Present and Future Water Demand in the South Saskatchewan River Basin

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A report prepared for

SASKATCHEWAN WATERSHED AUTHORITY
MOOSE JAW

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Canada

Executive Summary

In our era of environmental concern, water is being recognized as an increasingly valuable commodity. It is needed for ecological functions, as well as for many social and economic activities. In the South Saskatchewan River Basin (SSRB), water supplies are currently limited, and further expansion of water availability may be a costly measure. As the future economic base in the basin increases, leading to population growth, competition for water may become even fiercer. Climate change may pose another threat to the region, partly from reduced supplies and increased water demand. The development of sounder water management strategies may become a necessity in the future, but water management strategies would require information on future water demand levels. This study was undertaken to estimate current (2010) water demand levels and forecast them for the basin by type of demands for the 2020, 2040, and 2060 periods.

Basin Description

The SSRB is located in the south-central part of the province of Saskatchewan. It extends from the Alberta border to just northeast of the city of Saskatoon where it joins the North Saskatchewan River to form the South Saskatchewan River. The basin occupies an area of 35,000 square kilometers, 91% of which is used for agricultural purposes. The basin houses a 316,731 people – roughly a third of the provincial population. Four cities are located in the basin –Saskatoon, Martensville, Warman, and Swift Current. In addition, the basin provides water to other urban community demands, such as the city of Humboldt. Currently, there are three potash mines in the basin, along with some oil and gas activity, as well as manufacturing establishments. In the future, potash production is expected to increase significantly. Irrigation development is also planned in the basin, and major recreational facilities also exist in the basin.

Methodology

The total water demand was broadly divided into two classes of demands: One, that results from socio-economic activities, called direct anthropogenic water demand, and Two, that is subject to natural and policy-related factors, called indirect anthropogenic water demand. The second category of water demand include four types: evaporation, apportionment of water as subject to the Prairie Provinces Water Board agreement, meeting in-stream water flow needs, and requirements for environmental protection/preservation.

The direct anthropogenic water demand results from several types of economic and social activities. Some of these activities are related to the production of goods, while others need water for sustenance and related social activities. Total water demand for a given purpose was

estimated using water demand coefficients and scales of economic or social activity. Various types of water demands were identified.

In this study, future water demand (for the years 2020, 2040, and 2060) was estimated for three scenarios: Baseline Scenario; Climate Change Scenario, and Water Conservation Scenario. The Baseline Scenario assumed that trends based on past data will continue into the future. For the Climate Change Scenario, water demand was affected by changes in climate characteristics and the occurrence of extreme events. Water demand coefficients for any water demand related activity exposed to these conditions were adjusted for these future periods. The third scenario assumed that the province had developed a water conservation policy and that measures had been adopted by various water users to reduce water demand.

In the SSRB, in addition to water demand within the basin, some water is exported to the Qu'Appelle River Basin (QRB).[1] Much of this water is transferred through the Saskatchewan Southeast Water Supply (SSEWS) canal for potash mines, and for some recreational activities in Last Mountain Lake. In addition, some smaller communities in the QRB also receive water from the SSRB though the Wakaw-Humboldt Water Supply System (WHWSS). These water demands were estimated separately.

Water Demand Estimates under Baseline Scenario

Based on the above discussion, total water demand for the SSRB was first divided into two broad categories – direct anthropogenic and indirect anthropogenic. The direct anthropogenic water demand was then divided into two sub-categories – that within the basin, and that amount of water exported to the QRB. The distribution of total water in the SSRB for these three types is shown in Figure ES.1.

In the above set of estimates, the total indirect anthropogenic water demand for future years was set an equal to the 2010 level, since all these demands are related to the availability of water; which such availabilities be affected by a set of natural factors and policy changes. Over the 2010-2060 period this amount was estimated to be 331,201 dam^3. The direct anthropogenic water demand was predicted to increase over the period. By 2060, the total water demand in the basin will increase to 1.25 million dam^3 – an increase of 96.5% of the 2010 level.

Direct anthropogenic water demand in the SSRB also had another issue – that related to hydroelectric power generation. Since this water is related to direct anthropogenic activities, it is a non-consumptive water demand. Water released over the Gardiner Dam is still available to

[1] According to Saskatchewan Watershed Authority.in recent years, approximately 115,000 dam^3 of water have been released annually through the Qu'Appelle River dam to meet various water demands in the Qu'Appelle River Basin.

other users downstream and to meet the other indirect anthropogenic water needs. However, for the Lake Diefenbaker water users, this is a competitive demand and perhaps presents a situation of a trade-off. In 2010, an estimated level of 1.66 million dam^3 was released for this purpose.

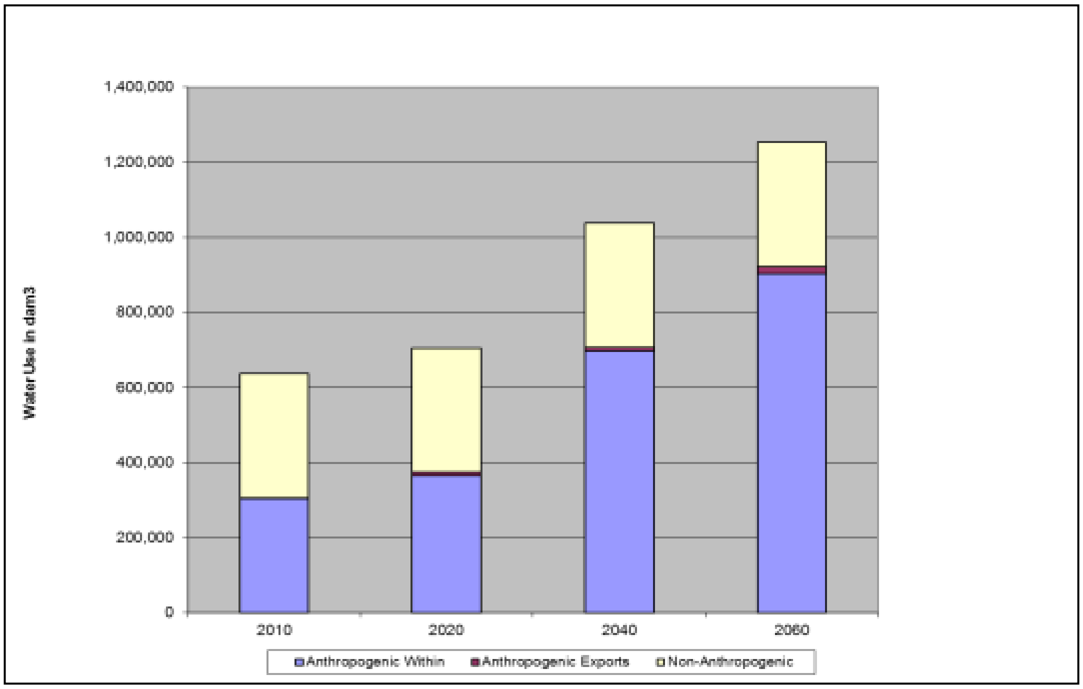

Figure ES.1: Distribution of Total Water Demand in the South Saskatchewan River Basin by Major Type of Demand, 2010 – 2060

Total direct anthropogenic water demand for the SSRB is presented in Table ES.1. In 2010, a total of 303 thousand dam^3 was demanded, of which that directed outside the basin (the QRB) constituted slightly less than one percent of the total. By 2060, it is estimated that exports to the QRB may increase to 2% of the total direct anthropogenic water demand.

The total direct anthropogenic water demand within the basin represents a sum of four types of socio-economic activities: (i) water required for agricultural production and related activities; (ii) water needed by industries and for mining; (iii) water demanded by people living in various communities in the basin, collectively called municipal and domestic water demands; and (iv) water needs for recreational and related human activities. These water demands are expected to increase over time. In total, direct anthropogenic water demand within the basin will increase to 902 thousand dam^3 in 2060, compared to its present level of only 303 thousand dam^3. As shown in Figure ES.2, much of this increase can be credited to agricultural water demand, and within it, to irrigation. Municipal/domestic water demands are the second most important growth sectors to be observed by 2060.

Table ES.1: Water Demand in the South Saskatchewan River Basin, Baseline Scenario, 2010-2060

Sector	2010	2020	2040	2060
Agriculture	237,299	285,014	599,072	789,120
Industry/Mining	7,883	15,891	24,143	27,937
Municipal (Domestic)	57,675	62,162	72,552	85,097
Recreational	67	68	70	71
Total Within Basin Direct Anthropogenic Water Demand*	302,924	363,134	695,837	902,225
Outside Basin Direct Anthropogenic Water Demand	2,990	10,144	10,212	18,512
Total Direct Anthropogenic Water Demand	**305,914**	**373,278**	**706,049**	**920,737**
Indirect Anthropogenic Water Demand	331,201	331,201	331,201	331,201
Total Water Demand	**637,115**	**704,479**	**1,037,250**	**1,251,938**
% Change in Direct Anthropogenic Water Demand over 2010		22.0%	130.8%	201.0%
% Change in Total Water Demand over 2010		10.57%	62.80%	96.50%
Hydroelectric Power Generation Water Release	1,660,092	1,660,092	1,660,092	1,660,092

* Totals may not add due to rounding

Industrial and mining water demands are also expected to increase, but not by a similar magnitude. The increased amount of irrigated area and population growth around the city of Saskatoon are the main forces behind the change in water demand. In 2010, as shown in Figure ES.3, irrigation accounted for 87% of the total 2010 water demand. By 2060, although the share of irrigation is reduced to 78%, that for municipal/domestic water demand increases to 19% of the total. As a result of varying trends over the 2010-2060 period, the composition of total direct anthropogenic water demand will change. As shown in Figure ES.3, agriculture would reduce its share (from 87% to 78%) and municipal/domestic water demands will increase the share (from 10% to 19%).

Water Demand Estimates under Climate Change Scenario

As noted above, in addition to the baseline forecasts of water demand, this study applies two other scenarios for making these forecasts. One of these scenarios is climate change. Climate change can have an impact both on water supplies (availability) as well as on water demand. However, in this study, investigation is limited to water demand aspects. Even here, several difficulties were encountered in making these estimates. One such problem was the availability of information on the nature of climate change for the basin and its impact on water demand. Therefore, the basis for making the forecasts is relatively weak, and more research information needs to be generated in the context of Saskatchewan (and more specifically to the SSRB) situation. The following results are based on our current knowledge.

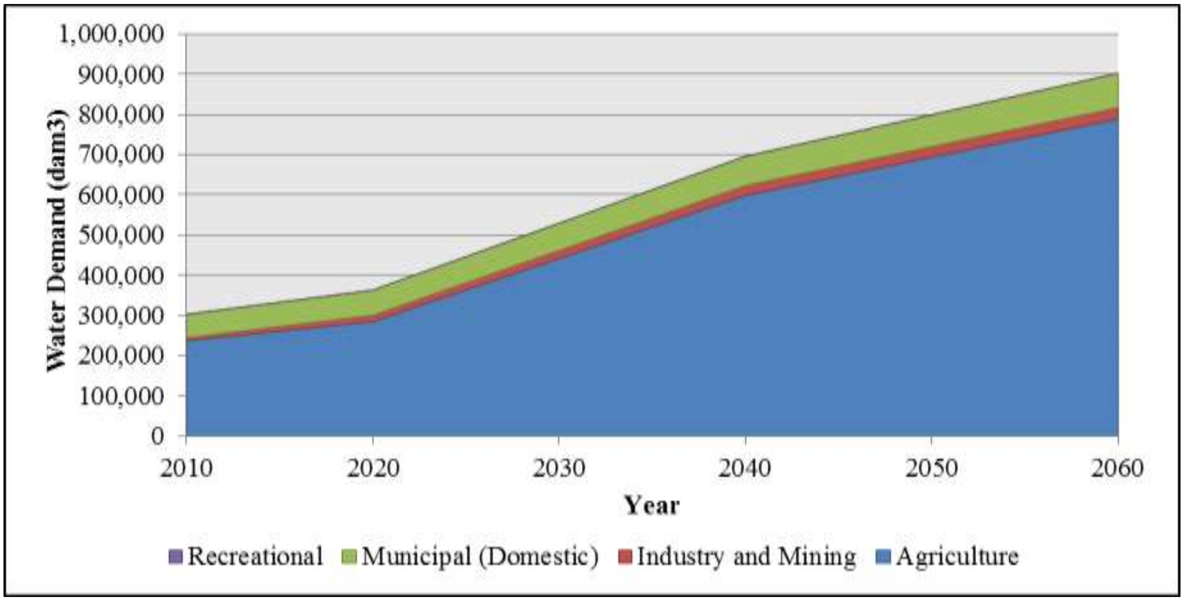

Figure ES.2: Trend in Anthropogenic Water Demands by Type, South Saskatchewan River Basin, 2010 – 2060

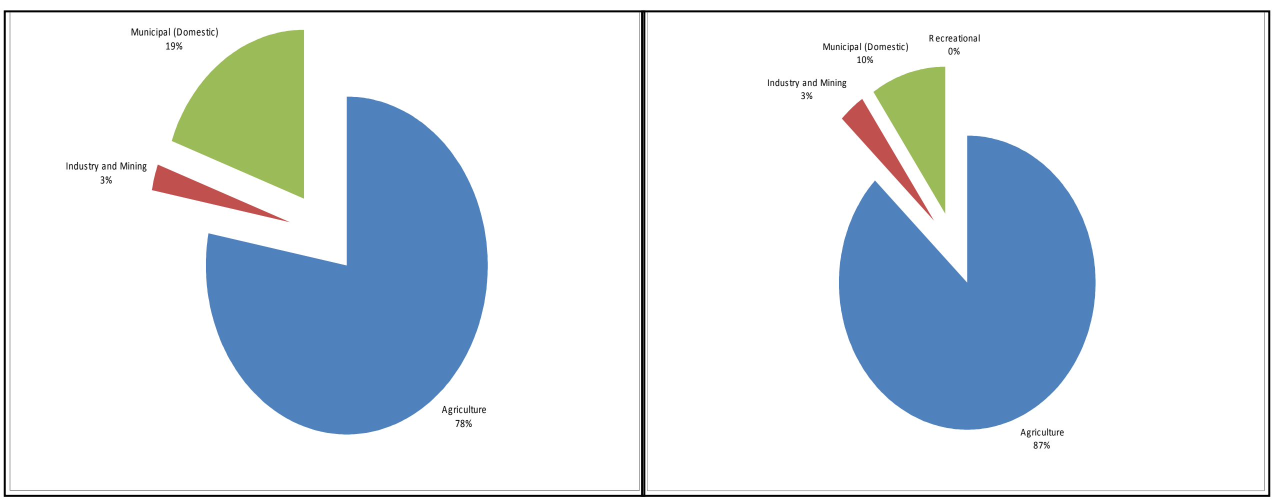

Figure ES.3: Distribution of Direct Anthropogenic Water Demand to Total Water Demand by Type, South Saskatchewan River Basin, 2010 (Left) and 2060 (Right)

The potential effects of climate change on the direct anthropogenic and indirect anthropogenic water demand activities in the SSRB are presented in Table ES.2. Since indirect anthropogenic water demands are governed by natural changes in the water supply and by policy changes, only evaporation losses were subjected to climate change. All other indirect anthropogenic demands were kept constant at the 2010 level. Since the South Saskatchewan River does not cross the Manitoba-Saskatchewan boundary, no apportionment water requirements are imposed. Similarly, for environmental water demand, although such projects do exist, there are no data available on their annual water demand after the initial start-up period.

Table ES.2: Water Demand under Climate Change Scenario, South Saskatchewan River Basin, 2010 - 2060

Sector	2010	2020	2040	2060
Agriculture	237,299	285,014	691,777	985,004
Industry/Mining	7,883	15,740	23,620	26,607
Municipal (Domestic)	57,675	62,162	74,330	89,370
Recreational	67	68	72	75
Total Within Basin Direct Anthropogenic Water Demand*	302,924	363,134	789,799	1,101,056
Outside Basin Direct Anthropogenic Water Demand	2,762	9,930	10,040	18,382
Total Direct Anthropogenic Water Demand	**305,914**	**373,278**	**799,839**	**1,119,438**
Indirect Anthropogenic Water Demands	331,201	331,201	347,513	363,826
Total Water Demand	**637,115**	**704,479**	**1,147,352**	**1,484,513**
% Change in Direct Anthropogenic Water Demand over 2010		22.02%	161.46%	265.93%
% Change in Total Water Demand over 2010		10.57%	80.09%	133.01%
Hydroelectric Power Generation Water Release	1,660,092	1,660,092	1,660,092	1,660,092

* Totals may not add due to rounding

Higher growing season temperatures will have a significant impact on the agricultural sector as both crops and livestock will demand more water. The evaporation from water bodies, which is already a major indirect anthropogenic water demand, is one of the major increased that can be expected with climate change. The total water demand in the basin is estimated to increase from the current level of 637 thousand dam^3 in 2010 to 1.48 million dam^3 by 2060. This is an increase by 133% of the 2010 level. Direct anthropogenic water demand for the SSRB is expected to increase at a faster rate than twill the total water demand. The increase in this water demand will range from 305 thousand dam^3 in 2010 to 1.12 million dam^3. Much of this increase is a result of higher agricultural water demands.

Water Demand Estimates under Water Conservation Scenario

The effect of water conservation measures on the water demand activities in the SSRB are presented in Table ES.3. Agricultural and industrial adoption of water conservation techniques and technologies has the greatest impact on the direct anthropogenic demand for water. However, the success of many such water conservation measures is partially dependent on legislations and regulations that may be in place in the future.

Table ES.3: Water Demand under Water Conservation Scenario, South Saskatchewan River Basin, 2010-2060

Sector	2010	2020	2040	2060
Agriculture	237,299	265,939	474,730	692,708
Industry/Mining	7,883	15,500	22,679	24,761
Municipal (Domestic)	57,675	60,742	67,552	75,156
Recreational	67	68	70	71
Total Within Basin Direct Anthropogenic Water Demand*	302,924	342,247	565,025	792,687
Outside Basin Direct Anthropogenic Water Demand	2,762	9,682	9,269	16,044
Total Direct Anthropogenic Water Demand	**305,914**	**351,928**	**574,295**	**808,731**
Indirect Anthropogenic Water Demand	331,201	331,201	331,201	331,201
Total Water Demand	**637,115**	**683,129**	**905,496**	**1,139,932**
% Change In Direct Anthropogenic Water Demand over 2010		15.04%	87.73%	164.37%
% Change in Total Water Demand over 2010		7.22%	42.12%	78.92%
Hydroelectric Power Generation Water Release	1,660,092	1,660,092	1,660,092	1,660,092

* Totals may not add due to rounding

Under the water conservation scenario, total water demand for direct anthropogenic purposes is estimated to be 808 thousand dam^3 by 2060 – an increase of approximately 164% over the 2010 level. Relative to the baseline scenario, water conservation could reduce direct anthropogenic water demand by 12% of the baseline estimate by 2060 (Table ES.4). Much of this decrease would likely occur through reduction in the agricultural demand, although other sectors will contribute to the reduction as well.

Table ES.4: Relative Change in 2060 Water Demand in the South Saskatchewan River Basin by Type of Demand under the Water Conservation Scenario Relative to Baseline Scenario

Type of Demand	Change in 2060 level % of 2010 Level
Agriculture	-12.2%
Industry/Mining	-11.4%
Municipal (Domestic and industrial)	-11.7%
Recreational	0.0%
Total Anthropogenic Water Demand	-12.1%

Water Demand by Source of Water

Most of the water for various types of demands is either obtained from surface water or groundwater. In some cases, groundwater can supplement any periodic shortfalls in surface water availability. Unfortunately data for total water demand by source of water is not very precise. Some information is available but other estimates are based on assumptions. The estimated water demand by type is shown in Table ES.4. Based on these estimates, it appears likely that the relative share of groundwater will decrease from 6% in 2010 to 2% by 2060. The proportion of surface water demand to total water demand increases from 94% in 2010 to 98% by 2060, as shown in Figure ES.4.

Table ES.5: Distribution of Within Basin Total Direct Anthropogenic Water Demand by Source of Water, South Saskatchewan River Basin, 2010 - 2060

Particulars	Total Amount of Water Demand in dam^3			
	2010	**2020**	**2040**	**2060**
Surface Water (dam^3)	284,844	344,864	677,592	883,966
Groundwater (dam^3)	18,080	18,270	18,245	18,259
Total Water Demand	**302,924**	**363,134**	**695,837**	**902,225**
Groundwater % of Total	6.0%	5.0%	2.6%	2.0%

Summary

A major increase in the water demand for various anthropogenic purposes is expected in the SSRB by 2060. The changes for the three scenarios and for the 2010 - 2060 period are shown in Figure ES.5.

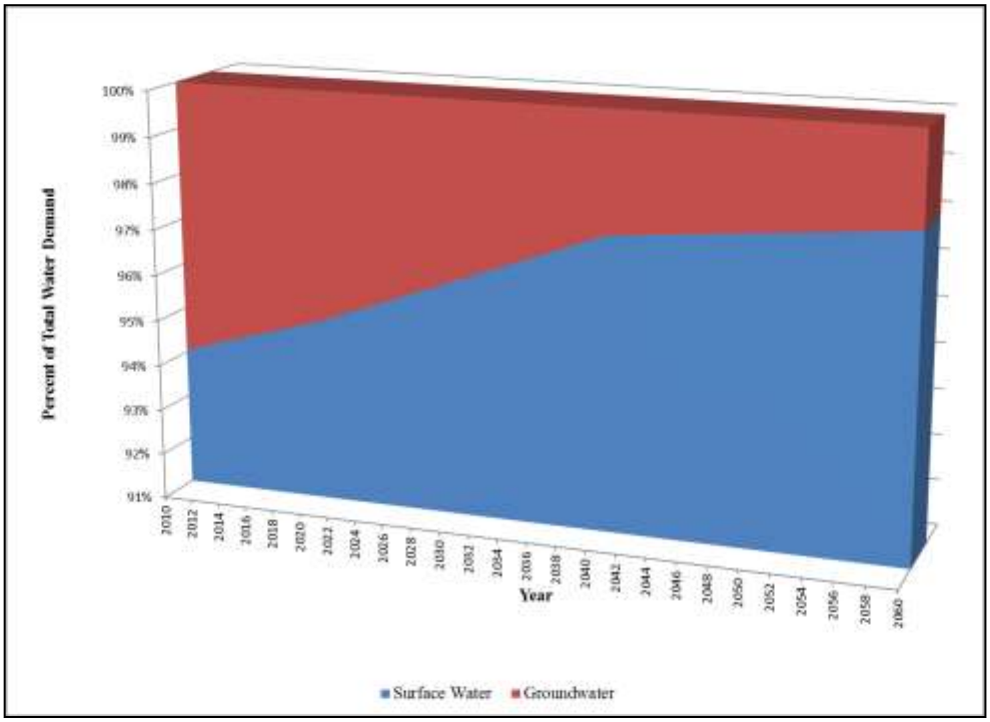

Figure ES.4: Proportion of Surface Water Demand to Total Direct Anthropogenic Water Demand, South Saskatchewan River Basin, 2010 – 2060

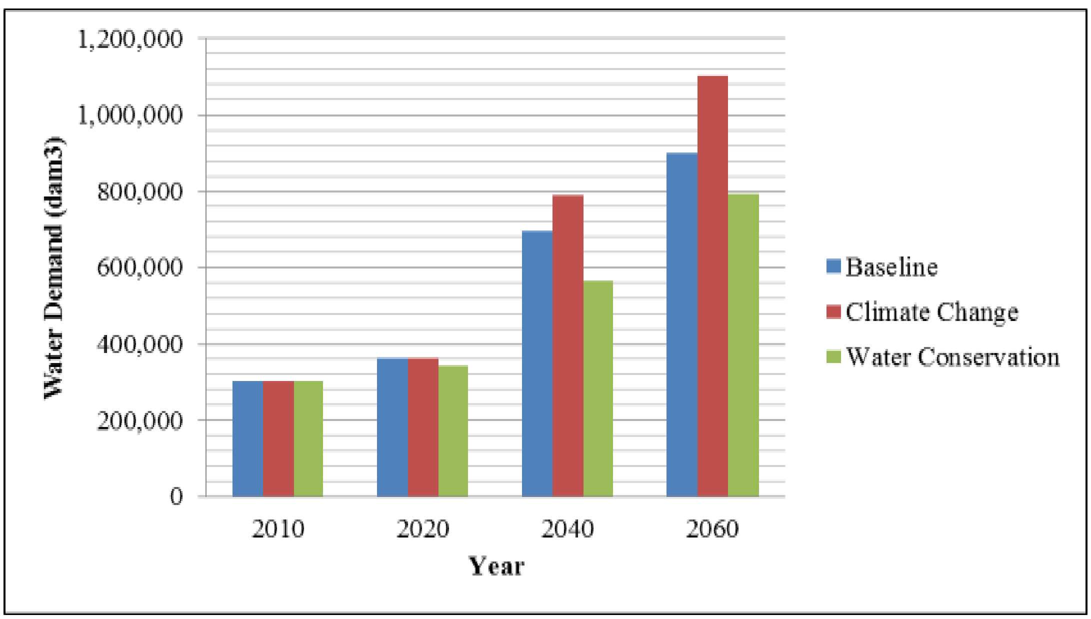

Figure ES.5: Direct Anthropogenic Water Demand under Alternate Study Scenarios in dam^3, South Saskatchewan River Basin, 2010-2060

Under baseline assumptions, the water demand in 2060 will increase by 200% of the 2010 level. Under climate change, further increases are expected. The total anthropogenic water demand could increase by 265% of its 2010 level. This increase is estimated to be 22% over the 2060 baseline water demand level. The adoption of water conservation measures by water users has the potential to reduce future water demand. Relative to the baseline scenario estimate, this reduction could be in the magnitude of 12%. However, the effectiveness of such measures will depend very much on the policy measures undertaken by the provincial government and by other jurisdictions.

The need for water conservation measures, including use of economic instruments has been suggested by the National Roundtable on Economy and Environment. The Roundtable also recommends "Recognizing that accurate water forecasting requires improving how we measure and report water-quantity data; governments and industry should work collaboratively to develop appropriate measurement and reporting requirements on a sector-by-sector basis" (NRTEE, 2012).

This study does exhibit a number of limitations, though. There are several data deficiencies related to factors that affect water demand. For instance, the impact of climate change on the basin's water demand is a relatively unstudied subject. Water conservation experience also suffers a similar deficiency. Also, this study treated the SSRB as a single entity, but significant variability in the water demand may exist within the basin. The identification of these water stress pockets needs to be done in conjunction with consideration of water supply information under alternative demand and supply scenarios.

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List of Acronyms Used

AAFC	Agriculture and Agri-Food Canada
BSE	Bovine Spongiform Encephalopathy
CCCSN	Canadian Climate Change Scenarios Network
CIBC	Canadian Imperial Bank of Commerce
CMHC	Canadian Mortgage and Housing Corporation
CMS	Cubic meters per second
CSWS	Canadian Soft White Spring
CWRS	Canadian Western Red Spring
CWAD	Canadian Western Amber Durum
DFO	Department of Fisheries and Oceans (Federal Government)
DPSIR	Drivers, Pressures, State, Impacts, and Responses
DUC	Ducks Unlimited Canada
ES	Executive Summary
FAO	Food and Agricultural Organization of the United Nations
EEA	European Environmental Agency
GCM	Global Climate Change Models
GDP	Gross Domestic Product
ICDC	Irrigation Crop Diversification Corporation
ICWE	International Conference on Water and the Environment
ILO	Intensive Livestock Operations
IPCC	Intergovernmental Panel on Climate Change
IWD	Irrigation Water Demand

LDDA	Lake Diefenbaker Development Area
LLID	Luck Lake Irrigation District
MAA	Master Agreement for Apportionment
MCOOL	Mandatory Country of Origin Labeling
ML	Mega (Million) Liters
NEB	National Energy Board
NRTEE	National Roundtable on Environment and Economy
OMAFRA	Ontario Ministry of Agriculture, Food and Rural Affairs
PFRA	Prairie Farm Rehabilitation Administration
QRB	Qu'Appelle River Basin
PPWB	Prairie Provinces Water Board
RHID	Riverhurst Irrigation District
SICC	Saskatchewan Indian Cultural Center
SIPA	Saskatchewan Irrigation Projects Association
SSEWS	Saskatchewan South East Water Supply
SSRB	South Saskatchewan River Basin
SSRID	South Saskatchewan River Irrigation District
SWA	Saskatchewan Watershed Authority
TWD	Total Water Demand
WID	Westside Irrigation District
WHWSS	Wakaw Humboldt Water Supply System

Chapter 1

Introduction

1.1 Background

Fresh water is our life line, supporting our economic activity, playing a vital role in our society, and maintaining our culture. It is therefore an essential element in the broad functioning of economic activities and sectors. Although a common myth is that Canada is fortunate to have plentiful freshwater resources, in reality there is a mismatch. Most of the water is available in the northern regions of the country where few people reside. The more populated areas of southern Canada have a relatively low water availability and this creates an increased need for effective water management. Parts of southern Saskatchewan face similar situations with respect to water availability.

Traditionally, water is seen as a basic necessity of life, an important and most consumed natural resource. As an important natural resource, water is used for various purposes, including agricultural production, electricity generation, human consumption, industrial and commercial economic activity, and recreation, among other purposes. In recent times, there has been increasing controversy and competition among various users of water because supplies are no longer meeting demands in some locations. This situation may be accentuated by future climate change, since there could be an increased need for water for irrigation. Economic development activities will also assert the same type of pressure on existing water supplies.

Saskatchewan has both surface water and groundwater. Water supplies do vary from one part of the province to the other. In fact, the South Saskatchewan River is the only reliable source of good quality water in Southern Saskatchewan. Although the province has groundwater resources, they remain a buried treasure (Nowlan, 2005). Perhaps for this reason, data and information on ground water remains very scarce (Rivera, 2005). For surface water, the province is divided into 29 watersheds further aggregated into 14 drainage basins. One of these major drainage basins is the SSRB, which is the focus of this study.

1.2 Water Management Issues

Water is a limited resource globally, but in semi-arid regions, such as in parts of Saskatchewan, this problem is even more acute. At the same time, society is increasingly concerned about water quality and environmental issues in general, and about those related to water in particular. In the past, the major issue in water management was water availability. To assist with this, many traditional steps have been taken, including additional storage of water, reduction of river flow variability, and redirection and utilization of groundwater flows (Cohen et al. 2004). As sources for supply enhancement dwindle, water resource management is leaning towards demand management.

In the past decades, policies have been focused on supply management, but recently, there has been a transition from water-supply management to water-demand management in order to strike a balance between the two in order to ensure efficient water use. Studies have shown that with the past and present trend in competition for water in different locations, the demand will continue to increase as population increases; other demands for water may also emerge. This study is relevant in the context of appropriate policy and planning on water supply and demand by policy makers. It is felt that these policies should be built on a better understanding of past and present trends in water consumption, climate change, population dynamics, migration and changes in socioeconomic and demographic characteristics of water consumers. Such work is important because the development of appropriate policies and programs requires good information on the current level of water consumption by different users (Kulshreshtha, 1996). This study is therefore relevant for future planning and management of water supply systems in western Canada.

Demand management involves ways and means to reduce wasteful water use. These measures are needed since, in some regions, available freshwater is inadequate for the local demand; moreover, diverting it from other regions is replete with economic and political problems. Similarly in some areas, facilities to treat, distribute, and discharge water may not meet expanding demands. In fact, in a Saskatchewan Water Corporation survey of various communities in 1994, of the 597 communities responding to the survey, 172 indicated that water supply is a constraint to their future economic growth (Kulshreshtha, 1994). Miller et al. (2000) also suggest that rural water resources are stressed in significant ways, affecting rural development; it is now, and will continue to be, limited by a wide variety of water issues.

The contamination of freshwater bodies is another issue in several parts of Saskatchewan. Run-off from farm land and nutrient loadings as a result of intensive agricultural practices lead to further deterioration of water quality for various uses. This condition further reduces water availability (both surface water and groundwater).

The instream flow needs of the flora and fauna that derive part or all their existence from the water resource need to be considered. Instream flow levels during critical points in the life cycle of the fish and plants in the river system need to be acknowledged and accounted for in the demand for water.

In addition to the above issues, future water availability will also be affected by climate change. The Intergovernmental Panel on Climate Change (IPCC) has indicated that among the most important impacts of climate change will be its effects on the hydrologic cycle and on water management systems (Ayibotele, 1992). For the Canadian prairies, Byrne et al. (2010) have stated that "much of the western half of the continent is showing historical trends that suggest an increasing influence of the dry tropical climate. Consequently, we can expect negative impacts on all watersheds originating in the Rocky Mountains and on the western Prairies." Similar conclusions have been reported by Whitefield et al. (2004). At the same time, demand for water is expected to increase with climate change, presenting a situation of conflict among water users. Resolving conflicts in water resources through proper demand management (by appropriate economic, legal and institutional mechanisms) has been proposed by the Dublin Statement in 1992 (See ICWE, 1992).

Demand management has been recognized as a manner through which future water management should be considered, along with traditional supply enhancement. Water demand management, according to Brooks and Peters (1988), is defined as "any measure that reduces average or peak water withdrawals from surface or groundwater sources without increasing the extent to which wastewater is degraded." The starting point in this process is knowledge of current water demand. However, in order to develop sustainable water management, information on the future is equally important. As the NRTEE (2012) has indicated, "Governments should develop new predictive tools such as water forecasting to improve their understanding of where and when water demands might increase. The information provided by forecasts will be important to inform water allocations and management strategies in the future." This study was carried out in order to provide such information for the SSRB.

1.3 Objectives and Scope of the Study

This study was designed to estimate water demand in the SSRB of Saskatchewan. Water demand estimates are developed both for the current period (Year 2010), as well as for future time periods (Years 2020, 2040, and 2060). The estimation is done by a disaggregated approach/method. Both consumptive and non-consumptive water demands are included. Factors affecting demand consist of population (or physical activity requiring water), policy measures, and climate change.

1.4 Organization of the Report

The rest of this report is divided into ten chapters. Chapter 2 provides an overview of the SSRB. Major economic activities and population centers are included in this description. Methods for estimating current water demand in the basin are provided in Chapter 3, which is followed by the methodology for future water demand estimation in Chapter 4. Study scenarios are described in Chapter 5. The water demand by type of users is presented in Chapters 6 to 9, starting with

Agriculture water in Chapter6, Industrial and mining water demand in Chapter 7, Municipal water demand in Chapter 8, and Recreational water demand in Chapter 9. All current and future water demand estimates under various study scenarios are presented in these chapters. Chapter 10 describes other water demands, mainly those that are not related to human activities. The last chapter provides a summary of results and areas for future research.

Chapter 2

Description of the South Saskatchewan River Basin

This chapter provides a description of the baseline conditions in the SSRB. This basin is extremely significant for the province since it houses major urban centers and major irrigation activity, besides numerous other economic activities. This documentation is based on available secondary data.

2.1 Location of the South Saskatchewan River Basin

The South Saskatchewan River (SSR) is a major Canadian river that flows through the provinces of Alberta and Saskatchewan. In fact, this river originates in Alberta by the confluence of the Bow and Oldman rivers. The waters of these two rivers, in turn, originate on the eastern slopes of the Rocky Mountains in Alberta and Montana. Just into Saskatchewan, the Red Deer River contributes water within the Saskatchewan portion of the SSR. From there on, the river flows northeast past the city of Saskatoon, and continues almost parallel to the North Saskatchewan to make the Saskatchewan River.

Some 100 km south of Saskatoon, the river enters Lake Diefenbaker, which is a 225 km long reservoir, created by the Gardiner dam in the north and the Qu'Appelle dam in the south. It is a large reservoir, with a surface area of 430 km^2 (Partners for the Saskatchewan River Basin, 2009). It has a live storage capacity of about four million dam,^{3}[2] although total storage is over twice that amount. Besides supplying domestic water demand, it serves as a major source of irrigation and power generation. Three provincial parks are located around this reservoir.

A canal, called the Saskatoon-Southeast Water Supply (SSEWS) canal, from the East Side Pump Station of the Gardiner Dam takes some water from the Lake northward along the east side of the river, first supplying the Broderick Reservoir; it then delivers water northeastwards to many domestic and industrial water users (Canada West Foundation, 1982). Many of these users are located in other river basins, notably the Qu'Appelle River Basin, and the North Saskatchewan River Basin.

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[2] 1dam^3=1000m^3

The SSR drains an approximately 35,000 km^2 area (Table 2.1). The basin is shown in Figure 2.1. The SWA broadly divides this basin into three planning units – West Unit (region before Lake Diefenbaker; Lake Diefenbaker Unit; and North Unit, the region that is located just south of the city of Saskatoon until the river meets the North Saskatchewan River. SSRB contains the mainstream SSR and includes three watersheds: (1) SSRB (2) Swift Current Creek Basin and (3) Rush Lake Watershed. Cypress Hills North Slope Watershed, also a sub-basin of SSRB, will not be analyzed in conjunction with the other sub-basins.

Table 2.1: Land Use in the South Saskatchewan River Basin

Land Cover Area	**Area in km^2**	**% of Total Area**
Total Area	35,000	100.0%
Deciduous Broadleaf Forest	700	2.0%
Shrubland	700	2.0%
Grassland	8,750	25.0%
Cropland and Seeded Pasture	22,925	65.5%
Other Land Cover	1,925	5.5%

Source: Statistics Canada (2000).

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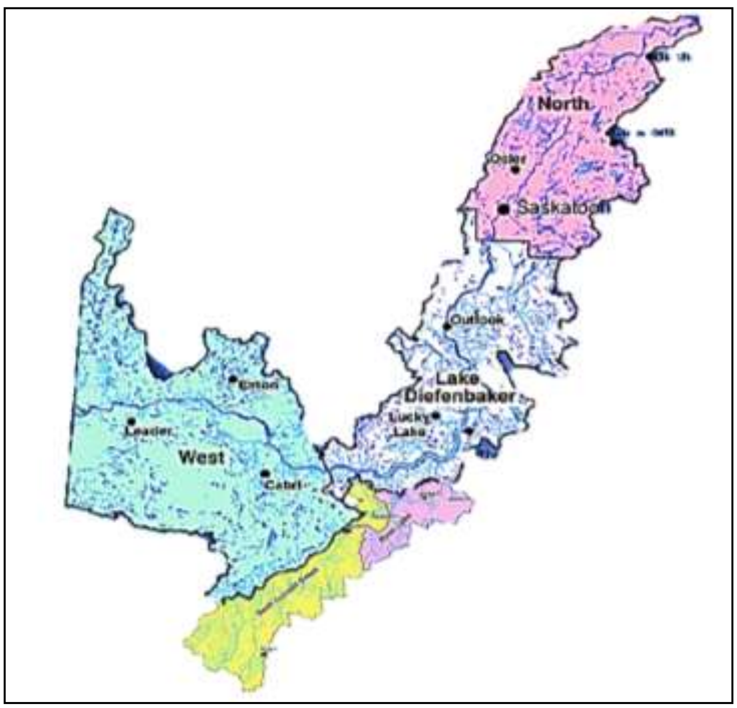

Source: Map courtesy of SWA.

Figure 2.1: Map of the South Saskatchewan River Basin

Land use in the basin is primarily for agricultural purposes. Of its total area, 90.5% is used for agriculture, about 25% is grassland, and less than 2% is forested. The basin contains one major urban center – Saskatoon. However, the area used for non-agricultural purposes is very small.

2.2 Population

The SSRB is one of the important basins from the standpoint of people. In 2009, it was estimated that some 316,731 thousand people resided within the basin (Table 2.2). Saskatchewan's population in 2011 was reported to be a little over a million (1,033,381 people, to be exact[3]). Thus, the basin houses 30.6% of the provincial population.

The total population of the basin was divided into different types of communities/regions. Initially, population was divided into urban and rural categories. Urban population included cities, towns, villages, bedroom communities, First Nations' Reserves, and recreational communities. The standard definition for these areas was followed. Towns were further divided into two groups: Larger towns -- those with 1000 or more people, and small towns -- those smaller than this level. Bedroom communities were defined as those that had their population increasing and were within a distance of 40 - 60 km (approximately 30-45 minutes of driving time) to a larger urban center (in this case Saskatoon). In the SSRB, these communities were identified only in the vicinity of the city of Saskatoon. No community around the cities of Martensville or Warman could be identified as belonging to this category.[4]

The rural population was divided into two categories: farm population, and rural non-farm residing in rural municipalities. Farm population was related to farm residences. The remaining population of a rural municipality was classified as non-farm rural population. This categorization was chosen because the water demand patterns in larger communities could be different from that from relatively smaller ones. In addition, over time, growth in these communities may also be different. A list of the various communities included in each category shown in Table 2.2 is presented in Appendix A. The city of Humboldt is located in the Qu'Appelle River Basin but receives water from the South Saskatchewan River Basin.

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[3] Data obtained from Statistics Canada (2012).

[4] The criterion for this selection was the rapid rate of growth in a community relative to that within its own class of communities.

Table 2.2: Estimated Population of the South Saskatchewan River Basin by Type of Communities, Selected Years

Type of Community	Current Population	Population in 1995	% Change
Martensville	7,716[a]	5,120[b]	50.7%
Saskatoon	222,189[a]	212,593[b]	4.5%
Swift Current	15,503[a]	16,130[b]	-3.9%
Warman	7,084[a]	4,655[b]	52.2%
Humboldt*	5,678[a]	5,608[b]	1.2%
Bedroom Communities	5,484[c]	4,876	12.5%
Towns > 1000	13,066[a]	12,140	7.6%
Towns < 1000	5,703[a]	5,689	0.2%
Villages	8,274[a]	8,645	-4.3%
Recreational Villages	172[c]	142	21.1%
First Nations Communities	875[a]	707	23.8%
Sub-Total Non-Rural Population	291,744	276,305	5.6%
Rural Municipalities**	9,048	Note 1	
Farm Population**	15,939	Note 1	
Total Population***	316,731		

[a] These population counts are for 2011.
[b] These values were obtained from SWA. They differ slightly from Statistics Canada's Census values.
[c] These population estimates are for the year 2009.
Note 1: These populations could not be estimated
* City of Humboldt is located in the Qu'Appelle River Basin, but the water for this community is provided by the South Saskatchewan River Basin, and is counted in this basin for purposes of water demand.
****** Based on 2006 Census values
*** Total would not add, since numbers are for different time periods.
Source: Saskatchewan Watershed Authority (2010), Saskatchewan Watershed Authority (2011), and Statistics Canada (2012).

The basin has not shown a sharp increase in its population. Non-rural population, for example, as shown in Table 2.2, has increased by 5.6% over the 1995-2009 period. Much of this increase has occurred through migration of people from other smaller centers within the province or from outside the province to Saskatoon and the surrounding communities. Warman and Martensville have had the highest rates of population growth, increasing 52% and 51%, respectively, over the 1995-2009 period. This may have affected the growth rate of the city of Saskatoon, which increased only by 4.5%. The number of people living in villages in the Saskatchewan River Basin declined by 10%, which is consistent with the general trend for villages in Saskatchewan.

Compared to other river basins (for example, the Qu'Appelle River Basin), the SSRB does not house many First Nations' people. In 2009, only 875 First Nations' people lived in the basin. Although this group's rate of growth is higher than that of many other communities in the basin, as shown in Figure 2.2, they still constitute a very small proportion of the total basin population.

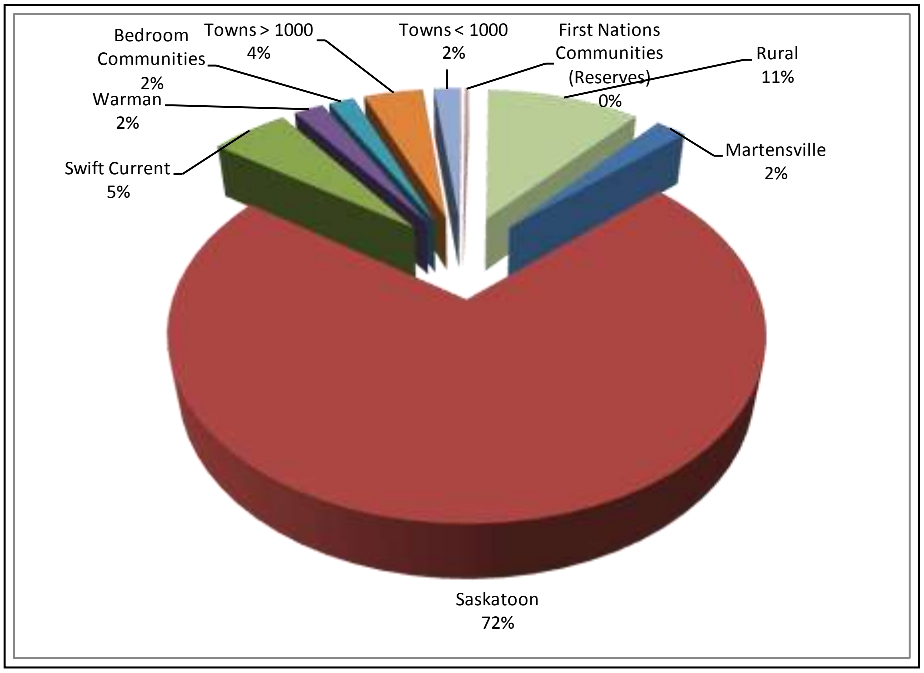

Figure 2.2: Distribution of South Saskatchewan River Basin Population by Type of Communities, 2009

Besides Martensville and Warman, the highest rate of population growth was noted in the population of First Nation's communities, recreational villages, and in bedroom communities of Saskatoon. In terms of population dynamics, smaller towns (those with less than 10,000 people) grow less rapidly than larger towns. Many of these communities have limited resources to maintain their infrastructures and social services. Those seeking such services move to nearby larger towns or cities.

Based on population numbers, the basin is primarily an urban basin, as 81% of the basin population resides in the four cities (Figure 2.2), with another 6% in the towns. The rural population (including farm, non-farm rural, villages, and recreational villages) constitutes only 11% of the total figure. Many of the towns act as service centers for the rural population, either for residing on farms or in other rural communities.

2.3 Major Economic Activities

A number of economic activities are pursued in the SSRB. The major goods and services producing economic activities in the basin are related to agricultural production, mining, and manufacturing. Recreational activities and tourism are also major activities, and these activities are described further in this section.

2.3.1 Agriculture

In terms of land use, as shown in Table 2.1, most of the SSRB is agricultural, with 65 to 90%[5] of the land base under such activities. An average farm in the SSRB has 1,535 acres of land (Table 2.3) plus, in some cases, a certain number of livestock. The basin has a large irrigated area, estimated to be over a million acres, as well as all types of livestock and poultry enterprises. In addition to crop and livestock enterprises, the SSRB also has specialty enterprises (greenhouses and orchards). A total of 12 million acres is occupied by farms,[6] and slightly under half of the total area is under crops, as shown in Figure 2.3.

Table 2.3: Agricultural Activities in the South Saskatchewan River Basin, 2006 and 2010

Particulars	Value in 2006	Value in 2010**
Number of Farms	5,313	
Total Area of Farms (Acres)	8,157,649	
Average Size of the Farm (Acres)	1,535	
Crop Production Activities		
Land in Crops (Acres)	3,948,217	4,217,233
Other Land (Acres)	1,052,974	853,892
Irrigated Area (Acres)	158,949	93,439
% Zero Tillage		
Livestock Production Activities		
Cattle and Calves	355,476	309,491
Dairy (Cows and Heifers)	8,316	11,934
Hogs	111,642	93,444
Sheep	5,867	7,150
Other Livestock	16,437	22,739
Broilers	927,545	1,016,572
Eggs (# of Layers)	278,214	290,804
Turkey		252,932

* Estimate of Statistics Canada revised to match the total area for the farms.

** Details on agriculture for 2010 were not available at the time of writing this report.

Source: Statistics Canada (2006); Statistics Canada (2009) and Saskatchewan Ministry of Agriculture (2011b)

[5] The lower limit is based on cropland and seeded pastures. The upper limit includes grasslands, which could be on the farm or elsewhere.

[6] According to Table 2.1, agricultural area is 2.293 million ha (equivalent to 5.66 million acres). In Table 2.3, total area of the farms is estimated at 5.07 million acres. This leaves a small discrepancy between the two tables. No official explanation for this difference was found. However, since these data are from different sources, one possible explanation could be that this remaining area is for the other jurisdictions (federal lands, provincial government lands, and First Nations reserves). However, this issue requires further investigation. For further analysis in this study, 5.07 million acres is used as the authentic estimate of farm area.

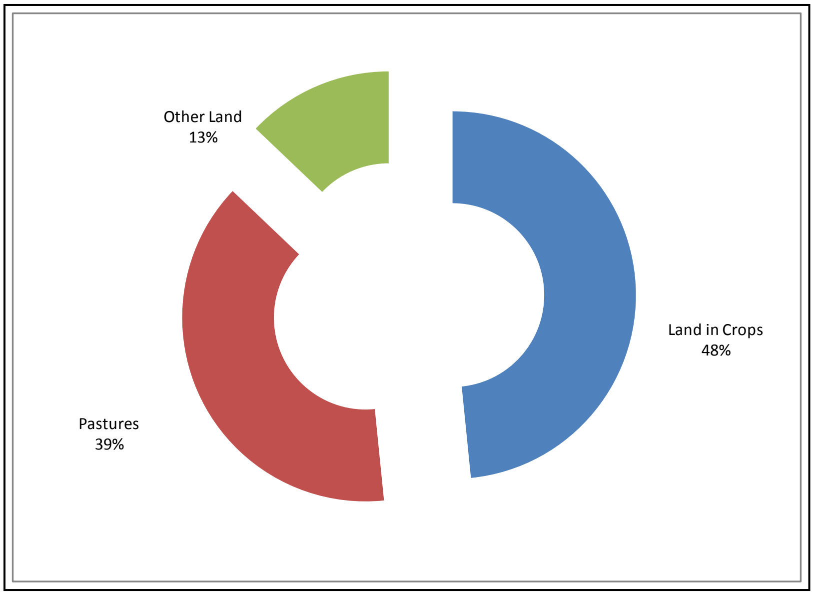

Figure 2.3: Farm Level Land Use in the South Saskatchewan River Basin, 2006

2.3.2 Natural Resource Extraction

Major types of mining activity in the SSRB consist of potash production, along with magnesium sulphate. However, details on the latter type of mining are not available at the time of writing this report.

2.3.2.1 Potash Mining

Potash mining in the SSRB consists of three mines, all owned and operated by the Potash Corporation of Saskatchewan. These are one at Patience Lake, which is a solution mine, and two underground mines at Cory and Allan (Table 2.4). Their total potash production is currently estimated at 4.5 million tonnes.

According to the NWER (undated), magnesium sulphate production is a proposed development in the basin. The company 'Touchwood Resources' was established in 2001 in Beechy, and produces Epson salt. However, no details are available on its current or future production. For the purposes of this study, this water demand will be set equal to zero.

Table 2.4: Salient Features of Current Potash Mines in the South Saskatchewan River Basin

Corporation	Location	Mining Technology	Source of Water	Production 5 Year Average (1000 tonnes)
Potash Corporation of	Cory	Underground	Surface	586
	Patience Lake	Solution	Surface	240
	Allan	Underground	Surface	1,122
Total for the South Saskatchewan River Basin				**1,948**

Source: Annual reports from Saskatchewan Potash Corporation (2006 to 2010).

2.3.2.2 Oil and Gas Well Drilling

Oil and gas well drilling occurs mainly in the south west part of the basin into the lower Shaunavon and the Viking formations that are within the SSRB. The conventional technology of vertical wells and water flood, along with the new technology of horizontal well drilling and multi-stage frac, are employed to extract oil and natural gas from these formations. The advent of horizontal well technology and the successful application under Saskatchewan conditions has substantially increased oil and gas activity in the Viking and Shaunavon formations. Saskatchewan has an estimated reserve, recoverable by present and expected technology developments, of 6.3 billion barrels of crude oil (NEB, 2008). The Viking formation has 214 million barrels of recoverable reserve while the Shaunavon formation has 235 million barrels of oil (NEB, 2008). Approximately, 25% of the Shaunavon and 25% of the Viking formations are in the SSRB, giving an estimated oil reserve of 112.3 million barrels in the SSRB. The ultimate amount of potential by extractable natural gas reserves in the SSRB is estimated at 40,794 $x10^6$ m^3, which is 27% of Saskatchewan; 150.6 $x10^9$ m^3 of marketable natural gas (NEB, 2008).

2.3.3 Forestry Water Demand

There are no forestry operations in the SSRB.

2.3.4 Industrial Water Demand

2.3.4.1 Manufacturing Water Demand

Manufacturing activities that derive their water outside of the municipal water systems in the SSRB are presented in Table 2.5. There are also other industries that are supplied through municipal systems of Saskatoon and other towns. These activities include a small refinery, two agricultural processing plants, and four chemical plants that do not receive water from a given municipal water system.

Table 2.5: Water Using Manufacturing Activity in the South Saskatchewan River Basin

Type of	Name of the Operation	Location

Manufacturing		
Refinery	Saskatchewan Ltd (Reynolds)	Lancer
Ag Processing	Cargill - Canola Crush Plant	Clavet
	BioExx Specialty Proteins Inc	Saskatoon
Water Treatment Chemicals	AKZO (Chemical Man)	Saskatoon
	Allan Division	Allan
	ERCO Worldwide	Saskatoon
	United Chemical Company	Saskatoon

2.3.4.2 Electrical Power Generation

There are two types of power generation facilities within the SSRB. Thermal power generation plants that use natural gas include the SaskPower Queen Elizabeth station at Saskatoon, the Success Power Station near Swift Current, and the co-generation plant of Atco Power Canada Ltd at the Cory potash mine. Hydroelectric power is generated at Couteau Creek (186 MW) where water is released from the Lake Diefenbaker reservoir. Several wind farms are also in the basin along with one generating facility that uses heat recovery. However, details on only some of these facilities are available and as listed in Table 2.6. In the estimation of water demand, only the water consuming power generation facilities are included. In 2010, the total quantity of water calculated to have passed through the turbines at Couteau Creek was 1,660,092 dam^3.

Table 2.6: Electricity Generation Sites in the South Saskatchewan River Basin

Name	Location	Fuel	Capacity (MW)
Non-Water Consuming Power Generation Facilities			
Coteau Creek Hydroelectric Station	Elbow	Hydroelectric	186
SunBridge Wind Power Project	Swift Current	Wind	11
Cypress Wind Power Facility	Gull Lake	Wind	11
Centennial Wind Power Facility	Swift Current	Wind	150
NRGreen Loreburn Heat Recovery Project	Loreburn	Waste Heat	5
Water Consuming Power Generation Facilities			
Queen Elizabeth Power Station	Saskatoon	Natural Gas	430
Cory Cogeneration Station	PCS Cory	Natural Gas	228
Success Power Station	Swift Current	Natural Gas	30

Source: SaskPower (2011).

2.3.5 Communities and Public Institutions

The SSRB houses many larger and smaller communities. As shown in Table 2.2, several large and small communities are located within this basin, with the largest community belong the city of Saskatoon; in 2011, it had a population of 222,189 people. There are nine communities around

Saskatoon, which are labeled as bedroom communities. These exclude some of larger communities such as Martensville and Warman, since they have already achieved city status. However, for all practical purposes, they do serve as bedroom communities to the city as well. Both of these communities have a higher rate of growth, which may have resulted in stunting the growth rate for the city of Saskatoon. In addition to these communities, there are 16 other towns, and 46 villages in the basin. Two First Nation's reserves are also located there, along with two recreation villages. A list of these communities is shown in Appendix A.

2.3.6 Recreation and Tourism

The SSR, along with Lake Diefenbaker, provides several areas for recreation and tourism, featuring such activities as fishing, camping, boating, and canoeing. A list of these facilities is shown in Table 2.7; they include provincial parks with various types of services available, as well as some resort villages. In addition, local rural municipalities also maintain regional parks for local residents.

Table 2.7: List of Available Recreational Sites in the South Saskatchewan River Basin

Provincial Parks	Blackstrap
	Pike Lake
	Saskatchewan Landing
Provincial Recreational Sites	Diefenbaker Lake Cottage
	Shields Resort Village
Regional Parks	Cabri Regional Park (R.P.).
	Chinook Pathway
	Eston Riverside R.P.
	Lac Pelletier R.P.
	Lucien Lake R.P.
	Meewasin Valley
	Outlook & District R.P.
	Palliser R.P.
	Pine Cree R.P.
	Prairie Lake R. P.
	Redberry Lake R. P.
	Valley R. P. (Wakaw)
	Valley R. P. (Waldheim)
	Wakaw R. P.

2.3.7 Indirect Anthropogenic Water Demands

In addition to the above socio-economic activities, there are a number of other water demands that can be identified. Although some of these are related to policies or agreements in place, most of them are not directly related to/or required to undertake various human activities. These demands include environmental, apportionment, and for evaporation water demand. Some more close by reasonable amount of water lost – such as in the case of evaporation water. The definition of water loss in this study is taken as synonymous with water not available to other water users.

2.3.7.1 Environmental and In-Stream Flow Needs

Water diverted for environmental purposes, such as lake stabilization and habitat restoration, represents a significant demand in the basin. Water diverted to such projects is licensed as an "Other" use by the province and is almost entirely consumed through evaporation. Ducks Unlimited Canada operates many waterfowl restoration projects in the province. In 2004, within the SSRB, 79 of 104 projects had a component involving wetland preservation or conservation.

Under the Prairie Provinces Water Board arrangements discussed in the following section, under normal flow conditions, Alberta is required to deliver SSR water to Saskatchewan continuously at a rate of 42.5 m^3/s or greater. Alberta subsequently established a conservation flow for the river of 42.5 m^3/s. Saskatchewan has also established a target flow for the river downstream to Lake Diefenbaker of 42.5 m^3/s. The minimum flow throughout the length of the river in Saskatchewan is a preliminary step towards establishing scientifically based in-stream flow needs. The annual volume of the target is 1,340,280 dam^3.

2.3.7.2 Apportionment[7]

The term 'Apportionment Flow' is defined as flow that is subject to apportionment. Typically this flow is equal to the calculated natural flow because natural flow at the boundary is subject to apportionment" (PPWB, 1997). The Prairie Provinces Water Board was established in 1948 to ensure that water resources in the three Prairie Provinces are shared fairly. To this effect, the Provinces of Alberta, Saskatchewan, and Manitoba and the Government of Canada created the Prairie Province Water Board. In 1969, the four governments changed the way the Prairie Provinces Water Board operated by signing the Master Agreement on Apportionment (MAA). This Agreement established an intergovernmental framework to manage transboundary waters. The purpose of the MAA is to apportion or share water equitably between the Prairie Provinces and to protect interprovincial surface water quality and groundwater aquifers. Under the Master Agreement on Apportionment among the three Prairie Provinces, Saskatchewan is required to pass on half of the water received from Alberta plus half of the water arising within the province of Saskatchewan to the province of Manitoba. One half of the median apportionment flow at the Alberta-Saskatchewan boundary is approximately 3,000,000 dam3. Typically, Saskatchewan receives 78% of the apportionment flow but in a dry year such as 2001, only 54% was received.

[7] This information was obtained from PPWB (Undated).

This still exceeded Saskatchewan's entitlement. The St. Mary River, an Oldman River tributary flowing from Montana into Alberta is apportioned between Canada and the United States under the provisions of the Boundary Waters Treaty. Annual reports to the International Joint Commission indicate the quantity of water diverted each year in the United States. This quantity is not included in the apportionment flow calculated by PPWB.

2.3.7.3 Evaporation and Percolation Water Losses

One of the major water demands in any basin is water lost through evaporation and percolation from rivers and large surface water bodies. Although some of the water percolates underground, since that becomes a part of the groundwater resource, it is not regarded as lost (or used). Evaporation losses are related to temperature change and to other climatic factors such a cloud cover, precipitation, and wind speed.

There are numerous surface water bodies in the basin. Each of these water bodies experiences in some evaporative water losses, which are related to water temperature and climate factors, such as air temperature, humidity, and wind speed. The additional evaporation from artificial impoundments, such as reservoirs, is taken into account in the natural flow calculations described in the previous section.

Chapter 3

Study Methodological Considerations

The study methods for estimating current water demand are described in this chapter. The methodology for forecasting future water demand is discussed in Chapter 4. By way of background, this chapter begins with nomenclature that appeared in the area of water demand. Concepts used in the reports are described. The identification of conceptual water demands in the basin is also developed as a part of the conceptual framework. This stage is followed by a review of the literature on water demand estimation. This review was undertaken with the hope of gathering some insights into a methodology that could be developed for the study. The methods followed here for estimation of 2010 water demand in the SSRB is described next.

3.1 Nomenclature of Water Demand

Water demand in a river basin can be described through various terms/concepts. In the literature, a variety of terms have been used, often synonymously, with water demand. However, it should be noted that water demand is an economic concept, and unless water users pay a price for the water and adjust their water use level in reaction to price, water demand is a very distinct concept in comparison to the others. Furthermore, the estimation of water demand requires micro-level data under period of different price levels. Since such data were not available and collection of primary data was considered to be beyond the scope of this project, this research reflects estimated water demand. However, given a certain charge for water paid by the water users, the current level of water use can be assumed to be a point on this water demand function, and is therefore called water demand. This study, drown upon various types of water demand-related concepts.[8] Each of these concepts is relevant to the estimation of water demand in the SSRB. Details on these concepts are shown in Table 3.1. Water losses are generally from natural factors, and include evaporation and percolation/leaching. Water requirements are determined by the need of water for sustaining a given economic activity, human or social activity. Water intake is the amount of water that is withdrawn to sustain a given economic activity. Part of this water may be returned to the original source of intake while some of it may be lost in the production process (typically called consumption). The total amount of water for a given economic activity is a sum of water intake and amount of water recirculated, less the amount returned to the original source.

[8] The definition of these concepts has been borrowed from the Terms of Reference for the Study as issued by the Saskatchewan Water Authority.

Table 3.1: Nomenclature on Water Use

WATER LOSSES: This refers to the amount of water that is lost due to certain natural activities such as evaporation, channel losses, etc. from the point of diversion to the point of use.

WATER REQUIREMENTS: This is the quantity of water needed to sustain or to maintain an activity. It is different from water intake only if a part of the requirement is satisfied from a source not usually measured. For example, water requirements of a crop can be satisfied by rainfall, snowmelt, and water withdrawn from surface or groundwater (including that for irrigation).

WATER INTAKE: Refers to the actual or measured amount of water withdrawn to sustain a given economic activity, requirement, or need.

RETURN FLOW: This is the amount of water returned to some ambient source of water following its use. This water is available to other users at other locations in the basin.

RECIRCULATION WATER USE: This is the amount of water which is used more than once within a given plant or economic activity.

3.2 Water Use Typology

Water use can be classified according to several criteria: Source of water, Type of use, Water as a catalyst (not consumed or lost) or consumed in the process, among others.

According to its source, water can be obtained from surface water or groundwater sources. Of course, the natural precipitation (less evaporation) is also a source of water, but is not typically included as such. Following the Type of water use criterion, all water demands can be broadly classified into two categories: One, Consumptive demands; and Two, Non-consumptive demands. In the non-consumptive demands, all water is either returned to the source or remains unaffected. Different types of users in these categories are shown in Table 3.2.

Conceptually, there can be eight direct anthropogenic and four indirect anthropogenic types of water demands. In four of the direct anthropogenic water demands, all or some part of the water is not available to other users (assumed to be lost to consumption), while the other four are totally non-consumptive water demands. Indirect anthropogenic water demands have two non-consumptive and two consumptive water demands.

Table 3.2: Taxonomy of Water Demand in South Saskatchewan River Basin

Consumptive Water Demand	**Non-Consumptive Water Demand**
Direct Anthropogenic Water Demands	
(1) Agricultural water demand: Further subdivided into five types: • Irrigation water demand • Crop Production related water demand • Stockwatering • Nurseries and greenhouse water demand • Aquaculture related water demand	(1) Recreational water demand (Active and Passive Water Recreational activities)
(2) Industrial and Mining related water demand • Industrial (Manufacturing) related water demand, including Intensive livestock operations, Biofuel processing, and other agricultural processing (Not served by a municipal system) • Mining water demand for metal and non-metal mining, and for oil and gas production	(2) Hunting water demand (Waterfowl) (3) Transportation related water demand (4) Hydroelectric power generation
(3) Municipal and domestic water demand, which can be further divided into the following types: • Municipal water demand to include residential, manufacturing, commercial, and other water demands • Non-municipal domestic water demand • Farm domestic water demand • Other domestic water demand (3a) Recreational communities and site maintenance	
(4) Thermal Power Generation water demand	
Indirect Anthropogenic Water Demands	
(5) Evaporation water demand	(5) Instream water demand
(6) Apportionment water demand	(6) Environmental water demand

Major direct anthropogenic consumptive water demands include water used for agricultural activities, industrial and mining production, municipal and domestic purposes, and for power generation (thermal electric power generation). Non-consumptive water demands may include hunting (waterfowl), transportation, and power generation (hydroelectric) related water demands.

Recreational water demand is a combination of consumptive and non-consumptive demands. The consumptive water demand is a result of people living in recreational communities or within recreational sites (national or provincial parks). The non-consumptive water demand related to recreation is from in-situ uses of water. Here, two types of uses can be identified. One, Active Water-Based Recreation -- Activities that require direct access to water (such as swimming, boating, fishing, among others). No water is lost as a result of these activities. Two, Passive Water-Based Recreation -- Activities that are indirectly-enhanced by water, such as camping and hiking, nature appreciation, aesthetics, among others. Here also water is not lost as a result of pursuing these activities.

Although most of these consumers withdraw water from surface water bodies, a limited quantity of domestic, farm related, mining, and industrial water demand is obtained from groundwater sources. Many of these demands have a return flow, making the consumption smaller than the total water intake. This return flow varies for changes water demands.

In addition to water demands for socio-economic activities within the basin, four other types, called indirect anthropogenic demands, are relevant. Most important among these are evaporation water demand and apportionment water demand. The first one is associated with large water bodies (such as lakes, reservoirs, and even rivers and streams). The second water demand is directed by regulations and agreements. Non-consumptive indirect anthropogenic water demands include in-stream water needs and water diverted to environmental projects.

3.3 Overview of Methods for the Study

The total water demand in the SSRB was estimated as a sum of two major categories of water demands: direct anthropogenic and indirect anthropogenic. The former type consists of all socio-economic demands of water in the basin. The second category includes water demands that are not directly related to human activities, although such activities are indirectly affected by them. Within each of these categories, water demand is estimated by type of water use. For each type of water demand the research methods are described in this chapter.

The direct anthropogenic water demand represents a sum of four types of water demands: (1) Agricultural and related production; (2) Industry and mining; (3) Municipal and domestic; and (4) Recreational purposes. Agricultural water demand consists of a variety of purposes, mainly for irrigation, but also water demanded by dryland farmers for crop production, livestock water needs, and other related demands for agriculture and fish production. Methods for the estimation of water demand for industrial and mining (particularly for potash production) is the second important direct anthropogenic activity. Domestic water demand is divided into municipal and non-municipal water systems. The former includes urban jurisdictions with a municipal water distribution system. It therefore takes in a combination of water demands – residential, manufacturing, commercial, and other service industries, public water demands, and other water demands. Available data did not permit a breakdown of this total water demand,[9] so this breakdown was not attempted here. Large industrial users that do not receive water through a municipal system are included as a separate category of water demand.

The total indirect anthropogenic water demand was a sum of four types: loss of water because of evaporation and percolation; need to release water to other regions under apportionment agreements; water required to maintain in-stream flows; and water needed to maintain environmental projects/activities.

3.4 Review of Previous Studies

In order to develop a sound methodology for water demand estimation, a review of the literature can be very helpful. This review was limited to studies involving estimation and forecasting of water demand dating back to the 1960s. Because of the enormity of such studies, the scope of this review was limited to research on North American (Canadian and U.S.), Australian, and European consumers. In this section, these studies are summarized, and the lessons learned from them are noted at the end of this section.

3.4.1 Residential Demand for Water

Residential (also called domestic) water demand estimation has been carried out using one of three approaches. The first type of study involves estimation of a water demand function, where the impact of water price on water use levels is tested. The second type of study examines actual measurements of water being utilized. The third type is more synthetic in nature – these estimates are based on a water requirement approach (where price data are not available or time series on water demand cannot be collected).

The first type of study is undertaken mainly for calculating the residential demand for water. For instance, by using cross-sectional data, Howe and Linaweaver (1967) looked at the impact of

[9] Information of this breakdown may be available at the municipal water utility level. Although this information could be collected from surveying each of these institutions, this was considered beyond the resources of this study. This work is left for future research in this area.

price on residential water demand along with its relation to system design and price structure in Melbourne, Australia. In a subsequent study, by Aitken et al. (1991) calculated other water demand predictors in the cross-sectional regression model of residential water demand in the same location to determine significant variables affecting household residential water consumption. Arbues et al. (2003) carried out a survey study on the main issues in the literature on residential water demand studies. Their study reviewed the main contributions to the literature on estimating residential water demand with particular attention to demand variables, model specification, data set, and econometric (estimation) problems. In reviewing other studies, the authors estimated residential water demand, taking into consideration other demand variables used in previous studies. The result shows that water price, income, and household composition are important determinants of residential water consumption.

The second type of study has been undertaken where water demand can be measured. This amount is recorded and utilized for different water demands. In the third type, data on measured water demand can also be used to estimate a water demand coefficient. Failing that, water demand coefficients can be based on a synthetic or a water requirement approach.

3.4.2 Municipal Water Demand

Municipal water demand can be a composite of several demands, including residential, non-residential, and outdoor water demand. However, household residential water demand is fundamental to municipal water demand in urban regions (Kindler and Russel, 1984) where municipal water systems are in place. Municipal water demand has been estimated in several studies, taking one of the following four approaches (Cheng and Ni-Bin, 2011): Multivariate regression approach using cross-section data, Time series analyses, Computational intelligence models, and Monte Carlo simulation approach.

One, Multivariate regression analyses, involve statistical estimations of the relationship between water demand and some water demand shifter variables. Per unit water use in these studies was related to factors that affect water demand (such as average income, number of persons per household, price of water, etc.). Data requirements for such studies are rather large and need to be collected through surveys.[10]

Two, Time series analyses, focusses on changes in water demand over time. These studies utilized univariate time series data to determine daily water demand and divided water demand according to both base and seasonal demand. Base demand was determined as a function of

[10] Examples of this type of study are: Howe and Linaweaver (1967); Cassuto and Ryan (1979); Foster and Beattie (1979); Hughes (1980); Maidment et al. (1986); Billings and Agthe (1998); Davis (2003); and Babel et al. (2007).

socioeconomic and climate variables. This method is used primarily for short-term water demand forecasting because of its reliance on controlling factors such as income and population (Cheng, and Ni-Bin, 2011).[11]

Three, Computational intelligence models, are purely data driven. Under this approach, different types of models have been applied to forecast the municipal demand for water. These methods include an Agent-Based model, a Fuzzy-logic model and, an Artificial Neutral Networks model. These studies utilized autoregressive integrated moving average (ARIMA) and the generalized autoregressive conditional heteroskedasticity (GARCH) models to estimate water demand. Such methods generally require a long time series data. Examples of these studies include Athanasiadis et al. (2005); Jain et al. (2001); Liu et al. (2003); Jain and Kumar (2006); Msiza et al. (2007); Ghiassi et al. (2008); Cutore et al. (2008); Yurdusev et al. (2009); and Caiado (2010).

Four, Monte Carlo Simulation Approach, is also used in water demand forecasting in municipal regions. Khatri and Vairavamoorthy (1984) employed historic time series data on water consumption and applied Monte Carlo and bootstrap methods to explain the effect of climate change, population, and economic growth on future water demand.

3.4.3 Agricultural Water Demand

Water demand in agriculture can be classified into four main categories: irrigation, water demand for livestock, agro-forestry, and aquaculture. In addition, in the context of Saskatchewan, water is also consumed by greenhouses. No studies were found that have estimated water demand for agro-forestry and aquaculture. Some studies have been carried out that estimated the water demand for irrigation. Heady and Agrawal (1972) utilized a linear programming technique to model agricultural production and water demand by individual farms, agricultural regions, and the entire economy. Anderson (1981) carried out an economic analysis of supplementary irrigation in Skane, US, to forecast the potential demand for irrigation water by employing crop (potatoes and sugar beets) prices and irrigation cost. A production function approach (as suggested by Hexem and Heady, 1978) was used. Some studies (e.g., EEA, 2001) utilized the FAO crop coefficient method, which is based on reference evapotranspiration and a crop

[11] Examples of studies using this approach include Hansen and Narayanan (1981); Maidment and Parzen (1984); Maidment et al. (1985); Franklin and Maidment (1986); Miaou (1990); Jowitt and Xu (1992); Homwongs et al. (1994); Molino et al. (1996); Zhou et al. (2000); Zhou et al. (2002); Fullerton and Elias (2004); Aly and Wanakule (2004); Gato et al. (2007); Caiado (2007); and Alvisi et al. (2007).

coefficient (Kc) that accounts for crop characteristics, development, and vegetative periods, among other points. Somewhat similar methodology was followed in Canada to estimate irrigation water use by Beaulieu et al. (2001).

Water demand for livestock has also been estimated by the water requirement approach. The total water demand for livestock is a sum of the number of animals times their water requirements. The water requirements cover all purposes for which water is needed, including that used for cleaning and the portion that is wasted. Water requirements have been developed according to types of animals.

3.4.4 Water Demand for Tourism

The tourism industry requires water for facilities such as landscaping, water parks, swimming pools, and golf courses (Stefano, 2004). Taylor et al. (2009) modeled the water demand for tourism in Australia, also estimating costs of water provision and operation. In modeling this type of water demand, the authors utilized secondary data to perform the sequential estimations needed to forecast the future level of water demand for tourism. Various steps included estimation of base water demand in the future and number of tourists (annually and during peak periods) to the region.

3.4.5 Water Demand for Hydroelectric Power Generation

No study was found on either estimating or forecasting water demand for hydroelectric power generation. According to Wisser (2004), water demand for hydroelectric power generation can be calculated by estimating the amount of water needed to produce a given amount of energy. Accordingly, the amount of energy that is converted by a hydraulic turbine through the energy of water is computed by technical relationships.

3.4.6 Review of Canadian Water Demand Studies

One of the first studies reporting water use in various river basins of the Prairie Provinces was conducted by the PPWB (1982). Estimated water use levels by types of use were presented for various river basins[12]. A comprehensive study of water demand patterns by river basins was completed by Kulshreshtha et al. (1988). For the SSRB, the level of 1984 water intake/use was estimated at 218,316 dam^3 if only basin users are considered (or 267,344 dam^3, including users in other river basins of Saskatchewan). A large part of this demand was for irrigation and for residential purposes. These demands represented about 39% and 29% of the total basin water

[12] Although the estimated water use for a given type of use was presented for each individual river basin, total water use was only presented for the Saskatchewan – Nelson River Basin and for the three provinces.

demand, respectively. Water demand was also forecasted for the year 1995, where in the basin's water demand was estimated to increase somewhere from 26.5% to 31.5% under alternative scenarios (Brockman and Kulshreshtha, 1988). Lacking time series data, estimations were made by either the requirement or the water demand coefficients based on related literature.

3.4.7 Synthesis of Literature Review

There are a number of observations to be made based on this review. First of all, there have not been many Canadian studies for various types of water uses. On research has also shown that different types of methodologies are needed for different types of water demands. The choice of a particular approach depends, to a certain extent, on the scenario for the consideration, but also largely on data availability. Given the number of studies that have adopted various methodologies and the inherent limitations of each approach, a multivariate regression analysis approach and the employing of water demand coefficients for forecasting water demand are most common. The latter approach is more common where time series data are not available.

3.5 Methodology for Current Water Demands

3.5.1 Correspondence between Administrative Boundaries and the River Basins

In Canada, much of the secondary data is collected by administrative boundaries. Examples of these include rural municipalities, census divisions, census agriculture regions, towns, villages, and First Nations' Reserves, among others. In order to use these data, a table showing the relationship among the various river basins and these administrative regions was created. The criterion for developing correspondence was the area within each administrative region that was within the river basin. It provided no challenge for those administrative regions that were wholly within the river basin. For those that were partially within the river basin, an overlay of the river basin map and administrative boundaries map was applied. Proportions were based on a visual estimate of the area within the basin. The resulting table is shown in Appendix B. This includes relationships for census divisions, for census agricultural districts, and for rural municipalities.

3.5.2 Overview of Methodology for Estimation of Current Water Demand

With a limited amount of time series information on price and quantity of water demand, water demand functions could not be estimated. As the next best alternative, the estimation of current water demand in this study was based on a water demand coefficient multiplied by the level of economic activity in question. Methods were modified where time series data were available. Specific details on the methodology adopted for various types of water demands are provided in the next section.

3.6 Water Demand Estimation Methodology by Type of Water Demand

3.6.1 Agricultural Water Demand

Agricultural water demand, in this study, was estimated in a disaggregated manner. Total agricultural water demand was divided into the following five types: (1) Irrigation water demand; (2) Stockwatering; (3) Crop Production related water demand; (4) Nurseries and greenhouse water demand; and (5) Aquaculture related water demand. The methodology followed for each of these demands is described below.

3.6.1.1 Irrigation Water Demand

The total irrigation water demand represents a product of irrigated area and the average quantity of water used for irrigation. Typically, one faces two major issues in its estimation. One, since irrigation is a supplementary use of water, precipitation and temperatures (which are measured through the use of evapotranspiration) play important roles in determining the amount of water needed for a given crop. Since evapotranspiration varies from year to year, irrigation water demand also has yearly variability. Two, irrigation in the basin is provided both through irrigation districts, and through private irrigation. The former is a block of land supplied by an irrigation infrastructure. Water use is regulated by the irrigation district. One of these regulations is that irrigation water is allocated along with a maximum amount allowed. Private irrigators develop their own systems of water withdrawal from the local water body and of its delivery to the farm gate. Private irrigators must obtain a water license from the province in order to irrigate, and this license states a maximum quantity of water that can be used. Both of these issues are taken into account in estimating irrigation water demand for the basin. In the following passage, estimation of irrigated area and average water demand is described.

Area for Irrigation: As noted above, the total irrigation water demand was a product of area irrigated times its water requirements, further adjusted for efficiency of water delivery. The area presently irrigated, by method of irrigation, in Saskatchewan rural municipalities was obtained from Irrigation Branch, Saskatchewan Ministry of Agriculture (2011a) and the Saskatchewan Watershed Authority (2011b). Irrigated area in 2010 for the SSRB was estimated at 158,949 acres, of which 93,439 acres are in Irrigation Districts as shown in Table 3.3. This basin has the largest irrigation districts and irrigation water demand. The Prairie Farm Rehabilitation Administration (PFRA) constructed twenty-six dams in the South-West Development Area (SWDA) of Saskatchewan. The South Saskatchewan Basin has six of these dams with a capacity of 137,719 dam^3. The primary purpose for the creation of the reservoirs was for irrigation. The rest of the area was assumed to be served by private (non-district) irrigation, constituting 41% of the total irrigation area in the basin. As shown in Figure 3.1, district irrigated area takes in only 48% of the total. There are 13 irrigation districts in the SSRB that receive water either from the South Saskatchewan River through Lake Diefenbaker, or through its tributaries. In addition, a large area is serviced through the SSWES canal, with water is supplied by Lake Diefenbaker.

Table 3.3: Irrigated Area in the South Saskatchewan River Basin, 2010

Irrigation District	Irrigated Area in Acres
South Saskatchewan River	35,271
Riverhurst	9,967
Lucky Lake	9,124
Macrorie	2,471
Grainland	2,141
Miry Creek	1,563
River Lake	985
Hillcrest	3,497
Saskatoon South East Water Supply	17,455
Chesterfield	686
Moon Lake	1,563
Herbert	1,671
Rush Lake	5,405
North Waldeck	1,640
Total District	**93,439**
Total Private	**65,510**
Total South Saskatchewan Basin	**158,949**

Source: SIPA (2008A); Saskatchewan Ministry of Agriculture (2011a) and Saskatchewan Watershed Authority (2011b).

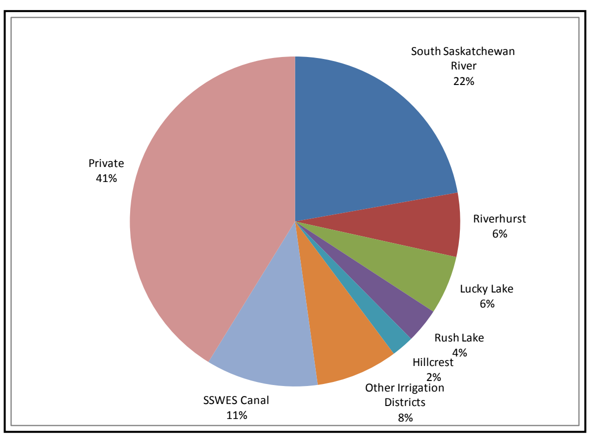

Figure 3.1: Distribution of Irrigated Area in the South Saskatchewan River Basin, 2010, by Type of Jurisdiction

Average Water Demand for Irrigation: Average irrigation water demand was equated to the crop water deficit for each crop. It was estimated as the crop water requirement of the crop minus the average growing season precipitation and spring time soil moisture amount. The crop mix and efficiency of the irrigation system is used to arrive at an average amount of water demanded.

Since there was no data available for the SSRB irrigation areas, the next best set of information was consulted. This information was for the Lake Diefenbaker Development Area (LDDA), as this area is within the SSRB. Time series data for water demand per unit of irrigated area were obtained from Saskatchewan Agriculture Irrigation Branch (undated) for various LDDA irrigation districts. To determine an average water demand for irrigation, a trend analysis in water demand per acre in the LDDA irrigation districts was undertaken by Irrigation Branch, Saskatchewan Ministry of Agriculture (2011a). These results were used in the present study.

In the LDDA, there are two types of technologies for water deliveries to the farms: (i) canals and pipelines to farms, and (ii) direct pipelines from the reservoirs to the farms. Those connected solely through pipelines should have a lower average water use relative to those employing other methods of farm water deliveries. Water for irrigation in the South Saskatchewan River Irrigation District (SSRID) within the LDDA is delivered by canal. Results suggested that, due to the technical efficiency of water delivery and other water conservation measures adopted by producers, water use in this district has declined from 450 mm per irrigated acre in 1968 to 275 mm per irrigated acre in 2009. Districts with pipelines include Riverhurst and Luck Lake Irrigation Districts. In these districts, the water use is much lower than that in the SSRID. Here, average water use declined from about 200 mm per acre to 175 mm per acre over the 1990 to 2009 period (Saskatchewan Agriculture Irrigation Branch, undated). However, the year-to-year water use is highly variable, depending on growing season temperatures and precipitation. Detailed data on these LDDA irrigation districts are shown in Appendix C (Table C.2).

The water demand for irrigation is dependent on the type of irrigation system used. Table 3.4 shows figures on irrigated are as in the SSRB by type of irrigation system. The majority of farmers choose a center pivot system of delivering water to crops. In fact, in the SSRB, a large proportion of irrigation is under pivot and other sprinkler systems, while only 15% is irrigated using surface irrigation systems (Figure 3.2).

Table 3.4: Irrigated Area in the South Saskatchewan River Basin by Type of Irrigation System, 2010

Water Delivery Method	Area	Percent
Wheelmove	12,360.2	7.8%
Pivot	110,772.4	69.7%
Linear	837.2	0.5%
Misc. Sprinklers	11,403.3	7.2%
Surface	9,852.8	6.2%
200mm Backflood	3,972.3	2.5%
Misc. Backflood	8,850.8	5.6%
Remainder	900.0	0.6%
Total	158,948.9	100%

Source: Saskatchewan Ministry of Agriculture (2011a) and the Saskatchewan Watershed Authority (2011b)

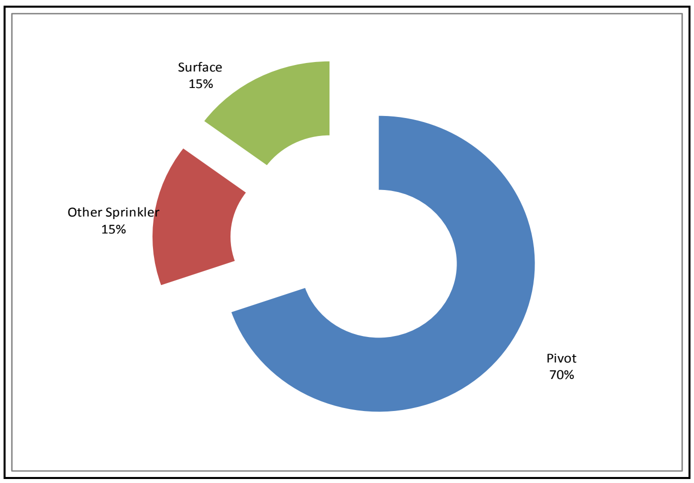

Figure 3.2: Distribution of Irrigated Area in the South Saskatchewan River Basin, 2010, by Irrigation System

Holm (2008) estimated a range of efficiencies for a number of irrigation systems for the Prairie Provinces. The details on water demand for various types of delivery systems are shown in Table 3.5. No adjustment was made to the coefficients to account for the conveyance method. However, it is implicitly assumed to be included in the coefficients for the SSRID. An average water demand for irrigation in the SSRB in 2010 was based on the amount used in the SSRID. Since water demand is determined by the method of water delivery to the crop, data on this aspect were collected. There is no data on the efficiency of the systems used in the SSRB.

Table 3.5: System Efficiency and Water Application Coefficients for the South Saskatchewan River Basin Irrigation, by Systems

Water Delivery Method	System Efficiency	2010 Coefficients (mm per acre)
Wheelmove	65%	395.8
Pivot	75%	353.7
Linear	65%	395.8
Miscellaneous Sprinklers	65%	395.8
Surface	45%	571.8
200mm Backflood		200.0
Misc. Backflood	45%	554.8
Remainder	45%	554.8

Source: Holm (2008) for technology efficiency; estimation of coefficients from crop water deficit, crop mix and system efficiency.

According to these estimates, water demand can vary from 200 mm per acre to 571.8 mm per acre. The lower amount occurs on account of the allocation of water for the 200 mm backflood irrigation method. The higher level of water demand is for surface irrigation methods (See Figure 3.3). The sprinkler systems typically have a higher efficiency and therefore, a lower per acre water demand.

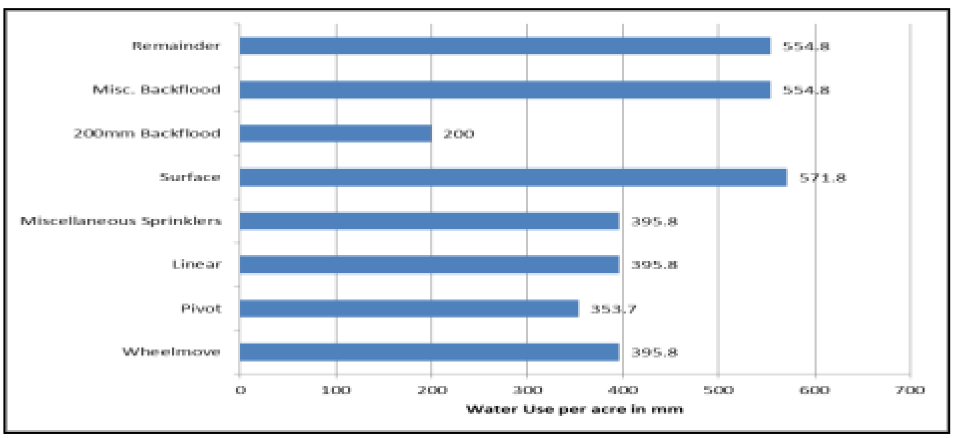

Figure 3.3: Water Demand Coefficients for different Types of Irrigation Systems in the South Saskatchewan River Basin

The distribution of various crops by water delivery system to crops was based on the crop mix shown in Table 3.6. There is a lack of actual crop mix data, most systems were assumed to be similar. Backflood, miscellaneous backflood, linear, surface, wheelmove, and remainder have a higher proportion of area for the cereals than does pivot. More details are shown in Table 3.7.

Table 3.6: Crop Mix in the LDDA Irrigation Districts and South Saskatchewan River Basin in Saskatchewan

Crop Type	Lake Diefenbaker Development Area	South Saskatchewan Basin
Oilseeds	34%	19%
Cereals	30%	49%
Pulse	12%	24%
Forage	14%	6%
Vegetables	9%	1%
Miscellaneous	1%	1%
Total	**100%**	**100%**

Source: ICDC (2008b), and Statistics Canada (2009).

Table 3.7: Crop Mix in South Saskatchewan River Basin by Irrigation System

Water Delivery Method	Crop as a % of Total irrigated Area					
	Oilseeds	Cereals	Pulse	Forage	Veg	Misc.
Wheelmove	19%	49%	24%	6%	1%	1%
Pivot	34%	30%	12%	14%	9%	1%
Linear	19%	49%	24%	6%	1%	1%
Misc. Sprinklers	19%	49%	24%	6%	1%	1%
Surface	19%	49%	24%	6%	1%	1%
200mm Backflood	19%	49%	24%	6%	1%	1%
Misc. Backflood	19%	49%	24%	6%	1%	1%
Remainder	19%	49%	24%	6%	1%	1%

Source: Estimations from ICDC (2008b) and Statistics Canada (2009).

Water demand coefficients for 2010 were estimated by crop type as the crop water requirement minus average growing season precipitation and average soil moisture reserve. These are shown in Table 3.8.

Source of Water for Irrigation: In the SSRB, irrigation water is supplied from surface water sources. Using data from Based on wok by R. Halliday & Associates (2009) for on-farm domestic use 96.9 percent of this water is from surface water.[13] For the purposes of

[13] Based personal communication with Mr. R. Halliday.

this study, all irrigation was assumed to be from surface water sources, while the remaining agricultural water demand was assumed to employ a combination of surface and groundwater.

Table 3.8: Current Irrigation Water Demand by Crops for the South Saskatchewan River Basin

Crop	Crop Requirements[a] (mm)	Average[b] Precipitation + Soil Moisture	Current Deficit [c]
Alfalfa	620	237.5	382.5
Grass/Hay	500	237.5	262.5
Potatoes	520	237.5	282.5
Faba Bean	610	212.5	397.5
Corn Silage	470	237.5	232.5
CWRS	460	212.5	247.5
CSWS	480	212.5	267.5
Canola	430	212.5	217.5
Flax	410	212.5	197.5
Field Pea	400	212.5	187.5
Barley Silage	390	212.5	177.5
Barley Malt	430	212.5	217.5
Dry Beans	380	212.5	167.5
Chick Pea	380	212.5	167.5
Fall Rye	390	212.5	177.5
CWAD	460	212.5	247.5
Vegetables[d]	263	212.5	150.5

CWRS = Canadian Western Red Spring Wheat; CSWS = Canadian Soft White Spring wheat; CWAD = Canadian Western Amber Durum.

Source: [a] ICDC (2008a).

[b] Estimate of 212 mm for crops maturing in 105 days or less, and 237.5 for crops over 105 days of maturity includes the average spring soil moisture and growing season precipitation.

[c] Crop requirement minus the average precipitation and soil moisture reserve.

[d] Based on estimates provided by Beauliu et al. (2001).

3.6.1.2 Water Demand for Dryland Crop Production

For the dryland crop production, water is used primarily for herbicide application. This water demand was estimated by the crop mix in the basin, tillage practices, rotations followed, and average amount of water used for such applications. Further consideration was made for the source of water. Each of these is described below.

Herbicide Application Rates and Average Water Demand: Typical application rates of most pesticides for crops grown in Saskatchewan are an in the 40 – 60 litres per acre range, there are usually 2-3 applications consisting of a pre-seed and in-crop (herbicide, fungicide, or insecticide) application depending on the type of crop, and the weed, disease or insect pressure.

Herbicide application rates are also affected by two other factors: tillage system and crop rotations. For the intensive tillage systems, tillage can be substituted for herbicide application. However, such is not possible for zero tillage, which makes the number of herbicide applications higher. Herbicides are also used for summerfallow[14] when Chem Fallow,[15] or Chem/Till fallow are used. The herbicide applications for these techniques range from 1 to 4 passes, depending on weed growth.

Water is also needed for cleaning the sprayer for end of day and sprayer cleanout of pesticide incompatible to the next crop or pesticide. The factor chosen to account for this use is 1% of the water consumed for spraying, as estimated by Beaulieu et al. (2001).

Source of Water: Water demanded for pesticide application can come from surface or groundwater sources. Through data from R. Halliday & Associates (2009) for livestock water demand, 51.3% of this water was assumed to be from groundwater sources.[16]

Crop Mix: the areas of various crops in the Saskatchewan crop districts for major grains and oilseeds (wheat, durum, canola, flax, and specialty crops of canary seed, chick pea, field pea, lentils, mustard, and sunflower) was obtained from Statistics Canada (2009). These data were subjected to proportional distribution in order to estimate their areas within the basin. These details are shown in Table 3.9.

Water Demand Coefficient: The area of crop multiplied by the spraying coefficient provided the amount of water demanded for this activity in the SSRB. The amount of water expended for such application was estimated at 0.000088375 dam^3 (equivalent to 88.4 litres) per acre for 2010, and this figure also accounts for the projected change in zero tillage adoption to 2010.

[14] Summerfallow is that cropland which is purposely kept out of production during a regular growing season. Resting the ground in this manner allows one crop to be grown using the moisture and nutrients of more than one crop cycle.

[15] Chem Fallow is the practice of using chemicals to control weeds on fallow lands under no-till production system.

[16] Similar to the figure for irrigation, this proportion should be verified using actual data, if and when available.

Table 3.9: Dryland Crop Production Area in the South Saskatchewan River Basin, 2009 – 2060

Crop Type	Area under Crop in Acres			
	2009	**2020**	**2040**	**2060**
Cereals	1,007,360	976,803	949,845	949,845
Oilseeds	343,111	374,964	331,580	331,580
Pulses	409,030	383,154	388,159	388,159
Fallow	339,640	257,110	322,309	322,309
Total	**2,099,142**	**1,992,031**	**1,991,894**	**1,991,894**

3.6.1.3 Livestock Production

Stockwater demand was estimated by following the water requirements approach. Since water requirements for different types of livestock are dissimilar, a disaggregated approach was undertaken. This method required information on the livestock inventory by type, which was obtained from Statistics Canada (2006 and 2011a) and from Agriculture Statistics of the Saskatchewan Ministry of Agriculture (2011b). These data included beef cattle, dairy, hogs, and sheep for 2010 and were available at the Crop District (Census Agriculture Region) level. Other livestock population records were obtained at the crop district level from Statistics Canada (2006). For a lack of a better criterion, percent area of a crop district was chosen to allocate the livestock populations to the river basin using the Correspondence Table shown in Appendix B.

The above data include livestock raised on intensive livestock operations in Saskatchewan. These numbers were obtained from Sask Pork (2011) for hog operations, from Saskatchewan Ministry of Agriculture (2008) for feedlot cattle and dairy operations, and from Saskatchewan Turkey Producers Marketing Board (2011) for turkey operations. The categories of hog, feedlot cattle, turkey, and dairy production within a crop district were adjusted to the river basin where the production took place. Again, the proportional area served to determine the river basin values if the crop district included more than one river basin.

The location of cattle feedlots in Saskatchewan, along with their stated capacity ranges, was obtained from Saskatchewan Ministry of Agriculture (2008). These data were used to estimate feedlot capacity within a river basin. To estimate the number of cattle fed in the feedlots in a year, those lots with a stated capacity of 10,000 head or greater were multiplied by a factor of 1.44 (indicative of number of times these feedlots are filled) while those with less than 10,000 head capacity were assumed to be filled once. The mid-range of the production capacity was used for feedlots less than 10,000 animals. In the SSRB, 16 feedlots were identified with 8 having a one-time capacity of 5,000 and accounting for 68% of the feedlot placements.

The barn capacity of the hog sector in the SSRB was estimated at 11,912, 71,954 and 39,682, for sows and boars, feeders, and weanlings, respectively. These data were collected by Sask Pork

(2011). The weanlings can either be fed out in the feeder barns or exported out of the basin. Mandatory Country of Origin Labeling (MCOOL) in the United States has affected the weanling market in Canada, resulting in less pig production and in fewer weanlings being exported to the USA (AAFC, 2011). Estimated hog numbers in the basin are also shown in Table 3.9.

The sheep industry in Saskatchewan has been adversely affected by the closure of the USA border when Bovine Spongiform Encephalopathy (BSE, commonly known as mad-cow disease) was detected in cattle in 2003; the MCOOL regulations in the USA have also affected sheep production. As a result, the sheep breeding herd has declined by 25% since 2001. In 2010, as shown in Table 3.9, there were 29,566 sheep on farms in the basin.

Data for the poultry sector were obtained from Statistics Canada (2006), Saskatchewan Ministry of Agriculture (2012): (Table 3-43, Egg Production and Disposition, Saskatchewan; Table 3-30, Chickens and Turkeys Placed in Saskatchewan; Table 3-32, Turkey Production, Value and Disposition, Saskatchewan; Table 3-36, Registered Chicken Production and Value, Saskatchewan). Farms in the basin are estimated to have around 8 million broilers, besides laying hens and pullets. Turkeys on farm, in the basin are relatively smaller in number only about 228 thousand birds.

In addition to the above types of livestock, farms in the basin house other animal types, including bison, horse, goat, Llamas, and Alpaca. The estimated number of these livestock in Saskatchewan was collected from Statistics Canada (2006). These data were available on a crop district basis. The 2006 values were taken as a proxy for 2010 levels of these inventories within the crop districts and allocated to the river basin. Provincial associations were contacted to see whether they had data available on the herd size of their respective animal types. Data were provided only by the bison association. In 2010 the number of horses in the basin was estimated at 22 thousand animals. Horse numbers were followed by those for bison at 14 thousand while other animal types were relatively smaller in number.

The pertinent literature suggests a range of water demand by type of livestock. These data are presented in Table 3.10. Different studies vary, but most of them have a common range. The main problem is to match the livestock categories in the data with an appropriate water demand coefficient.

The base coefficients employed for the estimation of stockwatering demand for the SSRB are shown in the last column of Table 3.11. These fall within the range shown in the previous columns; however, the water demand coefficients for dairy cows and swine include the water used for cleanup, unlike the referenced coefficients.

Table 3.10: Estimated Livestock Population in the South Saskatchewan River Basin by Type of Animals, 2010

Livestock Type	Number in 2010	Livestock Type	Number in 2010
Total Cattle and Calves		**Other Livestock**	
Bulls	6,538	Bison	8,722
Milk Cows	8,092	Horses	11,744
Beef Cows	128,133	Goats	1,599
Milk Heifers	3,864	Llamas	798
Beef replacement Heifers	21,228	Bees	8,906
Feedlot	36,779	Deer	1,079
Calves	118,662	**Poultry & Egg Sector**	
Hog Sector		Laying Hens	295,613
Sows		Pullets	98,695
Suckling Pigs		Broilers	6,676,072
Weaned Pigs		Other Poultry	8,583
Growing & Finishing Pigs	143,907	Turkeys (M)	156,991
Boars		Turkeys (F)	104,661
Sheep Sector		**Sheep Sector**	
Rams	182	Breeding	866
Ewes	3,681	Slaughter	2,757

Source: Statistics Canada (2011a), Saskatchewan Ministry of Agriculture (2011b); Sask Pork (2011), and the Saskatchewan Turkey Producers Marketing Board (2011).

3.6.1.4 Greenhouse's and Nurseries' Water Demand

According to Statistics Canada (2010), there were 145 greenhouses and 35 nurseries in Saskatchewan in 2010, with 476 hectares of field area and 26 hectares of container area operated by nurseries in 2010. Average months of greenhouses operation have gone from 5.6 months in 2007 to 6.1 months in 2010 -- an increase of 9.1%, while the area of Saskatchewan greenhouses has decreased from 235,254 m^2 in 2007 to 187,626 m^2 in 2010 -- a decline of 20% (Statistics Canada, 2010). Bedding plants and potted plants are the main products, along vegetables, in approximately 12,000 of 187,626 m^2 of greenhouse area in Saskatchewan.

Table 3.11: Estimated Range of Water Consumption by Type of Livestock

Type of Animal	Amount in Litres per Day			
	A la Olkowski[a]	A la OMAFRA[b]	A la Beaulieu et al.[c]	Water Demand Coefficient in L per day
Beef	26-66	22-54	45.0	
Feeder Calves	18-27			19.05
Steers	36-45	27-55	30.0	34.60
Background		15-40		
Cows Lactating		43-67		35.77
Bulls		36	36.0	38.17
Bison			10.0	10.00
Dairy	28-110			
Dairy Maintenance	55-68			
Dairy Lactating	68-114	90	90.0	108.54
Calves (4-8 weeks)	4.5-6.8			
Calves (12-20 weeks)	9.1-20	15	15.0	
Calves (26 weeks)	17-27			19.05
Heifers (pregnant)	32-45	25	25.0	29.73
Llama/Deer/Alpaca[d]	9.5	10.0		10.00
Lambs (weaned)	3.5-4.0	3.6-5.2	4.0	0.86
Ewes (dry)	4.0-5.0	4.0-6.5		4.50
Ewes (lactating)	4.0-12.0	9.0-10.5	7.4	5.36
Goats	3.0-15	4.0	4.0	4.00
Horses			42	32.50
Small		13-20		
Medium		26-39		
Large		39-59		
Suckling Pigs	0.27- 2.0			0.71
Weanling Pigs	1.0- 5.0	1.0-3.2	1.0	14.51
Growing Pigs	5.0- 10.0	3.2-7.3	4.5	7.58
Finishing Pigs	5.0-12.0	7.3-10.0	9.0	
Gestating Sows	5.0- 20.0	13.6-17.2		21.66
Lactating Sows	15- 35	18.1-22.7	20.5	23.14
Boars	8.0 -17.0	13.6-17.2	12.5	10.27

Source: [a] Olkowski (2009); [b] OMAFRA (2007); [c] Beaulieu et al. (2001); [d] British Columbia Ministry of Agriculture and Lands (2006); Frame (2010).

Saskatchewan crop-district level data from Statistics Canada (2006) were used to estimate the greenhouse area in the basin. Again, for lack of better proxy, relative area of the crop district within the SSRB was used to allocate provincial greenhouse area to the basin. The same procedure was followed for the area of nurseries for bedding plants and potted plants. The estimated area of greenhouses in the SSRB in 2010 was 39,519 m^2 or 9.8 acres.

Water demand for greenhouse and nursery activities was estimated by area in production and type of product grown. Water demand coefficients were obtained from Beaulieu et al. (2001), which included water used for spraying as well as for cleanup. Water demands for these activities were estimated and weighted for the two types of operation, yielding a coefficient of 30.41 dam^3/ha or 12.31 dam^3/ acre, which was used in this study.

3.6.1.5 Water Demand for Aquaculture

The level of activity of aquaculture in the SSRB could not be estimated because of a lack of data. However, there used to be a commercial fish farm at Lake Diefenbaker.[17] Commercial production of rainbow trout is almost entirely from the Cangro Fish Farm at this site. This facility was started in 1993 and was owned by the Saskatchewan Wheat Pool (Now Viterra Inc.). It raised rainbow trout from hatchlings to a two-kilogram market size, which were filleted and packaged on site and sold throughout North America. No current details on this operation were found.

3.6.2 Industrial/Mining Water Demand

Industrial water demand in this study included all goods producing industries (excluding agriculture). This water demand covers both mining operations and manufacturing. Manufacturing activities in the province are located either in communities with municipal water systems, or outside such centers. Since municipal/domestic water demand would include the first type of manufacturing water demand, only the second type requires further estimation. Various types of industrial water demand in the SSRB are described in this section.

3.6.2.1 Potash Production

The current amount of water demanded for the potash production process depends on the nature of mining technology and the level of production. In the basin, there is one mine that uses the solution mining process located at Patience Lake. The other two mines follow the conventional underground mining process to take potash ore out and process it. The water demand coefficient was estimated by dividing the total water demand by the level of potash production in 2008. The amount of water demanded was obtained from the Saskatchewan Watershed Authority (2011a), whereas the production data has been presented in Table 3.12. Solution mining of the ore, which is done at the Patience Lake mine site, has a significantly higher water demand coefficient than

[17] These statements are based on Drew (2005).

that for conventional (underground) mine sites. It should be noted that some of the surface water can be substituted by saline water in potash mining.

Table 3.12: Estimated Water Demand Coefficients for Potash Mines in the South Saskatchewan River Basin, 2010

Corporation	Location	Mining Technology	Source of Water	Water Demand Coefficient in dam^3/tonne
Potash Corporation of Saskatchewan	Cory	Underground	Surface	2.28
	Patience Lake	Solution	Surface	1.56
	Allan	Underground	Surface	1.42

Estimated coefficients for underground potash mining fell into the range of 0.67 to 0.82 dam^3 per thousand tonnes of potash produced, and 1.63 dam^3 per thousand tonne of potash produced by the solution mining process. These coefficients are based on the past five years average water demand and production. Differences in the technology of the milling process of the mines, along with the type of end product, appear to be the reason for the range in values of water coefficients.

3.6.2.2 Oil and Gas Production

Most of the oil and gas activity in the SSRB is located west and northwest of Swift Current in the Lower Shaunavon and Viking formations. Three types of oil and gas well drilling technologies are used; primary is the oil being pumped directly from the reservoir; secondary is the pumping of water into the reservoir to increase pressure; tertiary involves the injection of steam, gases, or chemicals (Saskatchewan Ministry of Energy and Resources 2011). In 2010, 54% of the wells drilled in Saskatchewan were horizontal (Enterprise Saskatchewan, 2011). Oil drilling activity has increased significantly over the past six years as the new technologies of horizontal well drilling and frac-ing have arisen. One hundred and thirty-five horizontal wells have been drilled in the Shaunavon formation as of June 2011 (Saskatchewan Geological Survey, 2011). About 25% of the Shaunavon formation is in the SSRB; therefore, approximately 34 horizontal wells and an equal number of conventional wells would have been drilled. Three hundred horizontal wells have been drilled into the Viking formation, of which approximately 25% is located in the SSRB or 75 wells (Saskatchewan Geological Survey, 2011). Vertical wells with water flood have been used and will continue to be working in both formations.

Water demand in enhanced oil recovery from 2002 to 2010, listed by company from Saskatchewan Watershed Authority (2011), indicates a wide range from a minimum of 0.8 dam^3 per well to a maximum of 966 dam^3 per well, with an average of 65.7 dam^3 per well. Further information was obtained about the company operations (where available) as to area of operation and gas or oil extraction. The 966 dam^3 per well was associated with CO_2 injection in the Bakken formation. Heavy oil extraction around Lloydminster uses, on average, 91 dam^3 per well.

Wu et al. (2009) report the average amount of water expended by the various oil recovery technologies (Table 3.13). The coefficients of 11.36 dam^3 of water per horizontal frac oil well (based on Energy Policy Research Foundation, 2011) and between 2,500 m^3 to 5,000 m^3 of water (Canadian Association of Petroleum Producers, 2011) for Shale gas using multi-stage frac completion technique are low compared to the Saskatchewan data. It appears that water demand in oil and gas extraction in Saskatchewan is considerably higher than the industry average for secondary, steam, and CO_2 injection. The average water demand from Saskatchewan data without the CO_2 injection is 53.3 dam^3 per well. This water demand coefficient was employed for horizontal wells with frac completion, while the water demand coefficients for primary and water flood were 0.39 and 16.71 dam^3, respectively.

Table 3.13: Water demand by Type of Technology Oil and Gas Sector

Technology	Water demand in dam^3 per well
Primary	0.39
Secondary	16.71
Steam	10.49
CO_2 Injection	25.26
Caustic Injection	7.58

Source**:** Wu et al. (2009).

3.6.2.3 Manufacturing Water Demand

The SSRB is home to several types of manufacturing. However, a majority of these are located within the municipal system of the city of Saskatoon. Since this water demand is captured under municipal/domestic water demand, these manufactures are excluded from this discussion here.

Several companies in the SSRB operate outside of the municipal water systems. All these companies are either private plants or branch plants, information on production or sales is limited.

The water demand for manufacturing is related to several factors -- type of manufacturing, source of water, and annual production level. The companies' water demand coefficients were estimated by taking into account these factors. These are presented in Table 3.14. Data on their water demand were obtained from Saskatchewan Watershed Authority (2011a). However, obtaining data on actual production of these industries was a difficult task due to confidentiality and propriety information concerns. As a proxy, the stated capacities of these firms were taken as a measure of production. Coefficients vary by type of production.

Table 3.14: Estimated Water Demand Coefficients for Manufacturing Industries by Type of Industry, in the South Saskatchewan River Basin, 2010

Type of Manufacturing	Source	Production	Units	Water Demand Coefficient (m^3/unit)
Refinery				
Saskatchewan Ltd (Reynolds)	ground	--		--
Ag Processing				
Cargill - Canola Crush Plant	surface	1,350,000	tonnes	0.0005619
BioExx Specialty Proteins Inc	ground	--		--
Water Treatment Chemicals				
AKZO (Chemical Man)	surface	--		--
Allan Division	surface	--		--
ERCO Worldwide	surface	50,000,000	$	0.0000077
United Chemical Company	surface	--		--

-- Not available

Source: Estimates based on Saskatchewan Watershed Authority (2011a).

3.6.2.4 Power Generation Water Demand

The water demand for power generation can be either consumptive or non-consumptive in nature. Generally speaking, hydroelectric power generation does not consume any water, but requires a large amount of water intake. However, this water is released from the reservoir for use by downstream users (if any). Other types of power generation have a large intake of water, as well as some consumption associated with it.

Water demand coefficients for the SSRB are not available. Based on studies for other jurisdictions, it is noted that in thermal power generation, water is required mainly for cooling purposes. In the US, a range of 300 – 400 gallons of water (equivalent to 1.136 to 1.514 m^3) is required to generate one MWh of electricity in a coal fired plant (Tzimas, 2011). Torcellini (2003) has also reported a value of 360 gallons per MWh for North Dakota, a situation perhaps closer to Saskatchewan's. In terms of withdrawal demand of water, Environment Canada (2011) reports that for a thermal power generation plant, 140 litres of water are needed to produce one kWh of electricity (mix of coal and natural gas). For hydro power, Larson et al. (2007) report a withdrawal of 42 gallons of water (equivalent to 0.159 m^3 for a small reservoir, and 53 gallons (equivalent to 0.201 m^3 for a large reservoir). using thermal power generation. Gleick (1990) maintains that hydropower generation results in consumptive demand, since reservoirs lose water through evaporation from the reservoirs[18]. This amount is reported to be 17 m^3 per MWh of electricity generated. However, the amount of loss will depend on the reservoir size and the configuration of generation facilities.

There are different types of power generation that take place in the SSRB. These include hydroelectric plants, thermal electric plants (using coal and natural gas), and electricity generated by wind and solar energy. Electricity generation plants in the SSRB that use natural gas are the SaskPower Queen Elizabeth station at Saskatoon, the Success Power Station near Swift Current, and the co-generation plant of Atco Power Canada Ltd, at the Cory potash mine. Hydroelectric power is generated at Couteau Creek (186 MW) from the Lake Diefenbaker reservoir. Several wind farms are in the basin, along with one generating facility that uses heat recovery.

The Queen Elizabeth power station at Saskatoon uses a once through cooling system with a license to withdraw 427,108 dam^3, with a yearly withdrawal of 75,000 dam^3 and consumption of 508.3 dam^3 (Table 3.15). The NRGreen heat recovery system employs new technology that requires no water for the production of electricity. Details on the Success Power Station were not available. The various wind farms are non-consumptive water users for the production of electricity. The Coteau Creek hydroelectric station has a non-consumptive water demand for its generation of electricity, although the difference in evaporative loss due to the reservoir should be apportioned to various demands of water served by the reservoir.

Table 3.15: Estimated Power Generation Water Consumption in the South Saskatchewan River Basin, 2010

Facility	Source	Consumption in dam^3
Cory Cogeneration Station	Surface	1,346.7
NRGreen Heat Recovery		0
Queen Elizabeth Power	Surface	508.3
Success Power Station		N/A

Source: Saskatchewan Watershed Authority (2011).

[18] Evaporation losses from Lake Diefenbaker also depend upon how much water is stored. This amount could be reduced significantly by including the annual generation at Nipawin and E. B. Campbell as generation at those run-of-river stations also depends on Lake Diefenbaker storage.

3.6.3 Municipal/Domestic Water Demand

All the basin population resides in various types of communities – cities, towns, and villages, or on farms and non-farm unincorporated settlements. Some of these communities have a municipal water system, while others do not. The total municipal/domestic water demand was estimated as a sum of six types of water demands: (i) Municipal water demand – for cities and other jurisdictions where a municipal water system is in place; (ii) Domestic water demand – for towns and other larger urban centers other than cities; (iii) Rural water demand – for villages, farms, and rural non-farm water demand; (iv) First Nations' Reserves' water demand; and (vi) Other domestic water demands — to include trailer courts and communities supplied by Elbow and Couteau Hills Pipelines. The methodology for these water demands is described in this section. The total municipal/domestic level water demand was a product of per capita water demand and population of a given community. Data on water demand and population of various types of communities were obtained from Saskatchewan Watershed Authority (2011).

One issue that surfaced in the estimation of municipal/domestic water demand was that of double counting. Some communities in the basin are supplied with water through pipelines. Some pipelines source their water from outside the basin, while others source theirs from larger communities. To avoid double counting in basin water demand through these two sources required further examination. In consultation with Sask Water,[19] it was assumed that the communities receiving water through pipelines are reporting their community water demand and therefore that there was no double counting for those communities receiving or providing water through pipelines. However, if the water being supplied is to communities outside the basin, additional adjustment was needed, and made. Communities for which this adjustment was made are noted in the results.

3.6.3.1 Overview of Estimation

The methodology for the estimation of municipal/domestic water demand was designed by estimating populations for various communities and their respective water demand on a per capita basis. Data for the period 1995 to 2009 were obtained from Saskatchewan Watershed Authority. Trend analysis was undertaken, using these time series data. Three types of trends were estimated: (1) Simple linear trend; (2) Non-linear trend following a quadratic model; and (3) Semi-log function with dependent variable in log form. In the case of per capita water demand, in addition to the trend variable, the population of the community was also used. The hypothesis was that as a community increases in size, its per capita water demand may decline, since some of the common (public) water demands will be shared by more people.

[19] Personal communication with Mr. Jeff Mander, May 22 2012.

If the trend analysis did not result in a meaningful result, an average of past five years was used. For most communities 2010 population was estimated through past trends. Where the estimated 2010 population was lower than the actual 2009 population, the 2010 population was revised as follows: the 2009 actual population was increased by the proportional change in forecasted 2010 over 2009 population. These analyses were undertaken for each of the six types of water demands listed above.

The total population of the SSRB was estimated at 316,731 (including the city of Humboldt or 311,053 people excluding it). Of this, urban (including First Nations' Reserves) population was estimated at 274 thousand people – some 89% of the total. The remaining 11% of the population resided on farms or other parts of the rural municipalities.

There are several communities located in other river basins to which SSRB provides water. The city of Humboldt, located in the Qu'Appelle River Basin, is one of these communities. In addition, the town of Bruno (town with population less than 1000 people) and the Village of Muenster, as well as two villages (Anaheim and Lake Lenore) are also supplied by SSRB. Some water is also provided to the rural municipalities through the SSEWS canal, whereas the other communities receive water through the Wakaw-Humboldt Water Supply System (WHWSS).

3.6.3.2 Municipal Water Demand

In the SSRB, there are four cities that have municipal distribution systems for water use: Martensville, Saskatoon, Swift Current, and Warman.[20] There is a fifth city that will be taken into account in this river basin: Humboldt. Even though the urban center is not physically located in this river basin, the water supplied to it is from SSRB through the SSRB. It should be noted that the population of Humboldt will not be accounted in the SSRB, but in the Qu'Appelle River Basin.

The population and per capita water demands for these communities are shown in Table 3.16. Saskatoon and Swift Current are the urban centers with higher water demand per capita values. Warman and Martensville have a relatively smaller water use per capita. This is perhaps because they are bedroom communities with little, if any, non-residential water use activities. However, further research needs to be employed to understand the dynamics of water demand per capita coefficients.

[20] The assumption made for estimating water use per capita for domestic water use was that the records provided by Saskatchewan Watershed Authority include individual records for each listed community.

Table 3.16: Estimated Variables Affecting Total Municipal (Cities) Water Demand in the South Saskatchewan River Basin, 2010

Particulars	2010 Population	Per Capita Water Demand in m^3	Proportion of Surface Water to Total Water Demand
Martensville	6,345	86.64	100.0%
Saskatoon	221,668	210.23	100.0%
Swift Current	16,291	171.57	100.0%
Warman	6,044	88.68	100.0%
Total City	250,348	--	--

Source: Saskatchewan Watershed Authority (2010).

3.6.3.3 Domestic Water Demand

Domestic water demand was estimated for two types of communities: towns and bedroom communities around the city of Saskatoon. Towns were further divided into two types: relatively larger towns (with populations of 1,000 or more), and smaller towns (with populations of less than 1,000 people). Details on the variables used for the estimation of total domestic water demand for these communities are shown in Table 3.17.

Table 3.17: Estimated Variables Affecting Domestic Water Demand in the South Saskatchewan River Basin, 2010

Category	2010 Population	Per Capita Water Demand in m^3	Proportion of Surface Water to Total Water Demand
Bedroom Communities around Saskatoon	5,999	93.22	82.0%
Towns >1000	12,609	139.02	58.0%
Towns < 1000	5,852	120.29	96.0%
Total Towns	24,460	--	--

Source: Saskatchewan Watershed Authority (2010).

3.6.3.4 Rural Water Demand

In addition to municipal and domestic water users, 31,624 people (constituting almost 10% of the total basin population) live in smaller communities called villages. Their estimated water demands and sources of water are shown in Table 3.18.

In addition to villages, some people also live on farms. This category of users was further separated in two subcategories: rural farm and rural non-farm population. Since the information available on the communities was scarce, farm and rural non-farm water demands were treated similarly to villages. The population was assumed to remain the same as the 2009 levels, since no other records were available.

Table 3.18: Estimated Variables Affecting Total Rural Water Demand in the South Saskatchewan River Basin, 2010

Category	2010 Population	Per Capita Water Demand in m^3	Proportion of Surface Water to Total Water Demand
Villages	6,637	125.16	69.0%
Rural farm	15,939	125.16	69.0%
Rural non-farm	9,048	125.16	69.0%
Total Rural	31,624	--	--

Source: Saskatchewan Watershed Authority (2010).

3.6.3.5 First Nations' Water Demand

There are two First Nations' Reserves in the basin. The estimated 2010 population of First Nations' people was 869. Their water demand per capita was 137.93 m^3. This coefficient was calculated as the average of the last five years. The two reserves in the SSRB are located close to surface water bodies, leading to the assumption that their source of water is 100% surface water.

3.6.3.6 Other Domestic Water Demands

Other water users in the basin include trailer courts' communities. This water demand is shown in Table 3.19. The determination of water demand coefficients or the population for these communities was challenging. In this study, an estimation of total water demand was based on the level of per capita water demand for these communities. A comparison of relative water demand per capita for all different users is shown in Figure 3.4. Their highest level of water demand was estimated for the city of Saskatoon, followed by Swift Current.

Table 3.19: Estimated Variables Affecting Total Rural Water Demand in the South Saskatchewan River Basin, 2010

Category	Total Water Demand in dam^3	Proportion of Surface Water to Total Water Demand
Trailer courts	101.67	100.0%
Couteau Hill and Elbow Pipelines*	275.99	100.0%

* These pipelines were assumed to supply water to other users that have already been accounted for elsewhere in the study. This water was excluded from the estimation of total water demand for the basin.

Source: Saskatchewan Watershed Authority (2010).

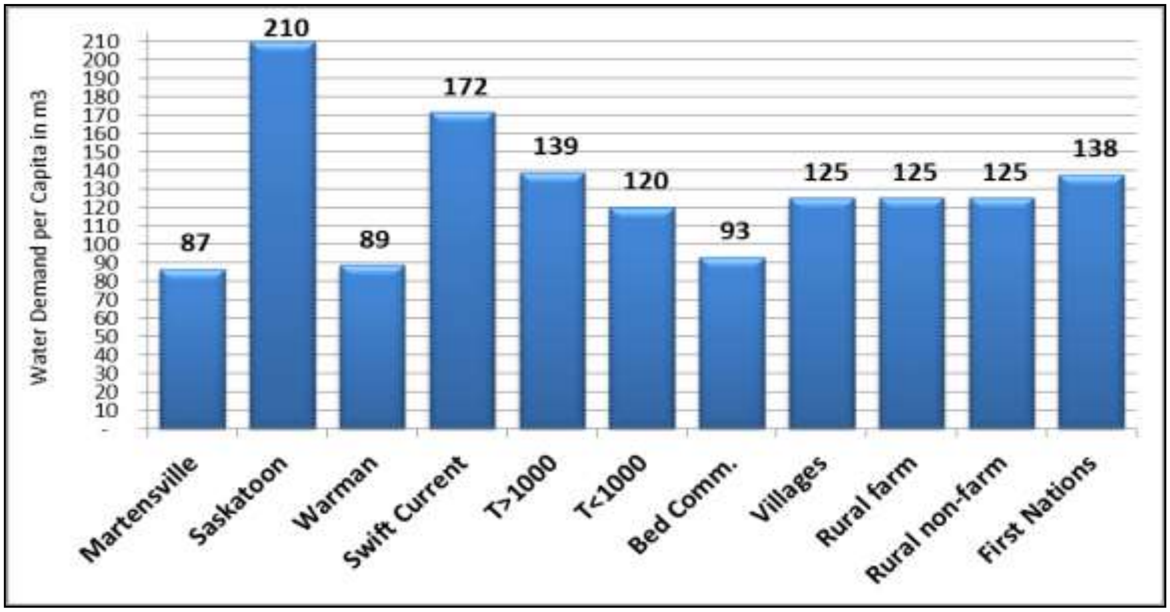

Figure 3.4: Estimated Water Demand Per Capita in Various South Saskatchewan River Basin Communities by Type of Communities

Higher water demand coefficients for larger cities perhaps reflect, besides residential water demand, industrial and public water demands. However, the reason for these differences is a pure conjecture at this point, and some further work is needed at each of these community levels.

3.6.4 Recreational Water Demand

Tourism and recreational water demand is a result of two types of water uses: One, non-consumptive water demand in surface water bodies, and Two, consumptive water demand related to the sites. The latter is a sum of two types of water demands: (1) water needed to maintain the recreation sites, and (2) that needed by permanent residents of the recreation sites. Both of these water demands are included in this sector. However, the first type is non-consumptive and is a part of the natural flow of water. It is therefore not included in this study.

Major recreational sites in the basin are within provincial parks and/or those mainlined by the local, regional governments. Over the last five years (2004 to 2009), there has been a significant increase in the number of visitors (Table 3.20). In 2005, a little more than half a million visitors were recorded, which increased by 66% in 2009 – over 790 thousand visitors. Most parks are showing signs of increased visitation. In addition to provincial parks, there are several regional parks, as shown in Table 2.7. Nevertheless, details on visitation and other information on these parks are not available. However, one can hypothesize that these parks are an important resource for the local people, and attract many such visitors for their recreational activities.

Table 3.20: Provincial Parks' Visitation Levels in the South Saskatchewan River Basin, Selected Periods

Location	No. of Visitors* in		Average 2004-2009	% Change in 2009 over 2004
	2004	2009		
Visitation based on Analysis of Permits				
Blackstrap	37,835	64,520	**52,611**	+70.5%
Pike Lake	125,596	221,499	**176,648**	+76.4%
Saskatchewan	91,110	187,186	**141,401**	+105.5%
Based on Estimates				
Fort Carlton	8,803	8,318	**8,811**	-5.5%

* Obtained from Ministry of Tourism, Parks, Culture and Sport (2009)

In addition to typical sites visited by tourists, there are several locations in the SSRB where there are permanent residents. These communities are called recreational villages or resorts and are shown in Table 3.21. There are two such communities with a combined population of 172 people. Details on the Diefenbaker Lake Cottage site are not available.

Table 3.21: Populated Recreational Sites in the South Saskatchewan River Basin

Designation	Community	Population in 2009
RV	Diefenbaker Lake Cottage	NA
RV	Shields Resort Village	172
Total Population		172

Note: RV – water based recreational sites

The water demand for recreational communities was estimated by applying a per capita water demand coefficient and the population of the community. These data were provided by Saskatchewan Watershed Authority (2010). The recreational site maintenance water demand was based on a trend analysis of total water use provided by Saskatchewan Watershed Authority (2010).

3.6.5 Indirect Anthropogenic Water Demands

3.6.5.1 Net Evaporation Loss Estimation

The area of the body of water and water depth, to a great extent, determine differences in the amount of evaporation loss among surface water bodies. Shallow water bodies warm up faster in the spring relative to deeper lakes, while deeper bodies of water are generally ice-free for longer periods into the fall. Streams generally break-up earlier and remain ice-free longer than surface water bodies because of current flow. In southern Saskatchewan, the average annual evaporation is greater than the available annual precipitation. As a result, very little precipitation makes its way into stream flows.

Some estimates of evaporation losses have been provided by Berry and Stichling (1954). However, these data are somewhat outdated, and therefore, not used. The estimates of the mean annual lake evaporation in the SSRB from the Atlas of Canada (see Natural Resources Canada, 2011) vary from 900 mm in the southwest part of the basin to 700 mm in the north section.[21] The mean annual net evaporation from small lakes and reservoirs varies from 600 mm in the south west to 425 mm in the north and to 375 mm in the east of the SSRB (Saskatchewan Watershed Authority, 2009).

The quantity of water lost to evaporation was simply a function of estimated area of lakes and other surface water bodies; net evaporation is used to estimate the quantity of water demanded in this activity for the SSRB. Estimated evaporation rates from various water bodies in the basin are shown in Table 3.22. These varied from 375 to 650 mm per annum.

3.6.5.2 Net Environmental Water Demand

Wetlands habitat restoration and preservation by organizations such as Ducks Unlimited Canada (DUC) and the Nature Conservancy of Canada are active in the basin. Public and private land is employed by these various organizations to increase or maintain wetland area. Water demand for these various projects is highly variable, as spring runoff and water flow are their main sources of recharge. Lack of data on this aspect of water use led to the assumption that after the initial intake to fill the wetlands, very small quantities of water are needed[22].

3.6.5.3 Apportionment Water Demand

As noted above, apportionment flow needs are based on the calculated natural flow of water in the river. However, since the South Saskatchewan River does not cross the Manitoba provincial boundary, the issue of apportionment does not arise.

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[21] The Atlas of Canada has listed a description of the methodology and caveats for these estimates. These are shown in Appendix D.

[22] It is possible that there may be significant water uses for this purpose due to evaporation losses from these projects. This may result in more water needed over time.

Table 3.22: Area and Evaporation on South Saskatchewan River Basin Surface Water Bodies

Particulars	Area of the Water Body in km^2	Net Evaporation in mm per km^2	2010 dam^3
Lakes			
Anerley Lake	1.6	575	920.0
Buffer Lake	11.5	425	4,896.0
Cabri Lake	0.2	625	93.8
Cheviot Lake	0.2	5.25	0.9
Duck Lake	4.0	425	1,700.0
Jumping Lake	8.6	375	3,240.0
Lenore Lake	3.9	400	1,568.0
Rabbit Foot Lake	0.2	560	89.6
Stink Lake	4.0	425	1,700.0
Stockwell Lake	4.0	575	2,300.0
Wakaw Lake	1.0	400	400.0
Total Lakes			**38,207.7**
PFRA Reservoirs			
Reid Lake	40.0	650	26,000.0
Lac Pelletier	5.0	650	3,250.0
Highfield Reservoir	4.5	650	2,925.0
Herbert	1.5	650	975.0
Shaheen	0.4	650	260.0
Sauder	0.3	650	195.0
Total PFRA			**33,605.0**
Other Reservoirs			
Blackstrap Reservoir	14.4	525	7,560.0
Bradwell East & West	4.4	525	2,296.9
Broderick Reservoir	3.0	560	1,680.0
Lake Diefenbaker	430.0	625	268,750.0
Patience Lake	6.0	500	3,000.0
Pike Lake	3.3	525	1,706.3
Total Reservoir	592.0		**287,153**
Total SSRB			**358,966**

Source: For List of Lakes (Wikipedia (2011). For evaporation rate, Saskatchewan Watershed Authority 2009`Mean Annual Net Evaporation for Small Lakes and Reservoirs`.

3.6.5.4 Other Water Demands: In-Stream Flow Requirements

The South Saskatchewan River System provides habitat for a variety of fish and wildlife species. The South Saskatchewan Dam may be operated to maintain in-stream flows for fish and wildlife production. In the United States and in Alberta, the Tennant Method (Tennant, 1976) has been used as a long-range planning tool for fisheries[23]. The criterion recommends winter and summer base flows as a percentage of average annual flows; however, the relationship between fish production and stream discharge has not been fully established in the Prairie Provinces, and empirical correlations suitable to calibrate the Tennant Method are unavailable. On a related note, the Department of Fisheries and Oceans (DFO) has commented that they could not endorse the Tennant Method for the South Saskatchewan River instream flow requirements at this time, pending further analysis.

The Alberta government has instituted a conservation flow rate of 42.5m^3/s on the South Saskatchewan River, which is the same rate as under the Master Agreement for normal stream flow conditions (R. Halliday and Associates, 2009). The Saskatchewan government is also committed to a normal flow rate of 42.5 m^3/s released from the Gardiner Dam.

3.7 Return Flow and Water Consumption Estimation

If one follows the methodology outlines in previous sections of this chapter, one would estimate gross water use as equivalent to water intake. To estimate water consumption, one needs to take into account the water returned to the original source. The latter is called return flow. The return flow is generally associated with District Irrigation projects, industries, and communities with a water and sewer system. Kulshreshtha et al. (1988) estimated these return flows as follows:

District Irrigation = 25% of the water intake
Urban Communities = 68% of the water intake

For manufacturing industries, Statistics Canada (2008a) has estimated the water used for Saskatchewan for 2005 and its discharge (return flow). Results are shown in Table 3.23. According to these estimates, 77.5% of the total water intake by manufacturing establishments is returned to the source. However, this ratio would not apply to weight-gaining processing firms such as ethanol production.

The water consumption for a given type of water demand was simply the total amount of water intake minus return flow. These water demand levels are shown in Table 3.24. The lowest proportion of water resulting as consumption is that from urban (municipal systems) water demand, followed by irrigation and manufacturing.

[23] The Tenant method tends to be used with water management structures and does not handle the hydrograph inversion associated with hydropower very well.

Table 3.23: Water Demand Parameters in Manufacturing Industries, 2005

Water Demand Parameter	Total Amount in 2005 (dam^3)	Percent of Total Water Intake
Water intake	60,100	100.0
Water recirculation	6,400	10.6
Water retained in the processed goods or lost	5,700	11.9
Water discharge	48,000	78.7

Source: Statistics Canada (2008a)

Table 3.24: Water Consumption Levels for Various Direct Anthropogenic Water Demands

Water Demand Activity Group	Direct Anthropogenic Activity	Total Water Consumption as % of Water Intake
Agricultural Water Demand	District Irrigation	75.0%
	Other Irrigation	100.0%
Industrial Water Demand	Potash Production	100.0%
	Oil and Gas Production	100.0%
	Manufacturing	21.3%
Municipal/Domestic Water Demand	Municipalities*	32.0%
	Other Communities	100.0%
	Institutions**	32.0%
Recreation and Indirect Anthropogenic water demands		100.0%

* The data for actual water consumption was not available. In this study, estimated consumption was based on urban residential water consumption for all river basins as provided in Kulshreshtha et al. (1988).

** Assumed to be drawing their water needs from a municipal system.

The data and information provided in this chapter was applied to estimate the current (for the year 2010) water demand in the SSRB. These results are presented in Chapters 6 to 9 of this report. The methods presented above were revised for the future water demand in the basin under there scenarios – baseline, climate change, and water conservation scenarios. This methodology is presented in Chapters 4 and 5.

Chapter 4

Forecasting Future Water Demand

Future water demand represents somewhat of an extension of past water demand pattern, although some future changes may also play important role in altering/determining the levels. In this chapter, these factors are identified and their roles played in designing the forecasting methodology for the study are explained.

Since current water is directly related to levels of economic activities and/or population, future water demand will also be governed by these factors in a similar way. The only exception to this statement would occur if there were a significant change in the water demand coefficients for various activities. Two factors that can affect water demand coefficients in the future are: One, the onset of climate change by 2030 or thereafter, and Two, the adoption of water conservation measures. Water conservation policy of the province and other levels of government regulations regarding water demand may also determine the rate of change in this level. A water demand levels in the future can also be altered by the state of water availability, leading to more water conservation or to curtailing of certain economic activities.[24] The methodology for estimating the water demand patterns under climate change and water conservation circumstances are presented in Chapter 5.

4.1 Factors Affecting Water demand Levels

Future water demand in any region is a culmination of four types of changes/factors: economic activities, population and its distribution; water use patterns/history (including conservation); and changes in the bio-physical system (such as climate change). A rising level of population in a given river basin would affect the amount of water used for various economic, sustenance, and social activities. Population is also a factor in determining the level of economic activities in the basin. Both of these factors are often very highly correlated. Gardiner and Herrington (1986) suggest three basic approaches to forecasting future activities. These are judgmental forecasts; visual forecasts, and causal or extrapolative forecasts. Judgmental and visual approaches rely on individuals' or a group's experiences, and may be entirely subjective in nature. These are only preferred if other approaches are not feasible. Causal or explanatory forecasts are those in which

[24] Investigation of implications of water supply on water use patterns is not attempted in this study, and therefore, is left for future studies.

an attempt is made to predict the variable of concern by reference to other variables which, it is assumed, control or influence it. This type of approach has been used for domestic and municipal water demands since the mid-1970s. However, such approaches require extensive data on water demand levels and on the various factors affecting it. The extrapolative forecasts are derived from time series data and involve consideration of variables of concern; and their predictions of future value are based on a trend in the past values.

4.2 Review of Studies on Water Demand Forecasting

The estimation of water demand for various sectors has not been a notably popular area of study except for municipal and/or domestic water demands. Some studies were found, which are summarized below. In all cases, it appears that the forecasting methodology for water demand is generally based on the assumption that the present trend and practices will continue into the future, with some alteration, if needed.

4.2.1 Future Water Demand for Agriculture

Water demand for agriculture is a complex set of demands with various types of water uses included within it. As noted in the previous chapter, these demands include: irrigation, on-farm demand (pesticide application, facilities, and machinery cleanup), livestock watering, aquaculture, and nurseries and greenhouses. Each of these may be affected by a different set of factors and the effects may exhibit varying magnitudes. For these reasons, a common (aggregated) analysis may lead to erroneous results.

Of the various demands, only the irrigation water demand has been reported in some studies. Several studies represent that crop irrigation water demand has been estimated by using the Food and Agriculture Organization's crop coefficient method (FAO, 1998); it is based on a reference evapotranspiration and a crop coefficient (Kc) that accounts for crop characteristics, as well as for development and vegetation periods. Reference evapotranspiration, according to Wisser (2004), refers to evapotranspiration from an extensive surface of green grass cover with a height of 12 cm adequately watered. The crop requirements were adjusted by the system efficiency which reflected the loss in delivery of the water to the crops.

4.2.2 Future Industrial/Mining Water Demand

No study was found that provided a specific methodology for industrial/mining water demands. Brockman and Kulshreshtha (1988) estimated basin level water demand for various activities (including industrial and mining water demand) through an input-output model that lead to final demand estimates. Final demand changes were associated with change in the industries' respective production levels. Smith (1986) identified factors such as manufacturing production, price or charges for water, and unemployment in the region for estimating future water demand. Although both of these approaches have some good suggestions for a methodology, these could not be followed. Developing an input-output model was considered beyond the scope of this project.

4.2.3 Future Municipal/Domestic Water Demand

Municipal water demand includes demands for residential, commercial, and industrial purposes. For residential and municipal water demand estimation, population projections provide a basis for estimates of future growth. Data on demographics and household use rates can be used. In one forecast from the United States, residential, municipal, and industrial water demands, a sequential methodology was applied (Water Supply Forum, 2009). The steps included calculation of individual utilities' water use factor (average amount of water used per single family or multifamily household per day or per employee), adjusted by future reductions in water use factors based on a plumbing code (water saved by customers as they remodel plumbing fixtures).[25]

The total water requirement or withdrawals by an industry is related to production, which in turn is related to employment, and even more indirectly, to population. For simplicity's sake, it is generally assumed that production per employee and water use per production unit remains the same over the forecast period. The future water demand can then be estimated by change in employment over the base period.

4.2.4 Future Recreational Water Demand

Water demand is related to water-based recreational demand. However, given that much of this water demand is non-consumptive in nature, a forecast of the water needed in the future cannot be established. Massey et al. (2006) developed a recreation model for angling based on site characteristics. Although this approach is meritorious, it could not be followed for this study since it requires survey of recreationalists. The quality of water at a given site is also a major factor affecting current and future water use (Cooper, 1990).

Although the above review of the literature was helpful in identifying a suitable forecasting methodology, on account of nature of data available the methods developed were similar to those applicable to the current water demand. This methodology is described below for each of the four direct anthropogenic, as well as for the indirect anthropogenic water demands.

[25] It should be noted that this reflects water conservation either on a volunteer basis or as induced by regulations.

4.3 Study Methodology for Forecasting of Agricultural Water Demand

The total future agricultural water demand in the basin was estimated as a sum of five types: Irrigation, Pesticide demand, Livestock, Greenhouses and Nurseries, and Aquaculture. Each of these methodologies is described in the sections below.

4.3.1 Future Irrigation Water Demand

For water demand for irrigation, time series data were used while total water demand was computed as a product of demand per unit area irrigated and total water deficit (total crop water requirements minus amount of rainfall). The methodology for projecting irrigation water demand was similar in essence to that followed for current water demand. Projected irrigated area in the basin was multiplied by the appropriate crop water demand coefficient.

Two factors also require further attention: expansion of irrigated area in the future, and change in the water demand coefficients. Each of these is described below.

4.3.1.1 Future Irrigation Area

In 2010, the irrigated area in the basin (per Table 3.2) was estimated to be 158,949 acres, of which 93,439 acres were in the irrigation districts. According to SIPA (2008b), a new irrigation district could be created – the Westside Irrigation Project, along with infill in three of the irrigation districts. The irrigated area and potential irrigated area for the irrigation districts around Lake Diefenbaker are presented in Table 4.1.

Table 4.1: Irrigation District Irrigated Area and Potential Expansion of Irrigated Area in the South Saskatchewan River Basin

Irrigation District	Irrigated Area in Acres		
	Existing	Expansion*	Total
SSRID	35,271	28,254	63,525
LLID	8,602	9,397	17,999
RHID	9,868	11,000	20,868
Westside ID	--	356,800	356,800
Sub Total	**53,741**	**405,451**	**459,192**
Other Districts	39,698	--	39,698
Private Irrigators	65,510	10,830	76,340
Total Irrigated Area	**158,949**	**416,281**	**575,230***

* It should be noted that this is the area that can be developed in the basin. However, as reported in Table 4.3, expansion by 2060 may be short of this level.
Source: SIPA (2008b)

Private irrigation, which in 2010 covered 65,510 acres, is also expected to increase in the future. To estimate this, a review of past irrigation growth in the province was completed. The average growth rate in irrigated area from 1990 to 2009 in Saskatchewan was 0.77%, with a range of 0.17% in 1993 to 2.24% in 1990. The area of surface, backflood, and miscellaneous backflood has remained static since 1992, indicating that most of the easily irrigable land in Saskatchewan has been developed (data from Saskatchewan Ministry of Agriculture, 2011b). The growth rate of irrigated area outside of the Lake Diefenbaker irrigation districts would, at best, be roughly a quarter-section per year to 2060, amounting to 1,137 acres by 2020, 3,546 acres by 2040, and 6,147 acres by 2060 for the SSRB. Future irrigated area in the newly developed districts would depend on the adoption rate of irrigation in the basin. Unfortunately, no study has been undertaken on this subject. As a crude proxy, evidence was collected from LDDA irrigation districts. The uptake of irrigation in two recent projects, Riverhurst (RHID) and Luck Lake (LLID), is shown Table 4.2. The amount of land irrigated in any one year was highly variable over the 20 year period of these projects, with an average of 52% and 61% for RHID and LLID, respectively.

Table 4.2: Adoption of Irrigation in the Riverhurst (RHID) and Luck Lake Irrigation Districts (LLID), 1990-2009

Year	% of Designed Capacity of the District Irrigated Area	
	RHID	LLID
1990	40%	65%
1991	33%	42%
1992	60%	61%
1993	47%	56%
1994	43%	61%
1995	50%	68%
1996	35%	51%
1997	56%	68%
1998	61%	87%
1999	26%	29%
2000	34%	42%
2001	72%	93%
2002	48%	71%
2003	92%	96%
2004	45%	40%
2005	44%	36%
2006	51%	52%
2007	69%	59%
2008	70%	77%
2009	71%	76%
Average	52%	61%

Source: Irrigation Branch, Saskatchewan Ministry of Agriculture (2011c).

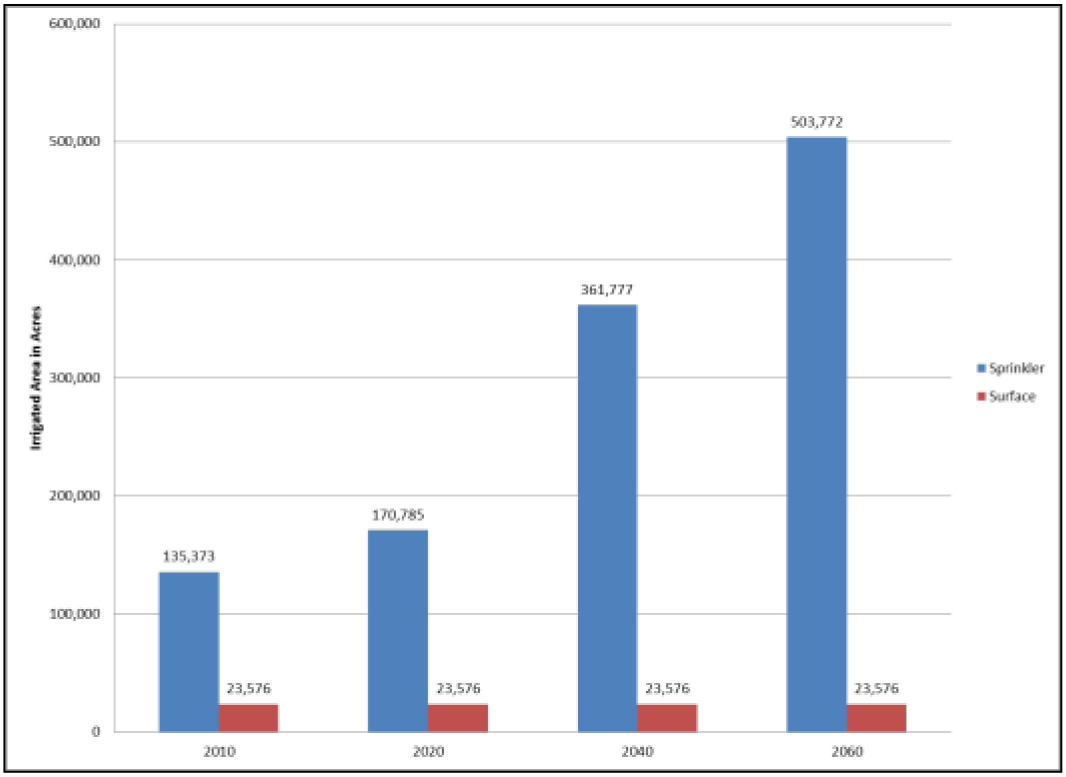


Figure 4.1: Trend in Irrigated Area Development for the South Saskatchewan River Basin, 2010 - 2060

The future irrigated area in the basin is shown in Figure 4.1. The total irrigated area in the basin will increase from its current (2010) area of 159 thousand acres to 527 thousand acres – an increase by 262% of the 2010 level. This area is somewhat lower than that reported in Table 4.1. Most of this increase is expected occur through the sprinkler irrigation system of water delivery – a change perhaps motivated by water saving/conservation thinking of governments and irrigators.

SIPA (2008A) estimated a period of 10 years for the uptake of irrigation in the proposed South Saskatchewan South. If 2020, 2040, or 2060 are drought years, the area for the irrigation would be quite high, as well as the amount of water used per hectare. The time involved to develop the South Saskatchewan South project is estimated at 11 years, after which irrigation would start (SIPA, 2008b). Therefore, by 2020, it is not likely that any of the proposed South Saskatchewan South area would be irrigated. The area of irrigated land in the SSRB is presented in Table 4.3. It is assumed that the additional land to be irrigated outside the irrigation districts and the proposed South Saskatchewan South would utilize center pivot. It is assumed that 65% of the proposed South Saskatchewan South project would be in operation by 2040 and 90% by 2060. The trend by two systems of irrigation is shown in Figure 4.1.

Table 4.3: Area of Irrigation in the South Saskatchewan River Basin in Acres, by Type of Irrigation System

Water Delivery Method	Area in Acres			
	2010	**2020**	**2040**	**2060**
Wheelmove	12,360	12,360	12,360	12,360
Pivot	110,772	146,185	337,177	479,172
Linear	837	837	837	837
Misc. Sprinklers	11,403	11,403	11,403	11,403
Surface	9,853	9,853	9,853	9,853
200mm	3,972	3,972	3,972	3,972
Misc. Backflood	8,851	8,851	8,851	8,851
Remainder	900	900	900	900
Total	**158,949**	**194,361**	**385,353**	**527,348**

Source: Irrigation Branch, Saskatchewan Ministry of Agriculture (2011c); Saskatchewan Watershed Authority (2011) & SIPA (2008a)

4.3.1.2 Future Irrigation Crop Water Demand Coefficients

The future irrigation water demand was derived from future irrigated area and water demand coefficient. As noted in Chapter 3, the distinction between district and private irrigation was maintained. In addition, climate change was taken into account in estimating the future water demand coefficient, which is described in the next chapter.

The future irrigation water requirements for crops were estimated by using ICDC (2008a) crop requirement data, combined with an estimate of the growing season precipitation plus seedbed moisture.

Metered irrigation water use from the Riverhurst Irrigation District over the 1990 to 2009 period ranged from 93.9 mm per acre in 1999 (wet year) to 290.2 mm per acre (2003) with an average for this period of 185.9 mm per acre and a standard deviation of 50.5 mm per acre (Saskatchewan Watershed Authority, 2011b). The specific crops being irrigated and the levels of water application to them are not recorded (or information is not available). However, on average, it appears to be consistent with the estimate of the normal crop water deficit applied in generating the 2010 water demand coefficients. The mix of crops produced to 2060 may change, depending on investment in intensive livestock operations in the region, as the demand for silage from feedlot cattle operations could significantly change the crop mix. At present, no further information is available.

Water demand coefficients for irrigation were developed from crop requirements and water deficits. These coefficients for 2020, 2040, and 2060 were estimated through water demand coefficients, as shown in Table 3.5, and the distribution of crop mix by irrigation system.

4.3.2 Dryland Crop Production Activities

4.3.2.1 Cropland Area

The estimation of the basin area in crops for 2020 was based on the AAFC (2011) Medium Term Outlook for 2017. Crop area for the major grains and oilseeds of wheat, durum, canola, flax, and specialty crops of canary seed, chick pea, field pea, lentils, mustard, and sunflower were forecasted in this study. The percentage change in area seeded to a crop from 2010 to 2020 was applied to the area seeded at the water basin level in 2009 to arrive at the estimated 2020 seeded area.

Estimates for 2040 and 2060 have to consider relative net returns, given the yield and price of a commodity that will determine the area seeded. Productivity gains in crop yields from 1964 to 2007 show a similar increasing linear trend of about 60% over this period (Veeman and Gray, 2009). However, this implies a declining proportional rate of growth because there is a constant absolute rate of growth in yields. So, the relative net returns will be affected mostly by the crop response to climate conditions in 2040 or 2060, given the expenditure on developing new varieties. Currently, in the SSRB, 15.6% of the cultivated area is in oilseeds, 47.9% in cereals, 20.0% in Pulse, and 16.6% in fallow (Table 4.4).

Table 4.4: Estimate of Percentage of Cultivated Area by Activity in South Saskatchewan River Basin, 2009-2060

Crop Type	Percent of Total Area			
	2009	2020	2040	2060
Cereals	47.9%	49.0%	48%	48%
Oilseeds	15.6%	17.9%	16%	16%
Pulses	20.0%	19.8%	20%	20%
Summerfallow	16.6%	13.2%	16%	16%
Total	**100.0%**	**100%**	**100%**	**100%**

Source: Statistics Canada (2009) for 2009. AAFC (2011) for 2020, Estimation for 2040 and 2060 .

One could expect that the percentages of these broad classifications would change only marginally over time. The market for the crops would have a greater impact on the types of crops grown within the categories. In terms of estimating the water used for spraying, areas of the broad categories of crops were used. The total cropped area was assumed to be unchanged. This total cropped area by crop categories is shown in Table 4.5. The area in summerfallow has decreased considerably since 2000 (from 26.8% of total cropped area in 2000 to 16.6% in 2009). This decline is expected to continue to 2020, but at a reduced rate. Projections to 2040 and 2060 of the area in summerfallow are based on a rotation with area in oilseeds typical for this region.

4.3.2.2 Crop Pesticide Application

In addition to crop mix, a number of other factors can change water demand for pesticide spraying in the basin. The majority of crop production in western Canada is small grains with cereal grains, pulses, and oilseeds comprising the majority of the seeded area. The major trend in crop production in Saskatchewan over the past 20 years has been the increased use of zero tillage (Statistics Canada, 2006). Associated with this trend has been the dramatic reduction in summerfallow and the greater diversity of crops grown. Removal of the Crow rate for transport of grains (a major transportation subsidy) has resulted in farmers seeding of higher value crops, primarily oilseeds and pulse crops. It is expected that these general trends will continue to 2020, after which the cultivated area of the basin will be 49.5% cereals, 33% oilseeds, 12.5% pulse crops, and 5% fallow.

Table 4.5: Estimate of Cultivated Area by Activity, South Saskatchewan River Basin, 2010 – 2060

Crop Type	**Area in Acres under Crop Type in**			
	2009	**2020**	**2040**	**2060**
Cereals	1,007,360	976,803	949,845	949,845
Oilseeds	343,111	374,964	331,580	331,580
Pulses	409,030	383,154	388,159	388,159
Summerfallow	339,640	257,110	322,309	322,309
Total	**2,099,142**	**1,992,031**	**1,991,894**	**1,991,894**

Source: Statistics Canada (2009) for 2009. AAFC (2011) for 2020, and estimation for 2040 and 2060.

The water demand per acre was calculated as follows: (i) A per pass rate of 50 litres per acre plus a 1% factor for cleanout was used; (ii) This was multiplied by the number of passes under different tillage systems; and (iii) The above was multiplied by the number of acres in zero tillage or minimum tillage, plus the area in Chem fallow (use of chemical to control weeds on summerfallow land) or Chem-Till Fallow (combination of use of chemicals and tillage to control weeds on summerfallow lands) Fallow. The result is an average water demand per acre for pesticide application. The water demand for pesticide spray for the future is shown in Table 4.6.

4.3.3 Livestock Production

For livestock, the direct and indirect (e.g. cleaning) water requirements were estimated and multiplied by the total number of livestock in the region. Each of these is described further.

Table 4.6: Estimates of Zero Tillage Adoption and Sprayer Passes to arrive at Water Demand in Litres per Acre for 2010

Particulars	Zero Tillage Adoption Rate (%)	Z-Till*	Min Till*
		No. of Passes for Weed Control	
Cereals	75%	2.00	1.00
Oilseeds	70%	2.50	2.00
Pulses	75%	3.00	2.00
Fallow	50%	1.75	0.90
Water Demand in L/acre	88.38		

* Z-till = Zero Tillage; Min Till = Minimum Tillage

4.3.3.1 Estimation of Livestock Population for Future Periods

The estimation of livestock production for 2020 used AAFC (2011) Medium Term Outlook for 2017. Inventories of animals within the dairy, poultry, sheep, hogs, beef sectors, and laying hens for egg production were forecasted by these results and other considerations, such as productivity growth. Productivity growth rates for the various sectors are important in estimating their activity levels in 2040 and 2060 for several reasons. First, relative growth rates can influence the profitability of a sector, as well as the resulting investment in that sector and production. Technical change in the livestock industry to 2060 will come from improved management techniques and improved genetics. The monitoring of individual animal performance (such as using microchips) to adjust feed intake and quality will be used in intensive animal operations. The continued industrialization of the production process for dairy, hog, poultry, and egg operations has implications for the number of animals needed to produce a given quantity of output. Mapping of the genome will allow for greater accuracy in selecting for desirable traits and in enhancing the traits related to productivity. Intensive livestock operations, at present, are able to implement these new technologies and to capture the increased productivity gains. Veeman and Gray (2009) report productivity gains: for beef – 34% increase in carcass weights (1980-2003); for sows – 38% increase over 1990 to 2003; and for dairy – 43% from 1991 to 2007. Therefore, it would take fewer livestock to attain a fixed level of final consumer product.

The total cattle population within the SSRB has, over the 2000 to 2010 period, ranged between 271,317 (2002 drought) to 368,141 (2005 BSE Crisis) and over the past three or four years, may be settling in at the 320,000 range. Efficiency gains in the dairy sector will come mainly from further consolidation as smaller enterprises leave the industry. Technology can then be more readily applied to increase the per unit output per cow. Another factor affecting the dairy industry is that per capita milk consumption is expected to fall with an aging population to 2040, could then rise to 2060 as the population gets younger.

The estimate from the Medium Term Outlook for fed cattle is a 10.7% increase from 2010 to 2020. This factor was used in estimating the change in feedlot capacity in the watershed to 2020, 2040, and 2060. Expansion of the irrigation capacity around Lake Diefenbaker could result in an increase in cattle feedlots, as irrigated crops for silage production make it a desirable location to establish feedlots.

After the calculations take into account the above considerations, the forecasted livestock numbers in the basin are shown in Table 4.7 for dairy and beef cattle, in Table 4.8 for hogs, in Table 4.9 for sheep, and in Table 4.10 for other livestock types. Poultry and egg layer forecasts are shown in Table 4.11.

Table 4.7: Forecasted Dairy and Beef Cattle Numbers for the South Saskatchewan River Basin, 2010-2060

Animal Type	Estimated Numbers on Farm			
	2010	2020	2040	2060
Bulls	6,538	7,011	7,224	7,369
Milk Cows	8,092	7,429	7,281	7,426
Beef Cows	128,133	137,398	140,146	142,949
Milk Heifers	3,864	3,551	3,476	3,546
Beef Replacement Heifers	21,228	21,202	23,218	23,683
Feedlot	45,308	50,156	55,172	60,689
Calves	118,662	127,242	129,787	132,383

Source: Statistics Canada (2006); Saskatchewan Ministry of Agriculture (2011b); 2020 projected using AAFC (2011).

Table 4.8: Hog Sector Estimated Population for the South Saskatchewan River Basin, 2010-2060

Animal Type	Estimated Numbers on Farm in			
	2010	2020	2040	2060
Gestating Sows	11,432	11,829	12,241	12,666
Suckling Pigs	248,986	269,473	291,084	313,873
Weaned Pigs	143,907	148,912	154,090	159,448
Growing & Finishing Pigs	143,907	148,912	154,090	159,448
Boars	309	364	335	317

Source: Statistics Canada (2006); Saskatchewan Ministry of Agriculture (2011b); 2020 projected using AAFC (2011).

Table 4.9: Sheep Sector Estimated Population for the South Saskatchewan River Basin, 2010-2060

Animal Type	Estimated Numbers on Farm			
	2010	2020	2040	2060
Rams	182	219	221	223
Ewes	3,681	4,431	4,475	4,520
Breeding	866	1,042	1,052	1,063
Slaughter	2,757	3,319	3,352	3,385

Source: Statistics Canada (2006); Saskatchewan Ministry of Agriculture (2011b); 2020 projected using AAFC (2011).

Table 4.10: Estimated Other Livestock Population for the South Saskatchewan River Basin, 2010-2060

Animal Type	Estimated Numbers on Farm			
	2010	2020	2040	2060
Bison	8,722	9,594	9,690	9,787
Horses	11,744	11,744	11,744	11,744
Goats	1,599	1,599	1,599	1,599
Llamas	798	798	798	798
Bees	8,906	8,906	8,906	8,906
Deer	1,079	1,079	1,079	1,079

Source: Statistics Canada (2006); Saskatchewan Ministry of Agriculture (2011b); 2020 projected using AAFC (2011).

Table 4.11: Estimated Poultry and Laying Hens Population for the South Saskatchewan River Basin, 2010-2060

Poultry Type	Estimated Number of Birds on Farms			
	2010	2020	2040	2060
Laying Hens	295,613	321,910	354,101	371,806
Pullets	98,695	114,772	126,249	132,561
Broilers	6,676,072	7,698,651	8,468,516	8,891,942
Other Poultry	8,583	9,442	10,386	10,905
Turkeys (Male)	156,991	183,819	202,201	212,311
Turkeys (Female)	104,661	122,546	134,801	141,541

Source: Statistics Canada (2006); Saskatchewan Ministry of Agriculture (2011b); 2020 projected using AAFC (2011).

4.3.3.2 Livestock Water Demand Coefficients

Forecasts of water demand of livestock to 2060 were based on the estimated livestock populations and estimated water demand coefficients. In this section, the estimation of water demand coefficients is described.

The type of livestock, their age, climate, feed, and location on farm (indoors/outdoors) all affect the uptake of water. Water needs are generally associated with the rate of water loss, which translates into temperature being a main factor. Generally, temperature has a greater effect on the water requirements of smaller animals than on those of larger animals. For example, a one week old broiler at 35°C barn temperature consumes 217% more water than at 30°C. Similarly, the six week old broiler consumes 13% more water (Rural Chemical Industries, undated). A grazing animal's water intake is affected by the type of pasture and the time of year as affected by the weather and moisture content of the forage.

Water use technology for the production of hogs has improved significantly over the last 10-15 years as bite type nipples replaced watering bowls; now, ball type nipples that reduce wastage even further are being adopted[26]. Small (2001) surveyed hog barns in Manitoba and Saskatchewan to determine water consumption for drinking, washing, cooling, and domestic. Regulations regarding the type of confinement for sows and feeders appear to be a major factor which may affect some of the water use activities. Water demand coefficients for hog production are presented in Table 4.12. The drinking water requirement of swine for various categories is presented in Table 4.13. The estimates were calculated from the average water demand by type of swine from Thacker (2001), plus the water used in production from Small (2001).

Table 4.12: Hog Production Related (Non-drinking) Water Use Requirements, 2001

Activity	Water Demand in Litres/sow/day
Washing	3.1
Cooling(grow/finish)	22.4
Cooling (farrowing)	0.3
Domestic	1.0
Total	**26.8**

Source: Estimations based on Small (2001).

Beef cattle consumption of water is affected by time of year and feed type. As expected, the moisture content of feed affects the amount of additional water needed (Olkowski, 2009). Dairy and feedlot operations generally use more silage in the livestock diets relative to beef cow-calf operations. The water consumption estimates at different temperatures for various categories of

[26] Some of these new technologies for livestock production also results in water losses. However, given lack of information on this aspect, no further adjustments were made.

beef cattle are presented in Table 4.14. These estimates were chosen to derive water demand coefficients for beef cattle in Saskatchewan, and then applied to the basin. First, the average normal high temperature for each month for several locations in a water basin was obtained from Environment Canada. Next, the water consumption for each month, as shown in the corresponding coefficients from Table 4.14, was used to estimate monthly consumption. The coefficients for estimating water demand are presented in Table 4.15. The water consumption estimates for dairy cattle employed various categories of milk production, given the temperature (Table 4.16), to arrive at water demand coefficients (Table 4.17). Water is also needed in the cleaning of dairy operations and it is estimated at 18.0 litres per cow per day (Beaulieu et al. 2001).

Table 4.13: Drinking Water Consumption for Swine

Type	Water Demand in L/day
Gestating Sows	8.78
Lactating Sows	20.04
Suckling Pigs	0.71
Weaned Pigs	2.01
Growing & Finishing Pigs	6.76
Boars	10.27

Source: Adapted from Thacker (2001).

Table 4.14: Beef Cattle Water Consumption (L/DAY) at Different Temperatures

Type	Weight of the animal (kg)	Water Consumption L/day at Temperature in °C					
		4.4	**10**	**14.4**	**21.1**	**26.6**	**32.2**
Background	182	15.1	16.3	18.9	22.0	25.4	36.0
	277	20.1	22.0	25.0	29.5	33.7	48.7
	364	23.0	25.7	29.9	34.8	40.1	56.8
Finishing	273	22.7	24.6	28.0	32.9	37.9	54.1
	364	27.6	29.9	34.4	40.5	46.6	65.9
	454	32.9	35.6	40.9	47.7	54.9	78.0
Pregnant	409	25.4	27.3	31.4	36.7		
	500	28.7	24.6	28.0	32.9		
Lactating	409	43.1	47.7	54.9	64.0	67.8	81.0
Bulls	636	30.3	32.6	37.5	44.3	50.7	71.9
	727	32.9	35.6	40.9	47.7	54.9	78.0

Source: Olkowski (2009).

Water consumption coefficients for six categories of poultry were derived through the same methodology used to estimate the coefficients for the beef and dairy sector; these coefficients are presented in Table 4.18. Water is also necessary in the cleaning of poultry operations, and it is estimated at 1.7 litres per bird per year (Beaulieu et al. 2001).

Table 4.15: Estimated Water Demand Coefficients for Beef Cattle

Type/Weight	Weight (kg)	Water Use in L/day
Background	182	19.05
	277	25.42
	364	29.73
Finishing	273	28.55
	364	34.93
	454	41.37
Pregnant	409	35.36
	500	36.17
Lactating	409	53.59
Bulls	636	38.17
	727	41.37

Table 4.16: Dairy Cattle Water Consumption L/Day at Different Temperatures

Milk production kg/day	Water Use for Min. Mean Temperature in degrees				
	4.4	**10.0**	**15.6**	**21.1**	**26.7**
18.1	69.7	76.5	83.3	89.7	96.5
27.2	82.5	89.0	95.8	102.6	109.4
36.3	95.0	101.8	108.6	115.1	121.9
45.4	107.9	114.7	121.5	127.9	134.8

Source: Looper and Waldner (2007)

Table 4.17: Estimated Water Demand Coefficients for Dairy Cattle

Milk Production in kg/day	Water Demand in Litres/day
18.1	94.8
27.2	107.5
36.3	120.1
45.4	133.0

Table 4.18: Estimated Water Demand Coefficients for Poultry

Poultry Type	Water Demand in Litres/ day
Laying Hens	0.275
Pullets	0.168
Broilers	0.413
Other Poultry	0.413
Turkeys (M)	0.566
Turkeys (F)	0.474

The coefficients presented in Tables 4.12, 4.13, 4.17, and 4.18 were used for estimation of total water demand in the basin for livestock production. Other than climate change, additional factors that affect water demand coefficients were assumed to remain the same as at present. The effect of climate change is incorporated in Chapter 5.

4.3.4 Greenhouse and Nursery Water Demand

For nurseries and greenhouses, the water needs or requirement per plant were estimated and multiplied by the total number of plants per nursery. This figure was calculated for all the nurseries in the region, depending on their sizes. These coefficients are shown in Table 4.19. The same procedure was applied to greenhouses. The trend in these parameters was appeared to forecast future demand for water for this purpose. The estimated future area for the greenhouses and nurseries is shown in Table 4.20.

Table 4.19: Water Demand Coefficients for Greenhouses and Nurseries, South Saskatchewan River Basin

Particulars	Amount of Water Used for		
	Irrigation in m/m^2	Pesticides Spraying in L/m^2	Wash[1] (%)
Vegetable	1.375	1.25	0.3
50% Flower Pots	4.500	9.00	0.3
50% Flowers	1.180	9.40	0.3
Other	0.800	0.75	0.3

Notes: 1: Percentage of Spray water
Source: Beaulieu et al. (2001).

Table 4.20: Area of Greenhouses in the South Saskatchewan River Basin, 2010 - 2060

Particulars	2010	2020	2040	2060
Area in Acres	9.4	9.5	10.0	10.5
Estimated Water Demand Coefficient	30.41	30.41	30.41	30.41

Source: Statistics Canada (2006)

4.3.5 Water Demand for Aquaculture

As noted in Chapter 2 of this report, information on aquaculture activities was unavailable for use in this study. Although there is a reported aquaculture operation in Lake Diefenbaker, its current existence and operational details were not confirmed. However, as a substitute, the level of this water demand was taken from R. Halliday & Associates (2009) report. Surface and ground water demand for aquaculture was estimated at 127 dam^3 and 172 dam^3, respectively. It was assumed that this quantity of water will remain unchanged to 2060.

4.4 Forecasting of Industrial/Mining Water Demand

The methods used for forecasting water demand for mining and manufacturing industries in the basin are described in this section. In addition to accuracy for existing industries, an effort was also made to project new industries that might be initiated as a result of irrigation development in the basin.

4.4.1 Future Potash Production Related Water Demand

4.4.1.1 Future Potash Production

The world demand for potash to 2040 and 2060 will depend on the area of land which is potash deficient, the potash requirement of the crops produced, and the profitability to the farmer of applying the nutrient. Traditionally, when producers face low agricultural commodity prices, potash is the first nutrient to be reduced or eliminated, as its effect on crop yield over a short period of time is not significant compared to that of reducing nitrogen or phosphorus application. There have been periods of overcapacity in the potash industry when the expected demand for potash has not materialized. Because of the high capital costs of establishing a mine the breakeven price for potash is estimated at US$200 and US$235 per tonne for solution and for underground mines, respectively (CIBC World Markets Inc., 2008). A 15% return on investment translates into a potash price of US$435 and US$580 per tonne for solution and underground mines, respectively (CIBC World Markets Inc., 2008). Whether future market price for potash will be in this range will determine further expansion world over, including the SSRB. It is estimated that the world potash market may increase annually by 3% to 2020 (CIBC World Markets Inc., 2008). At this rate of growth, the world potash industry will be in an oversupply situation from the time that all the new mines come on stream until 2022.

In the SSRB, there are no new mines projected to be built. This may be the case because eventually, new mines will have to be built by 2060 to replace the mines developed in the 1950s and 1960s; the distance to the ore body increases, making further extraction uneconomic at these sites. Water is used in the separation process in all potash mines and in the ore extraction of solution mines. A complete electrostatic process could reduce the demand for water for those mines using underground mining technology (Personal communication, Jack M. Nagy, P. Eng., Surface Project Coordinator, PCS Potash Rocanville). This may be an option for new mines as the design of the mill could accommodate the process flow more readily than an old mill.

The estimated total production of potash in the SSRB is shown in Table 4.21. The total production is expected to rise from the existing 4.5 million tonnes of potash to about 6.5 million tonnes – an increase of about 69% over the 2010 production level.

Table 4.21: Future Potash Production in the South Saskatchewan River Basin, 2020 - 2060

Corporation	**Mine Location**	**Potash Production in Thousand Tonnes**		
		2020	**2040**	**2060**
Potash Corp	Allan	1,900	2,900	2,900
	Patience Lake	610	610	610
	Cory	2,200	2,200	3,500
Total Production		**4,510**	**4,710**	**4,710**

Source: CIBC World Markets Inc. (2008); Saskatchewan Watershed Authority (undated).

The respective water coefficients for the existing mines were used to estimate their future water demands (see Table 3.10). The assumptions are that the percentage of potash in the mined ore and the final products being produced remain at their historical levels. Underground and solution mine coefficients of 0.82 and 1.63 dam^3 per tonne, respectively, are employed to estimate water demand for the new potash mines. These are coefficients for mines in the same region as the proposed new mines, and one would reasonably expect that similar water amounts would be required because they are operating in the same potash formation.

4.4.4.2 Water demand for Tailings Management

Recent government regulations call for the Saskatchewan potash producers to develop sustainable management plans for the tailings piles currently stored above ground. One possible solution is to inject the tailings, converted into slurry, into underground storage. Since the tailings program is just a proposal with no firm start date or commitment, this water demand will not be included in the estimates. The details of this proposal are shown in Appendix E.

4.4.2 Magnesium Sulphate Mining

Although a company producing magnesium sulphate has been established in the basin, and since its operational details are not available, its water demand is assumed to be equal to zero.

4.4.3 Oil and Gas Production

The Viking formation has an estimated proven reserve of 2.3 billion barrels of oil, of which recoverable reserves, based on vertical well and water flood technology, would produce 214 million marketable barrels. Vertical wells in the Viking formation have, on average, produced for 30+ years (PetroUno Resources Ltd 2010). Oil production from vertical wells in 2010 was 2.5 million barrels and from horizontal wells, 90,000 barrels (Canaccord Genuity, 2011). Given this rate of extraction, the Viking formation will produce for 80 years. The Shaunavon formation has an estimated marketable reserve of 235 million barrels of oil. The production of oil in the Shaunavon formation has been about 5.5 million barrels per year in 2008 and 2009 (Marsh & Jensen, 2010). At this rate, the Shaunavon formation would have a life of 42 years. Natural gas production for 2010 in Saskatchewan was estimated at 5.2 $x10^9$ m^3 (NEB, 2011). Given that there is 151 $x10^9$ m^3 in marketable reserves, at current extraction rates, there are 29 years of production with the current and immediate technology. Typically, oil field production follows a bell-shaped curve with the right-hand tail truncated where production becomes uneconomic. As of 2010, there were 27,000 and 20,000 producing wells of oil and natural gas, respectively, in Saskatchewan.

Saskatchewan in 2010 had drilling activity of 1,894 and 69 new oil and gas wells, respectively. Over the 2000 to 2010 period, on average, 3,584 wells were drilled in the province. Approximately 56% of the wells drilled in Saskatchewan in 2010 were horizontal, with the Bakken formation accounting for the majority of wells drilled. The amount of well drilling in the Viking and Shaunavon formations could be expected to remain at the average ten-year rate to 2020, reducing to 60% by 2040 and to 15% by 2060 as the field ages. The designated areas of natural gas exploration are relatively mature with most of the large pools having been discovered (NEB 2008). Oil production in the SSRB has occurred since the early 1950s. Changes in technology and increases in the price of oil have made extraction of oil in the Viking and Shaunavon formations profitable. As with natural gas, most of the large pools of oil have been discovered. The water demand for injection into a producing well declines over time as the field matures; the issue is not pressure but rather viscosity of the oil and porosity of the formation (Moore & Lunn, undated). Other techniques such as polymer, steam, or CO_2 maybe used to extend the life of the field. The estimated oil and gas well drilling activity in the SSRB is presented in Table 4.22.

Table 4.22: Estimate of Drilling Activity in the South Saskatchewan River Basin, 2010 - 2060

Technology of Production	No. of Wells in			
	2010	2020	2040	2060
Vertical	50	67	40	10
Horizontal	20	27	16	4

Table 4.23: Oil and Gas Well Drilling Water Demand, South Saskatchewan River Basin for 2010 to 2060

Type of Wells	2010	2020	2040	2060
Primary	18.56	24.92	14.95	3.74
Water Flood	41.86	56.20	33.72	8.43
Horizontal	106.43	142.89	85.73	21.43
Enhanced	38.18	51.26	30.76	7.69
Total	205.02	275.28	165.17	41.29

Table 4.24: Total Water Demand in the South Saskatchewan River Basin for Water Conservation Scenario 2010-2060

Year	Water Demand in
2010	205.02
2020	233.98
2040	140.39
2060	35.10

4.4.4 Manufacturing Water Demand

Manufacturing water demand in the basin during 2010 - 2060 will be a result of water required by existing industries, as well by some new developments. New industry groups could be of two types: new industry groups resulting from changes in the economic factors and those induced by developments in the basin. No forecasts of new industry groups moving to Saskatchewan (and thus to the basin) were found. However, the development of some industries is plausible. These industry groups were identified through a review of other studies. Most of these studies were based on the development of irrigation in the basin.

4.4.4.1 Existing Manufacturing Industries' Water Demand

The estimation of potential changes in the level of production, along with changes in water use technology for industry, is a complex task. Because of a lack of information on potential details for various establishments in the SSRB, estimations of their water demand coefficients could not be made. The only coefficient that could be estimated was for the Cargil canola crushing plants, where 0.56 dam^3 of water is required per 1,000 tonnes of canola crushed.

4.4.4.2 Induced Economic Development Activities

In addition to expansion in existing industrial water users, the basin may attract some other types of industrial water users. These developments are hypothesized to be induced by either irrigation projects, or by other related initiatives. SIPA (2008b) has suggested the following types of value-added building blocks for Saskatchewan, resulting from irrigation development:

- Beef livestock -- producing new heads of cattle and processing them in the province
- Pork livestock -- producing and processing hogs
- Dairy production coupled with additional dairy processing activity
- Vegetable processing – particularly potato processing
- Energy – production of 20 million litres of ethanol annually

For the SSRB, hog and dairy production were excluded from these developments, partly because the basin has not shown a big increase in hogs or in dairy (since dairy is subject to quotas for further expansion). Potato processing was also excluded since the crop mix, as proposed for irrigation, did not contain specialty crops (such as potatoes). In this section, three types of developments are envisaged in the basin: (i) more hog operations; (ii) more feedlots resulting from irrigated forage; (iii) higher ethanol production resulting from higher production of grains (and perhaps corn); and (iv) additional agri-processing firms to handle irrigated products.

Swine Expansion in the Irrigation Districts

Although hog breeding stock in the SSRB has declined by 17% from the 2001 levels, there has been a considerable decline (47%) in market hog production since 2001. Currently, the barn capacity for farrowing, weanlings, and feeders is 6,951, 33,700, and 19,551 head in crop districts 3B-N and 6B, which comprise most of the current and projected irrigated area in the basin. Given recent problems in the hog industry, expansion of capacity to 2020, especially for feeder barns, is unlikely. The Medium Term projection by Agriculture Canada of the demand for hogs, however, shows a slight increase over current levels of production. Access to water for watering the livestock would be one main advantage to their location in an irrigation district. This has to be balanced with having enough area to dispose of manure. Typically, a swine intensive livestock operation (ILO) buys all its feed inputs and processes them in their own mill or buys processed rations if such feed inputs are not available in the vicinity of the barn area. As irrigated area expands to 2060, there could be opportunities to expand the feeder barn sector in or near the irrigation districts. However, their location is not contingent on being near feedstocks. In this study, it was assumed that these feedlots would be operational because of the availability of water and feed grains.

Beef Feedlot Expansion in the Irrigation Districts

To estimate the level of expansion of intensive livestock operations allowed by increased irrigation in the SSRB, the area required for feed production, bedding, and manure disposal need to be considered. The magnitude of this area will determine the number of enterprises that could effectively operate. The production of silage using irrigation for dairy or cattle feedlots is the main enterprise that would be attracted to an irrigation district. Transportation costs for the bulk, low density products of silage, straw, and manure limit the range over which these products can be economically transported, making their location within the basin more likely.

The number of head and type of feeding (background, finishing, or both) will determine the amount of irrigated area needed for silage production and the amount of water needed for the livestock. The background feeder cattle typically require 1.18 tonnes of silage over a 128 day feeding period while finishing cattle will require 0.27 tonnes over a 143 day period (ICDC undated). Barley and corn are the main crops grown for silage, with average yield for silage of 14.5 and 21.7 tonnes per acre, respectively (ICDC, 2011). The economic hauling distance of silage and manure are two of the key factors in the overall profitability of an intensive livestock operation. The amount of land needed is dependent on the rotational constraints of crops grown, along with the amount of manure that can be applied.

A base unit of production for a 10,000 head capacity feedlot at a 1.45 refill rate for a feeder calf to finishing operation would require yearly 1,445 acres of barley or 967 corn acres (or a combination thereof) to meet the silage requirement. If the rotational constraints are set to every 2nd year, then 2,891 and 1,934 acres for barley or corn rotation, respectively, are needed. Therefore, up to 20 quarter sections are necessary for a barley-based feedlot and up to 14 for a corn-based feedlot.

Daily manure production in a feedlot is approximately 25.9 kilograms per animal (Saskatchewan Ministry of Agriculture, 2011d). Therefore, on a yearly basis, approximately 6,000 acres are needed for manure application given an application rate of 22.7 tonnes per acre. Since manure can be applied only every 3rd year, 18,000 acres must be available for manure application within an economical hauling distance. Therefore, the constraint that would limit the number of intensive livestock operations within an irrigation district is the requirement of adequate area to dispose of the manure within the economical hauling distance. Technological developments such as biodigesters enable greater economical hauling distances relative to raw manure, for a higher-value end product is created. The drawback is that it adds to the capital cost of starting a feedlot, combined with the capital cost of irrigation.

The proposed Westside irrigation project of up to 356,800 irrigated acres, along with infill in the Riverhurst Irrigation District (RHID) of 11,000 acres, Luck Lake Irrigation District (LLID) of 9,397 acres, and in the South Saskatchewan River Irrigation District (SSRID) 28,254 acres, could accommodate several beef ILOs. Presently, there are two beef ILOs located in the irrigation district – one near LLID (3,750 head) and another one in the SSRID (1,750 head). The locations of the ILOs such that the maximum amount of non-irrigated land could be accessed for manure disposal and a mix of sizes would be required if irrigation is not a sufficient condition for feedlot development. The induced number of feedlots is based on the Westside expansion project, while infill of irrigation area in the current irrigation districts will result in an increased number of feedlots.

Table 4.25: Induced Number of Feedlots in South Saskatchewan River Basin, 2020 - 2060

Year	Total Number of Induced Feedlots
2020	2
2040	14
2060	23

Future Ethanol Production

The National Renewable bio-Fuels mandate calls for 2% biodiesel and 5% ethanol in diesel and gasoline, respectively, while Saskatchewan has a 7.5% ethanol fuel requirement for gasoline. In 2009, 70 percent of the gasoline sales in Saskatchewan are for transportation, 11% for agriculture, and 17% for commercial purposes (Statistics Canada, 2011b). The amount of diesel and gasoline used in Saskatchewan from 2002 to 2009 is presented in Table 4.26. The rise in economic activity in the industrial and commercial sectors accounts for most of the increase.

Table 4.26: Fuel use in Saskatchewan 2002 to 2009

Year	Amount in ML for	
	Diesel Fuel	Gasoline
2002	1,407.8	1,684.6
2003	1,522.3	1,759.8
2004	1,595.3	1,747.9
2005	1,822.8	1,755.8
2006	1,913.1	1,911.3
2007	2,138.2	2,109.9
2008	2,153.6	2,279.1
2009	2,217.4	2,419.6

Source: Statistics Canada (2011b).

The current plant capacity in Saskatchewan for ethanol and biodiesel is presented in Table 4.27. At the Saskatchewan mandate of 7.5% ethanol blend, there is more than enough capacity to meet this regulation. However, for biodiesel use, production would have to increase by 40 times in order to fill the needs of the Saskatchewan market.

Table 4.27: Biofuel Plant Location and Capacity in Saskatchewan

Company	**Location**	**Feedstock**	**MLy**
Ethanol Plants in Saskatchewan			
Husky Energy Inc.	Lloydminster	Wheat	130
NorAmera BioEnergy	Weyburn	Wheat	25
North West Terminal Ltd	Unity	Wheat	25
Pound-Maker Agventures	Lanigan	Wheat	12
Terra Grain Fuels Inc.	Belle Plaine	Wheat	150
Total			**342**
Biodiesel Plants in Saskatchewan			
Milligan Bio-Tech	Foam Lake	Canola	4

Source: Canadian Renewable Fuels Association (2011 a & b)

Irrigated area in the proposed South Saskatchewan South Westside project could be used to produce feedstocks for the ethanol industry, either for a grain-based or a biomass-based plant. Husky Energy Inc. and the North West Terminals would be important markets for farmers wanting to grow high yielding, high starch grains. The improvement in the yield of grain corn that matures with less than 2400 heat units, combined with increased temperatures and longer growing seasons caused by climate change could result in irrigated area being devoted to grain corn. Competitive grain corn yields relative to other crops, and combined with a market for corn stover residue, could make this a profitable crop relative to other alternatives.

A biomass ethanol plant with a capacity of 30,000 tonnes, using corn stover as the primary feedstock at a yield of 1.6 tonnes per acre, would require 18,525 acres per year. If can were seeded once in a four-year rotation, the estimate would be 74,100 acres. The SSRB irrigation districts could accommodate up to five 30,000 tonne corn stover biomass plant or a larger plants if other biomass feedstocks were used.

Water Demand Implication of Future Beef Feedlots and Ethanol Production

The irrigated crop area for livestock production will be the competing agricultural activity for the biomass produced in the irrigation district. The economical hauling distance of the biomass, whether for the livestock feedlot or the ethanol plant, is a key factor in the profitability of either operation. The crop mix on the irrigated land in the SSRB would be influenced by the establishment of up to twenty-three 10,000-head livestock feedlots, or up to five 30,000 tonne ethanol plants, or combinations thereof. A shift from cereal crop production to silage for livestock or grain for ethanol would change the demand for water. Barley or corn silage crops have different water requirements and different water demands than those for the production of grain from small cereal grains or corn crops (Table 4.28).

Table 4.28: Water Demand of Selected Irrigated Crops

Crops	Water Demand per Acre in mm/Year	% of CWRS
Corn Grain	520	113%
Corn Silage	470	102%
Barley Silage	390	85%
CWWS	480	104%
CWRS	460	100%

Source: ICDC (2008a).

Increased production of barley silage or grain corn relative to the base crop mix would have the biggest effect on water demand for irrigation. An increase in the area seeded to grain corn in order to meet the biomass requirements for a 30,000 tonne ethanol plant in the South Saskatchewan South project would increase the water demand for irrigation by 1,230 dam^3, the number is estimated as the extra amount of water required to grow grain corn, as opposed to small grains. Likewise, an increase in area seeded to barley silage for accommodating 23 beef feedlots would reduce the water demand by 2,727 dam^3 from the base scenario.

Water will also be needed both for livestock watering and for the production of ethanol a 10,000 capacity feedlot requires 184.9 dam^3, and with 23 feedlots, the total would expand to 4,252.7 dam^3. Depending on the type of production process used, water consumption in a biomass ethanol production could be 33.7, 22.3, or 7.2 litres per litre of ethanol for current technology, advanced technology, or gasification, respectively (Wu et al., 2009). Therefore, a 30,000 tonne ethanol plant would require 364 dam^3, 241 dam^3, or 78 dam^3 if its technology used was the current technology, advanced technology or gasification, respectively.

The net effect of the induced activity from an expansion of irrigation in the SSRB is 23 livestock feedlot operations with a capacity of 10,000 head and 5 biomass ethanol plants. Using advanced technology would reduce the water demand by 58,468 dam^3 and increase the demand by 7,355 dam^3, respectively, for a net 51,113 dam^3 change by 2060 from the base scenario. The details are shown in Table 4.29.

In terms of the future ethanol and biodiesel market in the basin (or in the province), a number of factors need to be considered. New fuel efficiency standards for vehicles that will come into effect over the 2013-15 period will affect the demand for transportation fuels by 2020. Ethanol and biodiesel will have to be competitive with petroleum motor fuels and other alternative sources of energy in order to increase their respective market shares above the government-mandated levels. Biodiesel is price competitive with diesel if produced from sample grade canola or flax (Nagy & Furtan, 2006). New crops, such as Camelina, may provide a feedstock for biodiesel manufacture that is also competitive with petroleum diesel. However, the market in Saskatchewan of about 40 ML is small compared to the cost competitive plant sizes of 250 ML and over, of which two biodiesel plants of this size are proposed for Alberta. Beyond the expansion plans of Milligan BioTech of 20 ML by 2020, there will be no major growth for this biofuel production in Saskatchewan. Cellulosic ethanol plants using biomass are the next generation of plants that could have a growth potential in Saskatchewan. However, their relatively small size compared to grain ethanol plants (due to the limited economical range of feedstock transportation) requires a reliable, cheap source of biomass to be competitive.

The transportation fuel market in Saskatchewan could reasonably be expected to be in the 2,000 to 3,000 ML range for both gasoline and diesel markets by 2020, given economic growth and regulations on vehicle fuel consumption. Therefore, the mandated biofuel requirements for ethanol will be easily met from Saskatchewan production. Export markets in British Columbia, Alberta, and northern tier States are the growth areas for Saskatchewan ethanol production.

Table 4.29: Change in Water Demand due to Induced Impact of Irrigation Activity in the South Saskatchewan River Basin

Economic Activity	No. of Operations	Direct Water Demand (dam^3)	Change in Irrigation Water Demand (dam^3)	Change in Total amount of Water Demand
Feedlots	23	4,252.7	- 62,721.0	- 58,468.3
Ethanol Plant	5	1,205.0	6,150.0	7,355.0
Total Change in Water Demand		**5,457.7**	**- 56,571.0**	**- 51,113.3**

Agri-Processing Development

Associated with the feedlots could be an increase in the slaughtering and meat processing industry. On account of the late start of irrigation, no change is expected by 2020. For 2040, it is assumed that there will be 2 large and 2 small slaughtering and meat processing plants in place. By 2060, with the increased irrigated area, there will likely by 5 large and 3 small such plants. It was assumed that, by 2040, a total capacity of 30,000 head of cattle will be needed. By 2060, there could be 5 large and 3 small plants, with a total capacity of 65,000 head of cattle.

The water demand coefficient for these plants was based on a review of the relevant literature.[27] For North Carolina, US, plants, a coefficient of 567 to 1,703 litres of water per animal slaughtered was reported. Using a mid-value of this interval, it is assumed that 1,135 litres of water per animal (equivalent to 0.001135 dam^3) would be required by these plants.

4.4.5 Electricity Generation

SaskPower has a provincial generation capacity from both owned and purchased power of 3,982 MW, of which 1,031 MW capacity (26%) is in the SSRB. An estimated new capacity for Saskatchewan of 1,609 MW will be needed by 2020 and by 2033, of 2,159 MW along with replacement of, or reinvestment in the existing capacity to 2060 (SaskPower 2011). Many different generation and conservation options will be used to meet the expected demand, given the cost structure of each option along with the requirements of meeting base and peak load demand. Since a large percentage of the population and economic activity is centered on Saskatoon, its generation capacity within the basin would be expected to increase with the electricity demand in the basin. Also, the replacement of existing generating stations will likely occur by electricity generating plants located within the basin near existing transmission lines. It is also likely that to 2020, the current generating capacity (if replaced) will have similar technology. At 2040 and certainly 2060, other generating options will be available; they will have different water demand requirements from those the present technology. Estimates of electricity generation by source are presented in Table 4.23. The increased capacity, as forecast by SaskPower, is allocated to power generation by wind, co-generation, hydro, natural gas, waste heat, solar, Biomass, and nuclear.

4.5 Forecasting of Municipal/Domestic Water Demand

Forecasts for municipal/domestic water demand are typically done by applying past trends in factors that have been shown to influence future water demand. These factors, according to Whitford (1972), need to be taken into account in making any future estimate of water demand. Six factors that affect the future demand of water have been shown to be (1) regulations on the

[27] We are very thankful to Ms. Dolores Funk for providing information on water requirements for various types of uses based on a review of literature.

amount of water used by appliances, (2) type of pricing policy, (3) level of public education, (4) future housing patterns, (5) cost of supply, and (6) technological change.

Table 4.30: Electricity Generation Estimates in the South Saskatchewan River Basin, 2010 - 2060

Type	Amount of Electricity Generated in MW in			
	2010	2020	2040	2060
Wind	172.0	274.0	379.8	485.6
Cogeneration	228.0	362.9	503.1	643.2
Hydro	186.0	185.9	186.1	185.7
Nat Gas	460.0	616.4	833.3	882.4
Waste Heat	5.0	7.0	61.4	156.9
Solar	0	14.8	40.9	130.8
Biomass	0	14.8	40.9	130.8
Total	1,051.0	1,475.7	2,045.5	2,615.3

Source: SaskPower 2011; Authors' estimates for 2020 to 2060.

Regulations and pricing policy are important determinants of water demand in any community. Saskatchewan follows the National Building Code for Plumbing. Since it is a small market, the assumption is that such regulations on appliances are unlikely to be different than those at the national or North American level. In contrast, the pricing regime for water followed by the municipalities is totally within their control. For example, Saskatoon has implemented an increasing block rate structure for water rates. However, these policies are unlikely to change significantly unless there are severe supply side problems, such as extended droughts (or severe impact of climate change). Also, the cost of supplying water for many communities in the SSRB on a per capita basis is relatively high; new capital outlays, given a stagnant or declining population, seem prohibitively expensive. In Saskatchewan, of the total households supplied by municipal water systems, 91% had meters (Statistics Canada, 2006).

Provincially, through the Saskatchewan Watershed Authority and locally, through municipalities, efforts have been made to switch to lower water use appliances (i.e., rebates for low flush toilets). Programs for educating the public to varying degrees on the use of water have been, and are being, implemented. The urgency or force of the approach seems to depend on immediate supply side problems (drought, or plant shutdown, among others). These factors influence the adoption of water conservation and thereby affect water demand. However, to predict these changes is somewhat problematic.

The current pattern of residential development in Saskatchewan appears likely to hold until 2060, as well as the accompanying water demand characteristics that this entails. New housing replacing old housing, appliances being upgraded as useful lives end, and appliances either coming on to the market or expanding their market share will all affect the per capita water demand. Income and home ownership are two factors that affect the adoption of water conservation technology and conversely, the purchase of new water using appliances (Gibbons, 2008).

The effect of all these factors on per capita water demand is therefore mixed. For example, new demands or expanded market shares for appliances like hot tubs, would increase per capita demand. The rate of replacement from 1994 to 2006 of low flush toilets and low flow showerheads in Saskatchewan was 1.9% and 0.9% per year, respectively (Statistics Canada, 2008b). However, this rate of change is unlikely to be sustained in the future, as most households will have adopted these measures, and the scope for further change is limited. This circumstance may also be the end of the spectrum of technology change with low flush toilets representing forced change through regulation. By contrast, low flow showerheads' adoption is driven by education or rebates. These changes are even harder to predict for the future.

Combination of these factors resulted in a reduction in per capita water demand in the SSRB from 188.2 m^3 in 1995 to 181.9 m^3 in 2009 (Saskatchewan Watershed Authority, 2009). This alternation suggests a 0.5% per year decline in water use over this period.

Information on regulations, pricing, cost of supply and public education were not available for estimating future water demand in the basin. As a crude approximation, future water demand was first by change in number of water users (measured as population) and adjusted water demand coefficients based on past trends. The total water demand was simply a product of projected population (2020, 2040, and 2060) for a given type of community and their respective water demand coefficient for a given point in time. The methods followed for these forecasts are described in the following sub-sections.

4.5.1 Estimation of Future Population

Future population of the SSRB will be influenced by the overall population of the province. Within that, different cultural groups may also exhibit different trends of population growth over the future years. For example, population growth rates for First Nations' and non-First Nations' groups have been different and are expected to be different in the future. To take into account possible differences in their growth rates, future levels of these populations groups were estimated separately, starting with the overall provincial population. In addition, there may be a significant amount of interbasin migration of people. These migration patterns have not been studied.

4.5.1.1 Forecasts of Provincial Population

Statistics Canada (2011c) has estimated the Saskatchewan population over the period 2020 to 2036 by using six basic scenarios (Low, Medium, High, replacement fertility, no immigration, and 1% immigration). The projected rates of growth are presented in Table 4.31. Recent population growth trends reflect resource development in the potash and oil sectors; however, once the development/construction phase is completed employment levels generally fall. The lowest prediction for growth in the population occurs under the "no immigration" scenario, estimated at 0.14% per annum. The highest growth rate was estimated under the "replacement fertility" scenario, where Saskatchewan population could grow at the rate of 0.91% per annum.

The growth rates of Saskatchewan will not be shared equally by all regions. The rate of population growth in Saskatchewan by economic regions for three time periods from 1996 to 2009 is presented in Table 4.32. Basically, the growth has been in the larger cities. It is observed that the more rural and agricultural an economic region is, the higher is the loss in population. The fundamental trend in Saskatchewan has been the migration of people from rural areas to the larger centers or to other provinces, with a very small level of migration from other regions of Canada and/or the world.

Table 4.31: Statistics Canada's Population Growth Rate for Saskatchewan

Projection Scenario	% Growth per Annum
Low-Growth	0.335
Medium-Growth, Historical Trends (1981 To 2008)	0.617
Medium-Growth, 2006 To 2008 Trends	1.140
Medium-Growth, 1988 To 1996 Trends	0.374
Medium-Growth, 2001 To 2006 Trends	0.375
High-Growth	0.894
Replacement Fertility	0.915
Zero Immigration	0.142
1% Immigration	0.778

Source: Statistics Canada (2011c)

Statistics Canada's (2011d) analysis of the components of population growth by economic region reveals that only the Saskatoon and Regina regions have been the recipients of intra-provincial migration. The greatest percentage of population growth in Saskatchewan to 2060 will be in the larger cities (Regina, Saskatoon, Prince Albert, Moose Jaw) and associated bedroom communities (if any). Most villages in Saskatchewan are on a long term decline in population. However, it is conceivable that their future population may, at best, hold steady.

Table 4.32: Population Rate of Growth by Economic Region, Saskatchewan

Region	Rate of Growth per Annum		
	1996 to 2009	**2001 to 2009**	**2006 to 2009**
Saskatchewan	1.10%	2.99%	3.83%
Regina-Moose Mountain, Saskatchewan	1.87%	4.46%	4.36%
Swift Current-Moose Jaw, Saskatchewan	-10.05%	-4.62%	0.50%
Saskatoon-Biggar, Saskatchewan	8.90%	8.10%	6.19%
Yorkton-Melville, Saskatchewan	-13.05%	-6.94%	-0.17%
Prince Albert, Saskatchewan	-0.18%	0.73%	2.86%
Northern, Saskatchewan	13.89%	11.18%	4.40%

Source: Statistics Canada (2011d)

Rural population will continue to decline, as there will be fewer farms and smaller farm families. Also, larger equipment and the introduction of robotics/GPS will further reduce the need for farm labor. Towns that are dependent on the farm sector will either maintain their population or decline, since there are fewer retirees moving in from the farm, which has been the main source of new residents. As the rationalization of the grain handling sector has reduced delivery points, the same forces are at work in the consolidation of other farm services. The exception to this trend will be towns and villages located close to large urban centers such as Saskatoon or Humboldt.

Projected growth in mining, industry, and commercial activity will be the main determinants as to whether the population will increase for towns and the medium size cities (Swift Current, Estevan, Weyburn, Yorkton, North Battleford, Humboldt[28]). Most of this growth is relatively capital intensive, whether it is in the mining, industrial, farm, or commercial sector; moreover, such growth subject to proposals by firms, and then regulatory process.

In order to develop some guidelines for future changes, a forecast of provincial population was considered to be of some use. Since a systematic forecast of this variable for Saskatchewan is not available,[29] projections were made from Statistics Canada's growth assumptions. In particular, a low growth and a high growth scenario rate of change (as listed in Table 4.32) were used.

[28] It should be noted that many of these communities are in other river basins of Saskatchewan.

[29] In August 2011, the authors of this report were informed of a study being undertaken by Saskatchewan Health on future population projections. At the time of writing this report, these estimates were unavailable.

Assuming the growth rates to be linear per annum, a projected population was estimated. These are shown in Table 4.33. According to these estimates, the Saskatchewan population by 2060 could be anywhere from 1.23 to 1.52 million people, for an average of 1.375 million people. For this study, an average of these two estimates was used.

Table 4.33: Estimated Saskatchewan Population under Alternative Assumptions

Year	Low Growth Projection	High Growth Projection	Average Population
	No. of People in Thousands		
2020	1,087.3	1,146.1	1,116.7
2040	1,122.5	1,240.2	1,181.4
2060	1,228.3	1,522.3	1,375.3

4.5.1.2 Forecast of Population Changes in the South Saskatchewan River Basin:

The SSRB water supports municipal/domestic water demand in communities within the basin as well as outside the basin (in the Qu'Appelle River Basin). The estimated water demands were disaggregated for these two types of communities.

The Saskatchewan Watershed Authority has data on the use of water from 1995 to 2009 by urban municipality and for some businesses and institutions (Saskatchewan Watershed Authority, 2010). These data were analyzed by regression analysis (ordinary least squares) to forecast the future population of SSRB. Out of three tested models- linear, curvilinear, and logarithmic regression- the most suitable model was used to predict future values. In the cases where time did not show a trend, a different approach was applied. Specific growth rates and the rationality behind those assumptions will be further explained in the following sections.

Past trends and overall population forecasts were employed to create population growth scenarios for the SSRB.[30] The estimates, as described below, are based on the following assumptions:

- In order to forecast the future population of cities (Martensville, Saskatoon, Swift Current, Warman) located in the SSRB, regression analysis was undertaken. For Martensville and Warman, a linear trend regression was utilized to forecast future

[30] It is realized that these projections are somewhat subjective and requires a study of population growth in the province by River Basins.

developments, whereas for the rest, a non-linear trend (using log-linear functional form) was chosen. Cities located in the South Saskatchewan Watershed indicate an ascending trend in terms of population. Regressions equations are shown in Appendix F. Projections were made for 2010, 2020, 2040, and 2060; the values can be seen in the table below (see Table 4.34).

Table 4.34: Population Projection for Urban Communities and Villages, South Saskatchewan River Basin, for 2010 - 2060

Category	Population				2060 Population as % of 2010
	2010*	2020	2040	2060	
Communities within the SSRB					
Martensville	6,345	8,311	12,244	16,177	254.96%
Saskatoon	221,668	241,488	286,603	340,147	153.45%
Swift Current	16,291	16,626	17,315	18,034	110.70%
Warman	6,044	8,299	12,808	17,318	286.53%
Bed Comm.	5,999	8,329	12,989	17,649	294.20%
T>1000	12,609	13,506	15,300	17,094	135.57%
T<1000	5,852	6,073	6,700	7,370	125.95%
Sub-total Urban	**274,808**	**302,632**	**363,959**	**433,789**	**157.85%**
Villages	6,637	6,305	6,139	6,016	90.64%
Rural farm	15,939	14,345	11,476	11,157	70.00%
Rural non-farm	9,048	8,143	7,238	6,334	70.00%
Sub-total Rural	**31,624**	**28,793**	**24,853**	**23,507**	**74.33%**
First Nations	869	1,166	1,759	2,353	270.77%
Total Basin Population	**307,301**	**332,591**	**390,571**	**459,649**	**149.58%**
Communities in Qu'Appelle River Basin (Outside the SSRB)					
Humboldt	5,810	6,164	6,936	7,805	134.33%
Towns < 1000	689	721	684	680	98.65%
Villages	1,155	1,097	1,068	1,047	90.65%
Total Population outside the SSRB	7,654	7,982	8,688	9,532	124.53%
Total Population Served by SSRB	**314,955**	**340,573**	**399,259**	**469,181**	**148.97%**

* These values are prior to release of the 2011 Census population by Statistic Canada, and will not match with those presented in Table 2.2. All water demand estimates were based on these population levels.

- Urban centers that are expected to record high increase rates are Martensville and Warman. Martensville indicates an increase of around 155% by the year 2060; for Saskatoon, population is expected to increase from the current level of 221,668 to 340,147 by 2060. Swift Current's population is forecasted to increase only by 10%, but Warman's population is expected to grow by nearly 187%.

- Bedroom communities in the SSRB indicated an increasing trend over time (for regression equations, see Appendix F). These communities are expected to nearly triple their populations by the year 2060, accounting for a growth of 194% (Table 4.34).

- For both categories of towns with populations higher or lower than 1000 people, regression analysis was undertaken. A linear trend was utilized for both community sizes. The regression equations are also shown in Appendix F. As shown in Table 4.34, population for these community centers is expected to further increase in the future. Smaller towns are projected to increase their population by approximately 26% by 2060, and towns with a population over 1000 are expected to follow an ascending trend with a growth of nearly 36% by 2060.

- For villages located in the SSRB, regression analysis was first applied to determine the future developments in terms of population. Given that the regression analysis did not provide reasonable values, it was assumed that future population in these communities would decline. For rural farm and rural non-farm communities, data on population were scarce; therefore, it was assumed that these communities will follow a trend similar to that of villages. Decline rates in these communities were assumed to be 0.5% for 2010, 0.25% for 2040, and 0.1% for 2060. Under this hypothesis, the current rural population is expected to decline from 31,624 in 2010 to 23,507 in 2060.

As noted above, the total population that obtains water from the SSRB is located not only within the SSRB, as well in the Qu'Appelle River Basin. The estimates shown in Table 4.34 suggest that a majority of the population served is within the basin. In 2010, only 2.4% of the total SSRB water demanded for municipal/domestic purposes was diverted to the Qu'Appelle River Basin. Over time, this amount will become relatively lower (down to 2.1% of total). The trend in this distribution is shown in Figure 4.2.

4.5.1.3 First Nations' Population Forecast

For the SSRB, First Nations' population indicated an increasing trend over time. The future population of these communities was estimated with the use of a linear regression model (regression equations in Appendix F). Total First Nations population in the basin would increase from the present level of 869 people to 2,353 people, accounting for a growth rate of approximately 171% (Table 4.34).

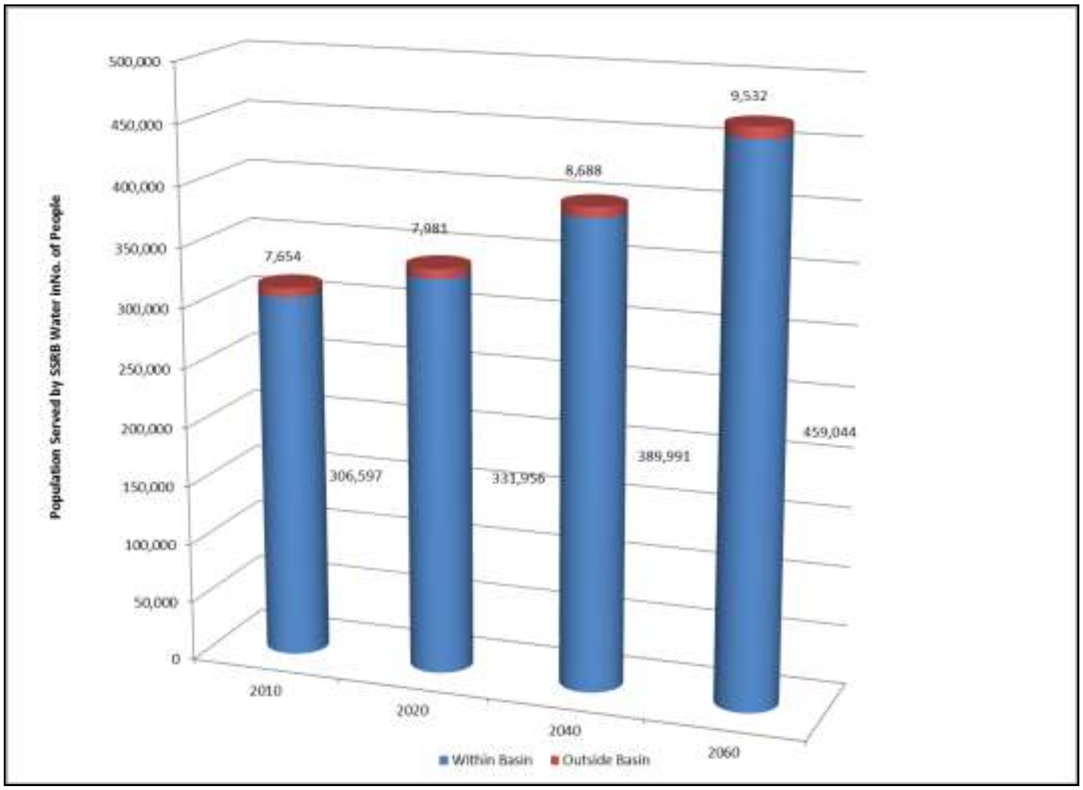


Figure 4.2: Population served by the South Saskatchewan River Basin Water by Location of Communities

4.5.1.4 Other Population Forecast

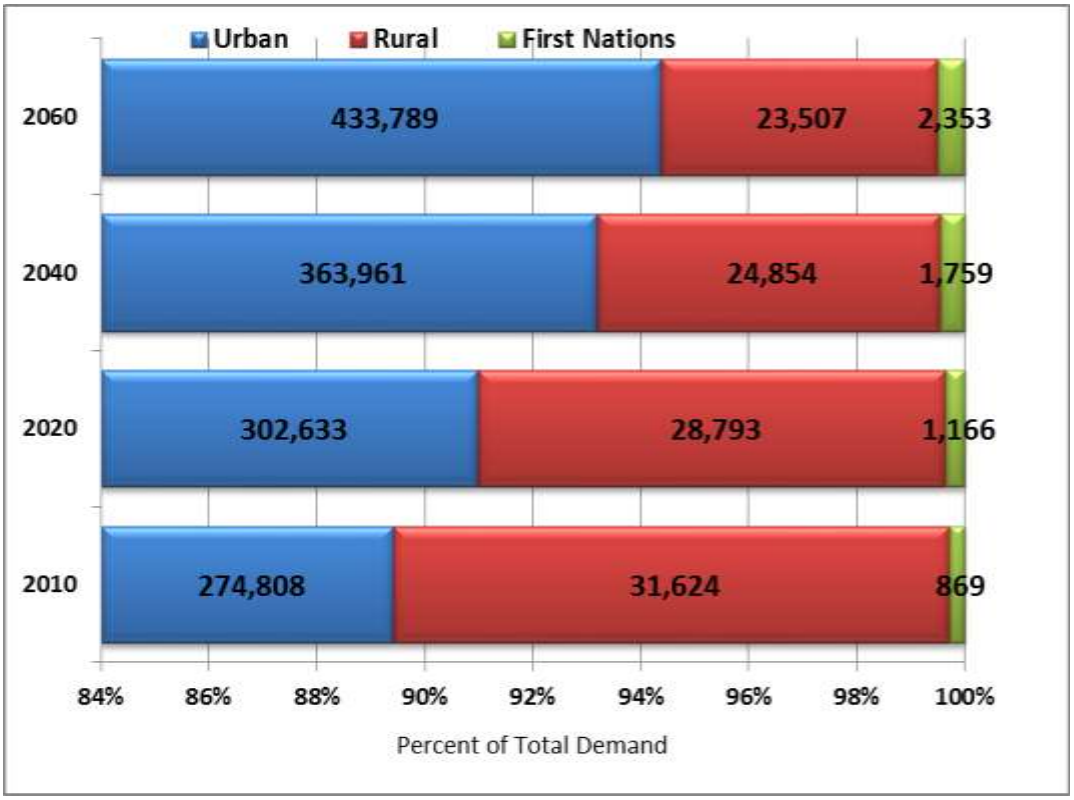
Under this category, trailer park communities and population centers supplied by the Couteau and Elbow Water Pipelines were included. For these communities located in SSRB, there was not sufficient data to elaborate a method for determining future population developments.

4.5.1.5 Total Basin Population

The total population of the basin is shown in Table 4.34. It is expected to grow from the current population of almost 247 thousand to 433 thousand – an increase of nearly 50%. Much of this growth is a result of expanding large urban centers and their associated bedroom communities. As can be noted in Figure 4.3, the population of SSRB will be more urbanized by 2060. While urban population will account for 94% of the total river basin population, rural communities moderately decrease from their current levels of 31,624 to 23,507 people.

4.5.2 Estimation of Future Water Demand per Capita

Regression analysis was carried out to determine the effect of population and time on per capita water consumption over time. The estimations were done individually for each type of community located in SSRB. In order to estimate the future water demand per capita, for each type of community, two contributing factors were included: trend over time, which could be reflective of water conservation and other factors,[31] and size of the community. The latter factor was reflective of the economies of size and its effect on water management. A summary of the results and effects of these factors is provided in Table 4.35.



Note: Figures shown in each bar is popualtion level.

Figure 4.3: Distribution of Population by Type of Major Population Groups, South Saskatchewan River Basin, 2010 – 2060

4.5.2.1 Water Demand by Type of Community

In order the estimate the future per capita water demand (for the no climate change and adoption of no additional water conservation practices), the following procedure was used:

[31] Based on the simple analysis of these communities, these other factors could not be identified. A community-by-community study of reason for the decline is required.

- For the communities showing no trend in water demand, and no effect of size of the community, the last five-year (2005-2009) average water demand was used as the per capita water demand for 2010, 2040, and 2060.

Table 4.35: Summary of Effect of Trend and Population on Community per Capita Water Demand, by Type of Community

Communities Showing No Effect of Trend or Size	Communities Showing Effect of Community Size but No Effect of Trend	Communities Showing No Effect of Community Size but Showing Effect of Trend	Communities Showing Effects of Both Community Size and Trend
Communities within the SSRB			
Martensville	T>1000	T<1000	Warman
Saskatoon			
Swift Current			
Bedroom Communities			
Villages			
Communities outside the SSRB			
Humboldt			

Source: Compiled from results shown in Appendix F.

- For communities that exhibited a noticeable effect of community size or trend, an adjusted water demand coefficient was estimated.

The results of the above adjustments on per capita water demand coefficient for various types of communities are shown in Table 4.36. The regression results are presented in Appendix F. Warman water demand per capita is expected to increase by nearly 20 % by 2060, whereas both towns with populations under and over 1000 are projected to record decreases in water consumption per capita of 44% and 34%, respectively.

4.5.2.2 Adjustment for Bottled Water Use

The consumption of bottled water in Saskatchewan has grown over the past decade. A Statistics Canada (2007) survey of households in Saskatchewan revealed that the primary source of drinking water consumed was municipal; 26% of the households used bottled water, and if it was a non-municipal source of water, the percentage using bottled water was 39%. Making an adjustment requires a study of factors affecting bottled water in various circumstances. Some communities with water quality (taste or odor) issues probably use more bottled water. However, that is not the case with all communities or all water users. Given that studies of the topic were found for Saskatchewan, it was decided to avoid making any adjustment in per capita water demand for this type of water demand. This area is left for future studies.

Table 4.36: Water Demand Coefficients on a per Capita Basis in m^3 by Community Type, South Saskatchewan River Basin, 2010 to 2060, Under Baseline Scenario

Community Type	Water Demand per Capita (m^3)			
	2010	2020	2040	2060
Communities within the SSRB				
Martensville	86.64	86.64	86.64	86.64
Saskatoon	210.23	210.23	210.23	210.23
Swift Current	171.57	171.57	171.57	171.57
Warman	88.68	92.21	99.27	106.34
Bedroom Communities	93.22	93.22	93.22	93.22
T>1000	139.02	127.79	107.98	91.24
T<1000	120.29	107.12	84.94	67.36
Villages	125.16	125.16	125.16	125.16
Rural farm	125.16	125.16	125.16	125.16
Rural non-farm	125.16	125.16	125.16	125.16
First Nations Reserves	137.93	137.93	137.93	137.93
Communities in the Qu'Appelle River Basin (Outside SSRB)				
Humboldt	117.02	117.02	117.02	117.02
Towns < 1000	120.29	120.29	120.29	120.29
Villages	125.16	125.16	125.16	125.16

4.6 Recreational Water Demand

Water demand for recreation was a sum of two types: that at the recreational communities; and that at various recreational sites. The first water demand was estimated by the population of these communities and per capita water demand (shown in Table 4.37). For the SSRB parks, water demand was examined for a time trend. The water demand for all four park sites (as shown in Table 3.18) was added together. A time trend was fitted, and the following results were obtained:

$$\begin{aligned} TWU &= 32084.71^{**} + 97.98\ TIME \qquad (4.1)\\ &\quad (3385.0) \quad (372.31)\\ R^2 &= 0.005 \qquad F = 0.07 \end{aligned}$$

Where, ** Hypothesis of all variables not affecting water demand rejected at $\alpha = 0.01$

Table 4.37: Population and Water Demand per Capita for Recreational Communities in the South Saskatchewan River Basin, 2010 – 2060

Year	Population	Water Demand per Capita in m^3	Source of Water
2010	172	188.4	Surface Water
2020	172	191.9	Surface Water
2040	172	195.9	Surface Water
2060	172	199.4	Surface Water

The results suggested that the level of water demand does not exhibit any trend. For this reason, an average water demand of 31.34 dam^3 per annum was used for all years. Limited space and the resulting congestion could act as a ceiling on the visitation of the parks and recreational vehicle sites. Weather that is suitable for the activities offered by these sites is the main determinant on their use. A cool, wet summer compared to a hot, dry summer would generate a significantly different level of demand.

4.7 Indirect Anthropogenic Water Demands

Three water demands are included in this category: Environmental purposes, In-Stream Needs, Evaporation losses from surface water bodies, and Apportionment purposes. These are described below.

4.7.1 Environmental Water Demand

Based on discussions with the Ducks Unlimited, it was determined that, at this time, no new wetlands or other environmental areas are planned for the duration of the 2020 to 2060 period. This water demand was therefore assumed to remain at the same level as that for 2010. Ducks Unlimited had 104 projects in the SSRB as of 2004; of these, 79 had some component of wetland restoration or preservation.

4.7.2 In-Stream Flow Needs

As noted in Section 3.6.5.4, some water has to be left in the rivers and streams to meet the need of minimum flows. Saskatchewan Watershed Authority estimates for 2010 were assumed to apply for the future time periods.

4.7.3 Evaporation Water Demand

It has been estimated that precipitation accounts for 55% of the variability in lake levels, while temperature accounts for 30% (Lemmen et al., 2008). There are, then, various factors that would have positive or negative effects on the rate of evaporation, with little or no guide as to how these influences will play out to 2060. The base coefficients for 2010 are used in estimating the future evaporation water demand.

4.7.4 Apportionment Water Demand

As noted in Chapter 2, since the SSR does not cross a provincial boundary, no apportionable flows are calculated. This requirement is therefore set equal to zero. However, it is conceivable that in order to meet the apportionment demand for the Saskatchewan River, some water may be released from the SSR. However, this discussion is deferred to the Saskatchewan River Basin.

Chapter 5

Current and Future Water Demand Evaluation Scenarios

Current and future water demands for the SSRB were estimated under alternative scenarios. Three scenarios were selected: (i) baseline scenario, (ii) climate change scenario, and (iii) water conservation scenario. The methodology followed for estimation of water demand under these scenarios is described in this chapter.

5.1 Baseline Scenario

A baseline scenario is also called a "Business as Usual" scenario. It is generally chosen as a reference for comparison against an alternative scenario. Alternative scenarios are selected from a list of alternatives that are relevant to the study at hand. In this study, the baseline scenario includes changes that are already described in Chapter 4. Included among these are assumptions regarding.

- **Population projections**: In the future, population growth will continue at the rate and/or level shown in Chapter 4;
- **Economic development**: Economic activity is a dominant driver of water demand. The economic development levels – direct and induced, would continue in the future at the levels shown in Chapter 4;
- **Land-use change**: Land-use change plays an important role in water demand since different land use activities have different impacts on water demand. These changes are also reported in Chapter 4.

Water demand under the baseline scenario reflects the past trends and best judgments of the available evidence. However, as true of any forecast, the outcomes depend on the assumptions made in developing the scenarios. In the event that these assumptions are wrong, the forecasts will not match the future reality.

5.2 Climate Change Scenario

Climate change is highly relevant in any forecast of future water demand. The essential question is whether Canadians (and those in the SSRB) can manage a change in water resources that they put on their crops, run through their turbines, and pipe into their homes (Paraphrased from Waggoner, 1990).

Human-induced climate change is caused by emissions of carbon dioxide and other greenhouse gases (GHGs) that have accumulated in the atmosphere over the last century or so. There is enough scientific evidence now that makes climate change serious and compelling (Stern, 2007). Many significant changes in climatologically-related variables have been credited to climate change. The nature of these changes for Canada has been described in Lemmen et al. (2008). They define the term “climate change” as any change in climate over time, whether it is the product of natural factors, human activity, or both.

5.2.1 Impact of Climate Change on Water Demand

The major changes identified by various IPCC reports (Easterling et al., 2007) include the following points:

- Change in average temperature
- Change in average precipitation
- Distribution of precipitation and its form (more in the form of rain and less as snow)
- Occurrence of extreme events
- Rise in sea level

The last impact is not relevant to the basin or to the Province of Saskatchewan, but rather to coastal regions.

Related to water resources, Lemmen and Warren (2004) have suggested that climate change would affect various parts of our environment: (1) changes in annual stream flow, possible large declines in summer rainfall, leading to shortage of supply; (2) increased likelihood of severe drought, increased aridity in semiarid zones; and (3) increases or decreases in irrigation demand and water availability. These changes would lead to serious concerns, and notable among these are (1) implications for agriculture, hydroelectric power generation, ecosystems, and water apportionment; (2) losses in agricultural production, accompanied by changes in land use; (3) uncertain impacts on farm sector incomes, groundwater, stream flow, and water quality. The same study also noted that climate change may also affect water demand. In addition to population growth and wealth distribution, climate change may increase demand for water by causing higher temperatures and drier conditions.

Two major changes that could occur on account of climate alterations are change in average temperature (and resulting evapotranspiration) and extreme events. Two types of extreme events are expected in the future: extreme dry events, called droughts (single period, back-to-back droughts and longer multi-period droughts), and extreme wet events (high rainfall and /or intense rainfall in a short period of time), resulting in floods in some regions.

Bonsal et al. (2010) reviewed work regarding future droughts in the Canadian Prairies and elsewhere. They reminded us that all Global Climate Models (GCMs) project future increases of summer continental interior drying and the associated risk of droughts. A main reason for this greater risk is the increasing temperatures and resulting potential evapotranspiration not being compensated for by projected changes in precipitation and longer warm seasons.

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2008) states that a future increased risk in areas affected by drought is likely (i.e. 66% probability of occurrence). Burke et al. (2006) used the Hadley Centre GCM and found that by the second half of the twenty-first century, droughts (as measured by the Palmer Drought Severity Index) are slightly more frequent and much longer, compared, with present conditions. Sheffield and Wood (2007) modeled soil moisture changes with eight GCMs to estimate future global drought conditions. The future projections show decreases in soil moisture globally for all scenarios, with a doubling of the area of severe soil moisture deficits and frequency of short term droughts (4-6 months) in the 2090s. Droughts longer than a year were estimated to triple in frequency.

It seems strange, but with the enhancement of the global hydrological cycles, not only does drought become worse, but extreme precipitation with associated excessive moisture and flooding also can increase. Current trends already seem to point to these changes. IPCC (2008) states that the frequency of heavy precipitation amounts has increased over most land areas and that this pattern is consistent with the observed increases of atmospheric water vapor. Precipitation extremes are expected to increase with increasing temperatures in general, because a warmer atmosphere can hold more moisture (Min et al., 2011). Sun et al. (2007) find that all GCMs consistently show a shift towards more intense and extreme precipitation globally, as well as over various regions. Extreme precipitation events are considered to be those with precipitation over 50 mm per day. Most GCMs show decreased daily precipitation frequency and increased daily precipitation intensity. This is a warning that dry areas (such as the southern Canadian prairies) could become drier, and wet areas could become wetter.

Even from this early body of literature, knowledge of the possible future characteristics of drought and intense precipitation and/or excessive rainfall remains a significant knowledge gap that is vital to address. These extremes may be the main mechanism by which climate change causes the most challenging problems.

One should also note that the SSRB would be affected by change in availability of water which would be related to climate change occurring in the eastern slopes of the Rockies. Since the focus of this study was on the demand for water in the SSRB, this effect is not included in the above discussion.

5.2.2 Studies Incorporating Effect of Climate Change and/or Its Effect on Water Demand

Studies incorporating climate change in water demand forecasting in Canada were not found. Tao et al. (2008) did suggest that the impact of climate change on rice water use in China would be positive. However, such estimates are not transferable since potential evapotranspiration induced by climate change differs from one location to the other. A site-specific assessment of such changes would be more meaningful.

Kulshreshtha et al. (1996) developed a conceptual model to estimate agricultural (irrigation and livestock) water use for climate change. Water demand was affected by the direct effect of climate change on water requirements; indirect effects of climate change on water requirements; and the policy-induced impact of climate change on water requirements. The direct effect was a result of change in the water production function, and in stockwatering requirements. The indirect effects included the impact on water delivery systems, and the effect on prices of food products, changing food composition. Policy-induced changes reflect the expansion of irrigated agriculture in the region.

In the United States, Peterson and Keller (1990) have projected irrigation expansion as a result of climate change in the west. The largest effects were predicted for the Great Plains, with minor consequences in the Pacific Northwest. They also predicted that transfer of water will be of increased importance in a warmer climate.

Cooper (1990) predicted that for the climate change in the US, urban and rural recreation, scenery, wildlife habitat, and fisheries are strongly affected by the quantity and quality of water. Water release policies, particularly from hydroelectric dams, are important to stream recreation. Water quality and depth affect fishing, swimming, and diving. Climate change can affect water quality through altering the low flow of the diluting water that defines quality in a stream, the quantity of water that dilutes pollutants in a lake, and the storms that flood sewers and erode fields (Waggoner and Revelle, 1990).

This review suggests significant implications of climate change on water resources. The following ones are noteworthy:

- Impact on the water demand may come through direct impact of climate characteristics, but also through indirect linkages.
- Two important indirect linkages occur through water quality and water availability. The former may affect water demand for domestic consummations as well as for recreational water demand. The availability is also a major factor in determining water demand patterns – adoption of water saving mechanisms may become more popular among water users. However, this aspect is dealt with in the next scenario – the water conservation scenario.

In the following section, only the direct impact of climate characteristics is described.

5.2.3 Incorporation of Climate Change Impacts in the Study Estimates

Climate change would create two types of factors that can affect future water demand: Change in the temperature and precipitation, with the net effects on evaporation[32], and frequency of extreme events such as droughts and excessive rains (causing flooding in some regions). Unfortunately, most work on the extreme events has been done on a global basis, rather than separately for Canada and its regions (such as the SSRB).

5.2.3.1 Effect of Temperature Change

The Canadian Climate Change Scenarios Network (CCCSN)[33] has set up a database such that the forecast of the average monthly temperatures at 2020, 2050, and 2080 can be made for a location. For this analysis, one town on each side of the SSRB was selected. For these locations, the temperate forecasts were obtained. The average of the temperature at these two locations revealed increases of 1.2°C, 2.7°C, and 4.7°C for 2020, 2050, and 2080, respectively. A +2°C for 2040 and a +3.5°C change for 2060 in the average monthly normal was used to adjust current water demand coefficients. In addition, climate change would also increase frequency of wind hail ad intense rain events, which could have a devastating effect on agricultural production.

Water demand levels are also affected by seasonality patterns, which are expected to change in the future. In effect, there is a shift in these patterns, as June and August average monthly normal temperatures in 2040 are the average normal monthly temperature for July over the 1971 to 2000 average. By 2060, May and September normal monthly temperatures are more like the 1971 to 2000 June and August. The effect of increasing temperature on water demand can be accounted for by estimating the time over which the increased water demand will occur, then multiplying by coefficients that have measured water demand at these increased temperatures. It is assumed for the purposes of this study that the water coefficients used to estimate the 2010 water demand will be reasonable for estimating 2020 water demand. The water demand coefficients for 2040 and 2060 were estimated by applying the increased consumption of water caused by the temperature rise to the yearly demand, then calculating an average daily use.

A warmer climate for 2040 and 2060 could result in more heat units, enabling the use of corn and soybean varieties with greater production potential. A warming climate to 2060 would favor

[32] One should note that estimation of climate change effect on evaporation is fraught with problems. For example, with increased heat units, one would expect evaporation to rise. In addition, there may be other factors that also affect evaporation levels. For example, Burn and Hesch (2006) have reported a decline in evaporation in the Canadian Prairies partly because of change in wind speed over time.

[33] For details see CCCSN (2011).

more corn production, as corn is better adapted to taking advantage of the higher heat units. Corn has a higher water demand coefficient, compared to present feed grains. Also, these corn varieties have higher yield potentials relative to the varieties currently grown in Saskatchewan and to barley silage. These changes may induce more feedlots and corn-based ethanol production.

A warmer and drier climate may also enhance people's participation in water related recreational activities.[34] Included here are both consumptive and non-consumptive water demand activities. Consumptive activities may include the use of provincial parks, which may result in more recreational areas being developed. Non-consumptive activities consist of swimming, boating, and other types of recreational activities.

5.2.3.2 Effect of Extreme Events

Another aspect of climate change is the frequency of extreme events – droughts and excessive rains. Based on the past yield records, it appears that during the last 50 years, there have been four major droughts – 1961, 1988, 2001, and 2002 (Wheaton et al., 2005). Recent droughts and excessive moisture events can be considered harbingers of the extremes likely to occur.

As noted above, studies have also predicted increase frequency of extreme events – both droughts and intense rains over the same time period (the latter may perhaps compensate the effect of drought conditions in some years). A precise forecast of such events is very complex. Some arbitrary decisions were made.[35] It was assumed that drought frequency by 2020 would remain unchanged (from the current 8%). As noted above, by 2090, drought frequency is expected to triple. A straight line projection was used to estimate the future frequency of droughts, which was 13% by 2040 and about 18% by 2060.

With respect to floods, no Canadian study was found that has predicted these events for climate change, however, Drakup and Kendall (1990) state that large-scale spring ravine flooding would be expected to decrease because of an expected increase in winter runoff, with a decreased snowmelt and spring runoff.

[34] As noted above, water quality has a significant influence on water-based recreation, particularly for fishing, and water-contact activities, among others. This effect is not considered in this report.

[35] This aspect of climate change requires some input from people whose expertise is climatology and climate change.

5.3 Water Conservation Scenario

Provincially, through the Saskatchewan Watershed Authority and locally, through municipalities, efforts have been made to make the water users aware of water shortages, and to convince them to adopt water conservation practices. This goal has been accomplished through several types of measures, including a switch to lower water use appliances (i.e., rebates for low flush toilets). Programs of various types to educate the public on conserving water have been and are being implemented. The urgency or force of the approach seems to depend on immediate supply side problems, (drought, or plant shutdown, among others). These factors influence the adoption of water conservation and thereby affect water demand. However, to predict these changes is somewhat problematic without a comprehensive study of the attitudes of people and of their willingness to adopt water conservation measures.

5.3.1 Introduction to Water Conservation

Conservation in general refers to the management of human use of the biosphere so that it may yield the greatest sustainable benefit to the present generation while maintaining its potential to meet the needs and aspirations of future generation (IUCN, 1980). Conservation of water can be placed within this context of conservation, which primarily refers to a reduction in the use or loss or increase in the efficiency of its use.

For the dwindling water supplies (as expected during climate change), water conservation provides an avenue to balance demand with supply. In addition, there could be several benefits of saving water: (i) conserving water saves money for water users; (ii) the need for publicly funded upgrades or new infrastructure to deliver and treat water can potentially be delayed or eliminated; (iii) less water goes to treatment facilities, saving energy and money; (iv) energy is utilized more efficiently because less energy is taken to heat water and to pump potable water and wastewater; (v) conserving water stimulates job creation. New economic activities are triggered for water-related manufacturing and service sectors, encouraging new business opportunities and job creation; and, (vi) conserving water is environmentally friendly. Reducing water use helps to preserve and protect fish and wildlife habitat. These natural attractions are essential to the economic health of any provincial economy, attracting tourism and outdoor recreation industries. According to Vickers (2004, p. 187), if we understand where and how much water is being used and apply proper efficiency practices and measures to reduce water waste, we can more easily endure – economically, environmentally, and politically.

Although some of the work on water conservation has been in the context of drought mitigation (since droughts cause severe shortages of water), it can be a tool for normal time, as well. Although water conservation is a powerful tool, it is as yet an underutilized tool that could stave off the severe water shortages, financial losses, and public policy risks that historically have been assumed to be inevitable consequence of a drought (Vickers, 2004, p. 178). There are a number of ways in which water is wasted when it could be conserved, provided that there are enough incentives for consumers to adopt water conservation practices. Examples of water wastes in various users include the following[36]:

- **Residential and domestic water demand**: old, inefficient plumbing fixtures and appliances, leaking toilets and faucets, wasteful water use habits, leaky water infrastructure.
- **Landscape water demand**: poor irrigation scheduling – watering too often and for too long – is the primary source of water waste associated with landscape irrigation.
- **Industrial, commercial, and institutional water demand**: water cost is such a small portion of total operating costs that reducing it is not a priority. Measurement is also an issue for this group of water users, since they produce a diverse set of products; the only index available for production is a dollar volume, which is not meaningful for comparison of water demand among similar facilities.
- **Agricultural water demand**: irrigation efficiency is influenced not only by the type of irrigation system, but also by an irrigator's ability to control the application of water, the physical characteristics of land, and the irrigation requirements of different crops.

Conservation or efficiency measures can be grouped into two general categories: (1) "hardware" devices or equipment and (2) behavior or management practices. Hardware measures are more reliable in achieving long-term water savings because they typically need to be installed only once and require no ongoing effort to maintain water savings. In contrast, educating people to adopt low water use methods requires considerable time and effort. Many factors play roles in changing human behavior to adopt water conservation measures. The relative net benefit from such adoptions is one of the major incentives that motivate water users to adopt a certain water conservation measure. Vickers (2004) has summarized a number of measures that reduce water use in various applications. These are shown in Table 5.1.

Measures suggested for water conservation include a combination of hardware and behavioral types. In all types of water use, pricing is noted as a primary incentive to change behavior and to adopt water conservation measures. These rates ought to be conservation oriented – i.e., they

[36] Much of the material provided below is adapted from Vickers (2001 and 2004).

would provide a motivation for the water users to think of (and possibly to adopt) water conservation measures.[37]

Table 5.1: Measures to Secure Water Conservation for Various Types of Water Demands

Measures	Residential (Indoors)	Lawn and Landscape Irrigation	Commercial, Industrial, and Institutional	Agricultural (Irrigation)
Conservation-oriented rates, rebates, and program and policy incentives	X	X	X	X
Installation of water saving equipment (Toilet and urinals -- low volume, non-water, composting, retrofit devices; Showerheads and faucets -- low volume, aerators, retrofit devices; Clothes washers and dishwashers -- high efficiency, full loads only; Efficient irrigation Systems; Efficient fixtures).	X	X	X	X
Leak repairs and maintenance	X	X	X	
Water efficient landscape designs		X		
Rainwater harvesting	X	X		
Metering of water use	X	X	X	X
Efficient Cooling And Heating			X	
Process and wastewater reuse, improved flow controls			X	
Efficient irrigation scheduling (e.g., customized, linked to soil moisture, local weather network)				X
Land conservation methods (e.g., conservation tillage, organic farming, integrated pest				X

Source: Paraphrased using information from Vickers (2004).

[37] The water rate structure also plays an important role. For example, decreasing block pricing (paying less for higher quantity of water) would not bring water conservation ethics among water users.

Changing the hardware is also another way to conserve water in different uses, although the nature of equipment would differ among users. For example, domestic (indoor) water demand can be reduced by installing water saving toilets, showers, dishwashers, clothes washers, etc. Outdoor irrigation of lawn or farm fields can be improved by installing water conserving irrigation systems, and proper irrigation scheduling. Reuse of water in industries and commercial establishments can also be a measure to consider for water conservation.

Unfortunately, the uncertainty in the potential water savings, based on a review of the related literature, is rather large due to the nature of measures selected. These ranges are shown in Table 5.2. With the exception of landscape irrigation, in most cases a maximum of 50% reduction in water demand is possible. Landscape irrigation water demand could be reduced by 100%. These ranges show the level of uncertainty that exists in this area.

Table 5.2: Range of Water Conservation Potential for Various Water Demands

Type of Water Demand	Range of Water Conservation Potential
Residential (Indoor)	10 – 50%
Lawn and landscape irrigation	15 – 100%
Commercial, industrial and institutional	15 – 50%
Agricultural (Irrigation)	10 – 50%

Source: Vickers (2004).

5.3.2 State of the Art in Water Conservation

5.3.2.1 Measures for Water Conservation

As noted in Section 4.2.4, information on water conservation in Saskatchewan is not available. Even the review of studies that were found suggested a large degree of uncertainty about potential water conservation practices. Further complications arise from the fact that the magnitude of water conservation is decided not only by the available technology (hardware) but also by people’s willingness to adopt conservation practices. Literature suggests that policy measures are required for bringing about such a change. Most studies suggest the use of economic instruments (water pricing) or regulations. Increased water rates can be a strong incentive for consumers to reduce excessive outdoor use, since low and middle residential (and non-residential) customers tend to be sensitive to the price of water (paraphrased based on Vickers, 2001, p. 143).

Both types of changes to bring about water conservation are subject to public decision making, which is highly unpredictable for any jurisdiction, including Saskatchewan. To incorporate the effect of water conservation on SSRB water demand, a review of similar experiences in Canada was undertaken.

5.3.2.2 Potential for Water Conservation for Domestic Water Demand

Technological advances in various types of appliances and other indoor home water uses have been made. These are shown in Table 5.3. These data suggest a large water use reduction by adopting new technology. For example, if new toilets are installed, the current water requirement of 20 litres per flush[38] can be reduced to 2 to 6 litres. This step would reduce water use currently at 32,850 litres per year to only 6,570 litres – a reduction of 80% from the original level. Similar reductions could be possible through adopting water efficient shower heads, faucets, and washers. In total, household water demand for indoor uses could decline from 0.08 dam^3 to 0.02 dam^3 – a reduction of 73.7%. In addition, domestic water demand can be reduced through conservation in outdoor water expenditures for cleaning and lawn irrigation.[39]

Table 5.3: Potential for Water Conservation for Indoor Home Water Demand for the Current and New Technologies

Appliance	% of Home Indoor Water	Water Requirements (litres)		
		Unit	Old	New
Toilets	40%-45%	Litres per Flush	20	2 to 6
Shower Heads	17%-22%	Litres per minute	10 to 20	2 to 5
Faucets	10%-15%	Litres per minute	10 to 20	2 to 5
Washing Machines	6% to 10%	Avg. per year	13,500	5,400
Leaks			9,000	450
Cooking and drinking	5%			
Total Water Demand per Year per household				
Toilets		Litres per year	32,850	6,570
Shower Heads		Litres per year	19,140	7,140
Faucets		Litres per year	10,200	1,214
Washing Machines		Litres per year	5,400	2,160
Cooking and Drinking		Litres per year	3600	3600
Leaks		Litres per year	9,000	450
Total Home (Indoor Water Demand)		Litres	80,190	21,134
		dam^3	0.0802	0.0211

[38] Based on the Toilet Rebate Program data provided by Ms. Dolores Funk, only about 25% of the old toilets are of this size. The remainder of the toilets are 18 or 13 litres per flush.

[39] No data are available for Saskatchewan or the Qu'Appelle River Basin for water use by type of domestic water use. According to the city of Richmond (Undated), lawn watering constitutes 15% of total domestic water use. However, this proportion will vary from location to location, depending on climate and water availability. It is recognized that differences between the precipitation received in the city of Richmond and the city of Saskatoon makes this estimate somewhat questionable.

5.3.2.3 Review of Water Conservation Experience for Domestic Water Demand

Much of the literature on water conservation is reported for the domestic water demand. A review of these initiatives is provided by CMHC (Undated). Several cities in Canada and in the US have adopted water conservation measures. Their experiences are summarized in Table 5.4. A variety of water conservation measures have been undertaken by various jurisdictions. Among these, rate increases and/or altered rate structures and public awareness programs are the most common. The detection of leaks through infrastructural improvements and retrofitting are also among these.[40] The results of these water conservation measures have been an astounding success. In all[41] cases examined here, water use was reduced and in some cases the reductions led to deferred savings in new infrastructural investments.

In terms of annual water use reduction, results vary from a high of 30% in Bogor, Indonesia, to a low of 2.9% for New Glasgow, Nova Scotia.[42] Within Canada, the range in reduction of residential (indoor) water demand is from 2.9% to 12.5%. One should also note that higher rates of decrease are associated with the pricing of water.

5.3.2.4 Review of Water Conservation Experience for Other Water Demands

Water conservation experiences with other water demands have not been prolific in the literature. According to the Policy Research Initiative (2005), water recycling is an important characteristic of the industrial response to a price change (a popular water conservation measure). Water costs seldom account for more than one percent of the total production cost in many industrial firms. Few studies have been done on the interaction of water price and the price of inputs other than water (Renzetti, 2002). Studies of cost structures of various types of industrial water users in Saskatchewan are needed.

For agricultural water demand, empirical studies have shown that irrigation water demand is relatively unresponsive to price changes, as a given crop requires a certain amount of water in a given setting (Policy Research Initiative, 2005). It has been argued that demand for irrigation water would remain inelastic until water costs rise substantially (Bazzani et al. 2004).

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[40] Although various studies make a note of leaks and loss of water use, no study has reported the magnitude of this loss.

[41] This review does not make any claim to be fully exhaustive of all water conservation programs in the world. Those listed here are available in published literature. A comprehensive review of all water conservation programs is required.

[42] It should be noted that these reductions are in perpetuity. In other words, this reduction would be effective for future time periods.

Table 5.4: Past Experiences with Water Conservation for Municipal Water Demand

Jurisdiction	Results of Water Conservation Measures	Rate of Change per Year	Measures Adopted	Source
Massachusetts Water Resource Authority	16% reduction between 1987 and 1991	4%	Water saving devices, Finding leaks, Literature on water conservation	Postel (1992)
Bogor, Indonesia*	30% reduction during June 1988 and April 1989	30%	Pricing	Postel (1992)
United Kingdom	10-15%	12.5%**	Metering	Postel (1992)
Winnipeg, MB	13% over 1993-1995	3.3%	Infrastructure improvements, Retrofit, New Buildings, Altered rate structure, Exterior water use, Industrial water use, Public awareness program	Waller and Scott (1998)
Kelowna, BC	20-30% reduction over 1996 to 1998	12.5%	Meter Installation, Fixture replacement, Rate Increases and altered rate structure, Public awareness programs,	Waller and Scott (1998)
London, ON	75% reduction in summer and 20% reduction in non-summer period over 1988 to 1995		Infrastructure improvements, Retrofit, Rate increases, Altered rate structure, Public awareness program	Waller and Scott (1998)
New Glasgow, NS	2.2ML/day in 1984 to 1.5ML/day in 1995	2.9%	Rate increases, Altered rate structure, Public awareness program	Waller and Scott (1998)
Vancouver, BC	Reduction from 800L/cap/day to 650L/cap/day during two years	9.4%	Infrastructure improvements, Retrofit, Pilot audit of large volume water users, Pilot water treatment plant, Increased meter reading, Public awareness program	Waller and Scott (1998)
Yellowknife, NWT	30% decrease over four years	7.5%	Infrastructure improvements, Retrofit, Rate increases, Altered rate structure, Exterior use, Public awareness program	Waller and Scott (1998)

* This study is merely an example of the effect of pricing. However, this experience may not be considered to be comparable to that in the basin.

** Mid-value

At the same time, relative water shortages in various locations, and the higher technical efficiency of sprinkler irrigation methods has prompted water management agencies to develop these methods, thereby reducing water demand for irrigation significantly. Water conservation measures for irrigation or any other type of farm level water demand were not found.

5.3.2.5 Review of Adoption of Water Conservation Measures

Very few studies were found that have reported precise adoption rates of water conservation measures. Babooram and Hurst (2010) reported results of a Statistics Canada survey of households regarding their adoption of water saving devices. These results indicated the following adoption levels:

Low-Flow Showerheads	=	64%
Low Volume Toilets	=	42%
Rainwater Collection Devices	=	17%

In general, the less expensive measures had a higher chance of being adopted than did the more expensive ones. The study also found that people who owned their homes were more likely to adopt water conservation measures than were those who rent.

For the city of Guelph, Oraclepoll Research (undated) reported that only 40% of the residents indicated that they had made some changes to reduce their water use. In fact, 30% made no changes, 26% were neutral, and the remaining 4% did not know.

A possible source of data on the adoption of water conservation practices may be obtained from the Saskatchewan Watershed Authority's program uptake for their Toilet Rebate Program.[43] The program started on January 1 2009. By the end of October 2011, some 30,098 households had availed themselves of the rebate[44] from this program, and 41,882 toilets were replaced. Thus, 7.7% of provincial households participated in the program over a 34 month period.

5.3.3 Incorporation of Water Conservation in Future Water Demand

In light of a large degree of uncertainty about the impact of water conservation programs and their rate of adoption, a scenario approach was adopted. This scenario involved potential levels of water conservation and a rate of adoption of water conservation practices. On account of the uncertainty in potential water conservation, a mid-value of the interval shown in Table 5.2 was used as the potential for water use reduction. For domestic water demand as proportion of water used indoor, and for lawn irrigation, an equal proportion was assumed. This yielded a value of

[43] For details on this program, see Saskatchewan Watershed Authority's web site at www.swa.ca.

[44] The rebate under this program was set at $50 per toilet, to a maximum of 3 toilets per household.

43% potential. For the commercial, industrial, and institutional water demand, this potential was assumed to be 32%. For both types of water consumers, an adoption rate of 1% per annum was assumed. Adjustment factors for water conservation are shown in Table 5.5.

Table 5.5: Reduction in Water Demand by Type of Demand, Resulting from Adoption of Water Conservation Practices, South Saskatchewan River Basin

Type of Demand	Maximum Potential	Maximum Population Adopting Measures	Maximum Reduction in Water Demand	Savings in Water Demand (Relative to Baseline Scenario) by		
				2020	2040	2060
Municipal Domestic (Community Water Demand)*	43%	40%	17.2%	2.5%	7.5%	12.5%
Non-Municipal Domestic Water	--	--	--	0.58%	1.16%	2.90%
Commercial, Industry and Institutional Water Demand***				2.5%	7.5%	12.5%
Recreational Water				N.C.	N.C.	N.C.
Irrigation Water Demand	Estimated using efficiency improvements in water delivery system for a given crop mix					

* Based on the experience of Kelowna, B.C.

** Based on the experience of New Glasgow, NS

*** Assumed to the level of water conservation for the municipal water demand

N.C. = No Change

Chapter 6

Agricultural Water Demand

Using the methodology presented in Chapter 3, current (2010) water demand levels for various activities related to agricultural water demand were estimated. This was followed by projecting water demands for three time periods: 2020, 2040, and 2060. The methodology for these projections was outlined in Chapter 4. For all four time periods, agricultural water demand was estimated for three study scenarios: Baseline, Climate Change, and Water Conservation scenarios. These results are presented in this chapter.

As noted in Chapter 2, agricultural water demand was disaggregated by five types of demands. Estimates of agricultural water demand were made for each of these types of demands. These are presented in this section, divided into the same five sections as noted earlier – Irrigation, Dryland crop, Livestock, Greenhouses and Nurseries, and Aquaculture.

6.1 Irrigation Water Demand

6.1.1 Irrigation Water Demand – Baseline Scenario

The water demand for irrigation was estimated by three factors: (i) irrigated area; (ii) type of y application system, accounting for the efficiency of the system and (iii) estimated water deficit for the mix of crops that would be grown. The SSRB water demand for irrigation by type of system is presented in Table 6.1. As shown in Figure 6.1, most of the increase is attributed to the growth of sprinkler irrigation in the basin.

In 2010, irrigation used 231,295 dam^3 of water. By 2060, irrigation would need a total of 723,787 dam^3 of water, an increase of 212% over the 2010 level. Major increases are also expected by 2040, when irrigation water demand will be 130% higher than the current level. This water demand increase is predicated on the development of the Westside Irrigation District (WID), which accounts for 97% of the new irrigated area and for 62% of the total irrigated area in the SSRB in 2060.

In the estimation of the irrigation water demand, an assumption was made that the future irrigated area will be served through sprinkler irrigation. Surface irrigation is a higher consumer of water and thus, in regions where water is in short supply, it is not a preferred method. As shown in Figure 6.1, in the future water demand from the area served through sprinkler irrigation will increase significantly, whereas the surface irrigated area would remain constant at the 2010 level. It is conceivable that the existing surface irrigation area may be converted to sprinkler irrigation. However, that assumption would have required more knowledge of the attitude of producers regarding water conservation, which was not available. This aspect was therefore considered to be beyond the scope of this study.

Table 6.1: Irrigation Water Demand by System Type in the South Saskatchewan River Basin for the Baseline Scenario, 2010 - 2060

Irrigation System	Water Demand in dam^3 for			
	2010	2020	2040	2060
Wheelmove	18,730.3	18,730.3	18,730.3	18,730.3
Pivot	148,085.2	195,425.9	450,752.0	640,576.8
Linear	1,099.5	1,099.5	1,099.5	1,099.5
Misc. Sprinklers	17,272.7	17,272.7	17,272.7	17,272.7
Surface	21,557.2	21,557.2	21,557.2	21,557.2
200mm Backflood	3,216.5	3,216.5	3,216.5	3,216.5
Misc. BackFlood	19,364.7	19,364.7	19,364.7	19,364.7
Remainder	1,969.1	1,969.1	1,969.1	1,969.1
Total Water Demand	**231,295**	**278,636**	**533,962**	**723,787**
% Increase over 2010	--	20.5%	130.9%	212.9%

* Since these estimates are based on past experience, actual number may be higher or lower than this estimate.

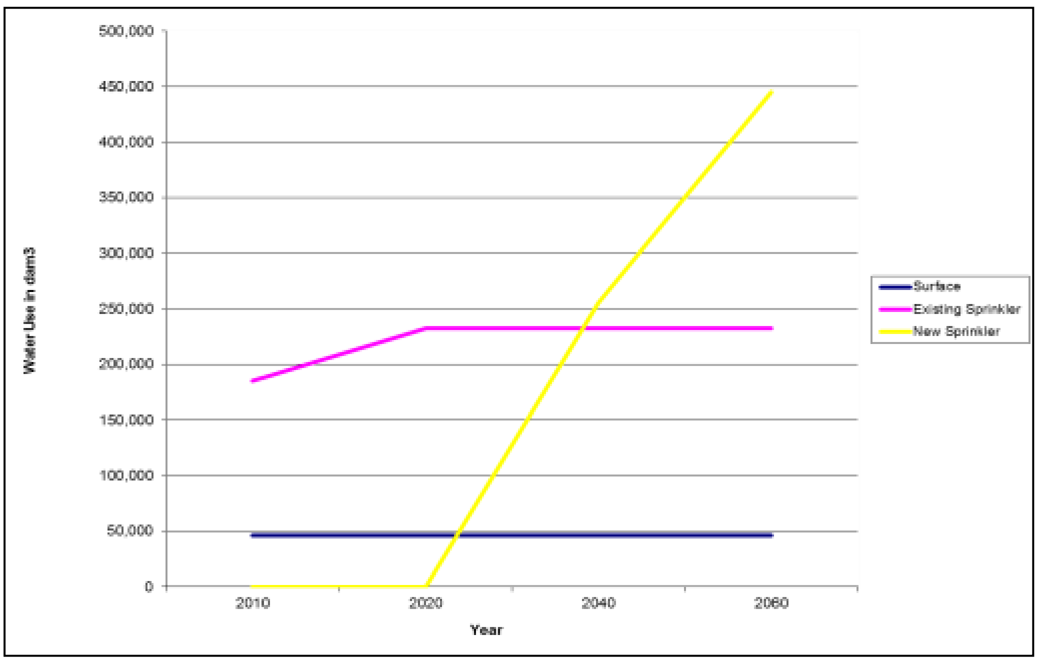


Figure 6.1: Future Irrigated Water Demand by Type of Irrigation, South Saskatchewan River Basin, 2010 – 2060

6.1.2 Irrigation Water Demand – Climate Change Scenario

The future irrigation water demand was derived from future irrigated area and water demand coefficients. As noted in Chapter 3, the distinction between district and private irrigation was maintained. In addition, climate change was taken into account for estimating the future water demand coefficients.

The estimation of the demand for water to irrigate crop and hay land is dependent on a number of factors: crop grown, growing and non-growing season precipitation, soil water-holding capacity, and growing season climate factors such as average wind speed, daily mean temperatures, heat units etc. The estimation of crop water demand is not a straightforward application of a percentage change in a climate factor leading to a percentage change in crop response. Let us first review studies of water use for the climate change scenario.

Lundstrom and Stegman (1995) estimated the daily water use of various crops by week of crop development over 5 temperature ranges. Basically, for most crops, as temperature range increases (i.e. going from 20-25°C to 25-30°C) the daily water requirement goes up by 1 mm. Using Table 6.2, the increased water demand of a crop can be estimated, given the number of days and rise in temperature range.

The future irrigation water requirements for crops were estimated by using ICDC (2008a) crop requirement data, combined with an estimate of the growing season precipitation plus seedbed moisture. The estimated change in moisture deficit from climate change for 2040 is 5 days at 2 mm and 10 days at 1 mm, while for 2060, it is 15 days at 1 mm and 10 days at 2 mm to give a total deficit of 20 mm and 35 mm for 2040 and 2060, respectively. This gives an estimate of the moisture deficit for various crops for a normal year, 2040 and 2060 (Table 6.3).

Table 6.2: Moisture Deficit Number of Days times Deficit (mm)

Days	Moisture Deficit (mm)	
	1.0	2.0
5	5	10
10	10	20
15	15	30
20	20	40
25	25	50
30	30	60

Source: Estimated from Lundstrom and Stegman (1995)

Table 6.3: Crop Water Demand Coefficients for Average, 2040 and 2060

Crop	Crop Requirements[a] mm	Average[b] 2010 Precipitation + Soil Moisture mm	Deficit[c]			Total Deficit	
			Normal/Current mm	Additional 2040 mm	Additional 2060 mm	2040 mm	2060 mm
Alfalfa	620	237.5	382.5	20	35	402.5	417.5
Grass/Hay	500	237.5	262.5	20	35	282.5	297.5
Potatoes	520	237.5	282.5	20	35	302.5	317.5
Faba Bean	610	212.5	397.5	20	35	417.5	432.5
Corn Silage	470	237.5	232.5	20	35	252.5	267.5
CWRS	460	212.5	247.5	20	35	267.5	282.5
CWWS	480	212.5	267.5	20	35	287.5	302.5
Canola	430	212.5	217.5	20	35	237.5	252.5
Flax	410	212.5	197.5	20	35	217.5	232.5
Field Pea	400	212.5	187.5	20	35	207.5	222.5
Barley Silage	390	212.5	177.5	20	35	197.5	212.5
Barley Malt	430	212.5	217.5	20	35	237.5	252.5
Dry Beans	380	212.5	167.5	20	35	187.5	202.5
Chick Pea	380	212.5	167.5	20	35	187.5	202.5
Fall Rye	390	212.5	177.5	20	35	197.5	212.5
CWAD	460	212.5	247.5	20	35	267.5	282.5

CWRS = Canadian Western Red Spring Wheat; CSWS = Canadian Soft White Spring wheat; CWAD = Canadian Western Amber Durum.

Source: [a] ICDC (2008a).

[b] Estimate of 212 mm for crops maturing in 105 days or less, and 237.5 for crops over 105 days of maturity includes the average spring soil moisture and growing season precipitation.

[c] Crop requirement minus the average precipitation and soil moisture reserve.

Metered irrigation water use from the Riverhurst Irrigation District over the 1990 to 2009 period ranged from 93.9 mm per acre in 1999 (wet year) to 290.2 mm per acre (2003), with an average for this period of 185.9 mm per acre and a standard deviation of 50.5 mm per acre (Saskatchewan Watershed Authority, 2011b). The type of crops this irrigation water was used on and its rate of application are unknown. However, on average, it appears to be consistent with the estimate of the normal crop water deficit. The mix of crops produced to 2060 may change, depending on investment in intensive livestock operations in the region as the demand for silage from feedlot cattle operations could significantly change the crop mix. However, no further information is available.

In addition to increasing water demand from higher temperatures and lower precipitation (or lower soil moisture), droughts can also increase water requirements for crops. Lacking of SSRB data, this research employ LDDA data. The district assumed to be close to the newer irrigation districts in the basin was SSRID. A regression analysis of the SSRID water use per acre (IWD) for the period 1990 to 2009 was undertaken, using a binary variable (BY) for the 2001 and 2002 drought years. To account for any possible economies of size in distribution, irrigated area (AREA) was also included. A TIME (trend) variable was included to reflect any technological developments. The results are shown below.

$$IWD = \underset{(313.17)}{259.15} - \underset{(13.66)}{11.34}\ TIME + \underset{(0.053)}{0.018}\ AREA + \underset{(62.2)}{178.38^{**}}\ BY \qquad (6.1)$$

$R^2 = 0.437$ $F = 4.14^*$

Where, ** coefficient is significantly different from zero at $\alpha = 0.01$

* Hypothesis of all variables not affecting water demand rejected at $\alpha = 0.05$

According to these estimates, although the time variable was negative, it was not significant. Therefore, no major water use reducing technologies have been adopted in the SSRID during the 1990 - 2009 period. The same conclusion was drawn for the effect of the basin area being irrigated.

The only significant coefficient in equation (6.1) was that for the binary variable for 2001 and 2002 droughts. Thus, the occurrence of droughts can increase water demand in non-pipeline systems. The increase during the 2001 and 2002 drought represented an average of 178.38 mm per acre. This amount is 68.8% over the water used during a normal year. The 95% confidence interval for this coefficient was estimated to be between 46.5 to 310.2 mm per acre.

The future irrigation water demand in the basin will depend on the frequency of droughts. As noted above, the past frequency of droughts in Saskatchewan is estimated as 8%. As noted earlier, for the future the estimated frequency of droughts was 13% by 2040 and about 18% by 2060. Assuming that in a drought year, one would need 178.4 mm more water, water demand per acre of irrigated land for 2040 was adjusted up by 23 mm and that for 2060, by 32 mm,[45] given the frequency of drought in 2040 and 2060.

The total amount of water required for irrigation under the climate change scenario is shown in Table 6.4. By 2060, water demand is estimated at 919,459 dam^3. This amount is 27% higher than that predicted under the baseline scenario in 2060.

[45] These amounts were calculated as 178.39 mm of water in drought year times the probability of a drought occurrence.

Table 6.4: Estimated Water Demand for Irrigation in the South Saskatchewan River Basin by Irrigation System for the Climate Change Scenario, 2010-2060

Irrigation System	Amount of Water in dam³			
	2010	**2020**	**2040**	**2060**
Wheelmove	18,730.3	18,730.3	22,024.2	23,862.6
Pivot	148,085.2	195,425.9	529,017.0	813,880.4
Linear	1,099.5	1,099.5	1,292.8	1,400.7
Misc. Sprinklers	17,272.7	17,272.7	20,385.7	22,134.7
Surface	21,557.2	21,557.2	25,442.4	27,625.2
200mm Backflood	3,216.5	3,216.5	3,216.5	3,216.5
Misc. Backflood	19,364.7	19,364.7	22,854.8	24,815.6
Remainder	1,969.1	1,969.1	2,324.0	2,523.4
Total Water Demand	**231,295**	**278,636**	**626,558**	**919,459**

6.1.3 Irrigation Water Demand – Water Conservation Scenario

Irrigation water demand can be reduced through water conservation in a variety of manners. Some notable avenues are listed here:

- Conversion of surface irrigation areas to sprinkler irrigation
- Adoption of existing water conservation measures for sprinkler irrigation
- Improvement in irrigation technology in the future
- Change crop mix through replacing higher water requirement crops to lower water requirements of crops
- Change in the off-farm delivery system from open and unlined canals to lined canals (to reduce seepage) or pipelines

In this study, with the exception of the last measure (change in off-farm delivery mechanism), effects were estimated directly. With respect to the conversion of area, gains are possible as already shown in Table 6.5. The current overall system efficiency of irrigation in the SSRB is estimated at 68%, given the current irrigation technology. Efficiency gains may occur in the future by changing the delivery method to the crops. For example, if a contour flooding system is in use, converting it to sprinkler, would gain 42-49% in terms of water use efficiency. Similarly, there is a 7% gain for sprinkler irrigation if high nozzle systems are converted to drop tube systems.

Table 6.5: Irrigation Efficiency in the South Saskatchewan River Basin, 2010 and Projected

Efficiency of the System	Irrigated Acres	% of total Acres	2010 System Efficiency		Improved System Efficiency	
			System	SSRB	System	SSRB
Wheelmove	12,360	7.8%	65%	5.1%	79%	6.1%
Pivot	110,772	69.7%	75%	52.3%	85%	59.2%
Linear	837	0.5%	75%	0.4%	79%	0.4%
Misc. Sprinklers	11,403	7.2%	65%	4.7%	80%	5.7%
Surface	9,853	6.2%	45%	2.8%	60%	3.7%
200mm Backflood	3,972	2.5%	0%	0.0%	30%	0.7%
Misc. Backflood	8,851	5.6%	45%	2.5%	60%	3.3%
Remainder	900	0.6%	45%	0.3%	60%	0.3%
Total	158,949	100.0%		**68%**		**80%**

Source: ICDC (2011) for area irrigated; Holm (2008) for technology efficiency.

In other words, it currently takes on average 541 mm of water per acre to get 300 mm to the crop. If the wheelmove, pivot, and miscellaneous sprinklers technology was adopted (with an improved efficiency of 79%), then the basin's irrigation efficiency would increase to 61%. Generally, an average of 489 mm of water per acre would be needed to get 300 mm at the crop. The cost of improving the irrigation system's efficiency versus the return to the farmer will determine if the technology will be undertaken and adopted. Improved yields or quality of the crop have been cited by farmers as the major reason influencing the adoption of more efficient irrigation technology (Bjornlund et al., 2009). The price of water plus pumping cost and the cost of the upgrade are the main cost determinants affecting the adoption of improved irrigation technology.

Moreover, it should be noted that the total water demand by farmers may not be reduced as farmers allocate savings in water from improved technology to other uses, including more irrigation (Bjornlund et al., 2009). Faced with a fixed supply of water, farmers will allocate the resource to its highest value applications. The initial allocation of water and the way this allocation changes over time will have more of an effect on the net water use by irrigators than will changes in technology.

The potential for reducing irrigation water demand is more complex, since it is affected by several factors. In agricultural (field) irrigation, a reduction can be achieved through various alternatives, including changing crop mix, water efficient equipment, improvements in water conveyance systems, among others. Various water delivery systems to the field have different water efficiencies as shown in Table 6.6. Backflood systems, for example, are only 30-55% efficient, in comparison to centre pivot systems that have 72-79% efficiency.

Table 6.6: Irrigation System Efficiency in Prairie Provinces

System	Avg. Efficiency
Contour Flood	30%
Leveled Surface	55%
Hand-Move	60%
Wheel-Roll	66%
Centre Pivot High Nozzle	72%
Centre Pivot Drop Tube	79%

Source: Holm (2008).

The estimated water demand by irrigation systems for the SSRB under the Water conservation scenario is presented in Table 6.7. The total water demand for irrigation under this scenario would not show any change until 2020. By 2040, a moderate decrease in water demand is estimated. This level will be 468 thousand dam^3, about 12% lower than that predicated under the baseline scenario (Table 6.8). By 2060, the effect of climate change would result in an even higher increase in the water used, as shown in Figure 6.2.

Table 6.7: Estimated Water Demand for Irrigation in the South Saskatchewan River Basin by Irrigation System for the Water Conservation Scenario

Irrigation System	Amount of Water Demand in dam^3			
	2010	**2020**	**2040**	**2060**
Wheelmove	18,730	17,392	16,233	16,233
Pivot	148,085	183,212	397,722	565,215
Linear	1,100	1,100	1,100	1,100
Misc. Sprinklers	17,273	16,039	14,970	14,034
Surface	21,557	19,401	17,638	16,168
200mm Backflood	3,217	3,217	3,217	3,217
Misc. Backflood	19,365	17,428	15,844	14,524
Remainder	1,969	1,772	1,611	1,477
Total Water Demand	**231,295**	**259,561**	**468,333**	**631,966**

6.2 Dryland Crop Water Demand

As reported in previous chapters, dryland farmers need water primarily for spraying pesticides and herbicides to different crops. The methodology for this estimation was reported in Chapters 3 and 4. The estimated water demand is reported in this section.

Table 6.8: Total Irrigation Water Demand in the South Saskatchewan River Basin under Alternative Scenarios, 2010-2060

Year	Climate Change Scenario		Water Conservation Scenario	
	Amount of Water Demanded (dam^3)	% Change from Baseline Scenario	Amount of Water Demanded (dam^3)	% Change from Baseline Scenario
2010	231,295	0.0%	231,295	0.0%
2020	278,636	0.0%	259,561	-6.8%
2040	626,558	17.3%	468,333	-12.3%
2060	919,459	27.0%	631,966	-12.7%

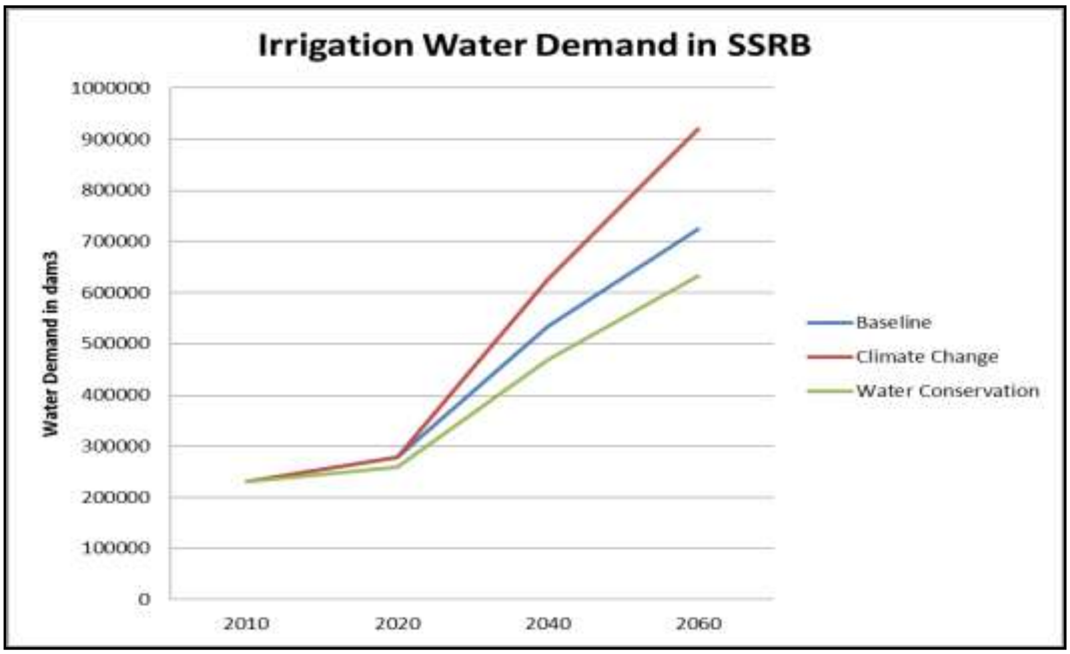


Figure 6.2: Irrigation Water Demand under Alternative Scenarios, South Saskatchewan River Basin, 2010 – 2060

6.2.1 Dryland Crop Water Demand – Baseline Scenario

The estimated crop area by crop category from Table 4.5 was multiplied by water coefficients that account for spray volume for the crop category, number of passes, extent of zero tillage adoption, and cleanup of sprayer. The results are presented in Table 6.9. In 2010, this water demand is estimated to be around 209 dam^3, but is forecasted to decline by 2040 to 2060 from the current 2010 level as cropping patterns revert to the long term averages.

6.2.2 Dryland Crop Water Demand – Climate Change Scenario

The area for each of the crop categories-cereal, oilseed and pulse- is expected to remain the same for the climate change scenario, given the crop rotation limitations. The type of crops within categories is likely to change as farmers adopt crops to fit the new climate regime. However, the number of pesticide applications needed for the replacement crops would not differ greatly from for crops currently grown. An indirect effect of climate change, higher evaporation, may make some surface water bodies currently used as sources unsuitable. Results are shown in Table 6.10. The water demand is estimated to increase by 3.9% over the 2010 level as a result of a changing climate in 2060.

Table 6.9: Water Demand for Crop Pesticide Application in the South Saskatchewan River Basin, 2010 - 2060, for the Baseline Scenario

Crop Type	Water Demand in dam^3			
	2010	**2020**	**2040**	**2060**
Cereals	89.0	86.3	83.9	83.9
Oilseeds	40.7	44.5	39.4	39.4
Pulses	56.8	53.2	53.9	53.9
Fallow	22.7	17.2	21.6	21.6
Total Water Demand	**209.3**	**201.2**	**198.8**	**198.8**
% Change from 2010 level		-3.8%	-5.0%	-5.0%

Table 6.10: Water Demand for Crop Pesticide Application in the South Saskatchewan River Basin, 2010 - 2060, under Climate Change Scenario

Crop Type	Water Demand in dam^3			
	2010	**2020**	**2040**	**2060**
Cereals	89.0	86.3	88.7	93.5
Oilseeds	40.7	44.5	40.2	41.0
Pulses	56.8	53.2	55.9	57.8
Fallow	22.7	17.2	24.3	25.0
Total Water Demand	**209.3**	**201.2**	**209.1**	**217.4**
% of 2010 Level		96.2%	99.9%	103.9%

6.2.3 Dryland Crop Water Demand – Water Conservation Scenario

Technology developments in weed elimination using hot water or lasers could be in use by 2060 as advances in computing technology and pattern recognition improve along with GPS guidance systems emerge. Pressure to reduce or eliminate pesticides in agricultural production may be the main driving force behind the change. Effective weed control for organic production is also another factor which could push the development of this technology. The assumption is that by 2040 10% of the area would have eliminated herbicide use and by 2060 50% of the area will have adopted this technology. Net result of these assumptions is shown in Table 6.11. Water demand for pesticide use could decrease considerably, particularly by 2060 under these assumptions. As much as 47.5% reduction in pesticide water demand is estimated for 2060 period.

Table 6.11: Water Demand for Crop Pesticide Application in the South Saskatchewan River Basin, 2010 - 2060, for the Water Conservation Scenario

Crop Type	**Water Demand in dam^3**			
	2010	**2020**	**2040**	**2060**
Cereals	89.0	86.3	75.5	42.0
Oilseeds	40.7	44.5	35.4	19.7
Pulses	56.8	53.2	48.5	27.0
Fallow	22.7	17.2	19.4	10.8
Total Water Demand	**209.3**	**201.2**	**178.9**	**99.4**
% of 2010 Level		96.2%	85.5%	47.5%

6.3 Stockwater Demand

Livestock production needs water for several purposes: direct use by animals or birds, and that used for maintenance (cleaning and/or manure disposal) of facilities, such as dairy barns. Both of these types of demands are combined and results are presented in this section.

6.3.1 Stockwater Demand -- Baseline Scenario

Stockwater demand was estimated by type of animals, following the methodology as reported in Chapters 3 and 4. The estimated water demand for various types of livestock is presented by type of livestock category. These results for dairy and cattle herds in the SSRB for the 2010 - 2060 period are presented in Table 6.12. The largest amount of water is needed for the beef cow herd, followed by that for feedlots and calves. Dairy animals are relatively fewer in number, and thus have lower water consumption than beef herds. By 2060, this water demand will increase by roughly 13% of the 2010 level.

For hog production, Agriculture Canada's Medium Term Outlook (see AAFC 2011) estimates were used. According to this source, hog production is to increase by 3.5% in 2020 from 2010. This projection was based mainly on expanding off-shore markets, as domestic demand is expected to decline, and MCOOL in the USA will limit market access. For the SSRB the 3.5% increase is used to estimate the size of the breeding herds for 2020, 2040, and 2060. From these estimates the number of boars, suckling, weaned, and feeder pigs are predicted. Productivity gains are included as an increase in the number of sows per boar and as an increase in the number of surviving piglets per litter. The estimated demand for water from the hog sector in the SSRB is attained in Table 6.13. The projection is for an increase of 11% in the water demand for hog production by 2060 over the 2010 level.

Table 6.12: Estimated Water Demand for Beef Cattle and Dairy Production in the South Saskatchewan River Basin, 2010 - 2060, for the Baseline Scenario

Livestock Type	Water Demand in dam^3			
	2010	**2020**	**2040**	**2060**
Bulls	91.1	97.7	100.6	102.6
Milk Cows	353.7	324.7	318.2	324.6
Beef Cows	1,672.7	1,793.6	1,829.5	1,866.1
Milk Heifers	41.9	38.5	37.7	38.5
Beef Replacement Heifers	230.4	230.1	252.0	257.0
Feedlot	572.2	633.5	696.8	766.5
Calves	825.1	884.7	902.4	920.5
Total Water Demand	**3,787.1**	**4,002.8**	**4,137.3**	**4,275.8**
% of 2010 Level		105.7%	109.2%	112.9%

Table 6.13: Estimated Water Demand, Hog Sector in the South Saskatchewan River Basin for the Baseline Scenario, 2010 - 2060

Type of Animal	Water Demand in dam^3			
	2010	**2020**	**2040**	**2060**
Gestating Sows	28.5	29.5	30.5	31.6
Lactating Sows	7.4	7.7	7.9	8.2
Suckling Pigs	3.7	4.0	4.3	4.7
Weaned Pigs	14.6	15.1	15.7	16.2
Grower Finishing Pigs	398.4	412.2	426.6	441.4
Boars	1.2	1.4	1.3	1.2
Total Water Demand	**453.7**	**469.8**	**486.2**	**503.2**
% of 2010 Level		103.6%	107.2%	110.9%

The projection for sheep is a 20.4% increase in production from 2010 to 2020. If this were to happen in Saskatchewan, the productive capacity would be back to where it was in 2001. The estimated demand for water for the SSRB from the sheep sector is presented in Table 6.14. The total water demand in 2060 would increase by 22.8% over the 2010 water demand level of 9.8 dam^3 to 12.0 dam^3.

Poultry and egg production is expected to be 15.3%, 17.1%, 8.9%, and 16.3% higher for chicken, turkey, shell eggs, and processing eggs by 2020 over the 2010 levels in Canada (AAFC 2011). Production for these agriculture commodities is controlled by quotas allocated to the provinces to meet provincial demand. A growth in population, along with changing demographics and tastes, can affect the demand for poultry and egg products.

Table 6.14: Estimated Water Demand, Sheep Sector in the South Saskatchewan River Basin for the Baseline Scenario, 2010 to 2060

Type of Animal	Water Demand in dam^3			
	2010	**2020**	**2040**	**2060**
Rams	0.30	0.36	0.36	0.37
Ewes	7.21	8.67	8.76	8.85
Breeding	1.42	1.71	1.73	1.75
Slaughter	0.87	1.05	1.06	1.07
Total Water Demand	**9.8**	**11.8**	**11.9**	**12.0**
% of 2010 Level		120.4%	121.6%	122.8%

The expected change in Saskatchewan's population from 2020 to 2036 forecasted by Statistics Canada (2011c) by using a number of scenarios, ranges from 0.0% to 18.4%. A reasonable estimated increase in population for Saskatchewan would be in the 5% to 10% range. For the purposes of estimating poultry and egg demand, an increase of 10% to 2040 from the 2020 level and 5% to 2060 from the 2040 level in Saskatchewan's population was chosen. The estimates for the water demand in the SSRB are presented in Table 6.15. In 2010, this sector used 946 dam^3 of water per year. By 2060, this amount would increase to 1,258 dam^3 – an increase of 33% over the 2010 level of water demand.

Table 6.15: Water Demand Estimates for the Poultry and Egg Sectors in the South Saskatchewan River Basin for the Baseline Scenario, 2010 - 2060

Type of Poultry	Water Demand in dam^3			
	2010	**2020**	**2040**	**2060**
Laying Hens	29.7	32.3	35.6	37.3
Pullets	6.0	7.0	7.7	8.1
Broilers	882.3	1017.5	1119.2	1175.2
Other Poultry	1.0	1.1	1.2	1.3
Turkeys (M)	16.0	18.7	20.6	21.6
Turkeys (F)	10.4	12.2	13.4	14.1
Total Water	**945.5**	**1,088.9**	**1,197.7**	**1,257.6**
% of 2010 Level		115.2%	126.7%	133.0%

The markets for products from the other livestock sector are all relatively small because their growth in the future is limited. Therefore, conservative estimates were chosen for forecasting changes in the herd size of these agricultural sectors. The water demand for the other livestock sector is presented in Table 6.16. A moderate 15% increase in the water demand is estimated for the 2060 year relative to the 2010 level. Relative to other livestock sectors (except for the sheep sector), water demand is relatively low. In 2010, this sector used 180 dam^3, which is expected to increase to 184 dam^3 by 2060.

Table 6.16: Water Demand Estimates for Other Livestock in the South Saskatchewan River Basin for the Baseline Scenario, 2010 - 2060

Type of Animal	**Water Demand in dam^3**			
	2010	**2020**	**2040**	**2060**
Bison	31.84	35.02	35.37	35.72
Horses	139.31	139.31	139.31	139.31
Goats	2.33	2.33	2.33	2.33
Llamas	2.91	2.91	2.91	2.91
Deer	3.94	3.94	3.94	3.94
Total Water	**180.3**	**183.5**	**183.9**	**184.2**
% of 2010 Level		101.8%	102.0%	102.2%

A summary of water demand for livestock use in the SSRB is presented in Table 6.17. The total water demand for livestock production was estimated at 5,376 dam^3 for 2010. The largest portion of this total is for dairy and beef cattle enterprises. As shown in Figure 6.3, 66% of the total livestock water is used by these types of livestock. By 2060, this demand will increase by 16% of the 2010 level. During this period, there will be a need for 6,233 dam^3 of water for this purpose in the basin. Again, the largest share would be claimed for the dairy and beef enterprises, followed by the poultry and egg sector.

Table 6.17: Water Demand Estimates for Livestock in the South Saskatchewan River Basin for the Baseline Scenario, 2010 - 2060

Livestock Type	**Water Demand in dam^3**			
	2010	**2020**	**2040**	**2060**
Dairy & Beef Cattle	3,787.1	4,002.8	4,137.3	4,275.8
Hog Sector	453.7	469.8	486.2	503.2
Sheep	9.8	11.8	11.9	12.0
Other Livestock	180.3	183.5	183.9	184.2
Poultry & Eggs	945.5	1,088.9	1,197.7	1,257.6
Total Livestock Water Demand	**5,376.4**	**5,756.9**	**6,017.0**	**6,232.9**
% Change from 2010		7.1%	11.9%	15.9%

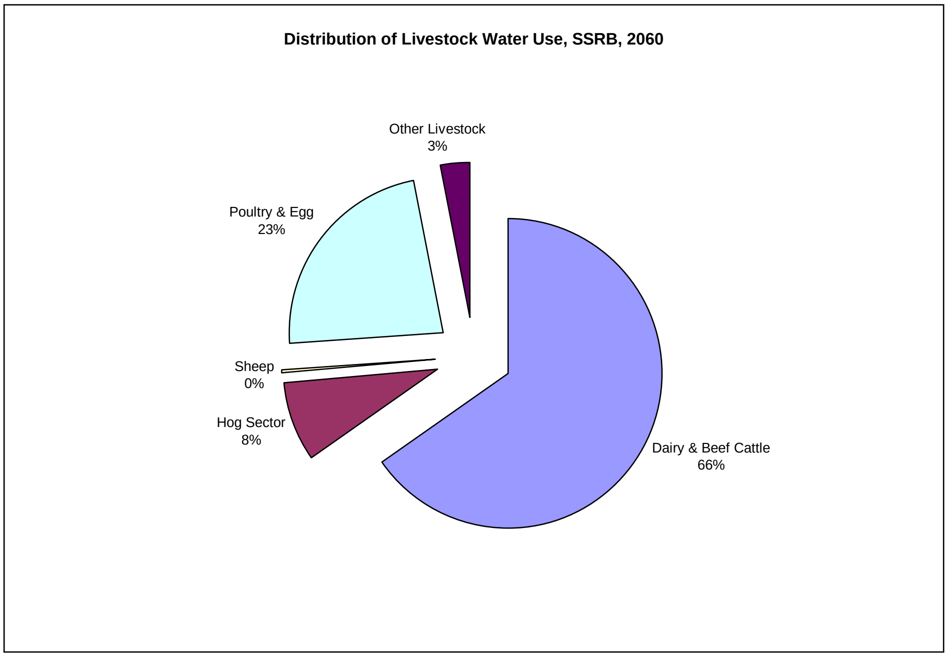


Figure 6.3: Distribution of Total Livestock Water Demand in the South Saskatchewan River Basin, 2060, by Type of Livestock

6.3.2 Stockwater Demand – Climate Change Scenario

Forecasts of water demand for livestock to 2040 and 2060 were based on the estimated livestock populations and estimated water demand coefficients as affected by climate change. Given the seasonal demands for livestock products (i.e., turkeys for Thanksgiving) and production constraints (e.g., spring calving) there is little opportunity to shift production out of the summer months.

The type of livestock, their age, climate, feed, and location on farm (indoors/outdoors) all affect the uptake of water. Water needs are generally associated with the rate of water loss. Therefore, an increase in the temperature is the main factor affecting water demand levels. Generally, temperature has a greater effect on the water requirements of smaller animals than on larger animals. For example, a one week old broiler at 35°C barn temperature consumes 217% more water than at 30°C. Similarly, the 6 week old broiler consumes 13% more water (Rural Chemical Industries, undated). A grazing animal's water intake is affected by the type of pasture and the time of year as affected by the weather and moisture content of the forage.

Water use technology for the production of hogs has improved significantly over the last 10-15 years, climate change may affect the amounts of water consumed by the hog and water used for cooling. Warmer springs and falls may extend the period over which cooling is required.

Water demand estimates for hog production are presented in Table 6.18. It is estimated that relative to 2010, by 2040 there will be 20% more days that require cooling and by 2060 there will be 40% more days that require cooling. The water required in 2060 will be about 36 litres per sow per day, which is 33.9% higher than that needed in 2010.

Table 6.18: Hog Production Water Use Requirements, 2010 - 2060

Activity	2001*	Forecast		
		2020	2040	2060
	Litres/sow/day			
Washing	3.10	3.10	3.10	3.10
Cooling(grow/finish)	22.40	22.40	26.88	31.36
Cooling (farrowing)	0.30	0.30	0.36	0.42
Domestic	1.00	1.00	1.00	1.00
Total Water Use for Hog production	**26.80**	**26.80**	**31.34**	**35.88**

* Estimations based on Small (2001).

The drinking water requirement of swine for various categories is presented in Table 6.19. The estimates were calculated following the average water use from Thacker (2001) for the average outside temperature, a projected 2°C rise, and for a projected 3.5°C rise in temperature in Saskatchewan. Higher temperatures are expected to result in higher water consumption for the May to September period relative to the present situation. The change in drinking water use for these temperature changes suggest that a lactating sow, that needs only 15 litres of water per day now, would need 35 litres per day if the increase in temperature is 3.5°C.

Table 6.19: Drinking Water Requirements for Various Categories of Hogs under Alternative Temperature Levels

Type of Animal	Drinking Water Demand in Litres per day per Animal for Change in Temperature		
	Normal	Increase over Normal	
		2°C	3.5°C
Gestating Sows	5.0	12.5	20.0
Lactating Sows	15.0	25.0	35.0
Suckling Pigs	0.3	1.1	2.0
Weaned Pigs	1.0	3.0	5.0
Growing & Finishing Pigs	5.0	7.5	10.0
Boars	8.0	12.5	17.0

Source: Adapted from Thacker (2001).

Using the above set of information, water requirements for various categories of hogs were estimated. This involved the following steps: (i) Average normal high temperature for each month for several locations in a water basin was obtained from Environment Canada. (ii) Water consumption for each month, using the corresponding coefficients from Table 4.13, was taken to estimate monthly consumption. (iii) To estimate water demand for 2040 and 2060, the average monthly temperatures were increased by 2°C and 3.5°C, respectively, and the corresponding water coefficients from Table 4.13 applied. The final set of estimates is shown in Table 6.20.

Table 6.20: Drinking Water Consumption for Swine

Type of Animal	Average 1971 - 2000	Increase Plus 2°C	Increase Plus 3.5°C
	Litres per Day		
Gestating Sows	8.78	10.03	10.67
Lactating Sows	20.04	21.71	22.56
Suckling Pigs	0.71	0.85	0.92
Weaned Pigs	2.01	2.34	2.51
Growing & Finishing Pigs	6.76	7.35	7.65
Boars	10.27	11.02	11.40

Source: Adapted from Thacker (2001).

To relate to climate change in the SSRB, no effect of climate change was assumed for 2020. By 2040, it was assumed that the average temperature would increase by 2°C above the base period (1971-2000) average temperature. For 2060, an increase in temperature of 3.5°C above the 1971-2000 level was assumed.

Beef cattle's consumption of water is affected by time of year and feed type. As expected the moisture content of feed also affects the amount of additional water needed (Olkowski, 2009). Dairy and feedlot operations generally use more silage in the livestock diets, relative to beef cow-calf operations. Water consumption estimates at different temperatures for various categories of beef cattle are presented in Table 6.21.

These estimates were used to derive water demand coefficients for beef cattle in Saskatchewan. First, the average normal high temperature for each month for several locations in a water basin was obtained from Environment Canada. Next, the water consumption for each month, following the corresponding coefficients from Table 6.21, was used to estimate monthly consumption. To estimate water demand for 2040 and 2060, the average monthly temperatures were increased by 2°C and 3.5°C, respectively, and the corresponding water coefficients from Table 6.6 were applied. The coefficients chosen to estimate water demand to 2060 are presented in Table 6.22.

Table 6.21: Beef Cattle Water Consumption (L/DAY) at Different Temperatures

Type/Weight (kg)	**Water Consumption L/day at Temperature in °C**					
Background	**4.4**	**10**	**14.4**	**21.1**	**26.6**	**32.2**
182	15.1	16.3	18.9	22.0	25.4	36.0
277	20.1	22.0	25.0	29.5	33.7	48.7
364	23.0	25.7	29.9	34.8	40.1	56.8
Finishing						
273	22.7	24.6	28.0	32.9	37.9	54.1
364	27.6	29.9	34.4	40.5	46.6	65.9
454	32.9	35.6	40.9	47.7	54.9	78.0
Pregnant						
409	25.4	27.3	31.4	36.7		
500	28.7	24.6	28.0	32.9		
Lactating						
409	43.1	47.7	54.9	64.0	67.8	81.0
Bulls						
636	30.3	32.6	37.5	44.3	50.7	71.9
727	32.9	35.6	40.9	47.7	54.9	78.0

Source: Olkowski (2009).

Table 6.22: Estimated Water Demand Coefficients for Beef Cattle

Type/Weight	**Average 1971 – 2000**	**Plus 2°C**	**Plus 4°C**
Background	**Litres per Day**		
182	19.05	20.38	21.54
277	25.42	27.19	28.84
364	29.73	31.85	33.67
Finishing			
273	28.55	30.50	32.28
364	34.93	37.32	39.46
454	41.37	44.22	46.74
Pregnant			
409	35.36	36.38	37.71
500	36.17	37.02	38.25
Lactating			
409	53.59	55.91	57.78
Bulls			
636	38.17	40.79	43.14
727	41.37	44.22	46.74

The water consumption estimates for dairy cattle use the categories of milk production, given the temperature, to arrive at water demand coefficients (Table 6.23). These coefficients are then used to estimate water consumption for the three climate regimes (Table 6.24). Water is also necessary for the cleaning of dairy operations and is estimated at 18.0 litres per cow per year (Beaulieu et al. 2001). For this report, water demand coefficients for alternative livestock as affected by temperature were not available, so the nearest animal type was used as a proxy. Water consumption coefficients for six categories of poultry were derived by following the same methodology of estimating the coefficients for the beef and dairy sector; these are presented in Table 6.25. Water is also used in the cleaning of poultry operations and it is estimated at 1.7 litres per bird per year (Beaulieu et al., 2001).

Table 6.23: Dairy Cattle Water Consumption, L/Day at Different Temperatures

Milk production kg/day	Min. Mean Temperature in degrees				
	4.4	**10.0**	**15.6**	**21.1**	**26.7**
18.1	69.7	76.5	83.3	89.7	96.5
27.2	82.5	89.0	95.8	102.6	109.4
36.3	95.0	101.8	108.6	115.1	121.9
45.4	107.9	114.7	121.5	127.9	134.8

Source: Looper and Waldner (2007)

Table 6.24: Estimated Water Demand Coefficients for Dairy Cattle

Milk kg/day	Average 1971 – 2000	Plus 2°C	Plus 4°C
	Litres per Day		
18.1	79.8	81.5	84.5
27.2	92.6	94.3	97.6
36.3	105.2	106.9	110.5
45.4	118.0	119.78	123.7

Table 6.25: Estimated Water Demand Coefficients for Poultry

Poultry Type	Average 1971 - 2000	Plus 2°C	Plus 4°C
	Litres per Day		
Laying Hens	0.275	0.284	0.292
Pullets	0.168	0.174	0.179
Broilers	0.413	0.434	0.455
Other Poultry	0.413	0.434	0.455
Turkeys (M)	0.566	0.584	0.601
Turkeys (F)	0.474	0.488	0.502

Total stockwater demand for the basin under the climate change scenario is presented in Table 6.26. In 2010, a total of 5,376 dam^3 of water was used. By 2060, this will experience a growth and will increase to 6,720 dam^3 – an increase of 7.8% of the 2010 level.

Table 6.26: Water Demand Estimates for Livestock in the South Saskatchewan River Basin for the Climate Change Scenario, 2010 - 2060

Livestock Type	Amount of Water in dam^3			
	2010	**2020**	**2040**	**2060**
Dairy & Cattle	3,787.1	4,002.8	4,264.5	4,555.8
Hog Sector	453.7	469.8	522.8	560.4
Sheep	9.8	11.8	13.0	13.7
Other Livestock	180.3	183.5	196.7	208.2
Poultry & Egg	945.5	1,088.9	1,257.8	1,381.6
Total Livestock Water Demand	**5,376.4**	**5,756.9**	**6,254.8**	**6,719.7**
% Change from Baseline	--	0%	4.0%	7.8%

6.3.3 Stockwater Demand – Water Conservation Scenario

The development of watering devices that reduce waste and adoption of the new technology are the key factors in water conservation to 2060. The cost of the technology relative to the savings will determine whether the technology will be adopted. Cooling of livestock in barns by using water during the summer months is another area that may see technological development. The adoption of water conservation technologies would most likely be in intensive livestock operations where all aspects of the production cycle are and will be more closely monitored. Li et al. (2005) report typical water wastage at 26% with a range of 15% to 42%, depending on the ages of feeder pigs. They cite better research on behavioral aspects of animals to fill the gaps in water requirements of livestock. It is assumed that by 2040, a 3.8% reduction in water demand for the poultry, hog, beef feedlot, and dairy sectors will result from water conservation. By 2060, it will reach 4.8%.

The total water demand for livestock under the water conservation scenario is shown in Table 6.27. This demand is expected to increase only to 5,934 dam^3 by 2060, as against 6,233 dam^3 under the baseline scenario – a decrease by 4.8% of the baseline scenario. A comparison of water demand for livestock purposes under the three study scenarios is shown in Figure 6.4.

Table 6.27: Water Demand Estimates for Livestock in the South Saskatchewan River Basin for the Water Conservation Scenario, 2010 - 2060

Livestock Type	Amount of Water in dam^3			
	2010	**2020**	**2040**	**2060**
Dairy & Cattle	3,787.1	4,002.8	3,995.1	4,127.9
Hog Sector	453.7	469.8	461.9	478.0
Sheep	9.8	11.8	11.9	12.0
Other Livestock	180.3	183.5	183.9	184.2
Poultry & Egg	945.5	1,088.9	1,137.8	1,131.9
Total Livestock Water Demand	**5,376.4**	**5,756.9**	**5,790.6**	**5,934.1**
% Change from Baseline		0%	-3.8%	-4.8%

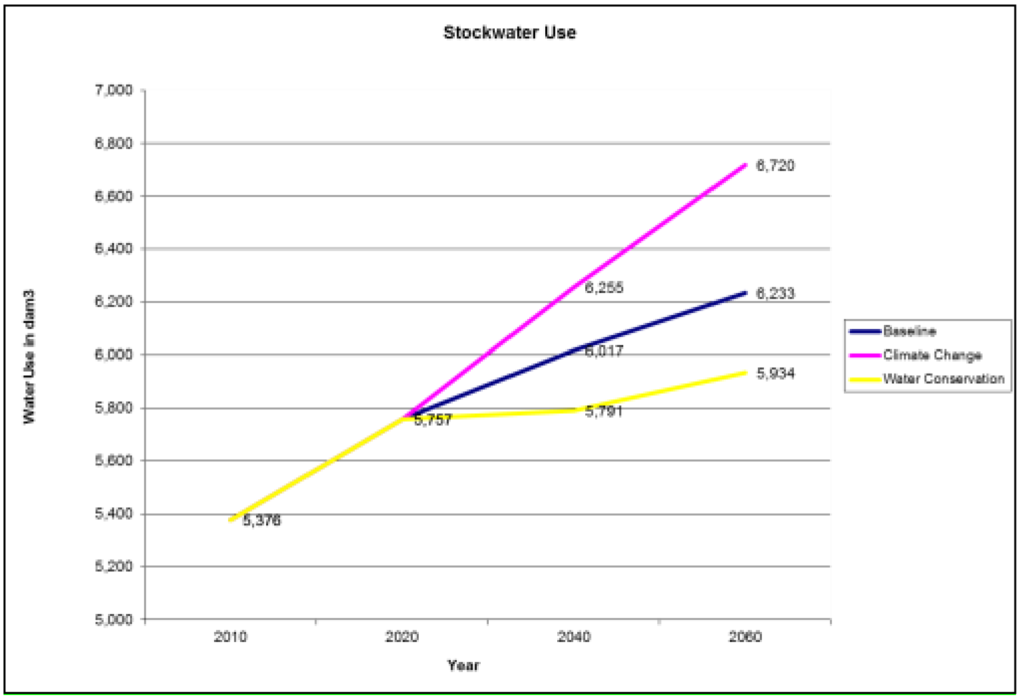


Figure 6.4: Change in the Stockwater Demand in the South Saskatchewan River Basin under Alternate Scenarios, 2010 – 2060

6.4 Water Demand for Greenhouses and Nurseries

Technological developments to increase the length of time that the greenhouse can profitably operate during the year, along with management techniques to improve the efficiency of the operation, are likely to occur by 2060. The question is whether these technological improvements give the greenhouse industry a relative advantage over other greenhouse producers outside of Saskatchewan or producers of field crop vegetables. The bedding plant and potted plant market of greenhouse production appears to be related to population growth and to disposable income. The competitiveness of the Saskatchewan greenhouse sector will determine its market share of the fresh vegetable market and determine whether this sector grows beyond supplying bedding plants and potted plants. The water demand for the greenhouse industry in the SSRB is shown in Table 6.28. The growth to 2020 was estimated at 1% over 2010, with a 5% increase from 2020 to 2040 and 2040 to 2060. The total water demand for this sub-sector is estimated to increase from 120 dam^3 in 2010 to 134 dam^3 by 2060.

Table 6.28: Greenhouse and Nursery Water Demand in the South Saskatchewan River Basin for the Baseline Scenario, 2010 - 2060

Year	Water Demand in dam^3
2010	120.2
2020	121.4
2040	127.4
2060	133.8

6.5 Water Demand for Aquaculture

The amount of water demand could not be estimated because of the lack of data on these operations. As a substitute, the level of this water demand was taken from R. Halliday & Associates' (2009) report at 127 dam^3 from surface and 172 dam^3 from groundwater sources, for a total demand of 299 dam^3 per year. For future years, the same amount of water is assumed to be used for aquaculture purposes. No impact of climate change or water conservation could be ascertained, since information on this sector is lacking.

6.6 Total Agricultural Water Demand

In this section, all different types of agricultural water demands are summarized in this section for the three study scenarios. Since they demand only a small amount of water, the greenhouses, nurseries, and aquaculture water demands were combined into a single category.

6.6.1 Total Agricultural Water Demand – Baseline Scenario

The projected water demand for the agriculture sector for the baseline scenario in the SSRB is presented in Table 6.29. Crop water demand (irrigation and pesticide spraying) is the biggest component, of which the water taken for irrigation is expected to account for 99% of the agricultural sector's water demand in the SSRB in 2060. The livestock sector (and within that, the dairy and beef cattle sub-sectors) is the next bigger component of water demand. By 2060, the basin could see an increase in this water demand by 208% -- from 237 thousand dam^3 to 731 thousand dam^3. Much of this increase will result from irrigation expansion in the basin, particularly the irrigation development in the Westside Irrigation District and other expansions through infill projects. In fact, as shown in Figure 6.5, irrigation dominates the total agricultural water demand in this basin.

Table 6.29: Agriculture Water Demand in the South Saskatchewan River Basin for the Baseline Scenario, 2010 - 2060

Activity	Water Demand in dam^3			
	2010	**2020**	**2040**	**2060**
Irrigation	231,295	278,636	533,962	723,787
Livestock	5,376	5,757	6,017	6,233
Pesticide	209	201	199	199
Other Agricultural (Greenhouses, Nurseries and Aquaculture)	419	420	426	433
Total Agricultural Water Demand	**237,300**	**285,014**	**540,604**	**730,651**
% Change over 2010 Level	--	20.1%	127.8%	207.9%

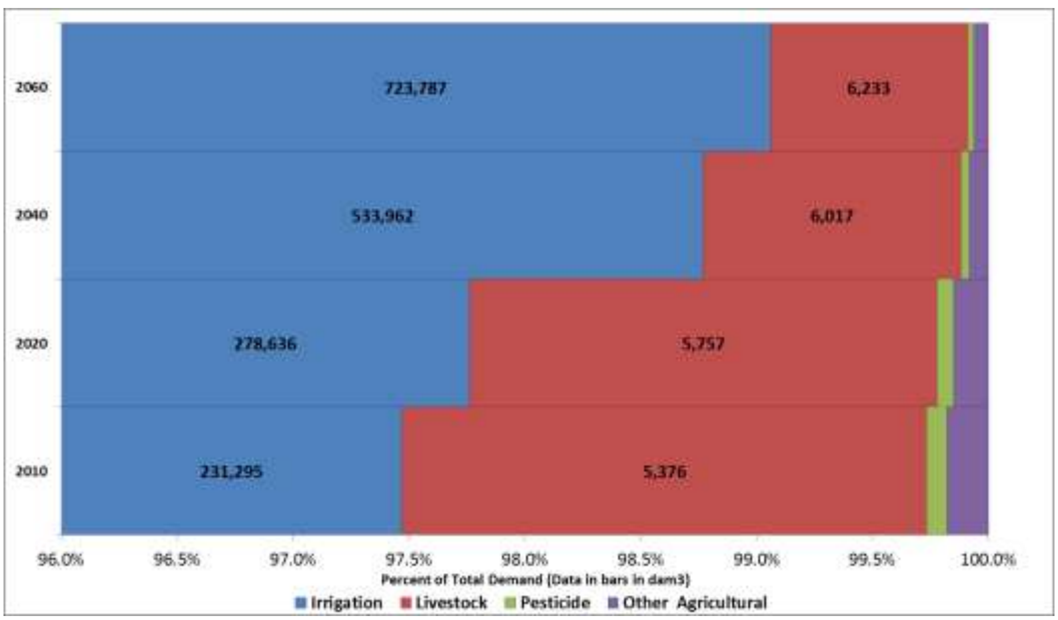


Figure 6.5: Total Agriculture Water Demand, South Saskatchewan River Basin, 2010 - 2060, Baseline Scenario

6.6.2 Total Agricultural Water Demand – Climate Change Scenario

Climate change through increased average temperature and higher frequency of droughts, will impart a significant increase in the water demand for agriculture purposes. In the SSRB, by 2060, this water demand will increase to 927 thousand dam^3, which is 27% higher than that observed under the baseline scenario. Increases will probably be observed by 2040, when the water demand increases by 17% above the baseline scenario level (Table 6.30).

Table 6.30: Agricultural Water Demand in the South Saskatchewan River Basin for Climate Change Scenario, 2010 - 2060

Activity	Water Demand in dam^3			
	2010	**2020**	**2040**	**2060**
Irrigation	231,295	278,636	626,558	919,459
Livestock	5,376	5,757	6,255	6,720
Pesticide	209	201	209	217
Other Agricultural (Greenhouses, Nurseries and Aquaculture)	419	420	426	433
Total Agricultural Water Demand	**237,300**	**285,014**	**633,448**	**926,829**
% Change over 2010 Level	--	20.1%	166.9%	290.6%

6.6.3 Total Agricultural Water Demand – Water Conservation Scenario

The adoption of water conservation offers a potential way to reduce agricultural water demand in the basin. These results are shown in Table 6.31. Under this scenario, the total agricultural water demand in 2060 could be as low as 638 thousand dam^3, some 13% lower than the baseline scenario.

Table 6.31: Agricultural Water Demand in the South Saskatchewan River Basin for Water Conservation Scenario, 2010 - 2060

Activity	Water Demand in dam^3			
	2010	**2020**	**2040**	**2060**
Irrigation	231,295	259,561	468,334	631,966
Livestock	5,376	5,757	5,791	5,934
Pesticide	209	201	179	99
Other (Greenhouses, Nurseries and Aquaculture)	419	420	426	433
Total Agricultural Water Demand	**237,300**	**265,939**	**474,729**	**638,432**
% Change over Baseline Scenario	--	12.1%	100.1%	169.0%

Relative trends over the 2010 – 2060 period under these scenarios are shown in Figure 6.6. By 2040, the impact of climate change will be noticeable, and it will become even more noticeable by 2060. The adoption of water conservation measures could reduce this impact somewhat, but not entirely. Depending on water availability in the basin by 2060, some of the water demand activities may have to be either postponed or reduced in magnitude.

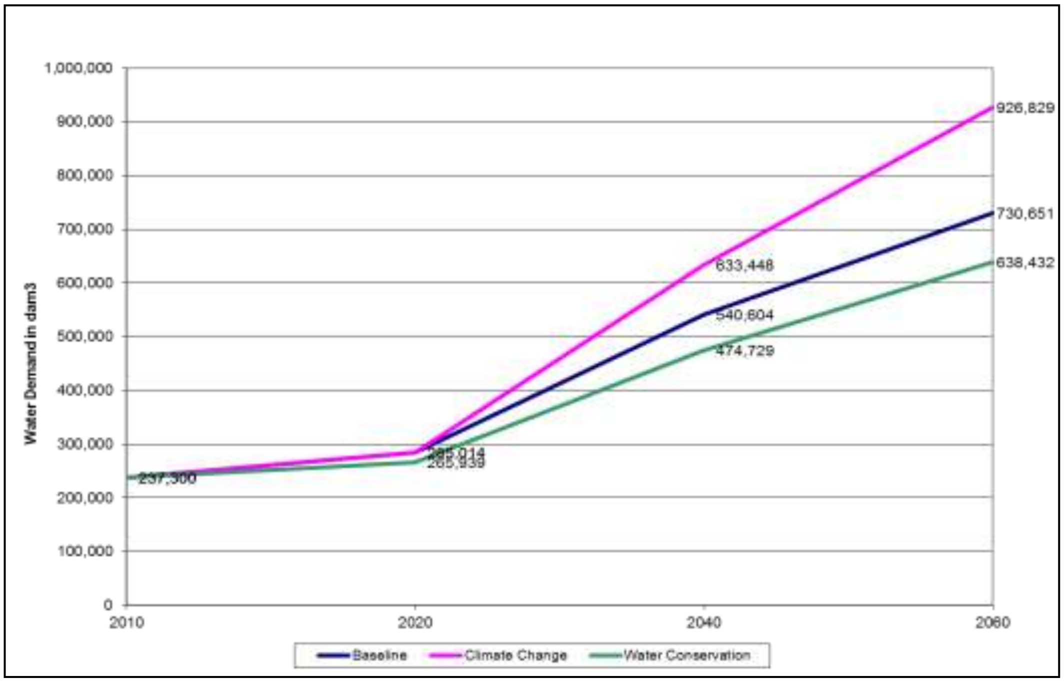


Figure 6.6: Estimated Agricultural Water Demand in the South Saskatchewan River Basin, 2010 - 2060, under Study Scenarios

6.7 Source of Water for Agricultural Activities

Depending on the location of the water demand, some of these demands have to be satisfied from surface water bodies, while others may be filled through drawing groundwater. In this section, a total agricultural water demand from these two sources is estimated.

6.7.1 Source of Water for Agricultural Activities – Baseline Scenario

Much of the irrigation water demand in the basin is supplied from surface water bodies, such as Lake Diefenbaker. Other demands could withdraw water from a combination of surface or groundwater sources. The proportion of surface water used by agricultural activity is shown in Table 6.32. These values pertain to year 2010. On account of a lack of information, the same proportions were used as for the future years.[46] For the same reason, water source estimates were developed according to the best information available. However, these predictions should be viewed as preliminary estimates, subject to primary data collection for various water users.

The difference in the source of water for livestock is determined primarily by production practices. For example, livestock enterprises with year-round confinement, such as the hog and poultry sectors, practice and industrial precision and monitoring of inputs including water to maximize production; they need consistency in the quality and quantity of water. Reliability of water from a given source is very important for these operations. Here, a larger proportion of water is withdrawn from groundwater sources (93% in Table 6.32).

Table 6.32: Share of Surface Water and Groundwater used in Agricultural Activities in South Saskatchewan River Basin in 2010

Type of Use	Share of Total Water Demand (Percent)	
	Surface water	Groundwater
Livestock		
Dairy and Cattle	50.0%	50.0%
Hog Sector	6.9%	93.1%
Sheep	50.0%	50.0%
Other Livestock	50.0%	50.0%
Poultry and Egg	6.9%	93.1%
Crops		
Irrigated	95.0%	5.0%
Pesticide	80.0%	20.0%
Greenhouse	20.0%	80.0%

Using the proportion of surface groundwater to total in Table 6.32, the total agricultural water demand from surface water bodies was estimated. The quantity of surface water withdrawn is presented in Table 6.33, whereas the split between groundwater and surface water for the agricultural sector as shown in Table 6.34. By 2060, about 38% of livestock water demand and 98% of crop water demand will be met from surface water sources. For agriculture as a whole, as shown in Table 6.34, although in 2010 94% of the total water is surface water, by 2060, this proportion is expected to rise to 98%. The larger proportion of crop water demand is for irrigation purposes, which is expected to be developed mostly through surface water bodies; for

[46] Share of surface water to total is also related to its availability. If such resources dwindle, users will be forced to seek groundwater sources to meet their demand.

example, water is presently released from Lake Diefenbaker to various irrigation districts in the LDDA. As shown in Figure 6.7, agriculture would depend increasingly on surface water in the future.

6.7.2 Source of Water for Agricultural Activities – Climate Change Scenario

Since information on the availability of water from surface or groundwater sources is very poor, it was assumed that water withdrawn ratios would be the same as those shown in Table 6.34. Results for the climate change scenario are presented in Table 6.35. Water withdrawals from surface water bodies in 2060 will increase from 713 thousand dam^3 (under the baseline scenario) to 911 thousand dam^3 under this scenario. This source would contribute 98.3% of the total water demand for agricultural purposes. A slightly heightened dependence on surface water is also noted under this scenario, relative to the baseline scenario.

Table 6.33: Surface Water Estimates for Agricultural Demand by Type of Use, South Saskatchewan River Basin, Baseline Scenario, 2010 - 2060

Type of Water Demand	Water Demand in dam^3			
	2010	2020	2040	2060
Livestock				
Dairy and Cattle	1,893.5	2,001.4	2,068.6	2,137.9
Hog Sector	31.3	32.4	33.5	34.7
Sheep	4.9	5.9	6.0	6.0
Other Livestock	90.2	91.8	91.9	92.1
Poultry and Egg	65.2	75.1	82.6	86.8
Total Livestock Water Demand	**2,085.2**	**2,206.6**	**2,282.7**	**2,357.5**
% of Total Livestock Water Demand	38.8%	38.3%	37.9%	37.8%
Crop				
Irrigated	219,730.3	267,071.0	522,397.1	712,221.9
Pesticide	167.4	161.0	159.0	159.0
Greenhouse	151.0	151.3	152.5	153.8
Total Crop Water Demand	**220,048.8**	**267,383.3**	**522,708.6**	**712,534.7**
% of Total Crop Water Demand	94.9%	95.7%	97.8%	98.4%

Table 6.34: Agricultural Water Demand by Source of Water, South Saskatchewan River Basin under Baseline Scenario, 2010 - 2060

Particulars	Water Demand in dam^3			
	2010	2020	2040	2060
Total Agriculture	237,300	285,014	540,604	730,651
Groundwater	15,166	15,424	15,613	15,759
Surface Water	222,134	269,590	524,991	714,892
Surface Water % of Total	93.6%	94.6%	97.1%	97.8%

6.7.3 Source of Water for Agricultural Activities – Water Conservation Scenario

The distribution of total water demand by source of water under the water conservation scenario is presented in Table 6.36. The amount of surface water demand is reduced from the baseline scenario. It falls from 713 thousand dam^3 in 2060 under the baseline scenario to only 623 thousand dam^3 – a reduction of 12.8% of the baseline level.

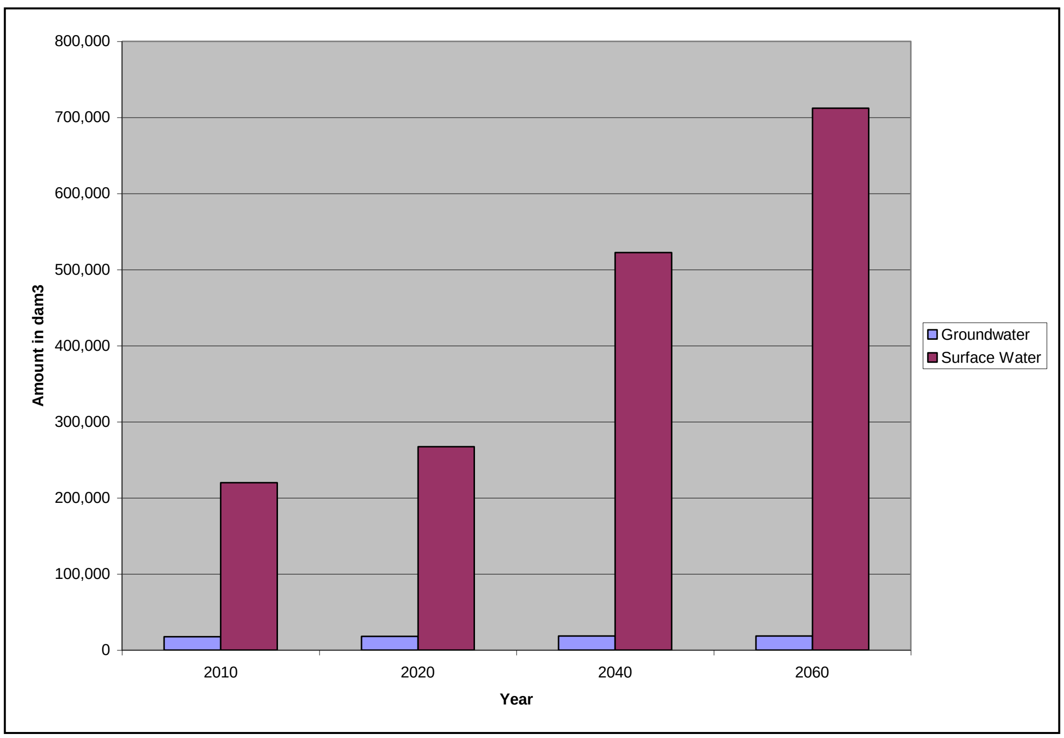


Figure 6.7: Proportion of Total Agricultural Water Demand by Source of Water in the South Saskatchewan River Basin, 2010 – 2060

Table 6.35: South Saskatchewan River Basin Agricultural Water Demand by Source of Water, Climate Change Scenario, 2010 - 2060

Particulars	Water Demand in dam³			
	2010	2020	2040	2060
Total Agriculture	**237,300**	**285,014**	**633,448**	**926,829**
Groundwater	15,166	15,424	15,775	16,084
Surface Water	222,134	269,590	617,673	910,745
Surface Water % of Total	93.6%	94.6%	97.5%	98.3%

Table 6.36: South Saskatchewan River Basin Agriculture Water Demand by Source of Water, Water Conservation Scenario, 2010 - 2060

Particulars	Total Water Demand in dam³			
	2010	2020	2040	2060
Total Agriculture	**237,300**	**265,939**	**474,729**	**638,432**
Groundwater	15,166	15,424	15,459	15,525
Surface Water	222,134	250,515	459,270	622,908
Surface Water % of Total	93.6%	94.2%	96.7%	97.6%

6.8 Agricultural Water Consumption

A part of the total water demand by agriculture is returned back to the original source. This methodology was described in Section 3.7 of this report. The estimated water consumption for agricultural demands is shown here for the three study scenarios.

6.8.1 Agricultural Water Consumption – Baseline Scenario

Not all water removed from a water body (source) for agricultural purposes is lost. In fact, a portion of this is returned back to the original source.[47] Following the methodology presented in Section 3.6 of this report, water consumption was estimated. For the baseline scenario, these estimates are presented in Table 6.37.

In 2010, the agriculture in the basin consumed 167 thousand dam^3 of water, most of which was drawn from surface water bodies. By 2060, it is estimated that agriculture's water consumption will increase to 536 thousand dam^3. In all four time periods, the consumption of groundwater is small, and it becomes smaller by 2060. In 2010, groundwater consumption was 6.8% of the total agricultural water consumption, which is reduced to 2.4% by 2060.

[47] This return flow may be contributed at a location different from the water intake location. Thus, this amount of water is not available to other users at intake location. However, it may be available to downstream users.

Table 6.37: Water Consumption for Agricultural Demands by Source of Water, South Saskatchewan River Basin, Baseline Scenario, 2010-2060

Particulars	Total Water Consumption in dam^3			
	2010	2020	2040	2060
Total Agriculture Water Consumption	**179,476**	**215,355**	**407,114**	**549,705**
Groundwater	12,275	12,081	13,477	13,407
Surface Water	167,201	203,275	393,637	536,298
Total Consumption as % of Water Intake	93.2%	94.4%	96.7%	97.6%

6.8.2 Agricultural Water Consumption – Climate Change Scenario

Water consumption for agricultural purposes under the climate change scenario is presented in Table 6.38. As the amount of water required for district irrigation increases under this scenario, so does the water consumption level. By 2060, agricultural activities are estimated to consume 696,964 dam^3 of water annually. The return flows as a proportion of total water intake under this scenario are still in the same magnitude as those for the baseline scenario.

Table 6.38: Water Consumption for Agricultural Demands by Source of Water, South Saskatchewan River Basin, Climate Change Scenario, 2010-2060

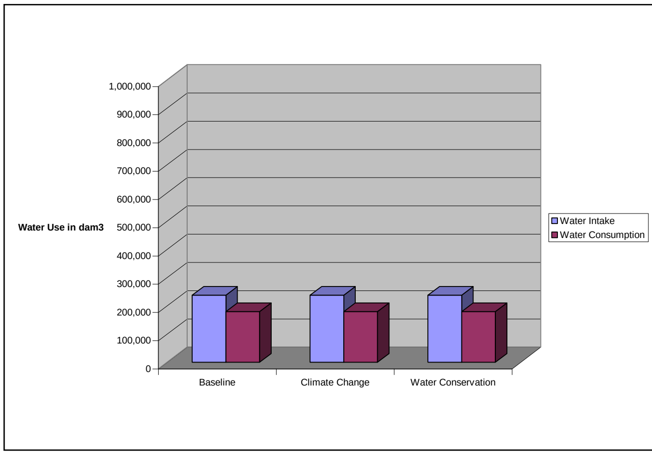
Particulars	Total Water Consumption in dam^3			
	2010	2020	2040	2060
Total Agriculture Water Consumption	**179,476**	**215,360.**	**476,809**	**696,964**
Groundwater	12,275	12,082	13,269	13,096
Surface Water	167,201	203,279	463,539	683,868
Total Consumption as % of Water Intake	93.2%	94.4%	97.2%	98.1%

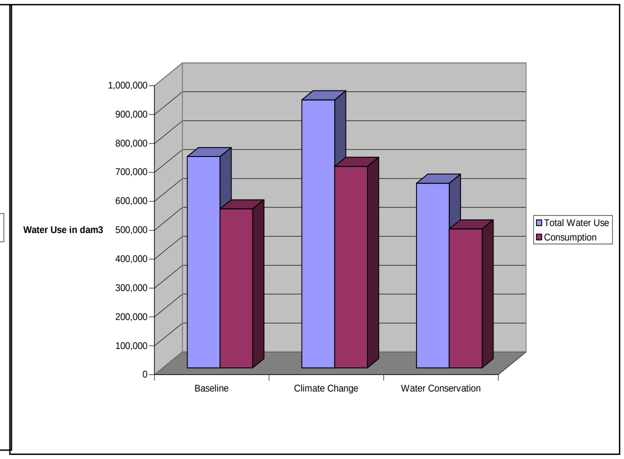
6.8.3 Agricultural Water Consumption – Water Conservation Scenario

Under the assumption that irrigators and other water users for agricultural production adopt water conservation practices, total water consumption will decrease to 358 thousand dam^3 by 2040 and 480 thousand dam^3 by 2060 (Table 6.39). By 2060, water consumption levels will be 268% of the 2010 level. A comparison of the three scenarios' water consumption is shown in Figure 6.8.

Table 6.39: Water Consumption for Agricultural Demands by Source of Water, South Saskatchewan River Basin, Water Conservation Scenario, 2010-2060

Particulars	Total Water Consumption in dam^3			
	2010	**2020**	**2040**	**2060**
Total Agriculture Water Consumption	**179,476**	**201,049**	**357,646**	**480,441**
Groundwater	12,275	12,310	13,586	13,471
Surface Water	167,201	188,740	344,060	466,970
Total Consumption as % of Water Intake	93.2%	93.9%	96.2%	97.2%





2010 **2060**

Figure 6.8: Water Intake and Water Consumption for Agriculture Purposes, South Saskatchewan River Basin, 2010 and 2060, Study Scenarios

6.9 Summary of Agricultural Water Demand

In the SSRB, agriculture is a prominent industry and a major water user. Water is used for crop production (through irrigation and pesticide spraying by dryland farmers) and for livestock. In addition, smaller amounts of water are also required for greenhouses, nurseries, and aquaculture. In the future, irrigation activity is expected to increase in the basin. This will be through the development of the Westside Irrigation District which could add another 356,800 acres under irrigation, over and above the existing district and private irrigated areas. This increase is 125% higher than the existing irrigated area in the basin. However, given past evidence on the adoption of irrigation in some districts in the Lake Diefenbaker Development Area, only 90% of this potential is expected to be realized by 2060. As a result, the total irrigated area in the basin will increase from 158,949 acres to 575,230 acres by 2060 – an over a three-fold increase.

The total agricultural water demand in the basin is estimated to increase from 237,300 dam^3 in 2010 to 730,651 dam^3 by 2060 – representing 208% of the 2010 level. Climate change will bring forth further increases in these levels. Under the climate change scenario, agriculture could demand as much as 926,829 dam^3 of water. The adoption of water conservation measures may bring a reduction to 638,432 dam^3 per annum. Most of this water is expected to be withdrawn from surface water bodies. In the future, surface water will constitute a higher proportion of total water demand for agriculture. However, not all a portion of withdrawn water is returned back, particularly from irrigation districts. It is estimated that, although at present 93% of the water withdrawn by agriculture is consumed, by 2060 this proportion will increase to 98%.

Chapter 7

Industrial/Mining Water Demand

Major industrial/mining activity in the SSRB is related mainly to potash production, although other manufacturing activities are also present. In this chapter, current and future water demands for mining and other industrial (manufacturing and power generation) activities are described. Manufacturing in this chapter includes only those establishments that do not receive water from a municipal water system, since many other manufacturers receive their water from urban municipal water systems.

This chapter is divided into four sections: Section 7.1 describes the estimated mining water demand, while section 7.2 addresses the estimated manufacturing water demand. The latter section includes two types of manufacturing establishments – those that exist at present, and those that could appear in the basin as a result of other economic development activities, particularly irrigation. Power generation water demand is described in Section 7.4, followed by a summary of industrial/mining water demand in Section 7.4.

7.1 Mining Water Demand

As noted above, the major mining water demand in the basin is devoted to potash production. However, there is a small amount of water used for oil and gas production. Although there is a reference made to a magnesium sulphate mine at Beechy, details are not available, and therefore its water demand could not be estimated. For the other mining sectors, water demands are reported in this section.

7.1.1 Potash Production

7.1.1.1 Potash production Water Demand – Baseline Scenario

Using the methodology described in Chapters 3 and 4 of this report, the total water demand for potash production was estimated. For future water demand, this required some projection of potash mining activity. At the time of writing this report, such information is highly preliminary, as many mines are proposed (or rumored); only some have shown indications of being in production by 2060 or earlier. In addition, their source of water is still not clear since no source of water has been identified for some mines. In these cases, the projections shown in Table 4.21 were used. All the water demands are met by the basin water, eliminating any need for drawing upon other basins.

The projected water demand from SSRB potash mines to 2060 is presented in Table 7.1. The total water from the SSRB is used within the basin, as well as exported to the Qu'Appelle River

Basin through the SSEWS canal. For these estimates, for those mines located within the basin, present (existing mines) water demand coefficients from Table 3.12 were applied. For those located in the Qu'Appelle River Basin, coefficients reported in Kulshreshtha et al. (2012) were used. It was further assumed that the replacement of existing mines is likely to occur by 2060, but these mines will be located in the same water basin to take advantage of experienced labor. Some marginal increase in production to 2040 is expected, as well as replacement of some exiting mines to 2060, with production capacity unchanged.

Table 7.1: Projected Water Demand for Potash Mining in the South Saskatchewan River Basin, Baseline Scenario 2010 – 2060

Particulars	Source of Water	Amount of Water Demand in dam^3			
		2010	2020	2040	2060
Water Demand by SSRB Potash Mines					
Potash Corporation of Saskatchewan Mines					
Allan	Surface	1,587.8	4,103.9	4,103.9	4,103.9
Patience Lake	Surface	373.4	949.1	949.1	949.1
Cory	Surface	1,336.7	5,018.4	5,018.4	7,983.7
Sub-Total		**3,297.9**	**10,071.4**	**10,071.4**	**13,036.8**
% of 2010 level		--	305%	305%	395%
Water Exported to Qu'Appelle River Basin Potash Mines					
Existing and New Mines*	Surface	2,082.4	9,209.1	9,209.1	17,423.1
Total SSRB Water Used for Potash Mining**	Surface	**5,380.3**	**19,280.5**	**19,280.5**	**30,459.9**
Exported Water % of Total Demanded for Potash Mining	Surface	38.7%	47.7%	47.7%	57.2%

* Water delivered through the SSEWS canal.

** Sum of SSRB and Qu'Appelle River Basin Potash Mines

Source: Estimations from CIBC (2008); Saskatchewan Watershed Authority (undated).

The total water demand for SSRB potash mining was estimated at 3,298 dam^3 per annum for 2010, whereas that for outside (Qu'Appelle River Basin) mines is 2082 dam^3, for a total of 5,380 dam^3. This includes water from surface water bodies – mainly the South Saskatchewan River and Lake Diefenbaker through the SSEWS canal. By 2060, potash mining water demand in the basin will increase by 395% of the 2010 level. Increases are also predicted for the Qu'Appelle potash mines supplied by the SSRB. This amount will rise to 17,423 dam^3 by 2060 and will constitute 57% of the total water potash mining in the SSRB. Relative sharer of in-basin and outside-basin water use for potash mining is shown in Figure 7.1.

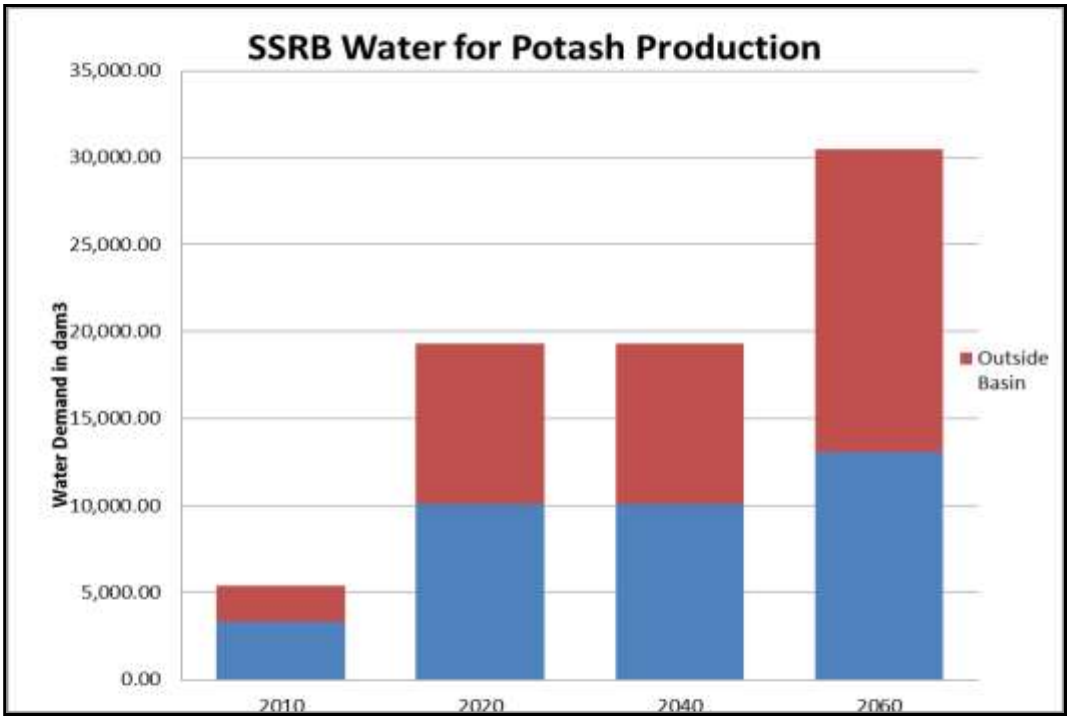


Figure 7.1: Water Demand for Potash Production from the South Saskatchewan River Basin, 2010 - 2060

7.1.1.2 Potash production Water Demand – Climate Change Scenario

The direct effect of climate change on the demand for water is likely to be minimal given the controlled production process. The indirect effect of climate change on those mines that rely on surface water bodies, though, may lead them to adopt technology to reduce demand or to find other sources of water. Lacking sufficient information on such potential measures, this study excluded effects of climate change on potash water demand.

7.1.1.3 Potash production Water Demand – Water Conservation Scenario

Water conservation in mining (particularly in potash mining) is limited but feasible. Reid (1984) has suggested several measures that can reduce the water levels for potash mining, including refrigeration units for cooling, reduction of housekeeping water use, reduction of losses in brine evaporation, and recycling. However, much depends on regulations and on the cost of water to the mines. For example, Mississippi Potash at Carlsbad, New Mexico increased the use of recycled water to reduce its demand from 8,252 dam^3 to 3,975 dam^3 of fresh water intake, a reduction of 52% (New Mexico State, 1999). The pressure to adopt water conservation measures in this case came from the need to reduce consumption from the Ogallala aquifer**.** Even brackish ground water could be used as a substitute for fresh water in the production of potash, thereby reducing the demand for surface water.

Furthermore, electromagnetic separation of the potash from the salt is a technology that can be used to reduce water demand. This technique adds a process step that reduces the amount of salt and other substances in the ore. Water is still needed to remove the remaining salt and other materials. Solution mining is the big water user in the potash industry. Currently, there are two such mines in the basin, and there is a possibility of at least four new solution mines. Greater recycling of the brine used in solution mining offers the largest reduction in the fresh water demand. The adoption of conservation measures for solution mines are estimated to result in reductions in water demands of 5%, 15%, and 25% by 2020, 2040, and 2060, respectively.[48] For lack of better information, the adoption of conservation measures for underground mining was assumed to be half of these amounts. The water demands for the potash industry under the assumption of adoption of water conservation measures are presented in Table 7.2.

Table 7.2: Water Demand for the Potash Industry for the Water Conservation Scenario, South Saskatchewan River Basin, 2020 – 2040

Company	Mine Site	Source	2020	2040	2060
SSRB Potash Mines	Allan	Surface	4,042.4	3,837.2	3,590.9
	Patience Lake	Surface	934.9	887.4	830.5
	Cory	Surface	4,943.1	4,692.2	6,985.8
	Total		**9,920.3**	**9,416.7**	**11,407.2**
Water Demand for Potash Mines in the Qu'Appelle River Basin			8,978.8	8,518.4	15,245.2
Total Amount of SSRB Water Demanded for Potash Mining*			**18,899.1**	**17,935.1**	**26,652.4**
Change in Total SSRB Water Demand for Potash Mining Relative to Baseline Scenario			-2.0%	-7.0%	-12.5%

* Sum of SSRB and Qu'Appelle mines.

Since the present demand is based on the current level of adopted water management practices, no further changes were made. By 2020, it is assumed that new management measures can reduce water demand, resulting in a 2% reduction. By 2040, water demand for potash production is estimated to fall to 17,935 dam^3, of which 8,518 will be in the Qu'Appelle River Basin. This represents a reduction of 7% over the baseline scenario water demand. By 2060, the reduction in water demand would be even higher, reaching by 12.5% over the baseline scenario.

[48] This assumption is not based on any scientific evidence on the possibility of water use reduction by adopting water conservation measures. This issue needs further investigation.

Comparison of the three study scenarios is shown in Figure 7.2. As noted above, climate change and baseline scenario water demand levels are identical since this amount was assumed to remain unaffected by climate change.

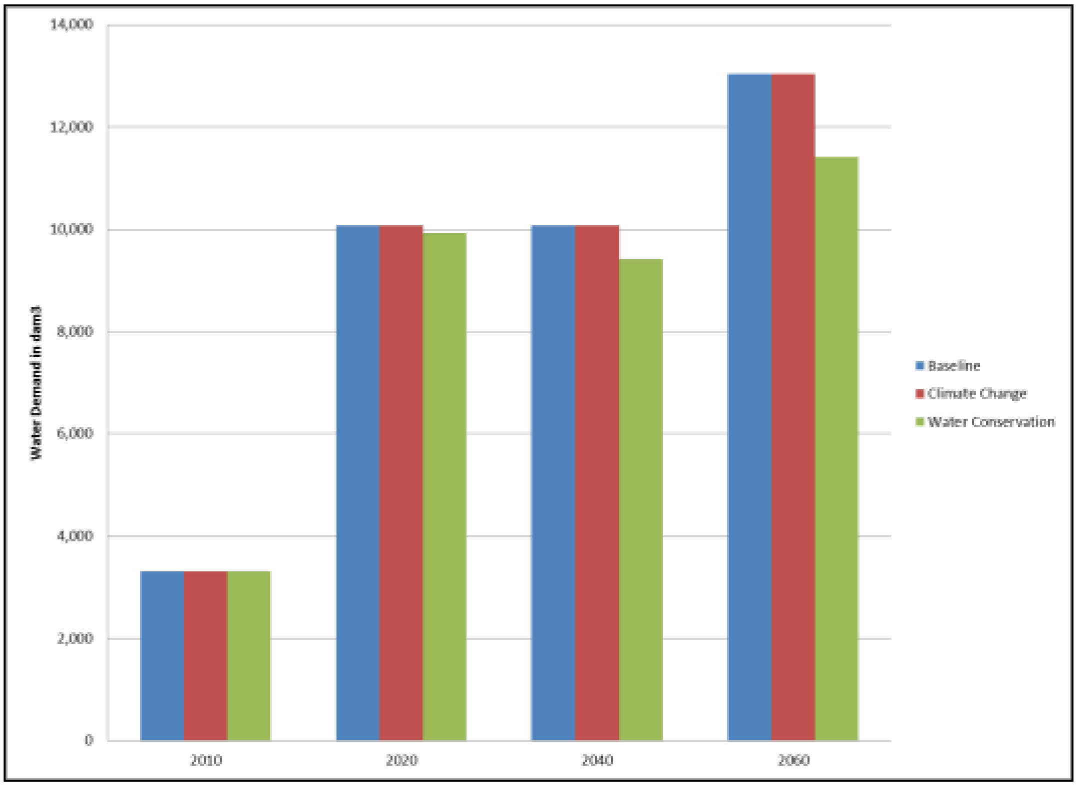


Figure 7.2: Total Water Demand (in dam^3) for Potash production within the South Saskatchewan River Basin under Study Scenarios, 2010 - 2060

7.1.1.4 Source of Water for Potash Production

All water demand for potash mining in the SSRB is drawn from surface water sources. No further estimation of source of water is required.

7.1.1.5 Water Consumption for Potash Production

The water intake by potash mines is not released to any original source. In the underground mining process, the salt tailings may contain some water which, over a period of time, may either evaporate or leach underground. For these reasons, all the water withdrawn (used) was assumed to be consumed.

7.1.2 Oil and Gas Production

7.1.2.1 Oil and Gas Production Water Demand – Baseline Scenario

Water demand in oil and gas production is limited to two types of uses: (i) for drilling of oil wells, and (ii) for recovery of oil during the production phase. Both of these demands were estimated for the basin. The projected number of wells drilled in an oil formation is estimated for 2020 as the number of wells drilled in the formation in 2010 divided by the number of wells drilled in the province in 2010, times the average number of wells drilled in the province over the 2000 to 2010 period. The estimate for 2040 and 2060 is 60% and 10% of the wells drilled in 2020, respectively. The estimated number of wells drilled is shown in Table 7.3. By 2060, wells in the basin will be reduced to 14 from an estimated 70 wells per annum drilled currently.

Table 7.3: Estimated Wells Drilled in South Saskatchewan River Basin, 2010-2060

Technology	**No. of Wells during**			
	2010	**2020**	**2040**	**2060**
Vertical	50	67	40	10
Horizontal	20	27	16	4
Total	**70**	**94**	**56**	**14**

Source: Author's estimates from Sask Energy and NEB reports various years.

Oil and gas exploration and development of the Bakken formation in the Qu'Appelle Basin by the frac completion process is expected to be limited to south of the Qu'Appelle valley. Water demanded in the production of oil and gas in the SSRB is based on the estimated well drilling activity by type in the SSRB times the effective coefficient. Enhanced oil recovery water use is estimated as 4.3% of the number of horizontal wells times the average enhanced oil well coefficient of 43.8.

The estimated water demand for oil and gas production in the basin is shown in Table 7.4. In 2010, water demand was estimated at 205 dam^3 per annum. This amount is expected to be reduced to 41 dam^3 by 2060 – a reduction by 80% of the 2010 level.

7.1.2.2 Oil and Gas Production Water Demand – Climate Change Scenario

The direct effect of climate change on the demand for water from the oil and gas industry is likely to be minimal.

Table 7.4: Water Demand for Oil Extraction Production Technique in the South Saskatchewan River Basin, under Baseline Scenario

Technology	Water Demand in dam^3			
	2010	**2020**	**2040**	**2060**
Primary	18.56	24.92	14.95	3.74
Water Flood	41.86	56.20	33.72	8.43
Horizontal	106.43	142.89	85.73	21.43
Enhanced	38.18	51.26	30.76	7.69
Total	**205.02**	**275.28**	**165.17**	**41.29**

Source: Author's estimates from Sask Energy and NEB reports of various years

7.1.2.3 Oil and Gas Production Water Demand – Water Conservation Scenario

In oil and gas production, water is demanded in the drilling of wells, for recovery of heavy oil, and for forcing oil from old conventional wells or natural gas from wells with tight or sandy formations. Oil recovery from oilsands is a water intensive process, although water demand for this type of oil production in Saskatchewan is still a few years in the future. Other than some recycling and water audits, very little information is available on feasible water conservation measures. Water demand coefficients used in estimating conventional oil production are presently 0.87 water: oil, falling to 0.6 water: oil with conservation measures. This translates into a water use between 400 m^3 to 600 m^3 per well. Shale gas using multi-stage frac completion technique, uses between 2,500 m^3 to 5,000 m^3 of water (Canadian Association of Petroleum Producers, 2011).

Using undrinkable water, recycling of water, and CO_2 injection are techniques that can limit the demand from fresh water sources by the oil and gas industry (Canadian Association of Petroleum Producers, 2011). Qu'Appelle Basin oil and gas is in the Bakken formation which requires the multi-stage frac technique. The Canadian Association of Petroleum Producers (2011) reports that up to 15% of the water used have been successfully recycled at some sites. This would translate into a 9.9 dam^3 per well water demand if the sector were able to attain a sustainable 15% recycle rate.

The estimates of water conservation on the demand for water from the oil and gas sector are presented in Table 7.5. . In the future, on average, water conservation measures could reduce their total water demand by 15% of the baseline level.

Table 7.5: Water Demand for Oil and Gas Production in the South Saskatchewan River Basin under Water Conservation Scenario, 2010 - 2060

Particulars	Total Water Demand in dam^3			
	2010	2020	2040	2060
Total Water Demand	205.02	233.98	140.39	35.10
% of Baseline Scenario	100.0%	85.0%	85.0%	85.0%

7.2 Manufacturing Water Demand

Existing and potential new industries' water demand forecast will depend on the life of the plant, reinvestment, capacity constraints, expansion to meet market opportunities, and new markets. Many of these factors are difficult to predict, especially over a 50 year period.

7.2.1 Existing Manufacturing Industries

7.2.1.1 Existing Manufacturing Industries – Baseline Scenario

Most of the water for manufacturing establishments in the SSRB is for water treatment chemicals. A smaller amount is used by the canola crushing plant, and a very low amount of water is used for the refinery in Reynolds. The total amount of water demanded in 2010 was estimated at 2,525 dam^3, which is expected to increase to 2,727 dam^3 by 2060 – an 8% increase over the 2010 level (Table 7.6).

Table 7.6: Manufacturing Water Demand in the South Saskatchewan River Basin, Baseline Scenario, 2010 - 2060

Industry Group	Industry	Water Demand Level in dam^3			
		2010	2020	2040	2060
Refinery	Saskatchewan Ltd (Reynolds)	28.0	28.7	29.5	30.2
Ag Processing	Cargill - Canola Crush Plant	758.6	778.3	798.5	819.3
Water Treatment Chemicals	AKZO (Chemical Man)	59.1	60.7	62.3	63.9
	Allan Division	1,283.1	1,316.5	1,350.7	1,385.8
	ERCO Worldwide	385.5	395.5	405.8	416.4
	United Chemical Company	10.2	10.4	10.7	11.0
Total Industrial Water Demand		**2,524.6**	**2,590.2**	**2,657.5**	**2,726.6**
Total Industrial Water Demand % 2010			2.6%	5.3%	8.0%
	Water Demand by Source of Water				
Groundwater		28.0	28.7	29.5	30.2
Surface Water		2,496.6	2,561.5	2,628.1	2,696.4
Surface Water as % of the Total		98.9%	98.9%	98.9%	98.9%

7.2.1.2 Existing Manufacturing Industries – Climate Change Scenario

Production processes that use water as a cooling agent may need more water during the summer months to achieve the same level of production. For this reason, industrial water demand may also be affected by climate change. The warming of surface waters will have a direct impact on the industrial operations by decreasing the efficiency of cooling systems (Lemmen and Warren, 2004, p. 42). Further reviews of the literature did not yield any basin related or Canadian studies showing the impact of climate change. As discussed in Section 5.2.3, the same change[49] in the water demand coefficients were applied to industrial water demand as those for domestic water demand. The estimates of industry water demand for the climate change scenario are presented in Table 7.7. This water demand is expected to increase to 2,836 dam^3 per annum by 2060.

Table 7.7: Manufacturing Water Demand in the South Saskatchewan River Basin, 2020 to 2060 for the Climate Change Scenario

Industry Group	Industry	Amount of Water in dam^3		
		2020	**2040**	**2060**
Refinery	Saskatchewan Ltd (Reynolds)	28.7	30.1	31.5
Ag Processing	Cargill - Canola Crush Plant	778.3	814.5	852.1
Water Treatment Chemicals	AKZO (Chemical Man)	60.7	63.5	66.4
	Allan Division	1,316.5	1,377.7	1,441.3
	ERCO Worldwide	395.5	414.0	433.0
	United Chemical Company	10.4	10.9	11.4
Total		**2,590.2**	**2,710.7**	**2,835.7**
Groundwater		28.7	30.1	31.5
Surface Water		2,561.5	2,680.6	2,804.2
Surface Water as % of the Total		98.9%	98.9%	98.9%

7.2.1.3 Existing Manufacturing Industries – Water Conservation Scenario

Water conservation in manufacturing processes that use once through cooling then discharge water can be changed to cooling tower technology for recycling purposes. However, the relative cost is the deciding factor in adopting these techniques. Technologies and techniques have been developed in the manufacturing sector in other countries where water conservation is a pressing issue. The extent to which various types of cooling systems are employed in the Saskatchewan manufacturing sector is not known. On account of a lack of data, an industry wide conservation

[49] This is an assumption made for simplifying the estimation at this time. However, this assumption requires a comprehensive scientific study.

potential was assumed. Results are shown in Table 7.8. By 2060, a 2% decline in the demand for water is expected for these industries by adopting water conservation practices.

Table 7.8: Manufacturing Water Demand in the South Saskatchewan River Basin, under Water Conservation Scenario, 2020 - 2060

Industry	Water Demand in dam^3		
	2020	**2040**	**2060**
Refinery			
Saskatchewan Ltd (Reynolds)	28.2	28.9	29.6
Ag Processing			
Cargill - Canola Crush Plant	762.7	782.6	802.9
Water Treatment Chemicals			
AKZO (Chemical Man)	59.5	61.0	62.6
Allan Division	1,290.2	1,323.7	1,358.1
ERCO Worldwide	387.6	397.7	408.1
United Chemical Company	10.2	10.5	10.8
Total	**2,538.4**	**2,604.4**	**2,672.1**
Groundwater	28.2	28.9	29.6
Surface Water	2,510.2	2,575.5	2,642.5

7.2.1.4 Sources of Water for Manufacturing Demands

The sources of water for industrial demand are reported in Table 7.6 for the baseline scenario and in Table 7.9 for the water conservation scenario. A graphical presentation of these water demands is shown in Figure 7.3. In the future, by 2060 one observes an increase in the demand of groundwater. The proportion of surface water under the baseline scenario in 2010 was 99% of the total, which remains constant until 2060. The same proportions are also estimated on the water conservation scenario for the basin.

7.2.1.5 Water Return/Discharge from Manufacturing Activities

Each industry after using the water returns a portion of it to the original source. Since information of each industry in the SSRB was not available, Canada-wide manufacturing industry estimates on share of return flow to total water intake were used. These results are shown in Table 7.9. The total water returned was 78.7% of the total water intake. These amounts are estimated at 1,987 dam^3 for 2010, increasing to 2,146 dam^3 by 2060.

7.2.1.6 Manufacturing Water Consumption

Since no water demanded in potash or salt or oil and gas manufacture is returned to ground or surface fresh water bodies, the amount of water that is consumed is equal to demand. Water consumption in industrial activities in the SSRB is presented in this section.

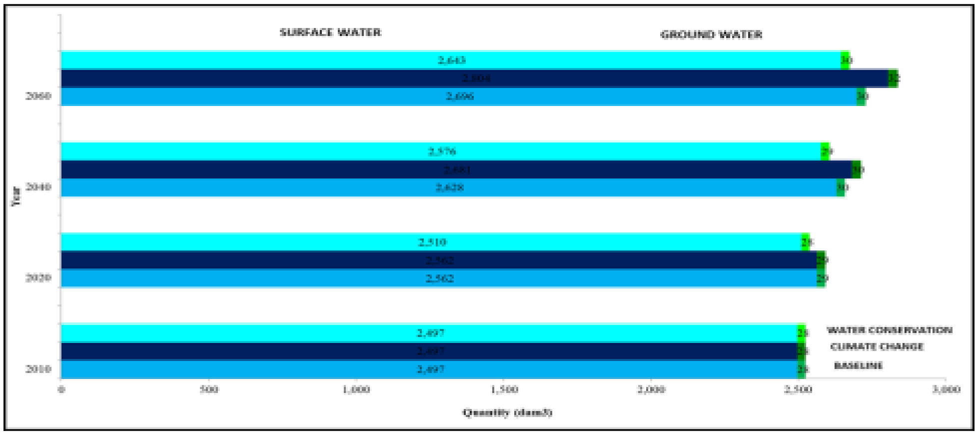


Figure 7.3: Manufacturing Water Demand by Source, Existing Establishments in the South Saskatchewan River Basin Under Study Scenarios, 2010 – 2060

Table 7.9: Water Return from Manufacturing Activities under Baseline Scenario, 2020 - 2060

Industry	%[1]	Water Return in dam^3			
		2010	**2020**	**2040**	**2060**
Refinery					
Saskatchewan Ltd (Reynolds)	78.7%	22	23	23	24
Ag Processing					
Cargill - Canola Crush Plant	78.7%	597	613	628	645
Water Treatment Chemicals					
AKZO (Chemical Man)	78.7%	47	48	49	50
Allan Division	78.7%	1,010	1,036	1,063	1,091
ERCO Worldwide	78.7%	303	311	319	328
United Chemical Company	78.7%	8	8	8	9
Total Water Returned		**1,987**	**2,039**	**2,091**	**2,146**
Total Water Consumption		538	551	567	581

[1] Percentage of Water Demand that is returned.

Manufacturing Water Consumption under Baseline Scenario

The return flow from different types of industrial activities is different, depending on the type of process and the source of water. For this reason, return flows were estimated by industry type. For the baseline scenario, these are shown in Table 7.10. Any water not returned is called water consumed.

Table 7.10: Manufacturing Water Consumption in South Saskatchewan River Basin, Baseline Scenario, 2010 – 2060

Industry	Water Demand in dam^3

	2010	2020	2040	2060
Refinery				
Saskatchewan Ltd (Reynolds)	6.3	6.5	6.6	6.8
Ag Processing				
Cargill - Canola Crush Plant	170.7	175.1	179.7	184.3
Water Treatment Chemicals				
AKZO (Chemical Man)	13.3	13.7	14.0	14.4
Allan Division	288.7	296.2	303.9	311.8
ERCO Worldwide	86.7	89.0	91.3	93.7
United Chemical Company	2.3	2.4	2.4	2.5
Total Water Consumption	**568.0**	**582.8**	**597.9**	**613.5**
Groundwater	6.30	6.46	6.63	6.80
Surface Water	561.7	576.3	591.3	606.7
Surface Water as % of 2010 Level		102.6%	105.3%	108.0%

Under the baseline scenario, the total consumption of water is estimated at 568 dam^3, which is about 81% of the total water demand for manufacturing activities. Thus, only 21% of the total water demand (intake) is lost during the production process, the rest is returned to the original source. This proportion does not change in the future. In terms of level of consumption, water treatment chemical plants have a higher level than other users in the basin. Surface water consumption increases by 8% over the 2010 level by 2060.

Manufacturing Water Consumption under Climate Change Scenario

Under the climate change scenario, there is a slight increase in water consumption by manufacturing concerns. Results are shown in Table 7.11. The total water consumption in 2060 is estimated to be 638 dam^3, about 2.8% higher than that under the baseline scenario.

Manufacturing Water Consumption under Water Conservation Scenario

Under the water conservation scenario, there is a slight decrease in water consumption by manufacturing concerns. Results are shown in Table 7.12. The total water consumption in 2060 is estimated to be 595 dam^3, about 3.1% lower than that observed under the baseline scenario. Thus, water conservation could offset the increase in water consumption induced by climate change.

Table 7.11: Manufacturing Water Consumption in South Saskatchewan River Basin under Climate Change Scenario, 2010 - 2060

Industry	Water Demand in dam^3			
	2010	2020	2040	2060
Refinery				
Saskatchewan Ltd (Reynolds)	6.3	6.5	6.8	7.1
Ag Processing				
Cargill - Canola Crush Plant	170.7	175.1	183.3	191.7
Water Treatment Chemicals				
AKZO (Chemical Man)	13.3	13.7	14.3	14.9
Allan Division	288.7	296.2	310.0	324.3
ERCO Worldwide	86.7	89.0	93.1	97.4
United Chemical Company	2.3	2.4	2.5	2.6
Total Water Consumption	568.0	582.8	609.9	638.0
Groundwater	6.30	6.46	6.76	7.08
Surface Water	561.7	576.3	603.1	631.0
Surface Water as % of 2010		102.6%	107.4%	112.3%

Table 7.12: Manufacturing Water Consumption in South Saskatchewan River Basin for the Water Conservation Scenario, 2010 - 2060

Industry	Amount of Water Demand in dam^3			
	2010	2020	2040	2060
Refinery				
Saskatchewan Ltd (Reynolds)	6.3	6.3	6.5	6.7
Ag Processing				
Cargill - Canola Crush Plant	170.7	171.6	176.1	180.7
BioExx Specialty Proteins Inc	-	-	-	-
Water Treatment Chemicals				
AKZO (Chemical Man)	13.3	13.4	13.7	14.1
Allan Division	288.7	290.3	297.8	305.6
ERCO Worldwide	86.7	87.2	89.5	91.8
United Chemical Company	2.3	2.3	2.4	2.4
Total Water Consumption	568.0	571.1	586.0	601.2
Groundwater	6.30	6.33	6.50	6.67
Surface Water	561.7	564.8	579.5	594.6
Surface Water as % of 2010		100.5%	103.2%	105.8%

7.2.2 Induced Development Activities

7.2.2.1 Water Demand for Induced Development Activities – Baseline Scenario

Induced economic activities were assumed to be related to the new irrigation development in the basin. As noted in Chapter 4, three types of new developments were expected: biomass ethanol, feedlots, and a red meat processing facility. Details on these were provided in Table 4.29.The net effect of establishing a feedlot is a reduction in water demanded for irrigation because of the reduced amount of water needed to grow silage in comparison to other crops (such as corn). Even with the increase in animal watering, the net effect is reduced water demand. As shown in Table 7.13, total net water demand for the industries is estimated to be -51,113 by 2040 and 2060. Since, the irrigation development in the SSRB will likely not begin till after 2020 no change is anticipated for 2020.

Table 7.13: Induced Water Demand Activities in the South Saskatchewan River Basin, Baseline Scenario, 2040 - 2060

Industry	Water Demand in dam^3	
	2040	2060
Feedlots	-58,468	-58,468
Agri. Processing	0	0
Ethanol Plant	7,355	7,355
Total Water Demand	**-51,113**	**-51,113**
Surface Water % of Total	**100%**	**100%**

7.2.2.2 Water Demand for Induced Development Activities – Climate Change Scenario

The primary climate change effect for induced water demand is increased water consumption by livestock in feedlots as the temperature rises. The same can be said about irrigation, which is also expected to have an increased water requirement. Results for this scenario for the induced economic development activities water demand level are shown in Table 7.14. By 2060, a decrease of 50,820 dam^3 is estimated, which represents an increase over the baseline estimates. Much of this elevation will result from water demand for the projected feedlots in the basin.

7.2.2.3 Water Demand for Induced Development Activities – Water Conservation Scenario

The predicted conservation of water for biomass ethanol and agricultural processing is 2% increase in efficiency from the base estimates. The increased efficiency of livestock watering will reduce the water demand from the feedlots. As shown in Table 7.15, there is an estimated reduction of 47,212 dam^3 of water by 2060, which is a reduction of almost 3,900 dam^3 from the baseline scenario level.

Table 7.14: Water Demand for Induced Activities in the South Saskatchewan River Basin for Climate Change Scenario, 2040 -2060

Industry	Water Demand in dam^3

	2040	2060
Biomass Ethanol	7,355.0	7,355.0
Agri. Processing	0.0	0.0
Feedlots	-58,328.8	-58,175.3
Total	**-50,973.8**	**-50,820.3**

Table 7.15: Water Demand for Induced Activities in the South Saskatchewan River Basin for Water Conservation Scenario, 2040 -2060

Industry	Water Demand in dam^3	
	2040	2060
Biomass Ethanol	7,207.9	7,063.7
Agri. Processing	0.0	0.0
Feedlots	-56,335.8	-54,275.8
Total	**-49,127.9**	**-47,212.0**

7.3 Power Generation Water Demand Estimates

7.3.1 Power Generation Water Demand under Baseline Scenario

The current water demand for power generation was divided by type of generation process – hydro vs. thermal. Water demand coefficients for these types are shown in Table 7.16. Both water intake and consumption coefficients were estimated from available literature on the topic.

Table 7.16: Estimated Water Intake and Water Consumption Estimates for Electric Power Generation, 2010

Generation Process	Unit	Water Intake	Water Consumption
Hydroelectric	dam^3/MWh	0.20061* to 1.935**	0
Cory Power Station	dam^3/MW	5.9	0.163***
Queen Elizabeth Station	dam^3/MW	1.2	0.033***
Heat Recovery	dam^3/MWh	0	0

* Based on Larson et al. (2007) for large reservoirs

** See footnote no. 44 below

*** Using Statistics Canada (2005) ratio of intake to consumption.

In the future, other sources of power can be foreseen, with different water demand levels. For example, wind, solar, cogeneration, biomass, conservation, and nuclear technologies have been proposed as alternatives; with only nuclear and biomass requires significant amounts of water. A nuclear power plant, as proposed by Bruce Power, would require 9,000 dam^3 of water for an evaporative cooling pond with a refilling rate of 2.6 m^3 s^{-1}, for a yearly total of 91,994 dam^3

(Halliday, 2009). Alternative methods of cooling are by evaporative towers or by recycled water released back into the river or lake. Three possible locations in each of two regions (Lake Diefenbaker and La Loche) were identified as possible sites for a nuclear plant (Stantec, 2007). A biomass plant would have similar water demand characteristics to fossil fuel thermal technology.

The water demand was a product of amount of electricity generated by type and its respective water demand coefficient. The baseline coefficients of 2010 were employed for this estimation. An amount of electricity generated was based on the forecast demand for electricity by SaskPower; along with their projected supply side options this amount is the basis for estimating water demand (see SaskPower 2011 for further details). These forecasts are shown in Table 7.17. The choices in the SSRB are natural gas, co-generation, biomass along with wind, solar, and heat recovery. Natural gas, co-generation, and biomass all require some amount of water. The baseline estimation of water demand is the current water demand for electricity generation from co-generation and natural gas, times the growth in supply for these two options to 2020, 2040, and 2060.

Table 7.17: Projected Growth Rates of Electricity Supply by Type

Generation Process	Rate of Growth for		
	2020	2040	2060
Wind	159%	221%	282%
Cogeneration	159%	221%	282%
Hydro	100%	100%	100%
Nat Gas	134%	181%	192%
Waste Heat	140%	1,227%	3,138%

Source: SaskPower (2005)

For future water demand estimation, hydroelectric generation was assumed to continue at that level in the future. Future cogeneration expansion may be possible for other potash mines in the basin while expansion of the existing natural gas facilities is anticipated. Biomass may be an alternative using agricultural crop residues or dedicated crops, but its scope at this time is rather limited.

The estimated water intake is shown in Table 7.18. The generation of hydroelectric power requires a large quantity of water, estimated at 1,660,092 dam^3 per annum.[50] However, as noted earlier, all this water is available to other water demands downstream. Nonetheless, it does create a situation of trade-off for other users of water from Lake Diefenbaker (such as irrigation and recreation). For other types of electric power generation, water demand is estimated to be 1,855 dam^3 for 2010, increasing to 4,777 dam^3 by 2060 – an increase of 158% over the 2010 level. Much of this increase will be a result of increased population, as well as higher incomes, heightened in more electric power needs.

Table 7.18: Water Intake for Electric Power Generation under Baseline Scenario, South Saskatchewan River Basin, 2010-2060

Plant Type	Amount of Water Intake in dam^3			
	2010	**2020**	**2040**	**2060**
Hydroelectric	1,660,092	1,660,092	1,660,092	1,660,092
Cogeneration	1,347	2,145	2,973	3,802
Natural Gas	508	809	921	975
Biomass	--	0.04	0.11	0.35
Total excluding Hydroelectric Power	**1,855**	**2,954**	**3,894**	**4,777**

7.3.2 Power Generation Water Demand under Climate Change Scenario

Climate change may affect the amount of water that is needed for cooling and may result in greater evaporation losses from power generation reservoirs. An estimate of 2% and 4% increases in water demand caused by climate change is used for 2040 and 2060, respectively. Water intake for non-hydroelectric power generation increases to 4,968 dam^3 per annum (Table 7.19). The water required for hydroelectric generation was left at the 2010 level since climate change would not have any effect on its water demand coefficient.

[50] This amount was estimated as follows: In consultation with Mr. Bob Parker (SWA), SaskPower's preferred rate of flow from Lake Diefenbaker is between 80 and 120 m^3/s. For this estimation of water use the mid-value of this range was employed. Capacity of the Coteau Creek station is 186 MW. If operated uninterrupted, it can produce 1,629 GHh of electricity. However, in 2010, electricity produced was only 857.7 GWh. This means the plant was operated only at 52.64% of the uninterrupted production level. Using these data, a water use coefficient of 1.935 dam^3 per MWh of electricity was estimated. Multiplying this value by the 2010 level of electricity generated yielded a water use of 1,660,092 dam^3.

Table 7.19: Water Intake for Electric Power Generation under Climate Change Scenario, South Saskatchewan River Basin, 2010-2060

Plant Type	Amount of Water Intake in dam^3			
	2010	2020	2040	2060
Hydroelectric	1,660,092	1,660,092	1,660,092	1,660,092
Cogeneration	1,347	2,145	3,033	3,954
Natural Gas	508	809	939	1,014
Biomass	-	0.0	0.1	0.4
Total excluding Hydroelectric Power	**1,855**	**2,954**	**3,972**	**4,968**
% of Baseline Scenario	--	0%	2.0%	4.0%

7.3.3 Power Generation Water Demand under Water Conservation Scenario

The power generation typical water conservation measures are conversions of once through cooling systems with closed loop or dry cooling. Each has different characteristics in terms of water demand and consumption with dry cooling having about half the water consumption as that of closed loop when fossil fuels are used to generate electricity (Larson et al., 2007). The refurbishing and replacement of existing generating capacity to 2060 would provide the opportunity to adopt such conservation measures. Therefore, it is estimated that water conservation technology could result in 5%, 15%, and 25% reductions in water demand by 2020, 2040, and 2060, respectively. The estimated water intake for non-hydroelectric power generation can be reduced to 3,583 dam^3 under this scenario by 2060 (Table 7.20).

Table 7.20: Water Intake for Electric Power Generation under Water Conservation Scenario, South Saskatchewan River Basin, 2010-2060

Plant Type	Amount of Water Intake in dam^3			
	2010	2020	2040	2060
Hydroelectric	1,660,092	1,660,092	1,660,092	1,660,092
Cogeneration	1,347	2,038	2,527	2,851
Natural Gas	508	769	783	731
Biomass	-	0.0	0.1	0.3
Total excluding Hydroelectric Power	**1,855**	**2,807**	**3,310**	**3,583**

7.3.4 Power Generation Water Consumption

A portion of the water intake is returned back to the original source (in some cases not at the same point of intake). The remaining water is lost primarily to evaporation. This latter amount of water is called consumption for electric power generation. Finally, these power generation estimates were made according to information from secondary data.

7.3.4.1 Power Generation Water Consumption under Baseline Scenario

Actual records of water consumption for power generation plants in Saskatchewan were not found. As a crude proxy, information for Canada was used. Statistics Canada (2005) has reported that for thermoelectric generation in Canada, water consumption at 2.76% of water intake. Using this proportion and level of water intake in Table 7.18, the consumptive losses of water were estimated. Results are shown in Table 7.21. Since no water is lost in the production of hydroelectric power, this consumption was set as equal to zero. For other types of power generation, water consumption in 2010 was estimated at 51 dam^3, increasing to 132 dam^3 by 2060.

Table 7.21: Water Consumption for Electricity Generation for the South Saskatchewan River Basin under Baseline Scenario, 2010-2060

Plant Type	**Amount of Water Consumption in dam^3**			
	2010	**2020**	**2040**	**2060**
Hydro	0	0	0	0
Cogeneration	37.3	59.4	82.3	105.3
Natural Gas	14.1	22.4	25.5	27.0
Biomass	-	0.0	0.0	0.0
Total Water Consumption	**51.4**	**81.8**	**107.8**	**132.3**

7.3.4.2 Water Consumption under Climate Change Scenario

Water consumption from power generation plants in the SSRB under climate change reflected higher intake. The consumption coefficients were assumed to be the same as those for the baseline scenario. However, it is conceivable that these coefficients may also change, but, no information on this possibility was found. Estimated consumption levels are shown in Table 7.22. In the climate change scenario, water consumed for power generation in the SSRB is expected to increase from the 2010 level of 51 dam^3 to 138 dam^3 by 2060.

Table 7.22: Water Consumption for Electricity Generation for the South Saskatchewan River Basin under Climate Change Scenario, 2010-2060

Plant Type	**Amount of Water Consumption in dam^3**			
	2010	**2020**	**2040**	**2060**
Hydro	0	0	0	0
Cogeneration	37.3	59.4	84.0	109.5
Natural Gas	14.1	22.4	26.0	28.1
Biomass	-	0.0	0.0	0.0
Total Water Consumption	**51.4**	**81.8**	**110.0**	**137.6**

7.3.4.3 Water Consumption under Water Conservation Scenario

The same method of calculation as that followed for the other two scenarios was employed to estimate water consumption by power generation plants under the water conservation scenario. Estimated levels, as shown in Table 7.23, suggest water consumption in 2060 of 99 dam^3, about 25% lower than those under the baseline scenario.

Table 7.23: Water Consumption for Electricity Generation for the South Saskatchewan River Basin under Water Conservation Scenario, 2010-2060

Plant Type	Amount of Water Consumption in dam^3			
	2010	**2020**	**2040**	**2060**
Hydro	0	0	0	0
Cogeneration	37.3	56.4	70.0	79.0
Natural Gas	14.1	21.3	21.7	20.3
Biomass	-	0.0	0.0	0.0
Total Water Consumption	**51.4**	**77.7**	**91.7**	**99.2**

7.4 Summary of Industrial/Mining Water Demand

In this section, a summary of various water demands related to mining and industry is presented. A presentation is made separately for each of the three scenarios.

7.4.1 Total Industrial/Mining Water Demand – Baseline Scenario

The industrial/mining water demand by sectors is presented in Tables 7.24 for the baseline scenario. The total water demand for these purposes is estimated at 9,965 dam^3 during 2010. This level will increase to 45,360 dam^3 by 2060, primarily as a result of expansion in the potash mining sector and induced activities resulting from irrigation.[51] In addition to water supplied to within basin mines and industries, some water is exported to the Qu'Appelle River basin through the SSEWS canal. This water is also used for various mines located in that basin. Over a period of time, outside SSRB water demand is expected to increase (Figure 7.4). By 2060, 38% of the basin water used for industrial/mining will be exported to neighboring river basins.

[51] The water use for irrigation is excluded from these estimates. On account of a large decrease in that water use, the overall total became negative. To avoid this issue, irrigation water use was not considered here.

Table 7.24: Total Industrial/Mining Water Demand in the South Saskatchewan River Basin under Baseline Scenario, 2010-2060

Activity	Water Demand in dam^3			
	2010	**2020**	**2040**	**2060**
Potash	3,298	10,071	10,071	13,037
Oil & Gas	205	275	165	41
Manufacturing	2,525	2,590	2,658	2,727
Irrigation Induced*	0	0	7,355	7,355
Power Generation**	1,855	2,954	3,894	4,777
Total Water Demand within the SSRB	7,883	15,891	24,143	27,937
Water Demand for Mining outside the SSRB	2,082	9,209	9,209	17,423
Total Water Demand for Industrial /Mining	**9,965**	**25,100**	**33,352**	**45,360**
Water Released for Hydroelectric Power	1,660,092	1,660,092	1,660,092	1,660,092

* Excluded irrigation water use associated with these developments

** Excluding water intake for hydroelectric power generation

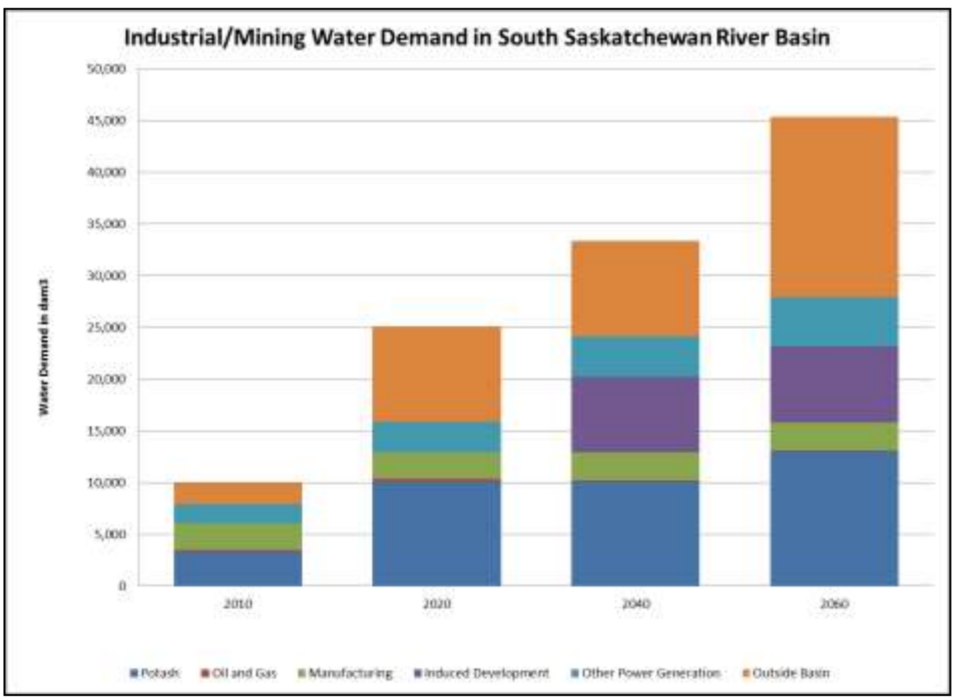


Figure 7.4: Water Demand of South Saskatchewan River Basin Water for Industrial/Mining Sectors, 2010-2060, Baseline Scenario

The water demand within the SSRB and that exported to the Qu'Appelle River Basin, show a different trend over time. Within basin water demand is expected to increase by 254% of the 2010 level, whereas the amount of water exported to the Qu'Appelle River Basin is expected to increase by 736% of the 2010 level. Expansion from new potash mining developments in the Qu'Appelle River Basin is responsible for this increase.

Within the basin water demand, industrial water demand will undergo some changes in the distribution of the total amount of water demanded for this purpose. At present, the potash mining demands 42% of the total water for this sector, which will increase to 47% by 2060 (Figure 7.5). The other demands, particularly the induced development activities as a result of more irrigation, would also claim a higher proportion of the total amount of water by 2060.

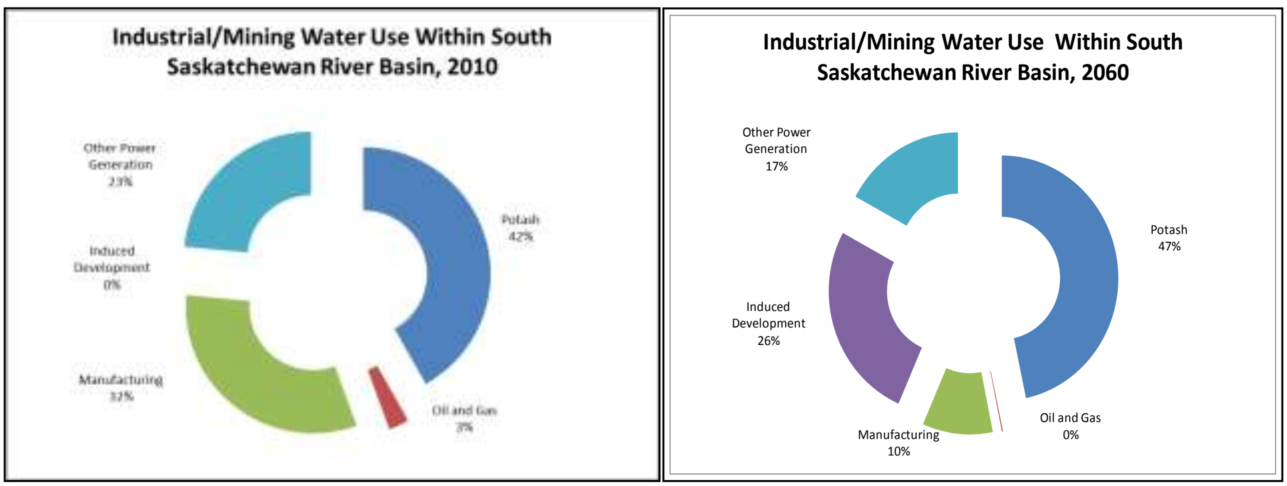


Figure 7.5: Distribution of Total Industrial/Mining Water Demand under the Baseline Scenario within the South Saskatchewan River Basin, 2010 and 2060

7.4.2 Total Industrial/Mining Water Demand – Climate Change Scenario

The predicted climate change does not appear to have any appreciable impact on the total water demand for the industrial/mining sector, as shown in Table 7.25. Part of the explanation for this situation is that potash mining water demand is not affected, and since it is the largest consumer within the sector, the total under this scenario is higher only by less than 1% of the baseline water demand level in 2060, and even lower in 2040.

Table 7.25: Total Industrial/Mining Water Demand, South Saskatchewan River Basin under Climate Change Scenario 2010-2060

Activity	Water Demand in dam^3			
	2010	**2020**	**2040**	**2060**
Potash	3,298	10,071	10,071	13,037
Oil & Gas	205	275	165	41
Manufacturing	2,525	2,590	2,711	2,836
Irrigation Induced*	0	0	7,355	7,355
Power Generation**	1,855	2,954	3,972	4,968
Total Water Demand within the SSRB	**7,883**	**15,891**	**24,274**	**28,237**
Water Demand for Mining outside the SSRB	2,082	9,209	9,209	17,423
Total Mining /Manufacturing Water Demand	**9,965**	**25,100**	**33,483**	**45,660**
Water Released for Hydroelectric Power	1,660,092	1,660,092	1,660,092	1,660,092

* Excluded irrigation water demand associated with these developments

** Excluding water intake for hydroelectric power generation

7.4.3 Total Industrial/Mining Water Demand – Water Conservation Scenario

Through several water conservation measures available to the industrial/mining sector, its water demand level may be reduced over the baseline scenario. Results are shown in Table 7.26. These changes could be observed by 2020, when water demand for this sector is estimated at 24,478 dam^3, which is 2.5% lower than that under the baseline scenario. By 2060, there is a potential to reduce this water demand by 11.8% to 40,007 dam^3. Thus, water conservation measures do offer a good potential for reducing consumption. Much depends on the systematic adoption of these practices which are decided by other factors, the most important of which is the total cost of water to the water user. If the cost is low, not much attention is paid to reducing water use.

A comparison of within basin and exported water demand for mining/industrial purposes is shown in Figure 7.6.

7.4.4 Industrial/Mining Water Demand by Source of Water

The water demands by source for each industry sector for the baseline, climate change, and conservation scenarios are presented in Tables 7.27 to 7.29. On account of potash production, water is basically supplied from surface water sources, and the importance of surface water remains unchanged in the three study scenarios.

Table 7.26: Total Industrial/Mining and Industrial Water Demand South Saskatchewan River Basin under Water Conservation Scenario, 2010-2060

Activity	Water Demand in dam^3			
	2010	**2020**	**2040**	**2060**
Potash	3,298	9,920	9,417	11,407
Oil & Gas	205	234	140	35
Manufacturing	2,525	2,538	2,604	2,672
Irrigation Induced*	0	0	7,207	7,064
Power Generation**	1,855	2,807	3,310	3,583
Total Within the SSRB	**7,883**	**15,500**	**22,678**	**24,761**
Water Demand for Mining outside the SSRB	2,082	8,979	8,518	15,245
Total Industrial/Mining Water Demand	**9,965**	**24,478**	**31,197**	**40,007**
Water Released for Hydroelectric Power Generation	1,660,092	1,660,092	1,660,092	1,660,092

* Excluded irrigation water use associated with these developments

** Excluding water intake for hydroelectric power generation

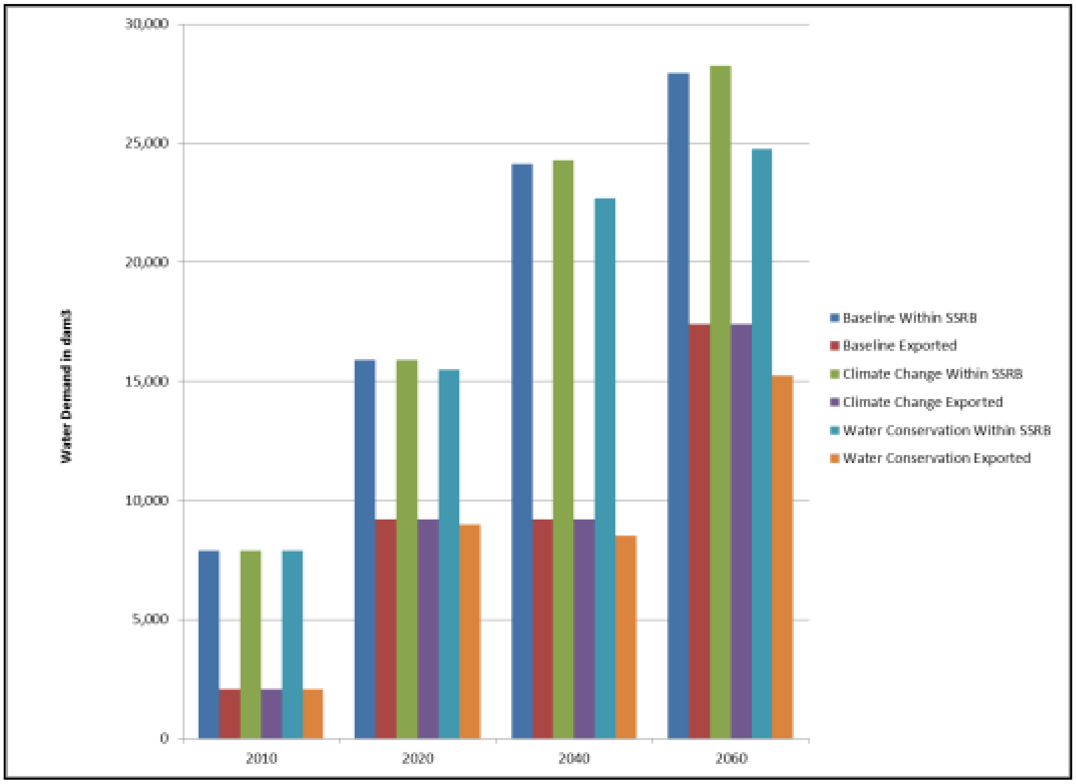


Figure 7.6: Total Water Demand for Industrial/Mining Sector by Study Scenarios and Destination, South Saskatchewan River Basin, 2010-2060

Table 7.27: Industrial/Mining Water Demand within the South Saskatchewan River Basin by Source of Water under Baseline Scenario, 2010-2060

Sector	Source	Total Amount of Water in dam^3			
		2010	2020	2040	2060
Potash	Surface	3,298	10,071	10,071	13,037
Oil & Gas	Surface	0	0	0	0
	Ground	205	275	165	41
Manufacturing	Surface	2,497	2,562	2,628	2,696
	Ground	28	29	30	30
Power Generation*	Surface	1,855	2,954	3,894	4,777
Induced	Surface	0	0	7,355	7,355
Total	**Surface**	**7,650**	**15,587**	**23,948**	**27,865**
	Ground	**233**	**304**	**195**	**72**
Surface Water as a % of Total		97.0%	97.0%	98.1%	99.2%

* Excludes water intake for hydroelectric power generation

Table 7.28: Industrial/Mining Water Demand within the South Saskatchewan River Basin by Source of Water under Climate Change Scenario, 2010-2060

Sector	Source	Total Amount of Water in dam^3			
		2010	2020	2040	2060
Potash	Surface	3,298	9,920	9,417	11,407
Oil & Gas	Surface	0	0	0	0
	Ground	205	275	165	41
Manufacturing	Surface	2,497	2,562	2,681	2,804
	Ground	28	29	30	32
Power Generation*	Surface	1,855	2,954	3,972	4,968
Induced	Surface	0	0	7,355	7,355
Total	**Surface**	**7,650**	**15,587**	**24,079**	**28,164**
	Ground	**233**	**304**	**195**	**73**

* Excludes water intake for hydroelectric power generation

Table 7.29: Industrial/Mining Water Demand within the South Saskatchewan River Basin by Source of Water under Water Conservation Scenario, 2010-2060

Sector	**Source**	**Total Amount of Water in dam3**			
		2010	**2020**	**2040**	**2060**
Potash	Surface	3,298	10,071	10,071	13,037
Oil & Gas	Surface	0	0	0	0
	Ground	205	275	165	41
Manufacturing	Surface	2,497	2,510	2,576	2,643
	Ground	28	28	29	30
Power Generation*	Surface	0	0	7,207	7,064
Induced	Surface	1,855	2,807	3,310	3,583
Total	**Surface**	**7,650**	**15,197**	**22,484**	**24,690**
	Ground	**233**	**303**	**194**	**71**

* Excludes water intake for hydroelectric power generation

Chapter 8

Municipal/Domestic Water Demand

The water demand by residents in different types of communities is an important part of the total quantity in the SSRB. This occurs because, in terms of total provincial population, the basin supplies water to five large cities – Martensville, Saskatoon, Swift Current, Warman, and Humboldt (which is located in the Qu'Appelle River Basin but has water supplied from the SSRB). In addition, there are a number of smaller communities in the basin, as well as a few First Nations Reserves, and recreational communities. The estimated water demand for municipal/domestic purposes is presented in this chapter.

8.1 Municipal Water Demand

8.1.1 Municipal Water Demand – Baseline Scenario

A municipal water demand was estimated for five large urban centers in the basin – Martensville, Saskatoon, Swift Current, Warman and Humboldt. The total water demand for these communities was estimated as a product of population[52] and water demand coefficient. Both of these were presented in Chapter 4. It should be noted that for large urban centers, this water demand includes the amounts for manufacturing, commercial, firefighting, street cleaning, and other public demands. This estimation was divided into three parts: For urban non-farm centers, Rural population, and Institutions.

For the baseline scenario, estimates were calculated with a simplifying assumption. The hypothesis was that past trends will continue in SSRB. However, future water consumption estimates for these cities require more accurate forecasts of population and of the adoption rate of water conservation technology. The expected values for water demand for the baseline scenario are presented in Table 8.1. The total municipal water demand in the basin is expected to increase from 51,162 dam^3 in 2010 to 78,759 dam^3 in 2060 – an increase of nearly 54%. Much of this increase is attributed to future growth in the city of Saskatoon and its water needs. It is expected that the city's water demand will increase from its current levels of 46,601 dam^3 to 71,509 dam^3 by 2060.

[52] Population used for estimating municipal/domestic water demand was that for the year 2009 – data available at the time of analysis. These population levels differed from those presented in Table 2.2.

Table 8.1: Estimated Municipal (Cities located Within Basin and Outside) Water Demand for South Saskatchewan River Basin, Study Scenarios, 2010-2060

Community Type	Water Demand in dam^3				2060 as a % of 2010
	2010	2020	2040	2060	
Baseline Scenario					
Martensville	550	720	1,061	1,402	254.9%
Saskatoon	46,601	50,768	60,253	71,509	153.4%
Swift Current	2,795	2,852	2,971	3,094	110.7%
Warman	536	765	1,272	1,841	343.5%
Total Within Basin Cities	**50,482**	**55,105**	**65,557**	**77,846**	154.2%
Outside Basin City (QEB* -- Humboldt)	680	721	812	913	134.3%
Total Water Demand for Cities	**51,162**	**55,826**	**66,369**	**78,759**	153.9%
Climate Change Scenario					
Martensville	550	720	1,086	1,472	267.6%
Saskatoon	46,601	50,768	61,699	75,085	161.1%
Swift Current	2,795	2,852	3,042	3,249	116.2%
Warman	536	765	1,290	1,877	350.2%
Total Water Demand for Cities	**50,482**	**55,105**	**67,117**	**81,683**	161.8%
Outside Basin City (QEB* -- Humboldt)	680	721	831	959	141.0%
Total Water Demand for Cities	**51,162**	**55,826**	**67,948**	**82,642**	161.5%
Scenario Water Demand % of Baseline	100.0%	100.0%	102.4%	104.9%	
Water Conservation Scenario					
Martensville	550	702	981	1,226	222.9%
Saskatoon	46,601	49,499	55,734	62,571	134.3%
Swift Current	2,795	2,781	2,748	2,707	96.9%
Warman	536	746	1,176	1,611	300.6%
Total Water Demand for cities	**50,482**	**53,728**	**60,639**	**68,115**	134.9%
Total Water Demand for Cities Located Outside the River Basin (Humboldt in QRB*)	680	703	751	799	117.5%
Total Within and Outside Basin City Water Demand	**51,162**	**54,431**	**61,390**	**68,914**	134.7%
Scenario Water Demand % of Baseline	100.0%	97.5%	92.5%	87.5%	

* Qu'Appelle River Basin

8.1.2 Municipal Water Demand – Climate Change Scenario

The total water demand for domestic purposes was a product of the adjusted water demand coefficient and the population as used for the baseline scenario. The adjustment in these coefficients is described in this section.

8.1.2.1 Adjustment of per Capita Water Demand for Climate Change

This second scenario incorporates the adjusted values of the per capita water demand coefficients for climate change. In order to estimate the effect, two aspects were considered: (i) Temperature and precipitation change; and (ii) Frequency of dry extreme events.

Climate change will affect indoor water demand differently from its influence on lawn irrigation. Since no study reporting the impact of climate change on domestic water demand in the basin was found, studies for other jurisdictions were reviewed.

Herrington (1996) reported the impact of climate change on UK domestic water use. Through applying climate models, Herrington predicted an increase of 5% by 2021 in per capita water demand was predicted. The scenario of climate change represents an increase in average temperature of 1ºC. Cohen (1985) estimated the impact of climate change in the Great Lakes region of Canada for the May to September period. The results suggested an increase in water demand by 5.6% and 5.2% for two scenarios. If one assumes that winter water use would remain unaffected, this translates into a 2.5% and 2.4% increase[53].

In developing the climate change scenario, it was assumed here that there will be no major impacts on the domestic water use by 2020. Assuming that the average temperature in the basin deriving climate change may be similar to the Great Lakes region, a 2.4% increase in domestic water use was assumed by 2040. For 2060, an increase of 5% of the baseline scenario's level of water use was assumed. Population predictions for all three time periods were assumed to be the same as the baseline scenario.

To estimate the impact of extreme events on domestic water consumption, per capita domestic water use data for 1995-2009 were used. It was assumed that the 2001 and 2002 droughts would impact the level of water demand in a positive manner. These events were introduced through a binary variable (which took a value of 1 if the year has an occurrence of drought and 0

[53] It is recognized that the Great lakes region may not be similar to the SSRB. However, no study on this subject was found that has reported such impacts in the basin.

otherwise). The other two variables – trend and size of the community– were retained for this analysis. For cities located in the SSRB, the coefficient for the drought occurrence was not significantly different from zero (See Appendix G). For this reason, it was decided that no effect of dry extreme events (droughts) on the municipal water demand will appear in the future. The effects of climate change on the water demand per capita are shown in Table 8.2.

Table 8.2: Adjusted Domestic Water Demand Coefficients for Climate Change Scenario, South Saskatchewan River Basin, 2010-2060

Community Type	Water Demand per Capita (m^3)			
	2010	2020	2040	2060
Communities within SSRB				
Martensville	86.64	86.64	88.72	90.97
Saskatoon	210.23	210.23	215.28	220.74
Swift Current	171.57	171.57	175.69	180.15
Warman	88.68	92.21	100.74	108.36
Bed Comm.	139.02	127.79	111.99	97.79
T>1000*	120.29	107.12	91.35	76.70
T<1000*	93.22	93.22	95.45	97.88
Villages	125.16	125.16	128.16	131.42
Rural farm	125.16	125.16	128.16	131.42
Rural non-farm	125.16	125.16	128.16	131.42
First Nations	137.93	137.93	141.24	144.82
Communities in Qu'Appelle River Basin				
Humboldt	117.02	117.02	119.83	122.87

* T>1000 = Towns with a population of over 1,000 people;
T<1000 = Towns with a population of less than 1,000 people

8.1.2.2 Estimated Municipal Water Demand under Climate Change

The total municipal (cities') water demand in the basin under climate change is expected to be higher than that for the baseline scenario. These estimates are presented in Table 8.1. Relative to 2010, the water demand for this purpose will increase by almost 5% by 2060. This situation is primarily a result of higher temperatures and an increased frequency of extreme events. The total municipal water demand under this scenario is expected to be 82,642 dam^3 by 2060 -- some 4.9% above the demand level in the baseline scenario.

8.1.3 Municipal Water Demand – Water Conservation Scenario

Applying the methodology described in Section 5.3 of this report, this section estimates SSRB municipal water demand. In this scenario, the water conservation was incorporated into the future water demand. For the municipal water demand, a mid-value water conservation potential of 25% and an adoption rate of 1% per annum were assumed. The reference year was 2010, and the relative savings in water demand by 2020 was 2.5%, 7.5% for 2040, and 12.5% by 2060. Table 8.3 shows the adjusted coefficients' values for the water demand per capita for communities located in the SSRB.

Table 8.3: Adjusted Domestic Water Demand Coefficients (m^3/capita) for Water Demand Conservation South Saskatchewan River Basin

Community Type	Water Demand per Capita m^3			
	2010	2020	2040	2060
Martensville	86.64	84.48	80.14	75.81
Saskatoon	210.23	204.98	194.46	183.95
Swift Current	171.57	167.28	158.70	150.12
Warman	88.68	89.91	91.83	93.04
Humboldt	117.02	114.09	108.24	102.39
Bed Comm.	139.02	127.02	106.68	88.59
T>1000*	120.29	106.48	83.92	65.40
T<1000*	93.22	92.66	92.10	90.51
Villages	125.16	124.41	123.66	121.53
Rural farm	125.16	124.41	123.66	121.53
Rural non-farm	125.16	124.41	123.66	121.53
First Nations	137.93	137.10	136.27	133.93

* T>1000 = Towns with a population of over 1,000 people;
T<1000 = Towns with a population of less than 1,000 people

The total municipal water demand for the basin is shown in Table 8.1., and it is estimated at 68,915 dam^3 for 2060. On average, this amounted to a reduction of 2.5% in 2020, 7.5% in 2040, and 12.5% in 2060 over the baseline scenario.

8.1.4 Municipal Water Demand - Summary

The results of municipal water demand from the three scenarios are summarized in Table 8.4. Water demand in the cities will remain virtually the same, partly because of declining trends in the water demand per capita, which may in part be due to past efforts in educating people on water saving technologies.

Table 8.4: Municipal (Within Basin and Outside) Water Demand in the South Saskatchewan River Basin, Study Scenarios, 2010 - 2060

Scenarios	Total Amount of Water in dam^3				2060 level % of Baseline
	2010	2020	2040	2060	
Baseline	51,162	55,826	66,369	78,759	100.0%
Climate Change	51,162	55,826	67,948	82,642	104.9%
Water Conservation	51,162	54,431	61,390	68,914	87.5%

8.2 Domestic Water Demand

The domestic water demand was estimated for larger urban centers other than cities. These included three types of communities: (i) Bedroom communities; (ii) Towns with population of 1,000 people or more and (iii) Towns with populations less than 1,000 people (which included water demand for the town of Bruno, located in Qu'Appelle River Basin, as it receives water from the SSRB). Results for this water demand are presented in this section.

8.2.1 Domestic Water Demand – Baseline Scenario

Domestic water demand was estimated from the estimated population of various communities and their respective water demand per capita. These methodologies for the baseline scenario were presented in Chapters 3 and 4. The estimated domestic water demand levels are presented in Table 8.5. With the exception of bedroom communities (which are expected to grow in the future) all domestic water demand is expected to decline over the 2010-2060 period. Overall, the 2060 water demand was estimated at 3,777 dam^3, which is nearly 24% higher than that in 2010. This increase is mainly contributed by increased water demand for the bedroom communities around the city of Saskatoon in the basin.

8.2.2 Domestic Water Demand – Climate Change Scenario

The water demand under climate change was estimated by making adjustment, in the per capita water demand for the communities included under the category of domestic water demand. These results are also shown in Table 8.5. In spite of the declining trends in the water demand by towns, the total domestic water demand will increase in 2060 by almost 30% over the 2010 level. The level for 2060 was estimated at 4,044 dam^3 – about 7% higher than that observed under the baseline scenario.

8.2.3 Domestic Water Demand – Water Conservation Scenario

For this scenario, the methodology for estimating the domestic water demand for the SSRB was similar to that followed for the climate change scenario. Water demand coefficients were adjusted, as shown in Table 8.3. The total water demand under their scenario is shown in Table 8.5. Under the conversation scenario, a reduction in total domestic water demand is noted. The total domestic water demand for 2060 is only 3,668 dam^3, which is 2.9% lower than its level under the baseline scenario.

Table 8.5: Estimated Domestic (Within Basin and Outside) Water Demand for South Saskatchewan River Basin, Study Scenarios, 2010 - 2060

Community Type	Water Demand in dam^3				2060 as a % of 2010
	2010	2020	2040	2060	
Baseline Scenario					
Towns > 1000 people	1,753	1,726	1,652	1,560	89.0%
Towns < 1000 people	702	657	588	526	75.0%
Bedroom Communities	559	776	1,211	1,645	294.2%
Total Water Demand for Communities located in SSRB	**3,014**	**3,159**	**3,451**	**3,731**	**123.8%**
Total Water Demand for Communities outside SSRB (Bruno)	83	77	58	45	55.1%
Total Domestic Water Demand	**3,096**	**3,236**	**3,509**	**3,777**	**122.0%**
Climate Change Scenario					
Towns > 1000 Population	1,753	1,726	1,713	1,672	95.4%
Towns < 1000 Population	702	657	629	593	84.6%
Bedroom Communities	559	776	1,240	1,727	308.9%
Total Water Demand for Communities Located in SSRB	**3,014**	**3,159**	**3,582**	**3,992**	**132.5%**
Total Water Demand for Communities outside SSRB (Bruno)	83	77	63	52	63.0%
Total Domestic Water Demand	**3,096**	**3,236**	**3,645**	**4,044**	**130.6%**
Water Conservation Scenario					
Towns > 1000 Population	1,753	1,716	1,632	1,514	86.4%
Towns < 1000 Population	702	653	581	511	72.9%
Bedroom Communities	559	772	1,196	1,597	285.7%
Total Water Demand for Communities Located in SSRB	**3,014**	**3,140**	**3,409**	**3,623**	**120.2%**
Total Water Demand for Communities outside SSRB (Bruno)	83	77	57	45	54.0%
Total Domestic Water Demand	**3,096**	**3,217**	**3,466**	**3,668**	**118.5%**

8.2.4 Domestic Water Demand -- Summary

A summary of domestic water demand in the SSRB for the three study scenarios is shown in Table 8.6. Generally speaking, climate change would impart an increase in the domestic water demand, which by 2060 could be as high as 7% over the baseline scenario. Water conservation could offer some relief – by about 2.9% in 2020, but not enough to cover the increase caused by climate change.

Table 8.6: Summary of Domestic (Within Basin and Outside) Water Demand in the South Saskatchewan River Basin, Study Scenarios, 2010 - 2060

Scenarios	Total Domestic Water Demand in dam^3				2060 level % of Baseline
	2010	2020	2040	2060	
Baseline	3,096	3,236	3,509	3,777	100.0%
Climate Change	3,096	3,236	3,645	4,044	107.1%
Water Conservation	3,096	3,217	3,466	3,668	97.1%

8.3 Rural Domestic Water Demand

Rural water demand in this study was defined as a sum of the amount needed for the villages, farm population, and rural non-farm population.

8.3.1 Rural Domestic Water Demand – Baseline Scenario

The method of estimation for the rural water demand was the same as the methods for other types of municipal/domestic water demands. The per capita water demand coefficients were multiplied by estimated populations for a given time period for the three types of rural communities listed above. The estimated rural water demand is shown in Table 8.7.

On account of declining population trends in various types of rural communities, water demand is expected to decline in 2060 from its 2010 level. Under the baseline scenario, the 2010 rural water demand level is estimated at 4,103 dam^3, which could decline to 3,073 dam^3. This decline is predicated on the present trends of the rural population. It is conceivable that this rate of decline in the future may be stabilized at a slightly higher level than that assumed in this study. Perhaps, as more people leave these areas, fewer will remain there and thus, less will be out-migrating to towns or cities.

8.3.2 Rural Domestic Water Demand – Climate Change Scenario

Under the climate change scenario, water demand per capita coefficients were adjusted to reflect its potential impact. These adjusted coefficients are shown in Table 8.2. The estimated population for various categories was multiplied by these coefficients to yield total water demands. Estimated rural water demand is shown in Table 8.7. The total rural water demand will still decline over time, but not as quickly as it will under the baseline scenario. This level in 2060 will be 3,227 dam^3, 5% higher than that predicted under the baseline scenario.

Table 8.7: Estimated Rural (Within Basin and Outside) Water Demand for the South Saskatchewan River Basin, Study Scenarios, 2010 - 2060

Community Type	Rural Water Demand in dam^3				2060 as a % of 2010
	2010	2020	2040	2060	
Baseline Scenario					
Villages	831	789	768	753	90.7%
Farm Population	1,995	1,795	1,436	1,396	70.0%
Rural Non-Farm	1,132	1,019	906	793	70.0%
Total Rural Water Demand for Communities located in SSRB	**3,958**	**3,604**	**3,111**	**2,942**	**74.3%**
Total Rural Water Demand for Communities outside SSRB*	145	137	133	131	90.3%
Total Rural Water Demand	**4,103**	**3,741**	**3,244**	**3,073**	**74.9%**
Climate Change Scenario					
Villages	831	789	787	791	95.2%
Farm Population	1,995	1,795	1,471	1,466	73.5%
Rural Non-Farm	1,132	1,019	928	832	73.5%
Total Rural Water Demand for Communities located in SSRB	**3,958**	**3,604**	**3,185**	**3,089**	**78.1%**
Total Rural Water Demand for Communities outside SSRB*	145	137	137	138	95.0%
Total Rural Water Demand	**4,103**	**3,741**	**3,322**	**3,227**	**78.6%**
Water Conservation Scenario					
Villages	831	784	759	731	88.0%
Farm Population	1,995	1,785	1,419	1,356	68.0%
Rural Non-Farm	1,132	1,013	895	770	68.0%
Total Rural Water Demand for Communities located in SSRB	**3,958**	**3,582**	**3,073**	**2,857**	**72.2%**
Total Rural Water Demand for Communities outside SSRB*	145	137	132	127	87.7%
Total Rural Water Demand	**4,103**	**3,719**	**3,205**	**2,984**	**72.7%**

*Includes: Munster, Anaheim, and Lake Lenore

8.3.3 Rural Domestic Water Demand – Water Conservation Scenario

The rural water demand under water conservation estimations followed the same methodology as the precedence described for the municipal and domestic water demands. The adjusted water demand coefficients for the three categories of communities are shown in Table 8.3. Estimated water demand is shown in the bottom panel of Table 8.7. This water demand is below that calculated for the baseline scenario by 2.9%, or at 2,984 dam^3.

8.3.4 Rural Domestic Water Demand -- Summary

A summary of rural water demand is presented in Table 8.8 for the three study scenarios. As noted above, there is a tendency in this water demand to decline over time, partly because of declining population base. Although climate change will increase this water demand by 5%, the water conservation scenario could produce approximately a 3% reduction compared to the baseline scenario. Water conservation in rural settings is a relatively unstudied subject. These estimates are therefore based on water demand coefficients that are not supported by science or observations. More attention needs to be paid to this aspect of conservation in future research projects.

Table 8.8: Summary of Rural (Within Basin and Outside) Water Demand in the South Saskatchewan River Basin, 2010 - 2060

Scenarios	Rural Water Demand in dam^3				2060 level % of Baseline
	2010	2020	2040	2060	
Baseline	4,103	3,741	3,244	3,073	100.0%
Climate Change	4,103	3,741	3,322	3,227	105.0%
Water Conservation	4,103	3,719	3,205	2,984	97.1%

8.4 First Nations' Water Demand

As a population group, First Nations' communities are the fastest growing communities in the SSRB. The population in these communities is expected to grow, although out migration patterns may reduce their sizes in the future. These results are presented in this section.

8.4.1 First Nations' Water Demand – Baseline Scenario

First Nations' communities' water demand was estimated by using the per capita water demand coefficient presented in Chapter 3, multiplied by the population for a given time period, which was presented in Chapters 3 and 4. The total water demand for these communities is expected to grow. Under the baseline scenario, the total water demand is expected to increase by nearly

171% over the 2010 level. In 2010, it was estimated at 120 dam^3, which will likely increase to 325 dam^3 by 2060.

8.4.2 First Nations' Water Demand – Climate Change Scenario

Climate change was assumed to have the same type of impact as it will on other water user groups. As a result, the water demand estimate for 2060 was 341 dam^3, 5% higher than the figure for the baseline level.

Table 8.9: Summary of First Nations' Water Demand in the South Saskatchewan River Basin, 2010 - 2060

Scenario	Estimated First Nations' Total Water Demand in dam^3 for				2060 as a % of 2010	% of Baseline Scenario Level
	2010	2020	2040	2060		
Baseline	120	161	243	325	270.86%	100.0%
Climate Change	120	161	248	341	284.41%	105.0%
Water Conservation	120	160	240	315	263.01%	97.1%

8.4.3 First Nations' Water Demand – Water Conservation Scenario

No information is available on the subject of water conservation and First Nations' communities. However, in the future, it is assumed that these communities will follow the same pattern in adopting water conservation measures as rest of the basin. This is predicated on improved education level of First Nations' people in future and on improved dissemination by provincial agencies of strategies for adopting water conservation measures in these communities. Under this assumption, the water demand for these communities, as shown in Table 8.9, will be 315 dam^3 by 2060. This scenario brings a reduction of approximately 3% from the baseline scenario.

8.4.4 First Nations' Water Demand -- Summary

The water demand for First Nations' communities is expected to modestly rise. Under a baseline scenario, water demand levels are expected to increase by 171% in 2060, relative to 2010. With climate change effects taken into consideration, the increase is forecasted to reach 184%, and 163% under a scenario with water conservation policies.

8.5 Other Municipal/Domestic Water Demand

Other domestic water demand comprises trailer courts communities. Available data for these communities is rather scarce. Therefore, estimating future water demands was realised by using the total water demand of these communities.

8.5.1 Other Municipal/Domestic Water Demand – Baseline Scenario

The results for the other domestic water demand levels are shown in Table 8.10. The water demand for trailer courts communities is expected to increase from 102 dam^3 to 253 dam^3 by the year 2060. In relative terms, this represents an increase of 148%.

8.5.2. Other Municipal/Domestic Water Demand – Climate Change Scenario

Climate change is expected to increase water consumption for these communities. Their water demand is assumed to increase from the current levels of 102 dam^3 to 265 dam^3 by 2060, accounting for an increase of 79% by 2060, relative to 2010 (Table 8.10).

8.5.3 Other Municipal/Domestic Water Demand – Water Conservation Scenario

Under a water conservation scenario, the water demand for these communities is expected to decrease in comparison with the baseline scenario. The increase in water demand is expected to be somewhat moderate, compared to the other two scenarios; from 102 dam^3 in 2010, water demand will reach 245 dam^3 by 2060. The estimations are presented in Table 8.10.

Table 8.10: Estimated Other Municipal/Domestic Water Demand for the South Saskatchewan River Basin, Study Scenarios, 2010 – 2060

Scenario	Type of Community	Total Water Demand in dam^3				2060 as a % of 2010
		2010	2020	2040	2060	
Baseline	Trailer Courts	102	132	192	253	248.4%
Climate Change	Trailer Courts	102	132	197	265	259.8%
Water Conservation	Trailer Courts	102	131	190	245	240.2%

8.5.4 Other Municipal/Domestic Water Demand – Summary

A summary of trailer courts communities' water demand is presented in Table 8.10 for the three scenarios. The tendency in water consumption for these communities is to increase, mostly due to population growth. Although climate change will increase this water demand by 5%, the water conservation scenario could bring forth a reduction of approximately 1% compared to the baseline scenario.

8.6 Source of Water for Municipal/Domestic Water Demand

Municipal/domestic water demands are served both by surface water bodies and by underground aquifers. A summary of this water demand for the baseline scenario is shown in Table 8.11. Almost the entire amount of the total water demand is supplied by surface water bodies. The relative proportion of surface to groundwater varies slightly among the three scenarios. Overall, the use of surface water dominates the total water demand for municipal/domestic purposes in the SSRB. In 2010, 95% of the total water demand was served from such sources. It increases to 97% by 2060.

Table 8.11: Total Municipal/Domestic (Within Basin and Outside) Water Demand by Source, South Saskatchewan River Basin, Baseline Scenario, 2010 - 2060

Particulars	Water Demand in dam^3			
	2010	**2020**	**2040**	**2060**
Total Surface Water Demanded in the Basin	55,292	59,855	70,337	82,880
Total Surface Water Demanded Outside Basin	838	864	927	1,006
Total Surface Water Demand	**56,130**	**60,719**	**71,263**	**83,887**
Total Ground Water Demanded in the Basin	2,384	2,307	2,216	2,217
Total Ground Water Demanded Outside Basin	69	72	77	83
Total Ground Water Demand	**2,453**	**2,379**	**2,292**	**2,300**
Total Water Demand Inside the Basin	57,675	62,162	72,552	85,097
Total Water Demand	**58,583**	**63,097**	**73,556**	**86,187**
	Percentage			
Surface Water % of Total in Basin	95.9%	96.3%	96.9%	97.4%
Surface Water % of Total Outside Basin	92.4%	92.3%	92.4%	92.4%
Surface Water % of Total	**95.8%**	**96.2%**	**96.9%**	**97.3%**

8.7 Water Consumption for Municipal/Domestic Water Demand

Not all water withdrawn (also called intake) is lost. A part of this water is returned back to the original surface water bodies. Although some water may be returned to groundwater sources[54], the knowledge of aquifer recharge rates and related information is relatively poor and therefore, it is typically assumed that all groundwater withdrawn is lost. The total consumption of water for municipal/domestic purposes is shown in Table 8.12.

The total water consumption under the baseline scenario for 2010 was estimated at 21,996 dam^3, which is about 37% of the total water withdrawn. Thus, 63% of the water withdrawn is returned

[54] Even if water is withdrawn from underground aquifers, treated effluent may be returned to surface water bodies.

to the original water source in some shape.[55] By 2060, the amount of water consumed increases slightly, but its proportion to total water intake does not change appreciably.

Table 8.12: Water Intake and Consumption for Municipal/Domestic (Within Basin and Outside) Water Demands, South Saskatchewan River Basin, Study Scenarios, 2010 - 2060

Particulars	Water Quantity in dam^3			
	2010	**2020**	**2040**	**2060**
Baseline Scenario				
Total Water Intake inside basin demand	57,675	62,162	72,552	85,097
Total Water Intake	**58,583**	**63,097**	**73,556**	**86,187**
Water Consumption inside basin	21,633	22,899	26,033	30,076
Water Consumption	**21,996**	**23,268**	**26,422**	**30,491**
Consumption as a % of Intake inside basin	37.51%	36.84%	35.88%	35.34%
Consumption as a % of Intake	**37.55%**	**36.88%**	**35.92%**	**35.38%**
Climate Change Scenario				
Total Water Intake inside basin demand	57,675	62,162	74,330	89,370
Total Water Intake	**58,583**	**63,097**	**75,361**	**90,518**
Water Consumption inside basin	21,633	22,899	26,669	31,585
Water Consumption	**21,996**	**23,268**	**27,069**	**32,022**
Consumption as a % of Intake inside basin	37.51%	36.84%	35.88%	35.34%
Consumption as a % of Intake	**37.55%**	**36.88%**	**35.92%**	**35.38%**
Water Conservation Scenario				
Total Water Intake inside basin demand	57,676	60,742	67,552	75,156
Total Water Intake	**58,583**	**61,658**	**68,491**	**76,127**
Water Consumption inside basin	21,633	22,428	24,399	26,818
Water Consumption	**21,996**	**22,790**	**24,768**	**27,193**
Consumption as a % of Intake inside basin	37.51%	36.92%	36.12%	35.68%
Consumption as a % of Intake	**37.55%**	**36.96%**	**36.16%**	**35.72%**

[55] Cities with a municipal water and sewer system have facilities to treat this water before releasing it to a given surface water body. Whether all towns have similar facilities needs further investigation. This proportion is based on an assumption reported in Chapter 3.

Under climate change and water conservation scenarios, although consumption levels do change, their proportion to the total water demand remains stable. The level of water intake and consumption for municipal/domestic purposes is shown in Figure 8.1.

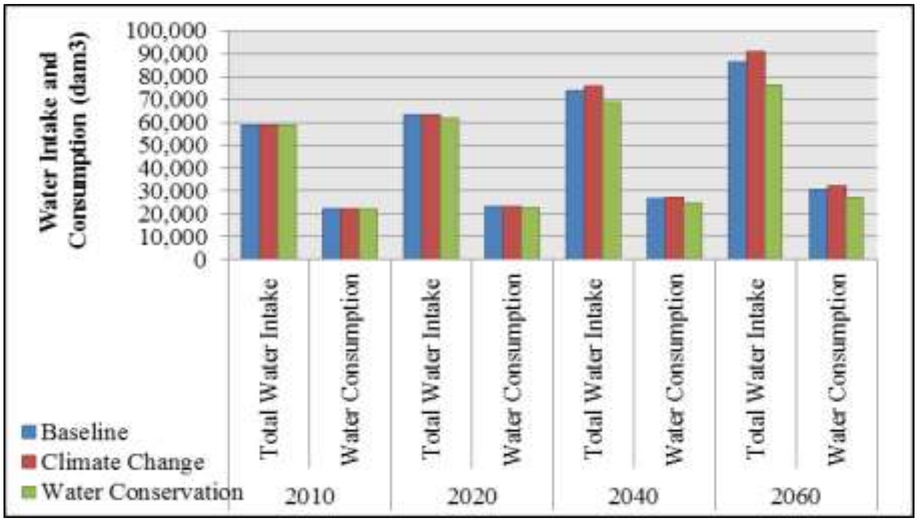


Figure 8.1: Distribution of Water Intake and Consumption for Municipal/Domestic (Within Basin and Outside) Water Demand in dam^3 in the South Saskatchewan River Basin, 2010 – 2060

8.8 Total Municipal/Domestic Water Demand

In this section, all different water demands described above are summarized. These estimates are grouped into five categories of municipal/domestic water demand: municipal water demand (cities); domestic water demands (towns); rural water demand (villages and open areas); First Nation communities' water demand; and other water demands. Results for the three study scenarios are summarized in this section.

8.8.1 Total Municipal/Domestic Water Demand – Baseline Scenario

The total municipal/domestic water demand in the SSRB in 2010 was estimated at 58,583 dam^3, of which cities have the largest share. In fact, 87% of the total water demand is for the five cities in the basin. The next largest level of water demand in 2010 belongs to rural communities, which includes farm and rural non-farm level water demands. This level was estimated at 4,103 dam^3. Domestic water demands (towns) showed similar levels of 3,096 dam^3. Lower water demand levels were indicated for other municipal/domestic communities and for First Nations' communities. A summary of results for the baseline scenario are shown in Table 8.13.

By 2060, although municipal water demand still has the largest share, the ranks of other water demands change. Now, rural water demand has the second highest level, followed by domestic water demand. The rural water demand level is presently only 4,103 dam^3 and is expected to decrease slowly by 2060 to 3,073. The largest increase in 2060 is expected to be in the urban communities' water demand level, which is expected to rise from 51,162 dam^3 in 2010 to 78,760 dam^3 by 2060. Relative shares of these five water demands are shown in Figure 8.2. Other domestic communities and First Nations' communities' water demand levels are expected to increase more rapidly, but their share in the total municipal/domestic water demand will remains low.

Table 8.13: Total Municipal/Domestic (Within Basin and Outside) Water Demand in the South Saskatchewan River Basin under Baseline Scenario, 2010 - 2060

Category	Total Municipal/Domestic Water Demand in dam^3				2060 as % of 2010 Level
	2010	2020	2040	2060	
Total Water Demand for Cities	51,162	55,827	66,368	78,760	153.9%
Total Domestic Water Demand for Urban Communities	3,096	3,236	3,509	3,777	122.0%
Total Rural Water Demand	4,103	3,741	3,244	3,073	74.9%
First Nations' Communities' Total Water Use	120	161	243	325	270.9%
Other Municipal/Domestic Water Use	101.67	131.84	192.19	252.54	248.4%
Total Municipal/Domestic Water Use	**58,583**	**63,097**	**73,556**	**86,187**	**147.1%**

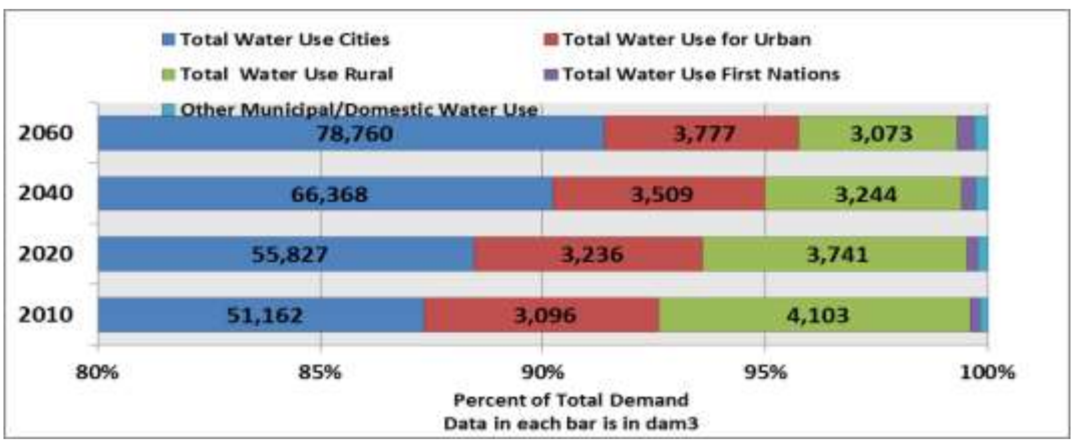


Figure 8.2: Distribution of Total Municipal/Domestic (Within Basin and Outside) Water in the South Saskatchewan River Basin by Type of Community, Baseline Scenario 2010 – 2060

The distribution of the municipal/domestic water in the SSRB is also expected to change over time. As shown in Figure 8.2, cities claim a hefty proportion of this total water; their proportion was estimated at 88% for 2010, and it increases to 91% by 2060.

8.8.2 Total Municipal/Domestic Water Demand – Climate Change Scenario

As expected, municipal/domestic water demand levels are expected to increase under the climate change scenario. Increases are expected in all categories of municipal/domestic water demand. The total amount in 2060 will increase to 90,518 dam^3, which is nearly 55% higher than that observed in 2010, as shown in Table 8.14. The two cities will continue to demand a large proportion of this water. Relative to the baseline scenario, the climate change could bring an increase of 5% in water demand for domestic water demand by 2060.

Table 8.14: Total Municipal/Domestic (Within Basin and Outside) Water Demand under Climate Change Scenario, 2010 2060

Category	Total Municipal/Domestic Water Demand in dam^3				2060 as % of 2010 Level
	2010	2020	2040	2060	
Total Water Demand for Cities	51,162	55,827	67,949	82,641	161.5%
Total Domestic Water Demand for Other Urban Communities	3,096	3,236	3,645	4,044	130.6%
Total Rural Water Demand	4,103	3,741	3,322	3,227	78.6%
First Nations' Communities' Total Water Demand	120	161	248	341	284.4%
Other Municipal/Domestic Water Demand	101.67	131.84	196.80	265.16	260.8%
Total Municipal/Domestic Water Demand	**58,583**	**63,097**	**75,361**	**90,518**	**154.5%**

8.8.3 Total Municipal/Domestic Water Demand – Water Conservation Scenario

The level of municipal/domestic water demand will diminish under the water conservation scenario. In comparison to the baseline scenario, the water conservation scenario is assumed to account for a reduction of nearly 12% by 2060. The total water demand for these purposes in 2060 will be 76,127 dam^3, and these results are summarized in Table 8.15.

Trends in the municipal/domestic water demand in the SSRB are shown in Figure 8.3. All scenarios provide the same pattern. In all cases, climate change after 2020 will bring about increased water demand levels for municipal/domestic purposes, whereas adoption of water conservation practices can reduce this level. Under this scenario, the 2020 level is lower than the previous scenario's water demand. This reduction is caused by the trend in Saskatoon's water demand, which is expected to decrease at the same rate as that exhibited in this past decade.

Table 8.15: Total Municipal/Domestic (Within Basin and Outside) Water Demand under Water Conservation Scenario, 2010 - 2060

Category	Total Municipal/Domestic Water Demand in dam^3				2060 as % of 2010 Level
	2010	2020	2040	2060	
Total Water Demand for Cities	51,162	54,432	61,390	68,915	134.7%
Total Domestic Water Demand for Urban Communities	3,096	3,217	3,466	3,668	118.5%
Total Rural Water Demand	4,103	3,719	3,205	2,984	72.7%
First Nations' Communities' Total Water Demand	120	160	240	315	263.0%
Other Municipal/Domestic Water Demand	101.67	131.05	189.88	245.21	241.2%
Total Municipal/Domestic Water Demand	**58,583**	**61,658**	**68,491**	**76,127**	**129.9%**

8.8.4 Total Municipal Water Demand -- Summary

A summary of total municipal/domestic water demand for 2010 - 2060 period under the three study scenarios is presented in Table 8.16. Under climate change in 2060, the basin will experience a 5% increase in municipal/domestic water demand, whereas under the water conservation scenario, a reduction of nearly 12% is a possibility. These estimates are based on a declining water demand level for the city of Saskatoon. This assumption requires further scrutiny. Regardless of the scenario, the growth in the basin water demand for municipal/domestic purposes will be dramatic, as shown in Figure 8.3.

Table 8.16: Summary of Municipal (Within Basin and Outside) Water Demand in the South Saskatchewan River Basin, 2010-2060, under Study Scenarios

Scenarios	Total Water Demand in dam^3				% of Baseline Scenario in 2060 2010
	2010	2020	2040	2060	
Baseline	58,583	63,097	73,556	86,187	100.0%
Climate Change	58,583	63,097	75,361	90,518	105.0%
Water Conservation	58,583	61,658	68,491	76,127	88.3%

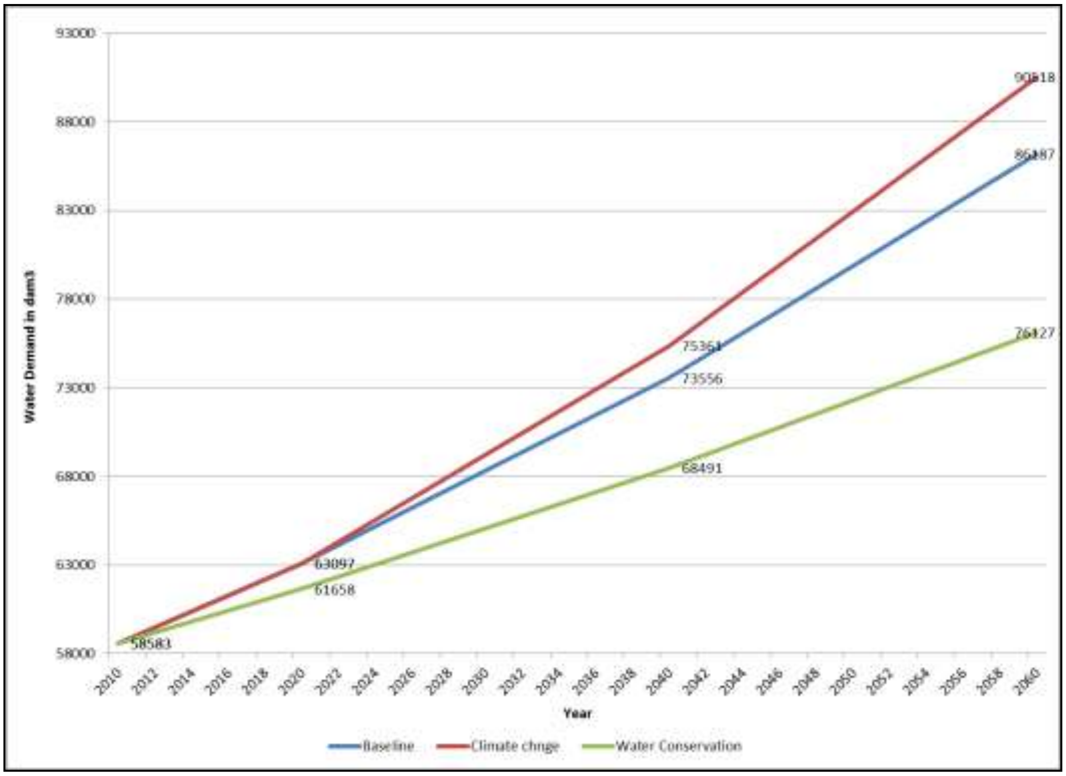


Figure 8.3: Total Municipal/Domestic (Within Basin and Outside) Water Demand for the South Saskatchewan River Basin under Study Scenarios, 2010 – 2060

Chapter 9

Recreational Water Demand

Water-based recreation activities are typically of two types: consumptive, which includes water demand by cottager owners and other residents near or at the surface water bodies; and non-consumptive in nature. The non-consumptive recreation category can be further divided into two types: water-contact recreation (such as swimming, fishing, etc.), and non-water-contact recreation (such as boating, aesthetic pleasure-seeking activities, walking near the water bodies, among others). The non-consumptive recreational water demand cannot be estimated, since the only loss occurs through evaporation but it is supplemented by natural flows. The consumptive water demand needs to be estimated as a part of the total calculation for the SSRB. This demand is reported the present chapter.

Consumptive water demand for recreational activities is needed for two types of water users: that for residents living in recreational communities and the water needed to maintain recreational facilities. The latter includes various federal and provincial parks and other recreational sites in the basin. Since there are no federal parks in the basin, only provincial and other recreational sites were included. Here, water is required for administrative purposes as well as for maintaining the park sites. The first type of demand is reported in section 9.1, while the second one is covered section 9.2.

9.1 Recreational Communities' Water Demand

Under the first type of recreational water demand, several communities in the SSRB were analyzed. These are listed in Table 3.19. Estimating the total water demand for this category required the multiple assumptions that were presented in Chapter 4.

9.1.1 Recreational Communities' Water Demand – Baseline Scenario

Because of limited information about these communities and the nature of water demand for recreational purposes, a time trend was fitted to the available data. Evidence of a growth or decline over time was not detected. As a result, the last five years' average was assumed to be applicable to the 2010 water demand. Furthermore, this level was assumed to remain unchanged for the 2020-2060 period. The total water demand for this purpose was therefore, related to the population growth in these communities. Their total water demand is shown in Table 9.1. Past population changes in these recreational villages have been uneven, as the population will increase/decrease or stay at the same level for a number of years. In the future, population growth will be restricted by real estate (and infrastructure) development in the villages because the area for development is limited. Since the recreational villages are relatively more attractive to retirees, the increase in the retired population to 2035-40 will have an effect on the demand for these resort properties. The water demand will likely increase from 32 dam^3 in 2010 to 34 dam^3 in 2060 -- a 6% growth in demand over this period.

Table 9.1: Water Demand for South Saskatchewan River Basin Recreational Communities, 2010 to 2060

Location	Water Demand (dam^3)			
	2010	**2020**	**2040**	**2060**
Diefenbaker Lake Cottage	7.5	7.6	7.8	7.9
Shields Resort Village	24.9	25.4	25.9	26.4
Total Water Demand	**32.4**	**33.0**	**33.7**	**34.3**
Percent Change over the 2010 Level		2.0%	4.0%	6.1%

Source: Estimations from Saskatchewan Watershed Authority (2010), and Ministry of Tourism, Parks, Culture and Sport

9.1.2 Recreational Communities' Water Demand under the Climate Change Scenario

The water demand under the climate change scenario was adjusted upwards by using a 2.4% and 5% increase over the estimated baseline for 2040 and 2060, respectively. Applying these coefficients and projected population produced water demand estimates, which are shown in Table 9.2. By 2060, it is expected that this level will increase to 36 dam^3, about 5% higher than that appearing under the baseline scenario.

9.1.3 Recreational Villages' Water Demand under the Water Conservation Scenario

Water conservation measures can be adopted by residents of recreational villages. However, comprehensive knowledge of the nature of water demand by these residents is not available, making adjustments through water conservation practices very difficult. For this reason, these residents were treated just like any other urban resident. Water demand for the communities will be lower after such measures are adopted, relative to the baseline scenario. The estimated water demand under this scenario is expected to be 30 dam^3, some four dam^3 lower than it to under the baseline scenario.

Table 9.2: Summary of Recreational Communities' Water Demand in the South Saskatchewan River Basin, 2010 - 2060

Scenario	Estimated Total Water Demand in dam^3 for				% Change in 2060 over 2010	2060 Level % of Baseline Scenario
	2010	**2020**	**2040**	**2060**		
Baseline	32	33	34	34	105.9%	100.0%
Climate Change	32	33	35	36	111.2%	105.0%
Water Conservation	32	32	31	30	92.6%	87.5%

9.1.4 Recreational Community Water Demand – Summary

Recreational communities' water demand in the SSRB is a relatively smaller amount. A range of 30 to 36 dam^3 was estimated over the 2010-2060 period under baseline and climate change scenarios. In the baseline scenario, it was assumed to remain unchanged in the future. The climate change scenario indicates an increase of 5% in water demand over the baseline. Employing water conservation practices is expected to reduce water demand by 2.5%, relative to the baseline scenario.

9.2 Water Demand for Maintenance of Recreation Sites

Provincial and regional parks require water for maintenance and for supporting visitor services. In the future, the recreational demand is expected to increase. A growing population in the basin, accompanied with increased urbanization, will result in higher levels of water demanded for recreational purposes. The water demand estimates are presented in this section.

9.2.1 Water Demand for Maintenance of Recreation Sites under the Baseline Scenario

Urban and rural recreation, scenery, wildlife habitat, and fisheries are all strongly affected by the quantity and quality of water; moreover, they are affected by climate change (Cooper, 1990). Hydrological droughts result in low stream flows and low lake levels. These factors will likely reduce some of the recreational activities, such as boating and sport fishing, among others. Drought conditions may also place some restrictions on recreational activities (open fires for campers), and loss of proximity to water from the beach area, for example. These activities may also be reduced.

As noted in Chapters 4 and 5, this water demand has two components: one, variable level of demand related to visitor services, which is determined by the number of visitors to the site; and, two, the fixed level of water required to maintain office services, lawns, and other facilities. Unfortunately details on these two elements were not available and therefore, analysis was undertaken by using a combined demand for these two uses. A time trend was fitted to the water demand for all recreation sites.

In light of these results, water demand for parks was estimated by employing a growth rate in visitations as a result of population growth and visitation rates. Results are shown in Table 9.3. The current demand for these sites is estimated at 35 dam^3. Large water demand sites include Saskatchewan Landing Provincial Park, and the Pike Lake Provincial Park; the two sites collectively demand 78% of the total calculated for recreational sites. By 2060, this water demand may rise to 37 dam^3, representing a 6.4% increase over the 2010 level.

The future projection of visitors is a complex exercise, since many factors could affect these levels. One major factor is the size of the water body at the sites, and other quality-related aspects. The quality of a site deteriorates as congestion to a site increases, unless infrastructure and other facilities are improved accordingly. The size of the water body is related to changes in the hydrological regime of the region. Such projections were considered beyond the scope of this study.

Table 9.3: Provincial and Regional Parks and Recreational Sites, South Saskatchewan River Basin 2010 to 2060

Location	Water Demand (dam^3)			
	2010	2020	2040	2060
Blackstrap	7.5	7.7	7.8	8.0
Pike Lake	10.8	11.0	11.2	11.5
Saskatchewan Landing	16.2	16.5	16.9	17.2
Total Water Demand	**34.5**	**35.2**	**35.9**	**36.7**
Percent Change over the 2010 Level	--	2.0%	4.1%	6.4%

Source: Estimations from Saskatchewan Watershed Authority (2010), and Ministry of Tourism, Parks, Culture and Sport (2009).

9.2.2 Water Demand for Maintenance of Recreation Sites under the Climate Change Scenario

Recreational site maintenance may increase from higher temperatures and lower precipitation. Assuming the same change as assumed for the domestic water demand (2.4% and 5% increase in water demand by 2040 and 2060, respectively), the estimated levels are shown in Table 9.4. Water demand under this scenario is estimated to increase to 38.5 dam^3 by 2060.

Table 9.4: Water Demand for Recreational Sites in the South Saskatchewan River Basin Sites, Climate Change Scenario with comparison with the Baseline Scenario, 2010 - 2060

Year	Baseline Demand in dam^3	Climate Change Demand in dam^3	Change over Baseline Scenario (%)
2010	34.5	34.5	0%
2020	35.2	35.2	0%
2040	35.9	36.8	2.4%
2060	38.5	38.5	5.0%

9.2.3 Recreational Water Demand for Maintenance of Recreation Sites under the Water Conservation Scenario

Water conservation in recreational related water demands is also different to estimate, since some of the recreational activities depend on water availability. For recreational site maintenance, some water conservation practices can be applicable. Assuming that these measures would result in a similar reduction as that shown for the municipal water systems' current and future levels, water demand was estimated. These estimates are shown in Table 9.5. This water demand, with the adoption of water conservation measures, could be as low as 32.1 dam^3 by 2060.

Table 9.5: Water Demand for Recreational Sites in the South Saskatchewan River Basin Sites, Water Conservation Scenario and Comparison with Baseline Scenario, 2010 - 2060

Year	Baseline Demand in dam^3	With Water Conservation Demand in dam^3	Change over Baseline Scenario (%)
2010	34.5	34.5	0%
2020	35.2	34.3	-2.5%
2040	35.9	33.2	-7.5%
2060	38.5	32.1	-12.5%

9.2.4 Summary of Recreational Water Demand

The total recreational water demand levels for the three study scenarios are presented in Table 9.6. These estimates include water needed for recreational communities as well as that required for the recreational sites. Under the baseline scenario, water demand may increase from 67 dam^3 in 2010 to 71 dam^3 by 2060 – an increase of 6%. Climate change may cause a higher increase in these water demand levels – 11% of the 2010 level in 2060, although water conservation does offer some, significant reduction.

Table 9.6: Summary of Recreation Water Demand under Study Scenarios, South Saskatchewan River Basin 2010 - 2060

Scenario	Water Demand in dam^3				Change in 2060 % of 2010 Level
	2010	2020	2040	2060	
Baseline	67	68	70	71	106.1%
Climate Change	67	68	71	75	111.4%
Water Conservation	67	66	64	62	92.9%

Chapter 10

Indirect Anthropogenic Water Demand

For the research to be comprehensive, the balancing of water demand against supply requires a consideration of all water demands. Included among these demands are those which result from natural processes or policy regulations. These demands are not related to any direct or indirect human use of water. Therefore, in this study, they are called indirect anthropogenic water demands. Three such demands comprise in this category: evaporation, apportionment, and environmental water demands, and these requirements are presented in this chapter.

10.1 Evaporation Water Demands

Evaporation is a natural loss of water from surface water bodies. Natural processes and the size of the water body are the two most important determinants for this type of water demand. The present estimates are based on these two factors, as described in Chapters 3 and 4.

10.1.1 Evaporation Water Demand – Baseline Scenario

On an annual basis, some 358,996 dam^3 of water is lost to evaporation. This higher quantity is a result of the large number of lakes and reservoirs in the basin, as well as several man-made reservoirs. Some of the large water bodies with high evaporation losses include Lake Diefenbaker, Luck Lake and Blackstrap Reservoir. Evaporation losses from these three water bodies constitute 83% of the total evaporation. Other water bodies are smaller in surface area, and therefore do not lose as much water to evaporation. For example, the Indi Lake loses only 59 dam^3 of water annually. In contrast, most of the PFRA man-made irrigation reservoirs in the SSRB are large, losing over 33,605 dam^3 of water.

The net evaporation losses for lakes and reservoirs in the SSRB are presented in Table 10.1. These values were estimated for the current situation (time period) and are called baseline estimates. For the future, without a change in the climate, these losses should remain the same. In fact, it was assumed that factors affecting evaporation (temperature, precipitation, sunny days, among others) would remain unchanged over the next 50 year period. Therefore, for the baseline scenario 2010 estimates were accepted as estimates for all three future time periods.

10.1.2 Evaporation Water Demand – Climate Change Scenario

It is generally agreed that higher water temperatures and longer ice-free periods on lakes and rivers, caused by climate change, will result in greater evaporation. It has been estimated that precipitation accounts for 55% of the variability in lake levels while temperature accounts for 30% (Lemmen et al., 2008). The estimates of the climate in southern Saskatchewan to 2060 are for higher yearly temperatures with higher September to April precipitation (CCCSN, 2011).

The level of snow pack and rate of snowmelt are then prime determinants of surface water body recharge. Unfortunately, the climate models give no measure of these factors. The water depth and area of surface water bodies in the spring are two factors affecting the rate of evaporation over the ice-free period. There are, then, many factors producing positive or negative effects on the rate of evaporation, with little or no guide as to the way these influences will play out to 2060.

Table 10.1: Evaporation Losses of Lakes and Reservoirs, South Saskatchewan River Basin, 2010-2060

Type of Water Body	Particulars	Baseline Scenario 2010 in dam^3	Climate Change Scenario in dam^3		
			2020	2040	2060
Lakes	Anerley Lake	920.0	920.0	966.0	1,012.0
	Buffer Lake	4,896.0	4,896.0	5,140.8	5,385.6
	Cabri Lake	93.8	93.8	98.4	103.1
	Cheviot Lake	0.9	0.9	1.0	1.0
	Duck Lake	1,700.0	1,700.0	1,785.0	1,870.0
	Indi Lake	59.4	59.4	62.4	65.3
	Jumping Lake	3,240.0	3,240.0	3,402.0	3,564.0
	Lenore Lake	1,568.0	1,568.0	1,646.4	1,724.8
	Luck Lake	21,240.0	21,240.0	22,302.0	23,364.0
	Rabbit Foot Lake	89.6	89.6	94.1	98.6
	Stink Lake	1,700.0	1,700.0	1,785.0	1,870.0
	Stockwell Lake	2,300.0	2,300.0	2,415.0	2,530.0
	Wakaw Lake	400.0	400.0	420.0	440.0
PFRA Reservoirs	Reid Lake (Duncairn)	26,893.8	26,893.8	28,238.4	29,583.1
	Lac Pelletier	3,250.0	3,250.0	3,412.5	3,575.0
	Highfield Reservoir	2,925.0	2,925.0	3,071.3	3,217.5
	Herbert	975.0	975.0	1,023.8	1,072.5
	Shaheen	260.0	260.0	273.0	286.0
	Sauder	195.0	195.0	204.8	214.5
Other Reservoirs	Blackstrap Reservoir	7,560.0	7,560.0	7,938.0	8,316.0
	Bradwell East & West	2,296.9	2,296.9	2,411.7	2,526.6
	Bridgewater Creek	2,160.0	2,160.0	2,268.0	2,376.0
	Broderick Reservoir	1,680.0	1,680.0	1,764.0	1,848.0
	Lake Diefenbaker	268,750.0	268,750.0	282,187.5	295,625.0
	Patience Lake	3,000.0	3,000.0	3,150.0	3,300.0
	Pike Lake	1,706.3	1,706.3	1,791.6	1,876.9
	Total	**358,966**	**358,966**	**376,914**	**394,862**
% of Baseline		--	100.0%	105.0%	110.0%

Waggoner and Revelle (1990) suggest that evaporation will change by approximately 6% for every degree by the capacity of the air for water vapor. Döll (2002) estimated water requirements for irrigation will increase between 3 to 5% by 2020, and between 5 to 8 % by 2070, which may lead to requirements for the development of man-made reservoirs. Although an estimation of precise evaporation coefficients requires a separate study for the basin, for the purposes of this research, it is assumed that the rate of evaporation will increase by 5% by 2040 and by 10% to 2060.[56]

The net evaporation losses for lakes and reservoirs in the SSRB are presented in the last three columns of Table 10.1. The base evaporation losses are employed to estimate the future water loss by adjusting it for 2040 and 2060. These losses were increased by 5% for 2040 and 10% for 2060. The total amount of water lost to evaporation is estimated at 394,862 dam^3 by 2060. Lake Diefenbaker could lose up to 296 thousand dam^3 of water under this scenario.

10.1.3 Evaporation Water Demand – Water Conservation Scenario

All indirect anthropogenic water demands are not subject to water conservation. Evaporation is no exception. Since these demands are determined by natural conditions, these values were assumed to be the same as those evident under the baseline scenario. It is recognized that there may be technological measures that can reduce evaporation losses; such knowledge is still in a developmental stage, and therefore not considered in this study.

10.2 Apportionment Water Demand

As noted in Chapter 3, since the South Saskatchewan River does not enter into the province of Manitoba, the apportionment water demand was set equal to zero. It should also be kept in mind that water released for hydroelectric power generation might be adequate to meet the apportionment needs for this river.

10.3 Environmental Water Demand

Greater evaporation from longer ice-free periods and higher temperatures is likely to severely impact waterfowl in the basin in years with low spring water levels of marshes and sloughs. No estimate has been made of this potential demand for water in this report.

The water demand for these various projects is highly variable, as spring runoff and water flow are their main sources of recharge. For this reason, it is assumed that after the initial intake to fill the wetlands, only small quantities of water should be needed. It is recognized that some water

[56] It should be noted that these levels are assumed. Further research is needed to ascertain them by using climate models.

may be needed to replenish the evaporative losses. However, these data were not available. For this reason, the environmental water demand was set equal to zero for current and future periods.

10.4 In-Stream Flow Requirements

As noted in Chapter 3, the South Saskatchewan River System provides habitat for a variety of fish and wildlife species. Saskatchewan Watershed Authority (2007a) provided a current fish and wildlife water demand of 4,946 dam^3. In this study, the latter estimate is used. This water demand was not subjected to climate change and/or water conservation scenarios.

Chapter 11

Summary and Implications

The entire water demand in the SSRB is composed of three types: direct anthropogenic within the basin, direct anthropogenic outside the basin (particularly in the Qu'Appelle River Basin), and indirect anthropogenic water demand. The projected water demand is estimated for three time periods (2020, 2040, and 2060) and for three scenarios – baseline, climate change, and water conservation.

11.1 Summary of Total Water Demand for the Baseline Scenario

The baseline scenario uses the estimated activity levels for various direct anthropogenic and indirect anthropogenic activities combined with water demand coefficients in order to estimate water demand levels for the SSRB. An increased amount of irrigated area and expansion of the potash sector are the main forces behind alterations in water demand. Direct anthropogenic activities are projected to triple by 2060, accounting for almost three-quarters of the total water demand (Table 11.1). Much of this increase is expected through irrigation development, particularly in the Westside irrigation District.

11.2 Summary of Total Water Demand for the Climate Change Scenario

The hypothesized effects of climate change on the direct anthropogenic and indirect anthropogenic water demand activities in the SSRB are presented in Table 11.2. Higher growing season temperatures will have a significant impact on the agricultural sector, as both crops and livestock will demand additional water. Evaporation of water from water bodies, which is already a major indirect anthropogenic water demand, is one of the other major increased demands that can be expected with climate change. The total direct anthropogenic and indirect anthropogenic water demand is expected to be 1.48 million dam^3 by 2060.

11.3 Summary of Total Water Demand for the Water Conservation Scenario

The effects of water conservation measures on the water demand activities in the SSRB are presented in Table 11.3. Agricultural and industrial adoption of water conservation techniques and technologies has the greatest impact on the direct anthropogenic demand for water. The Policy Research Initiative (2005) reported that Canada has made little use of economic instruments for water management. These instruments are often promoted as the least-cost approaches to efficient water management. They also have the merit in producing water supply cost recovery, internalizing environmental costs, and acting as a signal to users to reduce their water consumption. Such sentiments have also been voiced by the recent National Round table on Environment and the Economy (NRTEE, 2011) as it advocated the potential of two emerging policy instruments — water pricing and voluntary initiatives — to improve water conservation and efficiency.

Table 11.1: Water Demand in the South Saskatchewan River Basin, for the Baseline Scenario, 2010- 2060

Sector	Sub-Activity	Total Amount of Water Demand in dam^3			
		2010	2020	2040	2060
WITHIN BASIN DIRECT ANTHROPOGENIC ACTIVITIES					
Agriculture					
	Irrigation, including induced irrigation	231,295	278,636	592,430	782,255
	Livestock	5,376	5,757	6,017	6,233
	Pesticide	209	201	199	199
	Other (greenhouse and aquaculture)	419	420	426	433
	Sub-total	**237,299**	**285,014**	**599,072**	**789,120**
Industry & Mining					
	Potash	3,298	10,071	10,071	13,037
	Oil and Gas	205	275	165	41
	Manufacturing	2,525	2,590	2,658	2,727
	Induced Manufacturing Excl. Irrigation	0	0	7,355	7,355
	Power Generation	1,855	2,954	3,894	4,777
	Sub-Total	**7,883**	**15,890**	**24,143**	**27,937**
Municipal/Domestic					
	Municipal	57,675	62,162	72,552	85,097
	Sub-total	**57,675**	**62,162**	**72,552**	**85,097**
Recreation					
	Recreation Communities	32	33	34	34
	Parks/Recreation	35	35	36	37
	Sub-Total	**67**	**68**	**70**	**71**
Sub-total Within Basin Direct Anthropogenic Water Demand		**302,924**	**363,134**	**695,837**	**902,225**
Outside Basin Direct Anthropogenic Water Demand		2,990	10,144	10,212	18,512
Total Direct Anthropogenic Water Demand		**305,914**	**373,278**	**706,049**	**920,737**
Hydroelectric Power Generation Water Release		1,660,092	1,660,092	1,660,092	1,660,092
INDIRECT ANTHROPOGENIC ACTIVITIES					
Other Water Demands					
	Evaporation	326,255	326,255	326,255	326,255
	Apportionment	0	0	0	0
	Instream Flow	4,946	4,946	4,946	4,946
	Environment	0	0	0	0
Sub-Total Indirect Anthropogenic Water Demand		**331,201**	**331,201**	**331,201**	**331,201**
Total Water Demand Excl. Hydropower water release		**637,115**	**704,479**	**1,037,250**	**1,251,938**

Table 11.2: Water Demand in the South Saskatchewan River Basin, for the Climate Change Scenario, 2010- 2060

Sector	Sub-Activity	Total Amount of Water Demand in dam^3			
		2010	2020	2040	2060
WITHIN BASIN DIRECT ANTHROPOGENIC ACTIVITIES					
Agriculture					
	Irrigation, including induced irrigation	231,295	278,636	684,887	977,634
	Livestock	5,376	5,757	6,255	6,720
	Pesticide	209	201	209	217
	Other (greenhouse and aquaculture)	419	420	426	433
	Sub-total	**237,299**	**285,014**	**691,777**	**985,004**
Industry & Mining					
	Potash	3,298	10,071	9,417	11,407
	Oil and Gas	205	275	165	41
	Manufacturing	2,525	2,590	2,711	2,836
	Induced Manufacturing Excl. Irrigation	0	0	7,355	7,355
	Power Generation	1,855	2,954	3,972	4,968
	Sub-Total	**7,883**	**15,890**	**23,620**	**26,607**
Municipal/Domestic					
	Municipal	57,675	62,162	74,330	89,370
	Sub-total	**57,675**	**62,162**	**74,330**	**89,370**
Recreation					
	Recreation Communities	32	33	35	36
	Parks/Recreation	35	35	37	39
	Sub-Total	**67**	**68**	**72**	**75**
Sub-total Within Basin Direct Anthropogenic Water Demand		**302,924**	**363,134**	**789,799**	**1,101,056**
Outside Basin Direct Anthropogenic Water Demand		2,990	10,144	10,040	18,382
Total Direct Anthropogenic Water Demand		**305,914**	**373,278**	**799,839**	**1,119,438**
Hydroelectric Power Generation Water Release		1,660,092	1,660,092	1,660,092	1,660,092
INDIRECT ANTHROPOGENIC ACTIVITIES					
Other Water Demands					
	Evaporation	326,255	326,255	342,567	358,880
	Apportionment	0	0	0	0
	Instream Flow	4,946	4,946	4,946	4,946
	Environment	0	0	0	0
Sub-Total Indirect Anthropogenic Water Demand		**331,201**	**331,201**	**347,513**	**363,826**
Total Water Demand Excl. Hydropower water release		**637,115**	**704,479**	**1,147,352**	**1,483,264**

Table 11.3: Water Demand in the South Saskatchewan River Basin for the Adoption of Water Conservation Scenario, 2010- 2060

Sector	Sub-Activity	Total Amount of Water Demand in dam^3			
		2010	2020	2040	2060
WITHIN BASIN DIRECT ANTHROPOGENIC ACTIVITIES					
Agriculture					
	Irrigation, including induced irrigation	231,295	259,561	468,334	686,242
	Livestock	5,376	5,757	5,791	5,934
	Pesticide	209	201	179	99
	Other (greenhouse and aquaculture)	419	420	426	433
	Sub-total	**237,299**	**265,939**	**474,730**	**692,708**
Industry & Mining					
	Potash	3,298	9,920	9,417	11,407
	Oil and Gas	205	234	140	35
	Manufacturing	2,525	2,538	2,604	2,672
	Induced Manufacturing Excl. Irrigation	0	0	7,208	7,064
	Power Generation	1,855	2,807	3,310	3,583
	Sub-Total	**7,883**	**15,500**	**22,679**	**24,761**
Municipal/Domestic					
	Municipal	57,675	60,742	67,552	75,156
	Sub-total	**57,675**	**60,742**	**67,552**	**75,156**
Recreation					
	Recreation Communities	32	32	31	30
	Parks/Recreation	35	34	33	32
	Sub-Total	**67**	**68**	**70**	**71**
Sub-total Within Basin Direct Anthropogenic Water Demand		**302,924**	**342,247**	**565,025**	**792,687**
Outside Basin Direct Anthropogenic Water Demand		2,990	9,682	9,269	16,044
Total Direct Anthropogenic Water Demand		**305,914**	**351,928**	**574,295**	**808,731**
Hydroelectric Power Generation Water Release		1,660,092	1,660,092	1,660,092	1,660,092
INDIRECT ANTHROPOGENIC ACTIVITIES					
Other Water Demands					
	Evaporation	326,255	326,255	326,255	326,255
	Apportionment	0	0	0	0
	Instream Flow	4,946	4,946	4,946	4,946
	Environment	0	0	0	0
Sub-Total Indirect Anthropogenic Water Demand		**331,201**	**331,201**	**331,201**	**331,201**
Total Water Demand Excl. Hydropower water release		**637,115**	**683,129**	**905,496**	**1,139,932**

11.4 Conclusions

Water management in the SSRB is particularly complex on account of significant consumptive water demands and the importance of SSR as a reliable source of high quality water for southern Saskatchewan. Increased water demand upstream in Alberta and increasing water demand in Saskatchewan will make water management in the future even more complex. Significant changes are already happening and will happen in the future are going to alter water management.

A summary of these changes is shown in Figure 11.1. The methodology followed here is that developed in Europe for environmental assessment. The DPSIR (Drivers, Pressures, State, Impacts, and Responses) framework, illustrates the interconnectedness of various factors and changes that need to be considered in formulating policy responses. This study has shown the state of water demand in the basin at present and in the future. Also, the effect of specific pressures (such as climate change) and policy responses (water conservation) were also incorporated.

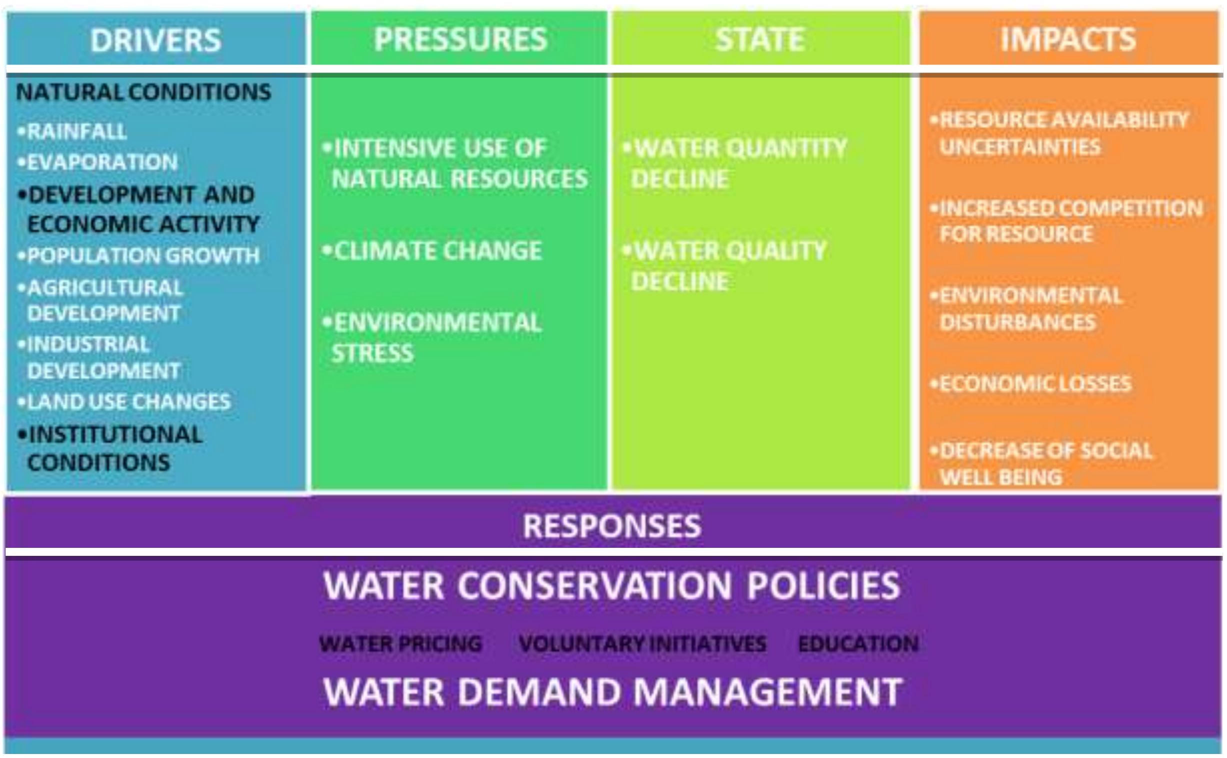


Figure 11.1: Overview of Issues Related to Water management in the South Saskatchewan River Basin

Based on the estimated water demand, a number of conclusions can be drawn. The most significant conclusion is that water demand in the SSRB is going to rise in the future. This circumstance is a result of two major trends: one, the expansion of irrigation in the basin, such as the development of the Westside Irrigation District; and two, the expansion of the urban population around the city of Saskatoon. However, the latter demand may be reduced through proper water conservation measures. In addition, future potash mining activities in the Qu'Appelle River Basin are also expected to increase. These first two demands combined would constitute over 90% of the total water demand in the basin by 2060. Whether this situation will result in water scarcity or merely tough competition among its users remains to be determined. Although municipal water demand is already a very important demand of water in the basin, its share is expected to increase in the future. All these increases are predicated on the best knowledge that we have at this time. For instance, new potash mines are proposed, and therefore, included in these estimates. Whether these mines will actual be in production of potash remains to be seen.

The importance of surface water in the future is expected to be higher, since, economic activities, such as irrigation and potash mining will draw more surface water. Although groundwater demand will still be important, it will be a smaller portion of the total water demand (claiming 2% of the total by 2060). As competition to the available water increases, there may be a need for demand management. Encouraging water use efficiency and water conservation through policy and pricing measures will become increasing important.

Water conservation offers the region a way to reduce water scarcity/stress in the future. However, one should realize that there must be some incentives for water users to adopt such measures. Water pricing and educating users on the merits of adopting such measures are often noted as the most important factors affecting the adoption of water conservation practices. The National Roundtable on the Environment and Economy (NRTEE, 2012) has also advanced such prescriptions. The Table has suggested the potential of two emerging policy instruments for water conservation — water pricing and voluntary initiatives. Improved water-use management starts with strong principles that value water so that it can be conserved and utilized efficiently. Sustainable water use will come from better knowledge and application of four key knowledge areas: water forecasts, water quantity data and information, policy instruments, and collaborative water governance (NRTEE 2012).

Moreover, climate change is extremely likely to increase water demand in the future, although our knowledge base for determining its impact on water demand is rather weak. More data need to be collected during the periods of drought, and extreme rain events to finalize such estimates. Parry et al. (2007) have concluded that semi-arid and arid areas are particularly exposed to the impacts of climate change in freshwater. Furthermore, these demands may not be feasible without further infrastructure development.

Water conservation may also be very important during the period when climate change impacts on the basin are felt. Although such measures may not be able to offset the increases triggered by climate change, particularly during periods of droughts, they do offer an avenue for water management in the future periods.

11.5 Areas for Further Research

In this study, several assumptions were made for the sake of completing the water demand estimates for current and future time periods. Like all assumptions, these can be improved when better data/information are available. These points are listed in this section. Some overall limitations of this study are noted below in three parts: Overall limitations; Major data gaps for various sectors; and Water demand reassessment.

11.5.1 Overall Limitations

- One of the major weaknesses of the forecasting methodology used in this study is that water demand is also affected by its availability. Since water supply data were not accessible, this aspect could not be included and perhaps needs to be considered in any future analyses.

- This study did not develop water demand coefficients by using primary data. These values were either borrowed from other studies, or calculated from the best available data.

- Municipal/domestic water demand was estimated by using a trend projection method. In many cases, it yielded unreasonable results. Better forecasting models need to be developed for these water demands.

- Information on the impact of climate change on various sectors needs to be investigated fully. There is a shortage of studies in this area, particularly for the basin.

- Information on adoption of water conservation measures in the basin (as well as in Saskatchewan) is also not a well-studied subject. This aspect needs to be investigated as better data on the effect of provincial regulation/incentives become available.

11.5.2 Need for Better Sectorial Information

A summary of needs for future research in this area are summarized in Figure 11.2.

11.5.2.1 Agricultural Water Demand

- Adoption of irrigation in the basin for an irrigation district, or by private irrigators, has not been studied. A more recent analysis of rates of adoption and factors that affect it is required, not only for this basin, but for all irrigation areas in the province.

- Data on actual water used by producers for different crops is not available. This type of information affects estimation of water demand under different crop mix, which could change in the future.

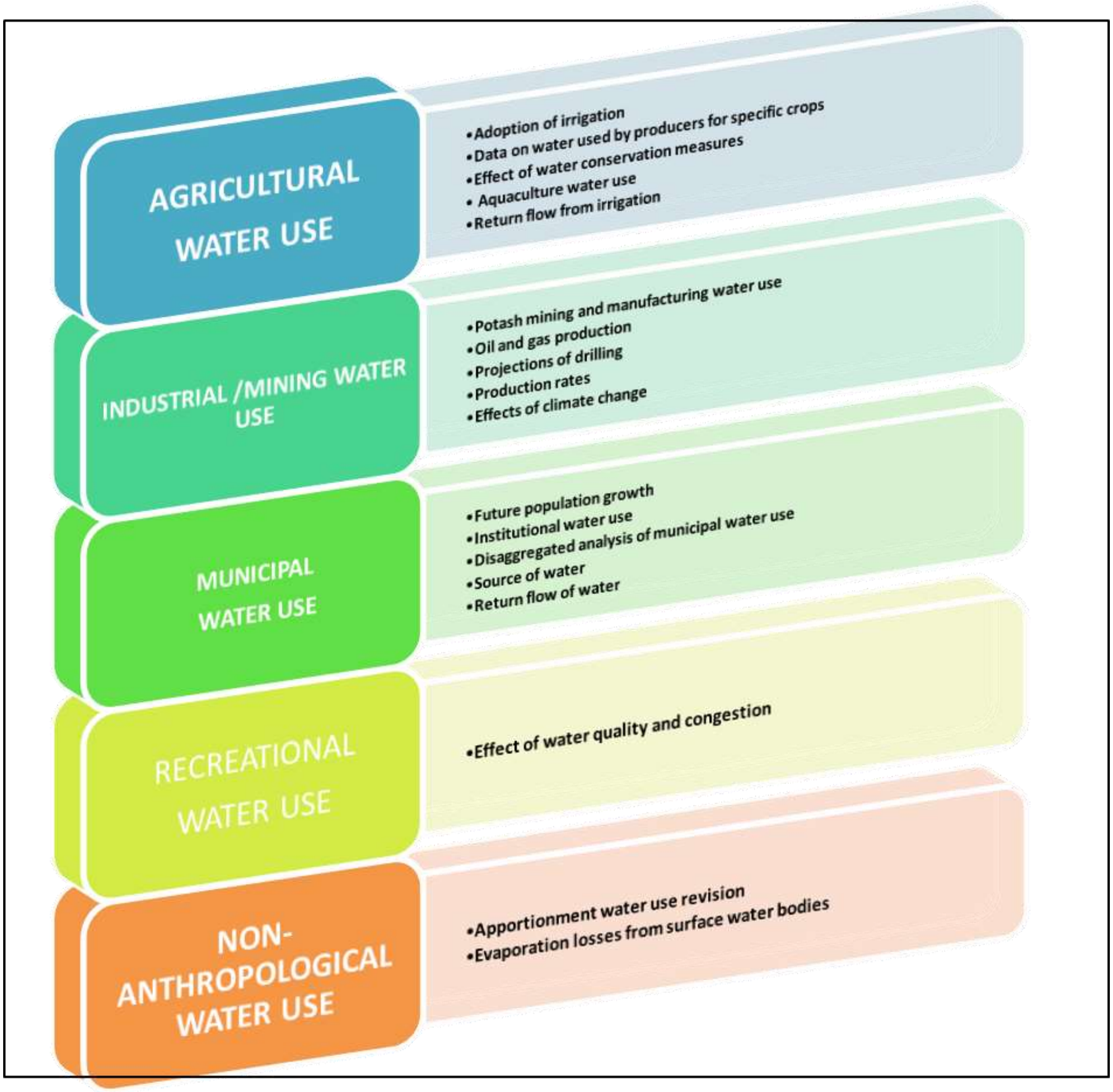


Figure 11.2: Summary of Further Research by Sector

- For stockwatering demand, information on the effect of water conservation measures based on new technology was not available in the literature. Further investigation is needed.
- Information on aquaculture water demand is very weak. Further study of this sector is needed. Given several large freshwater bodies in the basin, this type of water demand may increase in the future.
- Return flow from irrigation districts was based on past water use coefficients. More recent estimates are needed.
- Further work is required to identify measures that would encourage farmers to adopt water efficient irrigation methods.

11.5.2.2 Industrial/Mining Water Demand

- Potash mining water demand, as well as that used for oil and gas production, requires a fresh look. Projections of drilling and production rate should also be examined further.
- Water consumption for manufacturing was not based on actual data for various types of firms. Since the study estimate was based on an average proportion, it needs to be investigated for the basin.
- Effects of climate change on industrial water demand were an assumed number in this study. Further investigation of this impact is needed.
- Further research is needed into saline water replacement of fresh water in certain types of mining.

11.5.2.3 Municipal/Domestic Water Demand

- Data on future population growth for Saskatchewan by river basins would improve water demand estimates reported in this study.
- Identification of bedroom communities was based on two criteria: Closeness to a large urban center, and rapid rate of growth in the community. Other criteria may be added, and communities could be identified for medium sized urban centers.
- There is little information on the institutional water demand in the basin. These institutions need to be surveyed to determine their future water needs and the probable impact of climate change and water conservation measures.

- A disaggregated analysis of municipal water demand for large urban centers is needed to refine the water demand estimates, particularly under climate change and water conservation measures.

- Further work is needed to estimate residential water used for indoors vs. for outdoor activities.

- Some communities receive surface water through rural pipelines. This information was not used in this study since it is not readily available. Further investigation of this source of water is needed. Better data collection on this aspect is highly recommended

- Studies on the level of return flow of water from smaller communities were not found. An investigation of this aspect of water demand in required.

11.5.2.4 Recreation Water Demand

- Effect of water quality and congestion on recreational use of a recreation site could not be incorporated. These factors are important to plan future use of these sites for recreational activities.

- Further disaggregation of total water demand for maintenance of park sites could provide a better basis for water conservation and impact of climate change.

11.5.2.5 Indirect anthropogenic Water Demand

- There is a need to examine the resiliency of the Master Agreement on Apportionment in consideration of climate change and prolong droughts. Part of this investigation would include water demands in Alberta.

- Evaporation losses from lakes and reservoirs are important elements in considering water demand. Research into evaporative losses from small impoundments, such as environmental enhancement projects, is particularly desirable.

11.5.3 Revisions in Water Demand Estimates

At the time of writing this report, some data/information were not available. These data can be obtained and thus, there is a need for some revisions in the future water demand. These include:

- Farm and rural non-farm population numbers were not available at the time of writing this report. Data from the agriculture census will be released at some future date.

- Potash mining water demand will need to be revised as new mines come into operation or close to finalizations of their plans for production.

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Appendix A

List of Communities in the South Saskatchewan River Basin

Table A.1: Categories of Communities in South Saskatchewan River Basin

	1. CITIES
1.	Martensville
2.	Saskatoon
3.	Swift Current
4.	Warman

	2. TOWNS		
	2a. More than 1000		**2b. Less than 1000**
1	Dalmeny	1	Aberdeen
2	Eston	2	Allan
3	Hague	3	Cabri
4	Outlook	4	Cudworth
5	Rosthern	5	Hanley
6	Shaunavon	6	Leader
7	Wakaw	7	St.Louis
8	Waldheim	8	Vanscoy

	3. VILLAGES		
1	Strongfield [VL]	23	Hazlet
2	Abbey	24	Hoey
3	Alsask	25	Kenaston
4	Alvena	26	Lancer
5	Beechy	27	Loreburn
6	Birsay	28	Lucky Lake
7	Bradwell	29	Macrorie
8	Broderick	30	Marengo
9	Burstall	31	Pennant
10	Conquest	32	Prelate
11	Dana	33	Prud'Homme
12	Demaine	34	Riverhurst
13	Domremy	35	Sceptre
14	Duck Lake	36	ST Isadore De Bellevue
15	Elbow	37	Stewart Valley
16	Elstow	38	Stony Beach
17	Flaxcombe	39	Thode
18	Fulda	40	Vonda
19	Glenside	41	Waldeck

20	Grasswood	42	Webb
21	Haggen	43	White Bear
22	Hawarden		
	4.BEDROOM COMMUNITIES TO SASKATOON		
1	Dundurn	5	Casa RIO
2	Osler	6	Catherderal Bluffs
3	Clavet	7	Cedar Villa Estates
4	Riverside Estates		

	5. FIRST NATIONS RESERVES
1	One Arrow Reserve #95
2	White Cap Reserve #94

	6a. RECREATIONAL VILLAGE		**6b. PARKS RECREATIONAL SITES**
1	Shields Resort Village	1	Black Strap Provincial Park
		2	Fort Carlton Provincial Park
		3	Painted Rock Campground
		4	Pike Lake Provincial Park
		5	Saskatchewan Landing Provincial Park
		6	Diefenbaker Lake Cottage Development

	7. Trailer Courts
1	Ponderossa Trailer Court Swift Current
2	Sunset Estates Trailer Park

Appendix B

Correspondence Table for the South Saskatchewan River Basin

Most data are reported on an administrative boundary/region basis (such as Province, Census Division, Census Agriculture Region, and Rural Municipality). Since river basin boundaries do not always follow the administrative boundaries, some basis of correspondence among these regions is required. Under the strict assumption that economic activity is evenly distributed throughout the administrative regions, one could estimate the area in the river basin that falls within that administrative region. This is the basis followed in this study.

The percentage area of a rural municipality in a water basin was estimated by using a watershed and a rural municipality map. The area of the Census Divisions and the Crop Districts was obtained by multiplying the area of a rural municipality by the percentage of the basin for the municipalities in the divisions or districts. The percentages for the South Saskatchewan River Basin Watershed are presented in Tables B.1 for Census Divisions, in Table B.2 for Census Agriculture Regions, and in Table B.3 for Rural municipalities, respectively.

Table B.1: Census Division Correspondence to South Saskatchewan River Basin

Census	Total area		South Sask		
Division	**Acres**	**Hectares**	**Acres**	**Hectares**	**NEW**
1	3,397,016	1,374,725	-	-	0.0%
2	4,111,021	1,663,671	-	-	0.0%
3	4,306,852	1,742,923	-	-	0.0%
4	5,002,938	2,024,617	450,137	182,164	9.0%
5	3,407,147	1,378,824	-	-	0.0%
6	4,153,095	1,680,697	-	-	0.0%
7	4,477,117	1,811,825	1,083,258	438,379	24.2%
8	5,336,453	2,159,584	2,922,209	1,182,574	54.8%
9	2,904,925	1,175,581	-	-	0.0%
10	2,771,565	1,121,615	-	-	0.0%
11	4,019,224	1,626,524	1,566,442	633,918	39.0%
12	3,172,865	1,284,013	427,607	173,047	13.5%
13	4,361,876	1,765,188	435,150	176,099	10.0%
14	3,167,073	1,281,667	-	-	0.0%
15	4,343,955	1,757,934	1,509,103	610,712	34.7%
16	3,447,637	1,395,208	-	-	0.0%
17	3,272,829	1,324,468	-	-	0.0%

Table B.2: Rural Municipality Correspondence to South Saskatchewan River Basin

RM #	%RM in RB	RM #	%RM in RB	RM #	%RM in RB
68	45	163	85	252	100
69	55	164	15	253	60
70	4	181	30	254	35
98	40	183	100	276	60
99	100	184	100	277	100
100	85	185	100	278	100
101	40	186	100	279	100
122	10	187	100	280	100
123	10	189	100	281	100
124	5	190	100	282	65
125	10	191	100	307	100
126	30	193	100	308	100
127	60	194	80	309	100
128	65	211	5	310	100
129	96	213	40	312	100
130	100	214	30	313	65
131	90	215	80	336	10
132	30	216	100	337	95
133	10	217	100	338	100
151	65	218	100	339	100
152	60	219	100	340	100
153	90	220	100	341	100
154	95	221	100	342	70
155	100	222	100	343	5
156	100	223	100	367	50
157	100	224	20	368	65
158	100	246	65	369	60
159	100	247	100	370	40
160	100	248	100	371	40
161	100	250	100	372	5
162	100	251	100	400	4

Appendix C

Water Conveyance Methods and Water Use for Irrigation in Selected Irrigation Districts of the Lake Diefenbaker Development Area

Table C.1: Water Conveyance methods for the Lake Diefenbaker Development Area Irrigation Districts

Irrigation District	Method(s)
South Saskatchewan River	Canal and pipeline to farms
Macrorie	Canal and pipeline to farms
Thunder Creek	River/Lake pipeline to farms
River Lake	River/Lake pipeline to farms
Hillcrest	River/Lake pipeline to farms
Luck Lake	Pipeline
Riverhurst	Pipeline
Grainland	River/Lake pipeline to farms
Brownlee	River/Lake pipeline to farms
Qu'Appelle South	Canal and pipeline to farms
Westside	Canal and pipeline to farms

Source: SIPA (2008A)

Table C.2: Irrigation Water Use per Acre by Selected Irrigation Districts in the Lake Diefenbaker Development Area

Year	Riverhusrt ID		Luck Lake ID		SSRID	
	Acres	Applied mm	Acres	Applied mm	Acres	Applied mm
1990	5,138	232	6,544	260	33,878	370
1991	6,590	152	7,097	156	26,791	253
1992	7,085	253	7,334	218	32,873	411
1993	7,216	197	7,441	198	28,819	244
1994	7,568	171	7,909	204	30,324	347
1995	7,563	199	7,909	224	32,865	407
1996	7,563	138	7,909	170	29,276	263
1997	7,935	214	7,900	226	31,218	346
1998	8,427	219	8,764	261	32,706	405
1999	8,255	94	8,764	85	25,323	202
2000	8,255	124	8,913	125	30,696	295
2001	8,415	259	8,913	273	32,719	488
2002	8,881	164	8,602	217	33,671	413
2003	9,538	290	8,602	292	33,420	428
2004	9,870	136	8,602	121	33,457	287
2005	9,982	132	9,045	104	30,618	137
2006	10,071	151	9,045	149	32,312	227
2007	10,195	204	9,134	168	32,449	227
2008	10,443	201	9,829	205	33,806	247
2009	11,337	188	10,153	197	34,397	209
Average	8,516	186	8,420	193	31,581	310
Min	5,138	94	6,544	85	25,323	137
Max	11,337	290	10,153	292	34,397	488
ST.DEV	1,524	51	905	58	2,461	95

Appendix D

Description of Methodology Used by Natural Resources Canada for Evaporation Water Demand Estimates

The map represents the mean value (in millimeters) of the annual loss of water through the evaporation process from the surfaces of open water bodies, such as ponds and shallow lakes and reservoirs based on the 10-year period 1957 to 1966. The greatest mean annual lake evaporation (more than 900 millimeters) occurs in southwest Saskatchewan and southeast Alberta. The smaller means (less than 100 millimeters) appear in the Arctic Islands. The mean annual lake evaporation across Canada generally decreases from south to north. The map also shows the location of the stations, which are part of the "Class A pan evaporation network" used for the analysis and additional stations operating in 1974.

The rate at which water evaporates from a lake depends primarily on two factors: first, the rate at which energy is supplied to the evaporating surface to effect the change of state of water to water vapor (requires 2.47 joules per kilogram) and second, the rate of diffusion of water vapors away from the surface. The main energy supply for evaporation is generally through the heating of the upper part of the lake by the sun, although in some cases the net energy adverted into the water body, by streams for example, may also be important. For a specific lake surface temperature, the rate of diffusion of water vapor is determined in a complex manner by atmospheric temperature, humidity, and wind speed. For small, shallow water bodies evaporation is greater for sunny days during the summer when the water temperature is high, the humidity is low, and winds are brisk. For deeper lakes, heat storage becomes an important consideration, and evaporation is not as closely associated with the daily energy input by the sun's radiation. For example, large amounts of water evaporate from deep lakes during the autumn when their surface temperatures are much higher than air temperatures, while the smaller lakes, because they lack of energy storage, evaporate very little. The converse takes place during late spring and early summer when the large deep lakes evaporate very little because of their relatively low surface temperatures.

The plate contains four maps showing the mean river freeze-over date, the mean lake freeze-over date, the mean river ice-free date and the mean lake ice-free date. The four maps depict, in a general way, the average dates on which freshwater bodies in Canada become completely ice-covered in the fall and become completely ice-free in the spring. The formation of an ice cover on a water body is called freeze-up; and the melting and dissipation of this ice cover is called break-up.

Freeze-up begins when surface water is cooled to 0 degrees Celsius and ice crystals begin to form; it ends when the water body has attained its maximum ice coverage. Most lakes freeze over completely; rivers may or may not, depending on their location, size, and flow characteristics. The final stage of the freeze-up process may be termed "freeze-over".

Break-up normally begins when air temperatures rise above 0 degrees Celsius, and when surface and internal melting of the ice sheet begins. The process is aided by the action of winds and currents, which results in mechanical breaking of the ice. Break-up ends when the water body becomes completely clear of all ice. Many rivers and lakes in the Arctic region, however, may never become completely ice-free because of the shortness of the melting season.

In general, rivers freeze over later and clear earlier than lakes in the same area. This is due to the effect of river currents, which retard freezing in the fall and aid the breaking up of the ice in spring.

Appendix E

Water Demand for Potash tailings Disposal

Sask Water made a proposal to the Potash Producers of Saskatchewan to supply water for potash tailings dissolution. The mines that would be supplied water from the Qu'Appelle River system include PCS Lanigan and Rocanville mines, along with the Mosaic Canada mines at Belle Plaine and Esterhazy K1 & K2.Water demands were developed for 20 and 30-year tailings pile dissolution time frames. The water demand is assumed uniform throughout the year. The annual volume required for tailings pile dissolution is estimated at 59,926 dam^3 and 49,196 dam^3 for a 20 and 30-year project life, respectively (Saskatchewan Watershed Authority 2007b). Diversion volumes are shown in Table E.1.

Table E.1: Potash Mine Tailings Pile Dissolution Future Water Demand Flows

Mine Sites	Total amount in dam^3
PCS Lanigan	9,466
Mosaic- Belle Plaine	10,406
Mosaic Esterhazy and PCS	40,054
Total 20 Year	**59,926**
PCS Lanigan	8,197
Mosaic- Belle Plaine	8,197
Mosaic Esterhazy and PCS	32,802
Total 30 Year	**49,196**

Source: Saskatchewan Watershed Authority (2007b).

Given the recent investments in expanding potash production at these mines, it is likely that all these mines will be in production by 2060. The current tailings ponds have been grandfathered to accommodate the new production. The decision for a mine operator to take is "at what point will the cost of expanding the tailings pond be greater than adopting the technology to put the tailings underground?"

Appendix F

Regression Equations for Population Growth and per Capita Water Demand by Type of Communities in the South Saskatchewan River Basin

Table F.1: Regression equations Population South Saskatchewan River Basin

Category	Dependent variable	Intercept	Time	R^2	F-value
Martensville	Pop.	3198.781	196.6357	0.966011	369.47
	S.E.	93.01118	10.22987		
Saskatoon	Log pop.	12.17191	0.008564	0.737921	36.60
	S.E.	0.01287	0.001415		
Swift Current	Log pop.	9.665839	0.002033*	0.293909	5.41
	S.E.	0.007946	0.000874		
Warman	Pop.	2436.886	225.4643	0.926013	162.71
	S.E.	160.7095	17.67569		
Humboldt	Log pop.	8.572946	0.005903	0.729918	35.13
	S.E.	0.009055	0.000996		
Towns>1000	Pop.	11,174.23	89.696430*	0.671492	26.57
	S.E.	158.21	17.400290		
Towns<1000	Pop.	5,322.08	32.157140	0.550678	15.93
	S.E.	73.25	8.056299		
Bedroom Communities	Pop.	2,742.77	190.042000	0.958966	233.70
	S.E.	125.65	12.431390		
Villages	-	-	-	-	-
Rural non-farm	-	-	-	-	-
Rural Farm	-	-	-	-	-
First Nations	Pop.	393.74	29.686810	0.926647	138.96
	S.E.	24.55	2.518371		
Parks	-	-	-	-	-
Other	-	-	-	-	-

*Significantly different from zero at 5%
pop. = Population
log pop = Natural logarithm of population

Table F.2: Regression equations for Per capita Water Demand South Saskatchewan River Basin

Community Type	Dependent variable	Intercept	Population	Time	R^2	F-value
Martensville	-	-	-	-	-	-
Saskatoon	-	-	-	-	-	-
Swift Current	-	-	-	-	-	-
Warman	WUD	120.2376	-0.015269*	3.795754*	0.419097	4.33
	S.E.	13.82796	0.005521	1.293449		
Humboldt	-	-	-	-	-	
Towns>1000	Log WUD	6.118644	-0.000094*		0.300369	5.58
	S.E.	0.472835	0.000040			
Towns<1000	Log WUD	4.975487		-0.011598*	0.360942	7.34
	S.E.	0.038918		0.004280		
Bedroom Com	-	-	-	-	-	-
Villages	-	-	-	-	-	-
First Nations	-	-	-	-	-	-
Parks	-	-	-	-	-	-
Other	-	-	-	-	-	-

*Significantly different from zero at 5%

Appendix G

Regression Functions showing Results of Effect on Droughts on South Saskatchewan River Basin Community's per Capita Water Demand

Table G.1: Regression Equations for Effects of Droughts on the per Capita Water Demand Coefficients for the South Saskatchewan River Basin

Community Type	Dependent variable	Intercept	Population	Time	Binary	R^2	F-value
Martensville	-	-	-	-		-	-
Saskatoon	-	-	-	-		-	-
Swift Current	-	-	-	-		-	-
Warman	WUD	107.5918	-0.010714**	2.802815*	9.544881*	0.606246	5.645402
	S.E.	13.1141	0.005148	1.194022	4.174389		
Humboldt	-	-	-	-		-	
Towns>1000	Log WUD	6.175203	-0.000100*		0.105818*	0.496418	5.914644
	S.E.	0.418352	0.000035		0.048958		
Towns<1000	Log WUD	4.959140		-0.011238	0.100970	0.529928	6.764004
	S.E.	0.035621		0.003825	0.048614**		
Bedroom Communities	-	-	-	-		-	-
Villages	-	-	-	-		-	-
First Nations	-	-	-	-		-	-
Parks	-	-	-	-		-	-
Other	-	-	-	-		-	-

*Significantly different from zero at 5%

**Significantly different from zero at 10%