Bow River Live Simulation

Summary Report

December 2011

This report was prepared by WaterSMART Solutions Ltd. (WaterSMART) and Alberta Innovates – Energy and Environment Solutions. It may be freely downloaded from the Alberta WaterPortal at: http://www.albertawater.com.

Acknowledgements

As was the case with the Bow River Project, participants gave generously of their time and expertise for the purpose of testing their earlier recommendations in a live Simulation. They are listed in Appendix A. Agencies and organizations that funded the live Simulation are also gratefully acknowledged.

Contents

Tables and Figures

Executive Summary

In 2010, a diverse group of water users and managers in the Bow River basin proposed a different way of managing the river system that would make water available to existing and future users when and where it is needed most. One outcome of their work was the Bow River Operational Model (BROM). In 2011, the same group of individuals met again to test the impacts of their recommendations through a live simulation (the Simulation) using the BROM. This Simulation enabled participants to perform a realistic test of existing operations and to see the real-time operational impacts of their management choices.

The Simulation exercise enabled stakeholders to better understand the type and range of discussions that are needed to make decisions about managing the river. It confirmed a number of the key recommendations put forward through the Bow River Project to improve aquatic health and to make effective use of a water bank to manage the timing of downstream flows. In essence, the Simulation confirmed that the Bow River system can and should be managed differently to foster innovation and achieve many economic, environmental and social goals throughout the Bow basin.

Participants concluded that the BROM is a realistic model and a valuable tool for understanding the river system and exploring changes and potential opportunities to manage the system better. Additional refinements and improvements to the BROM were identified and proposed as a result of the Simulation.

1.0 Background on the Bow River Project

For the past 100 years, the flow of the Bow River has been controlled by dams and reservoirs and by the operating rules established by the owners of these facilities. Since 1911, TransAlta Utilities (TAU) has been the main influence on the on-stream storage and release of water in the river and its tributaries. Since the early 1900s, water diversions and off-stream storage in support of irrigated agriculture and municipalities have also affected the flow and timing of water in the Bow River basin. The fact that the timing and flow rate of the Bow River are already being managed offers a unique strategic opportunity to change the way decisions are made and make water available for environmental purposes as well as to users when and where it is needed most.

In 2010, the Bow River Project Research Consortium was established to explore options for re-managing the Bow River system from headwaters to confluence, in an integrated manner that considers all users, interests and values.[1] Participants worked with an interactive, hydrologic simulation model to develop plausible and achievable scenarios for protecting the health of the river throughout the basin while also meeting the needs of water users. A major outcome of the Bow River Project (BRP) was the fully functioning, data-loaded Bow River Operational Model (BROM). In addition, participants gained valuable collaborative experience as they worked with the model. Nine principles guided the BRP:

1. Causing no significant, measurable environmental harm.
2. Assuming Bow River basin remains closed to new licences.
3. Respecting TransAlta's reputation as an environmentally responsible and proactive corporation.
4. Compensating TransAlta for the cost of providing benefits to other parties.
5. Meeting Alberta's annual apportionment commitments to Saskatchewan.
6. Maintaining minimum flow requirements for municipalities.
7. Supporting the long term population/economic growth forecasts.
8. Meeting long-term forecast needs of the Siksika First Nation.
9. Respecting Alberta's water licensing priority system.

The BRP concluded that the Bow River system can and should be managed differently to achieve many economic, environmental and social 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. This preferred scenario involved stabilizing Lower Kananaskis Lake and Kananaskis River, establishing a water bank capable of managing 60,000 acre-feet in a different manner, and raising the priority of the environmental flows throughout the river, as represented by the flow at Bassano; all scenarios are described in more detail in the original BRP report.

Due to the short time frame for the BRP and the need to refine, test and refine again the data and the model functions, there was little time to experiment, test and use the model under different scenarios and circumstances. Water managers and licence holders were interested in seeking further innovation and improvements and were keen to further test the BROM and the recommendations they had put forward. Live simulation is a realistic and legitimate approach for

[1] More information on the Bow River Project is available at the Alberta WaterPortal at: http://www.albertawater.com.

validating proposed changes to the river operating rules and can build a fuller understanding of the potential impacts of these changes. Such simulations can also identify new management issues as well as areas where the model could be improved. Live simulation enables participants to explore these issues in real time and find ways to address them.

To gain a better, real-time understanding of the impacts of the changes proposed in the BRP, participants again came together in the fall of 2011 to engage in an interactive modeling exercise – the Bow River Live Simulation – using the existing model and data.

2.0 Bow River Simulation Objectives

The Bow River Live Simulation (the Simulation) had three main objectives:

1. Revisit and validate the BROM and the preferred scenario recommendations;
2. Test and improve the proposed integrated river management operating rules; and
3. Identify and address the consequences of the proposed integrated river management operating rules.

3.0 Simulation Rules and Roles

The Simulation enabled participants to perform a realistic test of existing operations and to see the real-time operational impacts of their management choices. The intent was to compare the current operations of the river system, the preferred scenario developed through the BRP, and the live operations from the Simulation. Prior to the exercise, participants were surveyed for the river conditions, water supply and demands, and river events that they thought would be most valuable to model. Some of the key performance measures identified in the BRP were also part of the interactive work. The live Simulation session was then set up to reflect those needs and priorities. Participants were guided in the Simulation by HydroLogics, the consultant who previously worked with the group to do the modeling work on the BROM.

Participants, listed in Appendix A, were asked to represent the interests of their organization or sector in the Simulation. A decision panel, also listed in Appendix A, was established to rule on any conflicts. Consensus was needed before the model was run with real data. As the Simulation proceeded, decisions came to be made by the group as a whole, as there was generally agreement on how to proceed.

Participants were asked to specify operations week-by-week based on antecedent conditions and forecasted inflows. Then using existing operations and assumptions embedded in the model, the BROM forecasted reservoir levels, deliveries, and river flows one week out. Participants were then asked to revise (or not revise) operations based on the forecasted results. Operations were then finalized for the next week, and this process was repeated for most of a year.

Before running each week, HydroLogics provided the following information:

- Weekly forecasts of flows (every Monday),
- Rough weekly forecasts of precipitation and temperature for Banff, Calgary and Brooks (every Monday) and snowpack data at Sunshine Village,
- Weekly demand requirements,

- Expected results (river flow, deliveries, reservoir stage, etc.) under Preferred Scenario operations for the week under forecasted inflows, and
- Results from the previous week(s).

A communications specialist played the role of a journalist who prepared two short "media" items based on conditions and management decisions throughout the Simulation. This served to highlight the perspective and concerns of the general public.

In this report, both metric and imperial units are used to describe volumes of water, the most common being cubic metres per second (cms), cubic feet per second (cfs) and acre-feet. Conversion factors are provided in Appendix C.

4.0 Simulation Recap

Prior to the Simulation, 1941 was selected as the year whose data would be used as the basis for the Simulation year (2013). HydroLogics ran the model for 2012, using the preferred scenario and legitimate inflow records for 1940 to set the starting conditions for 2013, the year being tested. Participants did not know in advance that 1941 was the year chosen. Additional parameters were also provided:

- Snowpack Snow Water Equivalent (SWE) at Sunshine Village was 325 mm, which is 60% of the average of the last 30 years.
- The Water Bank was at 50,000 acre-feet.
- The reservoirs in the irrigation districts were full.

Because there were no stressful or contentious situations in the first three months of the year, the Simulation began the week of April 7, 2013.

All performance measures developed for the BRP were available for use in the Simulation, but not all were used. HydroLogics presented the performance measures most often requested by participants prior to the Simulation to show the starting point on April 7, as shown in Table 1.

Table 1. Performance Measures

Performance Measure	**Description**
Water Bank Status	Extent to which the water bank is filled to its desired capacity of 60,000 acre-feet
Shortages (WID/BRID/EID/Calgary/Rest of System)	Daily shortage and maximum diversion for each of the irrigation districts, Calgary and the rest of the system
Power Revenue (7-day running average, year to date)	Average annual power generation revenue and average annual ancillary services revenue for the TransAlta system in the upper Bow Basin
Kananaskis River Flow	Flow stabilization in the Kananaskis River between Lower Kananaskis Lake and Barrier Lake to benefit the aquatic environment in cms
BRID/EID Diversion flow	Diversion flows to BRID and EID in cfs
Flow at Calgary	Flow below Bearspaw Dam in cfs
BRID Headworks flow	Flow at the BRID headworks in cfs

Performance Measure	Description
Bassano Flow	Number of flow events at Bassano across the simulation period where the flow is less than 1200 cfs, in three categories
Glenmore, McGregor, Travers, etc. elevation	Reservoir elevations for the major reservoirs downstream of the TAU reservoirs
TAU Reservoir elevations	Reservoir elevations for TAU reservoirs
Demand Schedule	Total daily system demand

The group began by working with the model on a weekly basis and developed the Simulation through to the end of September. Time constraints on the sessions did not permit the Simulation to extend beyond the early fall. The bullet points for each time period (usually a week) reflect the group's discussion, and decision(s) for the next time period are noted.

April 8-14

- Flow of 1400 cfs below Carseland matters most in the spring.
- The level in Glenmore appears high and needs to be checked, and EID's winter storage levels need to be corrected in the model as they were filled completely in fall 2012 and this is not realistic.

Decision: Set minimum flow below Carseland to 1400 cfs from April 1 to October 31; that is during diversion season. This is a correction to the model.

April 15-21

- Precipitation in April was low, the low elevation snow is gone and snow at higher elevations has not yet started to melt. TransAlta reservoirs were slow to fill.

Decision: No changes.

April 22-29

- In anticipation of certain coal-fired plants going offline for maintenance, TransAlta may want to store more water than normal (that is, reduce Bearspaw flows) to ensure it can meet increased power demands during the summer. But by the end of April, this is not possible because irrigators with senior licences will be taking priority.
- Forecasts and actual results for most performance measures were very close. The water bank has risen a little; temperatures were generally in the mid-20s (C) with no rain.

Decision: No changes.

April 30-May 6

- Experienced three days of very low flow in Upper Kananaskis River (from Pocaterra) as model indicates inflow to Lower Kananaskis Lake is zero.
- Are data missing in the model, related to inflow from minor tributaries and as a result of seepage from dams? The model does not account for leakage from the penstocks. As the

Lower Kananaskis penstock is being replaced, the model may be more accurate for future work.

- All inflows in the minor tributaries are rolled into the downstream node because a consistent suitable data source for the tributaries for the period of record is not available.
- Levels fell to below 800 cfs at Bassano, which triggered water bank withdrawals. Agreed to turn off these withdrawals and not fill BRID reservoirs and irrigators would ask TransAlta for natural flow, saving water bank withdrawals until later in the summer.
- In this situation, BRID withdrawals were reduced to maintain flows at Bassano.

<u>Decision</u>: 1. Make 2 cms as the minimum release from the Pocaterra plant into the Kananaskis River as the inflow to Kananaskis Lakes.
2. Turn off automated withdrawal (preferred scenario/current operations) from water bank.

The first media item was shared with the group at this point and it focused on what appeared to be shaping up as a serious drought in southern Alberta.

May 7-13

- Need to address low flows at Bassano (400 cfs) so consider water bank withdrawals of 300 cfs to supplement flows. This amount was needed to ensure a 100 cfs buffer; that is, to get Bassano flows from 400 cfs to the desired 600 cfs, a 300 cfs release was required because the assumption is that 100 cfs will not make it all the way downstream to Bassano but will be used by domestic users and junior licences and consumed through natural evaporation.
- On the first day, Bassano flows were still below 600 cfs due to the lag time from the water bank. Thus, BRID reduced its diversion slightly to meet Bassano needs for one day until the water bank release arrives. This eliminated the one-day drop and Bassano flows were always above 600 cfs.
- It was agreed that minimum flow at Carseland would be 1400 cfs plus what comes from the water bank, and this adjustment would be made manually.
- It was noted that BROM does not factor in evaporation losses on the river.

<u>Decisions</u>: 1. Maintain 2.0 cms minimum flow for Kananaskis River.
2. Make water bank withdrawals starting on Monday for 300 cfs additional flow.
3. Increase Carseland minimum flow to 1600 cfs for this week to ensure water bank releases arrive at Bassano.

May 14-20

- At this point, the water bank has about 51,000 acre-feet. In a year with higher snow and more water in the water bank, Bassano flows may have been kept at 900 cfs.
- Carseland flow = 1400 cfs plus water bank releases

<u>Decisions</u>: 1. Keep water bank releases at 300 cfs.
2. Maintain 2.0 cms minimum flow for Kananaskis River.

May 21-27

- Forecast included rain.
- Carseland flow was cut back to 1400 cfs. Model determined that reducing Carseland flow at this time affected Bassano flows; Carseland flow should have been changed sooner.

Decisions: 1. Maintain 2.0 cms minimum flow for Kananaskis River.
2. Stop water bank releases.

May 28-June 3

- An issue at this time is that Spray continues to not fill.
- City of Calgary would keep Glenmore at 1073.7 m; releases would be made as needed pending rainfall so natural flow would pass through. This limit on Glenmore would be added to the model.
- Need to add storage at Ghost. Ghost is exempt from reservoir balancing and was thus the only reservoir able to capture any extra water since inflows were coming in below Spray and Minnewanka. By eliminating Ghost from the balancing scheme, it can fill above the "normal curve."
- Would help to have actual TransAlta rule curves (normal pattern plus minimums/maximums).

Decisions: 1. Maintain 2.0 cms minimum flow for Kananaskis River.
2. Adjust Bearspaw flow to an additional 500 cfs for four days, and adjust model to store in Kananaskis Lake and Spray before Ghost.
3. City of Calgary to keep Glenmore at 1073.7 m.

June 4-10-17

- Snowpack SWE at Sunshine is down to 160 mm.
- Spray is starting to fill, high flows from Bearspaw through Calgary, Barrier and Ghost nearly full.
- Tributary flow is coming in and critical post-April period is over.
- Glenmore ran with original operations; rule curve needs to be reviewed.
- Goal at this time is to maximize storage in TransAlta reservoirs for later use, but because most water is coming down the mainstem, this is not possible.

Decision: Remove 2 cms minimum flow for Kananaskis River.

The second media item was prepared at this time. By now, the drought was described as "severe", many reservoirs were very low and river users were cooperating in an attempt to mitigate the impacts.

June 18-July 1

- All reservoirs are filling slowly, water bank is full, intent is to capture as much as possible in TransAlta reservoirs in this period.
- Simulation found that at end of two weeks, flows dropped off significantly and demands rose due to hot dry weather. This is the end of the snow melt period. Bassano flows dropped in the last 2-3 days of the period and natural inflows above Bassano are dropping. These are likely due to too much storage.

- EID gets 3000 cfs diversion at high flow and 1000 cfs at low flow on day-to-day fluctuation. Model will be adjusted to track natural flow on a rolling average to avoid the high and low thresholds from one day to the next.

Decision: Remove limit on Upper Kananaskis Lake rule curve and let it fill.

July 2-9-16

- Forecast is that Bassano will be below 400 cfs, so need water bank release of 300 cfs for two weeks. Water is coming from Upper Kananaskis rather than Spray.
- Simulation showed flow in Kananaskis River at zero, Bassano up as predicted to 500 cfs, and water bank is flat.
- Any time water is needed to increase Bassano flow, it comes from the water bank and is released by TransAlta. Part of the value of the water bank is sharing the inflow and that's how the model was set up. If the inflow is not being shared, what mechanism is available to ensure there is enough released? If 60,000 acre-feet represents 10% of total storage, then downstream users and environmental needs are entitled to 10% of the inflow. The accounting scheme is important for discussions and negotiations with TransAlta.

Decisions: 1. Increase Carseland flow to 1600 cfs.
2. Water bank release of 300 cfs for two weeks.

July 16-August 5

- Water bank is starting to come down slightly.

Decision: Water bank release of 300 cfs continued for three weeks.

August 6-September 30

- Need to supplement Bassano flows, getting Bassano consistently to just over 800 cfs.
- Water bank is coming down.
- Model issue that needs attention is that BRID has to let 1600 cfs pass through.

Decisions: 1. Water bank release for 8 weeks at 500 cfs.
2. Increase Carseland flow downstream to 1800 cfs.

5.0 Simulation Results

The Simulation exercise was very effective in enabling diverse stakeholders to see the types of discussions that are needed to make decisions about managing the river. Many perspectives, interests and issues came forward, and participants realized these were just some of the points for discussion. The Simulation helped participants expand their understanding and demonstrated the value of stakeholder engagement and collaboration.

Interestingly, the panel that was set up to deal with any decision-making conflicts that arose was never used. Once all of the issues and possibilities emerged through discussion, the group was able to balance the tradeoffs and quickly agree on a path forward.

After the Simulation was run, the consultant noted that the weather and flow conditions were taken from 1941, one of the five worst drought years on record in Alberta. This created some challenges and elicited good discussion about management options. In particular, the very low snowpack in the mountains caused participants to use the water bank conservatively. Unfortunately, time did not allow the Simulation to extend for the full year, as difficulties may have appeared if there was a wet fall.

5.1 Comparison of Performance Measures

In comparing the performance measures, the live Simulation outperformed the current management approach to the river (that is, the current operations) and in most cases, also outperformed the preferred scenario developed in the BRP. Four key performance measures are illustrated below.

Flows at Bassano. Changes to the flows below Bassano were used as a key indicator of improvement in environmental benefits to the system. Both the preferred scenario and the live Simulation were significant improvements over the current approach for managing the river system, as they keep flows higher than the minimum 400 cfs most of the year when compared to the current operations. Compared to the preferred scenario, the live Simulation provided lower flows in the early spring, and higher flows in the late summer and early fall. This would allow more water to be available in the summer and early fall if needed rather than having it all flow downstream in the spring when river flows are typically highest.

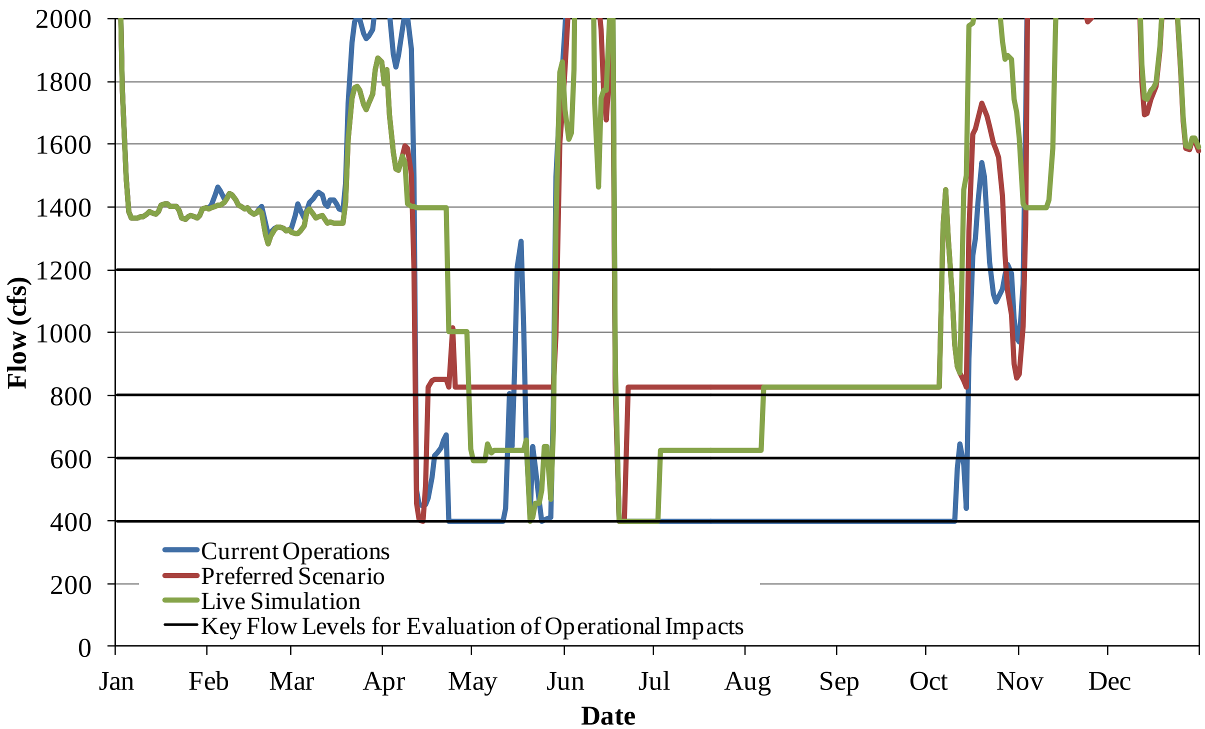

Figure 1. Flows at Bassano

Shortages in the System. As seen in Figure 2, the live Simulation outperformed current operations and the preferred scenario, as shortages were drastically lowered in the live Simulation operations.

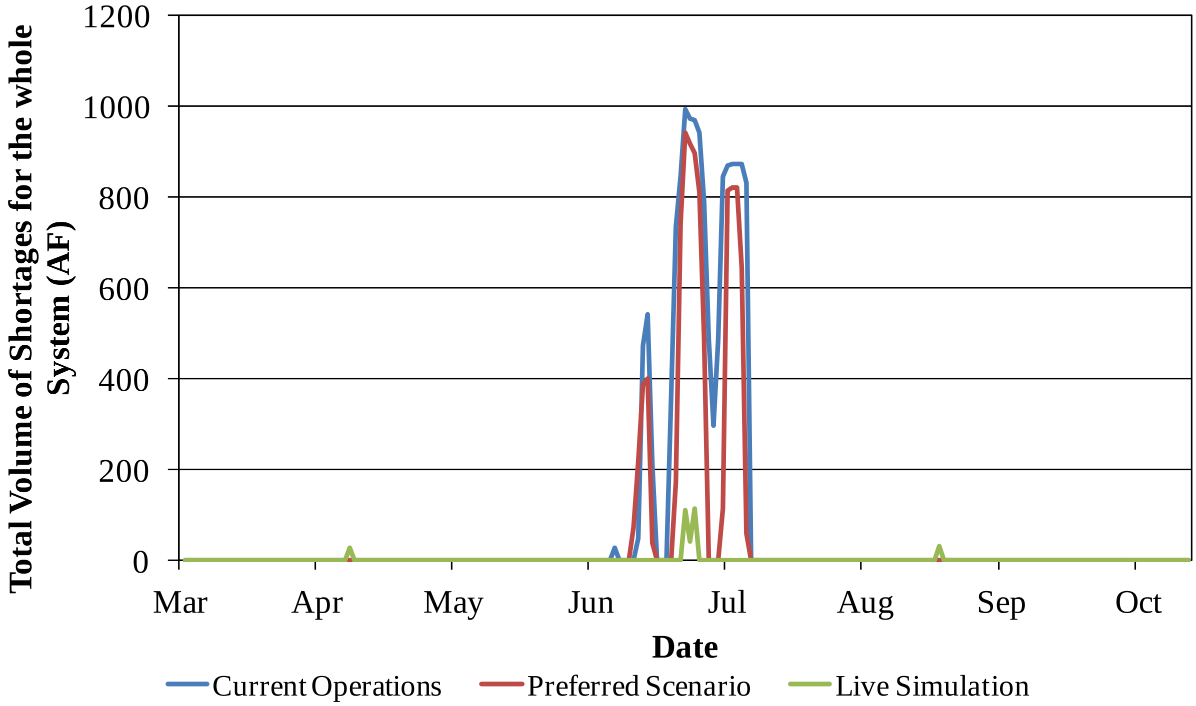

Figure 2. Shortages in the System

Flow in the Kananaskis River immediately below Pocaterra Plant. This performance measure shows flows through the Kananaskis River and how they change with the stabilization of Lower Kananaskis Lake. This was a focus of the live Simulation, which validated the BRP recommendation of stabilizing Lower Kananaskis Lake and the high degree of variation in the River. The Simulation also highlighted the need to provide a minimum flow requirement on the flows in the Kananaskis River during the critical period in later winter and early spring before flows from tributaries downstream of the Pocaterra plant arrive. Both the live Simulation and the preferred scenario keep flows higher throughout most of the year when compared to current operations, with higher flows in the fall season (September to November) seen in the live Simulation.

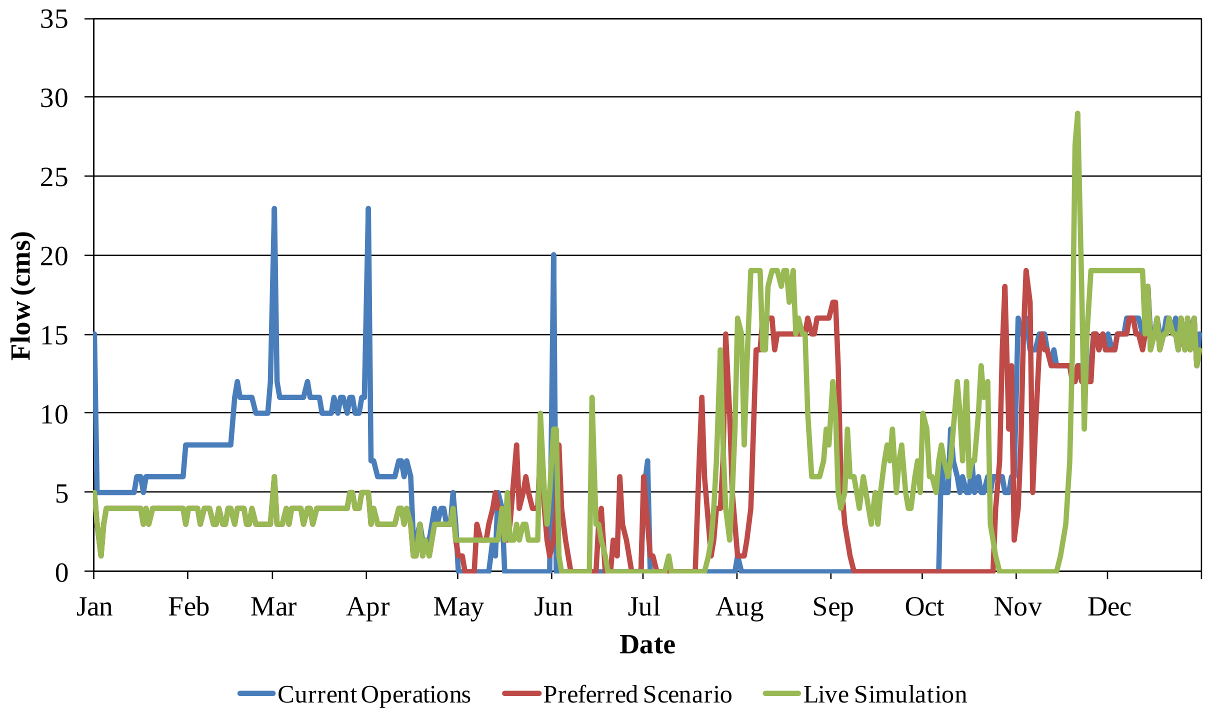

Figure 3. Flow in the Kananaskis River

Not reflected in this figure is the environmental benefit from reducing daily hydropeaking in the preferred scenario and the live Simulation from current operations. As the BRP report (2010) noted, studies have found that altering the operating criteria of the Pocaterra power plant could substantially increase biological productivity, including fish productivity, in Lower Kananaskis Lake. Another benefit is the potential value associated with fish habitat units.

Water Bank Storage. The live Simulation also validated the BRP concept of the water bank. It was very effective for supplementing the flows to and below Bassano (and therefore throughout the entire river) for a potential environmental benefit.

In the preferred scenario, the water bank completely empties by the end of the year as a result of the 500 cfs drawdown. In the live Simulation, participants were able to accomplish all desired results by drawing only 300 cfs for a key period of time, which left nearly half of the water (about 30,000 acre-feet) in the water bank at year's end. This reflected prudent decision-making by participants early in the year, given the prospect of a severe drought emerging in the live Simulation. The water bank was thus in a much better position going into 2014 than it would have been with other approaches.

It was reiterated that there is actually more than 60,000 acre-feet in the water bank if inflow shares are accounted for. The Simulation highlighted the need to be very clear in setting up the water bank agreement and accounting system to optimize the water use method for all parties (see Appendix B for discussion of two water bank approaches).

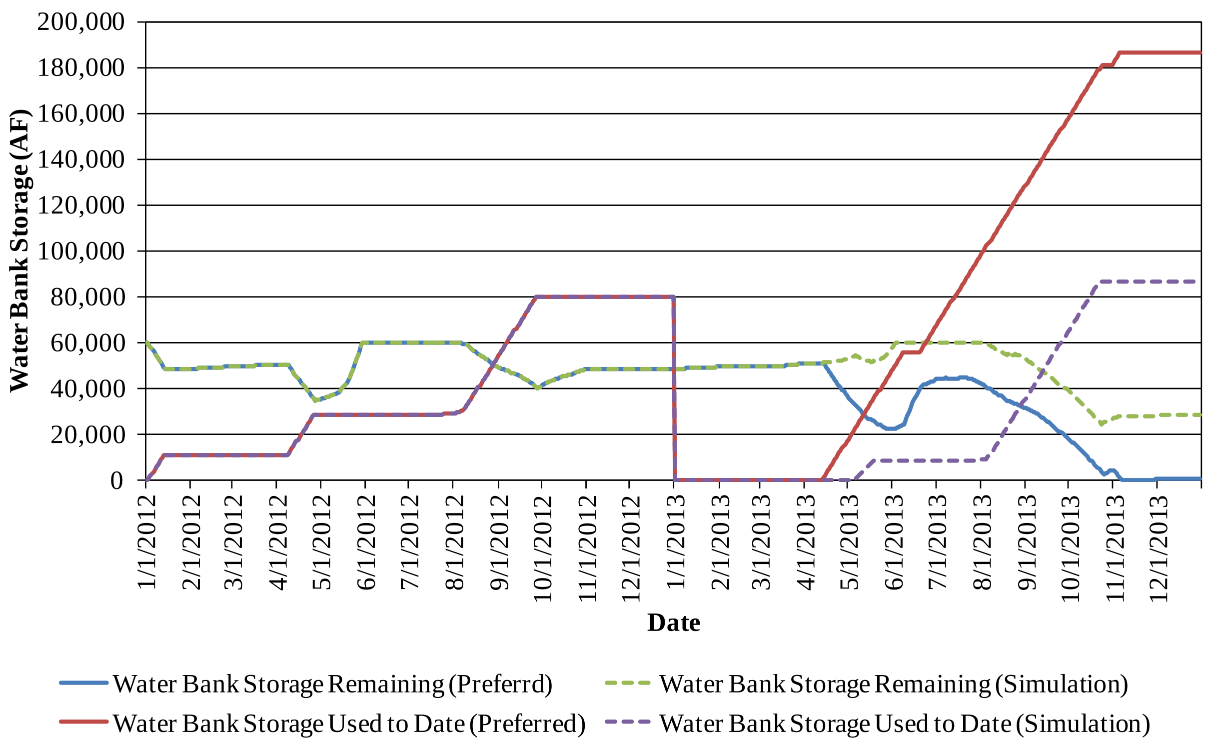

Figure 4. Water Bank Storage

At no point in the Simulation did apportionment drop to near the 50% minimum requirement, and there was no increased reliance on other rivers in the South Saskatchewan River Basin to meet apportionment.

5.2 Potential Refinements

The Simulation identified possible additions to the integrated river management recommendations included in the original report on the Bow River Project in December 2010; an example is the need to ensure a minimum flow in the Kananaskis River for aquatic health during the critical period in late winter and early spring. Current operations involve hydropeaking and include periods of time when there is no release of water from the Pocaterra plant.

The Simulation session identified two categories of improvements to the BROM: areas in which the model needed to be adjusted to correct possible errors or misinterpretations in the model, and areas where the model could be improved to make it a better tool.

The following aspects of the BROM needed to be corrected or adjusted:

- Review and confirm Glenmore operating rules and Calgary demands,
- EID storage rules (35,000 acre-feet at end of year),
- Smoothing daily flows to avoid low flow cut-offs seen in BRID and EID. Natural flow could be tracked on a 7-day rolling average to deal with the problem of crossing the high/low-flow threshold one day to the next,
- Carseland 1400cfs min flow (plus additional water bank amount), and
- Finish running the test (1941) year.

The following improvements were suggested to the BROM to make it a better tool:

- Reservoir balancing for more storage (with a greater preference for releasing water from Ghost),
- Create a new performance measure to address natural inflows above Bearspaw, and
- Build in a switch to allow a minimum flow rule in Kananaskis River.

The lack of data on inflows to Lower Kananaskis Lake from minor tributaries (Smith-Dorrien Creek, Boulton Creek, etc.) was noted as a data model limitation, rather than a potential improvement to the model. If such data were available, they could be incorporated into the BROM to better model and manage water flow in this environmentally important watershed.

The BROM was based on a sharing of inflow to the system proportional to the size of the water bank relative to the total system storage, but other water bank accounting schemes could be developed.

6.0 Conclusions

The Simulation confirmed that the Bow River system can and should be managed differently to achieve many economic, environmental and social goals throughout the Bow basin.

Participants also concluded that the BROM is a realistic model and a valuable tool for understanding the river system and exploring changes and potential opportunities to manage the system for improved performance outcomes. It responded to operational changes to meet instream flow needs and showed the impact of these decisions on the major water users, particularly the irrigation districts. Additional refinements and improvements were identified and proposed as a result of the Simulation.

The Simulation confirmed the key recommendations put forward in the BRP report of December 2010, specifically the value of stabilizing the Kananaskis system and establishing a water bank for instream benefits at Bassano, Kananaskis and elsewhere.

It also confirmed the substantial implied value of other suggestions in the BRP report, including:

- Potential benefits to healthy aquatic ecosystems. Bassano could serve as a proxy for aquatic health throughout the river system.
- Ecological and recreational benefits will arise with the successful stabilization of the Kananaskis system.
- Greater security of supply for current and forecast municipal demands.
- Maintained flows in the winter that may be used to reduce risk of ice jam flooding.
- Improved alignment of irrigation needs with environmental values and upstream user needs.
- Improved capacity to anticipate and mitigate drought conditions on behalf of all users.
- Initial flow modifications can be attained without major infrastructure changes.

The Simulation demonstrated that there is a valid and alternative way to manage the Bow River system that integrates the needs of all users. Project participants are committed to continued efforts to advancing this work.

Appendix A: Bow River Simulation Participants

Participant	**Organization**
Mark Bennett	Bow River Basin Council
Erwin Braun	Western Irrigation District
John Jagorinec	City of Calgary
Derek Lovlin	Alberta Environment and Water
Satvinder Mangat	Alberta Environment and Water
Jorie McKenzie	Rocky View County
Andrew Paul	Alberta Sustainable Resource Development
Richard Phillips	Bow River Irrigation District
Bob Riewe	Alberta Agriculture and Rural Development
Jason Rusu	Alberta Environment and Water
Jim Stelfox	Alberta Sustainable Resource Development
Earl Wilson	Eastern Irrigation District
Joey Young	Alberta Tourism, Parks and Recreation

Decision Panel

David Hill	Alberta Innovates – Energy-Environment Solutions
Allan Locke	Alberta Sustainable Resource Development
Kim Sturgess	WaterSMART

Simulation Support and Facilitation

Michelle Gurney	Alberta Innovates – Energy-Environment Solutions
Mike Kelly	WaterSMART
Mike Nemeth	WaterSMART
Dan Sheer	HydroLogics
Mike Sheer	HydroLogics
Kim Sanderson	Green Planet Communications
Megan Van Ham	WaterSMART

Appendix B: Two Water Bank Approaches

When designing the water bank for use in the preferred scenario, two accounting approaches came to mind:

1. An account that is drawn down with use and resets to 100% every January 1st, or
2. An account that receives a proportion of inflow and can thus refill to 100% mid-year, but is not guaranteed to be at 100% on January 1st.

Approach 1, the simplest, is an extremely straightforward method and can easily be managed. However, it has the major drawback of committing storage from TAU regardless of the status of their reservoirs; that is, if the TAU reservoirs only contain 60,000 acre-feet on January 1st, they would have no control over their water supplies as that water would be dedicated to other water users. This is a fairly large risk for TAU to take, and was deemed a non-starter in the time-limited development of the BROM.

Approach 2, as initially implemented in BROM, maintains a much smaller risk to TAU since the downstream water users can control at maximum only about 10% of inflows at any given time.[2] It also has the secondary advantage of allowing refill within a year. Whereas Approach 1 can only use at most 60,000 acre-feet, the refill of Approach 2 could allow for drawdown in the early part of the year, followed by refill, followed by drawdown again. Thus, in Approach 2, water bank releases can far exceed the account size of 60,000 acre-feet. The two approaches are illustrated in the charts below.

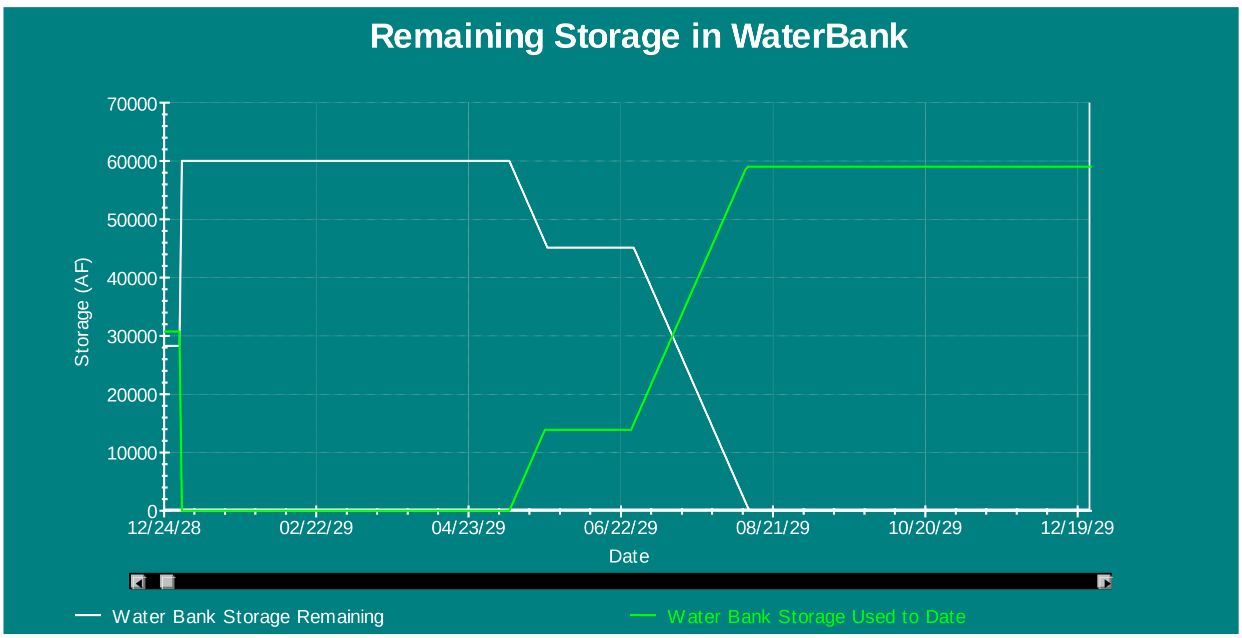

Figure 5. Water Bank Approach 1

[2] Approach 2 is common in the United States.

Under Approach 1, the water bank is reset to 60,000 acre-feet on January 1st and is steadily drawn down by releases until it empties in mid-August. There is no refill, so the lines are unidirectional and usage is maximized at 60,000 acre-feet of releases in that year before being reset January 1st.

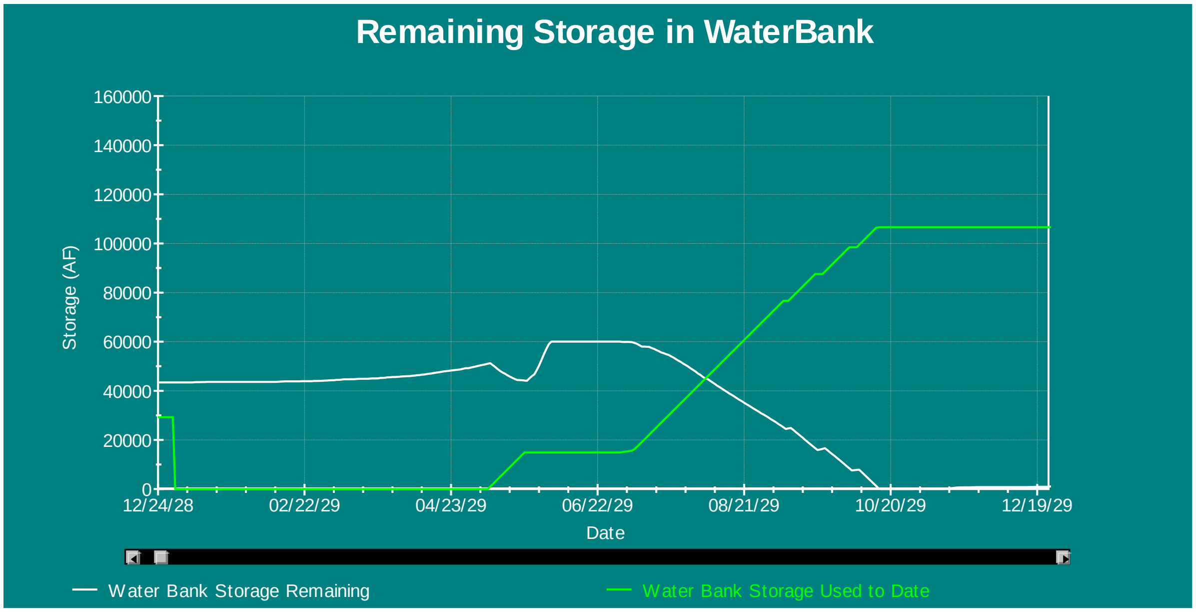

Figure 6. Water Bank Approach 2

As shown in Figure 6, the advantages of Approach 2 are easily apparent. Although the water bank begins the year at only around 40,000 acre-feet, it continues to refill through winter and spring. In May the bank is drawn down, but again refills to the maximum 60,000 acre-feet once releases stop. This, in combination with partial refill as summer releases are made, allows for substantially more than 60,000 acre-feet of water releases. The total summed releases for Approach 2 reach approximately 115,000 acre-feet for the year.

The consequences of this extra water for release are easily visible at Bassano. The green line in Figure 7, representing Approach 1, runs out of water mid-August and reverts to the bare minimum 400 cfs requirement for a time before gradually increasing. Approach 2 (in white), having refilled over the year, is able to maintain average flows of around 800 cfs for the entire season.

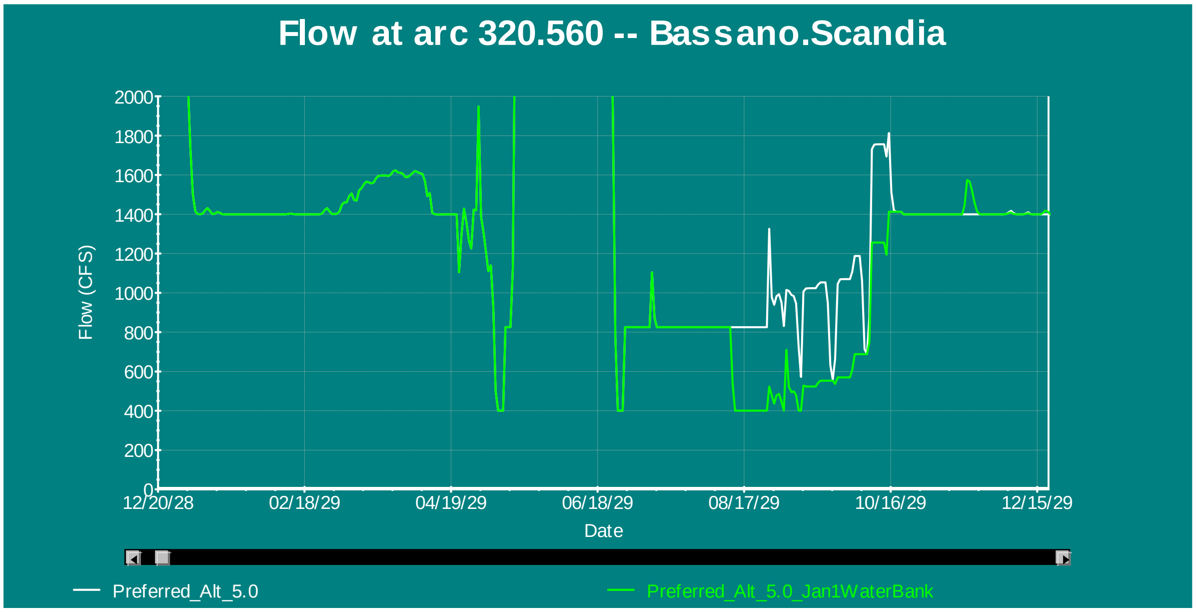

Figure 7. Benefits of Water Bank Approach 2 at Bassano

Appendix C: Acronyms, Abbreviations and Conversion Factors

Acre-foot	The volume of water required to cover one acre to the depth of one foot. One acre-foot = 1.23348 dam^3.
BRID	Bow River Irrigation District
BROM	Bow River Operational Model
BRP	Bow River Project
cfs	Cubic feet per second; one cfs = 0.02832 cms
dam^3	One cubic decametre (1,233.48 cubic metres)
mm	Millimetre(s)
cms	Cubic metres per second; one cms = 35.314 cfs
m	Metre(s)
SWE	Snow Water Equivalent
TAU	TransAlta Utilities