Present and Future Water Demand in the Qu'Appelle River Basin

Suren Kulshreshtha
Cecil Nagy
Ana Bogdan

With the Assistance of
Albert Ugochukwu
&
Edward Knopf

Department of Bioresource Policy, Business and Economics
University of Saskatchewan
Saskatoon, Saskatchewan

A report prepared for

SOUTH-CENTRAL ENTERPRISE REGION
&
SASKATCHEWAN WATERSHED AUTHORITY
MOOSE JAW

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Suren Kulshreshtha
Professor

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Research Associate

With the Assistance of
Ana Bogdan
Albert Ugochukwu
Research Assistant
&
Edward Knopf
Principal, Northern Bounty Trading, Regina

Department of Bioresource Policy, Business and Economics
University of Saskatchewan
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Executive Summary

Since water is a necessity for ecological functions, as well as for social and economic activities, its status as valuable commodity is an increasingly urgent concern for provincial planners. In the Qu'Appelle River Basin, the present water supplies are limited, and further expansion of water availability may be a costly measure. As the future economy in the basin increases, leading to population growth, competition for water could become even fiercer. Climate change may pose another threat to the region, partly due to reduced water supplies and increased demand for it. Development of sounder water management strategies may become a necessity. The development of future water management strategies will require information on future water demand and supply levels. This study was undertaken to estimate current (2010) water demand levels and to forecast them for the basin by type of users for 2020, 2040, and 2060 period.

Upper Qu'Appelle River

Basin Description

The Qu'Appelle River Basin is located in the southern part of the province of Saskatchewan. It extends from the South Saskatchewan River Basin to just inside the province of Manitoba, where the Qu'Appelle River joins the Assiniboine River. The basin occupies an area of 74,589 square kilometers, 93% of which is used for agricultural purposes. The basin houses a population of 328,365 people – roughly a third of the provincial population. Two major cities are located in the basin – the capital of the province, Regina, and the city of Moose Jaw. Currently, there are five potash mines in the basin; their production is expected to increase significantly. In addition, irrigation development is being planned in the basin. Major recreational facilities also exist within this area.

Methodology

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

The direct anthropogenic water demands result from several types of economic and social activity. 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 by using water demand coefficient and scale of economic or social activity.

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 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 has developed a water conservation policy with measures that have been adopted by various water users to reduce water demand.

Water Demand Estimates under Baseline Scenario

As shown in Figure ES.1, total indirect anthropogenic water demand in the future was set equal to the 2010 level, since all these demands are related to the availability of water, which in the future would be affected by a set of natural factors and policy changes. Over the 2010-2060 period, this amount was estimated to be 463,934 dam^3. By 2060, total water demand in the basin would increase to 830,057 dam^3 – an increase of 38.5% over the 2010 level.

Water demand in the Qu'Appelle River Basin is estimated for 2010 at 599,342 dam^3 of which direct anthropogenic demands accounted for 135,390 dam^3 (or 22.6% of the total water demand). Increased amount of irrigated area and expansion of the potash sector are the main forces behind the change in water demand. This proportion is expected to increase in the future, as by 2060, these activities would account for 44.1% of the total water demand, slightly less than doubling the 2010 share. By year 2060, the basin will experience an increase of 162% in the total direct anthropogenic water demand (Table ES.1).

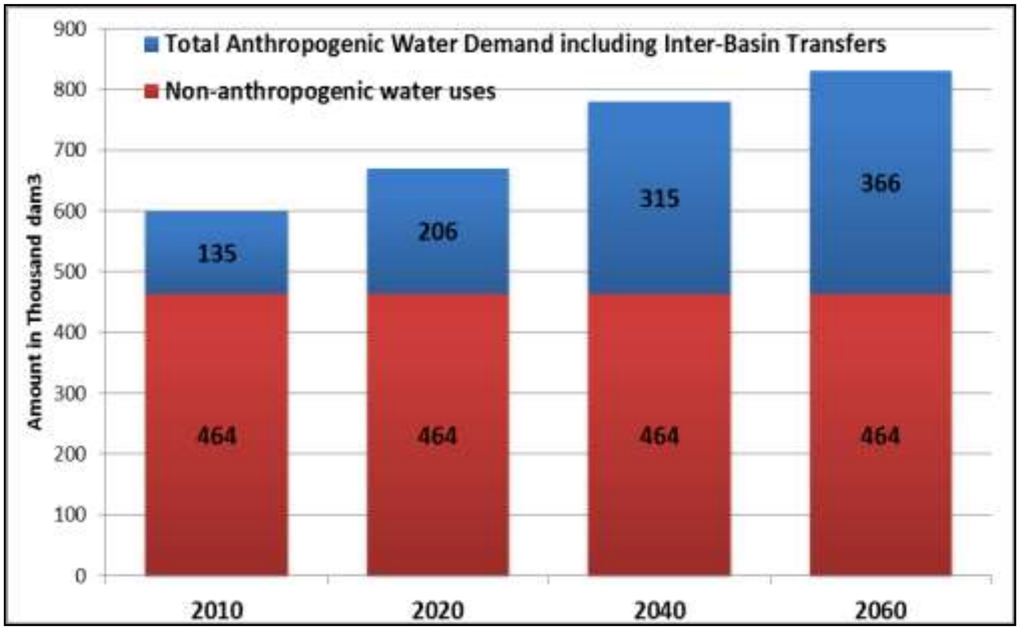


Figure ES.1: Distribution of Total Water Demand in the Qu'Appelle River Basin by Major Categories of Demand, Baseline Scenario, 2010 – 2060

Table ES.1: Water Demand in the Qu'Appelle River Basin, Baseline Scenario, 2010-2060

Sector	Amount of Water Demand in dam^3			
	2010	**2020**	**2040**	**2060**
Agriculture	64,697	67,090	165,358	206,353
Industry and Mining	21,815	83,779	94,879	95,460
Municipal (Domestic)	45,689	44,852	44,512	45,607
Recreational	199	183	186	191
Total Direct Anthropogenic Water Demand* Excluding Interbasin Transfers	**132,400**	**195,904**	**304,935**	**347,611**
Interbasin Transfers	2,990	10,144	10,212	18,512
Total Direct Anthropogenic Water Demand* Including Interbasin Transfers	**135,390**	**206,048**	**315,147**	**366,123**
Indirect Anthropogenic Water Demand	463,934	463,934	463,934	463,934
Total Water Demand Excluding Interbasin Transfers	**596,334**	**659,838**	**768,869**	**811,545**
Total Water Demand Including Interbasin Transfers	**599,324**	**669,982**	**779,081**	**830,057**
% Increase in Direct Anthropogenic Water Demand Over 2010		48.0%	130.3%	162.4%
% Increase in Total Water Demand Over 2010		11.8%	30.0%	38.5%

* Totals may not add precisely due to rounding

Total direct anthropogenic water demand in 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 in the basin will increase to 366 thousand dam^3 in 2060, compared to the present level of only 135 thousand dam^3. As shown in Figure ES.2, much of this increase can be credited to agricultural water demand, and within that, to irrigation water demand. Industrial and mining water demands are also expected to increase, but not by such a magnitude.

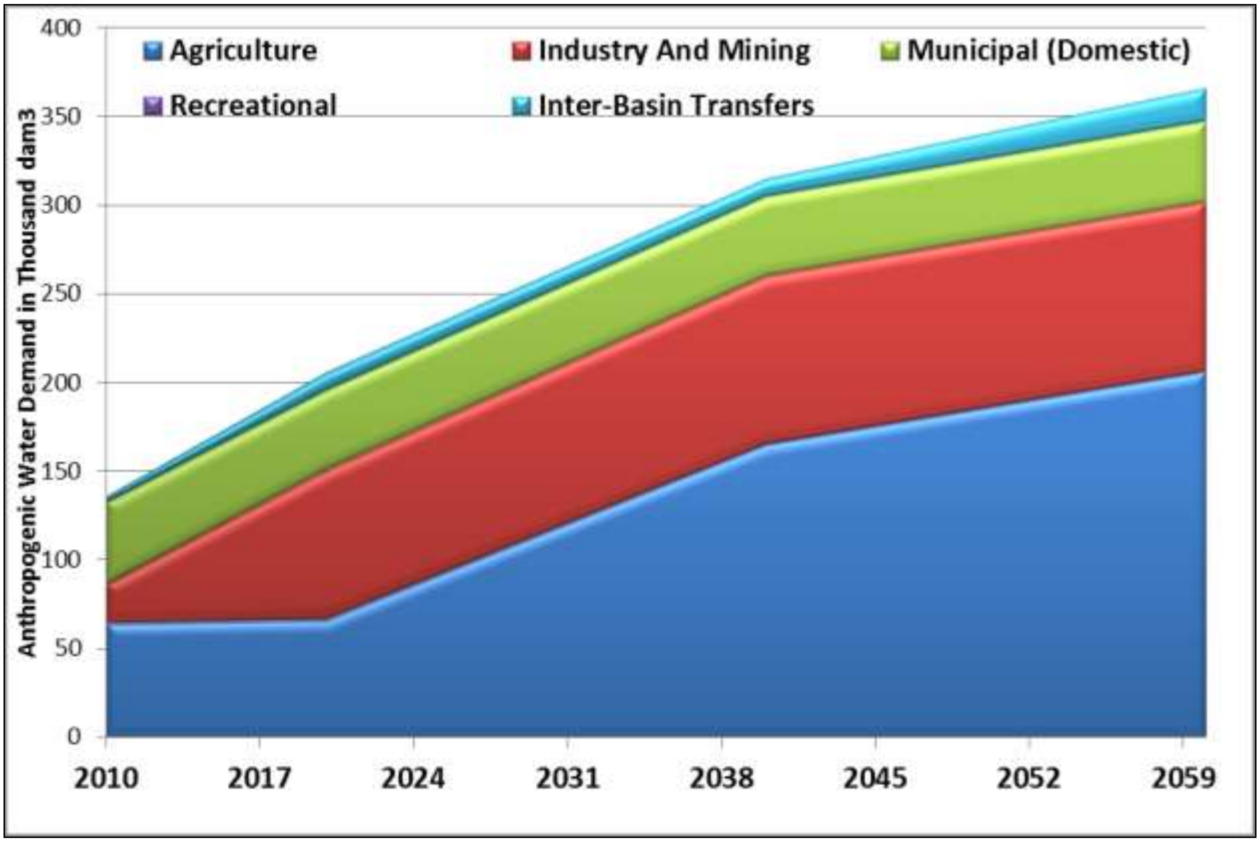
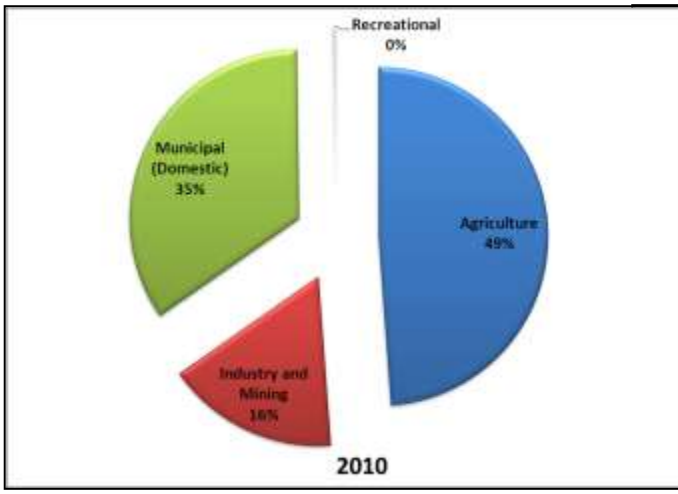


Figure ES.2: Trend in Water Demand for Direct Anthropogenic Demands by Type of Demand, Qu'Appelle River Basin, Baseline Scenario, 2010 – 2060

As a result of varying trends over the 2010-2060 period, the composition of total direct anthropogenic water demand will likewise change. As shown in Figure ES.3, agriculture will increase its share of the total to 59% as opposed to 49% in 2010. Industrial and mining water demand share will also rise from the present 16% to 28%



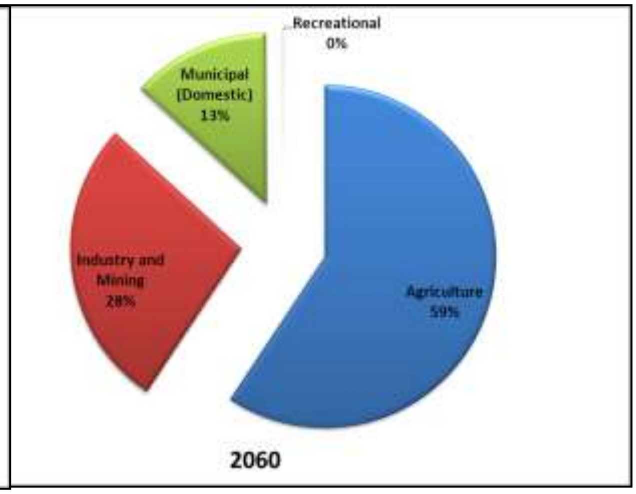


Figure ES.3: Distribution of Total Direct Anthropogenic Water Demand by Type of Demand in the Qu'Appelle River Basin, Baseline Scenario, 2010 and 2060

Water Demand Estimates under Climate Change Scenario

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

Effects of climate change on the direct anthropogenic and indirect anthropogenic water demand activities in the Qu'Appelle River Basin are presented in Table ES.2. Since indirect anthropogenic water demands are governed by natural changes in the water supply and policy changes, these demands were made constant at their respective 2010 levels, except for the evaporation losses. If knowledge of future supply of water under climate change becomes available, these estimates would need to be revised.

Moreover, higher growing season temperatures will have a significant impact on the agricultural sector because both crops and livestock will demand more water. Evaporation of water from water bodies, which is already a major indirect anthropogenic water demand, is one of the greatest increased demands expected with climate change. The total water demand for direct anthropogenic purposes is expected to increase by 215% of the 2010 level. For industrial and mining water demand, no evidence was found that climate change would affect the levels.

Table ES.2: Water Demand under Climate Change Scenario, Qu'Appelle River Basin, 2010 - 2060

Sector	Amount of Water Demand in dam^3			
	2010	2020	2040	2060
Agriculture	64,697	67,090	192,201	259,437
Industry and Mining	21,815	83,779	95,074	95,697
Municipal and Domestic	45,689	44,852	45,652	47,950
Recreational	**199**	**183**	**189**	**201**
Total Direct Anthropogenic Water Demand* Excluding Interbasin Transfers	**132,400**	**195,904**	**333,116**	**403,285**
Interbasin Transfers	2,990	10,144	10,240	18,572
Total Direct Anthropogenic Water Demand* Including Interbasin Transfers	**135,390**	**206,048**	**343,356**	**421,857**
Indirect Anthropogenic Water Demand	463,934	463,934	486,883	509,833
Total Water Demand Excluding Interbasin Transfers	**596,334**	**659,838**	**819,999**	**913,118**
Total Water Demand Including Interbasin Transfers	**599,324**	**669,982**	**830,239**	**931,690**
% Increase in Direct Anthropogenic Water Demand over 2010		48.0%	155.4%	214.8%
% Increase in Total Water Demand over 2010		11.8%	38.5%	55.5%

* Totals may not add precisely due to rounding

Water Demand Estimates under Water Conservation Scenario

The effect of water conservation measures on the water demand activities in the Qu'Appelle River Basin 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 potential success of conservation measures is partially dependent on legislations and regulations that may be in place.

The total water demand for direct anthropogenic purposes is estimated to be 315 thousand dam^3 by 2060 – an increase of approximately 126% over the 2010 level (Table ES.3). Relative to the baseline scenario, water conservation could reduce anthropogenic water demand by 14% of the baseline estimate by 2060 (Table ES.4). Much of this decrease would likely be the result of possible reductions in the agricultural and industrial and mining water demands.

Table ES.3: Water Demand under Water Conservation Scenario, Qu'Appelle River Basin, 2010-2060

Sector	Amount of Water Demand in dam^3			
	2010	2020	2040	2060
Agriculture	64,698	62,963	145,807	179,981
Industry and Mining	21,815	79,980	82,233	74,525
Municipal and Domestic	45,689	44,631	43,900	44,404
Recreational	199	179	178	179
Total Direct Anthropogenic Water Demand* Excluding Interbasin Transfers	**132,401**	**187,753**	**272,118**	**299,089**
Interbasin Transfers	2,990	9,896	9,458	16,216
Total Direct Anthropogenic Water Demand* Including Interbasin Transfers	**135,391**	**197,649**	**281,576**	**315,305**
Indirect Anthropogenic Water Demand	463,934	463,934	463,934	463,934
Total Water Demand Excluding Interbasin Transfers	**596,335**	**651,687**	**736,052**	**763,023**
Total Water Demand Including Interbasin Transfers	**599,325**	**661,583**	**745,510**	**779,239**
% Increase in Direct Anthropogenic Water Demand over 2010		41.8%	105.5%	125.8%
% Increase in Total Water Demand over 2010		10.4%	24.4%	30.0%

* Totals may not add precisely due to rounding

Table ES.4: Relative Change in Water Demand in the Qu'Appelle River Basin, by Type of Demand under the Water Conservation Scenario Relative to Baseline, 2060

Type of Demand	Change (Decrease) in 2060 level by % of 2010 Level
Agriculture	-12.8%
Industry and mining	-21.9%
Municipal (Domestic and industrial)	-2.6%
Recreational	-10.0%
Total Anthropogenic Water Demand	-14.0%

Water Demand by Source of Water

Most of the water for various demands is obtained either from surface water or groundwater. In some cases, groundwater is used to supplement any periodic shortfalls in surface water availability. Unfortunately total water demand data by source of water are rather imprecise. Some information is available but other estimates are based on assumptions. Estimated water demand by type is shown in Table ES.5. Based on these estimates, it appears likely that surface water demand will increase at a faster rate thereby reducing the share of groundwater. The proportion of surface water demand to total water demand increases from 82% in 2010 to 91% by 2060, as shown in Figure ES.4.

Table ES.5: Distribution of Total Direct Anthropogenic Within-Basin Water Demand by Source of Water, Qu'Appelle River Basin, Baseline Scenario, 2010 - 2060

Particulars	2010	2020	2040	2060
Surface Water (dam^3)	108,102	172,401	271,275	315,196
Groundwater (dam^3)	24,298	23,503	33,660	32,415
Total Water Demand	132,400	195,904	304,935	347,611
Groundwater % of Total	18.4%	12.0%	11.0%	9.3%

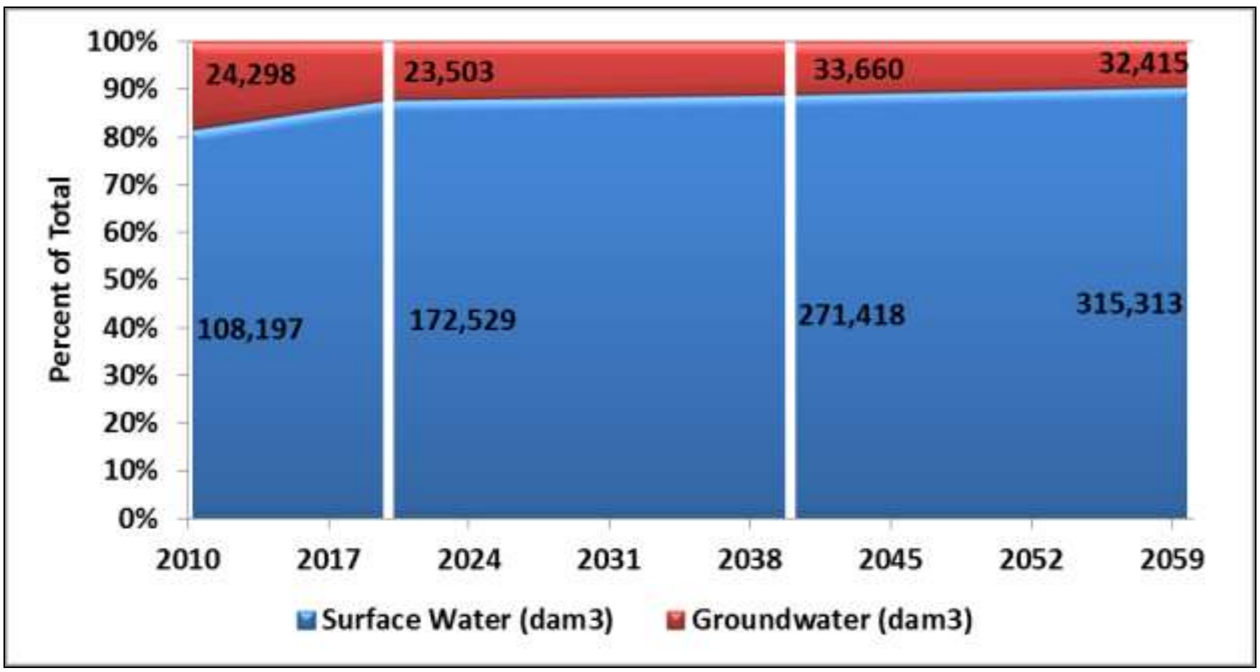


Figure ES.4: Proportion of Surface Water Demand to Total Anthropogenic Water Demand, Qu'Appelle River Basin, 2010 - 2060

Summary

A major increase in the water demand for various anthropogenic purposes is expected to occur in the Qu'Appelle River Basin by 2060. These changes for the three scenarios and for the 2010 - 2060 period are shown in Figure ES.5.

Under baseline assumptions, this increase may be as high as 39% of the 2010 level. Under climate change, further increases are expected, perhaps reaching 19% over the 2060 baseline water demand level. The adoption of water conservation measures holds the potential for reducing future water demand. Relative to the baseline scenario estimate, this reduction could be in the magnitude of 14%. However, the effectiveness of conservation measures will depend very much on the policy measures undertaken by the provincial government and other jurisdictions.

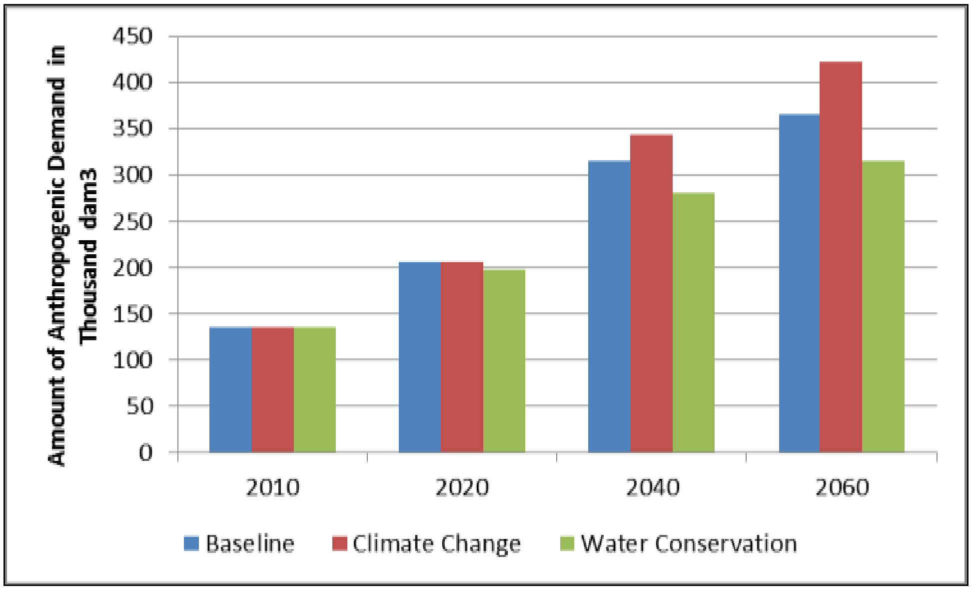


Figure ES.5: Direct Anthropogenic Water Demand (Within-Basin) under Alternate Study Scenarios (dam^3), Qu'Appelle River Basin, 2010-2060

The need for water conservation measures, including implementation of economic instruments, has been suggested by the National Roundtable on Economy and Environment. The Roundtable also recommends heightened diligence and collaboration in the reporting of data: "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 has a number of limitations; there are data deficiencies related to factors that affect water demand. 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 Qu'Appelle river basin as a single entity, although significant variability in the water demand may exist within the basin. Identification of these water stress pockets needs to be considered in conjunction with water supply information under alternative scenarios.

(Photo Courtesy of Saskatchewan Watershed Authority)
Upper Qu'Appelle at Muscowpetung Area

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LIST OF ACRONYMS USED

AAFC	Agriculture and Agri-Food Canada
BSE	Bovine Spongiform Encephalopathy
CCCSN	Canadian Climate Change Scenarios Network
CFB	Canadian Forces Base
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)
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
HACCP	Hazard Analysis and Critical Control Points
IBT	Interbasin Transfer
ICDC	Irrigation Crop Diversification Corporation
ICWE	International Conference on Water and the Environment
ILO	Intensive Livestock Operations
IPCC	Intergovernmental Panel on Climate Change
IPSCO	Interprovincial Steel and Pipe Corporation

IWD	Irrigation water Deamnd
LDDA	Lake Diefenbaker Development Area
LLID	Luck Lake Irrigation district
MAA	Master Agreement for Apportionment
MCOOL	Mandating Country of Origin Labeling
ML	Mega (Million) Liters
NATO	North Atlantic Treaty Organization
NEB	National Energy Board
NFTC	North American Treaty Organization's Flying Training in Canada
NRTEE	National Roundtable on Environment and Economy
OMAFRA	Ontario Ministry of Agriculture, Food and Rural Affairs
QSP	Qu'Appelle South Project
PPWB	Prairie Provinces Water Board
RHID	Riverhurst Irrigation District
SCER	South Central Enterprise Region
SICC	Saskatchewan Indian Cultural Center
SIPA	Saskatchewan Irrigation Projects Association
SSEWS	Saskatoon South East Water Supply
SSRID	South Saskatchewan River Irrigation District
SWA	Saskatchewan Watershed Authority
TWD	Total Water Demand
WDC	Per Capita Water Demand

Chapter 1

Introduction

1.1 Background

Fresh water is our life line – it supports our economic activity, plays an important role in our societies and maintains 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. The largest water supply is available in northern Canada where few people reside. The more heavily populated areas of southern Canada have relatively low water availability. This circumstance creates an increased need for effective water management.

Water, besides being a basic necessity of life, is an essential natural resource for various sectors of the economy. As an important natural resource, water is demanded for various purposes, including agricultural production, electricity generation, human consumption, industrial and commercial economic activity, and recreation, among others. Recently, there has been increasing controversy and competition among various users of water, since supplies are no longer meeting demands in some locations. This situation could be accentuated by future climate change, since there could arise increased needs for water for irrigation and potash mining. Economic development activities would also exert similar pressures on existing water supplies.

Saskatchewan has both surface water and groundwater. Groundwater is a buried treasure (Nowlan, 2005). However, data and information on it 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 Qu'Appelle River Basin, which is the focus of this study.

1.2 Water Management Issues

Water is a limited resource globally, but even more acutely so in semi-arid regions, such as parts of Saskatchewan. At the same time, society is increasingly concerned about water quality and environmental issues in general, and especially those related to water. In the past, the major issue in water management was water availability. To assist with this, various traditional steps have been taken, including additional storage of water, reduced variability of river flows, 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 the recent transition from water-supply management to water-demand management in order to strike a balance tries to ensure efficient water use. Studies have shown that with the past and present trend in competition for water use in different locations, water demand will continue to increase as population increases and other new demands for water 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 of water consumption, climate change, population dynamics, migration and changes in socioeconomic and demographic characteristics of water consumers. This is important as development of appropriate policies and programs requires good information on the current level of water use by different users (Kulshreshtha, 1996). The present study is, therefore, relevant for future planning and management of water supply systems in western Canada.

Demand management involves ways to reduce wasteful water use. These measures are needed since in some regions available freshwater is not adequate to meet local demands. Furthermore, 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 demand. In fact, in a Saskatchewan Water Corporation survey conducted 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 many ways, affecting rural development now, and will continue to be, limited by a wide variety of water issues.

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

In addition to 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 effect on the hydrologic cycle and on water management systems (Ayibotele, 1992). For the Canadian prairies, Byrne et al. (2010) state 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, the 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 (use of 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 major tool for future water management, along with traditionally used 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. The NRTEE (2012) has indicated that the "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 to provide such information for the Qu'Appelle River Basin.

1.3 Objectives and Scope of the Study

This study was designed to estimate water demand in the Qu'Appelle River Basin 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 using disaggregated approach / method to total demand. Both consumptive and non-consumptive water demands are included. Factors affecting demand included 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 Two provides an overview of the Qu'Appelle River Basin. Major economic activities and population centers are included in this description. The methods for estimating current water demand in the basin is provided in Chapter Three, which is followed by methodology for future water demand estimation in Chapter Four. All current and future water demand scenarios are presented in Chapter Five. Total water demand estimates by sectors under study scenarios are presented in Chapters 6 to 10 – Agricultural demand in Chapter 6, Industrial and mining demand in Chapter 7, Municipal and domestic demand in Chapter 8, Recreation demand in Chapter 9, and Indirect anthropogenic demand in Chapter 10. The last chapter provides a summary of results, suggesting areas for future research.

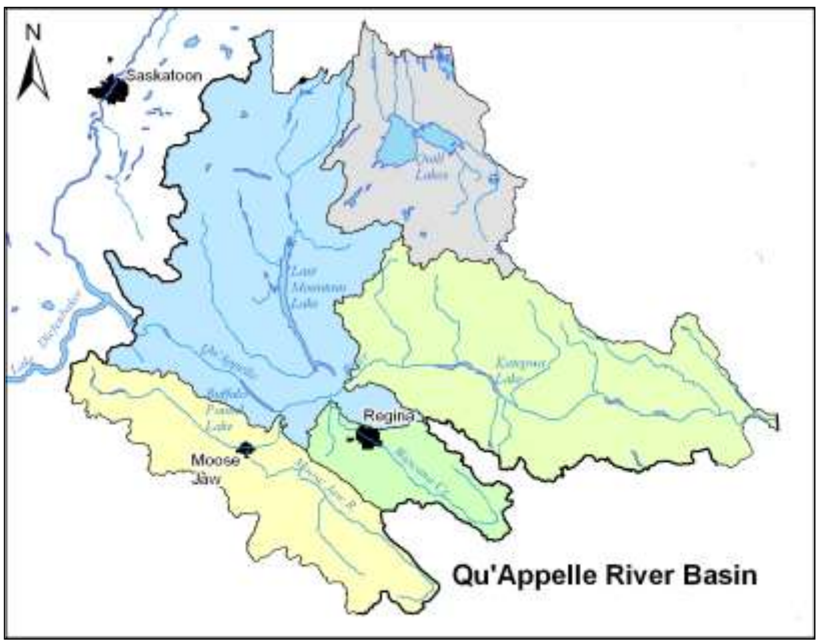
Chapter 2

Description of the Qu'Appelle River Basin

This chapter provides a description of the baseline conditions in the Qu'Appelle River Basin. The basin is highly significant for the province since it houses major urban centers besides numerous other economic activities. The documentation provided here is based on available secondary data.

2.1 Location of the Qu'Appelle River Basin

The Qu'Appelle River Basin is located in the southern part of the province, as shown in Figure 2.1. It extends from the eastern boundary of the South Saskatchewan River Basin in Saskatchewan to just inside the province of Manitoba.



Source: Map provided by SWA

Figure 2.1: Map of the Qu'Appelle River Basin

In Manitoba, the Qu'Appelle River joins the Assiniboine River. Its basin contains the mainstream Qu'Appelle River along with a number of tributaries creeks, lakes and rivers. The basin contains five watersheds: (1) Upper Qu'Appelle River watershed; (2) Quill Lakes watershed; (3) Lower Qu'Appelle River watershed; (4) Moose Jaw River watershed including Thunder Creek; and (5) Wascana Creek watershed where this creek joins the Qu'Appelle River.

The Qu'Appelle River drains an approximately 75,000 km^2 area (Table 2.1), which includes the 11,340 km^2 closed drainage area around the Quill Lakes, which is a part of the basin but does not contribute any water to the Qu'Appelle River. The basin is highly regulated as a major part of the flow is released from Lake Diefenbaker, which was established in 1968, with the development of the Qu'Appelle dam. A gravity diversion with a channel capacity of just over eleven m^3/s was developed.[1] The river contributes water to, as well as receives water from, the Last Mountain Lake northwards. In addition, the river channels in its central and lower reaches have been regulated to form Buffalo Pound Lake, Pasqua, Echo, Mission and Katepwa Lakes, Crooked Lake, and Round Lake before it drains into the Assiniboine River in Manitoba (Canada West Foundation, 1982). Many of these lakes have control structures. The lakes themselves are very important from a recreational and tourism point of view, as well as for commercial and subsistence uses by First Nations' people.

Land use in the basin is primarily agricultural. Of the total area of the basin, 93% serves agricultural purposes, about 5% is grassland, and less than 1% is forested. The basin contains two major urban centers – Regina and Moose Jaw. However, the area of water use is very small.

Table 2.1: Land Demand in the Qu'Appelle River Basin, 2000

Land cover category	Square Kilometers	Percent of the Total
Total Area	74,589	100.0%
Evergreen Needleleaf Forest Area	6	0.5%
Deciduous Broadleaf Forest Area	5	
Mixed Forest Area	181	
Disturbance Area	0	
Shrubland Area	218	
Grassland Area	3,398	4.6%
Low Vegetation And Barren Area	5	0
Cropland and Cropland with Woodland Area	69,596	93.3%
Snow and Ice Area	0	0
Other Land Cover Area	1,178	1.6%

Source: Statistics Canada (2000).

[1] The amount of water thus transferred from the South Saskatchewan River Basin to the Qu'Appelle River Basin is little over 350 thousand dam^3 per annum. This along with the natural supply within the Qu'Appelle River Basin satisfies the water demand. Without getting a full picture of water supply in the basin, it is impossible to estimate the proportion of total water demand that is met through interbasin transfers.

2.2 Population

The Qu'Appelle River Basin is one of the important basins in the province from the standpoint of people. In 2010, it was estimated that slightly more than 328 thousand people resided within the basin (Table 2.2). Saskatchewan's population on April 1, 2011 was reported to be a little over a million (1,053,960 people, to be exact). Thus, the basin houses 31.2% of the provincial population.

Table 2.2: Estimated Population of the Qu'Appelle River Basin By Type of Communities, Selected Years

Type of Community*	Population in 1995**	Population in 2010***	% Increase (decrease) in 2010 over 1995
Regina	178,726	193,707	8.38%
Moose Jaw	33,803	34,559	2.24%
Towns > 1000 people	17,240	17,352	0.65%
Towns < 1000 people	12,257	13,619	11.11%
Villages	13,996	15,154	8.27%
Bedroom Communities	7,068	10,564	49.46%
Recreational Villages	197	208	5.58%
First Nations Communities (Reserves)	1,267	6,710	429.60%
Institutions	701	800	14.12%
Sub-Total Non-Rural Population	265,255	292,673	10.34%
Rural Municipalities (Non-Farm)	Note 1	6,599	
Farm Population	Note 1	29093	
Total Population		328,365	

Note 1: These populations were not reported.

* The basin also houses the city of Humboldt. However, the water for this community is provided by the South Saskatchewan River Basin, and is counted there.

** Source: SWA (2010)

******* Based on SWA (2011) and Statistics Canada (2012).

The basin has not shown a sharp increase in population. Non-rural population, as an example shown in Table 2.2, has increased by 10.34% over the 1995-2010 period, 0.69% per annum (based on a simple growth, non-compounded). Much of this increase has happened through migration of people from other smaller centers within the province or from outside the province to the two cities in the basin. However, the highest rate of population growth was noted in First Nations' People living on reserves and in bedroom communities. The first category of population increased from 1,267 people in 1995 to 6,710 people by 2010 – an increase by 430% over the same period. Bedroom communities around Regina showed the next highest rate of growth, increasing by 49% over the same period. A movement of people from large cities to close-by communities may have affected the growth rate of the city of Regina, which only increased by 8.4%.

The total basin population was divided into different types of communities/regions. Initially, population was divided into urban and rural population. Urban population included cities, towns, villages, bedroom communities, First Nations Reservations, and recreational communities. The standard definition for these areas was followed. Towns were further divided into two groups: larger towns -- those with 1000 people or more 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 the Qu'Appelle River Basin, these communities were identified only in the vicinity of city of Regina. No community around the City of Moose Jaw could be identified as belonging to this category.[2]

The rural population was further 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 those are relatively smaller areas. In addition, over time, growth patterns 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.

Based on population numbers, the basin is primarily an urban basin, as 70% of the basin population resides in the two cities (Figure 2.2), with another 12.4% in towns. Rural population (including farm, non-farm rural, villages, and recreational villages) constitutes only 11% of the total, including the 9% who reside on farms.

2.3 Major Economic Activities

A number of economic activities are pursued in the Qu'Appelle River Basin. 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 in the basin. These activities are described further in this section.

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

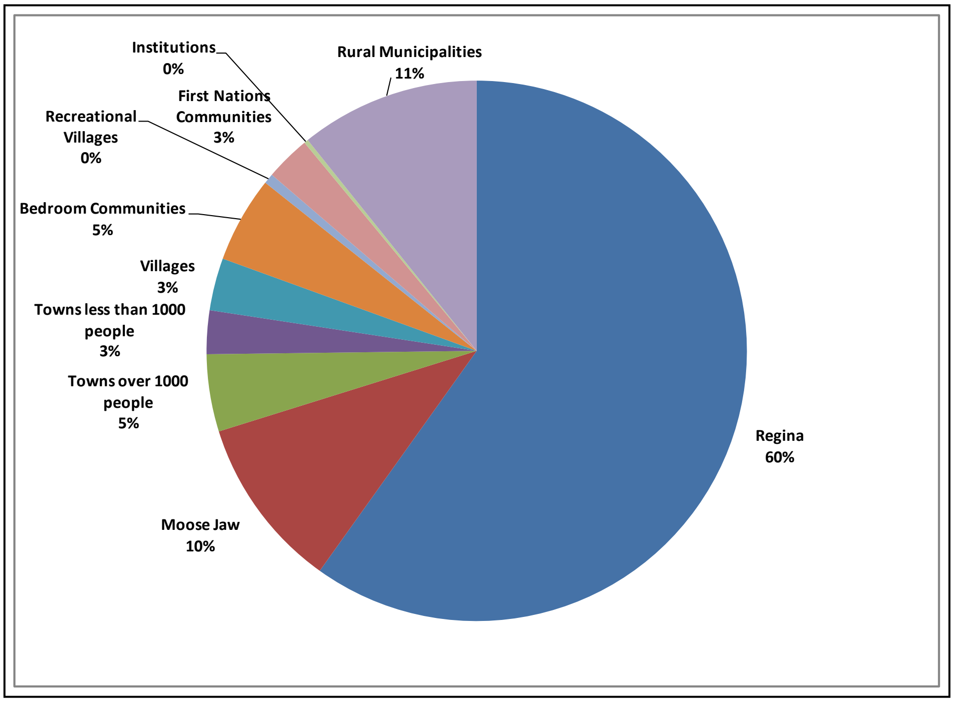


Figure 2.2: Distribution of Qu'Appelle River Basin Population by Type of Communities, 2010

2.3.1 Agriculture

As shown in Table 2.3, most of the basin is agricultural, with 93% of the land base suitable for crop and related agricultural activities. Of this area, 12.25 million acres are occupied by farms.[3] Given that the basin has 9,698 farms, the average size of a farm is 1,264 acres.

The total farm area supports crop and livestock enterprises, as well as other specialty enterprises (greenhouses and orchards). As shown in Figure 2.3, a little over two-thirds of this area is devoted to crops (called cropland), which includes some area for livestock forage. However, there is 7% of the total area devoted to seeded pastures. In addition, there is also 11% of the area for the native pastures. All these land uses are in support of livestock enterprises in the basin's livestock and poultry farms.

[3] According to Table 2.1, agricultural area is 6.9596 million ha (equivalent to 17.197 million acres). In Table 2.3, total area of the farms is estimated at 12.25 million acres. This leaves a discrepancy of almost 5 million acres. 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 analysis in this study, 12.25 million acres is used as the authentic estimate of farm area.

Table 2.3: Agricultural Activities in the Qu'Appelle River Basin, 2006 and 2010

Particulars	2006	2010**
Number of Farms	9,698	
Total Area of Farms (Acres)	12,256,783	
Average Size of the farm (Acres)	1263.85	
Crop Production Activities		
Land in Crops (Acres)	8,286,557	8,294,775
Tame Hay or Seeded Pasture (Acres)	821,626	
Natural Land for Pasture (Acres)	1,420,005	
Other Land (Acres)	1,728,595*	
Irrigated Area (Acres)	25,904	47,660
% Zero Tillage	59.7%	
Livestock Production Activities		
Cattle and Calves	646,688	580,954
Dairy (cows and Heifers)	12,722	8,212
Hogs	151,261	145,456
Sheep	40,244	29,566
Other Livestock	30,407	42,395
Broilers	1,186,486	1,300,367
Eggs (# of Layers)	210,212	219,725
Turkey	110,537	227,943

* 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)

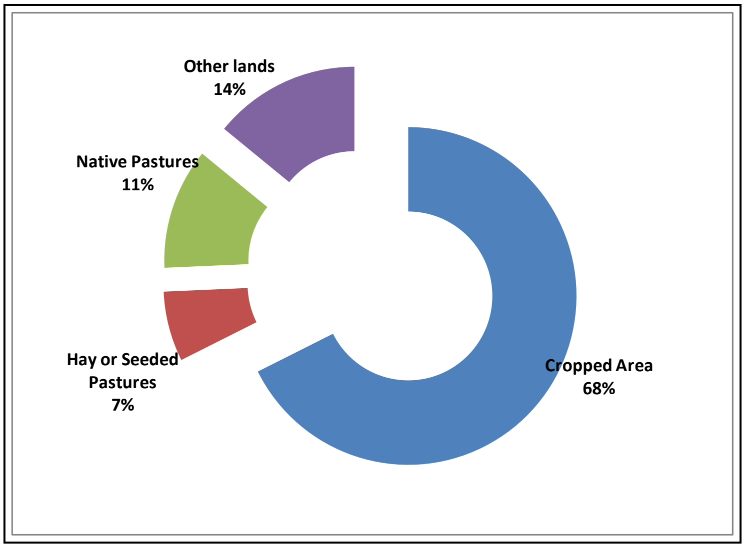


Figure 2.3: Farm Level Land Demand in the Qu'Appelle River Basin, 2006

2.3.2 Mining Activities

Major types of mining activity in the basin consist of potash production. However, there is also a salt mine in operation at Belle Plain plus another one at Esterhazy, where salt is produced along with potash.

2.3.2.1 Potash Mining

The basin has five potash mines -- one owned by the Potash Corporation of Saskatchewan, three by the Mosaic Corporation, and one by Big Quill Resources.[4] The current production capacity of potash mines in the Qu'Appelle River Basin by mine location and type of production process is presented in Table 2.4.

Table 2.4: Salient Features of Current Potash Mines in the Qu'Appelle River Basin

Corporation	Location	Mining Technology	Source of Water[1]	Production in Thousand Tonnes in	
				2008	2011[2]
Potash Corporation of Saskatchewan	Lanigan	Underground	S & G	3,800	3,800
Mosaic	Esterhazy	Underground	S & G	5,300	5,300
	Belle Plaine	Solution	Sask Water	2,800	2,900
	Colonsay	Underground	SSEWS Canal	1,800	2,100
Big Quill	Wynyard	Solution	S & G	450	483
Total for the Qu'Appelle River Basin				**14,150**	**14,583**

[1] S – Surface; G - Ground
[2] Please note the 2010 water demand is based on the 2011 level of production. These production levels are forecasts of production at the time of data collection. Actual production levels may differ from these levels. These data were obtained from company websites, financial statements, and annual reports.
Source: CIBC WORLD MARKETS INC. (2008).

Several operating mines have recently expanded capacity or are in the process of expanding production. In 2008, the basin had a production of 14.2 million tonnes of potash. By the time plans for expansion of various mines are in place, the production will increase to 14.6 million tonnes, an increase of almost 3%. Two of the mines are solution mines, while the others are underground mines. In terms of source of water, three mines use a combination of surface and

[4] This mine produces Potassium Sulphite.

groundwater, while the other two use surface water either through their own impoundment or from reservoirs and/or by withdrawing it from the Saskatoon South East Water Supply (SSEWS) canal.

2.3.2.2 Oil and Gas Well Drilling

There is only a limited amount of activity in the basin related to oil and gas production. Activities related to oil production were encountered near Whitewood. On average, approximately 100 oil wells are drilled annually in this area. The levels of production from these new wells and previously drilled wells are not available.

2.3.2.3 Salt Production Activities

Salt from potash mine tailings at Belle Plaine and at Esterhazy are used in the production of various salt products.

2.3.3 Forestry Water Demand

As shown in Table 2.1, only 0.5% of the total area of the basin is attributed to forests. For the most part of this forested land is shrubland. Since these areas are not irrigated, nor do they have any related activity that requires water, it is assumed that forest lands do not generate any water demand at present and will not have any water demand in the future.

2.3.4 Manufacturing

Manufacturing activities are generally located in the urban areas of Regina, and Moose Jaw. However, other manufacturers are also located outside these municipal water systems. A list of these is provided in Table 2.5. It should be noted that the list in Table 2.5 does not include any manufacturing concerns located within the cities of Moose Jaw or Regina.

Table 2.5: Water using Manufacturing Activity in the Qu'Appelle River Basin

Type of Manufacturing	Product Produced	Location
Ethanol		
Pound-Maker Agventures Ltd.	Ethanol	Lanigan
Terra Grain Fuels Inc.	Ethanol	Belle Plaine
Ag-Processing		
YARA Inc. (previously Saskferco)		Belle Plaine
Steel		
EVRAZ Inc. (formerly IPSCO)	Steel products	Regina
Petroleum Products processing		
Consumer Co-op Refineries	Gasoline and related products	Regina
Food Processing		
Lilydale		Wynyard

In the Qu'Appelle River Basin, three types of manufacturing activities exist where water is supplied from non-municipal sources. These include: fuel (including ethanol) production and processing, fertilizer manufacture, steel milling, and food processing. The locations of these firms and this production activities are shown in Table 2.5.

2.3.5 Communities and Public Institutions

Municipal water systems supply the two major urban centers in the basin -- Regina and Moose Jaw, which have domestic (residential), manufacturing, commercial, and public water demands. The public water demand is for street cleaning, firefighting, and other uses. Most towns and smaller communities provide water to their own residents and for other economic activities. These communities were classified into different types (Towns, Bedroom Communities, Villages, Resorts or Recreational Villages, and First Nations' Reservations), as listed earlier in Table 2.2.

Two public institutions are located in the Qu'Appelle River Basin -- the Canadian Forces training base at Moose Jaw (CFB 15 Wing) and the Regina Correctional Centre, which have water supply systems separate from the nearby communities. Approximately 300 prisoners plus staff are located at the correctional facility. The Canadian Forces training base is home base for training Canadian pilots plus NATO (North American Treaty Organization) Flying Training in Canada (NFTC); approximately 150 pilots are trained every year. Since 2000, there has been reinvestment in the base to meet the requirements of housing for the NFTC program participants, perhaps showing its future continuance.

2.3.6 Recreation and Tourism

The basin has large water resources for water-based recreational activities, often visited by local people as well as those from outside the basin. A list of these sites is shown in Table 2.6. The basin houses four provincial parks; some of these areas are in the vicinity of Lake Diefenbaker. On the Qu'Appelle River itself, several dams and impoundments have been built to create reservoirs that allow recreational activities. In addition, local municipalities maintain recreational facilities for local residents.

2.3.7 Power Generation

At present there is no power generation activity in the basin. However, in the past, the concept of diverting water from Lake Diefenbaker to the Poplar River Power station at Coronach has been considered.

2.3.8 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. Indirect anthropogenic demands include environmental, apportionment, and evaporation water losses.

Some of these demands are closer to 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.

Table 2.6: List of Available Recreational Sites in the Qu'Appelle River Basin

Provincial Parks	Provincial Recreational Sites	Regional Parks	Other Recreational Sites
Buffalo Pound	Crooked Lake	Esterhazy	Painted Rock Campground
Douglas	Katepwa Point	Ituna	Regina Beach Recreation Site
Echo Valley	Last Mountain House	Last Mountain	Besant Recreation Site
Rowan's Ravine		Dunnet	Birds Point Recreation Site
		Craik and District	Camp Easter Seal
		Wynyard and District	B-Say-Tah
		McNab	Etters Beach Resort
		Leroy Lesuireland	Grandview Beach
		Manitou and District	Kannata Valley
			Manitou Beach
			West End

2.3.8.1 Environmental

One of the major water demands is for environmental purposes. Two such environmental demands are present in the basin. The first one is for maintenance of wetlands, and the second one is for maintaining minimum flows in the streams.

Ducks Unlimited has several duck habitat projects in the province. According to SIPA (2008a), Ducks Unlimited has a total of fifty two large wetland segments in the province, consisting of 5,674 acres. They operate 34 wetland structures and have 17 wetlands with fixed crest structures. Typical examples of these wetlands are to be found on the South Saskatoon East Water Supply System derived from the South Saskatchewan River Irrigation District, the Thunder Creek Irrigation District, and the Luck Lake Irrigation District.

Within the Qu'Appelle River Basin, according to SIPA (2008a), the following projects are identified: (i) Thunder Creek Irrigation District – which contains a series of prairie wetlands over 4,000 hectares/10,000 acres of wetland habitat on 17 project segments and 1,200 hectares/3,000 acres of upland nesting cover on 10 parcels; (ii) Last Mountain Lake - Bird Observatory. (iii) Eyebrow Marsh – 0.7 m^3 per second or 3700 dam^3 (SWA, 2007a); (iv) Katepwa Fishway – 2.8 m^3 per second from break-up until late June. No further details on their respective water demand of these projects could be obtained. It should be noted that although these demands are termed indirect anthropogenic, the facilities listed do support recreational activities for local residents and tourists.

2.3.8.2 Apportionment[5]

According to the Prairie Provinces Water Board (PPWB) that regulates apportionment needs for a basin, the term 'Apportionment Flow' is defined as flow that is subject to apportionment. Typically this flow is equal to natural flow because natural flow at the boundary is subject to apportionment" (PPWB, 1997). The PPWB 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 this Board. In 1969, the four governments changed how the PPWB's operation 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 among the Prairie Provinces and to protect interprovincial surface water quality and groundwater aquifers. Under the MAA among the three Prairie Provinces, about half of the natural amount of water received has to be released to the downstream province. For the Qu'Appelle River Basin, this rule translates into releasing 50% of the natural flow to the Province of Manitoba.

The Qu'Appelle River drains into the Assiniboine River shortly after leaving the Province of Saskatchewan. However, there is no provision in the MAA for any specific (minimum) amount of water to be released to the Province of Manitoba. In most situations, the natural flow of the Qu'Appelle River exceeds this requirement,[6] and therefore, no additional water demand for apportionment is required. During years of low flows, apportionment requirements are generally met through releasing water from storage (if any). However, over the past 25- year period, this action was not needed[7].

2.3.8.3 Evaporation and Percolation Water Loses

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

There are many surface water bodies in the basin. Each of these areas does reveal some evaporative water losses.

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[5] This information was obtained from PPWB (Undated)

[6] This observation was confirmed by Mr. Bart Ogema of Saskatchewan Watershed Authority, Moose Jaw.

[7] This observation is based on Personal Communications with Mr. Bart Oegema of the Saskatchewan Watershed Authority, Moose Jaw.

Chapter 3

Study Methodological Considerations

The study methods for estimating current water demand are described in this chapter, and the methodology for forecasting future demand is discussed in Chapter 4. This chapter begins with nomenclature specific to research on water demand. The concepts used in the reports are described as well. The identification of conceptual water demands in the basin is also developed as a part of the conceptual framework. This step is followed by a review of the literature on water demand estimation. This review was undertaken with the hope of gathering some insights into methodology that could be developed for the study. Our methods for estimating the 2010 water demand in the Qu'Appelle River Basin are described next.

3.1 Nomenclature of Water Demand

Water demand in a river basin can be described by various terms and 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, adjusting their water use level in reaction to price, water demand is a very distinct concept in comparison to others. Furthermore, proper estimation of water demand requires micro-level data under periods 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 study has approximated water demand. The assumption made here is that if buyers pay a certain charge for water, the current water use level can be assumed to be a point on the theoretical water demand function.

In addition to water demand, several other concepts[8] are relevant. Their details on these concepts are shown in Table 3.1. Water losses generally arise from natural factors, including evaporation and percolation/leaching. Water requirements are determined by 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 water intake while some of it may be lost in the production process (typically called consumption). The total amount of water used 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 Demand

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 Demand Typology

Water demand can be classified according to several criteria: source of water, type of demand, and water as a catalyst (not consumed or lost) or consumed in the process, among others.

According to its source, water can be obtained from either surface water or groundwater sources. Of course, the natural precipitation (less evaporation) is also a source of water, but is not typically included as a water source. Using the type of water demand 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 demands 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 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: Types of Water Demand in Qu'Appelle 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
(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	(4) Hydroelectric 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 water demands withdraw water from surface water bodies, a limited quantity of domestic, farm related, mining, and industrial water demand is met from groundwater sources. Many of these uses have a return flow, making water consumption smaller than total water intake. This return flow varies for various 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 instream water needs, as well as quantities diverted to environmental projects.

3.3 Overview of Methods for the Study

Total water demand in the Qu'Appelle River Basin was estimated as a sum of two major categories of water demands: direct anthropogenic and Indirect anthropogenic. The former type includes all socio-economic demands of water in the basin. The second category includes water demands not directly related to human activities, although such activities are indirectly affected by these activities/decisions. Within each of these categories, water demand is estimated by its type of water demand. For each type of water demand the relevant methods are described in this chapter.

The direct anthropogenic water demand represents a sum of four types: (1) Agricultural and related production; (2) Industry and mining; (3) Municipal and domestic; and (4) Recreational purposes. Agricultural water demand includes a variety of water demands, mainly for irrigation, by dryland farmers for crop production, livestock water demand and other related demands for agriculture and fish production. Methods for the estimation of water demand for industrial and mining (particularly for potash production) concern the second important direct anthropogenic activity. Domestic water demand is divided into municipal and non-municipal water systems.

The former includes urban jurisdictions with municipal water distribution systems. It therefore includes a combination of water demands – residential, manufacturing, commercial, and other service industries, public water demands, and others. Available data did not permit a breakdown of this total water demand,[9] and, therefore such a breakdown is omitted 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 by evaporation and percolation; necessity release of water to other regions under apportionment agreements; water needed to maintain instream 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 North American (Canadian and U.S.), Australian, and European studies. In this section, these studies are summarized. 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, wherein the impact of water price on water demand levels is tested. The second one employs actual measurements of water being utilized. The third type is more synthetic in nature – these studies 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 the residential demand for water. In one work by Howe and Linaweaver (1967), the authors looked at the impact of price on residential water demand, as well as its relation to system design and price structure in Melbourne, Australia, using cross-sectional data. In a subsequent study by Aitken et al. (1991), other water demand predictors were included in the cross-sectional regression model of residential water demand in the same location in order to determine significant variables that affect household residential water consumption. Arbues et al. (2003) carried out a survey study on main issues in the

[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 available for this study. This work is left for future research in this area.

literature on residential water demand studies. This study reviews 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 by 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 and / or monitored. This amount is recorded and utilized for different water demands. In the third category of research, data on measured water demand can also be used to estimate a water use coefficient. Failing that, water use coefficients could be based on a synthetic or water requirement approach.

3.4.2 Municipal Water Demand

Municipal water demand can be a composite of several demands, including residential 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 which employ 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. Condensed explorations of these approaches are presented below.

One, Multivariate regression analyses, involve statistical estimation of the relationship between water demand and some water demand shifter variables. Per unit water demand in these studies relates 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, involve changes in water demand over time. These studies utilize univariate time series data to determine daily water demand and divide water demand according to base use and seasonal use. Base use is determined as a function of socioeconomic and climate variables. This method is mostly used for short-term water demand forecasting because of its reliance on controlling factors such as income and population (Cheng, and Ni-Bin, 2011).[11]

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[10] Examples of this type of studies 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).

[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.

Three, Computational intelligence models, which are purely data driven. Under this approach, different types of models are applied to forecast the municipal demand for water. These methods include: the Agent-Based, Fuzzy-logic, and Artificial Neutral Networks models. These studies utilize autoregressive integrated moving average and the generalized autoregressive conditional heteroskedasticity models to estimate water demand. These 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) use historic time series data on water consumption, applying 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 demanded by greenhouses. No studies were found that estimate water demand for agro-forestry and aquaculture. Some studies have been carried out that estimated the water demand for irrigation. Heady and Agrawal (1972) utilize linear programming technique to model agricultural production and water demand by individual farms, agricultural regions, and the entire economy. Anderson (1981) carries out an economic analysis of supplementary irrigation in Skane to forecast potential demand for irrigation water-using crop (potatoes and sugar beets) prices and irrigation cost. A production function approach, (as suggested by Hexem and Heady, 1978), is used. Some studies (e.g. EEA, 2001) utilize the FAO crop coefficient method, which is based on reference evapotranspiration and a crop coefficient (Kc) that accounts for crop characteristics, development, and vegetative periods, among other features. A 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 through the water requirement approach. The total water demand for livestock is a sum of number of animals, times their water requirements. The water requirements include all purposes for which water is needed, including that used for cleaning. Water requirements have been developed for each type of animal.

(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).

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 water demand for tourism in Australia, estimating costs of water provision and operation. In modeling this type of water demand, the authors utilize 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 to be converted by a hydraulic turbine using water energy 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 for individual type of use were presented for individual river basins[12]. A comprehensive study of water use patterns by river basins was completed by Kulshreshtha et al. (1988). For the Qu'Appelle River Basin, water intake/use is estimated at 118,604 dam^3. A large part of this use is for irrigation and for residential purposes. These figures account for about 39% and 29% of the total basin's water use, respectively. Water use is also forecasted for the year 1995, where the basin's water use is estimated to increase somewhere from 26.5% to 31.5% under alternative scenarios (Brockman and Kulshreshtha, 1988). Lacking time series data, the estimation is made using either requirements or water use coefficients based on the 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 demands. It is also shown that different types of methodologies are needed for different types of water demands. Hence, choice of a particular approach depends, to a certain extent, on the scenario under consideration, but also largely on data availability. Given the number of studies that have adopted various

[12] Although individual water uses were estimated for each river basin, total water use was only presented for the entire Saskatchewan – Nelson River Basin and the provinces.

methodologies and the inherent limitations of each approach, the multivariate regression analysis approach and that employing water use coefficients for forecasting water demand are most common. The latter approach is more common when 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 are collected by administrative boundaries. Examples of these boundaries include rural municipalities, census divisions, census agricultural regions, towns, villages, and First Nations' Reservations, among others. In order to use these data, a table showing the relationship between the various river basins and these administrative regions was created. The criterion for developing correspondences is the area within each administrative region that falls within the river basin. It provided no challenge for those administrative regions that were wholly within the river basin. For those that are partially within the river basin, an overlay of the river basin map and the administrative boundaries map was used. 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

Since only limited time series information exists on price and quantity of water use, water demand functions could not be estimated. As the next best alternative, an estimation of current water demand in this study is based on a water demand coefficient multiplied by the level of economic activity in question. Our methods were modified when time series data were available. 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 is estimated in a disaggregated manner here. The 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

Total irrigation water demand was a product of irrigated area times the average quantity of water used for irrigation. Typically, researchers face two major issues in its estimation. One, since irrigation is a supplementary use of water, precipitation and temperatures (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 displays yearly variability. Two, irrigation in the basin is provided through irrigation districts, and through private irrigation. The former are a blocks of land supplied by an irrigation infrastructure. Water demand is regulated by the Irrigation District. One such regulation 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. There are no regulations that govern the amount of water used by private irrigators. Both of these issues are taken into account in estimating irrigation water demand for the basin. In the following estimation of irrigated area and average water demand, the process is demonstrated:

Area for Irrigation: The current irrigated area in Saskatchewan rural municipalities was obtained from Irrigation Branch, Saskatchewan Ministry of Agriculture (2011a) and the SWA (2011b). The details included area by jurisdiction and method of irrigation. Total irrigated area in 2010 for the Qu'Appelle River Basin was estimated at 35,763 acres, of which 3,315 acres were in the Brownlee and Thunder Creek Irrigation Districts (Table 3.3). The rest of the area was assumed to be served by private (non-district) irrigation. As shown in Figure 3.1, district irrigated area represents only 9% of the total, while the remaining 91% is under private irrigation.

Table 3.3: Irrigated Area in the Qu'Appelle River Basin, 2010

Irrigation District	Irrigated Area in Acres
Thunder Creek Irrigation District	1,422
Brownlee Irrigation District	1,893
Total District Irrigation	**3,315**
Total Private Irrigation	32,448
Total Irrigated Area	**35,763**

Source: SIPA (2008A); Saskatchewan Ministry of Agriculture (2011a) and SWA 2(011b).

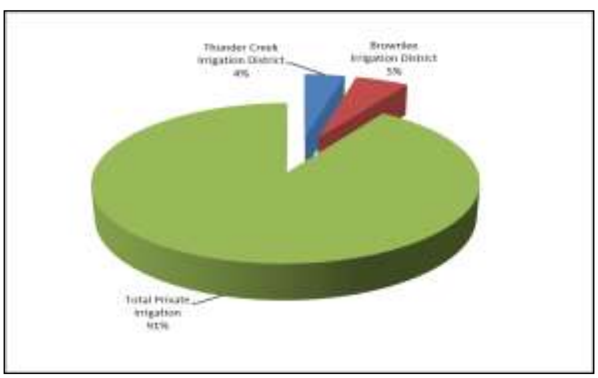


Figure 3.1: Distribution of Irrigated Area in the Qu'Appelle River Basin, 2010, by Type of Jurisdiction

Average Water Demand for Irrigation: Average irrigation water demand is then equated to the crop water deficit for each crop. This deficit was estimated as the water requirement of the crop, minus the average growing season precipitation and the amount of spring time soil moisture available to the crop. The crop mix and efficiency of the irrigation system are also calculated in order to arrive at an average water demand estimate.

Since there were no data available for the Qu'Appelle River Basin for measurements by method of irrigation, information for the Lake Diefenbaker Development Area (LDDA) was consulted. Time series data for water demand per unit of irrigated area were obtained from Saskatchewan Agriculture Irrigation Branch (undated) for three major LDDA irrigation districts – Riverhurst Irrigation District (RHID), Luck Lake Irrigation District (LLID), and South Saskatchewan River Irrigation District (SSRID). In the LDDA, there are two types of technologies exist for water delivery to the farms: (i) canals and pipelines, and (ii) direct pipelines from the reservoirs to the farms. Those connected solely through pipelines are expected to show a lower average water demand relative to those employing other methods of farm water delivery. Details on these conveyance methods are shown in Appendix C (Table C.1).

Water for irrigation in the SSRID is delivered by canal. Results suggested that, because of the technical efficiency of water delivery and other water conservation measures adopted by producers, water demand 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 RID and LLID. In these districts, the amount of water demand is much lower than that in the SSRID. Here, average water demand 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 demand is highly variable, depending on growing season temperature and precipitation. Detailed data on these three LDDA irrigation districts are shown in Appendix C (Table C.2).

The average water demand for irrigation in the Qu'Appelle River Basin in 2010 was based on the amount demanded in the SSRID. Because the irrigation districts in the Qu'Appelle River Basin are not connected by pipelines, their water demand was therefore assumed to be similar to that in the SSRID. Since water demand is determined by the method of its delivery to crops, data on this aspect were also collected.

Holm (2008) estimates a range of efficiencies for a number of irrigation systems considered to serve the Prairie Provinces. Details are shown in Table 3.4. No adjustment was made to these coefficients for efficiency of conveyance method. However, the conveyance efficiency is implicitly assumed to be included in the coefficients for the SSRID.

According to these estimates, water demand can vary from 200 mm per acre to 571.8 mm per acre. The lower amount occurs from the allocation of water for the 200 mm backflood irrigation method. The higher level of water demand results from surface irrigation methods (See Figure 3.2). The sprinkler systems typically have higher efficiency levels and therefore, a lower per acre water demand.

To estimate a water demand for the irrigated area of the Qu'Appelle River Basin, two other types of information were needed: one, distribution of total irrigated area by method of water delivery to the crops; and two, the crops grown for each method of water delivery. Details on distribution of total irrigated area in the basin categorized by method of water delivery are shown in Table 3.5. Almost a third of the total area (32.9%) is irrigated by pivots, followed by backflood system (19.9%), and miscellaneous backflood (16.4%). A little over half of the total irrigated area is served by sprinkler irrigation systems.

Table 3.4: System Efficiency and Water Application Coefficients for the Qu'Appelle River Basin Irrigation

Water Delivery Method	System Efficiency	2010 Coefficients (mm per acre)
Wheelmove	65%	395.8
Pivot	75%	353.7
Linear	65%	395.8
Miscellaneous	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.

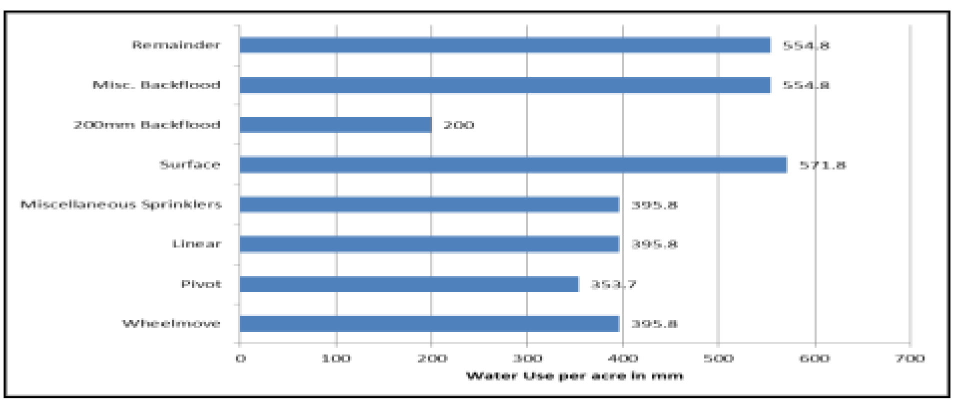


Figure 3.2: Water Demand Coefficients (mm per acre) for different Types of Irrigation Methods

Table 3.5: Irrigated Area in the Qu'Appelle River Basin by Type of Irrigation System, 2010

Irrigation System	**Area**	**Percent**
Wheelmove	3,951	11.0%
Pivot	11,759	32.9%
Misc. Sprinklers	2,863	8.0%
Surface	3,581	10.0%
200 mm Backflood	7,107	19.9%
Misc. Backflood	5,848	16.4%
Remainder	654	1.8%
Total	35,763	100%

Source: Saskatchewan Ministry of Agriculture (2011a), and SWA (2011b).

The second type of information needed for estimating the water demand coefficient for irrigation pertains to crop types grown on irrigated lands in the basin. However, data on the mix of crops grown on irrigated lands in the basin are not available. Although for irrigation districts, some data are collected, such information is unavailable from the private irrigators. Irrigation district producers in the LDDA have been surveyed, and their crop mix is reported in Table 3.6.

Table 3.6: Crop Mix in the LDDA Irrigation Districts and Qu'Appelle River Basin in Saskatchewan

Crop Type	**Lake Diefenbaker Development Area**	**Qu'Appelle River Basin**
Oilseeds	34%	34%
Cereals	30%	48%
Pulse	12%	12%
Forage	14%	6%
Vegetables	9%	
Miscellaneous	1%	
Total	**100%**	**100%**

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

The Qu'Appelle River Basin's crop mix was estimated in consultation with Mr. John Linsley and data from Saskatchewan Ministry of Agriculture (2011c). This crop mix for all seeded area reveals a greater area for the cereal crops and less for the forages. Unfortunately, data on vegetable, potato, fruit, and berry production are either not available at the crop district level or, if available, are unusable due to data suppression maintained to meet confidentiality requirements. These high value (on a per acre basis) crops, if grown, would likely be grown on irrigated land. The distribution of various crops by their water delivery system was based on the crop mix shown in Table 3.6. Because of lack in actual crop mix data, most systems were assumed to be similar. The exceptions were backflood, miscellaneous backflood, and remainder, which represent a higher proportion of area within the cereal crops. More details are shown in Table 3.7.

Table 3.7: Crop Mix in Qu'Appelle River Basin by Irrigation System

Irrigation System	Crop Mix					
	Oilseeds	**Cereals**	**Pulse**	**Forage**	**Veg**	**Misc.**
Wheelmove	30%	41%	13%	6%	9%	1%
Pivot	34%	30%	12%	14%	9%	1%
Misc. Sprinklers	30%	41%	13%	6%	9%	1%
Surface	30%	41%	13%	6%	9%	1%
200mm Backflood	34%	48%	13%	6%	0%	0%
Misc. Backflood	34%	48%	13%	6%	0%	0%
Remainder	34%	48%	13%	6%	0%	0%

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 estimates are shown in Table 3.8.

Source of Water for Irrigation: In the Qu'Appelle River Basin, irrigation water is supplied both from surface water and groundwater sources. Using data on irrigation water allocation in the basin for 2010, the groundwater share of the total is estimated at 2.3%. In this year, 44,051 dam^3 of surface water and 997 dam^3 of groundwater were allocated for irrigation purposes.

3.6.1.2 Water Demand for Dryland Crop Production

For dryland crop production, water is used primarily for herbicide application. This water demand was estimated by the crop mix in the basin, tillage practices and rotations followed, and average amounts of water needed for such applications. Further consideration was taken for 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 in the 40 – 60 litres per acre range, with 2-3 applications consisting of a pre-seed and an in-crop (herbicide, fungicide or insecticide) application, depending on 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 a practice is not possible for the zero tillage areas, which makes the number of herbicide applications higher. Herbicides are also applied to summerfallow[13] when Chem Fallow[14] or Chem/Till fallow are used. The herbicide applications for these techniques range from 1 to 4 passes, depending on weed growth.

Table 3.8: Irrigation Water Demand by Crops for the Qu'Appelle River Basin Irrigated Areas

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).

Water is also necessary for cleaning the sprayer for end-of-day shutdown and per sprayer cleanout after a pesticide incompatible to the next crop or next pesticide. The factor

[13] 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 by using the moisture and nutrients of more than one crop cycle.

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

suggested to account for this use is 1% of the water demanded for spraying, as estimated by Beaulieu et al. (2001).

Source of Water: Water demanded for pesticide application can come from surface or groundwater sources. This information suggested by source is, however, not available. Data from R. Halliday & Associates (2009) for livestock water demand, such that 51.3% of this water was assumed to be from groundwater sources[15].

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) were obtained from Statistics Canada (2009). These data were subjected to proportional distribution in order to estimate specific crop areas within the basin. These details are shown in Table 3.7.

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

3.6.1.3 Livestock Production

Stockwater demand was estimated by employing the water requirements approach. Since water requirements for different types of livestock are dissimilar, a disaggregated approach was undertaken. This procedure required information on the livestock inventory by type of livestock, which was obtained from Statistics Canada (2006 and 2011a) and from Agriculture Statistics of the Saskatchewan Ministry of Agriculture (2011b). These data include 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 used to allocate the livestock populations to the river basin, referring to the Correspondence Table shown in Appendix B.

The above data include livestock raised on intensive livestock operations in Saskatchewan. These data were obtained from Sask Pork (2011) for hog operations, Saskatchewan Ministry of Agriculture (2008) for feedlot cattle and dairy operations, and from Saskatchewan Turkey Producers Marketing Board (2011) for turkey producing operations. The categories of hog, feedlot cattle, turkey, and dairy production within a crop district were adjusted according to the

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

river basin where the production took place. Again, the proportional area was used for determining the river basin values if the crop district included more than one river basin.

The location of cattle feedlots in Saskatchewan, along with each lot stated capacity range 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 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 for those feedlots with less than 10,000 head capacity were assumed to be filled once. The mid-range of the production capacity was used for feedlots with less than 10,000 animals. In the Qu'Appelle River Basin, approximately, 80.1% of the feedlot capacity belongs to the over 10,000 head category. Estimated total numbers of cattle and calves on farms and on feedlots are shown in Table 3.9.

Table 3.9: Estimated Livestock Population in the Qu'Appelle River Basin, by Type of Animals, 2010

Livestock Type	Number in 2010	Livestock Type	Number in 2010
Total Cattle and Calves		**Other Livestock**	
Bulls	12,030	Bison	14,407
Milk Cows	5,532	Horses	22,117
Beef Cows	233,385	Goats	3,515
Milk Heifers	2,680	Llamas	1,091
Beef replacement Heifers	38,101	Bees	13,377
Feedlot	103,212	Deer	1,266
Calves	228,155	**Poultry and Egg Sector**	
Hog Sector		Laying Hens	219,725
Sows	16,789	Pullets	28,681
Suckling Pigs	365,656	Broilers	8,452,385
Weaned Pigs	293,992	Other Poultry	4,279
Growing Finishing Pigs	293,992	Turkeys (M)	136,766
Boars	590	Turkeys (F)	91,177
Sheep Sector		**Sheep Sector**	
Rams	718	Breeding	3,419
Ewes	14,539	Slaughter	10,890

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

The barn capacity of the hog sector in the Qu'Appelle River Basin was estimated at 17,906, 146,996 and 62,681, 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 Qu'Appelle basin. Mandatory Country of origin labeling (MCOOL) in the United States has also affected the weanling market in Canada, resulting in lessened 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.

In addition, the sheep industry in Saskatchewan has been 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, as well as by the MCOOL regulations mentioned above. 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). Farms in the basin are estimated to have around 8 million broilers, besides laying hens and pullets. Turkeys on farms in the basin are relatively fewer, numbering only about 228 thousand birds.

In addition to the above types of livestock, farms in the basin also house other animals, including bison, horses, goats, Llamas and Alpaca. The estimated number of these livestock types in Saskatchewan was collected from Statistics Canada (2006), from data available on a crop district basis. The 2006 values were taken as a proxy for 2010 levels of such livestock inventories within the crop districts and were allocated to the river basin. Provincial associations were contacted to check for data availability on herd sizes of their respective animal types. However, 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. Other animal types were relatively fewer in number.

The literature on animal husbandry 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 share a common range. The main problem is to match the livestock categories in the data with appropriate water demand coefficients. The base coefficients employed here to estimate stockwatering demand for the Qu'Appelle River Basin are shown in the last column of Table 3.10. These numbers fall within the range shown in the previous columns; however, the water coefficients for dairy cows and swine include the water used for cleanup, unlike the figures for the referenced coefficients.

3.6.1.4 Greenhouses' 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. The average annual operation of greenhouses has gone from 5.6 months in 2007 to 6.1 months in 2010 -- an increase of 9.1% while the area of greenhouses in Saskatchewan 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 this main products, along vegetables in approximately 12,000 of 187,626 m^2 of greenhouse area in Saskatchewan.

Table 3.10: Estimated Range of Water Consumption Litres per Day

	Amount in Litres per Day			
Animal	**A la Olkowski**[a]	**A la OMAFRA**[b]	**A la Beaulieu et al.**[c]	**Water Demand Coefficient in L per day**[d]
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 greenhouse area in the basin. Again, for lack of a better proxy, the relative area of the crop district within the Qu'Appelle River Basin was used to allocate provincial greenhouse area to the basin. The same procedure was followed for the area of nurseries in the basin for bedding plant, and potted plants. The estimated area of greenhouses in the Qu'Appelle River Basin in 2010 was 38,567 m^2 or 9.53 acres.

Water demand for greenhouse and nursery activities was estimated by the area in production and the type of product. Water demand coefficients were obtained from Beaulieu et al. (2001) and include water for spraying as well as for cleanup. Water demand for these activities were estimated and weighted for both types of operations, 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

There is a provincial hatchery at Fort Qu'Appelle that uses water from surface as well as groundwater sources. The Echo Lake Fish Hatchery has a 1,000 dam^3 Water Right license with nearly 100% returned to the lake (SWA 2007a). R. Halliday & Associates (2009) reported an estimated 111 dam^3 taken from groundwater sources for aquaculture in the Qu'Appelle River Basin. For lack of more concrete data, this latter estimate was used in this study for this purpose.

3.6.2 Industrial and Mining Water Demand

Industrial and mining water demand in this study includes all goods-producing industries (excluding agriculture), and mining operations[16]. 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 outside municipals demand requires further estimation. Various types of industrial water demand in the Qu'Appelle River Basin are described in this section.

3.6.2.1 Potash Production

The current amount of water demanded for potash production processes depends on the nature of the mining technology and the level of potash production. In the basin, two mines use the solution mining process; they are located at Belle Plaine and Wynyard. The other three mines employ the underground mining process, where potash ore is taken out and processed into usable fertilizer. The water demand coefficient was estimated by dividing the 5-year average water demand by the corresponding average potash production for each mine over the 2006-10 period. Amount of water demanded was obtained from the SWA (2011a), whereas the production data

[16] In addition, power generation water demand was also included here. However, there is no power generation in the basin.

were provided by the potash companies, as reported in Table 3.11. Solution mining of the ore, which is done at the Belle Plaine and Wynyard mine sites, has a significantly higher water demand coefficient than for underground mine sites.

Table 3.11: Estimated Water Demand Coefficients for Potash Mines in the Qu'Appelle River Basin, 2010

Corporation	Location	Mine Type	Potash Production 5-Year Average (Thousand tonnes)	Water Demand 5- Year Average (dam^3)	Water Demand Coefficient (dam^3/1000 t)
Potash Corporation of Saskatchewan	Lanigan	Underground	1,718	2,352.0	1.37
Mosaic	Esterhazy	Underground	3,148	2,498.6	0.79
	Belle Plaine	Solution	1,663	9,194.8	5.53
	Colonsay	Underground	1,069	859.4	0.80
Big Quill	Wynyard	Solution	475	1,176.8	2.48

Source: SWA (2011a) for water demanded; Potash companies' websites, financial statements and annual reports.

Estimated coefficients for underground potash mining were in the range of 0.79 to 1.37 dam^3 per thousand tonnes of potash produced. The estimated coefficient for the solution mine at the Belle Plaine was estimated to be almost seven times as high – at 5.53 dam^3 of water to produce 1,000 tonnes of potash. Differences in the technologies of the milling processes of the mines, along with the type of end product, appear to be the reason for wide-ranging coefficient values[17].

3.6.2.2 Oil and Gas Production

The Bakken oil formation in southeast Saskatchewan extends into the Qu'Appelle River Basin with current oil drilling activity in the Whitewood area. The technology used is primarily horizontal, with a multi-stage frac completion (Saskatchewan Geological Survey, 2011). Non-potable water (plus other chemicals and sand) is pumped down the well at high pressure to create fractures in the shale in order to enable the pumping of oil.

With information from Saskatchewan Ministry of Energy and Resources (2011), the number of wells drilled and producing in an oil formation was employed to estimate the activity in a watershed. The percentage of the oil formation in a watershed (Qu'Appelle = 5% of Bakken) was used to estimate oil reserves in a basin, number of wells drilled by type, and producing

[17] Reasons for these differences are not known at the time of writing this report. Further investigation is required.

wells. The estimated water demand for the oil sector in a watershed is then the number of wells by type multiplied by the water demand coefficient. For the Qu'Appelle watershed, it is estimated that 92 wells were drilled in 2010.

Water demand in enhanced oil recovery from 2002 to 2010, obtained from SWA (2011) indicated a wide range from a minimum of 0.8 dam^3 per well to a max of 966 dam^3 per well. This produced an average of 65.7 dam^3 per well. Further information was obtained about the company's 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.

Wu et al. (2009) report the average amount of water used by various oil recovery technologies (Table 3.12). The coefficients of 11.36 dam^3 of water per horizontal frac oil well (Energy Policy Research Foundation, 2011) and between 2,500 m^3 to 5,000 m^3 of water (Canadian Association of Petroleum Producers, 2011a) for Shale gas using a 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 is the coefficient that will be used for horizontal wells with frac completion, while the water demand coefficients for primary and water flood will be 0.39 and 16.71 dam^3, respectively (Table 3.12).

Table 3.12: 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 Salt Manufacture Water Demand

The Canadian Salt Company at Belle Plaine demanded 29.68 dam^3 of water in 2010 for producing approximately 250,000 tonnes of salt. This resulted in a water demand coefficient of 0.001185 dam^3 per tonne of salt produced. As well, Compass Mineral Group operates a 180 tonnes per day road salt plant at the Mosaic potash mine near Esterhazy (Dumont, 2008). However, no data on its water demand were available. Given that these mines also produce potash, it was assumed that the water demand for salt production is included in the water demand coefficient for potash[18].

3.6.2.4 Manufacturing Water Demand

The water demand for manufacturing is related to several factors -- type of manufacturing, source of water, and annual production level. Their water demand coefficients were estimated by taking into account these factors. These calculations are presented in Table 3.13. Data on their water demand were obtained from SWA (2011a). However, obtaining data on the actual production of these industries was a difficult task because of confidentiality and propriety information concerns. As a proxy, the stated capacity of these firms was taken as a measure of production. Coefficients vary by type of production.

Table 3.13: Estimated Water Demand Coefficients for Manufacturing Industries by Type of Industry, in the Qu'Appelle River Basin, 2010

Type of Manufacturing	Source of Water	Annual Production Level (with Units)	Water Demand in dam^3	Water Demand Coefficient (m^3 / unit)
Ethanol				
Pound-Maker Agventures Ltd.	Groundwater	12 MML/yr		0.0043/litre
Terra Grain Fuels Inc.	Surface Water	150 MML/yr	542.1	0.00361/litre
Fertilizer				
YARA Inc. (previously Saskferco)	Surface Water	1.829 Mt/yr	3,599.5	1.968/tonne
Steel				
EVRAZ Inc. (formerly IPSCO)	Surface Water	3.5 Mt/yr		0.00264/tonne
Petroleum Products Processing				
Consumer Co-op Refineries	Groundwater	34 Mbbl.		0.08829/bbl
Food Processing				
Lilydale	Groundwater	10.1 M birds		0.002395/ bird

Mbbl = million barrel; A barrel has a capacity of 26-53 U.S. gallons. According to Wikipedia (2012), a barrel has a capacity of 42 U.S. gallons. One U.S. gallon is 3.785 litres.

MML = Million litres

Source: Estimates based on SWA (2011a).

[18] It should be noted that this is an assumption at this time and requires further investigation.

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.

Total 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; (iv) Institutional water demand; (v) First Nations' Reservations water demand; and (vi) Other domestic water demands — to include farm and rural non-farm water demand. The methodology for estimating these water demands is described in this section. Total municipal/domestic level water demand represents a product of per capita water demand and population of that given community. Data on water demand and population of various types of communities were obtained from Saskatchewan Watershed Authority.

3.6.3.1 Overview of Estimation

The methodology for arriving at municipal/domestic water demand levels 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 SWA. Trend analysis was undertaken, using these time series data. Three types of trends were estimated: (1) Simple linear trend; (2) Non-linear trend using 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, community population enters the pictures. The hypothesis was that as 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.

If the trend analysis did not produce a meaningful result, an average of past five years was used. For most communities the 2010 population was estimated from 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 the forecasted 2010 over 2009 population. These analyses were undertaken for each of the six types of water demands listed above.

Finally the total population of the Qu'Appelle River Basin was estimated at 328,365. Of this, urban (including First Nations Reservations) population was estimated at 293 thousand people – some 89% of the total. The remaining 11% of the population resided on farms or on other parts of the rural municipalities.

3.6.3.2 Municipal Water Demand

Only two cities,[19] Regina and Moose Jaw, in the Qu'Appelle River Basin have municipal distribution system for water use. The population and per capita water demand for these communities are shown in Table 3.14. Of the two cities, Regina had a slighter lower water demand coefficient – at 143 m^3 per person, as against 180 m^3 per person for Moose Jaw. Relative differences in the composition of industrial production, water sold to neighborhood communities through pipelines, adoption of water conservation measures, and public demand of public water, may be partial explanations for this difference. However, this issue needs to be investigated further.

Table 3.14: Estimated Variables Affecting Total Municipal Water Demand in the Qu'Appelle River Basin, 2010

Particulars	2010 Population	Per Capita Water Demand in m^3	Proportion of Surface Water to Total Water Demand
Moose Jaw	34,559	179.84	100%
Regina	193,707	142.61	100%

Source: SWA (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 Regina. 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). Details on the variables used for estimation of total domestic water demand for these communities are shown in Table 3.15.

Table 3.15: Estimated Variables Affecting Domestic Water Demand in the Qu'Appelle River Basin, 2010

Category	2010 Population	Per Capita Water Demand in m^3	Proportion of Surface Water to Total Water Demand
Bedroom communities around Regina	10,564	123.60	0%
Towns < 1000	13,619	131.27	4.4%
Towns > 1000	17,352	134.07	10.9%

Source: SWA (2010).

[19] As noted in Chapter 2, the City of Humboldt is also in the Qu'Appelle River Basin. However, since the water for this city is provided by the South Saskatchewan River Basin, it is excluded from the municipal water use for the Qu'Appelle River Basin.

3.6.3.4 Rural Water Demand

In addition to populations with municipal and domestic water demands, 15,154 people (constituting almost 5% of the total basin population) live in smaller communities called villages. Estimated water demand and source of water are shown in Table 3.16. Moreover, some people also live in a number of recreational villages in the basin, which are described in Section 3.6.4.

Table 3.16: Estimated Variables Affecting Total Rural Water Demand in the Qu'Appelle River Basin, 2010

Category	2010 Population	Per Capita Water Demand in m^3	Proportion of Surface Water to Total Water Demand
Villages	15,154	112.92	20.7%
Rural Municipal	6,599	112.92	20.7%
Farm Population	29,093	112.92	20.7%

Source: SWA (2010).

Since no information was available, farm and rural non-farm water demands were treated similarly to those of villages. They were assumed to obtain 20.7% of their total water demand from surface water sources.

3.6.3.5 First Nations' Water Demand

There are 22 First Nations' Reservations in the basin. The estimated 2010 population of First Nations' people was 6,710. Their water demand per capita was relatively lower – only 87.92 m^3. This is the lowest per capita water demand of all communities included in this study. Partial explanations for this lower water demand, although it does need further investigation, may include lack of water availability, and/or lower needs for lawn watering and related purposes. Because of the lack of information on water sources for these communities, they were assumed to have similar sources of water as did villages. In other words, 20.7% of the water was assumed to be from surface water bodies, while the rest came from groundwater sources.

3.6.3.6 Other Domestic Water Demands

No water demand was found that belonged to this category of water demand.

The determination of water demand coefficients for these demands was challenging. Unfortunately, no established water demand coefficient was found in the literature. In this study, the estimation of total water demand was based on the level of water demand for villages. The source of their water was assumed to be from groundwater sources[20].

[20] There are farms in the province which are connected by rural pipelines drawing surface water. However, obtaining such details was considered beyond the scope of this study.

A comparison of relative water demand per capita for all different types of communities is shown in Figure 3.3. The highest was estimated for recreational villages (almost 410 m^3 per capita) and the lowest for First Nations' Reservations (at 88 m^3 per capita**)**.

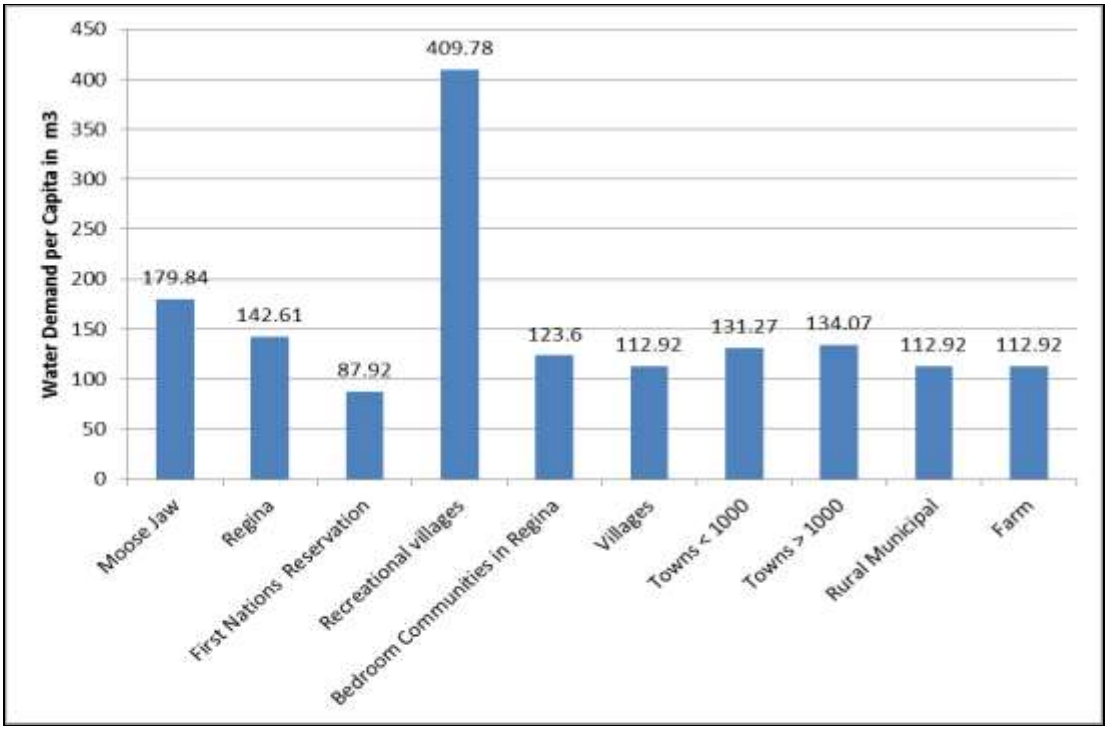


Figure 3.3: Estimated Water Demand per Capita in Various Qu'Appelle River Basin Communities, by Type of Communities, 2010

3.6.3.7 Institutional Water Demand

As noted in Chapter 2, two public institutions are located in the Qu'Appelle River Basin the Canadian forces training base at Moose Jaw Canadian Forces Base (CFB) 15 Wing and the Regina Correctional Centre, which have water supply systems separate from the nearby communities. The amount of water demanded at Moose Jaw CFB 15 Wing was 218,418 m^3 for 2009, with 800 people working at the base for a per capita amount of 273 m^3.

The latest water demand level available for the Regina Correctional Centre was 113,580 m^3 in 2007. A new section of the prison was added to replace an existing structure in 2008. The average water demand from 1995 to 2007 was 96,448 m^3 for the Regina Correctional facility. However, no estimate of the population was available. For this reason, the number of inmates was assumed to be 300 per annum at the Correctional Centre. The average 2000 to 2007 per inmate water demand was estimated at 364.7 m^3 for the Regina Correctional Centre. This multiplied by inmate number of 300, yielded a total water demand estimate for 2010 of 109.4 dam^3.

3.6.4 Tourism and Recreational Water Demand

Tourism and recreational water demand results from two types of water demands: non-consumptive water demand in surface water bodies and consumptive water demand through permanent residents at these recreational sites. The first type of water demand is related to the visitation of tourists (local and out of the region) to the basin facilities. However, this amount of water comes from natural sources and being non-consumptive in nature, is assumed not to vary from year to year.

Major recreational sites in the basin exist within provincial parks, and some others are maintained by the local / regional governments. Between 2004 and 2009, there has been a significant increase in the number of visitors (Table 3.17). In 2005, a little more than half a million visitors were recorded, which increased by 66% in 2009 – over 791 thousand visitors. Most parks are showing signs of increased visitation.

In addition to provincial parks, there are several regional parks, as shown in Table 3.18. However, information on these parks is not available. One can hypothesize that these parks are important resources for local people; the parks likely attract many of them for various recreational activities. These regional parks are reported to have no permanent residents using water.

Table 3.17: Qu'Appelle River Basin Provincial Parks Visitation Level, Selected Periods

Location	Visitors* in		Average 2004-2009	% Increase (decrease) in 2009 over 2004
	2004	2009		
Visitation based on Analysis of Permits				
Buffalo Pound	72,377	117,428	94,903	62.2%
Douglas	35,073	81,265	58,169	131.7%
Echo Valley	78,263	150,810	114,537	92.7%
Rowan's Ravine	78,616	153,781	116,199	95.6%
Based on Estimates				
Crooked Lake	40,000	31,115	31,740	-22.2%
Katepwa Point	93,000	102,000	99,333	9.7%
Based on Hand Counts				
Last Mountain House	972	1,116	1,003	14.8%
Total Visitors to Basin's Recreational Sites	474,877	791,019	630,923	66.6%

Table 3.18: Regional Parks / Recreational Sites in the Qu'Appelle River Basin

Esterhazy
Ituna
Last Mountain
Dunnet
Craik and District
Wynyard and District
McNab
Leroy Lesuireland
Manitou and District

In addition to the above two types of recreational activities within the basin, several recreational locations house permanent residents. These villages have a population of 208 people, and a per capita water demand of 409.78 m^3. All the water was assumed to be obtained from surface water bodies. The other water demand to be estimated is that for parks and other recreational sites. The starting point of these estimates was the water demand data provided by SWA. Some of the sites had an associated population whereas some other did not. The sites with associated population are shown in Table 3.19.

Table 3.19: Populated Recreational Sites in the Qu'Appelle River Basin

Designation	Community	Population in 2009
[OT]	Birds Point Recreation Site	66
[RV]	B-Say-Tah	--
[RV]	Etters Beach Resort Village	15
[RV]	Grandview Beach	35
[RV]	Kannata Valley	133
[RV]	Manitou Beach	25
Total Population		208

Note: RV – water based recreational sites, OT – other recreational sites.

For those parks with visitation data, average water demand per visit was estimated over the period 2004 to 2009. An average of these values was selected as the water demand coefficient for 2010. To estimate 2010 water demand, the average number of visits over the 2004-2009 period was multiplied by this average water demand coefficient. For recreational sites without any visitation data, average for 2004-2009 was used as the estimated water demand for 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 the 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 breakup 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 to stream flows.

Evaporation generally takes place from large surface water bodies. According to the Atlas of Canada (see Natural Resources Canada, 2011), estimates of the mean annual lake evaporation in the Qu'Appelle River Basin varies from 900 mm in the southwest part of the basin to 700 mm in the north section.[21] As a comparison, mean annual net evaporation from small lakes and reservoirs varies from 600 mm in the south west to 425 mm in the north and 375 in the east of the Qu'Appelle River Basin, which was used to record evaporation rates for various locations (Saskatchewan Watershed Authority, 2009). In some cases, interpolation was also made. These values are shown in Table 3.20.

The quantity of water lost to evaporation is simply a function of estimated area of lakes and other surface water bodies, and net evaporation is used to estimate the quantity of water demanded for this situation in the Qu'Appelle River Basin. Estimated evaporation rates from various water bodies in the basin are shown in Table 3.20. These varied from 375 to 550 mm per annum.

3.6.5.2 Net Environmental Water Demand

Environmental water demand is identified as the amount required maintaining or preserving some environmental goals of the society. Included in this category are activities such as wetland preservation and other maintenance of environmental sites. One must note that some of the activities also attract visitors from the basin and beyond. However, in this study, this water demand is classified as that allocated to environmental purposes. There are several environmental projects in the basin, as listed in Table 3.21. Included here are wetlands habitat restoration and preservation by Ducks Unlimited and the Nature Conservancy of Canada. Public and private land is kept by these various organizations to increase or maintain wetland area.

There are a number of wetlands which have been preserved through the Thunder Creek Irrigation District. These wetlands exist "over 4,000 hectares/10,000 acres on 17 project segments. In addition, there are 1,200 hectares/3,000 acres of upland nesting-cover on 10 parcels of land preserved" (SIPA, 2008a). The Nature Conservancy of Canada has 5 projects comprising 3 quarters of donated land, 4 quarters of purchased land, and 4 quarters of land with conservation easements, in the Upper Qu'Appelle watershed (SWA, 2007b).

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

Table 3.20: Area and Evaporation on Qu'Appelle River Basin Surface Water Bodies

Category	Site	Surface Water Body in Sq. Km*	Evaporation Losses in mm per Sq. km**
Lakes	Buffalo Pound	29	550
	Last Mountain Lake	227	525
	Round Lake	10.9	375
	Crooked Lake	15.0	425
	Katepawa Lake	16.5	475
	Echo Lake	12.6	475
	Mission Lake	7.7	475
	Pasqua Lake	20.2	500
	Quill Lakes	635	400
	Paysen Lake	1.0	450
	Foam Lake	2.1	375
	Eyebrow Lake	9.0	560
	Devils Lake	0.6	525
	Boulder Lake	0.6	475
	Bank Lake	0.2	450
	Mit Lake	0.005	450
	Whitewood Lake	2	425
	Kutawa Lake	0.2	450
	Horse Lake	1.0	425
	Kettlehut Lake	0.8	450
	Pelican Lake	8.2	550
	Little Manitou Lake	33	475
	Kutawagon Lake	2	450
	Humbolt Lake	1.2	425
	Wolverine Lake	0.2	425
	Jansen Lake	0.7	425
	Buffalo Lake	0.7	450
	Axe Lake	0.31	450
	Strap Lake	0.2	450
Reservoirs	Esterhazy Dam	0.1	375
	Wascana Lake Weir	0.1	550
	Zelma Dam	1.2	550
	Dellwood Brook Dam	0.1	550
	Five Mile Dam	0.1	550
	Hugonard Dam	0.1	550
	Kingway Dam	0.1	550
	Selcan Weir	0.1	550

* Water body areas were obtained from SWA 2007 (a); Google Maps – Area estimated from satellite maps; Wikipedia – List of Saskatchewan Lakes;

** Estimated using SWA (2009) map.

Table 3.21: List of Environmental Projects in the Qu'Appelle River Basin, 2010

Project Type	Location	Description	Amount of Water Demand
Wetland by Ducks Unlimited	Thunder Creek Irrigation Project	Series of wetlands over 4,000 ha (or 10,000 acres)	
Wetlands by Nature Conservancy of Canada	Upper Qu'Appelle Watershed	13 projects with land donated, or purchased, and land with conservation easements	
Bird Observatory	Last Mountain		0.7 m^3 per second
Fishway	Katepwa Fishway		2.8 m^3 per second

In addition to wetlands, there are a number of other environmental projects in the basin. Examples of these include the Last Mountain Lake Bird Observatory; Eyebrow Marsh, which requires a minimum of 0.7 m^3 per second of river flow to maintain the marsh; and Katepwa Fishway, which requires water release at a rate of 2.8 m^3 per second from break up until late June (SWA, 2007b).

Water demand for these various projects is highly variable because spring runoff and water flows are the main sources of recharge. For this reason, it is assumed that after the initial intake to fill the wetlands, a very small quantity of water is needed.

3.6.5.3 Apportionment Water Demand

The PPWB has calculated apportionable flows from the Qu'Appelle River to the Province of Manitoba. These, along with natural (recorded) flows of the river, are shown in Figure 3.4. Over the 33 year period (1977 to 2009), the natural flows of the river have been large enough to cover the apportionable flows to Manitoba. This condition applied during periods of low flows, as well as high flow.

Over the past few years, the natural flow of water in the Qu'Appelle River has been adequate to meet apportionment water requirements under the MAA.[22] Therefore, no specific data are associated with the apportionment requirements for the Qu'Appelle River. There may also be some dry years when additional water may have to be released. However, such has not been the

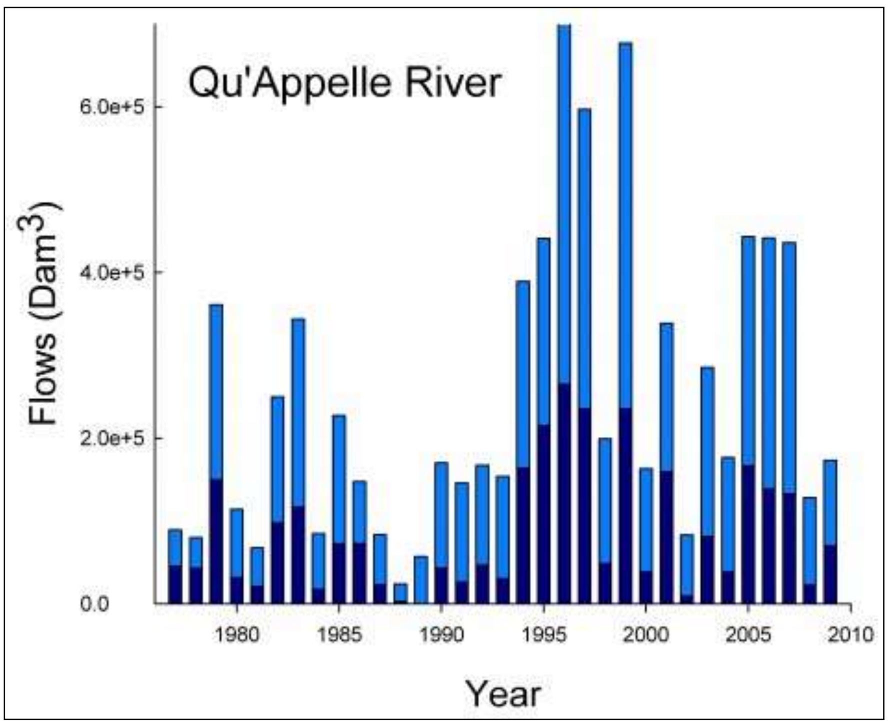
[22] This is based on advice received from Mr. Mike Renouf (Environment Canada) and Mr. Bart Oegema (Saskatchewan Watershed Authority).

case over the past 25 years. Using this information, it was assumed that for 2010, apportionment water demand would be negligible.

Assuming that these conditions would have applied to 2010, the current level of apportionable flow of water was estimated to be zero – it was covered by the natural flow of the river.

3.6.5.4 Other Water Demands: Instream Flow Requirements

The Qu'Appelle River System provides habitat for a variety of fish and wildlife species. The Qu'Appelle Dam may be operated to maintain instream 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. The method's criterion recommends winter and summer base flows as a percentage of average annual flows; however, for the Prairie Provinces, the relationship between fish production and stream discharge has not been fully established, 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 it could not endorse the Tennant Method for determining the Qu'Appelle River instream flow requirements at this time, pending further analysis.



Source: PPWB (2012).
Note: Dark blue area shows the apportionment flows, whereas the light blue shows natural flows, which include the apportionment flows.

Figure 3.4: Natural and Apportionable Flows in the Qu'Appelle River near Welby, 1977-2009

Saskatchewan Tourism and Renewable Resources completed a fish and wildlife management study for the Qu'Appelle River System (Dunn and Hjertaas, 1981). The study identified maximum, optimum and minimum flow as well as lake level requirements for fish and wildlife production in the Qu'Appelle River system. The average minimum monthly flows, interpolated from the graph, are shown in Table 3.23. A translation of these values in terms of annual water demand was not attempted in this study. However, if one takes the maximum water requirements (for the month of May), converting them to yearly flow yields a value of 89,247 dam^3 of water. Similarly, to meet the minimum flow needs, the requirement would be 44,466 dam^3 of water. Nonetheless, this number is subject to some challenges. SWA (2007a) provided a current fish and wildlife water demand of 4,946 dam^3. In this study, this latter estimate is used.

Table 3.22: Monthly Mean Minimum Instream Flows for Fish and Wildlife Production (CMS)

Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1.41	1.41	1.41	2.5	2.83	2.47	1.41	1.41	1.41	1.41	1.41	1.41

Source: SWA (2007a and 2007b)

3.7 Return Flow and Water Consumption Estimation

If one follows the methodology outlined in previous sections of this chapter, the resulting estimate would be gross water demand (GWD) – 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) estimate 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, 78.7% of the total water intake by manufacturing establishments is returned to the source. However, this ratio would not apply to weight-gaining[23] processing firms such as ethanol production.

[23] A weight gaining process is one where in the weight of raw materials used in the process is less that of the finished product. This effect occurs because some water is added to the finished product.

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)

Water consumption for a given type of water demand simply represents 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 comes from urban (municipal systems) water demand, followed by irrigation and manufacturing.

The data and information provided in this chapter was used to estimate current (for the year 2010) water demand in the Qu'Appelle River Basin. 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 three scenarios – baseline, climate change, and water conservation scenarios. This methodology is presented in Chapters 4 and 5.

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%
	Other Irrigation	100%
Industrial Water Demand	Potash Production	100%
	Oil and Gas Production	100%
	Manufacturing	21.3%
Municipal/Domestic Water Demand	Municipalities	32%
	Other communities	100%
	Institutions*	32%
Recreation and Indirect Anthropogenic Water Demands		100%

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

Chapter 4
Forecasting Future Water Demand

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

Since current water demand is directly related to level 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 will occur if there may be a significant change in the water demand coefficients for various activities. Two factors can affect water demand coefficients in the future: One, the onset of climate change by 2030 or thereafter, and Two, adoption of water conservation measures. Water conservation policies of the province and other levels of government regulations regarding water use may also determine the rate of change in this level. Future water demand levels can also be altered by the state of water availability, leading to further water conservation or to curtailing of certain types of economic activities.[24] The methodology for estimating the water demand patterns under climate change and water conservation 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 level of water demand 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: judgmental forecasts; visual forecasts, and causal or extrapolative forecasts. Judgmental and visual approaches rely on the individuals' or a group's experiences and may be entirely subjective in nature. These are preferred only if other approaches are not feasible. Causal or explanatory forecasts are those in which 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

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

has been used for domestic and municipal water demands since the mid-1970s. However, these calculations require extensive data on water demand quantities and the various factors affecting it. The extrapolative forecasts are derived from time series data, involving consideration of variables of concern and the prediction of future values 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 very popular area of study except for municipal and/or domestic water demands. Several studies were found, which are summarized below. In all cases, it appears that the forecasting methodology for water demand is generally based on an assumption that the present trend and practices will continue into the future, with some alteration, if needed.

4.2.1 Future Water Demand by Agriculture

Water demand for agriculture is a complex set, consisting of various demands. 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 elements may be affected by a different set of factors and, by their effects, may be of 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. The crop irrigation water demand, in some studies, is estimated using the Food and Agriculture Organization's crop coefficient method (FAO, 1998), which 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 12 cm high and 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 and Mining Water Demand

No study was found that provided a specific methodology for Industrial and Mining water demands. Brockman and Kulshreshtha (1988) estimate basin level water use for various activities (including industrial and mining water use) through an input-output model and final demand estimates. Final demand changes were associated with changes in their respective production levels. Smith (1986) identifies factors such as manufacturing production, price or charges for water, and unemployment in the region for estimating future water use. 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 the project.

4.2.3 Future Municipal/Domestic Water Demand

Municipal water demand includes residential, commercial, and industrial purposes. For residential and municipal water demand estimation, population projections provide a basis for an estimation of future growth. Data on demographics and household use rates can be used. For example, in a forecast of 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 reduction in water use factors based on 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 changes in employment over the base period.

4.2.4 Future Recreational Water Demand

Recreational activity related water demand is directly related to levels of water-based recreational activities. 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 a survey of recreationalists. The quality of water at a given site is also a major factor affecting current and future water demand (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 remain similar to those employed for current water demand. This methodology is described below for each of the four direct anthropogenic, as well as for the indirect anthropogenic water demands.

4.3 Study Methodology for Forecasting of Agricultural Water Demand

Total future agricultural water demand in the basin was estimated as a sum of five types: Irrigation, Required for pesticide spraying, Livestock, Greenhouses and nurseries, and Aquaculture. Each of these methodologies is described in the sections below.

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

4.3.1 Future Irrigation Water Demand

For irrigation water demand, 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. The projected irrigated area in the basin was multiplied by the appropriate crop water demand coefficient.

Two factors 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 3.3) was estimated to be 35,763 acres, of which 3,315 acres were in two irrigation districts. According to SIPA (2008b), a new irrigation district is to be created – the Qu'Appelle South Project (QSP). This proposed development concerns at two options: Option A – Irrigation of 108,181 acres, and Option B – Irrigation of 122,351 acres. In this study, the Option A scenario was used. For the Qu'Appelle River Basin, 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 for the Qu'Appelle River Basin

Irrigation District	Irrigated	Expansion in Acres	Total Area in Acres
TCID	1,422	0	1,422
BLID	1,893	0	1,893
Sub Total	**3,315**	**0**	**3,315**
Qu'Appelle South Project (QSP)	**Option A**	108,181	108,181
Total District Irrigation Area under Option A			**111,496**

Source: SIPA (2008b)

The time path of this future irrigated area in the newly developed QSP would depend on the adoption rate of irrigation by producers 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 irrigation projects, Riverhurst (RHID) and Luck Lake (LLID), is shown Table 4.2. Over the past 20 year period, the amount of land irrigated in any one year was highly variable,[26] ranging from 26 to 92% for the RHID and from 29 to 96% for the LLID. The average for these districts was 52% and 61%, respectively.

Table 4.2: Adoption of Irrigation in the Riverhurst (RHID) and Luck Lake Irrigation District (LLID)

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)

Private irrigation, which in 2010 was 32,448 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

[26] A possible reason for this is that although water is available, producers do have a choice of not using irrigation for a given point in time.

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 already been developed (data from Saskatchewan Ministry of Agriculture, 2011b). The irrigated area outside of the Lake Diefenbaker irrigation districts would, at best, see an average growth rate of 0.77% to 2060. This figure roughly equates to a quarter-section per year to 2060, amounting to 1,269 acres by 2020, 4,120 acres by 2040, and 7,443 acres by 2060 for the Qu'Appelle River Basin.

SIPA (2008A) estimated a period of 10 years for the uptake of irrigation in the proposed QSP. If 2020, 2040, or 2060 are drought years, the area for the irrigation would be quite high, as well as the amount of water demanded per hectare. The time involved to develop the QSP project is estimated at 11 years, after which irrigation can start (SIPA, 2008b). Therefore, by 2020, it is not likely that any of the proposed QSP area will be irrigated. The future irrigated area in the basin is shown in Figure 4.1. The total irrigated area will grow from its current (2010) 35,763 acres to 140,569 acres – an almost three-fold increase.

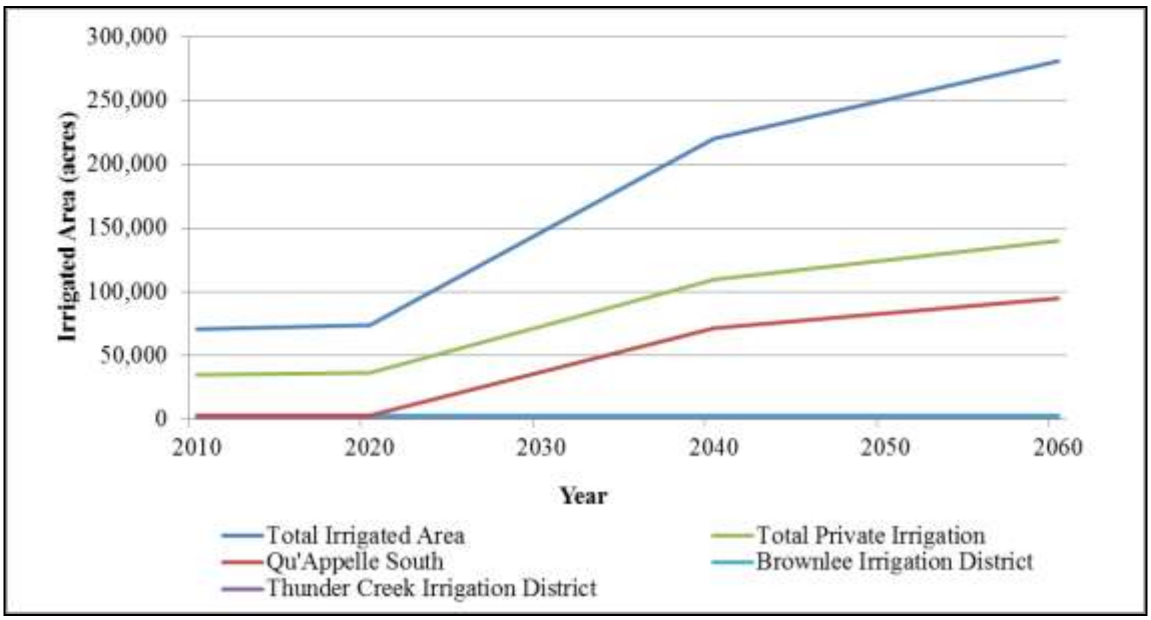

Figure 4.1: Trend in Irrigated Area Development for the Qu'Appelle River Basin,2010 - 2060

The area of irrigated land in the Qu'Appelle River Basin is presented in Table 4.3 by type of irrigation. It is assumed that the additional land irrigated outside the irrigation districts and the proposed Qu'Appelle South Project would be center pivot. It is also assumed that 65% of the proposed Qu'Appelle South Project will be in operation by 2040 and 90% by 2060. By 2060, 83% of irrigation water will be provided by pivots.

Table 4.3: Area of Irrigation in the Qu'Appelle River Basin, in Acres, by Type of Irrigation Method

Irrigation System	Area in Acres			
	2010	**2020**	**2040**	**2060**
Wheelmove	3,951	3,951	3,951	3,951
Pivot	11,759	13,028	86,197	116,565
Linear	-	-	-	-
Misc. Sprinklers	2,863	2,863	2,863	2,863
Surface	3,581	3,581	3,581	3,581
200mm Backflood	7,106	7,106	7,106	7,106
Misc. Backflood	5,848	5,848	5,848	5,848
Remainder	654	654	654	654
Total	**35,763**	**37,032**	**110,201**	**140,569**

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

4.3.1.2 Future Irrigation Crop Water Demand Coefficients

The future irrigation water demand was derived from future irrigated area and a 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 discussed in Chapter 5.

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. Data were obtained from various LDDA irrigation districts where metering of water is in place.

Metered irrigation water demand from the RHID 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 (SWA, 2011b). What crops this irrigation water was used on and at what rate is unknown. However, on average, it appears to be consistent with the estimate of the normal crop water deficit used 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. These operations would require more silage for feedlot cattle production, which has different water requirements. However, since no further information is available, possible effects of this issue were excluded in this study. In essence, water demand coefficients for irrigation were developed by using crop requirements and water deficit. These coefficients for 2020, 2040, and 2060 were assumed to remain the same as those shown in Table 3.3, along with the distribution of crop mix by irrigation system.

4.3.2 Dryland Crop Production Activities

4.3.2.1 Cropland Area

Estimation of the basin area under various crops for 2020 was based on the AAFC (2011) Medium Term Outlook for 2017. Crop areas 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 the AAFC (2011) study. The percentage change in area seeded to a crop from 2010 to 2020 in that study was applied to the area seeded at the water basin level in 2009 in order to arrive at the estimated 2020 seeded area for the Qu'Appelle River Basin.

Estimates for 2040 and 2060 have to consider relative net returns, given that the yield and price of a commodity will determine the area seeded. Productivity gains in crop yields from 1964 to 2007 show a similarly increasing linear trend of about 60% over this period (Veeman and Gray 2009). However, this implies a declining proportional rate of growth, as there is a constant absolute rate of growth in yields. So, the relative net returns will be affected primarily by the crop response to the climate conditions in 2040 or 2060, given the expenditure on developing new varieties. Currently, in the Qu'Appelle River Basin, 33.8% of the total cultivated area is in oilseeds, 47.6% in cereals, 13.1% in pulse, and 5.5% fallow (Table 4.4). These proportions may change slightly in the future, but such forecasts are left for future studies.

Table 4.4: Estimate of Percentage of Cultivated Area by Crop in Qu'Appelle River Basin

Crop Type	Percent of Total Area under Crops			
	2009	2020	2040	2060
Cereals	47.6%	46.2%	50.0%	50.0%
Oilseeds	33.8%	37.6%	33.0%	33.0%
Pulses	13.1%	12.0%	13.0%	13.0%
Fallow	5.5%	4.2%	5.0%	5.0%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**

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

One could expect that the percentages of these broad classifications would change only marginally over time. The world markets for the crops would have a greater impact on the types grown within the categories. For estimating the water demanded for spraying, the area of the broad categories of crops was used. The total cropped area was assumed to be unchanged. This condition assumes that in the basin, there will be no urban sprawl from the cities of Regina and Moose Jaw. Total cropped area by crop categories are shown in Table 4.5.

Table 4.5: Estimate of Cultivated Area by Activity, Qu'Appelle River Basin, 2009 - 2060

Crop Type	Area in Acres			
	2009	**2020**	**2040**	**2060**
Cereals	1,599,173	1,550,668	1,662,359	1,662,359
Oilseeds	1,133,860	1,263,042	1,108,239	1,108,239
Pulses	439,137	403,759	419,788	419,788
Fallow	186,039	140,833	167,915	167,915
Total	**3,358,208**	**3,358,301**	**3,358,301**	**3,358,301**

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

4.3.2.2 Crop Pesticide Application

In addition to crop mix, a number of other factors can change the 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 a dramatic reduction in summerfallow and a greater diversity of crops grown. Removal of the Crow rate for transport of grains (a major transportation subsidy) has also resulted in farmers seeding 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, and 5% fallow.

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 pass times 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 or Chem-Till Fallow. The result is an average water demand per acre for pesticide application, and future demand figures 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. At the outset, a graphical trend analysis was undertaken for sheep, pigs, cattle and calves, and chicken and hen inventory. The trend in sheep numbers shows a gradual increase in total sheep production from 2001 to 2004, but more recently production declined and continued to do so until 2010 (Figure 4.2).

For hogs, there was a slight increase in production in 2008, after which it declined (Figure 4.3). The annual increase in the total number of pigs produced grew from 2001 to 2004. The total production declined in 2005 and 2006 and then increased by about 212.07% in 2007. However, there was another decline in production from 2008 to 2010. Cattle and calf inventory, as shown in Figure 4.4, followed the same trend, but with a gradual annual increase from 2001 to 2005. In 2006, there was an approximately 5.6% decrease in total cattle and calf production, while production rose again in 2007 and declined from 2008 to 2010. Chicken inventory in the basin is on the rise, as shown in Figure 4.5.

Table 4.6: Estimates of Zero Tillage Adoption and Sprayer Passes Qu'Appelle River Basin, 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

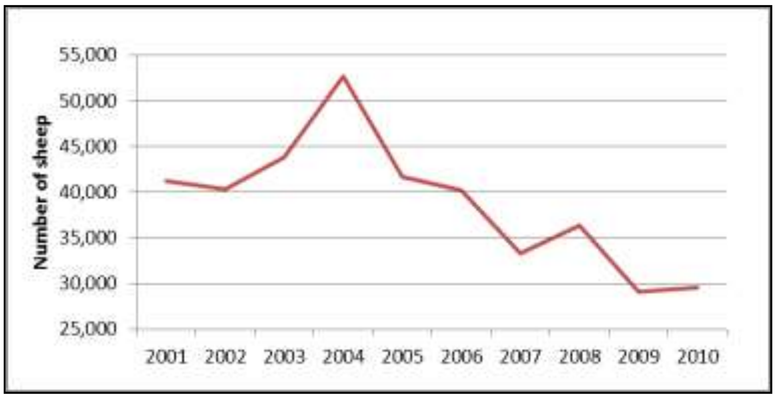

Figure 4.2: Trend in Sheep Production in the Qu'Appelle River Basin, 2001-2010

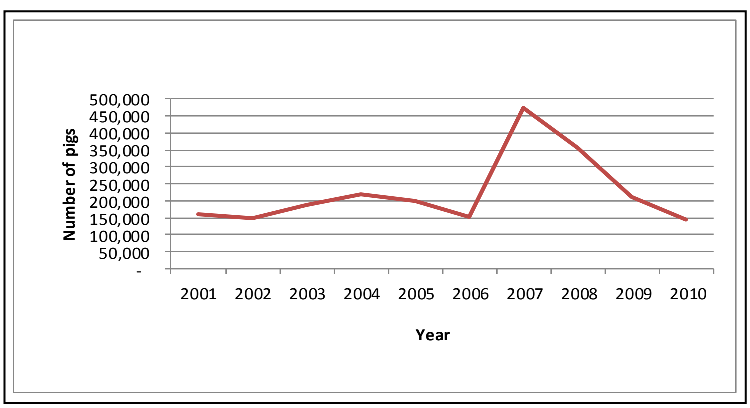

Figure 4.3: Trend in Hog Production, Qu'Appelle River Basin, 2001-2010

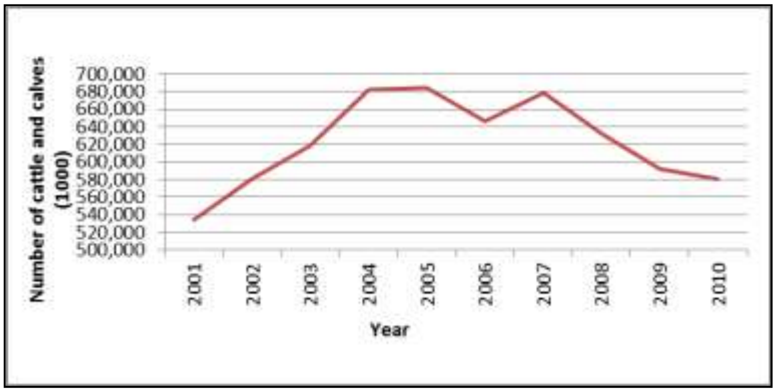

Figure 4.4: Trend in Cattle and Calves Production, Qu'Appelle River Basin, 2001-2010

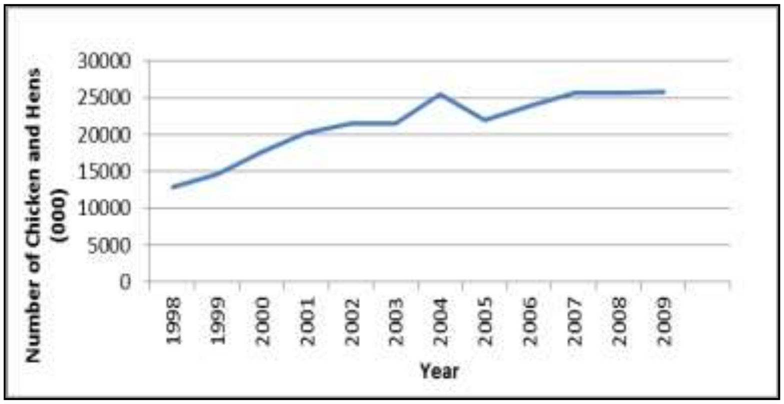

Figure 4.5: Trend in Chicken Production, Qu'Appelle River Basin, 2001-2009

4.3.3.1 Estimation of Livestock Population for Future Periods

Estimation of the production of livestock for 2020 followed AAFC (2011) Medium Term Outlook for 2017. Inventories of animals within the dairy, poultry, sheep, hog, and beef sectors, as well as laying hens for egg production were forecasted.

Productivity growth rates for the various sectors are important in estimating the activity levels for the various sectors in 2040 and 2060. First, relative growth rates can influence the profitability of a sector and thus the resulting investment in that sector and its production. Technical changes 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 employed 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. In addition, mapping of the genome will allow for greater accuracy in selecting animals for desirable traits and in enhancing these traits are related to productivity. Intensive livestock operations at present are able to implement these new technologies and therefore capture increased productivity gains. Veeman and Gray (2009) report productivity gains for various types of animals: 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.[27] Therefore, it would take fewer livestock to attain a specific level of final consumer product.

The total cattle population within the Qu'Appelle River Basin has over the 2000 to 2010 period, ranged between 534,000 (2001 drought) to 685,000 (2005 BSE Crisis) and over the past three or four years, may be settling in at the 580,000 to 600,000 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, and 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 river basin to 2020, 2040, and 2060. Expansion of the irrigation capacity around Lake Diefenbaker could result in a further increase in cattle feedlots as irrigated crops for silage production create a desirable location to establish feedlots.

After taking into account the above considerations, 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 Qu'Appelle River Basin, 2010-2060

Animal Type	Estimated Numbers on Farm in			
	2010	2020	2040	2060
Bulls	12,030	12,900	13,158	13,421
Milk Cows	5,532	5,078	4,977	5,076
Beef Cows	233,385	250,262	255,267	260,372
Milk Heifers	2,680	2,464	2,412	2,460
Beef replacement Heifers	38,101	38,054	41,673	42,507
Feedlot	103,212	114,256	125,681	138,250
Calves	228,155	244,654	249,547	254,538

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

[27] The effect of these technology gains on water use per animal has not been reported in the literature. It is therefore assumed that such an effect will not exist in the future. However, further verification of this assumption is needed.

Table 4.8: Hog Sector Estimated Population for the Qu'Appelle River Basin, 2010-2060

Animal Type	Estimated Numbers on Farm in			
	2010	2020	2040	2060
Gestating Sows	16,789	17,372	17,976	18,602
Suckling Pigs	365,656	395,743	427,481	460,947
Weaned Pigs	293,992	304,215	314,794	325,740
Growing Finishing	293,992	304,215	314,794	325,740
Boars	590	535	493	465

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

Table 4.9: Sheep Sector Estimated Population for the Qu'Appelle River Basin, 2010-2060

Animal Type	Estimated Numbers on Farm in			
	2010	2020	2030	2040
Rams	718	865	873	882
Ewes	14,539	17,499	17,674	17,850
Breeding	3,419	4,115	4,156	4,198
Slaughter	10,890	13,107	13,238	13,370

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

Table 4.10: Estimated Other Livestock Populations for the Qu'Appelle River Basin, 2010-2060

Animal Type	Estimated Numbers on Farm in			
	2010	2020	2040	2060
Bison	14,407	15,847	16,006	16,166
Horses	22,117	22,117	22,117	22,117
Goats	3,515	3,515	3,515	3,515
Llamas	1,091	1,091	1,091	1,091
Bees	13,377	13,377	13,377	13,377
Deer	1,266	1,266	1,266	1,266

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 for 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) 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 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 also affected by the type of pasture and the time of year as these factors are affected by the weather and moisture content of the forage.

Table 4.11: Poultry and Laying Hens Population Estimates for the Qu'Appelle River Basin, 2010-2060

Poultry Type	Number of Birds in			
	2010	2020	2040	2060
Laying Hens	219,725	239,271	263,198	276,358
Pullets	28,681	33,353	36,689	38,523
Broilers	8,452,385	9,747,042	10,721,747	11,257,834
Other Poultry	4,279	4,707	5,177	5,436
Turkeys (M)	136,766	160,137	176,151	184,958
Turkeys (F)	91,177	106,758	117,434	123,306

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

Furthermore, water use technology for the production of hogs has improved significantly over the last 10-15 years as bite type nipples replaced watering bowls and more recently, ball type nipples that reduce wastage even further are being adopted. Small (2001) surveyed hog barns in Manitoba and Saskatchewan to determine the water demand for drinking, washing, cooling, and domestic uses. 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 use by type of swine from Thacker (2001) plus the water used in production from Small (2001).

Beef cattle consumption of water is affected mainly by time of year and feed type. 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. Water consumption estimates at different temperatures for various categories of beef cattle are presented in Table 4.14.

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

Activity	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).

Table 4.13: Drinking Water Consumption for Swine

Type	L/day/Animal
Gestating Sows	8.78
Lactating Sows	20.04
Suckling Pigs	0.71
Weaned Pigs	2.01
Growing Finishing	6.76
Boars	10.27

Source: Adapted from Thacker (2001).

Table 4.14: Beef Cattle Water Consumption (l/day) at Different Temperature

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).

These estimates were used 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 using 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 applied various categories of milk production for given temperatures (Table 4.16) to arrive at water demand coefficients (Table 4.17). Water is also used in the cleaning of dairy operations and it is estimated at 18.0 litres per cow per day (Beaulieu et al. 2001).

Table 4.15: Estimated Water Demand Coefficients for Beef Cattle

Type/Weight	Weight (kg)	Water Demand 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 Demand 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

Water consumption coefficients for six categories of poultry were derived through the same methodology employed to estimate the coefficients for the beef and dairy sector and 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 4.18: 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 served to estimate the total water demand in the basin for livestock production. Apart from climate change, other factors that affect water demand coefficients were assumed to remain the same as at present. The potential effect of climate change in incorporated in Chapter 5.

4.3.4 Greenhouse and Nursery Water Demand

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

Table 4.19: Water Demand Coefficients for Greenhouses and Nurseries, Qu'Appelle River Basin

Particulars	Irrigation	Pesticides	Wash[1]
	m/m2	L/m2	%
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 Qu'Appelle River Basin, 2010 - 2060

Particulars	2010	2020	2040	2060
Area in Acres	9.5	9.6	10.1	10.6
Estimated water demand coefficient dam^3 /ha	30.41	30.41	30.41	30.41

Source: Statistics Canada (2006)

4.3.5 Water Demand for Aquaculture

The amount of water demand could not be estimated because of a lack of data on these operations.[28] As a substitute, the value of this water demand was taken from R. Halliday & Associates' (2009) report. In that report, this value was estimated at 111 dam^3 for the Qu'Appelle River Basin, which was assumed to continue at that level in the future.[29] All this water was assumed to be obtained from groundwater sources.

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 existing industries, an effort was also made to project new industries that might be developed as a result of added irrigation in the basin.

4.4.1 Future Potash Production Related Water Demand

4.4.1.1 Future Potash Production

An increased future production of potash would be a result by expansion of existing companies of their operation, and by the entrance of new companies into the province. There are a number of companies interested in developing new mines, as shown in Table 4.21. However, only BHP Billiton at Jansen, K+S at Bethune, Western Potash at Milestone, Karnalyte Resources at Wynyard, and Vale at Davin appear to be progressing and are likely to be in production by 2020.

The demand for potash is estimated to 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 these five mines come on stream until 2022. 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.

[28] As noted earlier, this is a serious gap in the information related to water use. Efforts are needed to for the take a survey of such users in the Basin (Province) to estimate their water requirements.

[29] Future water use will be affected by growth in this industry, which could be affected by several factors. This is left for further investigation in this area.

Since much of the potash produced in the basin is exported, any expansion of potash mining in the basin would also depend on economic conditions of farmers in the importing countries. In addition, the exchange rates between the Canadian dollar and the importing nations' currencies can also play an important role in determining the future of potash production in the basin.

Table 4.21: Proposed Mine Projects in Qu'Appelle River Basin

Proposing Mine Company	Location	Water Source	Technology of Production
BHP Billiton	Jansen	S&G*	Underground
	Burr	S&G	Underground
	Boulder	Surface	Underground
	Young	Surface	Underground
Karnalyte Resources	Wynyard	Groundwater	Solution
K+S (Potash One)	Bethune	Surface	Solution
Vale	Davin	Surface	Solution
Western Potash	Milestone	Surface	Solution
Canada Juiyi	Hanley	Surface	Unknown

* S&G = Demands both surface and groundwater

Source: CIBC World Markets Inc. (2008)

Traditionally, when producers face low agricultural commodity prices, the amount of potash applied is the first nutrient to be reduced or eliminated because the effect on crop yield over a short period 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. With 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). Expected market price, therefore, will be a determinant of future potash mining activity in the basin.

Another consideration in predicting future potash production is that eventually new mines will have to be built by 2060 to replace the mines developed in the 1950s and 1960s. This may be a result of increased distance to the ore body, which makes further extraction uneconomic at these sites. Water is used in the separation process in all potash mines and in the ore extraction in solution mines. A complete electrostatic process would reduce the demand for water for 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 could an old mill.

The estimated capacity for potash production for the existing mines was 19,300 tonnes per annum. This capacity is expected to increase by 12,129 tonnes per annum by 2020. The capacity for new mines in 2040 is expected to be 14,129 tonnes, which could increase to 20,129 tonnes by 2060. As noted above, these estimates are highly probabilistic.

The respective water coefficients for the existing mines were used to estimate their future water demand (see Section 3.6.2.1). 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 1.37 and 5.53 dam^3 per thousand tonne, respectively, were used to estimate water demand for the new potash mines. Since these are coefficients for mines in the same region as the proposed new mines, one would reasonably expect a similar water demand. This assumption is reasonable since they are operating in the same potash formation. However, future technology in the future may affect these coefficients.

One of the issues in water demand determination is the source of water. Although for most potash mines, the river basin that supplies the water is also the mines' location, there are some exceptions. These are shown in Table 4.22.

4.4.4.2 Water Demand for Tailings Management

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

4.4.3 Oil and Gas Production

Most of the drilling activity in the Bakken formation has occurred outside the Qu'Appelle River Basin to date. The potash layer overlaps the Bakken formation in the Qu'Appelle River Basin which may limit further exploration in this overlapping area. For this reason, limited exploration of oil and gas is assumed to be possible in the Qu'Appelle River Basin, primarily south of the Qu'Appelle Valley and east of Regina. The water demanded for the production of oil and gas comes mainly from groundwater, with an average quantity demanded per well of 53.3 dam^3 per annum[30].

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 them (Saskatchewan Geological Survey).

[30] This figure comes from the Saskatchewan Watershed Authority database on enhanced oil recovery by measure of water.

Details are shown in Table 4.23. The projected number of wells to be 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.

Table 4.22: List of Existing and Future Potash Mines in the Qu'Appelle River Basin by Location and Source of Water

Corporation	Corporation / Mine Site	Located in	Water	
		Basin	Source	From
Potash Corp	Lanigan	Qu'Appelle	S & G	South Sask
Mosaic	Esterhazy	Qu'Appelle	S & G	Qu'Appelle
	Belle Plaine	Qu'Appelle	Surface	Qu'Appelle
	Colonsay	Qu'Appelle	Surface	South Sask
Big Quill		Qu'Appelle	S & G	Qu'Appelle
	Possible New Development			
Potash Corp	Lanigan	Qu'Appelle	Surface	South Sask
			Groundwater	Qu'Appelle
Mosaic	Esterhazy	Qu'Appelle	Surface	Qu'Appelle
			Groundwater	Qu'Appelle
	Belle Plaine	Qu'Appelle	Surface	Qu'Appelle
	Colonsay	Qu'Appelle	Surface	South Sask
Big Quill	Wynyard	Qu'Appelle	Surface	Qu'Appelle
			Groundwater	Qu'Appelle
BHP Billiton	Jansen	Qu'Appelle	S&G	South Sask
	Melville	Qu'Appelle	S or G	Unknown
Karnalyte	Wynyard	Qu'Appelle	Groundwater	Qu'Appelle
K+S (Potash) One)	Bethune	Qu'Appelle	Surface	Qu'Appelle
Vale	Davin	Qu'Appelle	Surface	Qu'Appelle
Western Potash	Milestone	Qu'Appelle	Surface	Qu'Appelle

For the shaded mines, although located in the Qu'Appelle River Basin, their water needs are met from other river basins (South Saskatchewan River Basin through the SSEWS canal).

Table 4.23: Estimate of Drilling Activity in the Qu'Appelle River Basin

Type of Well Drilling	Number of Wells Drilled			
	2010	2020	2040	2060
Vertical	27	37	22	6
Horizontal	65	87	52	13

In the Qu'Appelle Basin oil and gas exploration and development of the Bakken formation by applying the frac completion process is expected to be limited to south of the Qu'Appelle valley. Water demanded for the production of oil and gas in the Qu'Appelle River Basin is based on the estimated well drilling activity by type times the effective coefficient. Enhanced oil recovery water demand is estimated as 4.3% of the number of horizontal wells times the average enhanced oil well coefficient of 43.8 dam^3 per well per year from SWA[31]. The enhanced oil well coefficient is the water demanded over the 2002 to 2010 period for this technique divided by the number of wells applying this technique in Saskatchewan. The total amounts for oil and gas well drilling and production related water demand is shown in Table 4.24.

Table 4.22: Oil and Gas Well Drilling Water Demanded, Qu'Appelle River Basin Forecast for 2010 – 2060

Technology of Production	**Total Water Demand in dam^3**			
	2010	**2020**	**2040**	**2060**
Primary	10.17	13.65	8.19	2.05
Water Flood	22.93	30.79	18.48	4.62
Horizontal	185.25	248.72	149.23	37.31
Enhanced	122.42	164.37	98.62	24.66
Total	**340.78**	**457.54**	**274.52**	**68.63**

In oil and gas production, water is used in well drilling, for the recovery of heavy oil, and for forcing oil from old conventional wells or natural gas from wells that have tight or sandy formations. Oil recovery from oilsands is a water intensive process, although a potential water demand for this type of oil production in Saskatchewan is still a few years in the future. Other than some records on recycling and water audits, very little information is available on feasible water conservation measures. Currently, water demand coefficients used in estimating conventional oil production were 0.87 water: oil (per unit of oil produced), which were estimated to fall to 0.6 water: oil with conservation measures. This translated into between 400 m^3 to 600 m^3 per well. Shale gas using the multi-stage frac completion technique takes between 2,500 m^3 to 5,000 m^3 of water (Canadian Association of Petroleum Producers, 2011)

Salvaging undrinkable water, recycling of water, and CO_2 injection are techniques that can limit the demand from fresh water sources in 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 use of the multi-stage frac technique. The Canadian Association of Petroleum Producers (2011) reports that up to 15% of the water expended has been successfully recycled at

[31] These data were obtained from SWA document "SWDS- Enhanced Oil Recovery 2002-2010.xls."

some sites. This would translate into 9.9 dam^3 per well per annum water demand if the sector were able to attain a 15% recycle rate. This reduction by 15% was applied to estimate the reduction in conservation of water demanded for oil and gas production. The total water demand for oil and gas well drilling and production are shown in Table 4.25.

Table 4.23: Total Water Demand for Oil and Gas Drilling and Production under Water Conservation Scenario in the Qu'Appelle River Basin, 2010-2060

Particulars	Total Water Demand in dam^3 for			
	2010	2020	2040	2060
Total Quantity	340.78	388.91	233.35	58.34

4.4.4 Salt Mining Activities

No new salt mines are assumed to come into production during 2010 - 2060 period. For the existing salt production will increase with demand for it. Road salt from the Esterhazy operation is included in the coefficient for potash production.

4.4.5 Manufacturing Water Demand

Manufacturing water demand in the basin during 2010 - 2060 will be a result of water required by existing industries as well as 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 by reviewing of other studies. Most of these were based on the development of irrigation in the basin.

4.4.5.1 Existing Manufacturing Industries' Water Demand

The estimation of changes in production levels, along with changes in water use technology for industry, is a complex task. For example, Pound-Maker Agventures is limited by the amount of distiller's grain it can feed into the adjacent feedlot. Economic hauling distance for silage and manure are two constraints on the size of the feedlot, which in turn limits the size of ethanol manufacturing. Not having to dry the distiller's grain is a cost advantage relative to the other larger plants. Growth in the ethanol industry to date has been the result of government mandated fuel requirements. It is assumed that the future growth in this industry to 2020 will be heavily dependent on government regulations. The competitive price of ethanol relative to other fuels will determine the market share for 2040 and 2060. Therefore, the ethanol plant at Belle Plaine is likely to see only capacity changes related to efficiency gains in the production process to 2020.

In another industrial example, petroleum refining in the future will change according to gasoline consumption and population growth. Assuming that Saskatchewan could have a population between 1.23 to 1.5 million by 2060 (see Table 4.33), the 2020 population will be 1.143 million. With the same rate of growth, the 2040 population level could be 1.32 million people. Gasoline demand in the future may still go down in response to higher fuel cost (and purchase of more hybrid vehicles). However, no projections of this demand were available for the province. Assuming that gasoline demand on a per capita basis can remain unchanged from 2009, and the refining capacity in the province would increase only in the basin, the estimated petroleum refining capacity for the 2020, 2040, and 2060 periods will increase by 8.4%, 25.2%, and 42.3%, respectively, from the 2010 level.

Another major industry, food production, follows guidelines and standards for safe food production from the Canadian Food Inspection Agency; there are established procedures to meet Hazard Analysis and Critical Control Points (HACCP) certification.[32] Therefore, changes in water use in the production process are limited in order to fall within an acceptable range. New water saving technologies would have to meet or exceed the standards for food safety, resulting in slower technological advancements in this area.

Poultry processing in Canada is under a supply management system, where each province is allocated a production quota. Population and per capita consumption in a province are among the factors considered in adjusting the provincial quota. Given that, production in poultry is estimated to increase from 2010 production levels by 15.4%, 26.9%, and 33.2% to 2020, 2040, and 2060, respectively, it would be reasonable to assume that Lilydale would be in a competitive position to capture a proportional amount of this increased demand.

For fertilizer manufacturing, the Prairie Provinces are the major fertilizer market for western Canadian fertilizer manufacturers. Pricing is secure such that it is price competitive with imported urea plus shipping and handling to interior points in the northern tier states. The demand for fertilizer is dependent on the mix of crops grown in this region, particularly canola, cereals and feed grains. Agricultural commodity prices and the price of nitrogen will, for the most part, drive the demand for nitrogen fertilizer. Any significant shift in this region to crops

[32] Hazard analysis and critical control points is a systematic preventive approach to food safety and pharmaceutical safety that identifies physical, chemical, and biological hazards in production processes that can cause the finished product to be unsafe, and designs measurements to reduce these risks to a safe level. This is designed to prevent hazards rather than to provide a finished product inspection.

that fix their own nitrogen or any biotechnology breakthrough that might allow nitrogen fixation in other crops could change this market. Technologies that increase the efficiency of nitrogen application, such as sideband application or urease[33] inhibitors that are increasingly being used, will reduce the demand for nitrogen. The seeded area in this region is unlikely to change significantly; the mix of crops among the broad categories of small grains and corn, oilseeds, and pulse crops is expected to change little.

The per annum gross domestic product (GDP) increase in Business Machinery and Equipment over the 1980 to 2009 period in Saskatchewan was 2.6% (Saskatchewan Bureau of Statistics 2011). This annual increase in GDP translates into an increase of 26.1%, 78.3%, and 130.4% to 2020, 2040, and 2060, respectively. Expansion at Evraz (formerly IPSCO) could follow this expansion in the economy, although international and domestic economic conditions would dictate such changes. These water demand coefficients were estimated for 2010 and assumed to be unchanged for 2020. Coefficients used for 2040 and 2060 are shown in Table 4.26.

Table 4.24: Current and Future Industrial Water Demand Coefficients for the Baseline Scenario in the Qu'Appelle River Basin, 2020 to 2060

Product & Name of Firm	Unit	**2010 & 2020**	**2040**	**2060**
Ethanol				
Pound-Maker Agventures Ltd.	Per litre	0.003909	0.004003	0.004105
Terra Grain Fuels Inc.	Per litre	0.003614	0.003700	0.003794
Fertilizer				
YARA Inc. (Previously Saskferco)	Per Tonne	1.968	2.015	2.066
Steel Manufacturing				
EVRAZ Inc. (formerly IPSCO)	Per Tonne	0.002643	0.002706	0.002775
Petroleum Products Processing				
Consumer Co-op Refineries	Per bbl	0.088290	0.090409	0.092704
Food Processing				
Lilydale	Per bird	0.002395	0.002452	0.002515

4.4.5.2 Induced Economic Development Activities

In addition to an expansion of existing industrial water users, the basin may attract some other types of industrial water users. These developments are hypothesized to be induced either by

[33] Urease is an enzyme that catalyzes the hydrolysis of urea into carbon dioxide and ammonia.

irrigation projects or 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 Qu'Appelle River Basin, 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 not included since the crop mix as proposed for the irrigation did not include specialty crops (such as potatoes). In this section, three types of developments are envisaged in the basin: (i) more feedlots resulting from irrigated forage; (ii) higher ethanol production resulting from higher production of grains (and perhaps corn); and (iii) additional agri-processing firms caused by irrigated products.

Beef Feedlot Expansion in the Irrigation Districts

To estimate the expansion level of intensive livestock operations allowed by increased irrigation in the Qu'Appelle River Basin, the area required for feed production, bedding and manure disposal needed consideration. The magnitude of this area will determine the number of enterprises that an effectively operate. The production of silage using irrigation and destined 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.

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 yields for silage of 14.5 and 21.7 tonnes per acre, respectively (ICDC, 2011). The economic hauling distance of silage and manure are the two key factors in the overall profitability of an intensive livestock operation. The amount of land needed is also dependent on the rotational constraints of crops grown and 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 need to be available for manure application within an economical hauling distance. Therefore, the constraint that may limit the number of intensive livestock operations within an irrigation district is the requirement of an adequate area to dispose of the manure, within an economical hauling distance. Technological developments such as biodigesters[34] enable greater economical hauling distances relative to raw manure as a higher valued 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 Qu'Appelle South Project of up to 108,000 irrigated acres, along with the Thunder Creek Irrigation District (1,422 acres) and the Brownlee Irrigation District (1,893 acres), could accommodate several beef intensive livestock operations (ILO).[35] Location of the ILOs would be decided by the maximum amount of non-irrigated land could be accessed for manure disposal, as well as by the size of these operations, if the goal were to maximize livestock production. It would appear from the proposed irrigated area of the QSP that four or five 10,000 head capacity feedlots, along with 2 or 3 smaller ones, could be accommodated. The water demand implications of these feedlots are described in a sub-section below.

<u>Future Ethanol Production</u>

In examining future ethanol and biodiesel markets in the basin (or in the province), a number of factors need to be considered. New fuel efficiency standards for vehicles,

[34] A biodigester is a technology that converts animal and organic wastes into biogas and nutrient-rich liquid fertilizer. The biogas can be piped to a simple gas cooking range and used as fuel, while the fertilizer can be put back on crops to increase yields. Biogas can also be converted into electricity.

[35] An intensive livestock operation is also called a factory farm. Such an operation typically holds large numbers (some up to hundreds of thousands) of animals, often indoors. These animals are typically cows, hogs, turkeys, or chickens. The distinctive characteristic of such farms is the concentration of livestock in a given space.

proposed to 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 and Furtan, 2006). New crops, such as Camelina, may provide a feedstock for biodiesel manufacture that is competitive with petroleum diesel. The market in Saskatchewan of about 40 ML is small compared to the cost-competitive plant sizes of 250 ML. In addition, two biodiesel plants of this size are already proposed for Alberta. Beyond the expansion plans of Milligan BioTech for 20 ML by 2020, there will be no major growth for this biodiesel in Saskatchewan. Cellulosic ethanol plants using biomass are the next generation of plants that could have growth potential in Saskatchewan. Their relatively small size compared to grain ethanol plants (caused by 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 the growth in the economy and the 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.

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. Seventy percent of the gasoline sales in Saskatchewan are for transportation, 11% agricultural and 17% commercial for 2009 (Statistics Canada, 2011b). The amount of diesel and gasoline used in Saskatchewan from 2002 to 2009 is presented in Table 4.27. The rise in economic activity in the industrial and commercial sectors accounts for most of the increase.

Table 4.25: Fuel Use in Saskatchewan 2002 to 2009 (ML)

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

Source: Statistics Canada (2011b).

The current plant capacity in Saskatchewan for ethanol and biodiesel is presented in Table 4.28. For the Saskatchewan mandate of 7.5% ethanol blend, there is more than enough capacity to meet this regulation. Biodiesel production would have to increase 40 times to supply the Saskatchewan market.

Table 4.26: 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 and b)

Irrigated area in the proposed QSP could be used for the production of feedstocks for the ethanol industry, either for a grain-based or a biomass-based plant. Currently, Terra Grain Fuels at Belle Plaine contracts for high starch wheat for use in the production of ethanol. The improvement in the grain corn yield that matures with less than 2400 heat units, combined with increased temperatures and longer growing seasons due to climate change, could result in irrigated areas being devoted to grain corn. Competitive grain corn yields relative to other crops combined with a market for corn stover[36] residue, may make this a profitable crop relative to other cropping 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 of corn per year. If the rotation followed is corn in one in four years, the area requirement would be 74,100 acres. The QSP could accommodate at least one 30,000 tonne corn stover biomass plant or a larger plant if other biomass feedstocks were used.

Water Demand Implication of Future Beef Feedlots and Ethanol Production

The irrigated crop area for livestock production would be the competing agricultural activity for the biomass produced in the irrigation district. The economical hauling

[36] Stover is the leaves and stalks of corn (maize), sorghum, or soybean plants that are left in a field after harvest. Corn stover is the major feedstock being used for generating ethanol through fermentation.

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 Qu'Appelle South Project could be influenced by the establishment of either a 10,000 head livestock feedlot or a 30,000 tonne ethanol plant or both. 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 demand than that required for the production of grain from small cereal grains or corn crops (Table 4.29).

Table 4.27: Water Demand of Selected Irrigated Crops

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

Source: ICDC (2008a).

An 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 to meet the biomass requirements for a 30,000 tonne ethanol plant in the Qu'Appelle South Project will increase the irrigation water demand by 1,230 dam^3. This amount was estimated as the extra amount of water to grow grain corn when substituting small grains in crop mix. Likewise, an increase in area seeded to barley for silage to accommodate 4 beef feedlots would reduce the water demand by 2,727 dam^3 from the base scenario.

It is conceivable that ethanol production may be linked with feedlots. This would mean that water will also be needed for livestock watering. An ethanol plant-linked 10,000 animal capacity feedlot would require 184.9 dam^3 of water. With 4 feedlots in the basin, the total amount of water needed would be 739.6 dam^3. Depending on the type of production process, 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 was the current technology, advanced technology, or gasification, respectively.

The net effect of the Qu'Appelle South irrigation project with the addition of 4 livestock feedlot operations (each with a capacity of 10,000 head) and a biomass ethanol plant (using advanced technology) would be a reduction in water demand by 1,987.4 dam^3 and an increase in demand by 1,471.0 dam^3, respectively, for a net reduction of 516.4 dam^3 by 2040. This net reduction would continue to 2060. Details are shown in Table 4.30.

Table 4.30: Change in Water Demand by Agri-Processing due to Induced Impact of Irrigation Activity in the Qu'Appelle River Basin, 2040

Economic Activity	No. of Operations	Direct Water Demand (dam^3)	Change in Irrigation Water Demand (dam^3)	Total amount of Water Demand (dam^3)
Feedlots	Four	739.9	-2,727.0	-1,987.4
Ethanol Plant	One	241.0	1,230.0	1,471.0
Total Change in Water Demand		980.6	-1,497.0	-516.4

Agri-Processing Development

Associated with the feedlots could be an increase in the slaughtering and meat processing industries. On account of 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 may be a likelihood of 5 large and 3 such small plants. It is also assumed that, by 2040, there will be a processing industry with a total capacity of 30,000 head of cattle. By 2060, there could be 5 large and 3 small plants, with a total capacity of 65,000 head of cattle.

Water demand coefficients for these plants were based on a review of the literature.[37] For North Carolina, US, plants, a coefficient of 567 to 1703 litres of water per animal slaughtered was reported. Using a mid-value of this interval, it is assumed that 1135 litres of water per animal (equivalent to 0.001135 dam^3) would be required by these plants.

4.5 Forecasting of Municipal / Domestic Water Demand

Forecasts for municipal/domestic water demand are typically done by using 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 for making any future estimate of water demand. Six factors that affecting future demand have been shown to be (1) regulations on the 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.

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

Regulations and pricing policy are important determinants of water demand in any community. Saskatchewan follows the National Building Code for Plumbing. Being a small market, Saskatchewan is assumed to have such regulations on appliances that are unlikely to be different than of the national or North American level. The pricing regime for water followed by the municipalities is totally within their control. However, these policies are unlikely to change significantly unless there are severe supply side problems, such as extended droughts (or severe impacts of climate change). Also, the cost of supplying water for many communities in the Qu'Appelle River Basin on a per capita basis is relatively high; new capital outlays, given a stagnant or declining population, seem prohibitive for changes. In Saskatchewan, of the total households supplied by municipal water systems, 91% had meters (Statistics Canada, 2006).

The current pattern of residential development in Saskatchewan appears likely to hold until 2060 keeping the accompanying water demand characteristics that this entails. New housing replacing old housing, appliances being upgraded as useful life ends, 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 similarly affect 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 uses or expanded market share, 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 already adopted these measures and the scope for further change is limited. This decade may also be the end of the spectrum of technology change, with low flush toilets representing forced change through regulation. In contrast, low flow showerheads' adoption is driven by education or rebates. These changes are even harder to predict for the future. A combination of these factors resulted in a reduction in per capita water demand in the Qu'Appelle River Basin from 153.2 m^3 in 1995 to 142.1 m^3 in 2009 (SWA, 2009). This alteration suggests a 0.5% per year decline in water demand 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 approximated by change in number of water users (measured as population), and then adjusted for climate change and technological advances (resulting in water conservation), as discussed in Chapter 5. 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

The future population of the Qu'Appelle River Basin will be influenced by the overall population of the province. Within that scope, 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. In addition, there may be a significant amount of interbasin migration of people. These migration patterns have not been studied.

To take into account possible differences in cultural growth rates, future levels of these population groups were estimated separately, starting with the overall provincial population.

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.

Table 4.28: 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).

Recent population growth trends are largely a reflection of resource development in the potash and oil sectors; however once the development/construction phase is completed, employment levels generally fall. The lowest population growth occurred under the "no immigration" scenario, estimated at 0.14% per annum. The highest growth rate was estimated under the "replacement fertility" scenario, where in Saskatchewan population could grow at the rate of 0.91% per annum.

The growth rates of Saskatchewan would 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 its 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 low level of migration from other regions of Canada and/or the world.

Table 4.29: Population Rate of Growth by Economic Region, Saskatchewan

Region	1996 to 2009	2001 to 2009	2006 to 2009
Saskatchewan	101.10%	102.99%	103.83%
Regina-Moose Mountain, Saskatchewan	101.87%	104.46%	104.36%
Swift Current-Moose Jaw, Saskatchewan	89.95%	95.38%	100.50%
Saskatoon-Biggar, Saskatchewan	108.90%	108.10%	106.19%
Yorkton-Melville, Saskatchewan	86.95%	93.06%	99.83%
Prince Albert, Saskatchewan	99.82%	100.73%	102.86%
Northern Saskatchewan	113.89%	111.18%	104.40%

Source: Statistics Canada (2011d)

Statistics Canada's (2011d) analysis of the components of population growth by economic region reveals that only the Saskatoon and Regina regions have been 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, and Moose Jaw) and their 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.

The rural population will continue to decline, as there will be fewer farms and smaller farm families. Also, larger equipment and the introduction of robotics/global positioning system (GPS) will further reduce the need for farm labor. Towns dependent on the farm sector will either maintain their population or decline, since there are fewer retirees moving in from the farm; this migration has been their 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 – Regina and Moose Jaw in the Qu'Appelle River Basin.

Potential growth in mining, industry and commercial activity will be the main determinant as to whether population will increase for towns and for the medium size cities (Swift Current, Estevan, Weyburn, Yorkton, North Battleford, and Humboldt).[38] Most of this growth is relatively capital intensive whether it is in the mining, industrial, farm or commercial sector. It is also subject to proposals by firms and then to regulatory processes.

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

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,[39] projections rely on Statistics Canada's growth assumptions. In particular, a low growth and a high growth scenario rate of change (as listed in Table 4.33) were used. Assuming the growth rates to be linear per annum, projected population was estimated. These figures 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, for an average of 1.375 million people. For this study, an average of these two estimates was used.

Table 4.30: Estimated Saskatchewan Population for 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 Qu'Appelle River Basin:

Past trends and overall population forecasts were used to create population growth scenarios for the basin.[40] The estimates as presented below are based on the following assumptions:

- The population of rural Saskatchewan will continue to decline at the rate seen for rural economic regions between 2001 and 2009; however; the rate of decline will decrease overtime. Projections of farm and rural non-farm populations were based on changes in the farm numbers in the basin during 1996 to 2006. During 1996-2001, farm numbers decreased by 9%, while the change during 2001-2006 was 12.4%. For future projection, it was assumed that farm numbers will decline in 2020 by 10%, by 20% in 2040, and by 30% in 2060.[41] The rural non-farm population was assumed to be tied to change in farm numbers. Estimated farm and rural non-farm population is shown in Table 4.34.

[39] 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.

[40] It is realized that these projections are somewhat subjective and require a study of population growth in the province by river basins.

[41] It should be noted that these numbers are merely assumptions. More careful analysis of future agriculture in the Qu'Appelle River Basin is required to produce more realistic population estimates.

Table 4.31: Estimated farm and Rural Non-farm Population for Qu'Appelle River Basin, 2010 - 2060

Year	Farm Population	Rural Non-Farm Population
2010	29,093	6,599
2020	26,184	5,939
2040	23,274	5,279
2060	20,365	4,619

- Low rates of growth were assumed for most towns. For towns less than 1000 people, the zero immigration rate estimated by Statistics Canada (2011c) was employed. This rate was 0.142% per annum. For towns with more than 1000 people, the low growth rate suggested by Statistics Canada (2011c) was used. Here, the growth rate was assumed to be 0.335% per annum.
- An average of the communities' trend in the population growth rate of bedroom communities was 2.8% for the 1995 to 2009 period. This is applied to estimate the 2020 level, then reduced by half to 2040, and half again to 2060.[42]

- For villages, trends in rural population were used. It was assumed that future population in these communities would decline. The decline in these populations was assumed to be 0.5% for 2010, 0.25% for 2040, and 0.1% for 2060.

The estimated populations for the above types of communities are shown in Table 4.35. These estimates indicate that the basin would become more urbanized by 2060, compared to 2010. In 2010, the urban population (cities, towns, and bedroom communities) would increase from 270 thousand in 2010 to 330 thousand people by 2060.

4.5.1.3 First Nations' Population Forecast

The population of the First Nations' people in Saskatchewan increased by 8.99% from 2001 to 2006, exhibiting an annual growth rate of 1.8% (Statistics Canada, 2006). The First Nations' population in Saskatchewan is expected to increase from 155,000 in 2006 to 203,000 in 2017 -- an annual growth rate of 2.8% (Norris et al. 1996). The expected range of annual growth rates of in this population extends from a low of 1.1% to a high of 2.8%. The underlying basis for the estimates is the projections for education attainment levels and workforce participation rates. Both of these rates are expected to rise among the First Nations' population, especially for

[42] The arbitrariness of this assumption is recognized. More factual research is needed to estimate future population in the bedroom communities in the Basin.

females. However, the Saskatchewan Indian Cultural Centre – SICC (Undated) has made a forecast of First Nations' population for 2045. According to this study, there will be 434,000 people of First Nations' ancestry in the province. This represents an annual increase of 4.43% over the 1995 level. This rate of growth is much higher than that noted above.

Table 4.32: Projected Population for Various Types of Communities, Qu'Appelle River Basin, 2010 - 2060

Category	Population				2060 Population as % of 2010
	2010	2020	2040	2060	
Moose Jaw	34,559	34,844	35,421	36,007	104.2%
Regina	193,707	200,301	217,469	236,108	121.9%
Bedroom Communities of City of Regina	10,564	12,884	19,163	28,504	269.8%
Towns < 1000	13,619	13,619	13,619	13,619	100.0%
Towns > 1000	17,352	16,909	16,461	16,025	92.4%
Sub-total Urban	**269,801**	**278,557**	**302,133**	**330,263**	**122.4%**
First Nations' Reservations	6,710	8,102	12,346	16,104	240.0%
Villages	15,154	15,154	15,154	15,154	100.0%
Recreational villages	208	166	166	166	79.2%
Farm Population	29,093	26,184	23,274	20,365	70.0%
Rural Non-Farm Population	6,599	5,939	5,279	4,619	70.0%
Total Non-Urban	**57,764**	**55,545**	**56,219**	**56,408**	**97.7%**
Institutions	800	800	600	400	50.0%
Total	**328,365**	**334,903**	**358,952**	**387,071**	**117.9%**

For the Qu'Appelle River Basin, First Nations' population was tied to the above sets of projections. A growth rate of 2.8% for 2010-2060 period was assumed.[43] The reason for not using a growth rate of 4.43% as estimated by the SICC study is that, although the First Nations' population may grow by this rate, not all of them will be living on reserves. Many of these people, once educated and ready to face the marketplace, will likely move to bigger cities in Saskatchewan or other parts of Canada. The total First Nations' population in the basin, under

[43] It should be noted that these growth rates are somewhat subjective and need to be ascertained by an authentic study of First Nations' population trends in the province by river basins over the 2010-2060 period.

these assumptions, may increase from the present level of 6,710 people to more than double – 16,104 people – an increase of 140% over the 2010 level (Table 4.36).

Table 4.33: Estimated First Nations' Population for Qu'Appelle River Basin, 2010 - 2060

Year	Rate of Change per annum over the Previous Period	First Nations Population
2010	--	6,710
2020	2.8%	8,589
2040	2.8%	12,346
2060	2.8%	16,104

4.5.1.4 Recreational Village's Population Forecast

Some population centers, such as the recreational villages, did not show any trends over time. In addition, any other alternative logical basis to make this forecast was also not found. The population in these communities suddenly increased in 2009 to 208 people. However, over the last five years, it has varied from a low of 108 to a high of 208 people. Regression analysis of 1995-2009 data indicated no trend in the number of people residing in these communities. Future population in these communities was estimated as a five year average population of 166 people, and was assumed to remain unchanged until 2060.

4.5.1.5 Institutional Population

As noted in Chapter 2, the basin houses two institutions that demand water – the Moose Jaw Canadian Forces Base, and the Regina Correctional Center. The future number of people at the Moose Jaw Canadian Forces Base is subject to renewal of the base after 2020. Nevertheless, for this study it was assumed that the base would continue to operate, but the number of people living on the base will decline to 600 by 2040 and to 400 by 2060.[44]

The future number of inmates at the Regina Correctional Center is also extremely hard to estimate. Part of the problem is that some of these inmates may migrate to local communities, and therefore projecting their current number may lead to double counting. In the census of population, according to Statistics Canada no distinction is among between inmates unless their sentences are over two years. In other words, they are assumed to be living at home.[45] For this reason, all of this population was assumed to be already counted in the estimates for various communities.

[44] The choice of thee numbers is subjective and was done since no reliable estimate was obtained.

[45] Based on personal communications with the Public Desk, Statistics Canada's Regina office on April 13 2012.

4.1.5.6 Total Basin Population

Applying above sets of estimated population projections, the basin population can be estimated. These results are shown in Table 4.35 above. For the above listed communities, the basin population in 2060 will increase by 17%, from 328 thousand people in 2010 to 387 thousand people. Much of the increase can be contributed to the city of Regina and its surrounding bedroom communities, which are estimated to increase in population in 2060 by almost 22% and 170%, respectively, over the 2010 level. The First Nations' population in 2060 is also expected to increase by 140% of the 2010 level.

There is also some evidence that the basin may become more urbanized by 2060. As shown in Figure 4.6, in 2010 only 270 thousand people resided in cities and towns (including bedroom communities), constituting 62% of the basin population. By 2060, 330 thousand or 86% of the population may live in these communities.

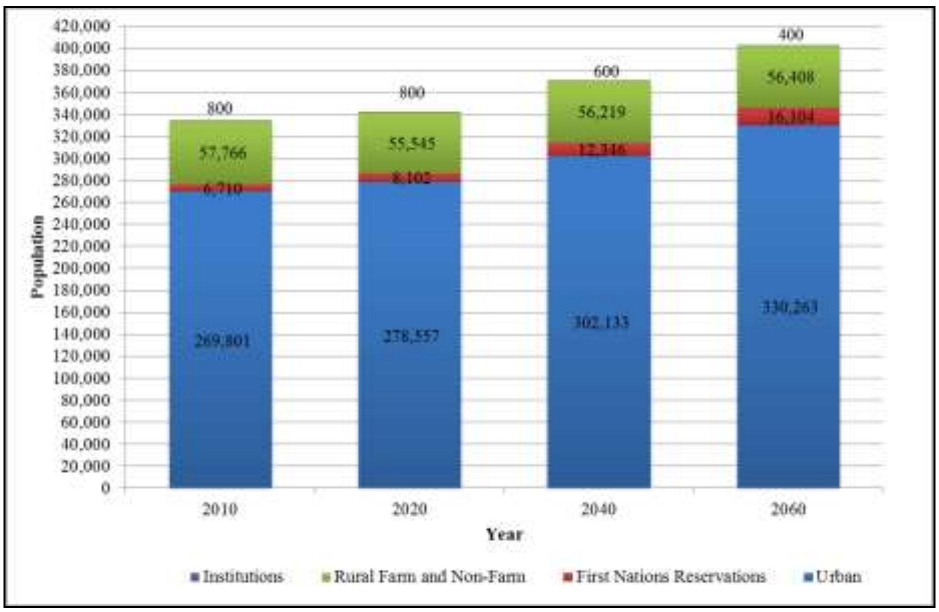

Figure 4.6: Distribution of Population by Type of Major Population Groups, Qu'Appelle River Basin, 2010 - 2060

4.5.2 Estimation of Future Water Demand per Capita

4.5.2.1 Water Demand by Type of Communities

The Saskatchewan Watershed Authority has collected data on the use of water from 1995 to 2009 by type of community and for some institutions (SWA, 2010). Regression analysis was carried out to determine the effect of population and trend on per capita water demand over the sample period. The estimation was done individually for each of the types of communities shown in Table 4.37. The results of these regressions are shown in Appendix Table F.2.

Table 4.34: Summary of Effect of Trend and Population on the Qu'Appelle River Basin Community's per Capita Water Demand, by Type of Community

Communities Showing Effect of Trend or Size	Communities Showing Effect of Trend and Community Size	Communities Showing Effect of Trend but No Effect of Community Size
Moose Jaw	Regina	Towns > 1000
Recreational Villages	Bedroom Communities of Regina	Towns < 1000
Institutions		Villages
		First Nations Reservations

Source: Compiled from Results shown in Appendix F.

For each type of community, two types of factors were included: trend over time, which could be reflective of water conservation and other factors,[46] and size of the community. The latter factor was reflective of the economies' size and their effects on water management. A summary of the results in terms of the effects of these factors is provided in Table 4.38.

Table 4.35: Water Demand Coefficients on a per Capita Basis in m^3 by Community Type, Qu'Appelle River Basin, 2010 - 2060, Baseline Scenario

Community Type	Coefficient per Capita in m^3			
	2010	2020	2040	2060
Moose Jaw	179.84	179.84	179.84	179.84
Regina*	142.61	136.33	122.04	109.26
Bedroom Communities of City of Regina	123.60	126.82	126.82	126.82
Towns < 1000	131.27	121.59	104.31	89.49
Towns > 1000	134.07	122.27	101.69	84.58
First Nations' Reservations	87.92	116.02	178.61	259.13
Villages	112.92	103.59	87.17	73.35
Recreational villages	409.78	409.78	409.78	409.78
Farm Population	134.07	103.59	87.17	73.35
Rural Non-Farm Population	134.07	103.59	87.17	73.35

* Based on personal communication with Mr. Neil Silva, Sr. Engineer, City of Regina Water Operations (dated November 21 2011), a possible reason for this decline is that water conservation practices are followed by residents.

[46] Because of a lack of data on socio-economic characteristics of water users, and nature of water use activities, other factors could not be included in this analysis. A community by community study of reasons for the change in the coefficient is required.

Of all the communities, the city of Moose Jaw, recreational villages, and institutions showed no trend over time. The impact of the size of the population base (called size of the community) was apparent for the city of Regina and for various Bedroom communities surrounding Regina. The trend was noted for towns, villages, and First National Reservations' water demand levels.

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

- For the communities showing no trend in water demand, and no effect from their size, the last five-year (2005-2009) average water demand was used as the per capita water demand for 2010, 2040, and 2060.
- For Regina, the estimated future population was used to forecast water demand.
- For Bedroom communities, since their population is expected to increase in the future, a very high water demand coefficient was estimated. Since many of these communities are small with limited water supply infrastructures[47] (affecting their capacities), their water demand, for 2020 were carried over for future years.
- For communities that exhibited trends over time, a trend adjusted water demand coefficient was estimated.
- For institutions, since no trend effect was estimated, a five-year average water demand was taken as the future value of this coefficient.

As shown in Table 4.38, higher water demand coefficients were estimated for recreational villages, followed by Moose Jaw and institutions. The lowest water demand was estimated for villages and for towns over 1,000 people.

4.5.2.2 Forecasting Water Demand for Public Institutions

Given that new infrastructure at both institutions has been installed, similar (2010 level) water demands can be expected in the future. However, the total water demand could be affected by the number of people in these institutions and the technology used. The estimates for 2040 and 2060 for CFB Moose Jaw can be somewhat problematic, since government policy and NATO operations requirements will decide the number of people at the base. Therefore, these numbers

[47] It is realized that as a community grows, its capacity to serve residents and industries would also increase by either public assistance for infrastructure or by raising local finances. However, since the regression model provided an estimate of more than doubling the water use coefficient, this was considered somewhat unrealistic.

are liable to change in the future. Technological advancements in unmanned aircraft will see major changes in the composition of an air force in terms of manned equipment, therefore requiring different training. Since no data were available on the nature of future technology for water demand, an average of the past five years was used for making a forecast of total water demand.

Unfortunate as it is, the need for the Regina Correctional Centre will still be there in 2040 and 2060 probable with similar numbers of inmates and staff as there are today. Efficiency gains in water use as water appliances are replaced can be expected; however, with all the features that influence it, water demand by such institutions over the future years remains very complex to estimate. Given the above set of reasons, it was assumed that the level of total water demand would remain unchanged from the 2010 level.

4.5.2.3 Adjustment for Bottled Water Demand

The use 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 purchased bottled water and if the community relied on 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 communities. For instance, areas with water quality (taste or odor) issues probably consume more bottled water. However, that is not the case with all communities or all water users. Given that a systematic study on bottled water was not found for Saskatchewan, this research avoids making any adjustment in per capita level to accommodate bottled water demand. This area is left for future studies.

4.6 Recreational Water Demand

Water demand for recreation was a sum of two types of water uses: that occurring at the recreational communities, and that occurring at various recreational sites. The first water demand was estimated by the population of these communities (shown in Table 4.35) and then per capita water demand (shown in Table 4.38).

For water demand at various recreation sites, a regression analysis was undertaken using data for the 1995-2009 period. Results are shown in Equation (4.1). Total water demand in m^3 was hypothesized to be determined by a trend (TIME). The level of the trend coefficient indicates that, on average, an additional 759 m^3 of water will be needed per year.

$$\underset{(4322.7)}{TWD = 29289.5} + \underset{(475.4)}{759.1}\ TIME \qquad (4.1)$$

$$R^2 = 0.164 \qquad F = 2.55^*$$

Where, * Hypothesis of all variables not affecting water demand rejected at $\alpha = 0.13$

The ratio of this coefficient to the intercept indicated this to be a change of 1.6% per year. The future rate of change was rounded to 2% per annum.

The water demand to 2020, 2040, and 2060 was estimated by applying a 2% increase over the previous period. Limited space and the resulting congestion could act as a ceiling on the use of the parks and recreational vehicle sites. Having weather that is suitable for the activities offered by these sites is the main determinant of their popularity. A cool, wet summer compared to a hot, dry summer would generate significantly different levels of use.

4.7 Indirect Anthropogenic Water Demands

Four types of water demands that are included in this category are Environmental purposes, Instream 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 organization, 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 be at the same level as that for 2010.

4.7.2 Instream 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. SWA 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 many factors that would have positive or negative effects on evaporation rates with little or no guide as to how these influences will play out to 2060. Consequently, base coefficients for 2010 are used in estimating the future evaporation water demand.

4.7.4 Apportionment Water Demand

Although past evidence suggests that water needed for apportionment has been met through the natural flow of the river, the simplest assumption that one can make is that this situation will continue. However, whether natural flow of water in the river can meet the apportionable water needs will depend on future water demand. It may also be partially dependent on amounts of natural water available in Saskatchewan (after that released by the Province of Alberta). It is conceivable that, during years of low natural water flow, some additional water may have to be released to meet apportionment demands. Since this circumstance cannot be reasonably foretold, estimation of this number is considered beyond the scope of this study

Chapter 5

Current and Future Water Demand Evaluation Scenarios

Current and future water demands for the Qu'Appelle River Basin 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 used as a reference for comparison against an alternative scenario, which is 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 of this report. 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 -- will 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 based activities have a different impact on water demand. These changes are also reported in Chapter 4 and were assumed to remain unchanged.

Water demand under the baseline scenario reflects the past trends and the best judgment that such reasonable evidence appears to suggest. However, as is true of any forecast, these calculations 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 can (and those in the Qu'Appelle River Basin) 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 the 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 impacts of climate change, as identified by various IPCC reports (Easterling et al. 2007), include the following points:

- Change in average temperature
- Change in the 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 here is not relevant to the basin or to the Province of Saskatchewan, since we are far from coastlines)

Related to water resources, Lemmen and Warren (2004) have suggested that climate change would affect us significantly through[48]: (1) changes in annual stream flow, possible large declines in summer rainfall, leading to a 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 many notable concerns: (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 the demand for water because of higher temperatures and drier conditions.

Two major changes that would occur on account of climate change are alterations 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

[48] It should be noted that these impacts are for Canada as a whole and not for the Qu'Appelle River Basin.

greater risk is the increasing temperatures and resulting potential evapotranspiration not being compensated by projected changes in precipitation and longer warm seasons.

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2008) states that 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) will be 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. Their future projections show decreases in soil moisture globally for all scenarios with a doubling of the area of severe soil moisture deficits and the frequency of short term drought (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 and associated excessive moisture or flooding also can increase. Current trends already suggest these changes. IPCC (2008) states that the frequency of heavy precipitation amounts has increased over most land areas; this pattern is consistent with the observed increases of atmospheric water vapor. Precipitation extremes, moreover, 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 research is a warning that dry areas (such as the southern Canadian prairies) could become drier and wet areas could become wetter.

Even with this early amount of literature, the knowledge about future possible 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 problems.

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 will differ 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 consumption for climate change. Water use was affected by the direct effect of climate change on water requirements; indirect effects of climate change on water requirements; and policy-induced impacts 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 effect includes impact on water delivery systems, on prices of food products, and on 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 effect in the Pacific Northwest. They also predicted that the 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 will be 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. In addition, 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 important implications of climate change on water resources. Impact on the water demand may come through the direct impact of climate characteristics, but also through indirect linkages. Two important indirect linkages happen through water quality and water availability. The former may affect water demand for domestic water, as well as for recreational purposes. The availability is also a major factor in determining water demand patterns – adoption of water saving mechanisms may become increasingly popular among water users. However, this aspect is dealt with in the next scenario – that of water conservation. In the following section, only the direct impacts of climate characteristics are described.

5.2.3 Incorporation of Climate Change Impacts in the Study Estimates

Climate change may create two types of factors that would affect future water demand: change in the temperature and precipitation, and in the frequency of extreme events such as droughts and excessive rain (causing flooding in some regions). Unfortunately, most work on the extreme events has been done on a global basis, rather than solely for Canada and its regions (such as the Qu'Appelle River Basin).

5.2.3.1 Effect of Temperature Change

The Canadian Climate Change Scenarios Network (CCCSN)[49] 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 Qu'Appelle River Basin was selected. For these locations, the temperate forecasts were obtained. The average of the temperature at these two locations represents 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.

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, multiplied by coefficients that have measured water demand at these increased temperatures. It is assumed for the purposes of this study that the water coefficients for estimating 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 because of the temperature rise to the yearly demand, then calculating an average daily use.

A warmer climate to 2040 and 2060 could also result in more heat units enabling the use of corn varieties with greater production potential. Consequently, a warming climate to 2060 would favor more corn production, as corn is better adapted to taking advantage of the elevated temperature. Corn has a higher water demand coefficient, compared to present feedgrains. Also, these corn varieties have higher yield potential relative to the varieties currently grown in Saskatchewan and to barley silage. The changing climate may induce more feedlots and corn-based ethanol production.

A warmer and drier climate would also enhance people's participation in water related recreational activities.[50] Included here would be both consumptive and non-consumptive water demand activities. Consumptive activities may include use of provincial parks, which may result in more recreational areas being developed. Non-consumptive activities may include swimming,

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[49] For details see CCCSN (2011).

[50] 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.

boating, and other types of recreational activities, all of which will increase the popularity of parks.

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 an increased 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. For this study some arbitrary decisions were made.[51] It was assumed that drought frequency by 2020 will 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 here, producing estimated frequencies of 13% by 2040 and about 18% by 2060.

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

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 result has been accomplished through several types of measures, including the switch to lower water use appliances (i.e. rebates for low flush toilets). Programs of various types to educate the public on water use have been and are being implemented. The urgency or force of the approach seems to depend on immediate supply side problems, such as drought and plant shutdown, among others. These factors influence the adoption of water conservation and thereby affect water demand. Nonetheless, to predict these changes is somewhat problematic without a comprehensive study of local attitudes and the willingness of the populace to adopt water conservation measures.

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

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). The conservation of water can be placed within this context of conservation, which primarily refers to a reduction in water use and loss, or an increase in the efficiency of water use.

For the dwindling water supplies (as expected in climate change), water conservation provides an avenue to balance demand with supply. In addition, there are 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 spent more efficiently because less energy is used 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 demand helps to preserve and protect fish and wildlife habitat. These natural attractions are essential to the economic health of any provincial economy, drawing 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 a normal time period 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 consequences of a drought (Vickers, 2004, p. 178). There are number of ways in which water is wasted when it could be conserved, provided that there are enough incentives to the water users to adopt water conservation practices. Examples of water wastes in various users include the following:[52]

- **Residential and domestic water demand**: old, inefficient plumbing fixtures and appliances, leaking toilets and faucets, wasteful water use habits.

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

- **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, used 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. Various factors play roles in changing the behavior of people to adopt water conservation measures. 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 consumption in various applications. These are shown in Table 5.1.

Measures suggested for water conservation include a combination of hardware and behavioral modifications. In all types of water demand, pricing is noted as a primary incentive for changing the behavior of water users towards water conservation. These rates ought to be conservation oriented – i.e., they would provide a motivation for the consumers to think (and possibly adopt) water conservation measures.[53]

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

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[53] 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.

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
Efficient Cooling And Heating			X	
Process and wastewater reuse, improved flow controls			X	
Efficient irrigation scheduling (e.g., customized, linked to soil moisture,				X
Land Conservation methods (e.g., conservation tillage, organic farming, integrated pest management)				X

Source: Paraphrased using information from Vickers (2004).

Unfortunately the uncertainty in the potential water savings based on a review of literature is rather large because of 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 exist in this area.

5.3.2 State of the Art in Water Conservation

5.3.2.1 Measures for Water Conservation

As noted above, information on water conservation in Saskatchewan is not available. Even the review of studies that were found suggested a large degree of uncertainty in the potential for water conservation practices. Further complications arise because the magnitude of water conservation is decided not only by the available technology (hardware) but also by people's willingness to adopt conservation practices. The literature suggests that policy measures are required for bringing about such a change. Most studies suggest the application 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 class residential (and non-residential) customers tend to be sensitive to water prices (paraphrased based on Vickers, 2001, p. 143).

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).

Both types of changes to bring forth water conservation are subject to public decision making, which is highly unpredictable for any jurisdiction, including Saskatchewan and/or the Qu'Appelle River Basin. To incorporate the effect of water conservation on Qu'Appelle River Basin 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 demand reduction by adopting new technology. For example, if new toilets are installed, a current water requirement of 20 litres per flush[54] can be reduced to 2 to 6 litres. This would reduce water demand 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 use for cleaning and lawn irrigation.[55]

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[54] 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 use 18 or 13 litres per flush.

[55] No data are available for Saskatchewan or the Qu'Appelle River Basin for water consumed by type of domestic water use. According to the city of Richmond (Undated), lawn watering constitutes 15% of total domestic water use.

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

Appliance	% of Home Indoor Water Use	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

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, and 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, as well as public awareness programs are most common.

The detection of leaks through infrastructural improvements and retrofitting are also among these effects.[56] Results of these water conservation measures have been an astounding success. In all[57]

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 Richmond and in Regina makes this estimate somewhat questionable.

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

[57] 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.

cases examined here, water demand was reduced and in some cases the improvements led to deferred savings in new infrastructural investments.

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)
City of Winnipeg	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 effect of pricing. However, this experience may not be considered to be comparable to that in the basin.
** Mid-value

In terms of annual water demand reduction, results vary from a high of 30% in Bogor, Indonesia, to a low of 2.9% for New Glasgow, Nova Scotia.[58] Within Canada, the range in reduction of residential (indoor) water demand was 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 industrial responses to a price change (a popular water conservation measure). Water cost seldom accounts for more than one percent of the total cost of production of many industrial firms. Few studies have been done on the interaction of water price and the price of inputs other than water (Renzetti, 2002). In addition, studies of cost structure 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 because a given crop requires a certain amount of water in a given setting (Policy Research Initiative, 2005). It has been argued that the demand for irrigation water would remain inelastic until water costs rise substantially (Bazzani et al. 2004).

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

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

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 issue of adopting water conservation practices may be obtained from the SWA's program uptake for their Toilet Rebate Program.[59] The program started on January 1 2009. By the end of October 2011, some 30,098 households have availed the measures of the rebate[60] 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 the large degree of uncertainty about the impact of water conservation programs and the rate of adoption, a scenario approach was adopted. This scenario involved a potential level of water conservation and a rate of adoption of water conservation practices. On account of uncertainty in potential water conservation, a mid-value of the interval shown in Table 5.2 was used as the potential for water demand reduction. For domestic water demand, an equal proportion of water used for indoor and for lawn irrigation was assumed. This yielded a value of 43% potential. For the commercial, industrial and institutional water demand this potential was assumed to be 32%. For both of these categories, an adoption rate of 1% per annum was assumed. Adjustment factors for water conservation are shown in Table 5.5.

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

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

Table 5.5: Reduction in Water Demand by Type of Demand, Resulting from Adoption of Water Conservation Practices, Qu'Appelle 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

Applying the methodology presented in Chapter 3, current (2010) water demand levels for various activities related to agricultural water use 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 scenario. These results are presented in this chapter.

As noted in Section 3.6.1, agricultural water demand was disaggregated by five types, and estimates were made for each of these types of uses, which are presented in this section. The presentation is divided into the five sections – Irrigation, Dryland crop, Livestock, Greenhouses and Nurseries, and Aquaculture. For each use, demand is estimated under the three study scenarios.

6.1 Irrigation Water Demand

6.1.1 Irrigation Water Demand – Baseline Scenario

The total water demand for irrigation was estimated by taking into account three factors: (i) irrigated area; (ii) type of application system, accounting for the efficiency of the system and (iii) estimated water deficit for the mix of crops that would be grown. The Qu'Appelle River Basin water demand for irrigation by type of system is presented in Table 6.1. As shown here, most of the increase is attributed to the growth of sprinkler irrigation in the basin.

In 2010, irrigation demanded 54,856 dam^3 of water. By 2060, irrigation would need a total of 194,965 dam^3 of water, an increase of 255% over the 2010 level. Major increases are also expected by 2040 when irrigation water demand will almost double the 2020 level, or reach some 181% higher than the current level. This water increase is predicated on the development of the Qu'Appelle South Irrigation District, although some private irrigation in this area may also develop.

In estimating the irrigation water demand, an assumption was made that 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 added knowledge of the attitude of producers regarding water conservation, which was not available. This was therefore considered to be beyond the scope of this study.

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

Irrigation System	Water Demand in dam^3 for			
	2010	**2020**	**2040**	**2060**
Wheelmove	5,897.0	5,897.0	5,897.0	5,897.0
Pivot	15,720.5	17,417.0	115,231.9*	155,829.5
Linear	-	-	-	-
Misc. Sprinklers	4,587.6	4,587.6	4,587.6	4,587.6
Surface	8,289.6	8,289.6	8,289.6	8,289.6
200mm Backflood	5,754.2	5,754.2	5,754.2	5,754.2
Misc. Backflood	13,137.3	13,137.3	13,137.3	13,137.3
Remainder	1,469.8	1,469.8	1,469.8	1,469.8
Total Water Demand	**54,856**	**56,552**	**154,367**	**194,965**
% Increase over 2010 Water Demand Level		3.1%	181.4%	255.4%

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

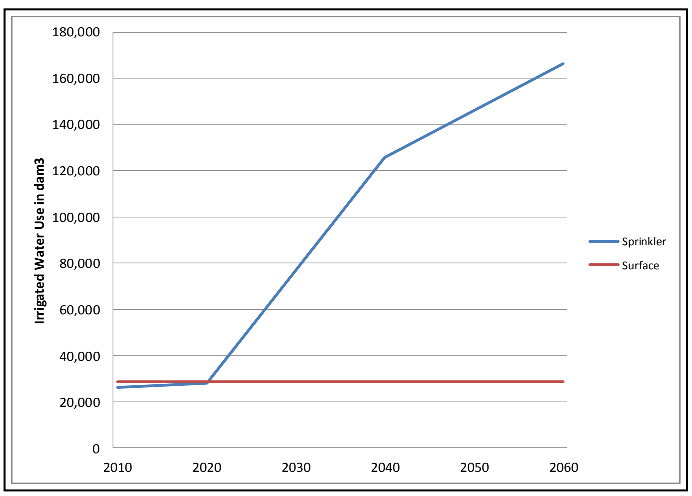


Figure 6.1: Future Irrigated Water Demand in the Qu'Appelle River Basin by Type of Irrigation, 2010 - 2060

6.1.2 Irrigation Water Demand – Climate Change Scenario

Future irrigation water demand was derived from future irrigated area and water demand coefficients. As noted in Chapter 3, a 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: crops 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. From Table 6.2 the increased water demand of a crop can be estimated, given the number of days and rise in temperature range.

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)

The future irrigation water requirements for crops were estimated by following 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).

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 (SWA, 2011b). The crops for which this irrigation water was used 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 alter the crop mix. No further information is available to produce specific results.

Table 6.3: Crop Water Use 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 Wheat	460	212.5	247.5	20	35	267.5	282.5
CWWS Wheat	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 Wheat	460	212.5	247.5	20	35	267.5	282.5

CWRS = Canadian Western Red Spring; CSWS = Canadian Soft White Spring; 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.

In addition to increases in water demand because of higher temperatures and lower precipitation (or lower soil moisture), droughts can also increase water requirements for crops. On account of lack of Qu'Appelle River Basin data, LDDA data were used. 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. Results are shown in Equation 6.1. According to these estimates, although the time variable was negative, it was not significant. Therefore, no major water demand 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.

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

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

Where, ** coefficient is significantly different from zero at $\alpha = 0.01$
* Hypothesis of all variables not affecting water demand rejected at $\alpha = 0.05$

The only significant coefficient in equation (6.1) is that for the binary variable for 2001 and 2002 droughts. Thus, occurrence of droughts can increase water demand in non-pipeline systems. The increase during the 2001 and 2002 drought was, on average, 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 drought. 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 that was used 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,[61] given the probable 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, the water demand is estimated at 247,158 dam^3. This amount is 4.5 times the amount used in 2010.

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

Irrigation System	Amount of Water in dam^3			
	2010	**2020**	**2040**	**2060**
Wheelmove	5,897.0	5,897.0	6,955.1	7,545.7
Pivot	15,720.5	17,417.0	135,239.9	197,988.0
Linear	-	-	-	-
Misc. Sprinklers	4,587.6	4,587.6	5,583.3	6,164.9
Surface	8,289.6	8,289.6	10,088.8	11,139.6
200mm Backflood	5,754.2	5,754.2	5,754.2	5,754.2
Misc. Backflood	13,137.3	13,137.3	15,422.4	16,697.9
Remainder	1,469.8	1,469.8	1,725.4	1,868.1
Total Amount of Water Demand	**54,856**	**56,552**	**180,769**	**247,158**

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

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 below:

- 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 of crop mix through replacing higher water requirement crops to lower water requirement corps;
- 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 3.4. If a contour flooding system is employed, converting it to sprinklers 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.

The current overall system efficiency of irrigation in the Qu'Appelle Basin is estimated at 56% given the current irrigation technology (as shown in Table 6.5). In other words, it now takes on average of 541 mm of water per acre to get 300 mm to the crop.

Table 6.5: Irrigation Efficiency in the Qu'Appelle River Basin, 2010 and Projected

System Type	Irrigated Acres	% of Total Acres	2010 System Efficiency		Improved System Efficiency	
			System	Weight[1]	System	Weight[1]
Wheelmove	6,422	13%	75%	10.1%	79%	10.6%
Pivot	19,116	40%	85%	34.1%	85%	34.1%
Linear	-	0%	75%	0.0%	79%	0.0%
Misc. Sprinklers	4,653	10%	80%	7.8%	80%	7.8%
Surface	3,634	8%	60%	4.6%	60%	4.6%
200mm Backflood	7,211	15%		0.0%	30%	4.5%
Misc. Backflood	5,935	12%	60%	7.5%	60%	7.5%
Remainder	688	1%	60%	0.9%	60%	0.9%
Total	**47,660**	**100%**		**65%**		**70%**

[1] Percent of irrigated area by system multiplied by system efficiency gives the weight for the basin irrigation efficiency.

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

If the wheelmove, pivot, and miscellaneous sprinklers technology was adopted (with an improved efficiency of 79%), then the basin irrigation efficiency would increase to 61%. That is to say, on average 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 whether the technology will be undertaken and adopted. Improved yields or quality of the crop have been cited by farmers as the major reasons influencing their 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.

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

The potential for reducing irrigation water demand is more complex, since it is affected by several factors. In agricultural (field) irrigation, reduction in water demand can be achieved through various types of changes, including crop mix, water efficient equipment, and improvements in water conveyance systems, among others. Various water delivery systems to the field have different water efficiency, as shown in Table 6.6. Backflood systems, for example, are only 30-55% efficient in comparison to center 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 system for the Qu'Appelle Basin is presented in Table 6.7. As noted above, water conservation measures were assumed to be adopted after the 2010 period. The total water demand for irrigation would not show any change until after 2020, as shown in Table 6.8. By 2040, a moderate increase in water will be expected. This level will be 180,769 dam^3, some 17% higher than that seen under the baseline scenario. By 2060, the effect of climate change will result in an even higher increase in the water demanded, as shown in Figure 6.2.

Table 6.7: Estimated Water Demand for Irrigation in the Qu'Appelle River Basin by Irrigation System for the Water Conservation Scenario

Irrigation System	Total Irrigation Water Demand in dam^3			
	2010	2020	2040	2060
Wheelmove	5,897.0	5,475.8	5,110.8	5,110.8
Pivot	15,720.5	16,328.4	101,675.2	137,496.6
Misc. Sprinklers	4,587.6	4,259.9	3,975.9	3,727.5
Surface	8,289.6	7,460.6	6,782.4	6,217.2
200mm Backflood	5,754.2	5,754.2	5,754.2	5,754.2
Misc. Backflood	13,137.3	11,823.5	10,748.7	9,852.9
Remainder	1,469.8	1,322.8	1,202.5	1,102.3
Total Water Demand	**54,856**	**52,425**	**135,250**	**169,261**

Table 6.8: Total Irrigation Water Demand in the Qu'Appelle River Basin under Alternative Scenarios, 2010-2060

Year	Climate Change Scenario		Water Conservation Scenario	
	Amount of Water Used (dam^3)	% Increase from Baseline Scenario	Amount of Water Used (dam^3)	% Increase from Baseline Scenario
2010	54,856	0.0%	54,856	0.0%
2020	56,552	0.0%	52,425	-7.3%
2040	180,769	17.1%	135,250	-12.4%
2060	247,158	26.8%	169,261	-13.2%

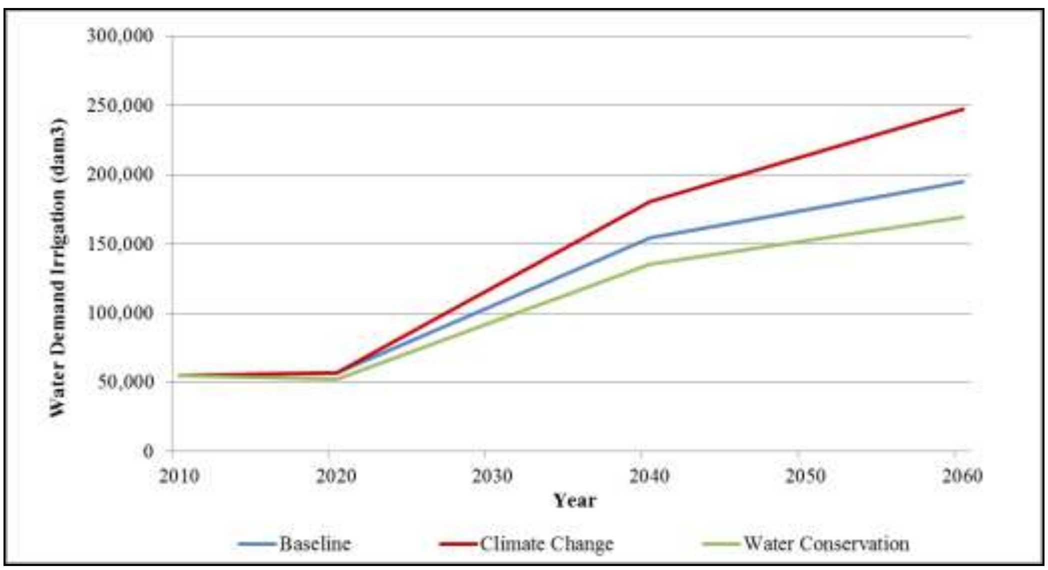


Figure 6.2: Irrigation Water Demand under Alternative Scenarios, Qu'Appelle River Basin, 2010 - 2060

6.2 Dryland Crop Water Demand

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

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 the 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. The total water demand for pesticide application is forecasted to remain unchanged by 2060. This happens because the crop mix has been kept constant. However, changes in the market conditions can bring forth major changes in the nature of crops grown in the basin, and subsequently, the change in water demand for this purpose.

Table 6.9: Water Demand for Crop Pesticide Application in the Qu'Appelle River Basin, 2010 - 2060, for the Baseline Scenario

Crop Type	Water Demand in dam^3			
	2010	**2020**	**2040**	**2060**
Cereals	141.5	137.2	147.1	147.1
Oilseeds	134.6	150.1	131.7	131.7
Pulses	61.0	56.2	58.4	58.4
Fallow	12.4	9.4	11.3	11.3
Total Amount of Water Demand	**349.3**	**352.9**	**348.4**	**348.4**
% Increase over 2010 level	--	1.0%	0%	0%

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 scenarios given the crop rotation limitations. The particular crops within the crop category are likely to change as farmers adopt crops that fit the new climate regime. However, the number of pesticide applications needed for the replacement crops would not differ greatly from the crops currently grown. The major change that would be experienced under climate change is the adoption of zero tillage. This proportion may increase to 95% from 75% for cereals and pulses, and to 90% from 70% for oilseeds. The net effect of these changes is an increase in the water demand for pesticide application of 8% over the 2010 level by 2060 (Table 6.10). The indirect effect of climate change, higher evaporation, may make some surface water bodies that are currently used as a water source unsuitable, which may have some implications for water-based recreation activity.

Table 6.10: Water Demand for Crop Pesticide Application in the Qu'Appelle River Basin, 2010 - 2060, for Climate Change Scenario

Crop Type	Water Demand in dam^3			
	2010	**2020**	**2040**	**2060**
Cereals	141.5	137.2	155.5	163.9
Oilseeds	134.6	150.1	134.5	137.3
Pulses	61.0	56.2	60.5	62.6
Fallow	12.4	9.4	12.7	13.1
Total Amount of Water Demand	**349.3**	**352.9**	**363.2**	**376.9**
% Increase over 2010 level	--	1.0%	4.0%	7.9%

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 emerging. 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 such technology. The net result of these assumptions is shown in Table 6.11. Water demand for pesticide spraying could decrease considerably, particularly by 2060, under these assumptions. As much as 50% reduction in pesticide water demand is estimated for the 2060 period.

Table 6.11: Water Demand for Crop Pesticide Application in the Qu'Appelle River Basin, 2010 - 2060, for the Water Conservation Scenario

Crop Type	Water Demand in dam^3			
	2010	**2020**	**2040**	**2060**
Cereals	141.5	137.2	132.4	73.6
Oilseeds	134.6	150.1	118.5	65.8
Pulses	61.0	56.2	52.5	29.2
Fallow	12.4	9.4	10.1	5.6
Total Amount of Water Demand	**349.3**	**352.9**	**313.6**	**174.2**
% Increase over 2010 level	--	1.0%	-10.3%	-50.0%

6.3 Stockwater Demand

Livestock production needs water for two purposes: direct use by animals or birds, and that used for maintenance (cleaning and/or manure disposal) of facilities, such as dairy barns. In this study, both of these functions are combined, and the results are presented in this section.

6.3.1 Stockwater Demand -- Baseline Scenario

Stockwater demand was estimated by type of animals, applying the methodology as reported in Chapters 3 and 4. The estimated water demand for various types of livestock is presented by livestock category. These results for dairy and cattle herds in the Qu'Appelle River Basin 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 smaller in numbers, and thus have a lower water demand than beef herds. By 2060, this water demand will increase roughly by 15% of the 2010 level.

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

Livestock Type	Water Demand in dam^3			
	2010	**2020**	**2040**	**2060**
Bulls	167.7	179.9	183.5	187.2
Milk Cows	242.2	222.3	217.9	222.2
Beef Cows	3,050.2	3,270.8	3,336.2	3,402.9
Milk Heifers	29.1	26.7	26.2	26.7
Beef replacement	413.9	413.4	452.8	461.8
Feedlot	1,328.8	1,471.0	1,618.1	1,779.9
Calves	1,588.1	1,703.0	1,737.0	1,771.8
Total	**6,820.0**	**7,287.0**	**7,571.6**	**7,852.4**
% Increase over 2010 Level		6.8%	11.0%	15.1%

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% to 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 Qu'Appelle River Basin, the 3.5% increase is employed to estimate the size of the breeding herd for 2020, 2040, and 2060. From the estimates of the breeding herd size, the number of boars, suckling, weaned, and feeder pigs are estimated. 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 Qu'Appelle River Basin is shown in Table 6.13. The projection is for a 11% increase in the water demand for hog production by 2060.

Table 6.13: Estimated Water Demand for Hog Production in the Qu'Appelle River Basin for the Baseline Scenario, 2010 - 2060

Type of Animal	Water Demand in dam^3			
	2010	2020	2040	2060
Gestating Sows	41.8	43.3	44.8	46.3
Lactating Sows	10.9	11.3	11.6	12.1
Suckling Pigs	5.4	5.9	6.3	6.8
Weaned Pigs	29.9	30.9	32.0	33.1
Grower Finishing Pigs	813.9	842.2	871.4	901.7
Boars	2.2	2.0	1.8	1.7
Total Water	**904.0**	**935.5**	**968.0**	**1,001.8**
% Increase over 2010 Level	--	3.5%	7.1%	10.8%

The projection for sheep is a 20.4% increase in production from 2010 to 2020 (Table 6.14). 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 Qu'Appelle River Basin from the Sheep producing farms is presented in Table 6.14. Total water demand in 2060 would increase by 22.8% over the 2010 water demand level of 38.7 dam^3 to 47.6 dam^3.

Table 6.14: Estimated Water Demand for the Sheep Production in the Qu'Appelle River Basin for the Baseline Scenario, 2010 - 2060

Type of Animal	Water Demand in dam^3			
	2010	2020	2040	2060
Rams	1.18	1.42	1.44	1.45
Ewes	28.49	34.29	34.64	34.98
Breeding	5.62	6.77	6.83	6.90
Slaughter	3.43	4.13	4.17	4.22
Total Water Demand	**38.7**	**46.6**	**47.1**	**47.6**
% Increase over 2010		20.4%	21.6%	22.8%

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 at 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. The expected change in Saskatchewan's population from 2020 to 2036 forecasted by Statistics Canada (2011c), 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 2040 level in Saskatchewan's poultry numbers was used. The estimates for the water demand in the Qu'Appelle River Basin are presented in Table 6.15. In 2010, this sector demanded 1,173 dam^3 of water per year. By 2060, this amount would increase to 1,561 dam^3 – an increase of 33% over the 2010 level of water demand.

Table 6.15: Water Demand Estimates for the Poultry and Egg Production in the Qu'Appelle River Basin for the Baseline Scenario, 2010 - 2060

Type of Animal	**Water Demand in dam^3**			
	2010	**2020**	**2040**	**2060**
Laying Hens	22.1	24.0	26.4	27.8
Pullets	2.6	3.0	3.3	3.4
Broilers	1117.3	1288.5	1417.3	1488.2
Other Poultry	0.5	0.5	0.6	0.6
Turkeys (M)	18.5	21.6	23.8	25.0
Turkeys (F)	12.0	14.1	15.5	16.3
Total Water Demand	**1,172.9**	**1,351.7**	**1,486.9**	**1,561.2**
% Increase over 2010		15.2%	26.8%	33.1%

The markets for the products produced by the other livestock sectors are relatively small for all types of livestock, because their growth in the future is limited. Therefore, conservative estimates were taken for forecasting changes in the herd size of these livestock sub-sectors. The water demand for the other livestock sub-sectors is presented in Table 6.16. A moderate 1% increase in the water demand is estimated. Relative to other livestock sectors (except for the sheep sector), water demand is relatively low. In 2010, this sector used 329 dam^3, which is expected to increase to 335 dam^3 by 2060.

Table 6.16: Water Demand Estimates for Other Livestock in the Qu'Appelle River Basin for the Baseline Scenario, 2010 - 2060

Type of Animal	**Water Demand in dam^3**			
	2010	**2020**	**2040**	**2060**
Bison	52.58	57.84	58.42	59.10
Horses	262.37	262.37	262.37	262.37
Goats	5.13	5.13	5.13	5.13
Llamas	3.98	3.98	3.98	3.98
Deer	4.62	4.62	4.62	4.62
Total Water Demand	**328.7**	**333.9**	**334.5**	**335.1**
% Increase over 2010		1.6%	1.8%	1.9%

A summary of water demand for livestock in the Qu'Appelle River Basin is presented in Table 6.17. The total water demand for livestock production was estimated at 9,264 dam^3 for 2010, with the largest portion of this total being for dairy and beef cattle enterprises. As shown in Figure 6.3, 73% of the total livestock water required is by bovines (dairy and beef). By 2060, this demand will increase by 16.6% of the 2010 level. During this period, there will be 10,798 dam^3 of water demanded for this purpose in the Qu'Appelle River Basin. Again, the largest share would be claimed for the dairy and beef enterprises.

Table 6.17: Water Demand Estimates for Livestock in the Qu'Appelle River Basin for the Baseline Scenario, 2010 - 2060

Livestock Type	Water Demand in dam^3			
	2010	**2020**	**2040**	**2060**
Dairy & Beef Cattle	6,820	7,287	7,572	7,852
Hog Sector	904	936	968	1,002
Sheep	38.7	46.6	47.1	47.6
Poultry & Egg	1,173	1,352	1,487	1,561
Other Livestock	329	334	335	335
Total Livestock Water Demand	**9,264**	**9,955**	**10,408**	**10,799**
% Increase over 2010		7.5%	12.3%	16.6%

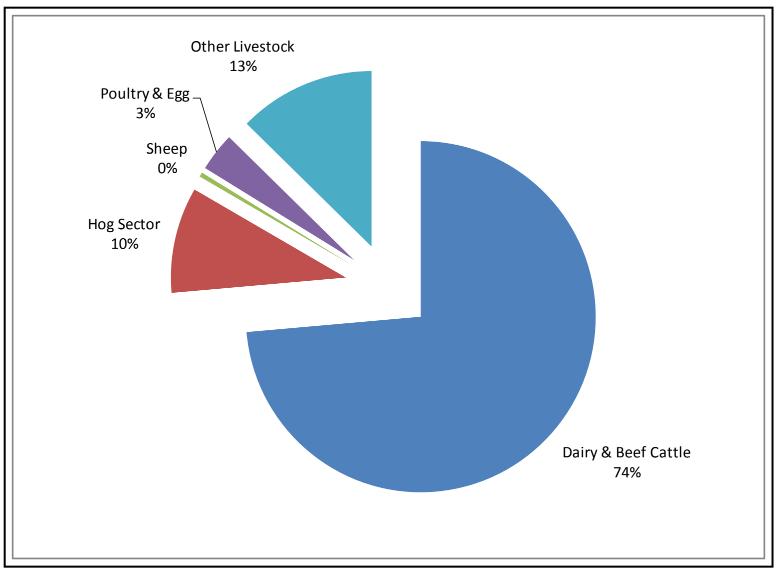


Figure 6.3: Distribution of Total Stockwater Demand in 2010 by Type of Livestock, Qu'Appelle River Basin

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 the estimated water demand coefficients as affected by climate change. Given the seasonal demands for livestock products (for example, turkeys for thanksgiving) and production constraints (such as spring calving), there is little opportunity to shift production out of the summer months.

Type of livestock, their age, climate, feed, and location on farm (indoors/outdoors) are the factors that affect uptake of water. Furthermore, water use technology for the production of hogs has improved significantly over the last 10-15 years, as described in Section 4.3.3.2. Using this information, 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 when cooling will be required, and by 2060, there will be 40% more such days. 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 Demand, 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	**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 from the average water levels from Thacker (2001) for the average outside temperature, 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, now needing only 15 litres of water per day, will need 35 litres per day if the increase in temperature is 3.5° C.

Using the above 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 used 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 6.19: Drinking Water Requirements for Various Categories of Hogs under Alternative Temperature Levels

Type of Animal	Drinking Water Demand in Litre per Day per Animal for Change in Temperature Level		
	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	5.0	7.5	10.0
Boars	8.0	12.5	17.0

Source: Adapted from Thacker (2001).

Table 6.20: Drinking Water Consumption for Swine, By Type of Animal

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	6.76	7.35	7.65
Boars	10.27	11.02	11.40

Source: Adapted from Thacker (2001).

In relation to climate change in the Qu'Appelle River Basin, no effect was assumed for 2020. By 2040, it was assumed that the average temperature would increase by 2°C over the base period (1971-2000) average temperature. For 2060, an increase in temperature of 3.5°C above the 1971-2000 average level was assumed.

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

These estimates serve 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 using the corresponding coefficients from Table 6.21 was employed 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 6.21 applied. The coefficients for estimating water demand to 2060 are presented in Table 6.22.

Table 6.21: Beef Cattle Water Consumption (L/day) at Different Temperature

Type/Weight (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

* Although this study was intended to use a temperature change of 3.5° C, such data were not available. Thus, calculations were made using 4° C temperature change. Implicitly, it was assumed that these differences would be minimal.

Source: Olkowski (2009).

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 it 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 the same methodology as that performed to estimate the coefficients for the beef and dairy sector. Results are presented in Table 6.25. Water is also needed in the cleaning of poultry operations and it is estimated at 1.7 litres per bird per year (Beaulieu et al. 2001).

Table 6.22: Estimated Water Demand Coefficients for Beef Cattle

Type/Weight	Average 1971 – 2000	Plus 2° C	Plus 4° C*
	Litres per Day		
Background			
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

* Although this study was intended to use a temperature change of 3.5° C, such data were not available. Thus calculations were made using 4° C temperature change. Implicitly it was assumed that these differences would be minimal.

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

* Although this study was intended to use a temperature change of 3.5° C, such data were not available. Thus calculations were made using 4° C temperature change. Implicitly it was assumed that these differences would be minimal.

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

* Although this study was intended to use a temperature change of 3.5° C, such data were not available. Thus, calculations were made using 4° C temperature change. Implicitly, it was assumed that these differences would be minimal.

Total stockwater demand for the basin under the climate change scenario is presented in Table 6.26. In 2010, a total of 9,266 dam^3 of water was used. By 2060, this measurement will experience growth, increasing to 11,660 dam^3 – an increase of 25.8% of the 2010 level.

Table 6.26: Water Demand Estimates for Livestock in the Qu'Appelle River Basin for the Climate Change Scenario, 2010 - 2060

Livestock Type	Amount of Water in dam^3			
	2010	2020	2040	2060
Dairy & Cattle	6,820	7,287	7,819	8,392
Hog Sector	904	936	1,042	1,117
Sheep	38.7	46.6	52	54.2
Poultry & Egg	1,173	1,352	1,562	1,716
Other Livestock	329	334	359	380
Total Livestock Water Demand	**9,264**	**9,955**	**10,834**	**11,660**

6.3.3 Stockwater Demand – Water Conservation Scenario

The development of watering devices that reduce waste and the 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. In addition, 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 will most likely come 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 age of a feeder pig. 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 5%

reduction in water demand will occur for the poultry, hog, beef feedlot, and dairy sectors because of water conservation; by 2060, this reduction will be 10%.

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 10,303 dam^3 by 2060, as against 10,799 dam^3 under the baseline scenario – a decrease by 4.6% 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 Qu'Appelle River Basin for the Water Conservation Scenario, 2010 - 2060

Livestock Type	Amount of Water in dam^3			
	2010	**2020**	**2040**	**2060**
Dairy & Cattle	6,820	7,287	7,313	7,582
Hog Sector	904	936	920	952
Sheep	38.7	46.6	45	45
Other Livestock	1,173	1,352	319	320
Poultry & Egg	329	334	1,413	1,405
Total Livestock Water Demand	**9,264**	**9,955**	**10,009**	**10,303**

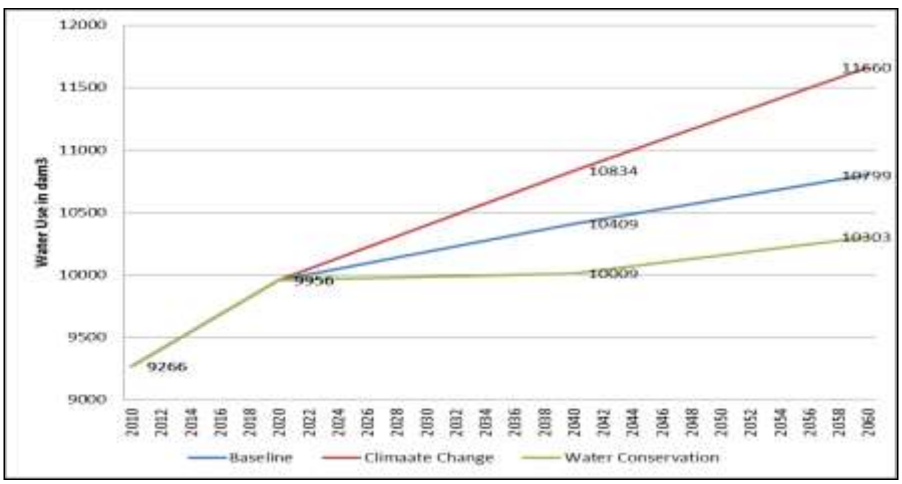


Figure 6.4: Change in the Stockwater Demand in the Qu'Appelle River Basin under Alternate Scenarios, 2010 - 2060

6.4 Water Demand for Greenhouses and Nurseries

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

Table 6.28: Greenhouse and Nursery Water Demand in the Qu'Appelle River Basin for the Baseline Scenario, 2010 - 2060

Year	Water Demand in dam^3
2010	117.3
2020	118.5
2040	124.4
2060	130.6

6.5 Water Demand for Aquaculture

The amount of water demand could not be estimated because there is a lack of data on these operations. As a substitute, the value of this water demand was taken from R. Halliday & Associates' (2009) report. In that report this value was estimated at 111 dam^3 for the Qu'Appelle River Basin. For future years, the same amount of water was assumed necessary for aquaculture purposes. All this water was obtained from groundwater sources. No impact of climate change or water conservation could be ascertained, since there is a lack of information on this sector.

6.6 Total Agricultural Water Demand

In this section, all different types of agricultural water demands are summarized 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 Qu'Appelle River Basin is presented in Table 6.29. Crop water demand (irrigation and pesticide spraying) is the biggest component, of which the water used for irrigation is expected to account for 95% of the agricultural sector's demand in the Qu'Appelle River Basin in 2060. The dairy and beef cattle sectors are the next largest component of water demand. By 2060, the basin could see an increase in their consumption by 219% -- from 65 thousand dam^3 to 206 thousand dam^3. Much of this increase will result for irrigation expansion in the basin, particularly the irrigation development in the Qu'Appelle South Project. In fact, as shown in Figure 6.5, irrigation water demand dominates the total agricultural water demand.

Table 6.29: Agriculture Water Demand in the Qu'Appelle River Basin for the Baseline Scenario, 2010 - 2060

Activity	Water demand in dam^3			
	2010	2020	2040	2060
Irrigation	54,856	56,552	154,367	194,965
Livestock	9,264	9,955	10,408	10,798
Pesticide	349	353	348	348
Other Agricultural (Greenhouses, Nurseries and Aquaculture)	228	230	235	242
Total Agricultural Water Demand	**64,697**	**67,090**	**165,358**	**206,353**
% Increase over 2010 Level		3.7%	155.6%	219.0%

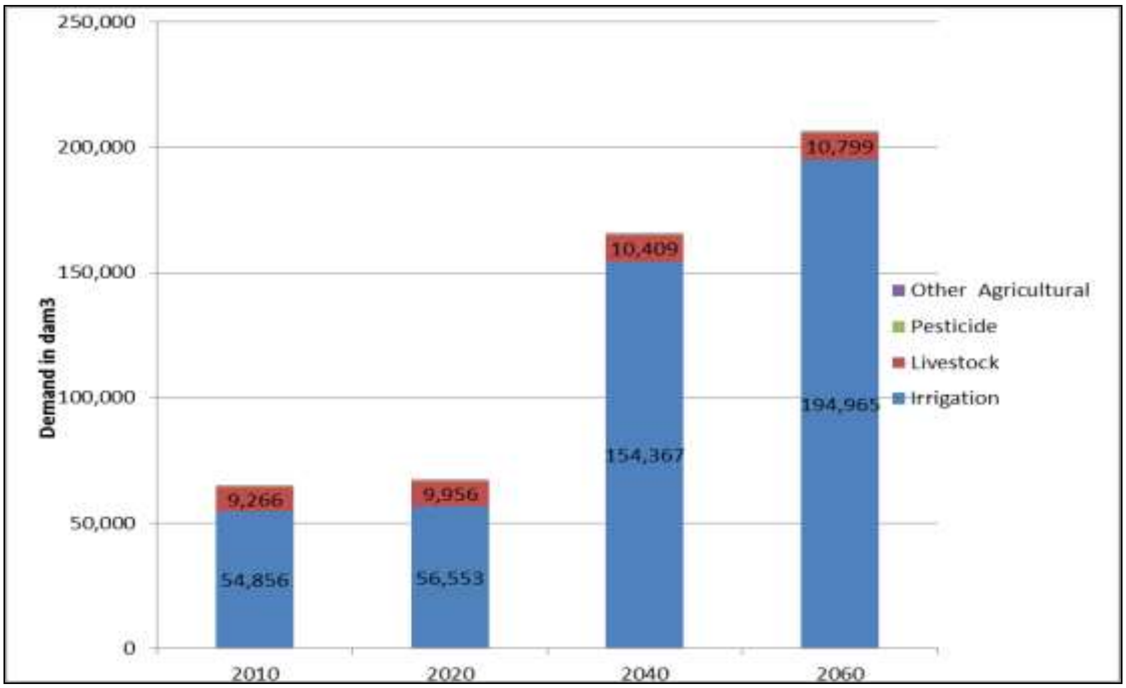


Figure 6.5: Total Agriculture Water Demand, Qu'Appelle River Basin, 2010 - 2060, Baseline Scenario

6.6.2 Total Agricultural Water Demand – Climate Change Scenario

Climate change, through increased average temperature, and a higher frequency of droughts will impart a significant increase to the water demand for agricultural purposes. In the Qu'Appelle River Basin, this water demand will increase to 259 thousand dam^3, which is three times higher than that seem during 2010. Increases will be observed by 2040 when some irrigation expansion in the Qu'Appelle River Irrigation District start. Compared to the baseline scenario, the climate change impact by 2040 would create an increase by 16% in the agricultural water demand. By 2060, an increase in this water demand by 26% is likely (Table 6.30).

Table 6.30: Agriculture Water Demand in the Qu'Appelle River Basin for Climate Change Scenario, 2010 - 2060

Activity	Water Demand in dam^3			
	2010	**2020**	**2040**	**2060**
Irrigation	54,856	56,552	180,769	247,158
Livestock	9,264	9,955	10,834	11,660
Pesticide	349	353	363	377
Other Agricultural (Greenhouses,	228	230	235	242
Total Agricultural Water Demand	**64,697**	**67,090**	**192,201**	**259,437**
% Increase over 2010 Level		3.7%	197.1%	301.0%
% Increase over Baseline Scenario		0.0%	16.2%	25.7%

6.6.3 Total Agricultural Water Demand – Water Conservation Scenario

The adoption of water conservation offers a way to reduce agricultural water demand in the basin. These results are shown in Table 6.31. Under this scenario, total agricultural water demand in 2060 could be 180 thousand dam^3, some 13% lower than the baseline scenario.

Table 6.31: Agriculture Water Demand in the Qu'Appelle River Basin for Water Conservation Scenario, 2010 - 2060

Activity	Water Demand in dam^3			
	2010	**2020**	**2040**	**2060**
Irrigation	54,856	52,425	135,250	169,261
Livestock	9,264	9,955	10,009	10,304
Pesticide	350	353	314	174
Other (Greenhouses, Nurseries and Aquaculture)	228	230	235	242
Total Agricultural Water Demand	**64,698**	**62,963**	**145,807**	**179,981**
% Increase (decrease) over 2010 Level		-2.7%	125.4%	178.2%
% Increase over Baseline Scenario		-6.2%	-11.8%	-12.8%

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

6.7 Source of Water for Agricultural Activities

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

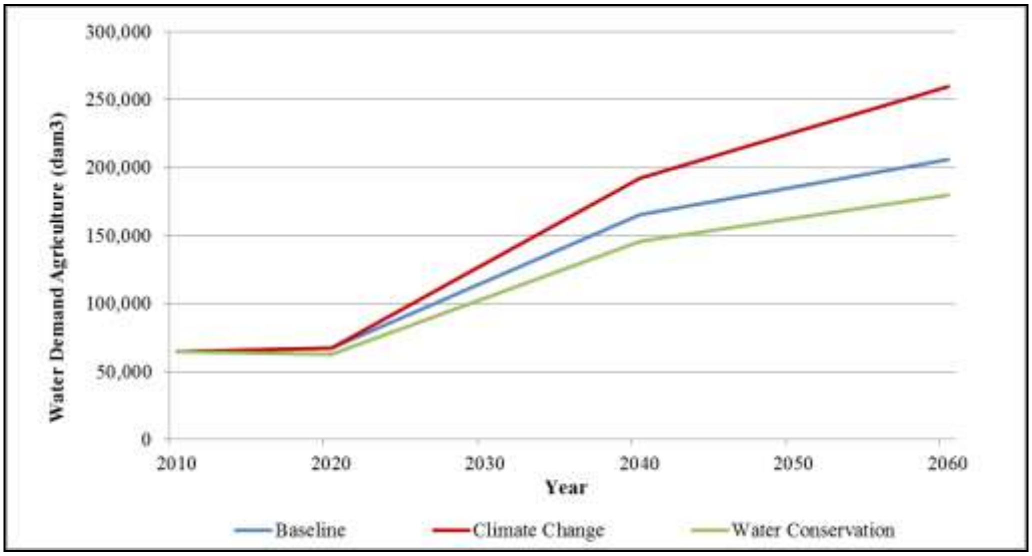


Figure 6.6: Estimated Agricultural Water Demand in the Qu'Appelle River Basin, 2010 - 2060, under Study Scenarios

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 (through releases over the Qu'Appelle dam). Other demands are withdraw water from a combination of surface or groundwater sources. The proportion of surface water demanded by agricultural activity is shown in Table 6.32. These values pertain to the year 2010. Since there is a lack of information, the same proportions were applied for the future years.[62] On account of non-availability of data on the source of water, these estimates were developed by using the best sets of information available. However, these 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 mainly determined by production practices. For example, livestock enterprises with year-round confinement, such as the hog and poultry sectors, and industrial precision and monitoring of inputs including water to maximize production, need consistency in the quality and quantity of water. The 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).

[62] 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 demands.

Table 6.32: Share of Surface Water and Groundwater Used in Agricultural Activities in Qu'Appelle River Basin in 2010

Type of Demand	Share of Total Water Demand (%)	
	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%
Greenhouses, Nurseries and Aquaculture	20.0%	80.0%

Considering 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 appears in Table 6.34.

Table 6.33: Agriculture Surface Water Estimates by Type of Demand, Qu'Appelle River Basin, 2010 - 2060

Type of Water Demand	Surface Water Demand in dam^3			
	2010	2020	2040	2060
Livestock				
Dairy and Cattle	3,410.0	3,643.5	3,785.8	3,926.2
Hog Sector	62.4	64.5	66.8	69.1
Sheep	19.4	23.3	23.5	23.8
Other Livestock	164.9	167.6	167.9	168.1
Poultry and Egg	80.9	93.3	102.6	107.7
Total Livestock Surface Water Demand	**3,737.6**	**3,992.2**	**4,146.6**	**4,295.0**
% of Total Water Demand	40.3%	40.1%	39.8%	39.8%
Crop				
Irrigated	52,113.2	53,809.7	151,624.6	192,222.2
Pesticide	279.8	282.3	278.7	278.7
Greenhouse	45.5	45.7	46.9	48.1
Total Crop Surface Water Demand	**52,438.5**	**54,137.7**	**151,950.3**	**192,549.1**
% of Total Water Demand	94.6%	94.8%	98.1%	98.5%

Table 6.34: Agriculture Water Demand by Source of Water in the Qu'Appelle River Basin, Baseline Scenario, 2010 - 2060

Particulars	Water Demand in dam^3			
	2010	2020	2040	2060
Total Agriculture	64,699	67,090	165,360	206,353
Groundwater	8,830	9,277	10,127	10,601
Surface Water	55,869	57,813	155,233	195,752
Surface Water % of Total	**86.4%**	**86.2%**	**93.9%**	**94.9%**

By 2060, about 40% of livestock water demand and 98% of crop water demand will be supplied from surface water sources. For agriculture as a whole, as shown in Table 6.34 (although in 2010), 87% of the total water is surface water. By 2060, this proportion is expected to rise to 95% of the total. The larger proportion of crop water demand is for irrigation purposes, which is expected to be developed through surface water bodies; water will be released from Lake Diefenbaker to Buffalo Pound Lake and other water bodies. As shown in Figure 6.7, agriculture will depend increasingly on surface water in the future.

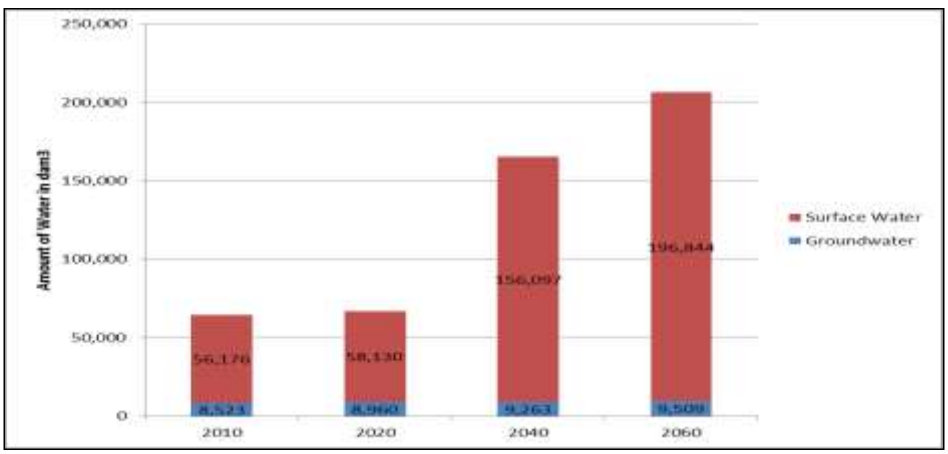


Figure 6.7: Proportion of Total Agricultural Water Demand by Source of Water in the Qu'Appelle River Basin, 2010 – 2060

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 6.32. The results for the climate change scenario are presented in Table 6.35. Water withdrawals from surface water bodies in 2060 would increase from 196 thousand dam^3 (under the baseline scenario) to 248 thousand dam^3 under this scenario. This represents an increase of 26.7% over the baseline scenario. Climate change may also increase the dependence of agriculture on surface water bodies, as now 96% of the total agriculture water demand is withdrawn from this source.

Table 6.35: Agriculture Water Demand by Source of Water in the Qu'Appelle River Basin, Climate Change Scenario, 2010 - 2060

Particulars	Water Demand in dam^3			
	2010	2020	2040	2060
Total Agriculture	64,699	67,097	192,201	259,436
Groundwater	8,830	9,278	10,554	11,446
Surface Water	55,869	57,819	181,647	247,990
Surface Water % of Total	86.4%	86.2%	94.5%	95.6%

6.7.3 Source of Water for Agricultural Activities – Water Conservation Scenario

A 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. The demand falls from 196thousand dam^3 in 2060 under the baseline scenario to only 170 thousand dam^3 – a reduction of 13.2% of the baseline level.

Table 6.36: Agriculture Water Demand by Source of Water in the Qu'Appelle River Basin, Water Conservation Scenario, 2010 - 2060

Particulars	Total Water Demand in dam^3			
	2010	2020	2040	2060
Total Agriculture	64,699	62,963	145,807	179,980
Groundwater	8,830	9,254	9,760	10,086
Surface Water	55,869	53,709	136,047	169,894
Surface Water % of Total	86.4%	85.3%	93.3%	94.4%

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 3.6 of this report. The estimated water consumption for agricultural purposes is discussed in this section for the three study scenarios.

6.8.1 Agricultural Water Consumption – Baseline Scenario

Since not all water removed from a water body (source) for agricultural purposes is lost; as noted above, a portion of this returns back to the original source.[63] Using the methodology presented in Section 3.6 of this report, water consumption was estimated.

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

For the baseline scenario, these estimates are presented in Table 6.37. In 2010, the agriculture in the basin consumed 51 thousand dam^3 of water, most of which was from surface water bodies. By 2060, it is estimated that the agricultural consumption will increase to 158 thousand dam^3 of water. In all four time periods, the consumption was almost three-quarter of the total water intake. Much of this water is returned from irrigation districts in the basin, namely Thunder Creek Irrigation District, Brownlee Irrigation District, and the newly developed Qu'Appelle South Project.

Table 6.37: Water Consumption for Agricultural Demands by Source of Water, Qu'Appelle River Basin, Baseline Scenario, 2010-2060

Particulars	Total Water Consumption in dam^3			
	2010	2020	2040	2060
Total Agriculture Water Consumption	50,985	52,952	126,768	157,612
Groundwater	7,837	8,281	8,645	8,876
Surface Water	43,148	44,670	118,122	148,736
Total Consumption as % of Water Intake	78.8%	78.9%	76.7%	76.4%

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 198 thousand 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.

6.8.3 Agricultural Water Consumption – Water Conservation Scenario

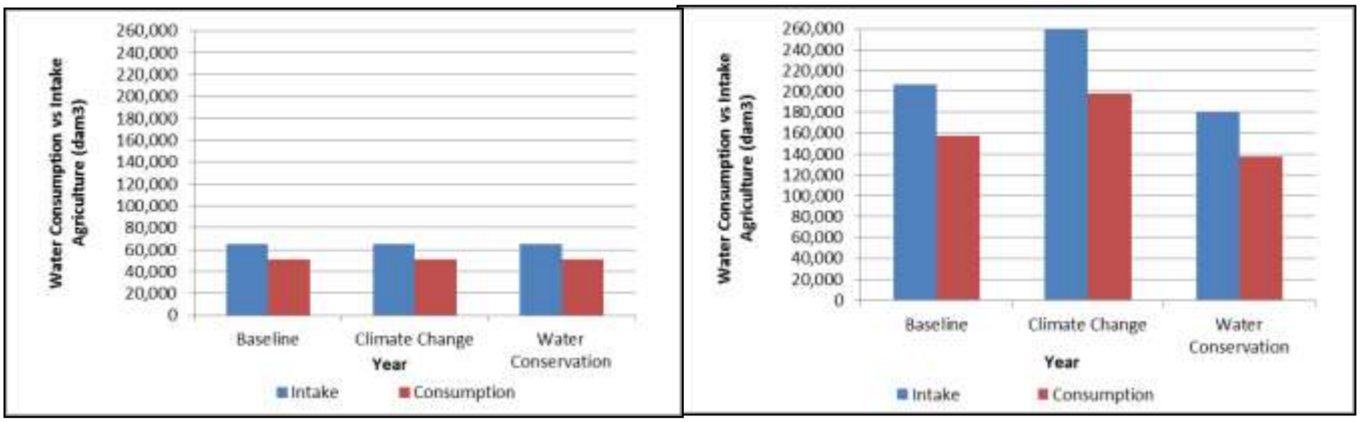
Under the assumption that irrigators and other water users in agricultural production adopt water conservation practices, the total water consumption will decrease to 112 thousand dam^3 by 2040 and 138 dam^3 by 2060 (Table 6.39). By 2060, water consumption levels will be 270% of the 2010 level. A comparison of three scenarios' water consumption is shown in Figure 6.8.

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

Particulars	Total Water Consumption in dam^3			
	2010	2020	2040	2060
Total Agriculture Water Consumption	50,985	52,959	147,008	197,646
Groundwater	7,837	8,283	8,819	9,259
Surface Water	43,148	44,676	138,189	188,388
Total Consumption as % of Water Intake	78.8%	78.9%	76.5%	76.2%

Table 6.39: Water Consumption for Agricultural Demands by Source of Water, Qu'Appelle River Basin, Water Conservation Scenario, 2010-2060

Particulars	Total Water Consumption in dam^3			
	2010	2020	2040	2060
Total Agriculture Water Consumption	50,985	49,856	111,994	137,665
Groundwater	7,837	8,331	8,462	8,588
Surface Water	43,148	41,526	103,533	129,077
Total Consumption as % of Water Intake	78.8%	79.2%	76.8%	76.5%



2010 **2060**

Figure 6.8: Water Intake and Water Consumption for Agriculture Purposes in the Qu'Appelle River Basin, 2010 and 2060, Study Scenarios

6.9 Summary of Agriculture Water Demand

In the Qu'Appelle River Basin, agriculture is a prominent industry and a major water user. Water is demanded for crop production (through irrigation and pesticide spraying by dryland farmers) and for livestock production. In addition, smaller amounts of water are also demanded for greenhouses, nurseries, and aquaculture. In the future, irrigation activity is expected to increase in the basin. This will occur through the development of the Qu'Appelle South Project which could add another 108,181 acres under irrigation, over the existing district and private irrigated areas. However, given past evidence on adoption of irrigation in some irrigation 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 35,763 acres in 2010 to 140,569 acres by 2020 – an almost three-fold increase.

The total agricultural water demand in the basin is estimated to increase from 64,588 dam^3 in 2010 to 206,353 dam^3 by 2060 – an increase of 219% of the 2010 level. Climate change may bring forth further increases in these levels. Under the climate change scenario, agriculture could demand 259,436 dam^3 of water. The adoption of water conservation measures could bring a reduction in the level of water demand to 179,980 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, part of the water withdrawn is regained by being returned back, particularly from irrigation districts. It is estimated that although at present 79% of the water withdrawn by agriculture is consumed; by 2060 this proportion will decrease to 76%.

(Photo Courtesy of Saskatchewan Watershed Authority)
Qu'Appelle River at Muscowpetung Area

Chapter 7

Industrial and Mining Water Demand

The major Industrial and Mining activity in the Qu'Appelle River Basin is related to potash production. A large proportion of provincial potash mines are located in this basin. In this chapter, mining water demand and other manufacturing activities' water demands are described. Manufacturing in this chapter includes only those establishments that do not receive water from a municipal water system. The other manufacturing establishments are included under the municipal/domestic water demand estimated in the next chapter.

This chapter is divided into three sections: Section 7.1 describes the mining water demand, while section 7.2 addresses estimation of manufacturing water demand. The latter section includes two types of manufacturing establishments – those existing at present, and those that could appear in the basin as a result of other economic development activities, particularly irrigation. A summary of industrial and mining water demand is presented in Section 7.3.

7.1 Mining Water Demand

As noted above, the major mining water demand in the basin is for potash production. However, there is a small amount of water used for oil and gas production and for salt production. These 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, total water demand for potash production was estimated. For future water demand, this required some projection of potash mining activity. At the time of the writing of 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 assumptions shown in Table 4.23 were used. The water demand for those mines that are located in the Qu'Appelle River Basin but withdraw their water from the adjoining basin are assumed to have no water demand met from the Qu'Appelle River Basin. These demands are included under interbasin transfers (IBT).

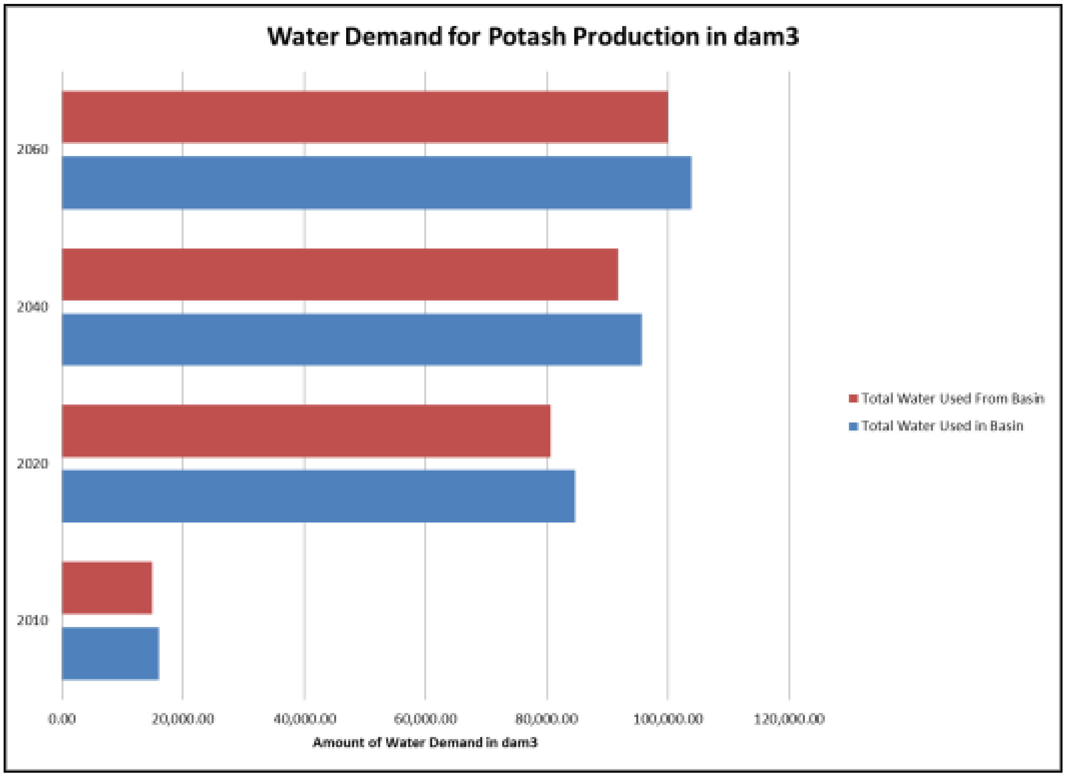
The projected water demand from potash mines to 2060 is presented in Table 7.1. For these estimates, present (existing mines) water demand coefficients from Table 3.11 were applied. The coefficients for the new mines are 5.53 dam^3 per 1000 tonnes of potash produced for solution mines, and for BHP Billiton the coefficient is 1.37 dam^3 per 100 tonnes of potash. It is further assumed that 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. There may be more solution mines as deeper deposits and more difficult formations are exploited, in which case the water demand could rise substantially. However, this information is rather poor and therefore, no adjustment in the water demand coefficients was made.

Table 7.1: Projected Water Demand for Potash Mining in the Qu'Appelle River Basin, Baseline Scenario, 2010 – 2060

Particulars	Source of Water	Water Demand in dam^3			
		2010	2020	2040	2060
Existing Mines	Surface Water	11,653	32,130	32,130	32,130
	Groundwater	2,346	2,440	2,440	2,440
	Interbasin Transfer from SSRB	2,082	6,471	6,471	6,471
New Mines	Surface Water	0	39,365	42,129	42,129
	Groundwater	0	1,544	9,836	9,836
	Interbasin Transfer from SSRB	0	2,738	2,738	10,952
All Mines	Surface Water	11,653	71,495	74,259	74,259
	Groundwater	2,346	3,984	12,276	12,276
	Interbasin Transfer from SSRB	2,082	9,209	9,209	17,423
Total Water Demand in Basin (Within-Basin and Interbasin Transfer)		16,082	84,688	95,744	103,959
Total Water Sourced in Basin		13,999	75,479	86,535	86,535

The total water demand (supplied within the basin) for potash mining was estimated at 13,999 dam^3 per annum for 2010. This includes water from both surface and groundwater sources. Several mines take water from both sources, and the split between them when there is a peak demand or some source is constraining. However, the data on the actual split were not available. Water withdrawn from surface and groundwater bodies is shown in Table 7.1, as well as water sourced outside the basin. During 2010, potash mining required a total of 16,082 dam^3 of water, of which 85.4% was surface water (72.5% supplied within the basin and 12.9% transferred from the South Saskatchewan River Basin). The rest of this water is procured from groundwater sources. By 2060, potash mining water demand is estimated to increase by almost five and a half times the 2010 level – at 103,959 dam^3, of which 88.2% will be obtained from surface water bodies (71.4% within the basin, and 16.8% from the South Saskatchewan River Basin). The remaining 11.8% will be sourced from groundwater.

Water needed for potash production is shown in Figure 7.1. Both total water demand and that from sources within the basin are shown in this figure. By 2060, this water demand is expected to increase to 104 thousand dam^3, of which about 86 thousand dam^3 will be from the basin sources. Thus the basin will support all but 16.8% of the total water demand for potash production. Over this period, relatively speaking, more water will be transferred from the adjoining basin.



Source: Estimations from CIBC World Markets Inc. (2008); SWA (undated).

Figure 7.1: Water Demand for Potash Production in the Qu'Appelle River Basin, Baseline Scenario, 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 may lead these mines to adopt technology that reduces demand or to find other sources of water. Lacking information, this study attributes no effect 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 types of measures that can reduce water demand in potash mining, including refrigeration units for cooling, reduction of housekeeping water use, reducing 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 water 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 water consumption from the Ogallala aquifer**.**

Electromagnetic separation of the potash from the salt is a technology that could be used to reduce water demand. This technique adds a process step that reduces the amount of salt and other substances in the ore, although water is still necessary 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 demand for fresh water. The adoption of conservation measures for solution mines is estimated to result in reductions of 5%, 15%, and 25% by 2020, 2040, and 2060, respectively.[64] For lack of better information, the adoption of conservation measures for underground mining was assumed to be half of these amounts. The water demand of the potash industry practicing the water conservation measures are presented in Table 7.2.

Table 7.2: Water Demand for the Potash Industry for the Water Conservation Scenario, Qu'Appelle River Basin, 2020 – 2040

Particulars	Source of Water	Water Demand in dam^3		
		2020	2040	2060
Existing Mines	Surface Water	30,663.2	27,729.9	24,796.6
	Groundwater	2,379.3	2,257.3	2,135.2
	IBT from SSRB	6,309.27	5,985.71	5,662.16
New Mines	Surface Water	37,396.8	35,809.8	31,596.9
	Groundwater	1,466.6	8,360.7	7,377.1
	IBT from SSRB	2,669.6	2,532.7	9,583.1
All Mines	Surface Water	68,059.9	63,539.7	56,393.5
	Groundwater	3,845.9	10,618.0	9,512.4
	IBT from SSRB	8,978.8	8,518.4	15,245.2
Total Water Demand in Basin (Within-Basin and IBT)		80,884.7	82,676.0	81,151.1
Total Water Sourced (Within Basin)		71,905.8	74,157.7	65,905.8
Within-Basin Water Demand % of Baseline Scenario		95.3%	85.7%	76.2%

IBT = Interbasin Transfers

64 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.

Since the current water demand is based on the present level of adoption of water management practices, no further changes were made. By 2020, it is assumed that new water conservation measures could reduce water demand, resulting in a 4.7% saving. By 2040, water demand for potash production is estimated to be reduced to 74,158 dam^3, which represents a reduction of 14.3% over the baseline scenario level. By 2060, the reduction in water demand would be even higher, by 23.8% over the baseline scenario.

A 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 water demand was assumed remain unaffected by climate change.

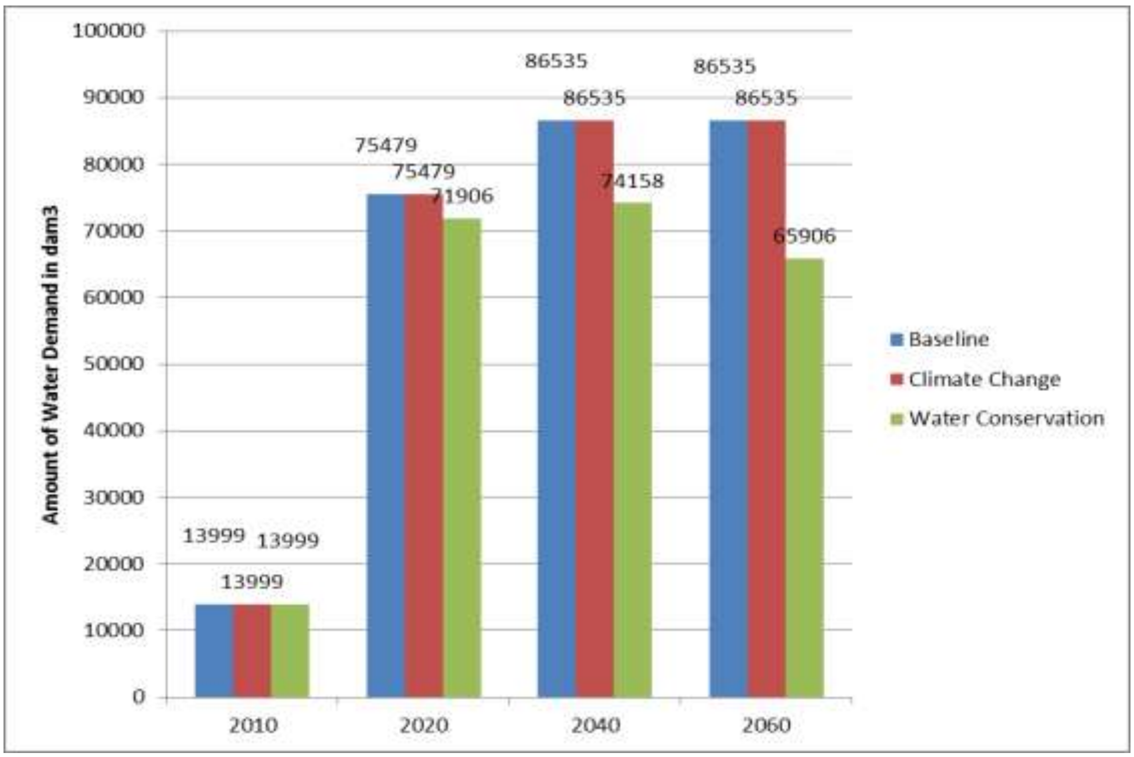


Figure 7.2: Total (Within-Basin) Water Demand (in dam^3) for Potash Production, Qu'Appelle River Basin under Study Scenarios, 2010 - 2060

7.1.1.4 Source of Water for Potash Production

During 2010, potash mining required a total of 16,082 dam^3 of water, of which 85.4% was supplied from surface water bodies, with the remaining past drain from groundwater sources. Some mines use both surface and groundwater, but their division is not known. The estimated values are shown in Table 7.3.

Table 7.3: Distribution of Total (Within-Basin and Interbasin Transfer) Water Demand under the Baseline Scenario, Qu'Appelle River Basin, 2010 - 2060

Source of Water	Total Amount of Water in dam^3			
	2010	**2020**	**2040**	**2060**
Surface	13,735	80,704	83,468	91,682
Groundwater	2,346	3,984	12,276	12,276
Total Water Demand	16,082	84,688	95,744	103,959
Surface water % of total	85.4%	95.3%	87.2%	88.2%

Over a period of time, the use of groundwater is expected to decrease as shown in Figure 7.3. By 2060, potash mining water demand will almost triple the current demand – 103,958 dam^3, of which 88% would be obtained from surface water bodies.

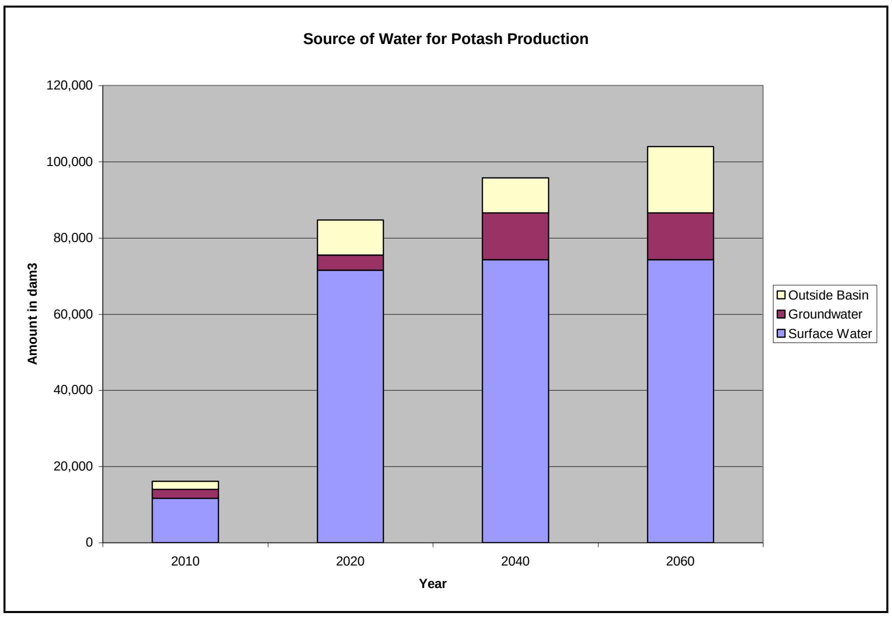


Figure 7.3: Distribution of Total Water Demand for Potash Production in the Qu'Appelle River Basin by Source of Water, Baseline Scenario, 2010 - 2060

7.1.1.5 Water Consumption for Potash Production

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 is regarded as consumed.

7.1.2 Oil and Gas Production

7.1.2.1 Oil and Gas Production Water Demand – Baseline Scenario

The water demand for 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 7.4. By 2060, the number of wells in the basin will be reduced to 19, from an estimated 92 wells per annum drilled currently.

Table 7.4: Estimated Wells Drilled in Qu'Appelle Basin

Technology	2010	2020	2040	2060
Vertical	27	37	22	6
Horizontal	65	87	52	13
Total	92	124	74	19

Source: Estimates using 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 to be consumed in the production of oil and gas in the Qu'Appelle River Basin is based on the estimated well drilling activity by type times the effective coefficient. Enhanced oil recovery water demand 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 7.5. In 2010, this requirement was estimated at 341 dam^3 per annum. This amount is expected to shrink to 69 dam^3 by 2060 – a reduction by 80% of the 2010 level.

Table 7.5: Water Demand by Oil Extraction Production Technique in the Qu'Appelle River Basin, 2010-2060

Technology	2010	2020	2040	2060
Primary	10.17	13.65	8.19	2.05
Water Flood	22.93	30.79	18.48	4.62
Horizontal	185.25	248.72	149.23	37.31
Enhanced	122.42	164.37	98.62	24.66
Total	340.78	457.54	274.52	68.63

Source: Estimates using Sask Energy and NEB reports various years

7.1.2.2 Oil and Gas Production Water Demand – Climate Change Scenario
The direct effect of climate change on the demand for water by the oil and gas industry is likely to be minimal.

7.1.2.3 Oil and Gas Production Water Demand – Water Conservation Scenario
In oil and gas production, water is used in drilling of oil and gas wells, for recovery of heavy oil, and in forcing oil from old conventional wells or natural gas from wells that have tight or sandy formations. Oil recovery from oilsands is a water intensive process, although the 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 water conservation measures that are feasible. The 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 demand between 400 m^3 to 600 m^3 per well. Shale gas using the 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 demands from fresh water sources in 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 use of the multi-stage frac technique. The Canadian Association of Petroleum Producers (2011) reports that up to 15% of the water taken has 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 steady 15% recycling rate.

Estimates of water conservation on the demand for water from the oil and gas sector are presented in Table 7.6. In the future, on average, water conservation measures may lessen the total water demand for oil and gas production by 15% of the baseline level.

Table 7.6: Water Demand dam^3 Conservation Scenario in the Qu'Appelle River Basin, 2010 - 2060

Particulars	Total Water Demand in dam^3			
	2010	2020	2040	2060
Total Water Demand	340.78	388.91	233.35	58.34
% of Baseline Scenario	100.0%	85.0%	85.0%	85.0%

7.1.3 Other Mining Demands

7.1.3.1 Other Mining Water Demand – Baseline Scenario
The Canadian Salt Company at Belle Plaine demanded 29.7 dam^3 of water in 2010. This water was used to produce 250,000 tonnes of salt, leading to a coefficient of 0.001185 dam^3 per tonne of salt. The company expects a 10% increase in production from 2010 to 2020, 2020 to 2040 and

2040, to 2060. The water demand coefficient estimated from 2010 production was assumed to remain constant. Therefore, the demand for water will be 30.5, 33.6, and 36.9 dam^3 in 2020, 2040, and 2060, respectively.

7.1.3.2 Other Mining Water Demand – Climate Change Scenario

The direct effect of climate change on the demand for water will probably be negligible because of the controlled production process. The indirect effect of climate change on those mines that rely on surface water bodies may cause them to adopt technology that reduces demand or to find other sources of water. Therefore, water demand under the climate change was assumed to maintain the same level as under the baseline scenario.

7.1.3.3 Other Mining Water Demand – Water Conservation Scenario

The salt is produced from by-product brines from the adjacent Mosaic Potash Plant by evaporation process. Fresh water is employed to create slurry to remove containments. Then, the water is vacuum evaporated from the salt brine. It is assumed that a water use efficiency of 2% is obtained in each of the forecast periods. The total water demand under this scenario is shown in Table 7.7. The water demand level of 29.7 dam^3 in 2010 could increase by 24% in 2060 under the baseline scenario. However, under the water conservation scenario, this increase would only be 22% of the 2010 water demand level.

Table 7.7: Other Mining Water Demand under the Baseline and Water Conservation Scenarios, Qu'Appelle River Basin, 2010 - 2060

Scenario	Total Water Demand in dam^3				2060 as % of 2010
	2010	2020	2040	2060	
Baseline	29.7	30.5	33.6	36.9	124.3
Water Conservation	29.7	29.9	32.9	36.2	121.9
Scenario Demand Level as % of Baseline Scenario	100.0%	98.0%	97.9%	98.1%	

7.2 Manufacturing Water Demand

Existing and potential new industries' water demand forecasts will depend on lifespan of the plants, reinvestment, capacity constraints, expansion to meet market opportunities, and new markets. Forecast of new manufacturing establishments is fraught with issues, since many factors affects new industry or re-location of existing industries. In this section, water demand two types of manufacturing activities are described: One, existing manufacturing in Section 7.2.1, and two, irrigation-induced manufacturing activities in Section 7.2.2.

7.2.1 Existing Manufacturing Industries

7.2.1.1 Existing Manufacturing Industries Water Demand under Baseline Scenario

Assuming that gasoline demand on a per capita basis will remain unchanged from 2009, and that the refinery at Regina will keep its market share, the estimated water demand for petroleum refining for 2020, 2040, 2060 period will be 3,002, 3,254, and 4,485 dam^3 per annum, respectively. Production at Lilydale will increase as poultry production increases with Saskatchewan's population. An expansion of capacity at the Evraz steel mill following the average per annum 2.6% growth will result in more than double the 2010 water demand by 2060. The total demand and the demand for surface and groundwater from existing industries in the Qu'Appelle River Basin are presented in Table 7.8. The total water demand in 2010 was estimated at 7,445 dam^3, which is expected to increase to 9,262 dam^3 by 2060. This is an increase of 24% over the 2010 period.

Table 7.8: Current and Future Manufacturing Water Demand in the Qu'Appelle River Basin, Baseline Scenario 2020 - 2060

Industry	Water Demand in dam^3			
	2010	2020	2040	2060
Pound-Maker Agventures Ltd.	46.9	46.9	48.0	49.3
Terra Grain Fuels Inc.	542.1	542.1	555.0	569.1
YARA (Previously Saskferco)	3,599.5	3,599.5	3,685.9	3,779.5
EVRAZ Inc. (formerly IPSCO)	9.3	11.7	16.9	22.4
Consumer Co-op Refineries	3,001.9	3,254.0	3,854.7	4,485.2
Lilydale	243.3	354.9	354.9	354.9
Agrium Fertilizer Storage	1.8	1.9	1.9	1.9
Total Manufacturing Water Demand	**7,444.8**	**7,811.0**	**8,517.3**	**9,262.3**
Change in Total Manufacturing Water Demand % of 2010	-	4.9%	14.4%	24.4%
Water Demand by Source of Water				
Groundwater	3,292.0	3,655.8	4,257.6	4,889.4
Surface Water	4,152.8	4,155.2	4,259.7	4,372.9
Surface Water as % of the Total	55.8%	53.2%	50.0%	47.2%

7.2.1.2 Existing Manufacturing Industries Water Demand under 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. A warming of surface waters would have a direct impact on industrial operations by decreasing the efficiency of cooling systems (Lemmen and Warren, 2004, p. 42). Further review of the literature did not yield any basin related or Canadian studies showing the impact of climate change. As discussed in Section 5.2.2, the same change[65] in the water demand coefficient were applied to industrial water demand as that used for domestic water demand. Estimates of industry water demand for the climate change scenario are presented in Table 7.9. This water demand is expected to increase to 9,448 dam^3 per annum by 2060.

Table 7.9: Current and Future Manufacturing Water Demand in the Qu'Appelle River Basin, 2020 to 2060 under Climate Change Scenario

Industry	Water Demand in dam^3			
	2010	2020	2040	2060
Pound-Maker Agventures Ltd.	46.9	46.9	49.0	50.2
Terra Grain Fuels Inc.	542.1	542.1	566.1	580.5
YARA (Previously Saskferco)	3,599.5	3,599.5	3,759.7	3,855.1
EVRAZ (formerly IPSCO)	9.3	11.7	17.2	22.8
Consumer Co-op Refineries	3,001.9	3,254.0	3,931.8	4,574.9
Lilydale	243.3	354.9	362.0	362.0
Agrium Fertilizer Storage	1.8	1.9	1.9	2.0
Total Manufacturing Water Demand	**7,444.8**	**7,811.0**	**8,687.7**	**9,447.5**
Water Demand by Source of Water				
Groundwater	3,292.0	3,655.8	4,342.8	4,987.2
Surface Water	4,152.8	4,155.2	4,344.9	4,460.3

7.2.1.3 Existing Manufacturing Industries Water Demand under Water Conservation Scenario

Water conservation in manufacturing processes that use once through cooling, then discharge of water, can be changed to cooling tower technology for the recycling of water. 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.

The Consumer Co-operative refinery has already implemented a waste water recycling program that reduces discharge from 5,700 m^3 per day to 1,700 m^3 per day (Sask Ministry of Environment 2008). Further declines in water demand to 2060, therefore will likely be minor. For instance, water is used in the manufacture of nitrogen fertilizer; the plant is relatively new such that the

[65] This is an assumption made for simplifying the estimation at this point in time. However, this assumption requires a comprehensive scientific study.

efficiency attained with the current technology cause little improvement to be possible. A 2% decline in the demand for water is expected for the industries, as presented in Table 7.10.

7.2.1.4 Sources of Water for Manufacturing Demands

The source of water for industrial demand is reported in Table 7.8 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 7.4. For the future, by 2060, one observes an increase in the use of groundwater. The proportion of surface water under the baseline scenario in 2010 was 56% of the total, which is reduced to 47% by 2060. The same proportions are also estimated for the water conservation scenario in the basin.

Table 7.10: Current and Future Manufacturing Water Demand in the Qu'Appelle River Basin under Water Conservation Scenario, 2020 - 2060

Industry	**Water Demand in dam^3**			
	2010	**2020**	**2040**	**2060**
Pound-Maker Agventures Ltd.	46.9	46.0	47.1	48.3
Terra Grain Fuels Inc.	542.1	531.2	543.9	557.7
YARA (Previously Saskferco)	3,599.5	3,527.6	3,612.2	3,703.9
EVRAZ Inc. (formerly IPSCO)	9.3	11.4	16.5	21.9
Consumer Co-op Refineries	3,001.9	3,188.9	3,777.6	4,395.5
Lilydale	243.3	347.8	347.8	347.8
Agrium Fertilizer Storage	1.8	1.8	1.8	1.9
Total Manufacturing Water Demand	**7,444.8**	**7,654.7**	**8,346.9**	**9,077.0**
Water Demand by Source of Water				
Groundwater	3,292.0	3,582.7	4,172.5	4,791.6
Surface Water	4,152.8	4,072.0	4,174.4	4,285.4

7.2.1.5 Water Return/Discharge from Manufacturing Activities

The estimated discharge of water from industrial activities in the Qu'Appelle River Basin is presented in Table 7.11. The percentage of the water demand that is returned is from company estimates for Consumer Co-operative Refinery and Pound-Maker; Statistics Canada estimates for Evraz and Lilydale; and from industry coefficients for Terra Grain and Yara. All the water is assumed to be discharged to surface water bodies as Consumers Co-operative, and Lilydale employs the municipal sewage system for disposal.

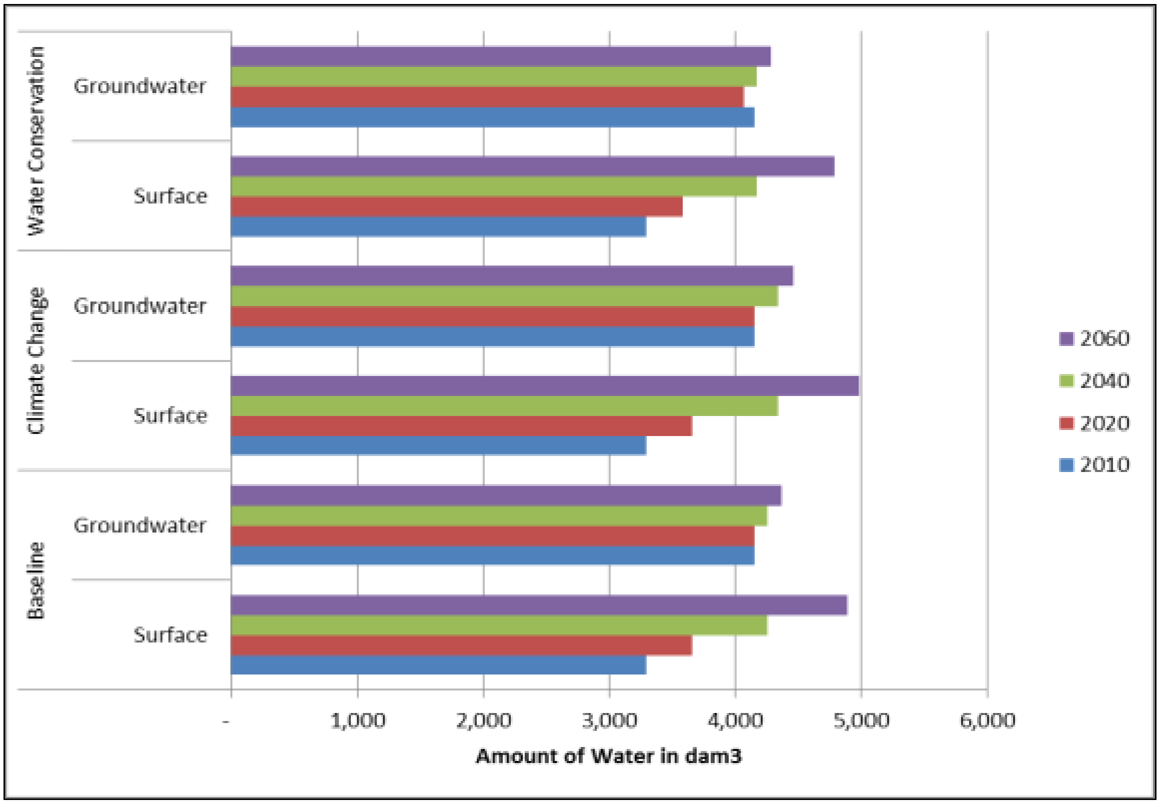


Figure 7.4: Manufacturing Water Demand, Existing Establishments in the Qu'Appelle River Basin under Study Scenarios, 2010 – 2060

Table 7.11: Water Return from Manufacturing Activities in the Qu'Appelle River Basin, Baseline Scenario, 2020 - 2060

Industry	%[1]	Water Return in dam^3			
		2010	2020	2040	2060
Pound-Maker Agventures Ltd.	0%[2]	-	-	-	-
Terra Grain Fuels Inc.	13%	69.4	69.4	71.0	72.8
YARA (Previously Saskferco)	15.2%	547.5	547.5	560.6	574.9
EVRAZ Inc. (formerly IPSCO)	77.5%	7.2	9.0	13.1	17.3
Consumer Co-op Refineries	19.8%	595.0	645.0	764.0	889.0
Lilydale	77.5%	188.5	275.1	275.1	275.1
Agrium Fertilizer Storage	1.4	1.5	1.5	1.5	1.4
Total Water Returned	1,407.6	1,545.9	1,683.8	1,829.1	1,407.6

[1] Percentage of water demand that is returned.

[2] The thin stillage from ethanol manufacture is used to water the cattle; no runoff from the pens into water bodies is assumed.

7.2.2 Induced Development Activities

7.2.2.1 Water Demand for Induced Development Activities under 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 4.30.

The net consequence of establishing a feedlot is a reduction in water used for irrigation because of the reduced amount of water needed to grow silage compared to other crops. Even with the increase in animal watering, the net effect is reduced water demand. The total net water demand for the industries is estimated to be -482.4 by 2040 and -442.6 by 2060. Since, the irrigation development in the Qu'Appelle basin is not profitable until after 2020, no change is anticipated for 2020. The total water demand for these industries is estimated to be 1,505 dam^3 by 2040, and there is a slight increase to 1,545 dam^3 by 2060 (Table 7.12). All water needs are met through surface water bodies.

7.2.2.2 Water Demand for Induced Development Activities under Climate Change Scenario

The climate change effect for induced water demand is on 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 7.13. By 2060, an increase of 45 dam^3 is estimated. Much of this increase will be a result of water demand for the projected feedlots in the basin.

Table 7.12: Induced Water Demand Activities in the Qu'Appelle River Basin, Baseline Scenario, 2040 - 2060

Industry	**Water Demand in dam^3**	
	2040	**2060**
Biomass Ethanol	1,471.0	1,471.0
Agricultural Processing	34.1	73.8
Feedlots	-1987.4	-1987.4
Total	**-482.4**	**-442.6**
Surface Water % of Total	**100%**	**100%**

Table 7.13: Induced Water Demand Activities in the Qu'Appelle River Basin, Climate Change Scenario, 2040-2060

Industry	Water Demand in dam^3	
	2040	**2060**
Biomass Ethanol	1,471.0	1,471.0
Agricultural Processing	34.1	73.8
Feedlots	-1,963.1	-1,936.4
Total	**-458.1**	**-391.7**

7.2.2.3 Water Demand for Induced Development Activities – Water Conservation Scenario

Conservation of water for the biomass ethanol and agricultural processing represents a 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 7.14, there is an estimated 55 dam^3 reduction for 2040, which increased to 109 dam^3 by 2060.

Table 7.14: Induced Water Demand Activities in the Qu'Appelle River Basin, Water Conservation Scenario 2040-2060

Industry	Water Demand in dam^3	
	2040	**2060**
Biomass Ethanol	1,441.6	1,412.7
Agricultural Processing	33.4	72.3
Feedlots	- 2,012.5	- 2,036.8
Total	**-537.6**	**-551.8**

7.2.2.4 Manufacturing Water Consumption

Since no water used 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 Qu'Appelle River Basin is presented in this section.

<u>Manufacturing Water Consumption under Baseline Scenario</u>

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 figures are shown in Table 7.15. Any water not returned is called water consumed.

Table 7.15: Manufacturing Water Consumption in Qu'Appelle River Basin, Baseline Scenario, 2010 - 2060

Industry	Amount of Water Demand in dam^3			
	2010	**2020**	**2040**	**2060**
Pound-Maker Agventures Ltd.	46.9	46.9	48.0	49.3
Terra Grain Fuels Inc.	472.7	472.7	484.0	496.3
YARA (Previously Saskferco)	3,052.1	3,052.1	3,125.3	3,204.7
EVRAZ (formerly IPSCO)	2.1	2.6	3.8	5.0
Consumer Co-op Refineries	2,406.9	2,609.0	3,090.7	3,596.2
Lilydale	54.7	79.9	79.9	79.9
Agrium Fertilizer Storage	0.4	0.4	0.4	0.4
Total Manufacturing Water Consumption	**6,035.8**	**6,263.6**	**6,832.1**	**7,431.8**
Manufacturing Water Consumption by Source of Water				
Groundwater Consumption	3,292.0	3,655.8	4,257.6	4,889.4
Surface Water Consumption	2,743.7	2,743.7	2,743.7	2,743.7
Share of Total Water Demand				
Total Water Intake	7,442.9	7,809.1	8,515.4	9,260.4
Consumption as a % of Water Intake	81.1%	80.2%	80.2%	80.3%

Under the baseline scenario, the total consumption of water is estimated at 6,036 dam^3, which is about 81% of the total water demand for manufacturing activities. Thus, only 19% of the total water demand (intake) is lost during the production process, and the rest is returned to the original source. This proportion does not change in the future. In terms of levels of consumption, YARA and the Consumer Coop Refinery are the two large consumers,

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 7.16. Total water consumption in 2060 is estimated to be 7,580 dam^3, about 2% higher than that observed 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 7.17. The total water consumption in 2060 is estimated to be 7,284 dam^3, about 2% lower than that shown under the baseline scenario. Thus, water conservation could offset the increase in water consumption induced by climate change.

Table 7.16: Manufacturing Water Consumption in Qu'Appelle River Basin under Climate Change Scenario, 2010to 2060

Industry	Amount of Water Demand in dam^3			
	2010	**2020**	**2040**	**2060**
Pound-Maker Agventures Ltd.	46.9	47.8	49.0	50.2
Terra Grain Fuels Inc.	472.7	482.1	493.6	506.2
YARA (Previously Saskferco)	3,052.1	3,113.1	3,187.8	3,268.8
EVRAZ (formerly IPSCO)	2.1	2.7	3.9	5.1
Consumer Co-op Refineries	2,406.9	2,661.2	3,152.5	3,668.1
Lilydale	54.7	81.5	81.5	81.5
Agrium Fertilizer Storage	0.4	0.4	0.4	0.5
Total Manufacturing Water Consumption	**6,035.8**	**6,388.8**	**6,968.7**	**7,580.4**
	Distribution by Source of Water			
Groundwater Consumption	3,292.0	3,728.9	4,342.8	4,987.2
Surface Water Consumption	2,743.8	2,659.9	2,625.9	2,593.2
% of Baseline Scenario Consumption	100.0%	102.0%	102.0%	102.0%

Table 7.17: Manufacturing Water Consumption in Qu'Appelle River Basin (dam^3) Conservation Scenario

Industry	Amount of Water Demand in dam^3			
	2010	**2020**	**2040**	**2060**
Pound-Maker Agventures Ltd.	46.9	46.0	47.1	48.3
Terra Grain Fuels Inc.	472.7	463.2	474.3	486.3
YARA (Previously Saskferco)	3,052.1	2,991.0	3,062.8	3,140.6
EVRAZ (formerly IPSCO)	2.1	2.6	3.7	4.9
Consumer Co-op Refineries	2,406.9	2,556.9	3,028.8	3,524.3
Lilydale	54.7	78.3	78.3	78.3
Agrium Fertilizer Storage	1.4	1.4	1.4	1.5
Total Manufacturing Water Consumption	**6036.8**	**6139.4**	**6696.4**	**7284.2**
Distribution by Source of Water				
Groundwater Consumption	3,292.0	3,582.7	4,172.5	4,791.6
Surface Water Consumption	2,744.8	2,556.7	2,523.9	2,492.6
Surface Water as % of 2010	83.4%	71.4%	60.5%	52.0%
% of Baseline Scenario	100.0%	98.0%	98.0%	98.0%

7.3 Summary of Industrial and Mining Water Demand

The industrial and mining water demand by sector is presented in sections 7.3.1 to 7.3.3 for baseline, climate change, and conservation scenarios. Potash mining activity currently has the largest demand for water among the sectors in the Qu'Appelle Basin. This dominance will only increase as the projected mines come on stream.

7.3.1 Total Industrial and Mining Water Demand – Baseline Scenario

The industrial and mining water demand by sectors is presented in Tables 7.18 for the baseline scenario. The total water demanded for these purposes is estimated at 23,897 dam^3 during 2010. This level will increase to 112,883 dam^3, primarily as a result of expansion in the potash mining sector. At present, potash mining uses 64% of the total water for this sector, which will increase to 90% by 2060 (Figure 7.5). The other demands, particularly for oil and gas production, and other mining activities, will become relatively unimportant in the basin in terms of water demand.

7.3.2 Total Industrial and Mining Water Demand – Climate Change Scenario

The expected climate change does not have any appreciable impact on the total water demand for the Industrial and Mining sector, as shown in Table 7.19. Part of the explanation is that potash mining water demand is not affected by climate and since potash has the largest water demand within the sector, total water demand under this scenario is higher by only 0.2% of the baseline water demand level in 2040, and by only 0.3% higher by 2060.

Table 7.18: Total Industrial and Mining Water Demand in the Qu'Appelle River Basin, Baseline Scenario, 2010-2060

Activity	Water Demand in dam^3			
	2010	**2020**	**2040**	**2060**
Water Demand excluding Interbasin Transfers				
Potash	13,999	75,479	86,535	86,535
Oil & Gas	341	458	275	69
Other Mining	30	31	34	37
Manufacturing	7,445	7,811	8,517	9,262
Irrigation Induced	0	0	-482	-443
Total Within-Basin Water Demand	**21,815**	**83,779**	**94,879**	**95,460**
Total Within-Basin Water Demand and Interbasin Transfers				
Interbasin Transfers	2,082	9,209	9,209	17,423
Total (Within-Basin plus Interbasin Transfers) Water Demand	**23,897**	**92,988**	**104,088**	**112,883**

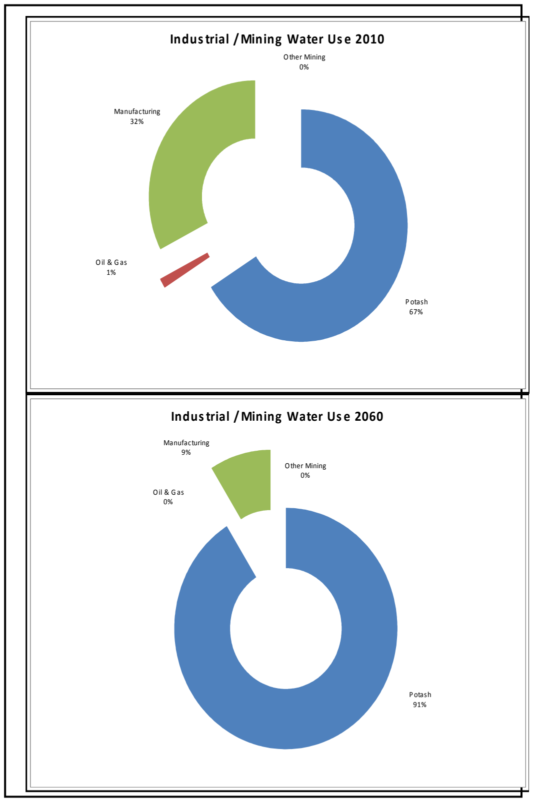


Figure 7.5: Distribution of Total Industrial and Mining Water Demand by Sectors, 2010 and 2060, Baseline Scenario, Qu'Appelle River Basin

Table 7.19: Total Industrial and Mining Water Demand in the Qu'Appelle River Basin, Climate Change Scenario, 2010-2060

Activity	Water Demand in dam^3			
	2010	**2020**	**2040**	**2060**
Water Demand Excluding Interbasin Transfers				
Potash	13,999	75,479	86,535	86,535
Oil & Gas	341	458	275	69
Other Mining	30	31	34	37
Manufacturing	7,445	7,811	8,688	9,448
Irrigation Induced	0	0	-458	-392
Total Within-Basin Water Demand	**21,815**	**83,779**	**95,074**	**95,697**
Total Within-Basin Water Demand and Interbasin Transfers				
Interbasin Transfers	2,082	8,979	8,518	15,245
Total (Within-Basin plus Interbasin Transfers) Water Demand	**23,897**	**92,758**	**103,592**	**110,942**

7.3.3 Total Industrial and Mining Water Demand – Water Conservation Scenario

On account of several water conservation measures available to the industrial sector, its water demand level may be reduced from the baseline scenario. Results are shown in Table 7.20. These changes would be observed by 2020, when water demand for this sector is estimated at 88,959 dam^3, which is 4.4% lower than that shown under the baseline scenario. By 2060, there is a potential to reduce this water demand by 21.2% to 89,770 dam^3. Thus, water conservation measures do offer a good potential for reducing water demand. Much of this again depends on adoption of these practices which are decided by other factors, the most important one is the total cost of water to the water user. If the cost is low, not much attention may be paid to reducing water demand level.

7.3.4 Industrial and Mining Water Demand by Source of water

The water demand by source for each industry sector for the baseline, climate change, and conservation scenarios are presented in Tables 7.21 to 7.23. On account of potash production, water is basically supplied from surface water sources. The importance of surface water does not change in the three study scenarios.

7.3.5 Industrial and Mining Water Consumption

Since no water used in potash, salt, or oil and gas manufacture is returned to ground or surface fresh water bodies, the amount of water consumed equals demand for those sectors. Water consumption in manufacturing activities in the Qu'Appelle River Basin is presented in Tables 7.15 to 7.17 for baseline, climate change, and conservation scenarios, respectively. Because all returned water goes to surface water bodies, the amount that is returned is subtracted from the water demand.

Table 7.20: Total Industrial and Mining Water Demand in the Qu'Appelle River Basin, Water Conservation Scenario, 2010-2060

Activity	Water Demand in dam^3			
	2010	2020	2040	2060
Water Demand Excluding Interbasin Transfers				
Potash	13,999	71,906	74,158	65,906
Oil & Gas	341	389	233	58
Other Mining	30	30	33	36
Manufacturing	7,445	7,655	8,347	9,077
Irrigation Induced	0	0	-538	-552
Total Within-Basin Water Demand	**21,815**	**79,980**	**82,233**	**74,525**
Total Within-Basin Water Demand and Interbasin Transfers				
Interbasin Transfers	2,082	8,979	8,518	15,245
Total (Within-Basin plus Interbasin Transfers) Water Demand	**23,897**	**88,959**	**90,751**	**89,770**

Table 7.21: Industrial and Mining Within-Basin Water Demand in the Qu'Appelle River Basin, by Source of Water, Baseline Scenario, 2010-2060

Sector	Source	Water Demand in dam^3			
		2010	2020	2040	2060
Potash	Surface Water	11,653	71,495	74,259	74,259
	Groundwater	2,346	3,984	12,276	12,276
Oil & Gas	Surface Water	0	0	0	0
	Groundwater	341	458	275	69
Manufacturing	Surface Water	4,153	4,155	4,260	4,373
	Groundwater	3,292	3,656	4,258	4,889
Other Mining	Surface Water	30	31	34	37
	Groundwater	0	0	0	0
Induced	Surface Water	0	0	-482	-443
Total	**Surface Water**	**15,836**	**75,681**	**78,071**	**78,226**
	Groundwater	**5,979**	**8,098**	**16,809**	**17,234**
	Total	**21,815**	**83,779**	**94,879**	**95,460**

Table 7.22 Industrial and Mining Within-Basin Water Demand in the Qu'Appelle River Basin, by Source of Water, Climate Change Scenario, 2010-2060

Sector	Source of Water	Water Demand in dam³			
		2010	2020	2040	2060
Potash	Surface Water	11,653	71,495	74,259	74,259
	Groundwater	2,346	3,984	12,276	12,276
Oil & Gas	Surface Water	0	0	0	0
	Groundwater	341	458	275	69
Manufacturing	Surface Water	4,153	4,155	4,345	4,460
	Groundwater	3,292	3,656	4,343	4,458
Other Mining	Surface Water	30	31	33	36
	Groundwater	0	0	0	0
Induced	Surface Water	0	0	-458	-392
Total	**Surface Water**	**15,836**	**75,681**	**78,179**	**78,363**
	Groundwater	**5,979**	**8,098**	**16,895**	**17,333**
	Total	**21,815**	**83,779**	**95,074**	**95,697**

Table 7.23: Industrial and Mining Within-Basin Water Demand in the Qu'Appelle River Basin, by Source, Water Conservation Scenario, 2010-2060

Sector	Source of Water	Water Demand in dam³			
		2010	2020	2040	2060
Potash	Surface Water	11,653	68,060	63,540	56,394
	Groundwater	2,346	3,846	10,618	9,512
Oil & Gas	Surface Water	0	0	0	0
	Groundwater	341	389	233	58
Manufacturing	Surface Water	4,153	4,072	4,174	4,285
	Groundwater	3,292	3,583	4,173	4,792
Other Mining	Surface Water	30	31	34	37
	Groundwater	0	0	0	0
Induced	Surface Water	0	0	-538	-552
Total	**Surface Water**	**15,836**	**72,163**	**67,210**	**60,164**
	Groundwater	**5,979**	**7,817**	**15,023**	**14,361**
	Total	**21,815**	**79,980**	**82,233**	**74,525**

Chapter 8

Municipal/Domestic Water Demand

Water demand by residents in different types of communities is an important part of the total water demand in the Qu'Appelle River Basin. This is so because, in terms of total provincial population, the basin includes two large cities – Moose Jaw and Regina. In addition, there are a number of smaller communities in the basin, as well as a few First Nations' Reserves, and some institutions[66]. 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

Municipal water demands were estimated for the two large urban centers in the basin – Moose Jaw and Regina. The total water demand for these communities was estimated as a product of population 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 that required for manufacturing, commercial, firefighting, street cleaning and other public demands. No attempt was made to disaggregate the total water use in these cities by various types of uses.

Total municipal water demand in the basin is expected to decline slightly from 33,839 dam^3 in 2010 to 32,272 dam^3 in 2060 – a reduction of 4.6% (Table 8.1). Much of this reduction is being contributed by a negative trend in Regina's water demand. In the future projections, it was assumed that this trend will continue. This aspect of water demand requires more scrutiny.

8.1.2 Municipal Water Demand – Climate Change Scenario

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

To estimate the effect of climate change, two aspects were taken into consideration: (i) temperature and precipitation change and (ii) frequency of dry extreme events. Climate change will affect indoor water demand differently than it will affect 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.

[66] The basin also houses some recreational communities. These are included in the next chapter.

Table 8.1: Estimated Municipal (Cities') Water Demand for Qu'Appelle River Basin, Study Scenarios, 2010-2060

Community Type	Water Demand in dam^3				Change 2010 - 2060 (%)
	2010	2020	2040	2060	
Baseline Scenario					
Moose Jaw	6,215	6,266	6,370	6,476	4.2%
Regina*	27,624	27,306	26,541	25,796	-6.6%
Total Water Demand for Cities within QRB**	33,839	33,572	32,911	32,272	-4.6%
Water Supplied from SSRB*** (Humboldt)	680	721	812	913	34.3%
Total Water Demand for all Basin Cities	**34,519**	**34,293**	**33,723**	**33,185**	**-3.9%**
Climate Change Scenario					
Moose Jaw	6,215	6,266	6523	6799	9.4%
Regina	27,624	27,306	27178	27086	-2.0%
Total Water Demand for Cities within QRB**	33,839	33,572	33,701	33,885	0.1%
Water Supplied from SSRB** (Humboldt)	680	721	831	959	41.0%
Total Water Demand for all Basin Cities	**34,519**	**34,293**	**34,532**	**34,844**	**0.9%**
Scenario Within-Basin Water Demand % of Baseline	100.0%	100.0%	102.4%	105.0%	
Water Conservation Scenario					
Moose Jaw	6,215	6110	5,892	5,666	-8.8%
Regina	27,624	27306	26,541	25,796	-6.6%
Total Water Demand for Cities within QRB**	33,839	33,416	32,433	31,462	-7.0%
Water Supplied from SSRB** (Humboldt)	680	703	751	799	-13.6%
Total Water Demand for all Basin Cities	**34,519**	**34,119**	**33,184**	**32,261**	**-20.7%**
Scenario Within-Basin Water Demand % of Baseline	100.0%	99.5%	98.6%	97.5%	

* A decline in the total water demand for the city is based on a very simplifying assumption. In these estimates, it was assumed that past trends would continue until 2060, which may not apply in the future. However, future water for the city of Regina requires a more accurate forecast of population and that for the adoption rate of water conservation technology.

** Qu'Appelle River Basin

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Herrington (1996) reported the impact of climate change on UK domestic water use. By applying climate models, an increase of 5% by 2021 in per capita water demand was predicted. The scenario of climate change was 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. Results suggested an increase in water demand by 5.6% and 5.2% for two scenarios. If one assumes that winter water demand will remain unaffected, this translates into a 2.5% and 2.4% increase.

Results from both of these studies were considered in developing a climate change scenario for the basin. It was assumed that there will be no major climate change impacts on the basin's domestic water demand by 2020. Assuming that the average temperature in the basin for the climate change may be similar to that of the Great Lakes region, a 2.4% increase in domestic water demand was assumed by 2040. For 2060, an increase of 5% of the baseline scenario's level was assumed. The 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 demand, per capita domestic water demand data for 1995-2009 were used. It was hypothesized that the 2001 and 2002 droughts would affect 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 otherwise). The other two variables – trend and size of the community, were retained for this analysis. Results of regression analysis are presented in Appendix G. With the exception of the bedroom communities around Regina, the coefficient for the drought occurrence was not significantly different from zero. For this reason, it was decided that no effect of dry extreme events (droughts) on the domestic water demand will exist in the future. The adjusted coefficients are shown in Table 8.2.

8.1.2.2 Estimated Municipal Water Demand under Climate Change

The total municipal 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, water demand for this purpose in the basin will increase by almost 5% by 2060. This is primarily a result of higher temperatures and the increased frequency of extreme events. The total municipal water demand is estimated to be almost 35 thousand dam^3.

8.1.3 Municipal Water Demand – Water Conservation Scenario

Using the methodology described in Section 5.3 of this report, municipal water demand was estimated for the Qu'Appelle River Basin. This step involved revision in the water demand coefficients under this scenario from the baseline scenario. As noted previously, the effect of water conservation was brought into the calculations for 2020 and onwards. Finally, estimated water demand with the adjusted coefficients is shown in Table 8.3.

Table 8.2 : Adjusted Municipal / Domestic Water Demand Coefficients under Climate Change Scenario for the Qu'Appelle River Basin by Type of Communities

Category	Water Demand Coefficient in			
	2010	2020	2040	2060
Moose Jaw	179.84	179.84	184.16	188.83
Regina	142.61	136.33	124.97	114.72
First Nations Reservation	87.92	116.02	182.90	272.09
Recreational villages	409.78	409.78	419.61	430.27
Bedroom Communities around Regina	123.60	126.82	129.86	133.16
Villages	112.92	103.59	89.26	77.02
Towns < 1000 People	131.27	121.59	106.82	93.97
Towns > 1000 People	134.07	122.27	104.13	88.81
Farm	112.92	103.59	89.26	77.02
Rural Non-farm	112.92	103.59	89.26	77.02

Table 8.3: Adjusted Domestic Water Demand Coefficients under the Water Conservation Scenario, Qu'Appelle River Basin, 2010 - 2060

Community Type	Water Demand Coefficient in m^3/capita			
	2010	2020	2040	2060
Moose Jaw	179.84	175.34	166.35	157.36
Regina	142.61	136.33	122.04	109.26
First Nations' Reservation	87.92	115.35	176.54	251.62
Recreational villages	409.78	407.40	405.03	397.90
Bedroom Communities in Regina	123.60	126.08	125.35	123.14
Villages	112.92	102.99	86.16	71.23
Towns < 1000	131.27	120.88	103.10	86.90
Towns > 1000	134.07	121.56	100.51	82.13
Farm	112.92	102.99	86.16	71.23
Rural Non-farm	112.92	102.99	86.16	71.23

The total municipal water demand for the basin is shown in Table 8.1, and it is estimated at 33,839 dam^3 for 2020, changing to 31,462 dam^3 by 2060, where water is supplied within the basin. On average, this amounted to a reduction of 0.5% in 2020 to 2.5% 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 be in part due to past efforts in educating people about water saving technologies.

Table 8.4: Municipal Water Demand, Excluding Interbasin Transfers, in the Qu'Appelle River Basin, Study Scenarios, 2010 - 2060

Scenarios	Total Amount of Water in dam^3				2060 level % of Baseline
	2010	2020	2040	2060	
Baseline	33,839	33,572	32,911	32,272	100.0%
Climate Change	33,839	33,572	33,701	33,885	100.1%
Water Conservation	33,839	33,416	32,433	31,462	93.0%

8.2 Domestic Water Demand

Domestic water demand was estimated for larger urban centers other than cities. These included three types of communities: (i) bedroom communities around Regina; (ii) towns with populations of 1,000 people or more; and (iii) town with populations of less than 1,000 people. Results for this water demand are presented in this section.

8.2.1 Domestic Water Demand – Baseline Scenario

Domestic water demand was estimated by the approximate population of various communities and their respective water demand per capita. These methodologies for the baseline scenario were presented in Chapters 3 and 4. 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 is estimated at 6,189 dam^3, which is 14% higher than that in 2010. This increase is mainly contributed by increased water demand for the bedroom communities in the basin.

8.2.2 Domestic Water Demand – Climate Change Scenario

Water demand under climate change was estimated by making adjustments 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 20% over the 2010 level. The level of domestic water demand in 2060 was estimated at 6,499 dam^3 – about 5% higher than that under the baseline scenario.

8.2.3 Domestic Water Demand – Water Conservation Scenario

The methodology for estimating the domestic water demand for the Qu'Appelle River Basin 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 the scenario is shown in Table 8.5. Under this scenario, a reduction in total domestic water demand is noted. Total domestic water demand 2060 is only 6,009 dam^3, which is 2.9% lower than that under the baseline scenario.

Table 8.5: Estimated Domestic Water Demand for Qu'Appelle River Basin, Study Scenarios, 2010 - 2060

Community Type	Water Demand in dam^3				Change 2010 - 2060 (%)
	2010	2020	2040	2060	
Baseline Scenario					
Town > 1000 people	2,326	2,067	1,674	1,355	-41.7%
Towns < 1000 people	1,705	1,579	1,363	1,174	-31.1%
Bedroom Communities of Regina	1,306	1,634	2,430	3,615	176.9%
Total Domestic Water Demand Excluding Interbasin Transfers	**5,337**	**5,280**	**5,467**	**6,144**	**15.5%**
Town Supplied by SSRB* (Bruno)	83	77	58	45	-45.8%
Total Domestic Water Demand including Interbasin Transfers	**5,420**	**5,357**	**5,525**	**6,189**	**14.2%**
Climate Change Scenario					
Towns > 1000 Population	2,326	2,067	1,714	1,423	-38.8%
Towns < 1000 Population	1,705	1,579	1,455	1,280	-28.4%
Bedroom Communities of Regina	1,306	1,634	2,489	3,796	21.8%
Total Domestic Water Demand excluding Interbasin Transfers	5,337	5,280	5,658	6,499	-37.3%
Town Supplied by SSRB* (Bruno)	83	77	63	52	30.0%
Total Domestic Water Demand including Interbasin Transfers	**5,420**	**5,357**	**5,721**	**6,551**	**21.8%**
Water Conservation Scenario					
Towns > 1000 Population	2,326	2,055	1,655	1,316	-43.4%
Towns < 1000 Population	1,705	1,568	1,347	1,138	-33.3%
Bedroom Communities of Regina	1,306	1,624	2,402	3,510	168.8%
Total Domestic Water Demand excluding Interbasin Transfers	5,337	5,247	5,404	5,964	11.7%
Town Supplied by SSRB* (Bruno)	83	77	57	45	-45.8%
Total Domestic Water Demand including Interbasin Transfers	**5,420**	**5,325**	**5,461**	**6,009**	**10.9%**

* South Saskatchewan River Basin

8.2.4 Domestic Water Demand -- Summary

A summary of domestic water demand in the Qu'Appelle River Basin 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 5.8% over the baseline scenario. Water conservation could offer some relief – by about 2.9% in 2020, but not enough to cover the increase produced by climate change.

Table 8.6 : Summary of Domestic Water Demand (Excluding Interbasin Transfers) in the Qu'Appelle River Basin, Study Scenarios, 2010 - 2060

Scenarios	Total Domestic Water Demand in dam^3				2060 level % of Baseline
	2010	2020	2040	2060	
Baseline	5,337	5,280	5,467	6,144	100.0%
Climate Change	5,337	5,280	5,658	6,499	105.8%
Water Conservation	5,337	5,247	5,404	5,964	97.1%

8.3 Rural Domestic Water Demand

Rural water demand in this study was defined as a sum of that 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 that used for other types of municipal/domestic water demands. The per capita water demand coefficients were multiplied by estimated population 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, their water demand is expected to decline in 2060 over the 2010 level. Under the baseline scenario, basin-provided 2010 rural water demand level is estimated at 5,596 dam^3, which could decline to almost half that level by 2060, to 2,814 dam^3. This decline is predicated on the present trends in the rural population. It is conceivable that this rate of future decline may be stabilized at a slightly higher level than that assumed in this study. Perhaps, as more people leave these areas, there will be fewer people remaining there and thus, less out-migration 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 impact. These adjusted coefficients are shown in Table 8.2. The estimated population for various categories was multiplied by these coefficients to yield a total water demand. The estimated basin-provided rural water demand is shown in Table 8.7. Total rural water demand will still decline over time, but not as fast as that level shown under the baseline scenario. This demand in 2060 would be 2,954 dam^3, about 5% higher than that under the baseline scenario.

8.3.3 Rural Domestic Water Demand – Water Conservation Scenario

Calculations for rural water demand under water conservation followed the same methodology as those 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 basin-provided water demand is shown in the bottom panel of Table 8.7. This water demand is below the levels seen under the baseline scenario by about 3%, or at 2,732 dam^3.

Table 8.7: Estimated Rural Water Demand for the Qu'Appelle River Basin, Study Scenarios, 2010 - 2060

Community Type	Rural Water Demand in dam^3				Change 2010 - 2060 (%)
	2010	2020	2040	2060	
Baseline Scenario					
Villages	1,566	1,433	1,188	981	-37.4%
Farm Population	3,285	2,712	2,029	1,494	-54.5%
Rural Non-Farm	745	615	460	339	-54.5%
Total Rural Water Demand Excluding Interbasin Transfers	**5,596**	**4,760**	**3,677**	**2,814**	**-49.7%**
Villages Supplied by SSRB*	145	137	133	131	-9.7%
Total Water Demand Including Interbasin Transfers	**5,741**	**4,897**	**3,810**	**2,945**	**-48.7%**
Climate Change Scenario					
Villages	1,566	1,433	1,216	1,029	-34.3%
Farm Population	3,285	2,712	2,077	1,569	-52.2%
Rural Non-Farm	745	615	471	356	-52.2%
Total Rural Water Demand Excluding Interbasin Transfers	**5,596**	**4,760**	**3,764**	**2,954**	**-47.2%**
Villages Supplied by SSRB*	145	137	137	138	-4.8%
Total Water Demand Including Interbasin Transfers	**5,741**	**4,897**	**3,901**	**3,092**	-46.1%
Water Conservation Scenario					
Villages	1,566	1,424	1,174	952	-39.2%
Farm Population	3,285	2,697	2,005	1,451	-55.8%
Rural Non-Farm	745	612	455	329	-55.8%
Total Rural Water Demand Excluding Interbasin Transfers	**5,596**	**4,733**	**3,634**	**2,732**	-51.2%
Villages Supplied by SSRB*	145	137	132	127	-12.4%
Total Water Demand Including Interbasin Transfers	**5,741**	**4,870**	**3,766**	**2,859**	-50.2%

* South Saskatchewan River Basin

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 a declining population base. Although climate change would increase this water demand by 5%, the water conservation scenario could produce a 3% reduction compared to the baseline scenario. Water conservation in a rural setting 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 subject in future research.

Table 8.8: Summary of Rural Water Demand (Excluding Interbasin Transfers) in the Qu'Appelle River Basin, 2010 - 2060

Scenarios	Rural Water Demand in dam^3				2060 % Change over Baseline
	2010	2020	2040	2060	
Baseline	5,596	4,760	3,677	2,814	0%
Climate Change	5,596	4,760	3,764	2,954	5.0%
Water Conservation	5,596	4,733	3,634	2,732	-2.9%

8.4 First Nations' Water Demand

As a population group, First Nations' communities are the fastest growing group in the Qu'Appelle River Basin. The population in these communities is expected to grow, although out migration patterns may reduce their size 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 at a rapid rate. Under the baseline scenario, this demand will grow almost seven fold (increase of 607%) over the 2010 level. In 2010, it was estimated at 590 dam^3, which would likely increase to 4,173 dam^3 by 2060 (Table 8.9).

8.4.2 First Nations' Water Demand – Climate Change Scenario

Climate change was assumed to have the same type of impact here as on other water user groups. As a result, the water demand estimate for 2060 was 4,382 dam^3, some 5% higher than that for the baseline level. It should be noted that available studies on this subject did not shed any light on the nature of these impacts. Thus, as a crude proxy, these communities were treated just like other communities. More attention needs to be paid to this issue in the future.

Table 8.9: Summary of First Nations' Water Demand in the Qu'Appelle River Basin, 2010 - 2060

Scenario	Estimated First Nations Total Water Demand in dam^3 for				% Increase in 2060 over 2010	% of Baseline Scenario Level
	2010	2020	2040	2060		
Baseline	590	940	2,205	4,173	607.4%	100.0%
Climate Change	590	940	2,258	4,382	642.8%	105.0%
Water Conservation	590	935	2,180	4,052	586.9%	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, for the future, it was assumed that these communities will follow the same pattern of adoption of water conservation measures as the 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 the need to adopt water conservation measures in these communities. Under this assumption, water demand for these communities, as shown in Table 8.9, will be 4,052 dam^3 by 2060.

8.4.4 First Nations' Water Demand -- Summary

Water demand for First Nations' communities is expected to rise at a very rapid rate relative to 2010. In all study scenarios, a six fold increase is expected by 2060. The growth rate is literally exponential – increase in water demand by 2020 by 68% of the 2010 level, and by 2040 313% of the 2010 level.

8.5 Communal (Public Institutions') Water Demand

Communal water demand was estimated for two institutions in the basin: Moose Jaw Forces Base, which is supplied by the Moose Jaw municipal system, and the Regina Correctional Centre which receives water from the Regina municipal system. Water demand for these two institutions was estimated under the three study scenarios.

8.5.1 Communal (Public Institutions') Water Demand – Baseline Scenario

8.5.1.1 Moose Jaw Canadian Forces Base

The amount of water demanded at Moose Jaw Canadian Forces Base (CFB 15 Wing) was 218,418 m^3 for 2009 with 800 people working at the base for a per capita amount of 273 m^3. The water demand estimate for 2020 at Moose Jaw CFB would be 190,841 m^3, using the average per capita times 800 on base personnel. A projected on-base personnel of 600 and 400 for 2040 and 2060, respectively, would result in 143 and 95 dam^3. Details are shown in Table 8.10.

Table 8.10: Water Demand by Public Institutions in the Qu'Appelle River Basin, 2010-2060, under Baseline Scenario

Scenarios	Total Water Demand in dam^3				2060 as % of 2010
	2010	2020	2040	2060	
Moose Jaw Canadian Forces Base	218	191	143	95	43.6%
Regina Correctional Center	109	109	109	109	100.0%
Total Institutional Water Demand	**327**	**300**	**252**	**204**	**62.4%**

8.5.1.2 Regina Correctional Centre

As noted earlier, the latest number available for total water demand by the Regina Correctional Centre was 113,580 m^3 in 2007. A new section of the prison was added to replace an existing structure in 2008. However, no details on water demand are available for a recent period. By applying the water demand coefficient estimated in Section 3.6.3.7, the total water demand for this facility was developed. Assuming an inmate population of 300 yielded an estimated water demand for 2010 of 109.4 dam^3. Given that the inmate population and staff complement at the facility will remain about the same to 2060, the water demand estimates for 2040 and 2060 were assumed to be similar.

The total institutional water demand for the baseline scenario is shown in Table 8.10. The current level of water demand by these institutions is estimated at 327 dam^3, which is expected to decrease to 204 dam^3 by 2060. As noted above, this decrease is primarily a result of reduced personnel at the Moose Jaw Canadian Forces Base.

8.5.2 Communal (Public Institutions') Water Demand – Climate Change Scenario

The behavior of institutions in the wake of climate change is not a well-studied subject. In fact, no information was found as to how institutions in the Qu'Appelle River Basin will react in terms of water demand, or how they might be impacted by it. Since these institutions are located in urban areas, their impacts were assumed to be similar to those for the municipal water demand. These estimates are shown in Table 8.11. Under the assumption that the number of inmates will be same as that of 2010, the water demand level under climate change for the Regina Correctional Centre will increase by 12.5% of the 2010 level. Water demand for the Moose Jaw Canadian Forces Base would still decline on account of reduced personnel being employed there.

8.5.3 Communal (Public Institutions') Water Demand – Water Conservation Scenario

Institutional water demand can also be subject to water conservation. However, no study was found that has reported feasible measures that to adopted for such institutions. Among the two institutions, Regina Correctional Facility was hypothesized[67] as an institution with a potential for water conservation. These institutions were treated just like municipal water users. The same impact of water conservation measures was assumed to be applicable here as well. Results are shown in Table 8.12. The water demand by institutions would decrease to 194 dam^3 per annum. This is 59.3% of the 2010 level for these institutions.

Table 8.11: Water Demand by Public Institutions in the Qu'Appelle River Basin, 2010-2060, under Climate Change Scenario

Scenarios	Total Water Demand in dam^3				2060 as % of 2010
	2010	2020	2040	2060	
Moose Jaw Canadian Forces Base	218	191	154	107	49.0%
Regina Correctional Center	109	109	117	123	112.5%
Total Institutional Water Demand	**327**	**300**	**271**	**230**	**70.2%**

Table 8.12: Water Demand by Public Institutions in the Qu'Appelle River Basin, 2010-2060, under Water Conservation Scenario

Scenarios	Total Water Demand in dam^3				2060 as % of 2010
	2010	2020	2040	2060	
Moose Jaw Canadian Forces Base	218	191	143	95	43.6%
Regina Correctional Center	109	109	106	99	90.8%
Total Institutional Water Demand	**327**	**300**	**249**	**194**	**59.3%**

8.5.4 Communal (Public Institutions') Water Demand -- Summary

The summary of communal (public institutions) water demand appears in Table 8.13 for the three study scenarios. The current water demand level is estimated at 327 dam^3. In all three study scenarios, the future water demand would be lower than it was in 2010. Part of the reason for this is a reduced number of personnel at the Moose Jaw Canadian Forces Base.

8.6 Other Municipal/Domestic Water Demand

Based on available data, other types of municipal/domestic water demands could not be identified. There is some water demand by recreational communities. However, this water demand is attributed to recreational purposes, and described in the next chapter.

[67] Please note that this is an assumption made in this study. These issues need to be examined further by experts in water use in public institutions.

Table 8.13: Summary of Water Demand by Public Institutions in the Qu'Appelle River Basin, 2010-2060, under Study Scenarios

Scenarios	Total Water Demand in dam^3				2060 as % of 2010
	2010	2020	2040	2060	
Baseline Scenario	327	300	252	204	62.4%
Climate Change Scenario	327	300	271	230	70.2%
Water Conservation Scenario	327	300	249	194	59.3%

8.7 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 8.14. Almost three-quarters of the total water demand is supplied by surface water bodies. The relative proportion of surface to groundwater does vary among the three scenarios. Although in the baseline scenario, this proportion varies between 72 to 77% of total water demand (intake), it increases to between 81 to 89% under climate change, but reduces to between 72 to 78% under the water conservation scenario.

Table 8.14: Total Municipal / Domestic Water Demand by Source in the Qu'Appelle River Basin, 2010 - 2060

Particulars	Water Demand in dam^3			
	2010	2020	2040	2060
Total Surface water	35,360	34,884	33,945	33,083
Total Groundwater	10,557	10,239	10,423	12,700
Total Municipal/Domestic Water Demand	45,917	45,123	44,368	45,783
Surface Water % of Total	77.0%	77.3%	76.5%	72.3%

8.8 Water Consumption for Municipal/Domestic Water Demand

As noted earlier, not all water withdrawn (also called intake) is lost because part of this water is returned back to the original surface water bodies. Although some water may be returned to groundwater sources, the knowledge of aquifer recharge rates and related information is relatively poor. Therefore, it is typically assumed that all groundwater withdrawn is lost. The total consumption of water for municipal/domestic purposes is shown in Table 8.15.

The total water consumption under the baseline scenario for 2010 was estimated at 19,221 dam^3, which is about 42% of the total water intake . Thus, 58% of the water withdrawn is returned to the original water source in some shape.[68] By 2060, the amount of water consumed increases slightly but its proportion to total water intake does not change appreciably.

Table 8.15: Water Intake and Consumption for Municipal/Domestic Water Demands, Qu'Appelle River Basin, Study Scenarios, 2010 - 2060

Particulars	Water Quantity in dam^3			
	2010	**2020**	**2040**	**2060**
	Baseline Scenario			
Total Water Intake	45,917	45,123	44,368	45,783
Water Consumption	19,221	18,651	18,232	19,630
Consumption as a % of Intake	41.9%	41.3%	41.1%	42.9%
	Climate Change Scenario			
Total Water Intake	45,917	45,131	45,446	48,088
Water Consumption	19,221	18,659	18,682	20,626
Consumption as a % of Intake	41.9%	41.3%	41.1%	42.9%
	Water Conservation Scenario			
Total Water Intake	45,917	44,902	43,757	44,576
Water Consumption	19,221	18,558	17,989	19,096
Consumption as a % of Intake	41.9%	41.3%	41.1%	42.8%

Under climate change and water conservation scenarios, although consumption levels do change, their proportion to total water demand does not. The level of water intake and consumption for municipal / domestic purposes are shown in Figure 8.1.

8.9 Total Municipal/Domestic Water Demand

In this section, all different water demands described above are summarized. These estimates are grouped into five categories of total municipal/domestic water demand: municipal water demand (cities); domestic water demands (towns); rural water demand (villages and open areas); First Nations' communities' water demand; and institutional water demand. Results for the three study scenarios are summarized in this section. It should also be noted that some of the water demanded in the Qu'Appelle River Basin is supplied from the South Saskatchewan River Basin.

8.9.1 Total Municipal/Domestic Water Demand – Baseline Scenario

The total municipal/domestic water demand in the Qu'Appelle River Basin in 2010 was estimated at 45,689 dam^3, of which cities have the largest share. In fact, almost three-quarters of

[68] 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.

the total water demand (73.7%) is for the two cities in the basin (Table 8.16). The next largest level of water demand in 2010 is for rural communities, which included farm and rural non-farm users. This level was estimated at 5,596 dam^3. Following these two larger demands are domestic water demands (towns), First Nations' communities, and institutions.

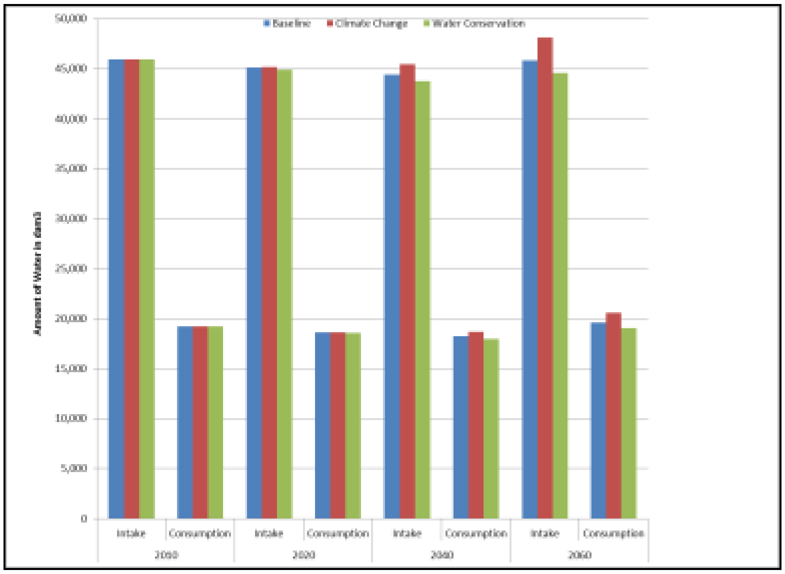

Figure 8.1: Distribution of Water Intake and Consumption for Municipal / Domestic Water Demand in the Qu'Appelle River Basin, 2010 - 2060

Table 8.16: Total Municipal/Domestic Water Demand under Baseline Scenario in the Qu'Appelle River Basin, 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	33,839	33,572	32,911	32,272	95.37%
Total Domestic Water Demand	5,337	5,280	5,467	6,144	115.12%
Total Rural Water Demand	5,596	4,760	3,677	2,814	50.29%
First Nations' Communities' Total Water Demand	590	940	2,205	4,173	707.29%
Institutional (Communal) Water Demand	327	300	252	204	62.39%
Total Municipal/Domestic Water Demand Inside Basin	**45,689**	**44,852**	**44,512**	**45,607**	99.82%
Total Municipal/Domestic Water Demand Interbasin Transfers	908	935	1,003	1,089	119.93%
Total Municipal/Domestic Water Demand	**46,597**	**45,787**	**45,515**	**46,696**	**100.21%**

By 2060, although municipal water demand still has the largest share, the ranks of other water demands change. Now, domestic water demand has the second highest water demand level, followed by First Nations' communities. Rural water demand level is now only 2,814 dam^3, which has been reduced to almost half of the 2010 level. The largest increase in 2060 is expected to be in the First Nation communities' water demand level, which will increase from 590 dam^3 in 2010 to 4,173 dam^3 by 2060. The relative shares of these five water demands are shown in Figure 8.2. On account of an increasing level of domestic water demand and that designed for the First Nation's communities, the municipal water demand share is reduced. However, continues to be the largest water demand in the basin.

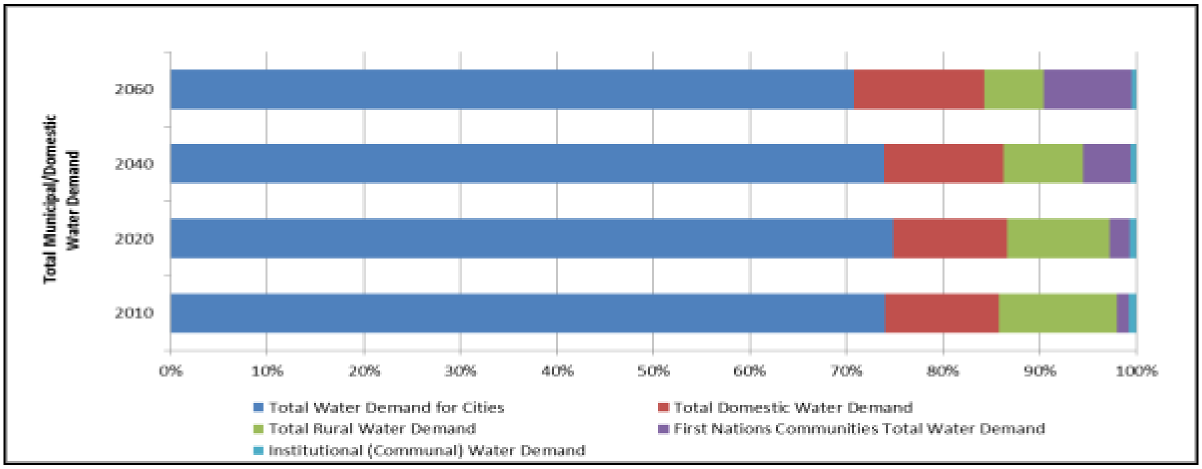

Figure 8.2: Distribution of Total Municipal/Domestic Water in the Qu'Appelle River Basin by Type of Community, 2010 - 2060

8.9.2 Total Municipal/Domestic Water Demand – Climate Change Scenario

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 except for the institutional aspects. The total water demand in 2060 will increase to 47,950 dam^3 per annum, which is 4.9% higher than that in 2010, as shown in Table 8.17. The two cities would continue to use a large proportion of this water, followed by domestic water demand and rural water demand.

8.9.3 Total Municipal/Domestic Water Demand – Water Conservation Scenario

Although the level of municipal/domestic water demand will change under the water conservation scenario, this pattern will not undergo any significant changes. The total water demand for these purposes in 2060 would be 44,404 dam^3, which is 2.8% lower than the 2010 level. These results are summarized in Table 8.18.

Table 8.17: Total Municipal/Domestic Water Demand under Climate Change Scenario, Qu'Appelle River Basin, 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	33,839	33,572	33,701	33,885	100.1%
Total Domestic Water Demand for Urban Communities	5,337	5,280	5,658	6,499	121.8%
Total Rural Water Demand	5,596	4,760	3,764	2,954	52.8%
First Nations' Communities' Total Water Demand	590	940	2,258	4,382	742.7%
Institutional (Communal) Water Demand	327	300	271	230	70.3%
Total Municipal/Domestic Water Demand	**45,689**	**44,852**	**45,652**	**47,950**	**104.9%**
Total Municipal/Domestic Water Demand through Interbasin Transfers	908	935	1,031	1,149	126.5%
Total Municipal/Domestic Water Demand including Interbasin Transfers	**46,597**	**45,787**	**46,683**	**49,099**	**105.4%**

Table 8.18 : Total Municipal / Domestic Water Demand under Water Conservation Scenario, Qu'Appelle River Basin, 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	33,839	33,416	32,433	31,462	93.0%
Total Domestic Water Demand for Urban Communities	5,337	5,247	5,404	5,964	111.7%
Total Rural Water Demand	5,596	4,733	3,634	2,732	48.8%
First Nations' Communities' Total Water Demand	590	935	2,180	4,052	686.8%
Institutional (Communal) Water Demand	327	300	249	194	59.3%
Total Municipal/Domestic Water Demand Inside Basin	**45,689**	**44,631**	**43,900**	**44,404**	**97.2%**
Total Municipal/Domestic Water Demand Interbasin Transfers	908	917	940	971	106.9%
Total Municipal/Domestic Water Demand	**46,597**	**45,548**	**44,840**	**45,375**	**97.4%**

Trends in the municipal/domestic water demand in the Qu'Appelle River Basin 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 water demand level. Under this scenario, the 2020 water demand level is lower than the previous period's level. This reduction is caused by the trend in Regina's water demand level, which is expected to decrease at the same rate as in the past decade. However, by 2060, other municipal/domestic water demand levels increase over this period.

8.7.4 Total Municipal Water Demand -- Summary

A summary of total municipal/domestic water demand for the 2010 - 2060 period under the three study scenarios is presented in Table 8.19. Under climate change in 2060, the basin will experience a 5% increase in municipal/domestic water demand, whereas under water conservation scenario a reduction of 2.8% is a possibility. These estimates are based on a declining water demand level for the city of Regina, but this assumption requires further scrutiny.

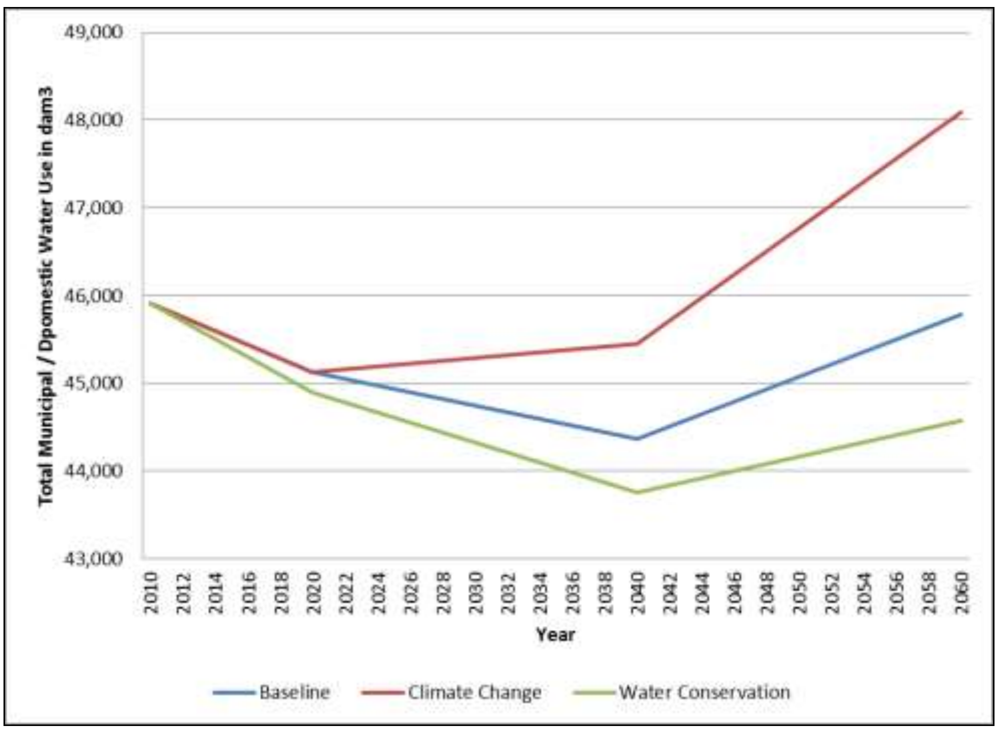

Figure 8.3: Total Municipal/Domestic Water Demand for the Qu'Appelle River Basin, Under Study Scenarios, 2010 - 2060

Table 8.19 : Summary of Municipal Water Demand in the Qu'Appelle River Basin, 2010-2060, under Study Scenarios

Scenarios	Total Water Demand in dam^3				% of Baseline Scenario in 2060
	2010	2020	2040	2060	
Baseline Scenario	46,597	45,787	45,515	46,696	100.0%
Climate Change Scenario	46,597	45,787	46,683	49,099	105.1%
Water Conservation Scenario	46,597	45,548	44,840	45,375	97.2%

Chapter 9

Recreational Water Demand

Water-based recreation activities are typically of two types: consumptive, which includes water demanded by cottager owners and other residents near or at the surface water bodies; and non-consumptive in nature. The non-consumptive recreation 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 is through evaporation but it is supplemented by natural flows. The consumptive water demand needs to be estimated as a part of the total water demand in the Qu'Appelle River Basin. This calculation is reported in this chapter.

9.1 Recreational Villages' Water Demand

9.1.1 Recreational Villages' Water Demand under the Baseline Scenario

Consumptive water demand for recreational activities is created for two situations: residents (i) living in recreational communities and (ii) 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 need to be included. Here, water is used for administrative purposes as well as for maintaining the park sites.

The water demand by residents of recreational villages is shown in Table 9.1. The data for this category of water demand are very poor. Thus, water demand was estimated with a per capita water demand coefficient of 409.78 dam^3 estimated from 2010 water consumption for these recreational villages. The resident population of 644 in 2010 of 208 is multiplied by the coefficient to arrive at an estimate of 86 dam^3 of water for these villages. Past population changes in the recreational villages has been uneven, as the population will increase/decrease and stay at that level for a number of years. In the future, population growth will be restricted by real estate development in these villages as the area for development is limited. Since the recreational villages are attractive to retirees, the increase in the retired population in 2035-40 will have an effect on the demand for these resort properties. The water demand will likely decrease from 86 dam^3 in 2010 to 68 dam^3 in 2040, with a population of 166, and maintaining that level till 2060.

9.1.2 Recreational Villages' Water Demand under the Climate Change Scenario

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. Using these coefficients and projected population, the water demand was estimated. These estimates are shown in Table

9.1. By 2060, it is expected that this water demand will be 71 dam^3, some 3 dam^3 higher than that under the baseline scenario.

Table 9.1: Recreational Villages' Water Demand, Qu'Appelle River Basin, Study Scenarios, 2010 - 2060

Scenarios	Total Water Demand in dam^3				% of Baseline Scenario in 2060 2010
	2010	2020	2040	2060	
Baseline Scenario	86	68	68	68	-20.80%
Climate Change Scenario	86	68	69	71	-16.90%
Water Conservation Scenario	86	67	67	66	-23.10%

9.1.3 Recreational Villages' Water Demand under the Water Conservation Scenario

Water conservation measures can be adopted by residents of recreational villages. However, knowledge of the nature of water demand by these residents is not available, thus making adjustments through water conservation practices is difficult. For this reason, these residents were treated just like any other urban resident. The water demand for their 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 66 dam^3, some 2 dam^3 lower than that under 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, recreational demand is expected to increase. An increased population in the basin, accompanied by increased urbanization, will result in higher levels of water demanded for maintenance purposes. These water demand estimates are presented in this section.

9.2.1 Water Demand for Maintenance of Recreation Sites under the Baseline Scenario

As noted in Chapters 4 and 5, this water demand has two components: one, a variable level of demand related to visitor services, which is determined by the number of visitors to the site; and, two, a fixed level of water required to maintain office services, lawns, and other facilities. Unfortunately, details on these two demands were not available and therefore, analysis was undertaken by using the total water demand by the recreational sites.

This water demand is shown in Table 9.2. The current demand for these sites is estimated at 113 dam^3. Large water demand sites include the Manitou Beach, Kannata Valley, and Buffalo Pound Lake sites. These three sites collectively use 65% of the total water demand for recreational sites. By 2060, this water demand may rise to 123 dam^3, representing 9.7% increase over the 2010 level. Future projection of visitors is a complex exercise, since many factors could affect these levels. One of the major factors among these is the size of the water body at the sites, and other quality-related aspects. The quality of a site deteriorates as the congestion 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 9.2: Water Demand for Recreational Sites in the Qu'Appelle River Basin, Baseline Scenario, 2010 - 2060

Location	Water Demand in dam^3			
	2010	**2020**	**2040**	**2060**
Buffalo Pound	16.8	17.09	17.50	18.38
Douglas	3.72	3.79	3.88	4.08
Echo Valley	6.1	6.24	6.39	6.71
Rowan's Ravine	7.4	7.53	7.71	8.10
Crooked Lake	0.63	0.65	0.66	0.70
Danielson	0.69	0.71	0.72	0.76
Katepwa Point	0.99	1.01	1.04	1.09
Last Mountain House	0.01	0.01	0.01	0.01
Painted Rock Campground	0.63	0.64	0.66	0.69
Regina Beach Recreation	0.61	0.62	0.64	0.67
Besant Recreation Site	1.84	1.88	1.92	2.02
Birds Point Recreation Site	0.35	0.36	0.37	0.39
Camp Easter Seal	5.56	5.67	5.81	6.10
B-Say-Tah	N.A.			
Etters Beach Resort Village	4.16	4.24	4.34	4.56
Grandview Beach	6.67	6.80	6.97	7.32
Kannata Valley	19.60	19.99	20.47	21.49
Manitou Beach	36.78	37.52	38.42	40.34
West End	N. A.			
Total	**112.5**	**114.8**	**117.5**	**123.4**
Percent Increase over 2010 Level	**--**	2.0%	4.4%	9.7%

Source: Estimations from SWA (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

Urban and rural recreation, scenery, wildlife habitat, and fisheries are all strongly affected by the quantity and quality of water, and all of these are affected by climate change (Cooper, 1990). Hydrological droughts result in low stream flows and low lake levels. These would 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 instance. These activities may also be reduced.

Recreational site maintenance may increase due to higher temperatures and lower precipitation. Assuming the same change as the effect assumed for the domestic water demand, (2.4% and 5% increase in water demand by 2040 and 2060, respectively), estimated water demand is shown in Table 9.3.

Table 9.3: Water Demand for Recreational Sites in the Qu'Appelle River Basin, Climate Change Scenario with comparison with the Baseline Scenario, 2010 - 2060

Year	Baseline 2010	With Climate Change	Increase over Baseline Scenario (%)
2010	112.5	112.5	0%
2020	114.8	114.8	0%
2040	117.5	120.3	2.4%
2060	123.4	129.6	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 hard to estimate, since some of the recreational activities depend on water availability. For recreational site maintenance, some water conservation practices can be applicable. Assuming these measures will result in a similar reduction as that shown for the municipal water systems, current and future water demand was estimated. These estimates are shown in Table 9.4. This water demand for the adoption of water conservation measures could be as low as 113 dam^3 by 2060.

9.1.4 Summary of Recreational Water Demand

Total recreational water demand levels for the three study scenarios are presented in Table 9.5. The increases in these levels are in the neighborhood of 10% in 2060, as compared to the 2010 level. Climate change may cause a higher increase in these water demand levels – 15% of the 2010 level in 2060, although water conservation does offer some reduction.

Table 9.4: Water Demand for Recreational Sites in the Qu'Appelle River Basin, Water Conservation Scenario and Comparison with Baseline Scenario, 2010 - 2060

Year	Baseline Estimates (dam^3)	Estimates for the Water Conservation Measures (dam^3)
2010	112.5	119.1
2020	114.8	111.8
2040	117.5	111.3
2060	123.4	113.4

Table 9.5: Summary of Recreational Sites Water Demand under Study Scenarios, 2010 - 2060

Scenario	Water Demand in dam^3				Increase in 2060 over 2010 (%)
	2010	2020	2040	2060	
Baseline	199	183	186	191	-3.6%
Climate Change	199	183	189	201	1.1%
Water Conservation	199	179	178	179	-9.6%

(Photo courtesy of Saskatchewan Water Authority)
Qu'Appelle River near Craven, Saskatchewan

Chapter 10

Indirect Anthropogenicc Water Demand

Balancing of water demand against supply requires all water demands. Included among these demands are those that result from natural processes or policy regulations. These demands are not related to any direct human use of water. Therefore, in this study, they are called indirect anthropogenic water demands. Three such types included in this category of water demands are: evaporation water demand, apportionment water demand, instream water needs, and environmental water demand. These water demands 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. It was based on these two factors, as described in Chapters 3 and 4.

10.1.1 Evaporation Water Demand – Baseline Scenario

The net evaporation losses for lakes and reservoirs in the Qu'Appelle River Basin are presented in Table 10.1. These values were estimated for the current situation (time period). It was assumed that factors affecting evaporation (temperature, precipitation, sunny days, among others) would remain unchanged over the next 50 year period, except under climate change. Therefore, for the baseline scenario, 2010 estimates were accepted as estimates for all three future time periods.

On an annual basis, some 458,988 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 the Quill Lakes and Last Mountain Lake. Evaporation losses from these two water bodies constitute 81.3% of the total evaporation. Other water bodies are smaller in surface area, and therefore, do not lose as much water to evaporation.

Similar to smaller lakes, man-made irrigation reservoirs also have a lower level of evaporation. Only the Zelma dam has a higher level of evaporation, estimated at 682 dam^3. The remaining reservoirs have evaporation levels between 39 to 57 dam^3 per annum.

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).

Table 10.1: Evaporation Losses of Lakes and Reservoirs, Qu'Appelle River Basin, 2010 - 2060

Water Body Type	Name of the Water Body	Evaporation Losses in dam^3			
		2010	2020	2040	2060
Lakes	Buffalo Pound	16,027	16,027	16,828	17,630
	Last Mountain Lake	118,976	118,976	124,924	130,873
	Round Lake	4,095	4,095	4,300	4,505
	Crooked Lake	6,362	6,362	6,680	6,998
	Katepawa Lake	7,833	7,833	8,224	8,616
	Echo Lake	5,961	5,961	6,259	6,557
	Mission Lake	3,653	3,653	3,835	4,018
	Pasqua Lake	10,115	10,115	10,621	11,127
	Quill Lakes	254,000	254,000	266,700	279,400
	Paysen Lake	465	465	488	511
	Foam Lake	775	775	814	852
	Eyebrow Lake	5,046	5,046	5,298	5,550
	Devils Lake	325	325	342	358
	Boulder Lake	277	277	291	304
	Bank Lake	89	89	94	98
	Mit Lake	2	2	2	2
	Whitewood Lake	666	666	700	733
	Kutawa Lake	93	93	98	102
	Horse Lake	439	439	461	483
	Kettlehut Lake	358	358	376	394
	Pelican Lake	4,500	4,500	4,725	4,950
	Little Manitou Lake	15,702	15,702	16,488	17,273
	Kutawagon Lake	706	706	741	776
	Humbolt Lake	527	527	553	580
	Wolverine Lake	79	79	83	87
	Jansen Lake	316	316	332	348
	Buffalo Lake	325	325	342	358
	Axe Lake	139	139	146	153
	Strap Lake	74	74	78	82
Reservoirs	Esterhazy Dam	39	39	41	43
	Wascana Lake Weir	57	57	60	63
	Zelma Dam	682	682	716	750
	Dellwood Brook	57	57	60	63
	Five Mile Dam	57	57	60	63
	Hugonard Dam	57	57	60	63
	Kingway Dam	57	57	60	63
	Selcan Weir	57	57	60	63
Total		**458,988**	**458,988**	**481,937**	**504,887**

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 that can affect the rate of evaporation over the ice-free period. There are then many factors that will have positive or negative effects on the rate of evaporation, yet little or no guidance as to how these influences will play out to 2060.

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) estimates that water requirements for irrigation will increase between 3 to 5% by 2020, and between 5 to 8 % by 2070, which may lead to a need for additional development of man-made reservoirs. Although estimation of precise evaporation coefficients requires a separate study for the basin, for the purposes of this study it is assumed that the rate of evaporation will increase by 5% by 2040 and by 10% to 2060.[69]

The net evaporation losses for lakes and reservoirs in the Qu'Appelle Basin are presented in Table 6.14. The base evaporation losses are used to estimate the water loss for 2010 and 2020 while the base evaporation loss is increased by 5% for 2040 and 10% for 2060. The total amount of water lost to evaporation is estimated at 504,887 dam^3 by 2060. The Quill Lakes and Last Mountain Lake remain as the water bodies with the largest volumes of evaporation.

10.1.3 Evaporation Water Demand – Water Conservation Scenario

All indirect anthropogenic water demands are not subject to water conservation. Evaporation is no exception. However, since these demands are determined by natural conditions, these values were assumed to be the same as those under the baseline scenario. It is recognized that there may eventually be technological measures to reduce evaporation losses, but such knowledge is still in a developmental stage; therefore, it is not considered in this study.

10.2 Apportionment Water Demand

As noted in Chapter 3, the natural flow of water to Manitoba is large enough to include the yearly average apportionable flow of water. Based on this evidence, in this study, apportionment water demand was set equal to zero for the 2010 - 2060 period. There is a possibility that in some years on account of hydrological drought conditions, resulting in lower stream flows, some water may have to be released to meet the need for apportionment water demand. However, prediction of these conditions was considered beyond the scope of this study.

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[69] It should be noted that these levels are assumed. Further research is needed to ascertain them using climate models.

10.3 Environmental Water Demand

Greater evaporation due to 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.

Water demand for these various projects is highly variable because spring runoff and water flow are the main sources of recharge. For this reason, it is assumed that after the initial intake to fill the wetlands, very small quantities of water will be needed. Based on this argument, this water demand is also set equal to zero for current and future periods.

10.4 Instream Flow Requirements

As noted in Chapter 3, the Qu'Appelle River System provides habitat for a variety of fish and wildlife species. SWA (2007a) provided a current fish and wildlife water demand of 4,946 dam^3. In this study, this latter estimate is used. This water demand was not subjected to climate change and/or water conserver conservation scenarios.

Chapter 11

Summary and Implications

Water demand in the Qu'Appelle River Basin is estimated for 2010 at 599,324 dam^3, of which direct anthropogenic demands account for 135,390 $dam^3$of the total or 23%. Of this total, about 2,990 dam^3 is supplied from the South Saskatchewan River Basin. The projected water demand is estimated for three years (2020, 2040, and 2060) under three study scenarios.

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, to estimate water demand levels for the Qu'Appelle River Basin. Increased amounts of irrigated area and expansion of the potash sector are the main forces behind the change in water demand. Direct anthropogenic activities are projected to account for 44% of the total water demand by 2060, slightly less than doubling the in 2010 share (Table 11.1).

11.2 Summary of Total Water Demand for the Climate Change Scenario

Effects of climate change on the direct anthropogenic and indirect anthropogenic water demand activities in the Qu'Appelle River Basin 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 more water. The evaporation of water from water bodies, which is already a major indirect anthropogenic water demand, is one of the major increased demands that can be expected with climate change.

11.3 Summary of Total Water Demand for the Water Conservation Scenario

The effect of water conservation measures on the water demand activities in the Qu'Appelle River Basin 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 for efficient water management. They also have merit in terms of water supply cost recovery, and in internalizing environmental costs, getting as a signal to users to reduce their water use. Such sentiments have also been voiced by the recent National Round Table on Environment and the Economy (NRTEE, 2011) in its remarks as 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 Qu'Appelle River Basin, for the Baseline Scenario, 2010-2060

Sector	Sub-Activity	Total Amount of Water Demand in dam^3			
		2010	2020	2040	2060
DIRECT ANTHROPOGENIC ACTIVITIES					
Agriculture	Irrigation	54,856	56,552	154,367	194,965
	Livestock	9,264	9,955	10,408	10,798
	Pesticide	349	353	348	348
	Other (greenhouse and Aquaculture)	228	230	235	242
	Sub-total	**64,697**	**67,090**	**165,358**	**206,353**
Industry & Mining	Potash	13,999	75,479	86,535	86,535
	Oil & Gas	341	458	275	69
	Manufacturing	7,445	7,811	8,517	9,262
	Other Mining	30	31	34	37
	Irrigation Induced	0	0	-482	-443
	Sub-Total Excluding IBT*	**21,815**	**83,779**	**94,879**	**95,460**
	Sub-total including IBT*	**23,897**	**92,988**	**104,088**	**112,883**
Municipal / Domestic	Municipal	45,362	44,552	44,260	45,403
	Public Institutions	327	300	252	204
	Sub-Total Excluding IBT*	**45,689**	**44,852**	**44,512**	**45,607**
	Sub-total including IBT*	**46,597**	**45,787**	**45,515**	**46,696**
Recreation	Recreation Communities	86	68	68	68
	Parks/Recreation	113	115	118	123
	Sub-Total	**199**	**183**	**186**	**191**
Sub-total Direct Anthropogenic Activities Excluding IBT*		**132,400**	**195,904**	**304,935**	**347,611**
Total IBT		2,990	10,144	10,212	18,512
Sub-total Direct Anthropogenic Activities Including IBT*		**135,390**	**206,048**	**315,147**	**366,123**
INDIRECT ANTHROPOGENIC ACTIVITIES					
Other Water Demands					
	Evaporation	458,988	458,988	458,988	458,988
	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 Excl. IBT*		**463,934**	**463,934**	**463,934**	**463,934**
Total Water Demand Excluding IBT*		**596,334**	**659,838**	**768,869**	**811,545**
Total Water Demand Including IBT*		**599,324**	**669,982**	**779,081**	**830,057**

*IBT – Interbasin Transfers

Table 11.2: Water Demand in the Qu'Appelle River Basin, for the Climate Change Scenario, 2010- 2060

Sector	Sub-Activity	Total Amount of Water Demand in dam^3			
		2010	**2020**	**2040**	**2060**
DIRECT ANTHROPOGENIC ACTIVITIES					
Agriculture	Irrigation	54,856	56,552	180,769	247,158
	Livestock	9,264	9,955	10,834	11,660
	Pesticide	349	353	363	377
	Other (Greenhouse and Aquaculture)	228	230	235	242
	Sub-total	**64,697**	**67,090**	**192,201**	**259,437**
Industry & Mining	Potash	13,999	75,479	86,535	86,535
	Oil & Gas	341	458	275	69
	Manufacturing	7,445	7,811	8,688	9,448
	Other Mining	30	31	34	37
	Irrigation Induced	0	0	-458	-392
	Sub-Total Excluding IBT*	**21,815**	**83,779**	**95,074**	**95,697**
	Sub-total including IBT*	**23,897**	**92,988**	**104,283**	**113,120**
Municipal / Domestic	Municipal	45,362	44,552	45,381	47,720
	Public Institutions	327	300	271	230
	Sub-Total Excluding IBT*	**45,689**	**44,852**	**45,652**	**47,950**
	Sub-total including IBT*	**46,597**	**45,787**	**46,683**	**49,099**
Recreation	Recreation Communities	86	68	69	71
	Parks/Recreation	113	115	120	130
	Sub-Total	**199**	**183**	**189**	**201**
Sub-total Direct Anthropogenic Activities Excluding IBT*		**132,400**	**195,904**	**333,116**	**403,285**
Total IBT*		2,990	10,144	10,240	18,572
Sub-total Direct Anthropogenic Activities Including IBT*		**135,390**	**206,048**	**343,356**	**421,857**
INDIRECT ANTHROPOGENIC ACTIVITIES					
Other Water Demands					
	Evaporation	458,988	458,988	481,937	504,887
	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 Excluding IBT		**463,934**	**463,934**	**486,883**	**509,833**
Total Water Demand Excluding IBT*		**596,334**	**659,838**	**819,999**	**913,118**
Total Water Demand Including IBT*		**599,324**	**669,982**	**830,239**	**931,690**

*IBT – Interbasin Transfers

Table 11.3: Water Demand in the Qu'Appelle River Basin for the Adoption of Water Conservation Measures

Sector	Sub-Activity	Total Amount of Water Demand in dam^3			
		2010	**2020**	**2040**	**2060**
DIRECT ANTHROPOGENIC ACTIVITIES					
Agriculture	Irrigation	54,856	52,425	135,250	169,261
	Livestock	9,264	9,955	10,009	10,304
	Pesticide	350	353	314	174
	Other (Greenhouse and Aquaculture)	228	230	235	242
	Sub-total	**64,698**	**62,963**	**145,807**	**179,981**
Industry & Mining	Potash	13,999	71,906	74,158	65,906
	Oil & Gas	341	389	233	58
	Manufacturing	7,445	7,655	8,347	9,077
	Other Mining	30	30	33	36
	Irrigation Induced	0	0	-538	-552
	Sub-Total Excluding IBT*	**21,815**	**79,980**	**82,233**	**74,525**
	Sub-total including IBT*	**23,897**	**88,958**	**90,752**	**89,771**
Municipal / Domestic	Municipal	45,362	44,331	43,651	44,210
	Public Institutions	327	300	249	194
	Sub-Total Excluding IBT*	**45,689**	**44,631**	**43,900**	**44,404**
	Sub-total including IBT*	**46,597**	**45,548**	**44,840**	**45,375**
Recreation	Recreation Communities	86	67	67	66
	Parks/Recreation	113	112	111	113
	Sub-Total	**199**	**179**	**178**	**179**
Sub-total Direct Anthropogenic Activities Excluding IBT		**132,401**	**187,753**	**272,118**	**299,089**
Total IBT		2,990	9,896	9,458	16,216
Sub-total Direct Anthropogenic Activities Including IBT		**135,391**	**197,649**	**281,576**	**315,305**
INDIRECT ANTHROPOGENIC ACTIVITIES					
Other Water Demands					
	Evaporation	458,988	458,988	458,988	458,988
	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 Excluding IBT		**463,934**	**463,934**	**463,934**	**463,934**
Total Water Demand Excluding IBT		**596,335**	**651,687**	**736,052**	**763,023**
Total Water Demand Including IBT		**599,325**	**661,583**	**745,510**	**779,239**

*** Interbasin Transfers**

11.4 Conclusions

Water management is a complex issue that will face the Qu'Appelle River Basin in the future. Many changes already happening and continuing in the future are going to alter water management strategies. 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, effects of some of the pressures (such as climate change) and policy responses (water conservation) were incorporated.

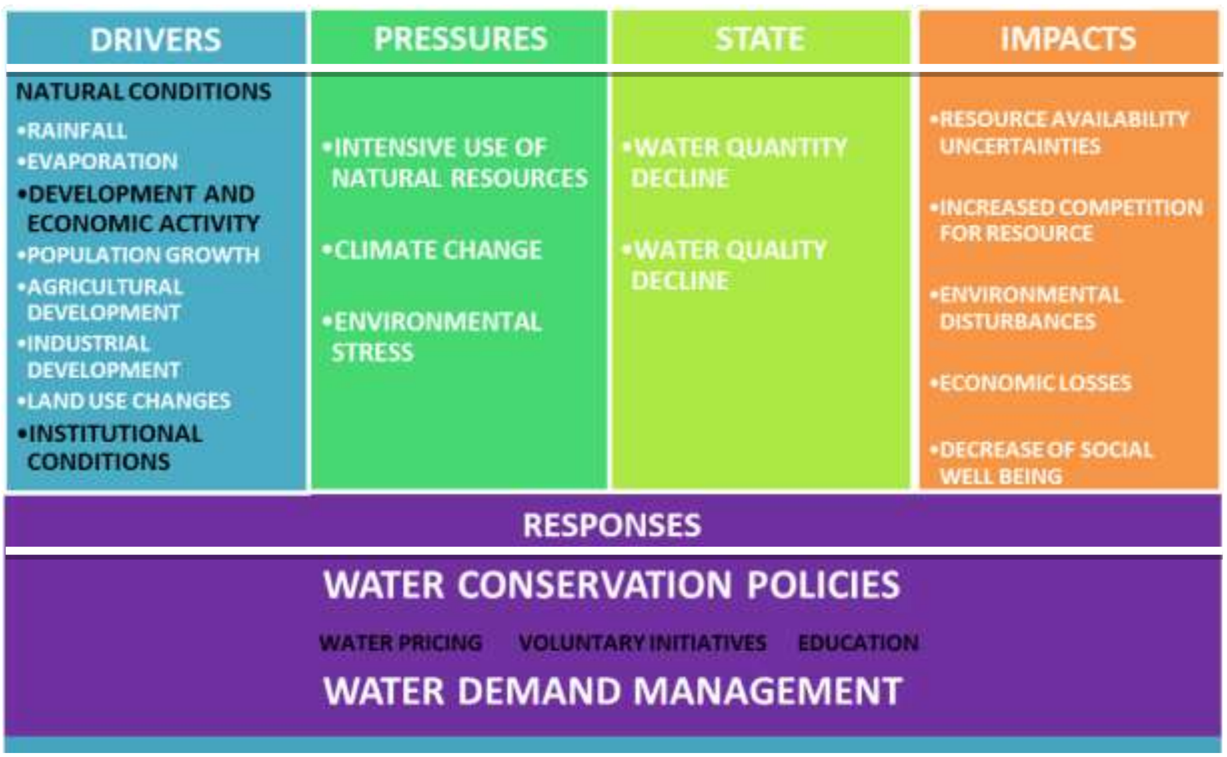

Figure 11.1: Overview of Issues Related to Water Management in the Qu'Appelle River Basin

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 will result from three major trends: one, expansion of more irrigation in the basin, such as development of the Qu'Appelle South Irrigation District; two, expansion of the urban population in and around the city of Regina and Moose Jaw; and three, expansion in potash mining activities in the Qu'Appelle River Basin. These demands combined would constitute over 90% of the total water demand in the basin by 2060. Whether this condition would result in water scarcity or tough competition among its users remains to be determined. Although municipal water demand is 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. New potash mines are proposed, and therefore included in these estimates. Whether these will actually be in production of potash remains to be seen.

Moreover, the importance of surface water in the future is expected to be higher. Economic activities, such as irrigation and potash mining, will draw more surface water. Although groundwater demand will still be important, it will represent a smaller portion of the total water demand (claiming 9% of total water demand by 2060). As competition for the available water increases, there may be a need for demand management. Measures encouraging water conservation may become more important in the future.

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 people about the merits of adopting such measures are often noted as the most important factors affecting adoption of water conservation practices. The National Roundtable on the Environment and Economy (NRTEE, 2012) has also advanced such prescriptions. The NRTEE 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 used 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).

Climate change is very 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 period of droughts and extreme rain events in order 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 critically 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 are listed in this section 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 presented in Figure 11.2. Some of the major deficiencies are listed below.

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 rate 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 demand by producers for different crops are not available. This type of information affects estimation of water demand under different crop mix, which could change in the future.

- 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 also needed. Given several large freshwater bodies in the basin, this type of water demand may increase in the future.

Figure 11.2: Summary of Further Research by Sector

- 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. Projection 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. Furthermore, such communities could be identified for medium size 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 to assess the 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 demand of a recreation site could not be incorporated. These factors are important in determining future demands 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 and related 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:

- Latest farm and rural non-farm population numbers were not available at the time of writing this report. Data from the agriculture census was to be released at some future date.

- Potash mining water demand will need to be revised as new mines come into operation or close to finalization of their plan for production.

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Appendix A

List of Communities in the Qu'Appelle River Basin

Table A.1: Categories of Communities in Qu'Appelle River Basin

	1. CITIES
1	Moose Jaw
2	Regina

	2. TOWNS		
	2a. More than 1000		**2b. Less than 1000**
1	Balcarres	1	Rouleau
2	Bredenbury	2	Sintaluta
3	Broadview	3	Southey
4	Bruno	4	Strasbourg
5	Central Butte	5	Watson
6	Colonsay	6	Wolseley
7	Craik	7	Carronport
8	Cupar	8	Davidson
9	Francis	9	Esterhazy
10	Govan	10	Foam Lake
11	Imperial	11	Grenfell
12	Ituna	12	Indian Head
13	Lemberg	13	Lanigan
14	Leroy	14	Wadena
15	Milestone	15	Watrous
16	Nokomis	16	Whitewood
17	Qu'Appelle	17	Wynyard
18	Raymore		

	3. VILLAGES		
1	Abernethy	43	Liberty
2	Atwater	44	Lipton
3	Avonlea	45	Lockwood
4	Aylesbury	46	Markinch
5	Bangor	47	Marquis
6	Belle Plaine	48	Meacham
7	Bethune	49	Mortlach
8	Bladworth	50	Muenster
9	Briercrest	51	Neudorf
10	Brownlee	52	Pangman
11	Buena Vista	53	Pense
12	Bulyea	54	Penzance
13	Caron	55	Plunkett
14	Chamberlain	56	Punnichy
15	Craven	57	Quill Lake
16	Dafoe	58	Quinton
17	Davin	59	Sedley
18	Dilke	60	Semans
19	Disley	61	Silton
20	Drake	62	Simpson
21	Drinkwater	63	Spalding
22	Dubuc	64	Spring Valley
23	Duff	65	St. Gregor
24	Duval	66	Stockholm
25	Dysart	67	Strongfield
26	Earl Grey	68	Tantallon
27	Edenwold	69	Tugaske
28	Edgeley	70	Tuxford
29	Elfros	71	Vibank
30	Englefeld	72	Viscount
31	Eyebrow	73	Waldren
32	Fenwood	74	Wilcox
33	Findlater	75	Wishart
34	Gerald	76	Yarbo
35	Girvin	77	Young
36	Goodeve	78	Keeler
37	Grand Coulee	79	Kelliher
38	Grayson	80	Killaly
39	Guernsey	81	Lebret
40	Holdfast	82	Leross
41	Hubbard	83	Leslie
42	Jansen	84	Lestock

	4.BEDROOM COMMUNITIES OF REGINA		
1	Balcarres	19	Ituna
2	Bredenbury	20	Lanigan
3	Broadview	21	Lemberg
4	Bruno	22	Leroy
5	Carronport	23	Milestone
6	Central Butte	24	Nokomis
7	Colonsay	25	Qu'Appelle
8	Craik	26	Raymore
9	Cupar	27	Rouleau
10	Davidson	28	Sintaluta
11	Emerald Park	29	Southey
12	Esterhazy	30	Strasbourg
13	Foam Lake	31	Wadena
14	Francis	32	Watrous
15	Govan	33	Watson
16	Grenfell	34	Whitewood
17	Imperial	35	Wolseley
18	Indian Head	36	Wynyard

	6. FIRST NATIONS' RESERVES		
1	Assiniboine 76	12	Pasqua 79
2	Cowessess 73	13	Peepeekisis 81
3	Day Star 87	14	Piapot Cree First Nation 75H
4	Gordon 86	15	Piapot 75
5	Kahkewistahaw 72	16	Poorman 88
6	Little Black Bear 84	17	Sakimay 74
7	Little Bone 74B	18	Shesheep 74A
8	Muscowpetung 80	19	Standing Buffalo 78
9	Muskowekwan 85	20	Star Blanket 83
10	Ochapowace 71	21	Star Blanket 83C
11	Okanese 82	22	Wa-Pii Moos-Toosis 83A

	6a RECREATIONAL VILLAGE		6b. PARKS/RECREATIONAL SITES
1	Balgonie	1	B-Say-Tah
2	Fort Qu'appelle	2	Etter's Beach Resort Village
3	Lumsden	3	Grandview Beach
4	Pilot Butte	4	Kannata Valley
5	Regina Beach	5	Manitou Beach
6	White City	6	West End
		7	Painted Rock Campground
		8	Regina Beach Recreation Site
		9	Besant Recreation Site
		10	Birds' Point Recreation Site
		11	Camp Easter Seal
		12	Buffalo Pound Provincial Park
		13	Crooked Lake Provincial Park
		14	Echo Valley Provincial Park
		15	Katepwa Provincial Park
		16	Rowan's Ravine Provincial Park
		17	Emerald Park

	7. INSTITUTIONAL
1	Moose Jaw CFB 15 Wing
2	Regina Correctional Centre

Appendix B

Correspondence Table for the Qu'Appelle 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 consulting both 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 Qu'Appelle 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 municipality, respectively.

Table B.1: Census Division Correspondence to Qu'Appelle River Basin

Census Division	Total Area		Qu'Appelle River Basin		Qu'Appelle River Basin as a % of Total Area
	Acres	Hectares	Acres	Hectares	
1	3,397,016	1,374,725	-	-	0%
2	4,111,021	1,663,671	656,907	265,841	16%
3	4,306,852	1,742,923	74,980	30,343	2%
4	5,002,938	2,024,617	-	-	0%
5	3,407,147	1,378,824	1,850,189	748,745	54%
6	4,153,095	1,680,697	3,790,679	1,534,033	91%
7	4,477,117	1,811,825	1,782,904	721,516	40%
8	5,336,453	2,159,584	-	-	0%
9	2,904,925	1,175,581	-	-	0%
10	2,771,565	1,121,615	2,322,542	939,902	84%
11	4,019,224	1,626,524	2,278,044	921,892	57%
12	3,172,865	1,284,013	-	-	0%
13	4,361,876	1,765,188	-	-	0%
14	3,167,073	1,281,667	213,437	86,375	7%
15	4,343,955	1,757,934	331,612	134,198	8%
16	3,447,637	1,395,208	-	-	0%
17	3,272,829	1,324,468	-	-	0%

Source: Area estimated from Statistics Canada Data Rural Municipality

Table B.2: Crop District Correspondence to Qu'Appelle River Basin

Crop District	Total area		Qu'Appelle River Basin		Qu'Appelle River basin % of Total
	Acres	Hectares	Acres	Hectares	
1	5,187,043	2,099,121	722,629	292,562	13.9%
2	5,206,448	2,106,975	3,206,522	1,298,187	61.6%
3	12,867,824	5,207,424	711,279	287,967	5.5%
4	5,663,713	2,292,023	-	-	0.0%
5	8,237,764	3,333,705	3,840,153	1,554,718	46.6%
6	8,108,898	3,281,554	4,489,098	1,817,449	55.4%
7	6,314,583	2,555,421	-	-	0.0%
8	5,199,395	2,104,120	331,612	134,256	6.4%
9	8,867,920	3,588,720	-	-	0.0%

Source: Area estimated from Statistics Canada Data Rural Municipality

Table B.3: Rural Municipality Correspondence to Qu'Appelle 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 Demand 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 Demand 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 Demand by Natural Resource Canada for Evaporation Water Demand Estimates

The evaporation map obtained from SWA (2009) 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 of 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 on 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 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; 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 occurs from 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

SaskWater 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 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 (SWA 2007b). Diversion volumes are shown in Table E.1.

Table E.1: Potash Mine Tailing 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: SWA (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 make 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 Qu'Appelle River Basin

Table F.1: Regressions Equation for Population of Cities in the Qu'Appelle River Basin

Dependent Variable	Intercept (S.E.)	Time (S.E.)	R^2	F-value
Log Population of Moose Jaw	10.437** (0.0060)	0.00082 (0.00066)	0.106	1.54
Log Population of Regina	12.101 (0.0103)	0.004111695 (0.00113043)	0.504	13.23
Log Population of Town over 1000	9.770 (0.012)	-0.0013 (0.0013)	0.073	1.02
Log Population of Towns under 1000	9.506 (0.019)	0.0017 (0.0021)	0.049	0.667
Log Population of Villages	9.596 (0.0172)	0.0028 (0.0019)	0.146	2.21
Log Population of First Nations' Reservations	8.167 (0.247)	0.0667* (0.027)	0.317	6.04*
Log Population of Bedroom Communities	8.961** (0.029)	0.0192** (0.0032)	0.735	36.09**

* Significantly different from zero at 5%

** Significantly different from zero at 1%

Table F.2: Regression Equation for Per Capita Water Demand by Type of Community

Dependent Variable	Intercept (S.E)	Population (S.E)	Trend (S.E)	R^2	F-value
Log WDC (Moose Jaw)	164.619** (5.578)		1.124286 (0.613576)	0.205	3.35
Log WDC (Regina)	21.344** (4.279)	-1.34585** (0.35269742)		0.528	14.56
WDC (Towns>1000)	5.045** (0.0413)		-0.00921* (0.004545)	0.240	4.10
Log WDC (Towns<1000)	4.999** (0.0208)		-0.00766** (0.00228)	0.463	11.21
Log WDC (Villages)	4.864** (0.020)		-0.00863** (0.002204)	0.541	13.33
WDC (Recreational Villages)	420.55** (93.7074)	-0.622381 (0.530955)	6.561906 (5.951031)	0.174	1.26
WDC (Bedroom Communities of Regina)	181.1112** (30.14576)	-0.006083* (0.003904)	0.42169 (0.775363)	0.301513	2.59
WDC (First Nations' Reservations)	45.8978** (5.274271)		2.590769** (0.619432)	0.593127	17.49

* Significantly different from zero at 5%

** Significantly different from zero at 1%

WDC = Per Capita Water Demand in m^3.

Appendix G

Regression Functions showing Results of Drought Effects on Community Per Capita Water Demand in the Qu'Appelle River Basin

Table G.1: Regression Equations for Per Capita Water Demand by Type of Community in the Qu'Appelle River Basin

Dependent Variable	Intercept (S.E.)	Population (S.E.)	Trend (S.E.)	Drought Binary (S.E.)	R^2	*F-value*
WDC of Moose Jaw	532.5119 (248.1307)	-0.010813 (0.007273)	1.448192 (0.63082)	5.886753 (7.587116)	0.365033	*2.107911*
WDC of Regina	434.1324 (73.79987)	-0.00155** (0.00041)	0.609292 (0.436032)	4.623841 (3.927484)	0.623535	*6.073074*
WDC of Towns>1000	292.9584 (159.5112)	-0.00782 (0.009114)	-1.6224 (0.770915)	2.577916 (9.576837)	0.293254	*1.521432*
WDC of Towns<1000	204.8078 (41.75535)	-0.00415 (0.003097)	-1.0077 (0.320026)	-3.43505 (3.995254)	0.573894	*4.938387*
WDC of Village	169.8751 (41.97199)	-0.00274 (0.002857)	-0.93857** (0.305557)	-0.23024 (3.73112)	0.579252	*5.047962*
WDC of Recreational Villages	375.9262 (96.37492)	-0.42851 (0.532803)	6.879396 (5.757706)	103.0498 (75.95732)	0.292559	*1.516331*
WDC of Bedroom Communities of Regina	191.9611 (28.405)	-0.00767** (0.003702)	0.725487 (0.733698)	8.16878* (4.589263)	0.457709	*3.094767*
WDC of First Nations' Reservation	*41.95667 (9.394227)*	*0.000919 (0.001702)*	*2.449907** (0.72126)*	*-1.46842 (8.217673)*	*0.604652*	*5.098067*

***** Significantly different from zero at 5%

** Significantly different from zero at 1%

WDC = Per Capita Water Demand in m^3.