South Saskatchewan River Basin Adaptation to Climate Variability Project

Phase II: Bow Basin Summary Report

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ALBERTA waterSMART
Water Management Solutions

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This report is available and may be freely downloaded from the Alberta WaterPortal website at www.albertawater.com.

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1 Executive Summary

This report summarizes work done in Phase II of the South Saskatchewan River Basin project, which focused on the Bow River Basin. Phase II aimed to improve understanding of climate variability in the Bow Basin using existing models and expertise, and then to identify adaptation strategies and build the resiliency of the system. Work done previously through the Bow River Project (BRP), using the Bow River Operational Model, showed that the river system could be managed in a more integrated manner that considers all users, interests and values. This was the foundation for the current project.

Phase II continued the collaborative modelling process that began with the BRP. Phase II was intended to build capacity in people, organizations and processes to better adapt to climate variability and change. Participants actively offered ideas and comments to advance the discussion, while respecting the views and opinions of others; however, this process was not designed to seek or achieve consensus. As well, the results are not being recommended or advocated; rather, they are presented in this and other project reports as a starting point for discussion and further consideration by those who use, manage and make decisions about water in the Bow Basin.

The Phase II work focused on four main areas, all of which are described in more detail in the associated project documentation:

- The preparation of the Bow River Basin Integrated River Management Business Case.
- Enhancements to the Bow River Operational Model (BROM).
- Development of future climate scenarios for the Bow Basin.
- Development of adaptation strategies for present and future climates in the Bow Basin.

The Business Case identified and, to the extent possible, measured the net incremental benefits associated with implementing the Preferred Scenario, proposed by the BRP to improve water management outcomes for the Bow River watershed (for a detailed description see: http://www.albertawater.com/index.php/projects-research/bow-river-project). These incremental benefits were determined by comparing the effects on water management in the Bow River Basin of implementing the Preferred Scenario, against current water management methods and capabilities. The Business Case analysis makes clear the individual and overall benefits to be gained by implementing the Preferred Scenario and demonstrates that the Scenario's implementation would be in the best overall interests of the diverse water users in the Bow River Basin.

The BROM is a mass balance, river system model that reflects the streamflows and operations of the Bow River system. It does not directly take into account groundwater or water quality aspects although adjacent groundwater in- and out-flows would be indirectly measured as more or less streamflow between each measuring device. As it is currently configured, the BROM is intended to provide as many benefits and meet as many existing and future water needs as possible. It focuses primarily on what water users actually need to do rather than strictly replicating decision making mandated by the current regulatory scheme in Alberta. That said, the operations within BROM do comply with the limitations established under the *Water Act.*

Several refinements were made to the BROM during this project, a major one being the addition of the Highwood and Sheep river systems. This addition provides a publicly available tool that could be used to analyze specific impacts and the potential mitigation of water source options for communities in the Highwood and Sheep sub-basins, in the context of the whole Bow River Basin.

One goal of the SSRB Adaptation Project was to propose an adaptive and robust water management framework that takes into account the regional impacts of climate variability and change. This required the development of a scientifically valid set of possible future streamflow conditions that would enable water users and managers to test water management alternatives under a range of potential future climate and hydrological scenarios. The innovative approach used in the project resulted in 50 climate scenarios, five of which were statistically chosen to reflect a realistic range of climate impacts and enable the discussion of potential management options. One of these, the "3yr Min" scenario, was used as the basis for modelling the impacts and potential benefits of each strategy. After the most extreme 10% of scenarios were removed to eliminate statistical outliers, the 3yr Min scenario emerged as the most severe climate scenario of the five examined and was regarded as the worst reasonably likely scenario, thus enabling a rigorous test of potential water shortage adaptation strategies.

Phase II concluded by using the BROM and heightened stakeholder capacity to develop potential risk management strategies to help southern Alberta adjust to climate variability and change. Performance measures were developed and used to assess and demonstrate the impact and benefits of changes made in the BROM, focusing on impacts to the river and aquatic ecosystem health as well as on the needs of the various water users. Fifteen individual and six combination strategies were identified:

- Seven suggested strategies could benefit the watershed and improve overall river management under current conditions if they were implemented now. These strategies could improve aquatic ecosystem health while continuing to meet the social and economic needs and interests throughout the basin.
- Eight suggested strategies may be less necessary under current conditions, but could be important components in managing risk and adapting to a more severe future climate, as reflected in the scenario modelled in the project. Some of these would require changes in how water is managed, while others involve new infrastructure. Any new infrastructure and storage would need to be evaluated carefully, considering economic impacts, positive and negative environmental tradeoffs and effects on the land and landowners.
- Six suggested combination strategies were modelled, ranging from modest cost, near term combinations that offer value under normal (current) conditions, to higher investment, longer term combinations that might be considered if the risk profile of climate variability warrants more substantial change in the system.

2 Introduction

Alberta's heritage and its social, economic and environmental history are directly tied to its water resources. While Alberta's economy is fuelled by hydrocarbons, it runs on water, and continued prosperity depends on sound water management decisions. In the face of climate variability and change, these decisions are becoming more complex and more critical.

Alberta is confronting important water challenges, including an expanding population, accelerating economic growth, and the increasing impact of this growth on the environment as the climate continues to shift.

The province's geographical landscape encompasses the spine of the Rocky Mountains on its western border, semi-arid plains in the south, parklands in central Alberta and boreal forest across the north. The mountain regions are the water towers for much of western Canada, while eastern and northern flowing rivers are vital to this province as well as downstream neighbours.

Water supply varies considerably throughout Alberta. Water demand is also variable, particularly between southern and northern regions. The health of Alberta's natural resources and its economic vitality depend on an integrated understanding of natural climate variability as well as the management capacity to confront the prospects and potential impacts of changes in climate.

These challenges present a timely opportunity to capitalize on the knowledge and experience of community and business leaders, government departments, environmental organizations and watershed groups. Water and climate adaptation issues are complex and cannot be appropriately addressed by any single initiative or sector. Alberta has a history of successfully meeting challenges through multi-sector collaboration and engagement, and the South Saskatchewan River Basin Adaptation to Climate Variability project will further enhance that legacy.[1]

Outcomes from the Bow River Project (BRP) and the subsequent Bow River Live Simulation, described in section 3, formed the foundation for the Phase II work. Climate change and variability were recognized as important factors affecting the environmental, social, and economic future of the basin during the BRP. The current project was an opportunity to better understand climate variability and risk in the Bow Basin and the SSRB using existing models and expertise, and then to enhance adaptive capacity by identifying implementable strategies that build system resiliency.

This report summarizes work done in the second phase of the South Saskatchewan River Basin (SSRB) project, which focused on the Bow River Basin, shown in Figure 1.[2] Phase II was designed to: advance climate adaptation decision making related to water resources, explore climate variability scenarios, identify impacts and risks to the river system and its users, and identify adaptation options to mitigate those risks. The Bow work will be incorporated into the larger SSRB project and the model results and stakeholder support can be used to facilitate a "pilot project" of integrated river management on the Bow River. The flood of June 2013 certainly adds to the urgency of getting an agreement in place between the Government of

[1] See Appendix A for more information on this project.
[2] The map in Figure 1 is provided courtesy of the Bow River Basin Council (www.brbc.ab.ca).

Alberta and TransAlta for ongoing river management. Whether or not there could have been any reduction in damage in this event remains to be seen, but collaborative management may be able to mitigate impacts from smaller floods if preplanned arrangements are in place.

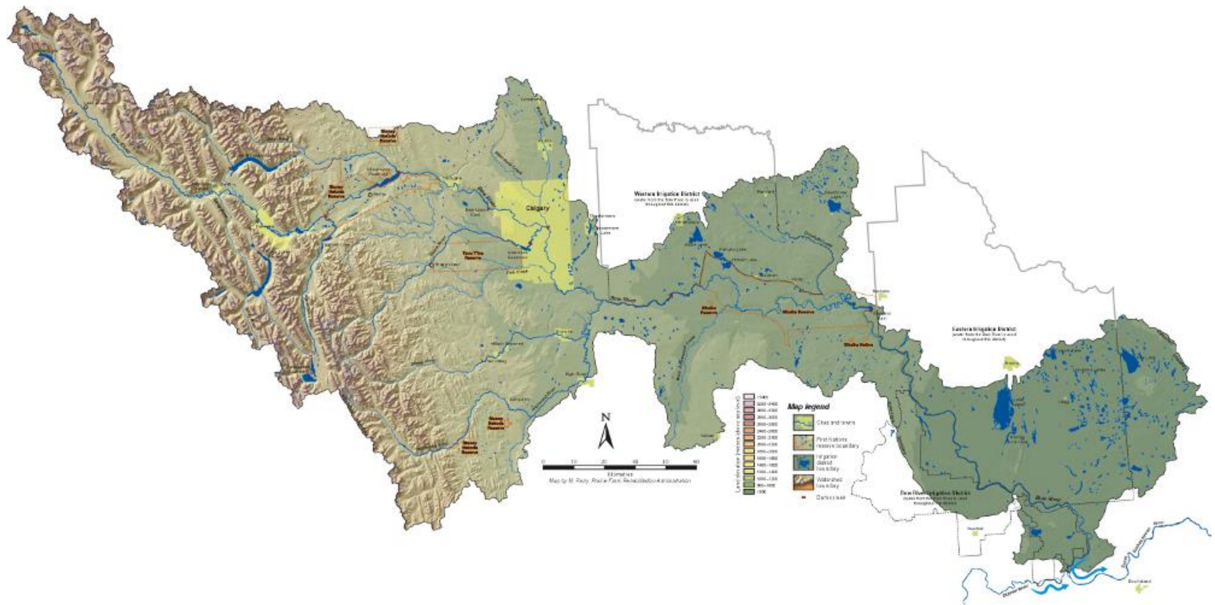

Figure 1: The Bow River Basin

Because this report summarizes a body of previous work, it includes text from some of those materials, all of which are referenced in the appropriate place as footnotes.

3 The Bow River Project and Simulation

For more than 100 years, the flow of the Bow River has been controlled by dams and reservoirs and by the operating rules established by the owners of these facilities. Since 1911, TransAlta has been the main influence on the storage and release of water in the river and its tributaries.

For more than a century, active management of various on-stream and off-stream storage facilities has altered the timing of the flow in the Bow River (see Figure 2). The BRP provided an opportunity for the full range of stakeholders to examine the way decisions are made, with a focus on improving environmental outcomes while meeting other water needs in the Bow River Basin.

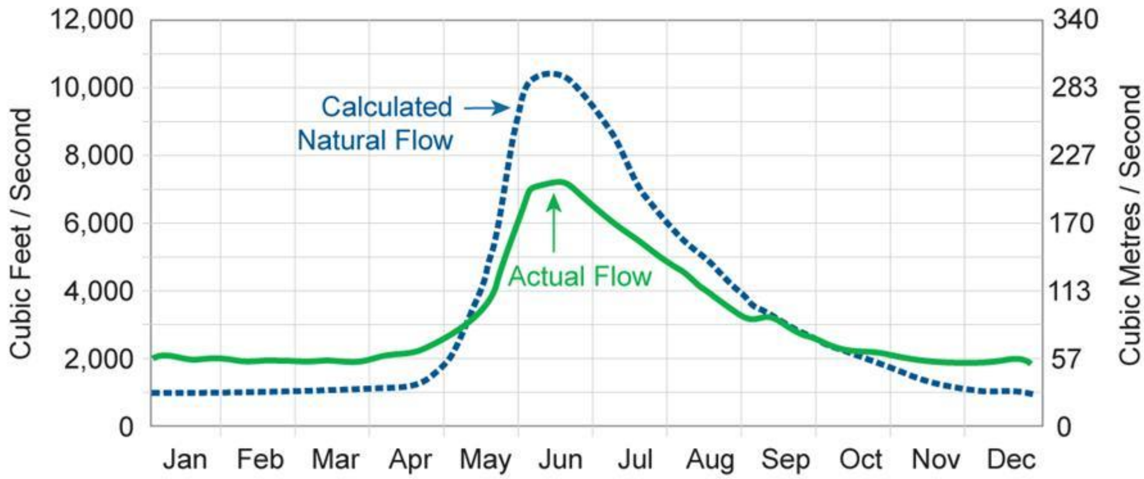

Figure 2: Bow River at Calgary – Natural vs. Managed Flows (1960 - 1997)

3.1 The Bow River Project

In 2010, the BRP Research Consortium, comprising water users and managers holding over 95% of the water licensed for diversion from the Bow, was established. It explored options for re-managing the Bow River system from headwaters to confluence, in an integrated manner that considers all users, interests and values.[3] Participants worked collaboratively with an interactive, hydrologic simulation model to develop plausible and achievable scenarios for protecting the health of the river throughout the basin and meeting the needs of water users. A key outcome of the BRP was the fully functioning, data-loaded Bow River Operational Model (BROM).

The BRP concluded that the Bow River system can and should be managed differently to achieve many economic, social and environmental goals throughout the basin, and that the changes required could be implemented for relatively modest cost. The BRP created four alternative scenarios, one of which became the “Preferred” Scenario for managing the river system. Two key components of the Preferred Scenario were a) establishing a virtual water bank within the existing TransAlta storage reservoirs, capable of providing 60,000 acre-feet of storage

[3] See the Bow River Project Final Report, March 2011; more information on the BRP and the simulation is available online at http://www.albertawater.com/index.php/projects-research/ssrb-adaptation-project?layout=edit&id=547.

to be used to offset low flow periods on the Bow, and b) stabilizing Lower Kananaskis Lake and Kananaskis River for additional environmental, recreational and economic benefits.

3.2 The Bow River Simulation

Following this initial work, water managers and licence holders in the Bow Basin expressed an interest in examining further improvements and testing the BROM through a live simulation. To gain a better, real-time understanding of the impacts of the changes proposed in the BRP, participants again came together in the fall of 2011 to engage in an interactive modelling exercise – the Bow River Simulation – using the existing model and data. The live Simulation allowed participants to make decisions about water use on a weekly basis, independent of each other, and to evaluate those decisions against the performance measures developed in the earlier work.

The Simulation confirmed the key findings and opportunities identified by the BRP, specifically the value of establishing some form of a flexible virtual water bank and stabilizing the Kananaskis system. Participants also concluded that the BROM is a realistic and real-world representative model and a valuable tool for understanding the river system and exploring changes and potential opportunities to manage the system for improved and sustainable outcomes. Further refinements and improvements were identified and proposed as a result of the Simulation.

As well as laying the foundation for the current project, the BRP and the Simulation helped launch discussions between TransAlta and the Government of Alberta about potential opportunities to manage the Bow River system differently. The Bow phase of the SSRB project has continued to inform discussions and negotiations between TransAlta and the Government of Alberta; the project team and participants remain willing to support and contribute to these discussions as appropriate.

4 SSRB Adaptation Project Phase II Process

Phase II of the SSRB Project re-engaged BRP participants as well as new participants with an interest in the Bow River Basin (see Appendix B for a participant list). This very diverse group included water users and managers with over 95% of the licensed water diversions on the Bow River.

4.1 The Collaborative Modelling Process

The BROM is a valuable legacy of the original Bow River Project and formed the foundational tool for the Phase II work. HydroLogics, Inc. the consultant who worked with the BRP Research Consortium, again led the modelling for the SSRB project, using the sophisticated simulation software they developed for modelling water systems throughout the US and internationally. HydroLogics' modelling software—called OASIS (Operational Analysis and Simulation of Integrated Systems)—is flexible, transparent, completely data-driven, and effectively simulates water facility operators' behaviour.

HydroLogics has pioneered the use of Computer-Aided Negotiations (CAN), which enables parties with disparate goals to collaboratively develop operating policies and solutions that mutually satisfy their diverse objectives. The CAN sessions integrate computer modelling techniques and real-world data with the existing water management structures.

Developing performance measures is one of the first steps in the process to help parties scope the issues. Performance measures reflect the objectives and desired outcomes for the project and indicate whether one result is better or worse than an alternative. They define the functional aspects that the model needs to have, and thus they inform and influence how the model is constructed. Participants identified and developed specific performance measures based on their individual and collective water outcome needs for this project, while continuing to draw on those that were used in the earlier BRP.

Once performance measures are in place, the model can be run and the results tested and vetted to determine if the outcomes are reasonable and realistic, based on the deep knowledge and experience of participants. Exploring and modelling alternative operations is what most often results in model improvements and updates, and strengthens model results. When the model is refined and ready to be tested, participants then spend a number of hours working collaboratively in small groups to identify and test opportunities and potential scenarios or strategies. Based on these outcomes and the results of the performance measures, collaborators can then work to reach agreement on the alternatives that are most beneficial to the basin and that meet as many user needs as possible.

4.2 Phase II Process

Building on the collaborative modelling process that began with the BRP, the full group of Phase II participants met five times between June 2012 and May 2013, with occasional teleconferences as needed. As appropriate, individuals also volunteered to further participate in specific project components including the Business Case, refinement of performance measures, modelling enhancements and the provision of data. A two-day live modelling session was held in February

2013 to examine the plausible range of climate impacts in the Bow Basin as developed for the watershed by Dr. David Sauchyn and his team specifically for this project, and to explore potential adaptation strategies in response to these impacts.

Throughout the project, participants worked collaboratively, providing advice and insight based on their extensive knowledge and experience. Project terms of reference were approved by the group, key components of which are included in Appendix C.

Participants actively offered ideas and comments to advance the discussion, while respecting the views and opinions of others; however, this process was not designed to seek or achieve consensus. As well, the results are not being recommended or advocated; rather, they are presented in this and other project reports as a solid foundation for discussion and further consideration by those who use, manage and make decisions about water in the Bow Basin.

The Phase II work focused on four main areas, which are summarized in section 5 of this report:

- The preparation of the Bow River Basin Integrated River Management Business Case.
- Enhancements to the Bow River Operational Model (BROM).
- Development of climate scenarios for the Bow Basin.
- Development of adaptation strategies for present and future climates in the Bow Basin.

Phase II developed and made available tools that could be used by all stakeholders to address changing climate patterns in the region. Refinements were made to the BROM throughout the project, as improvements were identified and data could be obtained. Basin-specific climate scenarios were developed in late 2012 for use in the live modelling session and the project concluded with the documentation of potential climate adaptation strategies in June 2013.

5 Project Results and Findings

This project produced a number of innovative outcomes, in particular the scientific approach used to develop the climate scenarios. The four main areas of focus are all supported by additional documentation and are summarized here.

5.1 The Bow River Basin Integrated River Management Business Case

The BRP concluded that the Preferred Scenario would be the most beneficial scenario to improve management of the Bow River watershed. Thus, one important component of the SSRB Phase II work was to identify and, to the extent possible, measure the net incremental benefits associated with implementing the Preferred Scenario. These incremental benefits were determined by comparing the effects on water management in the Bow River Basin from implementing the Preferred Scenario, with the current water management methods and capabilities, referred to in the BRP Final Report as the "Base Case."

The product of this work was the *Bow River Basin Integrated River Management Business Case* (the "Business Case").[4] The authors gathered information by reviewing relevant documents and other publications and through interviews, correspondence and discussions with knowledgeable individuals. A number of people associated with this project as well as other experts provided advice and feedback as the Business Case was developed. Interestingly, this effort was far more difficult than originally anticipated and surprisingly few examples of businesses cases with similar breadth and solid economic analyses were available from other jurisdictions.

Determining the incremental benefits of the Preferred Scenario involved quantitative and qualitative measures, including, for example, analysis of relevant revenues, associated costs, cost avoidance, intrinsic values and other benefits that are known but could not be measured in economic terms at this time. To better understand the overall benefits offered by the Preferred Scenario, the Business Case analysis focused on benefits that appeared to be more substantial and could have a greater potential impact on individuals and organizations. It was based on reasonable and transparent assumptions and provides a valid estimate of substantial benefits to be achieved as a consequence of implementing the Preferred Scenario.

As the Business Case describes in more detail, implementing the Preferred Scenario could provide the quantitative benefits noted below, recognizing that a) these benefits are not necessarily additive, b) this is not an exhaustive list of potential benefits, and c) new water or the potential for new water allocations is not in any way an implied benefit of the Preferred Scenario:

- The estimated annual incremental economic benefits of stabilizing Lower Kananaskis Lake are at least $2 million - $3 million with an estimated net present value between $30 million and $40 million.
- The estimated cost of securing a comparative amount of water equivalent to that managed by the virtual water bank has a net present value range of $41 million - $313 million.

[4] See *South Saskatchewan River Basin Adaptation to Climate Variability Project: Bow River Basin Integrated River Management Business Case*. January 2013. The impact(s) of potential climate change on the Preferred Scenario were not assessed in the Business Case.

- The estimated avoided cost of building equivalent water storage is $51 million - $148 million.

The Preferred Scenario offers direct and indirect environmental benefits to the ecosystem through, for example, improved outcomes and resilience for healthy aquatic and riparian environments in specific reaches of the basin, which are highly valued by many users. The Preferred Scenario also supports the three *Water for Life* goals. It provides a reliable, quality water supply for a sustainable economy (Goal 3) with assurance of minimum flows (1,250 cubic feet per second, or cfs)[5] through Calgary. These assured minimum flows provide security of water quality standards (Goal 1), along with fisheries protection and enhanced flows in the Bow River from Calgary to Bassano and beyond to the confluence with the Oldman River (Goal 2).

The Preferred Scenario and the virtual water bank might also assist in mitigating risks associated with meeting future water demands and the potential environmental impacts attributable to population growth. The Preferred Scenario also included the potential to ensure year-round availability of water to meet the needs of junior licensees in the basin.

This Business Case analysis makes clear only some of the individual and overall benefits to be gained by implementing the Preferred Scenario and demonstrates that the Scenario's implementation would be in the best interests of the diverse water users in the Bow River Basin.

5.2 BROM Enhancements

The Bow River Operational Model (BROM) is a mass balance, river system model that reflects the streamflows and operations of the Bow River system. It was developed as part of the 2010 BRP, which used the University of Lethbridge's SSRB model as the starting point. The BROM diverges from the SSRB model and from Alberta Environment and Sustainable Resource Development's Water Resources Management Model (WRMM) in that it attempts to model existing, real-world management and potential future operations beyond the constraints of a strict licensing system and includes the entire Bow system from headwaters to the confluence with the Oldman. As it is now configured, the BROM is intended to provide as many environmental benefits and meet as many needs as possible. It focuses primarily on what water users actually need to do rather than strictly replicating decision making mandated by the current regulatory scheme in Alberta. That said, the operations within BROM do comply with the limitations established under the *Water Act.*

The BROM does not directly take into account groundwater or water quality aspects although both are indirectly and partially encompassed. Groundwater inflows and outflows occur in each reach, between monitoring and measuring stations, and the resulting effect on streamflows (but not the actual amount of water) is measured and reflected in the BROM. Many point sources affect water quality; although these are not measured in the BROM, maintaining higher flows during low flow periods is a key variable in improving water quality and addressing issues such as lack of dissolved oxygen.

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[5] Imperial units are used throughout the SSRB Adaptation Project.

The schematic diagram in Figure 3 illustrates the breadth and complexity of the area modelled in the BROM, including the Highwood and Sheep river systems which were added for this project (see Section 5.2.1). Refinements made to the BROM during the Phase II work are listed here and described in more detail in the project report on climate adaptation strategies:[6]

- Meeting current and future Siksika demands
- Monthly Calgary return flows
- Demand 807 in the Highwood River System
- New demand and return flow data from Okotoks
- Correction to Lower Kananaskis Lake stabilization, and adjusted weighting on Lower Kananaskis Lake.

All BROM assumptions and input data will be described and documented in the publicly available electronic BROM files accessible through the University of Lethbridge servers, at http://www.uleth.ca/research/node/432/.

[6] *South Saskatchewan River Basin Adaptation to Climate Variability Project: Adaptation Strategies for Present and Future Climates in the Bow Basin.* May 2013.

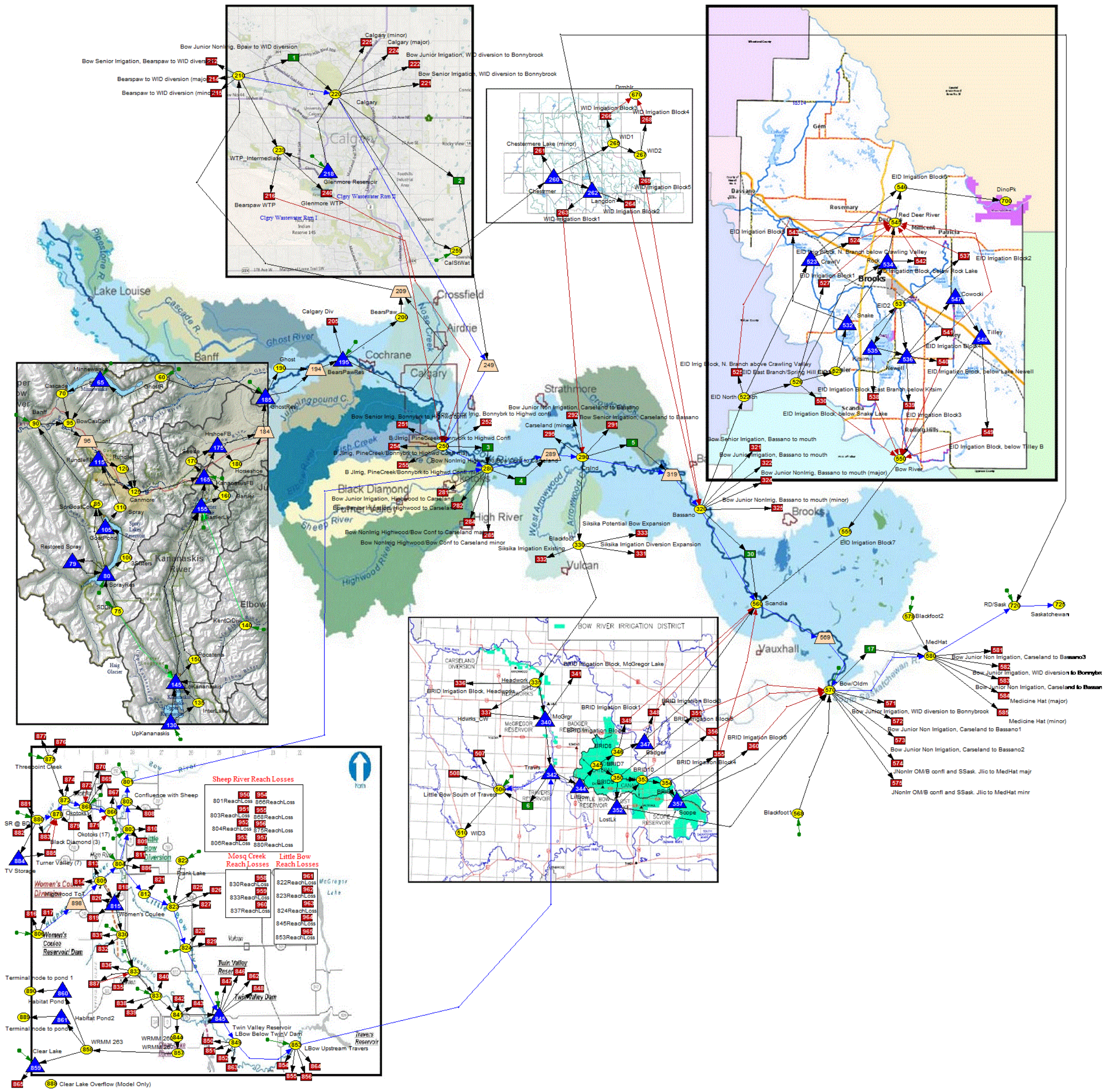

Figure 3: Schematic showing the area modelled in the BROM

5.2.1 Addition of the Highwood and Sheep River Systems to the BROM

The Highwood and Sheep river system model was added to BROM to provide a publicly available tool that could be used in the analysis of specific impacts and the potential mitigation of water source options for communities in the Highwood and Sheep sub-basins, within the context of the whole Bow River Basin. Scenarios could include infrastructure options, licence transfers and use, as well as demand management and other ideas that could be considered within the model. A version of the Highwood model existed within the WRMM but was not directly linked to the rest of the Bow River, and the Sheep River was not explicitly included in the original Highwood WRMM model. The original BRP used data from the Highwood confluence with the Bow as an input to the system without having access to data for modelling the upstream detail.

Much of the data for the Highwood River system came from the Highwood WRMM model and from Alberta Environment and Sustainable Resource Development (ESRD). ESRD operations staff, including Satvinder Mangat, Derek Lovlin and Kent Berg, also provided a substantial amount of information as did Shirley Pickering with the Highwood Management Plan – Public Advisory Committee. Documents from the Highwood Management Plan were also used. Data for the Sheep River portion of the model came primarily from ESRD and a stakeholder group that was doing some modelling work on the Sheep River. The model enhancement was completed by HydroLogics with assistance from Alberta WaterSMART.

The Highwood and Sheep river systems are unique in the Bow System in that there are no substantial management structures (i.e., dams) to enable augmentation or management of flows as is the case for the mainstem of the Bow River. Several municipalities rely on the natural flows of both rivers. With growing populations and potential impacts from changes in climate (e.g., changes in magnitude of high and low flows, frequency of high and low flow events), there is an increased future risk to water supply for users on these river systems. At the last meeting of Phase II participants, results from the initial climate variability analysis were presented to show preliminary impacts from forecast changes in climate in the Highwood and Sheep region.

The addition of the Highwood and Sheep systems into the BROM was paid for in part by the Calgary Regional Partnership and in part through the SSRB Climate Adaptation Project budget. The model is now available for more detailed analysis of specific impacts and the potential mitigation of some of these impacts by alternative infrastructure options, as well as demand management and other mitigation options that could be considered and run in the model. At present, only the Sheep portion of the Highwood sub-model has been actively examined and explored by stakeholders. Exploring and modelling alternative operations is what most often results in model improvements and updates and strengthens model results. In the Sheep system, this has already led to the removal of a false demand node, adjustment of a municipal licence priority, and improvement to demand and return data for Okotoks. Similar testing by regional stakeholders will likely discover other areas for improvement in the Highwood, Little Bow, and Mosquito Creek sections of the sub-model.

5.3 Climate Scenarios for the Bow Basin: Development and Impacts

One goal of the SSRB Adaptation Project is to propose an adaptive and robust water management framework that takes into account the regional impacts of climate variability and change. This required the development of a scientifically valid set of possible future streamflow conditions that would enable water users and managers to test water management alternatives under a range of potential future climate and hydrological scenarios. Thus, developing climate scenarios that could be used in the BROM was the first step in contemplating potential climate adaptation strategies.

The innovative approach to developing the climate scenarios is described in detail in a separate report[7] and is summarized here. This aspect of the Phase II work was led by the Prairie Adaptation Research Collaborative (PARC), which has been developing climate scenarios for ESRD for some time. To start, the PARC research team generated probability plots of future flows for all the gauges in the Bow Basin where records go back over 100 years in some cases. From the projections of annual average flows and the disaggregation of these annual data, they generated synthetic daily timeseries for the gauges, an innovative approach that had not previously been explored within a model operating on a daily time step for simulation. Capitalizing on groundwork laid with the previous ESRD climate scenarios, this approach was substantially advanced as a result of the SSRB Adaptation Project.

The Global Climate Models (GCMs) used for the BROM were chosen for their ability to simulate Pacific Ocean temperatures, which drive the Pacific Decadal Oscillation (PDO). The PDO is one of the main factors that control precipitation and streamflow patterns in southern Alberta due to complex atmospheric connections. Choosing climate models that can simulate the Pacific Ocean temperatures, and thus the PDO, gives a better representation of potential future climates than does focusing on mean changes in precipitation and temperature; the latter approach, known as the Delta Method, is commonly used in climate change work.

The strong regression relationship between the PDO and streamflow in southern Alberta enables the movement from projected changes in climate identified in the GCM, to annual streamflow in southern Alberta. The approach used for this project developed projected streamflows that reflect the expectation of more extreme droughts, as opposed to methods that represent change as shifts in mean climate.

Fifty annual flow projections (climate scenarios) were generated for 30 years into the future (2025 to 2054). Five of these 50 scenarios were then selected using a simple statistical procedure to rule out potential outliers and then identify a maximum average, a median and three annual low flow scenarios to reflect a realistic range of drought-focussed climate impacts and enable the discussion of potential management options. The 10^{th} percentile of minimum flows was used to eliminate outliers of extreme low flows.

Much of the range in streamflow from the five scenarios covers flow conditions that have been seen throughout the historical record and are well within the recent range of variability in terms of magnitude and duration. Most years in all five scenarios had flows with volumes and timing

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[7] *South Saskatchewan River Basin Adaptation to Climate Variability Project: Climate Variability and Change in the Bow River Basin.* June 2013.

of water that would not require changes in operations beyond those found in the original Preferred Scenario to meet user needs and retain and improve environmental conditions. Because a specific purpose of this project was to identify strategies for adapting to flow changes that affect water users, scenarios were chosen to highlight impacts related to water supply scarcity and low flow periods in the Bow River system.

Two of the scenarios produced average flows relative to the historical record, and their hydrology resulted in little or no impact on users. The other three scenarios did produce flows that affected users and highlighted the impacts on major licence holders. Among these potential impacts were much lower storage levels (and at times, no storage) for TransAlta reservoirs, reduced flows through Calgary as well as depleted storage in Calgary's Glenmore Reservoir, negative environmental implications for downstream aquatic health, shortages for the three irrigation districts in the Bow River system, and shortages to non-municipal users throughout the Highwood and Sheep sub-basins.

Figure 4 compares, at a weekly time step, the 30-year average flow produced from each of the five chosen climate scenarios, with the 67-year average flow from the historical record in the model (1928-1995), and the two-year average flow from 2000-2001. 2000-2001 was a recent two-year period of low flows, which, when plotted provides some context for the average flow conditions that are produced for each of the five chosen climate scenarios. The plotted historical time series provides context for the streamflow produced by the climate scenarios. The average flow conditions and range of streamflow shown in Figure 4 generally reflect what are considered "current" or average conditions.

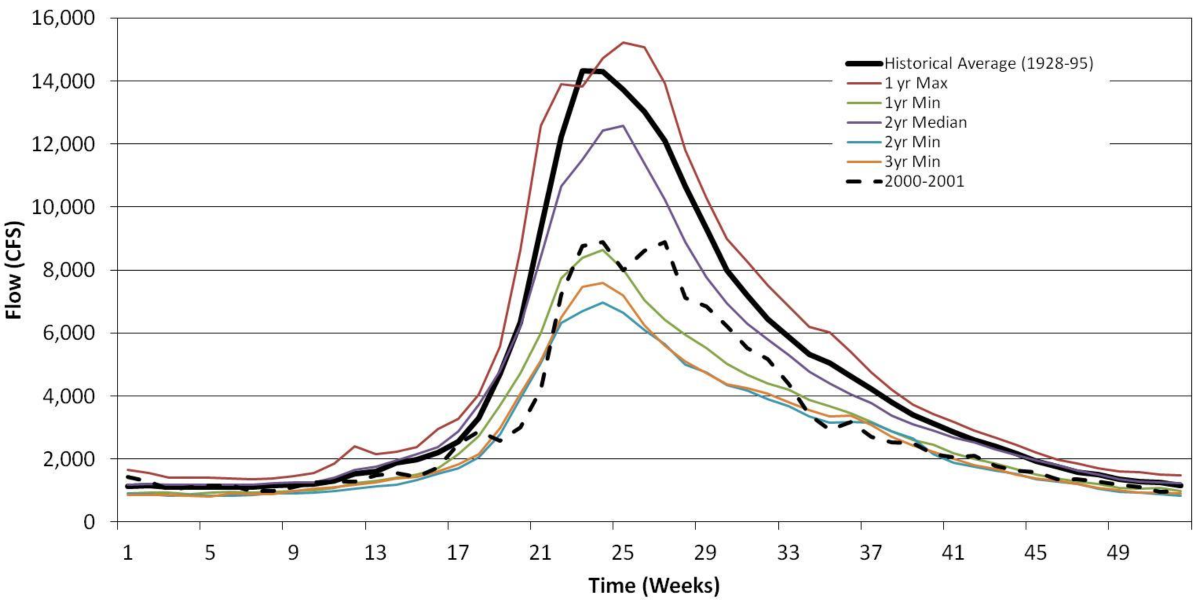

Figure 4: The 30-year average flow below Bassano, from each of the five chosen climate scenarios, with the 67-year average flow from the historical record in the model (1928-1995), and the 2-year average flow from 2000-2001

These potential impacts present risks to the environment, regional economy, and society, but they also present an opportunity to identify adaptation options and build resiliency in the SSRB to respond to future climate variability and change. Such options were explored in the two-day collaborative modelling session using the five scenarios. At this session, participants agreed to use the "3yr Min" scenario (CGCM3T47_3B1) as the basis for modelling the impacts and potential benefits of each strategy. The 3yr Min scenario was selected by taking the lowest summed 3-year (e.g., 2025+2026+2027, 2026+2027+2028) annual average flow from all years of all scenarios, and selecting the flow at the 10th percentile. The 3yr Min scenario has the lowest consecutive 3-year cumulative flow (occurring around 2044-2046), while 27 other years in this scenario have less severe flows. Notable effects of the 3yr Min scenario were:

- Extreme low natural inflows occur for an extended period of time.
- Low flows cause the irrigation districts to have near constant senior licence "river calls,"[8] not on junior licences, but on TransAlta to release calculated natural flows.
- TransAlta storage is unable to refill during a river call and thus eventually drains and cannot refill for an extended period.
- With TransAlta storage empty and low natural inflows, Calgary flows fall below 1,250 cfs.

The 3yr Min scenario is the most severe climate scenario of the five examined and was regarded as the worst reasonably likely scenario, thus enabling a rigorous test of potential adaptation strategies.

In general, total water flows are higher under the climate change scenarios, but more extremes are forecast (that is, more high and low flow periods), with fewer years of "average" streamflow. Although most of the time flows will be "average" or non-problematic from a management perspective, there are likely to be more periods with higher flood levels, and longer and more pronounced drought periods, both of which can create significant negative outcomes unless the region is prepared to respond and adapt to those conditions. Based on average weekly natural flow for the 3yr Min scenario (2025-2054), the historical modelling record (1928-1995), and the 2000-2001 low flow years in the Bow, the 3yr Min scenario is only 60% of the historical average and 87% of the 2000-2001 natural flows. The 3yr Min scenario provides a forecast of potential low flows, including a 3-year low flow period that is lower than anything in the historical record. Figure 5 shows flows below Bassano for the lowest consecutive 3-year period from the historical record in the model data (1939-1941), compared to the lowest consecutive 3-year flow period from the 3yr Min scenario (2044-2046), and the 2-year average flow from the 2000-2001 historical record, which was not part of the modelling data. The low flows of 2000 and 2001 had an impact on users in the Bow Basin, and a 3-year low flow period as seen in the 3yr Min scenario (red line in Figure 5), would cause substantial water shortages for users in the basin.

[8] A river call is made when low river flows cause irrigation districts to exercise their more senior licence priorities vis-à-vis TransAlta reservoir release of water, or for junior licensees to cease diversions, although the latter has never happened.

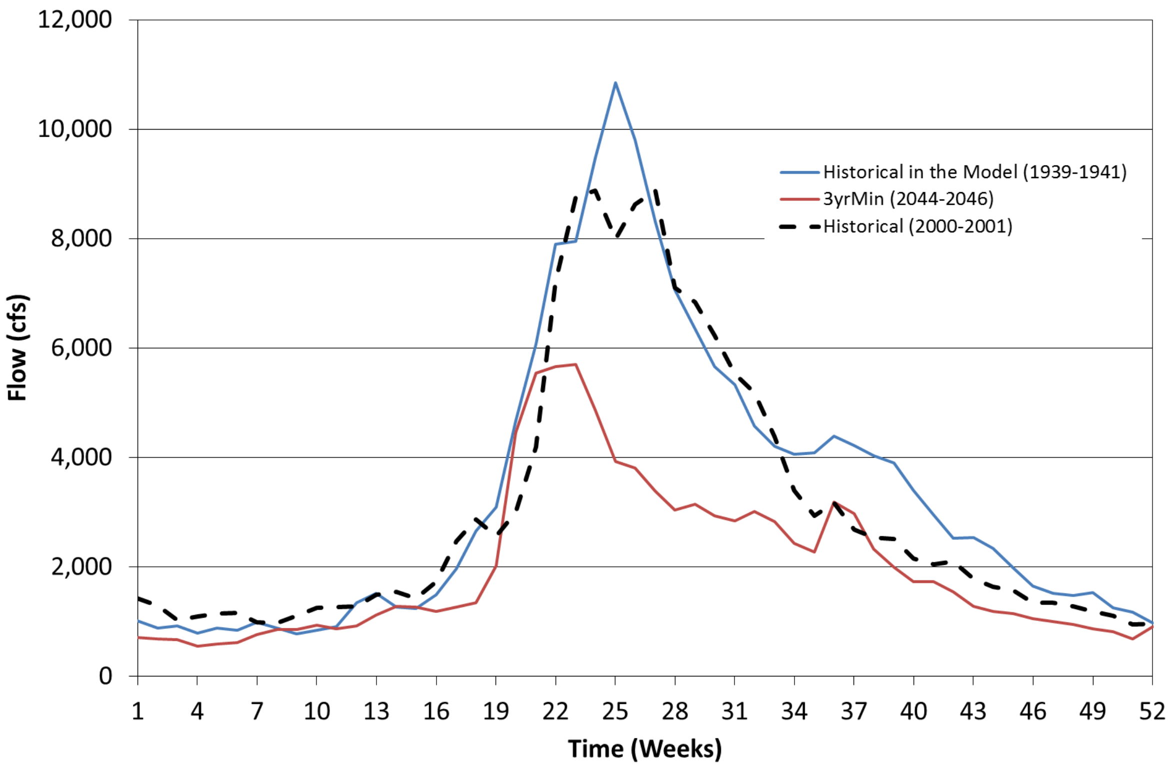

Figure 5: Weekly average flows below Bassano for the lowest 3-year flow period from the historical record in the model data (1939-1941), compared to the lowest consecutive 3-year flow period flows from the 3yr Min scenario (2044-2046), and the 2-year average flow from the 2000-2001 historical record (not in the model)

5.4 Adaptation Strategies for Present and Future Climates in the Bow Basin

Another objective of the SSRB Adaptation Project is to build robust adaptation options that would help southern Alberta adjust to climate variability and change, including potential periods of prolonged and severe drought. The strategies that were developed do not necessarily include every possible adaptation option, and the described approaches are potential alternatives that, in many cases, were suggested to address extreme circumstances. Other adaptation strategies that could not be modelled due to inadequate data, relate to groundwater storage, wetlands water retention, and greater reductions in consumptive water use. Many specific environmental impacts from some of the proposed strategies similarly could not be included due to the absence of additional data. These strategies are not being recommended or advocated; rather they are presented as a starting point for discussion and further consideration by those who use, manage and make decisions about water in the Bow Basin.

Throughout this work, performance measures were developed and used to assess and demonstrate the impact and benefits of changes made in the BROM. Performance measures focused on impacts to the river and aquatic ecosystem health as well as impacts to water users.

Six common measures were examined for all the individual strategies that were modelled; these are listed here and described in more detail in the adaptation strategies report:[9]

- TransAlta System Low Storage Days
- Calgary Low Flow Days
- Bassano Flow
- Carseland Flow
- Shortage Days
- Shortage Volume

During the two-day interactive modelling session, participants used the BROM to test potential climate adaptation strategies under a range of climate scenarios, finally focusing on the 3yr Min scenario as noted above. The Preferred Scenario for re-managing the Bow River, recommended by the BRP, included a virtual water bank and stabilization of Lower Kananaskis Lake (LKL). The Preferred Scenario is an important component of the strategies that were developed; it was refined for the purpose of this work by adding a trigger to enable more flexibility of use under extreme conditions. It is also important to note that the modelling findings are conservative because irrigation district demands were not increased in the dry years of the chosen scenario. A stress test using a 50% increase in irrigation demand showed an increase in low flow days below Bassano of only 7% and only five new very low flow days though Calgary throughout the 10,950 day simulation period. Thus the conservative assumptions of demand did not significantly affect the conclusions of this work.

Participants identified seven strategies that could benefit the watershed and improve overall river management outcomes if they were implemented now. These strategies could improve aquatic ecosystem health while continuing to meet the social and economic needs and interests throughout the basin. They would build resilience and help the region adapt to the drier conditions that may occur under future climate scenarios. These “current” condition strategies focus on changing demands and water management practices rather than building new infrastructure.

Eight strategies emerged that may be less necessary under current conditions, but could be important components in adapting to a more severe future climate. Some of these would require changes in how water is managed, while others involve new infrastructure. These “drought” options, once in place, would also be expected to benefit the region when conditions change again to more closely match current and historic experience. Any new infrastructure and storage would need to be evaluated carefully, considering economic impacts, positive and negative environmental tradeoffs and effects on the land and landowners.

Recognizing that the Bow River Basin is a complex, dynamic system, it is expected that potential adaptation strategies would be implemented in combinations, reflecting the needs of the basin and the appropriate degree of risk management. To examine how adaptation strategies might be layered to produce cumulative and offsetting impacts, the project modelled six strategy combinations. These combinations range from modest cost, near term combinations that offer

[9] *South Saskatchewan River Basin Adaptation to Climate Variability Project: Adaptation Strategies for Present and Future Climates in the Bow Basin*. May 2013.

value under current conditions, to higher investment, longer term combinations that might be considered if the risk profile of climate variability warrants more substantial change in the system.

The fifteen individual and six combination strategies are listed below.

Strategies to benefit the watershed under ordinary historic conditions

N1. Implement preferred scenario with trigger
N2. Adjust fill times for three largest TransAlta reservoirs (Minnewanka, Spray and Upper Kananaskis)
N3. Reduce seasonal consumptive demand in Calgary
N4. Implement seasonal consumptive reuse in Calgary
N5. Move municipal licences from Highwood/Sheep system to Bow River
N6. Increase winter carryover in Travers Reservoir
N7. Implement additional demand reduction in Irrigation Districts

Strategies for adapting to severe drought conditions

D1. Restore Spray Reservoir to full design capacity
D2. Draw Ghost Reservoir down preferentially to 6.6 feet (2 metres) below normal pattern
D3. Reduce minimum river flow through Calgary
D4. Increase off-stream storage in the WID (Bruce Lake)
D5. Manage return flows from WID through Crowfoot Reservoir
D6. Increase Little Bow/Travers storage capacity
D7. Increase on-stream storage downstream of Bassano (Eyremore Reservoir)
D8. Operate ID reservoirs to protect Junior licences

Combined Strategies

C1. Preferred scenario (water bank + stabilized LKL) + reduce minimum flow through Calgary (from Oct to Dec, with low storage trigger)
C2. Preferred scenario (water bank + stabilized LKL) + adjust fill times for three largest TransAlta reservoirs + increase winter carryover in Travers Reservoir
C3. Preferred scenario (water bank + stabilized LKL) + move municipal licences from Highwood/Sheep system to Bow River + implement additional demand reduction measures in Calgary and in irrigation districts
C4. Preferred scenario (water bank + stabilized LKL) + adjust fill times for three largest TransAlta reservoirs + increase winter carryover in Travers Reservoir + increase off-stream storage in the WID (Bruce Lake)
C5. Combination 4 + increase on-stream storage downstream of Bassano (Eyremore Reservoir)
C6. Stepwise combination for maximum drought adaptation

Of the fifteen individual strategies examined, several were regarded as having the most promise. Five were viewed as having the most promising benefits to the watershed under the “current” conditions that occurred over most years of the 30-year period for the chosen climate scenario.

They could be considered or implemented now and would also be valuable in building resilience and helping the basin adapt to more severe climate conditions should these conditions arise:

N1: Implement preferred scenario
N2: Adjust fill times for three largest TransAlta reservoirs (Minnewanka, Spray and Upper Kananaskis)
N5: Move municipal licences from Highwood/Sheep system to Bow River
N6: Increase winter carryover in Travers Reservoir
N3, N4, N7: Conservation and demand reduction

Three strategies were suggested as having the most promise for adapting to the most severe drought conditions that occurred over three years of the 30-year period for the chosen climate scenario. These “drought” options, once in place, would also be expected to benefit the region if and when conditions change again to more closely match current and historic experience.

D3: Reduce minimum river flow through Calgary
D4: Increase off-stream storage in the WID (Bruce Lake)
D7: Increase on-stream storage downstream of Bassano (Eyremore Reservoir)

Like the Bow River Project, the Phase II findings from this project provide a valuable and timely opportunity to implement environmental and integrated water management improvements that contribute to all three *Water for Life* goals. This project has identified options that would benefit the watershed now and into the future, and shows that water in southern Alberta could be managed collaboratively, innovatively and effectively in response to changing climate conditions.

6 Project Documentation

Four reports, including this one, have been published on Phase II work:

South Saskatchewan River Basin Adaptation to Climate Variability Project: Bow River Basin Integrated River Management Business Case. January 2013.

South Saskatchewan River Basin Adaptation to Climate Variability Project: Climate Variability and Change in the Bow River Basin. June 2013.

South Saskatchewan River Basin Adaptation to Climate Variability Project: Adaptation Strategies for Present and Future Climates in the Bow Basin. June 2013.

South Saskatchewan River Basin Adaptation to Climate Variability Project: Phase II: Bow Basin Summary Report. July 2013.

All reports, as well as the original Bow River Project reports, are available and may be freely downloaded from the Alberta WaterPortal website at www.albertawater.com. All BROM assumptions and input data will be described and documented in the publicly available electronic BROM files accessible through the University of Lethbridge servers, at http://www.uleth.ca/research/node/432/.

7 Next Steps

The findings from this project reflect important new ways of thinking about and planning for responses to climate variability and change in the Bow Basin. The strategies and outcomes are flexible and should be applied to each situation as appropriate. They are offered as starting points that can serve to stimulate enhancements and new approaches. As data are developed, additional risk management strategies can be modelled using the publicly available model.

Results will be shared with audiences that have an interest in the Bow Basin or in potentially designing a similar project for their region. Presentations were made to the Bow River Basin Council and the Canadian Water Summit in June 2013. Members of the project team are available to present this work to participant organizations and other forums as appropriate.

Continuing with a collaborative approach to implementation, the project team plans to work with Alberta Environment and Sustainable Resource Development and others in the SSRB to find ways to implement project results into policy and operational decisions. Work will also continue with licence holders and others in the region to effect changes within the existing regulatory framework. Project participants and others are also interested in seeing the Preferred Scenario implemented on a prototype basis through the negotiations now underway between TransAlta and the Government of Alberta.

Having identified some promising strategies for responding to climate variability and change in the Bow Basin, it would be prudent to undertake further study and analysis to look at these in more detail. Some initial analysis could be done at relatively low cost, such as gaining a better understanding of the benefits of specific forms of demand management. More extensive assessment of the socio-economic and environmental costs and benefits is also needed. Phase III of the current SSRB project will see the collaborative modelling work expanded to include the Oldman and South Saskatchewan systems. Later in 2013, work will start on the Red Deer Basin, thereby completing the SSRB. Land use considerations will be built into the work as the models and collaborative processes for the entire SSRB are integrated and explored together.

Since the collaborative work in the Bow Basin began in 2010, water users and managers have implemented changes to benefit the watershed while still meeting the needs of water users; one example is changes to the headworks in the Bow River Irrigation District to reduce their minimum flow-through requirement from 500 cfs to 300 cfs. As innovative possibilities emerge, other positive changes are expected to occur.

8 A Message from the Project Team

Water has been the lifeblood of southern Alberta since the region was settled, enabling the establishment of communities and diverse economic development to the benefit of the region and the province as a whole. Water management in southern Alberta will become increasingly critical in the face of existing and future pressures – population growth, economic expansion, competition for finite and shared resources and, not least of all, ongoing climate variability and change. The challenge will be to anticipate and respond to these pressures while retaining the features that enhance the region's quality of life and define its character.

The SSRB Adaptation Project brought together highly experienced and knowledgeable individuals who are intimately familiar with the Bow Basin. This integrated and collegial process enabled people to work collaboratively and creatively, drawing on the expertise and insights of each participant to explore practical options for adapting to climate variability and change. Fundamental to the outcome was the use of a trusted set of performance measures, data and tools that reflected the transparent input and contributions from participants. Because of this project and the work that preceded it, there is now a much better, and more integrated, understanding of the Bow River system. The collaborative work in the Bow Basin has substantially enhanced our knowledge and understanding about:

- How the system is actually managed and operated by its water managers, as compared with how water is allocated based on licence priority.
- The major issues and concerns that water managers, stakeholders and other interested parties watch for throughout the system (reflected in this work as the key performance measures).
- How streamflow might vary in the future due to climate variability and change, and what impact the changes in streamflow could have throughout the river system (as reflected in the development of climate scenarios).
- Suggested strategies that should be implemented now, under current conditions, to benefit environmental conditions in the watershed and improve overall river management – the "no regrets options." These include first, the two key components of the Preferred Scenario: the water bank consisting of storage to be used primarily for environmental purposes, and flexible stabilization of Lower Kananaskis Lake and Kananaskis River. And second, adjusting the current reservoir filling schedules for major TransAlta reservoirs to match forecast conditions, and reducing water demands.
- Suggested strategies that should be further studied so they could be implemented if the risk of severe or prolonged drought warrants; these include reducing minimum flow through Calgary, replacing diversions from the Sheep to the Bow, off-stream storage (e.g. Bruce Lake), and on-stream storage lower in the system (Eyremore Reservoir).
- If put in place, several of these strategies would also be expected to benefit the region during periods when conditions are similar to those of the last 70 years.

Given the complex and synergistic nature of the system and the many potential impacts of a changing climate, it is prudent to consider how possible strategies could be applied in combination. This project has done preliminary work on some combined strategies, but much more analysis is needed to refine these combinations and develop a reasonable and feasible approach for how they could be implemented. The Business Case analysis demonstrates that establishing a water bank for downstream use, and stabilizing Lower Kananaskis Lake (the

Preferred Scenario recommended by the Bow River Project) would be in the best interests of the diverse water users in the Bow River Basin. It provides many near-term benefits to the environment, recreational opportunities, and public assurance that water is being adequately managed by government. The Preferred Scenario is the logical starting point as a pilot project.

The Bow River Project was the first initiative to systematically assess, with a full range of stakeholders, the infrastructure that is in place throughout the Basin, how it is being managed, and the key performance requirements of the many users. It was also the first initiative to evaluate how the infrastructure could be managed differently and synergistically to improve environmental outcomes while maintaining and, in many cases, improving user access to their water allocations.

Personal and corporate memory, historic records and tree ring data all indicate that streamflow in the Bow System is highly variable from year to year. A severe or multi-year drought can begin at any time, and recorded historic flood flows were much higher than anything in recent experience including the 2013 flood. Population growth in the Bow Basin and agricultural and other water demands have increased dramatically since the 1930s when the last prolonged drought and major flood occurred, so the consequences of the next one will affect many more users living in the watershed. Restrictions on residential development and economic growth due to lack of water availability are a constant in and around Calgary. Flood prone areas are likely to see further restrictions on development as the 2013 flood was the largest since 1932. Southern Alberta can clearly capitalize on the billions of dollars of investment in existing water management infrastructure through heightened collaboration and coordination in the decision-making process. Looking to the future, the status quo will no longer serve our present water requirements, let alone our future needs under changing climate, population and economic conditions.

The considerable body of knowledge and insight established through this project and the BRP confirms that many timely and cost-effective actions could be taken now by parties who are key players in the basin to adapt to climate variability and change. Foremost among these are:

- TransAlta and the Government of Alberta should prototype the Preferred Scenario, quickly and on a cost recovery-only basis, to test the potential of what might be a long-term benefit to the watershed and to water users and managers throughout the basin.
- The Bow River Basin Council can play a leading role in communicating the potential strategies identified for the Bow Basin, to hear from basin residents, and begin to explore those strategies that appear most promising.
- The ESRD policy group can use the project's findings to inform their policy direction and address the Bow challenges raised by Albertans in the recent water conversations hosted by the Government.
- Licence holders can look for opportunities to implement changes within their licence parameters and within the existing regulatory framework.

There is real value in the concept of learning by doing. By pilot testing an altered streamflow regime in the Bow, and flexibly implementing and collaboratively testing components of the Preferred Scenario, water managers should be able to better anticipate and mitigate the consequences of the next drought or flood. Alberta has largely been successful in responding to water shortage crisis situations, but such responses do not consider the need for more comprehensive changes to build resilience and adaptive capacity against future challenges. There is substantial benefit to be gained by moving from testing alternative water management decisions in a virtual world (with the models developed in this project) to the real world while not operating in the midst of a crisis event. Another reason to pilot a more flexible water management system now is to support and test innovative solutions to sensitive environmental issues within the Bow System under current conditions. For example, low concentrations of dissolved oxygen in the reach below Bearspaw Dam and through Calgary may be improved by increasing streamflow for brief periods of known high risk. Environmental restrictions on withdrawals from the Sheep River may be relieved by alternative licensing arrangements and using water from the Bow River to supplement water users in the region. Populations of Bull Trout and Westslope Cutthroat Trout, both threatened species, may be enhanced by stabilizing Lower Kananaskis Lake.

These and many other innovations could be tested through a pilot project to confirm the scope of new arrangements between the Government of Alberta and TransAlta and other water managers in the basin. Such an agreement would lay the foundation for new perspectives on how best to manage the river system. The original Bow River Project uncovered many environmental improvements that could be made to the river system under nearly all conditions. This project examined actions that are more appropriate for the occasional but recurring extreme conditions.

More than one-third of Alberta's population lives in the Bow Basin. If, as a society, we want to ensure that access to water is not an unavoidable barrier to meeting future population and economic needs while better protecting critical environmental outcomes, then we need to take action when not operating in "crisis mode." Alberta has a history of successfully meeting sustainability challenges through multi-sector collaboration and engagement and this project further enhances that legacy. The activities undertaken as part of this project are just the beginning. Such efforts should be incorporated into the way the Bow Basin is managed as part of business as usual, and not just when a drought or flood emergency is declared.

Given the collective experience with this initiative it appears that the time is right, high expectations exist within the water community and the opportunities for improved decision making and outcomes are real. Working together, engaged and committed stakeholders have created strong momentum and a sense of shared future. They identified practical and implementable solutions to improve resilience and adapt to current and future water management challenges. Alberta continues to benefit from the commitment and involvement of the water community; now is the time to move from "talk" to "walk." The first step on that journey is to reach an agreement between the Provincial Government and TransAlta to pilot test some of the many environmental improvements and risk management benefits demonstrated by the original Bow River Project and confirmed by this collaborative work on Adaptation to Climate Variability.

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Glossary and Acronyms

(A)ESRD ~ (Alberta) Environment and Sustainable Resource Development

BROM ~ Bow River Operational Model

BRP ~ Bow River Project

Base Case ~ The Base Case is used to indicate no change from the current Bow River Basin water management methods and capabilities (referring to the Business Case)

CDF ~ Cumulative Distribution Function

Cfs ~ Cubic feet per second

Cost ~ For the purpose of the Business Case, *cost* generally "incorporates the procurement price and includes water-related operating costs such as: treatment, mitigation of water pollution, expansion of available water supplies, [and] charges imposed by suppliers."[10] This broad scope is occasionally reduced to refer more specifically to infrastructure-related capital costs.

GCM ~ Global Climate Model

In-stream Flow ~ The rate of flow in a river, without reference to its purpose.

Preferred Scenario ~ Scenario 3 in the *Bow River Project Final Report*, which sees the stabilization of Lower Kananaskis Lake and Kananaskis River, and a water bank of 60,000 AF.

LKL ~ Lower Kananaskis Lake

PARC ~ Prairie Adaptation Research Collaborative

PDO ~ Pacific Decadal Oscillation

River Basin ~ An area of land drained by a river and its associated streams or tributaries.

SSRB ~ South Saskatchewan River Basin. The South Saskatchewan River Basin includes the sub-basins of the Red Deer River, Bow River, and Oldman River (including the South Saskatchewan).

Watershed ~ An area of land that catches precipitation and drains into a body of water, such as a marsh, stream, river or lake.

WID ~ Western Irrigation District

WRMM ~ Water Resources Management Model

[10] World Business Council for Sustainable Development, "Water Valuation: Building the Business Case." http://www.wbcsd.org/Pages/EDocument/EDocumentDetails.aspx?ID=15099&NoSearchContextKey=true [Accessed: 12 November 2012]: 14.

Appendix A: SSRB Adaptation Project Introduction Memo

South Saskatchewan River Basin Adaptation to Climate Variability Project
May 2012

A new project being launched this spring will harness the energy and creativity of southern Albertans to explore practical options for adapting to climate variability and change. Water is fundamental to community sustainability and growth, and the way water is managed in the South Saskatchewan River Basin (SSRB) will become even more important in the face of changing weather patterns and climate.

In January 2012, the Climate Change Emissions Management Corporation awarded funding for the *SSRB Adaptation to Climate Variability Project*. The funds were provided to Alberta Innovates-Energy Environment Solutions and WaterSMART Solutions Ltd. to support the first stage of this adaptation work.

This initiative will build on and integrate existing data, tools, capacity and knowledge of water users and decision makers to improve understanding and explore how to manage for the range of potential impacts of climate variability throughout the SSRB's river systems. This understanding will support collaborative testing and development of practical and implementable adaptive responses to climate variability, from the local community scale to the provincial scale. Using existing analytical and decision-support tools, the project will engage many people and groups to build:

- a common understanding of feasible and practical mechanisms for adapting to climate variability and change, and
- increased capacity for an informed, collaborative and adaptive approach to water resource management throughout the SSRB. This will enable organizations, communities and individuals to assess their risks in near real-time and determine their most suitable responses to climate variability within the physical realities of SSRB river flows, requirements and infrastructure.

The first stage of the project is divided into four coordinated phase:

Foundational Blocks: Initial Assessment

The first phase of the work is an initial assessment of the data, tools, capabilities, processes and frameworks that already exist and could form elements of the foundational blocks to support integrated water management by water users, decision makers and other interested parties over the long term. This work will identify the core resources for the project, identify critical gaps to be addressed, and ensure existing knowledge, tools, and experiences are leveraged, while avoiding duplication of work already completed or underway.

Bow River Basin: Adaptation and Live Test Year

The second phase will re-engage Bow River Project participants and engage new participants with an interest in the Bow River Basin to: advance climate adaptation decision making related to water resources, explore climate variability scenarios, identify impacts and risks to the river system and its users, and identify adaptation options. Participants will also document the net benefits of re-managing flows in the Bow River and identify infrastructure options that could assist with adaptation strategies. All of this work will provide support for a 'virtual' river test year, or perhaps an actual test year of modified flow, to better match the three Water for Life goals

Oldman River Basin and South Saskatchewan River Modelling

In the third phase, participants will model the Oldman River Basin (Oldman River and Southern Tributaries, including the Belly, St. Mary and Waterton Rivers), and the South Saskatchewan River to the Alberta border. Users, decision makers and others in the Oldman and South Saskatchewan River (OSSK) Basins will form a river consortium and set principles to guide and inform the model-based work, incorporating an environmental and climate adaptation focus. A comprehensive river system model for the OSSK Basins will be developed. Inputs to the SSRB from the Milk River will be part of this data, but the Milk will not be explicitly modelled. Throughout the model building, participants will discuss work that has been or is being done, and possible next steps in building the capability and capacity for adaptation around river management in the SSRB.

Foundational Blocks: Development

The final phase will see development of new adaptation foundational blocks. This work will be based on the gaps identified in the initial assessment, which may include acquiring, updating, or purchasing useful data and tools for future work to develop adaptation options for integrated river management.

This project will take approximately two years to complete. It should significantly advance climate adaptation resilience in the SSRB, leave a legacy of data, information and tools, and inform similar future work throughout the rest of the SSRB. We hope, with subsequent support, to then expand the work to encourage climate adaptation throughout the entire SSRB.

Project updates and reports can be accessed through the Alberta WaterPortal at: www.albertawater.com

If you have any specific questions regarding this work, please contact AI-EES or WaterSMART Solutions Ltd.

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Appendix B: Project Participants

Organization	Representative(s)
Alberta Agriculture and Rural Development	Andrea Gonzalez Bob Riewe
Alberta Environment & Sustainable Resource Development	Allan Locke Andrew Paul Andy Ridge Anil Gupta Dave McGee Derek Lovlin Jim Stelfox Michael Seneka Satvinder Mangat Zahidul Islam
Alberta Innovates – Energy and Environment Solutions	David Hill Jon Sweetman
Alberta Tourism, Parks and Recreation	Joey Young
Bow River Basin Council	Mark Bennett Mike Murray
Bow River Irrigation District	Richard Phillips
Calgary Regional Partnership	Bob Miller Darrell Burgess
City of Calgary	Edith Phillips John Jagorinec Margaret Beeston
Eastern Irrigation District	Earl Wilson
Highwood Management Plan – Public Advisory Committee	Shirley Pickering
Kananaskis Improvement District	Arnold Hoffman
Municipal District of Bighorn	Erik Butters
Rocky View County	Jorie McKenzie
SEAWA - South East Alberta Watershed Alliance	Bob Phillips
TransAlta	Lora Brenan Roger Drury
Trout Unlimited Canada	Brian Meagher
Western Irrigation District	Erwin Braun
Alberta WaterSMART	Megan Van Ham Mike Kelly Mike Nemeth
HydroLogics Inc.	Dan Sheer A. Mike Sheer
Prairie Adaptation Research Collaborative	Dave Sauchyn Jeannine St. Jacques

Appendix C: Project Vision, Principles, Goals and Benefits

Vision Statement

The Bow River System will be managed as an integrated ecosystem, from headwaters and tributaries to confluence, with due consideration given for the growth and change of the key users and purposes along its course. As part of the management system, there will be open and readily available interactive, fit-for-purpose models. These models will be capable of providing information for decision-makers to assess implications of, respond to, and mitigate a wide array of weather patterns and climate variability.

Project Principles

1. Causing no significant, measurable environmental harm
2. Assuming Bow River basin remains closed to new licenses
3. Respecting TransAlta's reputation as an environmentally responsible and proactive corporation (fix problems not blame)
4. Not proposing TransAlta bear the cost of providing benefits to others
5. Meeting Alberta's annual apportionment commitments to Saskatchewan
6. Maintaining minimum flow requirements for municipalities
7. Supporting the long term population/economic growth forecasts
8. Meeting Siksika First Nation's needs
9. Respecting Alberta's water priority system (FITFIR)
10. Achieving Alberta's policy goals in Water for Life Strategy

Project Goals

- Develop a common understanding of river flow and the timing and uses of water by each large senior license holder and other key water users, including essential environmental processes.
- Agree upon the available data sets to be applied and computer model(s) to be used for purposes of this assessment of potential long-term climate variability effects, and practical measures for adaptation and mitigation of these effects.
- Select existing climate models and develop scenarios to be used as initial examples of realistic potential climate variability challenges for the Bow River System.
- Evaluate regional implications for water supply and timing under historic and calculated prehistoric conditions as well as forecast changes in climatological conditions.
- Use the agreed upon data and modeled scenarios to develop water demand and management responses. Options modeled would include altering on- and off-stream storage, flow rate timing, and water demand and uses to determine an optimal river system management regime under a variety of short and long term changes to weather patterns and climate.
- Based on the modeling results, assess water management alternatives and infrastructure changes to protect the basic aquatic ecosystem while better accommodating the interests of the many water uses along each reach under the modeled climate change scenarios.
- Determine within reasonable ranges the costs and benefits to existing water users and/or to other users to create the infrastructure, management, and commercial mechanisms necessary to implement the practical agreed upon scenarios.

- Prepare a Business Case document identifying and quantifying, to the extent practical, the monetary value of implementing the recommended scenario. Where monetary value is impractical to calculate, identify and recognize other values that may be realized.
- Communicate these scenarios and operating regimes effectively to municipal and provincial governments for their purposes.
- Develop a process for maintaining, updating and using the models to manage and prioritize the changes needed to adapt to climate variability, and support implementation of the recommended operational changes, while providing for on-going monitoring and management functions.
- Support to the extent practical, a live test year to determine the feasibility and benefits from managing the Bow River System on behalf of the key users as described in the Preferred Scenario in the BRP report. An alternative would be to conduct a "virtual" test year operating the Bow System normally, while modeling in parallel the operations of the Bow System in accordance with the collaborative decisions of the BRP participants in accordance with the Preferred Scenario.

Note: In addition to river operations and infrastructure, there are a broad set of socioeconomic, cultural and attitude issues related to water use and adapting to climate variability. The adaptation discussions and strategies developed in this project will endeavor to identify and consider as many related issues as possible, but will not have the time nor scope to address them all thoroughly.

Expected Benefits

- Improved data, knowledge, and management information supporting integrated river management and adaptation in the Bow basin
- Capacity to model the effects of a variety of weather pattern and climatological changes
- Capacity to model an array of adaptation responses to variable climate conditions including infrastructure, timing of flow, demand changes, management decisions, and other adaptation mechanisms
- Improved assurance of water for human use under variable climate and demand forecasts
- Improved aquatic ecosystems and recreational opportunities in certain reaches
- Identification of options to evaluate and reduce risk to high value users from drought
- Identification of options to protect from moderate flood events while enabling periodic high flows for riparian and littoral health
- Creation of a foundational piece for further socioeconomic and cultural discussion related to adaptation and river management