Bow River Water Management Project

Advice to Government on Water Management in the Bow River Basin

Submitted to:
Hon. Shannon Phillips
Minister
Environment and Parks
Government of Alberta

Submitted on:
May 17th 2017

Contents

List of Tables

List of Figures

List of Appendices

Abbreviations, Acronyms, and Definitions

~	approximately
AEP	Alberta Environment and Parks
AI-EES	Alberta Innovates – Energy and Environment Solutions
BRBC	Bow River Basin Council
BRID	Bow River Irrigation District
BROM	Bow River Operational Model
BRWG	Bow River Working Group
cfs	cubic feet per second
cms	cubic metres per second
CPR	Canadian Pacific Railway
dam^3	cubic decametre (1,000 cubic metres or 0.81 of an acre foot)
EID	Eastern Irrigation District
FSL	full supply level
GoA	Government of Alberta
OASIS	Operational Analysis and Simulation of Integrated Systems
PMF	probable maximum flood
SR1	Springbank Off-Stream Storage Reservoir
SSRB	South Saskatchewan River Basin
WCO	water conservation objective
WID	Western Irrigation District
WPAC	Watershed Planning and Advisory Council
WRRP	Watershed Resiliency and Restoration Program
Apportionment	The Master Agreement on Apportionment (1969)[1] between the Governments of Alberta, Saskatchewan, Manitoba, and Canada requires approximately 50% of the annual flow by volume of eastward-flowing provincial watercourses must be passed from Alberta to Saskatchewan.

[1] http://aep.alberta.ca/water/legislation-guidelines/master-agreement-on-apportionment-1969/default.aspx

Balancing the system	Matching projects advanced for flood mitigation with other projects that offset potential increases in drought risk or impacts to watershed health, thereby maintaining the current water management balance in the basin, providing more adaptability to changing conditions and avoiding unintended consequences.
Base case	The modelling scenario used to compare mitigation schemes and scenarios against. For floods, it is the four synthesized flood events with operating practices from 2013 in place. For balancing the system, it is flood mitigation Scenario A (1,200 cms) and the historical time series of flow data. For droughts, it is the historical time series and the two synthesized drought time series and current operating practices.
Flashy/flashiness	An indication of the rapidity and frequency of changes in streamflow. Flashy streams have rapid and frequent changes in flow in response to rainfall events.
Mitigation scheme	A single option used to reduce the effects of flood or drought.
Mitigation scenario	A combination of individual mitigation schemes (see definition above) to reduce the effects of flood or drought.
Naturalized flow	Naturalized flow is defined by AEP as “the quantity of water moving past a specific point on a natural stream or river where there are no effects from stream diversion, storage, power production, import, export, return flow, or change in consumptive use caused by land use activities”.

EXECUTIVE SUMMARY

The Bow River system is fundamental to the daily life of people in the watershed and downstream, providing water for drinking, irrigation, livestock, waste assimilation, electricity generation, wildlife and recreation.

Historical records and estimates for the Bow River show dramatic variation in volume from year to year as well as within years. The need to adapt to an ever-changing environment and often rapidly changing weather conditions is a simple reality of life in the basin. The flow in the Bow River is heavily influenced by water management infrastructure. The water from snowmelt and spring rains, partially captured by upstream and downstream reservoirs, has allowed for sufficient flows, in most years, for environmental protection, municipal purposes, power production and irrigation.

A less predictable water supply and an increasing demand for water as well as changing climate and demand patterns mean that careful water management will be critical to success in our economic, community, recreational, and environmental future. A fundamental principle of this work is that floods and droughts cannot be prevented, but we can be better prepared.

The 2005 and 2013 floods surpassed any observed on the Bow River since 1932 and illustrate the risks to public safety and infrastructure associated with populations and developments in the floodplain.

Droughts pose a risk to providing a reliable supply of clean water for municipal, residential, commercial, and agriculture needs. Droughts also place stress on environmental conditions in the watershed, and present significant economic risks.

Flood or drought mitigation cannot be assessed in isolation—they must be considered as part of a water management system that values watershed health.

> Water management cannot be looked at in isolation because it ties directly to many other government priorities, including climate change mitigation and adaptation, regional land-use planning, economic development, and recreation and tourism. Thus, this complex river system requires careful water management leadership and operations to balance environmental, social and economic values in the region.

PROJECT OBJECTIVES AND REPORT OVERVIEW

The Bow River Water Management Project, announced in October 2015 by Alberta Environment and Parks (AEP) and jointly chaired with the City of Calgary, is one of many water management projects and investments initiated in the Bow River Basin since the floods in 2013.

Specifically, the project had objectives to:

- Develop scenarios of potential operational and infrastructure flood mitigation opportunities in the upper Bow River Basin (above Calgary) to reduce peak flow during a defined range of synthesized flood events to approximately 1,200, 800, and 400 cms measured on the Bow River above the confluence with the Elbow River, and assess how these scenarios affect flow thresholds along other reaches of the Bow River.

- Identify schemes required to offset any increased water management risk in the basin created by the flood mitigation scenarios upstream.
- Develop scenarios of potential operational and infrastructure drought mitigation opportunities to reduce the volume of licence shortages by at least 5% to 10%, while continuing to meet apportionment requirements, and with improvement, or at minimum no reduction, in ecosystem health (all relative to current operations in the same time period).

The Bow River Basin is fortunate to have a strong history of collaborative exploration of water management challenges and opportunities. This project benefited from a similar collaborative effort, involving water users, water managers, and other stakeholders from across the basin. This process did not seek consensus; rather, it was designed to explore practical mitigation strategies and scenarios informed by the best available data and knowledge in the basin. The project was governed through three groups: the Advisory Committee, the Bow River Working Group (BRWG), and community groups.

This project focused on the water quantity impacts (peak flow rate and volume, storage, shortages) of a range of potential flood and drought mitigation schemes and drew on the expertise and knowledge of participants to comment on their perspectives on associated socio-economic, environmental, and design and operational considerations. The work was a screening assessment the contributors recognized as an essential first step, and one that must be followed with further analysis based on a prioritized set of schemes .

The Bow River Operational Model (BROM) provided the analysis required for the BRWG to consider a range of flood and drought events, assess the effect of individual mitigation schemes, and assess the cumulative effect of multiple mitigation schemes combined into mitigation scenarios. The BROM is a comprehensive, mass balance model of the Bow River system developed using 86 years of Government of Alberta water data broken into daily flows, combined with the latest data from TransAlta and the Water Survey of Canada for hourly flows during the 2005 and 2013 flood periods.

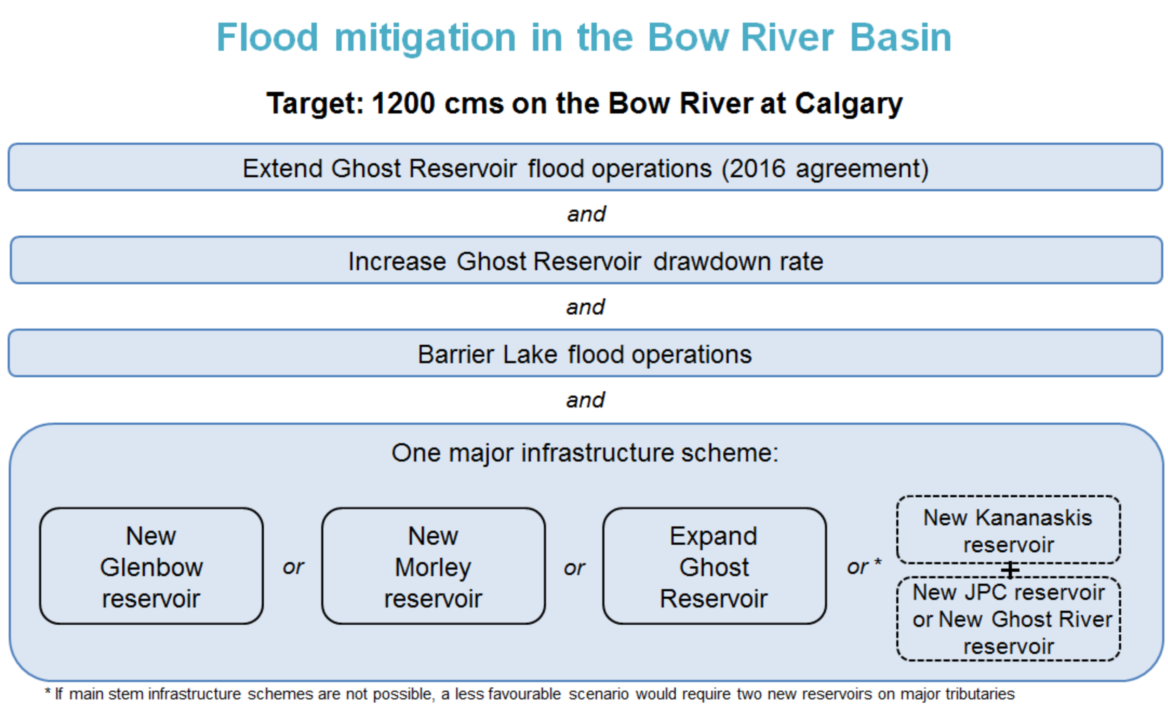
This report summarizes the findings of the project and offers it as advice to the Minister of Alberta Environment and Parks in developing a robust, strategic plan for water management in the Bow River Basin, from the headwaters to the confluence with the Oldman River and continuing through Medicine Hat. This advice focuses on screening structural flood and drought mitigation opportunities in the basin, assessing the resulting flow impacts downstream through the entire basin, and considering the associated effects on watershed health.

FLOOD MITIGATION RESULTS

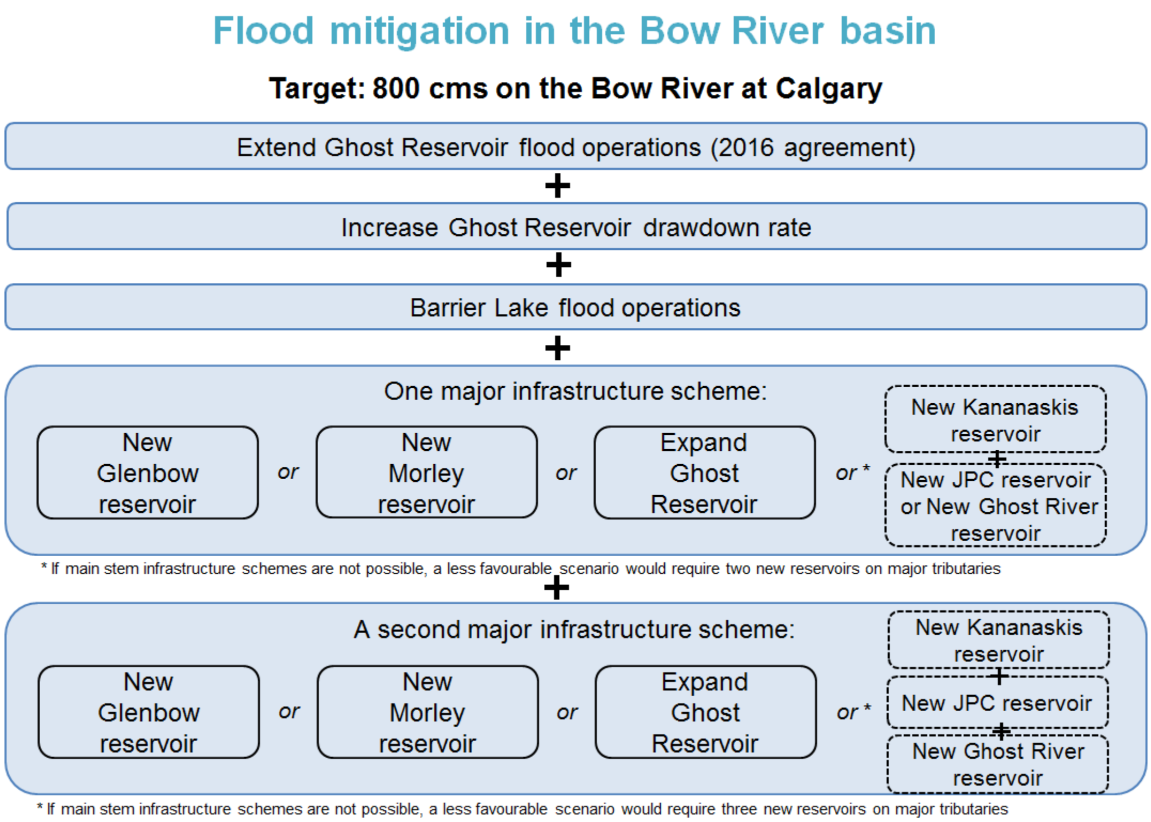
Four synthesized flood events, based on data from the actual 2005 and 2013 floods, were chosen to test and assess potential flood mitigation schemes. These flood events exhibited different characteristics, with 2005 having high volume and two peaks, and 2013 having less volume but a single, higher peak. The peak flow at Calgary was used to establish the baseline, but flow rates at many other locations throughout the Bow River system were also considered in the assessment of mitigation schemes.

Early in the process, discussion focused on whether 400 cms is a realistic flood mitigation target—given many schemes would be required to mitigate to that level and there would be potential for detrimental effects on the natural functions of the river and floodplain. Given these concerns of the BRWG and results of preliminary modelling, the Advisory Committee confirmed in August 2016 that flood mitigation scenarios should be developed for the 1,200 and 800 cms targets only.

Fifteen flood mitigation schemes were assessed by the BRWG. These schemes were located across the Bow River Basin upstream of Calgary. The most promising schemes were grouped into scenarios to achieve the flow target. Four scenarios were developed for the 1,200 cms flow target and three scenarios were developed for the 800 cms target.



Executive Summary Figure 1: Flood mitigation scenarios for target 1,200 cms on the Bow River at Calgary



Executive Summary Figure 2: Flood mitigation scenarios for target 800 cms on the Bow River at Calgary

The Bow River Basin is a complex, regulated, interconnected system. Implementing flood mitigation schemes and scenarios upstream of Calgary will change the historically managed flow regime the system has grown and adapted into. Changes to improve flood mitigation have already and could further reduce drought resiliency, which could result in more water shortages to licensed water users and impact watershed health.

Thus, early in this project, project participants emphasized the importance of balancing the system. To address this, six relatively minor schemes were identified as most promising and combined into a scenario to balance the system.

Balancing the System

Target: Offset the increased risk from the flood mitigations schemes

Increase Ghost Reservoir drawdown rate
+
Drought storage in expanded Glenmore Reservoir*
+
Increase diversion rate of the Carseland Canal and construct debris deflector*
+
Raise winter carryover in downstream reservoirs (e.g. Travers/Little Bow, McGregor)
+
Fill downstream reservoirs earlier (e.g. Travers/Little Bow)
+
Extend Kananaskis System water shortage mitigation operations (2016 agreement)

* Indicates scheme likely requiring a licence amendment

Executive Summary Figure 3: Scenario to balance the system

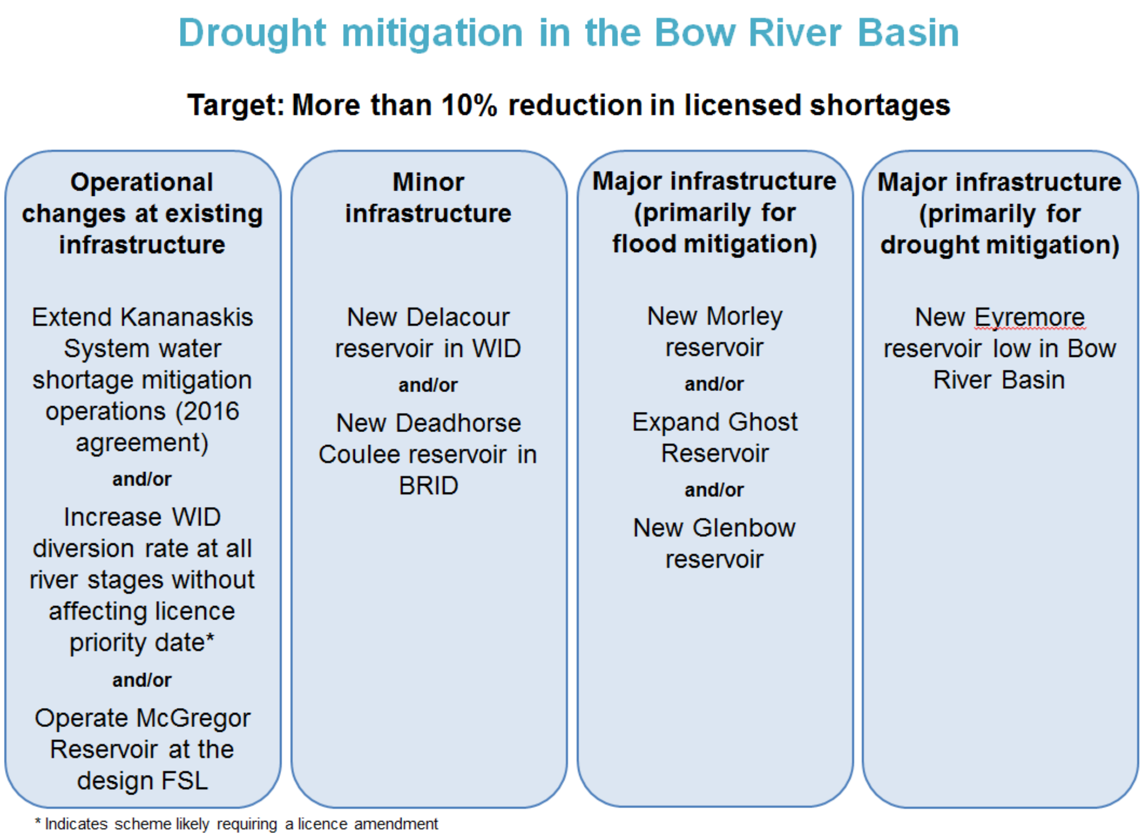
DROUGHT MITIGATION RESULTS

The historical record and two synthesized drought events (developed to simulate inflow time series that stress the Bow River system beyond what has been observed in the historical record and reflect potential impacts of climate change) were used to assess drought mitigation schemes.

Twelve drought mitigation schemes across the Bow River Basin were assessed by the BRWG. These were over and above the six schemes already covered in the balancing the system scenario.

The BRWG was assigned a drought mitigation objective that early modelling found to be quite conservative. Many of the individual drought mitigation schemes alone could achieve the 5% to 10% reduction in licence shortages without violating apportionment requirements and ecosystem health.

The nature of the BRWG discussion evolved from "How do we achieve the objective?" to "What are the most promising schemes for adding drought mitigation capacity to the Bow River Basin?" The most promising schemes fell into four types: operational changes, minor infrastructure projects, major infrastructure projects primarily for flood mitigation, and major infrastructure projects primarily for drought mitigation.



Executive Summary Figure 4: Drought mitigation in the Bow River Basin; in addition to the six schemes already identified to balance the system

WATER MANAGEMENT ADVICE

Participants in the BRWG were adamant that a flexible, resilient, and adaptive water management strategy is needed for the Bow River. During this project, the BRWG identified and assessed multiple potential structural flood and drought mitigation schemes and combined them into scenarios. As presented in this report, in a system as complex as this one, there are a number of promising scenarios that could be pursued following further study.

No single scenario can, at this point, be put forward as the ideal solution. Nor can a single combination of flood and drought mitigation schemes be put forward as the ideal strategy for the Bow River Basin. Instead, this project has reduced the number of potential schemes to a short list of those that appear most promising.

Water management in the Bow River Basin

Target: Balancing flood mitigation and drought mitigation

	Flood mitigation	Balancing the system	Drought mitigation
Operational changes	• Extend Ghost Reservoir flood operations (2016 agreement)* • Barrier Lake flood operations	• Drought storage in expanded Glenmore • Raise winter carryover in existing reservoirs • Fill downstream reservoirs earlier • Extend Kan. System water shortage mitigation operations (2016 agreement)*	• Increase WID diversion rate at all river stages without affecting licence priority date • Operate McGregor Reservoir at the design FSL
Minor infrastructure projects	• Increase Ghost Reservoir drawdown rate	• Increase Carseland diversion and construct debris deflector	• New Delacour reservoir in WID • New Deadhorse Coulee reservoir in BRID
Major infrastructure projects**	• New Glenbow reservoir • New Morley reservoir • Expand Ghost Reservoir		• New Eyremore reservoir low in Bow River Basin

*Ghost Reservoir flood operations and Kananaskis System water shortage mitigation operations are currently in place until 2021.
**One major infrastructure project would be required to meet the 1200cms flood mitigation target at Calgary. Two major infrastructure projects would be required to meet the 800cms flood mitigation target at Calgary.

Executive Summary Figure 5: Most promising water management schemes for the Bow River Basin

The varying scale of the potential schemes means many of the operational and minor infrastructure projects could be implemented relatively quickly, while larger infrastructure projects would typically require a longer assessment, design, and construction process.

Recognizing this, the BRWG offers the following next steps for a strategy to improve water management in the Bow River Basin:

1. Build on the 2016 GoA Modified Operations Agreement with TransAlta to put in place the prerequisite needed in the upper Bow system: a long-term flexible watershed agreement between the Province and TransAlta.

2. Implement the relatively quick wins, which can be completed while larger projects are assessed.

    - Extend Ghost Reservoir flood operations (2016 agreement) *
    - Barrier Lake flood operations

- Drought storage in expanded Glenmore Reservoir **
- Increase diversion rate of the Carseland Canal and construct debris deflector **
- Raise winter carryover in downstream reservoirs (e.g., Travers, McGregor)
- Fill downstream reservoirs earlier (e.g., Travers/Little Bow)
- Extend Kananaskis System water shortage mitigation operations (2016 agreement) *
- Increase WID diversion rate at all river stages without affecting licence priority date **
- Operate McGregor Reservoir at the design FSL

* indicates scheme already in place or underway

** indicates scheme likely requiring a licence amendment

3. Complete conceptual assessments and feasibility studies of the minor infrastructure schemes within 1 year.

   - Increase Ghost Reservoir drawdown rate
   - Increase diversion rate of the Carseland Canal and construct debris deflector
   - New Delacour reservoir in WID
   - New Deadhorse Coulee reservoir in BRID

4. Complete conceptual assessments of the 3 major infrastructure flood schemes within 2 years to determine which to advance to feasibility study.

   - New Glenbow reservoir
   - New Morley reservoir
   - Expand Ghost Reservoir

5. Complete conceptual assessment for Eyremore scheme.

6. Ensure full risk management, feasibility, cost–benefit, and triple bottom line assessments are completed in subsequent steps as the schemes and scenarios are advanced.

7. Balance the system to mitigate the increased drought risk from the 2016 GoA Modified Operations Agreement with TransAlta and do not implement further flood mitigation schemes without implementing the accompanying schemes to balance the system and improve its adaptive capacity.

8. Establish a process to set and achieve drought mitigation objectives for the Bow River Basin given that the most promising drought mitigation schemes assessed in this project can achieve far more than the original 5 to 10% objective.

9. Increase resourcing and support for precipitation monitoring and forecasting, flow monitoring, flood forecasting and drought forecasting to enhance the effectiveness and adaptability of water

management operations.

10. Continue to invest in natural watershed functions, floodplain protection and local mitigation.

11. Commit to a continual collaborative process with stakeholders and policy makers for advancing and implementing these schemes as part of the water management strategy in the Bow River Basin.

12. Review and strengthen where possible the current water management operational protocols of both public and private operators.

Most importantly, a coordinated and integrated approach to watershed management throughout the Bow watershed is essential to reduce risks from floods and droughts, minimize costs for mitigation options, and provide for a safe, clean, and healthy river system over the long term.

Much work has already been done, however, given the need for new and costly schemes to achieve flood and drought protection goals, a more formalized collaborative governance process may be needed to select the most effective and affordable options for implementation and to retain public confidence in the expenditures and expected results.

Participants in this project have indicated they are willing and eager to continue to provide their expertise and energy to the next several phases of this long-term, public interest project.

PART I. PROJECT OVERVIEW

1.0 Introduction

Building Alberta's flood defences will help protect families and businesses from a repeat of the devastation experienced in 2013, when more than $6 billion in damage was inflicted on our infrastructure and economy. Our government has carefully weighed the options and is moving forward with a plan that makes the most sense for families, businesses, and taxpayers. This investment will help safeguard our communities and economy against increasingly severe and frequent natural disasters.

Shannon Phillips, Minister of Environment and Parks, 26 October 2015

The flood of 2013 had a devastating impact on the lives of thousands of Albertans. I am very pleased that the new provincial government has moved to protect downtown Calgary and our flood prone communities from a similar flood in the future. The Springbank Off-stream Reservoir and the $150 million in provincial funding for additional mitigation along our rivers is a significant step forward. Of course, much more work is required for flood mitigation and watershed management on both the Bow and Elbow rivers, and we look forward to working collaboratively with both the provincial and federal governments on this issue.

Naheed Nenshi, Mayor of Calgary, 26 October 2016

Severe flooding in Alberta in 2013 highlighted the vulnerability of people and infrastructure in the Bow River Basin. In response, the Government of Alberta (GoA) has taken a systems approach to watershed management, focusing on river basins where flood and drought risks are highest. The approach emphasizes combinations of upstream, local, individual, and policy-based mitigation measures to protect against flooding and strengthen our ability to protect against drought.

The Bow River Water Management Project, announced in October 2015 by Alberta Environment and Parks (AEP) and jointly chaired with the City of Calgary, is one of many water management projects and investments initiated in the Bow River Basin since 2013. The mandate of this project is to provide the GoA with advice on opportunities to reduce future flood damage, improve the reliability of water availability, and protect the long-term health of the basin. This advice focuses on screening structural flood and drought mitigation opportunities in the basin, assessing the resulting flow impacts downstream through the entire basin, and considering the associated effects on watershed health.

A fundamental principle of this work is that floods and droughts cannot be prevented, but we can be better prepared. Investment in preparedness, protection, and resilience will reduce the economic, social, and environmental risks to individuals and communities in the Bow River Basin. Flood or drought mitigation cannot be assessed in isolation. They must be considered as part of a water management system that also values watershed health. Even water management cannot be looked at in isolation because it ties directly to many other government priorities, including climate change mitigation and adaptation, regional land-use planning, economic development, and recreation and tourism. Thus, this complex river system requires careful water management leadership and operations to balance environmental, social and economic values in the region.

The Bow River Working Group (BRWG) was tasked by AEP to provide water management advice to the government as part of this project. This group was informally established in 2010 as a technical collaboration of water managers and water users. In late 2013 and early 2014, the group worked together to identify and assess flood mitigation options in the Bow Basin.

In March 2014, the group released the *Bow Basin Flood Mitigation and Watershed Management Project* report, which identified the most promising mitigation options (Alberta WaterSMART and Alberta Innovates – Energy and Environment Solutions [AI-EES] 2014).

In 2015, a separate report prepared for AEP by Amec Foster Wheeler identified 11 potential flood storage schemes for the Bow River (Amec Foster Wheeler 2015). The Bow River Water Management Project expands on the findings of both of these prior projects. Specifically, the BRWG was asked to:

- Develop scenarios of potential operational and infrastructure flood mitigation opportunities in the upper Bow River Basin to reduce peak flow during a defined range of synthesized flood events to approximately 1,200, 800, and 400 cms measured on the Bow River above the confluence with the Elbow River, and assess how these scenarios affect flow thresholds along other reaches of the Bow River.
- Identify schemes required to offset any increased water management risk in the basin created by the flood mitigation scenarios upstream.
- Develop scenarios of potential operational and infrastructure drought mitigation opportunities to reduce the volume of licence shortages by at least 5% to 10%, while continuing to meet apportionment requirements, and with improvement, or at minimum no reduction, in ecosystem health (all relative to current operations in the same time period).

This report summarizes the findings of the Bow River Water Management Project and offers it as advice to the Minister of Alberta Environment and Parks in developing a robust, strategic plan for water management in the Bow River Basin, from the headwaters to the confluence with the Oldman River and continuing through Medicine Hat.

2.0 Project Participation and Methods

2.1 A Collaborative Approach

The Bow River Basin is fortunate to have a strong history of collaborative exploration of water management challenges and opportunities. This project benefited from a similar collaborative effort, involving water users, water managers, and other stakeholders from across the basin. Throughout the project, participants worked together, providing data, advice, and insight based on their knowledge and experience. They 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 consensus; rather, it was designed to explore practical mitigation strategies and scenarios informed by the best available data and knowledge in the basin.

2.2 Project Governance

Three groups governed the project: the BRWG (see Terms of Reference in Appendix B), the Advisory Committee (see Terms of Reference in Appendix A), and community groups. As indicated earlier, the BRWG is a technical collaboration of water managers and users that has come together in various forms over the past several years to lend technical expertise and experience regarding current and future water management issues.

For this project, the BRWG collaborated through a series of working sessions to identify, analyze, assess, and comment on flood and drought mitigation opportunities in the Bow River Basin. BRWG meetings were held by invitation and included representatives from the GoA, municipalities, industry, First Nations, irrigation districts, the Bow River Basin Council, and watershed stewardship groups, environmental non-governmental organizations, and others (see membership list in Appendix A). The Chair of the BRWG, Mike Kelly, provided periodic updates to the Advisory Committee, including progress on the project, next steps, and guidance required from the committee. Alberta WaterSMART was contracted by AEP to support the BRWG and AEP as needed during the project.

The BRWG met seven times for full-day meetings between March 2016 and March 2017 (Figure 1). Live hydrological modelling was part of each meeting and provided a factual basis to allow participants to consider a range of flood and drought events, assess the effect of individual mitigation schemes given the data available and assumptions used, and assess the cumulative effect of multiple mitigation schemes combined into mitigation scenarios. Work undertaken at the meetings was documented in a summary that was shared with all participants. Any information deemed proprietary or confidential was identified at the meetings, and participants were reminded not to share this information outside the BRWG.

To encourage open and frank discussion at the meetings, the Chatham House Rule was applied: *When a meeting, or part thereof, is held under the Chatham House Rule, participants are free to use the* *information received, but neither the identity nor the affiliation of the speaker(s) may be revealed.*

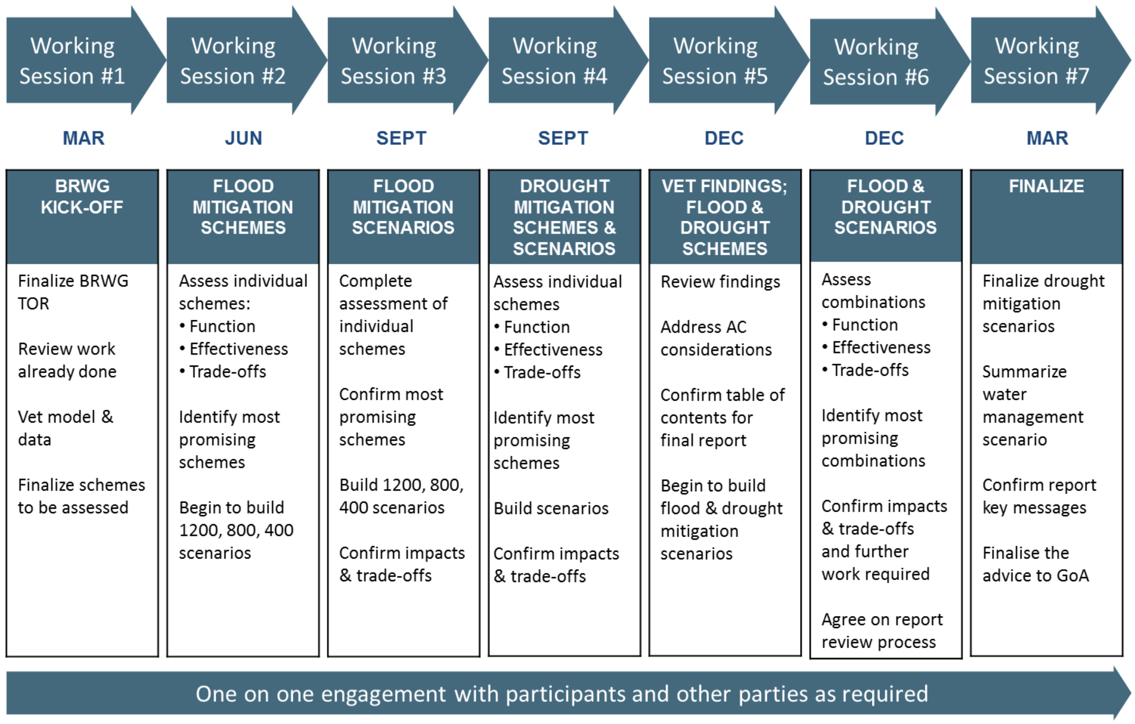


Figure 1: BRWG meetings (March 2016 to March 2017) and workplans for each meeting

The Advisory Committee was comprised of representatives from municipalities, industry, First Nations, irrigation districts, and the WPAC on the Bow River (see membership list in Appendix D). The Advisory Committee was co-chaired by AEP and the City of Calgary, and was responsible for:

- Providing strategic direction for the BRWG
- Championing the BRWG's work and its outcomes
- Identifying feasible implementation pathways and barriers for the various mitigation opportunities identified
- Acting as the liaison between various levels of government
- Providing issue resolution and addressing barriers, within a reasonable amount of time, that may arise within the BRWG, and
- Endorsing and providing the final report to the GoA for consideration.

The Advisory Committee met four times to discuss the project and provide advice on project planning. Recognizing the need for close alignment between the Advisory Committee and the BRWG, the committee focused on understanding the data and details leading to the conclusions of the BRWG and sought clarification when necessary. The Advisory Committee committed to providing the GoA's response on the project report to the BRWG once the report has been received, reviewed, and responded to by the GoA. Members of the Advisory Committee were invited to attend the BRWG meetings, and several of them attended one or more meetings.

Community groups included organizations with an interest in flood and drought mitigation in the Bow River Basin. Through the Advisory Committee the Watershed Resilience and Mitigation Branch of AEP periodically informed these groups on the progress of the project and they were invited to provide their perspectives on the project.

Other Committees

A Data Committee was formed in May 2016 (between BRWG Meetings 1 and 2) to review and provide guidance on the hydrological data and synthesized flood events used by the BRWG in its work. This committee included participants from the GoA, the City of Calgary, TransAlta, Bow River Basin Council (BRBC), and irrigation districts. The Data Committee held two teleconference meetings to discuss the project. Guidance from the committee was reviewed by the Advisory Committee and then provided to the BRWG.

A Drought Committee was formed in June 2016 (between BRWG Meetings 2 and 3) to review and provide guidance to the BRWG on the drought scope, objectives, schemes, and simulated events for the project. It included representatives from the GoA, irrigation districts, TransAlta, the City of Calgary, City of Medicine Hat, and the BRBC. The committee held three teleconference meetings to discuss the project. Guidance from the committee was reviewed by the Advisory Committee and provided to the BRWG.

2.3 Project Tools

Hydrological modelling used the Bow River Operational Model (BROM), which is a comprehensive, mass balance model of the Bow River system developed to enable users to examine and assess schemes and scenarios for adapting to changes in water supply and demand, including flood and drought events (see BROM Backgrounder in Appendix C).

BROM is built on the OASIS (Operational Analysis and Simulation of Integrated Systems) platform, which is flexible, transparent, and completely data-driven, and effectively simulates water-facility operations. OASIS preserves mass balance, where water enters the model through inflows and exits only through demands, evaporation, or an end point. Water is also allocated, in the general sense, to each use (e.g., minimum flows, demands, reservoir storage, licensed allocations) through a modifiable weighting system; that is, higher-weighted uses access water first. The model is limited because it cannot operate with the same real time adjustments the way a human operator would and uses assumed water travel times, rather than specific routing.

The project used two versions of the BROM: an hourly time step model for the flood mitigation assessment and a daily time step model for the drought mitigation assessment. The daily BROM is housed in a broader model—the South Saskatchewan River Operating Model—representing the entire South Saskatchewan River Basin (SSRB), which includes the Red Deer, Bow, Oldman, and South Saskatchewan River systems. Therefore, the effects of drought mitigation schemes and scenarios could be assessed at the scale of both the Bow River Basin and the larger SSRB.

A base case runoff scenario was used for the Oldman and Red Deer River basins and no operational manipulations were done in either basin for this project. The daily time step BROM was initially built in 2010 under the Bow River Project (December, 2010) and has since been improved and advanced through a series of collaborative projects. The hourly BROM was initially built in 2014 under the Bow Basin Flood Mitigation and Watershed Management Project (March, 2014).

The BRWG gathered the best available data to update the daily and hourly time step models for this project as needed. For the flood analysis using the hourly time step model, the BROM used hourly river flows and reservoir levels for the 2005 and 2013 flood events, with data provided by TransAlta and Water Survey of Canada.

These data were used to develop four hourly time series of data at all of the model node locations for use in the model. These included:

- **(Event 1)** the 2013 flood event of 2,400 cms naturalized[2] peak hourly streamflow for the Bow River at Calgary (above the Elbow River)
- **(Event 2)** the 2005 flood event of 1,250 cms naturalized peak flow scaled to approximately 2,000 cms peak hourly streamflow for the Bow River at Calgary (above the Elbow River)
- **(Event 3)** the 2005 flood event scaled to approximately 2,400 cms peak hourly streamflow for the Bow River at Calgary (above Elbow River), and
- **(Event 4)** the 2013 flood event scaled to approximately 3,300 cms peak hourly streamflow for the Bow River at Calgary (above the Elbow River).

It is important to note peak streamflow values were scaled based on naturalized streamflow. The 2005 and 2013 flood events were chosen because these floods exhibited very different hydrograph characteristics, with the 2005 event having high volume and two peaks, and the 2013 event having less volume but a single, higher peak. In addition to inflows, TransAlta provided hourly reservoir levels and stage-discharge relationships for each facility. Hourly operational rules were determined through discussions with AEP and TransAlta and were used to recreate the "base case" against which mitigation schemes and scenarios were compared. The base case for each event includes the relevant naturalized flow and the 2013 operations on the upstream reservoirs.

[2] Naturalized flow is defined by AEP as the calculated or measured "quantity of water moving past a specific point on a natural stream or river where there are no effects from stream diversion, storage, power production, import, export, return flow, or change in consumptive use caused by land use activities".

Also note these flood events are focused on flows at Calgary, upstream of the Elbow River, where inflow from the Elbow River was capped at 170 cms (an assumption given to this project based on the assumed future operations of the Springbank Off-stream Reservoir and Glenmore Dam) for all four synthesized events. Therefore, there is no change in the timing or magnitude of the events downstream along the Highwood or Oldman rivers. However, the Highwood and Oldman systems did contribute substantial flow to all events. The peak hourly flows for the Highwood River at the confluence with the Bow River were 2,600 cms for events 1 and 4, and 1,150 cms for events 2 and 3. The Oldman River peak flows at the confluence with the Bow River were 1,900 cms for events 1 and 4 and 2,200 cms for events 2 and 3.

The drought analysis required daily inflows, which were based on historical naturalized flows for the entire SSRB for the period for which Alberta Environment and Parks data was available: 1928 to 2009. In addition to the historical record, two synthesized 11-year drought time series were developed for use in the project (hereafter, Drought 1 and Drought 2). These time series were based on the historical period from 1935 to 1945, which was a period of prolonged drought in the basin; however, in Drought 1, 1936 inflows were repeated three times in the time series, and 1941 inflows were repeated twice in the time series. In addition, for Drought 2, daily streamflow values were scaled on a monthly basis, where the daily flows were multiplied by scaling factors to either increase or decrease streamflow on a given day. These scaling factors were based on hydrologic modelling of the effects of climate change on streamflow in the Bow Basin conducted by Golder (2014).

Water demand scenarios were an important component of the drought analysis dataset. Alberta Agriculture and Forestry provided irrigation-demand scenarios. Growth in irrigated acreage areas of 12% and 22% was simulated using the Irrigation Demand Model. The City of Calgary provided municipal-demand scenarios based on potential future water use in response to population growth out to 2033.

2.4 Project Scope and Assumptions

The GoA, Advisory Committee, and BRWG set the scope and assumptions for the flood and drought mitigation assessments to focus the work and ensure it could be completed. These were fully documented in the Terms of Reference (see Appendix A).

The scope and assumptions for the flood mitigation assessment included the following:

- The assessment will focus on flow quantity in the Bow River main stem from the headwaters to the confluence with Oldman River to below Medicine Hat, and the following major tributaries: Cascade River, Spray River, Kananaskis River, Ghost River, Jumpingpound Creek, Elbow River, Highwood River, and Sheep River.
- The starting list of options to be considered will come from the 2015 *Potential Flood Storage Schemes in the Bow River Basin* report (Amec Foster Wheeler 2015) and the 2014 *Bow Basin Flood Mitigation and Watershed Management Project* report (Alberta WaterSMART and AI-EES 2014).

- To assess mitigation potential, the BRWG will use a range of synthesized flood events including the 2013 and 2005 flood events with sensitivity factors applied to each.
- Out of scope elements include the following: flood mitigation options on steep mountain creeks (e.g., Cougar Creek); flood events and mitigation on the Oldman River; flood mitigation options beyond what are already planned for the Elbow, Sheep, and Highwood river systems; and flood mitigation options on the landscape rather than in the river, such as wetland protection, riparian zone restoration, road design, land access, and forestry practices.
- The current *Water Act* is assumed to remain the guiding legal authority.
- The primary performance measure used in the flood mitigation assessment will be reductions of peak flow at Calgary and at selected upstream and downstream locations.

The scope and assumptions for the drought mitigation assessment included the following:

- The assessment will focus on structural drought mitigation opportunities, including new storage and operational changes to existing infrastructure, both on and off stream.
- The assessment will focus on flow quantity on the Bow River, including its major tributaries to the confluence with the Oldman River to below Medicine Hat.
- To assess mitigation potential, the BRWG will use a range of synthesized drought events drawn from the historical record and scaled in duration and severity to reflect climate variability.
- Out-of-scope elements include the following: comprehensive review of natural storage functions and schemes; detailed analysis of demand management options; water quality and groundwater modelling; and drought mitigation schemes on the Oldman River.
- The *Water Act* is assumed to remain the guiding legal authority, and the Master Agreement on Apportionment is assumed to remain in place.
- The Bow River Basin is assumed to remain closed to new licence applications.
- Future demands may increase within current licences and pending licence applications reflecting expansion of municipalities, agriculture, and industry in the closed basin.
- New storage schemes will be modelled in accordance with regulatory requirements (WCO requirements as stated in the SSRB Water Management Plan; Alberta Environment 2006), and the BRWG will have the opportunity if they wish to explore the potential of schemes should the requirements be adjusted.
- The primary performance measures used in the drought mitigation assessment will be shortages, changes in apportionment, and changes in ecosystem health (as measured by low flow rates in certain locations).

The project was recognized as being a screening-level assessment of structural mitigation schemes and scenarios. These schemes and scenarios were assessed quantitatively using the BROM and qualitatively based on the experience and expertise of the participants. Schemes and scenarios deemed to have the most mitigation potential are presented in this report as advice to the GoA. The next step for these schemes and scenarios would be a full feasibility analysis.

3.0 Water Management in the Bow River Basin

3.1 Background on Current Water Management

Like many of Alberta's major river systems, the Bow River originates along the eastern slopes of the Rocky Mountains. The Bow is a snowmelt-dominated system, where water produced through the storage and melting of snow makes up the majority of the water supply. Although glacial meltwater contributes relatively little to total annual flow in the river, it plays an essential role in maintaining aquatic ecosystem health in the headwaters during late summer, and in maintaining streamflow in low-flow periods and drought years.

Approximately 645 km long and draining an area of nearly 25,000 km^2, the Bow River passes through Calgary and, further downstream, joins the Oldman River to become the South Saskatchewan River (Figure 2). The Bow River Basin is home to 22 urban municipalities, including the City of Calgary, 12 rural or regional municipalities, and three First Nations, making it the most populous river basin in Alberta (Bow River Basin Council 2010). The Bow River and its tributaries provide water for drinking, irrigation, livestock, waste assimilation, electricity generation, and wildlife, as well as for recreational activities such as fishing, rafting, kayaking, and canoeing. The river system and its banks provide important riparian vegetation and aquatic habitat for many plants and animals.

AEP is responsible for regulatory decisions for developments (other than oil, gas, and coal) pertaining to water management in Alberta. The Water for Life strategy and action plan reaffirms Alberta's commitment to the Water for Life approach. Alberta remains committed to its existing priority system of water allocation based on licence seniority. Since 2006 when the Lieutenant Governor in Council approved the South Saskatchewan River Basin Water Management Plan[3], no applications for new water allocations have been accepted in the Bow, Oldman, and South Saskatchewan sub-basins. The Master Agreement on Apportionment (1969)[4] 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.

Alberta faces important challenges in balancing water supply and demand from increasing population and economic growth, and in mitigating the increasing impact of this growth on the environment. Nowhere are these matters more pressing than in the Bow River Basin. As potential solutions are considered environmental, social and economic needs must all be addressed.

[3] See http://aep.alberta.ca/water/programs-and-services/river-management-frameworks/south-saskatchewan-river-basin-approved-water-management-plan/default.aspx

[4] See http://aep.alberta.ca/water/legislation-guidelines/master-agreement-on-apportionment-1969/default.aspx

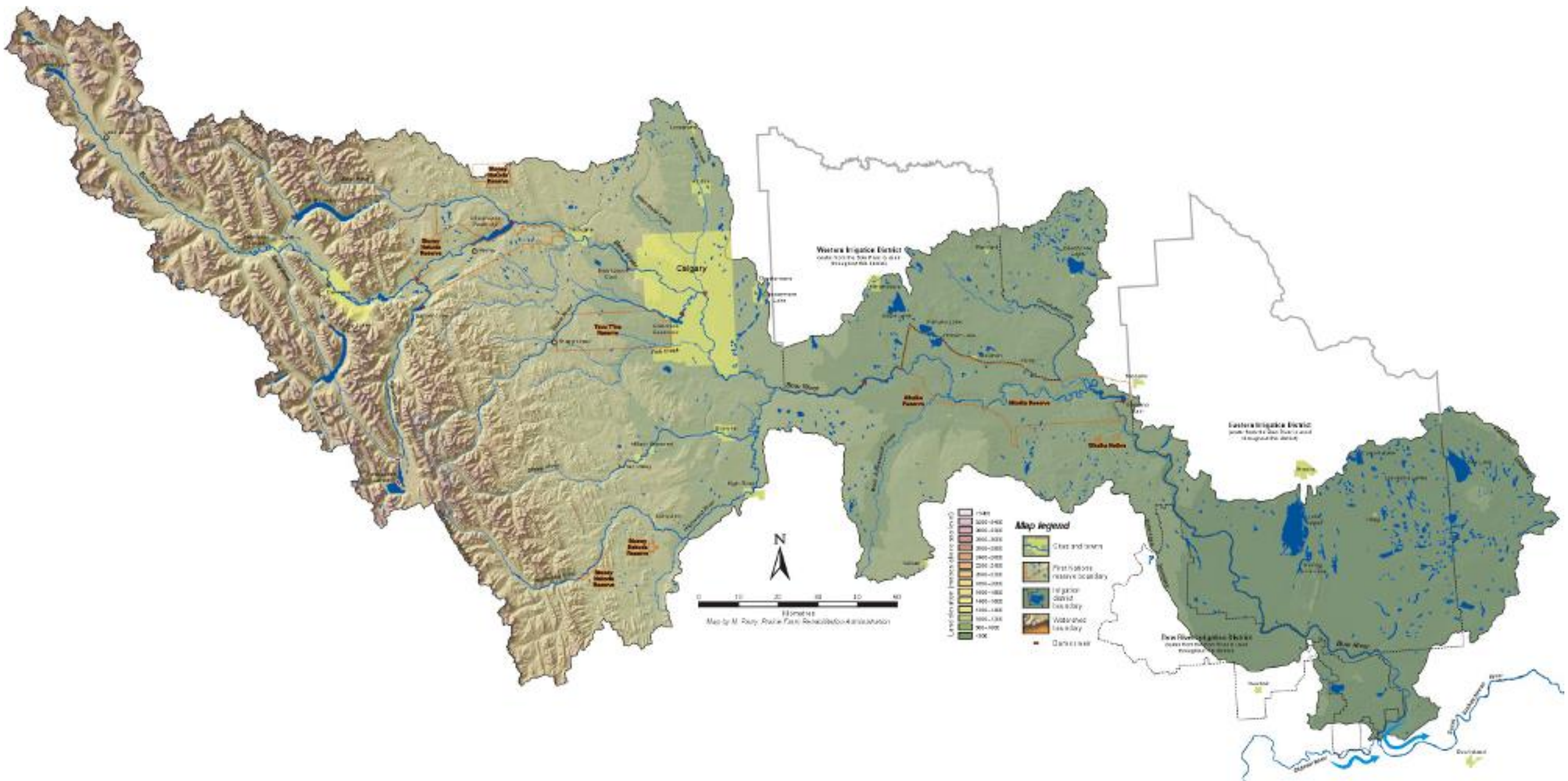


Figure 2: Map of the Bow River Basin

Source: Bow River Basin Council

Hydropower Generation

For the past 100 years, flows in the Bow River have been altered by dams and reservoirs, as well as the operating rules established by the owners of such facilities. In 1911, TransAlta (then Calgary Power) constructed the first of 11 hydroelectric stations on the Bow River (Table 1). Since that time TransAlta has been a major influence on the storage and release of water in the river and its tributaries.

Table 1: TransAlta hydro facilities on the Bow River system

Source: TransAlta

Plant	Reservoir	Primary Reservoir Supply	Installed Capacity (MW)	Live Reservoir Storage (dam^3)
Cascade	Lake Minnewanka	Cascade, N. Ghost	34	221,900
Spray Group (Three Sisters, Spray, Rundle)	Spray Lake	Spray River	155	177,600
Interlakes	Upper Kananaskis Lake	Kananaskis River	5	124,500
Pocaterra	Lower Kananaskis Lake	Kananaskis River	15	63,100
Barrier	Barrier Lake	Kananaskis River	13	24,800
Kananaskis	fore bay	Bow River	19	–
Horseshoe	fore bay	Bow River	16	–
Ghost	Ghost Lake	Bow River	56	92,500
Bearspaw	fore bay	Bow River	17	–
Bow Basin Total			**330**	**704,400**

Total storage in the hydro infrastructure upstream of Calgary is approximately 700,000 dam^3 compared with a highly variable, but average annual runoff volume of about 3 million dam^3 over the past 90 years (Seneka, 2004). The Bow River's hydro operations were designed to maximize power production and revenue.

The ability to almost instantly *spin up* its generators and produce electricity on demand allows TransAlta to balance the province's constantly changing electricity loads. This enables TransAlta to provide ancillary services to the provincial electricity grid to help maintain stability in the power system. Hydro facilities are, for the most part, operated to generate power when system electrical demand is highest, on both a daily and seasonal basis (known as peak power generation).

Agriculture and Irrigation

Agriculture is a major land use in the Bow River Basin. Alberta's irrigation industry annually generates about $3.6 billion to the provincial GDP and about $2.4 billion in labour income (Peterson Earth and Water Consulting Inc., 2015). Three of Alberta's 13 irrigation districts (corporations under the *Alberta Irrigation Districts Act* whose purpose is to convey and deliver water through irrigation works) draw water from the Bow River. The Bow River Basin accounts for approximately 40% of the irrigated land (private irrigation and irrigation districts) in the province.

Typically the irrigation districts withdraw water from the river from April up to October, to fill and refill reservoirs and to meet demands for irrigation water supply during the growing season, which is primarily May through September. Peak demands usually occur in July and reservoirs are used to augment supplies as required throughout the irrigation season.

In addition to supplying water for irrigation, irrigation district infrastructure conveys water for other uses including communities, livestock operations, food processors, other industries, and wetland/wildlife habitat projects. More than 64,000 acres of wetlands have been developed in the three Bow River irrigation districts in conjunction with Ducks Unlimited.

The three Bow River irrigation districts are the Bow River Irrigation District (BRID), Eastern Irrigation District (EID), and Western Irrigation District (WID). These three districts hold mostly senior licences totaling ~1,700,000 dam^3 of allocated water or ~70% of the total allocated water quantity in the Bow River Basin (Alberta Agriculture and Forestry, 2016).

In 2015, as an example year, the three districts in the Bow River Basin used ~1,170,000 dam^3 and of that, returned ~215,000 dam^3, or 20% to the Bow, Red Deer and Oldman Rivers (Alberta Agriculture and Forestry, 2016). Irrigation demands vary greatly from year to year depending on the weather. These three districts are relatively large, and contain over 45% of the total irrigable area included in all of the districts in Alberta.

Water for the irrigation districts is diverted from the river at the Calgary Weir (WID), the Carseland Weir (BRID) and the Bassano Dam (EID). The Carseland diversion also serves a 5,000 acre irrigation project on the Siksika First Nation reserve land. The GoA owns the WID and BRID diversion headworks while EID owns the Bassano Dam.

The three irrigation districts have access to ~1.1 million dam^3 of live reservoir storage in 23 reservoirs, 20 operated directly by an irrigation district and three owned and operated by the Province (see Table 2).

These reservoirs vary considerably in size; the major reservoirs in the basin are Badger, Lake McGregor, Travers Reservoir, Little Bow Reservoir, Lake Newell, Rolling Hills and Crawling Valley.

In addition to providing water supplies, many of the irrigation reservoirs are popular recreation sites, with several resorts and campgrounds, including two provincial parks. Most of the land in the BRID is downstream of reservoirs, whereas only half of the land in the EID is able to rely on reservoirs. The WID has only one effective reservoir, which supplements flow on one of their three primary canal systems.

Table 2: Irrigation District and Provincially Owned and Operated Reservoirs in the Bow River Basin

Source: Facts and Figures for the Year 2015, Basin Water Management Section, Irrigation and Farmwater Branch, September 2016, Alberta Agriculture and Forestry

Irrigation District Reservoirs			
Location	**Reservoir**	**Approx. Date of Impoundment**	**Live Storage (dam^3)**
Bow River Irrigation District	Badger	1985	57,120
	'D' Reservoir	2005	350
	'H' Reservoir	1953	2,790
	Lost Lake	1973/1987*	5,060
	'PFRID' Reservoir	2005	570
	Scope	1953	12,930
	Total storage		**78,820**
Eastern Irrigation District	Bantry # 1	1968	1,090
	Bantry # 2	1967	4,150
	Cowoki Lake	1937	8,370
	Crawling Valley	1984	94,300
	'J' Reservoir	1949/1966*	1,460
	Kitsim	1980	19,470
	Lake Newell	1914	315,300
	One Tree	1935	5,660
	Rock Lake	1956	3,990
	Rolling Hills	1949/2003*	40,640
	Snake Lake	1997	18,620
	Tilley 'B'	1972	21,070
	Total storage		**534,120**
Western Irrigation District	Chestermere	1944	5,090
	Langdon	1979/2014*	15,750
	Total storage		**20,840**

Provincially Owned and Operated Reservoirs			
Supply for:	**Reservoir**	**Approx. Date of Impoundment**	**Live Storage (dam^3)**
Bow River Irrigation District	Little Bow	1920	21,080[5]
	McGregor	1914	351,060
	Travers	1954	104,640
	Total storage		**476,780**
Total live reservoir storage serving irrigation in the Bow River Basin			**1,110,560**

Note: all reservoirs are off-stream storage sites except Travers, which is on the Little Bow River, but its water source is the Bow River.
* Year of reservoir enlargement.

To deliver water to almost 600,000 acres of land irrigated by the three Bow River Basin irrigation districts[6], the districts construct, maintain and operate ~4,000 km of pipeline and canal conveyance works.

The irrigation districts are improving their water use efficiency, which has enabled them to expand acreage, and they have amended their licences to allow this water to be used for other purposes. However, additional storage and water management infrastructure may be desirable to help meet the growing variety of water demands. Primary agricultural production makes the Bow River Basin an attractive location for food processing and other industries, all of which require reliable supplies of water.

The City of Calgary

Every day the City of Calgary's two water treatment plants, Glenmore Water Treatment Plant (on the Elbow River), and Bearspaw Water Treatment Plant (on the Bow River) provide treated river water for 1.25 million citizens, ~15,000 businesses and 17 regional customers including the communities of Airdrie, Strathmore and Chestermere.

Daily water demand comes from single family and multifamily homes, industrial, commercial and institutional operations and through The City's own municipal operations (Figure 3). However, the use of water by the majority of customers is generally non-consumptive; this means 80% to 90% of potable water, supplied to customers, returns to the rivers via one of The City's three wastewater treatment plants. Water demand in The City has a cyclical water use pattern. Higher consumption rates generally occur in summer months and are lower during the winter months. This results in an overall water demand pattern roughly the same shape year over year (Figure 4).

[5] Live storage in Little bow was increased to ~45,000 dam^3 in 2015/16

[6] Based on Bow Basin total quantity allocation by sector data from AEP

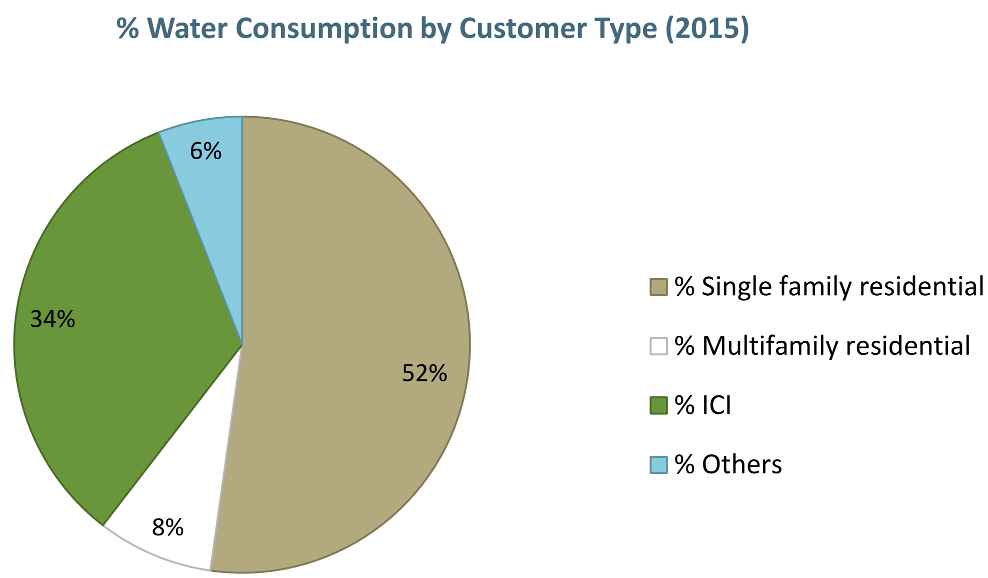


Figure 3: Water demand percentage in Calgary based on key customer groups
Source: The City of Calgary. Note: ICI refers to Industrial, Commercial, Institutional

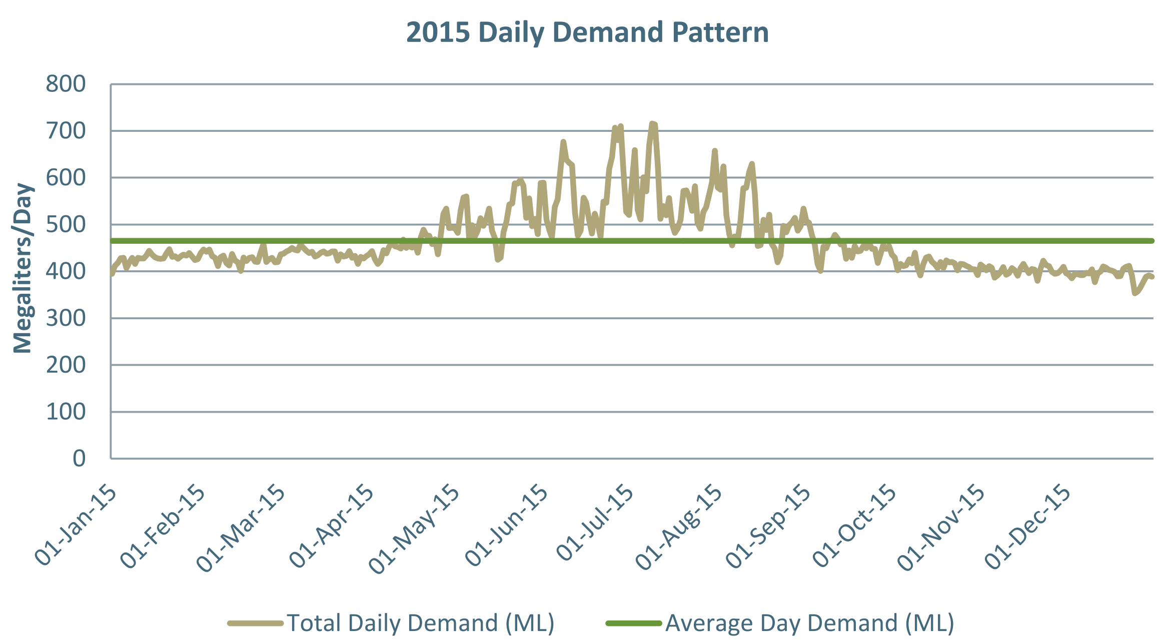


Figure 4: Total (Calgary and region) water demand pattern observed for 2015
Source: The City of Calgary

The City's total yearly water allocation is 460,088 dam^3 (108,546 from the Elbow River, and 351,542 from the Bow River). However, there is currently a licence limitation on the maximum instantaneous withdrawal rate from the Bow River, which limits The City to a maximum yearly withdrawal of 235,790 dam^3, giving a total of 344,336 dam^3 when adding the Elbow River licence. A licence amendment would be required before The City is able to take its full licence allocation amount.

Although The City's current licence allows an annual withdrawal of 344,336 dam^3, the current actual annual diversions are lower—the average yearly diversion between 2014 and 2016 was 176,300 dam^3 with ~90% returned to the river.

3.2 Floods

Significant floods have been recorded on the Bow River at Calgary in 1879, 1897, 1902, 1915, 1929, 1932, 2005, and 2013. River floods are most likely to happen between May and July when snowmelt in the mountains and the chance of heavy precipitation are both at their peak. However, floods can happen any time of year—in winter floods can happen when blocks of river ice pile up and block flow.

One key difference between estimated peak flows from the early 1900s and those measured during the 2005 and 2013 flood events is that the more recent events were moderated considerably by the existence and operation of six sizeable storage reservoirs upstream of Calgary (see Table 1). These reservoirs stored water and reduced peak flood flows downstream in Calgary by approximately 600 cms in 2013. Taking this into account would put the naturalized 2013 flood peak for the Bow River at Calgary (upstream of the Elbow River) at about 2,400 cms—approximately the same peak as the 1879 and 1897 flood events. Figure 5 shows the estimated and measured peak streamflows at Calgary upstream of the Elbow River confluence.

Antecedent conditions immediately before the rainfall events can have a significant impact on their actual effects. Factors such as soil moisture, ground water levels, snowpack, volume of empty storage in reservoirs, reservoir ability to capture runoff in relation to its location, dam ability to divert high water flows into downstream canals and reservoirs all contribute to the effects of a flood and the water management system resilience.

Flood mitigation also relies on forecasting—weekly and daily precipitation event monitoring—and communications systems that allow forecast centres and emergency responders to cope effectively with rapidly changing conditions.

River flooding is a natural process that benefits the floodplain environment. River flooding brings water and nutrients to vegetation growing near the river, and regenerates the ecosystem for new trees and shrubs to grow. During high flows, the power of the river can carve new channels, change its course, or deposit gravel and create gravel bars that will change the river's pattern of flow. These natural processes benefit the river valley, and are part of a healthy river system.

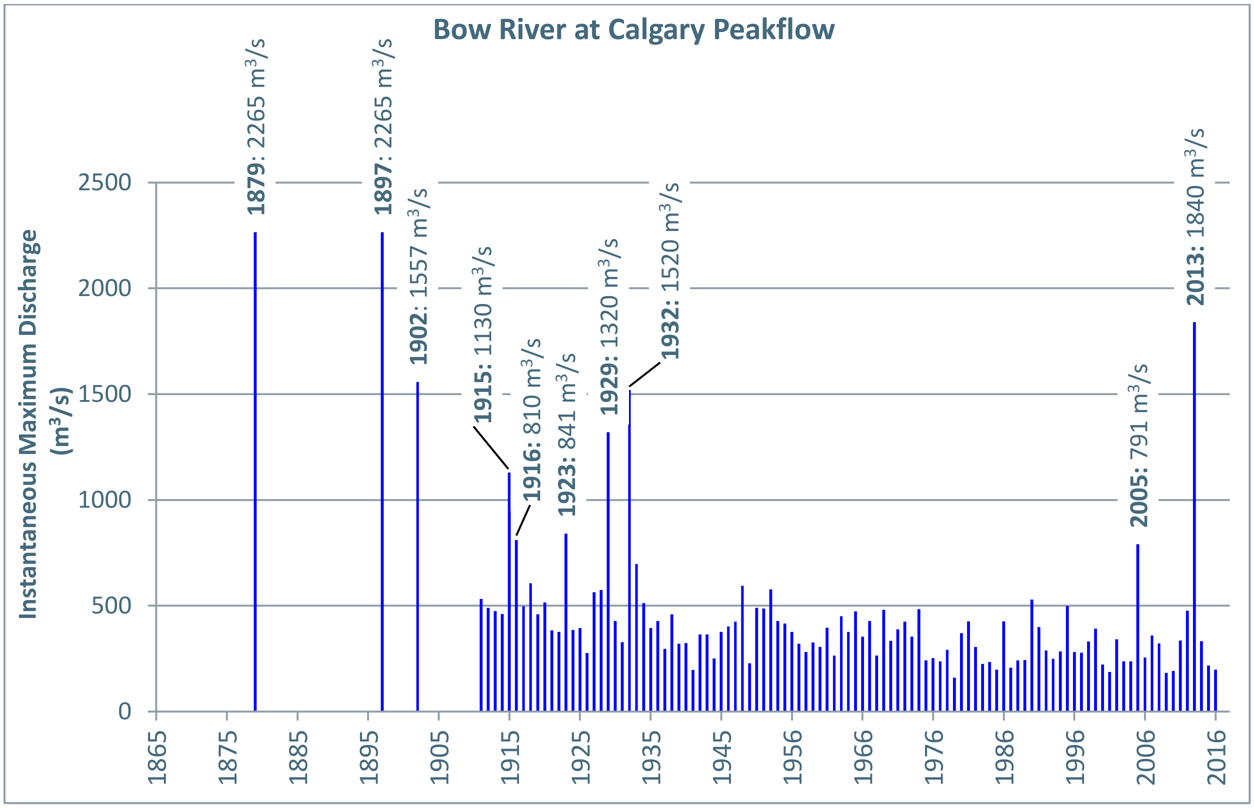


Figure 5: Peak streamflow through Calgary upstream of the Elbow River confluence between 1870 and 2016
Values from Water Survey of Canada and infilling from Golder (2014)

Calgary was established at the confluence of the Bow and the Elbow Rivers at a time when development in the floodplain area was not regulated to the degree it is today. As a result, much of The City is vulnerable to river flooding. Historic communities, a diverse population and much of the commercial downtown reside within the floodplain. Today, the impacts of floods, such as in 2013, can be devastating to human infrastructure. Historically, the damage caused by flooding did not outweigh the benefits of developing in the floodplain.

However, the amount and type of development within the floodplain has changed. Today, there is a significant amount of property and infrastructure within the Bow and Elbow River floodplains, including much of the downtown core. In urban environments, both the river and development must be wisely managed to reduce flood-people conflict, while acknowledging and giving room to the river to allow for natural processes wherever possible[7].

The City updated flood damage models created by the Province to include the most up-to-date technical

[7] Draws from material prepared by the City of Calgary for Flood Mitigation Public Engagement Sessions 2016 engage.calgary.ca/flood

information as well as many environmental and social factors of a triple bottom line analysis, which were not included in the Province's 2014 Flood Damage Assessment Study (IBI Group, 2015). The damage was calculated for all potential floods that could happen over 100 years.

On average, if flood damages were paid evenly as yearly payments floods cost Calgary about $170 million per year (average annual damage). This is the total exposure to flooding if no mitigation existed (i.e. if none of the mitigation completed since 2013 was in place). Providing upstream mitigation on the Bow River would significantly reduce this damage estimate[7]. More information on the City of Calgary's flood mitigation work can be accessed at www.calgary.ca/floodinfo.

3.3 Droughts

Drought is defined as little precipitation over a large geographic area for a prolonged period of time. Impacts can range from loss of crops and agricultural productivity, to municipal water use restrictions, to stress on coldwater fish species and aquatic habitat.

Alberta has a long history of drought. When the Palliser Expedition arrived in western Canada in 1857 the region was in the midst of a multi-decade drought. Palliser famously declared the Palliser Triangle—an area of about 200,000 km^2 spanning present-day southern Saskatchewan and southeastern Alberta—as being unsuitable for settlement, it was simply too dry.

For much of the 1930s the *dust bowl* drought lasted in the prairies. Bringing grasshopper plagues, crop failure, erosion of topsoil, and soil salinization[8], the drought had a major impact on Alberta's crops—most notably wheat—and compounded by the Great Depression resulted in a wave of settlers leaving the Prairie Provinces for other parts of Canada.

The year 1979 marked the beginning of another series of droughts. By 1984, the drought in Alberta became severe; it was the eighth consecutive dry year and the driest year since 1916.

The drought during 2001–2002 was devastating to Alberta. Net farm income was zero in Alberta in 2002, and the drought cost the Canadian economy $5.8 billion, making it one of Canada's most costly natural disasters. Farmers abandoned their farms and 41,000 jobs were lost across the country[9]. Alberta experienced recent droughts in 2009 and 2010. Central Alberta experienced the smallest amount of precipitation in the past 50 years and 10 counties declared states of emergency[10]. The economic value of Alberta's irrigation industry is reflected by the ~$3.6 billion that it contributes annually to the provincial gross domestic product (GDP)(Peterson Earth and Water Consulting Inc., 2015). Drought poses a direct

[8] http://albertawater.com/history-of-drought-in-alberta/drought-in-20th-century-alberta

[9] http://www.cbc.ca/news/canada/parched-prairies-latest-drought-a-sign-of-things-to-come-1.845429

[10] http://albertawater.com/history-of-drought-in-alberta/drought-in-21st-century-alberta

threat to that economy.

3.4 Adapting to Water Management Risks and Demands

Water managers and people with a keen interest in water management are aware the Bow River is highly regulated. During the spring melt and frequent spring rains, water is stored in the upstream reservoirs and released later in the year, passing through turbines to generate power. Senior licences held by irrigation districts and others allow for calls on current natural flows in the basin, resulting in water passed from the TransAlta system.

The managed flow provides sufficient flow to dilute Calgary effluent to meet environmental standards, especially in the winter. These relatively steady flows of more than double the natural flow in winter also support an excellent trout fishery downstream of Bearspaw dam.

Historically, this system has been adequate to meet the needs of various water users, provide a small but reliable supply of renewable electricity to the grid, and maintain relatively stable environmental conditions depending on the particular reach of river under consideration. In addition, these reservoirs have been operated in a manner that provides some protection against flooding.

As shown in Figure 6, a substantial portion of the annual flow in the Bow River and its tributaries upstream of Calgary is typically captured from early May through early September and gradually released during the year, smoothing out the natural flow.

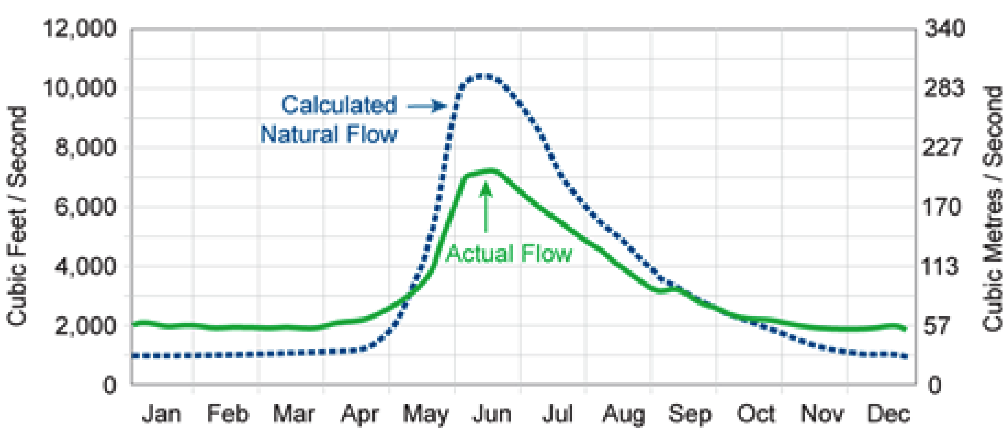


Figure 6: Hydrograph showing natural and managed flows on the Bow River at Calgary between January and December using daily averaged data over 38 years
Source: *BRBC State of the Watershed Summary (2010)*

Through time, increasing water demand associated with population growth and economic development, combined with climate variability, has reached the point where the risk of impacts—due to both flood and drought—are too high to continue under a system last significantly modified in the 1950s.

This project provides some comparative analysis of alternatives to the present infrastructure and its current operations that could reduce the risk of damage from flooding and could help reduce the impacts of harmful and costly water shortages during drought periods.

Flood or drought mitigation cannot be viewed in isolation. Both floods and droughts are relatively common occurrences in Eastern Slopes streams and rivers throughout southern Alberta. Managing exclusively for either flood or drought conditions can significantly reduce the ability to mitigate the other. Both droughts and floods can cause an unreliable supply of useful water; for example, floods can and have caused water treatment plants in some communities to become inoperable for extended periods.

Equally important as efforts to manage river systems to mitigate droughts and floods is the need to maintain the environmental system the river conveys and supports. Although not the focus of this project, the BRWG recognizes and strongly supports other projects that examine the ecological functions of the natural systems on land and water to help achieve these same goals. The Watershed Resiliency and Restoration Program (WRRP) supported by AEP is one excellent example among many (e.g., Cows and Fish, Alberta Conservation Association, Ducks Unlimited, Trout Unlimited) that focuses on natural solutions to improve overall adaptation to flood and drought events and build natural watershed resilience.

In Alberta, climate change will directly and significantly impact 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]

Natural climate variability and climate change pose huge challenges for Albertans and those downstream, as the headwaters for major east- and north-flowing rivers arise in Alberta. Some researchers believe global climate change impacts are likely to produce more extreme events and alter the timing of precipitation that supports surface water systems by shifting from primarily snowpack-driven events to more winter rainfall (Field et al. 2007a, b; Sauchyn and Kulshreshtha 2008). As the Rocky Mountain glaciers are substantially reduced in size, this will produce lower natural summer flows, and Alberta has limited storage options to capture the flow that does occur.

Adding to this uncertainty, tree-ring data correlated with river flow shows extreme climate variability in past centuries for flows in the Bow and Oldman rivers (Figure 7), suggesting that future flood and drought events could be much greater than those experienced in recent years. These events, combined with population and economic growth, will make it even more important for the region to be able to adapt to and cope with new pressures and demands, whether from droughts or floods.

---

[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/view?pref=2&pli=1

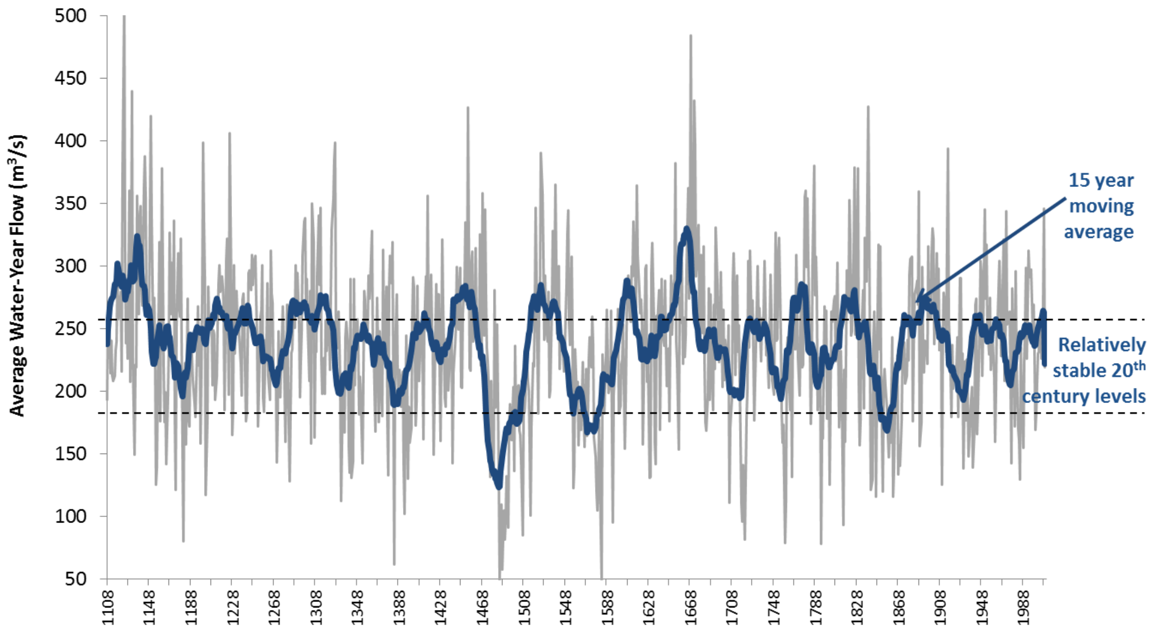


Figure 7: Reconstructed South Saskatchewan River Basin flows (Bow and Oldman) showing annual averages (grey line) and the 15-year moving average (blue line)
Source: Dr. David Sauchyn, Prairie Adaptation Research Collaborative, 2015

Since the 2013 flood, the GoA, the City of Calgary, and other municipalities have invested in, or are planning, a long list of flood mitigation and resiliency projects, studies, and community support programs including:

- More than $100 million in water management infrastructure including the Bassano Dam spillway and Travers Dam upgrades
- Adding operable gates to Glenmore Reservoir, with additional height for flood storage and attenuation
- Continuing studies and process to build Springbank Off-stream Reservoir for the Elbow River
- Berming and armoring of the Elbow River banks through Bragg Creek and Redwood Meadows
- Extensive erosion control projects supported by the provincial Flood Recovery Erosion Control (FREC) program
- Voluntary buyouts in some flood prone areas and assessment of buyout cost benefit potential in further flood plain areas.
- Implemented and proposed legislation to limit floodway developments e.g. the City of Calgary modified the Land Use Bylaw to improve resiliency in flood hazard area development
- Updates to flood inundation mapping and flood hazard mapping in high-risk areas
- WRRP funding and renewed funding to build greater natural resiliency in watersheds
- Developed flood mitigation options for Alberta's most flood-prone river basins: Peace River; Athabasca River; Bow, Elbow and Oldman Rivers; Highwood, Sheep, and South Saskatchewan Rivers; Red Deer River

- 2016 GoA Modified Operations Agreement with TransAlta for adaptive operational changes on the Bow River
- Over $150 million committed by The Province of Alberta to the City of Calgary for flood mitigation and resilience, over a ten year period. Further ACRP funding committed to other communities (see http://aep.alberta.ca/water/programs-and-services/alberta-community-resilience-program/default.aspx)
- Construction of berms and flood barriers at strategic locations in Calgary (design of West Eau Claire, Heritage Drive and Centre Street barriers underway, construction of Deane House, Calgary Zoo, Calgary Stampede and Deerfoot Trail at Glenmore Trail complete)
- Rebuilt and strengthened river banks, pathways, bridges, raised sanitary and stormwater lift stations to improve flood resilience and added gates to stormwater outfalls to mitigate river flood intrusion via the stormwater system
- City of Medicine Hat will have spent $33 million in overland flow protection projects along the South Saskatchewan River by the end of 2017
- The Overland Flow Protection Strategy is designed to protect the residents of Medicine Hat from a 1 in 100 year (5,480 cms) flood event, plus an additional metre of freeboard. The strategy consists of eight project locations including the water treatment plant, Harlow, Lions Park, River Road, Riverside, Industrial Avenue, Kingsway and Kipling areas. As of the end of 2016, nearly four kilometres of earthen berm has been constructed as well as six demountable barrier structures
- The strategy included the installation of 38 storm outfall backflow preventers along the South Saskatchewan River, Seven Persons Creek and Ross Creek. Further information on the strategy can be found at www.medicinehat.ca

Once the currently committed work is completed (not including the Springbank Off-stream Reservoir) the average annual damage Calgary is exposed to from flooding will decrease from $170 million to about $117 million per year—about a 30% decrease in potential damage.[12]

This same analysis by the City, shared in the IBI Damage Study report (IBI Group and Golder Associates Ltd. 2017) that focuses on flood damages within The City, concludes that the number could be reduced to ~$32 million per year. This would require building the Springbank Off-stream Reservoir, and a new upstream Bow River reservoir, and continuing the 2016 GoA Modified Operations Agreement with TransAlta. A copy of this report can be requested from the City of Calgary. Flood information is available from The City at http://www.calgary.ca/UEP/Water/Pages/Flood-Info/Recovery/Flood-projects.aspx.

[12] The City of Calgary. Participant Engagement Package: Flood Mitigation Engagement Sessions. Oct.–Nov. 2016. http://www.calgary.ca/_layouts/cocis/DirectDownload.aspx?target=http%3a%2f%2fwww.calgary.ca%2fengage%2fDocuments%2fFlood_Mitigation%2fFlood%2520Mitigation%2520Participant%2520Package%2520October%25202016%2520FINAL.pdf&noredirect=1&sf=1

The Bow River Basin faces uncertain climate conditions and risks of extreme events while supporting a growing population and carefully balanced environmental, social, and economic values. Water management is a fundamental component of this system, which needs to adapt continually to current conditions and expected future conditions. With this context for water management well understood, experts, decision makers, and the public can develop strategies and actions that support a long-term strategy for water management in the basin.

PART II. FLOOD MITIGATION

4.0 Flood Mitigation: Objective, Schemes, and Synthesized Flood Events

The objective of the flood mitigation assessment was to develop scenarios of potential operational and infrastructure flood mitigation opportunities in the upper Bow River Basin to reduce peak flow during a defined range of synthesized flood events to approximately 1,200, 800, and 400 cms (measured on the Bow River above the confluence with the Elbow River) and assess how these scenarios affect flow thresholds along other reaches of the Bow River. The 1,200, 800, and 400 cms targets were established by the co-Chairs of the project (AEP and the City of Calgary); partly based on the flood thresholds used by the City (see Table 3 below). This objective was completed first by evaluating individual flood mitigation schemes and then combining these schemes into scenarios.

Early in the process, discussion focused on whether 400 cms is a realistic flood mitigation target—given many schemes would be required to mitigate to that level and there would be potential for detrimental effects on the natural functions of the river and floodplain. Preliminary modelling suggested that even if all flood mitigation schemes identified at that point (i.e., Schemes 1–14) were implemented, flows in Event 1 could only be mitigated to ~550 cms; that is, they could not collectively achieve the 400 cms target (see Figure 8). Given the concerns of the BRWG and results of preliminary modelling, the Advisory Committee confirmed in August 2016 that flood mitigation scenarios should be developed for the 1,200 and 800 cms targets only.

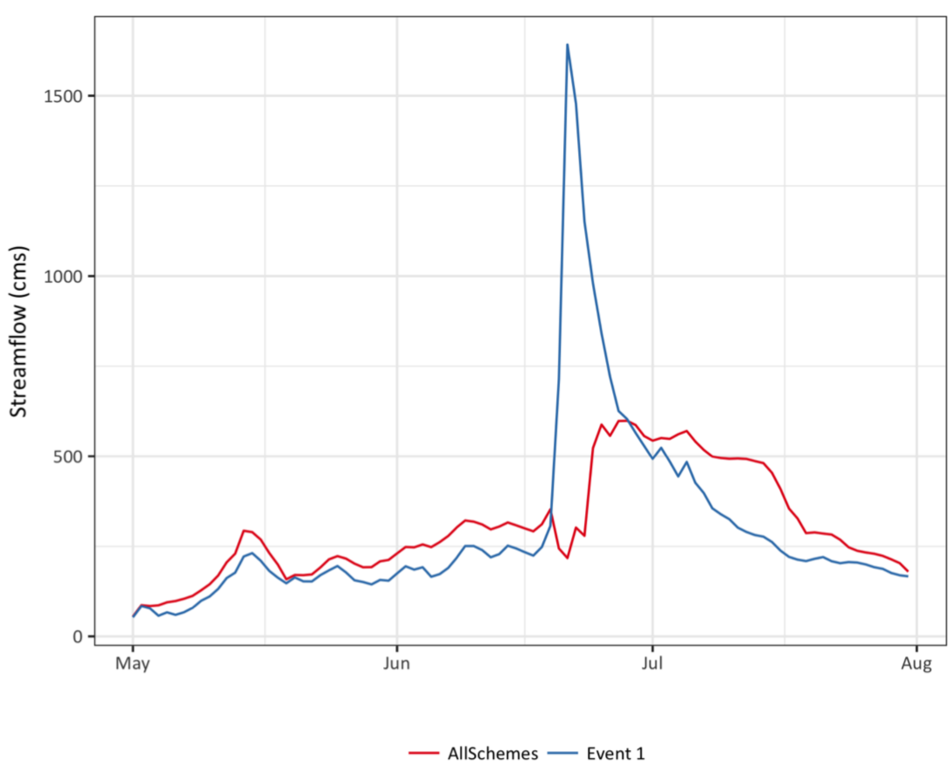


Figure 8: Preliminary modelling showing that implementing all flood mitigation schemes would not achieve the 400 cms target

In addition to the thresholds at Calgary, the project assessed how the flood schemes scenarios impact flow thresholds along other reaches of the Bow River. Municipalities and irrigation district participants provided the high river flow thresholds shown in Table 3.

Table 3: High river flow thresholds provided by municipalities and irrigation districts at select points

Location	Flood Threshold(s)
Canmore	**300 cms** for groundwater issues. **600 cms** for overland flooding – 2013 flows likely exceeded 600 cms, leading to loss of bank armour and bridge protection, flooded homes, bank erosion.
Cochrane	**1,200 cms** based on property damage.
City of Calgary (Bow River above Elbow River confluence)	**400 cms** (~2 year return period) - "No damage threshold" where flooding impacts are minimal, but this level triggers activation of the Water Emergency Response Centre (H2OC). **800 cms** (~8 year return period) – Additional basement seepage occurring; impacts to businesses occur; additional river water intrusion via stormwater system occurs; City of Calgary Emergency Operations Centre is activated; park areas flooded; underpass flooded; road, pathway closures required. **1,200 cms** (~20 year return period) - More significant overland flooding occurs; evacuations required; additional areas impacted by basement seepage; temporary barrier construction required; impacts to Bonnybrook WWTP; additional road closures required; additional storm sewers backed-up.
Carseland Weir	**3,540 cms** based on the design flood (1:100 year natural return flood) for the weir and fuse plug embankment, calculated in 1960 by the PFRA.
Bassano Dam	**4,000 cms** with existing infrastructure. **6,000 cms** with new infrastructure.
Medicine Hat	**3,700 cms** flood damages begin. **6,600 cms** permanent flood mitigations overtopped.

Mitigation schemes assessed by the BRWG included new infrastructure, upgrades or expansions of existing infrastructure, and changes to existing operations. Most of these schemes had been identified in two previous projects exploring flood mitigation opportunities in the Bow River Basin (Alberta

WaterSMART and AI-EES 2014; Amec Foster Wheeler 2015); participants at BRWG meetings also suggested other schemes.

Hydrological modelling was used to evaluate the performance of the schemes and the resulting scenarios to meet flow targets through Calgary and flow thresholds along other reaches. Floods on the Bow River have historically varied in peak flow and total volume. To plan for the adaptability needed to face known challenges of flood and drought risks, in addition to new risks potentially posed by climate change, the characteristics of modelled flood events must vary.

The flood mitigation work used two very different flood events in recent history as baseline events, and then scaled them up to test the effectiveness of various mitigation schemes:

- The 2005 flood had multiple peaks caused by a series of heavy rainstorms over a large area centered in the foothills and front ranges of the Rocky Mountains over a period of several weeks.
- By contrast, the 2013 flood event was caused by a single massive rainstorm delivered on a moderate snowpack in the front range of the Rocky Mountains, creating a single rapid peak with little warning of flash floods throughout the central range and foothills tributaries.

Table 4 shows the synthesized flood types and peak flows created for this project. The peak flow in each synthesized event is shown as the naturalized peak at Calgary; the hydrograph shape is shown by volume and whether it came as a single peak or multiple peak flows; and the general location of the precipitation is shown in the final two columns.

The peak flow at Calgary was used to establish the baseline, but flow rates at many other locations throughout the Bow River system were also considered in the assessment of mitigation schemes.

Table 4: The four synthesized flood events used in hydrological models to evaluate the performance of flood mitigation schemes and resulting scenarios

Range of Flood Characteristics vs. Set of Simulated Events to be Used in BRWG Screening Level Assessment								
Flood Characteristics	**Naturalized Peak at Calgary**			**Hydrograph Shape**			**Inflow Location**	
Simulated Flood Events	~2,000 cms	~2,400 cms	~3,300 cms	June volume @ Calgary (M m^3)	Steep incline, single peak	Slower incline, multiple peaks	Central ranges	Front range and foothills
1. 2013 event				~1,500				
2. 2005 event scaled to ~2,000 cms peak at Calgary				~1,700				
3. 2005 event scaled to ~2,400 cms peak at Calgary				~2,050				
4. 2013 event scaled to ~3,300 cms peak at Calgary				~1,950				

Although the project assessed absolute peak flow rates and volumes, the return period is sometimes considered as a reasonable estimate of frequency of risk. Return periods estimates can change over time as new annual peak flow information is incorporated into the frequency analysis, but according to Golder (2014), the 2013 flood at ~2,400 cms natural flow peak constituted approximately a 200-year return period. These estimates (shown in full in Appendix L) are being revised at the time of publication of this report, so caution is advised in using the return period as a guide to risk.

Sections 5.0 and 6.0 summarize results of the detailed assessments of flood mitigation schemes and scenarios completed by the BRWG.

5.0 Assessment of Flood Mitigation Schemes

Fifteen flood mitigation schemes (see 5.1) were assessed by the BRWG. These schemes were located across the Bow River Basin upstream of Calgary (Figure 9).

This section describes each scheme and:

- Summarizes the results of hydrological modelling used to evaluate how well each scheme is able to mitigate flood flows in the four synthesized flood events (see Section 4), and
- Summarizes commentary on these schemes from the BRWG, including an indicative time and cost; and provides an assessment of flood mitigation potential.

The indicative cost estimates are preliminary estimates indicating the present value of the direct costs of the scheme (capital and annual) over a 50 year life.

A summary table showing results for all schemes and scenarios can be found in Appendix E.

Observations common to flood mitigation schemes

Some observations by the BRWG common to the flood mitigation schemes and other key points relating to the schemes included:

- The flood mitigation flow targets were set at Calgary, but the BRWG considered flows all the way downstream to past Medicine Hat.
- The BRWG indicated that, in general, operations and designs of existing infrastructure should be optimized before developing new infrastructure, given that the existing reservoirs in the Bow River Basin already provide substantial flood mitigation, as demonstrated during the 2013 flood event and reflected in the modelling results for the four synthesized flood events.
- Operations for flood mitigation should be designed to minimize the need to fill reservoirs in mid to late July when streamflows typically drop as well as moderate impacts to downstream water users during the refill timeframe. Flood mitigation operations would need to be balanced with other water management considerations because water storage provides essential services later in the year.
- Many of the schemes would be effective at mitigating smaller floods than 2013 that occur more frequently and therefore would have a large potential benefit over a short period of time.
- While the modelling needs to use specific operating rules—for example, triggers and fill rates—the BRWG emphasized the need for flexibility and discretionary decision making in operations within some set of general boundaries and guidelines rather than rigorous and restrictive "if-then" decision making, which can be unresponsive to a rapidly changing environment. Water management is dynamic. It needs to be based on the best available information and highly responsive to rapidly changing information. This raises important questions regarding governance and operational decision making in the future.

- Potential mitigation benefits could include both delaying a peak flood flow (vital for implementing emergency response measures) and reducing the peak flood flow (vital for reducing damages).
- Some schemes could create a false sense of security downstream. For example, a dam could be built with the intent of protecting downstream residents, but if a flood is generated downstream of the dam's catchment area, downstream residents who thought they were protected by the structure could still be in jeopardy. Floodplain management cannot be ignored because structures are in place upstream.
- If large infrastructure projects are included in the scenarios, deliberate land management of the catchments upstream of these structures would be needed to prevent them from working harder than needed i.e. not having development or urbanization upstream increase runoff volumes and flood peaks into the reservoirs.
- Alberta's commitments to biodiversity protection, achieving International Union for the Conservation of Nature (IUCN) standards for global protected areas, and reaching Canada Target 1 biodiversity goals, must be considered when Parks and Protected Areas sites are being considered for large-scale flood mitigation projects.
- Structures would need to be built to current dam safety standards, including an adequately designed emergency spillway, because the consequences of failure would be extreme.
- Ongoing operation and maintenance costs, as well as initial costs, for flood mitigation infrastructure projects are significant. These structures would need to be operated and managed for public safety at all times (e.g., intermittent use of dry dams could be a public safety risk) and would require extensive and ongoing debris and sediment management.
- Post-flood event reservoir draw down would need to be understood and information shared appropriately because these releases would create temporary high flows throughout the Bow system.
- Structures should, where possible, be built and operated to help mitigate future droughts as well as floods, and would require a clear governance and decision-making process in all aspects of structure management.
- Cost for construction could be high because of weak bedrock in some areas. There could be groundwater issues and ice jam concerns.
- The farther upstream structures are placed, the less potential they have to mitigate a flood at Calgary, as flood events can be generated lower in the catchment. Schemes high in the system, for example, Spray Reservoir, would offer limited flood mitigation relative to those on the main stem.
- Under some conditions, tributary structures can protect communities upstream of Calgary as well as the city.
- An assessment would be needed on the cost of moving people away from the floodplain versus building new infrastructure to protect them. Part of this (looking at the floodway, not the full floodplain) has been completed by City of Calgary in their Flood Damage Study which concluded that it is much more expensive to move people away than to construct upstream mitigation or

barriers. To buy out the floodway area (defined by The City as "includes the channel of a river and adjacent land areas. Floodways carry the bulk of floodwater downstream and are usually the area where flow velocity is the highest and flow depth is significant") in Calgary would be in the order of $1.8 billion. Floodway buyouts were the only scenario examined in the flood damage study that did not yield a positive cost-benefit ratio (IBI Group and Golder Associates Ltd. 2017).

- Multiple large dams in succession would create operational complexity and therefore additional risk for operators. However, it may also offer additional flexibility, which is valuable.
- How a scheme is operated in different flood events has a massive impact on the amount of flood mitigation it can achieve; the operational decisions (e.g., pre-releases, timing of filling, drain rate) are driven by safety, antecedent conditions, forecast information, and the characteristics of the event itself. The operational triggers are vastly different based on the type of event, which would put a significant onus on the operators and forecasters and require coordination and co-operation between operators, industry, and governments.
- Holding existing upper Bow facilities low to provide flood mitigation would negatively impact drought mitigation; therefore, work would be needed to offset risks to water management and keep the system in balance.
- Some Albertans may be unsupportive of constructing new dams in the basin because of the value and environmental function of the existing system.
- Any mitigation option would involve trade-offs. The intent is that a balanced suite of mitigation schemes will be pursued to increase safety and reduce risk of damage while enhancing the long-term health and resiliency of the watershed. The full suite of mitigation effort would include not only infrastructure but also natural functions and floodplain management.
- The AC and BRWG questioned whether the application of a WCO (or IO) would significantly change the modelling results showing the potential of each mitigation scheme in the modelled scenarios. Based on this preliminary analysis, no storage schemes should be disqualified solely due to the potential introduction of a WCO requirement. More on this can be found in Appendix K.

The hydrological modelling results are shown for each mitigation scheme compared to the base case (which replicates how the system was operated in the 2013 event). The results provide an indication of the flood mitigation potential of the scheme in each of the four synthesized flood events (see Section 4). As a reminder, the four synthesized events were:

- **(Event 1)** the 2013 flood event of 2,400 cms naturalized[13] peak streamflow for the Bow River at Calgary (above the Elbow River)

[13] Naturalized flow is defined by AEP as the calculated or measured "quantity of water moving past a specific point on a natural stream or river where there are no effects from stream diversion, storage, power production, import, export, return flow, or change in consumptive use caused by land use activities".

- **(Event 2)** the 2005 flood event of 1,250 cms naturalized peak flow scaled to approximately 2,000 cms peak hourly streamflow for the Bow River at Calgary (above the Elbow River)
- **(Event 3)** the 2005 flood event scaled to approximately 2,400 cms peak hourly streamflow for the Bow River at Calgary (above Elbow River), and
- **(Event 4)** the 2013 flood event scaled to approximately 3,300 cms for the Bow River at Calgary (above the Elbow River).

5.1 Schemes Assessed by the BRWG

The 15 flood mitigation schemes assessed:

1. Spray Lake Reservoir flood operations (page 53)
2. Lake Minnewanka flood operations (page 55)
3. Upgrade Ghost River diversion to Lake Minnewanka (page 57)
4. New reservoir on Ghost River upstream of Waiparous confluence (page 59)
5. New reservoir on Waiparous Creek upstream of confluence with Ghost River (page 62)
6. Kananaskis Lakes flood operations (page 65)
7. New reservoir on Kananaskis River (page 68)
8. Barrier Lake flood operations (page 71)
9. New reservoir on Jumpingpound Creek (page 74)
10. New Glenbow reservoir on Bow River upstream of Bearspaw (page 77)
11. New Morley reservoir on Bow River upstream of Ghost Reservoir (page 82)
12. Extend Ghost Reservoir flood operations (2016 agreement) (page 86)
13. Expand Ghost Reservoir (by raising full supply level and/or adding a low-level outlet) (page 89)
14. Restore Spray Reservoir to full design capacity (page 93)
15. Increase Ghost Reservoir drawdown rate (page 96)

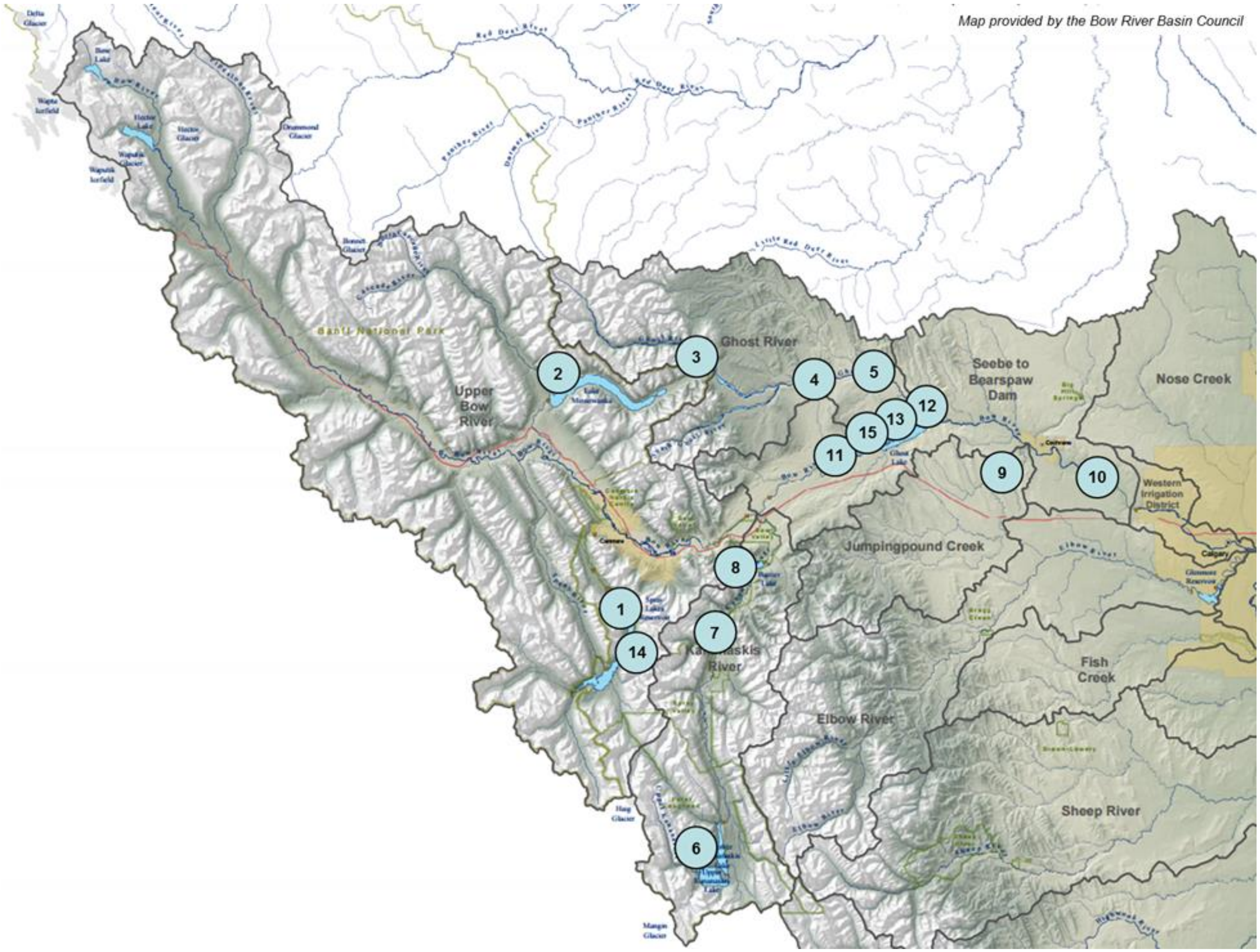


Figure 9: Locations of the 15 mitigation schemes assessed by the BRWG

Scheme 1. Spray Lake Reservoir flood operations

This scheme would involve a future agreement between GoA and TransAlta to operate existing facilities to provide increased levels of flood mitigation. If forecasts suggest high inflows (snowpack, rainfall, soil moisture), the reservoir would be lowered before the flood season (from May 15 to July 15) every year and would release 20 cms when flood storage operations begin until the reservoir is full (upper rule) and spill operations begin.

The reservoir controls runoff from a drainage basin area equal to about 6% of the Bow River Basin above Calgary (based on the Spray River at Canyon near Spray Lake Water Survey Canada gauge). The existing Spray Reservoir has about 177,600 dam^3 of total storage.

Indicative timeframe	Indicative cost
Implemented quickly	\$5–50 million

Results

The approximate reduction in peak flow in the Bow River at Calgary was zero for each synthesized flood event (Figure 10), which arises because Spray River has a relatively small catchment area, so does not generate much of flood peak flow or volume for the events modelled and Spray Reservoir is relatively large; therefore, inflows to the reservoir are easily captured with existing operations.

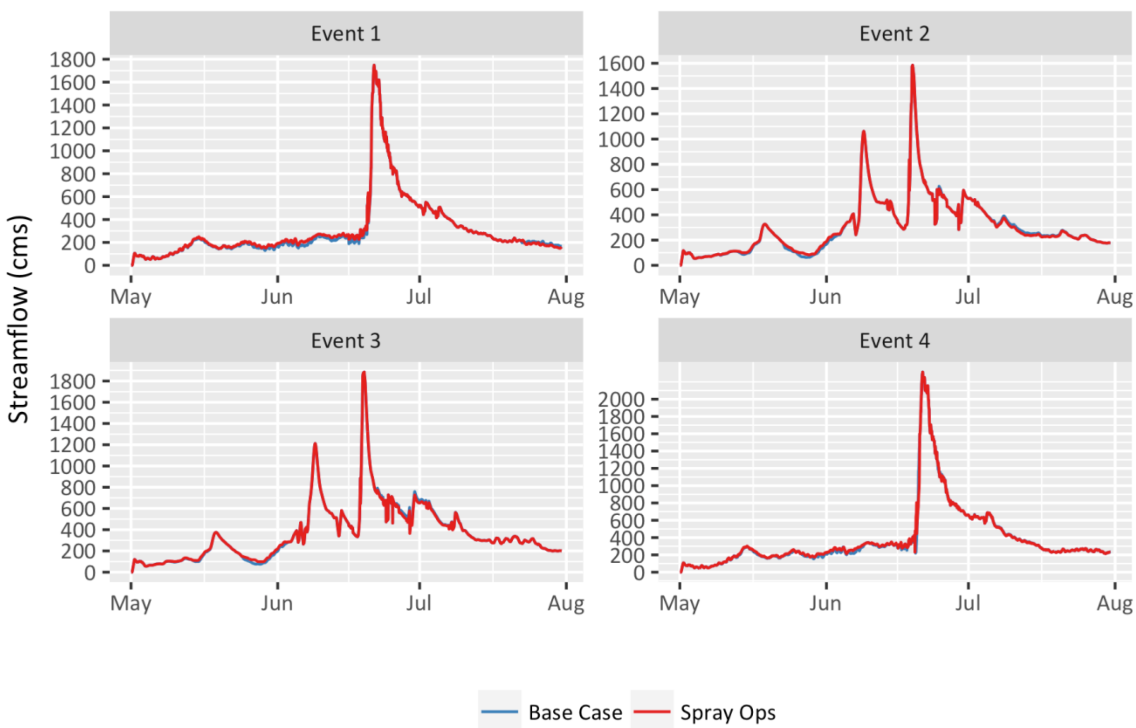


Figure 10: A comparison of synthesized Bow River streamflow between base case and Spray operations for Events 1–4

Scheme 1. Spray Lake Reservoir flood operations
Upstream and downstream notes of interest (see full results in Appendices F, G and H): • Flows on the Bow River at Canmore were reduced for Events 2 and 3 given that they were higher-volume events. In Event 2, this scheme reduced the peak on the Bow River at Canmore by 50 cms. In Event 3, this scheme reduced the peak on the Bow River at Canmore by 25 cms.
Commentary
Socio-economic and community considerations • This scheme would directly benefit Canmore, Exshaw and Morley by reducing flows at the town site during periods of peak flow on the Bow River. • This scheme would directly involve Alberta Parks Division lands, specifically Spray Valley Provincial Park, and would indirectly involve the Spray River through Banff National Park. • This scheme could have negative impacts on visitor experience, commercial tourism and recreation in Spray Valley Provincial Park. **Environmental and ecological considerations** • Risk to Lake Trout and Mountain Whitefish fisheries likely manageable due to likely emergence of these species earlier in the year. • Effect of drawdown on productivity is unknown depending on duration of lower water levels. • Potential, but unknown impacts on spring spawning fish (cutthroat trout), but not known whether pure westslope cutthroat trout still exist in the contributing Spray River. **Design and operational considerations** • The designed full supply level (FSL) is 4 m higher than current maximum operational levels so more storage might be available. • Historically, this scheme has been used informally for flood protection (e.g., in 2013). • Being located high in the Bow Basin means a rainfall event would need to occur in the upper Spray River watershed for the scheme to offer meaningful mitigation.
Flood mitigation potential
This scheme was considered to be one of the least promising schemes because there was no reduction in peak flow at Calgary for the four synthesized flood events. The scheme also may have limited mitigation because of its location high in the basin with a small catchment area. This scheme was not included in the 1,200 and 800 cms flood mitigation scenarios.

Scheme 2. Lake Minnewanka flood operations	
This scheme would involve a future agreement between GoA and TransAlta to operate the existing TransAlta facility at Lake Minnewanka to optimize flood mitigation. Operations would lower Lake Minnewanka (by ~5m) before the flood season (from May 15 to July 7) every year and release 35 cms when flood storage operations begin until the reservoir is full and spill operations begin. The existing Lake Minnewanka controls runoff from a drainage basin area equal to about 8% of the Bow River Basin above Calgary (based on the Cascade River near Banff Water Survey Canada gauge), not including the diversion from the Ghost River. Lake Minnewanka has about 221,900 dam^3 of live storage.	
Indicative time frame Implemented quickly	**Indicative cost** $5–50 million
Results	
The approximate reduction in peak flow in the Bow River at Calgary was approximately zero for each synthesized flood event (Figure 11) likely because inflows to the reservoir are easily captured with existing operations.	

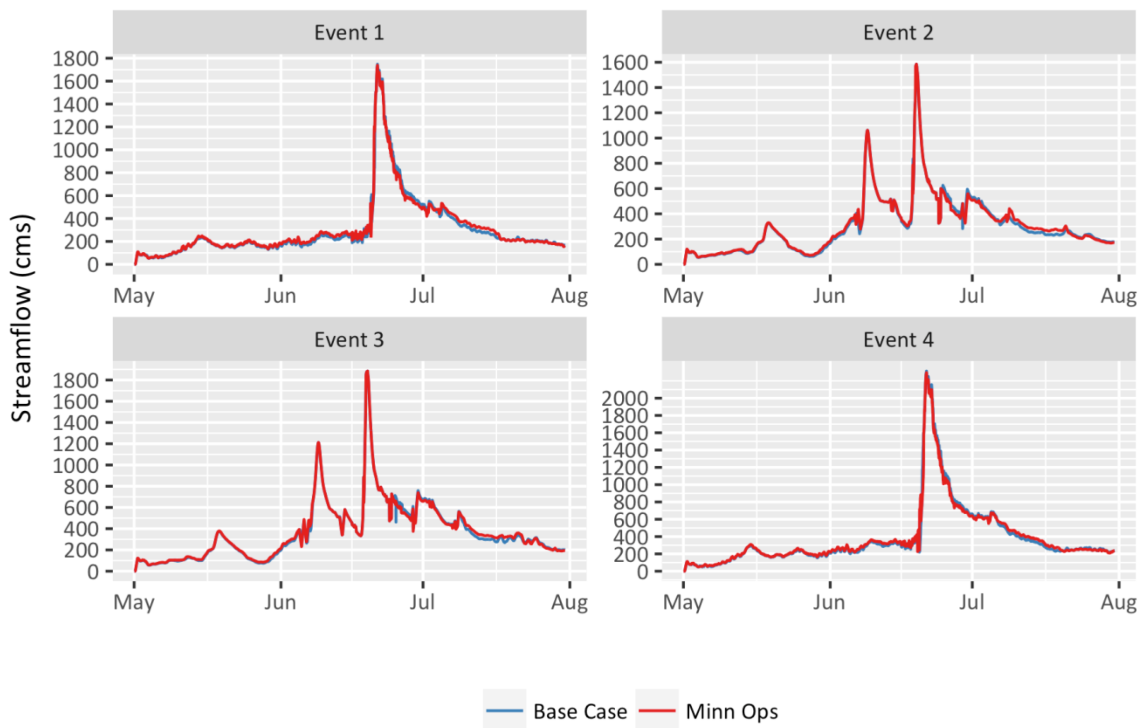


Figure 11: A comparison of synthesized Bow River streamflow at Calgary between base case and Lake Minnewanka operations for Events 1–4

Scheme 2. Lake Minnewanka flood operations
Upstream and downstream notes of interest (see full results in Appendices F, G and H): • Flows on the Bow River at Canmore were reduced by approximately 50 cms in Events 1 and 4 and by 75 cms in Events 2 and 3. Peak flows in the Bow River at Cochrane were reduced slightly. • Drawing down Lake Minnewanka to capture high flows results in higher streamflow downstream during the period of time when the Highwood River is at its peak. This results in higher flows downstream of the Bow-Highwood confluence.
Commentary
Socio-economic and community considerations • This scheme is located in Banff National Park; therefore, additional approvals and consultation would likely be required from the federal government. • This scheme could be a locally beneficial mitigation measure for Canmore, Exshaw, Morley and potentially the whole system in a bigger rainfall event centered on or upstream of this location. • Holding reservoir lower (by ~5m) during flood season could have negative impact on existing tour and outfitting industry. **Environmental and ecological considerations** • To be determined in discussion with Parks Canada e.g. discussion with Parks Canada aquatic ecologist should take place to determine potential effects. **Design and operational considerations** • The reservoir controls runoff from an area equal to about 8% of the Bow Basin above Calgary, not including the diversion from the Ghost River. • The potential storage capacity of the lake and therefore its flood attenuation capacity may be limited unless current operating rules are modified. • The location of the reservoir relatively high in the Bow Basin means a rainfall event would need to fall upstream in the Bow River Basin or on this location, as it did in 2013, for this scheme to offer meaningful mitigation.
Flood mitigation potential
This scheme was considered to be one of the least promising schemes because of its low flood mitigation potential in the events assessed. The large flood events typically do not result from water generation in the central range of the Rocky Mountains; therefore, the effectiveness of Lake Minnewanka operations would be limited in many large flood events. This scheme was not included in the 1,200 and 800 cms flood mitigation scenarios.

Scheme 3. Upgrade Ghost River diversion to Lake Minnewanka

The original diversion was heavily damaged in 2013, but a new, larger diversion of between 60–80 cms could be built. The trigger for diversion of water would be any flow >20 cms on the Ghost River at the diversion point.

Indicative time frame	**Indicative cost**
1–3 years	$5–50 million

Results

The approximate reduction in peak flow at Calgary was synthesized at zero for Events 1 and 3 (Figure 12). Peak flow at in the Bow River at Calgary increased by 30 cms for Event 2 and by 15 cms for Event 4 (Figure 12) relative to 2013 because a considerable amount from the North Ghost River diverted into Minnewanka when the old diversion was washed out. The new upgraded diversion would have less capacity than the flow which entered Lake Minnewanka in 2013.

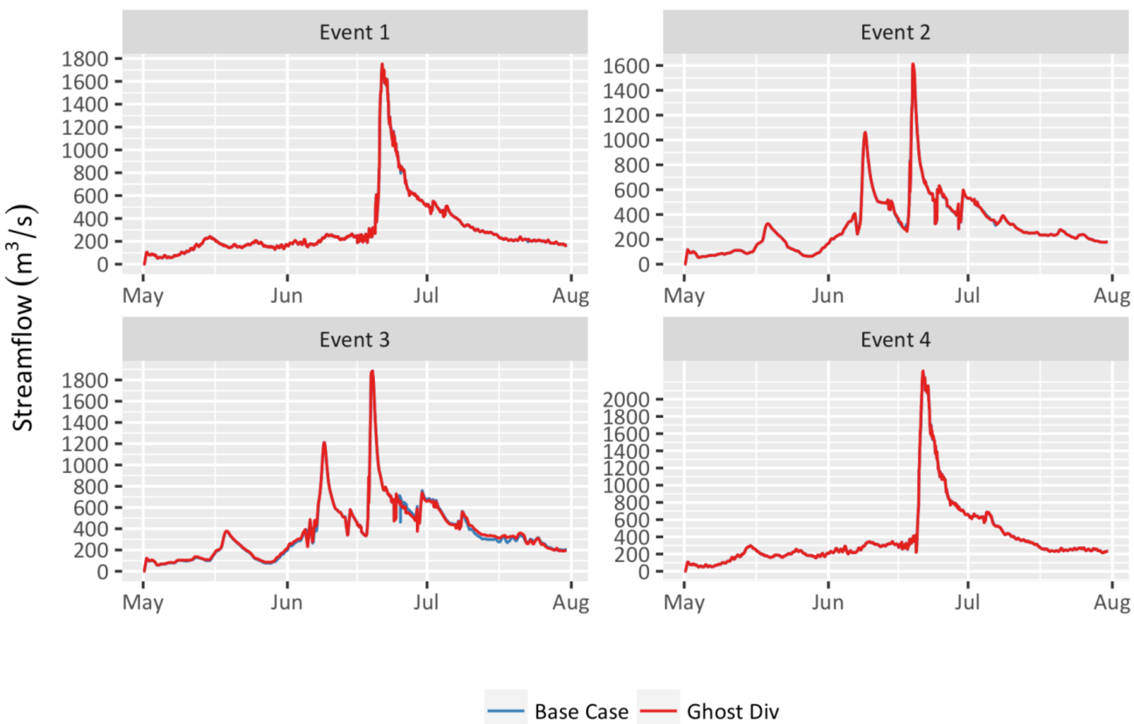


Figure 12: A comparison of synthesized Bow River streamflow at Calgary between base case and the Ghost diversion for Events 1–4

Upstream and downstream notes of interest (see full results in Appendices F, G and H):

- Flows on the Bow River were slightly reduced at Canmore for Event 1, given that less water is being diverted to Lake Minnewanka than occurred in 2013.

Scheme 3. Upgrade Ghost River diversion to Lake Minnewanka
Commentary
Socio-economic and community considerations • The limited spill capacity at Minnewanka and downstream diking (e.g., Canmore) could be of concern if more water is diverted into Lake Minnewanka instead of flowing down the Ghost River and into the Bow River downstream of Canmore. • Raising and extending dikes in Canmore may need to be considered if any upstream changes could result in higher flows through Canmore. • The project would impact Banff National Park, so additional federal government approvals and consultation may be required. • This scheme may impact recreational use of Lake Minnewanka. **Environmental and ecological considerations** • This scheme's success could depend on whether flow from Lake Minnewanka can be pre-released in advance of a flood event. This would require full assessment. • Rebuilding of Ghost River diversion is not yet approved, and is awaiting further information on impacts to bull trout and westslope cutthroat trout populations in the upper and lower Ghost Rivers and in the Cascade River system. **Design and operational considerations** • This scheme would provide additional water to the Lake Minnewanka and Cascade hydroelectric plant. Permitting work is currently underway to rebuild the diversion to the original capacity (8–10 cms), and up to 60–80 cms could be a new option. During the 2013 flood, 90 cms was conveyed to Lake Minnewanka. • The economic feasibility of this scheme would need to be considered, given costly enhancements required to meet dam safety requirements. • The diversion controls runoff from an area equal to about 3% of the Bow Basin above Calgary. • This scheme would require lowering Lake Minnewanka slightly before a flood. • The existing dam spillway would likely need to be upgraded to accommodate increased water from a new Ghost diversion. • Being located high in the Bow Basin means a rainfall event would need to occur in the upper watershed for the scheme to offer meaningful mitigation.
Flood mitigation potential
This scheme was considered to be one of the least promising schemes because it is difficult to divert a large proportion of the Ghost River's streamflow due to the unique characteristics of the location, the need to modify Lake Minnewanka infrastructure and operations, and its location high in the watershed. This scheme was not included in the 1,200 and 800 cms flood mitigation scenarios.

Scheme 4. New reservoir on Ghost River upstream of Waiparous confluence	
This scheme would involve a new dam and reservoir on the Ghost River, equivalent to BG1 (see Alberta WaterSMART and AI-EES 2014). Multiple flood operation triggers were used in this analysis to obtain the best possible flood mitigation. Three triggers were used, where streamflow > 200 cms in the Ghost River was used, where the reservoir would fill with all flows in excess of this trigger. Further flood mitigation could be obtained with streamflow triggers of 100 and 125 cms. The various triggers highlight the importance of forecasting and demonstrate that variable triggers must be used depending on the flood event. Stored flood flows would be released at a constant rate to attempt to empty excess storage over a 3-week period post-flood, without exceeding the flood operation trigger. The reservoir would control runoff from a drainage basin area equal to about 6% of the Bow River Basin above Calgary (based on the Ghost River above Waiparous Creek Water Survey Canada gauge). A new reservoir on the Ghost River upstream of Waiparous confluence would have 60,000 dam^3 of live storage.	
Indicative time frame 10–15 years	**Indicative cost** $100–300 million
Results	
Two triggers were synthesized (Figure 13). Using a trigger of >200 cms flows on the Ghost River, the approximate reduction in peak flow at Calgary was: Event 1: 300 cms Event 2: 200 cms Event 3: 400 cms Event 4: 300 cms Using a trigger of >100–125 cms flows on the Ghost River, the approximate reduction in peak flow in the Bow River at Calgary was: Event 1: 400 cms Event 2: 300 cms Event 3: 300 cms Event 4: 200 cms	

Scheme 4. New reservoir on Ghost River upstream of Waiparous confluence

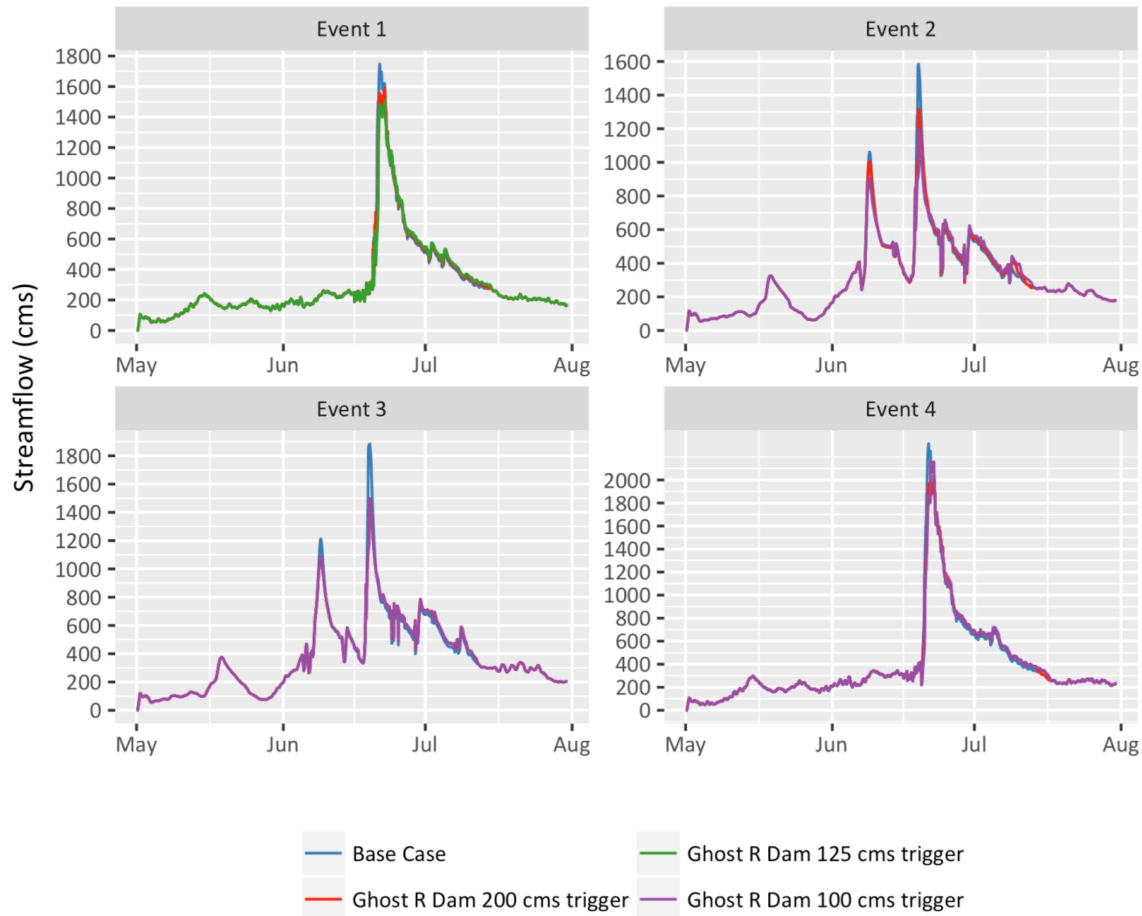


Figure 13: A comparison of synthesized Bow River streamflow at Calgary between base case and Ghost River dam for Events 1–4

Upstream and downstream notes of interest (see full results in Appendices F, G and H):

- The Bow River at Cochrane had similar reductions in peak flow as Calgary; these reductions were translated downstream to Carseland, with small reductions in peak flow at Medicine Hat.

Commentary

Socio-economic and community considerations

- If this scheme is located on private land, there could be ownership/tenure concerns.
- May require upgrading of Highway 40, as it is currently unsuitable for heavy truck traffic required for construction purposes.

Environmental and ecological considerations

- This scheme would have high potential risk to protected fisheries (bull trout and westslope

Scheme 4. New reservoir on Ghost River upstream of Waiparous confluence
cutthroat trout), as there is a potential for extirpation and permanent loss of critical fish habitat for all life stages for these species. • This scheme would have high potential for detrimental effects on wildlife, such as impacts to migratory pathways, riparian areas, terrestrial habitat, and aquatic habitat when a new area is flooded. The project area is already considered sensitive. • Project is within the Grizzly Bear Zone and the Key Wildlife and Biodiversity Zone and could affect these habitats. Grizzly bear (threatened species) are known to occur in the project area. Trumpeter swans (species of special concern) are known to breed in the area. **Design and operational considerations** • It is likely there would be more than typical geotechnical concerns specific to this site. • There would be engineering concerns with the structure's ability to pass water, specifically, channel migration and debris blockage, due to the steep reach of the Ghost River where the structure is proposed. • The engineering feasibility of a large gate size would need to be considered. There was discussion of the engineering feasibility of an extremely large low-level outlet. • The location of the reservoir on a tributary in the Bow Basin means that this scheme might have relatively little impact depending on where the rain event occurred.
Flood mitigation potential
This scheme was considered to be a somewhat promising scheme as historically the Ghost River at this location has contributed a substantial amount of flow during flood events originating within the Ghost watershed upstream of this point. This scheme was considered to have moderate flood mitigation potential, despite other locational issues, and was included in the 1,200 and 800 cms flood mitigation scenarios.

Scheme 5. New reservoir on Waiparous Creek upstream of confluence with Ghost River	
This scheme would involve a new dam and reservoir on Waiparous Creek, equivalent to BW1 (see Alberta WaterSMART and AI-EES 2014). Multiple streamflow triggers were used for this scheme in order to obtain the greatest possible flood mitigation. The flood operation triggers modelled were at flows >40 cms and >20 cms on Waiparous Creek, and the reservoir would fill with all flows in excess of the flood operation trigger. Stored flood flows would be released at a constant rate to attempt to empty excess storage over a 3-week period post-flood, without exceeding the flood operation trigger. The reservoir would control runoff from a drainage basin area equal to about 4% of the Bow River Basin above Calgary (based on the Waiparous Creek near the Mouth Water Survey Canada gauge). A new reservoir on Waiparous Creek upstream of the confluence with the Ghost River would have 35,000 dam^3 of live storage.	
Indicative time frame 10–15 years	**Indicative cost** $100–300 million
Results	
Two triggers were synthesized (Figure 14). Using a trigger of >40 cms flows on Waiparous Creek, the approximate reduction in peak flow at Calgary was: Event 1: 250 cms Event 2: 200 cms Event 3: 300 cms Event 4: 220 cms Using a trigger of >20 cms flows on Waiparous Creek, the approximate reduction in peak flow in the Bow River at Calgary was: Event 1: 250 cms Event 2: 150 cms Event 3: 0 cms Event 4: 100 cms	

Scheme 5. New reservoir on Waiparous Creek upstream of confluence with Ghost River

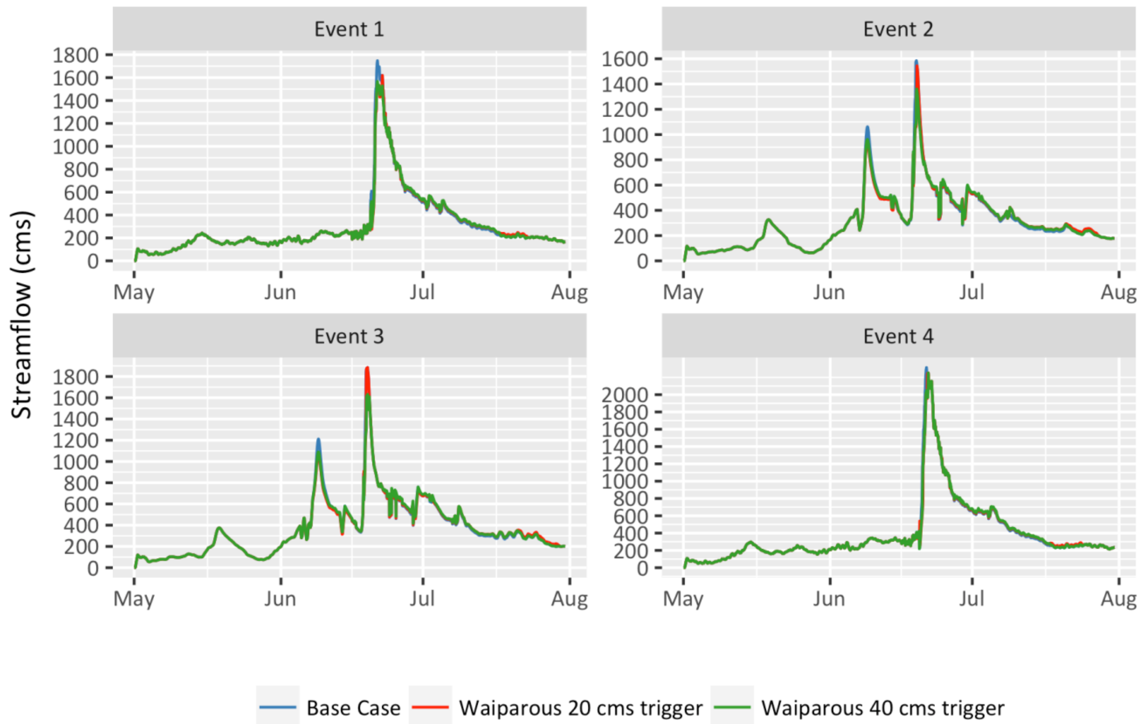


Figure 14: A comparison of synthesized Bow River streamflow at Calgary between base case and Waiparous Creek dam for Events 1–4

Upstream and downstream notes of interest (see full results in Appendices F, G and H):

- This scheme reduced Bow River flows at Cochrane and all the way downstream to Medicine Hat, but the reductions in peak flow at Medicine Hat were lower as flow attenuates progressively downstream.

Commentary

Socio-economic and community considerations

- If this scheme is located partly on private land, there could be ownership/tenure concerns.
- The proposed location is popular for recreation on public lands.
- May require upgrading of Highway 40, as it is currently unsuitable for heavy truck traffic required for construction purposes.

Environmental and ecological considerations

- The risks to fish habitat would be high. There are already completed management plans for Waiparous, which would need to be considered.
- In the Waiparous area, westslope cutthroat trout is a species at risk that could be affected by this dam. Compensation could add costs, permitting delays, and operational challenges to

Scheme 5. New reservoir on Waiparous Creek upstream of confluence with Ghost River
any dam. • This scheme would have high potential for detrimental effects on wildlife, such as impacts to migratory pathways, riparian areas, terrestrial habitat, and aquatic habitat when a new area is flooded; the project area is already considered sensitive. Project is within the Grizzly Bear Zone and the Key Wildlife and Biodiversity Zone and could affect habitats. **Design and operational considerations** • It is likely that there would be more than typical geotechnical concerns specific to this site and engineering concerns with the structure's ability to pass water until a flood event. • There is concern with the engineering feasibility of an extremely large low-level outlet. • The reservoir would control runoff from an area equal to about only 4% of the Bow Basin above Calgary. • Low flows on Waiparous Creek means this scheme would provide little capacity to store water for drought protection and other water supply needs. • This is not a very flashy system, and substantial watershed storage is provided by wetlands. • There is concern with the amount of material (gravel, logs) that would need to be passed through an empty structure each spring, and possible plugging of the passage. • This scheme would provide protection only against rainfall events falling on the Waiparous Basin.
Flood mitigation potential
This scheme was considered to be one of the least promising schemes because of the relatively small catchment area, substantial environmental consequences of flooding this area, and only moderate peak flow reductions. This scheme was not included in the 1,200 and 800 cms flood mitigation scenarios.

Scheme 6. Kananaskis Lakes flood operations	
This scheme would involve an agreement between GoA and TransAlta to operate existing facilities to optimize flood mitigation. If forecasts suggest high inflows (snowpack, rainfall, soil moisture), this scheme would lower both Upper and Lower Kananaskis Lakes before the flood season (from May 15 to July 15) every year and release 0 cms when flood storage operations begin until the reservoirs are full and spill operations begin. Upper and Lower Kananaskis Lakes are situated within Peter Lougheed Provincial Park. The reservoirs control runoff from a drainage basin area equal to about 5% of the Bow River Basin above Calgary (based on the Kananaskis River above Pocaterra Creek WSC gauge). The existing Kananaskis Lakes have about 187,600 dam^3 combined of live storage.	
Indicative time frame 1–3 years	**Indicative cost** $5–50 million
Results	
A trigger of >50 cms flows in the Kananaskis River was simulated after which 0 cms would be released. The approximate reduction in peak flow at Calgary was zero for each synthesized flood event (Figure 15), likely because inflows to the reservoirs are \ captured with existing operations.	

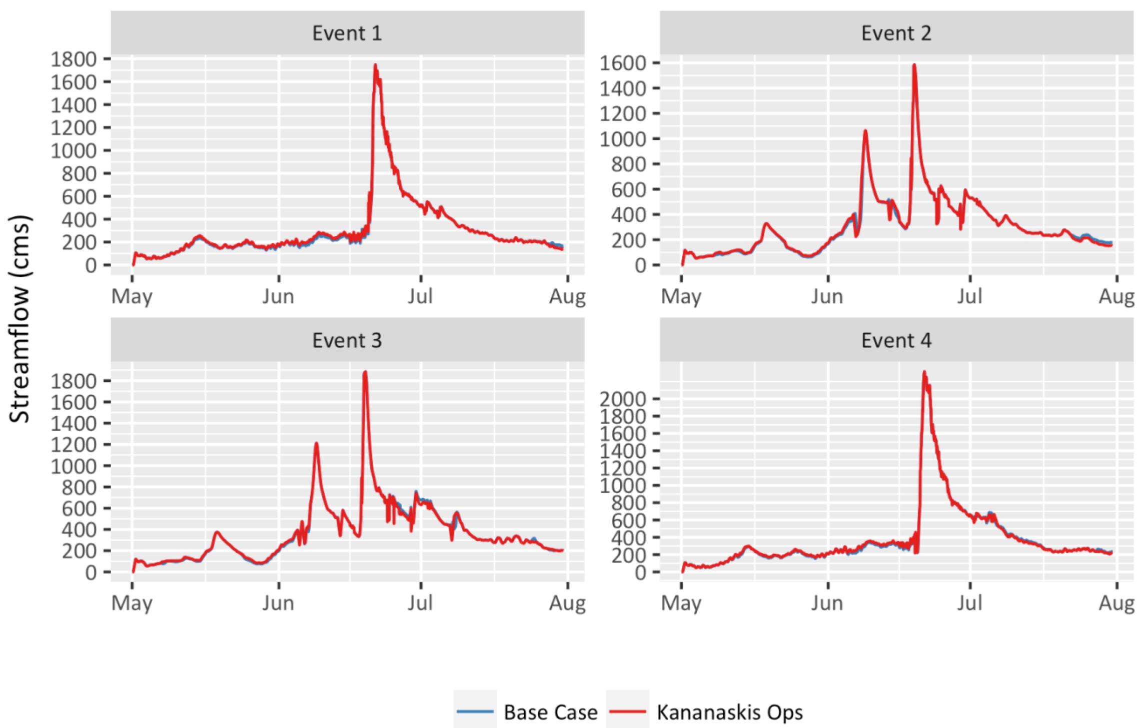


Figure 15: A comparison of synthesized Bow River streamflow at Calgary between base case and Kananaskis operations for Events 1–4

Scheme 6. Kananaskis Lakes flood operations
Upstream and downstream notes of interest (see full results in Appendices F, G and H): • Similar to results for Calgary, no noticeable effect on flows in the Bow Basin was observed.
Commentary
Socio-economic and community considerations • Proposed location is within Peter Lougheed Provincial Park and is a significant recreational asset to the Province. Flood mitigation operations could have negative impacts on visitor experience, recreation, and commercial tourism. **Environmental and ecological considerations** • This scheme would have potential for detrimental effects on wildlife, such as impacts to riparian areas, terrestrial habitat, and aquatic habitat; the project area is already considered sensitive. However, given existing infrastructure and recreational activity, incremental impacts would be limited. • This scheme has the potential to impact Mountain Goat and Sheep Zone. In addition, harlequin duck (species of special concern), and long-toed salamander (species of special concern), are known to occur in the project area. Grizzly bears (threatened species) use the landscape surrounding Upper and Lower Kananaskis Lakes extensively in spring, summer and fall. It is a known hotspot for breeding, cub rearing, and foraging. • The current fish management priority is to stabilize water levels on Lower Kananaskis Lakes (or at least not worsen current operations by increasing the amplitude of fluctuations) to ensure ongoing productivity is maintained or enhanced for native bull trout populations. • Decreasing productivity in Upper Kananaskis Lake by exercising lake levels may be an acceptable management approach, as the fishery is stocked (as discussed with AEP Operations and Policy staff, 2016). **Design and operational considerations** • There would be no geotechnical concerns specific to this site, as no new infrastructure will be built. • The reservoir controls runoff from an area equal to about 5% of the Bow Basin above Calgary. • Reservoir location in the Bow River Basin means it could have relatively little impact in some situations, depending on location of the rainfall generating the flood. • Key elements of this scheme would be the details of compensation to TransAlta for flood operations and the details of rule curves.
Flood mitigation potential
This scheme was considered to be one of the least promising schemes because it did not result in reductions in peak streamflow at Calgary. This scheme was not considered for inclusion in the 1,200 and 800 cms flood mitigation scenarios.

Scheme 7. New reservoir on Kananaskis River	
This scheme would involve a new dam and reservoir along the Kananaskis River in Bow Valley Provincial Park and Bow Valley Wildland Provincial Park, either across a narrow point in the valley near the south end of Barrier Lake or upstream of Barrier Lake. The flood operation trigger would be flows >50 cms on Kananaskis River, and the reservoir would fill with all flows in excess of the flood operation trigger. Stored flood flows would be released at a constant rate to attempt to empty excess storage over a 3-week period post-flood, without exceeding the flood operation trigger. The reservoir would control runoff from a drainage basin area equal to about 11% of the Bow River Basin above Calgary (based on the Kananaskis River below Barrier dam Water Survey Canada gauge). A new reservoir on Kananaskis River would have 85,000 dam^3 of live storage.	
Indicative time frame 10–15 years	**Indicative cost** $300–500 million
Results	
Using a trigger of >50 cms flows in the Kananaskis River (Figure 16), the approximate reduction in peak flow in the Bow River at Calgary was: Event 1: 100 cms Event 2: 50 cms Event 3: 100 cms Event 4: 250 cms	

Scheme 6. Kananaskis Lakes flood operations

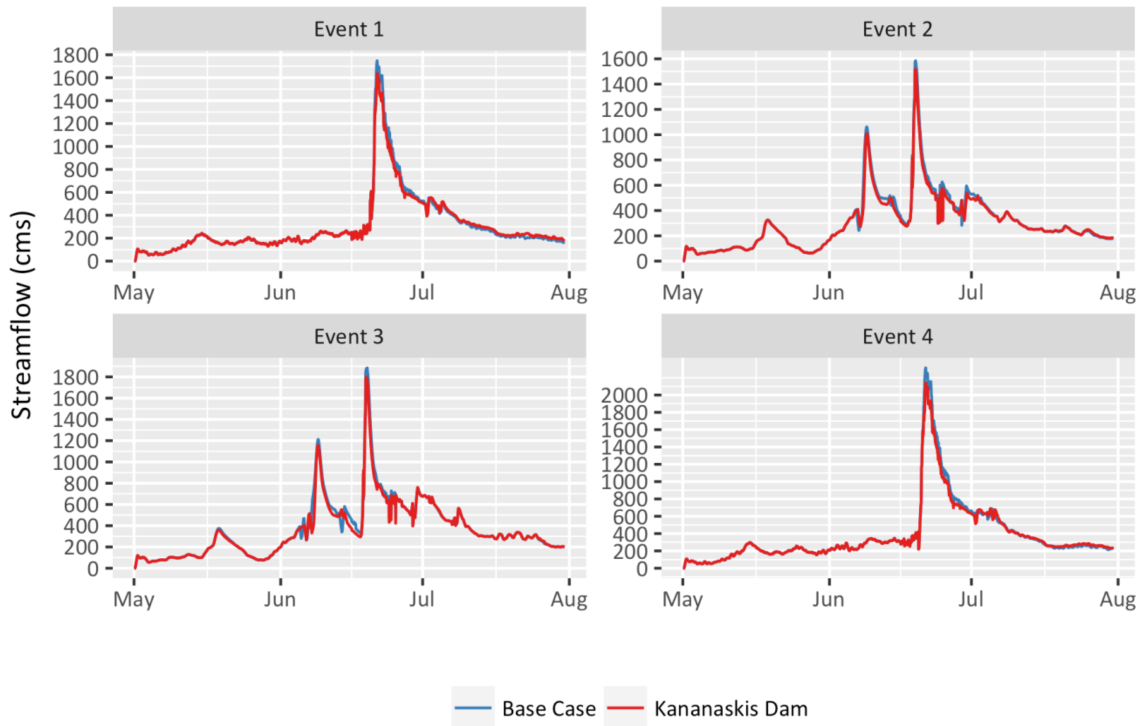


Figure 16: A comparison of synthesized Bow River streamflow at Calgary between base case and a new Kananaskis dam for Events 1–4

Upstream and downstream notes of interest (see full results in Appendices F, G and H):

- Similar reductions in peak flow to the above results were observed for the Bow River at Cochrane. Only slight flow reductions were observed in the Bow River at Carseland.

Commentary

Socio-economic and community considerations

- Being in provincial protected (park) lands, a new dam in this area could have significant environmental and social consequences, such as issues associated with public safety, recreational access, commercial tourism, and habitat availability and connectivity for wildlife.
- Gaining social acceptance for building another dam above Barrier may be challenging; there may be less reluctance with changes to operations or to raising the existing Barrier dam (Scheme 8).
- Regulatory land-use requirements exist because of provincial park regulations that may require reclassification of land use or rezoning of park lands.
- Highway 40 would likely be impacted.
- A new Kananaskis reservoir may offer some flood protection to Stoney Nakoda First Nations reserve land.

Scheme 6. Kananaskis Lakes flood operations

- Land required would be exclusively on provincial park lands.

Environmental and ecological considerations

- This project could impact Mountain Goat and Sheep Zone. In addition, harlequin duck (species of special concern), long-toed salamander (species of special concern), and grizzly bear (threatened species) are known to occur in the project area. The Kananaskis River upstream of Barrier Lake is a known Harlequin duck nesting and rearing habitat.
- A narrow, linear wildlife movement corridor exists on the west side of Barrier Lake and is zoned as Preservation, restricting development. This corridor, and hence, seasonal wildlife migrations, may be negatively impacted by this proposed scheme.
- The Kananaskis River is a heavily impacted system due to existing hydro operational requirements. Fisheries productivity in Barrier Lake is relatively low due to existing operations, and construction of a new dam would likely only affect marginally productive habitats.
- Fish populations within current Barrier Lake would likely be severely impacted due to isolation and reduce productivity from operation. However, the lost productivity in Barrier Lake would likely be shifted upstream to the new reservoir.
- An additional dam on the river could add cumulative stress to the ecosystem.

Design and operational considerations

- The reservoir would control runoff from an area equal to about 11% of the Bow Basin above Calgary.
- This scheme would have high potential for water storage for other uses, including drought and hydropower.
- The option to expand Barrier Lake over the current scheme to build a new dam may offer more hydro-generation potential because of potential for head increases.
- The location of the reservoir on a tributary in the Bow Basin means a rainfall event would need to fall over the Kananaskis Valley for this scheme to offer meaningful mitigation.
- If the project were planned as a dry dam, there would be engineering concerns with the structure's ability to pass water until a flood event, through an extremely large low-level outlet.

Flood mitigation potential

This scheme was considered to be a somewhat promising scheme because of its moderate flood mitigation potential. Its location may have less environmental consequences relative to tributaries where there are no reservoirs currently. This scheme was considered for inclusion in the 1,200 and 800 cms flood mitigation scenarios. It may also offer some drought mitigation opportunities.

Scheme 8. Barrier Lake flood operations	
This scheme would involve an agreement between GoA and TransAlta to operate existing facilities to optimize flood mitigation, including decreasing the upper rule by 3 m. It would be triggered by forecasts of an inflow to Barrier >100 cms. Barrier would be lowered before the flood season (from May 15 to July 15) every year. Barrier is too small to have a release target; it tries to release 100 cms less than inflow. The reservoir controls runoff from a drainage basin area equal to about 11% of the Bow River Basin above Calgary (based on the Kananaskis River below Barrier dam Water Survey Canada gauge). The existing Barrier Lake has about 24,800 dam^3 of live storage.	
Indicative time frame 1–3 years	**Indicative cost** $100–300 million, including capital cost of constructing new spillway
Results	

The approximate reduction in peak flow on the Bow River at Calgary (Figure 17) was:

Event 1: 75 cms
Event 2: 5 cms
Event 3: 50 cms
Event 4: 75 cms

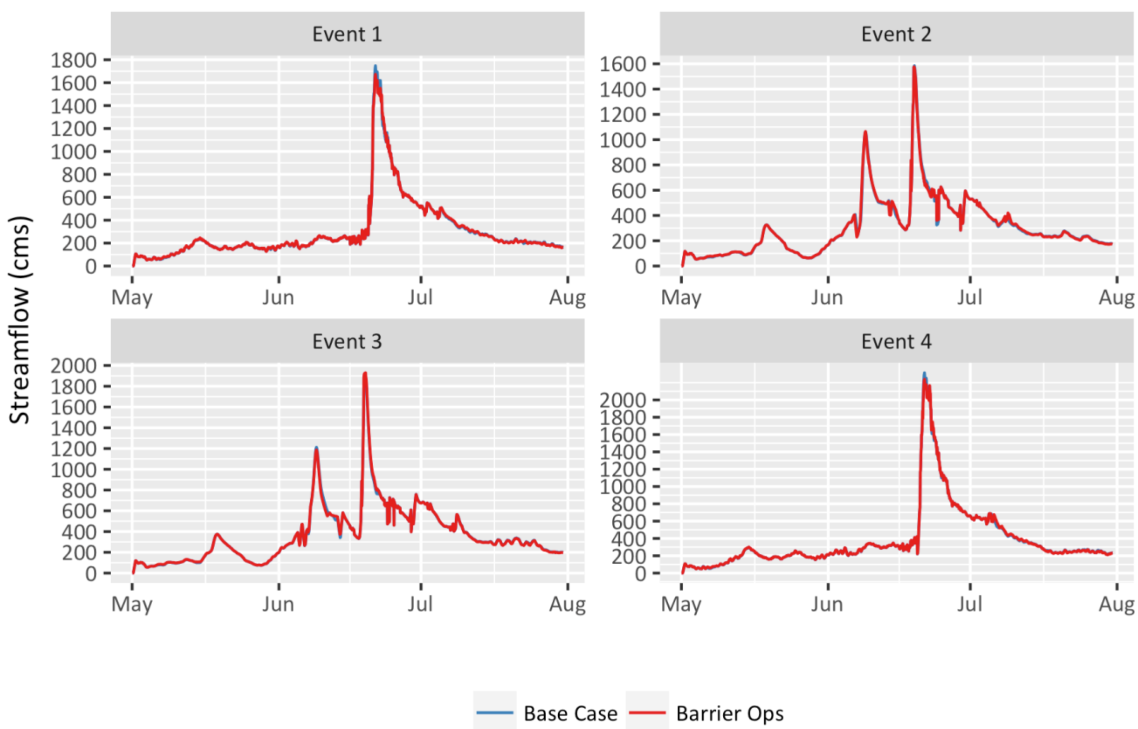


Figure 17: A comparison of synthesized streamflow at Calgary between base case and Barrier operations for Events 1–4

Scheme 8. Barrier Lake flood operations
Upstream and downstream notes of interest (see full results in Appendices F, G and H): • The Bow River at Cochrane had similar reductions in peak streamflow as Calgary, but reductions were not observed elsewhere in the system. This is due to peak reductions being muted as the Highwood River joins the Bow River.
Commentary
Socio-economic and community considerations • To implement this option, a new spillway would need to be constructed at an estimated cost <$100 million but construction of an upgraded spillway may already be required because of recent changes to the estimate of the new probable maximum flood (PMF). • Barrier Lake is a significant recreational destination for Albertans and this scheme would reduce tourism and visitor experiences at Barrier Lake when lake levels remain uncharacteristically low. • Substantial recreational use occurs downstream of Barrier Lake along the lower Kananaskis River including a world-class whitewater paddling industry. The proposed scheme may have negative impacts to the commercial paddling industry and the national and international paddling events held at this site. • When held low, the reservoir would offer less drought mitigation potential and be less attractive for recreation. • Provides a direct benefit to Morley. • Barrier Lake is entirely within provincial protected (park) lands. **Environmental and ecological considerations** • Barrier Lake is currently functioning as an overwintering habitat for mountain whitefish due to existing operations that create less favourable conditions in the upstream river (i.e. frazil and anchor ice). • Any new operations should maintain overwintering habitat at existing levels in Barrier Lake. • Changes to operations during spring and early summer are likely of less concern to the fishery. **Design and operational considerations** • Pre-releasing water in advance of flood season would impact storage available for drought mitigation and water supply protection. • The Kananaskis River below Barrier Dam controls runoff from an area that is about 11% of the contribution to the Bow River at Calgary. • Flood operations should consider antecedent conditions on an annual basis. • Barrier Lake would need to continue to be operated in conjunction with Ghost Reservoir. • Barrier Lake would need a new spillway, the size of which would be determined by the PMF. • This structure would not be able to recover, i.e., drain quickly, from a multiple-peak event.

Scheme 8. Barrier Lake flood operations
• This scheme could be incorporated into every scenario.
Flood mitigation potential
This scheme was considered to be one of the most promising schemes because it is an operational change of existing infrastructure with moderate flood mitigation potential and uses existing rather than new infrastructure. Even with the potential cost of a new spillway it was considered for inclusion in the 1,200 and 800 cms flood mitigation scenarios.

Scheme 9. New reservoir on Jumpingpound Creek	
This scheme would involve a new dam and reservoir on Jumpingpound Creek. The flood operation trigger would be flows 10 to 50 cms on Jumpingpound Creek, and the reservoir would fill with all flows in excess of the flood operation trigger. Stored flood flows would be released at a constant rate to attempt to draw down to pre-flood operating level over a 3-week period post-flood, without exceeding the flood operation trigger. The reservoir would control runoff from a drainage basin area equal to about 7% of the Bow River Basin above Calgary (based on the Jumpingpound Creek near the Mouth and Jumpingpound Creek at Township Road 252 Water Survey Canada gauges). A new reservoir on Jumpingpound Creek would have 60,000 dam^3 of live storage.	
Indicative time frame 10–15 years	**Indicative cost** $100–300 million
Results	
Using a trigger of >10–50 cms flows on Jumpingpound Creek (Figure 18), the approximate reduction in peak flow on the Bow River at Calgary was: Event 1: 150 cms Event 2: 325 cms Event 3: 0 cms Event 4: 145 cms	

Scheme 9. New reservoir on Jumpingpound Creek

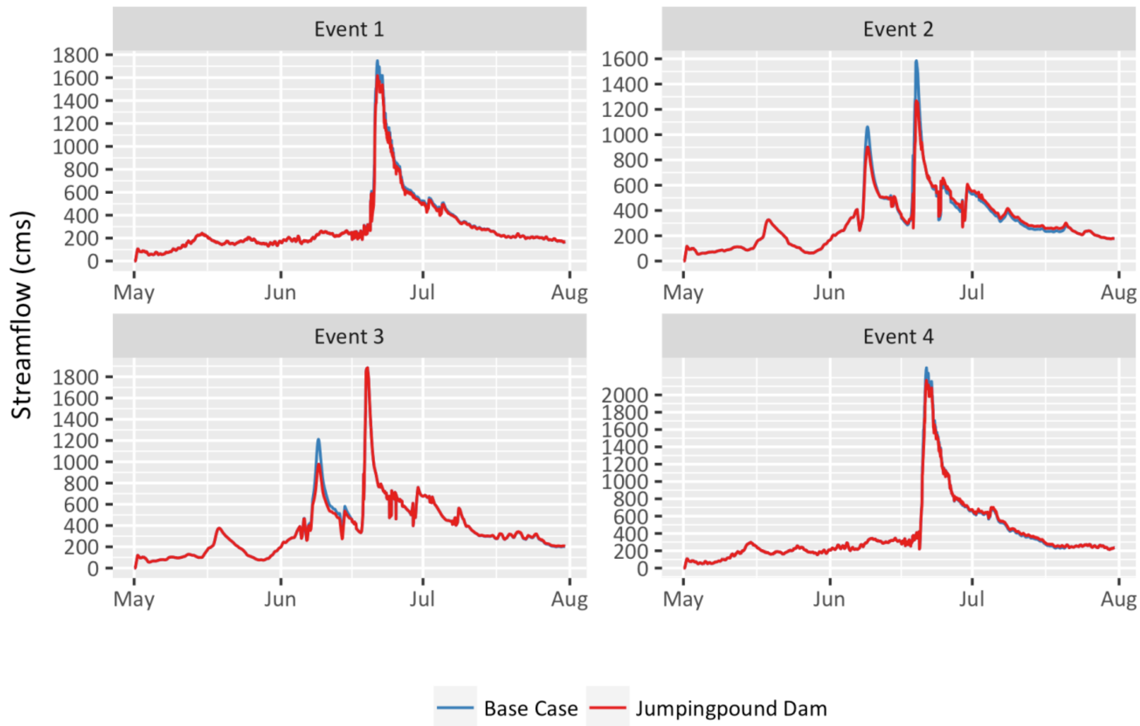


Figure 18: A comparison of synthesized Bow River streamflow at Calgary between base case and Jumpingpound Creek dam for Events 1-4

Upstream and downstream notes of interest (see full results in Appendices F, G and H):

- Flows were reduced on the Bow River downstream of Calgary through to the South Saskatchewan River at Medicine Hat.

Commentary

Socio-economic and community considerations

- Livestock grazing is an important land use in this area. The potential for this scheme to support this land use in most years should be considered.
- This scheme would have no benefits upstream of where Jumpingpound Creek joins the Bow River (in Cochrane), unless Ghost Reservoir operations could be adjusted knowing that the new reservoir would be controlling high flows from the Creek. This could benefit communities below but not above Ghost Reservoir.
- The dam site would be located on private land, so land-tenure issues may arise.

Environmental and ecological considerations

- Jumpingpound Creek is an important spawning stream for Bow River fish species between Ghost Dam and Bearspaw Dam. High concern for further fragmentation of fish populations,

Scheme 9. New reservoir on Jumpingpound Creek
and permanent loss of fish habitat in reservoir portion of Jumpingpound Creek. • This scheme would have high potential for detrimental effects on wildlife, such as impacts to migratory pathways, riparian areas, terrestrial habitat, and aquatic habitat when a new area is flooded; the project area is already considered sensitive. • This project could impact the Key Wildlife and Biodiversity Zone as well as several species within the Sensitive Raptor Range, including Bald Eagle, Golden Eagle, and Prairie Falcon. In addition, there is the potential for impact to a Prairie Falcon nesting site (species of special concern). **Design and operational considerations** • The reservoir would control runoff from an area equal to about 7% of the Bow Basin above Calgary. • Jumpingpound is the only significant tributary inflow between Ghost Reservoir and Calgary. Jumpingpound headwaters do not extend beyond the foothills; thus, snowpack and meltwater effects are minimal compared with other tributary watersheds. Jumpingpound Creek flows are very low compared to flood flows (i.e. flows can increase by 10 to 20 times the normal spring runoff level during a flood event). This watershed would need to receive rainfall similar to 2005 and 2013 for this scheme to be valuable. • The BRWG deemed this scheme as more attractive than Scheme 4 (new reservoir on Ghost River upstream of Waiparous confluence). • The flatter terrain means that this scheme could consist of a series of smaller structures rather than one large reservoir; however, this could add operational complexity. • The location is lower in the watershed, so it would be more likely to catch rain that falls in the foothills. • Jumpingpound is a flashy river and runs nearly dry once snowmelt is gone; therefore, annual flows volumes are typically insufficient to provide any capacity for drought mitigation and/or hydropower generation. • Bank stabilization and riparian restoration in ranching areas is ongoing, and there is a lot of momentum to implement these strategies.
Flood mitigation potential
This scheme was considered as a somewhat promising scheme because of its moderate flood mitigation potential and was included in the 1,200 and 800 cms flood mitigation scenarios.

Scheme 10. New Glenbow reservoir on Bow River upstream of Bearspaw	
This scheme would involve a new dam and reservoir on the Bow River equivalent to Flood Advisory Panel option BR1 (see Alberta WaterSMART and AI-EES 2014). This scheme used multiple streamflow triggers for operations in order to obtain the greatest flood mitigation. A first pass applied a 1,200 cms on the Bow River trigger, which was sufficient to meet the 1,200 cms target. However, it was determined that the 1,200 cms could not be obtained for large flood events. Therefore, 1,700 cms and 1,800 cms triggers were applied. Additionally, an 800 cms trigger was applied to maximize the flood mitigation potential. Under Event 1, the maximum potential was 1,200 cms, under Event 2 it was possible to reach 800 cms, under Event 3 1100 cms was reached, and 1700 cms was reached under Event 4. Under all operations, the reservoir would fill with all flows in excess of the flood operation trigger. Stored flood flows would be released at a constant rate to attempt to return to flood season operational levels over a three-week period post-flood without exceeding the flood operation trigger. The reservoir would control runoff from a drainage basin area equal to about 96% of the Bow River Basin above Calgary (part way between Bow River below Bearspaw Dam and Bow River near Cochrane Water Survey Canada gauges). A new Glenbow reservoir on the Bow River upstream of Bearspaw would have 70,000 dam^3 of live storage.	
Indicative time frame 15–20 years	**Indicative cost** >$500 million
Results	
Two triggers were synthesized (Figure 19). Using a trigger of >1,200 cms flows on the Bow River, the approximate reduction in peak flow at Calgary was: Event 1: 550 cms Event 2: 350 cms Event 3: 700 cms Event 4: 600 cms However, the >1,200 cms trigger was unable to obtain maximum flood peak reduction on the Bow River under all events because the reservoir filled too quickly under large events. Therefore, multiple triggers were evaluated (Figure 19) to obtain the most benefit. The approximate reduction in peak flow at Calgary was: Event 1: 550 cms Event 2: 650 cms Event 3: 800 cms Event 4: 500 cms	

Scheme 10. New Glenbow reservoir on Bow River upstream of Bearspaw

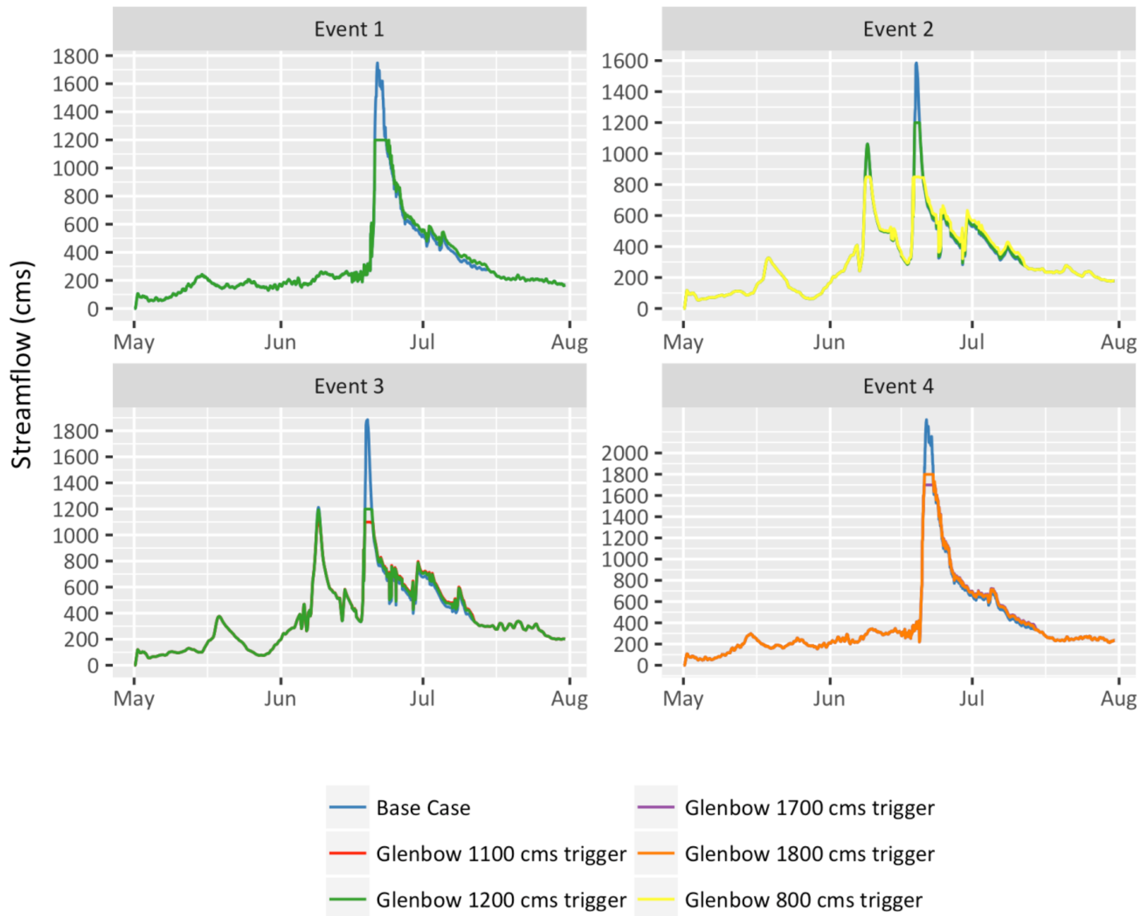


Figure 19: A comparison of synthesized Bow River streamflow at Calgary between base case and Glenbow dam for Events 1–4

Upstream and downstream notes of interest (see full results in Appendices F, G and H):

- Peak flow was reduced substantially through Calgary but was not reduced downstream at Carseland in Events 1 and 4; however, the sustained high flows post-peak are reduced, and lower flows were reached more quickly. This is due to the fact peak flows from the Highwood River occur earlier than peak flows from the Bow River at the confluence and the peak at Carseland occurred during the period where Highwood River flows were highest. Under different flood conditions, there could be substantial flow reductions at Carseland if flows do not line up in the same manner. For example, peak flow was reduced substantially in Events 2 and 3.

Scheme 10. New Glenbow reservoir on Bow River upstream of Bearspaw
Commentary
Socio-economic and community considerations • This scheme would be located near the Canadian Pacific Railway (CPR) line. • This scheme, as modelled, would not mitigate Bow River flows at Cochrane and could negatively affect current recreation in the area and significantly impact Provincial Park infrastructure at the recently donated Glenbow Ranch Provincial Park. • This scheme would offer no upstream flood mitigation (unless coordinated with Ghost Reservoir), and could conflict with development pressures west of Calgary. • This scheme may have fewer land ownership/tenure issues than the Morley dam site (Scheme 11) given that part of this project may be on Crown land, but land tenure issues would still be challenging. • An area structure plan is currently in process by Rocky View County and would need to be considered. • The Glenbow reservoir may be less politically sensitive than the Morley reservoir (Scheme 11). • Increasing the size of this reservoir, should that be needed for additional flood mitigation or other objectives, may be limited by developments in Cochrane and the railway. • This scheme would be located partially on a traditional area for First Nations but not directly on reserve land (Stoney First Nations). • Glenbow Ranch is a historical site donated to the Government of Alberta for long term protection as a provincial park; it may be challenging to repurpose this location for continuous flood mitigation with periodic inundation. **Environmental and ecological considerations** • Native grasslands are Alberta's most threatened Natural Region and very little remaining native grassland is protected for long-term conservation within parks. Glenbow Ranch Provincial Park was protected to conserve native fescue grassland and the wealth of species this grassland ecosystem supports. A new reservoir would have permanent detrimental impacts to the park. • Native grassland/prairie provides ground nesting habitat to a diversity of migratory songbirds; habitat would be heavily impacted within the inundation zone. • Significant archaeological, historical, and paleontological sites are found within Glenbow Ranch Provincial Park, and if within the inundation zone, would be permanently impacted. • Although there will be permanent loss of lotic habitat in the new reservoir portion above the dam, impacts will be on non-native rainbow trout and native mountain whitefish. Rainbow trout would still be able to access their major spawning tributary (Jumpingpound Creek). • Impact of habitat loss to Mountain Whitefish is unknown, but presumably negative. • Fish population within current Bearspaw Reservoir may be impacted due to isolation and reduce productivity depending on operation. However, the lost productivity in Bearspaw

Scheme 10. New Glenbow reservoir on Bow River upstream of Bearspaw
Reservoir would like be shifted upstream to the new reservoir. • The area is deemed overall ecologically sensitive. This project would impact the Key Wildlife and Biodiversity Zone and may affect several species within the Sensitive Raptor Range, including bald eagle, golden eagle, and prairie falcon. Due to the historic anthropogenic use of the site, however, the quality of wildlife habitat is lower in this location. **Design and operational considerations** • The modelling exercise demonstrated that simple operating rules for Glenbow dam could result in more flood mitigation for the Bow River at Calgary compared with Morley (Scheme 11) as it is located downstream of all the major tributaries. It is possible that Morley could provide additional mitigation, if more sophisticated operating rules were developed. However, this would require close operational coordination with the other control structures, particularly Ghost Reservoir. This would be particularly valuable in emergency situations when operators are making real-time decisions in response to streamflow conditions. The mitigation offered by each scheme would also be driven heavily by the nature of the flood event, in particular in which part of the catchment the event is generated. • It was suggested that it would be better to build Glenbow instead of multiple projects: one big dam in an excellent location (i.e., closer to Calgary) is better than two dams in upstream or tributary locations. • This scheme would not be adequate as a stand-alone measure to reach the 800 cms flow target for the Bow River at Calgary but does come close for Event 2. • This site would control runoff from about 96% of the Bow Basin above Calgary. • Because Glenbow dam is physically located lowest on the main stem while still being upstream of Calgary, it would have the highest catchment area of any scheme. • This scheme is downstream of Jumpingpound, so it would have greater benefits to Calgary in terms of flood mitigation than sites higher up in the basin. • It would be an on-stream facility with storage and may have recreational and drought mitigation potential. However, using capacity for drought mitigation will result in less flood mitigation potential. • It might be possible to raise the dam height more than 30 m if there was a willingness to build dikes in Cochrane and flood the railway periodically. • Glenbow could be built up to 70,000 dam^3, providing potential for water storage. • This scheme could be optimized even more through operations and refined triggers. • The spillway would need to be very large to meet the PMF requirements, as would be the case for any new dam under consideration. • Since Glenbow reservoir would be downstream of Ghost Reservoir, the outflows from the Ghost reservoir would provide a better idea of the inflows to Glenbow under extreme

Scheme 10. New Glenbow reservoir on Bow River upstream of Bearspaw
conditions even if stream gauges are inoperable. • A feasibility study should investigate the maximum feasible size of the structure, factoring a thorough analysis of backwater profile and its effect on Cochrane. • The site would be located between two TransAlta facilities and would require coordinated operations and an operating agreement between GoA and TransAlta.
Flood mitigation potential
This scheme was considered to be one of the most promising schemes because of its flood mitigation potential and was considered for inclusion in the 1,200 and 800 cms flood mitigation scenarios.

Scheme 11. New Morley reservoir on Bow River upstream of Ghost Reservoir	
This scheme would involve a new dam and reservoir in a wide floodplain area upstream of Ghost Reservoir. The new Morley reservoir was evaluated under a range of streamflow triggers. The triggers ranged between 250 cms and 800 cms. The lower the streamflow trigger, the earlier the reservoir would start to fill, and these triggers were used in an attempt to maximize the flood mitigation potential of the scheme. Under all cases, the reservoir would fill with all flows in excess of this trigger. Stored flood flows would be released at a constant rate to attempt to empty excess storage over a 3-week period post-flood, without exceeding the flood operation trigger. The reservoir would control runoff from a drainage basin area equal to about 68% of the Bow River Basin above Calgary (based on the Bow River near Morley Water Survey Canada gauges). A new Morley reservoir on the Bow River upstream of the Ghost Reservoir would have 150,000 dam^3 of live storage.	
Indicative time frame 15–20 years	**Indicative cost** >$500 million
Results	
Two triggers were synthesized (Figure 20). Using a trigger of >350–800 cms flows on the Bow River, the approximate reduction in peak flow at Calgary was: Event 1: 300 cms Event 2: 50 cms Event 3: 100 cms Event 4: 400 cms Using a trigger of >250–400 cms flows on the Bow River, the approximate reduction in peak flow at Calgary was: Event 1: 500 cms Event 2: 150 cms Event 3: 200 cms Event 4: 600 cms	

Scheme 11. New Morley reservoir on Bow River upstream of Ghost Reservoir

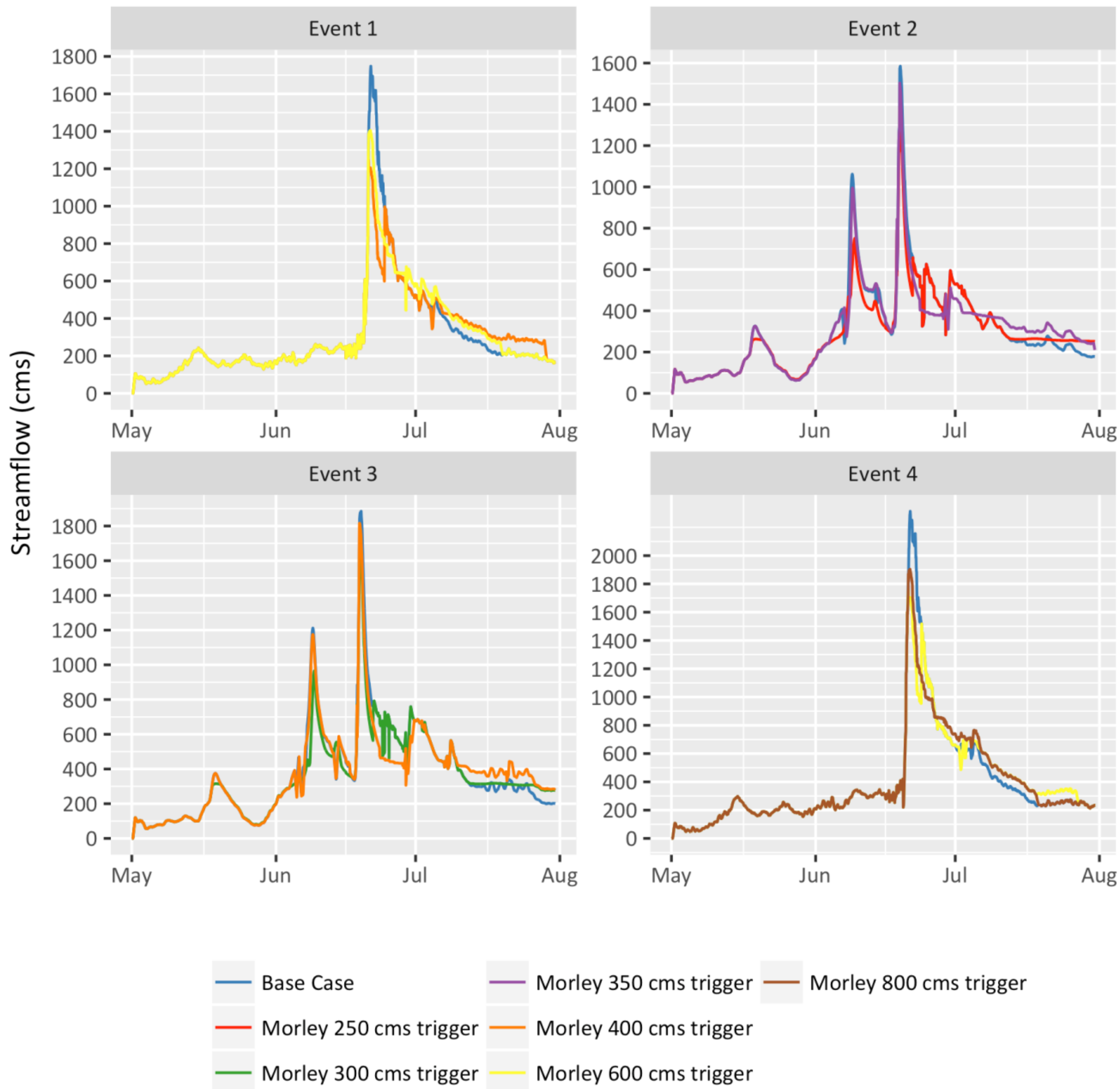


Figure 20: A comparison of synthesized Bow River streamflow at Calgary between base case and Morley dam for Events 1–4

Upstream and downstream notes of interest (see full results in Appendices F, G and H):

- Peak flows were dramatically reduced for the Bow River at Cochrane.
- Peak flow was not reduced downstream of the Highwood-Bow confluence for Events 1 and 4 due to the fact that peak inflows from the Highwood River occurred about 17 hours earlier than the Bow River peak at the confluence; however, the volume of flow during the descending limb of the hydrographs was reduced. Peak flow was reduced slightly and volume of water was reduced downstream for Events 2 and 3. However, there would be other realistic flood events where flood mitigation projects above Calgary, such as this one,

Scheme 11. New Morley reservoir on Bow River upstream of Ghost Reservoir
would mitigate downstream peaks by a similar magnitude to what is observed upstream.
Commentary

Socio-economic and community considerations

- This site may be limited to no greater than 30 m to avoid impacts on Highway 1A and the CPR line.
- This site would be located entirely within Stoney Nakoda First Nations reserve lands. The recent project on the southwest ring road may give some indication of the time, cost, and process of negotiation.
- This scheme would offer more reservoir capacity (approximately double) than the Glenbow scheme (Scheme 10) for a similar infrastructure investment cost.

Environmental and ecological considerations

- This section of the Bow River is highly fragmented by two upstream dams and Ghost Dam downstream. Creation of a new fish passage barrier in the system will further fragment the reach and have unknown (but presumably negative) impacts on existing mountain whitefish populations.
- AEP Wildlife Management does not manage wildlife within the First Nations, therefore will not provide specific comments regarding risks to wildlife. There is likely moderate wildlife habitat quality in the project area so sensitive species, such as grizzly bear, harlequin duck, and several species of bird may be impacted by this project.
- Downstream of Calgary fisheries impact may be improved by this scheme depending on operational decisions.

Design and operational considerations

- This scheme would control runoff from about 68% of the contributing area of the Bow River at Calgary.
- The modelling exercise demonstrated that simple operating rules for Glenbow dam (Scheme 10) could result in more flood mitigation compared with Morley. It is possible Morley could provide additional mitigation if more sophisticated operating rules were developed.
  However, this would require close operational coordination with the other control structures, particularly Ghost Reservoir, which would result in a higher level of complexity in terms of maximizing flood mitigation using Morley; this would be particularly important in emergency situations when operators are making real-time decisions in response to streamflow conditions. The mitigation offered by each scheme would also be driven heavily by the nature of the flood event, in particular in which part of the catchment the event is generated.
- There would be geotechnical challenges specific to this scheme (e.g., difficult topographical cut-off for dam construction).

Scheme 11. New Morley reservoir on Bow River upstream of Ghost Reservoir
• An advantage of this scheme is that it would control approximately half of the basin upstream of Calgary and would alleviate some mitigation pressure on Ghost Reservoir. • This scheme could have opportunities for drought mitigation and water storage, as well as hydropower, because of its large size. • The Amec Foster Wheeler (2015) flood storage report noted that this reservoir could be twice as big as the Glenbow reservoir, but it would be located upstream of Jumpingpound Creek, which can be a significant contributor to flooding depending on where the rain falls. • Morley dam could hold back flows in the main stem allowing Ghost dam to manage the Ghost high flows and reduce peak flows downstream to offset Jumpingpound inflows. • Further investigation would be needed to confirm whether Glenbow or Morley is a better mitigation scheme; the relative benefits of the two schemes will likely be different if assessed as flood mitigation schemes only or water management schemes offering both flood and drought mitigation. • This scheme would have to be operated in conjunction with TransAlta facilities; however, larger facilities are generally easier to operate than multiple smaller facilities.
Flood mitigation potential
This scheme was considered to be one of the most promising schemes because of its flood mitigation potential and was included in the 1,200 and 800 cms flood mitigation scenarios.

Scheme 12. Extend Ghost Reservoir flood operations (2016 agreement)	
This scheme would involve an agreement between GoA and TransAlta to operate existing facilities to optimize flood mitigation by decreasing the upper rule by 5 m. Ghost Reservoir would be lowered before the flood season (from May 15 to July 15) every year and would hold releases to 200 cms (although this can be exceeded) when flood storage operations begin until the reservoir is full and spill operations begin. Flood operations would be triggered when total inflows reach 400 cms. The reservoir controls runoff from a drainage basin area equal to about 83% of the Bow River Basin above Calgary (based on the Bow River below Ghost Dam Water Survey Canada gauge). The existing Ghost Reservoir has about 92,500 dam^3 of live storage.	
Indicative time frame Immediately	**Indicative cost** $5–50 million
Results	
Using a trigger of 400 cms flows into Ghost Reservoir (Figure 21), the approximate reduction in peak flow at Calgary was: Event 1: 250 cms Event 2: 0 cms Event 3: 0 cms Event 4: 250 cms	

Scheme 12. Extend Ghost Reservoir flood operations (2016 agreement)

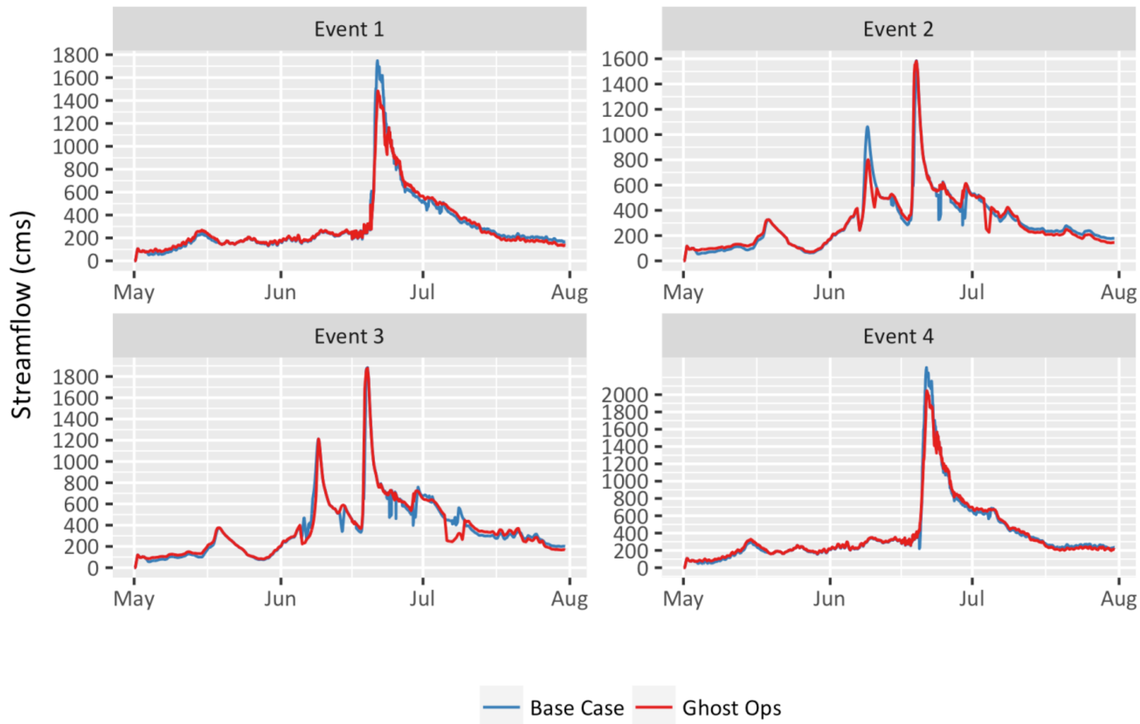


Figure 21: A comparison of synthesized Bow River streamflow at Calgary between base case and Ghost Reservoir operations for Events 1–4

Upstream and downstream notes of interest (see full results in Appendices F, G and H):

- Flows on the Bow River at Carseland and the South Saskatchewan River at Medicine Hat were reduced slightly. The effect of Ghost operations is noticed at Medicine Hat because the operations influence the timing of flow substantially.

Commentary

Socio-economic and community considerations

- This scheme would affect recreational activities; boating and sailing on the reservoir is popular.
- Depending on how the reservoir is filled after flood season, this scheme could result in lower levels in irrigation reservoirs therefore affecting many uses, including recreational activities.

Environmental and ecological considerations

- This scheme results in lower river flows in summer due to increased competition for water, since more water must be removed from the flow to be stored in Ghost in later summer than under the historical operating regime. In lower flow years this will stress the ecosystem.

Scheme 12. Extend Ghost Reservoir flood operations (2016 agreement)
• This scheme can easily result in lower levels in irrigation district reservoirs unless they are allowed to fill earlier. Lower levels in irrigation district reservoirs can adversely affect fish and wildlife. • Like other operational changes for flood mitigation, this scheme has potential consequences in times of low flow for the receiving Bow River. These consequences have not been addressed in this report but are being looked at in the overall flood/drought schemes by AEP. **Design and operational considerations** • This scheme increases the risk of water shortages for other users later in the year if Ghost is refilled in a dry year. This scheme requires 'balancing the system'. • This scheme would help mitigate lower-magnitude (intermediate) flow events. • This scheme would require a continuing agreement between TransAlta and GoA. • Power generation and flood mitigation objectives are competing goals. Holding the reservoir lower results in a reduction in electrical generating capability. • Re-filling the reservoir after flood season may be problematic if the reservoir is operated for flood mitigation. Operators and forecasters would need to assess snowpack and precipitation on an ongoing basis. • Operators and forecasters would need to assess snow pack and precipitation early in the season. • Operating Ghost only for flood protection may significantly impact drought mitigation and water supply. Ghost operations should consider how to optimize operations and flexibility for both flood mitigation and to minimize impacts to water supply during drought mitigation conditions. • Extending the Ghost agreement would depend on GoA and TransAlta reaching another termed agreement. • This scheme is currently in place until 2020, and continuation of the scheme could be implemented immediately.
Flood mitigation potential
This scheme was considered to be one of the most promising schemes because of its flood mitigation potential, its short time line to implement and the fact it makes use of existing infrastructure. It was included in the 1,200 and 800 cms flood mitigation scenarios.

Scheme 13. Expand Ghost Reservoir (by raising FSL and/or adding a low-level outlet)	
This scheme would involve increasing the height of the dam by ~3 m and changing operational rules to optimize flood storage in emergency situations, and/or installing a low level outlet in the dam to allow Ghost to draw down further than is currently possible, thereby increasing the live storage volume of the reservoir. Ghost Reservoir would be lowered before the flood season (from May 15 to July 15) every year and would release 200 cms when flood storage operations begin until the reservoir is full and spill operations begin under flood conditions. Operations would be triggered when flow into Ghost Reservoir is >400 cms. The reservoir controls runoff from a drainage basin area equal to about 83% of the Bow River Basin above Calgary (based on the Bow River below Ghost Dam Water Survey Canada gauge). The existing Ghost Reservoir has about 92,500 dam^3 of live storage.	
Indicative time frame 10–15 years	**Indicative cost** $100–300 million
Results	
Using a trigger of >400 cms flows into Ghost Reservoir (Figure 22), the approximate reduction in peak flow at Calgary was: Event 1: 550 cms Event 2: 400 cms Event 3: 550 cms Event 4: 550 cms	

Scheme 13. Expand Ghost Reservoir (by raising FSL and/or adding a low-level outlet)

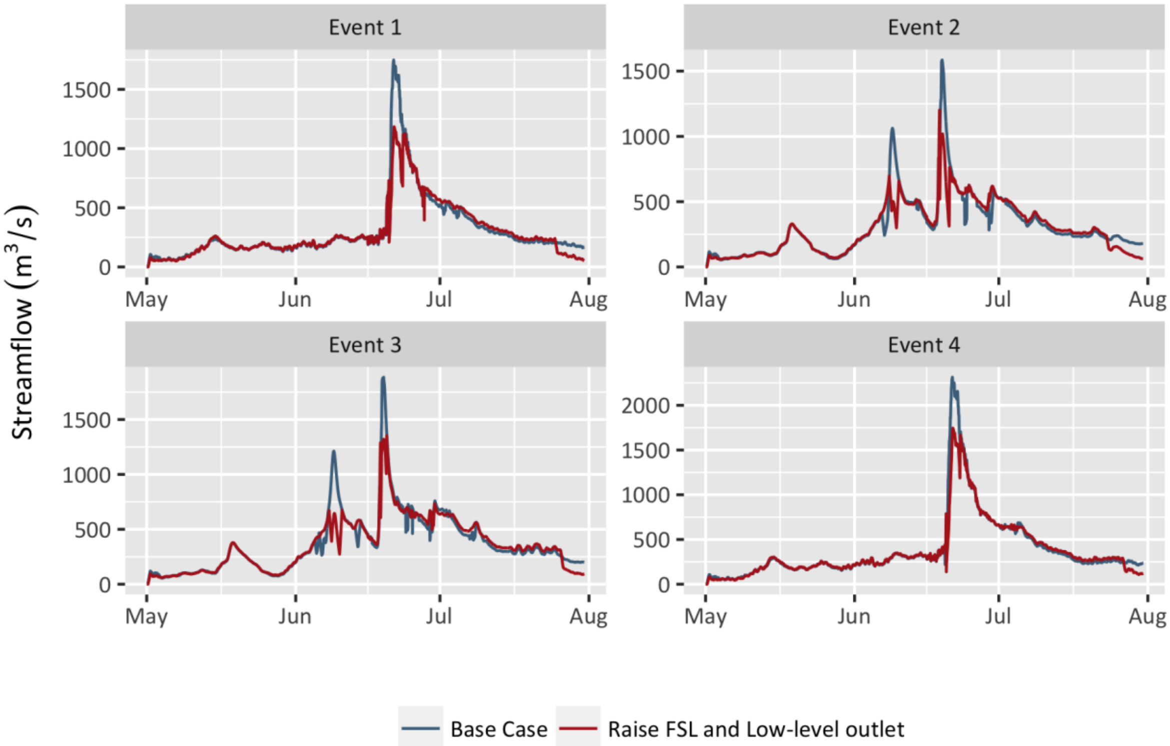


Figure 22: A comparison of synthesized streamflow at Calgary between base case and Ghost Reservoir with both increased FSL and a low-level outlet Events 1-4

Upstream and downstream notes of interest (see full results in Appendices F, G and H):

- Peak flows were substantially reduced in the Bow River at Cochrane.
- Peak flows were slightly reduced on the Bow River downstream of the Highwood-Bow confluence given that the flows from the Highwood River occurred earlier and were responsible for the peak downstream during events 1 and 4. Reductions in peak flow were synthesized during events 2 and 3.

Commentary

Socio-economic and community considerations

- Expanding Ghost Reservoir may have social and political issues.
- Will flood additional land in Stoney Nakoda First Nations reserve land.
- Summer Village of Ghost Lake (200 people) may need to be relocated.
- This scheme would result in occasional flooding along the reservoir's shoreline.
- Discussion with the Summer Village, First Nations, and CPR would be required.
- There would be recreational concerns if Ghost is raised or lowered, although the lower-level outlet may enable higher spring and summer water levels with similar flood protection as is

Scheme 13. Expand Ghost Reservoir (by raising FSL and/or adding a low-level outlet)
currently obtained by lowering it several metres each spring, enabling increased recreational use during high-demand periods. **Environmental and ecological considerations** • This scheme could impact a good local sport fishery in the reservoir. • Riparian habitat is limited in this area, so expanding the reservoir would not have a large impact on this habitat. • Lowering Ghost with a low-level outlet—if or when it would be used—could create recreational concerns. • This scheme would have few new impacts because it would use close to the existing reservoir footprint. • If the increased storage capacity means that the range of annual fluctuation in reservoir level is reduced, this would have environmental and recreational benefits. **Design and operational considerations** • The Ghost Reservoir captures runoff from about 83% of the contributing area to the Bow River at Calgary. • This scheme would be a significant undertaking to gain only a small amount of storage because it is very difficult to raise an existing structure by 3 m. A 3 m increase in the structure height would yield ~35,000 dam^3 of additional storage, so for the cost, it might be better to build an entirely new facility. • Raising the FSL may be complicated because the primary structure at Ghost is made of concrete. A structural assessment would be needed to determine whether concrete could be added to raise the structure and how high the structure could be raised. High cost to raise the dam could reduce its feasibility. Similarly, the cost and feasibility of installing low-level outlets would need to be investigated. • Ghost Dam is not a government-owned facility; ongoing negotiations and agreement with TransAlta would be required. • This scheme would provide a greater guarantee of storage availability compared with operations on tributaries, due to its location on the Bow River main stem, and its close proximity to Cochrane and Calgary. • Major concerns would exist with being able to fill the reservoir once it is lowered. This same challenge would exist whether the reservoir is expanded or not. • Increasing the drawdown rate to 5 ft./day is complementary to any flood or drought operations and could be a more effective flood mitigation option than expanding the reservoir for addressing the risk of back to back flood events; however, the most potential comes from a suite of changes to Ghost Reservoir infrastructure and operations. • Expanding Ghost would allow for more operational flexibility to mitigate both floods and droughts. This could be investigated while the feasibility of the faster drawdown rate is investigated.

Scheme 13. Expand Ghost Reservoir (by raising FSL and/or adding a low-level outlet)
• This scheme would have fewer legal administrative challenges, shorter timelines, etc., than other schemes because the site already exists. • Currently, about 20 m of inaccessible (unusable) storage exists because of the location of the outlet. • A low level outlet could gain at least an additional ~20,000 dam^3 of storage in addition to the 30,000-40,000 dam^3 of additional storage gained from raising the height of the dam. • It would cost >$100 million to implement the expansion, including raising the FSL by increasing the height of the dam and adding a low level outlet.
Flood mitigation potential
This scheme was considered to be a most promising scheme because of its flood mitigation potential. It also would not involve constructing a new facility so it would have fewer adverse environmental consequences. This scheme was included in the 1,200 and 800 cms flood mitigation scenarios.

Scheme 14. Restore Spray Reservoir to full design capacity	
This scheme would involve restoring the Spray Reservoir in the headwaters near Canmore to its original design full supply level, which would result in an additional 75,000 dam^3 of storage capacity. Currently, Spray is operated ~4 m lower than design because of seepage issues at the Three Sisters dam. A technically feasible solution could be to build a cut-off wall and use internal grouting that would allow operation back to the original FSL. This scheme would also involve changing operational rules to optimize flood storage in emergency situations. Spray Reservoir would be lowered before flood season (from May 15 to July 15) every year and release 20 cms when flood storage operations begin until reservoir is full and spill operations begin. Operations would be triggered when flow in the Spray River is >100 cms. The reservoir controls runoff from a drainage basin area equal to about 6% of the Bow River Basin above Calgary (based on the Spray River at Canyon near Spray Lakes Water Survey Canada gauge). The existing Spray Reservoir has about 278,000 dam^3 of live storage.	
Indicative time frame 5–7 years	**Indicative cost** $50–100 million
Results	
Using a trigger of >100 cms flows into Spray Reservoir the approximate reduction in peak flow, at Calgary, was zero for each synthesized flood event (Figure 23).	

Scheme 14. Restore Spray Reservoir to full design capacity

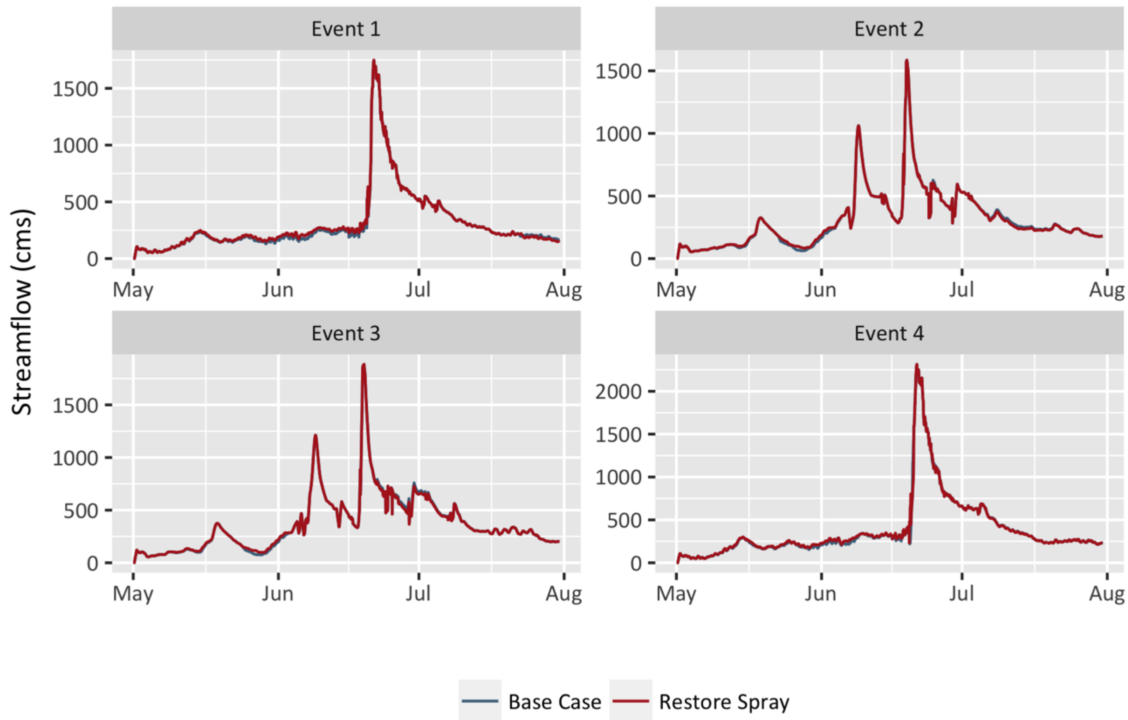


Figure 23: A comparison of synthesized Bow River streamflow at Calgary between base case and Spray Reservoir restoration to full design capacity for Events 1– 4

Upstream and downstream notes of interest (see full results in Appendices F, G and H):

- Restoring Spray Reservoir had no significant effect on peak flows, based on the two types of flood events modelled. This is likely because the existing Spray reservoir is very large and could virtually shut off releases as well as hold the flood runoff in that catchment in the synthesized events, as it did in 2013.

Commentary

Socio-economic and community considerations

- This flood mitigation scheme is entirely within Spray Valley Provincial Park and may have negative implications for tourism, recreation, and visitor experience.

Environmental and ecological considerations

- This project has the potential to impact the Mountain Goat and Sheep Zone. In addition, long-toed salamander (species of special concern) is known to occur in the project area, and grizzly bear (threatened species) use the area extensively.
- Terrestrial wildlife movement is currently constrained by topography, roads, and human infrastructure, and any raising to design FSL of Spray Lakes Reservoir may have significant negative impacts to the preservation zones surrounding Spray Lake that have been

Scheme 14. Restore Spray Reservoir to full design capacity
specifically protected for long-term wildlife movement and habitat use. This scheme would result in habitat loss, loss or decrease of wildlife movement corridors (landscape connectivity), and may result in increased human-wildlife conflicts, including with grizzly bears. • Due to the historic anthropogenic use of the site, however, the quality of aquatic habitat is reduced within the Spray Reservoir. • Potential benefit to Spray Reservoir, if mean annual drawdown amplitude is reduced because the need to exercise the Spray for flood Operations is negated. **Design and operational considerations** • Spray Reservoir captures runoff from about 6% of the total drainage area of the Bow River at Calgary. • Geotechnical issues and potential technology solutions to address reservoir seepage would need to be investigated. • The flood mitigation value of this scheme would be limited by its placement at the top end of the watershed. • This scheme would provide storage capacity high in the Bow Basin. • This scheme could be used to increase water storage and winter carry-over, to offset the risk of drought from lowering other reservoirs downstream for flood mitigation. • Spray already has significant extra capacity for flood storage. The existing Spray Reservoir managed the inflows in 2013 without running out of space, and even in the modelled scaled-up event, the existing reservoir did not run out of space, based on the rainfall distributions and runoff generated for this event.
Flood mitigation potential
This scheme was considered to be one of the least promising flood schemes because it is a large reservoir, and even if it were expanded, it would not have the catchment area to substantially change current performance. Given that inflows to this reservoir are low relative to the existing reservoir capacity, expansion did not result in reductions in peak streamflow at Calgary. This scheme was not included in the 1,200 and 800 cms scenarios.

<table>
<tr><th colspan="2">Scheme 15. Increase Ghost Reservoir drawdown rate</th></tr>
<tr><td colspan="2">This scheme would involve drawing down Ghost Reservoir faster than currently possible to create additional storage when a flood is imminent. Currently, the drawdown rate is limited to 1 ft./day, but additional geotechnical studies might show potential for increasing the drawdown rate.

The reservoir controls runoff from a drainage basin area equal to about 83% of the Bow River Basin above Calgary (based on the Bow River below Ghost Dam Water Survey Canada gauge). The existing Ghost Reservoir has about 107,600 dam^3 of live storage.</td></tr>
<tr><td>Indicative time frame
2–5 years</td><td>Indicative cost
$50–100 million</td></tr>
<tr><td colspan="2">Results</td></tr>
<tr><td colspan="2">Using a trigger of 400 cms inflow to Ghost and a 2 ft./day lowering rate, the approximate reduction in peak flow at Calgary was (Figure 24):
Event 1: 250 cms
Event 2: 100 cms
Event 3: 200 cms
Event 4: 250 cms

Using a trigger of 400 cms inflow to Ghost and a 5 ft./day lowering rate made approximately 32,000 dam^3 of storage available, and the approximate reduction in peak flow at Calgary was (Figure 24):
Event 1: 250 cms
Event 2: 250 cms
Event 3: 300 cms
Event 4: 250 cms</td></tr>
</table>

Scheme 15. Increase Ghost Reservoir drawdown rate

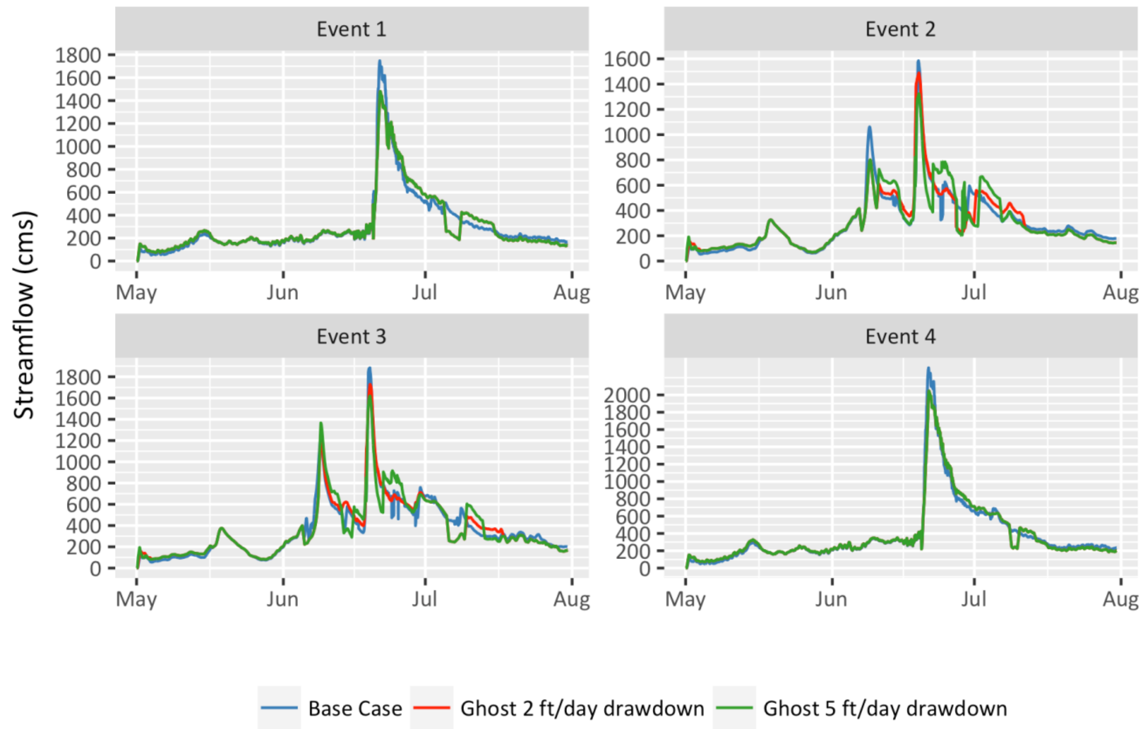


Figure 24: A comparison of synthesized Bow River streamflow at Calgary between base case and higher Ghost Reservoir drawdown rates for Events 1–4

Upstream and downstream notes of interest (see full results in Appendices F, G and H):

- Peak flows for the Bow River at Cochrane were also substantially reduced.

Peak flow was substantially reduced for the Bow River at Carseland and the South Saskatchewan River at Medicine Hat during Events 2 and 3, with a faster drawdown having a larger influence on reducing flow.

Commentary

Socio-economic and community considerations

- One objective of increasing the drawdown rate is to leave the reservoir fuller for longer with the intent to improve recreational use and provide some drought protection in addition to the flood mitigation, relative to the current 1 foot per day drawdown.

Environmental and ecological considerations

- Riparian habitat is limited in the reservoir, so increasing the drawdown rate at Ghost Reservoir would have little impact on this habitat.
- Potential benefit to Ghost Reservoir, if mean annual drawdown amplitude is reduced.

Design and operational considerations

Scheme 15. Increase Ghost Reservoir drawdown rate

• The Ghost Reservoir captures runoff from about 83% of the contributing area to the Bow River at Calgary.
• An extensive geotechnical examination would be required before cost could be precisely determined.
• Increasing the drawdown rate of Ghost Reservoir would be especially valuable in multi-peak events; forecasting would play an essential role in all events.
• If the drawdown rate exceeds the flood peak any downstream damage will be attributed to operations.
• A new drawdown rate would require robust forecasting to make this scheme effective.
• A faster drawdown rate would allow for more operational flexibility for mitigating floods, while reducing the risk from droughts, relative to Scheme 12.
• A higher drawdown rate would likely require graduating dam embankment slopes and installing drainage and erosion control measures. This requires geotechnical study:
  ○ 1 foot/day: Maximum allowable rate based on available geotechnical information.
  ○ 5 feet/day: Requires geotechnical study. May be feasible with existing infrastructure but will probably require some amount of embankment stability upgrade work.
  ○ 10 feet/day: Requires geotechnical study. Unlikely to be feasible with existing infrastructure. May require significant embankment stability upgrade work.
  ○ >10 feet/day: Not of interest due to flows through Calgary.

Flood mitigation potential
This scheme was considered to be one of the most promising schemes because of its flood mitigation potential and because it does not involve infrastructure in a new location. This scheme was included in the 1,200 and 800 cms flood mitigation scenarios.

5.2 Additional Schemes Not Assessed by the BRWG

Several additional schemes were raised during BRWG meetings but were not assessed. These schemes are listed below, with the rationale provided for excluding them from the assessment.

Land management

Land management was recognized as an important element of flood risk management; however, it was not included in the scope of this current project because it is being addressed through other programs, including AEP's renewed WRRP, forest harvest planning, and Land-use Framework.

Dredge Ghost Reservoir

The City of Calgary has concluded that negligible flood mitigation benefit would result from dredging Glenmore Reservoir. This conclusion is expected to be applicable to the Ghost Reservoir as well.

Wetland storage

Land management was recognized as an important element of flood risk management; however, it was not included in the scope of this current project because it is being addressed through other programs, including AEP's WRRP and its Land-use Framework.

Expand Lake Minnewanka Dam/Reservoir

This scheme was mentioned briefly in the first BRWG meeting; however, it did not receive support for further investigation and has not been presented in any previous reports.

Dam on Ghost River upstream of Devil's Gap by the Ghost Lakes

This scheme was mentioned briefly in the first BRWG meeting; however, it did not receive support for further investigation and has not been presented in any previous reports.

Off-stream storage in the Ghost Watershed

This scheme was mentioned briefly in the first BRWG meeting; however, it did not receive support for further investigation and has not been presented in any previous reports.

Lac Des Arc Hydro Site

This potential reservoir site was identified in the 2008 storage study commissioned by the GoA (MPE 2008); however, it has not been presented in any flood mitigation reports since that time nor was it put forward for further investigation by any member of the BRWG.

6.0 Flood Mitigation Scenarios

Schemes were grouped into scenarios that the BRWG felt would be effective in mitigating to the two flow targets through Calgary: ≤1,200 cms and ≤800 cms.

Four scenarios were developed for the 1,200 cms flow target, and three scenarios were developed for the 800 cms target. This section describes each scenario and:

- Summarizes the results of hydrological modelling used to evaluate how these scenarios affect streamflow in the four synthesized flood events (see Section 4.0);
- Summarizes commentary from the BRWG on these scenarios, including an indicative time and cost; and
- Provides an assessment of flood mitigation potential.

A summary table showing results for all schemes and scenarios can be found in Appendix E.

Some observations common to the 1,200 and 800 cms flood mitigation scenarios and other key points related to the scenarios are listed below. These observations are in addition to those listed for the individual schemes and would also apply to the schemes that are part of the four scenarios.

- For all mitigation schemes, operations of existing facilities should be better coordinated with flood, drought, and climate forecasting so that combinations of interdependent schemes operate at an optimal level. Reliable, timely forecasting information is beneficial to many of these mitigation schemes, including more robust and increased number of streamflow and reservoir level gauging stations.
- Adjusting operations at two existing facilities (Ghost and Barrier) could offer meaningful flood mitigation potential; these schemes were included in every scenario modelled. Operations are core to all scenarios.
- Each scenario would reduce the peak to a different level, but otherwise, the other environmental consequences would be similar.
- Other facilities would be in operation with these scenarios as per their existing operational rule curves, for example, Spray, Minnewanka, and Kananaskis Lakes.
- More information would be needed to better assess each scenario, including assessments of hydrology, costs-benefits, environmental and social impacts, and engineering feasibility.
- Impacts during construction and restoration of the disturbed landscape as well as the river systems would need to be considered including the initial permitting based requirements and the long-term effects on the watershed.
- Flood mitigation and drought mitigation scenarios must be evaluated together to understand the net impact on the water management system as a whole, that is, as a full water management scenario.

Initially, the BRWG was given a third flood mitigation target of 400 cms at Calgary. Early in the process, the 400 cms flood mitigation target was dropped for reasons described earlier (see page 45). Preliminary modelling suggested even if all flood mitigation schemes identified at that point were implemented, flows in Event 1 could only be mitigated to ~550 cms; that is, they could not collectively achieve the 400 cms target (see Figure 8).

Given these concerns of the BRWG and results of preliminary modelling, the Advisory Committee confirmed in August 2016 that flood mitigation scenarios should be developed for the 1,200 and 800 cms targets only.

The hydrological modelling results are shown for each mitigation scenario compared to the *base case* in each of the four synthesized flood events (see Section 4.0). As a reminder, the four are:

- **(Event 1)** the 2013 flood event of 2,400 cms naturalized peak streamflow for the Bow River at Calgary (above the Elbow River)
- **(Event 2)** the 2005 flood event of 1,250 cms naturalized peak flow scaled to approximately 2,000 cms peak hourly streamflow for the Bow River at Calgary (above the Elbow River)
- **(Event 3)** the 2005 flood event scaled to approximately 2,400 cms peak hourly streamflow for the Bow River at Calgary (above Elbow River), and
- **(Event 4)** the 2013 flood event scaled to approximately 3,300 cms for the Bow River at Calgary (above the Elbow River).

6.1 Flood mitigation scenarios to achieve 1,200 cms target

Four scenarios were developed to achieve the 1,200 cms target through Calgary. Scenarios A to D included three common schemes (see Figure 25):

- (Scheme 12) Extend Ghost Reservoir flood operations (2016 agreement)
- (Scheme 15) Increase Ghost Reservoir drawdown rate, and
- (Scheme 8) Barrier Lake flood operations.

The scenarios differed in that Scenario A includes a new Glenbow reservoir on Bow River upstream of Bearspaw (Scheme 10); Scenario B includes a new Morley reservoir on Bow River upstream of Ghost Reservoir (Scheme 11); Scenario C includes an expansion of Ghost Reservoir (by raising FSL and/or adding a low-level outlet) (Scheme 13); and Scenario D includes a new reservoir on Kananaskis River (Scheme 7) AND a new reservoir on Jumpingpound Creek (Scheme 9) OR a new reservoir on Ghost River upstream of Waiparous confluence (Scheme 4).

The 1,200 cms target scenarios were not ranked. They are lettered A, B, C, D for reference only.

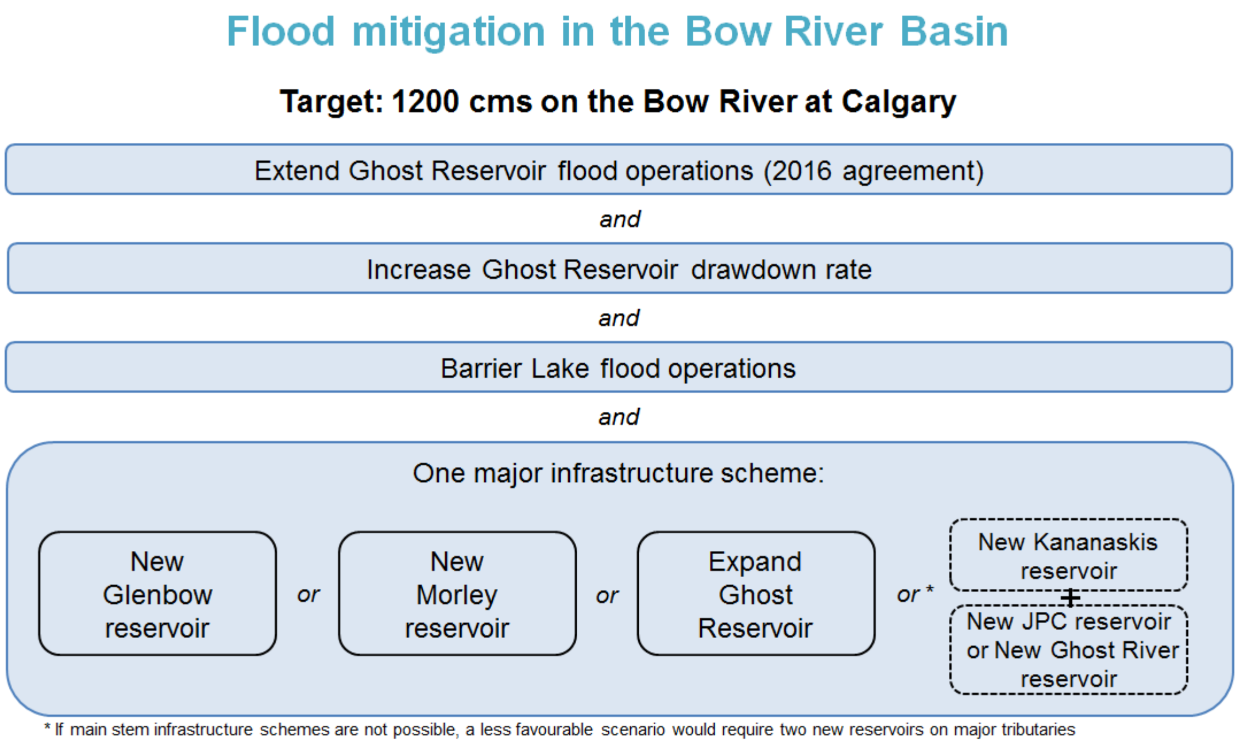


Figure 25: Flood mitigation scenarios for the Bow River Basin to achieve the flow target of 1,200 cms on the Bow River at Calgary

Scenario A: Glenbow + operational schemes (1,200 cms target)
Scenario A would gain flood mitigation capacity in Ghost Reservoir from the 2016 agreement and would use a similar agreement to gain flood mitigation capacity in Barrier Reservoir. This scenario would require a capital investment in Ghost Reservoir to allow it to safely draw down by up to 5 ft./day instead of the current 1 ft./day. These schemes and benefits are common to all flood mitigation scenarios in this report. In addition, this Scenario includes construction of a new dam on the Bow River main stem between Bearspaw and Cochrane to create a ~70,000 dam^3 reservoir that, in this particular scenario, would be operated entirely for flood mitigation. Scenario A would include: • Scheme 12: Extend Ghost Reservoir flood operations (2016 agreement) • Scheme 15: Increase Ghost Reservoir drawdown rate • Scheme 8: Barrier Lake flood operations • Scheme 10: New Glenbow reservoir on Bow River upstream of Bearspaw
Results

Scenario A: Glenbow + operational schemes (1,200 cms target)

Two sets of results are shown for Scenario A. The first results include only the operational schemes: Ghost Reservoir operations with a 400 cms trigger and a 5 ft./day lowering rate, and Barrier operations that release 100 cms less than inflow (Figure 26).

The second set of results include the operational changes plus the first of the potential new schemes: Glenbow dam with a 1,200 cms trigger, Ghost Reservoir operations with a 400 cms trigger and a 5 ft./day lowering rate, and Barrier operations that release 100 cms less than inflow (Figure 27).

Peak flow for the full Scenario A (including the operational changes and the new scheme) was:

Event 1: 1,200 cms peak instead of base case operations peak flow of 1,750 cms
Event 2: 1,200 cms peak instead of base case operations peak flow of 1,600 cms
Event 3: 1,200 cms peak instead of base case operations peak flow of 1,900 cms
Event 4: 1,500 cms peak instead of base case operations peak flow of 2,400 cms

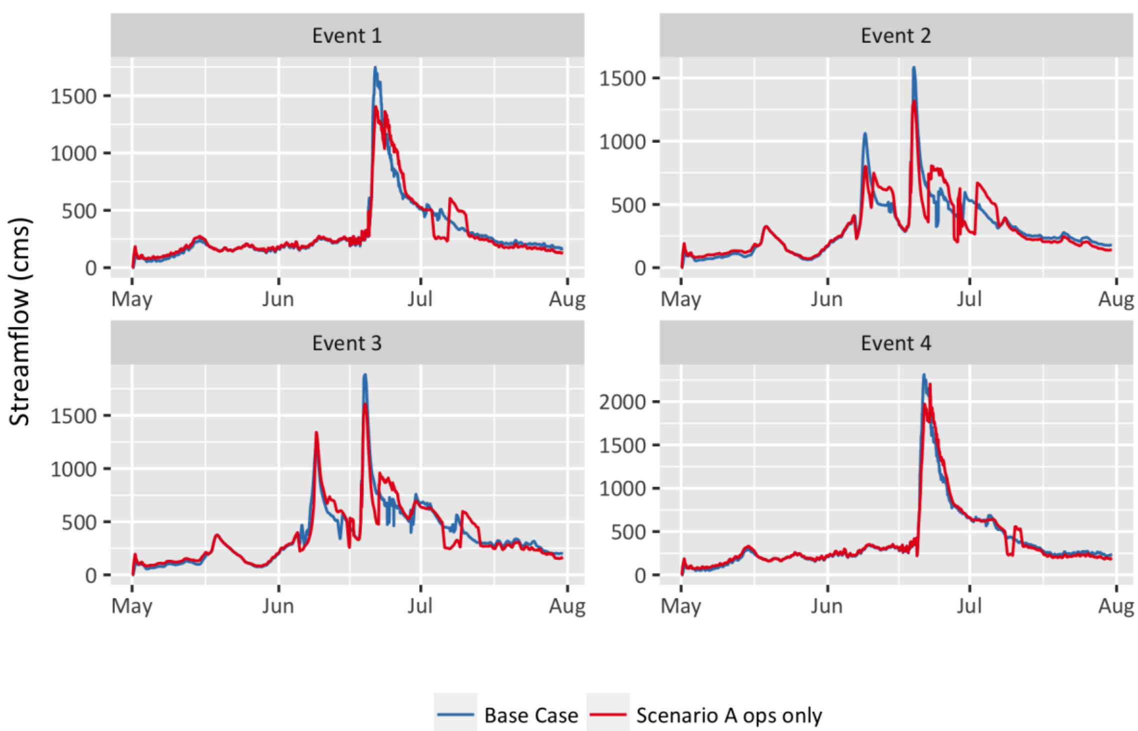


Figure 26: A comparison of synthesized Bow River streamflow at Calgary between base case and Scenario A operations only (1,200 cms) for Events 1–4

Scenario A: Glenbow + operational schemes (1,200 cms target)

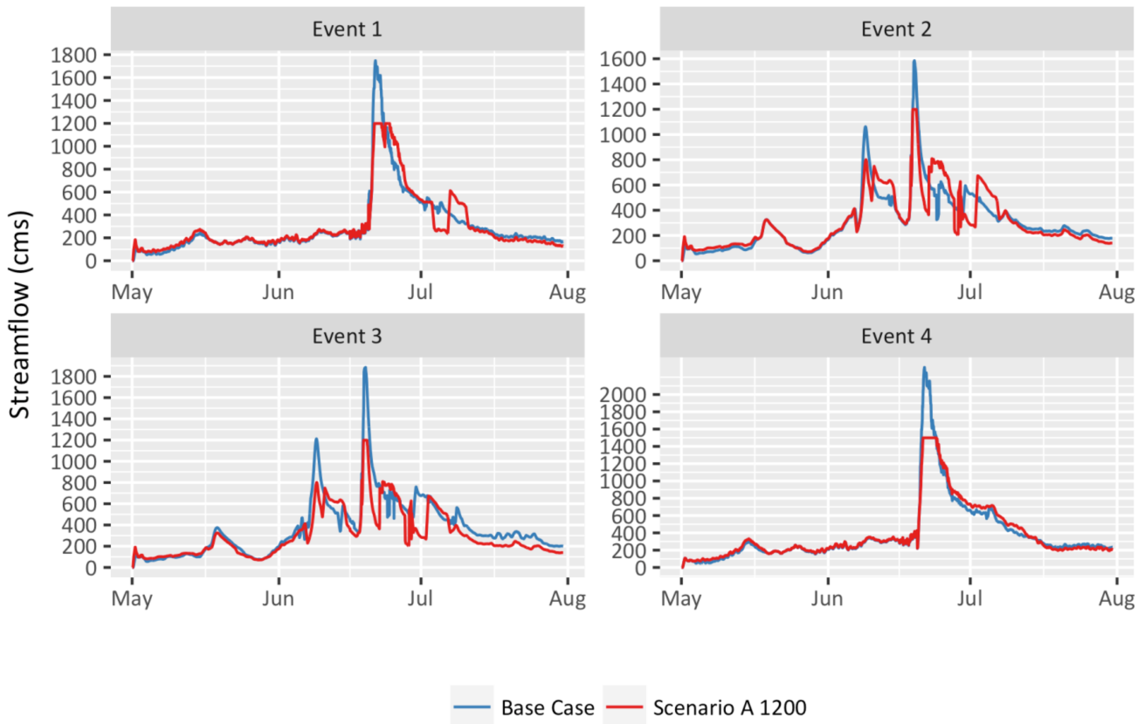


Figure 27: A comparison of synthesized Bow River streamflow at Calgary between base case and Scenario A (1,200 cms) for Events 1–4

Upstream and downstream notes of interest (see full results in Appendices F, G and H):

- Cochrane
  - Peak flow was substantially reduced for the Bow River at Cochrane, even though Glenbow dam is downstream, because of coordinated operation of Ghost Reservoir and Barrier.
- Carseland
  - Peak streamflow was slightly reduced at Carseland and in the region of Siksika Nation that experienced negative impacts from the 2013 flood; however, similar to Medicine Hat, the largest change was in the reduction in the number of high flow days post-flood.
  - Downstream of the Highwood confluence, the benefits started to taper for the flood scenarios modelled. If peak flow timing from the Highwood coincided with the Bow, benefits in terms of peak flow reductions could have been greater.
- Bassano
  - This scheme had little effect on Bow River flows at Bassano because it receives inflows from the Highwood River, where peak flow occurred earlier and was responsible for

Scenario A: Glenbow + operational schemes (1,200 cms target)
the peak downstream of the Highwood-Bow confluence in events 1 and 4. • Medicine Hat   ○ Scenario A had a small effect on South Saskatchewan peak streamflow at Medicine Hat as flows attenuated naturally downstream in part from the inflows from the Oldman River and Highwood River; however, the volume of water post-peak was reduced.
Commentary
• Commentary on the individual schemes is provided in Section 5.1. This section provides commentary on the overall scenario. • Overall, the BRWG agreed that this scenario was the most promising of the four scenarios. • This scenario would require one new dam, not multiple dams and/or rebuilds. Commentary common to all flood mitigation scenarios in this report: • Overall, operational changes could be put in place first; infrastructure could follow. • Overall, considerable mitigation could be achieved for about $100 million by focusing first on operational changes and could start immediately. • Some of the schemes included in this scenario would be located in already environmentally impacted areas. • Other facilities (Spray, Minnewanka, and Kananaskis) would contribute to this scenario's mitigation potential by operating in "2013" mode.
Flood mitigation potential
Based on these results, this scenario was considered to be one of the most promising scenarios to achieve the 1,200 cms flow target for the Bow River at Calgary because of its flood mitigation potential. Scenario A met the 1,200 cms target at Calgary in each synthesized flood event except Event 4, but peak flow was greatly reduced in that event.

Scenario B: Morley + operational schemes (1,200 cms target)
Scenario B would replicate Scenario A except the project on the main stem of the Bow River would be located upstream of Ghost reservoir on the Morley Reserve (Scheme 11) instead of between Bearspaw and Cochrane (Scheme 10). The new dam could create a reservoir up to ~150,000 dam^3 and could be operated for flood mitigation and potentially drought mitigation. Scenario B would include: • Scheme 12: Extend Ghost Reservoir flood operations (2016 agreement) • Scheme 15: Increase Ghost Reservoir drawdown rate • Scheme 8: Barrier Lake flood operations • Scheme 11: New Morley reservoir on Bow River upstream of Ghost Reservoir
Results
Results for Scenario B shown below included the following: Ghost Reservoir operations with a 300 cms trigger that is only triggered by inflow from the Ghost River and a 5 ft./day lowering rate, Barrier operations that release 100 cms less than inflow, and a new Morley dam with 600 cms (Event 1), 275 cms (Event 2), 375 cms (Event 3), and 800 cms (Event 4) outflow triggers (Figure 28). Peak flow for Scenario B was: Event 1: 1,200 cms peak instead of base case operations peak flow of 1,750 cms Event 2: 1,100 cms peak instead of base case operations peak flow of 1,600 cms Event 3: 1,300 cms peak instead of base case operations peak flow of 1,900 cms Event 4: 1,900 cms peak instead of base case operations peak flow of 2,400 cms

Scenario B: Morley + operational schemes (1,200 cms target)

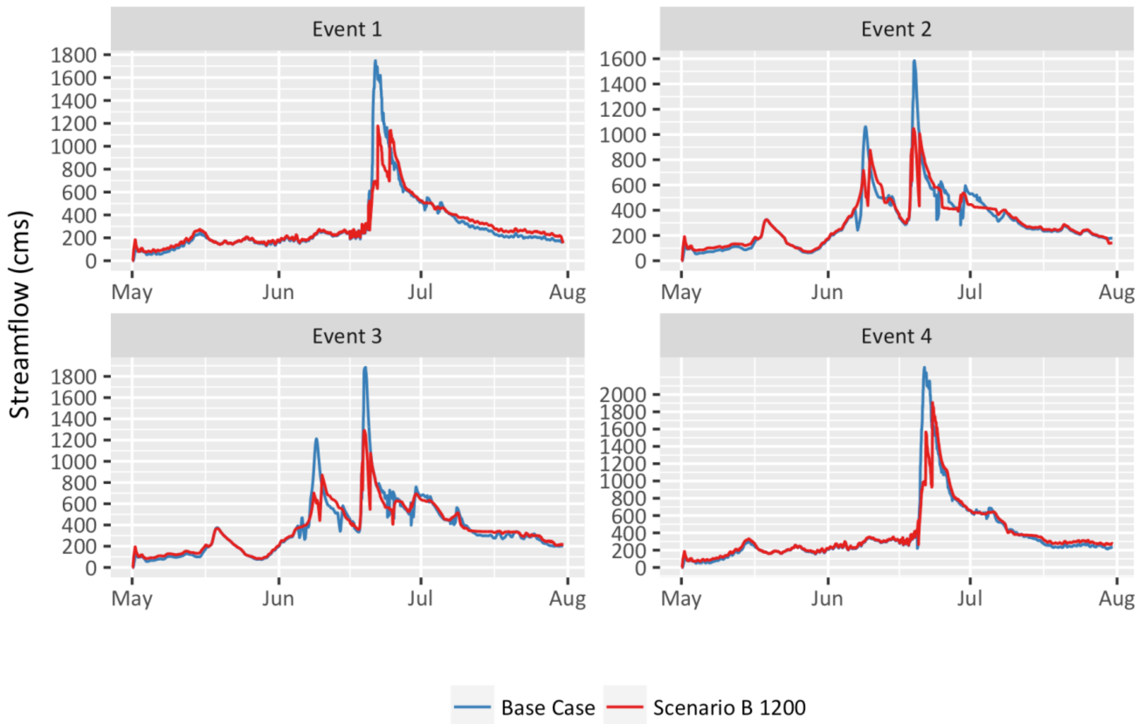


Figure 28: A comparison of synthesized streamflow at Calgary between base case and Scenario B (1,200 cms) for Events 1–4

Upstream and downstream notes of interest (see full results in Appendices F, G and H):

- Cochrane
  - Peak flow was substantially reduced for the Bow River at Cochrane, because of coordinated operations of Ghost Reservoir and Morley.
- Carseland
  - Peak flow was somewhat reduced for the Bow River at Carseland in the region of Siksika First Nation that experienced negative impacts from the 2013 flood; however, similar to the South Saskatchewan River at Medicine Hat, the largest change was in the sustained volume of water post-flood.
  - Downstream of the Highwood confluence, the benefits tapered. If there were less flow in the Highwood, benefits in terms of peak flow reductions would have been higher.
- Medicine Hat
  - Scenario B had a small effect on South Saskatchewan River peak streamflow at Medicine Hat; however, the volume of water post-peak was reduced.

Scenario B: Morley + operational schemes (1,200 cms target)
Commentary
• Commentary on the individual schemes is provided in Section 5.1. This section provides commentary on the overall scenario. • This scenario would require one new dam, not multiple dams and/or rebuilds. • Morley dam would take an estimated >10 years and >$500 million to complete. It would likely have greater infrastructure cost than Glenbow dam (Scheme 10). It may have a similar time frame as Glenbow, depending on the speed of negotiations with Stoney Nakoda First Nations. • Morley reservoir could be built twice as large and have a larger live pool than Glenbow reservoir, so it would have water security and drought protection benefits as well as flood mitigation benefits if it was so operated. Therefore, Morley would have more value as a water management facility. • Morley operations would necessarily be coordinated with other TransAlta facilities. • Morley would be located above Jumpingpound Creek, a tributary to the Bow River, which can generate significant flood flows. Morley reservoir would be unable to attenuate these flows. • Scenario B would provide more benefit to Cochrane than Scenario A but slightly less than Scenario A for Calgary, based on the flood events tested (generated from only two observed flood events). It would also provide more benefits to Stoney Nakoda First Nations at Morley than Glenbow, but Morley is not a river–flood prone area. Stoney Nakoda First Nations would understandably need to see other benefits and funding (e.g., overland flood protection, jobs). • This scenario may have lower risks to fish than other scenarios. • Commentary common to all flood mitigation scenarios in this report (see Scenario A, page 102.
Flood mitigation potential
Based on these results, this scenario was considered to be one of the most promising scenarios to achieve the 1,200 flow target through Calgary because of its flood mitigation potential. Scenario B met the 1,200 cms target in Events 1 and 2. In Event 3, it nearly met the flow target, and in Event 4, peak flow was substantially reduced.

Scenario C: Ghost expansion + operational schemes (1,200 cms target)
Scenario C flood mitigation would come from a rebuild or modification of existing facilities at Ghost Reservoir. This scenario would include agreements for operating Ghost and Barrier for flood mitigation and further capital investment to expand the existing Ghost Reservoir by raising its current height by ~3 m and using all the gained reservoir capacity for flood mitigation, and/or installing a low-level outlet in the dam to allow Ghost Reservoir to be drawn down further than is currently possible. Scenario C would include: • Scheme 12: Extend Ghost Reservoir flood operations (2016 agreement) • Scheme 15: Increase Ghost Reservoir drawdown rate • Scheme 8: Barrier Lake flood operations • Scheme 13: Expand Ghost Reservoir (by raising FSL and/or adding a low-level outlet)
Results
Results for Scenario C shown below included the following: Ghost Reservoir operations and expansion with 400 cms (raise FSL) and 600 cms (raise FSL and low-level outlet) triggers and a 5 ft./day lowering rate, and Barrier operations that release 100 cms less than inflow (Figure 29). Peak flow for Scenario C was: Event 1: 1,150 cms peak instead of base case operations peak flow of 1,750 cms Event 2: 1,200 cms peak instead of base case operations peak flow of 1,600 cms Event 3: 1,200 cms peak instead of base case operations peak flow of 1,900 cms Event 4: 1,550 cms peak instead of base case operations peak flow of 2,400 cms

Scenario C: Ghost expansion + operational schemes (1,200 cms target)

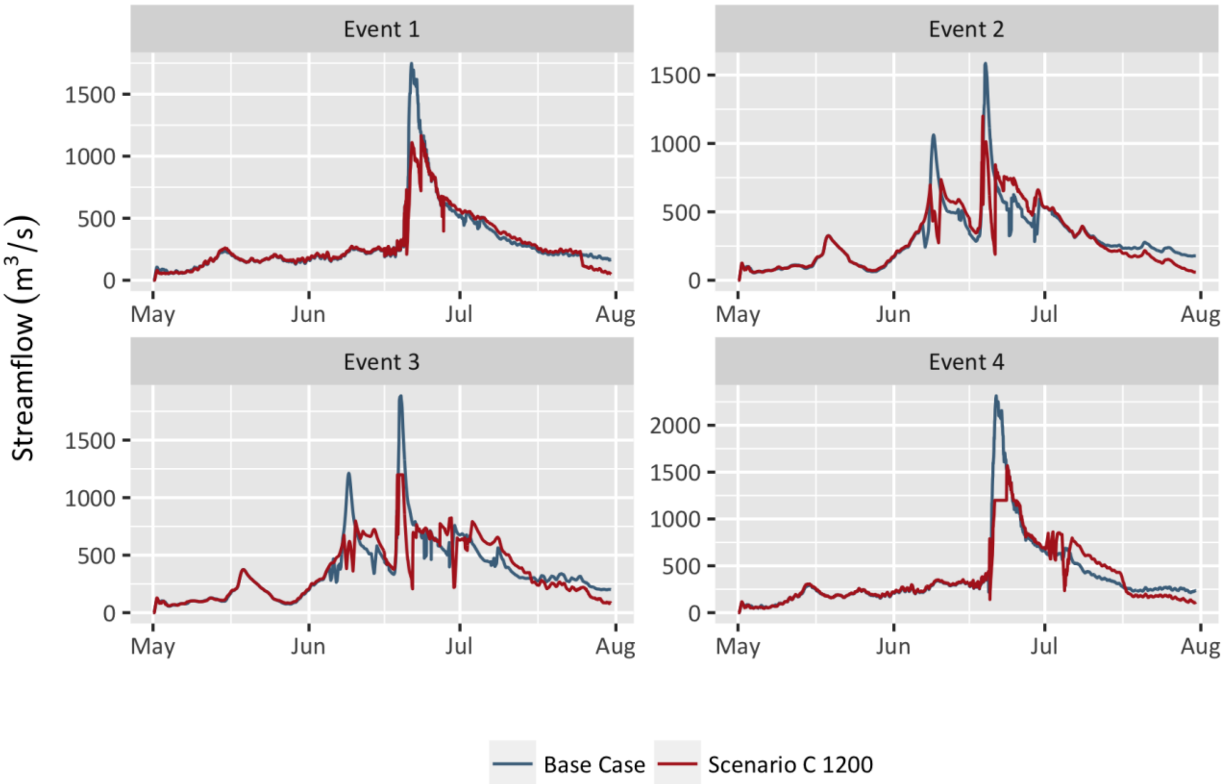


Figure 29: A comparison of synthesized Bow River streamflow at Calgary between base case and Scenario C 1,200 cms for Events 1–4

Upstream and downstream notes of interest (see full results in Appendices F, G and H):

- Cochrane
  - Peak flow was substantially reduced on the Bow River at Cochrane because of more storage in Ghost Reservoir and Barrier operations.
- Carseland
  - Peak flow was somewhat reduced for the Bow River at Carseland, although the largest change was in the volume of water post-flood.
  - The Bow River flowing through Siksika Nation would similarly have lower peak flows, although flood flows on the Highwood River, a tributary to the Bow River downstream of Calgary somewhat offsets the benefits seen in Calgary.
- Medicine Hat
  - Scenario C showed a small reduction in peak streamflow for the South Saskatchewan River at Medicine Hat as flows attenuated naturally downstream; however, the

Scenario C: Ghost expansion + operational schemes (1,200 cms target)
sustained volume of water post-peak was reduced.
Commentary
• Commentary on the individual schemes is provided in Section 5.1. This section provides commentary on the overall scenario. • This scenario would require no new dams but a major rebuild of an existing facility. • A new facility downstream might be less costly. The estimated cost of Scenario C would be >$500 million including potential costs from Morley Reserve, railway, and other land purchase or rental costs. • There are also fish and environmental concerns with having a low-level outlet as considerable exposure of the bottom may occur with a major drawdown. • There would be fewer new impacts because it is close to same footprint. • Commentary common to all flood mitigation scenarios in this report (see Scenario A, page 102.
Flood mitigation potential
Based on the results of only raising the FSL of Ghost, this scenario was considered a promising scenario to achieve the 1,200 cms flow target through Calgary because of its moderate flood mitigation potential. Scenario C with only increased FSL met the 1,200 cms flow target through Calgary for Events 1, 2 and 3 but not for Event 4. Scenario C with both an increased FSL and low-level outlet showed even more potential to mitigate peak streamflow. Under the large events (Events 3 and 4), this scenario performed as well or better than Scenario B due to its ability to capture inflows from the Ghost River, which had a significant impact on peak flows for the selected flood events modelled. This was considered a most promising scenario to achieve the 1,200 cms flow target through Calgary.

Scenario D: Tributary reservoirs + operational schemes (1,200 cms target)
Scenario D would be required if it were not feasible to build a new dam or rebuild Ghost dam on the Bow River main stem. It would include the same components as Scenario A except instead of the new main stem dam on the Bow River between Bearspaw and Cochrane (Scheme 10), two new dams would be required on the major front range tributaries: one new dam on the Kananaskis River upstream of Barrier creating an ~85,000 dam^3 reservoir and either a new dam on the Ghost River creating an ~60,000 dam^3 reservoir or a new dam on Jumpingpound Creek creating an ~65,000 dam^3 reservoir. All of these new dams would be operated entirely for flood mitigation for these runs. Scenario D would include: • Scheme 12: Extend Ghost Reservoir flood operations (2016 agreement) • Scheme 15: Increase Ghost Reservoir drawdown rate • Scheme 8: Barrier Lake flood operations • Scheme 7: New reservoir on Kananaskis River AND Scheme 9: new reservoir on Jumpingpound Creek OR Scheme 4: New reservoir on Ghost River upstream of Waiparous confluence
Results
Results for Scenario D shown below included the following: Ghost Reservoir operations with a 400 cms trigger and a 5 ft./day lowering rate, Barrier operations that release 100 cms less than inflow, a new Kananaskis dam with 100 cms (Events 1–3) and 50 cms (Event 4) outflow triggers, and a new Jumpingpound Creek dam with 50 cms (Events 1–3) and 10 cms (Event 4) outflow triggers (Figure 30). Peak flow for Scenario D was: Event 1: 1,300 cms peak instead of base case operations peak flow of 1,750 cms Event 2: 1,000 cms peak instead of base case operations peak flow of 1,600 cms Event 3: 1,500 cms peak instead of base case operations peak flow of 1,900 cms Event 4: 1,600 cms peak instead of base case operations peak flow of 2,400 cms

Scenario D: Tributary reservoirs + operational schemes (1,200 cms target)

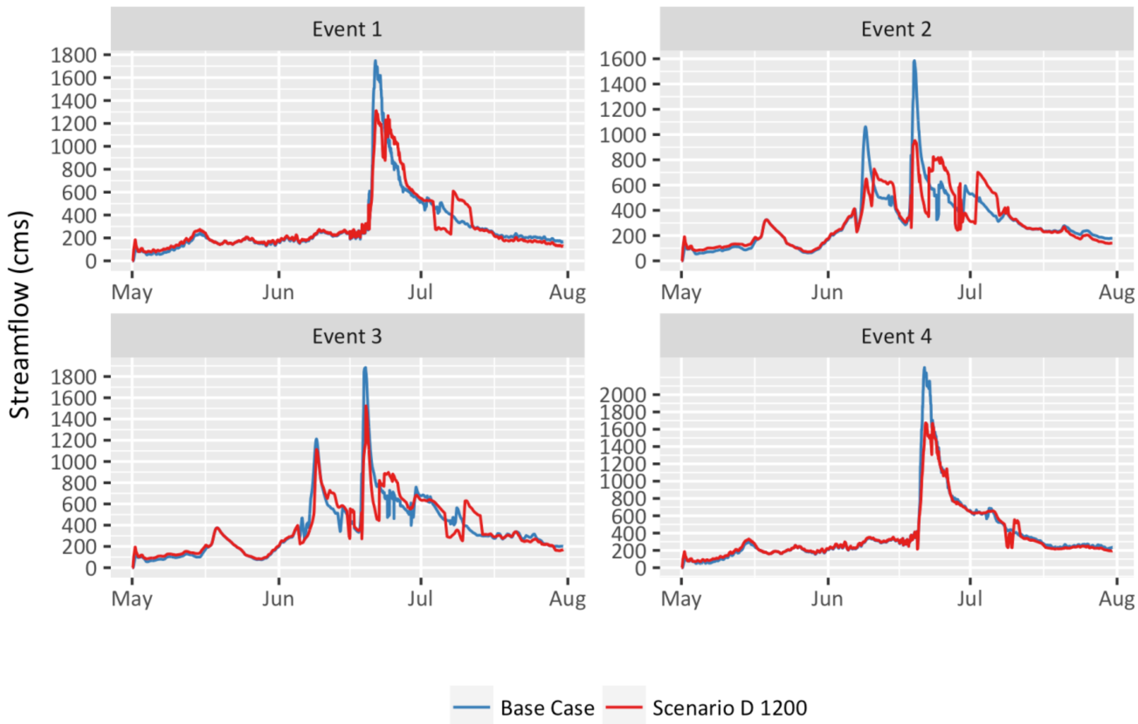


Figure 30: A comparison of synthesized Bow River streamflow at Calgary between base case and Scenario D (1,200 cms) for Events 1–4, including a new Jumpingpound Creek dam; when the Ghost River dam was used instead, it had the same effect in Event 1, slightly reduced performance in Event 2 (peak was 1,100 cms), improved performance in Event 3 (peak was 1,300 cms), and reduced performance in Event 4 (peak was 1,800 cms)

Upstream and downstream notes of interest (see full results in Appendices F, G and H):

- Cochrane
  - Peak flow was substantially reduced for the Bow River at Cochrane because of the new Jumpingpound Creek reservoir combined with upstream operations.
- Carseland
  - Some reduction in peak streamflow was observed for the Bow River at Carseland; however, similar to Medicine Hat, the largest change was in the flow rate of water post-flood.
  - Siksika Nation would experience similar reductions in peak flow for the Bow River as at Carseland.
- Medicine Hat
  - Scenario A slightly reduced peak streamflow on the South Saskatchewan River at Medicine Hat as flows attenuated naturally downstream; however, the sustained

Scenario D: Tributary reservoirs + operational schemes (1,200 cms target)
volume of water post-peak was reduced.
Commentary
• Commentary on the individual schemes is provided in Section 5.1. This section provides commentary on the overall scenario. • New dams on the tributaries typically involve more environmentally sensitive areas than those on the main stem. Given the amount of infrastructure required to achieve limited flood protection, this scenario may be unreasonable. • Some BRWG members questioned the economics of building such a large amount of infrastructure and whether non-structural options such as moving people out of floodplain would be more feasible to pursue. That said the City of Calgary has estimated the cost to move people out of the floodway (not floodplain) to be in the order of $1.8 billion, therefore the cost of new upstream infrastructure may not be unreasonable. • Building multiple smaller dams would likely be more costly and difficult to approve than building one larger dam. • Dams on the lower Bow River main stem will catch more runoff than dams on tributaries; tributary structures may miss the precipitation events causing flooding elsewhere in the catchment. • Of all the scenarios, this scenario would have the greatest risk to fish habitat and would be located in important wildlife habitat. • A new dam on Kananaskis may offer the highest mitigation potential of the tributary facilities but would be located in an area that is already relatively environmentally impacted. • Commentary common to all flood mitigation scenarios in this report (see Scenario A).
Flood mitigation potential
Based on these results, this scenario was considered a less promising scenario to achieve the 1,200 cms flow target through Calgary because of its moderate flood mitigation potential, the environmental effects were thought to be greater, costs higher, the difficulty of building more than one dam greater, and the odds of precipitation located here lower. Scenario D only met the 1,200 cms target at Calgary in Event 2, although peak flow was significantly reduced in the other events.

6.2 Flood mitigation scenarios to achieve 800 cms target

Three scenarios were developed to reach the 800 cms flow target through Calgary. Scenarios A to C included three common schemes (Figure 31):

- (Scheme 12) Extend Ghost Reservoir flood operations (2016 agreement)
- (Scheme 15) Increase Ghost Reservoir drawdown rate
- (Scheme 8) Barrier Lake flood operations, and

The scenarios differed in the two major infrastructure schemes that they include. Scenario A includes (Scheme 10) a new Glenbow reservoir on Bow River upstream of Bearspaw and (Scheme 11) a new Morley reservoir on Bow River upstream of Ghost Reservoir; Scenario B includes (Scheme 10) a new Glenbow reservoir on Bow River upstream of Bearspaw and (Scheme 13) an expansion of Ghost Reservoir (by raising FSL and/or adding low-level outlet); and Scenario C includes (Scheme 10) a new Glenbow reservoir on Bow River upstream of Bearspaw and (Scheme 7) a new reservoir on Kananaskis River, (Scheme 9) a new reservoir on Jumpingpound Creek, and (Scheme 4) a new reservoir on Ghost River upstream of Waiparous confluence.

The 800 cms target scenarios were not ranked. They are lettered A, B, C for reference only.

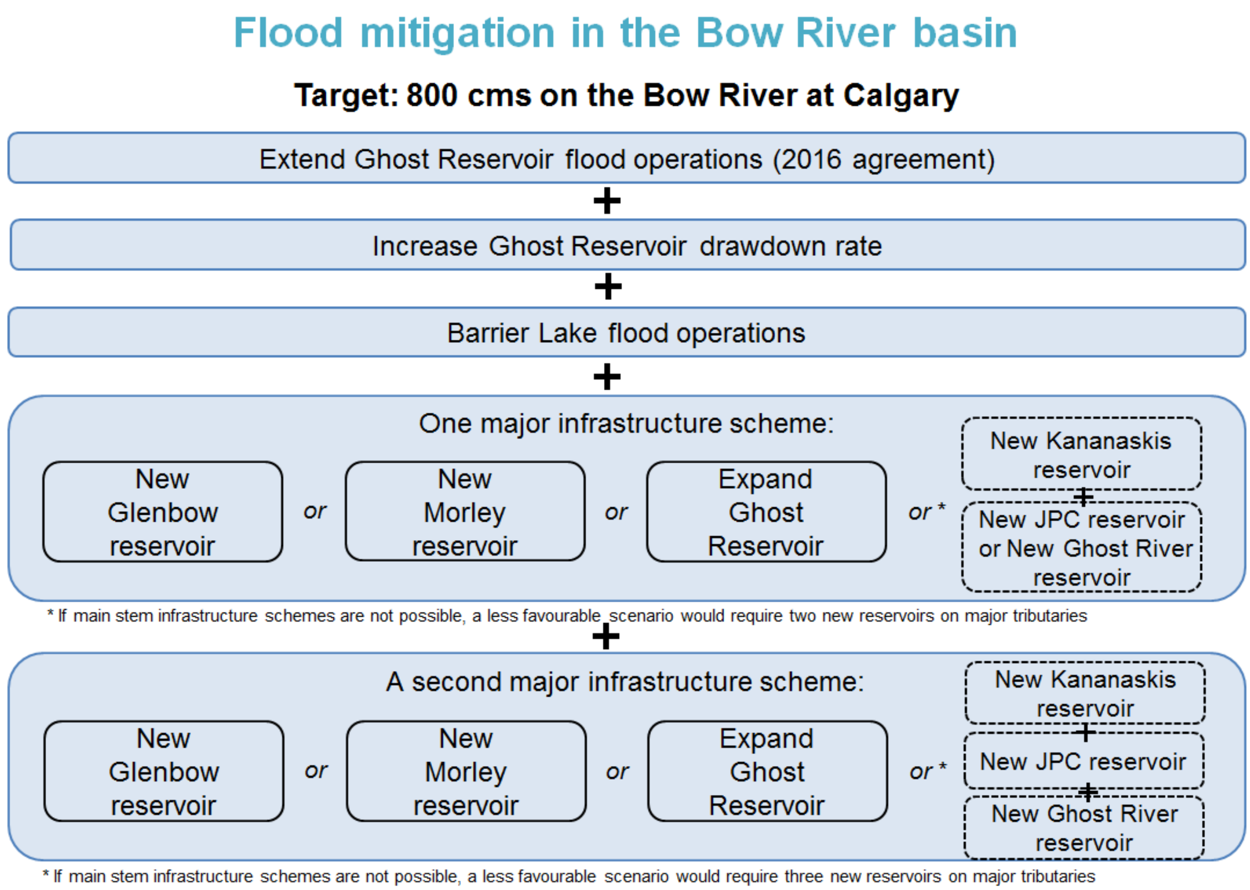


Figure 31: Flood mitigation scenarios for the Bow River Basin to achieve the flow target of 800 cms through Calgary

Some observations by the BRWG common to the flood mitigation scenarios for the 800 cms target and other key points relating to the scenarios are listed below. These observations are in addition to those listed for the individual mitigation schemes and 1,200 cms target scenarios.

- Overall, the BRWG indicated that achieving 800 cms is a big undertaking. Incremental benefits would need to be evaluated in terms of how much additional mitigation is achieved by layering additional mitigation schemes on the 1,200 cms scenario, particularly in relation to other flood mitigation options such as local mitigation including flood wall, and dykes and perhaps select relocation.
- Based on opinion, the marginal investment in new infrastructure would likely not translate into as much flood mitigation as the earlier investments. If scenarios cannot reduce the peak to 800 cms, the objective might be to get as much mitigation as possible.
- The BRWG questioned whether the 800 cms target is necessary because—in some individual's opinions—it may have negative environmental effects. For example, at 800 cms the river may not reach sufficient flood flows for environmental objectives including riparian regeneration and riverbed scouring, although significant regeneration was observed after the 2005 flood with a

peak of about 800 cms. Similarly, the recreational fishery is worth $50 million per year in the Bow. The impacts to fisheries, both positive and negative, associated with achieving a given maximum cms target would need to be investigated.

- There is potential to shrink the gap between 1,200 and 800 cms through local mitigation.
  - For Calgary, it could make sense to protect locally against floods on the Bow River in the ~800–1,200 cms range and then use upstream infrastructure to protect against floods >1,200 cms. However, it is much costlier from an economic, social, safety, and environmental standpoint to use berms, walls, etc., to protect against the larger floods.
  - In addition, local mitigation may move higher flows downstream slightly faster, and would provide no protection upstream.

Again, for each of the scenarios below, hydrological modelling results for streamflow are shown for the four synthesized flood events:

- **(Event 1)** the 2013 flood event of 2,400 cms naturalized[14] peak streamflow for the Bow River at Calgary (above the Elbow River)
- **(Event 2)** the 2005 flood event of 1,250 cms naturalized peak flow scaled to approximately 2,000 cms peak hourly streamflow for the Bow River at Calgary (above the Elbow River)
- **(Event 3)** the 2005 flood event scaled to approximately 2,400 cms peak hourly streamflow for the Bow River at Calgary (above Elbow River), and
- **(Event 4)** the 2013 flood event scaled to approximately 3,300 cms for the Bow River at Calgary (above the Elbow River).

[14] Naturalized flow is defined by AEP as the calculated or measured "quantity of water moving past a specific point on a natural stream or river where there are no effects from stream diversion, storage, power production, import, export, return flow, or change in consumptive use caused by land use activities".

Scenario A: Morley + Glenbow + operational schemes (800 cms target)
Scenario A would gain flood mitigation capacity in Ghost Reservoir from the 2016 agreement and would use a similar agreement to gain flood mitigation capacity in Barrier Reservoir. This scenario would require a capital investment in Ghost Reservoir to allow it to safely draw down by up to 5 ft./day instead of the current 1 ft./day. This scenario would include building two new dams on the Bow River main stem, one between Bearspaw and Cochrane to create an ~70,000 dam^3 reservoir (Glenbow) that would be operated entirely for flood mitigation and one upstream of Ghost reservoir on the Morley Reserve that would create a reservoir up to ~150,000 dam^3 that could be operated for flood mitigation and potentially drought mitigation. Scenario A would include: • Scheme 12: Extend Ghost Reservoir flood operations (2016 agreement) • Scheme 15: Increase Ghost Reservoir drawdown rate • Scheme 8: Barrier Lake flood operations • Scheme 10: New Glenbow reservoir on Bow River upstream of Bearspaw • Scheme 11: New Morley reservoir on Bow River upstream of Ghost Reservoir
Results
Results for Scenario A shown below included the following: Ghost Reservoir operations with a 400 cms trigger and 5 ft./day lowering rate, Barrier operations that release 100 cms less than inflow, a new Glenbow dam with 1,200 cms (Events 1–3) and 850 cms (Event 4) outflow triggers, and a new Morley dam with 350 cms (Events 1–3) and 600 cms (Event 4) outflow triggers (Figure 32). Peak flow for Scenario A was: Event 1: 800 cms peak instead of base case operations peak flow of 1,750 cms Event 2: 800 cms peak instead of base case operations peak flow of 1,600 cms Event 3: 800 cms peak instead of base case operations peak flow of 1,900 cms Event 4: 1,400 cms peak instead of base case operations peak flow of 2,400 cms

Scenario A: Morley + Glenbow + operational schemes (800 cms target)

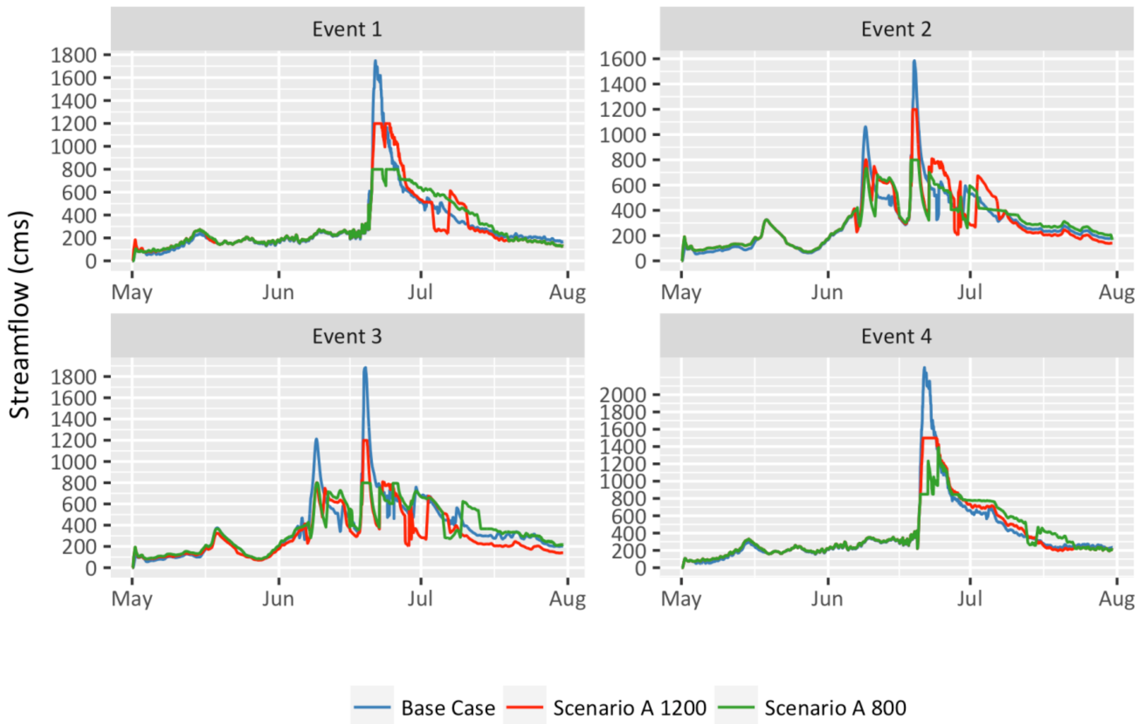


Figure 32: A comparison of synthesized Bow River streamflow at Calgary between base case, Scenario A (1,200 cms), and Scenario A (800 cms) for Events 1–4

Upstream and downstream notes of interest (see full results in Appendices F, G and H):

- This scenario would have some benefit for flood flows on the South Saskatchewan River at Medicine Hat and would protect Cochrane by reducing peak below its Bow River damage threshold of 1,200 cms.

Commentary

- This scenario would include two new facilities on the main stem and no infrastructure on the tributaries. Two large structures upstream would have positive water supply and storage impacts for the whole system.
- This scenario would have built-in safety redundancy with these two new facilities.
- A benefit of building new facilities would be that a portion of each could be kept wet and these facilities could be used for water management, drought mitigation, and environmental flows.
- Total cost would be estimated at $1 billion or more. This cost illustrates that a careful cost-benefit analysis will be needed to compare a second dam with alternative flood mitigation options such as local measures and relocation.
- If this scenario were implemented, it would be beneficial to have both structures approved

Scenario A: Morley + Glenbow + operational schemes (800 cms target)
at same time (systems approach). • Commentary common to all flood mitigation scenarios in this report (see Scenario A, page 102.
Flood mitigation potential
This scenario was considered to be one of the three most promising scenarios to achieve the 800 cms flow target through Calgary. This scheme reached the 800 cms target in Events 1 to 3. For Event 4, which is a relatively extreme event, this scenario reduced peak by an additional 1,000 cms in that event.

Scenario B: Ghost expansion + Glenbow + operational schemes (800 cms target)
Scenario B would include agreements for operating Ghost and Barrier for flood mitigation and further capital investment to expand Ghost Reservoir by raising its current height by ~3m and using all of the gained reservoir capacity for flood mitigation, and/or by installing a low-lying outlet to allow Ghost Reservoir to draw down lower than is currently possible, and to construct a new dam between Bearspaw and Cochrane to create an ~70,000 dam^3 reservoir that would be operated entirely for flood mitigation. Scenario B would include: • Scheme 12: Extend Ghost Reservoir flood operations (2016 agreement) • Scheme 15: Increase Ghost Reservoir drawdown rate • Scheme 8: Barrier Lake flood operations • Scheme 10: New Glenbow reservoir on Bow River upstream of Bearspaw • Scheme 13: Expand Ghost Reservoir (by raising FSL and/or adding low-level outlet)
Results
Results for Scenario B shown below included the following: Ghost Reservoir operations with a 400 cms trigger and a 5 ft./day lowering rate, Barrier operations that release 100 cms less than inflow, a new Glenbow dam with 900 cms (Events 1 and 2), 1000 cms (Event 3), and 1,300 cms (Event 4) outflow triggers (Figure 33), and an expanded Ghost Reservoir with a raised FSL and low-level outlet creating ~60,000 dam^3 of new capacity. Peak flow for Scenario B was: Event 1: 900 cms peak instead of base case operations peak flow of 1,750 cms Event 2: 900 cms peak instead of base case operations peak flow of 1,600 cms Event 3: 1,000 cms peak instead of base case operations peak flow of 1,900 cms Event 4: 1,300 cms peak instead of base case operations peak flow of 2,400 cms

Scenario B: Ghost expansion + Glenbow + operational schemes (800 cms target)

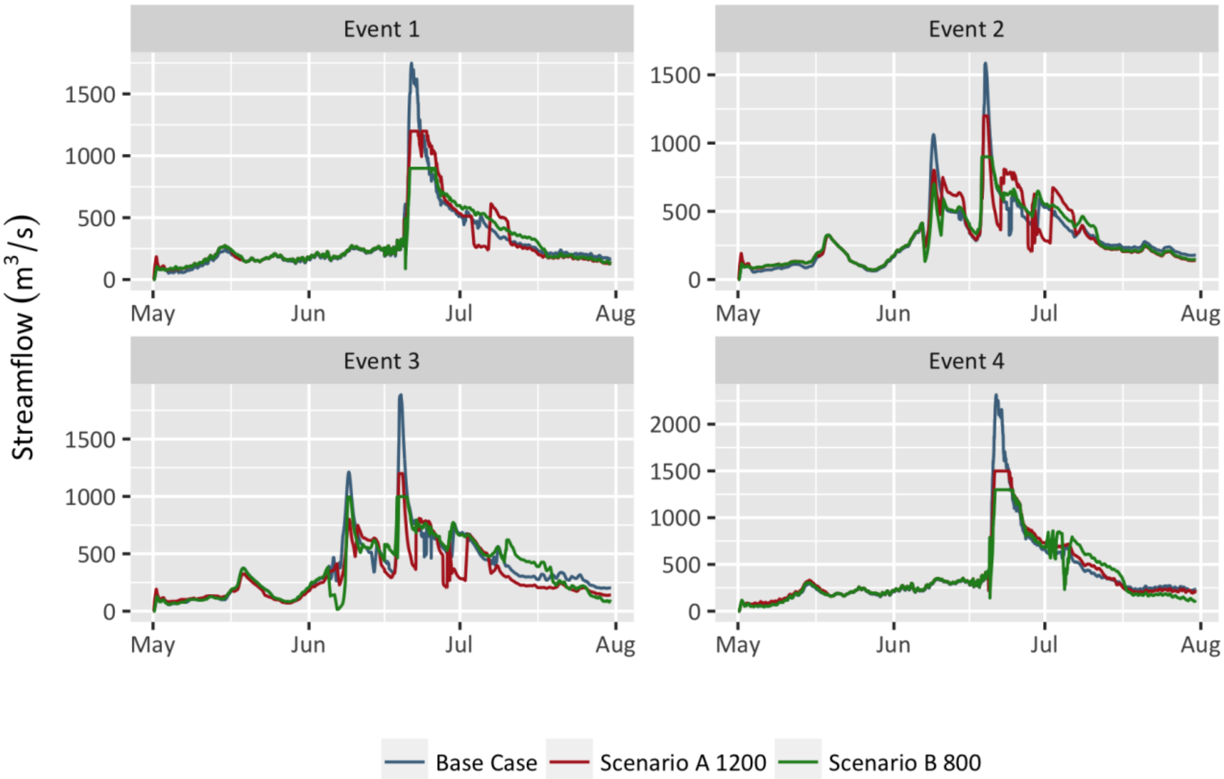


Figure 33: A comparison of synthesized Bow River streamflow at Calgary between base case, Scenario A (1,200 cms), and Scenario B (800 cms) for Events 1–4

Commentary

- Instead of, or in conjunction with increasing the height of the Ghost dam to raise FSL, a low-lying outlet would gain at least an additional ~20,000 dam^3 of storage on top of the 30,000-40,000 dam^3 of storage from raising the FSL.
- The expansion may be more economical than building two new large-scale projects on the tributaries.
- The incremental cost-benefit of more mitigation should be analyzed.
- Group discussed the costs-benefits of shrinking the gap between 1,200 and 800 cms through local mitigation, but there is safety, environmental, social and cost concerns with these solutions as well.
- Commentary common to all flood mitigation scenarios in this report (see Scenario A, page 102.

Flood mitigation potential

This scenario was considered to be one of the three most promising scenarios to achieve the 800 cms flow target through Calgary. Peak flow was reduced to 900 cms for Events 1 and 2, to 1,000 cms for Event 3 and substantially reduced for Event 4.

Scenario C: Kananaskis, Jumpingpound, and Ghost River reservoirs + Glenbow + operational schemes (800 cms target)
Scenario C would be required if it were not feasible to build two new dams or rebuild Ghost dam plus one new dam on the Bow River main stem. Scenario C would be similar to Scenario A, but instead of building a second new dam on the Bow River main stem (i.e., Morley), three additional new dams would be required on the major front range tributaries: one new dam on the Kananaskis River upstream of Barrier creating an ~85,000 dam^3 reservoir, a second new dam on the Ghost River creating an ~60,000 dam^3 reservoir, and a third new dam on Jumpingpound Creek creating an ~65,000 dam^3 reservoir. All of these new dams would be operated entirely for flood mitigation. Scenario C would include: • Scheme 12: Extend Ghost Reservoir flood operations (2016 agreement) • Scheme 15: Increase Ghost River drawdown rate • Scheme 8: Barrier Lake flood operations • Scheme 10: New Glenbow reservoir on Bow River upstream of Bearspaw • Scheme 7: New reservoir on Kananaskis River • Scheme 9: New reservoir on Jumpingpound Creek • Scheme 4: New reservoir on Ghost River upstream of Waiparous confluence
Results
Results for Scenario C shown below included the following: Ghost Reservoir operations with a 400 cms trigger and a 5 ft./day lowering rate, Barrier operations that release 100 cms less than inflow, a new Glenbow dam with 800 cms (Events 1–3) and 1,200 cms (Event 4) outflow triggers, a new Kananaskis dam with a 50 cms outflow trigger, a new Waiparous dam with a 40 cms outflow trigger, and a new Jumpingpound Creek dam with a 10 cms outflow trigger (Figure 34). Peak flow for Scenario C was: Event 1: 800 cms peak instead of base case operations peak flow of 1,750 cms Event 2: 800 cms peak instead of base case operations peak flow of 1,600 cms Event 3: 800 cms peak instead of base case operations peak flow of 1,900 cms Event 4: 1,200 cms peak instead of base case operations peak flow of 2,400 cms

Scenario C: Kananaskis, Jumpingpound, and Ghost River reservoirs + Glenbow + operational schemes (800 cms target)

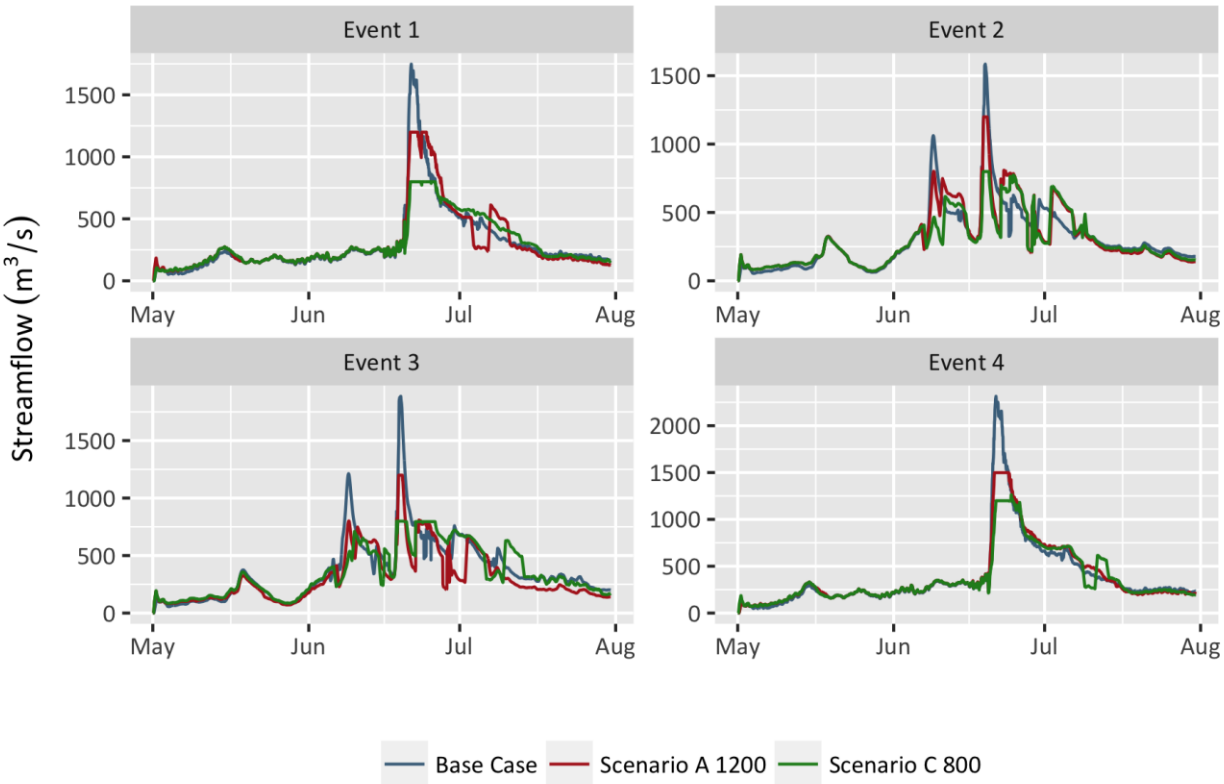


Figure 34: A comparison of synthesized Bow River streamflow at Calgary between base case, Scenario A (1,200 cms), and Scenario C (800 cms) for Events 1–4

Commentary

Scenario C: Kananaskis, Jumpingpound, and Ghost River reservoirs + Glenbow + operational schemes (800 cms target)
• If multiple new facilities cannot be built on the Bow River main stem, multiple facilities would be needed on tributaries, and still the mitigation may not be sufficient. • This scenario outperformed Scenario B, but its estimated cost of implementation and numerous sites may reduce its feasibility. • This scenario may appear more feasible than Scenarios A and B because some of these facilities would be on public land and in low-population areas, but additional facilities result in more uncertainty and greater potential for unintended consequences. • Tributary sites are more dependent on location of rainfall and runoff to be effective. • One new dam on main stem may still be preferable (Scenario B). • There would be risk of this scheme being "all-or-nothing"; if just one of these dams were not built, the system would not achieve the 800 cms target. • More dams would increase operational complexity and interdependency. • Commentary common to all flood mitigation scenarios in this report (see Scenario A, page 102.
Flood mitigation potential
Based on these results, this scenario was considered to be one of the three most promising scenarios to achieve the 800 cms flow target through Calgary. Scenario C met the 800 cms target at Calgary for Events 1 to 3 and reduced peak flow to 1,200 cms in Event 4.

7.0 Balancing the System

The Bow River Basin is a complex, regulated, interconnected system. Implementing flood mitigation schemes and scenarios upstream of Calgary (as presented in Sections 5 and 6) will change the historically managed flow regime that the system has grown and adapted into, and increase the ability of infrastructure to manage water supply. Changes to improve flood mitigation, in particular changes to the operations of existing reservoirs, will likely reduce drought resiliency, which could result in more water shortages to licensed water users and impact watershed health. Thus, early in this project, participants emphasized the importance of balancing the system.

Balancing the system means matching projects proposed for flood mitigation with other projects that, at a minimum, offset potential increases in drought risk or impacts to watershed health, thereby maintaining the current water management balance in the basin, providing more adaptability to changing conditions and avoiding foreseeable but unintended consequences. An example of this is the 2016 Ghost Reservoir flood operations agreement, which increases the need to divert water into storage when river flow is typically dropping. This may result in Ghost Reservoir or other reservoirs not filling in dry years or increased depletion of storage in other reservoirs to compensate for filling Ghost Reservoir; any of which increases the risk of water shortages if Ghost Reservoir cannot be refilled in dry years. To balance the system, the increased shortage risk of that existing agreement needs to be offset.

All schemes and scenarios put forward in this report are intended to build the adaptive capacity of the overall water management system in the Bow River Basin. Because of the nature of the system—flashy headwaters with high downstream demands and regulatory requirements—multi-year droughts cannot be fully mitigated. However, the schemes and scenarios presented in this report to balance the system close the gap on potential water shortages (stress on the system) in single-year and some multi-year droughts. Beyond drought concerns, the schemes and scenarios to balance the system also provide benefits in “normal” flow years, including increased adaptive capacity to deal with uncertain forecasting, inter-annual changes in supply and demand, provide higher flows during low-flow times to support a healthy aquatic ecosystem, and increase security of the water supply.

To investigate the need to balance the system, the BRWG first estimated the effect of flood mitigation Scenario A (1,200 cms target) on the water management system. As shown in Figure 35, in all but the most severe droughts experienced in the Bow River Basin, implementing Scenario A would create a deficit of ~50,000 dam^3 per year of total system storage (the total volume of water being stored at a given time in the system, including irrigation and TransAlta reservoirs) available for water supply and drought mitigation. This would result in more low-flow days for the entire system, as represented in Figure 36 using the number of days at or below 35 cms (1,250 cfs) in Calgary.

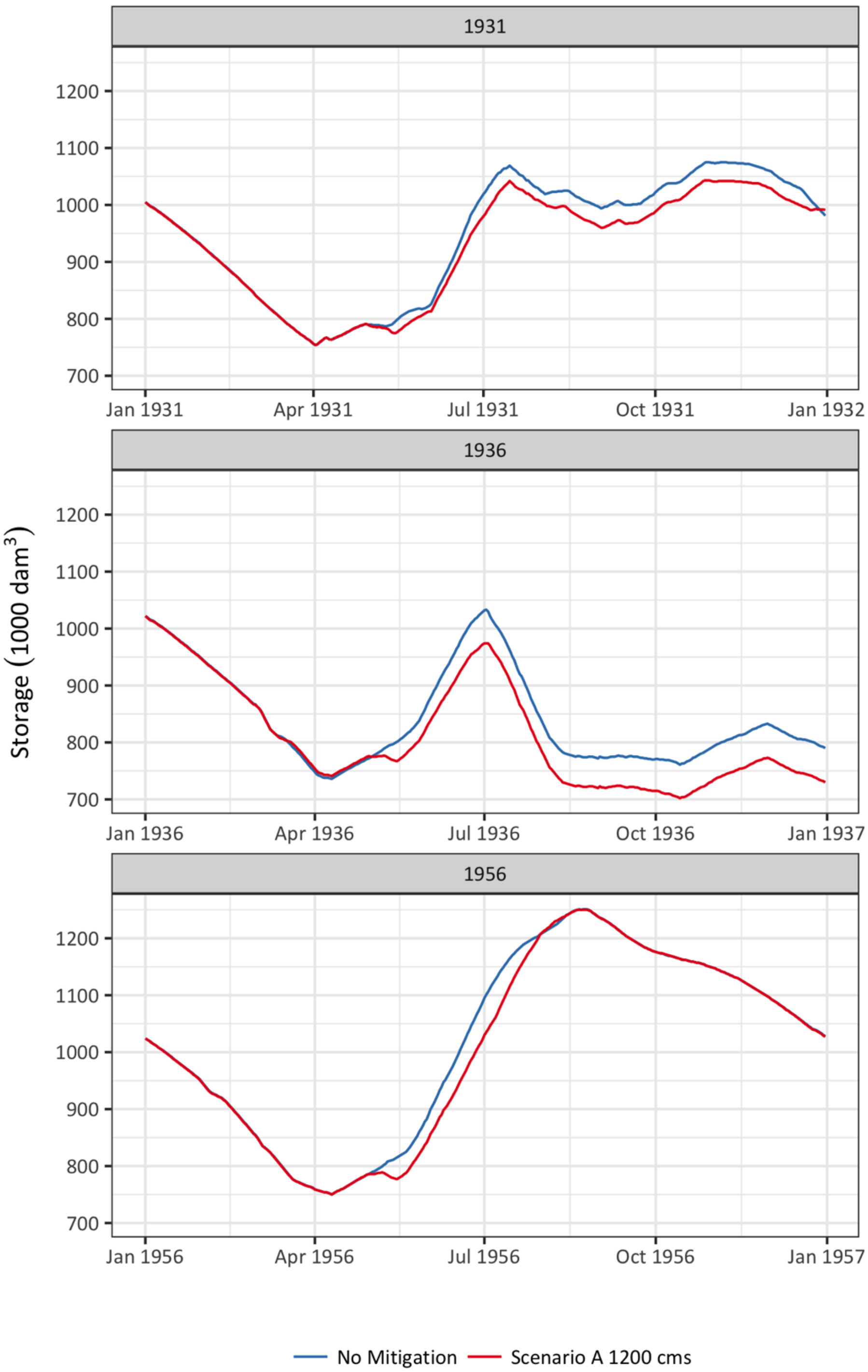


Figure 35: A comparison of total system storage between current operations (no flood mitigation) and Scenario A (1,200 cms target) implemented for flood mitigation; top graph shows a multi-year drought, middle graph shows an exceptional single-year drought, and bottom graph shows a "normal" year

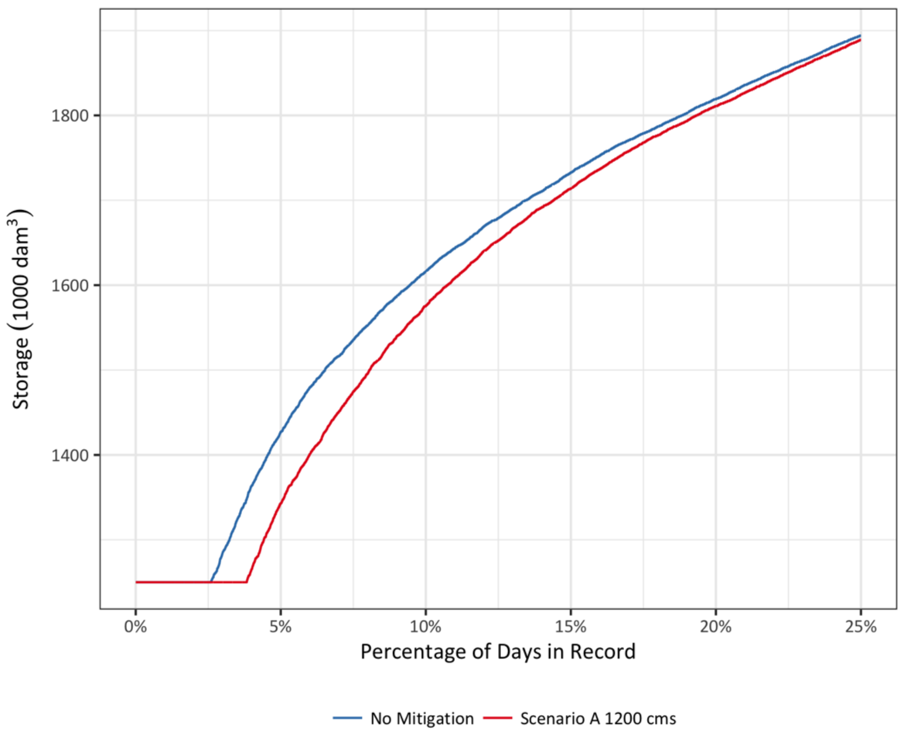


Figure 36: A comparison of the percentage of low-flow days for the Bow River in Calgary between normal operations (no flood mitigation) and Scenario A (1,200 cms target) flood mitigation [note: historical record used] for varying storage volumes

To offset this storage deficit and its consequences, the BRWG emphasized looking to relatively quick and inexpensive schemes that better use existing infrastructure differently.

7.1 Schemes Assessed by the BRWG to Balance the System

This section describes the five schemes assessed by the BRWG to balance the system; summarizes the results of hydrological modelling used to evaluate how these schemes reduce the storage deficit; summarizes commentary on these schemes from the BRWG, including an indicative time and cost; and provides an assessment of balancing potential. The six schemes assessed by the BRWG were located across the Bow River Basin and included the following:

1. Increase Ghost Reservoir drawdown rate (page 130)
2. Drought storage in expanded Glenmore Reservoir (page 133)
3. Increase diversion rate of the Carseland Canal and construct debris deflector (page 136)
4. Raise winter carryover in downstream reservoirs (e.g., Travers/Little Bow, McGregor) (page 140)
5. Fill downstream reservoirs earlier (e.g., Travers/Little Bow) (page 143)
6. Extend Kananaskis System water shortage mitigation operations (2016 agreement) (page 146)

A summary table showing results for all schemes and the scenarios can be found in Appendix I.

Scheme 1. Increase Ghost Reservoir drawdown rate	
This scheme would involve increasing the drawdown rate for Ghost Reservoir more than is currently possible to be able to keep it closer to FSL than required under the 2016 agreement, while still being able to rapidly lower the reservoir to capture flood waters when severe storms are forecast. This scheme would thus reduce the negative impacts of drawdown, as prescribed in the 2016 agreement, on water supply needs, while still providing flood mitigation (see Section 5.1, Scheme 15). Currently, the drawdown rate is limited to 1 ft./day but additional geotechnical studies may show potential for increasing the drawdown rate. Theoretically, a 5 ft./day drawdown rate is nearly equivalent to 3 m of head in two days, which would rapidly create about 32,000 dam^3 of storage for flood attenuation. This scheme is also recommended to be an integral part of each flood scenario. For balancing the system, Ghost Reservoir is drawn down less aggressively at a rate that results in flows downstream that are generally tolerable by the City of Calgary. This results in an average gain of 11,000 dam^3 of additional storage because Ghost Reservoir can be kept higher and drawn down providing a larger storage volume in the event of a flood. This is not the maximum possible storage gain, as demonstrated in the flood modelling.	
Indicative time frame 2–5 years	**Indicative cost** $10–50 million
Results	
For this scheme, ~11,000 dam^3 of storage was added to the system to represent the storage volume gained by keeping the spring flood season operational level of Ghost Reservoir at a higher elevation (Figure 38). Low-flow days at Calgary below 42 cms (1,500 cfs) were reduced by 3% and below 35 cms (1,250 cfs) were reduced by 17% (Figure 38).	

Scheme 1. Increase Ghost Reservoir drawdown rate

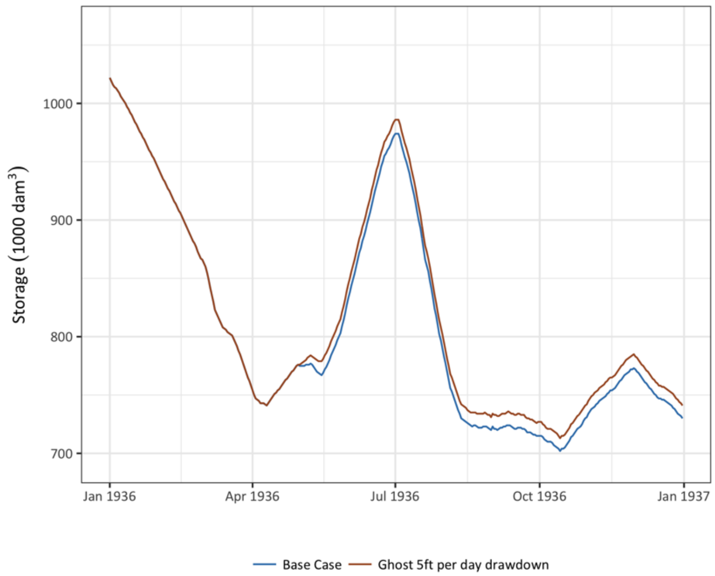


Figure 37: A comparison of total system storage between base case (Scenario A 1200 cms) and adding the 5 ft./day drawdown to Ghost Reservoir in 1936

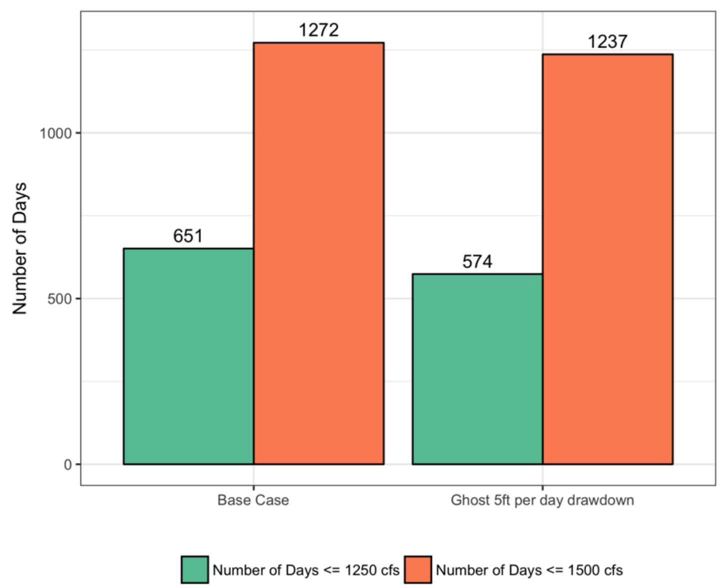


Figure 38: A comparison of the number of low-flow days (below 1,250 cfs and below 1,500 cfs) over the historical time series (~29,000 days) between base case and adding the 5 ft./day drawdown to Ghost Reservoir

Scheme 1. Increase Ghost Reservoir drawdown rate
Commentary
Socio-economic and community considerations • The maximum proposed rate of reservoir draining might be limited by what is viewed as an acceptable flow rate for municipalities immediately downstream. • Potential effects on fisheries may fall within the federal jurisdiction for environmental and safety impacts. **Environmental considerations** • To be determined in the next phase of study. **Design and operational considerations** • Having the flexibility to quickly draw down the reservoir level would allow it to be operated at a higher elevation while still offering some potential for flood mitigation. • Operational integration between this scheme and others is essential to optimize mitigation effects. • A geotechnical study to investigate feasibility of increasing the drawdown rate would cost approximately $100,000. • Must be considerate of other upstream operations. A new upstream reservoir cannot cause Ghost Reservoirs' release to exceed its maximum.
Balancing potential
This scheme was assessed as having high potential to balance the system because it had a large storage gain in response to an operational change. Drawing down Ghost Reservoir quickly would allow a higher water level to be maintained in case a flood does not occur, potentially improving recreational opportunities. This scheme also reduced the frequency of low-flow days at Calgary.

Scheme 2. Drought storage in expanded Glenmore Reservoir	
This scheme would involve changes to the Glenmore Reservoir licence that would provide new licensed storage capacity that could be taken advantage of due to the current project to upgrade the dam gates. The change here is to amend the licence so that a higher water level could be retained over the winter and used by downstream water licence holders for possible drought mitigation.	
Indicative time frame Infrastructure work is currently ongoing; to be completed in 2020, licensing may take 1 additional year	**Indicative cost** <$5 million (costs will be minimal)
Results	
For this scheme, storage in the system increased slightly through licensing allowing Glenmore Reservoir to routinely use additional space in the reservoir (Figure 39). Low-flow days at Calgary below 42 cms (1,500 cfs) increased by 3% and below 35 cms (1,250 cfs) increased by 1% (Figure 40), but both of these changes are within the margin of modelling uncertainty. Further, flows for this performance measure are taken upstream of Glenmore Reservoir, limiting the appearance of benefits. In real world application, extra releases from Glenmore Reservoir would be used to augment minimum Calgary flows for effluent dilution and other purposes.	

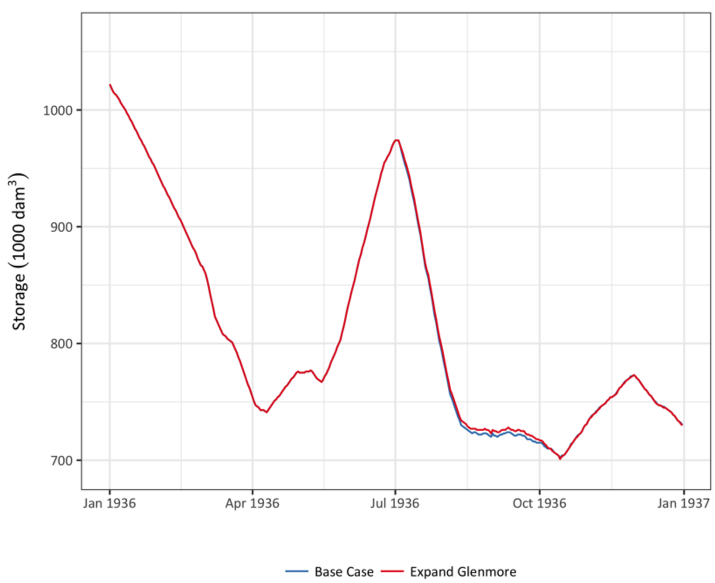


Figure 39: A comparison of total system storage between base case (Scenario A 1200 cms) and expanding Glenmore Reservoir in 1936

Scheme 2. Drought storage in expanded Glenmore Reservoir

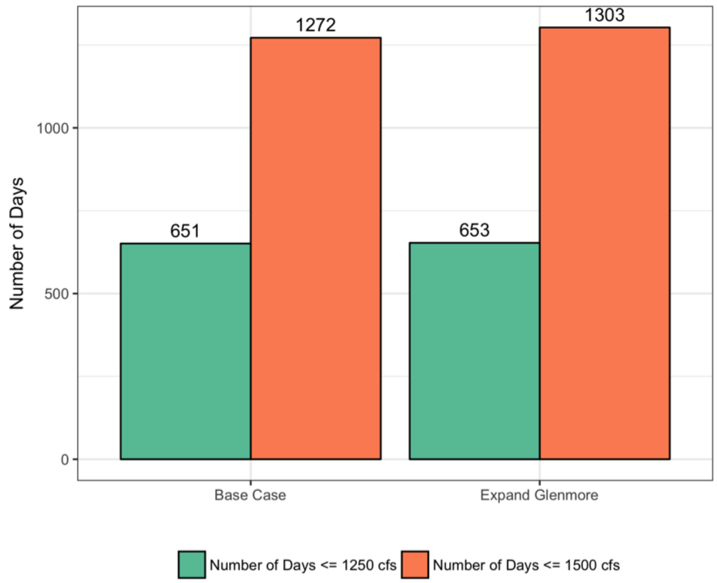


Figure 40: A comparison of the number of low-flow days (below 1,250 cfs and below 1,500 cfs) over the historical time (~29,000 days) series between base case and expanding Glenmore Reservoir

Commentary

Socio-economic and community considerations

- This scheme would be relatively inexpensive.
- Licence amendment should take <5 years.
- Issues related to this scheme could include impacts to existing licensed storage, operations and quantity for drinking water supply.

Environmental and ecological considerations

- Draw on the Bow for river dilution would be reduced, by relying on the Elbow for dilution.
- Lower Elbow River is used by brown trout in the fall and rainbow trout in the spring for spawning. Year-round rearing of juveniles for both species. Fish habitat could be impacted.
- Potential reduction to productivity of Glenmore Reservoir if drawdown amplitude increased.

Design and operational considerations

- An application to amend the *Water Act* licence would be required to use the extra capacity. Licence for storage could be operated by the Crown. Reservoir surface area and storage elevation are regulated under licence and could be amended. Conversations with AEP about licence changes have not occurred yet.
- Water licence changes could result in an additional 10,000 dam^3 that could be used for water storage.
- Using the extra storage for drought mitigation would involve operational flexibility in (and may cause impacts to) the reservoir's primary functions of (1) water supply, (2) flood

Scheme 2. Drought storage in expanded Glenmore Reservoir
mitigation and (3) recreation. • The reservoir could store water for use later in the season. • If SR1 is built, the extra 10,000 dam^3 could be used for drought storage. • Release of the extra drought protection storage would be limited by erosion and flood damage threshold on the Elbow River downstream of Glenmore Dam. A selective buyout program of the most vulnerable properties would allow for flood plain clearance that may facilitate raising release rates and thus promoting greater adaptation and balance.
Balancing potential
This scheme was assessed as having limited potential to balance the system because there was an increase in low-flow days and no increase in total system storage based on the modelling results and selected performance measures. However, based on the judgement of the group, this scheme was supported conceptually as it would offer additional well-placed capacity for relatively little cost. Therefore it was included in the list of schemes to be advanced to balance the system.

Scheme 3. Increase diversion rate of the Carseland Canal and construct debris deflector

This scheme could involve three independent actions:

- Construct a debris deflector to allow up to the current licenced rate (51 cms) to be diverted. It is currently impossible to maintain any set diversion rate much of the time because debris steadily accumulates and partially blocks the inlet. For example, if it is set at 51 cms and the inlet is cleaned in the evening, the diversion may be getting 40 cms or less by the morning, and if it is set at 30, the diversion may be getting only 25 cms by morning. This is the single most important action to take at Carseland, and the cost is under $1 million. This is a minor infrastructure project, but it is an order of magnitude cheaper than other projects which are considered minor.
- Increase the licenced diversion rate to match the physical capacity of the existing canal; probably an additional 2 to 5 cms. This could be done immediately with the existing infrastructure. Initially through a temporary diversion licence (TDL), the flow could be slowly increased to test the canal. Once tested, a permanent licence amendment would be applied for. This is an operational change.
- Consider physically increasing the capacity of the canal to some higher rate, possibly ~60 cms or higher. This would require detailed study to identify the optimum rate, followed by some construction. The existing system works well enough for the BRID, but the inability to fill these large downstream reservoirs (McGregor, Travers, Little Bow with cumulative storage of ~500,000 dam^3) more rapidly when river flows are high severely limits their ability to be used to improve overall water management. This is a minor infrastructure project. A permanent licence amendment would be required.

Actions 2 and 3 would yield better results if the debris deflector is built. For this project, the impact of the first action could not be appropriately modelled. The second and third actions were both modelled and the results are shown below.

Indicative time frame	**Indicative cost**
Implemented quickly	$5 - 50 million for the major canal upgrade

Results

In 1936, 4,000 dam^3 and 6,000 dam^3 of storage were added to the system with diversion rates of 53 cms and 60 cms, respectively (Figure 41 and Figure 42). In 1987, 27,000 dam^3 and 25,000 dam^3 of storage were added with diversion rates of 53 cms and 60 cms, respectively. Low-flow days at Calgary (below 42 cms (1,500 cfs)) decreased by 7% and 8% with 53 cms and 60 cms diversion rates, respectively. Low-flow days at Calgary (below 35 cms (1,250 cfs)) decreased by 8% and 7% with 53 cms and 60 cms diversion rates, respectively (Figure 43 and Figure 44).

Scheme 3. Increase diversion rate of the Carseland Canal and construct debris deflector

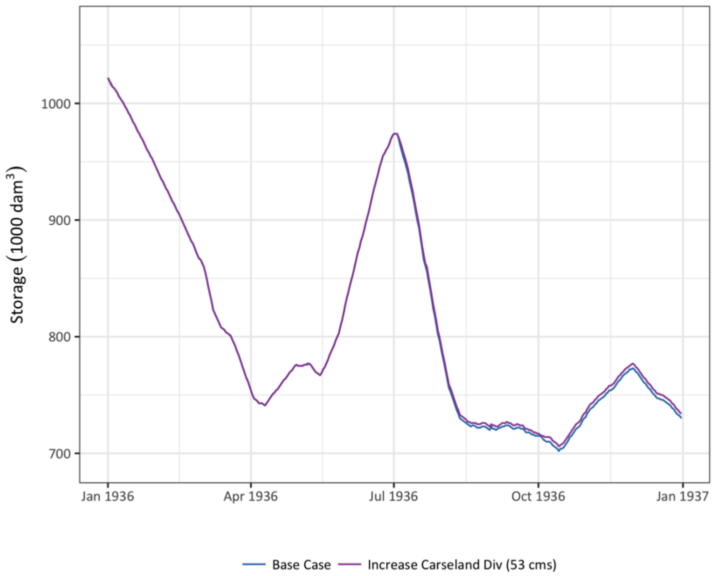


Figure 41: A comparison of total system storage between base case (Scenario A 1200 cms) and increasing the Carseland diversion rate to 53 cms in 1936

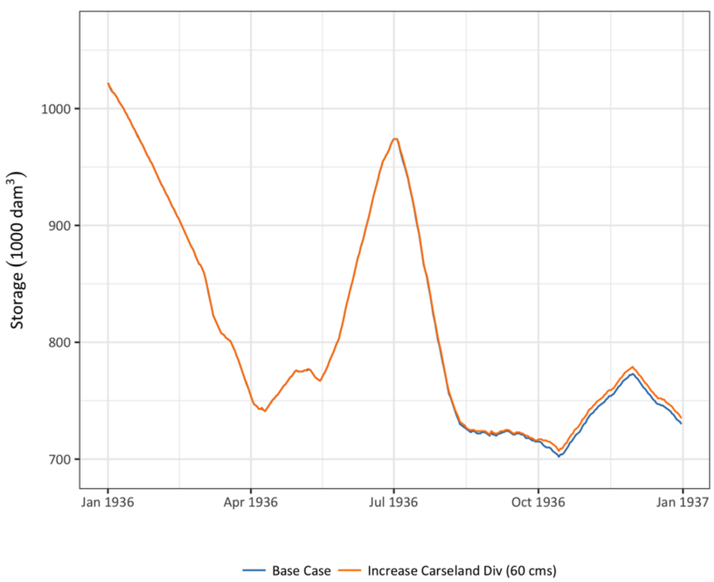


Figure 42: A comparison of total useable system storage between base case (Scenario A 1200 cms) and increasing the Carseland diversion rate to 60 cms in 1936

Scheme 3. Increase diversion rate of the Carseland Canal and construct debris deflector

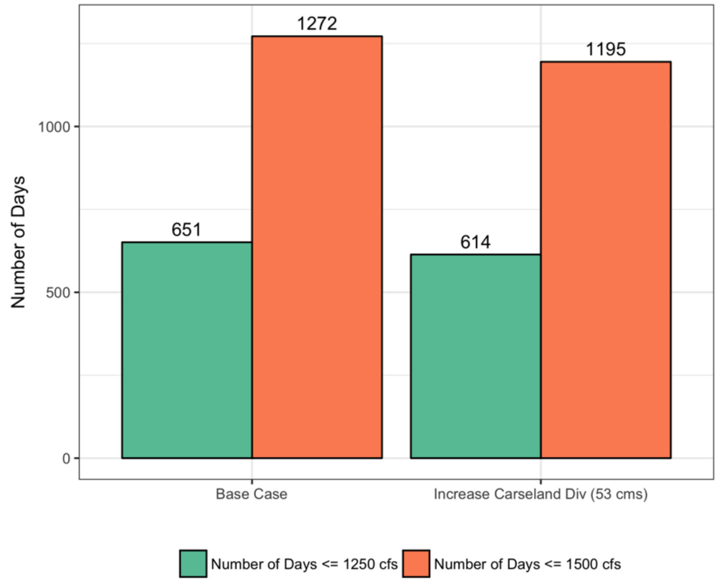


Figure 43: A comparison of the number of low-flow days (below 1,250 cfs and below 1,500 cfs) over the historical time series (~29,000 days) between base case and increasing the Carseland diversion rate to 53 cms

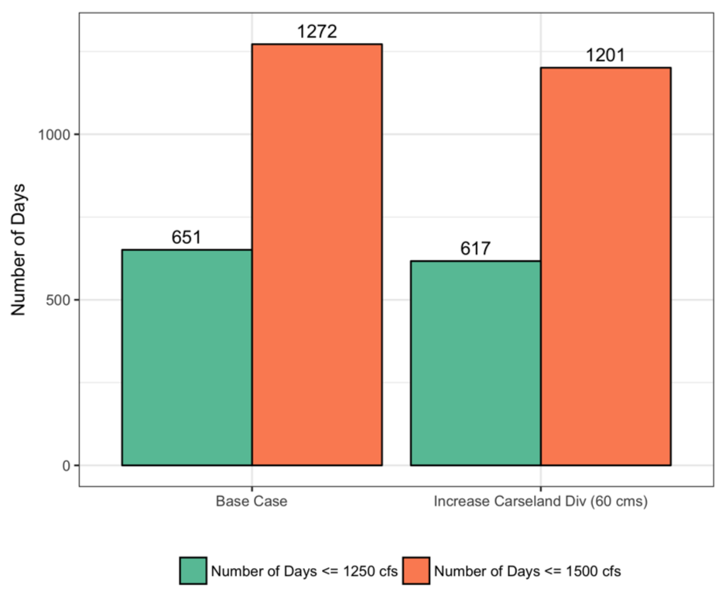


Figure 44: A comparison of the number of low-flow days (below 1,250 cfs and below 1,500 cfs) over the historical time series (~29,000 days) between base case and increasing the Carseland diversion rate to 60 cms

Scheme 3. Increase diversion rate of the Carseland Canal and construct debris deflector

Commentary

Socio-economic and community considerations

- This scheme would be relatively inexpensive.
- A feasibility study would be required, which would cost ~$60,000.
- The debris deflector could be constructed immediately and would cost <$700,000.

Environmental and ecological considerations

- Potential fish concerns regarding water temperature and entrainment should be assessed.
- If increased diversion allows a smaller % of water to be diverted (i.e., take more when flow is high and less when it is low), scheme has potential to benefit the Bow River fishery. However, if increased diversion simply results in a greater % of water to be diverted (especially under low flows) the scheme could have a detrimental impact to Bow River fisheries. This scheme would allow more diversion at high flow and will be subject to the instream objective. This scheme cannot allow more diversion at low flow because it is physically impossible to divert the current licenced rate at low flow.
- Could have a substantial benefit to fisheries if the debris deflector includes fish exclusion devices.

Design and operational considerations

- Government is currently reviewing this scheme.
- An application to amend the *Water Act* licence would be required to increase diversion rate.
- Even a flow of 60 cms may not be optimal, as there are additional changes to infrastructure that would be needed (redesign of 65 km of headworks canal and structures) but it may be possible for a relatively low cost. Feasibility study would be needed.
- Design FSL may be used to get to 53 cms immediately. Flow increase would need to be assessed based on the incremental benefit of various flow diversion levels.
- Larger capacity would increase chance of filling irrigation district reservoirs in dry years.
- This scheme would allow the irrigation district to take more water when Ghost is lowered during the spring.
- Scheme could have upstream benefits if Travers and McGregor can fill earlier and quicker because less stress would be put on the system by storing during lower demand periods rather than diverting from the Bow during high demand conditions.
- This scheme would require physical changes to the infrastructure at Carseland.
- Drop structures, irrigation intakes, large syphons and berms would have to be modified to reach the higher diversion rate.

Balancing potential

This scheme was assessed as having good potential to balance the system because it resulted in increased storage and reduced the number of low-flow days at Calgary.

Scheme 4. Raise winter carryover in downstream reservoirs (e.g., Travers/Little Bow, McGregor)	
This scheme would involve allowing Travers and McGregor reservoirs to retain additional storage over winter, rather than drawing them down to current winter levels. A 40 cm increase in winter levels in McGregor would equal 21,300 dam^3 of additional storage; this would still be 0.44 m below FSL. A 1.0 m increase at Travers/Little Bow would equal 29,000 dam^3 of additional storage; this would still be 1.13 m below FSL. The Travers spillway upgrades will be completed in 2017; the new improved service spillway gates make it possible to raise the winter level.	
Indicative time frame Implemented quickly	**Indicative cost** <$5 million
Results	
For this scheme, no storage was added to the system under a severe low-flow year (1936; Figure 45), but 22,000 dam^3 of storage was added during a moderate low-flow year (1987). Low-flow days at Calgary below 42 cms (1,500 cfs) were reduced by 1% and below 35 cms (1,250 cfs) were reduced by 2% (Figure 46).	

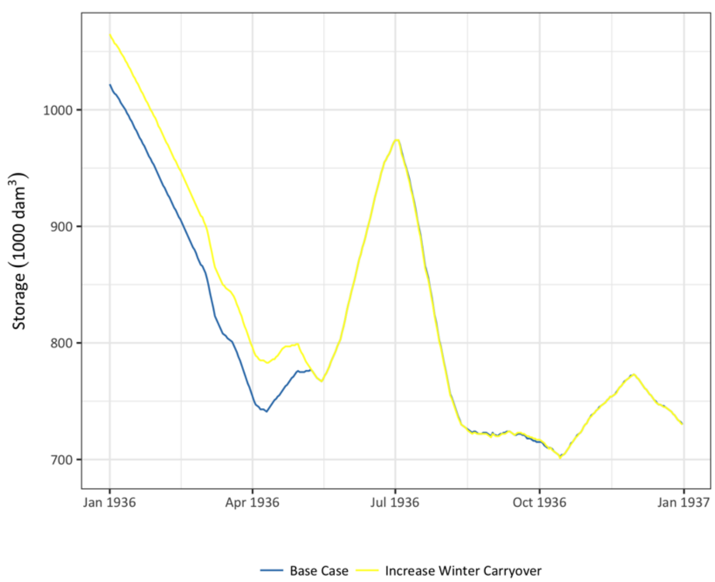


Figure 45: A comparison of total system storage between base case (Scenario A 1200 cms) and increasing winter carryover in 1936

Scheme 4. Raise winter carryover in downstream reservoirs (e.g., Travers/Little Bow, McGregor)

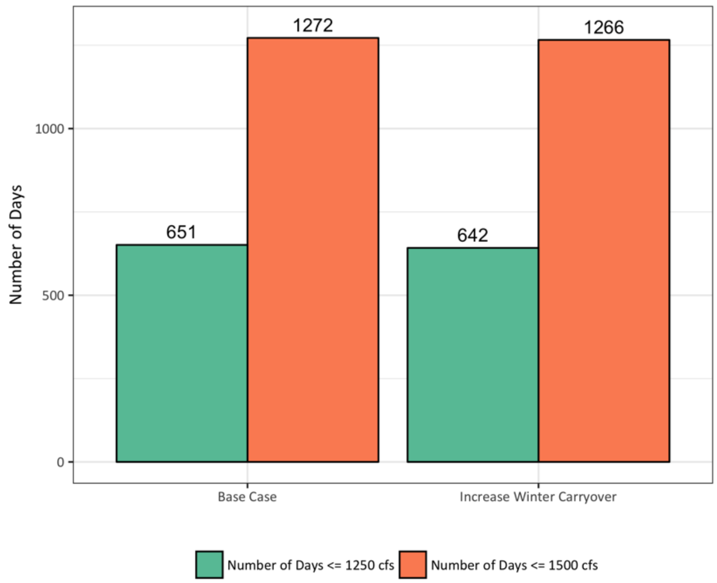


Figure 46: A comparison of the number of low-flow days (below 1,250 cfs and below 1,500 cfs) over the historical time series (~29,000 days) between base case and increasing winter carryover

Commentary

Socio-economic and community considerations

- Shoreline erosion is currently an issue in areas where developed properties are located, and raising winter levels may increase ice erosion. This could be a concern on McGregor Reservoirs; it would not be a concern for Travers/Little Bow, as it would still be operating far below the normal operating level.
- There could be concerns with loss of flood mitigation on the Little Bow River below Travers; first step would need to be a feasibility study.
- This would be very positive for recreation on Travers, where low water levels in the spring and fall related to the winter level impact boaters, and Travers is one of the most heavily used recreation lakes/reservoirs in the region.
- Scheme would cost very little to implement at Travers (<$0.05M).

Environmental and ecological considerations

- Erosion concerns would need to be investigated and fully mitigated.
- Reduced variation in water levels overall could improve habitat for fish, waterfowl and vegetation.
- Due to historic anthropogenic impacts, this site has diminished value for wildlife habitat;

Scheme 4. Raise winter carryover in downstream reservoirs (e.g., Travers/Little Bow, McGregor)
however, breeding colonies of western grebe (a threatened species) are known to occur on these two reservoirs. Any sudden water level changes in the nesting period could cause nest failure and sudden water level changes outside the nesting period would erode nesting vegetation and may cause colony abandonment, both of which are counter to the goals of the draft Western Grebe Recovery Plan. • Unknown effects of changes in water levels on fishery, particularly relating to spawning and incubation times for lake whitefish, walleye, northern pike, and burbot. However, this scheme would reduce the current fluctuations in water levels and this effect would be expected to be positive for fisheries and aquatic health. • Unknown effect of water level changes on overall productivity in system. **Design and operational considerations** • This scheme demonstrates the importance of catching water released during Ghost Reservoir's spring drawdown for other uses downstream. • Irrigation districts could draw on reservoirs in early spring as needed, reducing the need to draw water from the Bow during early spring low-flow periods. • Autumn filling occurs after peak irrigation demand. • There would be a trade-off with flood mitigation capacity for the on-stream reservoirs, e.g. Travers. • For Travers, there would be minimal impact of operating at a higher level in winter, unless much higher flows are initiated in the spring. • The gain would not be as significant for McGregor as for Travers. • Potential exists for issues caused by shoreline erosion. Further investigation by the government would be required (small cost). • Keeping McGregor at or near FSL during normal summer operations is acceptable, but during the winter months, there would likely be an operational need to keep space for spring runoff.
Balancing potential
This scheme was assessed as having moderate potential to balance the system because total system storage increased substantially during moderately dry years to support irrigation agriculture and low-flow days at Calgary were reduced slightly.

Scheme 5: Fill downstream reservoirs earlier (e.g., Travers/Little Bow)	
This scheme is already being applied to many downstream reservoirs. In this project, the group explored Travers as an example of where additional benefits could be achieved. This scheme would involve changing the operating rules of Travers reservoir to allow for earlier filling, once McGregor is full. In recent years this reservoir has been kept low until the end of June. The decision to keep this reservoir low was based on a desire to provide greater flood mitigation on the lower Little Bow River, and a new ability to do so without harming the BRID once the capacity from McGregor to Travers reservoirs was increased. It was filled near to full, prior to the irrigation season, until that work was completed. This scheme would capture unused water released from the TransAlta facilities in the spring, as well as capturing the normal high flow in June, reducing the need to capture water later in the season when flows are lower.	
Indicative time frame Implemented quickly	**Indicative cost** Nil for Travers/Little Bow
Results	

For this scheme, 1,000 dam^3 of storage was removed from the system during a severe low-flow year (1936; Figure 47), and 2,000 dam^3 of storage was added during a moderate low-flow year (1987). Low-flow days at Calgary below 42 cms (1,500 cfs) were reduced by 0.3% and below 35 cms (1,250 cfs) increased by 2% (Figure 48). In addition to these results, this scheme would create benefits for irrigation agriculture.

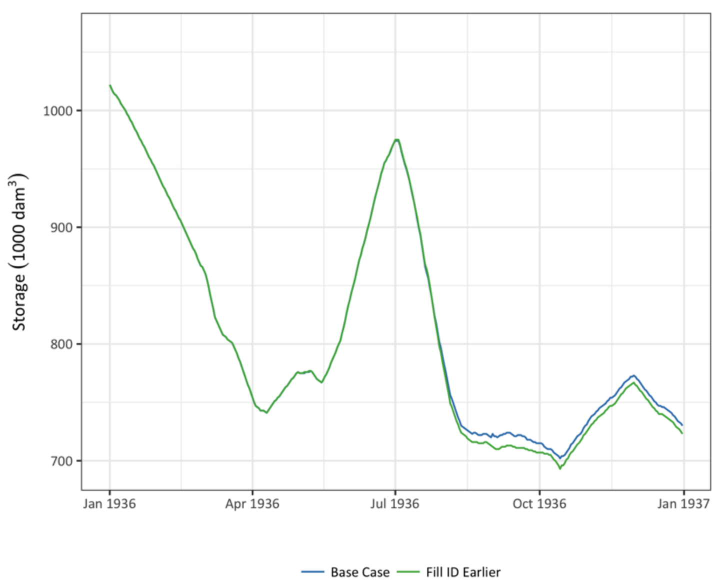


Figure 47: A comparison of total system storage between base case (Scenario A 1200 cms) and filling irrigation district reservoirs earlier in 1936

Scheme 5: Fill downstream reservoirs earlier (e.g., Travers/Little Bow)

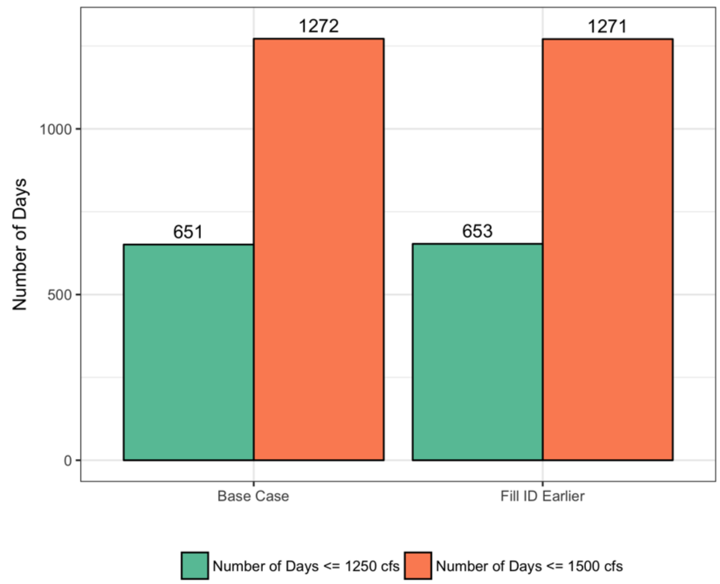


Figure 48: A comparison of the number of low-flow days (below 1,250 cfs and below 1,500 cfs) over the historical time series (~29,000 days) between base case and filling irrigation district reservoirs earlier

Commentary

Socio-economic and community considerations

- Shoreline erosion is not likely to be an issue in areas where properties are located because there are adequate setbacks to private property around Travers/Little Bow and the reservoir has historically been operated at FSL most years so unacceptable erosion will not increase.
- This scheme would be relatively inexpensive.

Environmental and ecological considerations

- Due to historic anthropogenic impacts, this site has diminished value for wildlife habitat; however, breeding colonies of Western grebe (a threatened species) are known to occur on these 2 reservoirs. Any sudden water level changes in the nesting period could cause nest failure and sudden water level changes outside the nesting period could erode nesting vegetation and cause colony abandonment, both of which are counter to the goals of the draft Western Grebe Recovery Plan.
- Unknown effects of changes in water levels on fishery, particularly relating to spawning and incubation times for lake whitefish, walleye, northern pike, and burbot.
- Unknown effect of water level changes on overall productivity in system.

Design and operational considerations

Scheme 5: Fill downstream reservoirs earlier (e.g., Travers/Little Bow)
Figure 47 and Figure 48 do not reflect the utility of this particular scheme well. In a normal to dry year, filling earlier to catch high June flows will at least result in much better downstream river conditions. In an extremely dry year where there is insufficient water to fill it may not make much difference.
Balancing potential
This scheme was assessed as having moderate potential to balance the system. The modelling results showed marginal increases in total system storage and relatively little effect on low-flow days. That said it is expected this scheme would result in better flow in the lower river later in the year in many years, may improve resilience for irrigation agriculture, and carries virtually no cost.

Scheme 6. Extend Kananaskis System water shortage mitigation operations (2016 agreement)	
This scheme would involve using storage at TransAlta facilities in Kananaskis to supplement flows in the main stem of the Bow River during low-flow periods using storage in the Kananaskis sub-basin. GoA has the ability to set intended reservoir elevations by May 1 of every year. This scheme was implemented for drought mitigation as part of the 2016 GoA Modified Operations Agreement with TransAlta.	
Indicative time frame Interim agreement already in place	**Indicative cost** $10–50 million
Results	
This scheme could not be effectively modelled and assessed against the performance measures used for the Balancing the System assessment. However, based on the conceptual understanding of the scheme and the informed opinion of the BRWG, it was strongly suggested that this scheme should be included in the list of schemes required to offset the flood mitigation schemes.	
Commentary	
Socio-economic and community considerations • To be determined in the next phase of study. **Environmental and ecological considerations** • Environmental (e.g., fisheries, instream objectives, winter flows) and social (e.g., recreational) constraints would need to be considered • The operational scheme is within the footprint of existing facilities, thereby limiting new disturbance. • The current fish management priority is to stabilize water levels on Lower Kananaskis Lakes (or at least not worsen current operations by increasing the amplitude of fluctuations) to ensure ongoing productivity is maintained or enhanced for native bull trout populations. • Decreasing productivity in Upper Kananaskis Lake by exercising lake levels is more acceptable, as the fishery is stocked. • These operational schemes were discussed with AEP Operations and Policy staff in 2016. **Design and operational considerations** • Under the 2016 agreement, there are boundary constraint conditions that limit the operations of each reservoir. • The GoA has the ability to set intended reservoir elevations by May 1 every year of the agreement. Elevations would be followed (within 10%) unless GoA directs additional water releases. • This scheme could provide 20,000–30,000 dam^3 of storage in a drought year.	
Balancing potential	
Based on the conceptual understanding of the scheme and the informed opinion of the BRWG, it	

Scheme 6. Extend Kananaskis System water shortage mitigation operations (2016 agreement)
was strongly suggested that this scheme should be included in the list of schemes required to offset the flood mitigation schemes.

7.2 Balancing the System Scenario

The schemes for balancing the system were grouped into a single scenario that the BRWG felt would be effective in balancing the system and avoiding unintended consequences of the flood mitigation previously outlined in this report (Figure 49). Scenario A would include the six schemes described:

- Scheme 1: Increase Ghost drawdown rate
- Scheme 2: Drought storage in expanded Glenmore Reservoir
- Scheme 3: Increase diversion rate of the Carseland Canal and construct debris deflector
- Scheme 4: Raise winter carryover in downstream reservoirs (e.g., Travers, McGregor)
- Scheme 5: Fill downstream reservoirs earlier (e.g., Travers/Little Bow)
- Scheme 6: Extend Kananaskis System water shortage mitigation operations (2016 agreement).

Balancing the System

Target: Offset the increased risk from the flood mitigations schemes

Increase Ghost Reservoir drawdown rate
+
Drought storage in expanded Glenmore Reservoir*
+
Increase diversion rate of the Carseland Canal and construct debris deflector*
+
Raise winter carryover in downstream reservoirs (e.g. Travers/Little Bow, McGregor)
+
Fill downstream reservoirs earlier (e.g. Travers/Little Bow)
+
Extend Kananaskis System water shortage mitigation operations (2016 agreement)

* Indicates scheme likely requiring a licence amendment

Figure 49: Scenario to balance the system

Results (Balancing the System)

Scenario A resulted in 30,000 dam^3 of storage being added to the system during a severe low-flow year (1936; Figure 50) and 72,000 dam^3 of storage being added during a moderate low-flow year (1987). Low-flow days at Calgary below 42 cms (1,500 cfs) were reduced by 16% and below 35 cms (1,250 cfs) were reduced by 30% (Figure 51).

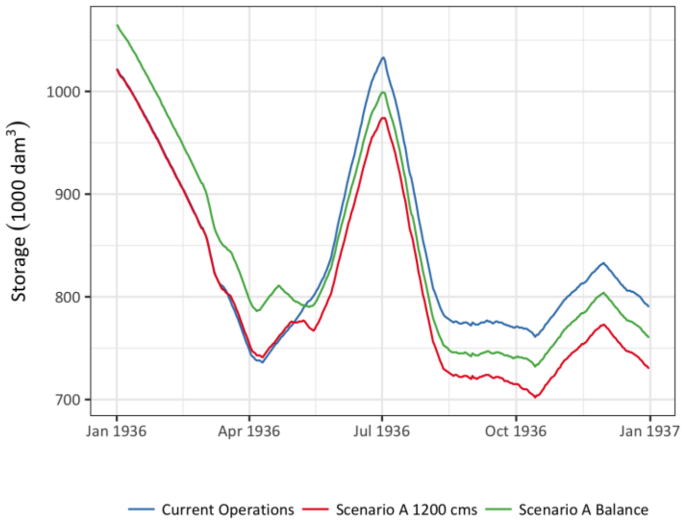


Figure 50: The impact of Scenario A Balanced on total system storage in 1936 (one year)

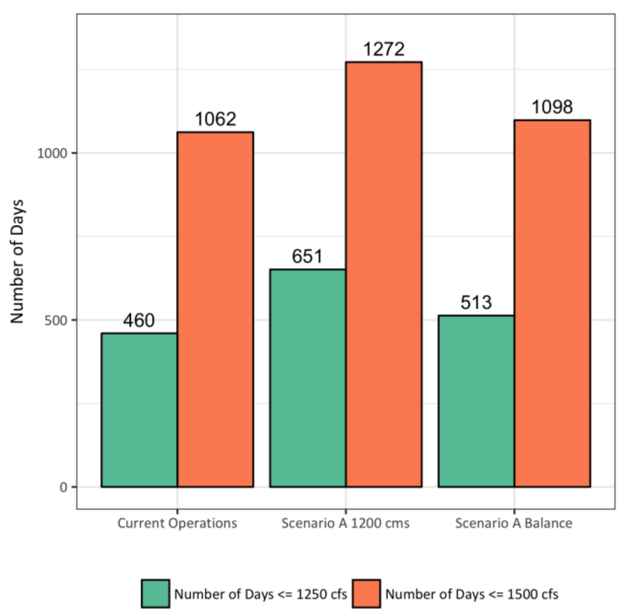


Figure 51: The impact of Scenario A Balanced on the total number of low flow days (historical time series, ~29,000 days)

Results (Balancing the System)
Commentary
• To be determined in the next phase of study.
Balancing potential
Based on these results, this scenario was considered more than adequate for offsetting the increased drought risk from implementing flood mitigation Scenario A 1,200 cms (i.e., Glenbow + operational schemes) during low-flow years, in particular the potential increased risk due to the 2016 Ghost Flood operations agreement. Acknowledging the potential unintended consequences of that agreement should not be considered a criticism of the agreement or its authors. It is a good agreement, and it is definitely in the public's best interest, but some changes in operations may be required elsewhere to avoid potential harm. There was a substantial increase in total system storage and relatively large reductions in low-flow days at Calgary.

PART III. DROUGHT MITIGATION

8.0 Drought Mitigation: Objective, Schemes, and Synthesized Drought Events

The objective for the drought mitigation assessment was to develop scenarios of potential operational and infrastructure drought mitigation opportunities to reduce the volume of licence shortages by at least 5% to 10%, while continuing to meet apportionment requirements, and with improvement, or at minimum no reduction, in ecosystem health (all relative to current operations in the same time period). This was accomplished by evaluating individual drought mitigation schemes then combining these schemes into scenarios.

Mitigation schemes assessed by the BRWG included, new infrastructure builds, upgrades or expansions of existing infrastructure, and changes to existing operations. Most of these schemes had been identified in previous projects exploring drought mitigation and storage opportunities in the Bow River Basin (MPE 2008; Alberta WaterSMART and AI-EES 2014; Amec Foster Wheeler 2015; Alberta WaterSMART, 2016; City of Calgary, 2016); other schemes were suggested by participants at BRWG meetings.

To evaluate the performance of schemes and scenarios to meet the drought objective, hydrological modelling used the historical record plus two synthesized drought events, which were developed to simulate inflow time series that stress the Bow River system beyond what has been observed in the historical record and that reflect potential impacts of climate change. Two 11-year synthesized time series of inflows were used to create the two drought events:

Drought 1: The period 1935–1945 with 1936 inflows repeated three times and 1941 inflows repeated two times
Drought 2: The same time series scaled monthly using climate change scenario data

Sections 9 and 10 summarize the results of the assessments of drought mitigation schemes and scenarios by the BRWG. A summary table showing results for all schemes and scenarios can be found in Appendix J.

9.0 Assessment of Drought Mitigation Schemes

Twelve drought mitigation schemes were assessed by the BRWG. These were over and above the six schemes covered in the Balancing the System section and also address drought mitigation. The 12 schemes were located across the Bow River Basin (Figure 52). This section describes each scheme, summarizes hydrological modelling results using the historical record and the two synthesized drought events (see Section 8), summarizes commentary from the BRWG, including an indicative time and cost estimate, and provides an assessment of drought mitigation potential. The indicative cost estimates are preliminary estimates indicating the present value of the direct costs of the scheme (capital and annual) over a 50 year life.

Some observations by the BRWG common to the drought mitigation schemes and other key points relating to the schemes are listed below.

- Operations and designs of existing infrastructure should be optimized before adding new infrastructure because the existing reservoirs in the Bow River Basin already provide some level of drought mitigation.
- Several of the structures should be built and operated to help mitigate future droughts as well as floods, and would require a clear governance and decision-making process in all aspects of structure management.
- Any mitigation would involve trade-offs. The hope is that a balanced suite of mitigation options will be pursued to increase safety and reduce risk of damage while enhancing the long-term health and resiliency of the watershed.

The 12 drought mitigation schemes assessed by the BRWG included the following:

1. Restore Spray Reservoir to full design capacity (page 155)
2. Upgrade Ghost diversion to Lake Minnewanka (page 157)
3. Extend Kananaskis System water shortage mitigation operations (2016 agreement) (page 159)
4. New storage capacity in Kananaskis system (page 161)
5. New Morley reservoir on Bow River upstream of Ghost Reservoir (page 165)
6. Expand Ghost Reservoir (by raising FSL and/or adding a low-level outlet) (page 168)
7. New Glenbow Reservoir on Bow River upstream of Bearspaw (page 170)
8. New Delacour reservoir in WID (page 172)
9. Increase WID diversion rate at all river stages without affecting licence priority date (page 174)
10. New Deadhorse Coulee reservoir in BRID (page 176)
11. Operate McGregor Reservoir at the design FSL (page 178)
12. New Eyremore reservoir low in the Bow River Basin. (page 180)

Please note six additional drought mitigation schemes were assessed by the BRWG for use in balancing the system to offset potential water storage deficit and impacts to watershed health from flood mitigation. Details of those six schemes are presented in Section 7.0.

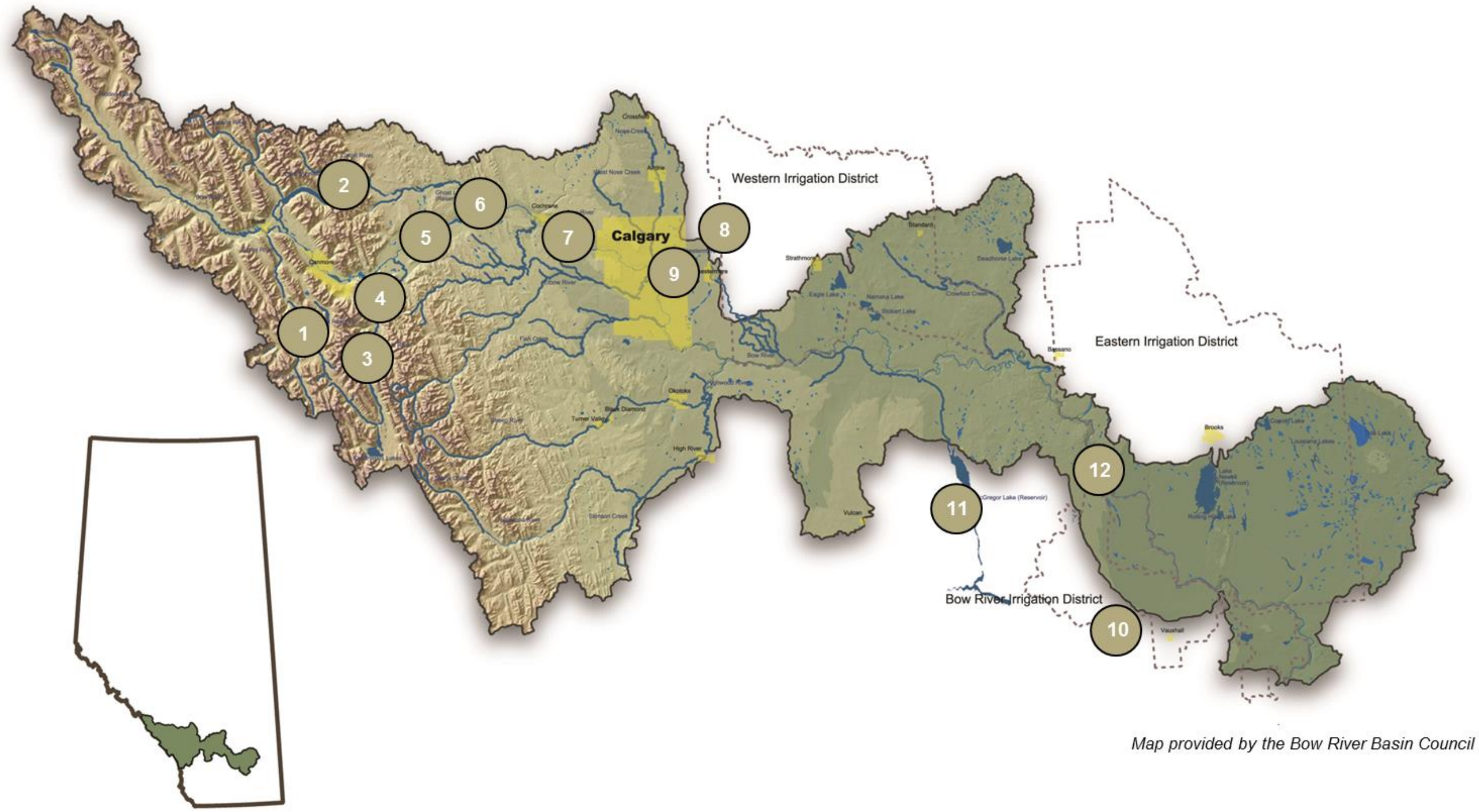


Figure 52: Locations of the 12 drought mitigation schemes in the Bow River Basin assessed by the BRWG

9.1 Schemes Assessed by the BRWG

Scheme 1. Restore Spray Reservoir to full design capacity

This scheme would involve restoring the Spray Reservoir in the headwaters near Canmore to its original design full supply level, which would result in an additional 75,000 dam^3 of storage capacity. Currently, Spray is operated ~4 m lower than design because of seepage issues at the Three Sisters dam. A technically feasible solution could be to build a cut-off wall and use internal grouting that would allow operation back to the original FSL.

Indicative time frame	Indicative cost
5–10 years	$50–100 million

Results

For this scheme, shortages were reduced by 17%, 13%, and 1% under the Historical, Drought 1, and Drought 2 time series, respectively. There were no changes to apportionment. WCO violations were reduced by 5% and 2% under the historical and Drought 1 time series, respectively, but were not reduced under Drought 2 (Table 5).

Table 5: The effect of restoring Spray Reservoir to full design capacity on shortages, WCO violations, and apportionment violations under the Historical, Drought 1, and Drought 2 time series

	Performance Improvement (relative to current operations)		
Time Series	**Total Shortages (volume)**	**New WCO Violations (Carseland to Bassano)**	**New Apportionment Violations (yes/no)**
Historical	-17%	-5%	no
Drought 1	-13%	-2%	no
Drought 2	-1%	0%	no

Commentary

Socio-economic and community considerations

- To be determined in the next phase of study.

Environmental and ecological considerations

- Potential benefit to Spray Reservoir, if annual drawdown amplitude is reduced because the need to exercise the Spray Reservoir for flood operations is negated.
- This scheme would be located in the Mountain Goat and Sheep Zone. In addition, long-toed salamander (species of special concern) and grizzly bear (threatened species) are known to occur in the project area. Due to the historic anthropogenic use of the site, however, the quality of wildlife habitat is already reduced in the immediate area of the Spray Reservoir.

Design and operational considerations

- Restoring Spray reservoir to its original FSL by grouting or other safe technological means

Scheme 1. Restore Spray Reservoir to full design capacity
could provide a cost-effective drought mitigation scheme if it were to be operated using the same annual volumes of water relative to inflows as it does now without the original FSL. This would provide for an additional ~75,000 dam^3 that would be carried over in non-drought years, keeping the reservoir at a higher level than at present but not increasing flood risk since the current operations would remain in place and with the same volume of flood mitigation storage available in the spring, which does not increase the flood threat. The feasibility of key components would be safety and price, which could be addressed with a geophysical study and engineering review to determine costs, benefits, and risks. • Refilling in only one year to the FSL would be less likely than for Scheme 1. • The usefulness of this scheme depends on how long it takes the catchment area to fill the restored storage and how urgent the refill is considered. • The refill may only be an issue if operations fully drain the storage each year. With the restored storage, the reservoir could be filled once, even if took a couple of years, and then only the required volume of water would be used, thus storing (overwintering) additional water for drought protection and slightly improving environmental conditions in the reservoir.
Drought mitigation potential
This scheme was assessed as having moderate mitigation potential. It resulted in substantial reductions in shortages under the Historical and Drought 1 time series and showed marginal benefits in terms of reducing WCO violations. Its drought mitigation potential may be higher if allowed to hold multi-year carryover, thus reducing the need to refill the newly created storage capacity every season.

Scheme 2. Upgrade Ghost River diversion to Lake Minnewanka

This scheme would involve rebuilding the Ghost diversion to be larger than original infrastructure (~15 cms capacity instead of ~8 cms capacity). Rather than building new storage capacity on the Ghost River, some of the Ghost River flow could be captured in dry years, stored in an existing upstream reservoir (Lake Minnewanka) thus moving through the TransAlta system and arriving at Ghost Reservoir later.

Indicative time frame
1–3 years

Indicative cost
$50–100 million

Results

For this scheme, shortages increased by 1% and 3% under the Historical and Drought 1 time series, respectively which is within the modelling error. This scheme is most effective if a higher Ghost Reservoir drawdown (scheme 15) and flood operations (scheme 12) are implemented; otherwise Ghost Reservoir has no available void to fill when the diverted water arrives. There was no change in shortages under Drought 2, and there were no changes to apportionment or WCO violations (Table 6).

Table 6: The effect of upgrading Ghost River diversion to Lake Minnewanka on shortages, WCO violations, and apportionment violations under the Historical, Drought 1, and Drought 2 time series

	Performance Improvement (relative to current operations)		
Time Series	**Total Shortages (volume)**	**New WCO Violations (Carseland to Bassano)**	**New Apportionment Violations (yes/no)**
Historical	1%	0%	no
Drought 1	3%	0%	no
Drought 2	0%	0%	no

Commentary

Socio-economic and community considerations

- None specified by the BRWG.

Environmental and ecological considerations

- Rebuilding of Ghost River diversion is not yet approved, and is awaiting further information on impacts to bull trout and westslope cutthroat trout populations in the upper and lower Ghost Rivers. Impacts of rebuilding Ghost Diversion are likely high for bull trout in the upper Ghost River (due to loss of flow and entrainment into diversion) and westslope cutthroat trout and bull trout in the Lower Ghost River, due to reduced flow.
- Ghost River goes underground soon after the diversion point. If the entire flow were diverted, the river could be dry further downstream where it comes back above ground.

Scheme 2. Upgrade Ghost River diversion to Lake Minnewanka
Design and operational considerations • It would need to be a controlled, not a fixed, diversion. • Before 2013, the diversion was typically used seasonally. It could be operated more frequently throughout the year to direct Ghost River flow to be stored in Lake Minnewanka. • Modelling indicated that by routing portions of the Ghost River's flow through Lake Minnewanka, the rest of the TransAlta system would be able to accommodate more storage. • Ghost River disappears under a large and lengthy boulder and gravel field soon after the diversion point. The river returns to the surface downstream due to sloping bedrock formations and carries additional groundwater at that point. However if a larger portion of the upstream flow was diverted, some accommodation may be needed for the reduced flow after the river resurfaces..
Drought mitigation potential
This scheme was assessed as having limited mitigation potential because it did not meet the drought objective to reduce shortages by at least 5% to 10% and did not reduce WCO violations.

Scheme 3. Extend Kananaskis System water shortage mitigation operations (2016 agreement)

This scheme would involve using storage at TransAlta facilities in Kananaskis to supplement flows in the main stem of the Bow River during low-flow periods using storage in the Kananaskis sub-basin. GoA has the ability to set intended reservoir elevations by May 1 of every year.

Indicative time frame	**Indicative cost**
Interim agreement already in place	$10–50 million

Results

For this scheme, shortages were reduced by 34%, 49%, and 12% under the Historical, Drought 1, and Drought 2 time series, respectively. There were no changes to apportionment.

WCO violations were reduced by 1% and 2% under the Historical and Drought 1 time series, respectively, and increased by 1% under Drought 2 (Table 7). The changes in WCO violations are considered to be within the range of modelling uncertainty; therefore, are not meaningful.

Table 7: The effect of extending Kananaskis System water shortage mitigation operations on shortages, WCO violations, and apportionment violations under the Historical, Drought 1, and Drought 2 time series

	Performance Improvement (relative to current operations)		
Time Series	**Total Shortages (volume)**	**New WCO Violations (Carseland to Bassano)**	**New Apportionment Violations (yes/no)**
Historical	-34%	-1%	no
Drought 1	-49%	-2%	no
Drought 2	-12%	1%	no

Commentary

Socio-economic and community considerations

- This scheme could provide 20,000–30,000 dam^3 of storage in a drought year.
- Environmental (e.g., fisheries, instream objectives, winter flows) and social (e.g., recreational) constraints would need to be considered.

Environmental and ecological considerations

- The operational scheme is within the footprint of existing facilities, thereby limiting new disturbance.
- Priority is to stabilize water levels on Lower Kananaskis lakes (or at least not worsen current operations by increasing the amplitude of fluctuations) to ensure ongoing productivity is maintained or enhanced for native bull trout populations.
- Decreasing productivity in Upper Kananaskis Lake by exercising lake levels is more acceptable, as the fishery is stocked.

Scheme 3. Extend Kananaskis System water shortage mitigation operations (2016 agreement)
• These operational schemes were discussed with AEP Operations and Policy staff in 2016. **Design and operational considerations** • Under the 2016 agreement, there are boundary constraint conditions that limit the operations of each reservoir. • The GoA has the ability to set intended reservoir elevations by May 1 every year of the agreement. Elevations would be followed (within 10%) unless GoA directs additional water releases.
Drought mitigation potential
This scheme was assessed as having substantial drought mitigation potential. It met the drought objectives under the Historical, Drought 1, and Drought 2 time series. It did not reduce WCO violations substantially, and there was potential for violations to increase under Drought 2 depending on operational decisions.

<table>
<tr><th colspan="2">Scheme 4. New storage capacity in Kananaskis System</th></tr>
<tr><td colspan="2">The Kananaskis River is a relatively large tributary in the upper Bow River system. There are a number of different ways by which additional storage capacity could be created in the Kananaskis system. These could include:

• Raising the FSL of Upper Kananaskis Lake. This reservoir is located in the headwaters on the Kananaskis River. Current operations result in maximum fill elevation of ~1,700 m but the design FSL is 1,702 m. Raising the reservoir by 2 m might gain ~25,000 dam^3. Operations could vary between full flood operations (the additional 2 m would be kept empty, preserved only for flood mitigation), emergency drought use storage (some or all of the new storage would be kept full, drawn on only as TransAlta storage as a whole is drawn below acceptable levels), or typical use (some or all of the expansion would be anticipated for use in a typical year, drawn down and subsequently refilled).
• A new dam and reservoir on the Kananaskis River in the headwaters upstream of Barrier Reservoir, with approximately 85,000 dam^3 of storage capacity. It would be a mixed-use reservoir (~70% dry, ~30% wet), and three times the size of Barrier, with a 25,000 dam^3 live pool.
• Expanding the existing dam or constructing a new dam to create additional storage capacity (~25,000 dam^3) at the existing Barrier Reservoir.

Any of these could be operated as per historical operations or more recent operations that include the Kananaskis System water shortage mitigation operations (2016 interim agreement). Regardless of which specific project is implemented, the result of each was an additional ~25,000 dam^3 in the Kananaskis. This, under historic operations (not the interim 2016 agreement), is what was modelled and reviewed in this project.</td></tr>
<tr><td>Indicative time frame
Up to 10-15 years depending on which specific project is implemented</td><td>Indicative cost
Up to $300-500 million depending on which specific project is implemented</td></tr>
<tr><td colspan="2">Results</td></tr>
<tr><td colspan="2">For this scheme, shortages were reduced by 5%, 2%, and 1% under the Historical, Drought 1, and Drought 2 time series, respectively. There were no changes to apportionment. WCO violations were reduced by 2% under the Historical time series, did not change under Drought 1, and increased by 1% under Drought 2 (Table 8). Note, changes in WCO violations are considered to be within the range of modelling uncertainty; therefore, are not meaningful.</td></tr>
</table>

Scheme 4. New storage capacity in Kananaskis System

Table 8: The effect of new storage in the Kananaskis System on shortages, WCO violations, and apportionment violations under the Historical, Drought 1, and Drought 2 time series

	Performance Improvement (relative to current operations)		
Time Series	**Total Shortages (volume)**	**New WCO Violations (Carseland to Bassano)**	**New Apportionment Violations (yes/no)**
Historical	-5%	-2%	no
Drought 1	-2%	0%	no
Drought 2	-1%	1%	no

Commentary

Socio-economic and community considerations

- Scheme may require moving backcountry campground(s) and/or hiking trails.
- There are existing regulatory land use requirements because of provincial park regulations, so there may need to be a reclassification of land use.
- If option 2 (new dam), there would be environmental and social consequences of a new dam in this area (issues associated with public safety and recreational access).
- If option 2 (new dam) or 3 (expanded dam), a portion of Highway 40 may need to be moved and upgraded, and valley habitat would be flooded. A benefit is that there would be a single owner for land access.
- If option 2 (new dam) or 3 (expanded dam), construction may be difficult because it is in a provincial park and Highway 40 may need to be moved. Benefit is that there would be a single owner for land access.

Environmental and ecological considerations

- This scheme is located in Mountain Goat and Sheep Zone. In addition, harlequin duck (species of special concern), long-toed salamander (species of special concern), and grizzly bear (threatened species) are known to occur in the project area and would be included in environmental impact assessments.
- If option 1 (raised UKL), Upper Kananaskis Lake is a stocked fishery so overall ecological risk is reduced.
- If option 1 (raised UKL), increase in drawdown amplitude would likely decrease lake productivity and reduce the recreational fishery value.
- If option 1 (raised UKL), potential loss of surrounding tributary habit by raising lake levels, overall fish impact low as fish not present (or rarely present) in tributary systems. Possible impact to non-fish aquatic species.
- If option 2 (new dam) or 3 (expanded dam), the Kananaskis River is a heavily impacted system due to existing hydroelectric operational requirements. Fisheries productivity in

Scheme 4. New storage capacity in Kananaskis System
Barrier Lake is relatively low due to existing operations, and construction of a new dam would likely only affect marginally productive habitats. Fish population within current Barrier Lake would likely be impacted due to isolation and reduce productivity from operation although the lost productivity in Barrier Lake would like be shifted upstream to the new reservoir. • If option 2 (new dam) or 3 (expanded dam), Additional damming on the river could add cumulative stress to the ecological system **Design and operational considerations** • There is limited variation between the lowest and highest annual inflows, resulting in predictable reservoir refill. These structures are high up in the catchment of a tributary to the Bow River, so would need to study the water availability (i.e. potential to reliably fill over a specified period). • Upper Kananaskis Lake controls 2% and Barrier controls 11% of the Bow Basin above Calgary depending on location. • This scheme should be coordinated with the 2016 GoA-TransAlta Kananaskis System Water Shortage Mitigation Agreement (Scheme 3). Additional storage under such an agreement would likely perform better (than under historic operations) because it directs water downstream for multiple uses, and does not prioritize hydro power. • Any increased storage capacity could be considered for year-to-year carryover. • Increased storage capacity may not be filled in severe droughts but could offer mitigation potential in less severe droughts. • For option 1 (raising UKL), raising the FSL would be “relatively simple.” It would involve increasing the crest elevation of two existing dams and would be a structural build. Relatively little land would be needed because it is in a steep basin. • For option 1 (raising UKL), the 2016 Ghost agreement already keeps the reservoir higher (it is part of the Kananaskis water bank), although this condition was not assumed in modelling. • For option 2 (new dam), construction would be difficult if a new dam were located at the upstream end of the existing Barrier Reservoir. • For option 3 (expanded dam), if storage increased through an expanded Barrier Lake, may offer more hydro-generation potential than a new dam because of potential for head increases. • For option 3 (expanded dam), scheme would impact Barrier operations: Barrier is currently operated to fluctuate levels for hydropower peaking and somewhat for recreation.
Drought mitigation potential
This scheme was assessed as having limited mitigation potential because it did not meet the drought objectives to reduce shortages by 5% to 10%, there was relatively little benefit in terms of reducing WCO violations, and had no meaningful effects on WCO violations. However, this storage was

Scheme 4. New storage capacity in Kananaskis System
modelled as if operated by TransAlta for primarily hydropower purposes as if the 2016 agreement with TransAlta were not extended. When combined with GoA operation of the Kananaskis Dams, one should expect substantially greater performance.

Scheme 5. New Morley reservoir on Bow River upstream of Ghost Reservoir

This scheme would involve a new dam on the Bow River in a wide floodplain area upstream of Ghost Reservoir. This dam could be 150,000 dam^3 of storage. In this assessment, 75,000 dam^3 of that storage capacity was assumed to be used for water storage and drought mitigation while still offering 75,000 dam^3 for flood mitigation potential.

Indicative time frame	Indicative cost
15–20 years	>$500 million

Results

For this scheme, shortages were reduced by 55%, 54%, and 13% under the Historical, Drought 1, and Drought 2 time series, respectively. There were no changes to apportionment. WCO violations were reduced by 11%, 9%, and 2% under the Historical, Drought 1, and Drought 2 time series, respectively (Table 9).

Table 9: The effect of a new Morley reservoir on shortages, WCO violations, and apportionment violations under the Historical, Drought 1, and Drought 2 time series

	Performance Improvement (relative to current operations)		
Time Series	Total Shortages (volume)	New WCO Violations (Carseland to Bassano)	New Apportionment Violations (yes/no)
Historical	-55%	-11%	no
Drought 1	-54%	-9%	no
Drought 2	-13%	-2%	no

Commentary

Socio-economic and community considerations

- This site may be limited to no greater than 30 m to avoid impacts on Highway 1A and the CPR line.
- This site would be located entirely within Stoney Nakoda First Nations reserve lands. The cost estimate does not include substantial cost and time for land negotiations. The recent project on the southwest ring road may give some indication of the time, cost, and process of negotiation.
- This scheme could offer substantially more reservoir capacity for drought mitigation (~75,000 dam^3) than the Glenbow scheme (Scheme 7, ~10,000 dam^3) for a similar infrastructure investment cost.

Environmental and ecological considerations

- Impact of habitat loss to Mountain Whitefish is unknown, but presumably negative.

Scheme 5. New Morley reservoir on Bow River upstream of Ghost Reservoir
• This section of the Bow River is highly fragmented by two upstream dams and Ghost Dam downstream. Creation of a new fish passage barrier in the system will further fragment the reach and have unknown (but presumably negative) impacts on existing mountain whitefish populations. • AEP Wildlife Management does not manage wildlife within the First Nation, therefore will not provide specific comments regarding risks to wildlife. There is likely moderate wildlife habitat quality in the project area so sensitive species, such as grizzly bear, harlequin duck, and several species of bird may be impacted by this scheme. • Downstream of Calgary fisheries impact may be improved by this scheme depending on operational decisions. **Design and operational considerations** • This scheme would control runoff from about 68% of the contributing area of the Bow River at Calgary. • There would be geotechnical challenges specific to this scheme (e.g., difficult topographical cut-off for dam construction). • An advantage of this scheme is that it would control approximately half of the basin upstream of Calgary and would alleviate some mitigation pressure on Ghost Reservoir. • This scheme could have opportunities for drought mitigation and water storage, as well as hydropower, because of its large size. • If the Ghost diversion to Lake Minnewanka is not rebuilt, this scheme may be needed to store more of the flow on the Bow River, to enable Ghost Reservoir to manage the high inflow from Ghost River. • The Amec Foster Wheeler (2015) flood storage report noted that this reservoir could be twice as big as the Glenbow reservoir, but it would be located upstream of Jumpingpound Creek, which can be a significant contributor to flooding depending on where the rain falls. • Morley dam could hold back flows in the main stem allowing Ghost dam to manage the Ghost high flows and reduce peak flows downstream to offset Jumpingpound inflows. • Further investigation would be needed to confirm whether Glenbow or Morley is a better mitigation scheme; the relative benefits of the two schemes will likely be different if assessed as flood mitigation schemes only or water management schemes offering both flood and drought mitigation. • This size of the reservoir, used in coordination with Ghost Reservoir, allows some storage to be maintained to mitigate a potential drought, while still able to manage a moderate flood. Specific design and operating criteria would need to be built into the scheme to be adaptable for both flood and drought mitigation.
Drought mitigation potential
This scheme was assessed as having substantial mitigation potential in terms of reducing shortages

Scheme 5. New Morley reservoir on Bow River upstream of Ghost Reservoir
and downstream WCO violations. The scheme performed well under the Historical, Drought 1, and Drought 2 time series, suggesting it is a reliable source of water for drought mitigation.

Scheme 6. Expand Ghost Reservoir (by raising FSL and/or adding a low-level outlet)

This scheme would involve expanding Ghost Reservoir on the Bow River upstream of Cochrane. One version of the expansion would increase storage at the site by approximately 30,000 dam^3 by raising the height of the dam by 3 m. A second version would expand storage by 60,000 dam^3 by raising the height of the dam and installing a low-level outlet. Operations could vary between three modes:

- Full flood operations: the additional ~3 m would be kept empty, preserved only for flood (i.e., operate as empty at all times except during a flood).
- Emergency drought use storage: some or all of the new storage would be kept full, drawn on only as TransAlta storage as a whole is drawn below acceptable levels.

Typical use: some or all of the expansion would be anticipated for use in a typical year, drawn down and refilled.

Indicative time frame	**Indicative cost**
10–15 years	>$500 million

Results

For this scheme, two storage volumes were used: 30,000 dam^3 and 60,000 dam^3. Under the Historical time series, shortages were reduced by 49% with an additional 30,000 dam^3 of storage and by 55% with an additional 60,000 dam^3 of storage.

Under Drought 1, shortages were reduced by 41% with an additional 30,000 dam^3 of storage and by 53% with an additional 60,000 dam^3 of storage. Under Drought 2, shortages were reduced by 13% with an additional 30,000 dam^3 of storage and by 10% with an additional 60,000 dam^3 of storage. There were no changes to apportionment. WCO violations were reduced by 5% for both storage volumes under the historical and Drought 1 time series and by 2% under Drought 2 (Table 10).

Table 10: The effect of expanding Ghost Reservoir on shortages, WCO violations, and apportionment violations under the Historical, Drought 1, and Drought 2 time series for the two storage volumes (30,000, 60,000 dam^3)

	Performance Improvement (relative to current operations)					
Time Series	Total Shortages (volume)		New WCO Violations (Carseland to Bassano)		New Apportionment Violations (yes/no)	
	30k	60k	30k	60k	30k	60k
Historical	-49%	-55%	-5%	-5%	no	no
Drought 1	-41%	-53%	-5%	-5%	no	no
Drought 2	-13%	-10%	-2%	-2%	no	no

Scheme 6. Expand Ghost Reservoir (by raising FSL and/or adding a low-level outlet)
Commentary
Socio-economic and community considerations • Raising the dam by ~3 m may impact all or some of the railway, reserve, private land, and village. • This project would probably be easier than Morley (Scheme 5), given that it is smaller and on an existing reservoir footprint. **Environmental and ecological considerations** • If the expansion of the reservoir results in a reduction in the annual variation in the reservoir level, this would offer environmental and recreational benefits. **Design and operational considerations** • If the reservoir were to be expanded, it would likely be coupled with faster drawdown (see Scheme 15 in Section 5.1 and Scheme 1 in Section 7). Faster drawdown would enable Ghost Reservoir to be held higher yet still offer the same flood mitigation thus reducing the risk posed by a deeper drawdown during flood threat years. • Construction would be challenging: a new dam is essentially built on an existing dam. • Consideration should be given to how to use the additional space—before and after flood risk has been determined low from a drought management perspective—if it is able to refill. • Even with current operating rules, 36,000 dam^3 of water supply storage could be made available relatively easily at Ghost in a drought year.
Drought mitigation potential
This scheme was assessed as having substantial mitigation potential given that it met the drought objective to reduce shortages by 5% to 10% under the Historical, Drought 1, and Drought 2 time series. There were also reductions in downstream WCO violations. This scheme would involve the same upgrades to Ghost Dam as for flood mitigation, and provide for flexible and adaptive situational management.

Scheme 7. New Glenbow reservoir on Bow River upstream of Bearspaw

This scheme would involve a new dam and reservoir on Bow River upstream of Bearspaw that would have a total storage capacity of ~70,000 dam^3. In this assessment, 10,000 dam^3 of that capacity is used for water storage and drought mitigation while the remaining 60,000 dam^3 is held empty for flood mitigation.

Indicative time frame	Indicative cost
15–20 years	>$500 million

Results

For this scheme, shortages were reduced by 21%, 18%, and 1% under the Historical, Drought 1, and Drought 2 time series. There were no changes to apportionment or WCO violations except for a 1% increase in WCO violations under Drought 2 (Table 11). Note, changes in WCO violations are considered to be within the range of modelling uncertainty; therefore, are not meaningful.

Table 11: The effect of a new Glenbow reservoir on shortages, WCO violations, and apportionment violations under the Historical, Drought 1, and Drought 2 time series

	Performance Improvement (relative to current operations)		
Time Series	**Total Shortages (volume)**	**New WCO Violations (Carseland to Bassano)**	**New Apportionment Violations (yes/no)**
Historical	-21%	0%	no
Drought 1	-18%	0%	no
Drought 2	-1%	1%	no

Commentary

Socio-economic and community considerations

- Proposed location of dam is in Glenbow Provincial Park, so it would affect wildlife, recreation, riparian areas, and possibly the CPR line.
- A live pool reservoir above the dead storage in a park could be an amenity.
- Dam may conflict with development pressures west of Calgary, but it could have fewer land ownership/tenure issues than Morley (Scheme 5).
- Nearly the full flood mitigation capacity of the facility (it would be kept mostly dry) would be maintained, while offering meaningful storage volume for water supply value to Calgary and other users.
- Reservoir may have recreational potential, however if this scheme is implemented, it should be an operating reservoir, not a recreational development that would limit its use.

Environmental and ecological considerations

- Although there will be permanent loss of lotic habitat in the new reservoir portion above the

Scheme 7. New Glenbow reservoir on Bow River upstream of Bearspaw
dam, impacts will be on non-native rainbow trout and native mountain whitefish. • Rainbow Trout would still be able to access their major spawning tributary (Jumpingpound Creek). • Impact of habitat loss to Mountain Whitefish is unknown, but presumably negative. • Fish population within current Bearspaw Reservoir would likely be severely impacted due to isolation and reduce productivity, though the lost productivity in Bearspaw Reservoir would like be shifted upstream to the new reservoir. • Located in Key Wildlife and Biodiversity Zone as well as several species within the Sensitive Raptor Range, including bald eagle, golden eagle, and prairie falcon. Due to the historic anthropogenic use of the site, however, the quality of wildlife habitat is lower at this location. **Design and operational considerations** • The reservoir would control runoff from an area >95% of Bow Basin above Calgary. • It may be possible for the Glenbow facility to have a relatively small live pool that could regulate releases for downstream flow augmentation, licences, etc. If Calgary can accommodate ~600 cms release, a live pool of ~13,000 dam^3 could be drained in ~6 hours. • Operations would need to be synchronized with Ghost Reservoir operations. The Ghost's maximum drawdown rate in particular must be considered, as that reservoir could form a bottleneck. • One scheme might include ~20% of the capacity (10,000–15,000 dam^3) in a live pool that could be drawn down very fast if forecasts suggest a flood. This project is onstream, so a live pool would likely be required even if the facility were intended for flood mitigation.
Drought mitigation potential
This scheme was assessed as having moderate mitigation potential; however, the total storage volume was not as large as Morley (Scheme 5) and therefore does not offer the same level of drought mitigation. The scheme met the drought objective for shortages under the Historical and Drought 1 time series and showed very minor improvement under Drought 2. WCO violations were not reduced under the Historical and Drought 1 time series and increased under Drought 2.

Scheme 8. New Delacour reservoir in WID

This scheme would use topography and diking to create a new reservoir in the WID with 26,000 dam^3 of storage capacity. It would require early filling (during high runoff) and would work in conjunction with the revision to the WID licence (Scheme 9). It would be operated to deliberately preserve upstream storage so that the WID would not need to and, as modelled in this project, could not place a licence priority call to fill this reservoir. This reservoir would only serve demands not fed by Langdon Reservoir, thereby reducing the demands that are unable to be fed by stored water, decreasing reliance on river diversions while maintaining reliability of the water supply.

Indicative time frame	**Indicative cost**
5–10 years	$50–100 million

Results

For this scheme, shortages were reduced by 39%, 32%, and 9% under the Historical, Drought 1, and Drought 2 time series, respectively. There were no changes to apportionment. WCO violations did not change under the Historical time series, were reduced by 1% under Drought 1, and increased by 2% under Drought 2 (Table 12). Note, changes in WCO violations are considered to be within the range of modelling uncertainty; therefore, are not meaningful.

Table 12: The effect of a new Delacour reservoir on shortages, WCO violations, and apportionment violations under the Historical, Drought 1, and Drought 2 time series

	Performance Improvement (relative to current operations)		
Time Series	**Total Shortages (volume)**	**New WCO Violations (Carseland to Bassano)**	**New Apportionment Violations (yes/no)**
Historical	-39%	0%	no
Drought 1	-32%	-1%	no
Drought 2	-9%	2%	no

Commentary

Socio-economic and community considerations

- This scheme would be located on high-value land. Land acquisition price is currently unknown, but this scheme would require 1,500 acres of land and three structures. Cost would be ~$25 million for just the infrastructure.
- Reservoir could be used for recreation.
- A small section of McKnight Boulevard would be flooded.
- Local citizens may perceive location as less obtrusive in comparison to other facilities being considered. This site has been previously discussed as a potential irrigation district storage facility.

Scheme 8. New Delacour reservoir in WID
Environmental and ecological considerations • If storage reduces WID demand during lower flows, increased water in the river has a potential beneficial impact to the Bow River fishery and other users. • This area is largely low quality wildlife habitat due to previous anthropogenic impacts. However, appropriate wildlife mitigations may need to be implemented to limit impacts within the Sensitive Raptor Range and to many sensitive bird species, including burrowing owl, piping plover, and great blue heron. **Design and operational considerations** • This scheme is well placed in the Bow system, potentially benefiting a large number of downstream irrigators (means WID can divert less flow during peak demand periods using storage, and more when demand is lower and flows potentially higher so more water is available in the river for other purposes). • With cooperation among the irrigation districts, new off-stream storage anywhere in the system can benefit both upstream and downstream users as well as environmental conditions. • Although located in Red Deer Basin, this reservoir would store Bow water and impact the Bow system because it would divert flows from the Bow River. • This scheme had an overall feasibility score of “B” in the storage assessment report by MPE (2008). • The reservoir could also be used for Rocky View County and Wheatland County supply. • The reservoir would be located at the top of the WID system and would work well with the existing canal system. • There are local areas of soft-weathered shale. • Evaporative loss would be a concern. • The reservoir could also be used as a stormwater management facility, but this could result in water quality and sedimentation issues (as per Chestermere Lake). • No new withdrawal licence would be needed. • WID would gain much needed storage.
Drought mitigation potential
This scheme was assessed as having substantial drought mitigation potential and met the drought objectives under the Historical, Drought 1, and Drought 2 time series. WCO violations did not meaningfully change under the Historical or Drought 1 time series; however, they increased slightly under Drought 2.

Scheme 9. Increase WID diversion rate at all river stages without affecting licence priority date

This scheme would revise the licensed WID diversion to add an additional 5.6 cms at each river stage level. Original priority would be retained for the original diversion rates; the new diversion rates may be subject to a new priority. Current WID diversion limits are:

- 13 cms when flows are below 143 cms
- 17 cms when flows are below 297 cms
- 21 cms when flows are above 297 cms

This scheme would allow the WID to withdraw more water during higher flows to help fill future storage needs and reduce the need to divert during low flows. This would be especially beneficial if Ghost Reservoir were to make early season releases to prepare for flood mitigation.

Indicative time frame	**Indicative cost**
<5 years	<$5 million

Results

Shortages were reduced by 16% and 13% under the Historical and Drought 1 time series, respectively, but were not reduced under Drought 2. There were no changes to apportionment or WCO violations, except for a 1% reduction in violations under Drought 1 (Table 13). Note, changes in WCO violations are considered to be within the range of modelling uncertainty; therefore, are not meaningful.

Table 13: The effect of a WID licence revision on shortages, WCO violations, and apportionment violations under the Historical, Drought 1, and Drought 2 time series

	Performance Improvement (relative to current operations)		
Time Series	**Total Shortages (volume)**	**New WCO Violations (Carseland to Bassano)**	**New Apportionment Violations (yes/no)**
Historical	-16%	0%	no
Drought 1	-13%	-1%	no
Drought 2	0%	0%	no

Commentary

Socio-economic and community considerations

- If the WID takes more water earlier and a storage void exists, then more water could remain in the Bow River or in storage (if available) for later in year.
- An amendment to the *Water Act* licence would be required, which could be involved.
- An understanding or agreement between the irrigation districts would mitigate concerns caused by the licence change.

Scheme 9. Increase WID diversion rate at all river stages without affecting licence priority date
• No infrastructure changes would be involved, so scheme would be relatively inexpensive. • Licence amendment should take <5 years. • Other irrigation districts will need to evaluate the impact on their own operations. **Environmental and ecological considerations** • If increased diversion allows a smaller % of water to be diverted (i.e., take more when flow is high and less when it is low), scheme has potential to benefit the Bow River fishery, which could be built into the amended licence. However, if increased diversion simply results in a greater % of water to be diverted (especially under low flows) the scheme would likely have a detrimental impact to Bow River fisheries. **Design and operational considerations** • WID storage is currently too small (lasts 1.5 weeks currently). • Diversion is currently 13 cms at low flow stage, but if it were higher (e.g. the 21 cms currently allowable at high flow stage) the WID would still benefit if there were additional storage for that water given that the higher stages are when TransAlta reservoirs are releasing water for flood mitigation. This water can be captured and stored rather than released downstream. • This would require a significant licence change. • Formal agreement would be needed between irrigation districts to ensure no other licenced user is adversely impacted. • WID is constrained by the diversion, so this scheme would enable WID to use Langdon Reservoir and any new storage sites more effectively.
Drought mitigation potential
This scheme was assessed as having moderate drought mitigation potential if combined with additional WID storage, for example a new Delacour reservoir, because it met the drought objectives under the Historical and Drought 1 time series. There was a negligible reduction in WCO violations under Drought 1.

Scheme 10. New Deadhorse Coulee reservoir in BRID

This scheme would involve a new dam on the BRID main canal where it flows through a coulee east of the Little Bow River and directly west of Vauxhall with about 28,000 dam^3 of storage. It would provide off-stream storage in the BRID and would fill off the Carseland diversion between May and October. Similar to a new Delacour reservoir, this scheme was modelled in this project to be operated to deliberately preserve upstream storage so that the BRID could not place a licence priority call to fill this reservoir.

An update was provided by the BRID after the last BRWG meeting: The most cost effective option would give 26,400 dam^3 at a total cost of $46.1 million including land acquisition.

Indicative time frame	**Indicative cost**
3–5 years	$5 - 50 million

Results

For this scheme, shortages were reduced by 16% and 14% under the Historical and Drought 1 time series; there were no reductions in shortages under Drought 2. There were 2% and 1% reductions in WCO violations under the Historical and Drought 1 time series, respectively. There were no changes to apportionment (Table 14). Note, changes in WCO violations are considered to be within the range of modelling uncertainty; therefore, are not meaningful.

Table 14: The effect of a new Deadhorse Coulee reservoir on shortages, WCO violations, and apportionment violations under the Historical, Drought 1, and Drought 2 time series

	Performance Improvement (relative to current operations)		
Time Series	**Total Shortages (volume)**	**New WCO Violations (Carseland to Bassano)**	**New Apportionment Violations (yes/no)**
Historical	-16%	-2%	no
Drought 1	-14%	-1%	no
Drought 2	0%	0%	no

Commentary

Socio-economic and community considerations

- Although this reservoir would be located in Oldman Basin, it would store Bow River water and impact the Bow River Basin.
- The benefit of this scheme would support irrigation in the BRID. However, and perhaps more importantly, it would benefit all users as additional storage would enable the BRID to not divert water during drought or low-flow periods while the storage is being used, thus enhancing the flow remaining in the Bow.
- In times of drought, water could be shared with livestock producers and municipalities.

Scheme 10. New Deadhorse Coulee reservoir in BRID
• Land acquisition could be expensive. **Environmental and ecological considerations** • The proposed location is on farmland, which would limit environmental impacts. • Appropriate wildlife mitigations must be studied in the environmental assessment to limit impacts to sensitive bird species, including burrowing owl, peregrine falcon, and prairie falcon as well as nests of piping plover, great blue heron and colonial nesting birds. • If increased diversion allows a smaller % of water to be diverted (i.e., take more when flow is high and less when it is low), scheme has potential to benefit the Bow River fishery and this could be built into the licence. **Design and operational considerations** • There may be challenges with filling in dry years, however, one of the biggest benefits of reservoirs is that they can be filled in wet years and then used in a following dry year. • Proposed site would be good from a technical perspective. • Scheme would be enhanced by increased diversion off of Carseland (see Section 7, Scheme 3) however would also be viable during normal years without the diversion increase. • Construction would be relatively inexpensive however proposed location is on privately owned land, so land acquisition could be expensive. • Scheme had an overall feasibility score of “A” (the highest possible score) in the storage assessment report by MPE (2008), but it was flagged for incomplete information in that assessment. • A consultant for the BRID recently completed an investigation of the viability of this project.
Drought mitigation potential
This scheme was assessed as having moderate drought mitigation potential because it met the drought objectives under the Historical and Drought 1 time series. WCO violations were somewhat reduced and did not increase under any of the time series.

Scheme 11. Operate McGregor Reservoir at the design FSL

This scheme would involve operating McGregor to its design FSL, which would be ~25 cm higher than current operations and equal ~13,000 dam^3 of storage gained. The reservoir is currently operated lower because of erosion concerns and risk to property.

Indicative time frame	Indicative cost
5–10 years	<$5 million

Results

For this scheme, shortages were increased by 2% under the Historical time series, did not change under Drought 1, and were reduced by 1% under Drought 2. There were no changes to apportionment. WCO violations were reduced by 1% under the Historical and Drought 1 time series, but there were no changes in WCO violations under Drought 2 (Table 15). Note, changes in WCO violations are considered to be within the range of modelling uncertainty; therefore, are not meaningful.

Table 15: The effect of operating McGregor Reservoir at the design FSL on shortages, WCO violations, and apportionment violations under the Historical, Drought 1, and Drought 2 time series

	Performance Improvement (relative to current operations)		
Time Series	**Total Shortages (volume)**	**New WCO Violations (Carseland to Bassano)**	**New Apportionment Violations (yes/no)**
Historical	2%	-1%	no
Drought 1	0%	-1%	no
Drought 2	-1%	0%	no

Commentary

Socio-economic and community considerations

- Compensation may be required for landowners who lose land because of erosion.
- This scheme would need further study to determine its relative cost benefit.

Environmental and ecological considerations

- Increasing McGregor to FSL would include a study of potential impacts on sensitive shoreline species at risk.
- Erosion concerns would need to be investigated.
- Due to historic anthropogenic impacts, this site has diminished value for wildlife habitat; however, breeding colonies of Western grebe (a threatened species) are known to occur on this reservoirs. Any sudden water level changes in the nesting period could cause nest failure and sudden water level changes outside the nesting period could erode nesting vegetation and cause colony abandonment, both of which are counter to the goals of the draft Western Grebe Recovery Plan.

Scheme 11. Operate McGregor Reservoir at the design FSL
• Likely few fisheries concerns relative to current operations, however if within season operational changes occur (i.e. large fluctuations in water levels), would need to assess changes in productivity. • Unknown effect of water level changes on overall productivity in system. • If increased diversion allows a smaller % of water to be diverted (i.e., take more when flow is high and less when it is low), scheme has potential to benefit the Bow River fishery. **Design and operational considerations** • The GoA is currently reviewing this scheme internally, in particular with respect to shoreline erosion, property risk, and species at risk. • This scheme would benefit from increased capacity at the Carseland diversion to fill the reservoir in dry years by diverting earlier when flows may be highest (see Section 7, Scheme 3). Further benefit would come from filling the extra capacity in a wet or normal year for use in a following dry year.
Drought mitigation potential
This scheme was assessed as having limited drought mitigation potential because it did not meet the 5%–10% reduction in shortages. WCO violations and apportionment did not change meaningfully; however, they were not worse than current operations. Based on discussion, the BRWG agreed that while this scheme does not show improvements in the performance measures used in the modelling, there was conceptual support for this scheme that offers additional well-placed storage capacity at relatively low cost. Therefore it was considered one of the most promising schemes for drought mitigation.

Scheme 12. New Eyremore reservoir low in Bow River Basin

This scheme would involve constructing a large new dam on the lower Bow (up to 300,000+ dam^3), with the reservoir reaching back to the Bassano Dam. This dam would allow the Eastern Irrigation District (EID) to functionally draw the Bow River down to nearly zero flow (~3 cms), because the Eyremore dam would be able to release the 11 cms minimum flow requirement during droughts and much higher flow under most conditions for downstream South Saskatchewan River environmental needs and apportionment.

Indicative time frame	Indicative cost
15–20 years	>$500 million

Results

For this scheme, shortages were reduced by 66%, 63%, and 47% under the Historical, Drought 1, and Drought 2 time series. There were no changes to apportionment, but there is potential to not meet apportionment during severe droughts if the refill timing is not managed appropriately. WCO violations were reduced by 5% under the Historical time series, 10% under Drought 1, and 13% under Drought 2 (Table 16).

Table 16: The effect of a new Eyremore reservoir on shortages, WCO violations, and apportionment violations under the Historical, Drought 1, and Drought 2 time series

	Performance Improvement (relative to current operations)		
Time Series	**Total Shortages (volume)**	**New WCO Violations (Carseland to Bassano)**	**New Apportionment Violations (yes/no)**
Historical	-66%	-5%	no
Drought 1	-63%	-10%	no
Drought 2	-47%	-13%	Potentially

Commentary

Socio-economic and community considerations

- This scheme may have small hydropower potential and recreational opportunities.
- Proposed location is on public, private, and First Nations land, all with a range of land uses.
- This scheme would have flood mitigation potential for Medicine Hat and drought mitigation for the Oldman River water users.

Environmental and ecological considerations

- Scheme would have negative effects on flooded native grassland habitat.
- Footprint of new reservoir would remove existing riverine habitat. Productivity and fisheries value of the newly created reservoir is unknown.
- Potential to use storage behind Eyremore Dam to increase flows (or provide functional

Scheme 12. New Eyremore reservoir low in Bow River Basin
flows) that target desired benefits to ecological components in Bow River below (e.g., fish, riparian, water quality, etc.) • Would need to consider project in light of current designation as Class A habitat under Alberta's Code of Practice, depending on the location of dam and back-flooding of reservoir. • As with all projects an environmental impact assessment will determine impacts on high quality wildlife habitat due to the location on native prairie. This project will impact the Burrowing Owl Range and Sensitive Amphibian Range as well as several species within the Sensitive Raptor Range, including ferruginous hawk, golden eagle, and prairie falcon. In addition, the location has known breeding sites for many species listed as sensitive, including burrowing owl, prairie falcon, peregrine falcon, golden eagle, and northern leopard frog. • Scheme has the potential to improve downstream flow regime relative to current conditions. **Design and operational considerations** • This dam would benefit upstream and downstream water users in the Bow basin and greatly benefit water users in the Oldman basin and South Saskatchewan Rivers because it would alleviate pressures and provide more flexibility for managing existing Oldman facilities. The water storage study by Amec Foster Wheeler (2015) identified water shortages in the Oldman basin as a concern, particularly to future demands. • Large downstream storage would give irrigation districts more flexibility to take water because less water is needed to be sent down the river just to reach minimum flows. This situation could only work if agreements are in place and the river is managed as a system. It would be beneficial to assess the SSRB system holistically when considering how to mitigate water shortages. • This scheme would improve the reliability of supply for EID by meeting the 11 cms pass by requirement at Bassano Dam from Eyremore Reservoir. • Scheme would improve GoA's ability to manage releases to meet apportionment requirements. • There are concerns with evaporative loss because of reservoir size. • Reservoir could be drawn down for flood mitigation once a flood is certain to occur, because the time of travel of flows from the mountains provides operators with information on what flood peak flows and volume could be expected.
Drought mitigation potential
This scheme was assessed as having significant drought mitigation potential, substantially reducing shortages under all three of the time series. WCO violations were also substantially reduced.

9.2 Additional Schemes Not Assessed by the BRWG

Several additional schemes were raised during BRWG meetings but were not assessed by the BRWG. These schemes are listed below, with a rationale provided for their exclusion from the assessment.

1. Crowfoot Creek dam: This scheme was deemed impractical because it would be very costly to upgrade the WID canals, the return location is low in the Bow system, but above the EID diversion, and there would be water quality concerns.
2. Eagle Lake pump storage: This scheme was deemed to have prohibitive operating costs.
3. Langdon Reservoir expansion: This work has already been completed.
4. Peanut Lake: This reservoir would have low drought mitigation potential because it would be very small.
5. Increase Little Bow/Travers storage capacity: The work has already been completed.
6. New reservoir on Jumpingpound Creek: Jumpingpound Creek has very low mean annual flow, so during drought years would not likely have sufficient inflow volume to be considered a drought mitigation benefit.
7. Extend Ghost Reservoir flood operations (2016 agreement): This scheme is being operated for flood mitigation.
8. Stimson Creek Dam Site, Highwood: This project has previously been shown to not be viable.
9. Tongue Creek Dam Site, Highwood: This project has previously been shown to not be viable.
10. East Chin Coulee, South Saskatchewan: This scheme would not directly benefit the Bow system.
11. Meridian Dam, South Saskatchewan: This project has previously been shown to not be viable.
12. Springbank Off-stream Reservoir (SR1): This planned project is intended for flood mitigation only.
13. Raise Spray Reservoir: This would involve raising the dam to offer a higher FSL than current design. It is unlikely the extra capacity would be refilled in a second drought year if fully used in the first year of drought.
14. New reservoir on Ghost River upstream of Waiparous: This reservoir would have geotechnical and potential land ownership/tenure concerns, a long-time frame for construction, and risks to protected fisheries (e.g., bull trout and westslope cutthroat trout). In addition, the site is high in the basin potentially making it a less effective drought mitigation option.
15. New reservoir on Waiparous Creek upstream of confluence with Ghost: This reservoir would have a small catchment and potential impacts on fish.
16. Bruce Lake Reservoir: The reservoir would be too expensive to construct.
17. Hornberger Lake: This reservoir would have limited drought mitigation potential because it would be very small.
18. Eagle Lake Reservoir: This reservoir would require substantial infrastructure upgrades and be of minimal use to the WID.
19. Eagle Pond: This reservoir would be very small and might have limited drought mitigation potential relative to its construction and operation costs.
20. Hammerhill Reservoir: This reservoir supports few licences, so its value would be minimal.
21. Steinbach Reservoir: This reservoir would not be useful to water users.

10.0 Drought Mitigation Scenarios

The BRWG was assigned a drought mitigation objective that early modelling found to be quite conservative. Many of the individual drought mitigation schemes alone could achieve the 5% to 10% reduction in licence shortages without violating apportionment requirements and ecosystem health. The nature of the BRWG discussion evolved from “How do we achieve the objective?” to “What are the most promising schemes for adding drought mitigation capacity to the Bow River Basin?”

The BRWG identified the most promising schemes based on modelling results for each scheme and associated the commentary. Through this discussion, the most promising schemes fell into four different types:

- Operational changes at existing infrastructure
- Minor infrastructure projects
- Major infrastructure (primarily for flood mitigation), and
- Major infrastructure (primarily for drought mitigation).

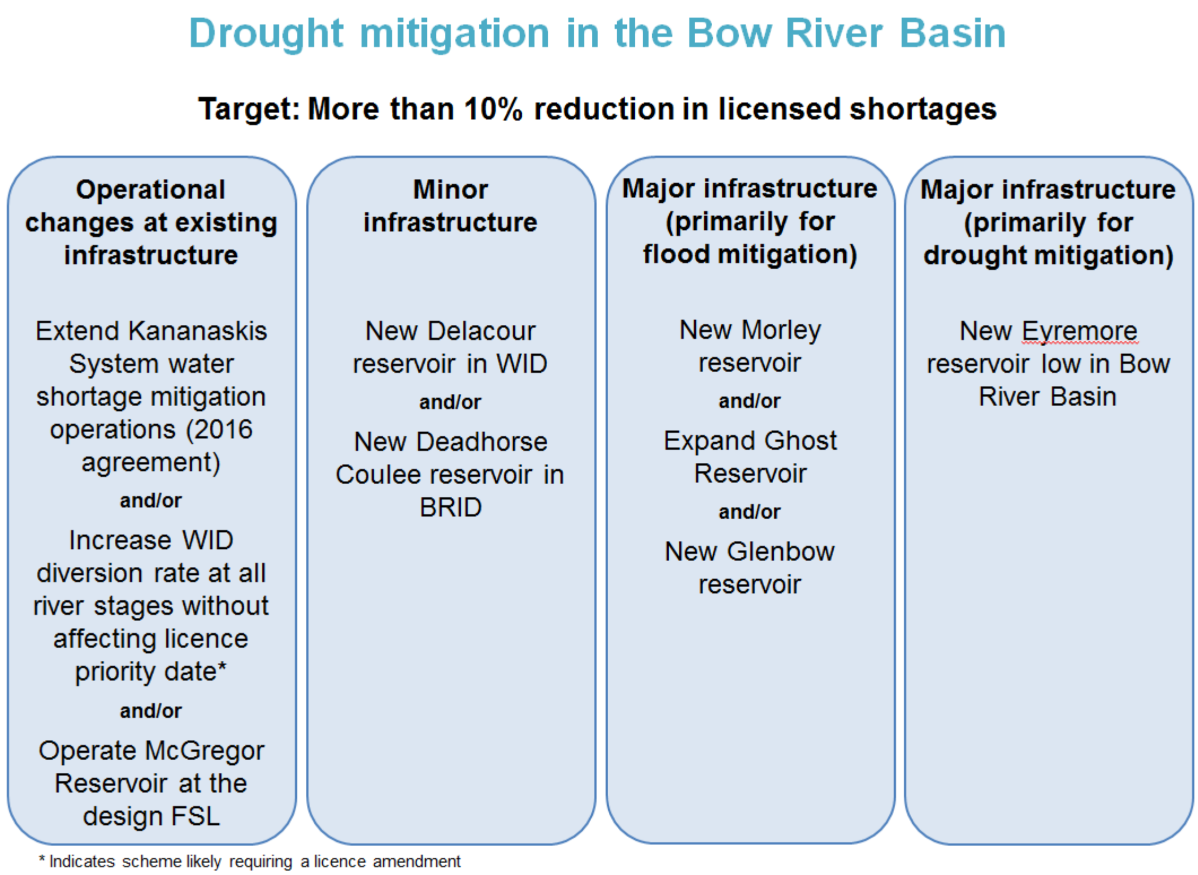


Figure 53: The most promising schemes for adding drought mitigation capacity to the Bow River Basin

Scenario: Operational changes at existing infrastructure + Minor infrastructure

This scenario includes:

- Scheme 3: Extend Kananaskis System water shortage mitigation operations (2016 agreement)
- Scheme 8: New Delacour reservoir in WID
- Scheme 9: Increase WID diversion rate at all river stages without affecting licence priority date
- Scheme 10: New Deadhorse Coulee reservoir in BRID
- Scheme 11: Operate McGregor Reservoir at the design FSL

Results

For this scenario, shortages were reduced by 57%, 61%, and 19% under the Historical, Drought 1, and Drought 2 time series, respectively. There were no changes to apportionment. WCO violations were reduced by 2% under the Historical time series, did not change under Drought 1, and increased by 1% under Drought 2 (Table 17). Note, changes in WCO violations are considered to be within the range of modelling uncertainty; therefore, are not meaningful.

Table 17: The effect of the scenario on shortages, WCO violations, and apportionment violations under the Historical, Drought 1, and Drought 2 time series

	Performance Improvement (relative to current operations)		
Time Series	**Total Shortages (volume)**	**New WCO Violations (Carseland to Bassano)**	**New Apportionment Violations (yes/no)**
Historical	-57%	-2%	no
Drought 1	-61%	0%	no
Drought 2	-19%	1%	no

Scenario: Major infrastructure (primarily for flood mitigation)

This scenario includes a designated amount of water storage capacity in any one of the following major new flood mitigation projects:

- Scheme 5: New Morley reservoir on Bow River upstream of Ghost Reservoir
- Scheme 6: Expand Ghost Reservoir (by raising FSL and/or adding low-level outlet)
- Scheme 7: New Glenbow reservoir on Bow River upstream of Bearspaw

Results

For Scheme 5, shortages were reduced by 55%, 54%, and 13% under the Historical, Drought 1, and Drought 2 time series, respectively. There was no change to apportionment. WCO violations were reduced by 11%, 9%, and 2% under the Historical, Drought 1, and Drought 2, time series, respectively (Table 18). For Scheme 6, which used 30,000 dam^3 and 60,000 dam^3 storage volumes, shortages were reduced by 49% and 55% under the Historical time series, by 41% and 53% under Drought 1, and by 13% and 10% under Drought 2. There was no change to apportionment. There was a 5% reduction in WCO violations for both storage volumes under the Historical and Drought 1 time series, and a 2% reduction under Drought 2 (Table 19). For Scheme 7, shortages were reduced by 21%, 18%, and 1% under the Historical, Drought 1, and Drought 2 time series, respectively. There was no change to apportionment and no change in WCO violations except for a 1% increase under Drought 2 (Table 20).

Table 18: The effect of Scheme 5 on shortages, WCO violations, and apportionment violations under the Historical, Drought 1, and Drought 2 time series

	Performance Improvement (relative to current operations)		
Time Series	**Total Shortages (volume)**	**New WCO Violations (Carseland to Bassano)**	**New Apportionment Violations (yes/no)**
Historical	-55%	-11%	no
Drought 1	-54%	-9%	no
Drought 2	-13%	-2%	no

Scenario: Major infrastructure (primarily for flood mitigation)

Table 19: The effect of Scheme 6 on shortages, WCO violations, and apportionment violations under the Historical, Drought 1, and Drought 2 time series for two storage volumes (30,000, 60,000 dam^3)

	Performance Improvement (relative to current operations)		
Time Series	**Total Shortages (volume; 30,000 and 60,000 dam^3)**	**New WCO Violations (Carseland to Bassano; 30,000 and 60,000 dam^3)**	**New Apportionment Violations (yes/no; 30,000 and 60,000 dam^3)**
Historical	-49%, -55%	-5%, -5%	no, no
Drought 1	-41%, -53%	-5%, -5%	no, no
Drought 2	-13%, -10%	-2%, -2%	no, no

Table 20: The effect of Scheme 7 on shortages, WCO violations, and apportionment violations under the Historical, Drought 1, and Drought 2 time series

	Performance Improvement (relative to current operations)		
Time Series	**Total Shortages (volume)**	**New WCO Violations (Carseland to Bassano)**	**New Apportionment Violations (yes/no)**
Historical	-21%	0%	no
Drought 1	-18%	0%	no
Drought 2	-1%	1%	no

Scenario: Major infrastructure (primarily for drought mitigation)

This scenario includes a single large project, primarily for drought mitigation:

- Scheme 12: New Eyremore reservoir low in Bow River Basin.

Results

For this scheme, shortages were reduced by 66%, 63%, and 47% under the Historical, Drought 1, and Drought 2 time series, respectively. There was no change to apportionment. WCO violations were reduced by 5% under the Historical time series and by 10% and 13% under Drought 1 and Drought 2, respectively (Table 21).

Table 21: The effect of a single mega-project on shortages, WCO violations, and apportionment violations under the Historical, Drought 1, and Drought 2 time series

	Performance Improvement (relative to current operations)		
Time Series	**Total Shortages (volume)**	**New WCO Violations (Carseland to Bassano)**	**New Apportionment Violations (yes/no)**
Historical	-66%	-5%	no
Drought 1	-63%	-10%	no
Drought 2	-47%	-13%	Potentially

PART IV. WATER MANAGEMENT ADVICE

11.0 Conclusions for Water Management in the Bow River Basin

The Bow River system is fundamental to the daily life of people in the watershed, whether as a source of clean and safe drinking water, a traffic bottleneck to cross for work, a fabulous recreational asset, or simply a beautiful landscape to be enjoyed for its diverse flora and fauna. The need to adapt to an ever-changing environment and often rapidly changing weather conditions is a simple reality of life in the basin.

Historical records and scientific estimates of precipitation and annual water volumes for the Bow River over the past 800 years show dramatic variation from year to year as well as within years. Even more concerning are indications of droughts lasting ten years and more in this region. Globally, climate change is being recognized and understood as potentially leading to more rapid and extreme change than experienced before, which will lead to greater variability in water supply—that is, more years with too much water at the wrong time, and more years with too little water over longer periods of time.

The annual demand for water from the Bow River is approaching the limits of our expectations for reliable supply because of population and economic growth, even with tremendous demand management. The water from snowmelt and spring rains, partially captured by upstream and downstream reservoirs, has allowed for sufficient flows, in most years, for environmental protection, municipal purposes, power production and irrigation. A less predictable water supply and an increasing demand for water as well as changing climate and demand patterns mean that careful water management will be critical to success in our economic, community, recreational, and environmental future. Our reliance on an adequate and reliable source of clean water from the Bow River has fundamental implications for future investments in water infrastructure in the region.

Participants in the BRWG were adamant that a flexible, resilient, and adaptive water management strategy is needed for the Bow River. The 2005 and 2013 floods surpassed any observed on the Bow River since 1932 and illustrate the risks to public safety and infrastructure associated with locating populations and developments in the floodplain. Drought poses a risk to providing a reliable supply of clean water for municipal, residential, commercial, and agriculture needs, stresses environmental conditions in the watershed, and presents significant economic risk.

Further complexity in our reliance on the river relates to the timing of higher or lower flow rates throughout each year. Earlier in this report, a hydrograph was presented (see Figure 6) that showed extreme variability in the annual flow of water and the importance of upstream storage for managing this flow throughout the year.

> This project clearly showed that protecting only against floods could increase the risk of drought. Similarly, protecting only against droughts reduces our ability to provide flood mitigation, particularly when floods occur with little warning.
>
> Fortunately, the project also showed that an integrated and adaptive management approach could be used to accomplish both goals.
>
> The key is balance.

A balanced approach starts with considering all aspects of flood and drought risk, threats, and options to mitigate. Storage and operational schemes to provide the optimal targeted protection level play a major role in balancing the risks for the existing Bow River circumstances.

This project assessed schemes and scenarios to achieve the target peak flows of 1,200 and 800 cms on the Bow River at Calgary. The extent and cost of upstream mitigation to reach extremely low maximum peak flows may be reduced when balanced with continued exploration and investment in natural watershed functions, floodplain protection and local mitigation. These other components of a resilient watershed continue to be and should continue to be assessed and appropriately implemented through provincial, municipal and environmental bodies.

Implementing flood mitigation schemes and scenarios upstream of Calgary (as presented in Sections 5 and 6) will change the historically managed flow regime that the system has grown and adapted into, and increase the ability of infrastructure to manage water supply. Changes solely dedicated to improve flood mitigation will likely reduce drought resiliency, which could result in more water shortages to licensed water users and impact watershed health. Thus, early in this project, participants emphasized the importance of balancing the system. This means matching projects proposed for flood mitigation with other projects that, at a minimum, offset potential increases in drought risk or impacts to watershed health, thereby maintaining the current water management balance in the basin, providing more adaptability to changing conditions and avoiding unintended consequences.

There are a number of schemes that would further mitigate the substantial risks associated with drought in the basin. Initially defined as a reduction in licensed shortages, building drought mitigation was demonstrated as achievable through different schemes whether quick win operational changes and minor projects or larger multi-purpose facilities.

Ultimately, a balanced approach can only be achieved with integrated management of the overall water system and would be supported by a formalization of the high level of voluntary co-operation currently existing between irrigation districts, municipalities, TransAlta, and other water managers in the Bow River Basin.

During this project, the BRWG identified and assessed multiple potential flood and drought mitigation schemes for the Bow River Basin and combined them into scenarios. As presented in this report, in a system as complex as this one, there are a number of promising scenarios that could be pursued following further study.

Although no single scenario was found to be ideal, several alternative scenarios can achieve most of the goals of the project. This project has reduced the number of potential schemes to a short list of those that appear most promising (Figure 54). This list includes operational changes, minor infrastructure projects, and major infrastructure projects. The varying scale of these potential schemes means that many of the operational and minor infrastructure projects could be implemented relatively quickly, while the larger infrastructure projects would typically require a longer assessment, design, and construction process.

Water management in the Bow River Basin

Target: Balancing flood mitigation and drought mitigation

	Flood mitigation	Balancing the system	Drought mitigation
Operational changes	• Extend Ghost Reservoir flood operations (2016 agreement)* • Barrier Lake flood operations	• Drought storage in expanded Glenmore • Raise winter carryover in existing reservoirs • Fill downstream reservoirs earlier • Extend Kan. System water shortage mitigation operations (2016 agreement)*	• Increase WID diversion rate at all river stages without affecting licence priority date • Operate McGregor Reservoir at the design FSL
Minor infrastructure projects	• Increase Ghost Reservoir drawdown rate	• Increase Carseland diversion and construct debris deflector	• New Delacour reservoir in WID • New Deadhorse Coulee reservoir in BRID
Major infrastructure projects**	• New Glenbow reservoir • New Morley reservoir • Expand Ghost Reservoir		• New Eyremore reservoir low in Bow River Basin

*Ghost Reservoir flood operations and Kananaskis System water shortage mitigation operations are currently in place until 2021.
**One major infrastructure project would be required to meet the 1200cms flood mitigation target at Calgary. Two major infrastructure projects would be required to meet the 800cms flood mitigation target at Calgary.

Figure 54: Most promising water management schemes for the Bow River Basin

Perhaps most importantly, this shortlist of schemes serves multiple purposes:

- Mitigating floods,
- Balancing the system, and
- Mitigating droughts.

Some of these schemes could, and likely should, be developed to serve multiple purposes. Operational parameters will need to be further investigated and defined; however, the multi-purpose potential is promising and offers flexibility in water management, which is valuable in a diverse and challenging basin like the Bow.

12.0 Next Steps for a Strategy to Improve Water Management in the Bow River Basin

Perhaps the most difficult and complex challenge created by the recent floods and the apparent changes to natural weather patterns and climate are not about what to do, but rather, the order in which to do things.

This section offers next steps for flood and drought mitigation in the Bow River Basin that draw from among the scenarios, and move toward their implementation.

1. **Build on the 2016 GoA Modified Operations Agreement with TransAlta to put in place the prerequisite needed in the upper Bow system: a long term flexible watershed agreement between the Province and TransAlta**

   Continuing or expanding the GoA-TransAlta agreement to manage Ghost and Barrier reservoirs showed significant benefits, as did increasing the maximum drawdown rate of Ghost Reservoir. All three of these schemes were recommended by the BRWG as being part of any flood mitigation scenario. Continuing to improve through experience and the operational modifications of the upstream reservoirs covered under the GoA-TransAlta agreement and extending and lengthening this agreement at the end of its five-year term will be essential to any scenario evaluated and was proposed to effectively mitigate flood and drought risk on the Bow.

2. **Implement the relatively quick wins that can be completed while larger projects are being assessed**

   - Extend Ghost Reservoir flood operations (2016 agreement) *
   - Barrier Lake flood operations
   - Drought storage in expanded Glenmore Reservoir **
   - Increase diversion rate of the Carseland Canal and construct debris deflector **
   - Raise winter carryover in downstream reservoirs (e.g., Travers, McGregor)
   - Fill downstream reservoirs earlier (e.g., Travers/Little Bow)
   - Extend Kananaskis System water shortage mitigation operations (2016 agreement) *
   - Increase WID diversion rate at all river stages without affecting licence priority date **
   - Operate McGregor Reservoir at the design FSL

   * indicates scheme already in place or underway

   ** indicates scheme likely requiring a licence amendment

3. **Complete conceptual assessments and feasibility studies of the minor infrastructure schemes within 1 year**

   - Increase Ghost Reservoir drawdown rate

- Increase diversion rate of the Carseland Canal and construct debris deflector
- New Delacour reservoir in WID
- New Deadhorse Coulee reservoir in BRID

4. Complete conceptual assessments of the 3 major infrastructure flood schemes within 2 years to determine which to advance to feasibility study

- New Glenbow reservoir
- New Morley reservoir
- Expand Ghost Reservoir

All of the large-scale schemes and scenarios reviewed in the report pose challenges, many with significant obstacles to overcome, but if the strategic goal of protecting Calgary from a serious but realistic flood event is to be achieved or even approached, one of these major projects will be needed. Three different but relatively speedy assessments would be needed in parallel for the purpose of prioritizing among the three large main stem dam and reservoirs for further study. These assessments would be in keeping with the typical project life cycle for major projects as seen in the figure below. The question to be addressed in the next phase of assessment is whether any of the three are simply not physically feasible or realistic to implement.

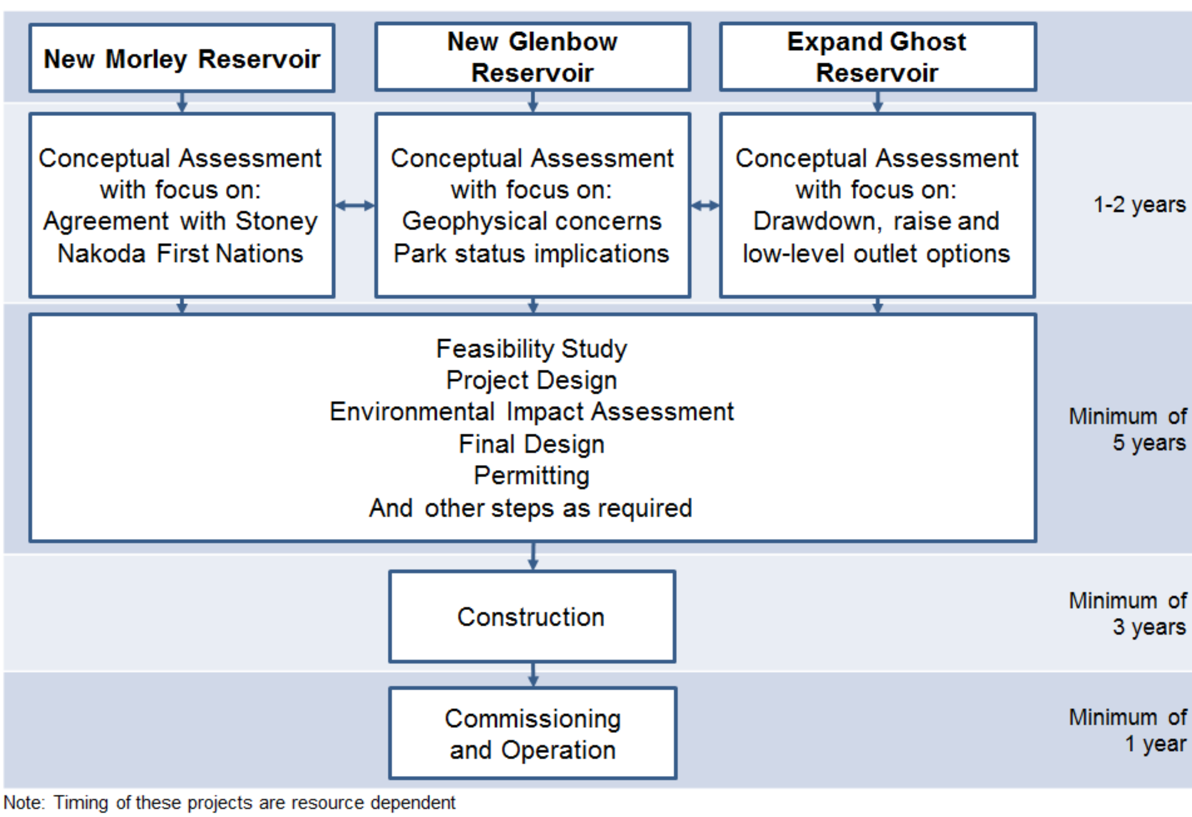


Figure 54: Project life cycle: conceptual assessments within two years

It would need to be determined whether the First Nations on the Stoney Nakoda First Nations reserve land are amenable to being compensated for a large new dam and reservoir located almost entirely on their land. If the answer is clearly no, this project could be eliminated from consideration. If the answer were yes, under certain clearly agreed upon principles, timelines, and conditions, the option would proceed to the next phase of preliminary engineering and geophysical assessment to determine its feasibility. This evaluation would require some direct discussions with the First Nations and with Indigenous and Northern Affairs Canada at a minimum. Legal and other issues would have to clarified and understood by all parties unless there is clearly no desire or agreement to develop the required lands and river rights by the Nations from the outset.

A geotechnical study and policy review of the Glenbow Ranch provincial park site would be needed to determine whether the proposal is technically feasible from a geophysical perspective and from a park's review and redesign perspective. Most of this scheme would occur on provincially owned and controlled lands. However, some private land will be involved on the south shore, the extent of which depends on the precise location of the dam and reservoir in this reach of river. There is a proposed residential development overlooking the provincial park on the north side of the river in Rocky View County that may be affected although not flooded. The railway and developments in Cochrane are also factors, but a geophysical review and terrain analysis of the area should clarify the location, boundaries, and thus the size of this scheme.

Assessing increased drawdown rates at Ghost Reservoir will require a geotechnical investigation and engineering feasibility study to determine modifications required to achieve rates of drawdown of 2 m or more per day. An engineering feasibility study will also be required to determine the practicality of raising Ghost dam by ~3 m and/or installing a low-level outlet. These studies could be conducted separately but economies of scale and time could likely be achieved by conducting all the engineering feasibility work at the same time. Modifications to increase the drawdown rate would be important to the success of all the flood and drought scenarios, but either or both the other schemes for Ghost Reservoir would keep the Ghost Expansion project in contention as an option for flood and drought mitigation.

If all three options are not feasible, then the much less desirable fourth option of three large structures on three major tributaries needs to be considered. This option, while potentially achieving the strategic goal, was not recommended because of concerns regarding locational effectiveness, cost, environmental impacts, and potential geophysical feasibility.

Assuming the preliminary assessments of the three primary schemes eliminates one or more options and narrows the field from a geophysical or tenure perspective, the GoA can make informed decisions as to how to proceed over the following 10+ years it may take to complete any one of the three Bow River main stem projects to achieve the strategic goal.

5. **Complete conceptual assessment for Eyremore scheme**

   The larger and more beneficial scheme identified for drought mitigation is the Eyremore dam and reservoir located below the Bassano dam with the reservoir tail water reaching back to the Bassano dam when filled. Eyremore provides many opportunities for adaptive water management in both the Bow and Oldman/South Saskatchewan River systems. During floods on the Bow, it could capture high flows and reduce peak flows downstream, particularly through Medicine Hat. It could similarly capture flows on the Bow during floods on the Oldman system, both reducing peak flows in Medicine Hat and enabling the Oldman dam and other reservoirs to hold back more water to reduce drought risk after a flood. Although it is one of the larger and more expensive schemes, modelling showed it to be quite valuable by adding adaptive capacity for flood and drought scenarios both on the Bow and Oldman/South Saskatchewan systems.

6. **Ensure full risk management, feasibility, cost–benefit, and triple bottom line assessments are completed in subsequent steps as the schemes and scenarios are advanced**

   This project focused on the water quantity impacts (peak flow rate and volume, storage, shortages) of a range of potential flood and drought mitigation schemes and drew on the expertise and knowledge of participants to comment on their perspectives on associated socio-economic, environmental, and design and operational considerations. It was a screening assessment that the contributors recognized as an essential first step and one that must be followed with further analysis based on a prioritized set of schemes.

7. **Balance the system to mitigate the increased drought risk from the 2016 GoA Modified Operations Agreement with TransAlta and implement further flood mitigation schemes only after implementing the accompanying schemes to balance the system and improve its adaptive capacity**

   “Balance” means not creating foreseen but unintended consequences or problems, that is, making sure that what is done to achieve one objective cannot make other objectives worse off than they were prior to the 2016 GoA Modified Operations Agreement with TransAlta and, if possible, would improve them. Opting for relatively simple and effective local and regional measures can provide for some quick wins, increasing safety and reducing risk in the short and medium term, while other larger and more costly infrastructure projects are being assessed, designed, constructed, commissioned and operated. It would not be prudent to ignore the risk of drought in our current circumstances, nor to implement the major flood mitigation projects without first putting in place several of the quick win schemes designed to balance the system, each of which can improve conditions in the many years without floods or droughts.

8. **Establish a process to set and achieve drought mitigation objectives for the Bow River Basin given that the most promising drought mitigation schemes assessed in this project can achieve far more than the original 5 to 10% objective**

   The BRWG sought to find effective synergies, or at a minimum, drought adaptation compatibilities with the proposed new flood mitigating infrastructure. The goal was to develop drought mitigation scenarios of potential operational and infrastructure opportunities reduce shortages to licence holders under drought conditions that would be as severe as or more severe than those experienced in the last 100 years, while continuing to meet apportionment requirements, and with improvement, or at minimum no reduction, in ecosystem health from what it would be with no mitigation. The BRWG evaluated 19 potential drought mitigation schemes.

9. **Increase resourcing and support for precipitation monitoring and forecasting, flow monitoring, flood forecasting and drought forecasting to enhance the effectiveness and adaptability of water management operations**

10. **Continue to invest in natural watershed functions, floodplain protection and local mitigation**

    - Take measures to reduce and preclude new high value floodplain developments throughout the basin that would risk human safety and present high societal costs from future flooding.
    - Continue to evaluate relocation throughout the basin as complementary to upstream flood protection, potentially decreasing the need for some high-cost infrastructure to achieve a diminishing return of flood protection downstream.
    - Continue to evaluate and invest in natural watershed functions, such as those funded through the WRRP and many other projects and organizations working on riparian restoration, wetlands development, land use practice, and streamflow protection.

11. **Commit to a continual collaborative process with stakeholders and policy makers for advancing and implementing these schemes as part of the water management strategy in the Bow River Basin**

    Most importantly, a coordinated and integrated approach to watershed management throughout the Bow watershed is essential to reduce future risks from floods and droughts, minimize costs for mitigation options, and provide for a safe, resilient, and healthy river system over the long term.

12. **Review and strengthen where possible the current water management operational protocols of both public and private operators**

Much work has already been done, but given the need for new and costly schemes to achieve flood and drought protection goals, a more formalized collaborative governance process may be needed to select the most effective and affordable options for implementation and to retain public confidence in the expenditures and expected results. Participants in this project have indicated that they are willing and eager to continue to provide their expertise and energy to the next several phases of this long-term, public interest project.

13.0 Literature Cited

Alberta Agriculture and Forestry. 2016. Alberta Irrigation Information, Facts and Figures for the Year 2015. Government of Alberta. 32 pp. Available online at http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/irr7401/$FILE/altairriginfo2015.pdf

Alberta WaterSMART. 2016. Climate Vulnerability and Sustainable Water Management in the South Saskatchewan River Basin, Final Report. 129 pp. Available online at http://albertawater.com/ and http://www.ai-ees.ca.

Alberta WaterSMART and Alberta Innovates – Energy and Environment Solutions. 2014. Bow Basin Flood Mitigation and Watershed Management Project. Final Report: Adaptation Roadmap for Sustainable Water Management in the SSRB. Submitted to the Flood Recovery Task Force on March 31, 2014. 120 pp.

Alberta Environment. 2006. Approved Water Management Plan for the South Saskatchewan River Basin (Alberta). Edmonton, Alberta. 45 pp.

Amec Foster Wheeler. 2008. Potential Flood Storage Schemes in the Bow River Basin. Submitted to Alberta Environment and Parks, Resilience and Mitigation Branch, Edmonton, Alberta. 16 pp. + App.

Bow River Basin Council. 2010. Web Based State of the Watershed Summary. 23 pp. Available online at http://www.brbc.ab.ca/30-resources/publications

City of Calgary. 2016. “Glenmore Dam infrastructure improvements”. Water Construction Projects. Available online at http://www.calgary.ca/UEP/Water/Pages/construction-projects/Construction-projects-and-upgrades/Glenmore-Dam-infrastructure-improvements.aspx?redirect=/glenmoreupgrades. Accessed Feb 22, 2017.

Field, C.B., D.B. Lobell, H.A. Peters, and N.R. Chiariello. 2007a. Feedbacks of Terrestrial Ecosystems to Climate Change. Annual Review of Environment and Resources 32. doi: 10.1146/annurev.energy.1132.053006.141119.

Field, C.B., L.D. Mortsch, M. Brklacich, D.L. Forbes, P. Kovacs, J.A. Patz, S.W. Running, and M.J. Scott. 2007b. North America. In: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Edited by M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J.V.D. Linden, and C.E. Hanson. Cambridge University Press, Cambridge. Pp. 617–652

Golder Associates Ltd., 2014. Basin-Wide Hydrology Assessment and 2013 Flood Documentation. Submitted to Alberta Environment and Sustainable Resource Development, Edmonton, Alberta and the City of Calgary. Available online at: http://www.calgary.ca/_layouts/cocis/DirectDownload.aspx?target=http%3a%2f%2fwww.calgary.ca%2fUEP%2fWater%2fDocuments%2fWater-Documents%2fFlood-Info-Documents%2fRiver%2520Hydrology%25202014.pdf&noredirect=1&sf=1

IBI Group. 2015. Provincial Flood Damage Assessment Study. Prepared for Government of Alberta ESRD. 73 pp. Available online at http://open.alberta.ca/publications/7032365

IBI Group and Golder Associates Ltd. 2017. Flood Mitigation Options Assessment Report, report Prepared for the City of Calgary. Available online at http://www.calgary.ca/UEP/Water/Pages/Flood-Info/Recovery/Flood-projects.aspx

MPE Engineering Ltd. 2008. Assessment of Potential Water Storage Sites and Diversion Scenarios. Report prepared by MPE Engineering Ltd. for Alberta Environment, Edmonton, Alberta. Available online at http://ceaa.gc.ca/050/documents_staticpost/cearref_2996/131.pdf.

Paterson Earth & Water Consulting Ltd. 2015. Economic Value of Irrigation in Alberta. Report prepared for Alberta Irrigation Projects Association. Available online at http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/irr15523

Sauchyn, D., and S. Kulshreshtha. 2008. Prairies. In: From Impacts to Adaptation: Canada in a Changing Climate 2007. Edited by D.S. Lemmen, F.J. Warren, J. Lacroix, and E. Bush. Government of Canada, Ottawa, Ontario. Pp. 275–328.

Sauchyn, D., E. Barrow, R. Hopkinson, and P. Leavitt. 2003. Aridity on the Canadian Plains: Future Trends and Past Variability. Summary Document. Prairie Adaptation Research Collaborative (PARC). 12 pp. Available online at http://www.parc.ca/pdf/research_publications/earth1.pdf

Seneka, M. 2004. Trends in Historical Annual Flows for Major Rivers in Alberta. Prepared for Environmental Assurance Alberta Government. Available online at https://extranet.gov.ab.ca/env/infocentre/info/library/6792.pdf

APPENDICES

Appendix A.
Advisory Committee
Terms of Reference

Background

The Bow River Working Group, a technical collaboration of water managers and users, was informally established in 2010. In late 2013 and early 2014 they worked together to identify and assess flood mitigation options in the Bow Basin. Their March 2014 *Bow Basin Flood Mitigation and Watershed Management Project* report put forward the most promising mitigation options including a number of operational changes for the TransAlta facilities in the upper Bow system. A separate report conducted by Amec Foster Wheeler in 2015 for Alberta Environment and Parks identified 11 potential flood storage schemes for the Bow River. This 2016 project is a continuation of both of these prior studies.

Vision

To have a robust, strategic plan for water management in the Bow River Basin, from the headwaters to the confluence with the Oldman River and continuing through Medicine Hat.

Mandate

To provide the Government of Alberta with strategic advice on opportunities to reduce future flood damage, improve the reliability of water supply, and protect the long-term health of the Bow River Basin. The advice in 2016 will focus on screening flood and drought mitigation opportunities in the Bow River Basin, the resulting flow impacts downstream through the entire Bow River Basin, and consideration of the connected impacts on watershed health. This advice is to be provided to the Minister of Alberta Environment and Parks.

Goals

- To provide advice for consideration of a long term plan to reduce the economic, social and environmental costs of flood and drought in the Bow River Basin.
- To meet common objectives through collaboration that benefit the needs of stakeholders while maintaining protection of the watershed.
- To develop scenarios of potential operational and infrastructure flood and drought mitigation opportunities throughout the Bow River basin. These scenarios will include additional measures required to offset any detriment to watershed health.

Scope

- The Bow River Water Management Advisory Committee (Advisory Committee) is responsible for delivering the mandate as stated above.
- The Advisory Committee will support a technical committee of experts called the Bow River Working Group (Working Group) in this work by:
    - Providing strategic direction for the Working Group;
    - Championing the Working Group's work and its outcomes;
    - Identifying feasible implementation pathways and barriers for the various mitigation opportunities identified;

- Acting as the liaison between various orders of government;
- Providing issue resolution and addressing barriers; within a reasonable amount of time; that may arise within the Working Group; and
- Endorsing and providing the final report to the Government of Alberta for consideration.

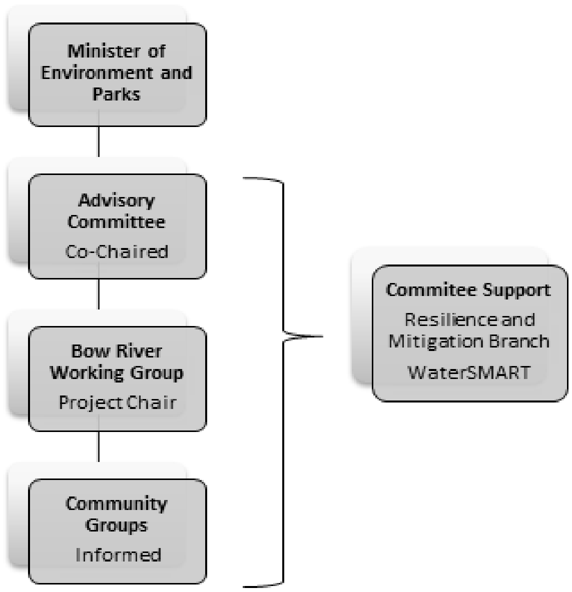
Timeline

- The following shows the draft workplan for the Bow River Working Group.

Working Session #1	Working Session #2	Working Session #3	Working Session #4	AC/BRWG Session #5	Working Session #6	Final Reporting
MAR	JUN	SEPT	SEPT	DEC	DEC	SPRING 2017
BRWG KICK-OFF	**FLOOD MITIGATION SCHEMES**	**FLOOD MITIGATION SCENARIOS**	**DROUGHT MITIGATION SCHEMES & SCENARIOS**	**VET FINDINGS; FLOOD & DROUGHT SCHEMES**	**FLOOD & DROUGHT SCENARIOS**	**POST-MEETINGS WORK**
Finalize BRWG TOR Review work already done Vet model & data Finalize schemes to be assessed	Assess individual schemes: • Function • Effectiveness • Trade-offs Identify most promising schemes Begin to build 1200, 800, 400 scenarios	Complete assessment of individual schemes Confirm most promising schemes Build 1200, 800, 400 scenarios Confirm impacts & trade-offs	Assess individual schemes • Function • Effectiveness • Trade-offs Identify most promising schemes Build scenarios Confirm impacts & trade-offs	Review findings Address AC considerations Confirm table of contents for final report Begin to build flood & drought mitigation scenarios	Assess combinations • Function • Effectiveness • Trade-offs Identify most promising combinations Confirm impacts & trade-offs and further work required Agree on report review process	Draft final report Solicit review from BRWG and AC Finalize & submit final report Prepare presentation of findings

One on one engagement with participants and other parties as required

Governance Structure



- The Advisory Committee will be comprised of ~10 representatives from the major municipalities, industries, First Nations and WPAC on the Bow River. Co-chaired by AEP and The City of Calgary.
- The Bow River Working Group (Working Group) will be responsible for overall coordination, development and management of the project, and will carry out specific tasks as appropriate. The Chair of the Working Group will provide on-going reports directly to the Advisory Committee.
- The Community Groups will be informed by WRAM through the Advisory Committee, their perspectives will be invited, and they may be invited to participate in a mitigation modelling session if budget permits.
- WaterSMART Solutions Ltd. (WaterSMART) has been contracted by AEP to support the Working Group and AEP as needed.

Membership

- Invitations to participate in the Advisory Committee will be based on the following criteria:
  - You represent a municipality with a large physical or economic footprint on the Bow River main stem.
  - You represent one of the five largest Bow River licence holder.
  - You represent a First Nation along the Bow River main stem.
  - You represent the Bow River Basin Council.
- Membership of the Advisory Committee can be found in Annex A.

Terms of Membership

- If a member is not able to attend a meeting, an alternate will be permitted.
- Advisory Committee members may be considered non-compliant if:
  - They miss three consecutive meetings;
  - They miss more than 50% of meetings in a 12-month period.
- Non-compliant members may be asked by the Co-Chairs to resign their position and provide an alternate representative.
- This convening the Advisory Committee will be considered formally closed when the final report is provided to the Minister of Alberta Environment and Parks; and;
- A response document detailing how the Government of Alberta will take action on the findings and advice in the final report is return to the Advisory Committee and the Working Group.

Decision Making

- Decision making on specific advice will be made by consensus of the Advisory Committee membership and representative membership present at the meeting where the decision is made.
- A consensus decision requires at least 75% participation of community membership to be present at the meeting where the decision is made.
- Should a consensus not be possible, the majority opinion will be adopted with the size of the voting majority noted.
  - A minority report written by at least two members of the Advisory Committee to officially state a position counter to the committee's majority will be included.

Meeting process

- Meetings of the Advisory Committee are at the call of the Co-Chairs as required.
- Meetings of the Advisory Committee will be considered confidential and must be treated as such by members. Committee materials, proposals, business cases and procurement decisions that come into a committee member's possession must only be used or disclosed for the purpose of the Advisory Committee function.
- It is anticipated that the Advisory Committee will meet at least 2 weeks after each of the Working Group meetings in order to receive an update regarding the Working Groups activities and progress.

Agenda Preparation and Minutes Circulation

- Agendas will be determined by the Advisory Committee Co-Chairs prior to meetings.
  - Agenda items must be forwarded to the Committee Support team at least one week prior to circulation of the agenda, i.e. two weeks before the next meeting.
- Meeting summaries will be prepared and distributed to members for review before being considered final.

Reporting mechanism

- Progress reports will be provided to the Advisory Committee by the Working Group on a regular basis.

Communications

- Advisory Committee members will communicate within the team through regular meetings and email.
- Communication with community groups will be the responsibility of the committee support team through a series of update notices.
- All shared information will be kept by the Committee support team.

Annexes:

A. Bow River Water Management Advisory Committee – Members, Roles and Responsibilities

ANNEX A

Bow River Water Management Advisory Committee – Members, Roles and Responsibilities

Advisory Group Members	Roles and Responsibilities
Co - Chairs Alberta Environment and Parks City of Calgary	• Champion the Final report from the Working Group • Establish the work schedule and agenda for all meetings; • Establish the overall code of conduct and rules of procedure that the Advisory Committee will abide by; • Collaborate with other members of the Advisory Committee in establishing strategic direction, directing the work for the Working Group and determining what advice will be provided to government • Report to Government regarding the progress of the BRWG and issues facing the Advisory Committee; • Work to build consensus among members; and • Communicate with the media if required.

Municipalities
Rocky View County
Medicine Hat
First Nations
Siksika First Nation
Stoney Nakoda First Nations
Industry
TransAlta
Irrigation District
One representative of for all three Irrigation Districts
WPACs
Bow River Basin Council (BRBC)
	• Attend and actively participate in meetings regularly;
	• Support the Co-Chairs with aspects related to managing the Advisory Committee activities;
	• Represent organization and organization interests;
	• Report on progress to their respective organizations;
	• Support the plan development process and provide advice to the Working Group relative to water management issues;
	• Contribute to the exchange of information and ideas;
	• Evaluate the key issues affecting the Bow River Basin from a water management perspective;
	• Review information provided by the BRWG;
	• Identify feasible implementation pathways and barriers for the identified mitigation opportunities;
	• Play an active role by:
	  ○ Participating in-person at the regularly scheduled meetings;
	  ○ Reviewing pre-read materials prior to meetings and coming prepared for engaged discussion, active listening, and respectful dialogue; and
	• Constructively manage conflict between themselves and others in the group.

Appendix B.
Bow River Working Group
Terms of Reference

Background

The Bow River Working Group, a technical collaboration of water managers and users, was informally established in 2010. In late 2013 and early 2014 they worked together to identify and assess flood mitigation options in the Bow Basin. Their March 2014 *Bow Basin Flood Mitigation and Watershed Management Project* report put forward the most promising mitigation options including a number of operational changes for the TransAlta facilities in the upper Bow system. A separate report conducted by Amec Foster Wheeler in 2015 for Alberta Environment and Parks identified 11 potential flood storage schemes for the Bow River. This 2016 project is a continuation of both of these prior studies.

Vision

To have a robust, strategic plan for water management in the Bow River Basin, from the headwaters to the confluence with the Oldman River and continuing through Medicine Hat.

Mandate

To provide the Government of Alberta with strategic advice on opportunities to reduce future flood damage, improve the reliability of water supply, and protect the long-term health of the Bow River Basin. The advice in 2016 will focus on screening flood and drought mitigation opportunities in the Bow River Basin, the resulting flow impacts downstream through the entire Bow River Basin, and consideration of the connected impacts on watershed health. This advice is to be provided to the Minister of Alberta Environment and Parks.

Goals

- To provide advice for consideration of a long term plan to reduce the economic, social and environmental costs of flood and drought in the Bow River Basin.
- To meet common objectives through collaboration that benefit the needs of stakeholders while maintaining a healthy watershed.
- To develop scenarios of potential operational and infrastructure flood mitigation opportunities in the upper Bow River basin to reduce peak flow during a defined range of simulated flood events of approximately 1,200, 800 and 400 cubic meters per second (cms) measured on the Bow River above the confluence with the Elbow River.

- Develop scenarios of potential operational and infrastructure drought mitigation opportunities to reduce the volume of licence shortages by at least 5% to 10%, while continuing to meet apportionment requirements, and with improvement, or at minimum no reduction, in ecosystem health (all relative to current operations in the same time period).
- In addition to the flow rate in Calgary, the scenarios will assess and address threshold flows along other reaches of the Bow River. The scenarios will include additional measures required to offset any detriment to drought mitigation and watershed health.

Alberta Government

Initial Flood Scope

- Flow quantity in the Bow River main stem from headwaters to confluence with Oldman to below Medicine Hat, and the following major tributaries: Spray River, Kananaskis River, Ghost River, JumpingPound Creek, Elbow River, Highwood River, and Sheep River.
- Flood mitigation opportunities upstream of the City of Calgary including new storage, operational changes to existing infrastructure, and natural functions. The starting list of options to be considered will come from the 2015 *Potential Flood Storage Schemes in the Bow River Basin* report and the 2014 *Bow Basin Flood Mitigation and Watershed Management Project* report.
- AEP will update the Working Group on any operational changes stemming from ongoing discussions between GoA and TransAlta.
- To assess mitigation potential, the Working Group will use a range of simulated flood events including 2013 and 2005 with sensitivity factors applied to each. This range of simulated events will be determined with the BRWG using currently available data to best represent a broad range of event sizes, hydrograph shapes and rainfall locations. The range of events used in the study will be clearly stated in the final report.
- Mitigation options will be assessed against a range of criteria including: storage capacity, peak flow attenuation at specific locations, indicative project cost, and other metrics developed by the Working Group. This list will be maintained and refined throughout the course of the work. Criteria of social and indirect economic impact will not be comprehensively assessed.
- New data will be incorporated into the modelling tools and assessment as it becomes available and as timing and budget permits.
- Out of Scope
    - Flood mitigation options on steep mountain creeks e.g. Cougar Creek are not in scope.
    - Flood events and mitigation on the Oldman River are not in scope.
    - Flood mitigation options beyond what are already planned for the Elbow, Sheep and Highwood river systems are not in scope. These river systems will be treated as inputs based on the currently proposed mitigation options.
    - Flood mitigation options on the landscape rather than in the river, for example, wetland protection, riparian zone restoration, road design, land access, and forestry practices. These options are recognized as vital to the watershed and are being addressed through other programs including the Watershed Resiliency and Restoration Program (WRRP).
    - Feasibility assessment of flood mitigation concepts.
    - Cost/benefit analysis of flood mitigation concepts.

Ingoing Flood Assumptions

- The current Water Act is assumed to remain the guiding legal authority.
- GoA will provide target levels of flood mitigation on the Bow.
- The 1% flood is still the provincial standard; it will be provided by GoA and included as an important reference point.
- SR1 will be assumed to be built on the Elbow River.
- The berms in High River will be assumed to be completed.

- The data, findings and materials from the Working Group will be considered public domain unless specified as confidential or proprietary. The final report will be considered public domain once it has been approved for release by the Minister of Environment and Parks.

Initial Drought Scope

- Structural drought mitigation opportunities including new storage and operational changes to existing infrastructure, both on and off stream.
- Flow quantity on the Bow River including its major tributaries to the confluence with the Oldman to below Medicine Hat.
- Range of simulated drought events drawn from the historic record and scaled in duration and severity to reflect climate variability.
- Mitigation required to offset flood mitigation schemes upstream.
- The BRWG will be looking at three types of infrastructure schemes: 1) those dedicated to flood control; 2) those dedicated to drought mitigation; and 3) those operated to offer both flood and drought mitigation.
- Out of scope
  - Comprehensive review of natural storage functions and schemes.
  - Detailed analysis of demand management options.
  - Water quality modelling.
  - Groundwater modelling.
  - Drought mitigation on the Oldman River.
  - Full cost/benefit and feasibility analysis of mitigation schemes

Ingoing Drought Assumptions

- The Water Act is assumed to remain the guiding legal authority and the Master Agreement on Apportionment is assumed to remain in place.
- The Bow River Basin is assumed to remain closed to new licence applications.
- The existing target flow requirements on specific reaches of the Bow River are assumed to remain in place.
- Future demands may increase within current and pending licenses reflecting expansion of municipalities, agriculture and industry in the closed basin.
- New storage schemes will be modelled in accordance with regulatory requirements (WCO requirement as stated in the SSRB WMP) and the BRWG will have the opportunity if they wish to explore the potential of schemes should the requirements be adjusted.
- This work is being done without specific government policy direction on the intended priorities for any new storage.
- It is recognized that this work will not simulate the uncertainty of knowing whether the basin is experiencing a drought nor how long it may last.

Timeline

The following shows the draft workplan for the Bow River Working Group:

Working Session #1	Working Session #2	Working Session #3	Working Session #4	AC/BRWG Session #5	Working Session #6	Final Reporting
MAR	JUN	SEPT	SEPT	DEC	DEC	SPRING 2017
BRWG KICK-OFF	**FLOOD MITIGATION SCHEMES**	**FLOOD MITIGATION SCENARIOS**	**DROUGHT MITIGATION SCHEMES & SCENARIOS**	**VET FINDINGS; FLOOD & DROUGHT SCHEMES**	**FLOOD & DROUGHT SCENARIOS**	**POST-MEETINGS WORK**
Finalize BRWG TOR Review work already done Vet model & data Finalize schemes to be assessed	Assess individual schemes: • Function • Effectiveness • Trade-offs Identify most promising schemes Begin to build 1200, 800, 400 scenarios	Complete assessment of individual schemes Confirm most promising schemes Build 1200, 800, 400 scenarios Confirm impacts & trade-offs	Assess individual schemes • Function • Effectiveness • Trade-offs Identify most promising schemes Build scenarios Confirm impacts & trade-offs	Review findings Address AC considerations Confirm table of contents for final report Begin to build flood & drought mitigation scenarios	Assess combinations • Function • Effectiveness • Trade-offs Identify most promising combinations Confirm impacts & trade-offs and further work required Agree on report review process	Draft final report Solicit review from BRWG and AC Finalize & submit final report Prepare presentation of findings

One on one engagement with participants and other parties as required

Working Group Deliverable

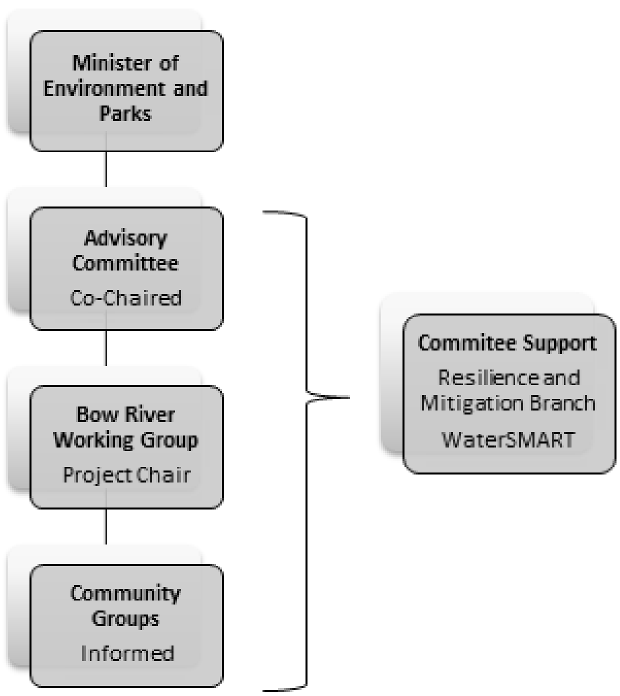
A final report providing advice to GoA on water management opportunities for flood and drought mitigation and consideration of the related impacts on watershed health in the Bow Basin,

The final report will specify the operational and infrastructure flood and drought mitigation opportunities in the Bow River Basin, the resulting flow impacts downstream through the entire Bow River Basin, and consideration of the connected impacts on watershed health.

- The report will be drafted by WaterSMART based on the meeting summaries documenting each of the Working Group meetings and prior related reports. This draft report will be sent to Working Group members for review and suggested revisions before being finalized.
- The Advisory Committee will be briefed as the project proceeds and the final report from the Working Group is expected to be reviewed and endorsed by the Advisory Committee.

- Any suggested changes to the final report by the Advisory Committee must be brought back to the Working Group for consideration.
- The final report will be made public once it has been approved for release by the Minister of Environment and Parks.

Governance Structure



- The Advisory Committee will be comprised of ~10 representatives from the major municipalities, industries, First Nations and WPAC on the Bow River. Co-chaired by AEP and The City of Calgary, it will be responsible for the following:
  - Providing strategic direction for the Working Group;
  - Championing the Working Group's work and its outcomes;
  - Identifying feasible implementation pathways and barriers for the various mitigation opportunities identified;
  - Acting as the liaison between various orders of government;
  - Providing issue resolution and addressing barriers; within a reasonable amount of time; that may arise within the Working Group; and
  - Endorsing and providing the final report to the Government of Alberta for consideration.

- The Bow River Working Group (Working Group) will be responsible for overall coordination, development and management of the project, and will carry out specific tasks as appropriate. The Chair of the Working Group will provide on-going reports directly to the Advisory Committee.
- The Community Groups will be informed by RAM through the Advisory Committee, their perspectives will be invited, and they may be invited to participate in a mitigation modelling session if budget permits.
- WaterSMART Solutions Ltd. (WaterSMART) has been contracted by AEP to support the Working Group and AEP as needed.

Membership

- Working group members are asked to volunteer their time to attend up to 5 full day working group meetings in 2016 and to complete some additional work (primarily data provision and document review) in between. If a member is not able to attend a meeting, an alternate will be permitted, provided he or she is well briefed on the current status of the project.
- Invitations to participate in the Working Group will be based on the following criteria:
  - You represent a municipality with a physical or economic footprint on the Bow River main stem.
  - You represent one of the five largest Bow River licence holders.
  - You represent a First Nation along the Bow River main stem.
  - You represent a WPAC or WSG in the study area.

  AND:

  - You will bring technical water management expertise to the discussion.
  - You have been involved in water management in the basin over the long term.
  - You will contribute to the collaborative process in the interest of the Bow River Basin.
- This convening of the Bow River Working Group will be considered formally closed when their report is provided to the Minister of Alberta Environment and Parks; and;
- A response document detailing how the Government of Alberta will take action on the findings and advice in the final report will be returned to the Working Group through the Advisory Committee.

Meeting process

- Proposed meeting dates will be set at the first meeting of the Working Group meeting and confirmed at least three weeks in advance.
- Working Group meetings will be by invitation only.
- Chatham House Rule will be applied to the Working Group meetings: *When a meeting, or part thereof, is held under the Chatham House Rule, participants are free to use the information received, but neither the identity nor the affiliation of the speaker(s), nor that of any other participant, may be revealed.*
  - **Note:** Any information that is deemed proprietary or confidential will be stated at the beginning of each meeting and will not be able to be shared outside the Working Group

- Meeting summaries will be prepared and distributed to members for review before being considered final.
- The Working Group Chair, and others, will provide periodic updates to the Advisory Committee including progress, next steps, and any guidance required from the Advisory Committee.

Annexes:

B. Bow River Working Group Members

ANNEX A - Bow River Working Group Members

Government
Alberta Environment and Parks
Alberta Agriculture and Forestry
Fisheries and Oceans Canada

Municipalities
Town of Canmore
Municipal District of Bighorn
Kananaskis Improvement District
Town of Cochrane
City of Calgary
Rocky View County
Municipal District of Foothills
Vulcan County
Wheatland County
Municipal District of Taber
Cypress County
Forty Mile County
Medicine Hat

First Nations
Siksika Nation
Stoney Nakoda Nation

Industry
TransAlta
Spray Lakes Sawmills

Irrigation District
Bow River Irrigation District
Western Irrigation District
Eastern Irrigation District

WPACs and WSG
Bow River Basin Council (BRBC)
Ghost River Watershed Alliance

Jumping Pound Creek Watershed Partnership (JPCWP)
South East Alberta Watershed Alliance (SEAWA)

Environmental Non-Governmental Organizations
Ducks Unlimited Canada
Trout Unlimited Canada

Other
Calgary Regional Partnership
Alberta WaterSMART

Appendix C.
Bow River Operational Model Backgrounder

Introduction

The Bow River Basin is fortunate to have a strong history of collaborative exploration of water management challenges and opportunities. The Bow River Basin Council (BRBC) has been successful in leading the water community through the development and implementation of many projects including the Bow River Watershed Management Plan. The Bow River operations team in Alberta Environment and Parks (AEP) has led in the delicate balance of managing licence holder interests throughout the highly variable water supply years. The Bow River Working Group (BRWG) has come together in various forms over the years to lend technical expertise and experience to identify and assess specific current and future opportunities. This backgrounder provides a brief overview of the projects, analyses and recommendations of the BRWG since 2010.

The Bow River Project Research Consortium (2010)

In 2010, the Bow River Project (BRP) Research Consortium (the first incarnation of the BRWG) was established comprising water users and managers holding over 95% of the water licensed for diversion from the Bow. It explored options for re-managing the Bow River system from headwaters to confluence, in an integrated manner that considers all users, interests and values.[15] Participants worked collaboratively with an interactive, hydrologic simulation model to develop plausible and achievable scenarios for protecting the health of the river throughout the basin while meeting the needs of water users.

A key product of the BRP was the fully functioning, data-loaded Bow River Operational Model (BROM), built with the BRWG, to simulate the actual water management operations in the Bow system over a daily historic flow record from 1928 – 2009 using Environment and Sustainable Resource Development (ESRD) naturalized flow data. The BROM is a water balance model built on the OASIS modelling platform created by HydroLogics Inc. The platform was selected from seven others, applying over 50 criteria and reviews by eight modelling experts, including several from AEP (then ESRD). The BROM 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 offstream 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, downstream irrigation reservoirs, and electricity demand and pricing systems for hydropower facilities.

The BRWG reviewed, tested and accepted the generally accurate nature of the model and the outcomes of its analyses. Their results showed that integrated management of the Bow River from headwaters to confluence could realize a number of benefits from establishing a "Water Bank" in the upper Bow system.

---

[15] See more information on the Bow River Project and its final report online at http://albertawater.com/work/research-projects/bow-river-project

The Water Bank would see part of the TransAlta reservoir system used to store and release ~10% of their annual inflow to meet environmental, social and economic needs of the Bow River Basin, with hydropower generation as a by-product instead of the primary objective. The associated benefits were shown to include:

- Releases from upstream storage reservoirs can significantly improve minimum flows downstream without negatively affecting water quality.
- Changes in management of the Lower Kananaskis Lake and the Kananaskis River have potential to greatly improve aquatic ecology, the existing fishery including some threatened species, and create new and enhanced recreational and tourism experiences.
- Long-term water demand forecasts for the City of Calgary, the Siksika First Nation, the Calgary Regional Partnership, Rocky View County and other surrounding municipalities can be accommodated.
- Minimum flows through Calgary will continue to be met under all historic conditions of supply, and the Water Bank may be able to improve dissolved oxygen levels at critical times of the year protecting the aquatic ecosystem and to assure effluent level continue to meet environmental standards over the long term.
- Modest irrigation expansion is expected to result from improvements in conservation and efficiency with no impact on the river.

The BRP concluded that the Bow River system can and should be managed differently to achieve many economic, social and environmental goals throughout the basin, and that the changes required could be implemented for relatively modest cost. The BRP created four alternative scenarios, one of which became the "Preferred" Scenario for managing the river system. Two key components of the Preferred Scenario were a) establishing a Water Bank within the existing TransAlta storage reservoirs, capable of providing ~60,000 acre-feet of storage to be used to offset low flow periods on the Bow, and b) stabilizing Lower Kananaskis Lake and Kananaskis River for additional environmental, recreational and economic benefits.

The Bow River Simulation (2011)

The following year, the BRWG assembled for a one-day simulation to validate how they would manage outflows from the TransAlta reservoirs and downstream demands to mitigate very low water levels. The simulation used the AEP-provided calculated natural flows for the year 1941 as its water supply and the current level of water demands. The participants did not know the year being used in the simulation and made decisions on a weekly or daily basis as to how they would manage the storage for environmental, municipal, and agricultural purposes. Participants were provided with data on snowpack, precipitation, temperature, storage levels, license demands, and other relevant data. It was shown that working collaboratively resulted in a significant improvement on the baseline of current operations and enhanced the previously modelled improvements from using the Water Bank. The Simulation confirmed the key findings and opportunities identified by the BRP, specifically the value of establishing some form of a flexible Water Bank, stabilizing the Kananaskis system and providing for some form of collaborative river management. Participants also concluded that the BROM is a valuable tool for understanding the river system and exploring changes and potential opportunities to manage the system for improved and sustainable outcomes.

The South Saskatchewan River Basin Adaptation Project (2012 - 2014)

In 2012 and 2013 the Bow River Working Group convened again under the South Saskatchewan River Basin Adaptation to Climate Variability Project, or the SSRB Adaptation Project. This Climate Change and Emissions Management Corporation (CCEMC) funded initiative incorporated additional improvements to the BRWG's model for speed and flexibility and enabled testing water management strategies under scientifically derived climate change scenarios. At this point, the participants subtly transformed from a highly technical working group of water managers and experts to a wider group of participants to ensure interests from tributary streams and environmental groups were better represented.

Plausible streamflow scenarios for the Bow River were assembled using Global Circulation Models (GCMs) by Dr. David Sauchyn and his colleagues; six out of the ~50 were selected based on similarities to historic and Pacific Decadal Oscillation patterns in this region and were used to derive streamflow input data to the BROM model. Some severe droughts were surfaced by the GCM models, although the most extreme 10% were dropped to eliminate the simply catastrophic estimates generated by some GCM scenarios. The BRWG assembled for this two-year project to identify and assess several dozen drought mitigation options[16].

Results showed the original Water Bank concept was even more valuable under climate change conditions of less overall water supply, with growing demands, and more difficult environmental conditions. A series of additional options to mitigate dry periods and drought were identified, tested, interconnected in the model, and reported as a step-by-step order of actions that could or should be done with little or no downside, leading to some substantial and expensive infrastructure options to mitigate some scenarios of extreme drought periods. These options ranged from bringing the upstream Spray Lake Reservoir back to its original design capacity, to building a large reservoir downstream of Bassano. Many options of water conservation, reducing agricultural demands, and other interim measures were placed in a continuum of alternatives to cope with various degrees of drought and needs.

In parallel, river management models similar to BROM were developed based on detailed and current data for the Red Deer and Oldman watersheds including the Southern Tributaries and South Saskatchewan River within Alberta. Two projects focusing on each of these rivers systems were conducted, with the purpose of strategic water management under historic and climate change supply conditions using current and forecast future water demands. Similar to earlier Bow projects, various mitigation options were generated, tested, and placed in context as potential step-by-step adaptation measures to provide the resilience need to cope with expected future conditions.

[16] See more information on the South Saskatchewan River Basin Adaptation Project and its final report online at http://albertawater.com/work/research-projects/ssrb-adaption

The Bow Basin Flood Mitigation and Watershed Management Project (2013 - 2014)

In 2013 the Bow River Working Group was convened through funding from Alberta Innovates – Energy and Environment Solutions (AI-EES) and Government of Alberta's (GoA) Southern Alberta Flood Recovery Task Force (FRTF) to look at flood mitigation options throughout the Bow River Basin.

To effectively use the BROM model as a flood mitigation assessment tool, it was adapted to provide hourly rather than daily flow rates because flood peak flows and their escalating and deescalating flow curves require an hourly analysis rather than daily. This was accompanied by a visualization tool simulating the flood inundation through the City of Calgary. The 2014 Bow Basin Flood Mitigation and Watershed Management Project (BFM) used this hourly version of BROM to identify and assess a broad range of operational, natural, and new infrastructure flood mitigation opportunities for the entire Bow River Basin. This project identified the most promising near-term options for flood mitigation throughout the Bow River Basin including operating TransAlta facilities for flood control and presented scenarios of the options needed to achieve a range of mitigation targets throughout the Bow River Basin. The final report highlighted that the enormous scale, scope, and impact of the 2013 flood were such that many of the proposed mitigation alternatives were similarly large with significant costs and environmental, social, or economic consequences. The report recommended next steps in flood mitigation decision making including the need for policy decisions on mitigation targets in each basin, comparative cost-benefit analyses of mitigation options, and allocation of funding to natural mitigation functions[17].

Flood mitigation scenarios developed and tested in the 2014 BFM Project primarily applied to infrastructure options to control, delay, and reduce peak flows. A second project was conducted to examine the applicability of the Dutch flood risk mitigation program called Room for the River. A multi-meeting collaborative project of stakeholders and water managers was conducted in both the Bow and the Red Deer watersheds. In the Bow, this group was essentially an extended version of the BRWG. The advice to GoA generated by the Working Groups included a preliminary inventory of smaller but significant steps that could be taken to increase each river's conveyance, diversion, detention and defence. The opportunities were identified without ecological, engineering or fiscal feasibility analyses. Examples include retention and restoration of wetlands, removal of infrastructure and residences out of the primary floodway, localized dredging to increase flows where river beds have been artificially raised by bridges and other obstructions, and berming around critical infrastructure.

[17] See more the final report for the BFM Project online at http://albertawater.com/bow-basin-flood-mitigation-and-watershed-management-project-final-report

The South Saskatchewan River Basin Adaptation Roadmap (2013 - 2015)

Most recently, some members of the BRWG participated in a South Saskatchewan River Basin Working Group (SSRBWG) with colleagues from the Oldman, Red Deer and South Saskatchewan basins. This SSRBWG was tasked with determining how to best build the adaptive capacity of the water management systems throughout the entire SSRB to respond to future flood and drought. To do this, the BROM model was interlinked with the Red Deer and Oldman and South Saskatchewan River operating models. Historic inflows as well as climate variability and change scenarios were developed for the whole SSRB. Current and various forecasted growth in land use and land cover was modeled and input to the renamed South Saskatchewan River Operating Model (SSROM) model to test “what ifs” such as various scales of forest burns, restoring wetlands to various levels of its historic land coverage, different scenarios of oil and gas developments, municipal expansion and so forth. Most of the detailed input was applied in the Red Deer watershed to assess the different characteristics relative to the Bow watershed.

The final report from this Working Group was released in early 2016 as the Adaptation Roadmap for Sustainable Water Management in the SSRB. It provides three levels of adaptation strategies over and above what is already being done to provide the resilience and flexibility of response needed to manage the modelled supply and demand and timing of water availability for environmental support systems, agricultural and industrial needs, and municipal growth[18].

Conclusion

The Bow River Working Group has come together under six basin-scale projects since 2010 to test water management strategies under practically every conceivable condition of calculated natural flows, climate change modelled input flows, and “what if” scenarios. The findings of the Working Group have laid the foundation for this next phase of work to refine and advise government on how to proceed in the implementation of managing the Bow River system for the benefit of the environment, economy and safety of its current residents and future generations.

[18] See more information on the South Saskatchewan River Basin Water Project and its final report online at http://albertawater.com/work/research-projects/ssrb-water-project

Appendix D. Organizations Contributing to the Project

City of Calgary
City of Medicine Hat
Kananaskis Improvement District
Municipal District of Bighorn
Municipal District of Foothills
Town of Canmore
Town of Cochrane
Rocky View County
Vulcan County
Wheatland County

Bow River Irrigation District
Eastern Irrigation District
Western Irrigation District

Siksika First Nation
Stoney Nakoda First Nations

The Bow River Basin Council (BRBC)
Ghost Watershed Alliance Society
Jumpingpound Creek Watershed Partnership

Ducks Unlimited Canada
Trout Unlimited Canada

Spray Lake Sawmills
TransAlta
Calgary Regional Partnership

Amec Foster Wheeler
Alberta WaterSMART
HydroLogics Inc.
Alberta Agriculture and Forestry
Alberta Environment and Parks

Appendix E: Modelling Results Summary: Flood Mitigation Schemes and Scenarios

Most promising scheme
Somewhat promising scheme
Least promising scheme

		Event 1	Event 2	Event 3	Event 4	Observations Event 1	Observations Event 2	Observations Event 3	Observations Event 4
Flood Mitigation Schemes *Note: These results are based on each scheme acting alone. Results are not necessarily additive.*	**Operational Notes**	**Approximate peak reduction* at Calgary (cms)**	**Approximate peak reduction** at Calgary (cms)**	**Approximate peak reduction** at Calgary (cms)**	**Approximate peak reduction*** at Calgary (cms)**	*** Event 1 baseline peak is 1800 cms with mitigation (basecase)**	**** Event 2 baseline peak is 1600 cms with mitigation**	**** Event 3 baseline peak is 1900 cms with mitigation**	***** Event 4 baseline peak is 2400 cms with mitigation**
1. Spray Lake Reservoir flood operations	177,600 dam^3 total storage >100cms trigger	0	0	0	0	Spray already catches all it can in Event 1	-	-	100 cms trigger
2. Lake Minnewanka flood operations	221,900 dam^3 live storage >100cms trigger	0	0	0	0	Minnewanka already does what it can in Event 1	-	-	100 cms trigger
3. Upgrade Ghost River diversion to Lake Minnewanka	>20 cms trigger, 60 cms max diversion	0	30	0	15	Rebuilding diversion would result in lower flows going to Minnewanka	-	-	Canmore peak was decreased by 40 cms
4. New reservoir on Ghost River upstream of Waiparous confluence	60,000 dam^3 >200 cms trigger	300	200	400	300	200 cms trigger	200 cms trigger	200 cms trigger	200 cms trigger; this would have to be an operable structure
	60,000 dam^3 >100 - 125 cms trigger	400	300	300	200	125 cms trigger	100 cms trigger	100 cms trigger	100 cms trigger
5. New reservoir on Waiparous Creek upstream of confluence with Ghost River	35,000 dam^3 >40 cms trigger	250	200	300	220	40 cms trigger	40 cms trigger	-	50 or 60 cms trigger
	35,000 dam^3 >20 cms trigger	250	150	0	100	20 cms trigger	20 cms trigger	-	-
6. Kananaskis Lakes Flood Operations	187,600 dam3 live storage >50 cms trigger	0	0	0	0	50 cms trigger (not that much inflow in Event 1)	-	-	50 cms trigger
7. New reservoir on Kananaskis River	85,000 dam^3 >50 cms trigger	100	50	100	250	50 cms trigger (not that much inflow in Event 1)	-	-	50 cms trigger
8. Barrier Lake flood operations	24,800 dam^3 live storage Hold back 100 cms less than inflow	75	5	50	75	Hold back 100 cms less than inflow	Hold back 100 cms less than inflow	-	Hold back 100 cms less than inflow
9. New reservoir on Jumpingpound Creek	60,000 dam^3 >10-50 cms trigger	150	325	0	145	10 cms trigger	-	50 cms trigger - only affected the first peak, was full for second peak	10 cms trigger
10. New Glenbow reservoir on Bow River upstream of Bearspaw	70,000 dam^3	550	350	700	600	1200 cms trigger	1200 cms trigger	1200 cms trigger	1700 cms trigger
	70,000 dam^3	550	650	800	500	Can't be set lower than 1200 or reservoir fills up in Event 1)	800 cms trigger	1100 cms trigger	1800 cms trigger
11. New Morley reservoir on Bow River upstream of Ghost Reservoir	150,000 dam^3 >350-800 cms trigger	300	50	100	400	600 cms trigger	350 cms trigger	400 cms trigger	800 cms trigger
	150,000 dam^3 >250-400 cms trigger	500	150	200	600	400 cms trigger	250 cms trigger	300 cms trigger	600 cms trigger
12. Extend Ghost Reservoir flood operations (2016 agreement)	92,500 dam^3 live storage >400-1200 cms trigger	250	0	0	250	400 cms trigger	400 cms inflow trigger, 1ft/day lowering rate	400 cms inflow trigger, 1ft/day lowering rate	1200 cms trigger, also delays peak
13. Expand Ghost Reservoir (by raising full supply level and/or adding a low-level outlet)	>400 cms trigger ~35,000 dam^3 new	300	0	0	200	400 cms trigger	400 cms inflow trigger, 1ft/day lowering rate	400 cms inflow trigger, 1ft/day lowering rate	-
	>400 cms trigger ~60,000 dam^3 new	550	400	550	550	400 cms trigger	400 cms inflow trigger, 1ft/day lowering rate	400 cms inflow trigger, 1ft/day lowering rate	-
14. Restore Spray Reservoir to full design capacity	Create additional ~75,000 dam^3 >100 cms inflow trigger	0	0	0	0	-	-	-	~150 cms reduction at Canmore (~8 hours after peak at Calgary)
15. Increase Ghost Reservoir drawdown rate	400 cms inflow trigger, 2ft/day lowering rate	250	100	200	250	350 cms inflow trigger	400 cms inflow trigger	400 cms inflow trigger	400 cms inflow trigger
	400 cms inflow trigger, 5ft/day lowering rate	250	250	300	250	400 cms inflow trigger	400 cms inflow trigger	400 cms inflow trigger	400 cms inflow trigger

		Event 1	Event 2	Event 3	Event 4	
Flood Mitigation Scenarios		**Approximate peak**	**Approximate peak**	**Approximate peak**	**Approximate peak**	**Observations**
1200 cms Scenario A	12 + 15 + 8 + 10	1200	1200	1200	1500	Ghost > 400 cms trigger and 5 ft/day lowering rate, Barrier hold back 100 cms less than inflow, Glenbow 1200 and 1500 (event 4) cms outflow triggers.
1200 cms Scenario B	12 + 15 + 8 + 11	1200	1100	1300	1900	Ghost > 400 cms trigger and 5 ft/day lowering rate, Barrier hold back 100 cms less than inflow, Morley 600 (event 1), 275 (event 2), 375 (event 3), and 800 (event 4) cms outflow triggers.
1200 cms Scenario C	12 + 15 + 8 + 13	1150	1200	1200	1550	Ghost > 400 cms trigger and 1 ft/day (event 1) and 5 ft/day (event 2 and 3) lowering rates, Barrier release 100 cms less than inflow. Additional lower level outlet is also included. Note - refined operations may be able to achieve more peak flow reduction.
1200 cms Scenario D	12 + 15 + 8 + 7 + 9 or 4	1300	1000	1500	1600	Ghost > 400 cms trigger and 5 ft/day lowering rate, Barrier hold back 100 cms less than inflow, Kananaskis 100 and 50 (event 4) cms outflow triggers, Jumpingpound 50 and 10 (event 4) cms outflow triggers.
800 cms Scenario A	12 + 15 + 8 + 10 + 11	800	800	800	1400	Ghost > 400 cms trigger and 5 ft/day lowering rate, Barrier hold back 100 cms less than inflow, Glenbow 1200 and 850 (event 4) cms outflow triggers, Morley 350 and 650 (event 4) cms triggers.
800 cms Scenario B	12 + 15 + 8 + 10 + 13	900	900	1000	1300	Ghost > 400 cms trigger and 5 ft/day lowering rate, Barrier hold back 100 cms less than inflow, Glenbow 900 (event 1 and 2), 1000 (event 3) and 1300 (event 4) cms outflow triggers.
800 cms Scenario C	12 + 15 + 8 + 10 + 7 + 9 + 4	800	800	800	1200	Ghost > 400 cms trigger and 5 ft/day lowering rate, Barrier hold back 100 cms less than inflow, Glenbow 800 (event 1, 2, and 3), 1200 (event 4) cms outflow triggers, Kananaskis 50 cms outflow trigger, Waiparous 40 cms outflow trigger, Jumpingpound 10 cms trigger.

Appendix F: Flood Mitigation Results at Cochrane

This table demonstrates the approximate peak flow for Cochrane under all fifteen flood mitigation schemes and seven flood mitigation scenarios for each of the 4 synthesized events. Each scheme and scenario is listed on the left, with the results for all 4 events shown in the four columns on the right.

Flood Mitigation Schemes *Note: These results are based on each scheme acting alone.Results are not necessarily additive.*	**Event 1** **Approximate peak at Cochrane (cms)**	**Event 2** **Approximate peak at Cochrane (cms)**	**Event 3** **Approximate peak at Cochrane (cms)**	**Event 4** **Approximate peak at Cochrane**
Base case	1600	1200	1450	2100
1. Spray Lake Reservoir flood operations	1600	1200	1450	2100
2. Lake Minnewanka flood operations	1600	1200	1450	2100
3. Upgrade Ghost River diversion to Lake Minnewanka	1600	1250	1500	2100
4. New reservoir on Ghost River upstream of Waiparous confluence	1400	1000	1300	2000
5. New reservoir on Waiparous Creek upstream of confluence with Ghost River	1400	1000	1300	2000
6. Kananaskis Lakes Flood Operations	1600	1200	1450	2100
7. New reservoir on Kananaskis River	1450	1150	1350	1950
8. Barrier Lake flood operations	1500	1200	1500	2000
9. New reservoir on Jumpingpound Creek	1600	1200	1500	2100
10. New Glenbow reservoir on Bow River upstream of Bearspaw	1600	1200	1500	2100
11. New Morley reservoir on Bow River upstream of Ghost Reservoir	1100	1000	1250	1600
12. Extend Ghost Reservoir flood operations (2016 agreement)	1300	1200	1450	1800
13. Expand Ghost Reservoir (by raising full supply level and/or adding a low-level outlet)	1100	800	1100	1600
14. Expand Spray Reservoir	1600	1200	1450	2100
15. Increase Ghost Reservoir drawdown rate	1350	1000	1200	1800

Flood Mitigation Scenarios	**Event 1** **Approximate peak**	**Event 2** **Approximate peak**	**Event 3** **Approximate peak**	**Event 4** **Approximate peak**
1200 cms Scenario A	1250	900	900	1800
1200 cms Scenario B	1000	800	900	1500
1200 cms Scenario C	1200	900	800	1650
1200 cms Scenario D	1300	900	1150	1700
800 cms Scenario A	1000	900	1000	1300
800 cms Scenario B	1200	1200	1500	1700
800 cms Scenario C	1100	700	850	1700

Appendix G: Flood Mitigation Results at Carseland

This table demonstrates the approximate peak flow for Cochrane under all fifteen flood mitigation schemes and seven flood mitigation scenarios for each of the 4 synthesized events. Each scheme and scenario is listed on the left, with the results for all 4 events shown in the four columns on the right.

Flood Mitigation Schemes *Note: These results are based on each scheme acting alone.Results are not necessarily additive.*	**Event 1** **Approximate peak at Carseland (cms)**	**Event 2** **Approximate peak at Carseland (cms)**	**Event 3** **Approximate peak at Carseland (cms)**	**Event 4** **Approximate peak at Carseland**
Base case	3500	2900	3200	5500
1. Spray Lake Reservoir flood operations	3500	2800	3200	5500
2. Lake Minnewanka flood operations	3800	2800	3300	5000
3. Upgrade Ghost River diversion to Lake Minnewanka	3500	2900	3300	5500
4. New reservoir on Ghost River upstream of Waiparous confluence	3300	2700	3000	5200
5. New reservoir on Waiparous Creek upstream of confluence with Ghost River	3300	2700	3000	5200
6. Kananaskis Lakes Flood Operations	3500	2900	3300	5500
7. New reservoir on Kananaskis River	3500	2900	3300	5500
8. Barrier Lake flood operations	3500	2900	3300	5500
9. New reservoir on Jumpingpound Creek	3400	2600	3300	5500
10. New Glenbow reservoir on Bow River upstream of Bearspaw	3500	2500	2500	5500
11. New Morley reservoir on Bow River upstream of Ghost Reservoir	3500	2800	3000	5500
12. Extend Ghost Reservoir flood operations (2016 agreement)	3500	2900	3300	5000
13. Expand Ghost Reservoir (by raising full supply level and/or adding a low-level outlet)	3600	2300	2800	4800
14. Expand Spray Reservoir	3500	2900	3300	5500
15. Increase Ghost Reservoir drawdown rate	3500	2600	2900	5000

Flood Mitigation Scenarios	**Event 1** **Approximate peak**	**Event 2** **Approximate peak**	**Event 3** **Approximate peak**	**Event 4** **Approximate peak**
1200 cms Scenario A	3500	2500	2500	5000
1200 cms Scenario B	3500	2500	3000	5000
1200 cms Scenario C	3200	2300	2600	4700
1200 cms Scenario D	3300	2300	2800	4800
800 cms Scenario A	3500	2200	2200	4500
800 cms Scenario B	3300	2300	2500	4900
800 cms Scenario C	3300	2100	2100	4800

Appendix H: Flood Mitigation Results at Medicine Hat

This table demonstrates the approximate peak flow for Medicine Hat under all fifteen flood mitigation schemes and seven flood mitigation scenarios for each of the 4 synthesized events. Each scheme and scenario is listed on the left, with the results for all 4 events shown in the four columns on the right.

Flood Mitigation Schemes *Note: These results are based on each scheme acting alone.Results are not necessarily additive.*	**Event 1** **Approximate peak at Medicine Hat (cms)**	**Event 2** **Approximate peak at Medicine Hat (cms)**	**Event 3** **Approximate peak at Medicine Hat (cms)**	**Event 4** **Approximate peak at Medicine Hat**
Base case	5800	3300	3700	7800
1. Spray Lake Reservoir flood operations	5800	3300	3700	7800
2. Lake Minnewanka flood operations	6100	3300	3700	7500
3. Upgrade Ghost River diversion to Lake Minnewanka	5800	3300	3700	7900
4. New reservoir on Ghost River upstream of Waiparous confluence	5600	3000	3200	7600
5. New reservoir on Waiparous Creek upstream of confluence with Ghost River	5600	3100	3400	7600
6. Kananaskis Lakes Flood Operations	5800	3300	3700	7900
7. New reservoir on Kananaskis River	5800	3300	3600	7800
8. Barrier Lake flood operations	5800	3300	3700	7900
9. New reservoir on Jumpingpound Creek	5600	3200	3600	7600
10. New Glenbow reservoir on Bow River upstream of Bearspaw	5800	3000	3700	7800
11. New Morley reservoir on Bow River upstream of Ghost Reservoir	5700	3300	3600	7800
12. Extend Ghost Reservoir flood operations (2016 agreement)	5700	3300	3000	7500
13. Expand Ghost Reservoir (by raising full supply level and/or adding a low-level outlet)	5400	2800	3600	7000
14. Expand Spray Reservoir	5800	3300	3700	7900
15. Increase Ghost Reservoir drawdown rate	5800	3100	3300	7900

Flood Mitigation Scenarios	**Event 1** **Approximate peak**	**Event 2** **Approximate peak**	**Event 3** **Approximate peak**	**Event 4** **Approximate peak**
1200 cms Scenario A	5400	3000	3000	7400
1200 cms Scenario B	5400	3000	3200	7400
1200 cms Scenario C	5300	2800	3000	7000
1200 cms Scenario D	5600	2800	3100	7000
800 cms Scenario A	5600	3000	3000	6700
800 cms Scenario B	5500	3000	3000	7200
800 cms Scenario C	5400	2600	3000	6500

Appendix I: Modelling Results Summary: Balancing the Mitigation Schemes and Scenarios

Most promising scheme
Somewhat promising scheme
Least promising scheme

Balancing the System Schemes *Note: These results are based on each scheme acting alone. Results are not necessarily additive.*	**Operational Notes**	**Performance Improvement** Total system storage at start of irrigation in normal year (04/15/1956, cdm)	Max total system storage in exceptional drought (10/24/1936, cdm)	Max total system storage in "normal" drought (10/14/1987, cdm)	Calgary Low Flow (Days with flow <= 1500 cfs)	Calgary Low Flow (Days Less with flow at 1250 cfs)	**Observations**
Initial Performance (Scenario A 1200 cms)	"Damage" caused by flood mitigation ops	0	-59,000	-48,000	19.3%	42.0%	
1. Increase Ghost Reservoir drawdown rate (Allows Ghost to stay higher on the assumption it can draw down almost instantaneously)	1 foot per day drawdown (current operations, no change)	0	0	0	0.0%	0.0%	Only thing that can help save storage in severe multi-year droughts is not to release in the first place. Beneficial in all ways. Est Base flow (2013) = 340 cms, 1'/day = + 55cms Flow through Calgary = 395 cms
	5 feet per day drawdown	0	11,000	4,000	-3.3%	-17.0%	Est Base flow (2013) = 340 cms, 5'/day = +140 cms Flow through Calgary = 480 cms
	10 feet per day drawdown	0	25,000	18,000	-8.8%	-26.1%	Est Base flow (2013) = 340 cms, 10'/day = +292 cms Flow through Calgary = 632 cms
2. Drought storage in expanded Glenmore Reservoir	Glenmore replaces stoplogs with permanent structure. Raises to 2.5m above current crest and no longer requires as big a winter drawdown	0	0	-1,000	3.4%	1.3%	Very beneficial for multi year droughts. Slightly exacerbates flow problem as TA no longer sends additional water for Calgary demands.
3. Increase diversion rate of the Carseland Canal and construct debris deflector	Increase max diversion to 53 cms with little to no cost	0	4,000	27,000	-6.8%	-7.6%	Allows BRID to capture extra releases and keep them in their ample storage, leading to fewer calls. Doesn't help in multi-year droughts though, as there's simply no water
	Further increase to 60 cms, but potentially has meaningful cost	0	6,000	25,000	-8.3%	-7.4%	See above. Seems to pass diminishing returns though, as BRID continues to take water to maintain their reservoirs. Likely not a problem in real life. Debris not technically modeled as it's external.
4. Raise winter carryover in existing reservoirs (e.g. Travers/Little Bow, McGregor)	Winter storage raised 50% closer to full	36,000	0	22,000	-0.6%	-2.0%	Comparatively small benefit in selected years, but shows much more use in milder droughts. Recommended as it requires no infrastructure changes.
5. Fill irrigation district-serving reservoirs earlier (e.g. Travers/Little Bow)	Refill starts 2 weeks earlier for ID reservoirs	13,000	-1,000	2,000	-0.3%	-2.0%	Very beneficial in single-year events. After year 1, however, storage cannot replenish. Recommended as it requires no infrastructure changes.
6. Extend Kananaskis System water shortage mitigation operations (2016 agreement).	Not modelled	-	-	-	-	-	

Balancing the System Scenario		**Performance Improvement** Total system storage at start of irrigation in normal year	Max total system storage after exceptional drought	Max total system storage in "normal" drought (10/14/1987,	Calgary Low Flow (Days with flow <= 1500 cfs)	Calgary Low Flow (Days Less with flow at 1250	**Observations**
Scenario A	1 (10 feet /day) + 2 + 3 (53 cms) + 4 + 5 + 6	56,000	30,000	72,000	-16.3%	-30.3%	

Appendix J: Modelling Results Summary: Drought Mitigation Schemes and Scenarios

Most promising scheme
Somewhat promising scheme
Least promising scheme

Drought Mitigation Schemes *Note: These results are all compared relative to current operations, without consideration of Flood operations or "Balancing the System" operations.*	Operational Notes	Historical Performance Improvement (Relative to Current Operations): Total Shortages (Volume)	Historical: New WCO Violations (Carseland to Bassano)	Historical: New Apportionment Violations (yes/no)	Drought 1 Performance Improvement (Relative to Current Operations): Total Shortages (Volume)	Drought 1: New WCO Violations (Carseland to Bassano)	Drought 1: New Apportionment Violations (yes/no)	Drought 2 Performance Improvement (Relative to Current Operations): Total Shortages (Volume)	Drought 2: New WCO Violations (Carseland to Bassano)	Drought 2: New Apportionment Violations (yes/no)	Observations
1. Restore Spray Reservoir to full design capacity	Creates additional ~75,000 dam^3	-17.2%	-4.5%	NO	-13.2%	-2.2%	NO	-0.9%	0.0%	NO	
2. Increase Ghost River diversion to Lake Minnewanka	Force all Ghost river flow through Minnewanka in drought	0.8%	0.3%	NO	2.6%	-0.4%	NO	-0.1%	0.0%	NO	Historical: Benefits only shown when in combination with Ghost drawdown from Flood Ops helps refill Ghost void)
3. Extend Kananaskis System Water Shortage Mitigation operations (2016 agreement)	GoA operates the Kananaskis river and makes releases as desired (modeled as ~37,000 dam^3 storage and 8cms releases)	-33.6%	-1.4%	NO	-49.3%	-1.5%	NO	-12.2%	0.6%	NO	
4. New storage capacity in Kananaskis system	~25,000 dam^3, tied to Barrier Ops	-4.9%	-1.6%	NO	-2.0%	0.0%	NO	-0.9%	1.2%	NO	
5. New Morley reservoir on Bow River upstream of Ghost Reservoir	Tied to Ghost operation, assumed 50% capacity wet/50% dry, approx 75,000 cdm	-54.9%	-11.1%	NO	-53.9%	-9.0%	NO	-12.5%	-1.5%	NO	
6. Expand Ghost Reservoir (by raising full supply level and/or adding a low-level outlet)	+3m rise or lowering outlet, approx +36,000 cdm storage	-49.2%	-4.8%	NO	-41.4%	-4.9%	NO	-12.5%	-1.5%	NO	
	+3m rise and lowering outlet, approx +60,000 cdm storage	-54.9%	-4.8%	NO	-53.3%	-4.9%	NO	-10.2%	-1.5%	NO	Historical: Incremental gains over 36k AF not substantial enough to be promising
7. New Glenbow reservoir on Bow River upstream of Bearspaw	Tied to Bearspaw operations, assumes only minimal (i.e. drain in one day) storage, approx. 10,000 AF	-21.3%	0.1%	NO	-18.4%	0.0%	NO	-0.8%	0.6%	NO	
8. New Delacour reservoir in Western Irrigation District	~26,000 cdm of storage, connected to northern WID demands (i.e. not those met by Langdon/Chestermere). No calls on TA to refill this storage.	-39.3%	-0.2%	NO	-32.2%	-1.1%	NO	-9.1%	2.1%	NO	Historical: Shows substantially more benefit when combined with Ghost drawdown, as it captures early releases Drought 2: License for Delacour will need to be careful around allowance of filling when flows are especially low in order to avoid new WCO violations
9. Increase WID diversion rate at all river stages without affecting licence priority date	WID gains additional diversion capacity of +200 cfs at all river stages	-16.4%	0.1%	NO	-13.2%	-0.7%	NO	-0.5%	0.3%	NO	
10. New Deadhorse Coulee reservoir in Bow River Irrigation District	~28,000 dam^3 of storage in BRID downstream of headworks. No calls on TA to refill this storage.	-16.4%	-1.8%	NO	-14.5%	-0.7%	NO	0.1%	0.3%	NO	Historical: Shows substantially more benefit when combined with Ghost drawdown, as it captures early releases
11. Operate McGregor Reservoir at the design full supply level	Max storage raised by ~13,000 dam^3	2.5%	-1.0%	NO	0.0%	-0.7%	NO	-0.8%	0.0%	NO	
12. New Eyremore reservoir low in Bow River Basin	~300,000 dam^3 (could be more) live storage immediately downstream of existing Bassano dam. Operated in conjunction with both Bow and Oldman systems.	-65.6%	-5.1%	NO	-62.5%	-10.4%	NO	-47.1%	-12.8%	MAYBE	Drought 2: Fast refill following multi-year drought could risk apportionment violations
		Less than 5.0% = no significant change	*Less than 1.0% = no significant change*		*Less than 5.0% = no significant change*	*Less than 1.0% = no significant change*		*Less than 5.0% = no significant change*	*Less than 1.0% = no significant change*		

Drought Scenarios *Note: These results are based on each scheme acting alone. Results are not*		Historical Performance Improvement (Relative to Current Operations): Total Shortages (Volume)	Historical: New WCO Violations	Historical: New Apportionment Violations	Drought 1 Performance Improvement (Relative to Current Operations): Total Shortages (Volume)	Drought 1: New WCO Violations	Drought 1: New Apportionment	Drought 2 Performance Improvement (Relative to Current Operations): Total Shortages (Volume)	Drought 2: New WCO Violations at Bassano	Drought 2: New Apportionment	Observations
Operational changes at existing infrastructure + Minor infrastructure	3 + 8 + 9 + 10 + 11	-57.4%	-2.2%	NO	-61.2%	-0.4%	NO	-19.4%	1.2%	NO	
Major infrastructure (primarily for flood mitigation)	8. New Glenbow reservoir on Bow River upstream of Bearspaw	-21.3%	0.1%	NO	-18.4%	0.0%	NO	-0.8%	0.6%	NO	
	5. New Morley reservoir on Bow River upstream of Ghost Reservoir	-54.9%	-11.1%	NO	-53.9%	-9.0%	NO	-12.5%	-1.5%	NO	
	7a. Expand Ghost Reservoir (~35,000)	-49.2%	-4.8%	NO	-41.4%	-4.9%	NO	-12.5%	-1.5%	NO	
	7b. Expand Ghost Reservoir (~60,000)	-54.9%	-4.8%	NO	-53.3%	-4.9%	NO	-10.2%	-1.5%	NO	
Major infrastructure (primarily for drought mitigation)	16. New Eyremore reservoir low in Bow River Basin	-65.6%	-5.1%	NO	-62.5%	-10.4%	NO	-47.1%	-12.8%	MAYBE	Fast refill following multi-year drought could risk apportionment violations

Appendix K: IO/WCO Implications for Reservoirs Upstream of Calgary

The *Water Management Plan for the South Saskatchewan River Basin* (AENV, 2006) indicates that the Water Conservation Objective for all storage licenses under the Crown Reservation should be the existing instream objective plus 10% at any point in time. Recognizing this, the AC and BRWG questioned whether the application of a WCO (or IO) would significantly change the modelling results showing the potential of each mitigation scheme in the modelled scenarios.

Prior work in the Oldman River Basin determined that there could be significant implications to applying the WCO to new reservoir infrastructure. In fact, it was shown that applying the existing WCO to new structures could completely negate the positive objectives of building the structure in the first place.

It was expected that the model used in this project would be able to indicate expected impacts of either applying or relaxing IOs/WCOs should a new reservoir be built or if an existing reservoir is sufficiently modified that it would be issued a new licence. A preliminary analysis was conducted.

The WCO release requirement is defined as 45% of natural flow or the previously existing Instream Objective (IO), whichever is larger. As existing Bow River reservoirs are currently only bound by the IO, this is potentially often a much higher requirement. There was substantial concern that the introduction of the WCO requirement would thus drain any new storage to the point that would offset any potential benefits in terms of storing during high flows and releasing during lower flows or higher downstream demand.

During modeling efforts, however, it was discovered that although the WCO is higher than the existing IO, it is (during the winter low flow period) often lower than the 1250 cfs (35.4 m^3/s) release that TransAlta has generally committed to release at Bearspaw. Although there are examples where the introduction of a WCO would force additional releases by TransAlta, they are relatively few and may have only minor impact on TransAlta storage. We concluded that, based on this preliminary analysis, no storage schemes should be disqualified solely due to the potential introduction of a WCO requirement.

There are two important caveats to this analysis:

1. This model only examined daily impacts. Although the 1250 cfs (35.4 m^3/s) is met on a daily basis, instantaneous releases could be well below 1250 cfs (35.4 m^3/s) and in substantial violation of existing WCO requirements. Study via a model with hourly or better resolution is both necessary and recommended to fully assess the impact of a new WCO application to new storage facilities.
2. The 1250 cfs (35.4 m^3/s) release commitment by TransAlta is not legally binding. Should the TransAlta system not meet this minimum release, negative downstream effects from the WCO application would be substantial and requires further study as decisions are made on upstream infrastructure.

Appendix L: Return Period Estimates (Golder, 2014)

BOW RIVER AND ELBOW RIVER HYDROLOGY

Table 2.2: Estimated Daily Flood Flows (m^3/s) for Various Return Periods - Derived from Frequency Analysis of Natural or Naturalized Annual Maximum Daily Flows for Streams with Storage Reservoirs

Return Period (Year)	Local Inflow to Lower Kananaskis Lake	Inflow to Upper Kananaskis Lake	Inflow to Lake Minnewanka	Inflow to Spray Lake	Local Inflow to Spray River at Mouth	Inflow to Barrier Lake	Bow River at Banff	Inflow to Ghost Reservoir	Inflow to Bearspaw Reservoir without Historical Data	Inflow to Bearspaw Reservoir with Historical Data	Inflow to Glenmore Reservoir
Drainage Area (km^2)	**151**	**150**	**647**	**520**	**230**	**899**	**2,210**	**6,550**	**7,770**	**7,770**	**1,236**
2	17.4	22.4	53.6	65.2	12.0	70.8	205	348	376	354	58.5
5	21.8	28.2	80.4	87.8	20.0	113	262	471	520	592	108
10	24.7	32.5	101	107	27.0	148	296	573	641	814	156
20	27.4	36.9	124	129	35.8	188	326	688	781	1,060	218
50	30.9	42.9	158	164	50.4	250	361	869	1,000	1,420	331
100	33.5	47.7	187	196	63.8	307	385	1030	1,210	1,720	448
200	36.1	52.8	219	235	79.6	375	407	1,220	1,450	2,040	602
500	39.6	60.1	268	298	105	482	435	1,530	1,840	2,480	885
1,000	42.2	65.6	309	357	127	581	455	1,810	2,210	2,830	1,180