

Climate Vulnerability and Sustainable Water Management in the South Saskatchewan River Basin

Final Report

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Executive Summary

Alberta faces important water challenges including a growing economy, expanding population, and the increasing impact of this growth on the environment as weather and climate patterns shift. The recent experience of both floods and droughts has made climate variability a reality for residents in the South Saskatchewan River Basin (SSRB). Growth in southern Alberta in the face of fluctuating water supply underscores the need for adaptive management of this crucial resource. The global effort to mitigate climate change must be paralleled with an equal local effort on adaptation in Alberta to reduce the risks to water resources that will come as a result of climate change. An adaptive management approach aims to develop resilient and adaptive capacity to respond to a wide range of different situations by exploring what we can do with today's infrastructure and management and then look at what else could be done now and into the future. It also aims to raise social awareness of potential flood and drought risks in support of efforts to get appropriate water management arrangements in place now.

Watershed management and climate adaptation issues are complex and cannot be appropriately addressed by any single initiative or sector, making collaboration essential. Since 2010, a series of initiatives has brought together water managers and knowledgeable water users in each of the SSRB sub-basins to explore potential adaptation approaches. Building on these prior modelling collaborations, this project integrated the sub-basin models into one comprehensive model for the entire SSRB. A number of adaptation strategies were developed for each sub-basin and where data were available strategies were modelled and assessed using the South Saskatchewan River Operational Model (SSROM). The SSROM is a comprehensive, daily, mass balance river model that enabled the collaborative working groups to compare individual strategies and evaluate the net benefits of combinations of strategies across the full basin. Strategies were sorted into three Levels that reflect degrees of adaptation:

- Level 1: Strategies that could be implemented now to adapt to current flows and conditions
- Level 2: Strategies that would add another level of resilience to the basin
- Level 3: Strategies that would make the basin more resilient to climatic changes

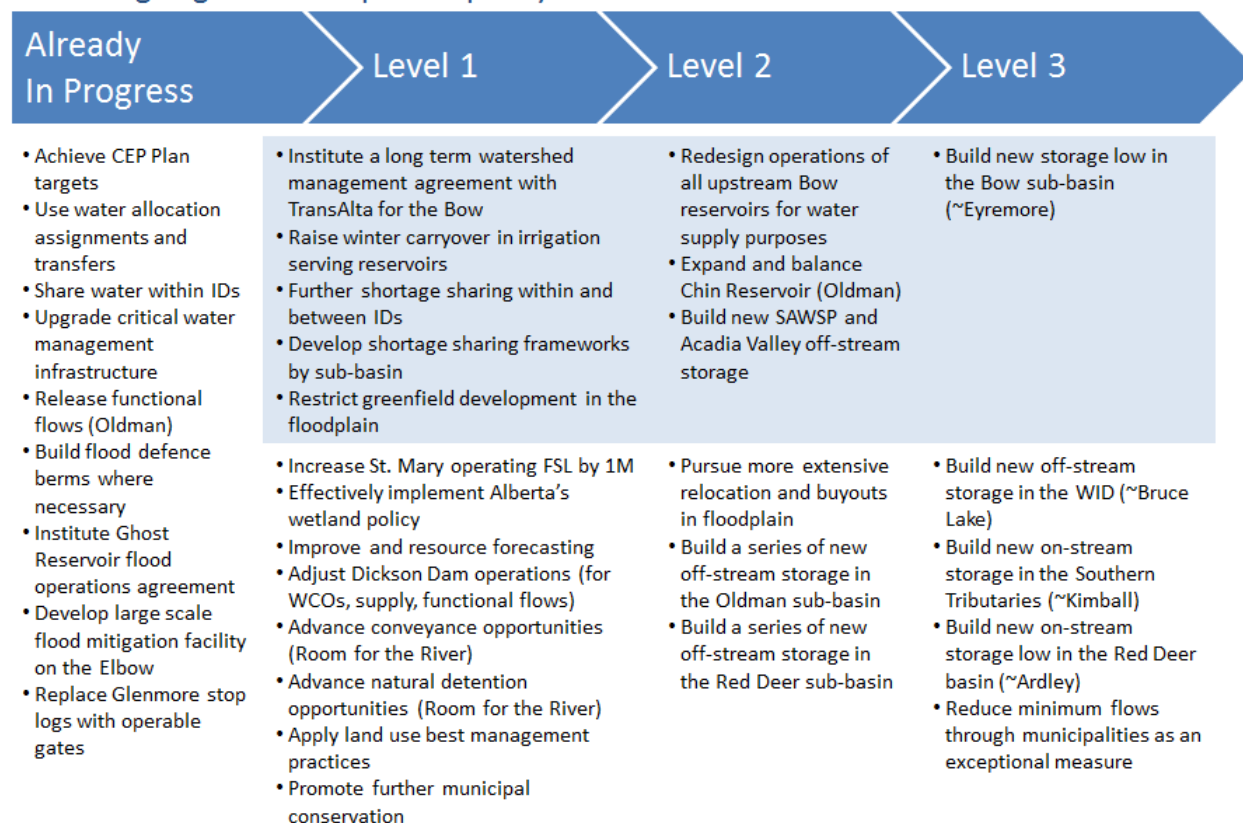
Based on the modelling results, some strategies within each Level were further categorized as “most promising.” Firm criteria were not established or used to identify “most promising” strategies; however, considerations of relative simplicity, cost, impact and contribution to resilience were typically used to distinguish these from other strategies within and between Levels. The detailed results are presented in section 3 of this report.

This report puts forward the Adaptation Roadmap for Sustainable Water Management in the SSRB, based on previous and current collaborative efforts. The Roadmap recognizes the adaptation strategies already being implemented as well as the three Levels of adaptation strategies.

This executive summary briefly describes the benefits and implementation opportunities for each strategy in the Roadmap.

SSRB Adaptation Roadmap

Increasing degrees of adaptive capacity →

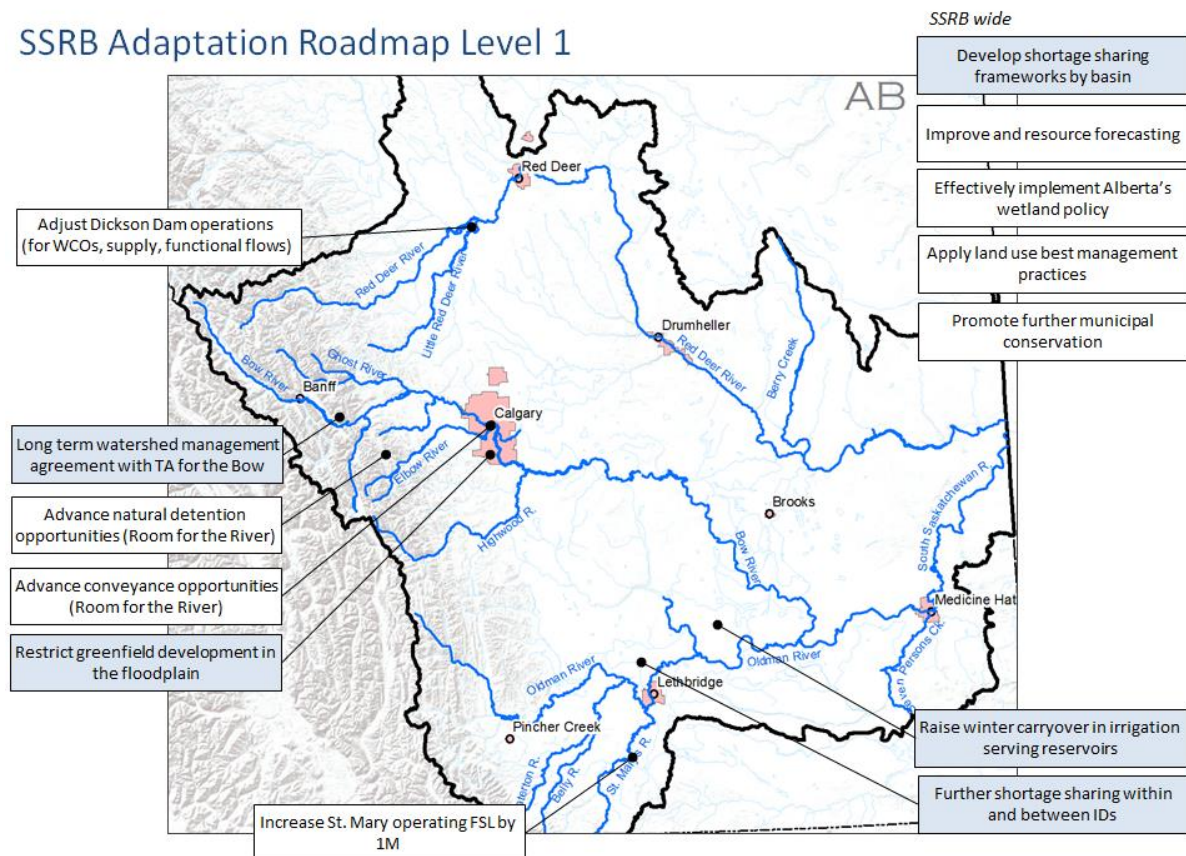


Blue highlights the most promising strategies within a level

Acronyms used in this figure are defined on page x.

The intention is not that all Level 1 strategies would be implemented immediately or all at once; rather, Level 1 identifies strategies that should be considered before moving to Level 2. Level 2 and 3 strategies could be further explored and implemented when the water supply and demand balance in the basin warrants it.

SSRB Adaptation Roadmap Level 1



In the map above, strategies in the blue boxes were viewed as “most promising.”

Institute a long-term, flexible and comprehensive water management agreement with TransAlta to use part of the existing reservoirs in the upper Bow to meet the environmental needs of a closed basin and provide extreme flood and drought mitigation, while still creating hydropower. This requires a negotiated agreement with TransAlta, fair compensation for lost revenue, a basin-driven governance model, and robust forecasting support.

Raise winter carryover in existing irrigation-serving reservoirs, starting with Travers Reservoir in the Bow River Irrigation District, to increase water supply security for irrigators while leaving more flow in the river. This can be piloted in 2016 through a Government of Alberta (GoA) approval for Travers, and then extended to other reservoirs with appropriate study of shoreline erosion impacts and dam safety.

Implement further forecast-based shortage sharing within and between irrigation districts, when conditions and forecasts suggest a dry year, to optimize crop planting and irrigation decisions across a region. These temporary assignments and transfers of water rights or licences are enabled through the existing *Water Act* and should continue to be used by the irrigation districts in coordination with GoA, forecasters and other agencies.

Develop basin-wide shortage-sharing and reallocation frameworks for each of the SSRB sub-basins to inform and enable severe drought mitigation before emergency measures need to be triggered. Championed by GoA, the strategy and frameworks could potentially be developed in two years.

Restrict new greenfield development in the floodplains and develop strict regulations against changing the nature of brownfield developments to reduce disturbance of the floodplain and reduce flood damage. This requires policy leadership from Alberta Environment and Parks (AEP) with Alberta Municipal Affairs, as well as support and cooperation from municipalities in the floodplains.

Increase St. Mary Reservoir operating full supply level (FSL) by 1 metre to increase the usable storage capacity of an existing reservoir that is extremely well placed in the Oldman sub-basin, and which offers water supply benefits to irrigators and municipalities. This requires dam safety and shoreline studies prior to implementation, but could potentially be completed within 12 months.

Effectively implement Alberta's Wetland Policy to protect and restore the wetland functions of water retention, slowing release, and natural filtering. This depends on AEP's implementation plans, timelines, offset opportunities, and enforcement of the regulations.

Improve resourcing for and effectiveness of forecasting infrastructure, monitoring, modelling and communications systems and teams to anticipate, prepare for, and respond to extreme events across the SSRB in a consistent and coordinated manner.

Adjust Dickson Dam operations to consider downstream needs (retain the Red Deer River Water Conservation Objectives (WCOs), implement functional flows, meet some new demands) to maximize how the existing infrastructure can support the growth of the sub-basin before new infrastructure is required. These refinements could be adopted by the Dickson Dam operations team in AEP within three years.

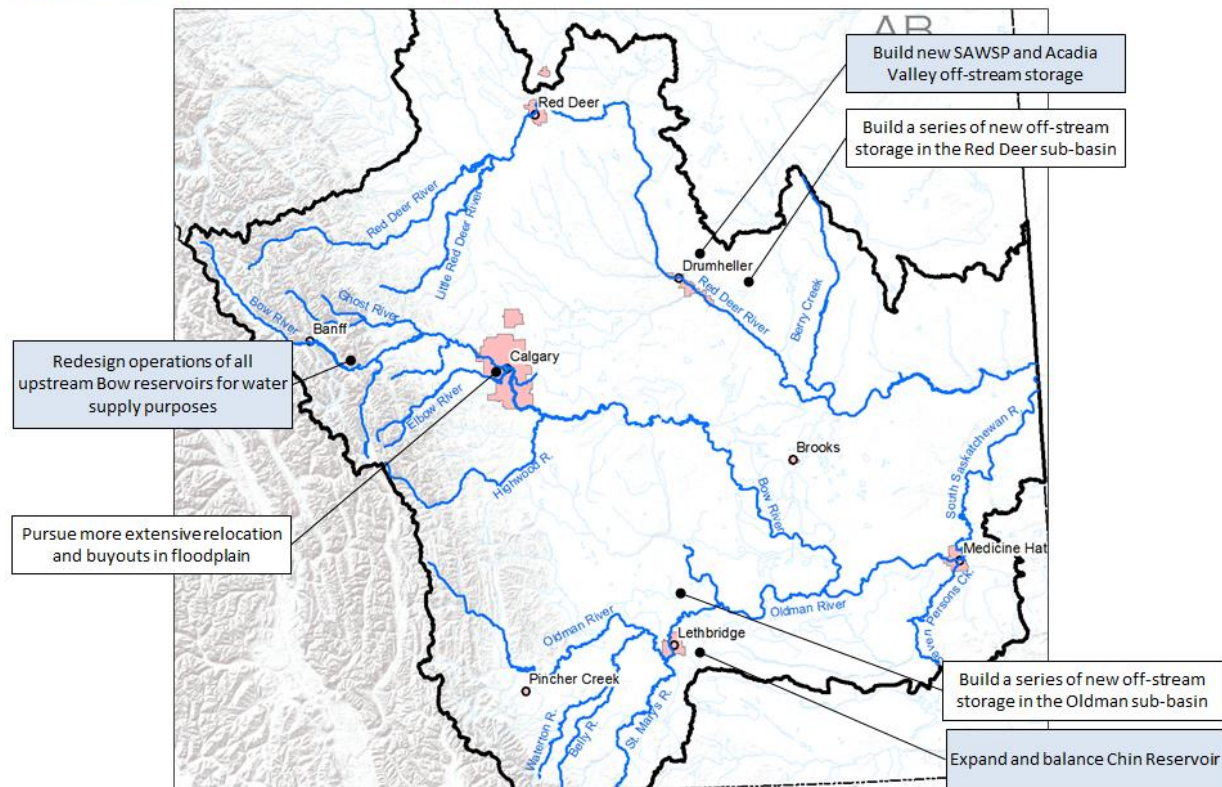
Advance Room for the River conveyance opportunities in the Bow and Red Deer sub-basins to identify and select practical projects that will alleviate constrictions on the rivers and allow greater flow to pass without flooding. This requires datasets already being compiled by AEP, AEP committing to initial high priority projects, and an approximate five-year collaborative process.

Advance Room for the River natural detention opportunities in the Bow and Red Deer sub-basins to identify and select restoration efforts that will hold high flows upstream in a flood event. This requires a commitment to AEP's Watershed Resiliency and Restoration Program and the continued support and work of Watershed Stewardship Groups.

Further apply land use best management practices to minimize impacts of land use changes on the water supply and demand balance of the region. This is currently championed through the South Saskatchewan Regional Plan Secretariat and the South Saskatchewan Regional Plan.

Promote further municipal conservation relative to today to maximize what treatment technology, stormwater management, residential use, and commercial use can contribute to the water balance in the basin, particularly in times of drought. This requires ongoing action from municipalities and industry groups as well as leadership from the Alberta Urban Municipalities Association and the Alberta Association of Municipal Districts and Counties.

SSRB Adaptation Roadmap Level 2



In the map above, strategies in the blue boxes were viewed as “most promising.”

Redesign operations and expand, where beneficial, existing reservoirs in the upstream Bow for water supply, drought and/or flood mitigation, and watershed health to change priorities toward highly valued public interest outcomes while maximizing hydro revenues as an important but, in some instances, secondary objective. This requires engaging key water users in a substantial negotiation between GoA and TransAlta, followed by operational support requiring a new governance and decision-making structure supported by advanced forecasting.

Expand and fully balance Chin Reservoir in the Oldman sub-basin to optimize the usefulness of an existing reservoir for providing irrigation water and to alleviate storage demands in other upstream reservoirs, thus keeping more water closer to the headwaters and available to support ecosystems and human water uses throughout the system. This requires a significant capital investment and a shift in operational priorities and control for a major irrigation district facility.

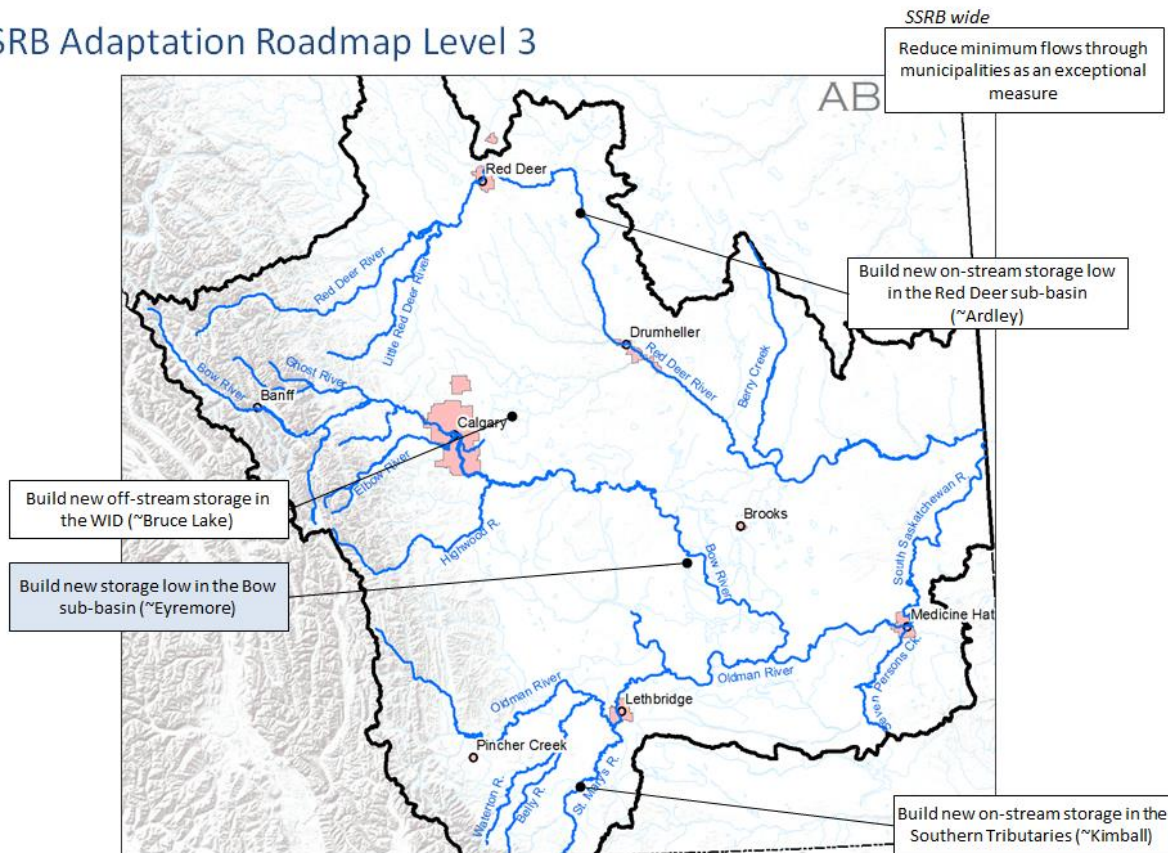
Build new off-stream storage in the Red Deer sub-basin as already proposed in the Special Areas Water Supply Project (SAWSP) and Acadia Valley Project to provide irrigation and municipal water supply to promote growth in regions currently not supported by water storage infrastructure. This project has been under consideration for at least 15 years and requires both approval and funding from GoA to proceed.

Pursue more extensive relocation and buyouts in the Bow and Elbow River floodplains to effectively and permanently mitigate flood damage and reduce the need for upstream mitigation structures. This requires strong policy leadership and funding from GoA in partnership with municipalities to successfully implement this costly shift that will have significant social impact on individuals and communities.

Build a series of new, small off-stream storage projects throughout the Oldman sub-basin as needed and where feasible to provide water supply for local demands and as a preferred solution over new on-stream infrastructure. This requires a program to enable selection and development of off-stream projects by local beneficiaries with some form of funding mechanism.

Build a series of new off-stream storage throughout the Red Deer sub-basin as needed and where feasible, in addition to the already noted SAWSP and Acadia Valley Projects, to provide water supply for further municipal, industrial and agricultural growth in the lower basin while still maintaining the environmental health of the watershed. As in the Oldman system, this requires a program to enable selection and development of off-stream projects by local beneficiaries with some form of funding mechanism. If further study demonstrates that off-stream storage sites would not be possible or effective, then a midstream facility on the Red Deer system should be moved from Level 3 to Level 2.

SSRB Adaptation Roadmap Level 3



In the map above, the strategy in the blue box was viewed as “most promising.”

Build a new on-stream reservoir low in the Bow system, potentially at the previously identified Eyremore site, to supplement Oldman River flows meeting the interprovincial apportionment agreements with Saskatchewan, accommodate some of the irrigation and environmental demands currently on upstream reservoirs in the Bow system, improve minimum flow rates in the downstream Bow, and offer flood mitigation to downstream communities. This new reservoir may also have hydropower potential. This would be a large infrastructure project requiring extensive engineering and environmental study and a large capital investment.

Build new off-stream storage in the Bow sub-basin, for example the Bruce Lake project already identified and proposed by the Western Irrigation District, to improve water supply security for irrigators and multiple other users in the region east of Calgary. This would require approvals and funding support from GoA.

Build new on-stream storage high in the Southern Tributaries of the Oldman sub-basin, potentially the previously identified Kimball site, and balance this new reservoir with the other reservoirs in the Oldman sub-basin to reduce water shortages for irrigation and municipal users and improve the ability of all reservoirs to maintain environmental flows. This would be a large infrastructure project requiring extensive engineering and environmental study and a large capital investment.

Build a new reservoir midstream in the Red Deer system, potentially at the previously identified Ardley site, to support and enable significant future growth in the sub-basin by providing water supply security for future licences and to offer flood mitigation to downstream communities. This would be a large infrastructure project requiring extensive engineering and environmental study and a large capital investment.

Reduce minimum flows through municipalities and other downstream users as an exceptional measure in drought years to temporarily slow the draining of upstream reservoirs thus ensuring some level of releases for water users and aquatic health over a longer period of time. This requires an accommodation in policy, operational flexibility, and careful application informed by advanced forecasting and science-based understanding of the aquatic impacts of severe low flows.

While discussing adaptation strategies and opportunities, a number of notable aspects related to basin dynamics in the SSRB emerged or were reinforced from prior work. They have a direct or indirect effect on water use and management in the basin. These dynamics are listed here and explained further in section 3.1:

- The observed flows from the United States in the St. Mary River have been considerably higher than the volumes to which Alberta is entitled.
- Apportionment requires ~50% of annual flow by volume be passed to Saskatchewan.
- Further reducing minimum flows could negatively affect aquatic ecosystems.
- The Eastern Irrigation District and Western Irrigation District return flows to the Red Deer River contribute significantly to meeting that system's WCOs during summertime low flow periods.
- Irrigation district expansion will continue to be enabled through improved conservation, efficiency and productivity, not through increased withdrawals from the rivers. This could mean that somewhat greater flow rates may occasionally be needed from Dickson Dam to meet summer WCOs, given lower irrigation return flows from the Bow to the Red Deer.
- Building new water management infrastructure should build adaptive capacity; it should not lead to new licence allocations in closed basins.
- Connections among sub-basins mean that building new infrastructure in one sub-basin could yield benefits in another.
- Operations of TransAlta reservoirs on the Bow interact with many of the other potential adaptation strategies for this river system.
- The forecasting window in the SSRB is extremely short; investment in forecasting resources and systems are imperative for ongoing adaptation.
- The uncertain length of a drought makes it challenging to develop management responses.
- Flood mitigation and drought mitigation can be achieved in the same season, but not at the same time using the same infrastructure capacity. Flexibility and responsiveness to changing conditions are essential.

The work resulting in this report was recognized as a screening level study, after which most strategies would require more detailed study (e.g., project based cost-benefit analysis, engineering feasibility studies, environmental impact assessments, socio-economic analysis, consideration of impacts on landowners and First Nations). It was recognized that the trade-offs between the strategies were partially represented in the models and well-represented in the expertise and experience of working

group participants. The best available information was compiled and provided a solid reflection of the operations of the sub-basins both today and into the future. Although the strategies and text in this report use the term “build” with reference to infrastructure, this should not be interpreted as a recommendation or advice to immediately construct that infrastructure; no construction would be started before local consultations and detailed, site-specific studies are undertaken.

Throughout the collaborative work since 2010, a short set of messages has been repeatedly reinforced:

- Activity already underway to develop and promote a market system for temporarily trading or assigning water within irrigation districts and between licensees should continue to be supported. Licence transfers and trades to optimize use of existing licences is a way to manage water shortages, but people need to understand what their options are and how to take advantage of those options.
- The Bow River has a real and immediate need for a water bank that reserves approximately 10% of the annual storage and flows within TransAlta’s reservoirs for release in accordance with downstream needs, including improving environmental flows during low flow periods while minimizing shortages to junior and senior licence holders. Establishing a mechanism for managing the water bank for flood and drought should be a high priority. This should be part of a broad watershed agreement between the GoA and TransAlta that includes the elements described in the pertinent Level 1 strategy of the Adaptation Roadmap.
- Each sub-basin needs a framework, beyond what is available today, for sharing shortages. Such frameworks should be developed soon, during “normal” conditions so that they are ready to implement by the time the next drought crisis arrives. Work is needed to determine what components such a framework should have and who needs to be part of it.
- Building on what is already being done, there are a number of practical and immediate actions that can be taken by watershed groups, irrigation districts, municipalities and others in coordination with the Province to expand the adaptive capacity of the SSRB using the infrastructure, regulations and policy in place today. These proactive efforts, for example piloting a higher winter carryover in Travers Reservoir, assessing the dam safety impact of a higher operating FSL on St. Mary Reservoir, and modelling the hydraulic impacts of Room for the River conveyance opportunities along the Bow River, are each important steps in either implementing adaptation or preparing for implementation as warranted by the conditions in the basin.

Adaptive water management will involve implementing and regularly revisiting the Roadmap as this dynamic river basin continues to change and demands grow. To build resilience and sustainability in the face of climatic and environmental change and increased growth, a layered approach will be needed, as no single solution can meet every need. The Roadmap provides a solid foundation on which to determine, refine and implement appropriate actions; adapt the plans; and invest in the science needed to better prepare the SSRB’s water management system to respond when new demands and challenges arise.

Acronyms and Abbreviations

| | |
|-------------------|---|
| ~ | Approximately |
| AAF | Alberta Agriculture and Forestry |
| AEP | Alberta Environment and Parks |
| AI-EES | Alberta Innovates – Energy and Environment Solutions |
| ALCES | A Landscape Cumulative Effects Simulator |
| AAMDC | Alberta Association of Municipal Districts & Counties |
| AUMA | Alberta Urban Municipalities Association |
| BMP | Best Management Practice |
| BRID | Bow River Irrigation District |
| BROM | Bow River Operational Model |
| cfs | cubic feet per second |
| dam ³ | cubic decametre (1,000 cubic metres or 0.81 of an acre foot) |
| CEP | (Water) Conservation, Efficiency and Productivity |
| EID | Eastern Irrigation District |
| ESRD | (Alberta) Environment and Sustainable Resource Development |
| FSL | Full Supply Level |
| GoA | Government of Alberta |
| IDM | Irrigation Demand Model |
| IJC | International Joint Commission |
| IO | Instream Objective |
| m ³ /s | cubic metres per second (also written as cms; 1 m ³ /s = 35.3 cubic feet per second) |
| OASIS | Operational Analysis and Simulation of Integrated Systems |
| OHV | Off-highway vehicle |
| OSSK | Oldman and South Saskatchewan (sub-basin) |
| OSSROM | Oldman and South Saskatchewan River Operational Model |
| PM | Performance Measure |
| RDRM | Red Deer River Operational Model |
| RDRWA | Red Deer River Watershed Alliance |
| SAWSP | Special Areas Water Supply Project |
| SMRID | St Mary River Irrigation District |
| SSRB | South Saskatchewan River Basin |
| SSROM | South Saskatchewan River Operational Model |
| US | United States |
| WCO | Water Conservation Objective |
| WID | Western Irrigation District |
| WPAC | Watershed Planning and Advisory Council |
| WRMM | Water Resources Management Model |
| WSRP | Water Shortage Response Plan |

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1. Introduction

Alberta's environmental, social, and economic vitality depend, in large part, on how the province's natural resources are managed. An adequate, safe supply of water is vital to support manufacturing, tourism, agriculture, our resource industries, and our very lives. An expanding population, long-term economic growth, the impact of this growth on the environment, and continuing climate variability and change make it essential to adaptively manage our river basins to meet these challenges. This means making proactive and informed water management decisions in collaboration with knowledgeable water stakeholders in each basin. Such action should be based on a clear and shared understanding of how future growth and climatic change could affect water resources, the users who depend on them, and Alberta's ability to respond and adapt.

1.1 The Opportunity

With the recent experience of both floods and droughts in many parts of Alberta, climate variability has become personal, especially for residents in the South Saskatchewan River Basin (SSRB). Growth in southern Alberta in the face of fluctuating water supply has underscored the need for adaptive management of this crucial resource.

This report presents the results of collaborative efforts to develop adaptive water management strategies in the four sub-basins of the SSRB.¹ Emerging from this work is an Adaptation Roadmap for Sustainable Water Management in the SSRB, which is intended to inform water management decisions, investment, and future study; it is referred to in this report as “the Adaptation Roadmap” or simply “the Roadmap.”

Each sub-basin was modelled extensively,² and the models were then integrated into one comprehensive mass balance model for the entire SSRB; these models are described in sections 2.3 and 2.4. The integrated model, the South Saskatchewan River Operational Model (SSROM), enables users to examine and assess strategies for adapting to climate variability as well as the impacts the strategies could have across the full basin,³ not just in an individual watershed.

The Roadmap began with a list of the most promising individual adaptation strategies for the SSRB as identified by the working groups within each sub-basin and these were then evaluated using the SSROM. Subsequent work focused on the strategies considered most promising, defined as those that offered the most net benefits under both current and future conditions, including circumstances such as increasing growth and more severe climate conditions. Strategies were combined as appropriate and then grouped into three levels that reflect degrees of adaptation:

Level 1: Strategies that could be implemented now to adapt to current flows and conditions.

Level 2: Strategies that would add another level of resilience to the basin.

Level 3: Strategies that would make the basin more resilient to climatic changes.

¹ These are the Bow, Oldman, South Saskatchewan, and Red Deer River sub-basins.

² A full list of the 14 reports prepared for the sub-basins appears in Appendix A; all reports are available on the Alberta WaterPortal at <http://albertawater.com/work/research-projects>.

³ In this report, when the term “basin” is used by itself, it refers to the entire SSRB.

The intention is not that all Level 1 strategies would be implemented immediately or all at once; rather, Level 1 identifies strategies that should be considered before moving to Level 2. Level 2 and 3 strategies could be further explored and implemented when the water supply and demand balance in the basin warrants it. This project was not designed to explore the technologies and activities that contribute to demand management and reduction, but many of these are included in the water conservation, efficiency and productivity plans prepared for the seven major water-using sectors,⁴ which is the first listed strategy in the Adaptation Roadmap.

Numerous other demand management actions are contained in the three Levels. These actions are expected to lead to continuous improvement that will provide the resilience and adaptability needed over the long run.

Adaptive water management will involve implementing and regularly revisiting the Roadmap as this dynamic river basin continues to change and demands grow. Important outcomes from this work are first, a greater shared knowledge of the SSRB water system, its management, and the potential changes that could be in store for the region's environment and climate; and second, an available suite of tools, models, and data along with high functioning working groups to support ongoing adaptive river management.

The work described in this report was recognized as a screening level study, after which most strategies would require more detailed study (e.g., cost-benefit analysis, engineering feasibility studies, environmental impact assessments, socio-economic analysis, consideration of impacts on landowners and First Nations). It was also recognized that the trade-offs needed to properly identify and evaluate the strategies were partially represented in the models and well-represented in the expertise and experience of working group participants. The best available information was compiled and provided a solid reflection of the operations of the basin both today and into the future.

1.2 Water and the South Saskatchewan River Basin

Water is the foundation for life in the SSRB, as well as for many downstream residents and water users in neighbouring provinces. All of the major rivers in the SSRB originate in the Rocky Mountains, and protecting the headwaters has been identified as a high priority. In an area with complex geography and land uses and growing water needs, water supplies in the SSRB have historically been, and continue to be, under serious pressure and scrutiny. In much of the basin, water management has focused on drought mitigation, but the floods of 1995, 2005, and 2013 reminded everyone of the diverse hydrological conditions experienced in the region—and of the need to be resilient and adaptable in responding to a wide range of future climate events and impacts. In seeking the best solutions to sustain Alberta's prosperity and quality of life, water management issues must be top-of-mind for residents, elected officials, and other decision makers.

Alberta Environment and Parks (AEP) is responsible for regulatory decisions for developments (other than oil, gas and coal) that pertain to water management in Alberta. Several specific considerations provide a context for water management in the SSRB:

⁴ These plans and their progress reports are available on the Alberta Water Council website at <http://awchome.ca/Projects/CEP/tabid/209/Default.aspx>

- The *Water for Life* strategy and action plan reaffirm Alberta's commitment to the *Water for Life* approach: the wise management of the province's water resources for the benefit of all Albertans.⁵
- Alberta remains committed to its existing priority system of water allocation based on licence seniority. The *Water Act* provides considerable flexibility in terms of water reallocation among licence holders for new or existing purposes. Further use of the adaptive clauses and administrative policies related to the *Water Act* may be valuable in adapting to changing conditions and demands within the sub-basins of the SSRB.
- Since 2006 when the South Saskatchewan River Basin Water Management Plan⁶ was approved by the Lieutenant Governor in Council, no applications for new water allocations have been accepted in the Bow, Oldman, and South Saskatchewan sub-basins. The Red Deer is the only sub-basin in the SSRB that is still open for new applications.
- The Master Agreement on Apportionment (1969)⁷ between the Governments of Alberta, Saskatchewan, Manitoba, and Canada requires that approximately 50% of the annual flow by volume of eastward-flowing provincial watercourses must be passed from Alberta to Saskatchewan. Historically, the average flow to Saskatchewan has typically been more than 75%. Fifty percent is a minimum and reflects choices and trade-offs of water use, but the river ecosystem benefits from these higher flows which are closer to the natural flows. The proportion passed on to Saskatchewan, while meeting Apportionment obligations, was much lower during low flow years such as 1988, 2000, and especially 2001 when it was 54%.
- The Boundary Waters Treaty (1909)⁸ governs the sharing of international streams between Canada and the United States (US). It establishes the terms and conditions for water sharing with Montana and is relevant to the Milk and St. Mary river systems. Historically, Alberta has received more water than its entitlement allows because Montana lacks diversion and storage infrastructure to take and use its full allocation. It is not known if and when the US might take the full allotment of water to which it is entitled in the St. Mary system, which would considerably reduce the amount that is available to Alberta.

1.3 The Drivers for Adaptation

As the climate continues to change, Alberta faces important challenges with respect to balancing water supply and demand due to an expanding population, economic growth, and the increasing impact of this growth on the environment. Nowhere are these matters more pressing than in the SSRB. As potential solutions are considered, environmental, economic, and social needs must all be addressed.

Table 1 compares the four sub-basins in the SSRB by area and population.⁹ Both urban and rural municipalities in the SSRB continue to grow. They require a safe, secure supply of drinking water as well as water to meet wastewater treatment and dilution needs and other municipal demands. An

⁵ See <http://www.waterforlife.alberta.ca>

⁶ See <http://aep.alberta.ca/water/programs-and-services/river-management-frameworks/south-saskatchewan-river-basin-approved-water-management-plan/default.aspx>

⁷ See <http://aep.alberta.ca/water/legislation-guidelines/master-agreement-on-apportionment-1969/default.aspx>

⁸ See <http://aep.alberta.ca/water/legislation-guidelines/boundary-waters-treaty-1909/default.aspx>

⁹ Although there are four sub-basins, the Oldman and South Saskatchewan sub-basins were modelled and studied together as part of the OSSK project.

expanding population will create new demands for recreational opportunities, which could have implications for river flows as well as reservoir volumes and operations. Further, the clearing of land for settlement purposes and construction of buildings, storm sewer conveyance systems, and hard surfaces such as roads and parking lots tend to increase the rate at which precipitation flows off land into streams, rivers, and lakes, thus decreasing infiltration. As a result, settlements and their associated infrastructure increase both total streamflow and peak flow.

Table 1: Area and population of SSRB sub-basins

| Sub Basin | Area in Alberta (km ²) | % of SSRB area | Total population | % of SSRB population |
|--------------------|------------------------------------|----------------|------------------|----------------------|
| Bow | 25,000 | 22 | 1,200,000 | 69 |
| Oldman | 23,000 | 20.5 | 210,000 | 12 |
| South Saskatchewan | 14,000 | 12.5 | 66,000 | 4 |
| Red Deer | 50,000 | 45 | 268,000 | 15 |
| Total | 112,000 | | 1,744,000 | |

Sources: Information in this table was obtained from the websites and publications of the respective Watershed Planning and Advisory Councils for the sub-basins. Much of the population data is from 2006, and numbers are rounded.

To deal with impending shortages, many Alberta municipalities are implementing water conservation, efficiency, and productivity plans along with water reuse opportunities. However, the attractiveness of the SSRB as a place to live and work makes further population growth and the associated demands for water inevitable if current trends continue.

The natural beauty of the SSRB, its biodiversity, and its archaeological and paleontological resources support a strong and growing recreation and tourism industry. However, some plant and animal species, particularly fish, are being threatened by habitat loss and modification, over-fishing, water management infrastructure, and pressure from introduced non-native species.¹⁰

Agriculture is a major land use throughout the SSRB. Primary agricultural production makes the basin an attractive location for food processing and other industries, all of which need assured supplies of water. Other opportunities will also be important to regional growth and diversification, including the service industry, forestry, energy development, and the manufacture of value-added goods. Associated land use changes often lead to more linear developments, particularly roads. Roads fragment the landscape and create a larger human footprint. Other activities lead to wetland drainage and, at best, a temporary loss of the services wetlands provide, among them natural water storage, which lowers peak flows during flood events and helps alleviate drought conditions.

Forestry activities occur toward the western end of the SSRB. Generally, more water is transmitted to streams more quickly from forested areas when forests are young or non-existent, although it has been demonstrated again in recent studies that slope, aspect, and adjacent forestry status also contribute to the delivery of water to streams.

In the southern part of the SSRB, irrigation districts hold licences for most of the allocated water. The districts are improving their water use efficiency, which has enabled them to expand acreage and

¹⁰ Fish species under threat include the Rocky Mountain sculpin, bull trout, native cutthroat trout, and lake sturgeon.

amend their licences to allow this water to be used for other purposes. However, additional storage and water management infrastructure may be desired to help meet the growing variety of water demands. The Government of Alberta (GoA) continues to investigate opportunities to increase traditional on- and off-stream storage, while other storage options using aquifers, gravel beds, wetlands, and other natural features are receiving more attention

Water management pressures have been acknowledged through the closure of three sub-basins to new water licences. Growth in southern Alberta continues but water supply remains the same or less. Compared with most river systems in Alberta, these watersheds are subject to extreme variability in weather patterns. Debate continues about the specific impacts long-term climate change will have on water supplies locally and globally. Compounding this uncertainty, tree-ring data correlated with river flow show extreme climate variability in past centuries for flows in the Bow and Oldman Rivers (Figure 1). These data suggest that future flood and drought events could be much more serious than those experienced in recent years. The same variability in river flow can also be observed in the Red Deer River. These events, combined with population and economic growth, will make it ever more important for the region to be able to adapt to and cope with new pressures and demands, whether due to droughts or floods.

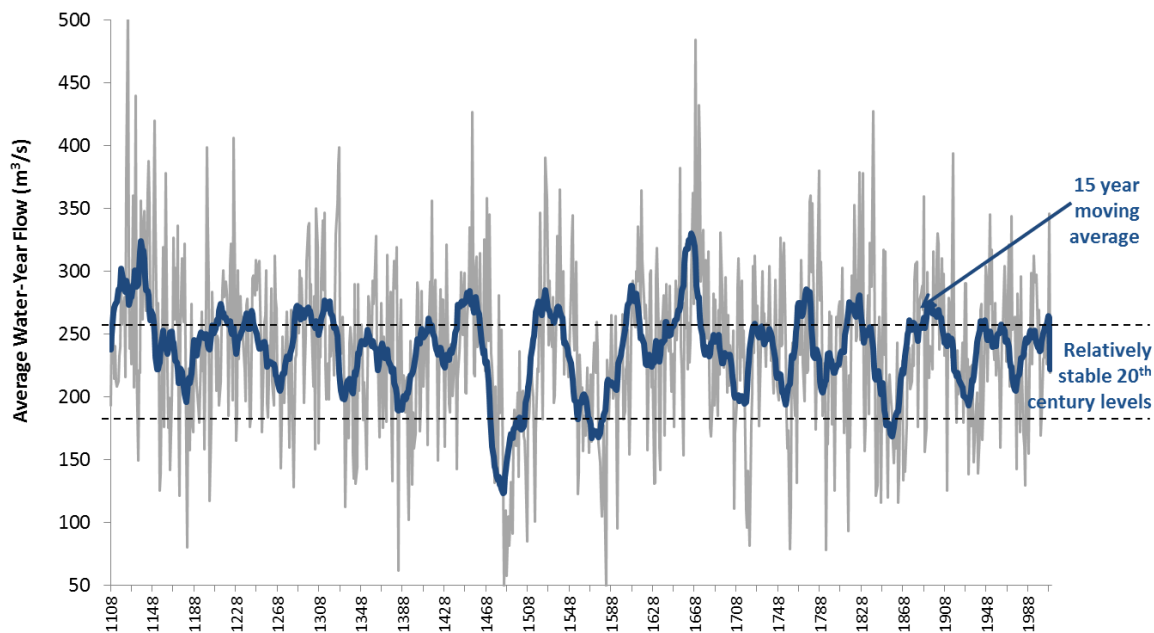


Figure 1: Reconstructed South Saskatchewan River Basin flows (Bow + Oldman) showing annual averages (grey line) and 15 year moving average (blue line)

Source: Dr. David Sauchyn, Prairie Adaptation Research Collaborative, 2015

Climate change has become a dominant global debate. Much of the recent attention has focused on emissions mitigation to address the root causes of climate change, and to lower and stabilize the levels of existing greenhouse gases. Here in Alberta, climate change will have a direct and significant impact on our water resources, as stated in the GoA's Alberta Climate Dialogue 2014: "The strong link between climate change and water has contributed to the view that if mitigation is about carbon, then

adaptation is about water."¹¹ Alberta must put sufficient effort and resources into climate change adaptation to reduce the risks that arise as a result of climatic changes. This requires action by local and regional leaders, groups and businesses to best prepare for changes in the timing and volume of their natural water supply, both as a result of gradual change and extreme events.

Water management challenges in the SSRB present a timely opportunity to capitalize on the knowledge and experience of community and business leaders, government departments, irrigation districts, environmental organizations, and watershed groups. Watershed management and climate adaptation issues are complex and cannot be appropriately addressed by any single initiative or sector. Collaboration is essential. Alberta has a history of successfully meeting challenges through multi-sector collaboration and engagement, and the projects that have led to the Adaptation Roadmap for Sustainable Water Management in the SSRB, presented in this report, add to that legacy.

2. Project History, Process, and Methodology

2.1 Project History

Alberta WaterSMART has led several collaborative modelling projects that examined opportunities and identified a wide range of strategies to increase resilience and make the SSRB more adaptable to climate variability and change. The first major project (the Bow River Project) looked at options and strategies in the Bow River sub-basin. Building on the momentum and ideas that emerged from this multi-stakeholder initiative, another project was launched in 2013 that integrated a climate variability layer into the modelling and flow component for the Oldman-South Saskatchewan sub-basin.

Following the disastrous floods in 2013, the modelling work was applied to examining practical and resilient flood mitigation strategies in the Bow River system, including the Elbow, Sheep and Highwood tributaries. Among other things, the project clearly showed that a systemic, watershed-based approach is essential. During 2014 and 2015, river and land use models were examined and tested by water users and managers in the Red Deer sub-basin.

Table 2 lists the detailed reports produced for the sub-basins, all of which are available on the Alberta WaterPortal at <http://albertawater.com/work/research-projects>. In total, 14 reports were prepared that describe methodologies, flood management opportunities, and other aspects of water management in the SSRB; these are shown in Appendix A. The operational modelling assumptions and input data for the Bow, Oldman-South Saskatchewan, and Red Deer River systems are documented in the publicly available files accessible through the University of Lethbridge servers at <http://www.uleth.ca/research-services/node/432/>.

¹¹ Alberta Climate Dialogue. 2014. "Water in a Changing Climate: Citizen Panel, Summary and Synthesis," p. 8; online at <http://www.albertaclimatedialogue.ca/watershed>; the report is available at <https://drive.google.com/a/uAlberta.ca/file/d/0B0epQHfB5rvHLTB3ZWpxazVNT0lpTUstX1JhNXVqUkM0dHU4/vie w?pref=2&pli=1>

Table 2: SSRB sub-basin final reports

| Report title | Date |
|--|---------------|
| South Saskatchewan River Basin Adaptability to Climate Variability Report: Adaptation Strategies for Current and Future Climates in the Bow Basin; Final Report | June 2013 |
| South Saskatchewan River Basin Adaptation to Climate Variability Project Final Report; Phase III: Oldman and South Saskatchewan (OSSK) River Basins Summary Report | April 2014 |
| Climate Variability and Sustainable Water Management in the SSRB Project: Red Deer River Basin Modelling, Final Report | February 2015 |

This report refers to and draws on the earlier sub-basin work, but focuses on the integrated findings, application, and results across the entire SSRB.

2.2 The Collaborative Modelling Process

As was done for each sub-basin, this integrated project engaged a diverse group of representatives from major water-using sectors and others with an interest in how water is used and managed in the region (see Appendix B for a list of project contributors).

HydroLogics, Inc., the consultant who was involved in modelling the sub-basins, led the integration of the modelling across the SSRB, using their sophisticated simulation software called OASIS (Operational Analysis and Simulation of Integrated Systems). OASIS is flexible, transparent, and completely data-driven, and effectively simulates water facility operations. The project team and most participants had been involved in the sub-basin work and thus were familiar with the OASIS software used to develop the SSROM; the SSROM is described in section 2.4.

In addition to the many working group meetings in the earlier projects and phases, the SSRB working group participants met three times for full-day meetings—in May, June and September 2015, in Red Deer, Lethbridge, and Calgary, respectively. Live modelling sessions were part of each meeting. The first meeting was an opportunity to review the SSROM and potential performance measures, review and refine the adaptation strategies and combinations from the sub-basin work, and begin to develop a manageable set of plausible future SSRB water supply and demand scenarios against which to refine potential adaptation strategies. At the second meeting, participants focused on improving the most promising strategies for ameliorating issues resulting from high and low flow conditions. The final meeting was spent reviewing and refining the most promising strategies and actions that could be implemented now and in the future to enhance adaptation and increase resilience in the SSRB.

Throughout the project, participants worked collaboratively, providing data, advice, and insight based on their knowledge and experience. Participants actively offered ideas and comments to advance the discussion while respecting the views and opinions of others. This process was not intended to seek or achieve total consensus; rather, it was designed to explore practical water management strategies and ideas, based on the best data and knowledge in the basin. The results are presented as a solid foundation for discussion and implementation by those who use, manage, and make decisions about water in the SSRB as they anticipate and respond to future changes in water supply, water demand, and climate. The expectation is that the ideas and strategies developed through this collaboration would serve as an Adaptation Roadmap for the basin.

This project brought together some of the most knowledgeable and experienced water users and managers in Alberta, many of whom have lived and worked in the SSRB for decades. They have seen first-hand the impacts of both droughts and floods on the region's people, environment, and economy, and are very aware of the need to be prepared for a wide range of possible future flow conditions. Working openly and collaboratively, they identified a number of strategies that could benefit the basin now and could help the region adapt to more challenging future water supply and climate conditions, whether they involve too much or too little water.

2.3 Modelling the SSRB Sub-basins

Throughout this project and its predecessors, the comprehensive, daily, mass balance river models developed for the sub-basins and the SSRB have been the primary tools to support collaborative exploration and assessment of opportunities and build common understanding of the water management system. The models enable users to examine and assess strategies for adapting to changes in water supply and demand and climate variability, as well as the impacts the strategies could have across the full basin. Although operations and priority water allocations differed among the sub-basins, the core of the mass balance models was essentially the same for all of them. OASIS models preserve mass balance by having water enter the model only at nodes with inflows, and exit only through demands, evaporation, or a terminal junction node. Water is also, in the general sense, allocated to each "use" (minimum flows, demands, reservoir storage, licensed allocations, etc.) through a weighting system; that is, higher weighted uses get water first. These weights can be modified in various alternatives to increase the priority of one use over another, but the fundamental concept is applied regardless. The models do not explicitly calculate and account for groundwater or include water quality aspects, but groundwater contribution to streamflow is inherently part of the naturalized flow data, which are used as inflows to the model. Implications for water quality as it relates to flows at points in the river can be assessed using the sub-basin model when relationships between water quality and quantity at a particular point in the system are known.

The OASIS modelling system derived from a long history of continuous improvement of water resources modelling techniques (see Appendix C). It includes a wide variety of features not found in other modelling systems, which makes it extraordinarily flexible. OASIS has been widely used to model some of the world's most complex water systems, as well as small and simple systems. It has been used widely in the US, as well as in New Zealand, Canada, and other places for evaluating alternative management plans. Many of those exercises explicitly incorporate or link to other models.

One objective of modelling the SSRB sub-basins was to propose adaptive and robust water management strategies that take 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 testing of water management alternatives under a range of plausible future climate and hydrological scenarios (described in section 2.4). Thus, in addition to an operational model for each sub-basin river system, climate scenarios were developed to realistically advance the adaptation discussion. The innovative approaches used by the Prairie Adaptation Research Collaborative to develop these climate scenarios are described in detail in the three sub-basin reports. In all cases, both flood and drought conditions were examined and measures contemplated to mitigate their effects. The 95% of relatively normal periods were also examined for potential environmental, recreational, and other improvements using 81 years of real historical data with current and future demands built onto each year. Adaptation options were examined under various science-based climate change and

variability scenarios, all of which were reviewed by senior water managers and regulators throughout multiple projects. The result was nearly 1,500 model runs (excluding flood-focused work) for the three sub-basins and the SSROM; this amounts to approximately 42,000,000 simulated days, or 115,100 simulated years.

An important early step in collaborative modelling processes is developing performance measures (PMs) to help parties scope the issues. PMs 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 models need to have, and thus they inform and influence how the models are constructed. Focusing on measures that reflect basin-wide or specific concerns, participants refined and developed specific PMs based on their individual and collective water outcome needs. Although numerous PMs were developed and used to demonstrate and assess the impacts of changes made in the sub-basin models, typically a subset of key PMs was selected for regular use. Each sub-basin report lists all PMs that were processed and describes the key subsets.

Performance measures used in the report were derived from previous work and have maintained the unit convention. The reader should be aware that both metric and imperial units are used, as the various PMs were developed for specific interpretations.

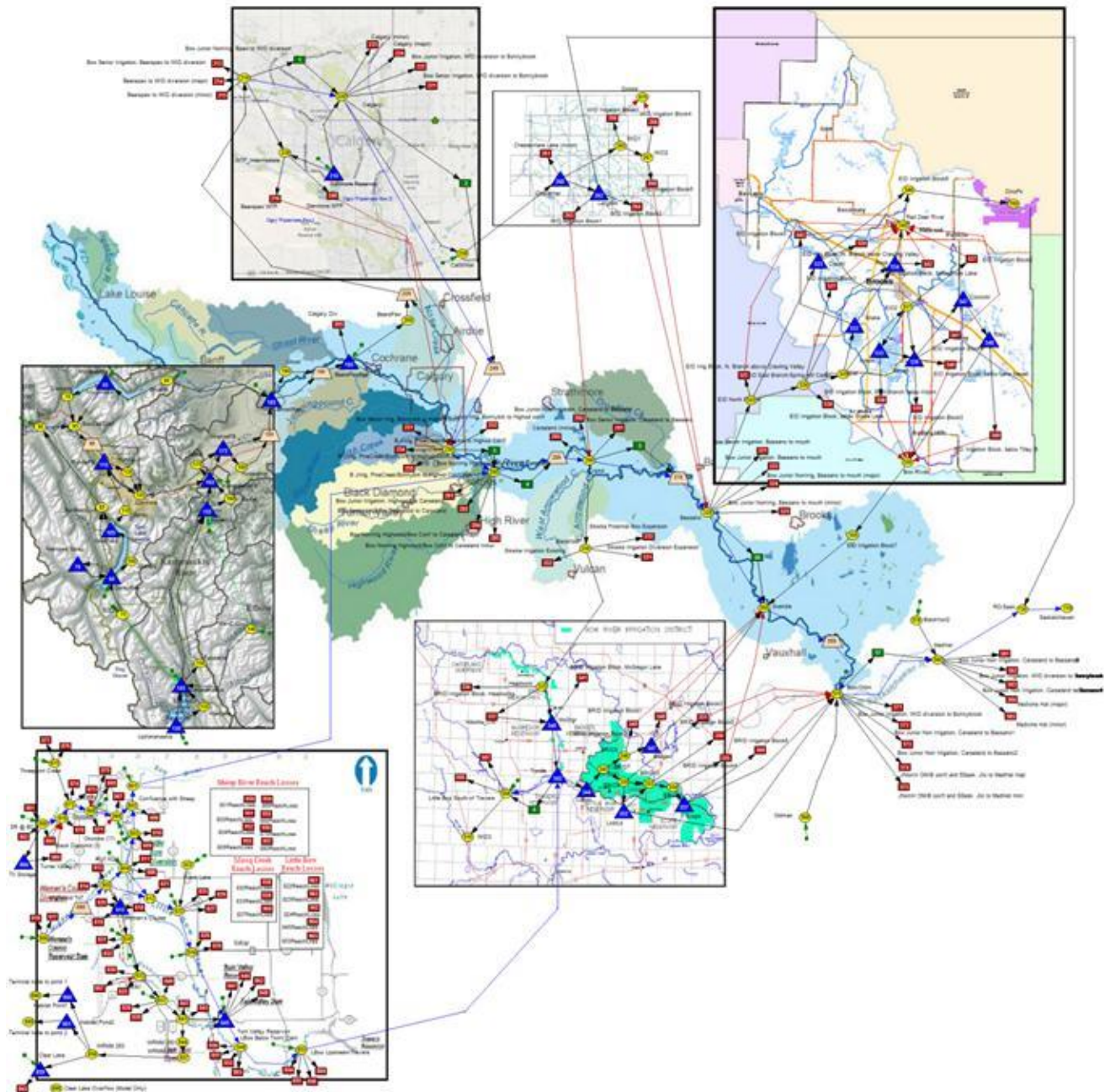
The three sub-basin models were developed with considerable input from the working group involved in each project. A brief overview of each model is provided here with more details in Appendix D and in the relevant sub-basin report. If unspecified, data were obtained from AEP and its Water Resources Management Model (WRMM) or from Alberta Agriculture and Forestry's Irrigation Demand Model (IDM). Inflows were provided weekly, but converted to daily, utilizing methodology available in the individual sub-basin reports. In some instances, hourly models of parts of the basin were developed to properly reflect flood events. Irrigation demands were provided as Irrigated Area x Depth using current crop decisions and historical precipitation data.

2.3.1 Bow River Operational Model (BROM)

The BROM is a comprehensive mass balance river model built in collaboration with Bow River licence holders and stakeholders. However, it contains substantial information beyond a simple water balance, including facility operations, power prices, informal sharing agreements, and more. This allows the model to provide results that recognize real operation projections while ensuring that mass balance remains inviolate. The BROM base case simulates current operations of facilities on, and withdrawals from, the Bow, Elbow, Highwood and Sheep Rivers from the headwaters to the confluence with the Oldman River, including major off-stream canals and storage reservoirs. Primary inputs to the BROM include naturalized flows, lake evaporation, precipitation, consumptive uses (irrigation and municipal demands), return flows (seasonal and annual), physical infrastructure data including upstream dams and reservoirs, and electricity demand and pricing systems for hydropower facilities. The BROM includes the historic flow record (1928–2009) using AEP naturalized flow data and future climate variability scenarios derived from Global Climate Models.

The best available data on the physical system (reservoir, dam, canal, and diversion structure information), inflows from the naturalized flows for 81 years of record, demand data (actual current use, allocations, irrigation demand data, return flows, municipal water use, diversion

rates and limits, instream objectives and Water Conservation Objectives, or WCOs), and system operations (licence constraints, water sharing agreements, priority systems, reservoir and dam operating rules) were used in the model. Figure 2 shows the schematic for the BROM.



Legend

▲ Reservoir node
 ■ Demand node
 ■ Instream "demand" node
 ● Junction node
 Green arrows indicate unregulated inflow.
 Black arrows indicate regular flow arcs.
 Red arrows indicate return flow arcs.

Figure 2: Schematic showing the area represented by the BROM

A number of PMs were developed for the BROM and six common PMs were examined for all the individual strategies modelled in this project:

1. TransAlta System Low Storage Days

This PM notes the number of times that TransAlta live storage reaches critical (<5% storage remaining) and near-empty (<1% storage remaining) levels.

2. Calgary Low Flow Days

This PM captures the number of days Calgary experiences extreme low flows, noting flows below 1,250 cubic feet per second (cfs) as well as flows below 900 cfs.

3. Bassano Flow

This PM captures the number of low flow days below Bassano Dam. It is the same performance measure as shown in previous reports using BROM. It captures the number of days in which flow below Bassano falls into the < 400 cfs, 400–800 cfs, 801–1200 cfs, and > 1200 cfs categories. As flow that passes below Bassano has necessarily been in the river all the way to Bassano, this PM is used as a surrogate for whole river health.

4. Carseland Flow

This PM is identical to the Bassano flow PM, except that it measures flow in the river just after the Carseland diversion. In runs including Eyremore Reservoir, the flow past Bassano is no longer indicative of whole river health, as Eyremore makes releases downstream of Bassano. Carseland flow is thus used as a replacement surrogate for upstream river health in strategies that include Eyremore Reservoir.

5. Shortage Days

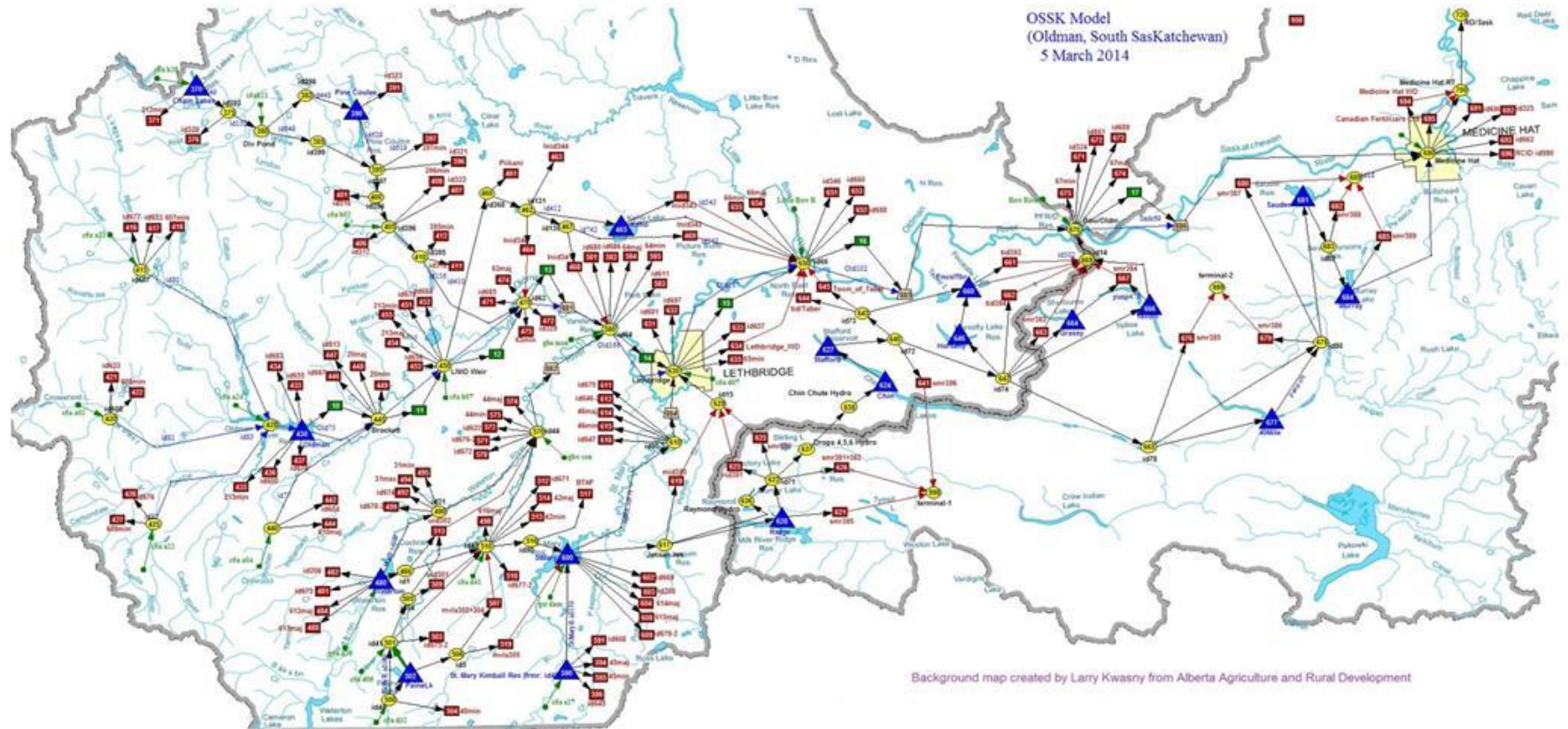
This PM captures the number of days of shortages experienced by various groups of licence holders on the Bow River. This is a sum of all days over the entire 30-year climate variability scenario record (10,950 total days) or 81-year historical record (approximately 30,000 days).

6. Shortage Volume

This PM captures the total volume (in acre-feet) of all shortages experienced by various groups of licence holders on the Bow River. This is a sum of all shorted volumes over the entire 30-year climate variability scenario record (10,950 total days) or 81-year historical record (approximately 30,000 days).

2.3.2 Oldman-South Saskatchewan River Operational Model (OSSROM)

The OSSROM includes the Oldman and South Saskatchewan (OSSK) sub-basins with all their major tributaries, including the Southern Tributaries (the Belly, Waterton and St. Mary Rivers). The primary inputs to the OSSROM are naturalized flows, lake evaporation, precipitation, consumptive uses, return flows, and physical data. The base case applies how the river is currently operated, within the context of licensed priorities and water management plans, to historical flows (1929–2009). Although there has been a progression of reservoir development in the Oldman River basin, the OSSROM does not account for this progression; rather it implies that all existing infrastructure was present in the basin for the model period since the objective is to model current and future scenarios. The model's base case assumes that the sub-basin only gets the minimum International Joint Commission (IJC) entitlement flow; if that flow is increased, it is noted in the alternative. The OSSROM schematic is shown in Figure 3.



Legend

▲ Reservoir node
 ■ Demand node
 ■ Instream "demand" node
 ● Junction node

Green arrows indicate unregulated inflow.
 Black arrows indicate regular flow arcs.
 Red arrows indicate return flow arcs.

Figure 3: Schematic showing the area represented by the OSSROM

More than 20 PMs were developed for this project and eight key PMs were used to examine all the individual strategies that were modelled:

1. Annual weekly minimum flows

This PM attempts to capture a sense of biological performance by examining the absolute minimum weekly flows for each year in a particular scenario at various locations. Minimum flow is measured in m^3/s .

2. Minimum flows for fisheries

This PM assesses the ability to meet instream fish requirements in the Oldman River at Lethbridge. It uses Tessman Method¹² instream flow needs estimates and shows percentage of months each year with failures to meet minimum flows.

3. Cottonwood recruitment

This PM estimates the likelihood of successful cottonwood recruitment and captures the quality of successful recruitment events. It shows the number of years when optimal recruitment can be expected and the number of years when partial recruitment can be expected.

4. Fish Weighted Usable Area (WUA)

This set of PMs is designed to capture the effects of operations on fish habitat in selected stream reaches (the St. Mary River below St. Mary Reservoir and the Oldman River near Lethbridge) for selected indicator species. WUA is the wetted area of a stream weighted by its suitability for use by aquatic organisms or recreational activity. This PM is expressed as a proportion of total usable area.

5. Cumulative irrigation shortage days

This PM examines the effects of operations schemes on irrigation districts by assessing shortage days. Shortage means that water delivered was less than water requested in any amount. Some of these shortages might be volumes too small to be significant.

6. Total annual outflow from Oldman River as percent of natural flow (apportionment proxy)

This PM indicates the likelihood of violating the Apportionment Agreement by comparing natural flows at the Oldman-Bow confluence with simulated flow under various operations scenarios.

7. Energy generation

This PM examines the effects of operations schemes on power generation opportunities. It is shown as total energy generated in megawatt-hours over the 81-year period for the hydro generation facilities in the OSSK sub-basins.

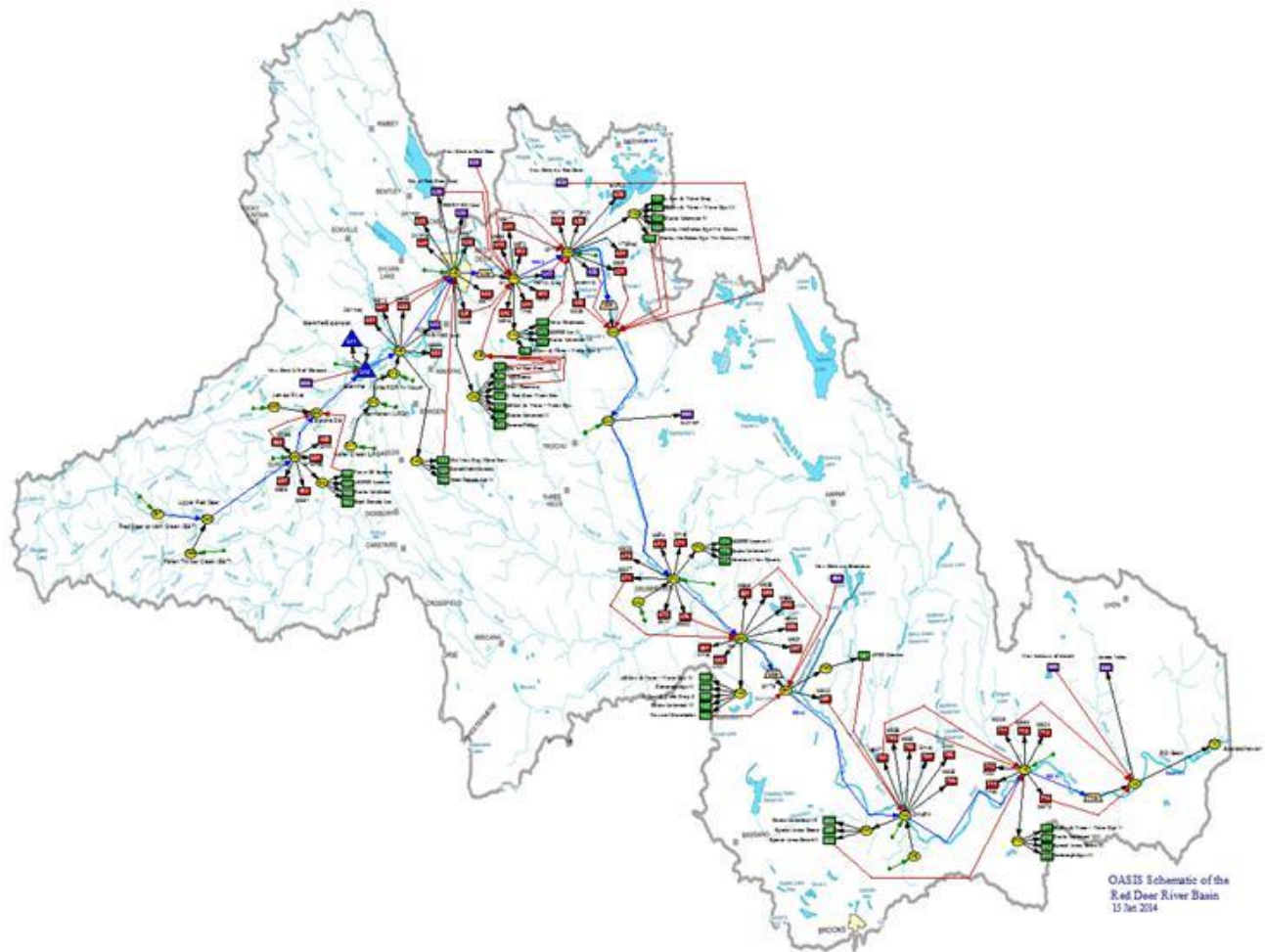
¹² The Tessman (1979) Instream Flow Needs (IFN) method is a commonly used streamflow method for determining the range of suitable flow conditions. It calculates the annual and monthly average flows and establishes thresholds based on 40% of the annual and monthly averages. If the average monthly flow is lower than 40% of the annual average flow, then the IFN threshold is set to the average monthly flow. Alternatively, the IFN is the greater of 40% of the average annual or 40% of the average monthly flow (Goater et al., 2007).

8. Additional drought capacity






This PM refers to the number of days in a specific year by which total storage in AEP reservoirs will extend water availability and thus capacity to respond to drought conditions. It is plotted as AEP total storage in dam³.

2.3.3 Red Deer River Operational Model (RDRM)

The RDRM was developed for the Red Deer system to run on a daily timestep. Primary inputs include naturalized flows, evaporation and precipitation, licensed allocation for the whole system or consumptive use (in some cases actual use numbers were provided by users), return flows, and physical data for diversions and reservoirs with associated operations. Since the naturalized inflow data included substantial reach losses, the decision was made to apply the same methodology that AEP chose when using the data: naturalized reach losses were adjusted to zero. The RDRM schematic is shown in Figure 4.



Legend

-  Reservoir node
-  Demand node
-  Instream "demand" node
-  Junction node
-  Demand node (future demand or current demand with actual use data)

Green arrows indicate unregulated inflow. Black arrows indicate regular flow arcs. Red arrows indicate return flow arcs.

Figure 4: Schematic showing the area represented by the RDRM

More than 20 PMs were developed for this project and six key PMs were regularly used in the RDRM:

1. Flows at the Mouth of the Red Deer River (weekly)

This PM identifies periods of low flows that might be of concern for environmental, economic, and social objectives as well as noting violations of the WCO. The WCO is an important PM as it represents an agreed upon water use threshold in an approved Water Management Plan under the *Alberta Water Act*. WCO requirements at the mouth of the river are a minimum of 10 m³/s in the summer and 16 m³/s in the winter. Weekly (rather than daily) flows were analyzed for this PM as operations in the model were targeted towards meeting the WCO on a weekly basis.

2. Elevation of Gleniffer Reservoir (daily/annual)

As Gleniffer Reservoir is the only on-stream storage in the Red Deer system, remaining storage in the reservoir is of critical importance, in particular during drought periods. Gleniffer Reservoir serves to maintain the WCO in the winter. Monitoring its storage helps to identify years where both the WCO and junior licences would be at risk.

3. Outflow from Gleniffer Reservoir

Gleniffer Reservoir releases are primarily of interest in terms of the functional flow alternatives looking at environmental flows below the dam and correlating those with reservoir storage targets and operational priorities. Outflow from the reservoir is shown to establish the effect of ramping on flows immediately downstream of the reservoir.

4. Cottonwood Recruitment

This PM estimates the likelihood of successful cottonwood recruitment and captures the quality of successful recruitment events. It shows the number of years when optimal recruitment can be expected and the number of years when partial recruitment can be expected.

5. Shortages to New Demands (annual/daily)

Since existing demands in the system are nearly all senior to the WCO and never saw shortage in any scenario or alternative, shortages in the system were analyzed as how many occurred in demands junior to the WCO (i.e., new demands introduced in sub-basin scenarios). Although presented primarily in annual terms in the report, they were often examined on a daily basis in the working group sessions.

6. Mid-stream Storage

This PM tracks the drawdown in the hypothetical mid-stream storage and operations proposed by participants to estimate the additional volume of storage needed to remedy shortages to new and current users and occasional deficits in Gleniffer Reservoir storage. It is presented where appropriate based on alternatives.

In addition to modelling the river system, the Red Deer project used the ALCES¹³ model to consider land use in the sub-basin and began to explore how changing land cover impacts streamflow at the sub-basin scale. It examined five categories of land use (settlements, energy development, agriculture, forestry and fire, and wetland restoration) and how changes in these uses might influence the volume and timing of flow to the Red Deer River system over time. The ALCES model simulates spatial and temporal variance in hydrological indicators. It uses runoff coefficients to simulate water yields from different landscapes and accounts for many variables that affect hydrology (ALCES Group, 2014). ALCES was chosen for this project because it is widely applied in Alberta and it supported the project's need to explore and understand how management of changes on land affect streamflow.

2.4 The South Saskatchewan River Operational Model (SSROM)

As the respective groups worked through the modelling to explore each sub-basin and identify practical adaptation opportunities, questions frequently arose that could not be answered within the confines of the modelling for that sub-basin alone. The sub-basin models, described above, interact in critical and sometimes surprising ways. Introducing the SSROM made it possible to take a comprehensive integrated look at the entire SSRB, including the effects of operations on the Apportionment Agreement with Saskatchewan. It supported the SSRB working group as it looked for adaptation opportunities across the basin, explored combinations of sub-basin strategies to enhance the entire system without sacrifice to individual sub-basins, and consider where the best “bang for the buck” might be to guide the investment of limited adaptation effort, energy, and dollars.

The SSROM demonstrated how the SSRB sub-basins have a number of interesting interactions and opportunities, although they are often viewed as independent and unique. For example, the impacts of improving irrigation efficiency in the Bow sub-basin ripple through into the Red Deer sub-basin as the loss of return flows affects the ability to meet the system's WCOs. Extra storage in the Southern Tributaries allows the Oldman Dam to maintain extra storage, as the minimum flows and demands downstream of Lethbridge can be sourced from new storage.

The SSROM focuses on real-world operations and the opportunities that arise. It enabled stakeholders to explore combinations of sub-basin strategies and find ways to enhance the entire system without sacrifice to individual basins.

SSROM Platform, Contents, Operations, and Assumptions

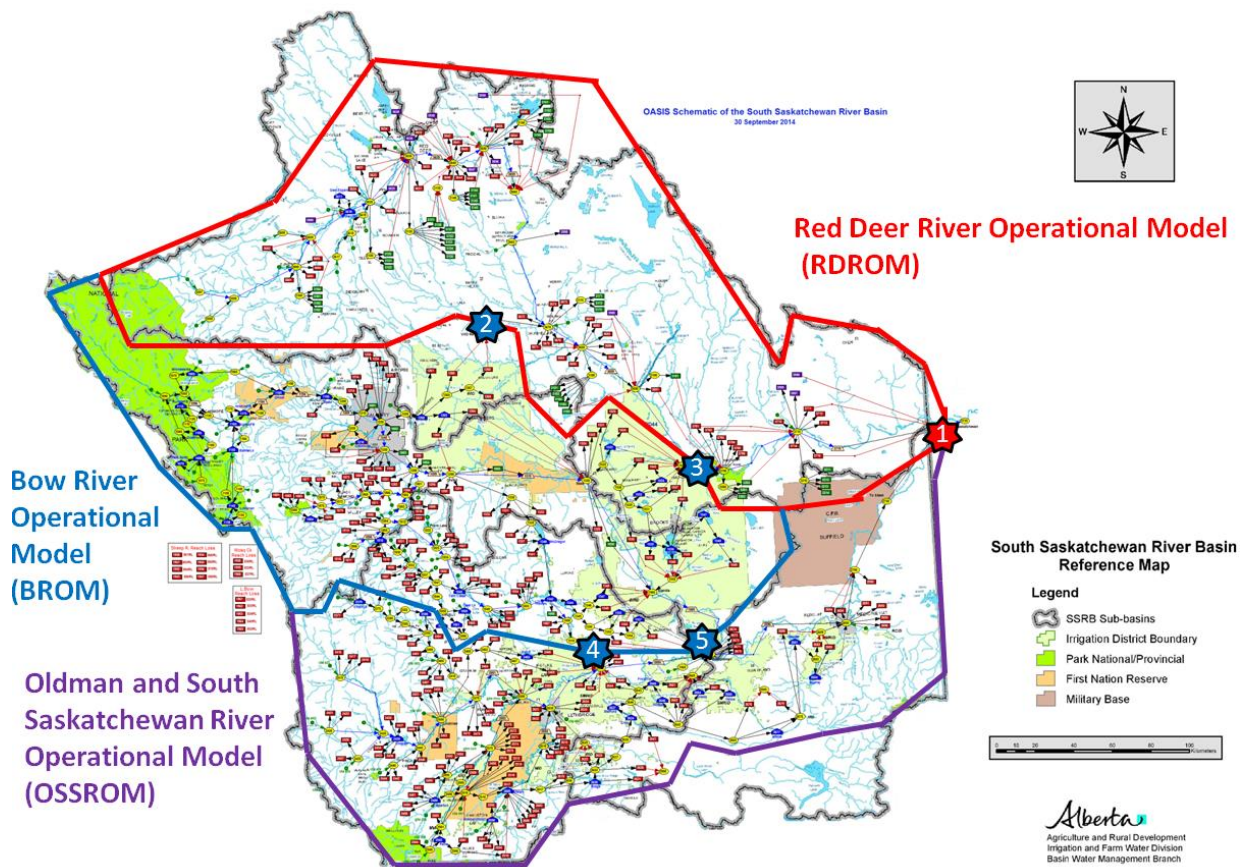
Like the sub-basin models, SSROM is built on the OASIS platform developed by HydroLogics. SSROM was built by combining the existing models described above (BROM, RDRM, and OSSROM); a complete description of operations in those systems can be found in their respective reports. Primary inputs include: naturalized flows, evaporation and precipitation, licensed allocation for the whole system or consumptive use (in some cases actual use numbers were provided by users), return flows, and physical data for diversions and reservoirs, with associated operations. Operations remained generally intact from the originating models, with one major change: previously static data sources were replaced with live model interactions.

¹³ ALCES is “A Landscape Cumulative Effects Simulator.”

During the project, participants raised a number of important issues to be addressed that were beyond the scope of the data gathered or the project mandate. While many of these more detailed local-scale hydraulic modelling, engineering, economic, and environmental factors, risk assessments, and systemic issues were not part of this screening level modelling, they would likely be the next steps for consideration by decision makers as these adaptation strategies are specifically evaluated for implementation. In SSRM, five major sites of basin connectivity were noted:

1. Red Deer River at the mouth
2. Western Irrigation District (WID) returns at Drumheller
3. Eastern Irrigation District (EID) returns at Dinosaur Park
4. Flow into/through the Little Bow River south of Travers Reservoir
5. The Bow/Oldman River confluence

Figure 5 shows the three sub-basins covered in the SSRM.



Legend

- ▲ Reservoir node
- Demand node
- Instream "demand" node
- Junction node
- Demand node (future demand or current demand with actual use data)
- ★ Basin connection point

Green arrows indicate unregulated inflow. Black arrows indicate regular flow arcs. Red arrows indicate return flow arcs.

Figure 5: Schematic showing the area represented by the SSRM

Source: This map, originally from Alberta Agriculture and Forestry Irrigation and Farm Water Division, Basin Water Management Branch was overlain on the SSRM schematic.

Minimum flows throughout the system are maintained according to their originating model, but SSROM introduces the ability to directly measure and consider apportionment. Apportionment in the SSRB is not explicitly maintained by SSROM. It is instead evaluated separately as a PM but still merits some discussion here. The Apportionment Agreement with Saskatchewan does not dictate a strict daily minimum flow; rather it requires that approximately 50% of annual natural flow volume proceed into that province. There is a small window of exception for this 50% measure (shown below in Figure 6), as long as a daily minimum of $42.5 \text{ m}^3/\text{s}$ (1500 cfs)¹⁴ is maintained every day. If the flow dips below this daily threshold even once, the requirement immediately jumps back to 50%. Figure 6 shows Alberta's apportionment performance for the SSRB from 1970–2009.

¹⁴ This number is the sum of the flows from the Oldman, Bow and Red Deer rivers at their confluence, just inside the Saskatchewan border.

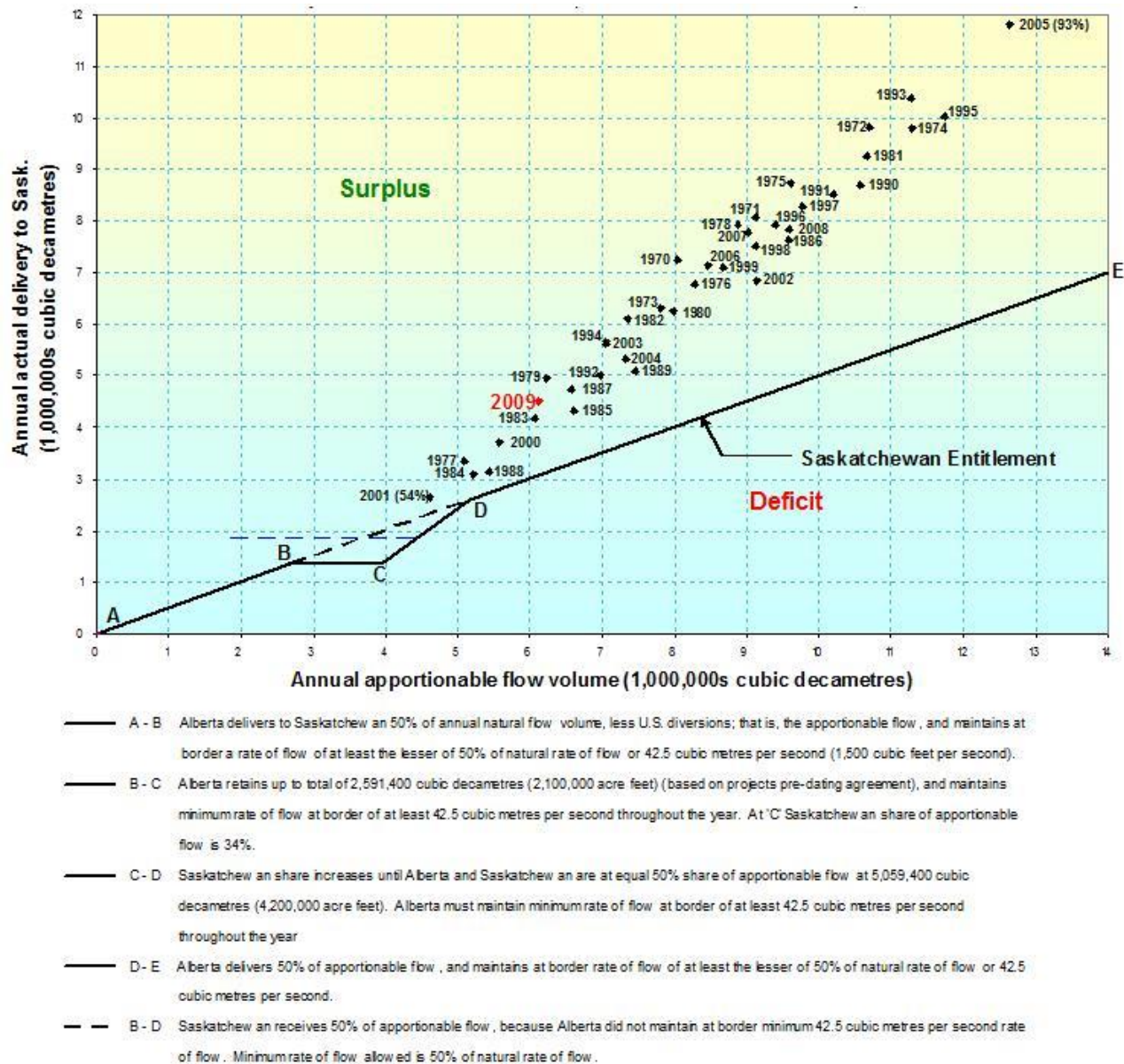


Figure 6: Alberta SSRB Apportionment Performance, 1970-2009

Note: The horizontal dashed line illustrates what happens when the minimum flows of 42.5 m³/s on the South Saskatchewan River and 16 m³/s on the Red Deer River are maintained as minimums regardless of natural flow.

Alberta Environment and Parks data, 1970-2001; Prairie Provinces Water Board data, 2002-2009. Source: Work done by Dave McGee, Sal Figliuzzi, and Doug Ohrn with the provincial department that is now Alberta Environment and Parks, from 2003-2012.

The Climate Variability “Frankenflow” Dataset

A set of plausible future SSRB water supply and demand scenarios was needed to further test and refine potential adaptation strategies. To do this, a “Frankenflow”¹⁵ dataset of streamflows, demands and returns in the SSRB was created.

The logical method for the demands and return datasets was to rely on the previously completed climate variability work for each of the sub-basin models in which historical demands and returns were averaged monthly over the entire 1928–2009 record. These average monthly demands were then applied for all “future” model runs. Since they are averages, however, the demand for water is likely under-represented during dry years and over-represented during wet years since water use by irrigators and municipalities varies according to precipitation amounts. The OSSROM working group participants requested that a measure be taken to correct for this (demands increased 25% in dry years, decreased 25% in wet years), but it was not deemed necessary for other sub-basins. This correction in the Oldman and Southern Tributaries was applied in SSROM.

Daily naturalized streamflow from 1953 was used in the sub-basin models (RDRM, OSSROM, and BROM) to provide a flood scenario. This year represents the second highest peak daily streamflow for the whole SSRB. Drought years applied the lowest three years on record for the whole SSRB, which were 1977, 2001, and 1941, from lowest to highest, respectively. Normal years are represented by the median annual average streamflow over the 81-year time period +/- 5%. A 15-year time-series was derived, which follows the general trend of 1 normal year, 1 flood year, 3 normal years, 3 drought years, 3 normal years, 1 drought year, 3 normal years (Table 3). The drought years used in Frankenflow are scaled by 0.63, which is an extreme low annual flow scenario from previous work with the BROM, OSSROM, and RDRM. See Appendix E for more details on derivation of the Frankenflow time series.

Table 3: Years used in the Frankenflow time series

| Year in the 15-year time series | Year(s) used |
|---------------------------------|------------------|
| 1 normal year | 1946 |
| 1 flood year | 1953 |
| 3 normal years | 1963, 1946, 1950 |
| 3 drought years | 1977, 2001, 1941 |
| 3 normal years | 1950, 1963, 1946 |
| 1 drought year | 1977 |
| 3 normal years | 1946, 1950, 1963 |

Note: Drought years were scaled based on droughts used in the future climate scenario work.

The final Frankenflow time series is demonstrated at an annual scale in Figure 7 and at a daily scale in Figure 8. This time series of inflows was used to challenge and advance the development of adaptation strategies in the face of drought and flood for the whole SSRB.

¹⁵ Called “Frankenflow” because the components were stitched together to create a realistic but artificial dataset.

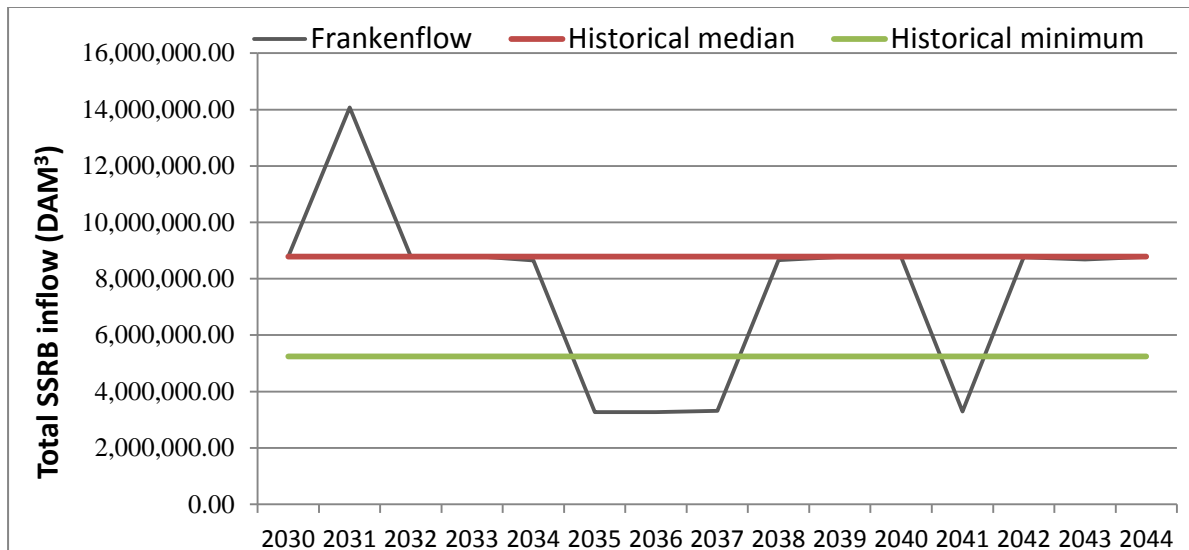


Figure 7: Frankenflow time series at an annual scale

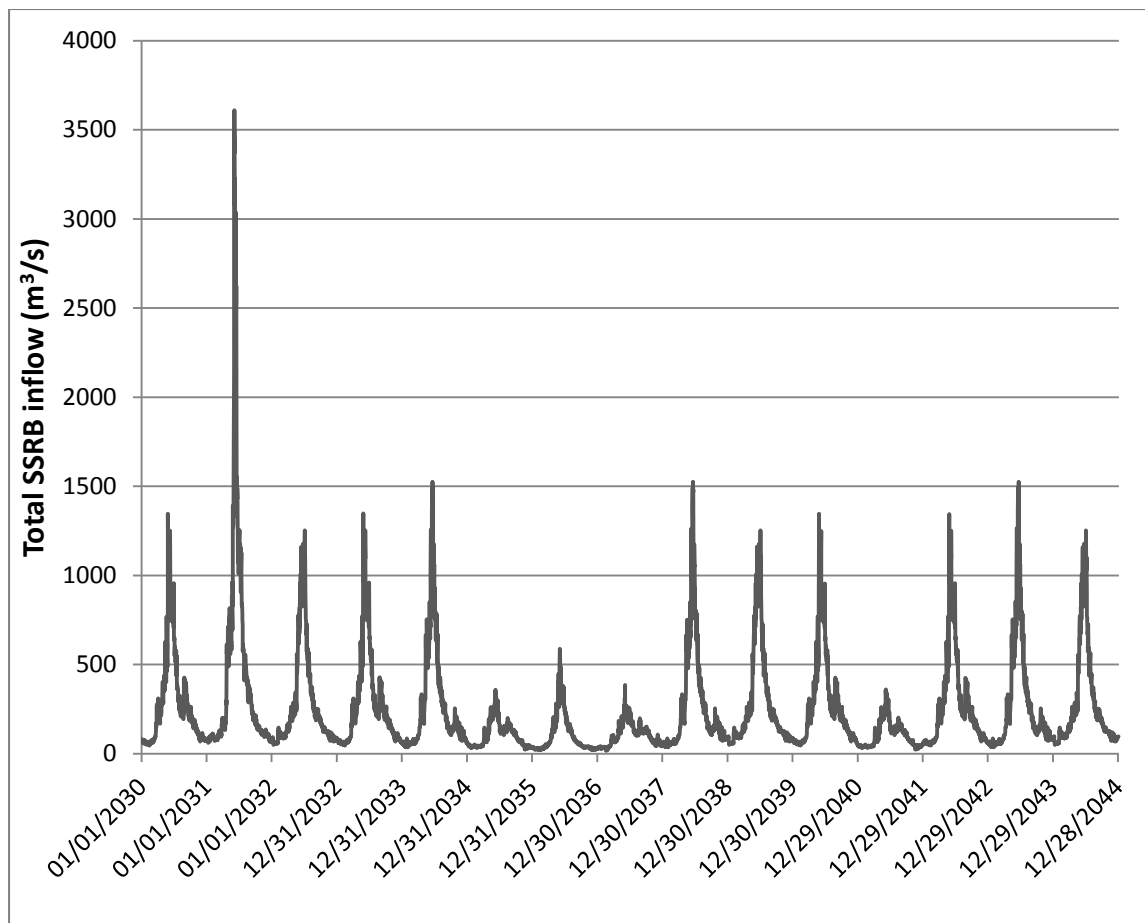


Figure 8: Frankenflow daily time series for the 15-year period from 2030–2044

Four switches were then developed that could be applied or not to the Frankenflow data scenario to reflect changes in specific conditions in the SSRB. This allowed the working group to explore how the system might be further stressed over and above the range of climate variability. The switches reflect changes in:

- Prairie wetland restoration.
 - This switch was developed using the relationship between percent change in annual flow and percent watershed existing as wetland, derived by Pomeroy et al. (2014) and was implemented in ALCES Online to derive potential flow change scenarios as a function of wetland loss.
- Major forest disturbance in the headwaters.
 - This switch was developed using forest age data from ALCES Online, where younger forests had higher runoff coefficients relative to older forests. A major forest disturbance was assumed to result in a younger forest; therefore, it had a higher runoff coefficient and higher streamflow as a result.
- Growth in water demands in each of the sub-basins. This was created using the following assumptions suggested by the working group:
 - Red Deer: licence allocation of 550,000 dam³/year
 - Bow: 50% closer to full Calgary licence allocation than current use
 - OSSK: 50% closer to full municipal licence allocation than current use for Lethbridge, Taber, and Medicine Hat.
- Change in St. Mary inflow due to changed entitlement flows from the US (approximately 35% less inflow than current in “normal” conditions).
 - This was developed using the same methods as previous work (Alberta WaterSMART, 2014b), which was based on the 1921 IJC order.

SSROM Performance Measures

The SSROM project maintained all PMs from previous projects; the full lists are found within individual project reports and key PMs were noted in section 2.3. PMs were also developed to observe both major areas of impact in sub-basins as well as full system effects for the SSROM in four categories. Only a sub-set of the most significant of these PMs is used in this report.

Water supply PMs:

- Total SSRB-Wide Shortages by Sub-basin and Type of Demand – Municipal/Irrigation/Other (intended to capture raw economic performance in the whole system)
- Total Shortage as a Percentage of Total Demand (another way to look at direct performance)
- Average Annual Movement of Water between Sub-basins (to see the effect of any new intra-basin transfers)

Environmental PMs:

- Below Bassano/Carseland Low Flow Days (a surrogate for Bow River environmental performance)
- Percentage of Weeks where Average Weekly Flow at the Mouth is Less than the WCO Flow Threshold (intended to capture environmental performance in the Red Deer system)
- Percentage of Days where 45% of Naturalized Flows are Met or Exceeded (an ecological health indicator)

- Minimum Flow Violations (to ensure no worse performance for river needs)
- Number of Days where Total South Saskatchewan River Flow at the Border is Less than 20% of Mean Annual Discharge (an ecological health indicator)

Flood PMs:

- Maximum Flow Violations (to check against basic flood performance, recognizing that this daily PM will not identify hourly peaks)

Apportionment PMs:

- Number of Years where Apportionment is Violated (to check apportionment)
- Annual Volume of Water from the South Saskatchewan and its Sub-basins as a Percentage of Naturalized Flow (to see relative contributions to apportionment flows)
- Contribution to Total South Saskatchewan by Source Sub-basin (another way to see relative contributions by source)
- Number of Years where the Total South Saskatchewan Minimum Flow is Violated (to see how many times the minimum $42.5 \text{ m}^3/\text{s}$ (1500 cfs) was violated even if apportionment was not for the year)
- Average Annual Volume of Water Flowing Out of each Sub-basin that is in Excess of 50% of Naturalized Flow (to determine contribution over required apportionment flow)

Performance measures used in the following sections were derived from previous work and have maintained the unit convention. The reader should be aware that both metric and imperial units are used, as the various PMs were developed for specific interpretations.

3. SSRB Adaptation Roadmap for Sustainable Water Management

A great deal of attention has been focused on water management in southern Alberta over many decades. In seeking the best solutions to sustain prosperity and quality of life in the SSRB, water management issues are a potential limiting factor, and must be top of mind for residents, elected officials, and other decision makers.

Throughout the modelling of the sub-basins, many dozens of potential adaptation strategies were proposed and tested, individually and in combination. All working groups acknowledged the often substantial value of combining strategies to maximize efficiencies and improve environmental, economic, and social benefits.

3.1 Notable Basin Dynamics

While discussing adaptation strategies and opportunities, a number of notable aspects related to basin dynamics in the SSRB emerged or were reinforced from prior work. They have a direct or indirect effect on water use and management in the basin and are briefly noted here to provide additional context for the strategies that are described later in this report.

The observed flows from the US in the St. Mary River have been considerably higher than the volumes to which Alberta is entitled.

The Boundary Waters Treaty establishes the terms and conditions under which Alberta and Montana share water. Alberta's water entitlement to the St. Mary River system was noted under this agreement and the subsequent 1921 IJC Order. Alberta has historically received more water through the St. Mary River system than it was entitled to, because Montana lacks diversion and storage infrastructure. Figure 9 compares the natural flow in the St. Mary River to Alberta's historically received flow and its entitlement flow under the IJC Order.

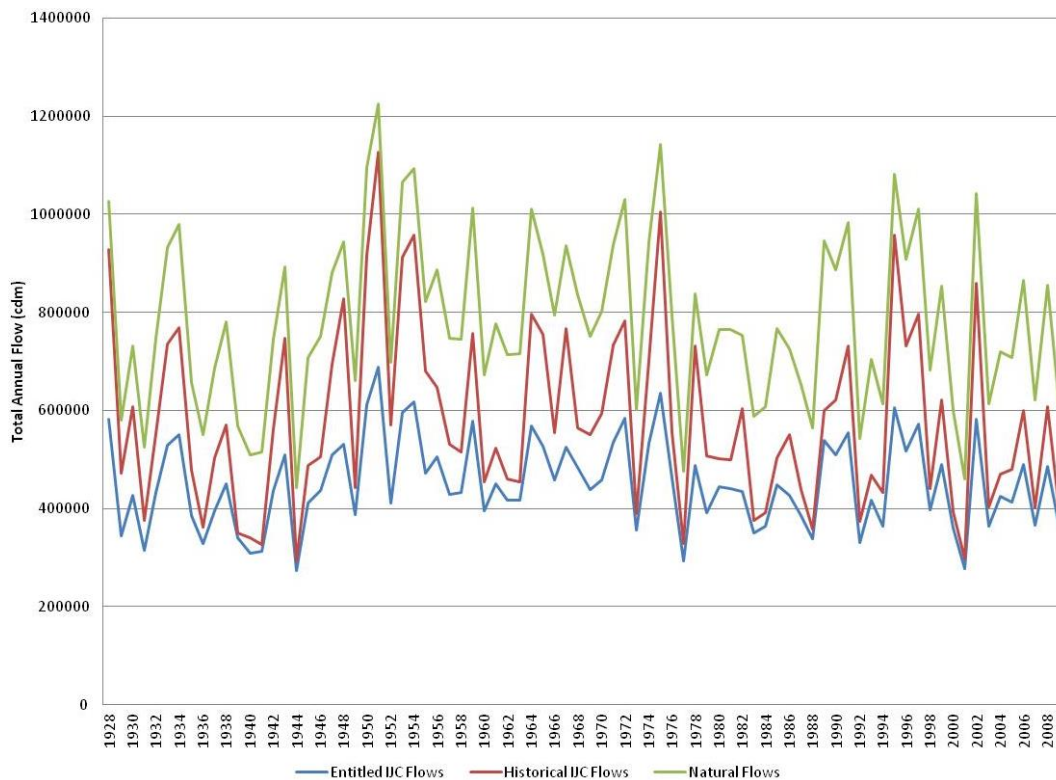


Figure 9: Total annual flow from the St. Mary River

The blue line represents the minimum entitled IJC flow, the red line represents IJC flow historically observed during the period, and the green line represents naturalized flow at the US–Canadian border if no diversions took place on the US side.

As the figure shows, in low flow years such as 2000 and 2001, Montana withdrew almost its full entitlement. Conversely, in normal and high flow years, Montana’s withdrawal was proportionally lower. If Montana takes its full allotment, the volume of water coming into Alberta will be substantially reduced and water management decisions will need to take this into account. Adaptation strategies were developed using a conservative approach in which the modelling assumed the IJC flow to which Alberta is entitled was received, not the flow that has historically been received.

Apportionment requires ~50% of annual flow by volume be passed to Saskatchewan.

Under the Master Agreement on Apportionment, 50% of the annual flow by volume of eastward-flowing rivers must be passed from Alberta to Saskatchewan. Historically, the average annual flow to Saskatchewan has been more than 75%. Fifty percent is a minimum and reflects choices and trade-offs of water use, but the river ecosystem benefits from these higher, closer-to-natural flows. Each sub-basin contributes to meeting the Apportionment Agreement. Figure 10 shows the contribution from each sub-basin to meet the apportionment requirement.

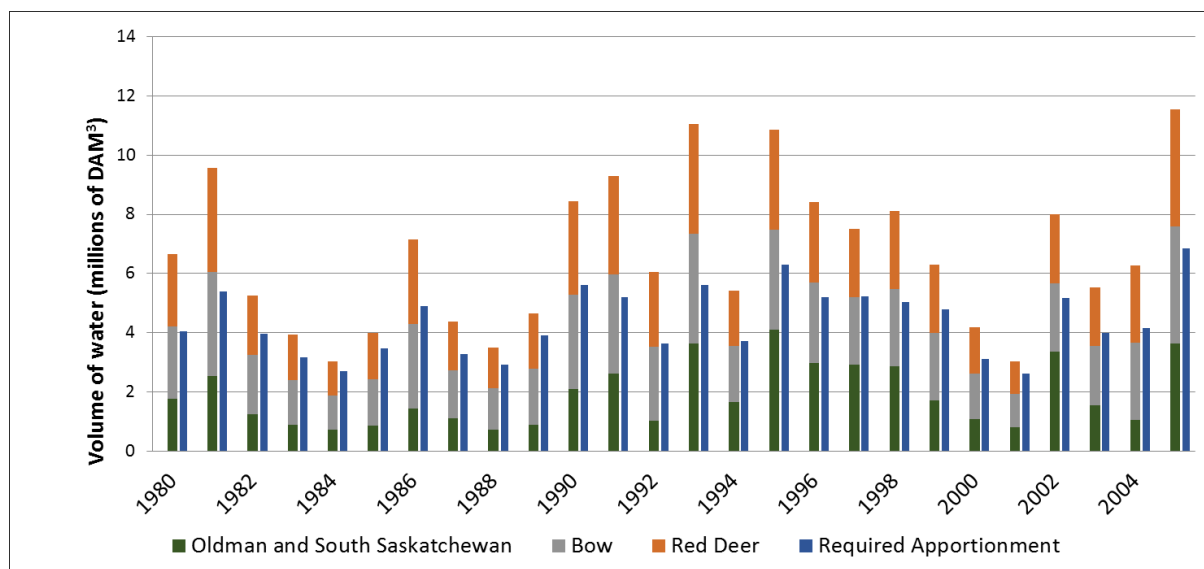


Figure 10: Contribution to total South Saskatchewan flow by source sub-basin (historical)

Further reducing minimum flows could negatively affect aquatic ecosystems.

Many river reaches in the SSRB are already stressed and strategies that contemplate further reductions to minimum flow rates during times of drought could have serious impacts on the aquatic ecosystem. For example, an established minimum flow rate of 400 cfs (11.3 m³/s) below Bassano Dam takes into account the higher flows needed downstream from Calgary to enable the EID to take its licensed allocation of water for irrigation and municipal purposes and still meet this flow rate. The original BROM project recommended that this minimum flow be increased substantially and showed how this could be done using a relatively small water bank held in TransAlta reservoirs upstream and released to improve minimum environmental flows throughout the Bow system to and below the Bassano Dam.

During a prolonged or extreme drought period, one of the mitigation strategies was to reduce the minimum flow through Calgary for short periods of time. The current 1250 cfs (35.4 m³/s) minimum flow through Calgary helps sustain fish habitat through the winter and helps with wastewater dilution and maintenance of minimum dissolved oxygen levels. It also helps maintain a stable ice regime so that stormwater outlets can continue to function in case of a chinook or winter run-off event, apart from direct damages that might occur due to ice jams. There is also minor benefit for one of the city's two water intakes as it is more likely to function properly with flows above the threshold. Depending on the reduced flow rate contemplated, this could have serious consequences for water quality downstream and eventually could significantly stress the aquatic ecology of the river system. On the other hand, maintaining current minimum flows in a prolonged drought could risk much lower levels once the upstream reservoirs fall below their operating levels.

Municipal minimum flows at some level are necessary to dilute even tertiary treated wastewater effluent and to protect other environmental conditions and values. Return flows from Calgary may average well over 80% year around, but during summer months this return

rate often drops, largely due to irrigation of lawns, parks and recreation areas. During a dry or drought period, lower minimum flows from TransAlta at the Bearspaw Dam entering Calgary's reach of the river combined with WID withdrawals and slightly reduced return flow from the city can have negative downstream effects on the environment due to a greater concentration of nutrients. Low flows and high water temperature can affect fisheries and the ability of irrigation districts to take water for food production. This illustrates again the need for a more comprehensive and system-wide approach to managing the component parts of the SSRB as an interdependent system rather than a series of isolated and single-purpose sections of river (e.g., hydropower, recreation, human water supply, livestock water supply, recreational fishery, food production, riparian health and wildlife corridors, and quality of life). All are important, all are interrelated, and many are synergistic if the rivers were managed with this in mind.

The EID and WID return flows to the Red Deer River contribute significantly to meeting that system's WCOs.

Water taken by the EID and WID from the Bow River but returned to the Red Deer River plays a surprisingly important role in the lower Red Deer system, especially in times of low flows. This only became evident when the sub-basin models were integrated into the SSROM. The Red Deer presently has little difficulty maintaining the 10/16 m³/s (summer/winter) minimum flow of the WCO, but when the full licence allocation scenario used in SSROM is applied, the WCO is violated in a number of weeks (Figure 11). This is primarily because most existing licences are senior to the WCO. To explore the return flow impact, the EID and WID return flows were removed completely or reduced to only 10%, resulting in WCO violations increasing by about 75%. To demonstrate the acute difficulties during these periods, Figure 12 shows flows at the Red Deer mouth during 1929–1930 of the historical run.

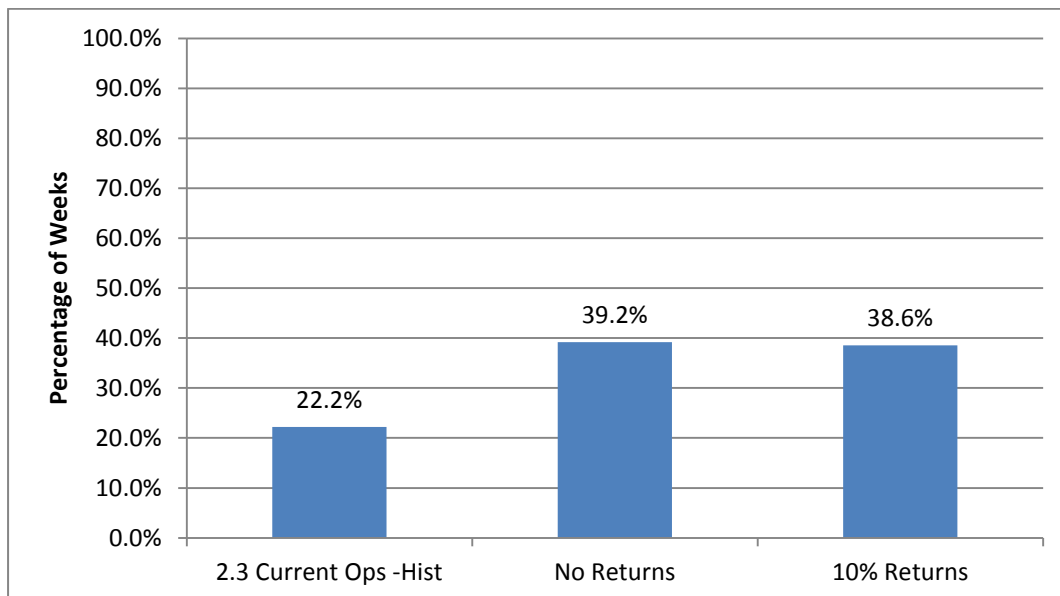


Figure 11: Percentage of weeks in the historic record where average weekly flow at the mouth is less than the WCO flow threshold in the Red Deer system

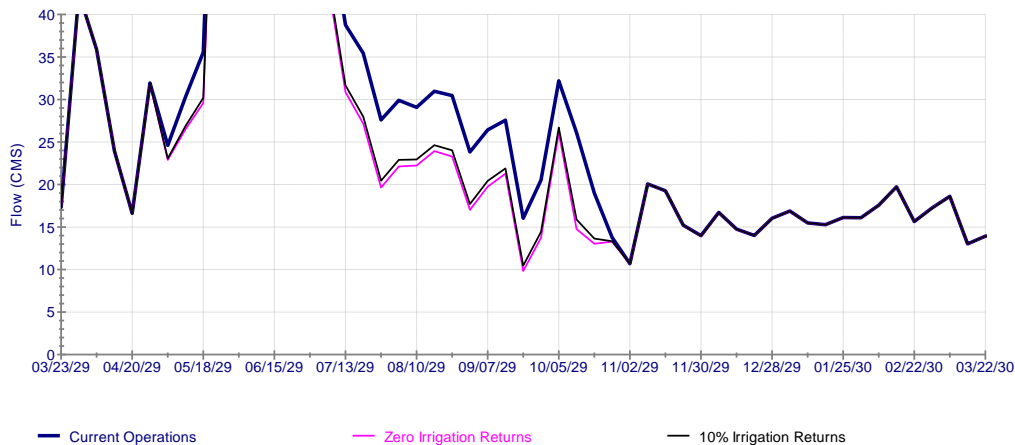


Figure 12: Flows at the Red Deer mouth, 1929–1930 of the historical run

To see the results of interest (low flows) at an appropriate scale, the upper part of the figure is cut off.

During certain times of the year, especially during relatively dry years in the Bow sub-basin (causing greater use of the available water) or the Red Deer sub-basin (reducing base flows), or both, unused water from the WID and EID taken from the Bow and normally redirected to the Red Deer would likely be reduced at exactly the time it may be most needed for environmental purposes in the Red Deer. As irrigation districts achieve continued conservation and efficiency, it is likely that these return flows will fall in the coming years. If the WCO is to remain a top priority, operators will have to be attentive to this trend.

Irrigation district expansion will continue to be enabled through improved conservation, efficiency and productivity, not through increased withdrawals from the rivers.

Irrigation is the major water use in southern Alberta and has played an important role in Alberta's agriculture sector for over a century. Irrigation districts are major water users, holding licences for 85% of the water allocated in the OSSK sub-basin and for 75% of allocations in the Bow sub-basin. They continue to make efficiency improvements, which has enabled them to expand their acreage and amend their licences to allow their allocated water to be used for other purposes. The GoA's 2014 Irrigation Strategy¹⁶ describes five key strategies for the future of the industry: productivity, efficiency, conservation, water supply, and environmental stewardship. The irrigation sector, through the Alberta Irrigation Projects Association, has published a Water Conservation, Efficiency and Productivity (CEP) Plan, which describes the commitments made by the industry.¹⁷ Improvements in water CEP rather than increased water withdrawals will be the basis for future irrigation district expansion.

¹⁶ Available online at [http://www1.agric.gov.ab.ca/\\$department/deptdocs.nsf/all/irr14885/\\$file/2014-alta-irrig-strategy.pdf](http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/irr14885/$file/2014-alta-irrig-strategy.pdf)

¹⁷ This report is available on the AIPA website at <http://www.aipa.ca/wp-content/uploads/2013/11/AIPA-CEP-Final-Version-1.pdf>.

Building new water management infrastructure should build adaptive capacity; it should not lead to new licence allocations in closed sub-basins.

Although opportunities for new infrastructure were considered as part of adaptation to climate variability, participants pointed out the need to maintain current allocations in closed sub-basins. Increased storage capacity could make it tempting to increase allocations, but storage does not make more water available in a watershed. Given the real risk to current licensed water users from both historic and climate variability scenarios of water supply, additional storage and other infrastructure improvements were considered as reducing risk rather than enabling additional licensing. Current licensees that are not using their full allocation should also be given incentives to refrain from using a greater percentage of their licence to the extent possible. Under the *Water Act* and regulations it may also be advisable as a risk mitigation tool to recover certain wholly unused licence allocations in accordance with the Alberta Water Council's 2009 report, *Recommendations for Improving Alberta's Water Allocation Transfer System*.¹⁸

Connections among sub-basins mean that building new infrastructure in one sub-basin could yield benefits in another.

Integrating work across the entire SSRB underscored the importance of looking at and understanding the connections and interactions among the sub-basins. This was particularly highlighted when considering the advantages that could accrue to one sub-basin by building new infrastructure in another sub-basin. For example, new storage capacity built in the Lower Bow to catch any flow above minimum flow and apportionment requirement could benefit the Oldman system. In addition to the modelled benefits to the Bow system, the new storage could be used to meet minimum flows and apportionment requirements rather than drawing on the existing Oldman reservoirs, potentially enabling greater resilience and mitigation of a dry period or multi-year drought in the south.

Operations of TransAlta reservoirs on the Bow interact with many of the other potential adaptation strategies for this river system.

Nearly all of the large scale, near-term flood and drought mitigation options on the mainstem of the Bow are related to how the TransAlta reservoirs are operated. Stated in its most simple and direct form, water management on the Bow River must engage and involve the operation of TransAlta's upstream reservoirs and hydro operations. Even if various proposed "dry dams" are built on the Bow and some tributaries, TransAlta operations would still have a strong bearing on if, when and how these other structures could be used. TransAlta owns and operates 11 hydro generation facilities upstream of Calgary, encompassing five reservoirs of significant size including, from the lowest site in the system to the highest, Ghost, Barrier, Upper Kananaskis Lake, Spray Lake, and Lake Minnewanka.

The TransAlta reservoir system is highly interdependent over the course of any given year, although each upstream reservoir can store and release as needed until it impinges on the

¹⁸ Available on the Alberta Water Council's website at:
<http://www.awchome.ca/LinkClick.aspx?fileticket=fVWx%2b%2b%2fwG3A%3d&tabid=59>

capacity of the lower system to fill or release. For example, if all the reservoirs upstream of Ghost released at full capacity, Ghost may be unable to manage all the inflows and be forced to use the emergency spillway in addition to the turbines and dam spillways. The consequences for Bearspaw Dam downstream may be catastrophic. This is a condition to be avoided by managing all the reservoirs in combination, depending on inflows and reservoir elevations (available storage), rather than as independent entities based on various physical contingencies, power prices and the complexities of ancillary services provided mostly by the Spray group of facilities.

The forecasting window in the SSRB is extremely short; investment in forecasting resources and systems are imperative for ongoing adaptation.

There are many risks and trade-offs to be considered in system-level water management. To manage flood and drought risks, a more comprehensive and multi-factor forecasting system is needed to guide water managers and regulators. This is true of all the sub-basins in the SSRB, but the most urgent need is for drought and flood management on the Bow system. Some of these factors include the obvious ones of snowpack, reservoir levels, streamflow data, and rainfall forecasts throughout the system compared with similar previous years, combined with licence allocation data and historic use patterns. Possibly the most important forecast for flood mitigation is reliable rainfall forecasts and accurate precipitation monitoring at a small grid size to allow for more advanced flow modelling and warning of coming flooding conditions. Other existing but perhaps less well-known data sources are available to inform water management decisions, such as soil moisture content in the foothills and in the agricultural areas as well as shallow groundwater levels in the upper basin. Depending on the time of year, other factors include the composition of agricultural crop acreage; crop planting plans, timing and expected water demands for irrigated crops; seasonal demands for municipal use and expected return flows; livestock numbers and type and their expected water demands; industrial water use and operational vulnerability (e.g., meat packing, thermal power, or fertilizer production); water quality data; short-, medium- and long-term precipitation forecasts and trends; and hydropower demand and pricing.

The uncertain length of a drought makes it challenging to develop management responses.

Once a drought begins, it is impossible to know how long it will last, and this makes water management very challenging. Irrigation districts, for example, will typically aim to maximize yield from the crop that is already in the ground rather than cut back in the first year of a drought to reserve more water to carry over in case a dry year occurs next year. Management options become more limited the longer a drought lasts. The recent California and Australian droughts provide clear evidence of this and illustrate the need for early action, careful stewardship of the remaining stored water, and improving the forecast system. Most of the existing infrastructure in the SSRB is sized for a one-year operational cycle—that is, one year of filling and emptying. This would accommodate a one-year drought and, in some cases, with prudent management could provide help for two years, but by the third year, the reservoirs may be empty or nearly so. Once the reservoirs are unable to continue supplying water, streamflow would be seriously depleted leading potentially to great harm to fisheries and environmental conditions generally, and to significant shortages for both rural and urban water users. Everyone would be affected.

Flood mitigation and drought mitigation can be achieved in the same season, but not at the same time using the same infrastructure capacity.

A number of the more promising adaptation strategies seek to achieve a balance between mitigating flood and mitigating drought. However, there is a natural tension between these two situations, and planning for one can increase the risk of being unprepared for the other. For example, filling a reservoir in the spring to be ready to meet downstream needs could mean that there is no room to retain water in the event of a flood. Keeping a reservoir well below full supply level (FSL) to accommodate possible flood flows could result in a shortage for downstream users later in the year if a flood does not materialize and rainfall is limited. However, a structure such as the Eyremore Dam (a Level 3 strategy) would have enough time to make pre-releases as a major rain event was happening in the headwaters, so it would offer significant flood mitigation capacity.

Under some conditions it is quite possible to have both a flood and a drought in the same year. This risk is greater if the snowmelt and flood flow come earlier in the year as is often forecast by climate change models. Accurate forecasts based on a variety of factors described previously are an essential component of adaptive basin management that balances flood and drought risks and mitigation actions.

3.2 Adaptation Roadmap for the SSRB

The Adaptation Roadmap for Sustainable Water Management in the SSRB is shown in Figure 13. It includes adaptation strategies ranging from operational changes, to natural functions to new infrastructure to policy options, which are ultimately designed to increase the SSRB's adaptive capacity to changing inflows and demands.

Through a series of projects since 2010, a large number of adaptation strategies were considered for each of the sub-basins in the SSRB. Some of these suggested strategies are already underway but more work is needed. The most promising strategies for each sub-basin emerged through collaborative modelling and discussion. All the adaptation strategies that were explored have been documented and described in the relevant sub-basin project reports. Participants in this project were asked to identify and consider strategies that could offer potential benefits between sub-basins and across the full SSRB.

SSRB Adaptation Roadmap

Increasing degrees of adaptive capacity →

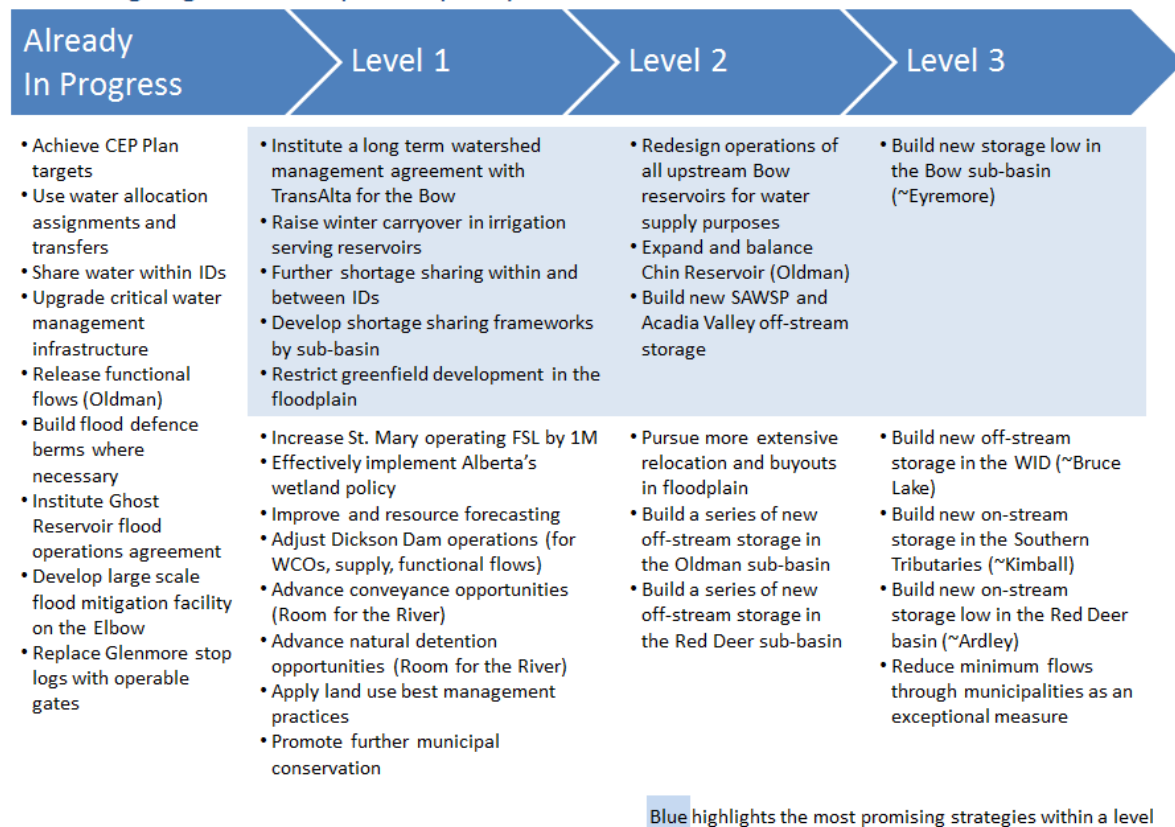


Figure 13: Schematic of the SSRB Adaptation Roadmap demonstrating all three levels of adaptation as well as what is already in progress

Strategies were then grouped into three levels that reflected “degrees of adaptation.” The Levels are not meant to be read chronologically and are not related to time; rather, they reflect an increasing level of adaptive capacity with those in Level 1 viewed as the most feasible options for increasing the adaptive capacity of the SSRB. Levels 2 and 3 include additional strategies that could be pursued to build more adaptive capacity into the basin’s water management systems. Based on the modelling results, some strategies within each Level were further categorized as “most promising.” Firm criteria were not established or used to identify “most promising” strategies. However, through the course of discussion, typically-used considerations of relative simplicity, perceived cost, beneficial impact and contribution to resilience were used to distinguish the “most promising” strategies from the others within a Level.

Although the strategies and text in this report use the term “build” with reference to infrastructure, this should not be interpreted as a recommendation or advice to construct that infrastructure; no construction would be started before detailed studies are undertaken.

The strategies that are already underway and those in each of the three Roadmap levels are listed in Table 4, along with other sources that discuss the strategies further or provide related information; references for these sources are shown below the table. Strategies with an asterisk (*) are not currently modelled in the SSROM, typically due to limited data. Less promising strategies from the SSRB integration project and strategies from previous sub-basin work are shown in Appendix F.

Table 4: Individual adaptation strategies

| Strategy | Sub-basin | Other sources |
|--|------------|-----------------|
| Strategies in progress but still needing work | | |
| Achieve municipal and agricultural Conservation, Efficiency and Productivity Plan targets | Basin-wide | 1, 2 |
| Use licence assignments and transfers to optimize use of water allocations* | Basin-wide | 3 |
| Temporarily share or assign water within irrigation districts in dry seasons | Bow, OSSK | 5, 10 |
| Upgrade critical water management infrastructure to minimize damage and ensure operation in case of floods (Bassano,* Travers, Taylor Coulee Wasteway,* Bullhorn Wasteway*) | OSSK | 5 |
| Release functional flows from the Oldman and St. Mary dams | OSSK | 5, 15, 16 |
| Build flood defence berms in the Red Deer, South Saskatchewan and Bow sub-basins where necessary* | Basin-wide | 6, 9 |
| Develop a large scale flood mitigation facility on the Elbow River (SR1, MC1, tunnel)* <i>(The GoA announced on October 26, 2015 it would be proceeding with the off-stream reservoir at Springbank, referred to as SR1.)</i> | Bow | 6 |
| Replace Glenmore Dam stop logs with operable gates | Bow | 6 |
| | | |
| Level 1: | | |
| Most promising strategies | | |
| Institute a long-term, flexible and comprehensive water management agreement for drought mitigation, flood mitigation, and watershed health with TransAlta, including: water bank for river basin management purposes, flexibly stabilizing Lower Kananaskis Lake and Kananaskis River, flood mitigation using Ghost Reservoir and other reservoirs, functional flow releases as needed for riparian and fisheries health, and adjusted fill times for Minnewanka, Spray, and Upper Kananaskis Lakes | Bow | 4, 5, 9, 15, 16 |
| Raise winter carryover in existing irrigation-serving reservoirs (start with Travers which draws water from the Bow, then investigate feasibility for the St. Mary, McGregor and other reservoirs) | Bow, OSSK | 5 |
| Implement further forecast-based shortage sharing (including agreed-upon temporary reductions in diversions and voluntary assignments of remaining licence allocations in times of drought), within and between irrigation districts | Bow, OSSK | 5, 12 |
| Develop basin-wide shortage-sharing and reallocation frameworks to inform and enable severe drought mitigation* | Basin-wide | 5, 10, 13 |
| Restrict greenfield development in the floodplains to reduce flood damage and develop strict regulations against changing the nature of brownfield developments* | Basin-wide | 6, 9, 14 |
| And | | |
| Increase St. Mary Reservoir operating FSL by 1 metre | OSSK | 5 |

| Strategy | Sub-basin | Other sources |
|---|---------------|---------------|
| Effectively implement Alberta's Wetland Policy* | Basin-wide | 11 |
| Improve resourcing for and effectiveness of forecasting infrastructure, systems and teams* | Basin-wide | 4, 6, 12 |
| Adjust Dickson Dam operations to consider downstream needs (retain WCOs, functional flows, some new demands) | Red Deer | 9, 15, 16 |
| Advance Room for the River conveyance opportunities in the Bow and Red Deer sub-basins* | Bow, Red Deer | 7, 8 |
| Advance Room for the River natural detention opportunities in the Bow and Red Deer sub-basins* | Bow, Red Deer | 7, 8 |
| Further apply land use best management practices* | Basin-wide | 4, 5, 9 |
| Promote further municipal conservation relative to what is being done now | Basin-wide | 4, 5, 9 |
| Level 2: Most promising strategies | | |
| Redesign operations and expand, where beneficial, existing reservoirs in the upstream Bow for water supply and watershed health* | Bow | 4 |
| Expand (74,000 dam ³) and fully balance Chin Reservoir (285,000 dam ³) | OSSK | 5 |
| Build new SAWSP and Acadia Valley off-stream storage (35,000 dam ³ SAWSP + 45,000 dam ³ Acadia = 80,000 dam ³ total) | Red Deer | 9 |
| And | | |
| Pursue more extensive relocation and buyouts in the Bow and Elbow floodplains to reduce risk and reduce the need for upstream mitigation structures* | Bow | 6, 14 |
| Build series of new off-stream storage facilities* | Oldman | 5 |
| Build series of new off-stream storage facilities (~80,000 dam ³)* | Red Deer | 9 |
| Level 3: Most promising strategies | | |
| Build new on-stream storage low in the Bow system, below Bassano Dam (~Eyremore site, ~477,000 dam ³) | Bow | 4 |
| And | | |
| Build new off-stream storage in the Western Irrigation District (Bruce Lake, ~51,000 dam ³) | Bow | 4 |
| Build new on-stream storage in the Southern Tributaries balanced with other reservoirs (~Kimball site, ~125,800 dam ³) | OSSK | 5 |
| Build new midstream storage (~Ardley site, ~400,000 dam ³) | Red Deer | 9 |
| Reduce minimum flows through municipalities and other downstream users as an exceptional measure in drought years to slow the draining of upstream reservoirs | Basin-wide | 4, 5, 9 |

- 1 Alberta Irrigation Projects Association. nd. Irrigation Sector Conservation, Efficiency, Productivity Plan 2005 – 2015.
- 2 Alberta Urban Municipalities Association. 2009. AUMA Water Conservation, Efficiency and Productivity Plan.
- 3 Alberta Water Council. 2008. Recommendations for Water Conservation, Efficiency and Productivity Sector Planning.
- 4 Alberta WaterSMART. 2010. Bow River Project: Final Report.
- 5 Alberta WaterSMART. 2014. South Saskatchewan River Basin Adaptation to Climate Variability Project: Phase III: Oldman and South Saskatchewan (OSSK) River Basins Summary Report.

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- 13 Paterson Earth & Water Consulting. 2014. Drought Strategy for Irrigation Districts in the Oldman River Sub-Basin of Southern Alberta.
- 14 Pomeroy, J., R.E. Stewart, and P.H. Whitfield. 2015. The 2013 flood event in the Bow and Oldman River basins; causes, assessment, and damages. (in press)
- 15 Rood, S.B., G.M. Samuelson, J.H. Braatne, C.R. Gourley, F.M.R. Hughes, and J.M. Mahoney. 2005. "Managing river flows to restore floodplain forests," in *Front. Ecol. Environ.* 3(4): 193-201.
- 16 Rood, S.B., S. Kaluthota, K.M. Gill, E.J. Hillman, S.G. Woodman, D.W. Pearce, and J.M. Mahoney. 2015. "A twofold strategy for riparian restoration: combining a functional flow regime and direct seeding to re-establish cottonwoods," in *River Res. Applic.* DOI: 10.1002/rra.2919

The next section presents a comparison of the expected results of each Level of the Roadmap using common PMs to illustrate the magnitude of change obtained from the implementation of each Level. Following that, the remainder of this section provides additional description and specific benefits relevant to each of the strategies within the three Levels.

The work described in this report was recognized as a screening level study, after which most strategies would require more detailed study (e.g., cost-benefit analysis, engineering feasibility studies, environmental impact assessments, socio-economic analysis, consideration of impacts on landowners and First Nations).

3.2.1 Roadmap Results: Comparison of Levels using Performance Measures

This section compares the different adaptive levels to show the increased resilience gained from one Level to the next. Levels are compared using relevant PMs.

The number of low flow days at Bassano and Carseland is a good indicator for ecosystem health and water availability in the Bow River sub-basin. One objective of building resiliency in the SSRB is to decrease the number of low flow days throughout the river system. Resiliency can be achieved through Level 1 of the Adaptation Roadmap with the implementation of the water bank as part of a watershed agreement with TransAlta. Level 3 shows slight increases in the number of days where flow is between 400 and 800 cfs (11.3 and 22.6 m³/s) in Frankenflow (Figure 14A). This is because the Bow River Irrigation District (BRID) has the capability to take extra water with the addition of the Eyremore reservoir.

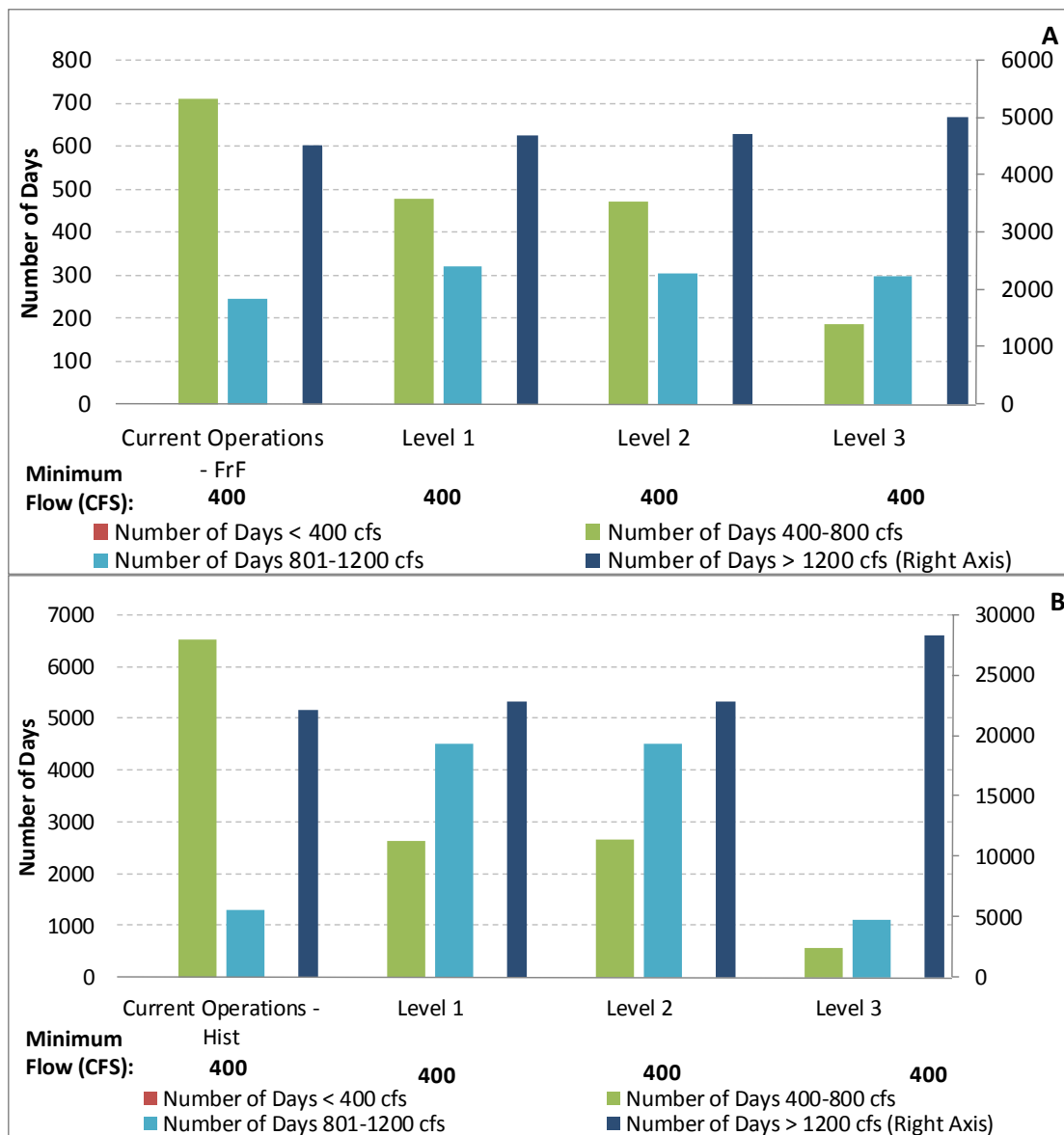


Figure 14: An inter-level comparison of the number of days in flow categories under 15-year Frankenflow (A) and 1928–2009 Historical (B) periods, where the objective is to decrease the number of days in low flow categories

Note: Values shown for current operations, Level 1, and Level 2 are for Bassano; values shown for Level 3 are for Carseland.

The percentage of weeks where average weekly flow at the mouth of the Red Deer is less than the WCO is a good indicator of the capacity of the Red Deer system to expand while meeting required flows during low flow periods (Figure 15). Operational and infrastructure changes implemented from Level 1 to Level 3 demonstrate continual improvement by decreasing the percentage of weeks that are lower than the WCO in Frankenflow (FrF) and the Historical periods. The largest change is noticeable between Levels 1 and 2, with the implementation of new off-stream storage (Figure 15). This allows for greater flexibility and increased capacity to meet demands throughout the Red Deer sub-basin.

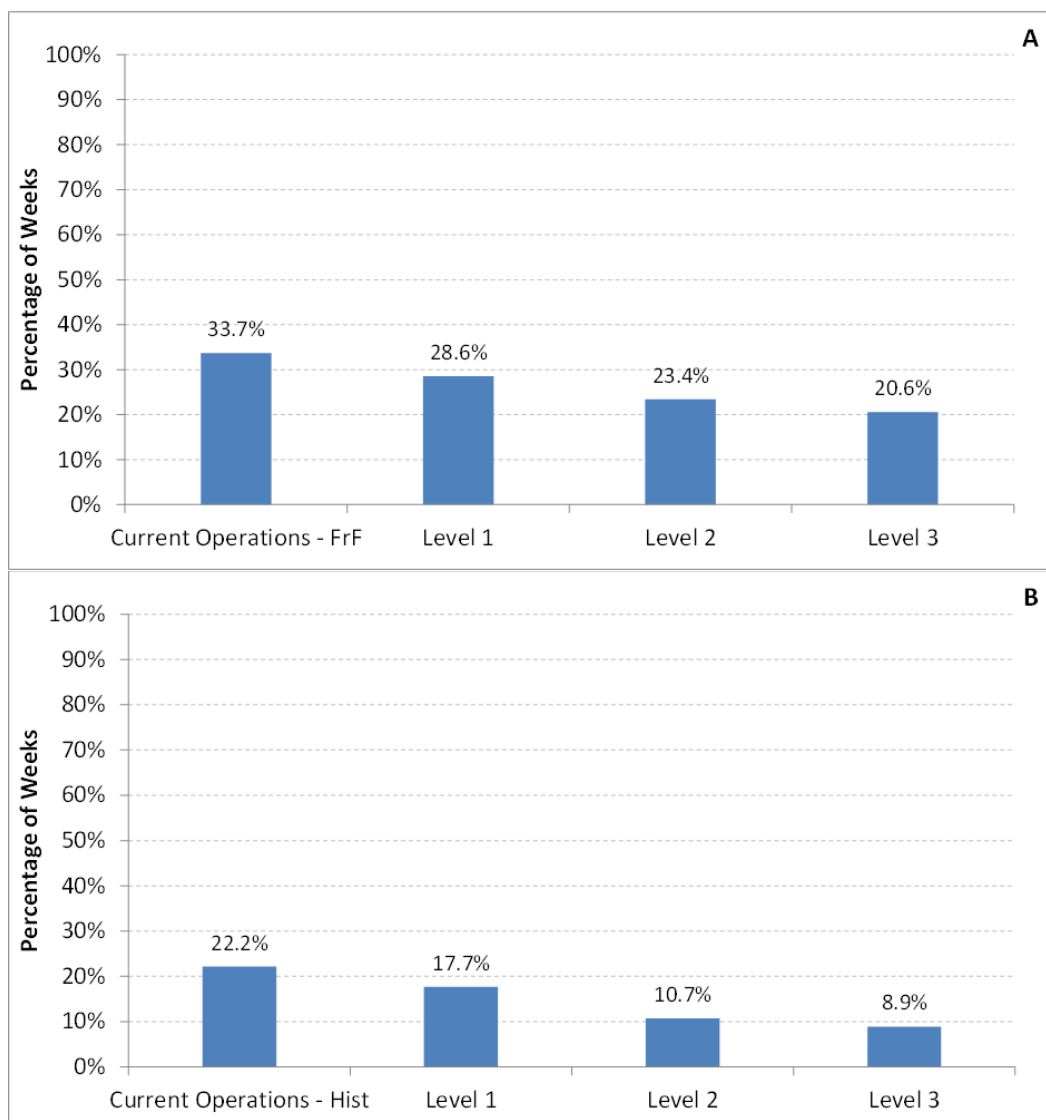


Figure 15: An inter-level comparison of the percentage of weeks where weekly average streamflow (m^3/s) is lower than the WCO (45% of natural or $16 \text{ m}^3/\text{s}$ from November to March and $10 \text{ m}^3/\text{s}$ from April to October) at the mouth of the Red Deer River during the 15-year Frankenflow (A) and 1928–2009 Historical (B) periods

Note: The objective is to obtain a lower percentage of weeks below the WCO.

The largest change between Levels in the number of shortages was seen in the OSSK sub-basins. This change in shortages occurred primarily in the irrigation sector (Figure 16), given that irrigation demand was reduced through forecast-based shortage sharing, resulting in less demand for the water. Shortage reductions did not occur in the Bow sub-basin; this finding is important given that environmental performance was improved by allowing more water to remain in-stream during low flow periods.

Irrigation shortages in the Red Deer system were also substantially reduced due to increased off-stream storage. In the Historical period (Figure 16B), shortages go to zero, even at full licence use and

with substantial growth to 550,000 dam³ with new demands. Only a slight reduction in shortages occurred during Frankenflow, indicating that under extreme drought situations the effects of increased storage can be exhausted.

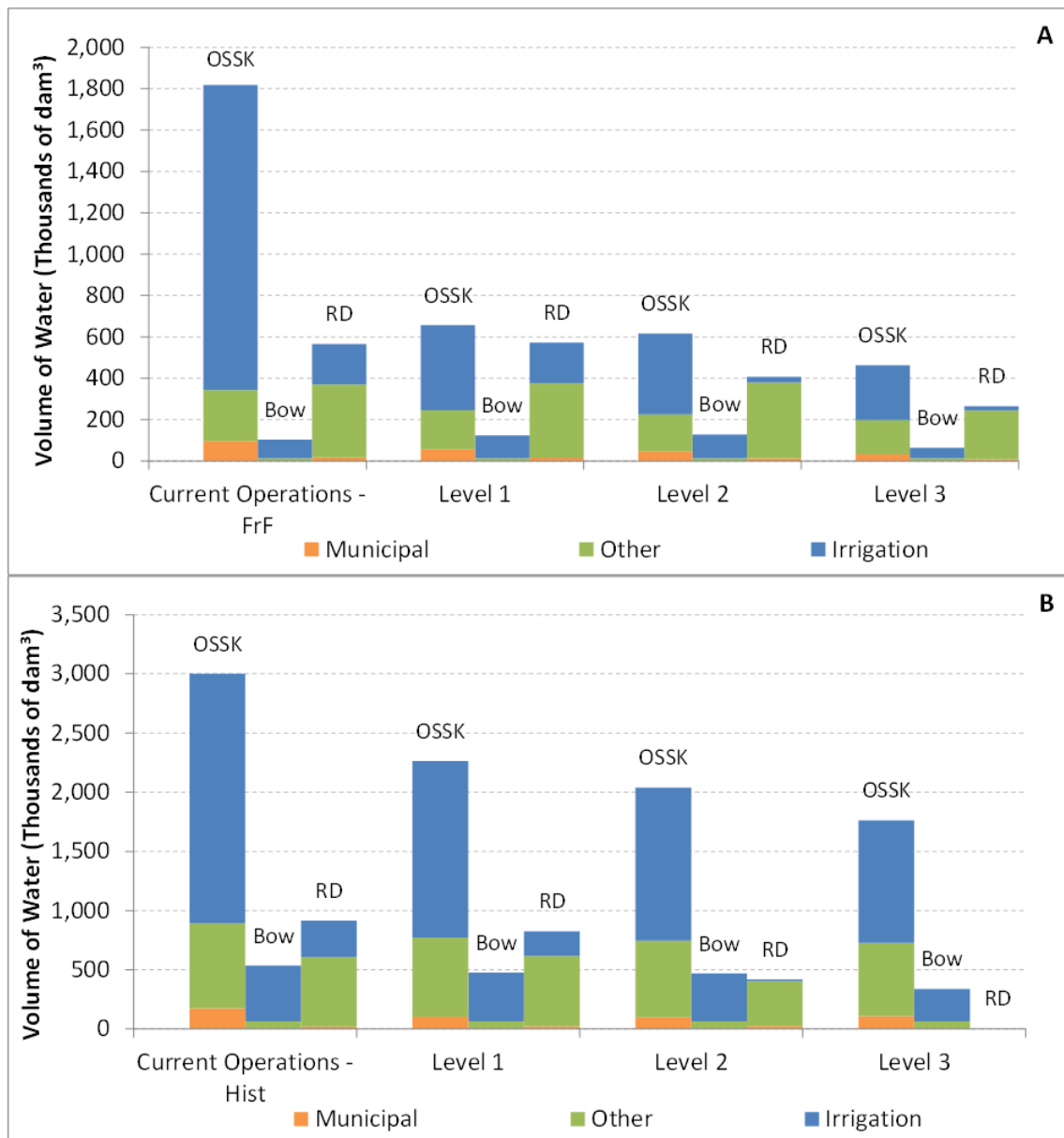


Figure 16: An inter-level comparison of the volume (dam³) of shortages to municipal (orange), other (green), and irrigation (blue) users in all three sub-basins during the 15-year Frankenflow (A) and 1928–2009 Historical (B) periods

Note: The objective is to decrease the volume of shortages.

In addition to shortages, environmental minimum flow violations are an excellent metric for evaluating system performance. Figure 17 presents the minimum flow violations for the Red Deer, Bow, and Oldman systems and demonstrates that violations can be reduced under Level 1. Although Level 1 has a number of benefits, changing the operational scheme can have unintended consequences; for

example, Level 1 operations also increase minimum flow violations in the Bow. This is only apparent in the Frankenflow simulation and when the TransAlta reservoirs are releasing extra water preceding a drought year. This extra release reduces available storage to meet minimum flow targets on the Bow near Calgary. In reality, and with good forecasting, operators may have the ability to foresee this type of situation and could take mitigation measures such as reducing releases, as was demonstrated in the 2011 drought simulation project. This increase in minimum flow violations does not occur in the historical scenario (Figure 17B).

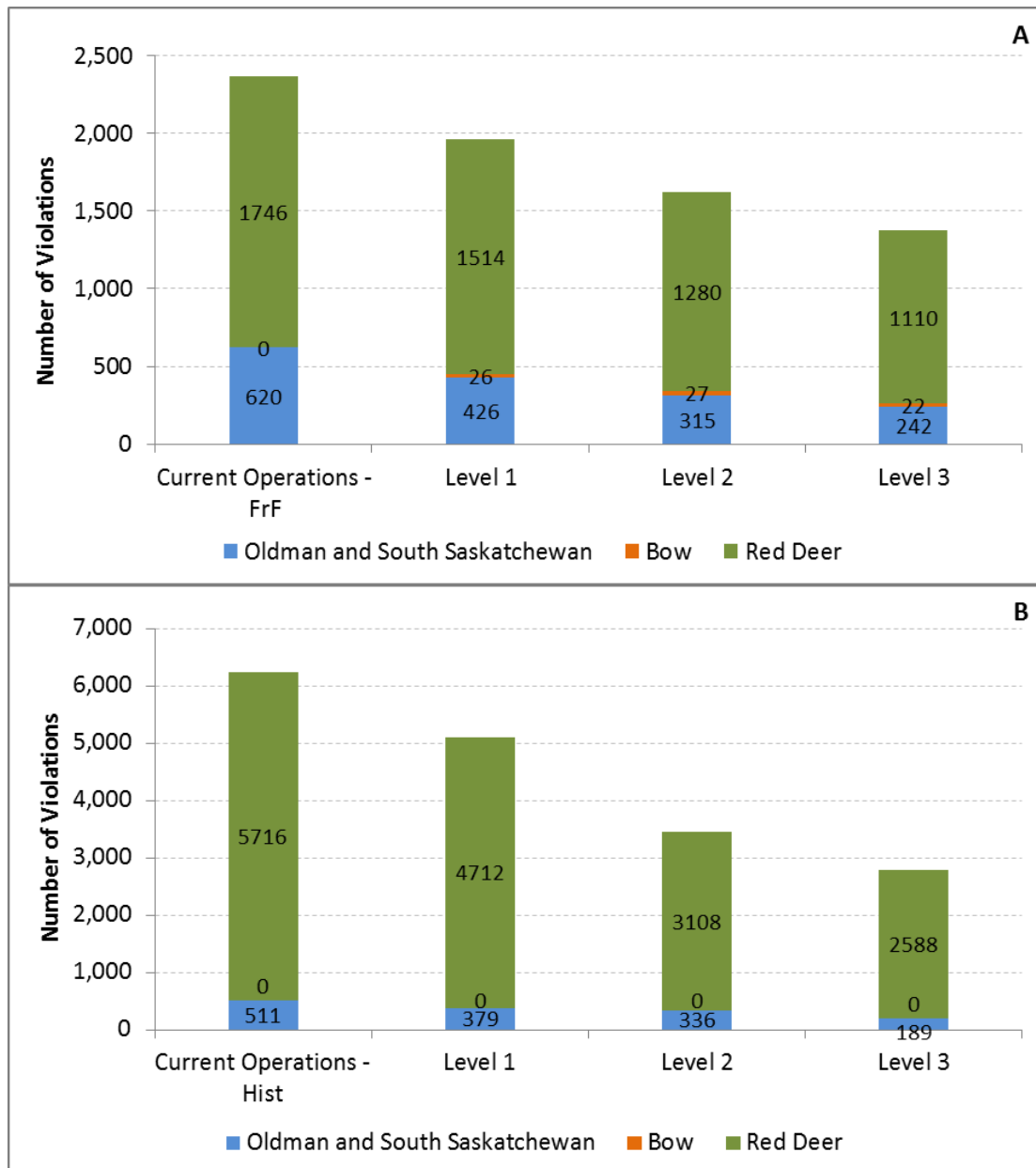


Figure 17: The number of minimum flow violations for the OSSK (dark blue), Bow (green), and Red Deer (light blue) systems, where, minimum flows are 11.5–20 m³/s at Lethbridge (Fish Rule Curve), 30 m³/s at Medicine Hat, 35.4 m³/s at Calgary, 11.3 m³/s at Bassano, and 10 or 16 m³/s at Bindloss (WCO). Results are shown for the 15-year Frankenflow (A) and 1928–2009 Historical (B) periods

The “20% of mean discharge” PM, seen in Figure 18, is an indicator of aquatic ecosystem health in the South Saskatchewan River at the Saskatchewan border (immediately after the confluence with the Red Deer River), integrating all SSRB sub-basins. Although profoundly beneficial in other areas, implementing Level 1 of the Adaptation Roadmap increased the number of days where streamflow is lower than the 20% mean annual discharge threshold under Frankenflow and Historical scenarios. This increase was due to increased storage carryover in Travers Reservoir during the winter. With the introduction of other strategies and additional storage and releases in Level 2, the negative effect is compensated for and further improved. Level 3 introduces Eyremore and releases substantial additional water from the new storage. This increased the streamflow in the South Saskatchewan during drought periods, resulting in a complete removal of days exceeding the threshold in Level 3 under both Frankenflow (Figure 18A) and Historical periods (Figure 18B).

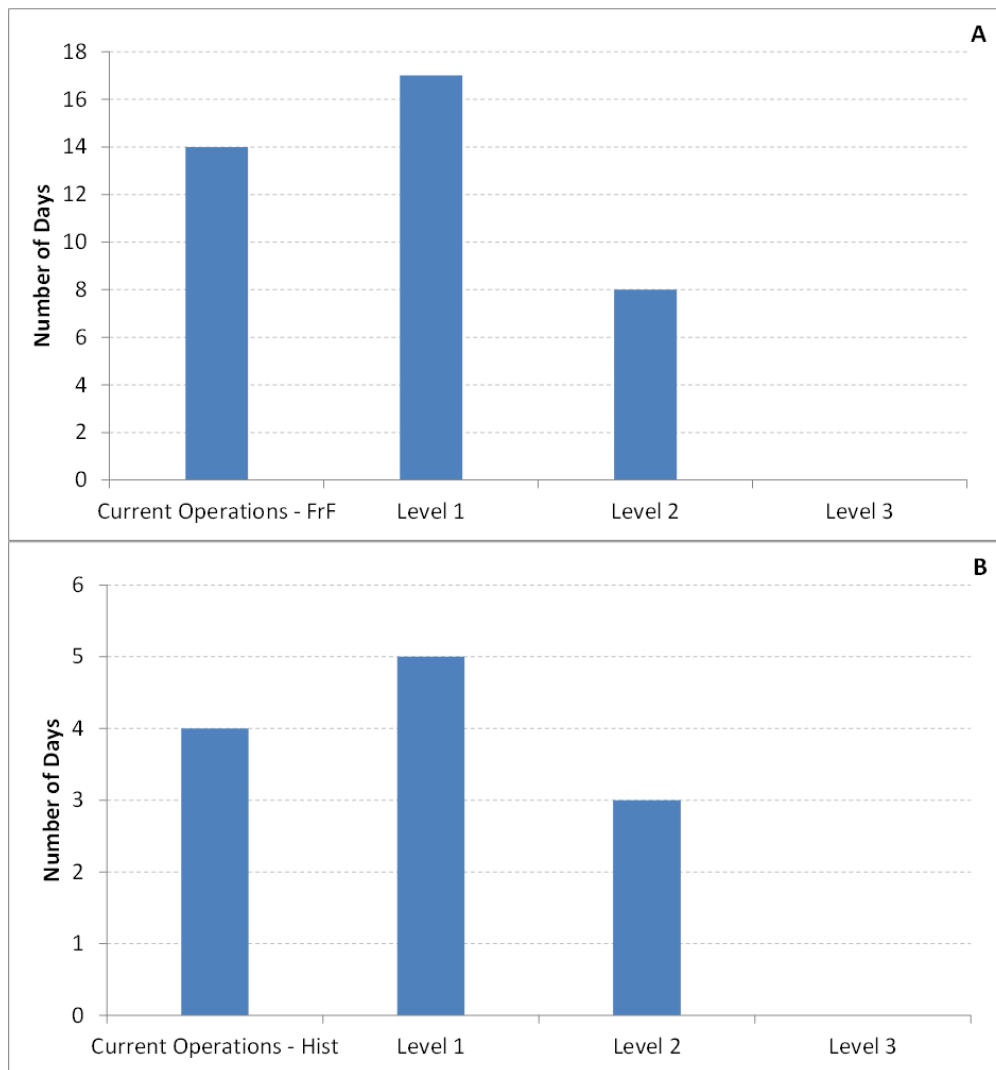


Figure 18: An inter-level comparison of the number of days where flows are below 20% of the average discharge (m^3/s) over the 15-year period in Frankenflow (A) and 1928–2009 Historical (B) periods

Note: The objective is to decrease the number of days.

3.2.2 Roadmap Strategies: Already In Progress

Water management in the SSRB is continually advancing as evidenced in the current performance of our water management operations. Many adaptive strategies have already been implemented and others are being advanced, as seen in Figure 19.

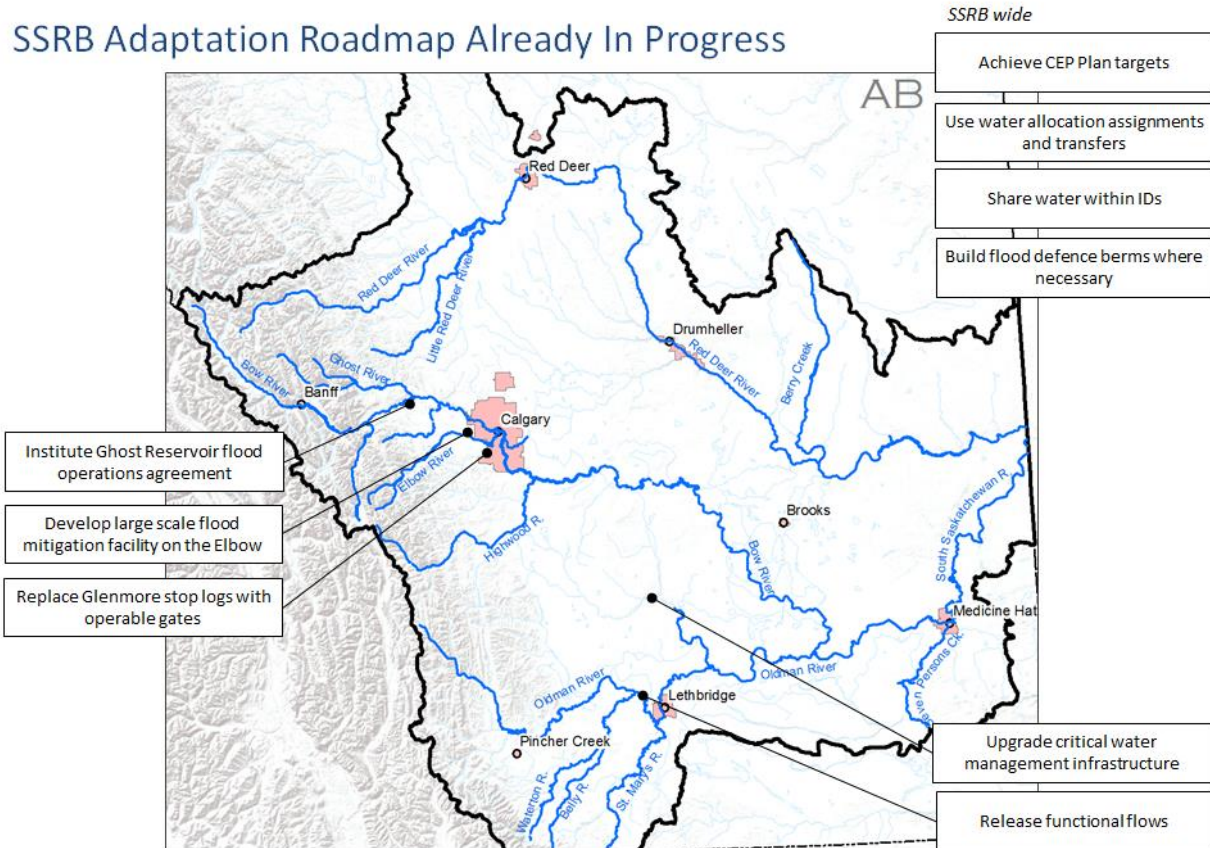


Figure 19: Map of the SSRB showing the adaptation strategies already in progress and their approximate location

At the foundation of adaptation is water conservation through careful management of agricultural, urban, and industrial water use coupled with technological advancements in water treatment, irrigation infrastructure and equipment, industrial cooling, household water applications, and other areas. Careful water use management has historically also involved the ability to optimize water allocations through licence transfers and assignments. This flexibility in the water management system enables adaptive measures to be applied during times of water scarcity, as demonstrated with decreases in irrigation demand during 2001 in the Oldman sub-basin.

In addition to water conservation, the adaptive capacity of the SSRB relies heavily on water management infrastructure, developed to manage streamflow for irrigation and municipal use and hydropower generation. Upgrading and maintaining this critical infrastructure is essential to ensure long-term operability and minimize the risk of flood and drought damage. The replacement of stop

logs with operable gates that will also increase the storage capacity of Glenmore Reservoir is an example of an infrastructure-based adaptive strategy that is underway. This improvement to the Glenmore Dam has the potential to offer substantial benefit during flood periods, even beyond what was demonstrated in 2013 when Glenmore operations enabled a significant reduction in flows downstream on the Elbow River. Increasing the capacity to capture streamflow from the Elbow River further enhances the ability of operators to manage flood flows.

Reservoir operation changes are also fundamental to developing the adaptive capacity of the SSRB. Many operational changes have occurred historically, such as the implementation of functional flows for restoring and enhancing riparian cottonwood and willow recruitment in the Waterton and Oldman rivers. The 2014 and 2015 agreements between the GoA and TransAlta for operating Ghost Reservoir for flood mitigation also demonstrate applicability of operational changes for managing high streamflows. Although extreme high streamflows were not observed in 2014, the Ghost Reservoir was operated to capture potential high flows by lowering the reservoir volume prior to the typical freshet period in June. These types of reservoir operations potentially offer substantial benefit in terms of minimizing the downstream risk of damage from flooding, but they should be informed by advanced forecasting capacity. More advanced forecasting capacity requires further resourcing for infrastructure, systems, and collaborative teams in all three sub-basins.

New infrastructure has been the focal point of much discussion after the flooding in 2013, particularly in the Bow and Elbow watersheds. Large-scale flood mitigation facilities have been discussed, including a dam on a tributary in the upper Elbow, an off-stream storage reservoir on the Elbow at Springbank, and a conveyance tunnel on the Elbow at Glenmore Reservoir. On October 26, 2015, the GoA announced it would be proceeding with the off-stream storage reservoir at Springbank.¹⁹ In addition to large-scale infrastructure, small-scale infrastructure has been constructed in numerous locations in all three sub-basins through the GoA-led Alberta Community Resilience Program (ACRP) and the Watershed Resiliency and Restoration Program (WRRP). It is expected that these types of projects will continue well into the future and will play a role in mitigating damage to infrastructure in the floodplain during high streamflow events.

Numerous strategies must be implemented strategically to develop a high level of adaptive capacity in the SSRB. The SSRB has proven resilient in the past but future climates, land use changes, human population growth, and a high range of natural streamflow variation all pose new challenges to water and watershed management. This project evaluated adaptive strategies that can be implemented to help increase the capacity of the basin to deal with these challenges. The following sections describe the results of the three presented levels of adaptation.

3.2.3 Roadmap Strategies: Level 1

The first level of adaptation relies largely on existing water management infrastructure while focusing on improving operations, establishing new frameworks, and implementing new and existing policy. Achieving the Level 1 adaptive capacity relies on a very wide range of strategies, which are shown in Figure 20. In the figure, the blue boxes represent the most promising Level 1 strategies. Strategies with an asterisk (*) in the text below are not currently modelled in the SSROM, typically due to limited data.

¹⁹GoA news release, October 26, 2015; <http://alberta.ca/release.cfm?xID=3873971607DE6-AA9E-CE00-9521CF82FC5D4567>

SSRB Adaptation Roadmap Level 1

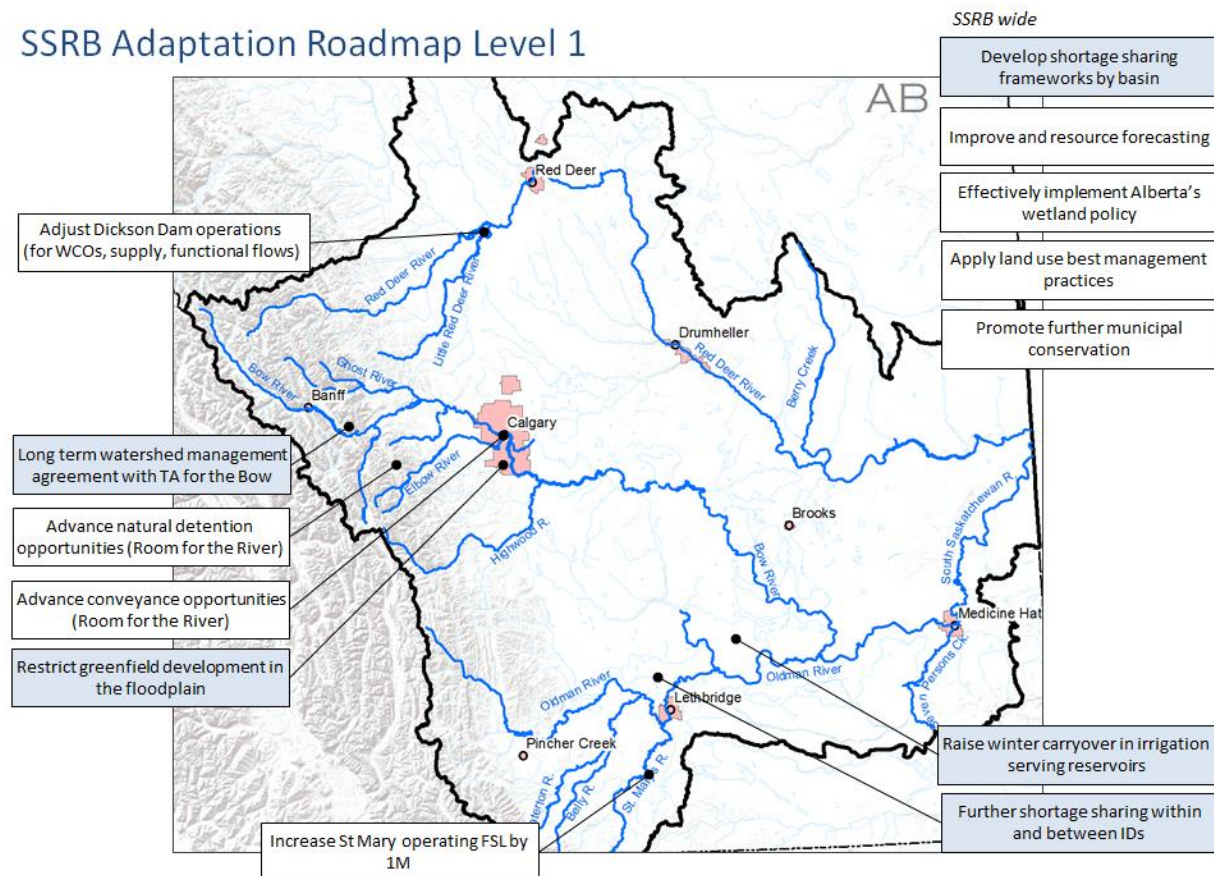


Figure 20: Map of the SSRB showing the adaptation strategies applied in Level 1 and their approximate location

This project identified the five “most promising” strategies in Level 1 through several working group meetings. These strategies are described below.

Institute a long-term, flexible and comprehensive water management agreement for drought mitigation, flood mitigation, and watershed health with TransAlta, including: water bank for river basin management purposes, flexibly stabilizing Lower Kananaskis Lake and Kananaskis River, flood mitigation using Ghost Reservoir and other reservoirs, functional flow releases as needed for riparian and fisheries health, and adjusted fill times for Minnewanka, Spray, and Upper Kananaskis Lakes

This comprehensive water management agreement would include the introduction of a water bank located in the TransAlta-operated reservoirs upstream in the Bow sub-basin governed to make releases in the interest of the whole sub-basin rather than solely for peak prices for hydropower generation. One version of the water bank strategy was modelled as being effective with 74,000 dam³ (60,000 acre-feet) of capacity accessing about 10% of the natural inflows which it then released for downstream environmental needs, in particular low flow

supplementation. Figure 21 shows an example of the water bank storage concept, where available stored water remaining extends through the summer and well into the fall. In this example, water bank releases exceed 74,000 dam³ because inflows of up to 10% of the total flow refill the water bank storage simultaneously as water is being released.

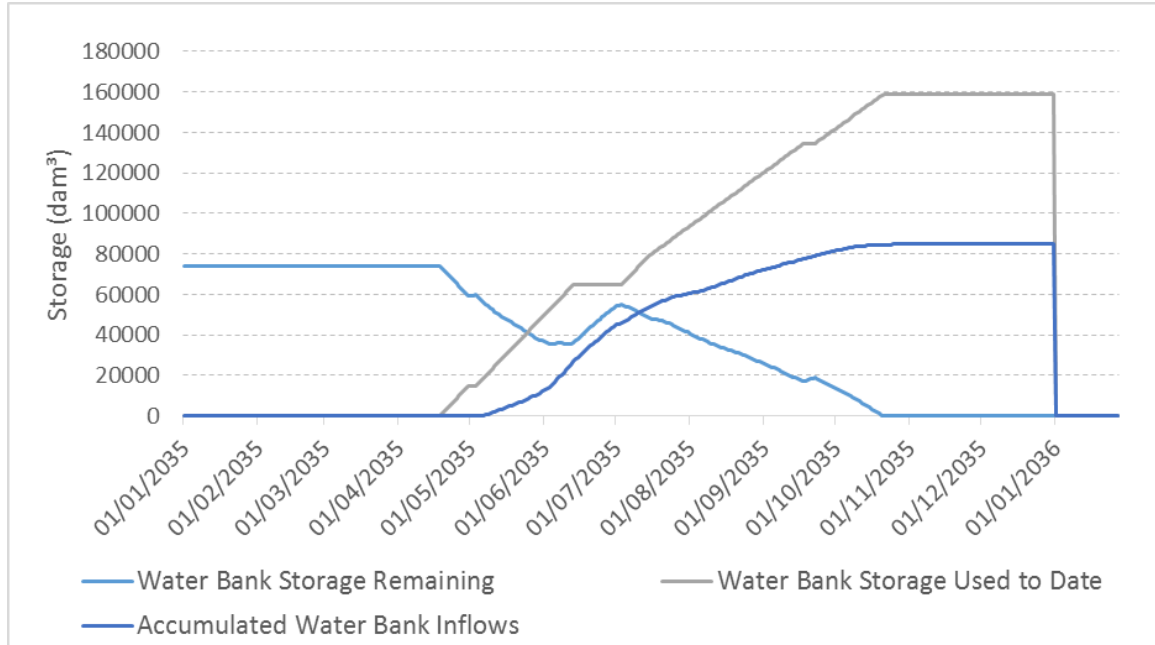


Figure 21: An example of water bank storage for the year 2035 in Frankenflow

Note: The light blue line represents the water bank storage remaining, the grey line represents water bank storage used to date for that year, and the dark blue line represents accumulated water bank inflow for that year.

Figure 22 demonstrates one of the main advantages of the water bank and the broader TransAlta Watershed Agreement, showing that the number of low flow days near Bassano can be reduced. Specifically, the shift in the number of days between 400 and 800 cfs (11.3 and 22.6 m³/s) is notable. This change in the number of low flow days indicates that there would be environmental benefit by increasing the buffering capacity of the Bow River to tolerate changes in dissolved oxygen and water temperature.

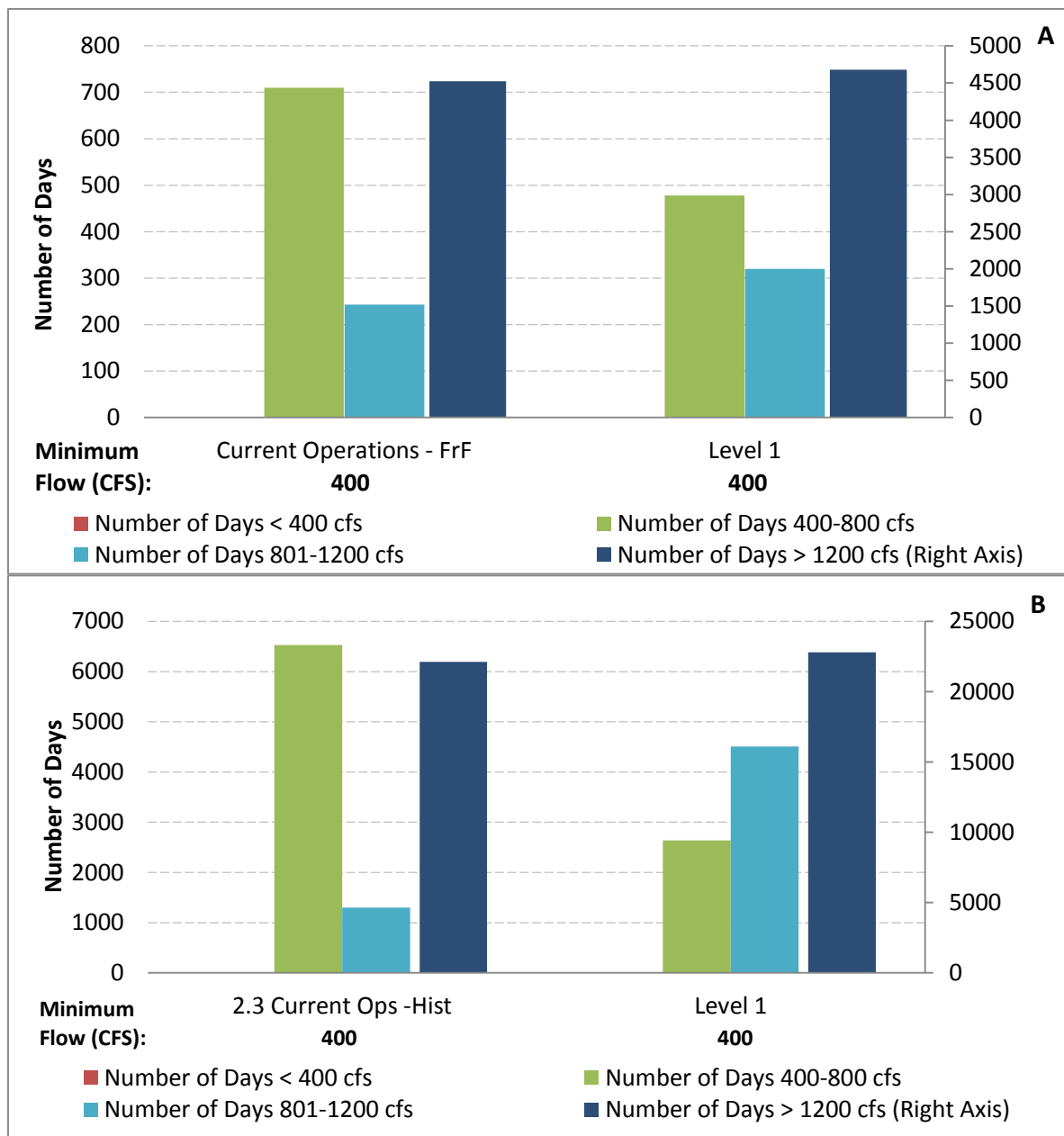


Figure 22: The number of days within flow categories at Bassano in the 15-year Frankenflow (A) and 1928–2009 Historical (B) periods

Note: It is ideal to have a lower proportion of light blue (<400 cfs) and green (400-800 cfs) bars.

The 2014 Bow Basin Flood Mitigation and Watershed Management Report (Alberta WaterSMART, 2014a) demonstrated that the Ghost Reservoir offers meaningful opportunity to reduce the magnitude of flood flows in the Bow River downstream. The new GoA–TransAlta agreement would include operating Ghost Reservoir for flood mitigation, which involves adjusting the reservoir fill curve to start refilling later in the season (Figure 23) and allowing flow from spring snowmelt and rainfall to be captured in the reservoir. This type of operation

requires careful consideration of antecedent snow and soil moisture conditions and should be coordinated with forecast tools to minimize the uncertainty in the operations best suited to a particular year.

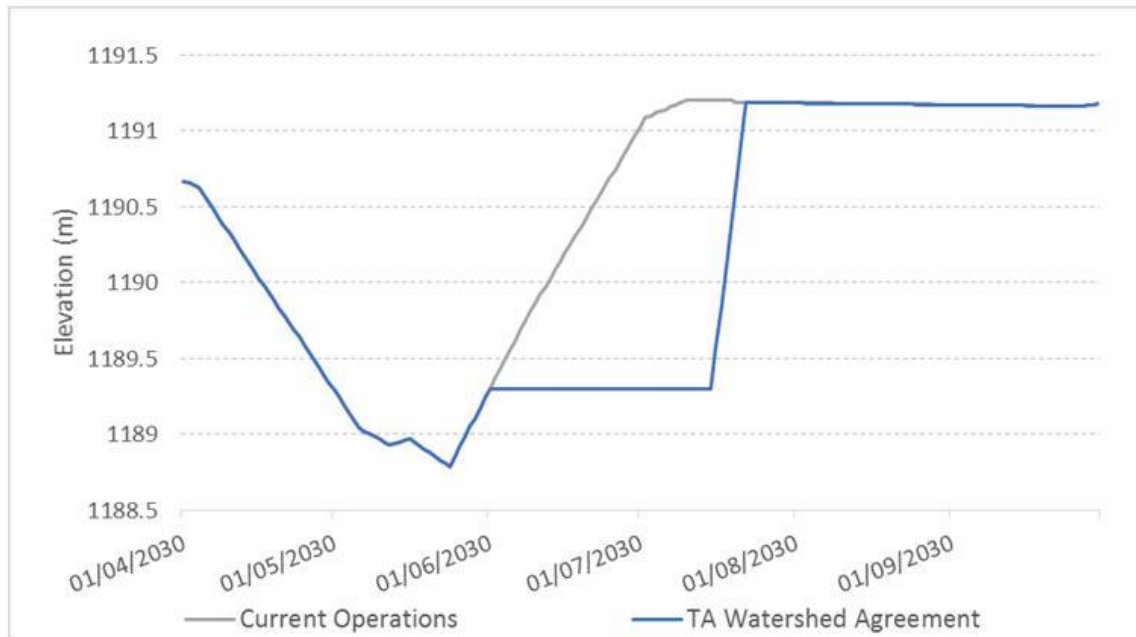


Figure 23: An example of changes in Ghost Reservoir operations to allow for the capture of more spring freshet in the year 2030 of Frankenflow

The grey line shows the model representation of current operations and the blue line represents operations applied in 2014 that could be applied again under the TransAlta Watershed Agreement.

This agreement would include stabilizing Lower Kananaskis Lake at 1663.5 metres (3.5 metres below the current 1667-metre FSL) (Figure 24). The stabilization of Lower Kananaskis Lake was simulated using the operation parameters suggested by the Fisheries and Recreation Enhancement Working Group report (2001). Although this specific suggestion was included in BROM, it was understood that best efforts and operator discretion in flexible and adaptive management was essential. Resilience to extreme conditions will require significant variation from the specifics above under flood or drought conditions.

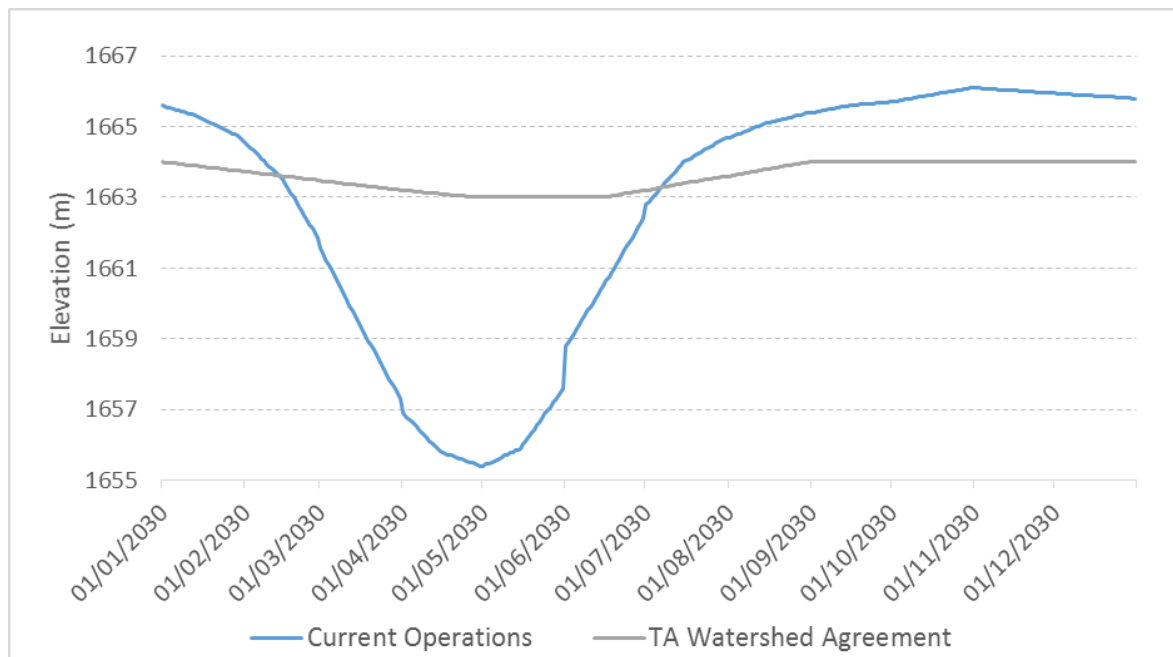


Figure 24: An example of stabilizing Lower Kananaskis Lake for the year 2030 in Frankenflow

The blue line represents the normal pattern for current operations and the grey line represents operations aiming to stabilize the lake.

In addition to stabilizing Lower Kananaskis Lake, discharge flows into the Kananaskis River from the Pocaterra power plant could be held steadier, again recognizing that these objectives would be undertaken as best efforts, enabling adaptive management to accord with the changing conditions in the region and downstream.

Adjusting the fill curves for Minnewanka, Spray, and Upper Kananaskis reservoirs would involve reservoir refill starting sooner in the year, and reaching full levels about a month earlier. This would minimize competition for flow in the high use period because the reservoirs are not trying to fill late into the summer when water is most needed downstream. Figure 25 provides an example of the Lake Minnewanka fill curves under current and new operations. The fill curves for Spray and Upper Kananaskis would resemble those for Minnewanka.

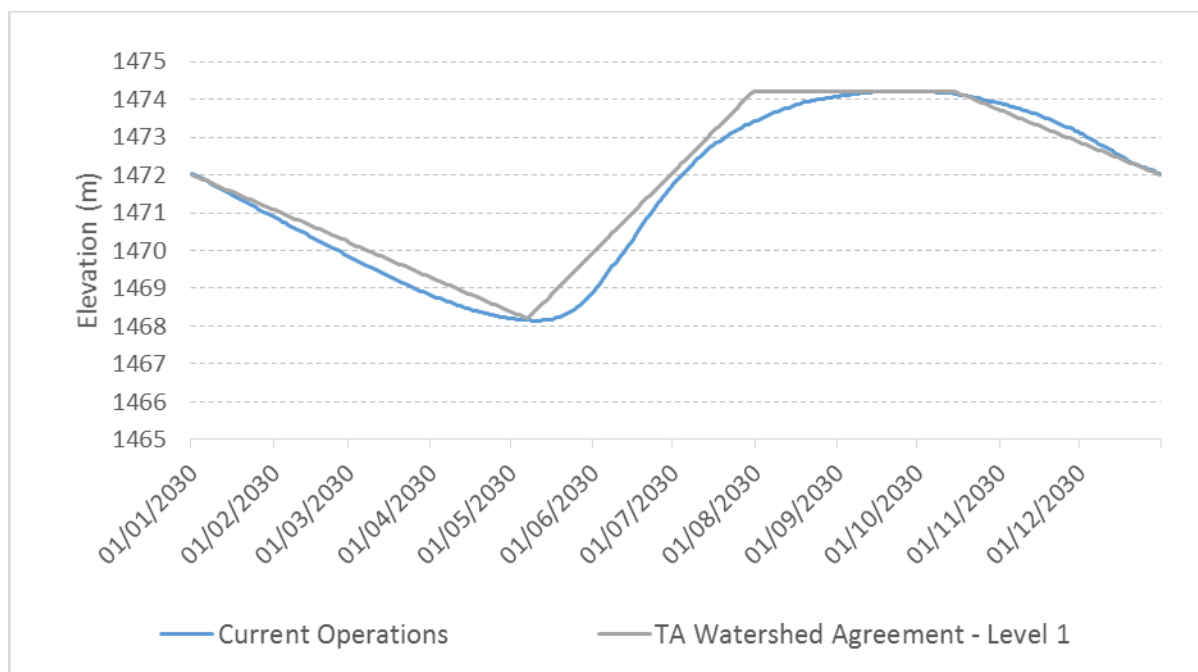


Figure 25: An example of the differences in fill between current (blue) and operations under the TransAlta Watershed Agreement (grey) for Lake Minnewanka

Implementing functional flows to benefit riparian and fisheries health is an important part of this strategy and is described under the strategy “Adjust Dickson Dam operations.”

Raise winter carryover in existing irrigation-serving reservoirs; start with Travers which draws water from the Bow, then investigate feasibility for the St. Mary, McGregor and other reservoirs

This strategy would maintain higher winter water levels in irrigation reservoirs to allow higher potential to meet water demands during dry periods. This type of operation would be applied first to Travers Reservoir to determine suitability, following which similar types of operations could be investigated for the St. Mary, Oldman, Waterton, and McGregor reservoirs.

Implement further forecast-based shortage sharing (including agreed-upon temporary reductions in diversions and voluntary assignments of remaining licence allocations in times of drought), within and between irrigation districts

This strategy would apply temporary reductions and assignments in times of drought (Alberta WaterSMART, 2014b). Forecast-based shortage sharing allows water users both within and between districts to voluntarily and simultaneously reduce demand on the system. The water sharing agreement implemented for the Southern Tributaries during the drought of 2001 set a precedent for this strategy.

Forecasting is critical for this strategy to be implemented properly. Irrigation districts evaluate water availability based on winter reservoir levels and incoming early spring snowpack because these are the primary sources of water for irrigation. Water availability estimates are communicated to irrigators and can be used to set preliminary allocations. Snowpack data are not included in the model; therefore, AEP reservoir storage on June 1 is used as a surrogate to inform rationing decisions that would in reality be informed by snowpack, soil moisture, reservoir levels, and other factors not currently available to the model.

In the model, irrigators in the OSSK sub-basins would begin rationing for a given year if total AEP storage is less than 75% of the upper rule. Once this decision is made, deliveries to irrigators (districts and private) are capped at 80% of full demand for the entire year (Alberta WaterSMART, 2014b).

Shortage sharing offers substantial benefit in surviving extended droughts for the OSSK sub-basins when it is compared with current operations and Level 1 without shortage sharing, as seen in Figure 26. This figure shows that shortage sharing allows for an extension of storage well into the winter at the onset of the worst drought explored using Frankenflow. This extension of storage benefits the environment and water users by supplementing flows for a longer period. Although this strategy was modelled in the OSSK sub-basins, it could be applied effectively in the Bow and Red Deer sub-basins too.

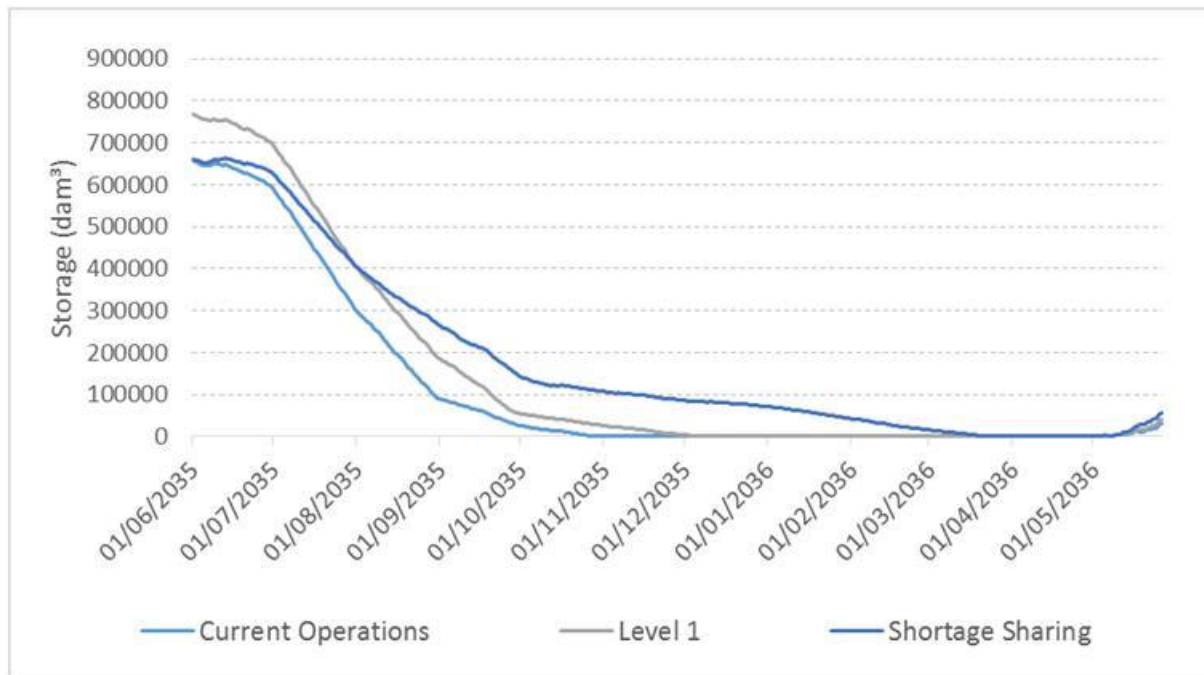


Figure 26: An example of the change in storage obtainable with Level 1 and forecast-based shortage sharing in the Oldman

The lines represent Oldman, Waterton, and St. Mary reservoir storage under current operations (light blue), Level 1 (grey), and with only forecast-based shortage sharing (dark blue).

One of the most notable changes relative to current operations is, not surprisingly, the effect of forecast-based shortage sharing on shortages in the Oldman. Figure 27 demonstrates that irrigation shortages will be substantially reduced with this type of proactive shortage-sharing agreement. Similar results may be expected if a shortage-sharing agreement were implemented in the Bow and Red Deer systems; however, most irrigation shortages seen in the model are in the Oldman, and this is the sub-basin where the most substantial benefits are likely to accrue.

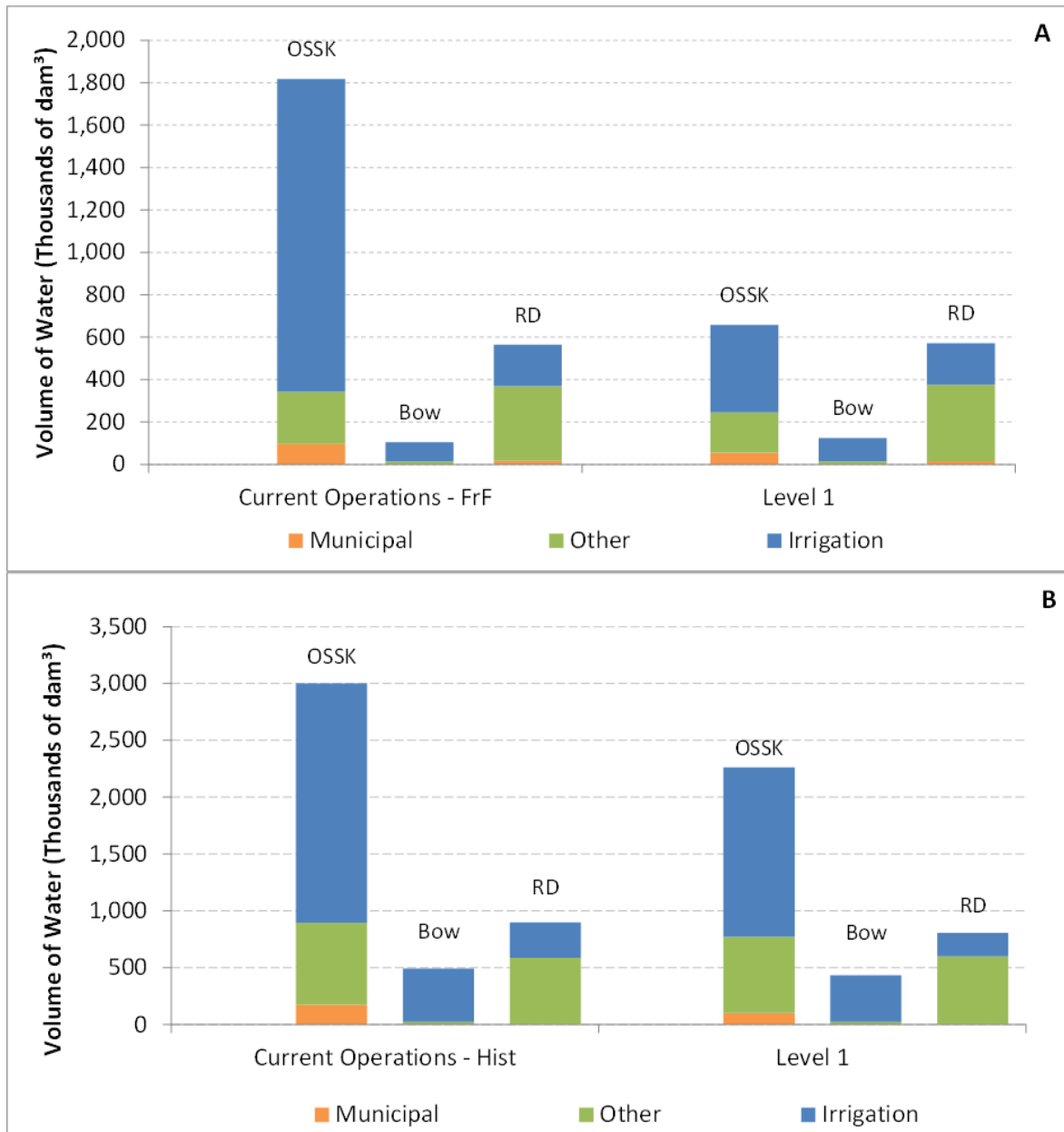


Figure 27: The volume of municipal (green), other (orange), and irrigation (blue) shortages in the OSSK, Bow, and Red Deer systems under the 15-year Frankenflow (A) and 1928–2009 Historical (B) periods

Develop basin wide shortage-sharing and reallocation frameworks to inform and enable severe drought mitigation*

This strategy was not part of the modelling work, but participants discussed that a framework is required to enable implementation of shortage-sharing agreements. This strategy is discussed in section 4 on Implementation.

Restrict new greenfield development in the floodplains to reduce flood damage and develop strict regulations against changing the nature of brownfield developments*

This strategy has been the topic of many discussions throughout the SSRB following the 2013 flood. This continues to be a preferred flood mitigation strategy, and relies on the implementation of existing and potentially new policy for development in the floodplain, but was not part of the modelling work.

OTHER LEVEL 1 STRATEGIES

Level 1 included other strategies that were considered important but had less effect on performance measures used in this work. In addition, several cannot be evaluated in the SSROM and are indicated by an asterisk (*). All of the other Level 1 strategies are described below.

Increase St. Mary Reservoir operating FSL by 1m

This strategy would increase the storage capacity of the St. Mary Reservoir, thus increasing the capacity to apply functional flows, increasing the downstream minimum flow and supporting water users during dry periods. An evaluation to determine the feasibility of these operations in terms of dam safety would be required.

Effectively implement Alberta's Wetland Policy*

As of May 31, 2015, applications in the White Area will be reviewed under the Alberta Wetland Policy. Once Green Area field assessments are complete (May 31, 2016), Green Area applications will also be assessed under the Policy.

Effective implementation of the Wetland Policy involves “minimizing the loss and degradation of wetlands, while allowing for continued growth and economic development in the province.” The primary goals of the policy are to conserve, restore, protect, and manage Alberta’s wetlands.

Importantly, not all Alberta wetlands are of equal value. Wetland value should be assessed based on relative abundance in the landscape, supported biodiversity, ability to improve water quality, importance to flood reduction, and human uses. These values should be used to inform wetland management. Ultimately, avoidance and minimization of wetland loss is preferred.

Improve resourcing for and effectiveness of forecasting infrastructure, systems and teams*

This strategy was not part of the modelling but working group participants in all of the sub-basin projects identified the need for improved forecasting. This strategy is discussed in section 4 on Implementation.

Adjust Dickson Dam operations to consider downstream needs (retain WCOs, functional flows, some new demands)

The current operations of Dickson Dam are driven primarily by upstream conditions; the objective is to meet reservoir target elevations and ensure the reservoir fills by late fall. Presently, 16 m³/s plus a buffer is released from Dickson Dam based on upstream conditions; proposed new Dickson Dam operations would calculate the buffer based on downstream conditions. This buffer is flexible and if the reservoir falls below the lowest permissible level, only the minimum 16 m³/s (and not the buffer) is released (Alberta WaterSMART, 2015).

This type of operation is beneficial to the Red Deer system, providing additional downstream water during low flow periods (Figure 28). Previous studies suggest there is some capacity to provide water for some but not all potential new users. In addition, many downstream users are senior to the WCOs, which can result in WCO violations during low flow periods. This strategy can also be used to improve functional flows downstream of Dickson Dam on the Red Deer River.



Figure 28: A comparison of streamflow (m³/s) in the Red Deer River at the mouth of the Red Deer during current operations (blue) and operations that aim to address downstream needs (grey)

To see the results of interest (low flows) at an appropriate scale, the upper part of the figure is cut off.

Changes in the Red Deer system as a function of Level 1 implementation are most noticeable when looking at the percentage of weeks where the average weekly flow is below the WCO threshold at the mouth of the Red Deer (Figure 29). Dickson Dam operational changes are included in Level 1, where operations are set to look downstream at demands prior to making releases. This new style of operation would attempt to release enough water to meet existing and new demands as well as maintain the WCOs. Figure 29 demonstrates that these changes are favourable and reduce the percentage of weeks where the WCO is not met at the mouth of the Red Deer.

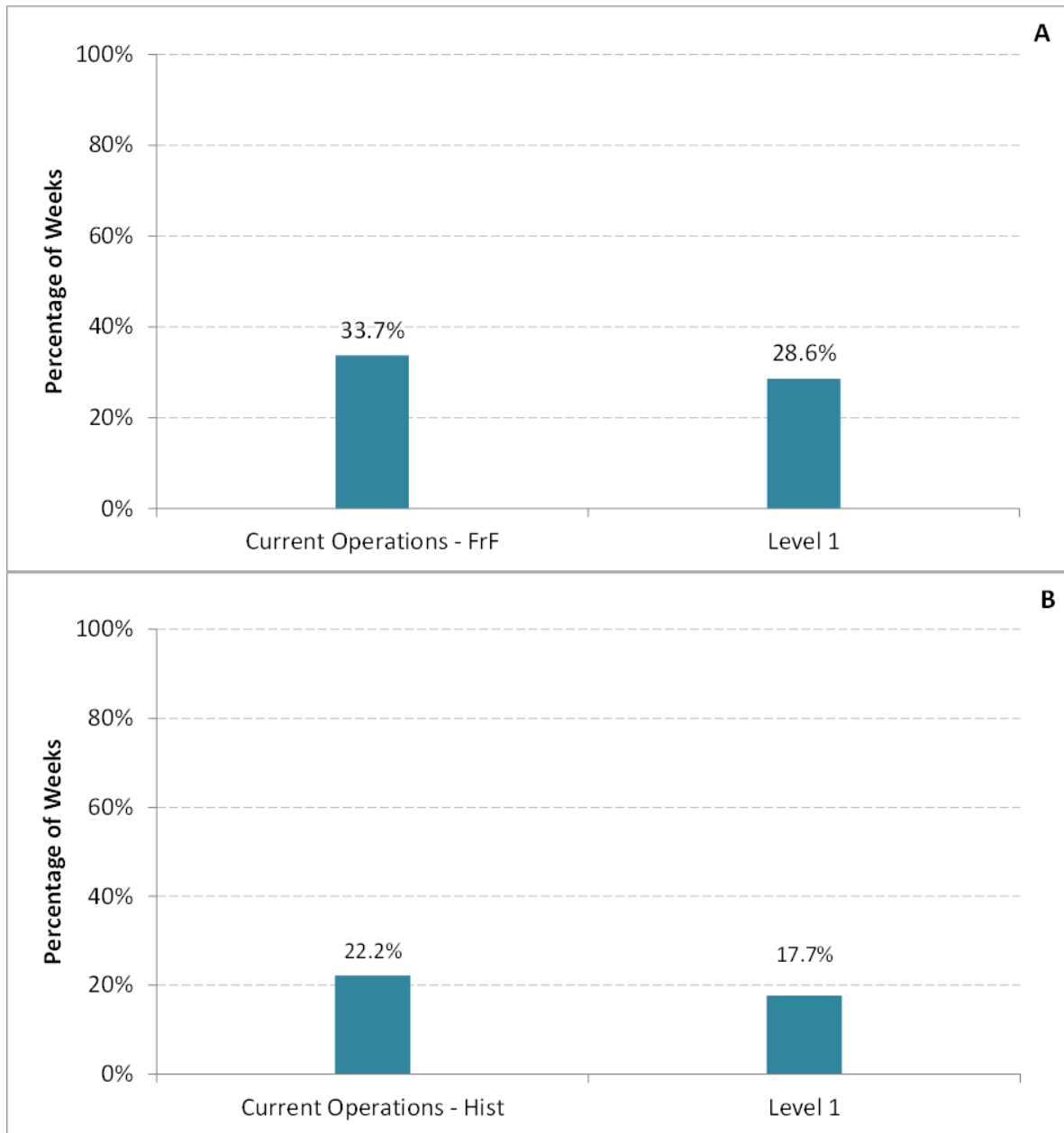


Figure 29: The percentage of weeks where weekly average streamflow is below the WCO at Bindloss for the 15-year Frankenflow (A) and 1928–2009 Historical (B) periods

One other strategy that has been partially implemented in the Oldman system and offers various environmental benefits is the release of **functional flows** using existing dams on the Red Deer and the Bow. Functional flow releases are intended to support a wide range of ecosystem goods and services by operating a reservoir to more gradually ramp down flows after a high flow event deemed suitable for cottonwood recruitment. This ramping down of flow gives a more natural snowmelt-driven hydrograph, which provides benefit to aquatic ecosystems as they are better adapted to natural flow regimes. Figure 30 illustrates an example in which the Dickson Dam is operated to ramp the flow of the Red Deer River by 4 cm/day, as measured along the banks following spring freshet. This figure also demonstrates that more water is required to conduct these types of operations, potentially resulting in lower streamflow late in the season. Therefore, these types of operations should only be done opportunistically. It should be noted that simulated reservoir operations cannot capture real-world operation dynamics due to simplified modelling assumptions. Dam operators would have to adjust operations according to real-world conditions, including pulsing, and potentially ramping at a faster rate if required.

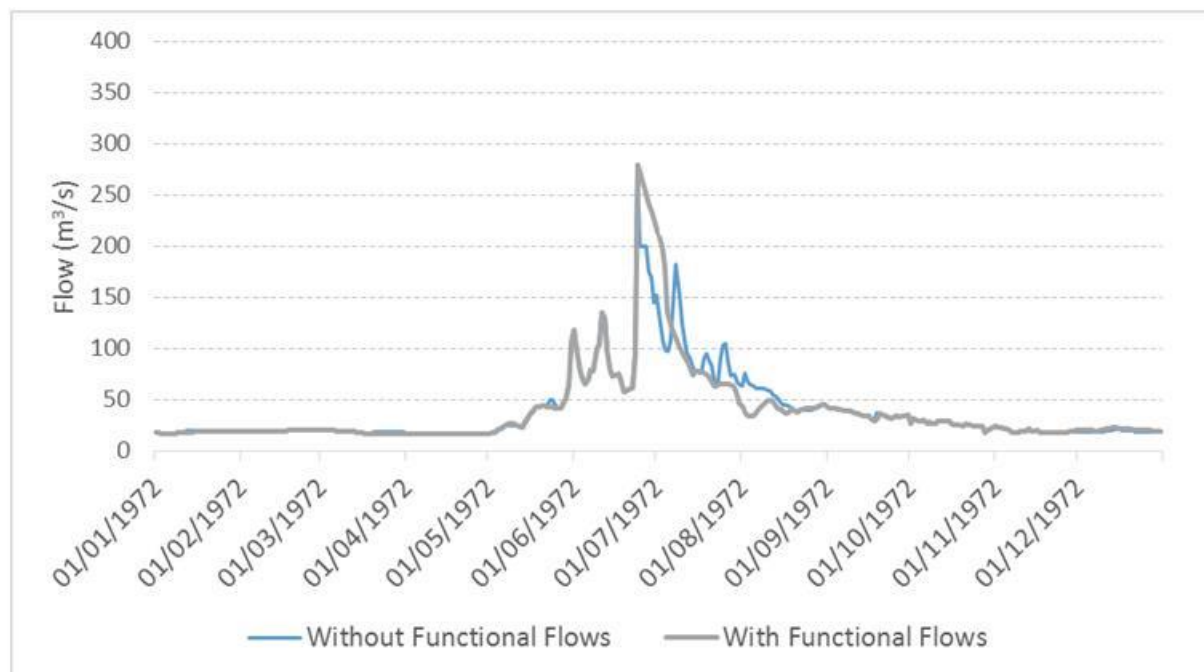


Figure 30: An example of the effect of implementing functional flows on streamflow below Dickson Dam on the Red Deer

The grey line represents streamflow below the dam with operations for functional flows, and the blue line represents streamflow below the dam without functional flows.

Advance Room for the River conveyance opportunities in the Bow and Red Deer sub-basins*

Increasing the conveyance capacity of specific segments along the Bow and Red Deer rivers would increase the overall capacity for the system to manage flood flows. Examples of increasing conveyance include removing debris between Sundre and Dickson Dam, selective aggregate removal, and bridge redesign (increasing the span).

Advance Room for the River natural detention opportunities in the Bow and Red Deer sub-basins*

Natural detention opportunities help lower downstream flood risk and offer benefits to the system by improving the connectivity between river channels and their floodplains. Examples of natural detention opportunities include restoring wetlands in targeted areas and reducing linear footprint in the headwaters to increase watershed storage capacity. While these natural detention opportunities will have limited impact on major flood flows, they would contribute to improved water quality and alluvial aquifer recharge as well as potentially benefitting the river during periods of low flow.

Further apply land use best management practices*

Land use best management practices (BMPs) are an effective means of reducing the overall effect of a particular land use on water quantity and quality. Examples of BMPs that provide benefit are building bridges instead of culverts, maintaining adequate riparian buffer widths and set-backs from rivers and streams, and incorporating stormwater detention in urban developments.

Promote further municipal conservation relative to what is being done now

The effects of reducing municipal water consumption are most pronounced during low flow periods. Conservation is most effective during the summer months when urban irrigation is most common. Therefore, implementing a strategy such as 20% more conservation in the summer and 5% in the winter would likely result in the highest benefit.

The results presented here demonstrate that there is flexibility within the SSRB water management system to make beneficial changes without incurring significant economic, environmental, or social costs. This work also demonstrates that flexibility must be maintained within the water management system to mitigate potential negative consequences of new (and old) operations. Operational and decision-making changes should integrate forecasting in a meaningful way. This is particularly important given that each year is likely to present a unique situation and potential water management challenges. Benefits to the environment and water users within the range of operations presented here clearly indicate that it is possible to adaptively manage year-to-year variability and long-term change in hydrologic conditions; additional adaptive capacity may be required as future water supply and demands change.

3.2.4 Roadmap Strategies: Level 2

Level 2 strategies build on the strategies from Level 1 with six additional adaptive strategies as seen in Figure 31. In the figure, the blue boxes represent the most promising Level 2 strategies. Strategies with an asterisk (*) in the text below are not currently modelled in the SSROM, typically due to lacking or unavailable data.

SSRB Adaptation Roadmap Level 2

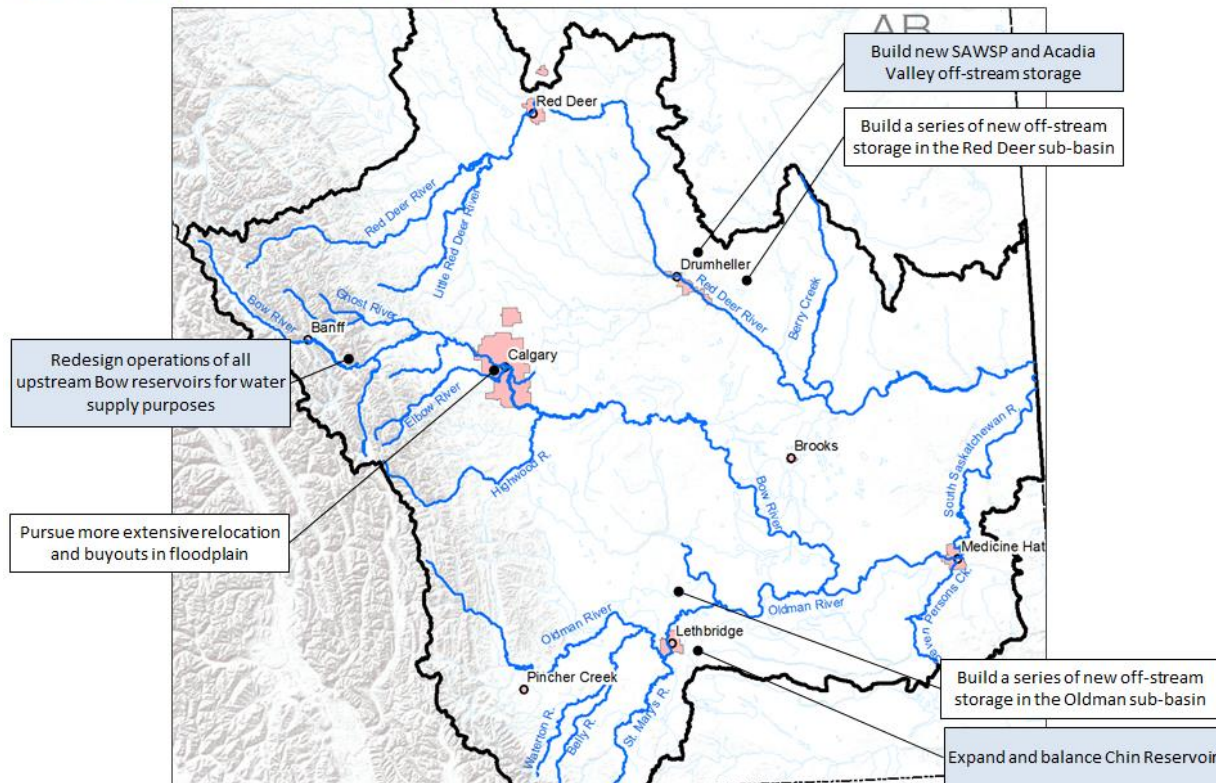


Figure 31: Map of the SSRB showing the adaptation strategies applied in Level 2 and their approximate location

Level 2 consists mainly of relatively small new infrastructure projects and infrastructure upgrades, including changes to operational regimes of some reservoirs. These strategies are described below.

Redesign operations and expand, where beneficial, existing reservoirs in the upstream Bow for water supply and watershed health*

The 11 hydro facilities and system of reservoirs upstream of Calgary on the Bow River system were originally constructed to provide a small but stable source of electricity close to the growing demand in southern Alberta. The first run-of-river dams were built in the early 1900s, and the latest was completed in the 1950s. During the early 20th century, the hydro system provided much of the electricity needed in the region. Advancements in transmission infrastructure led to the current grid-based electrical system, making hydro generation far less important to electricity demand in the later

20th century. The Bow hydro system now supplies only a tiny percentage of the electricity used by Albertans, but provides some ancillary services that help to stabilize the transmission system.

The purpose of the Bow hydro system has gradually been moving toward a water supply system. The reservoirs are filled over the summer and fall and the stored water is released at a relatively steady pace over the winter months (see example in Figure 32). This pattern originated because electricity demand (and price) was much higher in the cold, dark winter months and therefore more water was run through the turbines during winter. Now electricity demand is balanced between winter and summer due to air conditioning, computer use, summer irrigation demand, and other year-round industrial uses. However, capture and storage during the spring snowmelt period, summer filling, and winter release of the stored Bow water has enabled Calgary and other population centres to increase water demands to their current levels. Without the reservoirs following their historic pattern of fill and release, the natural pattern of water supply could not support anything close to the modern total demand and treated effluent assimilation needs in the Bow system.

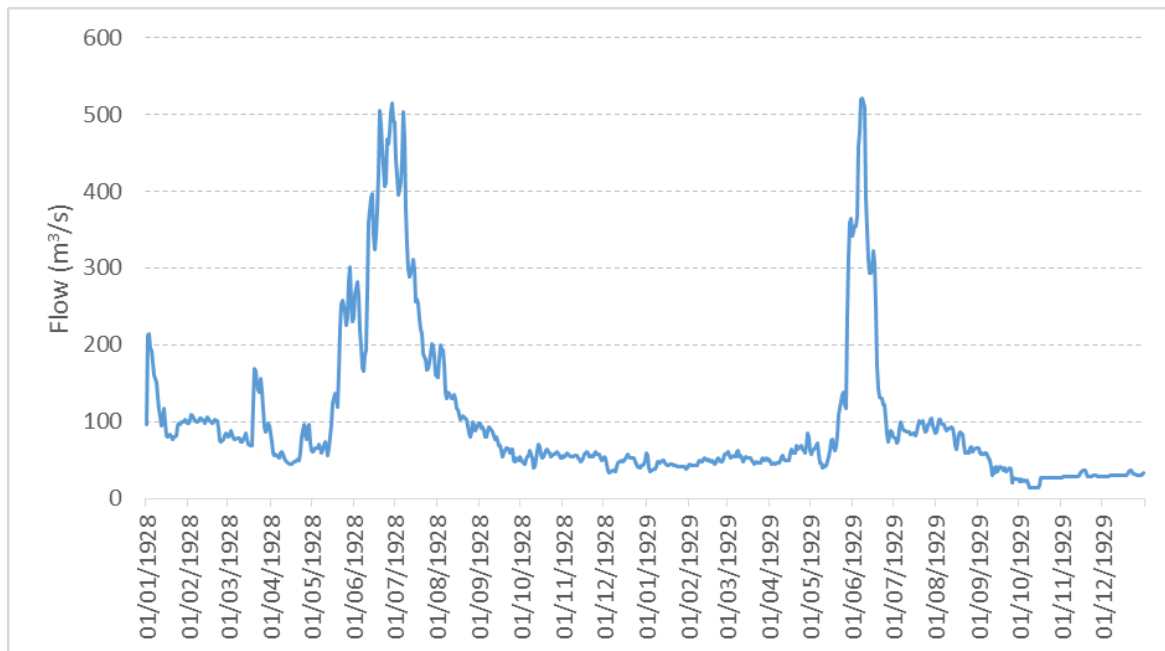


Figure 32: Daily average streamflow in the Bow River at Calgary during 1928 and 1929

The time has now come to reconsider the primary purpose of the entire upstream Bow water storage system to extend beyond its original purpose in the early 20th century: generating power during winter months. Using the water for other purposes in the public interest does not reduce the amount of electricity generated except in extreme cases, but does alter the timing of the production. Managing for these other purposes may reduce the profit from power production, but not the total amount of electricity generated. Highly valued competing purposes for this water storage and release system have now emerged. Flood and drought mitigation, environmental protection, food supply and recreational uses for the Bow water now substantially challenge the value of this water purely for peak power generation. The most recent and dramatic example is the 2013 flood, but many other examples are available.

Expand (74,000 dam³) and fully balance Chin Reservoir (285,000 dam³) (OSSK sub-basin)

Previous work demonstrated that expanding and balancing Chin Reservoir provides an opportunity to increase the adaptive capacity of the OSSK sub-basins. This strategy includes an expansion of approximately 74,000 dam³ and balances the operations of the reservoir to maintain proportional storage alongside the Oldman, St. Mary, and Waterton reservoirs. This differs from current operations in that Chin Reservoir presently has higher storage priority, resulting in preferential storage in Chin. Balancing Chin with the other upstream reservoirs means that those reservoirs can maintain higher storage for longer in the season as illustrated in Figure 33. This keeps water closer to the headwaters and makes it available system-wide to support ecosystems and human uses.

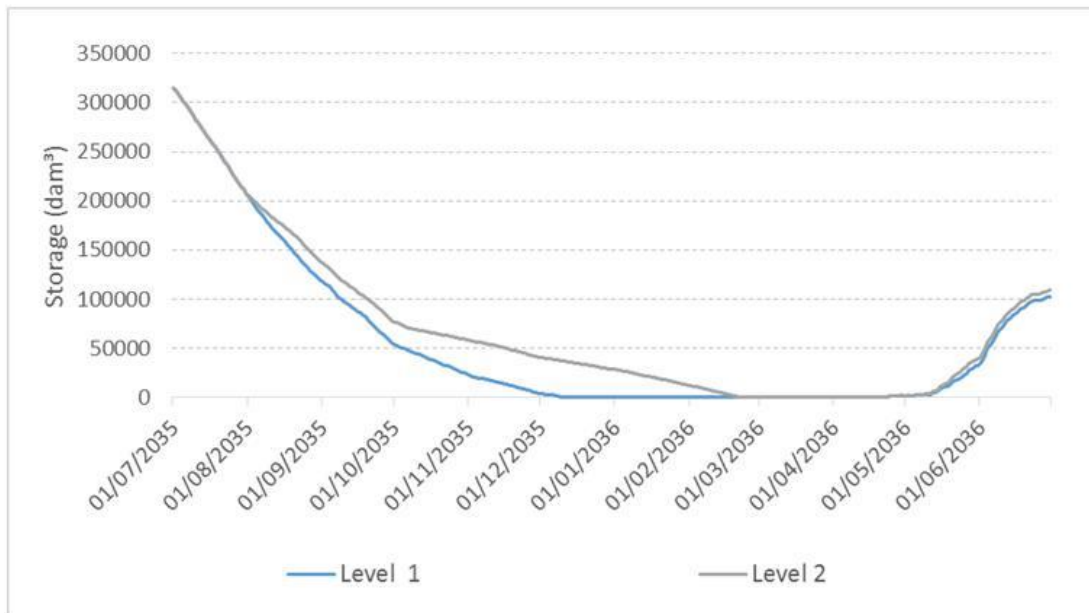


Figure 33: Comparison of Oldman Reservoir storage for Level 1 (blue) and Level 2 (grey)

This demonstrates that the available storage is extended later through the lowest flow period.

Expanding and balancing Chin Reservoir would require multiple upgrades to infrastructure as more aggressive filling would be necessary (that is, higher flows on shorter notice) (Figure 34). Initial infrastructure upgrades would include expanding and reinforcing conveyance canals to Chin Reservoir and upgrading run-of-river hydropower turbines along the canal, specifically in Drops 4, 5, and 6. An increased willingness to use spillways in that area may also be required.

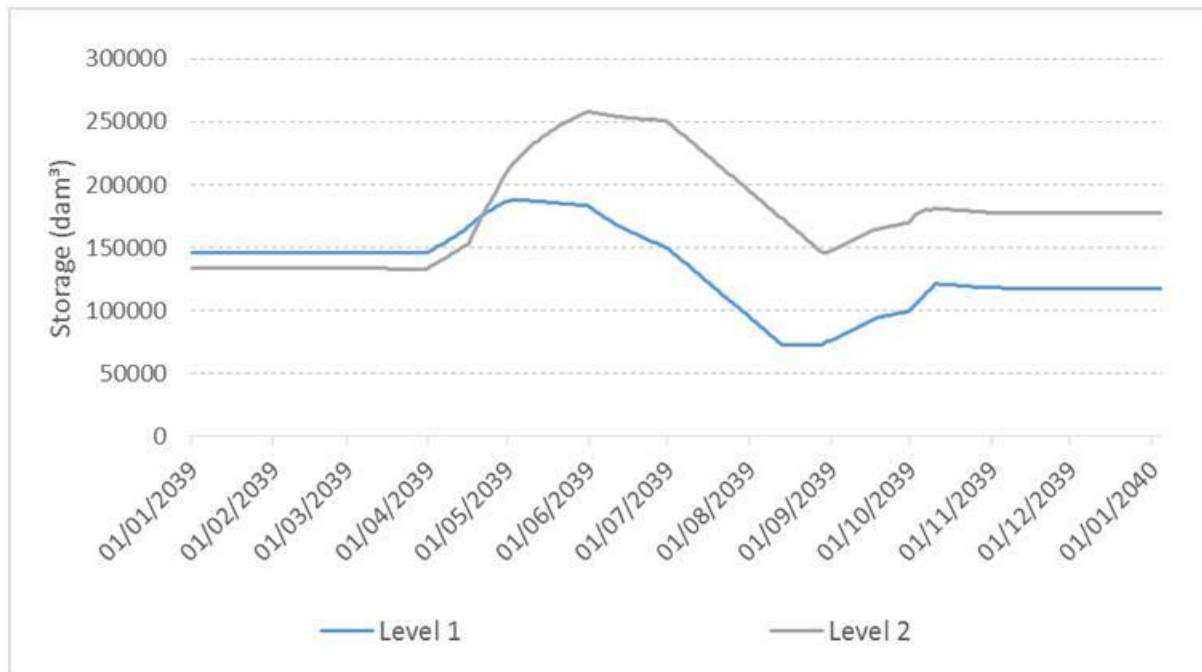


Figure 34: Chin Reservoir storage comparison in a non-drought year, demonstrating that higher fill rates and expansion result in higher late-season storage

Build new SAWSP and Acadia Valley off-stream storage (35,000 dam³ SAWSP + 45,000 dam³ Acadia = 80,000 dam³ total) (Red Deer sub-basin)

The Red Deer sub-basin has limited capacity for increased water demand and growth while maintaining WCOs during low flow periods in the Red Deer River. Building new off-stream storage would expand the storage capacity of the Red Deer sub-basin by adding a total of 80,000 dam³ (35,000 dam³ storage for SAWSP²⁰ and 45,000 dam³ storage for Acadia Valley). The location and storage capacity of the SAWSP and Acadia Valley irrigation projects was investigated in previous studies (Alberta Environment, 2008).

An additional 80,000 dam³ of storage would likely be located in various places off stream for additional users where appropriate. Working group participants suggested that these storage options should be modelled together in Level 2, as storage increases would need to be coordinated to ensure an appropriate distribution of benefits to all water users.

Figure 35 demonstrates that the storage from SAWSP and Acadia Valley projects is used extensively during Frankenflow; the use was seen during a relatively severe drought. Figure 36 shows water use over the historical period; storage is used but is not drawn down as far during the Historical period as during Frankenflow.

²⁰ Special Areas Water Supply Project



Figure 35: Storage in the new SAWSP and Acadia Valley project – Frankenflow

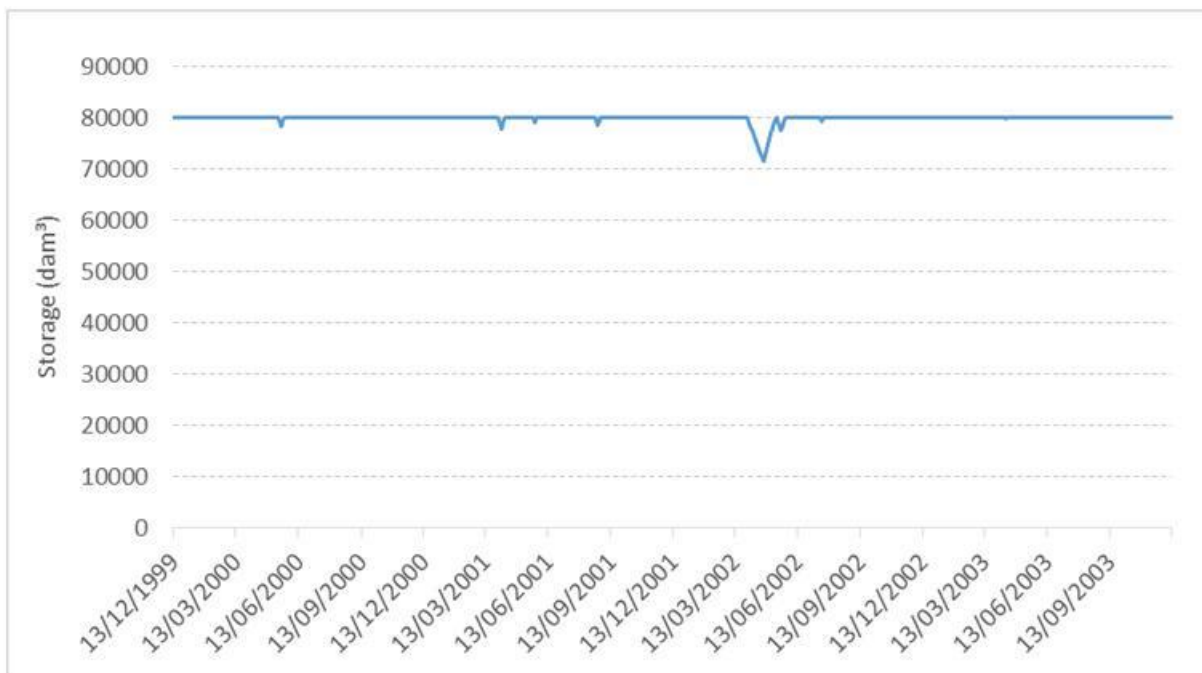


Figure 36: Storage in the SAWSP and Acadia Valley project – Historical

Figure 37 shows that shortages in the Red Deer sub-basin can be reduced by adding storage to the system. In addition, there is substantial further improvement of WCO flows, as violations to the WCOs are reduced by 5.2% (Figure 38).

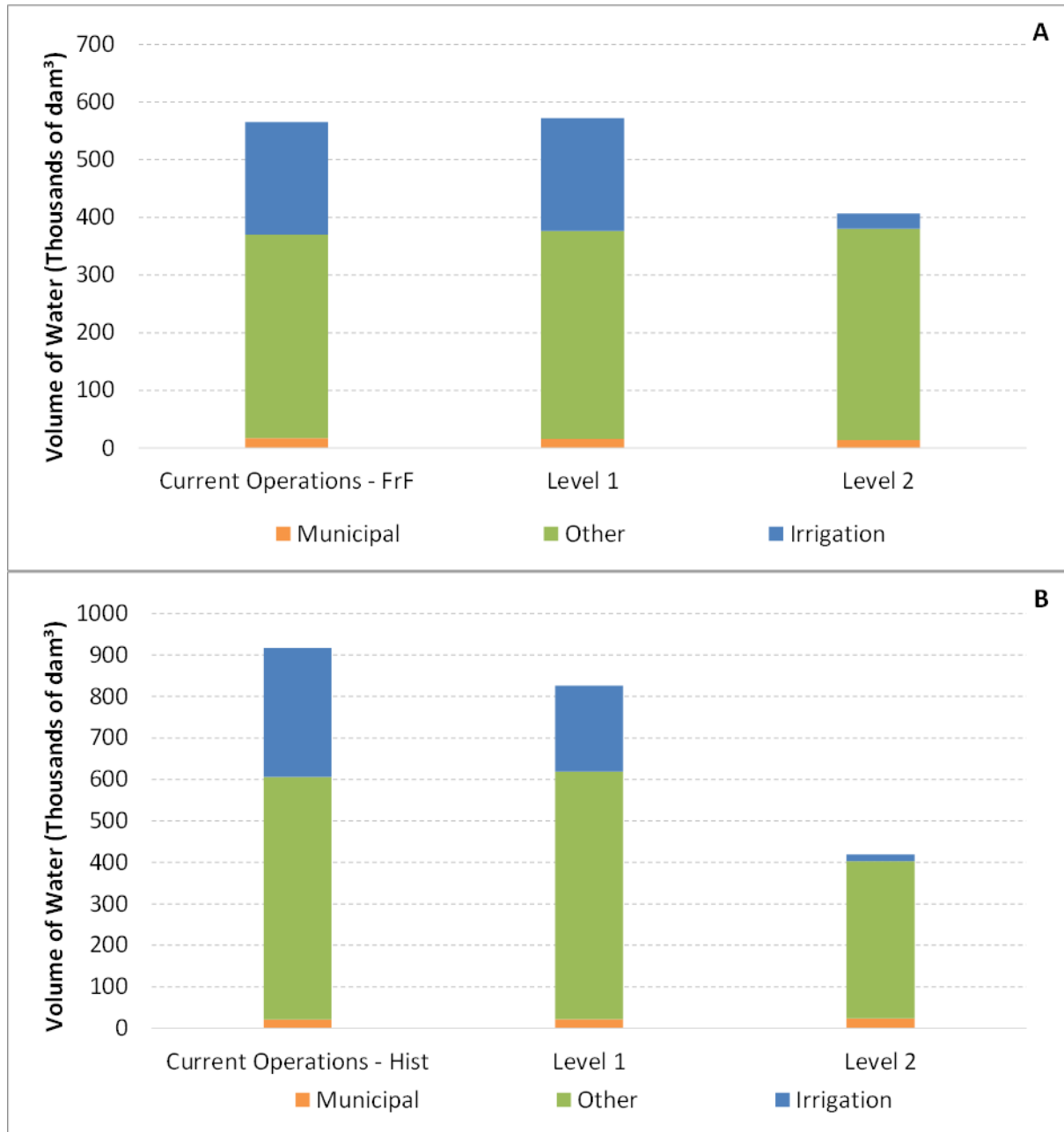


Figure 37: Total Red Deer shortages, demonstrating that Level 2 SAWSP and Acadia Valley storage almost eliminates irrigation shortages in the Red Deer under the 15-year Frankenflow (A) and 1928–2009 Historical (B) periods

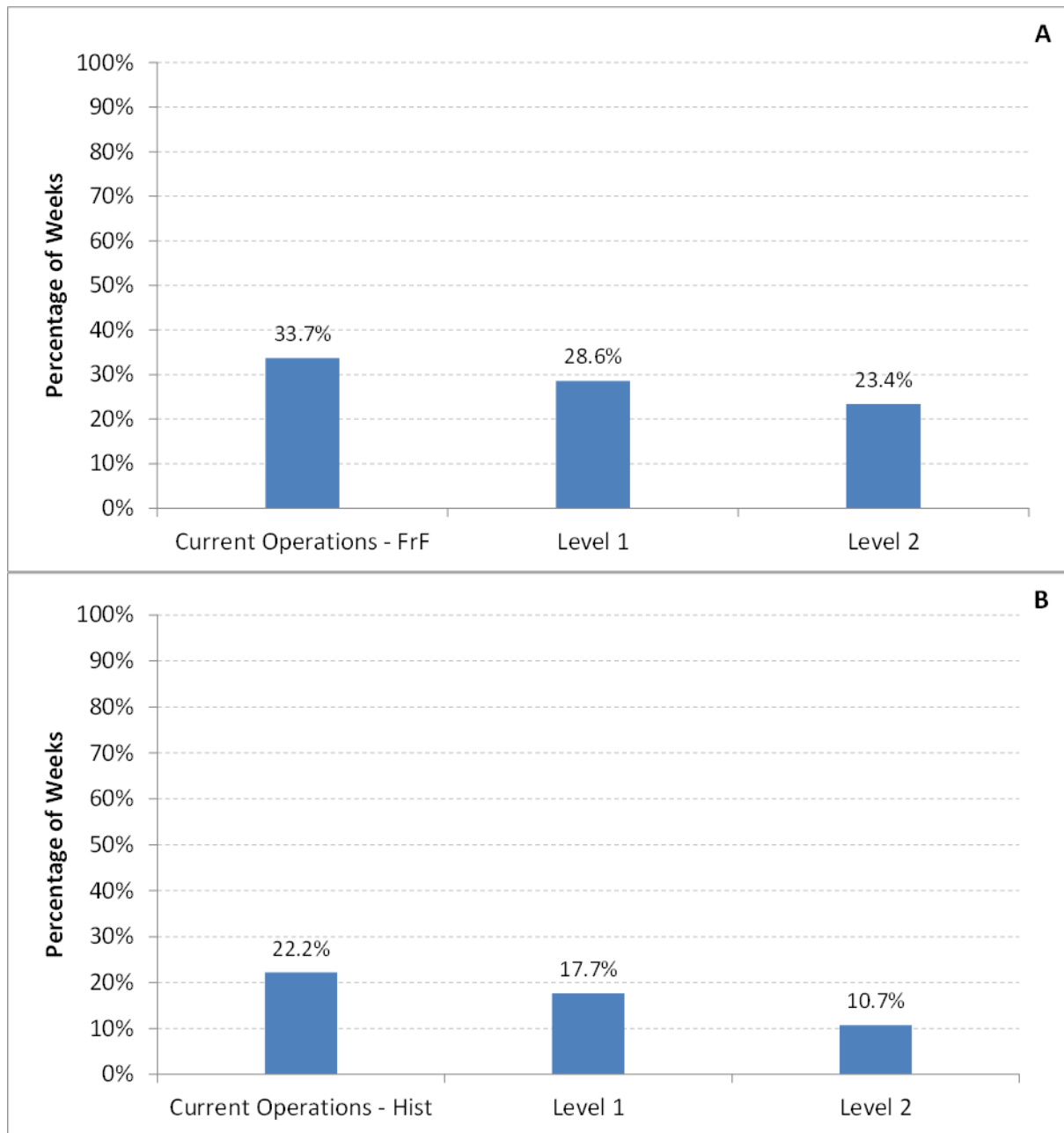


Figure 38: A comparison of the percentage of weeks where average weekly flow at the mouth of the Red Deer is less than the WCO threshold between Current, Level 1, and Level 2 under the 15-year Frankenflow (A) and 1928-2009 Historical (B) periods

Three additional strategies were determined to be appropriate for achieving Level 2.

Pursue more extensive relocation and buyouts in the Bow and Elbow River floodplains to reduce risk and reduce the need for upstream mitigation structures*

This strategy has been discussed as a way to effectively and permanently mitigate flood damage over the longer term and reduce the need for upstream mitigation. Buyouts create room in the floodplain for normal river processes, such as channel migration and over-bank flooding, without imposing risk to infrastructure. However, buyouts must be recognized as a costly endeavour with significant social and economic impact on individuals and the community.

Build a series of new off-stream storage facilities in the Oldman sub-basin*

Off-stream storage was discussed as an option for the Oldman sub-basin as a preferred alternative to building large on-stream structures. A series of smaller off-stream reservoirs could be built as needed throughout the sub-basin to meet local demands. Off-stream reservoirs can also create important lentic habitat for aquatic and terrestrial species and do not have the same environmental consequences as on-stream reservoirs.

Build a series of new off-stream storage facilities in the Red Deer sub-basin*

In addition to the SAWSP and Acadia Valley project, off-stream storage was discussed as an option for the Red Deer sub-basin rather than building large on-stream structures. This storage would supply water for municipal, industrial and agricultural growth in the lower sub-basin while still maintaining the environmental health of the watershed. Working group participants suggested that these storage options should be modelled together with the proposed SAWSP and Acadia Valley storage in Level 2, as storage increases would need to be coordinated to ensure an appropriate distribution of benefits to all water users. If further study demonstrates that off-stream storage sites would not be possible or effective, then a midstream facility on the Red Deer system should be moved from Level 3 to Level 2.

3.2.5 Roadmap Strategies: Level 3

Level 3 of the Adaptation Roadmap involves adding new on- and off-stream storage and adapting minimum flow values through municipalities during drought periods. Figure 39 shows the adaptive strategies contained in Level 3; these would be layered onto implemented strategies in Levels 1 and 2. In the figure, the blue boxes represent the most promising Level 3 strategies. Strategies with an asterisk (*) in the text below are not currently modelled in the SSROM, typically due to limited data.

SSRB Adaptation Roadmap Level 3

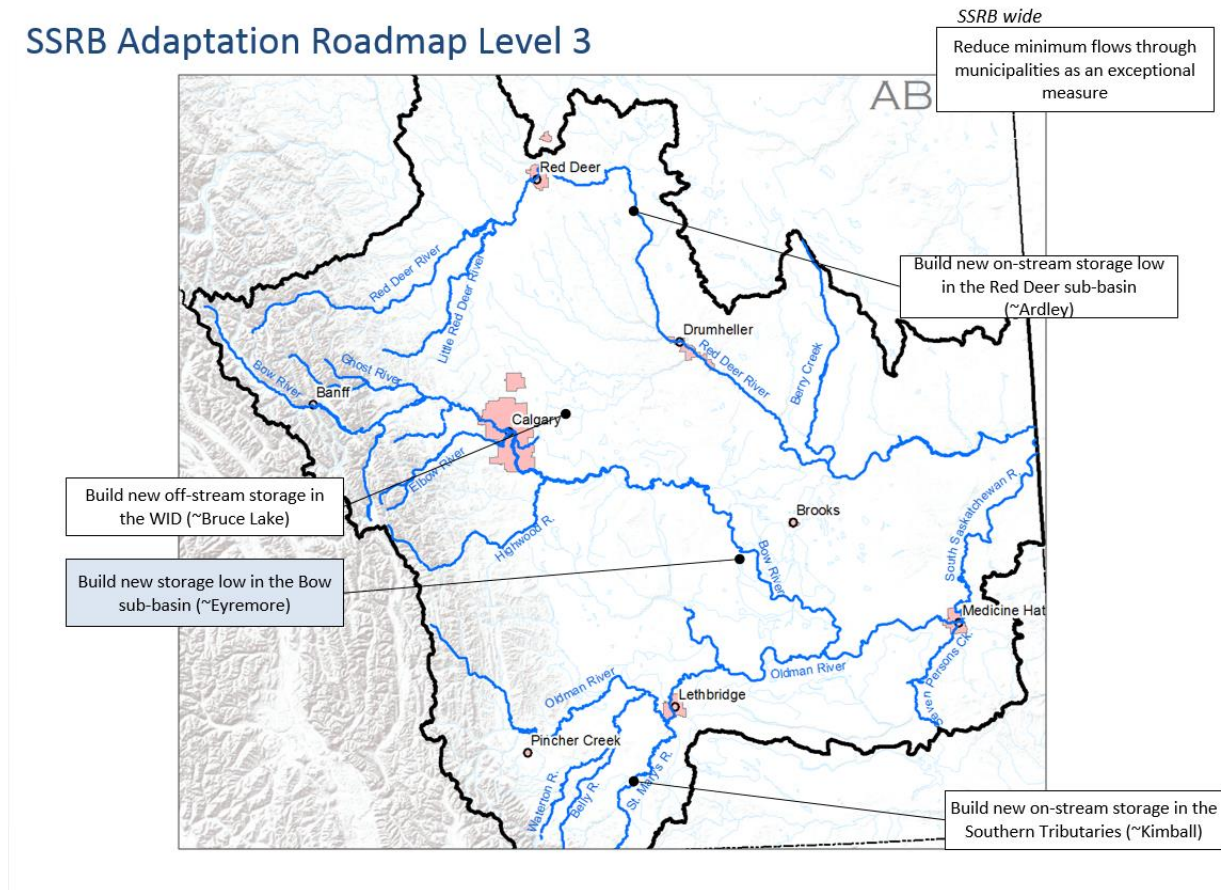


Figure 39: Map of the SSRB showing the adaptation strategies applied in Level 3 and their approximate location

The strategies in Level 3 are described below.

Build new on-stream storage low in the Bow system below Bassano Dam (Approximately (~) Eyremore site, ~477,000 dam³)

The most promising strategy in Level 3 is building a new on-stream reservoir low in the Bow system. The location that has been discussed is the Eyremore site located below Bassano Dam, as seen in Figure 39. This work assumed that Eyremore would be a large storage facility with 954,000 dam³ total storage and an approximate live storage capacity of 477,000 dam³.

This large facility allows for increased flexibility of the water management system in the SSRB by supplementing downstream flow. Model runs sought to use the additional storage to supplement Oldman River flows and increase water available for use on the Bow. The additional storage could also be used to improve flows in the Bow River and the freeboard could help mitigate downstream flooding. Finally, Eyremore could be used to provide water during lower flow periods downstream and, potentially, for municipal water supply at Medicine Hat and other communities.

Oldman flow supplementation was achieved using the Eyremore Reservoir to maintain minimum flows on the South Saskatchewan. This results in less demand on the upstream reservoirs in the Oldman, allowing for additional storage to be maintained higher in the watershed, as seen in Figure 40.

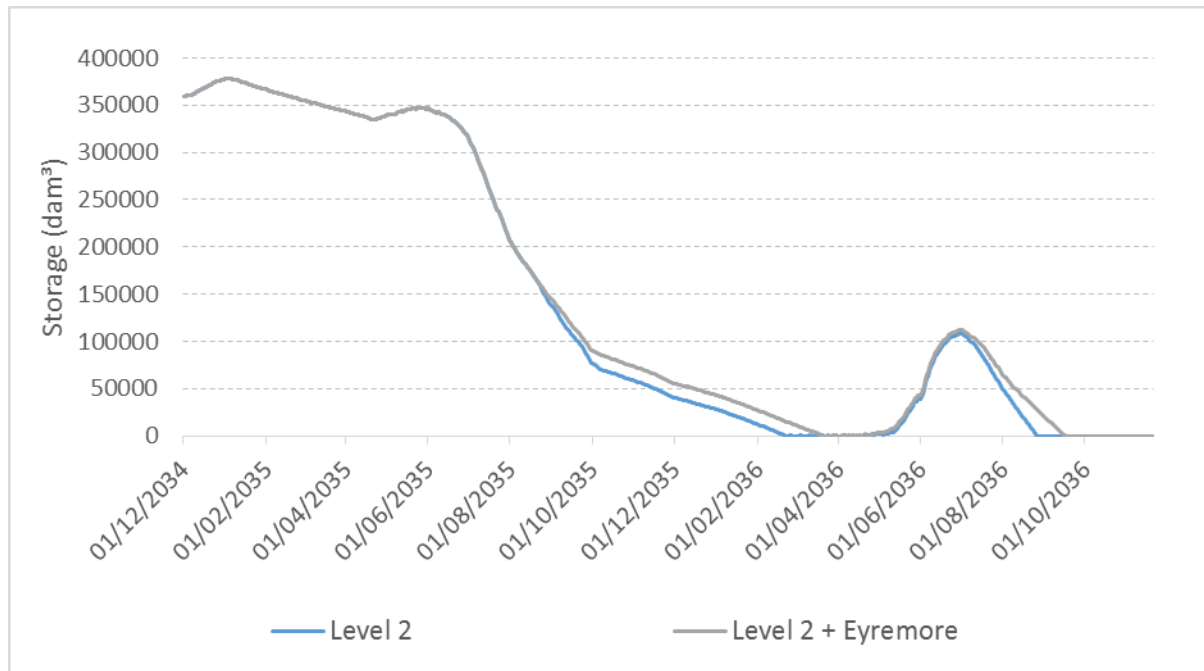


Figure 40: A comparison of storage in the Oldman Reservoir with (grey) and without (blue) Eyremore during a drought year

The additional storage increased the capacity to meet water needs in the Bow and Oldman systems. This is partly due to the EID no longer being required to pass 400 cfs (11.3m³/s) downstream, given that the new reservoir would extend to the EID diversion and could increase downstream flows more than before. This results in more water being available for other uses. In this case, the BRID uses the additional water, decreasing shortages in the Bow by 50%. A 10% reduction in shortages was found in the Oldman, again a function of increased upstream capacity to meet demands (Figure 41). When Eyremore is operated to meet environmental needs, the shortages are unchanged relative to Level 2 (Figure 42).

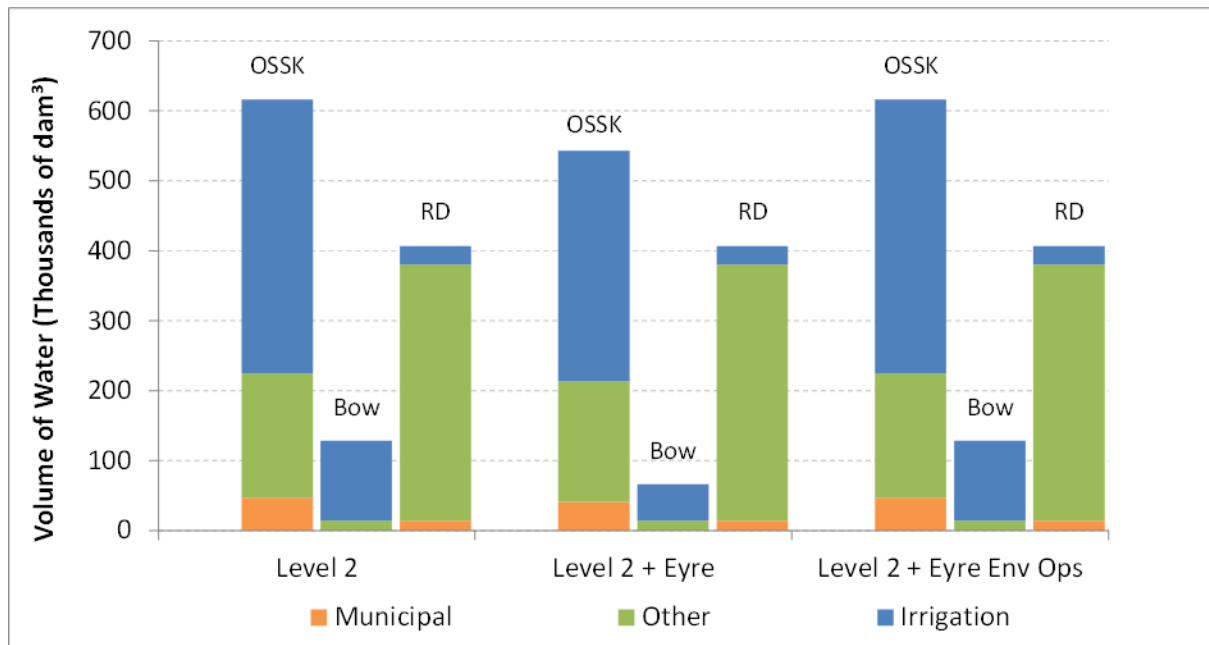


Figure 41: A comparison of municipal (orange), other (green) and irrigation (blue) shortages between Level 2, Level 2 plus Eyre with operations to meet shortages, and Level 2 plus Eyre with environment operations during the 15-year Frankenflow period

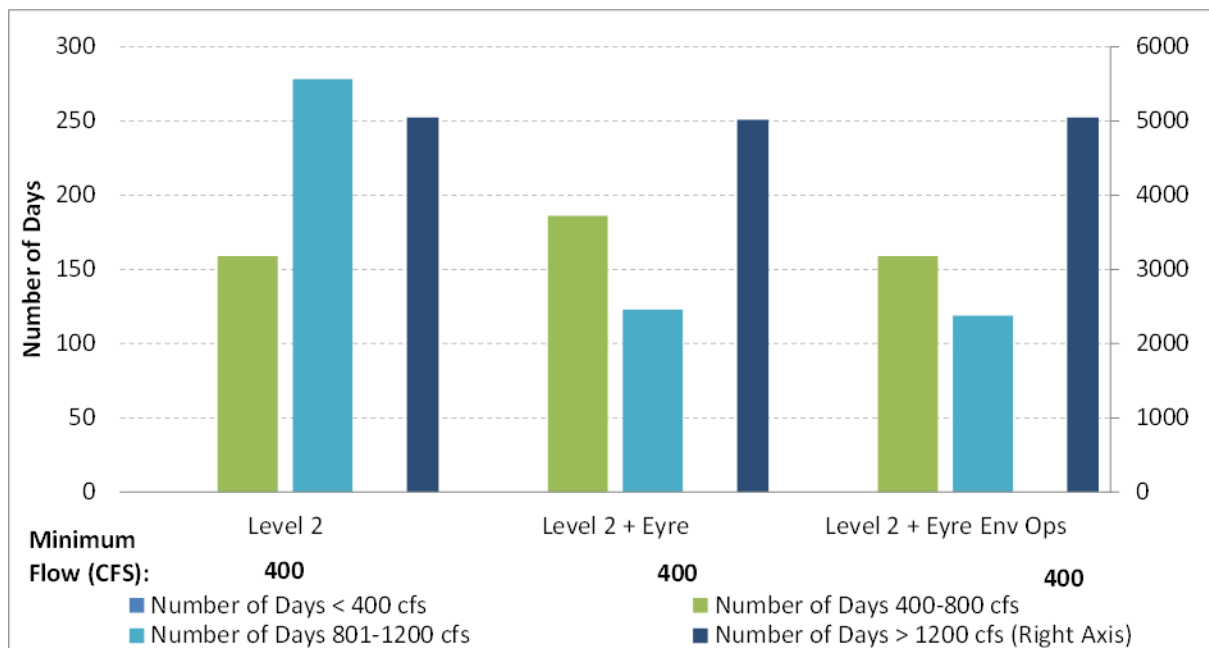


Figure 42: A comparison of low flow days between Level 2, Level 2 plus Eyre with operations to meet shortages, and Level 2 plus Eyre with operations for meeting downstream environmental needs during the 15-year Frankenflow period

Because Eyremore would be located downstream in the Bow sub-basin, it cannot be used directly to support upstream water needs. However, an upstream beneficial effect is possible since the flow past Bassano can be made up from Eyremore releases, allowing upstream users to take more water, conditional on environmental requirements, when required. Without a prior agreement, environmental performance could slightly decrease as the BRID may be able to take a small amount of extra water (Figure 42). Introducing Eyremore would require an evaluation of how to mitigate reduced environmental performance.

Building a new reservoir comes with potential challenges. For example, environmental effects such as potential impacts on downstream fish habitat would have to be addressed prior to any construction. That said, this reservoir could be extremely positive for downstream fish habitat if it is operated with the objective of greatly reducing the number of days with very low flow. A comprehensive investigation into the relative costs and benefits of such a large on-stream facility would be required. This dam would likely offer some hydropower potential.

Build new off-stream storage in the Western Irrigation District (~Bruce Lake, ~51,000 dam³)

New off-stream storage in the Bow sub-basin could include Bruce Lake, which was modelled as a facility with 51,000 dam³ live storage; the location of Bruce Lake is shown in Figure 39. This strategy offers benefit by reducing shortages in the WID. Under dry or drought conditions, Bruce Lake could enable WID to provide water to its members without diverting from an extremely low Bow River. Further analysis to evaluate the extent of system-wide benefits would be useful.

Build new on-stream storage in the Southern Tributaries of the Oldman sub-basin, balanced with other reservoirs (~Kimball site, ~125,800 dam³)

The Kimball site, shown in Figure 39, would be a new on-stream facility on the St. Mary River with total storage of 125,800 dam³ (Alberta Environment, 2008). This site has been examined in various studies, including the storage study done by Alberta Agriculture and Rural Development (now Alberta Agriculture and Forestry, or AAF). The location of this potential site is higher up in the watershed than many other locations and is thus better positioned to increase system flexibility by capturing and delivering water. For modelling purposes, it was assumed that the Kimball Reservoir would be responsible for meeting a new downstream WCO for the reach before the St. Mary Reservoir, while the existing instream objective (IO) would remain unchanged below the St. Mary Reservoir. This would need to be confirmed with AEP.

The effect of adding Kimball storage is to reduce shortages in the OSSK system, as shown in Figure 43. This reduction in shortages is demonstrated during both the Frankenflow and Historical time periods. Shortage reductions are most noticeable in the Historical time period, where drought periods are not as severe (Figure 43B).

Building a new reservoir does come with potential challenges, as noted for the Eyremore site. Environmental costs could outweigh environmental benefits, such as loss of riverine habitat to a reservoir and fragmentation of fish populations due to another barrier to movement.

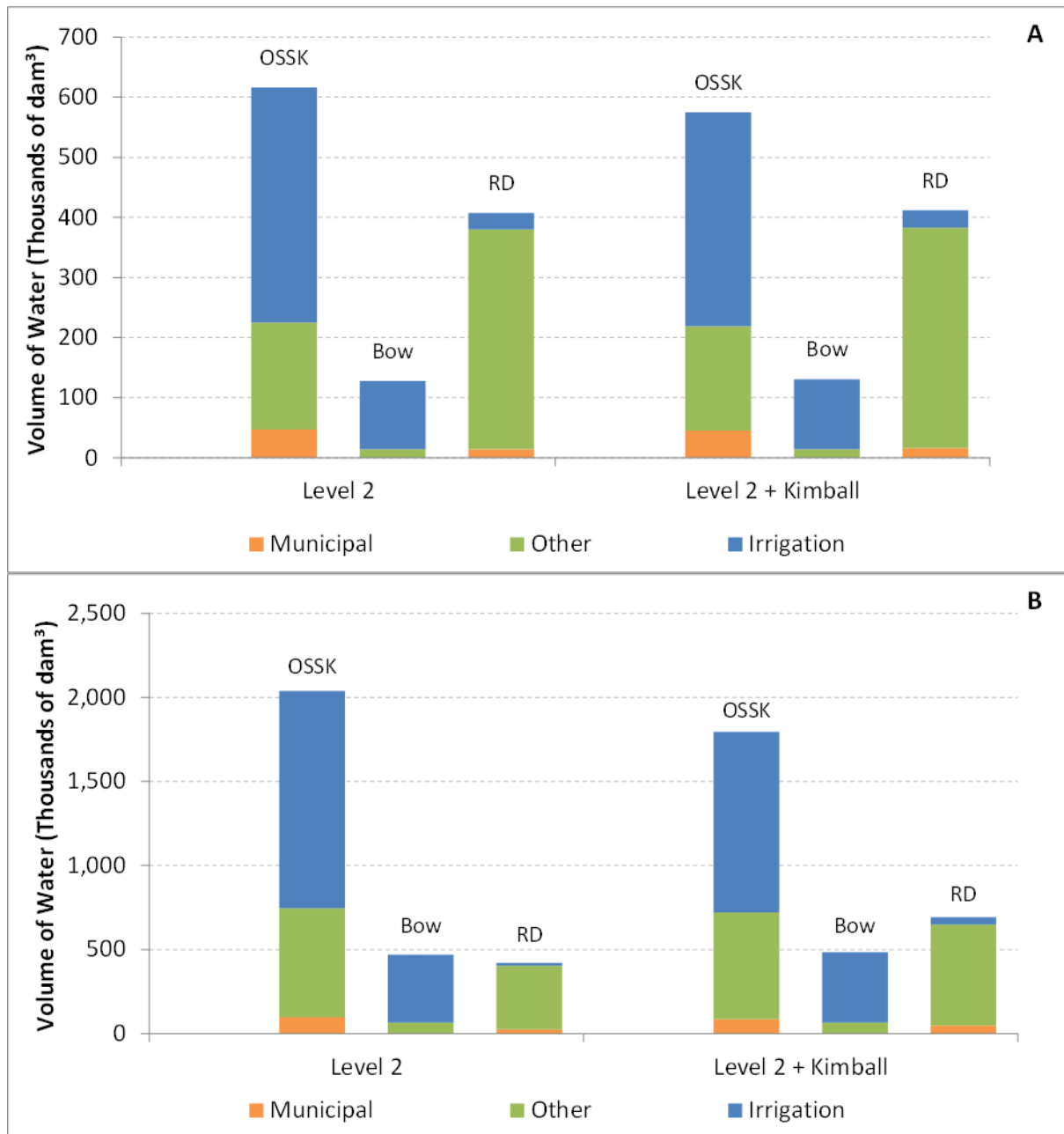


Figure 43: A comparison of municipal (orange), other (green), and irrigation (blue) shortages between Level 2 and Level 2 plus Kimball Reservoir for 15-year Frankenflow (A) and 1928–2009 Historical (B) periods

Off-stream storage was discussed as an option for the Oldman sub-basin as an alternative to building large on-stream structures. A series of smaller off-stream reservoirs could be built as needed throughout the sub-basin to meet local demands. Off-stream reservoirs can also create important lentic habitat for aquatic and terrestrial species and do not have the same environmental consequences as on-stream reservoirs.

Build new storage midstream in the Red Deer sub-basin (~Ardley site, ~400,000 dam³)

An example often used for mid-stream storage is Ardley Reservoir, previously proposed downstream of the city of Red Deer but upstream of the Buffalo Lake diversion. The Ardley Reservoir was modelled with a maximum storage of 700,000 dam³ (based on Alberta Environment, 2008), with 300,000 dam³ reserved as empty storage for flood mitigation for downstream communities. This results in a 400,000 dam³ live storage facility. This large storage facility has the potential to play a substantial role in building adaptive capacity in the Red Deer system, demonstrated by improved environmental flows downstream of the reservoir (shown previously in Figure 15) and reduced shortages (shown previously in Figure 16). It must be acknowledged, however, that there are also costs to such a large facility in terms of lotic habitat loss and fragmentation. Careful operations would also have to be implemented, particularly during the fill periods to ensure apportionment is met and downstream WCOs are maintained.

Reduce minimum flows through municipalities and other downstream users as an exceptional measure in drought years to slow the draining of upstream reservoirs

This strategy could be implemented in extreme drought periods to help slow upstream reservoir draining. The maintenance of upstream storage enables releases to be made for a longer time period to the benefit of water users and overall aquatic health. Maintaining higher minimum flow values can result in a more abrupt change in flows and potentially lower flows late in the season due to a lack of available storage for supplementation.

4. Implementation and Support for an Adaptation Roadmap

The strategies that form the Adaptation Roadmap for sustainable water management in the SSRB were identified through a series of collaborative projects. Now the discussion must turn to advancing and implementing these strategies. This section of the report shares what has been collected so far from the various working groups in terms of implementation planning.

A consistent theme running through the discussion over the last six years has been the importance of advancing and implementing strategies now, in a proactive informed manner and in anticipation of future challenges rather than waiting for a crisis to drive a quick and reactionary response. A second repeating theme has been the need for flexibility in implementation. A number of the adaptive strategies outlined in the Roadmap apply to either flood or drought situations; these strategies will need to be implemented flexibly. For example, raising the winter carryover in existing irrigation-serving reservoirs, as seen in Level 1, would maintain higher winter water levels in irrigation reservoirs to allow higher potential to serve water demands during dry periods. This strategy is adapted for dry years and may not be necessary during wet, high snowpack years; indeed, in wet years this strategy would increase flood risk if high spring flows occurred. It was also reinforced that implementing some strategies can influence other strategies and the dynamics between them should be considered when deciding on implementation priorities.

Strategies presented for implementation in this plan generally appear in priority order; that is, within each Level, those regarded as the “most promising” appear higher on the list. Other strategies that were viewed as offering some benefits are subsequently listed. All strategies were presented in section 3.2 of this report. Those marked with an asterisk (*) are not currently modelled in the SSROM. For each strategy, in a bold italicized font, there is a discussion of benefits, barriers, actions needed for implementation, who should be involved and, where possible, potential timelines.

4.1 Level 1 Implementation

Level 1 strategies focus on using existing infrastructure without the need to build anything new. Ideally, several components of the Level 1 strategies would be implemented before the next water year begins—that is, by April 2016. Flexibility and the opportunity to make revisions as implementation proceeds will be crucial to success. Time is of the essence as another flood can occur during any given spring, or an ongoing drought can begin at any time and may already have started in 2015. Perhaps the key objective of the collaborative work by water managers and stakeholders on this and the many other projects on which this report is based is to provide some assurance to government that these strategies are practical, effective, and capable of step-by-step implementation in accordance with the informed guidance provided. The stakeholder groups engaged in these reports are interested and available to provide additional detailed information wherever needed.

Institute a long-term, flexible and comprehensive water management agreement for drought mitigation, flood mitigation, and watershed health with TransAlta, including: water bank for river basin management purposes, flexibly stabilizing Lower Kananaskis Lake and Kananaskis River, flood mitigation using Ghost Reservoir and other reservoirs, functional flow releases as needed for riparian and fisheries health, and adjusted fill times for Minnewanka, Spray, and Upper Kananaskis Lakes

Potential benefits:

Many of the benefits accruing from changing the operations of some portion of the TransAlta reservoirs upstream of Calgary were documented in the Bow River Project Final Report (Alberta WaterSMART, 2010). Other benefits have been identified and documented since that time in projects simulating real-time management under drought conditions, simulating climate change water supply scenarios, stress testing with 86 years of historic data using current and forecast water demands, modelling the 2013 and 2005 floods to assess mitigation options, applying Room for the River concepts for local and regional flood mitigation, and the current study integrating operations in the Red Deer, Bow, Oldman, and South Saskatchewan sub-basins.

Initially identified benefits were associated with the recommendation for an agreement for a water bank that reserves approximately 10% of the annual storage and flows within the TransAlta reservoirs for release in accordance with downstream needs, including improving environmental flows during low flow periods while minimizing shortages to junior and senior licence holders. These benefits included: greater assurance of flow minimums to support fisheries and aquatic and riparian ecosystems, adequate flow through Calgary to accommodate tertiary treated wastewater and raw water demand for forecast population growth, and generally improved environmental conditions from Bearspaw to downstream of Bassano to the confluence with the Oldman River. Added to the water bank proposal was stabilizing Lower Kananaskis Lake and adding functional flows to the Lower Kananaskis River to improve fisheries, environmental conditions, and recreational opportunities at relatively low cost.

Additional modelling confirmed that today's water management infrastructure could mitigate drought conditions to a significant extent for the first dry year. But even with some conscious decisions to carry over higher winter water storage, the second year of a drought brought serious shortages to licence holders and the possibility of reservoirs running dry, which did occur in the third year of a serious but not unrealistic drought. However, operating the reservoirs primarily for water supply rather than power demand-driven releases improved conditions and reduced shortages up to the point at which reservoirs were nearly empty.

Collaborative modelling of flood mitigation based on altering operations of the upstream reservoirs showed meaningful potential for reducing flood magnitudes downstream. However, a flood similar to the 2013 event still resulted in considerable flooding, although not as much as would otherwise be the case. For smaller floods, the reservoirs were able to substantially reduce or prevent downstream flooding. Project participants concluded that the reservoirs were not built for, nor are they capable of, eliminating all risk and damages from extreme events. Recent experience using only the Ghost Reservoir for potential flood mitigation during late spring and early summer has not proved entirely satisfactory. The voluntary lowering of Ghost in 2014 and the commercial agreement of 2015 between the GoA and TransAlta has been criticized for not being flexibly implemented to accommodate some summer village residents and water recreationists. Lowering only Ghost without including the operations of the other reservoirs in the agreement may have required a greater reduction of water levels in Ghost than would otherwise be necessary, with less flexibility in raising and lowering the water levels in Ghost. Adjustments to the bottom structure in the upstream portion of Ghost have been completed to prevent fish stranding in future low reservoir levels in the spring.

Additional apparent problems were identified with an increased risk of slumping along the non-concrete portions of the Ghost Dam structures. This has led risk managers at TransAlta to limit the rate of reduction in Ghost water levels to only 0.3 m (one foot) per day. This is much less than what was originally considered (potentially several metres per day), limited only by the initiation of flood level flows downstream. A reduction of only 0.3 m per day in the water level requires the reservoir to be held at a lower level for a longer period of time than would be the case if more rapid drawdowns were allowed. Technical “fixes” could be applied to the at-risk portions of the dams and dikes which could provide additional flexibility in operations. The operations could then be run according to more sophisticated reporting and forecasting of conditions, as described below. Regardless of the technical outcome, other upstream reservoirs need to be involved in annual flood mitigation actions and drought risk management, whether flood protection is needed in any given year or not, because they are all interrelated.

For normal conditions of water supply, extreme or prolonged drought, or moderate to extreme floods, TransAlta reservoirs can provide some highly valuable mitigation and improvements to what would otherwise be the case.

Implementing functional flows is part of this strategy and the aspects of implementation are described under the strategy “Adjust Dickson Dam operations.”

Barriers to implementing this strategy:

- Clarifying and agreeing on the flexible, risk management decision-making criteria needed to determine reservoir levels and flow rates throughout the system to mitigate flood or drought, or improve environmental conditions while enabling licence users access to their allocations.
- Determining how to mitigate extreme floods while managing overall water supply and storage to meet needs of other users and maintain watershed health.
- Clarifying the governance and decision making related to reservoir management; e.g., who makes the final decision about whether to “fill or spill”²¹ and where to do so?
- The lack of availability of solid and timely forecasting data, modelling tools, and shared information is a barrier to effective deal negotiation and operational decision making. Multi-factor assessments are needed that include multiple data sources; e.g., soil moisture content, snowpack, air temperature, precipitation, fish spawning periods, and other environmental conditions such as streamflow rates, phosphorous loading and dissolved oxygen.
- Meeting TransAlta’s need to address cost, maintenance and liability issues related to dam safety, downstream flow rate, flood concerns related to infrastructure, potential loss of revenue and compensation from additional spillway use, timing of releases, ancillary services, and permitting requirements.
- Implementing a flexible and relatively stable level for Lower Kananaskis Lake and functional flows in the Kananaskis River below Pocaterra power plant may need to be part of a “best efforts” clause in the original agreement. More study on spillway capacity may be needed to fully stabilize the lake, but some operational improvements to improve fisheries and recreation should be expected during the study period.

²¹ “Spill” or “spillage” refers to water directed down spillways rather than through turbines due to rapid lowering of reservoir levels.

- Once overall costs are known, determining the economic and environmental factors and who benefits from these strategies would be valuable to government decisions. Water management is a flexible and adaptive decision process based on numerous inputs and conditions. The environmental benefits, municipal and commercial flood protection, access to licensed water, and irrigation water supply can vary greatly within a year and across years, making it difficult to ascertain the “typical” or “average” value of benefits. What is clear, is that these valuable benefits will occur to a greater extent with a conscious and deliberate effort to achieve them in balance with the current, single purpose operations.

Action needed:

- Allocate more resources to develop reliable short-term forecasting to reduce unnecessary use of spillways rather than electricity generation spillage in anticipation of flood risk. Improved multi-factor forecasting enables a pre-release strategy to be implemented three or more days before an expected event rather than keeping reservoir levels low during the entire flood season, as was done in 2014 and 2015. Improvements in long-term (beyond 72 hours) forecasting capability and technology are also needed. These functions should draw on information from many new monitoring and data sources and be properly staffed, and the information should be integrated, assessed, and communicated in a timely manner.
- Ensure the provincial river forecasting group has adequate staff and communications capacity. Snowpack, soil moisture levels, reservoir levels, air temperature, and precipitation weather forecasts, both short and long term from local, provincial, federal, and US National Weather Service and other international information can be used to better manage flood and water supply dynamics while balancing risks.
- Establish a flexible, easily amended, and improved long-term commercial and operational water management agreement between the GoA and TransAlta on the Bow River as soon as reasonably possible and, at least in part, before the next water year (April 2016). This is essential so it can be tested, learned from, and gaps identified, remedied and improved under “normal” conditions rather than waiting until the next emergency, be it flood, drought or environmental degradation.
- Engage large water licence allocation holders, including municipal, irrigation, commercial, and recreational interests and other key water users in a structured collaborative manner prior to final approval of the GoA–TransAlta agreement. This will ensure rapid and smooth implementation by reducing the risk and numbers of concerns raised, appeals filed, and legal and political proceedings that could tie up this important new water management arrangement for years, leaving homeowners, municipal water supply, infrastructure, irrigation, and the environment at continuing risk from flood and drought.
- Create an interim governance process or structure to enable key licence holders and water interests to participate in water management decisions under the new agreement, supporting a final single-window decision maker directing and taking full accountability for reservoir operations.

Who should be involved:

- TransAlta
- GoA (with input from relevant departments)

- Bow River Basin Council (enabling some form of participation by the City of Calgary, Town of Canmore and other affected municipalities, irrigation districts, Ghost recreation users, Calgary River Community Action Group, and the Stoney and Siksika First Nations)

GoA and TransAlta have been engaged in on-again, off-again negotiations about water management on the Bow River for over five years. What is needed is a firm commitment by the GoA to get a deal done, and a clear mandate given to those at the negotiating table.

Timeframe:

This commercial and operational arrangement between TransAlta and GoA should be completed, at least in part, early in 2016 to provide sufficient time for reviews and approvals by potentially affected licence holders (in accordance with the *Water Act*) and with the intent to be in force for the 2016 water year beginning in April.

Raise winter carryover in existing irrigation-serving reservoirs; start with Travers which draws water from the Bow, then investigate feasibility for the St. Mary, McGregor and other reservoirs

Potential benefits:

The benefits from increasing the reservoir levels over winter are several, depending on various factors. First, these reservoirs can be drawn upon by irrigation districts in the early spring as needed, reducing the need to draw water from their respective rivers during early spring periods of low flow, thus improving environmental conditions in the rivers. Second, higher levels of winter carryover water provide an additional insurance policy against low snowpack and potential drought the following year. Third, filling up to near the FSL of the reservoirs in the fall is often an opportune time to do so since the irrigation season is over and little water is needed for other purposes.

Barriers to implementation:

Only a few barriers to increasing winter carryover in Travers and McGregor reservoirs are known.

- Consideration should be given to shoreline erosion and potential erosion buffers in some locations where local recreational residences and cottages have located, despite impinging on the primary irrigation purposes of the reservoir. Flexibility would be required in implementing this change so the operators can manage the reservoir fill and releases to minimize any negative impact on the downstream flow and the dependent aquatic resources.
- As with all reservoir operations in southern Alberta, there are risks of flood and drought in any given year, and how reservoirs are operated can affect the agricultural economy, ecosystems, and other water users and residents during these naturally occurring weather conditions.
- St. Mary Reservoir would require additional study to determine impacts on fish and aquatic habitat from higher winter carryover.
- Flood mitigation capacity trade-offs between the St. Mary and Oldman systems may be questioned. There is a social expectation for flood mitigation that depends on levels well below FSL in the reservoirs.

Action needed:

- Increase winter carryover for Travers Reservoir on a pilot basis beginning in 2016.
- Undertake additional engineering study for Travers and McGregor reservoirs to review dam safety and understand impacts on the shoreline, erosion, landowners, and aquatic ecosystems.
- Do additional modelling for the other reservoirs in the St. Mary and Oldman systems on the possible trade-offs between flood retention capacity, drought risk reduction and environmental improvements.
- Undertake studies on dam safety, shoreline impacts and aquatic ecosystem impacts for St. Mary and McGregor reservoirs as needed.

Decisions would need to be informed by improved and integrated forecasting. Flexibility in implementation is essential for success and must rely on a basin-wide, informed, information-sharing approach to daily decision making.

Who should be involved:

- Owners, beneficiaries, and regulators of the reservoirs, including the relevant irrigation districts, AEP, and AAF
- Local municipalities
- Adjacent affected landowners

Timeframe:

This strategy could be implemented quickly for Travers Reservoir and likely within five years for the others.

Implement further forecast-based shortage sharing (including agreed upon temporary reductions in diversions and voluntary assignments of remaining licence allocations in times of drought), within and between irrigation districts

Potential benefits:

Informal water licence sharing and formal short-term agreements to either share licensed water or assign licensed water from one licence to another have been fairly common in times of drought or periods when someone reduces crop plantings for a year for one reason or another. During a dry period when demand exceeds water availability, irrigation districts may issue water restrictions which affect individual farmers differently depending on their particular crop mix, timing of their planting, the water needs of the particular varietal planted, and other factors. This can quickly lead to informal trading of water rights and water use from those with higher value to those with lower value, or to greater need from less.

Often this occurs between neighbours or relatives to optimize net return or crop production, shifting a limited water supply to more productive lands or higher value crops. This practice is enabled under the *Water Act* in the form of Assignments which do not require AEP approval, although notification is desirable, and reporting after the fact is required though often not enforced. Temporary licence transfers can be used for water sharing for longer than one growing season and require AEP approval.

It must be recognized that forecast-based rationing or reallocation for emergency use, which is already done informally within many irrigation districts, is not a strategy to be used all the time because it fundamentally shifts the risk profile for farmers. Further, it does not remove the need for increased storage in certain areas.

It may be prudent to determine in general terms the policy and procedures needed to enable greater use of shortage-sharing agreements in the event of a severe or prolonged drought or other conditions, making such agreements beneficial to water users while protecting the stream ecology. Waiting until a drought or other emergency arises to develop a plan, policy and procedures is often too late to most effectively manage people, resources, and outcomes. The concept of “black swan events”²² should only apply to truly unforeseen circumstances, and not to events that have been shown to be not only commonly foreseen, but practically inevitable.

Barriers to implementation:

- Accurate meteorological forecasts, including snow pack, reservoir levels, soil moisture, and other information, available for use by all irrigation districts to inform water restrictions and the promotion of water assignments.
- Defining what “sharing” means and developing a fair and equitable way for everyone to share “the pain.”
- Obtaining a commitment from users to share the shortages under certain pre-described and agreed upon situations.

Action needed:

- Provide support to irrigation districts to develop or access the forecasting data and tools needed to anticipate shortage-sharing needs.
- Provide a simple platform to transact and document water assignments and transfers within and between districts.

Who should be involved:

- AAF
- Irrigation districts

Timeframe:

Beginning in the 2016 water year, with two years to complete.

Develop basin-wide shortage-sharing and reallocation frameworks to inform and enable severe drought mitigation*

Once rivers and streams run dry it is very difficult to recover any resemblance of the rich and diverse ecosystems they originally supported. At the same time, it is in everyone’s interest to maintain and retain the economic base in southern Alberta, much of which relies directly and indirectly on the successful operation of the irrigated agriculture economy.

²² The theory of black swan events is a metaphor describing an event that comes as a surprise, has a major effect, and is often inappropriately rationalized after the fact with the benefit of hindsight. The theory was developed by Nassim Nicholas Taleb. Source: https://en.wikipedia.org/wiki/Black_swan_theory.

Making arrangements under the duress of an extreme drought period to voluntarily redistribute water allocations to derive maximum benefit from senior licences may result in suboptimal outcomes for our publicly owned water resource. Simply put, severe drought response plans should be prepared proactively, not in time of crisis. Redistribution to the most economically valuable uses for water during severe drought conditions seems logical since, once water conservation programs are applied, municipalities and industrial uses (including agricultural processing) likely have higher value than at least some forms of agriculture. The *Water Act* enables short-term and temporary reallocations for just such circumstances. However, as shown by the Australian experience, rational economics-based reallocations may not protect minimum flows to retain the ecological support system of a river. This may be a societal choice to maintain jobs and the economic support base of the population in a region, but such a trade-off should be based on some prior consideration.

Recognizing that drought is a recurring condition throughout the SSRB, it is prudent to plan for the next occurrence of this social, environmental, and economic threat. The extensive irrigation infrastructure built in the last century in the Bow, Oldman and Southern Tributary systems was intended to improve productivity and reduce risks to agriculture from drought and it has served the region well. But experience from the 2000–2001 drought shows that reservoir storage and infrastructure were not enough to ensure adequate water supply to all users and uses. A voluntary agreement among the senior licence holders to share water allocations was reached for the 2001 water year and proved successful in getting through that dry year. However, many participants have suggested that the agreement would not have held for another year of drought, and that water allocation in a future drought should not rely on the same voluntary sharing as seen in the past.

The benefits of reaching some level of agreement now on how water allocations might be shared or redistributed during the next drought could be substantial. Only regional and local water users and managers have a good understanding of where the various higher value water uses reside and these uses change from year to year. As agreed to in writing by all irrigation districts,²³ water for humans and livestock is a first priority in any serious shortage. But what of all the other uses, and how to determine which part of a municipal licence goes to human use versus the many other water uses contained in that licence? Some agreement on first principles and a documented plan for when and how licensees might collaboratively work towards minimizing damages from a prolonged or severe drought would be easier and more thoughtful, fair and equitable than simply waiting for the crisis to occur and then scrambling for some portion of the remaining water.

The alternative to reaching agreement by the licence holders is for the provincial government to implement its emergency authority to take over allocations and distribute water as and when it sees fit. Four questions arise for the licence holders and residents of the basin:

- Does the provincial government have the information readily available to allocate optimally and objectively to those most in need or to those with the highest value use for the remaining water?
- Once the drought is over would the costs to licence holders from the centrally controlled reallocation of their licensed water be repaid and how would costs and compensation levels be determined?

²³ *Human Use of Water and Livestock Sustenance Declaration*. This declaration was adopted by the Alberta Irrigation Projects Association at its annual general meeting on December 6, 2010.

- Once the allocations are held by the provincial government for emergency purposes, would there be a reluctance to go back to the old system of seniority allocations, given that the emergency showed that it was unworkable under stress?
- And finally, what criteria would provincial government administrators apply to choose between minimum environmental flows versus agricultural, industrial and municipal water users under the most extreme drought conditions?

Thus, the Best Alternative To a Negotiated Agreement (BATNA)²⁴ among licensed water allocation holders is to entrust the complex water management system and their access to limited supplies of water to an unknown plan. A negotiated agreement completed prior to any crisis, that covers at least the principles, trigger mechanisms, general priorities, criteria to adjust environmental flows, and use of transfers, temporary transfers, and assignments may be worth considering.

A component of this strategy is to develop a framework for water sharing via reallocations, but not at the level of specific individual transfers, as these would change from year to year and even month to month. The proposed framework would include the requirement for a Water Shortage Response Plan (WSRP)²⁵ by existing junior licence holders and those with critical water needs year round above a certain size cut-off, such as residential developments, municipalities, industrial facilities, livestock operations and so forth. The purpose of WSRPs is to ensure:

1. *The applicant or licence holder develops full appreciation of the involved risk to the intended purpose of water use.*
2. *All possible opportunities (to cope with water shortage) are considered and analyzed in advance.*
3. *The proposed activity [in the licence] is sustainable during water shortage periods (ESRD, 2014, p.1).*

Widening the requirement for WSRPs from newly issued licences to all licensees in the Bow and Oldman watersheds will encourage and create the means to cope with water shortage risk. Requiring prearrangements for dealing with the risk of severe drought or shortages caused by other factors places initial responsibility for reducing shortage risk where it should fall—upon each licence holder in the basin. Requiring WSRPs is consistent with the Alberta Water Council's 2009 report, *Recommendations for Improving Alberta's Water Allocation Transfer System*, and with the recommendations from an advisory group to the Minister in 2009.²⁶

²⁴ The well-known acronym BATNA, is from the book *Getting to Yes: Negotiating Agreement without Giving In*, by Roger Fisher and William L. Ury, originally published in 1981.

²⁵ See *Preparing Water Shortage Response Plans*, 2014, by Alberta Environment and Sustainable Development, online at <http://aep.alberta.ca/forms-maps-services/directives/documents/PreparingWaterShortageResponse-Apr23-2014A.pdf>. See also *AENV Water Shortage Procedures for the South Saskatchewan River Basin*, revised April 2009, online at <http://aep.alberta.ca/water/programs-and-services/south-saskatchewan-river-basin-water-information/documents/WaterShortageProcedures-SSRB-Apr2009.pdf>

²⁶ Minister's Advisory Group, August 2009. *Recommendations for Improving Alberta's Water Management and Allocation*, online at <http://esrd.alberta.ca/water/water-conversation/documents/RecommendationsWaterManagement-2009.pdf>

The discussion of these measures was based on the most extreme drought conditions, not ordinary, regularly-experienced low flow conditions. The first steps would be for WSRPs to be implemented, none of which should affect established minimum flows and would be based largely on economic considerations among licence holders. These could include moving cattle herds or reducing demands for lower value purposes. However, as a last resort it was suggested and modelled that if a framework were in place that had negotiated criteria and an agreed-upon absolute minimum for adjusting environmental flows, or if there were at least a mechanism for such adjustments under extreme drought conditions, then considerable water may be saved. Without adjusting minimum flows to cope with extreme drought, no trade-offs may have been considered to protect social interests such as human use and jobs versus normal operations of existing standards for minimum flow rates. In other words, streams may run dry because the minimum environmental flow is maintained until the reservoirs are emptied rather than flow rates being reduced to the lowest possible flow to ensure at least some environmental water remains flowing in the river. Quickly moving to water trading and reallocation can save a lot of water for human, livestock, and job retention purposes. How much water can be saved for later environmental flows and other purposes would be a matter for future modelling and scenario testing, but it is reasonable to expect substantial water savings.

Barriers to implementation:

- Getting major water users to develop and agree upon the general principles to be followed in an emergency drought plan, and then commit to and follow the principles under extreme stress conditions.
- Ensuring a higher level of accurate and reliable forecasts on which to base the reductions and assignments.
- Gaining agreement on a process to better understand and adjust minimum flows under extreme conditions before it's too late for the river ecology.
- Enforcing adherence to the agreed-upon temporary reductions and flexible use of assignments.
- Insurance and other considerations may be a barrier if they do not reflect the reality of how commercial arrangements for sharing might occur.
- There is no requirement for junior licensees or those with critical needs to develop a WSRP to deal with drought conditions.

Action needed:

- Access or create a background document summarizing the current situation with regard to shortage sharing, its history and practicality going forward.
- Collaboratively develop a principled and flexible framework for dealing with drought risk.
- Secure access to a tested and reliable water balance model to quickly and inexpensively demonstrate the effects of various options and plans to reallocate among licensed water users and uses.
- Develop a draft policy and planning framework to mitigate severe shortages.
- Provide adequate public engagement to review and advise on the draft policy.
- Implement a final version of a shortage-sharing framework and the conditions under which it may be triggered.
- As part of the long-term drought response plan, each licence holder above a certain size or with critical needs (human, livestock, industrial processes) must develop a formal WSRP and file it with AEP.

Who should be involved:

- Individual irrigators
- Irrigation districts
- Municipalities
- Water managers
- AEP
- Other licence holders as appropriate

Timeframe:

Because there is a drought precedent, this strategy could be undertaken in less than one year with expected completion of the framework by the water year 2017, to begin in April of that year, with filing of the WSRPs by the following water year.

Restrict new greenfield development in the floodplains to reduce flood damage and develop strict regulations against changing the nature of brownfield developments***Potential benefits:**

Virtually all participants agreed that there may be a need for further buyouts in select locations in a fair, cost-effective and permanent manner to reduce damages from the next flood. There was more debate about additional development in floodplains and the issue seems to be around the definition of new development. Some interpreted the strategy as potentially preventing residences currently in the floodplain that are not part of the buyout plan from adding a garage or making other improvements to their property. Others viewed the intent as preventing new greenfield residential, commercial or other inappropriate developments in the floodplains.

Some new development may be acceptable in floodplains on the condition that no protection or compensation for flooding of the development would ever be forthcoming, or the development could be built in a “flood-proofed” condition. Such uses could include temporary fishing or kayaking camps with assured access in and out of the floodplain or park settings, hiking trails, and other similar uses that may be damaged or destroyed by flooding, but no lives would be put at risk. Whether to rebuild would be at the cost of the developer or owner.

If no development would be allowed, significant compensation may be required for the “rule change” as many near-river areas have been purchased by investors and are slated for development that is possible under the current rules. The same applies for regulation changes in brownfield areas.

Clearly defined restrictions are needed on changing the nature of existing development on floodplains. This is to prevent expensive new infrastructure from being built on floodplain sites with existing but different types of developments, or infrastructure that adds flood risk to taxpayers beyond what is already on the same site. An example of an unpermitted development might be building a multi-family residence on a site within the floodplain that already contains a single family residence.

Barriers to implementation:

- Lack of specific and clear definitions of what is meant by new development, greenfield development versus brownfield, and what is allowed.
- Lack of clearly denoted boundaries for the floodplain based on data agreed upon by all levels of government.
- Socio-economic cost.
- Past apparent preference to institute floodplain development guidelines instead of regulations.
- Poor optics and lack of public support from property owners and construction and development industries.
- Need to financially compensate landowners and investors with greenfield property that has established plans or permitting underway for development for their potential economic losses.

Action needed:

- Develop clarity of meaning and specific definitions to place into regulation of what is allowed and not allowed. This is essential for municipalities to have the backing to consistently enforce this strategy.
- Assess the financial implications of implementing this strategy, and decide who should bear this cost (the developer or landowner, municipality, provincial government or federal government).
- Form a small team of knowledgeable representatives from relevant provincial departments, city planners, and landowners and/or developers to draft definitions, review internally, create a communications plan, put out for comment, revise as needed and put into regulations governing land allocation decisions.

Who should be involved:

- Appropriate provincial government departments (e.g., Municipal Affairs, Infrastructure and Transportation, AEP)
- Municipalities with flood risk such as Calgary, Edmonton, Canmore, Drumheller, Fort McMurray, Peace River (and possibly others through the Alberta Urban Municipalities Association (AUMA) and the Alberta Association of Municipal Districts & Counties, or AAMDC)
- Landowners and developers as appropriate

Timeframe:

This strategy is complex and requires the engagement of many key stakeholders, which should be initiated in the near future. Draft regulations could be prepared over the coming year with municipal consultations providing the basis for a collaborative approach. A variety of studies may be needed to assess various potential outcomes from alternative actions suggested, with a public comment period and legislative debate, likely taking up to five years to complete.

OTHER LEVEL 1 STRATEGIES

Increase St. Mary Reservoir operating FSL by 1 metre

Potential benefits:

Based on the surface area elevation curve in the current model, increasing the St. Mary Reservoir FSL by 1 metre adds approximately 57,000 dam³ of additional storage to the Oldman sub-basin. This reservoir provides irrigation water and municipal water to a large area of southern Alberta and the additional security of supply could bring significant benefits in the event of a drought or a particularly dry period over one or more years.

Barriers to implementation:

- Concerns related to flooding and dam safety.
- Concerns related to erosion, aquatic health and landowner impacts.
- Limited study of the value of the potential benefits from the additional water in reducing agricultural risk, improving crop type, value, and productivity.

Action needed:

- Conduct dam safety review with various FSL increases up to 1 metre.
- Conduct shoreline impact evaluation.
- Engage local landowners on potential raise, benefits, issues and mitigation.
- Conduct digital elevation model to determine how much additional water would be contained in various increases up to 1 metre.
- Do additional water balance modelling under historic conditions to assess water allocation benefits.
- Adjust reservoir water licence to accommodate change in storage capacity and increased evaporation loss.

Who should be involved:

- Affected GoA departments, including AEP and AAF
- St. Mary River, Taber, Raymond and Magrath irrigation districts
- Local residents
- Other potential beneficiaries or negatively affected parties downstream

Timeframe:

Most additional studies can be done relatively quickly, although consultations with affected parties would require a few months. Permitting should be straightforward as it would be an expansion of the current facility and operated by government. The timeframe for implementation is 6-12 months and longer in cases where new licences are required.

Effectively implement Alberta's Wetland Policy*

Potential benefits:

Effective implementation of Alberta's Wetland Policy would incorporate strategies designed to protect existing wetlands in areas that experienced high historical wetland loss and to restore wetlands where such restoration can provide the most environmental, social and economic value. Wetlands help

reduce flooding and soil erosion by storing runoff and slowing its downstream release. Wetlands are also recognized as ecologically important habitat areas for dozens of important birds as well as terrestrial and aquatic animals. The Alberta Wetland Policy has been approved and is in effect, but some participants were not optimistic about it being fully implemented and employed to restore or increase wetland acreage and functionality in the SSRB. Part of the concerns related to regulatory conditions against longer distance mitigation offsets that prevent wetland restoration in the areas with the most wetland losses and most in need of enhanced wetland functions—that is, the SSRB.

Other concerns related to wetland reduction due to improving irrigation efficiency by reducing evaporative losses, seepage losses, and inefficient flow rates by converting canals to pipelines. These conservation efforts may result in lost wetland areas even though these areas were artificially created in the first place. Clearly defining how such wetland losses are treated under the new policy was raised as a concern for irrigation districts and others with wetlands of an artificial or temporary nature.

Barriers to implementation:

- Overlap and potential lack of alignment of goals and objectives in relevant strategies, policies and frameworks; e.g., the Wetland Policy, Land-use Framework, *Water for Life* strategy, Climate Change plan, and flood mitigation initiatives all need to be aligned and communicated effectively to municipalities and others in a way that will enable them to advance these goals at the local watershed scale.
- Offset restrictions against restoring wetlands at some distance from where the wetland is disturbed or destroyed, even though the provincial priority area for wetland restoration is the SSRB, while many areas have abundant wetlands already.
- Clarity around converting irrigation canals to buried pipelines if artificially created wetlands along the canals have to be offset.

Action needed:

- Clarify wetland policy application to irrigation canals.
- Seek creative ways (e.g., through regional and provincial plans) to enable wetlands offsets to be restored, improved, and developed in the SSRB where 50–70% of wetlands have reportedly been lost.

Who should be involved:

- Ducks Unlimited Canada
- Impacted Municipalities
- Alberta Irrigation Projects Association and selected representatives from irrigation districts
- AEP, AAF, and the Alberta Energy Regulator
- Other agencies as needed (e.g., Alberta Departments of Transportation and Infrastructure)

Timeframe:

It should be relatively simple to provide information on how the Alberta Wetland Policy will be implemented, shared with the above groups, and clarified and agreed upon by the participants. The process and policy clarification can be completed by summer 2016 for budgeting and implementation in the 2017 construction season.

Improve resourcing for and effectiveness of forecasting infrastructure, systems and teams*

Effectively planning for and managing responses to droughts and floods depends on good forecasts and communications. Improved forecasting underpins the success of many of the other strategies discussed in this report. Managing for floods, including releasing water in advance of a possible flood, needs to be carefully monitored and balanced with environmental flow management and with managing for drought. Reservoirs can serve multiple purposes but only with a sound basis for forecasting inflows as well as outflows, current reservoir levels, downstream demands, short- and medium-term ensemble precipitation forecasts, and several other factors described below. All of the collaborative sub-basin projects and the previous flood and climate change projects reinforced the need for the best possible streamflow and snowpack data, soil moisture content, temperature and meteorological forecasts to inform operational decisions. For all farmers, but especially for irrigators whose operations significantly affect water management, water supply information and forecasts are needed well before the start of the season to make decisions about crop types, seeding and other investment choices.

The existing system for forecasting weather, snowpack, river flow, dam releases, and flood hazards is complex and relies on skilled, dedicated and hard-working people in several provincial and federal agencies. Their work goes largely unnoticed until there is an emergency at which point they quickly become central figures in our efforts to understand what is occurring where and why, and what alerts and emergency functions should be contacted and brought into play. This often occurs precisely when monitoring stations are flooded or destroyed by debris, communications are disrupted, and locally-affected residents are seeking information from limited staff resources with many critical responsibilities to fulfill. The current system has served us well for many decades, but recent droughts and floods combined with large increases in populations at risk, greater demand for water use, and realistic concerns about climate change and extreme events have created an urgent need for allocation of more resources to this often neglected area. The monitoring stations and the data they collect over the long term are critical inputs to the ongoing forecasting and modelling work. The provincial and federal governments need to make a commitment to maintain, and significantly expand, these monitoring networks over the long term.

The good news is that a wide array of useful data sources exists. The problem is that many of these data sources are dispersed in their collection, used by separate agencies and organizations for single purposes, and are not integrated and applied in any organized or comprehensive manner. Thus there is an opportunity to fully integrate these various data series into a watershed-by-watershed management system. Scenarios, implications, probabilities, and possible management responses can then be empirically and rationally evaluated based on many factors applied together. The time to develop a more sophisticated and useful operations support system is now, before these long-time experts retire and move away.

Simply put, the elements of a world-class forecasting and management system are largely in place, but the number of climate gauges, the resources, and a plan to pull it all together are lacking. This is understandable as the perceived need for more comprehensive forecasting and management was not seen as urgent until the recent flood and follow-up studies illustrated how valuable forecasting will be in meeting future drought or flood challenges. Post-flood conferences and research have also shown the relative lack of resourcing available for integrating forecasting and operations compared to other jurisdictions such as Colorado.

Although the forecasting portion of this strategy applies equally to each sub-basin, there are notable differences. Given these differences, and the importance of this perspective of combining forecasting and total operations to mitigate flood and drought risk to Calgary, an initial focus should be on the Bow system, including all private and publicly owned and operated reservoirs. Benefits to the entire SSRB and all of Alberta will be achieved by implementing the forecasting portion of this strategy and the information system structure. However, the specific application of improved and integrated forecasting to reservoir operations would initially apply primarily to Calgary and other communities and licensees on the mainstem of the Bow all the way to Medicine Hat.

Perhaps the key thing to remember about risk management related to water is that it is continuously variable and thus requires real-time monitoring and reporting on an array of essential factors. Near real-time monitoring is important for other factors that may begin to play a critical role when conditions are most risky. Fortunately a template exists that describes the components of data and the technology needed to provide a best-in-class management system for the Bow River system. It is the New York City Operations Support Tool, illustrated in Figure 44.

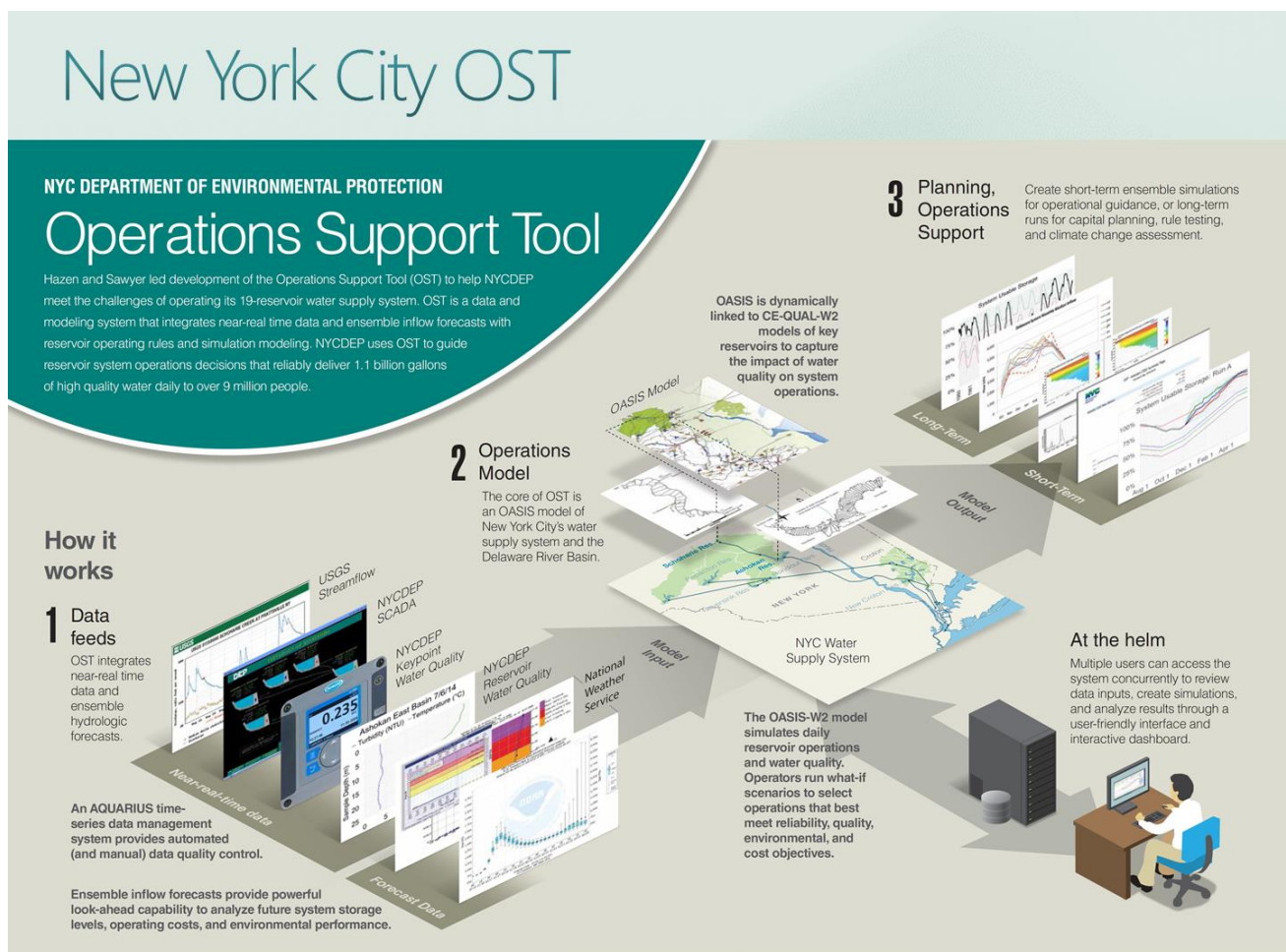


Figure 44: Example of a tool to support real-time water management operations

Source: Hazen and Sawyer, via HydroLogics Inc.

Given the extreme variability of our weather patterns and climate, the close proximity of large population centres to the water towers of the Rocky Mountains, and southern Alberta's irrigation-based economy, it is only prudent for our provincial, regional, and local leaders and water managers to be prepared for conditions known to have appeared in our short history of settlement in this region. As important, climate research has shown more dramatic risks in the prehistory of this region and the potential extremes that may arise from a changing climate.

Like the Room for the River concept, some adaptation of the template to fit the Alberta situation will be needed, but the basic structure of the technology is solid and applicable. Similarities are that the New York City system manages 11 upstream reservoirs used for multiple purposes prior to managing the drinking water supply and flow rates through the city. These reservoirs were originally constructed for different purposes and were only recently operated in an integrated fashion with the priority on water supply management, while still accommodating their original purposes. One major difference is that the flood and drought risk and threat to southern Alberta and Calgary in particular is much greater than for New York City. Thus there is an urgent need to build this relatively inexpensive component of the resilience and mitigation strategy on the Bow system.

Potential benefits:

- Electronic assemblage of many types of data from many and diverse sources (SCADA) into a useful ensemble of meteorological forecasts, river flow prediction and ready-to-use management tool for decision makers.
- Improved ability to adjust and adapt to changing weather and demand conditions, daily or hourly as required.
- Reduced risk of overcompensation by pre-emptive draining and holding of reservoirs at a low level, potentially leading to water shortages later.
- Improved capacity to account for multiple uses in water management decisions.
- Opportunity to become a centre of excellence in technology, governance and expertise in the rapidly growing global area of water management.
- Practical tool for scenario building, long-term planning, and science-, data- and probability-based infrastructure investment decisions.

Barriers to implementation:

- Diversity of agencies and organizations collecting needed data with competing interests.
- Lack of coordination and integration of data sources.
- Potential turf protection, lack of precedents for budget and data sharing partnerships, and claims of "ownership and proprietary data".
- Need for a focal point to champion need for the system (e.g., AEP's Resilience and Mitigation Branch, AEP's Operations Division, City of Calgary, irrigation districts, AI-EES).

Action needed:

- Hold a workshop to assess and determine forecasting and management vision and plans.
- Allocate funds to ensure access to current best in class models.
- Develop integrated decision-support tool based on New York City template. This could be a modification to tools already being used by the Province. These tools should be accessible to multiple stakeholders.

- Train people and apply decision-support and planning tools during normal times in preparation for next flood or drought conditions.

Who should be involved:

- Lead: AEP's Resilience and Mitigation Branch and forecasting group
- AEP Water Management Operations group
- AAF
- Environment Canada
- US National Weather Service
- TransAlta
- City of Calgary (Glenmore Reservoir, and possibly an Elbow River control structure)
- Other affected municipalities (e.g., Medicine Hat)
- Irrigation districts

Timeframe:

Initial workshop and plan development would require three months. Building the decision support tool would require one year. Integrating all the needed data in single system would require one additional year.

Adjust Dickson Dam operations to consider downstream needs (retain WCOs, functional flows, some new demands)

It was noted that, based on modelling, storage in Gleniffer Reservoir cannot meet all the medium- and long-term new demands that are forecast for the Red Deer sub-basin. However, some additional demands, functional flows, and most WCOs can be met with refined operations. This strategy has real potential for the next several years and some work is already underway.

Barriers to implementation:

- Need for additional streamflow monitoring and improved time of travel accuracy to guide operational knowledge on how to functionally control to meet WCOs.
- Need for some new data on streamflow-stream stage relationships to most efficiently provide functional flows.

Action needed:

- Need a precipitating event or senior government direction to drive the need for modifications to downstream operations.
- Develop a communications plan and infrastructure process.
- Engage Red Deer River Watershed Alliance (RDRWA) participants to build this into their water management plans.

Who should be involved:

- GoA (AEP and AAF)
- Downstream water users (Special Areas Water Supply, Town of Drumheller, and others as appropriate)

One suggestion is simply to let the operators provide for additional WCO and functional flow waters when appropriate without a specific implementation plan. If a specific plan is needed, local water and river users could be engaged via the RDRWA.

Timeframe:

Demand drivers are not high at this time. Full implementation could be done in less than three years, as operations are already being refined. In the meantime, functional flows could be implemented when conditions warrant and as advised by researchers.

Functional Flows

The use of functional flows is part of this strategy and has already been partially implemented in parts of the SSRB using releases from existing dams to support basic ecosystem functions (including riparian health, fisheries, and aquatic ecosystem health) in managed river systems. Options exist in all four sub-basins to implement this strategy. Work is already in progress below the Oldman Dam and in the Southern Tributaries, and there has been preliminary discussion about its use downstream of Gleniffer Reservoir in the Red Deer system. The strategy could also potentially be implemented downstream of Glenmore Reservoir on the Elbow and Bearspaw Reservoir on the Bow, although Glenmore and Bearspaw were not modelled for the purpose of functional flow releases in this project.

Potential benefits:

River systems downstream of control structures are subject to flow regimes that meet the needs of those operating the structures on behalf of the owners. In many cases on the Red Deer, Oldman and Southern Tributaries these control structures are owned and operated by the provincial government. Their primary purpose varies but generally includes multi-purpose water supply for municipalities, irrigators and other commercial and industrial uses. By their very nature, streamflow volumes and timing vary significantly from the calculated “naturalized” flow. In some cases and at some times, this can be beneficial to the ecological health of the river system. But often there are changes to the annual, weekly and daily flow rates that are not optimal for fish, riparian vegetation, or other factors that affect overall aquatic and ecosystem health.

Over the last several years, or decades in some cases, provincial dam operators have accommodated ecosystem needs by increasing flow rates or slowly ramping down flood flows to support such things as willow and cottonwood growth in riparian areas, seasonal fish spawning, supplementary releases during exceptionally low flow periods and others. These are generically called “functional flows.”

Recent studies by University of Lethbridge researchers in conjunction with AEP have demonstrated the effectiveness of these functional flows in various locations and circumstances. Functional flows are not needed all the time or even every year, so they can be built into operating plans when conditions are right. When water supply permits, these functional flows contribute to sport fishing, environmental health and aesthetics throughout the SSRB, and they provide cover for terrestrial animals from mice to foxes and deer, nesting sites for many types of birds and waterfowl, food for owls and diurnal raptors, and many other benefits.

Barriers to implementation:

- Specific elevation levels for effective and efficient use of functional flow water are not known in all suitable locations.

- Slowly ramping down flow levels after a flood tends to use more water than may be desired for a variety of reasons.
- Functional flow benefits aren't easy to document, making justification for releases above normal difficult especially if water supply later runs low.
- Accountability for decision making about functional flows may not be well determined or shared.

Action needed:

- Continue this work below the Oldman Reservoir and in the Southern Tributaries.
- Initiate functional flows on the Red Deer River in 2016 if conditions are suitable.
- Determine more precise flow rates and elevation levels required for effective functional flows.
- Test the effectiveness of pulsing the ramp period after a flood to save water for other uses.
- Investigate opportunities below other reservoirs (e.g., St. Mary, Glenmore, Ghost and Bearspaw).

Who should be involved:

- Dam operators (AEP, irrigation districts, TransAlta)
- AEP river and fisheries experts
- The science community (e.g., University of Lethbridge)
- Watershed Planning and Advisory Councils (WPACs) active in river systems appropriate to functional flows

Timeframe:

Functional flows on the Red Deer River could be implemented in the short term, beginning in the coming water year (2016).

Advance Room for the River conveyance opportunities in the Bow and Red Deer sub-basins*

Potential benefits:

"Room for the River" is a phrase created by the Dutch as part of their most recent approach to water management and water security in the Netherlands. It was adapted to the Alberta situation and an extensive collaborative exercise was developed to identify and prioritize opportunities for flood mitigation on the Bow River from the Ghost Reservoir downstream, the Upper Elbow, and the entire Red Deer River system. Examples of conveyance opportunities noted in this process include removing debris between Sundre and the Dickson Dam where appropriate, selective aggregate removal where positive reduction in upstream flood levels could be achieved, and bridge redesign to alleviate constriction.

Barriers to implementation:

- Priorities have not been set comparing benefits and costs among various projects.
- Availability of existing site-specific hydraulic models for some locations to assess the benefit of various options is limited.
- Accountabilities, responsibilities and funding sources for conveyance efforts are dispersed among several government agencies and municipalities.

Action needed:

- Establish clear conveyance targets for specific reaches; these objectives will guide how much more room needs to be created.
- Conduct the next level of analysis to determine which of the Room for the River proposals and concepts are most workable and of highest priority.
- Form a working group in each sub-basin (Red Deer, Elbow, Bow) to assess priorities across watershed jurisdictions.
- Provide the necessary data in key river segments to enable comparison of the hydraulic impacts of competing projects.
- Clarify how funding would be achieved and what agency (or agencies) and individuals will be held accountable for inaction resulting in avoidable damages from future floods.

Who should be involved:

- WPACs with their many specific member participants
- Municipalities in the respective areas
- Alberta Departments of Environment and Parks, Municipal Affairs, and Infrastructure, and forestry staff in Alberta Agriculture and Forestry

Timeframe:

- An initial scan and consolidation of most promising options could be done by summer 2016, depending on data availability
- Completion of some already identified projects in 2016 to address known issues in key locations
- Detailing accountabilities and collaborating on getting things established by summer 2016
- Hydraulic modelling already initiated by GoA completed by 2018
- Ongoing implementation of high priority selections begun by fall 2016 for budgeting
- Initial work done before 2017 water year for selected critical infrastructure not already underway
- Longer-term project identified for completion within five-year program

Advance Room for the River natural detention opportunities in the Bow and Red Deer sub-basins***Potential benefits:**

A great many participants in this project and in Room for the River projects have recommended that restoring wetlands, building new wetlands, or leaving more beaver dams in place in the headwaters region would have a positive impact on water management. Others suggested that such natural detention sites would all wash away in a large flood and so would have no long-term impact and perhaps a slightly negative impact as the stored water adds to the downstream flow. Nonetheless, everyone agreed that more natural wetlands in the upper Bow and Red Deer sub-basins would have a positive effect during dry periods and droughts and, for floods less severe than the 2013 event, could slightly reduce or delay flood flows downstream particularly on a local scale. These detention sites could also have a positive impact on water quality. Examples of natural detention opportunities include restoring wetlands in targeted areas and reducing linear footprint in the headwaters. These measures would have further benefit in low flow years where flows would be sustained later into the summer from these small detention sites.

Recognizing the benefits of this approach, AEP established the Watershed Resiliency and Restoration Program,²⁷ which includes support for restoring wetlands and riparian areas. This initiative is underway and funds have been allocated to evaluate, plan, and restore wetlands in some areas of the foothills and headwaters.

A complementary Room for the River approach to upstream retention is the prevention or slowing of runoff that has been artificially enhanced by human activities. Roads, power lines, deeply entrenched trails (linear disturbances), and unmanaged off-highway vehicle (OHV) use can all create new and rapid runoff in the foothills and headwaters regions. Recreational use of OHVs is not well-controlled. While many recreationists are responsible, careful users of the back country, some are not and it doesn't take many vehicles to create new pathways for water to run off at a rapid and destructive rate. In contrast, forest harvesting, oil and gas exploration and production, and other industrial uses of the Eastern Slopes are all regulated and controlled to mitigate undue runoff and protect water quality from siltation and spills.

Substantial benefits to water management and a healthy environment can be attained by selectively increasing wetland retention in the foothills and mountainous areas. But improvements to water quality and fish habitat, and slowed or reduced peak runoff can also be attained by better managing motorized recreationists in the Eastern Slopes. Many examples of controlled and successful management of motorized back-country recreation are available from similar areas in the US. It can be done by designating specific areas and trails for motorized recreation while minimizing the negative effects on runoff and other environmental values. Given the nature of our magnificent recreational areas so close to relatively large population centres, it should be a high priority to protect ecosystem integrity and reduce unnaturally powerful and swift flood runoff from the Eastern Slopes. Many organized OHV groups and organizations have volunteered their support, expertise and labour to improve the off-road conditions in these areas.

Barriers to implementation:

- Approved trails and recreational areas are needed first as adequate alternatives to the current wide-open, "go anywhere" situation.
- Locating and creating attractive and controlled off-road recreational trails and "mud-holes" is not simple, easy, or inexpensive.
- Once approved trails and off-road areas are in place, ongoing maintenance will require new human resources.
- Enforcement can be expensive and labour intensive.

Action needed:

- Strong government commitment to allocate the resources necessary to plan and implement new trails, new localized areas for off-road events and recreation, new signage, and additional enforcement activities.
- Recruit the many willing organizations devoted to off-roading and motorized recreation to engage with government, local residents, and industry to identify locations, build or improve trails, and self-enforce off-road recreation.

²⁷ See <http://aep.alberta.ca/water/programs-and-services/watershed-resiliency-and-restoration-program/documents/WatershedRestorationProgramGuide-Aug-2014.pdf>.

Who should be involved:

- AEP, AAF, Alberta Transportation
- Off-road and outdoor recreation organizations (e.g., Alberta Fish and Game Association, Trout Unlimited Canada, Alberta Off-Highway Vehicle Association)
- Local resident representation
- Eastern Slopes industries active in the region (e.g., forestry, oil and gas, power line companies)

Timeframe:

- Wetlands restoration initiative is underway now and will continue for five years
- Initial planning, recruitment of participants and collaboration of off-road recreation activities for the upper Ghost, Elbow, and Sheep watersheds during early 2016, with preliminary plans and agreements in place for these regions by fall 2016. It is critical not to let planning delay various short-term improvements already underway and being considered for the coming year
- Budgeting and field activities identified by 2017 and ongoing thereafter

Further apply land use best management practices***Potential benefits:**

Many BMPs are available to help minimize impacts of land use change on water resources. BMPs that can be improved in the municipal sector include intensification of urban and rural residential footprints, and water conservation. A common standard for management of urban and rural residential footprints is the maintenance of current population density. This management practice could be improved by decreasing the footprint expansion required by population growth by 25%, a goal of the City of Edmonton. Optimistically, this percentage could go as far as 50%, which is Calgary's goal.

Similarly, maintaining and improving current per capita water use would be the basic practice for water conservation. This could be done by reducing per capita water use by 25%, or optimistically, 50%. It is important when setting these goals to consider what proportion of the municipal licence is for basic domestic water use versus water used for industrial and commercial activities in the city. Depending on the breakdown, a 30% reduction in domestic water use may or may not have an impact on overall municipal water use.

The natural resource extraction sector has land use management practices for reclaiming semi-permanent energy sector infrastructure, accelerated reclamation of transitory footprint, efficient footprint layout, and water conservation. Presently it is expected that semi-permanent energy sector infrastructure would remain over a 50-year period. There are several ways in which this could be managed differently. Reclamation of a well site 20 years after production would be a better land use management practice, while immediate reclamation would be the best management practice taking into account potential for applying new technologies to the existing wells. Reclamation of the transitory footprint could be accelerated as a BMP. A standard cutline has a life of 60 years. If the cutline had a life of only 40 years that would be an improved land use management practice, while a cutline life of 20 years would be the BMP (ALCES Group, 2014). In many cases, cutline width has been reduced from about six metres to one metre, and some technologies no longer need cutlines at all.

The historical rates of road growth to access new resource developments could be reduced to give land use footprints a more efficient layout. Coordinated planning can achieve a 25% reduction in road required to access new wells and harvest areas. For example, in-block roads can have a life of 40 years in regions with steep slopes, and a life of only 25 years in regions with moderate or flat slopes. In each region the lifespan could be reduced by 25%, regardless of steepness of slope. This lifespan could be further reduced by as much as 50%, or completely removed (ALCES Group, 2014). A study in northeastern Alberta concluded that road access could be reduced by 34% when energy and forestry companies coordinated their road planning (Schneider and Dyer, 2006).

Work is already underway to implement land use BMPs with the sub-regional planning that is occurring in support of the South Saskatchewan Regional Plan. Examples include the development of a Linear Footprint Plan and Recreation Management Plans, starting with Porcupine Hills and Oldman–Livingstone areas. The designation of the Castle Wildland Provincial Park to protect the area’s ecological integrity is another example.

Barriers to implementation:

- Multiple uses require multiple best practices, and integrating cumulative effects and prioritizing approaches is a complex process.
- Regulatory change is a lengthy and complex undertaking.
- Enforcement of non-industrial uses is complex and dispersed.
- Creating partnerships among diverse groups to optimize BMP voluntary compliance is time-consuming and costly.

Action needed:

- Assemble general best practices literature on resource use types found in the headwaters and foothills of the SSRB.
- Convene a series of workshops on improving or adapting best practices for various resources uses (e.g., OHVs, forest products, grazing, ranching, residential and recreational developments).

Who should be involved:

- Lead: South Saskatchewan Regional Plan Secretariat
- Individual industries active in the sub-basin as well as their umbrella associations that can share information and urge the adoption of BMPs by their members
- Municipalities and their associations (AUMA and AAMDC)
- Provincial government agencies with regulatory or management responsibilities (Alberta Energy Regulator, AEP, AAF, Transportation, Municipal Affairs)
- Stakeholder groups as appropriate to the topic (e.g., Trout Unlimited Canada, Alberta Wilderness Association, OHV associations, Fish and Game Association)

Timeframe:

- One year to conduct workshops and develop plan for implementation
- Regulatory approaches and guidelines implemented in the following year
- Enforcement resourcing and prioritization in the next budget year

Promote further municipal conservation relative to what is being done now

While much less than irrigation licences, municipal water allocation licences are among the largest diversions in southern Alberta. However, because most of the flow is returned to the river from which it came, they have less impact on water quantity than one might expect; water quality impacts are considered of greater concern.

Despite the fact that most municipal water usage is based on long-life infrastructure, it is probably the area of greatest potential for improvement based on technological development. Stormwater runoff management, water treatment facilities, water reuse technologies, highly efficient water heating systems, low and no flush toilets, efficient showerheads, smart controls and others have been subject to rapid and impressive technological developments over the past two decades. More is expected and, more importantly, the consumer appeal and steady market penetration of existing highly water efficient technologies holds considerable promise for reducing the urban water footprint.

Other promising developments for conserving municipal water use include better technologies to evaluate and find water main leakage. Repair and replacement of old water mains, improving stormwater systems, and ensuring a separation between the two continues to improve overall efficiency of urban water use. Commercial water use within municipal licence allocations has also seen substantial improvement in water efficient technology. More efficient heating, ventilation, and air conditioning systems save some incremental water use in high rise buildings, while greater density of population residences, more urban xeriscape lawns and parks, rooftop gardens and green roofs reduce runoff and ultimately reuse rainwater more effectively. Many golf courses have found ways to reduce their net water use, including more efficient automated and soil-water-conscious sprinkler systems, drought tolerant grasses, and more natural “rough” areas. Adoption of all these technologies leads to considerable optimism for urban water conservation, reuse and effective management.

Reducing net water use by municipalities can result in substantial taxpayer savings by delaying or eliminating the need for additional water treatment facilities both for incoming and outgoing water. Other benefits from additional urban water conservation include improved natural river systems, higher river flow rates during critical dry or hot periods, reduced risk to fish populations, greater natural wetlands retention adjacent to source water bodies, and less need to draw down source water reservoir storage thus reducing risk and prolonging water supply during drought periods. Many other less direct benefits are derived from urban water conservation efforts, and the rapid development of water-smart technologies makes their application economically attractive.

Return flows in summer vary but participants generally agreed that a further 20% reduction in net municipal water use during summer months, when demand is greatest and treated water return flows are lowest, would be a challenging but achievable goal. The goal of 5% during the winter months reflects the much lower overall water use by municipalities in winter and higher rates of return flow, likely approaching or exceeding 90%.

Enormous and commendable efforts are underway throughout the SSRB to improve every municipal aspect of water use. These efforts should be encouraged and rewarded while recognizing that new technologies continue to emerge; the challenge to improve and to reduce risk and costs is ongoing.

Barriers to implementation:

- Balancing efficient use or reuse of water that reduces return flow with a compensating reduction in raw water intake from what it would otherwise be, to avoid harmful effects to the aquatic environment due to net lower flow rates downstream.
- There may be technological limits on how far municipal conservation can go without incurring impractical overall costs.

Action needed:

- Improve the information available to small and medium sized municipalities regarding the latest technologies available.
- Continue to improve the availability of information and incentives to residential developers and particularly to homebuyers, renovators, renters, and consumers of water efficient devices that can improve their quality of life and family budgets.
- Periodically review and upgrade the water conservation, efficiency, and productivity plans of the AUMA and AAMDC and the technologies they contain and recommend.
- Look to leading municipalities such as Okotoks for practical technologies appropriate to the water risk and environmental conditions found in Alberta.
- Develop and disseminate comparisons of water conservation strategies used by various municipalities, developers, and renovators.
- Initiate, continue, or expand recognition for innovative municipal water conservation achievements into existing awards categories within such organizations as AUMA, AAMDC, Emerald Awards, Urban Development Institute, Alberta Low Impact Development Partnership, and others.
- Require a simple assessment of current best practices when reviewing area structure plans and specific developments using municipal water licences.
- Determine what further policy options related to demand management the GoA and/or municipalities should be considering.

Who should be involved:

- Larger municipalities generally have the resources to keep up with the rate of new technology in the use, treatment, and consumer applications of water.
- The Urban Development Institute and individual development companies for residential, commercial and industrial developments play a key role in water conservation.

Timeframe:

Participants generally viewed this overall strategy as one of continuous improvement, encompassing hundreds and perhaps thousands of large and small improvements throughout the municipalities in the SSRB. Reaching the 20% summer and 5% winter objectives should be achieved within 10 years.

4.2 Level 2 Implementation

Redesign operations and expand, where beneficial, existing reservoirs in the upstream Bow for water supply and watershed health*

As described in section 3.2.4, this strategy involves re-purposing and possibly expanding existing TransAlta reservoirs in the upper Bow, changing their priorities toward public interest outcomes and maximizing revenues from hydropower as an important but, in some instances, secondary matter. In most cases the total amount of power generated from this renewable resource would remain the same since the same total amount of water would be released. But in the re-purposed strategy, timing of storage levels and water released through the turbines would be governed by considerations of flood and drought risk, environmental effects, and year-round assured water for people and other commercial water uses in addition to considering short-term power prices.

This strategy differs from the watershed management agreement described in Level 1 which included using approximately 10% of the upstream storage and supply for other purposes. However, the difference is not as great as it may seem. Modifying Bow hydropower operations to mitigate flood damages may appear only to affect the Ghost Reservoir, but in fact all the other reservoirs are affected to some extent, depending on various internal TransAlta forecasts and strategies to meet commitments and maximize revenues from the remaining stored water. Taking the Level 1 TransAlta strategy to its logical conclusion would engage all of the reservoirs to provide the additional flexibility and resilience needed to serve multiple purposes during the course of any given year. Water supply from snowpack, glacial melt, rain, and groundwater flows varies dramatically from year to year. Managing only the Ghost Reservoir in the general public interest for flood protection or for drought mitigation utilizes only a small portion of the water supply resource available. An agreement with TransAlta to keep them financially whole while using their entire system for multiple public interest purposes may be more effective than working with only parts of the total system.

A number of factors need to be considered and addressed as part of implementation:

- Ensure instream flow needs and obligations are met under all normal conditions and under more extreme conditions than would otherwise be the case.
- Manage supply and flow rates during the winter to reduce the risk of ice dams forming in Canmore, Cochrane, and Calgary.
- Enable overall integrated management of upstream reservoirs with provincially-owned and irrigation district reservoirs to minimize flood risk at predetermined flow rates and elevations.
- Minimize drought risks from what they would otherwise be, recognizing that these steps can only mitigate conditions up to a certain level of severe or prolonged drought.
- Improve environmental conditions in normal times (including both a water quantity and a water quality component, as quantity is not always a direct surrogate for environmental conditions), while enabling licensed access to water.
- Provide the flexible agreement to conduct the needed studies to determine any feasible expansion or different operations in the public interest (e.g., restoring Spray Reservoir to its original design capacity; flexibly stabilizing Lower Kananaskis Lake).
- Improve recreational opportunities for environmentally sound uses of the upper Bow River.
- Enable greater monitoring and control over cumulative effects in the watershed.
- Implement several components of the South Saskatchewan Regional Plan (e.g., headwaters protection, minimum environmental flows, improved recreational opportunities).

- Provide the basis for a collaborative governance process engaging key stakeholders.
- Significantly and measurably improve on all three of the *Water for Life* goals.

Barriers to implementation:

- Confidentiality relating to certain of TransAlta's pricing forecasts and other business operations.
- Commitments to meet existing water licences must be built into the operations.
- Uncertain forecasting accuracy of weather patterns, snowpack, river flow, soil moisture content, precipitation distribution, cropping data, and air temperature.
- The fact that reservoirs are located in protected areas could make expansion difficult.
- Potential opposition from recreational and other users.
- With the current economic challenges in Alberta, step-by-step implementation needed.

Action needed:

- Study options and benefits and collaboratively model flexibility and resilience characteristics and potential unintended consequences of the redesigned operations and flow regimes.
- Determine governance requirements and new operational roles.
- Develop an understanding of how risks and liabilities are structured and the impact of changes under redesigned direction of operations.
- Assess potential impact on shorelines, fish habitat, dam safety upgrades (if needed), and other positive or negative environmental components.
- Develop an integrated database of various factors related to decision making on water storage and release including ensemble forecasting and other Alberta data sources similar to the New York City upstream water management system (see Figure 44).
- Design an acceptable agreement between the GoA, TransAlta, and downstream water users.
- Clearly communicate benefits and how environmental, recreation and other issues will be addressed.
- Develop costs and benefits from modelling and economic assessments.²⁸
- Provide early and frequent opportunities for public comments, upgrades, and constructive participation.

Who should be involved:

- TransAlta
- Government of Alberta (AEP, AAF, and other departments as appropriate)
- First Nations in the region
- Affected irrigation districts
- City of Calgary
- Parks Canada
- Municipalities in the region
- City of Medicine Hat

²⁸ The City of Calgary's triple bottom line approach is one example of cost-benefit analysis that takes into account the cost of environmental impacts, socio-economic costs, and others (<http://www.calgary.ca/CA/cmo/Pages/Triple-Bottom-Line/Triple-Bottom-Line.aspx>)

- Other groups would be directly involved on an as-needed basis (e.g., Alberta Transportation, Parks Canada, Trout Unlimited and other positively or negatively affected interest groups)

Timeframe:

A potential timeframe for implementing this strategy is less than one year for an initial agreement for the 2016/17 water year; one year for an adaptive comprehensive agreement; and seven to ten years for full implementation and development.

Expand (74,000 dam³) and fully balance Chin Reservoir (285,000 dam³) (OSSK sub-basin)

Chin Reservoir is part of the St. Mary River Irrigation District (SMRID) and is an off-stream storage site downstream from the St. Mary Project headworks at the provincially-owned Ridge Reservoir. Before entering Chin Reservoir, main canal flow serves a hydro generation facility operated by Irrigation Canal Power Cooperative Ltd. (Irrican), which has a generation capacity of 11 megawatts. At present, Chin Reservoir is managed by SMRID and is not part of AEP's balancing system.²⁹

Potential benefits:

- Because Chin has access to more of the watershed by being further downstream, it will have a large benefit and good chance of refill.
- Expanding and fully balancing Chin would improve storage on the other upstream reservoirs, thus keeping more water closer to the headwaters and available to support ecosystems and human water uses throughout the system.
- Irrigation shortages would be decreased and the irrigable period extended during drought.

Barriers to implementation:

- Loss of autonomy and control on the part of SMRID.
- Limits to existing canal capacity and infrastructure and the costs of necessary upgrades and expansion.
- Existing cabins around Stafford Reservoir would be a barrier to expansion.
- Licensing may pose some difficulty but new licences are allowed for reservoirs providing economic and/or environmental benefits.
- Complexity of balancing other operational requirements.

Action needed:

- Undertake engineering studies of existing and proposed new infrastructure.
- Conduct water supply studies to determine fill risk and demand growth.
- Review and revise existing operational agreements.
- Undertake negotiations related to hydro generation.

²⁹ The "balancing system" means that AEP reservoirs in the OSSK sub-basins are proportionally balanced; that is, each reservoir attempts to maintain the same percent full as the others. To do this, reservoirs with excess storage (storage above the percent full of the others) are preferentially drawn on to meet demands that are able to draw from multiple locations; for example, the Oldman River past Lethbridge can draw from the Oldman, St. Mary and Waterton reservoirs, while the Ridge system can draw from Ridge, St. Mary and Waterton reservoirs.

Who should be involved:

- Irrican Power
- Affected irrigation districts
- AEP
- AAF
- Town of Taber
- Affected Hutterite colonies
- Affected First Nations

Timeframe:

A potential timeframe for implementing this strategy is one year for feasibility and determination whether to proceed at all, two more years for overall assessment (e.g., geophysical, design, costing, environmental impact assessment), two years for permitting, and five years to build (10 years in total).

Build new SAWSP and Acadia Valley off-stream storage (35,000 dam³ SAWSP + 45,000 dam³ Acadia = 80,000 dam³ total) (Red Deer sub-basin)

Potential benefits:

The addition of SAWSP and Acadia Valley off-stream storage facilities would allow irrigation and other demands to be expanded substantially in the Red Deer sub-basin. These reservoirs would allow for greater capacity to meet a growing population and associated demands on the Red Deer system without having large environmental costs. This strategy was well-investigated in previous studies as well as in this project.

Barriers to implementation:

Few barriers exist to implementing this strategy but adding this storage to the Red Deer system would require that demands are expanded to ensure the reservoirs are used to their full capacity. At this time, it is difficult to establish a positive cost-benefit for new infrastructure, but that may change in time. Therefore, it will be important to ensure adequate resourcing is available to support additional development in this part of the sub-basin.

Action needed:

- Design the system in such a way that it remains efficient, environmentally and economically viable.

Who should be involved:

- The owners, beneficiaries, and regulators of the reservoirs, including relevant irrigators
- AEP
- AAF
- Local municipalities and Special Areas irrigators as appropriate

Timeframe:

This strategy is already being explored and should be implemented when demands grow enough to require additional water storage.

OTHER LEVEL 2 STRATEGIES

Pursue more extensive relocation and buyouts in the Bow and Elbow River floodplains to reduce risk and reduce the need for upstream mitigation structures*

Potential benefits:

Relocation and buying out properties in the floodplain is the most effective—and the only permanent—flood mitigation solution. Relocating non-critical infrastructure provides an opportunity to mitigate future flood damages and, although potentially costly at the onset, this is a long-term strategy that may be less costly in the long run. It would benefit those who own properties in the floodplain by removing potential future risk, but this strategy is not without challenges.

Barriers to implementation:

- The willingness of landowners to sell their land is perhaps the largest barrier to implementing this strategy.
- Realizing that upstream or local level mitigation cannot completely remove the risk of flooding is important, although upstream mitigation does reduce risk and may present a barrier to the full implementation of this strategy.
- The cost of implementing this strategy in well-established, densely populated urban areas such as parts of central Calgary and downtown may be substantially higher than upstream mitigation measures. It is an extremely difficult discussion and substantial resources are already being applied to maintain infrastructure in the floodplain. For the Elbow River, this strategy may not be cost-beneficial with the SR1 reservoir at Springbank in place. Similarly, for the Bow, upstream mitigation may be more cost-beneficial than buyouts.

Action needed:

- Improve education and awareness around the costs and potential risks of living or maintaining infrastructure in the floodplain.
- Develop policy and allocate funding to implement this strategy within all levels of government.

Who should be involved:

- Various departments within the GoA including AEP and Municipal Affairs
- Developers
- Landowners
- Municipal governments

Timeframe:

Work on this strategy can begin immediately recognizing that it will take a while to implement, given the time needed to address factors such as how to proceed, what compensation should be offered, what to do with “bought-out” land, and so on. Once initiated, this effort should continue into the future as populations grow.

Build a series of new off-stream storage facilities in the Oldman sub-basin*

Potential benefits:

The Oldman sub-basin is already fully allocated. Therefore, new off-stream storage would help to reduce the stress on the system overall, as long as the storage was situated where local demands could be easily met. Small storage facilities offer many benefits in terms of supplying water locally; they also provide wildlife habitat, recreation opportunities, and reduce the demand on larger on-stream facilities.

Barriers to implementation:

- Proper environmental and economic analyses should be conducted to ensure additional storage is viable and does not negatively affect important environmental values.
- In the prairie environment, water quality in smaller reservoirs is often of poorer quality, with moderate to high nutrient levels and, often, high organic matter content. This can make it challenging for municipal drinking water systems to treat the water using present technology and standards.

Action needed:

- Undertake further study regarding the most appropriate location and sizing for these structures.
- Undertake full cost-benefit analyses.
- Conduct modelling analyses at the screening level to identify a range of potential benefits.

Who should be involved:

- Irrigation districts
- AEP
- AAF
- Local land owners

Timeframe:

Investigation into potential sites could be conducted in the near term. Implementation of this strategy could occur over the next several years and as demands require.

Build a series of new off-stream storage facilities (~80,000 dam³) in the Red Deer sub-basin*

Potential benefits:

An additional 80,000 dam³ of storage would allow all sectors in the Red Deer sub-basin to grow along with irrigation. This would provide increased flexibility to diversify growth and maintain healthy instream aquatic ecosystems.³⁰

Barriers to implementation:

- In the prairie environment, water quality in smaller reservoirs is often of poorer quality, with moderate to high nutrient levels and, often, high organic matter content. This can make it challenging for municipal drinking water systems to treat the water using present technology and standards.

Action needed:

- Assess at the screening level, potential off-stream storage locations.
- Undertake study to determine costs and potential limitations to ensure there are viable options in preparation for growth.

Who should be involved:

- City of Red Deer and other municipalities
- Red Deer River Municipal Users Group
- Red Deer River Watershed Alliance

Timeframe:

This expansion should accompany additional demands on the system, which means growth in the Red Deer sub-basin would be required prior to implementing this strategy. That said, investigation into potential storage sites could occur immediately, and implementation could occur as demands require.

³⁰ If further study demonstrates that off-stream storage sites would not be possible or effective, then a midstream facility on the Red Deer system should be moved from Level 3 to Level 2.

4.3 Level 3 Implementation

Build new on-stream storage low in the Bow system, below Bassano Dam (~Eyremore site, ~477,000 dam³)

Eyremore Reservoir was identified as a potential strategy to capture flows below Bassano in the lower portion of the Bow system, which could then be released to meet the environmental needs of the lower river. The reservoir could also offer potential flow augmentation during dry periods downstream, meet minimum flow needs at Medicine Hat, and provide flood mitigation benefits to downstream users by storing flood water to reduce peak flows at Medicine Hat. The reservoir would also enable the EID and possibly upstream users to access water during periods when they would otherwise be prevented from doing so due to the 400+ cfs minimum flow release agreement below Bassano Dam.

Potential benefits:

- Increased flexibility of the water management system by supplementing downstream flow.
- Allows upstream reservoirs in the OSSK sub-basins to remain at a higher level, potentially alleviating occasional extreme low flows in the Bow River between Calgary and Bassano.
- Flood mitigation for Medicine Hat.
- The proposed location for Eyremore Reservoir is such that when a large rainfall occurs in the headwaters, it would take days for the first flood water to reach this reservoir. This allows days to initiate a release from storage to mitigate downstream flooding, thus removing weather forecasting from the equation. If a flood event does not materialize, water would be kept in storage for possible drought mitigation later in the year.
- Potential low flow mitigation for Medicine Hat.
- Reduction in shortages for irrigation districts.
- Capturing some of the higher than natural winter flows to optimize environmental flows.
- Reducing risk to downstream river ecosystems and threatened lake sturgeon below Bassano Dam.
- Potential use for functional flows below the reservoir.
- Increased capacity to manage Bow and Oldman systems together for resilience in drought and flood periods.
- Potential for hydropower generation.

Barriers to implementation:

- High capital cost compared to alternative mitigation options.
- Long regulatory process and time for construction.
- Likely to be significant resistance to new storage in any location.
- Disruption to aquatic ecosystem function in the reservoir footprint.
- Integrating water management from headwaters to confluence would improve benefits of Eyremore, including revised TransAlta operations as described elsewhere in this report.

Action needed:

- Comprehensively investigate the relative costs and benefits of such a large on-stream facility.
- Model in more detail to evaluate benefits from optimizing operations of the proposed reservoir in conjunction with upstream operations during various flow scenarios.

- Obtain agreement by affected parties to proceed.
- Undertake engineering studies and formal applications.
- Undertake permitting process.
- Design, engineer, build, and operate if decision is made to proceed with this strategy.

Who should be involved:

- EID, BRID, WID
- TransAlta
- City of Medicine Hat
- Government of Alberta

Timeframe:

Given the need for various studies, negotiations, and permitting, 10 years is a likely timeframe if the project is determined to be in the public interest.

OTHER LEVEL 3 STRATEGIES

Build new off-stream storage in the Western Irrigation District (~Bruce Lake, ~51,000 dam³)

Potential benefits:

The WID has little substantial storage available and thus relies on nearly constant diversion from the Bow River as and when water is needed throughout its system, whether for environmental flows, municipal use, or crop irrigation. Having more storage within the WID could prevent or reduce its diversions during periods when water is most needed in the Bow for environmental flow purposes. As and when more residential and commercial or industrial development occurs within or near the WID, demand for a continuous supply of water will increase. Given known historic conditions, never mind prehistoric or possible new conditions due to climate change, additional storage within the WID may be able to provide a more reliable water supply for residents and agricultural purposes without further impairing environmental conditions in the Bow through Calgary and downstream. Bruce Lake would not eliminate risk due to drought, either to farmers in the district or to Bow River conditions, but under some conditions would provide some benefit.

Interestingly, most of the return flow from the WID goes to the Red Deer River and these flows are occasionally important in meeting the WCOs on that river. Bruce Lake under some conditions could extend the water supply to irrigators during a period of drought, and may also marginally benefit the Red Deer system if environmental conveyance flows are maintained.

Barriers to implementation:

- Cost: land acquisition and oil and gas wells and rights are expensive to purchase or mitigate.
- Although benefits are occasionally significant, the water supply created by this new storage is not always needed.

Action needed:

- Undertake additional modelling to determine under what conditions Bruce Lake provides what level of benefits to which users, including environmental uses, but this is a low priority.

Who should be involved:

- WID
- AEP's Resilience and Mitigation Branch

Timeframe:

As and when participants believe more information is needed

Build new on-stream storage in the Southern Tributaries of the Oldman sub-basin, balanced with other reservoirs (~Kimball site, ~125,800 dam³)**Potential benefits:**

The Kimball site was selected for evaluation primarily as a means of providing benefit if the water users in the US were to take their legal entitlement from the St. Mary River. This reduction in flow into Alberta would substantially reduce the amount of water available for environmental flow and for irrigators. A reservoir at the Kimball location just downstream of the US border showed benefits only if there were some modifications to the current WCO and instream flow needs requirements. At present, the introduction of a new reservoir would require a new WCO (rather than the lower IO requirement) to be enacted. If the existing WCO applied to the entire St. Mary River, no benefits to irrigators or other water users beyond environmental flows would result. Few participants believe that such a reservoir would be built without showing economic benefits to the region. If the WCO were adjusted and applied instead only to the stretch between Kimball and the existing St. Mary Reservoir (as would be expected) there is considerable advantage to having this reservoir in place if and when the US decides to take the full annual flow volume to which it is legally entitled.

Barriers to implementation:

- Cost versus benefits under current regulatory conditions.
- Benefit is small unless and until the US takes its maximum quota of water.
- Potential international dispute depending on how close to the border the reservoir extends.
- Potential loss of key aquatic habitat for species at risk.

Action needed:

- Further explore how environmental protection can be assured or improved without applying the WCO to new or existing reservoir operations.
- Reconsider the reservoir location, size and operating conditions if the US indicates possible reduction in cross-border flows.

Who should be involved:

- Affected irrigation districts
- AEP, AAF
- Other interests as appropriate to specific issues under consideration

Timeframe:

No current drivers for further study.

Build new storage midstream in the Red Deer sub-basin (~Ardley site, ~400,000 dam³)

Potential benefits:

As described previously, the Ardley site chosen for modelling purposes was located downstream from the city of Red Deer and upstream of the Buffalo Lake diversion. The Ardley Reservoir was modelled with a maximum storage of 700,000 dam³ (based on Alberta Environment, 2008), with 300,000 dam³ reserved as empty storage for flood mitigation. This results in a 400,000 dam³ live storage facility.

Modelling showed this reservoir would not be needed for many years until the total net demand on the Red Deer system reached about 440,000 dam³. Alternative reservoirs to support the proposed expansion of irrigation acreage were considered to be of greater value and were recommended as an earlier build. The Ardley site did show considerable drought mitigation potential when increased future demand began to reveal shortages to new licences that would be junior to the WCOs. Because of the large potential storage and routine use of only about 60% of the total, flood mitigation downstream was substantial and Dickson Dam could be used more effectively, reducing risk to the WCO flows at Bindloss.

Barriers to implementation:

- No demonstrated need for the extra storage at this time.
- Cost to build and operate.
- Environmental trade-offs between effects of the storage site versus improved low flow and WCO support potential.

Action needed:

- Monitor growth of licence demands, success in meeting WCOs and licence demands from altered Dickson Dam operations, but no further action at this time.

Who should be involved:

- AEP
- Alberta Environmental Monitoring, Evaluation and Reporting Agency for licence demands, monitoring, reporting

Timeframe:

Ongoing for monitoring licences, WCO compliance, and shortages

Reduce minimum flows through municipalities and other downstream users as an exceptional measure in drought years to slow the draining of upstream reservoirs

This strategy was only considered for severe drought conditions in which the ecology of the affected river system is threatened by reservoirs running extremely low with little expectation of refill in the short term. A previous study of the Bow River system under climate change effects showed the upstream reservoirs running dry in the second or third year, depending on the scenario. Such a condition during any time of the year could lead to catastrophic results to ecosystem services and basic functioning of the river ecology. The Bow River, as an example, obtains about 80% of its total flow volume from melting snowpack, some of which is stored in the upstream TransAlta reservoirs and a small amount in the Glenmore Reservoir. Under severe drought conditions with minimal winter snowpack and lack of rainfall in the upper watershed, in the second year of these conditions, the reservoirs are soon depleted below the level at which they can release water. Groundwater is normally

also depleted under such dry conditions, and as a result the rivers can drop to flow rates that cannot support the existing ecosystem.

Under these circumstances it was important to seek any and all potential responses available to retain water, not only for environmental purposes, but to extend the time available for other critical uses for the remaining water. Only Calgary was modelled for various reductions in minimum flows since it has by far the largest population in the SSRB. The minimum flow of approximately 1250 cfs is generally agreed to be a flow rate at which it is environmentally acceptable for current effluent release rates from the City's sewage treatment facilities. Temporarily dropping the flow rate through Calgary to 900 cfs or even less for short periods was thought to be acceptable, and some additional water was reserved for storage and later release. This strategy is considered a short-term, stop-gap measure and may not conserve enough water to get through the drought, depending on when precipitation is expected. Effectively implementing this strategy depends, as do so many other strategies for flood and drought mitigation, on an improved forecasting and real-time modelling system similar to the New York City system described earlier.

Potential benefits:

- Extending the time available for minimal flow releases from upstream reservoirs under extreme drought conditions
- The alternative of doing nothing increases the risk of zero flow in the river resulting in long-term or irreversible consequences to the river ecology

Barriers to implementation:

- Lack of real-time modelling of upstream storage, flow rates, forecasting and other data needed to determine when, by how much, and for how long minimum flows could be reduced.
- Drought conditions are unpredictable and subtle in their onset, thereby reducing the sense of urgency needed to understand when and how this strategy might be most effectively deployed.

Action needed:

- Undertake integrated modelling of actual reservoir storage, river flows, and improved forecasting systems to inform when such an extreme measure is likely to improve overall environmental conditions well before the reservoirs run dry.
- Incorporate groundwater studies to improve accuracy of flow rates under drought conditions.
- Undertake additional study by municipalities, particularly Calgary, of what the flow rate can be reduced to and over what period of time as a risk reduction strategy to mitigate irreversible damage to the river ecology.

Who should be involved:

- City of Calgary
- AEP's Resilience and Mitigation Branch
- TransAlta
- Fisheries, river ecology experts, and modellers with accurate water models

Timeframe:

Most of the data are in place to study what conditions might lead to implementing this strategy. With a few months of work, a small team with clear study terms could identify, assess and recommend criteria for when to consider this strategy, when to put plans in place and when to trigger the strategy.

5. Closing Remarks

The results of this project reflect the importance of thinking about and planning for how we respond to climate variability and change in the SSRB. They provide a Roadmap to stimulate enhanced and new approaches to water and watershed management in the basin that can be implemented before we face imminent crises of flood or drought. When extreme situations arise, there may be very little we can do to mitigate or respond. The strategies put forward in each of the three levels demonstrate what we can do with today's infrastructure and management, and what more could be done to build the adaptive capacity of the water management system in the SSRB. The Roadmap is intended to first, develop resilient and adaptive capacity to be able to respond to a range of different situations, and second, raise social awareness of potential flood and drought risks in support of efforts to get water management arrangements in place now.

Working collaboratively, knowledgeable and experienced water users and managers from across the SSRB identified many opportunities to optimize the legal and physical infrastructure already in place to support continued population and economic growth with improved environmental health in the basin. Flexibility in implementation will be critical for success with many of the strategies for the SSRB so that adjustments can be made to refine and adapt the concepts. Although good data and models are the foundation for informed decision making, political priorities and economic conditions are also key factors.

A number of activities are already in progress to make the SSRB more resilient in the face of climate variability. This project and its predecessors identified a number of additional strategies for increasing the adaptive capacity of the basin. Level 1 strategies should be advanced and implemented now and were viewed as the most feasible and practical options across the SSRB. Water management decisions are informed by risk and hazard assessments, regulations, science, political decision making, and economic conditions. All of these elements will need to align to see a true shift in the adaptive capacity of the basin. The regulations, science, public awareness, sense of urgency and Adaptation Roadmap are in place. What is needed now are local, watershed-based choices in coordination with provincial leadership to move forward in a step-by-step, reasoned and practical manner before the next weather extreme or a changing climate brings a new water crisis to southern Alberta.

The Level 1 results of the Adaptation Roadmap demonstrate that there is flexibility within the SSRB water management system to make beneficial changes without incurring significant economic, environmental, or social cost. This work shows that flexibility must be maintained within the water management system to mitigate potential negative consequences of new (and old) operations. Operational and decision-making changes should further integrate forecasting into a meaningful and data rich framework. This is particularly important given that each year is likely to present a unique situation and new water management challenges. The various strategies included in Level 1 encompass an adaptive management approach to manage year-to-year variability and long-term change in hydrologic conditions. Practical and feasible adjustments, such as a long-term watershed management agreement for the Bow, raising winter carryover in irrigation reservoirs, restricting greenfield development in the floodplain, and further effort in defining and promoting shortage sharing do not necessarily require major infrastructure investments or other expensive or socially disruptive steps.

Level 2 provides many benefits to water users while maintaining ecosystem integrity with relatively little cost, given that infrastructure projects are off stream and operational changes are the main focus. Level 2 results in increased adaptive capacity for the SSRB during low flow and drought periods. Buyouts in the floodplains increase long-term ability to withstand flood events by minimizing the potential risk of damage. Drought adaptation as part of Level 2 is tied largely to changes in reservoir operations and increased water storage capacity. Changes to the operations of headwater reservoirs in the Bow sub-basin enable water to be managed more effectively for water supply higher in the system, offering a wider range of potential benefits downstream without significantly reducing power generation. Interestingly, balancing Chin Reservoir with other irrigation-serving reservoirs also results in more water being stored higher in the system. The Chin Reservoir expansion increases overall capacity and ability to meet water demands later in the irrigation season. Similarly, increasing the storage capacity of the Red Deer sub-basin allows current and future demands to be met while maintaining WCOs and not further compromising the ecological health of the river.

The new storage through Level 3 substantially increases capacity for dealing with low flow periods and has the potential to increase adaptive ability during flood events. The Level 3 strategies would require a high level of infrastructure investment throughout the SSRB, and further detailed analysis would be needed to determine the feasibility and effects of these projects. Operations would have to be well-defined to optimize the use of these storage facilities. Parts of Level 3, such as reduced minimum flows during the most extreme drought periods, could be tested using additional modelling in the near term with the intent of refining the location and types of operations that may be needed to effectively implement this strategy during real-life drought situations.

Parallel to the development of the Roadmap, a short set of messages has been repeatedly reinforced throughout the collaborative work since 2010:

- Activity already underway to develop and promote a market system for temporarily trading or assigning water within irrigation districts and between licensees should continue to be supported. Licence transfers and trades to optimize use of existing licences is a way to manage water shortages, but people need to understand what their options are and how to take advantage of those options.
- The Bow River has a real and immediate need for a water bank that reserves approximately 10% of the annual storage and flows within TransAlta's reservoirs for release in accordance with downstream needs, including improving environmental flows during low flow periods while minimizing shortages to junior and senior licence holders. Establishing a mechanism for managing the water bank for flood and drought should be a high priority. This should be part of a broad watershed agreement between the GoA and TransAlta that includes the elements described in the pertinent Level 1 strategy of the Adaptation Roadmap.
- Each sub-basin needs a framework, beyond what is available today, for sharing shortages. Such frameworks should be developed soon, during "normal" conditions so that they are ready to implement before the next drought crisis arrives. Work is needed to determine what components such a framework should have and who needs to be part of it.
- Building on what is already being done, there are a number of practical and immediate actions that can be taken by watershed groups, irrigation districts, municipalities and others in coordination with the Province to expand the adaptive capacity of the SSRB using the infrastructure, regulations and policy in place today. These proactive efforts, for example piloting a higher winter carryover in Travers Reservoir, assessing the dam safety impact of a

higher operating FSL on St. Mary Reservoir, and modelling the hydraulic impacts of Room for the River conveyance opportunities along the Bow River, are each important steps in either implementing adaptation or preparing for implementation as warranted by the conditions in the basin.

Participants and collaborators contributed an enormous amount of time and expertise to this project and to the work on the sub-basins. Their insight and experience were invaluable to the success of these projects, and their enthusiasm for the collaborative process was remarkable. Alberta WaterSMART is deeply grateful to the individuals and organizations that played a part in building this Roadmap to take water management in the SSRB into the future.

This Roadmap provides a solid foundation on which to determine, refine and implement appropriate actions, adapt the plans, and invest in the science needed to better prepare the SSRB's water management system to respond when new demands and challenges arise.

We hope GoA will consider this report and find a permanent home for the Roadmap—someone to advance and own the Roadmap for the benefit of all Albertans. And we trust individual water managers, watershed groups, and water users will act on this opportunity to champion and support the advancement of effective water management strategies for their stakeholders and their watersheds.

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Appendix A: Reports Prepared for the SSRB

All of these reports are available on the WaterPortal at <http://albertawater.com/work/research-projects>.

Alberta WaterSMART. 2010. Bow River Project: Final Report. 62 pages.

Alberta WaterSMART. 2011. Bow River Live Simulation: Summary Report. 22 pages.

Alberta WaterSMART. 2012. South Saskatchewan River Basin Adaptation to Climate Variability Project: Initial Assessment of the Current State of the Foundational Blocks to Support Adaptation in the SSRB. 74 pages.

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Alberta WaterSMART. 2014. South Saskatchewan River Basin Adaptation to Climate Variability Project: Final Report. 25 pages.

Alberta WaterSMART. 2015. Room for the River in the Red Deer River Basin: Advice to the Government of Alberta. 60 pages.

Alberta WaterSMART. 2015. Climate Vulnerability and Sustainable Water Management in the SSRB Project: Red Deer River Basin Modelling, Final Report. 99 pages.

Appendix B: Project Contributors

These tables list the organizations and individuals that generously gave their time, energy and expertise to this work through many SSROM and sub-basin working group meetings. Being on this list does not mean that they necessarily supported all of the identified strategies. Any errors or omissions are those of the authors, not the contributors.

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Appendix C: A Brief History of the OASIS Modelling System

Simulation models have long been used in water resources management, starting with the increasing availability of mechanical calculators in the late 1940s and 1950s. In those days, simulation models were built in spreadsheets – physical paper sheets covered with numbers filled in manually, cell by cell, by very patient and careful engineers and their assistants. With the advent of computers, most simulations began to be written in programming languages, most notably FORTRAN. Each simulation was an independent program, and considerable time, care, and skill were required to manipulate assumptions and evaluate alternatives.

Beginning in the late 1970s general purpose simulation models began to be developed. HEC5, developed by the US Army Corps of Engineers, was one of the most successful of these programs. HEC5 allowed the user to input the parameters of pre-programmed forms of operating rules and other model features (e.g., size of facilities, changes in demands) as data rather than requiring program changes. Others, notably the Texas Water Development Board and John Labadie at Colorado State University, used the same general structure for a “general purpose” simulation, but used formal optimization techniques, the Out-of-Kilter algorithm (OKA) in particular, to describe the form of the operating rules. This increased computational efficiency at the cost of requiring that the operating rules be described in a very specific and often limiting form. Alberta Environment’s WRMM model was initially (and largely still is) limited to utilizing the forms of rules that can be solved using an OKA.

By the mid-1990s, HydroLogics Inc. had developed its own OKA based modelling system. That system was used to model the combined Federal and State water systems in California and the Yellow River in China, as well as numerous other applications. HydroLogics was well aware of the limitations of that modelling system. A project for the Alameda Water District in central California required more complex rules than could be handled with the OKA. HydroLogics substituted a Mixed Integer Linear Programming solver for the OKA, enormously increasing the flexibility in specifying rule forms and greatly enhancing computational efficiency. Still, some FORTRAN programming was required to enter new forms of rules.

The South Florida Water Management District’s (SFWMD) system contains about 150 structures, each with its own rules. The rules have many, many forms. In order to model that system, HydroLogics created a language for entering forms of operating rules as data, instead of requiring program modifications. The language, OCL (Operations Control Language) is very simple, has very few keywords, and a “natural syntax” based on the way in which operating rules are usually described – by operators and in manuals. This made the development of the SFWMD system model much, much more efficient. The resulting, fully data driven simulation system was named OASIS. 20 years later, it is still the state-of-the-art for water resources simulation model development.

The development of OASIS and OCL was guided by practical professionals with well over 100 years of combined experience in management of water resources. As a result, the model:

- automates the use of nonlinear functions to describe management rules and system responses,
- has built in features for dynamic linkages to other models,
- is designed specifically to utilize almost any form of external data without programming changes,

- automatically performs evaluation of operations based on hydrologic and meteorologic forecasts, including ensemble forecasts,
- stores all data and output in standard data base formats accessible to other programs
- can be run independent of its GUI (graphical user interface),
- includes post-processing programs to access and plot easily any and all model variables, including user defined variables,
- has extensive debugging features, and
- has an integrated gaming mode for testing real-time operational modification of rules, for operator training, and for educational purposes.

OASIS has been extensively for evaluating alternative management plans in places that include: South Florida, North Carolina, Kansas, New York City, Delaware River Basin, Susquehanna River Basin, Federal and State combined system in California, Lakes Rotoiti and Rotorua in New Zealand, South Saskatchewan River Basin in Alberta, Salt River Project in Arizona, and many others.

Many of these models explicitly incorporate or link to other models. The New York City System model, for example, includes:

- 24 managed reservoirs,
- operating rules based on real time National Weather Service Forecasts,
- dynamic linkages to hydrodynamic water quality models – simulated water quality is used to control operations on a time-step by time-step basis,
- snow-pack driven flood control operations with operating curves dependent on snowpack,
- full simulation of complex inter-state water allocation decrees and agreements, and
- hydropower operations and evaluation.

The NYC model has been used to support negotiations over modifications to inter-state operating agreements, to develop real-time responses to flood and water quality events, as well as for in-house development and enhancement of standard operating rules. Hundreds of millions of dollars of benefits have resulted in the form of increased reliability, elimination of proposed new water intake facilities (by meeting water quality constraints with existing facilities, and environmental benefits. The model has been so useful that a custom GUI has been developed to automatically obtain data needed to support daily operations from the NYC data system and from other sources on the web, and to streamline daily operator interaction with the model.

OASIS has also been used extensively to support dispute resolution processes. This kind of Computer Aided Negotiation has been widely applied:

- Susquehanna River Basin – New York, Pennsylvania, Maryland
- Cape Fear and Roanoke Basins in North Carolina
- Lakes Rotoiti and Rotorua in New Zealand
- Stanislaus River in California
- South Florida

Appendix D: SSRB Sub-Basin Model Descriptions

The text in this appendix provides more detailed descriptions of each of the sub-basin models mentioned in section 2.3. Schematics for each model were shown in that section.

The Bow River Operational Model (BROM)

The first component of SSRB, the Bow River portion was the result of the Bow River Project Consortium's work in 2010. It encompasses the Upper Bow system (primarily TransAlta storage reservoirs), major irrigation systems, major municipal uses, and all junior licensees. It also contained initial data for the downstream Saskatchewan River after the Bow/Oldman confluence. This was later replaced and refined in the OSSROM model. The Highwood/Sheep system was developed early on as a sub-model and integrated into BROM (despite major sections arguably belonging in the Oldman system) as it forms one of the major inflows to the lower Bow River.

Inflows for this system came from weekly naturalized data in WRMM, converted to daily (see BROM report for weekly-daily conversion details). Demands were sourced from WRMM or the IDM as appropriate, and scaled down or replaced by actual use data at the discretion of individual stakeholders. Based on conversations with those stakeholders, it was determined that water in this system should generally be distributed as follows:

1. Junior licences (it was found that these licences are so small that the IDs generally don't bother to call on them)
2. Municipal demands (voluntary agreements already exist ensuring the primacy of anthropocentric use over agricultural)
3. Major Irrigation Districts (WID, EID, BRID – roughly in that order)

The major irrigation districts perform some limited licence sharing, in which demands are given priority if they are unable to draw on irrigation district storage. Thus, although BRID is broadly junior to EID, there are some circumstances in which EID would forego some entitled water (choosing instead to rely on storage) in order to allow BRID's river-dependent demands to be met.

TransAlta, although rather junior in the system, has no requirement to utilize storage for purposes other than its own. Thus, when senior users call on their licences, they can at most call for natural inflows to pass through. TransAlta storage in the SSRB model attempts to follow a "normal pattern" that represents average elevation over the 2000-2010 period in each respective reservoir.

Although several minimum flow requirements exist in the system, the major two for the Bow River occur immediately past Bassano (11.3 m³/s or 400 cfs) and into Calgary (35.4 m³/s or 1250 cfs). The flow into Calgary isn't a legally entitled minimum flow per se, but rather representative of a consistent voluntary minimum applied by TransAlta.

The Oldman and South Saskatchewan River Operational Model (OSSROM)

OSSROM was the second major model developed and encompasses the Oldman River and Southern Tributaries (St. Mary, Belly, Waterton, and Saskatchewan Rivers). It also includes the Willow Creek and Chain Lakes system, although this is generally operationally separate. Willow Creek use has preference for all Willow Creek inflows. The Saskatchewan River portion of BROM was expanded upon and refined in OSSROM, and replaced BROM data for that part of the river during the eventual SSRB integration.

Inflows for this system came from weekly naturalized data in WRMM, converted to daily (see BROM report for weekly-daily conversion details). Demands were sourced from WRMM or the IDM as appropriate, and scaled down or replaced by actual use data at the discretion of individual stakeholders. Based on conversations with those stakeholders, it was determined that water in this system should generally be distributed as follows:

1. Municipalities,
2. Small demands
3. Irrigation lacking licence priority information
4. Large Irrigation Districts

Within the large irrigations districts, proper licence priority was applied using available licence information.

In contrast to the Bow, most storage in this system is directly managed by Alberta Environment and Parks. Thus the operations of the major OSSROM reservoirs are much broader in scope. Generally speaking, the reservoirs in this system are “balanced” (i.e., they attempt to maintain proportional storage). This means that St. Mary and/or Waterton reservoirs will attempt to meet needs downstream of Lethbridge if Oldman storage falls too low.

The major exception to this operation is Chin reservoir. Under current operations, Chin attempts to stay as full as possible all the time. The major constraint to this is the canal limitations in routing water to Chin, and the preference to route water only through the turbines in drops 4, 5, and 6.

Similar to the Bow, several minimum flow requirements exist and are modelled within the OSSROM system. The major driving flows, however, exist past Medicine Hat ($28.32 \text{ m}^3/\text{s}$ or 1000 cfs) and at several locations along the Oldman River utilizing the 80% of Fish Rule Curve (FRC) threshold. The FRC minimums primarily draw water from Oldman Reservoir, though inflows from other sources along the way are considered. At Medicine Hat, the minimum represents the lowest flow that still allows the city easy withdrawal. Ideally the minimum flow at the location would be $42.5 \text{ m}^3/\text{s}$ (1500 cfs), but discussion with stakeholders concluded that is a target rather than an operational constraint. This is particularly important since the minimum flow from the Bow is only $11.33 \text{ m}^3/\text{s}$ (400 cfs). The Oldman system must thus, in extreme droughts, make up the remaining $17 \text{ m}^3/\text{s}$ (600 cfs).

One other important piece to note in the OSSROM systems is the international cross-border flows in the St. Mary River. The International Joint Commission reached an agreement on what the minimum flows from the United States must be, although historically the flows have rarely come close to these minimums. In order to maintain conservative assumptions it was decided to apply only the minimum “entitlement” flows in the base conditions for OSSROM.

The Red Deer River Operational Model (RDROM)

The RDROM was the final individual model constructed prior to the SSROM integration. It covers the area beginning at Vam Creek and extends all the way to the mouth and confluence with the Saskatchewan River. The model also includes a few smaller streams, such as Fallen Timber Creek and the Little Red Deer. In the initial RDROM modelling effort, interactions with the Bow (such as irrigation district return flows) were assumed static. Following SSROM integration, these returns became variable based on Bow River operations.

Although nominally “simpler” than the other systems, the Red Deer River presented a number of unique challenges not present in the other systems. Inflows remained based on Alberta Environment and WRMM data, but the Red Deer proved much more reliant on the First in Time, First in Right (or FITFIR) system. To that end, approximately 72.5% of water use was allocated using a strict licence priority system. The remaining 27.5% consisted of too many individual licences to remain in scope, and were thus left in the rough demand “groups” that the original WRMM maintained. As the Red Deer system remains an open basin with room for more licences, participants decided to generally consider operations in the context of full licence allocation. Water in the Red Deer system is thus provided as follows:

1. Senior Irrigators (identified by and remaining in WRMM blocks)
2. Major Demands (identified by and remaining in WRMM blocks)
3. Senior Licences (by licence date priority, pre- 17-Apr-1982)
4. Mid-Licence Irrigators (identified by and remaining in WRMM blocks)
5. Junior Licences (by licence date priority, post- 17-Apr-1982)
6. Junior Irrigators (identified by and remaining in WRMM blocks)
7. Minor Demands (identified by and remaining in WRMM blocks)

In contrast to the Bow and Oldman/Southern Tributaries, the Red Deer River only has one substantial source of available storage in the system - Gleniffer Reservoir, upstream of the city of Red Deer (Buffalo Lake is treated as a demand, see the Red Deer Report for more details). Gleniffer is not operated for traditional water supply, however. Storage in the Red Deer is primarily operated to maintain the Water Conservation Objectives (WCOs) in the system. That means that Gleniffer generally stores water in the spring, summer, and fall with the intention of releasing it over winter and maintaining a WCO minimum release of $16 \text{ m}^3/\text{s}$.

As an open basin, RDROM also experimented more with growth than the other systems. To that end, both specific (SAWSP, Acadia Valley) and generic growth was enabled in the model. Generic growth was modelled as occurring proportionally throughout the system. Importantly, however, all new demands are considered Junior to the WCO. At present, nearly all current demand is senior to the WCO.

The WCO represents the major driving minimum flow in the Red Deer system. Immediately below Gleniffer Reservoir it is maintained at $16 \text{ m}^3/\text{s}$. At the bottom of the system, however, it is only $16 \text{ m}^3/\text{s}$ in the winter (Nov 1 to Mar 31), dropping to $10 \text{ m}^3/\text{s}$ during the spring and summer (Apr 1 to Oct 31). For existing licences where the WCO is junior, the downstream minimum flow utilizes the older instream objective of $4.25 \text{ m}^3/\text{s}$ for non-irrigation use or $8.5 \text{ m}^3/\text{s}$ for irrigators.

Appendix E: Additional Background on the Frankenflow Time Series Derivation

To derive the Frankenflow streamflow dataset, an extreme high and low flow analysis was carried out using hydrometric monitoring site data along the Oldman, Bow, and Red Deer rivers. Sites were grouped into Headwater, Mid-Plains/Prairie, and Confluence catchments based on their drainage area and proximity to their mountain headwaters. High flows were defined by annual maximum daily flows, while low flows were defined by annual minimum 7-day average flows, and extreme events were calculated by fitting data to a Log-Pearson Type III distribution. Maximum flows generally peak at the furthest downstream, confluence catchments, except for the Red Deer River, where flows are significantly greater at its Mid-Plains/Prairie site (Drumheller).

Grouped probability analysis finds that the probability of extreme high flows is between two and four times higher in the Mid-Plains/Prairie catchments than in the headwater or confluence catchments. This is a function of significantly higher correlations between high flows at the Mid-Plains/Prairie catchment sites. Maximum flow correlations do not translate to extreme low flow conditions, suggesting that the probability of all sub-basins flooding is substantially higher than all three sub-basins being in drought conditions. This analysis suggests that the Frankenflow time series must use SSRB-wide low flow years for defining droughts – where not all sub-basins are necessarily in the worst drought on record. The analysis also suggests that a combination of years can be used for defining floods – where all three sub-basins are in the worst flood on record. However, for consistency, we used an SSRB-wide analysis to define droughts and floods. A ranking analysis was used to assess streamflow records for the whole SSRB, where the highest and lowest annual flows were determined.

Appendix F: Additional Adaptation Strategies

PART 1: SSRB Integration Project

The strategies in Part 1 were identified in the SSROM project as having less promise. Those marked with an asterisk (*) are not currently modelled in the SSROM.

Bow sub-basin:

- Raise full supply levels in Barrier and/or Upper Kananaskis Reservoirs*
- Construct a channel for the Highwood River through the town of High River*
- Restore Spray Reservoir to full design capacity*
- Reduce minimum flow through Calgary in severe drought*
- Manage return flows from WID through Crowfoot Reservoir*
- Increase Little Bow/Travers storage capacity* (This change was already underway at the time of the project)

OSSK sub-basin

- Build a Lower Belly Reservoir*
- Build Meridian Dam downstream of Medicine Hat *
- Oldman reservoir flood control operations*
- Raise St Mary Reservoir by 1m by increasing the dam height
- Build new reservoir for flood control downstream on Oldman River*

Red Deer sub-basin

- Dry dams for flood control in the main stem and tributaries*
- Expand Dickson Dam
- Higher level of protection for aquatic ecosystem e.g. 85% natural flow threshold *
- Investigate the need for berming between the Clearwater and Raven rivers to prevent a catastrophic overflow *

All strategies identified in Parts 2, 3 and 4 are listed in the following sections.

PART 2: Bow sub-basin project

Adaptation strategies for current and future climates in the Bow sub-basin are noted in the following list (Alberta WaterSMART 2013).

Strategies to benefit the watershed under normal conditions

- Implement preferred scenario with trigger
- Adjust fill times for three largest TransAlta reservoirs (Minnewanka, Spray and Upper Kananaskis)
- Reduce season consumptive demand in Calgary
- Implement seasonal consumptive reuse in Calgary
- Move municipal licences from Highwood/Sheep system to Bow River
- Increase winter carryover in Travers Reservoir
- Implement additional demand reduction in irrigation districts

Strategies for adapting to severe drought conditions

- Restore Spray Reservoir to full design capacity
- Draw Ghost Reservoir down preferentially to 6.6 feet (2 metres) below normal pattern
- Reduce minimum river flow through Calgary
- Increase off-stream storage in the WID (Bruce Lake)
- Manage return flows from WID through Crowfoot Reservoir
- Increase Little Bow/Travers storage capacity
- Increase on-stream storage downstream of Bassano (Eyremore Reservoir)
- Operate irrigation district reservoirs to protect junior licences

Combined strategies

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

PART 3: OSSK sub-basin project

Strategies in the following list emerged from the OSSK sub-basin project (Alberta WaterSMART 2014). They are categorized as having varying degrees of promise and some were also identified in the SSROM project.

Strategies with most promise

- Adding a Lower Belly Reservoir
- Minimum flow augmentation below reservoirs
- Adding a Kimball Reservoir
- Chin Reservoir expanded and fully balanced
- Forecast-based rationing

Strategies with some promise

- Oldman Reservoir flood control operations
- Chin Reservoir balanced
- Chin Reservoir expanded, and expansion balanced
- Drought-modified Fish Rule Curves

Strategies with limited promise

- 1m additional storage in existing St. Mary Reservoir
- Chin Reservoir expanded without balancing

- Downstream dry dam for flood control
- Simple triggered shared shortages
- Lower FSL in all AEP reservoirs by 2m when needed until July 1
- Developing a storage reserve

Combined strategies

- C1. Chin Reservoir expanded + fully balanced + St. Mary augmentation
- C2. Chin Reservoir expanded + fully balanced + Kimball Reservoir + St. Mary augmentation
- C3. Chin Reservoir expanded + fully balanced + Kimball Reservoir + St. Mary augmentation + forecast-based rationing

The following ideas also emerged from the OSSK project, some of which were modelled in very limited detail and others were not pursued at all for various reasons. A number of these offer local opportunities to improve resiliency.

- Allocate water for increased urban growth and development
- Castle River (Canyon Site) Reservoir
- Dam upstream of Cardston/Lee Creek
- Double municipal licence demands and double return flows
- Expand LNID acreage by 30%, reduce return flows from 18% to 5%
- Expand RID acreage by 20%, reduce return flows from 15% to 5%
- Expansions to Ridge
- Further use of Irrigation District licence amendments
- Headwaters tourism opportunities
- Hydro development opportunities
- Increase canal capacity on diversion from Belly to St. Mary
- Increase flow at Lethbridge
- Increase on-farm efficiencies in irrigation districts
- Kenex site in LNID
- Oldman Dam case study
- Plug and play demands
- Possible flooding of non-urban land
- Regional impacts of oil and gas
- Reservoir at Taylorville site (SMRID)
- Restore and improve river flows on Southern Tributaries
- Risk management for expansion
- Several small reservoirs
- Spillway on St. Mary main canal
- Stafford spillway to Oldman River
- Surcharge canals for short periods under high demand conditions
- Transfer from BRID canal
- Upper Belly Reservoir
- Upper Oldman (Gap) Reservoir
- Use all reservoirs for original purposes (i.e., storing water for use)
- Water reuse opportunities
- West Raymond Reservoir

PART 4: Red Deer sub-basin project

The strategy ideas in the list below were identified in the Red Deer sub-basin modelling project (Alberta WaterSMART 2015).

Strategy ideas related to managing demand

- Demand thresholds of 335,000 dam³, 445,000 dam³, and 550,000 dam³ with WCO reductions
- SAWSP and Acadia Valley new demands and current allocations
- Conservation of water through best management practices and increased efficiency.
- Effects of Temporary Diversion Licences
- Distribution of shortages
- Back calculate possible growth (population and economic) that could occur without environmental degradation
- Back calculate the maximum growth possible prior to construction of new infrastructure

Strategy ideas to enhance environmental flows

- Dynamically adjusting the WCO to provide water for environmental flows
- Functional flows for riparian vegetation
- High level of protection for aquatic ecosystems (e.g., 85% Natural Flow threshold)
- Make the WCO the most senior priority
- Flow stability and flow augmentation to benefit fish communities
- Wetland restoration (through effective policy implementation)

Strategy ideas related to infrastructure operations

- Dynamic operations of Dickson Dam to meet downstream demands and WCO
- Downstream storage for water supply
- Dickson Dam release buffer for meeting demand
- Off-stream storage for irrigation
- Expanding Dickson Dam storage
- Modifications to Dickson Dam structure

Strategy ideas for flood mitigation

- Increase local flood protection
- Dry dams
- Upstream dams in places where dry dams have been proposed

Of these, seven individual water management strategies were shown to have the most promise, and some were also explored as part of the SSRM project:

- Implementation of functional flows
- Dickson Dam operations to meet WCO (downstream focus)
- Dickson Dam operations to meet WCO and new demands (downstream focus)
- Additional storage
- Local flood protection
- Water conservation
- Application of land use best management practices
- Effective implementation of Alberta's Wetland Policy