LEARNING WITH LOCAL HELP: EXPANDING THE DIALOGUE ON CLIMATE CHANGE AND WATER MANAGEMENT IN THE OKANAGAN REGION, BRITISH COLUMBIA, CANADA*

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Abstract. The research activity described in this report is a comprehensive regional assessment of the impacts of climate change on water resources and options for adaptation in the Okanagan Basin. The ultimate goal of the project is to develop integrated climate change and water resource scenarios to stimulate a multistakeholder discussion on the implications of climate change for water management in the region.

The paper describes 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.

This collaborative study has relied on field research, computer-based models, and dialogue exercises to generate an assessment of future implications, and to learn about regional views on the prospects for adaptation. Along the way, it has benefited from strong partnerships with governments, researchers, local water practitioners, and user groups. Building on the scenario-based study components, and a series of interviews and surveys undertaken for the water management and adaptation case study components, a set of stakeholder dialogue sessions were organized which focused on identifying preferred adaptation options and processes for their implementation. Rather than seeking consensus on the “best” option or process, regional interests were asked to consider a range of available options as part of an adaptation portfolio that could address both supply side and demand side aspects of water resources management in the Okanagan.

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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 (see reviews in Schriener and Street, 1998; Arnell et al., 2001) suggest changes in total annual flows, seasonal aspects of water supply and demand, and implications for ecosystems. Challenges can be expected for water managers as they seek to meet multiple objectives (energy, irrigation, navigation, flood control, etc.).

The Columbia Basin has been the subject of a number of detailed case studies (Mote et al., 1999; Hamlet and Lettenmaier, 1999; Miles et al., 2000), and there have been initial attempts to introduce transboundary perspectives (Cohen et al., 2000; Hamlet, 2003). This body of 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 studies have contributed to a growing dialogue on water management and climate change on the American side of the Columbia Basin, and drew attention to the need for similar processes in Canada, and ultimately, a bi-national study. Although basin-wide hydrologic assessments have been completed, detailed hydrologic studies on the Canadian side were not included. The Okanagan region is one such area needing attention. The Okanagan is already experiencing stresses on its water systems associated with rapid population growth and land-use changes. The drought of 2003 exposed some vulnerability, as illustrated by the emergence of local water conflicts (Moorhouse, 2003) and the implementation of emergency and longer-term conservation measures (Watershed News, 2003; Johnson, 2004).

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 for adaptation, 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. Researchers within natural and social sciences have long been faced with the trade-off between the difficulties of accounting for complex regional detail, and the ease of simpler aggregation accompanied by questionable assumptions about natural processes and human behaviour. National and global model-based impacts studies are, by necessity, highly aggregated, and 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 assumptions about levels of shoreline protection, choice of tree species for planting, market adjustments in land values, etc., and how widespread these 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? The importance of local conditions implies that dialogue with stakeholders needs to be an explicit part of the process of framing research questions and carrying out impact and adaptation assessments.

The research activity described in this report is designed as a comprehensive regional assessment of the possible 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 (EC), Agriculture and Agri-Food Canada (AAFC), the University of British Columbia (UBC), the British Columbia Ministry of Water, Land and Air Protection (MWLAP) and the District of Summerland.

In this paper, we focus on the development of an integrated framework for assessing the implications of climate change for water management in the Okanagan region of British Columbia. This framework relies on team building, where researchers and stakeholders are asked to provide insights and analyses for the Okanagan using a common set of climate change scenarios and shared learning of both scenario impacts and the regional context on which these impacts would be felt.

2. Okanagan Water Management

The 8200 km² Okanagan valley is a long-narrow basin in southern British Columbia, Canada. It extends 182 km from Armstrong (north of Vernon) to the United States

Figure 1. Okanagan region, British Columbia.

border at Osoyoos Lake (Figure 1). From here, water flows south via the Okanagan River (note the different spelling) connecting with the larger Columbia Basin system in Washington State.

There are three primary features of the Okanagan watershed which contribute to the complex, convoluted and multiscale structure of interacting organisations and institutions involved in water management decisions:

- Binational water system
- Multiple levels of government
- Multiple in-stream and out-of-stream water uses, with many associated advocacy organisations operating at different scales

A number of federal and provincial government bodies have water-related responsibilities, including MWLAP. The seven Indian Bands within the Okanagan Nation Alliance (ONA) participate in the Okanagan Nation Fisheries Commission (ONFC), which provides technical assistance and acts as a liaison with federal and provincial agencies (ONA, 2000a,b). There is also an 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 (Canada–British Columbia Consultative Board, 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 Okanagan 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 the Canadian Department of Fisheries and Oceans (DFO), MWLAP, and ONFC. This group identifies and “steers” 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. The role of these players 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 important groups include:

Fisheries	Okanagan Similkameen Boundary Fisheries Partnership
Watersheds	Community Watershed Round Tables
Agriculture	British Columbia Fruit Growers' Association
	Okanagan Valley Tree Fruit Authority.
Water Management	Water Supply Association
	British Columbia Water and Waste Association

The Okanagan Basin represents an interesting forum for exploring water allocation and licensing given its semiarid climate, its growing population (Figure 2) and the importance of irrigation to the regional economy. As of July 2002,

Figure 2. Okanagan population, 1976–1999 (Embley et al., 2001).

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 m³ 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 m³. 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 Authority,” 31% for incorporated areas and residential use (“Waterworks Local Authority” and “Waterworks (Other)”) and the remaining 2% for other purposes including “Watering,” “Domestic,” and “Enterprise.”

3. First Phase, 2000–2001

This study of Okanagan water resources and climate change implications builds on two studies conducted during 2000–2001. The first focused on hydrologic aspects whereas the second was oriented toward irrigated agriculture, the largest consumer of water in the region.

The hydrologic study (Cohen and Kulkarni, 2001) had two main goals:

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

Figure 3 illustrates how the 2001 study was organized. The relatively short duration of this study (1 year) precluded 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 with stakeholders to complement mathematical models. This enabled the inclusion of issues that are more challenging to model. 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).

Climatic change scenarios, obtained from simulations from three climate models (see Acknowledgements), indicated a temperature increase of 1.0–2.5 °C from the 1961–1990 base period to the 2020s (2010–2039), and 3–5 °C by the 2080s (2070–2099). 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 in the Okanagan Basin indicated earlier onset of spring peak flows, by as much as 4–6 weeks.

Figure 3. Okanagan climate and water resource impacts 2001 study framework (Cohen and Kulkarni, 2001).

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, whereas 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 suggestions included development of alternative uses for resources (e.g. alternative energy, grey water) and changes to land-use plans (e.g. densification of urban land). Participants were then asked to consider the implications of adaptation choices. Considerable attention was given to water licensing, flow regulation through dams, and potential restrictions on development. Many stakeholders indicated a need for additional research and outreach activities or changes in consultative processes associated with a particular option.

The study on irrigated agriculture (Nielsen et al., 2001) addressed potential impacts in the south Okanagan on crop water use under climate change scenarios during the next 100 years. The objectives of the study were to develop a 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. The latter were acquired from a variety of sources and incorporated into a GIS.

Overall average predicted water use for present day conditions was compared with values of expected water use provided by the British Columbia Ministry of

Agriculture Fisheries and Food (BCMAFF) for sites within the region 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 in the gridded climate dataset which had 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 ($46.9 \times 10^6 \text{ m}^3$ vs. $51.8 \times 10^6 \text{ m}^3$). 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 a current estimate of 745 mm/year ($80 \times 10^6 \text{ m}^3$) to 1021 mm/year ($110 \times 10^6 \text{ m}^3$) during the 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 upland storage may not. A major limitation in this study was the availability of data from only one global climate model (GCM) scenario. In the current (2004) study, data from a range of models and scenarios is being used to capture the uncertainty associated with GCM experiments (see Section 6 below).

4. Study Objectives

The primary goal of this project is to develop integrated climate change and water resource scenarios to stimulate a multistakeholder 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.

The team building effort emerged from combining the two preceding study groups that had focussed on climate scenario effects on water resources and irrigated agriculture, respectively. This collaboration expanded to include adaptation costs, adaptation history, and regional frameworks for water management.

5. Study Framework

The study comprises five key components:

- *Climate change scenarios*: downscaling global climate change scenarios to the regional level;
- *Hydrological scenarios*: determining impacts of climate change on basin hydrology;
- *Water supply and demand scenarios*: developing future demand scenarios particularly for municipalities and irrigated agriculture, factoring in socioeconomic trends;

- *Adaptation options*: exploring previous management experiences and potential future approaches for augmenting water supply and/or reducing water consumption; and
- *Adaptation dialogue with stakeholders*: learning about regional perspectives on adapting to climate change.

Figure 4 illustrates the overall study framework. 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) 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 (Hisschemöller et al., 2001). It provides an important opportunity for people with lay or practitioner knowledge, as well as those with economic, political or social attachments to a place or issue, to become directly engaged in a shared learning process. This is especially needed when the issues are complex and

Figure 4. Framework for 2004 study on climate change and water management in the Okanagan region.

multidisciplinary, and when processes interact at different scales in space and time (Van Asselt and Rijkens-Klomp, 2002).

A number of participatory integrated assessment (PIA) methods have been applied in various circumstances, each of them with the potential to create a productive shared learning experience, but there are no standardized frameworks for applying such methods, and there are challenges to be overcome which are unique to each case. Learning depends on both the quality of the scientific content and the dialogue process itself (Van de Kerkhof, 2004).

PIA methods have been applied to regional climate change impacts studies, including the Mackenzie Basin Impact Study–MBIS (Cohen, 1997) and Climate and Environment in Alpine Regions–CLEAR (Cebon et al., 1998). The former used scientist–stakeholder workshops to discuss the implications of projected climate impacts for issues such as ecosystem management, sustainability of native lifestyles and economic development in northwest Canada. The latter used focus groups which utilised an information tool designed to convey information from the CLEAR project. This tool was a resource for facilitating a dialogue on risk and policy options (Schlumpf et al., 2001). Model-assisted dialogue has also been used in a study of regional sustainability in the Georgia Basin region of British Columbia (Tansey et al., 2002).

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).

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

1. A clear sense of what the dialogue's objectives are,
2. An understanding of the regional context, and
3. A gradual build-up of trust through shared learning.

Outreach activities have been instrumental in helping the research team achieve the first and third goals 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 relate 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 related to 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 2001 study (Cohen and Kulkarni, 2001), the stakeholder dialogue was primarily an exercise in identifying adaptation options. Implications were touched on but not thoroughly examined. In the current study, the team has sought to build upon this foundation through an anticipatory adaptation policy exercise. It is not only a question of how stakeholders 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 the current study, one of the key mechanisms for learning about regional management context, as well as regional approaches to adaptation, is the set of early adopters case studies (see Section 7.1). The results of these case studies 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 proved to be a rich, rewarding and useful exercise.

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. Stakeholders may also be motivated to participate in this dialogue because it offers them respect for local experience, which helps to achieve trust and reduce tensions that could lead to conflicts around sensitive issues.

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 fora (e.g. British Columbia Water Supply Association, British Columbia Tree Fruit Growers Association, Canadian Water Resources Association, Okanagan Basin Water Board). This has attracted regional media attention (e.g. Squire, 2000; Steeves, 2001).

6. Setting the Stage: Building Scenarios

Creating a dialogue on adaptation to future climate change requires information about future climate and potential impacts, so that regional stakeholders would have an idea about what it is they may be adapting to. In this study, scenario building involves a number of components, including climate, hydrology, agriculture, and regional context. The latter has both financial and institutional (or governance) dimensions which are necessary for understanding the opportunities and constraints that confront decision makers as they consider how best to adapt to climate change.

6.1. 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 3-month period (August 1st–October 31st), differences among sites for maximum daily temperature were from 2 to 7 °C and from 2 to 8 °C for minimum daily temperature. One of the potential implications of climate change is that certain microclimates that are currently at the upper maximum temperature limit for a certain crop (e.g. apples) may not be suitable for that crop under future climates.

It might be expected that climatic trends of recent decades would be a good indicator of future climate. An analysis of temperature observations in the Okanagan valley over the last 30 years shows a warming trend that is consistent with future projections. However, from the late 1970s to the mid-1990s, there has been a trend toward increasing summer precipitation which is contrary to the climate change projections for reductions in summertime precipitation. Similarly, future projections for an increase in winter precipitation run counter to the observed trend since the late 1970s. Precipitation has been highly variable over the 20th Century with successive years of above average precipitation and also periods of prolonged precipitation deficits. In western Canada, there is evidence that these patterns are a function of decadal scale natural variability related to the Pacific Decadal Oscillation (PDO). As this pattern of natural variability may not be well simulated by the climate models, projected changes in temperature and precipitation were superimposed onto the existing climate records under the assumption that these patterns will continue into the future.

Climate change scenarios were developed from three different GCMs (CGCM2-Canada, HadCM3-United Kingdom, CSIRO Mk2-Australia), and two scenarios of global greenhouse gas emissions from the Intergovernmental Panel on Climate Change's (IPCC) SRES series (Figure 5). Scenarios were constructed using the "delta" method whereby historic station data were perturbed by GCM-derived changes in the 30-year means of monthly temperature and precipitation. Variability in the monthly deltas can be quite large for individual grid cells, which is an inherent feature of this approach.

For the 2050s (2040–2069), increases in winter temperature relative to the 1961–1990 baseline lie in the range 1.5–4 °C with winter precipitation increases on the order of 5–25%. For summer, all models show a warming of roughly 2 to 4 °C and precipitation changes ranging from almost no change to a 35% decrease in precipitation compared to the 1961–1990 baseline. The greatest change in winter conditions are reflected by the Australian model (CSIRO Mk2) whereas the UK Hadley Centre model (HadCM3) shows the greatest change in summer climate.

Figure 5. Scatterplots of projected changes in average daily temperature (degrees C) and precipitation (percent) for the 2050s relative to 1961–1990 for winter (top) and summer (bottom) for three GCMs and two SRES scenarios, A2 and B2 (Taylor and Barton, 2003).

Due to the small size of the study area, these scenarios were by necessity based on only one grid cell from the various GCMs. The use of outputs from three different models is meant to provide some indication of the range of uncertainty in climate projections, though this does not cover all possible outcomes from increases in global greenhouse gas emissions.

6.2. HYDROLOGY

The UBC Watershed Model (Quick, 1995) was chosen to model precipitation–runoff processes in a number of gauged watersheds in the basin and tributaries entering Okanagan River and the main-stem lakes. This model has been used extensively in British Columbia, has been shown to adequately reproduce the hydrologic response of watersheds, and has previously been used in climate change studies (e.g. Morrison et al., 2002; Loukas et al., 2002).

Overall, the UBC Watershed model has been shown to be a suitable model for application to a region such as the Okanagan Basin (Merritt et al., in preparation).

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-spatial variability in precipitation. 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. This behaviour strengthens the application of the model to ungauged tributaries in the basin. Likewise, model performance over the verification period indicated that the model is capable of predicting hydrologic response over different climatic periods.

The results presented in this paper provide an idea of the range in hydrological response to the climate scenarios (Figure 6). All scenarios consistently predicted an early onset of the freshet, a tendency toward a more rainfall-dominated hydrograph and considerable reductions in annual and freshet flow volumes. The HadCM3 and

Figure 6. Hydrologic scenarios for Whitman Creek. See Figure 1 for map location. Scenarios are provided for 30-year time slices provided by the climate models: base90 = 1961–1990 base case, s20 = 2010–2039, s50 = 2040–2069, s80 = 2070–2099 (Merritt and Alila, 2004).

Figure 7. Scenario changes in flow volumes at Ellis Reservoir (Merritt and Alila, 2003). See Figure 1 for map location.

CSIROMk2 climate scenarios provide two quite different, although equally plausible, outlooks for the future hydrology of watersheds of the Okanagan Basin. With the HadCM3 climate model, the hydrograph is peaky and quite confined in the period of elevated flows. Such a scenario would pose difficulties for 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 CSIROMk2 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 hydrology model. The CGCM2 scenarios have a more conservative effect on modelled hydrological change, compared with the other climate models.

Changes in annual flow volume for one of the tributary reservoirs, Ellis, are shown in Figure 7. Annual flow volumes decline in all scenarios. Changes in timing are evident, as the proportion of annual volume occurring in winter increases, whereas spring and summer volumes decline.

6.3. AGRICULTURE

In British Columbia, agriculture is carried out within a land reserve that protects farmland from encroachment by development. Agriculture in the Okanagan valley consists of unirrigated rangeland and irrigated crop-land of which the majority (84%) is planted to perennial crops (tree fruits, grapes, pasture/forage). Between 70 and 80% of consumed water is used for irrigation.

For this study, estimates of crop water demand were derived in GIS using detailed land-use mapping, a gridded climate dataset and estimates of evapotranspiration for

individual crop types. An agricultural land-use database for the Okanagan Basin was compiled and incorporated into a GIS using ArcInfo. Land use was held constant during modelling of future water demand. Station climate data were extrapolated across the landscape using a modified version of PRISM (Daly et al., 1994) in which the original 4×4 km grid was interpolated to a 1×1 km grid using GIS and in consultation with C. Daly (personal communication). Climate data were perturbed by monthly biases from GCM output as described previously.

To estimate evapotranspiration (ET) based on the data available in the PRISM dataset, (min and max temperatures) an empirical relationship was derived between measured daily evaporative demand (atmometer), weather station maximum daily temperature (T) and extraterrestrial solar radiation (R_a). Potential evapotranspiration (PET) estimated from this relationship was highly correlated to daily ET_0 calculated from mid-April to mid-October using the Penman Monteith model (Allen et al., 1998) for the years 1994–1998 ($PET = 0.9048 ET_0 + 0.14$; $R^2 = 0.812$, $n = 950$). Estimates of actual ET were derived by modifying potential ET with crop coefficients related to canopy development through the growing season. The length of the growing season was estimated from growing degree day (GDD) base 5 or 10°C accumulation.

An example of basin-wide, annual crop-water demand scenarios is illustrated in Figure 8 for six GCM/SRES scenario outputs. CGCM2 scenarios were the most conservative and HadCM3 the most extreme. Increases in crop water demand appear high when compared with the average annual increase in mean temperature for GCM/SRES output of $1\text{--}5^\circ\text{C}$. However, some monthly adjustments for daily maximum temperature, as high as 11°C for the 2080s, coincided with crop coefficients greater than 1.0, resulting in estimates of high-crop water demand. High demand was also associated with considerable lengthening of the growing season as a result of changes in the start and end of GDD accumulation. Additional demand for irrigation water both mid-season (higher temperatures) and at the end of the

Figure 8. Total annual crop water use scenarios for the Canadian portion of the Okanagan Basin. Scenarios are provided for 30-year time slices from three climate models: historic = 1961–1990, s20 = 2010–2039, s50 = 2040–2069, s80 = 2070–2099 and two SRES scenarios A2 and B2.

Figure 9. Frequency of modeled crop annual water demand for a hypothetical hectare of apple at Summerland CDA/CS based on climate data from historical record 1916–2003 and estimated for 1961–1990, and three time slices using CGCM2-A2.

season (extended growing season) is potentially problematic for water purveyors, as supply comes almost entirely from storage after the spring freshet is completed.

In assessing potential impacts of climate change and the vulnerability of systems to climate variability, it is useful to compare scenarios with historical data. Using the record of climate data from Summerland-CDA/CS station, the variation in annual crop water demand was calculated for a hypothetical hectare of apple (Figure 9). Between 1916 and 2003, water demand ranged from 519 to 915 mm, with an average of 712 mm. Average estimated crop water demand for 1961–1990 climate normals, and data adjusted by the “delta” method using CGCM2-A2 output for 2020, 2050 and 2080 time-slices, was 680, 787, 901 and 1059 mm, respectively. It should be noted that the average for the 1961–1990 normal data was considerably lower than the average calculated for 1916–2003 daily data. These scenarios 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 during 1916–2003, the highest crop water demand (~900 mm), exceeded 1% of the time in the historical record, would potentially be exceeded 46% of the time by the 2050s.

7. Water Management

The scenarios of changing water supply and demand provide a picture of an impending challenge for regional water managers and user groups, as well as various levels of government. 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 situ*, increased water stress makes the situation more difficult. Under the same conditions, the beneficial use principle could become a more significant requirement in allocating licenses as water sources become fully subscribed. The perpetual nature of water licenses and the limited ability of managers to modify water rights (e.g. transferability and conditionalities), may create restrictions 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 increasingly difficult under a climate change scenario. The failure in British Columbia to proclaim the Fisheries Protection Act (as of 2004) and to define acceptable minimum fish flows adds to this difficulty.

7.1. ADAPTATION CASE STUDIES

Four case studies of water management practises were carried out in order to explore the actual “adaptation process,” and thereby gain an appreciation for the context and conditions that shaped local authority decisions and actions (Shepherd et al., in preparation). Each case represented adoption by local authorities of a different water efficiency approach: domestic metering in Kelowna, irrigation metering in Southeast Kelowna Irrigation District (SEKID), wastewater reclamation in Vernon and institutional change in Greater Vernon, specifically amalgamation of separate water utilities into the Greater Vernon Water Utility (GVWU). The latter three cases represented “early adopters” of innovative management practises in the region.

The study explored how and why decisions were made and what factors triggered, influenced and limited “adaptation” – or change – to take place. The reasoning behind this research approach 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 Loë et al., 2001). 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:

- Values and perceptions
- Financial and human resource issues
- Politics and decision-making processes.

Although adaptation is the act of adapting (the decisions that are made, their 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 (Smit et al., 2001) defines adaptive capacity as the: "...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."

It is clear that many objective factors contributed to adaptation in the four case studies: financial capacity, expertise, technology, and institutional structures. For example, federal Green Plan funding contributed to the implementation of irrigation metering in SEKID, whereas access to provincial loans ensured lower domestic water rates in GVWU. Access to expertise is a requirement in any new development both in option evaluation and implementation. Technology that fits the specific physical challenges as well as user and operator needs contributes to a successful outcome. Legislation and regulation can be effective barriers as some are institutionally entrenched, such as the BC prior appropriation system of water rights. However, changes in regulatory regimes can also be key motivators of change. Subjective capacities also influence the adaptation process, for example, *the desire to act* in Kelowna's case, *decision-maker values* in Vernon's changing political landscape, or simply the *perception that it needs to be done* in SEKID's case. Trust is a pivotal element in enabling the adaptation process whereas perceptions of each initiative were equally influential in triggering action and determining outcome success.

Criteria to screen adaptation options based on appropriateness have been developed (Ivey et al., 2001; de Loë et al., 2001). These criteria portray various characteristics that would make an option suitable for adapting to near-term climatic change: (1) least resistance, i.e. ease of implementation and available resources; (2) financially viable, i.e. cost effective and equitable; (3) applicable under uncertainty, i.e. no regrets, flexible and reversible; (4) sensitive to other goals, i.e. minimum environmental impacts and consistency with community goals; and (5) applicable under climatic change, i.e. flexible and reduced vulnerability. Metering domestic water use with a rate structure fulfills all of these criteria: it is a least cost option, equitable, flexible, requires minimal institutional and structural overhaul, and reduces pressure on the water resource. Metering irrigation fulfills many of the same criteria, however, it isn't a path of least resistance as growers take for granted that water is cheap and plentiful (Shepherd et al., in preparation). Wastewater reclamation is potentially difficult due to issues of physical barriers (e.g. vulnerability to vagaries in weather), and perceived barriers (e.g. perceptions of health risk) to implementation. Utility amalgamation requires significant initial financial outlay and institutional reorganization, would not represent a path of least resistance, is not flexible or easily reversible, and at least in the example of GVWU, resulted in domestic users subsidising agricultural-water use.

In conclusion, according to these screening criteria, institutional reorganization would be the last approach to take after acceptable technical and economic fixes were in place. There is a time and place for each adaptation option, starting with

those that represent paths of least resistance, while simultaneously endeavouring to pave the way for more substantial, yet challenging approaches.

7.2. FINANCIAL 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, utilising the large storage capacity of Okanagan Lake.

The costs of both demand and supply side options vary greatly depending on various features of the individual water supply systems and the types of demands served. In summary, there is no single least cost adaptation option for all water systems since costs will vary significantly from system to system. Other factors, such as water quality and treatment options will also enter into the decision. Often a combination of options will be necessary 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 CAN\$ 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 CAN\$2000 per acre-foot would be a reasonable figure to consider (Hrasko, 2003). Site-specific engineering studies would have to follow to obtain more accurate figures.

7.3. WATER SUPPLY AND DEMAND SCENARIOS

Research for this component examines the vulnerability of water resource systems in the Okanagan Basin to the impacts of climate change and population growth on water supply and demand. The role that various adaptation options can play in reducing vulnerability is also examined. This study uses 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.

One case, described in Neilsen et al. (2004) is for the District of Summerland, which draws its water from Trout Creek. Local managers use a drought threshold of $30.3 \text{ m}^3 \times 10^6$ (36% of average annual flow). During 1961–1990, there was only one occurrence below this threshold. For the climate change scenarios, this threshold would be exceeded more often. During the 30-year time slice centred on the 2080s, the three A2 scenarios would have an exceedance frequency of 31–44%, or 9–13 occurrences. Meanwhile, the current peak demand threshold of $10.1 \text{ m}^3 \times 10^6$, which

was observed in 2002, would be exceeded almost every year in the A2 scenarios in the 2080s. The resulting frequency of high risk years in the A2 scenarios, when peak demand and drought level flows occur simultaneously, would be 25–50% of years during the 2080s.

The scenarios approach aims 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. The next step is to use these scenarios to 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.

7.4. DIALOGUE ON AN ADAPTATION PORTFOLIO

Having established researcher-stakeholder relationships and built a range of climate impact scenarios, the study enters a new phase. Some preliminary analyses of adaptation options, in terms of their feasibility and costs, have been provided. This sets the stage for a discussion on how these various options could become part of an adaptation portfolio. The portfolio idea suggests a range of measures that facilitates risk sharing and risk reduction for the region as a whole, as well as for individual communities and water purveyors. However, this portfolio would have to fit in to the regional context of future planning and development, including consideration of various long-term goals and objectives of such plans.

The dialogue process needs to engage a wide range of stakeholders. In the Okanagan, regional planning responsibilities are shared between different levels of government, including regional districts, municipalities, First Nations, as well as the Province of British Columbia. Specific concerns related to water would engage both government and non-government interests in water. Although the Okanagan Basin Water Board (OBWB) exists as a regional water management body, it does not have (at this time) the mandate to produce a comprehensive water management plan for the region.

Climate Impact Assessment faces challenges similar to Risk and Environmental Assessment. For both substantive and procedural reasons,¹ researchers have developed a range of methods for incorporating the knowledge and values both of citizens and local experts into assessments. For instance, citizen understanding of climate change has been examined using intensive focus groups (Kasemir et al., 2003) and sustainable development strategies have been examined using modelling tools inspired by computer games (Tansey et al., 2002; cf. Dahinden et al., 2003).

In this dialogue phase, the primary objective is to engage local decision-makers who have practical knowledge of the social and institutional context within which any future anticipatory adaptation interventions would occur. The Okanagan region is particularly vulnerable to changes in the availability of water. In this study we identified a range of supply and demand side interventions that would reduce the

vulnerability of the region to climate variability in the short term and, potentially, to climate change in the longer term. From a purely technical perspective many of these interventions, including water metering in the residential and agricultural sector, drip irrigation, groundwater extraction and expansion of surface water supply represent low or no regrets options in a water scarce region. Nonetheless, these interventions would alter the distribution of benefits and costs among stakeholders. In metaphorical terms, the objective was to map out the political landscape of the region so that enabling and constraining factors could be understood in greater detail. The design of these sessions was informed by the PIA approach (Section 5) and a structured approach to decision analysis (Keeney and McDaniel, 2001; Gregory et al., 2003) although the latter is typically applied to real rather than hypothetical choices.

Two case study locations, the Town of Oliver and the planning region designated as the Trepanier Landscape Unit, were selected for the two community adaptation workshops in the Okanagan. Oliver is a small agricultural community north of Osoyoos Lake. Trepanier Landscape Unit, including some unincorporated communities, is a fast-growing area to the west of Kelowna. Participants in the workshops were presented with a range of technically viable supply and demand side water management options and were asked to evaluate them according to eight questions. The questions addressed three broad themes: the social acceptability of the options, the current legal acceptability and political/jurisdictional concerns.

Participants were recruited from governmental, non-governmental and business organisations. The workshop spanned a full day and participants were broken into heterogeneous groups of between six and eight to ensure that each contained a diverse range of views. Each group was directed by a facilitator and a note taker and addressed two to three adaptation options in the course of the day.

These workshops reveal the complex political landscape that overlay the physical landscape of the region (Tansey and Langsdale, 2004). Historical commitments to users in the agricultural community shape the current allocation of water resources and strongly influence the acceptability of adaptation options. Education and conservation interventions were considered useful in both communities. With respect to groundwater utilisation, many participants pointed out that while it may represent a viable alternate source in some areas, extraction is currently unregulated. Increasing drought pressure on traditional water sources may therefore result in largely unregulated groundwater withdrawal.

A third workshop focused on the topic of implementing an adaptation portfolio at the basin scale. This event was an additional opportunity to discuss the feasibility of anticipatory adaptation measures, but this time the discussion centered on changes that would affect, or be implemented in, the entire region. Because the scale of discussion was broader in geographic area, the adaptation measures discussed were also broader. General supply side and demand side approaches were discussed rather than site-specific strategies. There was also a greater emphasis on governance structures that could implement and orchestrate change on this scale.

Dialogue at this scale was more strategic. Participants expressed support for expanding the role of the OBWB and Okanagan Mainline Municipal Association (OMMA) in regional water quantity management. There was support for basin-wide management of various measures, including increased use of Okanagan Lake and groundwater sources, a coordinated “water smart” program for residential users, and various measures that could be regionally coordinated for agricultural users such as irrigation scheduling.

Recurring themes at the regional scale were the need for support from the local level, and for encouragement of a sense of “belonging to the basin.” Participants also expressed the need for better integration of water issues with local development and planning.

8. The Integration Process – Continuous Learning with Local Help

As this study continues to evolve, there is an incremental building of a relationship between researchers and regional interests through sharing of knowledge about biophysical processes, decision making, and perspectives about future development in the Okanagan. After an initial exploration of climatic and hydrologic scenarios that began in 1997 (Cohen et al., 2000), with associated discussions about “what if” questions, the dialogue is now starting to broaden to include implications for local development plans. These “so what” and “what should be done” questions can now be pursued within the context of regional development, but with well established and plausible connections to global climate change. This effort to “downscale” climate change into the regional context goes well beyond the specific task of providing climate scenarios for this study. The creation of a collaborative effort involving researchers and stakeholders has been central to the task of addressing complex questions in an integrative manner.

Participatory integrated assessment (PIA) of climate change impacts and adaptation is very much dependent on attracting knowledgeable stakeholders in a process of shared learning. Our strategy within this study has been to target professional water managers, irrigators, municipal staff, and members of watershed and regional planning authorities, as well as First Nations, provincial and federal government agencies, and members of local watershed stewardship groups.

As the relationship between researchers and regional interests continues to mature, we anticipate that this research will evolve into a more concerted effort at creating a dialogue around adaptation policy. Ideally, this would be accompanied by additional technical studies where needed, including improvements in downscaling of climate model outputs, improvements in hydrologic and water demand modelling (e.g. to include groundwater, land-use change, new irrigation delivery systems, reservoir operations, etc.), and site specific estimates on costs of adaptation options. These varied sources of information and knowledge could be applied to the development of a decision support tool to aid in the visualization of future

scenarios of water resource *management* under different climate futures. Plans are now underway to use a group model building process to create such a tool (Cohen et al., 2004) for use in a model-assisted policy dialogue (Tansey et al., 2002).

The policy dialogue itself represents a shift to a more active effort at integrating climate change adaptation into regional planning processes, in other words, to make this an explicit part of how long-term plans are constructed. Having used scenarios to create a new image of the future condition of water resources in the Okanagan, this new phase will enable the dialogue to focus on present and near-term adaptation opportunities and challenges (as suggested by Burton et al., 2002).

There are many challenges in sustaining a PIA process. One is the maintenance of working relationships as funding ends for one study and is sought for another. Individual and organizational memory will play important roles in facilitating the linking of successive projects. Second, as the assessment moves toward addressing matters of adaptation policy, roles of regional collaborators would likely change. The dialogue could still be initiated by the research group, but ultimately should be led by regional interests themselves. A key objective would be that the dialogue events would take place outside of any specific political process, while being supported by those with political standing, as well as by regional and technical/professional interests knowledgeable about water management.

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Note

¹Local experts are often able to provide substantive input that matches the expertise of credentialed researchers. From a procedural perspective, impact assessment that fails to build local credibility with citizens and decision-makers is less likely to succeed in securing adaptation options.

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