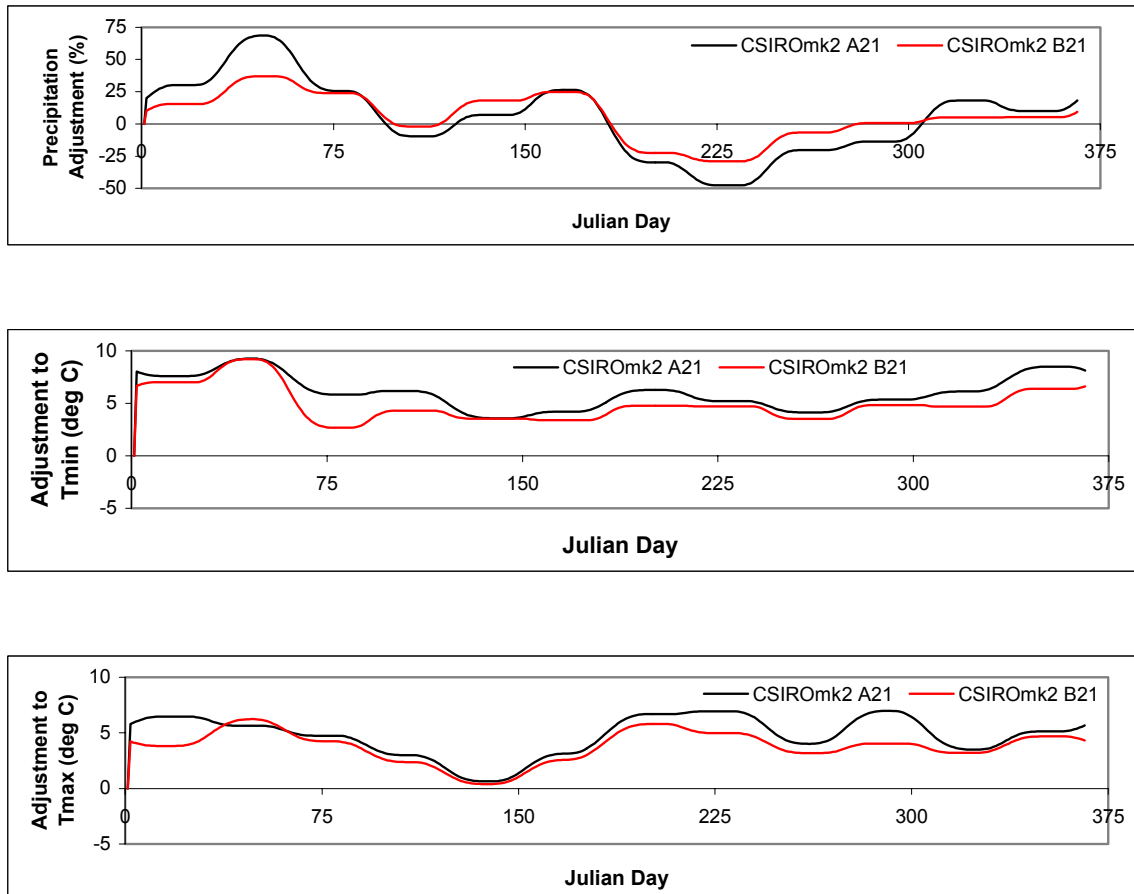


Figure 3.4.4: Daily adjustments to precipitation, minimum temperature, and maximum temperature for the CSIRO A2 and B2 emissions scenarios for the 2080's.

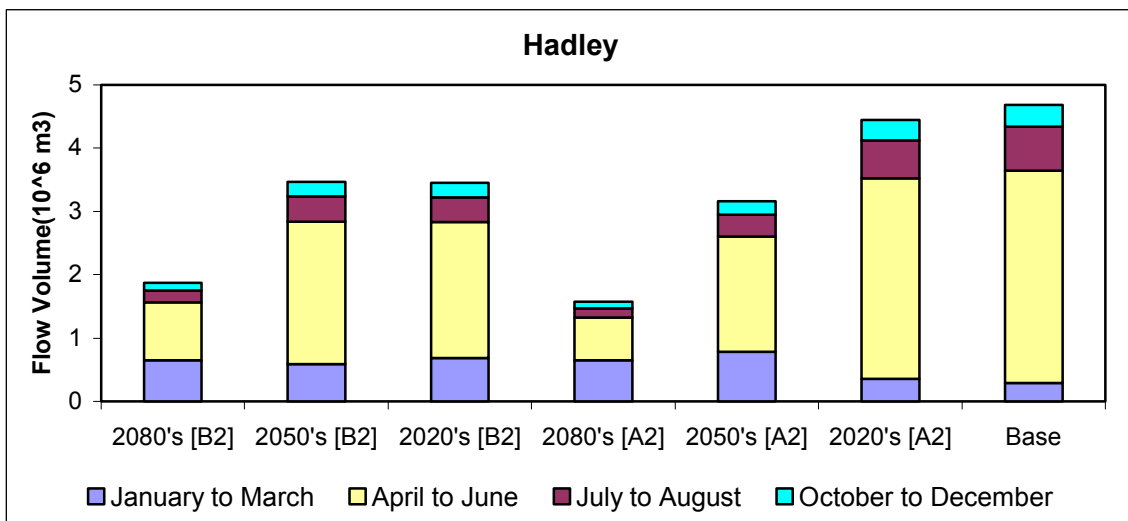
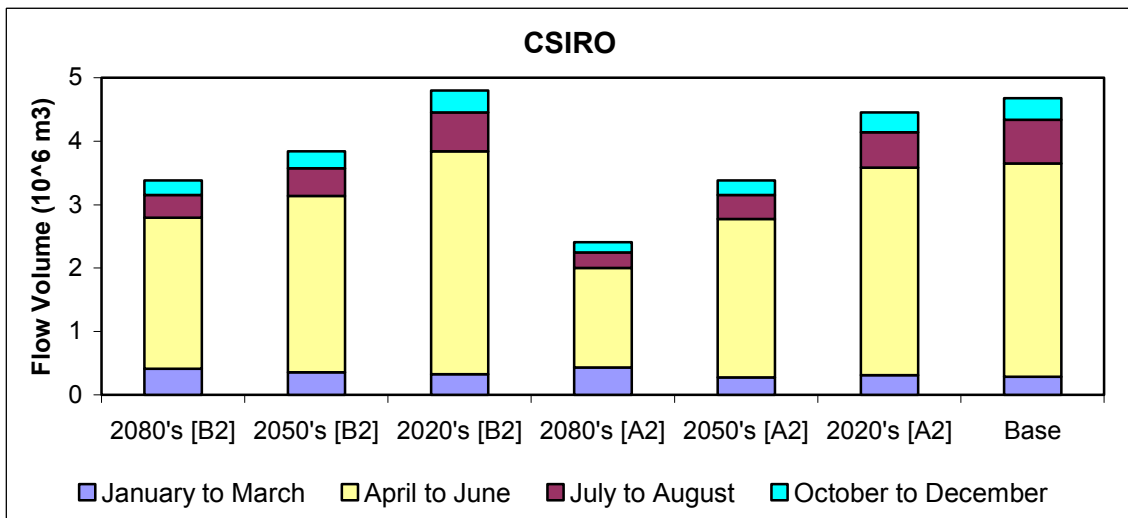
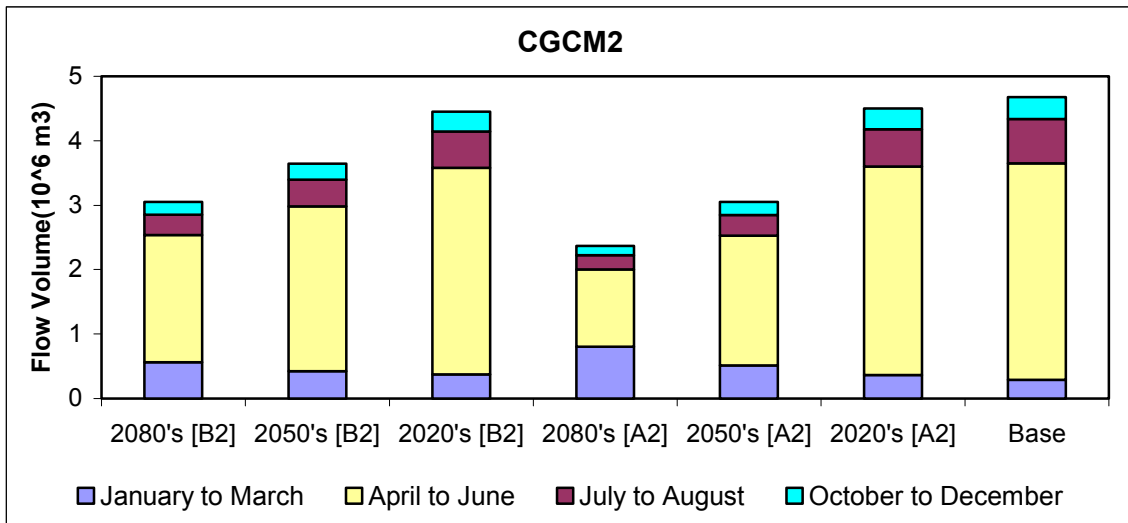


Figure 3.4.5: Mean seasonal flow volumes contributing to Ellis Reservoir

3.5 Discussion

The hydrology component of the project has involved

- testing the UBC Watershed Model on nine unregulated and gauged watersheds in the Okanagan Basin,
- regionalising model parameters from the gauged watersheds to ungauged watersheds in the Okanagan basin, and
- application of the climate scenarios to explore possible changes in the hydrological regime under climate change.

The UBC Watershed Model was demonstrated to be suitable for application to regions like the Okanagan Basin. Model calibrations were of reasonable quality for most watersheds and the model was generally shown to reproduce streamflow adequately for periods of record on which the model was not calibrated. The geographic transferability of the model was tested to verify that reasonable results could be expected when applying the model in ungauged watersheds. An average set of most parameters can be applied whilst still maintaining acceptable simulations of streamflow. The key parameters that require estimation for each ungauged watershed are the precipitation parameters. These parameters vary considerably, depending on the elevation range, the location of the watershed and the climate data used to drive the model. The calibration results show that much of the existing meteorological network is not representative of higher elevation watersheds. Despite these complications, the simple rules for allocating model parameters to ungauged tributaries appear to provide plausible results. Strengthening this work would require a detailed investigation of the relationship(s) between elevation and precipitation (amount and form) in a number of watersheds representing the different climatic regimes of the Okanagan Basin.

Model parameter sets were defined for the tributaries entering the main stem lakes and Okanagan River. The larger tributaries were sub-divided into a number of watersheds to which the UBC Watershed Model was applied. In addition, parameter sets were defined for watershed areas contributing to key reservoirs of interest in the region (Thirsk Dam, Greyback Lake, Ellis Reservoir, and the reservoir on McDonald Creek near Brenda Mines).

All scenarios have been run for the model watersheds and analyses of the scenario outputs are currently being undertaken. The preliminary results presented in this report provide an idea of the range in hydrological response to the climate scenarios. All scenarios consistently predicted an early onset of the freshet, a tendency towards a more rain dominated hydrograph and considerable reductions in annual and freshet flow volumes. The Hadley and CSIRO climate scenarios provide two quite different, although plausible, outlooks for the future hydrology of watersheds of the Okanagan Basin. With the Hadley climate model, the hydrograph is peaky and quite confined in the period of elevated flows. Such a scenario would pose difficulties with water managers who would have to cope with the majority of water entering their reservoirs in a very short time frame. They would have to manage water levels in the reservoir(s) keeping in mind the prolonged shortage of flows in the dry season downstream of the reservoir. In contrast, the CSIRO scenarios produce flatter hydrographs that distribute water more evenly through the season, in this sense making the job of managers easier. However, this would be offset by the extreme reduction in flows predicted by the climate model.

3.6 Acknowledgements

The UBC watershed model was developed, and provided for use in this project, by Dr. M.C. Quick and Civil Engineering, University of British Columbia. Edmond Yu provided technical support and assistance in running the hydrology model for which we are greatly appreciative. Bob Nicholson from the Ministry of Sustainable Resource Management (Decision Support Services) provided the Baseline Thematic Mapping data for use in this project.

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Chapter 4. Crop Water Demand

Denise Neilsen, Scott Smith

4.1 Agricultural Land Use

An agricultural land use database for the Okanagan basin has now been compiled and incorporated into a GIS using ArcInfo™ (Figure 5.1). Several data sources were used – Okanagan Vineyards (PARC, 2001) at a scale of 1:10,000; Tree fruit database (OVTFA, 1994) updated by data from the Okanagan Valley Sterile Insect release program at a scale of 1:20,000; Terrestrial Ecosystem Mapping (BCMSRM, 2001) at a scale of 1:20,000. Where gaps existed, they were filled by reference to the Canada Land Inventory (Statistics Canada, 1966) at a scale of 1:125,000, updated from cadastral survey data to eliminate urbanized areas. These data are now ready to be incorporated into a valley wide model for crop water demand estimates. (Figure 4.1.1)

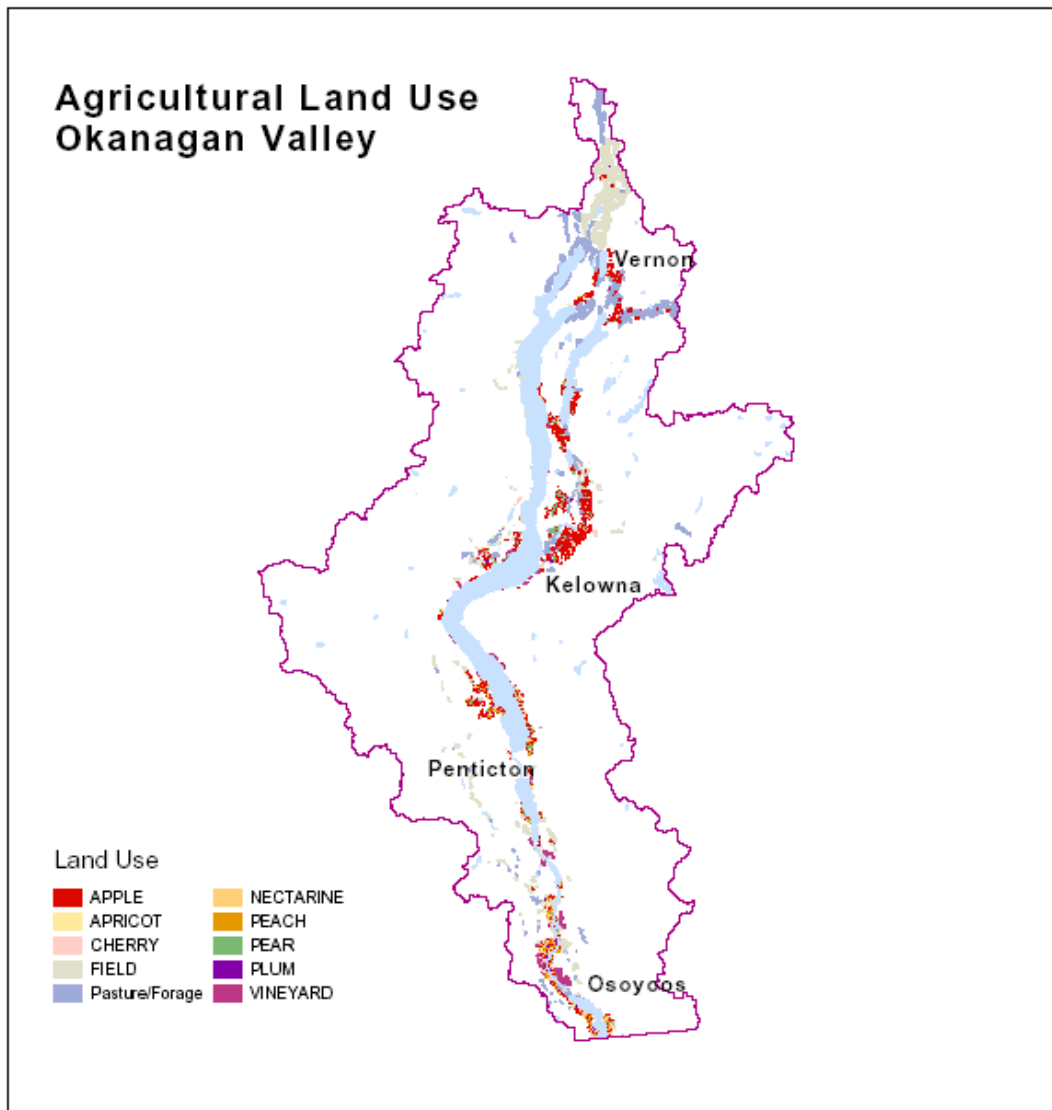


Figure 4.1.1: Agricultural land use in the Okanagan Valley

4.2 Agricultural Water Supply and Demand

Analysis of regional crop water demand is carried out, by integrating climate with estimates of water use for specific crops and the spatial land use data described above (section 4.1). The following outlines the data sources, assumptions and methodology used in calculating regional crop water demand.

4.2.1 Climate data

Historic and future crop water demand for the whole basin will be estimated for 1961-90 climate normals, and climates produced from perturbing 1961-90 data by output from GCM scenarios (section 2.3), using the 'delta' method. Potential inter-annual variability will be assessed for selected sub-watersheds from historic data.

4.2.1.1 Downscaling and Transformations of Climate Data for Basin – Wide Estimates

For basin-wide crop water demand estimates, station 1961-90 monthly normals for maximum and minimum daily temperature are perturbed using GCM scenario climate output and spatially interpolated using PRISM (Parameter-elevation Regressions on Independent Slopes Model) to an approximate 1 km x 1 km grid. PRISM is an expert system that uses point data and a digital elevation model (DEM) to generate gridded estimates of climate parameters (Daly et al., 1994). In a previous study, (Neilsen et al., 2001), it was noted that the spatial downscaling of temperature data based on the original 4x4 km grid-cell output from PRISM likely underestimated temperatures in crop use polygons because of the large elevation changes within the 4x4 km grid cells. This was based on observed differences between PRISM estimates and weather station temperatures. In consultation with Chris Daly (pers. comm.), the 4x4km has been re-scaled to a 1x1 km grid by calculating local average lapse rates based on existing grid cell temperature and elevation data. Data from the 24 nearest neighbour cells were pooled to calculate lapse rates. A sample output for July 1990 max temperature is given in Figure 4.2.1. Valley wide crop water use will be calculated based on the new 1x1 km grid.

A second transformation of scenario data involves the derivation of daily minimum and maximum temperature values during the growing season from PRISM monthly climate data (Tmax, Tmin). Daily mean temperature estimates are required to calculate growing degree day accumulations and daily maximum temperature is required to calculate evapotranspiration. The methodology is based on the observation that there is an approximate straight line relationship between temperature and Julian day (JD) from Jan 1- July 31 (JD 1-212) and a separate straight line relationship between August 1 and Dec 31 (JD 213-365). Each monthly average was assigned to the middle of the month and the value for most other days was then estimated by linear interpolation. Estimates for days between mid July and the end of July (JD 198-212) were extrapolated from June and July monthly means. Estimates for the days between August 1st and mid August (JD 213-228) were extrapolated from August and September monthly means.

Derivation of temperatures for a given Julian day was based on the algorithm:

$$T(JD_x) = T(JD_1) + ((JD_x - JD_1) / (JD_2 - JD_1)) * (T(JD_2) - T(JD_1)) \quad \text{where}$$

$T(JD_1)$ = monthly average temperature associated with Julian day 1

$T(JD_2)$ = monthly average temperature (for the next month) associated with Julian day 2

$T(JD_x)$ = monthly average temperature associated with Julian day 'x'

for interpolation	$JD_1 < JD_x < JD_2$
for extrapolation	$JD_2 < JD_x (198 < x < 212)$
	$JD_x < JD_1 (213 < x < 228)$

4.2.1.2 Downscaling and Transformations of Climate Data for selected sub-basins

For selected sub-basins, daily maximum and minimum temperature data for the nearest climate station for all years 1961-90 will be estimated from monthly GCM output using the approach outlined in section 2.2 after the method of Morrison (2002). Model output will be compared with the daily interpolation equation derived from long term weather records at the Summerland- CDA weather station, described above. Extrapolation of station data within the sub-basin will be determined from relationships derived for individual PRISM cells and the station PRISM cell.

4.2.1.3 Estimating potential evapotranspiration ET_o

Algorithms to estimate daily potential evapotranspiration during the growing season (JD92 - JD306) were developed from daily maximum temperature (T_{max}), day of the year (JD) and the latitude (LAT) of the site. A potential evapotranspiration (ET_o) value was calculated for each PRISM cell as:

$$ET_o = -3.26 + 0.210 T_{max} + 0.058 Q_o$$

Calculating ET_o requires derivation of Q_o , the solar energy ($MJ m^{-2}$) reaching the top of the atmosphere based on JD and LAT, and a set of intermediate variables ϕ , Δ , R, H1 and H2 where:

$$\phi = 0.01721 * JD$$

$$\Delta = 0.4093 * \sin(\phi - 1.405)$$

$$R = 1 + 0.033 * \cos(\phi)$$

$$H1 = -\arccos(-\tan(LAT) * \tan(\Delta))$$

$$H2 = \arccos(-\tan(LAT) * \tan(\Delta)) \quad \text{and}$$

$$Q_o = (18.838868 * R) * [\{\cos(LAT) * \cos(\Delta) * (\sin(H2) - \sin(H1))\} + \{\sin(LAT) * \sin(\Delta) * (H2 - H1)\}]$$

4.2.2 Crop water use

Equations for estimating seasonal crop coefficients (K_c) and growing season length have been derived for tree fruits and grapes and when combined with the estimates of maximum and minimum daily temperature and potential evapotranspiration outlined above allow a first estimate of crop water use.

4.2.2.1 Seasonal Crop Coefficients

The crop coefficient is the ratio of actual crop water use to estimated evapotranspiration. It varies with canopy size and for perennial crops increases to a maximum both over the growing season

and as the plant matures. In general, crop coefficient maxima for fruit trees are close to the Penman reference (grass) ET_o (1.0) despite the potential for greater transpiration in response to the increased wind speed and boundary layer conductance resulting from tree height. This has been attributed to the diurnal pattern of stomatal conductance in which stomatal closure occurs mid-afternoon regardless of water demand (Jarvis, 1985). Maximum mid-season crop coefficients (based on Penman ET_o) range from 0.9-0.95 for apricot, peach, pear and plum and from 0.95 - 1.0 for apple and cherry under clean cultivated conditions (Feres and Goldammer, 1990). These may be expected to be 20-30% higher under a cover crop (Doorenbos and Pruitt, 1977).

Water balance data from the Summerland lysimeter, have indicated that a maximum crop coefficient for drip irrigated apple is around 1.3mm ET/mm evaporation measured using an Etagage atmometer (Etagage Company, Loveland CO.). The atmometer is constructed with a ceramic evaporating surface covered by green baize cloth that is considered to be equivalent to a well-watered grass surface (the standard condition for the Penman ET_o). A relationship was derived from measured daily ET_o (atmometer-based) and corresponding daily weather data at PARC, Summerland ($R^2 = 0.58$).

For the purpose of the current climate change study, the seasonal crop coefficient curve derived from the Summerland lysimeter was applied for maximum canopy development in apple (

Figure 4.2.2).

Under the following assumptions the same curve was applied to other types of tree fruit:

1. Crop coefficients reported in the literature for different tree fruit crops are similar.
2. When the factor for cover crops (20-30% increase) is included, the crop coefficients for mature canopies of other fruits are similar to that derived at Summerland for apples.
3. To determine maximum demand, all orchards were considered mature.
4. All tree fruits were considered to be under sprinkler irrigation and an 'efficiency factor' was built into the equation (75%) (British Columbia Sprinkler Irrigation Manual 1989).
5. Despite slight differences in growing season lengths, irrigation duration is, in practice, similar for most tree fruits (first week of April to third week of October).
6. In all cases, daily crop water demand was calculated until evaporative demand ceased in the fall.

There are few water use data available for grapevines in the Okanagan valley. Published water use data for grapes in other regions are often presented as annual totals (Williams and Matthews 1990) and were consequently inappropriate for the current study where daily water demand estimates are required. Literature crop coefficients for wine grapes, where crop water use is directly measured in lysimeters (e.g. Evans et al., 1993) are greatly affected by local water management practices that are adopted to influence grape quality. Thus, crop water use in the fall may drop off considerably compared with peak demand. In the absence of any appropriate data for water use by grapes under Okanagan conditions, crop coefficient curves were derived from data presented by Peacock et al. (1987) for clean cultivated table grapes in the San Joaquin valley, California, where water deficit management techniques were not imposed. The absence of imposed water deficits in this study allowed for crop coefficients to be based on potential crop water use irrespective of management techniques which may differ according to variety, site and to the state of current knowledge regarding their benefits. These crop coefficient data (Peacock et al., 1987) were linked to phenological stage and could thus be adapted to growing seasons of different length. Generalized crop coefficient curves for both clean cultivated grapes and for grapes with a cover crop are shown in

Figure 4.2.2. Data for grapes with a grass cover crop were generated from the findings of Kottwitz (1984) who showed that 50% of total water use in centre-pivot sprinkler irrigated wine grapes was due to a 50% grass cover.

4.2.2.2 Length of growing season

Part of the increase in crop water demand is determined by the length of the growing season. Previously (Nielsen et al., 2001) the start of the growing season for apple was determined by the start of accumulation of growing degree day base 10°C (GDD10). This was thought to correspond with the timing of full bloom in apple, which coincides the time of rapid canopy development and hence increased demand for water for transpiration. For all other crops, the start of the growing season was based on previously observed average differences between their dates of full bloom and that of apple. The timing of budbreak in deciduous trees is a complex issue, and is related not only to genetic factors and increases in photoperiod and air temperature in the spring, but also to the magnitude and duration of cold temperatures experienced in the winter (Kramer and Koslowski, 1979). For the current study, we examined the relationships between degree day accumulations and bloom date in a complete and well recorded, set of data collected between 1937 and 1964 at the Summerland Research Centre. The advantages of these data were that they were 1) collected on the same trees over the period, 2) collected by the same individual, 3) there was a range of species at one location 4) collected for phenological studies. Regression analysis indicated that the relationship between the bloom dates of apple and start of accumulation of GDD10 was better than that of all other species with either GDD5 or GDD 10 (Figure 4.2.3 and Figure 4.2.4). Regression analysis also indicated that there were strong relationships between the data of apple bloom and the date of bloom for other species (Figure 4.2.5), although this was less well established for apricot and peach than for pear, cherry and plum. It is not surprising that there are strong relationships among bloom dates for different species in any given year as all are responding to similar ranges of conditions. Consequently, a combination of the equation for GDD10 and apple bloom, and the relationships derived for apple and other species, will be used for assessing the start of the growing season for each crop.

4.2.2.3 Irrigation District Mapping for Assessment of Water Demand

To match crop water demand against licensed irrigation supply, the boundaries for local government and irrigation jurisdictions were incorporated into the GIS (Figure 4.2.6). For this map, smaller districts within the central and north Okanagan have been grouped within regional districts. However, calculations are available for each individual district. For cities, towns and regional districts, digital maps were acquired. For other jurisdictions, paper maps were obtained from the B.C. Ministry of Municipal Affairs and boundaries created by digitizing.

4.2.2.4 Modelling Regional Crop Water Demand

ARC Macro Language programming within ARC/INFO was used to assemble climate scenarios and land use coverage. PRISM grid data for the twelve mean monthly maximum and minimum temperatures have been overlain with the agricultural land use coverage. This procedure created a database that described climatic conditions, over the year, for each unique land unit (polygon). The centroids of latitude and longitude for each polygon were added to the database and the values converted to radians, a necessary input for the calculation of ET. Visual Basic programming was used with Microsoft Access™ to perform daily time-step calculations of crop water demand. The final coverage was then exported to a GIS viewer (ESRI ARC View™) for query and summary at the grid, local authority or regional scale of yearly values by land unit for PE, growing degree days base 5°C and 10°C and volume of water demand. Two additional

queries were also developed to summarize weighted mean values for these attributes by crop type.

4.2.3 Risk Assessment

Risk assessment for irrigation water supply, will require an understanding of inter-annual variation in both demand and supply. Using the historical record of climate data from Summerland-CDA, the variation in crop water demand was calculated for a hypothetical hectare of apple (Figure 4.2.7). Between 1916 and 2002, the water demand ranged from 900 to 1180mm, with an average of 1026mm. Using PRISM cell based estimates for 1961-1990 climate normals and data adjusted by the 'delta' method using CGCM_1 output for 2020, 2050 and 2080 time-slices, the average estimated crop water use was 872, 1015, 1119 and 1239 mm respectively. It should be noted that the average for the 1961-1990 normal data was considerably lower than the average calculated for 1916-2002 daily data (Figure 4.2.7). These estimates indicate that, within the next 100 years, 'average' water demand, estimated from 'adjusted normals' data is likely to meet and exceed the most extreme demand experienced in the historical record. If the variation in climate continues to follow a distribution similar to that observed between 1916-2000, the highest crop water demand (1180mm) exceeded 1% of the time in the historical record, would potentially be exceeded 27% of the time by the 2050's. Calculations for the Summerland CDA station data, perturbed by additional GCM scenario output will be available shortly. It is anticipated that some estimate of inter-annual variability will be included in estimates of crop water demand for the detailed case studies for the Trout Creek, Ellis Creek and Penticton Creek watersheds based on this information and/or weather generator modeling.

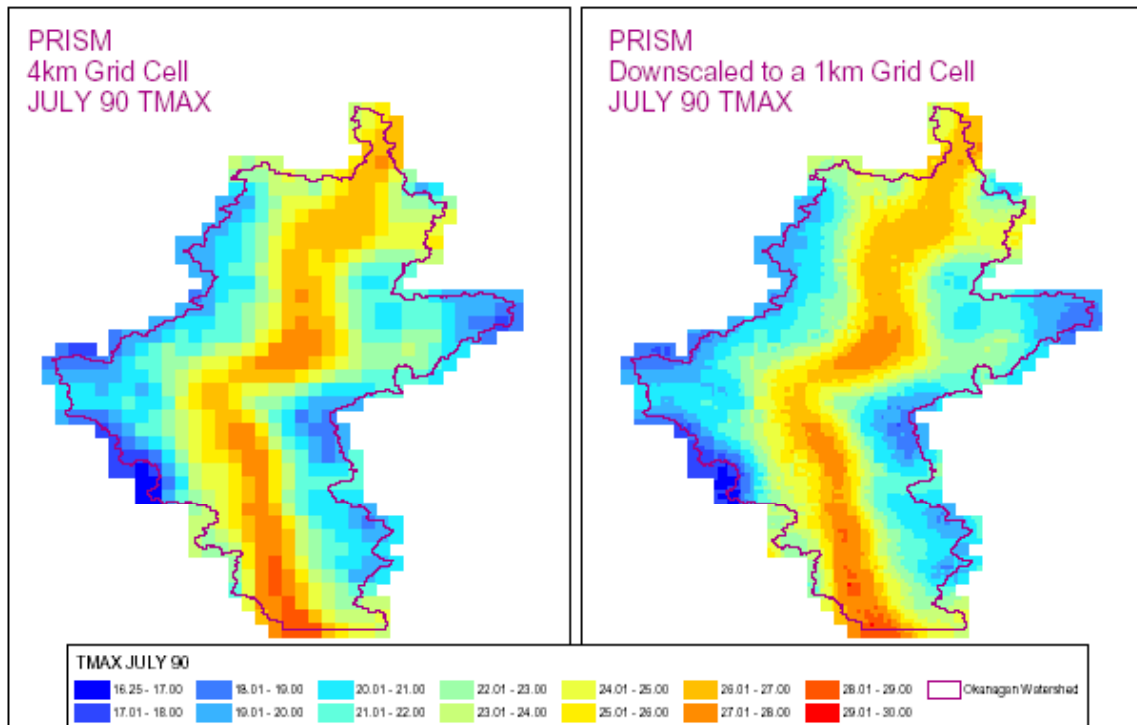


Figure 4.2.1: Rescaling Prism from a 4x4 km grid to a 1x1 km grid

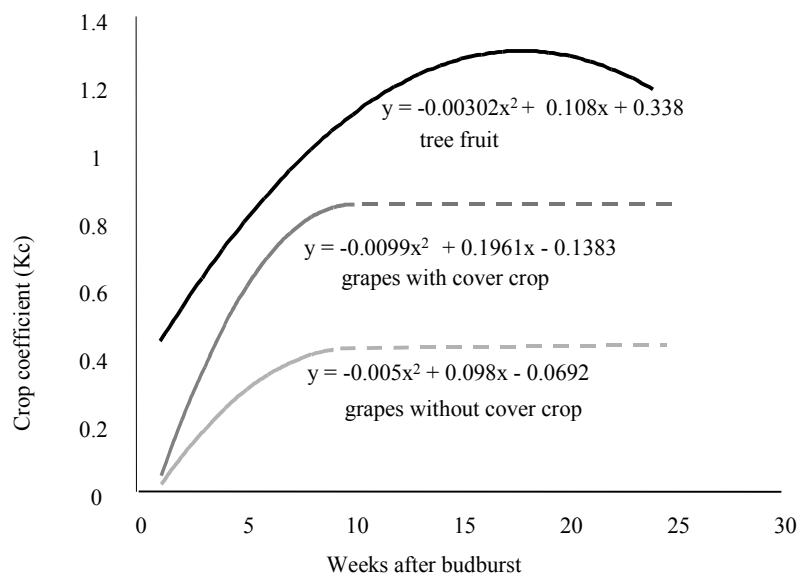


Figure 4.2.2: Seasonal crop coefficient (Kc) curves for mature deciduous fruit trees and grapes in the Okanagan valley (mm water use/mm evaporation).

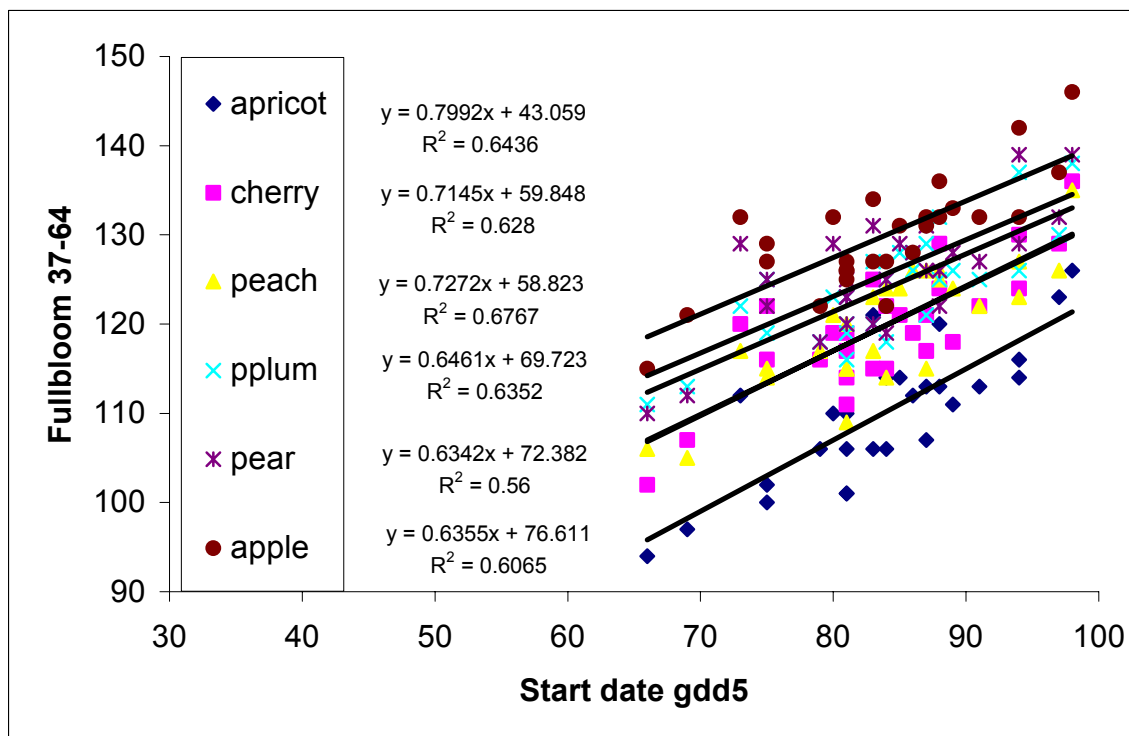


Figure 4.2.3: Relationship between timing of full bloom and the start of GDD5 accumulation

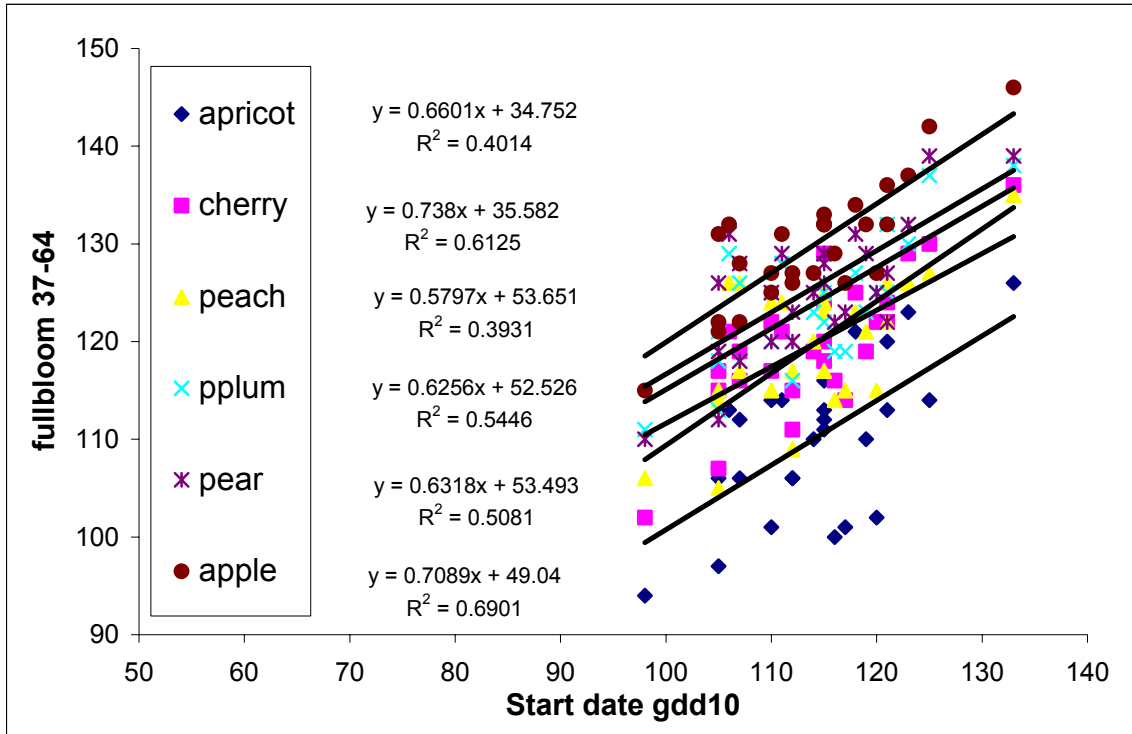


Figure 4.2.4: Relationship between timing of full bloom and the start of GDD10 accumulation

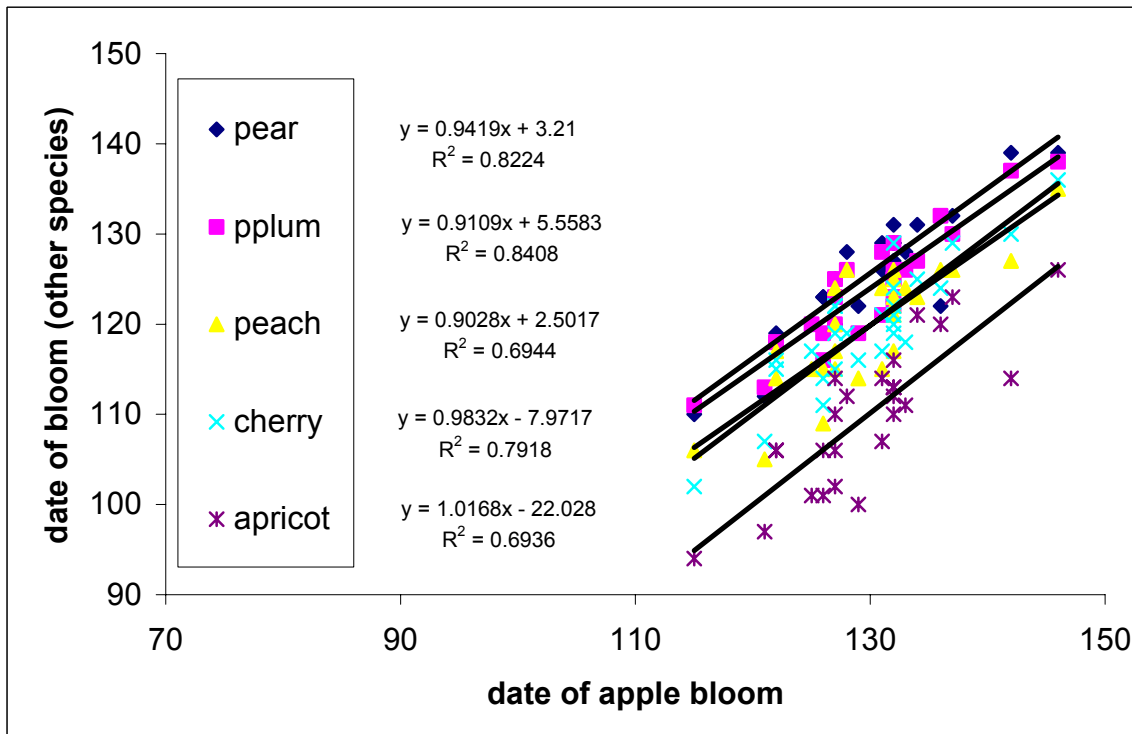


Figure 4.2.5: Relationships among timing of full bloom in apple and in other species

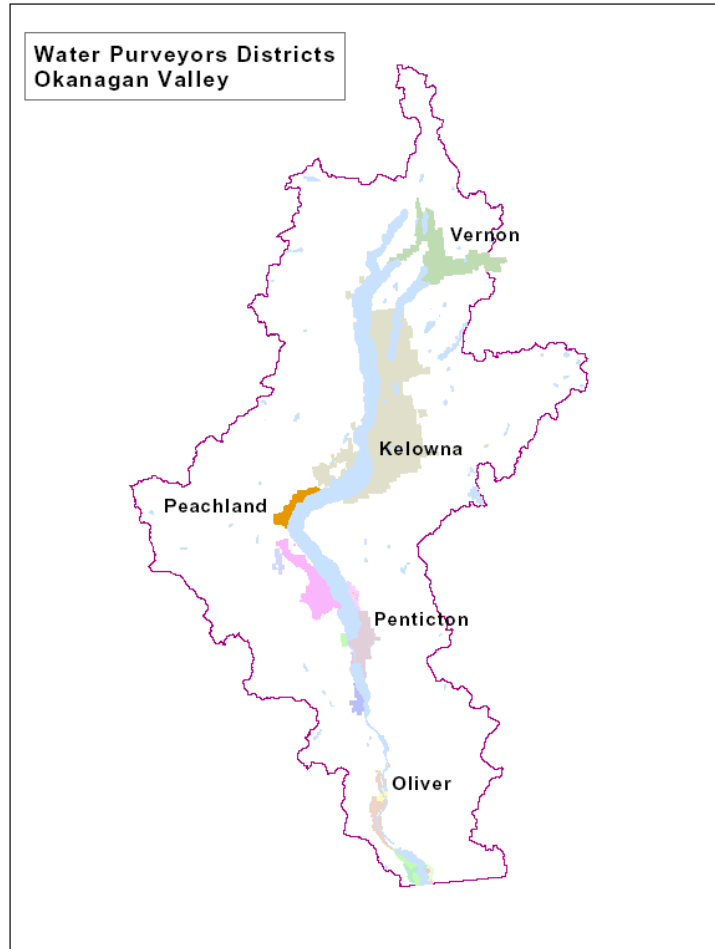


Figure 4.2.6: Water Purveyor districts in the Okanagan Basin

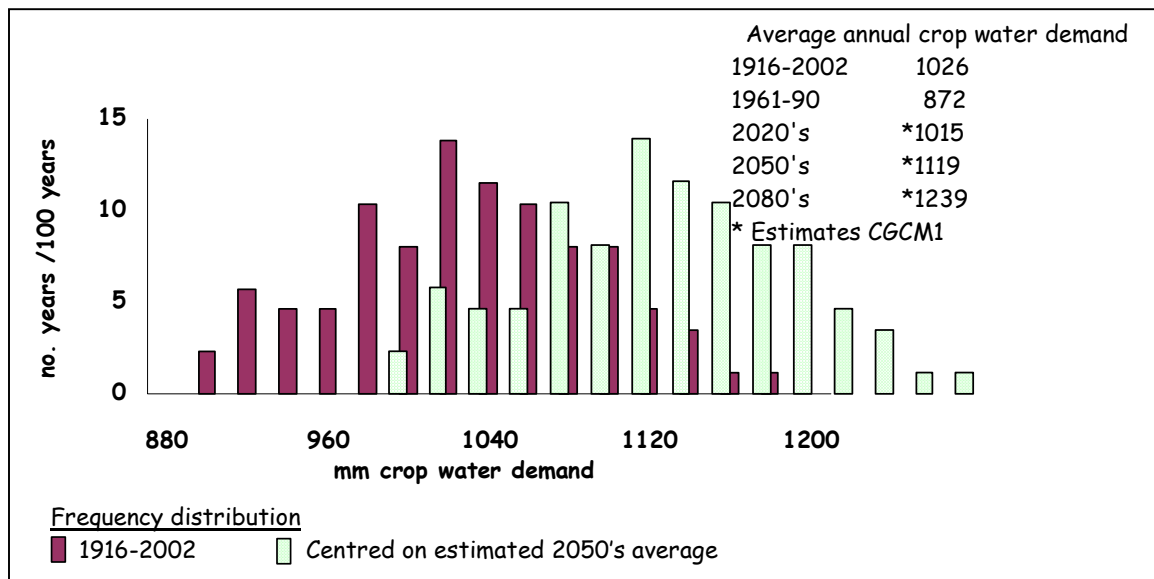


Figure 4.2.7: Frequency of modeled crop water demand for hypothetical hectare of apple at Summerland based on climate data from historical record 1916-2002 and estimated from CGCM1

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Chapter 5. Water Management

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5.1 Institutional Framework for Water Management

There are three primary features of the Okanagan watershed which emphasise the complex, convoluted and multi-scale structure of interacting organisations and institutions involved in water management decisions:

- The water system crosses an international border
- Multiple levels of government
- Multiple in-stream and out-of-stream water uses meaning many advocacy organisations at different scales

The Okanagan Basin adjoins the Columbia Basin at the Canada-US border, which crosses Osoyoos Lake. Two organisations are concerned with cross-border relationships regarding water resources and the environment. The International Joint Commission (IJC) is an independent bi-national organization, which was established by the Federal Boundary Waters Treaty of 1909. This treaty set the basic principles for guiding boundary water relations between Canada and the US. To assist it with supervision, monitoring and research functions, the IJC created bilateral boards of which the Osoyoos Lake Board of Control was one. It was established to supervise the operation of the upgraded Zosel Dam (completed in 1987), which controls the level of Osoyoos Lake, and to ensure compliance with the IJC's Order of Approval. The Environmental Co-operation Agreement of 1992 established the BC/Washington Environmental Cooperation Council to ensure coordinated action and information sharing on critical cross-border environmental issues.

Governance and regulation of water supply, quality and demand in the Okanagan Basin is divided amongst four levels: federal, provincial, regional and local. Division of responsibilities for water between federal and provincial agencies is complex and often shared. Under the Constitution Act 1867, provinces own both surface and groundwater resources, while water on federal lands (e.g. National Parks), in the territories and on Indian Reserves falls under federal jurisdiction. The federal government also has responsibility for boundary and transboundary waters under the International River Improvements Act, which controls activities that may affect the flow of rivers entering the US. Provincial ministries are the key regulatory bodies governing a wide-range of water-related issues: pollution, flow regulation, watershed management, etc. Federal responsibilities, on the other hand, primarily cover areas that have the potential for significant national economic impact such as navigation and fisheries. The key federal agencies and provincial ministries directly and indirectly involved in regulation of water quantity and quality are:

- Federal**
 - Environment Canada (EC)
 - Fisheries and Oceans Canada (FOC)
 - Agriculture and Agri-Food Canada (AFFC)

- Provincial**
 - Ministry of Sustainable Resource Management (MSRM)
 - Land and Water BC (LWBC)
 - Ministry of Water, Land and Air Protection (MWLAP)
 - Ministry of Health Services (MHS)
 - Ministry of Forestry (MF)
 - Ministry of Agriculture, Food and Fisheries (MAFF)

The degree to which responsibilities are shared between federal and provincial bodies varies from year to year, and includes interprovincial water issues, agriculture, significant national water issues, and health. The Canada Water Act defines provisions for formal consultation and agreements with the provinces “to provide for management of the water resources of Canada, including research and the planning and implementation of programs relating to the conservation, development and utilization of water resources.”

The Local Government Act RSBC 1996, c. 224 administered by the BC Ministry of Community, Aboriginal and Women’s Services, sets out the framework for the local government system in British Columbia. It defines the creation, structure and operation of the three types of local government: regional districts, municipalities and improvement districts, as well as their powers and responsibilities, which differ between the three. The Okanagan is split into three regional districts, 11 municipalities and 40 improvement districts. Regional districts are the latest form of local governance, being established in the Okanagan in the mid-1960s to provide basic services, such as water, to residents of unincorporated areas. Municipalities generally provide multiple services to an urban customer base, while improvement districts were established to deliver one or more public services to a community, such as water, fire protection, street lighting, dyking, drainage, garbage collection and parks. The smallest bodies providing water are Water User Communities – public corporate bodies incorporated under the Water Act RSBC 1996, c. 483. Six or more different licensees, each of whom hold their own license(s), can form a Water User Community.

Water on Indian Reserves is under federal jurisdiction. The Okanagan Nation Alliance is the Tribal Council representing the people of the Okanagan Nation, which is comprised of seven Indian Band Reserves (ONA, 2000a). The Bands participate in the Okanagan Nation Fisheries Commission (ONFC), which was established in 1995. “The goal and mandate of the ONFC is the conservation, protection, restoration, and enhancement of indigenous fisheries (anadromous and resident) and aquatic resources within Okanagan Nation territory. The ONFC provides technical assistance to the member Bands and also acts as a liaison with federal and provincial agencies” (ONA, 2000b).

There is one key inter-regional body in the Okanagan region - the Okanagan Basin Water Board (OBWB). The Board was established after the completion of the Okanagan Basin Agreement study in 1974 as a first step to creating a body responsible for valley-wide water resource issues. Until now activities have focused on control of Eurasian water milfoil and funding of liquid waste treatment projects in partnership with the provincial government. As the OBWB has achieved its main objectives of reducing phosphorus loading to the lake and controlling milfoil, the role of the OBWB is being questioned and is currently under review. The Okanagan Basin Technical Working Group is a tripartite body with representatives from DFO, MWLAP, and ONFC. General objectives for this group are to identify and 'steer' initiatives designed to rebuild fish stocks, including salmon, in the Okanagan River basin in Canada.

In addition to the legally mandated organisations party to water management in the Okanagan Basin, there are several significant non-governmental players at the regional level. These can be divided into four primary topics: protection of fisheries and their habitats, watershed stewardship, supporting the local agricultural community and aiding better local water management practices. Some of the most predominant groups include:

- | | |
|-------------------------|---|
| Fisheries | <ul style="list-style-type: none">• Okanagan Similkameen Boundary Fisheries Partnership |
| Watersheds | <ul style="list-style-type: none">• Community Watershed Round Tables |
| Agriculture | <ul style="list-style-type: none">• BC Fruit Growers' Association• Okanagan Valley Tree Fruit Authority. |
| Water Management | <ul style="list-style-type: none">• Water Supply Association• BC Water and Waste Association |

Appendix C provides a brief description of the key institutions involved in water management in the Okanagan.

5.2 Regulatory Framework

This section outlines the provincial and federal regulatory framework for water supply, quality, use and ecosystem health. Due to ongoing changes to the regulatory framework, the information in this section is considered current as of April 1, 2003.

5.2.1 Water Allocation and Licensing

British Columbia's water allocation and licensing system evolved in the context of settlement patterns and associated land uses during the latter half of the 1800s (Wilson, 1989). The early importance of irrigation for agriculture and water supplies for gold mining in the BC interior favoured a system of water rights allowing use of water on non-riparian lands. Under English Common Law, only riparian landowners had the right to use water flowing through or adjacent to their lands. This was found to be restrictive to the development of agriculture and mining because riparian rights did not allow use of water on non-riparian lands or grant water rights to non-riparian landowners. To overcome these restrictions, a system based on appropriative rights, became the dominant water rights system in British Columbia.

The appropriative system, which evolved during the European settlement of the western United States, has two characteristics that remain central to British Columbia's system of water rights: beneficial use and prior appropriation (Scott, 1991). Prior appropriation grants the right to use water on a "first come, first served" basis, giving priority access to the water resource to the earliest license holder. In drought conditions, holders of the earliest licenses issued on a source have the right to use their entire allotment before holders of later licenses. The concept of beneficial use is designed to ensure that efficient use is being made of scarce water resources. Under the appropriative system, a license holder who does not demonstrate beneficial use of water forfeits the water right, regardless of the priority of the right. British Columbia's current water rights law retains the principles of beneficial use and prior appropriation.

An examination of the regulatory framework for water rights in British Columbia must begin with the Canadian Constitution, the supreme law of Canada. The Constitution Act 1867 divides legislative powers between the Canadian parliament and the provincial legislatures. Section 92.13 gives the provinces legislative authority over "Property and Civil rights in the Province" and is most relevant to a discussion of water rights in British Columbia. Section 92.16 is also important, allowing provinces to legislate in "Generally all Matters of a merely local or private Nature in the Province." Other sections of the Constitution Act apply more generally to water management. These include s. 91.12 giving the Parliament of Canada legislative authority over "Sea Coast and Inland Fisheries" and s. 95 stating that the Parliament of Canada and the provincial legislatures have concurrent authority to legislate in matters pertaining to agriculture.

Following from s. 92.13 of the Constitution Act, the Province of British Columbia has the power to make legislation regarding property rights, including water rights, in the province. In British Columbia, water rights are governed primarily by the Water Act RSBC 1996 c. 483. Section 2(1) of the Water Act vests ownership of all surface water resources in the government of British Columbia. The province uses a water licensing system, also defined in the Water Act, to "allow users to occupy the Crown's own water rights" (Scott, 1991, p.356). Water licenses, therefore, give the license holder a legal right to use water, but not ownership of the water resource.

The Water Act, and the associated system of water rights, applies only to surface waters in British Columbia. Section 3 of the Water Act states that the Lieutenant Governor in Council may develop regulations to apply the Act to groundwater, however this has not occurred to date. While there are several statutes, regulations and guidelines that affect groundwater use in British Columbia¹, there are no laws specifically pertaining to management of groundwater or allocation of rights to use groundwater (Foweraker et. al., no date). Unlike surface water, groundwater sources may be developed without a water license.

The Water Act states that water licenses issued after June 21, 1995 must specify the date of precedence, the purposes for which the water will be used and the land or undertaking to which the license is appurtenant. The date of precedence is the feature of water licenses that allows prior appropriation rules to be applied. Section 15 describes how the date of precedence is used, giving priority to licenses with the earliest precedence dates. For licenses with the same date of precedence on the same source, priority of purposes is used to determine precedence of the water right. Water licenses may specify up to three purposes such as domestic, irrigation, stock watering, electrical generation, etc. The Water Act ranks these purposes in priority order, with domestic uses ranked as the highest priority over other purposes. Specification of purposes for

¹ These include the Waste Management Act, Health Act and the Environment Management Act.

which water will be used also supports the concept of beneficial use. Section 23(2)(a) of the Water Act allows a water license to be suspended or revoked if the licensee does not make beneficial use of the water as outlined in the terms of the license. Beneficial use is not defined in the Water Act; however, s. 39 (1)(c) gives “engineers and officers” employed by the government the power to determine what constitutes beneficial use.

The British Columbia Ministry of Sustainable Resource Management (MSRM) is responsible for administering the water allocation functions indicated in the Water Act. MSRM has delegated certain functions, such as the administration of water license applications, to Land and Water BC, a provincial crown corporation.

The availability of water for allocation is determined using stream flow measurements averaged over five years as well as an analysis of the probability that enough water will be available to supply new and existing water rights in a specified number of years (probability of occurrence) (Mike Collette and Neil Banera, pers. comm.). A variety of legal persons, such as government agencies, owners or administrators of lands or undertakings (eg. mines), water utilities, etc., may apply for water licenses. The water license application must specify the purpose(s) for which the water will be used, the quantity to be used for each purpose, any constructed works required to make use of the water, the source (eg. creek, lake, spring, etc.) and the point of diversion. If the application is approved, this information is incorporated into the terms of the license along with any conditions that the comptroller deems necessary. Conditions may specify a date for completion of works, a date from which beneficial use of the water must be made, requirements for installation of monitoring equipment, such as meters, or requirements for storage.

Water rights issued with a license are perpetual; they do not expire or require renewal. Licenses are transferred or divided when the land or undertaking to which they are appurtenant is sold, subdivided or otherwise transferred. The date of precedence does not change with transfer or division of a water license therefore the priority of the water license on the source remains constant.

In general, the Ministry of Sustainable Resource Management and Land and Water BC appear to carry out little active management of water licenses beyond the processing of applications and approvals. The Ministry does not monitor actual consumption or beneficial use on a regular basis (Mike Collette, pers. comm.), however it may take these into consideration when evaluating new license applications (Neil Banera, pers. comm.). The Water Act provides for a reporting system in Section 22.01, stating that licensees are required to submit signed declarations that water has been used beneficially in accordance with the terms of the license, however it is unclear whether these provisions are used in practice. Determining the relationship between the quantities of water allocated in water licenses and the amount used is therefore a challenging task. Outside of the more sophisticated water utilities that use monitoring equipment such as water meters, information on actual consumption may not be readily available.

The Okanagan Basin presents an interesting forum for exploring water allocation and licensing given its semi-arid climate, its growing population and the importance of irrigation to the regional economy. As of July 2002, there were approximately 4130 active water licenses in the Okanagan Basin listed in the Water License Query database maintained by Land and Water BC (Land and Water BC, no date). These licenses represent approximately 1.05 billion cubic meters of allocated water on 980 streams for both consumptive and in stream uses. Sixty-six water license applications were also listed requesting a further 209 million cubic meters. Of the 1.05 billion m³ of water allocated in the Okanagan, 476.8 million m³ is allocated for consumptive purposes, where water is removed from the source. Of this licensed quantity, approximately 67% is

allocated for the purposes of “Irrigation” and “Irrigation Local Auth,” 31% for “Waterworks Local Auth” and “Waterworks (Other)” and the remaining 2% for other purposes including “Watering,” “Domestic” and “Enterprise”² (see Figure 5.2.1).

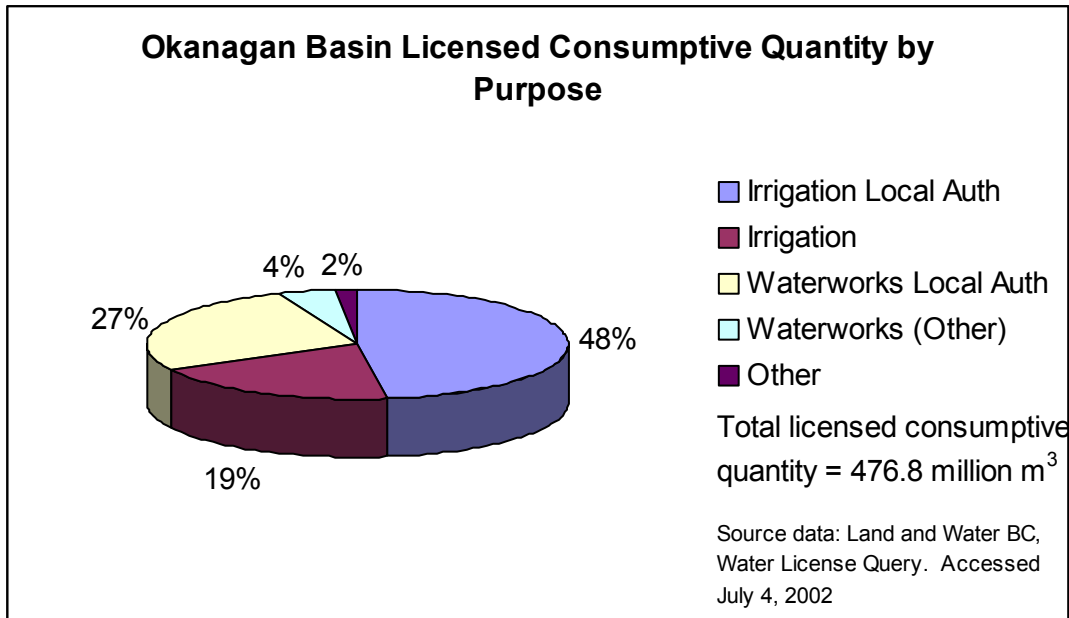


Figure 5.2.1: Licensed consumptive quantity in the Okanagan Basin by purpose.

Given the lack of information on actual water consumption in the Okanagan Basin, it is difficult to determine how licensed quantity relates to water demand in the region. However, management practices do appear to make the assumption that licensed quantity and actual use are approximately the same. Unlike riparian rights systems in which the rights of downstream riparians with respect to water quality and quantity must be considered, the prior appropriation system allows the allocation of more water than actually exists in a particular source. Management of water rights in British Columbia appears to have incorporated procedures to limit this occurrence and to consider the impact of new allocations on existing licensees and other parties. One example of this is the use of five-year stream flow averages and probability of occurrence analyses mentioned above to ensure that water is available for allocation. The water license application procedure also requires that other agencies be notified of new allocations and may require that downstream licensees and landowners whose land may be affected by the construction of works be given an opportunity to comment (Neil Banera, pers. comm.).

Another management tool is the maintenance of a List of Stream Restrictions and Water Reserves. Approximately 300 streams in the Okanagan were listed in the July 17, 2002, version of this document published on the Land and Water BC website (Land and Water BC, 2002). 235 of the streams on this list are designated as “fully recorded” (insufficient water to grant further licenses), fully recorded with some limited use (eg. small domestic withdrawals or new uses supported by storage) or “refused no water” implying the stream is fully recorded and license applications have been rejected. 39 streams have the designation “possible water shortage” and

² For full descriptions of the water license purposes, refer to <http://www.elp.gov.bc.ca:8000/wat/wrs/fs3fees2.doc>

the remaining streams are either designated as reserves or are restricted in use (eg. during spring freshet only).

Given the proportion of streams that are fully recorded or have possible water shortages, it is not surprising that conflicts between water users can arise during low flow periods. Under strict prior appropriation rules, the highest priority licenses would have first access to any water in these situations. While prior appropriation is practiced, other options, such as cooperative agreements among licensees are also used regularly (eg. all licensees agree to use 10% less water) (Neil Banera, pers. comm.). The principle of beneficial use has been applied much less frequently to resolve water shortage situations. Only one example of the application of beneficial use has been found during this investigation. In this case, an irrigation district's application for a water license to develop a new source was refused on the basis that the district had not proved it was using its existing supply efficiently (Neil Banera, pers. comm.).

Ecological considerations, such as ensuring sufficient water for fish habitat, are not explicitly considered in the Water Act. Under the licensing system laid out in the Act, the entire flow (or more) of a stream can be allocated for consumptive uses without consideration of the stream's ecological functions. In 1985/6 the Deputy Minister of Environment, Lands and Parks enacted a policy giving the managers of the water licensing system the power to refuse water license applications which would have a "significant and adverse impact" on fish populations, or include conditions in the license for the benefit of fish habitat (eg. requirements for fish screens on intakes, reductions in consumptive use during low flow periods) (Neil Banera, pers. comm.). While there have been challenges in implementing fish flow requirements, water licensing decisions currently incorporate a fish flow reserve of 10% of mean annual stream flow (see section 5.2.4 Fish and Habitat Management).

5.2.2 Water Quality Regulation

5.2.2.1 Drinking water: regulation, monitoring and assessment

Federal

Water quality management is primarily a provincial responsibility. However, the Canada Water Act R.S., c.5(1st Supp.), s.1 (Part II) specifies the prohibition of polluting any waters that have been designated a water quality management area either through a federal-provincial agreement where water assessment is deemed of federal interest, or "where the water quality management of any inter-jurisdictional waters has become a matter of urgent national concern." Water quality concerns on federal lands e.g. Indian Reserves and National Parks, are the jurisdiction and responsibility of the Federal Government.

Health Canada has published Guidelines for Canadian Drinking Water Quality (GCDWQ) since 1968, which apply to most, if not all, provinces (Federal-Provincial-Territorial Committee on Drinking Water, 2002). The Federal-Provincial Subcommittee on Drinking Water prepares the guidelines. The Subcommittee is made up of representatives from each province and territory, as well as from Health Canada. Health Canada also produces Guidelines on Recreational Water Quality.

In 2002, the Federal-Provincial-Territorial Committee on Drinking Water and the Water Quality Task Group of the Canadian Council of Ministers of the Environment (CCME) published a position paper advocating a multi-barrier approach to protecting water quality including source water protection, drinking water treatment, and distribution systems³.

Provincial

Currently, the only proclaimed drinking water regulation in BC is the Safe Drinking Water Regulation, B.C. Reg. 230/92, (SDWR) adopted under the Health Act RSBC 1996, c. 178. It deals only with the presence of fecal coliform, E. coli and total coliform presence, and under section 5 specifies that the water purveyor has the responsibility to provide potable (“water that meets the standards established by Schedule A, *Microbiological Standards*, and is safe to drink and fit for domestic purposes without further treatment”) water to all users served by a water works system. Under section 5 of the SDWR, a water purveyor must ensure that water samples are collected from locations at a minimum frequency and shipped to a laboratory in accordance with procedures established by the medical health officer or public health inspector.

Due to deteriorating water quality in B.C., decreased tolerance of colour, greater public concern over water quality and disinfection by-products, and the death of seven people in Walkerton, Ontario caused by unsafe levels of E.coli bacteria in the town water supply, the provincial (New Democratic Party) government enacted the Drinking Water Protection Act, Bill 20, in 2001 prior to the provincial election. The Act attempts to integrate the current mix of legislation dealing with drinking water quality concerns as well as strengthen water quality standards. Groundwater legislation was proposed at the same time. In September 2001, the new (Liberal Party) government appointed a nine-member Drinking Water Review Panel to review the Drinking Water Protection Act and new groundwater provisions. The Panel released its final report on February 13, 2002 and recommended the Act be brought into force together with a relatively limited number of amendments (Drinking Water Review Panel, 2002). The government is currently reviewing the Panel’s recommendations. One major re-emphasis is the need to protect the water source, which is not covered in the Safe Drinking Water Regulation (although monitoring is partially covered in the Environment Management Act RSBC 1996, c. 118).

The Ministry of Health Planning is now the lead ministry for ensuring drinking water quality standards. Within the Ministry, the Public Health Protection Branch administers the Drinking Water Program, under which the new government has developed a Drinking Water Protection Plan – a comprehensive framework for the protection of drinking water. The plan has eight main principles (Ministries of Health Planning and Services, 2002):

- The safety of drinking water is a health issue
- Prevention and source protection are a critical part of drinking water protection.
- Providing safe drinking water requires an integrated approach.
- All water systems need to be thoroughly assessed to determine risks.
- Proper treatment and water distribution system integrity are important to protect human health.

³ See CCME’s website at http://www.ccme.ca/assets/pdf/mba_eng.pdf

- Tap water must meet acceptable safety standards and be monitored.
- Small systems require a flexible system with safeguards.
- Safe drinking water should be affordable, with users paying appropriate costs.

The government has established various advisory boards and committees to review BC water regulation: an inter-ministry committee to identify emerging issues and develop integrated policy if required; a Groundwater Advisory Board to advise on drinking water standards and protection of groundwater sources, and a Drinking Water Advisory Committee to provide technical expertise on standards for tap water (Ministry of Health Services, 2002). The following ministries are also involved in ensuring high water quality standards:

- Ministry of Water, Land and Air and Protection (MWLAP) in collaboration with the Ministry of Health Planning is responsible for developing an action plan to improve the protection of drinking water at groundwater sources (MWLAP, 2002).
- Ministry of Agriculture, Food and Fisheries (MAFF) is responsible for farm management relating to the environment and ensuring that land-use planning takes into consideration drinking water protection plans.
- Ministry of Sustainable Resource Management (MSRM) is responsible for ensuring that land use plans consider drinking water issues (MSRM, 2001).
- Ministry of Forests (MF) will ensure through the amended Forest Practices Code Act of BC (to be the Forests Practices and Range Act in 2005) that drinking water sources aren't impacted by forestry activities (see below).

The Canada-BC Infrastructure Program (administered by the Ministry of Community Services, Aborigines and Women) is the primary source of funding for local improvement projects, including water treatment and infrastructure needs. In 2002, the provincial government approved 92 water-related improvement projects worth \$239 million to be funded through the program. The government is also increasing funding for water quality monitoring by \$1.5 million a year for the next three years.

5.2.2.2 Ambient water quality: regulation, monitoring and assessment

Federal

Environment Canada plays a significant part in water quality issues regarding source quality. Its role is to aid the protection of water sources (as part of the 'environment') through establishing nationally consistent standards of ambient water quality, and restrictions on pollution discharges. In 1999, the federal government passed the Canadian Environmental Protection Act, 1999, "respecting pollution prevention and the protection of the environment and human health in order to contribute to sustainable development". Specifically applicable to water management issues, the Act stipulates the federal government's role in monitoring air, land and water pollution; establishment of pollution prevention plans for specific substances if deemed necessary, and preventing pollution of international (i.e. non-Canadian) waters from Canadian sources.

The Canadian Council of Ministers of the Environment (CCME) is an important forum for facilitating federal, provincial and territorial collaboration on environmental priorities of national concern, including water quality. Its Water Quality Task Group is responsible for establishing

national ambient environmental quality guidelines for specific substances published in the Canadian Environmental Quality Guidelines.

Provincial

The primary ministry responsible for protecting, monitoring and assessing water quality in BC is the Ministry of Water, Land and Air Protection (MWLAP). The Water Protection Branch of MWLAP is responsible for developing water quality guidelines based on the CCME criteria (MWLAP, 1998). Water quality criteria specify the “safe” concentrations of specific contaminants for five water classes (Dorcey & Griggs, 1991):

- Drinking, public water supply and food processing;
- Aquatic life and wildlife
- Agriculture
- Recreation and aesthetics
- Industrial

MWLAP is specifically responsible for the health of water sources with respect to drinking water and in terms of maintaining the health of aquatic ecosystems. As part of the Drinking Water Action Plan, the Ministry is responsible for establishing standards and monitoring, and ensuring compliance and enforcement to protect surface and ground water quality. The Environment Management Act RSBC 1996, c.118 specifies that the duty of the Minister is the management, protection and enhancement of the environment including, amongst other activities, “the preparation and publication of policies, strategies, objectives and standards for the protection and management of the environment.” MSRM administers the Environmental Assessment Act RSBC 2002, c.43, which provides the framework for managing specific projects that might have a detrimental impact on the environment, including water sources. The Water Regulation B.C. Reg. 204/88 under the Water Act, Part 7 - Changes in and about a stream, covers water quality protection in the case of modification to a stream.

The Water and Air Monitoring and Reporting Section (WAMR) of the Water, Air and Climate Change Branch (WACB) within the Environmental Protection Division of MWLAP is responsible for water monitoring. The Branch develops legislation and policies to protect air, water and land. It sets standards for, and monitors and reports on, ambient air and water quality. The WAMR Section is responsible for monitoring, auditing and reporting on the quality of the province’s water and air. It operates BC’s ambient water and air monitoring network. Administration is split into seven regional offices, including the Thompson-Okanagan office of the Southern-Interior Region.

The designation of Community Watersheds in the *Forest Practices Code of BC Act* RSBC 1996 c.159 (FPCA) further ensures the protection of water quality (and ecosystem health) in BC. The general definition being any natural watershed area on which a community holds a valid water license issued under the Water Act by the Comptroller of Water Rights (defined in s.41 (8) of the FPCA). A forest licensee operating within a community watershed is required to submit a long-term forest development plan for that portion of the area. The designation of Community Watersheds, which is based on character criteria, such as drainage area of less than 500 km², is carried out by the Ministry of Forests regional manager and the designated environment official (i.e. regional water manager as defined in the Operational Planning Regulation B.C. Reg. 107/98 under the FPCA). The FPCA brings into effect restrictions on forestry and range practices in

community watersheds of which there are 450 in British Columbia. There are 64 such Community Watersheds in the Okanagan Basin (Vernon and Penticton Forest Districts). The Ministry of Forests administers the Forest Practices Code, other than the designation of community watersheds which is under the authority of the Ministry of Sustainable Resource Management.

On December 17, 2002, streamlining amendments to the Forest Practices Code of British Columbia Act and regulations came into effect. These amendments give licensees immediate relief from regulatory burden, during the two-year transition period until the new Forest and Range Practices Act (Bill 74-2002) is fully implemented in April 2005⁴. Under the new Forest and Range Practices Act, Part 9, Section 150 the Lieutenant Governor in Council may make regulations to designate extended land as a community watershed, a domestic watershed or fisheries sensitive watershed and prescribe requirements thereof.

Riparian management is also defined in the Operational Planning Regulation BC Reg. 107/98. Depending on the status, character and size of the stream, wetland or lake a riparian reserve zone, a riparian management zone and a riparian management area are designated. The designation of riparian buffers is primarily to minimize the impacts of forest and range use on stream and lake water quality and maintain stream channel stability. The Riparian Management Area Guidebook provides details on riparian management issues.

5.2.3 Water conservation

5.2.3.1 Federal

One of the goal's of Canada's 1987 Federal Water Policy is "to promote the wise and efficient management and use of water" (Environment Canada, 1987). Section 7 of the Agricultural and Rural Development Act (ARDA) R.S. 1985, c.A-3 stipulates that programs of research can be initiated for "the development and conservation of water supplies and for soil improvement and conservation in the province". In mid-1994, the Canadian Council of Ministers of the Environment (CCME) formed a national task force to develop a National Action Plan to encourage Municipal Water Use Efficiency. The goal of this action plan "is to achieve more efficient use of water in Canadian municipalities in order to save money and energy, delay or reduce expansion of existing water and wastewater systems, and conserve water" (CCME, 1994). In 1999, Environment Canada in co-operation with the Canadian Water and Wastewater Association (CWWA) developed a Municipal Water Use Database along with a Water Efficiency Experiences Database.

5.2.3.2 Provincial

The BC Provincial Water Conservation Working Group was appointed in July 1997 to develop a Strategy Document on water conservation. A merger of this Working Group with the BCWWA Committee resulted in the creation of an interagency working group – the Water Conservation Strategy Working Group⁵. The Working Group represented federal and provincial agencies, local governments, utilities, water managers, professional associations and special water use interests.

⁴ see <http://www.for.gov.bc.ca/code/>

⁵ see the 1997 Water Use Efficiency Catalogue
http://wlapwww.gov.bc.ca/wat/wamr/wat_use_catalogue/toc.html

In the fall of 1997, the Ministry of Environment, Lands and Parks (now MWLAP) finalised a Water Conservation Strategy for British Columbia. The objectives of the strategy are (MWLAP, 1997a):

- to demonstrate the need for and benefits of improved water use efficiency measures;
- to reinforce the value of British Columbia's water resource;
- to present a menu of water use efficiency tools and techniques;
- to identify, acknowledge and learn from water use efficiency initiatives in British Columbia;
- to guide the development of provincial and local legislation, policies, guidelines and standards to improve water use efficiency;
- to engage community leaders, water managers, government agencies, water utilities, suppliers and the public in addressing water supply issues through creative partnerships; and
- to recommend next steps for advancing water use efficiency in British Columbia.

As part of the Strategy, water use efficiency measures and tools were collected at the level of senior government, regional and municipal local authorities and irrigation/improvement districts. Table 1 highlights some key federal and provincial initiatives in the area of water conservation as stated in the Water Use Efficiency Catalogue of BC (MWLAP, 1997b).

Hard Conservation Measures
<i>Legal Tools</i>
The Fish Protection Act (1997) administered in conjunction with the Water Act, can provide for water conservation to be licensed specifically. (MWLAP)
In 1993 the Union of BC Municipalities (UBCM) passed a resolution in response to " <i>continuing growth and increased per capita consumption of water</i> " which requested that the Building Standards Branch (MMA) amend the BC Building and Plumbing Code to require the use of water conservation devices in all new construction. (MWACS)
The proposed "Municipal Sewage Regulations" are encouraging the use of reclaimed water to address the issues of water shortages, the use of reclaimed water will decrease supply needs from, and discharges to fish bearing streams. (Municipal Water Reduction Branch)

<i>Economic and Financial Tools</i>
The Ministry of Municipal Affairs and Housing adopted a water conservation policy in 1992. The policy states: " <i>The Ministry encourages water conservation initiatives, and supports consumption-based water rates. For new water supply or treatment projects it is important that water conservation be part of project planning. As funding is limited, priority will be given where water conservation measures and universal metering are in place.</i> "
Presently, municipalities applying for infrastructure grants may be required to demonstrate that the proposed project uses water efficiently; and that a water audit and leak detection programs have been implemented.
<i>Operations and Management Tools</i>
1989, The Okanagan Valley Water Supply and Demand Management Study (MAFF)
In spring 1997 the British Columbia Buildings Corporation adopted technical standards which require increased efficiencies in irrigation and landscaping for all BCBC owned and operated buildings.
Fraser River Action Plan (FRAP) (Federal Government)
The BC Building and Plumbing Code was amended to include low-flow fixtures and maximum flush flows (Mowers)
"Municipal Sewage Regulations" are encouraging the use of reclaimed water to address the issues of water shortages (Municipal Water Reduction Branch)
Soft Conservation Measures
1997 Fraser River Action Plan (FRAP): An Action Plan was developed for implementation over a 3-year period to facilitate a Province-wide Partnership Agreement regarding municipal water-use efficiency (Water Use Efficiency Committee) + a 3-year program of Annual Seminars
The Water Use Efficiency committee organized Technology Transfer Seminars in conjunction with the 1993 and 1994 Annual BCWWA Conferences. The themes of the seminars were "Water Conservation Strategies and Experiences", and "Planning and Implementing Water Conservation".
The Know H ₂ O! eco-education project was developed by the Ministry in partnership with Alliance Professional Services and the BC Water and Waste Association. The project is being designed to inform local government administrators and elected officials about water-related issues; regulatory and non-regulatory management tools; and opportunities to maintain and enhance water management efforts at the local level.

Table 5.2.1: Major federal and provincial initiatives in the area of water conservation selected from the 1997 Water Use Efficiency Catalogue of BC.

The Ministry of Agriculture, Food and Fisheries is actively involved in encouraging water conservation through participation in water conservation projects and publication of relevant material e.g. *B.C. Trickle Irrigation Manual*. Currently a series of Environmental Farm Plans are being developed by MAFF. The objective of the water management component of the Plans is to

inform and guide farmers on water efficient management methods and options, such as irrigation scheduling (Janine Nyvall, MAFF, pers. comm.).

5.2.4 Fish and Habitat Management

5.2.4.1 Federal government

Fisheries and Oceans Canada has a clear, legislative mandate for the protection of fish habitat. The Fisheries Act R.S. 1985, c. F-14 gives the Minister of Fisheries and Oceans the responsibility to protect fish and fish habitat from destructive activities in marine and inland waters. The main provision under the Fisheries Act dealing with the protection of fish habitat is s. 35. Subsection 35(1) states "No person shall carry on any work or undertaking that results in the harmful alteration, disruption or destruction of fish habitat." However, subsection 35(2) qualifies this prohibition, in that it allows for the authorization by the Minister of Fisheries and Oceans, or through regulation, of the alteration, disruption or destruction of fish habitat. Operationally, decisions on whether subsection 35(2) authorizations are issued are made by regional habitat staff within the Fisheries and Oceans Canada.

In 1986, the Federal Government published their Policy for the Management of Fish Habitat. This provided the framework for ensuring the protection of fish habitat including engaging and actively involving Canadians in stewardship activities. Fisheries and Oceans Sustainable Development Strategy (2002) is an update of the department's policy concerning management of marine and freshwater fish resources in Canada. The main program managing fish habitat, is the Fish Habitat Management Program. Its mandate is to: protect and conserve fish habitat in support of Canada's coastal and inland fisheries resources; and conduct environmental assessments under the Canadian Environmental Assessment Act.

Fisheries and Oceans Canada is now developing a detailed national action plan for Fish Habitat Stewardship. The Action Plan will ensure that Fisheries and Oceans Canada is directly involved in stewardship activities across Canada and is applying the proactive strategies outlined in the Policy. The Action Plan will also strive to build partnerships with industry, developers, NGO's, governments and community groups to advocate the benefit of protecting fish habitat so they too can contribute to the net gain of this habitat. The Habitat Conservation and Stewardship Program in British Columbia and the Yukon is an example of such stewardship activities. Up until March 2003, Fisheries and Oceans Canada funded a full-time Stewardship Co-ordinator for the Okanagan, Similkameen and Boundary areas as part of their Habitat Conservation and Stewardship Co-ordinator Program across Canada.

Habitat Restoration and Salmon Enhancement Program (HRSEP) was established in 1996-1997 to complement the Pacific Salmon Revitalisation Strategy. The main objective of the federally funded HRSEP is to revitalise salmon populations in the Pacific Region through habitat restoration, stock rebuilding, and resource and watershed stewardship. Other important goals are to develop and strengthen partnerships at the community level and (where feasible) train/employ displaced fishery workers. The projects are run by a variety of community groups and agencies.

The Pacific Region is the operational unit of Fisheries and Oceans Canada that covers fish issues in British Columbia. The Habitat and Enhancement Branch (HEB) of BC and the Yukon is responsible for:

- The protection and restoration of fish habitat

- Salmonid Enhancement Programs (SEP)
- Integrated resource management planning
- Community involvement programs and public education.

In 1999 Canada and the United States reached a comprehensive agreement under the Pacific Salmon Treaty. The agreement signals a cooperative, conservation-based approach to the management of Pacific salmon fisheries, and a more equitable sharing of salmon catches between Canada and the United States.

5.2.4.2 Province

Commercial fisheries

The Fisheries Act RSBC 1996, c.149 covers licensing and regulatory control of activities associated with commercial fisheries and aquaculture operations. Currently, there are 129 commercial freshwater fish farms and hatcheries. MAFF is responsible for the management of commercial fisheries and the administration of the Act. A new Aquaculture Regulation which came into force in 2002 strengthens the environmental controls related to aquaculture activities e.g. fish escape and pollution.

Fish habitat protection and minimum fish flows

In 1997, the then BC government proposed a Fish Protection Act RSBC 1997, c.21(FPA). Its four major objectives are: ensuring sufficient water for fish; protecting and restoring fish habitat; improved riparian protection and enhancement; and stronger local government powers in environmental planning. The Act would allow managers to issue orders to temporarily reduce water use during droughts, grant licenses to protect in stream flow, and to reduce licensed allocations. Sections 8 to 11 of the Fish Protection Act that would allow these actions have not yet been proclaimed into force, so it remains to be seen how application of these sections would be applied in the Okanagan.

MSRM is responsible for the general administration of the Fish Protection Act. In addition, the Ministry administers the Sensitive Streams Designation and Licensing Regulation (B.C. Reg. 89/2000) under the FPA. A general streams regulation, to ensure consideration of potential impacts on fish and fish habitat in water allocation decisions or approvals for changes in or about streams, is also under consideration.

The Resource Management Division is responsible for developing Land Resource Management Plans, which include policy on fish concerns. The Aquatic Information Branch within the Registries and Resource Information Division of MSRM manages the Fisheries Information Program involving the provision of inventory data and documents. This program includes the BC Fisheries Data Warehouse (eg. the FishWizard), Fisheries Project Registry and the Fisheries Inventory, created under the Canada-BC Agreement on the Management of Pacific Salmon Fishery Issues.

MWLAP is responsible for the administration of the Fish Protection Act Section 12 concerning streamside protection, which is enforced through the Streamside Protection Regulation (B.C. Reg. 89/2000). The Regulation calls on local governments to establish streamside protection and enhancement areas in residential, commercial and industrial zones and to identify these areas through their land use plans and regulations by the year 2006. Only 12 such sites have thus far

been designated (Niel Banera, Ministry of Sustainable Resource Management, pers. comm.). The SPR is currently undergoing a review to determine what revisions to the regulation, guidelines or implementation strategy might be necessary to ensure protection of fish while respecting private property interests.

MWLAP has various responsibilities related to fish management including:

- Species at Risk — Identify, protect and restore species at risk and their habitat e.g. Sockeye has yellow status;
- Wildlife and Wild Fish — Manage and protect fish, wildlife and their habitat e.g. Sockeye, Kokanee, Chum, Chinook, Trout and many introduced fish species inhabit the Okanagan Watershed;
- Habitat Conservation — Manage conservation in parks and protected areas system;
- Sport fishing management;
- Non-commercial freshwater aquaculture management;
- Water quality monitoring.

The department responsible in MWLAP for fish issues is the Environmental Stewardship Division (ESD). The BC Biodiversity Branch deals exclusively with biodiversity issues, while the Fisheries Branch administers projects concerned with freshwater fish species and habitat management. A Recreation Stewardship Panel was named in spring 2002 to make recommendations for a new management model for angling, hatcheries, hunting and park recreation that connects fees with services and opportunities and allows greater public involvement in decision making.

The Thompson-Okanagan Region Office of the ESD supervises the Okanagan Lake Action Plan (OLAP). Public and government concern for the future of Okanagan Lake kokanee during the early 1900s led to formation of a proactive plan in 1996. This forward-looking plan with a twenty-year time horizon attempts to address all of the physical and biological factors that influence Okanagan Lake and the kokanee populations that inhabit it.

Fish and Forests

The Forest Practices Code of BC Act outlines the protection of community watersheds (drinking water) and riparian zones (habitat and surface water quality protection through prevention of erosion) on crown lands. Resource management planning including watersheds is now the administrative responsibility of MSRM rather than MF (see section on water quality).

Inter-departmental projects

The government is committed to developing a Living Rivers Strategy to protect and improve the province's river systems through watershed management, and enhancements and restoration of fish habitat (MWLAP, 2002a). Working with the Ministry of Sustainable Resource Management, MWLAP has begun to analyze and review options and prepare recommendations for public review during 2002, targeting implementation of an integrated strategy by 2004. MWLAP has created the Living Rivers Section within the Biodiversity Branch to lead the initiative. This takes over activities from the Fisheries Renewal BC and Watershed Restoration Program from the

previous government. A \$2-million trust fund to protect and restore B.C.'s rivers as been established as the first step in developing the Strategy (MWLAP, 2002b).

Under the Resource Management Branch, is a joint initiative between MAFF, MWLAP (previously MELP) and the B.C. Agriculture Council – The Partnership on Agriculture and the Environment. The initiative involves a 10-Point Action Plan to integrate agriculture and environment ministry activities. The Agricultural Watercourse Maintenance Policy was established under this partnership to minimize the impact of agricultural runoff (from ditches) on fish. MAFF also produces various guidance documents on farming practices, and partners in (provides resource to) various projects, to reduce agricultural environmental impact and conserve resources e.g. irrigation, water storage, wastewater runoff, nutrient use, etc.

5.3 Regulation and Regional Vulnerability

In the context of adaptation to climate change in the Okanagan, British Columbia's regulatory system provides several challenges. Rising water demands due to population growth and changes in water supply and demand due to climate change may result in increased activation of the prior appropriation principle, resulting in increased conflict. Even though conflict is often resolved in the field through more informal methods, increased water stress makes the situation more vulnerable (Neil Banera, Ministry of Sustainable Resource Management, pers. comm.). Under the same conditions, the beneficial use principle could become a more significant requirement in divvying out licenses as water sources become saturated. The perpetual nature of water licenses and the limited ability of managers to modify water rights e.g. transferability and conditionalities, may become restrictive in the face of increasing demands to manage water for multiple objectives (which may or may not be subject to water licensing). Balancing in-stream e.g. fish, and out-of-stream uses e.g. domestic, could become an increasingly difficult under a climate change scenario. The failure to proclaim the Fisheries Protection Act and to define acceptable minimum fish flows adds to this difficulty.

Although improved water quality standards under the impending Drinking Water Quality Act are essential in providing clean and acceptable potable water to users, the challenge in the Okanagan (and other regions) will be the cost of implementation. Currently, the Canada-British Columbia Infrastructure Program, launched in January 2001 provides grants to local government. The agreement calls for the investment of more than \$800 million over six years to improve urban and rural local government infrastructure in British Columbia. The two governments each agreed to contribute \$268 million towards the program, with the remaining amount coming from municipal governments and other project proponents. The program's first priority is green local government infrastructure.

The challenge will be providing potable water to rural communities in the Okanagan. Under the Local Government Grants Act, irrigation districts are still not eligible for unconditional funding, unlike municipalities. It is often cited that access to funding is used as leverage for the province's agenda of regionalisation i.e. move from local to regional administration of services (Erik Karlsen, pers. comm.).

Although water efficiency is a priority both in the federal and provincial governments the question of who should bear the cost is again pertinent. MAFF is actively involved in encouraging farmers to move toward more efficient means of irrigation (Janine Nyvall, pers. com.). The 'green' priority of the Canada-BC Infrastructure means that local authority water efficiency programs (amongst other things) will take precedence. Significant steps toward greater

efficiency are taking place in local authorities throughout the Okanagan, as well as some Irrigation Districts. Increased efficiency will alleviate initial strains from the many factors that stress water resources in the Okanagan, including climate change, the question is at what point will it not be enough.

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Chapter 6. Adaptation Case Studies

Philippa Shepherd, Roger McNeill, Tina Neale

6.1 Early Adopter Case Studies Analysis

6.1.1 Introduction and objectives

“Adaptations are adjustments in human or natural systems in response to actual or expected climatic stimuli” (IPCC, 2001:72). These adjustments can be anticipatory, autonomous, planned or unplanned (see Box 6-1). They may take the form of institutional, technological and behavioural changes. Decisions to adapt can be made by individuals, communities, corporations, local, regional and national government, and international bodies (Smithers & Smit, 1997; Smit et al., 1999). The aim of this part of the study was to learn how the process of adaptation to *water resource stresses* in the Okanagan currently occurs.

In order to explore the adaptation process, “early adopters” of non-mainstream and “up-and-coming” management practices were selected as case studies. The research was carried out at the local authority level as local authorities represent the key decision-making bodies for water resource management. Cases were chosen to reflect the two major water consumers in the region, domestic and agriculture, and to represent “no regrets” options, or those that are relevant and feasible both now and in the future.

Choosing to study current “adaptation” to water stresses was based on three arguments. Firstly, adaptation options should make good water management sense on their own, as well as representing appropriate adjustments to anticipated climate changes (de Loe, et al., 2001). This is crucial because of the inherent uncertainties in predicting climate change. Secondly, studying how water management practices are currently evolving in response to water stresses will provide insight into how managers will respond to climatic impacts on water resources in the future. This focus is relevant because water purveyors experience climate change as a water management problem not a climate change problem. Finally,

Box 6-1: The meaning of adaptation

According to the IPCC (2001) “adaptations are adjustments in human or natural systems in response to actual or expected climatic stimuli” (p.72). However, adaptation comes in various forms depending on spatial and temporal scale; whether the reaction to the stimuli was early or late; whether the ensuing change resulted in superficial adjustments or fundamental institutional change; whether change was planned or incremental. Here are some of the different identified characteristics of adaptation:

Proactive versus reactive: The latter occurs in response to a past event or series of events, whereas the latter is a form of anticipatory adaptation and requires some form of planning and consideration prior to a predicted event. Proactive adaptation often occurs in light of great uncertainty, and has a precautionary nature (Smithers & Smit, 1997).

Policy-related (planned) versus autonomous: Autonomous adaptation often refers to adaptation by the private sector i.e. farmers or business, as opposed to adaptation in the public domain (policy-making). It also refers to adaptation that occurs by a single entity e.g. farmers implementing drip-irrigation on their farm, compared to a local authority introducing a by-law that makes drip-irrigation (where appropriate) mandatory (Bryant et al, 2000; Burton, et al, 2002).

Long-term adaptation versus short-term adjustments: Adaptation is usually synonymous to change that has long-term implications as opposed to incremental change that results in short-term adjustments to an existing system. However, many short-term adjustments can result in adaptation. Adaptation is considered to be a change in behaviour, institutional structure or policy that has long-term implications (Burton et al., 1993).

adaptation to climatic variability (seasonal) is something that water managers have always done and they are therefore highly knowledgeable of how adaptation takes place on the ground, in practice.

Several factors, including population growth, increasing costs and limitations of upland supplies and sites for new reservoir development, are prompting a shift in water management practices in the Okanagan Basin. Traditional, more expensive, supply side management options, such as expanding reservoir storage, are being considered along side demand-side management practices, such as water metering, which can extend existing supplies at lower cost. A shift to regional administration of water supplies is also occurring with smaller local authorities (mainly municipalities) amalgamating to form regional administrative bodies. Where new water sources are required, many local authorities are looking to pump water from the main stem system, specifically the Okanagan Lake, instead of developing local watersheds i.e. tributaries and related upland lakes.

Cases representing demand-side management practices and regional administration were selected for this study. The four cases selected for the study were as follows:

City of Kelowna: In 1996, the City of Kelowna Water Utility began to implement universal water metering. All residential, commercial and multi-family accounts are now metered. In 1999 residential customers began paying for water on a volume-based rate. Since 1999, the average per capita July water consumption has reduced by 23% (Neal Klassen, pers. comm.). Kelowna is currently exploring alternative rate structures in order to encourage further water use efficiency.

City of Vernon: In 1977 the City implemented the area's first full-scale water re-use program. The City's entire yearly wastewater flow is treated, stored and applied to irrigation fields. Currently, agricultural, forestry and recreational lands participate in the water re-use program. In addition, Vernon has implemented extensive rebate programs for installing domestic water-saving devices and all domestic connections in the city are metered.

South East Kelowna Irrigation District (SEKID): A demand-side management project was implemented in 1995 in SEKID to investigate more efficient ways of using water and to study the effectiveness of demand side management in reducing water use. A 5 – 23% reduction in water use was estimated as a result of water metering, scheduling and educational initiatives implemented during the program (Nyvall & Van der Gulik, 2000). SEKID is the only rural local authority in the region that has implemented metering of irrigation connections.

Greater Vernon Water Utility: In 2002, the municipalities of Armstrong, Vernon and Coldstream, along with the North Okanagan Regional District amalgamated to form a single water utility. All administration of water resource management is now the responsibility of the new regional utility.

Three broad key questions were explored:

1. How does the process of adaptation evolve from initial motivation to final implementation?
2. What subjective and objective factors drive or constrain the adaptation process?
3. How can 'success' be duplicated in other local authorities?

6.1.2 The interview process

In total 27 interviews were conducted. Philippa Shepherd and Tina Neale (either separately or together) conducted the interviews in the Okanagan. Each interview took between 45 minutes and 2 hours. Notes were taken during the interviews, although interviews were recorded and were subsequently transcribed (in note form). On occasion the interview included questions outside of the case study material, specifically when the interviewee at hand could provide knowledge of another sort. This included information about the Okanagan Basin Water Board, water licensing policy and regulation under Land and Water BC, and responsibilities and tasks of the Ministry of Agriculture, Food and Fisheries (MAFF).

Interview transcripts were coded using Atlas/ti and summarised into tables. Some code definitions are presented in Table 6.1.1.

Code	Definition
DRIVER	Circumstances and motivational factors that drove the authority to make a decision to go ahead with the management option.
ENABLING FACTOR	Factors that aided adoption i.e. initial conditions that meant the management option would be considered.
BARRIERS	Factors that could have prevented the management option from being implemented.
OBSTACLES	Factors that impeded or caused difficulties in the implementation phase.
CONFLICT RESOLUTION	Mechanisms, approaches and tools used to resolve or avoid conflict.

Table 6.1.1: Some interview code definitions

6.1.2.1 Limitations to the interviews

There are several limits to an open interview process:

- Opinions and thoughts are retrospective and require recall; both facts influence what is expressed in the interview.
- The information collected is a set of opinions of different actors. They are in no way ‘objective’; they represent subjective values and thoughts.
- Interviews only provide some of the story. Additional information should be collected i.e. Board minutes, newspaper articles, management documents, etc. to verify facts. This has been done only where possible.
- Interview output data is subject to interpretation by the analyst when ordering and coding data.

6.1.3 Discussion: Early Adopter Case Studies and Climate Change

6.1.3.1 Why is the 'Adaptation Process' Important?

Climate change research has focussed on different aspects of 'adaptation': social, behavioural and institutional factors that define adaptive capacity and vulnerability (Kelly and Adger, 2000; Yohe & Tol, 2002); appropriate method of action – what adaptation processes are available, and which would be most effective (Cohen and Kulkarni, 2001; Bryant et al 1997; Brklacich et al. 1997); defining generic characteristics of adaptation (Smith, 1997; Smithers & Smit, 1997); and studies looking into the actual 'adaptation process' itself, the category in which this study falls. Amongst other projects on the adaptation process Smit et al. (1996) undertook a study of changes over a five-year period to determine what strategies were taken to cope with climatic change/variability and what factors determined a farmer's response. Risbey, Kandlikar and Dowlatabadi (1997) explored the importance of scale in adaptation to climate variability by the agricultural community in Australia. Kelly and Adger (2002) studied 'institutional adaptation' (as the indicator of vulnerability) through a tropical storm in coastal Vietnam. Some think that there is a lack of research on the social, behavioural and other obstacles in the adaptation process (Rosenzweig and Parry, 1994) as well as the forms that adaptation takes, triggers and keys to success or causes of failure (Smithers & Smit, 1997).

The early adopter study explored the actual 'adaptation process' in the four cases: Kelowna (domestic metering), Vernon (water reclamation), GVWU (regionalisation) and SEKID (metering irrigation). It explored how and why decisions were made and what factors influenced or limited 'adaptation' – or change – to take place, specifically changes in practises and structures of systems at a local level with respect to water management. The reasoning was that climate change impacts on water resources would likely be experienced and viewed as a water management problem, not a climate change problem. A key challenge for the near term (i.e. the next decade) is identifying adaptation options that represent appropriate adjustments to anticipated climate changes, but which also make good water management sense on their own i.e. 'no regrets' measures (de Loe, Kreutzwiser, Moraru, 2001).

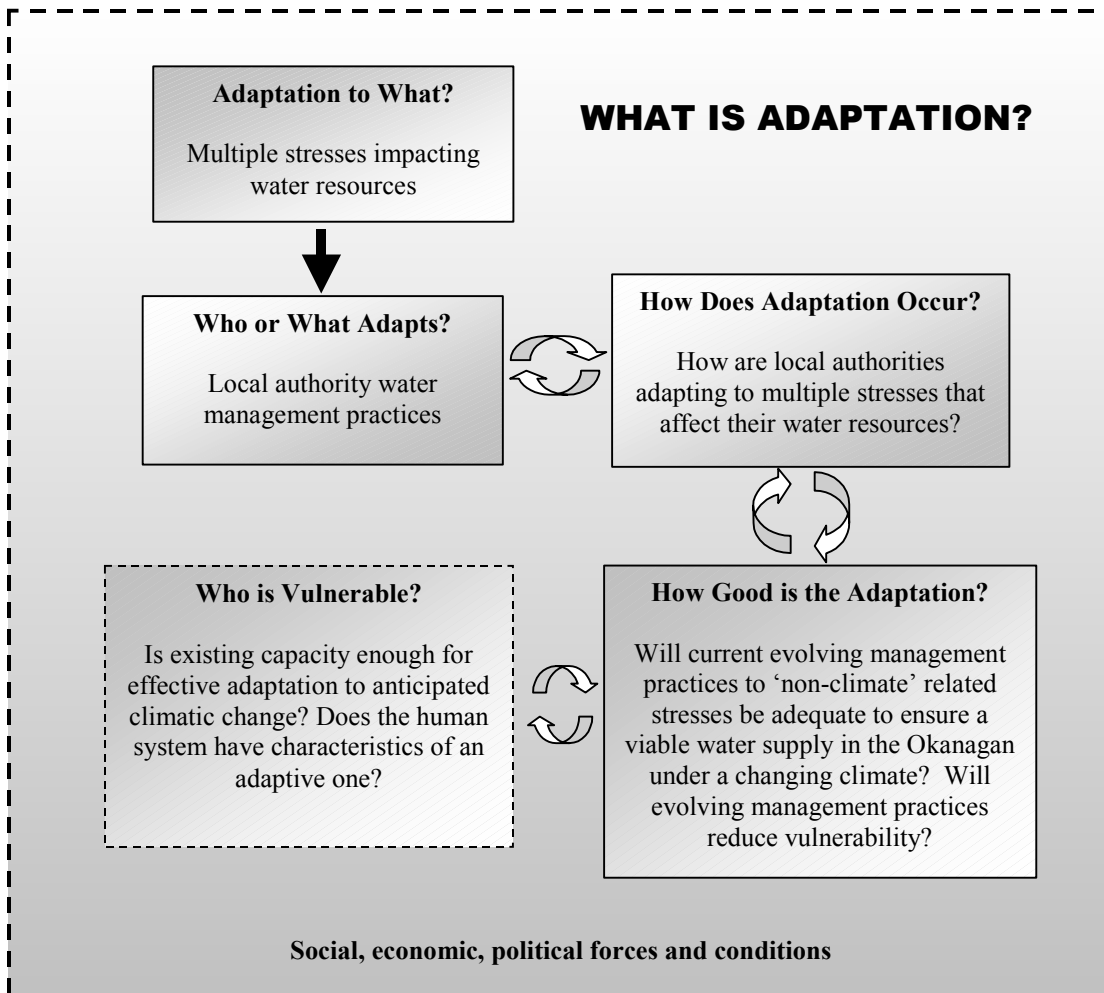


Figure 6.1.1 Adapted from Smit et al 1999. Adaptation is embedded in a socio-economic and political context.

Why is the adaptation process important? What can we learn from past decisions? Climate change isn't an isolated phenomenon. There is no clear linear relationship between a climatic signal and a response; institutions do not 'adapt' smoothly from signal to response either reactively or proactively. Adaptation is part of a complex shifting web of individual, institutional, attitudinal, political and financial agendas at different governance, cognitive, spatial and temporal scales. It is these non-climatic factors that dominate the ability to adapt, the selection of an adaptation option and the process of adaptation (see Figure 6.1.1).

6.1.3.2 Lessons learned: barriers, constraints and keys to success

The case studies illustrate the challenge of adaptation in this complex web; the many factors that influence decision-making. The character of adaptation, keys to success, barriers to avoid as well as potential rigid (unmovable) constraints to effective change were explored. Table 6.1.2 summarises some of the initial interview results.

There are some clear lessons learned from these case studies that are important in answering the question of how to adapt to climate change in the Okanagan. The fear of change - the challenge of transition - runs throughout. Many factors either exacerbate the difficulty of change or smooth out the process. Three common (interrelated) problematic areas were identified:

- Attitudinal - public perceptions and values.
- Financial - the initial substantial capital outlay;
- Political - political will, leadership, manipulation and acceptability.

	KELOWNA Domestic metering (1994 to present)	SEKID Irrigation metering (1993 to present)	VERNON Water reclamation (1970's to present)	GVWU Regionalisation (1970's to present)
Drivers	<p><i>Internal*:</i></p> <p>Growing population</p> <p>Impending capital investment</p> <p>Comparative high per capita consumption</p> <p><i>External**:</i></p> <p>Cryptosporidium outbreak</p> <p>Regional push for water conservation</p>	<p><i>Internal:</i></p> <p>Extended hot growing season i.e. concern over supply</p> <p>Overuse of water during dry spells</p> <p>Increased residential development</p> <p>Green Plan Funding</p> <p><i>External:</i></p> <p>Regional push for water conservation</p> <p>Conditional water license for further reservoir expansion</p>	<p><i>Internal:</i></p> <p>Staff interest in the alternative to treatment</p> <p><i>External:</i></p> <p>Federal-Provincial study to reduce input of phosphorus into the Okanagan Lake</p>	<p><i>Internal:</i></p> <p>Need to update infrastructure</p> <p>Concern over water quality</p> <p>Growing population</p> <p>Impending drinking water regulations</p> <p>Limited resources</p> <p>Limited financial capacity</p> <p><i>External:</i></p> <p>Push from provincial government to become “model region”</p> <p>Financial support</p>
Enabling factors	<p>High level of awareness and interest of staff, Council and public</p> <p>Learning from neighbour experiences e.g. Vernon</p> <p>General “user pays” philosophy</p> <p>Progressiveness and proactiveness of staff</p> <p>Political acceptability of the approach i.e. average user would not be significantly affected</p> <p>Municipal financial stability</p> <p>Win-win approach</p>	<p>Management pro-metering</p> <p>Board’s open-mindedness toward metering</p> <p>Access to funding</p> <p>External expertise</p>	<p>Vernon’s self-image</p> <p>Openness of the Council at the time</p> <p>Success of the pilot study on the commonage area</p> <p>Farmer benefits from application of reclaimed water</p> <p>Citizen support for avoiding discharge into the lake</p>	<p>Political leadership</p> <p>Willingness to compromise</p> <p>Mutual benefits</p>

Barriers	No significant barriers identified	Grower attitudes, discontent and distrust Potentially cost Potentially lack of vehicles of finance	Political agendas Limited viable land for application Initial farmer attitudes against the use of reclaimed water (Spallumcheen)	Political concerns over control (over the water management) Disagreement about water quality issues Public acceptance of the expense
Obstacles	Public attitudes i.e. water considered a plentiful resource Meters considered intrusive and controlling Internal communication	Communication and misinformation Lack of awareness Grower attitudes toward metering	Differing attitudes of farmers, the public, politicians... “Held hostage” by users i.e. abuse of incentives Cost of the project	Definition of irrigation i.e. who bears the cost Information heavy Political sensitivity – differing political agendas and attitudes Reaching consensus
Conflict resolution	Awareness i.e. general and targeted education Preparation i.e. pilot study and grace period for adjustment	Communication and discussion: public information meeting and one-on-one meetings New management New bid on meters Information and education e.g. field days, water use reports, etc.	Farmer incentives Buffer zones around residential areas Scientific evidence	Comfortable governance structure Expert information

Table 6.1.2: Summary table of results from the case study interviews

*Internal = drivers that originated from within the municipality/irrigation district even though it might be an external physical driver e.g. drought.

**External = drivers that originated from other institutions (mainly provincial)

Attitudes/perceptions/values

The attitude of growers toward the water resource is a significant issue. 'Saving water' is not a concept easily swallowed; water efficiency is a much more preferred idea. The value of irrigation water has been low for many years. Residential spread onto agricultural dry lands and into the agricultural community is an increasing challenge for local authorities and farmers. But in order to maintain low rates, capital will have to come from another source - so who will foot the bill? How do farmers feel about residential spread, when they represent a long history in the Okanagan? Farmer attitudes are not the only perceptions that one needs to be cognisant. The sense of ownership of the water resource extends to the local authorities themselves.

In each case study, perceptions (consumer, political, other) were an issue that had to be dealt with head on. Openness/ transparency, communication, education, 'ownership of the decision' and preparation are simple mechanisms that were stated as lacking; or having been applied, contributed to a smooth transition. Education and communication (not only public education, but

staff and Council education as well as interdepartmental communication) were highlighted time and time again. How information was framed seemed crucial to fuelling or dissipating public dissent. Complexity of information seemed a difficult hurdle. How to communicate complex information simply without losing the message? Or how to communicate the importance and relevance of something that most people do not consider? This is where preparation comes in. Being tentatively or experimentally proactive – exploring how to react to the initial signals – allows time to lay the ground and explore before action. Transparency between the authority in charge and those that will be affected is a must as it strengthens trust.

Financial issues

Access to money was potentially a barrier for all the cases. The key issues regarding cost are:

- Who should bear the cost?
- Under what conditions should funding be disseminated?
- What will the cost be to the individual?
- What is acceptable cost? (differing perceptions of political acceptability)
- Who should have access to provincial/federal funds?

A question that needs to be explored is: What are the current trends in provincial funding for local water management infrastructure projects? This will highlight whether the future burden of cost will fall more and more on the local authority and consumer. Increased water rates, however, seem inevitable. What are the implications of this? What about those that cannot afford increased water rates? What will the impact be on the agricultural community? How does cost relate to crop type and global food markets? Should the urban community subsidize the agricultural community? It was intimated in the interviews that funding is used to forward provincial agendas. Unsurprisingly, access to provincial funds is key.

Politics and policy

In each case, political will was cited as an important enabling factor; without political buy-in, a decision is hard to make. However, adaptation (especially over the long-run) is susceptible to changes in political agendas. As one interviewee put it, the action has to be politically resistant. Differences in perceived public (political) acceptability is another potential barrier. What might be considered acceptable in one region might not in another. Regionalisation is most prone to political concerns because the challenge is getting ‘buy-in’ from multiple stakeholders. In terms of inter-governmental issues, transparency is needed to engender trust between the different levels of government.

Regulatory change is an effective motivator for local change. The challenge is to ensure that the resources are there for effective implementation. For example, it was noted that there is no longer adequate ‘extension staff’ to go out and talk to farmers in the field (Janine Nyvall, pers. comm.). In terms of water quality, more stringent standards will be costly for local government if funding is not available. The application of “beneficial use” is another example of regulatory pressure. Could this be applied more stringently as water resources become scarcer?

6.1.3.3 Adaptation Theory and What the Case Studies Suggest

As previously mentioned, adaptation is a multifaceted concept, that has many forms and occurs at many scales. How do the case studies match up to adaptation theory?

Who, how (perceptions) and when (conditions) a signal⁶ is interpreted, and how this signal relates to others, influences the level of response and its success. Risbey, Kandlikar and Dowlatabadi (1999) describe a four-step process: signal detection, signal evaluation, response and feedback. Even when a signal has been detected, action doesn't necessarily follow. In order for a signal to turn into action, it has to be recognised as a problem. In the creation of the GVWU, action only occurred when need was *considered* great enough; when benefits outweighed the costs. Although there was signal detection e.g. concern for water quality, the interpretation of the signal initially resulted in minimal collective action. With regard to water reclamation in Vernon, the signal was clear – phosphorus level inputs into the Okanagan Lake had to be reduced. The question was what should be the response? Water reclamation came about because a key individual at the time was 'conservation-minded', interested in re-using water. Values matter in signal detection, evaluation and response.

In characterizing adaptation, a distinction is often made between "reactive" versus "proactive" (anticipatory or planned) adaptation. Reactive adaptation is considered a response to an event or series of events. Proactive adaptation requires some form of planning and consideration prior to an expected event, or in response to a worrisome trend. It has a precautionary nature because it often occurs in light of great uncertainty (Smithers & Smit, 1997). SEKID was initially quite anticipatory in that it started considering metering before any direct regulatory push, seeing the potential benefits of metering i.e. savings. But part of this proactiveness was due to a previous drought event. This comes back to signals. SEKID interpreted the signal regarding water conservation at the Winnipeg conference⁷ as significant and relevant to their circumstances. So, the difference between reactive and proactive adaptation is more precisely *when* one reacts to *what strength of signal*. It is often assumed that the earlier one acts the better i.e. being proactive. In some circumstances, an adaptation/adjustment can occur too early. When there is no direct need should one act differently? The water reclamation project exemplifies this conundrum. They were extremely proactive but there were many unanticipated hurdles. When to respond to a signal is as important a question as how to act.

The reference, starting point or timing i.e. the initial conditions, is crucial to how adaptation pans out. Kelowna is a good example of this. The city was financially stable, it was not the first to implement metering and it had had an educational program on water conservation in place for several years before the event. These conditions aided the process of change; not necessarily determined the smooth ride but aided it. Being the first – the early adopter – is on the other hand much more problematic. SEKID did not foresee such grower opposition. Implementing water reclamation gave Vernon its environmental image, but there were many significant unexpected consequences along the way. Being first in something is always an experimental procedure as unforeseen repercussions are inevitable.

A final note regards the difference between "short-term adjustments" versus "adaptation". The latter is considered to be a change in behaviour, institutional structure or policy that has long-term

⁶ A signal can be an event, information, or the like, that incites action.

⁷ 1993 National Conference on Water Conservation.

implications (Burton et al., 1993). Were these cases adjustments or adaptation? The GVWU would under this definition be an adaptation because significant institutional restructuring has resulted. SEKID again is adaptation as it had involved significant behavioural changes. Water reclamation required an attitude shift from “wastewater as treated sewage” to “wastewater as a valuable resource”. Kelowna on the other hand is a little more difficult to place. Is a reduction in water consumption a behavioural change? In essence adjustment-adaptation is not a dichotomy but a spectrum. For example, many small adjustments might lead to significant adaptation. Or adaptation might result in insignificant change.

6.1.3.4 What do the case studies tell us about adaptive capacity?

While adaptation is the act of adapting (the decisions that are made, its evolution from initiation to implementation), adaptive capacity defines the conditions that allow (or prevent) adaptation to occur. In the context of climate change, the IPCC (2001) defines adaptive capacity as the: “ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or cope with the consequences” (p. 6), and goes on to say that the “ability of human systems to adapt to and cope with climate change depends on such factors as wealth, technology, education, information, skills, infrastructure, access to resources, and management capabilities” (p. 8). Gary Yohe & Richard Tol (2000) go further than providing a definition and develop an equation that estimates adaptive capacity based on eight determinants: technology, resources, institutional set-up, human capital, social capital, risk sharing, information management and public risk perception.

The case studies indicate that adaptive capacity is more than such ‘objective’ characteristics. While access to funds is primary for change to occur, equally important is the desire to act e.g. Kelowna; being proactive, or simply having a perception that it needs to be done e.g. SEKID. As Irene Lorenzoni et al (2000) put it: subjective capacity is “self-perception of stakeholders with regard to their ability to respond to challenges arising from environmental/climate impacts. Arguably the simple perception that ‘something needs to be done’ in an organisation to respond to a particular threat is as, if not more, important than the presence of a particular threat” (p.150).

6.2 Costs of Adaptation Options

Because climate change is likely to change precipitation patterns, reduce snowpack storage and increase crop water demands, many water supply systems in the Okanagan may not be able to meet future demands based on their current supply capacity. A number of adaptation options are available that can help meet possible shortages due to climate change and other factors such as population growth. These options include both demand side measures and supply side measures. Demand side options include water conservation alternatives such as irrigation scheduling, public education, metering and adoption of efficient micro irrigation technologies. Supply side options include increasing upstream storage and switching to the mainstem lakes or rivers as a supply source, thereby relying on the large storage capacity of Okanagan lake.

The costs of both demand and supply side options will vary greatly depending on various features of the individual water supply systems and the type of demands served. It is difficult to advise or present site-specific adaptation options and their costs to individual water supply systems without detailed engineering assessments. However, the questions of managing water supply and demand are not new to the area. Continuing population growth and changing land use patterns have already placed stress on many local water supply systems and a great deal of engineering knowledge and experience exists in the study area relevant to adaptation options. Therefore the

study team contracted the services of Earthtech Environmental Services in Kelowna, who have worked on development and management of numerous water supply systems in the Okanagan, to assess the range of adaptation costs and relevant system characteristics that would affect the choice of adaptation options (Hrasko, 2003).⁸ The report by Earthtech forms the basis for the costs presented in this section.

6.2.1 Demand Side Management Options

These options have proven effective in several areas of the Okanagan and in other regions in North America. They can be used singly or more commonly as part of a package of water conservation initiatives. They include both technological options, such as changing to efficient micro irrigation systems, and social behaviour options where consumers are persuaded through public information or rational water pricing to reduce waste and conserve water.

6.2.1.1 Public Education

This option can achieve a 10% reduction in water use if a consistent effort is made to reach the public, stressing the importance of reducing consumption and showing how water can be used efficiently. The per unit cost of water saved will vary depending on the size of the system since there are definite economies of scale. For example a large system can afford to hire a full time coordinator in charge of public mail-outs and disseminating information to customers. For medium to large systems the costs of water saved by this option are estimated at \$835 per acre-foot for a system with 10,000 connections and a full time coordinator.

6.2.1.2 Irrigation Scheduling

This involves metering of individual agricultural operations without per unit pricing. The objective is to provide each grower with an accurate figure of how much water he is using compared to how much is actually required based on soil and weather conditions. This option has proved to be very cost effective in the South East Kelowna Irrigation district which achieved a 10% water saving. For irrigation districts with large holdings, fewer meters are required on a per acre basis resulting in a low cost of \$500 per acre-foot of water saved. For an irrigation district with smaller holdings the costs would go up to \$835 per acre-foot.

6.2.1.3 Efficient Irrigation Systems

The Earthtech report analyzed both a microjet system and a trickle irrigation system. The figures discussed below are for trickle irrigation systems, which were slightly more cost effective in terms of per unit cost of water saved. Costs of installation are constant on a per acre basis meaning that there are no real economies of scale for larger conversions.

The trickle irrigation system should result in a savings of 30% of the water used by a conventional sprinkler system. In areas of high crop water demand the actual water saved will be higher on a per acre basis giving a lower cost per acre-foot of water conserved. As rough examples the analysis considers annual water demands of 2 feet, 3 feet and 4 feet with per acre-foot costs of water saved at \$2500, \$1667 and \$1250 respectively.

⁸ This report was jointly funded by the Municipality of Summerland and by the Okanagan Climate Change Project.

6.2.1.4 Leak Detection

The amount of water that can be saved by leak detection and repair depends upon the age and maintenance of the system. Several older systems in the area could benefit by such a program with savings of 10% to 15% of current usage. The costs will depend on the nature of the leaks, as large leaks will have a lower cost per unit of water. An approximate range for the costs of water saved by leak detection is from \$1300 to \$1900 per acre-foot.

6.2.1.5 Domestic Water Metering

Larger communities in the Basin have already instituted domestic metering, but several smaller communities are unmetered and charge domestic users a flat rate. Based on the experience with larger communities, such as Kelowna, a reduction of 20 to 30% in domestic water use is reasonable with the implementation of meters and a usage based price. The cost of metering will be less for communities with over a 1000 connections because of bulk purchasing and installation. The cost range is from \$275 per installed meter for the larger communities to \$350 for the smaller systems. On a per acre foot basis the lowest cost would be \$1882 assuming greater than 1000 connections and a 30% reduction. If a 20% reduction is assumed costs would be 50% greater ranging up to \$2800 per acre-foot of water saved.

6.2.2 Supply Side Options

Historically most water supply systems have relied on water from tributary streams stored in upstream reservoirs. These types of systems, using gravity to distribute water, tended to be more economical than systems that required pumping from the mainstem lakes and rivers. Population growth and water quality concerns have resulted in some of the larger communities changing over to mainstem water supplies. The use of mainstem water also provides a measure of security against climate change because of the huge reservoir capacity represented by Okanagan Lake in comparison to small upstream reservoirs.

For a smaller system that may face shortages due to climate change, there are two basic supply side options:

- Supplement or replace tributary water supplies from other sources (usually mainstem water)
- Increase upstream storage capacity

Under the first option the principle source of supplementary water will be the mainstem lakes or river. This water would have to be pumped up to a balancing reservoir to feed the domestic and irrigation connections often located at a considerable altitude above the lake level. In some limited cases there may be groundwater supplies that could help supplement tributary water, although this option has not been analyzed in this report.

The second option involves increasing the height of current dams or building new dams and reservoirs on tributary water systems to increase the catchment during the freshet.

6.2.2.1 Switching to Mainstem Water Supply

For a single water supply system, the option of switching to mainstem water is worth considering because the potential exists to supply 100% of current and future water demands, a potential that does not usually exist with other supply or demand side options. On a larger scale there is

enough storage in Okanagan Lake for every individual system to go to mainstem water as primary supply although the lake management regime would be affected. Currently the lake is managed for a combination of flood control and fishery concerns. A larger scale analysis would be required to determine an optimal rule curve to accommodate the potentially larger demands that would occur as well as the requirements for flood control, fisheries and transboundary lake level accords.

The economic cost of switching to mainstem water is very specific to the size and physical setting of the water supply system. Cost factors include the maximum daily demand, the elevation and distance from the mainstem water supply, the lake bottom characteristics near the intake, and how much of the current supply infrastructure could be incorporated. A major factor is whether the current balancing reservoir could be used in a lake pumping system or if a new one would have to be constructed. The report by Earthtech developed cost curves, which can be applied with site-specific cost factors to develop cost estimates of supplying mainstem water to individual systems. Given a reasonable range of assumptions about the current systems, the cost per acre foot of supplying lake water ranges from \$648 per acre foot for a low elevation system with no new balancing reservoir to over \$2,600 for a higher elevation system requiring construction of a new balancing reservoir.

6.2.2.2 Increasing Upstream Storage

Because upstream storage on tributaries has been the historically preferred way of supplying water since the early 1900's, most of the low cost sites have already been developed. A very limited amount of low cost storage enhancement may be available through raising the height of current dams or development of small sites. These low cost options would be in the order of \$600 per acre-foot but are not available in most tributaries. Most systems, if any potential for increased storage exists, would be facing costs of at least \$1500 per acre-foot. It is difficult at this stage to gauge the potential increase in water that could be supplied through storage without detailed engineering studies.

6.2.3 Summary of Adaptation Cost Information

In summary, there is no one least cost adaptation option for all water systems since costs will vary significantly from system to system. The lowest cost option in one area may turn out to be a higher cost option in other areas. Other factors, such as water quality and treatment options will also enter into the decision. Often a combination of options will be necessary in order to achieve full insurance against future water shortages and demand increases.

For future budgeting purposes, it appears that systems that are already near capacity would have to consider costs of least \$1000 per acre-foot to conserve or develop supplies of water to adapt to climate change. If projections indicate that large amounts of water must be conserved or supplied then probably \$2000 per acre-foot would be a reasonable figure to consider in future budgets. Site-specific engineering studies would have to follow to obtain more accurate figures.

As an initial reference, Table 6.2.1 below shows adaptation costs per acre-foot from lowest to highest. It must be noted that each figure in Table 6.2.1 applies to specific circumstances; managers of a particular water system would have to consider the physical characteristics and customer base of their system before determining where they fall on the spectrum of water adaptation costs.

Option	Cost per Acre Foot	Potential water saved or supplied
Irrigation scheduling - large holdings	\$500	10%
Lowest cost storage	600	limited
Lowest cost lake pumping	648	0-100%
Public education -large and medium communities	835	10%
Irrigation Scheduling - small holdings	835	10%
Medium cost storage	1000	limited
Low cost lake pumping (no balancing reservoir)	1160	0-100%
Trickle irrigation in high demand areas	1500	30%
Average leak detection	1567	10-15%
Trickle irrigation in medium demand areas	1666	30%
Lowest cost domestic water metering	1882	30%
Medium cost lake pumping	2200	0-100%
Domestic water metering, small communities	2300	30%
Higher cost lake pumping	2700	0-100%
Higher cost metering	2700	20%
Highest cost metering	3400	20%

Table 6.2.1: Range of Adaptation Costs

6.3 Water Supply and Demand Scenarios

6.3.1 Introduction

Research for this component, which will take place in year two of the project, will examine the vulnerability of water resource systems in the Okanagan Basin to the impacts of climate change on water supply and demand. The role that various adaptation options can play in reducing vulnerability will also be examined. This study will use results generated from other components of the regional assessment as well as projections of future development in the region to create scenarios of future water supply and demand. These scenarios will be presented to stakeholders in the region during dialogue sessions focusing on the implications of climate change for water management in the Okanagan.

6.3.1.1 Climate Change in the Okanagan

Two preliminary studies investigating the impacts of climate change on hydrology and irrigation demand in the Okanagan Basin were completed in 2001. Cohen and Kulkarni (eds., 2001) carried out hydrological modeling of the impacts of climate change on six unregulated sub-catchments, comparing future hydrographs for the 2020s, 2050s and 2080s to the period of record. Results for all six sub-catchments indicated an earlier onset of peak flows in spring by approximately four to six weeks. Neilsen et. al. (2001) used future projections of regional climate based on downscaled global circulation models to estimate future crop water demand for the area around the District of Summerland. The study showed an increase in crop water demand by as much as 37%, resulting from a combination of warmer temperatures and lengthened growing season. With this projected increase in irrigation demand, the study also showed that several irrigation districts in the study area would come close to using their entire licensed supply.

6.3.1.2 Significance for Water Management

The implication of these studies for water management is that reservoirs are likely to fill earlier in the year and these supplies will have to meet a significantly increased demand over a longer growing season. Such dramatic changes in water supply and demand will have major impacts on water management planning, particularly as they are combined with the projected increases in population, agriculture's continued dependence on irrigation and other existing and future pressures on water resources. A preliminary survey of water management plans in the Okanagan has indicated that some future pressures on water resources, such as population increase, have been incorporated into projections of future water demand by some local authorities. However, this is not the case for climate change impacts. While climate change is considered as a source of uncertainty by some municipalities and irrigation districts, allowances for the impacts of climate change on water supply and demand have not been incorporated into water management strategies in the region. This is not surprising considering that climate change is a relatively new threat and there is a lack of information on climate change impacts, particularly at the scale of water management decision-making. Aside from the two studies mentioned above, which are limited in scope, there are few tools available to water managers to apply the impacts of climate change to their supply and demand situations.

To make effective decisions about infrastructure, programs and technologies, water managers and political representatives will need to visualize future water supply and demand for their jurisdictions in the context of climate change, development pressures and competing interests. In the Okanagan, the majority of water management decisions occur at the utility level. Water utilities in the Okanagan are operated by irrigation districts, municipalities, regional districts or user cooperatives. These organizations hold licenses to use specific water sources and are responsible for managing the supply, and associated treatment and delivery infrastructure, to meet the demand of their customers. Utilities also have the ability to use demand side management techniques, such as water metering, pricing, public education and use restrictions, to influence customer demand. As the interface between the water resource and the users, the job of balancing supply and demand rests with these local authorities and it is at this level of decision-making that the question "will there be enough water?" is most important.

6.3.1.3 Literature Review

Water quantity evaluations were carried out in the 1970s as part of the Canada-British Columbia Okanagan Basin Agreement (Canada-British Columbia Consultative Board, 1974). The study used low, medium and high economic growth projections to calculate consumptive requirements

for tributary systems and total water requirements, including consumptive and non-consumptive uses, for the main stem system. The evaluation estimated the then present day (1970) water requirements for the basin to be 312,000 acre-feet. The total basin water requirement for the year 2020, based on a range of growth projections, was estimated to be between 344,000 and 347,000 acre-feet. A variety of supply and demand-side management options were recommended for the region to cope with increasing water needs.

A regional dialogue on adapting to the impacts of climate change on water resources in the Okanagan Basin was carried out as part of a preliminary impacts study in the region (Cohen and Kulkarni eds., 2001). Hydrological modelling results of six sub-catchments in the basin were presented to participants in multi-stakeholder workshops. The presentations were followed by facilitated discussions on sector-specific impacts, options for adaptation and implications of various adaptation options. Results of the stakeholder dialogue indicated a preference for structural interventions, such as increasing upland storage, and increased regulation of land and water use. Stakeholders also identified a need for scenarios of water demand as an important next step for continued research on water resources and climate change in the region

Carter and La Rovere (2001) provide guidelines for the development and use of scenarios to explore the impacts of climate change and options for adaptation as part of the contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. The IPCC defines a scenario as “a coherent, internally consistent and plausible description of a possible future state of the world” (Carter and Rovere, 2001, p. 149). Scenarios can be applied at a variety of scales and can focus on a specific issue, such as water resources, or incorporate a variety of sectoral and cross cutting issues. Scenarios can be used for a variety of purposes including communicating the potential consequences of climate change and strategic planning.

Lorenzoni et. al. (2000) used integrated scenarios of climate change impacts in dialogue with stakeholders in the East Anglian region of England. The scenarios linked greenhouse gas emission scenarios with socio-economic futures for the region to explore the feedbacks between natural and human systems in the context of climate change. The stakeholder dialogue focused on enhancing understanding of vulnerability and adaptive capacity for various “exposure units,” or human and natural systems sensitive to climate change. The authors found the scenarios to be effective in meeting the information needs of decision-makers at the regional level, exploring the links between adaptive responses to climate change and possible outcomes and encouraging social learning.

Stevens et., al. (1992) investigated demand side management as a means of increasing the efficiency of water use in the Okanagan Valley. The study focused on universal water metering and drip/trickle irrigation systems as the water conservation mechanisms. Universal metering combined with installation of drip/trickle irrigation systems on 60% of irrigated land in the valley was estimated to result in an annual reduction in water use from 95,000 acre-feet to 63,000 acre-feet. The cost for installation of metering and irrigation systems was estimated to be between \$39 million and \$58 million (1990 dollars).

6.3.2 Research Questions and Objectives

The primary question for this research is:

Are water resource systems in the Okanagan Basin of British Columbia vulnerable to the combined impacts of development and climate change?

A secondary question is also posed:
If so, what adaptation options can be used to reduce vulnerability?

Three objectives have been identified for the study:

- Generate scenarios of water supply and demand for a selection of water utilities in the Okanagan Basin, incorporating development trends and the impacts of climate change.
- Assess the effectiveness of adaptation options in balancing future water demand and supply as depicted in the scenarios.
- Evaluate the suitability of adaptation options for specific water utilities through examination of physical parameters for each water utility and dialogue with stakeholders.

6.3.3 Research Approach and Methodology

This component will use action research methods and integration of various data in scenarios to examine the vulnerability of water resources in the Okanagan Basin to the impacts of climate change and future development.

6.3.3.1 Scenario Development

The scenarios approach will aim to create “plausible futures”, or depictions of future water supply and demand that are plausible given the range of development, climate change and water management trends that could occur in the future. Scenarios will address the questions of how regional development and climate change will shape future water supply and demand in the Okanagan Basin and how changes in water management practices can reduce vulnerability. The scenarios will be based on the following conceptual model:

$$\begin{array}{l} \text{Current Water Supply and} \\ \text{Consumption Trends} \end{array} + \begin{array}{l} \text{Development \&} \\ \text{Climate Change Projections} \end{array} = \begin{array}{l} \text{Supply and Demand} \\ \text{Scenarios} \end{array}$$

$$\begin{array}{l} \text{Supply and Demand} \\ \text{Scenarios} \end{array} + \begin{array}{l} \text{Water Management Practices \&} \\ \text{Level of Adoption} \end{array} = \begin{array}{l} \text{Adaptation Scenarios} \end{array}$$

Construction of the scenarios will include the following steps:

- Establish an advisory panel of experts based in the study area to participate in the research by suggesting sources of information and providing input on utility selection and scenario development.
- Collect data on current water use, water supply, management practices, development trends and climate change impacts for scenario input.
- Define scenarios of population growth, industrialization and changes in irrigated area in consultation with the advisory panel.
- Compile data in a spreadsheet program and input calculations to construct scenarios.
- Work with the advisory panel to test the plausibility of scenarios and select scenarios for further investigation in the stakeholder dialogue component.

Scenarios will be calculated in a spreadsheet model using data in four categories:

- **Supply:** Data on current water supplies will be obtained from Land and Water BC and will be verified with the utilities being investigated. Scenarios of water supply under climate change conditions will be taken from the hydrological modeling component of the project (see Chapter 3).
- **Demand:** Information on current agricultural, domestic and ICI (industrial, commercial, institutional) water use will be obtained from the water utilities and Land and Water BC. Data on future agricultural water demand will be taken from the crop water demand modeling component of the project (see Chapter 4). Data on the impacts of climate change on domestic and ICI water use will be taken from the available literature.
- **Development:** Projections of future population and possible changes in irrigated area will be obtained from BC Stats and local planning authorities (regional districts).
- **Water Management:** Existing trends in water management and water use efficiency, such as the gradual upgrading of overhead sprinkler irrigation systems to more efficient systems, will be defined based on consultation with local experts involved in water management and agriculture. Data on the applicability of various demand and supply side management (adaptation) options for each purveyor, such as availability of suitable reservoir sites, will be obtained from a survey of water utilities. The water use reduction or supply increase potentials and costs per unit of water saved/supplied for a variety of adaptation options will be obtained from the study of costs and effectiveness of adaptation options (see section 6.2).

6.3.4 Stakeholder Dialogue

The supply/demand scenarios and assessment of adaptation options will be presented to groups of stakeholders during a dialogue process. The stakeholder dialogue will aim to both inform stakeholders about the outcomes of the research and learn about stakeholder perceptions of the threat of climate change in the context of other factors influencing water resources in the region. Discussion will focus on the trade-offs associated with adaptation options and the range of views expressed among various sectors and levels of decision-making. A more detailed discussion regarding stakeholder dialogue can be found in Chapter 7.

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Chapter 7. Dialogues with Stakeholders

Stewart Cohen, Philippa Shepherd

7.1 Objectives and Methodology

When considering the issues of climate change, climate impacts, and adaptive response options, dialogue will be effective as long as the scenario exercise is presented in a way that shows that it is plausible and relevant to stakeholders in the region, in order to be valuable both to stakeholders and to researchers.

This dialogue with stakeholders will be used to examine whether the scope of the research program on climate change and climate impact scenarios, complemented by studies of regional water management frameworks, institutions, and adaptation options, is appropriate for bringing global scale climate concerns to the regional scale. Stakeholders will participate in the evaluation of potential adaptation options according to their specific water use interests. An adaptation evaluation exercise will give stakeholders the opportunity to identify evaluation criteria, indicators for measuring criteria, and other aspects of the evaluation exercise using some level of consensus-based decision-making. While illustrating the effectiveness of such an exercise to stakeholders, the evaluation will also help identify barriers and/or other aspects of adaptation not considered in the review of water management frameworks (Chapter 5) and the synthesis of adaptation case studies described in Chapter 6.

At this time, the research team is planning to build on the interviews and surveys undertaken for the water management and adaptation case study components to organize a series of focus group sessions on identifying preferred adaptation options and processes for their implementation. Rather than seeking consensus on the "best" option or process, the focus groups will be asked to consider available options as part of a portfolio that could address both supply side and demand side aspects of water resources management in the Okanagan. The shaping of the adaptation portfolio would build on the results of previous focus group sessions held in 2001 (Cohen and Kulkarni, 2001) and the adaptation cost component from the current study (see section 6.2). The discussion on implementation process would build from the 'early adopters' case studies (see sections 6.1 and 7.2), in which particular attributes such as attitudes, drivers, obstacles and enabling factors can be considered.

It is anticipated that this would happen in two stages: a) homogeneous groups (e.g. irrigators, municipal, fisheries) expressing their preferences for an adaptation portfolio and associated implementation processes based on their management objectives, and b) heterogeneous groups (whole region or possibly based on subregions, e.g. north, central, south) considering tradeoffs between various sets of management objectives, and expressed preferences of homogeneous groups. Throughout this exercise, various members of the study team would be available as resources to address participants' questions related to climate, hydrology, crop water demand and other results from this study.

7.2 Role of Early Adopters Cases in Establishing Dialogue

For a dialogue process to be meaningful, there needs to be a number of elements in place:

- A clear sense of what the dialogue's objectives are,

- An understanding of the regional context, and
- A gradual build-up of trust through shared learning.

Outreach activities (see 7.3) have been instrumental in helping the research team achieve ‘a’ and ‘c’, to some degree, but outreach on its own provides only a limited sense of the management context in which water-related decisions have been made in the past, as well as any trends or recent developments that may affect this context in the future. It is desirable for research to help in relating theoretical issues to matters of operational practice for which local knowledge can be applied most effectively. In order for theoretical notions of proactive adaptation to be translated into practical terms, there needs to be concrete examples of how this has been done, regardless of whether or not the particular case was explicitly addressing climate change. Such cases also complement scenario studies in that there can be important lessons learned that may be applicable to the scenarios being addressed.

In the precursor to this study (Cohen & Kulkarni, 2001), the stakeholder dialogue was primarily an exercise in identifying adaptation options. Implications were touched on but not thoroughly examined. What needs to be fleshed out is a mock, but plausible, action plan: a discussion of the steps needed to be taken to prepare the ground for change. It is not only a question of how do we act, but who should act and what is required for action to take place e.g. new regulation, resources, expertise, better planning. In other words, what factors would help facilitate change e.g. education?

In this study, one of the key elements in learning about regional management context, as well as regional approaches to adaptation, is the set of early adopters cases described in 7.1. These cases enable both the research team and prospective stakeholder participants to see regional examples of proactive adaptation to challenges that can be analogous to the climate change scenarios being considered. Each of the cases deals with a potential near-term shortage in water quantity for major user groups (municipal, irrigation). Insights into the decision making process and the options selected provide valuable information about institutions, resource constraints, technological applications, economic considerations, and local perceptions and attitudes. It enables the research team to know the people, appreciate local history, and observe the effectiveness of these measures.

The results of these case studies are more for the benefit of the facilitators than stories to be told directly in a stakeholder setting. However, they indicate some of the complex issues that might arise from implementation of certain adaptation options e.g. grower perceptions of metering, as well as some of the solutions to barriers to change. A discussion, not only of the implications (potential barriers) of a specific adaptation option, but of strategies that would help overcome hurdles would be a rich, rewarding and useful exercise.

Table 7.2.1 provides some preliminary questions that could be explored or considered implicitly (not asked directly).

1. What are the potential barriers to adapting to climate change?	Knowledge/data Understanding (accepting the signal) Resources Regulation
2. What is appropriate when and where?	Are there steps that should be taken before others e.g. education? What options apply to the whole region? Which apply to specific areas? Are there any effective adjustments that can occur before full-blown adaptation?
3. What is needed?	Information/knowledge Direction Regulatory framework Funding
4. Who should do what?	Who should adapt and when? Who should fund adaptation? Who should drive the agenda?
5. How do we go about determining the best form of action?	Would an adaptive management approach e.g. experimentation, be applicable?
6. What are the issues surrounding each adaptation option? What can be done about it?	What actions could reduce the obstacles to implementation?

Table 7.2.1: Stakeholder dialogue questions

There are a number of incentives for stakeholders to participate as partners in research, such as the potential for problem solving, and an opportunity to consider new technical information. However, it also offers stakeholders an important incentive to participate to this dialogue - respect for local experience, which helps to achieve trust and reduce tensions that could lead to conflicts around sensitive issues.

7.3 Outreach with Stakeholder Groups

Since 1997, various members of the research team have been engaged in research and awareness raising on climate change, climate impacts, and adaptation within the Okanagan region, through research reports (Cohen et al., 2000; Neilsen et al., 2001, Cohen and Kulkarni, 2001) and presentations at various regional for a (e.g. BC Water Supply Association, BC Tree Fruit Growers Association, Canadian Water Resources Association, Okanagan Basin Water Board). This has attracted regional media attention (e.g. Kelowna Daily Courier, Sept. 3, 2000; Kelowna Capital News, March 14, 2001).

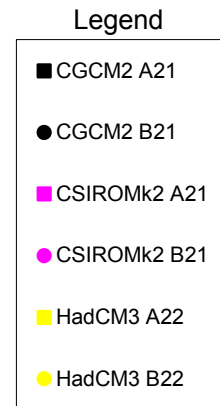
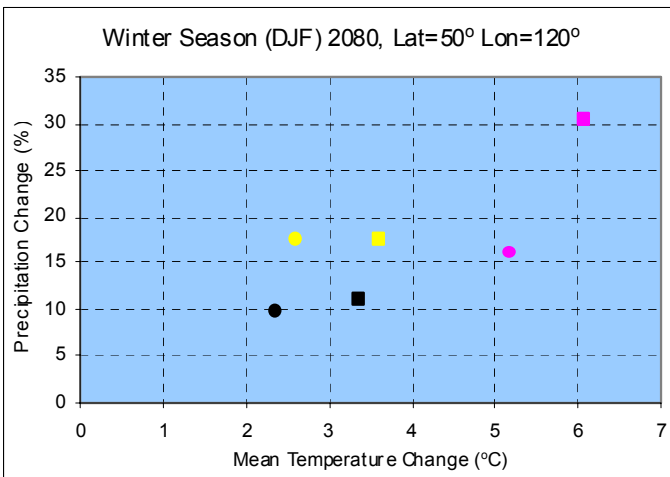
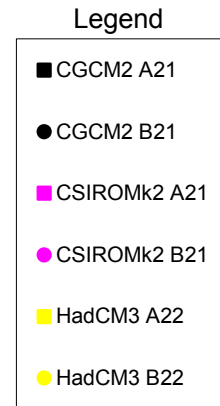
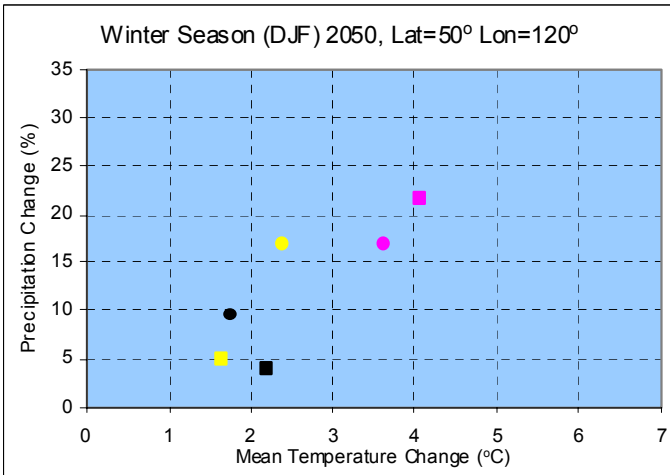
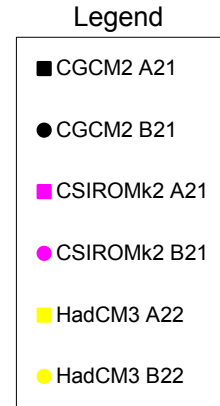
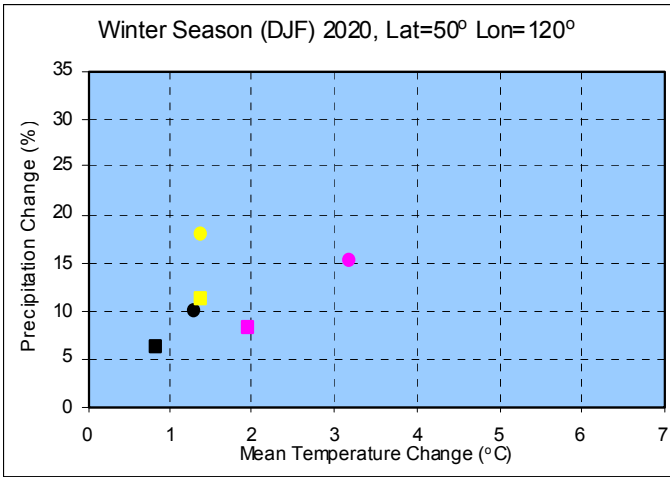
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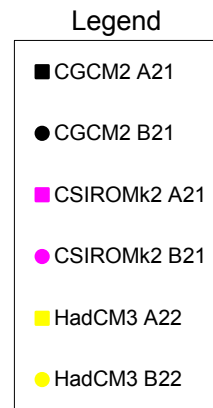
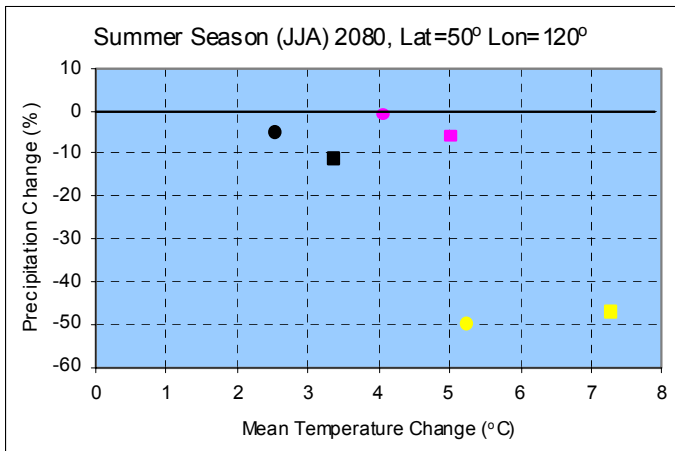
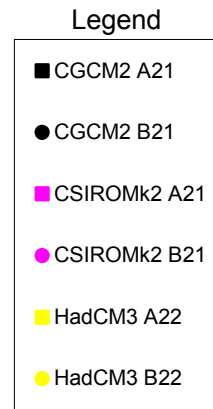
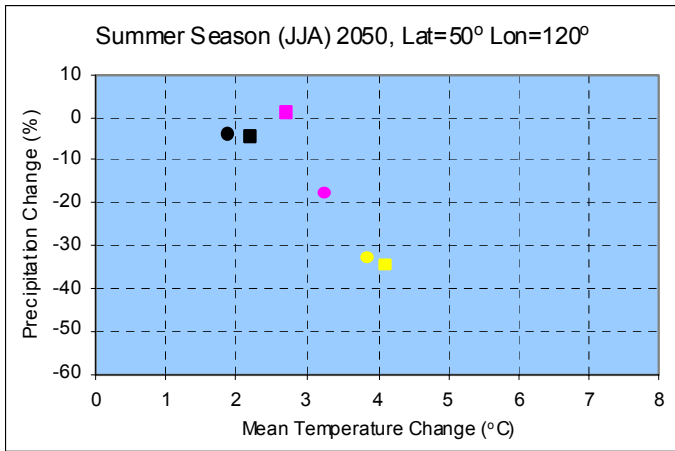
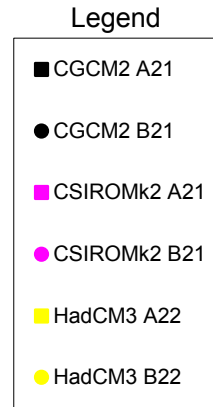
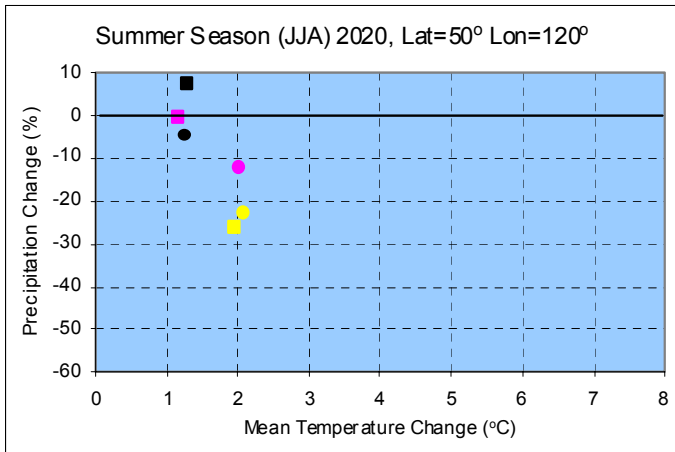
Focus group workshops will be held during Year II to inform stakeholders of the research results from all components, including water management and adaptation case studies, and to ask

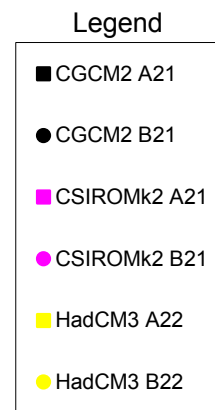
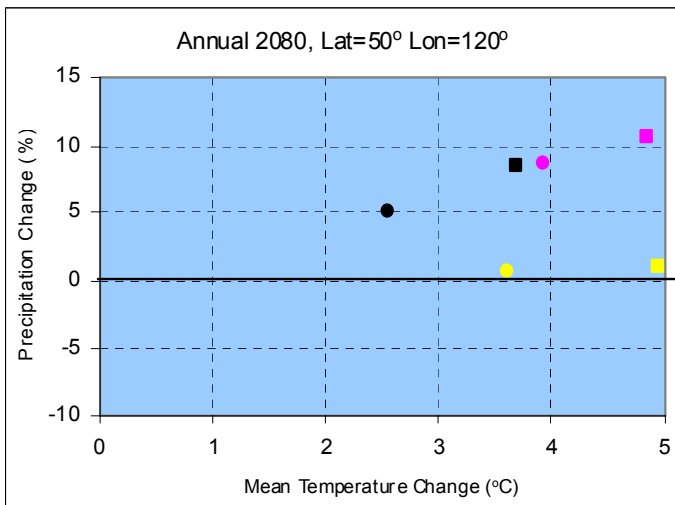
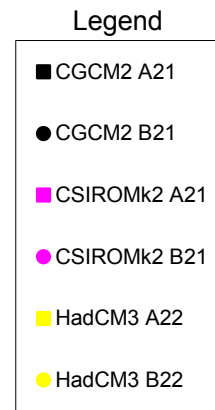
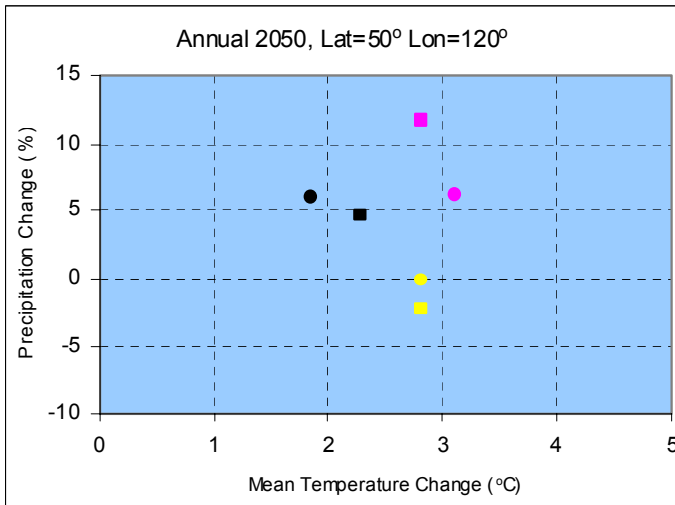
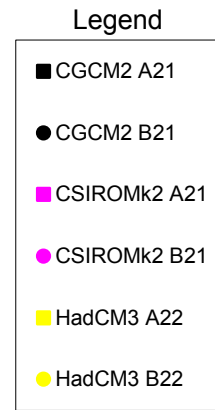
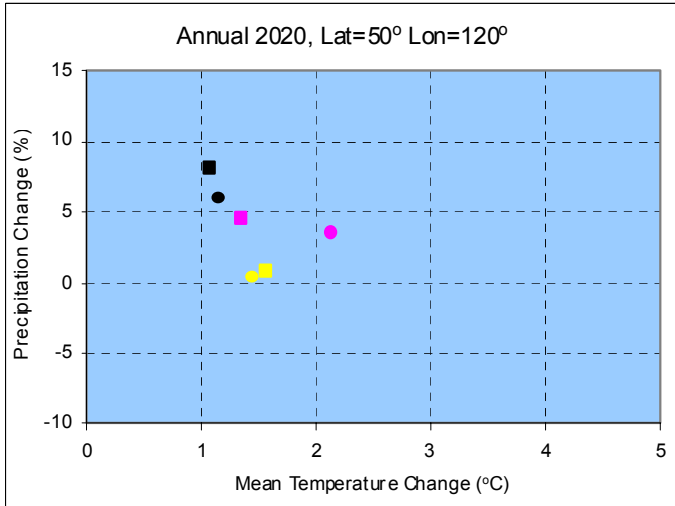
stakeholders for their preferences of adaptation options. Planning for the focus groups session will take place during April-August, 2003, including setting agendas, identifying local venues, organizing facilitators and establishing lists of invitees. The homogeneous group sessions would take place during September-November, 2003, to be followed by the heterogeneous groups in January 2004.

Appendix A: Climate Change Scenarios

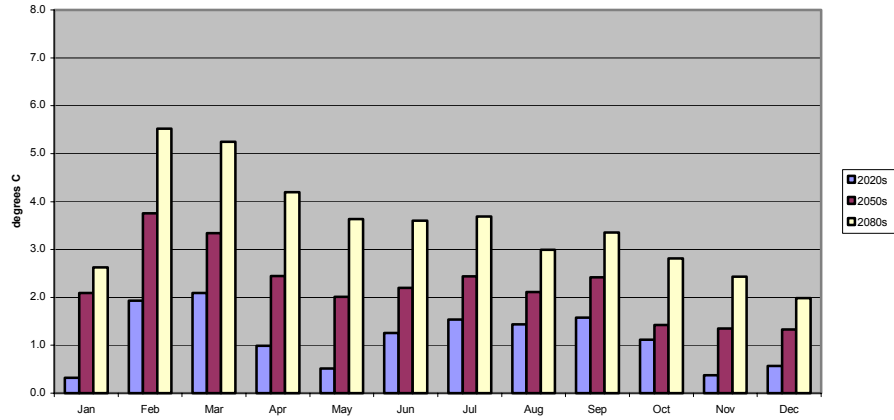
The following figures show scatter plots of projected changes in average daily temperature (degrees C) and precipitation (percent) for the 2020s, 2050s and 2080s relative to 1961-1990 for winter, summer and annual periods for three GCMs and two SRES scenarios.







CGCM2 Tmin changes SRES A2 - 1



CGCM2 Precip changes SRES A2 - 1

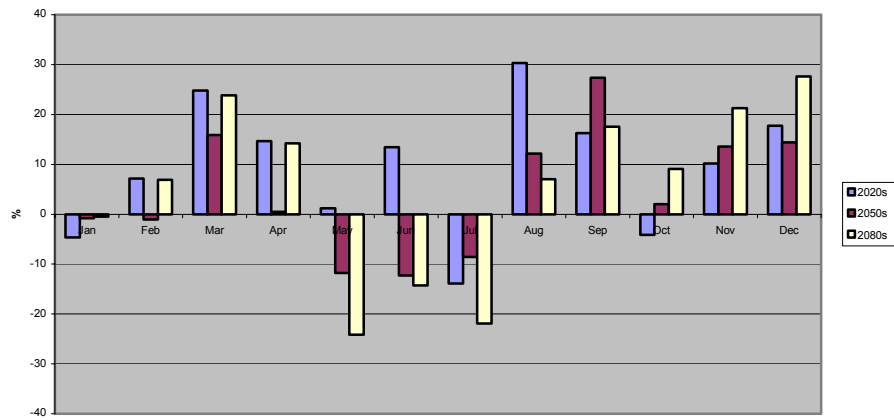
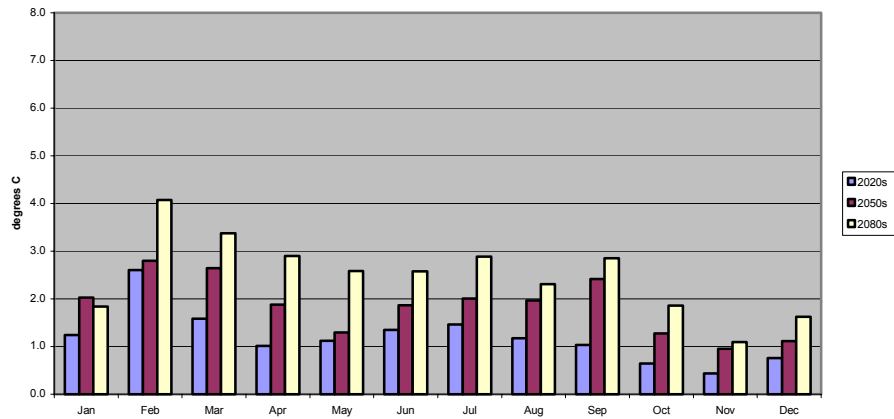


Figure A-1: Canadian model CGCM2. SRES emissions scenario A2.

CGCM2 Tmin changes SRES B2 - 1



CGCM2 Precip changes SRES B2 - 1

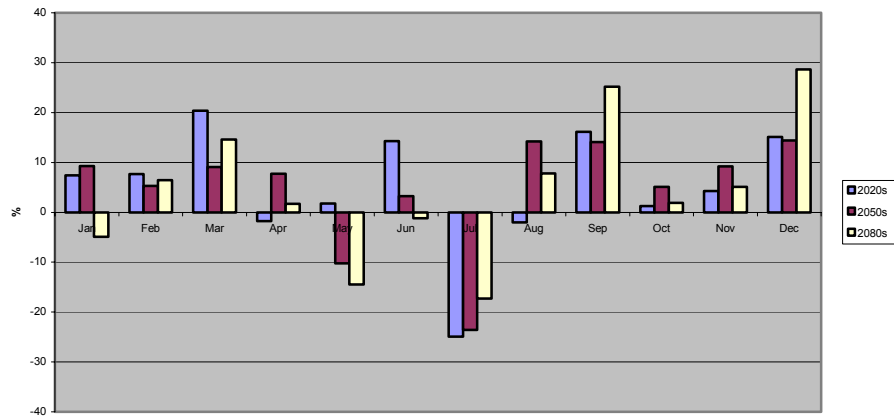
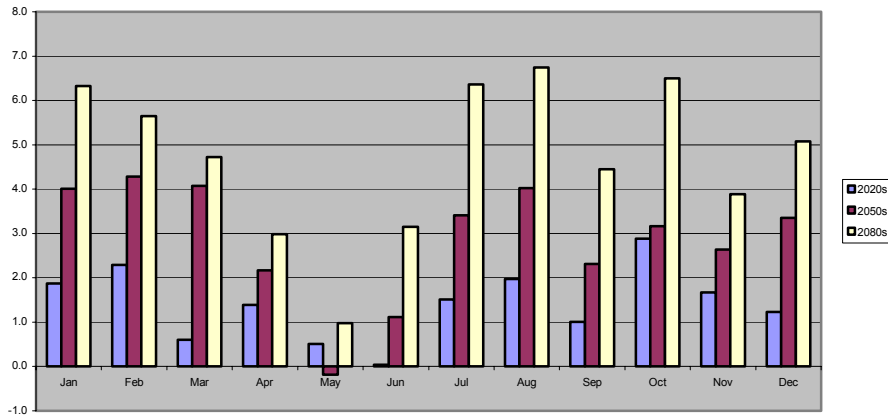
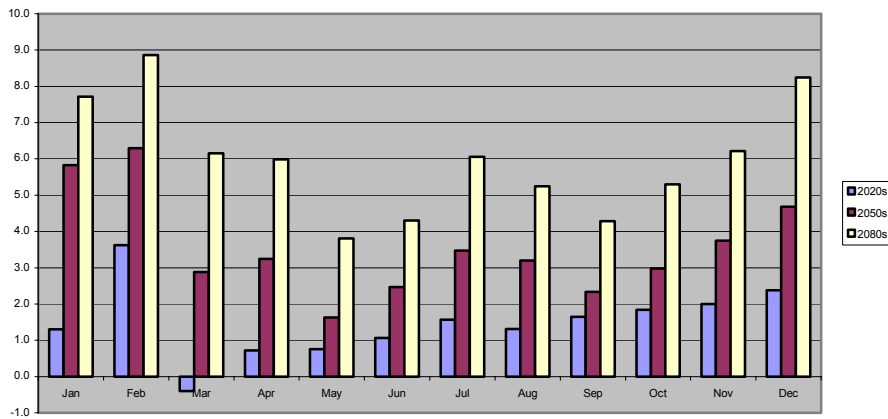


Figure A-2: Canadian model CGCM2. SRES emissions scenario B2.

CSIROMk2 Tmax changes SRES A2 - 1



CSIROMk2 Tmin changes SRES A2 - 1



CSIROMk2 Precip changes SRES A2 - 1

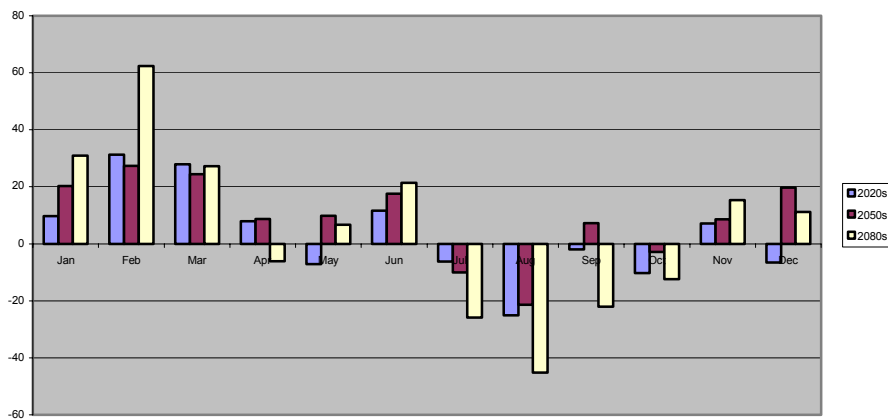


Figure A-3: Australian model CSIROMk2. SRES emissions scenario A2

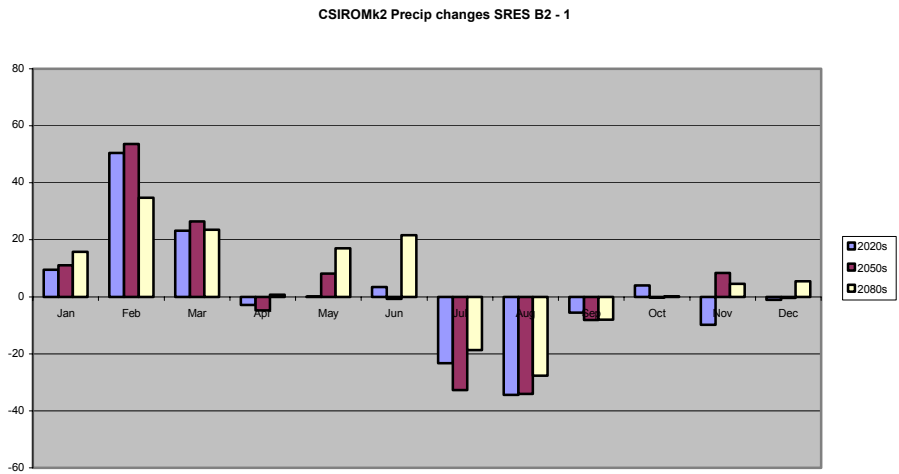
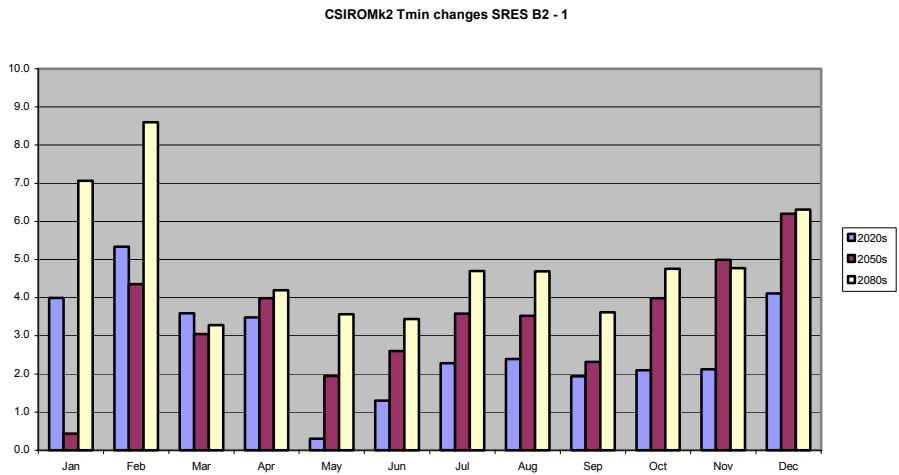
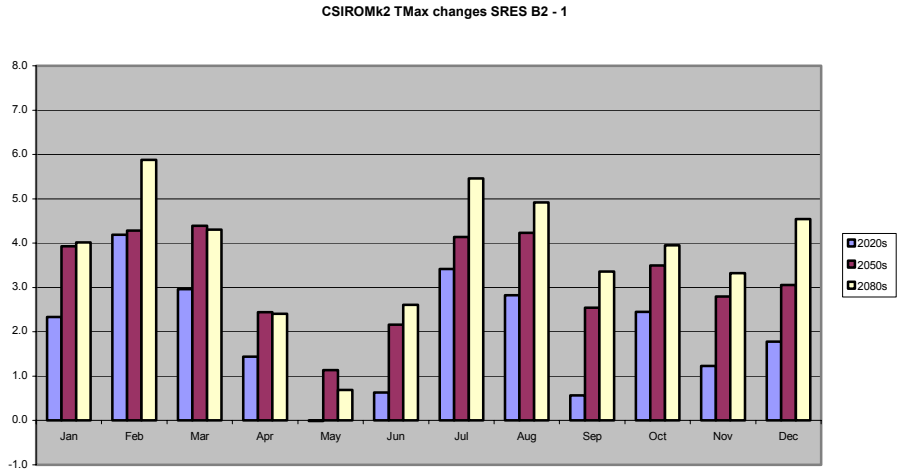


Figure A-4: Australian model CSIROMk2. SRES emissions scenario B2

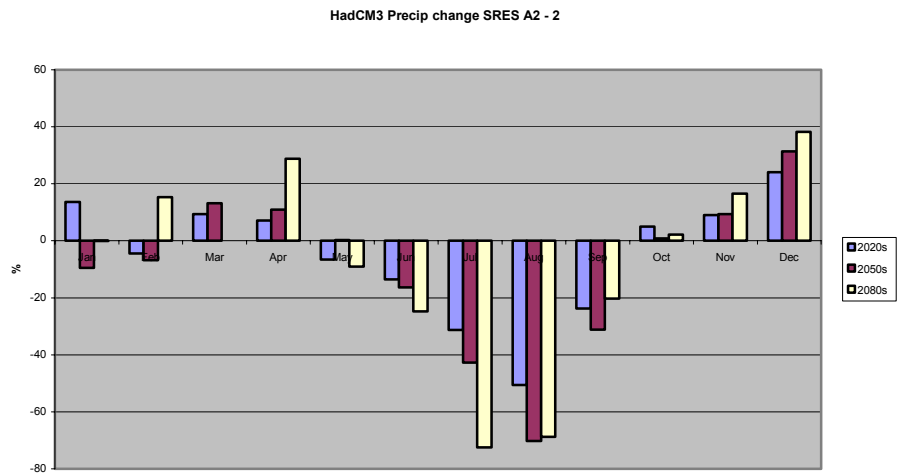
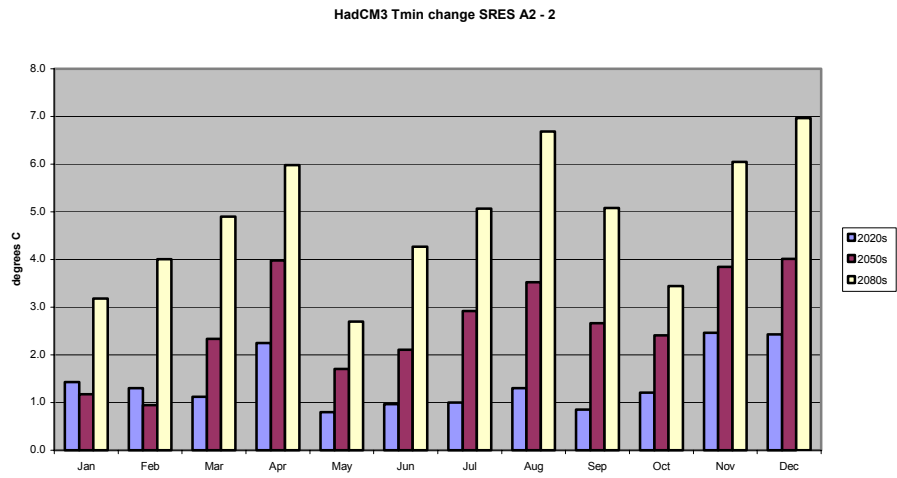
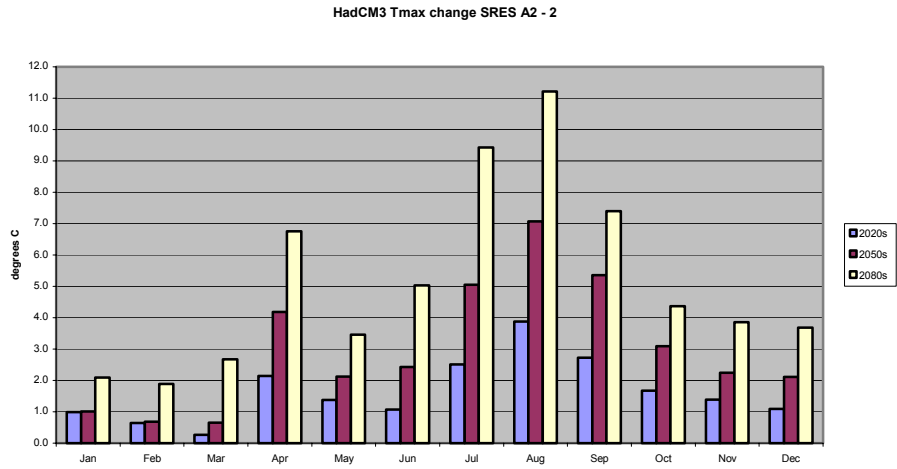


Figure A-5: British model HadCM3. SRES emissions scenario A2

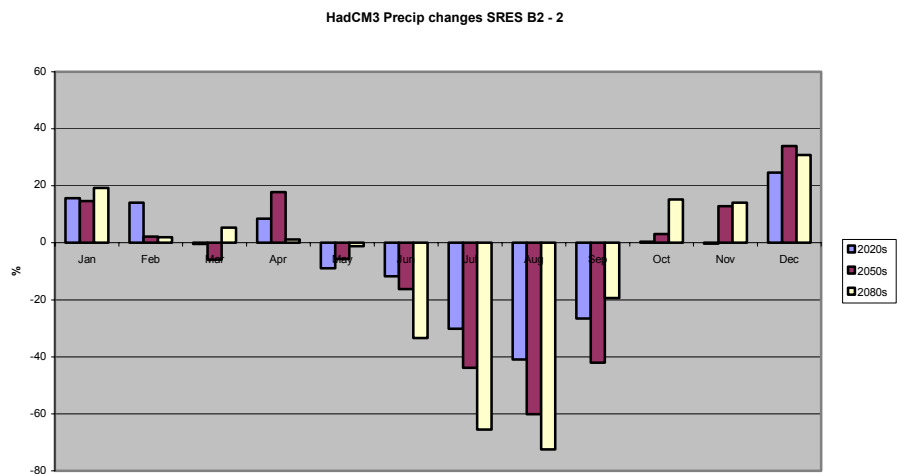
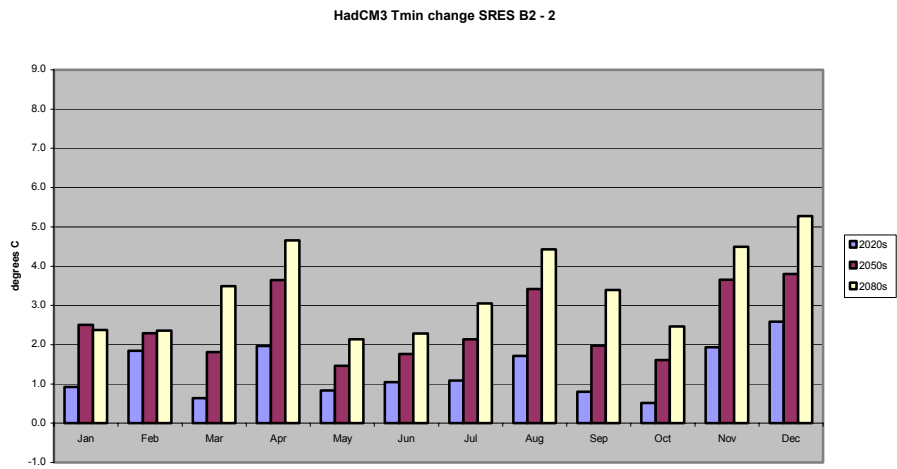
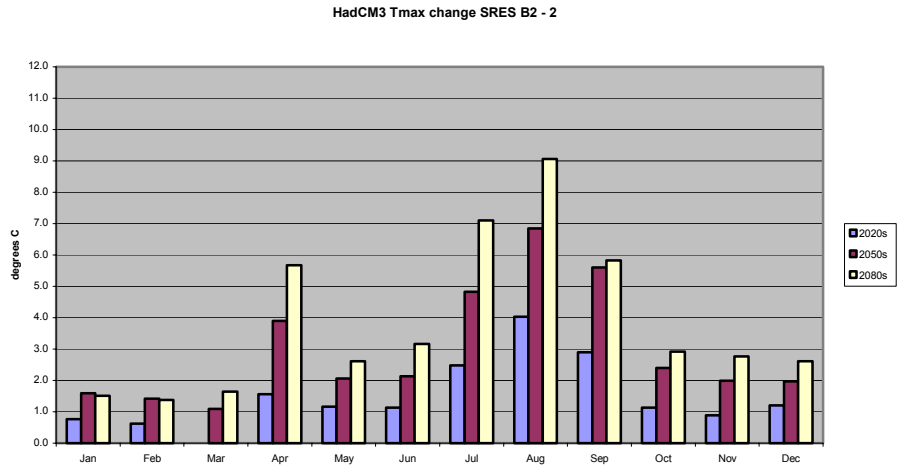


Figure A-6: British model HadCM3. SRES emissions scenario B2

Appendix B: Hydrology

B-1: Model Watersheds

ID	Tributary Name ¹	Elevation Bands	Climate Station ²	Area (km ²)	Elevation Range (m) ³	Major lake (yes/no) ⁴
<i>Tributaries entering main-stem lakes or Okanagan River</i>						
nwk01a	Deep Creek	6	1128580	247	1319	no
nwk02a	Irish Creek	5	1128580	31.1	1080	no
nwk03a	Newport and Bradley Creeks	5	1128580	39	1002	no
nwk04a	Equesis Creek	7	1128580	200	1417	yes
nwk05a	--	3	1128580	4.9	594	no
nwk06a	Naswhito Creek	7	1128580	88	1483	no
nwk07a	--	4	1128580	13.9	801	no
nwk08a	Whiteman Creek	8	1128580	212	1488	yes
nwk09a	--	6	1128580	33.1	1236	no
nwk10a	Shorts Creek	7	1123970	1.85	1559	no
nwk11a	--	4	1123970	55.3	968	no
nwk12a	Lambly Creek	7	1123970	242	1543	yes
nwk13a	Faulkner and Keefe Creeks	5	1123970	40.2	1069	yes
nwk14a	MacDonald Creek	6	1123970	52.6	1221	no
nwk15a	Smith and Westbank Creeks	5	1123970	22.9	1090	no
nwk16a	Powers Creek	7	1127800	145	1503	yes
nwk17a	Drought Creek	3	1127800	10.8	662	no
nwk18a	Trepanier Creek	7	1127800	257	1562	yes
nwk19a	McCall Creek	4	1127800	62.6	723	no
nwk20a	Peachland Creek	7	1127800	149	1487	yes
nwk21a	--	3	1127800	23.3	756	no
nwk22a	Eneas Creek	7	1127800	90	1422	yes
nwk23a	Prairie Creek	3	1127800	27.2	775	no
nwk24w	Trout Creek	8	1127800	759	1663	yes
nwk25a	Madeleine Creek	5	1126150	35	1048	no
nwk26a	Shingle Creek	8	1126150	284	1862	no
nwk27a	Skaha and Felis Creeks	5	1126150	43.3	1083	no
nwk28a	Marron River	6	1126150	105.2	1268	no
nwk29a	--	3	1126150	27.9	619	no
nwk30a	Park Rill Creek	6	1126150	165	1293	yes
nwk31a	--	7	1125865	36.1	1495	no
nwk32a	Reed Creek	7	1125865	23.4	1420	no
nwk33a	Hester Creek	7	1125865	10	1534	no
nwk34a	Testalinden	7	1125865	14.7	1578	no
nwk35a	Strawberry Creek (etc)	4	1125865	67.2	909	no
nwk37a	Haynes Creek	6	1125865	34	1394	no
nwk38a	Mica Creek (and others)	6	1125865	46	1263	no
nwk39a	Inkaneep Creek	9	1125865	114	2007	no

nwk40a	--	3	1125865	33.5	681	no
nwk41a	--	3	1125865	7.1	665	no
nwk42a	Wolf Cub Creek	7	1125865	86.4	1423	no
nwk43a	Vaseaux Creek	9	1126150	296	1985	no
nwk44a	Irrigation Creek	5	1126150	25	1000	no
nwk45a	Shuttleworth Creek	7	1126150	100	1564	yes
nwk46a	--	2	1126150	4.3	322	no
nwk47a	McLean and Matheson Creeks	8	1126150	61	1405	no
nwk48a	Gillies Creek (and others)	6	1126150	52	1386	no
nwk49a	Ellis Creek	8	1126150	157	1667	yes
nwk50a	--	1	1126150	5.2	112	no
nwk51a	Penticton Creek	9	1126150	185	1802	yes
nwk52a	Strutt, Naramata, and Robinson Creeks	7	1126150	141	1563	no
nwk53a	Chute Creek	8	1123970	80	1662	yes
nwk54a	--	6	1123970	157	1223	no
nwk55a	Bellevue Creek	9	1123970	185	1803	no
nwk56a	--	1	1123970	6.1	184	no
nwk57w	Mission Creek	9	1123970, 1123750	845	1813	yes
nwk58a	--	1	1123970	11.4	34	no
nwk59a	Kelowna Creek	6	1123970, 1123750	261	1322	yes
nwk60a	--	3	1128551	87.5	722	no
nwk62a	--	2	1128551	39.4	490	no
<i>Mission Creek subwatersheds</i>						
nwk57a	Upper Mission Creek (Ideal Lake)	5	1123750	175	1058	yes
nwk57b	Mission Ck above Joe Rich Ck	7	1123750	279	1329	yes
nwk57c	Joe Rich Creek	4	1123750	44.8	828	no
nwk57d	Cardinal Ck and un-named creeks	4	1123750	25	841	no
nwk57e	Leech, Grouse and un-named creeks	5	1123750	42.8	980	no
nwk57f	Daves Creek	5	1123750	37.2	971	no
nwk57g	--	4	1123970	13.7	703	no
nwk57h	Hydraulic Ck	7	1123970	102.8	1462	
nwk57i	KLO Creek	8	1123970	61.9	1682	no
nwk57j	Ruhmohr Creek	5	1123970	31.5	1091	no
nwk57k	Priest Creek	7	1123970	30.7	1460	no
<i>Trout Creek subwatersheds</i>						
nwk24a	Above Thirsk Dam	5	1127800	240	923	yes
nwk24b	Camp Creek	5	1127800	37.3	978	no
nwk24c	--	3	1127800	7.8	559	no
nwk24d	--	5	1127800	35.2	999	no
nwk24e	Tsuh Creek	4	1127800	20.3	780	yes

nwk24f	O'Hagen Creek	4	1127800	8.5	738	no
nwk24g	Lost Chain Ck	4	1127800	15.7	715	no
nwk24h	Bearpaw Ck	5	1127800	38.9	1000	no
nwk24i	--	5	1127800	37.7	1000	no
nwk24k	Bull Creek	4	1127800	32.9	857	no
nwk24l	Isintok Creek	6	1127800	47.8	1121	yes
nwk24m	Darke Creek	6	1127800	47.1	1208	no
nwk24n	Denike Creek	5	1127800	76.7	1090	no
nwk24o	--	4	1127800	18.9	845	no
nwk24p	--	4	1127800	18.9	753	no
nwk24q	--		1127800	16.7	1145	no
nwk24r	--	4	1127800	17.9	861	no
nwk24s	--	4	1127800	12.7	891	no
nwk24t	--	2	1127800	2.1	363	no
<i>Vernon Creek/ Kalamalka Lake subwatersheds</i>						
nwk61a	B.X. Creek	8	1128580	131	1524	yes
nwk61b	--	5	1128580	23.8	1008	no
nwk61c	Coldstream Ck	6	1128580	204	1269	yes
nwk61d	Brow Stream, Cosens Creek, Sturt Creek	5	1128580	53.7	1069	no
nwk61e	Oyama Creek	6	1128580	44.1	1231	yes
nwk61f	Ribbleworth Ck and un-named tributaries	5	1128580	42.1	1058	no
nwk61g	Clark Creek	5	1128580	27.5	1042	no
nwk61h	Vernon Creek	4	1128580	80.5	722	yes
nwk61i	--	2	1128580	91.7	1681	no
nwk61j	--	2	1128580	13.1	459	no
<i>Other Model Watersheds</i>						
nwk18x	Contributing area to McDonald Ck Reservoir near Brenda Mines (Trepanier Ck)	3	1127800	17.9	506	no
nwk49x	Contributing area to Ellis Ck Reservoir (Ellis Ck)	3	1126150	45.6	678	no
nwk51x	Contributing area to Greyback Lake (Ellis Ck)	2	1126150	33.6	467	no

¹ indicates minor un-named tributary

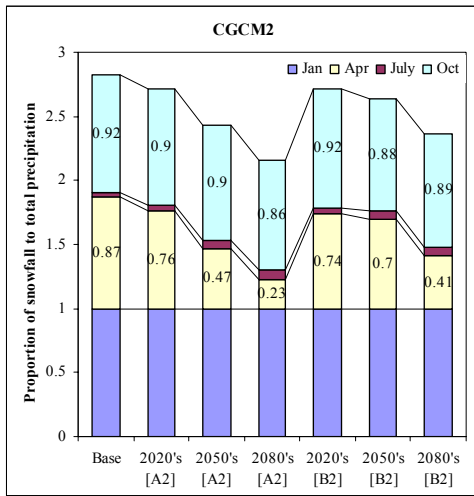
² All stations, with the exception of station 1123970 used in the scenario had records for the entirety of the 1961 to 1990 baseline period. Details about each station are provided in Table 3.2.3

³ derived from TRIM 1:20000 data

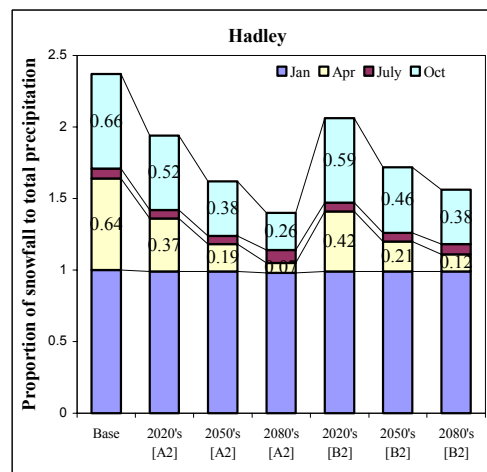
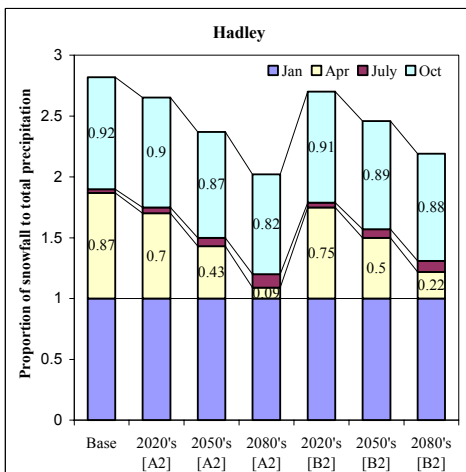
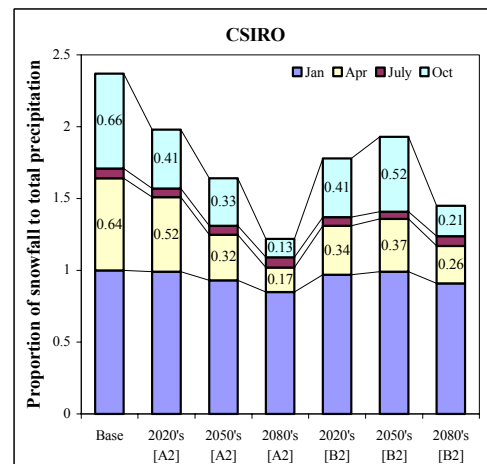
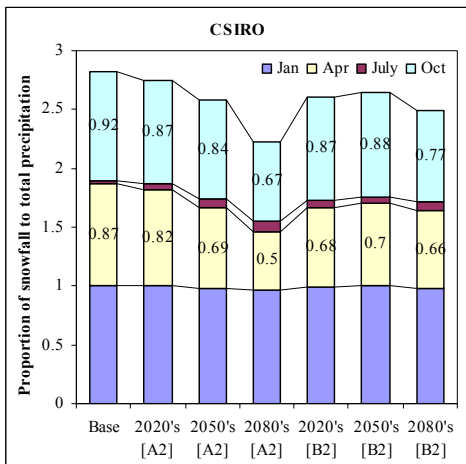
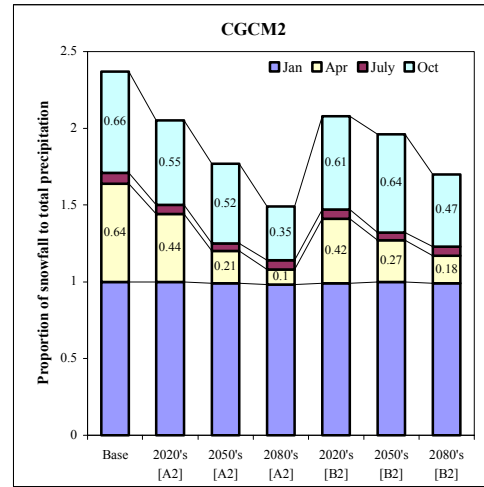
⁴ This work concentrates on modeling the natural flow in watersheds of the Okanagan Basin. Lake and reservoirs were not considered in this phase. In watersheds with significant lakes or reservoirs, flow related model outputs will not provide a realistic representation of flow. Remaining model outputs such as snow water equivalence and potential evapotranspiration are, however, valid.

B-2: Precipitation Form

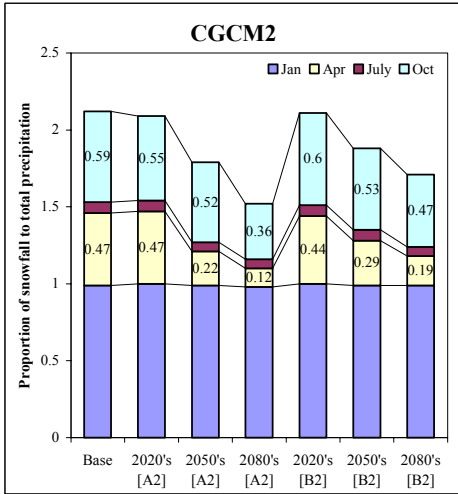
Station ID: 08NM015 (Vaseaux Ck)
Reference Climate Station: 1126150



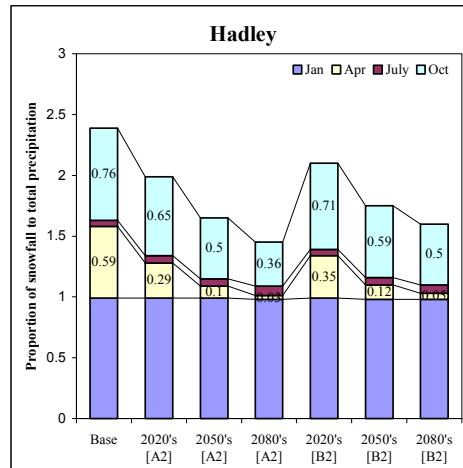
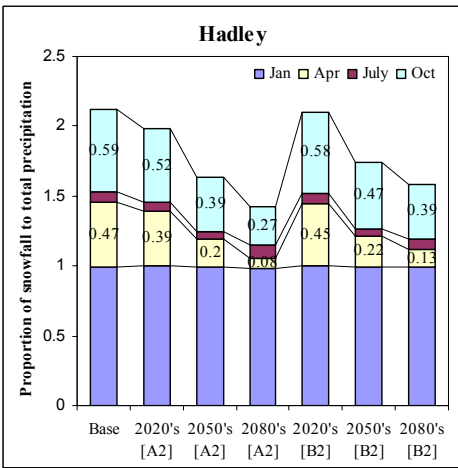
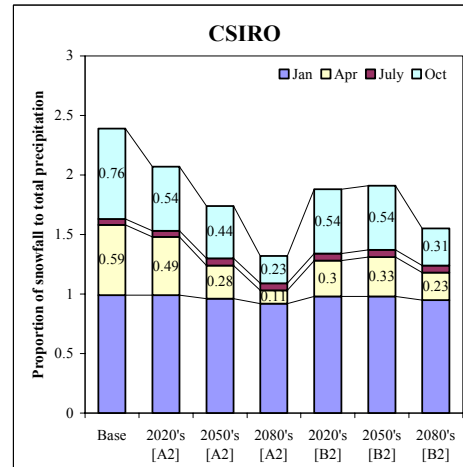
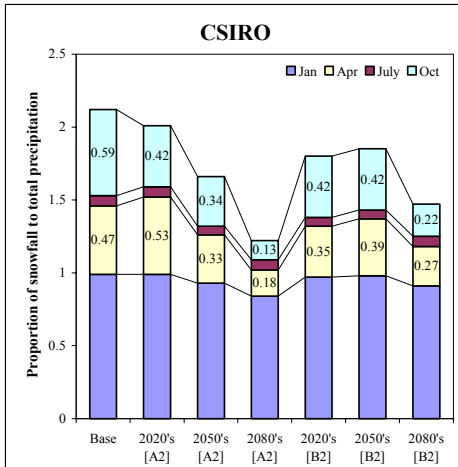
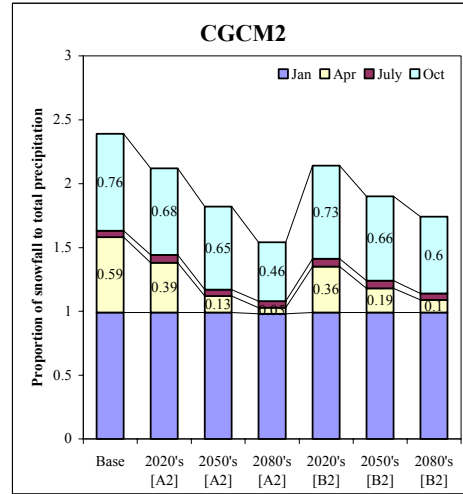
Station ID: 08NM035 (Bellevue Ck)
Reference Climate Station: 1128580



Station ID: 08NM172 (Pearson Ck)
Reference Climate Station: 1123750

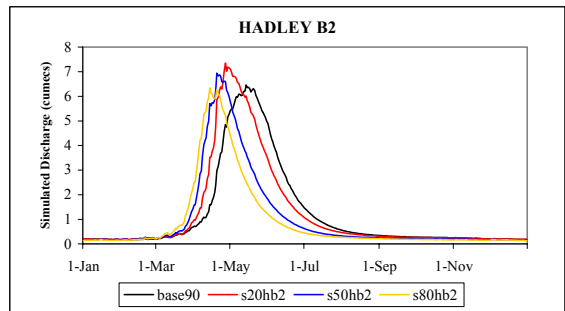
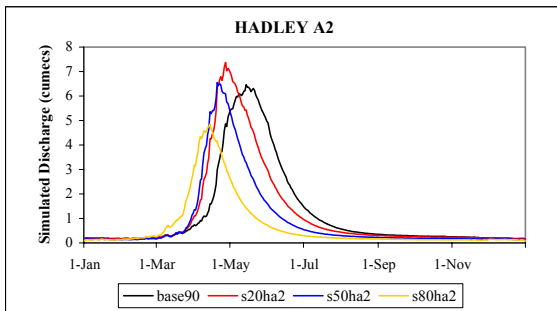
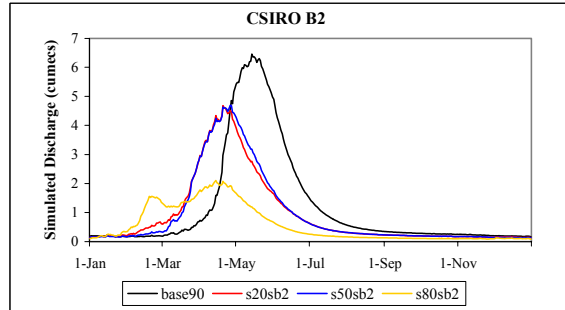
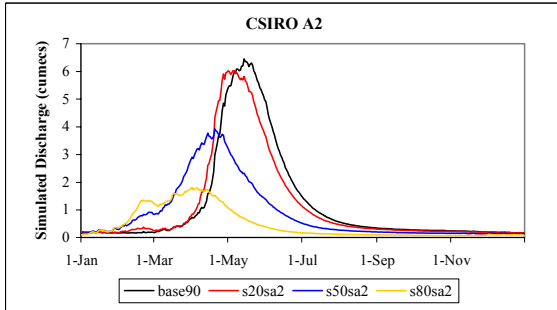
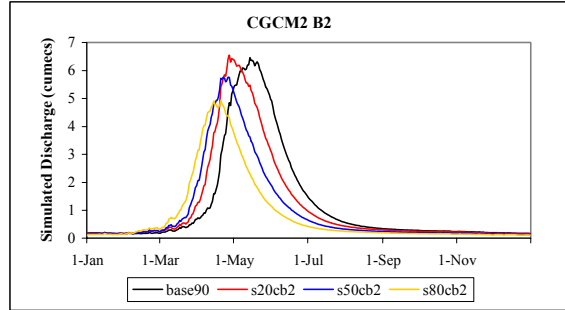
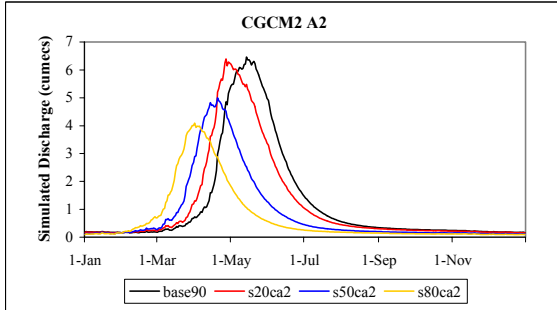


Station ID: Trepanier Creek (nwk18x in B-1)
Reference Climate Station: 1127800

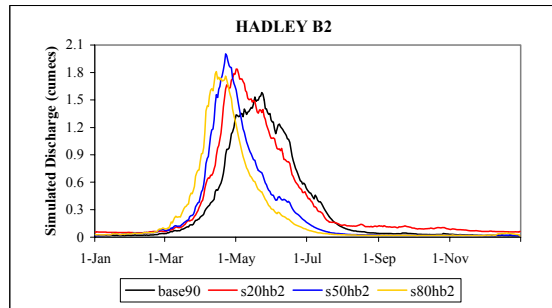
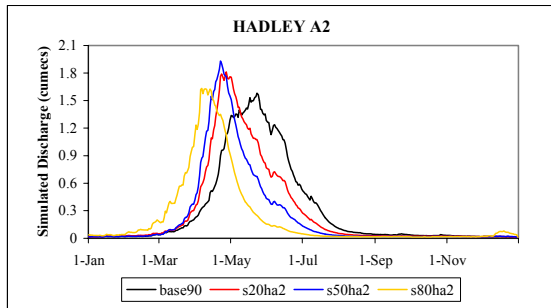
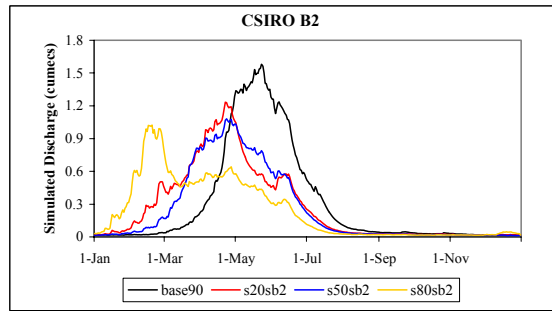
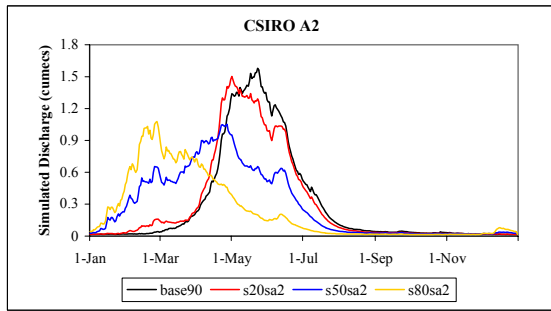
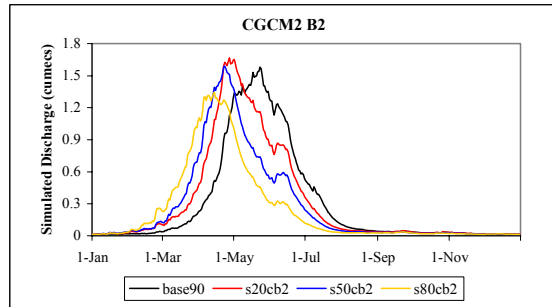
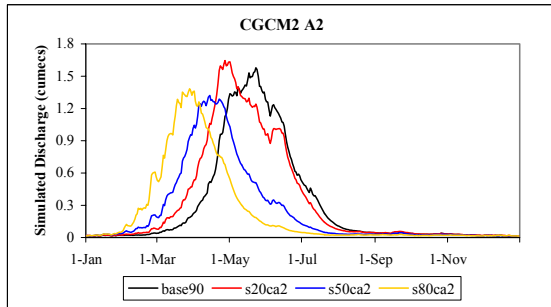


B-3: Peak Flows

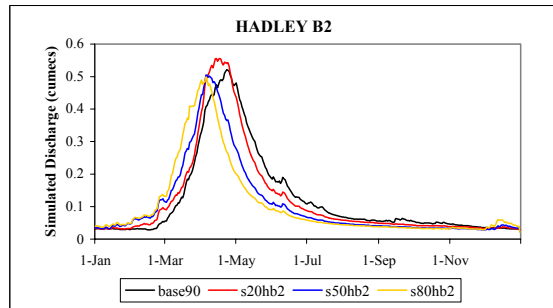
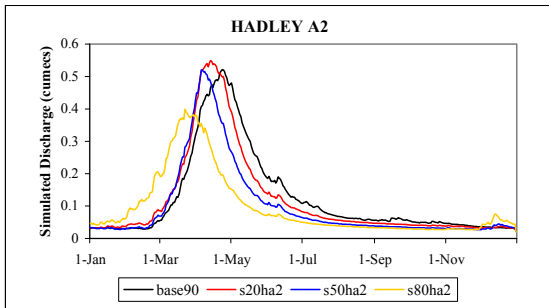
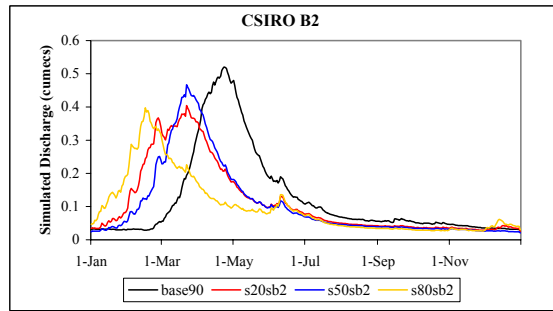
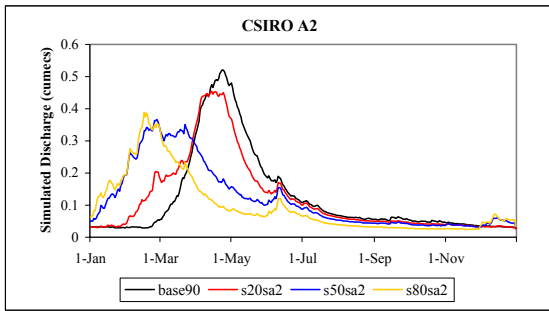
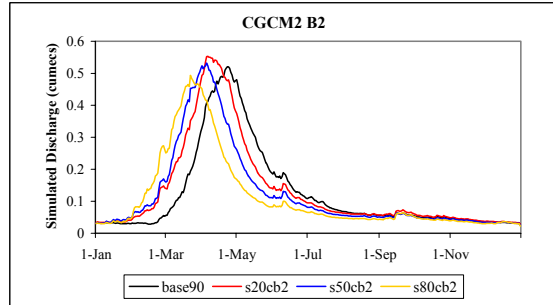
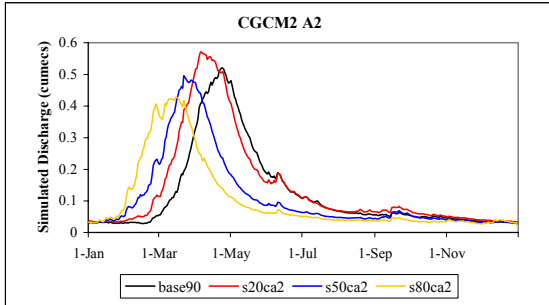
Mean Annual Hydrograph: Vaseaux Creek above Dutton Creek (08NM015)



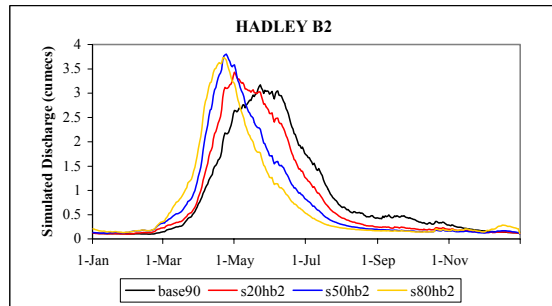
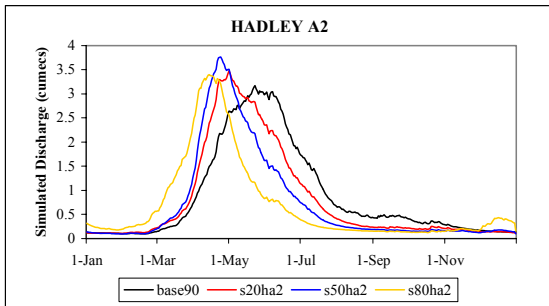
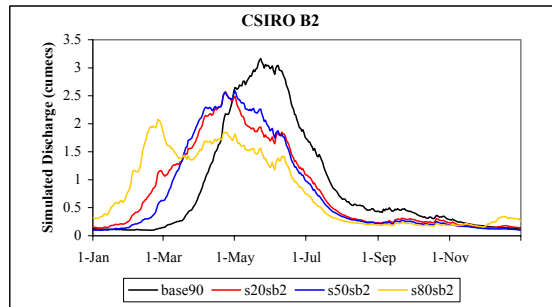
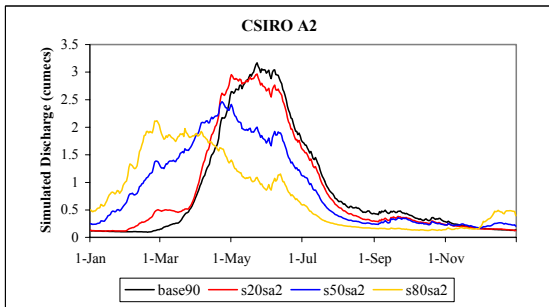
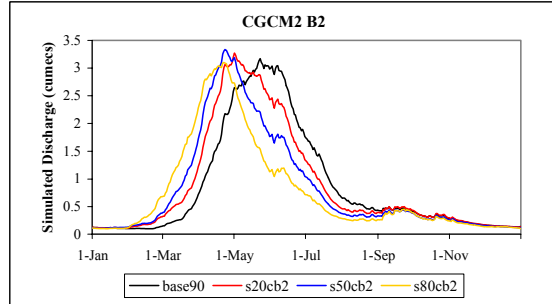
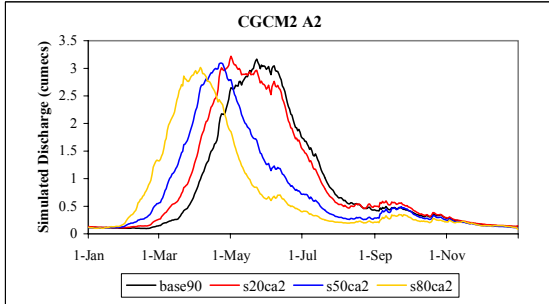
Mean Annual Hydrograph: Bellevue Creek (08NM035)



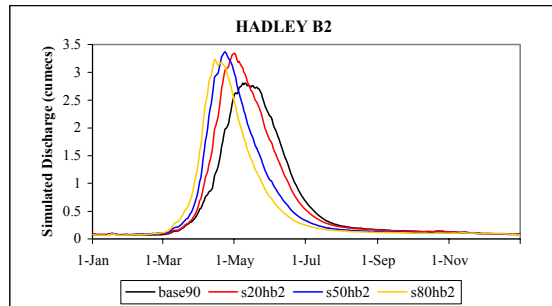
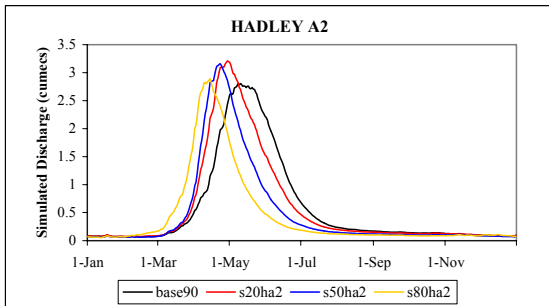
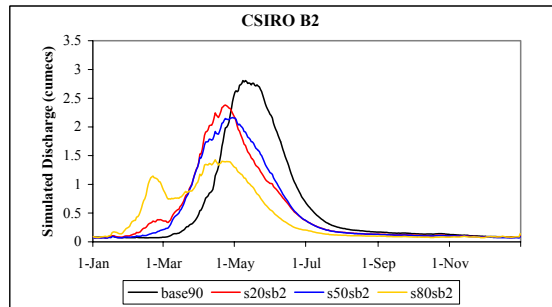
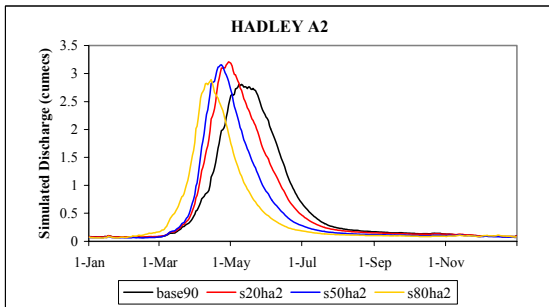
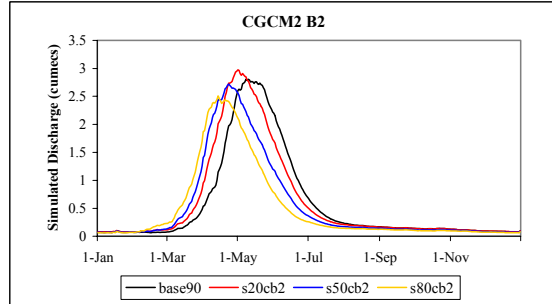
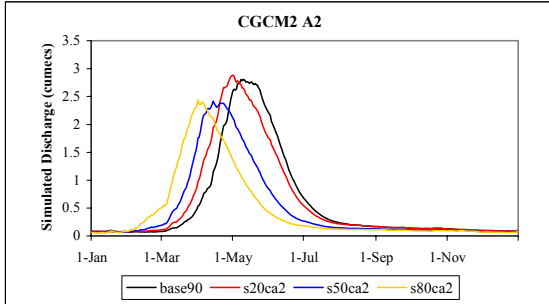
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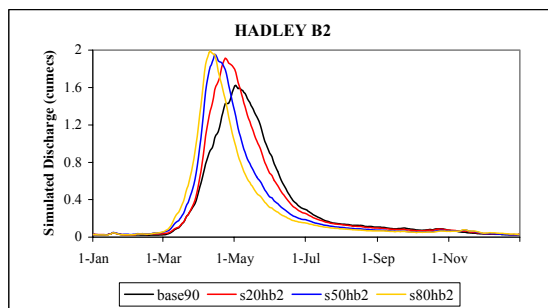
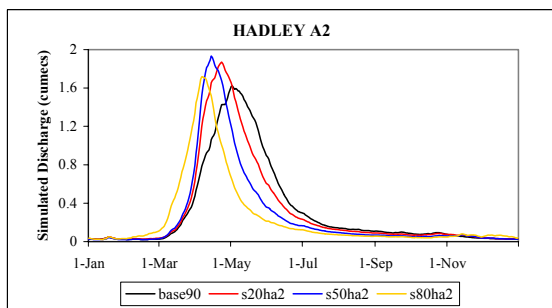
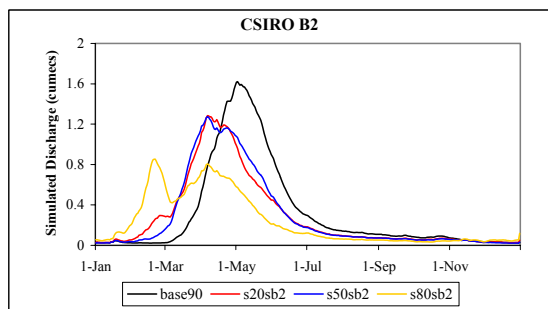
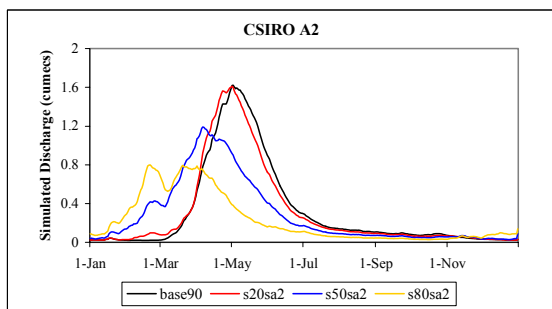
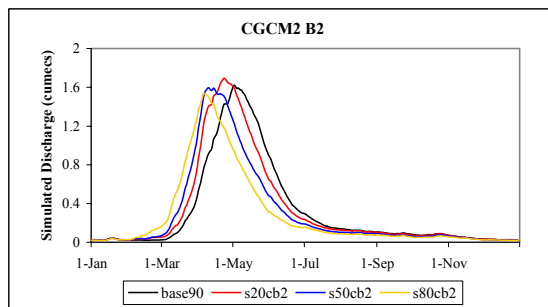
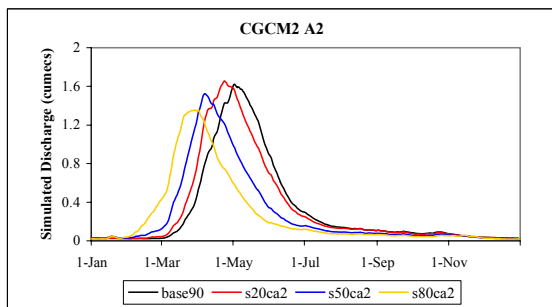
Mean Annual Hydrograph: Pearson Creek above Dutton Creek (08NM172)



Mean Annual Hydrograph: Whiteman Creek above Dutton Creek (08NM174)

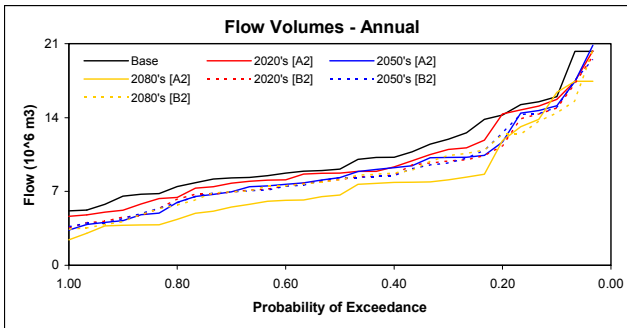
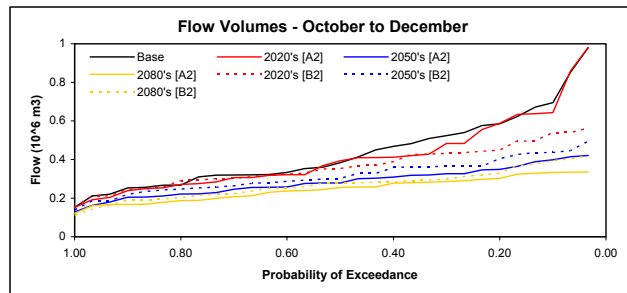
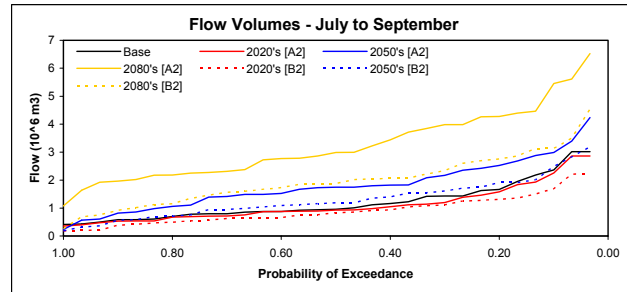
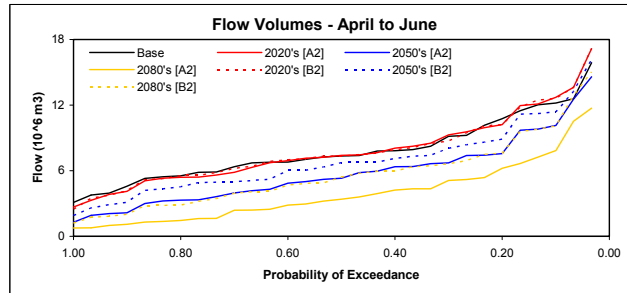
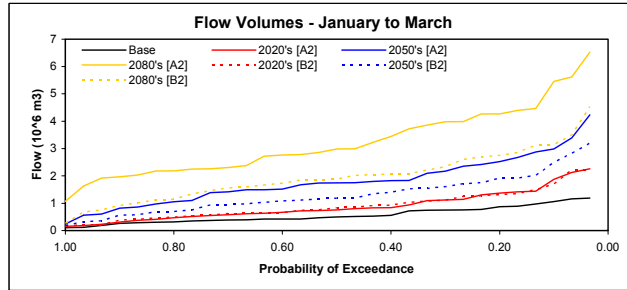


Mean Annual Hydrograph: Ewer Creek above Dutton Creek (08NM176)

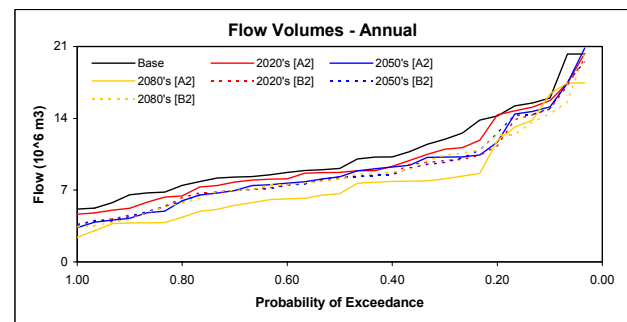
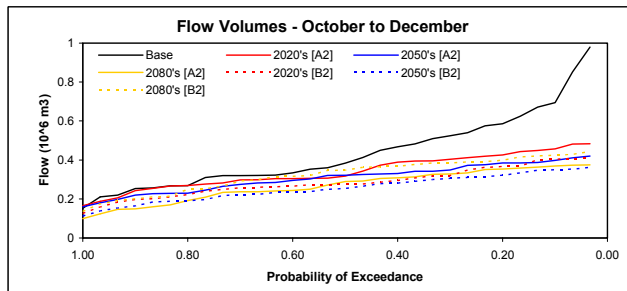
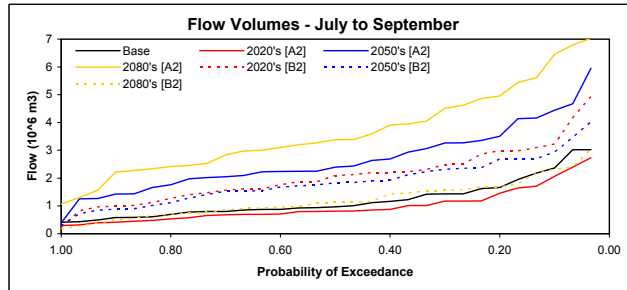
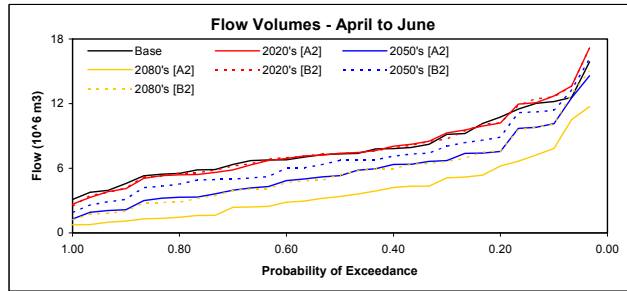
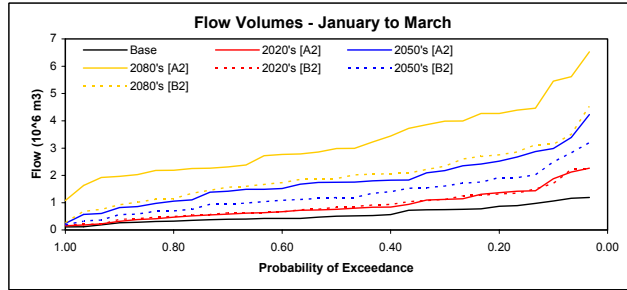


B-4: Annual and Seasonal Volumes

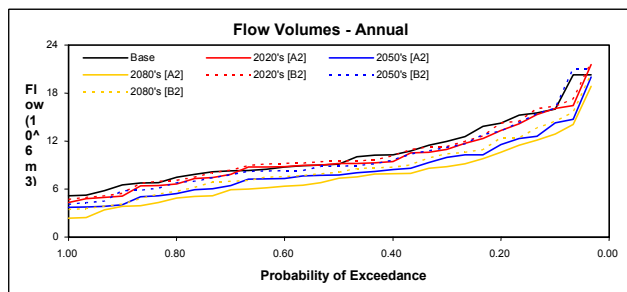
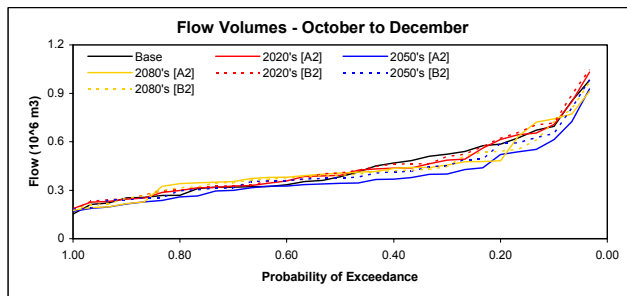
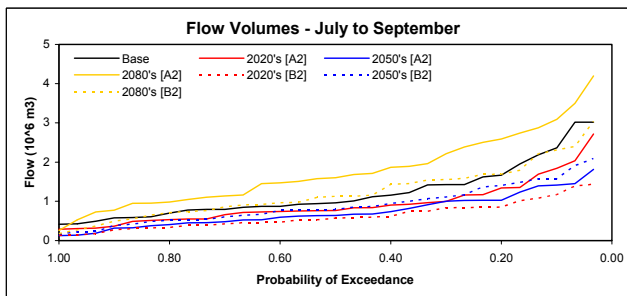
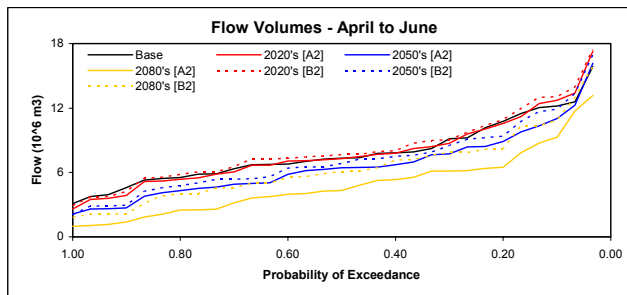
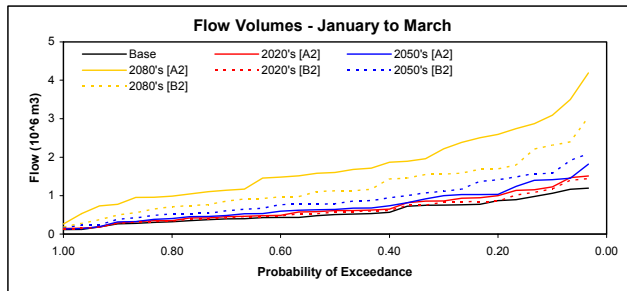
Ewer Creek above Dutton Creek (08NM176) – CGCM2



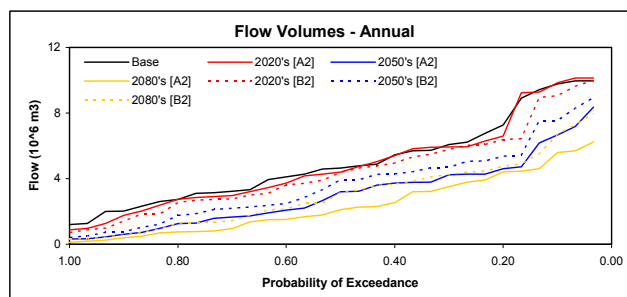
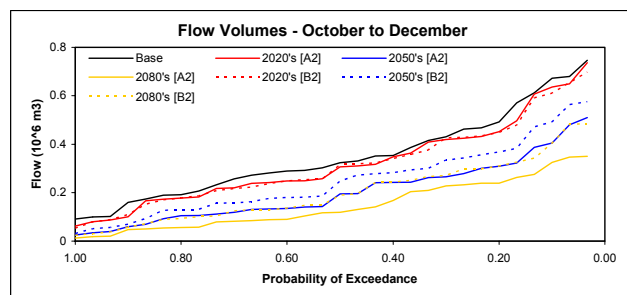
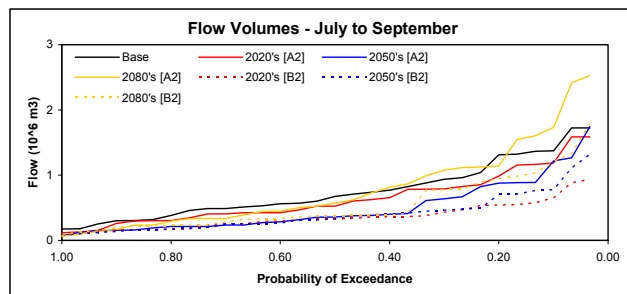
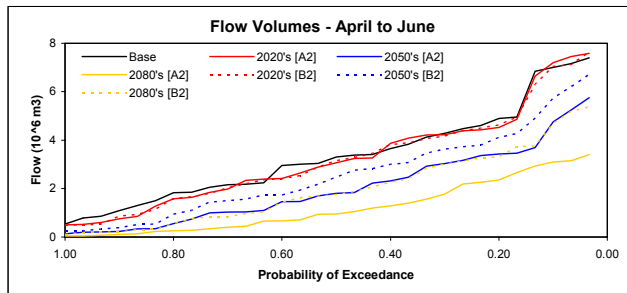
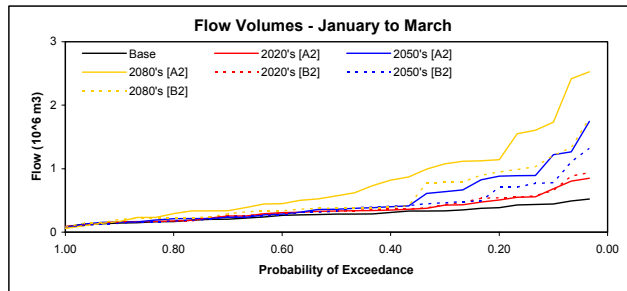
Ewer Creek above Dutton Creek (08NM176) – CSIRO



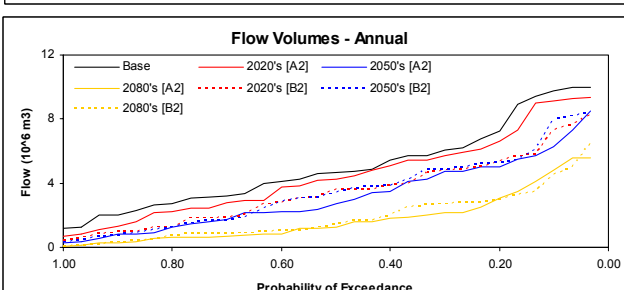
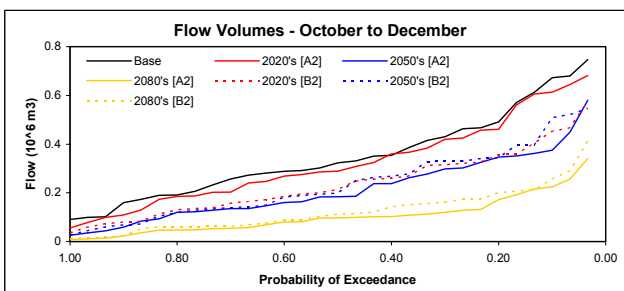
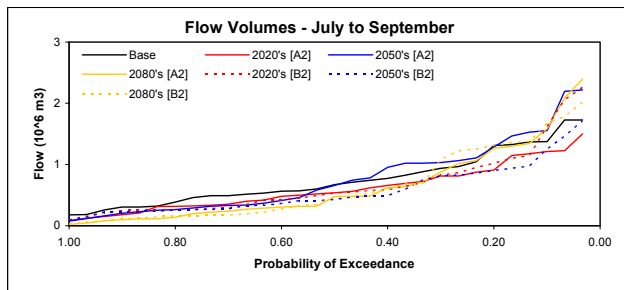
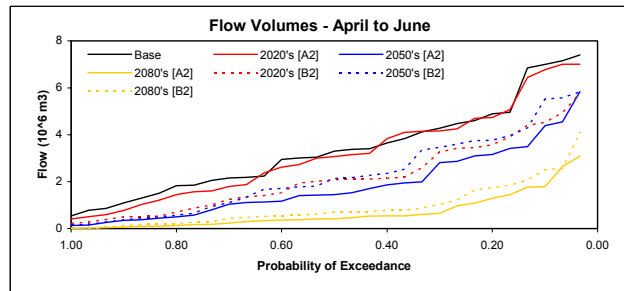
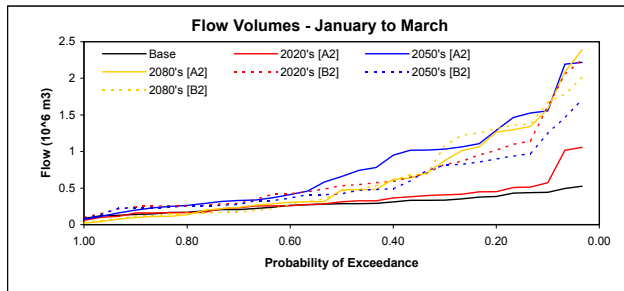
Ewer Creek above Dutton Creek (08NM176) – Hadley



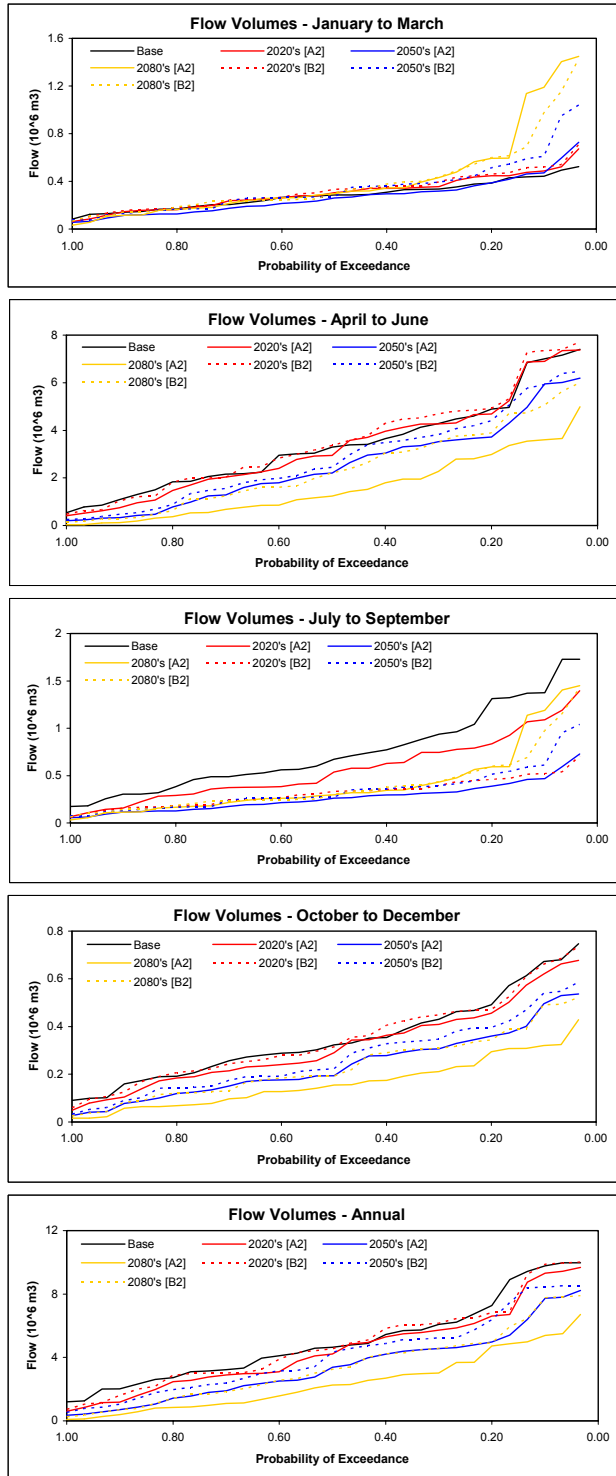
Ellis Reservoir (nwk49a) – CGCM2



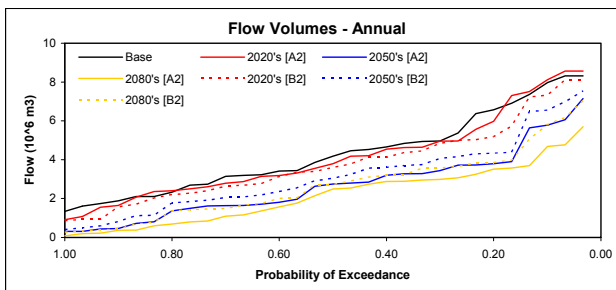
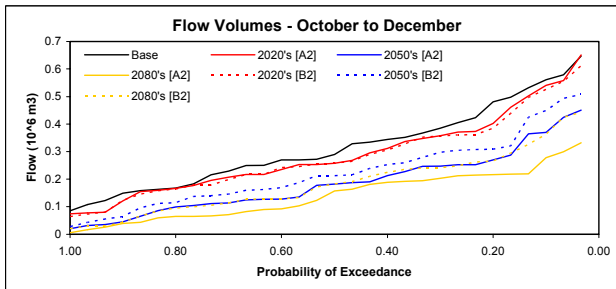
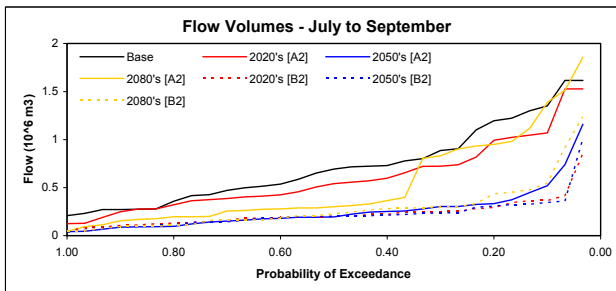
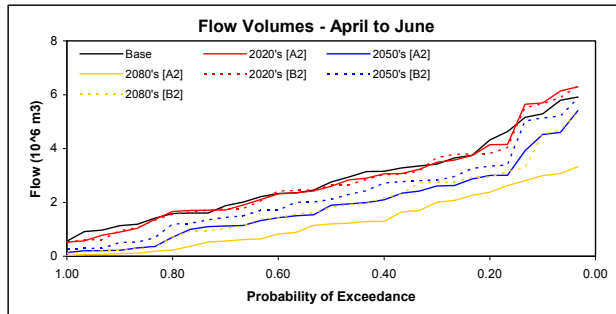
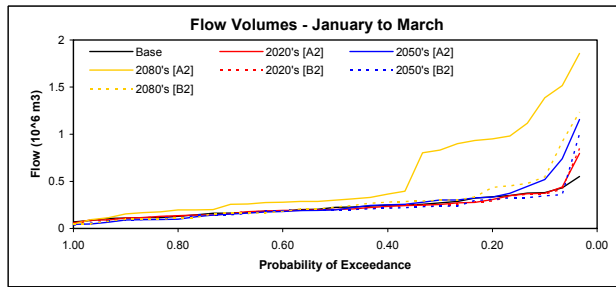
Ellis Reservoir (nwk49a) - CSIRO



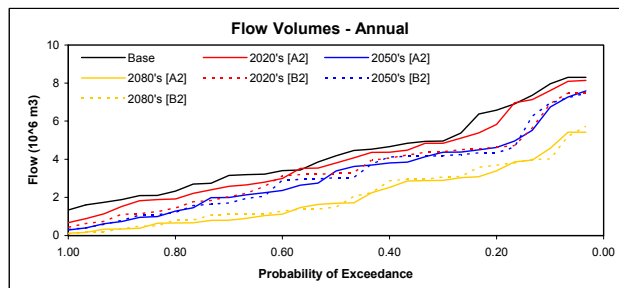
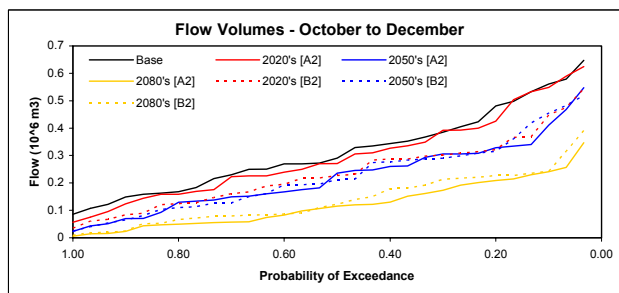
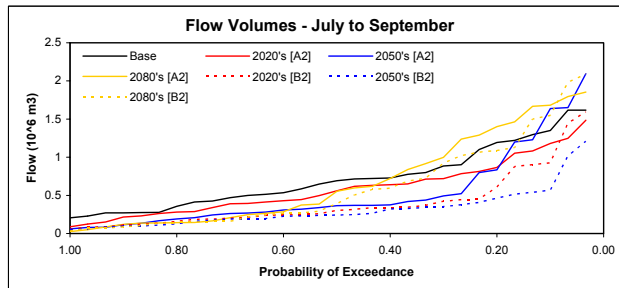
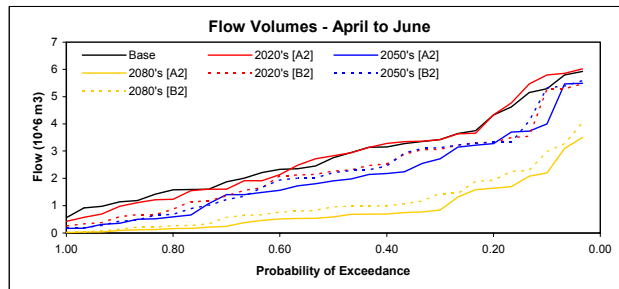
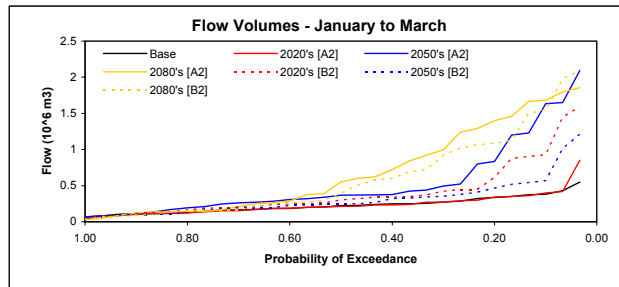
Ellis Reservoir (nwk49a) - Hadley



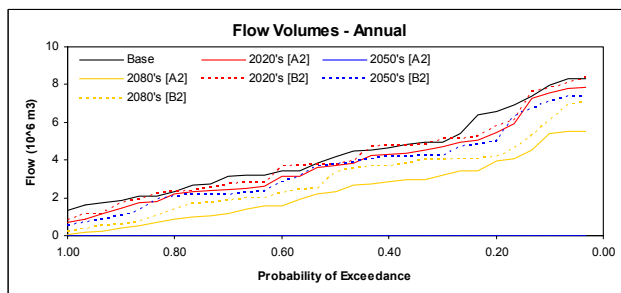
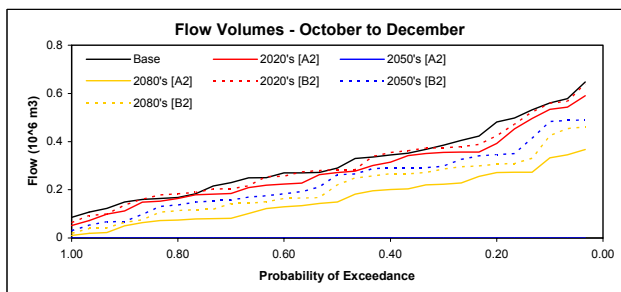
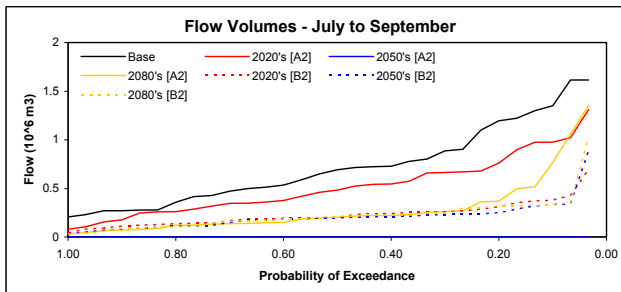
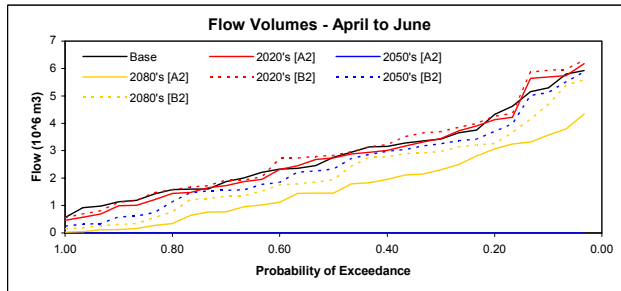
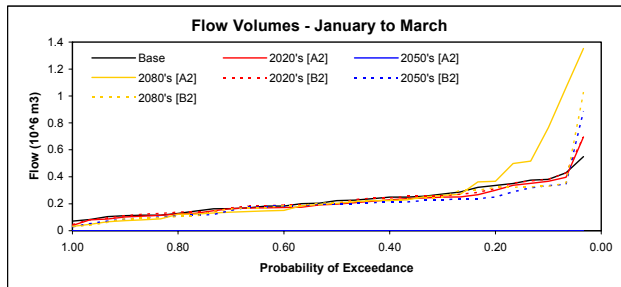
Greyback Reservoir (nwk51a) – CGCM2



Greyback Reservoir (nwk51a) – CSIRO



Greyback Reservoir (nwk51a) – Hadley



Appendix C: Institutions

C-1: Inventory of Institutions

Institutions: Definition – public agencies that have legal authority over water management in the Okanagan basin.

Organization Name	Description/Mandate with respect to water resources	Other Notes
<i>International Organizations</i>		
International Joint Commission	<p><i>The International Joint Commission</i> is an independent bi-national organization established by the Boundary Waters Treaty of 1909. Its purpose is to help prevent and resolve disputes relating to the use and quality of boundary waters and to advise Canada and the United States on related questions.</p>	<p>Boundary Waters Treaty of 1909</p> <ul style="list-style-type: none"> • established the IJC with three members from Canada and three from the US • gives IJC jurisdiction over all cases involving the use, obstruction or diversion of boundary waters • approval of the IJC is required for obstructions and diversions or other activities that affect the natural flow or alters the levels of boundary waters • each country has the right to develop and use water on their own side of the border as they wish • any party injured as a result of activities on the other side of the Canada/US border is entitled to the same compensation as an injured party in the originating country • boundary waters must remain free for navigation • boundary waters shall not be polluted so as to cause harm on the other side of the border • order of precedence for uses: 1. domestic/sanitary, 2. navigation, 3. power and irrigation
Osoyoos Lake Board of Control	<p>Established in 1946 by the IJC to oversee operations of the Zosel Dam (located 2.7km below Osoyoos Lake), which controls the level of Osoyoos Lake.</p> <p>In 1980 the State of Washington sought the Commission's approval to construct works replacing the deteriorating Zosel dam. The application to</p>	<p>One of the Board's responsibilities is to issue drought declarations, and their removal when such criteria, contained in the Orders, are satisfied. Such declarations allow Washington to raise the Lake level above that for non-drought conditions.</p>

Organization Name	Description/Mandate with respect to water resources	Other Notes
	<p>replace Zosel dam was approved by the Commission in 1982 followed by a Supplementary Order in 1985 to address certain specific matters including the relocation of the new structure. Construction of the new control structure was completed in 1987 with funding provided by the Province of British Columbia and the State of Washington,. Actual operation of the dam is conducted by the Oroville and Tonasket Irrigation District under contract to the project owner, the State of Washington Department of Ecology (WDOE).</p> <p>A new International Osoyoos Lake Board of Control was established to supervise the operation of the new structure in compliance with the Commission's Order of Approval. The six-member Board holds an annual meeting and reports to the Commission each April. Monthly reports of daily lake levels and flows are kept to assure compliance with the Orders.</p>	<p>During normal years the lake elevation is held between a maximum elevation of 911.5 feet and a minimum elevation of 909.0 feet. However, during a drought year water may be stored to lake elevation as high as 913.0 feet. Zosel Dam effectively controls the elevation of Osoyoos Lake except during periods of very high snowmelt runoff when natural conditions force the lake above elevation 913.0 feet.</p>
<p>BC/Washington Environmental Cooperation Council</p>	<p>Established by the Environmental Cooperation Agreement entered into by the Governor of Washington State and Premier of British Columbia on May 7, 1992. Its purpose is to ensure coordinated action and information sharing on environmental matters of mutual concern.</p> <p>Task Forces have been established to address several critical cross-border environmental issues that require joint attention by Washington State and BC. The Task Forces facilitate information sharing, coordination and cooperation on issues of mutual interest.</p>	
<p><i>Federal Agencies</i></p>		
<p>Fisheries and Oceans Canada</p>	<p>“responsible for policies and programs in support of Canada's economic, ecological and scientific interests in oceans and inland waters; for the conservation and sustainable utilization of Canada's fisheries resources in marine and inland waters; for leading and facilitating federal policies and program on oceans; and for safe effective and environmentally sound marine services responsive to the needs of Canadians in a global economy.” In the Okanagan, DFO is responsible for the Okanagan River Sockeye run.</p>	<p>Division of responsibilities for water is complex and often shared. Under the <i>Constitution Act</i>, provinces own water resources, which includes both surface and groundwater and are responsible for:</p> <ul style="list-style-type: none"> • flow regulation; • authorization of water use development; and

Organization Name	Description/Mandate with respect to water resources	Other Notes
Transport Canada	Responsible for the <i>Navigable Waters Protection Act</i>	<ul style="list-style-type: none"> • authority to legislate areas of water supply, pollution control, thermal and hydroelectric power development.
Environment Canada	Administers the federal <i>Water Act</i> . <i>Federal Water Policy</i> goals include protection and enhancement of the water resource and promotion of efficient use of water.	<ul style="list-style-type: none"> • Federal responsibilities are in areas that have the potential for significant national economic impact: • navigation; and • fisheries. <p>Water on federal lands (e.g., National Parks), in the territories and on the reserves of Canada's aboriginal peoples falls under federal jurisdiction. The federal government also has responsibility for boundary and transboundary waters.</p> <p>Shared federal-provincial responsibilities:</p> <ul style="list-style-type: none"> • interprovincial water issues; • agriculture; • significant national water issues; and • health <p>(from http://www.ec.gc.ca/water/index.htm)</p>

Organization Name	Description/Mandate with respect to water resources	Other Notes
Agriculture and Agri-Food Canada	Research branch conducts scientific research, produces reports and works to establish and promote standards and best practices with respect to water management. There are plans to develop a National Land and Water Information Service that would provide farmers and municipalities with up-to-date web-based water resource information at a scale relevant to environmental farm planning.	<p>Okanagan Valley Tree Fruit Authority mandate was extended, through to March 31, 2006, supported by a \$25 million government funding commitment, mainly financing replant programs. The purpose of the corporation is to:</p> <ul style="list-style-type: none"> - assist in the rehabilitation and improvement of orchard land and orchards, - develop and operate programs to improve productivity of the tree fruit industry and the marketability of tree fruit, - commission applied research into production and marketing, - provide for the training of growers and farm workers, and - subject to the regulations, assist growers, packinghouses, processors and marketing enterprises by providing advice and assistance.
<i>Provincial Agencies</i>		
Ministry of Sustainable Resource Management	<p>Responsible for land use planning and coordination of land and water policies.</p> <p>Mission: To provide provincial leadership for sustainable economic development of the province's land, water and resources.</p> <p>Note:</p> <p>The ministry has strategic policy responsibility for land and water management. LWBC has responsibility for operational delivery of land and water management. The budget for land management is allocated to LWBC, and the budget for water management is allocated to the ministry, which sub-contracts delivery to LWBC.</p>	See goals, objectives and strategies from the Management Services Plan for a more detailed list of activities.

Organization Name	Description/Mandate with respect to water resources	Other Notes
Land and Water BC Inc.	<p>Provincial crown corporation responsible for operational aspects of water allocation (water licensing), dam safety, water use planning and water utilities. Under the “umbrella” of MSRM.</p> <p>Mandate: Allocating Crown land and water resources for the benefit of all British Columbians.</p>	Applications for water licenses made to existing MSRM regional or district offices. The LWBC website has not been completely updated since water was added to its mandate. Check back for further updates.
Ministry of Water, Land and Air Protection	<p>Mission: The ministry helps British Columbians limit the adverse effects of their individual and collective activities on the environment. The ministry works to protect human health and safety by ensuring clean and safe water, land and air; to maintain and restore the natural diversity of ecosystems, and fish and wildlife species and their habitat; and to provide park and wildlife recreation services and opportunities to British Columbians and visitors.</p> <p>Responsible for environmental protection functions (eg. water quality).</p>	<p>Water, Air and Climate Change Branch Environmental Protection Branch</p> <p>See goals, objectives and strategies from the Management Services Plan for a more detailed list of activities.</p>
Ministry of Health Services	Public Health Protection Branch responsible for food and environmental health protection programs including inspection and monitoring of public drinking water supplies and sewage disposal facilities. Administered by regional medical and environmental health officers.	Enforces the Health Act (includes Safe Drinking Water Regulation and Sewage Disposal Regulation) and Drinking Water Protection Act (not in force).
Ministry of Forests	Administers BC’s Forest Practices Code. The FPC includes considerations of water quality and resource integrity in logging operations. Developed watershed assessment procedure under the FPC for assessment of logging impacts on watersheds.	The BC Government is currently undertaking a consultation process on restructuring of the Forest Practices Code to a more “results based” code. See http://www.resultsbasedcode.ca/ for info.
Ministry of Agriculture, Food and Fisheries	<p>Administers the <i>Farm Practices Protection (Right to Farm) Act</i></p> <p>Publishes environmental guidelines under this act for agricultural sectors (eg. fruit growers) that include water management and other practices which impact water (eg. irrigation, drainage and nutrient management).</p> <p>Fisheries focus is on aquaculture.</p>	

Organization Name	Description/Mandate with respect to water resources	Other Notes
<i>Regional Agencies</i>		
Regional District of North Okanagan	Responsible for parks and recreation programs and facilities; fire protection, noxious weeds and insects control, solid waste disposal, recycling, tourism/economic development, water supply and distribution, planning and development services.	North Okanagan Water Authority (formerly Vernon Irrigation District) Water Stewardship Committee Silver Star Water Utility Whitevale Water Utility Grinrod Water Utility
Regional District of Okanagan Similkameen	Responsible for waste management, some water and sewer systems, land use planning.	The Public Works Division manages, operates, and maintains the Naramata, Olalla, Faulder, and Apex water systems, and the Okanagan Falls sewer system.
Regional District of Central Okanagan	Responsible for land use planning, parks and recreation, waste management, water and sewer services. Administers six water systems servicing from 8 to 645 properties. Collects user fees and maintenance fees.	Regional District of Central Okanagan Water Utility Drainage Systems Westside Regional Sewer System
Okanagan Basin Water Board	The OBWB was established as a coordinating agency for implementing the recommendations of the Okanagan Basin Study conducted from 1969 to 1974 and is responsible for water management functions identified in the study that pertain to the basin as a whole. Current board activities focus on control of Eurasian water milfoil and funding of liquid waste treatment projects in partnership with the provincial government. A broader mandate can be established with the agreement of the three Okanagan regional districts. The board consists of three representatives from each of the Okanagan Basin's three regional districts.	

<i>Local Agencies</i>		
Improvement Districts	<p>Incorporated under the Local Government Act to provide services (eg. water distribution and fire protection) in a specified geographic area. Most improvement districts are outside of municipal boundaries within regional districts.</p> <p>Local Government Act Improvement District Governance</p>	<p>Most improvement districts provide only one service. The most popular service is water. Most improvement districts that provide water services provide both irrigation and domestic uses.</p> <p>Rutland Waterworks District South East Kelowna Irrigation District Black Mountain Irrigation District Lakeview Irrigation District Winfield Okanagan Centre Irrigation District Westbank Irrigation District Meadow Valley ID West Bench ID Lower Nipit ID Kaleden ID OK Falls ID Sun Valley ID Skaha Estates ID Rolling Hills WWD Parkdale ID Poplar Grove ID Vaseaux Lake ID Fairview Heights ID Boundary Line ID Keremeos ID Cawston ID Hedley ID Similkameen ID Allison Lake ID Osprey Lake WWD</p>
Development / Irrigation Districts	See Improvement Districts	

Municipalities	Incorporated under the Local Government Act	Okanagan Similkameen Regional District municipal water systems: http://www.rdos.bc.ca/business_directory/rp_d_infrastructure.htm
Water User Communities	A Water Users' Community is a public corporate body incorporated under Section 51 of the <i>Water Act</i> . WUCs are formed when six or more licensees would benefit from joint use of a water storage or delivery system. WUC Manager is responsible for assessing and collecting fees under the supervision of the comptroller.	for information http://srmwww.gov.bc.ca/wat/wrs/wuc/wucinfo.htm
<i>First Nations</i>		
Okanagan Nation Alliance and Okanagan Nation Fisheries Commission	<p>ONA is the Tribal Council which represents the people of the Okanagan Nation. The ONA's mandate includes: "<i>Protection, enhancement and preservation of the peoples, lands and resources of the Member Bands of the Okanagan Nation.</i>"</p> <p><i>Protection, enhancement and preservation of the environment, fish and wildlife resources located within the traditional territories of the Okanagan Nation.</i>"</p> <p>"The Okanagan Nation Fisheries Commission (ONFC) was formally established in 1995. The seven bands of the Okanagan participate in the ONFC. The goal and mandate of the ONFC is the conservation, protection, restoration, and enhancement of indigenous fisheries (anadromous and resident) and aquatic resources within Okanagan Nation territory. The ONFC provides technical assistance to the member Bands and also acts as a liaison with federal and provincial agencies."</p>	<p>"The Okanagan people have not signed a treaty with the Federal Government nor do they recognize the Provincial Government as having jurisdiction within their homeland. These issues are being dealt with at the present time.</p> <p>The Okanagan Nation is comprised of the following Indian Band Reserves located within the Nation's traditional homeland boundaries:</p> <p>Upper Nicola, Nicola Okanagan, S-Ooknahchinx Westbank, Tsinstikeptum Penticton, Sn Pint'Kin Osoyoos, Inkameep Upper Similkameen, Simikameugh Lower Similkameen, Simikameugh"</p>

C-2: Other Stakeholder Organizations

BC Watershed Stewardship Association	Stewardship advocacy organization. Province wide with strong membership in Okanagan
Water Supply Association of BC	Representing the interests of British Columbia's public domestic and irrigation water suppliers and their customers.
Okanagan Basin Technical Working Group	Tripartite group comprised of representatives from DFO, MWLAP, and ONFC. Initiated as a result of efforts in Douglas County, Washington, to respond to declining Okanagan River Sockeye runs. Funded by Douglas County. General objectives for this group are to identify and 'steer' initiatives designed to rebuild fish stocks, including salmon, in the Okanagan River basin in Canada.
Okanagan Similkameen Boundary Fisheries Partnership	Supports locally driven community planning around watershed issues and will be providing regional context / connection between roundtables, as well as future liaison support to fisheries agencies for local roundtables.
Friends of Brandt's Creek	The Friends of Brandt's Creek is an environmental organization established in 1994 to protect Brandt's Creek from further deterioration and to try and restore it to a healthy environment.
BC Lake Stewardship Society	The purpose of the BCLSS is to promote stewardship, understanding and comprehensive management of lakes and reservoirs and their watersheds
South Okanagan-Similkameen Conservation Program	Created by the Ministry of Environment, Lands and Parks and Environment Canada in 2000 to coordinate and harmonize conservation and habitat restoration efforts between governments, NGOs and community groups.
Community Watershed Round Tables	The community watershed round tables were initiated by Michelle Boshard in an effort to enhance community dialogue on watershed management in the region. There are five round tables: Trout Creek, Coldstream, Okanagan Indian Band, Lake Country, Mission Creek, Pentiction(?). Administrative support is provided by the Okanagan Similkameen Boundary Fisheries Partnership.
BC Water and Waste Association	Non-profit association dedicated to the safeguarding of public health and the environment through the sharing of skills, knowledge and experience in the water and wastewater industries.
BC Fruit Growers' Association	The BCFGA is an industry association representing fruit growers interests. The BCFGA activities include lobbying government for positive change to risk management programs, such as crop insurance and the Net Income Stabilization Program, and providing services and products to growers. Services and products are provided at a discount to members.