## 1.1 Annotated Bibliography

The table below summarizes key findings and recommendations identified in the literature review, organized by topic (i.e. water storage, management, and operations vs. climate change impacts on water availability within CMRB watersheds); water quality constraints for consideration are also provided. Note that the purpose of this table is to provide a summary of information from the reports; interpretation and relevance to the CMRB is provided in the final report.

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| **Climate Vulnerability and Sustainable Water Management in the SSRB** | • Adaptation strategies were developed for each sub-basin and then modelled using SSROM. The modelling allowed the group to compare individual strategies and evaluate net benefits of combined strategies across the basin. This work identified strategies that could offer potential benefits between sub-basins and across the full SSRB.<br>• Level 1 strategies are the most feasible options for increasing adaptive capacity of the SSRB. Level 2 and 3 are additional strategies to build more adaptive capacity. Based on modelling results, strategies were then identified as most promising.<br>• A range of climate scenarios were used to assess the different adaptation options. | **Key findings**<br>• Further reductions to minimum flow rates during drought could have serious impacts on aquatic ecosystem. For example, lower minimum flows through Calgary and reduced return flow combined with WID withdrawals increases concentration of nutrients, affects fisheries and ability of ID to withdraw water. p.27<br>• EID and WID return flows to Red Deer River are significant. When full licence allocation scenario is applied, WCO is violated because most existing licences are senior to WCO p.28.<br>• Storage does not make more water available for allocation.<br>• New storage in lower Bow could benefit the Oldman system. p.30<br>• Most existing infrastructure in SSRB is sized for one-year operational cycle. Three or more years of drought may result in near empty reservoirs. p.31<br>**Recommendations**<br>• <u>Level 1 most promising (pages 34-35):</u><br>• Long-term, flexible and comprehensive water management agreement with TA for drought and flood mitigation and watershed health (Bow)<br>• Raise winter carryover in reservoirs (Bow, Oldman and South Sask. Sub-basins)<br>• Implement forecast-based shortage sharing within and between irrigation districts (Bow, Oldman and South Sask. Sub-basins)<br>• Basin wide shortage sharing and reallocation frameworks to inform and enable severe drought mitigation (SSRB-wide)<br>• Restrict greenfield development in floodplains and develop strict regulations against changing the nature of brownfield developments (SSRB-wide<br>• <u>Level 2 most promising (page 35):</u><br>• Redesign operations and expand reservoirs in upstream reservoirs in upstream Bow for water supply and watershed health (Bow Sub-basin)<br>• Expand and balance the Chin Reservoir<br>• <u>Level 3 most promising (page 35):</u><br>• Build new on-stream storage low in the Bow below Bassano i.e. Eyremore site (Bow Sub-basin) | **Key findings**<br>• The best possible streamflow and snowpack data, soil moisture content, temperature and meteorological forecasts are needed to inform operational decisions. This relates to one of the report recommendations to improve resourcing for forecasting (see below).<br>• Climate model outputs indicate and earlier snowmelt and spring freshet each year.<br>• Risk of flood and drought in a single year if snowmelt and flood flow come earlier in the year.<br>**Recommendations**<br>• Recommend initial focus on improving resourcing and forecasting in the Bow including all private and publicly owned and operated reservoirs. Accurate forecasts are essential for adaptive basin management to balance flood and drought risks and mitigation actions.<br>• Example tool: New York City Dept of Environmental protection Operations Support Tool (OST) | • A reduced minimum flow at Calgary as a mitigation strategy for upstream water shortage in prolonged droughts could have serious consequences for water quality downstream and significantly stress aquatic ecology of the river system.<br>• Natural detention opportunities (through Room for the River approach) have a positive impact on water quality.<br>• Water quality impacts of municipal return flow are considered of greater concern than impacts on quantity.<br>• Smaller reservoirs often have poorer water quality with elevated nutrient levels and often high organic matter content. This is a challenge for municipal drinking water systems to treat and use. | WaterSMART Solutions Ltd. 2016. Climate Vulnerability and Sustainable Water Management in the South Saskatchewan River Basin, Final Report.129 pages. |
| **Climate Variability and Change in the Bow River Basin** | • Developed a set of possible future streamflow conditions in the Bow River Basin to test a series of water management alternatives under a series of hydrological and climate scenarios. Examined impacts on:<br>○ TransAlta storage in the headwaters<br>○ Flows through the City of Calgary and at Bassano<br>○ Flows from the Elbow River into Glenmore Reservoir<br>• The purpose was to identify strategies for adapting to flow changes that affect water users; scenarios were chosen to highlight impacts related to low-flow periods<br>• Five scenarios were selected and used in a collaborative modelling session | **Key findings**<br>• [1]Of the five simulated climate scenarios; two scenarios resulted in limited impact on users, three produced flows that affected users (particularly major licence holders) (p.28, PDF p.33)<br>• [1]Low flow scenarios could affect the ability of TransAlta to fill its storage system and could result in their storage being empty at times (p.21, p. 26 PDF)<br>• [1]Low flows could cause depleted storage in Glenmore Reservoir, which, combined with low flows in the Bow River, could cause issues with meeting municipal demand. (p.28, PDF p. 33)<br>• [1]Low flows could negatively impact aquatic ecosystems downstream of Calgary (p.28, PDF p. 33)<br>• [1]Scenarios projected increased shortages for non-municipal water users on the Highwood and Sheep Rivers and less frequently met Instream Objectives (there were | **Key findings**<br>• Lower mean annual flows and a greater probability of extreme low flows can be expected based on the simulated scenarios, and in keeping with previous climate projections, and natural variability (p.12)<br>• Earlier spring runoff and larger flood events are possible, with rain-on-snow events more likely with warmer spring and late winter temperatures (p.25)<br>**Recommendations**<br>• See recommendations in previous column. | • Reduced flows projected for the City of Calgary could impact water quality (due to less flow to assimilate discharge from wastewater treatment plants) (p. 20, PDF p. 25) | [1]Alberta Innovates – Energy and Environment Solutions and WaterSMART Solutions Ltd. 2013. Climate Variability and Change in the Bow River Basin, Final Report. 39 pages<br>[2]Alberta Innovates – Energy and Environment Solutions and WaterSMART Solutions Ltd. 2013. Phase II: Bow Basin Summary Report. 33 pages. |

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| | | few shortages for municipal water users on these rivers because the licences are very senior) (p. 28, PDF p 33)<br>**Recommendations**<br>• [2]Report identified several strategies to benefit the watershed under historical conditions including: implementing the "preferred scenario" (establishing a virtual 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 in the Bow and stabilizing Lower Kananaskis Lake and Kananaskis River) adjusting fill times for the three largest TransAlta reservoirs (Minnewanka, Spray, Upper Kananaskis), reducing seasonal consumptive demand in Calgary, implementing seasonal consumptive reuse in Calgary, moving municipal licences from the Highwood/ Sheep system to the Bow River, increasing winter carryover in the Travers Reservoir, and implementing additional demand reduction in irrigation districts. (p. 22, PDF p. 19)<br>• [2]Adaptation strategies for severe drought conditions include: restoring the Spray reservoir to full design capacity, drawing the Ghost Reservoir down to 2 m below normal, reducing minimum river flow through Calgary, increasing off-stream storage in Bruce Lake (WID), managing return flows from the WIS through Crowfoot Reservoir, increasing Little Bow/ Travers storage capacity, increasing on-stream storage downstream of Bassano in the Eyremore Reservoir, and operating irrigation district reservoirs to protect junior licences (p. 22, PDF p 19)<br>• [2]Several 'combination' strategies were developed which combine two or more of the strategies listed above (p. 22, PDF p. 19) | | | |
| **Tree-Ring Analysis to Support the City of Calgary Drought Management Plan** | • Objective of the project was to reconstruct the annual flow of the Bow River at Calgary using tree-rings from the Bow River Basin, primarily from the Wildcat Hills near Cochrane, where the tree-ring chronology spans from 1340-2004.<br>• Report interprets variability of streamflow and climate as recorded in the tree rings. | **Key findings**<br>• The focus of the report was historical flow reconstruction; there were no key findings related to water storage, management, and operations.<br>**Recommendations**<br>• City of Calgary could consider water storage upstream as a potential option to address lower flows expected with warmer climate in coming decades, but also note that drought and/or reduced snowpack could reduce naturally available water and reservoir storage (p.23) | **Key findings**<br>• There is periodic behavior in flows on 3-9 year and 60-year cycles, related to El Nino and Pacific Decadal Oscillation, respectively over the last 900 years (p.22)<br>• Future flows discussed only generally; report expects that flows in Bow Basin will decrease due to warming climate over the next several decades (p.23)<br>**Recommendations**<br>• Consider that longer periods of low flow in the Bow River have occurred in the past than recorded by gauges (p.23) | • None identified in the report | Sauchyn, D., Vanstone, J., and Dickenson, J. (Prairie Adaptation Research Collaborative). 2012. Tree-ring inferences on water level fluctuations of Lake Athabasca. Final Report, November 20, 2012. 26 pages. |
| **Climate Change Adaptation Research: Vulnerabilities, Risks, and Adaptation Actions** | • This report reviews the global and localized climate change trends, and breaks down an associated risk profile for the City of Calgary<br>• The report evaluates several localized climate risks and adaptation protocols including major river flooding, multi-year droughts, loss of water supply, winter storms, heat waves, cold spells, high wind events, tornadoes, air pollution, power outages, wildfires, etc. | **Key findings**<br>• The rate of temperature rise due to climate change has been twice the global average since 1948, increasing at a rate of 1.6°C per century. Warming is expected to be most significant in the winter months. This presents increased winter snowfall intensity and risks of freezing rain for the CMR<br>• Shifts in local climate have important effects on service delivery, infrastructure design, and related planning and resource allocation for the City of Calgary | **Key findings**<br>• Climate change is likely to cause high risk of short duration, high intensity storms, multi-year droughts and loss of water supply (p. 66)<br>• 10% of The City's assets are in an area that would be flooded in a major flood (p. 94)<br>• The City's risks are often derived from broader environmental conditions in the surround area (i.e. water storage and watershed conditions upstream) | • Loss of water supply to the City of Calgary due to water quality issues or any other factor was evaluated as a climate impact scenario and given a risk score. | WaterSMART Solutions Ltd., Risk Sciences International, Inc., Nodelcorp Consulting, Inc., WSP Global Inc., and MMM Group Ltd. 2017. Climate Change Adaptation Research: Vulnerabilities, Risks, and Adaptation Actions. |
| **South Saskatchewan River Basin Adaptation to Climate Variability Project** | • Project brought together water experts in the SSRB to identify and assess a range of potential adaptation strategies for the Bow, Oldman, and South Saskatchewan River basins<br>• Also identified potential next steps toward implementation of adaptation strategies<br>• Modelling scenarios only considered drought as the work was completed pre-2013 flood, and drought was seen as the Bow Basin's greatest water management challenge. | **Key findings**<br>• Identified seven climate adaptation strategies for the Bow River Basin (p.12; PDF p. 17):<br>○ Implement preferred scenario (described in recommendations below) with a low storage trigger for action<br>○ Adjust fill times for the three largest TransAlta reservoirs (Minnewanka, Spray, and Upper Kananaskis)<br>○ Reduce seasonal consumptive demand in the City of Calgary<br>○ Implement seasonal consumptive reuse in Calgary<br>○ Move municipal licences from Highwood/ Sheep system to Bow River<br>○ Increase winter carryover in Travers Reservoir<br>○ Implement additional demand reduction in irrigation districts | **Key findings**<br>• Climate variability results were reflected in the development of the climate scenarios. Five scenarios were selected for collaborative modelling (p.11, PDF p. 16):<br>○ The 2yr Median scenario - has some drought periods and some wet periods, but its purpose is to assess alternatives under historic-like conditions.<br>○ The 1yr Max scenario - generally wetter and puts almost no drought pressure on the system.<br>○ The 1yr Min scenario – includes a severe drought in 2033. Subsequent years (2034 and 2035) are also dry.<br>○ The 2yr Min scenario - has two consecutive dry years (2034-2035) with other low years as well. The years 2032 and 2033 are also dry.<br>○ The 3yr Min - the driest scenario. Includes two severe dry periods, one at the beginning of the time period and one later; | • Report mentions that *Water for Life Strategy* includes assurance of minimum flows of 1,250 cfs through Calgary under the maximum forecast future demands by municipalities up to 2049 (p.10; PDF p. 15). | Alberta Innovates – Energy and Environment Solutions and WaterSMART Solutions Ltd. 2014. South Saskatchewan River Basin Adaptation to Climate Variability Project, Final Report. |

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| | | **Recommendations**<br>• Implement the preferred scenario of the Bow River Project Consortium which includes:<br>○ Stabilizing Lower Kananaskis Lake at 1663.5 m with a fluctuation of ±0.5 m (i.e. 3.5 m lower than the current full supply level)<br>○ Stabilize flows in the Kananaskis River by placing limits on the discharge of the Pocaterra power plant<br>○ Double the capacity of the Langdon Reservoir in the Western Irrigation District<br>○ Use the "Water Bank" approach using all reservoirs in combination to open up access to 74,000 $dam^3$<br>• Support the Government of Alberta (GoA) in reaching an agreement with TransAlta and other key stakeholders and licensees in the Bow Basin to collaboratively manage the Bow watershed. Two phases are proposed (p. 15; PDF p. 20):<br>○ Phase 1: Support an interim agreement between the GoA and TransAlta, endorsed by the major downstream licensees, to manage the upstream hydro system in the event of a potential or emerging flood situation during the coming water year.<br>○ Phase 2: Collaboratively implement a longer-term agreement to manage the watershed, incorporating a flexible approach similar to the Preferred Scenario of the original BRP, but including the latest data and what was learned from the climate variability and flood mitigation collaborative modelling projects. T | key years are 2027-2029.<br>**Recommendations**<br>• Support interactions among universities, irrigation districts, government, and others to allow for future collaborative modelling<br>• Integrate Bow, Red Deer, and Oldman/ South Saskatchewan river models into a single model using the OASIS system under future climate scenarios | | |
| **Global Water Futures projects** | • Global Water Future's overarching goal is to deliver risk management solutions—informed by leading-edge water science and supported by innovative decision-making tools—to manage water futures in Canada and other cold regions where global warming is changing landscapes, ecosystems, and the water environment.<br>• GWF aims to deliver on the following; 1) improved disaster warning, 2) predicting water futures, and 3) adapting and managing risk.<br>• Research at GWF Coldwater Laboratory located in Canmore (opened 2017) will improve the flood and drought resiliency of downstream communities such as Calgary | **Key findings**<br>• An ongoing, multiyear project within the GWF lab may be relevant and valuable for the CMRB.<br>"Integrated Modelling for Prediction and Management of Change in Canada's Major River Basins" (IMPC) aims to develop integrated modelling capability for predication and management of water resources within Canada's major river basins. In the Nelson-Churchill system, a water resources model simulating water supplies and demands, present operating policies and water infrastructure is operational to explore future scenarios of change. Work is ongoing to integrate high-resolution atmospheric modelling, hydrologic modelling and water quality modelling capability to this infrastructure, as well as a hydro-economic model, and environmental and cultural flows to examine triple bottom line tradeoffs between water policy alternatives and climate change impacts.<br>○ Dr. Saman Razavi is the Principal Investigator, he leads much of the water resources research in Global Water Futures.<br>○ The project research covers quite a large domain, but the Bow River Basin is covered in detail and linked with the rest of the system upstream and downstream.<br>○ 1 year left of the project research and will likely get renewed for another 3 years until August 2023.<br>○ Resulting publications and workshops could be a good resource moving forward. | • Climate change impacts are being modelled as part of the "Integrated Modelling for Prediction and Management of Change in Canada's Major River Basins" project. See notes in cell at left. | • None identified | https://gwf.usask.ca/articles/2017/new-research-centre-opens-in-canmore.php |
| **Predicting Alberta's Water Future (PAWF)** | • This report explains the development of a comprehensive calibrated and integrated dynamic water model for all of Alberta used to project future water availability and reliability under various climate change and global warming scenarios | **Key findings**<br>• Model results found great disparity between the variability of climate predictions in the northern and southern regions of the province of Alberta, citing Pacific Decadal Oscillation (PDO) as a likely cause not accounted for in the model algorithms (p. 90)<br>• Groundwater stress in the Bow River basin is not expected to be of concern by 2050, however groundwater use by volume is expected to increase by 45% (p. 84) | • The results of the hydrological and climate analysis demonstrate that Alberta is going to experience large changes in the climate and subsequently, large changes in the hydrology of the province (p. 91)<br>• Although the model has some noted shortcoming, the model now allows for integrated scenarios of future demand to assess sector-based risks and opportunities, and for integration of future water availability (both at a provincial scale and sub-watershed scale) into government policy and planning | • None identified in the report. | Alberta Innovates. 2017. Predicting Alberta's Water Future (PAWF) |
| **SSRB Water Management Plan: Phase 2 Scenario Modeling Results** | • The document provides results from 8 modelled scenarios for the Water Resources Management Model (WRMM) to explore the potential consequences of various water management actions using data from 1945 to 1995. No | • The results from this study are not considered relevant because this was published before the SSRB WMP was implemented.<br>• The scenarios that were modelled included the benefits to | • No climate change projections were used. | • None identified in the report. | Alberta Environment. 2003. South Saskatchewan River Basin Water Management Plan: Phase 2 Scenario Modelling |

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| | climate change projections were used.<br>• This study informed the Water Conservation Objective (WCO) recommended for the SSRB. | other licence holders if all licensees reduced their consumption volume by 20%, and also the water shortage impacts to other basins if the Red Deer Basin users withdrew the full 50% of flow permitted under the apportionment agreement. | | | Results. |
| **South Saskatchewan River Basin in Alberta Water Supply Study** | • Study was commissioned by the SSRB Water Supply Steering Committee to:<br>o Assess current and future water supply and demand in the SSRB<br>o Identify constraints to water supply and economic growth<br>o Identify, analyze and evaluate structural and non-structural water management alternatives to address constraints and issues | **Key Findings**<br>• Surface water consumed by all sectors in the SSRB is ~40% of the total volume of water allocated for use. Irrigation is the highest water use sector.<br>• Water Conservation Objectives (WCOs) were established for all mainstem rivers in SSRB in 2007<br>• Increase in future water demand would modestly increase deficits throughout the SSRB. Junior water users in the Bow and Oldman Sub-basins would experience substantial increase in deficits.<br>• Non-structural measures to improve water management will probably not fully address current and future issues.<br>• Deficits in the Red Deer and infrequent and low in volume. Optimizing existing storage and other non-structural measures may be adequate to manage supply constraints.<br>• Storage requirements in the Bow River Sub-basin are much higher than in the Red Deer. Additional storage should reduce deficits to IOs, however junior projects are subject to the IOs rather than WCOs and the size and frequency of deficits are much larger in the Bow Basin. Sharing use of TA storage is much preferred over new storage development.<br><br>**Recommendations**<br>• Recommendations are divided into simulation modelling, non-structural water management opportunities, and structural water management opportunities (p. 163-169)<br>• <u>Simulation modelling recommendations:</u><br>• Performance thresholds for water use sectors and in-stream conditions (IOs and WCOs) are recommended to improve the ability to develop water management and operations plans in Southern AB.<br>• Systematic water use reporting for sectors other than municipalities and I.D.s would improve water management planning.<br>• Recommendation to AEP to include in WRMM an algorithm that enables modifying operations depending on forecasted water supply and storage conditions in the basin.<br>• <u>Non-structural water management opportunities:</u><br>• Operational refinements and shared use of existing hydroelectric storage facilities. Further analysis and discussion with TransAlta (TA) to modify operations of TA storage is recommended.<br>• Continue to improve irrigation efficiencies and reductions in irrigation return flows. Regulatory changes could be required to ensure conserved water is used to meet consumptive deficits or retained in the stream rather than used to expand irrigation area.<br>• Consider measures to facilitate market-based water allocation transfers.<br>• Incorporate concept of sharing risk of deficit using stored water into reservoir operation plans.<br>• Explore other means of sharing deficits during low-flow conditions.<br>• <u>Structural water management opportunities:</u><br>• New storage in the Oldman sub-basin could help meet in-stream objectives and reduce deficits to junior private irrigation and non-irrigation projects and development on Piikani FN Reserve. | **Key Findings**<br>• Water supply for use in Alberta may be constrained by in-stream flow requirements<br>• Streamflow variability may be higher in the future than experienced during the past century<br>• Future reductions in natural streamflow volumes are more likely than increases in all SSRB sub-basins (includes Red Deer, Bow, Oldman). Report did not specify whether reductions are seasonal or annual.<br>• Declining summer flows in the Bow River are a concern given the reduction in glacial area and declining contribution to streamflow<br>• Reduced streamflow due to climate change will have significant impact on potential irrigation district expansion in the Oldman Sub-basin<br>• If southern Alberta climate becomes warmer and drier as projected, irrigation demand would increase. Changes in demands for non-irrigation water users would likely be small in relation to changes in demands for irrigation use.<br>• Future mountain runoff may occur during the winter and early spring, before off-stream diversion canals can operate. On-stream storage may therefore be more effective to capture snowmelt.<br>• Less natural storage (snow) due to warmer conditions may make water supplies in the SSRB more sensitive to drought.<br>**Recommendations**<br>• Recommendation given to perform periodic analyses of natural flow and precipitation to determine if significant trends are developing and to estimate long term impacts on streamflow should those trends persist. | • Lower water flows may cause increased retention times in reservoirs, higher nutrient retention and larger algal blooms.<br>• Lower water levels in prairie lakes can increase lake salinity. | AMEC Earth & Environmental. 2009. South Saskatchewan River Basin in Alberta Water Supply Study. Alberta Agriculture and Rural Development. Lethbridge, Alberta. |
| **NRCB Decision on Highwood Diversion Plan** | • Contains NRCB's decision to approve the 2006 *Revised Highwood Diversion Plan*, including recommendations and the factors that went in to the decision-making progress. | **Key findings**<br>• None. Intent of the report was not to produce new information. | • None identified in the report | • Same as seen in Water Management Plan for the Watersheds of the Upper Highwood and Upper Little Bow. | Natural Resources Conservation Board. 2008. NRCB decision on Highwood Diversion Plan. |

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| | | **Recommendations**<br>• The NRCB made the following recommendations related to the Plan:<br>○ Procedures and conditions for declaring an Alert condition related to drought or flood conditions in the Highwood River be developed. This was included in the final Plan.<br>○ GoA should develop a comprehensive fish monitoring plan for the Highwood River to validate the revised IFN, confirm success of adaptive management, and assist the long-term viability of the Highwood fishery. In the final Plan, sampling for mercury levels in fish in the Little Bow River and Twin Valley Reservoir and monitoring of fish population in Little Bow were included. There is no monitoring for fish in the Highwood River. | | | |
| **Water Management Plan for the Watersheds of the Upper Highwood and Upper Little Bow, Volume 1** | • Developed to make recommendations to Alberta Environment concerning water quantity management in the Upper Highwood and Upper Little Bow watersheds | **Key findings**<br>• Decided that expansion of the existing Women's Coulee reservoir would not go ahead due to high cost and small environmental benefits<br>• For the purposes of the Highwood/ Little Bow Project, AEP will permit allocations for the amount of water needed to irrigate 16,500 acres. This amount includes municipal use (p. 27, PDF p. 32)<br>• The establishment of WCOs for the Highwood River, Upper Little Bow River, and Mosquito Creek will be considered in future planning. (p. 27, PDF p. 32)<br>• Plan commits to meeting existing licence demands at least as frequently as met prior to Plan (p.4, PDF p. 9)<br>**Recommendations**<br>• An official schedule for review of this plan is not recommended at this time; instead it should be reviewed as required. Review and amendment could happen if and when future phases are added to the plan<br>• First Nations are anticipated to be engaged in future water and watershed planning in the basin<br>• Any future watershed planning should include interested parties from headwaters, tributaries and the Sheep River Watershed. Partnership and cooperation of the Bow River Basin Council and Oldman Watershed Council is recommended<br>• The plan includes several recommendations to the Director with respect to decision-making, including:<br>○ Removal of a July cutoff for irrigation licences that have the condition<br>○ Establishment of a WCO<br>○ Development of a communications system to time water deliveries to match when irrigators can use the water<br>○ A licence for the pre-project Little Bow Diversion (2.83 m3/s) be issued to the Crown Right in Alberta, as the original diversion was never issued because licences were not required at that time<br>○ Consideration of an amendment to the licences of the Women's Coulee and Little Bow Diversion works to incorporate the Highwood Diversion Plan as a condition<br>○ Consideration of applications for licenced allocations from the Twin Valley Reservoir and the Little Bow River to Travers Reservoir for all purposes, up to 30,167 dam3. The licences would be subject to the IO for the Highwood River, the minimum operating flow target for the Little Bow River and Mosquito Creek, or any future WCOs<br>○ Favorably consider transfer applications in the planning area if they are benign to beneficial to the aquatic environment and water quality, do not increase demand for diversion in the Highwood River, and/ or improve flows in the Little Bow River | • None identified in the report. | • Water quality issues considered in the plan included (p.20, 26):<br>○ Water temperature and dissolved oxygen in the Highwood River between the diversion to the Women's Coulee Reservoir and the confluence with the Sheep River (especially in late summer during low flow season) for the Highwood River Fishery<br>○ Frank Lake water quality impacts on the Little Bow River and Twin Valley Reservoir<br>○ Downstream impacts on oxygen, ammonia, and metals in the Little Bow<br>○ Fish mercury residues in Twin River Valley Reservoir and downstream Little Bow<br>○ Sediment loads in Mosquito Creek | Alberta Environment 2008. Water management plan for the watersheds of the Upper Highwood and Upper Little Bow Rivers, Vol. 1. |
| **Water Management Plan for the Watersheds of the Upper Highwood and** | • Contains general operating rules and diversion rates for the Little Bow Project, including the Women's Coulee Reservoir, Twin Valley Dam and Reservoir and the Clear | **Key findings**<br>• Municipal and industrial uses are given higher priority than they would have under the *Water Act* because they are a | • None identified in the report. | • When water is available in the Highwood River, diversions will be provided as necessary to provide a freshening flow to improve water quality in Mosquito Creek and the Little Bow River for | Alberta Environment 2008. Water management plan for the watersheds of the Upper Highwood and Upper Little Bow |

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| **Upper Little Bow, Volume 2** | Lake Project. | small overall volume (**Error! Reference source not found.**).<br>• There are three special operating requirements to manage Highwood River<br>○ Highwood stress conditions – Highwood River flow downstream of the Little Bow Canal is 4.25 m3/s or less; water temperature exceeds 24 C or dissolved oxygen is less than 5 mg/L at the Highwood River at Aldersyde Water Survey station<br>○ Drought conditions – diversion for reservoir recharge will be allowed in second and third years of drought, as defined in the plan (operations continue as normal during the first drought year)<br>○ Flood conditions – diversions will be managed and operated to avoid downstream flooding and damage, where possible<br>• Reservoir operation is as follows:<br>○ Women's Coulee – used to meet irrigation demand from April 1 to Sept. 30. When the Highwood River is under stress, water will be released from the reservoir to meet needs as per the list of priorities. The reservoir will not be used to meet the minimum flow requirements in Mosquito Creek under stress conditions; outside of stress conditions (depending on flow river flow forecasts), the reservoir will be used to help meet minimum flow requirements for Mosquito Creek.<br>○ Clear Lake Project -subject to limits outlined in the plan, water may be diverted from Mosquito Creek to fill habitat ponds along the canal and adjacent to the lake (between Sept 15 and Oct 30, subject to certain conditions). The lake has an FSL of 966.3 m and minimum operating elevation of 964.5 m to protect recreational use and fish populations in the lake.<br>○ Twin Valley Dam and Reservoir – intended to meet existing demands downstream of the reservoir and support irrigation of 16,500 acres of land. From Apr 1 to Oct 31, pre-project licences downstream of the reservoir have priority over reservoir filling. Reservoir has an FSL of 964.8 m and minimum operating elevation of 950 m. Normal operating capacity at lower level outlet is 8.49 m3/s.<br>**Recommendations**<br>The focus of the report is operating rules; no recommendations are provided. | | domestic and municipal use. Total diversion will be up to 4.53 m3/s in the spring and 1.42 m3/s in the summer and fall<br>• To maintain riparian habitat in the Upper Little Bow, between 2.83 m3/s and 8.49 m3/s will be diverted when Highwood River flow conditions are favorable | Rivers, Vol. 2. |
| **Hydro-Climate Modelling of Alberta South Saskatchewan Regional Planning Area** | • The report discusses the modelling methods and the results for each of the major watersheds in the SSRP area.<br>• For the study, five Global Climate Models (GCM) scenarios were used for the future climate data, baseline data was provided by AEP from hydrometric monitoring stations. | • There is no discussion of water storage or management options. | **Key findings**<br>• Bow River: Most model scenarios showed increasing flows in winter months, decreasing flows in summer months, and significant variability between months. The change in mean annual flow for the Bow River was projected to decrease by up to 13% in 2020 and up to 18% in 2050. (p. 34)<br>• Oldman River: Most model scenarios showed increasing flows in winter months, decreasing flows in summer months, and significant variability between months. The change in mean annual flow for the Oldman River was projected to decrease by up to 15% in 2020 and up to 30% in 2050. The annual flow projections for 2050 also vary widely, including potential increase of up to 9%. (p. 47)<br>• Red Deer River: Almost all modeled scenarios project decreased monthly flows throughout the year but vary significantly from month to month. Changes in the mean annual flows for the Red Deer River range in projected decrease from 2% to 25% for 2020. For 2050 the mean annual flows are projected to decrease by between 2% and 44%. (p. 68)<br>These results are in line with and support climate projections in the SSRB in more recent years. Early spring melt, overall lower annual flows, and lower flows in the late summer and fall are all likely projections in the SSRB, especially in the Bow and Oldman systems. | • There is no discussion no water quality measurements. | Golder Associates for Alberta Environment. 2010. Hydro-climate modelling of Alberta South Saskatchewan Regional Planning Area. |
| **Future flows: Climate resilience,** | • Report provides recommendations on water policy and legislative reform to the Government of Alberta. | **Key findings**<br>• Report did not generate any new information, only | **Key findings**<br>• Report did not generate any new information, only provided | • None identified in the report. | Unger, J (Environmental Law Centre (Alberta). 2019. Future |

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| **environmental flows and Alberta's water law** | | provided recommendations.<br>**Recommendations**<br>• Relevant recommendations related to water storage, management, and operations include (all from PDF p. 7 and 8):<br>○ Development of a provincially mandated water conservation guideline.<br>○ Formalization of guidelines for the determination of "potential" effects on the aquatic environment in allocation decisions<br>○ A government assessment aimed at cancellation of unused licences to free up water supply | recommendations.<br>**Recommendations**<br>• Relevant recommendations related to climate change that if implemented by government could impact CMR natural/ managed water supply include:<br>○ Updating the *Framework for Water Management Planning* to include climate change considerations and long-term water budgets in the matters and factors to be considered in authorization decisions under the *Water Act* (PDF p. 7 and 8)<br>○ Consideration of climate change in the 2006 *Approved Water Management Plan for the South Saskatchewan River Basin* (p.34, PDF p. 43) | | flows: climate resilience, environmental flows, and Alberta's water law. |
| **Approved Population Projections from CMRB** | • Report is a series of graphs and tables of population projections for the CMR; water is not mentioned.<br>• Relevant population projection results that could impact natural/ managed capacity and water quality include (p.5):<br>○ The total CMR population is estimated to grow to 2.5 million by 2048, from approximately 1.6 million in 2018.<br>○ The population of each CMR municipality is estimated to approximately double between 2018 and 2048, with most of the population increase occurring in Calgary | • None identified in the report. | • None identified in the report. | • None identified in the report. | Rennie Intelligence. December 2018. Population projections produced for the Calgary Metropolitan Region Board and its member municipalities. |
| **Bow River Phosphorus Management Plan** | • A strategic plan to address sources of phosphorus in the middle reach of the Bow Basin between the Bearspaw and Bassano Dams<br>• Objectives were to improve understanding and change behavior to reduce phosphorus inputs into Bow River, reduce additions of phosphorus, and remove excess phosphorus from water before it reaches the river.<br>• Levels of phosphorus today are within acceptable limits today, mainly due to upgrades to wastewater treatment | **Key findings**<br>• Wastewater treatment plants in the planning area have total loading objectives which require their effluent concentration to comply with agreed upon phosphorus loads (p.25, PDF p. 33)<br>**Recommendations**<br>• The plan provides recommendations for future work that could impact natural/ managed capacity, including ensuring lagoon operators coordinate to release effluent at optimal times, establishing regional watershed targets for phosphorus, reviewing the lagoon Code of Practice and regulations to allow for maximum phosphorus removal, and exploring opportunities to address cumulative effects | • None identified in the report | • Measures to manage phosphorus include manure management, removal of phosphorus in stormwater prior to release into the river, wetland restoration and protection, land use management (e.g. protecting wetlands, riparian areas, minimizing linear features)<br>• Population growth is expected to result in higher phosphorus loading in coming decades caused by urban development, agricultural intensification, increased food production, activity on the land, landscape modifications, and increased volumes of wastewater (p. 11, PDF p. 19)<br>• Water quality metrics include total phosphorus, total dissolved phosphorus, dissolved oxygen, periphyton concentration, TSS, nitrogen (total and nitrate), erosion, riparian health, wetland loss, agricultural BMP adoption rates (p. 33, PDF p. 41). | Government of Alberta. 2014. Bow River Phosphorus Management Plan. 50 pgs. |
| **Bow River Maximum Allowable Load, Fact Sheet** | • Project is in progress.<br>• Project was developed to support the Phosphorus Management Plan strategy to collect information to establish and enforce phosphorus targets for development in the planning area.<br>• The Bow River Maximum Allowable Load (BRMAL) study will determine the maximum Total Phosphorus (TP) load that can be present in the Bow River mainstem from Bearspaw to Bassano Dam such that it still maintains DO water quality objectives considering critical conditions and seasonal variation.<br>• The analysis will be conducted in two sub reaches: Bearspaw Dam to upstream Highwood River and Highwood River to Bassano Dam | **Key findings**<br>• Effluent from wastewater treatment plants and City of Calgary stormwater will be a key input for modelling.<br>**Recommendations**<br>• None to date, project is still in progress. | • None identified in the report. | • Phosphorus loading will be modelled to reach a desired frequency of compliance<br>• Concerned with phosphorus loading from upstream, tributaries, point sources, stormwater, and agricultural return flows | Government of Alberta. 2018. Bow River Maximum Allowable Load Project Fact Sheet. |
| **Bow River Maximum Allowable Load, PowerPoint presentation** | • Same as previous source. | • Same as previous source. | • None identified in the report. | • Mean and median total phosphorus concentrations are higher downstream of Calgary than upstream<br>• Tributaries are the main source of phosphorus loading in the Bow downstream of Calgary, with the Highwood River being the largest contributor<br>• Point sources (undefined) are the largest contributor to total phosphorus loading | Government of Alberta. 2018. Bow River Maximum Allowable Load: Source identification and assessment of Total Phosphorus. PowerPoint presentation, 41 slides. |
| **Assessment of current water allocation and water quality in the Elbow, Highwood, and Sheep Water Management Areas.** | • Report deals with surface water supply and current surface water allocation status of the Elbow, Sheep and Highwood River Water Management Areas (WMAs) | **Key findings**<br>• Sheep, Elbow, Highwood Water Management Areas (WMAs) have received many applications for licence transfers. There is a risk that there is insufficient water supply to meet transfer demand (p. 2, PDF p. 3)<br>• Instream objective analysis highlights:<br>○ Elbow River: Only analyzed from 2014-2017. IO met >50% of the time in each year; environmental base flow frequently met in the winter but less often in the open water season (not met 87% of the time in 2017)<br>○ Highwood River: IO not met 82% of the time from Nov to | • None identified in the report. | • Poor water quality has led to fish kills on all three rivers historically; current management intends to protect against these occurring in the future. (p. 5, PDF p. 6)<br>• Water quality analysis highlights:<br>○ Dissolved oxygen (DO) and temperature – Elbow River: no DO or temp exceedances; Highwood River: minimum DO was always above the acute guideline, max temperature exceeded warning limits in 25 of 28 years of record, and reached levels requiring management intervention in 15 of 28 years; Sheep River: no DO exceedances upstream of Okotoks, often exceeded downstream, likely due to effluent loading from the WWTP, | Alberta Environment and Parks. 2018. Assessment of current water allocation and water quality in the Elbow, Highwood, and Sheep Water Management Areas. |

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| | | March and not met 61% of the time from April to Oct based on simulated results for years 1928-2001. For 2014-2017 based on actual data, IO was met >50% of the time every year except 2016 (not met 80% of the time). EBF was not met >50% of the time every year.<br>○ Sheep River: IO not met 60% of the time Nov to March, 17% from April to Oct based on simulated results for years 1928-2001. For 2014-2017 based on actual data, IO was almost always met, except in 2017 and EBF was met >50% of the time except during the 2017 open water season.<br>• Municipal allocations:<br>○ Elbow River: 87.1% of existing water allocation is for municipal purposes (**Error! Reference source not found.**) (p. 40, PDF p. 41)<br>○ Highwood River: 6.2% of existing water allocation is for municipal purposes; 86.2% of allocation is for management purposes (i.e. lake level stabilization, Little Bow Canal Diversion, Women's Coulee diversion) (**Error! Reference source not found.**) (p. 47, PDF p. 48)<br>○ Sheep River: 59.6% of existing water allocation is for municipal purposes (**Error! Reference source not found.**) (p. 53, PDF p. 54)<br>**Recommendations**<br>• Report only provided technical information and interpretation; recommendations were not given. | | temperature exceedances are infrequent upstream of Okotoks but nearly constant downstream.<br>○ Ammonia – Elbow River: below detection limit 85% of the time, there are no major point sources; Highwood River: below detection limit 84% of the time, Okotoks WWTP is a considerable point source and it is expected that the proposed Aldersyde WWTP would be as well; Sheep River: below detection limit 78% of the time, point sources are Westend and Okotoks WWTP, concentration of ammonia is higher downstream of Okotoks than upstream. | |
| **City of Calgary Regional Water License Update** | • This short report document is intended to provide the base information regarding the City of Calgary's water licence capacity to inform a discussion around regional water servicing. | **Key findings**<br>• Municipalities in the CMR do not have sufficient water assurance for current and future needs (p. 3 of 5)<br>• The City of Calgary has entered into long-term water supply agreements to extend water supply from the City's licenced allocation to regional municipalities, however the City has calculated its projected growth and may not be able to meet peak daily water demand as of 2036 (p. 1)<br>• Due to projected limitations of peak daily water demand there is a need to understand if the Bow River watershed will be able to provide sufficient water for the growth aspirations of the region and how that will be managed.<br>**Recommendations**<br>• To address the challenges of finite water supply, The City, with the Province and regional stakeholders should develop a long-term water supply strategy to ensure the sustainable provision of water to the region (p. 3)<br>• To meet peak daily demand projects beyond 2036 the City must negotiate with Trans Alta and the Province to increase the instantaneous diversion rate from the Bearspaw Reservoir (p. 3) | **Recommendations**<br>• The City of Calgary administration plans to complete a Drought Risk and Vulnerability Assessment by end of 2019 (p. 3 of 5) | • None identified in this report. | City of Calgary. June 27 2018. The City of Calgary Regional Water Licence Update. Utilities & Environmental Protection Report to Intergovernmental Affairs Committee. 5 pages. |
| **Review of the Implementation of the Approved Water Management Plan for the South Saskatchewan River Basin** | • The purpose of this report is to provide an assessment of the Plan's implementation in the four SSRB sub-basins since its approval in 2006.<br>• The report:<br>○ Reviews the implementation of Plan recommendations and provisions;<br>○ Identifies emerging themes from the Basin Advisory Council discussions, along with related challenges and opportunities; and<br>○ Offers suggestions for next steps. | **Key findings**<br>• Estimated that 70% of surface water is allocated in the Bow River sub-basin.<br>• Between 2007 and 2017, 57 water licence transfers were completed in the Bow River sub-basin.<br>• How to match economic growth, municipal growth, and other needs with water supply and aquatic needs was identified as a key challenge<br>• Water use efficiencies have been realized in many sectors, including municipalities, but this has led to further development rather than a reduction in water diversions<br>**Recommendations**<br>• GoA should provide the resources necessary to fill data and information gaps for water and water management and for modelling and monitoring capacity in the SSRB.<br>• GoA needs to link water data to a cumulative effects approach.<br>• More needs to be done to restore and protect the long-term health of the aquatic and riparian environment, with attention to the implications of changing water pattern use through allocation transfers on the tributaries. | • Climate change was out of scope for the review. | • Water quality was out of scope for the review. | Basin Advisory Committees for the Bow River, Oldman River, and South Saskatchewan (sub-basin) River. 2018. Review of the Implementation of the Approved Water Management Plan for the South Saskatchewan River Basin. Report to the Government of Alberta. 37 pgs. |

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| | | • WCOs for headwater tributaries should be reviewed in terms of water quantity, water quality, groundwater, groundwater-surface water interactions and riparian ecosystems and possibly changed.<br>• Alternatives to WCOs should be explored (e.g. allowing private entities to hold WCO licences, protected water, implementation of a fee system for transfer allocations)<br>• AEP should complete a water reuse and stormwater policy | | | |
| **Bow River Water Management Project: Advice to Government on Water Management in the Bow River Basin** | • This was a joint project between Alberta Environment and Parks and the City of Calgary.<br>• Objectives were to develop scenarios for flood mitigation, schemes to offset increased water management risk, and identify opportunities for drought mitigation within those scenarios while maintaining ecosystem health.<br>• Schemes and scenarios to achieve target peak flows of 1,200 and 800 cms on the Bow River were assessed. | **Recommendations**<br>• Continue or expand the GoA-TransAlta agreement to manage upstream reservoirs<br>• Drought storage in expanded Glenmore Reservoir<br>• Fill downstream reservoirs earlier (e.g. Travers, Little Bow)<br>• Complete conceptual assessments of the 3 major infrastructure flood schemes (New Glenbow, New Morley, Expanded Ghost)<br>• Complete conceptual assessment for Eyremore scheme<br>• Increase resourcing and support for monitoring and forecasting to enhance water management operations | There were no key findings or recommendations specific to climate change. Climate change scenario data were incorporated into the modelling work to evaluate the performance of schemes and scenarios in the context of a changing climate. | • Water quality was out of scope of this work. | Alberta Environment and Parks. (2017). Advice to Government on water management in the Bow River Basin. Edmonton: Alberta Environment and Parks. |