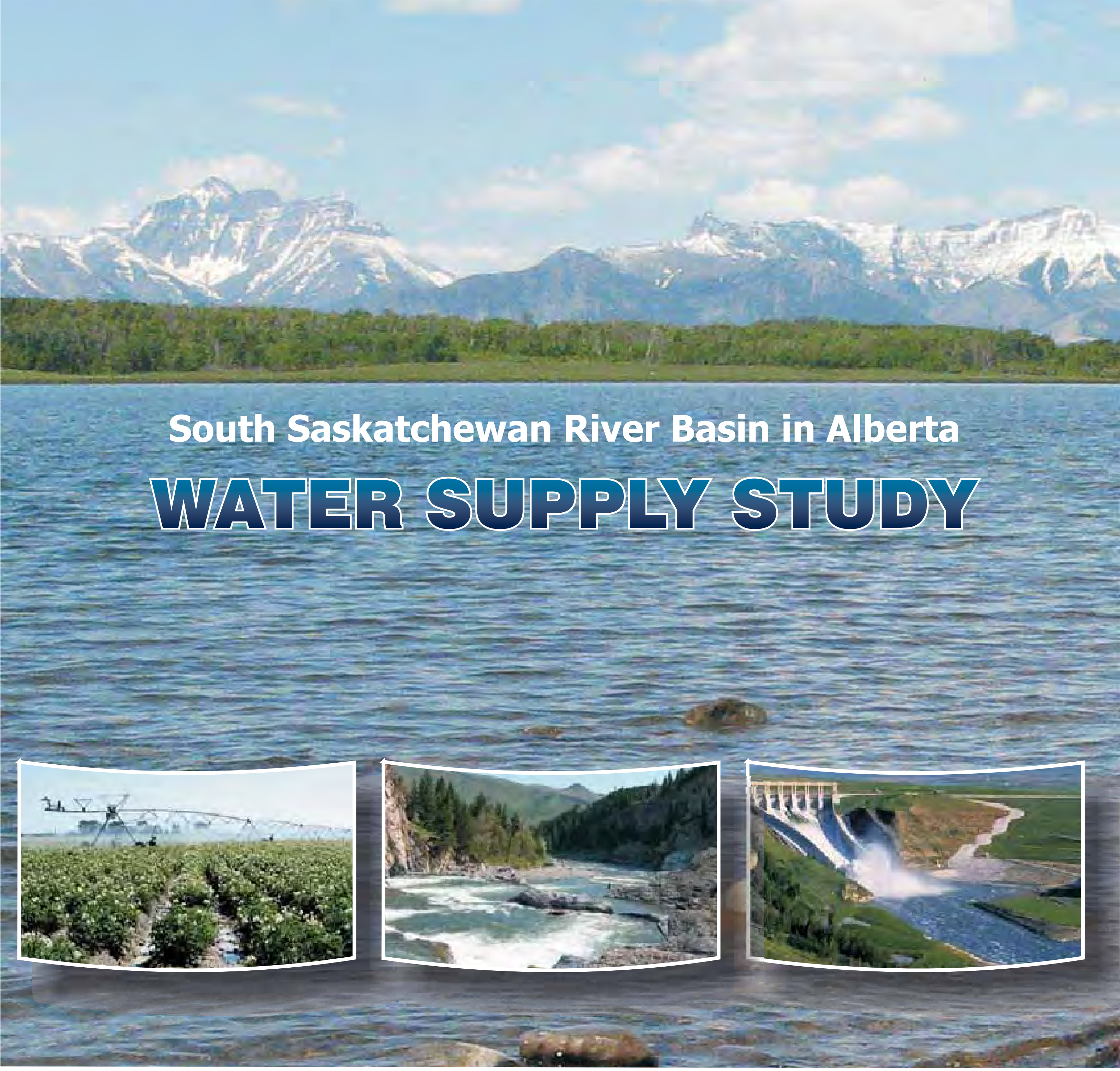

# South Saskatchewan River Basin in Alberta

# WATER SUPPLY STUDY


AMEC Earth & Environmental
Calgary, Alberta

In Association with:
Marv Anderson & Associates Ltd.
Unitech Solutions Inc.
Klohn Crippen Berger Ltd.
Calgary, Alberta


2009

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# SOUTH SASKATCHEWAN RIVER BASIN IN ALBERTA

# WATER SUPPLY STUDY

# FINAL REPORT

Submitted to:

**SSRB Water Supply Steering Committee**
Lethbridge, Alberta

Submitted by:

**AMEC Earth & Environmental**
Calgary, Alberta

In association with:

**Marv Anderson & Associates Ltd.**
**Unitech Solutions Inc.**
**Klohn Crippen Berger Ltd.**
Calgary, Alberta

November 2009

**ACKNOWLEDGEMENTS**

This report is the result of a joint effort of the study team comprised of staff of AMEC Earth and Environmental, Unitech Solutions Inc., Klohn Crippen Berger Ltd., and Marv Anderson and Associates Ltd. The report was reviewed by the SSRB Water Supply Steering Committee. Their collective input improved the report considerably.

Input throughout the course of the study was obtained from Tom Tang and Kent Berg, Alberta Environment, primarily related to simulation modelling and associated databases, and from Bob Riewe, Alberta Agriculture and Rural Development, primarily related to irrigation demand. Their respective contributions are gratefully acknowledged.

The report was written by J. R. (Dick) Hart, AMEC Earth and Environmental. Draft reports were reviewed by study manager Al McPhail, AMEC Earth and Environmental, and other team members. Their helpful comments were much appreciated.

# EXECUTIVE SUMMARY

The water management plan for the South Saskatchewan River Basin (SSRB) was approved by the Alberta Government in August 2006. This plan led to establishment of the basin's Water Conservation Objectives (WCOs) in January 2007, and restricted the use of all unallocated water in the Bow, Oldman and South Saskatchewan Sub-basins, by Regulation 171/2007, in August 2007. The plan and subsequent decisions have heightened competition for water in the SSRB. Water users throughout the basin are concerned about the security of supply and economic growth now and in the future.

The SSRB Water Supply Steering Committee commissioned a science-based study with objectives as follows:

- assess current and future water supply and demand in the SSRB;
- identify constraints to water supply and economic growth; and,
- identify, analyze and evaluate structural and non-structural water management alternatives to address constraints and issues.

## KEY STUDY FINDINGS

### *Current Water Supply*

1. **The Red Deer River Sub-basin is the largest of the three primary sub-basins, but has the lowest mean annual flow volume, primarily due to the low proportion of the basin in the mountain and foothills regions.**

   Much of the Red Deer River Sub-basin has flatter slopes and poorly developed drainage compared with the Bow and Oldman Sub-basins. Flow in the Red Deer River has been regulated by the Dickson Dam (Glennifer Lake Reservoir) since 1983. Increasing low winter flows to improve water quality is a high priority for operation of the Dickson Dam. Flow regulation and a relatively low level of water use have had little effect on annual flow volumes.

2. **The Bow River and Oldman River have similar runoff volumes, but historically the Oldman River has been more highly variable and more susceptible to droughts than the Bow River.**

   The median annual natural flow of the Bow and Oldman Rivers are about double that of the Red Deer River. Flow regulation and extensive water use have had significant impacts on the flow in both the Bow and the Oldman Rivers. In general, the impact has been lower summer flows. Winter flows have significantly increased in the Bow River due to winter releases from hydro-electric reservoirs. Water use in both basins is dominated by diversions for irrigated agriculture.

**3. The South Saskatchewan River Sub-basin has low runoff potential, primarily because of low precipitation and high evapotranspiration.**

Flow in the South Saskatchewan River near Medicine Hat is essentially the sum of flows of the Bow and Oldman Rivers. The South Saskatchewan River Sub-basin contributes very little flow to the river. Annual flow is heavily impacted by regulation and water use in the Bow and Oldman Sub-basins.

**4. Alberta has consistently met its commitments to Saskatchewan under the Prairie Provinces Master Agreement on Apportionment.**

Apportionment on the South Saskatchewan River is administered downstream of the confluence with the Red Deer River. Surplus water has been delivered to Saskatchewan even in dry years. Surplus deliveries from 1970 to 2006 have averaged 2 573 000 $dam^3$, varying from 350 000 $dam^3$ in 2001 to 5 498 000 $dam^3$ in 2005. On average, Alberta has passed 81% of the apportionable flow to Saskatchewan, considerably higher than the 50% required. This suggests that water may be available for additional use in Alberta.

**Volume Units**
1 $dam^3$ = 1 000 $m^3$
1 $m^3$ = 1 000 litres
1 $dam^3$ = 0.811 acre-feet

***Future Water Supply***

**5. Future reductions in natural streamflow volumes are more likely than increases for all streams in the SSRB.**

From studies of tree rings, lake sediments and other climatic indicators on the Canadian prairies, researchers have concluded that stream flows were relatively high on the Canadian Prairies during the 20th century compared with earlier centuries. Streamflow variability may be somewhat higher in the future than experienced during the past century.

Climate change studies conducted by the National Water Research Institute indicated a wide range of potential positive and negative impacts on natural stream flow in the SSRB, but future reductions in flows are more likely than increases in all of the sub-basins.

The reduction in glacial area and declining contribution to stream flow in the Bow River give rise to concerns related to the sustainability of Bow River late-summer and fall flows.

### *Current Water Demands*

6. **Current actual surface water consumed by all sectors in the SSRB in Alberta is estimated to be about 1 981 000 dam$^3$, which is approximately 40% of the total volume of water (4 987 700 dam$^3$) allocated for use. Irrigation is the highest water-use sector in the SSRB, representing 84% of the total current actual water use.**

   The total allocation of 4 987 700 dam$^3$ excludes projects that do not impact mainstem flows. These projects were not considered in the study analysis. The full allocation for the geographic area of the SSRB is 5 403 000 dam$^3$.

   Current actual surface water use represents about 22% of the median natural flow of the South Saskatchewan River downstream of the Red Deer River confluence, and about 46% of Alberta's entitlement under the apportionment agreement (after adjusting the flow subject to apportionment for uses of the St. Mary River in the United States).

7. **In 2007, Water Conservation Objectives (WCOs) were established for all mainstem rivers in the SSRB.**

   In general, the WCOs were set as the maximum of either 45% of the natural flow or 10% more than the previously established In-stream Objectives (IOs). The former condition (45% of the natural flow) usually applies during normal and higher flow periods; the latter condition (110% of the IO) usually applies during low flow periods.

   In the Red Deer River Sub-basin, the WCOs apply to existing licences with provisions for retrofitting in-stream flow requirements, and to licences issued after 1 May 2005. New allocations are permitted in the Red Deer Sub-basin. For the remainder of the SSRB, the WCOs apply to applications received after 1 May 2005. The WCOs for the highly allocated Bow and Oldman Sub-basins were set to provide direction and opportunities to increase in-stream flows and improve the aquatic environment.

   The WCOs are subject to review and refinement pending improved knowledge and information about the aquatic environment and water quality.

8. **The frequency of deficits to the WCOs and current junior non-irrigation water users are high throughout most of the SSRB.**

   Junior water users are those subject to the recently established WCOs in the Red Deer River Sub-basin, and those subject to IOs established since the mid-1990s in the Bow and Oldman Sub-basins. The junior projects that are not supported by dedicated storage are particularly vulnerable to deficits. The various water-use sectors (municipal, stock water, irrigation, industrial, commercial, wetlands) have different tolerances to deficits.

Deficits to irrigation district water users are minor for the current level of demands.

### *Future Water Demands*

9. **By 2030, water use could increase from the current 1 981 000 dam$^3$ to about 3 040 000 dam$^3$, an increase of 53%. This magnitude of increase would occur if irrigation districts were to implement, under their existing licence allocations, the maximum level of expansion modelled in this study. The maximum expansion considered assumed 32% expansion of the irrigation district area in the Bow Sub-basin and 19% expansion in the Oldman Sub-basin.**

   There is significant potential for expansion of irrigation districts in the Bow Sub-basin, but a more limited potential for expansion of districts within the Oldman Sub-basin. However, if southern Alberta's climate becomes warmer and drier, irrigation demand per unit of irrigated area would increase, which could potentially curb the desire of irrigation districts to expand.

   Climate change could affect water uses by all water-use sectors. Changes in demands for non-irrigation water users would likely be small in relation to changes in demands for irrigation use.

10. **Potential increases in future water use, primarily within the irrigation districts, will increase deficits to WCOs, junior private irrigation users, and junior non-irrigation users, particularly in the Bow, Oldman and South Saskatchewan Sub-basins.**

    The Bow and Oldman Sub-basin irrigation districts perform adequately with existing water allocations (including two pending applications) for future expansion options considered in this study, except the climate change scenario.

    Generally, the impact of future water demand on the WCOs would be a modest increase in deficits throughout the SSRB. The impact on junior water users in the Red Deer Sub-basin would also be a modest increase in deficits. The increase in deficits to junior users in some parts of the Bow, Oldman and South Saskatchewan Sub-basins would be substantial.

11. **It is likely that climate change will reduce streamflows in the SSRB. Reduced streamflows will have significant impacts on potential irrigation district expansion in the Oldman Sub-basin.**

    If streamflow decreases, deficits in meeting district irrigation demands in the Bow Sub-basin would increase, but performance would still be acceptable for all expansion scenarios considered in this study. Deficits to district irrigators in the Oldman Sub-basin would be beyond the tolerable limits for the highest level of expansion considered in this study.

If decreases in streamflow are experienced, the WCOs that are indexed to streamflow will also decrease. Performance in meeting the reduced WCOs will improve throughout the SSRB. Deficits to junior water users throughout the SSRB would significantly increase.

***Non-structural Adjustments***

12. **Refining or modifying the operations of existing storage reservoirs in the Red Deer and Bow Sub-basins would potentially reduce or eliminate deficits to the WCOs and junior consumptive users in those basins.**

    In the Red Deer Sub-basin, deficits are infrequent, low in volume, and primarily in the winter months. It is believed that refining the operation of Dickson Dam would reduce or eliminate current and future deficits.

    In the Bow Sub-basin, studies indicate that much improved performance in meeting demands could be achieved through shared use of existing hydroelectric storage facilities. Because it is preferred over new storage development, it should be pursued to its eventual conclusion before considering new storage to address basin-wide issues.

13. **Other non-structural measures include improved irrigation efficiencies and reduced return flows, market-based water allocation transfers and deficit sharing. While all have a role to play in improving water management in the SSRB, the collective benefits of all these measures would probably not fully address current and future issues identified in this study.**

    Irrigation district efficiencies have increased substantially during the past three decades. Reduced return flows from the irrigation districts have been a major result of the improvements. Further improvements from the current 53% to 63% efficiency within the next 10 to 15 years would conserve an average of about 326 000 $dam^3$ per year.

    Research in Alberta and elsewhere indicates that market-based allocation transfers will gradually shift water use to higher value purposes, to more efficient uses, and to help meet in-stream requirements. However, the contribution of the transfers and associated environmental holdbacks to reduce basin-wide deficits identified in this study is likely to be small because of the large volume of transfers required to have a significant impact on the issues identified.

In water-short years, voluntary deficit sharing among licensees through allocation assignments or by other means is a valuable tool for reducing the impacts of periodic droughts.

***Structural Adjustments***

14. **A preliminary review of the hydrology of the Red Deer, Bow and Oldman Sub-basins indicates that there is unused flow available at various locations in each sub-basin. Additional storage and flow regulation can assist in reducing deficits to in-stream requirements (WCOs or IOs), and junior consumptive users.**

    On-stream storage at strategic upstream locations in the SSRB would enable capture and release of water for downstream users and in-stream flow needs. Additional on-stream storage of over 1 000 000 $dam^3$ may be possible at on-stream locations in the Red Deer, Oldman and Bow River Sub-basins.

    Climate change research suggests that future mountain runoff may occur during the winter and early-spring seasons, before off-stream diversion canals can operate. On-stream storage will be more effective than off-stream storage in capturing these snowmelt events.

    Off-stream storage has made a significant contribution to water management in the SSRB and should be considered to address specific issues in the future. Historically, off-stream storage in the SSRB has not been located or utilized to divert water from a main river system for storage and later release back to the source stream for flow regulation purposes. While this may be possible, it is unlikely to be as effective as on-stream storage for this purpose.

    To test the value of additional storage in the Oldman River Sub-basin, a new reservoir with storage capacity about the same as the Oldman River Reservoir (490 000 $dam^3$) was assumed, and a 19% increase over the current irrigation district area in the Oldman Sub-basin was modelled with the additional storage. The modelling results indicated improvements in meeting all junior demands as well as the ability to meet commitments on the Piikani First Nation Reserve.

    If it is decided to pursue the option of additional storage development in the SSRB, various sizes and locations for storage development could be considered. Economic, environmental, and social impact studies would be required on the most favourable options.

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**APPENDICES**

# 1.0 INTRODUCTION

## 1.1 Background

In August 2006, the Alberta Government approved a water management plan for the South Saskatchewan River Basin (SSRB)[1]. The plan recommended in-stream flow requirements, referred to as Water Conservation Objectives, for the Red Deer, Bow, Oldman and South Saskatchewan River Sub-basins, and closed the latter three sub-basins to further allocations pending a Crown Reservation specifying how unallocated water should be used. On 1 August 2007, the Minister of Alberta Environment (AENV) reserved all unallocated water in the Oldman, Bow and South Saskatchewan Sub-basins (Regulation 171/2007)[2]. The Minister directed that reserved water may be allocated only for the following purposes:

- use by a First Nation;
- to contribute toward meeting a Water Conservation Objective;
- for storage development (if the storage is used for protection of the aquatic environment or improving availability of supply for existing licence holders and registrants); and,
- for outstanding complete applications as of the date Regulation 171/2007 was filed (13 August 2007).

The approved plan and Regulation 171/2007 have heightened competition for water from the South Saskatchewan River Basin for uses within and beyond the boundaries of the three main sub-basins. In light of the recommendations of the SSRB Plan, high population growth rates in some parts of the SSRB, potential climate change, impacts of increasing demands and full utilization of licensed allocations, sources of water for meeting apportionment commitments, and recent licence applications (in the Red Deer River Basin), water users throughout the SSRB are concerned about the security of supply and economic growth now and in the future.

## 1.2 Purpose and Scope

### 1.2.1 Study Purpose

The SSRB Water Supply Steering Committee has commissioned a science-based study with objectives as follows:

- assess current and future water supply and demand in the SSRB;
- identify constraints to water supply and economic growth; and,
- identify, analyze and evaluate structural and non-structural options to address constraints and issues.

It is the desire of the Steering Committee to have a clear understanding of issues related to current and future water supply security, potential measures to increase security, and strategic direction for the future.

[1] http://environment.alberta.ca/1674.html
[2] http://www.qp.gov.ab.ca/documents/Regs/2007_171.cfm?frm_isbn=9780779725748

### 1.2.2 Study Scope

The study involved the following components:

- a detailed assessment of current and projected future water demand in the basin;
- an assessment of historical, current and future water supply, including an assessment of trends and the impacts of climate change;
- simulation modelling of current and future water supply and demand to determine magnitude, frequency, and locations of water supply deficits for both in-stream and consumptive uses;
- assessment of the impacts of climate change on water supply security, on the economic and social well-being of residents of the area, and on the aquatic and riparian environments;
- identification and evaluation of structural and non-structural measures to improve water supply security; and,
- preparation of a report.

## 1.3 Report Format

Following this introductory chapter, *Chapter 2* provides an overview of the SSRB watershed and its water supply and demand characteristics. Key water management decisions and water management procedures are outlined, and an overview of socio-economic and environmental conditions is provided.

*Chapter 3* analyses water supply conditions in the basin, noting in particular, the differences among the four primary sub-basins. *Chapter 4* analyses current water uses and estimates future 2030 demands. Chapters 3 and 4 draw on three Technical Memorandums on water supply, urban and rural domestic water supply, and non-municipal water use. These memorandums are bound separately in Volume 2 of this report. The relationships between water supply and demand are dealt with in *Chapter 5*. Simulation modelling is used extensively to identify water supply and demand issues in the basin. Immediately following Chapter 5, Attachments 5-A and 5-B contain tables showing the results of simulation modelling for four scenarios of water supply and demand conditions.

*Chapter 6* identifies and evaluates non-structural options for addressing current and future issues. *Chapter 7* identifies and evaluates structural options for addressing issues; *Chapter 8* provides a summary of findings and recommendations. *References* used in this study are listed following Chapter 8.

SI units (metric) are used throughout the report. A table of *Metric Conversions* is provided in Appendix A. A large number of significant digits are often carried forward in tables to avoid annoying round-off errors. These numbers are generally not indicative of the accuracy of the values. *Abbreviations and acronyms* used in this report are shown in brackets following first use of the full name or term, and may be repeated from time to time. *Definitions of terms* are provided in sidebars located where they are first used.

## 2.0 WATERSHED OVERVIEW

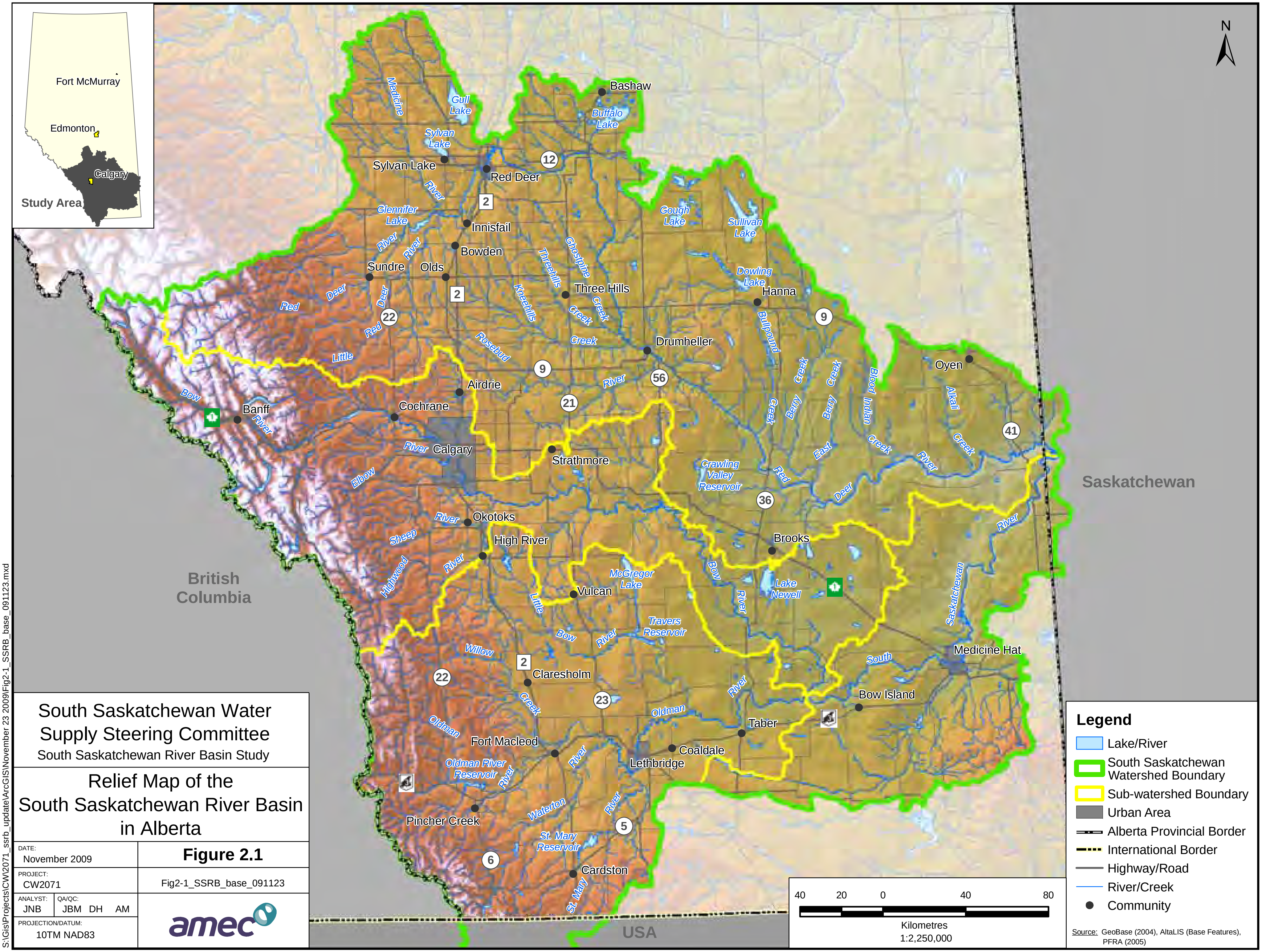
Water management in the South Saskatchewan River Basin (SSRB) in Alberta has a history dating back to the late-1800s. The climate and physical attributes of the basin, and various landmark events and circumstances have shaped decision-making during the 120-year history of water management in the basin. Closure of the Waterton, Belly and St. Mary tributaries of the Oldman River to further allocations in 2002, and subsequent closure of the entire Oldman, Bow and South Saskatchewan Sub-basins in 2006 (Alberta Environment, 2006) ranks high among a number of significant historical events affecting water management in the SSRB. In August 2007, the Alberta Government filed a *Regulation* under the *Water Act* reserving all unallocated water in the Bow, Oldman, and South Saskatchewan Sub-basins, and limiting further licences in these three sub-basins only to outstanding applicants, First Nations, water conservation objectives (in-stream needs) and for storage development providing it, for the protection of the aquatic environment or to improve water supply availability to existing licence holders and registrants. Only the Red Deer River Sub-basin can proceed with licensing allocations in the usual manner. This was a decision unprecedented in Alberta, with far-reaching implications that need to be explored.

An overview of physical attributes of the basin, significant events, and the social, economic and environmental setting provides a context for analysis and exploring possible courses of action for the future.

### 2.1 Physical Attributes

The SSRB extends from the Rocky Mountain Continental Divide in Alberta, across southern Alberta and into south-central Saskatchewan where it joins the North Saskatchewan to form the Saskatchewan River. The SSRB is a tributary basin of the Nelson River system which empties into the Hudson Bay in Manitoba. A small but significant portion of the SSRB rises in Montana.

A relief map for the SSRB is shown in **Figure 2.1**. The basin comprises terrain ranging from mountainous in the west descending to foothills, parkland, prairie and semi-arid plains in the east. Elevations vary from about 3500 m in the west to about 600 m in the east. The unique topography and landscape of the basin influences the climate, soils, vegetation, settlement patterns, and the quantity and quality of streamflow. The eco-regions within the four primary sub-basins are shown in **Figure 2.2**. The characteristics of the eco-regions and the areas of each region within the sub-basins are shown in **Table 2.1**.


South Saskatchewan Water
Supply Steering Committee
South Saskatchewan River Basin Study
Relief Map of the
South Saskatchewan River Basin
in Alberta
DATE:
November 2009
Figure 2.1
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Fort McMurray
Edmonton
Calgary
Study Area
N
Legend
Lake/River
South Saskatchewan Watershed Boundary
Sub-watershed Boundary
Urban Area
Alberta Provincial Border
International Border
Highway/Road
River/Creek
Community
40 20 0 40 80
Kilometres
1:2,250,000
Source: GeoBase (2004), AltaLIS (Base Features), PFRA (2005)
British Columbia
Saskatchewan
USA
Bashaw
Sylvan Lake
Red Deer
Innisfail
Bowden
Sundre
Olds
Three Hills
Hanna
Drumheller
Oyen
Airdrie
Cochrane
Banff
Calgary
Strathmore
Okotoks
High River
Brooks
Vulcan
Medicine Hat
Claresholm
Bow Island
Taber
Fort Macleod
Coaldale
Lethbridge
Pincher Creek
Cardston
Gull Lake
Buffalo Lake
Sylvan Lake
Glennifer Lake
Gough Lake
Sullivan Lake
Dowling Lake
Crawling Valley Reservoir
McGregor Lake
Lake Newell
Travers Reservoir
Oldman River Reservoir
St. Mary Reservoir
Medicine River
Red Deer River
Little Red Deer River
Rosebud River
Kneehills Creek
Threehills Creek
Ghostpine Creek
Bullpound Creek
Berry Creek
Blood Indian Creek
Alkali Creek
Red Deer River
Bow River
Elbow River
Sheep River
Highwood River
Little Bow River
Willow Creek
Oldman River
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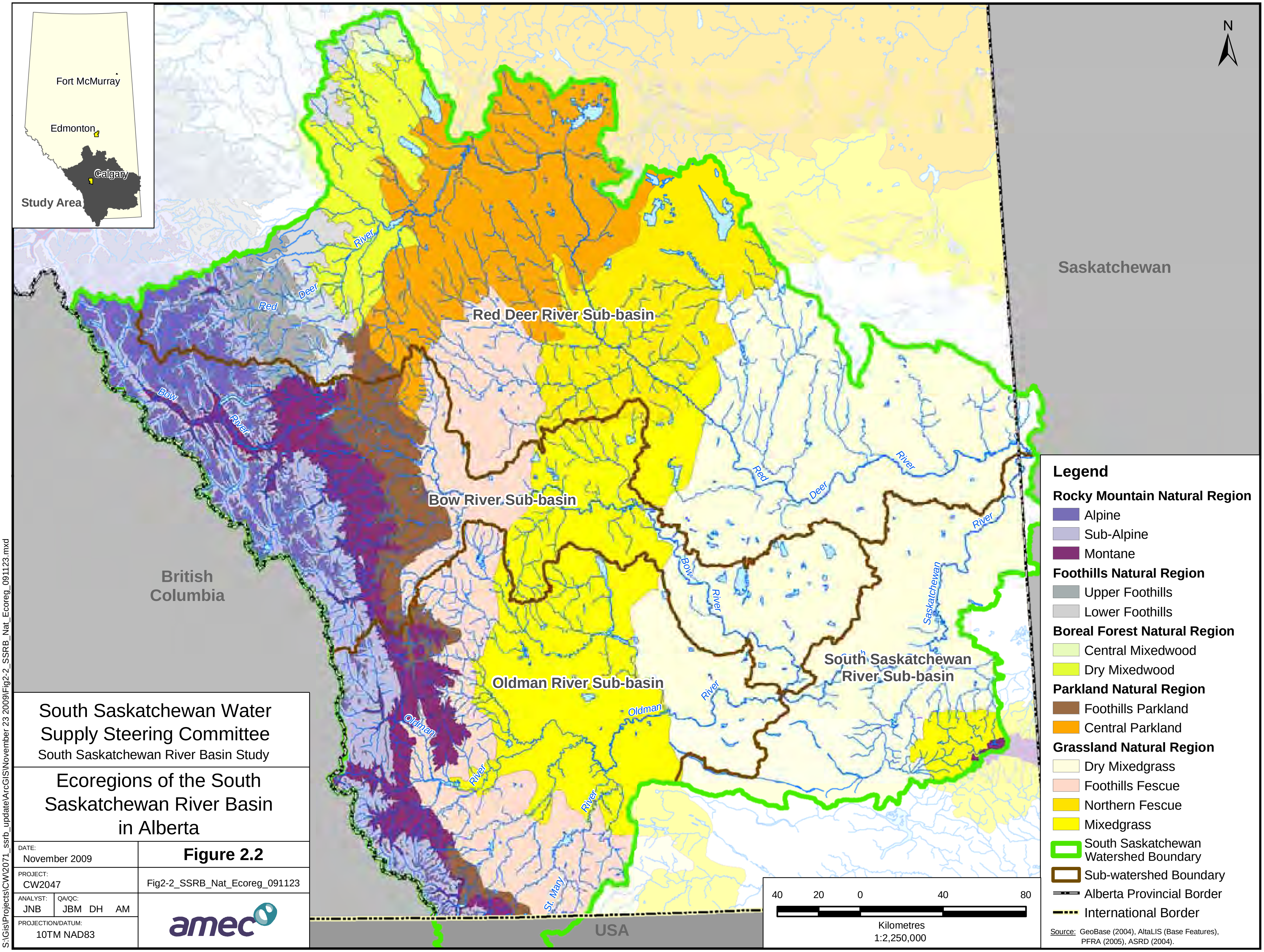
Fort McMurray
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Study Area
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USA
Red Deer River Sub-basin
Bow River Sub-basin
Oldman River Sub-basin
South Saskatchewan River Sub-basin
Red Deer River
Bow River
Oldman River
St. Mary River
Saskatchewan River
Legend
Rocky Mountain Natural Region
Alpine
Sub-Alpine
Montane
Foothills Natural Region
Upper Foothills
Lower Foothills
Boreal Forest Natural Region
Central Mixedwood
Dry Mixedwood
Parkland Natural Region
Foothills Parkland
Central Parkland
Grassland Natural Region
Dry Mixedgrass
Foothills Fescue
Northern Fescue
Mixedgrass
South Saskatchewan Watershed Boundary
Sub-watershed Boundary
Alberta Provincial Border
International Border
Source: GeoBase (2004), AltaLIS (Base Features), PFRA (2005), ASRD (2004).
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Kilometres
1:2,250,000
South Saskatchewan Water Supply Steering Committee
South Saskatchewan River Basin Study
Ecoregions of the South Saskatchewan River Basin in Alberta
DATE: November 2009
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## TABLE 2.1
## Biophysical and Climatic Characteristics Within Each of the Four Sub-basins of the SSRB in Alberta

| Eco-region[1] | Median Temp.[2] (°C) | Total Precip.[2] (mm) | Percent of Total Area Within Each Sub-basin | | | | Total for South Sask Basin |
|---|---|---|---|---|---|---|---|
| | | | Red Deer | Bow | Oldman | South Sask. | |
| **Rocky Mountains Natural Region** | | | | | | | |
| Alpine | 6 | 650 | 2.0% | 11.4% | 1.1% | | 3.7% |
| Sub-alpine | 10 | 930 | 1.8% | 15.4% | 9.4% | | 6.4% |
| Montane | 12 | 600 | | 13.2% | 10.9% | 0.7% | 5.6% |
| **Foothills Natural Region** | | | | | | | |
| Upper Foothills | 11 | 540 | 2.9% | 0.6% | | | 1.4% |
| Lower Foothills | 12 | 465 | 4.7% | 0.1% | | | 2.1% |
| **Boreal Forest Natural Region** | | | | | | | |
| Central Mixedwood | 12 | 380 | 0.9% | | | | 0.4% |
| Dry Mixedwood | 12 | 380 | 9.0% | | | | 3.9% |
| **Parkland Natural Region** | | | | | | | |
| Central Parkland | 13 | 400 | 23.0% | 1.4% | | | 10.4% |
| Foothills Parkland | 13 | 575 | 0.8% | 11.0% | 2.8% | | 3.4% |
| **Grassland Natural Region** | | | | | | | |
| Northern Fescue | 14 | 400 | 16.4% | 0.5% | | | 7.3% |
| Foothills Fescue | 12 | 575 | 6.5% | 9.8% | 26.8% | | 11.2% |
| Mixed Grass | 15 | 340 | 3.3% | 16.3% | 35.6% | 8.5% | 14.2% |
| Dry Mixed Grass | 16 | 270 | 28.7% | 20.2% | 13.4% | 90.9% | 30.1% |
| | | | **Sub-basin Hydrologic Characteristics** | | | | **Total for South Sask Basin** |
| | | | **Red Deer** | **Bow** | **Oldman** | **South Sask.** | |
| Gross Drainage Area (GDA) ($km^2$)[3] | | | 46 800 | 25 300 | 27 500 | 13 200 | 112 800 |
| Effective Drainage Area (EDA) ($km^2$)[3] | | | 32 400 | 19 200 | 20 900 | 6 600 | 79 100 |
| EDA / GDA Ratio (%) | | | 69% | 76% | 76% | 50% | 70% |
| Weighted Median Annual Temperature (°C)[4] | | | 13.6 | 12.4 | 13.4 | 15.9 | 13.6 |
| Weighted Median Annual Precipitation (mm)[4] | | | 393 | 538 | 488 | 278 | 435 |
| Median Annual Natural Flow Volume ($dam^3$)[5] | | | 1 666 000 | 3 829 000 | 3 343 000 | 3 662 | 8 842 000 |
| Median Runoff Yield over EDA (mm)[6] | | | 51 | 199 | 160 | 0.6 | 112 |

Notes:

1 Eco-regions data in table are based on Strong and Leggat, 1992.

2 Temperature and precipitation are based on average of the range for each eco-region.

3 Reference: Water Survey of Canada.

4 Median annual temperature and precipitation are based on the values in the table for each eco-region. Values are weighted by area of the eco-region within each basin.

5 Reference: Alberta Environment's natural flow database 1912–2001 for Red Deer River near Bindloss, Bow River near the Mouth, Oldman River near the Mouth and South Saskatchewan River at Highway 41 plus Red Deer River near Bindloss for the total SSRB.

6 Median Runoff Yield (mm) = Median Annual Natural Flow ($dam^3$) divided by Effective Drainage Area ($km^2$).

The basin can be divided into *five principal natural regions*: the Rocky Mountains, Foothills, Boreal Forest, Parkland and Grassland natural regions (Strong and Leggat, 1992). The *Rocky Mountains* are comprised of the Alpine, Sub-alpine and Montane Eco-regions, which differ mainly in elevation and aspect. The Bow Sub-basin has the highest percentage of its drainage area within the Rocky Mountain natural region; the Red Deer Sub-basin has only a small amount of the region in its headwaters. The Rocky Mountains generally have lower summer temperatures and higher annual precipitation than areas eastward. Average annual precipitation within the region is highly variable due to **orographic** effects on prevailing westerly winds. On average, precipitation would probably exceed 700 mm annually, much of it as snowfall. The mountainous regions are sometimes referred to as the "water towers" of the prairies due to their high runoff generating characteristics. However, some interior valleys on the leeward side of the mountains (east side) may be quite dry due to rain-shadow effects.

**Orographic precipitation** – rain, snow, or other precipitation produced when moist air is lifted as it moves over a mountain range.

As the air rises and cools, orographic clouds form and precipitation ensues, most of which falls upwind of the mountain ridge. Some also falls a short distance downwind of the ridge.

The mountains consist primarily of folded, faulted and lifted sedimentary rock, resulting in sharp peaks and ridges criss-crossed by deep valleys eroded along softer rock beds and fault lines. Vegetation in the mountains ranges from lichen to low growing shrubs and isolated clumps of trees in the Alpine Eco-region, to coniferous forests in the Montane and Sub-alpine Eco-regions.

The Rocky Mountain region in the SSRB has several parks and other protected areas, such as Banff and Waterton National Parks, Peter Lougheed Provincial Park, Kananaskis Country, and a number of protected wild lands. The mountains provide important wildlife habitat and are critical for water quantity and quality management purposes.

The *Foothills* region provides the transition between the mountains to the west and the Boreal and Parkland Eco-regions to the east. Comprised of the Upper Foothills and Lower Foothills eco-regions, it represents very large areas of Alberta north of the SSRB. In the SSRB, it is most predominant in the Red Deer River Sub-basin. The Upper Foothills are characterized by rolling topography with morainal deposits over bedrock. Outcrops are relatively frequent. Moving eastward in the Lower Foothills eco-region, relief gradually smoothes out into rolling topography, merging into high plains and the Boreal forests. In the Lower Foothills eco-region, extensive organic deposits in valleys and depressional areas are common. Average precipitation is about 505 mm, most of it occurring in the summer months. July is the highest precipitation month in this and other eco-regions in the north-western part of the Red Deer River Sub-basin. Soils in the Foothills are generally Luvisols and Brunisols, with Gleysolics in wetter areas. Vegetation is lush due to the high growing-season precipitation. Vegetation in the Upper Foothills Eco-region is almost pure coniferous forests, with white spruce, black spruce and lodgepole pine dominant. In the Lower Foothills Eco-region, a mixture of coniferous and deciduous forests provides excellent habitat for diverse wildlife. Black and grizzly bear, elk and moose occupy the area. Forest harvesting and recreational activities take place throughout the region.

The *Boreal Forest* natural region is comprised of the Central Mixedwood and Dry Mixedwood Eco-regions, both of which are solely in the Red Deer Sub-basin. Climate is continental, with large differences between summer and winter temperatures. Cold, dry Arctic air masses can be a significant factor in winter and spring. In summer and fall, warm, moist westerlies from the Pacific become more dominant. Average annual precipitation is about 380 mm, about two-thirds of which occurs in summer. July is the wettest month. Rolling to undulating morainal uplands, hummocky plains and plateaus crossed by steep-sloped valleys are the prevalent landforms in the Foothills. Gleyed Luvisols and Gleysols are the most common soils. Vegetation varies from lodgepole pine forests in the higher elevations, to mixed wood forests and cleared areas at the lower elevations. Forestry, oil and gas activity, and recreation are common land uses. Agriculture is restricted to the eastern edge of the Foothills region. Topography and climate preclude agricultural use in the remainder of the region. The area is important winter habitat for ungulates. It is also home to North America's most inland race of grizzly bears.

**Morainal** – material transported and deposited by a glacier.

**Hummocky** – rounded knolls or hills.

**Plateaus** – relatively flat, elevated surfaces.

The *Parkland* natural region is comprised of the Central Parkland Eco-region covering 23% of the Red Deer Sub-basin, and the Foothills Parkland Eco-region which parallels the Rocky Mountains and covers 11% of the Bow River Sub-basin. Surficial deposits range from extensive areas of hummocky and ground moraines, to glacial lake deposits and coarse glacial outwash materials. The Central Parkland Eco-region has an average annual precipitation of about 400 mm; the higher elevation Foothills Parkland Eco-region averages about 575 m precipitation. Predominant soils are Chernozems in the grassland areas and Luvisols in the woodland areas. Vegetation is a west-to-east continuum of aspen forests, to rough fescue grasslands with aspen groves, to predominantly grasslands. Native vegetation is scarce in some areas due to extensive agricultural activities. The Parkland region is one of the most productive non-irrigated field crop zones in Alberta. The region is home to a wide variety of birds, small mammals and amphibians in the rich riparian areas.

The *Grassland* natural region is the largest region within the SSRB. It includes the Foothills and Northern Fescue Grass, Mixed Grass, and Dry Mixed Grass Eco-regions. The Grassland region extends from just west of Calgary to the Saskatchewan border and constitutes about 63% of the SSRB. The Northern Fescue Eco-region is almost exclusively in the Red Deer River Sub-basin. The reverse is true for the Foothills Fescue Ecosystem; a very small area is in the Red Deer River Sub-basin and larger areas are in the Bow and Oldman River Sub-basins. Large areas of the Mixed Grass and Dry Mixed Grass Eco-regions prevail in all three sub-basins. The Dry Mixed Grass Eco-region covers almost the entire South Saskatchewan Sub-basin.

The climate of the Grassland region is continental, with long cold winters, short summers and generally low precipitation. Occasional chinook winds provide some relief from the cold winter temperatures, particularly in the southwest part of the region. Summer temperatures become increasingly warmer and precipitation diminishes from west to east within the region. The long summer days and minimal cloud cover maximizes solar radiation. June is the highest precipitation month in the grassland region. The Dry Mixed Grass Eco-region has the lowest median summer precipitation (156 mm) of any region of Alberta. Warm temperatures, coupled with the low precipitation and generally high winds, produce the highest potential evapotranspiration deficit in the province. The median annual precipitation in the Dry Mixed Grass Eco-region is 270 mm.

Topography in the Grassland climatic region varies from level to undulating, with some pockets of rolling terrain. Brown, Dark Brown and Black Chernozemic soils dominate the region. Vegetation ranges from northwest to southeast as a mix of native grassland and deciduous forest, to predominantly mixed grassland, to drought resistant grasses toward the southeast. The predominant activity in the grassland regions is dry-land or irrigated crop production and cattle grazing. In westerly parts of the region cattle grazing is usually limited to areas of rough terrain. Grazing becomes more popular eastward where precipitation will not support dry-land cropping and irrigation water is not available, or the soils or terrain is unsuitable for crop production.

Landscape characteristics of the grassland region of the SSRB have been strongly influenced by the Laurentide glaciation. The landscape consists of rolling, hummocky glacial till underlain by pockets of glacial debris deposited directly from the ice. An interesting aspect of glaciation is the large coulees that appear to be out of place with the general landscape. The valleys are much too large for the tiny streams that occupy them. Geomorphologists often refer to these as “underfit streams”. Beaty (1975) gives an account of the origin of these coulees in the Oldman River Sub-basin.

Continental glaciations obliterated pre-glacial drainage patterns which generally drained the Canadian Prairies easterly and northerly. As the glaciers gradually began to recede to the east, the melting ice and runoff from the Rockies formed massive lakes between the toe of the glaciers and higher ground to the west. Water levels built up until the lakes spilled over the height of land to the south cutting a series of deep channels running in a south-easterly direction to the Milk and Missouri Rivers. This erosive action of lake drainage left a number of modern-day large coulees, including:

- Whiskey Gap
- Lonely Valley
- Middle Coulee
- Kipp Coulee
- Verdigris Coulee
- Etzikom Coulee
- Chin Coulee
- Forty Mile Coulee
- Pakowki or Pendant d’Orielle Coulee
- Seven Persons Coulee

Initially, the Etzikom, Chin and Forty Mile channels conveyed water to the Milk River via Pakowki Lake. As glacial recession continued, drainage became possible to the north of the Cypress Hills. The Chin and Forty Mile channels then joined and began flowing north toward Medicine Hat along what is now known as Seven Persons Creek. With the South Saskatchewan River drainage still blocked by ice, the flow made its way east along the broad channel that is now occupied by the Trans-Canada Highway and CPR mainline, and around the east flank of the Cypress Hills.

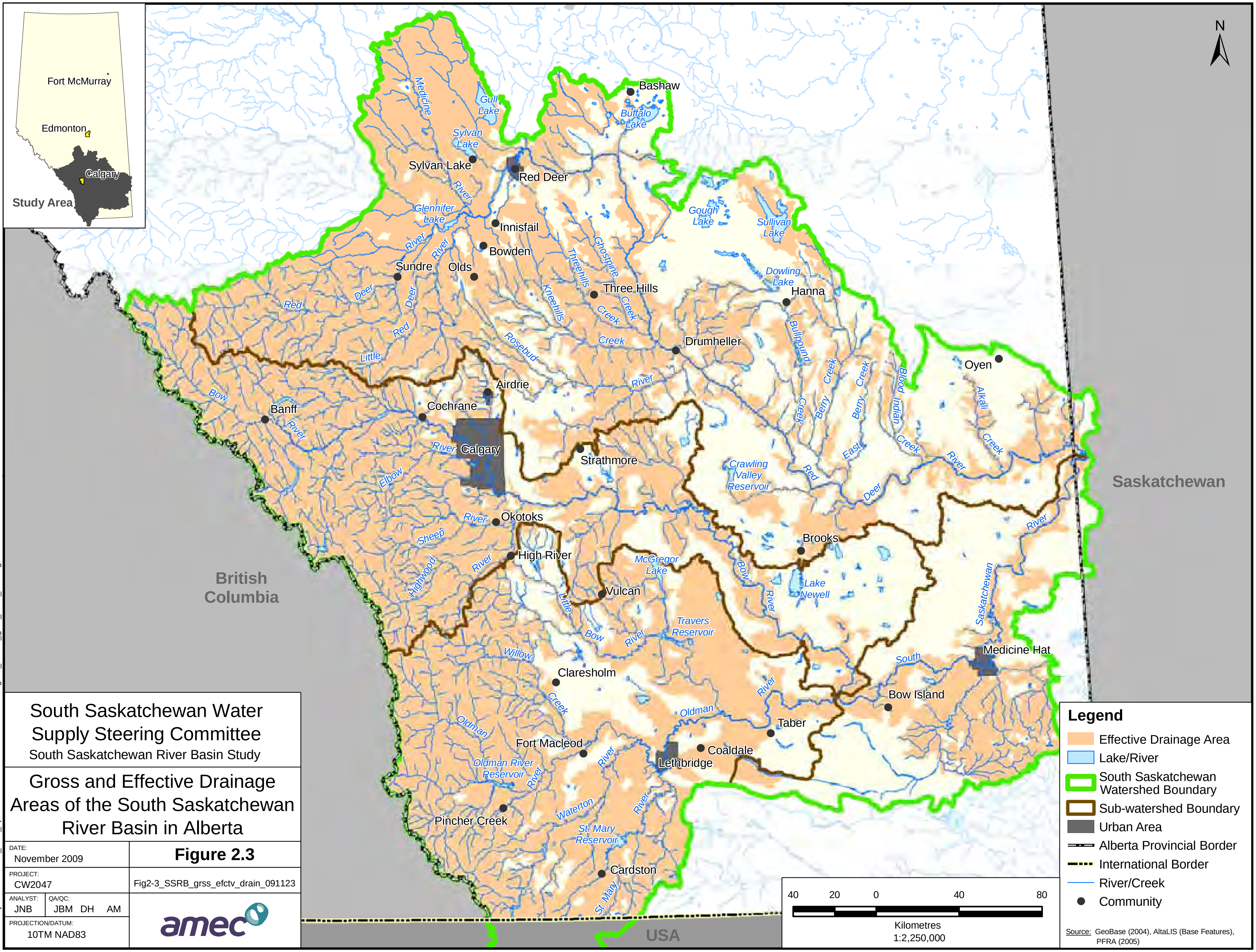
Several of these coulees have played a major role in water management in the SSRB. The characteristics of the large coulees make them ideal sites for off-stream storage for irrigation and other uses in southern Alberta. The deep valleys and steep valley walls provide efficient storage. With upstream and downstream dams, the reservoirs can be sized to precisely meet their intended needs. Because of low natural flows within the coulees, spillway and dam safety costs are low relative to sites on larger streams. Environmental impacts of storage development are often less significant than on larger streams because the aquatic and riparian eco-systems are usually less extensive. Reservoirs developed on underfit streams in the SSRB include:

- Milk River Ridge Reservoir on Middle Coulee
- Chin and Stafford Reservoirs on Chin Coulee
- Forty Mile Reservoir on Forty Mile Coulee
- Murray Reservoir on Seven Persons Creek
- Pine Coulee Reservoir on Pine Coulee
- Twin Valley and Travers Reservoirs on the Little Bow River
- Women's Coulee Reservoir on Women's Coulee

The locations of these reservoirs are shown in **Figure 2.5** (Page 21) (reservoirs are numbered or labelled). These storage sites have contributed to the level of water management and economic development that has been attained in southern Alberta. For instance, without coulee storage the St. Mary Project (irrigation) would not have attained the size it is today, nor would it have its current high level of water-use efficiency. Strategically located reservoirs within irrigated areas are used to capture surplus irrigation deliveries for later release and downstream use. Also, reservoirs located close to demands make it easier for operators to match releases with requirements, which reduces over-deliveries and return flows.

## 2.2 Hydrologic Characteristics of the Sub-basins

The SSRB in Alberta is comprised of *four major sub-basins*: the Red Deer, Bow, Oldman and South Saskatchewan Sub-basins (**Figure 2.3**). The gross and effective drainage areas of the four major sub-basins are given in **Table 2.1**. The hydrologic and meteorological characteristics of the sub-basins are influenced by the elevations, topography and landscape features of the various eco-regions within the sub-basins.




S:\Gis\Projects\CW2071_ssrb_update\ArcGIS\November 23 2009\Fig2-3_SSRB_grss_efctv_drainage.mxd

The *Red Deer River* Sub-basin has a gross drainage area of 46 800 km$^2$. It is the largest of the four sub-basins. Its effective drainage area is 32 400 km$^2$, or 69% of the gross drainage area (**Table 2.1**). The effective- to gross-drainage ratio is considerably lower than that of the Bow and Oldman River Sub-basins, indicating relatively flatter slopes and poorly developed drainage in some parts of the basin. There are two glaciers in the headwaters of the Red Deer River: the Drummond and the Bonnet.

The median natural flow for the Red Deer River near its mouth is 1 666 000 dam$^3$ (1912 to 2001). Its median runoff yield over the effective drainage area is 51 mm, which is much lower than the Bow and the Oldman River Sub-basins (**Table 2.1**). Its small area within the Rocky Mountain eco-regions is a primary reason for low average annual precipitation (393 mm), annual flow and runoff yield of the Red Deer River Sub-basin, compared with the other two primary basins.

**Gross and Effective Drainage Areas** – the *gross drainage area* is the entire area that may be expected to contribute to flow in a stream at a specific location under very wet conditions. It is usually defined by the drainage divide between adjoining watersheds.

Drainage areas on the Canadian prairies vary from year to year depending on precipitation and runoff in current and preceding years.

The *effective drainage area* is the area judged to contribute to flow in a stream during a median-flow year, or, on average, every second year. The effective drainage area excludes poorly developed drainage areas that do not contribute to streamflow in median- and lower-runoff years. The area between the gross and effective drainage boundaries (**Figure 2.3**) may contribute in less than 50% of the years, usually under wet conditions in the watershed.

**Runoff Yield** – is the amount of runoff expressed as a uniform depth of water over an area of land. In the case of **Table 2.1** and the text of **Section 2.2**, runoff yield is expressed as mm of water over the effective drainage area (Runoff yield = Median Natural Flow (dam$^3$) divided by Effective Drainage Area (km$^2$).

The *Bow River* Sub-basin has a gross drainage area of 25 300 km$^2$. It is the smallest of the three primary sub-basins. Its effective drainage area is 19 200 km$^2$, or 76% of the gross drainage area. There are several large glaciers in the headwaters of the Bow River; including the renowned and much photographed and painted Victoria Glacier above Lake Louise, and Bow Glacier above Bow Lake.

The median natural flow for the Bow River at its mouth is 3 829 000 dam$^3$ (1912 to 2001), the highest of all four sub-basins. Its median runoff yield over the effective drainage area is 199 mm, about four times the yield of the Red Deer River Sub-basin. The Bow River Basin has a very large Rocky Mountain area, which accounts for its high average annual precipitation (538 mm) and runoff yield.

The *Oldman River* Sub-basin has a gross drainage area of 27 500 km$^2$. Its effective drainage area is 20 900 km$^2$, or 76% of the gross drainage area. The effective- to gross-drainage ratio is the same as the Bow River Sub-basin. There are glaciers in the headwaters of the St. Mary River in Montana.

The median natural flow for the Oldman River at its mouth is 3 343 000 dam$^3$ (1912 to 2001). Its median runoff yield over the effective drainage area is 160 mm, which is much higher than the Red Deer Sub-basin but lower than the Bow River Sub-basin. Its area within the Rocky Mountain

Eco-region is about 50% of the corresponding area in the Bow River Sub-basin. Average annual precipitation in the Oldman River Sub-basin is about 488 mm.

The St. Mary, Belly and Waterton Rivers are important tributaries of the Oldman River. Their headwaters are in Montana as well as Alberta. The combined flows of the three rivers support an extensive amount of development south of the Oldman River between Lethbridge and Medicine Hat. Hydrologic characteristics of the rivers are as follows.

| | **St. Mary** | **Belly** | **Waterton** |
|---|---|---|---|
| Gross Drainage Area ($km^2$) | 3 530 | 1 210 | 1 730 |
| Effective Drainage Area ($km^2$) | 3 310 | 1 130 | 1 710 |
| Effective/Gross Ratio (%) | 94% | 93% | 99% |
| Median Annual Natural Flow ($dam^2$) | 854 237 | 317 503 | 736 485 |
| Effective DA Runoff Yield (mm over Effective DA) | 258 | 281 | 431 |

Reference: Water Survey of Canada.

Almost the entire drainage area of each stream is effective and the runoff yields are very high. The combined flow of all three streams (1 908 000 $dam^3$) constitutes 57% of the flow of the Oldman River at its mouth.

The *South Saskatchewan River* Sub-basin has a gross drainage area of 13 200 $km^2$ of undulating grassland. Its effective drainage area is 6 600 $km^2$, or 50% of the gross drainage area. The effective- to gross-drainage ratio is the lowest of the four sub-basins.

Average annual precipitation in the South Saskatchewan River Sub-basin (278 mm) is the lowest of all four sub-basins. The hydrology of the sub-basin has been an enigma for hydrologists and water management planners. The median natural local inflow for the sub-basin is estimated to be 3662 $dam^3$. However, there are many years when the estimated local inflow is a large negative value. For instance, the 10 percentile local inflow is minus 122 400 $dam^3$. The South Saskatchewan Sub-basin local inflow is computed as recorded and estimated natural flow of the South Saskatchewan River at Highway 41 *minus* the Bow River at its mouth *minus* the Oldman River at its mouth (1912 to 2001). It is not unusual for the runoff contribution of a small sub-basin computed in this manner to be negative, but in this case the magnitude of the negative flow has confounded hydrologists since the 1960s. A number of possibilities for the negative flows have been researched, such as gauging errors, evaporation and seepage losses, channel and bank storage, travel time, return flow estimates, natural flow computations, and gap filling for missing records, but none of these explain the large and frequent negative flows. Arbitrary adjustments to the data to eliminate or reduce the negative values may introduce a bias into the record since there may be just as many unrealistically large gains between the stations that are accepted as local runoff. This issue was addressed by Alberta Environment's Hydrologic Modelling Committee in 1978 (Alberta Environment, 1978). The committee concluded that awareness of the anomaly is important and should be considered in analyzing model output.

The entire *South Saskatchewan River Basin* in Alberta (just downstream of its confluence with the Red Deer River) has a drainage area of 112 800 km$^2$ of which 79 100 km$^2$ or 70% is effective drainage area. Median annual discharge is estimated to be 8 842 000 dam$^3$. Its median runoff yield over the effective drainage area is 112 mm. This median natural runoff yield compares with other major basins in Alberta as follows:

| **Location of Water Survey of Canada Gauging Station** | | **Median Natural Yield** (mm over effective DA) |
|---|---|---|
| South Saskatchewan D/S Red Deer Confluence | Natural Flow | 112 mm |
| Milk River at East Crossing of International Boundary | Natural Flow | 16 mm |
| North Saskatchewan at Deer Creek | Recorded Flow | 159 mm |
| Athabasca River below McMurray | Recorded Flow | 156 mm |
| Peace River at Peace Point | Recorded Flow | 224 mm |

## 2.3 Water Management Legislation

### 2.3.1 History of Water Legislation in Alberta

Prior to 1894, the allocation of surface water in western Canada was governed by the Doctrine of Riparian Rights. The doctrine was derived from court decisions in England where water is more abundant. The underlying principle of riparian rights is that only a riparian landowner (the owner of land adjacent to a stream or water body) has the right to divert water, and only in quantities that would not noticeably reduce flows or water quality available for use by other riparian landowners.

Riparian rights were considered to be a major deterrent to large-scale irrigation on the Canadian prairies, since only riparian landowners could divert water, and only in quantities that were generally insufficient for irrigation. Federal government officials of the day felt that large-scale irrigation was the key to rapid settlement of the west. Hence, the deterrent was removed with the passage of the *Northwest Irrigation Act*.

With the passing of the *Northwest Irrigation Act* by the Dominion Parliament in 1894, the parts of western Canada now known as Alberta and Saskatchewan had in place the statutory tool needed to control the distribution and use of water in a manner that would minimize conflicts and encourage development. Responsibility for managing natural resources was transferred from the federal government to Alberta in 1930, and the early federal water management legislation gave way to Alberta's *Water Resources Act* in 1931. In 1999, the *Water Resources Act* was replaced by the *Water Act*. The *Water Act* provides greater flexibility for managing water and introduces new approaches for managing water-short basins. However, all legislation since 1894 had the same four basic principles:

- suppression of riparian rights and declaring Crown ownership of water;
- government control of the allocation and use of water;
- an allocation process designed to promote development; and,
- a first-in-time-, first-in-right-priority system designed to protect existing development.

### 2.3.2 Administration of the *Water Act*

The *Water Act* requires that a licence be obtained before diverting and using surface water or ground water for all uses except statutory household, traditional agricultural, fire fighting, and other small quantity uses available primarily to riparian landholders. Licences identify the purposes of the projects, water sources, points of diversion, maximum allocations (withdrawal, diversion or storage), the rates of diversion or withdrawal, the operating periods, and the priorities of the water right. The priorities are based upon the dates of complete applications. Conditions under which diversions or withdrawals may take place are noted. Conditions may include monitoring and reporting requirements.

An application for a licence must be supported by engineering drawings accurately showing the location and key characteristics of the project. Depending on the scale and complexity of the project, reports may be required to describe engineering design and operating details, impacts on the stream and other water users, and environmental impacts.

Alberta Environment staff review the applications for impacts on the source, the aquatic environment, public safety, and other users. The application may be referred to other agencies for comments. Public notice may be required to provide for public statements of concern. The applicant may be required to address concerns raised by government agencies or the public. In making a decision on the project, the Director (Approvals Officer appointed by the Minister) **must consider** licensing guidelines in an approved water management plan.

The Director may reject the application or issue an approval to construct a project with conditions. Upon successful completion of construction and certification that the works are in accord with the application, a licence would be issued granting the allocation and use of water with conditions. The licence will have an expiry date. Decisions made by the Director are subject to appeal to the Environmental Appeals Board.

Approvals under the *Alberta Environmental Protection and Enhancement Act* are required for activities with a high potential to impair or damage the environment, property or human health and safety. Environmental Impact Assessments (EIAs) are mandatory for:

- dams greater than 15.0 m high;
- diversion structures and canals with capacities greater than 15.0 $m^3/s$; and,
- a reservoir with a capacity greater than 30 000 $dam^3$.

For non-mandatory projects, the Director decides (with public input) if potential impacts can be adequately addressed through the approval process, or if a more detailed environmental assessment is required. Full EIAs may be referred to the Natural Resources Conservation Board for public hearings and a decision on whether or not the project is in the public interest considering social, environmental and economic impacts.

### 2.3.3 Enforcement of Priorities in Water-Short Years

Licences are given a priority number based on the date that a completed application is received by Alberta Environment. Higher priority projects (earlier projects) are entitled to divert their full water requirements before projects with lower priorities (later projects) have any right to divert. Alberta Environment's water masters have the difficult task of enforcing priorities in sub-basins when water demands exceed supplies. The task is difficult because the livelihoods of water users are often at stake when they are directed to curtail diversions.

In water-short basins, all licences are reviewed and information is organized in a way that would facilitate determining the order in which licenses would be cut off in the event that water demands exceed supplies. Minimum flow requirements are included in the database if they are a condition on any of the licences. When streamflow and demand data indicate a trend toward deficits, the status of provincially-owned storage projects are reviewed to see if there is an alternative to restricting diversions. If no other options are available, the water master initiates restrictions on licensed diversions.

The most junior license with an in-stream flow condition is the first diversion ordered to stop diverting, or not to start diverting if the project is not yet in operation. Each licensee is directed in this way until minimum streamflow has been restored and the needs of all higher priority licences can be met. If demands by senior licenses increase, or streamflows decrease, additional licenses are restricted. This procedure generally leads to user requests to waive certain conditions, to make water-sharing arrangements, to investigate over-diversions and to undertake other measures that may provide some relief to licenses that have been shut down. Meetings with water-user groups may be held to share information and discuss options.

## 2.4 Water Management Infrastructure and Management

### 2.4.3 History of Government Involvement in Water Management

The Government of Alberta takes an active, hands-on approach to managing its water resources. This approach grew out of necessity in the early days of development and management of the irrigation industry.

Prior to 1930, the Dominion Government held responsibility for managing water and other natural resources. In the late-1800s and early-1900s, interest in irrigation was strong. In addition to administering water management legislation, government policy of the day was to conduct sufficient soil and water surveys and engineering studies to point the way to feasible irrigation developments. Actual development was left to private enterprise, including individual land owners and large private corporations, such as the Canadian Pacific Railway (Western and Eastern Irrigation Districts), Alberta Railway and Coal Company (St. Mary Project), and Southern Alberta Land Company (Bow River Irrigation District).

Generally, the early years of project operations were disappointing to both the developers and producers. Land sales were slow, administration of large projects was cumbersome, and irrigation yields and returns were lower than expected, resulting in financial difficulties. A number of special commissions were established by the federal and provincial governments to address specific issues. Administrative adjustments were made and financial assistance was provided by the two governments and the parent corporate enterprises for the various projects. The Irrigation Districts Act was passed in 1915, which provided for co-operative, farmer-owned, and operated districts. By 1950, most of the corporate enterprises were replaced by Irrigation Districts, which proved to be the most effective administrative bodies for managing districts.

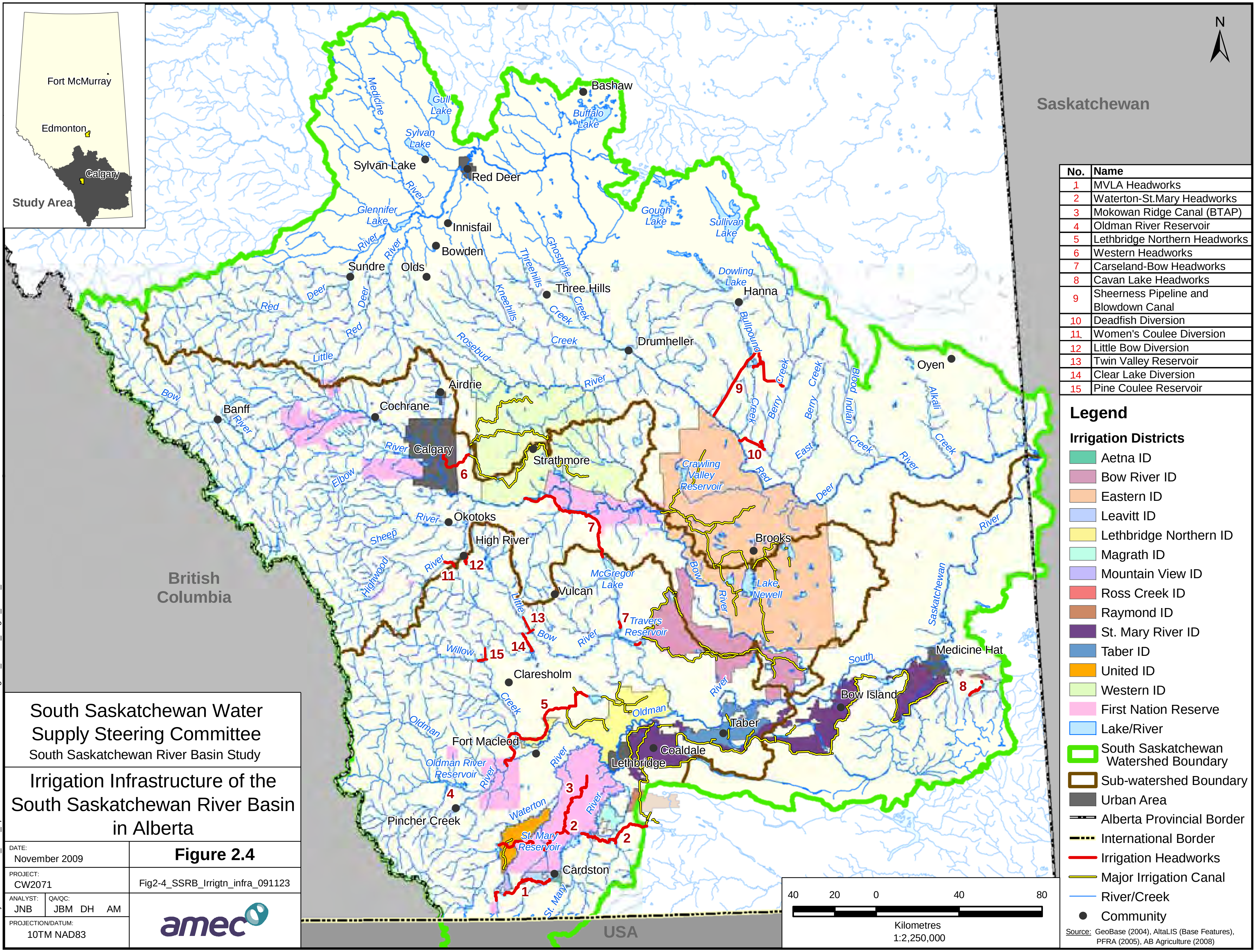
During the struggling years, 1920 to 1950, the irrigation infrastructure was not adequately maintained and by 1950 had deteriorated to the extent that major rehabilitation was required to bring the works up to standard and to enlarge the system where expansion was feasible and desired. The creation of the Prairie Farm Rehabilitation Administration (PFRA) in 1935 increased federal involvement in construction and management of irrigation infrastructure. In 1943, Canada and Alberta signed an agreement that initiated construction by PFRA of the Milk River Ridge, St. Mary and Waterton Reservoirs, and associated connecting canals. The agreement also authorized federal purchase of the assets of the Canada Land and Irrigation Company and rebuilding of the Bow River Irrigation District works. The province committed to constructing certain components of irrigation district works and agreed to assume responsibility for managing the districts following construction of works. Through subsequent agreements, Canada and the Province continued their commitment to improve irrigation infrastructure until, by 1970, almost all districts had works that were rehabilitated by the two governments.

In 1975, the Province announced a policy whereby Alberta Environment would assume responsibility for rehabilitation and operation and maintenance of Irrigation District Headworks (sidebar). The objective of provincial ownership of the works was to operate them for multi-purpose use and provide a continuous and secure supply of water to the districts and other users[3]. By agreement with the districts, the province has now taken over responsibility for all headworks except those for the Eastern and United Irrigation Districts (**Figure 2.4**). In the same 1975 policy, an agreement between Alberta Agriculture and Rural Development committed to a cost-share program for funding rehabilitation of Irrigation District works [3]. These programs are continuing. However, for the most part, irrigation infrastructure is now modernized and in good condition. The districts are well established and operating as progressive, responsible enterprises.

**Irrigation Headworks** are defined as the works required diverting water from the mainstem source streams and conveying it to the districts. These works are owned and operated by Alberta Environment for 11 of the 13 districts.

**District works** are works generally within the boundaries of the districts that are required to distribute water to the producers. The Irrigation Districts own and operate these works.

[3] Brochure: Water Management for Irrigation Use. Alberta Environment and Alberta Agriculture and Rural Development, 1975.


South Saskatchewan Water Supply Steering Committee
South Saskatchewan River Basin Study
Irrigation Infrastructure of the South Saskatchewan River Basin in Alberta
DATE: November 2009
Figure 2.4
PROJECT: CW2071
Fig2-4_SSRB_Irrigtn_infra_091123
ANALYST: JNB
QA/QC: JBM DH AM
PROJECTION/DATUM: 10TM NAD83
amec
S:\Gis\Projects\CW2071_ssrb_updateArcGIS\November 23 2009\Fig2-4_SSRB_Irrigtn_infra_091123.mxd
Fort McMurray
Edmonton
Calgary
Study Area
Saskatchewan
British Columbia
USA
N
No. | Name
1 MVLA Headworks
2 Waterton-St.Mary Headworks
3 Mokowan Ridge Canal (BTAP)
4 Oldman River Reservoir
5 Lethbridge Northern Headworks
6 Western Headworks
7 Carseland-Bow Headworks
8 Cavan Lake Headworks
9 Sheerness Pipeline and Blowdown Canal
10 Deadfish Diversion
11 Women's Coulee Diversion
12 Little Bow Diversion
13 Twin Valley Reservoir
14 Clear Lake Diversion
15 Pine Coulee Reservoir
Legend
Irrigation Districts
Aetna ID
Bow River ID
Eastern ID
Leavitt ID
Lethbridge Northern ID
Magrath ID
Mountain View ID
Ross Creek ID
Raymond ID
St. Mary River ID
Taber ID
United ID
Western ID
First Nation Reserve
Lake/River
South Saskatchewan Watershed Boundary
Sub-watershed Boundary
Urban Area
Alberta Provincial Border
International Border
Irrigation Headworks
Major Irrigation Canal
River/Creek
Community
40 20 0 40 80
Kilometres
1:2,250,000
Source: GeoBase (2004), AltaLIS (Base Features), PFRA (2005), AB Agriculture (2008)
Bashaw
Buffalo Lake
Gull Lake
Sylvan Lake
Red Deer
Innisfail
Bowden
Olds
Sundre
Three Hills
Hanna
Drumheller
Oyen
Airdrie
Cochrane
Banff
Calgary
Strathmore
Okotoks
High River
Brooks
Vulcan
Claresholm
Medicine Hat
Bow Island
Taber
Coaldale
Lethbridge
Fort Macleod
Pincher Creek
Cardston
Gough Lake
Sullivan Lake
Dowling Lake
Glennifer Lake
Crawling Valley Reservoir
McGregor Lake
Lake Newell
Travers Reservoir
Oldman River Reservoir
St. Mary Reservoir
Medicine
Red Deer River
Ghostpine Creek
Threehills Creek
Kneehills Creek
Rosebud
Bullpound Creek
Berry Creek
Blood Indian Creek
Alkali Creek
Little Red Deer River
Bow River
Elbow River
Sheep River
Highwood River
Little Bow River
Willow Creek
East
South Saskatchewan River
Oldman River
Waterton River
St. Mary River

### 2.4.4 Water Management Infrastructure in the SSRB

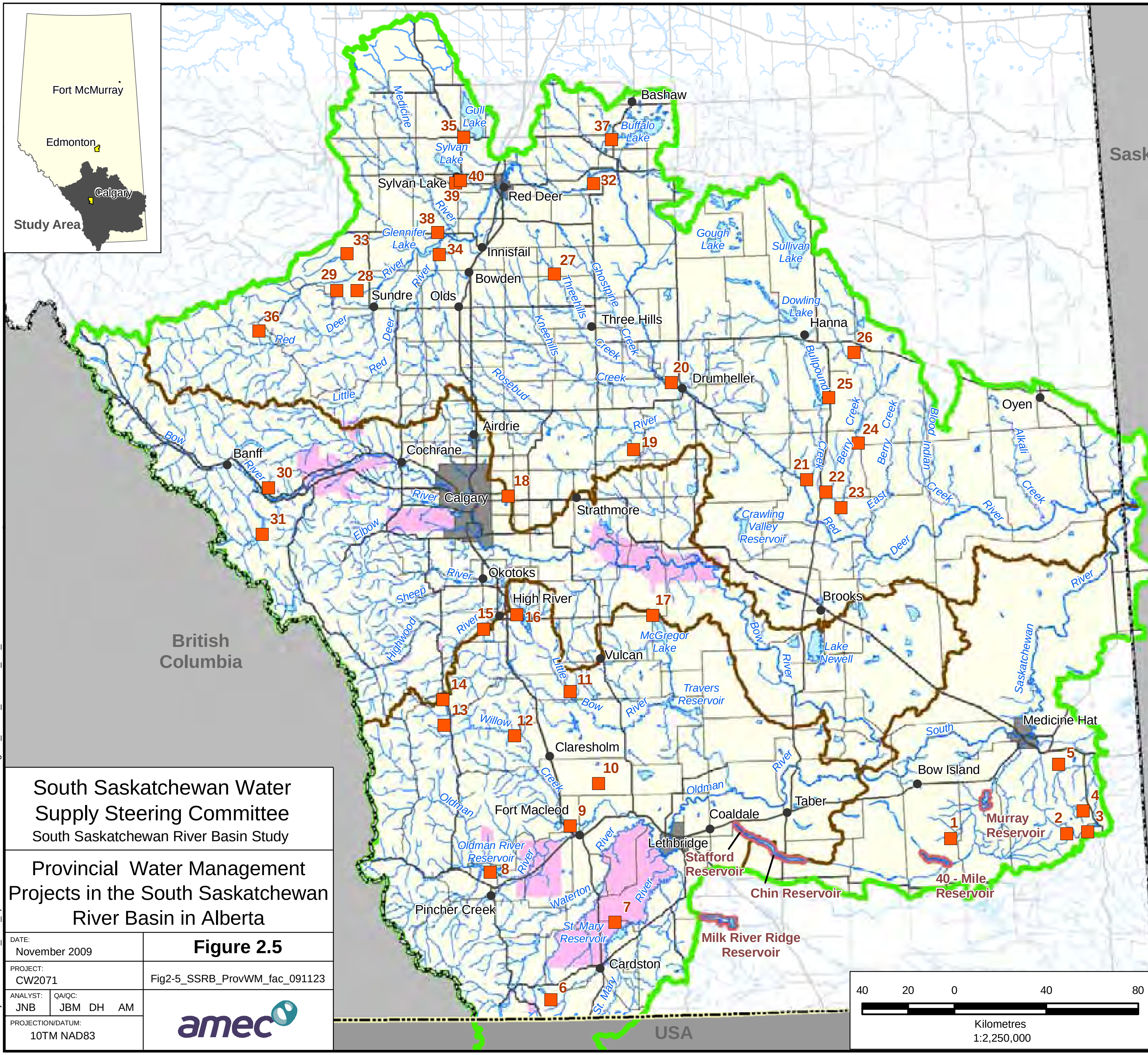
Developing works to secure water supplies for the irrigation industry in southern Alberta has been a major commitment of the Province. (Many projects currently owned and operated by the province were implemented with considerable federal government involvement.) Provincial works go far beyond those required for irrigation. Other major works constructed in the SSRB to support the overall economy and quality of life are listed in **Table 2.2**. The licensed purpose and the priority date of each project are provided in the table. The priority date (yyyy/mm/dd) is based on the date of a completed application for a licence. It gives some idea of how old the project is, but the interval between the priority date and a completed project could vary from about 1 to 5 or more years. The locations of the projects are shown in **Figure 2.5**.

**TABLE 2.2**
**Major Provincial Water Management Projects**
**Within the South Saskatchewan River Basin in Alberta**

| Project | | Works | Licensed Purpose | Priority Date |
|---|---|---|---|---|
| 1 | Granlea Reservoir | Dam | Domestic, stock water. | 1960/03/21 |
| 2 | Bullshead Reservoir | Dam | Stock water, domestic. | 1961/07/19 |
| 3 | Elkwater Lake Reservoir | Dam | Stabilization. | 1918/12/06 |
| 4 | Ambrose Reservoir | Dam | Stock water. | 1970/09/28 |
| 5 | Cavan Lake Headworks | Weir, canal, dam, dykes | Irrigation, domestic, recreation. | 1951/03/02 |
| 6 | Mountain View, Leavitt, Aetna Headworks | Weir, canal, dam, syphon | Irrigation, domestic. | 1923/07/10 |
| 7 | Waterton–St. Mary Headworks | Weirs, dams, canals, siphon | Water management, flood control, erosion control, flow regulation and conservation. | 1950/05/31 |
| 8 | Oldman River Dam | Dam | Water management, flow regulation, flood and erosion control, recreation, and conservation. | 1988/02/03 |
| 9 | Ft. Macleod Dykes | Dykes | Flood control. | N/A |
| 10 | Lethbridge Northern Headworks | Weir, canal, flumes, dykes | Water management, flow regulation, conservation and recreation. | 1917/11/16 |
| 11 | Twin Valley Dam and Reservoir | Dam | Water management, recreation, fish, wildlife, irrigation and other agric uses, and conservation. | 1997/09/02 |
| 12 | Pine Coulee Dam and Reservoir | Weir, canal, dam | Water management, flow regulation, water supply, conservation and recreation. | 1994/05/10 |
| 13 | Chain Lakes South | Dam | Flow Regulation. | 1944/02/07 |
| 14 | Chain Lakes North | Dam | Flow Regulation. | 1944/02/07 |
| 15 | Women's Coulee Reservoir and Canal | Dam, canal | Water management, flow regulation, flood and erosion control, conservation and recreation. | 1933/10/05 |

| Project | | Works | Licensed Purpose | Priority Date |
|---|---|---|---|---|
| 16 | Little Bow Canal | Weir, canal | Water management, recreation, fish, wildlife, irrigation and other agric uses, and conservation. | 1997/09/02 |
| 17 | Carseland-Bow River Headworks | Weir, canal | Water management, flow regulation, water supply, conservation and recreation. | 1908/10/27 |
| 18 | Western Headworks | Weir, canal, wasteways | Serve the WID and other licensees. | 1973/11/09 |
| 19 | Severn Reservoir | Dam | Domestic, recreation. | 1970/10/23 |
| 20 | Drumheller Dykes | Dykes | Flood control. | N/A |
| 21 | Janet Dam | Dam | Stabilization, habitat. | 1981/12/02 |
| 22 | Woodrow Reservoir | Dam | Stabilization, habitat. | 1981/12/02 |
| 23 | Deadfish Creek Dam, Canal, Pumps and Pipeline | Pump, pipe, canal, dams | Irrigation, other. | 1983/11/24 |
| 24 | Carolside Dam | Dam | Irrigation, stock water. | N/A |
| 25 | Sheerness Water Supply | Pumps, pipe, dam, canal | Irrigation and other purposes. | 1981/12/02 |
| 26 | Richdale Dam | Dam | Habitat enhancement. | 1916/11/30 |
| 27 | Bigelow Reservoir | Dam | Flow regulation, habitat enhancement. | 1971/03/23 |
| 28 | Bearberry Creek Diversion | Canal, dykes | Flood control. | N/A |
| 29 | Sundre Dykes | Dykes | Flood control. | N/A |
| 30 | Canmore Flood Control | Dykes | Flood control. | N/A |
| 31 | Buller Lake Stabilization | Weir | Stabilization, fish habitat. | 1987/05/28 |
| 32 | Buffalo Lake Stabilization | Pump, pipe, canal | Stabilization. | 1991/12/19 |
| 33 | Burnstick Lake | Weir | Stabilization. | 1977/04/22 |
| 34 | Dickson Dam | Dam | Flow regulation. | 1977/08/02 |
| 35 | Gull Lake Stabilization | Pump, canal | Stabilization, recreation. | 1974/01/07 |
| 36 | Klein Lake | Dam | N/A | N/A |
| 37 | Parlby Creek, Spotted Lake, Alix Lake | Channelization, erosion control | Flood control, irrigation. wildlife habitat. | N/A |
| 38 | Red Deer River Erosion | Groynes | Erosion control. | N/A |
| 39 | Sylvan Lake Creek | Channelization | Flood control. | N/A |
| 40 | Sylvan Lake Retaining Wall | Erosion control works | Erosion control, recreation. | N/A |

Notes:
1. The locations of projects are shown (by number) in **Figure 2.5**.
2. Information in the table is based primarily on Alberta Environment's licensing database.
3. The priority date is based on the date that a complete license application was received by the licensing agency.  Some projects have multiple licenses and priorities.  The earliest priority is given in the table.




| No. | Facility Name |
|---|---|
| 1 | Granlea Reservoir |
| 2 | Bullshead Reservoir |
| 3 | Elkwater Lake (Reservoir) |
| 4 | Ambrose Reservoir |
| 5 | Cavan Lake Headworks System |
| 6 | Mountainview - Aetna Headworks System |
| 7 | Waterton St. Mary Headworks System |
| 8 | Oldman River Dam & Reservoir |
| 9 | Fort Mcleod Dykes |
| 10 | Lethbridge Northern Headworks System |
| 11 | Twin Valley Dam & Reservoir |
| 12 | Pine Coulee Reservoir & Dam |
| 13 | Chain Lakes South |
| 14 | Chain Lakes North |
| 15 | Women's Coulee Reservoir/Canal |
| 16 | Little Bow Canal |
| 17 | Carseland Bow River Headworks System |
| 18 | Western Headworks System |
| 19 | Severn Reservoir |
| 20 | Drumheller Dykes All Phases |
| 21 | Janet Dam |
| 22 | Woodrow Reservoir |
| 23 | Deadfish Creek Dam/Canal/Pumphouse/Pipeline |
| 24 | Carolside Dam |
| 25 | Sheerness Water Supply |
| 26 | Richdale Dam |
| 27 | Bigelow Reservoir |
| 28 | Bearberry Creek Diversion |
| 29 | Sundre Dykes |
| 30 | Canmore Flood Control Phase 1, 2, 3 |
| 31 | Buller Lake Stabilization |
| 32 | Buffalo Lake Stabilization |
| 33 | Burnstick Lake |
| 34 | Dickson Dam |
| 35 | Gull Lake Stabilization |
| 36 | Klein Lake |
| 37 | Parlby Creek/Spotted Lake/Alix Lake Structure |
| 38 | Red Deer River Erosion |
| 39 | Sylvan Lake Creek |
| 40 | Sylvan Lake Retaining wall |

## Legend

- First Nation Reserve
- Lake/River
- South Saskatchewan Watershed Boundary
- Sub-watershed Boundary
- Urban Area
- Alberta Provincial Border
- International Border
- Highway/Road
- River/Creek
- Water Management Facility
- Community

Source: GeoBase (2004), AltaLIS (Base Features), PFRA (2005), AENV (2005)

South Saskatchewan Water Supply Steering Committee
South Saskatchewan River Basin Study

# Provincial Water Management Projects in the South Saskatchewan River Basin in Alberta

| | |
|---|---|
| DATE: November 2009 | **Figure 2.5** |
| PROJECT: CW2071 | Fig2-5_SSRB_ProvWM_fac_091123 |
| ANALYST: JNB; QA/QC: JBM DH AM | amec |
| PROJECTION/DATUM: 10TM NAD83 | |

S:\Gis\Projects\CW2071_ssrb_update\ArcGIS\November 23 2009\Fig2-5_SSRB_ProvWM_fac_091123.mxd

Major non-government projects in the SSRB include:

- hydropower reservoirs and diversion works owned and operated by TransAlta;
- numerous off-stream irrigation storage and conveyance works owned and operated by the Irrigation Districts;
- Bassano Dam on-stream diversion works owned and operated by the Eastern Irrigation District; and,
- numerous large and small wetland complexes owned and operated by Ducks Unlimited Canada (often under agreement with landowners).

## 2.5 Population

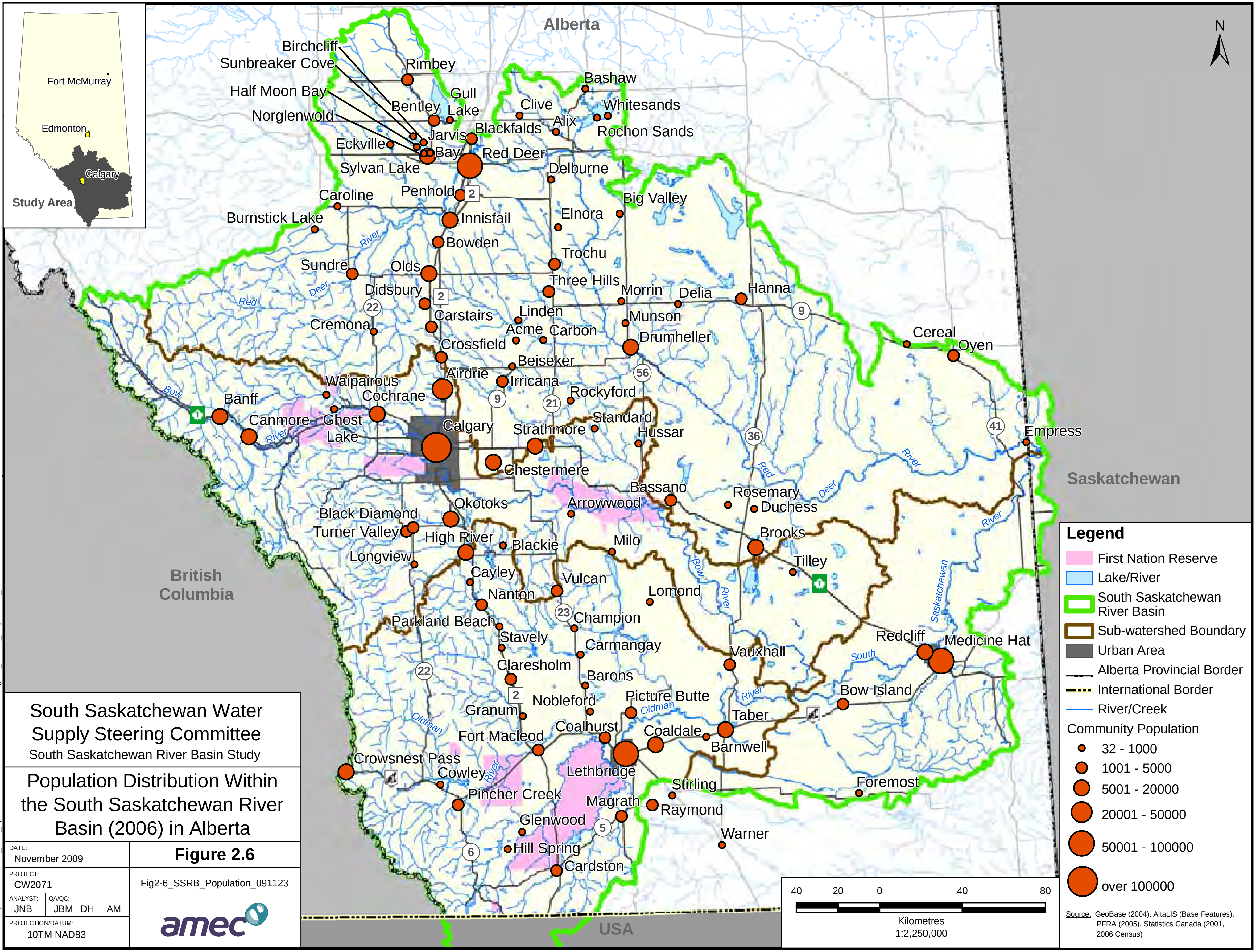
The 2006 population of the SSRB has been estimated to be 1,650,389 distributed among the sub-basins as shown in **Table 2.3**. The distribution of population within urban centres is shown in **Figure 2.6**. There is a concentration of population along QEII Highway (Highway No. 2) corridor, which includes dominant populations in Calgary and Red Deer. Red Deer, Calgary, Lethbridge and Medicine Hat are centres of economic and industrial development in the basin, and the locations of a number of cultural, educational and research institutions. The population density (based on gross drainage area) is by far the highest in the Bow River Sub-basin, largely because of the one million residents within the City of Calgary.

**TABLE 2.3**
**Populations Within the Four Sub-basins of the South Saskatchewan River Basin, 2006**

| Sub-basin | Number of Municipalities | | | 2006 Population | Population Density (persons/km$^2$) |
|---|---|---|---|---|---|
| | Urban | Rural | First Nations | | |
| Red Deer | 57 | 17 | | 256,106 | 5.5 |
| Bow | 22 | 12 | 3 | 1,155,363 | 45.7 |
| Oldman | 26 | 11 | 2 | 167,383 | 6.1 |
| South Saskatchewan | 4 | 6 | | 71,537 | 5.4 |
| **Totals** | **109** | **46** | **5** | **1,650,389** | **14.6** |

## 2.6 Water-use Overview

In Alberta, the right to divert and use water is granted by a licence or registration under the *Water Act*. The licensee is given an annual allocation, which is the maximum amount of water that the water user is allowed to divert each year. The licence also provides an estimate of consumptive use, losses and return flow. None of these three values are enforceable. However, they provide sufficient information to estimate annual use for the project at the time that the application was made, which is equal to allocation minus return flow. In this document, the use computed on this basis will be referred to as "**licensed use**". **Actual water use** is usually less than the licensed use for a variety of reasons. Actual withdrawals from the source cannot




S:\Gis\Projects\CW2071_ssrb_updateArcGIS\November 23 2009\Fig2-6_SSRB_Population_091123.mxd legally exceed the licence allocation. Actual use varies from year to year depending on factors such as weather, economic conditions, and irrigation crop rotations. Some licensees may have larger allocations than currently needed so that they have room to grow.

In this document, **licensed use** refers to an estimate of the project use at the time the licence was issued. It is based on information in the licence document. Licensed use equals *Allocation minus Return Flow* or *Consumptive Use plus Losses*.

**Actual use** is the recorded or estimated consumption plus losses, or withdrawal from the source minus return flow. Actual use is often lower than licensed use. It is based on recorded data when such data are available.

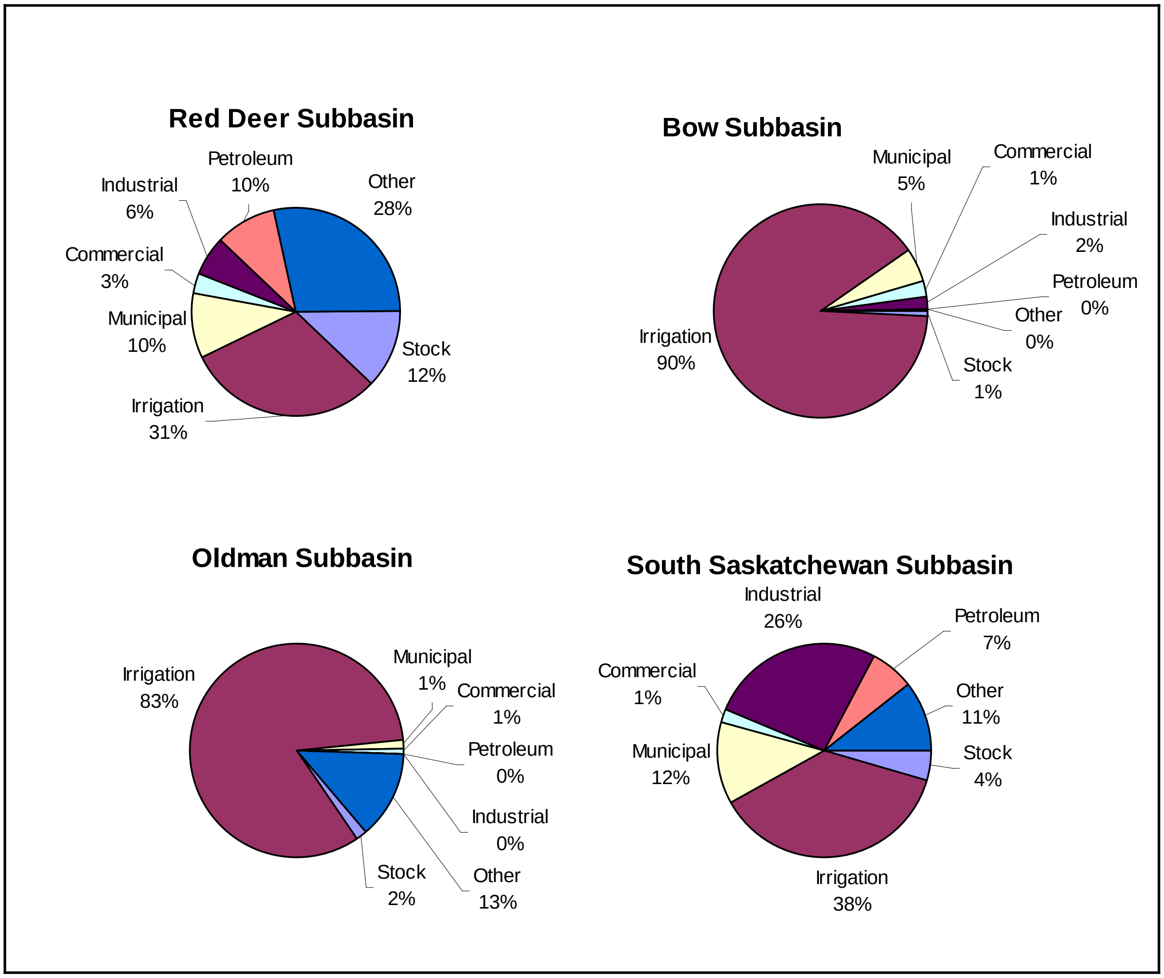
During the past 110 years, large amounts of water have been allocated in the SSRB for irrigation, industries, municipal water supplies, and other purposes. The water has been used to support the economy, culture, and quality of life of the people in southern Alberta. The volume of allocated water is an indicator of the level of economic activity supported by water development in a river basin. A recent study reviewed licence allocations and use, and estimated actual water uses for the four sub-basins of the SSRB (AMEC, 2007). The study considered both surface water and ground water. AMEC's findings are summarized in **Table 2.4 and Figure 2.7**.

**TABLE 2.4**
**Surface and Ground Water Licensed Water Use and Estimated 2005 Actual Water Use in the South Saskatchewan River Basin**

| Sub-basin | Median Natural Flow ($dam^3$) | Licensed Allocation ($dam^3$) | | | SW Licensed Use | | SW Actual Use | |
|---|---|---|---|---|---|---|---|---|
| | | Total GW and SW | GW | SW | Volume ($dam^3$) | % of Natural Flow | Volume ($dam^3$) | % of Natural Flow |
| Red Deer | 1 666 000 | 372 830 | 37 444 | 335 386 | 267 946 | 16.1 | 223 060 | 13.4 |
| Bow | 3 829 000 | 2 597 894 | 36 550 | 2 561 345 | 2 030 257 | 53.0 | 1 124 097 | 29.3 |
| Oldman | 3 343 000 | 2 292 401 | 61 075 | 2 231 326 | 2 055 620 | 61.5 | 1 140 988 | 34.1 |
| South Sask | 3 662 | 285 874 | 10 938 | 274 936 | 205 316 | | 66 112 | |
| South Sask Basin | 8 842 000 | 5 548 999 | 146 007 | 5 402 993 | 4 559 139 | 51.6 | 2 554 257 | 28.9 |

Source: AMEC, 2007. SW = surface water; GW = groundwater.

The Bow and the Oldman Sub-basins are heavily allocated. The two sub-basins are highly dependent on water to support irrigated agriculture and associated food processing industries. AMEC (2007) indicated that irrigation accounts for 90% of total actual use of the Bow River Sub-basin waters and 83% of the total actual use of the Oldman Sub-basin waters. (A substantial amount of irrigation supplied by the Bow River Sub-basin waters is located in the Red Deer and Oldman Rivers Sub-basins.) Irrigation accounts for 31% of total actual use of the Red Deer River Sub-basin waters. The licensed and actual surface water use, expressed as a percent of the median natural flow, is considerably lower for the Red Deer River Sub-basin than for the Bow and Oldman Sub-basins (Table 2.4). Overall in the SSRB, about 30% of the median natural flow is currently being used. Groundwater use accounts for only about 2.5% of total water use in the SSRB.




Source: AMEC, 2007

**Figure 2.7 Surface and Groundwater Estimated 2005 Actual Water Use Distribution by Purpose within the Four Sub-basins in the SSRB (Alberta)**

Estimates of actual surface water use are updated and discussed in further detail in Chapter 4.0.

As a high percentage of Alberta's share of the natural flow in the SSRB became allocated and as the allocations were more fully utilized, it became apparent that a growing population and economy were putting pressures on the water resource, the aquatic environment and the security of existing allocations. To address this issue, Alberta Environment launched a two-phased study on the SSRB, leading to the South Saskatchewan River Basin Plan approved by Cabinet in August 2006.

## 2.7 The South Saskatchewan River Basin Plan

The SSRB water management plan reflects a balance between protecting the aquatic environment and the amount of river water required for economic development in the South Saskatchewan River Basin (SSRB). The plan was developed during the 5-year period 2001 to

2006, with extensive public involvement. Albertans were asked for their views on the direction water management should take in the SSRB. Their comments and concerns were carefully considered in the preparation of the plan.

The plan recognizes and accepts that limits for water allocations have been reached or exceeded in the Bow, Oldman, and South Saskatchewan River Sub-basins. It is also recognized that the limit of the water resource in the Red Deer River Sub-basin will be reached in the foreseeable future.

### 2.7.1 Recommendations of the SSRB Plan

Principal recommendations of the plan are as follows:

- Alberta Environment no longer accepts applications for new water allocations in the Bow, Oldman and South Saskatchewan River Sub-basins until the Minister of Environment specifies, through a Crown Reservation, how water not currently allocated is to be used.

  A Crown Reservation is now in place (Regulation 171/2007; August 2007). The Bow, Oldman and South Saskatchewan River Basins Water Allocation Order stipulates that reserved water may be allocated:
  - for use by First Nations;
  - to contribute toward meeting Water Conservation objectives;
  - for meeting outstanding completed applications received as of the date of this reservation; and,
  - for storage of peak flows to mitigate impacts on the aquatic environment and to support existing licences.
- When allocations in the Red Deer River Sub-basin reach 550 000 $dam^3$, a thorough review be conducted to identify the maximum allocation limit.
- Alberta Environment establish Water Conservation Objectives (WCOs) for the Bow, Oldman and South Saskatchewan River Sub-basins. The WCOs should be 45% of the natural rate of flow, or the existing in-stream objective plus 10%, whichever is greater at any point in time. Any licences issued for applications received after 1 May 2005 should be subject to the WCOs. Existing licences should retain their original conditions for in-stream objectives.
- AENV establish WCOs for the Red Deer River Sub-basin as follows:
  - for the Red Deer River between Dickson Dam and the confluence with the Blindman River:
    - for new licences issued after 1 May 2005 and for existing licences with a retrofit provision, a rate of flow that is 45% of the natural flow or 16.0 $m^3/s$, whichever is greater;

> **Retrofit provision:** water licences issued since about February 1997 usually contain a condition that indicates that the licence may be amended to include a WCO once one has been established. (Individual licences should be checked to determine if they contain the retrofit provision.)
>
> On amended licences, the licensee would not be permitted to divert when the river flow is less than the WCO.

- o for the Red Deer River downstream of the confluence with the Blindman River:
  - for licences issued after 1 May 2005 with withdrawals in November to March, a rate of flow that is 45% of the natural flow or 16.0 $m^3$/s, whichever is greater;
  - for licences issued after 1 May 2005 that withdraw from April to October inclusive, a rate of flow that is 45% of the natural flow or 10.0 $m^3$/s, whichever is greater; and,
  - for existing licences with a retrofit provision, a rate of flow that is 45% of the natural flow or 10.0 $m^3$/s, whichever is greater.

Closure of the Bow, Oldman, and South Saskatchewan Sub-basins to new allocations and new WCOs will put recent licensees, and those seeking new water supplies to support an economic initiative, into new territory with respect to water supply security. Licensees subject to the new WCOs may be facing more frequent and larger deficits. Those seeking additional or new water supplies in the Bow, Oldman and South Saskatchewan Sub-basins will be required to search for a willing seller of a water allocation and will be facing unfamiliar rules and procedures related to obtaining government approval of a transfer. Planners will be pondering the question of how much storage would be required to fully meet WCOs, the requirements of First Nations, and the requirements of existing water users. How may climate change affect security of water supply and adjustments to water-use practices? These are some of the issues that will be explored in this study. The *Water Act* provides some provisions for dealing with issues related to fully allocated basins.

### 2.7.2 Key Provisions of the Water Act for Water-Short Basins

The *Water Act* introduced flexibility in how water in Alberta could be managed in times of shortages, and provided new tools to encourage water-use efficiency and to acquire licences in fully allocated basins.

- Recognition of the Role of Water Management Planning

  The *Water Act* formalizes water management planning, and, for the first time in Alberta, provides the ability to manage water, recognizing specific characteristics of a river basin or aquifer, and local and regional issues. The *Act* authorizes the development of water management plans for both surface water and ground water, and encourages an integrated approach to planning which considers water, lands, forests, fish, wildlife, petroleum extraction and minerals. Public consultations are a key component in developing plans. Water management plans that are approved by the Lieutenant Governor in Council or the Minister **must be** considered by the *Water Act* Director in issuing an approval, allocating water, approving an allocation transfer, or establishing a moratorium on new allocations.

- Crown Reservations

  The Minister may reserve unallocated water where necessary to defer decision-making until a basin plan has been completed, or to save water for any particular purpose, including in-stream protection. The *Water Act* stipulates that the Minister may prescribe a priority for water allocated from the reserved quantity; however, the priority must not be based on a date earlier than the date that the reservation was made.

- Water Allocation Transfers

  In areas of Alberta where water is at or near full allocation, provision for transfer of all or parts of allocations from a willing seller to a willing buyer will allow new or alternative uses of water. Transfers may be temporary or permanent. They may be considered only where an approved water management plan or an Order-in-Council provides for such transfers. Transfers have been authorized in the SSRB water management plan. It is expected that, with time, the transfer provision will shift licences to higher value uses as determined in the marketplace. It will also encourage water conservation and improve water-use efficiency since saved water will have a market value through the transfer provisions (Palacios and Brown, 2005; Alberta Environment, 1994).

  Applications for transfers are subject to review and approval by the Director. The Director's review may include:

  - confirmation that the transferred licence is in good standing;
  - effects on the aquatic environment, the hydrology of the source, and other users of the source stream or aquifer;
  - effects on public safety; and,
  - any other matters that the Director may consider relevant or that is specified in an approved water management plan.

  The Director may consider withholding up to 10% of the quantity of water being transferred if he or she is of the opinion that withholding water is in the public interest to protect the aquatic environment and if withholding water from transfers has been authorized in a water management plan or an Order-in-Council. Holdbacks have been authorized in the SSRB water management plan.

  Public input will be sought on all applications for transfers. The Director may reject, approve with conditions or approve an application for a transfer, with or without a holdback. An approved transfer retains the priority of the seller's licence. Decisions made by the Director related to transfer applications are appealable to the Environmental Appeal Board.

- Allocation Assignments

  Although licensees with senior priorities have the first right to water, the *Water Act* has an assignment provision for sharing available supplies between senior and junior users who have access to the same water. The *Act* requires that a formal written agreement be developed between the two licensees. The agreement may be cancelled by the Director if there are adverse effects on the source stream or aquifer, the aquatic environment or other water users with a higher priority than the party with the lowest priority in the agreement.

  Agreements to assign water were used in response to severe water shortages in the southern tributaries of the Oldman River (Waterton, Belly and St. Mary Rivers) in 2001. Based on water supply forecasts and the volumes of water in reservoirs, it was determined that under the priority provisions of the Water Act, there would be only enough natural flow and stored water to meet the needs of users with licences having priorities of 1950 or earlier.

This meant that about 336 licensees with priorities junior to 1950 would be faced with the prospect of having their diversions suspended. Seven Irrigation Districts with senior priorities jointly offered to use the assignment provisions of the Water Act to share available supplies with junior users provided there was a willingness to ration. Most of the water users in the southern tributaries decided to participate in the water-sharing agreement, which affected about 650 licences. The agreement called for irrigators to apply not more than 10 inches to their irrigated lands, and non-irrigators to restrict usage to about 60% of their requirements.

The 2001 drought was a learning experience for both water users and administrators of the *Water Act*. The cooperative arrangement was considered to be successful and is looked on with a source of pride in the ability of water users to come together and share, under difficult circumstances, for the good of all. It has given water users confidence in being able to withstand future periodic water shortages in a manner that would minimize impacts on the region as a whole. Administrators who were suddenly pressed into using a new provision of the *Act* will now be better equipped to deal with similar circumstances in the future.

- Emergency Provisions

  The *Water Act* has provisions for the government to declare an emergency, suspend diversions for all or any part of selected licences, and designate the purposes for which available water can be used. Affected licensees **may be eligible** for compensation for losses incurred. The predecessor *Water Resources Act* had similar provisions. These provisions of the water management legislation have very rarely, if ever, been used in Alberta. Common practice in water-short situations has been to suspend diversions in order of junior to senior priority until the water supply and use is in balance.

  Although licensees with senior priorities have the first right to water, the *Water Act* has an assignment provision for sharing available supplies between senior and junior users who have access to the same water (as noted above). In this case, compensation is negotiated between a willing buyer and a willing seller, thus avoiding the difficult issue of government compensation under the emergency provisions.

## 2.8 Overview of Social and Economic Conditions

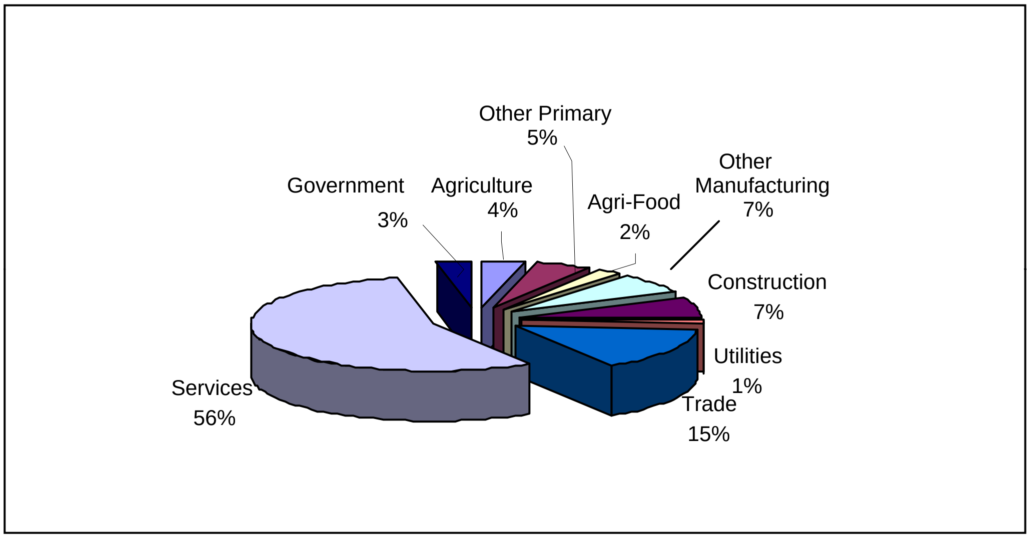
An analysis by Martz *et al.*. (2007) indicated that the SSRB is an important employment and economic driver in the Province of Alberta. In 1996, the SSRB had a population of approximately 1.3 million, which is about 47% of the provincial total. About 72% of these people lived in the major urban centers of Calgary (Bow Sub-basin), Red Deer (Red Deer Sub-basin), Lethbridge (Oldman Sub-basin), and Medicine Hat (South Saskatchewan Sub-basin). About 14% of the people reside in smaller centers (<1,000 people) and rural areas (**Table 2.5**).

**TABLE 2.5**
**SSRB Population in Alberta by Sub-basin, 1996 (Thousands)**

| | Red Deer | Bow | Oldman | S. Sask | Total |
|---|---|---|---|---|---|
| Urban | 124 | 827 | 118 | 283 | 1,353 |
| Agriculture | 14 | 2 | 5 | 17 | 38 |
| Total | 138 | 830 | 123 | 300 | 1,391 |

Based on Martz *et al.*, 2007 and Stats Canada Census.

In 1996, the SSRB in Alberta generated about 40% of the provincial economic activity and employment (Martz *et al.*, 2007). Out of the total population in the basin, about 900,000 are employed, principally in the service sector (56%). The second highest employment sector is trade (15%). Agriculture and agri-food, manufacturing, construction, and other primary production (almost entirely oil and gas) each contribute between 5% and 7% to employment in the SSRB (**Figure 2.8**).

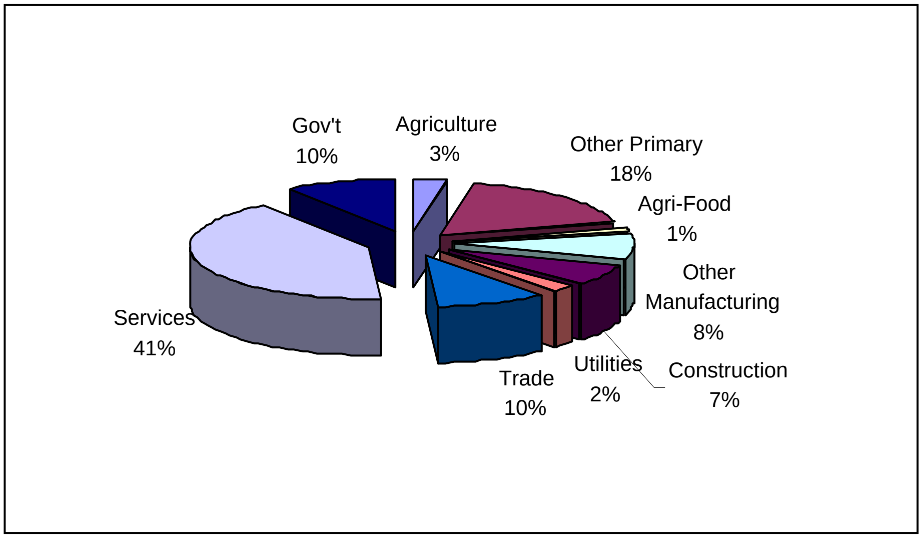



Source: Martz *et al.*, 2007; Page 78.

**Figure 2.8 Composition of Employment in the SSRB, 1996**

The economic growth of a region is typically measured as the new wealth created, one measure of which is the Gross Domestic Product (GDP). In 1996, the GDP for the Province of Alberta was $95.4 billion (Anielski, 2002). The SSRB in Alberta contributed about $55.5 billion, or 58% toward this total (Martz *et al.*, 2007). The SSRB GDP breakdown, by sector, is approximately as indicated in **Figure 2.9**.

The sustainability of the physical and socio-economic resource base of the SSRB is essential to the long-term well-being of all Albertans.




Source: Martz *et al*., 2007; Page 77.

**Figure 2.9 GDP Composition in the SSRB, 1996**

## 2.9 Overview of Environmental Conditions

The SSRB occurs within 5 of the 6 natural regions in Alberta. These include the Rocky Mountains, Foothills, Boreal Forest, Parkland and Grassland natural regions, within which there are a number of sub-regions. These regions share characteristics such as climate, geology, soils, vegetation and wildlife. Land use in the basin ranges from relatively undisturbed in the mountainous headwaters to agricultural, urban, and industrial land uses further east. Water quality and other aquatic resources are relatively pristine at the headwaters, but become more degraded along the length of the basin as land use, water use and water withdrawals increase.

There are many fish species that are known to reside in the SSRB. In the cold mountain headwaters, and throughout several of the sub-basins, species such as mountain whitefish (*Prosopium williamsoni*), rainbow trout (*Oncorhynchus mykiss*), bull trout (*Salvelinus confluentus*), and brown trout (*Salmo trutta*) occur (Clipperton *et al*., 2003). In the Parkland and Grassland regions, cool water fish species such as goldeye (*Hiodon alosoides*), sauger (*Sander canadensis*), northern pike (*Esox lucius*), and walleye (*Sander vitreus*) also occur (Clipperton *et al*., 2003). Lake sturgeon (*Acipenser fulvescens)* can also be found in the South Saskatchewan River mainstem, which are listed as an endangered species by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC, 2000).

A water quality index (WQI) is often used to discuss water quality conditions. Water quality indices provide a general framework by which to assess water quality conditions according to water quality guidelines, and condense this information into a single numerical value (CCME, 2001). The WQI used in this report is the Alberta Provincial Water Quality Index and is calculated based on:

1. the number of water quality variables that exceed specific guidelines (AENV, 1999);
2. the frequency; and,

3. magnitude of the guideline exceedences (AENV, 2007).

The Alberta WQI has been tailored to assess particular water quality issues in Alberta and is the average of four water quality sub-indices: nutrients, bacteria, pesticides and metals. WQI values range from 0 to 100, with 100 being the highest quality and a ratings system used as follows:

- Excellent (96–100);
- Good (81–95);
- Fair (66–81);
- Marginal (46–65); and,
- Poor (0–45).

Riparian areas are the transition zones between aquatic areas and their terrestrial uplands. Riparian areas perform important ecological functions including trapping sediment to maintain and build stream and river banks, recharging groundwater supplies, storing flood water and energy, filtering runoff water, reducing and dissipating stream energy, maintaining biodiversity, and creating primary productivity (Fitch *et al*., 2001). Excessive removal or alteration of vegetation in the riparian zone decreases friction on the banks and increases stream rate of flow, which can increase erosion (AENV, 2007). Riparian health as discussed below is generally based on a visual inspection of sample areas and a subsequent scoring (of either "healthy", "healthy with problems", or "unhealthy") of various factors that are thought to contribute to riparian health (AENV, 2007).

For the purposes of an overview of the environmental conditions in the SSRB, the mainstem of the Red Deer, Bow, Oldman, and South Saskatchewan Rivers, and their major tributaries, are discussed separately below. Natural flow in the Red Deer River is similar to natural flow in most years (**Figure 3.6**). However, in the Bow, Oldman and South Saskatchewan Sub-basins, natural flows have been significantly altered by storage, flow regulation, diversions and water uses (**Figures 3.7, 3.8 and 3.9**). The reduced flows in these streams have impacted water quality, and the aquatic and riparian environments throughout a large portion of the SSRB.

### 2.9.1 Red Deer River Sub-basin

The Red Deer River Sub-basin is the largest of the four SSRB sub-basins, and accounts for 41% of the SSRB land base in Alberta. However, it is the smallest in terms of flow volume. The Red Deer River Sub-basin flows through 10 natural sub-regions (**Figure 2.2**) beginning in the Rocky Mountains and Foothills Fescue natural regions and ending in the Dry Mixed Grass natural sub-region. Agriculture is the dominant land use throughout the basin, with the exception of the upper reaches in the mountain and foothills regions. As such, nutrients are an issue, particularly in wet years. Point source discharges in the sub-basin include municipal effluents and industrial releases. Municipal effluents are also a large source of nutrients, and there are two large municipal wastewater treatment plants (WWTPs) in the basin at Red Deer and at Drumheller. The petrochemical plants at Prentiss and Joffre also contribute to the nutrient load of the river, although the plants contribute a low percentage of the total load, particularly in comparison with the WWTPs (North/South Consultants, 2007). Dickson Dam also affects water quality through downstream scouring and erosion, and altered hydrology and thermal regime (North/South Consultants 2007). Dickson Dam flow regulation increases winter flows to improve water quality along the Red Deer River, particularly in the lower reaches.

Overall, water quality is rated fair in the Red Deer River, with some reaches near its headwaters receiving a rating of good (AENV, 2007). Based on nutrient concentrations, the Red Deer River is oligotrophic near its headwaters, but becomes mesotrophic to eutrophic as the river flows downstream (North/South Consultants, 2007). Total phosphorus and nitrogen levels increase substantially with increasing distance downstream (North/South Consultants, 2007). Summer water temperatures frequently reach 24°C and can approach 27°C, occasionally exceeding the tolerance of mountain whitefish (Clipperton *et al*., 2003). Dissolved oxygen levels can at times fall dangerously low during the winter months, particularly during ice cover. Dickson Dam operations are designed to address this problem by sustaining winter flows (Clipperton *et al*., 2003).

The nutrient enrichment of a water body is referred to as eutrophication. Increased nutrients can lead to aquatic plant and algal growth and, ultimately, depletion of dissolved oxygen. The trophic state of a water body is a measure of the degree of its productivity. Commonly used trophic states are:

1. **Oligotrophic** – A nutrient-poor waterbody characterized by clear, usually cold, infertile waters often found in headwater lakes and streams.
2. **Mesotrophic** – A water body with a moderate level of nutrients and biological production. Such waters would be suitable for recreation.
3. **Eutrophic** – A water body with a high concentration of nutrients and high or excessive biological production. Such waters may become depleted in oxygen in warm conditions that favour algal blooms.
4. **Hypereutrophic** – A water body with a very high level of nutrients and productivity, including persistent algal blooms and layers of organic muck. Such waters are unsuitable for recreation.

Riparian health of the Red Deer River is rated as “healthy” in its upper reaches but is rated “healthy with problems” for most reaches further downstream (AENV, 2007). Bank alterations due to livestock and recreation, the often widespread occurrence of invasive plant species, and flow alterations by Dickson Dam are all issues affecting riparian health in this sub-basin.

### 2.9.2 Bow River Sub-basin

The Bow River originates at Bow Lake in the Rocky Mountains, and flows southeast through Banff National Park, through the foothills and out onto the prairies to the east. While streamflows upstream of Banff can be considered relatively natural, most of the Bow River is highly altered from its natural flows (BRBC, 2005). The Bow River is the most regulated river in Alberta, with 11 hydroelectric facilities within its watershed (North/South Consultants, 2007). Irrigation is the largest water use in the basin, with water use also being allocated between industry, municipal and recreational users. There are several weirs, irrigation canals and withdrawal sites for agriculture located within the basin. The City of Calgary is in the Bow River Basin, and in addition to landscape alterations caused by the City, treated wastewater effluent and stormwater are discharged to the Bow River. The communities of Lake Louise, Banff and Canmore also release wastewater effluent to the Bow River.

Water quality in the Bow River Sub-basin has been rated as excellent in the headwaters, to good further downstream, in recent years using the WQI (AENV, 2007). Some fair ratings occurred in some years for nutrients in several reaches and marginal ratings for pesticides occurred in some years in the furthest downstream reaches (North/South Consultants, 2007). The Bow River is considered oligotrophic based on nutrient concentrations in the headwaters, but it becomes more mesotrophic further downstream as concentrations of total phosphorus and nitrogen increase (North/South Consultants, 2007). Some agricultural pesticides such as organochlorines and DDT, many of which are not used in Canada anymore, have been detected in the Bow River headwaters (BRBC, 2005). This is thought to be due to long-range transport and deposition processes, and concentrations are very low (BRBC, 2005). Conventional pesticides concentrations increase further downstream, due to increased urbanization and agricultural use in the lower basin. Detected levels of some pesticides in lower reaches of the Bow River exceeded CCME water quality guidelines for the protection of aquatic life (North/South Consultants, 2007).

Water temperatures can reach up to 29°C in the summer in the lower reaches of the Bow, which exceeds the tolerance for many fish species (Clipperton *et al*., 2003). As well, during low flow, aquatic plants can cause low dissolved oxygen concentrations and fluctuations in pH. These factors cause stress to fish and can occasionally lead to fish kills (Clipperton *et al*., 2003). Historical diversion of up to 90% of the Bow River's flow for irrigation at the dam at Bassano drastically reduced discharge, and consequently the downstream fish-bearing capability of the remaining length of the river downstream (Clipperton *et al*., 2003).

Riparian area health in the basin ranges from "healthy" in the headwaters to "unhealthy" in the furthest downstream reaches, with the majority of the sub-basin receiving a rating of "healthy with problems" (AENV, 2007). In reaches outside of the headwaters, housing developments, pipelines, upstream dams, and widespread occurrences of invasive species are issues affecting the health of riparian eco-systems in the basin.

### 2.9.3 Oldman River Sub-basin

The Oldman River headwaters are made up of three rivers: the Oldman, the Castle, and the Crowsnest, which merge at the Oldman Reservoir. Further downstream in the Lethbridge area, the Oldman River is joined by the Belly and St. Mary Rivers, The St. Mary, Belly and Waterton (major tributary of the Belly River) Rivers are often referred to as the Southern Tributaries. The Oldman River joins with the Bow to become the South Saskatchewan River. Besides the natural watercourses found in this basin, an extensive network of storage reservoirs, canals and pipelines are part of the irrigation infrastructure that supports a wide range of crops in addition to communities, industry, and recreation (Saffran, 2005). The grasslands portion of the basin is considered to be one of the most intensive agricultural regions in Canada due to the large amount of irrigated crop land and high densities of livestock operations (Saffran, 2005). The area is considered semi-arid, and water supply issues are a concern within the basin because of the potential for drought conditions and subsequent water shortages (North/South Consultants, 2007). There are 8 WWTPs that discharge effluent to the Oldman River, with the largest being the City of Lethbridge's facility (North/South Consultants, 2007).

Water quality in the basin has been rated as excellent in the headwaters and through the foothills, to good in grassland areas (AENV, 2007). However, pesticide index ratings were fair in the furthest downstream reaches (North/South Consultants, 2007). Downstream from Lethbridge, water quality in tributaries of the Oldman River, some of which are irrigation return-flow drains and some are natural streams that receive irrigation return water, had nutrient concentrations and pesticide detections that were much higher than elsewhere in the basin (Saffran, 2005). The Oldman River is considered to be oligotrophic, based on nutrient concentrations; however, nutrient levels increase with increasing distance along its length. Both phosphorus and nitrogen concentrations have been shown to be strongly correlated with flow, which suggests potential effects from agricultural runoff, irrigation return flows, and discharges from urban WWTPs (North/South Consultants, 2007).

Riparian health of the Oldman River Sub-basin ranges from “healthy” in its upper reaches to “unhealthy” in its furthest downstream reach but was rated “healthy with problems” for most reaches (AENV, 2007). Issues of concern identified by AENV (2007) include:

- disturbance-caused species;
- invasive species;
- upstream dams affecting vegetation cover and type; and,
- human-caused bare ground that occurs in the form of roads, paths, bridges, and livestock operations.

### 2.9.4 South Saskatchewan River Sub-basin

The main stem of the South Saskatchewan River is formed at the confluence of the Bow and Oldman rivers. The river flows through prairie, much of which is used for agricultural production. The river is impacted by water withdrawals and wastewater discharges at the City of Medicine Hat. Other human activities in the basin include oil and gas development, industry, agriculture, and the Canadian Forces Base at Suffield (North/South Consultants, 2007).

The South Saskatchewan River has been reported to have better water quality than the Bow or the Oldman rivers, potentially due to higher flows and increased assimilative capacity, recovery from upstream impacts, and no significant additional effluents downstream of the Bow/Oldman confluence (North/South Consultants, 2007). Water quality in the river upstream of Medicine Hat has been rated good overall with fair ratings in most years for nutrients, excellent bacteria levels all years except one (with a rating of “good”), and marginal ratings occurring for pesticides in some years (AENV, 2007). The South Saskatchewan River Sub-basin is considered to be oligotrophic, based on generally low levels of both phosphorus and nitrogen; however, both total phosphorus and total nitrogen concentrations do occasionally exceed guidelines (North/South Consultants, 2007).

Riparian health has been rated as “unhealthy” to “healthy with problems” in the South Saskatchewan River Sub-basin. Invasive and disturbance-related plant species are of concern, with livestock activities in the riparian zone also being an important issue (AENV, 2007).

Upstream dams on major tributaries result in more than 50% of the flow of the SSRB being regulated by dams, which causes modifications to flood timing and intensity, and subsequent effects to the riparian zone (AENV, 2007). With 25% to 50% of the average river discharge being removed from within the reach between the confluence and Medicine Hat, dewatering is having a negative effect on overall riparian health ratings within this reach (AENV, 2007).

# 3.0 HISTORICAL, CURRENT AND FUTURE HYDROLOGY

## 3.1 Introduction

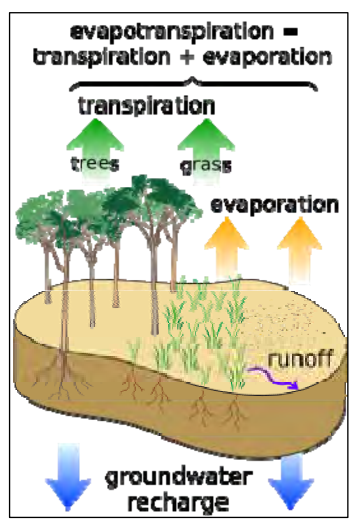
Surface water in the SSRB is used for a variety of purposes, including municipal water supply, irrigation, livestock watering, waterfowl conservation, recreation, industry and maintaining the aquatic and riparian health of the streams. Streamflow in the SSRB is highly variable from year to year and from season to season. From a water supply perspective, the variability of streamflow is a major concern, particularly the magnitude, frequency and duration of low flows and drought. There are numerous reservoirs and other control works throughout the SSRB that are used to reduce the impact of droughts and water supply-and-demand conflicts during low-flow periods (**Figures 2.4 and 2.5**). Despite the flow regulation capabilities within the basin, the impact of droughts on water users and the natural aquatic and riparian communities remain a current issue, and may become even more of an issue if climate change reduces water availability and increases demands within the basin. A good understanding of current and possible future hydrologic characteristics of key streams within the basin will help to identify water supply issues and methods to improve water supply security now and in the future.

The objectives of the hydrologic component of this study are to:

- identify historical and current climatic and water supply characteristics within the four primary sub-basins within the SSRB;
- review evidence of climate change in precipitation and streamflow historical records;
- review studies of the potential impact of climate change on water availability in the SSRB; and,
- determine Alberta's performance in meeting inter-jurisdictional apportionment agreements.

This chapter provides a summary of the water supply component of this study. More detailed information is contained in Technical Memorandum 1.0: Water Supply. Technical Memorandum 1.0 (TM 1.0) can be found in Volume 2 of this report. The TM contains numerous graphics that are not repeated in this volume.

## 3.2 Precipitation, Evapotranspiration and Runoff



Source: Wikipedia

Precipitation, evapotranspiration and runoff are three key climatic parameters that are important components of the water budget in the SSRB (inset graphic). Precipitation in the form of rain and snow is the primary source of surface water runoff. Evapotranspiration (ET) is one of several factors that affect the amount of water available for producing runoff. ET is the sum of evaporation and plant transpiration from the earth's land surface to the atmosphere[4]. Evaporation accounts for the movement of water to the air from sources such as the soil, vegetation canopies and water bodies. Transpiration involves the movement of water within a plant and the subsequent loss of water as vapour through stomata in its leaves.

[4] USGS. The Water Cycle: http://ga.water.usgs.gov/edu/watercycle.html.

**3-Year Mean** – Moving averages are often used in time series analyses to dampen short-term fluctuations and reveal variations in consecutive time steps that have specific meaning for an issue being investigated. The minimum 3-year means of annual precipitation reveal potential prolonged drought situations in a long-term dataset. Comparisons of low 3-year means at different locations reveal areas that are more susceptible to droughts than others.

Referring to the inset graphic, in simple terms, water available for runoff would be precipitation minus ET minus groundwater recharge. However, numerous other factors come into play, such as winter snow accumulation and spring thaws, rainfall duration and intensity, surface water storage, and glacial contributions. This study will address precipitation, ET and runoff. A quantification of all aspects of the water cycle is beyond the scope of this study.

Estimates of median annual precipitation in the four sub-basins in the SSRB, based on eco-regional characteristics, are given in **Table 2.1** (Chapter 2). To further examine precipitation and ET characteristics in the SSRB, mean values at the four major urban centres in the SSRB are shown in **Table 3.1**. The lowest 3-year precipitation means are also shown. The monthly distribution of ET and precipitation are shown in **Figure 3.1**.

**TABLE 3.1**
**Precipitation and Evapotranspiration Characteristics**
**at Four Urban Centres in the SSRB**

| Location | Precipitation | | | | Mean ET (mm) | Net Precip. (Precip. minus ET in mm) |
|---|---|---|---|---|---|---|
| | Mean Annual (mm) | % Summer (May-Oct) | Lowest 3-Year Means (mm) | % of Years 3-Year Means <300 mm | | |
| Red Deer | 476 | 76 | 280 | 1 | 401 | +77 |
| Calgary | 421 | 75 | 240 | 3 | 410 | +11 |
| Lethbridge | 403 | 68 | 250 | 4 | 416 | -13 |
| Medicine Hat | 335 | 69 | 220 | 25 | 359 | -25 |

Notes: ET = Evapotranspiration
Sources: Alberta Environment (undated).
Environment Canada (http://www.climate.weatheroffice.ec.gc.ca/climateData/canada_e.html).

**Drought Conditions** – Annual precipitation of 300 mm or less is used as an informal index of drought conditions for the purposes of this discussion only. In actuality, drought has different meanings for various activities, interest groups, or environmental concerns.

Climatic factors can be used as an indicator of the runoff producing potential of an area. Precipitation is much higher along the Continental Divide and in the mountainous region than on the plains further east (**Table 2.1**). On the plains area, precipitation decreases from northwest to southeast. Red Deer has a slightly greater proportion of summer precipitation than the more southerly stations. The magnitude, frequency and duration of droughts are greater at Medicine Hat than at the other three locations. Precipitation records at Medicine Hat show that for 8 consecutive years, 1903 to 1910 inclusive, annual precipitation was

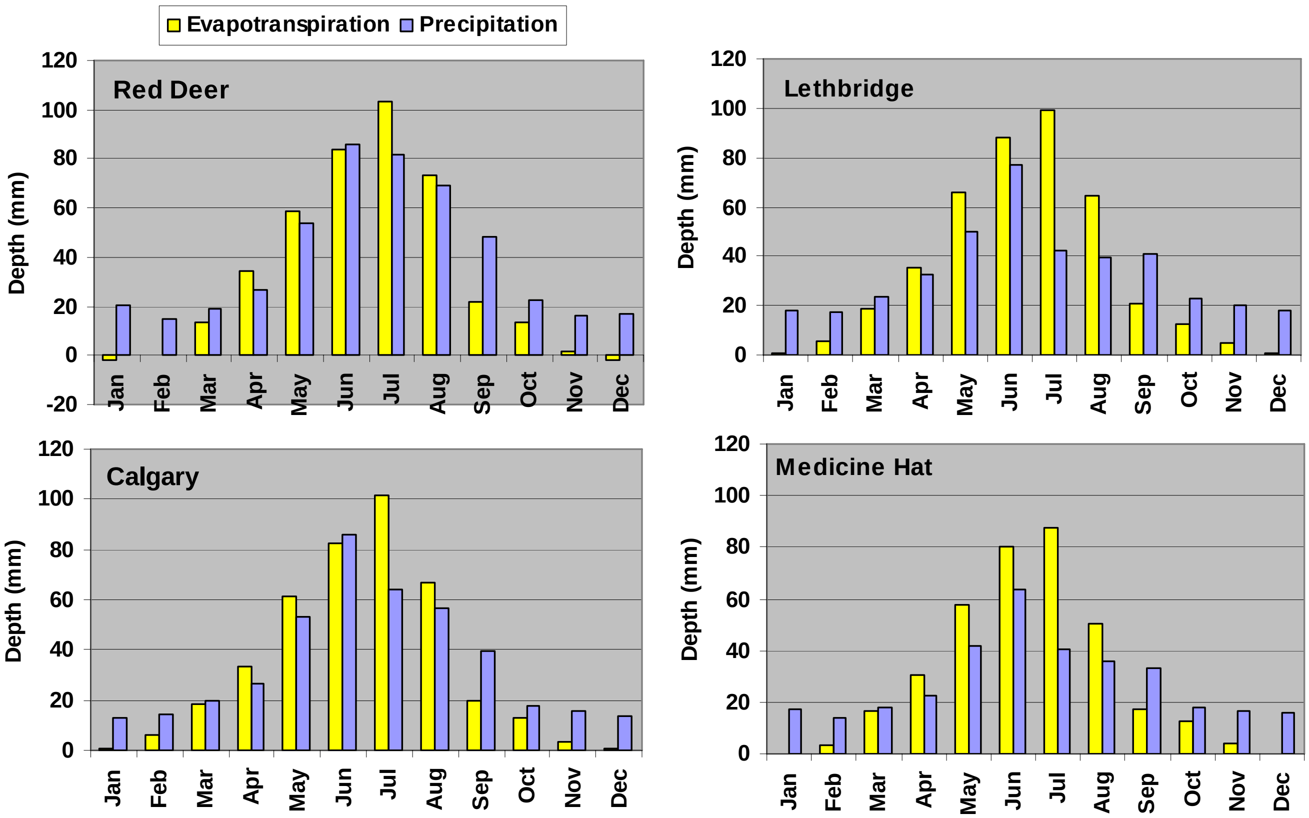



**Figure 3.1 Monthly Distribution of Evapotranspiration and Precipitation at Four Urban Centres in the SSRB**

less than 300 mm. Similar conditions extend to the Special Areas of Alberta in the south-eastern part of the Red Deer River Sub-basin.

The high precipitation and steep slopes of the mountainous regions are attributes that have high runoff-generating capability. This runoff-generating capability diminishes toward the eastern part of the SSRB due to low precipitation and flatter slopes. In low runoff years, the contribution to mainstem flows from the eastern part of the basin is very low, and in some years is insignificant.

Mean ET and net precipitation values for the four urban areas are given in **Table 3.1**. Lower net precipitation values indicate lower runoff-producing potential. Lethbridge and Medicine Hat have a negative net precipitation, indicating that, on average, annual ET exceeds annual precipitation. Climatic factors that influence ET include temperature, humidity, wind and solar radiation. At all four urban centres, precipitation peaks in June and ET peaks in July (**Figure 3.1**). On average, there is a very large precipitation deficit (precipitation minus ET) in July. Winter ET is minimal.

Technical Memorandum No. 1 (AMEC, 2008A) analyzed streamflow at 8 hydrometric stations in the SSRB (**Table 3.2**).

**TABLE 3.2**
**Hydrometric Stations Analyzed in Technical Memorandum No. 1**

| Station No. | Station Name | Land Location | Location Notes |
|---|---|---|---|
| 05CC002 | Red Deer River at Red Deer | SE 20-38-27 W4M | Downstream of WTP; upstream of Waskasoo Creek and WWTP. |
| 05CE001 | Red Deer River at Drumheller | SE 11-29-20 W4M | Downstream of Michichi Creek and WTP; upstream of Rosebud River and WWTP. |
| 05BB001 | Bow River at Banff | SE 35-25-12 W5M | Downstream of WTP; upstream of Spray River and WWTP. |
| 05BH004 | Bow River at Calgary | NE 15-24-01 W5M | Downstream of Bearspaw WTP; upstream of Elbow River, Nose Creek, Fish Creek, WID Diversion, Glenmore WTP and WWTPs. |
| 05AA023 | Oldman River near Waldron's Corner | NE 10-10-02 W5M | 2 km northwest of Highway 22 bridge across Oldman River. |
| 05DD007 | Oldman River near Lethbridge | NW 01-09-22 W4M | Downstream of St. Mary River, Nine Mile Coulee and WTP; upstream of WWTP. |
| 05AE006 | St. Mary River near Lethbridge | SE 24-7-22-W4M | Downstream of Pothole Creek, upstream of all Lethbridge Utilities. |
| 05JJ001 | South Saskatchewan River at Medicine Hat | NW 31-12-05 W4M | Downstream of WTP; upstream of Ross Creek and WWTP. |

Notes: 1. WTP = Municipal Water Treatment Plant.
2. WWTP = Municipal Wastewater Treatment Plant.
3. WID = Western Irrigation District.
4. Natural Flow Data extends from 1912–2001: recorded flow periods are variable but all are long-term stations (see Technical Memorandum No. 1, Volume 2).
5. Sources: Alberta Environment (2004); Water Survey of Canada (http://www.wsc.ec.gc.ca/hydat/H2O/index_e.cfm).

For the purposes of this summary, the Red Deer, Calgary, Lethbridge (Oldman River) and Medicine Hat hydrometric stations were examined. Readers are encouraged to refer to the Technical Memorandum for information at additional hydrometric stations, more detailed discussion, and graphics.

Hydrologic terms used in this chapter are defined as follows:

- *Natural flow* (or discharge) is flow that is not noticeably affected by direct human activities such as reservoir operation, water withdrawals, diversions or releases. The flow may, however, be indirectly affected by human activities such as land-use changes.
- *Regulated flow* is flow that is noticeably affected by direct human activities.

- *Historical flow or recorded flow* is the discharge recorded at a hydrometric station. It may include a combination of regulated and natural flows.
- *Naturalized flow* is an estimate of natural flow at a site, calculated by adjusting the historical flow record to remove the effects of regulation. The current study used naturalized discharges as published by Alberta Environment (1998 and updates) at a weekly time increment. Alberta Environment's naturalized flows included estimated discharges to fill portions of the record when historical data were missing, and are available to the end of 2001 only. Alberta Environment's natural flow database was supplemented by natural flows determined by the Prairie Provinces Water Board for the Oldman River near Lethbridge (2006 only) and South Saskatchewan River at Medicine Hat (2002 to 2006).
- *Annual flow volume* is the total volume of flow for an entire year.
- *Summer flow volume* is of particular interest for irrigation because irrigation water demands occur primarily in the summer. For the current study, the summer period was defined as 01 May–31 October.
- *Summer low flow* is of interest for in-stream flow needs and for irrigation, particularly for irrigators dependent on water supply directly from the river or from a canal where there is no storage reservoir upstream. The statistic used to characterize the summer low flow is the lowest 7-day mean discharge during the May–October period.
- *Winter low flow* is generally lower than summer low flow, and is of interest for in-stream flow needs and for year-round water demands such as municipal, domestic and industrial needs. The statistic used to characterize the winter low flow is the lowest 7-day mean discharge during the November–March period.

The historical (recorded) and reconstructed naturalized flows for the 4 hydrometric stations are shown in **Figures 3.2 to 3.5**. Note that, **Figures 3.2, 3.3 and 3.4** have the same vertical scale for comparison purposes. The vertical scale for **Figure 3.5** is double the scale for the other figures. Key characteristics of the data for 1972 to 2001, the period for which both recorded and naturalized flows are available, are summarized in **Table 3.3**.

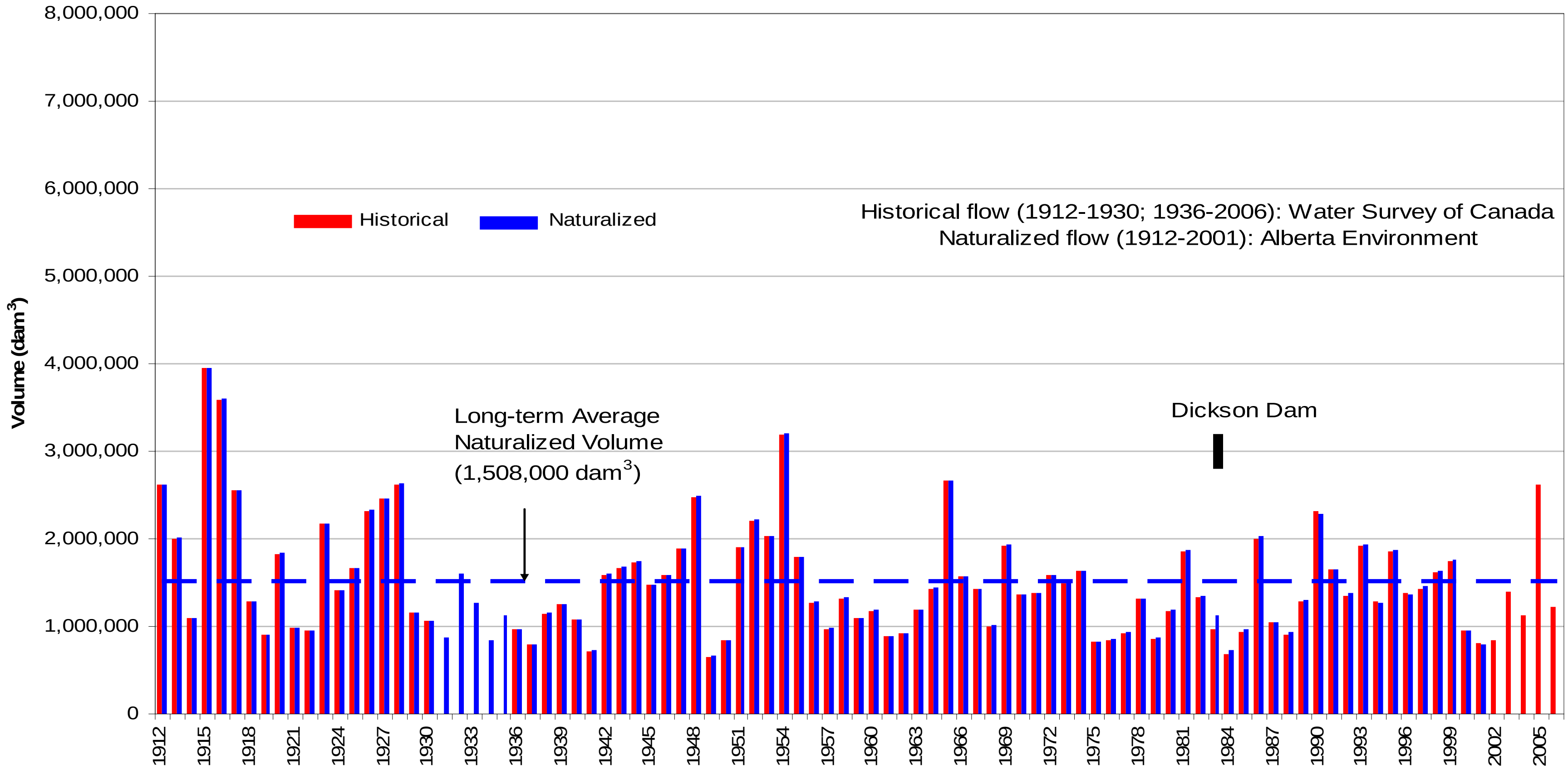



**Figure 3.2 Red Deer River at Red Deer Annual Historical and Naturalized Flow Volumes**

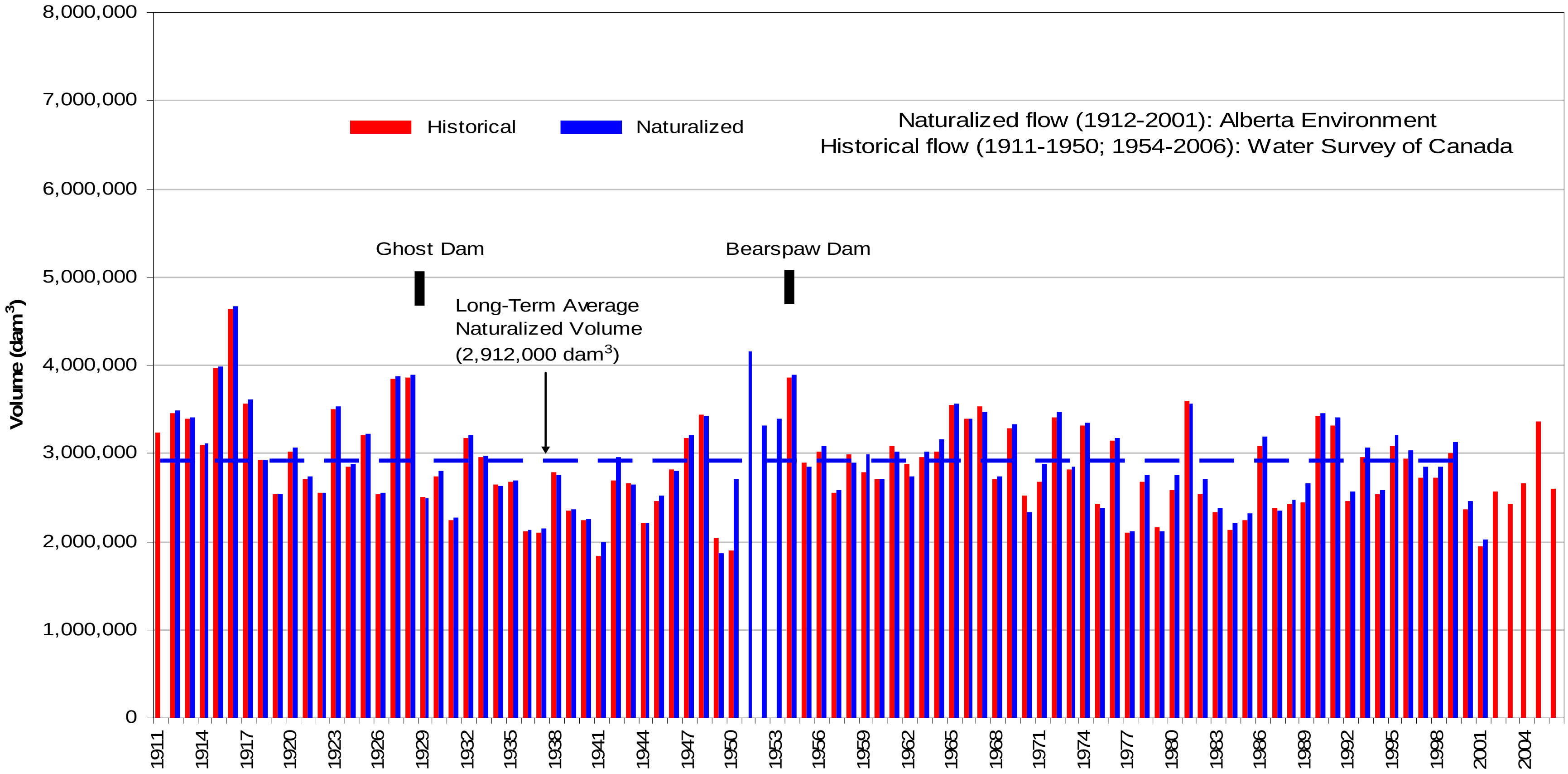



**Figure 3.3 Bow River at Calgary Annual Historical and Naturalized Flow Volumes**

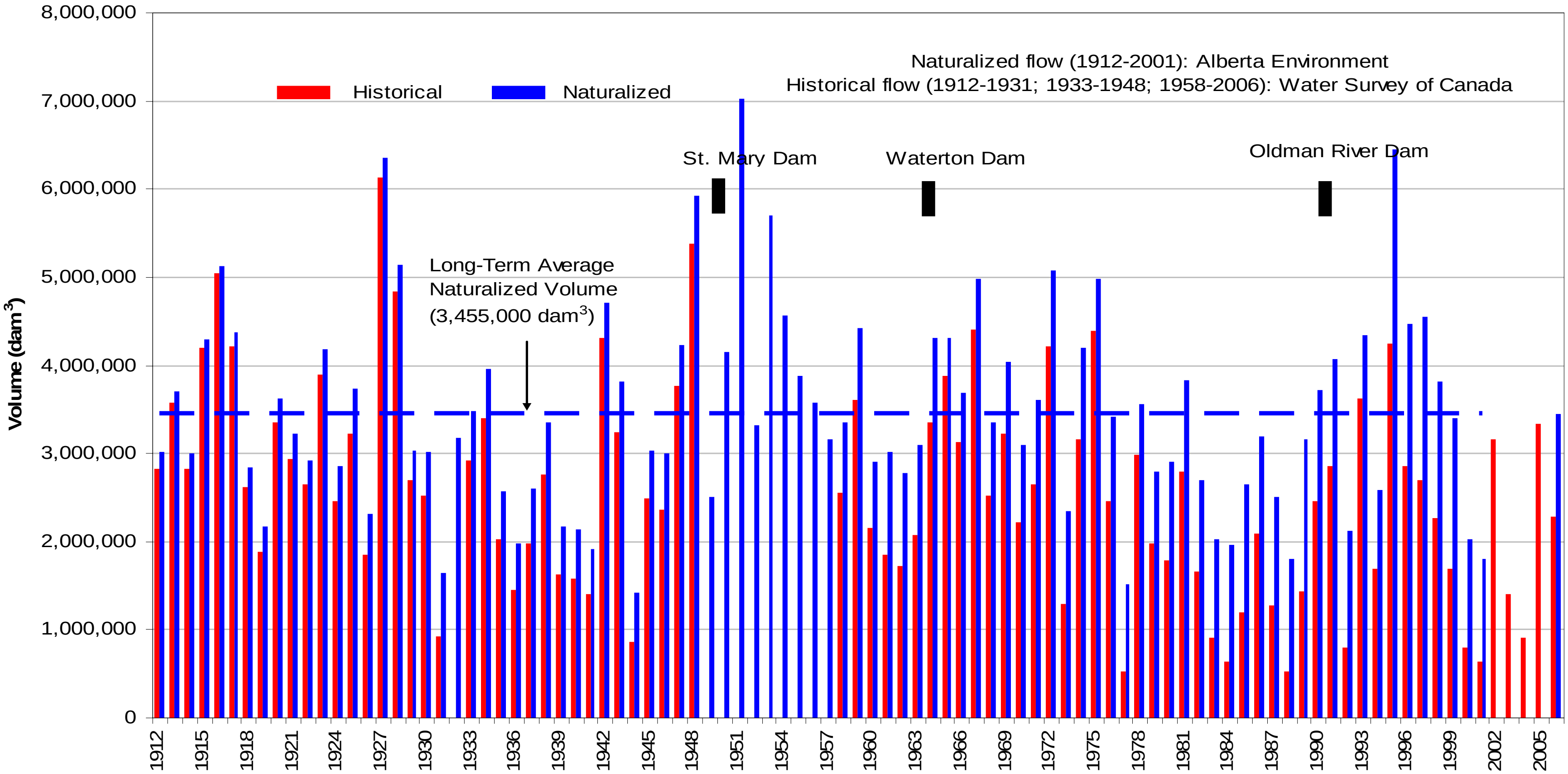



**Figure 3.4 Oldman River Near Lethbridge Annual Historical and Naturalized Flow Volumes**

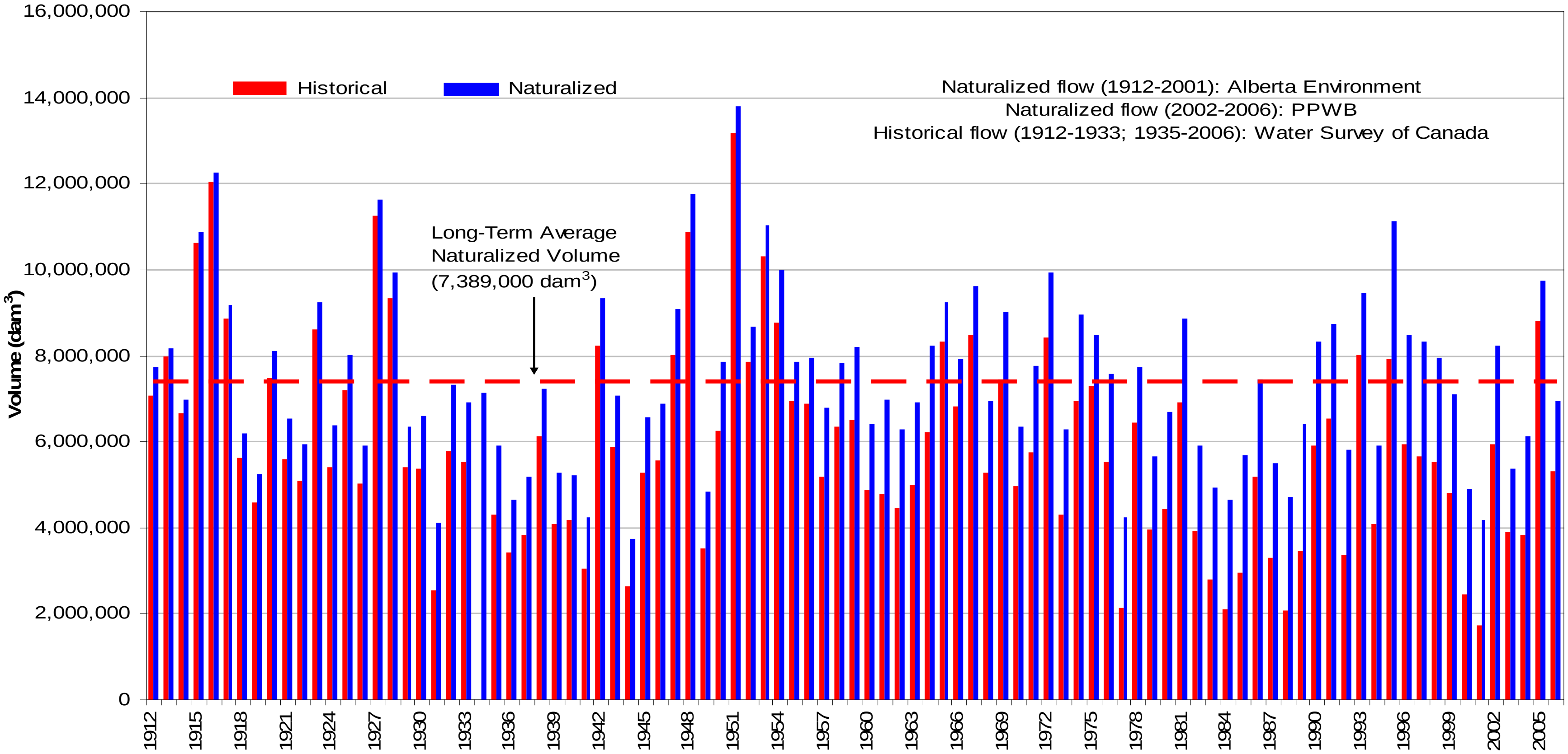



**Figure 3.5 South Saskatchewan River at Medicine Hat Annual Historical and Naturalized Flow Volumes**

**TABLE 3.3**
**Statistical Characteristics of Streamflow at**
**Four Hydrometric Stations in the SSRB 1972–2001**

| Statistic | Red Deer River at Red Deer | | Bow River at Calgary | | Oldman River near Lethbridge | | South Saskatchewan River at Medicine Hat | |
|---|---|---|---|---|---|---|---|---|
| | Naturalized | Recorded | Naturalized | Recorded | Naturalized | Recorded | Naturalized | Recorded |
| **Annual Volume** | | | | | | | | |
| Mean ($dam^3$) | 1 349 000 | 1 333 000 | 2 782 000 | 2 708 000 | 3 267 000 | 2 066 000 | 7 002 000 | 4 803 000 |
| Minimum ($dam^3$) | 723 000 | 683 000 | 2 030 000 | 1 942 000 | 1 515 000 | 526 000 | 4 181 000 | 1 739 000 |
| Coefficient of Variation (%) | 31% | 32% | 16% | 16% | 36% | 55% | 26% | 41% |
| **Summer Volume (May–Oct, inc.)** | | | | | | | | |
| Mean ($dam^3$) | 1 025 000 | 978 000 | 2 259 000 | 1 852 000 | 2 576 000 | 1 565 000 | 5 595 000 | 3 270 000 |
| Minimum ($dam^3$) | 534 000 | 421 000 | 1 587 000 | 1 259 000 | 1 136 000 | 282 000 | 3 279 000 | 826 000 |
| Coefficient of Variation (%) | 36% | 39% | 18% | 22% | 39% | 66% | 28% | 53% |
| **Summer Low Flow** | | | | | | | | |
| Mean annual 7-day ($m^3/s$) | 19.9 | 20.3 | 42.0 | 50.7 | 29.9 | 16.6 | 99.9 | 49.1 |
| Minimum 7-day ($m^3/s$) | 8.73 | 11.8 | 31.9 | 31.7 | 8.45 | 2.40 | 29.2 | 16.9 |
| Coefficient of Variation (%) | 25% | 21% | 15% | 16% | 46% | 72% | 28% | 52% |
| **Winter Low Flow (Nov–Mar, inc.)** | | | | | | | | |
| Mean annual 7-day ($m^3/s$) | 5.32 | 10.8 | 18.1 | 40.7 | 13.4 | 9.57 | 23.2 | 34.8 |
| Minimum 7-day ($m^3/s$) | 0.84 | 3.16 | 11.8 | 28.9 | 4.29 | 2.40 | 5.30 | 13.4 |
| Coefficient of Variation (%) | 42% | 43% | 17% | 14% | 42% | 58% | 49% | 36% |

Note: Data sources: Alberta Environment (2004); Water Survey of Canada (http://www.wsc.ec.gc.ca/hydat/H2O/index_e.cfm)

### 3.2.1 Red Deer River

The mean annual naturalized (reconstructed) flow in the Red Deer River at Red Deer for the period 1972 to 2001 is 1 349 000 dam$^3$ (**Table 3.3**), only slightly higher than that of the recorded flows due to the low level of water use upstream of Red Deer. To further demonstrate the low level of water use in the entire sub-basin, naturalized and recorded flows at Bindloss (near the mouth of the Red Deer River) for the period 1992 to 2001 are plotted in **Figure 3.6**. The differences between the datasets during the period 1992 to 2001 provide a reasonable indication of the impact of the current level of flow regulation and use. The differences are minor. The Red Deer River Sub-basin as a whole has a relatively low level of use.

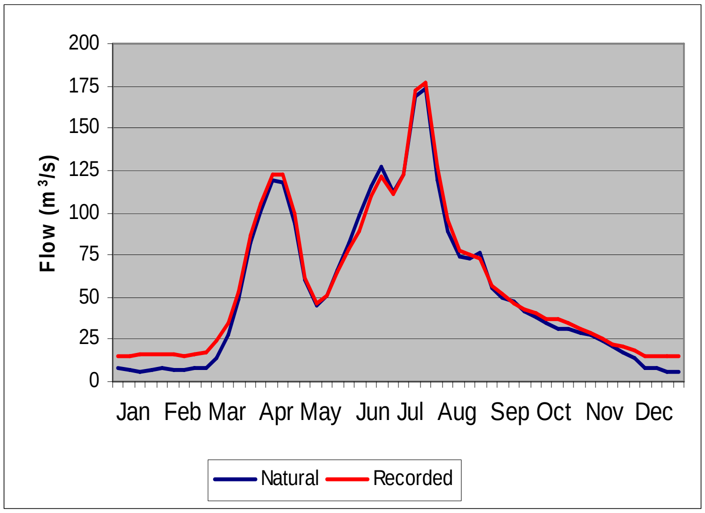



**Figure 3.6 Mean Monthly Recorded and Naturalized Flow for Red Deer River Near the Mouth, 1992– 2001**

The coefficient of variation is high (**Table 3.3**), indicating high variability in annual flows. Sustained periods of above-average or below-average annual volumes are typical, as shown in **Figure 3.2** for the 1930s and from 1975 to 1989.

> **Coefficient of Variation** – a measure of dispersion of a sample from its mean, expressed as a percent.
>
> CV = SD/Mean x 100
>
> Where,
> CV = Coefficient of Variation
> SD = Standard Deviation
> Mean = Sample Mean

The minimum annual flow is about 54% of the mean flow. On average, about 76% of the annual naturalized flow and 73% of the annual historical flow occurred during the summer months, May to October inclusive. Under natural conditions, winter minimum flows were very low, dropping to less than 1.0 m$^3$/s occasionally.

Flow in the Red Deer River has been regulated since the construction of Dickson Dam (Gleniffer Lake Reservoir) in 1983. Regulation has had little effect on annual flow volumes, but it has increased the summer low flows by a small amount, and winter low flows have substantially increased. Increasing minimum winter flow to improve water quality is a high priority for operation of Dickson Dam. The minimum weekly winter flow at Red Deer since Dickson Dam became operational is about 12.0 m$^3$/s.

**Figure 3.6** shows that the Red Deer River typically has a double-peaked annual hydrograph. The river begins to rise in March or April as runoff from snowmelt at lower elevations reaches the river. Flow drops off as the snow pack at lower elevations becomes depleted. Warmer temperatures in May and June bring runoff from higher elevations. These snowmelt flows may be augmented by heavy rains in the foothills. Recession from the June peak flows usually begins in early- to mid-July and continues until winter. Winter flows are low without much variation.

### 3.2.2 The Bow River

The mean annual naturalized flow of the Bow River at Calgary for the period 1972 to 2001 is 2 782 000 dam$^3$. The mean recorded flow is 2 708 000 dam$^3$, which is only about 3.0% lower than the naturalized flow (**Table 3.3**). Flow in the Bow River at Calgary is influenced primarily by TransAlta hydropower operations and withdrawals at the City of Calgary's Bearspaw municipal water supply intake. However, downstream of the Calgary hydrometric station, the Bow River is heavily utilized. Flows are influenced by diversions to 3 large irrigation districts with a total irrigated area in 2006 of 215 500 ha, and a variety of irrigation and other water supply projects on the Bow River as well as on its Elbow and Highwood River tributaries. The mean annual recorded volume for the Bow River near its mouth (2 617 000 dam$^3$) for the period 1992 to 2001 is about 70% of the natural flow (3 766 000 dam$^3$), indicating the impact of withdrawals on Bow River flows (**Figure 3.7**).

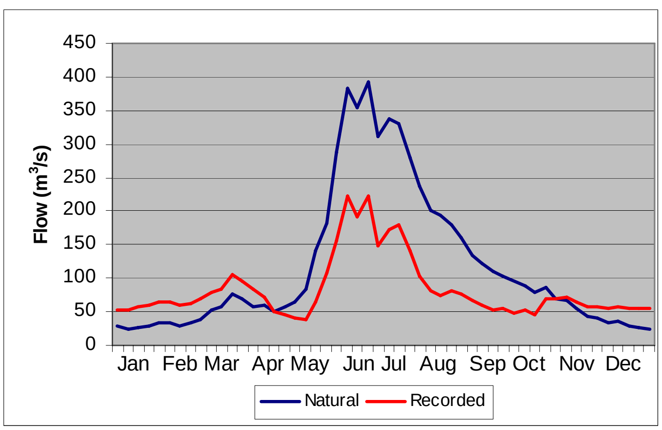



**Figure 3.7 Mean Monthly Recorded and Naturalized Flow for Bow River Near the Mouth, 1992–2001**

Bow River flows are relatively consistent from year to year for both naturalized and recorded flow conditions, with coefficients of variation of 16%, about half of the coefficients for the Red Deer River at Red Deer (**Figure 3.3**; **Table 3.3**). This could be due, at least in part, to the regulatory effect of natural and constructed storage in the basin and supplemental flows from glacial ablation. Natural storage in the basin includes the large Kananaskis and Spray Lakes, and

Lake Minnewanka. There are also numerous smaller lakes, such as Hector Lake, Bow Lake, Lake Louise, Moraine Lake and others. Hydropower reservoirs have been created by increasing the size of some of the larger lakes, as well as by constructing dams to create new water bodies (most notably, Ghost Reservoir and Barrier Lake Reservoir). Sustained periods of below-average annual volumes occurred during the 1930s and 1980s, but the Bow River appears to have more consistent annual flow volumes than the Red Deer and Oldman Rivers. The minimum annual flow is about 73% of the mean flow, compared with 54% for the Red Deer River and 46% for the Oldman River.

On average, about 81% of the annual natural flow and 68% of the annual recorded flow occurred during the summer months, May to October inclusive. Hydropower regulations have shifted flows to the winter months, more than doubling the average and minimum winter low flows.

The Bow River is primarily a snowmelt stream. The seasonal pattern of Bow River flow is dominated by a single-peaked hydrograph with a rising limb, a broad peak comprised of minor peaks, a falling limb and a base flow. This contrasts with the more complex double-peaked hydrograph for the Red Deer River. The Bow River hydrograph rises progressively from April to mid- or late-June (**Figure 3.7**). Flow usually decreases steadily from early-July to November. Recorded fall and winter base flows at Calgary do not show much variation, likely due to hydropower operations. They are much higher than winter flows on the Red Deer River.

### 3.2.3 The Oldman River

The mean annual natural flow of the Oldman River near Lethbridge is 3 267 000 $dam^3$. The mean recorded flow is substantially less at 2 066 000 $dam^3$ (**Table 3.3**). Recorded flows are influenced primarily by regulation by the Oldman River Dam, Waterton Dam and St. Mary River Dam, diversions from the St. Mary River to the Milk River in Montana, diversions to the Lethbridge Northern Irrigation District (irrigating about 70 900 ha in 2006), diversions from the Belly River to 4 small irrigation districts (13 500 ha), and diversions from the Waterton/Belly/St. Mary system to 4 irrigation districts (188 800 ha) and the Blood Tribe Agricultural Project (10 000 ha) south and west of Lethbridge. In comparison, water uses along the Oldman River downstream of Lethbridge are small. The impact of flow regulations and diversions on the average flow on the river at its mouth for the period 1992 to 2001 are shown in **Figure 3.8**.

Oldman River flows are highly variable from year to year for both naturalized and recorded flow conditions, with respective coefficients of variation of 36% and 55% (**Figure 3.4**; **Table 3.3**). This variability is much higher than that of the Bow River and higher than the Red Deer River. Similar to the Bow River, sustained periods of below-average annual volumes occurred during the 1930s and 1980s (**Figure 3.4**), but the Oldman River appears to be more severely impacted than the Bow River. The minimum annual flow is about 46% of the mean for natural flows and 25% of the mean for recorded flows. Comparable values for the Bow River are 73% and 72%.

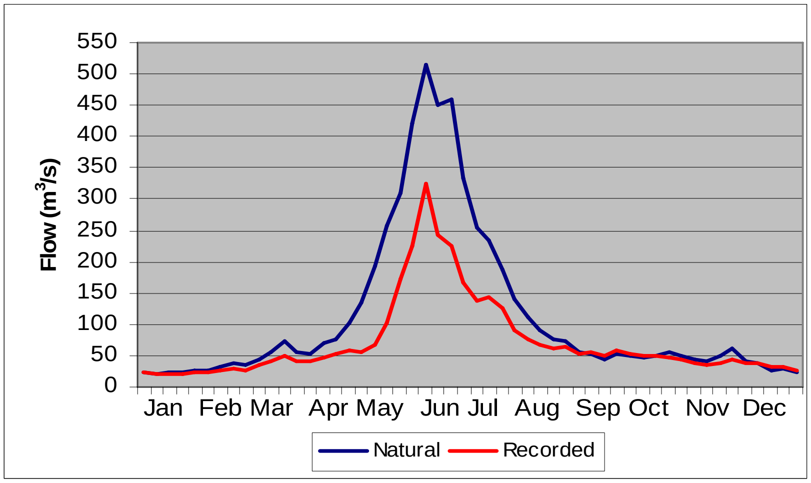



**Figure 3.8 Mean Monthly Recorded and Naturalized Flow for Oldman River Near the Mouth, 1992– 2001**

On average, about 77% of the annual natural and recorded flows for the Oldman River at Lethbridge occur during May to October inclusive (**Table 3.3**). Both summer and winter 7-day low flows for the Oldman River near Lethbridge are much lower for the recorded flows than for natural flows. Summer and winter low flows have increased since 1990 possibly due to the establishment of in-stream flow targets and operation of the Oldman Dam.

Like the Bow River, the Oldman River near Lethbridge has a single-peak hydrograph. However, **Figure 3.8** shows that the Oldman River near Lethbridge has a substantially different flow pattern than the Bow River at Calgary. The Oldman River rises earlier in the spring (early-April), peaks much higher and slightly earlier (early-June), and recedes to its winter flow level much earlier (August).

### 3.2.4 The South Saskatchewan River

The flows for the South Saskatchewan River at Medicine Hat are essentially the sum of the Bow and Oldman Rivers at their respective mouths.

The mean annual natural flow of the South Saskatchewan River at Medicine Hat is 7 002 000 $dam^3$. The mean recorded flow is substantially less at 4 803 000 $dam^3$ (**Table 3.3**). Recorded flows are affected by the collective impacts of all projects in the Bow and Oldman River Basins (**Figure 3.9**). On average, about 80% of the annual natural flow and 68% of the annual recorded flow occurs during the summer months (**Table 3.3**).

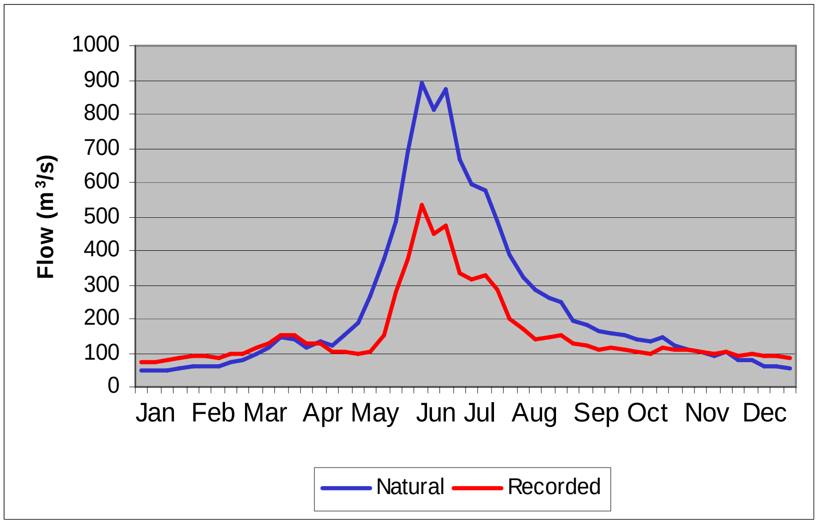



**Figure 3.9 Mean Monthly Recorded and Naturalized Flow for South Saskatchewan River at Medicine Hat, 1992–2001**

The coefficients of variation for natural and recorded flows are respectively 26% and 41% (**Table 3.3**). As expected, these are about midway between those of the Bow River at Calgary and the Oldman River near Lethbridge. Like the Bow and Oldman Rivers, prolonged periods of low flows occurred at Medicine Hat in the 1930s and 1980s (**Figure 3.5**). Annual volumes close to 2.0 million $dam^3$ have occurred more frequently in the past 30 years, and the lowest recorded volume of 1.7 million $dam^3$ occurred in 2001. The impacts of flow regulation and diversions have reduced the mean and minimum 7-day summer low flows by about 50% compared to the natural condition (**Table 3.3**). However, winter 7-day low flows have increased substantially, largely due to the influence of hydropower regulations in the upper Bow River Sub-basin.

The seasonal distribution of flow at Medicine Hat is shown on **Figure 3.9**. Typically, the South Saskatchewan River rises slightly in late-March and early-April in response to snowmelt runoff on the plains, but the highest flows typically occur in June, with relatively low flows from August through April.

## 3.3 Performance in Meeting Inter-jurisdictional Apportionment Arrangements

Water in the SSRB is shared between the United States, Alberta and Saskatchewan under the 1909 Boundary Waters Treaty and the 1969 Master Agreement on Apportionment.

### 3.3.1 Water Sharing with the United States

Canada and the United States signed the Boundary Waters Treaty in 1909 to provide the principles and mechanisms for preventing and resolving water-related disputes along the entire Canada-United States Boundary. With respect to the St. Mary and Milk Rivers, the Treaty required some interpretation on how the water was to be administered on a day-to-day basis. The two countries could not agree on how the 1909 Treaty was to be implemented. The matter was referred to the International Joint Commission (IJC), and following information gathering and public hearings, the IJC issued an Order in 1921 clarifying the apportionment arrangement. With respect to the St. Mary River, the 1921 Order stipulated that during the irrigation season when the natural flow in the St. Mary River is 666 cfs (18.86 $m^3$/s) or less, Canada is entitled to 75% of the natural flow. Any portion of the natural flow in excess of 666 cfs, and all of the natural flow outside of the irrigation season, is to be shared equally between the two countries. Reciprocal arrangements were made for the Milk River flows.

St. Mary flows apportioned and received by the two countries during the past 55 years (1950 to 2004) are summarized in **Table 3.4**.

During the years 1950 to 2004, Canada received 26% more than its share of the natural flow of the St. Mary River. This was offset, at least in part, by the United States receiving more than its share of the Milk River flow. Under current administrative arrangements and with the capacity of the works constructed in Montana to divert flow from the St. Mary River to the Milk River, the United States has not been able to fully utilize its St. Mary River entitlement. The original capacity of the 1917 diversion works was 850 cfs (24.1 $m^3$/s). The works have deteriorated and the current capacity is in the order of 650 to 675 cfs (18.4 to 19.1 $m^3$/s).

**TABLE 3.4**
**Summary of Annual Apportioned Entitlements and**
**Apportion Received of St. Mary River Natural Flows, 1950–2004**

| | **St. Mary Flows Apportioned to and Received by *Canada* ($dam^3$)** | | | |
|---|---|---|---|---|
| | **CA Apportioned Entitlement** | **% Apportioned** | **Received** | **% Received** |
| Maximum | 719 800 | | 1 167 800 | |
| Mean | 478 600 | 59% | 604 600 | 75% |
| Minimum | 277 900 | | 290 900 | |
| | **St. Mary Flows Apportioned to and Received by *United States* ($dam^3$)** | | | |
| | **US Apportioned Entitlement** | **% Apportioned** | **Received** | **% Received** |
| Maximum | 546 500 | | 326 800 | |
| Mean | 332 600 | 41% | 206 500 | 25% |
| Minimum | 154 700 | | 98 500 | |

Based on International St. Mary-Milk Rivers Administrative Task Force Report (April 2006).

In April 2003, the Governor of Montana requested the IJC to review the administrative arrangements set out in the 1921 Order. After a series of public meetings, the IJC established the St. Mary/Milk Rivers Administrative Task Force to examine opportunities to improve administration of apportionment arrangements to ensure more beneficial and optimal use of the waters in both Canada and United States. The Task Force reported in April 2006. Work is proceeding on implementation of recommendations of the Task Force. In addition, Montana is considering rehabilitation and possible enlargement of the St. Mary diversion works.

### 3.3.2 Water Sharing with Saskatchewan

The general principle of the 1969 Master Agreement on Apportionment is that the waters of eastward-flowing rivers are to be divided equitably between Alberta and Saskatchewan. The agreement is monitored and enforced by the Prairie Provinces Water Board (PPWB). Alberta is entitled to consume or store one-half of the apportionable flow of the South Saskatchewan River and Red Deer River. Alberta has the option of considering the South Saskatchewan and Red Deer River basins as a single basin for apportionment calculations. The agreement includes a clause that allows Alberta to take a minimum annual "prior allocation" volume of 2 590 000 $dam^3$ (2,100,000 acre-feet), even if that amount is more than 50% of the annual volume, provided that a minimum flow of 42.5 $m^3/s$ (1500 cfs) or 50% of the instantaneous natural flow, whichever is less, is maintained at the provincial boundary.

***Apportionable flow*** of the South Saskatchewan River at the Alberta-Saskatchewan Border is the natural flow of the South Saskatchewan River downstream of its confluence with the Red Deer River, minus U.S. withdrawals from the St. Mary River system in Montana. The apportionable flow is subject to the 1969 PPWB Agreement.

Apportionable flows, Saskatchewan entitlements, and actual deliveries to Saskatchewan from 1970 to 2006 are illustrated in **Figure 3.10**. The required delivery shown in the figures is computed simply as 50% of the apportionable flow of the combined South Saskatchewan and Red Deer Rivers. The figure shows that Alberta has met its commitments and that surplus deliveries have been made each year since the agreement was implemented. Surplus deliveries have averaged 2 573 000 $dam^3$, varying from 350 000 $dam^3$ in 2001 to 5 498 000 $dam^3$ in 2005. On average, Alberta has passed 81% of the apportionable flow to Saskatchewan compared to the 50% required under the agreement. Surplus deliveries are typically highest in June and lowest in August. Surplus deliveries also commonly occur throughout the winter.

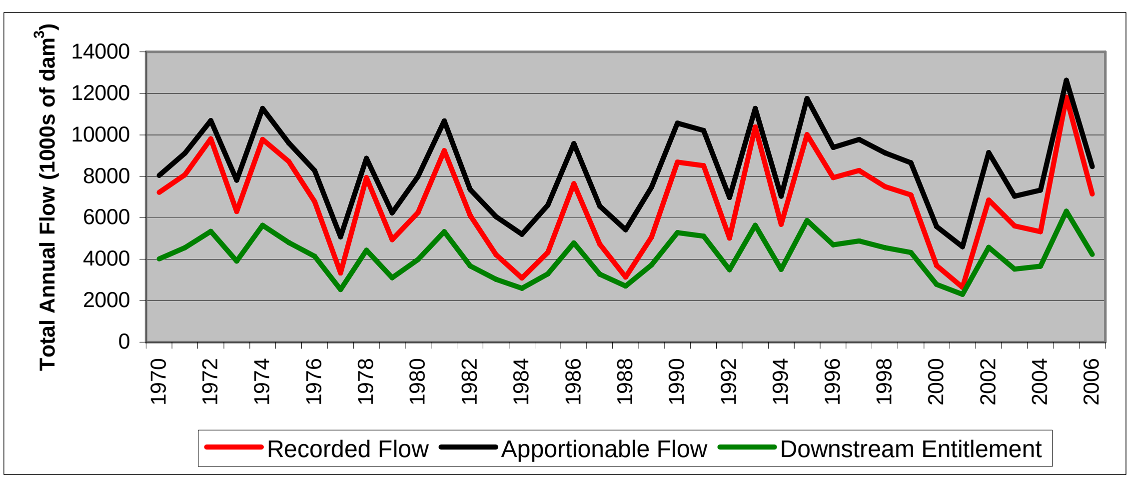



**Figure 3.10 South Saskatchewan River Apportionable Flow, Recorded Flow and Downstream Entitlement, 1970–2006**

Alberta Environment (2002) examined the recorded and naturalized flows of the major rivers in the SSRB to evaluate their relative contribution to Alberta's apportionment commitments. The analysis was based on the period 1975 to 1995, which was the latest 21-year period for which natural flow calculations were available at the time. Alberta Environment drew the following conclusions:

- The Red Deer River Sub-basin passes a relatively constant 98% of its natural flow to Saskatchewan.
- The Bow River Sub-basin delivery to Saskatchewan has varied from 58% to 86% of its natural flow, with an average of 72%.
- The Oldman River Sub-basin has delivered between 41% and 92% of its apportionable flow, with an average of 69%.
- Alberta's surplus deliveries during low-flow years could increase in the future as a result of recently established In-stream Objectives and Water Conservation Objectives (in-stream flow requirements) implemented for the Medicine Hat reach of the South Saskatchewan River, as well as other reaches of the system. These in-stream flow requirements may increase the flow delivered to Saskatchewan in low natural flow years.

### 3.4 Future Hydrologic Conditions

Will streamflow in the future have similar characteristics to that of the past? Has climate change impacted streamflow in the SSRB? How could climate change impact streamflows in the future? These are important questions for water managers and water users.

These questions will be addressed by reviewing four potential impacts of climate change: increased streamflow variability, streamflow trends, global warming, and glacial recession. This section will include a discussion of potential impact of climate change on the aquatic environment.

#### 3.4.1 Increased Streamflow Variability

The performance of water supply systems during droughts is a key factor in determining the feasibility of water management projects on the Canadian Prairies. The future performance of large and complex water management systems such as the SSRB are often tested using computer-based modelling conducted for the historical period of weather and streamflow conditions. How well the 20th century weather conditions might represent conditions in the 21st century has recently come into question. Studies of tree rings, lake sediments and other climatic indicators on the Canadian prairies have shed some light on the climate of past centuries (Sauchyn, 1997; Case *et al*., 2003; Sauchyn *et al*., 2007). Researchers have concluded that streamflows were relatively high on the Canadian Prairies during the 20th century compared with earlier centuries. Sauchyn concludes that, ".... the recent occupants of the Palliser triangle have not yet experienced the extremes of summer precipitation that occurred in the 19th and late-18th centuries, and that could re-occur in the near future." This conclusion suggests that modelling results using 20$^{th}$ century weather and streamflow conditions could present an overly optimistic picture of future long-term water supply and demand.

### 3.4.2 Streamflow Trends

Three recent studies have been conducted to identify and quantify streamflow trends in recorded flows in western Canada and the United States, including the SSRB in Alberta. Key findings are summarized below.

Seneka (2004) assessed the total annual flow at several locations in Alberta, including four locations in the South Saskatchewan River Basin. The flow analysis utilized naturalized flows extending through 2001. Using the Mann-Kendall test, Seneka found that there was no detectable trend for annual streamflow volumes in the Bow River at Calgary and the Oldman River near Lethbridge. The Red Deer River at Red Deer and the South Saskatchewan River at Medicine Hat showed decreasing trends, but the trends were not significant at the 95% level of confidence. Although not part of the study, Seneka also indicated that analysis of the Bow River at Banff did not indicate a significant trend. In contrast, annual precipitation showed a slight increasing trend combined with decreasing year-to-year variability. Seneka suggested that changes in the seasonality of precipitation could explain the differences between precipitation and runoff trends.

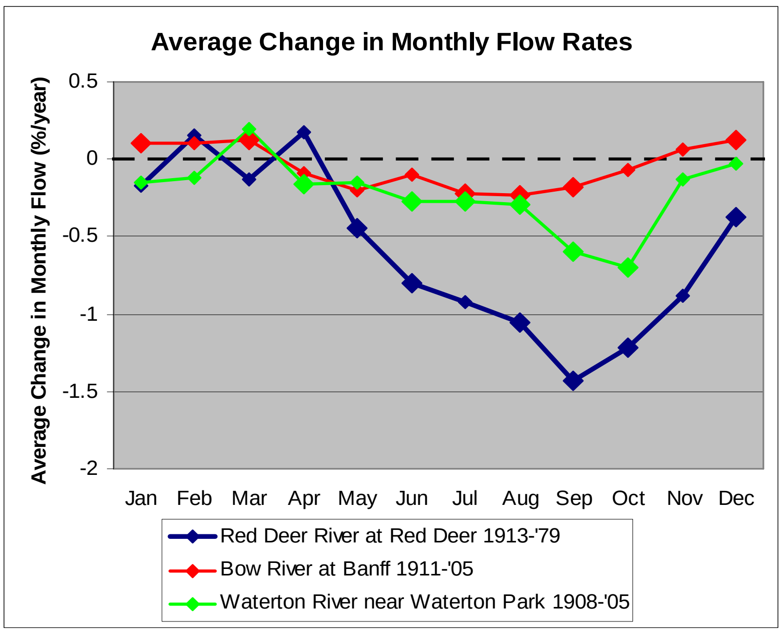
Rood *et al*. (2005) analyzed annual flow volumes for 31 locations in Alberta, B.C. and north-western U.S., of which 10 locations are within the western portion of the SSRB. The study used recorded flows rather than the naturalized flows examined by Seneka (2004), although the following 5 of the 10 stations were examined in the SSRB's monitor natural flow:

1. Bow River at Banff
2. Highwood River at Diebel's Ranch
3. Oldman River near Waldron's Corner
4. Castle River near Beaver Mines
5. Waterton River near Waterton Park

The analyses "included (1) Spearman r ('rho'); (2) Kendall t ('tau') non-parametric rank correlations; and, (3) parametric bivariate analyses consisting of linear regressions followed by Analyses of Variance (ANOVA)". The examined period of record typically ended in 2002. The study concluded that for most of the South Saskatchewan River Basin stations, annual flow volumes show decreasing trends, although the trends were not always statistically significant. Of the 5 natural flow stations, significant decreasing trends at the 95% level of confidence were indicated for 4 of the 5 stations, the exception being Oldman River near Waldron's Corner.

The major difference between the two studies is that Seneka used Alberta Environment's reconstructed natural flow in his analysis, while Rood *et al*. used Water Survey of Canada's recorded flows. Recorded flow reflects historical levels of water use and regulation, except on unregulated streams with an insignificant level of water use. Reconstructed natural flow removes most anthropogenic impacts contained in recorded flow. The only natural flow station with a common database is the Bow River at Banff. Seneka indicated no significant trend. Rood *et al*. indicated that the trend was significant at the 95% level. Reasons for the differing conclusions between Seneka (2004) and Rood *et al*. (2005) for this hydrometric station are unknown.

In a follow-up study, Rood *et al*. (2007) examined two natural flow stations in the SSRB, Bow River at Banff (1911 to 2005) and Waterton River near Waterton Park (1908 to 2005), and one near-natural flow station, Red Deer River at Red Deer prior to regulation by Dickson Dam (1913 to 1979). The objective of the follow-up study was to investigate historic changes in seasonality of streamflow from relatively pristine watersheds. Trend analyses were conducted for individual months using similar techniques as was used in the 2005 study. Positive (increasing flow) and negative (decreasing flow) change rates were computed based on the sign (+ or -) and slope of the linear regression (b-value in the standard linear regression equation; Y = a + bX) divided by the mean flow for the month. The results of the analysis are summarized in **Figure 3.11**.




- Based on Rood *et al*., 2007.
- Enlarged data points indicate a significant trend at the 95% level of confidence.

**Figure 3.11 Percent Change Rates Based on Slope of the Regression Equation for Monthly Flow Versus Year**

From these and similar analyses on other streams outside the SSRB, Rood *et al*. concluded that winter flows have increased slightly, and summer flows (especially late-summer flows) have decreased. The strongest pattern of change in streamflow seasonality was observed for the Red Deer River at Red Deer. But Rood *et al*. cautioned that the analysis for this location was based on a relatively short period of record that ended in a low-flow period, and this probably exaggerated the seasonal pattern.

### 3.4.3 Global Warming

There is evidence that the climate on the Canadian Prairies is changing (Wheaton, 1998; Henderson *et al*., 2008). There appears to be agreement that temperatures are rising and will probably continue to rise, based on Global Climate Model (GCM) projections. There is less certainty about precipitation, particularly on a regional level. Some GCMs project decreases in precipitation, but most project increases. Much of this increase in both temperature and precipitation is weighted toward the winter and spring months.

The National Water Research Institute (Martz *et al*., 2007) used hydrologic modelling to assess the effect of projected climate change on streamflows in the SSRB in Alberta and Saskatchewan. A range of climate forecasts for a period centered on 2050 was used to predict the potential range of impacts on surface water supply. Conclusions related to climate change and water supply included the following:

- Climate model predictions of future annual precipitation ranged from a decrease of 3.8% to an increase of 11.5%, with an average increase of 3.6%. Temperature increases ranged from 1.5°C to 2.8°C.
- Despite the increased precipitation, streamflows were predicted to decrease by 8.4%, averaged across the sub-basins and the various climate models.
- Natural flows under a range of future climate models and future adaptive economic and environmental scenarios were projected to change as shown in **Table 3.5**.

**TABLE 3.5**
**Projected Changes in Natural Flow Due to Climate Change, Circa 2050**

| Location | Projected Change in Natural Annual Volume (%) | | |
|---|---|---|---|
| | Minimum Scenario | Mean | Maximum Scenario |
| Red Deer River at Red Deer | -30% | -13% | +10% |
| Red Deer River at Drumheller | -32% | -13% | +12% |
| Bow River at Banff | -12% | -5% | +1% |
| Bow River at Calgary | -19% | -10% | 0% |
| Oldman River at Waldron's Corner | -18% | -6% | +4% |
| St. Mary River near Lethbridge | -15% | -4% | +7% |
| Oldman River near Lethbridge | -14% | -3% | +7% |
| South Saskatchewan River at Medicine Hat | -17% | -6% | +6% |

Source: Martz *et al*., 2007.

Clearly, the various model and scenario results reflect a wide range of potential future conditions. However, on average, the simulations indicate future reductions in flow in all of the sub-basins of the SSRB.

### 3.4.4 Glacial Recession

The Rocky Mountain glaciers contribute only a small amount of flow to the Red Deer and Oldman River Sub-basins, but they are an important source of runoff for the Bow River, which has the largest extent of glaciation. Glaciers act as self-regulating storage reservoirs that contribute to flow during otherwise low-flow periods. Glaciation results in a delayed and extended period of summer discharge and reduced monthly variations (PARC, 2008). There is evidence of decreases in the aerial extent of glacial ice cover during the 20$^{th}$ century and corresponding decreases in the summer flows on western prairie streams (Brown *et al*., 2003). Pietroniro and

Demuth (2006) indicated that the SSRB experienced a reduction in glacial area of 76 $km^2$ between 1975 (152 $km^2$) and 1998 (76 $km^2$). They estimate that glacial melt contributes an average of 0.6% of the annual flow and about 2.4% of the base flow in the Bow River at Calgary. In low-flow years, these percentages could be significantly higher. With the reduction in glacial area and declining contribution to streamflow, the sustainability of Bow River summer flows is a concern (Brown *et al*., 2003). Research is continuing on the longevity of glacial regulation of flows with projected changes in climate.

**Base Flow** – The relatively constant flow of water in streams during periods of low surface runoff. Base flow is generally considered to be the ground-water component of streamflow. Glacial runoff contributes to base flow during periods of glacial melt.

### 3.4.5 Climate Change Impacts on the Aquatic Environment

Currently, there remains considerable uncertainty regarding potential impacts of climate change on precipitation and streamflow. Research and modelling indicate that reduced streamflow is more likely than increased streamflow, but either case is possible. In a worst case scenario, supplies would decrease and water demands would increase. The combination of reduced supplies and increased water demands may have considerable adverse effects on the already impacted aquatic eco-system of the SSRB.

The largest effect of climate change in the SSRB is the potential for water scarcity (Schindler and Donahue, 2006). While climate change is predicted to increase total precipitation in the watershed, higher evaporation rates, reduced summer and fall soil moisture, and earlier peak streamflow may lead to drier summers, when irrigation and municipal demand for water is highest (Saunders and Byrne, 1994). It has been predicted that a larger proportion of winter precipitation will fall as rain as opposed to snow (Lapp *et al*., 2005). Warmer winter conditions will subject snow packs to periodic melting. Although existing storage development in the SSRB could capture some of the increased cold season runoff, there will be less natural storage of water, which may make water supplies in the SSRB more sensitive to drought (Schindler and Donahue, 2006).

The potential for warmer temperatures, with increased evapotranspiration, changes in precipitation, retreating glaciers, and greater frequencies of extreme events, will affect both water quality and quantity.

Other concerns include the impact of reduced streamflows on in-stream needs, such as fisheries. Meeting in-stream flow needs in the Bow and Oldman rivers downstream of the major water withdrawals requires more flow than is currently available (Clipperton *et al*., 2003). The majority (22 of 33) mainstem river reaches in the SSRB have already been rated as 'Moderately Impacted', 5 reaches as 'Heavily Impacted', and 3 as 'Degraded' due to flow and/or water quality issues (AENV, 2003). These issues may become even more significant under the predicted lower flows and higher temperatures of climate change.

Lower water flows may cause increased water retention times in reservoirs, resulting in higher nutrient retention and larger algal blooms (Schindler and Donahue, 2006). Increased water retention time in reservoirs can cause some water quality parameters to increase in concentration

(Schindler, 2001). Lower water levels in lakes on the prairies have been shown to result in increased salinity, which can have considerable adverse effects on aquatic biota (Schindler, 2001). As well, decreased flows reduce the capacity of rivers to dilute and assimilate wastes.

The effects of climate change on fish include changes in water temperature, species distributions, and habitat quality (CCIAD, 2004). Higher temperatures can have many effects on fish species. Studies have shown that warm-water fish, such as sturgeon, generally benefit from increased water temperatures, while cold water species like trout and salmon tend to show reductions in growth rate, survival, and reproductive success with temperature increases (CCIAD, 2004). The warming of mountainous regions is predicted to make a high proportion of streams uninhabitable for native fish species due to increased water temperatures (Rahel *et al*., 1996).

There is also the potential for new species to become established as they move north due to increasing temperatures, which can have negative effects on existing resident species (Jackson and Mandrak, 2002). Climate change may also enable the spread of introduced or invasive species, which may affect resident population numbers (Jackson and Mandrak, 2002). The length of the ice-free period is expected to increase substantially due to a later freeze-up and an earlier break-up under climate change (Jackson and Mandrak, 2002). A longer ice-free period may improve winter fish survival due to higher late-winter dissolved oxygen levels.

## 3.5 Key Findings

Precipitation is relatively high in the mountainous and foothills regions in the western part of the SSRB. It progressively declines eastward to the Saskatchewan border. Evapotranspiration (ET) is low in the northern part of the basin and increases southwardly (**Table 2.1**, Chapter 2; **Table 3.1**). These climatic characteristics influence hydrology and water demands in the SSRB.

The Red Deer River Sub-basin is the largest of the three primary sub-basins, but it has the lowest mean annual flow volume primarily due to the low proportion of the basin in the Mountains and Foothills regions (**Table 2.1**, Chapter 2; **Table 3.3**). The Bow River and Oldman River have similar runoff volumes, but, historically, the Oldman River has been more highly variable and more susceptible to droughts than the Bow River (**Table 3.3**; **Figures 3.2 to 3.5**). The South Saskatchewan River Sub-basin has low runoff producing potential primarily because of low precipitation and high ET.

Flow regulation and water use has had a significant impact on flow in the Bow, Oldman and South Saskatchewan Rivers (**Figures 3.7, 3.8 and 3.9**). In general, the impact has been lower summer flows. Winter flows have significantly increased in the Bow River.

Alberta has consistently met its commitments under the Prairie Provinces Master Agreement on Apportionment. Surplus water has been delivered to Saskatchewan even in dry years, indicating that water may be available for additional use in Alberta. However, water supply for use in Alberta may be constrained by recently established in-stream flow requirements.

Analyses for trends in the natural flow data and projections of future water supply changes have led to the following conclusions:

- From studies of tree rings, lake sediments and other climatic indicators on the Canadian prairies, researchers have concluded that streamflows were relatively high on the Canadian Prairies during the 20th century compared with earlier centuries. Streamflow variability may be somewhat higher in the future than experienced during the past century.
- Tentative indications of trends within the period of record as well as climate change studies conducted by the National Water Research Institute indicate that future reductions in natural streamflows are more likely than increases in all of the sub-basins in the SSRB.
- The reduction in glacial area and declining contribution to streamflow in the Bow River give rise to concerns related to the sustainability of Bow River summer flows.
- The combination of reduced water supplies and increased water demands may have considerable adverse effects on the already impacted aquatic ecosystem of the SSRB.

# 4.0 HISTORICAL, CURRENT AND FUTURE WATER DEMANDS

## 4.1 Introduction

In Alberta's portion of the South Saskatchewan River Basin, water is used for a variety of purposes to sustain the economy, quality of life and environmental values. Climate change has the potential to impact the amount and quality of water available to meet demands. Also, the demands themselves may be impacted. This is of major importance in the SSRB in Alberta because of the historical dependence on water management and use in the semi-arid climate, and also because of concern about impacts on environmental resources.

**Semi-arid** is a climatic term used to describe regions that have average annual precipitation between 250 mm and 500 mm. These regions usually have short grass or scrub vegetation. In Canada, southern Alberta, southern Saskatchewan, and south-western Manitoba are considered to have a semi-arid climate. This area is commonly referred to as the Palliser Triangle, after the British explorer Captain John Palliser. Following his exploration of the area in 1857 to 1859, a period of severe drought in western Canada, Captain Palliser reported that the area was unfit for agricultural settlement (Nemanishen, 1998).

The SSRB in Alberta has an extensive amount of water management infrastructure designed to assist in matching the variable supply with the variable demand. This study will assess the performance of the system considering scenarios of historical and potential future supplies, and current and potential future demands.

The purpose of this chapter is to describe the current and potential future levels of water use and in-stream flow requirements (Water Conservation Objectives and In-stream Objectives) that provide the demand database and constraints for simulation modelling. The assessment will focus on surface water uses that impact the main river systems, particularly in low-runoff years when there are likely to be water deficits. Modelling will identify issues related to water supply and demand that will set the stage for identification and assessment of adjustments or adaptation strategies intended to improve water supply security.

This chapter utilizes data from Technical Memoranda No. 2A: Urban and Rural Domestic Water Demand, and No. 2B: Non-municipal Water Uses, both of which were prepared as part of this study (Volume 2). The two technical memoranda drew heavily on a recent study of actual water uses throughout Alberta, completed under the Water for Life program (AMEC 2007). Recognizing that the demand database in this study will be used for simulation modelling, this current study differs from the 2007 study in that an attempt was made to exclude projects that would not affect flow in the mainstem rivers. For instance, projects in areas that rarely contribute to mainstem flows, or are in closed sub-basins such as Pakowki Lake, were excluded from the analysis. Also, actual recorded demands were used for municipal projects, and Alberta Agriculture's estimated demands were used for private irrigation projects. Both the 2007 study and this current study use recorded demands for irrigation districts.

Terminologies used in this chapter and elsewhere in the report are defined as follows:

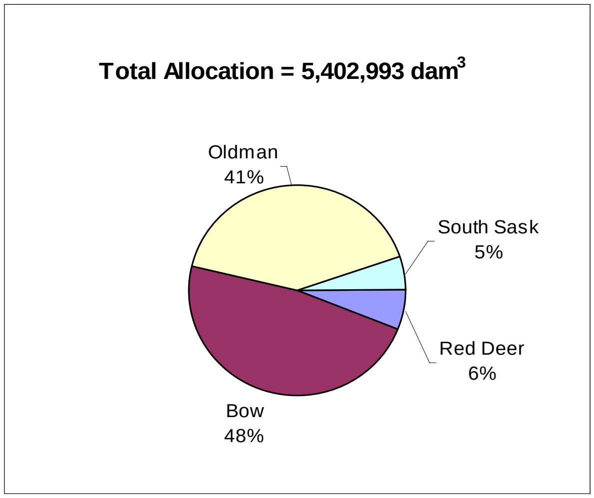
- **Water Allocation** – The maximum amount of water that a licensee is entitled to divert for uses set out in a licence under the *Water Act.* The allocation is an enforceable quantity generally reflecting the maximum annual amount that the licensee intends to divert during the licensing period. It includes consumptive use, losses and return flows.

- **Water Consumption, Losses and Return Flow** – These are unenforceable estimated amounts defined in a licence. They reflect the intent of the applicant at the time the licence application is made. Consumption is the amount of water used for the applicant's project. It is not available for re-use by others. Losses refers to water that is diverted and lost due to evaporation, seepage or other means that are not beneficial to the applicant. The lost water is not available for immediate re-use, although it generally remains a component of the hydrologic cycle. Return flow is water returned to the environment that is available for re-use by others. Typical return flows in the SSRB are treated wastewaters from municipalities or industries, irrigation operational surpluses or runoff from irrigated fields, and returns of industrial cooling waters.
- **Licensed Use** – Water use based on information provided in the licence. Licensed use is equal to Consumption plus Losses, or Allocation minus Return Flow (which will give the same value). Licensed use is usually larger than actual use because the full allocation is not required in most years. However, licensed use can be less than actual use if return flows are less than the estimated licensed amounts, or losses are larger than the licensed amounts.
- **Withdrawal or Diversion** – The impoundment, storage, consumption or removal of water in a manner that reduces the amount of water in the source. All or some of the withdrawal or diversion may be returned to the source at a later date and at a different location.
- **Actual Use** – Actual Withdrawals minus Return Flows determined by direct monitoring of projects or a sample of projects in specific activity categories. If the sample is large enough to establish a relationship between actual use and licensed use, the relationship is applied to all licences in the category. Actual water use reflects the fact that the licensee may not always withdraw the full entitlement, and return flow and losses may differ from the amounts recorded in the licence. In this study, if no information on actual use is available, actual use is assumed to equal licensed use.

## 4.2 Surface Water Allocations

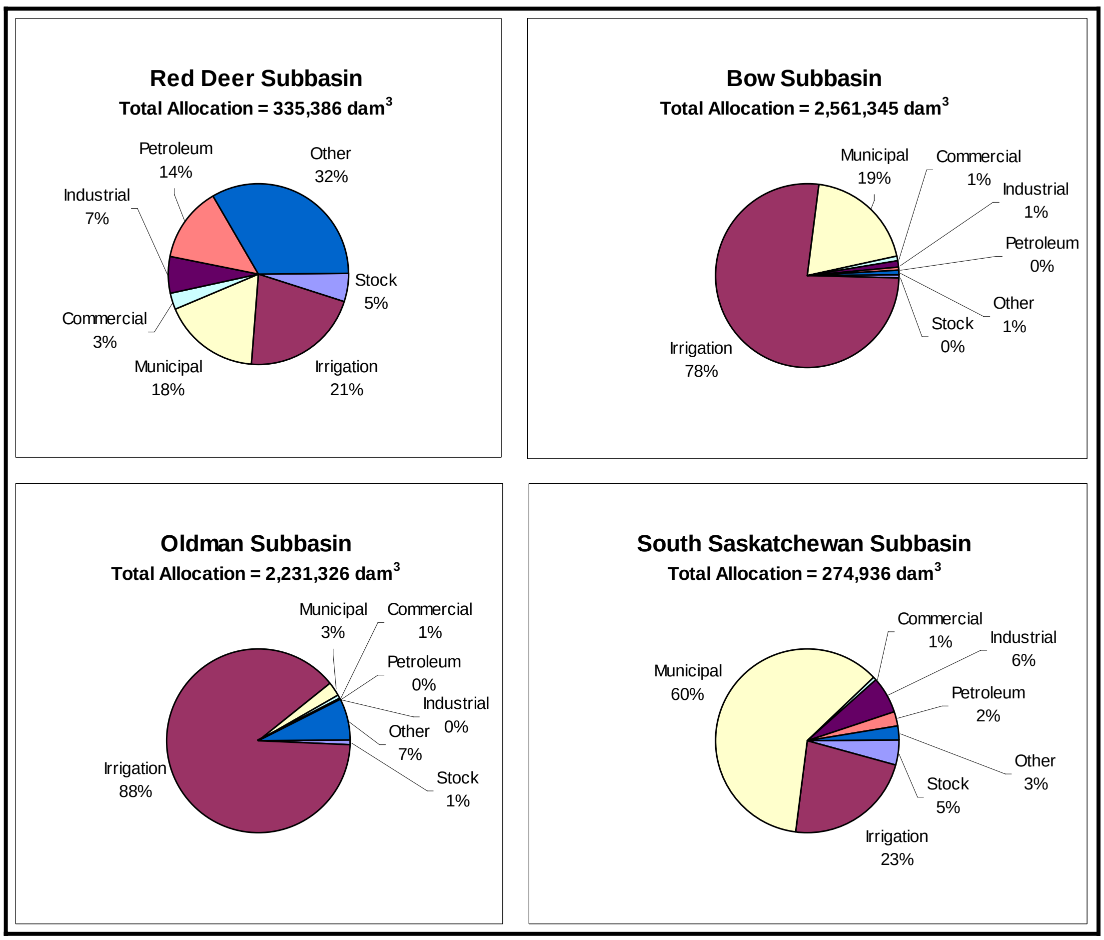
Water Act licences define the locations and purposes of water management projects, and provide an indication of the magnitude of water use. A review of water licences is a valuable first step in addressing water demands. This study draws on the Water for Life study (AMEC, 2007) for this information. **Figure 4.1** shows the distribution of allocations among the four sub-basins of the SSRB. A total of 5.4 million dam$^3$ of surface water has been allocated in the SSRB. The Bow and Oldman Sub-basins have by far the highest allocations, primarily related to extensive irrigation development.

**Figure 4.2** shows the distribution of allocations by purpose within each of the four sub-basins. The Red Deer Sub-basin has significant allocations for a range of purposes, with irrigation, municipal petroleum and other water-use sectors dominant. Irrigation dominates allocations in the Bow and Oldman Sub-basins. The largest allocation in the South Saskatchewan Sub-basin is for municipal purposes, a large portion of which is for cooling purposes at the city-owned Medicine Hat power plant.




Source: AMEC 2007

**Figure 4.1 Sub-basin Distribution of Surface Water Allocations in the SSRB**




Source: AMEC, 2007

**Figure 4.2 Purpose Distributions of Surface Water Allocations in the Four Sub-basins of the SSRB**

## 4.3 Current and Projected Population

Population is a key indicator of some types of water use, particularly municipal and rural domestic use. Municipal decision makers usually make population projections in order to plan for land and infrastructure requirements. Provision of water supplies sufficient in quantity and quality is an important consideration. For this study, the current populations were based on the 2006 StatsCan census (Statistics Canada, 2008), Alberta Municipal Affairs Community Profiles (Alberta Municipal Affairs, 2007) and communication with individual municipalities. Population projections have been made to year 2030.

Population projections are typically based on trends in fertility, mortality and migration rates to the subject area. Projections for each of the four sub-basins were made using two independent methods (AMEC, 2008B). First, projections were made using growth rates for individual urban and rural municipalities determined from census data, recent regional planning studies, general municipal plans, or other planning documents prepared for municipalities. Second, projections for each sub-basin as a whole were made based on Alberta Health and Wellness (AHW) projections (AHW, 2007). The two independent estimates for the sub-basins were compared to determine the degree of similarity.

Current (2006) and projected population, so determined, is summarized in **Table 4.1**. The total populations for the Bow, Oldman, and South Saskatchewan River Sub-basins, based on census data and municipal planning studies, are within 10% of those projected using the Alberta Health Region growth rates. The degree of similarity validates the methods used for projecting the populations to the Year 2030. In the Red Deer Sub-basin, the projection based on planning studies is about 30% higher than that based on the AHW data. The dissimilarity observed in the Red Deer River Sub-basin is primarily due to recent high growth rates along the Edmonton-Calgary corridor and methodology used for some municipalities in projections for the future. This methodology is discussed in the Red Deer River Basin Municipal Water Needs Study, TM No. 1 (Associated Engineering, 2007).

Recognizing that municipal population projections are intended for land and infrastructure planning, high-side projections may be logical and justified considering the consequences of underestimating population and inadequate preparations for growth. It was decided to accept the municipal growth rate projections to 2030 in all four sub-basins for the purposes of this study.

The SSRB is highly urbanized with about 88.8% of the population living in urban centers (cities, towns and villages). Approximately 10.5% of the population lives in rural areas, and an additional 0.7% live on First Nation Reserves.

The distribution of population among the four sub-basins and the population densities are shown in **Figure 4.3**. The Bow River Sub-basin has by far the highest population and population density, because of Calgary's large population. The South Saskatchewan Sub-basin has the lowest population. The Red Deer, Oldman, and South Saskatchewan Sub-basins have similar population densities.

**TABLE 4.1**
**Urban, Rural and First Nation Reserves Population for 2006 and Projections**

| Sub-basin | | Population Based on Census Data and Municipal Growth Rate Projections | | | Based on AHW Growth Rates to 2030 |
|---|---|---|---|---|---|
| | | 2006 Population | Growth Rate | 2030 Population | |
| **Red Deer River Sub-basin** | **Urban** | 172,598 | 2.76% | 331,912 | 234,539 |
| | **Rural** | 83,508 | 1.59% | 121,993 | 113,476 |
| | **TOTAL** | 256,106 | | 453,905 | 348,015 |
| **Bow River Sub-basin** | **Urban** | 1,107,733 | 2.58% | 1,720,748 | 1,623,427 |
| | **Rural** | 43,985 | 1.04% | 85,687 | 63,622 |
| | **Reserves** | 5,666 | 1.70% | 13,315 | 11,194 |
| | **TOTAL** | 1,157,384 | | 1,819,751 | 1,698,243 |
| **Oldman River Sub-basin** | **Urban** | 126,207 | 0.77% | 175,838 | 151,338 |
| | **Rural** | 35,699 | 0.40% | 41,833 | 44,395 |
| | **Reserves** | 5,477 | 0.00% | 5,477 | 6,475 |
| | **TOTAL** | 167,383 | | 223,148 | 202,207 |
| **South Sask. Sub-basin** | **Urban** | 64,407 | 1.18% | 87,904 | 86,779 |
| | **Rural** | 7,130 | 0.23% | 9,331 | 9,578 |
| | **TOTAL** | 71,537 | | 97,235 | 96,356 |
| **South Sask. Basin** | **TOTAL** | 1,652,410 | 1.90% | 2,594,039 | 2,344,821 |

Notes: AHW = Alberta Health and Wellness; Reserves = First Nations Reserves.

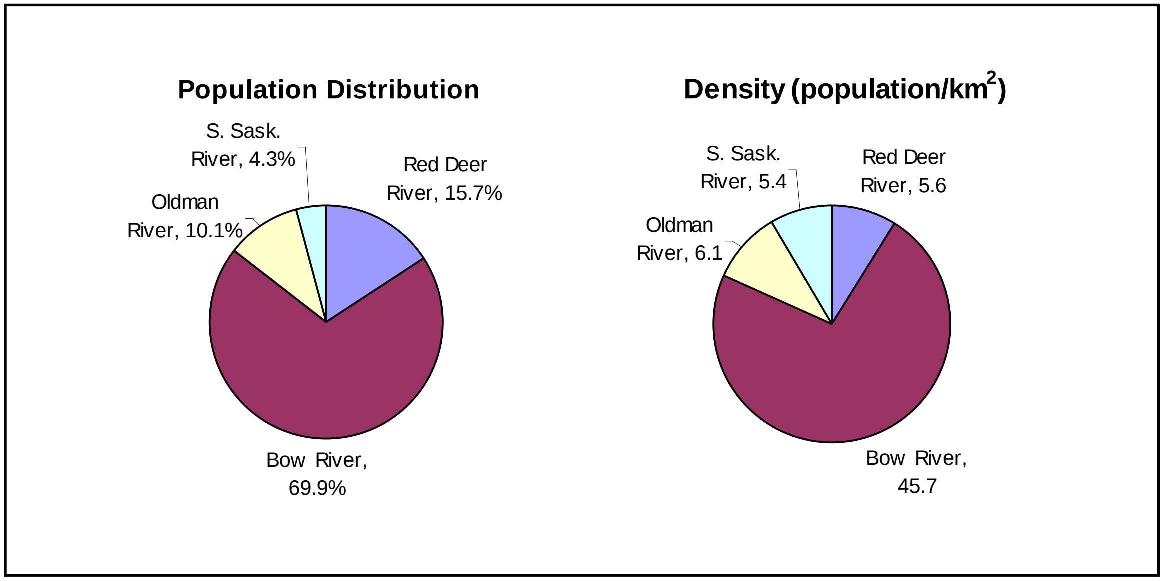



**Figure 4.3 Population and Density Distribution Among Sub-basins**

## 4.4 Municipal Water Demand

### 4.4.1 Current Municipal Surface Water Demands

**Municipal use:** Water use by cities, towns, villages and summer villages supplied by a municipal distribution system or a regional water supply commission. It includes industrial, commercial and institutional uses. For example, about 30% of Calgary's municipal use is for such purposes.

**Rural domestic use:** Household and outside watering uses occurring outside of urban municipal boundaries, usually supplied by individual systems or water co-ops. Groundwater is a primary source for rural domestic use, although it is not always available in suitable quantity and quality.

Current (2006) water withdrawals for communities in the basin, including both surface- and ground-water sources, were obtained from the communities themselves or from Alberta Environment Water Use Reports. The data include all domestic, commercial, institutional and industrial uses within the communities. The 2006 average per capita withdrawals were computed based on the withdrawal volumes and populations. **Table 4.2** summarizes results for each sub-basin. Average per capita use in Alberta and Canada are included for comparison purposes. The average 2006 withdrawal for all communities in the SSRB was computed to be 493 litres per capita-day (L/c-d). The 2006 average per capita withdrawal for the Red Deer River Sub-basin is considerably less than the 2001 overall water use average for Alberta and Canada published by Environment Canada (2004). The Bow and the Oldman River Sub-basins are between the Alberta and Canada per capita withdrawals and the South Saskatchewan River Sub-basin is somewhat higher than both Alberta and Canada average per capita withdrawals.

**TABLE 4.2**
**Municipal Water Withdrawal Rates Per Capita**

| Sub-basin (2006) | Average Withdrawal (L/c-d) |
|---|---|
| Red Deer River | 426 |
| Bow River | 531 |
| Oldman River | 562 |
| South Saskatchewan River | 670 |
| Alberta (2001) | 519 |
| Canada (2001) | 622 |

Note: Alberta and Canada average withdrawal rates are based on a sample of communities in 2001.

Regional projects have been developed to supply water to both rural and urban users and occasionally across sub-basin boundaries. In addition, Alberta Environment and the 13 irrigation districts within the SSRB own and operate irrigation headworks and conveyance systems to carry water to irrigators and other users in southern Alberta. Forty-seven communities (cities, town, villages and hamlets) within the Bow, Oldman and South Saskatchewan Sub-basins receive water through Alberta Environment or irrigation district works (Irrigation Water Management Study Committee 2002).

The primary source of water for rural domestic users and hamlets is groundwater. However, rural water co-ops supplying surface water to rural residents have become popular in areas where groundwater is limited in quantity and quality. Several water cooperatives are operating in each of the sub-basins. Alberta Environment's water licence database lists the number of surface water co-ops within each sub-basin as follows:

- 9 in the Red Deer River Sub-basin
- 29 in the Bow River Sub-basin
- 21 in the Oldman River Sub-basin
- 6 in the South Saskatchewan River Sub-basin.

Rural domestic use includes household use and lawn and garden watering. There are few records quantifying rural domestic water use in the study area. A per capita use of 350 L/c-d is often used for design of rural water co-ops or regional systems serving rural users and hamlets. In this study, an average withdrawal of 350 L/c-d was assumed for all villages and hamlets with unreported water use volumes.

All municipal and rural domestic water users return flow to the hydrologic cycle in one way or another. Return flow to the environment occurs as direct discharges to the source stream or one of its tributaries, groundwater via a septic field or seepage from a holding pond, or, atmospheric moisture via evaporation or transpiration. For purposes of this study, the return flow of interest is that which is available for downstream re-use in the Red Deer River, the Bow River, the Oldman River, or the South Saskatchewan River in Alberta. This discussion will be restricted to this category of return flows. Thirty-six communities in the SSRB have significant return flows in this category, including six communities that return flows to surface water from groundwater withdrawals. Almost all other communities in the basin have lagoon wastewater treatment systems that either do not discharge, or discharge only once or twice per year to locations on tributaries, and intermittent streams that are distant from the main-stem streams. Most of the treated wastewater would be consumed in evaporation, transpiration, seepage, and stream priming losses prior to reaching the mainstem rivers.

The quantity of return flow can vary substantially from community to community. Some communities with high-water tables return more water than they withdraw due to groundwater seepage into their sewage systems. Others have unrecorded amounts of treated wastewater that is used for waterfowl or irrigation projects. Wastewater lagoons have evaporation and seepage losses that reduce the quantity of flow that is returned to the source stream. For planning purposes, an average of 80% return flow is commonly used for municipal systems. For this study, 80% return flow has been assumed for municipalities with continuous discharge, and 70% for municipalities with lagoons that discharge once or twice per year.

### 4.4.2 Future Municipal Surface Water Demands

Future municipal and rural domestic surface water demands for Year 2030 were estimated primarily based upon population projections and current per capita consumption. The following assumptions were used:

- Continuation of the current trend to alleviate water quantity and quality concerns by converting from ground water to surface water sources for both urban and rural users was assumed. In the Red Deer River Sub-basin, east of Highway 2, 30% of the ground water sources were assumed to have converted to surface water sources by 2030. In all other areas in the SSRB, 15% of the ground water sources were assumed to have switched to surface water sources by 2030. It was assumed that future surface sources would be major rivers (Red Deer, Bow, Oldman and South Saskatchewan) or a major tributary, and there would be insignificant return flow to the mainstem rivers.
- Future water demand projections were based on 2030 population projections and current per capita consumption. Water conservation could significantly reduce future demand.

Current water demand and projected demand for the Year 2030 are summarized in **Table 4.3**.

**TABLE 4.3**
**Current and Projected 2030 Municipal and Rural Domestic Surface Water Allocations and Use in the SSRB**

| | Sub-basin Allocations and Use ($dam^3$) | | | | SSRB Total ($dam^3$) |
|---|---|---|---|---|---|
| | Red Deer | Bow | Oldman | South Sask. | |
| Allocations (AMEC 2007) | 59 234 | 491 192 | 58 425 | 167 503 | 776 354 |
| Licensed Use (AMEC 2007) | 27 449 | 106 298 | 24 389 | 101 120 | 259 256 |
| **Estimated Actual Withdrawals and Use** | | | | | |
| Current Withdrawal | 29 480 | 199 277 | 33 256 | 17 310 | 279 323 |
| Current Actual Use | 12 093 | 43 702 | 8 791 | 3 462 | 68 048 |
| Year 2030 Withdrawal | 59 050 | 307 391 | 47 052 | 24 056 | 437 549 |
| Year 2030 Actual Use | 26 698 | 68 901 | 12 779 | 4 341 | 112 719 |

## 4.5 Irrigation Water Demand

### 4.5.1 Current Irrigation Demand

Irrigation represents the largest demand in the SSRB, considering both the withdrawal from source streams and the actual consumptive use. About 83% of the irrigation demand in the SSRB occurs within the 13 irrigation districts in the basin. Irrigation has a highly variable temporal and spatial demand in southern Alberta, largely dependant on irrigation crop types, and growing season temperature and precipitation. Alberta Agriculture and Rural Development (ARD) has developed an Irrigation District Model (IDM) which is used to determine weekly irrigation crop demand, on-farm losses, irrigation district conveyance losses and return flows for various levels of technology changes and crop mixes. This variable weekly information is input into Alberta Environment's Water Resource Management Model (WRMM) for simulation modelling of supply and demand in the SSRB (Chapter 5: Integration and Analysis).

For the purposes of this study, the average irrigated areas, gross diversions to irrigation districts, and monitored and estimated return flows for 2004 to 2007 are used to represent the current level of demand for the irrigation districts (**Table 4.4**). The gross diversions include a relatively small amount of water that is supplied to non-irrigation users through the works of the irrigation districts. These users include industries, municipalities, domestic and stock water users, recreation, and wildlife projects.

Return flows from irrigation districts are a function of several variables, such as the amount of gravity flood irrigation within the district, the proportion of the conveyance system converted from canals to pipelines, and district density (irrigated area per km of conveyance works). Definitive return flow data are not yet available for all districts, but sufficient monitoring has taken place to provide rough approximations, which are included in **Table 4.4**. A portion of the return flows from 6 of the 13 districts are returned to streams other than the source streams.

Private irrigation projects have been developed in all four sub-basins. These projects are also modelled using variable demand produced by ARD. The irrigated areas are available from the water licence listing. Approximate average annual demands for private projects in each sub-basin are given in Table 4.4. There is little or no return flow from private irrigation projects.

### 4.5.2 Future Irrigation Demand

With regard to future irrigation demand, the Bow, Oldman and South Saskatchewan Sub-basins are closed to new allocations. However, the *Irrigation Districts Act* allows districts to increase their irrigated area provided that expansion is approved by district members. This would allow districts to expand within existing water right allocations with efficiency improvements and more effective water use.

The average district irrigated areas from 2004 to 2007 in the Bow River Sub-basin were 9.5% lower than the district irrigation expansion limits defined for the Bow Sub-basin (239 170 ha) in the *1991 South Saskatchewan Basin Water Allocation Regulation* (now repealed) and 7.3% lower than the limit for the Oldman Sub-basin (296 230 ha). The Irrigation Water Management Study Committee (2002) indicated that a 10% to 20% expansion beyond the expansion limit would be sustainable in the Bow River Sub-basin with improvements in water-use efficiency, reduced return flows and higher crop water applications. Similarly, the Committee stated that a 10% expansion in the Oldman River Sub-basin could be considered. AMEC (2007) felt that an expansion to the 1991 limit would represent a medium-growth scenario, and an expansion of 10% above the 1991 limit would represent a high-growth scenario. For the purposes of this study, two levels of irrigation district expansion were considered for the 2030 irrigation demand:

- Level 1 – expansion to the 1991 Regulation areas of 239 170 ha in the Bow River Sub-basin and 296 230 ha in the Oldman River Sub-basin; and,

- Level 2 – expansion to 20% above the 1991 Regulation area in the Bow River Sub-basin and 10% above the 1991 Regulation area in the Oldman River Sub-basin. For Level 2, the irrigated area in the Bow River Sub-basin is 326 809 ha, and in the Oldman River Sub-basin 388 199 ha.

Future net demands (gross diversions minus return flows) of 391 mm for the Bow Sub-basin districts and 314 mm for the Oldman Sub-basin districts are based on transitions to higher value crops, improved district and on-farm efficiencies, and higher on-farm applications (Irrigation Water Management Study Committee, 2002, Table A-3, Scenario S9). Higher irrigation applications increase crop yields and farm revenues, and improve the ability of producers to withstand occasional irrigation deficits.

With respect to expansion of private irrigation, including field crops, gardens, parks and golf courses, annual growth rates for private irrigation over the past 20 years has been very low at about 0.3% (AMEC, 2007). Projections for the Red Deer River Sub-basin have been made based upon water licence applications for the Special Areas Water Supply Project (SAWSP) and the Acadia Project, and historical trends for private individual agricultural and recreation projects. The SAWSP project would divert 2.5 $m^3/s$ from the Red Deer River west of Stettler for multi-purpose use, including about 3 240 ha (8,000 acres) of sprinkler irrigation (AMEC, 2007A). The Acadia project near the Alberta/Saskatchewan border would irrigate about 10 930 ha. Private irrigation projects are most likely to be developed along valley lands in the lower reaches of the Red Deer River where the growing season's moisture deficit is high and soils are irrigable (Acres, 1988). Park and golf course irrigation is expected to increase at approximately the same rate as population. Demand for private irrigation in the Red Deer and other sub-basins is summarized in **Table 4.4**.

With the closure of the Bow, Oldman and South Saskatchewan Sub-basins, private irrigation expansion will be limited to projects that have been approved for licensing (Highwood/Little Bow and Pine Coulee Projects, the Summerview Project for which water has been reserved, expansion related to First Nation projects, and applications on hand that are approved for licensing). The recently completed Highwood/Little Bow Project has been fully allocated to meet the objective of expanding the irrigation area by 20,000 acres (8 097 ha). The Pine Coulee Project has a target irrigation expansion area of 5 263 ha. At an estimated irrigation application of about 300 mm, the total allocation for full development would be 15 789 $dam^3$. As of early 2008, licences for 8 795 $dam^3$ have been issued [5]. Additional water available for allocation from the project is about 7 000 $dam^3$ or enough to add about 2 330 ha of irrigation. About 13 600 $dam^3$ of Oldman River water has been reserved for irrigation in the area of the Oldman River Dam (Summerview project), sufficient for the irrigation of about 4 500 ha (Government of Alberta, 2007). The Piikani and the Siksika First Nations have a firm or near-firm commitment of 3 200 $dam^3$ each. Most of the committed amount would be used for irrigation[6]. Other private applications on hand may or may not be approved for development depending on water supply performance

[5] Alberta Environment's Licence Viewer: http://ssrb.environment.alberta.ca/licence_viewer.html.
[6] Communication with Alberta Environment's modelling staff.

SSRB Water Supply Study Steering Committee
South Saskatchewan River Basin in Alberta
Water Supply Study
November 2009

## TABLE 4.4
## Current and Projected 2030 Irrigation Water Withdrawals, Return Flows and Use in the SSRB

| Sub-basin | Licence Allocation (dam$^3$) | Current Water Use | | | | Projected 2030 Demand with Level 1 Expansion within Irrigation Districts | | | | Projected 2030 Demand with Level 2 Expansion within Irrigation Districts | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Irrigated Area (ha) | Withdrawal (dam$^3$) | Return Flow (dam$^3$) | Water Use (dam$^3$) | Irrigated Area (ha) | Withdrawal (dam$^3$) | Return Flow (dam$^3$) | Net Water Demand (dam$^3$) | Irrigated Area (ha) | Withdrawal (dam$^3$) | Return Flow (dam$^3$) | Net Water Demand (dam$^3$) |
| **Red Deer River Sub-basin** | | | | | | | | | | | | | |
| Private Projects | 67,400 | 13,972 | 48,900 | - | 48,900 | 16,072 | 56,250 | - | 56,250 | 16,072 | 56,250 | - | 56,250 |
| SAWSP Project | | | | | | 3,240 | 12,900 | - | 12,900 | 3,237 | 12,900 | - | 12,900 |
| Acadia Project | | | | | | 10,926 | 43,700 | - | 43,700 | 10,926 | 43,700 | - | 43,700 |
| **Sub-basin Total** | **67,400** | **13,972** | **48,900** | **-** | **48,900** | **30,238** | **112,850** | **-** | **112,850** | **30,235** | **112,850** | **-** | **112,850** |
| **Bow River Sub-basin** | | | | | | | | | | | | | |
| Irrigation Districts | 1,689,800 | 217,094 | 852,959 | 213,240 | 639,719 | 239,169 | 1,180,514 | 259,713 | 920,801 | 287,003 | 1,398,686 | 293,724 | 1,104,962 |
| Private | 71,300 | 27,806 | 108,480 | - | 108,480 | 27,806 | 108,480 | - | 108,480 | 27,806 | 108,480 | - | 108,480 |
| Siksika Expansion | | | | | | 12,000 | 43,200 | | 43,200 | 12,000 | 43,200 | | 43,200 |
| **Sub-basin Total** | **1,761,100** | **244,900** | **961,439** | **213,240** | **748,199** | **278,975** | **1,332,194** | **259,713** | **1,072,481** | **326,809** | **1,550,366** | **293,724** | **1,256,642** |
| **Oldman River Sub-basin** | | | | | | | | | | | | | |
| Irrigation Districts | 1,756,700 | 276,629 | 849,887 | 152,980 | 696,907 | 300,279 | 1,096,368 | 153,491 | 942,876 | 330,307 | 1,192,143 | 154,979 | 1,037,164 |
| Private | 99,200 | 41,834 | | - | 129,270 | 41,834 | 129,270 | - | 129,270 | 41,834 | 129,270 | - | 129,270 |
| Willow Cr./Pine Coulee | | | | | | 2,330 | 7,000 | - | 7,000 | 2,330 | 7,000 | - | 7,000 |
| Summerview Project | | | | | | 4,500 | 13,600 | | 13,600 | 4,500 | 13,600 | | 13,600 |
| Piikani Expansion | | | | | | 6,192 | 18,600 | | 18,600 | 6,192 | 18,600 | | 18,600 |
| Blood Expansion | | | | | | 3,036 | 9,100 | | 9,100 | 3,036 | 9,100 | | 9,100 |
| **Sub-basin Total** | **1,855,900** | **318,463** | **979,157** | **152,980** | **826,177** | **358,171** | **1,273,938** | **153,491** | **1,120,446** | **388,199** | **1,369,713** | **154,979** | **1,214,734** |
| **South Saskatchewan River Sub-basin** | | | | | | | | | | | | | |
| Irrigation Districts | 3,700 | 324 | 405 | | 405 | 486 | 1,700 | | 1,700 | 486 | 1,700 | | 1,700 |
| Private | | 10,549 | 42,200 | - | 42,200 | 10,549 | 42,200 | - | 42,200 | 10,549 | 42,200 | - | 42,200 |
| **Sub-basin Total** | **3,700** | **10,873** | **42,605** | **-** | **42,605** | **11,035** | **43,900** | **-** | **43,900** | **11,035** | **43,900** | **-** | **43,900** |
| **SSRB Total** | **3,688,100** | **588,208** | **2,032,101** | **366,220** | **1,665,881** | **678,419** | **2,762,881** | **413,204** | **2,349,677** | **756,278** | **3,076,829** | **448,703** | **2,628,126** |

Bow River Sub-basin private includes full development of the Highwood/Little Bow Project and existing irrigation on Siksika First Nations Reserve for both current and future scenarios.
Oldman River Sub-basin private includes existing development on Willow Creek/Pine Coulee Project, and on Blood and Piikani First Nations Reserves.

which is expected to be poor. For purposes of this study, it is assumed that none of these additional applications will proceed to the development stage, either because of non-approval or voluntary withdrawal.

## 4.6 Livestock Current Water Use and Future Demand

Secure sources of good quality water are essential for the livestock industry in the study area. Cow-calf operations and the feedlot industry have the largest livestock water requirement in the basin. Water supplies well distributed within grazing lands enable sound range management practices. Feedlots and winter-feeding areas must have ready access to secure water supplies. Common sources of stock water in the study area are wells, dugouts, small stock-water dams on intermittent streams, and the streams themselves. Well-managed use of riparian areas and controlled access to streams is important to maintain healthy streams and riparian vegetation.

Surface water allocations and licensed use for the four sub-basins are summarized in **Table 4.5**. There is no information on actual water uses for the livestock industry in Alberta Environment's water-use database. Based on procedures used in AMEC (2007), estimates of current actual and projected future actual water uses are made for each of the four sub-basins based on the following steps:

1. Determine cattle populations in each basin based on 2001 agricultural census data.
2. Determine actual annual cattle consumption based on cattle population and daily consumption data published by Alberta Agriculture and Rural Development (2001).
3. Determine total livestock consumption based on the ratio of cattle consumption to total livestock consumption defined by AMEC (2007).
4. Determine surface water livestock consumption based on surface/total licensed consumption ratio.
5. Add surface water losses based on losses identified in the licensing database.
6. Estimate 2030 annual demands based on projected growth rates of the cattle industry defined by AMEC (2007) based on research conducted by Alberta Agriculture and Rural Development and the Natural Resources Conservation Board, the agency responsible for controlling expansion of the confined livestock industry. It is assumed that future livestock supplies will have the same surface water/ground water ratio and the same ratio of losses to consumption.

**Table 4.5** summarizes the results of the analysis for each of the four sub-basins. The livestock demands are highest in the Red Deer River Sub-basin, but only slightly higher than the Oldman River Sub-basin. Actual use estimates exceed the licence allocations in the Red Deer Sub-basin. Possible reasons for this are as follows.

- In addition to the allocations, producers can use up to 1.250 $dam^3$/year of water for household use, some of which can be used for livestock (Section 21 of the *Water Act*).
- A riparian landowner (or occupier) may divert up to 6.250 $dam^3$/year of water as an exempted agricultural user (Section 19 of the *Water Act*).

- Some cow-calf operators may move cattle out of the basin for summer grazing, which would reduce the actual demand below what has been defined in this analysis.

The Bow and South Saskatchewan Sub-basin livestock demands are currently about the same. Livestock demand is small in relation to irrigation demand in the Bow, Oldman and South Saskatchewan River Sub-basins, at less than 2.0%. Livestock demand is much more significant in the Red Deer River Sub-basin at 37% of the irrigation demand.

**TABLE 4.5**
**Current and Projected 2030 Livestock**
**Surface Water Allocations and Use in the SSRB**

| | Sub-basin Allocations and Use ($dam^3$) | | | | SSRB Total ($dam^3$) |
|---|---|---|---|---|---|
| | **Red Deer** | **Bow** | **Oldman** | **South Sask** | |
| Current Allocations | 17 085 | 11 272 | 21 176 | 12 497 | 62 030 |
| Current Licensed Use | 17 081 | 10 162 | 21 176 | 12 497 | 60 916 |
| **Estimated Use** | | | | | |
| Current Actual Use | 17 992 | 8 006 | 15 970 | 8 004 | 49 972 |
| Projected 2030 Demand | 33 820 | 15 050 | 30 020 | 11 310 | 90 200 |

## 4.7 Current Commercial Water Use and Projected Demand

Commercial activities account for 3.0% or less of total allocations in the four sub-basins (**Figure 4.2**). The commercial sector includes aggregate washing, food processing, water hauling and other activities. Golf courses, gardening and parks are sometimes included under the commercial sector. They have a similar demand pattern to crop irrigation, and in this study they were considered with crop irrigation under the agricultural sector.

There is no information in Alberta Environment's Water Use Reporting System (WURS) database on actual use for commercial activities. AMEC (2007) assumed that actual use was equal to licensed use. This assumption probably overstates actual use, but the commercial sector accounts for only a very small portion of total water use. For this study, AMEC's water-use estimates minus the irrigation components that were considered with the irrigation sector were adopted.

AMEC used the forecast of Alberta's average long-term economic growth rate of 2.2% to project the growth in all three categories of commercial activities. Current and projected surface water use for the commercial sector is summarized in **Table 4.6**.

**TABLE 4.6**
**Current and Projected 2030 Commercial Sector**
**Surface Water Allocations and Use in the SSRB**

| | Sub-basin Allocations and Use[1] (dam$^3$) | | | | SSRB Total (dam$^3$) |
|---|---|---|---|---|---|
| | **Red Deer** | **Bow** | **Oldman** | **South Sask** | |
| Current Allocations | 1 719 | 7 502 | 8 493 | 743 | 18 457 |
| Current Licensed Use | 1 037 | 7 295 | 4 957 | 743 | 14 032 |
| **Estimated Use** | | | | | |
| Current Actual Use | 1 037 | 7 295 | 4 957 | 743 | 14 032 |
| Projected 2030 Demand | 1 748 | 12 299 | 8 358 | 1 253 | 23 658 |

[1] Excludes golf course, garden and park irrigation.

## 4.8 Current Petroleum Water Use and Projected Demand

The petroleum sector includes gas and petrochemical plant processing, injection for secondary oil recovery and other petroleum activities. This water-use sector represents 15% of allocations in the Red Deer Sub-basin. It is of lesser significance in the Bow, Oldman and South Saskatchewan Sub-basins at 0%, 1% and 3% of total allocations, respectively (**Figure 4.2**).

A detailed review of water use for injection purposes in each of the four sub-basins was conducted in 2005. The review indicated that actual surface water use for this purpose was 1.7% of licensed use in the Red Deer Sub-basin, 10.5% in the Bow Sub-basin, and 9.5% in the Oldman Sub-basin (AMEC, 2007). There are no surface-water allocations for injection purposes in the South Saskatchewan Sub-basin. These ratios are accepted for the purposes of this study.

There is no data on actual water use for other petroleum purposes. Actual water use was assumed to be equal to licensed water use for this activity.

AMEC (2007) projected that future water use for petrochemical plants and other petroleum activities would remain about the same the next 20 years, but water use for injection purposes would decline at a rate consistent with the expected rate of decline of conventional crude in Alberta, which is about 5% per year. For the purposes of this study, future water use to 2030 was projected on the basis of AMEC's rationale.

Current and projected surface water use for the petroleum sector is summarized in **Table 4.7**.

**TABLE 4.7**
**Current and Projected 2030 Petroleum Sector**
**Surface Water Allocations and Use in the SSRB**

| | Sub-basin Allocations and Use ($dam^3$) | | | | SSRB Total ($dam^3$) |
|---|---|---|---|---|---|
| | Red Deer | Bow | Oldman | South Sask | |
| Current Allocations | 46 240 | 9 414 | 4 267 | 6 869 | 66 790 |
| Current Licensed Use | 41 876 | 9 290 | 3 526 | 6 097 | 60 789 |
| **Estimated Use** | | | | | |
| Current Actual Use | 18 108 | 1 244 | 822 | 4 069 | 24 243 |
| Projected 2030 Demand | 17 960 | 671 | 655 | 4 069 | 23 355 |

## 4.9 Current Industrial Water Use and Projected Demand

The industrial sector includes water allocations for cooling, fertilizer plants, mining and other industrial activities that are in addition to such activities that are located within urban areas. (About 30% of Calgary's water use is for industrial, commercial and institutional purposes (CH2M Hill, 2007) Industrial use outside urban areas is a relatively minor surface water use in the SSRB. Licensed water use is dominated by cooling in the Red Deer Sub-basin; fertilizer manufacturing, cooling, and other activities in the Bow Sub-basin and fertilizer manufacturing in the South Saskatchewan Sub-basin. There are no significant licensed surface water uses for industrial purposes in the Oldman Sub-basin.

There is no information in Alberta Environment's WURS database on actual uses for this sector. For the purposes of this analysis, it is assumed that licensees are using the full amount of their licensed water use.

AMEC (2007) projected that there would be no growth in water used for cooling or for fertilizer manufacture for the next 20 years. For the purposes of this study, it is projected that there will be no growth to 2030. Current and projected water use for the Industrial sector is summarized in **Table 4.8**.

**TABLE 4.8**
**Current and Projected 2030 Industrial Sector**
**Surface Water Allocations and Use in the SSRB**

| | Sub-basin Allocations and Use ($dam^3$) | | | | SSRB Total ($dam^3$) |
|---|---|---|---|---|---|
| | Red Deer | Bow | Oldman | South Sask | |
| Current Allocations | 22 210 | 30 312 | 0 | 18 894 | 71 416 |
| Current Licensed Use | 13 929 | 20 137 | 0 | 17 167 | 51 233 |
| **Estimated Actual Use** | | | | | |
| Current Actual Use | 13 929 | 20 137 | 0 | 17 167 | 51 233 |
| Year 2030 Actual Use | 13 929 | 20 137 | 0 | 17 167 | 51 233 |

## 4.10 Current Other Sector Water Use and Projected Demand

The other sector includes water management projects, habitat enhancement projects, and projects designated as “other” by the Water Act director. Allocations for other purposes are significant in the Red Deer and Oldman Sub-basins (**Figure 4.2**).

Water management includes water level stabilization projects and storage development for multi-purpose use. In some cases, the entire capacity of storage reservoirs is included in the allocation. If the stored water is used to meet the needs of other licensed users, only the reservoir losses are considered to be a water management use to avoid double-counting of uses. Flood control projects (dykes, channel improvements, etc.) are included as water management projects, but apart from temporary reservoir storage during high-flow periods or diversions to other streams (uncommon in Alberta), they are generally not water-use projects.

Within the Red Deer River Sub-basin, the water management category includes water level stabilization at Buffalo, Gull and Burnstick Lakes, and 26 Ducks Unlimited Canada projects, and evaporation losses on Glennifer Lake Reservoir. Habitat management projects are almost entirely Ducks Unlimited Canada projects. There is a lack of information on actual diversions and water use for this activity. AMEC has assumed that licensees are using their full licensed use, and that water use will remain constant for the forecast period. The AMEC assumptions have been adopted for the Red Deer and other sub-basins for the purposes of this study. However, in this study projects outside of the effective drainage area, flood control projects, and water management storage capacities have been excluded for reasons listed previously.

Within the Bow River Sub-basin, the water management category includes evaporation losses for the Women’s Coulee, Little Bow and Clear Lake projects, and stabilization requirements for Frank Lake and several Ducks Unlimited Canada projects. Habitat projects are primarily Ducks Unlimited Canada projects.

The water management category in the Oldman Sub-basin includes losses from the St. Mary and Lethbridge Northern Headworks, evaporation from the Oldman River Reservoir, and stabilization of 3 Ducks Unlimited Canada projects.

There are no projects in the Other Sector within the effective drainage area of the South Saskatchewan Sub-basin.

Estimates of current and 2030 water use for the Other Sector are listed in **Table 4.9**.

**TABLE 4.9**
**Current and Projected 2030 "Other" Sector**
**Surface Water Allocations and Use in the SSRB**

| | Sub-basin Allocations and Use (dam³) | | | | SSRB Total (dam³) |
|---|---|---|---|---|---|
| | Red Deer | Bow | Oldman | South Sask | |
| Current Allocations [1] | 111 636 | 32 303 | 151 885 | 8 680 | 304 504 |
| Current Licensed Use [1] | 61 687 | 12 100 | 140 068 | 7 021 | 220 876 |
| **Estimated Actual Use** | | | | | |
| Current Actual Use [2] | 55 616 | 8 487 | 43 629 | 0 | 107 732 |
| Year 2030 Actual Use [2] | 55 616 | 8 487 | 43 629 | 0 | 107 732 |

[1] Allocations and licensed uses include all licensed projects within the gross drainage areas.
[2] Actual uses and demands exclude projects outside the effective drainage areas.

## 4.11 Water Conservation Objectives

Phase 2 of the Water Management Plan for the SSRB addressed the need for, and magnitude of, Water Conservation Objectives (WCOs) to protect all or a part of the aquatic environment and other in-stream uses of water in our main river systems. The strategy was to strike a publicly acceptable balance between environmental protection and consumptive use to support economic development and quality of life.

The aquatic environment in many reaches of the mainstem streams in the SSRB have been negatively impacted; particularly the lower reaches of the Bow, Oldman, St. Mary, Belly, Waterton and South Saskatchewan Rivers (Clipperton *et al*., 2003). In these reaches, flow regulation and water diversions have modified river flows to the extent that cottonwood forests have diminished, fish habitat has been reduced and water quality has deteriorated. Clipperton *et al*. (2003) conducted a study to determine the river flows necessary to restore and provide a high level of protection for the aquatic environment. The study considered:

- fish habitat
- riparian vegetation (cottonwood forests)
- water quality
- channel maintenance.

A guiding principle in determining the in-stream flow requirements was flow variability, sometimes referred to as the "natural flow paradigm" (sidebar). Flow variability plays an important role in creating the natural eco-system. The current biological view is that flows that mimic natural variability are a key factor in restoring and protecting the aquatic environment.

The **"natural flow paradigm"** is becoming widely accepted among aquatic scientists and natural resource agencies around the world. Aquatic ecosystems have adapted to long-term variability in flow magnitude, frequency, duration, timing, and rate of change. Maintaining a similar pattern of flow variability is critical to the long-term sustainability and biodiversity of the aquatic and associated eco-systems.

Knowing the in-stream flows necessary for protecting the natural aquatic eco-system, the process for developing WCOs involved an iterative approach whereby scenarios assuming various levels of aquatic protection and consumptive uses were tested using simulation modelling. Modelling output was evaluated by provincial staff, and performance of each scenario in meeting in-stream objectives and consumptive uses were reviewed with four Basin Advisory Committees (BACs) representing the public in each of the four sub-basins. Public meetings were also held throughout the basin. Public involvement was an integral component of the planning process. The combined recommendations of the BACs provided the foundation for the plan[7]. The plan was approved by the Alberta Government in August 2006.

WCOs have now been established in the main river systems of the SSRB. The WCOs vary by river reach and are indexed to natural flow, thus maintaining some of the variability of the natural flow regime. The WCOs for the lowest reaches of the 4 mainstem streams in the basin are provided in **Table 4.10**.

**TABLE 4.10**
**Water Conservation Objectives for Lowest Reaches of Mainstem Rivers in the SSRB in Alberta**

| River | Reach | WCO ($m^3/s$) | Average WCO Volume ($dam^3/yr$) |
|---|---|---|---|
| Red Deer River | Bindloss to Sask Border | Nov–Mar Maximum ($0.45Q_{nat}$ or 16.0)<br>Apr–Oct Maximum ($0.45Q_{nat}$ or 16.0) | 915 580 |
| Bow River | Bassano Dam to Mouth | Maximum ($0.45Q_{nat}$ or 1.1 IO) | 2 066 262 |
| Oldman River | Lethbridge to Mouth | Maximum ($0.45Q_{nat}$ or 1.1 IO) | 1 584 341 |
| South Sask River | Upstream of Sask Border | Maximum (0.45 $Q_{nat}$ or 1.1 IO) | 3 504 579 |

**Notes:**

1. Stated WCOs apply only to the most downstream reaches and affect licence applications received or licences issued after 1 May 2005. The reader should review the SSRB Approved Plan for WCOs in other reaches and in-stream constraints on other licences and applications.
2. $Q_{nat}$ = Natural flow at a hydrometric station that is representative of the flow in the applicable reach.
3. IO = In-stream Objective (Bow, Oldman and South Saskatchewan Rivers) that existed prior to establishing the WCO.

WCOs can be implemented in a number of ways[8]:

- incorporating WCO requirements in reservoir operating plans for the use of stored water;
- specifying conditions on a water allocation licence indicating the flows above which the licensee can divert from a stream. In this regard, water licences issued since 1999 may have a condition allowing back-fitting a WCO condition on the licence, provided that it will not render the licence unusable[9];

[7] Report of the SSRB BACs: http://environment.alberta.ca/documents/BAC_Recommendations.pdf

[8] Alberta Environment Information sheet on Water Conservation Objectives: http://environment.alberta.ca/documents/Infosheet WCOs.pdf

[9] Alberta Environment Fact sheet on Water Conservation Objectives.

- providing guidelines for Alberta Environment water licensing administrators; and,
- guiding decisions related to Crown Reservations of water.

The high level of development in the Bow and Oldman River Sub-basins limits the ability to meet the WCOs in the Bow, Oldman and South Saskatchewan Rivers. The development supports the economy, culture and quality of life in southern Alberta. In light of government and private sector investment in, and dependence on, water management infrastructure and water use, the SSRB approved plan (AENV. 2006) recommends that,

- all existing licences, renewed licences and transferred licences should retain their original in-stream constraints, rather than be subject to the newly established WCOs;
- operating plans for existing reservoirs should retain their original in-stream flow targets, rather than the WCOs; and,
- In-stream flow targets for new reservoirs developed under the Crown Reservation should be the existing IO plus 10%.

These recommendations apply only to the Bow, Oldman and South Saskatchewan Sub-basins. The Red Deer River Sub-basin is less developed and will have greater success in meeting the WCOs.

### 4.12 Potential Climate Change Impacts on Future Water Demand

The foregoing analysis estimates current water use and projects future water demand based on continuation of historical climatic conditions. Future increases in water demand are the result of population increases and new economic development. Climate change will probably impact unit demand for water irrespective of increases in economic development. Although increases may be at least partially offset by increases in precipitation for instance, increased temperatures may increase demand for summer watering in municipalities to sustain lawns and gardens. Evaporation from open water surfaces (reservoirs and canals) may increase. Livestock requirements will increase with higher temperatures.

Changes in water use for non-irrigation purposes will likely be small in relation to changes in demand for irrigation, since irrigation is the largest water-use sector in the SSRB. A relatively small change in the unit demand for irrigation could have a significant impact on the water balance in the basin. Also, a dryer climate will increase the desire of current dry-land producers to incorporate irrigation into their farming operations. Warmer temperatures and a longer growing season would enhance crop choices and would probably lead to changes in the irrigation cropping patterns to higher-value crops, but not necessarily higher-water demanding crops. Double-cropping may be possible in some areas, which would undoubtedly increase irrigation water demands.

A study conducted for Alberta Agriculture and Rural Development considered the results of four climate scenarios representing potential climate, circa 2050s, in southern Alberta (Marv Anderson and Associates, 2007). In each of the four scenarios, the average annual temperature increased by 3°C and the number of degree-days in excess of 5°C increased by about 50%. The average annual precipitation decreased by about 10% in the driest scenario, and increased by about 15% in the wettest scenario, indicative of the uncertainty in predicting precipitation changes. Anderson (2007) indicated that with this range of outcomes, the unit irrigation demands for cereals, oil seeds, and pulse crops could amount to plus or minus about 6.0%, depending on the precipitation changes. This is a modest change in the irrigation demand, and one that could increase or decrease. The significant issues are changes in crop types, double-cropping, additional cuts on hay crops, and expansion of the irrigated area. It was projected that, with warmer temperatures and a longer growing season, the value of irrigation will increase, which will increase the number of producers and the area of land that would benefit from irrigation development (Marv Anderson and Associates, 2007).

The potential impact of climate change on irrigation crop demand will be discussed further in Chapter 5.

## 4.13 Summary of Findings and Discussions of Results

1. The licensed allocation for projects considered in this study totalled 4 987 700 $dam^3$, which is about 8% lower than the allocations considered for the entire basin in AMEC's 2007 study (**Figure 4.1**). A summary of estimated current and projected future surface water use for each sub-basin in the South Saskatchewan River Basin, and for each water-use sector is provided in **Table 4.11**. Current actual surface water use in the SSRB is estimated to be about 1 981 000 $dam^3$. By 2030, surface water demand is expected to increase by as much as 57% to 3 037 000 $dam^3$, assuming Level 2 irrigation district expansion and no increase in demand due to climate change.
2. Irrigation is the highest water-use sector in the South Saskatchewan River Basin, with 84% of the total current water use (**Figure 4.4**). Irrigation demand could increase to 86% by 2030, assuming Level 2 expansion within irrigation districts. The distribution of water use by other purpose sectors is expected to be essentially unchanged during the next 25 years. Potential irrigation expansions in the SSRB include:
    - the Acadia and the Special Areas Water Supply projects in the Red Deer River Sub-basin;
    - the Siksika First Nation's project in the Bow River Sub-basin;
    - an estimated 10% to 32% expansion in district irrigated area in the Bow River Sub-basin;
    - the Piikani First Nation, Blood First Nation, Summerview and Pine Coulee projects in the Oldman Sub-basin; and,
    - an estimated 8% to 19% expansion in district irrigated area in the Oldman River Sub-basin.
3. Of the total current water use in the SSRB, the Oldman River Sub-basin has the highest percentage (47%) among the four sub-basins, followed by the Bow (41%), Red Deer (8%), and South Saskatchewan (4%) Sub-basins (**Figure 4.5**). By 2030, the Bow Sub-basin could increase its share from 41% to 45%. The Oldman's share may decrease by 4%, while the Red Deer and South Saskatchewan remain about the same.

SSRB Water Supply Study Steering Committee
South Saskatchewan River Basin in Alberta
Water Supply Study
November 2009

# TABLE 4.11
## Summary of Current Surface Water Use and Projected Future Demands in the South Saskatchewan River Basin in Alberta

| Water Use Sector | Estimates of Actual 2006 Use and Projected 2030 Demand in the Subbasins (dam$^3$)[1] | | | | | | | | | | Total Demands in the South Saskatchewan River Basin (dam$^3$) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Red Deer | | Bow | | | Oldman | | | South Saskatchewan | | | | |
| | 2006 | 2030 | 2006 | 2030 Level 1 | 2030 Level 2 | 2006 | 2030 Level 1 | 2030 Level 2 | 2006 | 2030 | 2006 | 2030 Level 1 | 2030 Level 2 |
| **Municipal** | | | | | | | | | | | | | |
| -- Urban Withdrawal | 29,480 | 59,050 | 199,277 | 307,391 | 307,391 | 33,256 | 47,052 | 47,053 | 17,310 | 24,056 | 279,323 | 437,549 | 437,549 |
| -- Urban (Net) Use | 12,093 | 26,698 | 43,702 | 68,901 | 68,901 | 8,791 | 12,779 | 12,779 | 3,462 | 4,341 | 68,048 | 112,719 | 112,719 |
| | | | | | | | | | | | | | |
| **Agriculture** | | | | | | | | | | | | | |
| -- Irrigation Withdrawal | 48,900 | 112,850 | 961,439 | 1,332,190 | 1,550,366 | 979,160 | 1,273,940 | 1,369,710 | 42,605 | 43,900 | 1,983,204 | 2,762,880 | 3,076,826 |
| -- Irrigation (Net) Use | 48,900 | 112,850 | 748,200 | 1,072,480 | 1,256,640 | 826,180 | 1,120,450 | 1,214,730 | 42,605 | 43,900 | 1,665,885 | 2,349,680 | 2,628,120 |
| -- Livestock | 17,992 | 33,820 | 8,006 | 15,050 | 15,050 | 15,970 | 30,020 | 30,020 | 8,004 | 11,310 | 49,972 | 90,200 | 90,200 |
| | | | | | | | | | | | | | |
| **Commercial** | 1,037 | 1,748 | 7,295 | 12,299 | 12,299 | 4,957 | 8,358 | 8,358 | 743 | 1,253 | 14,032 | 23,658 | 23,658 |
| | | | | | | | | | | | | | |
| **Petroleum** | 18,108 | 17,960 | 1,244 | 671 | 671 | 822 | 655 | 655 | 4,069 | 4,069 | 24,243 | 23,355 | 23,355 |
| | | | | | | | | | | | | | |
| **Industrial** | 13,929 | 13,929 | 20,137 | 20,137 | 20,137 | 0 | 0 | 0 | 17,167 | 17,167 | 51,233 | 51,233 | 51,233 |
| | | | | | | | | | | | | | |
| **Other** | 55,616 | 55,616 | 8,487 | 8,487 | 8,487 | 43,629 | 43,629 | 43,629 | 0 | 0 | 107,732 | 107,732 | 107,732 |
| **Totals – Net Use** | **167,675** | **262,621** | **837,071** | **1,198,025** | **1,382,185** | **900,349** | **1,186,607** | **1,310,171** | **76,050** | **82,040** | **1,981,145** | **2,758,577** | **3,037,017** |

Notes:
1. Municipal -- Urban Withdrawals and Uses are for urban municipal and regional surface water projects.
2. Urban and Irrigation (Net) Uses equal withdrawals minus return flows. Only municipal return flows to mainstem streams are considered. Some irrigation return flows are to sub-basins adjacent to the source sub-basins.
3. Sub-basin totals are for actual net uses. Withdrawals (yellow highlighting) are not included in totals.

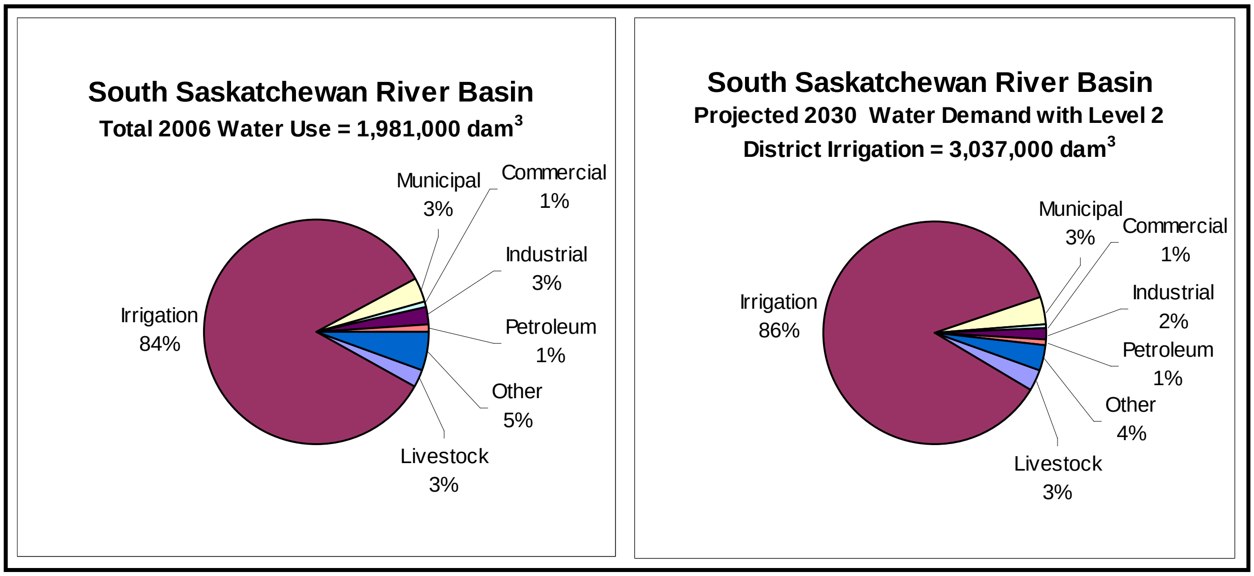



**Figure 4.4 Distribution of Water Use and Projected Demand by Purpose**

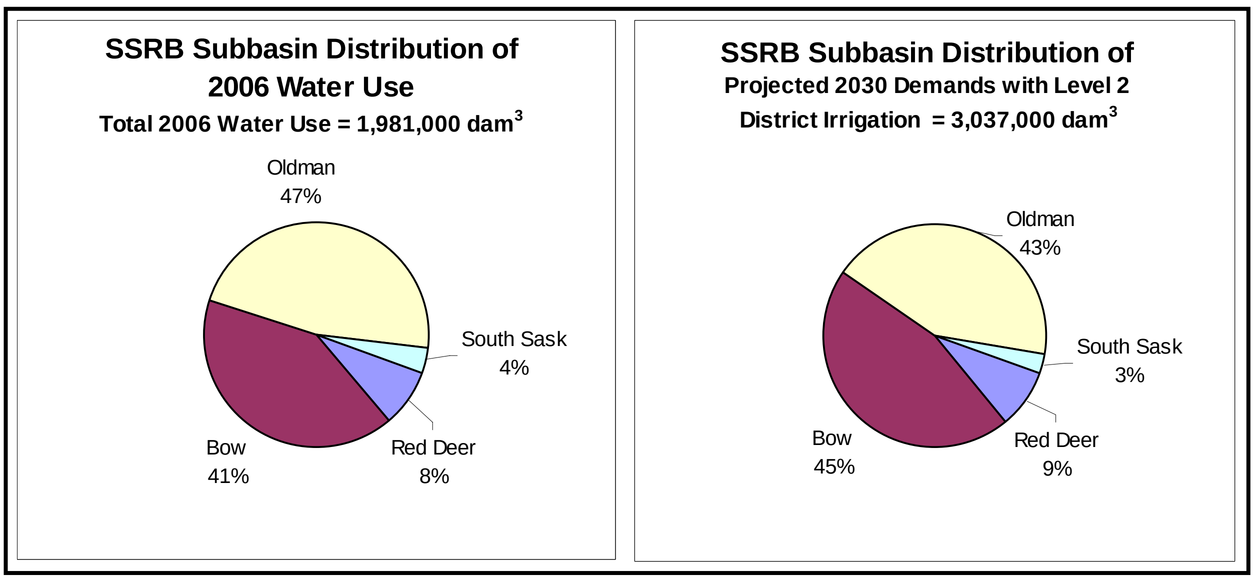
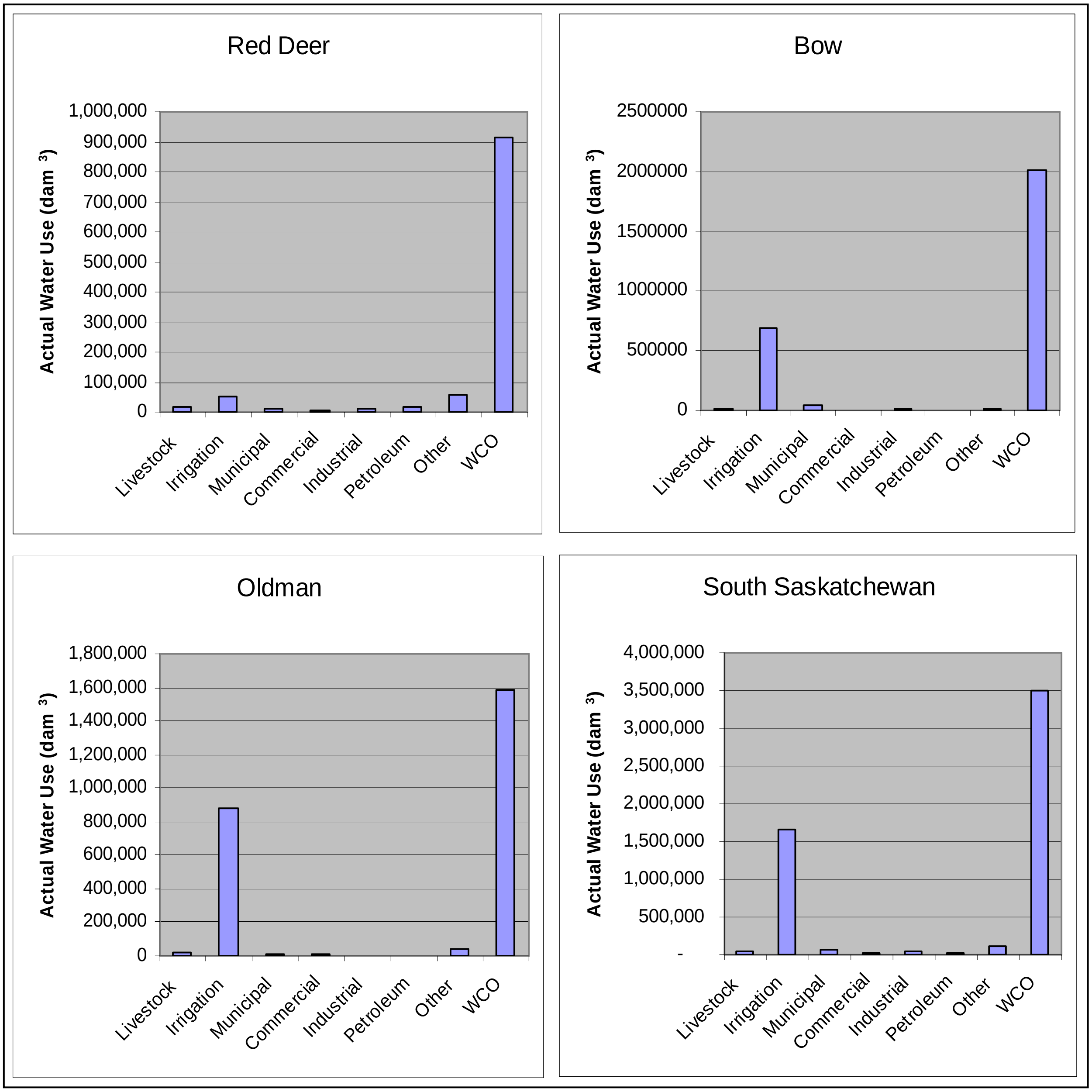



**Figure 4.5 Distribution of Water Use and Projected Demand by Sub-basin**

4. WCOs have now been established in the main river systems of the SSRB. The WCOs vary by river reach and are indexed to natural flow, thus maintaining some of the variability of the natural flow regime. The volume of the WCOs in the most downstream reaches of major streams are provided in **Table 4.10** and shown in relation to consumptive uses in **Figure 4.6**. The current level of allocations and consumptive uses preclude maintaining WCO flows in the Bow, Oldman and South Saskatchewan Rivers.
5. Potential climate change will probably impact unit demands for water irrespective of increases in economic development and population. Changes in water uses for non-irrigation purposes will likely be small in relation to changes in demands for irrigation since irrigation is the largest water-use sector in the SSRB. A relatively small change in the unit demand for irrigation could have a significant impact on the water balance in the basin because irrigation is already a high fraction of existing demands. Also, a dryer climate will increase the desire of current dry-land producers to incorporate irrigation into their farming operations. Warmer temperatures and a longer growing season would enhance crop choices and would probably lead to changes in the irrigation cropping patterns to higher-value crops, but not necessarily higher-water demanding crops.
6. A study conducted for Alberta Agriculture and Food (Marv Anderson and Associates, 2007) considered the results of four climate scenarios representing potential climate, circa 2050s, in southern Alberta. In each of the four scenarios, the average annual temperature increased by 3°C and the number of degree-days in excess of 5°C increased by about 50%. The average annual precipitation decreased by about 10% in the driest scenario, and increased by about 15% in the wettest scenario. Marv Anderson and Associates (2007) indicated that with this range of outcomes, the unit irrigation demands for cereals, oil seeds, and pulse crops could amount to plus or minus about 6.0%, depending on the precipitation changes.




Notes:

1. WCO flow requirements are for Red Deer River downstream of Bindloss, Bow River downstream of Bassano Dam, Oldman River downstream of Lethbridge and entire South Saskatchewan River in Alberta. Other reaches in the Red Deer, Bow and Oldman Rivers have different requirements.
2. South Saskatchewan consumptive uses include all uses in the SSRB.
3. See notes in **Table 4.10** for WCO formulas.

**Figure 4.6 Water Requirements to Meet Water Conservation Objectives in Relation to Current Actual Consumptive Use**

# 5.0 INTEGRATION AND ANALYSIS

## 5.1 Introduction

This chapter defines the relationship between water supply and demand throughout the SSRB. How well the water supply and existing infrastructure is capable of meeting current and projected future consumptive and in-stream needs for water will be the primary determining factor used to identify issues within the basin. Simulation modelling is the key analytical tool to explore the relationship between water supply and demand.

This chapter includes a perspective of how changing water supply-demand imbalances will likely impact socio-economic conditions in the SSRB. Also, the potential environmental implications of current and future water supply conditions will be identified and discussed based on historical trends and the results of simulation modelling.

## 5.2 Simulation Modelling

### 5.2.1 Input Data and Assumptions

Simulation modelling assists in identifying and developing an understanding of issues, and provides a basis for a rational discussion of alternative remedial measures. Modelling mathematically determines the performance of a physical system over a sequence of time steps. Inputs to the model include the physical system, which is the configuration of streams, diversions, canals and water management infrastructure (**Figure 5.1**). The physical system is

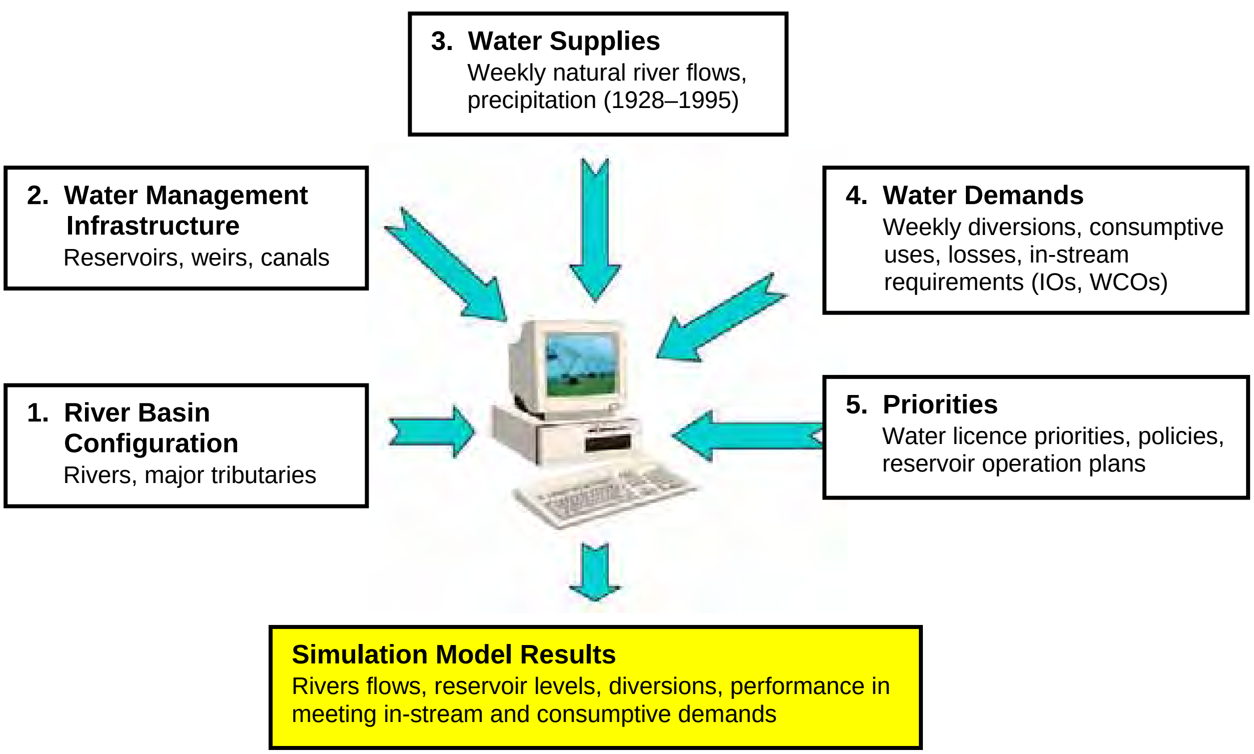



**Figure 5.1 Input Data Required for Simulation Modelling in this Study**

represented in the model as a network of nodes and links. The nodes represent locations in the SSRB where there are reservoirs, stream or canal junctions, river diversions or return flows. Links are streams and canals. Other input data include water supplies, consumptive and in-stream demands, licence priorities, water management policies, and structure characteristics and operating plans.

In this study, AENV's Water Resource Management Model (WRMM) was used as the analytical tool. It is the same model that was used for SSRB water management planning. The use of the model in this study differs from its use in the SSRB plan in the following respects:

- "Actual current uses" and "projected actual demands" to year 2030 were used as demand data (in alternative scenarios) rather than "licensed demands". Actual uses and demands are often lower than licensed demands. This study assesses the actual supply/demand relationship and impact on the source streams, rather than the relationship and impact if licensees utilize their full legal entitlement.
- In-stream Objectives (IOs) and Water Conservation Objectives (WCOs), as specified in the approved SSRB Plan, are used for all scenarios modelled (**Table 5.1**). Licences issued since about 1990 usually have in-stream flow constraints on withdrawals. These limitations may be a constant minimum flow or variable minimum flows indexed to natural flows. Older licences may have no in-stream conditions or very low in-stream conditions attached. Some licences have provisions to retrofit an in-stream flow constraint if and when such a constraint is established. A listing of in-stream constraints used in this study is provided in **Table 5.1**.

**Retrofit provision:** water licences issued since about February 1997 usually contain a condition that indicates that the licence may be amended to include a WCO once one has been established. (Individual licences should be checked to determine if they contain the retrofit provision.)

On amended licences, the licensee would not be permitted to divert when the river flow is less than the WCO.

- A climate change scenario is tested using a recent projection of climate impacts on water supply in the SSRB.

Modelling is intended to reflect reality insofar as possible, but certain approximations are required to accommodate modelling practicality and limitations. Priorities are input to the model through a penalty-point system. Water-use priorities under the *Water Act* are based on the date of a completed licence application. Each licence issued in the SSRB has a unique priority. In water-short years, uses would be cut off in order of junior (most recent projects) to senior priority (older projects). In this study, the licence priorities are respected, although simulation modelling does not address the priority of each individual licence. Water demands of similar priority in relation to in-stream needs (IOs or WCOs) are accumulated, assigned to a node, and treated as a single-demand block. Within the model, deficits to high-priority uses are assigned high penalties; deficits to low-priority uses have lower penalties. The model contains an optimization procedure that minimizes the penalties throughout the entire system in each time step (week) to establish an operational solution for that time step. Licence priorities are respected; in effect, high-priority uses are given preference for meeting their needs.

## TABLE 5.1
## In-stream Flow Requirements Used for Simulation Modelling

| Location within SSRB | WCO or IO [1] | Application of the WCO or IO |
|---|---|---|
| **Red Deer River** | | |
| Dickson Dam to Blindman River confluence | WCO = max ($0.45Q_{nat}$ or 16.0 $m^3/s$)[2] | Applications received or licences issued after 1 May 2005, and earlier licences with retrofit provisions are subject to the WCO. |
| Blindman River confluence to Sask. border | WCO = max ($0.45Q_{nat}$ or 16.0 $m^3/s$) | Applications received or licences issued after 1 May 2005 with withdrawals between Nov to Mar, inclusive. |
| | WCO = max ($0.45Q_{nat}$ or 10.0 $m^3/s$) | Applications received or licences issued after 1 May 2005 with withdrawals between Apr and Oct inclusive, and all existing licences with a retrofit provision. |
| **Bow River, Oldman River, South Saskatchewan River Sub-basins** | | |
| All streams in the sub-basins | WCO = max ($0.45Q_{nat}$ or 1.1IO) | All storage reservoirs constructed under the Crown Reservation and new licences with priority later than 1 May 2005. (Not applicable to operating procedures for existing dams and weirs.) |
| Bow River – Ghost Reservoir to Bassano Dam | IO = 0.8 FRC [3] | Existing licences for which off-stream storage is constructed to reduce deficits. All licences with priority before 1 May 2005. |
| Bow River – Bassano Dam to the mouth | IO = 39.6 $m^3/s$ | All licences except EID licences. |
| | IO = 2.83 $m^3/s$ | EID's 1963 licence (1903 priority). |
| | IO = 11.3 $m^3/s$ | EID's 1998 licence. |
| Highwood River – Women's Coulee to Sheep River confluence | IO = 0.0 $m^3/s$ | All private licences. |
| | IOs within 1994 Operating Guidelines for diversion works.[4] | Applicable to 1.70 $m^3/s$ Women's Coulee diversion and 2.83 $m^3/s$ Little Bow diversion. |
| | IOs within the Highwood Diversion Plan.[4] | Applicable to AENV's 28 March 2000 licence for enlargement of the Little Bow diversion works by 5.66 $m^3/s$. |
| Oldman River – Oldman River Dam to the mouth | IO = max(0.8FRC or T & O protection flows).[5] | Variable flows applicable to 6 reaches along the river. |
| Waterton River at its mouth | IO = 2.27 $m^3/s$ | Downstream of Waterton River Dam. |
| Belly River at its mouth | IO = 0.93 $m^3/s$ | Downstream of the Belly River Diversion. |
| St. Mary River at its mouth | IO = 2.75 $m^3/s$ | Downstream of St. Mary River Dam. |
| Willow Creek – downstream of Pine Coulee confluence. | IO = 0.40 $m^3/s$ | September to June. |
| | IO = 0.80 $m^3/s$ | July and August. |
| South Saskatchewan River | IO = 42.5 $m^3/s$ | Bow/Oldman confluence to Saskatchewan border. |

Table notes on next page.

1. WCOs and IOs listed in the table are based on reports by AENV (2007 and 2003). Only the IOs that were in existence on 1 May 2005 on streams that are modelled in this study are included in the table. Other IOs exist in the SSRB for earlier licences and on other streams. Generally, for streams noted in the table, earlier IOs range in values from zero to the 1 May 2005 IO.
2. max ($0.45Q_{nat}$ or 16.0 $m^3/s$) = the maximum of either 0.45 times $Q_{nat}$ or 16.0 $m^3/s$. $Q_{nat}$ = the natural flow at a nearby hydrometric station.
3. FRC = Fish Rule Curve. The FRC flows are intended to protect habitat for fish species and life stages within the river.
4. Highwood River IOs are outlined by AENV (2008) and Highwood Management Plan Phase 1 Public Advisory Committee (2006).
5. T & O = Temperature and Dissolved Oxygen.

The model computes water deliveries to meet consumptive and in-stream demands in accordance with priorities and considering constraints within the system, such as canal and reservoir outlet capacities. Output from the model includes stream and canal flows, reservoir levels, and performance in meeting in-stream demands and consumptive uses. Subject to assumptions and the limitations of the database and model physical representations, the model output represents the conditions that would have existed if the management scenario had been in place during the 1928 to 1995 historical period of streamflow and climatic conditions that are simulated.

### 5.2.2 Limitations of Simulation Modelling

Simulation modelling is a powerful, but imperfect, analytical tool for assessing water management options in large and complex water resource systems. Realistic supply and demand databases, model representation of the physical systems, and the legal and policy frameworks for water management are important factors in producing meaningful outputs for evaluation. The WRMM has been used for simulating water management in the SSRB for almost 30 years. Many important water management decisions have been made based on its careful use and evaluation of its output. It has continually been improved and made more user-friendly. It is the best available tool for modelling water management in the SSRB at this time.

In addition to limitations of the WRMM noted above, two other important limitations must be noted.

- **Historical Climate Variability**

  This study conducts simulation modelling for the historical period of weather and streamflow conditions from 1928 to 1995. How well the 68-year period of recorded conditions represent the variability in water supply and demand that can be expected in the future Is open to question. Studies of tree rings, lake sediments and other climatic indicators on the Canadian prairies have shed some light on the climate of past centuries (Sauchyn, 1997; Case *et al*., 2003). Researchers have concluded that streamflows were relatively high on the Canadian Prairies during the 20th Century compared with earlier centuries. Sauchyn concludes that,

  > ".... the recent occupants of the Palliser triangle have not yet experienced the extremes of summer precipitation that occurred in the 19th and late-18th centuries, and that could reoccur in the near future."

This conclusion suggests that modelling results using the 1928 to 1995 recorded period could present an overly optimistic picture of long-term water supply and demand.

- **Future Climate Change**

  How will climate change affect the performance of the water management system in the South Saskatchewan River Basin? Was the 2000/2001 drought in southern Alberta a harbinger of what can be expected in the future? Or was it an outlier in the recorded period with a very low probability of re-occurrence, much like the 1995 Oldman flood was on the other side of the scale? No one can say for certain. There is evidence that temperatures are rising (Henderson, 2008). There is less certainty about precipitation, particularly on a regional level.

  The National Water Research Institute assessed the impact of climate change on Streamflow for a 30-year period centered on 2050 (Martz *et al*., 2007). Temperature and precipitation projections of several Global Climate Models and scenarios of economic and societal trends were used in the analyses. Their findings indicated a wide range of potential impacts on streamflow in the SSRB. The climate change condition analyzed in this study will be based on the mean impacts projected by Martz *et al* (2007). However, the uncertainty of precipitation projections and the wide range of potential climate change impacts on streamflow must be kept in mind. The climate change scenario is further discussed and the model output is evaluated in Section 5.5 of this chapter.

## 5.3 The Scenarios

Initially, four scenarios were formulated and modelled to identify water supply and demand issues. These four scenarios are described and evaluated in this chapter. Additional scenarios were simulated to assess various measures for addressing issues. These additional scenarios are described in Chapter 4.

It is essential to clearly understand the differences among the scenarios for proper interpretation of the results. All four scenarios assume existing WCOs and IOs for all scenarios with priorities as established in the SSRB Plan. Existing water management infrastructure in the SSRB is assumed for Scenario 1. Scenarios 2 and 3 assume new infrastructure associated with irrigation expansion projects noted in Section 5.3.2.2. Also, for Scenarios 2 and 3, it is assumed that two planned off-stream storage projects in the WID, Bruce Lake and Langdon Reservoirs, have been constructed and are in operation. Scenarios 1, 2 and 3 assume historical climate and natural streamflow in the basin for the 68-year historical period 1928 to 1995.

### 5.3.1 Scenario 1: Current Conditions

#### 5.3.1.1 Purpose

Scenario 1 simulates the current relationship between water supply and demand and is used as a basis of comparison for scenarios that project changes from current conditions.

#### 5.3.1.2 Water Demands

Scenario 1 assumes the current (2006) level of actual water use within the basin as defined in Chapter 4. It does not include projects that have been applied for but not yet been issued a licence, such as the Special Areas Water Supply Project (SAWSP) or the Acadia Irrigation Project. Nor does it include committed projects for the Piikani and Siksika First Nations. In keeping with licences issued to date, it includes full development of the Highwood/Little Bow Project, but only partial development of the Pine Coulee Project. Unit demands for irrigation (mm) are variable from week to week depending on weather conditions. Irrigation demands assume current levels of on-farm and irrigation district efficiencies and irrigation water applications, which average about 80% of the optimal level of application. The methodology for water demand estimates is provided in Chapter 4.

**On-farm Irrigation Applications –** it has long been known that irrigators in Alberta apply less water than that considered to be optimal for crops grown in Alberta. Monitoring has indicated that they are currently applying about 80 to 83% of optimal. However, applications are gradually increasing. Alberta Agriculture and Rural Development (ARD) predicts that applications will continue to increase to a maximum of 90% of optimal (Irrigation Water Management Study Committee 2002). For this study, simulation modelling assumes 80% of optimal application for current conditions and 90% for future conditions.

**Optimal Level of Application** – the term "optimal irrigation" is used by ARD to refer to an irrigation application schedule based on the objective of keeping available soil moisture in an irrigated field above 70% for centre pivot systems and above 50% for wheel move and surface irrigation systems (Irrigation Water Management Study Committee 2002A).

Municipal demands are non-varying from year to year and are based on 2006 populations and current levels of per capita use. Other non-irrigation demands are recorded or estimated non-varying average annual demands.

### 5.3.2 Scenario 2: Year 2030 Projected Demands and Level 1 Irrigation District Expansion

#### 5.3.2.1 Purpose

Scenario 2 simulates a projected future level of water demand. Scenario 2 is considered to represent a minimal level of irrigation district expansion coupled with private irrigation projects that have been applied for and/or committed to by the Province.

#### 5.3.2.2 Water Demands

Scenario 2 assumes the 2030 level of demand for private irrigation, municipalities and other non-irrigation uses. Municipal use is based on population projections to 2030 and the current level of per capita use.

Irrigation demands are based on:

- the irrigation district expansion areas specified in the South Saskatchewan Basin Water Allocation Regulation (Alberta Environment, 1991);

- implementation of the SAWSP and Acadia Projects in the Red Deer River Sub-basin;
- a small amount of additional private irrigation along the Red Deer River;
- full development of the Pine Coulee Project;
- development of irrigation projects by the Piikani and Siksika First Nations; and,
- irrigation expansion in the Oldman River Reservoir area (often referred to as the Summerview Project) in accord with the Oldman River Basin Water Allocation Order, Regulation 319/2003 (Alberta Environment, 2003).

The irrigation expansion areas in the 1991 Regulation are approximately equal to the assessed areas within the districts (sidebar). The increase over current irrigated areas varies from district to district. Considering all districts, the 1991 Regulation area is about 9% higher than the current actually irrigated area (**Table 5.2**).

Irrigation demands assume future levels of on-farm and irrigation district efficiencies, reduced return flows, and irrigation water applications averaging about 90% of the optimal level of application.

**Assessed Area** – the area of land within irrigation districts for which a water rate has been assessed. It is always larger than the area actually irrigated for several reasons, such as crop rotations, weather conditions, and social / economic circumstances. Also, in some districts, permanent water rights were given for irrigation of small parcels that are not practical to irrigate today. Owners of such parcels may use water for livestock or domestic purposes and continue to pay their water rates to ensure deliveries (Irrigation Water Management Study Committee, 2002).

### 5.3.3 Scenario 3: Year 2030 Projected Demands and Level 2 Irrigation District Expansion

#### 5.3.3.1 Purpose

Scenario 3 simulates a higher level of irrigation expansion within irrigation districts and 2030 level of demand for private irrigation and non-irrigation demands. Scenario 3 represents a level of irrigation expansion deemed to be sustainable and worthy of further consideration by the Irrigation Water Management Study Committee (2002). Sustainability would be dependant on improved efficiencies, reduced return flows, and higher unit on-farm crop water applications.

#### 5.3.3.2 Water Demands

Non-irrigation demands for Scenario 3 are the same as for Scenario 2. Non-district irrigation demands are also the same as in Scenario 2. Irrigation district demands are based on 20% expansion of the irrigated area assumed for Scenario 2 for the three Bow River Sub-basin districts, and 10% expansion above the Scenario 2 area for the nine Oldman River Sub-basin districts (**Table 5.2**).

**TABLE 5.2**
**Irrigation District Irrigated Areas Assumed for Scenarios 1, 2 and 3**

| Sub-Basin | Scenario 1 ha | Scenario 2 | | Scenario 3 | |
|---|---|---|---|---|---|
| | | ha | % increase over Scenario 1 | ha | % increase over Scenario 1 |
| Bow | 217 094 | 239 169 | 10.2 | 287 003 | 32.2 |
| Oldman | 276 629 | 300 279 | 8.5 | 330 307 | 19.4 |
| Total | 493 723 | 539 448 | 9.3 | 617 310 | 25.0 |

As in Scenario 2, irrigation demands in Scenario 3 assume future levels of on-farm and irrigation district efficiencies, reduced return flows, and irrigation water applications averaging about 90% of the optimal level of application.

The climate change scenario is discussed in Section 5.5.

## 5.4 Evaluation of Scenarios

### 5.4.1 Evaluation Parameters and Criteria

The performance of the SSRB water management system during low-flow years and high demand seasons is a key factor in determining the impacts of a water management scenario. Performance is assessed by analyzing output data to determine how well objectives are met, or are not met. The severity, frequency, and duration of failure to meet objectives are the most common measures of performance. Water management is multi-objective. Multiple performance measures are required. Balancing the performance of multiple objectives often requires trade-offs and value judgments. The recently completed SSRB planning program considered the balance between meeting the needs of consumptive users and in-stream environmental values. In-stream environmental values included the aquatic ecosystem, water quality, riparian vegetation and river morphology. Decisions in that regard have been made. This study did not repeat that exercise. Evaluations of model results assess performance in meeting both consumptive needs and in-stream needs that have been established through the SSRB Plan. Simplified tables or graphics that highlight the performance in meeting specific objectives are displayed to assist in evaluating the performance of one management scenario against others.

The frequency and magnitude of deficits to consumptive demands and in-stream requirements have been assessed to provide an indication of performance for each scenario. Sufficient detail has been presented within each of the four sub-basins to provide a basin overview of performance and comparisons among the four sub-basins. Priority distinctions for demands were modelled. Senior demands have no significant in-stream constraints; junior demands were those subject to the newly established WCOs or recent IOs (**Table 5.1**). A purpose and priority breakdown of demands and river reaches that were considered in the evaluation are given in **Table 5.3**. Locations of the reaches evaluated are shown in **Figure 5.2**.

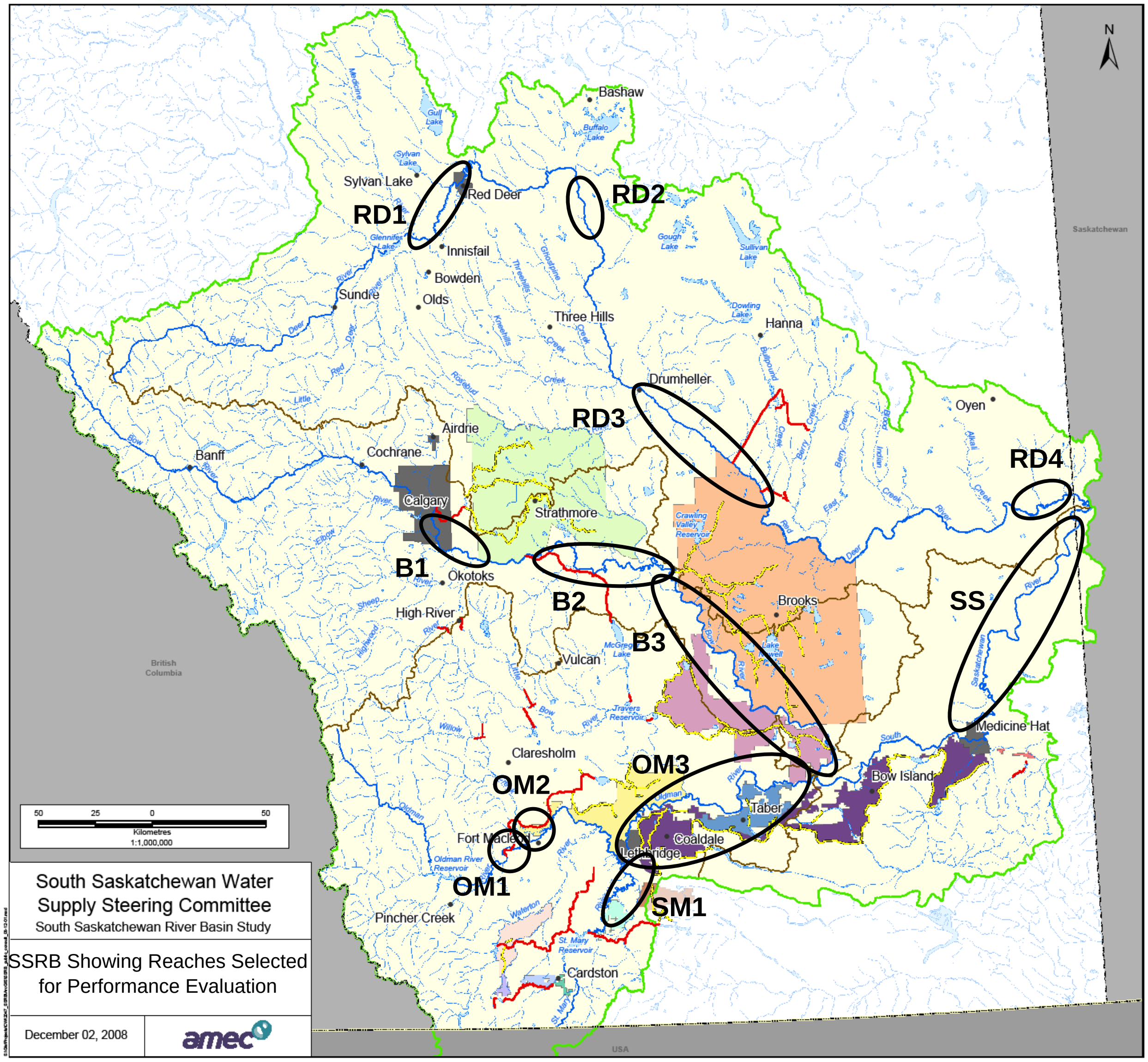
**TABLE 5.3**
**Demands and River Reaches Considered for Scenario Performance Evaluations**

| Sub-basin | Demands | Priority[1] | River Reaches Considered (All Demands and Priorities are Considered Within Each Reach) |
|---|---|---|---|
| Red Deer | WCO<br>Private Irrigation<br>Non-irrigation | <br>Junior (WCO)<br>Junior (WCO) | Medicine R Confluence to Blindman R Confl.<br>Nevis to Delburne<br>Drumheller to Dinosaur Provincial Park<br>Bindloss to the Saskatchewan Border |
| Bow River | WCO<br>District Irrigation<br>Private Irrigation<br>Non-irrigation | <br>Senior and Junior (IO)<br>Junior (IO)<br>Junior (IO) | Elbow R Confluence to Highwood R Confl.<br>Carseland Weir to Bassano Dam<br>Bassano Dam to the Mouth |
| Oldman | WCO<br>District Irrigation<br>Private Irrigation<br>Non-irrigation | <br>Senior and Junior (IO)<br>Junior (IO)<br>Junior (IO) | Oldman R Dam to Pincher Creek Confl.<br>LNID Diversion to Willow Creek Confl.<br>St. Mary R Confluence to the Mouth<br>St Mary R Dam to St Mary R Mouth |
| S. Sask | WCO<br>Private Irrigation<br>Non-irrigation | <br>Junior (IO)<br>Junior (IO) | Medicine Hat to Saskatchewan Border |

[1] WCO or IO designate the in-stream constraint that junior licences are subject to in the sub-basins.

The evaluation of scenarios is primarily comparative rather than absolute. That is, the relative improvement or decline in the performance of the scenarios will be determined, documented and discussed. Scenario 1 represents current (2006) conditions and is a key scenario for comparisons. Absolute performance criteria vary among water-use sectors. For instance, it is generally considered that municipalities and industries require more assured water supplies than recreation or wildlife projects. Irrigators can withstand occasional deficits. For irrigation use, several previous studies have used the criteria that gross diversion deficits greater than 100 mm in more that 10% of the years or in any back-to-back years would cause financial hardship and perhaps insolvency to some irrigation farmers. However, even in this case, the criteria have not been universally accepted by irrigation farmers. Because irrigation is such a dominant water use in the SSRB, reference to these criteria are made in the evaluations. Apart from irrigation, evaluations are comparative among the scenarios.

A discussion of the socio-economic and environmental implications of the scenarios will follow the analyses of deficits.




| Reach Number | Description of Reach | | Reach Number | Description of Reach |
|---|---|---|---|---|
| **Red Deer River** | | | **Oldman River** | |
| RD1 | Medicine R to Blindman R | | OM1 | Oldman Dam to Pincher Cr |
| RD2 | Nevis to Delburne | | OM2 | LNID Weir to Willow Cr |
| RD3 | Drumheller to Dinosaur Prov Park | | OM3 | St Mary R to the Mouth |
| RD4 | Bindloss to Sask Border | | **St. Mary River** | |
| **Bow River** | | | SM1 | St Mary Dam to Mouth |
| B1 | Elbow R to Highwood R | | **South Saskatchewan River** | |
| B2 | Carseland Weir to Bassano Dam | | SS | Medicine Hat to Sask. Border |
| B3 | Bassano Dam to the Mouth | | | |

**Figure 5.2 SSRB Showing River Reaches Selected for Performance Evaluation**

### 5.4.2 Evaluations

The performance in meeting in-stream and consumptive needs in selected reaches throughout the SSRB are summarized in attached **Tables 5-A1** (WCOs), **5-A2** (district irrigation), **5-A3** (private irrigation), **and 5-A4** (non-irrigation demands) located at the end of this chapter. The results are discussed below. Performance is reflected in the magnitude and frequency of deficits in meeting the demands. Graphics provide *typical* characteristics of deficits, primarily focussing on frequency. For additional information, the reader should refer to the tables in the attachment.

#### 5.4.2.1 Red Deer River Sub-Basin

- **Water Conservation Objectives**

Simulation modelling indicates relatively small, infrequent deficits in meeting the WCOs along the Red Deer River (**Figure 5.3**). Performance deteriorates slightly from west to east. For Scenarios 2 and 3, WCO deficits increase only slightly from current conditions. Deficits are similar for Scenarios 2 and 3 since there is little change in demands in the Red Deer River basin between those two scenarios.

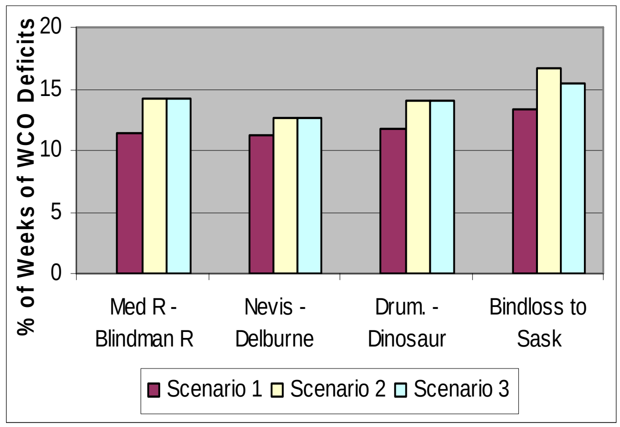



**Figure 5.3 Frequency of WCO Deficits Along the Red Deer River**

Almost all the deficits occur in the winter months (**Figure 5.4**). Deficits occur when winter releases from Dickson Dam and downstream tributary inflows are insufficient to meet the needs of both the senior consumptive licensees (licensees that are not subject to the WCO) and the WCO. The operating plan for Dickson Dam calls for a flow release of 16.0 $m^3/s$ in the winter months, which is the same rate of flow as the minimum WCO. Hence, when withdrawals by senior licensees exceed winter inflows from tributaries such as the Medicine and Little Red Deer Rivers, a WCO deficit occurs.

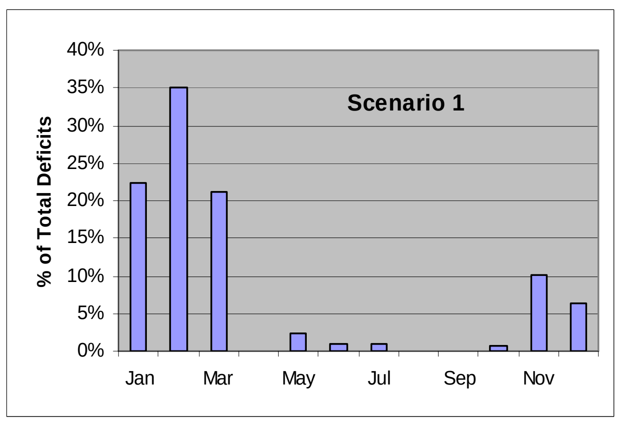



**Figure 5.4 Monthly Distribution of WCO Deficits for the Red Deer River Reach Bindloss to Saskatchewan Border**

- **Irrigation Use**

There are no district irrigation licences issued from the Red Deer River. Under current conditions (Scenario 1), there is only one junior private irrigation licence from the Red Deer River. That licence is in the reach between Medicine and Blindman Rivers. It has no significant deficits (**Table 5-A3**).

The magnitude and frequency of irrigation deficits for the future SAWSP multi-use project (which has an irrigation component) and the Acadia irrigation project would be well within acceptability for Scenarios 2 and 3. Both of these projects are supported by off-stream storage. Simulation modelling indicates that projected demands for additional private irrigation projects along the lower reaches of the Red Deer River would have significant deficits, assuming no additional storage development to support these projects (**Figure 5.5**). The deficits are higher than the informal performance criteria that have been used on past studies (deficits >100 mm in no more that 10% of the years).

There is no significant difference in the performance between Scenarios 2 and 3 for private irrigation projects in the Red Deer River Sub-basin.

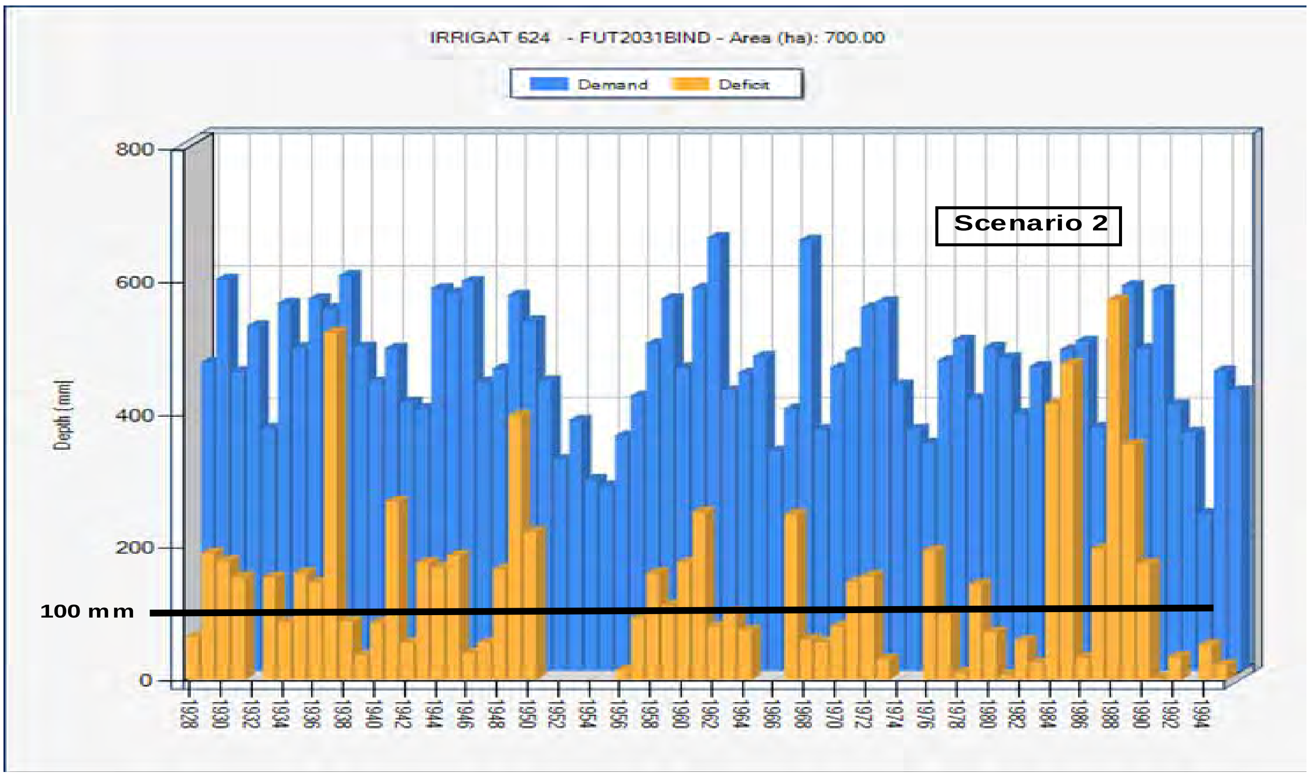



**Figure 5.5 Irrigation Deficits for Future Private Irrigation Along the Lower Reaches of the Red Deer River (Assuming No Additional Storage)**

- **Non-irrigation Consumptive Use**

Junior non-irrigation uses in the Red Deer River Sub-basin include uses for the following junior priority regional municipal water supply projects, each serving several communities and rural users:

- North Red Deer River Regional Water Services Commission
- Highway 12/21 Regional Water Services Commission
- Shirley McClellan Regional Water Services Commission
- Kneehills Regional Water Services Commission

Simulation modelling indicates that junior non-irrigation licences would experience frequent and relatively large deficits for all scenarios (**Table 5-A4**). For example, the annual deficits for junior non-irrigation projects in the Nevis to Delburne reach for Scenario 2 are shown in **Figure 5.6**. Junior licensees would experience deficits during periods when the Red Deer River WCO is not being met. Modelling assumes that during these periods diversions would cease due to the senior priority of the WCO. Deficits would most commonly occur in the winter months; however, in very low runoff years such as 1984 and 1985, summer deficits would be experienced.

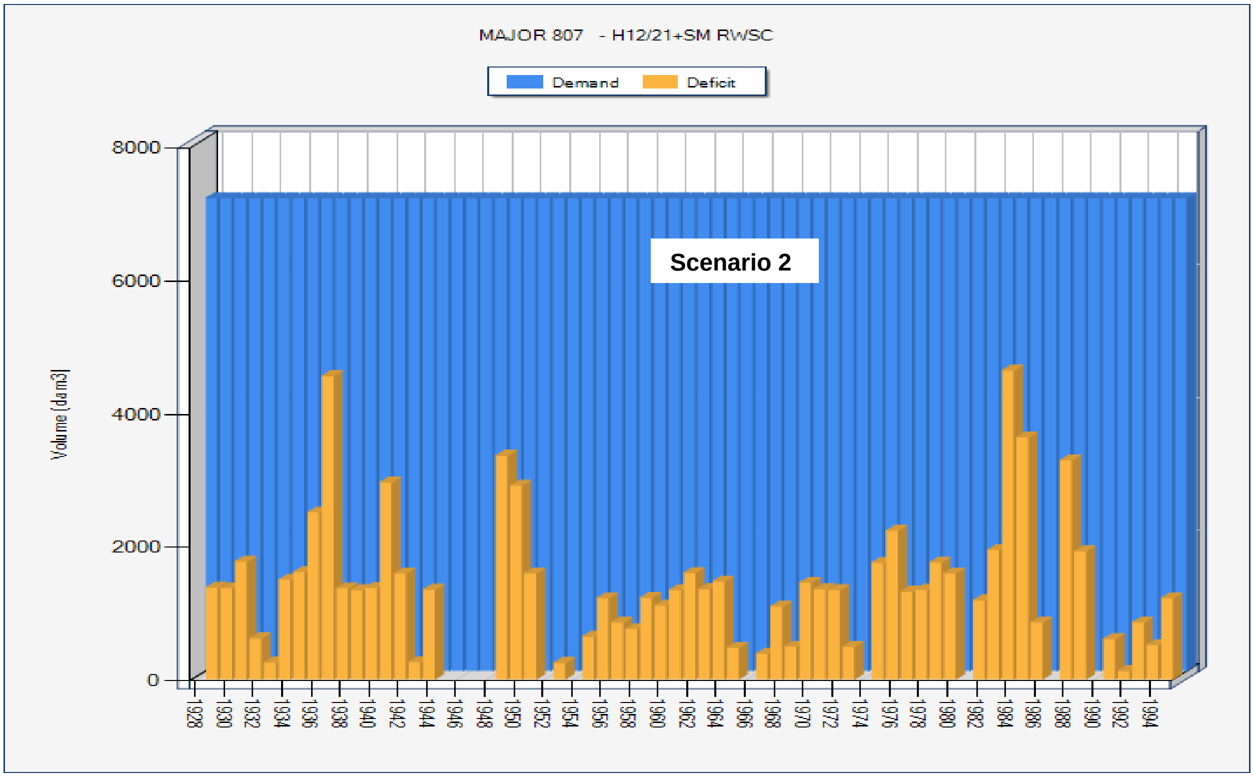



**Figure 5.6 Scenario 2 Non-irrigation Deficits for the Nevis to Delburne Reach of the Red Deer River**

For Scenarios 2 and 3, the frequency and magnitude of deficits increase over current conditions by a small amount (**Figure 5.7**). Deficits in the lower reaches of the Red Deer River are less than in the upper reaches, due to irrigation return flows from the Western and Eastern Irrigation Districts in summer months and higher tributary inflows during winter.

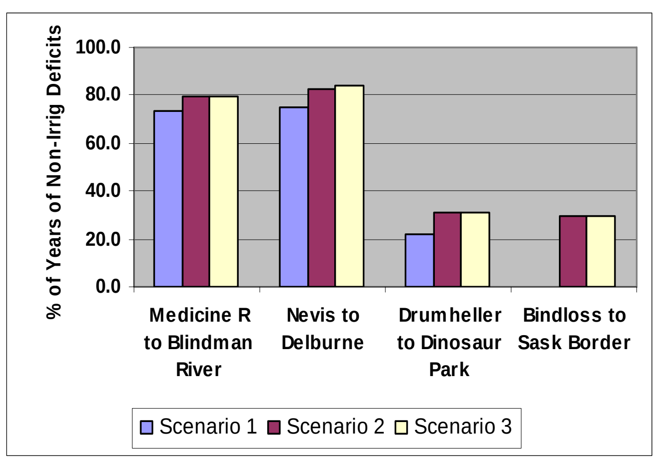



**Figure 5.7 Frequency of Deficits to Junior Non-Irrigation Licences Along the Red Deer River**

- **Summary of Findings of Simulation Modelling for the Red Deer River Basin**

  a) WCO deficits would occur in 10 to 15% of the weeks for all scenarios. WCO deficits are low volume and primarily in winter months. There is little difference in WCO deficits among the three scenarios or among the four reaches evaluated.

  b) SAWSP and Acadia projects have acceptable irrigation performance due to off-stream storage incorporated within the projects. Junior private irrigation not supported by storage will have a high frequency of deficits for all scenarios. There is little difference among the three scenarios.

  c) Junior non-irrigation projects have high frequency of deficits for all scenarios. Lower reaches perform better than upper reaches due to irrigation return flows from the WID and EID. There is little difference among the three scenarios modelled.

### 5.4.2.2 Bow River Sub-basin

- **Water Conservation Objectives**

Simulation modelling indicates relatively minor deficits to the Bow River WCO in the reach extending from the Elbow River confluence to the Highwood River confluence (**Table 5-A1**). Deficits are more significant further downstream (**Figure 5.8**).

In Scenarios 2 and 3, WCO deficits increase from current conditions in the lower reaches of the Bow River. Deficits in the lower two reaches are higher for Scenario 3 than for Scenario 2 due to the increased diversions to irrigation districts. Note that return flows from the three Bow River districts discharge to the Red Deer and Oldman Rivers as well as the Bow River.

For all scenarios, WCO deficits along the Bow River occur primarily during the summer months when irrigation demands are highest (**Figure 5.9**).

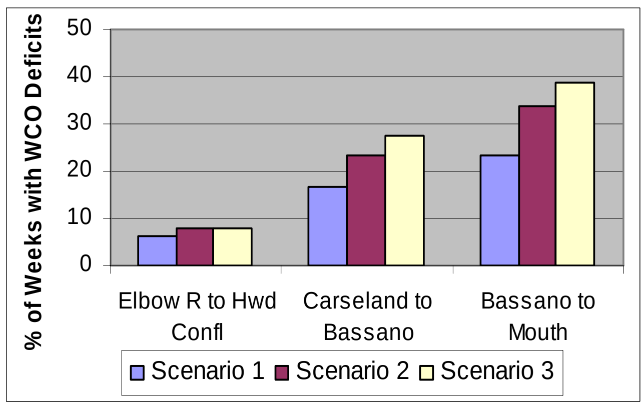



**Figure 5.8 Frequency of WCO Deficits Along the Bow River**

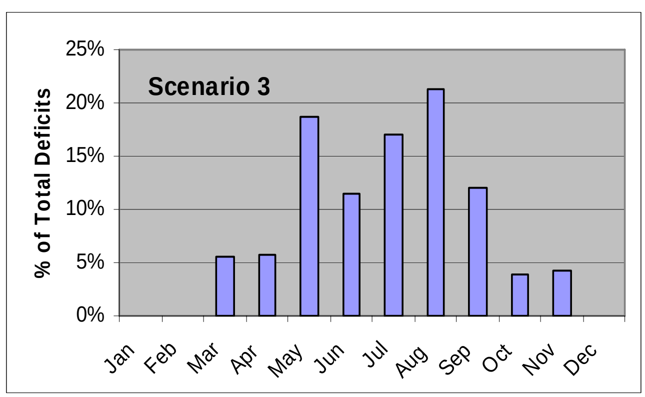



**Figure 5.9 Monthly Distribution of WCO Deficits for the Bow River Reach Bassano Dam to the Mouth**

- **Irrigation Use**

Simulation modelling indicates no significant deficits to district irrigation in any of the three scenarios (**Table 5-A2**). Note that for Scenarios 2 and 3, it is assumed that there will be improvements in irrigation efficiencies and reduced return flows. For Scenarios 2 and 3, it is also assumed that planned off-stream storage projects within the WID would be constructed. These storage projects would be Bruce Reservoir, with live storage of 51 000 $dam^3$, and enlargement of Langdon Reservoir to a live storage of 12 150 $dam^3$.

There is no junior private irrigation in the Bow River reach between Carseland and Bassano. Junior private irrigation in the Bow River reach between the Elbow River and Highwood River confluences performs adequately for Scenarios 1 and 2, but performance is borderline for Scenario 3 using the criteria of deficits >100 mm in no more than 10% of the years (**Figure 5.10**). Using the same criteria, private irrigation downstream of Bassano has just adequate performance in Scenario 1 and inadequate performance in Scenarios 2 and 3. The differences in performance between Scenarios 2 and 3 are minor.

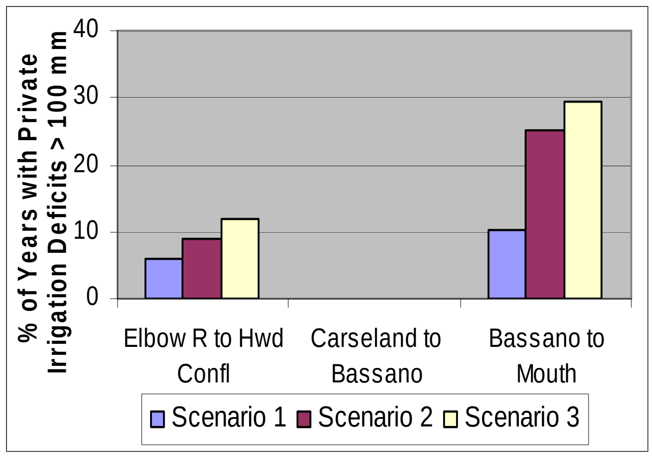



**Figure 5.10 Frequency of Private Irrigation Deficits >100 mm Along the Bow River**

Irrigation expansion on the Siksika First Nation Reserve would perform well for all scenarios.

- **Non-irrigation Consumptive Use**

Junior non-irrigation consumptive use licences perform poorly in all reaches of the Bow River. Performance improves somewhat from upstream to downstream, due to irrigation district return flows (**Figure 5.11**). In the most downstream reach, deficits are higher for Scenarios 2 and 3 than for Scenario 1.

Almost all the deficits would occur in the May to October period. Winter flows on the Bow River are relatively high due to hydropower operations upstream of Calgary.

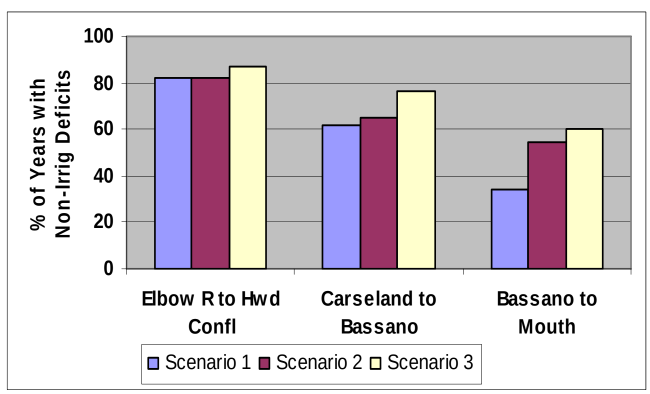



**Figure 5.11 Frequency of Deficits to Non-Irrigation Demand in Reaches Along the Bow River**

- **Summary of Findings of Simulation Modelling for the Bow River Basin**
  a) WCO summer deficits in Bow River reaches downstream of Carseland are high. They increase significantly for Scenarios 2 and 3.
  b) There would be a substantial increase in private irrigation deficits for Scenarios 2 and 3 downstream of Bassano Dam.
  c) There would be high deficits to existing junior non-irrigation licensees in all reaches and for all scenarios. Deficits increase for Scenarios 2 and 3 downstream of Bassano Dam.
  d) District irrigation performs well for all scenarios.

#### 5.4.2.3 Oldman River Sub-basin

- **Water Conservation Objectives**

Simulation modelling for Scenario 1 indicates frequent but minor (in volume) deficits to the WCO in the two reaches upstream of the Willow Creek confluence (**Figure 5.12; Table 5-A1**). The deficit volumes increase significantly in the reach downstream of the St. Mary River confluence. The differences in performance among the three scenarios are minor.

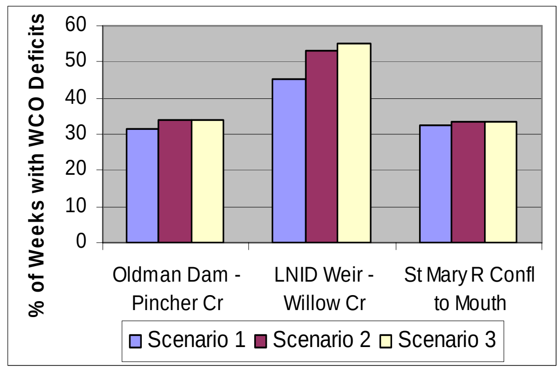



**Figure 5.12 Frequency of WCO Deficits Along the Oldman River**

Almost all the deficits occur in the months of April to August (**Figure 5.13**).

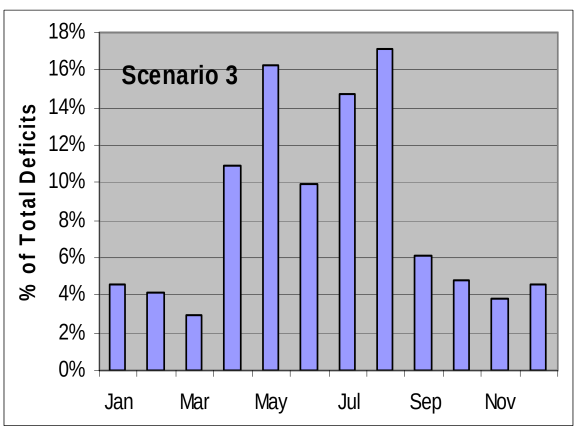



**Figure 5.13 Monthly Distribution of Deficits to the WCO for the Oldman River Reach Downstream of the St. Mary River Confluence**

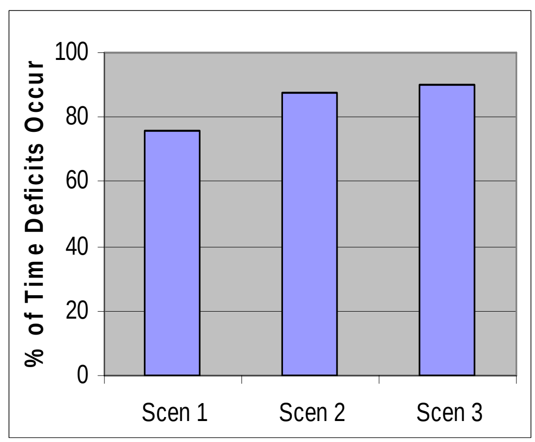



**Figure 5.14 Frequency of WCO Deficits Along the St. Mary River Downstream of St. Mary River Dam**

Modelling indicates poor performance in meeting the St. Mary River WCO downstream of the St. Mary River Dam (**Figure 5.14**). Deficits were more frequent for Scenarios 2 and 3 than for Scenario 1. Deficits in Scenarios 2 and 3 were about equal. Almost all the deficits for the St. Mary River occurred from March to November.

- **Irrigation Use**

Simulation modelling indicates acceptable performance within the Oldman River irrigation districts for all three scenarios (**Table 5-A2**). This conclusion is predicated on improvements in on-farm and district operating efficiencies, and reduced return flows. Scenarios 2 and 3 also included a shift toward higher value crops and increased water applications to increase revenues and improve farm financial performance.

For junior private irrigation, Scenario 1 performance is borderline acceptable for the Oldman River reach between the Oldman River Dam and the confluence with Pincher Creek, unacceptable for the reach between the LNID diversion and the Willow Creek confluence, and borderline acceptable downstream of the St. Mary River confluence (**Figure 5.15**). The improvement in performance in the lower reach compared with the middle reach may be due to return flows from the irrigation districts in the southern tributaries.

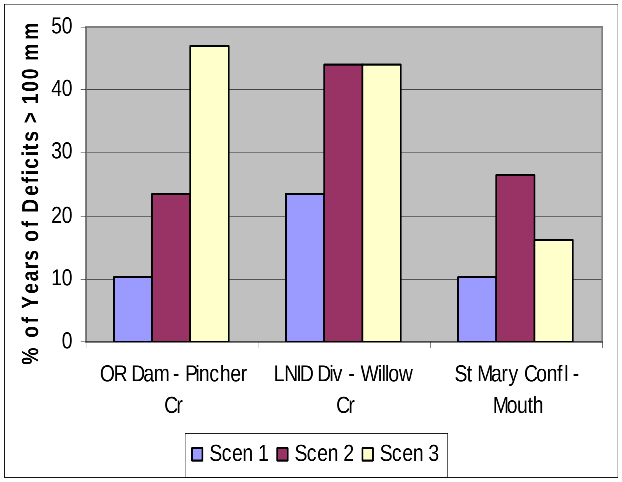



**Figure 5.15 Frequency of Deficits >100 mm for Private Irrigation Projects in Reaches Along the Oldman River**

Compared with Scenario 1, performance is substantially poorer for Scenarios 2 and 3. Scenarios 2 and 3 include irrigation expansion in the area of the Oldman River Dam, in accord with Regulation 319/2003 (Government of Alberta, 2003).

Simulation modelling indicates that a new irrigation project on the Piikani First Nation Reserve would have frequent deficits (**Table 5-A3**).

For the small amount of junior private irrigation along the St. Mary River downstream of the St. Mary Dam, performance is acceptable for Scenario 1, but substantially poorer for Scenarios 2 and 3 (**Table 5-A3**). Performance on the Blood (Kainai) First Nation's BTAP project is acceptable for all three scenarios.

- **Non-irrigation Consumptive Use**

Modelling indicates extensive deficits for all three scenarios in the two reaches between the Oldman River Dam and the confluence with Willow Creek (**Figure 5.16**). Deficits were lower and fewer for the reach downstream of the St. Mary River confluence, but still relatively high for Scenarios 2 and 3.

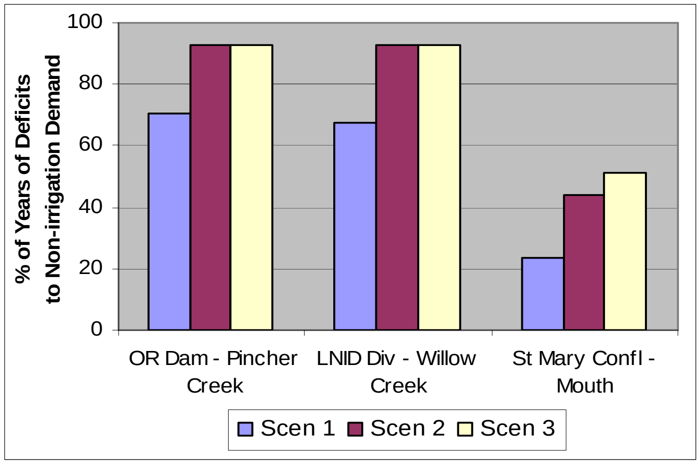



**Figure 5.16 Frequency of Deficits to the Junior Non-Irrigation Demand Along the Oldman River**

Performance for junior non-irrigation projects supplied from the St. Mary Reservoir, including those within the irrigation districts supplied by the St. Mary Project (SMRID, RID, MID, TID), deficits are low for Scenario 1, but very high for Scenarios 2 and 3 (**Table 5-A4**). Increased high priority diversions to support the irrigation district expansions assumed for Scenarios 2 and 3 would limit water availability for the lower priority uses.

- **Summary of Findings of Simulation Modelling for the Oldman River Basin**

a) WCO deficits in the Oldman River are high, particularly in the summer months. Deficits are most frequent in the middle reach, LNID Diversion Weir to Willow Creek. The differences among the three scenarios is not significant.

b) The frequency of WCO deficits along the St. Mary River downstream of the St. Mary Dam are very high for all scenarios. They increase somewhat for Scenarios 2 and 3.

c) Simulation modelling indicates substantial increases in private irrigation deficits for Scenarios 2 and 3 downstream of the Oldman River Dam. Irrigation expansion on the Piikani First Nation Reserve would experience high deficits for all three scenarios.

d) Scenario 1 modelling indicates high deficits to junior non-irrigation licensees in reaches along the Oldman River upstream of Lethbridge. Deficits become even more frequent for Scenarios 2 and 3.

e) Deficits to junior non-irrigation licensees along the St. Mary River downstream of the St. Mary Dam are low for Scenario 1 but increase substantially for Scenarios 2 and 3. BTAP irrigation project performs very well for all scenarios.

#### 5.4.2.4 South Saskatchewan River Sub-basin

- **Water Conservation Objectives**

Simulation modelling indicates WCO deficits would occur in about 18% of the weeks in Scenario 1, increasing to 26% in Scenario 2, and 32% in Scenario 3 (**Figure 5.17**).

The deficits to the WCO occur entirely in the months of April to October.

- **Irrigation Use**

Performance for junior private irrigation projects along the South Saskatchewan River is judged to be satisfactory for Scenario 1, but deteriorates for Scenarios 2 and 3 (**Figure 5.17**).

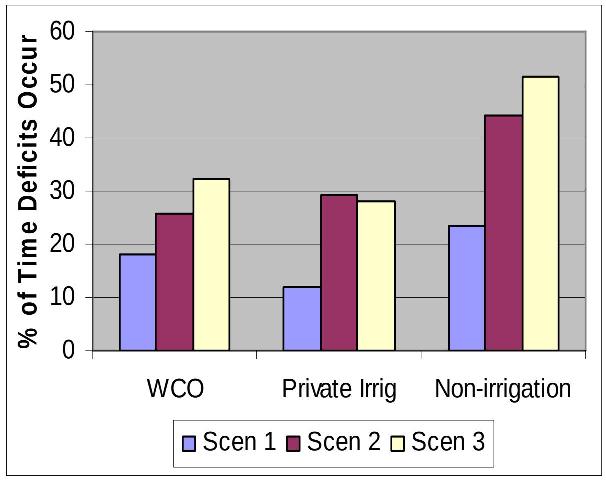



**Figure 5.17 Frequency of Deficits to Demands Along the South Saskatchewan River**

- **Non-irrigation Consumptive Use**

Similar to private irrigation, deficits for junior non-irrigation along the South Saskatchewan River use are relatively low for Scenario 1, but increase significantly for Scenarios 2 and 3 (**Figure 5.17**).

- **Summary of Findings of Simulation Modelling for the South Saskatchewan River Sub-basin**

There are increases in deficits along the South Saskatchewan River to the WCO, junior private irrigation and junior non-irrigation water uses for Scenarios 2 and 3. These increases in deficits can largely be attributed to increases in upstream irrigation demands in the Bow and Oldman River Sub-basins.

#### 5.4.2.5 South Saskatchewan River Basin As a Whole

To provide an indication of relative performance among the main tributaries of the SSRB, **Figures 5.18, 5.19 and 5.20** compare the frequency of deficits in the most downstream reaches of the tributaries. The most downstream reach is often but not always the most severely impacted reach. For junior private irrigation, the deficits greater than 100 mm are shown; for all other uses, all deficits are considered.

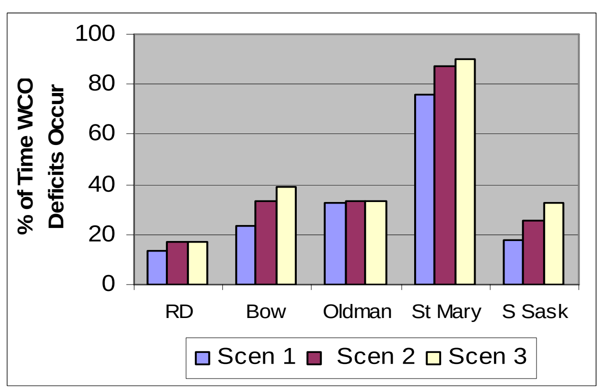



**Figure 5.18 Sub-basin Comparison of WCO Deficit Frequencies**

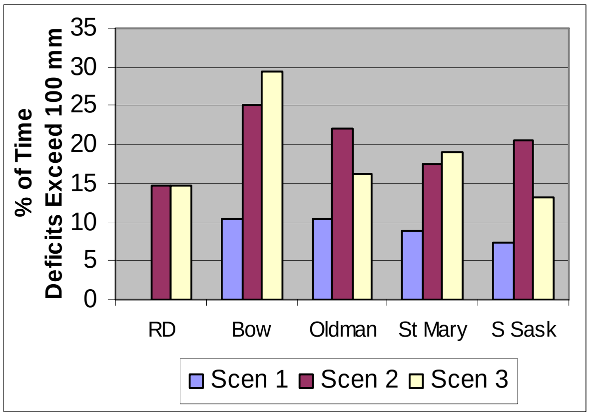



**Figure 5.19 Sub-basin Comparison of Junior Private Irrigation Deficit Frequencies**

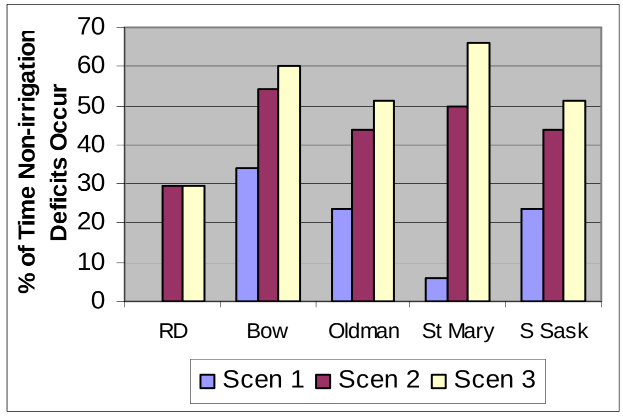



**Figure 5.20 Sub-basin Comparison of Non-Irrigation Deficit Frequencies**

Comparing the performance in the most downstream reaches of the five rivers, the Red Deer River has the best performance in Scenario 1. (There are no existing junior projects in the Bindloss to Saskatchewan Border reach. New projects in this reach will likely experience frequent deficits unless they are supported by storage.) The Red Deer River is also the least impacted by future increases of water use assumed for Scenarios 2 and 3. This is a reflection of the relatively low level of current use in the sub-basin and the low increased uses assumed for the future. There is little difference in the impacts between Scenarios 2 and 3 for the Red Deer River. The primary issue in the Red Deer River Basin is frequent deficits to existing junior non-irrigation projects in reaches upstream of Bindloss (**Figure 5.7**). The future uses assumed for Scenarios 2 and 3 result in a minor increase in the frequencies of these deficits. The deficits to the WCO in the Red Deer River are relatively small compared to the deficits in the other primary rivers. There is an opportunity to meet the WCOs in the Red Deer River with a small amount of additional storage. Meeting the WCO deficits in the other rivers would be a much more difficult task because of the high level of prior allocations.

For the Bow, Oldman, St. Mary and South Saskatchewan Rivers, the WCO deficits are high for Scenario 1, which was known at the time the WCOs were established. Deficits to the WCOs are moderately increased for Scenarios 2 and 3 (although there is no increase in the WCO deficit for the most downstream reach of the Oldman River) (**Figure 5.18**). Junior consumptive uses (private irrigation and non-irrigation projects) are significantly impacted by the expansion of water use assumed for Scenarios 2 and 3 for all four rivers, although there is only one junior private irrigation project along the St. Mary River.

In summary, the findings of simulation modelling in the SSRB indicate the following with respect to the performance of potential future development and their impacts on the WCOs and junior projects in the SSRB:

- Expansions within irrigation districts perform well within the informal performance criteria for irrigation (deficits greater than 100 mm in no more than 10% of the years) for all scenarios (not considering climate change).

- Irrigation proposed for SAWSP and Acadia projects perform well because they are supported by off-stream storage. Siksika and Blood irrigation expansion performs well. Piikani and Oldman Reservoir area projects have high frequencies of deficits.
- The frequency of WCO deficits for current conditions (Scenario 1) are relatively low for the Red Deer River, but high for the other major rivers in the SSRB. Generally, water use increases assumed for Scenarios 2 and 3 have a moderate impact on performance in meeting the WCOs in all sub-basins. Performance usually deteriorates from upstream to downstream, and from Scenario 1 to Scenario 3.
- Junior priority private irrigation projects in all sub-basins perform well under current conditions. Deficits increase substantially for Scenarios 2 and 3, although there is only one existing junior private irrigation project on the Red Deer River and one on the St. Mary River.
- Similarly, deficits to junior priority non-irrigation projects (municipalities, industries, recreation, wetland stabilization, etc.) increase from Scenarios 1 to 3 in most reaches. Deficits are sometimes worse in upper reaches than in downstream reaches.

#### 5.4.2.6 Social and Economic Implications

A thorough socio-economic impact assessment is beyond the scope of this study. However, Marv Anderson and Associates Limited has provided a perspective on possible impacts of Scenarios 2 and 3 based on rudimentary analyses (Marv Anderson and Associates, 2008). The average economic values of uses of water for various purposes have been taken from Klohn Crippen (2003) for use in this analysis (See **Table 6.4** in the next chapter). The use of water for various purposes was taken from chapter 4, which are the demands used in simulation modelling.

Marv Anderson and Associates (2008) has concluded the following:

- In the absence of periodic deficits, the value of water uses would be expected to increase about 40% for Scenario 2 and 47% for Scenario 3. If projected supplies remain the same, acute deficits in some reaches, water-use sectors, and sub-basins will likely negate about 20% of the benefits otherwise achievable.
- The purpose distribution of actual water uses in the SSRB is inconsistent with the relative socio-economic value of water for various purposes in the basin. For instance, municipal and domestic use represents only about 4% of total water use in the basin, but provide about 32% of the total value of water in the basin. Irrigation, consuming about 85% of total water use in the basin, provides about 40% of the total value of water use.
- The expansion of water use assumed for Scenario 3 would increase the SSRB Gross Domestic Product (GDP) in the order of 17%, assuming no deficits. With the deficits indicated by simulation modelling, the increase in the GDP might drop to about 5 or 7%. The costs of deficits would be least acute for the irrigation district water users, and most acute for junior private irrigators and the remaining water-use sectors. These rudimentary computations suggest a need to address how the adverse socio-economic impacts could be mitigated.

- With respect to the non-irrigation water-use sectors, acceptable levels of deficits are highly variable and largely unknown. It is essential that water-deficit thresholds be established for individual water-use sectors, even at a rule-of-thumb level of accuracy as exists for the irrigation sector. These thresholds could be of benefit to water management planning. Similarly, defining the magnitude and frequency of deficits to the in-stream flow requirements that could be tolerated (on a seasonal basis) without endangering the ecological health of our streams is particularly important for water managers and planners.

#### 5.4.2.7 Environmental Implications

The environmental implications of expansion of water use in the SSRB are as follows.

- **Red Deer River Sub-basin**

The simulation modelling indicates that there will be low-magnitude deficits in meeting WCOs in winter in this sub-basin. It also indicated that there will be small increases in deficits under Scenarios 2 and 3 as compared to Scenario 1 (current conditions). A reduction in flows for Scenarios 2 and 3 would result in a reduced assimilative capacity of the river. There are large point source discharges in the sub-basin, including treated municipal wastewater at Red Deer and Drumheller, and industrial releases from petrochemical plants at Prentiss and Joffre. Currently, water quality is only rated as fair in the Red Deer River, with some reaches near its headwaters receiving a rating of good (AENV, 2007). Total phosphorus and nitrogen levels increase substantially with increasing distance downstream (North/South Consultants, 2007). The lower flows predicted by the model would exacerbate these problems.

> **Assimilative Capacity** is the capacity of a waterbody to receive wastewater or toxic materials without deleterious effects and damage to aquatic life or consumptive users of the water.

- **Bow River Sub-basin**

Modelling indicates that for the Bow River, large summer WCO deficits will occur under current conditions (Scenario 1) in reaches downstream of Carseland, and that these deficits increase for Scenarios 2 and 3. This could have a negative effect on the aquatic environment of the Bow River. Records indicate that water temperatures have reached up to 29°C in the summer in the lower reaches of the Bow, which exceeds the tolerance for many fish species (Clipperton *et al*., 2003). As well, aquatic plant growth during low-flow periods have caused low dissolved oxygen concentrations and fluctuations in pH. These factors caused stress to fish and have occasionally led to fish kills (Clipperton *et al*., 2003). Lower flows could increase fish kills. As well, the assimilative capacity of the river could be decreased. Concentrations of some pesticides in the lower reaches of the Bow River have exceeded Canadian Council of Ministers of the Environment (CCME) water quality guidelines for the protection of aquatic life (North/South Consultants, 2007). Historical diversions of up to 90% of the Bow River's flow for irrigation has drastically reduced discharge downstream of Bassano Dam, and consequently the downstream fish-bearing capability of the remaining length of the river downstream (Clipperton *et al*., 2003). In 2002, the Eastern Irrigation District licence was amended to require a minimum flow downstream of the Bassano Dam of 400 cfs, replacing the previous minimum flow of 100 cfs. With this recent amendment, the low flows experienced prior to 2002 may not reoccur with the same frequency, and the fish bearing capacity of the river may improve over historical conditions. Nevertheless, under the reduced flows of the modelling Scenarios 2 and 3, the fish-bearing capacity of the river may be reduced from current conditions.

- **Oldman River Sub-basin**

Modelling indicates that there will be WCO deficits under current conditions in the Oldman River, particularly during summer when irrigation demands are highest. These deficits are highest in the reach upstream of Lethbridge and increase slightly from Scenario 1 to Scenarios 2 and 3. As well, it is predicted that very large deficits will occur along the St. Mary River, and these deficits increase for Scenarios 2 and 3. Water supply issues are already a concern within this basin because of the potential for drought conditions and subsequent water shortages (North/South Consultants, 2007). This could be exacerbated under the increased irrigation demand of Scenarios 2 and 3. There are eight wastewater treatment plants (WWTPs) that discharge effluent to the Oldman River, with the largest being the City of Lethbridge's facility (North/South Consultants, 2007). As well, both phosphorus and nitrogen concentrations have been shown to be strongly correlated with flow in this sub-basin, which suggests effects from agricultural runoff, irrigation return flows, and discharges from urban WWTPs (North/South Consultants, 2007). A reduction in the capacity of the river to assimilate these wastes would have negative effects on water quality and aquatic biota within the river.

- **South Saskatchewan River Sub-basin**

Modelling has predicted that there will be increased deficits in meeting WCOs in the South Saskatchewan River under Scenarios 2 and 3, and that these can be largely attributed to increases in irrigation demand in the Bow and Oldman River Sub-basins. The South Saskatchewan River has been reported to have better water quality than the Bow or the Oldman Rivers, potentially due to higher flows and increased assimilative capacity, as well as there being no significant additional effluent inputs downstream of the Bow/Oldman confluence (North/South Consultants, 2007). However, a decrease in water quality in those two rivers, as well as a reduction in flows as predicted under the model, would have negative effects on the aquatic environment of the South Saskatchewan River.

- **Summary**

In all basins, the modelling predicts a decrease in flows and an inability to meet WCOs at certain times of the year. It is worth noting that the WCOs are meant to strike a balance between water consumption and environmental protection. Therefore, from an environmental perspective, the WCOs are considerably less stringent than the fish habitat in-stream flow needs (IFN) (Clipperton *et al*., 2003) that were determined for each of these watercourses. As a result, the modelling indicates that the aquatic environment may be at greater risk under increased irrigation demands in the South Saskatchewan River Basin.

## 5.5 Climate Change

### 5.5.1 Introduction

The potential effects of a changing climate could impact the water supply and demand balance in southern Alberta. As a result, it is important for decision makers to understand the potential magnitude and consequences of the impacts.

Climate change impacts on meeting demands in the SSRB have not yet been modelled in the detail possible through the use of Alberta Environment's Water Resource Management Model (WRMM). In a sense, this study is breaking new ground in water management planning in southern Alberta. The study team is somewhat apprehensive in taking this step. Estimates of the impacts of climate change on streamflow in the SSRB, based on several economic and environmental scenarios and Global Climate Model (GCM) projections, yield a broad range of possible outcomes (Martz *et al*., 2007). This study is based on mean streamflow impacts, circa 2050, noted in **Table 5.4**. The reader should be mindful of the potential range of impacts in reviewing and interpreting the results of this analysis. The reader should also be aware that there remains some uncertainty of the scientific basis for climate change projections, and, in particular, the role of human induced carbon dioxide emissions in the gradual warming that has occurred during the past century.

**TABLE 5.4**
**Projected Impacts on Natural Flow due to Climate Change at Various Locations in the SSRB**

| Locations | Projected Change in Natural Annual Flow Volume (%) | | |
|---|---|---|---|
| | Minimum Scenario | Mean | Maximum Scenario |
| Red Deer River at Drumheller | -32% | -13% | +12% |
| Bow River at Calgary | -19% | -10% | 0% |
| Oldman River near Lethbridge | -14% | -3% | +7% |
| South Saskatchewan River at Medicine Hat | -17% | -6% | +6% |

Source: Martz *et al*. 2007.

### 5.5.2 Scenario 4: The Climate Change Scenario

#### 5.5.2.1 Purpose

Scenario 4: Climate Change is a first attempt to use the WRMM to define impacts of projected changes in temperature, precipitation and streamflow on the water supply and demand balance in the SSRB. The model run is limited to the 30-year period 1961 to 1990 due to data availability. (Scenarios 1 to 3 were based on the period 1928 to 1995.)

#### 5.5.2.2 Water Supply

Average monthly climate change streamflow projections for 11 hydrometric stations throughout the Alberta portion of the SSRB were used to adjust the 46 natural flow stations required for WRMM modelling. Generally, Martz *et al*. (2007) projected that in the fall and winter months flows may increase in the Bow, Oldman and South Saskatchewan Sub-basins, and result in a less negative impact in the Red Deer Sub-basin. In the summer months, negative impacts would likely be experienced in all sub-basins (**Figure 5.21**). Climate change adjustments to the natural flow database required for the WRMM were made in a manner that preserved the projected annual and monthly impacts within each sub-basin.

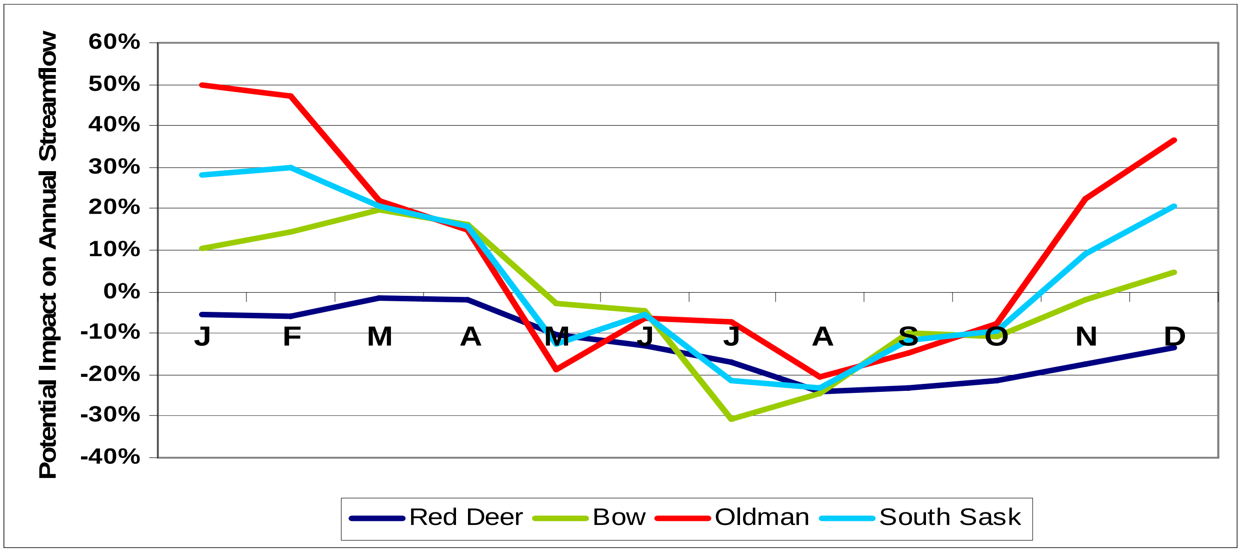



**Figure 5.21 Potential Climate Change (%) Impacts on Natural Flows in the Sub-Basins of the South Saskatchewan River Basin**

#### 5.5.2.3 Water Demands

Irrigated areas assumed for Scenario 3 were adopted for this scenario. Irrigation demands were increased by 10% to 16% to reflect increased average annual temperatures of 3 to 5°C and growing season precipitation decreases by 3% to 12% projected for the SSRB. Return flows were estimated to increase by 2% to 5%. Irrigation demands and return flows were estimated using Alberta Agriculture and Rural Development's Irrigation Demand Model. All other demands were the same as assumed for Scenario 3. While there will probably be some increases in evaporation and some water-use sector demands, such as municipal (outside watering), these changes would be small and probably insignificant in relation to the total demands assumed for this scenario, and, recognizing the uncertainties in water supply, no change was made in non-irrigation demands.

The WCOs and IOs were re-computed to reflect the new flow regime. In effect, these in-stream requirements were reduced from those of Scenarios 1, 2 and 3.

### 5.5.3 Scenario Evaluation

Scenario 3 and Scenario 4 (Climate Change) performances in meeting in-stream and consumptive needs in selected reaches throughout the SSRB are summarized in the attached **Tables 5-B1** (WCOs), **5-B2** (district irrigation), **5-B3** (private irrigation) and **5-B4** (non-irrigation demands) located at the end of this chapter. The results are discussed below. Graphics provide *typical* characteristics of deficits, primarily focussing on frequency. For additional information, the reader should refer to the tables in Attachment B.

Note that the improved performance in meeting the WCO is primarily due to decreased WCO requirements due to lower flows in the climate change scenario. The WCO requirements are indexed to the natural flow regime, Scenario 4 natural flows are 4% to 13% lower than Scenario 3 natural flows.

#### 5.5.3.1 The Red Deer River

Simulation modelling shows a slight improvement in meeting the WCO requirements (**Figure 5.22**). However, the WCO flows in the Bindloss to Saskatchewan reach are about 10% lower in Scenario 4 than in Scenario 3, which would probably have a negative impact on in-stream conditions.

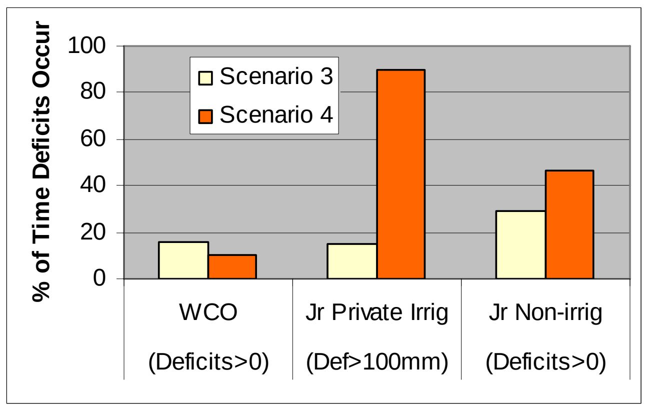



**Figure 5.22 Performance in Meeting Demands Along the Bindloss to Saskatchewan Border Reach of the Red Deer River**

For junior private irrigation, the frequency of deficits greater than 100 mm are much higher for Scenario 4 than for Scenario 3. Performance is acceptable for SAWSP, but marginal for the Acadia Project (**Table 5-B3**).

For junior non-irrigation, deficits for Scenario 4 increase significantly.

#### 5.5.3.2 The Bow River

As for the Red Deer River, the frequency of WCO deficits also decrease on the Bow River (**Figure 5.23**); however, the WCO flows are about 10% lower for Scenario 4 than for Scenario 3.

District irrigation in the Bow River Basin would have occasional deficits, but none as high as 100 mm (**Table 5-B2**). Deficits would be insignificant.

Both junior private irrigation and non-irrigation deficits along the Bow River would increase for the climate change scenario.

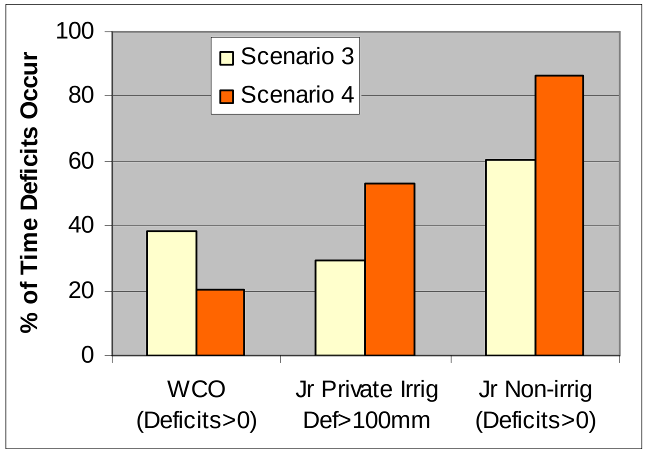



**Figure 5.23 Performance in Meeting Demands Along the Bow River from Bassano Dam to the Mouth**

#### 5.5.3.3 The Oldman River

With respect to performance in meeting the WCOs, the Oldman River follows the same pattern as the Red Deer and Bow Rivers, with decreased deficit frequencies in meeting the lower WCO values (**Figure 5.24**).

Deficits to district irrigation would increase substantially for Scenario 4 over Scenario 3 (**Figure 5.25**). The average deficits greater than 100 mm would occur in about 13% of the years, which exceeds the informal criteria for feasibility that specifies deficits of that magnitude in no more than 10% of the years.

Deficits would increase for both junior private irrigation and non-irrigation projects along the Oldman River for the climate change scenario.

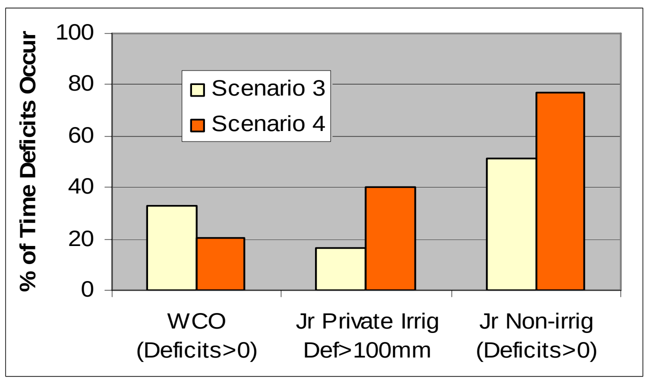



**Figure 5.24 Performance in Meeting Demands Along the Oldman River from the St. Mary Confluence to the Mouth**

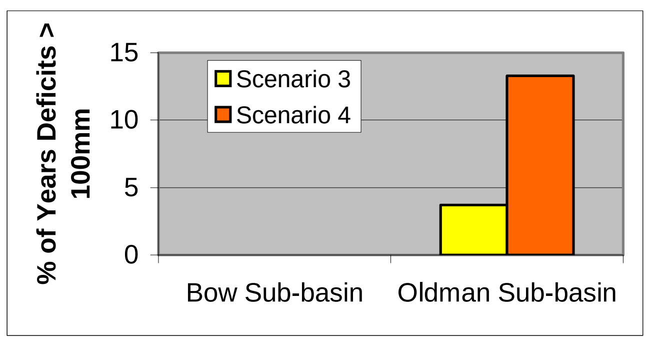



**Figure 5.25 Performance in Meeting Irrigation District Demands in the Bow and Oldman River Sub-basins**

#### 5.5.3.4 Summary

- Simulation modelling for Scenario 4 indicates there would be improved performance over Scenario 3 in meeting the WCOs in all sub-basins. However, this is primarily due to the WCO flows being lower for the climate change scenario than for Scenario 3. The simulated flows for Scenario 4 are actually lower than those of Scenario 3, which would suggest a deterioration of in-stream conditions. Section 5.4.2.7 provides a general discussion of the impacts of lower in-stream flows in the major rivers of the SSRB. The combined impacts of lower in-stream flows and higher temperatures due to global warming could exacerbate the risk to the aquatic environment.
- The Bow River Sub-basin irrigation districts perform adequately for all scenarios, including the climate change scenario. For Scenario 4, the irrigation districts in the Oldman River Sub-basin do not perform within the informal performance criteria often used to evaluate irrigation projects in southern Alberta. Deficits greater than 100 mm would occur in about 13% of the years.
- Deficits to junior private irrigation projects and junior non-irrigation projects would be significantly increased in all sub-basins under climate change conditions assumed for Scenario 4.
- Because of the wide range of possible impacts of climate change on streamflow in the SSRB, it is not possible to be definitive on the effect climate change has on water users. However, water users should be aware that increased deficits are more likely than the status quo or fewer deficits.
- In the words of renowned hydrologist and professor, Vit Klemes (1990),

  > *"Climate variability has long been a factor in dealing with water resource systems and represents only one of the uncertainties which water resource professionals had always to cope. The possibility of a climate change is adding one more element to these uncertainties, a relatively benign one is its graduality and monotonousness of direction which allows for adaptation and adjustment. The real issues in water resource systems lie elsewhere, everywhere, right now, not 30, 50 years hence; and they are crying out for solutions, for action, for political will to act, for resources, rather than deep analyses of shallow facts and conjecture."*

  These words were penned almost 20 years ago. How much have we progressed in our understanding of causes and impacts of climate change since that time?
- Periodic analysis of annual and monthly natural flow data should be conducted to determine whether or not significant trends exist, and the potential long-term impacts on streamflow if the trends persist. Such analysis should be conducted mindful of the findings of Martz *et al*. (2007) on projected changes in streamflow in the SSRB under climate change conditions, or updates thereof, with a view to narrowing the range of uncertainty in the projections. There is evidence that natural flows are decreasing, although in most cases trends are not significant using the commonly accepted 95% level of confidence. While there may now be sufficient evidence available for water managers and water users to think about adaptive measures to changing water supply conditions, there are more pressing problems that need to be addressed on a priority basis.

# Attachment 5-A

# Magnitude and Frequency of Deficits for Scenarios 1, 2 and 3

**TABLE 5-A1** **Summary of Current and Projected Future Performance in Meeting WCOs in the SSRB Based on Simulation Modelling**

**TABLE 5-A2** **Summary of Performance in Meeting Current and Projected Future Irrigation District Demands in the SSRB Based on Simulation Modelling**

**TABLE 5-A3** **Summary of Performance in Meeting Current and Future Junior Private Irrigation Demands in the SSRB Based on Simulation Modelling**

**TABLE 5-A4** **Summary of Performance in Meeting Current and Future Junior Non-Irrigation Demands in the SSRB Based on Simulation Modelling**

# TABLE 5-A1 Summary of Current and Projected Future Performance in Meeting WCOs in the SSRB Based on Simulation Modelling

**Red Deer River**

| Reach | Medicine R to Blindman Confluence | | | Nevis to Delburne | | | Drumheller to Dinosaur Provincial Park | | | Bindloss to Sask Border | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WCO | Max( 0.45 Qnat or 16.0 $m^3/s$) | | | Max(0.45 Qnat or 10.0 $m^3/s$ Apr to Oct or 16.0 $m^3/s$ Nov to Mar) | | | Max(0.45 Qnat or 10.0 $m^3/s$ Apr to Oct or 16.0 $m^3/s$ Nov to Mar) | | | Max(0.45 Qnat or 10.0 $m^3/s$ Apr to Oct or 16.0 $m^3/s$ Nov to Mar) | | |
| Scenario | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| **X** % of WCO | % of weeks that deficits exceed **X** percent of WCO demand: | | | | | | | | | | | |
| 0% | 11.4 | 14.2 | 14.2 | 11.3 | 12.6 | 12.6 | 11.7 | 14.1 | 14.1 | 13.4 | 16.7 | 15.4 |
| 10% | 3.1 | 5.1 | 5.1 | 3.9 | 4.0 | 3.8 | 7.4 | 8.6 | 8.6 | 10.7 | 12.6 | 12.7 |
| 20% | 0 | 0.1 | 0.1 | 0.1 | 0.2 | 0.1 | 1.5 | 2.0 | 1.7 | 7.1 | 8.2 | 8.1 |
| 40% | 0 | 0 | 0.0 | 0 | 0 | 0.0 | 0 | 0 | 0.0 | 0.4 | 0.5 | 0.5 |
| 60% | 0 | 0 | 0.0 | 0 | 0 | 0.0 | 0 | 0 | 0.0 | 0 | 0 | 0 |

**Bow River**

| Reach | Elbow R to Highwood Confluence | | | Carseland to Bassano Dam | | | Bassano Dam to Mouth | | |
|---|---|---|---|---|---|---|---|---|---|
| WCO | Max(0.45Qnat or 1.1(0.8FRC)) | | | Max(0.45Qnat or 1.1(0.8FRC)) | | | Max(0.45Qnat or 12.5 Mar to Nov or 1.1(Tennet Tessman) Nov to Feb | | |
| Scenario | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| **X** % of WCO | % of weeks that deficits exceed **X** percent of WCO demand: | | | | | | | | |
| 0% | 6.4 | 8.1 | 8.1 | 16.6 | 23.4 | 27.3 | 23.4 | 33.6 | 38.7 |
| 10% | 2.7 | 2.8 | 2.8 | 6.1 | 9.2 | 10.8 | 18.5 | 29.0 | 34.1 |
| 20% | 0.9 | 0.8 | 0.8 | 2.9 | 4.8 | 6.3 | 14.8 | 25.3 | 31.1 |
| 40% | 0.1 | 0.2 | 0.2 | 0 | 0.5 | 0.6 | 9.6 | 20.0 | 25.1 |
| 60% | 0 | 0 | 0 | 0 | 0 | 0.0 | 6.5 | 14.8 | 19.3 |

**Oldman River**

| Reach | Oldman R Dam to Pincher Creek | | | LNID Diversion to Willow Creek Confluence | | | St Mary R Confluence to Mouth | | |
|---|---|---|---|---|---|---|---|---|---|
| WCO | Max(0.45Qnat or 1.1(80%FRC)) | | | Max(0.45Qnat or 1.1(80%FRC)) | | | Max(0.45Qnat or 1.1(80%FRC)) | | |
| Scenario | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| **X** % of WCO | % of weeks that deficits exceed **X** percent of WCO demand: | | | | | | | | |
| 0% | 31.6 | 33.9 | 33.9 | 45.3 | 53.0 | 55.0 | 32.5 | 33.2 | 33.2 |
| 10% | 6.7 | 7.7 | 7.7 | 5.4 | 8.1 | 9.1 | 17.8 | 19.9 | 19.9 |
| 20% | 2.0 | 3.4 | 3.4 | 3.9 | 6.1 | 6.9 | 14.5 | 16.1 | 16.1 |
| 40% | 0.7 | 1.6 | 1.8 | 1.4 | 3.1 | 3.9 | 8.9 | 10.4 | 10.4 |
| 60% | 0.3 | 0.6 | 0.6 | 0.5 | 1.3 | 1.5 | 4.0 | 5.1 | 5.1 |

| | **St Mary River** | | | **South Saskatchewan River** | | |
|---|---|---|---|---|---|---|
| Reach | St Mary Dam to Mouth | | | Medicine Hat to Sask Border | | |
| WCO | Max(0.45Qnat or 3.0 $m^3/s$) | | | Max(0.45Qnat or 46.73 $m^3/s$) | | |
| Scenario | 1 | 2 | 3 | 1 | 2 | 3 |
| **X** % of WCO | % of wks that deficits exceed **X** percent of demand: | | | | | |
| 0% | 75.9 | 87.5 | 90.2 | 17.9 | 25.7 | 32.4 |
| 10% | 49.9 | 61.7 | 64.6 | 14.0 | 21.2 | 26.4 |
| 20% | 45.6 | 57.7 | 60.7 | 11.4 | 18.4 | 22.7 |
| 40% | 37.2 | 47.7 | 50.3 | 6.8 | 12.3 | 14.3 |
| 60% | 26.8 | 35.1 | 37.2 | 2.2 | 4.8 | 5.5 |

**Tables are read as follows:**
For Red Deer River – Medicine River to Blindman Confluence % of weeks that deficits exceed 10% of WCO demand
= 3.1% for Scenario 1
= 5.1% for Scenario 2
= 5.1% for Scenario 3

## TABLE 5-A2 Summary of Performance in Meeting Current and Projected Future Irrigation District Demands in the SSRB Based on Simulation Modelling

| | Bow River Sub-basin | Oldman River Sub-basin |
|---|---|---|
| **Scenario 1:** | Representative of current level of water use | |
| Irrigated Areas (ha) | 217,094 | 276,629 |
| "X" mm | % of years with deficits greater than "X" mm | |
| 50 mm | 0 | 0 |
| 100 mm | 0 | 0 |
| 200 mm | 0 | 0 |
| **Scenario 2:** | Representative of irrigation district expansion to the 1991 Regulation areas and projected 2030 demands for other uses. | |
| Irrigated Areas (ha) | 239,169 | 300,279 |
| "X" mm | % of years with deficits greater than "X" mm | |
| 50 mm | 0 | 12.1 |
| 100 mm | 0 | 3.4 |
| 200 mm | 0 | 0 |
| **Scenario 3:** | Representative of irrigation district expansion to the 1991 Regulation areas plus 20% for the Bow Basin districts, and plus 10% for the Oldman districts. Projected 2030 demands for other water use purposes. | |
| Irrigated Areas (ha) | 287,003 | 330,307 |
| "X" | % of years with deficits greater than "X" mm | |
| 50 mm | 2.9 | 12.6 |
| 100 mm | 0 | 3.7 |
| 200 mm | 0 | 0 |

# TABLE 5-A3 Summary of Performance in Meeting Current and Future Junior Private Irrigation Demands in the SSRB Based on Simulation Modelling

**Red Deer River Sub-basin**

| Reach | Medicine R to Blindman Confluence.(Block 668) | | | Nevis to Delburne | | | Drumheller to Dinosaur Prov Park (Block 601) | | |
|---|---|---|---|---|---|---|---|---|---|
| Irrig Areas (ha) | 22 | 22 | 22 | 0 | 0 | 0 | 0 | 700 | 700 |
| Scenario | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| **"X"** mm | % of years with deficits greater than **"X"** mm. Only irrigation licences subject to WCO considered. | | | | | | | | |
| 50 mm | 2.9 | 7.4 | 8.8 | N/A | N/A | N/A | N/A | 30.9 | 30.9 |
| 100 mm | 1.5 | 7.4 | 8.8 | | | | | 23.5 | 20.6 |
| 200 mm | 0 | 4.4 | 7.4 | | | | | 10.3 | 11.8 |

| Reach | Bindloss to Sask Border (Block 624) | | | SAWSP Project | | | Acadia Project | | |
|---|---|---|---|---|---|---|---|---|---|
| Irrig Areas (ha) | 0 | 700 | 700 | 0 | 3237 | 3237 | 0 | 10,926 | 10,926 |
| Scenario | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| **"X"** mm | % of years with deficits greater than **"X"** mm. Only irrigation licences subject to WCO considered. | | | | | | | | |
| 50 mm | N/A | 25.0 | 25.0 | N/A | 0 | 1.5 | N/A | 5.9 | 7.4 |
| 100 mm | | 14.7 | 14.7 | | 0 | 1.5 | | 5.9 | 7.4 |
| 200 mm | | 8.8 | 10.3 | | 0 | 0 | | 1.5 | 2.9 |

**Bow River Sub-basin**

| Reach | Elbow R to Highwood Confluence (Block 769) | | | Carseland to Bassano Dam | | | Bassano Dam to Mouth (Block 378) | | | Siksika Expansion Project | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Irrig Areas (ha) | 192 | 192 | 192 | 0 | 0 | 0 | 645 | 645 | 645 | 0 | 9443 | 9443 |
| Scenario | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| **"X"** mm | % of years with deficits greater than **"X"** mm. Only irrigation licences subject to the IO are considered. | | | | | | | | | | | |
| 50 mm | 14.7 | 23.5 | 29.4 | N/A | N/A | N/A | 17.6 | 32.3 | 35.3 | N/A | 1.5 | 1.5 |
| 100 mm | 5.9 | 8.8 | 11.8 | | | | 10.3 | 25.0 | 29.4 | | 0 | 0 |
| 200 mm | 1.5 | 0 | 1.5 | | | | 2.9 | 13.2 | 14.7 | | 0 | 0 |

**Oldman River Sub-basin**

| Reach | Oldman R Dam to Pincher Cr (Block 655) | | | LNID Diversion to Willow Cr (Block 656) | | | St Mary R to Mouth (Blocks 657 and 660) | | | Peigan First Nation Project | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Irrig Areas (ha) | 4,167 | 8563 | 8563 | 708 | 708 | 708 | 1,726 | 1,726 | 1,726 | 0 | 6192 | 6192 |
| Scenario | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| **"X"** mm | % of years with deficits greater than **"X"** mm. Only irrigation licences subject to the IO are considered. | | | | | | | | | | | |
| 50 mm | 16.2 | 42.6 | 69.1 | 33.8 | 63.2 | 69.1 | 17.6 | 33.8 | 33.8 | N/A | 77.9 | 80.9 |
| 100 mm | 10.2 | 23.5 | 47.1 | 23.5 | 41.2 | 44.1 | 10.3 | 22.1 | 16.2 | | 45.6 | 47.1 |
| 200 mm | 1.5 | 7.4 | 14.7 | 5.9 | 11.8 | 13.2 | 2.9 | 8.8 | 8.8 | | 11.8 | 13.2 |

**St Mary River** / **South Saskatchewan River Sub-basin**

| Reach | St Mary R Dam to Mouth (Block 646) | | | Blood First Nation BTAP Expansion | | | Med. Hat to Sask Border (Blocks 689, 690) | | |
|---|---|---|---|---|---|---|---|---|---|
| Irrig Areas (ha) | 21 | 21 | 21 | 7082 | 10,121 | 10,121 | 3213 | 3213 | 3213 |
| Scenario | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| **"X"** mm | % of years with deficits greater than **"X"** mm. Only irrigation licences subject to WCO considered. | | | | | | | | |
| 50 mm | 23.5 | 41.2 | 45.6 | 0 | 0 | 0 | 11.8 | 29.4 | 27.9 |
| 100 mm | 8.8 | 17.6 | 19.1 | 0 | 0 | 0 | 7.4 | 20.6 | 13.2 |
| 200 mm | 0 | 4.4 | 4.4 | 0 | 0 | 0 | 1.5 | 8.8 | 7.4 |

# TABLE 5-A4 Summary of Performance in Meeting Current and Future Junior Non-Irrigation Demands in the SSRB Based on Simulation Modelling

**Red Deer River**

| Reach | Medicine R to Blindman Confl. (Block 671) | | | Nevis to Delburne (Block 807) | | | Drumheller to Dinosaur P Park (Block 674) | | | Bindloss to Sask Border (Block 693) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Demand ($dam^3$) | 3727 | 21,197 | 21,197 | 3097 | 7099 | 7099 | 600 | 2618 | 2618 | 0 | 16 | 16 |
| Scenario | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| **X** % of demand | % of years that deficits exceed **X** percent of demand: | | | | | | | | | | | |
| 0% | 73.5 | 79.4 | 79.4 | 75.0 | 82.4 | 83.8 | 22.1 | 30.9 | 30.9 | N/A | 29.4 | 29.4 |
| 10% | 52.9 | 64.7 | 63.2 | 61.8 | 66.2 | 66.2 | 4.4 | 8.8 | 14.7 | | 5.9 | 14.7 |
| 20% | 13.2 | 26.5 | 29.4 | 17.6 | 33.8 | 32.4 | 1.5 | 7.4 | 10.3 | | 5.9 | 7.4 |
| 40% | 0.0 | 5.9 | 8.8 | 0.0 | 10.3 | 11.8 | 0 | 1.5 | 4.4 | | 0 | 0 |
| 60% | 0.0 | 1.5 | 1.5 | 0.0 | 2.9 | 4.4 | 0 | 0 | 0 | | 0 | 0 |

**Bow River**

| Reach | Elbow R to Highwood Confl. (Block 2) | | | Carseland to Bassano Dam (Block 640) | | | Bassano Dam to Mouth (Block 25) | | |
|---|---|---|---|---|---|---|---|---|---|
| Demand ($dam^3$) | 12,976 | 12,976 | 12,976 | 2190 | 2190 | 2190 | 10,199 | 10,240 | 10,240 |
| Scenario | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| **X** % of demand | % of years that deficits exceed **X** percent of demand: | | | | | | | | |
| 0% | 82.4 | 82.4 | 86.8 | 61.8 | 64.7 | 76.5 | 33.8 | 54.4 | 60.3 |
| 10% | 42.6 | 44.1 | 57.4 | 22.1 | 33.8 | 50.0 | 19.1 | 38.2 | 42.6 |
| 20% | 17.6 | 26.5 | 36.8 | 10.3 | 20.6 | 32.4 | 13.2 | 27.9 | 29.4 |
| 40% | 2.9 | 10.3 | 10.3 | 2.9 | 8.8 | 14.7 | 2.9 | 13.2 | 14.7 |
| 60% | 0 | 2.9 | 0.0 | 0.0 | 1.5 | 1.5 | 0.0 | 2.9 | 5.9 |

**Oldman River**

| Reach | Oldman R Dam to Pincher Cr (Block 600) | | | LNID Diversion to Willow Cr (Block 213) | | | St Mary R to Mouth (Block 66) | | |
|---|---|---|---|---|---|---|---|---|---|
| Demand ($dam^3$) | 8,154 | 8,154 | 8,154 | 86 | 86 | 86 | 899 | 899 | 899 |
| Scenario | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| **X** % of demand | % of years that deficits exceed **X** percent of demand: | | | | | | | | |
| 0% | 70.6 | 92.6 | 92.6 | 67.6 | 92.6 | 92.6 | 23.5 | 44.1 | 51.5 |
| 10% | 67.6 | 91.2 | 92.6 | 54.4 | 86.8 | 89.7 | 5.9 | 22.1 | 22.1 |
| 20% | 66.2 | 88.2 | 91.2 | 41.2 | 72.0 | 80.9 | 1.5 | 8.8 | 10.3 |
| 40% | 26.5 | 70.6 | 67.6 | 7.4 | 39.7 | 45.6 | 0 | 0 | 0 |
| 60% | 16.2 | 45.6 | 47.1 | 4.4 | 14.7 | 13.2 | 0 | 0 | 0 |

| | **St Mary River** | | | **South Saskatchewan River** | | |
|---|---|---|---|---|---|---|
| Reach | St Mary Dam to Mouth (Block 46) | | | Medicine Hat to Sask Border (Block 6) | | |
| Demand ($dam^3$) | 6580 | 6580 | 6580 | 4798 | 4798 | 4798 |
| Scenario | 1 | 2 | 3 | 1 | 2 | 3 |
| **X** % of demand | % of years that deficits exceed **X** percent of demand: | | | | | |
| 0% | 5.9 | 50.0 | 66.2 | 23.5 | 44.1 | 51.5 |
| 10% | 2.9 | 35.3 | 52.9 | 7.4 | 22.1 | 19.1 |
| 20% | 2.9 | 29.4 | 36.8 | 1.5 | 7.4 | 10.3 |
| 40% | 0 | 13.2 | 16.2 | 0 | 1.5 | 0 |
| 60% | 0 | 4.4 | 8.8 | 0 | 0 | 0 |

# Attachment 5-B

# Magnitude and Frequency of Deficits for Scenario 3 and Scenario 4 (Climate Change)

## TABLE 5-B1 Summary of Performance in Meeting WCOs in the SSRB Based on Simulation Modelling of Climate Change Conditions (Scenario 4)

**Red Deer River**

| Reach | Medicine R to Blindman Confl. | | Nevis to Delburne | | Drumheller to Dinosaur Provincial Park | | Bindloss to Sask Border | |
|---|---|---|---|---|---|---|---|---|
| WCO | Max( 0.45 Qnat or 16.0 $m^3/s$) | | Max(0.45 Qnat or 10.0 $m^3/s$ Apr to Oct or 16.0 $m^3/s$ Nov to Mar) | | Max(0.45 Qnat or 10.0 $m^3/s$ Apr to Oct or 16.0 $m^3/s$ Nov to Mar) | | Max(0.45 Qnat or 10.0 $m^3/s$ Apr to Oct or 16.0 $m^3/s$ Nov to Mar) | |
| Scenario | 3 | 4 | 3 | 4 | 3 | 4 | 3 | 4 |
| **X** % of WCO | % of weeks that deficits exceed **X** percent of demand: | | | | | | | |
| 0% | 14.2 | 11.2 | 12.6 | 9.2 | 14.1 | 9.8 | 15.4 | 10.2 |
| 10% | 5.1 | 5.5 | 3.8 | 3.7 | 8.6 | 6.3 | 12.7 | 8.3 |
| 20% | 0.1 | 0.5 | 0.1 | 0.3 | 1.7 | 2.3 | 8.1 | 5.8 |
| 40% | 0.0 | 0.1 | 0.0 | 0.1 | 0.0 | 0.1 | 0.5 | 0.5 |
| 60% | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0 | 0 |

**Bow River**

| Reach | Elbow R to Highwood Confl. | | Carseland to Bassano Dam | | Bassano Dam to Mouth | |
|---|---|---|---|---|---|---|
| WCO | Max(0.45Qnat or 1.1(0.8FRC)) | | Max(0.45Qnat or 1.1(0.8FRC)) | | Max(0.45Qnat or 12.5 Mar to Nov or 1.1(Tennet Tessman) Nov to Feb | |
| Scenario | 3 | 4 | 3 | 4 | 3 | 4 |
| **X** % of WCO | % of weeks that deficits exceed **X** percent of demand: | | | | | |
| 0% | 8.1 | 4.7 | 27.3 | 13.2 | 38.7 | 20.2 |
| 10% | 2.8 | 1.4 | 10.8 | 7.8 | 34.1 | 18.6 |
| 20% | 0.8 | 0.3 | 6.3 | 5.0 | 31.1 | 17.1 |
| 40% | 0.2 | 0.1 | 0.6 | 0.3 | 25.1 | 15.2 |
| 60% | 0 | 0 | 0.0 | 0.0 | 19.3 | 12.6 |

**Oldman River**

| Reach | Oldman R Dam to Pincher Cr | | LNID Diversion to Willow Cr | | St Mary R Confluence to Mouth | |
|---|---|---|---|---|---|---|
| WCO | Max(0.45Qnat or 1.1(80%FRC)) | | Max(0.45Qnat or 1.1(80%FRC)) | | Max(0.45Qnat or 1.1(80%FRC)) | |
| Scenario | 3 | 4 | 3 | 4 | 3 | 4 |
| **X** % of WCO | % of weeks that deficits exceed **X** percent of demand: | | | | | |
| 0% | 33.9 | 12.2 | 55.0 | 26.5 | 33.2 | 20.6 |
| 10% | 7.7 | 3.0 | 9.1 | 6.3 | 19.9 | 12.5 |
| 20% | 3.4 | 2.3 | 6.9 | 5.4 | 16.1 | 10.4 |
| 40% | 1.8 | 1.0 | 3.9 | 2.1 | 10.4 | 6.5 |
| 60% | 0.6 | 0.2 | 1.5 | 1.2 | 5.1 | 3.4 |

| | **St Mary River** | | **South Saskatchewan River** | |
|---|---|---|---|---|
| Reach | St Mary Dam to Mouth | | Medicine Hat to Sask Border | |
| WCO | Max(0.45Qnat or 3.0 $m^3/s$) | | Max(0.45Qnat or 46.73 $m^3/s$) | |
| Scenario | 3 | 4 | 3 | 4 |
| **X** % of WCO | % of wks that deficits exceed **X** percent of demand: | | | |
| 0% | 90.2 | 42.7 | 32.4 | 19.2 |
| 10% | 64.6 | 34.2 | 26.4 | 15.4 |
| 20% | 60.7 | 31.7 | 22.7 | 12.8 |
| 40% | 50.3 | 26.3 | 14.3 | 7.6 |
| 60% | 37.2 | 19.1 | 5.5 | 3.1 |

**TABLE 5-B2 Summary of Performance in Meeting Irrigation District Demands in the SSRB Based on Simulation Modelling of Climate Change Conditions (Scenario 4)**

| | Bow River Sub-basin | Oldman River Sub-basin |
|---|---|---|
| **Scenario 3:** Representative of irrigation district expansion to 1991 Regulation areas plus 20% for the Bow Basin districts, and plus 10% for the Oldman districts. Projected 2030 demands for other uses. | | |
| Irrigated Areas (ha) | 287,003 | 330,307 |
| "X" mm | % of years with deficits greater than "X" mm | |
| 50 mm | 2.9 | 12.6 |
| 100 mm | 0 | 3.7 |
| 200 mm | 0 | 0 |
| | | |
| **Scenario 4:** Representative of Scenario 3 demands with projected 2050 climate change precipitation, temperatures and streamflow. | | |
| Irrigated Areas (ha) | 287,003 | 330,307 |
| "X" mm | % of years with deficits greater than "X" mm | |
| 50 mm | 6.6 | 22.5 |
| 100 mm | 0 | 13.3 |
| 200 mm | 0 | 2.5 |

## TABLE 5-B3 Summary of Performance in Meeting Junior Private Irrigation Demands in the SSRB Based on Simulation Modelling of Climate Change Conditions (Scenario 4)

**Red Deer River Sub-basin**

| Reach | Medicine R to Blindman Confl.(Block 668) | | Nevis to Delburne | | Drumheller to Dinosaur Provincial Park (Block 601) | |
|---|---|---|---|---|---|---|
| Irrig Areas (ha) | 22 | 22 | 0 | 0 | 700 | 700 |
| Scenario | 3 | 4 | 3 | 4 | 3 | 4 |
| **"X"** mm | % of years with deficits greater than **"X"** mm. | | | | | |
| 50 mm | 8.8 | 43.3 | N/A | N/A | 30.9 | 90.0 |
| 100 mm | 8.8 | 30.0 | | | 20.6 | 86.7 |
| 200 mm | 7.4 | 10.0 | | | 11.8 | 43.3 |

| Reach | Bindloss to Sask Border (Block 624) | | SAWSP Project | | Acadia Project | |
|---|---|---|---|---|---|---|
| Irrig Areas (ha) | 700 | 700 | 3237 | 3237 | 10,926 | 10,926 |
| Scenario | 3 | 4 | 3 | 4 | 3 | 4 |
| **"X"** mm | % of years with deficits greater than **"X"** mm. | | | | | |
| 50 mm | 25.0 | 100 | 1.5 | 1.5 | 7.4 | 16.7 |
| 100 mm | 14.7 | 90 | 1.5 | 1.5 | 7.4 | 10.0 |
| 200 mm | 10.3 | 56.7 | 0 | 1.5 | 2.9 | 10.0 |

**Bow River Sub-basin**

| Reach | Elbow R to Highwood Confluence (Block 769) | | Carseland to Bassano Dam | | Bassano Dam to Mouth (Block 378) | | Siksika Expansion Project | |
|---|---|---|---|---|---|---|---|---|
| Irrig Areas (ha) | 192 | 192 | 0 | 0 | 645 | 645 | 9443 | 9443 |
| Scenario | 3 | 4 | 3 | 4 | 3 | 4 | 3 | 4 |
| **"X"** mm | % of years with deficits greater than **"X"** mm. Only irrigation licences subject to the IO considered. | | | | | | | |
| 50 mm | 29.4 | 40 | N/A | N/A | 35.3 | 70 | 1.5 | 66.7 |
| 100 mm | 11.8 | 60 | | | 29.4 | 53.3 | 0 | 43.3 |
| 200 mm | 1.5 | 20 | | | 14.7 | 26.7 | 0 | 3.3 |

**Oldman River Sub-basin**

| Reach | Oldman R Dam to Pincher Cr (Block 655) | | LNID Diversion to Willow Cr (Block 656) | | St Mary R to Mouth (Blocks 657 and 660) | | Peigan First Nation Project | |
|---|---|---|---|---|---|---|---|---|
| Irrig Areas (ha) | 8563 | 8563 | 708 | 708 | 1,726 | 1,726 | 6192 | 6192 |
| Scenario | 3 | 4 | 3 | 4 | 3 | 4 | 3 | 4 |
| **"X"** mm | % of years with deficits greater than **"X"** mm. Only irrigation licences subject to the IO considered. | | | | | | | |
| 50 mm | 69.1 | 96.7 | 69.1 | 90 | 33.8 | 63.3 | 80.9 | 90.0 |
| 100 mm | 47.1 | 93.3 | 44.1 | 83.2 | 16.2 | 40 | 47.1 | 86.7 |
| 200 mm | 14.7 | 66.6 | 13.2 | 43.3 | 8.8 | 16.7 | 13.2 | 36.7 |

**St Mary River** / **South Saskatchewan River Sub-basin**

| Reach | St Mary R Dam to Mouth (Block 646) | | Blood First Nation BTAP Expansion | | Med. Hat to Sask Border (Blocks 689, 690) | |
|---|---|---|---|---|---|---|
| Irrig Areas (ha) | 21 | 21 | 10,121 | 10,121 | 3213 | 3213 |
| Scenario | 3 | 4 | 3 | 4 | 3 | 4 |
| **"X"** mm | % of years with deficits greater than **"X"** mm. | | | | | |
| 50 mm | 45.6 | 93.3 | 0 | 0 | 27.9 | 56.7 |
| 100 mm | 19.1 | 86.7 | 0 | 0 | 13.2 | 26.7 |
| 200 mm | 4.4 | 53.3 | 0 | 0 | 7.4 | 16.7 |

**TABLE 5-B4 Summary of Performance in Meeting Junior Non-irrigation Demands in the SSRB Based on Simulation Modelling of Climate Change Conditions (Scenario 4)**

**Red Deer River**

| Reach | Medicine R to Blindman Confl. (Block 671) | | Nevis to Delburne (Block 807) | | Drumheller to Dinosaur P Park (Block 674) | | Bindloss to Sask Border (Block 693) | |
|---|---|---|---|---|---|---|---|---|
| Demand ($dam^3$) | 21,197 | 21,197 | 7099 | 7099 | 2618 | 2618 | 16 | 16 |
| Scenario | 3 | 4 | 3 | 4 | 3 | 4 | 3 | 4 |
| **X** % of demand | % of years that deficits exceed **X** percent of demand: | | | | | | | |
| 0% | 79.4 | 100 | 83.8 | 100 | 30.9 | 53.3 | 29.4 | 46.7 |
| 10% | 63.2 | 83.3 | 66.2 | 83.3 | 14.7 | 26.6 | 14.7 | 23.3 |
| 20% | 29.4 | 63.3 | 32.4 | 70 | 10.3 | 20.0 | 7.4 | 16.7 |
| 40% | 8.8 | 30 | 11.8 | 23.3 | 4.4 | 3.3 | 0 | 3.3 |
| 60% | 1.5 | 6.7 | 4.4 | 13.3 | 0 | 0.0 | 0 | 0 |

**Bow River**

| Reach | Elbow R to Highwood Confl. (Block 2) | | Carseland to Bassano Dam (Block 640) | | Bassano Dam to Mouth (Block 25) | |
|---|---|---|---|---|---|---|
| Demand ($dam^3$) | 12,976 | 12,976 | 2190 | 2190 | 10,240 | 10,240 |
| Scenario | 3 | 4 | 3 | 4 | 3 | 4 |
| **X** % of demand | % of years that deficits exceed **X** percent of demand: | | | | | |
| 0% | 86.8 | 100.0 | 76.5 | 96.7 | 60.3 | 86.7 |
| 10% | 57.4 | 86.7 | 50.0 | 83.3 | 42.6 | 66.7 |
| 20% | 36.8 | 80.0 | 32.4 | 76.7 | 29.4 | 50.0 |
| 40% | 10.3 | 66.7 | 14.7 | 33.3 | 14.7 | 20.0 |
| 60% | 0.0 | 10.0 | 1.5 | 13.3 | 5.9 | 10.0 |

**Oldman River**

| Reach | Oldman R Dam to Pincher Cr (Block 600) | | LNID Diversion to Willow Cr (Block 213) | | St Mary R to Mouth (Block 66) | |
|---|---|---|---|---|---|---|
| Demand ($dam^3$) | 8,154 | 8,154 | 86 | 86 | 899 | 899 |
| Scenario | 3 | 4 | 3 | 4 | 3 | 4 |
| **X** % of demand | % of years that deficits exceed **X** percent of demand: | | | | | |
| 0% | 92.6 | 100.0 | 92.6 | 100.0 | 51.5 | 76.7 |
| 10% | 92.6 | 100.0 | 89.7 | 100.0 | 22.1 | 33.3 |
| 20% | 91.2 | 100.0 | 80.9 | 96.7 | 10.3 | 26.7 |
| 40% | 67.6 | 90.0 | 45.6 | 76.7 | 0 | 3.3 |
| 60% | 47.1 | 60.0 | 13.2 | 50.0 | 0 | 0.0 |

| | **St Mary River** | | **South Saskatchewan River** | |
|---|---|---|---|---|
| Reach | St Mary Dam to Mouth (Block 46) | | Medicine Hat to Sask Border (Block 6) | |
| Demand ($dam^3$) | 6580 | 6580 | 4798 | 4798 |
| Scenario | 3 | 4 | 3 | 4 |
| **X** % of demand | % of years that deficits exceed **X** percent of demand: | | | |
| 0% | 66.2 | 90 | 51.5 | 73.3 |
| 10% | 52.9 | 80 | 19.1 | 46.7 |
| 20% | 36.8 | 60 | 10.3 | 23.3 |
| 40% | 16.2 | 16.7 | 0 | 3.3 |
| 60% | 8.8 | 3.3 | 0 | 0 |

# 6.0 NON-STRUCTURAL WATER MANAGEMENT OPPORTUNITIES

## 6.1 Introduction

Simulation modelling indicated that water demands for potential expansion of the irrigation areas within districts could be met within the current licence allocations (and licence applications). However, results for Scenarios 2 and 3 indicate that additional demands by the districts would increase deficits to in-stream flow requirements, private irrigation users, and private non-irrigation users. The objectives of this section of the report are to identify and explore non-structural options for reducing deficits to in-stream requirements and junior private irrigation and non-irrigation users.

## 6.2 Identification and Screening of Options

A total of 14 non-structural measures were identified in workshops involving the study team, the Steering Committee, and invited participants. Discussions involved the effectiveness and practicality of each measure in reducing the deficits to in-stream requirements and junior private irrigation and non-irrigation projects in the basin. The intent was to select the most promising options for further analysis. Options identified and a brief summary of discussions follow.

### 6.2.1 Review Infrastructure Operations

Operational adjustments on existing reservoirs probably offer the most cost effective method for increasing the benefit derived from costly infrastructure investments. Optimum operation procedures vary over the life of infrastructure due to changes in societal needs, economic conditions, or water management legislation and policies. There are no capital costs in optimizing reservoir operations barring physical constraints of outlet works' capacity or dam safety measures. It was concluded that this measure warranted further consideration due to its low cost and potential benefits.

Primary targets would be the major provincial on-stream reservoirs: Gleniffer, Oldman River, St. Mary and Waterton. TransAlta (TA) reservoirs in the upper Bow River basin could possibly be considered if TA was receptive to exploring alternative operational scenarios. Existing off-stream reservoirs were considered to have limited potential for resolving mainstem water supply issues since they are not located in areas were they could conveniently return water to the source streams.

### 6.2.2 Use of Long-Range Weather Forecasts for Operations

Alberta Environment provides water supply and peak flow forecasts that assist in operating the numerous storage projects in the SSRB owned by the province, TA, and the irrigation districts. Water supply forecasts are made based primarily on snowpack accumulations in the mountain headwaters, which provide a 3- or 4-month lead time to the July/August peak demand. During the peak demand period, reservoir operators are uncertain of what the future holds for snowpack and runoff in the following year. As a result, reservoirs must be operated to conserve water in the event that the following year is going to be a low runoff year, or worse, the start of a 3-year drought, such as in 1983, 1984 and 1985. Reservoir rule curves reflect this reality. Under low reservoir conditions some uses will be foregone to conserve water for the following year or years. If the operator was assured of a high probability of reservoir filling in the following year, he or she would be less hesitant to draw down the reservoir to meet all demands, including in-stream requirements, and fill off-stream storage reservoirs. The value of storage reservoirs could be significantly enhanced.

Studies in the US and Australia have shown that long-range forecasts of streamflow can be made by exploiting the lag relationship between streamflow and the El Nino Southern Oscillation (ENSO) and the serial correlation in streamflow itself. Whether or not this applies to the eastern slopes of the Rockies has not yet been confirmed. Experimental long-range forecasts (7 to 12 months) are being produced by the University of Washington for 5 river basins, one of which is the Columbia River Basin with several streamflow stations in British Columbia (Piechota, 1999).

While the benefits of long-range streamflow forecasting are acknowledged, it is viewed to be a long shot in terms of its success. The reliability of streamflow forecasts and the consequence of forecasting errors are considered to be major issues. Long-range forecasts were not considered worthy of further consideration at this time.

The point was made that the use of existing short-term forecasts prepared by Alberta Environment could be enhanced if the WRMM model was modified to enable varying the reservoir rule curves based on streamflow forecasts. The model, as it now stands, uses fixed rule curves for the entire study period.

### 6.2.3 Improved Irrigation Efficiencies and Reductions in Irrigation Return Flows

The Water for Life program set increased efficiency and productivity targets of 30% by 2015 for all water-use sectors (Government of Alberta, 2003). Reduction in return flows is a key component of irrigation efficiency improvements. Irrigation is the largest user in the SSRB. There are large differences in water-use efficiencies among the districts and considerable scope for improvements. While efficiency improvements in all water-use sectors are important, improvements in the irrigation sector holds the most promise for conserving water for other uses. This measure is worthy of further consideration. Increased monitoring, increased number of strategically located balancing reservoirs within districts, increased use of pipeline distribution, and structure automation are all measures that should be considered.

### 6.2.4 Municipal Water Conservation

A culture of water conservation is important for all water-use sectors. Many communities in the SSRB have adopted water conservation programs for environmental preservation and to reduce water use and water and wastewater treatment costs. With closure of the Bow, Oldman and South Saskatchewan Sub-basins to new allocations, the communities now have an additional incentive in prolonging the time that their water use reaches the limit of their licence allocation. Municipal water conservation is important but the relatively small volume of water that could be freed up is not considered to be large enough to have a major impact on the basin-wide issues being addressed in this study.

### 6.2.5 Deficit Sharing

Deficit sharing has been practiced on a limited scale in the Bow River and Willow Creek basins and on a much broader scale in the Oldman River Basin in 2001. While all experiences have been considered to be worthwhile, the 2001 experience in the Oldman River Basin was considered to be a major success in minimizing the impacts of a serious water shortage on any users who participated in the sharing arrangements. For this reason it is considered to be an option that is worthy of further consideration in this study.

### 6.2.6 Drought Monitoring and Response Planning

Drought is a frequent phenomenon in the Palliser Triangle. The impacts can be devastating, as was seen in the 1930s and 1980s. Some work on drought monitoring and awareness is being carried out by Alberta Agriculture and Rural Development and PFRA. Development of a drought response plan for southern Alberta, with specific responses depending on the severity of the drought would be desirable, particularly for the agricultural water users in the SSRB. A drought mitigation program would help to increase public awareness of the need to conserve water. It would also assist in the implementation of measures such as deficit sharing. The primary benefit of drought mitigation planning is to reduce the impact of drought on water users. As such, it is not a mechanism for reducing demands and freeing up water for distribution to uses that are impacted by deficits. Hence, it is not a measure that warrants further consideration in this study.

### 6.2.7 Reservoir Sharing

Reservoir sharing for multi-purpose use and ownership sharing will be considered in addressing infrastructure operations.

### 6.2.8 Allocation Transfers

Allocation transfers can be a powerful tool to foster water-use diversity, improve efficiencies, increase water-use productivity and increase in-stream flows for aquatic protection. Allocation transfers are worthy of further consideration in this study.

### 6.2.9 Crop Shifts Within Irrigation Districts

Producers should be aware of differing water requirements for crops that can be grown in southern Alberta so that they can make an informed crop choice. While important to on-farm water management and financial sustainability, crop shifts are not likely to have a significant impact on issues identified in this study.

### 6.2.10 Industrial Use Conservation

Industrial water conservation, such as waterless cooling and water re-use is an important objective. But, like municipal water conservation, the amount of water freed up would be insufficient to make a significant impact on the issues being addressed in this study.

### 6.2.11 Increased Demand Monitoring and Enforcement

Demand monitoring and reporting would help to enforce licences and associated conditions. It would also help to improve water conservation and efficient use. Demand and return-flow monitoring should be considered as a component of irrigation water-use conservation. Probably the primary benefit of demand monitoring would be improved planning. The water-use database in the SSRB is fragmentary. Demands for several water-use sectors are based on licensing information and assumptions (AMEC, 2007).

### 6.2.12 On-Farm Storage Where Opportunities Exist

On-farm storage would help to balance water supply and demand for agricultural uses, and in some cases may help to reduce irrigation return flows. On-farm storage should be considered where opportunities exist, but this measure would not likely make a significant impact on the basin-wide issues being addressed in this study.

### 6.2.13 Improved Wastewater Treatment

During low-flow periods, in-stream flow requirements are largely determined based on water quality requirements. It has been reasoned that improvements in wastewater treatment would permit in-stream requirements during low-flow periods to be lowered.

Municipal and industrial wastewater treatment standards in Alberta are high. Significant improvements in treatment have been made during the past two decades, particularly in the larger urban centres (Sosiak, 2002). While additional improvements for some communities and industries may be warranted, the problem is not widespread and unlikely to make a significant reduction to in-stream flow requirements.

### 6.2.14 Alter Demand Priorities in Low-flow years

Section 107 of the *Water Act* provides that the Lieutenant Governor in Council may declare an emergency in all or any part of Alberta. When an emergency has been declared, the priority system under the *Water Act* can be overridden. Water uses that are deemed to be most important, regardless of priority, could be met. If higher priority uses are denied water to which they would normally be entitled, compensation may be required. This provision of the *Water Act* and its predecessor, the *Water Resources Act,* has rarely if ever been used. It could be considered a form of forced sharing of deficits, as opposed to the preferred voluntary sharing of deficits. It is possible that the emergency provision could be used to temporarily waive the in-stream flow requirement to accommodate uses that are deemed to be more important. This possibility will be addressed as part of the deficit sharing option.

#### 6.2.15 Summary

In summary, it was decided to further consider the following four measures that were considered to be most promising:

- review infrastructure operations;
- improved irrigation efficiencies and reductions in irrigation return flows;
- water allocation transfers; and,
- deficit sharing.

## 6.3 Review Infrastructure Operations

Operational refinements often provide the single most cost effective opportunity for increasing the benefits of a complex water management system involving several reservoirs, diversions, and multi-purposes uses. Generally, there are no capital costs involved in fine tuning existing infrastructure operations to ensure that benefits are at the optimum level. Operations should be reviewed periodically, perhaps every 5 to 10 years, to ensure that they reflect current policies, and changing demands within their areas of influence. Also, improved databases, technology and analytical techniques can help to refine operations from time to time. Above all, water storage reservoirs must be operated in accordance with dam safety guidelines to minimize the risk to life and property.

### 6.3.1 Provincial Infrastructure

There is a considerable amount of storage in the SSRB owned and operated by Alberta Environment, TransAlta, the irrigation districts and others. Most of Alberta Environment's storage is for multi-purpose uses. When a reservoir serves two or more purposes, operation becomes more complex. Reservoir rule curves developed through modelling and operational experience help to guide day-to-day operations. Rule curves divide the reservoir (or reservoirs in a multi-reservoir system) into zones that define the minimum water levels required in the reservoir to meet specific needs for which the reservoir is designed. Some zones within the reservoir may indicate a need to forgo benefits for a lower priority use to ensure there is sufficient water to meet later higher priority uses.

Development of rule curves for multi-purpose objectives becomes difficult when not all the purposes have value functions that can be expressed in common terms, such as monetary values. Compromises, value judgments, and trade-offs are almost always required in optimizing the operation of a highly allocated water management system. Simulation modelling can help to explore various trade-off opportunities and to define the inter-relationships among various objectives. Release of stored water for the benefit of downstream uses has a valuable property in that it is not subject to downstream licensing priorities. It can, if so desired, be used to achieve equitable performance amongst all downstream uses (including in-stream needs).

The operation of Gleniffer Reservoir is an interesting case study that demonstrates the need to periodically update and refine operational procedures.

In 1975, a 4-year planning study of the Red Deer River Basin (Alberta Environment, 1975) recommended that a dam be built on the Red Deer River west of Innisfail for the following purposes:

- present and future water supply;
- improvement of water quality along the river; and,
- provide additional benefits such as some erosion and flood control, improved fish habitat below the dam, increased lake-based recreational opportunities, and hydro-electric energy.

The Alberta Government announced construction of the multi-purpose dam on 18 July 1977, indicating that it would provide,

> "an assured water supply, improve water quality, and decrease flood and erosion damage."

The announcement added that there would be provision for the future installation of hydro-power facilities, and potential for water-based recreation and improved flows for fish and other aquatic life (Alberta Environment 1977). The licensed purpose for Dickson Dam is "*storage (flow control)*".

Hydro-electric facilities were added in 1991. Over the past 25 years, reservoir operational policies have evolved somewhat from those envisioned when the decision to implement was made. Adjustments have been made in response to changing needs and societal pressures. Flow augmentation for water quality improvements remains the highest priority for reservoir operations (AENV, 2006). Reservoir recreation has increased in prominence, but does not play a major role in operational decisions[10]. Water supply for existing and future consumptive needs appears to have a lesser priority than was envisioned when the decision was made to implement the project (Associated Engineering, 2008).

With respect to water quality, the 1975 study revealed a late-winter water quality problem along the Red Deer River. High nutrient concentrations caused extensive weed and algal growth during the summer months. Decaying vegetation under ice cover during winter reduced dissolved oxygen concentrations to below guidelines by late-winter. This issue became the focus for determining late-winter flow requirements along the river. The study indicated that,

> "…the minimum flow necessary to maintain 5.0 milligrams per litre dissolved oxygen at Empress would be 540 cfs. It is likely that this flow would be necessary only in the latter part of winter."

Accordingly, following construction of the dam and reservoir filling in 1983, 16.0 $m^3/s$ (565 cfs) was adopted as a minimum release from the reservoir. Winter water withdrawals along the river downstream of the dam frequently reduce the flow to less than 16.0 $m^3/s$ and, less often, to less than the recommended minimum flow of 15.3 $m^3/s$ (540 cfs). The minimum release remains at 16.0 $m^3/s$.

[10] Personal communication with Rick Friedl, Operations Manager, Alberta Environment.

On 16 January 2007, Alberta Environment established 16.0 $m^3/s$ as the November to March Water Conservation Objective from Dickson Dam to the Saskatchewan Border (Alberta Environment, 2007A). The document establishing the WCO indicated that it would apply to,

> "… any applications received or licences issued after 1 May 2005."

This decision gave new significance to flows along the river, and, in particular, the 16.0 $m^3/s$ release from Dickson Dam. When November to March flows drop below 16.0 $m^3/s$, water users with licences issued after 1 May 2005 are required (or, in some cases, will be required when all requirements for implementation of the WCOs are in place) to cease withdrawing water. This would apply to several regional municipal and rural domestic projects that have been licensed since 2005. Water Survey of Canada records for January to March, and November and December 2007 indicate that river flow dropped below 16.0 $m^3/s$ for 19 days at Red Deer, 4 days at Drumheller, and 69 days near Bindloss. For the same months in 2008, flows were below 16.0 $m^3/s$ for 23 days at Red Deer, 44 days at Drumheller and 62 days near Bindloss. (Most of these measurements were taken under ice conditions; their accuracy may be questioned.) The newly established WCOs would not affect water users who were licensed before 1 May 2005, but those with licences issued after that date and who require winter withdrawals may be significantly impacted unless their projects include storage to carry them through the low-flow periods.

A solution to this issue may lie in refining the operation policy for Dickson Dam. **Figure 6.1** shows the existing operating rule curves for Gleniffer Reservoir. If the reservoir is below the lowest desirable drawdown line, releases from the reservoir are limited to 16.0 $m^3/s$. When the reservoir is above the elevation of the lowest desirable drawdown line, it is highly probable that the reservoir will fill by the end of summer. In Scenario 3, which assumes the current operation, the reservoir fails to fill and spill only once in 68 years (1949).

In real time operation, the reservoir has been at or near its maximum capacity almost every year since operation began in 1984. The ideal situation is to have the reservoir between the lowest desirable drawdown and highest desirable fill lines. The range narrows during the summer months to ensure favourable recreation levels and to ensure adequate supplies for winter releases. The reservoir is held below the highest desirable fill line to provide storage for flood attenuation.

In 2007, Water Survey of Canada records indicated that there were 69 days during the winter when the flow was less than 16.0 $m^3/s$ near Bindloss. During the 69 days, the average flow was 13.8 $m^3/s$. The total deficit in meeting the WCO for that period was about 13 000 $dam^3$. The lowest recorded level in Gleniffer Reservoir in 2007 was elevation 940.7 m (3 May 2007), which is 3.7 m and about 55 000 $dam^3$ above the lowest desirable drawdown rule curve. There was sufficient storage to easily make up the deficit to the WCO without jeopardizing a high probability of filling the reservoir in 2008.

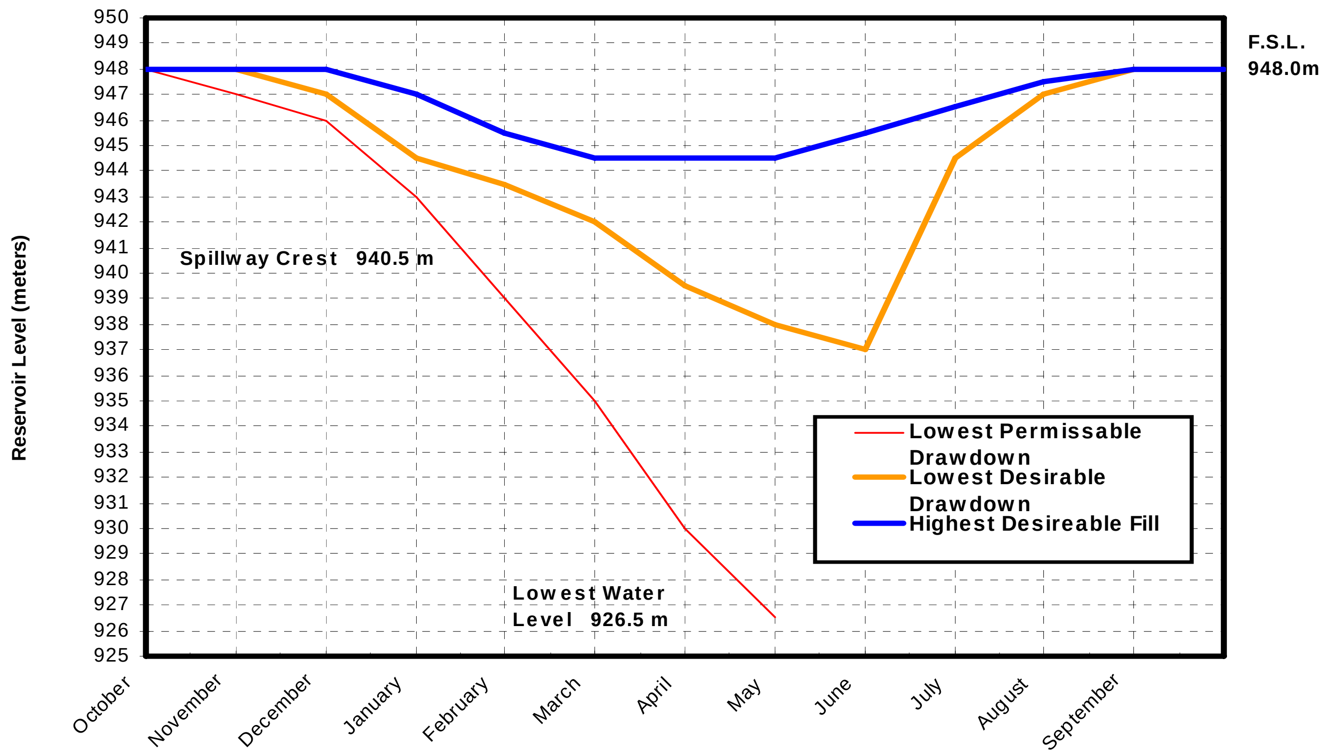



**Figure 6.1 Gleniffer Reservoir Operating Rule Curves**

The 2030 (Scenario 3) junior non-irrigation demands downstream of Dickson Dam during the 5 winter months are estimated to be about 34 000 $dam^3$. Simulation modelling indicated that the average annual deficit to junior non-irrigation demands would be about 9 000 $dam^3$. In 2007, there would have been sufficient water in the reservoir to meet the mean deficit to the 2030 junior non-irrigation demands, without the reservoir falling below the lowest desirable drawdown line. This will not always be the case, but it merely points out the need to thoroughly review operations from time to time to ensure that the infrastructure is used to maximum advantage, considering all uses, while ensuring legal priorities, licensing conditions, and government policies are respected.

The capacity of Gleniffer Reservoir is relatively small. There may not be much scope for modifying the rule curves without jeopardizing the primary purpose of the reservoir, or merely shifting the deficits from one period to another. However, there is sufficient evidence to suggest that it warrants further investigation using simulation modelling.

A review of the Gleniffer Reservoir operating procedures would involve simulation modelling and should include the following:

- A water quality study to determine if 16.0 $m^3/s$ is needed for the entire length of the river and for the entire winter to maintain favourable water quality conditions. Much has changed in the basin over the past 25 years. Populations have increased, industrial development has expanded, and agricultural practices have changed. So too have wastewater treatment technologies and standards. It is possible that the 16.0 $m^3$/s is no longer the required flow for water quality maintenance.

- When water is available in the reservoir and there is a high probability of filling, consider making releases to meet the needs of consumptive users along the river in addition to meeting the WCO and water quality needs. It may be possible to eliminate most of the winter deficits without jeopardizing the other uses of the reservoir.
- Consider sharing the risk among all users to minimize impacts of deficits. For instance, if recreation users and in-stream requirements could tolerate less than ideal conditions in 10% of the years (or some other appropriate percentage), the lowest desirable drawdown rule curve could be lowered making more of the reservoir storage available for meeting needs. With the current operation plan, the range of reservoir storage below the lowest desirable drawdown rule curve is not utilized for meeting downstream consumptive and in-stream demands.
- Utilize existing water supply forecasts to maximum advantage. Consider adjusting rule curves based on forecasted runoff and probabilities of filling.

Other large on-stream reservoirs in the SSRB that are owned and operated by the province are the Oldman River, Waterton and St. Mary Reservoirs. Operation procedures on these reservoirs have been reviewed from time to time. The rule curves for the St. Mary Reservoir were modified in 2008. The Waterton Reservoir operation is scheduled to be reviewed this year (2009). This practice of periodic reviews should be continued to ensure that operations are consistent with changing legislation and policies, projects are operated in a safe manner, and infrastructure is used to maximum advantage of all users. The province and irrigation districts own numerous off-stream storage reservoirs. Some of these reservoirs may be capable of reducing mainstem deficits, but not to the same extent as on-stream reservoirs for reasons discussed in Chapter 7.

Simulation modelling is an important analytical technique for reservoir operation planning for river basins. Current WRMM modelling requires that a reservoir follow identical rules for every year of simulation, regardless of the water supply. This is a very conservative operation procedure that results in the reservoir being operated as though every year has the lowest supply, and subsequent years are the beginning of a long-term drought. As a result, potential benefits are foregone to protect against the large impacts of prolonged droughts.

In practice, reservoir operators are provided, at the start of the irrigation season and every few weeks thereafter, with forecasts of expected water supply. Some real-time adjustments to operations are made based on the forecasts. It is recommended that Alberta Environment incorporate into the WRMM an algorithm that enables modifying rule curves depending on the forecasted water supply and storage conditions in the basin. This would facilitate operation planning that would capture additional reservoir benefits and assist real-time operators.

### 6.3.2 Operation of TransAlta's Reservoirs

TransAlta (TA) owns and operates six large reservoirs in the Bow River Sub-basin upstream of Calgary to regulate flows for their 11 hydro-electric power generating stations (**Table 6.1, Figure 6.2**). The Bow River hydro-electric facilities provide only about 3% of TA's total annual power production; however, this small percentage belies the importance of the facilities to their overall operation. The hydro plants provide rapid response to peak demands and short-term fluctuations in demands.

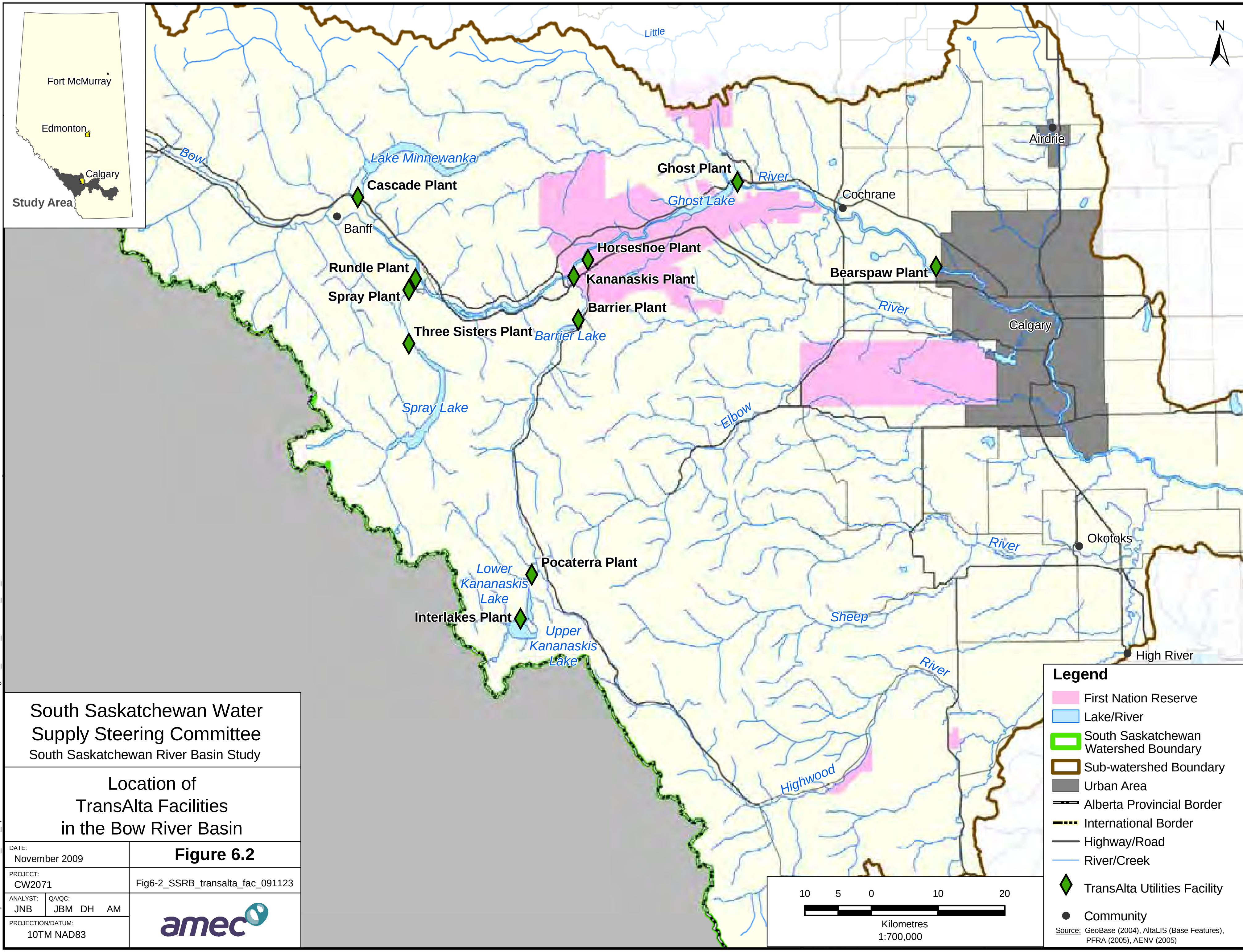
In general, these reservoirs are operated to store water in spring and summer and release water to supplement natural flow of the rivers for power generation during the remainder of the year.

**TABLE 6.1**
**TransAlta Hydro-electric System Basic Information**

| Plant | Reservoir | Primary Reservoir Supply | Installed Capacity (MW) | Reservoir Storage ($dam^3$) |
|---|---|---|---|---|
| Cascade | Lake Minnewanka | Cascade, North 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 | Forebay | Bow River | 19 | -- |
| Horseshoe | Forebay | Bow River | 16 | -- |
| Ghost | Ghost Lake | Bow River | 56 | 92 500 |
| Bearspaw | Forebay | Bow River | 17 | -- |
| **Bow Basin Total** | | | **330** | **704 400** |

Source: TransAlta

The difference between natural flow and recorded flow in the Bow River at Calgary hydrometric station is primarily due to operation of the hydro power facilities **(Figure 6.3)**. (The Calgary hydrometric station on the Bow River is upstream of the Elbow River.) While the reservoirs are operated primarily to provide timely power production, other uses of water are also considered. For instance, licensing on some reservoirs has minimum down-stream flow requirements and reservoir water level constraints. Releases are made in summer months to accommodate river recreation, fish and riparian habitat, and water quality. Higher than natural winter flows enhance municipal and industrial wastewater assimilation.




South Saskatchewan Water Supply Steering Committee

South Saskatchewan River Basin Study

Location of TransAlta Facilities in the Bow River Basin

DATE: November 2009

**Figure 6.2**

PROJECT: CW2071

Fig6-2_SSRB_transalta_fac_091123

ANALYST: JNB

QA/QC: JBM DH AM

PROJECTION/DATUM: 10TM NAD83

amec

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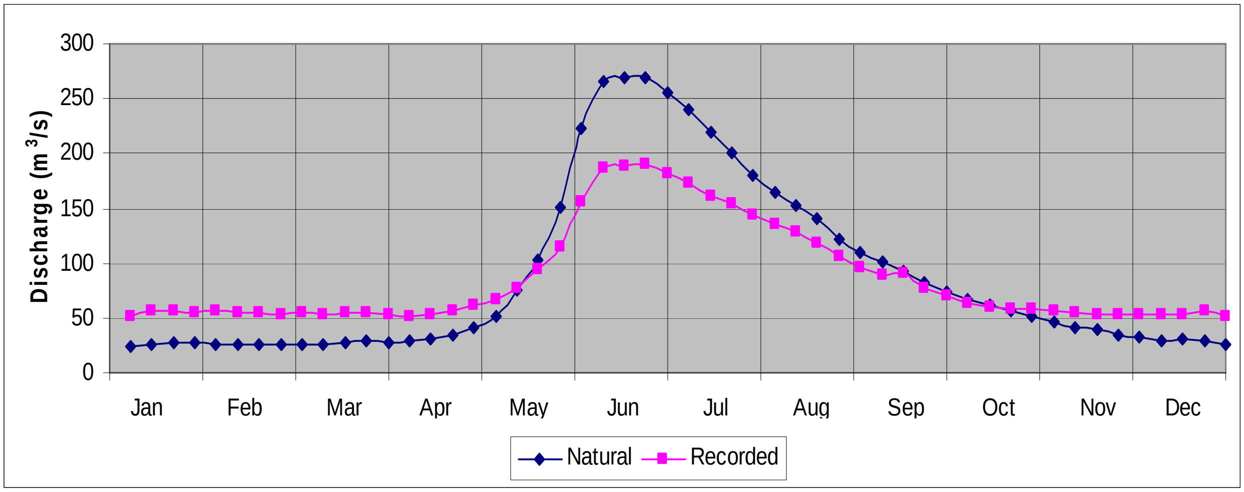



**Figure 6.3 Discharge of the Bow River at Calgary**

TransAlta is also bound under the legislative authority of the Alberta Energy Act to a Power Purchase Arrangement (PPA) which obligates TransAlta to supply pre-determined amounts of energy and reserves to the Alberta Electrical System Operator. The PPA obligations have a direct influence on reservoir operations and resulting power generation.

Simulation modelling conducted in Scenarios 1 to 4 assumed TA operating guidelines for storage projects in the upper Bow River Sub-basin. Simulation modelling indicated that increased irrigation district demands (primarily) assumed for Scenarios 2 and 3 would significantly increase deficits to the WCO, junior private irrigation projects and non-irrigation projects in the SSRB. It was felt that modifying the operation TA reservoirs in the upper Bow River Sub-basin may help to alleviate the impact on these uses of water in the sub-basin. A meeting was held with officials of TA, the study team and members of the Steering Committee to discuss the option of modifying the operation of one or more TA reservoirs. TA officials agreed to work with the study team to develop a scenario to determine the extent to which modifying the operation of the TA reservoirs would reduce the Scenario 3 deficits.

As a first step, it was suggested that the study team assume full control of all TA storage reservoirs with exception of Spray Lake. This provided 526 800 $dam^3$ of additional storage on the Bow River to assist in meeting consumptive and in-stream demands. While this is a substantial amount of storage, it is significant that most of the storage is on Bow River tributaries. The lower flows in the tributaries may not replenish reservoir storage as quickly as desired. Optimal Solutions Ltd., consultants for TA, worked with Unitech Solutions Ltd. of the study team to develop the modelling scenario (Scenario TA). The five TA reservoirs dedicated to meeting consumptive and in-stream needs were operated with those needs having a higher priority than hydro-electric energy production. The study team evaluated the performance of Scenario TA in meeting consumptive and in-stream needs. As a subsequent step to this study, TA will assess the impact which revised reservoir operations would have on power production as well as on TA's regulatory obligations under the PPA.

The performance in meeting the consumptive and in-stream needs for Scenario TA were compared with Scenario 1 (current conditions) and Scenario 3 (maximum district expansion considered in this study).

With respect to meeting the WCO, the performance for Scenario TA is comparable to that of Scenario 3. Scenario TA deficits are somewhat more frequent than Scenario 1 for the lower reach of the Bow River (**Figure 6.4**).

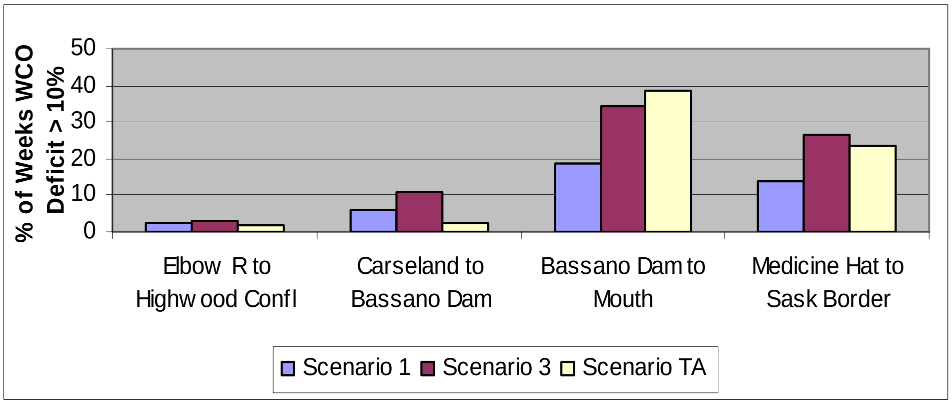
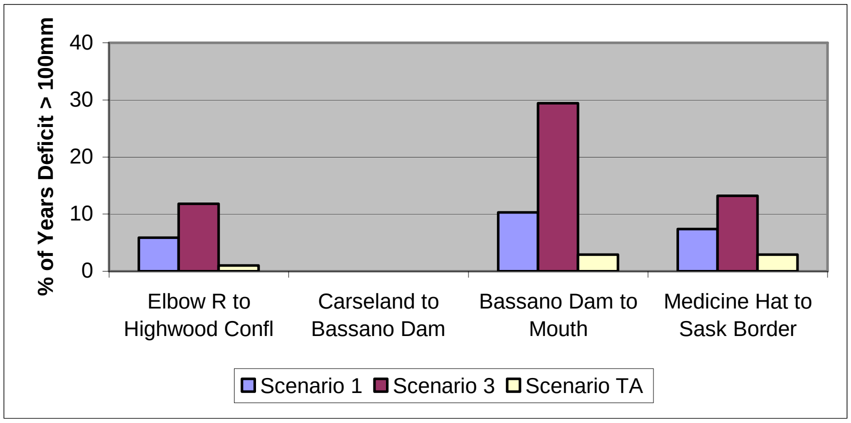



**Figure 6.4 Frequency of WCO Deficits Greater than 10% Along the Bow and South Saskatchewan Rivers**

There are two issues regarding WCOs and IOs that affect the interpretation of results related to in-stream requirements. First, there are few, if any, projects in the Bow, Oldman or South Saskatchewan Sub-basins that are subject to the WCO. In all of the scenarios simulated in this study, the IO is the in-stream target for reservoir operations in the Bow, Oldman or South Saskatchewan River Sub-basins. This is in keeping with the recommendations of the approved SSRB plan. Any improvements in meeting the WCO are primarily the coincidental result of reducing deficits to the IO. In Scenario TA, the IOs are always met on the Bow River. In Scenarios 1 to 3, there are occasional deficits to the IOs. In Scenario TA, releases are made from TA reservoirs to reduce deficits to consumptive users. Hence, there is less water in the system to contribute to WCOs. Second, there have been no detailed studies on winter (November to March) in-stream flow requirements in the SSRB. Winter IOs, and hence WCOs (which are often computed as the IO plus 10%), are based on the Tennant Tessman hydrologic approach to determining environmental flow requirements (inset). The Tennant Tessman flows tend to be much higher than natural flows during low-flow years. In some reaches of the Bow River, these flows proved to be difficult to meet in Scenario TA. A detailed assessment of winter flow requirements is required to determine if the Tennant Tessman flows are the appropriate in-stream flows for the winter months.

| **Tennant Tessman In-stream Flows for Fish** | |
|---|---|
| **Monthly Flow Condition** | **Required Monthly Flow** |
| MMF <40% MAF | MMF |
| 40% MAF <MMF <MAF | 40% MAF |
| MMF >MAF | 40% MAF |
| Flushing Flow Requirements | 200% MAF for 14-day period during month of highest runoff |
| MMF = Mean Monthly Flow<br>MAF = Mean Annual Flow | |

There are no significant deficits to irrigation district water demands in Scenario TA. With respect to junior private irrigation demands, performance is much improved for Scenario TA (**Figure 6.5**). Scenario TA has very few deficits, and significantly improves on Scenario 1 (current conditions) performance.




Note: There are no junior private irrigation projects in the Carseland to Bassano Dam reach.

**Figure 6.5 Frequency of Deficits Greater than 100 mm for Junior Private Irrigation Projects Along the Bow and South Saskatchewan Rivers**

With respect to junior non-irrigation projects, simulation modelling indicated a very high frequency of deficits in Scenarios 1 and 3. Scenario TA would decrease the deficits substantially (**Figure 6.6**).

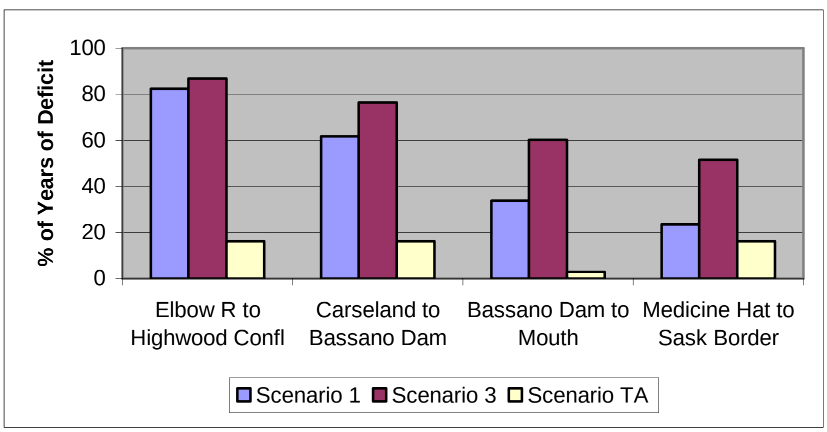



**Figure 6.6 Frequency of Deficits to Junior Non-irrigation Projects along the Bow and South Saskatchewan Rivers**

In summary, results of simulation modelling indicate that operation of the five TA reservoirs to meet in-stream and junior consumptive needs in the Bow River Sub-basin would eliminate deficits to the IOs and substantially improve performance in meeting consumptive demands. Performance in meeting the WCO would be about the same as Scenario 3.

Compared with recorded flow, on average, Scenario TA would result in reduced flows in Calgary during winter and increased flows in spring and summer (**Figure 6.7**). Average winter flows would be just slightly higher than natural flows. Spring flows would be higher than natural, and summer flows lower than natural.

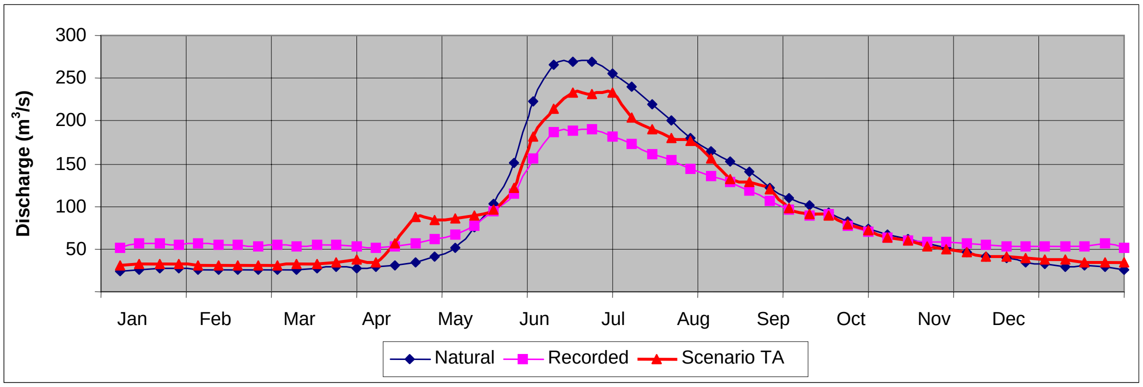



**Figure 6.7 Scenario TA Simulated Mean Weekly Flow Compared with Natural and Recorded Flows at Calgary**

This analysis in no way represents a definitive solution to the potential future water supply issues in the Bow River Sub-basin. It merely indicates that changes to the operating patterns of the TA storage reservoirs would have potential for reducing deficits to in-stream demands, and existing and future consumptive demands in the sub-basin. Further studies related to the environmental impacts of the modified flow regime and the hydro-electric generation benefits foregone are required. This study sets the stage for further discussion and analyses.

## 6.4 Irrigation District Water-Use Efficiency

With closure of the Bow, Oldman, and South Saskatchewan Sub-basins to new allocations for most water-use sectors, existing users with growth potential and developers requiring a new water allocation to pursue economic development opportunities are looking to the irrigation industry to improve water-use efficiency and free up water for other important purposes. Why focus on irrigation? Water conservation and efficient use are important for all water-use sectors. However, irrigation has by far the highest water allocation and is the most predominant consumptive water-use sector in the SSRB. Most of the irrigation licences, and particularly the irrigation district licences, pre-date in-stream flow constraints that have been developed during the past two decades. Hence, most withdrawals for irrigation purposes have priority over in-stream constraints.

The deficits to in-stream flow requirements and non-irrigation water demands being addressed in this section of the report are largely due to the potential expansion of the irrigated area within Alberta. Most of this expansion can take place within existing licence allocations, outstanding licence applications, and government commitments to development. With respect to water-use efficiencies, irrigation efficiency improvements hold the most promise of all the water-use sectors in the SSRB, for being part of the solution to the issues being addressed. It is important that water conservation and efficiency improvements be pursued in other water-use sectors as well, but their contributions to basin-wide issues are likely to be much smaller than efficiency improvements in irrigation.

Of the amount of water allocated for irrigation in the SSRB, the 13 irrigation districts account for over 91% and private irrigation about 9%. Generally speaking, withdrawals per unit of irrigated area for private irrigation are somewhat lower than those for district irrigators since private irrigators do not have a delivery system with evaporation and seepage losses. In addition, return flows for private irrigators are usually insignificant; whereas, in irrigation districts return flows can be a major component of withdrawals. Because of the scale of allocations and water use within the irrigation districts and the scope for improvements, the primary focus for this analysis is irrigation efficiencies within the 13 irrigation districts of southern Alberta.

In late-2001, the Government of Alberta embarked on a public process to develop a new water management approach and strategy for managing Alberta's water needs, maintaining the province's economic prosperity and addressing environmental concerns. The Water for Life strategy was released in November 2003 (Government of Alberta, 2003). One of the long-term goals established by the strategy is to improve overall efficiency and productivity associated with water use by 30% from 2005 levels, by 2015. To assist in accomplishing this goal, seven water-use sector groups were established to prepare Conservation Efficiency Productivity (CEP) plans for each water-use sector. In February 2009, a draft report on the Irrigation Sector CEP Plan was available (AECOM, 2009). The draft report describes the progress the irrigation industry has made related to water-use efficiency, and recommends specific measures to assist in achieving further gains toward CEP objectives.

The irrigation industry in Alberta has made significant gains in water-use efficiency over the past several decades. The gross diversion per hectare of irrigated lands has been declining steadily since 1976 when systematic collection of data began (**Figure 6.8**). A Mann-Kendall trend analysis indicates that the trend is significant at a 99% level of confidence. The trend line indicates an average annual reduction in withdrawal of 1.46% or about 7.4 mm/y.

Efficiency improvements during the past three decades have been realized as the combined impacts of on-farm application efficiencies, district conveyance improvements, and reduced return flows. Past efficiency improvements and prospects for future improvements of each component are discussed in turn below.

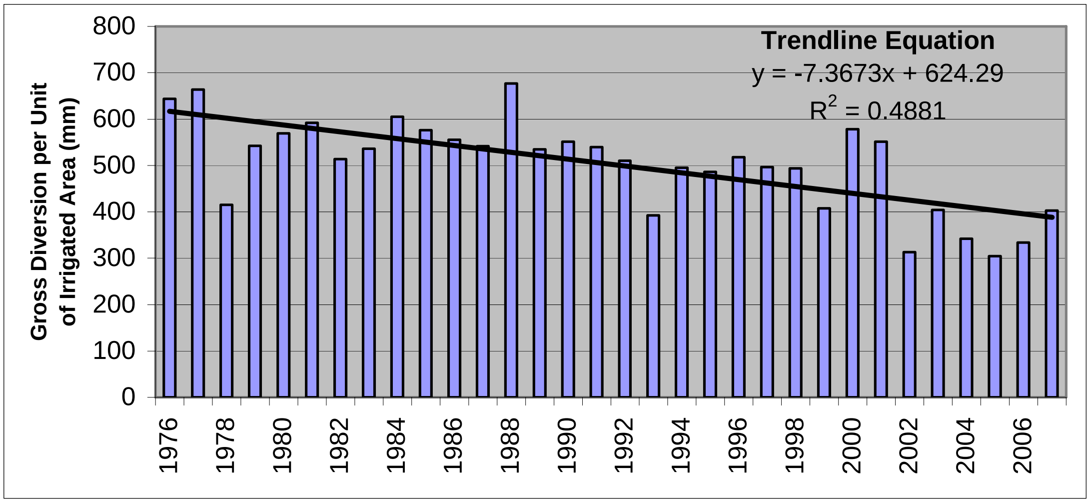



**Figure 6.8 Gross Diversion to the Irrigation Districts Expressed as Depth Over the Irrigated Area**

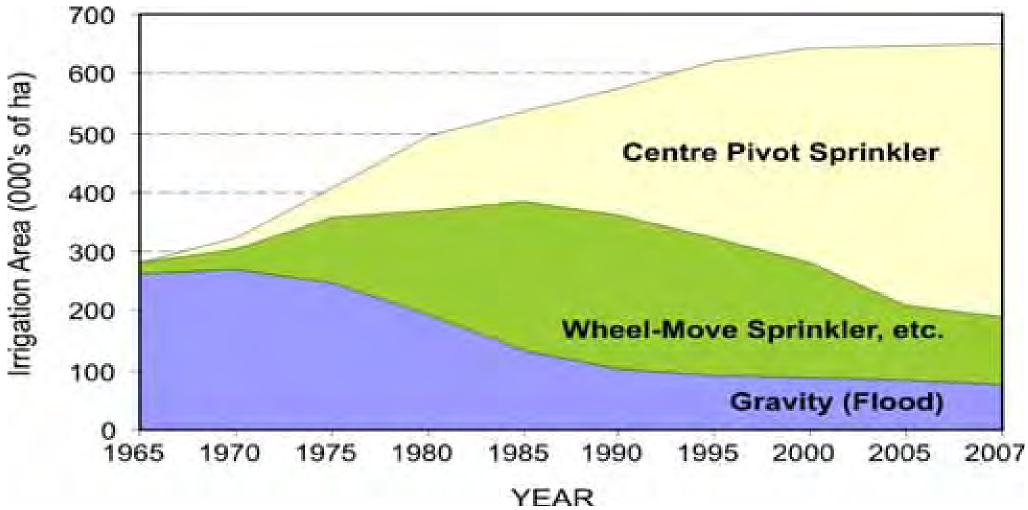
### 6.4.1 On-Farm Application Efficiencies

The on-farm component represents about 70 to 75% of the total water withdrawn from the source streams (gross diversion). On-farm efficiency improvements hold potential for significant reductions in total water demand for the irrigation sector. During the past four decades, changes in the mix of irrigation methods and equipment have been the primary influence on on-farm efficiency (**Figure 6.9**). **Table 6.2** lists the on-farm application efficiencies that are considered by ARD to be representative of the most common irrigation equipment used in Alberta.

> In Alberta, **on-farm application efficiency** is defined as the amount of irrigation water applied and retained within the active root zone as a percentage of the total amount of irrigation water delivered to the on-farm system. (Irrigation Water Management Study Committee 2002.)

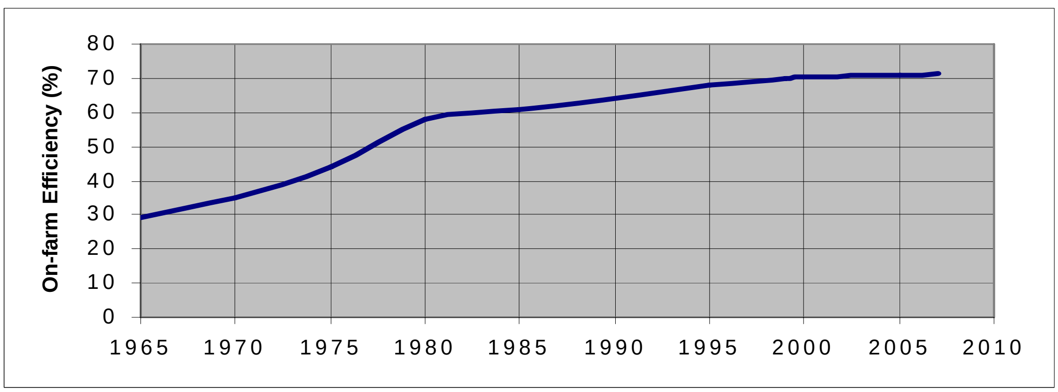
The migration of irrigation methods and equipment from gravity flood irrigation, to wheel-move sprinklers, and to centre-pivot sprinklers has improved on-farm control of water, reduced labour costs, enabled irrigation of additional areas "above the ditch", and improved irrigation efficiencies (**Figure 6.10**).

Low pressure centre pivots, with efficiencies of 80% or higher, are currently the equipment of choice in southern Alberta and are leading the way in on-farm efficiency improvements. These centre pivots occupied almost half of the irrigated land within districts in 2007. AECOM (2009) speculates a future systems mix within the districts as listed in **Table 6.2**. AECOM has projected that this shift in systems will reduce gross diversion requirements by about 4.2%.




Source: AECOM, 2009.

**Figure 6.9 Historical Growth in Irrigation Area within Irrigation Districts in Alberta and Shifts in On-farm Irrigation Methods**




Data source: AECOM, 2009.

**Figure 6.10 Historical Improvements in On-farm Application Efficiency within Irrigation Districts**

**TABLE 6.2**
**Current and Possible Future On-farm Systems Mix within the Irrigation Districts**

| | Efficiency | District Systems Mix in % of Irrigated Area | |
|---|---|---|---|
| | | 2007[1] | Future[2] |
| Surface – Gravity | 30% to 65% | 14% | 5.3% |
| Wheel Move | 68% | 20% | 9.3% |
| Centre Pivot | | | |
| High Pressure | 74% | 16% | 10.4% |
| Low Pressure | 80% | 49% | 75.0% |
| Other | | 1% | |

1. ARD, 2007. 2. AECOM, 2009.

A survey of irrigators in the Raymond and Taber Irrigation Districts (Nicol *et al*., 2008) indicated that the motivations for irrigation producers to implement new technologies are, in order of most to least importance:

1. to improve crop yields and quality and improve their financial performance;
2. to reduce labour input;
3. to reduce energy consumption; and,
4. to reduce water use.

These reasons for adopting new irrigation technologies are consistent with research of private irrigation producers in Alberta (Nicol *et al*., 2008) and irrigators in other jurisdictions, such as Australia and United States.

Reasons for not implementing new technologies are, in order of most to least importance:

1. they have already implemented what is practical. Additional improvements would not be practical;
2. financial constraints did not permit additional investments;
3. physical field conditions preclude system improvements; and,
4. sufficient water is now available.

A cash subsidy of $10,000 to $30,000 would be required to overcome the financial constraints to investing in a new low pressure centre-pivot. These findings of Nicol *et al*. for southern Alberta were similar to findings of other researchers who indicate that technology adoption begins at a subsidy of about 60% and flourishes with a subsidy of 80% (Scheirling *et al*., 2006).

### 6.4.2 Irrigation District Conveyance Efficiency

Primary conveyance losses are seepage and evaporation from canals and reservoirs. Prior to 1970 seepage losses from canals were thought to be high, although no comprehensive monitoring or research was conducted to quantify it. Seepage caused considerable water logging and soil salinity problems downslope from canals, as well as inefficient water use. This prompted the provincial government and irrigation districts to initiate a cost-sharing program to rehabilitate district-owned infrastructure in 1969. In the early-1970s, the province initiated a program to rehabilitate provincially-owned headworks. Both these programs are continuing today. Rehabilitation of the provincial headworks is nearing completion. The cost-share Irrigation Rehabilitation Program (IRP) has improved about 70% of district conveyance works. Canals were upgraded and impervious liners were installed, where necessary, to prevent seepage. Structures were replaced and water control gates automated, and many canals were replaced by buried pipelines.

**Conveyance Efficiency (CE)** = one minus seepage (S) plus net evaporation (NE) losses divided by gross diversion (GD):

**CE = 1 – (S + NE)/GD**

**Net evaporation** = gross evaporation minus precipitation directly on the open water surface.

Research by ARD conducted in the late-1990s found that conveyance losses were reduced to the following values expressed as a percent of the gross diversion:

- Canal seepage 2.5%
- Canal net evaporation 0.5%
- Reservoir net evaporation 3.4%

Pipelines now comprise about 38.5% of the total length of conveyance works within the districts. Replacement of canals with pipelines is continuing, further reducing seepage and evaporation losses. Reservoir evaporation is not likely to reduce in the future. In fact, with potentially warmer summer temperatures as a result of a changing climate, reservoir evaporation may increase by a small amount.

AECOM (2009) has projected that further improvements in conveyance efficiencies will reduce gross diversion requirements by about 1.0%.

### 6.4.3 Return Flows

Return flows are the inevitable consequence of the inability to perfectly match *variable water supplies* with *variable water demands* in a canal distribution system. Surplus deliveries are returned to streams through drainage channels. Prior to 1995, monitoring of return flows was minimal. The Prairie Provinces Water Board (PPWB) and Water Survey of Canada did occasional synopsis monitoring to enable estimates of return flows for determining inter-provincial apportionment shares. Prior to 1995, PPWB estimates of return flow for all districts were usually in the order of 500 000 to 600 000 $dam^3$ (Irrigation Water Management Study Committee, 2002).

Since the mid-1990s, most irrigation districts have made concerted efforts to monitor their return flows. Since monitoring began, there has been a modest but steady decrease in the volume of return flow and a more pronounced decrease in the gross diversion. The volume of return flow is decreasing at a rate of about 3.0% per year in spite of the increased irrigation area. During the past decade, return flow has averaged 19 to 20% of the gross diversion.

Return flows will continue to decrease with expansion of the use of pipe conveyance, automation of structures and perhaps strategically located balancing reservoirs. AECOM (2009) has projected that the volume of return flow for the current irrigated area could be reduced from 19.5% to about 11.5% of the gross diversion during the next 15 to 20 years.

The total reduction in the average gross diversion as a result of improvements in on-farm and conveyance efficiencies and reduced return flows has been projected by AECOM to be about 15% over the next 10 to 15 years.

Ideally, for the purposes of resolving issues identified in this study, as return flows decrease the gross diversion demand will decrease. More water will remain in the source streams to meet the needs of the aquatic environment and downstream consumptive needs between the point of diversion and the mouths of return flow drains. In some cases this can be a considerable distance, or even the entire length of the source stream in cases where districts drain substantial amounts of return flow to adjacent sub-basins. However, the argument has been made that on some drains a consumption and environmental dependency on flow in the return flow channels has developed over time, and reducing that return flow would be counter productive. The argument may be valid related to incidental benefits to the aquatic ecology, riparian vegetation, and associated wildlife habitat along the drainage channels. Consumptive needs, however, can continue to be met by diversions through the works of the districts within the constraints of the licences of users of return flows and the districts.

### 6.4.4 Summary

AECOM (2009) established that current (2007) irrigation efficiencies are about 53%. They suggest a target irrigation efficiency of 63% within the next 10 to 15 years as the irrigation industry's contribution to the Water for Life CEP program. The component breakdown of current and projected efficiencies is outlined in **Table 6.3**. This level of improved efficiency for the current irrigated area of 494 087 ha would conserve about 326 000 $dam^3$ of water in the SSRB.

The findings of researchers Nicol (2007, 2008) and Bjornlund (2008) suggest that this degree of improvement may be difficult to accomplish. Nicol indicated that the most feasible technological improvements have already been implemented. Considerable progress was made prior to 2001, but efficiency improvements since that time have slowed considerably, and will probably further drop off over the next 5 years unless considerable subsidies or improved market conditions become available. Nicol noted that current policy and legislation in Alberta leave it up to the water users to decide how conserved water is used. Regulatory changes would be required to ensure that conserved water is used to meet consumptive deficits, or retained in the stream to reduce in-stream deficits rather than used to expand the irrigated area. Alternatively, this could be possible through an implementation agreement that includes cost sharing for efficiency improvement measures. Such an agreement between government agencies and the Sunnyside Valley Irrigation District in the State of Washington is touted as a win-win accomplishment (inset).

**TABLE 6.3**
**Current and Projected Breakdown of Water Use and Efficiencies by Component**

| | Current Conditions | | Future Projections | |
|---|---|---|---|---|
| **Water Use Component** | **Efficiency (%)** | **Net Loss to Gross Diversion (mm)** | **Efficiency (%)** | **Net Loss to Gross Diversion (mm)** |
| Crop Use | | 235 | | 235 |
| On-farm Application | 72.0 | 91 | 76.4 | 73 |
| Conveyance[1] | 93.7 | 28 | 93.6 | 24 |
| Return Flow | 80.5 | 86 | 88.7 | 43 |
| Total Gross Diversion[2] | | 441 | | 375 |

Data Source: AECOM, 2009.

1. Conveyance losses = seepage and evaporation losses from district infrastructure.
2. Overall Efficiency (OE) = Crop Use divided by Total Gross Diversion.
   For current conditions OE = 53%; for future projections OE = 63%.

Bjornlund (2009) indicated that irrigators left to their own resources will be slow to adopt new efficient technologies in the future. A survey of SSRB irrigation district officials in 2005 indicated that the expectation for conservation and efficiency gains within districts was variable from district to district, but the collective gain would be far below Water for Life targets.

Innovative opportunities may arise from time to time that will benefit the irrigators and assist in meeting societal goals for increased in-stream flows, more efficient water use, increased water-use productivity and economic growth. Partnering on implementation may ensure that surplus water is shared in a manner that contributes to broader societal goals and directly benefits the water users.

The **Sunnyside Valley Irrigation District** diverts water from the Yakima River (Washington State) into a 110 km canal. The aging infrastructure of the district was very inefficient and badly in need of improvements. Works required were replacement and automation of erosion control structures and 3 small off-stream balancing reservoirs adjacent to the canal. The improved efficiency would reduce diversion requirements for the existing 35 000 ha of irrigated land by about 35 800 $dam^3$. Project costs were estimated to be $32.6 million. A 9-year implementation agreement allocated 65% of the costs to the U.S. Bureau of Reclamation, 17.5% to the State of Washington, and 17.5% to the Irrigation District. The agreement specified that two-thirds of the saved water was to remain in the stream. The remaining one-third could be used by the district to reduce deficits or expand their irrigated area. Implementation of the project is underway.

(http://www.svid.org/images/SCIP%20FACT%20AND%20MAP%209.25.07.pdf)

In that vein, the Raymond Irrigation District has explored the feasibility of developing a comprehensive pressure pipe water supply system for the district (Russell Consulting, 2008). This system would take advantage of the 110 m difference in elevation between its supply source on Milk River Ridge and its irrigation area to provide sufficient pipe pressure to operate sprinkler systems without on-farm pumping. The analysis concluded that the project would be financially attractive from the irrigation farmer's point-of-view. The district is actively seeking provincial support for the project. The project would almost eliminate district canal seepage, evaporation losses, and return flows. Like the Sunnyside project, it could contribute to societal goals such as the Water for Life goals of improved efficiencies, productivity, and aquatic ecosystem health. It would also reduce the carbon footprint of the Raymond Irrigation District by eliminating the need for on-farm pumping using fossil fuels. The saved water could be used for irrigation expansion and other non-irrigation purposes.

## 6.5 Market-based Water Allocation Transfers

With the passage of the *Water Act* in 1999, Albertans for the first time had the ability to detach a water licence, in good standing under the *Act*, from land at a particular location and move it to other land within the same basin. The *Water Act* refers to this as an allocation transfer. In essence, the *Water Act* transforms licences into government regulated marketable commodities.

Allocation transfers can be either temporary or permanent. They can be for the entire allocation or a fraction thereof, for the same purpose or for differing purposes. Financial arrangements for a transfer are negotiated between a willing buyer and willing seller. An approved transfer retains the priority of the original licence. Alberta Environment reserves the right to hold back up to 10% of a transfer to assist in meeting a Water Conservation Objective (WCO).

The provincial objectives in establishing provision for water allocation transfers are to:

- enable existing water users requiring an additional allocation or a higher priority allocation, or a new water user requiring a licence, an opportunity to expand or implement an economic development opportunity in river basins that are fully allocated and closed to new licence applications;
- improve water-use efficiencies by providing an incentive for reducing demands. Water saved would be available for transfer for monetary gain;
- improve water-use productivity by transfer of allocations from lower value purposes to higher value purposes; and,
- decrease deficits in meeting the WCOs through allocation transfer holdbacks and purchase of allocations specifically for that purpose (holdbacks and transfers may be licensed by government to assist in achieving WCOs).

An allocation transfer requires prior approval by Alberta Environment. A public review of a proposed transfer is mandatory. Alberta Environment's review of a transfer application may include the following considerations:

- cumulative impacts on the aquatic environment or meeting the WCO, effects on household users, traditional agricultural users or licensees, and effects on public safety;
- with respect to transfer for irrigation purposes, the suitability of land for sustainable irrigation;
- the historical amount and seasonality of diversions by the seller; and,
- other matters deemed to be relevant or identified in an approved water management plan.

Several unique factors pertaining to water and water development tend to be constraints to the free market process. Water markets are complicated by the mobile and uncertain nature of water quantity and quality. Water has different, highly variable values depending on end uses **(Table 6.4).**

The regulatory process involved in gaining provincial approval of a transfer can be onerous, time consuming and costly. Urban and rural municipalities sometimes fear the erosion of their economic base or way of life as a result of cumulative effects of several transfers that change the water-use purpose.

Water markets have developed in areas of water scarcity, such as Australia, Chile and the western United States. Like other jurisdictions, early water market activity in Alberta has been slow. The transfer process in Alberta is still in its infancy – only a few "arms length" transfers have taken place. (Other transfers between landholdings within the same family and for the same purpose have taken place. Such transfers are not a good gauge of the full transfer process and impacts.) While the transfer experience is too immature to draw definitive conclusions, analysis of six arms-length transfers indicates that the process is going in the right direction with respect to the provincial objectives (Nicol *et al*., 2007):

**TABLE 6.4**
**Range and Average Annual Values for Water in Canada[1]**

| Water Use Purpose | Range of Values ($ Canadian/dam³) | | |
|---|---|---|---|
| | Low | High | Average |
| Municipal [2] | 100 | 2430 | 1220 |
| Residential [3] | 5 | 3356 | 1681 |
| Irrigation [3, 6] | 51 | 104 | 69 |
| Livestock Watering [4] | 27 | 682 | 355 |
| Industrial [2] | | | |
| Food and Beverages | 10 | 124 | 67 |
| Petroleum/Chemicals | 17 | 130 | 74 |
| Hydro or Thermal Electricity [3] | 7 | 18 | 13 |
| Sports Fishing [2, 5] | 20 | 74 | 47 |
| Waste Assimilation [2] | 1 | 4 | 3 |

1. Source: Klohn Crippen, 2003, Page 520. Table based on studies conducted between 1985 and 2001.
2. Muller 1985.
3. Saskatchewan Water Corporation, 1986.
4. AMEC, 2001.
5. Sports fishing brackets most in-stream value estimates (Colby 1987).
6. Irrigation excludes value added enterprises.

- There was a wide variation in trading prices for the transactions. Prices ranged from $140/dam^3$ to $740/dam^3$, with an average price of $448/dam^3$. The highest prices were paid for water allocations with senior priority, indicating that security of water supply was a motivating factor. The highest prices were paid for water purchased for domestic or specialty crop use.
- Of 6 transfers in southern Alberta, 4 moved water from lower-value use to higher-value use, in keeping with the provincial objective of increasing the productivity of water and enhancing economic output. The remaining two uses were for similar purposes.
- In 5 of the 6 transfers, water moved from irrigation projects with relatively low efficiency on-farm irrigation equipment, to farms with higher efficiency equipment. These transfers increased water-use efficiency.
- Overshadowing the above findings is the fact that in this limited sample, sellers are primarily transferring rights to unused water, which is similar to experience in early markets in other countries. As a result, the transfers that have taken place will increase water use in southern Alberta.

One additional, highly publicized transfer took place in 2007. The Municipal District of Rocky View agreed to pay the Western Irrigation District $15 million toward replacing a leaky canal with a pipeline in return for a transfer of 2 466 $dam^3$ of the saved water. The allocation purchased by the municipal district will be used in a shopping and horse racing complex north of Calgary and other undisclosed future uses. A 10% environmental holdback was applied. The unit price for this water is $6,080/$dam^3$, which stands out as a high-side anomaly among transfers that have taken place in Alberta. The transfer met all provincial objectives of the market process. The irrigation district was able to improve their water-use efficiency; a commercial/municipal user was able to secure a licence allocation that otherwise was unavailable; the allocation was transferred to a higher-valued use; and, the 10% environmental holdback helped to improve Bow River in-stream flows by a small amount.

Early indications are that the water market in southern Alberta is developing very slowly and cautiously, similar to early markets for water rights in other jurisdictions (Nicol *et al*., 2008). However, economic adjustments have been facilitated by allocation transfers. Given sufficient time and continued water supply constraints, there will be a gradual shift of allocations to higher value uses, generally in keeping with the relative value of water listed in **Table 6.4** (Klohn Crippen, 2003). Greater market activity is required to make a significant contribution to the provincial goals of increased efficiency and productivity (Nicol *et al*., 2008).

Reported impediments to the transfer process in Alberta and elsewhere are as follows:

- Buyers and sellers sometimes have difficulty finding each other. A central registry where participants in the market process could register their willingness to buy or sell would help to connect buyers and sellers.
- Buyers and sellers struggle to determine a reasonable price for a transfer. Information on sale prices in past transactions would assist in negotiating a fair price.
- In some jurisdictions, the high costs of transactions were impediments to active water markets. Transaction costs in southern Alberta have been comparatively low. However, this may change as the process matures and common issues are identified and required to be addressed by the buyer or seller. Efforts should be made to avoid escalation of transaction costs.
- Time delays in obtaining government approval for a transaction appear to be more of an issue in southern Alberta than transaction costs. Some participants expressed frustration with the process and the length of time it took for decisions. Complex rules and the unpredictability of outcomes of government interventions in the process is a deterrent to a vibrant market. However, it is recognized that government regulation of the transfer process is essential to protect other licensees, environmental values and other public interests. Government interventions should be consistent and their outcomes predictable to minimize risks and uncertainties to buyers and sellers (Ait Ouyahia *et al*., 2005).

### 6.5.1 Summary

With population growth and increased economic activity, water use within the SSRB will increase through existing licensees using a higher percentage of their allocations; approval of outstanding applications for feasible projects; and, implementation of outstanding government commitments for projects in the basin. In Chapter 5, it was established through simulation modelling that increases in water use could increase deficits to WCOs and junior priority private irrigation and non-irrigation water users. The purpose of this section is to determine if water allocation transfers hold promise as a measure that could be used to alleviate the basin-wide impacts on the WCOs and junior licensees.

The analysis conducted indicates that, in the long term, allocation transfers will gradually shift water use to higher value purposes, to more efficient users and to meeting in-stream requirements. The contribution of transfers to reducing basin-wide deficits identified in this study is likely to be small in light of the large amount of transfers required to have a significant impact on the issues identified and given the low level of market activity experienced in the first 9 years since the transfers were authorized under the *Water Act*. Certain measures could be taken to help foster a more robust water market. Even with more robust markets, water allocation transfers are not likely to become the primary means of addressing issues identified in this study, but they can play an important role.

### 6.6 Deficit Sharing

During drought years in the 1980s and early-1990s, major water users in the Bow River Basin determined that it would be in their collective best interests to share available water rather than strictly abide by the priority system under the *Water Resources Act*. Diversion and reservoir operation plans were worked out to the satisfaction of the users, the objective being to share the impact of the drought and minimize the impact on any one user. Care was taken not to impact other users and in-stream values of the river. The sharing arrangements were legitimized by temporary transfers under the *Water Resources Act*. In some years, changes in the weather precluded the need to implement the plan, but the idea of "*sharing the pain*" was deemed to be a good management strategy. Equitable sharing of available water supplies among irrigators in water-short years was also common practice in the Willow Creek Basin prior to construction of the Pine Coulee Reservoir. It was considered to be the neighbourly thing to do.

The *Water Act* (1999) now contains a provision that permits a licence or registration holder to assign or share their water allocation with another licence or registration holder using the same source (Section 33). Assignments are temporary transfers that can be used to distribute the impacts of water supply deficits over a large number of licence or registration holders to minimize the impact on any one user. Without a sharing arrangement, senior priority users may receive their full allocation, while some junior priority users receive no water.

The provision for allocation assignments specify that an allocation may not be assigned to an individual who does not have a licence or registration. The total amount of water that can be used by the receiver (use under the receiver's own licence plus the transferred amount) cannot exceed the allocation of the receiver's licence. A written agreement between the two parties is required. Compensation is negotiated between the buyer and seller. The government has the right to cancel the agreement if there is an

**Key Provisions of the *Water Act* Regarding Assignments**

1. With respect to <u>priority for use</u> of the assigned water, Section 33(1)(c) says:

   Water may be assigned when "no rights of a household user, or of a licensee or traditional agricultural user with a higher priority than the party to the agreement who has the lowest priority, are adversely affected by the temporary assignment."

2. With respect to <u>conditions for use</u> of assigned water, Section 32(3)(b) says:

   "the diversion of water by the licensee or traditional agriculture user temporarily receiving the water must be done in accordance with the licence or registration of the traditional agriculture user or licensee receiving the water" adverse impact on the environment or other water users with higher priorities than the party with the lowest priority in the agreement.

In 2001, over 600 water users shared their allocations as a result of a water shortage in the Waterton, Belly and St. Mary River Basins. Following review of the 2001 experience in southern Alberta, Nicol (2005; 2006) concluded that:

- the temporary assignment provision of the *Water Act* helped to ensure that irrigators growing higher value crops were able to meet processing contracts in 2001, in spite of the drought;
- water moved from lower- to higher-valued uses, enhancing the productivity of water;
- water moved from less efficient on-farm irrigation equipment to more efficient equipment, increasing water-use efficiency;
- sellers viewed the assignment market as an opportunity to earn additional income. Buyers viewed the market as a way to increase crop yields and meet contract obligations during a water deficit year;
- the market functioned relatively smoothly in 2001. It did not have the administrative impediments and 3rd-party interventions experienced by participants in the allocation transfer market;

Water sharing in 2001 was considered to be a success story. The 2001 assignment process would probably be used again and perhaps expanded in subsequent droughts (Watrecon, 2005). Judging by the actions of water users and water managers during the drought of the 1980s and in 2001, in stressful times of water supply deficits the well-being of water users in the region as-a-whole takes precedence over individual prosperity.

### 6.6.1 Summary

Allocation assignments definitely have an important role in future water management in the SSRB. Assignments are a valuable tool in reducing the impacts of periodic droughts. However, assignments would not have a major impact on the issues identified in this study. Model results indicate that expansion of the irrigated areas assumed for Scenarios 2 and 3, primarily within irrigation districts, will result in significant increases in deficits to junior private irrigation water users, junior non-irrigation water users, and WCOs. Deficits would be frequent and, in some cases, large. Section 33(3)(b) of the *Water Act* indicates that the receiver of the assigned water must adhere to the conditions of his own licence. Hence, a condition of a junior licensee would not allow diversions when the in-stream flow conditions are not being met. Furthermore, to cope with frequent deficits using assignments, repeated annual assignments would be required. Repeated assignments between the same buyer and seller may be considered by *Water Act* administrators as a method of avoiding the regulatory control and hold-back provision of permanent allocation transfers, and may be disallowed on that basis.

Another form of sharing deficits would involve giving special status to some individual water users or entire water-use sectors that would allow users within those sectors to infringe on WCOs or IOs under certain conditions. For instance, suppose that a municipality with a junior licence is successful in making a case to government that it is unduly impacted when flow in the source stream drops below the in-stream requirement and diversions must cease. The municipality requires only a small amount of water to meet its needs. The municipality has looked at various mitigation options and nothing appears to be feasible or could be implemented as quickly as needed. The municipality requests special status that allows it to encroach on the IO or WCO during these trying times recognizing the low level of impact it would have on in-stream conditions. After due consideration, the government may grant the community special status, which could be permanent or temporary. Conditions to the special status designation may be assigned, such as:

- The municipality develops a water conservation program or has one in place and is progressing toward meeting water conservation targets.
- The municipality continues to search for a feasible alternative, such as an allocation transfer or storage development, within the time frame of a temporary status designation.

Such a concession would promote a water conservation culture within the community which would reduce withdrawals from the source stream on an ongoing basis. River flows would be improved most of the time in exchange for short-term encroachment on the WCO.

Changes in the *Water Act* may be required to make provision for such special status for individual licensees or water-use sectors.

# 7.0 STRUCTURAL WATER MANAGEMENT OPPORTUNITIES

## 7.1 Introduction

As noted in Chapter 6, simulation modelling indicated that increased water demands due to expansion of the irrigation areas within districts could be met with the current allocations (and applications). However, results for Scenarios 2 and 3 indicate that the additional demands by the districts would increase deficits to in-stream flow requirements, junior private irrigation, and junior non-irrigation users. The objectives of Chapter 7 are to identify and explore structural options for reducing deficits to in-stream requirements and junior private irrigation and non-irrigation users.

Significant water storage reservoirs and diversion works exist within the SSRB. They are owned and operated by Alberta Environment (AENV), TransAlta, irrigation districts, and private entities. Most of these reservoirs are for multi-purpose uses including maintaining in-stream flows for protection or enhancement of water quality and the aquatic ecosystem, irrigation, improved water management, flood control, hydropower, recreation, and fisheries.

Additional storage, either on-stream or off-stream, could improve water management within the SSRB. On-stream storage would retain a portion of the river flow during periods of higher flows to be released during lower flow periods. Off-stream storage would enable diverting a portion of the source stream to an off-stream reservoir to be used for specific purposes generally near the reservoir, or temporarily storing the water during high flow periods, and releasing back to the source stream during periods of lower flows to assist in meeting in-stream requirements. Also, increasing off-stream storage within the irrigation districts could provide opportunities to store water during periods of higher source river flows (usually May, June and July) for irrigation delivery during lower river flow months (August, September), thereby leaving more water in the river during low-flow periods to assist in meeting in-stream requirements or consumptive uses. The total volume of water diverted from the source river may be unchanged but additional storage could provide for a beneficial change in the timing of river diversions. This mode of operation may require increased diversion canal capacities.

This section will focus on documenting advantages and disadvantages of on-stream and off-stream storage projects, determining the hydrologic potential for additional on-stream storage, identifying on-stream and off-stream storage sites, and determining the effectiveness of additional storage in addressing the issues identified. Site-specific storage sites will not be addressed in this analysis. Follow-up studies will be required for this purpose if this study determines that additional storage would be effective in resolving issues, and are as good as, or better than, non-storage options.

There may be other structural measures required to improve site-specific water management issues, such as canal enlargements, fish exclusion facilities, and erosion control structures. These projects may be essential and beneficial in their own right, but they are unlikely to impact the basin-wide issues being addressed in this study.

## 7.2 On-Stream Versus Off-stream Storage

Existing reservoir storage within the SSRB fulfils several purposes. In Alberta, on-stream storage reservoirs predominantly provide hydropower production, recreation, and flow regulation for meeting municipal, industrial and irrigation demands, and in-stream needs for protection or enhancement of water quality and the aquatic ecosystem. Off-stream storage reservoirs are predominantly for irrigation and other consumptive uses. Recreation facilities usually are developed adjacent to off-stream reservoirs. Sport and commercial fishing opportunities are often associated with off-stream reservoirs in southern Alberta.

Generally, off-stream reservoirs have not been used for flow regulation and overall river basin management in Alberta. Currently, Pine Coulee Reservoir in the Willow Creek Basin is the only off-stream storage project in the SSRB that is used to divert water from a stream for temporary storage and diversion back to the source stream to improve basin water management. Other existing off-stream storage projects may indirectly provide some improved water management within the river basin by diverting river water during periods of higher flows and releasing the stored water for licensed use (predominantly irrigation within the SSRB) when river flows are lower, thus reducing demand from the source stream during lower flow periods.

On-stream storage projects provide more flexibility to water managers than do off-stream projects. They are better able to store peak river flows, can provide a degree of flood flow reduction, and have greater flow regulation capability. Off-stream storage reservoirs have lower impacts on river flow patterns and are often perceived to be less environmentally disruptive. **Table 7.1** presents the advantages and disadvantages of off-stream and on-stream storage reservoirs.

Off-stream storage has made a significant contribution to water management in the SSRB and should be considered to address specific issues in the future. However, the issues identified in this study are primarily related to water management across entire sub-basins. These types of issues could possibly be resolved by refining the operation of existing storage or construction of new storage to enable additional flow regulation on the mainstem rivers or their major tributaries. With the exception of the Pine Coulee project in the Willow Creek Basin, off-stream storage in the SSRB has not been located or utilized to divert water from a main river system for storage and release back to the source stream for flow regulation purposes. While this may be possible, it is unlikely to be as effective as on-stream storage for this purpose. For this reason, on-stream storage is the focus of the remainder of this chapter.

**TABLE 7.1**
**Advantages and Disadvantages of Off-stream and On-stream Storage Reservoirs**

| Storage Reservoir Type | Usual (Not Always) Advantages | Usual (Not Always) Disadvantages |
|---|---|---|
| **Off-Stream** | • Less impact on:<br>- Aquatic environment<br>- Riparian environment<br>- Fisheries<br>• Less impact on historical resources.<br>• River diversion works have less impact on river flow patterns, sediment regime, ice regime, and possibly navigation.<br>• Less impact on up-stream and downstream fish migrations.<br>• Less costly spillway structures because off-stream storage reservoirs have lower inflows than on stream.<br>• Less capital cost (smaller dams, river diversion works, spillway structures, low-level outlet works, fish passage facilities, etc.).<br>• Usually creates new recreation and fishing opportunities. | • No precedent in Alberta for temporary storage of river flows being diverted back to the source river for improved water management.<br>• Higher evaporation losses per unit of storage, as surface areas are generally larger than on-stream storage areas for similar storage volumes (less efficient storage).<br>• Diversion works may require expensive and maintenance-intensive fish passage and exclusion facilities.<br>• Off-stream storage may require costly pumping systems resulting in higher capital and significantly higher operating costs.<br>• Reduced potential for hydropower development.<br>• Costly diversion and conveyance works, particularly if climate change results in a more peaky flow regime and larger diversions are required over a shorter time period.<br>• Water quality may deteriorate making it unsuitable for end uses, particularly for reservoirs with low flow-through, long residence times, and high evaporation. |
| **On-Stream** | • On-stream storage is more effective at capturing and storing river flows and releasing water for downstream requirements.<br>• Provides some flood flow reduction benefits.<br>• On-stream storage able to supplement winter flows without significant ice effects.<br>• On-stream storage has greater potential for hydropower development.<br>• On-stream storage has a record of providing effective river basin water management in Alberta.<br>• Under future climate change scenarios, on-stream storage is better suited to capture more runoff from extreme runoff events than off-stream storage. | • On-stream storage can have significant impact on:<br>- Aquatic environment<br>- Terrestrial environment<br>- Historical resources<br>- Fisheries and fish passage<br>- Navigation<br>- River ice regime<br>- River sediment transport<br>- Natural river flow patterns<br>• Dam safety concerns/issues due to potential risk to downstream habitation, infrastructure, and environment.<br>• Generally higher capital cost than off-stream storage due to larger dams, spillways and outlet works.<br>• Potentially larger impact on existing infrastructure (roads, utilities) and habitation (farmsteads, towns, etc.). |

## 7.3 Hydrologic Potential for New On-stream Storage Development

If the dependable flow of a water supply source is insufficient to supply current or desired future in-stream and consumptive demands, but the average flow volume is more than ample, the demand may be met by storage development in the basin. In simple terms, the benefits of reservoir storage in a water-short river system is to store surplus natural flows and supplement natural flow by releases from the reservoir during low-flow periods to meet in-stream and consumptive uses. Storage provides the opportunity to regulate the natural flow in a river system to better match water supplies and demands.

To illustrate this point, in some years prior to construction of the Oldman River Dam, there was insufficient flow in the Oldman River to meet consumptive demands, and flows near Lethbridge (downstream of the St. Mary River confluence) frequently dropped to very low levels during the high demand months. During the 5-year period 1984 to 1988, minimum weekly flow during July ranged between 2.7 $m^3/s$ and 5.6 $m^3/s$ in each year. Since 1992 when the Oldman River Dam began operation, weekly July flows have been well above the minimum IO of 20.0 $m^3/s$, even in 2001, a very low-flow year. In addition, storage in the Oldman River Reservoir made it possible to expand irrigation within the LNID, including development of the Keho / Barons Project, and supply increased demands for other purposes. Storage in the Oldman River Reservoir reduced deficits to existing consumptive users, substantially increased in-stream flows during low-flow periods, and enabled expansion of consumptive use and economic development.

The ratio of median annual natural inflow to storage capacity for the Oldman River Reservoir is about 2.5 (**Table 7.2**; Column G). The reservoir has been filled (or nearly filled) in 80% of years since operation began. The reservoir is heavily utilized to meet demands within Alberta and is occasionally required to meet Alberta's apportionment commitments to Saskatchewan under the Prairie Provinces apportionment agreement. From a water supply point-of-view, the Oldman River Reservoir is a success story, and a key component of water management in the SSRB.

The potential for, and benefits and impacts of, new on-stream storage in the SSRB is best evaluated by simulation modelling, and environmental, social, and economic impact studies. Such studies are beyond the scope of this study. However, a first step in this regard is to determine the potential for new storage from a hydrological or water availability perspective.

All major streams within the SSRB have their headwaters in the high runoff producing Rocky Mountain and Foothills Natural Regions. All have similar runoff patterns, although some streams have higher annual variability than others. The patterns of demands in the major streams are similar, being dominated by in-stream requirements and irrigation. Because of these similarities, the ratio of median annual natural inflow to the Oldman River Reservoir and its storage capacity could be used as a benchmark to determine the hydrological potential for storage development in other streams in the SSRB. Inclusion of the ratio of lower quartile runoff to reservoir capacity in the analysis would provide an index of low-side flow variability on storage potential. The frequency and magnitude of low runoff years have a significant impact on the ability to fill reservoirs. High-side flow variability is less important since reservoirs will fill and spill during high runoff years.

**TABLE 7.2**
**Analysis of Hydrologic Potential for New Storage Development in the SSRB**

| Column A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|
| Hydrometric Station | Natural Flow ($dam^3$) | | Flow Variability Ratio Q50/Q25 | Existing Storage | | Existing Natural Flow/Storage Ratios | | Additional Storage Potential[1] | |
| | Median (Q50) | Lower Quartile (Q25) | | Storage at Full Supply ($dam^3$) | Fill Frequency (% of Yrs) | Median (Q50) | Lower Quartile (Q25) | Based on Q50 Ratio | Based on Q25 Ratio |
| Oldman R near Waldren's Corner | 382,836 | 284,897 | | | | | | | |
| Castle R near Cowley | 563,934 | 471,531 | | | | | | | |
| Crowsnest R near Lundbreck | 203,912 | 169,817 | | | | | | | |
| Oldman R near Brocket | 1,203,919 | 952,019 | 1.26 | 490,180 | 80% | 2.456 | 1.942 | | |
| Waterton R near Stand Off | 736,485 | 634,024 | 1.16 | 111,196 | 84% | 6.6 | 5.7 | 188,666 | 215,253 |
| Belly R near Stand Off | 287,803 | 240,132 | 1.20 | | | | | 117,180 | 123,640 |
| Belly R near the Mouth | 1,062,525 | 895,872 | 1.19 | 111,196 | 84% | 9.6 | 8.1 | 321,415 | 350,075 |
| St. Mary R near Lethbridge | 848,949 | 742,091 | 1.14 | 369,310 | 64% | 2.3 | 2.0 | (23,657) | 12,782 |
| Oldman R near Lethbridge | 3,338,748 | 2,715,311 | 1.23 | 970,686 | | 3.4 | 2.8 | 388,697 | 427,386 |
| Oldman R near the Mouth | 3,342,824 | 2,772,757 | 1.21 | 970,686 | | 3.4 | 2.9 | 390,357 | 456,964 |
| Red Deer R near Sundre | 753,163 | 631,382 | 1.19 | 203,000 | 92% | 3.7 | 3.1 | 103,653 | 122,089 |
| Red Deer R at Red Deer | 1,370,090 | 1,020,839 | 1.34 | 203,000 | 92% | 6.7 | 5.0 | 354,837 | 322,614 |
| Red Deer R at Drumheller | 1,538,673 | 1,189,323 | 1.29 | 203,000 | 92% | 7.6 | 5.9 | 423,476 | 409,364 |
| Red Deer R near Bindloss | 1,666,212 | 1,164,047 | 1.43 | 203,000 | 92% | 8.2 | 5.7 | 475,404 | 396,350 |
| Bow R at Calgary | 2,852,208 | 2,550,009 | 1.12 | 704,400 | | 4.0 | 3.6 | 456,886 | 608,560 |
| Bow R near Mouth | 3,829,289 | 3,290,379 | 1.16 | 704,400 | | 5.4 | 4.7 | 854,709 | 989,766 |
| Highwood R near the Mouth | 662,847 | 480,206 | 1.38 | | | | | 269,881 | 247,251 |

1. Storage potential is not cumulative within each sub-basin.

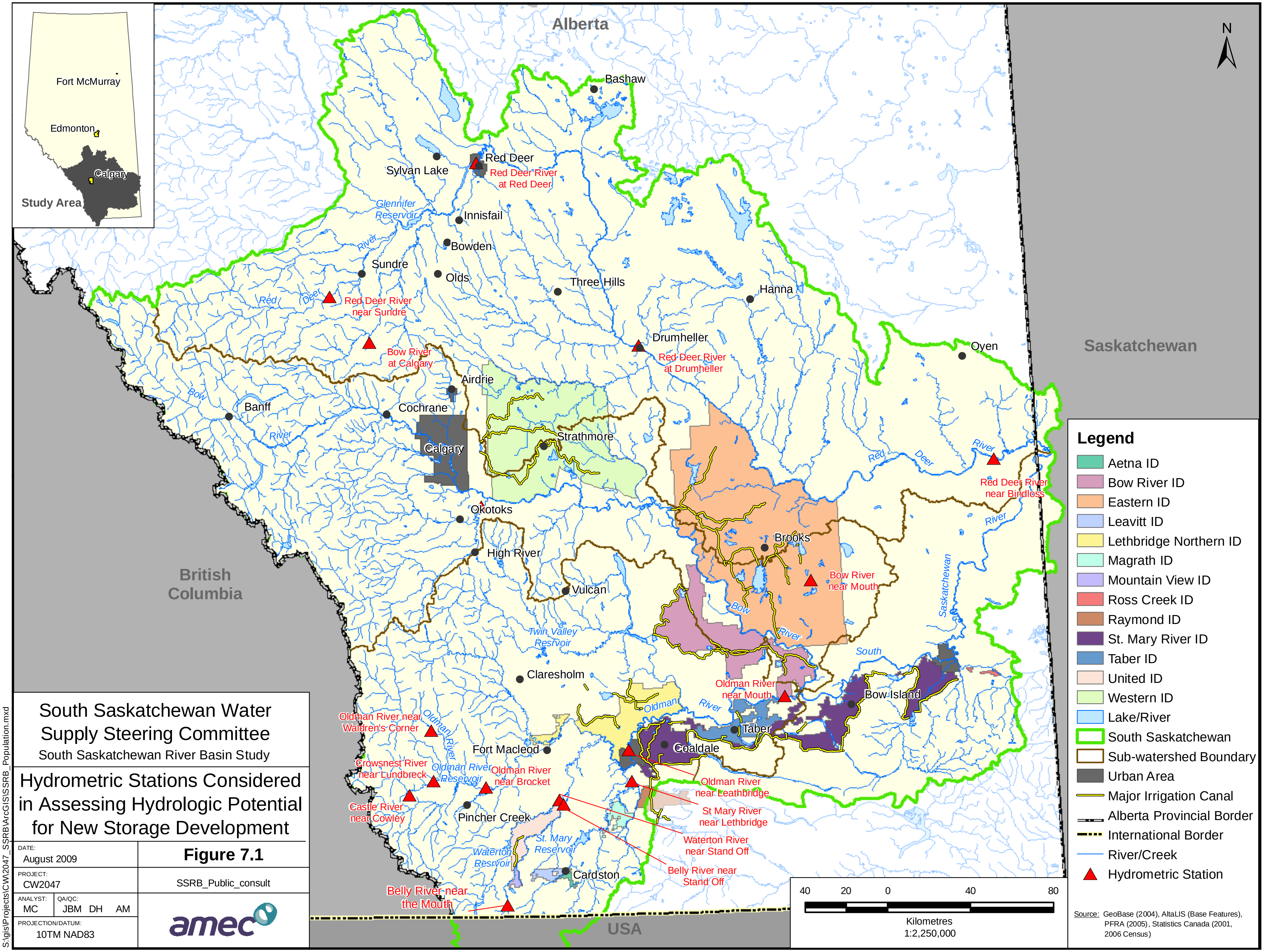

Alberta
Saskatchewan
British Columbia
USA
Fort McMurray
Edmonton
Calgary
Study Area
Bashaw
Red Deer
Red Deer River at Red Deer
Sylvan Lake
Glennifer Reservoir
Innisfail
Bowden
Sundre
Olds
Three Hills
Hanna
Red Deer River near Sundre
Drumheller
Red Deer River at Drumheller
Oyen
Bow River at Calgary
Airdrie
Banff
Cochrane
Strathmore
Red Deer River near Bindloss
Okotoks
Brooks
High River
Vulcan
Bow River near Mouth
Twin Valley Resrvoir
South Saskatchewan
Claresholm
Oldman River near Mouth
Bow Island
Oldman River near Waldren's Corner
Taber
Fort Macleod
Coaldale
Crowsnest River near Lundbreck
Oldman River Reservoir
Oldman River near Brocket
Oldman River near Leathbridge
Castle River near Cowley
Pincher Creek
St Mary River near Lethbridge
Waterton River near Stand Off
St. Mary Reservoir
Waterton Resrvoir
Belly River near Stand Off
Cardston
Belly River near the Mouth
N
Legend
Aetna ID
Bow River ID
Eastern ID
Leavitt ID
Lethbridge Northern ID
Magrath ID
Mountain View ID
Ross Creek ID
Raymond ID
St. Mary River ID
Taber ID
United ID
Western ID
Lake/River
South Saskatchewan
Sub-watershed Boundary
Urban Area
Major Irrigation Canal
Alberta Provincial Border
International Border
River/Creek
Hydrometric Station
40 20 0 40 80
Kilometres
1:2,250,000
Source: GeoBase (2004), AltaLIS (Base Features), PFRA (2005), Statistics Canada (2001, 2006 Census)
South Saskatchewan Water Supply Steering Committee
South Saskatchewan River Basin Study
Hydrometric Stations Considered in Assessing Hydrologic Potential for New Storage Development
DATE: August 2009
Figure 7.1
PROJECT: CW2047
SSRB_Public_consult
ANALYST: MC
QA/QC: JBM DH AM
PROJECTION/DATUM: 10TM NAD83
amec
S:\gis\Projects\CW2047_SSRB\ArcGIS\SSRB_Population.mxd

**Table 7.2** summarizes the median- and lower-quartile natural flows at various hydrometric stations in the SSRB (Columns B and C). The locations of the hydrometric stations are shown in **Figure 7.1**. The ratio between median flows and lower quartile flows provides an indication of low-side flow variability; the higher the ratio, the higher the variability (Column D). The variability of flows in the Oldman River is relatively high, as was noted in Chapter 3 of this report (**Table 3.3**). The variability of the lower Red Deer and Highwood Rivers exceed that of the Oldman. All other streams have lower variability.

Existing on-stream storage includes the Oldman River Reservoir on the Oldman River, Waterton Reservoir on the Waterton River, St. Mary Reservoir on the St. Mary River, Gleniffer Reservoir on the Red Deer River, and TransAlta Reservoirs (Spray, Upper and Lower Kananaskis, Barrier, Minnewanka, and Ghost) in the upper Bow River Basin. Their respective frequency of filling gives an indication of the potential for additional storage, but it is also dependant on how the projects are operated.

For the Oldman River near Brocket, the ratio between median natural flow and Oldman Reservoir storage capacity is 2.456. Between lower quartile flow and storage capacity, the ratio is 1.942. The ratios are about the same for the St. Mary River and Reservoir. For all other streams in **Table 7.2**, the ratios are higher than that of the Oldman River near Brocket, inferring that there may be potential for additional storage on the other streams.

The last two columns of **Table 7.2** (Columns I and J) show the amount of new storage that would be required to bring the natural flow-versus-storage ratio to the same values as for the Oldman River near Brocket, considering both median- and lower-quartile natural flows. For example, the Waterton River has existing storage capacity of 111 196 $dam^3$ in the Waterton Reservoir. The amount of new storage that would be required along the lower Waterton River to provide the same median natural flow/storage capacity ratio as for the Oldman River near Brocket can be computed as:

736 485 / (111 196 + X) = 2 456, where X is the volume of new storage.

Solving for X gives, X = 188 666 $dam^3$

The same computation using the lower quartile flow and ratio (1.942) would yield an additional storage volume of 215 253 $dam^3$. These two values would give a range of possible storage development, solely based on preliminary hydrological considerations.

New storage values for the St. Mary River are not computed due to the unique situation with respect to the availability of close to 500 000 $dam^3$ of off-stream storage associated with the St. Mary project, as well as additional supplies diverted from the Waterton and Belly Rivers. Simulation modelling would be required to represent that unique situation.

From this analysis, preliminary conclusions regarding the hydrologic potential for additional storage in various reaches of key river systems in the SSRB are summarized in **Table 7.3**. As noted earlier, this is only the starting point for consideration of new storage development.

Simulation modelling of various reservoir sizes and locations would assist in determining the benefits of new storage. Ideally, storage reservoirs should be located upstream of high demand areas. Some of the river reaches identified in **Table 7.3** may be too far downstream to have a significant positive impact on water management in the basin. Simulation modelling would address that issue. In addition to simulation modelling, engineering, social, environmental and economic studies would be essential.

**TABLE 7.3**
**Preliminary Findings of Analyses of the Hydrologic Potential for New Storage Development in the SSRB**

| Rivers and Reaches | Hydrologic Potential for New Storage Development ($dam^3$)[1] |
|---|---|
| Oldman R – U/S of Oldman Dam | Low |
| Lower Castle R | Low |
| Lower Crowsnest R | Low |
| Inflow to Oldman R Reservoir | Low |
| | |
| Waterton R – Waterton Dam to Belly R Confl. | 175 000 to 225 000 |
| Belly R – U/S Waterton Confluence | 120 000 |
| Belly R – D/S Waterton R Confluence | 300 000 to 350 000 |
| St. Mary R – D/S of St. Mary Dam | Not Estimated |
| | |
| Oldman R – St. Mary Confl to L. Bow Confl | 375 000 to 425 000 |
| Oldman R – L. Bow Confl to Mouth | 375 000 to 450 000 |
| | |
| Red Deer R – U/S of Dickson Dam | 100 000 to 125 000 |
| Red Deer R – Medicine R to Blindman R | 300 000 to 350 000 |
| Red Deer R – Blindman R to Drumheller | 400 000 to 450 000 |
| Red Deer R – Drumheller to Mouth | 400 000 to 475 000 |
| | |
| Bow R – U/S of Elbow R Confluence | 450 000 to 600 000 |
| Bow R – Highwood Confluence to Mouth | 850 000 to 950 000 |
| Lower Highwood R | 200 000 to 275 000 |

[1] Storage potential is not cumulative within each sub-basin.

## 7.4 Identification of Storage Sites

An inventory of potential storage projects within the SSRB was prepared by AENV to address a key goal of the Water for Life Strategy to provide,

> *"Reliable, quality water supplies for a sustainable economy."*

This inventory was presented in the report entitled "Provincial Inventory of Potential Water Storage Sites and Diversion Scenarios" (MPE Engineering Ltd. (MPE), 2005). The inventory was based on a comprehensive literature review of previous studies that had identified new storage sites and potential modifications to existing dams and reservoirs throughout Alberta. The literature review included studies conducted by provincial government departments, Prairie Farm Rehabilitation Administration, irrigation districts, Ducks Unlimited, utility companies, and local municipal authorities. Potential storage sites identified were limited to those with storage greater than 1000 $dam^3$.

Subsequent to the inventory of potential water storage sites, AENV commissioned MPE to create an assessment tool to aid in comparing water storage sites. The assessment tool considered several technical and subjective criteria and used a weighted scoring system to rate and compare storage sites within the same major river basin (MPE, 2008). The assessment tool was not intended to determine if a site should be developed; rather, it allows the user to compare sites within the same major river basin to help determine if a site warrants further investigation and evaluation.

Criteria / parameters considered in the assessment include:

- historical average water supply versus current, circa 2007, downstream licensed demand;
- environmental, sociological, historical, infrastructure, and land ownership impacts and issues;
- site availability, including proximity to protected or environmentally significant areas, and types and significance of developments affected at the time the project was assessed;
- geotechnical aspects / issues including dam foundation conditions, reservoir stability, borrow sources, etc.;
- storage efficiency which considers the reservoir flooded area and dam embankment size / height versus reservoir storage volume; and,
- dam safety issues / concerns including the relative location of the dam with respect to downstream development and habitation.

The inventory and assessment tool considered all major river basins within Alberta. Specific to the SSRB, the numbers of potential storage sites for each major river basin in the SSRB are:

| | | |
|---|---|---|
| Bow River Basin | 24 on-stream sites | 11 off-stream sites |
| Oldman River Basin | 31 on-stream sites | 8 off-stream sites |
| Red Deer River Basin | 19 on-stream sites | 14 off-stream sites |
| South Saskatchewan Sub-basin | 3 on-stream sites | 2 off-stream sites |

The MPE 2008 assessment provides an easily used tool that allows analysts to take advantage of earlier studies in selecting potential new storage projects for further assessment and analysis. Two cautionary notes are worthy of mention.

- There may be more potential storage sites in the SSRB than those identified by MPE based on past studies. Site selection in past studies may have been purpose-driven to reflect water management objectives of the day. Water management objectives have shifted somewhat to protection and preservation of environmental values that may not have been considered in past studies.
- Numerous projects identified by MPE were considered as alternatives to Dickson Dam in the Red Deer River Sub-basin and the Oldman River Dam in the Oldman Sub-basin. These two projects were selected for implementation and are now owned and operated by Alberta Environment. While the identified alternative sites may have some potential for improving water management in their respective sub-basins, their effectiveness must be considered in light of the reduced hydrologic potential of the rivers to support additional storage, and the benefits already captured by the existing projects.

## 7.5 Performance of Additional Storage Developments

It was the intention of the study team to determine the effectiveness of additional storage in reducing Scenario 3 deficits to in-stream requirements, junior private irrigation and junior non-irrigation projects by simulation modelling. The objective was to either eliminate the deficits or, at least, reduce deficits to that of the current situation (Scenario 1). However, as a first step it is essential that the operation of existing infrastructure be optimized. This is a task that should be led by the project owners and operators, in consultation with stakeholders. It is possible that some value judgements and difficult trade-offs may be required in fine tuning the operations.

Each of the three major sub-basins is unique in this regard. Each is discussed in turn below.

### 7.5.1 Red Deer River Sub-basin

Junior projects in the Red Deer River Sub-basin are subject to the WCO established in January 2007 (Alberta Environment, 2007). Hence, it is essential that the WCO deficits be reduced before deficits to the junior projects can be reduced. This is particularly important in the Red Deer River Sub-basin where there are several regional municipal projects that have been licensed since 1 May 2005 and are therefore subject to the WCO.

Simulation modelling for Scenario 1 (current conditions) indicates there will be minor deficits to the WCO in the winter months. This is confirmed by recorded streamflow in recent years. The deficits will increase by a small amount as demands in the sub-basin grow.

If and when additional storage in the Red Deer River Sub-basin is considered, one option that should be addressed is increasing the full supply level of Gleniffer Reservoir by 1 or 2 metres. Such a measure would have to be studied in detail, but it would probably be less costly and less disruptive environmentally and socially than a new storage project elsewhere in the basin.

However, the deficits in the sub-basin will not be significantly reduced by storage at or up-stream of Gleniffer Reservoir until the operation of Dickson Dam has been modified. In fact, because the deficits are low and infrequent, additional storage may not be required for some time in the future. For this reason, simulation modelling of additional storage in the Red Deer River Sub-basin was not completed.

### 7.5.2 Bow River Sub-basin

Junior projects in the Bow, Oldman and South Saskatchewan Sub-basins are subject to the IOs rather than the WCOs (Alberta Environment, 2006). The objective of additional storage in the Bow River Sub-basin would be to reduce deficits to the IOs so that junior projects could divert to meet their needs. Deficits are more frequent and larger in the Bow River Sub-basin than in the Red Deer Sub-basin. Storage requirements to meet the IOs and provide additional water for consumptive uses would be much higher than that required in the Red Deer Sub-basin. As noted in Chapter 6, discussions have been initiated with TransAlta (TA) to explore sharing the use of their storage facilities for needs other than hydro-electric power generation and other current uses that TA considers in their operations. Modelling results indicate much improved performance in the Bow River Sub-basin through shared use of TA storage facilities (Section 6.4). Much more work needs to be done on this option but, because it is much preferred over new storage development in the Bow River Sub-basin, it should be pursued to its eventual conclusion before considering new storage to address basin-wide issues.

New off-stream storage development at Bruce Lake and enlarging Langdon Reservoir are currently being considered by the Western Irrigation District. These projects will assist with control of water within the district to reduce return flows, and improve irrigation efficiency.

### 7.5.3 Oldman River Sub-basin

Like the Bow River Sub-basin, junior water-use projects are subject to the IOs rather than the WCOs (Alberta Environment, 2006). In the Oldman River Sub-basin the IOs downstream of the Oldman River Dam are currently almost always being met because of the flow regulation influence of the dam. As irrigation demands increase (within existing allocations), IO deficits will just be met with no surplus flow for other uses, and occasional IO deficits will occur. This will affect the availability of water for junior projects within the basin. Non-structural measures will help to reduce the deficits to junior projects to some degree, but to eliminate the deficits or reduce them to an acceptable level, additional storage would be required.

As with the other sub-basins, it is important to update operation plans for existing storage development and diversion works prior to considering new storage. However, operations of projects in the Oldman River Sub-basin are reviewed periodically, and the operations are believed to be near optimum.

To test the value of additional storage, a new reservoir with storage capacity about the same as the Oldman River Reservoir (490 000 $dam^3$) was assumed, and water supply and demands for Scenario 3 were modelled with the additional storage. In this very preliminary analysis, model output showed that the reservoir filled in about 75% of the years, and the storage was fully utilized. The reservoir was fully depleted during the droughts of the 1930s and 1980s, indicating that the reservoir was not oversized.

With the additional storage, the IOs are always met and deficits to junior consumptive users are much reduced over those of Scenario 3.

Referring to the graphics, WCO deficits are significantly increased over Scenario 1 (Current Conditions) in the lower two reaches of the Oldman River and along the South Saskatchewan River (**Figure 7.2**). In this model run, priority for the use of new storage was given to meeting the IO and consumptive needs. Supplying additional water to reduce deficits to consumptive needs reduced the magnitude of river flows in excess of the IOs, which increased deficits to the WCOs.

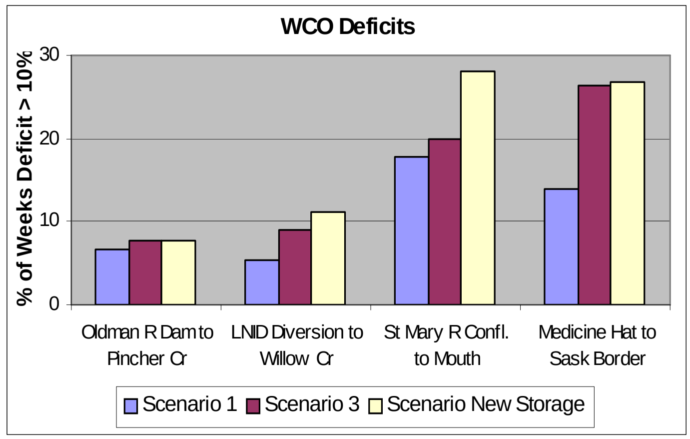



**Figure 7.2 Frequency of WCO Deficits Along the Oldman and South Saskatchewan**

Junior private irrigation and the Piikani First Nation's Project deficits are much reduced compared to Scenario 3, and are less than those of Scenario 1 (**Figure 7.3**). Junior private irrigation performance would now be within the acceptable criteria usually used for evaluating irrigation projects.

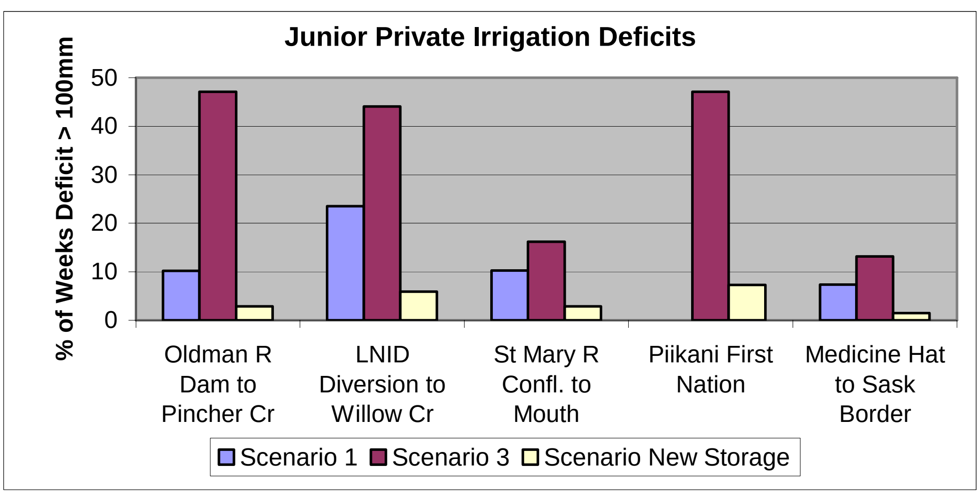



**Figure 7.3 Frequency of Junior Private Irrigation Deficits Along the Oldman and South Saskatchewan Rivers**

Junior non-irrigation deficits for the new storage scenario are also substantially reduced from Scenario 3 and Scenario 1 (**Figure 7.4**).

Overall, the performance in meeting the IOs and junior consumptive needs was much improved over Scenario 3, and improved over Scenario 1. Deficits to the WCO increased over Scenario 3 since junior licensees have priority over the WCOs and the additional storage enabled surplus flows to be stored for later delivery to the licensed users.

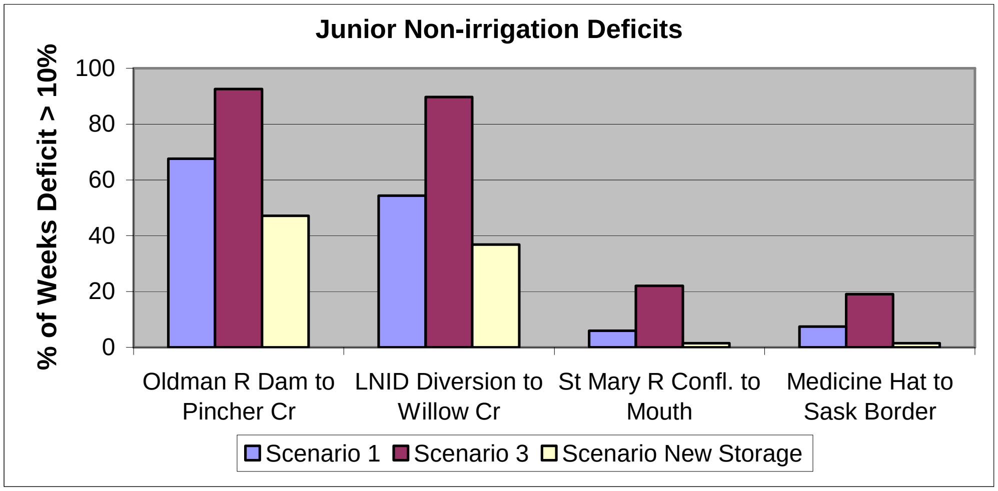



**Figure 7.4 Frequency of Junior Non-irrigation Deficits Along the Oldman and South Saskatchewan Rivers**

## 7.6 Summary

Modelling additional storage in the Red Deer River Sub-basin was deferred until the operation policy for existing storage is reviewed and confirmed or amended. Because deficits are infrequent and low in volume, it is possible that no new storage is required if the use of existing storage is optimized and other non-structural measures are taken, such as sharing deficits.

Similarly, in the Bow River Sub-basin, sharing the use of TransAlta (TA) storage is much preferred over new storage development. Discussions between the province and TA should proceed to their ultimate conclusion to determine whether or not new storage development is required in the basin prior to considering options for new storage.

Simulation modelling indicated that new storage development in the Oldman River Sub-basin would ensure that the IOs would be met and greatly reduce deficits to junior private irrigation and non-irrigation projects, as well as development on the Piikani First Nation Reserve. A storage project the size of the Oldman River Reservoir was assumed in the analysis. In the analysis, performance in meeting Scenario 3 demands was improved over Scenario 1 performance (current demands without new storage). Alternate sizes and locations of storage could be considered if the storage option is deemed to be worthy of more detailed study.

# 8.0 SUMMARY OF FINDINGS AND RECOMMENDATIONS

## 8.1 Simulation Modelling

Assuming historical streamflow and climate conditions, and current water demands (Scenario 1), simulation modelling indicates that the frequency of deficits to the WCOs and junior non-irrigation water users are high throughout most of the SSRB. Junior water users are those subject to the WCOs in the Red Deer Sub-basin, and those subject to IOs established since the early 1990s in the Bow and Oldman Sub-basins. Junior projects that are not supported by dedicated storage are particularly vulnerable to deficits. The various water-use sectors (municipal, stock water, irrigation, industrial, commercial, wetlands, and recreation) have different tolerances to deficits and are impacted in various ways. Deficit tolerance thresholds for water-use sectors other than irrigation are largely unknown and impacts are undetermined.

Modelling indicates that expansions of irrigation districts of up to 30% above the current actual irrigated areas within the Bow River Sub-basin perform well within the informal performance criteria for irrigation projects (deficits greater than 100 mm in no more than 10% of the years). Similarly, district expansions up to 19% above current actually-irrigated areas within the Oldman River Sub-basin perform well. The irrigation district expansions in both basins assume no increase in existing and pending licence allocations. There are two pending irrigation district licence applications from the Bow River under consideration within Alberta Environment.

There are several proposed non-district irrigation projects that are in the licence application stage or at various other levels of consideration within government. Simulation modelling indicates that irrigation proposed for future SAWSP and Acadia projects in the Red Deer River Sub-basin perform well because they are supported by off-stream storage. Siksika and Blood Tribe irrigation expansions perform well. Piikani and Oldman Reservoir area projects have high frequencies of deficits.

Potential future irrigation expansion and increases in water demands for other purposes, assumed for Scenarios 2 and 3, would have a modest impact on WCOs throughout the SSRB. Generally, performance deteriorates from up-stream to down-stream, and from Scenario 1 (Current Conditions) to Scenario 3 (Year 2030 private irrigation and non-irrigation demands and high levels of irrigation district expansions).

Similarly, potential increases in water use will increase deficits to junior priority private irrigation users and non-irrigation users (municipalities, industries, recreation, wetland stabilization, etc.). Deficits increase from Scenario 1 to 3 in most reaches throughout the SSRB. Increases in deficits in the Red Deer River basin would be modest. The increases in deficits in some parts of the Bow, Oldman and South Saskatchewan Sub-basins would be substantial. Deficits are sometimes more frequent and higher in magnitude in upper reaches than in down-stream reaches.

Recent climate change projections indicate a wide range of possible impacts on streamflow in the SSRB. Studies indicate that streamflow could increase or decrease, but decreases are more likely than increases. While, at present, it is not possible to definitively determine the potential impacts of climate change on the SSRB water supply and demand, evidence to date indicates that it is more likely that water supply deficits will increase rather than decrease.

***Recommendations Related to Simulation Modelling and Planning***

1. Performance thresholds for the various water-use sectors and in-stream conditions (IOs and WCOs) would greatly improve the ability to develop water management and operation plans in southern Alberta. The informal guideline that has been used for irrigation performance criteria has proven to be very useful. Similar guidelines for other sectors are required.
2. Systematic water-use monitoring and reporting would also improve water management planning. Reasonable good data are available for municipalities and irrigation districts. Water uses for other sectors are primarily based on licensing data, fragmentary recorded data, and rough estimates.
3. It is recommended that Alberta Environment incorporate into the WRMM an algorithm that enables modifying reservoir rule curves depending on the volumes of water available in storage reservoirs and forecasted water supplies. This would facilitate operation planning that would assist reservoir operators to capture additional benefits.
4. With respect to climate change, it is recommended that periodic analyses of natural flow and precipitation be carried out to determine if significant trends are developing, and to estimate the long-term impacts on streamflow should the trends persist. This information is required to narrow the range of uncertainty in current projections of impacts on streamflow based on Global Climate Model projections of future climate.

## 8.2 Non-structural Water Management Opportunities

### 8.2.1 Infrastructure Operations

Operating plans for infrastructure in the SSRB should be reviewed periodically to ensure that the operations are consistent with changing legislation and policies, are operated in a safe manner, and are used to maximum collective advantage of all users. Water management infrastructure is costly to construct. Refining operation plans periodically is a relatively low-cost way to ensure projects are operated in a manner that will maximize project benefits.

Review and refinement of operating guidelines for Dickson Dam holds promise for reducing the infrequent and low-magnitude deficits to the WCO and junior consumptive users in the Red Deer River Sub-basin. An operational planning study should include a review and update of water quality conditions in the basin to determine the flows required to maintain acceptable water quality in the river, utilizing stored water in a manner that would share the deficits among several water-use sectors to minimize the impacts on any one sector, and adjusting reservoir rule curves based on currently available water supply forecasts and probabilities of filling the reservoir.

With respect to the Bow River, TA owns and operates several reservoirs on the Bow River's mainstem and tributaries for hydro power production. Normal operation of the reservoirs follows a pattern of storage to replenish the reservoirs during the summer months and releases during the winter months for power production. If the reservoirs were operated to meet in-stream and consumptive needs in the sub-basin, additional releases would be required during the high demand summer period and winter releases could be reduced somewhat. Results of simulation modelling conducted in co-operation with TA indicate that modifying operations of TA reservoirs to meet in-stream and junior consumptive needs in the Bow River Sub-basin would eliminate deficits to the IOs and substantially improve performance in meeting consumptive demands. This sets the stage for further discussions between the province and TA.

With respect to the Oldman River Sub-basin, the operations of the Oldman River Dam, Waterton Dam, and St. Mary Dam are reviewed and refined from time to time. Recent operational changes have been made to improve aquatic and riparian eco-system conditions without impairing the ability to meet consumptive use requirements. The practice of periodic reviews should be continued.

***Recommendations Related to Infrastructure Operations***

5. It is recommended that operation procedures for Dickson Dam be reviewed and confirmed or refined. The review should consider:
   - a water quality study to determine the various downstream seasonal flows required along the entire length of the river to maintain favourable water quality conditions;
   - making releases to meet the needs of consumptive users along the river in addition to meeting the WCO and water quality needs;
   - sharing the risks among all users to minimize impacts of deficits. For instance, if reservoir recreation users and in-stream requirements could tolerate less than ideal conditions in 10% of the years (or some other appropriate percentage), more water would be available for meeting other needs along the river; and,
   - utilizing existing water supply forecasts to maximum advantage. Consider adjusting rule curves based on forecasted runoff and probabilities of filling.
6. It is recommended that further analyses and discussions with TransAlta be held to explore the feasibility of modification of operations of TransAlta storage projects to improve performance in meeting in-stream and consumptive needs along the Bow River. Studies to determine the environmental impacts of the modified flow regime and the hydroelectric generation benefits foregone are required.
7. The practice of periodic reviews of the operation of storage projects in the Oldman River Sub-basin should be continued.

### 8.2.2 Irrigation District Water-Use Efficiency

Improved efficiencies for all water-use sectors in the SSRB are important, but improved irrigation district efficiencies hold the most promise for a significant impact on the issues being addressed in this study. AECOM (2009) has suggested a target for irrigation district efficiency of 63% to be achieved within the next 10 to 15 years as the irrigation industry's contribution to the Water for Life Conservation, Efficiency, Productivity (CEP) program. This level of improved efficiency for the current irrigated area of 494,087 ha would conserve about 326 000 $dam^3$.

Irrigation water-use efficiencies can contribute to resolving issues identified in this study, but to make a significant impact, researchers studying the issue in southern Alberta and elsewhere suggest that subsidies accompanied by agreements on the use of freed-up water would probably be required to make a significant contribution.

Innovative opportunities may arise from time to time that will mutually benefit the irrigators as well as assist in meeting societal goals for increased in-stream flows, more efficient water use, increased water-use productivity and economic growth. Partnering on implementation may ensure that conserved water is shared in a manner that contributes to broader societal goals as well as the direct water users.

***Recommendations Related to Irrigation District Water Use Efficiency***

8. It is recommended that measures to encourage and expedite water-use efficiency within irrigation districts be considered to conserve water.
9. It is recommended that partnering on the implementation of innovative projects that will help to improve efficiencies and conserve water be considered.

### 8.2.3 Market-based Water Allocation Transfers

In the long term, allocation transfers will gradually shift water use to higher-value purposes, to more efficient users, and to meeting in-stream requirements. The contribution of transfers to reducing basin-wide deficits identified in this study is likely to be small in light of the large amount of transfers required to have a significant impact on the issues identified, and given the low level of market activity experienced in the first 9 years since the transfers were authorized under the *Water Act*. (The Waterton, Belly and St. Mary River Sub-basins were closed to new applications for about 7 of those 9 years, and the entire Oldman, Bow and South Saskatchewan River Sub-basins were closed for about 3 of those 9 years.) Certain measures could be taken to help foster a more robust water market. Even with more robust markets, water allocation transfers are not likely to become the primary means of addressing issues identified in this study, but they can play an important role.

***Recommendations Related to Market-Based Water Allocation Transfers***

10. It is recommended that measures to facilitate market-based water allocation transfers be considered to increase the number of transfers and progress toward meeting the objectives that allocation transfers were intended to achieve. Experience in other jurisdictions should be used as guidance to determine the most effective measures to implement.
11. It is recommended that irrigation districts consider the extent to which they foresee expansion of their irrigated areas, in light of the findings of this study, and to explore how they may be part of the solution to reducing deficits to in-stream needs and junior consumptive uses through participation in the market-based allocation transfer process or other non-structural means.

### 8.2.4 Deficit Management

Deficit sharing through allocation assignments have an important role in future water management in the SSRB. Assignments are a valuable tool in reducing the impacts of periodic droughts. However, assignments would not have a major impact on the issues identified in this study. Section 33(3) (b) of the *Water Act* indicates that the receiver of the assigned water must adhere to the conditions of his own licence. Hence, the conditions of a junior licensee experiencing deficits would not allow diversions of assigned water when the in-stream flow conditions are not being met.

Managing deficits may also be implemented through infrastructure operation planning. The use of legally stored water is exempt from the priorities of the *Water Act*. Reservoir rule curves could be developed that would use stored water to spread the risk of water deficits to two or more water-use sectors regardless of the priorities of individual licences. Of course, licence priorities would still apply to the natural flow of the stream.

***Recommendations Related to Deficit Management***

12. It is recommended that the concept of sharing the risk of deficit using stored water be incorporated into reservoir operation plans.
13. It is recommended that other means of sharing deficits during extreme low-flow conditions be explored, while recognizing the extensive private- and public-water management investments that have been made on the basis of the priority system that has been the foundation of water management legislation in Alberta for over 100 years.

## 8.3 Structural Water Management Opportunities

A preliminary review of the hydrology of the Red Deer, Bow, and Oldman River Sub-basins concluded that there is sufficient unregulated flow available in parts of each sub-basin to justify a more detailed assessment of new storage development.

Further consideration of additional storage in the Red Deer River Sub-basin is deferred until the operation policy for existing storage is reviewed and confirmed or amended. Because deficits are infrequent and low in volume, it is possible that no new storage is required if the use of existing storage is optimized and other non-structural measures are taken, such as sharing deficits.

Similarly, in the Bow River Sub-basin, sharing the use of TA storage is much preferred over new storage development. Discussions between the province and TA should proceed to their ultimate conclusion to determine whether or not new storage development is required in the basin prior to considering options for new storage in the sub-basin.

With respect to the Oldman River Sub-basin, simulation modelling indicated that new storage development in the sub-basin could ensure that the IOs would be met and greatly reduce deficits to junior private irrigation and non-irrigation projects, as well as development on the Piikani First Nation Reserve. A storage project the size of the Oldman River Reservoir was assumed in the analysis. With new storage in place, performance for Scenario 3 demands was improved over performance with current demands. Various sizes of projects and alternative locations could be considered if the storage option is deemed to be worthy of more detailed study.

***Recommendations Related to Structural Water Management Opportunities***

14. It is recommended that storage options be considered only after thorough consideration of non-structural options. In particular, refinement of operational procedures for existing storage in the Red Deer and Bow River Sub-basins may delay or eliminate the need for new storage in those basins.
15. If it is decided to pursue the option of additional storage development in the Oldman River Sub-basin, it is recommended that various sizes and locations for storage development be considered in a screening process, and the most favourable sites be subjected to economic, environmental, and social impact scrutiny.

## 9.0 CLOSURE

This report has been prepared for the exclusive use of **SSRB Water Supply Steering Committee**. This report is based on, and limited by, the interpretation of data, circumstances, and conditions available at the time of completion of the work as referenced throughout the report. It has been prepared in accordance with generally accepted engineering practices. No other warranty, express or implied, is made.

Please destroy or return all draft documents to AMEC.

Yours truly,

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# APPENDIX A: UNIT CONVERSION FACTORS

| SI Units (metric) | Imperial Units |
|---|---|
| **Area** | |
| 1.0 hectare (ha) | = 2.471 acres |
| 1.0 square kilometres ($km^2$) | = 0.386 square miles |
| **Length** | |
| 1.0 millimetre (mm) | = 0.039 inches |
| 1.0 metre (m) | = 3.281 feet |
| 1.0 kilometre (km) | = 0.621 miles |
| **Volume** | |
| 1.0 litre (L) | = 0.0353 cubic feet |
| 1.0 cubic metre ($m^3$) | = 35.315 cubic feet |
| 1.0 decametre ($dam^3$) = 1000 $m^3$ | = 0.811 acre feet |