Present and Future Water Demand in the North Saskatchewan River Basin

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A report prepared for

SASKATCHEWAN WATERSHED AUTHORITY
MOOSE JAW

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Executive Summary

Water is being recognized as an increasingly valuable commodity; always recognized as vital for life, it is necessary for ecological functions, as well as for social and economic activities. In the North Saskatchewan River Basin, the present water supplies are limited, and further expansion of water availability may be a costly measure. As the future economic base increases, leading to growth in the basin's population, competition for water could become even fiercer. Climate change may pose another threat to the region, partly from reduced supplies and increased demands. In short, the development of sounder water management strategies may become a necessity in the future, requiring information on future water demand levels. This study was undertaken to estimate current (2010) water demand levels and to forecast them for the basin by type of demands for the 2020, 2040, and 2060 periods.

North Saskatchewan River Watershed near North Battleford
Photo Courtesy of Saskatchewan Watershed Authority

Basin Description

The North Saskatchewan River Basin is located in the north-western part of the province of Saskatchewan. It extends from the Alberta boundary to the west, to the point where the North Saskatchewan River joins the South Saskatchewan River to form the Saskatchewan River. This basin is just north of the South Saskatchewan River Basin, occupying an area of 41,000 square kilometers, 94% of which is used for agricultural purposes. The basin houses a population of 197 thousand people – roughly a fifth of the provincial population. Three major cities are located in the basin – the cities of Lloydminster (a border town on both sides of the Alberta – Saskatchewan border), North Battleford, and Prince Albert. The basin is situated on the western edge of the potash belt, therefore, containing only one potash mine. In addition, irrigation development is planned for the area. The basin also houses major recreational facilities, including national and provincial parks, resort villages, and other facilities.

Methodology

To begin these estimates, the total water demand was broadly divided into two classes: One, that is a result of socio-economic activities, called direct anthropogenic water demand, and Two, that is subject to natural and policy-related factors, called indirect anthropogenic water demand. The second category includes four types of demands: evaporation, apportionment of water as subject to the Prairie Provinces Water Board agreement, meeting instream water flow needs, and satisfying environmental protection/preservation projects' needs.

The direct anthropogenic category results from several types of economic and social activities. Some of these activities are related to the production of goods, while others need water for sustenance and related social activities. The total water demand for a given type of demand was estimated by water demand coefficients and scale of economic or social activity. Various types of water demands were identified.

In this study, future water demand (for the years 2020, 2040, and 2060) was estimated for three scenarios: Baseline, Climate Change, and Water Conservation Scenarios. The Baseline Scenario assumed that trends based on past data will continue into the future. For the Climate Change Scenario, water requirement was affected by changes in climate characteristics and occurrence of extreme events. Water demand coefficients for any water 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 and that measures have been adopted by various consumers 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 as equal to the 2010 level, since all these demands are related to availability of water; will be affected by a set of natural factors and policy changes. Over the 2010-2060 period, this amount is estimated to be 327,505 dam^3. By 2060, total water demand in the basin will increase to 463,034 dam^3 – an increase of 9.9% of the 2010 level.

Water demand in the North Saskatchewan River Basin is estimated for 2010 at 421,302 dam^3 of which, the direct anthropogenic type accounted for 93,797 dam^3 (or 22.3% of the total water demand). An 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 will account for 29.3% of the total water demand, a slight increase in the 2010 share. By year 2060, the basin will experience an increase of 47.1% in its total direct anthropogenic water demand (Table ES.1).

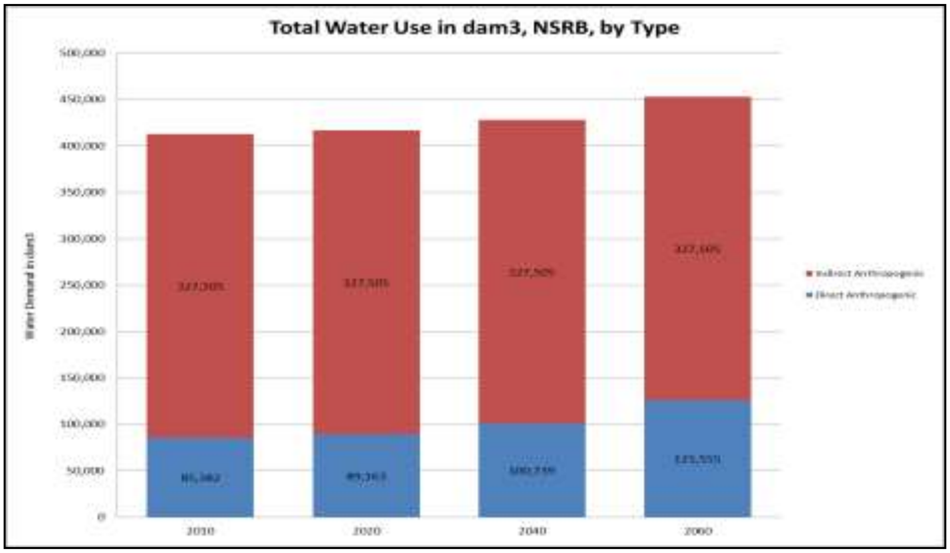

Figure ES.1: Distribution of Total Water Demand in the North Saskatchewan River Basin by Major Categories of Demand, Baseline Scenario, 2010 – 2060

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

Sector	**Amount of Water Demand in dam^3**			
	2010	**2020**	**2040**	**2060**
Agriculture	48,332	50,221	59,459	80,944
Industry/Mining	10,532	11,821	11,523	12,135
Municipal (Domestic)	26,428	27,008	29,620	32,291
Recreational	90	113	137	185
Total Direct Anthropogenic Water * Excluding Transfers**	**85,382**	**89,163**	**100,739**	**125,555**
Interbasin Transfers	1,663	3,220	3,220	3,220
Inter-Provincial Transfers	6,752	6,752	6,752	6,752
Total Direct Anthropogenic Water Demand* Including Transfers	**93,797**	**99,135**	**110,711**	**135,527**
Indirect Anthropogenic Water Demand	327,505	327,505	327,505	327,505
Total Water Demand Excluding Transfers**	**412,887**	**416,668**	**428,244**	**453,060**
Total Water Demand Including Transfers**	**421,302**	**426,640**	**438,216**	**463,032**
% Increase in Direct Anthropogenic Water Demand Over		4.4%	18.0%	47.1%
% Increase in Total Water Demand Over 2010		1.3%	4.0%	9.9%

* Totals may not add precisely due to rounding

**The term refers to both Interbasin and Inter-Provincial Transfers

The total direct anthropogenic water demand in the basin was 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 used 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 demands are expected to increase over time. In total, direct anthropogenic water demand in the basin will increase to 135 thousand dam^3 in 2060, compared to the present level of only 94 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. Industrial and mining water demands are also expected to increase, but not by a similar magnitude.

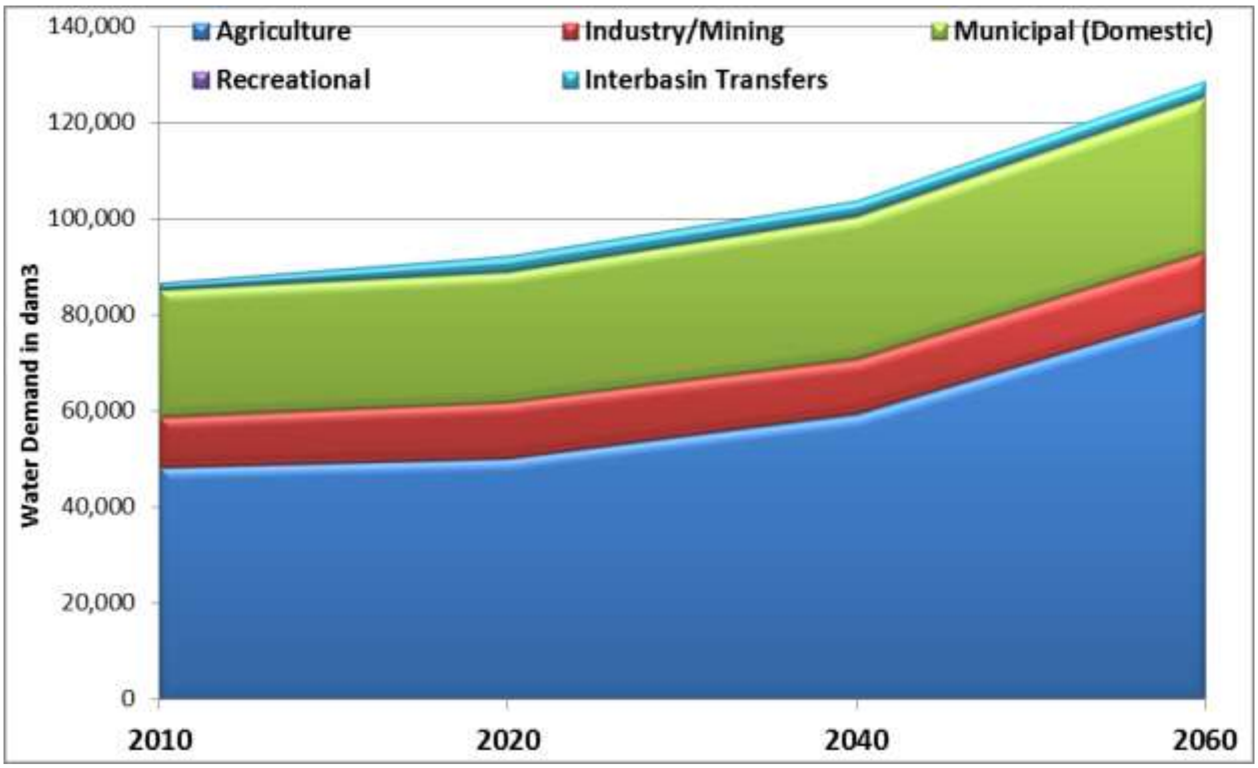

Figure ES.2: Trend in Water Demand for Direct Anthropogenic Demands by Type, North Saskatchewan River Basin, Baseline Scenario, 2010 – 2060

As a result of varying trends over the 2010-2060 period, the composition of total direct anthropogenic water demand will change. As shown in Figure ES.3, agriculture will increase its share of the total to 64%, as opposed to 57% in 2010. Industrial and mining water demand share will decrease from the present 12% to 10%.

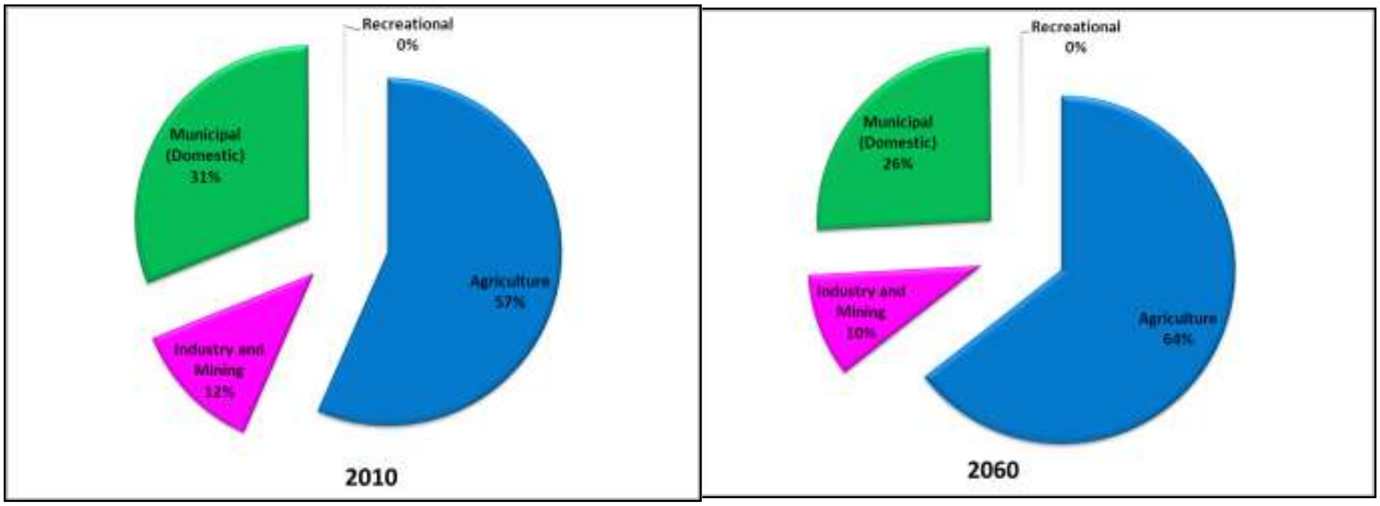

Figure ES.3: Distribution of Total Direct Anthropogenic Water Demand, Within Basin, by Type of Demand in the North Saskatchewan River Basin, Baseline Scenario, 2010 and 2060

Water Demand Estimates under Climate Change Scenario

As noted above, in addition to the baseline forecasts of water demand, two other scenarios were used for making these forecasts. One of these scenarios was climate change. Climate change can have an impact both on water supplies (availability) and on water demand. However, in this study, investigation was limited to water demand aspects. Even here, several difficulties were encountered in making the estimates. One such problem was availability of information on the nature of climate change for the basin and its impact on water demand. Therefore, the basis for making these forecasts is relatively weak, and more research information needs to be generated in the context of Saskatchewan (and more specifically, to the North Saskatchewan 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 North Saskatchewan River Basin are presented in Table ES.2. Since indirect anthropogenic water demands are governed by natural changes in the water supply, as well as by policy changes, these demands were made constant at their respective 2010 levels, except for the evaporation losses. As supply of water under climate change becomes available, these estimates may need to be revised.

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. Total water demand for direct anthropogenic purposes is expected to increase by 74% of the 2010 level. For industrial and mining water demand, no evidence was found that climate change would affect this section.

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

Sector	Amount of Water Demand in dam^3			
	2010	**2020**	**2040**	**2060**
Agriculture	48,332	50,221	68,204	100,495
Industry/Mining	10,532	11,821	11,762	12,657
Municipal and Domestic	26,428	27,008	31,201	35,236
Recreational	90	113	141	195
Total Direct Anthropogenic Water Demand* Excluding Transfers	**85,382**	**89,163**	**111,308**	**148,583**
Interbasin Transfers	1,663	3,220	3,220	3,220
Inter-Provincial Transfers	6,752	6,752	6,887	7,022
Total Direct Anthropogenic Water Demand* Including Transfers**	**93,797**	**99,135**	**121,415**	**158,825**
Indirect Anthropogenic Water Demand	327,505	327,505	341,783	356,062
Total Water Demand Excluding	**412,887**	**416,668**	**453,091**	**504,645**
Total Water Demand Including	**421,302**	**426,640**	**463,198**	**514,887**
% Increase in direct Anthropogenic Water Demand Over		4.4%	30.4%	74.0%
% Increase in Total Water Demand Over 2010		1.3%	9.9%	22.2%

* Totals may not add due to rounding

**The term refers to both Inter Basin and Inter Provincial Transfers

Water Demand Estimates under Water Conservation Scenario

The effect of water conservation measures on the water demand activities in the North Saskatchewan 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 success of most conservation measures is partially dependent on legislations and regulations that may be in place in the future.

The total water demand for direct anthropogenic purposes is estimated to be 119 thousand dam^3 by 2060 – an increase of approximately 29% over the 2010 level. Relative to the baseline scenario, water conservation could reduce anthropogenic water demand by 12% of the baseline estimate in 2060 (Table ES.4). Much of this decrease would likely be through reduction in the agricultural and industrial, and mining sections.

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

Sector	Amount of Water Demand in dam^3			
	2010	**2020**	**2040**	**2060**
Agriculture	48,332	45,750	52,132	69,540
Industry/Mining	10,531	11,319	10,676	10,754
Municipal and Domestic	26,428	26,579	28,217	29,535
Recreational	90	112	134	178
Total Direct Anthropogenic Water Demand* Excluding Transfers**	**85,381**	**83,760**	**91,159**	**110,007**
Interbasin Transfers	1,663	3,172	3,011	2,817
Inter-Provincial Transfers	6,752	6,617	6,617	6,617
Total Direct Anthropogenic Water Demand* Including Transfers	**93,796**	**93,549**	**100,787**	**119,441**
Indirect Anthropogenic Water Demand	327,505	327,505	327,505	327,505
Total Water Demand Excluding	**412,886**	**411,265**	**418,664**	**437,512**
Total Water Demand Including	**421,301**	**421,054**	**428,292**	**446,946**
% Increase in Direct Anthropogenic Water Demand Over 2010		-1.9%	6.8%	28.8%
% Increase in Total Water Demand Over 2010		-0.1%	1.7%	6.1%

* Totals may not add due to rounding

**The term refers to both Inter Basin and Inter Provincial Transfers

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

Type of Demand	Change (Decrease) in 2060 level % of 2010 Level
Agriculture	-14.1%
Industry/Mining	-11.4%
Municipal (Domestic and industrial)	-8.5%
Recreational	-4.1%
Total Anthropogenic Water Demand	-12.4%

Water Demand by Source of Water

Most of the water for various demands is either obtained from surface water or groundwater. In some cases, groundwater can supplement any periodic shortfalls in surface water availability.

Unfortunately, data for total water demand by source of water is not very precise. Some information is available, but other estimates are based on assumptions. 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 than that of groundwater. The proportion of surface to total water demand increases from 67.6% in 2010 to 75.7% by 2060, as shown in Figure ES.4.

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

Particulars	Amount in dam^3			
	2010	**2020**	**2040**	**2060**
Surface Water (dam^3)	57,720	60,550	71,114	94,993
Groundwater (dam^3)	27,663	28,613	29,625	30,562
Total Water Demand	**85,382**	**89,163**	**100,739**	**125,555**
Groundwater % of Total	32.4%	32.1%	29.4%	24.3%

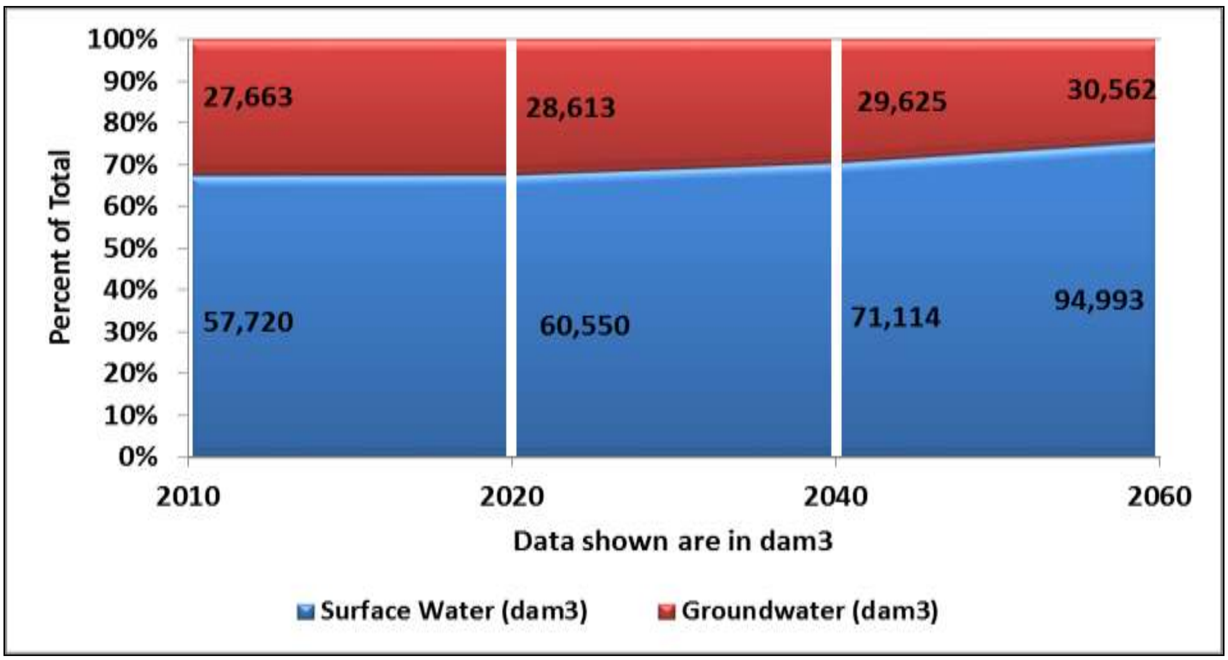

Figure ES.4: Total Direct Anthropogenic Water Demand, Within Basin by Source, North Saskatchewan River Basin, 2010 - 2060

Summary

A major increase in the water demand for various anthropogenic purposes is expected in the North Saskatchewan 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 47% of the 2010 level. Under climate change, further increases would be expected, probably 17% over the 2060 baseline water demand level. The adoption of water conservation measures by water users has the potential to reduce future levels. Relative to the baseline scenario estimate, this reduction could be in the magnitude of 12%. However, the effectiveness of these measures would depend very heavily on the policy measures undertaken by the provincial government and other jurisdictions.

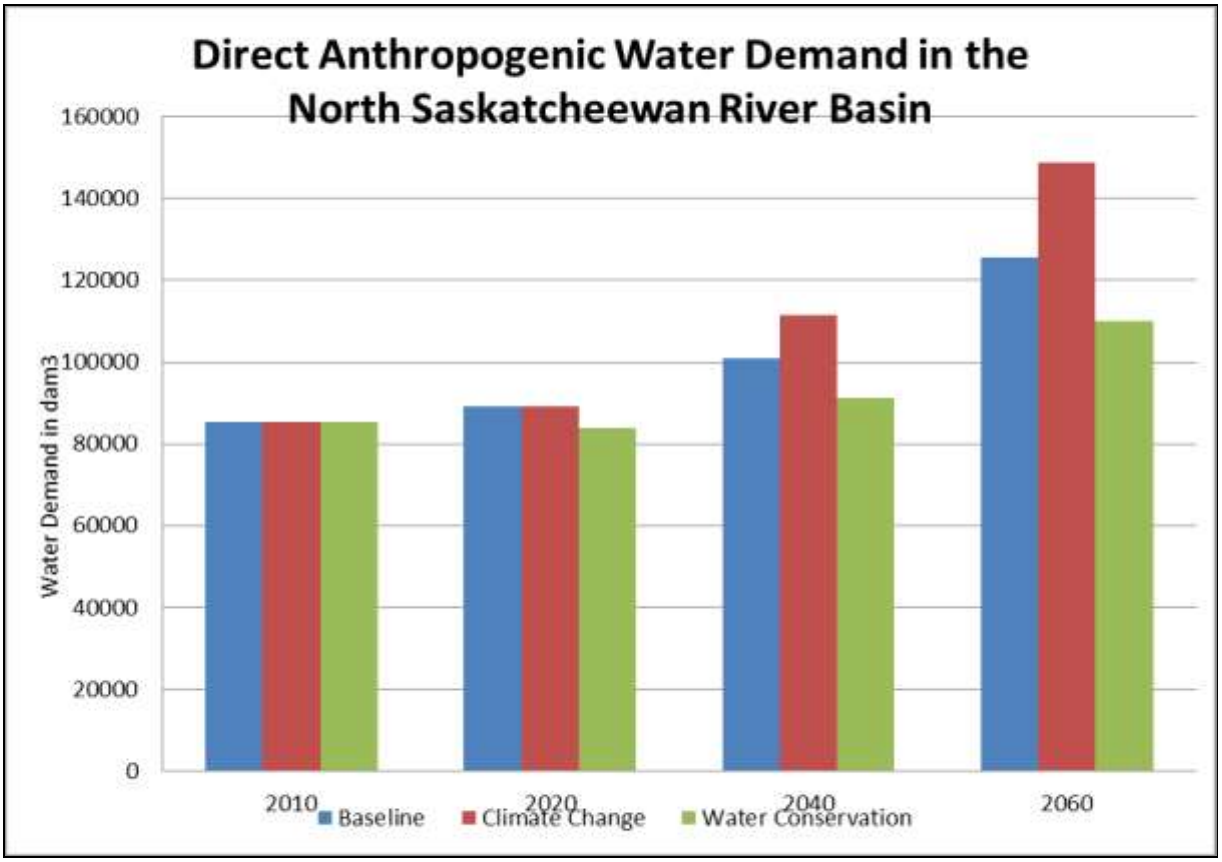

Figure ES.5: Direct Anthropogenic Water Demand under Alternate Study Scenarios in dam^3, North Saskatchewan River Basin, 2020, 2040 and 2060

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

This study exhibits a number of limitations. There are several data deficiencies related to factors that affect water demand. For instance, the impact of climate change on the basin's water demand is a relatively unstudied subject. Water conservation experience also suffers from a similar deficiency. Also, this study treated the North Saskatchewan River Basin as a single entity, but significant variability in the water demand may exist within it. Identification of these water stress pockets needs to be done in conjunction with research on water supply information under alternative scenarios.

North Saskatchewan River in Prince Albert
Photo Courtesy of Saskatchewan Watershed Authority

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List of Acronyms Used

AAFC	Agriculture and Agri-Food Canada
BSE	Bovine Spongiform Encephalopathy
CCCSN	Canadian Climate Change Scenarios Network
CIBC	Canadian Imperial Bank of Commerce
CMHC	Canadian Mortgage and Housing Corporation
CMS	Cubic meters per second
CSWS	Canadian Soft White Spring
CWRS	Canadian Western Red Spring
CWAD	Canadian Western Amber Durum
Dam^3	Cubic decameters, equivalent to 1,000 m^3
DFO	Department of Fisheries and Oceans (Federal Government)
DPSIR	Drivers, Pressures, State, Impacts, and Responses
DUC	Ducks Unlimited Canada
ES	Executive Summary
FAO	Food and Agricultural Organization of the United Nations
EEA	European Environmental Agency
GCM	Global Climate Change Models
GDP	Gross Domestic Product
HACCP	Hazard Analysis and Critical Control Points
IBT	Interbasin Transfer
IPT	Inter-Provincial Transfer
ICDC	Irrigation Crop Diversification Corporation

ICWE	International Conference on Water and the Environment
ILO	Intensive Livestock Operations
IPCC	Intergovernmental Panel on Climate Change
LDDA	Lake Diefenbaker Development Area
LLID	Luck Lake Irrigation district
MAA	Master Agreement on Apportionment
MBBL	Million barrels
MBF	Million board-feet
MCOOL	Mandatory Country of Origin Labeling
ML	Mega (Million) Liters
NEB	National Energy Board
NID	Northminster Irrigation District
NRTEE	National Roundtable on Environment and Economy
NSR	North Saskatchewan River
NSRB	North Saskatchewan River Basin
OMAFRA	Ontario Ministry of Agriculture, Food and Rural Affairs
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	Saskatchewan South East Water Supply

SSRB	South Saskatchewan River Basin
SSRID	South Saskatchewan River Irrigation District
SWA	Saskatchewan Watershed Authority
TWD	Total Water Demand
WDC	Water Demand per Capita

Chapter 1

Introduction

1.1 Background

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

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

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

1.2 Water Management Issues

Water is a limited resource globally, but in semi-arid regions, such as in parts of Saskatchewan, this problem is even more acute. At the same time, society is increasingly concerned about water quality and environmental issues in general, particularly 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, reducing variability of river flows, and redirecting and utilizing groundwater flows (Cohen et al., 2004). As sources for supply enhancement dwindle, water resource management is leaning towards demand management.

In the past decades, policies have been focused on supply management, but recently, there has been a transition from water-supply management to water-demand management; the goal is to strike a balance between supply and demand, that by ensuring efficient use of water. Studies have shown that with the past and present trend in competition for water in different locations, the demand will continue to increase with the population and other water emerging alternative. 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 as well as demographic characteristics of 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 and means to reduce wasteful water expenditure. These measures are needed since, in some regions, available freshwater is inadequate for the local demand; diverting it from other regions is often replete with economic and political problems. Similarly, in some areas, facilities to treat, distribute, and discharge water may not be capable of meeting expanding demands. In fact, in a Saskatchewan Water Corporation survey of various communities in 1994, of the 597 communities responding to the survey, 172 indicated that water supply is a constraint to their future economic growth (Kulshreshtha, 1994). Miller et al. (2000) also suggest that rural water resources are stressed in many ways, affecting rural development; it is now, and will continue to be, limited by a wide variety of water issues.

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

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

1.3 Objectives and Scope of the Study

This study was designed to estimate water demand in the NSRB of Saskatchewan. Water demand estimates are developed both for the current period (Year 2010) as well as for future times (Years 2020, 2040, and 2060). The estimation is done by a disaggregated approach/method. Both consumptive and non-consumptive water demands are included. Factors affecting them 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 NSRB. Major economic activities and population centers are included in this description. Methods for estimating current water demand in the basin are provided in Chapter Three, which is followed by the methodology employed for future water demand estimation in Chapter Four. Study scenarios are described in Chapter 5. Water demand by type of consumer is presented in Chapters 6 to 9, starting with agricultural water in Chapter 6, industrial and mining water demand in Chapter 7, municipal water demand in Chapter 8, and recreational water demand in Chapter 9. All current and future water demand estimates under various study scenarios are presented in these chapters. Chapter 10 describes other water demands, mainly those that are not related to human activities. The last chapter provides a summary of results and areas for future research.

Chapter 2

Description of the North Saskatchewan River Basin

This chapter provides a description of the baseline conditions in the NSRB. This basin is especially significant for the province since it houses major urban centers, and major agricultural activity, besides numerous other economic activities such as recreation and non-economic water needs such as environmental maintenance. This documentation is based on available secondary data.

2.1 Location of the North Saskatchewan River Basin[1]

Like the South Saskatchewan River Basin, the NSRB is a river basin that extends over the provinces of Alberta and Saskatchewan. Its entire drainage area covers the region from the Rocky Mountains to the point where it joins with the South Saskatchewan River, just east of Prince Albert (Canada West Foundation, 1982, p. 176). Within Saskatchewan, the North Saskatchewan River watershed occupies 41 thousand square kilometers. It stretches from Lloydminster (a city at the boundary of Saskatchewan and Alberta) in the west to beyond Prince Albert in the east, and from Luseland in the south almost to Big River in the north. Within the basin, there are two major river systems (Battle River and North Saskatchewan River), along with many lakes and significant groundwater resources. The North Saskatchewan River itself runs from the bountiful head waters of the Columbia ice fields in the Rocky Mountains and through the industrial heartland of Alberta before delivering a robust flow into Saskatchewan (SWA, Undated). In contrast, the Battle River is fed mainly through run-off and groundwater collected as it meanders through central Alberta, bringing a more modest flow.

The North Saskatchewan River (NSR) has a more reliable source of flow since 90% of its flow originates from mountain run-off. The other tributaries (such as the Battle River, Eyehill Creek, and others) rise in the prairies and have less reliable flows. This results in more opportunities for water-using development for the NRS than those depending on ephemeral tributary flows[2].

[1] More detailed discussion of the basin can be found in SWA (2007c) and Partners For the Saskatchewan River Basin (2009).

[2] Paraphrased using a suggstion made by Mr. Bob Halliday.

The basin receives water from Alberta as a part of the PPWB master agreement both in the North Saskatchewan River and in the Battle River. In the Battle River watershed supply from Alberta can be as low as 0.6 m^3 /s (Canada West Foundation 1982, p. 182). As eastern flowing streams, the North Saskatchewan River and its tributaries such as the Battle River and Eyehill Creek are subject to the PPWB Master Agreement on Apportionment. While the North Saskatchewan River is regulated by two dams in its headwaters, water withdrawals in Alberta are modest. By contrast, consumptive water demands on tributaries of the NSR that cross the Alberta-Saskatchewan border are significant enough that water apportionment concerns can arise in very dry years.

The basin includes a diversity of ecosystems, including short grass prairie, aspen parkland and boreal forest, along with the full scope of human enterprises that our natural resources can support. The growing population of 116,500 people shares the cities of Lloydminster, North Battleford, and Prince Albert, as well as 100 towns and villages, 51 rural municipalities, and 29 First Nations (NSRBC, 2008). The basin is shown in Figure 2.1.

The basin could be broadly divided into six watersheds – (1) West watershed (just after the NSR enters the province of Saskatchewan, with the city of Lloydminster being the major commercial center; (2) Battle River watershed, which is located in the south side of the basin, with the cities of Battleford and North Battleford being the centers of major economic activity; (3) Central watershed, with numerous tributaries of the NSR; (4) East watershed, where the city of Prince Albert is located. East of this region is the point where the NSR joins the South Saskatchewan River, forming the Saskatchewan River; (5) Eagle Creek watershed; and (6) Goose Lake drainage basin.

According to the NSRBC (2008), the NSRB has a drainage area of 41,000 km^2. Land use details are difficult to find since the basin extends over two provincial boundaries and most data are available on a watershed basis. Using three watersheds in the larger basin and Natural Resources Canada data (as provided by Statistics Canada, 2005), land use in the basin was estimated. More details on this methodology are presented in Appendix A. Results for the combined Alberta and Saskatchewan basins are shown in Table 2.1.

Under the strict assumption that the Alberta and Saskatchewan portion of the basin are similar in terms of land use, one may conclude that the Saskatchewan NSRB is primarily agricultural. Of the total area of the basin, 89% is used for agriculture, about 4% is under grassland, and about 6% is forested or covered by shrublands.

(Map courtesy of Water Security Agency, Moose Jaw)

Figure 2.1: Map of the North Saskatchewan River Basin

Table 2.1: Land Use in Selected Watersheds of the North Saskatchewan River Basin*

Land Cover Category	Area in km^2	% of Total
Forested area	5,309	4.3%
Shrubland	1,842	1.5%
Grassland	4,328	3.5%
Cropland (incl. woodland)	108,782	89.0%
Other	1,908	1.6%
Total Area	122,169	100.0%

* Includes both Alberta and Saskatchewan portions of the basin.

2.2 Population

With regard to population concentration, the NSRB is not one of the most populated basins in the province. In 2009, it was estimated that some 197 thousand people resided within the basin

(Table 2.2). Saskatchewan's population in 2011 was reported to be a little over a million (1,033,381 people to be exact[3]). Thus, the basin houses 19% of the provincial population.

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

Type of Community	Population in 2010	Population in 1995	% Increase in 2010 over 1995
North Battleford	17,917	13,487	32.8%
Prince Albert	46,556	33,507	38.9%
Lloydminster*	28,765	18,953	51.8%
T>1000	27,341	23,413	16.8%
T<1000	11,686	8,839	32.2%
Villages	9,863	13,821	-28.6%
Recreational Villages	329	74	186.5%
First Nations Reservations**	12,774	628	1934.1%
Sub-total Non-rural	155,231	112,722	37.7%
Rural Municipalities	22,983	Note 1	-
Farm Population	19,170	Note 1	-
Total Population* **	**197,384**		**--**

Note 1: These populations could not be estimated
***** Based on 2011 Census values
** Accuracy of this value is a suspect. It differs from the estimated population by Reseves.
***Total estimate is not accurate since it is based on different time periods.
Source: SWA (2010) and SWA (2011).

The total population of the basin was divided into different types of communities/regions. Initially the population was divided into urban and rural Population. Urban population estimates included cities, towns, villages, bedroom communities, First Nations' Reservations, and recreational communities. Standard definitions for these areas were 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 populations increasing and were within a distance of 40 - 60 km (approximately 30-45 minutes of driving time) to a larger urban center (in this case, the cities of Lloydminster, North

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

Battleford, and Prince Albert). However, such communities were not found to exist within this basin.

The rural population was divided into two categories: farm population and rural people non-farm residing in rural municipalities. The farm population was related to farm residences. The remaining population of a rural municipality was the component classified as non-farm rural population. This categorization was applied since the water demand patterns in larger communities could be different from those that are relatively smaller. In addition, over time the growth in these communities may also be different. A list of the various communities included in each category is shown in Table 2.2 presented in Appendix B.

The basin has shown a sharp increase in population. Non-rural population, as shown in Table 2.2, has increased by 37.8% over the 1995-2010 period. Much of this increase has occurred through the migration of people from other smaller centers within the province or from outside the province into the three cities – North Battleford, Lloydminster and Prince Albert.

Compared to other river basins (for example, the South Saskatchewan River Basin), the NSRB contains a large First Nations' population. In 2010, over 12 thousand people of this ancestry resided there, and the rate of growth in this population group is also the largest of all groups within the basin. In spite of the high growth rate, First Nations' people constitute only 6% of the total basin population (Figure 2.2).

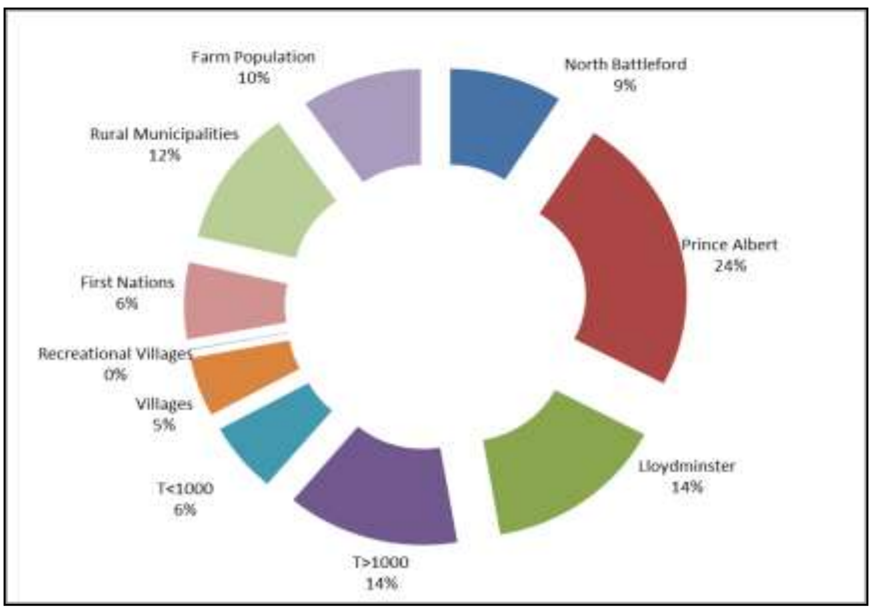

Figure 2.2: Distribution of North Saskatchewan River Basin Population by Type of Communities, 2009

The basin is predominantly urban, as the three cities house 47% of the population. Rural population (including farm, non-farm rural, villages, and recreational villages) constitutes only 27% of the total population. Many of the towns act as service centers for the rural population, either for those residing on farms or in other rural communities.

2.3 Major Economic Activities

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

2.3.1 Agriculture

The NSRB is an agricultural region, as shown in Table 2.1. Within this basin, 7,551 farms occupy some 11.5 million acres of land (Table 2.3). An average farm in this basin is 1,519 acres. Over the last five years (2006 – 2010), farm size have increased by about 6.6%, partly because of the fact that their number decreased by 17%.

The total farm area is employed for crop and livestock enterprises, as well as for other specialty enterprises (greenhouses, and orchards). As shown in Figure 2.3, a little under two-thirds of this area is devoted to crops (called cropland), which includes some area for livestock forage. However, there is also 10% of the total area devoted to seeded pastures, and an additional 22% is comprised by native pastures. All these land uses support livestock enterprises. The basin has all types of livestock and poultry enterprises.

2.3.2 Mining Activities

2.3.2.1 Potash Mining

The NSRB touches on the western edge of the potash ore region, and thus does not have many potash mines. In fact, there is only one potash mine, which is owned by Agrium and located at Vanscoy. The current production capacity of this mine is 2.1 million tonnes of potash (Table 2.4), obtained by the underground (conventional) process using water received from the South Saskatchewan River Basin.

2.3.2.2 Oil and Gas Well Drilling

Oil and Gas well drilling extends mainly into the North Lloyd, Birdbear, and Viking formations that are within the NSRB. The conventional technology of vertical wells and water flood, along with the new technology of horizontal well drilling and multi-stage frac, are used to extract oil and natural gas from these formations.

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

Particulars	Value in	
	2006	2010**
Number of Farms	9,098	7,551
Total Area of Farms (Acres)	12,892,220	11,467,534
Average Size of the Farm (Acres)	1,425	1,519
Crop Production Activities		
Land in Crops (Acres)	7,030,479	7,349,248
Tame Hay or Seeded Pasture (Acres)	1,003,480	1,081,567
Natural Land for Pasture (Acres)	2,757,775	2,533,635
Other Land (Acres)	1,064,816	503,085
Irrigated Area (Acres)	37,305	19,367
% Zero Tillage	60.2%	74.8%
Livestock Production Activities		
Cattle and Calves	755,841	633,915
Dairy (cows and Heifers)	9,240	11,099
Hogs	260,770	274,454
Sheep	19,978	11,218
Other Livestock	32,978	45,411
Broilers	683,906	4,895,414
Eggs (# of Layers)	257,468	268,800
Turkey	N.A.	143,659

N.A. – Not available

* 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)

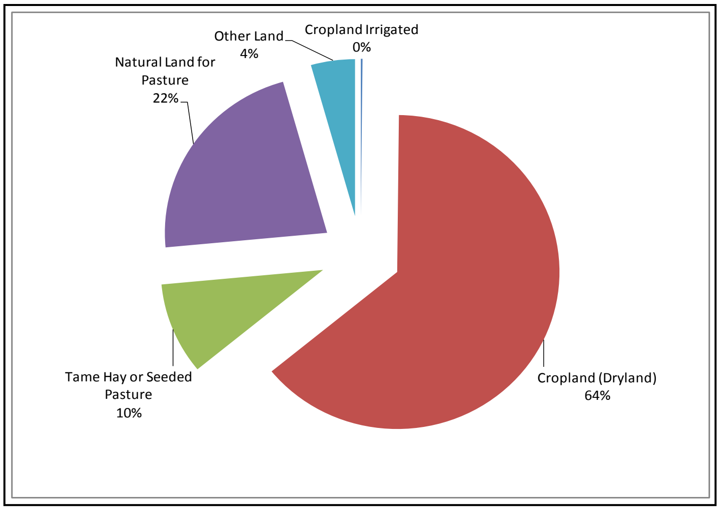

Figure 2.3: Farm Level Land Use in the North Saskatchewan River Basin, 2006

Table 2.4: Potash Mines in the North Saskatchewan River Basin

Particulars	Details
Corporation	Agrium
Location	Vanscoy
Mining Technology	Underground
Source of Water[1]	Surface
5-year Average Production in Thousand Tonnes	2,100

[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).

The advent of horizontal well technology and its successful application under Saskatchewan conditions has substantially increased the oil and gas activity in the Viking and Birdbear formations. Saskatchewan has an estimated reserve, recoverable through present and expected technology developments, of 6.3 billion barrels of crude oil (NEB, 2008). The Viking formation (conventional) has 214 million barrels of recoverable reserve, while the Birdbear formation (heavy oil) has 0.447 million barrels of oil, and the North Lloyd (heavy oil) has 3,750.0 million barrels of oil (NEB, 2008). Approximately 35% of the Viking, 25% of the North Lloyd, and 95% of the Birdbear formations are in the NSRB, giving an estimated oil reserve of 1,012.8 million barrels in the NSRB. The amount of ultimate potential extractable natural gas reserves in the NSRB is estimated at 50,755 $x10^6$ m^3, which is 33.6% of Saskatchewan's 150.6 $x10^9$ m^3 of marketable natural gas (NEB, 2008).

2.3.2.3 Salt Production Activities

Sifto Canada Ltd. operates a salt producing mine at Unity, which is located in the NSRB. The plant uses a mechanical evaporation process by injecting water into an underground salt deposit to create saturated brine. The brine is drawn out and evaporated in a series of large crystallizers. As the water evaporates, salt crystals grow. As shown in Table 2.5, the mine producers significant amounts of salt.

Table 2.5: Salt Mining Activity in the North Saskatchewan River Basin

Particulars	Details
Corporation	Sifto Canada Ltd.
Location	Unity
Mining Technology	Underground
Source of Water	Surface and Groundwater
5-year Average Production in Tonnes	154,360

2.3.4 Forestry Water Demand

As shown in Table 2.1, only 0.5% of the total area of the basin is taken up by forests. For the most part, this forested land is scrubland. Since these areas are not irrigated nor supporting of any related activity that requires water, it is assumed in this study that forest lands do not generate any water demand at present. Furthermore, they are expected not to have any water demand in the future. However, there were a number of forestry product industrial concerns in the basin. These are included in the industrial water demand section in the estimations of water demand for the three scenarios.

2.3.5 Industrial -- Manufacturing

Manufacturing activities that derive their water outside of the municipal water systems in the NSRB are presented in Table 2.6. The activities include a small refinery, the Biprovincial Heavy Oil Upgrader, enhanced oil recovery, three agricultural processing plants, and four forest products-related activities that do not receive water from a given municipal water system. In addition, there are other industries supplied through municipal systems of Lloydminster and other towns.

Table 2.6: Water Using Manufacturing Activity in the North Sask River Basin

Type of Manufacturing	Product Produced	Location
Ag Processing		
North West Terminal Ltd - Ethanol	Ethanol	Unity
Husky Oil Ethanol	Ethanol	Lloydminster
Prairie Malt	Malt	Biggar
Refineries		
Canadian Crude Separators Inc.	Oil	Unity
Husky Energy (Enhanced Oil Recovery)	Oil	Mervin
Husky Oil Upgrader	Oil	Lloydminster
Liquid Natural Gas Storage		
BP Canada Energy Co.	Natural Gas	Kerrobert
Trans Gas	Natural Gas	Landis
Construction		
Kohlruss Bros. Enterprises (gravel)	Gravel	Lloydminster
Other		
Nisbet Fire Control Centre*	Fire Control	Prince Albert
Wapawekka Lumber Ltd (CLOSED)	Lumber	Prince Albert
Carrier Forest Products	Lumber	Prince Albert
Prince Albert Forest Nursery	Nursery	Prince Albert

* Included under institutions

2.3.6 Industrial -- Electricity Power Generation

There are two types of power generation facilities within the NSRB – natural gas, and waste heat. Thermal power generation plants that use natural gas include Ermine Power Station at Kerrobert, Landis Power Station at Landis, Yellowhead Power Station at North Battleford, North Battleford Energy Centre at North Battleford, and the co-generation plant at Lloydminster. One generating facility uses heat recovery. However, details on only some of these facilities are available and are listed in Table 2.7. In the estimation of water demand, only the water consuming power generation facilities are included.

Table 2.7: Electricity Generation Sites in the North Saskatchewan River Basin

Name	Location	Fuel	Capacity (MW)
Non-Water Consuming Power Generation Facilities			
NRGreen Heat Recovery Project	Kerrobert	Waste Heat	5
Water Consuming Power Generation Facilities			
Ermine Power Station	Kerrobert	Natural Gas	92
Landis Power Station	Landis	Natural Gas	79
Yellowhead Power Station	North Battleford	Natural Gas	138
Meridian Cogeneration Station	Lloydminister	Natural Gas	210
North Battleford Energy Centre	North Battleford	Natural Gas	261

Source: SaskPower (2011).

2.3.7 Communities and Public Institutions

Municipal water systems supply the three major urban centers in the basin – Lloydminster, North Battleford, and Prince Albert. All these have domestic (residential), manufacturing, commercial, and public water demands. The public water demand is for street cleaning, firefighting, and other such purposes. Most towns and smaller communities provide water to the residents and for other economic activities. These communities were classified into five different types – Cities, Towns (further divided into large – with a population of over 1,000 people, and small – with a population of less than 1,000 people), Villages, Resorts or Recreational Villages, and First Nations' Reservations, as listed in Table 2.2.

2.3.8 Recreation and Tourism

The basin has large water resources for water-based recreational activities; many of them are visited by local people and those who travel from outside the basin. A list of these sites is shown in Table 2.8.

Table 2.8: List of Available Recreational Sites in the North Saskatchewan River Basin

National and Provincial Parks	Provincial Recreational Sites	Regional Park (R.P.) Sites	
Emma Lake	Anderson Point Campground	Atton's Lake R.P.	Martin's Lake R.P.
The Battlefords	Battlefords Provincial Park	Battlefords River Valley	Meaota R.P.
Candle Lake Park	Murray Point Campground	Bright Sand Lake	Meeting Lake R.P.
Prince Albert National Park	North Bay Mobile Home Park	Canwood R.P.	Memorial Lake R.P.
	Sunset View	Clearwater Lake	Morin Lake R.P.
	West Chatfield Beach	Eagle Creek R.P.	Silver Lake R. P.
	Aquadeo Resort Village	Emerald Lake R.P.	Sturgeon Lake Regional Park
	Cochin Resort Village	Glenburn R.P.	Suffern Lake Regional Park
	Kenderdine Campus (EmmaLake)	Kindersley R.P.	Wilkie R.P.
	Lanz Point	Little Loon R.P.	
	Martinson's Beach	Little Red River Natures Park	
	Metinota Resort Village	Macklin Lake R.P.	

2.3.9 Indirect Anthropogenic Water Demands

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

2.3.9.1 Environmental and Stream-Flow Needs

One of the major water demands is that designated for environmental purposes. There are two major environmental purposes for water in the basin. The first one is for maintenance of wetlands, and the second one is for maintaining levels of recreational lakes. The Brazeau and Bighorn dams on the North Saskatchewan River in Alberta have a combined capacity of 25% of the annual flow (SWA 2007b), thus reducing average spring and summer flows and increasing average winter flows.

2.3.9.2 Apportionment[4]

The Prairie Provinces Water Board was established in 1948 to ensure water resources in the three Prairie Provinces are shared fairly. To this effect the Provinces of Alberta, Saskatchewan, and Manitoba and the Government of Canada created the Prairie Province Water Board. In 1969, the four governments changed how the Prairie Provinces Water Board operated by signing the Master Agreement on Apportionment (MAA). This Agreement established an intergovernmental framework to manage transboundary waters of eastward flowing streams.

Under the master agreement, Alberta is entitled to deplete the annual flows of the North Saskatchewan River and transboundary tributaries such as Battle River and Eyehill Creek by fifty percent. Saskatchewan in turn must pass on to Manitoba one half of all the waters it receives from Alberta plus one half of the natural flows arising in Saskatchewan within the Saskatchewan River Basin. The PPWB performs calculations of the naturalized flows, known as apportionment flows, to support the administration of the agreement. However, since the river does not cross a provincial boundary, no apportionment requirements are needed for this river. All apportionemnt needs area counted for in the context of the Saskatchewan River Basin.

2.3.9.3 Evaporation and Percolation Water Loses

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

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

Chapter 3

Study Methodological Considerations

The study methods for estimating current water demand are described in this chapter, and the methodology for forecasting future demands is discussed in chapter 4. This chapter begins with nomenclature applied in the area of water demand. Concepts found in these reports are described. 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 a methodology that could be developed for the study. The specific methods followed in this study for the estimation of 2010 water demand in the NSRB are described next.

3.1 Nomenclature of Water Demand

Water demand in a river basin can be described through the use of various terms/concepts. In the literature, a variety of terms have been used, often synonymously, with water demand. However, it should be noted that water demand is an economic concept and unless water users pay a price for the water and adjust their water consumption in reaction to price, water demand is a very distinct concept compared to others. Furthermore, the 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 estimated water demand. However, given a certain charge of prices paid by the water users, the current water use can be assumed to be a point on this water demand function. However, in this study, a number of related concepts are used.[5] Each of these concepts is relevant in the estimation of water demand in the NSRB. Details on these concepts are shown in Table 3.1. Water losses are generally from natural factors, and include evaporation and percolation/leaching, while requirements are determined by the need of water for sustaining a given economic, human, or social activity. Water intake is the amount that is withdrawn to sustain a given economic activity. Part of this water may be returned to the original source of water intake, but some of it may be lost in the production process (typically called consumption). The total amount of water demand for a given economic activity is a sum of water intake and amount of water recirculated, less the amount returned to the original source.

[5] 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, water as a catalyst (not consumed or lost) or consumed in the process, among others.

According to its source of water, water can be obtained from surface water or groundwater sources. Of course, the natural precipitation (less evaporation) is also a source of water, but is not typically included as 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 category, all water is either returned to the source or remains unaffected. Different types of users in these categories are shown in Table 3.2.

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

Table 3.2: Types of Water Demand in North Saskatchewan River Basin

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

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

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

In addition to water demands for socio-economic activities within the basin, four 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 as noted earlier, is directed by regulations and agreements. Non-consumptive indirect anthropogenic water demands consist of instream water needs and water diverted to environmental projects.

3.3 Overview of Methods for the Study

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

The direct anthropogenic water demand represents a sum of four types: (1) agricultural and related production; (2) industrial and mining, including power generation; (3) municipal and domestic; and (4) recreational purposes. Agricultural water demand includes a variety of purposes, mainly for irrigation, water used by dryland farmers for crop production, livestock water demand, and other related amounts for agricultural production. Water demand for industrial and mining is the next type of direct anthropogenic water demand. Domestic needed demand is divided into municipal and non-municipal water systems. The former includes urban jurisdictions with a municipal water distribution system. It therefore takes in a combination of water demands – residential, manufacturing, commercial, and other service industries, public water demands, and other water demands. Available data did not permit a breakdown of this total water demand,[6] for this reason, such a breakdown was not attempted here. Large industrial users that do not receive water through a municipal system are included under manufacturing water demand.

The total indirect anthropogenic water represents a sum of four types of water demands: loss of water due to evaporation and percolation; water released 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 extremely helpful. This review was limited to studies involving estimation and forecasting of the demand for water dating back to the 1960s. Because of the enormity of such studies, the scope of this review was limited to those for North American (Canadian and U.S.), Australian, and European researches. In this section, these studies are summarized. Lesson learned from them are noted at the end of this section.

3.4.1 Residential Demand for Water

Residential (also called municipal or domestic) water demand estimation has been carried out by applying one of three approaches. The first type of study involves estimation of a water demand function, where in the impact of water price on water use levels is tested. The second type uses actual measurements of water being utilized. The third type of study is more synthetic in nature – they 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 is undertaken mainly for the residential water demand. In a study by Howe and Linaweaver (1967), the authors looked at the impact of price on residential water demand and its relation to system design and price structure in Melbourne, Australia by using cross sectional

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

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 for 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 the main issues in the literature on residential water demand studies. This study reviewed the main contributions to the literature on the estimation of 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 found 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 in locations where water demand can be measured. This amount is recorded and utilized for different water demands. In the third type of study, data on measured water demand can also be employed to estimate a water demand coefficient. Failing that, water demand coefficients can 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 the residential aspect. However, household residential water demand is fundamental to municipal water demand in urban regions (Kindler and Russel, 1984) where municipal water systems are in place. Municipal water demand has been estimated in several studies taking one of the following four approaches (Cheng and Ni-Bin, 2011): Multivariate regression approach using cross-section data, Time series analyses, Computational intelligence models, and Monte Carlo simulation approach.

One, <u>Multivariate regression analyses,</u> involve statistical estimation of the relationship between water demand and some water demand shifter variables. Per unit water demand in these studies was related to factors that affect water demand (such as average income, number of persons per household, price of water, etc.). Data requirements for such studies are rather large, and need to be collected through surveys.[7]

Two, <u>Time series analyses,</u> involve changes in water demand overtime. These studies utilized univariate time series data to determine daily water demand and then divided water demand

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

according to base and seasonal demands. Base demand was 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).[8]

Three, Computational intelligence models, are purely data driven. Under this approach, different types of models have been applied to forecast the municipal demand for water. These methods include: Agent-Based model, Fuzzy-logic model and Artificial Neutral Networks model. These studies utilized autoregressive integrated moving average (ARIMA) and the generalized autoregressive conditional heteroskedasticity (GARCH) models to estimate water demand. These methods generally require a long time series data. Examples of such calculations 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) used historic time series data on water consumption and applied Monte Carlo and bootstrap methods to explain the effect of climate change, population, and economic growth on future water demand.

3.4.3 Agricultural Water Demand

Water demand in agriculture can be classified into four main categories: irrigation, water demand for livestock, agro-forestry, and aquaculture. In addition, in the context of Saskatchewan, water is required by greenhouses. No studies were found that have estimated water demand for agro-forestry and aquaculture. However, several studies have been carried out that estimated the water demand for irrigation. Heady and Agrawal (1972) utilized a linear programming technique to model agricultural production and its water demand by individual farms, agricultural regions and the entire economy. Anderson (1981) carried out an economic analysis of supplementary irrigation in Skane to forecast the 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, was chosen. Some studies (e.g. EEA, 2001) utilized the FAO crop coefficient

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

method, which is based on reference evapotranspiration and a crop coefficient (Kc) that accounts for crop characteristics, development, and vegetative periods, among other elements. A somewhat similar methodology was followed in Canada to estimate irrigation water demand by Beaulieu et al. (2001).

Water demand for livestock has also been estimated by the water requirement approach. The total water demand for livestock is a sum of the number of animals times their water requirements. The water requirements include all purposes for which water is needed, including that necessary for cleaning. Water requirements have been developed by type of animals.

3.4.4 Water Demand for Tourism

The tourism industry requires water for facilities such as landscaping, water parks, swimming pools, and golf courses (Stefano, 2004). Taylor et al. (2009) modeled water demand for tourism in Australia and estimated the costs of water provision and operation. In modeling this type of water demand, the authors utilized secondary data to perform the sequential estimations needed to forecast the future level of water demand for tourism. Various steps included estimation of base water demand in the future, and consideration of the 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 converted by a hydraulic turbine through the energy of water is computed by technical relationships.

3.4.6 Review of Canadian Water Demand Studies

One of the first studies reporting water demand in various river basins of the Prairie Provinces was conducted by the PPWB (1982). Estimated water use was reported for the entire Saskatchewan-Nelson River Basin, as well as by individual basins[9]. A comprehensive study of water demand patterns by river basins was completed by Kulshreshtha et al. (1988). For the NSRB, water intake/demand was estimated at 68,233 dam^3. A large part of this demand was for irrigation and for residential purposes. These demands were about 50% and 17% of the total basin water demand, respectively. Water demand was also forecasted for the year 1995, in which

[9] In this study although individual water sues were presented by river basins, total water use was at the provincial and entire Saskatchewan – Nelson River Basin.

the basin's water use was estimated to increase somewhere from 27.5% to 30.6% under alternative scenarios (Brockman and Kulshreshtha, 1988). Due to a lack of time series data, the estimation was made using either the requirement or water use coefficients based on the available 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. Research also shows that different types of methodologies are needed for different types of water demands. The choice of a particular approach depends, to a certain extent, on the scenario for the consideration, but largely on data availability. Given the number of studies that have adopted various methodologies and the inherent limitations of each approach, a multivariate regression analysis approach and method of employing water demand coefficients for forecasting are the most common. The latter approach is more common where time series data are unavailable.

3.5 Methodology for Current Water Demands

3.5.1 Correspondence between Administrative Boundaries and the River Basins

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

3.5.2 Overview of Methodology for Estimation of Current Water Demand

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

3.6 Water Demand Estimation Methodology by Type of Water Demand

3.6.1 Agricultural Water Demand

Agricultural water demand, in this study, was estimated in a disaggregated manner. 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

The total irrigation water demand represents a product of irrigated area and the average quantity of water used for irrigation. Typically, since irrigation is a supplementary use of water, precipitation and temperature (which is measured through the use of evapotranspiration) play important roles in determining the amount of water needed for a given crop. Furthermore, as evapotranspiration varies from year to year, irrigation water demand also has yearly variability. In the NSRB, most of the irrigation is organized on individual irrigator basis, called private irrigation. There is some block irrigation[10] where water is supplied through an irrigation infrastructure and its use is regulated by the Irrigation District. This district is a block of land where water use is regulated. One of these regulations is that irrigation water is allocated along with a maximum amount allowed. Private irrigators develop their own systems of water withdrawal from the local water body and arrange its delivery to the farm gate. There are no regulations that govern the amount of water expended by private irrigators.

These issues are taken into account in estimating irrigation water demand for the basin. In the following explanation, the estimation of irrigated area and average water demand are described.

> 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. The total irrigated area in 2010 for the NSRB was estimated at 23,567 acres, of which 1,709 acres were in the Northminster Irrigation District (NID), as shown in 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 in only 7% of the total, while the remaining 93% is under private irrigation.

[10] In the NSRB, thee is one irrigation district with smaller irrigated area and another one is in planning stages.

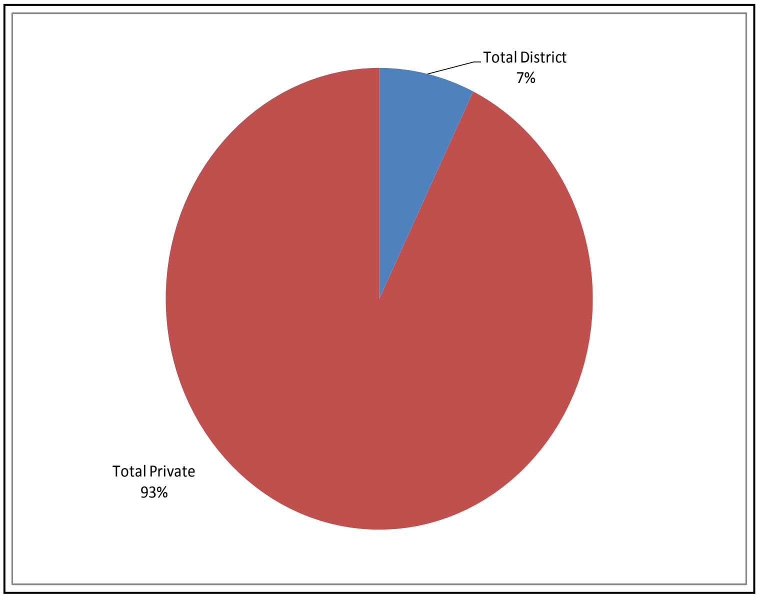

Figure 3.1: Distribution of Irrigated Area in the North Saskatchewan River Basin, 2010, by Type of Jurisdiction

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

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

Irrigation District	**Area in Acres**
Northminster Irrigation District	1,709
Total District Irrigation Area	**1,709**
Total Private Irrigation Area	21,858
Total North Saskatchewan River Basin Irrigated Area	**23,567**

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

Since there were no data available for the NSRB by method of irrigation, the information was consulted for the Lake Diefenbaker Development Area (LDDA). 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 employed 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 have a lower average water demand relative to those utilizing other methods of farm water deliveries. Details on these conveyance methods are shown in Appendix D (Table D.1).

Water for irrigation in the SSRID is delivered by canal. The results suggested that, due to 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. Those districts with pipelines include RID and LLID. In these districts, the amount is much lower than that used 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 D (Table D.2).

The average water demand for irrigation in the NSRB in 2010 was based on the amount used in the SSRID. Since the amount is determined by the method of water delivery to the crop, data on this aspect were also collected.

Holm (2008) estimated a range of efficiencies for a number of irrigation systems for the Prairie Provinces. The details of this research are shown in Table 3.4. No adjustment was made to these coefficients for the efficiency of the conveyance method. However, it is implicitly assumed to be included in the coefficients for the SSRID.

According to these estimates, water consumption can vary from 200 mm per acre to 571.8 mm per acre depending on the type of irrigation system employed. The lower amount occurs on account of the allocation of water for the 200 mm backflood irrigation method. The higher level is taken with surface irrigation methods (See Figure 3.2). The sprinkler systems typically have a higher efficiency and therefore a lower per acre water demand, especially if low pressure drop tube technology is used (where water use efficiency increase to 80%).

To estimate the water demand for the irrigated area of the NSRB, two other types of information were needed. One, the distribution of total irrigated area by method of water delivery to the crops; and, two, types of crops grown for each method of water delivery. The details on distribution of total irrigated area in the basin by method of water delivery are shown in Table 3.5. Almost a third of the total area (34.8%) is irrigated by pivots, followed by backflood system (7.3%), and by miscellaneous backflood (31.2%). 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 North Saskatchewan River Basin Irrigation

Water Delivery Method	System Efficiency	2010 Coefficients (mm per acre)
Wheelmove	65%	395.8
Pivot	75%	353.7
Low Pressure Drop Tube Pivot*	80%	332.7
Linear	65%	395.8
Miscellaneous Sprinklers	65%	395.8
Surface	45%	571.8
200mm Backflood		200.0
Misc. Backflood	45%	554.8
Remainder	45%	554.8

* Obtained from Alberta Irrigation Projects Association (Undated).

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

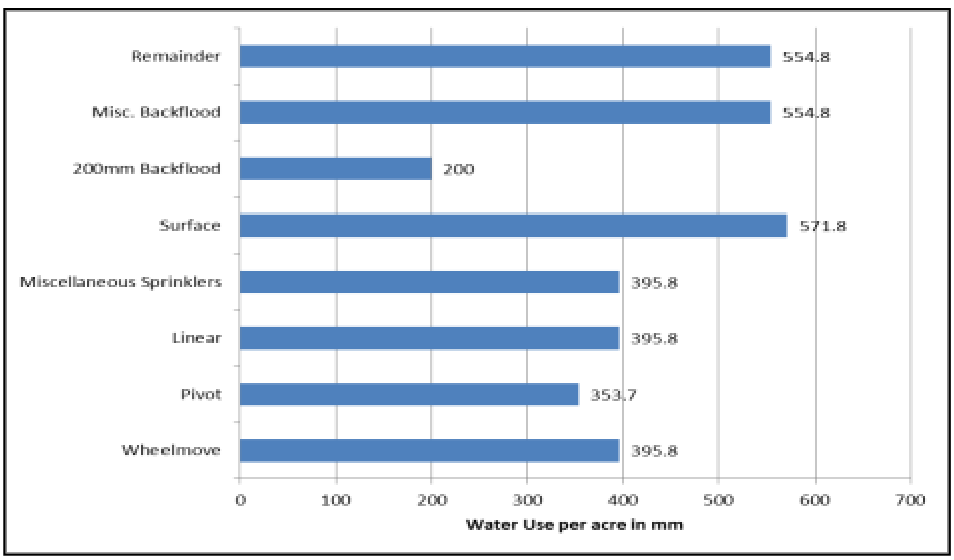

Figure 3.2: Water Demand Coefficients for Different Type of Irrigation Methods

Table 3.5: Irrigated Area in the North Saskatchewan River Basin, by Type of Irrigation System, 2010

Irrigation System	Total Area	Percent of Total
Wheelmove	3,606	15.3%
Pivots	8,212	34.8%
Linear	104	0.4%
Misc. Sprinklers	1,595	6.8%
Surface	427	1.8%
200 mm Backflood	1,719	7.3%
Misc. Backflood	7,344	31.2%
Remainder	560	2.4%
Total	**23,567**	**100.0%**

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

The second body of information needed for estimating the water demand coefficient for irrigation is that pertaining to crop types grown on the 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 for the private irrigators is not available. Irrigation district producers in the LDDA have been surveyed, and their crop mix is reported in Table 3.6. The NSRB's crop mix was estimated in consultation with Mr. John Linsley of the Saskatchewan Ministry of Agriculture (2011c). This mix of crops for all seeded area shows more area for the cereal crops and less for the forages. Unfortunately, data on vegetable, potato, fruit, and berry production is either not available at the crop district level, or-if available-unusable because of data suppression 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 water delivery system to crops was based on the crop mix shown in Table 3.6. With the lack of actual crop mix data, most systems were assumed to be similar. The exceptions to this estimation were backflood, miscellaneous backflood, and remainder, which covered a higher proportion of the cereals area. Additional details are shown in Table 3.7. The 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.

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

Crop Type	Lake Diefenbaker Development Area	North Saskatchewan River Basin
Oilseeds	34%	24%
Cereals	30%	51%
Pulse	12%	17%
Forage	14%	6%
Vegetables	9%	1%
Miscellaneous	1%	1%
Total	**100%**	**100%**

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

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

Irrigation System	Crop Mix					
	Oilseeds	Cereals	Pulse	Forage	Veg	Misc.
Wheelmove	24%	51%	17%	6%	1%	1%
Pivots	34%	30%	12%	14%	9%	1%
Misc. Sprinklers	24%	51%	17%	6%	1%	1%
Surface	24%	51%	17%	6%	1%	1%
200mm Backflood	24%	51%	17%	6%	1%	1%
Misc. Back Flood	24%	51%	17%	6%	1%	1%
Remainder	24%	51%	17%	6%	1%	1%

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

Source of Water for Irrigation: In the NSRB, irrigation water is supplied from both surface water and groundwater sources. Using SWA data on irrigation water allocation in the basin for 2010, the groundwater share of the total was estimated. In 2010 there were 15 projects using groundwater in the NSRB. The total irrigation water demand (as reported in Chapter 6) was estimated at 39,344 dam^3. Thus, 0.95% of total water demand is supplied from groundwater sources. Lacking further information, this study assumes the same proportion of groundwater for future demand.

3.6.1.2 Water Demand for Dryland Crop Production

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

Table 3.8: Irrigation Water Demand by Crops for the North Saskatchewan 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).

<u>Herbicide Application Rates and Average Water Demand</u>: The 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 is not possible for the zero tillage, which makes the number of herbicide applications higher. Herbicides are also used for summerfallow[11] when Chem Fallow[12] or Chem/Till fallow are used. The herbicide applications for these techniques range from 1 to 4 passes depending on weed growth.

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

Source of Water: Water for pesticide application can come from surface or groundwater sources. This information is, however, not available. Using data from R. Halliday and Associates (2009) for livestock water demand, this study assumes 51.3% of the water to be from groundwater sources.[13]

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 to estimate their 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 expended for this activity in the NSRB. The amount of water for such applications 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 to 2010.

3.6.1.3 Livestock Production

Stockwater demand was estimated through the water requirements approach. Since water requirements for different types of livestock are dissimilar, a disaggregated approach was undertaken. This step required information on the livestock inventory by type, which was obtained from Statistics Canada (2006 and 2011a) and from agriculture statistics of the Saskatchewan Ministry of Agriculture (2011b). These data included beef cattle, dairy, hogs, and

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

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

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

sheep for 2010 and were available at the Crop District (Census Agriculture Region) level. Other livestock populations 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 by the Correspondence Table shown in Appendix C.

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 to the river basin where the production took place. Again, the proportional area determined the river basin values if the crop district included more than one river basin.

The location of cattle feedlots in Saskatchewan, along with the stated capacity range of the feedlot, was obtained from Saskatchewan Ministry of Agriculture (2008). These data served to estimate feedlot capacity within a river basin. To estimate the number of cattle fed in the feedlots in a year, those lots with a stated capacity of 10,000 head or greater were multiplied by a factor of 1.44 (indicative of number of times these feedlots are filled) while those feedlots with less than 10,000 head capacity were assumed to be filled once. The mid-range of the production capacity was adapted for feedlots were less than 10,000 animals. In the NSRB, approximately 80.1% of the feedlot capacity was found in feedlots over 10,000 head. The estimated total number of cattle and calves on farms and on feedlots are shown in Table 3.9.

The barn capacity of the hog sector in the NSRB 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 basin. However, Mandatory Country of origin labeling (MCOOL) in the United States has affected the weanling market in Canada, resulting in less pig production and in fewer weanlings being exported to the USA (AAFC, 2011). Estimated hog numbers in the basin are also shown in Table 3.9.

The sheep industry in Saskatchewan has likewise 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 and by the MCOOL regulations in the USA. As a result, the sheep breeding herd has declined. In 2010, as shown in Table 3.9, there were 5,789 sheep (rams and ewes) on farms in the basin.

The data for the poultry sector were obtained from Statistics Canada (2006), and Saskatchewan Ministry of Agriculture (2012). Farms in the basin are estimated to have around 5 million broilers, besides laying hens and pullets. Turkeys on farms in the basin are relatively fewer, with only about 144 thousand birds.

Table 3.9: Estimated Livestock Population in the North Saskatchewan River Basin, by Type of Animals, 2010

Livestock Type	Number in 2010	Livestock Type	Number in 2010
Total Cattle and Calves		**Other Livestock**	
Bulls	13,477	Bison	16,385
Milk Cows	7,557	Horses	22,778
Beef Cows	277,250	Goats	1,983
Milk Heifers	3,541	Llamas	1,274
Beef replacement Heifers	47,293	Bees	19,452
Feedlot	45,097	Deer	2,991
Calves	250,798	**Poultry and Egg Sector**	
Hog Sector		Laying Hens	268,800
Sows	12,032	Pullets	110,290
Suckling Pigs	262,065	Broilers	4,895,414
Weaned Pigs	145,650	Other Poultry	16,448
Growing Finishing Pigs	145,650	Turkeys (M)	86,196
Boars	356	Turkeys (F)	57,464
Sheep Sector		**Sheep Sector**	
Rams	273	Breeding	1,297
Ewes	5,516	Slaughter	4,132

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

In addition to the above types of livestock, farms in the basin contain other animal types, including bison, horses, goats, Llamas, and Alpacas. The estimated number of these livestock types in Saskatchewan was collected from Statistics Canada (2006), made available on a crop district basis. The 2006 values were taken as a proxy for 2010 levels of these inventories within the crop districts and allocated to the river basin. Provincial associations were contacted to see whether they had data available on the herd sizes of their respective animal types. Data were provided only by the bison association. In 2010, the number of bison in the basin was estimated at 16 thousand animals. Horse numbers were estimated at 22 thousand and other animals were relatively fewer.

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

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**
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).

The base coefficients for the estimation of stockwatering for the NSRB are shown in the last column of Table 3.10. These figures fall within the ranges shown in the previous columns; however, the water coefficients for dairy cows and swine include the water necessary for cleanup, unlike the referenced coefficients. It would have been desirable to know what portion of this water use for animal consumption, and what proportion is for water wasted by animal or for other livestock pr0oduction related purposes.

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 months of operation of greenhouses have 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 their main products, along with vegetables, in approximately 12,000 of 187,626 m^2 of greenhouse area in Saskatchewan.

Saskatchewan crop district level data from Statistics Canada (2006) were employed to estimate greenhouse area in the basin. Again, for lack of a better proxy, the relative area of the crop district within the NSRB served to allocate provincial greenhouse area to the basin. The same procedure was followed for the area of nurseries in the basin for bedding plants and potted plants. The estimated area of greenhouses in the NSRB in 2010 was 38,567 m^2 or 9.53 acres.

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

3.6.1.5 Water Demand for Aquaculture

The amount of water demand could not be estimated due to lack of data on these operations.[14] As a substitute, the value was taken from R. Halliday and Associates' (2009) report. Surface and groundwater demand for aquaculture was estimated at 4 dam^3 and 12 dam^3, respectively. It is assumed that this quantity of water will remain static for aquaculture to 2060.

[14] As noted earlier, this is a gap in the information related to water use. Efforts are needed to make an inventory of such users and their water uses.

There is a provincial hatchery at Fort North, Saskatchewan, that takes 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). For this reason, this water is not included in the total water calculation in this study.

3.6.2 Forestry Water Demand

Lumber, pulp, and paper mills have operated in Saskatchewan. However; the soft wood lumber issue and the decline in demand for certain paper products has resulted in several plant closures. Wapawekka Lumber Ltd., located at Prince Albert, is closed at this time; they have a capacity to produce 70 million board feet. In addition, the former Weyerhauser pulp and paper mill is closed. This mill had an annual capacity of producing 280,000 tonnes of paper and 130,000 tonnes of pulp. In 2005, it was the largest industrial user of water at 36,849 dam^3. Carrier Forest Products has a sawmill at Prince Albert with a capacity of 45 million board feet of lumber. However, further details are not available. For this study, it is assumed that these plants are not in operation and will not be reopened during the forecast period.

3.6.3 Industrial/Mining Water Demand

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

3.6.3.1 Potash Production

The current amount of water expended in the potash production process depends on the nature of mining technology and level of production. The only mine in the basin is located at Vanscoy, very close to the eastern boundary of the central watershed of the NSRB. The mine uses the underground mining technology/process, where potash ore is taken out and processed into useable fertilizer. The water demand coefficient was estimated by dividing the 5 year average water demand by the 5 year average potash production for the mine over the 2006-10 period. The amount of water was obtained from the SWA (2011a), whereas the production data is from the potash companies as reported in Table 3.11. At this mine site, although the allocation of water is 1,472 dam^3 per annum, on average the mine used 1,663 dam^3 of water – 1.13 dam^3 per 1,000 tonnes of potassium fertilizer produced. Water demand at the mine is from an interbasin transfer from SSRB.

Table 3.11: Estimated Water Demand Coefficients for Potash Mines in the North Saskatchewan River Basin, 2010

Corporation	Location	Mining Technology	Potash 5 Year Average (Thousand tonnes)	Water Demand 5 Year Average (dam^3)	Water Demand Coefficient (dam^3/ 1000 t)
Agrium	Vanscoy	Underground	1,472	1,663.0	1.13

Source: SWA (2011a) for water demand; Potash company's website, financial statements and annual reports for other data.

3.6.3.2 Oil and Gas Production

Most of the oil and gas activity in the NSRB is located in the Birdbear, North Lloyd and Viking formations. Three types of oil and gas well drilling technologies are used; primary exists where the oil is pumped directly from the reservoir; secondary requires the pumping of water into the reservoir to increase pressure; tertiary involves the injection of steam, gases or chemicals (Saskatchewan Ministry of Energy and Resources, 2011). In 2010, 54% of the wells drilled in Saskatchewan were horizontal (Enterprise Saskatchewan, 2011). Oil drilling activity has increased significantly over the past six years as the new technology of horizontal well drilling and frac-ing has been used. Three hundred horizontal wells have been drilled into the Viking formation of which approximately 35% is in the NSRB, equal to 105 wells (Saskatchewan Geological Survey, 2011). Vertical wells with water flood have been used, and will continue to be used in the formations.

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

Wu et al. (2009) report the average amount of water used by the various oil recovery technologies (Table 3.12). The coefficients of 11.36 dam^3 of water per horizontal frac oil well (based on Energy Policy Research Foundation, 2011) and between 2,500 m^3 to 5,000 m^3 of water (Canadian Association of Petroleum Producers, 2011) for Shale gas using a multi-stage frac completion technique are low compared to the Saskatchewan data. It appears that water demand for oil and gas extraction in Saskatchewan is considerably higher than the industry average for secondary, steam, and CO_2 injection. The average from Saskatchewan data without the CO_2 injection is 25.26 dam^3 per well. This water demand coefficient was applied for horizontal wells with frac completion, while the water demand coefficients for primary and water flood were 0.39 and 16.71 dam^3, respectively.

Table 3.12: 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).

3.6.3.3 Salt Manufacture Water Demand

Sifto Canada Ltd. was a salt producing mine at Unity, yielding approximately 154,000 tonnes of salt in 2010. This resulted in a water demand coefficient of 0.00183 dam^3 per tonne of salt produced (Table 3.13).

Table 3.13: Estimated Water Demand Coefficients for Salt Mining Activity

Particulars	Location	Production in Tonnes	Water Use in (dam^3/tonne)
Sifto Canada Ltd	Unity	154,360	0.00183

3.6.3.4 Manufacturing Water Demand

The NSRB is home to several types of manufacturing. Since this water demand is captured under municipal/domestic demand, these companies are excluded from the discussion here. Several companies in the NSRB, though, do operate outside of the municipal water systems. All these companies are either private or branch plants such that information on production or sales is limited.

The water demand for manufacturing is related to several factors -- type of manufacturing, source of water, and annual production level. Their water demand coefficients were estimated by taking into account for these factors, and are presented in Table 3.14. The data on manufacturers water demand were obtained from SWA (2011a). However, obtaining data on 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.

The level of production in Husky Energy Heavy Oil Biprovincial Upgrader, Asphalt Refinery, and Ethanol Plant (Lloydminster) the NSRB are presented in Table 3.14. The upgrader and ethanol plant are located on the Saskatchewan side, while the asphalt plant is in Alberta. Although, Husky Oil's Upgrader and Ethanol Plant are located in Saskatchewan, their water withdrawals are under an Alberta Environment Water Diversion License. Withdrawals of up to 6,752 dam^3 of water are obtained from the city of Lloydminster infrastructure (SWA 2007, personal communication with Dave Kay, Husky Energy, June 2012).

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

Type of Manufacturing	Source	Production Units per year	Water Demand dam^3	Coefficient ($dam^{3/}$unit)
Ag Processing				
North West Terminal Ltd	GW	25 ML/year	145.7	.00583
Husky Oil Ethanol	SW	260 ML/year	Sourced from Alberta	
Prairie Malt	SW	220,000 tonnes	1,042.7	0.0000047
Refineries				
Canadian Crude Separators Inc.	GW	N/A	20.9	N/A
Husky Energy (Enhanced Oil)	SW	N/A	2,010.9	N/A
	GW	N/A	2,753.2	N/A
Husky Oil BiProvincial Upgrader	SW	65.4 mbbl	Sourced from Alberta	
Liquid Natural Gas Storage				
BP Canada Energy Co	GW	Storage	16.5	N/A
Trans Gas	GW	Storage	1,201.8	N/A
Construction				
Kohlruss Bros. Enterprises	SW	N/A	7.83	N/A
Other				
Wapawekka Lumber Ltd		70 mbf	N/A	N/A
Carrier Forest Products		45 mbf	N/A	N/A
Prince Albert Forest Nursery		N/A	None	None

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.

Mbf = million board-feet; One board-foot is 144 cubic inches.
ML = Million litres
GW = Groundwater; SW = Surface water
Source: Estimates based on SWA (2011a).

3.6.3.5 Power Generation Water Demand

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

There are two types of power generation that take place in the NSRB. These are thermal electric plants (using natural gas) and heat recovery generation. Electricity generation plants in the NSRB that use natural gas are the Ermine Power Station at Kerrobert, Landis Power Station at Landis, Yellowhead Power Station at North Battleford, North Battleford Energy Centre at North Battleford and the co-generation plant at Lloydminster. One generating facility uses heat recovery. SaskPower has identified hydropower development on the Saskatchewan River and its north and south branches, the Churchill River, and the Fond du Lac River (SaskPower, 2011).

The NRGreen heat recovery system employs a new technology that requires no water for the production of electricity.

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

Facility	Source	Level in dam^3 in 2010
Cogeneration	Surface	1,541.6
Natural Gas	Surface	573.5
Biomass		0
Total		**2,115**

3.6.4 Municipal/Domestic Water Demand

The population of NSRB 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. Their 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) First Nations' Reservations water demand; and (vi) Other domestic water demands. The methodology for estimating these demands are described in this section. The total municipal/domestic level represents a product of per capita water demand and population of that given community. The available data on water demand and population of various types of communities were obtained from Saskatchewan Watershed Authority.

3.6.4.1 Overview of Estimation

The methodology for the estimation of municipal/domestic water demand was designed by estimating populations for various communities and their respective water demand on a per capita basis. Data for the period 1995 to 2009 were obtained from SWA. Trend analysis was then 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, population of the community was also used. The hypothesis was that as a community increases in size, its per capita water level may decline since some of the common (public) water uses will be shared by more people.

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

The total population of the NSRB, as reported in Table 2.1, was estimated at 197,384 people. Of this, the urban population was estimated at 142 thousand people – some 72% of the total. The rural population accounts for 22% of the basin's population, while First Nations' Communities represent 6% of it.

3.6.4.2 Municipal Water Demand

In the NSRB, there are three cities which municipal distribution systems for water demand: North Battleford, Prince Albert, and Lloydminster. The population and per capita water demand for these communities are shown in Table 3.16. Prince Albert and Lloydminster are the urban centers with higher water demand per capita values. These coefficients could be an indication of increasingly active economies within those community centers, but further research should be employed to understand the dynamics of water demand per capita coefficients.

3.6.4.3 Domestic Water Demand

Domestic water demand was estimated for towns, which were further divided into two types: relatively larger towns (with population of 1,000 or more), and smaller towns (with a population of less than 1,000 people). The details on the variables used for estimation of total domestic water demand for these communities are shown in Table 3.17. Larger towns have a slightly higher water demand per capita relative to smaller towns.

3.6.4.4 Rural Water Demand

In addition to municipal and domestic water users, 9,863 people (constituting 4% of the total basin population) live in smaller communities called villages. Their estimated water demand and source of water are shown in Table 3.18. Since no information was available, farm and rural non-farm water demands were treated similarly to that of the villages. They were assumed to obtain 45.4% of their total water from surface water sources.

Table 3.16: Estimated Variables Affecting Total Municipal Water Demand in the North Saskatchewan River Basin, 2010

Particulars	2010 Population	Per Capita Water Demand in m^3	Proportion of Surface Water to Total Water Demand
North Battleford	17,917	119.52	23.5%
Prince Albert	46,556	147.77	100.0%
Lloydminster	28,765	150.79	0%

Source: SWA (2010).

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

Category	2010 Population	Per Capita Water Demand in m^3	Proportion of Surface Water to Total Water Demand
Towns >1000	27,341	142.06	7.0%
Towns < 1000	11,686	117.01	28.8%

Source: SWA (2010).

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

Category	2010 Population	Per Capita Water Demand in m^3	Proportion of Surface Water to Total Water Demand
Villages	9,863	129.11	45.4%
Rural Non-farm	22,983	129.11	45.4%
Rural Farm	19,170	129.11	45.4%

Source: SWA (2010).

3.6.4.5 First Nations Water Demand

There are 16 First Nations Reservations in the basin. The estimated 2010 population of First Nation's people was 12,405. Their water demand per capita was 74.33 m^3, the lowest among communities located in this river basin. A partial explanation for this lower water demand, although it needs further investigation, may include lack of water availability, and/or lower needs for lawn watering and related purposes. This coefficient was calculated as the average of the last five years. On account of a lack of information on the source of water for these communities, they were assumed to have a surface water supply if they were located near an opened water source. In other words, 68.75% of the water was assumed to be from surface water bodies, while the rest is drown from groundwater sources.

3.6.4.6 Institutional (Other) Domestic Water Demands

In addition to communities, three are two other water demands in the NSRB -- (i) Nisbet Fire Control Center, just outside the city of Prince Albert, where water is used for forest firefighting; and (ii) Interlake Regional Water Supply System, which is a water utility located in Cochin. It started operations in 2008, serving the resort village of Cochin and 190 users in surrounding rural municipalities (Interlake Water Utility, Undated). The total water demand for these institutions is shown in Table 3.19. In the case of the Nisbet Fire Control Centre and Interlake Regional Water System, their total was utilized to determine future water consumption. Groundwater is assumed to be the main source for these organizations.

Table 3.19: Estimated Variables Affecting Institutional Water Demand in the North Saskatchewan River Basin, 2010

Category	Total Water Demand in m^3 2010	Proportion of Surface Water to Total Water Demand
Nisbet Fire Control Centre	1,158[a]	0.0%
Interlake Regional Water System	150,515	0.0%

[a] Value was obtained through communications with Suzanne Goota from Interlake Regional Water System.

A comparison of water demand per capita coefficients for different users is shown in Figure 3.3. The highest level of water demand was estimated for Lloydminster, followed by Prince Albert. The lowest coefficient of water demand belongs to the First Nations' communities.

3.6.5 Recreational Water Demand

Tourism and recreational water demand is a result of two types: non-consumptive water demand in surface water bodies, and consumptive water demand through permanent residents at these recreational sites. The first type is related to visitations 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.

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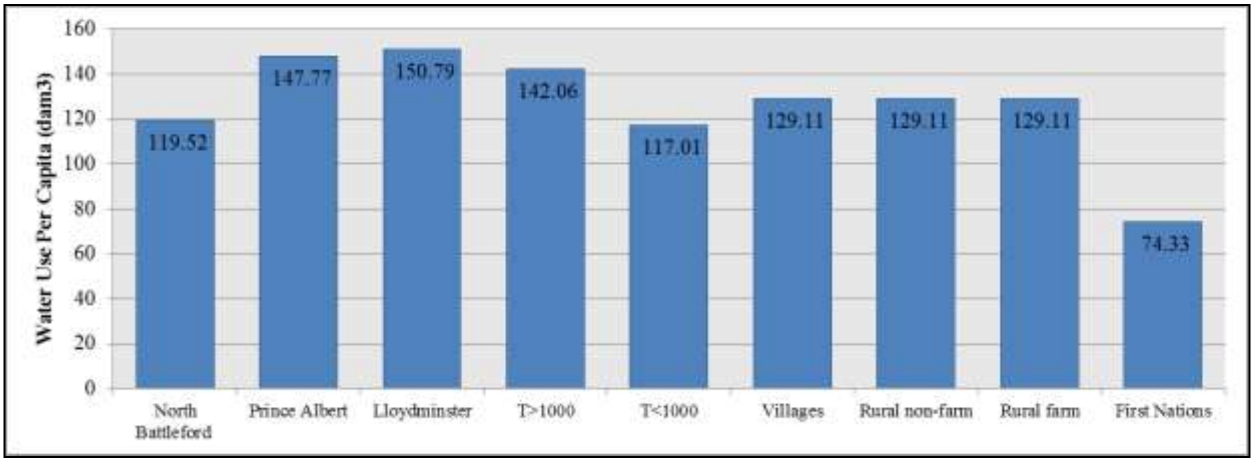

Figure 3.3: Estimated Water Demand per Capita (m^3) in Various North Saskatchewan River Basin Communities, by Type of Communities

The lake levels for a number of lakes within the NSRB are controlled with the objective of meeting minimum levels. The amount of water demand is reported in the lake evaporation section of this report. The Emma Lake diversion project pumps water from the Spruce River into the Gladys, Blanche, May, and Christopher Lake chain.

The major recreational sites in the basin are within provincial parks, plus some that are maintained by the local/regional governments. These are listed in Table 2.7 of this report. Data on the number of visitors was not sufficient to determine a method of estimation. For some selected sites visitation rates are shown in Table 3.20.

Table 3.20: North Saskatchewan Valley Provincial Parks Visitation Level, Selected Periods

Location	Visitors in		Average 2004-2009	% Change in 2009 over 2004
	2004	2009		
Visitation based on Analysis of Permits				
Battlefords Provincial Park	63,516	167,154	121,976	163%
Minowakaw Beach - Candle Lake Provincial Park	54,956	97,649	75,898	78%
Emma Lake Provincial Park	35,303	64,871	49,851	84%

Source: Ministry of Tourism, Culture and Sport (2009)

Recreational water demand for parks and other recreational sites' estimations were realized through total water use records. For estimating water demand for 2010, the average of the last five years was applied. For recreational villages, water demand was estimated by the population and the water demand per capita coefficients. Variables affecting the total water demand for recreational villages are shown in Table 3.20, whereas in Table 3.21, details on Parks and Other Recreational Sites are shown.

Table 3.21: Estimated Variables Affecting Total Recreational Villages Water Demand in the North Saskatchewan River Basin, 2010

Category	2010 Population	Per Capita Water Demand in m^3	Proportion of Surface Water to Total Water Demand
Aquadeo Resort Village	122	168.00	95.67%
Cochin Resort Village	362	88.94	95.67%
Metinota Resort Village	102	178.24	95.67%

Table 3.22: Estimated Variables Affecting Total Parks and Other Recreational Sites' Water Demand in the North Saskatchewan River Basin, 2010

Category	Total Water Demand in m^3	Proportion of Surface Water to Total Water Demand
Parks and Other Recreational Sites	43,065	54.29%

3.6.6 Indirect Anthropogenic Water Demands

3.6.6.1 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 break-up earlier and remain ice free longer than surface water bodies because of current flow. In southern Saskatchewan, the average annual evaporation is greater than the available annual precipitation. As a result, very little precipitation makes its way 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 NSRB vary from 150 mm in the northern part of the NSRB to 550 mm in the southwest part.[15] As a comparison, the mean annual net evaporation from reservoirs

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

was estimated at 300 mm per annum. The evaporation from lakes varied from 150 mm for those located in the northern part of the basin (such as Montreal Lake) to 550 mm for those located in the southern part of the basin (such as Alsask Lake). These rates were based on recorded evaporation rates for various locations (Saskatchewan Watershed Authority, 2009). In some cases interpolation was also made. For the NSRB, these values are shown in Table 3.23.

Table 3.23: Area and Evaporation on North Saskatchewan River Basin Surface Water Bodies

Water Body Type	Site	Surface water body in Sq Km*	Net Evaporation losses in mm**
Lakes	Ajawaan Lake	0.7	225
	Alsask Lake	2.0	550
	Christopher Lake	10.0	300
	Cowan Lake	0.1	250
	Emma Lake	14.0	300
	Jackfish Lake	19.8	425
	Lone Island Lake	1.0	275
	Manitou Lake	56.3	425
	Redberry Lake	56.0	300
	Sturgeon Lake	8.0	300
	Tramping Lake	24.0	550
	Turtle Lake	105.0	350
Reservoirs	Scott Dam	0.2	300
	Spruce River Dam	8.0	300
	Woody Lake Weir	1.8	300
Total		**306.8**	

* Water body area were obtained from SWA (2007a); Google Maps – Area estimated from satellite maps; Wikipedia (2011).

** Estimated using SWA (2009) map.

3.6.6.2 Net Environmental Water Demand

There is no allocation of water for environmental use within the NSRB (SWA 2007). Ducks Unlimited has 32,213 acres of wetland habitat projects that are operated as either owned, easement, leased, management agreement, or conservation agreement (SWA 2007). This is a significant use of water in the basin. List of environment-enhanced projects in the NSRB is shown in Table 3.24. Annual allocation of water for these projects is estimated at 42 thousand dam^3.

Table 3.24: List of Environmental Projects in the North Saskatchewan River Basin, 2010

Project Type	Location	Description	Annual Allocation in dam^3
Lake Level	Jack Fish Lake	Lake Level	26,700
Diversion Project	Emma Lake	Lake Level	4,200
Lake Level	Christopher Lake	Lake Level	8,429
Lake Level	Spruce River Dam	Lake Level	2,400
Flood Control	Laird-Waldhiem		208
Total Annual Allocation			41,937

3.6.6.3 Apportionment Water Demand

Since the NSR originates in Alberta[16], under the MAA, one half of the naturalized flow received from Alberta must be passed on to Manitoba. Since the North Saskatchewan River does not cross the Saskatchewan-Manitoba provincial boundary, there are no requirements for apportionment under the MAA.[17] Therefore, this water demand was set to be equal to zero.

3.6.6.4 Instream Minimum Flow Need

There is no allocation of water for instream water demand within the NSRB (SWA 2007). However, the target flow of the Saskatchewan River is 75 m^3/s while for the South Saskatchewan it is 32.5 m^3/s, which leaves 32.5 m^3/s to be made up from the North Saskatchewan.

3.7 Return Flow and Water Consumption Estimation

Following the methodology outlined in previous sections of this chapter, one would estimate gross water demand as equivalent to water intake. To estimate water consumption, one needs to take into account any 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

[16] According to Mr. Bon Halliday (Personal Communication), Alberta withdraws very little water from the NSR. This provides adequate quantities of water to meet apportionment needs. Water from the NSR is needed to meet the target flow of 75 m^3/s on the Saskatchewan River. The flow of the South Saskatchewan River is 42.5 m^3/s, which leaves a need of 32.5 m^3/s to be met from the NSR.

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

with a water and sewer system. Kulshreshtha et al. (1988) estimated these return flows as follows:

District Irrigation = 25% of the water intake

Urban Communities = 68% of the water intake[18]

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 3.25. According to these estimates, 77.5% of the total water intake by manufacturing establishments is returned to the source. However, this ratio would not apply to weight-gaining[19] processing firms such as ethanol production.

Table 3.25: 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 was simply total amount of water intake minus return follow. These levels are shown in Table 3.26. 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 applied to estimate current (for the year 2010) demand in the NSRB. These results are presented in Chapters 6 to 9 of this report. The methods presented above were revised for calculating the future water demand in the basin under three scenarios – baseline, climate change, and water conservation scenarios. This methodology is presented in Chapter 4 and 5.

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[18] Actual return flow for some communities in the basin may be higher than this level. These values were not available, and thus, average for all urban communities of Saskatchewan was used. Future work in this area may improve on this limitation of this study.

[19] 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 is due to the fact that some water is added to the finished product.

Table 3.26: 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		100%

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

Chapter 4

Forecasting Future Water Demand

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

Since current water is directly related to levels of economic activity and/or population, future water demand will also be governed by these factors in a similar way. The only exception to this situation would be a significant change in the water demand coefficients for various activities. Two factors can affect future water demand coefficients: One, the onset of climate change by 2030 or thereafter, and Two, the adoption of water conservation measures. Water conservation policies of the province and other levels of government regulations regarding water demand may also determine the rate of change in this level. Water demand levels in the future can also be altered by water availability, leading to further conservation or to curtailing of certain economic activities.[20] The methodology to estimate 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 demand patterns/history (including conservation); and changes in the bio-physical system (such as climate change). For instance, a rising population in a given river basin would affect the level of water needed 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 an individual’s 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

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

forecasts attempt to predict the variable of concern by reference to other variables which, it is assumed, control or influence it. Such an approach has been employed for domestic and municipal water demands since the mid-1970s. However, these predictions require extensive data on water demand and on the various factors affecting it. The extrapolative forecasts are derived from time series data involving consideration of variables of concern and thereby predicting a future value 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. Some studies were found, which are summarized below. In all cases, it appears that the forecasting methodology for water demand is generally based on the assumption that the present trend and practices will continue into the future, with some alterations, if needed.

4.2.1 Future Water Demand for Agriculture

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

Of the various uses, only irrigation has been systematically reported in some studies. The crop irrigation water demand has been reported as estimated by the Food and Agriculture Organization's crop coefficient method (FAO, 1998), which is based on a reference evapotranspiration[21] and a crop coefficient (Kc) that accounts for crop characteristics, as well as for development and vegetation periods. The crop requirements were adjusted by the system efficiency, which then reflected the loss in water delivery to the crops.

4.2.2 Future Industrial/Mining Water Demand

No study was found that provided a specific methodology for industrial/mining water demands. Brockman and Kulshreshtha (1988) estimated basin level water use for various activities (including industrial and mining) through an input-output model and final demand estimates. Final demand changes were associated with change in the industries respective production levels. Smith (1986) identified factors such as manufacturing production, price or charges for water, and

[21] Reference evapotranspiration, according to Wisser (2004), refers to evapotranspiration from an extensive surface of green grass cover 12 cm high and adequately watered.

unemployment in the region for estimating future water use. Although both of these approaches have some good suggestions for a methodology, they could not be followed here. 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 uses for residential, commercial, and industrial purposes. For residential and municipal water demand estimation, population projections provide a basis for estimating future growth. Data on demographics and household use rates can be used. In one United States forecast, for example, on residential, municipal and industrial water demands, a sequential methodology was applied (Water Supply Forum, 2009). The steps included calculation of individual utilities' water demand factor (average amount of water used per single family or multifamily household per day or per employee), which were adjusted by future reduction in water demand factors based on a plumbing code (water saved by customers as they remodel plumbing fixtures).[22]

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 demand 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

Water demand is strongly related to water-based recreational demand. However, given that much of this demand is non-consumptive in nature, a forecast of the water needed in the future cannot be established. Massey et al. (2006) developed a recreation model for angling based on site characteristics. Although this approach is meritorious, it could not be followed for this study since it requires survey of recreationalists. The quality of water at a given site is also a major factor affecting current and future water 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 were similar to those used for the current water demand. This methodology is described below for each of the four direct anthropogenic, as well as for the indirect anthropogenic water demands.

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

4.3 Study Methodology for Forecasting of Agricultural Water Demand

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

4.3.1 Future Irrigation Water Demand

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

Two factors that required 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, irrigated area in the basin (per Table 3.3) was estimated to be 23,567 acres, of which 1,709 acres are in the Northminster Irrigation Project. There are plans to create another irrigation district called NSRB-Westside Irrigation Project. According to Miller (2007), the Westside Irrigation District comprises a total of 375,000 acres, of which 17,670 acres would be irrigated from the North Saskatchewan River, 25,000 acres from the South Saskatchewan River, and the remainder from Lake Diefenbaker. In this study, only the area irrigated from the North Saskatchewan River is included in its water demand estimates for 2040 and 2060 levels. Expected expansion in irrigated area in the NSRB is presented in Table 4.1. According to these data, irrigated area in the basin could double by 2060, primarily as a result of the NSRB-Westside Irrigation Project.

Table 4.1: Irrigation District Irrigated Area and Potential Expansion for the North Saskatchewan River Basin

Irrigation Jurisdiction	Irrigated	Expansion	Total
Northminster	1,709	-	1,709
NSRB-Westside Irrigation Project		17,670	17,670
Sub-Total District Irrigation	1,709	17,670	19,379
Private Irrigation	21,858	5,847	27,705
Total Irrigated Area	**23,567**	**23,517**	**47,084**

Source: SIPA (2008b)

The time path of future irrigated area in NSRB will depend on the adoption rate of irrigation by producers in the newly developed project. 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,[23] ranging from 26 to 92% for the RHID and from 29 to 96% for the LLID. The averages for these districts were 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	
	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)

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

Private irrigation, which in 2010 was 21,858 acres, is also expected to increase. To estimate this, a review of past irrigation growth in the province was completed. The average growth rate in irrigated area from 1990 to 2009 in Saskatchewan was 0.77% with a range of 0.17% in 1993 to 2.24% in 1990. The area of surface, backflood, and miscellaneous backflood has remained static since 1992, indicating that most of the easily irrigable land in Saskatchewan has 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 would roughly be an increase of 26.7% over the 2010 level.

The timing of development and other details for the NSRB-Westside Irrigation Project are not formalized at the time of writing this report. However, considering similar development in the Qu'Appelle River Basin (such as the Qu'Appelle South Irrigation district), a start-up period of 11 years-after which irrigation would start-is assumed (SIPA, 2008b). Therefore, by 2020, it is not likely that any of the proposed irrigation district area would be irrigated. The future irrigated area in the basin is shown in Figure 4.1. The total irrigated area will increase, but mostly from the expansion of sprinkler irrigation systems. The surface irrigation will continue at the current levels.

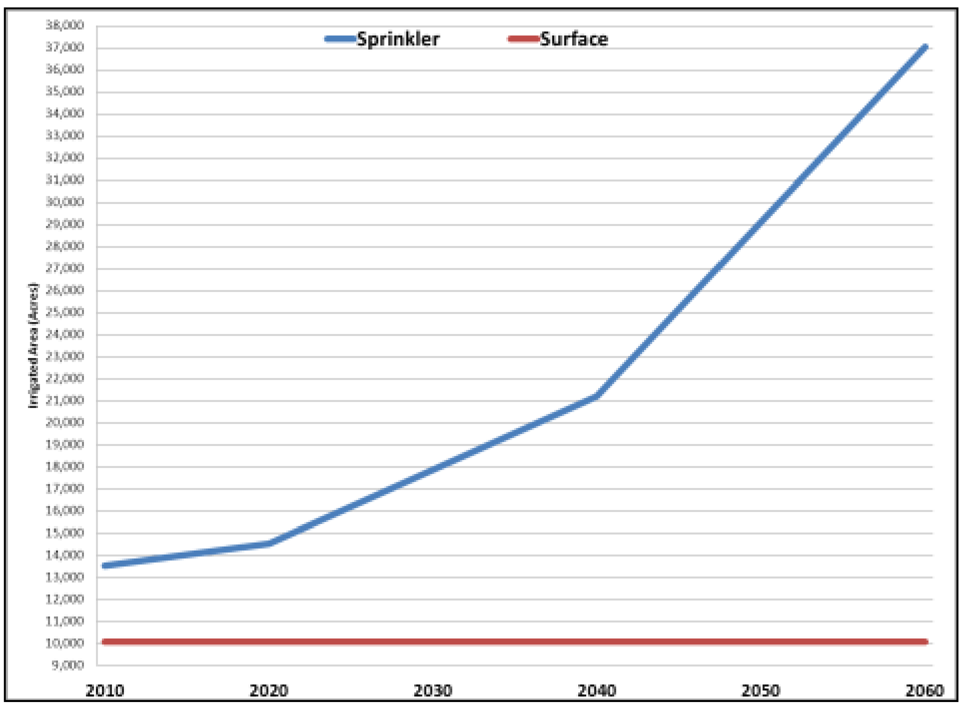

Figure 4.1: Trend in Irrigated Area Development for the North Saskatchewan River Basin, 2010 - 2060

A further breakdown of total irrigated area in the NSRB by irrigation systems 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 NSRB-Westside Irrigation Project will be high efficiency center pivot[24]. Furthermore, this study assumes that 65% of the proposed NSRB-Westside Project will be in operation by 2040 and 90% by 2060. By 2060, 79% of irrigation water will be provided by pivots or sprinkler irrigation systems.

Table 4.3: Area of Irrigation in the North Saskatchewan River Basin in Acres, by Type of Irrigation Methods

Irrigation System	Irrigated Area in Acres			
	2010	**2020**	**2040**	**2060**
Wheelmove	3,606	3,606	3,606	3,606
Pivots	8,212	9,209	15,865	31,728
Linear	104	104	104	104
Misc. Sprinklers	1,595	1,595	1,595	1,595
Surface	427	427	427	427
200mm	1,719	1,719	1,719	1,719
Misc. Backflood	7,344	7,344	7,344	7,344
Remainder	560	560	560	560
Total	**23,567**	**24,564**	**31,220**	**47,084**

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 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 for 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

[24] Although it is highly likely that new irrigation area will be served by higher efficiency water delivery systems, it is still an assumption at this time.

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). On what crops this irrigation water was used, and at what rate, is unknown. However, on average it appears to be consistent with the estimate of the normal crop water deficit applied in generating the 2010 water demand coefficients. The mix of crops produced to 2060 may change, depending on investment in the required intensive livestock operations because the demand for silage from feedlot cattle operations could significantly change the crop mix. However, since no further information is available, the effect of this issue was excluded in this study. In essence, water demand coefficients for irrigation were developed by employing 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 distribution of crop mix by irrigation system.

4.3.2 Dryland Crop Production Activities

4.3.2.1 Cropland Area

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

Any estimates for 2040 and 2060 have to consider relative net returns -given the yield and price of a commodity- that will determine the area seeded. Productivity gains in crop yields from 1964 to 2007 show a similar increasing linear trend, expanding by 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 mostly by the crop response to the climate conditions in 2040 or 2060, given the expenditure on developing new varieties. Currently, in the NSRB 23.2% of the total cultivated area is in oilseeds, 48.1% in cereals, 16% in pulse, and 12.7% in fallow (Table 4.4). These proportions may change slightly in the future, but such forecasts are left for further studies.

One could expect that the percentages of these broad classifications should change only marginally overtime. The world markets for the crops will have a greater impact on the types of crops grown within the categories. In terms of estimating the water demanded for spraying, the area of the broad categories of crops was considered. The total agricultural area subject to spraying is shown in Table 4.5. It is expected to decrease by 3.3% in 2060. The reasons for this decrease include increased forage area in the basin, which will reduce the cropped area subject to spraying water demand.

Table 4.4: Estimate of Percentage of Cultivated Area by Activity in North Saskatchewan River Basin

Crop Type	Percent of Total Area in			
	2009	2020	2040	2060
Cereals	48.1%	48.8%	48%	48%
Oilseeds	23.2%	26.4%	23%	23%
Pulses	16.0%	14.9%	16%	16%
Fallow	12.7%	10.0%	13%	13%
Total	100%	100%	100%	100%

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

Table 4.5: Estimate of Cultivated Area by Activity, North Saskatchewan River Basin, 2009 – 2060

Crop Type	Percent of Total Area in			
	2009	2020	2040	2060
Cereals	1,410,563	1,385,671	1,363,042	1,363,042
Oilseeds	681,089	748,878	658,724	658,724
Pulses	470,418	421,819	454,971	454,971
Fallow	373,196	282,513	360,942	360,942
Total	**2,935,266**	**2,838,881**	**2,837,679**	**2,837,679**

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

4.3.2.2 Crop Pesticide Application

In addition to crop mix, a number of other factors can change water demand for pesticide spraying in the basin. The majority of crop production in western Canada consists of 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 an increased use of zero tillage (Statistics Canada, 2006). Associated with this trend has been the dramatic reduction in summerfallow and the greater diversity of crops grown in the province. The removal of the Crow rate for transport of grains (a major transportation subsidy) has 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 48% cereals, 23% oilseeds, 16% pulse crops, and 13% 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. The future water demand for pesticide spray is shown in Table 4.6.

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

Particulars	Zero Tillage	Z-Till	Min Till
	Adoption	Passes	
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	88.38		

4.3.3 Livestock Production

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

4.3.3.1 Estimation of Livestock Population for Future Periods

The estimation of the livestock production for 2020 applied the AAFC (2011) Medium Term Outlook for 2017. Inventories of animals within the dairy, poultry, sheep, hog, and beef sectors, and of laying hens for egg production, were forecasted. Productivity growth rates for the various sectors are important in estimating their activity levels in 2040 and 2060. First, relative growth rates can influence the profitability of a sector and the resulting investment in its production. Furthermore, the technical change in the livestock industry to 2060 will come from improved management techniques and improved genetics. Monitoring of individual animal performance (such as using microchips) to adjust feed intake and quality will be part of intensive animal operations. The continued industrialization of the production process for dairy, hog, poultry, and egg operations also has implications for the number of animals needed to produce a given quantity of output. Mapping of the genome will allow for greater accuracy in selecting for desirable traits and in enhancing the traits specifically related to productivity. Intensive livestock operations at present are able to implement such new technologies and to capture the increased productivity gains. Veeman and Gray (2009), for instance, 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.[25] Therefore, it will take fewer livestock to attain a given level of final consumer product.

The total cattle population within the NSRB over the 2000 to 2010 period ranged between 607,000 (in 2002 due to the drought) to 814,000 (2005 BSE Crisis), and over the past three years may be settling between 653 to 690 thousand animals level. There is also an increasing trend for feedlot cattle, which jumped from 29,118 in 2001 to 64,730 by 2010.

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, then expected to 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 is applied in estimating the change in feedlot capacity in the River Basin to 2020, 2040, and 2060. Expansion of the irrigation capacity in the basin could result in a further increase in cattle feedlots as irrigated crops for silage production make it 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, 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 NSRB, 2010-2060

Animal Type	Estimated Numbers on Farm in			
	2010	2020	2040	2060
Bulls	13,477	14,451	15,631	15,944
Milk Cows	7,557	6,938	6,799	6,935
Beef Cows	277,250	297,298	303,244	309,309
Milk Heifers	3,541	3,255	3,186	3,250
Beef replacement Heifers	47,293	47,235	51,727	52,762
Feedlot	45,097	49,922	54,914	60,406
Calves	250,798	268,934	274,313	279,799

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

[25] Effects of these technology gains on water use per animal have 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: Forecasted Hog Sector Population for the NSRB, 2010-2060

Animal Type	Estimated Numbers on Farm in			
	2010	2020	2040	2060
Gestating Sows	12,032	12,451	12,884	13,332
Suckling Pigs	262,065	283,629	306,376	330,361
Weaned Pigs	145,650	150,715	155,956	161,379
Growing Finishing Pigs	145,650	150,715	155,956	161,379
Boars	356	383	353	333

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

Table 4.9: Forecasted Sheep Sector Population for the NSRB, 2010-2060

Animal Type	Estimated Numbers on Farm in			
	2010	2020	2030	2040
Rams	273	328	331	335
Ewes	5,516	6,639	6,706	6,773
Breeding	1,297	1,561	1,577	1,593
Slaughter	4,132	4,973	5,023	5,073

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

Table 4.10: Forecasted Other Livestock Populations for the NSRB, 2010-2060

Animal Type	Estimated Numbers on Farm in			
	2010	2020	2040	2060
Bison	16,385	18,023	18,203	18,385
Horses	22,778	22,778	22,778	22,778
Goats	1,983	1,983	1,983	1,983
Llamas	1,274	1,274	1,274	1,274
Bees	19,452	19,452	19,452	19,452
Deer	2,991	2,991	2,991	2,991

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

Table 4.11: Forecasted Poultry and Laying Hens Population for the NSRB, 2010-2060

Poultry Type	Estimated Number of Birds in			
	2010	2020	2040	2060
Laying Hens	268,800	292,712	321,983	338,082
Pullets	110,290	128,255	141,081	148,135
Broilers	4,895,414	5,645,248	6,209,773	6,520,261
Other Poultry	16,448	18,093	19,902	20,897
Turkeys (M)	86,196	100,925	111,018	116,569
Turkeys (F)	57,464	67,283	74,012	77,712

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.

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

The 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 now ball type nipples that reduce wastage even further are being adopted. Small (2001) surveyed hog barns in Manitoba and Saskatchewan to determine water use for drinking, washing, cooling, and domestic. Regulations regarding the type of confinement for sows and feeders appear to be a major factor which may affect some of the water demand 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), along with the water needed in production from Small (2001).

Beef cattle's consumption of water is affected by time of year and feed type. As expected, the moisture content of feed influences the amount of additional water needed (Olkowski, 2009). Dairy and feedlot operations generally utilize 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 Use Requirements, 2001

Activity	Small 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
Gestating Sows	8.78
Lactating Sows	20.04
Suckling Pigs	0.71
Weaned Pigs	2.01
Growing Finishing Pigs	6.76
Boars	10.27

Source: Adapted from Thacker (2001).

Table 4.14: Beef Cattle Water Consumption (L/DAY) at Different 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 taken 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 calculated to estimate monthly consumption. The coefficients for estimating water demand are presented in Table 4.15.

The water consumption estimates for dairy cattle employed various categories of milk production given the temperature (Table 4.16) to arrive at water demand coefficients (Table 4.17). Water is also required in the cleaning of dairy operations; it is estimated at 18.0 litres per cow per day (Beaulieu et al., 2001).

Water consumption coefficients for six categories of poultry were derived by the same methodology used 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, estimated at 1.7 litres per bird per year (Beaulieu et al., 2001).

Table 4.15: Estimated Water Demand Coefficients for Beef Cattle

Type/Weight	Weight (kg)	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

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

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

4.3.4 Greenhouse and Nursery Water Demand

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

Table 4.19: Water Demand Coefficients for Greenhouses and Nurseries, North Saskatchewan 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

[1] Percent of Spray water

Source: Beaulieu et al. (2001).

Table 4.20: Area of Greenhouses in the North Saskatchewan River Basin, 2010 – 2060

Particulars	Value for			
	2010	2020	2040	2060
Area in Acres	12.3	12.4	13.1	13.7
Estimated Water Demand Coefficient	**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 the lack of data on these operations.[26] As a substitute, the value of this water demand was taken from R. Halliday and Associates' (2009) report. Surface and groundwater demand for aquaculture was estimated at 4 dam^3 and 12 dam^3, respectively. It is assumed that this quantity of water will be static for aquaculture to 2060.

4.4 Forecasting of Industrial/Mining Water Demand

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

4.4.1 Future Potash Production Related Water Demand

4.4.1.1 Future Potash Production

Future production of potash will result from the expansion by existing companies of their operation, and by the entrance of new companies into the province. As noted in Chapter 3, there is a single mine owned by Agrium. New mines are not reported for future location in this basin. More details on the future potash production are shown in Table 4.21.

Table 4.21: List of Existing and Future Potash Mines in the North Saskatchewan River Basin by Location and Source of Water

Corporation	Location	Potash Production in Thousand Tonnes		
		2020	2040	2060
Existing Mines				
Agrium	Vanscoy	2,850	2,850	2,850
Total Capacity		2,850	2,850	2,850

Source: CIBC World Markets Inc. 2008, Saskatchewan Watershed Authority undated.

Based on the facts known at the time of writing this report, no expansion in the current mine production is planned. The source of water used by this mine is the South Saskatchewan River Basin, and all the water drawn is surface water. In addition, no basin water is used for potash production.

[26] 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.

4.4.4.2 Water Demand for Tailings management

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

4.4.2 Oil and Gas Production

The Viking formation has an estimated proven reserve of 2.3 billion barrels of oil; its recoverable reserves, based on vertical well and water flood technology, can produce 214 million marketable barrels. Vertical wells in the Viking formation have, on average, produced for 30+ years (PetroUno Resources Ltd., 2010). Oil production from vertical wells in 2010 was 2.5 million barrels and from horizontal wells, 90,000 barrels (Canaccord Genuity, 2011). Given this rate of extraction, the Viking formation will produce for 80 years. The North Lloyd has recoverable reserves, based on current technology, of 3,750 million marketable barrels. Natural gas production for 2010 in Saskatchewan was estimated at 5.2 $x10^9$ m^3 (NEB, 2011). Given that there is 151 $x10^9$ m^3 in marketable reserves, at current extraction rates, there will be 29 years of production by the present and intended technology. Typically, oil field production follows a bell shaped curve with the right-hand tail truncated where production becomes uneconomic. As of 2010, there were 27,000 and 20,000 producing wells of oil and natural gas, respectively, in Saskatchewan.

Saskatchewan in 2010 had drilling activity of 1,894 and 69 new oil and gas wells, respectively. Over the 2000 to 2010 period, on average of 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. The amount of well drilling in the Viking and Birdbear formations can be expected to remain at its average ten year rate to 2020, reducing to 60% by 2040, and 15% by 2060 as the field ages. The active (play) areas of natural gas exploration are relatively mature with most of the large pools having been discovered (NEB 2008). Oil production in the NSRB has occurred since the early 1950s. Changes in technology and increases in the price of oil have made its extraction in the Viking formation profitable. As with natural gas, most of the large pools of oil have been discovered. Water demand for injection into a producing well decline over time as the field matures because the issue is not pressure, but viscosity of the oil and porosity of the formation (Moore and Lunn, undated). Other techniques such as polymer, steam, or CO_2 may be used to extend the life of the field. In addition, heavy oil in the North Lloyd formation requires enhanced techniques for extraction. The estimated oil and gas well drilling activity in the NSRB is presented in Table 4.22.

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

Technology of Production	No. of Wells in			
	2010	2020	2040	2060
Vertical	122	164	98	25
Horizontal	53	71	42	11

4.4.3 Salt Mining Activities

In addition to oil and gas mining, there is a single salt producing mine in the NSRB, located at Unity. The details of production are shown in Table 4.23. Based on the data obtained from the company, salt production water demand for this mine may increase by 25% in 2060 to 352 dam^3.

Table 4.23: Estimate of Production in Salt Mining Activity in the North Saskatchewan River Basin, 2010 - 2060

Company	Production in Tonnes			
	2010	2020	2040	2060
Sifto Canada Ltd	154,360	159,016	174,918	192,404

4.4.4 Manufacturing Water Demand

4.4.4.1 Existing Manufacturing Industries' 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 may 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, potential development of some industries is plausible. These industry groups were identified through a review of other studies. Most of these projections were based on the development of irrigation in the basin.

Estimating changes in the level of production along with changes in water use technology for industry is a complex task. With lack of information on operational details for various establishments in the NSRB, estimation of their water demand coefficient could not be made. One illustration of this difficulty arose for the Husky Energy factory located at Lloydminster, the details of which are presented in Appendix G. Only two coefficients could be estimated -for the North West Terminal ethanol plant, where 5.24 dam^3 of water are required per 1,000 litres and for Prairie Malt of 0.0047 dam^3 per tonne of malt (Table 4.24).

Table 4.24: Future Industrial Water Demand Coefficients for the Climate Change in the North Saskatchewan River Basin, 2020 to 2060

Product and Name of Firm	Water Demand in dam^3		
	2020	2040	2060
Ag Processing			
North West Terminal Ltd	5.24	4.51	3.61
Husky Ethanol	Alberta Withdrawal		
Prairie Malt	0.0047	0.0047	0.0047
Refineries			
Canadian Crude Separators Inc.	N/A	N/A	N/A
Husky Energy (Enhanced Oil Recovery)	N/A	N/A	N/A
Husky Oil BiProvincial Upgrader	Alberta Withdrawal		
Liquid Natural Gas Storage			
BP Canada Energy Co.	N/A	N/A	N/A
Trans Gas	N/A	N/A	N/A
Construction	N/A	N/A	N/A
Kohlruss Bros. Enterprises	N/A	N/A	N/A
Other			
Wapawekka Lumber Ltd (CLOSED)	Not estimated		
Carrier Forest Products	Not estimated		
Prince Albert Forest Nursery	Not estimated		

4.4.4.2 Induced Economic Development Activities

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

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

For the NSRB, 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 because of irrigated products.

Beef Feedlot Expansion in the Irrigation Districts

To estimate the expansion level of intensive livestock operations from increased irrigation in the NSRB, the area required for feed production, bedding, and manure disposal needed consideration. The magnitude of this area will determine the number of enterprises that can effectively operate. The production of silage using irrigation for dairy or cattle feedlots is the main enterprise that would be attracted to an irrigation district. Transportation costs for the bulk, low density products of silage, straw, and manure limit the range over which these products can be economically transported.

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 economical hauling distance of silage and manure are the two key factors determining the overall profitability of an intensive livestock operation. The amount of land needed is also dependent on the rotational constraints of crops and the amount of manure that can be applied.

A base unit of production of 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 its silage requirement. If the rotational constraints are every 2nd year, then 2,891 and 1,934 acres for barley or corn rotation, respectively, are needed. Therefore, up to 20 quarter sections will be needed for a barley-based feedlot and up to 14 for a corn-based feedlot.

As well, 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 the economical hauling distance. Technological developments such as biodigesters[27] enable greater economical hauling distances, relative to raw manure, as a more highly 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 NSRB-Westside Irrigation (Lake Diefenbaker) Project of up to 17,670 acres could accommodate several intensive beef livestock operations (ILO).[28] Location of the ILOs such that the maximum amount of non-irrigated land could be accessed for manure disposal, and as well as mix of sizes, would be required if the goal were to maximize livestock production. It would appear from the proposed irrigated area that two 10,000 head capacity feedlots, along with 1 or 2 smaller ones, could be accommodated. The water demand implications of these feedlots are described in a sub-section below.

Future Ethanol Production

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 will come into effect over the 2013-15 period and will affect the demand for transportation fuels by 2020. Ethanol and biodiesel will have to be competitive with petroleum motor fuels and with 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 Saskatchewan market 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 of 20 ML by 2020, there is no major growth predicted for this biodiesel in Saskatchewan. Cellulosic ethanol plants using biomass are the next generation of plants

[27] 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.

[28] An intensive livestock operation is also called a factory farm. Such operations typically hold 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.

that can 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 fall into the 2,000 to 3,000 ML range for both gasoline and diesel markets by 2020, given the growth in the economy and regulations on vehicle fuel consumption. Therefore, the mandated biofuel requirements for ethanol will be easily met from Saskatchewan production. Export markets in British Columbia, Alberta, and northern tier states are the growth areas for Saskatchewan ethanol production.

The national renewable biofuels 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 were for transportation, 11% for agriculture, and 17% for commercial purposes in 2009 (Statistics Canada, 2011b). The amount of diesel and gasoline used in Saskatchewan from 2002 to 2009 is presented in Table 4.25. The rise in economic activity from industrial and commercial sectors accounts for most of the increase.

Table 4.25: Fuel Use in Saskatchewan, 2002 to 2009

Fuel Type	**Level of Fuel Use in ML for**							
	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 4.26. 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.

The irrigated area in the proposed NSRB-Westside Irrigation Project in the NSRB could be used for the production of feedstocks for the ethanol industry, either for a grain-based or a biomass-based plant. Currently, Husky Energy and North West Terminal Ltd. contract for high starch wheat to produce ethanol. The improvement in the yield of grain corn that matures with less than 2400 heat units, combined with increased temperatures and longer growing seasons from climate change, could result in irrigated area being devoted to grain corn. Competitive grain corn yields relative to other crops, combined with a market for corn stover[29] residue, could make this a profitable crop to compete with other cropping alternatives.

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)

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 NSRB would be able to 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 distance of the biomass -whether for the livestock feedlot or ethanol- plant is a key factor in the profitability of either operation.

The crop mix on the irrigated land in the NSRB part of the NSRB-Westside Irrigation Project may 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 will change the demand for water. Barley or corn silage crops have different water requirements from those of the grain production from small cereal grains or corn crops (Table 4.27).

[29] 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.

Table 4.27: Water Demand of Selected Irrigated Crops

Crops	Water Demand per acre in	% of CWRS
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 expansion in the area seeded to grain corn to meet the biomass requirements for a 30,000 tonne ethanol plant in the North Saskatchewan South Project would raise the water demand for irrigation by 1,230 dam^3. This amount was estimated as the additional water needed to grow grain corn when substituting small grains in the crop mix. Likewise, an increase in area seeded to barley silage adequate 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 arrangement would mean that water is also needed for livestock watering. An ethanol plant-linked 10,000 animal capacity feedlot will require 184.9 dam^3 of water directly. Depending on the type of production process used, water consumption in a biomass ethanol production could be 33.7, 22.3, or 7.2 litres per litre of ethanol for current technology, advanced technology, or gasification, respectively (Wu et al., 2009). Therefore, a 30,000 tonne ethanol plant may require 364 dam^3, 241 dam^3, or 78 dam^3 if its technology is the current type, advanced technology, or gasification, respectively.

The net effect of the NSRB-Westside Irrigation project with the addition of one livestock feedlot operation (with a capacity of 10,000 head) and a biomass ethanol plant (using advanced technology) would be a reduction in water demand by 2,542.1 dam^3, expand with an increase by 1471.0 dam^3, for a net reduction of 1,071.1 dam^3 by 2040, which would continue to 2060. Details are shown in Table 4.28.

4.4.5 Power Generation water demand

SaskPower has a provincial generation capacity -from both owned and purchased power- of 3,982 MW, of which 1,031 MW capacity (26%) is in the NSRB. An estimated new capacity for Saskatchewan of 1,609 MW will be needed by 2020 and by 2033, of 2,159 MW along with replacement of (or reinvestment in) its existing capacity to 2060 (SaskPower 2011).

Table 4.28: Change in Water Demand by Agri-Processing due to Induced Impact of Irrigation Activity in the North Saskatchewan 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	1	184.9	-2,727.0	- 2,542.1
Ethanol Plant	1	241.0	1,230.0	1,471.0
Total Change in Water Demand		**425.9**	**-1,497.0**	**- 1,071.1**

In the future, several different generation and conservation options will be used to meet the expected demand given the cost structure of each option, as well as the requirements to meet base and peak load demand. Since a large percentage of the population and economic activity is centered on Saskatoon, generation capacity within the basin will be expected to increase with the governing electricity demand. Also, the replacement of the Queen Elizabeth II generation station and other generating stations will likely occur through electricity generating plants located within the basin near existing transmission lines. It is also likely that to 2020, the current generating capacity, if replaced, will be with similar technology. At 2040, and certainly 2060, other generating options will be available that have different water demand requirements from the current technology. Estimates of electricity generation by source are presented in Table 4.29. The increased capacity, as forecast by SaskPower, is allocated to power generation by wind, co-generation, hydro, natural gas, waste heat, solar, Biomass, and nuclear.

4.5 Forecasting of Domestic and/or Municipal Water Demand

Forecasts for domestic water demand are typically done by past trends in factors that have been shown to influence future water demand. These factors, according to Whitford (1972), need to be taken into account in any future water estimates. Six factors that affect such prediction have been shown to be (1) regulations on the amount of water demand by appliances, (2) type of pricing policy, (3) level of public education, (4) future housing patterns, (5) cost of supply, and (6) technological change.

Regulations and pricing policy are important determinants of water demand in any community. Saskatchewan follows the National Building Code for Plumbing and is a small market such that regulations on appliances are unlikely to differ from national or North American standards. The pricing regime[30] for water followed by 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 impact of climate change). In Saskatchewan, of the total households supplied by municipal water systems, 91% had meters (Statistics Canada, 2006).

Table 4.29: Electricity Generation Estimates in the North Saskatchewan River Basin, 2010 - 2060

Type	Amount of Electricity Generated in MWh in			
	2010	2020	2040	2060
Wind	-	5.5	7.6	9.8
Cogeneration	261.0	366.5	508.0	649.5
Hydro	-	5.5	7.6	9.8
Nat Gas	519.0	695.6	933.7	1,076.6
Waste Heat	5.0	7.0	9.7	12.4
Solar		11.0	30.6	97.7
Biomass		11.0	30.6	97.7
Total	785.0[a]	1,102.2	1,527.8	1,953.4

[a] This level is the actual power generated, and should not be confused with the capacity noted in the previous page.

Source: Estimated using SaskPower (2011).

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

The current pattern of residential development in Saskatchewan appears likely to hold until 2060, along with the accompanying water demand characteristics that this entails. New housing replacing old housing, appliances being upgraded as their useful lives end, and appliances either coming on to the market or expanding their market share will affect the per capita water demand.

[30] The nature of pricing regime has a significant influence on water demand. For example, decreasing block pricing encourages water use while the increasing block pricing schemes deter water use.

Income and home ownership are two factors that affect the potential 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 shares for appliances (like hot tubs) will increase per capita use. For conservation, though, the rate of replacement from 1994 to 2006 of low flush toilets and low flow showerheads in Saskatchewan was 1.9% and 0.9% per year, respectively (Statistics Canada, 2008b). However, this rate of change is unlikely to be sustained in the future, as most households will have adopted these permanent measures; the scope for further change is limited. These examples may be two ends of the spectrum of technology change, with low flush toilets representing forced change through regulation, while low flow showerheads' adoption is driven by education or rebates.

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). This procedure results in a number of alternate estimates of future water demand in the basin.

The projected population (2020, 2040, and 2060) for a given type of community was multiplied by its water demand coefficient for the given period of time in order to arrive at the estimate of municipal water demand.

4.5.1 Estimation of Future Population

Future population of the South Saskatchewan River Basin will be influenced by the overall population of the province. Within that generality, 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 continue so. In addition, there may be a significant amount of interbasin migration of people. These migration patterns have not yet been studied. To take into account possible differences in growth rates, future levels of certain populations groups were estimated separately, starting with the overall provincial population.

Regression analysis was used to forecast the future population within the NSRB. Out of three tested models -- linear, curvilinear, and logarithmic regression -- the most suitable model was chosen to predict future values. In the cases wherein time did not show a trend, a different approach was applied, and specific growth/decline rates were employed. The rationale behind those assumptions will be further explained in the following sections.

4.5.1.1 Forecasts of Provincial Population

Statistics Canada (2011c) has estimated Saskatchewan's population over the period 2020 to 2036 by six basic scenarios (Low, Medium, High, replacement fertility, no immigration, and 1% immigration). The projected rates of growth are presented in Table 4.30. Recent population growth trends reflect resource development in the potash and oil sectors; however, once the development/construction phase is completed, employment levels generally fall. The lowest population growth occurs under the "no immigration" scenario, it is estimated at 0.14% per annum. The highest growth rate is suggested under the "replacement fertility" scenario, in which Saskatchewan's population could grow at the rate of 0.91% per annum.

Table 4.30: Statistics Canada Population Growth Rate

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)

The growth rates in Saskatchewan may not be shared equally by all regions; the growth rate in Saskatchewan by economic regions for three time periods from 1996 to 2009 is presented in Table 4.31. Basically, their growth has happened 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 centres or to other provinces, with a minimal migration from other Canadian regions and/or the world.

Table 4.31: Population Rate of Change 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 the recipients of intra-provincial migration. The greatest percentage increase to 2060 will take place in the larger cities (Regina, Saskatoon, Prince Albert, Moose Jaw) and their associated bedroom communities (if any). In contrast, most villages in Saskatchewan are on a long term decline in population. However, it is conceivable that their future populations 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/GPS will further reduce the need for farm labour. Towns dependent on the farm sector will either maintain their population or decline because there are fewer retirees to move in from farm; this section has been the main source of new residents. As the rationalization of the grain handling sector has reduced delivery points, the same forces are at work in consolidating other farm services. The exception to this trend will be seen in towns and villages located close to large urban centers.

Future growth in mining, industry, and commercial activity will be the main determinant as to whether populations will increase for towns and medium size cities (Swift Current, Estevan, Weyburn, Yorkton, North Battleford, Humboldt).[31] 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 by regulatory process.

In order to develop some guidelines for future changes, a forecast of provincial population was considered to be of some use. Since a systematic forecast of this variable for Saskatchewan is not available,[32] projections were made from Statistics Canada's growth assumptions. In particular, a low growth and a high growth scenario rate of change (as listed in Table 4.32) were used. Assuming the growth rates to be linear per annum, projected populations were estimated. These are shown in Table 4.34. According to these estimates, Saskatchewan population by 2060 could be anywhere from 1.23 to 1.52 million people, producing an average of 1.375 million people. For this study, that average was employed.

4.5.1.2 Forecast of Population Changes in the North Saskatchewan River Basin

The Saskatchewan Watershed Authority has data on the water demand from 1995 to 2009 by urban municipalities as well as for some businesses and institutions (SWA, 2010). Past trends

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

[32] 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.

and overall population forecasts were applied to create population growth scenarios for the eight river basins.[33] The estimates as described below are based on assumptions that will be detailed in this section.

Table 4.32: 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

In order to forecast the future population of cities (North Battleford, Prince Albert, and Lloydminster) located in the NSRB, regression analyses were undertaken. For all three cities, a linear trend regression was utilized to forecast future developments. Cities located in the North Saskatchewan Watershed indicate an ascending trend of population. Regressions equations are shown in Appendix H. Projections were made for 2010, 2020, 2040, and 2060: the values can be seen in the Table 4.33 below. North Battleford indicates an increase by around 30% of the year 2060; Prince Albert's population is expected to increase by 46% from its current 46,556 to 68,285 by 2060, and Lloydminster population is forecasted to double by that time.

For both categories of towns, those with populations higher or lower than 1000 people, regression analysis was undertaken. A non-linear trend (log-linear functional form) was utilized for towns with populations less than 1000, whereas for towns with a higher populations, linear trends appeared to develop over time. The regression equations are also shown in Appendix H. As shown in Table 4.33, the population for these communities is expected to further increase in the future. Smaller towns are projected to arise by approximately 65% by 2060, and towns with populations over 1000 are expected to follow an ascending trend of nearly 16% growth by 2060.

For villages located in the NSRB, regression analysis was first applied to determine the future population developments. Partially lacking data from the 1995-2009 period, the regression analysis failed to indicate any trends over time. It was assumed that future population in these communities would decline. The decline in these populations was assumed to be 0.5% for 2010,

[33] It is realized that these projections are somewhat subjective and requires; for greater accuracy, a study of population growth in the province by river basins is needed.

0.25% for 2040, and 0.1% for 2060. Under this hypothesis, the current rural population is expected to decline from 52,016 in 2010 to 38,448 in 2060, accounting for a decline rate of nearly 26%.

Table 4.33: Population Projection for Urban Communities and Villages, North Saskatchewan River Basin for 2010, 2020, 2040, and 2060

Category	Population Level for				2060 Population as % of 2010
	2010	2020	2040	2060	
North Battleford	17,917	19,017	21,218	23,418	30.7%
Prince Albert	46,556	48,086	58,186	68,285	46.7%
Lloydminster	28,765	32,785	44,430	56,074	94.9%
T>1000	27,341	28,226	29,996	31,766	16.2%
T<1000	11,686	12,791	16,081	19,295	65.1%
Sub-Total Urban	**132,265**	**140,906**	**169,910**	**198,838**	**50.3%**
Villages	9,863	9,370	9,123	8,941	-9.3%
Rural Non-Farm	22,983	20,685	18,386	16,088	-30.0%
Rural Farm	19,170	17,253	13,802	13,419	-30.0%
Sub-Total Rural	**52,016**	**47,308**	**41,312**	**38,448**	**-26.1%**
First Nations	12,774	17,066	24,220	31,373	145.6%
Total	**197,055***	**205,279**	**235,442**	**268,659**	**36.3%**

* The total population in this table is different from that in Table 2.1 because recreational villages are included under recreational water demand.

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, 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). Expected rates of growth in the First Nations' population range from a low of 1.1% to a high of 2.8%. The underlying basis for the estimates combines projections for education attainment levels and workforce participation rates. Both these rates are expected to rise among the First Nations' population, especially for 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 is an increase of 4.43% over the 1995 levels, and much higher than that noted above.

For the North Saskatchewan River Basin, First Nations' population prediction was tied to the above sets of projections. A growth rate of 2.8% for 2010-2060 was assumed.[34] 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 may be living on reserves, many of these people, once educated and ready to face the marketplace, will likely move to bigger cities. The total First Nations' population in the basin, under these assumptions, could increase from the present level of 12,774 people to more than double – 31,373 people (Table 4.34)

Table 4.34: Estimated First Nations' Population for North Saskatchewan River Basin, 2010 to 2060

Year	Rate of Change per annum over the Previous Period	First Nations' Population
2010	--	12,774
2020	2.8%	17,066
2040	2.8%	24,220
2060	2.8%	31,373

4.5.1.4 Institutional (Other) Population Forecast

Under this category, the Interlake Regional Water System facility and Nisbet Fire Control Center were included. For these centers located in NSRB, there was in sufficient data in elaborating a method determining future population developments.

4.5.1.5 Total Basin Population

The total population of the basin is shown in Table 4.33. It is expected to grow from the current level of almost 197 thousand to 268 thousand – an increase of 36%. Much of this effect is a result of growth in large urban centers.

As can be noted in Figure 4.2, the population of the NSRB urban population will account for 75% of the total river basin population, while the First Nations communities will account for approximately 12% by 2060.

[34] 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 over the 2010-2060 period.

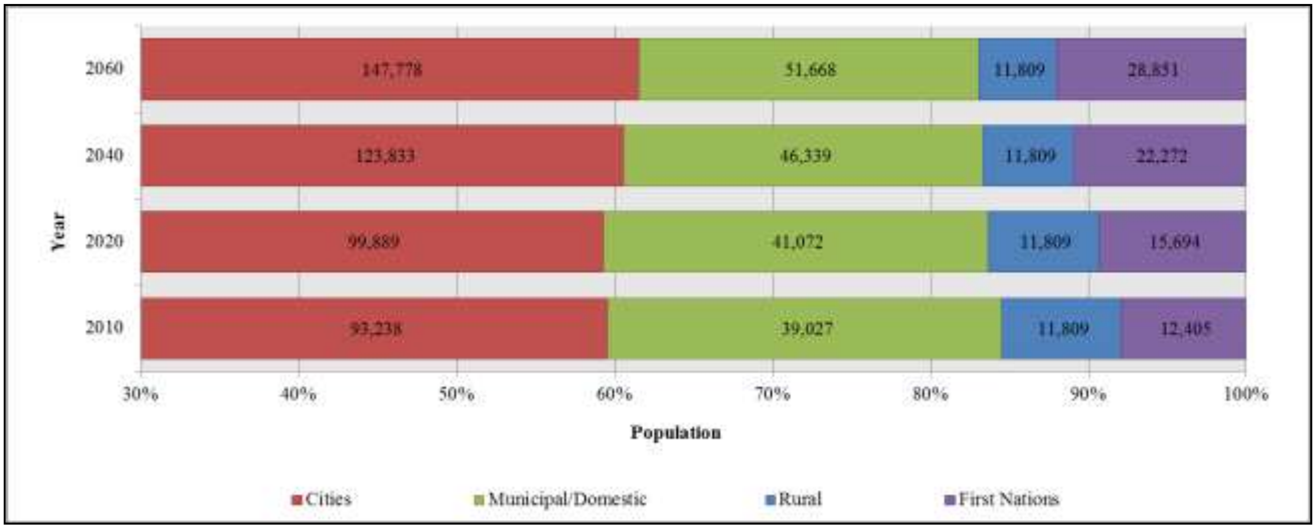

Figure 4.2: Distribution of Population by Type of Major Population Groups, North Saskatchewan River Basin, 2010 – 2060

4.5.2 Estimation of Future Water Demand per Capita

Regression analysis was carried out to determine the effect of population and time trend on per capita water consumption over the sample period (1995-2009). The estimations were done individually for each type of community located in NSRB. In order to estimate the future water demand per capita for each type of community two factors were included: Trend over time, which could be reflective of water conservation and other influences,[35] and size of the community. The latter factor reflects the sizes of economies and their effects on water management. A summary of the results and effects of these factors is provided in Table 4.35.

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

- For the communities showing no trend in water demand, and no effect of community size, the last five-year (2005-2009) average water demand was taken as the per capita figure for 2010, 2040, and 2060.
- For communities that exhibited effects of community size, an adjusted water demand coefficient was estimated.

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

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

Communities Showing No Effect of Trend or Size	Communities Showing Effect of Community Size but No Effect of Trend
North Battleford, Prince Albert	Lloydminster
T<1000	T>1000
First Nations	Villages

Source: Compiled from results shown in Appendix H.

The results of the above adjustments on per capita water demand coefficients for various types of communities are shown in Table 4.36. The regression results are presented in Appendix H. Communities that are expected to increase their future population indicate a decrease in water consumption per capita: North Battleford, Lloydminster, and towns with a population above 1000. Rural communities are assumed to record declines in population, and their water demand per capita is expected to rise.

Table 4.36: Water Demand Coefficients on a per Capita Basis in m^3 by Community Type, North Saskatchewan River Basin, 2010 to 2060, for No Climate Change or Water Conservation Scenarios

Community Type	Water Demand per Capita (m^3)			
	2010	2020	2040	2060
North Battleford	119.52	119.52	119.52	119.52
Prince Albert	147.77	147.77	147.77	147.77
Lloydminster[1]	150.79	140.94	123.13	107.57
T>1000	142.06	133.89	118.43	103.67
T<1000	117.01	116.33	115.16	113.71
Villages	129.50	133.32	136.95	135.57
First Nations	74.33	74.33	74.33	74.33

[1] Reasons for the city of Lloydminster to reduce the water use while the other two cities have not requires further investigation.

4.5.3 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 used bottled water, and if it was a non-municipal source of water, the percentage using bottled water was 39%. Making an adjustment requires a study of factors affecting bottled water in various communities. Some communities with water quality (taste or odour) issues probably consume more bottled water. However, that is not the case with all communities or all water users. Given that this type of study was not found for Saskatchewan, it was decided not to make any adjustment here in per capita water demand for purchased bottled water.

4.6. Recreational Communities' Population Forecast

Recreational water demand represents a sum of two types of: One, for recreational villages, and Two, for recreational facilities such as parks and other similar areas.

For estimating the future population of recreational villages, regression analysis was carried out. These communities revealed a trend over time. The results are shown in Table 4.37 for the three resort villages located in the NSRB. All three villages -- Aquadeo, Cochin, and Metinota Resort Villages -- are expected to increase their populations by 2060 for a total of 1,010 people – almost three times their current population.

Table 4.37: Estimated Resort Villages' Population for North Saskatchewan River Basin, 2010 to 2060

Category	Number of People in				2060 Population
	2010	2020	2040	2060	
Aquadeo Resort Village	123	184	245	367	198.37%
Cochin Resort Village	122	187	251	381	212.30%
Metinota Resort Village	84	129	173	262	211.90%
Total Population	**329**	**499**	**669**	**1,010**	**206.99%**

Regression analysis was undertaken to test whether there is any trend in the per capita water demand for the recreational villages. Results were negative. For this reason, future water demand per capita was assumed remain at the current level, are shown in Table 4.38.

Table 4.38: Water Demand per Capita for Recreational Communities in the South Saskatchewan River Basin, 2010 – 2060

Community Type	Water Demand Per Capita (m^3)			
	2010	2020	2040	2060
Aquadeo Resort Village	168.00	168.00	168.00	168.00
Cochin Resort Village	88.94	88.94	88.94	88.94
Metinota Resort Village	178.24	178.24	178.24	178.24

For the NSRB parks and other recreational sites, water demand was examined for a time trend. The results suggested that the level of water demand does not exhibit any trend. For this reason, an average water demand of 43.06 dam^3 per annum was applied for all years. Limited space and the resulting congestion could act as a ceiling on the use of the parks and recreational vehicle sites. As well, weather that is suitable for the activities offered by these sites is the main determinant of their attendance. A cool wet summer, compared to a hot dry summer, would generate significantly different levels of use.

4.7 Indirect Anthropogenic Water Demands

Four water demands are included in this category: environmental purposes, instream needs, evaporation losses from surface water bodies, and apportionment purposes. These are described below.

4.7.1 Environmental Water Demand

As shown in Table 3.22, environmental projects have an annual allocation of 41,937 dam^3 of water. For the future time periods, it was assumed that this demand will remain static.

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. However, no information was found for any specific amount to save this purpose. This water was assumed to be zero for this study.

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 have positive or negative effects on the rate of evaporation, with little or no guide as to how these influences will play out to 2060. The base coefficients for 2010 are employed in estimating the future evaporation water demand; rates were assumed to remain the same as the current ones, as presented in Table 3.22.

4.7.4 Apportionment Water Demand

As noted in Chapters 2 and 3, since the North Saskatchewan River does not cross any provincial boundaries, there is no obligation for this purpose. This water demand was assumed to be zero. The nature flow of the river is adequate to cover the apportionment demand

Chapter 5

Current and Future Water Demand Evaluation Scenarios

Current and future water demands for the NSRB 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 estimations 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 taken as a reference for comparison against an alternative scenario selected from a list of alternatives that are relevant to the study at hand. In this study, the baseline scenario includes changes 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 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 different impacts on water consumption. These changes are also reported in Chapter 4.

Water demand under the baseline scenario reflects the past trends and the best judgment according to available evidences. However, as is true of any forecast, these predictions 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[36]. The essential question is whether Canadians (and those in the NSRB) can manage a change in the water

[36] It should be noted that climate change would affect the basin in two ways: (1) climate change in the mountains would affect the river flows and thus water supply; and (2) climate change in the basin would affect water demand. These two types of changes may be either synergistic or antagonistic.

resources that they put on their crops, run through their turbines, and pipe into their homes (Paraphrased from Waggoner, 1990).

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

5.2.1 Impact of Climate Change on Water Demand

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

- 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 is not relevant to the basin or to the province of Saskatchewan, since it does not have any coastal areas.)

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

Two major alterations that could also occur are: variations in average temperature (and resulting evapotranspiration) and extreme events. Two types of extreme events are expected: 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 remind us that all Global Climate Models (GCMs) project future increases of summer continental interior drying and its associated risk of droughts. A main reason for this greater risk is the increasing temperatures and resulting potential evapotranspiration not being compensated for by projected changes in precipitation and longer warm seasons.

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

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

Even with this early accumulation of literature, knowledge of the future possible characteristics of drought and intense precipitation and/or excessive rainfall remains a significant knowledge gap that is vital to address. These weather 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 differs from one location to the other. A site-specific assessment of such changes would be more meaningful.

Kulshreshtha et al. (1996) developed a conceptual model to estimate agricultural (irrigation and livestock) water use for the expected climate change. Water demand was affected by the direct effect of climate change on water requirements, indirect effects of climate change on water requirements, and policy-induced impact of climate change on water requirements. The direct effect was a result of change in the water production function and in stockwatering requirements. The indirect effects included impact on water delivery systems and on prices of food products, thus 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. The researchers also predicted that the transfer of water will be of increased importance in a warmer climate.

Cooper (1990) predicted that, 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 for those from hydroelectric dams, are important to stream recreation. Water quality and depth affect fishing, swimming, and diving. Climate change can affect water quality through altering the low flow of the diluting water that defines quality in a stream, the quantity of water that dilutes pollutants in a lake, and the storms that flood sewers and erode fields (Waggoner and Revelle, 1990).

This review suggests various implications of climate change on water resources. The impact on water demand may come through the direct impact of climate characteristics, but also through indirect linkages. Two important indirect linkages occur through water quality and water availability. The former may affect water demand for domestic water use, as well as for recreational purposes. The availability is also a major factor in determining water demand patterns – the adoption of water-saving mechanisms may become more popular among consumers. However, this aspect is dealt with in the next scenario – the water conservation scenario. In the following section, only the direct impact of climate characteristics is described.

5.2.3 Incorporation of Climate Change Impacts in the Study Estimates

Climate change could create two types of factors that will 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 specifically for Canada and its regions (such as the NSRB).

5.2.3.1 Effect of Temperature Change

The Canadian Climate Change Scenarios Network (CCCSN)[37] 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 NSRB was selected their temperate forecasts were obtained. The average temperatures at these two locations reflected 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 applied 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 temperatures on water demand can be accounted for by estimating the time over which the increased water demand will occur, then multiplying by coefficients that have measured water demand at these increased temperatures. It is assumed for the purposes of this study that the water coefficients in estimating the 2010 demand will be reasonable for estimating 2020 levels. The water demand coefficients for 2040 and 2060 were estimated by applying the increased consumption of water caused by the temperature rise to the yearly demand then calculating an average daily use.

A warmer climate to 2040 and 2060 will result in increased heat units enabling the use of corn varieties with greater production potential. A warming climate to 2060 favors heightened corn and soybean production, as these crops are better adapted to taking advantage of the higher heat units. Corn also has a higher water demand coefficient, compared to present feedgrains. As well, certain corn varieties have higher yield potentials relative to the varieties currently grown in Saskatchewan and to barley silage. These changes may induce more feedlots and corn-based ethanol production.

A warmer and drier climate will also enhance people's participation in water related recreational activities[38]. Included here are both consumptive and non-consumptive water demand activities. Consumptive activities may include utilizations of provincial parks, which may result in

[37] For details see CCCSN (2011).

[38] 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.

additional recreational areas being developed. Non-consumptive activities may include swimming, boating, and other types of recreational activities.

5.2.3.2 Effect of Extreme Events

Another aspect of climate change is the frequency of extreme events – droughts and excessive rains. Based on the past yield records, it appears that during the last 50 years, there have been four major droughts – 1961, 1988, 2001, and 2002 (Wheaton et al., 2005). Recent droughts and excessive moisture events can be considered harbingers of the extremes likely to occur[39].

As noted above, relative studies have also predicted the increasing frequency of extreme events – both droughts and intense rains over the same time period (the latter may perhaps compensate the effects of drought conditions in some years). A precise forecast of such events is very complex. Some arbitrary decisions were made.[40] It was assumed that drought frequency by 2020 would remain unchanged (from the current 8%). As noted above, by 2090 drought frequency is expected to triple. A straight line projection was utilized to estimate the future frequency of droughts: 13% by 2040 and about 18% by 2060.

With respect to floods, no Canadian study was found that has predicted these events for the scenarios of climate change; however, Drakup and Kendall (1990) state that large-scale spring ravine flooding is expected to decrease because of an expected increase in winter runoff and a decrease in 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 consumers aware of water shortages, and to convince them to adopt water conservation practices. This aim has been accomplished through several types of measures, including a switch to lower water use appliances (i.e., rebates for low flush toilets). Programs of various types to educate the public on the use of water have been and are being implemented. The urgency or force of the approach seems to depend on immediate supply side problems, (i.e., drought, and plant shutdown, among others). These factors influence the adoption of water conservation and thereby affect water demand. However, to predict such

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[39] This statement is based on studies looking at the Saskatchewan as a whole. No study was found that has reported drought and heavy precipitation events' frequency in the NSRB.

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

attentions is somewhat problematic without a comprehensive study of attitudes the willingness of people to adopt water conservation measures.

5.3.1 Introduction to Water Conservation

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

For the dwindling water supplies (as expected for the climate change), water conservation provides an avenue to balance demand with supply. In addition, there could be several benefits of saving water, such as (i) conserving water saves money for consumers; (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 expanded more efficiently because less energy is needed to heat water and to pump potable water and wastewater; (v) conserving water stimulates job creation. New economic activities are triggered for water-related manufacturing and service sectors, encouraging new business opportunities and job creation; and, (vi) conserving water is environmentally friendly. Reducing water use helps to preserve and protect fish and wildlife habitats. These natural attractions are essential to the economic health of any provincial economy attracting tourism and outdoor recreation industries. According to Vickers (2004), 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 (p.187).

Although some of the work on water conservation examined the context of drought mitigation (since droughts cause severe shortages of water), it can be a tool for normal time periods as well. Albeit that 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 for people to adopt water conservation practices. Examples of water wastes in various situations include the following:[41]

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

- **Residential and domestic water demand**: old, inefficient plumbing fixtures and appliances, leaking toilets and faucets, wasteful water use habits.
- **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 expenses 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 most reliable in achieving long-term water savings because they typically need to be installed only once and thereafter require no on-going effort to maintain water savings. In contrast, educating people to adopt low water use methods requires considerable time and effort. Several factors play a role in changing human behavior to adopt water conservation measures. Relative net benefits from such adoption are 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 demand in various applications. These are shown in Table 5.1.

The various measures suggested for water conservation include a combination of hardware and behavioral types. In all types of water demand, pricing is noted as a primary incentive for change behaviors of consumers to adopt water conservation measures. These rates ought to be conservation oriented – i.e., they would provide a motivation to the water users to think ahead (and possibly to adopt) water conservation measures.[42]

Changing the hardware is clearly one way to conserve water in different circumstances, although the nature of equipment would differ among users. For example, domestic (indoor) water

[42] 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.

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 by practicing proper irrigation scheduling. The reuse of water in industries and commercial establishments can also be a measure to consider.

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

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	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 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 could be reduced by 100%. These ranges show the level of uncertainty that exist in this area.

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

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

Source: Vickers (2004).

5.3.2 State of the Art in Water Conservation

5.3.2.1 Measures for Water Conservation

As noted in Section 4.2.4, information on water conservation in Saskatchewan is not available. Even the review of existing studies 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 the appropriate practices. The literature suggests that policy measures are required for bringing about such a change. Most studies advise the implementation of economic instruments (water pricing) or regulations. Increased water rates can be a strong incentive for water users to reduce excessive outdoor use, since low and middle residential (and non-residential) customers tend to be sensitive to price (paraphrased based on Vickers, 2001, p. 143).

Both types of changes to actualize water conservation are subject to public decision making which is highly unpredictable for any jurisdiction, including Saskatchewan. To incorporate the effect of water conservation on NSRB 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 demands 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, the current water requirement of 20 litres per flush[43] can be reduced to 2 to 6 litres. This would reduce water

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

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 demand for cleaning and lawn irrigation.[44]

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

Appliance or purposes	% of Home Indoor Water	Water Requirements (Litres)		
		Unit	**Old**	**New**
Toilets	**40%-45%**	Litres per Flush	20	2 to 6
Shower Heads	**17%-22%**	Litres per minute	10 to 20	2 to 5
Faucets	**10%-15%**	Litres per minute	10 to 20	2 to 5
Washing Machines (Laundry)	**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 (Laundry)		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. Their experiences are summarized in Table 5.4,

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

and they reveal that a variety of water conservation measures have been undertaken by various jurisdictions. Among these, rate increase and/or altered rate structure and public awareness programs are most common.

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 form 800L/cap/day to 650L/cap/day during two years	9.4%	Infrastructure improvements, Retrofit, Pilot audit of large volume water users, Pilot water treatment plant, Increased meter reading, Public awareness program	Waller and Scott (1998)
Yellowknife, NWT	30% decrease over four years	7.5%	Infrastructure improvements, Retrofit, Rate increases, Altered rate structure, Exterior use, Public awareness program	Waller and Scott (1998)

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

** Mid-value

The detection of leaks through infrastructural improvements and retrofitting are also among these programs.[45] The results of such water conservation measures have been an astounding success. In all[46] cases examined here, water demand was reduced and in some cases the decrease led to deferred savings in new infrastructural investments.

In terms of annual water use reduction, results vary from a high of 30% in Bogor, Indonesia, to a low of 2.9% for New Glasgow, Nova Scotia.[47] Within Canada, the range in reduction of residential (indoor) consumption ranges from 2.9% to 12.5%. One should also note that the higher rates of decrease are associated with 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 response to a price change (a popular water conservation measure). Water costs seldom account for more than one percent of the total cost of production in many industrial firms. Few studies have been done on the interaction of water price and the price of inputs other than water (Renzetti, 2002). Studies of cost structure for various types of industrial water demand in Saskatchewan are needed.

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

At the same time, relative water shortages in various locations and 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.

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

[46] 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.

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

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. One study by Babooram and Hurst (2010) reports results of a Statistics Canada survey of households regarding their adoption of water saving devices. These results indicate the following adoption levels:

Low-Flow Showerheads	=	64%
Low Volume Toilets	=	42%
Rainwater collection devices	=	17%

In general, less expensive measures have a higher chance of being adopted than do the more expensive ones. The study also finds that people who owned their homes were more likely to adopt such strategies than users those who rent.

For the city of Guelph, Oraclepoll Research (undated) reported that only 40% of the residents indicated having made some changes to reduce their water demand. 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.[48] The program started on January 1 2009. By the end of October 2011, some 30,098 households had availed the rebate[49] 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 their rate of adoption, a scenario approach was followed. This scenario involved potential level of water conservation and rates of adoption of water conservation practices. Because of uncertainties in potential water conservation, a mid-value of the interval shown in Table 5.2 was taken as the potential reduction. For domestic water demand as proportion of demand indoors and for lawn irrigation, an equal proportion 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 types of consumers, an adoption rate of 1% per annum was assumed. Adjustment factors for water conservation are shown in Table 5.5.

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

[49] 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, Resulting from Adoption of Water Conservation Practices, North Saskatchewan River Basin

Type of Use	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

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

As noted in Chapter 2, agricultural water demand was disaggregated into five types. Estimates of agricultural water needs were made for each of these types. Their presentation is divided into the same five sections, as noted earlier – Irrigated crop production, Dryland crop production, Livestock, Greenhouses and Nurseries, and Aquaculture.

6.1 Irrigation Water Demand

6.1.1 Irrigation Water Demand – Baseline Scenario

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

In 2010, irrigation used 39,344 dam^3 of water. By 2060, irrigation will need a total of 70,782 dam^3 of water, an increase exceeding the 2010 level by almost 80% over. Major increases are expected between 2040 and 2060, when irrigation water demand in the NSRB-Westside Irrigation Project is forecasted to expand. Most of this increase for irrigation is predicated on the development of the NSRB-Westside Irrigation Project, although some private irrigation in this area may also develop.

In the estimation of the irrigation water demand, an assumption was made that future irrigated areas will be served through sprinkler irrigation. Surface irrigation requires more water per unit of land, and is therefore not the most efficient. As shown in Figure 6.1, the future water demand in the area served through sprinkler irrigation will increase significantly, whereas the surface irrigated area will remain constant at the 2010 level. It is conceivable that the existing surface irrigation area may also be converted to sprinkler irrigation[50]. However, that assumption would have required more knowledge about attitudes of producers regarding water conservation, which was not available. Such performance and attitudes therefore considered beyond the scope of this study.

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

Irrigation System	Water Demand in dam^3 for			
	2010	2020	2040	2060
Wheelmove	5,616	5,616	5,616	5,616
Pivots	10,978	12,311	21,209	42,415
Linear	141	141	141	141
Misc. Sprinklers	2,482	2,482	2,482	2,482
Surface	961	961	961	961
200mm Backflood	1,392	1,392	1,392	1,392
Misc. Backflood	16,515	16,515	16,515	16,515
Remainder	1,260	1,260	1,260	1,260
Total Water Demand	**39,344**	**40,677**	**49,576**	**70,782**
% Change over 2010		3.4%	26.0%	79.9%

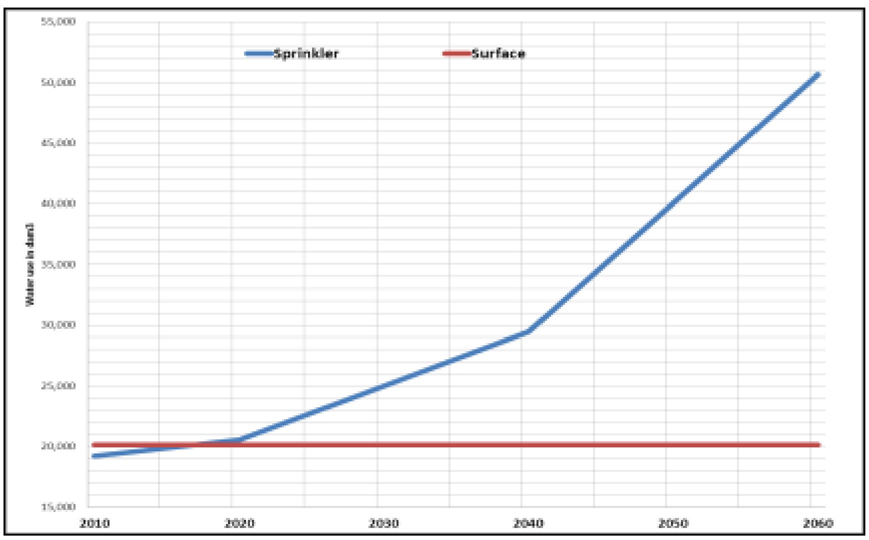


Figure 6.1: Future Irrigated Water Demand in the North Saskatchewan River Basin by Type of Irrigation, 2010 - 2060

[50] It is conceivable that on account of reliable flow of water in the NSR, n irrigators in this basin may be good candidates for adoption of high efficiency irrigation systems (Based on Persona Communications with Mr. Bob Halliday).

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, the distinction between district and private irrigation was maintained. In addition, climate change was taken into account in estimating the future water demand coefficients.

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

Lundstrom and Stegman (1995) estimated the daily needs 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. The increased water demand of a crop can be estimated using data in Table 6.2, and given the number of days and the rise in temperature range.

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

Table 6.2: Moisture Deficit Number of Days Times Deficit

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)

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 type of crops using this irrigation water 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 also change, depending on investment in intensive livestock operations in the region because the demand for silage from feedlot cattle operations could significantly change the crop mix. However, no further information is available at this time.

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

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

CWRS = Canadian Western Red Spring Wheat; CSWS = Canadian Soft White Spring wheat; CWAD = Canadian Western Amber Durum.
Source: [a] ICDC (2008a).
[b] Estimate of 212 mm for crops maturing in 105 days or less, and 237.5 for crops over 105 days of maturity includes the average spring soil moisture and growing season precipitation.
[c] Crop requirement minus the average precipitation and soil moisture reserve.

In addition to elevated in water demand from higher temperatures and lower precipitation (or lower soil moisture), droughts can also increase crop water requirements. On account of a lack of NSRB 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 demand per acre (WD) for the period of 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 below.

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

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

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

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

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.

The only significant coefficient in equation (6.1) was that for the binary variable for 2001 and 2002 droughts. Thus, the occurrence of droughts can increase water demand in non-pipeline systems. The increase during the 2001 and 2002 drought represented an average of 178.38 mm per acre. This amount is 68.8% above the water required 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%. Also noted earlier, the estimated frequency of future droughts was 13% by 2040 and about 18% by 2060. Assuming that, in a drought year, one would need 178.4 mm more water, water demand per acre of irrigated land for 2040 was adjusted up by 23 mm and that for 2060 by 32 mm,[51] given the frequency of drought in 2040 and 2060.

The total amount of water required for irrigation under the climate change scenario is shown in Table 6.4. By 2060, water demand is estimated at 89,639 dam^3. This amount is 27% higher than the amount calculated under the baseline scenario.

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

Table 6.4: Estimated Water Demand for Irrigation in the North Saskatchewan 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	5,616	5,616	6,581	7,120
Pivots	10,978	12,311	24,892	53,891
Linear	141	141	165	178
Misc. Sprinklers	2,482	2,482	2,920	3,166
Surface	961	961	1,131	1,226
200mm Backflood	1,392	1,392	1,392	1,392
Misc. Backflood	16,515	16,515	19,425	21,060
Remainder	1,260	1,260	1,482	1,607
Total Amount of Water Demand	**39,344**	**40,677**	**57,987**	**89,639**

6.1.3 Irrigation Water Demand – Water Conservation Scenario

Irrigation water demand can be reduced through water conservation by a variety of methods. Some notable avenues include

- Conversion of surface irrigation areas to sprinkler irrigation;
- Adoption of existing water conservation measures for sprinkler irrigation;
- Improvement in irrigation technology in the future.
- Changing crop mix through replacing higher water requirement crops by lower water requirement crops;
- Changing 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 4.3. If a contour flooding system is in use, converting it to sprinkler would gain 42-49% in terms of water use efficiency. Similarly, there is a 7% gain for sprinkler irrigation if high nozzle systems are converted to drop tube systems.

The current overall system efficiency of irrigation in the NSRB is estimated at 56%, given the current irrigation technology (as shown in Table 6.5). In other words, it currently takes on average 541 mm of water per acre to get 300 mm to the crop. If the wheelmove, Pivots, and miscellaneous sprinklers technologies were adopted (with an improved efficiency of 79%), then the basin irrigation efficiency would increase to 61%. In this case, an average 489 mm of water per acre would be needed to get 300 mm to 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 the adoption of more efficient irrigation technology (Bjornlund et al., 2009). The price of water plus pumping cost and the cost of the upgrade are the main cost determinants affecting the adoption of improved irrigation technology.

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

Efficiency of the System	**Irrigated Acres**	**% of total Acres**	**2010 System Efficiency**		**Improved System Efficiency**	
			System	**NSRB**	**System**	**NSRB**
Wheelmove	3,606	15.3%	65%	9.9%	79%	12.1%
Pivots	8,212	34.8%	75%	26.1%	85%	29.6%
Linear	104	0.4%	75%	0.3%	79%	0.3%
Misc. Sprinklers	1,595	6.8%	65%	4.4%	80%	5.4%
Surface	427	1.8%	45%	0.8%	60%	1.1%
200mm Backflood	1,719	7.3%	0%	0.0%	30%	2.2%
Misc. Back Flood	7,344	31.2%	45%	14.0%	60%	18.7%
Remainder	560	2.4%	45%	1.1%	60%	1.4%
Total	23,567	100.0%		**57%**		**71%**

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

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 uses, including more irrigation (Bjornlund et al., 2009). Faced with a fixed supply of water, farmers will allocate the resource to its highest value purpose. The initial allocation of water and its allocation changes over time will have more of an effect on the net water consumption by irrigators than will changes in technology.

The potential for reducing irrigation water demand is quite complex, since it is affected by several factors. In agricultural (field) irrigation, a reduction in water demand can be achieved through various types of changes, including an altered crop mix, water efficient equipment, and improvements in water conveyance systems, among others. Various water delivery systems to the field have different water efficiencies as shown in Table 6.6. Backflood systems, for example, are only 30-55% efficient, in comparison to 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 NSRB 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 illustrated in Table 6.8. By 2040, a moderate increase in water will be expected. This level will be 59,894 dam^3, some 17% higher than that calculated under the baseline scenario. By 2060, the effect of climate change would result in an even higher increase in water demand, as shown in Figure 6.2.

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

Irrigation System	Total Irrigation Water Demand in dam^3			
	2010	**2020**	**2040**	**2060**
Wheelmove	5,616	5,214	4,867	4,867
Pivots	10,978	10,291	18,714	37,425
Linear	141	141	141	141
Misc. Sprinklers	2,482	2,305	2,151	2,017
Surface	961	865	786	721
200mm Backflood	1,392	1,392	1,392	1,392
Misc. Back Flood	16,515	14,863	13,512	12,386
Remainder	1,260	1,134	1,031	945
Total Irrigation Water	**39,344**	**36,206**	**42,594**	**59,894**

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 Chapters 3 and 4, and the estimated water demand itself is reported in this section.

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

Year	Climate Change Scenario		Water Conservation Scenario	
	Amount of Water Demand (dam^3)	% Change from Baseline Scenario	Amount of Water Demand (dam^3)	% Change from Baseline Scenario
2010	39,344	0%	39,344	0%
2020	39,344	-3%	36,206	-11%
2040	57,987	17%	42,594	-14%
2060	89,639	27%	59,894	-15%

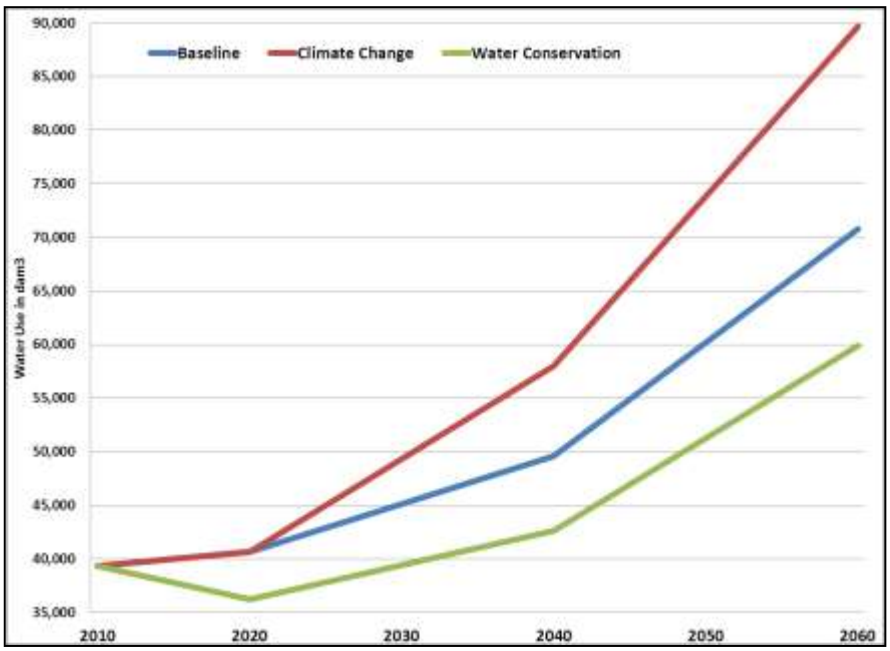


Figure 6.2: Irrigation Water Demand under Alternative Scenarios, North Saskatchewan River Basin, 2010 - 2060

6.2.1 Dryland Crop Water Demand – Baseline Scenario

The estimated crop area by crop category from Table 4.5 was multiplied by water coefficients that account for spray volume needed for the crop category, number of passes, extent of zero tillage adoption, and cleanup of sprayer. The results are presented in Table 6.9. In 2010, producers have used 296 dam^3 of water for spraying purposes. By 2010, this water would decrease slightly to 286 dam^3. This effect occurs 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, and subsequently, a change in water demand for this purpose.

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

Crop Type	**Water Demand for in dam^3**			
	2010	**2020**	**2040**	**2060**
Cereals	124.7	122.5	120.5	120.5
Oilseeds	80.8	88.9	78.2	78.2
Pulses	65.3	58.6	63.2	63.2
Fallow	25.0	18.9	24.2	24.2
Total Amount of Water Demand	**295.8**	**288.8**	**286.0**	**286.0**
% Change from 2010 Level		-2.4%	-3.3%	-3.3%

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 during climate change, given the crop rotation limitations. The type of crops within the crop category is likely to change as farmers adopt crops to fit the new climate regime. However, the number of pesticide applications needed for the replacement crops will not differ greatly from the crops currently grown. The major change to be experienced under climate change is the adoption of zero tillage. This proportion will 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 5.3% over the 2010 level by 2060 (Table 6.10). The indirect effect of climate change -- higher evaporation -- may make some surface water bodies currently used as sources unsuitable, a situation which may also have some implications for water-based recreation activity.

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

Crop Type	**Water Demand in dam^3**			
	2010	**2020**	**2040**	**2060**
Cereals	124.7	122.5	127.3	134.2
Oilseeds	80.8	88.9	79.8	81.5
Pulses	65.3	58.6	65.5	67.8
Fallow	25.0	18.9	27.3	28.0
Total Amount of Water Demand	**295.8**	**288.8**	**299.9**	**311.5**
% Change from 2010 Level		-2.4%	1.4%	5.3%

6.2.3 Dryland Crop Water Demand – Water Conservation Scenario

Technology developments in weed elimination using hot water or lasers could be employed by 2060, as advances in computing technology and pattern recognition improve along with emerging GPS guidance systems. The 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 will 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 could decrease considerably, particularly by 2060, under these assumptions. As much as 50% reduction in pesticide water demand is estimated for 2060 period.

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

Crop Type	Water Demand for in dam^3			
	2010	**2020**	**2040**	**2060**
Cereals	124.7	122.5	108.4	60.2
Oilseeds	80.8	88.9	70.4	39.1
Pulses	65.3	58.6	56.9	31.6
Fallow	25.0	18.9	21.7	12.1
Total Amount of Water Demand	**295.8**	**288.8**	**257.4**	**143.0**
% Change from 2010 Level		97.6%	87.0%	48.3%

6.3 Stockwater Demand

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

6.3.1 Stockwater Demand -- Baseline Scenario

Stockwater demand was estimated by the type of animals, following the methodology as reported in Chapters 3 and 4. The estimated water demand for various types of livestock is presented here by livestock category. These results for dairy and cattle herds in the NSRB for the 2010 - 2060 period are presented in Table 6.12. The largest amount of water is needed for the beef cow herd, followed by that for feedlots and calves. Dairy animals are relatively fewer in number, and thus have a lower water demand than beef herds. By 2060, this water demand will increase by roughly 12.5% of the 2010 level.

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

Livestock Type	Water Demand in dam^3			
	2010	**2020**	**2040**	**2060**
Bulls	187.7	201.3	217.8	222.1
Milk Cows	330.3	303.2	297.2	303.1
Beef Cows	3,619.3	3,881.0	3,958.6	4,037.8
Milk Heifers	38.4	35.3	34.6	35.3
Beef replacement Heifers	513.3	512.6	561.4	572.6
Feedlot	569.6	630.5	693.5	762.9
Calves	1,743.9	1,870.0	1,907.4	1,945.5
Total	**7,002.4**	**7,434.0**	**7,670.4**	**7,879.3**
% Change from 2010 Level		6.2%	9.5%	12.5%

For hog production, Agriculture Canada's Medium Term Outlook (see AAFC 2011) estimates were utilized. 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 NSRB, the 3.5% increase is allocated to estimate the size of the breeding herd for 2020, 2040, and 2060. From the estimates of the size of the breeding herd, the numbers 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 NSRB appears in Table 6.13. The projection is for an 11% increase in the water necessary for hog production in 2060.

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

Type of Animal	Water Demand in dam^3			
	2010	**2020**	**2040**	**2060**
Gestating Sows	30.0	31.0	32.1	33.2
Lactating Sows	7.8	8.1	8.3	8.6
Suckling Pigs	3.9	4.2	4.5	4.9
Weaned Pigs	14.8	15.3	15.8	16.4
Grower Finishing Pigs	403.2	417.2	431.7	446.7
Boars	1.3	1.4	1.3	1.2
Total	**461.0**	**477.3**	**493.9**	**511.1**
% Change from 2010 Level		3.5%	7.1%	10.9%

The projection for sheep is a 23% increase in production from 2010 to 2020 (Table 6.14). Their total water demand in 2060 would increase to 18 dam^3 by 2060 from 14.7 dam^3 in 2010.

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

Type of Animal	**Water Demand in dam^3**			
	2010	**2020**	**2040**	**2060**
Rams	0.45	0.54	0.54	0.55
Ewes	10.80	13.00	13.13	13.26
Breeding	2.13	2.56	2.59	2.62
Slaughter	1.30	1.57	1.58	1.60
Total Water Demand	**14.7**	**17.7**	**17.8**	**18.0**
% Change from 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 chickens, turkeys, shell eggs, and processing eggs at 2020 over the 2010 levels in Canada (AAFC 2011). The production for these agricultural commodities is controlled by quotas allocated to the provinces to meet provincial demand. A growth in population, along with changing demographics and tastes, can additionally affect the demand for poultry and egg products. The expected change in Saskatchewan's population from 2020 to 2036, as forecasted by Statistics Canada (2011c) by using a number of scenarios, ranges from 0.0% to 18.4%. A reasonable estimated increase in population for Saskatchewan would fall into 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 population, was employed. The estimates for the poultry and egg water demand in the NSRB are presented in Table 6.15. In 2010, this sector used 697 dam^3 of water per year. By 2060, the amount would increase to 927 dam^3 – growth of 33% over the 2010 level.

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

Type of Animal	**Water Demand dam^3 in**			
	2010	**2020**	**2040**	**2060**
Laying Hens	27.0	29.4	32.3	34.0
Pullets	6.7	7.8	8.6	9.1
Broilers	647.0	746.1	820.7	861.7
Other Poultry	1.9	2.1	2.3	2.4
Turkeys (M)	8.8	10.3	11.3	11.9
Turkeys (F)	5.7	6.7	7.4	7.7
Total Water Demand	**697.1**	**802.4**	**882.7**	**926.8**
% Change from 2010		15.1%	26.6%	32.9%

The markets for products produced from the other livestock sector are all relatively small because their growth in the future is limited. Therefore, conservative estimates were utilized in forecasting changes in the herd size of these agricultural sectors. The water demand for the other livestock sector is presented in Table 6.16, and a moderate 2% increase is predicted. Relative to other livestock sectors (except for the sheep sector), their water demand is relatively low. In 2010, this sector used 349 dam^3, which is expected to increase to 356 dam^3 by 2060.

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

Type of Animal	**Water Demand (dam^3) in**			
	2010	**2020**	**2040**	**2060**
Bison	59.80	65.78	66.44	67.11
Horses	270.20	270.20	270.20	270.20
Goats	2.90	2.90	2.90	2.90
Llamas	4.65	4.65	4.65	4.65
Deer	10.92	10.92	10.92	10.92
Total Water Demand	**348.5**	**354.4**	**355.1**	**355.8**
% Change from 2010		1.7%	1.9%	2.1%

A summary of water demand for livestock in the NSRB is presented in Table 6.17. The total water consumed for livestock production was estimated at 8,524 dam^3 for 2010. The largest portion of this total is for dairy and beef cattle enterprises. As shown in Figure 6.3, 82% of the total livestock water is used by cattle. By 2060, this demand will increase by 13.7% of the 2010 level. During this period, there will be 9,691 dam^3 of water devoted to this purpose in the NSRB. Again, the largest share will be claimed by the dairy and beef enterprises.

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

Livestock Type	**Amount of Water in dam^3**			
	2010	**2020**	**2040**	**2060**
Dairy and Beef Cattle	7,002.4	7,434.0	7,670.4	7,879.3
Hog Sector	461.0	477.3	493.9	511.1
Sheep	14.7	17.7	17.8	18.0
Poultry and Egg	348.5	354.4	355.1	355.8
Other Livestock	697.1	802.4	882.7	926.8
Total Livestock Water Demand	**8,523.7**	**9,085.7**	**9,419.9**	**9,691.0**
% Change from 2010		6.6%	10.5%	13.7%

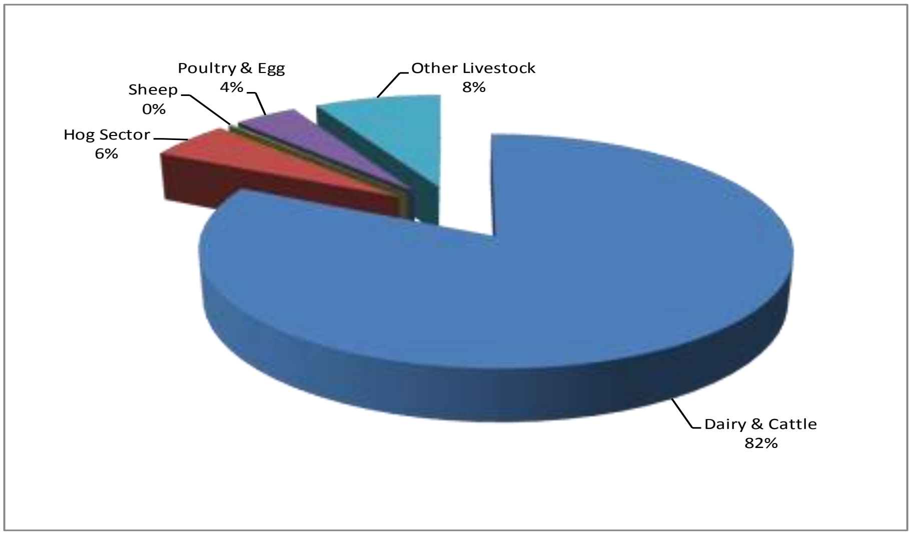


Figure 6.3: Distribution of Total Stockwater Demand in 2010 by Type of Livestock, North Saskatchewan River Basin

6.3.2 Stockwater Demand – Climate Change Scenario

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

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

Water use technology for the production of hogs has improved significantly over the last 10-15 years as bite type nipples replaced watering bowls; now, ball type nipples that reduce wastage even further are being adopted. Small (2001) surveyed hog barns in Manitoba and Saskatchewan to determine water needed for drinking, washing, cooling, and domestic. Regulations regarding the type of confinement for sows and feeders appear to be a major factor which may affect some of the water requirements. Climate change may affect both the amounts of water consumed by the hog and water used for cooling. Warmer springs and falls may extend the period over which cooling is required.

Predicted 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 as which 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.

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

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

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

* Estimations based on Small (2001).

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

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

Source: Adapted from Thacker (2001).

From the above set of information, water requirements for various categories of hogs were estimated. This involved the following steps: (i) Average normal high temperature for each month for several locations in a water basin was obtained from environment Canada. (ii) Water consumption for each month, using the corresponding coefficients from Table 4.13, was 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 6.20: Drinking Water Consumption for Swine

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

Source: Adapted from Thacker (2001).

Relating to climate change in the NSRB, no significant effect was assumed for 2020. By 2040, it was assumed that average temperatures 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 level was assumed.

Beef cattle's consumption of water is affected by time of year and feed type. As expected, the moisture content of feed 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 displayed in Table 6.21.

These estimates were used to derive water demand coefficients for beef cattle in Saskatchewan. First, the average normal high temperature for each month for several locations in a water basin was obtained from Environment Canada. Next, the water consumption for each month, following the corresponding coefficients from Table 6.21, was 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 6.6 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

Livestock 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).

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.

The water consumption estimates for dairy cattle apply the categories of milk production, given the temperature, to arrive at water demand coefficients (Table 6.23). These coefficients are then taken to estimate water consumption for the three climate regimes (Table 6.24). Water is also necessary in the cleaning of dairy operations, and 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 following the same methodology used to estimate the coefficients for the beef and dairy sector; these figures are presented in Table 6.25. Water is also needed in the cleaning of poultry operations, estimated at 1.7 litres per bird per year (Beaulieu et al., 2001).

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

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

Source: Looper and Waldner (2007)

Table 6.24: Estimated Water Demand Coefficients for Dairy Cattle

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

* 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.

The total stockwater demand for the basin under the climate change scenario is presented in Table 6.26. In 2010, a total of 8,523 dam^3 of water was used. By 2060, this consumption will experience a growth and will increase to 10,359 dam^3 – an addition of 21.5% of the 2010 level.

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.

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

Livestock Type	Amount of Water in dam^3			
	2010	2020	2040	2060
Dairy and Cattle	7,002.4	7,434.0	7,882.8	8,349.3
Hog Sector	461.0	477.3	531.0	569.1
Sheep	14.7	17.7	19.5	20.6
Other Livestock	348.5	354.4	380.0	402.0
Poultry and Egg	697.1	802.4	926.9	1,018.1
Total Livestock Water Demand	**8,523.7**	**9,085.7**	**9,740.1**	**10,359.1**

6.3.3 Stockwater demand – Water Conservation Scenario

Development of watering devices that reduce waste and adoption of new technologies 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. The 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 occur in intensive livestock operations where all aspects of the production cycle are, and will be, more closely monitored. For instance, Li et al. (2005) report typical water wastage at 26% with a range of 15% to 42%, depending on the ages of feeder pigs. They site 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 use for the poultry, hog, beef feedlot, and dairy sectors practicing water conservation will occur, while by 2060, it 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 9,318 dam^3 by 2060, as against 9,691 dam^3 under the baseline scenario – a decrease by 4% 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 North Saskatchewan River Basin for the Water Conservation Scenario, 2010 – 2060

Livestock Type	**Amount of Water in dam^3**			
	2010	**2020**	**2040**	**2060**
Dairy and Cattle	7,002.4	7,434.0	7,422.9	7,624.1
Hog Sector	461.0	477.3	469.2	485.6
Sheep	14.7	17.7	17.8	18.0
Other Livestock	348.5	354.4	355.1	355.8
Poultry and Egg	697.1	802.4	838.5	834.1
Total Livestock Water Demand	**8,523.7**	**9,085.7**	**9,103.6**	**9,317.6**

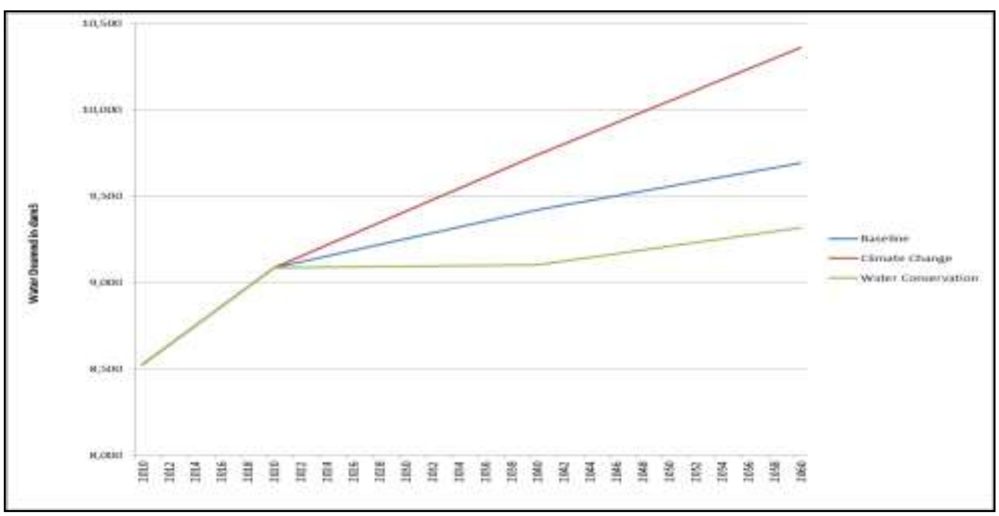


Figure 6.4: Change in the Stockwater demand in the North Saskatchewan River Basin under Alternate Scenarios, 2010 - 2060

6.4 Water Demand for Greenhouses and Nurseries

Technological developments that can increase the length of time that greenhouses can profitably operate during the year, along with management techniques to improve their efficiency, are likely to occur by 2060. The question is whether these technological improvements give the greenhouse industry a relative advantage over other greenhouse producers outside of Saskatchewan or over producers of field crop vegetables. The bedding plant and potted plant market of greenhouse production appears to be related to population growth and to disposable income. The competitiveness of the Saskatchewan greenhouse sector will determine their 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 NSRB is illustrated in Table 6.28. The growth to 2020 was estimated at 1% over 2010, following by a 5% increase from 2020 to 2040 and 2040 to 2060. The total water demand is smaller relative to other agricultural uses – only 169 dam^3 by 2060.

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

Year	Water Demand in dam^3
2010	151.7
2020	153.2
2040	160.9
2060	168.9

6.5 Water Demand for Aquaculture

As noted in Chapter 3, information on aquaculture production in the basin is very poor. Using R. Halliday and Associates' (2009) report, surface and groundwater demand for aquaculture was estimated at 4 dam^3 and 12 dam^3, respectively. It is assumed that this quantity of water will remain constant until 2060.

6.6 Total Agricultural Water Demand

In this section, all different types of agricultural water demands are summarized in this section for the three study scenarios. On account of the small amount of water used, the greenhouses, nurseries, and aquaculture water users 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 NSRB is presented in Table 6.29. Crop water demand (irrigation and pesticide spraying) is the biggest component of irrigation water and is expected to account for 95% of the agricultural sector's water demand in the NSRB in 2060. The dairy and beef cattle sectors are the next biggest component of water demand. By 2060, the basin could see an increase in this water demand by 67% -- from 48 thousand dam^3 to 81 thousand dam^3. Much of this increase will result from irrigation expansion in the basin, particularly the irrigation development in the North Saskatchewan South Project. In fact as shown in Figure 6.5, irrigation water demand dominates the total agricultural water estimates. Irrigation is the major water demand within the total agricultural requirements use at present. This situation does not change by 2060.

Table 6.29: Agricultural Water Demand in the North Saskatchewan River Basin for the Baseline Scenario, 2010 – 2060

Activity	Water Demand in dam^3 for			
	2010	2020	2040	2060
Irrigation	39,344	40,677	49,576	70,782
Livestock	8,524	9,086	9,420	9,691
Pesticide	296	289	286	286
Other Agricultural (Greenhouses, Nurseries, and Aquaculture)	168	169	177	185
Total Agricultural Water Demand	**48,331**	**50,221**	**59,458**	**80,944**
% Change over 2010 Level		3.9%	23.0%	67.5%

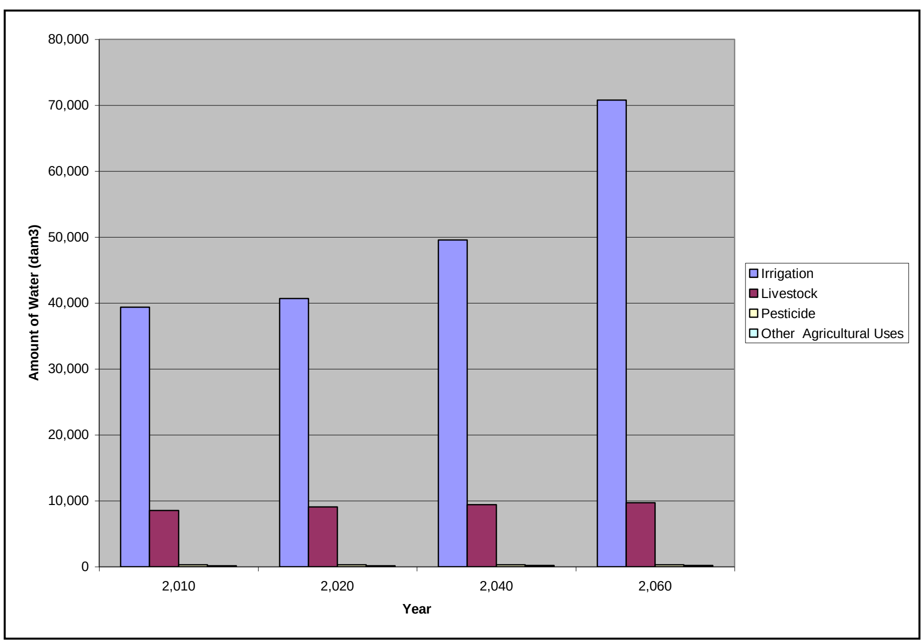


Figure 6.5: Total Agriculture Water Demand, North Saskatchewan River Basin, 2010 - 2060, Baseline Scenario

6.6.2 Total Agricultural Water Demand – Climate Change Scenario

Climate change, through increased average temperature and higher frequency of droughts, will impart a significant increase in the water demand for agriculture purposes. In the NSRB, this water demand will increase to 100 thousand dam^3, which is 108% higher than that consumed during 2010. Increases will be observed by 2040 when some irrigation in the NSRB-Westside Irrigation Project starts. Compared to the baseline scenario, the expected climate change impact by 2040 will represent an increase by 15% in agricultural water demand. By 2060, an increase in this water demand by 24% is likely (Table 6.30).

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

Activity	Water Demand in dam^3 for			
	2010	**2020**	**2040**	**2060**
Irrigation	39,344	40,677	57,987	89,639
Livestock	8,524	9,086	9,740	10,359
Pesticide	296	289	300	312
Other Agricultural (Greenhouses, Nurseries and Aquaculture)	168	169	177	185
Total Agricultural Water Demand	**48,331**	**50,221**	**68,204**	**100,495**
% Change over 2010 Level	--	1.2%	41.1%	107.9%
% Change over Baseline Scenario	--	--	14.7%	24.2%

6.6.3 Total Agricultural Water Demand – Water Conservation Scenario

The potential 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, the total agricultural water demand in 2060 could be almost 70 thousand dam^3, some 14% lower than the baseline scenario.

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

Activity	Water Demand in dam^3 for			
	2010	**2020**	**2040**	**2060**
Irrigation	39,344	36,206	42,594	59,894
Livestock	8,524	9,086	9,104	9,318
Pesticide	296	289	257	143
Other (Greenhouses, Nurseries, and Aquaculture)	168	169	177	185
Total Agricultural Water Demand	**48,331**	**45,750**	**52,132**	**69,539**
% Change over 2010 Level	0%	-5.3%	7.9%	43.9%
% Change over Baseline Scenario	0%	-8.9%	-12.3%	-14.1%

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

6.7 Source of Water for Agricultural Activities

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

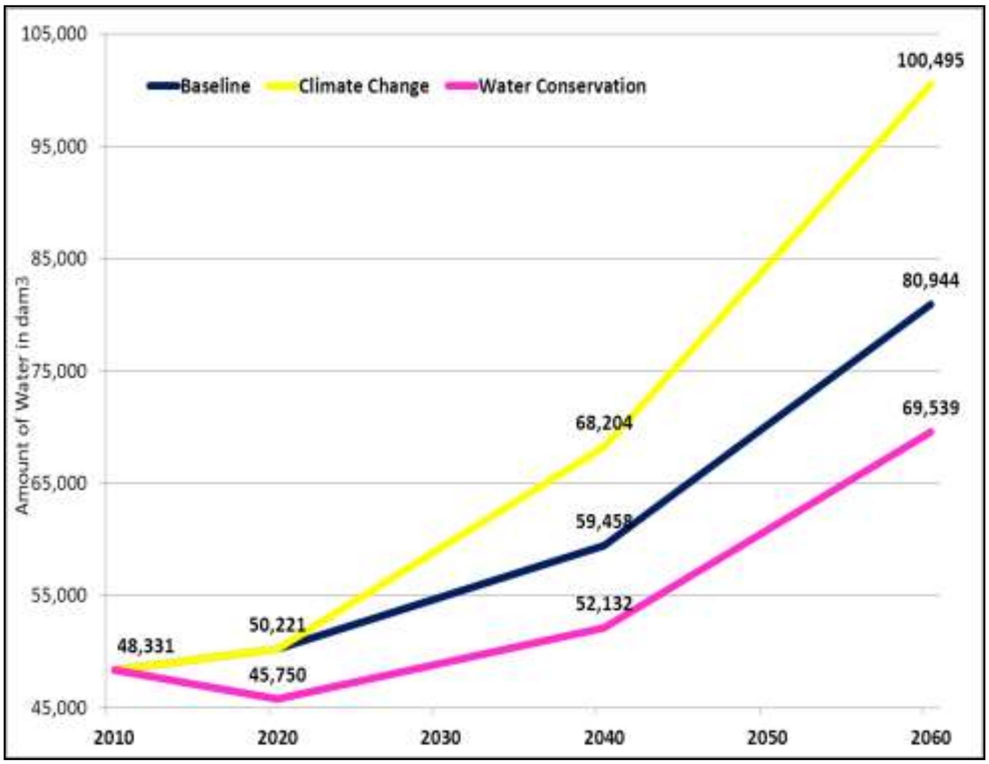


Figure 6.6: Estimated Agricultural Water Demand in the North Saskatchewan River Basin, 2010 - 2060, under Study Scenarios

6.7.1 Source of Water for Agricultural Activities – Baseline Scenario

Much of the irrigation water in the basin is supplied from surface water bodies. Other uses could withdraw water from a combination of surface or groundwater sources. The proportion of surface water consumed by agricultural activity is shown in Table 6.32. These values pertain to year

2010. On account of the lack of information, the same proportions were employed for the future years.[52] Despite the non-availability of data on the source of water, these estimates were developed by using the best set of information available. However, these predictions should be viewed as preliminary estimates, subject to primary data collection from various water users.

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

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

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 that seen in the hog and poultry sectors, along with industrial precision and monitoring of inputs -including water- to maximize production, need consistency in the quality and quantity of water. Hence, the reliability of water from a given source is extremely important for these operations. Here, a larger proportion of water is withdrawn from groundwater sources (93% in Table 6.32).

Using the proportion of surface; groundwater to total in Table 6.32, the total agricultural water demand from surface water bodies was estimated. The quantity of surface water withdrawn is presented in Table 6.33, whereas the split between groundwater and surface water for the agricultural sector appears in Table 6.34. By 2060, about 44% of livestock water and 95% of crop water will be supplied from surface water sources. For agriculture as a whole, as shown in Table 6.34, in 2010, 86% of the total water is surface water. By 2060, this proportion is expected to rise to 91% of the total. The larger proportion of crop water demand is for irrigation purposes,

[52] 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.

is expected to develop through surface water bodies, such as the water released from Lake Diefenbaker to the NSRB-Westside Irrigation project and perhaps to other water bodies. As shown in Figure 6.7, agriculture will depend more heavily on surface water in the future.

Table 6.33: Agricultural Surface Water Estimates by Type of User, North Saskatchewan River Basin, Baseline Scenario, 2010 – 2060

Type of water demand	Amount of Water in dam^3 in			
	2010	2020	2040	2060
Livestock				
Dairy and Cattle	3,501	3,717	3,835	3,940
Hog Sector	32	33	34	35
Sheep	7	9	9	9
Other Livestock	174	177	178	178
Poultry and Egg	48	55	61	64
Total Livestock	3,763	3,991	4,117	4,226
% of Total Water Demand	44.1%	43.9%	43.7%	43.6%
Crop				
Irrigated Crops	37,377	38,710	47,609	68,815
Pesticide	237	231	229	229
Greenhouse	34	35	36	38
Total Crop Water	37,648	38,975	47,873	69,081
% of Total Water	94.6%	94.8%	95.7%	97.0%

Table 6.34: Agricultural Water Demand by Source of Water in the North Saskatchewan River Basin, Baseline Scenario, 2010 – 2060

Particulars	Amount of Water in dam^3 in			
	2010	2020	2040	2060
Total Agriculture	48,331	50,221	59,458	80,944
Groundwater	6,921	7,254	7,468	7,637
Surface Water	41,410	42,967	51,990	73,307
Surface Water %	85.7%	85.6%	87.4%	90.6%

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 will increase from 41 thousand dam^3 (under the baseline scenario) to 92 thousand dam^3 under this scenario. This represents an increase of 26% over the baseline scenario. Climate change may also increase slightly the dependence of agriculture on surface water bodies, whereas 92% of the total agriculture water demand is now withdrawn from this source.

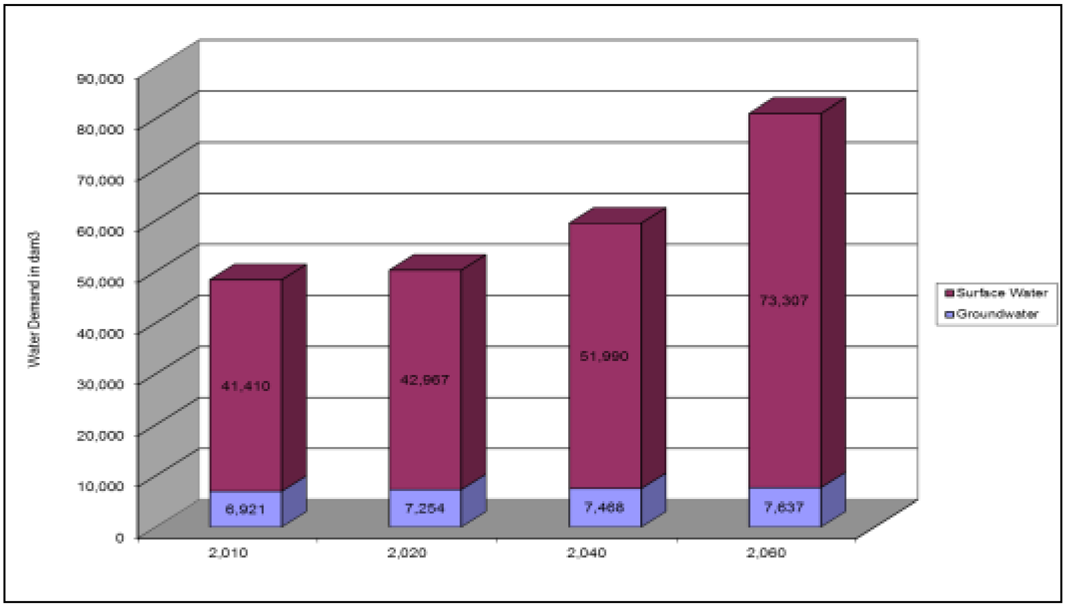


Figure 6.7: Proportion of Total Agricultural Water Demand by Source of Water in the North Saskatchewan River Basin, 2010 – 2060

Table 6.35: Agricultural Water Demand by Source of Water in the North Saskatchewan River Basin, Climate Change Scenario, 2010 – 2060

Particulars	**Total Water Demand in dam^3**			
	2010	**2020**	**2040**	**2060**
Total Agriculture	**48,331**	**48,894**	**68,204**	**100,495**
Groundwater	6,921	7,255	7,666	8,040
Surface Water	41,410	41,639	60,538	92,454
Surface Water % of Total Water Demand	85.7%	85.2%	88.8%	92.0%

6.7.3 Source of Water for Agricultural Activities – Water Conservation Scenario

The distribution of total water demand by its source under the water conservation scenario is presented in Table 6.36. The amount of surface water demand is reduced from the level in the baseline scenario. The amount of surface water demand is reduced from 73,307 dam^3 in 2060 under the baseline scenario to only 62,169 dam^3 – a reduction by 15.2% of the baseline level.

Table 6.36: Agricultural Water Demand by Source of Water in the North Saskatchewan River Basin, Water Conservation Scenario, 2010 – 2060

Particulars	Total Water Demand in dam^3			
	2010	2020	2040	2060
Total Agriculture	**48,331**	**45,750**	**52,132**	**69,539**
Groundwater	6,921	7,254	7,275	7,371
Surface Water	41,410	38,496	44,857	62,169
Surface Water % of Total	85.7%	84.1%	86.0%	89.4%

6.8 Agricultural Water Consumption

A part of the total water demand by agriculture is returned back to the original source. The methodology for estimating consumption was described in Section 3.6 of this report. The estimated water consumption for agricultural under the three study scenarios is presented in this section.

6.8.1 Agricultural Water Consumption – Baseline Scenario

Not all water removed from a water body (source) for agricultural purposes is lost. In fact, a portion of this is returned, as noted above.[53] For the NSRB, under the baseline scenario, these estimates are presented in Table 6.37. In 2010, the agriculture in the basin consumed 38.5 thousand dam^3 of water, most of which was drown from surface water bodies. By 2060, it is estimated that agricultural water consumption will increase to 63 thousand dam^3 of water. In all four time periods, the consumption of water amounts is 83 to 88% of the total water intake. Much of this water that is not consumed is that returned from irrigation districts in the basin, namely Northminster and the proposed NSRB-Westside Irrigation Project.

6.8.2 Agricultural Water Consumption – Climate Change Scenario

The 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 78,085 dam^3 of water annually. The return flows as a proportion of total water intake under this scenario are slightly lower than those for the baseline scenario.

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

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

Particulars	Total Water Consumption in dam^3			
	2010	2020	2040	2060
Total Agriculture Water Consumption	38,495	40,052	47,065	63,248
Groundwater	6,429	6,766	7,270	7,407
Surface Water	32,066	33,286	39,795	55,842
Total Consumption as % of Water Intake	83.3%	83.1%	84.6%	88.3%

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

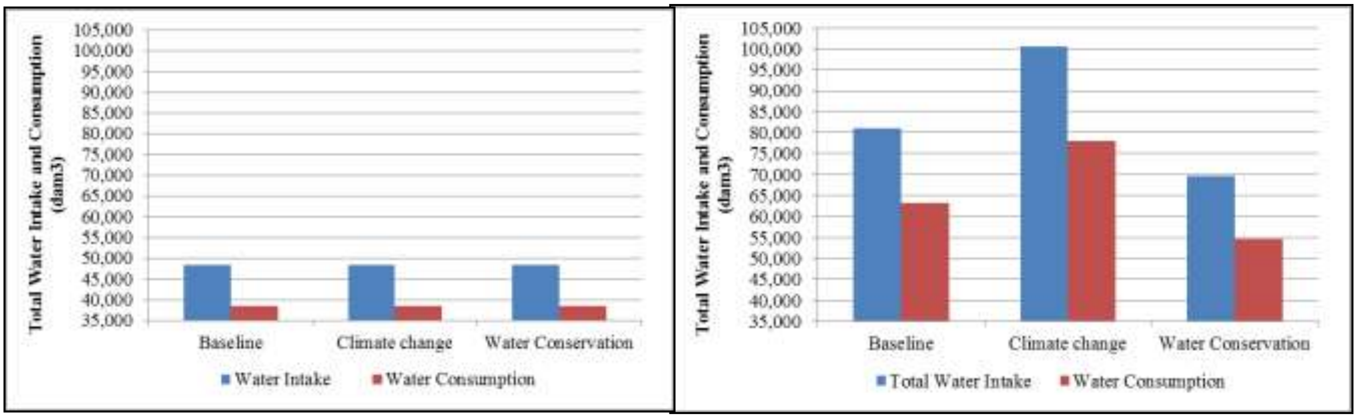
Particulars	Total Water Consumption in dam^3			
	2010	2020	2040	2060
Total Agriculture Water Consumption	38,495	39,058	53,707	78,085
Groundwater	6,429	6,783	7,434	7,749
Surface Water	32,066	32,275	46,273	70,336
Total Consumption as % of Water Intake	83.3%	82.6%	86.2%	90.1%

6.8.3 Agricultural Water Consumption – Water Conservation Scenario

Under the assumption that irrigators and other water users for agricultural production adopt water conservation practices, their total water consumption will decrease to 41 thousand dam^3 by 2040 and to 54.5 thousand dam^3 by 2060 (Table 6.39). By 2060, water consumption levels will be 41.7% of the 2010 level. A comparison of the three scenarios water consumption is shown in Figure 6.8.

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

Particulars	Total Water Consumption in dam^3			
	2010	2020	2040	2060
Total Agricultural Water Consumption	38,495	36,698	41,484	54,566
Ground	6,429	6,820	7,104	7,176
Surface	32,066	29,879	34,379	47,390
Total Consumption as % of Water Intake	83.3%	81.4%	82.9%	86.8%



2010 **2060**

Figure 6.8: Water Intake and Water Consumption for Agricultural Purposes in the North Saskatchewan River Basin, 2010 and 2060, Study Scenarios

6.9 Summary of Agricultural Water Demand

In the NSRB, agriculture is a prominent industry and a major water user. The water is required 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 for aquaculture. In the future, irrigation activity is expected to increase in the basin. This expansion will occur through the development of the NSRB-Westside Irrigation Project with an irrigated area of 17,670 acres, a ten-fold increase in the district irrigated area. In addition, there are private irrigators in the basin. The total irrigated area will increase from the current level of 23,567 acres to 47,083 acres by 2060 –almost doubling its present.

The total agricultural water demand in the basin is estimated to increase from 48,331 dam^3 in 2010 to 80,944 dam^3 by 2060 – an increase by 67% of the 2010 level. Climate change would bring forth further increases in these levels. Under the climate change scenario, agriculture may use 100,495 dam^3 of water by 2060. The adoption of water conservation measures could bring a reduction in the level of water demand to 69,539 dam^3 per annum.

In the NSRB, most of the agricultural uses will withdraw water from surface water bodies. In the future, surface water will constitute a higher proportion of the total agricultural demand. However, not all of the water withdrawn is lost, since a portion of it is returned to the sources, particularly from irrigation districts. It is estimated that although at present 83% of the water withdrawn by agriculture is consumed, by 2060 this proportion would increase to 88%. Nonetheless, a more aggressive adoption of irrigation by private irrigators can perhaps change this proportion.

Chapter 7

Industrial/Mining Water Demand

The major industrial/mining activity in the NSRB is consists of a combination of several sources. Although there is a small water demand for potash, as well as for oil and gas production, water is also demanded for power generation along with that for manufacturing. In this chapter, mining and industrial (including power generation) activities' water uses are described. Manufacturing, in this chapter, designates 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 four sections: Section 7.1 describes the mining water demand, while section 7.2 addresses estimation of manufacturing water use. The latter section covers two types of industrial/manufacturing establishments – present manufacturing establishments, and new manufacturing establishments that could develop as a result of other economic activities (such as irrigation). The Section 7.3 covers water demand for power generation, which is followed by a summary of industrial/mining water use in Section7.4.

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 taken 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

Following the methodology described in chapters 3 and 4 of this report, total water demand for potash production was estimated. For future calculations, this required some projection of potash mining activity. One feature of potash production in the basin is that no basin water is used for it. All water for the potash mine at Vanscoy is supplied by the South Saskatchewan River Basin.

The projected water demand from potash mines to 2060 is presented in Table 7.1. For these estimates, present (existing mines) the water demand coefficients from Table 3.11 were applied. The water demand coefficient was 1.13 dam^3 per 1,000 tonnes of potash produced. The total water demand (supplied within the basin) for potash mining was estimated at 1,663 dam^3 per annum for 2010. This includes water that is drawn solely from surface water sources. By 2060, potash mining water demand is estimated to double the current level – to 3,220 dam^3 per annum. All this water is supplied by the South Saskatchewan River Basin.

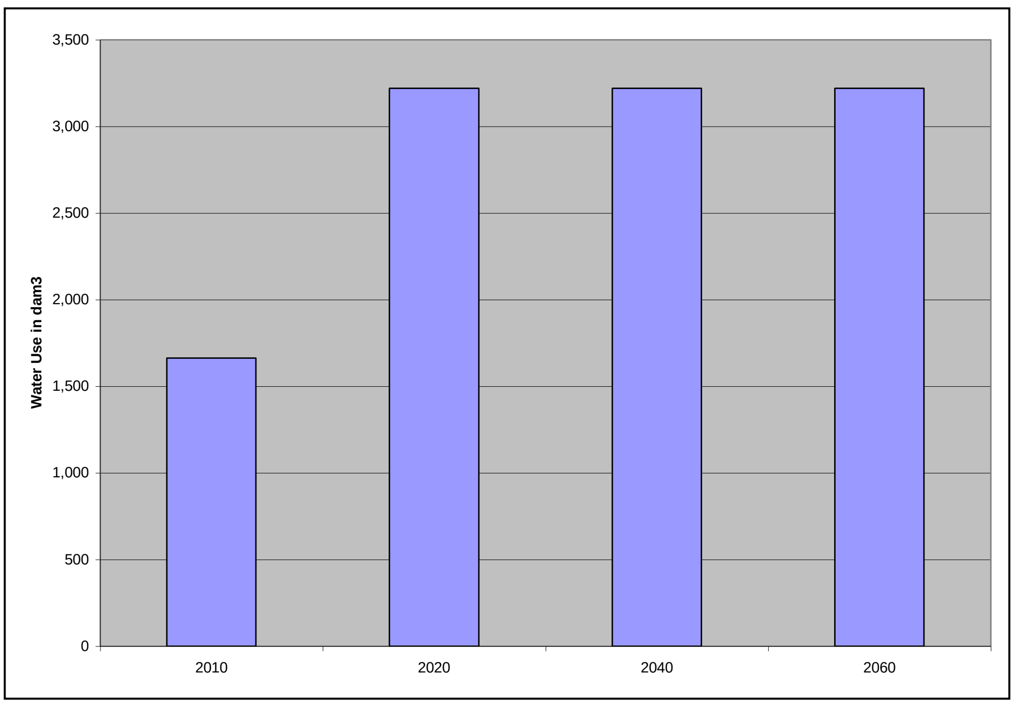
Table 7.1: Projected Water Demand for Potash Mining in the North Saskatchewan River Basin, Baseline Scenario, 2010 – 2060

Particulars	Source of Water	Amount of Water in dam^3			
		2010	2020	2040	2060
Existing Mines	**Surface**	1,663.0	3,219.9	3,219.9	3,219.9
Future Mines	**Surface**	0	0	0	0
Water Obtained from SSRB*		1,663.0	3,219.9	3,219.9	3,219.9
Total Basin Water Demand		0	0	0	0
Total Water Sourced in Basin		**1,663.0**	**3,219.9**	**3,219.9**	**3,219.9**

* South Saskatchewan River Basin

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

The water needed for potash production is shown in Figure 7.1. By 2060, this demand is expected to increase to 3.2 thousand dam^3, of which none will be from the basin sources.



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

Figure 7.1: Water Demand for Potash Production in the North Saskatchewan River Basin, Baseline Scenario 2010 - 2060

7.1.1.2 Potash Production Water Demand – Climate Change Scenario

The direct effect of climate change on their 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 to reduce demand or to find other sources of water. Lacking information, this study considers that to be no effect of climate change on potash water demand. Furthermore, since no basin water is taken for this production, no impact on the basin is foreseen.

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 such water use, including refrigeration units for cooling, reducing 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 in order 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**.**

The 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, altering water is still used 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 in water demand of 5%, 15% and 25% by 2020, 2040, and 2060, respectively.[54] For lack of better information, the adoption of conservation measures for underground mining was assumed to be half of these amounts. The water demand for the potash industry in the NSRB under the assumption that water conservation measures are adopted is presented in Table 7.2.

Since the current water demand is based on the current level of adoption of water management practices, no further changes were made. By 2020, it was assumed that new water conservation measures could reduce water demand, resulting in a 4.7% reduction. By 2040, the water demand for potash production is estimated to be reduced to 3,172 dam^3, which is a reduction of 1.5% over the baseline scenario level. By 2060, the reduction will be even higher, by 12.5% over the

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

baseline scenario. Again as noted above, this reduction does not affect total water demand in the basin.

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 to remain unaffected by climate change.

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

Particulars	Source	Total Amount of Water in dam^3		
		2020	2040	2060
Existing Mines	Surface	3,171.6	3,010.6	2,817.4
Water Obtained from SSRB*	Surface	3,171.6	3,010.6	2,817.4
Total Basin Water Demand	Surface	0	0	0
Total Interbasin Transfer		3,171.6	3,010.6	2,817.4
% Change from Baseline Level		98.5%	93.5%	87.5%

* South Saskatchewan River Basin

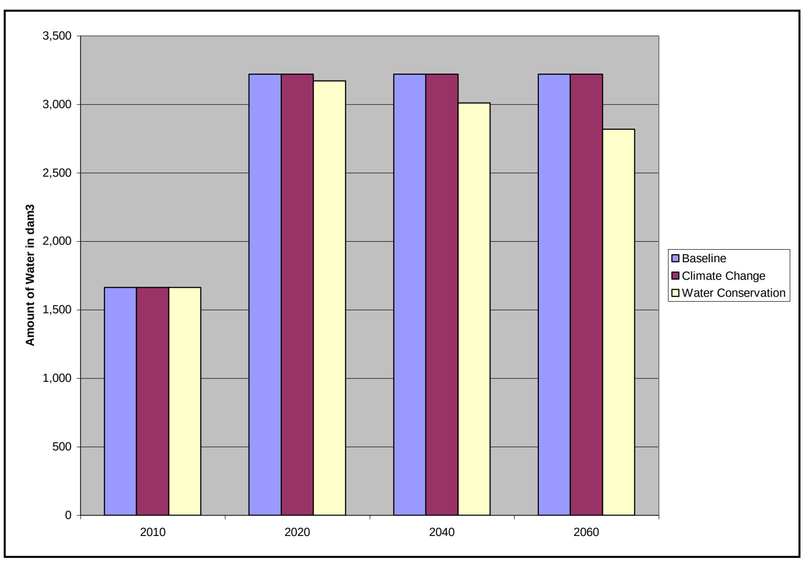


Figure 7.2: Total (Including Interbasin Transfer) Water Demand (in dam^3) for Potash Production, North Saskatchewan River Basin, under Study Scenarios, 2010 - 2060

7.1.1.4 Source of Water for Potash Production

Since all water taken for potash production in the basin is transferred from the South Saskatchewan River Basin, 100% of the water is surface water. No groundwater is drawn in this basin for potash production. Saline groundwater could be used in the future.

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, as is the case with the potash mine in the basin, 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 was assumed to be consumed.

7.1.2 Oil and Gas Production

7.1.2.1 Oil and Gas Production Water Demand – Baseline Scenario

Water demand in oil and gas production is limited to two types: (i) for drilling of oil wells, and (ii) for recovery of oil during the production phase. Both of these demands were estimated for the basin. The projected number of wells drilled in an oil formation is estimated for 2020 as the number of wells drilled in the formation in 2010, divided by the number of wells drilled in the province in 2010, times the average number of wells drilled in the province over the 2000 to 2010 period. The estimate for 2040 and 2060 is 60% and 10% of the wells drilled in 2020, respectively. The estimated number of wells drilled is shown in Table 7.3. By 2060, the number of wells in the basin will be reduced to 35, from an estimated 175 wells per annum drilled currently.

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

Technology	No. of Wells during			
	2010	**2020**	**2040**	**2060**
Vertical	122	164	98	25
Horizontal	53	71	42	11
Total	**175**	**234**	**141**	**35**

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

The water expanded in the production of oil and gas in the NSRB 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.

The estimated water demand for oil and gas production in the basin is shown in Table 7.4. In 2010, this level was estimated at 933.4 dam^3 per annum. The amount is expected to shrink to 188 dam^3 by 2060 – a four-fold reduction from its 2010 level.

7.1.2.2 Oil and Gas Production Water Demand – Climate Change Scenario

The direct effect of climate change on the demand for water from the oil and gas industry is likely to be minimal. Thus, the water demand is the same as that for the baseline scenario.

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

Technology	Water Demand in dam^3			
	2010	2020	2040	2060
Primary	45.2	60.6	36.4	9.1
Water Flood	101.9	136.7	82.1	20.5
Horizontal	687.2	922.6	553.6	138.4
Enhanced	99.2	133.2	79.9	20.0
Total	**933.4**	**1,253.2**	**751.9**	**188.0**

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

7.1.2.3 Oil and Gas Production Water Demand – Water Conservation Scenario

In oil and gas production water is used in the drilling of oil and gas wells, for 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 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 for estimating conventional oil production are presently 0.87 water: oil, falling to 0.6 water: oil with conservation measures. This set of ratios translates into a water demand between 400 m^3 to 600 m^3 per well. Shale gas mined with a 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 for limiting the demand from fresh water sources in the oil and gas industry (Canadian Association of Petroleum Producers, 2011). The Canadian Association of Petroleum Producers (2011) reports that up to 15% of the water demand has been successfully recycled at some sites. This figure would translate into a 9.9 dam^3 per year per well water demand if the sector were able to attain a 15% recycle rate.

The estimates of water conservation on the oil and gas demand are presented in Table 7.5. In the future, on average, water conservation measures could reduce total water demand for oil and gas production by 15% of the baseline level.

Table 7.5: Water Demand for Oil and Gas Production in the North Saskatchewan River Basin under Water Conservation Scenario, 2010 - 2060

Particulars	**Total Water Demand in dam^3**			
	2010	**2020**	**2040**	**2060**
Total Water Demand	933.4	1,065.2	639.1	159.8
% of Baseline Scenario	100.0%	85.0%	85.0%	85.0%

7.1.3 Salt Mining Water Demand

7.1.3.1 Salt Mining Water Demand – Baseline Scenario

The Sifto Canada Ltd. Mine at Unity produces 154 thousand tonnes of salt at present. Applying the water demand coefficient presented in Chapter 3, the water demand was estimated at 282.5 dam^3 (Table 7.6). The company expects a 3% increase in production from 2010 to 2020, a 10% increase from 2020 to 2040 and from 2040 to 2060. The water demand coefficient estimated from 2010 production was assumed to remain constant. Therefore, the demand for water will increase to 291, 320, and 352 dam^3 at 2020, 2040, and 2060, respectively.

Table 7.6: Estimate of Water Demand in Salt Mining Activity in the North Saskatchewan River Basin, 2010 - 2060

Company	**Water Demand in dam^3**			
	2010	**2020**	**2040**	**2060**
Sifto Canada Ltd	282.5	291.0	320.1	352.1
% Change from 2010 level	--	3.0%	13.3%	24.6%

7.1.3.2 Other Mining Water Demand – Climate Change Scenario

The direct effect of climate change on the demand for water for salt production is likely to be minimal, given the controlled production process. 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

As noted in Chapter 2, salt is produced through a mechanical evaporation process by injecting water into an underground salt deposit creating saturated brine. The brine is drawn out and evaporated in a series of large crystallizers. It is assumed that water use efficiencies of 2% are obtained for each of the forecast periods. The total water demand under this scenario is shown in Table 7.7. The water demand level of 285.2 dam^3 in 2010 could increase by 25% in 2060 under the baseline scenario. However, under the water conservation scenario, this increase would be only 22% of the 2010 level.

Table 7.7: Salt Mining Water Demand in the North Saskatchewan River Basin under Water Conservation Scenario, 2020 - 2060

Particulars	Amount of Water in dam^3		
	2020	2040	2060
Sifto Canada Ltd.	285.2	313.7	345.1
% Change from Baseline Scenario	-2.0%	-2.0%	-2.0%

7.2 Manufacturing Water Demand

Estimating the water demand for manufacturing establishments was more challenging in this basin. This challenge was a result of a lack of published data on many of these water users. In addition, existing and potential new industries' water demand forecast will depend on the lives of the plants, reinvestment, capacity constraints, expansion to meet market opportunities and new markets, among other things.

In this section, an attempt is made to estimate manufacturing water demand under three study scenarios – baseline, climate change, and water conservation. The discussion is divided into two sub-sections: (i) Water demand by existing industries; and (ii) Water demand by industries that could be developed from irrigation development in the basin. The water required for power generation is presented in a section following these estimates.

7.2.1 Existing Manufacturing Industries

7.2.1.1 Existing Manufacturing Industries – Baseline Scenario

Manufacturing industries located in the NSRB that get their water from non-municipal sources vary from agricultural processing activities to crude oil recovery and refining. The results are shown in Table 7.8. Data on the activity levels was unavailable for those activities operated by private companies, branch plants or large diversified companies. The water demand was available from SWA for 2010 for companies without production data. To estimate future water demand, this water demand amount was increased for the 2040 and 2060 projections to take into account increased economic activity.

Table 7.8: Future Industrial Water Demand in the North Saskatchewan River Basin, Baseline Scenario, 2010 to 2060

Industry	Water Demand Level in dam^3			
	2010	**2020**	**2040**	**2060**
Ag Processing				
North West Terminal Ltd	145.7	148.6	151.6	154.6
Husky Ethanol*	Part of the Interprovincial Transfer 6,752 dam^3			
Prairie Malt	1,042.7	1,063.6	1,084.8	1,106.5
Refineries				
Canadian Crude Separators Inc.	20.9	21.3	21.7	22.2
Husky Energy (surface)**	2,010.9	2,051.2	2,092.2	2,134.0
(ground)**	2,753.2	2,808.2	2,864.4	2,921.7
Husky Energy Upgrader*	Part of the Interprovincial Transfer 6,752 dam^3			
Liquid Natural Gas Storage				
BP Canada Energy Co.	16.5	16.9	17.2	17.5
Trans Gas	1,201.8	1,225.8	1,250.3	1,275.3
Construction				
Kohlruss Bros. Enterprises	7.8	8.0	8.1	8.3
Total Basin and Interprovincial Transfer Industrial Water	**13,951.5**	**14,095.6**	**14,242.3**	**14,392.1**
Inter-Provincial Water Transfer				
Water Demand Sourced from Alberta	6,752.0	6,752.0	6,752.0	6,752.0
Within Basin Manufacturing Water Demand	**7,199.5**	**7,343.6**	**7,490.3**	**7,640.1**
Total Within Basin Industrial Water Demand % of 2010 Level		2.0%	4.0%	6.1%
Within Basin Water Demand by Source of Water				
Groundwater	4,139.9	4,222.7	4,307.1	4,393.2
Surface Water	3,059.6	3,120.9	3,183.2	3,246.9
Surface Water as % of the Total	42.5%	42.5%	42.5%	42.5%

* The Husky Oil Upgrader and Ethanol Plant are located in Saskatchewan; however, the water withdrawals are under an Alberta Environment Water Diversion License. Withdrawals of up to 6,752 dam^3 of water are obtained from the city of Lloydminster infrastructure (SWA 2007, personal communication with Dave Kay, Husky Energy June 2012).

** Water is used for enhanced oil extraction of the heavy oil deposits by using steam.

7.2.1.2 Existing Manufacturing Industries – Climate Change Scenario

Production processes that use water as a cooling agent may need more water during the summer months in order to achieve the same level of production. For this reason, industrial water demand may also be affected by the climate change. Significant warming of surface waters will have a direct impact on the industrial operations by decreasing the efficiency of cooling systems (Lemmen and Warren, 2004, p. 42). A further review of the literature did not yield any basin related or Canadian studies demonstrating the impact of climate change. As discussed in Section 5.2.2, the same changes[55] in the water demand coefficient were applied to industrial water demand as those followed for domestic water demand. Estimates of industry water demand for the climate change scenario are presented in Table 7.9, and this amount is expected to increase to 14,968 dam^3 per annum by 2060.

7.2.1.3 Existing Manufacturing Industries – Water Conservation Scenario

Water conservation in manufacturing processes that use it once through cooling and then discharged, can be accomplished through the use of cooling tower technology for water recycling. However, the relative cost is the deciding factor in the adoption of 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 utilized 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 will likely be minor. The water required for the manufacture of nitrogen fertilizer in the plant is relatively new, such that, in terms of efficiency with the current technology, little improvement can be expected. A 2.4% decline in the demand for water from the baseline scenario is expected for the industries as presented in Table 7.10.

7.2.1.4 Source of Water for Manufacturing Uses

The sources of water for industrial use are reported in Table 7.8 for the baseline scenario and in Table 7.10 for the water conservation scenario. A graphical presentation of these water demands is shown in Figure 7.3. In the future, by 2060, one observes an increase in the use of groundwater. The proportion of surface water under the baseline scenario in 2010 was 70.3% of the total, which is reduced to 69.8% by 2060. The same proportions are also estimated for the water conservation scenario in the basin.

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

Table 7.9: Industry (Manufacturing) Water Demand in the North Saskatchewan River Basin, 2020 to 2060 Climate Change Scenario

Industry	Water Demand Level in dam^3			
	2010	**2020**	**2040**	**2060**
Ag Processing				
North West Terminal Ltd	145.7	148.6	154.6	160.8
Husky Ethanol*	6,752.0	6,752.0	6,887.0	7,022.1
Prairie Malt	1,042.7	1,063.6	1,106.5	1,150.8
Refineries				
Canadian Crude Separators Inc.	20.9	21.3	22.2	23.1
Husky Energy (surface)**	2,010.9	2,051.2	2,134.0	2,219.4
(ground)**	2,753.2	2,808.2	2,921.7	3,038.6
Husky Energy Upgrader*	Part of the Interprovincial Transfer 6,752			
Liquid Natural Gas Storage				
BP Canada Energy Co.	16.5	16.9	17.5	18.2
Trans Gas	1,201.8	1,225.8	1,275.3	1,326.3
Construction				
Kohlruss Bros. Enterprises	7.8	8.0	8.3	8.6
Total Basin and Interprovincial Transfer Industrial Water	**13,951.5**	**14,095.6**	**14,527.1**	**14,967.9**
Inter-Provincial Water Transfer				
Water Demand Sourced from Alberta	6,752.0	6,752.0	6,887.0	7,022.1
Within Basin Manufacturing Water Demand	7,199.5	7,343.6	7,642.1	7,947.8
Total Industrial Water Demand % of 2010 Level		2.0%	6.1%	10.4%
Within Basin Water Demand by Source of Water				
Groundwater	4,139.9	4,222.6	4,393.2	4,569.0
Surface Water	3,059.6	3,121.0	3,248.9	3,378.8
Surface Water as % of the Total	42.5%	42.5%	42.5%	42.5%

* The Husky Oil Upgrader and Ethanol Plant are located in Saskatchewan; however, the water withdrawals are under an Alberta Environment Water Diversion License. Withdrawals of up to 6,752 dam^3 of water are obtained from the city of Lloydminster infrastructure (SWA 2007, personal communication with Dave Kay, Husky Energy, June 2012).

** Water is used for enhanced oil extraction of the heavy oil deposits by using steam.

Table 7.10: Industry Water Demand in the North Saskatchewan River Basin, under Water Conservation Scenario, 2020 - 2060

Industry	Water Demand Level in dam^3			
	2010	**2020**	**2040**	**2060**
Ag Processing				
North West Terminal Ltd	145.7	131.1	112.8	90.3
Husky Ethanol*	6752.0	6,617.0	6,617.0	6,617.0
Prairie Malt	1,042.7	1,042.3	1,063.1	1,084.4
Refineries				
Canadian Crude Separators Inc.	20.9	20.88	21.30	21.73
Husky Energy (surface)**	2,010.9	2,010.1	2,050.3	2,091.3
(ground)**	2,753.2	2,752.1	2,807.1	2,863.3
Husky Energy Upgrader*	Part of the Interprovincial Transfer 6,752			
Liquid Natural Gas Storage				
BP Canada Energy Co.	16.5	16.5	16.9	17.2
Trans Gas	1,201.8	1,201.3	1,225.3	1,249.8
Construction				
Kohlruss Bros. Enterprises	7.8	7.8	8.0	8.1
Total Basin and Interprovincial Transfer Industrial Water	**13,951.5**	**13,799.1**	**13,921.8**	**14,044.9**
Inter-Provincial Water Transfer				
Water Demand Sourced from Alberta	6752.0	6,617.0	6,617.0	6,617.0
Within Basin Manufacturing Water Demand	7,199.5	7,183.9	7,306.7	7,428.0
Total Industrial Water Demand % of 2010 Level		-0.2%	1.5%	3.1%
Within Basin Water Demand by Source of Water				
Groundwater	4,139.9	4,123.7	4,185.2	4,244.1
Surface Water	3,059.6	3,058.4	3,121.5	3,183.9
Surface Water as % of the Total	42.5%	42.7%	42.7%	42.9%

* The Husky Oil Upgrader and Ethanol Plant are located in Saskatchewan; however, the water withdrawals are under an Alberta Environment Water Diversion License. Withdrawals of up to 6,752 dam^3 of water are obtained from the city of Lloydminster infrastructure (SWA 2007, personal communication with Dave Kay, Husky Energy, June 2012).

** Water is used for enhanced oil extraction of the heavy oil deposits by using steam.

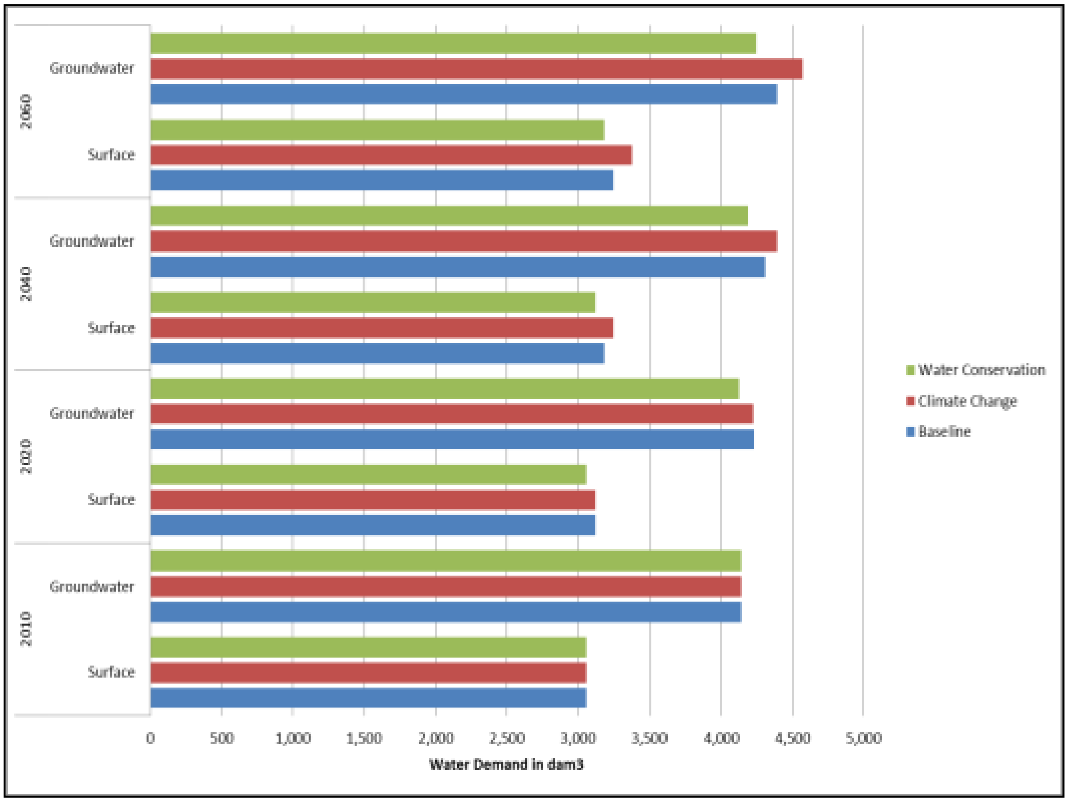

Figure 7.3: Manufacturing Water Demand, Within Basin, Existing Establishments in the North Saskatchewan River Basin, under Study Scenarios, 2010 – 2060

7.2.1.5 Water Return/Discharge from Manufacturing Activities

The estimated discharge of water from industrial activities in the NSRB is presented in Table 7.11. The percentage of the water demand that is returned is taken from company estimates where available, and from Statistics Canada estimates as reported in Chapter 3. All the water is assumed to be discharged to surface water bodies. About 3 thousand dam^3 of water is returned annually from the manufacturing establishments.

The consumption of water was estimated as the difference between water demand and water return. These values are shown in Table 7.12. Further details on the consumption can be found in Appendix I. Under all three study scenarios, about 72% of the total water intake is returned to the original source. The quality of this water was not ascertained and is left for future studies in this area.

Table 7.11: Within Basin Water Return from Industrial (Manufacturing) Activities in the North Saskatchewan River Basin, Baseline Scenario, 2020 – 2060

Industry	%[1]	Water Return Level in dam^3			
		2010	2020	2040	2060
Ag Processing					
North West Terminal Ltd	13.0%	18.9	19.3	19.7	20.1
Agrium Products Inc.	77.5%	1.4	1.4	1.5	1.5
Husky Ethanol*	13.0%	98.5	100.5	102.5	104.5
Prairie Malt	13.0%	135.6	138.3	141.0	143.9
Refineries					
Canadian Crude Separators Inc.	19.8%	4.1	4.2	4.3	4.4
Husky Energy (Surface)	19.8%	398.2	406.1	414.3	422.5
(ground)	90.0%	2,477.9	2,527.4	2,578.0	2,629.5
Husky Energy Upgrader*					
Liquid Natural Gas Storage					
BP Canada Energy Co.	0.0%	-	-	-	-
TransGas	0.0%				
Construction					
Kohlruss Bros. Enterprises	0.0%	-	-	-	-
Total		**3,134.6**	**3,197.2**	**3,261.2**	**3,326.4**

[1] Percentage of water intake that is returned.

*Part of the same Alberta Water License.

Table 7.12: Water Intake and Consumption (Within Basin and Transfers) for Manufacturing Activities in the North Saskatchewan River Basin, 2010-2060 by Study Scenarios

Particulars	Amount in dam^3			
	2010	2020	2040	2060
Baseline Scenario				
Water Intake	**13,952**	**14,096**	**14,242**	**14,392**
Water Consumption	10,039	10,122	10,207	10,294
Consumption % of Intake	72.0%	71.8%	71.7%	71.5%
Climate Change				
Water Intake	**13,952**	**14,096**	**14,527**	**14,968**
Water Consumption	10,039	10,122	10,411	10,706
Consumption % of Intake	72.0%	71.8%	71.7%	71.5%
Water Conservation				
Water Intake	**13,952**	**13,799**	**13,922**	**14,045**
Water Consumption	10,039	9,907	9,972	10,035
Consumption % of Intake	72.0%	71.8%	71.7%	71.5%

7.2.2 Induced Development Activities

7.2.2.1 Water Demand for Induced Development Activities – Baseline Scenario

For prediction purpose, induced economic activities were assumed to exist in relationship to the new irrigation development in the basin. As noted in Chapter 4, three types of new developments were expected: biomass ethanol, feedlots, and a red meat processing facility. Details on these were provided in Table 4.29.The net effect of establishing a feedlot is a reduction in water demand for irrigation because silage needs less water compared to other crops. Results are shown in Table 7.13. Even with the increase in animal watering, the net effect is still reduced water demand. The total net water demand for the industries is estimated to be a reduction of 1,071 dam^3 by 2040, which will continue to 2060. Since the irrigation development in the NSRB will likely begin after 2020, no change is anticipated for 2020.

Table 7.13: Induced Water Demand Activities in the North Saskatchewan River Basin, Baseline Scenario, 2040 – 2060

Industry	Water Demand in dam^3	
	2040	**2060**
Biomass Ethanol	1,471.0	1,471.0
Feedlots	-2,542.1	-2,542.1
Total		**-1,071.1**
Surface Water % of Total	100%	100%

7.2.2.2 Water Demand for Induced Development Activities – Climate Change Scenario

The main climate change effect for induced water demand will be the 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 induced economic development activities' water demand level are shown in Table 7.14. By 2060, a decrease of 1,058 dam^3 is estimated. Much of this decrease will result from water demand for the projected (silage-consuming) feedlots in the basin.

Table 7.14: Induced Water Demand Activities in the North Saskatchewan River Basin, Climate Change Scenario

Industry	Water Demand in dam^3	
	2040	**2060**
Biomass Ethanol	1,471.0	1,471.0
Feedlots	-2,536.0	-2,529.4
Total	**-1,065.0**	**-1,058.4**
Surface Water % of Total	100%	100%

7.2.2.3 Water Demand for Induced Development Activities – Water Conservation Scenario

The conservation of water for biomass ethanol and agricultural processing will bring a 2% increase in efficiency from the base estimates. Increased efficiency of livestock watering will reduce the water demand from the feedlots. As shown in Table 7.15, there is an estimated 1,008 dam^3 reduction for 2040, which decreases to 947 dam^3 by 2060.

Table 7.15: Induced Water Demand Activities in the North Saskatchewan River Basin, Water Conservation Scenario, 2040-2060

Industry	**Water Demand in dam^3**	
	2040	**2060**
Biomass Ethanol	1,441.6	1,412.7
Feedlots	-2,449.4	-2,359.8
Total	**-1,007.8**	**-947.1**
Surface Water % of Total	100%	100%

7.3 Power Generation Water Demand

7.3.1 Power Generation Water Demand under Baseline Scenario

In the NSRB there is no hydro power generation. The current water demand for power generation arises from thermal power generation processes. Water demand coefficients for these types are shown in Table 7.16. Both water intake and consumption coefficients were estimated following available literature on power generation needs.

Table 7.16: Estimated Water Intake and Water Consumption Estimates for Electric Power Generation, 2010

Generation Process	**Unit**	**Water Intake**	**Water Consumption**
Cogeneration	dam^3/MW	5.9	0.163*
Once through Cooling	dam^3/MW	1.2	0.033*
Heat Recovery	dam^3/MWh	0	0

*** Using Statistics Canada (2005) ratio of intake to consumption.

In the future, other sources of power can be foreseen, along with potentially different water demand levels. For example, wind, solar, cogeneration, biomass, conservation, and nuclear technologies have been proposed as alternatives, with only nuclear and biomass requiring significant amounts of water. A nuclear power plant, as proposed by Bruce Power, would require 9,000 dam^3 of water for an evaporative cooling pond with a refilling rate of 2.6 $m^3\ s^{-1}$ for a yearly total of 91,994 dam^3 (Halliday, 2009). Alternative methods of cooling are evaporative towers or water recycled back into the river or lake. Three possible locations in each of two regions (Lake Diefenbaker and La Loche) were identified as possible sites for a nuclear plant (Stantec, 2007). A biomass plant would have similar water demand characteristics to those of fossil fuel thermal technology.

The water demand represents a product of the amount of electricity generated by type and its respective water demand coefficient. The baseline coefficients of 2010 were applied for this estimation. The amount of electricity generated was based on the forecast demand for electricity by SaskPower, along with their projected supply side options; this generated amount is the basis for estimating water demand (see SaskPower, 2011, for further details). These forecasts are shown in Table 7.17. The choices in the NSRB are natural gas, cogeneration, biomass along with wind, solar, and heat recovery. Natural gas, cogeneration and biomass all require some amount of water. The baseline estimation of water demand is the current water demand for electricity generation from cogeneration and natural gas, times the growth in supply for these two options to 2020, 2040, and 2060.

Table 7.17: Projected Growth Rates of Electricity Supply by Type

Generation Process	**Growth Rates for**		
	2020	**2040**	**2060**
Cogeneration	140%	195%	249%
Nat Gas	134%	180%	207%
Waste Heat	140%	195%	249%

Source: Sask Power (2005)

In the future, cogeneration expansion may be possible in the potash and oil sectors in the basin while expansion of the existing natural gas facilities is anticipated. Biomass may be an alternative that uses agricultural crop residues or dedicated crops, but its scope at this time is rather limited.

The estimated water intake is shown in Table 7.18. An electric power generation, water demand is estimated to be 2,116 dam^3 for 2010, increasing to 5,026 dam^3 by 2060 – or 138% over the 2010 level. Much of this increase will be the result of a growing population, as well as higher income, culminating in greater electric power needed.

7.3.2 Power Generation Water Demand under Climate Change Scenario

Climate change may affect the amount of water needed for cooling and may result in greater evaporation losses from power generation reservoirs. Estimates of 2% and 4% increases in water demand because of climate change are used for 2040 and 2060, respectively. Water intake for non-hydroelectric power generation increases to 5,227 dam^3 per annum (Table 7.19).

Table 7.18: Water Intake for Electric Power Generation under Baseline Scenario, North Saskatchewan River Basin, 2010-2060

Plant Type	Amount of Water Intake in dam^3			
	2010	**2020**	**2040**	**2060**
Cogeneration	1,542	2,165	3,000	3,836
Natural Gas	574	769	1,032	1,190
Biomass	0.0	0.0	0.1	0.3
Total	**2,116**	**2,933**	**4,032**	**5,026**

Table 7.19: Water Intake for Electric Power Generation under Climate Change Scenario, North Saskatchewan River Basin, 2010-2060

Plant Type	Amount of Water Intake in dam^3			
	2010	**2020**	**2040**	**2060**
Cogeneration	1,542	2,165	3,060	3,990
Natural Gas	574	769	1,053	1,237
Biomass	-	0.0	0.1	0.3
Total Excluding Hydroelectric Power	**2,116**	**2,933**	**4,113**	**5,227**
% of Baseline Scenario		100.0%	102.0%	104.0%

7.3.3 Power Generation Water Demand under Water Conservation Scenario

The applicable water conservation measures rely on the conversion of once through cooling systems with closed loop or dry cooling. Each has different characteristics in terms of water demand and consumption with dry cooling having about half the water consumption as closed loop when fossil fuels are used to generate electricity (Larson et al., 2007). The refurbishing and replacement of existing generating capacity to 2060 will provide the opportunity to adopt conservation measures. For example, the natural gas combined cycle systems that are being installed at the QE Station will take the same amount of water to generate greater amount of electricity. Therefore, it is estimated that water conservation technology can result in 5%, 15%, and 25% reductions in water demand by 2020, 2040, and 2060, respectively. The estimated water intake for non-hydroelectric power generation can be reduced to 3,770 dam^3 under this scenario by 2060 (Table 7.20).

7.3.4 Power Generation Water Consumption

A portion of the water intake is returned into the original source (in some cases, not at the same point of intake). The remaining water is lost primarily to evaporation. This latter amount of water is called consumption for electric power generation. These estimates were conducted by applying secondary data.

Table 7.20: Water Intake for Electric Power Generation under Water Conservation Scenario, North Saskatchewan River Basin, 2010-2060

Plant Type	Amount of Water Intake in dam^3			
	2010	2020	2040	2060
Cogeneration	1,542	2,056	2,550	2,877
Natural Gas	574	730	877	892
Biomass	-	0.0	0.1	0.2
Total Excluding Hydroelectric Power	**2,116**	**2,787**	**3,427**	**3,770**

7.3.4.1 Power Generation Water Consumption under Baseline Scenario

Data on water consumption for power generation plants in Saskatchewan was not found. As a crude proxy, information for Canada was used. Statistics Canada (2005) has reported that for thermoelectric generation in Canada, water consumption represents 2.76% of water intake. Using this proportion and the levels of water intake in Table 7.18, consumptive losses of water were estimated. Results are shown in Table 7.21. For power generation, the water consumption in 2010 was estimated at 58.6 dam^3, increasing to 139 dam^3 by 2060.

Table 7.21: Water Consumption for Electricity Generation for the North Saskatchewan River Basin under Baseline Scenario, 2010-2060

Plant Type	Amount of Water Consumption in dam^3			
	2010	2020	2040	2060
Cogeneration	42.7	59.9	83.1	106.2
Natural Gas	15.9	21.3	28.6	32.9
Biomass	-	0.0	0.0	0.0
Total Water Consumption	**58.6**	**81.2**	**111.7**	**139.2**

7.3.4.2 Water Consumption under Climate Change Scenario

The water consumption from power generation plants in the NSRB under climate change reflected higher intake. For these estimates the water consumption coefficients were assumed to be the same as for the baseline scenario. However, it is conceivable that these coefficients may also change; no decisive information though, was found to estimate that possibility. Estimated consumption levels are shown in Table 7.22. The water consumption for power generation in the NSRB is expected to increase from its 2010 level of 58 dam^3 to 145 dam^3 by 2060.

Table 7.22: Water Consumption for Electricity Generation for the North Saskatchewan River Basin under Climate Change Scenario, 2010-2060

Plant Type	Amount of Water Consumption in dam^3			
	2010	2020	2040	2060
Cogeneration	42.7	59.9	84.8	110.5
Natural Gas	15.9	21.3	29.1	34.3
Biomass	-	0.0	0.0	0.0
Total Water Consumption	**58.6**	**81.2**	**113.9**	**144.8**

7.3.4.3 Water Consumption under Water Conservation Scenario

The same method of calculation as that followed for the other two scenarios was employed to estimate water consumption by power generation plants under the water conservation scenario. Estimated levels, as shown in Table 7.23, suggest water consumption in 2060 of 104 dam^3, about 25% lower than those levels under the baseline scenario.

Table 7.23: Water Consumption for Electricity Generation for the North Saskatchewan River Basin under Water Conservation Scenario, 2010-2060

Plant Type	Amount of Water Consumption in dam^3			
	2010	2020	2040	2060
Cogeneration	42.7	56.9	70.6	79.7
Natural Gas	15.9	20.2	24.3	24.7
Biomass	-	0.0	0.0	0.0
Total Water Consumption	**58.6**	**77.2**	**94.9**	**104.4**

7.4 Summary of Industrial/Mining Water Demand

The industrial and mining water demand by sector is presented in sections 7.4.1 to 7.4.3 for baseline, climate change, and conservation scenarios. The potash mining activity currently has the largest requirement for water among the various sectors in the NSRB. This dominance will only increase as the projected mines come on stream.

7.4.1 Total Industrial/Mining Water Demand – Baseline Scenario

The industrial and mining water demand by sectors is presented in Tables 7.24 for the baseline scenario. The total water demand for these purposes is estimated at 18,947 dam^3 during 2010. This water demand level will increase to 22,107 dam^3, primarily as a result of expansion in the potash mining sector. At present, manufacturing uses 72% of the total water for this sector, which will decrease to 54% by 2060 (Figure 7.4). Power generation water demand will increase to 35% by 2060, in comparison to its current 21%. The other uses, particularly for oil and gas production, and for other mining activities, will become relatively unimportant in the basin's water demand.

Table 7.24: Total Mining and Industrial Water Demand in the North Saskatchewan River Basin, Baseline Scenario, 2010-2060

Activity	Water Demand in dam^3			
	2010	2020	2040	2060
Within Basin Water Demand				
Potash	0	0	0	0
Oil and Gas	933	1,253	752	188
Manufacturing	7,200	7,346	7,490	7,640
Other**	283	291	320	352
Irrigation Induced	0	0	-1,071	-1,071
Power Generation	2,116	2,933	4,032	5,026
Total Within Basin Water Demand	**10,532**	**11,823**	**11,523**	**12,135**
Interbasin Transfer from SSRB*	1,663	3,220	3,220	3,220
Inter-provincial Transfer from Alberta	6,752	6,752	6,752	6,752
Total Within and Transferred Water Demand	**18,947**	**21,795**	**21,495**	**22,107**

* South Saskatchewan River Basin

** Sifto Canada Ltd salt manufacture.

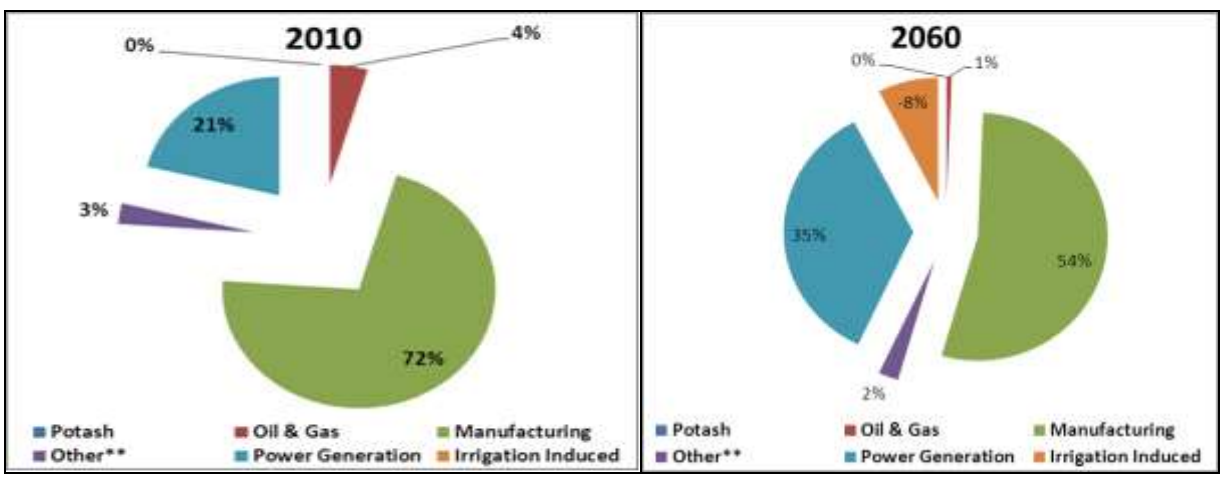

Figure 7.4: Distribution of Total Industrial/Mining Water Demand by Sectors, 2010 and 2060, Baseline Scenario, North Saskatchewan River Basin

7.4.2 Total Industrial/Mining Water Demand – Climate Change Scenario

The potential climate change impacts the total water demand for the industrial/mining sector, by slightly increasing the water demand levels, as shown in Table 7.25. The total water demand under this scenario is higher by 1.7% of the baseline level in 2040 and 3.6% higher by 2060.

Table 7.25: Total Mining and Industrial Water Demand in the North Saskatchewan River Basin, Climate Change Scenario, 2010-2060

Activity	Water Demand in dam^3			
	2010	2020	2040	2060
Within Basin Water Demand				
Potash	0	0	0	0
Oil and Gas	933.4	1,253.20	751.9	188
Manufacturing	7,200	7,344	7,642	7,948
Other	282.5	291	320.1	352.1
Irrigation Induced	--	--	-1,065	-1,058
Power Generation	2,116	2,933	4,113	5,227
Total Within Basin Water Demand	**10,532**	**11,821**	**11,762**	**12,657**
Outside Basin Water Transfers				
Interbasin Transfer from SSRB	1,663	3,220	3,220	3,220
Inter-provincial Transfer from Alberta	6,752	6,752	6,887	7,022
Total Including Transferred Water Demand	**18,947**	**21,793**	**21,869**	**22,899**

7.4.3 Total Industrial/Mining Water Demand – Water Conservation Scenario

On account of several water conservation measures available to the industrial/mining sector; its water demand level may be reduced from the baseline scenario. Results are shown in Table 7.26. These changes will be observed by 2020, when water demand for this sector is estimated at 21,110 dam^3, or 3.1% lower than that seen under the baseline scenario. By 2060, there is a potential to further reduce this water demand by 8.7% to 20,190 dam^3. Thus, water conservation measures do offer a good potential for reducing water demand. Much of this outcome depends on the adoption of conservation practices which are decided by other factors, the most important of which is the total cost of water to the water user. If the cost is low, not much attention is paid to reducing water consumption.

Table 7.26: Total Mining and Industrial Water Demand in the North Saskatchewan River Basin, Water Conservation Scenario, 2010-2060

Activity	Water Demand in dam^3			
	2010	**2020**	**2040**	**2060**
Within Basin Water Demand				
Potash	0	0	0	0
Oil and Gas	933.4	1,065.2	639.1	159.8
Manufacturing	7,201	7,184	7,307	7,428
Other	283	285	314	345
Irrigation Induced	--	--	-1,008	-947
Power Generation	2,116	2,787	3,427	3,770
Total Within Basin Water Demand	**10,533**	**11,321**	**10,678**	**10,756**
Interbasin Transfer from SSRB	1,663	3,172	3,011	2,817
Inter-provincial Transfer from Alberta	6,752	6,617	6,617	6,617
Total Including Transferred Water Demand	**18,948**	**21,110**	**20,306**	**20,190**

7.4.4 Industrial/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 7.27 to 7.29. 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.

Table 7.27: Industrial and Mining Within Basin Water Demand in the North Saskatchewan River Basin, by Source of Water, Baseline Scenario, 2010-2060

Sector	Source of Water	Amount of Water in dam^3			
		2010	2020	2040	2060
Potash	Surface	1,663	3,220	3,220	3,220
Oil and Gas	Surface	0	0	0	0
	Ground	933	1,253	752	188
Manufacturing	Surface	9,814	9,875	9,937	10,001
	Ground	4,140	4,223	4,307	4,393
Other (Salt Mining)	S/G	283	291	320	352
	Ground	0	0	0	0
Power Generation	Surface	2,116	2,933	4,032	5,026
Induced	Surface	--	--	-1,071	-1,071
Total Within and Transferred Water Demand	**Surface**	**13,593**	**16,028**	**16,118**	**17,176**
	Ground	**5,073**	**5,476**	**5,059**	**4,581**
	S/G	**283**	**291**	**320**	**352**
Interbasin Transfers	**Surface**	1,663	3,220	3,220	3,220
Inter-Provincial Transfers	**Surface**	6,752	6,752	6,752	6,752
Within Basin Water Demand					
Within Basin Water Demand	**Surface**	5,178	6,056	6,146	7,204
Within Basin Water Demand	**Ground**	5,073	5,476	5,059	4,581
Within Basin Water Demand	**S/G**	283	291	320	352
Total In-Basin Water Demand		**10,533**	**11,823**	**11,525**	**12,137**

S/G = Surface or groundwater use

Table 7.28: Industrial and Mining Within Basin Water Demand in the North Saskatchewan River Basin, by Source of Water, Climate Change Scenario, 2010-2060

Sector	Source of Water	Amount of Water Demand in dam^3			
		2010	**2020**	**2040**	**2060**
Potash	Surface	1,663	3,220	3,220	3,220
Oil and Gas	Surface	0	0	0	0
	Ground	933	1,253	752	188
Manufacturing	Surface	9,814	9,875	10,136	10,401
	Ground	4,140	4,223	4,393	4,569
Other (Salt Mining)	S/G	283	291	320	352
	Ground	0	0	0	0
Power Generation	Surface	2,116	2,933	4,113	5,227
Induced	Surface	--	--	-1,065	-1,058
Total Within and Transferred Water Demand	**Surface**	**13,593**	**16,028**	**16,404**	**17,789**
	Ground	**5,073**	**5,476**	**5,145**	**4,757**
	S/G	**283**	**291**	**320**	**352**
Interbasin Transfer	**Surface**	1,663	3,220	3,220	3,220
Inter-Provincial Transfer	**Surface**	6,752	6,752	6,887	7,022
Within Basin Water Demand					
Within Basin Water Demand	**Surface**	5,178	6,056	6,297	7,547
Within Basin Water Demand	**Ground**	5,073	5,476	5,145	4,757
Within Basin Water Demand	**S/G**	283	291	320	352
Total In-Basin Water Demand		**10,533**	**11,823**	**11,762**	**12,657**

S/G = Surface or groundwater use

Table 7.29: Industrial and Mining Within Basin Water Demand in the North Saskatchewan River Basin, by Source, Water Conservation Scenario, 2010-2060

Sector	Source of Water	Amount of Water Demand in dam^3			
		2010	**2020**	**2040**	**2060**
Potash	Surface	1,663	3,172	3,011	2,817
Oil and Gas	Surface	0	0	0	0
	Ground	933	1,065	639	160
Manufacturing	Surface	9,814	9,677	9,738	9,801
	Ground	4,140	4,124	4,185	4,244
Other (Salt Mining)	S/G	283	285	314	345
	Ground	0	0	0	0
Power Generation	Surface	2,116	2,787	3,427	3,770
Induced	Surface	--	--	-1,008	-947
Total Within and Transferred Water Demand	**Surface**	**13,593**	**15,636**	**15,168**	**15,441**
	Ground	**5,073**	**5,189**	**4,824**	**4,404**
	S/G	**283**	**285**	**314**	**345**
Interbasin Transfer	**Surface**	1,663	3,172	3,011	2,817
Inter-Provincial Transfer	**Surface**	6,752	6,617	6,617	6,617
Within Basin Water Demand					
Within Basin Water Demand	**Surface**	5,178	5,847	5,541	6,007
Within Basin Water Demand	**Ground**	5,073	5,189	4,824	4,404
Within Basin Water Demand	**S/G**	283	285	314	345
Total In-Basin Water Demand		**10,533**	**11,321**	**10,679**	**10,756**

As shown in Figure 7.5, half of the industrial water is supplied either from the South Saskatchewan River Basin or from the province of Alberta. Within the remaining in-basin water demand, the groundwater source serves 30% of the total water demand, and the remaining water need is met through surface water bodies.

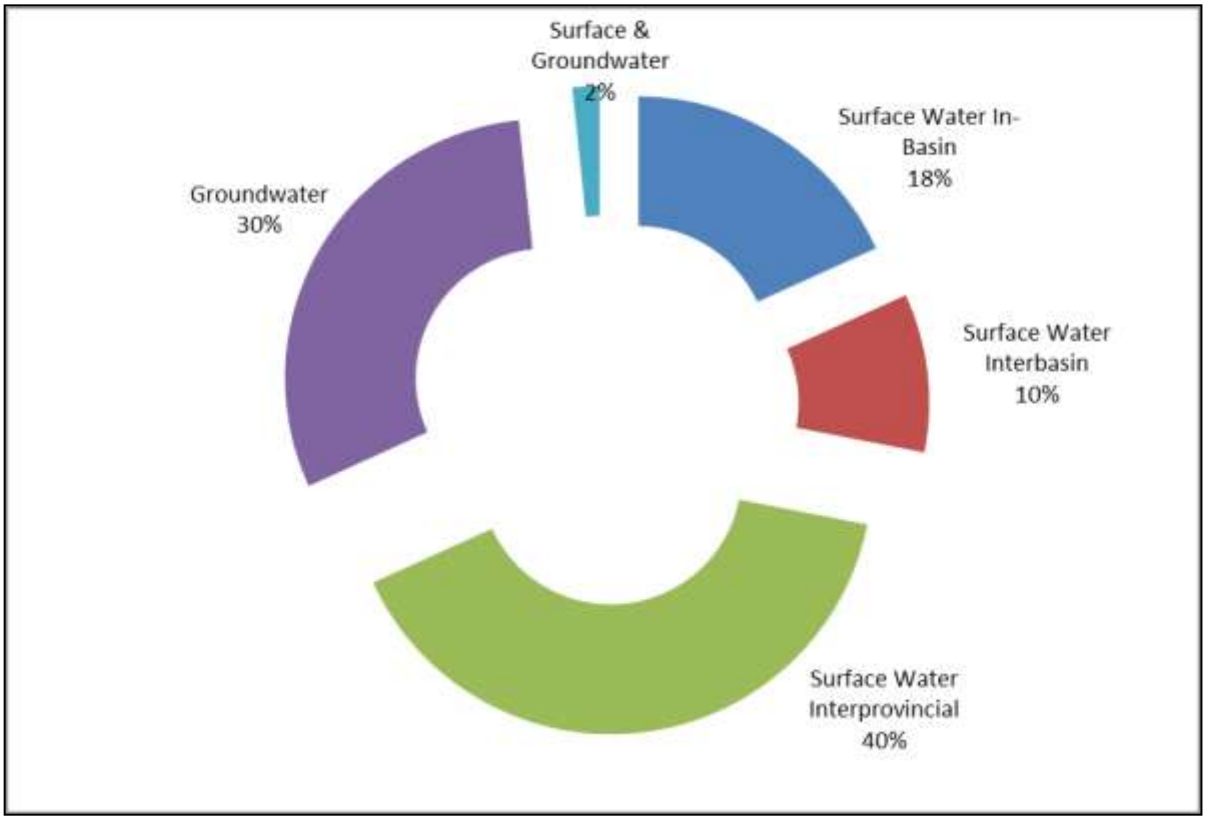

Figure 7.5: Distribution of Total (Within Basin, Interbasin Transfer, and Inter-Provincial Transfer) Water Demand by Source of Water, North Saskatchewan River Basin, 2010

Chapter 8

Municipal/Domestic Water Demand

The community (domestic) level water demand encompasses water demands of urban centers, towns, villages, and First Nations located in NSRB. In the following three subchapters, water for these purposes under the baseline, climate change, and conservation scenarios are respectively presented, with indications regarding the methodology undertaken and the results of the estimations.

8.1 Municipal Water Demand

8.1.1 Municipal Water Demand – Baseline Scenario

Municipal water demand was estimated for the three cities located in the NSRB. The total water demand for these communities was estimated as a product of population and water demand coefficient. Both of these concepts were presented in Chapter 4. It should be noted that for large urban centers, this water demand also includes that for manufacturing, commercial, firefighting, street cleaning, and other public uses.

For the baseline scenario, estimates were calculated based on a simplifying assumption. The hypothesis was that past trends will continue in the NSRB. However, future water consumption estimates for these cities require more accurate forecasts of population and of the adoption rate of water conservation technology. The expected values for water demand for the baseline scenario are presented in Table 8.1.

From the present forecasts, the total municipal water demand in the basin is expected to increase from 13,358 dam^3 in 2010 to 18,921 dam^3 in 2060 – an increase of nearly 42%. Prince Albert's water demand has a significant share in this increase. It is expected that the city's water demand will rise from its current levels of 6,879 dam^3 to 10,090 dam^3 by 2060 -- increase of nearly 47%.

8.1.2 Municipal Water Demand – Climate Change Scenario

Under this scenario, similar to the baseline scenario, the total water demand for domestic purposes was a product of the adjusted water demand coefficient and the population as used for the baseline scenario. The adjustment in these coefficients is described in this section. Regression functions showing results of effect of droughts on community in the NSRB are shown in Appendix J.

8.1.2.1 Adjustment of Per Capita Water Demand for Climate Change

This scenario incorporates the adjusted values of the per capita water demand coefficients for climate change. In order to estimate the effect, two aspects were considered: (i) temperature and precipitation change; and (ii) frequency of dry extreme events.

Table 8.1: Estimated Municipal Water Demand for North Saskatchewan River Basin, Study Scenarios, 2010-2060

Community Type	Water Demand in dam^3				Change 2010 - 2060 (%)
	2010	2020	2040	2060	
Baseline Scenario					
North Battleford	2,141	2,273	2,536	2,799	30.7%
Prince Albert	6,879	7,106	8,598	10,090	46.7%
Lloydminster	4,337	4,621	5,471	6,032	39.1%
Total Water Demand for	**13,358**	**13,999**	**16,605**	**18,921**	**41.6%**
Climate Change Scenario					
North Battleford	2,141	2,273	2,597	2,939	37.3%
Prince Albert	6,879	7,106	8,804	10,595	54.0%
Lloydminster	4,337	4,621	6,199	7,305	68.4%
Total Water Demand for	**13,358**	**13,999**	**17,600**	**20,838**	**56.0%**
Scenario Water Demand % of Baseline		0.0%	6.0%	10.1%	
Water Conservation Scenario					
North Battleford	2,141	2,216	2,346	2,449	14.4%
Prince Albert	6,879	6,928	7,953	8,829	28.3%
Lloydminster	4,337	4,505	5,060	5,278	21.7%
Total Water Demand Cities	**13,358**	**13,649**	**15,359**	**16,556**	**23.9%**
Scenario Water Demand % of Baseline	0.0%	-2.5%	-7.5%	-12.5%	

Climate change will affect indoor water demand differently from that utilized for lawn irrigation. Since no study reporting the impact of climate change on domestic water demand in the basin was found, studies for other jurisdictions were reviewed.

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

In developing the climate change scenario, it was assumed here that there will be no major impacts on the domestic water demand by 2020. Assuming that the average temperature in the basin for the climate change may be similar to 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 of water demand was assumed. The population predictions for all three time periods were assumed to be the same as those the baseline scenario.

To estimate the impact of extreme events on domestic water demand in NSRB, per capita domestic water demand data for 1995-2009 were used. It was assumed that the 2001 and 2002 droughts would impact the level of water demand in a positive manner. These events were introduced through a binary variable (which took a value of 1 if the year has an occurrence of drought, and 0 otherwise). Other two variables – trend and size of the community -- were retained for this analysis. The effects of climate change on the water demand per capita are shown in Table 8.2.

Table 8.2: Adjusted Domestic Water Demand Coefficients (m^3/capita) for Climate Change Scenario, North Saskatchewan River Basin

Community Type	Water Demand per Capita (m^3)			
	2010	2020	2040	2060
North Battleford	119.52	119.52	122.39	125.49
Prince Albert	147.77	147.77	151.31	155.16
Lloydminster	150.79	140.94	139.52	130.27
T>1000	142.06	134.66	132.35	123.32
T<1000	117.01	117.01	119.81	122.86
Villages	129.11	132.95	138.11	143.11
First Nations Reservations	74.33	74.33	76.12	78.05

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 10% by 2060. This situation is primarily a result of higher temperatures and the increased frequency of extreme events. Taking such probabilities into account, the total municipal water demand under this scenario is expected to be 20,838 dam^3 by 2060.

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 NSRB. In this third scenario, the potential effect of water conservation in future water demand was incorporated. For the municipal water demand, a mid-value of water conservation potential of 25% and an adoption rate of 1% per annum were assumed. The reference year was 2010 and the relative savings in water demand by 2020 was 2.5%, 7.5% for 2040 and 12.5% by 2060. Table 8.3 shows the adjusted coefficients' values for the water demand per capita for communities located in the NSRB.

Table 8.3: Adjusted Domestic Water Demand Coefficients (m^3/capita) for Water Demand Conservation scenarios, North Saskatchewan River Basin

Community Type	Water Demand per Capita (m^3)			
	2010	2020	2040	2060
North Battleford	119.52	116.53	110.56	104.58
Prince Albert	147.77	144.07	136.68	129.30
Lloydminster	150.79	137.42	113.90	94.13
T>1000	142.06	133.86	118.88	103.58
T<1000	117.01	116.30	115.60	113.61
Villages	129.11	132.16	133.25	132.34
First Nations Reservations	74.33	73.89	73.44	72.18

The total municipal water demand for the basin is shown in Table 8.1, and the total amount for this purpose is estimated at 16,556 dam^3 for 2060. On average, this accounted for a reduction of 2.5% in 2020, 7.5% in 2040, and 12.5% in 2060 over the baseline scenario.

8.1.4 Municipal Water Demand -- Summary

The results of municipal water demand from the three scenarios are summarized in Table 8.4. Water Demand in the cities will remain virtually the same, partly because of declining trends in the water demand per capita, which may be in part due to past efforts in educating people about water saving technologies.

Table 8.4: Municipal Water Demand in the North Saskatchewan, Study Scenarios, 2010 - 2060

Scenarios	Total Amount of Water in dam^3				2060 Level % of Baseline
	2010	2020	2040	2060	
Baseline	13,358	13,999	16,605	18,921	0.0%
Climate Change	13,358	13,999	17,600	20,838	10.1%
Water Conservation	13,358	13,649	15,359	16,556	-12.5%

8.2 Domestic Water Demand

The domestic water demand was estimated for larger urban centers other than cities. These categories included two types of communities: (i) Towns with populations of 1,000 people or more; and (ii) Towns 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 employing the estimated population of various communities and their respective water demand per capita. These methodologies for the baseline scenario were presented in Chapters 3 and 4. Estimated domestic water demand levels are presented in Table 8.5. Overall, the 2060 water demand is predicted to be at 5,646 dam^3, which is 7.5% higher than 2010 levels.

Table 8.5: Estimated Domestic Water Demand for North Saskatchewan River Basin, Study Scenarios, 2010 - 2060

Community Type	Water Demand in dam^3				Change 2010 - 2060 (%)
	2010	2020	2040	2060	
Baseline Scenario					
Towns > 1000 people	3,884	3,801	3,609	3,389	-12.7%
Towns < 1000 people	1,367	1,497	1,882	2,258	65.2%
Total Domestic Water Demand	**5,252**	**5,298**	**5,491**	**5,646**	**7.5%**
Climate Change Scenario					
Towns > 1000 Population	3,884	3,801	3,970	3,917	0.8%
Towns < 1000 Population	1,367	1,497	1,927	2,370	73.4%
Total Domestic Water Demand	**5,252**	**5,298**	**5,897**	**6,288**	**19.7%**
Water Conservation Scenario					
Towns > 1000 Population	3,884	3,778	3,566	3,290	-15.3%
Towns < 1000 Population	1,367	1,488	1,859	2,192	60.4%
Total Domestic Water Demand	**5,252**	**5,266**	**5,425**	**5,482**	**4.4%**

8.2.2 Domestic Water Demand – Climate Change Scenario

Expected water demand under climate change was estimated by making adjustment, in the per capita water demand for the communities included under the category of domestic water demand. These results are also shown in Table 8.5. In spite of the declining trends in the water demand by towns, the total domestic water demand will increase in 2060 by almost 20% over the 2010 level. The level of domestic water demand in 2060 was estimated at 6,288 dam^3 – about 11% higher than that demand under the baseline scenario.

8.2.3 Domestic Water Demand – Water Conservation Scenario

The methodology for estimating domestic water demand under a water conservation scenario for the NSRB 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 values for this scenario are shown in Table 8.5. Under this scenario, a reduction in total domestic water demand is noted; by 2060 it is 5,482 dam^3, which is 3% lower than the increase forecasted under the baseline scenario.

8.2.4 Domestic Water Demand -- Summary

A summary of domestic water demand in the NSRB for the three study scenarios is shown in Table 8.6. Generally speaking, climate change will impart an increase in the domestic water demand, which by 2060 could be as high as 11% over the baseline scenario. Water conservation could offer some relief – by about 12.8% in 2020, which is not enough to cover the increase caused by climate change.

Table 8.6 : Summary of Domestic Water Demand in the North Saskatchewan River Basin, Study Scenarios, 2010 - 2060

Scenarios	Total Domestic Water Demand in dam^3				2060 level % of Baseline
	2010	2020	2040	2060	
Baseline	5,252	5,298	5,491	5,646	0.0%
Climate Change	5,252	5,298	5,897	6,288	11.4%
Water Conservation	5,252	5,266	5,425	5,482	-2.9%

8.3 Rural Domestic Water Demand

Rural water demand in this study was defined as a sum of that needed for communities living in villages. In addition, under this category other rural communities, such as rural farm and non-farm populations, were also included.

8.3.1 Rural Domestic Water Demand – Baseline Scenario

The method of estimation for rural water demand was the same as that utilized for other types of municipal/domestic water demands. The per capita water demand coefficients were multiplied by estimated populations for a given time period for the three types of rural communities listed above. Estimated rural water demand is shown in Table 8.7.

Table 8.7: Estimated Rural Water Demand for the North Saskatchewan River Basin, Study Scenarios, 2010 - 2060

Community Type	Rural Water Demand in dam^3				Change 2010 - 2060 (%)
	2010	2020	2040	2060	
Baseline Scenario					
Villages	1,273	1,246	1,230	1,219	-4.2%
Farm Population	2,967	2,750	2,480	2,193	-26.1%
Rural Non-Farm	2,475	2,294	1,862	1,829	-26.1%
Total Rural Water Demand	**6,716**	**6,290**	**5,572**	**5,240**	**-22.0%**
Climate Change Scenario					
Villages	1,273	1,246	1,260	1,280	0.5%
Farm Population	2,967	2,750	2,539	2,302	-22.4%
Rural Non-Farm	2,475	2,294	1,906	1,920	-22.4%
Total Rural Water Demand	**6,716**	**6,290**	**5,706**	**5,502**	**-18.1%**
Water Conservation Scenario					
Villages	1,273	1,238	1,216	1,183	-7.1%
Farm Population	2,967	2,734	2,450	2,129	-28.2%
Rural Non-Farm	2,475	2,280	1,839	1,776	-28.2%
Total Rural Water Demand	**6,716**	**6,252**	**5,505**	**5,088**	**-24.2%**

On account of declining population trends in various types of rural communities, water demand is expected to decline in 2060 for the 2010 level. Under the baseline scenario, the 2010 rural water demand level is estimated at 6,716 dam^3, which is expected to decline to 5,240 dam^3. This decline is predicated on the present trends in the rural population. It is conceivable that this rate of decline in the future may be stabilized at a slightly higher level than that assumed in this study. Perhaps, as more people leave these areas, there will be fewer people reaming there and thus, fewer people out-migrating to towns or cities.

8.3.2 Rural Domestic Water Demand – Climate Change Scenario

Under the climate change scenario, water demand per capita coefficients were adjusted to reflect the climate change impact. These adjusted coefficients are shown in Table 8.2. Estimated populations for various categories of population were multiplied by these coefficients to yield total water demand levels. Estimated rural water demand is shown in Table 8.7. The total rural water demand will still decline over time, but not as rapidly as that level decreased under the baseline scenario. Total rural water demand in 2060 would be 5,502 dam^3, 5% higher than it was under the baseline scenario.

8.3.3 Rural Domestic Water Demand – Water Conservation Scenario

The estimation of rural water demand under water conservation followed the same methodology as described for the municipal and domestic water demands. The adjusted water demand coefficients for the three categories of communities are shown in Table 8.3. Estimated water demand is shown in the bottom panel of Table 8.7. This water demand is below that predicted under the baseline scenario by 2.9% or at 5,088 dam^3.

8.3.4 Rural Domestic Water Demand -- Summary

A summary of rural water demand is presented in Table 8.8 for the three study scenarios. As noted above, there is a tendency in this water demand to decline over time, partly because of a declining population base. Although climate change may increase this water demand by 5%, the water conservation scenario could bring about a 2.9% reduction compared to the baseline scenario. Water conservation in a rural setting is a relatively unstudied subject; consequently, these estimates are therefore based on water demand coefficients that are not supported by science or observations. Further attention needs to be paid to this aspect of the study.

Table 8.8: Summary of Rural Water Demand in the North Saskatchewan River Basin, 2010 - 2060

Scenarios	Rural Water Demand in dam^3				2060 Level % of Baseline
	2010	2020	2040	2060	
Baseline	6,716	6,290	5,572	5,240	0.0%
Climate Change	6,716	6,290	5,706	5,502	5.0%
Water Conservation	6,716	6,252	5,505	5,088	-2.9%

8.4 First Nations' Water Demand

As a population group, First Nations' communities are the fastest growing communities in the NSRB. 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 applying per capita water demand coefficients presented in Chapter 3, multiplied by the population for a given time period (a concept also presented in Chapter 3 and 4). The total water demand for these communities is expected to grow. Under the baseline scenario, their total water demand is expected to have an increase of nearly 245% over the 2010 level (Table 8.9). In 2010, it was estimated at 950 dam^3, which will likely increase to 2,332 dam^3 by 2060.

Table 8.9: Summary of First Nations' Water Demand in the North Saskatchewan River Basin, Study Scenarios, 2010 - 2060

Scenario	Estimated First Nations' Total Water Demand in dam^3 for				% Change in 2060 over 2010	% of Baseline Scenario Level
	2010	2020	2040	2060		
Baseline	950	1,269	1,800	2,332	145.6%	0.0%
Climate Change	950	1,269	1,843	2,449	157.9%	5.0%
Water Conservation	950	1,261	1,779	2,264	138.5%	-2.9%

8.4.2 First Nations' Water Demand – Climate Change Scenario

Climate change was assumed to have the same impact as on other water user groups. As a result the water demand estimate for 2060 was 2,449 dam^3, 5% higher than that calculated for the baseline level (Table 8.9).

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, it was assumed that in the future these communities will follow the same pattern of adoption of water conservation measures as will be rest of the basin. This estimation is predicated on the improved education level of First Nations' people in future and on improved dissemination by provincial agencies of the need for adopting water conservation measures in these communities. Under this assumption, water demand for these communities (as shown in Table 8.9) will be 2,264 dam^3 by 2060. This scenario brings a reduction in water demand of approximately 3% from the baseline scenario.

8.4.4 First Nations' Water Demand -- Summary

Water demand for First Nations' communities is expected to modestly rise. Under a baseline scenario, water demand levels are expected to increase by 145% by 2060, relative to 2010. With climate change effects taken into consideration, the increase is forecasted to reach 158%, and 139% under a scenario with water conservation policies.

8.5 Other Institutional Water Demand

Other water demands consist of two institutions: Interlake Regional Water System Facility, and Nisbet Fire Control Centre. Available data for these communities is rather scarce. Estimating future water demands was realised by using the total water demand of these communities.

8.5.1. Other Municipal/Domestic Water Demand – Baseline Scenario

The water demand for these centers, as shown in Table 8.10, was assumed to remain constant thorough the 2010-2060 period. The estimated amount based on available data resulted in a yearly consumption of approximately 152 dam^3.

Table 8.10: Summary of Other Municipal/Domestic Water Demand in the North Saskatchewan River Basin, 2010 - 2060

Scenario	Estimated Total Water Demand in dam^3 for				% of Baseline Scenario Level
	2010	2020	2040	2060	
Baseline	151.7	151.7	151.7	151.7	0.0%
Climate Change	151.7	151.7	155.3	159.3	5.0%
Water Conservation	151.7	150.8	149.0	144.6	4.6%

8.5.2. Other Municipal/Domestic Water Demand – Climate Change Scenario

Climate change is expected to increase water consumption for these communities. Their water demand is assumed to increase from the current level of 152 dam^3 to 159 dam^3 by 2060, accounting for an increase of 5% by 2060, relative to 2010.

8.5.3. Other Municipal/Domestic Water Demand – Water Conservation Scenario

Under a water conservation scenario, the water demand for these communities is expected decrease in comparison with the baseline scenario. The expected to decrease from 152 dam^3 in 2010 water consumption will result in a level of 145 dam^3 by 2060. Estimations are presented in Table 8.10

8.5.4. Other Municipal/Domestic Water Demand – Summary

A summary of other domestic water demand is presented in Table 8.10 for the three scenarios. The tendency of the water consumption for these centers could not be determined based on the available data. Climate change is expected to increase water demand by 5%, whereas the water conservation scenario could bring forth an approximately 5% reduction compared to the baseline scenario.

8.6 Source of Water for Municipal/Domestic Water Demand

Municipal/domestic water demands are served both by surface water bodies as well as by underground aquifers. A summary of this water demand for the baseline scenario is shown in Table 8.11. Less than half of the total water demand is presently supplied by surface water bodies, and the relative proportion of surface to groundwater varies slightly among the three scenarios. Surface water, however, dominates the future total water demand for municipal/domestic purposes in the NSRB. In 2010, 41% of the total water demand was served from such sources. It increases by nearly 44% by 2060.

Table 8.11: Total Municipal/Domestic Water Demand by Source, North Saskatchewan River Basin, 2010 - 2060

Particulars	Water Demand in dam^3			
	2010	**2020**	**2040**	**2060**
Total Surface Water Demand	10,900	11,270	12,682	14,122
Total Groundwater Demand	15,527	15,736	16,938	18,169
Total Water Demand	**26,427**	**27,007**	**29,619**	**32,291**
Surface Water % of Total	41.2%	41.7%	42.8%	43.7%

8.7 Water Consumption for Municipal/Domestic Water Demand

Not all water withdrawn (also called intake) is lost. A part of this water is returned back to the original surface water bodies. Although some water may be returned to groundwater sources, knowledge of aquifer recharge rates and related information are relatively poor; therefore, it is typically assumed that all groundwater withdrawn is lost[56]. The total consumption of water for municipal/domestic purposes is shown in Table 8.12.

Table 8.12: Water Intake and Consumption for Municipal/Domestic Water Demands, North Saskatchewan River Basin, Study Scenarios, 2010 – 2060

Particulars	Water Quantity in dam^3			
	2010	**2020**	**2040**	**2060**
	Baseline Scenario			
Total Water Intake	26,427	27,007	29,619	32,291
Water Consumption	13,772	13,885	14,594	15,586
Consumption as a % of Intake	**52.1%**	**51.4%**	**49.3%**	**48.3%**
	Climate Change Scenario			
Total Water Intake	26,427	27,007	31,201	35,236
Water Consumption	13,772	13,885	15,223	16,790
Consumption as a % of Intake	**52.1%**	**51.4%**	**48.8%**	**47.7%**
	Water Conservation Scenario			
Total Water Intake	26,427	26,579	28,217	29,536
Water Consumption	13,772	13,716	14,084	14,550
Consumption as a % of Intake	**52.1%**	**51.6%**	**49.9%**	**49.3%**

[56] It is recognized that in some cases groundwater may be returned to surface water bodies.

As illustrated above, the total water consumption under the baseline scenario for 2010 was estimated at 13,772 dam^3, which is about 52% of the total water withdrawn. Thus, 48% of the water withdrawn is returned to the original water source in some shape.[57] By 2060, the amount of water consumed increases slightly but its proportion to total water intake does not change appreciably.

Under both the 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 is shown in Figure 8.1.

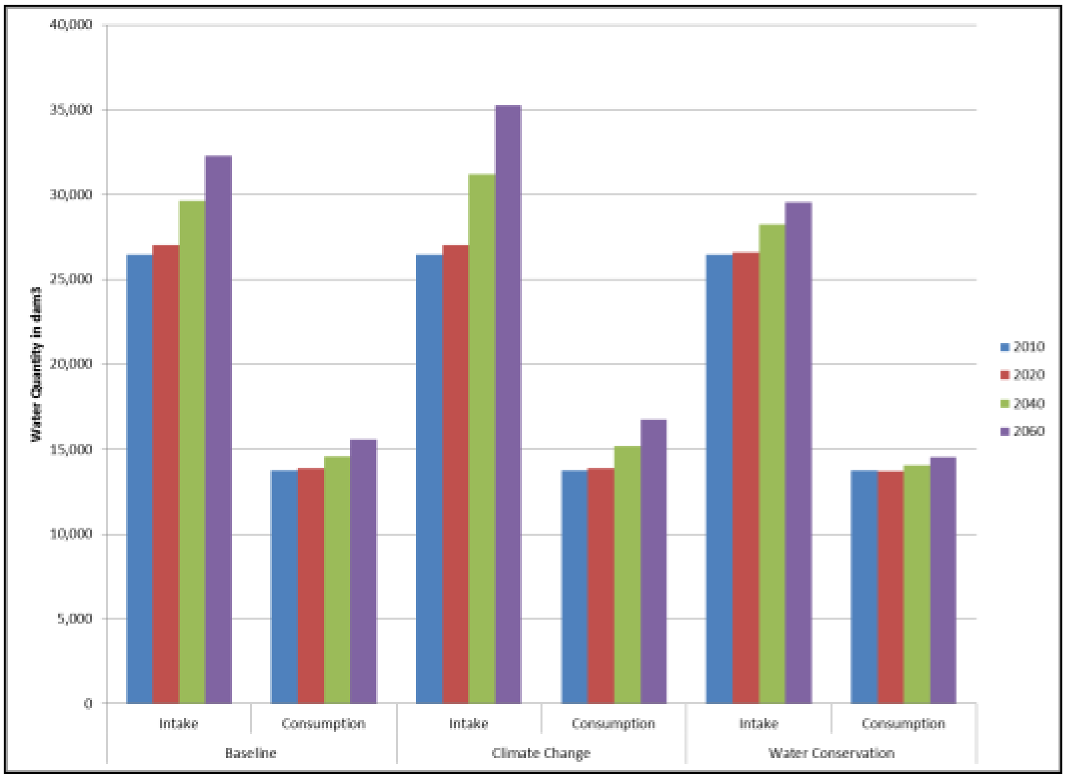

Figure 8.1: Distribution of Water Intake and Consumption for Municipal/Domestic Water Demand in the North Saskatchewan River Basin, 2010 - 2060

[57] 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.

8.8 Total Municipal/Domestic Water Demand

In this section, the all different water demands described above are summarized. These estimates are grouped into five categories of municipal/domestic water demand: municipal water demand (cities); domestic water demands (towns); rural water demand (villages and open areas); First Nations communities' water demand; and institutional water demand. Results for the three study scenarios are summarized in this section.

8.8.1 Total Municipal/Domestic Water Demand – Baseline Scenario

The total municipal/domestic water demand in the NSRB in 2010 was 26,427 dam^3, of which cities have the largest share. In fact, almost half of the total water demand (49.2%) is for the cities in the basin. The next largest level of water demand in 2010 is for rural communities, including farm and rural non-farm level, totaling 6,716 dam^3. Following these two larger uses are domestic (towns) and First Nations' communities water demands. Table 8.13 provides a summary of results for total water demand under a baseline scenario.

Table 8.13: Total Municipal/Domestic Water Demand, North Saskatchewan River Basin under Baseline Scenario, 2010 - 2060

Category	Total Municipal/Domestic Water Demand in dam^3				2060 as % of 2010 Level
	2010	2020	2040	2060	
Total Water Demand for Cities	13,358	13,999	16,605	18,921	41.6%
Total Domestic Water Demand for Urban Communities	5,252	5,298	5,491	5,646	7.5%
Total Rural Water Demand	6,716	6,290	5,572	5,240	-22.0%
First Nations' Communities' Total Water Demand	950	1,269	1,800	2,332	145.5%
Other Water Demand	151.67	151.67	151.67	151.67	0.0%
Total Municipal/Domestic Water Demand	**26,427**	**27,007**	**29,619**	**32,291**	**22.2%**

By 2060, although municipal water demand still has the largest share, the rank of other water demands changes. Now domestic water demand has the second highest level, followed by rural water demand. The rural water demand level is now 5,240 dam^3, which has been reduced by 22% in comparison with 2010 levels. Overall, the largest relative increase in 2060 is expected to occur in the First Nations' communities' share, which is expected to increase from 950 dam^3 in 2010 to 2,332 dam^3 by 2060. The relative shares of these five water demands are demonstrated in Figure 8.2.

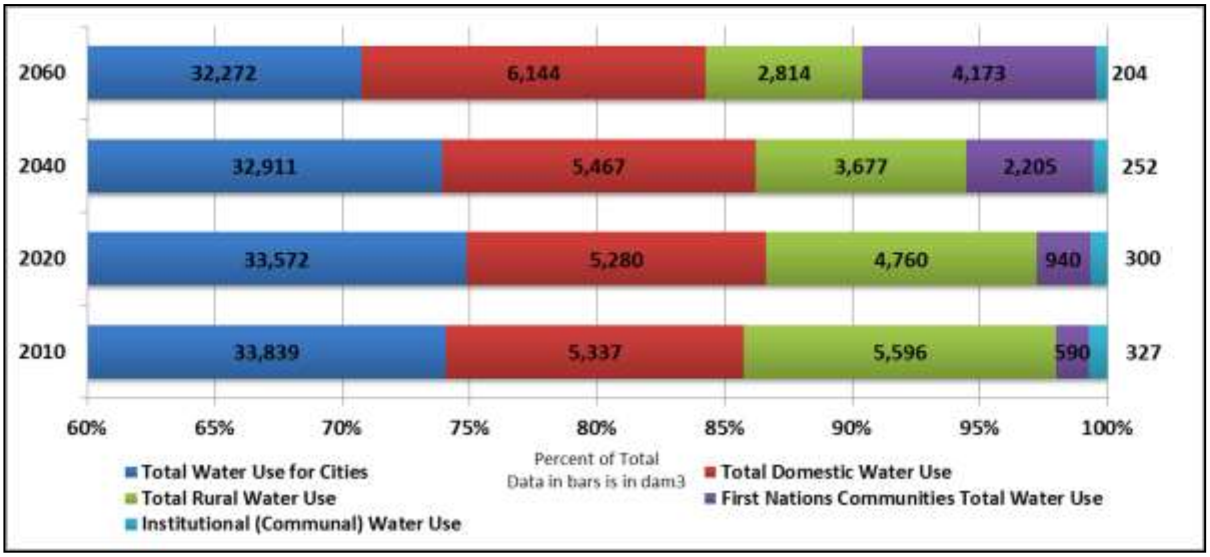

Figure 8.2: Distribution of Total Municipal/Domestic Water in the North Saskatchewan River Basin by Type of Community, Baseline Scenario, 2010 - 2060

8.8.2 Total Municipal/Domestic Water Demand – Climate Change Scenario

Municipal/domestic water demand levels are expected to increase under the climate change scenario. Expansion is expected in all categories of municipal/domestic water demand. The total water demand in 2060 will increase to 35,236 dam^3 per annum, which is nearly 33% higher than in 2010, as shown in Table 8.14. The three cities will continue to consume a large proportion of this water, followed by rural and domestic water users.

Table 8.14: Total Municipal/Domestic Water Demand under Climate Change Scenario, North Saskatchewan 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	13,358	13,999	17,600	20,838	56.0%
Total Domestic Water Demand for Urban Communities	5,252	5,298	5,897	6,288	19.7%
Total Rural Water Demand	6,716	6,290	5,706	5,502	-18.1%
First Nations’ Communities’ Total Water Demand	950	1,269	1,843	2,449	157.8%
Institutional (Communal) Water Demand	151.67	151.67	155.31	159.26	5.0%
Total Municipal/Domestic Water Demand	**26,427**	**27,007**	**31,201**	**35,236**	**33.3%**

8.8.3 Total Municipal/Domestic Water Demand – Water Conservation Scenario

Although the level of municipal/domestic water demand will change under the water conservation scenario, its pattern will not undergo any significant changes. The total water demand for these purposes in 2060 will be 29,536 dam^3, which is 11% higher than the 2010 level. These results are summarized in Table 8.15.

Trends in the municipal/domestic water demand in the NSRB are shown in Figure 8.3. All scenarios provide the same pattern. In all cases, climate change (after 2020 will bring increases in water demand levels for municipal/domestic purposes, whereas adoption of water conservation practices would reduce the levels. Under this scenario, the 2020 water demand level is lower than the previous period's figure.

Table 8.15: Total Municipal/Domestic Water Demand under Water Conservation Scenario, North Saskatchewan 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	13,358	13,649	15,359	16,556	23.9%
Total Domestic Water Demand for Urban Communities	5,252	5,266	5,425	5,482	4.4%
Total Rural Water Demand	6,716	6,252	5,505	5,088	-24.2%
First Nations' Communities' Total Water Demand	950	1,261	1,779	2,264	138.3%
Institutional (Communal) Water Demand	151.67	150.76	148.95	144.63	-4.6%
Total Municipal/Domestic Water Demand	**26,427**	**26,579**	**28,217**	**29,536**	**11.8%**

8.8.4 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 8.16. Under climate change in 2060, the basin will experience a 9% increase in municipal/domestic water demand, whereas under water conservation scenario a reduction of 8.5% is a possibility.

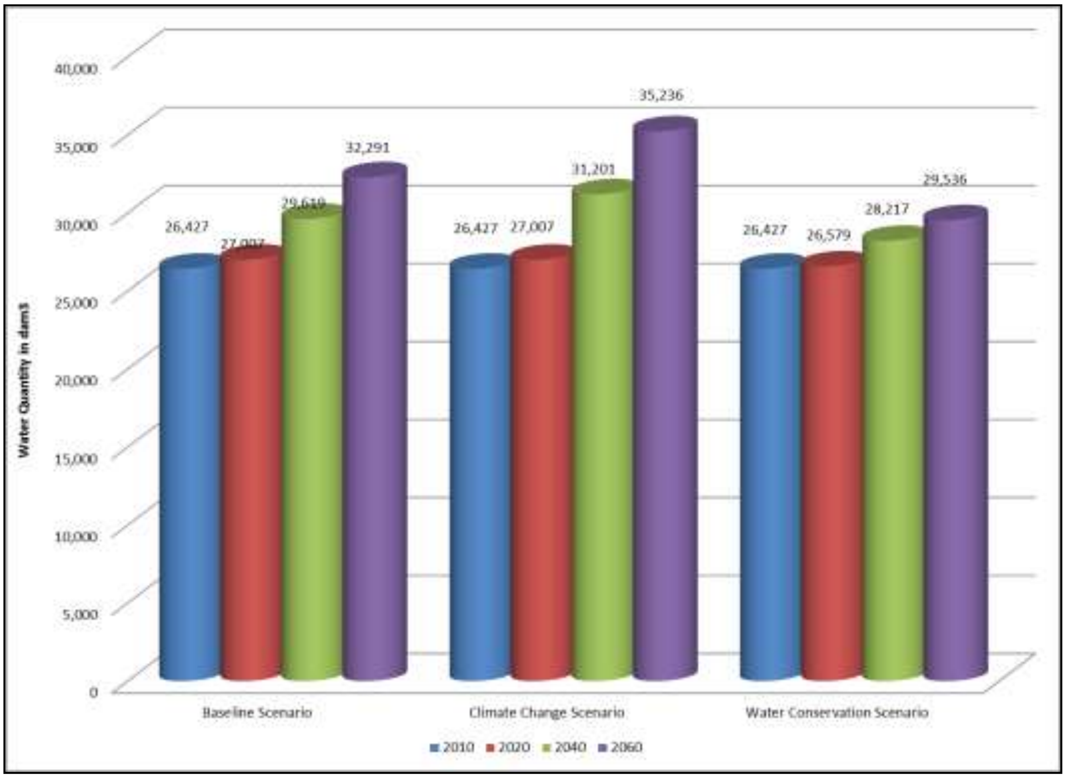

Figure 8.3: Total Municipal/Domestic Water Demand for the North Saskatchewan River Basin, Under Study Scenarios, 2010 – 2060

Table 8.16: Summary of Municipal Water Demand in the North Saskatchewan River Basin, 2010-2060, under Study Scenarios

Scenarios	Total Water Demand in dam^3				% of Baseline Scenario in 2060 2010
	2010	2020	2040	2060	
Baseline Scenario	26,427	27,007	29,619	32,291	0.0%
Climate Change Scenario	26,427	27,007	31,201	35,236	9.1%
Water Conservation Scenario	26,427	26,579	28,217	29,536	8.5%

Chapter 9

Recreational Water Demand

Water-based recreation activities are typically of two types: consumptive, which includes water demand by cottager owners and other residents near or at the surface water bodies; and non-consumptive in nature. The non-consumptive recreation 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, and 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 demand in the NSRB, and this procedure is reported in the present chapter.

The consumptive water demand for recreational activities is needed for two purposes: residents living in recreational communities; and water needed to maintain recreational facilities. The latter includes various federal and provincial parks and other recreational sites in the basin. Since there are no federal parks in the basin, only provincial and other recreational sites were included in this chapter. Here, water is used for administrative purposes as well as for maintaining the park sites. The first type of use is reported in Section 9.1, while the second one in Section 9.2.

9.1 Recreational Communities' Water Demand

Under the first type of recreational water demand, several communities in the NSRB were analyzed. These are listed in Table 3.19. Estimating the total water demand for this category required the multiple assumptions that were presented in Chapter 4.

9.1.1 Recreational Communities Water Demand – Baseline Scenario

Because there is limited information about these communities on the nature of water demand for recreational purposes, a time trend was fitted to the available water demand data. Significant evidence of a growth or decline over time was not detected. As a result, the last five years' average was assumed to be applicable to 2010 water demand. Furthermore, this level was assumed to remain unchanged for the 2020-2060 period. The total water demand for this purpose was therefore related to the population growth in these communities, and this estimate is shown in Table 9.1. Past population changes in these recreational villages has been uneven, as the population will increase/decrease or stay at the same level for a number of years. In the future, any population growth will be restricted by real estate (and infrastructure) development in these villages, as the area for development is limited. Since the recreational villages are relatively more attractive to retirees, the increase in retired population to 2035-40 will have an effect on the demand for such resort properties. The water demand will increase in these communities from 46 dam^3 in 2010 to 142 dam^3 in 2060.

Table 9.1: Water Demand for North Saskatchewan River Basin Recreational Communities, 2010 to 2060

Location	Water Demand (dam^3)			
	2010	**2020**	**2040**	**2060**
Aquadeo Resort Village	20.7	30.9	41.1	61.7
Cochin Resort Village	10.9	16.6	22.4	33.9
Metinota Resort Village	15.0	22.9	30.9	46.7
Total Water Demand	**46.6**	**70.4**	**94.4**	**142.3**
Percent Change Over the 2010 Level		51.4%	103.0%	206.2%

Source: Estimations from SWA (2010), and Ministry of Tourism, Parks, Culture and Sport (2010)

9.1.2 Recreational Communities' Water Demand under the Climate Change Scenario

Calculations of water demand under the climate change scenario were adjusted upwards by using a 2.4% and a 5% increase over the estimated baseline for 2040 and 2060, respectively. Applying these coefficients and projected population, water demand was estimated. These figures are shown in Table 9.2. By 2060, it is expected that this water demand will increase to 149 dam^3, about 5% higher than that projected under the baseline scenario.

Table 9.2: Summary of Recreational Communities' Water Demand in the North Saskatchewan River Basin, 2010 - 2060

Scenario	Estimated Total Water Demand in dam^3 for				% Change in 2060 Over 2010	2060 Level % of Baseline Scenario
	2010	**2020**	**2040**	**2060**		
Baseline	46.6	70.7	94.4	142.3	206.2%	0.0%
Climate Change	46.6	70.4	96.6	149.5	221.5%	5.0%
Water Conservation	46.6	70.0	93.2	138.2	197.3%	-2.9%

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 about the nature of water demands by these residents is not available, making adjustments through water conservation practices very difficult. For this reason, these residents were treated just like any other urban resident. The water demand for these 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 138 dam^3, some 4 dam^3 lower than that under the baseline scenario.

9.1.4 Recreational Communities' Water Demand – Summary

Recreational communities' water demand in the NSRB is a relatively small amount. A range of 46 to 149 dam^3 was estimated for the 2010-2060 period under baseline and climate change scenarios. Under a baseline scenario the water demand per capita coefficients were assumed to remain unchanged in the future. The change in the water demand under this scenario is merely a reflection of the population changes. The climate change scenario indicates an increase of 5% over the baseline. Employing water conservation practices is expected to reduce water demand by 2.9%, relative to the baseline scenario.

9.2 Water Demand for Maintenance of Recreation Sites

Provincial and regional parks require water for maintenance and for supporting visitor services. In the future, the recreational demand is expected to increase. The growth of population in the basin, accompanied with increased urbanization, will result in a higher level of water being used for these purposes. These water demand estimates are presented in this section.

9.2.1 Water Demand for Maintenance of Recreation Sites under the Baseline Scenario

Urban and rural recreation, scenery, wildlife habitat, and fisheries are all strongly affected by the quantity and quality of water and all of these are affected by climate change (Cooper, 1990). Hydrological droughts result in low stream flows and low lake levels. These conditions will likely reduce some of the recreational activities, such as boating and sport fishing, among others. Drought conditions may also place some restrictions on recreational activities (open fires for campers, and a loss of proximity of water from the beach area, among others). These activities may also be reduced.

As noted in Chapters 4 and 5, this water demand has two components: one, a variable level of use related to visitor services, which is determined by number of visitors to the site; and two, a fixed level of water required to maintain office services, lawns, and other facilities. Unfortunately, precise details on these two categories were not available and therefore, analysis was undertaken using a combination of these two uses.

For estimating future water demand for these communities, an average of the last five years' total water demand was utilized. Results are shown in Table 9.3. The current use for these sites is estimated at 43.06 dam^3.

Future projection of visitors is a complex exercise since many factors are affects these levels. One of the major factors among these is the size of the water body at these sites, as well as other quality related aspects. In addition, the quality of a site deteriorates as congestion to a site increases, unless infrastructure and other facilities are improved accordingly. The size of the water body is related to changes in the hydrological regime of the region. Such projections were considered beyond the scope of this study.

Table 9.3: North Saskatchewan River Basin Provincial Parks and Recreational Sites, 2010 to 2060

Community	Water Demand (dam^3)			
	2010	**2020**	**2040**	**2060**
Provincial Parks and Recreational Sites	43.1	43.1	43.1	43.1

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

Recreational site maintenance may increase due to higher temperatures and lower precipitation. Assuming the same change as that assumed for the domestic water demand (2.4% and 5% increase in water demand by 2040 and 2060, respectively), estimated maintenance water demand is shown in Table 9.4, and under this scenario it is estimated to increase to 45 dam^3 by 2060.

Table 9.4: Water Demand for Recreational Sites in the North Saskatchewan River Basin Sites, Climate Change Scenario with Comparison with the Baseline Scenario, 2010 - 2060

Year	Baseline Use in dam^3	Climate Change Use in dam^3	Change over Baseline Scenario (%)
2010	43.1	43.1	0%
2020	43.1	43.1	0%
2040	43.1	44.1	2.4%
2060	43.1	45.2	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 that these measures will result in a similar reduction as the effect for the municipal water systems' current and future demand produces the estimates shown in Table 9.5. This water demand for the adoption of water conservation measures could be as low as 40 dam^3 by 2060.

Table 9.5: Water Demand for Recreational Sites in the North Saskatchewan River Basin Sites, Water Conservation Scenario and Comparison with Baseline Scenario, 2010 - 2060

Year	Baseline Use in dam^3	With Water Conservation Use in dam^3	Change over Baseline Scenario (%)
2010	43.1	43.1	0%
2020	43.1	42.0	-2.5%
2040	43.1	40.9	-5.0%
2060	43.1	39.6	-8.0%

9.3 Summary of Recreational Water Demand

The total recreational water demand levels for the three study scenarios are presented in Table 9.6. These estimates include water needed for recreational communities, as well as that required for recreational sites. Under the baseline scenario, water demand may increase from 90 dam^3 in 2010 to 185 dam^3 by 2060. Climate change may bring about a higher increase in these water demand levels – 5% of the 2010 level in 2060, although water conservation does offer some reduction in it.

Table 9.6: Summary of Recreation Water Demand under Study Scenarios, North Saskatchewan River Basin 2010 - 2060

Scenario	Water Demand in dam^3				Change in 2060 % of 2010 Level
	2010	2020	2040	2060	
Baseline	89.6	113.4	137.4	185.4	0.0%
Climate Change	89.6	113.4	140.7	194.7	5.0%
Water Conservation	89.6	111.9	134.1	177.8	4.1%

Chapter 10

Indirect Anthropogenic Water Demand

Any comprehensive balancing of water demand against supply requires all water demands. Included among these uses are those demands resulting from natural processes or policy regulations. These uses are not related to any direct or indirect human use of water. Therefore, in this study, they are called indirect anthropogenic water demands. Three such estimates included in this category of water demands are evaporation, apportionment, and environmental water demands. These 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. The estimates presented before were 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 NSRB are presented in Table 10.1. These values were forecast for the current situation (time period). It was assumed that factors affecting evaporation (temperature, precipitation, sunny days, among others) will remain unchanged over the next 50 year period, except for conditions 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 285,568 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: Waskesiu Lake north of Prince Albert, Turtle Lake, and Crean Lake. Evaporation losses from these three water bodies constitute 41% 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 smaller 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, conditions caused by climate change will result in greater evaporation. It has been estimated that precipitation accounts for 55% of the variability in lake levels while temperature accounts for 30% (Lemmen et al., 2008). The estimates of the climate in southern Saskatchewan to 2060 are for higher yearly temperatures with higher September to April precipitation (CCCSN, 2011). The level of snow pack and rate of snowmelt are then prime determinants of surface water body recharge. Unfortunately, the climate models give no specific measure of these factors. The water depth and area of surface water bodies in the spring are two factors that affect the rate of evaporation over the ice free period. There are then many factors that would have positive or negative effects on the rate of evaporation with little or no guide as to how these influences will play out to 2060.

Table 10.1: Evaporation Losses of Lakes and Reservoirs, North Saskatchewan River Basin, 2010 – 2060

Particulars	**Net Evaporation Losses in dam^3**			
Lakes	**2010**	**2020**	**2040**	**2060**
Ajawaan Lake	146.3	146.3	153.6	160.9
Alsask Lake	1,100.0	1,100.0	1,155.0	1,210.0
Christopher Lake	3,000.0	3,000.0	3,150.0	3,300.0
Cowan Lake	31.3	31.3	32.8	34.4
Emma Lake	4,200.0	4,200.0	4,410.0	4,620.0
Jackfish Lake	8,424.1	8,424.1	8,845.3	9,266.5
Lone Island Lake	275.0	275.0	288.8	302.5
Manitou Lake	23,906.3	23,906.3	25,101.6	26,296.9
Redberry Lake	16,800.0	16,800.0	17,640.0	18,480.0
Sturgeon Lake	2,400.0	2,400.0	2,520.0	2,640.0
Tramping Lake	13,200.0	13,200.0	13,860.0	14,520.0
Turtle Lake	36,750.0	36,750.0	38,587.5	40,425.0
Reservoir				
Scott Dam	60.0	60.0	63.0	66.0
Spruce River Dam	2,400.0	2,400.0	2,520.0	2,640.0
Woody Lake Weir	525.0	525.0	551.3	577.5
Total	**113,217.9**	**113,217.9**	**118,878.8**	**124,539.6**

Waggoner and Revelle (1990) suggest that evaporation will change by approximately 6% for every degree by the capacity of the air for water vapor. Döll (2002) estimated that water requirements for irrigation will increase between 3 to 5% by 2020, and between 5 to 8 % by 2070, which may lead to additional needs for the 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.[58]

The net evaporation losses for lakes and reservoirs in the NSRB are presented in Table 10.1 (last two columns representing levels under climate change). The base evaporation losses are applied 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 124,540 dam^3 by 2060. Larger lakes remain the major water bodies contributing to the total 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 uses are determined by natural conditions, their values were assumed to remain the same as those described under the baseline scenario. It is recognized that there may be technological measures that can reduce evaporation losses, but such knowledge is still in a developmental stage, and therefore, not considered in this study.

10.2 Apportionment Water Demand

Although the North Saskatchewan River contributes towards the apportionment demand for the Saskatchewan River, as noted in Chapter 3 no specific apportionment demand is calculated for this river. Based on the arguments presented in Chapter 3, this water demand was set equal to zero for the 2010 - 2060 period.

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. Based on the data presented in Chapter 3, this water demand was set at 41,937 dam^3 annually. This amount was assumed to remain at this level for the future time periods.

10.4 Instream Flow Requirements

As noted in Chapter 3, in the NSRB, no evidence was found to support a minimum flow requirement in the North Saskatchewan River. This water demand was set equal to zero for the current and future time periods.

[58] It should be noted that these levels are assumed. Further research is needed to ascertain them using climate models.

Chapter 11

Summary and Implications

Water demand in the NSRB is estimated for 2010 at 421,302 dam^3, of which direct anthropogenic uses account for 93,797 dam^{3}of the total, or 22%. The projected water demand is estimated for three years (2020, 2040, and 2060) and for three scenarios.

11.1 Summary of Total Water Demand for the Baseline Scenario

The baseline scenario utilizes the estimated activity levels for various direct anthropogenic and indirect anthropogenic activities combined with water demand coefficients to estimate water demand levels for the NSRB. The increased amount of irrigated area, expansion of the power generation sector and increased domestic water demand are the main forces behind the change in water demand. Direct anthropogenic activities are projected to account for 29% of the total water demand by 2060, slightly increasing their 2010 share (Table 11.1).

11.2 Summary of Total Water Demand for the Climate Change Scenario

The potential effects of climate change on the direct anthropogenic and indirect anthropogenic water demand activities in the NSRB are presented in Table 11.2. Higher growing season temperatures will have a significant impact on the agricultural sector, since both crops and livestock will demand additional water. Evaporation of water from water bodies, which is already a major indirect anthropogenic water demand, is one of the 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 NSRB are presented in Table 11.3. Agricultural and industrial adoption of water conservation techniques and technologies has the greatest impact on the direct anthropogenic demand for water. The Policy Research Initiative (2005) reported that Canada has made little use of economic instruments for water management. These instruments are often promoted as the least-cost approaches to efficient water management. They also have merit in terms of water supply cost recovery, internalizing environmental costs, and acting as a signal to users to reduce their water consumption. Such sentiments have also been voiced by the recent National Roundtable on Environment and the Economy (NRTEE, 2011); it points out 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 North Saskatchewan 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	39,344	40,677	49,576	70,782
	Livestock	8,524	9,086	9,420	9,691
	Pesticide	296	289	286	286
	Other (Greenhouse and Aquaculture)	168	169	177	185
	Sub-Total	**48,332**	**50,221**	**59,459**	**80,944**
Industry/Mining	Potash	0	0	0	0
	Oil and Gas	933	1,253	752	188
	Manufacturing	7,200	7,344	7,490	7,640
	Other Mining	283	291	320	352
	Irrigation Induced	0	0	-1,071	-1,071
	Power Generation	2,116	2,933	4,032	5,026
	Sub-Total Excluding IBT*and IPT**	**10,532**	**11,821**	**11,523**	**12,135**
	Interbasin Transfers	1,663	3,220	3,220	3,220
	Inter-Provincial Transfers	6,752	6,752	6,752	6,752
	Sub-total including IBT and IPT	**18,947**	**21,793**	**21,495**	**22,107**
Municipal/Domestic	Municipal	26,276	26,856	29,468	32,139
	Public Institutions	152	152	152	152
	Sub-Total	**26,428**	**27,008**	**29,620**	**32,291**
Recreation	Recreation Communities	47	71	94	142
	Parks/Recreation	43	43	43	43
	Sub-Total	**90**	**113**	**137**	**185**
Sub-total Direct Anthropogenic Activities Excluding IBT and IPT		**85,382**	**89,163**	**100,739**	**125,555**
Total Interbasin Transfers		1,663	3,220	3,220	3,220
Total Inter-Provincial Transfers		6,752	6,752	6,752	6,752
Sub-total Direct Anthropogenic Activities Including		**93,797**	**99,135**	**110,711**	**135,527**
INDIRECT ANTHROPOGENIC ACTIVITIES					
Other Water Demands	Evaporation	285,568	285,568	285,568	285,568
	Apportionment	0	0	0	0
	Instream Flow	0	0	0	0
	Environment	41,937	41,937	41,937	41,937
Sub-Total Indirect Anthropogenic Water Demand		**327,505**	**327,505**	**327,505**	**327,505**
Total Water Demand excluding IBT		**412,887**	**416,668**	**428,244**	**453,060**
Total Water Demand Including IBT		**421,302**	**426,640**	**438,216**	**463,032**

*IBT – Interbasin Transfers
**IPT – Inter-Provincial Transfers

Table 11.2: Water Demand in the North Saskatchewan River Basin for the Climate Change Scenario, 2010- 2060

Sector	Sub-Activity	Total Amount of Water Demand in			
		2010	2020	2040	2060
DIRECT ANTHROPOGENIC ACTIVITIES					
Agriculture	Irrigation	39,344	40,677	57,987	89,639
	Livestock	8,524	9,086	9,740	10,359
	Pesticide	296	289	300	312
	Other (Greenhouse and Aquaculture)	168	169	177	185
	Sub-Total	**48,332**	**50,221**	**68,204**	**100,495**
Industry/Mining	Potash	0	0	0	0
	Oil and Gas	933	1,253	752	188
	Manufacturing	7,200	7,344	7,642	7,948
	Other Mining	283	291	320	352
	Irrigation Induced	0	0	-1,065	-1,058
	Power Generation	2,116	2,933	4,113	5,227
	Sub-Total Excluding IBT*and IPT**	**10,532**	**11,821**	**11,762**	**12,657**
	Interbasin Transfers	1,663	3,220	3,220	3,220
	Inter-Provincial Transfers	6,752	6,752	6,887	7,022
	Sub-total including IBT and IPT	**18,947**	**21,793**	**21,869**	**22,899**
Municipal/Domestic	Municipal	26,276	26,856	31,046	35,077
	Public Institutions	152	152	155	159
	Sub-Total	**26,428**	**27,008**	**31,201**	**35,236**
Recreation	Recreation Communities	47	70	97	150
	Parks/Recreation	43	43	44	45
	Sub-Total	**90**	**113**	**141**	**195**
Sub-total Direct Anthropogenic Activities Excluding IBT and IPT		**85,382**	**89,163**	**111,308**	**148,583**
Total Interbasin Transfers		1,663	3,220	3,220	3,220
Total Inter-Provincial Transfers		6,752	6,752	6,887	7,022
Sub-total Direct Anthropogenic Activities Including IBT and		**93,797**	**99,135**	**121,415**	**158,825**
INDIRECT ANTHROPOGENIC ACTIVITIES					
Other Water	Evaporation	285,568	285,568	299,846	314,125
	Apportionment	0	0	0	0
	Instream Flow	0	0	0	0
	Environment	41,937	41,937	41,937	41,937
Sub-Total Indirect Anthropogenic Water Demand		**327,505**	**327,505**	**341,783**	**356,062**
Total Water Demand excluding IBT and IPT		**412,887**	**416,668**	**453,091**	**504,645**
Total Water Demand Including IBT and IPT		**421,302**	**426,640**	**463,198**	**514,887**

* IBT – Interbasin Transfers
** IPT – Inter-Provincial Transfers

Table 11.3: Water Demand in the North Saskatchewan River Basin for the Adoption of Water Conservation Measures

Sector	Sub-Activity	Total Amount of Water Demand in dam^3			
		2010	2020	2040	2060
ANTHROPOGENIC ACTIVITIES					
Agriculture	Irrigation	39,344	36,206	42,594	59,894
	Livestock	8,524	9,086	9,104	9,318
	Pesticide	296	289	257	143
	Other (Greenhouse and Aquaculture)	168	169	177	185
	Sub-Total	**48,332**	**45,750**	**52,132**	**69,540**
Industry/Mining	Potash	0	0	0	0
	Oil and Gas	933	1,065	639	160
	Manufacturing	7,200	7,184	7,307	7,428
	Other Mining	283	285	314	345
	Irrigation Induced	0	0	-1,008	-947
	Power Generation	2,116	2,787	3,427	3,770
	Sub-Total Excluding IBT*and	**10,532**	**11,321**	**10,679**	**10,756**
	Interbasin Transfers	1,663	3,172	3,011	2,817
	Inter-Provincial Transfers	6,752	6,617	6,617	6,617
	Sub-total including IBT and IPT	**18,947**	**21,110**	**20,307**	**20,190**
Municipal/Domestic	Municipal	26,276	26,428	28,068	29,390
	Public Institutions	152	151	149	145
	Sub-Total	**26,428**	**26,579**	**28,217**	**29,535**
Recreation	Recreation Communities	47	70	93	138
	Parks/Recreation	43	42	41	40
	Sub-Total	**90**	**112**	**134**	**178**
Sub-total Direct Anthropogenic Activities Excluding IBT and IPT		**85,382**	**83,762**	**91,162**	**110,009**
Total Interbasin Transfers		1,663	3,172	3,011	2,817
Total Inter-Provincial Transfers		6,752	6,617	6,617	6,617
Sub-total Direct Anthropogenic Activities Including IBT and IPT		**93,797**	**93,551**	**100,790**	**119,443**
INDIRECT ANTHROPOGENIC ACTIVITIES					
Other Water Demands	Evaporation	285,568	285,568	285,568	285,568
	Apportionment	0	0	0	0
	Instream Flow	0	0	0	0
	Environment	41,937	41,937	41,937	41,937
Sub-Total Indirect Anthropogenic Water Demand		**327,505**	**327,505**	**327,505**	**327,505**
Total Water Demand excluding IBT		**412,887**	**411,267**	**418,667**	**437,514**
Total Water Demand Including IBT		**421,302**	**421,056**	**428,295**	**446,948**

* IBT – Interbasin Transfers
** IPT – Inter-Provincial Transfers

11.4 Conclusions

Water management is a complex issue that will face the NSRB in the future. Significant changes are already happening and will happen in the future; these alternatives are going to change the way in which water is managed in the future. A summary of these changes is shown in Figure 11.1.

Figure 11.1: Overview of Issues Related to Water management in the North Saskatchewan River Basin

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 (EEA, 2007). 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) have also been incorporated.

Based on the estimated water demand, a number of conclusions can be drawn. The most significant conclusion is that water demand in the NSRB is going to rise in the future. This will be a result of two major trends: one, expansion of irrigation in the basin, such as development of the NSRB-Westside Irrigation District; and two, expansion of urban population around the city of Saskatoon. In addition, future potash mining activities in the NSRB are expected to increase. These first two uses combined would constitute over 90% of the total water demand in the basin by 2060. Whether this proportion will result in water scarcity or in tough competition among its users remains to be determined. Although municipal water demand is presently an extremely important use of water in the basin, its share is expected to increase in the future. All these increases are predicated on the best knowledge that we have at this time. For instance, new potash mines are proposed, and therefore included in these estimates. Whether the mines will actually be in production of potash remain to be seen.

Moreover, the importance of surface water in the future is expected to be higher. For examples, economic activities, such as irrigation and potash mining, will draw more surface water. Although groundwater demand will still be important, it will constitute a smaller portion of the total water demand (claiming 2% of total water demand by 2060). As competition to 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 users on the merits of adopting such measures are often noted as the most important factors affecting the adoption of water conservation practices. The National Roundtable on the Environment and Economy (NRTEE, 2012) has also advanced such prescriptions. The Table has suggested the potential of two emerging policy instruments for water conservation — water pricing and voluntary initiatives. Improved water use management starts with strong principles that value water so that it can be conserved and used efficiently. Sustainable water consumption 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 periods of drought, and extreme rain events to finalize such estimates. Parry et al. (2007) have concluded that semi-arid and arid areas are particularly exposed to the impacts of climate change in freshwater. Furthermore, these uses may not be feasible without further infrastructure development.

Water conservation may also become critically very important during the period when climate change impacts on the basin are felt. Although such measures may not be able to offset the increases triggered by climate change, particularly during periods of drought, 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. Some overall limitations of this study are noted below in three parts: Overall limitations; Major data gaps for various sectors; and Water demand reassessment.

11.5.1 Overall Limitations

- One of the major weaknesses of the forecasting methodology used in this study is that water demand is also affected by its availability. Since water supply data were not available, this aspect could not be included and perhaps needs to be considered in any future analyses.

- This study did not develop water demand coefficients from primary data. These values were either borrowed from other studies, or calculated applying 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 not a well-studied subject. This aspect needs to be investigated as better data on the effect of provincial regulation/incentives become available.

11.5.2 Need for Better Sectorial Information

A summary of needs for future research in this area are summarized in Figure 11.2.

11.5.2.1 Agricultural Water Demand

- Adoption of irrigation in the basin for an irrigation district, or by private irrigators, has not been studied. A more recent analysis of rates of adoption and factors that affect it is required, not only for this basin but for all irrigation areas in the province.

- Data on actual water demand by producers for different crops is not available. This type of information affects

Figure 11.2: Summary of further research by sector

- For stockwatering use, information on the effect of water conservation measures based on new technology was not available in the literature. Further investigation is needed to look at actual animal needs and reduction of waste through new technology.
- Information on aquaculture water demand is very weak. Further study of this sector is needed. Given several large freshwater bodies in the basin, this water demand may increase in the future.

- Return flow from irrigation districts was based on past coefficients. More recent estimates are needed.

11.5.2.2 Industrial/Mining Water Demand

- Potash mining water demand, as well as that expanded in oil and gas production requires a fresh look in terms of reducing fresh water by the substitution with saline water. 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 specifically for the basin.

- Effect of climate change on industrial water demand was an assumed number in this study. Further investigation of this impact is needed.

11.5.2.3 Municipal/Domestic Water Demand

- Data on future population growth for Saskatchewan by river basins would improve the water demand estimates reported in this study.

- There is little information on the institutional water demand in the basin. These institutions need to be surveyed to determine their future water need and 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.

- Some communities receive surface water through rural pipelines. This information was not employed 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 is also required.

11.5.2.4 Recreational Water Demand

- Effect of water quality and congestion on recreational use of a recreation site could not be incorporated. These factors are important for future use of these sites for recreational activities.

11.5.2.5 Indirect Anthropogenic Water Demand

- Apportionment water demand needs to be revised for future periods. As availability of water fluctuates, there may be some need for this type of water demand.

- Evaporation losses from surface water bodies were based on a study undertaken in the 1980s. A revised look at this issue would have some merits, particularly in the context of climate change.

11.5.3 Revisions in Water Demand Estimates

At the time of writing this report, some data/information were not available. These data can be obtained and thus, there is a need for some revisions in the future water demand:

- Farm and rural non-farm population numbers were not available at the time of writing this report. Data from the agriculture census will be released at some future date.

- Potash mining water demand will need to be revised as new mines come into operation or become close to finalization of their plan for production.

- Use of groundwater for irrigation was based on a visual examination of a graph. This estimate requires further checking and perhaps some revision.

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Appendix A

Estimation of Land Use for the North Saskatchewan River Basin

Since details on the Saskatchewan portion of the North Saskatchewan River Basin (NSRB) were not available, data were collected for the entire basin (Alberta and Saskatchewan combined). These data were available for the Nelson River drainage area where the NSR is a part of it. A map of the drainage area is shown in Figure A.1.

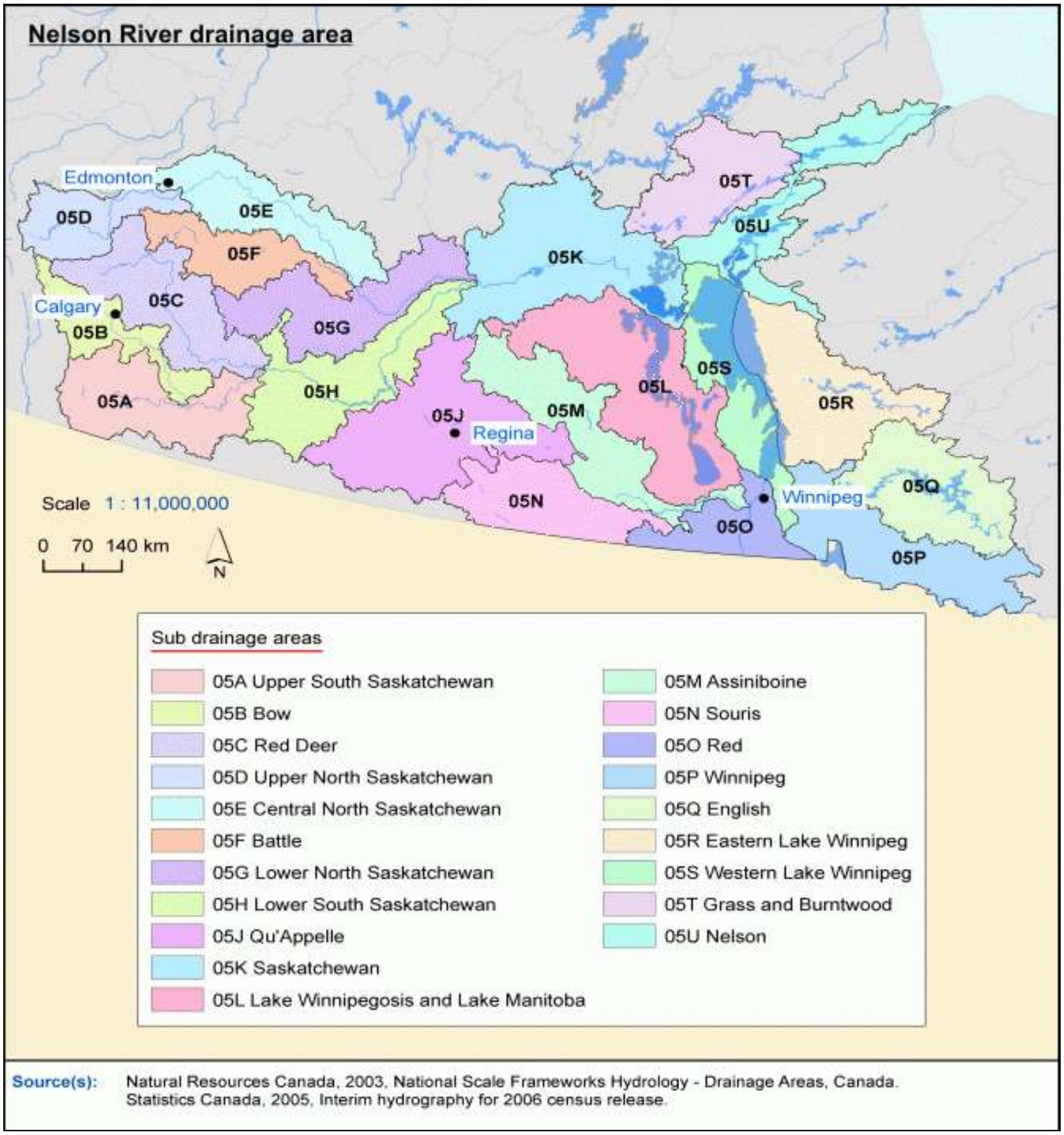

Figure A.1: Map of Nelson River Drainage Area

From Figure A.1, three watersheds were selected that represented the NSRB. These were: Watershed 05D – Central North Saskatchewan; 05E – Battle watershed; and 05G – Lower North Saskatchewan. Assuming that the Alberta portion of these watersheds is similar in terms of land use, these data were added together. These are shown in Table A.1.

Table A.1: Land Use in Alberta – Saskatchewan North Saskatchewan River Basin, 2000

Land Cover Category	Central North Saskatchewan	Battle River	Lower North Saskatchewan	All Watersheds
	Square Kilometers			
Forested area	2,447	56	2,806	5,309
Shrubland	1,050	64	728	1,842
Grassland	367	230	3,731	4,328
Cropland (incl. woodland)	37,274	29,691	41,817	108,782
Other	1,137	201	570	1,908
Total Area	42,275	30,242	49,652	122,169

Appendix B

List of Communities in the North Saskatchewan River Basin

Table B.1: Categories of Communities in North Saskatchewan River Basin

	1. CITIES
1.	North Battleford
2.	Prince Albert
3.	Lloydminster

	2. TOWNS		
	2a. More than 1000		**2b. Less than 1000**
1	Battleford	1	Asquith
2	Biggar	2	Blaine Lake
3	Delisle	3	Cut Knife
4	Kerrobert	4	Debden
5	Kindersley	5	Eatonia
6	Langham	6	Elrose
7	Macklin	7	Kyle
8	Maidstone	8	Lashburn
9	Rosetown	9	Luseland
10	Shellbrook	10	Marshall
11	Unity	11	Neilburg
12	Wilkie	12	Paradise Hill
		13	Perdue
		14	Radisson
		15	St. Walburg
		16	Turtleford

	3. VILLAGES		
1	Arelee	30	Salvador
2	Borden	31	Scott
3	Canwood	32	Senlac
4	Coleville	33	Smiley
5	Denholm	34	Sovereign
6	Denzil	35	Speers
7	Dinsmore	36	Spruce Lake
8	Dodsland	37	Tramping Lake
9	Glaslyn	38	Vawn
10	Glidden	39	Waseca
11	Hafford	40	Wiseton
12	Handel	41	Zealandia
13	Harris	42	Bayview Heights

14	Laird	43	Brancepeth
15	Albertville	44	Canwood
16	Landis	45	Crystal Bay Sunset
17	Leask	46	Day's Beach
18	Major	47	Delmas
19	Marcelin	48	Evergreen Acres
20	Marsden	49	Fairholme
21	Maymont	50	Frenchman Butte
22	Medstead	51	Greenstreet
23	Meota	52	Hillmond
24	Milden	53	Livelong
25	Paddockwood	54	Lone Rock
26	Paynton	55	Mayfair
27	Plenty	56	Sleepy Hollow
28	Primate	57	Spruce Bay
29	Rabbit Lake	58	Weyakwin
	5. FIRST NATIONS RESERVES		
1	Ahtahkakoop Reserve #104	9	Muskoday Reserve #99
2	Birch Lake Reserve #159A	10	Poundmaker Reserve #114
3	Little Pine Reserve #116	11	Red Phesant Reserve #108
4	Little Red River Reserve #106B	12	Saulteaux Reserve #159
5	Mistawasis Reserve #103	13	Sturgeon Lake Reserve #101
6	Moosomin Reserve #112B	14	Sweetgrass Reserve #113
7	Mosquito Grizzly Bears Head Reserve #109	15	Thuderchild Reserve #115B
8	Muskeg Lake Reserve #102	16	Witchekan Lake Reserve #117

	6a RECREATIONAL VILLAGE		**6b. PARKS/RECREATIONAL SITES**
1	Aquadeo Resort Village	1	Anderson Point Campground- Anglin Lake
2	Cochin Resort Village	2	Battlefords Provincial Park
3	Metinota Resort Village	3	Minowakaw Beach - Candle Lake Prov Park
		4	Murray Point Campground Emma Lake
		5	North Bay Mobile Home Park
		6	Sunset View
		7	West Chatfield Beach
		8	Kenderdine Campus (Emma Lake)
		9	Lanz Point
		10	Martinson's Beach

	7. Others
1	Interlake Regional Water System
2	Nisbet Fire Control Centre
3	Prince Albert Forest Nursery

Appendix C

Correspondence Table for the North Saskatchewan River Basin

Most data are reported on an administrative boundary/region basis (such as Province, Census Division, Census Agriculture Region, and Rural Municipality). Since river basin boundaries do not always follow the administrative boundaries, some basis of correspondence among these regions is required. Under the strict assumption that economic activity is evenly distributed throughout the administrative regions, one could estimate the area in the river basin that falls within that administrative region. This is the basis followed in this study.

The percentage area of a rural municipality in a water basin was estimated using a watershed and rural municipality map. The areas of the Census Divisions and the Crop Districts were 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 NSRB Watershed are presented in Tables C.1 for Census Divisions, in Table C.2 for Census Agriculture Regions, and in Table C.3 for Rural municipality, respectively.

Table C.1: Census Division Correspondence to North Saskatchewan River Basin

Census Division	Total area		North Saskatchewan River Basin		North Saskatchewan River Basin as a % of Total
	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 C.2: Crop District Correspondence to North Saskatchewan River Basin

Crop District	Total area		North Saskatchewan River Basin		North Saskatchewan River basin
	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 C.3: Rural Municipality Correspondence to North Saskatchewan River Basin

RM #	%RM in RB	RM #	%RM in RB	RM #	%RM in RB
68	45	163	85	252	100
69	55	164	15	253	60
70	4	181	30	254	35
98	40	183	100	276	60
99	100	184	100	277	100
100	85	185	100	278	100
101	40	186	100	279	100
122	10	187	100	280	100
123	10	189	100	281	100
124	5	190	100	282	65
125	10	191	100	307	100
126	30	193	100	308	100
127	60	194	80	309	100
128	65	211	5	310	100
129	96	213	40	312	100
130	100	214	30	313	65
131	90	215	80	336	10
132	30	216	100	337	95
133	10	217	100	338	100
151	65	218	100	339	100
152	60	219	100	340	100
153	90	220	100	341	100
154	95	221	100	342	70
155	100	222	100	343	5
156	100	223	100	367	50
157	100	224	20	368	65
158	100	246	65	369	60
159	100	247	100	370	40
160	100	248	100	371	40
161	100	250	100	372	5
162	100	251	100	400	4

Appendix D

Water Conveyance Methods and Water Demand for Irrigation in Selected Irrigation Districts of the Lake Diefenbaker Development Area

Table D.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 D.2: Irrigation Water Use per Acre by Selected Irrigation Districts in the Lake Diefenbaker Development Area

Year	Riverhusrt ID		Luck Lake ID		SSRID	
	Acres	Applied mm	Acres	Applied mm	Acres	Applied mm
1990	5,138	232	6,544	260	33,878	370
1991	6,590	152	7,097	156	26,791	253
1992	7,085	253	7,334	218	32,873	411
1993	7,216	197	7,441	198	28,819	244
1994	7,568	171	7,909	204	30,324	347
1995	7,563	199	7,909	224	32,865	407
1996	7,563	138	7,909	170	29,276	263
1997	7,935	214	7,900	226	31,218	346
1998	8,427	219	8,764	261	32,706	405
1999	8,255	94	8,764	85	25,323	202
2000	8,255	124	8,913	125	30,696	295
2001	8,415	259	8,913	273	32,719	488
2002	8,881	164	8,602	217	33,671	413
2003	9,538	290	8,602	292	33,420	428
2004	9,870	136	8,602	121	33,457	287
2005	9,982	132	9,045	104	30,618	137
2006	10,071	151	9,045	149	32,312	227
2007	10,195	204	9,134	168	32,449	227
2008	10,443	201	9,829	205	33,806	247
2009	11,337	188	10,153	197	34,397	209
Average	8,516	186	8,420	193	31,581	310
Min	5,138	94	6,544	85	25,323	137
Max	11,337	290	10,153	292	34,397	488
ST.DEV	1,524	51	905	58	2,461	95

Appendix E

Description of Methodology Used by Natural Resource Canada for Evaporation Water Demand Estimates

The map represents the mean value (in millimeters) of the annual loss of water through the evaporation process from the surfaces of open water bodies, such as ponds and shallow lakes and reservoirs based on the 10-year period 1957 to 1966. The greatest mean annual lake evaporation (more than 900 millimeters) occurs in southwest Saskatchewan and southeast Alberta. The smaller means (less than 100 millimeters) appear in the Arctic Islands. The mean annual lake evaporation across Canada generally decreases from south to north. The map also shows the location of the stations, which are part of the “Class A pan evaporation network” used for the analysis and additional stations operating in 1974.

The rate at which water evaporates from a lake depends primarily on two factors: first, the rate at which energy is supplied to the evaporating surface to effect the change of state of water to water vapor (requires 2.47 joules per kilogram) and secondly, the rate of diffusion of water vapors away from the surface. The main energy supply for evaporation is generally through the heating of the upper part of the lake by the sun, although in some cases, the net energy adverted into the water body, by streams for example, may also be important. For a specific lake surface temperature, the rate of diffusion of water vapor is determined in a complex manner by atmospheric temperature, humidity, and wind speed. For small, shallow water bodies, evaporation is greater for sunny days during the summer when the water temperature is high, the humidity is low, and winds are brisk. For deeper lakes, heat storage becomes an important consideration and evaporation is not as closely associated with the daily energy input by the sun's radiation. For example, large amounts of water evaporate from deep lakes during the autumn when their surface temperatures are much higher than air temperatures, while the smaller lakes, because of lack of energy storage, evaporate very little. The converse takes place during late spring and early summer when the large deep lakes evaporate very little because of their relatively low surface temperatures.

The plate contains four maps showing the mean river freeze-over date, the mean lake freeze-over date, the mean river ice-free date and the mean lake ice-free date. The four maps depict, in a general way, the average dates on which freshwater bodies in Canada become completely ice-covered in the fall, and become completely ice-free in the spring. The formation of an ice cover on a water body is called freeze-up; and the melting and dissipation of this ice cover is called break-up.

Freeze-up begins when surface water is cooled to 0 degrees Celsius and ice crystals begin to form; it ends when the water body has attained its maximum ice coverage. Most lakes freeze over completely; rivers may or may not, depending on their location, size, and flow characteristics. The final stage of the freeze-up process may be termed “freeze-over”.

Break-up normally begins when air temperatures rise above 0 degrees Celsius, and when surface and internal melting of the ice sheet begins. The process is aided by the action of winds and currents, which results in mechanical breaking of the ice. Break-up ends when the water body becomes completely clear of all ice. Many rivers and lakes in the Arctic region, however, may never become completely ice free because of the shortness of the melting season.

In general, rivers freeze over later and clear earlier than lakes in the same area. This is due to the effect of river currents, which retard freezing in the fall and aid the breaking up of the ice in spring.

Appendix F

Water Demand for Potash Tailings Disposal

Sask Water made a proposal to the Potash Producers of Saskatchewan to supply water for potash tailings dissolution. The mines that would be supplied with water from the North Saskatchewan River system include PCS Lanigan and Rocanville mines, along with Mosaic Canada mines at Belle Plaine and Esterhazy K1 and 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 G.1.

Table F.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 take is “at what point will the cost of expanding the tailings pond be greater than adopting the technology to put the tailings underground?”

Appendix G

Water Demand by Husky Energy Located at Lloydminster

Estimation of the changes in the level of production, along with changes in water use technology for industry, is a complex task. Part of this complexity exists on account of different uses of water within the manufacturing process. Unfortunately, as noted in Chapter 3, for some of these establishments, data on total water demand are not available. For others, obtaining the quantity of their production was difficult. One such difficulty was encountered with the Husky Energy facility located in the city of Lloydminster.

The company produces through three operations at the Lloydminster location: Heavy Oil Biprovincial Upgrader, Asphalt Refinery, and Ethanol Plant. The upgrader and ethanol plant are located on the Saskatchewan side, while the asphalt plant is in Alberta. The first two operations, although located in Saskatchewan, withdraw their water under an Alberta Environment Water Diversion License from the Alberta side of the basin. Withdrawals of up to 6,752 dam^3 of water are obtained using the City of Lloydminster infrastructure (SWA 2007, personal communication with Dave Kay of Husky Energy, June 2012).

According to Husky Oil, its steam heavy oil recovery operation uses only non-potable[59] groundwater, of which 90% of the water used is recycled (Husky, 2009). Husky has initiated "Enhanced Fluid Management Techniques" in areas that have high drilling rates so that water demand can be reduced by 50%- 60% by recycling and reconditioning water for use in all aspects of the drilling program (Husky, 2009).

Production levels for the three operations are shown in Table G.1. The upgrader in 2011 produced 69.6 thousand barrel of oil (mbbl), and the refinery produced 28.1 mbbl of asphalt. Ethanol is produced in two locations: Lloydminster and Minnedosa (Manitoba). Unfortunately, detailed production data for the Lloydminster plant only were not available.

[59] Non-potable water is that water which is not suitable for human or animal use.

Table G.1: Husky Energy Production Levels by Product Type, 2007-2011

Product	Production Level in				
	2011	2010	2009	2008	2007
Upgrader (mbbl)*	69.6	65.4	74.1	68.1	61.4
Asphalt Refinery (mbbl)	28.1	27.8	24.1	26.1	25.3
Ethanol (Litres)[a]	711,300	619,700	676,900	627,200	324,600

* One thousand barrels. One barrel is 45 U.S. gallons (equivalent to 34.97 imperial gallons, or 158.98 litres.

a. Includes the Husky Lloydminster and two Minnedosa, Manitoba plants. Since these plants use a different mix of feedstock, their individual production levels could not be determined.

Source: Husky Annual Reports 2008-2011.

Appendix H

Regression Equations for Population Growth and Per Capita Water Demand by type of Communities in the North Saskatchewan River Basin

Table H.1: Regression equations for Population, North Saskatchewan River Basin

Category	Dependent variable	Intercept	Time	R^2	F-value
North Battleford	Pop.	14,211.33	96.77500***	0.22560	3.79
	S.E.	452.14	49.72879		
Prince Albert	Pop.	34,956.84	504.97860	0.57469	17.57
	S.E.	1,095.48	120.48630		
Lloydminster	Pop.	17,647.06	582.22860	0.93819	182.16
	S.E.	405.83	43.13911		
Towns>1000	Log pop.	10.13	0.003379**	0.349863	7.00
	S.E.	0.01	0.001278		
Towns<1000	Pop.	9,219.60	161.825000	0.802110	52.69
	S.E.	202.69	22.292990		

Pop. = Population of the community; Log Pop. – Natural logarithm of the population of the community

**Significantly different from zero at 5%

***Significantly different from zero at 10%

Table H.2: Regression equations for Per capita Water Demand, North Saskatchewan River Basin

Community Type	Dependent variable	Intercept	Population	Time	R^2	F-value
North Battleford	-	-	-	-	-	-
Prince Albert	-	-	-	-	-	-
Lloydminster	Log WDC	5.3286	-0.0000116*		0.425657	8.893442
	S.E.	0.0881	0.000004			
Towns>1000	Log WDC	6.5129	-0.0000589*		0.446419	10.48345
	S.E.	0.4680	0.0000182			
Towns<1000	-	-	-	-	-	-
Villages	WDC	205.919	-0.008431		0.903086	121.1396
	S.E.	10.0346	0.000766			
First Nations	-	-	-	-	-	-
Parks	-	-	-	-	-	-
Other	-	-	-	-	-	-

*Significantly different from zero at 1%

Appendix I

Water Consumption for the North Saskatchewan River Basin Manufacturing Activities, 2010-2060

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 that is consumed is equal to demand for those sectors. Water consumption in industrial activities in the NSRB is presented in Tables H.1 to H.3 for baseline, climate change, and conservation scenarios, respectively. Since all the water is returned to surface water bodies, the amount that is returned is subtracted from the water demand.

Table I.1: Industrial Water Consumption in North Saskatchewan River Basin under Baseline Scenario, 2010-2060

Industry	**Water Consumption in dam^3**			
	2010	**2020**	**2040**	**2060**
Ag Processing				
North West Terminal Ltd	127	129	132	135
Husky Ethanol	5,874	5,874	5,874	5,874
Prairie Malt	907	925	944	963
Refineries				
Canadian Crude Separators	17	17	17	18
Husky Energy (Surface)	1,613	1,645	1,678	1,711
(Groundwater)	275	281	286	292
Husky Energy Upgrader	Included in Husky Ethanol			
LNG				
BP Canada Energy Co.	17	17	17	18
TransGas	1,202	1,226	1,250	1,275
Construction				
Kohlruss Bros. Enterprises	8	8	8	8
Total Water Demand	**10,039**	**10,122**	**10,207**	**10,294**
Groundwater	1,637	1,637	1,637	1,637
Surface Water	8,402	8,485	8,570	8,657
Surface Water as % of 2010	83.7%	83.8%	84.0%	84.1%

Table I.2: Industrial Water Consumption in North Saskatchewan River Basin under Climate Change Scenario, 2010 – 2060

Industry	Water Consumption in dam^3			
	2010	2020	2040	2060
Ag Processing				
North West Terminal Ltd	127	129	135	140
Husky Ethanol	5,874	5,874	5,992	6,109
Prairie Malt	907	925	963	1,001
Refineries				
Canadian Crude Separators Inc.	17	17	18	18
Husky Energy (Surface)	1,613	1,645	1,711	1,780
(Groundwater)	275	281	292	304
Husky Energy Upgrader	Included in Husky Ethanol			
LNG				
BP Canada Energy Co.	17	17	18	18
TransGas	1,202	1,226	1,275	1,326
Construction				
Kohlruss Bros. Enterprises	8	8	8	9
Total	**10,039**	**10,122**	**10,411**	**10,706**
Groundwater	1,637	1,637	1,637	1,637
Surface Water	8,402	8,485	8,774	9,069
Surface Water % of Total	83.7%	83.8%	84.3%	84.7%

Table I.3: Industrial Water Consumption in North Saskatchewan River Basin Under Water Conservation Scenario

Industry	Water Consumption in dam^3			
	2010	**2020**	**2040**	**2060**
Ag Processing				
North West Terminal Ltd	127	114	98	79
Husky Ethanol	5,874	5,757	5,757	5,757
Prairie Malt	907	907	925	943
Refineries				
Canadian Crude Separators Inc.	17	17	17	17
Husky Energy (Surface)	1,613	1,612	1,644	1,677
(Groundwater)	275	275	281	286
Husky Energy Upgrader	Included in Husky Ethanol			
LNG				
BP Canada Energy Co.	17	17	17	17
TransGas	1,202	1,201	1,225	1,250
Construction				
Kohlruss Bros. Enterprises	8	8	8	8
Total Water Demand	**10,039**	**9,907**	**9,972**	**10,035**
Groundwater	1,637	1,637	1,637	1,637
Surface Water	8,402	8,270	8,335	8,398
Surface Water as % of 2010	83.7%	83.5%	83.6%	83.7%

Appendix J

Regression Functions Showing Results of Effect of Droughts on Community Per Capita Water Demand in the North Saskatchewan River Basin

Table J.1: Regression Equations for Effects of Droughts on the per Capita Water Demand Coefficients, North Saskatchewan River Basin

Community Type	Dependent variable	Intercept	Population	Time	Binary	R^2	F-value
Lloydminster	log WDC	5.317929	-0.000011		0.042181**	0.543663	6.552487
	S.E.	0.082277	0.000004		0.025010		
T>1000	log WDC	6.689663	-0.000066		0.072340*	0.638092	10.578790
	S.E.	0.400080	0.000016		0.028695		

*Significantly different from zero at 5%

**Significantly different from zero at 10%