# ECONOMIC VALUE OF WATER IN ALTERNATIVE USES IN THE SOUTH SASKATCHEWAN (ALBERTA AND SASKATCHEWAN PORTIONS) RIVER BASIN


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**REPORT PREPARED FOR**
**THE PRAIRIE PROVINCES WATER BOARD**
**ENVIRONMENT CANADA**
**REGINA**


**DEPARTMENT OF AGRICULTURAL ECONOMICS**
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**SASKATOON, SK., S7N 5A8**



**RESEARCH REPORT** **MARCH 2006**

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# ACKNOWLEDGEMENTS

This study would not be possible without the generous financial support from the Prairie Provinces Water Board, Environment Canada. Author would like to thank Mr. Wayne Dybvig and Richard Kellow for their timely guidance over the course of this study. Mr. Dybvig also provided many helpful comments on the draft report.

In addition the author would like to acknowledge the following contributions made by the following individuals:

- Barbra Fortin who undertook the responsibility of finalizing the draft including format and other changes;
- Tony Samarawickrema who developed an earlier analysis for the irrigation values, livestock values and drought mitigation value of water;
- Tony Samarawickrema who provided inputs into the climate change section of this report;
- Robert Bewer who developed an earlier draft of recreation water use;
- Amanda Neall who provided some input into the climate change section of this report.

Technical editing of this report was provided by Ms. Miranda Traub, which is sincerely appreciated. Final touches in terms of formatting of the document were undertaken by Mr. Ramakrishna Alluri of University of Saskatchewan.

The above assistance provided by these individuals is gratefully acknowledged. Any remaining errors of omission or commission are the responsibility of the author.

S.N.K.

# Chapter 1

# INTRODUCTION

*It is an incontrovertible fact that we cannot live without water. Like air, water is a basic need. Water is sometimes described as "the provider of the infrastructure for life." It is fundamentally important.*

*Standing Senate Committee on Energy, the Environment and Natural Resources (2005)*

The importance of good quality water in sufficient quantities to meet all basic needs of the society is incontestable. Statements such as the above illustrate the social, economic and political importance of water to Canadian people. Although water is important for the survival of the environment and of ecosystems, it is equally, if not more, important for the continuance of social and economic activities in the society. In many circles, availability of good quality water in ample quantities is taken for granted. Its importance is realized only when members of the society are faced with water shortages, or when water quality deterioration affects society directly or indirectly. Among the many causes that threaten a society with water shortages, is predicted climate change. The accumulation of greenhouse gases in the atmosphere is expected to have a significant impact on the quantity and quality of water resources in the Prairies. Rising temperatures are predicted to alter the hydrologic cycle by changing precipitation patterns, runoff regimes, evaporation rates, as well by increasing the occurrence of floods or droughts. While the precise effects of climate change are uncertain, the estimation of the value of water will provide the basis for informed management decisions when faced with future water scarcity.

## 1.1 Background

The South Saskatchewan River Basin (SSRB) is a sub-basin within the Saskatchewan-Nelson river system. The larger system extends from the Rocky Mountains in Alberta, and drains into the Hudson Bay. The SSRB is a conglomerate of several watersheds, including the Bow River basin, the Oldman River basin, and the Red Deer River basin; which then join to create the South Saskatchewan River basin. The basin extends from the eastern slopes of the Rockies in Alberta and travels in an easterly direction until the South Saskatchewan River joins the North Saskatchewan River in Saskatchewan. Major cities within the SSRB are Calgary, Red Deer, Medicine Hat, Lethbridge, Swift Current, and Saskatoon. The major river systems include the South Saskatchewan River, Red Deer River, Oldman River, Bow River, and the North Saskatchewan River. These rivers are necessary to sustain biological, social, and economic activities in all communities within the boundaries of the SSRB.

## 1.2 Need for the Study

Although water is a renewable resource, there is still the need for its efficient distribution. For all allocation decisions, whether allocating water among various users or allocating scarce funds among competing uses (for example, water resource development vs. environmental protection), decision makers require knowledge of value of water. The five sub-basins in the SSRB use water in different proportions, thus each location could have a different value placed on water. Such values can be introduced into project evaluation (estimation of benefits) as well as into long term management of water projects / resources in the region. Such water use management as well as its development in the SSRB is the responsibility of the provincial governments of Saskatchewan and Alberta within their respective borders. These decisions are guided, in addition, by the Prairie Provinces Water Boards agreement on the sharing of water resources between the two provinces.

In the long run, determining the value of water is required for selecting the best adaptation option for the water users in the wake of global change, such as climate change. This requires, in addition to an identification of adaptation options, an economic assessment of costs and benefits, which requires knowledge of the value of water. The value of water is the necessary ingredient to make informed estimates about how our water resources will be compromised due to climate change.

## 1.3 Objectives of the Study

The major objective of the proposed study is to estimate the value of water in major withdrawal uses within the South Saskatchewan River Basin (SSRB) for both the current time period and future period (under climate change). This is accomplished by applying the state-of-the-art techniques to value the water use for major uses, such as agriculture. Other uses are based on a literature review. Subject to availability of data, valuations is done on a disaggregated basis for the five various sub-basins within the SSRB. A second objective of the study is to conceptualize the relationship between the value of water and climate change.

## 1.4 Scope of the Study

The study encompasses the value of water in the all consumptive and non-consumptive uses in the SSRB, and is analyzed in a disaggregated manner for the five sub-basins within Alberta and Saskatchewan. The sub-basins include the Bow River basin, the Oldman River basin, the Red River basin, the SSRB Alberta (lower) basin and the SSRB Saskatchewan (upper) basin. The last two are in fact one sub-basin, which are divided into two for study because they are between the two provinces of Saskatchewan and Alberta.

## 1.5 Organization of the Report

The report is divided into four main parts. Part one provides a background of the physical and economic profile of the basin and a background of the water uses. Part two provides the main valuation of water in the SSRB, starting with a conceptual framework and continuing with the main valuation components. The components discussed in order are irrigation, livestock, drought mitigation, municipal (including domestic and industrial), mining, power generation and valuation of in-situ water uses. In part three, a review of studies dealing with impact of climate change on water value is provided. This is followed by the summary and conclusions of the study.

# PART ONE

# BACKGROUND INFORMATION

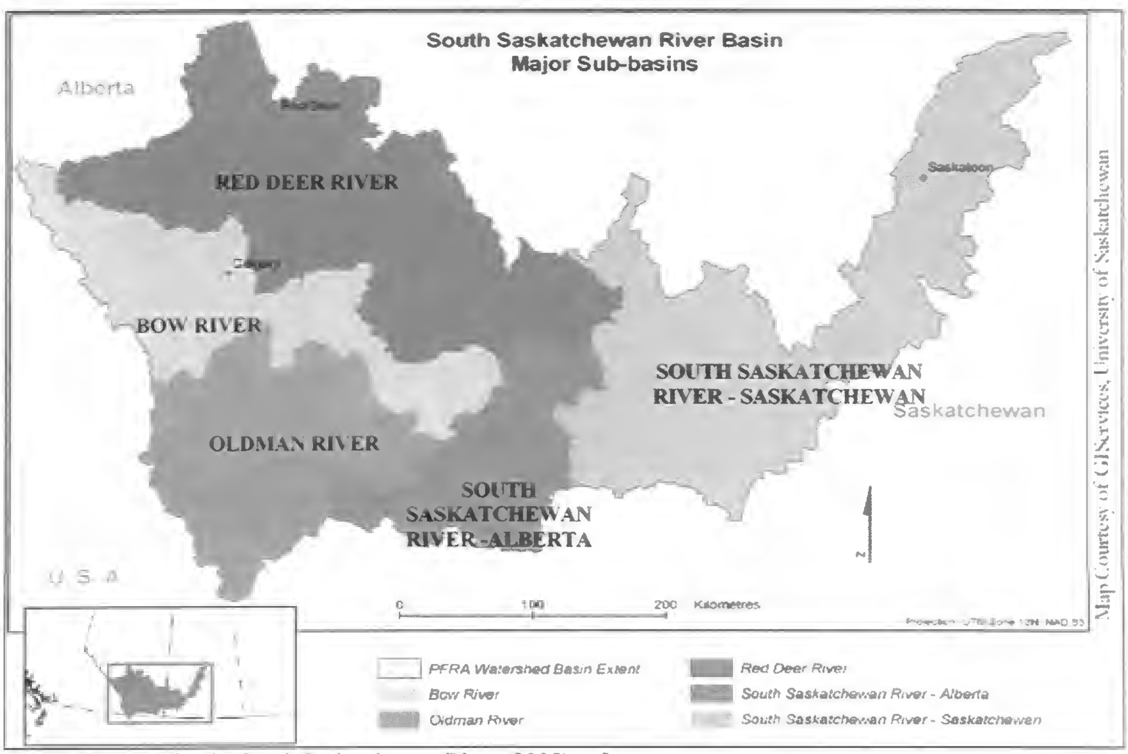
## Chapter 2

# PHYSICAL AND ECONOMIC PROFILE OF THE SOUTH SASKATCHEWAN RIVER BASIN

The South Saskatchewan River Basin (SSRB) is a very important region of the Prairie Provinces on account of the share of economic activity that lies herein. In 2001, the Alberta portion of the SSRB had a population of 1,582,981 and the Saskatchewan portion 324,356 (Sobool and Kulshreshtha, 2003). This represents 53.2% of the total population of Alberta and 33.1% of the population of Saskatchewan residing within the boundaries of the SSRB (Statistics Canada, 2002). In this chapter, information regarding its location, climate, population, and industrial base is provided.

## 2.1 Location and Description of the Basin

The SSRB extends from the Continental Divide through southern Alberta and into south-central Saskatchewan (Fig. 2.1). The SSRB is part of a major river system within the Nelson River basin beginning from the Rocky Mountains, which extends through the Prairie Provinces before emptying into the Hudson Bay. The entire SSRB extends over an area of about 150,000 km$^2$ (Armstrong, Pietroniro and Rolfe, 2004).




Source: Partners for the South Saskatchewan River (2005), p 2

**Figure 2.1. Map of South Saskatchewan River Basin**

There are three ecozones in the SSRB: The Prairies, the Boreal Plains, and the Montane Cordillera. The Prairies make up 80% of the SSRB and occupy the entire central and eastern portions of the entire basin. Together, the Boreal Plains and Montane Cordillera comprise 20% of the basin. The Boreal Plains are found in eastern Saskatchewan and western Alberta, while the Montane Cordillera is found only in Alberta, in the western corner of the SSRB. The Prairie ecozone consists mostly of grasslands and possesses a characteristic water deficit. This ecozone is divided into aspen parkland, moist mixed grassland, mixed grassland, cypress upland, and fescue grassland (found only in Alberta). The Boreal Plains ecozone is primarily dominated by mixedwood and conifer forests that are present in the boreal transition zone and the western uplands. Finally, the Montane Cordillera consists of the eastern continental ranges and the northern continental divide (Canadian Council of Ecological Areas, 2004).

Climate within the SSRB varies slightly throughout. Temperature increases southward, yet precipitation increases north and westward. The average annual temperature in the SSRB is between 2°C and 6°C. Average precipitation rates are between 282-800 mm. annually. The higher amounts of precipitation occur over the Rocky Mountains. With the Canadian Rockies on the western border of the SSRB, elevation is the greatest in this area (~ 3000m) compared to lower elevations to the east (~280m). Potential evapotranspiration increases to the south and east with values ranging from 450 mm to >800 mm (Acton, Padbury and Stushnoff., 1998).

The SSRB is an area that is particularly susceptible to drought. Droughts can be meteorological, agricultural, hydrological, or socioeconomic. Droughts occur in the SSRB due to the existence of natural barriers (i.e. Canadian Rocky Mountains) that obstruct incoming moisture from the Pacific Ocean. The most vulnerable areas of the SSRB are located northwest of Medicine Hat, west of Swift Current, and south of Saskatoon. These regions are deemed sensitive based on their aridity index, wind speed, soil texture, slope gradient and aspect, agricultural land use, and available water capacity (Acton, Padbury and Stushnoff, 1998).

## 2.2 Sub-Basins

The SSRB is comprised of four major sub-basins: Red Deer, Oldman, Bow, and South Saskatchewan. The last basin is divided into two parts for the study because it includes area that are administered by different provinces -- the South Saskatchewan (lower) in Alberta and the South Saskatchewan (upper) in Saskatchewan. The largest sub-basin in the SSRB is the South Saskatchewan at about 48,000 $km^2$, and the smallest is the Bow River basin at just over 25,000 $km^2$ (Table 2.1). Rivers within the SSRB are very important to the communities therein. Dams and reservoirs have been constructed on several of the major rivers within the SSRB and are owned and operated by different organizations for different purposes, including irrigation, power generation, and recreational purposes.

**Table 2.1. Drainage Area of Major Rivers in the SSRB**

| River | Drainage Area ($km^2$) |
|---|---|
| Entire South Sask. River Basin to St.Louis (Sask. and Alta.) | 148,000 |
| Bow River near mouth | 25,300 |
| Red Deer River Near Empress | 46,800 |
| Oldman River Near mouth | 27,500 |
| South Saskatchewan River | 48,400 |

Source: Armstrong, Pietroniro and Rolfe (2004)

## 2.3 Population Base

The current (2001) population of the SSRB was estimated at 1.5 million, with 80% residing in the Alberta portion (Armstrong, Pietroniro and Rolfe, 2004). Less than 5% of the population was estimated to be rural (Armstrong, Pietroniro and Rolfe, 2004). A socio-economic database of the SSRB was produced by Sobool and Kulshreshtha (2003) and in this they derive the population by sub-basin, rural municipality, census division and municipal division (as applicable) from 1951- 2001. They summarized the urban, rural and farm population statistics for the SSRB among sub-basins. The population totals for each sub-basin in 1991 and 2001 is outlined in Table 2.2. More detailed results are presented in Table A.2 of Appendix A.

**Table 2.2. Total Population of Each Sub-Basin in the SSRB in 1991 and 2001**

| Sub-basin | Population[1] | |
|---|---|---|
| | 1991 | 2001 |
| Red Deer River | 208,932 | 272,599 |
| Bow River | 805,563 | 1,016,856 |
| Oldman River | 156,205 | 207,804 |
| S. Saskatchewan River (AB) | 65,302 | 85,722 |
| S. Saskatchewan River (SK) | 277,504 | 324,356 |

1 Population totals were obtained by the summation of urban, rural, and farm populations from Sobool and Kulshreshtha (2003).

Within the entire SSRB, Calgary is the largest city with a population of 876,519 (2001) and is located in the Bow River sub-basin. The next largest city in the basin is Saskatoon with a population of 196,811 (2001). This city is situated in the Saskatchewan portion of the South Saskatchewan River sub-basin. Other larger cities include the City of Lethbridge, which lies within the Oldman River sub-basin and has a population of 68,712 (2001). In the Red Deer River sub-basin is found the city of Red Deer with a 2001 population of 68,308. Finally, within the Alberta portion of the South Saskatchewan River sub-basin is the city of Medicine Hat with a population of 50,152 (2001) (Sobool & Kulshreshtha, 2003). Most other communities are smaller in population size.

## 2.4 Major Industries

Contribution of various industry groups can be measured through number of workers employed as well as through value of net output generated. The latter is generally measured in terms of gross domestic product (GDP). Details on employment by major industry groups are shown in Table 2.3. The SSRB is predominantly service oriented, as 53% of total employment is in this sector (Figure 2.2). Trade and manufacturing are the next two largest sectors in the entire SSRB.

**Table 2.3. Employment by Major Industry Groups, and Its Distribution, Saskatchewan and Alberta Portions of the SSRB, 2001**

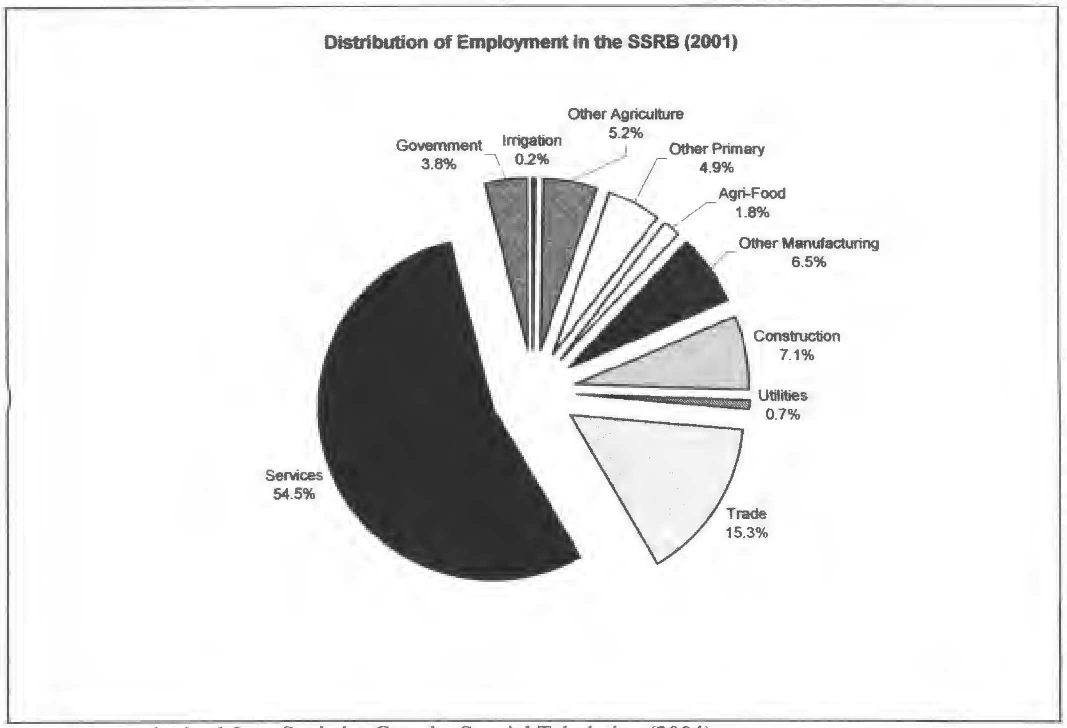
| Sector | Total SSRB | Saskatchewan Portion | | Alberta Sub-basins | |
|---|---|---|---|---|---|
| | Total Employment | Total Employment | % of Basin Employment | Total Employment | % of Basin Employment |
| Irrigation | 2,338 | 663 | 28.3 | 1,676 | 71.7 |
| Other Agriculture | 56,934 | 18,551 | 32.6 | 38,382 | 67.4 |
| Other Primary | 53,165 | 5,905 | 11.1 | 47,260 | 88.9 |
| Agri-Food | 19,505 | 3,675 | 18.8 | 15,830 | 81.2 |
| Other Manufacturing | 70,715 | 12,300 | 17.4 | 58,415 | 82.6 |
| Construction | 78,115 | 12,105 | 15.5 | 66,010 | 84.5 |
| Utilities | 8,050 | 1,390 | 17.3 | 6,660 | 82.7 |
| Trade | 167,560 | 33,125 | 19.8 | 134,435 | 80.2 |
| Services | 596,770 | 114,440 | 19.2 | 482,330 | 80.8 |
| Government | 42,030 | 12,660 | 30.1 | 29,370 | 69.9 |
| **Total Employment** | **1,095,182** | **214,814** | | **880,368** | |

Source: Data obtained from Statistics Canada, Special Tabulation (2004).

Individual provincial basins within SSRB are relatively similar in composition with respect to employment pattern. However, in terms of absolute size, Alberta portion of the SSRB is over four times larger than that of the Saskatchewan portion (See Table 2.3). The other distinguishing feature of the two portions of the SSRB are the following. (1) Alberta has a larger employment in irrigated agriculture as a proportion of the total SSRB. In fact, almost three-quarters of the total irrigated agricultural employment are in this portion of the SSRB. (2) The Alberta portion of the SSRB is also more industrially developed as shown by employment in agri-food processing and other manufacturing industries. The importance of various sectors in the SSRB to each of the two provinces is shown in Table 2.4.

Table 2.4 shows the employment contributions of the SSRB portions of Saskatchewan and Alberta and how they are related to the economies of both provinces. Irrigation in both Saskatchewan and Alberta has the majority of employment within the boundary of the SSRB in each respective province. Employment in the Agri-Food industry also represents over 60% of each province's employment occurring within the SSRB. Many industries in Alberta have the majority (>50%) of their sectors employed within the

SSRB. In Saskatchewan, the proportion of employment in the SSRB is still quite significant at 43% of the total provincial employment.




Source: Data obtained from Statistics Canada, Special Tabulation (2004).

**Figure 2.2. Distribution of Employment in 2001 among Major Industries in the SSRB (Alberta and Saskatchewan Portions)**

**Table 2.4. Importance of SSRB Economic Activity Related Employment to Provincial Economies, 2001**

| Sector | Employment in Saskatchewan | Employment SSRB Saskatchewan | Proportion of Saskatchewan Employment Within SSRB | Employment in Alberta | Employment SSRB Alberta | Proportion of Alberta Employment Within SSRB |
|---|---|---|---|---|---|---|
| Irrigation | 955 | 663 | 69% | 1,846 | 1,676 | 91% |
| Other Agriculture | 68,225 | 18,551 | 27% | 78,172 | 38,382 | 49% |
| Other Primary | 18,005 | 5,905 | 33% | 93,815 | 47,260 | 50% |
| Agri-Food | 6,100 | 3,675 | 60% | 22,885 | 15,830 | 69% |
| Other Manufacturing | 23,290 | 12,300 | 53% | 112,055 | 58,415 | 52% |
| Construction | 27,230 | 12,105 | 44% | 130,015 | 66,010 | 51% |
| Utilities | 4,890 | 1,390 | 28% | 13,565 | 6,660 | 49% |
| Trade | 73,425 | 33,125 | 45% | 258,735 | 134,435 | 52% |
| Services | 250,630 | 114,440 | 46% | 896,755 | 482,330 | 54% |
| Government | 31,280 | 12,660 | 40% | 77,455 | 29,370 | 38% |
| **Total** | **504,030** | **214,814** | **43%** | **1,685,298** | **880,368** | **52%** |

Source: Based on data obtained from Statistics Canada, Special Tabulation (2004)

Evidence on the contribution of various industries to the GDP of the basin is shown in Table 2.5 and its distribution by major sectors in Figure 2.3. Consistent with employment patterns, GDP distribution shows that service sectors is the single largest economic activity in the basin. Over half the total basin GDP is generated by the service sector. This sector includes a variety of services, such as accommodation and foods, business services, health and educational services, among others. While significantly lower than that of the service sector, trade and construction sectors are the next higher contributors to the SSRB's GDP. As a whole, the Alberta portion of the SSRB contributes more to the GDP of the basin with over a $57.5 billion dollar contribution. The Saskatchewan SSRB contribution is significantly lower at just over $11 billion dollars.

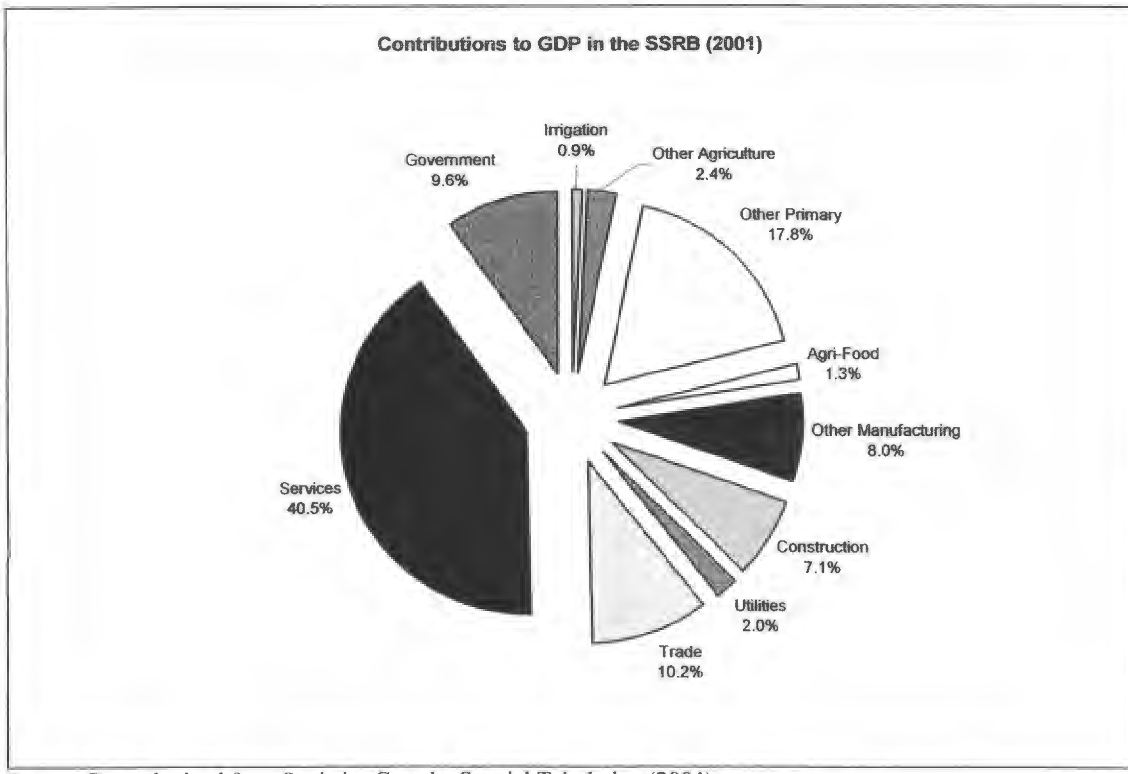
**Table 2.5. Distribution of GDP ($ Millions) in Major Industries within the SSRB in 2001**

| Sector | GDP Total SSRB | GDP SSRB Saskatchewan | GDP SSRB Alberta |
|---|---|---|---|
| | Millions of Dollars | | |
| Irrigation | 596 | 92 | 504 |
| Other Agriculture | 1,672 | 582 | 1,090 |
| Other Primary | 12,280 | 1,396 | 10,884 |
| Agri-Food | 920 | 232 | 688 |
| Other Manufacturing | 5,492 | 722 | 4,770 |
| Construction | 4,919 | 745 | 4,174 |
| Utilities | 1,401 | 215 | 1,186 |
| Trade | 7,065 | 1,370 | 5,695 |
| Services | 27,950 | 4,190 | 23,760 |
| Government | 6,639 | 1,898 | 4,741 |
| Total GDP | 68,934 | 11,442 | 57,492 |

Source: Based on data obtained from Statistics Canada (Special Tabulation, 2004)

## 2.5 Agricultural Land Use and Irrigation

Agricultural practices such as crop farming and livestock operations are a very important sector in the SSRB in their contributions to the economy. In using agricultural land to grow crops, producers are reliant on good growing conditions especially in dryland crop production. This means that in order to maximize their crop yields, producers require fertile soil and the right combination of sunlight and precipitation. To compensate for less than optimal conditions, crop producers use methods such as irrigation to reduce the effects of drought and pesticides and herbicides to combat weeds, insects and disease. Livestock operations include all populations of animals raised for production. Livestock such as beef cows and pigs are used for food products, whereas sheep and horses are also raised for non-consumptive purposes.




Source: Data obtained from Statistics Canada, Special Tabulation (2004).

**Figure 2.3. Contributions of Major Industries to the GDP ($ Millions) of the SSRB (Alberta and Saskatchewan Portions), 2001**

Irrigation in the SSRB falls under two categories, district irrigation and private irrigation. District irrigation is organized by a water users association and operates over a continuous parcel of land called an irrigation district. Producers pay a water charge to the association, while construction of pipelines and other infrastructure is paid for by the public. In contrast, private irrigation is not organized and the initiative to irrigate land is the responsibility of the producer. Instead of a water charge paid to an association, the producer must purchase a license to remove water from its source. Water is removed by the producer directly from the source (river, creek, or lake) and there is no requirement for additional infrastructure (Sobool and Kulshreshtha, 2003). Producers who use irrigation have a different choice of crops, and it is generally believed that irrigation brings diversification and stability to the region.

Table 2.6 illustrates the differences between the irrigated and dryland crop mixes in both the Alberta and Saskatchewan portions of the SSRB. Dryland crop practices are more prevalent in both provinces, but even more so in Saskatchewan. Oilseed crops, such as canola and flax, comprise the largest portion of irrigated crops in Saskatchewan's SSRB while forages, such as tame hay and silage, possess the largest crop percentage that is irrigated in the Alberta SSRB sub-basins.

With respect to dryland farming, there are a variety of farm types in the Basin. Their contribution in terms of employment and GDP are shown in Tables 2.7 and 2.8, respectively. A large proportion of farms in the Saskatchewan portion of the SSRB are grain farms, followed by beef cattle farms. Alberta's farm types, in contrast, are dominated by beef cattle farms with grain farms close behind.

**Table 2.6. Irrigated and Dryland crop mix for the Alberta and Saskatchewan portions of the SSRB (2001)**

| Crop | Alberta SSRB (% Total) | | Saskatchewan SSRB (% Total) | |
|---|---|---|---|---|
| | Dryland | Irrigated | Dryland | Irrigated |
| Cereals | 95.15 | 4.85 | 99.66 | 0.34 |
| Oilseeds | 88.56 | 11.44 | 97.11 | 2.89 |
| Forages | 77.84 | 22.16 | 99.85 | 0.15 |
| Other/Specialty | 96.43 | 3.57 | 99.55 | 0.45 |

Source: AAFRD (2003b), Statistics Canada (2005)

**Table 2.7. Distribution of Employment in Commercial Agricultural Activities in the SSRB in 2001**

| Sector | Employment SSRB Saskatchewan | Employment SSRB Alberta | Employment SSRB Total |
|---|---|---|---|
| Grains | 12,127 | 10,414 | 22,541 |
| Irrigation | 663 | 1,676 | 2,338 |
| Dairy Cattle | 374 | 1,261 | 1,635 |
| Beef Cattle | 3,686 | 17,046 | 20,732 |
| Hog | 492 | 1,163 | 1,655 |
| Poultry | 167 | 683 | 850 |
| Livestock Comb. | 1,002 | 5,376 | 6,379 |
| Miscellaneous | 246 | 779 | 1,025 |
| **Total Employment** | **18,757** | **38,398** | **57,155** |

Source: Based on data from Kulshreshtha and Thompson (2004)

**Table 2.8. Contributions of Commercial Agricultural Activities to GDP ($ Millions) in the SSRB in 2001**

| Sector | SSRB Saskatchewan | SSRB Alberta | SSRB Total |
|---|---|---|---|
| Grains | 147 | 52 | 199 |
| Irrigation | 92 | 504 | 596 |
| Dairy Cattle | 21 | 22 | 43 |
| Beef Cattle | 342 | 840 | 1,182 |
| Hog | 34 | 64 | 98 |
| Poultry | 5 | 43 | 48 |
| Livestock Combination | 20 | 48 | 68 |
| Miscellaneous | 13 | 21 | 34 |
| **Total GDP** | **674** | **1,594** | **2,268** |

Source: Based on data from Kulshreshtha and Thompson (2004)

In terms of GDP, agriculture contributed $2.2 billion in the basin, most of which was from beef cattle farms. About two-thirds of the basin GDP from beef cattle farms was generated in Alberta. In Alberta, this was followed by irrigated farms (or more appropriately irrigated production of various crops). The remaining farm types had relatively smaller contributions in this portion of the SSRB. In the Saskatchewan portion of the SSRB, agricultural GDP is mostly contributed by beef cattle and grain farms.

## 2.6 Other Primary Industries

### 2.6.1 Mining Activities

Mining activities in the SSRB include petroleum and coal, non-metal minerals, coal mines, and metal and non-metal mines. In Saskatchewan, mining includes metals (gold, iron, uranium, and base metals), fuel (oil, coal, natural gas), and industrial minerals (potash, salt, and others) (Government of Saskatchewan, 2005). In Alberta, mining is done for recovery of coal, minerals, natural gas, petrochemicals, and oil. Table 2.9 shows the contributions of this sector to the Basin's economy. In the Saskatchewan portion of the basin, this activity is limited to potash mining and some non-metal mining. The employment in this sector was estimated to be 4,595 workers. In Alberta, in contrast, this sector is ten times larger than that in Saskatchewan, employing about 46 thousand workers. The mining industry makes a net addition of $12 billion annually (based on 2001 data). Much of this is in the Alberta portion of the SSRB.

**Table 2.9. Economic Indicators for Other Primary Industries in the SSRB, 2001**

| Industry / Sector | Employment SSRB Saskatchewan | Employment SSRB Alberta | Employment SSRB Total |
|---|---|---|---|
| | EMPLOYMENT IN PERSON-YEARS | | |
| Mining and Oil & Gas Extraction | 4,595 | 44,885 | 49,480 |
| Forestry & logging | 275 | 495 | 770 |
| | G.D.P. IN MILLION $ | | |
| Mining and Oil & Gas Extraction | 1,350 | 10,810 | 12,160 |
| Forestry & Logging | 27 | 33 | 60 |

Source: Based on data from Kulshreshtha and Thompson (2004)

### 2.6.2 Forestry

Forestry in the SSRB is a very small sector. This is because much of the basin is used for agricultural purposes. Its total employment is only 770 workers, contributing some $60 million to the basin's GDP. Much of this activity is limited to farm woodlots, and other public lands.

## 2.7 Manufacturing

The SSRB has a strong manufacturing industry. However, much of this industrial base is located in the Alberta portion of the basin. Employment by various manufacturing industries is shown in Table 2.10., while contribution of these industries to the basin's GDP is shown in Table 2.11. The largest contribution sector in the SSRB is the agricultural processing industries. Much of the Alberta's contributions in this sector are through livestock slaughtering and meat processing. However, when one peruses the contribution to GDP, chemical industries are the largest sector in the basin. Second in terms of employment in the Saskatchewan portion of the SSRB, are the machinery manufacturers, which are followed by primary metal manufacturing. In the Alberta portion of the basin, furniture and related product manufacturing followed by fabricated metal industries and machinery manufacturing provide the top employment.

## 2.8 Power Generation

Hydro-electric power generation is a non-consumptive water use. Twenty hydropower developments are located in Alberta, eleven of which are in the Kananaskis/Bow River system while seven smaller facilities are located along canals and watercourses in central and southern Alberta. Alberta's hydroelectric system is capable of meeting 5% of their power requirement (Alberta Environment, 2003). In Saskatchewan, there are several power plants that use the South Saskatchewan River, including the Coteau Creek hydro-electric plant, Queen Elizabeth natural gas plant (SaskPower, 2005)., and the Cory cogeneration plant (Nielson, 2003).

## 2.9 Service Sectors

The service sector is the highest employer in the SSRB (>54%) and provides the highest contribution to the basin's GDP (>40%). The majority of the service sector activity is located in the Alberta portion of the SSRB. Employment in the various sectors of the service industry is outlined in Table 2.10. and the contribution of these sectors to the SSRB's GDP is shown in Table 2.11. The top service industries with regards to employment in both the Alberta and Saskatchewan portions of the basin are health care and social services. The second highest service employers in the Alberta portion are that of professional, scientific and technical services. In the Saskatchewan portion, the second highest service employers are in accommodation and food services. The top two highest service employers are in accommodation and food services. The top two contributors to the GDP of both provinces' portions of the SSRB are the same. The highest contributor is finance, insurance, and real estate renting and leasing while transportation and warehousing are the second highest.

**Table 2.10. Distribution of Employment in the Manufacturing Sector within the SSRB in 2001**

| Manufacturing Sector | Employment SSRB Saskatchewan | Employment SSRB Alberta | Employment SSRB Total |
|---|---|---|---|
| Agri-Food Processing* | 3,675 | 15,830 | 19,505 |
| Tobacco | 10 | 1,270 | 1,280 |
| Textile mills | 50 | 255 | 305 |
| Textile product mills | 270 | 520 | 790 |
| Clothing | 355 | 830 | 1,185 |
| Leather and allied products | 50 | 195 | 245 |
| Wood and Paper | 1,590 | 5,195 | 6,785 |
| Printing and associated activities | 1,070 | 3,400 | 4,470 |
| Petroleum and coal products | 195 | 1,400 | 1,595 |
| Chemicals | 810 | 4,905 | 5,715 |
| Plastics and rubber products | 250 | 2,030 | 2,280 |
| Non-metallic minerals | 370 | 3,360 | 3,730 |
| Primary metals | 95 | 1,790 | 1,885 |
| Fabricated metals | 1,665 | 7,400 | 9,065 |
| Machinery | 2,480 | 6,515 | 8,995 |
| Computer and electronic products | 580 | 5,850 | 6,430 |
| Electrical equipment, appliances, and components | 335 | 1,575 | 1,910 |
| Transportation equipment | 990 | 2,610 | 3,600 |
| Furniture and related products | 560 | 6,450 | 7,010 |
| Miscellaneous | 575 | 2,865 | 3,440 |
| **Total Manufacturing** | **15,975** | **72,245** | **90,220** |

* Includes all food and beverage manufacturing
Source: Based on data from Kulshreshtha and Thompson (2004)

**Table 2.11. Distribution of GDP ($ Millions) throughout the Manufacturing Sector of the SSRB in 2001**

| Manufacturing Sector | GDP SSRB Saskatchewan | GDP SSRB Alberta | GDP SSRB Total |
|---|---|---|---|
| Agri-Food Processing* | 232 | 688 | 920 |
| Tobacco | 0 | 0 | 0 |
| Textile mills | 1 | 7 | 8 |
| Textile product mills | 14 | 38 | 52 |
| Clothing | 10 | 44 | 54 |
| Leather and allied products | 18 | 8 | 26 |
| Wood and Paper | 191 | 606 | 797 |
| Printing and associated activities | 23 | 181 | 204 |
| Petroleum and coal products | 8 | 150 | 158 |
| Chemicals | 129 | 1,326 | 1455 |
| Plastics and rubber products | 7 | 34 | 41 |
| Non-metallic minerals | 59 | 280 | 339 |
| Primary metals | 17 | 276 | 293 |
| Fabricated metals | 49 | 307 | 356 |
| Machinery | 62 | 546 | 608 |
| Computer and electronic products | 12 | 510 | 522 |
| Electrical equipment, appliances, and components | 44 | 29 | 73 |
| Transportation equipment | 49 | 141 | 190 |
| Furniture and related products | 6 | 176 | 182 |
| Miscellaneous | 23 | 111 | 134 |
| **Total GDP** | **954** | **5,458** | **6,412** |

* Includes all food and beverage manufacturing

Source: Based on data from Kulshreshtha and Thompson (2004)

**Table 2.12. Distribution of employment in the Service Sector within the SSRB in 2001**

| Service Sector | Employment SSRB Saskatchewan | Employment SSRB Alberta | Employment SSRB Total |
|---|---|---|---|
| **Transportation and warehousing** | 10,980 | 49,300 | 60,280 |
| **Information and cultural industries** | 4,525 | 23,280 | 27,805 |
| **Finance, insurance, and real estate renting and leasing** | 9,840 | 47,175 | 57,015 |
| **Professional, scientific, and technical services** | 8,070 | 74,095 | 82,165 |
| **Administrative and other support services** | 5,670 | 35,220 | 40,890 |
| **Educational services** | 18,160 | 52,865 | 71,025 |
| **Health care and social services** | 25,195 | 75,240 | 100,435 |
| **Arts, entertainment, and recreation** | 4,495 | 18,580 | 23,075 |
| **Accommodation and food services** | 16,670 | 65,720 | 82,390 |
| **Other services (except public administration)** | 10,835 | 40,855 | 51,690 |
| **Operating, office, cafeteria, and laboratory supplies** | 0 | 0 | 0 |
| **Travel and entertainment, advertising and promotion** | 0 | 0 | 0 |
| **Transportation margins** | 0 | 0 | 0 |
| **Non-profit institutions serving households** | | | |
| **Total Employment** | **114,440** | **482,330** | **596,770** |

Source: Based on data from Kulshreshtha and Thompson (2004)

Table 2.13. **Distribution of GDP ($ Millions) throughout the Service Sector of the SSRB in 2001**

| Service Sector | GDP SSRB Saskatchewan | GDP SSRB Alberta | GDP SSRB Total |
|---|---|---|---|
| **Transportation and warehousing** | 760 | 3,301 | 4,061 |
| **Information and cultural industries** | 296 | 1,810 | 2,106 |
| **Finance, insurance, and real estate renting and leasing** | 1,727 | 10,007 | 11,734 |
| **Professional, scientific, and technical services** | 306 | 3,181 | 3,487 |
| **Administrative and other support services** | 116 | 1,041 | 1,157 |
| **Educational services** | 15 | 120 | 135 |
| **Health care and social services** | 251 | 1,026 | 1,277 |
| **Arts, entertainment, and recreation** | 50 | 304 | 353 |
| **Accommodation and food services** | 310 | 1,579 | 1,889 |
| **Other services (except public administration)** | 189 | 890 | 1,079 |
| **Operating, office, cafeteria, and laboratory supplies** | 0.4 | 0 | 0.4 |
| **Travel and entertainment, advertising and promotion** | 0 | 0 | 0 |
| **Transportation margins** | 0 | 0 | 0 |
| **Non-profit institutions serving households** | 169 | 502 | 671 |
| **Total GDP** | **4,189.4** | **23,761** | **27,950.4** |

Source: Based on data from Kulshreshtha and Thompson (2004)

## 2.10 Summary

Overall, the SSRB has many sectors which contribute to its economy, both in their additions to each province's employment and to the GDP. The SSRB provides 43% of Saskatchewan's total employment and 52% of the total employment of Alberta. The service sector is the highest provider of gainful employment in the SSRB as well as the highest contributor to the GDP of the basin. The Alberta portion of the SSRB represents a much higher percentage of employment and its industries offer a larger input to the basin's GDP than does the Saskatchewan portion. This is explained by the higher overall population and area in the Alberta side of the SSRB.

# Chapter 3

# WATER USE IN BASIN BY SUB-BASINS

Water use is a broad term describing the employment of water in association with other inputs in the production of certain economic activity or meeting a social need. Water for use is derived from both surface water bodies and groundwater aquifers. It is needed for almost all economic activities. In addition, it is critical for human use, which could be through withdrawal of water or using the water in the water bodies. In this chapter, water use in the SSRB is reviewed. Major emphasis is on that part of the use which is included for economic valuation.

## 3.1 Nomenclature related to Water Use

In the context of water use, it is necessary to distinguish among various terms.

*Water intake*: refers to the amount of water that is physically transferred from a source in order to satisfy a need.

*Water consumption*: is the actual volume of water lost during the production process of the activity or meeting the social need. It is the amount of water that is not available to any other user.

*Water demand*: quantity of water that is purchased by various users at a given price or user fee.

*Water withdrawal use*: refers to the water being physically removed from its source, used in a production activity, and then discharged.

*In-situ water use*: involves water being used without its removal from a source. Therefore, it does not entail discharge of water.

In this report, water use is identified as the amount of water that is required to sustain a given need of the society. The water needs of the ecosystems, although equally important, are not addressed.

## 3.2 Major Water Uses in the Basin

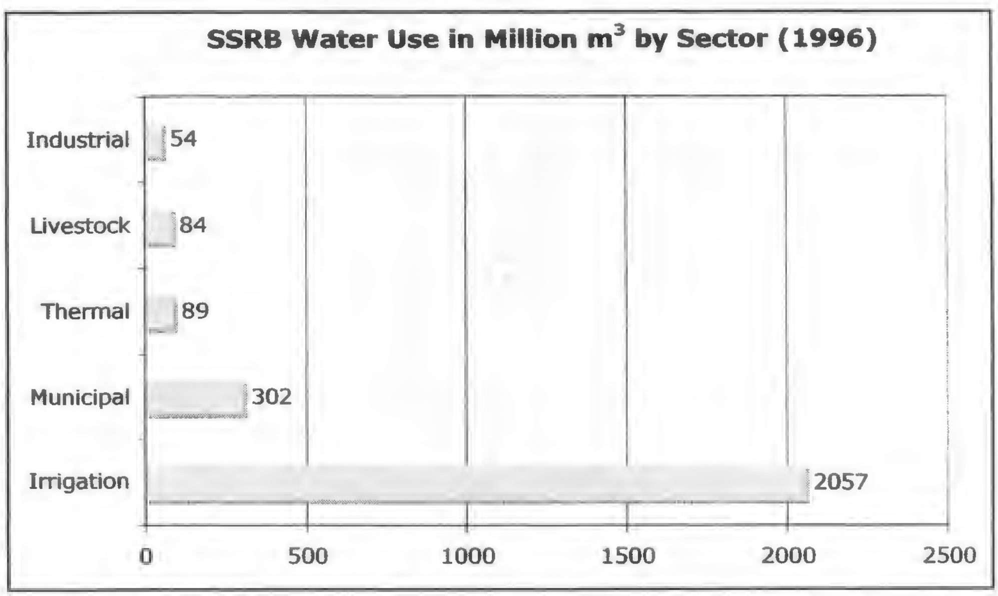
Water can have many uses including agricultural, municipal and residential, industrial, and recreational. A general classification of these uses is shown in Table 3.1. Direct uses of water include those for residential or domestic purposes. This type of use requires water to be withdrawn from the original source. In addition, water is withdrawn for its use in industrial activities, and for power generation. In-situ water uses include hydropower generation, recreational activities, and waste assimilation.

**Table 3.1. A Taxonomy of Water Use**

| Type of Use | Direct Use | Indirect Use | |
|---|---|---|---|
| | | Water as primary input | Water as secondary input |
| Withdrawal use | Residential | Irrigation | Thermal power generation |
| | | Livestock | |
| | | Mining<br>Potash<br>Non-metallic minerals | |
| | | Agricultural processing | Other manufacturing |
| | | Public water use | Commercial water use |
| In-situ use | Recreation | Hydro-electric | Waste assimilation |
| | Transportation | Fish and wildlife | |

Source: Kulshreshtha et al. (1988)

Major withdrawal type of water uses in the SSRB include: irrigation, livestock, thermal power generation, municipal and industrial. In 1996, Armstrong, Pietroniro and Rolfe (2004) estimated the total water use[1] in the SSRB for these uses at 2.586 million dam$^3$, as shown in Figure 3.1.




Source: Data obtained from Armstrong, Pietroniro, and Rolfe (2004).

**Figure 3.1. Water Withdrawals in the SSRB, by Major Sectors, 1996**

[1] These estimates were accepted at face value since they provided a comparative water use picture. This study also estimated irrigation water use in the basin, and the estimated irrigation water use was found to be higher than the total shown here. Details are provided in Chapter 5.

Agriculture is a primary industry in the SSRB and is dependant upon having sufficient water supplies and often farmers are faced with drought. Figure 3.2 illustrates the distribution of water withdrawal in the SSRB by different sectors. Irrigation withdraws the most water in the Basin, estimated at 80% of the total. This is followed by municipal uses (12%). Other water uses are relatively small in magnitude. It should be noted that these are withdrawal water use, and not consumptive water use. Some of this water is returned to the original source as return flows. Irrigation and residential water use fall under this category.

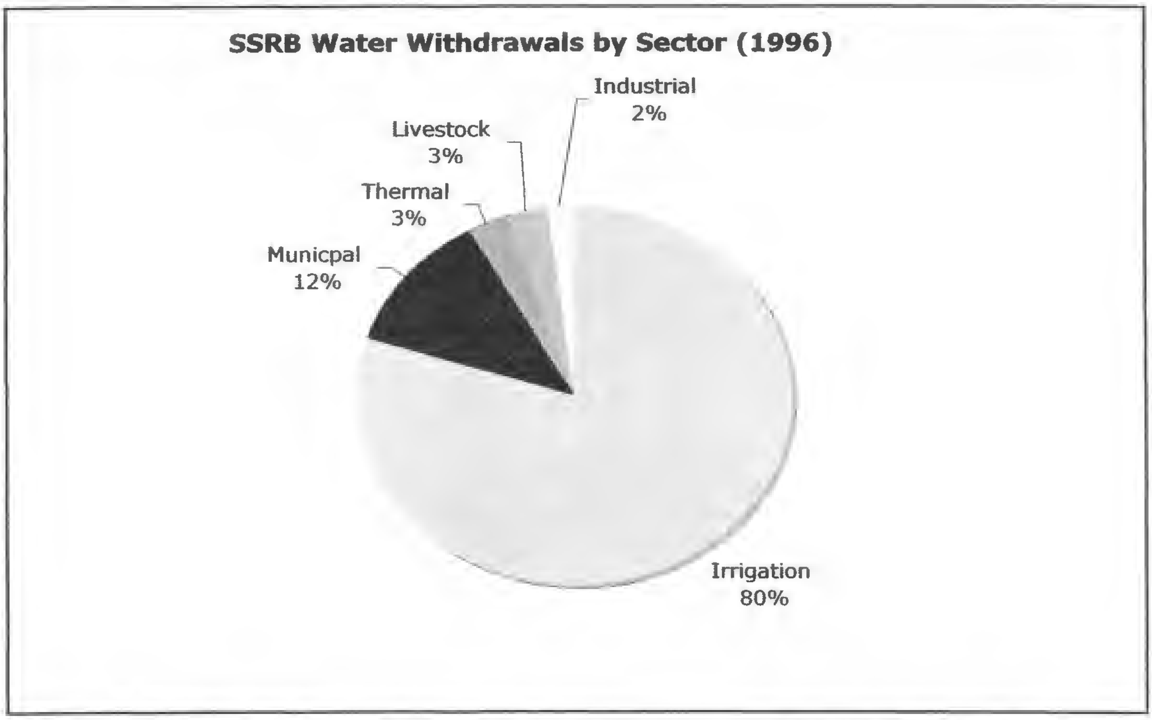
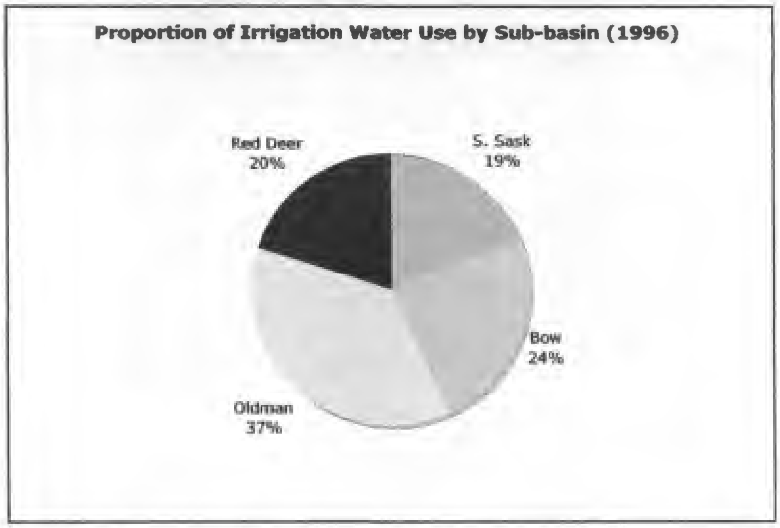



**Figure 3.2. Distribution of Withdrawal Water Use in the SSRB, by Major Sectors, 1996**

## 3.3 Irrigation Water Use

Irrigation water use is a result of four sub-categories of irrigation in the Basin using administration of activities and method of delivery of water. These are District Irrigation, which can be further classified into sprinkler and surface irrigation methods; and Private Irrigation which could also be divided into the same two methods of delivery. The surface irrigation methods include primarily backflood irrigation

In the SSRB, the sub-basin with the largest proportion of irrigation water use is the Oldman with 37% or 932 million $m^3$ of water use. The proportion and total quantity of water use for 1996 by all sub-basins are shown in Figure 3.3.

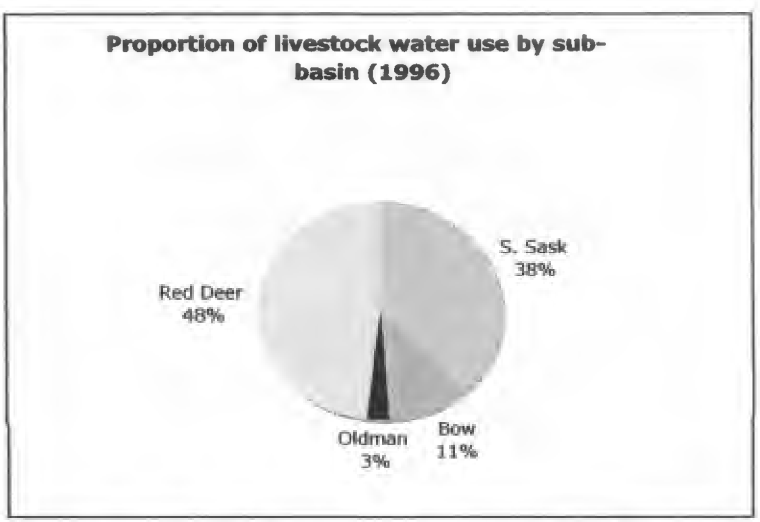



Source: Data obtained from Armstrong, Pietroniro and Rolfe (2004)

**Figure 3.3. Proportion of Irrigation Water Use by Sub-Basin in the SSRB, 1996**

## 3.4 Other Agricultural Water Uses

Other agricultural water uses include water required for herbicide application, livestock watering, as well as for farm residential needs. Herbicide application is vital to the success of many crops in the SSRB. The highest proportion of water use for livestock is from the Red Deer sub-basin at 48% or 40 million cubic meters. The proportion and quantity of livestock water use for the other sub-basins is shown by Figure 3.4. Details of the annual water usage by different types of livestock in each sub-basin are outlined in Appendix B.




Source: Data obtained from Armstrong, Pietroniro and Rolfe (2004)

**Figure 3.4. Proportion of Livestock Water Use by Sub-Basin, 1996**

## 3.5 Community/Municipal Water Use

As a critical component of urban life, municipal water uses are diverse. To start with, a municipality serves several types of establishments: residents, industries, commercial businesses, customers outside the municipal boundaries, plus all local municipal governments. Each one of these concerns use water to meet different types of need. For example, residents require water for drinking, cooking, bathing and sewerage, as well as for maintaining lawns. Local governments need it for cleaning streets, watering municipal green spaces, and controlling fires (Brandes and Ferguson, 2004). Commercial businesses and a variety of smaller scale enterprises such as bakeries and breweries also require high quality water for their production process (Brandes and Ferguson, 2004).

Most analyses of municipal water use focus either on total municipal demand or on residential water demand (Gibbons, 1986). In the context of the SSRB, the first approach is used. Water use data are available on a community level, with no further disaggregation by type of user. Water is withdrawn from surface as well as from groundwater sources. In Canada, approximately 74% of Canadians use surface water and the remaining 26% use ground water as sources. Source water limitations force users to use less desirable sources, such as deeper aquifers with higher mineral content in the Prairies (Environment Canada, 2004). In fact, a quarter of Canadian municipalities experienced water supply difficulties between 1994 and 1999, particularly those reliant on ground water supply (Environment Canada, 2004).

Rural private drinking water systems do not have the same water quality safeguards as municipal water systems. Therefore, rural residents do not enjoy the same level of confidence in terms of water quality as their urban counterparts. The contamination of surface water and groundwater could impact water quality. There is a perception that water quality degradation is a result of agricultural activities (AAFC-PFRA, 2003).

Tabulation of water use for each community of the SSRB from 1966 to 2001 is provided by Sobool and Kulshreshtha (2003), and is shown in Table 3.2. Communities in each of the sub-basin of the SSRB were included for two time period: 1996 and 2001. The Bow River basin had the highest water use and showed the largest increase in usage from 1996 to 2001. The Red Deer River basin had the lowest total usage among its aggregated communities. This is because the Bow River sub-basin houses the largest population center – City of Calgary. The second largest municipal water use in the Saskatchewan portion of the SSRB, which is also caused by the largest Saskatchewan city in the Basin – City of Saskatoon. In fact, the Bow and the South Saskatchewan sub-basins together account for around 86% of the urban water use. Rural water use is considerably less than urban water use but here too the Bow and South Saskatchewan basins together use around 91% of the rural water (Armstrong, Pietroniro and Rolfe, 2004).

**Table 3.2. Community Water Use in the SSRB ($dam^3$/year) by Sub-Basin in 1996 and 2001**

| Community Type[1] | Water Use ($dam^3$/year) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Oldman River (Alberta) | | Red Deer River (Alberta) | | Bow River (Alberta) | | SSR (Alberta) | | SSR (Saskatchewan) | |
| | 1996 | 2001 | 1996 | 2001 | 1996 | 2001 | 1996 | 2001 | 1996 | 2001 |
| Cities | 15.92 | 16.84 | 13.79 | 15.96 | 172.50 | 198.44 | 15.81 | 17.28 | 46.78 | 47.48 |
| Towns | 16.60 | 17.62 | 7.88 | 9.43 | 7.87 | 8.61 | 2.13 | 2.23 | 3.39 | 3.51 |
| Villages | 0.488 | 0.489 | 1.40 | 1.53 | 0.165 | 0.169 | 0.457 | 0.468 | 1.22 | 1.28 |
| Other | 0.455 | 0.457 | 0.278 | 0.293 | 0.057 | 0.064 | 0.068 | 0.073 | 0.162 | 0.152 |
| TOTAL | **33.46** | **35.41** | **23.35** | **27.21** | **180.60** | **207.28** | **18.46** | **20.05** | **51.55** | **52.42** |

[1] Alberta designation based on no. of people: City=10,000+, Town=1000+, Village=300+, Other= <300
Saskatchewan designation based on no. of people: City=5000+, Town=500+, Village=100+, Other= <100
(Government of Alberta, 2005; Government of Saskatchewan, 2004)
[2] Sobool and Kulshrestha (2003).

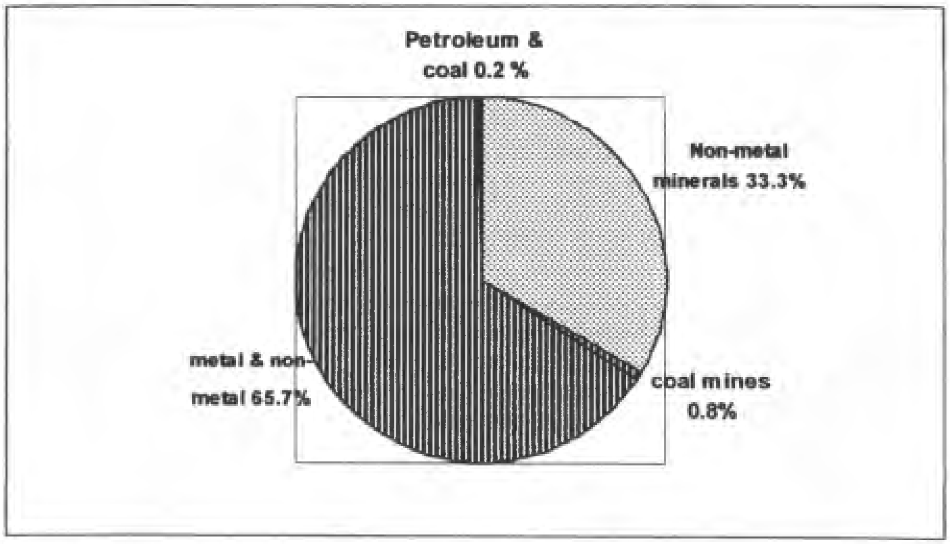
Although most communities obtain their water from surface water bodies (particularly the rivers), groundwater is also used, particularly for the smaller communities and for rural farm and non-farm purposes. Water is present underground in aquifers (permeable rock) which can be tapped by wells to provide vast amounts of water for use. Ground water is often more reliable and less expensive than surface water sources (Environment Canada, 2005). Based on the Prairie Provinces Water Board (PPWB) database, distribution of communities by source of water could not be obtained.

## 3.6 Mining Water Use

Mining operation types in the SSRB include petroleum exploration, non-metal minerals (such as potash), coal mines, and metal and non-metal mines (Armstrong, Pietroniro and Rolfe, 2004). Water is used for different purposes in different mining operations. Potash mines use water primarily for the refining process. Water used in potash mining is consumptive and thus no water is returned to the environment. Sodium sulfate and salt mining operations use water to dissolve and precipitate the minerals (Kulshreshtha et al., 1988). Water is also used to wash sand and gravel from mining pits in order to recover precious metals (Government of Alberta, 2004).

The oil and gas industry uses water for recovering oil (injection of water into wells), drilling oil and gas wells, and for recovering of heavy crude oil (injection of steam). The latter two uses utilize surface water, while oil recovery utilizes ground water resources (Kulshreshtha et al., 1988). In recent years there has been increased concern about over use of surface water in petroleum production. In Alberta, while the overall use of water in petroleum production has been increasing, the volume of water diverted from fresh surface and fresh ground water sources has been declining. The majority of this type of water usage is outside the SSRB and in northern Alberta (Wittrock, 2004).

The proportion of water intake for mining sectors is shown in Figure 3.5. Metal and non-metal mines are the largest water users in the SSRB. A distribution by water intake (withdrawal) in various sub-basins is shown in Table 3.3. The South Saskatchewan sub-basin has the highest intake of water for mining purposes, with 90% of water intake for metal and non-metal mines being consumed. The Oldman sub-basin withdraws the least amount of water among all the sub-basins in the SSRB. The Red Deer sub-basin is the only sub-basin that withdraws water for coal mining. In the process of coal mining, 100% of the water withdrawn is consumed. Non-metal mineral mining has a lower consumption rate of the water withdrawn than do coal, petroleum and metal/non-metal mining, with a consumption of 30 to 50% of the water intake for this purpose.




Source: Data Obtained from Armstrong, Pietroniro and Rolfe (2004)

**Figure 3.5. Distribution of Mining Water in the SSRB, 1996, by Type of Mining**

**Table 3.3. Mining Water Intake and Percentage Consumption by Sub-Basin, 1996**

| Type of Mining | Oldman | | Bow | | Red Deer | | South Sask. | |
|---|---|---|---|---|---|---|---|---|
| | Intake ($M^3$) | Cons. (%) | Intake ($M^3$) | Cons. (%) | Intake ($M^3$) | Cons. (%) | Intake ($M^3$) | Cons. (%) |
| Non-metal minerals | 69,381 | 32 | 3,651,931 | 51 | 185,977 | 41 | 88,948 | 33 |
| Petroleum & coal | - | - | - | - | 18,235 | 96 | - | - |
| Metal & non-metal | 7,200 | 83 | - | - | - | - | 7,865,091 | 90 |
| Coal mines | - | - | - | - | 98,032 | 100 | - | - |
| **Total** | **76,581** | | **3,651,931** | | **302,264** | | **7,954,039** | |

Source: Armstrong, Pietroniro and Rolfe (2004).

## 3.7 Power Generation Water Use by Sub-Basin

An Environment Canada survey on Industrial Water Use in 1996 found 13 hydro-power plants in the SSRB, 12 in Alberta and one in Saskatchewan (Armstrong, Pietroniro and Rolfe, 2004). However, by 2005 those numbers increased to include 20 hydro-power developments in Alberta, 11 of which are located in the Kananaskis/Bow river system and seven smaller ones located along canals and watercourses along central and southern Alberta (Alberta Environment, 2003; Wittrock, 2004). Alberta's hydro-electric generating facilities are capable of generating 5% of their electricity requirements. In Saskatchewan, hydro-electric facilities generate 27% of the requirement (Bruneau, 2004; Wittrock, 2004). Among the power generating plants that use the water from the South Saskatchewan River are the Coteau Creek hydro-electric plant, the Queen Elizabeth natural gas plant, and the Corey cogeneration plant (Wittrock, 2004). Table 3.4 shows the hydro-power plants in the Alberta and Saskatchewan portions of the SSRB along with their respective water use. While SaskPower owns and operates all the facilities in Saskatchewan, Alberta deregulated its power generation facilities in 2001, and currently has four private-public operators (Bruneau, 2004).

The Environment Canada Industrial Water Use Survey indicated there were two steam-thermal plants in the Alberta portion of the SSRB (Armstrong, Pietroniro and Rolfe, 2004). Alberta and Saskatchewan generate 75% and 92% respectively, of their power with conventional steam; while gas turbines contribute 0.9% and 2.4% respectively (Bruneau, 2004). Four natural gas fueled power plants operate in Saskatchewan to meet their peak demands, two of which are located in the SSRB. These thermal plants are shown in Table 3.5.

Hydroelectric power generation is net non-consumer of water. However, water is lost in the reservoirs through evaporation. In thermal power generation, water is lost through evaporation in cooling ponds as well as in the generation of electricity. The degree to which water evaporates is a function of the uses to which the water is put and the technology used in cooling the water (Bruneau, 2004). About 18% of the water intake in the thermal power production in the prairie provinces is consumed and at the same time 154% of the water intake is recycled (Bruneau, 2004). In the prairie-provinces, the production of 1 MW of electricity (thermal generation) requires 40 $m^3$ of water intake or 7.3 $m^3$ of water to be consumed (Bruneau, 2004).

## 3.8 Other Water Uses Within the Basin

Besides the main water uses discussed above, other water uses in the basin include industrial, community and in-situ water uses like recreational, wetland conservation, and navigation. It should be noted that in larger cities and towns, the industrial and commercial water is supplied though the municipal water systems.

**Table 3.4. Hydro-Power Plants in Saskatchewan and Alberta**

| Plant | River System | MW | Water Use (million cubic meters / yr) |
|---|---|---|---|
| **Saskatchewan** | | | |
| Coteau creek | SSK-River | 186 | 10,340 |
| | | | **Alberta** |
| Barrier | Bow River | 13 | 13,826 |
| Bearspaw | Bow River | 17 | 60,008 |
| Cascade | Bow river | 36 | 7,887 |
| Ghost | Bow river | 51 | 88,505 |
| Horseshoe | Bow river | 14 | 41,966 |
| Interlakes | Bow river | 5 | 4,661 |
| Kananaskis | Bow river | 19 | 62,387 |
| Pocaterra | Bow river | 15 | 7,015 |
| Rundle | Bow river | 50 | 13,525 |
| Spray | Bow river | 103 | 13,525 |
| Three sisters | Bow river | 3 | 9,103 |
| Oldman river | Oldman river | 32 | |
| Chin chute | Chin Main Canal | 13 | |
| Raymond reservoir | | 18 | |
| Belly river | St. Mary River | - | |
| Waterton | Waterton River | - | |
| St Mary | St. Mary | - | |
| Brazeau | Brazeau River | 355 | |
| Taylor Hydro | | 12 | |

Source : Bruneau (2004) and http://www.saskpower.com/aboutus/genfac/genfac.shtml.

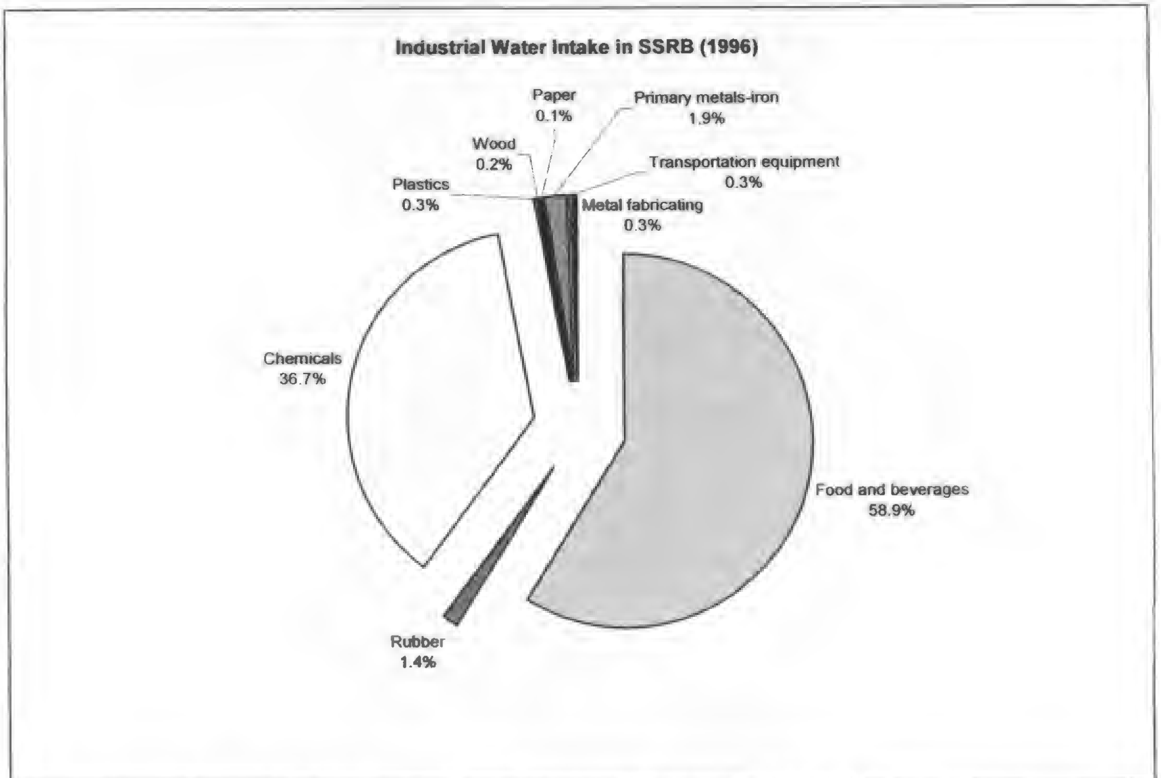
**Table 3.5. Thermal Power Plants in Saskatchewan**

| Plant | Location | MW | Water Use (million cubic meters / yr) |
|---|---|---|---|
| Saskatchewan | | | |
| Queen Elizabeth | Saskatoon | 386 | N.A |
| Success | Swift Current | 30 | N.A |

Source: Obtained from http://www.saskpower.com/aboutus/genfac/genfac.shtml.

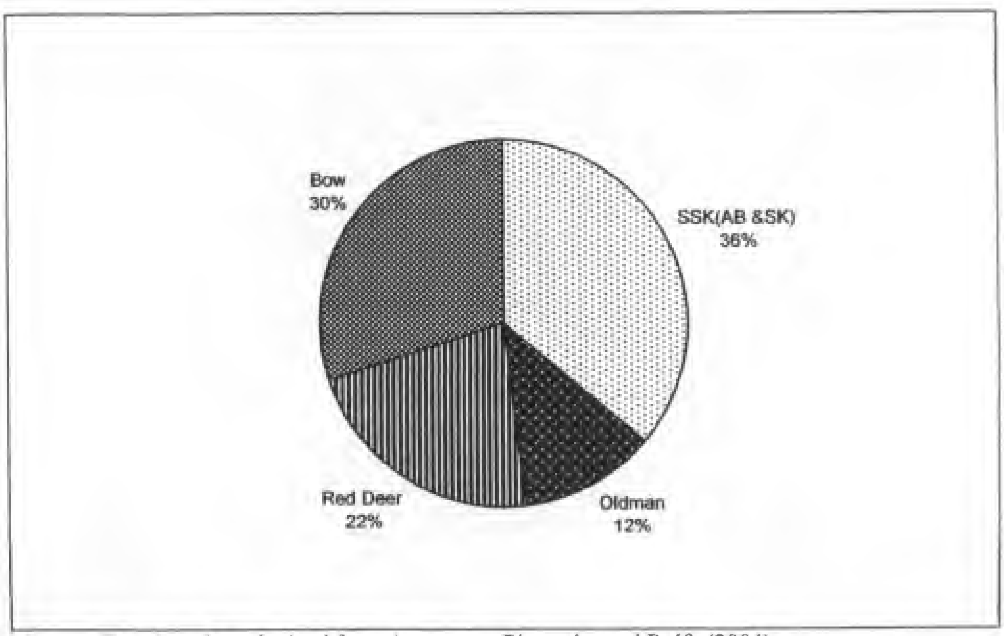
### 3.8.1 Industrial Water Use

Manufacturing industry sectors include food and beverage, chemicals, primary metals-iron, rubber, plastics, transportation equipment, paper, wood and metal fabrication (Armstrong, Pietroniro and Rolfe, 2004). Food and beverage and chemicals together account for almost 95% of the total water intake in the SSRB (Figure 3.6.). Industrial water use by sub-basin is detailed in Figure 3.7. Industrial use is largest in the South Saskatchewan River sub-basin and lowest in the Oldman River Basin. A summary of industrial water intake and percentage consumed is given in Table 3.6.




Source: Based on data obtained from Armstrong, Pietroniro and Rolfe (2004)

**Figure 3.6. Manufacturing Water Intake Proportion in the SSRB, 1996**




Source: Based on data obtained from Armstrong, Pietroniro and Rolfe (2004)

**Figure 3.7. Manufacturing Water Use by Sub-Basin, 1996**

**Table 3.6. Industrial Water Use by Sector and Sub-Basin, 1996**

| Sector | Oldman | | Bow | | Red Deer | | S.Sask (AB&SK) | |
|---|---|---|---|---|---|---|---|---|
| | Intake ($M^3$) | Cons. | Intake ($M^3$) | Cons. | Intake ($M^3$) | Cons. | Intake ($M^3$) | Cons. |
| Food & beverages | 6,461,075 | 91% | 11,386,744 | 76% | 844,068 | 82% | 5,908,510 | 73% |
| Rubber | - | - | - | - | - | - | 593,558 | 89% |
| Chemicals | 202 | 66% | 194,764 | 53% | 10,512,268 | 15% | 4,619,878 | 23% |
| Plastics | 4,509 | 82% | 84,238 | 60% | 7,679 | 74% | 12,165 | 91% |
| Wood | 12,641 | 85% | 25,357 | 96% | 33,738 | 81% | - | - |
| Paper | - | - | 24,630 | 10% | 23,576 | 5% | - | - |
| Primary metals- iron | 10,613 | 45% | 780,838 | 62% | 6,330 | 8% | 4,200 | 100% |
| Metal Fabricating | 2,241 | 91% | 118,433 | 95% | 4,835 | 92% | 11,856 | 91% |
| Transportation equipment | 27,258 | 100% | 79,788 | 98% | 1,200 | 100% | 2,820 | 100% |
| **Total Water Use** | **6,518,539** | | **12,694,792** | | **11,433,694** | | **11,152,987** | |

Source: Armstrong, Pietroniro and Rolfe (2004).

The Bow River sub-basin withdraws the most water for industrial purposes. The Red Deer and South Saskatchewan sub-basins are a close second and third with their high withdrawal volumes. The Oldman basin withdraws nearly half of the amount as the Bow River basin and is therefore the lowest user of industrial water in the SSRB. It is only within the South Saskatchewan sub-basin that water is withdrawn for the rubber industry, and it is the only sub-basin that does not use water for the wood industry. Industrial sectors such as transportation equipment and metal fabricating consume nearly all of the water withdrawn, while the paper and chemical industries consume a much smaller portion of their intake volumes.

### 3.8.2 In-Situ Water Use

In-situ water uses include those which are for recreation (boating, fishing and swimming), wetlands (waterfowl conservation or hunting) and for transportation or navigation (Armstrong, Pietroniro and Rolfe, 2004). Since water is not used directly, water use related to these activities cannot be estimated.

Recreational water use can be either direct or indirect. Activities such as boating, fishing, and swimming require the direct usage of the water resource. Camping and hiking, on the other hand, use water indirectly to promote the recreational activity (Kulshreshtha et al., 1988).

An actual measure of water use in recreation is not possible; rather, the number of people visiting parks and recreation sites maybe estimated (Armstrong, Pietroniro and Rolfe, 2004). A summary of recreational parks that provide water based recreational activities (by community and activity) for Alberta and Saskatchewan were provided by Sobool and Kulshreshtha (2003), and the geographic location of recreational parks is illustrated by Armstrong, Pietroniro and Rolfe (2004).

Water is used in the SSRB for navigation with the operation of a large number of ferry systems. The ferries transport people and vehicles across lakes and rivers either as a shortcut or as the only feasible way to travel to a destination. Other navigational water uses include barges for freight and ice roads (Kulshreshtha et al., 1988). These last two in-situ water uses, although present in Alberta and Saskatchewan, are not located inside the boundary of the SSRB.

### 3.8.3 Wetlands

Besides lakes and rivers, prairie landscape includes other water bodies, notably the wetlands. Wetlands are multi-functional and provide benefits directly and indirectly. These productive marshy areas support widespread food webs and a rich biodiversity of species. Wetlands are important for nutrient cycling, water storage, habitat, and for recreational purposes such as bird watching (Barbier, Acerman and Knowler, 1997). Data on wetlands within the SSRB are not available except in terms of some gross characteristics. These by sub-basins of SSRB and size categories are shown in Table 3.6. Most of the wetlands in the SSRB tend to be less than an acre. The Red Deer sub-basin had the largest proportion of large wetlands.

**Table 3.7. Estimated Numbers of Wetlands in the SSRB by Categories**

| Area of the Wetland (acres) | Bow | Oldman | Red Deer | SSR | Total SSRB |
|---|---|---|---|---|---|
| <1 | 77 | 267 | 429 | 12,557 | 35,920 |
| 1-3 | 270 | 70 | 1,146 | 21,667 | 26,330 |
| 3-5 | 155 | 41 | 810 | 6,613 | 8,395 |
| 5-10 | 239 | 86 | 1,340 | 5,220 | 7,439 |
| 10-25 | 173 | 51 | 750 | 3,158 | 4,390 |
| >25 | 153 | 18 | 581 | 1,624 | 2,465 |
| Total | 1,067 | 533 | 50,056 | 50,839 | 84,939 |
| Average Area (Acres) | 8.86 | 2.03 | 76.63 | 2.14 | 5.78 |

Source: Sobool and Kulshreshtha (2003)

## 3.9 Summary

Water is an important input in many of the economical sectors of the SSRB. Irrigation uses the largest amount of total water in the region (~80%). The Oldman sub-basin consumes 37% of the total water withdrawn for irrigation. In livestock water use, the

Oldman basin is the lowest water user at only 3%. The Red Deer sub-basin is the highest user of water in the livestock sector with 48% of the total water used for this purpose.

The municipal sector is the second highest water user and withdraws 12% of all of the water used in the SSRB. Municipal usage includes water used in domestic, commercial, and governmental settings. The Bow River sub-basin consumes the highest proportion of water for municipal purposes. This coincides with the Bow River sub-basin having the highest population base at over one million residents.

The manufacturing sector requires water as an input in many of its sectors. Three percent of all water used in the SSRB is withdrawn for manufacturing/industrial purposes. The food and beverage sector consumes the largest proportion of manufacturing water in the SSRB, followed by chemicals manufacturing. The Bow River sub-basin withdraws 30% of the water used for manufacturing purposes with the Red Deer and South Saskatchewan (Alberta and Saskatchewan portions) not far behind with 27% each of the total water used in manufacturing. Also, three percent of the total water use in the SSRB is used in thermal power generation.

Mining for metal and non-metal minerals withdraws over 65% of the total water used in mining. This type of usage is 90% consumptive, and, therefore very little water is returned to the original source. The South Saskatchewan River sub-basin is the largest withdrawer of water for the purpose of metal and non-metal mining, and, thus, is the largest mining water user in the SSRB with well over twice the intake volume of the second highest water user, the Bow River sub-basin.

Overall, the South Saskatchewan River Basin, with a population of 1.5 million, uses over 2.5 million $dam^3$ of water annually (1996 approximation by Armstrong, Pietroniro and Rolfe (2004)). This water is distributed among different sectors with some commanding more water than others to satisfy their needs.

# PART TWO

# VALUATION OF WATER

# Chapter 4

# CONCEPTUAL FRAMEWORK

In this chapter, a discussion of conceptual framework related to value of water is described. The concept of value is discussed in Sub-section 4.1, followed by a discussion of types of values used in water valuation in Section 4.2. Approaches to valuation of water are described in the next section, which is followed by the measurement of value in this context in Section 4.4.

## 4.1 Concept of Values

One of the greater obstacles in compiling values is how to value non-market activity. This is difficult because many of the services provided by water are not traded in a market under a competitive price. Moreover, value cannot always be expressed in economic terms. Since we cannot obtain another substance to substitute for water, we cannot place an economic value on water in terms of its importance to sustaining life, health and ecosystems (Dybvig and Kulshreshtha, 1988). Thus, with low levels of precision, objectivity and reliability, the need to find non-market valuation techniques for water exists. For near-market or non-market activities, environmental and resource economists use proxies as well as develop alternative techniques that impute values indirectly (some of these are described in Section 4.4). Such values range from those that rely on observed behavior such as the travel cost method or on hedonic valuation to those that rely on non-behavioral data, such as contingent valuation.

## 4.2 Typology of Values in the Context of Allocation of Water

For goods without markets or without well-functioning markets, value is measured by society's Willingness To Pay (WTP). Use of these goods at the estimated level of WTP for a good increases the society's welfare. This is equated to the economic value of the good. In the context of water resources, values can be differentiated further by stock value and flow value.

A stock value is applicable to a water-based ecosystem, such as lakes, wetlands, or rivers. This value can be broken down into three major components (Environment Canada and Statistics Canada, 2002):

- actual expenditures made by users in the course of their individual uses where water is a market good;
- values that can be imputed using methods that include some of the non-marketed values (such as rent valuation techniques, travel cost methods, hedonic pricing); and,

- values that could not be estimated using earlier methods but can be based on the estimation of consumers' surplus using contingent markets.

All three values are captured by a concept called "Total Economic Value – TEV" of a resource or ecosystem. Conceptually, total economic value (TEV) can be visualized in terms of various components, as shown in Figure 4.1. The use values are related to the use of water from a given source for various purposes. However, other values, particularly the non-use values, can only be estimated using the contingent markets. Use of this concept is recommended in use for the System of National Accounts for natural resources.

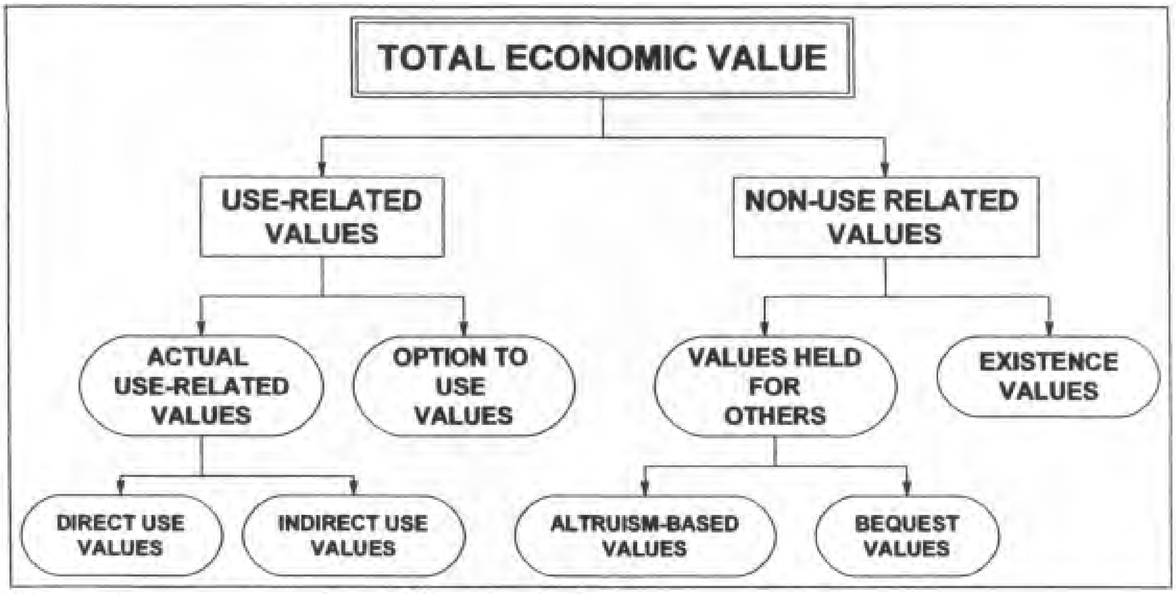



**Figure 4.1. Elements of Total Economic Value**

A flow value is related to actual use of a resource or an ecosystem. In the context of water, these values would be related to various types of uses. In fact, value of water will differ from one use to another, particularly upon the degree of importance of water to the end use. Two major categories of water uses are direct and indirect water use. Residential water use would be an example of the former, and irrigation water use for crops an example of the latter, since it is the demand for the products of irrigated lands that lead to economic demand for water. If a demand function for a particular water use is known, the value of water for a specific water use can be approximated using the concept of economic surplus (producer or consumer surplus depending on who is demanding the water). When a demand function for water is not observable, such a function can be approximated using analytical techniques, such as linear programming, or contingent valuation (Dybvig and Kulshreshtha, 1988).

Value of water can further be distinguished using the concept of marginality. This leads to two types of values – average values and marginal values. Average value is based on the average WTP for the total quantity demand by the users. It is simply the ratio of total

WTP to quantity used. Marginal value is the level of WTP associated with the last unit of the flow of resource (use of water).

Conceptually, the market value (if one exists) that is paid in the exchange of the last unit of water for use underestimates the total value of goods and services to consumers. Because consumers (or producers) pay the price of the last or marginal unit for all units consumed in the market, they enjoy a surplus of total satisfaction over total cost to them.

## 4.3 Approaches to Valuation of Water

As discussed above, the TEV is consistent with WTP approach, and the SNA is consistent with marginal value approach. A study by Environment Canada and Statistics Canada (2002) has identified the appropriate methods to follow in order to estimate various values of water. These are listed in Table 4.1. Various values associated with water were divided into four categories: (1) Direct Use Values, which included value of water in specific uses (such as agricultural domestic/municipal, and industrial (including power generation); (2) Indirect Use Values, which included benefits accruing to the society from various ecosystem functions associated with water, as well as commercial navigational and recreational uses of water; (3) Option Use Values for recreation, aesthetics, and property values; and (4) Passive Non-Use Values, including existence values and bequest values.

The method of estimation for direct use values proposed by the Environment Canada and Statistics Canada (2002) was the estimation of demand functions. The demand curve approach uses a given price to determine what quantity of water is demanded at that price. Given a budget constraint, a demand curve (or willingness to pay curve) can be mapped. The demand curve is useful in that it shows the maximum price a consumer would pay for the amount of water used (Kulshreshtha et al., 1988). However, its data requirements are immense. The two exceptions to the demand estimation are for irrigation, where a method of cost savings approach was suggested, and for stockwatering where a replacement cost method was proposed. Other methods included hedonic price model, travel cost model, and contingent valuation method.

In addition to the above methods, a variety of other methods are also used for valuation of water. One of these is the Residual Imputation where value of water is estimated as the difference between the value of the product less that of all other inputs. Alternative Cost method is another method where the value of water is approximated by the difference in per unit cost of current method of production and a more expensive, water-saving method.

Indirect valuation approaches include the hedonic pricing and travel cost. The hedonic price method estimates the value of water based on the attributes of water, rather than the water itself. The travel cost method estimates value by using the cost incurred in traveling to a site as proxy for the price. Both of these methods are based on observations of the consumer's behavior.

**Table 4.1. Recommended Valuation Techniques Consistent with Total Economic Value[1]**

| Water use/function | Valuation method | Compatibility with SNA |
|---|---|---|
| **DIRECT USES** | | |
| 1. Agriculture | | |
| - Irrigation | Cost saving approach | Estimates producers' surplus (PS) as proxy for farmers' WTP for water |
| -Stock watering | Replacement cost | Estimates PS |
| 3. Domestic/Municipal | | |
| -Municipal domestic use | Derived demand | Estimates WTP |
| -Rural domestic use | Derived demand | Estimates WTP |
| -Commercial | Derived demand | Estimates WTP |
| 4. Industrial | | |
| -Pulp & paper prod. | Derived demand | Estimates WTP |
| -Chemical products | Derived demand | Estimates WTP |
| - Mineral Extraction | Derived demand | Estimates WTP |
| -Petroleum products | Derived demand | Estimates WTP |
| -Power generation | Derived demand | Estimates WTP |
| -Hydro | Residual Imputation | Estimates PS |
| -Thermal | Residual Imputation | Estimates PS |
| -Metal smelting | Derived demand | Estimates WTP |
| -Food processing | Derived demand | Estimates WTP |
| -Plastic manufacturing | Derived demand | Estimates WTP |
| -Textile manufacturing | Derived demand | Estimates WTP |
| **INDIRECT USES** | | |
| 1.Commercial navigation | Cost Savings Method | Rent values consistent with SEEA |
| 2. Recreation & tourism | | |
| - Recreational fishing | Hedonic TCM[2] or CVM[3] | Estimates WTP |
| - Canoeing, Sailing | Hedonic TCM or CVM | Estimates WTP |
| - Power boating | Hedonic TCM or CVM | Estimates WTP |
| - Swimming | Hedonic TCM or CVM | Estimates WTP |
| - Waterfowl viewing, Hunting | Hedonic TCM or CVM | Estimates WTP |
| 3. Regulation function | | |
| - Flood protection | Cost of alternative | Estimates PS |
| - Erosion protection | Cost of alternative | Estimates PS |
| - Habitat maintenance | Cost of alternative | Estimates PS |
| - Storm protection | Cost of alternative | Estimates PS |
| - Drought recovery | Cost of alternative | Estimates PS |
| - Biodiversity maintenance | Cost of alternative | Estimates WTP |
| - Bioenergy fixation | Cost of alternative | Estimates PS |
| - Climate regulation | Cost of alternative | Estimates PS |
| - Storage/recycling of organic matter, nutrients, human waste | Cost of alternative | Estimates PS |
| **OPTION USES:** | | |
| - Recreation | CVM or Benefit transfer | Estimates WTP |

| Water use/function | Valuation method | Compatibility with SNA |
|---|---|---|
| - Scenic | CVM or Benefit transfer | Estimates WTP |
| - Property | CVM or Benefit transfer | Estimates WTP |
| **PASSIVE USES** | | |
| 1. Bequest values | | |
| -Spiritual & cultural values | CVM or Benefit transfer | Not consistent with SEEA |
| -Species | CVM or Benefit transfer | Not consistent with SEEA |
| -Habitats | CVM or Benefit transfer | Not consistent with SEEA |
| 2. Existence Values | | |
| - Aesthetic values | CVM or Benefit transfer | Estimates WTP |
| -Educational and scientific information | CVM or Benefit transfer | Estimates WTP |

1 Environment Canada and Statistics Canada (2002)
2 Travel Cost Method (TCM)
3 Contingency Valuation Method (CVM)

The contingent valuation method is a direct approach used to estimate non-market value of water. This method involves the creation of a market by requesting consumer's willingness to pay for non-market water uses. The benefits transfer approach uses data from previous studies and applies them to another study (Environment Canada and Statistics Canada, 2002).

## 4.4 Measurement of Values through Concept of Producer and Consumer Surplus

A typical measure of the welfare of a producer is level of profit from a given activity. The profit is determined as the difference between total revenue and total costs (to include both variable costs and fixed costs). Although profit can serve as an appropriate measure of welfare effects of a change in economic parameters, such as price, according to Just, Hueth and Schmitz (1982), it is not always appropriate in other cases. An alternative to profit was suggested by Marshall (1930). The concept was that of quasi-rent or producer surplus. Marshall defined producer's net benefit as the excess of gross receipts which a producer received from a given production activity over the extra cost that the firm incurs to produce that product. Quasi-rent is defined as the difference between gross receipts and total variable costs. Thus, it is a measure of return to producers over all variables costs, which includes profit and fixed costs.

The other measure, particularly for the water users is the concept of consumer surplus. This is the area under the demand function over the price paid by the user (or cost to the user). This estimate measures the value as the net WTP. It is the portion of value that is not paid for by the consumer. A sum of the producer surplus and consumer surplus is a measure of social welfare from a change in the quantity of water available to water users (Kulshreshtha et al., 1988).

## 4.5 Summary

This chapter has laid the foundation on the concepts of value of water. It also categorized the valuation techniques under a typology and introduced the concepts of TEV, marginal and average value. Finally, the chapter highlighted the preferred valuation techniques used for TEV as proposed by Environment Canada and Statistics Canada (2002). The following chapters further discuss marginal and average value in the context of water value in irrigation, agriculture, power generation, residential, industrial, municipal, and mining uses. Also, the value of water in in-situ uses of recreation and waste assimilation is examined.

# Chapter 5

# VALUE OF WATER FOR IRRIGATION

## 5.1 Introduction

Agricultural production in Canada consumes water primarily for irrigation (85 percent) and livestock watering (15 percent) (Brandes and Ferguson, 2004). Agriculture is also a highly consumptive user of water because of high evapotranspiration (Brandes and Ferguson, 2004). Seasonally drier regions of Canada, like the southern prairies, could not be agriculturally productive if without irrigation. Agriculture is not only the largest user of water but also the largest net consumer. In this chapter, valuation of water for irrigation purposes is reported. Valuation is done for the five sub-basins of the SSRB.

## 5.2 Irrigation in the SSRB

Irrigation is required in the prairies where the annual precipitation ranges between 300-500 mm (Environment Canada, 2004). In 2000, Alberta and Saskatchewan were the two provinces with the largest irrigated area. Alberta had a total of 499,241 ha of irrigated lands, while Saskatchewan's area was around 68,470 ha.[2] Much of the irrigation in the province of Alberta was concentrated in the SSRB, as 492,706 ha of irrigated lands were estimated to be in the SSRB (Sobool and Kulshreshtha, 2003). In Saskatchewan, the situation was somewhat different. The Saskatchewan portion of the SSRB had an irrigated area of 34,969 ha. Thus, in Saskatchewan, SSRB contributes only half of the provinces irrigated area.

Irrigation use of water is through two types of irrigation: district (or group) irrigation projects, and private irrigation. In Alberta SSRB sub-basins, there are 13 irrigation districts found, whereas in Saskatchewan portion of the SSRB, irrigation is organized under thirteen such districts (or twelve, since information on one irrigation district were not available) such districts or water user groups. These areas are located in two regions of the province: The Lake Diefenbaker Development Area (LDDA), and (SWDA) Development Area. These areas also have a distinctly different irrigation pattern. In the LDDA, irrigation is very intense. Although farms have both irrigated and dryland areas, a wider set of crop choices are made for production. In the SWDA, irrigation is practiced as a small-plot irrigation system. Forages are the major crops on these irrigated lands.

2 This figure is based on the estimate provided by the Census of Agriculture. Data from Provincial sources (Saskatchewan Agriculture and Food, 2000) reported an irrigated area for the province of 134,301 ha, some two times the area reported by the Agricultural Census.

## 5.3 Conceptual Valuation Methodology

The valuation methodology suggested for valuation of irrigation water by the Environment Canada and Statistics Canada (2002) was that of willingness to pay using the concept of producer surplus. This surplus is the return to producers when all factors of production have been paid. In the short-run, this means only the cash (variable) costs need to be paid, while in the long-run all cost items are included.

The two significant concepts in this context of water allocation among competing uses are:

(1) What does the last unit of water contribute to the production of the product it is applied to?; and

(2) What, on average, are the returns to producers for application of water to various uses?

The first concept is called marginal value product, and is very useful in deciding which crops to irrigate and the quantity of water used in its production. The marginal value is based on the concept of producer surplus associated with a marginal (incremental) change in the amount of water as an input in the production process. Here, value reflects the change in the quasi-rent associated with that amount of water. This value is referred to as the 'marginal' value.

The second concept is called the average value product or benefits from water application. This estimate reflects whether water should be allocated for irrigation or not, relative to other uses of water in a sub-basin. This value of water reflects a change in the economic welfare of the producer from applying water-using technology and related cultural practices. This gain is also measured in terms of producer surplus, except that the value is measured relative to alternative technology. In the context of irrigation, this technology is dryland production system. Each of the marginal and average values is described further below.

### 5.3.1 Concept of Marginal Value Product of Water

Marginal value product (MVP) of water reflects additional benefit to producer to apply an addition unit of water to a given crop. It would reflect on one side gain in revenue through increased yield (derived from the value of total production function) and on the other side by the cost of application of that additional unit of water to the crop. The additional costs may include a variety of agricultural inputs, such as fertilizer, chemicals, energy for water application, among others. This additional cost is typically called marginal cost (MC) of water[3]. The difference between change in gross revenue associated with a given quantity of water and that in the MC yields the aforesaid MVP of water in a given crop (use), is called the marginal value of water.

[3] For a more comprehensive description of production functions and graphical illustration, the reader is referred to a Micro-Economic textbook (Varian, 1992).

### 5.3.2 Concept of Average Value of Water

As noted above benefits from the use of a resource typically accrue to producers or consumers or both. Consumer surplus is relevant only when price of a product is affected by the change in the production system (change from dryland production to irrigated production). However, given that scale of irrigated production is relatively small[4], it can be assumed that irrigated producers are price takers.

The value of water is captured through a change in producer surplus resulting from a change in alternative production systems. Two alternative systems of production can be envisaged. One, if farmers had no access to water, crop production would be based on dryland production system. Two, if farmers had an access to water, the relative change in producer surplus would be over and above that under the dryland system. A somewhat simplified concept of this value is shown in Figure 5.1. Producer surplus under dryland production system is reflected by the area '*aPb*', whereas that under irrigation is reflected by area '*Pcd*'. Thus, the net gain in producer surplus is the area '*abcd*', which, if divided by the total amount of water applied for irrigation, would yield average benefits or value of per unit of water.

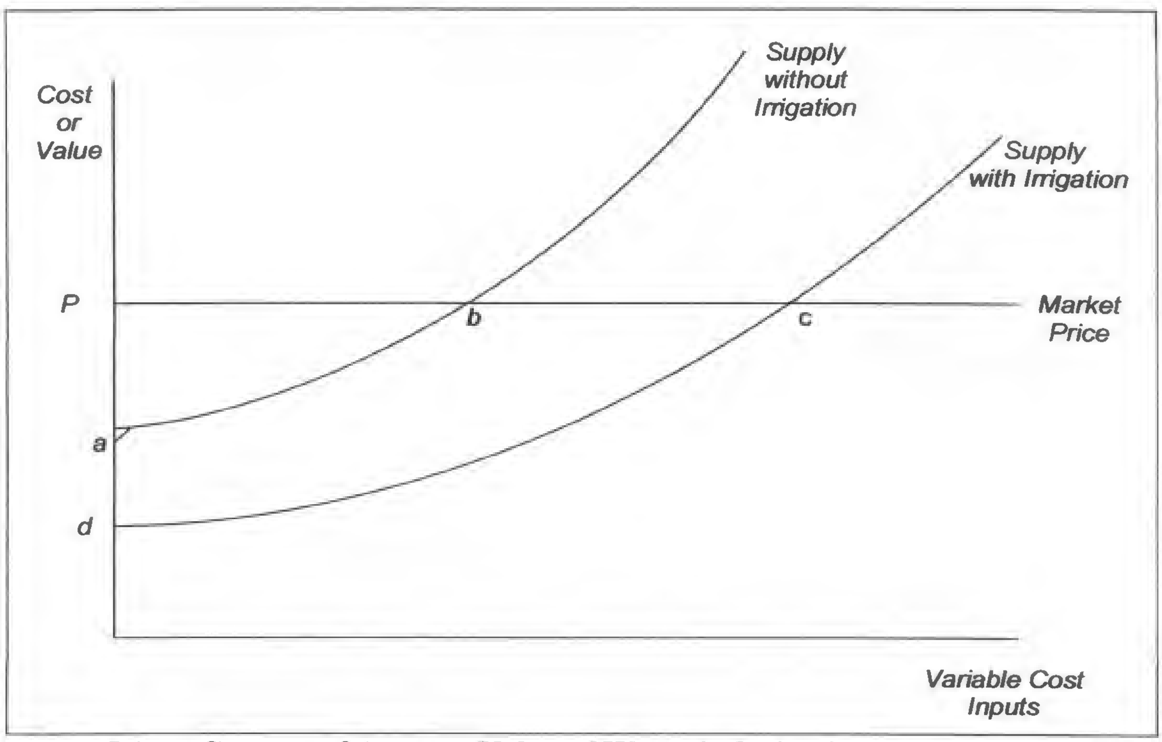



**Figure 5.1 Concept of Average Value of Water in Irrigation**

[4] This is reflected in the area under irrigation, relative to total cropped area. During 2000, irrigated area in Canada was less than two percent of total cropped area (see Kulshreshtha, Sobool, and Grant, 2005).

## 5.4 Estimation of Value of Water

In this section, conceptual methodology for the estimation of marginal and average value of water in irrigation is described.

### 5.4.1 Estimation of Marginal Value of Water

Estimation of marginal value of water requires the knowledge of a water production function further translated into a value of water function, and its incremental cost. This is because assessment of this value is related to the total value of a product associated with various levels of water application. Under the assumption of producers being price takers, the physical product function can be translated into a total value function by simply multiplying the physical product by the market price.

Under arid and semi-arid climates, crop water requirements are typically met through two sources: (1) natural precipitation (net amount available to the crop); and (2) supplementary irrigation. Relevant section of a value of production function is shown in Figure 5.2 (top). As water is added to the crop, production will increase until some maximum value of production is reached. Assuming rationality on the part of producers, no irrigation is provided beyond this point. The approximate shape of this function is considered to be non-linear in nature, although the shape of the function is subject to empirical testing.

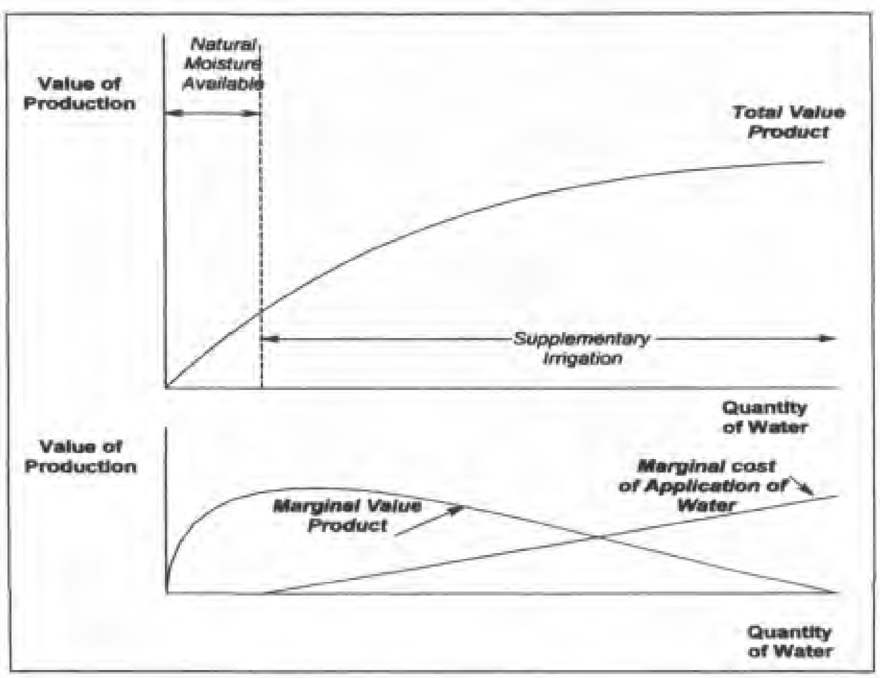



**Figure 5.2. Total Value of Production Function for Water, and Associated Marginal Value Product**

### 5.4.2 Estimation of Average Value of Water

As shown in Figure 5.1., average value of water requires the estimation of producer surplus from two production systems — irrigated production system and the dryland production system. This is measured as the difference between gross or total value of production under each of the production systems, and the associated costs. Total value of production, as noted above, is a result of two items – crop yields under different levels of supplementary water application (irrigation), and the price the product fetches in the market. Since price of the product is assumed to be fixed (does not change with the change in the production level), this function is primarily a result of water-yield relationship, also known as the water production function.

The concept of cost of production is related to time horizon of the producer. In this context, two types of costs can be identified: Short run cost of production and Long run cost of production. The former includes only the variable costs of production associated with either of the two production systems. The latter includes short run costs as well as fixed costs. In the long run, use of water, therefore, has to pay for all costs of production.

Associated with these two costs are two different average values of water: Short-run value of water and Long run value of water. These are estimated as follows:

| | | | | | |
|---|---|---|---|---|---|
| Short run Value of Water | = | Incremental Gross Revenue over Dryland | - | Incremental Variable costs over Dryland | (5.1) |

The long run value of water is calculated in a similar manner except that all costs (variable and fixed costs) are deducted from the incremental gross revenue.

## 5.5 Empirical Methodology for Valuation of Irrigation Water

### 5.5.1 Overview of the Methodology

In order to operationalize the concepts of marginal and average value of water in irrigation, several steps were undertaken. These steps were common to both the valuation, and therefore, are described first. More detailed steps that were followed to estimate either the marginal or average value of water are discussed in Section 5.5 and 5.6, respectively. The common steps include the following:

Step 1: Disaggregate the SSRB into sub-basins, and ascertain sub-basin specific crop mix for irrigation. This step is described in Section 5.4.2.

Step 2: Estimate the cropping mix on irrigated farms in various sub-basins. This step is described in Section 5.4.3.

Step 3: Estimate the distribution of various crops by irrigation technology. This is discussed in Section 5.4.4.

### 5.5.2 Disaggregation of the SSRB into Sub-Basins

As noted in Chapter One, the SSRB can be disaggregated into the following five sub-basins, the first four of which are within the province of Alberta and the fifth within the province of Saskatchewan.

(1) Bow River basin, Alberta
(2) Oldman River basin, Alberta
(3) Red Deer River basin, Alberta
(4) South Saskatchewan River basin (lower), Alberta
(5) South Saskatchewan River basin (upper), Saskatchewan

In each of these river basins, irrigation is organized under two types: one, district irrigation, and two, private irrigation. Unfortunately most of the irrigation-related data are collected only for the district irrigation. Although some private irrigation does exist in the SSRB, details on the crop mix or any other aspect of irrigation are unavailable.

Irrigation districts in Alberta and Saskatchewan are located in various sub-basins. Therefore, the first step required was that of developing a correspondence system between the sub-basins and the irrigation districts. Although primary data on each parcel of land would have generated better quality data, in this study such data was not considered feasible. As a substitute, land area was used for such a correspondence. Using the geographical information system (GIS) data, area of each irrigation district in a sub-basin was estimated[5]. Many irrigation districts were found to be located in more than sub-basins. Details are shown in Table 5.1 for Alberta, and in Table 5.2 for Saskatchewan. Many irrigation districts in Alberta were located in one or more sub-basins. For example, the Bow River irrigation district is located in the Oldman River sub-basin and in the Red Deer River sub-basin.

The Saskatchewan SSRB sub-basin included 12 irrigation districts, all of which were totally within the boundary of the sub-basin. These districts belonged to two Irrigation Development Areas of Saskatchewan[6], the Lake Diefenbaker Development Area (LDDA) and the SWDA. Most of the irrigated area (87% of the total) was located within the LDDA. In contrast to Alberta, irrigation districts, with the exception of the South Saskatchewan River Irrigation District

[5] This information was provided by Mr. Robert Armstrong, Pietroniro, and Rolfe of the Geography Department, University of Saskatchewan.

[6] Province of Saskatchewan is organized into four irrigation development areas: South west, Lake Diefenbaker, North, and South east.

**Table 5.1. Apportionment of Irrigation Districts to Sub-Basins – Alberta**

| Sub-basin | Irrigation District | % of District in Sub-basin | Area of District in Sub-basin (ha.) |
|---|---|---|---|
| Oldman | Aetna | 100% | 868 |
| | Bow River | 48% | 38,338 |
| | Leavitt | 100% | 1,732 |
| | Lethbridge Northern | 100% | 57,954 |
| | Magrath | 100% | 5,806 |
| | Mountain View | 100% | 1,358 |
| | Raymond | 29% | 4,592 |
| | St. Mary | 40% | 55,601 |
| | Taber | 100% | 30,270 |
| | United | 100% | 5,723 |
| Bow | Eastern | 45% | 49,057 |
| | Western | 55% | 15,439 |
| Red Deer | Bow River | 52% | 41,036 |
| | Eastern | 52% | 60,361 |
| | Western | 45% | 12,379 |
| South Sask. (AB) | Eastern | 3% | 329 |
| | Ross Creek | 100% | 297 |
| | St. Mary | 60% | 81,686 |
| | Raymond | 71% | 11,465 |
| Total for the SSRB (Alberta Portion) | | | 474,291 |

Source: Armstrong (2005)

**Table 5.2. Irrigation Districts within the Saskatchewan Sub-Basin**

| Sub-basin | Irrigation District | % of District in Sub-basin | Area of District in Sub-Basin (ha.) |
|---|---|---|---|
| LDDA | Grainland | 100% | 1,047 |
| | Luck Lake | 100% | 3,307 |
| | Macrorie | 100% | 847 |
| | Riverhurst | 100% | 2,912 |
| | South Sask. River | 100% | 15,272 |
| | Saskatoon South East Water Supply | 100% | 7,070 |
| Total LDDA | | | 30,455 |
| SWDA | Chesterfield | 100% | 280 |
| | Hillcrest | 100% | 1,291 |
| | Miry Creek | 100% | 675 |
| | Moon Lake | 100% | 616 |
| | North Waldeck | 100% | 667 |
| | River Lake | 100% | 985 |
| | Maple Creek | 100% | n/a |
| Total SWDA | | | 4,514 |
| Total SSRB (Saskatchewan Portion) | | | 34,969 |

Source: Armstrong (2005) and ICDC (2004)

### 5.5.3 Irrigated Crop Mix

Irrigation crop mix for a sub-basin was estimated as a weighted average of crop mixes in various irrigation districts that exist within the sub-basin. It is assumed that the irrigation crop mix is homogenous in all parts of the district. Data on crop mix for various irrigation districts were obtained from the Alberta Agriculture, Food and Rural Development (AAFRD, 2003 b) for Alberta, and from Mr. John Linsley of Saskatchewan Agriculture and Food for the SSRB (Saskatchewan portion). Details on these crops are shown in Table 5.3. A more detailed distribution by sub-basisns is presented in Section 5.6.

**Table 5.3. Crop Mix for Alberta Irrigation Districts and the LDDA, Saskatchewan**

| Crop | Alberta | | LDDA Saskatchewan | |
|---|---|---|---|---|
| | Area in Ha | Percent of Total | Area in Ha | Percent of Total |
| Alfalfa | 108,188 | 26% | 6,822 | 22.% |
| Barley | 62,650 | 15% | 1,797 | 6% |
| Barley Silage | 36,501 | 9% | 761 | 3% |
| Canola | 36,057 | 9% | 3,289 | 11% |
| Dry beans | 19,723 | 5% | 2,040 | 7% |
| Lentils | - | - | 609 | 2% |
| Peas | 2,254 | 1% | 609 | 2% |
| Tame Grass | 51,540 | 12% | 305 | 1% |
| HRS* Wheat | 34,748 | 8% | 5,086 | 17% |
| SWS** Wheat | 14,535 | 3% | - | - |
| Durum | 26,696 | 6% | 7,492 | 25% |
| Potatoes | 17,888 | 4% | 1,035 | 3% |
| Sugar Beet | 11,662 | 3% | 0 | 0 |
| TOTAL | 422,442 | 100% | 30,455 | 100% |

* Hard Red Spring Wheat

** Soft White Spring Wheat

*Note:* The list of irrigated crops for Alberta is non-exhaustive. These data were obtained from AAFRD (2003). The list for LDDA was derived using the percentages presented by Kulshreshtha, Sobool and Grant (2005), and the total irrigated LDDA component from Armstrong (2005). The proportions of irrigated crops in the SWDA are shown in a latter section of this report.

Source: AAFRD (2003 b); Armstrong (2005); SIDC (2004); Linsley (2005).

### 5.5.4 Distribution of Irrigated Crops by Method of Water Delivery (Irrigation Technology)

Value of water is determined in part by the efficiency of the water distribution system. Irrigation efficiency of a particular irrigation technology refers to the proportion of water that reaches the root zone of the crop from the water applied in irrigation. However, a given crop in a sub-basin could be irrigated using different technologies. Hence, efficiency for each crop was calculated by multiplying the proportion of cropping extent that particular irrigation technology covers in that sub-basin[7] (which is shown in Table 5.4). The proportion of water delivery is also somewhat variable across sub-basins. In Alberta, the Oldman River sub-basin has the highest proportion of crops where water is delivered through pivots. This sub-basin also has the highest proportion of specialty crops in the SSRB.

**Table 5.4. Percentage of Crop under Different Irrigation Technology*, SSRB Alberta**

| Irrigation Technology | Cereal** | Forage | Misc. | Oilseeds | Specialty Crops** | Grand Total |
|---|---|---|---|---|---|---|
| **Bow River Basin** | | | | | | |
| Gravity | 5.98% | 17.04% | 0.18% | 1.60% | 1.13% | 25.9% |
| Other | 0.12% | 0.45% | 0.02% | 0.03% | 0.27% | 0.9% |
| Pivot | 17.84% | 22.39% | 0.03% | 7.53% | 7.60% | 55.4% |
| Wheels | 5.51% | 9.40% | 0.09% | 1.10% | 1.68% | 17.8% |
| Grand Total | 29.5% | 49.3% | 0.3% | 10.3% | 10.7% | 100% |
| **Oldman River Basin** | | | | | | |
| Gravity | 0.90% | 4.72% | 0.11% | 0.15% | 0.06% | 6.0% |
| Other | 0.15% | 0.58% | 0.10% | 0.02% | 0.16% | 1.0% |
| Pivot | 22.49% | 24.01% | 0.14% | 6.78% | 12.97% | 66.4% |
| Wheels | 8.37% | 14.98% | 0.19% | 1.46% | 1.66% | 26.7% |
| Grand Total | 31.9% | 44.3% | 0.5% | 8.4% | 14.8% | 100% |
| **SSRB (Alberta) and Red Deer River Basin** | | | | | | |
| Gravity | 3.21% | 10.33% | 0.14% | 0.81% | 0.55% | 15.0% |
| Other | 0.13% | 0.52% | 0.06% | 0.02% | 0.21% | 1.0% |
| Pivot | 20.37% | 23.27% | 0.09% | 7.12% | 10.53% | 61.4% |
| Wheels | 7.07% | 12.44% | 0.14% | 1.29% | 1.67% | 22.6% |
| Grand Total | 30.8% | 46.6% | 0.4% | 9.2% | 13.0% | 100.0% |

* The irrigation technologies have been apportioned by cropped area of crop groups among the respective sub-basin. Values are expressed in percentage of total area irrigated. For more details, see footnote no. 7

** Cereals include barley and wheat. Forages include alfalfa, barley silage and canola. Specialty crops include dry beans, potato and sugar beet (AAFRD, 2003 c)

Source: Chinn (2005)

Distribution of water delivery methods used by producers is shown in Table 5.5. Unfortunately the data available are only for the LDDA, where the most dominant

[7] Detailed values are provided only for the Oldman and Bow River Basins or as a roll-up for the two basins combined, Red Deer River and the South Saskatchewan Basin (Alberta portion). The roll-up of the Red Deer and South Saskatchewan Alberta Basin was done because the data available for 2003 was collected specifically for each of the 13 irrigation districts, all of which derive their water either from the Oldman or the Bow Rivers. None of the districts divert water from the Red Deer River Basin. There are other irrigation areas within the Red Deer River Basin, as there are in the Bow and the Oldman, but these are all privately licensed individual projects for which there is currently is no coordinated data collection process. According to Chinn (2005), in general, these private projects typically have a higher proportion of cereals and forages and slightly higher proportion of centre pivot systems.

method of water delivery to crops is pivots – high pressure or low pressure. In the SWDA, since irrigation is organized over small plots, surface irrigation methods are more common.

**Table 5.5. Percentage of Cropping Cropped Area under Irrigation Technology, SSRB Saskatchewan, 2004**

| Irrigation Technology | Water Availability |
|---|---|
| Sprinkler-pivot-high pressure | 45% |
| Sprinkler-pivot-low pressure | 45% |
| Gravity-flood | 1.67% |
| Gravity-developed | 1.67% |
| Gravity-controlled | 1.67% |

Source: Linsley (2005).

Data on technical efficiency of various irrigation methods are available only for Alberta. Under standard conditions, a low pressure sprinkler system provides the second highest efficiency in water application, second only to the micro irrigation systems (Table 5.6). The latter are not commonly used on account of their high initial cost.

**Table 5.6. On-Farm Irrigation System Efficiencies, SSRB Alberta**

| Irrigation* Technology | Standard | Good |
|---|---|---|
| Gravity-Flood | 20% | 30% |
| Gravity-Developed | 54% | 62% |
| Gravity-Controlled | 70% | 80% |
| Sprinkler-Handmove, solid set or | 65% | 70% |
| Sprinkler-pivot/linear – high pressure | 71% | 74% |
| Sprinkler-pivot/linear – low pressure | 75% | 80% |
| Sprinkler-volume gun, traveler | 63% | 66% |
| Micro | 82% | 87% |

* Each irrigation technology (center pivot, gravity etc.) has a characteristic efficiency of how much of the water supplied actually reaches the roots of the crop. This application efficiency represents different levels of on-farm system management by an irrigation system operator (Heikkila et al., 2002). Each irrigation technology also has a characteristic on-farm irrigation cost, both a capital cost and a marginal cost that varies by quantity of water supplied. Application efficiency and irrigation costs are both discussed in Heikkila et al. (2002).

Source: SSRB (2002)

## 5.6 Estimation of Marginal Value of Water

### 5.6.1 Overview of the Methodology

Given the methodology discussed above, steps were undertaken for placing a marginal value to the use of water in irrigation. This value determines the gain (or loss) in producer surplus if the water is reduced (or increased) by a small amount. In order to undertake this valuation, several steps were required, which are listed below:

Step 1: Selection of crops for valuation. This is described in Section 5.5.2.

Step 2: Selection of production function to estimate change in total production, which is discussed in Section 5.5.3.

Step 3: Calculate standard irrigation requirement (with data on precipitation and evapotranspiration). Details on this step are shown in Section 5.5.4.

Step 4: Using a water production function estimate yield of various crops associated with application of water, and the associated total revenue under standard water requirement. This step is further described in Section 5.5.5.

Step 5: Compute irrigation cost and net revenue at standard irrigation requirement. Details on this step are provided in Section 5.5.6.

Each of these steps is described below, while the results of the analysis are presented in Section 5.5.7.

### 5.6.2 Selection of Crops for Estimation of Marginal Value

Since under irrigation, producers have a choice of variety of crops, marginal valuation of irrigation water is restricted to a limited number of crops. Reasons for this choice included the following:

- Production function exhibiting the relationship between water use and productivity of crops are required for each crop.
- Change in the yield requires data on crop water requirements.
- Collection of crop specific data for various sub-basins for all crops was considered a major task, not feasible under the resources available for this study.

For the above reasons, from these crop mix data, ten crops were selected for marginal value estimation. These included: Alfalfa, Barley for grain, Barley for silage, Canola, Dry beans, Tame grass, Hard Red Spring (HRS) wheat, Soft White Spring (SWS) wheat, Potatoes, and Sugar beets. Reason for the selection of these crops was the availability of information required for estimation of marginal value of irrigation water.

### 5.6.3 Crop Yield Production Functions for Irrigation

In order to assess the change in the producer surplus associated with a small unit increase in water application, a production function showing the relationship between yield of a crop and the amount of water applied to it is required. These were obtained for southern Alberta from Heikkila et al. (2002). The equation suggested for this calculation is shown in Equation 5.1.

$$Y_a = K_{ay}.[A_0 + \{A_1.(ET_a / ET_p)\} + \{A_2.(ET_a / ET_p)^2\}].Y_m \qquad (5.1)$$

where;

$Y_a$ = actual yield from each crop under prevailing water supply conditions (kg/ha)
$Y_m$ = maximum yield attainable from each crop where no inputs are limiting (kg/ha)
$ETa$ = actual evapotranspiration
$ETp$ = potential evapotranspiration
$K_{ay}$, $A_0$, $A_1$, *and* $A_2$ are crop specific coefficients.

In order to estimate the crop yields under different levels of water application, one needs values of various parameters in Equation 5.1. The crop specific coefficients were also obtained from Heikkila et al. (2002) and are shown in Table 5.7. The aforementioned *TPP* estimation was made at the point where irrigation met the total deficit between crop water demand and precipitation.

**Table 5.7. Coefficients for Selected Crops in Alberta**

| Parameters | Alfalfa | Barley | Barley silage | Canola | Dry beans | Tame grass | HRS wheat | SWS wheat | Potato | Sugar beets |
|---|---|---|---|---|---|---|---|---|---|---|
| $K_{AY}$ & $K_{PY}$ | 1.44 | 1.18 | 1.18 | 1.22 | 1.22 | 1.2 | 1.2 | 1.2 | 1.19 | 1.19 |
| *Ao* | -0.297 | -0.299 | -0.201 | 0.021 | -0.65 | -0.334 | -0.291 | -0.291 | -0.618 | -0.501 |
| *A1* | 1.272 | 1.696 | 2.763 | 1.121 | 2.498 | 1.781 | 1.628 | 1.628 | 2.467 | 2.528 |
| *A2* | -0.313 | -0.644 | -0.244 | -0.36 | -1.038 | -0.701 | -0.557 | -0.557 | -1.014 | -1.144 |

Source: Heikkila et al. (2002)

These production functions were based on certain coefficients for crop growth and evapotranspiration for the region. No models were found for Saskatchewan. It was therefore, assumed that the southern Alberta model, adjusted to local climatic conditions, is applicable to Saskatchewan as well.

### 5.6.4 Standard Irrigation Requirement Calculation

The total moisture requirements of various crops are supplied by precipitation and supplemented by irrigation. The first step in determining the marginal value of water is to determine the moisture availability to the crops from natural conditions, and their respective requirements for optimal crop growth. This first step required collecting data on potential transpiration (*ETp*) and effective precipitation, in addition to other aspects of climate on irrigation systems. These data for various sub-basins of SSRB in Alberta were obtained from Chinn (2005) and Heikkila et al. (2002).

Variability in effective precipitation is a characteristic of both crops and sub-basins. This is because each crop has a different growing period compared with other crops. Therefore, even if they are in the same field within the same sub-basin, they would draw different quantities of water from precipitation. The average effective precipitations for individual crops by sub-basin are depicted in Table 5.8. Typically, in the various sub-basins, effective precipitation is higher for alfalfa, potatoes, and sugar beets, and lower for barley silage, barley and canola.

**Table 5.8. Mean Effective Precipitation by Crops and by Sub-basin mm/ha/growing season)**

| Sub-Basin | Alfalfa | Barley | Barley silage | Canola | Dry beans | Tame grass | HRS wheat | SWS wheat | Potato | Sugar beets |
|---|---|---|---|---|---|---|---|---|---|---|
| SSRB-AB* | 232 | 147 | 134 | 155 | 144 | 232 | 155 | 155 | 211 | 184 |
| Red Deer | 250 | 164 | 143 | 175 | 173 | 250 | 175 | 175 | 230 | 209 |
| Oldman | 271 | 173 | 159 | 182 | 169 | 182 | 182 | 182 | 251 | 214 |
| Bow | 259 | 168 | 149 | 178 | 165 | 259 | 178 | 178 | 237 | 206 |
| SSRB-SK** | 378 | 204 | 191 | 204 | 207 | 232 | 205 | 210 | 211 | N.A. |

* Mean effective precipitation values are from 1928 to 1995 and in case of Alfalfa in the Bow basin from 1928 to 2003. Credits for the data are attributed to the Gridded Prairie Climate Database developed initially by Agriculture and Agri-Food Canada and Environment Canada.

** Separate precipitation values for SSRB-SK were not available; hence average values for the entire SSRB were used.

Source: Chinn (2005).

To calculate crop yield using Equation 1, one needs to know, in addition to effective precipitation, potential evapotranspiration (*ETp*), and actual evapotranspiration (*ETa)* for various crops within a sub-basin. The potential evapotranspiration is used in reference to a particular location, and varies from sub-basin to sub-basin (AAFRD, 2002). The product of *ETp* and a crop specific coefficient helps arrive at crop evapotranspiration (*ETc*). However, *ETc* assumes that the crop grows under no water constraints and when the slightest water constraint is evident, the physiology of the crop (such as closing of stomata) reduces the evapotranspiration. This reduced evapotranspiration actually experienced in the field is called *ETa.* The product of *ETc* and a crop scaling factor produce *ETa* and the aforementioned crop production or yield function relates yield to *ETa* (AAFRD, 2002). Hence, the water required by precipitation and irrigation (in case of irrigated crops) would have to meet *ETa.* The *ETp* and *ETa* values are summarized by crops for Alberta sub-basin in Table 5.9.

Table 5.9. **Model Values of *ETa* and *ETp* (mm/ha/growing season) by Crop and Sub-Basin**

| Particulars | Alfalfa | Barley | Barley silage | Canola | Dry beans | Tame grass | HRS* wheat | SWS** wheat | Potatoes | Sugar beets |
|---|---|---|---|---|---|---|---|---|---|---|
| **Bow River Basin** | | | | | | | | | | |
| *ETp* | 896 | 591 | 518 | 635 | 601 | 896 | 635 | 635 | 837 | 721 |
| *ETa* | 573 | 344 | 319 | 369 | 297 | 296 | 404 | 404 | 520 | 484 |
| **Oldman River Basin** | | | | | | | | | | |
| *ETp* | 881 | 578 | 505 | 622 | 591 | 880 | 622 | 622 | 821 | 710 |
| *ETa* | 563 | 338 | 312 | 362 | 294 | 290 | 398 | 398 | 513 | 479 |
| **Red Deer River Basin** | | | | | | | | | | |
| *ETp* | 880 | 584 | 513 | 628 | 594 | 880 | 628 | 628 | 824 | 711 |
| *ETa* | 565 | 341 | 316 | 365 | 293 | 291 | 400 | 400 | 513 | 476 |
| **SSRB (Alberta Basin)*** ** | | | | | | | | | | |
| ETp | 904 | 596 | 521 | 641 | 610 | 904 | 641 | 641 | 845 | 731 |
| ETa | 579 | 349 | 323 | 374 | 303 | 299 | 411 | 411 | 528 | 492 |
| **SSRB (Saskatchewan Basin)#** | | | | | | | | | | |
| ETp | 906 | 644 | 570 | 690 | 641 | 973 | 690 | 690 | 912 | N.A. |
| ETa | 617 | 369 | 344 | 394 | 312 | 320 | 432 | 432 | 558 | N.A. |

* Hard Red Spring;

** Soft White Spring

*** ET values are from 1928 to 1995 and in case of Alfalfa in the Bow basin from 1928 to 2003. These data are credited to the Gridded Prairie Climate Database developed initially by Agriculture and Agri-Food Canada and Environment Canada. These values are reported even in situation where these crops are not grown.

# Separate ET values for SSRB-SK were not available, hence average values for the entire SSRB were used.

Source: Chinn (2005)

### 5.6.5 Total Yield under Standard Water Requirements and Total Revenue Calculation

The value of coefficients in Table 5.7 were applied to obtain total yield (or TPP), which was a starting point for the estimation of gross revenues from irrigated production. To complete this calculation, average price for these products is required. In this study these prices were average 10-year nominal crop prices. These data were obtained from SAFRR (2005) and AAFRD (2003 b). Where the aforementioned sources could not provide commodity prices, crop price indices from Statistics Canada were used to adjust real crop prices reported by Heikkila et al. (2002). Total physical product from irrigation at standard crop requirement levels are shown in Table 5.10.

### 5.6.6 Marginal Irrigation Cost and Net Revenue at Standard Irrigation Requirement

The marginal value product, as described above, is net of any additional cost incurred in connection with application of water. Conceptually, these costs may include labor, repair and maintenance and energy costs. According to Heikkila et al. (2002), these costs differ only by irrigation technology, and not necessarily by crops grown. These costs have been estimated for various irrigation technologies by Heikkila et al. (2002). The differential costs with each additional unit of water include labor, repair and maintenance and energy costs. These remain constant for the entire range of water application. These costs are shown in Table 5.11.

**Table 5.10. Total Physical Product (Crop Yields) in Kg/Ha under Standard Irrigation Requirements**

| Sub-Basin | Alfalfa | Barley | Barley silage | Canola | Dry beans | Tame grass | HRS wheat | SWS wheat | Potato | Sugar beet |
|---|---|---|---|---|---|---|---|---|---|---|
| Bow | 13,081 | 5,447 | 25,163 | 2,959 | 2,301 | 4,253 | 3,719 | 5,379 | 34,430 | 57,935 |
| Oldman | 12,829 | 5,321 | 24,540 | 2,924 | 2,285 | 4,202 | 3,649 | 5,278 | 34,122 | 57,509 |
| Red Deer | 12,876 | 5,382 | 24,879 | 2,936 | 2,252 | 4,243 | 3,673 | 5,313 | 34,057 | 57,127 |
| SSRB-AB | 13,210 | 5,528 | 25,494 | 2,991 | 2,385 | 4,276 | 3,781 | 5,470 | 34,996 | 58,854 |
| SSRB-SK | 14,421 | 5,878 | 27,327 | 3,101 | 2,463 | 4,382 | 3,987 | 5,767 | 36,020 | -- |

-- Not applicable

**Table 5.11. Marginal Cost of Irrigation by System**

| System | Labor Cost ($/mm/ha) | Repair and maintenance ($/mm/ha) | Energy Cost ($/mm/ha) |
|---|---|---|---|
| Gravity-Flood | 0.101 | 0.0065 | 0.000 |
| Gravity-Developed | 0.079 | 0.0200 | 0.000 |
| Gravity-Controlled | 0.045 | 0.0490 | 0.037 |
| Sprinkler-Hand-move, Solid set or Wheel move | 0.067 | 0.0570 | 0.195 |
| Sprinkler-Pivot-High pressure | 0.022 | 0.1090 | 0.220 |
| Sprinkler-Pivot-Low pressure | 0.022 | 0.1110 | 0.160 |
| Sprinkler-volume gun, traveler | 0.045 | 0.0840 | 0.350 |
| Micro | 0.027 | 0.1850 | 0.067 |

Source: Heikkila et al. (2002).

### 5.6.7 Estimation of Marginal Value

In order to assess the marginal value of water for various crops in a sub-basin of the SSRB, water availability was reduced and its consequences for the irrigation farmer estimated. This was accomplished by assuming that water available for irrigation is reduced by one hectare-inch (or 254 $m^3$). Various crop water production functions were used under these reduced water applications to estimate net revenue. Value of lost production was compensated by a reduction in costs to yield net revenue loss to producer from the decreased amount of water. The change in net revenue was divided by the reduction in irrigation water application (254 $m^3$). This was subsequently converted into value of water per $dam^3$. Estimated values for various crops and sub-basins are shown in Table 5.12.

Table 5.12. **Marginal Value Product by Crop and Sub-Basin ($/dam$^3$)**

| Sub-Basin | Alfalfa | Barley | Barley silage | Canola | Dry beans | Tame grass | HRS wheat | SWS wheat | Potato | Sugar beet |
|---|---|---|---|---|---|---|---|---|---|---|
| Bow | 196 | 128 | 111 | 112 | 644 | 160 | 93 | 147 | 1,114 | 282 |
| Oldman | 189 | 131 | 114 | 116 | 658 | 169 | 94 | 151 | 1,153 | 290 |
| Red Deer | 185 | 129 | 113 | 114 | 656 | 165 | 94 | 149 | 1,141 | 290 |
| SSRB-AB | 185 | 129 | 113 | 113 | 662 | 163 | 94 | 149 | 1,133 | 286 |
| SSRB-SK | 141 | 181 | 118 | 140 | 661 | 159 | 96 | 151 | 1,094 | N.A. |

Generally speaking, marginal value of water for specialty crops, such as potatoes, dry beans, and sugar beets, was higher than that for other more traditional crops. Forages such as alfalfa had a relatively higher marginal value than say hard red spring wheat, but still lower than that for the specialty crops. One must note that these values are only for production of the forage. Since reduced forage production may have implications for livestock production, these values may be underestimated.

Three striking features of these estimates are:

(1) Marginal values of water in various sub-basins are fairly close. This is to be expected since all changes in TPP are based on the same model, and irrigation practices are fairly uniform across sub-basins. In addition, climatic features of the sub-basins are not that distinct from each other.

(2) The Marginal Value Product (MVP) of water (equivalent to marginal value of water) varies significantly across crops. Cash crops, such as potatoes, and sugar beets score the higher MVP of water. For these crops, irrigation is highly desirable from an economic point of view. This is not to be interpreted to be suggesting that for these crops irrigation is a virtual necessity, since potatoes can be grown under dryland conditions.

(3) One would note that these values of water are relatively high. This is because they were estimated under the assumption that other costs, other than water application costs, do not change. Thus, these reflect the cost to producers if the water application rate is reduced on account of water shortages, and no other production related adaptation is undertaken. Again the caution is advised since this a short-run situation and the producers do not have options to make adjustments.

In order to represent short-run costs of water shortages, one needs compare the entire range of water production. This entailed reducing water application to the point that there was no irrigation provided to that crop. Crops were then arranged by the relative level of marginal value of water. Total water use was estimated by multiplying each crop by their respective area. A plot of amount of water used and its marginal value was developed is shown in Figures 5.3. to 5.7. for each of the five sub-basins.

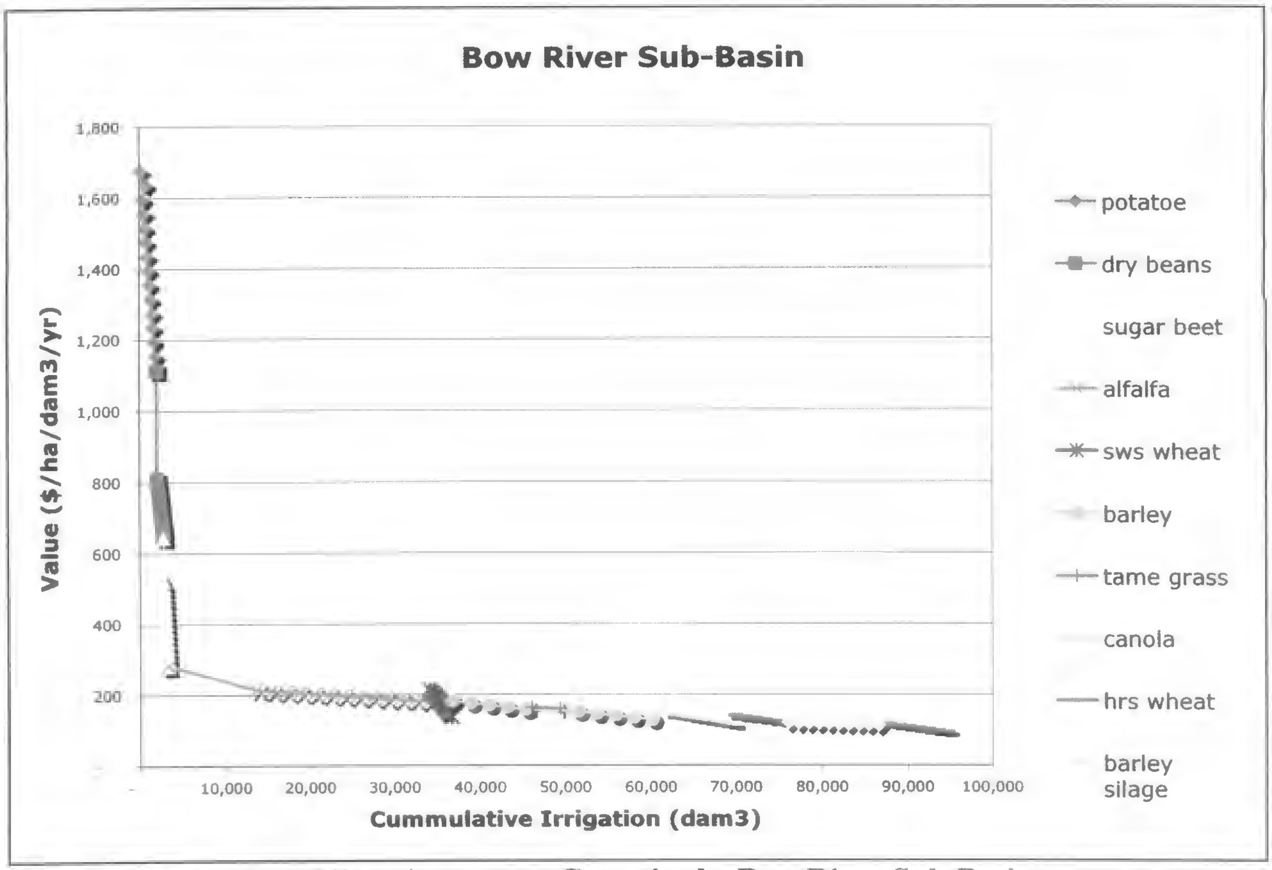



**Figure 5.3. Water Allocation among Crops in the Bow River Sub-Basin**

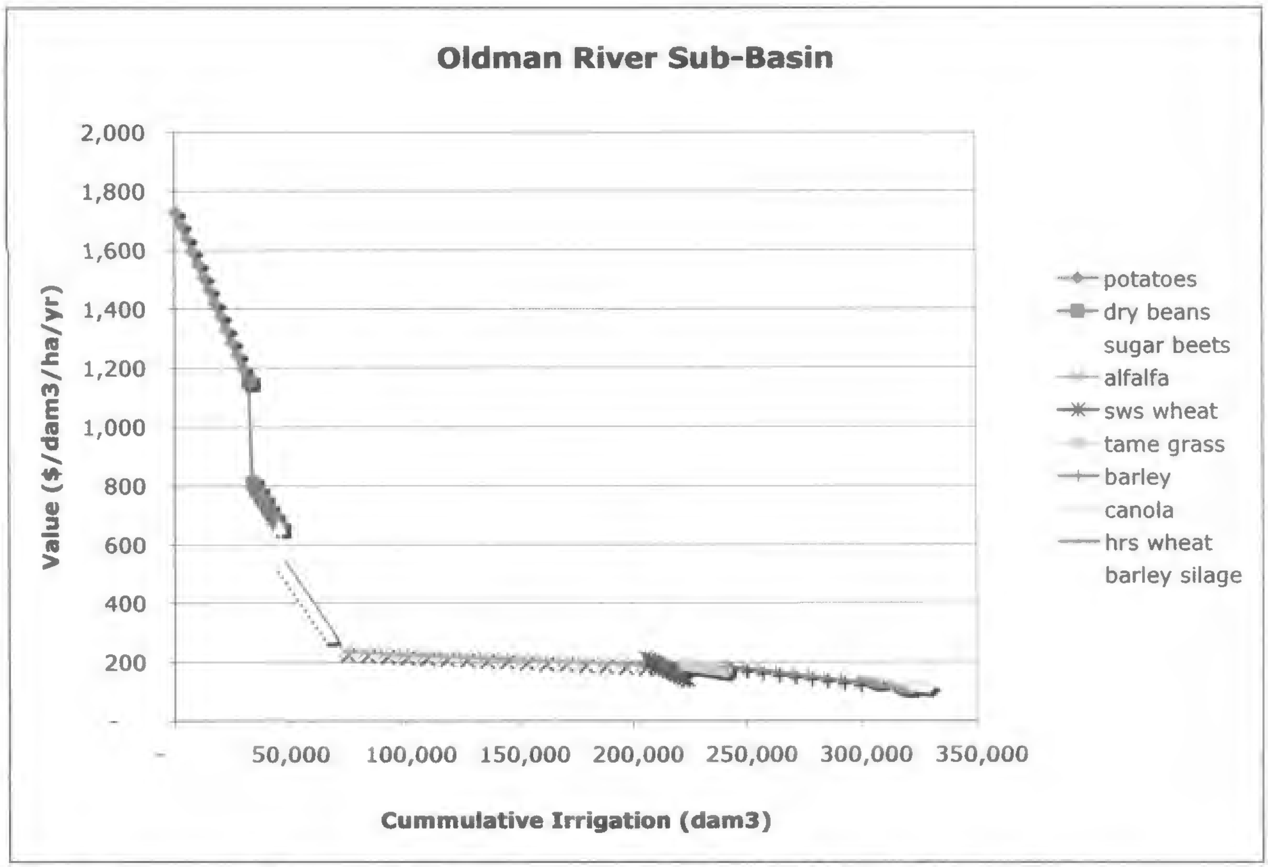



**Figure 5.4. Water Allocation among Crops in the Oldman River Sub-Basin**

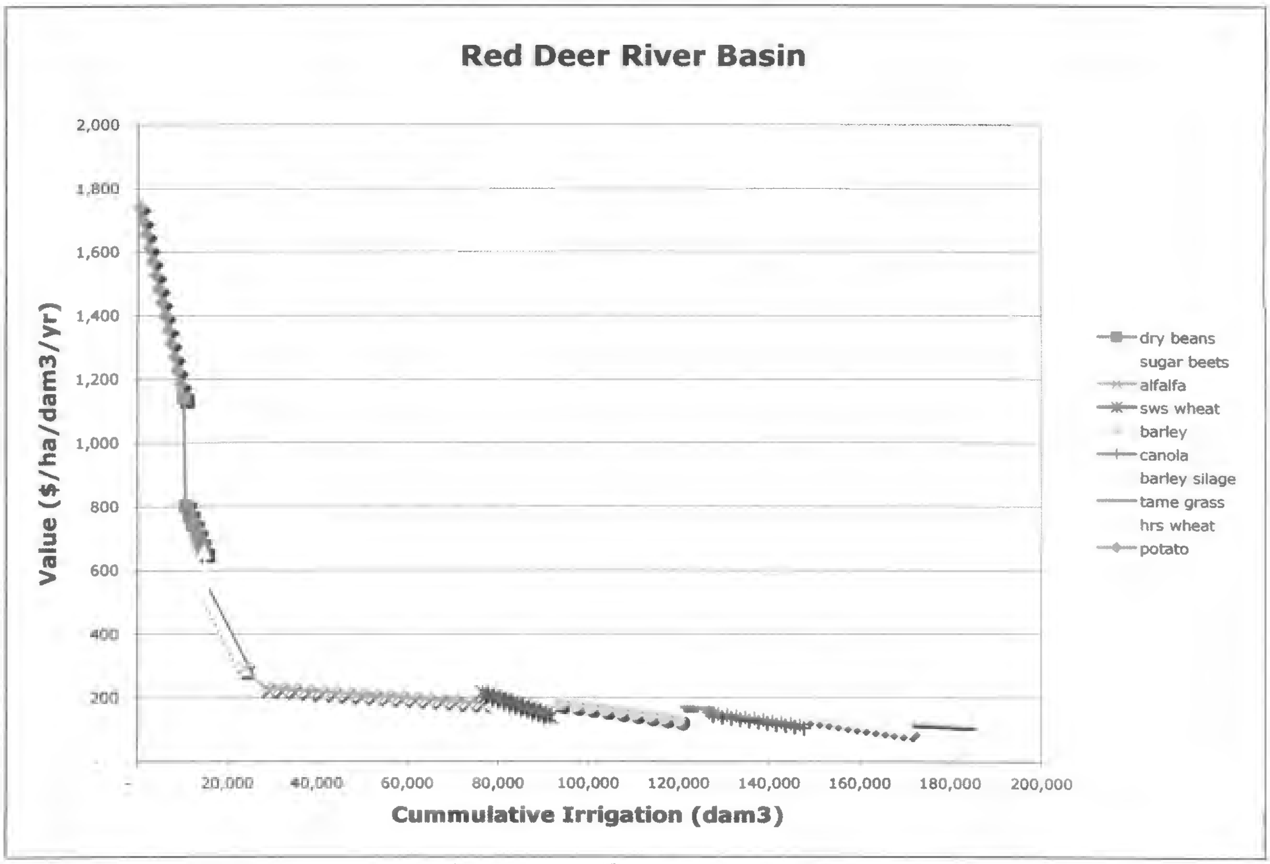



Figure 5.5. Water Allocation among Crops in the Red Deer Basin

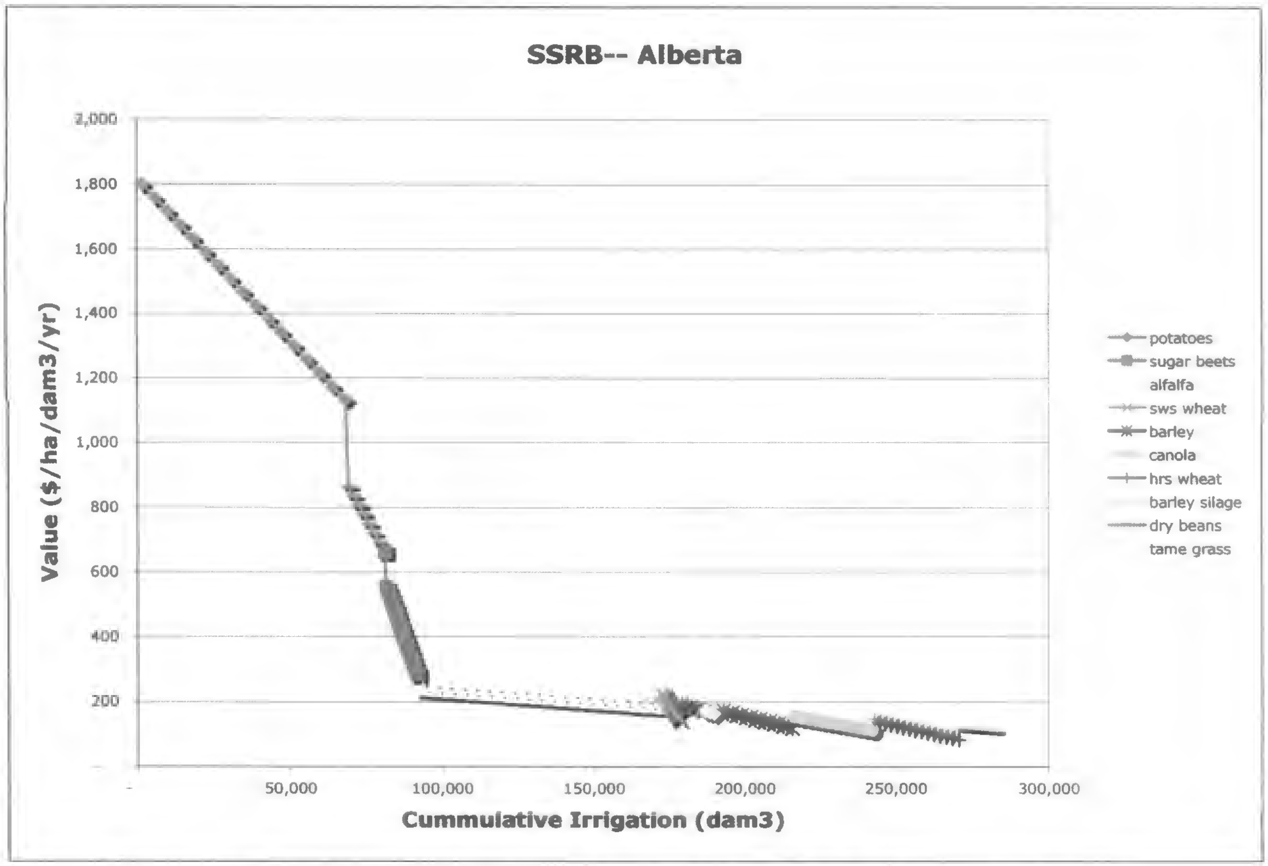



**Figure 5.6. Water Allocation among Crops in the SSRB-Alberta Sub-Basin**

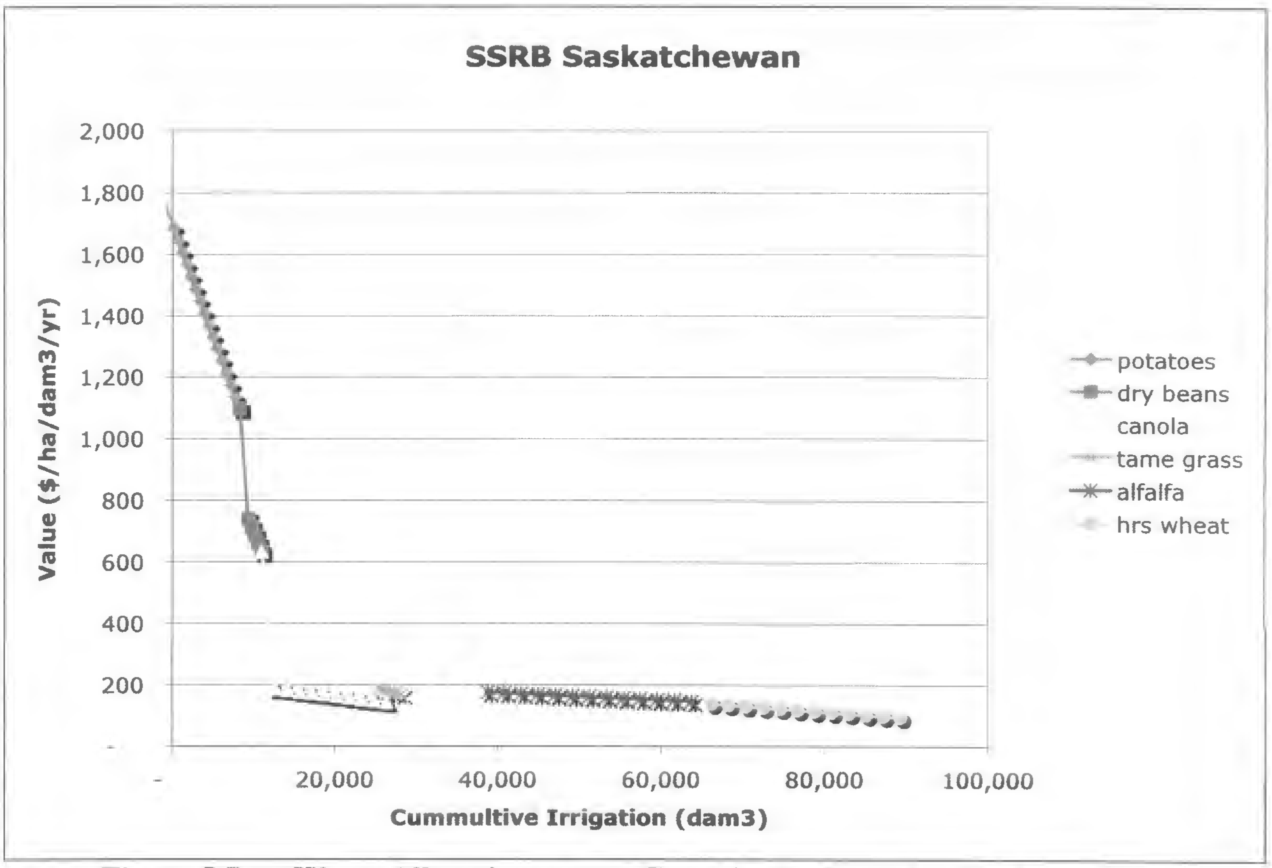



**Figure 5.7. Water Allocation among Crops in the SSRB-Saskatchewan Sub-Basin**

In most cases, marginal value product for each crop was separable, except that in some cases a small degree of overlap did exist. For example, the overlap between barley and tame grass in the Oldman river sub-basin shows that it would be efficient to first allocate water for barley up until cumulative irrigation reaches 45,500 dam$^3$ and then allocate water to tame grass up until 49,000 dam$^3$ before re-allocating water for the rest of barley. In the Saskatchewan sub-basin of the SSRB there was no data on cultivated extent for sugar beets, SWS wheat, or barley.

A perusal of these five figures indicates a fair amount of similarities in all regions. Assuming rationality on the part of producers, it appears that under water shortages, hard wheat and alfalfa would be the crops not preferred for irrigation. However, this reasoning will have to be altered if rotational and disease considerations dictate their inclusion in the irrigation priority scheme. The sharp drop in all five basins is reflective of relative proportion of specialty crops (potatoes, sugar beets, and dry beans) grown in that sub-basin. In all five sub-basins, marginal value of water becomes lower than $200 fairly early, and the values stay fairly flat from that point onwards. Much of the shortage would then impact the crops with lower marginal value. It should be noted that these values are in the crop production only, and do not consider any forward linkages of these crops (particularly those of forages through cattle production). Also linkages with non-farm sectors are also not included in these values.

It should be noted that the above valuation utilized data for the LDDA in Saskatchewan. Information on water production function for the SWDA was very poor, and, therefore, not included.

## 5.7 Average Value of Water

As discussed previously, the two values of significance in the context of water allocation among competing crops are marginal and average valuation. The first type of value may be useful in the decisions of producers of allocating water among various crops, as well those made by water management agencies in terms of estimating the economic cost of reduced supply in the very short run. However, these values do not reflect whether irrigation should be developed in the long run. This requires the gain in social well-being from using irrigation water and converting dryland production of crop to irrigated production. This requires knowledge of average value of irrigation water in the short-run and in the long-run. These estimates are provided in this section.

### 5.7.1 Methodology

The method of estimation for estimating the average value of water in this study was based on a change in the producer surplus under dryland and irrigated crop production systems. Much of this analysis is based on secondary data. Although collection of primary data on production budgets under the two systems would have been preferable, such was not possible on account of resource constraints. However, in order to maintain comparability between the two systems, data were collected on similar landscape with similar bio-physical characteristics.

The data needed for this assessment included the following for each of the two systems of production: Crop mix, crop budget, and water requirements for various crops. For Saskatchewan, dryland and irrigated crop budgets were obtained from Saskatchewan Agriculture and Agri-Food and Rural Revitalization (SAFRR, 2004) and Irrigation and Crop Diversification Corporation (ICDC, 2004b). For Alberta, these data for the four sub-basins were obtained from AAFRD (2003a) and AAFRD (2003b).

Short-run Average Value

Short-run average value of water in various sub-basins of the SSRB was computed as the change in producer surplus per unit of water between dryland and irrigated systems. This was calculated as the difference between weighted producer surpluses per hectare in the short-run dryland production system from those under irrigated production. This difference was then divided by the amount of water typically used for irrigation, to obtain average value per unit of irrigation water. All major crops were included in this analysis. Area under that crop was used as the weight for this calculation.

The short-run net returns were estimated as the difference between returns from a crop and short-run production costs. The production costs included for this calculation were:

- Seed treatment and cleaning costs,
- Fertilizer cost,
- Chemicals cost,
- Machinery operating (fuel and repair) costs,
- Custom work and hired labor costs,
- Crop insurance premium,
- Interest on operating capital (at 5.3% in Saskatchewan and 5.5% in Alberta), and
- Variable overhead costs (taxes, utilities, building repairs and insurance, auto expenses, legal and accounting fees).

Producer surplus under any of the tow production systems was equated to the net returns to producers (in the short-run). This was estimated as the difference between gross returns and short-run cost of production. The former was estimated using the average yield for various crops and their respective price per unit. Crop prices used were the same as those used for calculating marginal value of water.

Weighted net return under dryland or irrigated production systems were estimated using the sub-basin specific crop mix. However, for Saskatchewan an additional consideration was important. Water from the South Saskatchewan in the SSRB is used for two types of irrigation. As shown in Table 5.2, 13% of the total irrigated area in the SSRB-Saskatchewan area in the SWDA while the remaining 87% is used for irrigation in the LDDA portion of the SSRB. Irrigation water delivery systems and crop mixes in the two sub-regions of Saskatchewan are distinctly different. In the LDDA, almost all irrigation areas are organized under Irrigation Districts. In contrast, in the SWDA, much of the irrigation is organized as Water Users Districts, where much of irrigation activity is confined to small-plot irrigation. In the SWDA, much of the irrigation is for forages to support the need of cattle herds in the region. The costs of production in the two sub-regions are also very different, partly because of irrigation water delivery system, and partly due to other physical features of the region. For these reasons, analysis for Saskatchewan portion of the SSRB was divided into two parts; one, for the LDDA, and the other for the SWDA. In the final valuation, these two regions were combined together.

The crop budgets for irrigated and dryland production systems in Alberta were for the Dark Brown soils. Information on the crop mix under the dryland production system was obtained from Statistics Canada (2005). For the LDDA, this information was for the Census Agricultural District (CAR) 6A, whereas for the SWDA, it was for the CAR 3BN. Costs of production budgets for Alberta were obtained from AAFRD (2004), whereas those for the LDDA from ICDC (2004b). Similar budgets for the SWDA were obtained from Prairie Farm Rehabilitation Administration[8]. Crop mixes under irrigated

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[8] Personal communications with Mr. Mark Pederson, PFRA, March 2004.

production system for Alberta were obtained from AAFRD (2004). For Saskatchewan these were obtained from Kulshreshtha, Sobool and Grant (2005).

Long-run Average Value

Basic methodology for the estimation of long-run value of water in the SSRB was the same as followed for the short-run valuation. The only difference was that in estimating the producer surplus, long-run costs associated with the two production systems were used. The long run net returns involved, in addition to the aforementioned short-run costs, those associated with fixed investment, this included machinery and building depreciation (at 10 % for Saskatchewan), opportunity cost of investment in them (at the going rate of interest) and in the case of irrigated production systems, the investment cost of irrigation equipment. Thus, the net return reflects returns to land, owner/operator management and labor.

### 5.7.2 Data Requirements for the Estimation of Average Value of Irrigation Water

Producers under irrigation have a different choice of crops. It is generally believed that through such choices, irrigation brings diversification and stability to the region. These crop mixes that are presented in Table 5.13. describe the irrigated crop mix in various sub-basins of Alberta SSRB. A comparable dryland crop mix for the same regions is shown in Table 5.14. The former was derived from AAFRD (2003 b) but excluded some minor crops with less than a cumulative area of 1000 ha. The latter was derived first by cumulating the entire cropping extents for the Census Agricultural Regions 1, 2, 3, and 5 for Alberta, and then by subtracting the irrigated cropped area. Overall, it shows that irrigated cropping areas include a greater proportion of cash crops, such as potatoes and sugar beet and the dryland areas include a relatively larger area of cereals and summerfallow.

The irrigated cropped area for the SWDA and LDDA were obtained from Kulshreshtha, Sobool and Grant (2005). For the dryland crop mix in the SWDA, the same crop proportions were assumed. This is under the assumption that dryland and irrigated rotations are very similar in nature. The relative distribution of the irrigated cropland for the LDDA is found in Table 5.15., while the corresponding dryland crop mixes for the region in Table 5.16. Table 5.17. lists the crops in the SWDA and the percentage of total irrigation used for each crop.

The next step in calculating the short run and long run average value of water was estimation of net returns (both short-run and long-run) from crops grown under dryland and irrigation production systems. As noted above, these estimates were based on availability of crop budgets under the two production systems. For some minor crops, such returns could not be estimated and, therefore, were not included in the analysis. Furthermore, for various sub-basins of Alberta portion of the SSRB, budgets were available at the provincial level. Thus, it was assumed that cost of production of a crop did not vary across sub-basins in Alberta.

**Table 5.13. Irrigated Cropped Area in SSRB Sub-Basins of Alberta (ha), in 2001**

| Crops | Oldman | Bow | Red Deer | SSRB Alta. | Total Alberta SSRB |
|---|---|---|---|---|---|
| Alfalfa Hay | 35,783 | 20,718 | 29,311 | 17,069 | 102,881 |
| Alfalfa Silage | 2,955 | 959 | 1,263 | 130 | 5,307 |
| Timothy | 9,763 | 1,341 | 3,233 | 3,754 | 18,091 |
| Triticale Silage | 2,330 | 402 | 747 | 1,255 | 4,733 |
| Barley | 28,497 | 8,656 | 13,106 | 12,391 | 62,650 |
| Barley Silage | 21,287 | 4,663 | 5,450 | 5,101 | 36,501 |
| Corn Silage | 9,672 | 867 | 2,022 | 1,970 | 14,532 |
| Grass Hay | 6,697 | 2,122 | 2,660 | 1,812 | 13,291 |
| Green Feed | 2,041 | 2,241 | 2,880 | 501 | 7,664 |
| Native Pasture | 2,130 | 142 | 187 | 617 | 3,077 |
| Canola | 15,150 | 3,584 | 8,012 | 9,311 | 36,057 |
| Flax | 1,210 | 327 | 909 | 811 | 3,256 |
| Fresh Peas | 1,429 | 30 | 315 | 480 | 2,254 |
| Dry Beans | 9,209 | 479 | 3,260 | 6,775 | 19,723 |
| Tame Grass | 13,935 | 13,273 | 18,095 | 6,236 | 51,540 |
| HRS Wheat | 13,833 | 4,645 | 8,241 | 8,028 | 34,748 |
| CPS Wheat | 1,248 | 2,838 | 3,276 | 1,163 | 8,525 |
| SWS Wheat | 6,912 | 733 | 5,169 | 1,721 | 14,535 |
| Durum | 12,781 | 355 | 3,387 | 10,173 | 26,696 |
| Winter Wheat | 914 | 125 | 291 | 806 | 2,136 |
| Potatoes | 9,815 | 540 | 2,900 | 4,633 | 17,888 |
| Sugar Beets | 6,541 | 157 | 2,670 | 2,294 | 11,662 |
| Oats | 1,052 | 988 | 1,397 | 285 | 3,722 |
| Summerfallow | 307 | 829 | 1,007 | 271 | 2,414 |
| Total | 215,491 | 71,014 | 119,790 | 97,588 | 503,883 |

Source: AAFRD (2003 b)

**Table 5.14. Dryland Cropped Area for SSRB Sub-Basins, (Alberta, 2001)**

| Crops | Dryland Cropped Area (ha) | Percent of Total |
|---|---|---|
| Spring wheat (excluding durum) | 1,169,291 | 22.10% |
| Durum wheat | 349,715 | 6.60% |
| Winter wheat | 25,801 | 0.50% |
| Oats | 191,534 | 3.60% |
| Barley | 1,151,254 | 21.70% |
| Mixed grains | 84,260 | 1.60% |
| Corn for grain | 1,244 | 0.02% |
| Total rye | 28,964 | 0.50% |
| Alfalfa and alfalfa mixtures | 616,190 | 11.60% |
| All other tame hay | 291,602 | 5.50% |
| Canola (rapeseed) | 277,603 | 5.20% |
| Flaxseed | 3,232 | 0.06% |
| Mustard seed | 22,848 | 0.40% |
| Sunflowers | 550 | 0.01% |
| Dry field peas | 104,093 | 2.00% |
| Lentils | 7,063 | 0.10% |
| Total dry field beans | 40,090 | 0.80% |
| Dry white beans | 6,227 | 0.10% |
| Chick peas | 37,096 | 0.70% |
| Other dry beans | 15,486 | 0.30% |
| Canary seed | 1,162 | 0.02% |
| Sugar beets | 12,029 | 0.20% |
| Triticale | 15,608 | 0.30% |
| Potatoes | 4,940 | 0.10% |
| Other field crops | 3,076 | 0.06% |
| Summerfallow | 834,805 | 15.80% |
| Total | 5,295,763 | 100.00% |

Source: Original data from Statistics Canada (2005)

**Table 5.15. Irrigated Crop Cropped Area, LDDA Saskatchewan, 2004**

| Crops | Irrigated (ha) | Percent of Total |
|---|---|---|
| Spring wheat | 3,995 | 11.9% |
| Durum | 897 | 2.7% |
| Barley/Oats | 3,752 | 11.1% |
| Canola | 5,762 | 17.1% |
| Peas | 423 | 1.3% |
| Lentils | 227 | 0.7% |
| Beans | 1,184 | 3.5% |
| Silage crops | 2,512 | 7.5% |
| Potatoes | 3,739 | 11.1% |
| Alfalfa mix. | 9,883 | 29.4% |
| Tame Pasture | 1,287 | 3.8% |
| TOTAL | 33,661 | 100.0% |

Source: Linsley (2005 b)

**Table 5.16. Dryland Crop Cropped Area for LDDA, Saskatchewan, 2000**

| Crops | Total Cropped Area (ha) | Percent of Total |
|---|---|---|
| Spring wheat | 497,876 | 21.7% |
| Durum wheat | 279,234 | 12.2% |
| Winter wheat | 3,609 | 0.2% |
| Oats | 54,327 | 2.4% |
| Barley | 183,939 | 8.0% |
| Mixed grains | 6,009 | 0.3% |
| Total rye | 6,127 | 0.3% |
| Alfalfa mix. | 125,010 | 5.5% |
| Hay/fodder | 36,882 | 1.6% |
| Canola | 133,681 | 5.8% |
| Flaxseed | 14,643 | 0.6% |
| Mustard seed | 15,419 | 0.7% |
| Potatoes | 2,552 | 0.1% |
| Dry field peas | 137,442 | 6.0% |
| Lentils | 171,035 | 7.5% |
| Total dry field beans | 96,908 | 4.2% |
| Chick peas | 95,893 | 4.2% |
| Canary seed | 16,116 | 0.7% |
| Forage seed for seed | 3,636 | 0.2% |
| Other field crops | 4,367 | 0.2% |
| Summerfallow | 408,129 | 17.8% |
| Total | 2,292,834 | 100.0% |

Note: Data for CAR 6A.

Source: Statistics Canada (2005).

**Table 5.17. Cropping Area for the SWDA*, Saskatchewan**

| Crops | Percent of the Total Irrigated Area in the SWDA Region |
|---|---|
| Wheat | 3.00% |
| Durum | 4.00% |
| Oats/barley | 6.00% |
| Canola | 2.00% |
| Lentils | 2.00% |
| Hay (Alfalfa) | 82.40% |
| Total | 100.00% |

* It should be noted that this information is for entire SWDA and not just for the water user districts within the SSRB.

Source: Kulshreshtha and Russell (1995)

### 5.7.3 Estimated Net Returns from Irrigation by Crops

Short-run and long-run net returns from irrigated and dryland production systems were estimated using 10-year average prices. Results for Alberta are shown in Tables 5.18. and 5.19. respectively for irrigation and dryland crop production. Under irrigation, the crop that provides the highest level of net return, both in the short-run and long-run is alfalfa silage, used primarily for dairy cattle. Potatoes were the next profitable crop, followed by peas, lentils, and certain cereals. Some crops, such as green feed, did not generate a positive net return. However, these may be seeded for rotational requirement as cover crops during the initial establishment period for the alfalfa rotation.

Results for Saskatchewan LDDA irrigation and dryland net returns are shown in Tables 5.20 and 5.21, respectively.

Under the dryland production systems, most crops showed positive net returns. Crops that fared better included forage crops, lentils, and specialty crops, such as chick peas, canary seed, among others. However, in the long-run, many crops showed a negative net return. Exceptions to this were durum wheat, winter wheat, alfalfa and other forages, lentils and specialty crops.

### 5.7.4 Estimated Average Value of Irrigation Water by Sub-Basins

<u>Alberta Sub-Basins</u>

Average value of water was estimated as the ratio of weighted average net additional return from irrigation (over and above dryland production) and the amount of water used for irrigation. Since water use by crops is not available, and could vary from year to year, only sub-basin level estimates of average values could be made. The weighted average net return was estimated both for irrigation and dryland production systems first. The net return was estimated both for irrigation and dryland production systems first. The weights chosen for this calculation were the relative area under various crops, as shown in the earlier sections. Table 5.22 shows the weighted irrigated short-run and long-run net returns for the four Alberta sub-basins of SSRB. These net returns were very similar in magnitude, caused in part by the assumption that cost of production in various sub-basins was identical. Differences were only present due to crop mix. The short-run net returns varied from $340 per ha in the Bow River basin to $398 per ha in the Oldman River basin.

**Table 5.18. Irrigated Net Returns in the Southern Alberta, by Crops**

| Crops | Short-run Returns($/ha) | Long-run Returns ($/ha) |
|---|---|---|
| Alfalfa Hay | $334.26 | $136.49 |
| Alfalfa (Two cuts) | $613.90 | $445.40 |
| Alfalfa (3 cuts) | $711.86 | $543.36 |
| Alfalfa or Triticale Silage | $3,076.26 | $2,915.56 |
| Timothy | $376.16 | $115.45 |
| Barley | $95.11 | $-71.46 |
| Barley Silage | $304.54 | $151.57 |
| Corn Silage | $723.22 | $536.88 |
| Grass Hay | $334.26 | $136.49 |
| Green Feed | -$32.74 | -$145.57 |
| Native Pasture | $90.67 | -$77.83 |
| Canola | $212.97 | $27.02 |
| Flax | $350.37 | $237.05 |
| Fresh Peas | $256.88 | $131.38 |
| Dry Beans | $175.46 | -$85.01 |
| Tame Grass | $90.67 | -$77.83 |
| HRS Wheat | $196.35 | -$12.59 |
| CPS Wheat | $383.90 | $271.07 |
| SWS Wheat | $340.69 | $131.75 |
| Durum | $388.02 | $179.08 |
| Potatoes | $1,765.70 | $884.56 |
| Sugar Beets | $66.28 | -$229.85 |
| Oats | $71.52 | $70.46 |
| Summerfallow | -$67.88 | -$95.84 |

**Table 5.19. Weighted Dryland Net Returns for the Alberta Portion of the SSRB**

| Crops | Short-run** Return ($/ha) | Long-run** Return ($/ha) |
|---|---|---|
| Spring wheat (excluding | $73.29 | $9.07 |
| Durum wheat | $174.06 | $109.84 |
| Winter wheat | $79.75 | $15.53 |
| Oats | $13.20 | -$26.53 |
| Barley | $37.93 | -$26.29 |
| Alfalfa and alfalfa | $163.24 | $133.50 |
| All other tame hay and | $217.11 | $152.89 |
| Canola (rapeseed) | $46.84 | -$17.38 |
| Flaxseed | $136.90 | $76.75 |
| Mustard seed | $80.72 | $23.74 |
| Sunflower | $216.53 | $144.20 |
| Dry field peas | $97.07 | $32.85 |
| Lentils | $154.42 | $90.20 |
| Chick peas | $109.56 | $39.78 |
| Canary seed | $126.65 | $66.50 |
| Summerfallow | -$67.88 | -$95.84 |
| Weighted Net Return* | $65.48 | $12.31 |

* Weighted net return is estimated by weighting each crop by the respective proportion of total cropped area.

**Table 5.20. Weighted Irrigated Net Returns for the LDDA, Saskatchewan**

| Crops | Percent of Total Irrigated Area | Short Run Return ($/ha) | Long Run Return ($/ha) |
|---|---|---|---|
| Spring wheat | 11.9% | $216.24 | $103.41 |
| Durum | 2.7% | $355.51 | $242.68 |
| Barley/Oats | 11.1% | $71.52 | $70.46 |
| Canola | 17.1% | $532.11 | $418.76 |
| Peas | 1.3% | $256.88 | $131.38 |
| Lentils | 0.7% | $247.84 | $122.34 |
| Beans | 3.5% | $728.12 | $577.52 |
| Silage crops | 7.5% | $515.70 | $346.05 |
| Potatoes | 11.1% | $2,708.31 | $1,827.16 |
| Alfalfa mix. | 29.4% | $552.87 | $397.35 |
| Tame Pasture | 3.8% | $90.67 | -$77.83 |
| Weighted Net Returns | 100% | 669.81 | 463.54 |

**Table 5.21. Weighted Dryland Net Returns for the LDDA, Saskatchewan**

| Crops | Area* in Ha. | Short-run** Dryland Return ($/ha) | Long-run** Dryland Return ($/ha) |
|---|---|---|---|
| Spring wheat | 497,876 | $57.30 | $-2.84 |
| Durum wheat | 279,234 | $102.17 | $33.33 |
| Winter wheat | 3,609 | $183.07 | $105.86 |
| Oats | 54,327 | $13.20 | $-26.53 |
| Barley | 183,939 | $168.66 | $108.51 |
| Alfalfa mix. | 125,010 | $81.01 | $71.27 |
| hay/fodder | 36,882 | $217.11 | $152.89 |
| Canola | 133,681 | $118.76 | $58.61 |
| Flaxseed | 14,643 | $136.90 | $76.75 |
| Mustard seed | 15,419 | $80.72 | $23.74 |
| Sunflowers | 706 | $216.53 | $144.20 |
| Potatoes | 2,552 | $1,674.23 | $805.20 |
| Dry Field peas | 137,442 | $97.07 | $32.85 |
| Lentils | 171,035 | $201.04 | $27.67 |
| Chick peas | 95,893 | $109.56 | $39.78 |
| Canary seed | 16,116 | $125.78 | $56.94 |
| Caraway seed | 168 | $-37.71 | $-178.01 |
| Summerfallow | 408,129 | $-67.88 | $-95.84 |
| Total | 2,177,661 | – | – |
| Weighted Return | | $67.05 | $17.51 |

* The total cropped area here is needed for weighting and so only includes the cropped areas of those crops for which net return budgets are available.

** Values of net returns were rounded to the nearest integer

**Table 5.22. Weighted Average Net Returns from Irrigation, Alberta Sub-Basins**

| Sub-Basin | Short-run Weighted Net Returns ($/ha) | Long-run Weighted Net Returns ($/ha) |
|---|---|---|
| Oldman | $398.23 | $176.43 |
| Bow | $340.00 | $164.59 |
| Red Deer | $352.67 | $155.77 |
| SSRB-AB | $362.27 | $136.27 |

The long-run net returns from irrigation were also positive but slightly lower than the short-run returns. Here the returns varied from $136 per ha for the SSRB (AB) sub-basin to a high of $176 per ha for the Oldman River sub-basin.

Weighted net return from dryland production in the region was estimated to be $67.05 per ha in the short-run and $17.51 per ha in the long run (as shown in Table 21). As one would expect, these values are lower than those under irrigation. Since dryland crop mix is not available by sub-basins, the same value was applied to all four Alberta sub-basins.

Saskatchewan Sub-Basin

The same computations were repeated for the Saskatchewan portion of the SSRB. As noted above, on account of different crop production and irrigation technology, this estimation was done separately for the LDDA and SWDA portion of the sub-basin. Table 5.24 displays the irrigated and dryland net returns for both the LDDA and SWDA. The weighted net return from irrigation in the LDDA was higher than that in the SWDA. In this portion of the sub-basin, short-run net returns were estimated to be $670 per ha, in part due to high returns from potatoes and a relatively high proportion of this crop. In the long-run the net returns declined to $464 per ha. The dryland net returns in the Area were relatively small – $67 per ha in the short-run and only $17 in the long-run. The weighted average net return for the typical forage rotation was $192 per ha in the short-run under irrigation compared to a total of $82 per ha under dryland.

In the SWDA portion of the sub-basin, net returns from irrigation were only $192 in the short-run and reduced to $132 per ha in the long-run. This reduction was partly on account of the high proportion of forages in the rotation, which, of course, is the primary purpose of irrigation in the area. The dryland net returns in this area of the sub-basin were slightly higher than those in the LDDA.

**Table 5.23. Weighted Net Returns for Various Sub-Regions of SSRB-Saskatchewan**

| Particulars | Irrigation ($/ha) | Dryland ($/ha) |
|---|---|---|
| **LDDA** | | |
| Short-run Net Returns ($/ha) | $669.81 | $67.05 |
| Long-run Returns ($/ha) | $463.54 | $17.51 |
| **SWDA** | | |
| Short-run Net Returns ($/ha) | $192.15 | $81.69 |
| Long-run Returns ($/ha) | $132.40 | $61.99 |

Average Value of Irrigation Water per $dam^3$, by Sub-Basins

In order to estimate the value per unit of water applied through irrigation in various sub-basins of the SSRB, two sets of information were required: estimation of amount of water used for irrigation of various crops; and average value of water per ha of irrigated land.

With respect to the first set of information, data on irrigation water use by crops was not available. As a very poor substitute, water use of the sub-basin was estimated. These data were obtained in terms of diversion of water for various Alberta irrigation projects from Kulshreshtha, Sobool and Grant (2005). Converting these into per ha diversion for irrigation, and weighting them by area within a sub-basin, an estimate of water use for irrigation in various sub-basins of Alberta was calculated. These estimates are shown in Table 5.25.

**Table 5.24. Estimated Water Use for Irrigation in the SSRB**

| Sub-Basin | Amount of Water in $dam^3$/ha |
|---|---|
| **Alberta** | |
| Oldman | 4.26 |
| Bow | 5.72 |
| Red Deer | 5.49 |
| SSRB (AB) | 4.08 |
| **Saskatchewan** | |
| LDDA | 2.21 |
| SWDA | 3.05 |

The amount of water use for irrigation in the LDDA was also obtained from Kulshreshtha, Sobool and Grant (2005). This amount for the LDDA was estimated at 2.21 $dam^3$ per ha, equivalent to 8.7 inches of water over the entire surface (Kulshreshtha, Sobool and Grant, 2005). The estimate for the SWDA from Kulshreshtha, Sobool and Grant (2005) was 2.15 $dam^3$. However, data on various federal irrigation projects in the SWDA suggested a higher level of water used. This value was based on the average of seven irrigation projects and was estimated to be 7.44 $dam^3$ per ha. However, after further consultations with the project managers in the Southwest Saskatchewan irrigation projects, it was suggested that a typical allocation in the region is about one-acre foot for a single irrigation. This translates into 3.05 $dam^3$ of water. This estimate was used to estimate the average value of water. Total water use in the basin for irrigation was estimated at 2.47 million $dam^3$ per annum (Table 5.26). It should be noted that this estimate is slightly higher than that estimated by Armstrong, Pietroniro and Rolfe, and is based on several assumptions as listed above.

**Table 5.25. Irrigation Total Water Use in SSRB Sub-Basins**

| Sub-Basin | Water Use ($dam^3$) |
|---|---|
| Oldman | 917,991 |
| Bow | 406,201 |
| Red Deer | 657,645 |
| SSR (AB) | 398,158 |
| LDDA | 74,391 |
| SWDA | 13,768 |
| SSRB TOTAL | 2,468,154 |

Source: Saskatchewan area data from SAFRR (2003); Alberta area data from AAFRD (2002)

The average value was estimated using per ha difference in the net returns from irrigated and dryland production divided by the amount of water use. These estimates are shown in Table 5.27.

**Table 5.26. AVP Calculation SSRB Sub-Basins, SSRB**

| Sub-Basin | Short-run Value per $Dam^3$ | Long-run Value per $Dam^3$ |
|---|---|---|
| **Alberta** | | |
| Oldman | $78.13 | $38.60 |
| Bow | $48.01 | $26.68 |
| Red Deer | $52.24 | $26.15 |
| SSRB (AB) | $72.64 | $30.41 |
| **Saskatchewan** | | |
| LDDA | $272.75 | $201.82 |
| SWDA | $36.22 | $23.09 |
| SSRB (SK) | $235.81 | $173.91 |

The average value of water in irrigation in Alberta was estimated to be $48 to $78 per $dam^3$ in the short-run, and ranged from $26 to $39 per $dam^3$ in the long-run. Given the positive value of water, every unit of water applied to irrigating crops produces a net gain in economic welfare of the Alberta society by these amounts. What cannot be determined at this point is whether it is the best use of water without a comparison with other users. In Saskatchewan, the value of water is higher in the LDDA compared to Alberta or the SWDA. This higher value could be attributed to the reported use of water for irrigation, which, as shown in Table 5.25, is almost half that reported for Alberta sub-basins. In the short-run, weighted average value in the Saskatchewan portion of the SSRB is estimated to be $236 per $dam^3$ in the short-run and $174 per $dam^3$ in the long-run.

Based on the results of this study, a lower value of water is also indicative of low water use efficiency in the SWDA. Since the region was assumed to have a larger proportion of flood (surface) irrigation system; furthermore, since much of these irrigated areas in this region are located on poor soils, productivity is lower and water use is higher. A case can be made to convert these projects to sprinkler irrigation and locate them on better quality of land.

## 5.8 Total Economic Value of Irrigation Water

The total value of water ($) in each sub-basin was estimated in both the short and long run by multiplying the average value ($/$dam^3$) by the total amount of water use ($dam^3$). These estimates are shown in Table 5.28.

Total economic value of water used for irrigation within the SSRB was estimated to be $175 million in the short-run, and almost $91 million in the long-run. Thus, if this water is not allocated for this purpose, the basin economy would lose this amount in additional gain in the society's well-being. Along with that, all forward and backward linkages would also be lost.

**Table 5.27. Total Value of Irrigation Water in SSRB Sub-Basins**

| Sub-Basin | Total Irrigated Area in Ha | Total Water Use for Irrigation in $dam^3$ | Short-run Value (Mill. $) | Long-run Value (Mill. $) |
|---|---|---|---|---|
| **Alberta** | | | | |
| Oldman | 215,491 | 917,991 | $71.72 | $35.43 |
| Bow | 71,014 | 406,201 | $19.50 | $10.84 |
| Red Deer | 119,790 | 657,645 | $34.36 | $17.20 |
| SSRB (AB) | 97,588 | 398,157 | $28.92 | $12.11 |
| **Saskatchewan** | | | | |
| LDDA | 33,661 | 74,391 | $20.29 | $15.01 |
| SWDA | 4,514 | 13,768 | $0.50 | $0.32 |
| Total SSRB | 542,058 | 2,468,154 | $175.29 | $90.91 |

# Chapter 6

# VALUE FOR OTHER AGRICULTURE USES

Use of water in irrigation could produce two types of benefits: one, it increases the producer surplus (over that under dryland production systems); two, it could provide some benefits during a drought year. The first benefit is already discussed in Chapter Five. The second category of benefits from irrigation is discussed in this chapter. In addition to the irrigation water, there are two other types of uses of water on farms: livestock, and farm domestic water use. The chapter reviews these three types of values associated with agricultural water use.

## 6.1 Drought Mitigation

### 6.1.1 Concept of Benefit

Droughts can have direct as well as indirect impacts on the farm. The direct impacts will be through crop production, whereas indirect impact will be forthcoming through forward linkages of crop products with other activities on farms. Livestock production is one such activity that is linked to forage production. Total value of irrigation water in drought mitigation should be estimated as a sum of both of these benefits.

Crop Production Related Benefits

The hydrologist's definition of drought concerns a lengthy period of time with below mean monthly or annual streamflows (Dracup and Kendall, 1990). An agricultural drought is defined in terms of below mean monthly (or crop season) precipitation leading to lack of soil moisture available for crops. Under these conditions, crop growth suffers and all forward linkages of such production activities also suffer as well.

The conceptual benefit of using irrigation as a drought-proofing/drought mitigation on dryland farming can be illustrated with the aid of Figure 6.1 for crops. The figure plots crop yield against soil moisture availability for a dryland cropping system. The first crop production line from the horizontal axis represents crop production function under dryland farming with no irrigation. The crop production under a drought year would be limited by lack of moisture (denoted by the distance "*A*"). The second crop production line from the horizontal represents the raised crop production function as a result of applying irrigation during an average (non-drought) year, and the difference between the first and second functions is the marginal value of irrigation with respect to irrigation under an average year. The third line from the horizontal represents the crop production function under irrigation during a drought year (with growth-conducive temperatures that raises the crop yield represented by the distance "*B*"). The sum of the distances *A* and *B* is known as the benefit of irrigation for drought mitigation.

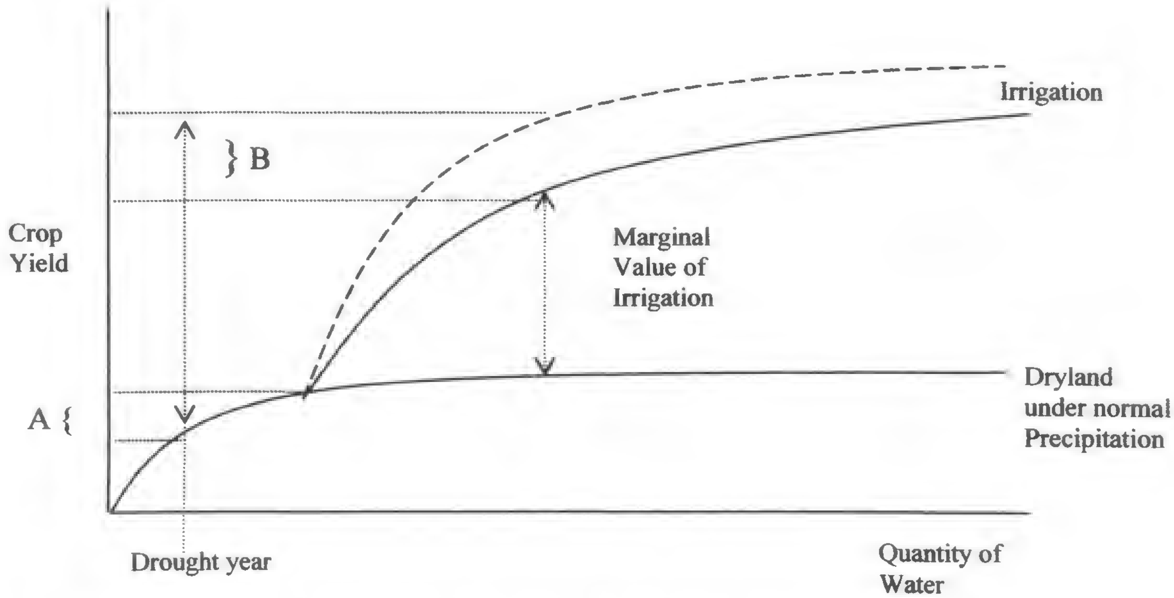


**Figure 6.1. Drought Mitigation for Crop Production through Irrigation**

Livestock Production Related Benefits

The livestock industry is sensitive to drought. Livestock production during a drought year is affected by a variety of factors; among these is the pastures' carrying capacity and forage availability. When these resources become a binding constraint, producers may sell a portion of their herd. In some extreme cases, producers may liquidate a part of the breeding herd that has implications for the income from livestock not only during the year of the drought but also during subsequent years (Kulshreshtha and Marleau, 2005).

Figure 6.2 shows that with the drought years beginning in year zero the cattle producers may take alternative measures of hauling water to maintain the existing herd for the short term (1-2 years). However, it does not take more than that before some downsizing of herd size would be seen. When the downsizing begins, the excess sale of cattle may make the accounting profit seem more favorable than should actually be reflected. This is because the cattle sold are a source of capital that would be a future source of revenue.

### 6.1.2 Methodology for Estimation

Crop Production

The drought mitigation benefit for crop production is composed of two parts: component *'A'* which is the yield (and hence net return) for an average year above a drought year where no irrigation is provided, and component '*B*' which is the yield (and hence net return) under a drought year relative to an average year where irrigation is provided. Drought period in this study is the average of 2001 and 2002 period.

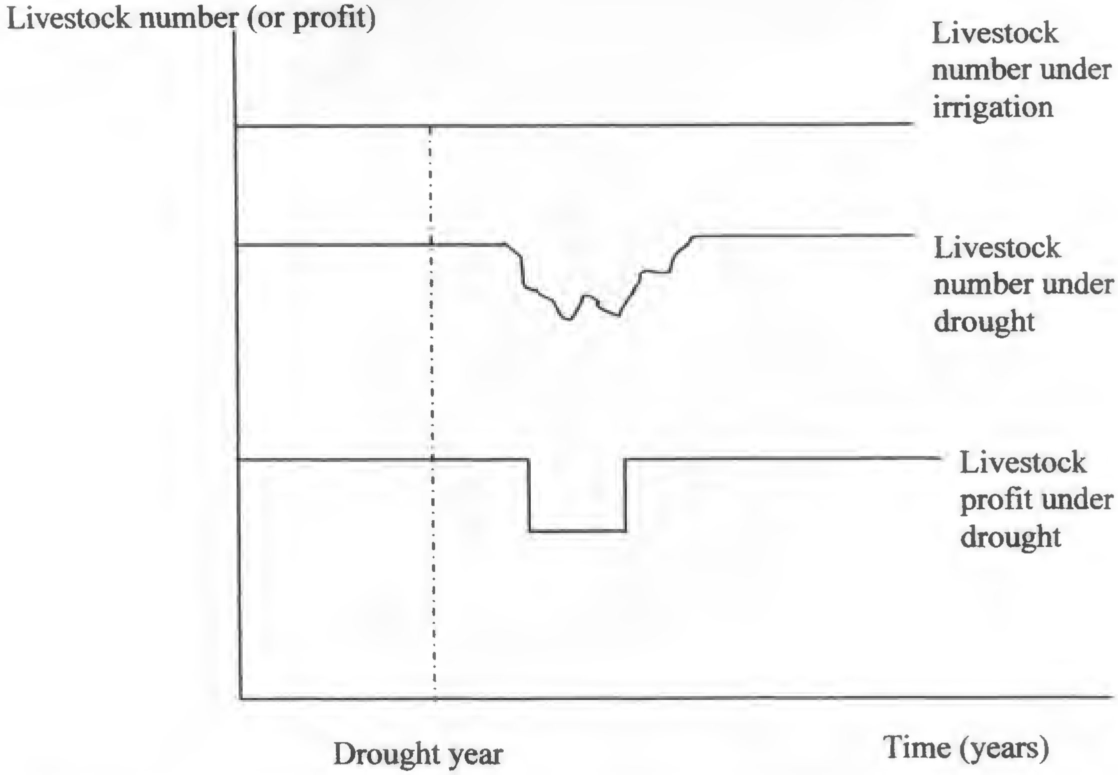


**Figure 6.2. Schematic of Value of Water in Drought Mitigation through Livestock Production**

The difference '*A*' (or yield difference for an average year over a drought year under dryland farming) was found by subtracting drought year yields (mean of 2001 and 2002) from non-drought year yields (mean of 1999 to 2000), where historic crop yields were borrowed from Wittrock (2005), Sobool, Kulshreshtha and Belcher (2004), Alberta Agriculture, Food and Rural Development (2003a) and Saskatchewan Agriculture and Food (2005). Next, the difference in crop yields represented by '*A*' was converted to a difference in gross returns by multiplying it by the ten-year annualized crop prices from AAFRD (2003 a), Saskatchewan Agriculture and Agri-Food, and Rural Revitalization (2003) (See Table 6.1). With the assumption that all other input costs do not change between the two situations, the difference in gross returns were assumed to approximate the difference in net returns. The results suggested that in Alberta, these returns ranged from $52/ha for potatoes to $371 /ha for dry beans. The range for Saskatchewan was for the same crops but from $26 to $217/ha.

The difference '*B*' in yields (the difference with drought conditions as opposed to an average year where irrigation is provided in both situations) was found by subtracting simulated crop yield (and net returns) under drought conditions relative to non-drought conditions where irrigation was provided under both. The simulation was performed using crop production functions of Heikkila et al. (2002) calibrated with evapotranspiration and precipitation data by Chinn (2005) representative of each sub-basin. As with difference '*A*', the assumption that all other inputs remain unchanged between the two scenarios was maintained except for the difference in incremental irrigation costs provided in the model by Heikkila et al. (2002). The economic part of the Heikkila model was calibrated with the same ten year annualized crop prices (1994-2003). Results for Alberta for this benefit are shown in Table 6. 2.

**Table 6.1. Crop Production and Net Return Differences '*A*' (Difference in Average Year over Drought Year, Both under Dryland Farming); Saskatchewan and Alberta**

| Particulars | HRS Wheat | Barley | Canola | Dry Beans | Potato | Tame Hay | Alfalfa |
|---|---|---|---|---|---|---|---|
| | **Alberta** | | | | | | |
| Dryland Avg. Yield (Kg) | 2,791 | 3,255 | 1,513 | 1,233 | 37,660 | 5,622 | 9,950 |
| Dryland Drought Year Yield (Kg) | 1,782 | 2,313 | 1,121 | 549 | 37,346 | 3,793 | 6,714 |
| Yield Difference (Kg/Ha) | 1,009 | 941 | 392 | 684 | 314 | 1,829 | 3,237 |
| Net Return Difference ($/Ha) | $168 | $112 | $135 | $371 | $52 | $144 | $308 |
| | **Saskatchewan** | | | | | | |
| Dryland Avg. Year Yield (Kg) | 2,186 | 2,650 | 1,429 | 1,247 | 33,223 | 3,262 | 4,958 |
| Dryland Drought Year Yield (Kg) | 1,261 | 1,560 | 897 | 715 | 33,066 | 1,804 | 2,742 |
| Yield Difference (Kg/Ha) | 925 | 1,089 | 532 | 532 | 157 | 1,458 | 2,216 |
| Net Return Difference ($/Ha) | $154 | $170 | $217 | $99 | $26 | $115 | $168 |

**Table 6.2. Marginal Change in Irrigated Crop Production in a Drought Year (Difference '*B*') for SSRB-Alberta**

| Particulars | HRS Wheat | Barley | Canola | Dry Beans | Potato | Tame Hay | Alfalfa |
|---|---|---|---|---|---|---|---|
| Irrigated drought year. yields (kg/ha) | 4,200 | 6,173 | 3,190 | 2,666 | 37,731 | 4,439 | 14,459 |
| Irrigated average year yields (kg/ha) | 3,781 | 5,528 | 2,991 | 2,385 | 34,996 | 4,276 | 13,210 |
| Yield difference (kg/ha) | 418 | 645 | 199 | 282 | 2,735 | 163 | 1,249 |
| Net return difference ($/ha) | $12 | $24 | $16 | $100 | $378 | -$59 | $36 |

Livestock Production

Impact of a drought on livestock production, as noted above, are more dynamic in nature. A drought can affect livestock enterprises in the drought year, and also may have some impact on the subsequent periods. Much of the impacts depend on the adaptation measure that livestock producers adopt in the wake of a forthcoming drought. Information of this aspect of livestock production is not well understood. However, a study by Marv Anderson and Associates (1980) suggested that producers undertake two types of adjustments on farms. One, reduce the input combinations and make adjustments in cultural practices. Since Marv Anderson and Associates (1980) provide a minimum and maximum range of adjustments that could be made to input costs, this study used two estimates, a minimum and a maximum adjustment. Two, sell a part of the herd to reduce cost of transporting hay or purchasing it at higher prices. Both of these adjustments were used in the estimation of drought mitigation value of irrigation water. However, as discussed before, the sale of livestock has a favorable effect on net farm income during the drought year. However, during the subsequent period, producers must undertake herd building, which may have a reduction in net income for these periods.

### 6.1.3 Estimated Value of Irrigation Water for Drought Proofing

Crop Production

The benefit of irrigation in terms of difference *'A'* (yield difference for an average year over a drought year under dryland farming and the subsequent net return difference) is shown for the crops in the Saskatchewan and Alberta portions of the SSRB in Table 6.1. This was added to the crop production, and the net return difference *'B'* (the difference with a drought year over an average year where irrigation is provided in both situations) is shown for each of the sub-basins in Tables 6.2-6.6. It is noteworthy that although tame hay has a yield advantage under drought mitigation in both components *'A'* and *'B'*, the net returns under component *'B'* tend to be a small negative. This is because the irrigation requirements become increasingly more expensive for tame hay under drought condition.

**Table 6.3. Crop Productions and Net Return Difference *'B'* (Drought Year Irrigated Crop) for Red Deer River Sub-Basin**

| Particulars | HRS Wheat | Barley | Canola | Dry Beans | Potato | Tame Hay | Alfalfa |
|---|---|---|---|---|---|---|---|
| Irrigated drought yr. yields (kg/ha) | 4,270 | 6,325 | 3,249 | 2,660 | 37,322 | 4,398 | 14,230 |
| Irrigated average yr. yields (kg/ha) | 3,673 | 5,382 | 2,936 | 2,252 | 34,057 | 4,243 | 12,876 |
| Yield difference (kg/ha) | 597 | 943 | 313 | 408 | 3,266 | 155 | 1,355 |
| Net return difference ($/ha) | $36 | $54 | $49 | $158 | $469 | -$54 | $51 |

**Table 6.4. Crop Production and Net Return Difference 'B' (Drought Year Irrigated Crop) for Oldman River Sub-Basin**

| Particulars | HRS Wheat | Barley | Canola | Dry Beans | Potato | Tame Hay | Alfalfa |
|---|---|---|---|---|---|---|---|
| Irrigated drought yr. yields (kg/ha) | 4,282 | 6,317 | 3,256 | 2,757 | 37,510 | 4,418 | 14,139 |
| Irrigated average yr yields (kg/ha) | 3,649 | 5,321 | 2,924 | 2,285 | 34,122 | 4,202 | 12,829 |
| Yield difference (kg/ha) | 633 | 996 | 332 | 472 | 3,388 | 216 | 1,310 |
| Net return difference ($/ha) | $31 | $43 | $43 | $195 | $488 | -$44 | $61 |

**Table 6.5. Crop Production and Net Return Difference '*B*' (Drought Year Irrigated Crop) for Bow River Sub-Basin**

| Particulars | HRS Wheat | Barley | Canola | Dry Beans | Potato | Tame Hay | Alfalfa |
|---|---|---|---|---|---|---|---|
| Irrigated drought yr. yields (kg/ha) | 4,193 | 6,218 | 3,209 | 2,796 | 37,561 | 4,400 | 14,139 |
| Irrigated average yr yields (kg/ha) | 3,719 | 5,447 | 2,959 | 2,301 | 34,430 | 4,253 | 13,081 |
| Yield difference (kg/ha) | 474 | 771 | 250 | 495 | 3,131 | 147 | 1,058 |
| Net return difference ($/ha) | $25 | $41 | $36 | $209 | $455 | -$45 | 36 |

**Table 6.6. Crop Production and Net Return Difference '*B*' (Drought Year Irrigated Crop) for SSRB-Saskatchewan**

| Particulars | HRS wheat | Barley | Canola | Dry beans | Potato | Tame hay | Alfalfa |
|---|---|---|---|---|---|---|---|
| Irrigated drought yr. yields (kg/ha) | 4,236 | 6,259 | 3,226 | 2,721 | 37,534 | 4,414 | 15,528 |
| Irrigated average yr yields (kg/ha) | 3,706 | 4,935 | 2,953 | 2,306 | 34,406 | 4,244 | 13,000 |
| Yield difference (kg/ha) | 531 | 1,323 | 274 | 414 | 3,128 | 170 | 2,529 |
| Net return difference ($/ha) | $26 | $136 | $51 | $167 | $449 | -$53 | $97 |

## 6.2 Livestock Production

Value of water for drought mitigation was estimated using the data on adjustments made by livestock producers per Marv Anderson and Associates (1980). Although it would have been preferable to estimate the cost of selling herd during such periods, insufficient data did not permit such a valuation. Results are shown in Table 6.7.

**Table 6.7. Change in Net Farm Income from Livestock Production under Drought in All Sub-Basins of the SSRB in Alberta, 2004**

| Items of Cost | $/ cow Wintered/yr | Minimum % Change | Cost / Cow under Minimum change | Maximum % Change | Cost / Cow under Maximum change |
|---|---|---|---|---|---|
| Winter feed | $130 | 10% | $143 | 80% | $234 |
| Pasture | $201 | 20% | $241 | 20% | $241 |
| Fuel | $ 13 | 20% | $16 | 20% | $16 |
| Operating interest paid | $ 2 | 50% | $3 | 100% | $4 |
| Other Variable Costs | $130 | | $130 | | $130 |
| **Variable costs** | $476 | | $533 | | $625 |
| **Change in Variable costs during a drought year = Difference in return to equity due to drought** | | | $57 | | $149 |

The difference in net farm income due to drought is the difference between the return to equity under average non-drought conditions less the return to equity under drought. Thus, the additional cost to producers could range from $57 to $149 during a drought period.

In order to estimate value per $dam^3$ of water, one needs water use for forages grown under irrigated conditions plus water used for livestock consumption. The water use for irrigation was an average for the Saskatchewan and Alberta portions of the SSRB. Details are shown in Table 6.8. For Alberta, this estimate was 4.7 $dam^3$ per ha, while for the Saskatchewan portion of the SSRB it was estimated to be 2.3 $dam^3$. Given that a cow requires 16.58 $m^3$ of water (based on Kulshreshtha, Sobool and Grant (2005)), the value of water per $dam^3$ is estimated between $96 and $251 for Saskatchewan and between $138 and $361 for Alberta.

**Table 6.8. Estimation of Value of Water for Livestock Production During a Drought Year**

| Particulars | Saskatchewan | Alberta |
|---|---|---|
| Total no. of Cattle and Calves on Irrigated Farms* | 157,391.0 | 1,437,084.0 |
| Total Irrigated Area | 90,082.0 | 495,840.0 |
| Cattle and Calves / ha Irrigated | | |
| Forage area (% of Total) | 43.4% | 24.3% |
| Total water use/ha | 2.3 | 4.7 |
| Total water use for forage ($dam^3$) | 90,878.9 | 569,424.0 |
| Water per cow-calf | 0.0 | 0.0 |
| Total Cow-calf water use ($dam^3$) | 2,609.5 | 23,826.9 |
| Total water use (Irrg+Cow-calf) | 93,488.4 | 593,250.8 |
| | | |
| Increase cost in cow-calf -- Low limit | $57.00 | $57.00 |
| Total cost | $8,971,287.00 | $81,913,788.00 |
| Value per $dam^3$ | $95.96 | $138.08 |
| | | |
| Increase cost in cow-calf -- High limit | $149.00 | $149.00 |
| Total cost | $23,451,259.00 | $214,125,516.00 |
| Value per $dam^3$ | $250.85 | $360.94 |

Source: * Statistics Canada, Special Tabulation, 2005

The above estimates are for a drought period. These need to be converted over a long-run perspective by taking into account drought frequency in the region. 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). Thus, the drought frequency is in the neighborhood of 8% over the period. Adjusting the values shown in Table 6.8 for this drought frequency results in a long-run value of water in irrigation for drought proofing in livestock operations. These values are shown in Table 6.9.

**Table 6.9. Long-Run Value of Irrigation Water through Drought Mitigation for Livestock Operations**

| Particulars | Saskatchewan Sub-basin of SSRB | Alberta SSRB Sub-basins |
|---|---|---|
| | *Dollars per dam$^3$* | |
| Low Cost of Adjustments | \$7.68 | \$11.05 |
| Higher Cost of Adjustments | \$20.07 | \$28.87 |

As shown in the table, benefits from irrigation in terms of mitigation of drought impacts could range between \$8 and \$20 in Saskatchewan, and between \$11 and \$29 per dam$^3$ in Alberta. It should be noted that additional value of irrigation water in supporting the livestock industry is not included either in the estimates provided in Chapter Five or in the above table.

## 6.3 Value of Water in Livestock

The livestock industry is very important to Canada. In 2001, Western Canada made up more than 67% of the total beef cattle, dairy cattle, hog, poultry and other animals in Canada (Wittrock, 2005). Beef cattle in Western Canada made up over 84% of the total number in all of Canada for 2001 with 40% located in Alberta and 25% in Saskatchewan (Wittrock, 2005). Alberta is a major producer of livestock products, particularly cattle and calves and has a healthy and sizable meat processing industry in Western Canada. For the province as a whole, 63% of the total farm cash receipts are from livestock sources (Kulshreshtha and Marleau, 2005).

The value of water required for livestock would mainly include that which is needed for drinking and cleaning the livestock operation. Cattle are watered by means of surface water (such as impoundments or dugouts that retain water from the runoff and snow trapped through the fields) or groundwater by means of wells. Under normal (non-drought) conditions, around 85% of pastured livestock in the SSRB use surface water as their primary source (dugouts 60%, reservoirs 10%, and streams 15%) and the remaining 15% use groundwater sources[9]. According to Bell (2005), the trend of groundwater use for livestock production is slightly increasing over time.

### 6.3.1 Methodology

The value of water for livestock production can be estimated using several alternative methods. It can be assumed that if water is not there, the region would lose the entire

9 This is particularly true of the springs especially in the foothills and around Cypress Hills and deep wells with a shallow pipeline delivery system.

livestock industry. This would be a rather drastic assumption, since producers would make adaptation measures facing such a situation. Bruneau (2004) valued water for livestock as an input into livestock drinking and cleaning, with certain caveats discussed. He used the residual imputation method that calculates value added in the production of cattle attributable entirely to water as an input. He assumed that a decrease in water availability would result in a decreased stock (one-for-one), and like wise an increase in water would see the converse with no substitute nor increase in efficiency. Operators were assumed to have no alternate water source, hauling ability or capacity to divert water from another activity. This would overestimate the long-run cost of water. Value added assumes that other factors of production (labor, capital) would be idle if water resources were unavailable and would not transfer to another crop or livestock alternative. In reality this would not be true. These other factors would move to the next highest value added activity and hence there would not be as much a decline in value added.

The cost of such adaptation over and above the present cost of water supply to livestock operations might therefore be a preferred method. This alternative cost might be the cost of procuring water from other sources.

Under drought, the surface water sources, such as dugouts and reservoirs, according to Bell (2005) are typically replaced by wells (about 75% of the time) and by municipal water systems (about 10% of the time). New technologies like remote wells with solar powered pumps are also gaining popularity, but have not claimed a significant portion of the adaptation measures.

In the central part of the SSRB (eastern Alberta, Medicine Hat to Hanna regions) a 2,000$m^3$ capacity dugout can be constructed for approximately \$2,500. However, this cost could multiply as much as three times depending on the location, being more expensive in the western regions of the SSRB (Bell, 2005). This study decided to use the lower value (\$2,500) for the SSRB Alberta and Saskatchewan sub-basins as well as the Red Deer River sub-basin, but twice the value (\$5,000) for the Oldman and Bow River sub-basins. Once constructed, dugouts are generally ignored for many years before any rehabilitation is considered (annual operating costs are minimal) (Bell, 2005). However, depreciation of 5% of capital cost for a one-time maintenance down the road was recommended (Bell, 2005).

This study assumed that reservoirs will be half the cost of a dugout for the respective sub-basin but free of cost for watering livestock off a stream. The cost of constructing a well was estimated at \$6,215 by the Prairie Farm Rehabilitation Administration (PFRA, 2005). The operating and maintenance cost was assumed at 1.5% and the depreciation at 4% (hence, an annual cost of 5.5% would be assumed).

In this study, the value of water for livestock was calculated as follows:

(1) Data on number of irrigation farms by type of livestock were obtained from Statistics Canada (2002). These included number of irrigated farms with cattle, swine, poultry and other farms. These are shown in Table 6.10.

(2) By multiplying the number of each type of farms (cattle, poultry, swine and other) described above with the proportion of dugouts, reservoirs, streams and wells provided by Bell (2005), and, shown above, an approximate of number of dugouts and reservoirs was made for each of these sources of water for the respective farms. Under the assumption that each type of farm will have the same proportion of the water sources and the proportions of these water sources apply uniformly across the SSRB, these numbers were estimated and are shown in Table 6.11.

**Table 6.10. Number of Farms by Farm Type in the Alberta CAR2 Region**

| Type | Number |
|---|---|
| Cattle farms | 4,440 |
| Pig farms | 230 |
| Sheep farms | 472 |
| Poultry farms | 722 |
| Horse farms | 3,391 |
| Other farms | 532 |
| Total | 7,122 |

* Numbers may not add to the total since some farms would have more than one type of livestock

Source: Statistics Canada (2002)

**Table 6.11. Number of Farms with Source of Water**

| Farm Type | Dugouts | Reservoir | Stream | Groundwater |
|---|---|---|---|---|
| Proportion of Farms by Source of Water | 60% | 10% | 15% | 15% |
| No. of farms | 4,273 | 712 | 1,068 | 1,069 |

Source: Using proportions provided by Bell (2005) and number of farms by Statistics Canada (2002)

(3) By multiplying the cost of each source (again provided by Bell, 2005) by the number of the individual sources of water for each individual type of farm, the cost of water for each type of farm was computed. These costs are shown in Table 6.12. This again assumes that the proportion of water sources is uniformly distributed across the SSRB, that the cost of each water source is the same across the SSRB, and that all the farms in this CAR are unique (i.e., each farm is either cattle or poultry or hog but not a combination of two or more at the same time.)

### 6.3.2 Estimated Value

Alberta

The present cost of water provision to various types of livestock farms was estimated using the above methodology. Results are shown in Table 6.13. The value of water in livestock operations was a difference between present cost of water and cost under the condition that surface water does not exist and has to be obtained from groundwater sources. This value for Alberta was estimated at $911,786 per annum.

**Table 6.12. Annual Operational and Depreciation Charge by Source of Farm Water**

| Source of Farm Water | Annual Operation and Depreciation Costs (Dollars) |
|---|---|
| Dugout | $250.00 |
| Reservoir | $125.00 |
| Stream | 0 |
| Groundwater Well | $341.82 |

Source: Bell (2005); PFRA (2005)

**Table 6.13. Estimated Value of Water in Livestock for Alberta CAR2**

| **Type of Farms** | **Cost of Water Obtained from** | | | | **Total value of water** |
|---|---|---|---|---|---|
| | **Dugout** | **Reservoir** | **Stream** | **Groundwater** | |
| | *Present Source of Water* | | | | |
| All farms | $1,068,250 | $89,000 | 0 | $365,406 | **$1,522,656** |
| | *Source of Water under no surface water* | | | | |
| Proportion | 0 | 0 | 0 | 100% | |
| Cost | 0 | 0 | 0 | $2,434,442 | **$2,434,442** |
| Total Value of Water | | | | | **$911,786** |

Saskatchewan

The methodology used for Alberta was repeated for Saskatchewan. The Saskatchewan portion of the SSRB was represented by CAR 3BN and 6B. Number of farms in the sub-basin is shown in Table 6.14, and the cost of obtaining water in Table 6.15. Total value of water for livestock operations in Saskatchewan portion of the SSRB was estimated at $775,128 per annum. To estimate the value of water per $dam^3$, the total value of water in the Alberta and Saskatchewan portions of the SSRB was divided by the total water withdrawn in the livestock sector from Figure 3.2 (84,000 $dam^3$). The value was estimated to be $9.22/$dam^3$.

Table 6.14. **Number of Farms by Farm Type in the Saskatchewan CAR3 BN and 6B Region**

| Type | Number |
|---|---|
| Cattle farms | 2,659 |
| Pig farms | 197 |
| Sheep farms | 228 |
| Poultry farms | 448 |
| Horse farms | 866 |
| Other farms | 329 |
| Total Number of Farms | 6,054 |

Source: Statistics Canada (2002)

**Table 6.15. Estimated Value of Water in Livestock for Saskatchewan CAR3 BN and 6B Region**

| Particulars | Cost of Water from | | | | Value of Water |
|---|---|---|---|---|---|
| | Dugout | Reservoir | Stream | Groundwater | |
| Proportion of Livestock Water from Source | 60% | 10% | 15% | 15% | 100% |
| All farms | 908,100 | 75,765 | 0 | 310,407 | 1,,294250 |
| Proportion of farms with source of water under surface water shortage | 0 | 0 | 0 | 100% | |
| All farms with cost of water | 0 | 0 | 0 | 2,069,378 | 2,069,378 |
| Value of water for livestock | | | | | 775,128 |
| Value per $dam^3$ for SSRB | | | | | 9.22 |

The method of estimation used average values of costs for water delivery mechanisms whereas actual costs depended on the sizing of the mechanism to the number of animals within the farm. As well, the sizing depended on whether the farm is in the drier, eastern part of the basin or in the wetter, western part.

## 6.4 Farm Domestic Water Use

Farmers and other rural water users, unlike their urban counterparts are directly responsible for their water supply (Agriculture and Agri-Food Canada, 2000). Developing a dependable source of water usually involves considerable costs, ranging from $5,000 to $25,000 (Agriculture and Agri-Food Canada, 2000). Rural residents must also pay for in-home treatment systems and ongoing operation and maintenance costs. Their source of water may include one or a combination of the following (Agriculture and Agri-Food Canada, 2000):

- A shallow or deep groundwater well
- A lake, stream, river, or on-farm storage pond or dugout
- A cistern filled by rainwater or by hauling water from a distant source
- A regional water supply pipeline

Different sources may be used for different purposes such as drinking, cooking, watering lawn and garden etc. Development of many rural water pipelines during the 1980s and 1990s provided a reliable and high-quality supply of water to many people living in the prairies (Agriculture and Agri-Food Canada, 2000). Although pipelines have been owned and operated by local associations, they have been technically and financially assisted by Agriculture and Agri-Food Canada (Prairie Farm Rehabilitation Administration). Pipelines benefit rural communities in reducing the number of times residents had to haul water long distances and store it (Agriculture and Agri-Food Canada, 2000).

Canadians are highest next only to Americans in average daily household water use per person at 258 to 445 L (Agriculture and Agri-Food Canada, 2000). The lower figure is based on household that paid for water on a volume basis, and the higher figure for those who paid a flat fee, regardless of volume used (Agriculture and Agri-Food Canada, 2000). Very little evidence was found on domestic use in rural areas and how it compares with this average. This in part is because there are no provincial requirements for licensing domestic on-farm water use, and domestic water used by rural residents is rarely metered. An exception to this occurs in the Prairies where recently constructed pipelines are metered. Meters on individual connections to pipelines in southeast Saskatchewan show that average daily water use per person, assuming little water is used for outdoor purposes, ranges from 225 to 373 L with higher consumption in households with babies and young children. In comparison, metered water use in southern Alberta, for a family of five with a private water supply and treatment system was 155L, per person per day, assuming little outdoor use (Agriculture and Agri-Food Canada, 2000).

Within the SSRB, as with urban water use, the Bow River and South Saskatchewan River sub-basins account for the major part of rural water use, at about 91% of total rural water use. Water use for rural communities within the South Saskatchewan sub-basin is about 600 $dam^3$ more than for communities in the Red Deer River sub-basin. Rural water use in the Bow and Oldman sub-basins are 242 $dam^3$ and 202 $dam^3$ respectively (industrial water use has been separated from the community water use information) (Armstrong, Pietroniro and Rolfe, 2004).

No study was found on the value of water to the farm household for domestic use. A study of cost of water from pipelines vs. conventional groundwater sources may shed some light on this issue.

# Chapter 7

# VALUE OF WATER FOR SELECTED NON-AGRICULTURAL WITHDRAWAL USES

As shown in Chapter Three, although agriculture is the single largest use of water in the SSRB, a number of other uses of water also exist. These uses include industrial and domestic (or residential), and that for power generation. The former uses are sometimes combined into a single source use called municipal water use. These uses and the related value of water are described in this chapter. Much of the discussion is based on a review of studies.

## 7.1 Thermal Power Generation

### 7.1.1 Introduction

This section looks at the value of water used in power generation. It looks at two types of power generation: thermal and hydroelectric power generation. The first one is described in this section, while the second one in the next chapter.

### 7.1.2 Value of Water in Thermal Power

On account of time and data limitations, this value of water was based on a review of existing studies. Unfortunately few studies have reported value of water in thermal electric power generation. One of the Canadian studies was that by Kulshreshtha et al. (1988). This study suggested that thermal power cooling water be valuated using the alternative cost approach. The alternative production technology used is the long run recirculation of water. The cost of this alternative would involve the construction and operation of a cooling tower in addition to existing thermal facilities. Value is determined by comparing the difference in construction and operating costs of two thermal plants, one of which has the facilities to re-circulate the water. The quantity of water associated with the difference in cost is the difference in water intake between the two plants (Kulshreshtha et al., 1988). However, on account of lack of data, this value was not estimated.

Muller (1985) applied an average willingness-to-pay (WTP) of \$8.784 per $dam^3$ to estimate the value of water for recirculation in thermal electric plants. This value was based on the Young and Gray (1972) estimate of value of C\$10.83 per acre-foot in USA, converted into a per $dam^3$ value for the Canadian estimate. Translating this value to reflect 2004 dollars would result in a value of water of \$9.66 per $dam^3$.

Another US study that estimated the value of water in thermal electric power generation is that reported by Frederick, Vandenberg and Hanson (1996). Value of water in this study was based a review of studies in the US. A mean value of US$34 per acre-foot of water was reported. The median value was slightly lower at $29 per acre-foot. Converting these into Canadian dollar value for 2004 (under the assumption of a 16% and an exchange rate of 1.25 Canadian to one US dollar), would make the range of this value of water between C$51.84 and C$60.78 per dam$^3$. Comparability of these estimates with the other studies is somewhat suspect since the method of estimation of these values is not clear for the Frederick, Vandenberg and Hanson (1996) study.

## 7.2 Value of Water for Municipal Uses

### 7.2.1 Introduction

For descriptive purposes, municipal water use can contain various types of water uses. Gibbons (1986) categorized these into residential, public and "other". A study for Newfoundland by A.D.I. Nolan Davis and Gardner Pinfold Consulting Economists Ltd. (referred to as A-G Study, 1996) categorized this water use into industrial, commercial, residential and other water uses. In some instances water use is recorded at a community level, which according to Sobool and Kulshreshtha (2003) includes residential, industrial and commercial, and public water uses. In other studies, no distinction is made to the type of use in a municipality, and a single value of water is estimated. This makes a comparison of estimates from different studies somewhat difficult.

### 7.2.2 Review of Literature

Most of the studies on municipal water use have focused on the estimation of a demand function. The resulting demand elasticities are then used to estimate value of consumer surplus, which if divided by the quantity of water used is equated to the value of water or net WTP of water. A compilation of early demand elasticities for municipal water have been documented by time and cross-section (Gibbons, 1986). Elasticities differ if water is used indoors (for drinking, cooking etc.,) or outside for sprinklers; they differ by seasons (summer and winter are largely different), by socio-economic profile, by weather patterns, and by residential, commercial and industrial shares of use. It was also mentioned that demand curves may shift over time. With increasing levels of income, the price paid for water may become less significant, and a shift in the mix of users to those who are less responsive to price.

An empirical valuation of municipal water for three North American municipalities (Toronto, Ont.; Raleigh, N.C.; and Tucson, Ariz.) was undertaken by Gibbons (1986) using the deriving market demand approach. In each of the three municipalities, the calculations were done for four different absolute reductions in consumption from average household consumption in summer or winter. The reductions were ¼, 1/2, 1 and 2 ccf (1ccf=100 cubic feet) per household per month. The final column in Table 7.1 gives the value of water at a 10 percent reduction. The prices in each locality were converted to

1980 dollars. Average value of water in 2004 Canadian dollars for Toronto would then be \$39.30 per $dam^3$ for the summer time[10] and \$57.80 per $dam^3$ for the winter time.

Study by Kulshreshtha et al. (1988) for Saskatchewan used the demand function approach with block rate pricing. Value of water was estimated for various communities and ranged from \$5 to \$3,356 per $dam^3$. Converting these to 2004 values will translate into a municipal water use value between \$6.7 and \$4,497 per $dam^3$.

**Table 7.1. Marginal Values for Residential Water Demand, Selected Periods**

| Locality & date | Season | Price (1980 $/ccf) | Elasticity | Avg. cons. (ccf / house / mo.) | Marginal water values (1980 $/ac-ft) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Reductions from avg. monthly cons. (ccf) | | | | 10% reduction |
| | | | | | ¼ | ½ | 1 | 2 | |
| Toronto, Ont. 1967 | Winter | 0.79 | -0.75 | 5.30 | 11 | 23 | 51 | 124 | 25 |
| | Summer | 0.79 | -1.07 | 6.55 | 6 | 13 | 27 | - | 17 |
| Tucson, Ariz. 1979 | Winter | 0.72 | -0.23 | 9.44 | 19 | 40 | 89 | 225 | 82 |
| | Summer | 0.83 | -0.70 | 16.43 | 4 | 8 | 17 | 35 | 28 |
| Raleigh, N.C. 1973 | Winter | 1.27 | -0.305 | 7.82 | 30 | 64 | 142 | 358 | 105 |
| | Summer | 1.23 | -1.380 | 8.81 | 6 | 11 | 24 | - | 21 |

Muller (1985) reported a value of water for municipal uses in Canada. The range of values was from a low of \$100 per $dam^3$ to a high of \$2,430 per $dam^3$. A disaggregated approach to estimation of value of municipal water was undertaken by the A-G (1996) study. In this study water use was identified by purpose and value was estimated for each of these uses in Newfoundland. The willingness to pay (WTP) for residential water, for example, was obtained by approximating consumer surplus (CS). Once the CS is estimated, the value of water is calculated by adding the actual consumer expenditure on water to the consumer surplus. The consumer surplus was estimated using the following formula:

$$CS = P_0 Q_0 \{(P_a / P_0)^{n+1} - 1\} / (n+1) \qquad (7.1)$$

Where, $P_0$ = the original price of water (\$/$m^3$)
$P_a$ = the new price of water, or maximum price paid (\$/$m^3$)
$Q_0$ = the original quantity of water consumed ($10^6 m^3$/year)
n = price elasticity of demand for water in the region

Results are shown in Table 7.2. Value of water was the highest for industrial use and lowest for residential and other water uses.

10 Assuming an inflation rate of 50% and the value of Canadian dollar at 1.25 per US dollar.

**Table 7.2. Estimated Value of Water for Municipal Uses, by Type of Use, Newfoundland**

| Type of Use of Municipal Water | Value per $dam^3$ in 1994 | Estimated Value per $dam^3$ for 2004* |
|---|---|---|
| Residential | $510 | $561 |
| Industrial | $560 | $616 |
| Commercial | $580 | $638 |
| Other | $510 | $561 |

* Assuming an inflation rate of 10% over the 1994 to 2004 period.
Source: ADI Nolan Davis and Gardner Pinfold (1996)

## 7.3 Value of Water for Industrial Purposes

Industrial processes require water for several distinct purposes: one, for cooling and condensation; two, for manufacturing and refining processes; three, for washing raw materials and equipment; four, as a method of conveying production inputs; and five, as an incorporated ingredient in the final product (e.g., beverage industry). The latter is called "process" water use (Gibbons, 1986). Each industrial water use may have different quality requirements. For example, the food and beverage industry would have the highest quality requirement while a cooling plant may not. Moreover, industrial water uses invariably result in some water quality degradation.

Trends in manufacturing water use (Environment Canada, 2004) showed that total national water intake has declined since 1981 and that water intake relative to output has declined within the last two decades (mostly a function of environmental regulations, technological improvements, and change in other input prices). Manufacturing water sources have continued to be largely from surface water (82% and roughly unchanged since 1991). The functions of water have been for processing water (49%) and for cooling (47%). The reuse rates were modestly up since 1991 and waste water discharge is down from 1991. Manufacturing water consumption (water that is not returned to its original source) was 7% in 1991 and 9% in 1996.

Industrial water demand is a derived demand of other variables such as population levels, industrial output, water allocation regulations (including water pricing), and technological conditions. In addition, the use of newer technologies can lead to decreased water intake and increased water recirculation.

The three valuation methods suggested by Environment Canada and Statistics Canada study (2002) include (1) a derived market demand curve approach, (2) rent valuation/return to factor approach, and (3) alternative cost approach. In the economics of industrial water use, water costs are a small fraction of total costs and industrial demand for water is mostly inelastic (De Rooy, 1974: Stone and Whittington, 1983: Brebenstein and Field, 1979 and Gibbons, 1986). Theoretically, demand and value of water in industrial use could be derived statistically, but as a practical matter this appears to be a vain hope and residual imputation is unreliable when water costs are a miniscule element of total costs (Gibbons, 1986). Kulshreshtha et al. (1988) suggest that the value for water in industrial purposes be calculated as willingness to pay using a demand function. The water demand curve can be estimated from industry survey information. The demand of water intake is the relationship between the cost of water to the firm and the amount of output.

In light of these limitations, value has been equated with the internal cost of water recirculation. In other words, the producer should be willing to pay only for what it would cost to produce water of adequate quality through treatment and reuse (Gibbons, 1986). However, unlike Gibbons' method of equating the shadow price of water only with the cost of reusing or recycling water, Bruneau (2004) calculated the water value for industries in the SSRB by equating the shadow value with the cost of water intake and treatment; that is, with the cost of reusing and recycling as well as with the cost of waste-water disposal and treatment.

Renzetti (1986) has estimated value of industrial water use for British Columbia using a demand function approach. His estimates for the year 1981 are shown in Table 7.3. In 2004 prices, these values can range from a low of $1.4 for primary metal industries to a high of $71.4 for the food and beverage industries.

**Table 7.3. Estimated Value of Industrial Water Use in British Columbia, 1981**

| Industry | 1981 Level of Value per $dam^3$ | 2004 Projected* Value per $dam^3$ |
|---|---|---|
| Paper manufacturing | $2.0 | $3.0 |
| Chemical Industries | $34.0 | $51.0 |
| Primary Metal | $0.9 | $1.4 |
| Metal Fabricating | $23.0 | $34.5 |
| Non-Metallic Mineral products | $31.0 | $46.5 |
| Petroleum refining | $17.0 | $25.5 |
| Food and Beverage | $47.6 | $71.4 |
| Wood industries | $16.4 | $24.6 |
| Transportation equipment | $4.0 | $6.0 |

* Using an inflation rate of 150% during the 1981 to 2004 period.
Source: Renzetti (1986)

Muller (1985) reported value of water in industrial water use based on US estimates provided by Young and Gray (1972). He estimated these values for the year 1984 as follows: food and beverage: $123.65 per $dam^3$ ; paper and allied products industries: $86.74 per $dam^3$; chemical industries: $75.92 per $dam^3$; primary metal industries: $29.82 per $dam^3$; and petroleum products and refineries: $18.55 per $dam^3$.

Frederick, VandenBerg and Hanson (1996) also reported a value of industrial water use based on a review of literature. Mean value in US dollars was $282 per acre-feet, while the median value was reported to be $132 per acre-feet. If converted to 2004 value in Canadian dollars, the mean value will be C$504 per $dam^3$ and the median value of C$236 per $dam^3$.

## 7.4 Value of Water for Mining

Mining in Alberta and Saskatchewan is a vital part of each province's economy. In the course of mining for minerals, oil, metals, or other non-metal resources, water is needed for many purposes. This includes processing, sanitation, cooling, and condensing. Mining can be characterized as a non-municipal industry as most mines or oil drills are located outside of urban municipal areas.

Literature on the valuation of water in the mining industry is limited. The only study for the SSRB that was found was that by Kulshreshtha et al. (1988), which pertained to the valuation of water in potash mining in Saskatchewan. The study suggested two methods that could be applied: direct approach and the alternative cost approach. Of these two approaches, the latter approach was deemed to be the most practicable.

The direct approach assumes that the value of water in potash mining is equal to the cost of acquiring the water for use in the mine. To use this method, one must first calculate how much water is used for the mining and processing of potash. Kulshreshtha et al. (1988) determined how much water (in $dam^3$) was needed to mine 1,000 tonnes of potash. The nest step in the direct approach is to then figure out the cost of the water system. The water system includes equipment for water intake into the mine, as well as machinery to treat the water for processing needs. Once the total annual costs of operating the water system are calculated, the dollar value can be converted into a unit ($\$/dam^3$) cost. From these two calculations, a value for water ($\$/dam^3$) can be estimated. This value provides a lower limit to the real value of water. This is because an assumption is made that "if the potash mines are willing to spend this money, it must be at least worth that much to them". In fact, it is conceivable that the benefits from that water use may be higher than that.

The alternative cost method compares the costs of production at normal water input with the least cost alternative means of production that generates the same output, but with lower water input. The difference in costs is associated with the value placed on water. When choosing the least cost alternative, it is important to note that for the long run, one must consider all costs of production while in the short run, only short run costs need to be regarded (Kulshreshtha et al., 1988).

The two methods of production to be compared in potash mining are conventional mining and brine processing. Mining involves the removal of ore from the surface using conventional methods. Water is then needed in the milling process to remove the potash from the ore. Brine processing involves water being forced into potash beds where it becomes saturated with potash. The brine solution is then brought to the surface for milling where the product is removed. The effluent left over from the milling process in the brine method is not able to be released into the environment, so it is considered to be entirely consumed. The cost of mining for potash using the brine method (which uses more water) is compared with the least cost alternative, conventional mining (which uses less water). The difference in costs between the two methods is regarded as the value of water in potash mining.

In the province of Saskatchewan, the value of water in mining was estimated to be \$240.00/dam$^3$ in 1986 dollars (Kulshreshtha et al., 1988). Using the Consumer Price Index, this value works out to be \$347.47/dam$^3$ in 2004.

In Newfoundland, A-G (1996) study estimated value of water in mining using demand function elasticities obtained from Tate, Renzetti and Shaw (1992). The study estimated this value in Newfoundland to be \$7.64 million (in 1994 dollars). Given a water use of 557 Mm$^3$ (equivalent to 555,000 dam$^3$), this represents a value of \$13.72 per dam$^3$ in 1994 dollars and projected to be \$15.91 per dam$^3$ in 2004 dollars.

# Chapter 8

# VALUE OF WATER FOR IN-SITU USES

In-situ water use refers to that part of the water that is removed from the source or, if removed, is available in its entirety to other users downstream. One of the major in-situ water uses is that for in-stream needs. This is to support various ecosystem functions related to rivers and lakes. It is a very important environmental aspect of water management and needs to be included in any water management decision. Unfortunately much of the information needed to undertake this valuation is missing, particularly regarding the minimum needs of stream flow to maintain a healthy ecosystem. For this reason, this value of in-situ water use is not estimated in this study.

Other major in-situ water uses include those for navigation, for waste assimilation, for recreation and for hydroelectric power generation. Of these uses, navigational water use is not a major use in the SSRB. With the exception of some ferries across the river at various points in the basin, the river system is not used for navigational purposes. For this reason this use is also excluded.

In this chapter, the three remaining in-situ water uses are values using secondary data. These include: hydroelectric power generation, recreational activities, and waste assimilation.

## 8.1 Value of Water in Hydroelectric Power Generation

### 8.1.1 Introduction

Hydropower generation uses water but does not consume water. Hydroelectricity is generated as water turns a hydraulic turbine which rotates the generator producing electricity. Once water has been through the turbine, it leaves the system and is returned to the river it came from but in a downstream location. The electricity load generated by hydropower for a given river depends on the number of feet of average net head on the river, and on the technology of the hydropower facilities (efficiency of converting kinetic energy of falling water to electrical energy) (Gibbons, 1986). Moreover, since each unit of water dropped over a given head makes the same amount of electricity, the physical productivity of falling water is constant; hence, the marginal and average productivities of water are the same (Gibbons, 1986).

The complicated issues of valuing water are not in identifying the physical productivity, but in assigning a dollar value per kilowatt-hour (kWh) produced by hydropower. In an unregulated market place, the commodity price which balances supply and demand at equilibrium represents the value of the commodity. However, the electric utility industry is price regulated. This makes the most practical means of deriving a marginal value of water the alternate cost of electricity generating electricity by another means (Gibbons, 1986; Kulshreshtha et al., 1988). The following sub-section describes the methods of valuing water in hydropower generation.

### 8.1.2 Conceptual Methodology of Valuation

The method of alternative cost of water is typically used to estimate the value of water for hydroelectric power generation. The alternatives sought in this context are the other means of generating the same amount of electricity. The simple assumption is that of substitutability; that is, electricity generated from one source is totally substitutable by that from another source. The alternative cost of valuing water would depend on how long the replacement is needed (short-run or long-run), and also on whether it replaces the base load or peak use of water. The methodology would, hence, encompass three values for water: the short-run marginal value, the long-run replacement capacity value and the long run average value and consider if the replacement is for base load or peak.

Short-run Marginal Value

In the short-run, all fixed costs and capital outlays are considered unchanged. The costs that are considered to change in the short-term are fuel, operating and maintenance costs. The alternative value of lost kWh worth of water would be electricity generated through gas turbine or coal. In general, hydropower is used for peak demands though some is used for base load as well (Bruneau, 2004). While coal is used during base load, gas is used during the peak. Hence, the short-run marginal replacement cost value would depend on weather the replacement was during the peak (gas) or base load (coal) period.

Long-run Replacement Capacity Value

If water is reduced from a given river *ad infinitum,* thus necessitating an increase in alternate electricity generating capacity for the region, the long-run value of water is used. This is calculated as the cost of new alternate electric capacity less the production costs of hydropower forgone (Gibbons, 1986). A caveat expressed by Gibbons is that it ignores consumer price demand elasticity in that, if the electricity prices rises as a result of new-capacity construction and rising fuel costs, the growth of electricity demand slows. As with the short-run marginal value, this value would also depend on what proportion of new capacity would be used for base load and what proportion is used for peak demand.

Long-run Average Value

This is the total cost of alternate electricity generation capacity (capital plus production) less total cost of hydropower (Gibbons, 1986). Again, it would be necessary to know what proportions are base load and peak.

### 8.1.3 Estimated Value of Water in Hydroelectric Power

Very few studies have attempted to estimate value of water in hydroelectric power generation for the SSRB. Two studies that have reported such values for the basin include Bruneau (2004) and Kulshsreshtha et al. (1988). Other relevant studies for Canada include that be A-G (1996) study and Muller (1985). Such values have also been reported for the USA by Frederick, Vandenberg and Hanson (1996). These are reported here first by location, and then by year of study.

Kulshreshtha et al. (1988) applied the method of alternative cost to measure the value of water in hydroelectric power generation. Results suggested a value between $7 and 18 per dam$^3$, which in 2004 dollars would be equivalent to $8 to $21 per dam$^3$.

Bruneau (2004) reported a value of water in hydroelectric power generation between $0.11 and $0.24 per dam$^3$.

Muller (1985) did not report a value of water in hydroelectric power generation in terms of per unit of water used, but on the basis of per kWH of electricity generated. Total value for Canada in 1980 was estimated to be between $4.2 and $6.6 billion, which, if translated in terms of per kWH, amounts to 1.6 to 2.49 cents in 1980 dollars.

The A-G study (1996) also reported a value of water in hydroelectric power generation but combined it with thermal power generation. In addition, the method was based on the residual imputation method, where all costs were deducted from the value-added. The total value of power generation for Newfoundland was reported to be $45 million. This value, on account of the method used is not comparable to any of the other studies.

In the USA, Frederick, Vandenberg and Hanson (1996) reviewed various studies related to value of water in hydroelectric power generation. The method of estimation used in these studies was not clear[11]. The mean value of water in 1995 dollars was $34 per acre-feet and the median value was $29 per acre-feet. Converting these values into Canadian 2004 dollars would result in an estimate of C$60.29 per dam$^3$ at the mean, and C$51.42 per dam$^3$ at the median.

## 8.2 Value of Water for Recreational Uses

### 8.2.1 Introduction

Nature based activities, including recreational water use, have an important place in the lives of Canadians. This is due to the ecological services provided by these ecosystems and the benefits to the lives of Canadians who participate in outdoor recreation. In the South Saskatchewan River Basin, there are a number of parks and recreational areas

[11] This is not to suggest that this method could not be deciphered from a review of original studies. However, time and resource constraints did not permit this activity.

providing access to water for recreational use. In Alberta and Saskatchewan, visitors to parks and recreational areas spent $901.7 Million (CAD) and $263.7 Million (CAD) respectively on nature related activities in 1996 (Statistics Canada, 2000). The willingness of people to spend this amount of money on nature based recreational activities represents a value of these natural areas for recreational use. However, determining the value of water in these recreational activities is more difficult. With no real directly observable market for nature based recreation, one must rely on other methods of determining the economic value of these activities (O'Grady, Brockman and Kulshrestha, 1987). These methods must be thorough in order to prevent inaccurate information being used in policy development. Otherwise there will be an inefficient use of nature to meet recreational demand.

This section looks at the value of water for use in recreation, and how much people in the South Saskatchewan River Basin (SSRB) use water for recreational purposes. There is an economic value of water since the water must be allocated away form other potential uses[12]. This would present an opportunity cost of the water used in recreation since it may not be available for diversion direct consumption[13] or as an input for in-stream ecological services. The water used for recreation may still be used as an input for other uses as long as the quality of the water is still high enough to support other potential uses. Generally speaking, water used for recreation is typically a part of a stream, river, or lake where the flow or stock of water will be unaffected by recreational use.

The question is: is this price economically efficient? To begin to address the question – "what is the economic value of this water allocated for recreation?": this section will review the level of participation in water recreation by people who visit provincial parks in the SSRB, surveys that are intended to show the preferences for different types of activities with respect to water recreation, and estimates of economic value of water for recreation.

### 8.2.2 Water Recreation in the South Saskatchewan River Basin

The SSRB contains provincial parks and recreation areas within Alberta and Saskatchewan, the most of which lie in Alberta. This is due to larger numbers of sub-basins containing rivers, and a higher population in Alberta[14]. Swimming, boating, and

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12 However, the amount explicitly allocated for recreation by governments is usually quite small due to recreation, and non-use in-stream services have low priority over other uses.

13 These uses include: domestic, municipal, industrial (both input and output waste), agricultural, and irrigation.

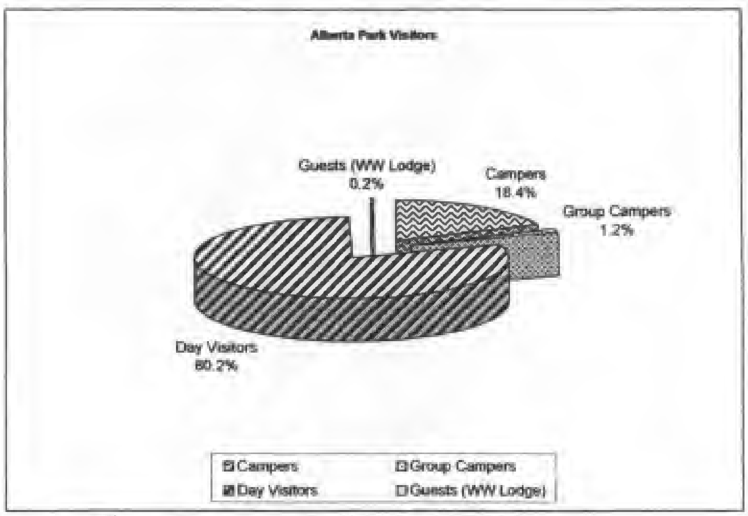
14 It is assumed that there will be an investment in parks and water recreation based on population. The higher the population, the more parks will be present. As well, more adjoining rivers, streams and tributaries are in Alberta.

fishing are the direct uses of water for recreation in these parks and enjoying the picturesque view of the water is an indirect use of the water for recreation[15].

Parks in Alberta

There are 15 provincial parks and 26 recreational areas in Alberta that lay within the SSRB (Alberta Community Development, 2004)[16]. More details on these are provided in Appendix C. These parks and recreational areas offer a variety of services to facilitate water recreational use, namely beaches (swimming), boat launches (boating, waterskiing, and fishing), and trails (non-use enjoyment) (Alberta Community Development, 2004).

There were a total of 8.2 million visitors to the parks and recreational areas of Alberta (Alberta Community Development, 2004)[17]. The large majority of these visitors to parks, as shown in Figure 8.1, were day users[18] followed by campers, group campers[19], and those staying in hotels and cabins[20] (Alberta Community Development, 2004). The parks that were closer to larger urban areas tended to have higher numbers of visitors than parks further away due to the reduced travel cost.




Source: Alberta Community Development (2004).

**Figure 8.1. Distribution of Visitor Types to Alberta Parks**

15 For example, activities such as walking, biking, hiking, etc. are included here.

16 Based on a visual count of recreational sites and provincial parks.

17 This is for ALL parks and recreation areas, not just the ones in the SSRB. Data for the SSRB parks was not found.

18 These visitors include those who travel to the park and back home again in the same day.

19 These are people who camp in larger groups sometimes taking up several campsites.

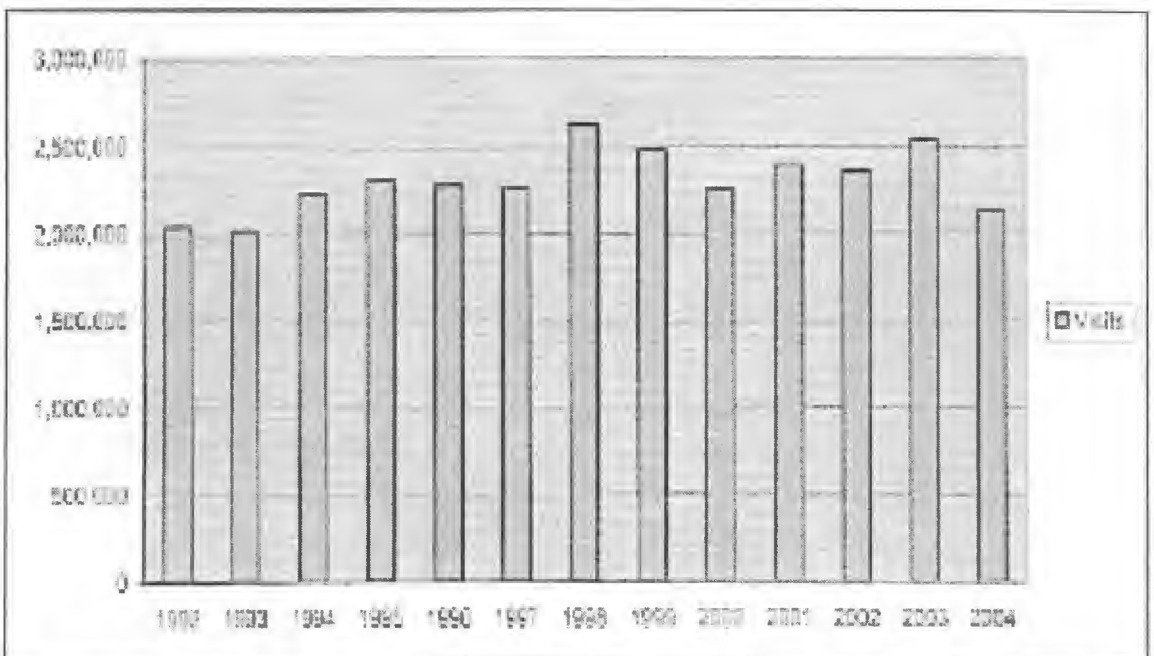
20 These are referred to as "fixed roof" accommodations (Alberta Community Development, 2004).

This high level of day use requires that parks be close to urban areas in order to ensure that visiting for the day is a feasible venture. Many parks in the Alberta portion of the SSRB lie within an hour's drive of Calgary, Red Deer, or Lethbridge. This creates opportunity for visitors to make day trips and to avoid the extra cost of overnight stays and long travel times. In 1996, Albertans spent $901.7 Million (CAD) on nature based activities[21]. This includes all expenses relating to recreational water use like travel, accommodation, fees, etc.

Parks in Saskatchewan

There are about 22 parks and recreational areas along the Saskatchewan portion of the SSRB[22]. The Diefenbaker Lake consists of the largest water storage along the SSRB and has three parks associated with it alone. These parks provide access to water sources for recreational purposes as in Alberta.

Saskatchewan, as shown in Figure 8.2, had a total of 2,124,333 people visiting provincial parks during 2004 season (Saskatchewan Environment, 2004). Generally the number of visitors is between 2 million to 2.5 million (Saskatchewan Environment, 2004). More details on these trends can be found in Appendix C.




Source: Saskatchewan Environment (2004).

**Figure 8.2. Saskatchewan Provincial Parks Recorded Visits, 1994 to 2002**

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21 Data on expenditures by Albertans for years after 1996 were not available or accessible for use in this report.

22 Based on 37 provincial parks in Alberta and Saskatchewan in the SSRB (O'Grady et al., 1986), with 15 being in Alberta. The remaining 22 were then classed as those within the Saskatchewan portion of the SSRB.

Visitors to Saskatchewan's parks spent a total of $129 Million (CAD) in 2003 (Derek Murray Consulting Associates, 2004). This generated an increase of $64.16 million to Saskatchewan's economy as a result of participation in park based activity (Derek Murray Consulting Associates, 2004). Like Alberta, this includes all aspects of travel, accommodation, and equipment.

### 8.2.3 Participation in Water-Based Recreational Activities

In 2003, a survey was conducted by the Community-University Institute for Social Research (CUISR) to understand better how people felt about the water resource management of the Saskatchewan River Basin. In this survey, people were asked about their water recreation activities and preferences. Although specific data on the SSRB were not collected, these do represent a good picture of the SSRB activities. Table 8.1 summarizes the results. The indirect uses of water for recreation were the most popular with swimming as the most popular direct recreational use of water (Ofosuhene, 2003). Surveys such as these provide an idea of what people value the most about their water recreational activities and of what most are willing to pay for the activities.

**Table 8.1. Survey Results of Water Recreation Preferences for Residents of the Saskatchewan River Basin, Alberta and Saskatchewan Portions**

| Type of Activity | Alberta (n=116) | | Saskatchewan (n=76) | |
|---|---|---|---|---|
| | Average # of Times | Percent Involved | Average # of Times | Percent Involved |
| Walking/Cycling on Shore of River/Lake | 45 | 81% | 35 | 78% |
| Camping/Cottage by Lake/River | 11 | 65% | 14 | 62% |
| Swimming/Wading | 18 | 60% | 16 | 58% |
| Sport Fishing | 12 | 31% | 16 | 40% |
| Canoeing/ Sport fishing | 8 | 43% | 6 | 30% |
| Power Boating | 9 | 28% | 12 | 32% |
| Photography/Painting | 20 | 28% | 12 | 29% |
| Hunting | 15 | 10% | 12 | 8% |
| Jet-Skiing | 29 | 5% | 7 | 9% |
| Commercial Fishing | 94 | 1% | 7 | 3% |

Source: Ofosuhene (2003), p. 29.

According to this survey, most people made use of these recreational facilities in terms of walking/cycling on shores, or in terms of camping/cottages by the lakes and rivers.

### 8.2.4 Valuation of Water Recreation: Existing Studies

This section summarizes the results of a literature search for existing studies on the value of water for recreation. The search included the *Environmental Valuation Reference Inventory* (EVRI) by Environment Canada (2006), library sources form the University of Saskatchewan, and sources from the internet. The items found are listed in Table 8.2. Kulshrestha et al. (1988) estimated the value of water in recreation in the province of Saskatchewan to be anywhere between \$2.00 to \$787.00/dam$^3$ (1984 dollars) in the short run. These values for recreation included only recreational water users and not existence, option, or bequest values for water. Translation of the 1984 value using the Consumer Price Index provides a value between \$2.90 and \$1,139.42/dam$^3$.

**Table 8.2. Estimate Value of Water in Water-Based Recreational Activities**

| Author's Name & Year of Publication | Location of Study | Method of estimation | Preliminary Results: Value of Water Recreation |
|---|---|---|---|
| Aiken (1985) | Fort Collins, Colorado | Contingent Valuation | \$1,344.5 million NPV state-wide |
| Carson and Mitchell. (1993) | Across US | Contingent Valuation | Annual Aggregate benefit of \$29.2 billion, (1990 U.S. dollars) |
| Greenley, Walsh, and. Young (1981) | South Platte River, Colorado | Contingent Valuation | Option Value for Recreational use was \$23 per household |
| Kulshreshtha and Gillies. (1993) | Saskatoon SK | Contingent Valuation | River Value of \$2.6 million for residents in 1989 |
| Lang (Undated)* | Braddock Run Watershed, Maryland | Various, based on review of studies | WTP of \$10.98 to \$27.17 per day for trout fishing |
| O'Grady, Brockman and Kulshreshtha, (1987) | South Saskatchewan River Basin | Travel Cost (TC)& Contingent Valuation (CV) | WTP per trip of \$31.94 - \$72.91 (CV), & \$26.79 - \$62.03 (TC) |
| Sutherland and Walsh (1985) | Flat Head Lake, Montana | Contingent Valuation | WTP of \$7.37 for water recreation (1981 USD) |
| UMA Engineering ltd. (1990) | South Saskatchewan River Basin | Contingent Valuation & Travel Cost | Site values ranged from \$458,000 per season to \$20,000 per season |
| US fish & Wildlife Service. (2001) | Across US | Analysis of attendance, and expenditure data | \$6.39 per day for fishing in US |
| Ward, Raoch, & Henderson (1996) | Sacramento, California | Regional travel cost model | WTP of \$6 to \$600 per acre-foot of water. |
| Adamowicz and Phillips (1983) | Alberta | Willingness-to-pay | \$73.93 per day |
| Muller (1985) | Canada | | \$20 - \$74 per dam$^3$ |
| Frederick, Vandenberg and Hanson (1996) | U.S.A. | Review of Past Studies | US\$48 per acre-feet (Mean) and US\$6 per acre-feet at the median. |

* The exact year of the study is not listed on the National Resources Conservation Services website where this study is summarized. The website is http://www.economics.nrcs.usda.gov/technical/recreate/ and was updated on Feb 14, 2006

Review of other studies also indicates that the value of water in recreation is a highly variable entity and very location- and activity-specific. There is no question whether or not people value water for use in recreation. Whether they enjoy walking by a river or lake, swimming, or boating, there is a definite benefit.The problem is the non-market nature of these activities. Without an observable market for these services, there is difficulty in discovering what the economically efficient price for the water is.

The methods that have developed over time all offer a means of determining the WTP for the water recreation experience, each has its benefits and drawbacks in their application. Generally the best method is one that obtains greater amounts of good information for analysis. This, however, involves more time and financial resources to complete. Society needs to be willing to pay for the information needed to ensure sound choices about the use of natural resources are made.

There is a general lack of studies that address water value for recreation in the SSRB. The studies that could be found were from 1989 to 1993 and are in need of updating. Knowledge of water management issues and public attitudes has changed greatly since these last studies were done. Further research is needed to bring the current knowledge up to date, as well as add to the knowledge of the EV of water based recreation.

## 8.3 Value of Water for Waste Assimilation

### 8.3.1 Introduction

Flowing rivers have the ability to absorb and dilute all kinds of anthropogenically-generated wastes. Point source pollutants are identifiable and directly enter the streamflow. This type of pollutant is generally from industrial or municipal wastes, or from effluent from treatment plants. The wastes must be extensively diluted before being released into the environment. Pollutants discharged into the water contain several components: nitrogen (N), phosphorus (P), bacteria, viruses, heavy metals, and other toxins. These elements are all biochemical oxygen-demanding (BOD) materials which depletes the stream or river of oxygen. Water contamination of BOD materials has negative and potentially dangerous consequences not only to aquatic ecosystems, but to human health as well (Gibbons, 1986).

Dilution flows are the major tools used to minimize the impact of pollutant discharge into rivers and streams. Waste assimilation potential is increased when water is added to the river to augment its flow. This release of storage water is a very important use of reservoirs. Natural stream and river flow is dependant on seasonal variations within the hydrological cycle. Thus, the value of water in waste assimilation is also affected by natural changes in stream-flow (Gibbons, 1986).

### 8.3.2 Review of Studies Dealing with Value of Water

Gibbons (1986) suggests that water has a value in this use because waste assimilation reduces damages to the environment. This study outlined two methods for the valuation of water in waste assimilation. The first approach is the direct method in which the benefits of dilution are a betterment of water quality and reduction of ecological damage.

This approach can be difficult to implement because damages are difficult to estimate. Also, the dilution of wastes in a water body is not the only way to reduce or mitigate damages.

A second suggested approach is the alternate cost method. This method assumes that the value of dilution water is less than the cost of providing the same quality water (without dilution) as a result of treating the effluent. The alternate cost framework compares the cost of dilution in the river with an alternative means of treating polluted effluent. This is a particularly good technique for point source pollutants because alternate treatment costs are usually well known. Whichever valuation technique is used, it is imperative to also know the quantity of dilution water from which to determine the financial advantage of dilution. This requires knowledge of the water quality in a given stream at different levels of dilution flow (Gibbons, 1986).

The A-G study (1996) estimated the value and benefits of water in waste assimilation in Newfoundland. The authors used the replacement cost approach to put a value on water used by communities in the dilution of waste. The focus of the study was on industries which discharged wastewater directly into fresh water with the methodology being applied to municipalities. For municipalities, to calculate the indirect use value for waste assimilation it is necessary to know the average yearly per capita total treatment cost ($/year) and the population of the municipality. Economic value of water treatment was calculated as the amount of untreated waste generated per person per year multiplied by the cost of treatment. In this study, this value was calculated to be $1.79 million for a community of 28,539 people. To figure out the total benefit provided by water to municipalities which discharge into freshwater, this value was then added to the economic value of residual loading. The successful removal of BOD and total suspended solids (TSS) is calculated for each treatment and subtracted from the total amounts present in the untreated wastewater. These values for residual pollutants were then divided by the per capita generation of pollution (0.08 kg BOD and 0.09 kg TSS/person/year) to get an estimate of the number of people that would generate the amount of waste. Finally, the estimate was multiplied by the per capita treatment cost of treating *municipal* wastes to calculate the economic value of residual waste. In this study, the value of residual loading was found to be $1.38 million. Therefore the total benefit to the municipality of water in waste assimilation is $3.17 million (A-G study, 1996).

Using the alternative cost method, Gray and Young (1974) found the value of water in BOD assimilation to be ~$1.00 per acre foot (1980 dollars) in numerous river basins. In the removal of salt pollution and thus the reduction of the salinity of the river, the water was valued at $9.00/af (1980 dollars). Waste heat from industrial processes also adds to the pollution of the river. Using the same method, Gray and Young (1974) estimated the value of water in assimilating waste heat from the river at approximately $10.00/af (1980 dollars). For total waste assimilation (including BOD, salinity, and heat) the value of water is estimated to be $20.00/acre-feet in 1980 dollars, which works out to be $33.94/dam$^3$ (2000 dollars) (Gibbons, 1986).

Muller (1985), following the study by Fraas and Manley (1984) for the USA, reported a value of water for waste assimilation ranging from $1 to $4 per dam$^3$. Translating this value to reflect 2004 WTP resulted in a value of $1.2 to $4.8 per dam$^3$. This value is closer to that reported by Fredrick, Vandenberg and Hanson (1996) of $3 per acre-feet (at mean) and $1 per acre-feet at the median.

# Chapter 9

# ECONOMIC VALUE OF WATER QUALITY

## 9.1 Degradation of Water Quality

Agricultural practices typically cause non-point source pollution that can have detrimental effects on both surface and groundwater quality. A primary source of this pollution is from the leaching of nitrogen fertilizers (Jordan and Elnagheeb, 1993). Other water quality problems that have also been identified with agricultural lands (USDA, 2003) include the following:

- Eroding and collapsing banks can remove valuable agricultural land, particularly if left unchecked;
- Soil from bank erosion becomes sediment in the waterway which can damage aquatic habitat, degrades drinking water quality, and fill wetlands, lakes, and reservoirs.
- Nitrates and pesticides can be toxic to humans and aquatic organisms;
- Fecal bacteria and other microbes in animal wastes can cause disease; and,
- Phosphate can promote algae blooms which suffocate fish and other aquatic organisms.

In addition, flooding caused by larger storm runoff can erode valuable cropland, and deposit debris in fields. Runoff from agricultural or urban land can contain harmful pesticides or fertilizers which can be deadly to aquatic organisms. The seepage of chemicals into the water table and nitrate-containing acid rain pose a threat to all organisms that depend on water for their survival–including humans (Gibbons, 1986).

Water quality is an issue that has come into a very close scrutiny since the occurrence of such problems in Walkerton, Ontario and in North Battleford, Saskatchewan. In part, this is because social costs from such disasters can be very high financially, and in part, because of their impacts on humans, such issues become highly emotionally charged. According to Livernois (2002), the tangible costs to society from any future contamination in magnitude similar to Walkerton are estimated at $64.5 million. Although no economic costs for the North Battleford incident were reported, the Commission of Inquiry (see Laing, 2002) recommended a series of measures to protect water quality in the province, which may have serious cost implications both for the water users as well as for the regulating authorities.

Water quality affects households in many different ways. Besides human health and mortality impacts, it is also a factor in water-based recreation demand, as suggested by Parkes (1974). According to this study, users of the lakes with poor water quality are willing to pay a significant amount per user-day per season over and above the additional costs that are normally incurred in the recreation experience.

Improvement of groundwater quality is also linked to riparian area management. However, some caution is advised here as Raucher (1986) has reported that potential contamination sites are unique, and efficiency of alternative policies would be site specific. Furthermore, he noted that benefits from preventing groundwater contamination might not always exceed its cost. However, Ducks Unlimited (see Gabor et al. 2001) has argued that investment in wetland and riparian area protection and restoration is probably a cost-effective way to improve water quality.

Water quality affects households as well as the municipalities through increased water treatment costs. Thus, valuation requires a different methodology for the two groups of entities.

## 9.2 Valuation of Water Quality for the Households

Valuation of water quality improvements is a complex subject. Value can be estimated as the willingness of consumers to pay for improvements in the quality of water. Economic value of water quality improvements has been a subject of several studies in Canada. Hauser and van Kooten (1993), in a study of the Abbotsford aquifer, British Columbia, estimated the lower bound for these benefits at $70/household in terms of defensive expenditures. Their willingness-to-pay was estimated between $78-$90 / household. Similar results were shown by Athwal (1994).

The only Saskatchewan study that has estimated the benefits of riparian area improvement is by Spasic (2002). He undertook a survey of 300 randomly selected Saskatchewan residents and estimated their willingness-to-pay for riparian management. The sample consisted of 60.7% urban households, 15.3% rural non-farm (towns) households, and 15.3% farm households. The average willingness-to-pay for such improvements was estimated at $39.92 per household, with the median value being $23.60 per household. The willingness-to-pay in this study was an average over all households. No distinction was made for the type of households.

The contingent valuation method (CVM) can also be employed as a direct means to estimate WTP (Jordan and Elnagheeb 1993). This method is useful in that it can elicit values for non-market goods by asking consumers what they would pay for water quality under certain conditions (Dybvig and Kulshreshtha, 1989). It includes option, bequest, and existence values for water as well as an estimation of option prices for water quality protection.

The CVM uses dichotomous questioning, checklists, open or closed questions to approximate the willingness of consumers to pay for the quality of water they use (Jordan and Elnagheeb 1993). The CVM method was used in 1991 by Jordan and Elnagheeb (1993) to determine what Georgia residents were willing to pay for water quality improvements. The study found that the median WTP among residents was $ 65.88 USD/ year ($75.14 CAD) for residents using a public water supply, and $ 88.56 USD/year ($101.00 CAD) for those using a private supply. These values are in 1991 funds. The survey also questioned the income and residence of respondents. It was found that those with higher levels of income were willing to pay more for improvements in their water quality. Also, farm or ranch dwellers were willing to pay more compared to those living outside a farm or ranch setting (Jordan and Elnagheeb 1993).

Another CVM survey was conducted in 1994 in the Grand River Watershed in Ontario. Residents were asked a series of dichotomous choice questions regarding their willingness to pay for improvements in water quality and their willingness to accept compensation for a loss in water quality. The mean WTP for improvements ranged from \$2.33 CAD to \$11.50 CAD (1994 funds) per household per month. This was equivalent to \$27.96 to \$138.00 per household per year (1994 funds). These values were calculated only from surveys that provided positive WTP/WTA responses (Brox, Kumar and Stollery, 1996).

A benefit/cost analysis (B/C) can also be used to evaluate the benefits incurred from improvements in water quality over the cost of implementing best management practices (BMPs). The protection of water quality is not priced; therefore non-market valuation techniques must be used. Benefit transfer methodology is a means to estimate this using data from previous studies (Salvano et al., 2004).

Another method that can be applied for the valuation of water quality is the averting-behavior costs. Here the costs incurred to select alternative sources of water can be equated to the value placed by people on having good quality water. The costs of practices such as buying bottled water, installing filtration systems, or changing routine for example, the boiling of contaminated water, are used to approximate the value of water quality improvements. This estimate provides a lower bound on the economic value because there are other extenuating household costs from water pollution that cannot all be accounted for in this manner (Dunford and Murdock, 1997).

Demand function techniques can be applied to residential, commercial, and governmental sectors to estimate the value of municipal water quality. Over time, data can be collected on both the price of water and the quantity consumed. When the water supply becomes contaminated, municipalities must embark on expensive measures in order to replace or treat the polluted water. These high costs are transferred to the customers in the form of higher water prices. The loss to the public as a result of contaminated groundwater can be used as a measurement for the value of non-polluted water. The loss to the public is the reduction in consumer surplus. When water prices increase, consumers receive fewer surpluses as the area under the demand curve and above the price line decreases (Dunford and Murdock, 1997)

No study was found that estimated the cost of water treatment with degraded water quality. In theory, one would expect these costs to be higher, but their magnitude is a subject for empirical scrutiny.

# Chapter 10

# SUMMARY OF VALUE OF WATER

## 10.1 Introduction

In the South Saskatchewan River Basin (SSRB), water is used in a variety of economic and social activities. All activities can be broadly divided into two categories: those that depend on withdrawal of water from the source, and those where water is used in the source itself, called in-situ use. Water is a valuable commodity. Not only does it directly sustain human life through drinking, but activities such as industry and irrigation rely on water for the manufacture of their end product. With such a variety of uses, water itself possesses a different economic value for each different function. This chapter provides a brief summary of the value of water in alternate uses which have been discussed in previous chapters of this report.

## 10.2 Value of Water in Alternate Withdrawal Uses

### 10.2.1 Value of Water in Agricultural Uses

Agricultural water uses include water used for irrigation and for stockwatering purposes. As noted in Chapter Three, irrigation is the largest use of water in the SSRB. For this reason, more attention was paid to this water use, although other uses were also studied.

Estimation of value of water for irrigation was undertaken using the concept of producer surplus. This is the additional income in the hands of the producers from converting crop area from dryland production system to irrigated production system. Furthermore, it was undertaken by assuming two time periods – short-run and long–run. In the short run, value of water reflects return to all fixed factors of production. In the long-run, however, all factors are paid for, except those that are owned by the producers. Thus, the long-run value of water represents returns to all owned resources (land, labor and capital). These values should not be interpreted as the producer's willingness-to-pay for the water, since they include returns to owned labor and management. In order to establish producers' WTP, such owned resources should be paid for first.

Value of irrigation water was also estimated on a disaggregated basis. All five sub-basins of the SSRB were included. Although marginal values of water were also estimated for the five sub-basins, these are not reported here. Table 10.1 below outlines the values of water for various agricultural uses. As one would expect, short-run value of water for irrigation was higher than that estimated for the long-run. On a per $dam^3$ basis, water was estimated to have higher value in the Lake Diefenbaker Development Area (LDDA).

**Table 10.1. Value of Water in Agricultural Uses, SSRB, 2004**

| Sub-Basin | Short-run Value per Dam$^3$ | Long-run Value per Dam$^3$ |
|---|---|---|
| **Irrigation** | | |
| | *Alberta Portion of SSRB* | |
| Oldman | $78.13 | $38.60 |
| Bow | $48.01 | $26.68 |
| Red Deer | $52.24 | $26.15 |
| SSRB-AB | $72.64 | $30.41 |
| | *Saskatchewan Portion of the SSRB* | |
| LDDA | $272.75 | $201.82 |
| SWDA | $36.22 | $23.09 |
| Average SSRB-Saskatchewan | $235.81 | $173.91 |
| **Non-Irrigation** | | |
| Drought Proofing -- Saskatchewan | | $7.68 to $11.05 |
| Drought Proofing -- Alberta | | $11.05 to $28.87 |
| Livestock (this Study) | | $9.22 |
| Livestock (Bruneau 2004) | | $46,330 |

Two possible explanations for this higher value could be hypothesized. One, water use per ha in the LDDA is the lowest of all sub-basins in the SSRB. As reported in Chapter Five, water use in the LDDA was reported to be only 2.21 dam$^3$ ,whereas in Alberta for sprinkler irrigation water use per ha ranged between 4.08 to 5.78 dam$^3$. This power water use may be a result of the pipelines that are used in much of the LDDA, whereas much of irrigation water in Alberta is distributed using canals. Two, a major part of the irrigated crop mix in the LDDA is under seed potatoes which are reported to yield higher net returns under irrigation than many other specialty crops.

In addition to increasing the profitability of crops, irrigation provides two other benefits to producers: one, it reduced the variability in production due droughts, and two, irrigated farms have a higher density of beef cattle than dryland farms. This is because of the higher availability of forages under irrigation. The second effect was not estimated in this study since it requires data that are not easily available. Value of water for drought proofing in the SSRB, adjusted for drought frequency, was estimated to range from $7.68 to $20.07 per dam$^3$ for Saskatchewan and from $11.05 to $28.87 per dam$^3$ for Alberta. This is the additional producer surplus created by having irrigation on farm.

Value of water for livestock production was estimated using the concept of alternative cost. If surface water was not to be available, producers would likely develop wells and use groundwater. However, this is a more expensive method of providing water for livestock watering needs. This value was estimated to be around \$9.22 per $dam^3$.

### 10.2.2 Value of Water in Non-Agricultural Uses

In addition to agricultural uses of water, there are several non-agricultural water uses that are present in the SSRB. These include municipal, industrial, mining and thermal power generation water uses. These uses were valued using secondary data based on other studies. Preference was first given to Canadian studies, although the US studies were also consulted for a comparison purpose. Values for various non-agricultural water uses are shown in Table 10.2.

**Table 10.2. Value of Water in Non-Agricultural Withdrawal Water Uses**

| Type of Use | Author | Location of Study | Value per $dam^3$ in 2004 Canadian Dollars |
|---|---|---|---|
| Municipal – Residential | A-G Study (1996) | Newfoundland | \$561 |
| Municipal – Industrial | A-G Study (1996) | Newfoundland | \$616 |
| Municipal – Commercial | A-G Study (1996) | Newfoundland | \$638 |
| Municipal – Residential | Bruneau (2004) | SSRB | \$1,270 to \$2,040 |
| Municipal – Commercial and Industrial | Bruneau (2004) | SSRB | \$1,410 to \$2,170 |
| Industrial | Bruneau (2004) | SSRB | \$80 to \$49,000 |
| | Renzetti (1986) | British Columbia | \$1.40 to \$71.40 |
| Mining | Kulshreshtha et al. (1988) | Saskatchewan potash mining | \$347.47 |
| | A-G Study (1996) | Newfoundland | \$15.91 |
| Thermal Power Generation | Muller (1985) | Canada | \$9.60 |
| | Bruneau (2004) | SSRB | \$1.12 to \$627 |

Value of water in the SSRB was estimated by Bruneau (2004) using 1996 community water use data for the SSRB communities. This value was \$1,270 to \$2,170 per $dam^3$. In this study no distinction was made among the various users of municipal water. A study for Newfoundland was then used (see A-G Study, 1996). The value of water was found to be higher for commercial operations in a municipality, followed by industrial and then residential and other users.

Industrial water use valuation is very complex and requires primary data collection. This was not attempted in this study. Values provided by Renzetti (1986) were updated for this study. These values ranged from \$1.40 per dam$^3$ to \$71.4 per dam$^3$ for the food and beverage industries.

No study on value of water use for mining was found except the earlier Saskatchewan study by Kulshreshtha et al. (1988). This value was for potash mining and when projected to 2004 value was estimated to be \$347 per dam$^3$. The only other Canadian estimate that estimated value of mining water was that by A-G study (1996) for Newfoundland, where the value of this water use was significantly lower than that for Saskatchewan (at \$15.91 per dam$^3$). However, the nature of mining for which this water was used was not clear from the study.

Value of water in thermal power generation for the SSRB was estimated by Bruneau (2004). This value was estimated as a range between \$1.12 and \$627 per dam$^3$.

## 10.3 Value of Water in Alternate In-Situ Uses

In addition to the withdrawal uses of water, several economic / social activities are undertaken using water in the SSRB. These activities include generation of hydroelectric power, use of reservoirs and rivers for recreational activities, and use of rivers for waste assimilation. Results of value of water in these uses are summarized in Table 10.3.

**Table 10.3. Value of Water in Non-Agricultural In-Situ Water Uses**

| Type of Use | Author | Location of Study | Value per dam$^3$ in 2004 Canadian Dollars |
|---|---|---|---|
| Hydroelectric Power Generation | Frederick, Vandenberg and Hanson (1996) | USA | \$60.29 |
| | Bruneau (2004) | SSRB | \$0.11 to \$0.24 |
| | Kulshreshtha et al. (1988) | Saskatchewan<br>Short-run Base<br>Short-run Peak<br>Long-run | <br>\$1.57<br>\$15.31<br>\$0.27 |
| Recreation | Kulshreshtha et al. (1988) | Saskatchewan | \$2.90 to \$1,139.42 |
| Waste Assimilation | Muller (1985) | Canada | \$1.20 to \$4.80 |
| | Kulshreshtha and Gillies (1993) | Saskatoon (South Saskatchewan River) | \$15.92 to \$21.71 million * |

* Total value for waste assimilation. Value per unit of water not estimated.

The only study that estimated a value for the SSRB was that by Bruneau (2004) who estimated the value of water in hydroelectric power generation to be very low (between

$0.11 to $0.24 per dam$^3$). No other study was found that was close to these uses in the SSRB. Extending the review to other Canadian studies led to a study by Muller (1985) that reported value of water for waste assimilation to range from $1.20 to $4.80 per dam$^3$. The only study on value of water-based recreation was that undertaken for Saskatchewan by Kulshreshtha et al. (1988), where the 2004 project value was estimated to vary from $3 - $1,139/dam

# PART THREE

# CLIMATE CHANGE AND VALUE OF WATER

# Chapter 11

# INTERRELATIONSHIPS BETWEEN CLIMATE CHANGE AND VALUE OF WATER

There is a general agreement that climate change (through greenhouse warming) will have major impacts on water resources. Many of these changes would be a result of changes in the hydrological cycle, altering precipitation, the magnitude and timing of run-off, and the intensity of floods and droughts in various parts of the world (Frederick and Major, 2002). Accordingly, sensitivity to climate in Canada and the cross-cutting nature of the water issues are important considerations for future water management in semi-arid and arid regions of Canada, such as the SSRB. Decreased water levels, according to Lemmen and Warren (2004) would impact many sectors, including transportation, tourism and recreation, fisheries, industry and energy, municipalities, agriculture and health. It is reasonable to predict that the value of water will be influenced under climate change, but to what extent is highly unknown.

Study of climate change impacts on water resources is a complex area. Even more complex is the investigation of the issue of how water will be valued under a different climate regime. As will be made clear later on this chapter, very few studies have addressed this issue, either for SSRB, Canada, or elsewhere in North America.

The primary objective of this chapter is to review the nature of studies undertaken on this subject, and to develop a conceptual model for the study of water values. It begins by outlining the conceptual interrelationships that would be used in understanding climate change and water value. This is followed by a review of the literature on climate change impacts on water supply, water use and water value. The last section proposes a methodology for valuing water under expected climate change.

## 11.1 Conceptual Interrelationships between Climate Change and Value of Water

Climate change refers to changes in the climate of the earth due to the increased amount of heat-trapping greenhouse gases found in our atmosphere (Government of Canada 2004b). It is an issue that has become of great concern to the Canadian economy over the past few years. The Intergovernmental Panel on Climate Change (IPCC), Third Assessment Report (TAR) is unequivocal that the climate is changing and with limitations; they have both detected[23] and attributed[24] climate change to natural and anthropogenic forcing agents (Albritton et al., 2001). However, the magnitude and

[23] Detection shows that a change in the climate is statistically significantly different from that can be explained by natural variability, but does not necessarily imply a particular cause (Albritton et al., 2001).

[24] Attribution, nonetheless, establishes a cause and effect with a specific degree of confidence (Albritton et al, 2001).

direction of expected climate changes has been both hard to define, as it would not be correct for statistical models to extrapolate past data (Albritton et al., 2001).

Major physical impacts in the context of water resources include the following:

- An increase in the average temperature
- An increase of slight decrease in some region in precipitation
- Change in the intra-seasonal distribution of precipitation, and
- Increase likelihood of extreme events, such as floods and droughts.

The magnitude of these changes would vary according to location, although higher impacts are predicted for the higher latitudes, such as the SSRB and northern Prairies. The IPCC predicts a temperature increase of between 1.4° C to 5.8° C by the year 2100 (Natural Resources Canada, 2002), which will likely have great impacts on the society. Change in the intra-seasonal distribution of precipitation would have an impact on agricultural water use, particularly for irrigation. Similarly, increased frequency of droughts would reduce the net returns from dryland agriculture and may provide enough incentives to producers to switch to irrigation. Other sectors may also find the need to make adjustments in their water use under an altered climate regime.

For the prairies, temperatures would increase by 2 to 4.5 degrees Celsius, with a greater increase in the southern most parts of the prairies. The area covered by the SSRB would see mean annual minimum temperatures rise by 4 to 4.5 degrees Celsius of the 1961-1990 mean values (-5 to 0). Mean annual maximum temperatures would rise by 3 to 3.5 degrees Celsius from the 1961-1990 mean values (9 to 12). Precipitation in the southern most prairies would not increase more than 5% from the 1961-1990 mean (an increase of about 3.75-15 mm from the 1961-1990 mean values 285-450 mm). Despite the precipitation increase the moisture deficit (precipitation minus the potential evapotranspiration) would increase in all of the prairies, except for the mountains. The moisture deficits for southern Alberta and southern Saskatchewan would be between 375 to 490 mm between the forecasted 2040-2069 period (they used to be between 300-425 mm between 1961-1990). The Temperature Factor or Effective Growing Degree Days (EGDD) calculated from the season length, degree days, and day length is expected to be around 2000 to 2400 for the southern prairies, which is a considerably longer growing season from the 1200 to 1650 EGDD values seen between 1961 and 1990.

Impact of climate change on value of water would be a culmination of impact on water supply (availability) and its use, further complicated by institutions and their policies. Since the focus of this study is not on the water supply issues, these are reviewed in lesser details. More details are described for water use, with implications for water value.

### 11.1.1 Impact of Climate Change on Water Supply (Availability)

Literature is very rich in terms of impact of climate change on water supply. Early studies on climate change impacts on water supply or on hydrology include Stockton and

Boggess (1979), Revelle and Waggoner (1983), Nemek and Schaake (1982), Gleick (1987b) Lettenmaier et al., (1992), Waggoner (1990), Frederick, Vandenberg and Hanson (1993). Investigations into the relationship between climate change and water were commissioned by the American Association for the Advancement of Science (AAAS) panel on climate variability, on climate change, and on the planning and management of US water resources. Based on a review of various studies, the following impacts are discernible:

(1) Change in Temperature and precipitation regimes affecting stream flow: Most studies point to the fact that changes in temperature and precipitation will likely effect run-off and evaporation patterns, the amount of water stored in glaciers, snow packs, lakes, wetlands soil moisture and ground water, but the magnitude and direction of these changes are uncertain. In general, it is predicted that climate change will increase precipitation, evaporation, water temperature and hydrologic variability. In the context of the SSRB, the most important stress to the water supply that may occur as a result of climate change is the decrease in snowmelt runoff, a large source of water. Of the total water supplied to the South Saskatchewan River Basin, 90 per cent flows from the Rocky Mountains while the remaining 10 per cent comes from prairie run-off (Prairie Adaptation Research Collaborative, 2005). Already, 32 significant trends have been found in the flow of the North and South Saskatchewan Rivers at the Alberta-Saskatchewan border, only five of which are increasing. The remaining 27 trends show a significant decrease in the flow of these rivers (Shrubsole and Halliday, 2003).

The AAAS panel's final report was edited by Waggoner (1990). In this report, it was mentioned that even though the panelists could forecast that temperatures were rising, there was less clarity on the direction regional precipitation would take. However, for the Canadian prairies the balance of studies drawn under the IPCC TAR chapter on North America (Cohen et al., 2001) as well as other studies indicate that winter precipitation would increase with a shift from nival to pluvial based precipitation (snowmelt dominated to rainfall dominated regimes).

Among the expected impacts of climate change on stream flow and water yield in the Canadian prairies as a result of increased temperatures, are greater increases in winter and spring temperatures than in summer. These temperature increases would subsequently raise potential evapotranspiration[25] (Cohen et al., 2001). Unlike an increase in potential evapotranspiration, actual evapotranspiration could increase or decrease, depending on soil moisture availability of each region at that time (Frederick and Major, 1997). The expected increase in temperature would be such that even under expected unchanged or increased (winter) precipitation, stream flows would decline in the summer for the prairies (Frederick and Major, 1997). Increases in temperatures would produce early freshets characterized by

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[25] Evapotranspiration is the sum of both pan evaporation from soil moisture and transpiration from crops and trees that lie upon the respective land.

spring snow melt and shifting of peak stream flow from summer to spring (Cohen et al., 2001).

The sensitivity of the above discussed stream flow to climate variables (temperature, evapotranspiration, precipitation) is greater in semi-arid or arid regions (Schaake, 1990). Estimates of runoff elasticity[26] are higher in the more arid zones where soil moisture is limited (Schaake, 1990). This sensitivity is also greater when snowfall is the primary source of precipitation and spring/summer snowmelt is the primary source of stream flow (Frederick and Major, 1997). It is likely, therefore, that the semi-arid SSRB, which also depends on snowfall as the primary source of precipitation, would find the reduction in stream flow more sensitive to a reduction in precipitation or to an increase in temperatures or both.

(2) Impact on water quality: All of above noted changes would likely have a negative impact on water quality (Natural Resources Canada, 2002). Besides lower summer flows, lower quality water is expected with higher suspended solids from more frequent severe storms and potential re-growth of bacteria resulting from higher water temperatures (Natural Resources Canada, 2002; Natural Resources Canada, 2004).

(3) Extreme Events: It is also predicted that extreme hydrologic events such as ice storms, droughts and floods will increase due to climate change (Alberta Government, 2004). An increase in the drought frequency could have a devastating effect on the SSRB economy, as suggested Wheaton et al. (2005).

Spring floods are a characteristic of many Canadian rivers and climate change could significantly change the magnitude and frequency of spring floods (Environment Canada, 2004). Because peak stream flow moves to the earlier spring, stream flow in summer would decline. However, greater atmospheric temperatures would melt snowcaps faster, and river basins fed by snowcap melt influenced by earlier snow melt would see peak stream flow earlier in spring and be rendered with lesser snowcap cover to feed them in summer (Cohen et al., 2001). This early onset of spring peak flows may increase flooding in the spring and water shortage in summer, with the increased likelihood of severe drought and increasing aridity of semi-arid zones (Cohen et al., 2001).

(4) Impact on groundwater and other water bodies: A decline in the stream flow and the change in the intra-seasonal distribution of precipitation along with the impact on evapotransipration may drain groundwater levels, water storage as glaciers, snowcaps as well as negatively impact wetlands, with respect to the Prairies (Environment Canada, 2004). Moreover, the decline in summer stream flow would negatively impact the ground water and wetlands in the prairies (Natural Resource Canada, 1997). An impact assessment on the ground water supply (in the Ogallala aquifer in North Dakota) suggests that climate change would make

26 This is the percentage change in runoff for a one percent change in temperature and precipitation.

the mining of this aquifer even less sustainable. The impact assessment states that increased evaporation will counter the increased precipitation in recharging basins. A caveat, though, is that our ability to measure the potential impacts of climate change and variability on ground water is limited due to the following (Environment Canada, 2004). First, the magnitude and timing of the impact of climate variability and change on aquifers (reflected in water levels) are difficult to recognize and quantify due to the difference in time frame between climate variations and the aquifer's response to them. Second, different types of aquifers respond in different ways; shallow aquifers are more responsive to stresses imposed at the ground surface compared to deep aquifers. These aquifers are affected by local climate changes and deep aquifers by regional climate changes. Shallow aquifers will also be more impacted by climate variability (which has a shorter term than climate change), whereas, deep aquifers have an increased capacity to buffer the effects of climate variability (Environment Canada, 2004).

Moreover, the decline in summer stream flow would negatively impact the ground water and wetlands in the prairies (Natural Resource Canada, 1997). The impact assessment states that increased evaporation will counter the increased precipitation in recharging basins. A caveat, though, is that our ability to measure the potential impacts of climate change and variability on ground water is limited due to the following reasons (Environment Canada, 2004):

(i) The magnitude and timing of the impact of climate variability and change on aquifers (reflected in water levels) are difficult to recognize and quantify due to the difference in time frame between climate variations and the aquifer's response to them.

(ii) Different types of aquifers respond in different ways; shallow aquifers are more responsive to stresses imposed at the ground surface compared to deep aquifers. These aquifers are affected by local climate changes and deep aquifers by regional climate changes. Shallow aquifers will also be more impacted by climate variability (which has a shorter term than climate change), whereas, deep aquifers have an increased capacity to buffer the effects of climate variability (Environment Canada, 2004).

(5) Soil moisture shortage: Associated with changing patterns of precipitation, is the availability of soil moisture that governs the use of water by crops, and thus their productivity. These reductions are also predicted by the climate change models.

(6) Interaction between surface water and groundwater: These interactions exist and may impact surface water systems. Interactions between groundwater and surface water include the following:

(i) Wetlands, supported by and interact strongly with groundwater in some areas;

(ii) Stream flow is sustained by groundwater when contributions from direct precipitation (base flow) are lacking;

(iii) Influent rivers, which contribute recharge to aquifers;

(iv) Springs, which are groundwater discharge features, and

(v) Coastal waters, which receive discharging fresh ground water to support delicate ecosystems (Environment Canada, 2004).

Therefore, climate variability that would impact groundwater would impact these other systems as well (Environment Canada, 2004). Qualitative assessments of hydrographs for Saskatchewan and Alberta have been made by Gabert (1986) and Maathuis and van der Kamp (1986).

Some evidence of the above changes has started to emerge. In the southern prairies, winter temperatures increased around three degrees Celsius from 1970 to 2000; spring temperatures increased a modest 0.3 degrees with no change in summer temperatures (Bruce, Martin and Colucci, 2003). Winter precipitation declined 10% but no change was seen in spring/ fall (Bruce, Martin and Colucci, 2003). Temperature increases in the last 75 years have led to a 40% reduction in stream levels in many Alberta rivers (Brandes and Ferguson, 2004), a 7% decline in the past 30 years in St Mary's, though minimum flows have increased (Bruce, Martin and Colucci, 2003). The flow declines were partly due to increased upstream consumption and partly to climate change (Bruce, Martin and Colucci, 2003). Natural flows during the irrigation period of April to October declined from 800,000 $dam^3$ to 700,000 $dam^3$ from 1910 to the 1990's (Bruce, Martin and Colucci, 2003). A water balance model, applied to the SSRB, suggested that that the Oldman and Bow Rivers may experience a serious water supply problem if they intended to divert enough water to sustain current level of irrigation development (the increase in demand and decrease in supply suggested that the Oldman and Bow Rivers may experience a serious water supply problem (Byrne, Barendregt and Schaffer, 1999). Furthermore, glacial-melt water flows, which contribute significant volumes of water to rivers such as the Bow during summer months, will cease to exist as key glaciers disappear within the next 50 to 60 years. This will have significant impacts (10% of flow) on water availability for irrigation and in-stream flows (Cohen et al., 2001).

Canadian prairies have been the most susceptible region to droughts in Canada due to the high variability of precipitation in time and space caused by disruptions to an expected precipitation pattern and can be intensified by an exceptionally high temperature that increase evapotranspiration (Environment Canada, 2004). High surface temperatures could intensify drought conditions through enhanced evaporation in summer and increased sublimation and melting of the snowpack in winter (Environment Canada, 2004).

### 11.1.2 Water Use / Demand of Water under Climate Change

Studies of climate change impacts on water use/demand, or response of water users to changes in runoff are relatively few, particularly for the SSRB or other parts of Canada. Studies have been undertaken for other locations and include those by Lettenmaier and Sheer (1991), Gleick (1993), Cline (1992) and Titus (1992). Gibbons (1986) illustrates valuation methods, demand elasticities of water for each of the different competing consumptive uses like irrigation, industry, municipalities, waste assimilation as well as non consumptive and instream uses like hydropower generation, aesthetics, recreation and navigation. Although Gibbons does not discuss the impacts of climate change on water value, her demand elasticities for each of the competing water uses are used by Titus (1992) and Hurd et al. (1998) for valuation of climate change on different water uses.

The hydrologic effects of climate change discussed above will put stresses on the amount of water available for withdrawal uses, especially in already dry areas of the country, such as the SSRB. An already reduced volume of water in the Saskatchewan Rivers puts increased pressure on allocation, and increases the conflicts between water users (Shrubsole and Halliday, 2003). These probably have consequences for municipal water supply, navigation, hydroelectric power, recreation and ecosystem health (Natural Resources Canada, 2002).

Impact of climate change on water use may be induced through international sources as well as national situation. This is due to relative competitiveness of Canadian products. Climate change could alter market variables like product prices and input prices. Although production is determined locally, by local weather conditions, international markets determine many market prices. Demand for Canadian products would be determined by how Canadian productivity changes relative to the rest of the world. If our competitors' experience sharp declines in some of the crops we are capable of producing under a changed climate scenario, this situation would be beneficial to some of our farmers (Senate Committee, 2003). Although food production is likely to decline in most critical regions (e.g., tropical and subtropical areas) as a result of global warming, agriculture in developed countries may actually benefit where the technology is more available and if appropriate adaptive adjustments are employed (Environment Canada, 1997).

Issues of climate variability and climate change are expected to have a significant effect on agricultural practices, which in turn will affect water demand and availability. There are drought sensitive regions in Southern and Eastern Alberta, which currently do not have sustainable water supplies, Agricultural activities found in these regions (livestock operations and grain farming) need a consistent supply of good quality water (AAFC-PFRA, 2003). The overriding issue, therefore, tends to be an inadequate supply of acceptable water quality for agricultural use (AAFC-PFRA, 2003). Excessive withdrawals of ground and surface water supplies, particularly during periods of drought, not only reduce groundwater and reservoir levels but can also degrade water quality. Nearly all livestock water use in Canada is from ground water sources (Environment

Canada, 2004). Alberta is viewed as having more groundwater than surface water resources but there is no detailed data to indicate magnitude, quality or location of these. Moreover it is considered that only 0.01% of these are recoverable (AAFC-PFRA, 2003). It is encouraging to observe great progress made in reducing surface water use for irrigation; it remains to be the largest consumer of water. Changes in demand for groundwater are also likely to occur as development increases and as land use changes or intensifies. While these effects will be largely driven by population increase, climate variability and change may also play some role.

Scarcity of surface water could impact many aspects of agriculture, including supplies for irrigation and watering livestock. Warmer conditions in the summer can lead to stress on livestock due to dry pastures, poor hay and feed production and shortages of water. On the other hand, increased temperatures during the winter months can reduce the cold stress experienced by livestock remaining outside, as well as reduce energy requirements to heat the facilities of those animals inside. In areas where moisture is not a crucial issue, the increased temperature would have a positive effect on growth of the pasture, and provide better feed for the livestock.

Higher ambient temperatures with climate change imply greater cooling requirements at industrial plants, which will drive increased water demands, particularly during the summer. This increased water demand may add to the increased competition among other sectors for available water supply. Should climate change mean decreased water flows, this problem would be exacerbated. Climate change will also alter the demand for some other products, which changes the water demand again (Environment Canada, 2004).

An assessment of climate change on agricultural practices for the prairies was carried out by Prairie Adaptation Research Collaborative (PARC) who used a Canadian GCM (CGCM1) to predict scenarios for the years 2040-2069 (Nyrfa and Harron, 2005)[27]. For the area covering the SSRB, the Land Suitability Rating System dropped from a rating of 3A (3 implies moderate limitations; A implies limited by aridity) between 1961 and 1990 to 4A (4 implies severe limitations) for the forecasted period 2040-2069. The SSRB would face a warmer and drier growing season (despite greater precipitation) and degradation by one climatic class. A further 1% of areas in the southern prairies would experience two class degradations. Currently, none of the climatically marginal 4A land classes is cropped (Nyrfa and Harron, 2005). Much of the present grain growing area would face a more severe climate limitation for spring seeded small grain production. The authors suggest this would possibly mean greater summerfallow extents to compensate for aridity, or narrower range of crops within these areas or pasture lands (Nyrfa and Harron, 2005). Other studies show that in recent years many farmers have begun to diversify into specialty crops (e.g., mustard seed, dry peas, and lentils) and in areas of extreme moisture deficit, extensive irrigation systems have also been developed (Environment Canada, 1997). Livestock operations across the prairies are also diversifying with the introduction of buffalo, emus, and elk, which are more adaptable to

[27] The results of the CGCM1 were within the range projected by two other models, the British Hadley Centre GCM and a second, a Japanese CGM (Nyrfa and Harron, 2005).

the climate of the prairies than traditional livestock, and which might reduce some of the climate-induced stress. More than half of Canada's beef cattle are now raised in western Canada, and hog production is becoming increasingly important (Environment Canada, 1997). Livestock is more resistant to climate change than crops because of its mobility and access to feed. Livestock production could be one of the key methods for farmers to adapt to climate change through diversification of their farming mix (Environment Canada, 1997).

More work will be required to study the adaptability of the current crops to such warmer drier climates, as well; the study used only one scenario[28]. Moreover, since other factors such as economic growth could mask the sensitivities to climate change and variability, it may be difficult to separate the impact of climate change on agriculture.

The indirect effects of climate through its effect on energy may be just as important as the direct effects (activities such as irrigation, grain drying, seeding and harvesting are examples of climate dependant agricultural activities that have high energy uses). For example, transportation energy use is affected by climatic variation (winter energy use by cars is lowered in mild winters as compared to cold winters). An increase in mean annual temperature by several degrees centigrade would result in longer frost-free period, in more evaporation in summer, and in fewer shorter cold spells in winter for which the possible postulated implications by Environment Canada (1997) are:

(1) Reduced winter heating load and potential for increased summer cooling loads;
(2) Surface waters likely to be warmer and the subsequent increased evaporation resulting in reduced volumes and water quality;
(3) Changes to soil water availability could result in changing land use, particularly in marginal areas;
(4) The demographic changes that would be required to accommodate changed land use. Domestic water use especially for showers and watering lawns and gardens, is also sensitive to climate variability;
(5) Climate also influences the demand for industrial, thermo electric power, and instream water. The demand for cooling water would be affected by higher water temperatures that reduce the efficiency of cooling systems and higher air temperatures that alter the demand for air conditioning and space heating (Frederick and Schwarz, 1999).

A significant potential impact on hydropower production for the SSRB (as well for all three provinces) would occur through the effect of droughts and increasing temperatures on river flow. Glaciers in the eastern Rocky Mountains have lost between 25 and 75 percent of their maximum volume over the last century. This trend will augment stream base flow in the shorter term (20 to 30 years). In the longer term (30 to 100 years), the reduced melt volumes from glaciers will reduce river flow, particularly in summer, from these sources. Loss of base stream flow is especially important during dry summers when

[28] The IPCC recommends using multiple simulation scenarios such as those depicted in www.cics.uvic.ca/scenarios/.

the demand for electricity is high. Decreased base flow contribution and changes in timing would influence hydro-power reservoir operating strategies in preparation, for example.

Reduced hydropower production caused by decreasing water flow in a changing climate could be compensated by increasing thermal power production. This will likely result in an increase in fossil fuel consumption and GHG emissions (Environment Canada, 1997). An assessment of possible impacts on the energy sector in Alberta reported the following impacts:

(1) Net savings of about 0.5 percent of total electrical consumption resulting from the balance of the decrease in winter months and increase in summer months (heating degree-days projected to decrease by 20 percent),
(2) Natural gas consumption would flatten out, decreasing in winter (about 80 percent of the use is for heating, and this amount would decrease by about 20 percent),
(3) Overall system efficiency would increase (investment saving of over $300 million),
(4) Marked shift in electrical energy requirements within specific sector requirements within specific sectors (e.g., irrigation energy demands could increase by 20 percent) (Environment Canada, 1997).

Thermal power stations become less efficient as surface temperatures increase and potentially, volumes decrease. Thermoelectric cooling process heats the water which is then returned to the stream; only about two percent of the water is consumed through evaporation. Concerns over the environmental impacts of the large withdrawals and heated return flows associated with once-through cooling systems have brought a shift in recent decades to wet tower cooling, which are about 2.4 times more expensive but reduce withdrawals from 47 to 3 gallons per kilowatt hour produced (Frederick and Schwarz, 1999). Hydroelectric production will have to compete with a number of other uses, primarily agricultural, for the diminishing water supply.

Oil production over much of the Prairies will rely increasingly on the availability of water, either for water-flooding [29] or for the production of steam for thermal recovery of heavy oil and bitumen. Where these procedures rely on the availability of near surface ground water or on surface water, there is the potential for oilfield use to compete with other uses.

Alteration of the hydrologic cycle can result in impacts on many water users. These effects will likely lead to a decrease in the amount of water available for the multiple users. Depending on the season, it may also lead to increased stresses on the in-stream availability. There may also be increased pressures to transfer water from agricultural to municipal, industrial, and environmental uses.

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[29] Water can be pumped into the reservoir as a liquid to assist in pressure maintenance and to help push more oil to the producing well. In heavy oil and bitumen deposits steam is forced into the reservoir to make it move more freely.

### 11.1.3 Impact of Climate Change on the Value of Water

Relative to impact of climate change on water supply and use, very few studies have addressed the issue of economic value of water. One such study is by Hurd et al. (1998), a study based on the work started by Vaux and Howitt (1984). The FAO report on water valuation report anecdotally mentions climate change as a driver in the valuation of water (Turner et al., 2004).

## 11.2 Conceptual Approach to Estimation of Water Value under Climate Change

Under dwindling water supplies, value of water will be determined by the level of effective water demand/use. Given the nature of linkages between water use and climate change, one can formalize different types of impacts of climate change on the society through water resources. These can be categorized into the following categories:

(1) First generation effects,
(2) Second generation effects, and,
(3) Third generation effects.

Each of these impacts is discussed below.

### 11.2.2 First Generation Effects – Climate Change and Water Use Patterns

The first generation effects include the direct effects of climate change on water use levels, and through that on various water users. First and foremost, the impacts of climate change will be realized by the direct water users. To domestic water users, this would translate into a higher water use, and thus, if there is a charge for water, a higher outlay for obtaining water. To the irrigators, this may translate into altered level of profitability from irrigating various crops, and into a change in their decision to irrigate or not.

Water resources are involved directly or indirectly, according to the World Health Organization (WHO, 1978), in 80% of all diseases. Both surface and groundwater receive large amounts of industrial waste which can cause health hazards, namely cancer or cardiovascular diseases. On the other hand, water contributes in many aspects to our good health by its recreational and environmental value. Mineral waters are used to treat rheumatic and digestive problems, and for bathing and drinking. All these health aspects may be influenced by the future climatic changes.

### 11.2.2 Second Generation Effects – Impact on Water Using Sectors

These impacts would follow the first generation effects. For example, the first generation impacts from adjustments in irrigation would lead to altered income levels of agricultural producers. This may be a result of higher outlay for water, unless new technology of water use can be adopted. Some of these water saving technologies are capital-intensive. Both of these measures would have implications for the economics of farming in the region. Livestock production may also require more/less inputs under the changed climate, which would translate into change in the relative competitive position of livestock production, particularly in colder and harsher climates.

The indirect effects of climate change may come through the following types of changes:

(1) Change in the demand pattern by consumers. The climate would result in some substitution of products by those which become more urgently needed under the global climate change. Food consumption as well other demand for certain types of apparels would undergo some changes under the changed climate.

(2) Change in the power requirements. An important change would be in terms of changed energy demand patterns. In most cases, this would mean higher power needs, which would increase the water requirements in the region.

### 11.2.3 Third Generation Effects – National and Regional Level Effects:

These impacts would be a culmination of the previous two types of impacts. These would be more felt at the aggregate levels, regional or national, and in some instances at the international levels.

The impact of climatic change will be different in developed, transition and developing countries. In developed countries the major problems will be connected with the increase of water pollution due to reduction of flows. In the transition economies, the general tendency to cope with the climatic changes will be the same, but due to the lack of capital investment this process may be hindered and the negative impacts of the climatic changes may be quicker that the economic counterbalance actions. The developing countries may be affected by the climatic change catastrophically. Many regions are not served by the public water supply and diseases caused by the pollution of drinking water are the most important aspect of water related diseases. The climatic changes can even worsen this situation by an increase in pollution, by reduction of the water resources for drinking purposes, and by reduction of the scarce capital that can be allocated to development of water resources systems with drinking water supply objective. In 1980, around 25,000 people died every day because of lack of clean drinking water (WHO). The warmer temperature will increase the drinking water requirements, and unless the quantity and quality of drinking water is enhanced, the water related diseases will increase in number and seriousness.

The climatic change may necessitate additional area under irrigated agriculture. In developing countries, the irrigated agriculture may be the source of increased incidence of schistosomiasis. The irrigation ditches provide an ideal habitat for the snail hosts and the irrigation workers become the host for the schistosome worm.

Adjustments in food supply could trigger a variety of socio-economic and political problems. The trade patterns among countries as well as among regions may be altered, which may ultimately affect inflation rate, and balance of payment situation. Increased use of water will result in an increased competition for water, which may lead to more conflicts along water users regionally as well as internationally.

How would this translate into value of water is a subject for future studies? Studies that attempt to deal with values of water resources under climate change (Cline, 1992; Titus, 1992) are according to Hurd et al. (2002) "divorced from that of economic response", and are mere "back of the envelop estimates". One needs to develop models that take into account water demand, supply and society's response to adaptation to the climate regime in an integrated manner.

Figure 11.1 shows that all climate-induced physical changes would affect water supply and use. Water use would be affected by all three types of changes listed above. Valuation of water could be modified by a number of related factors. First and foremost is the policy on charging for water. Property rights on water use licenses would also play an important part in setting the price of water. On the use side, cost of re-use and water conservation would be a major factor determining the value of water. On the availability side, cost of developing new water sources (to replace and/or supplement those affected under the climate change) would be a major consideration in valuing water. Each of these issues is described in the next section.

## 11.3 Water under a Climate Change Regime

Water demand forecasting is important in the context of climate change since the society must prepare to adapt to the inevitable changes. Prediction of climate-induced water use change must encompass judgments on two types of relationships. One, the relationship between water use and characteristics that can alter the use level and/or its pattern of use, and, two, how the climate would change alter the relationship between water use and the characteristics. Since water use is diverse, and a different set of characteristics affect each water use, it is desirable to analyze total water use by categorizing it by major types.

Diversity of water use suggests that there is a different impact on demand for water for human settlements, industrial demand, electric power demand, agricultural demand (combined with the changes of water quality especially salinity problem), navigation, waterways and water related recreation demands. Therefore, vulnerability of the society to climate change reflected in these different categories of water demand should be analyzed separately. Four major water uses are discussed in this section. These are domestic, industrial including power generation, irrigation, and in-situ use such as recreation.

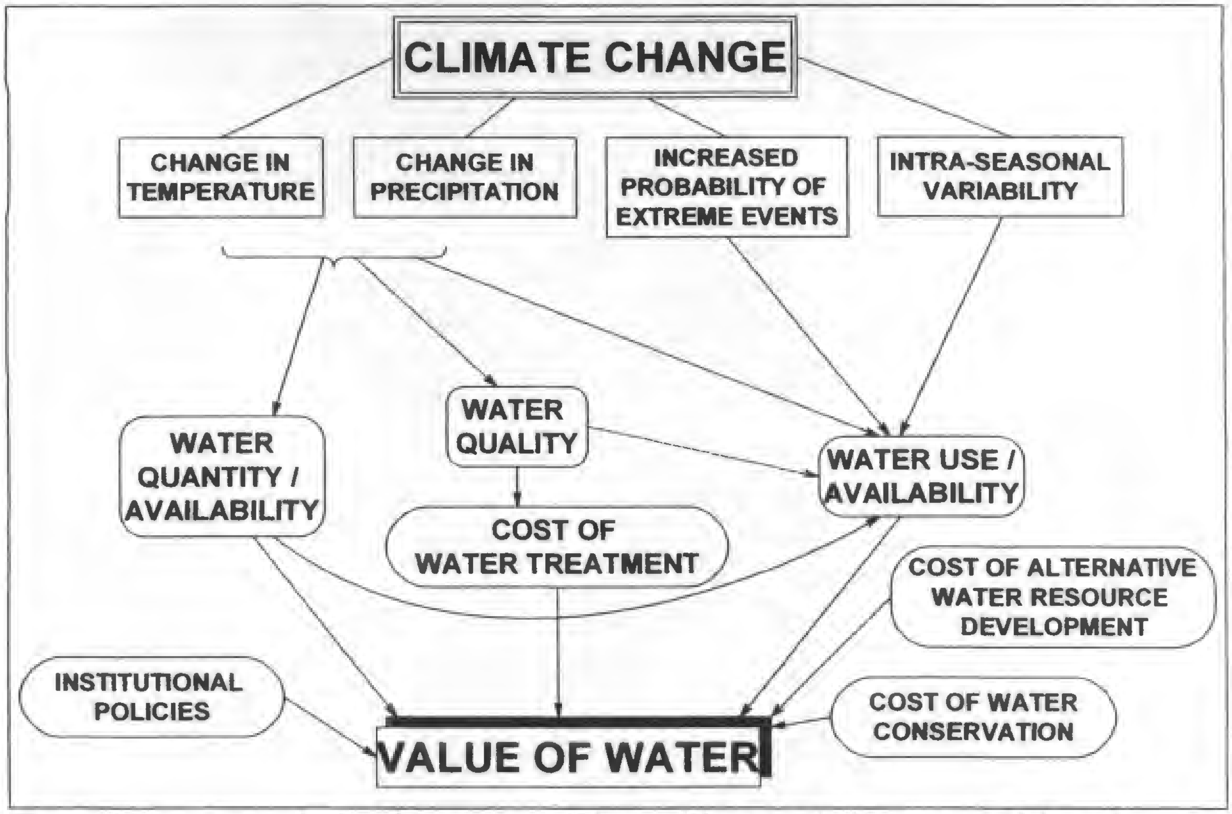


**Figure 11.1. Interrelationships among Climate Change Attributes and Value of Water**

### 11.3.1 Domestic Water Use Levels

Significant variations in residential water use occur according to the time of the day, and the season[30]. This water use also depends on climatic conditions, cultural practices, economic characteristics of the water users, and cost of water to the user (Dworkin, 1975). The change of climate will be reflected directly in the change of domestic water requirement and indirectly by socio-economic changes induced by climate change.

A general form of a water use/demand relationship for domestic use can be specified as follows:

$$Q_{DOM} = \beta_0 + \beta_1 * P + \beta_2 * N + \beta_3 * SZ + \beta_4 * CL + \epsilon \qquad (11.1)$$

where, Q Quantity of water used by a resident, in a single billing period,
P Price per $m^3$ of water per billing period,
N Income of the household per annum,

[30] Factors affecting demand of water in alternate uses has been reviewed by Kindler and Russell (1984).

| | |
|---|---|
| SZ | Size of the family[31], |
| CL | Climatic attributes of the region where the household is located, |
| $\beta$'s | Parameters to be estimated, and |
| $\varepsilon$ | A stochastic error term. |

The effect of climate in this equation can be direct as well indirect through the relationship between the characteristics of the households and their respective water use. The direct relationship between climate and water use is captured by the parameter $\beta_4$. The indirect impact of climate change can be specified as follows:

$$\beta_k = f(CL, CUL, INST) \qquad for\ k = 1, 2, 3. \qquad (11.2)$$

where, CUL Cultural Reference for the region,
INST Institutional Framework facing the households.

In other words, the relationship between price, income of the households, and size of the households would vary from one region to the other in response to climatic variability, cultural differences, and institutional framework. The institutional framework is reflected in a variety of measures related to pricing of water. Let us consider the following examples.

(1) Domestic consumption is higher when no measurement of the amount of water used is done.

(2) Level of water use varies for households facing different type of pricing – minimum charge, flat charge, versus block pricing system. Generally speaking, flat charge pricing provides the least incentives for conservation.

(3) Under the block pricing system, domestic customers conserve more water under the increasing block pricing than either under decreasing block, or constant block pricing structures.[32]

The climatic influence on water use is reflected in seasonal variations in the level of water use as well as in terms of reaction of the customers to longer term changes in weather and through that on the factors affecting water use. Griffin and Chang (1990) have shown that in Texas communities residential water users were twice more responsive to price change during the summer period relative to winter period.[33]

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31 The size of the family can be measured in several alternate ways. Some studies combine number of adults and children in the same measure, while others separate them as two variables. Conceptually, it is possible to make an aggregate measure of family size by using some water use conversion coefficients based on relative water use, as well by taking into account working versus non-working adults.

32 The increasing block pricing refers to a system of pricing where successively higher quantities of water cost more. In contrast, under the constant block pricing, each block is priced the same, and under the decreasing block system, each successive block of water used costs less to the customer.

33 The price elasticity for the summer months was -0.37 as against only -0.19 for the winter period.

In a cross-sectional study of water use patterns, for example, regional climate was an important determinant of water use levels. Brockman, Kulshreshtha and O'Grady (1987) in a study of Saskatchewan communities have shown that a one percent increase in the net evapotranspiration[34] in sample, increased water use by 0.406 percent.[35] This would suggest that under a warmer climate, water use for residential purposes would increase significantly.

Effect of short term variability in climate has been studied by Kulshreshtha and Spriggs (1982), and by Cohen (1987). The study by Kulshreshtha and Spriggs (1982) was carried out to estimate the effects of drought on the municipal water use, and within that on the residential water use. For every increase in the net evaporation by one mm, the residential water use per capita per year increased by 180.5 $m^3$. The elasticity coefficient for the net evaporation variable was estimated to be 0.43, which suggests, that for every one percent increase in it, increases the residential water use by about half a percent.

Cohen (1985) has shown that there is a significant correlation between potential evapotranspiration and municipal water withdrawals during the summer months. Cohen (1987) used this basis to estimate municipal water use under climate change in various municipalities in Ontario, Canada, and in Illinois, Michigan, Pennsylvania, and Ohio in the USA. Correlation coefficients between water withdrawals and potential evapotranspiration (PE) varied from 0.49 to 0.94. In addition, a model using net evapotranspiration (P - PE) was also used, which produced slightly lower correlation between climate and water withdrawals. Two climate change scenarios -- GISS (Goddard Institute for Space Studies), and GFDL (Geophysical Fluid Dynamics Laboratory) -- were used in the study to project municipal water use in the Great Lakes region for the months of May to September. The results suggested for an increase in the water use by 5.6 and 5.2 percent for the two scenarios, respectively. This translated into a 2.6 and 2.4 percent increase on an annual basis, under the assumption that the winter water use remains unaffected by climate change.

### 11.3.2 Industrial and Power Generation Water Use

The water use in industry provides cooling water for thermal power stations, besides being used in the processing of food products, and for general industrial use. The industrial water use varies considerably with the type of industry. Relatively speaking, primary metal, pulp and paper and agricultural processing industries (such as the slaughtering and meat processing operations) require more water to produce a similar value of final product. These figures should be used with caution, since even for the same type of industry, the water use levels will vary from region to region depending on the level of technology being

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[34] This variable was defined as the evapotranspiration for the region less precipitation, and was measures in millimeters.

[35] Communities for which this variable was a significant determinant of water use levels were those where customers were billed on a quarterly basis.

employed. Therefore, the effect of climate change on the industrial water use would be very industry-specific, as well as region-specific.

Water use by industries may be affected by climate change in several ways. Major lines of influence are shown in Figure 11.2. The climate change would increase the requirements for cooling in manufacturing as well as in the thermal power generation plants. This change would alter the average water requirements for these industries. However, two types of indirect effects of climate change may also be present. One, climate change may alter the demand for some products. This type of change would alter the product mix produced in the region. To the extent different industries have different water requirements, and to the extent new demand is created for those industries that are more water intensive, total industrial water use would be different. The second influence may be through a second round effect of climate change. Here, change in the demand for certain goods due to climate change may alter the power requirements for the region, which may then affect the water use levels. In addition, climate change may also affect consumption of power itself. Under this condition there would be a need for more (less) power in the region. These two effects coupled together would affect the water use level for industrial uses.

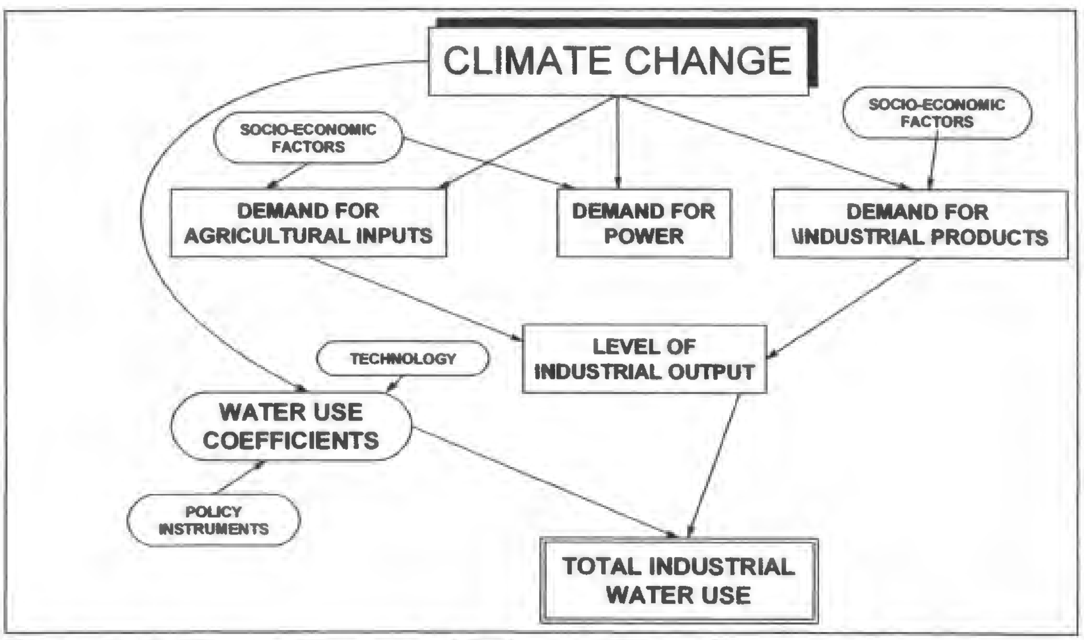


**Figure 11.2. Climate Change and Industrial Water Use**

The climatic change, however, may increase the consumptive loss. This loss in streams and ponds can be computed in a similar way as the potential evaporation for irrigation demand. It is estimated that the consumptive loss increase due the average temperature rise of 4 °C can be approx 7%. If the temperature rise is accompanied by the relative humidity decrease (as indicated by regression analysis in semi-humid climate), the increase of consumptive loss increase may even double to approximately 15%. For the thermal power plants with cooling towers where approximately 75% of the total heat is transferred to water evaporation, the consumptive loss will be reduced accordingly (5% and 11%, respectively).

The less reliable factor in the estimation of water requirements for power production under climate change is the total power requirements. In cooler climates, global warming may translate into lesser amount of power needed, whereas in the arid and semi-arid hotter climates, more power demands may emerge from the cooling needs of households and businesses. With increasing economic prosperity, the demand for power in many of these countries would increase over time. In addition, hydroelectric power may become more attractive as a means of both abating the greenhouse effect and adapting to increased power demands that might accompany it (Scott et al., 1990).

### 11.3.3 Agricultural Water Use

Among various uses of water, agricultural water use is the largest source. In fact, during the past 30 years (1950 to 1980) period, 60% of the net increase in total water use in the world was accounted by agricultural water use. Estimation of agricultural water under climate change is a complex subject. The complexities can be viewed in terms of three types of impacts that may occur, some of them, simultaneously:

(1) Direct effect of the changed climate on the water requirements
(2) Indirectly-Induced effect of climate change, and,
(3) Policy-Induced effects of the climate change.

Each of these impacts is conceptualized in Figure 11.2. The direct effect of climate change on the agricultural water use can be seen in terms of two major interrelationships, each of which could have a major impact on the agricultural water use in a region. These are:

(i) Change in the irrigation production function, and
(ii) Change in the water requirements for stockwatering.

The first effect would basically be a biological one. It is possible that under a warmer climate, coupled with a higher occurrence of droughts in a region, more water would be required to produce the same quantity of cereals. In a similar vein, under a warming earth, livestock may also require more water to sustain themselves. Both of these may increase the total agricultural water requirements.

The indirectly-induced effects of climate change would be realized through a number of changes that will be produced by the climate change. These include:

(i) Effect on the efficiency of the water delivery system,
(ii) Effect on the dryland food production,
(iii) Effect on demand for food and its composition, and
(iv) Change in the livestock production function, particularly with respect to feedgrains consumption.

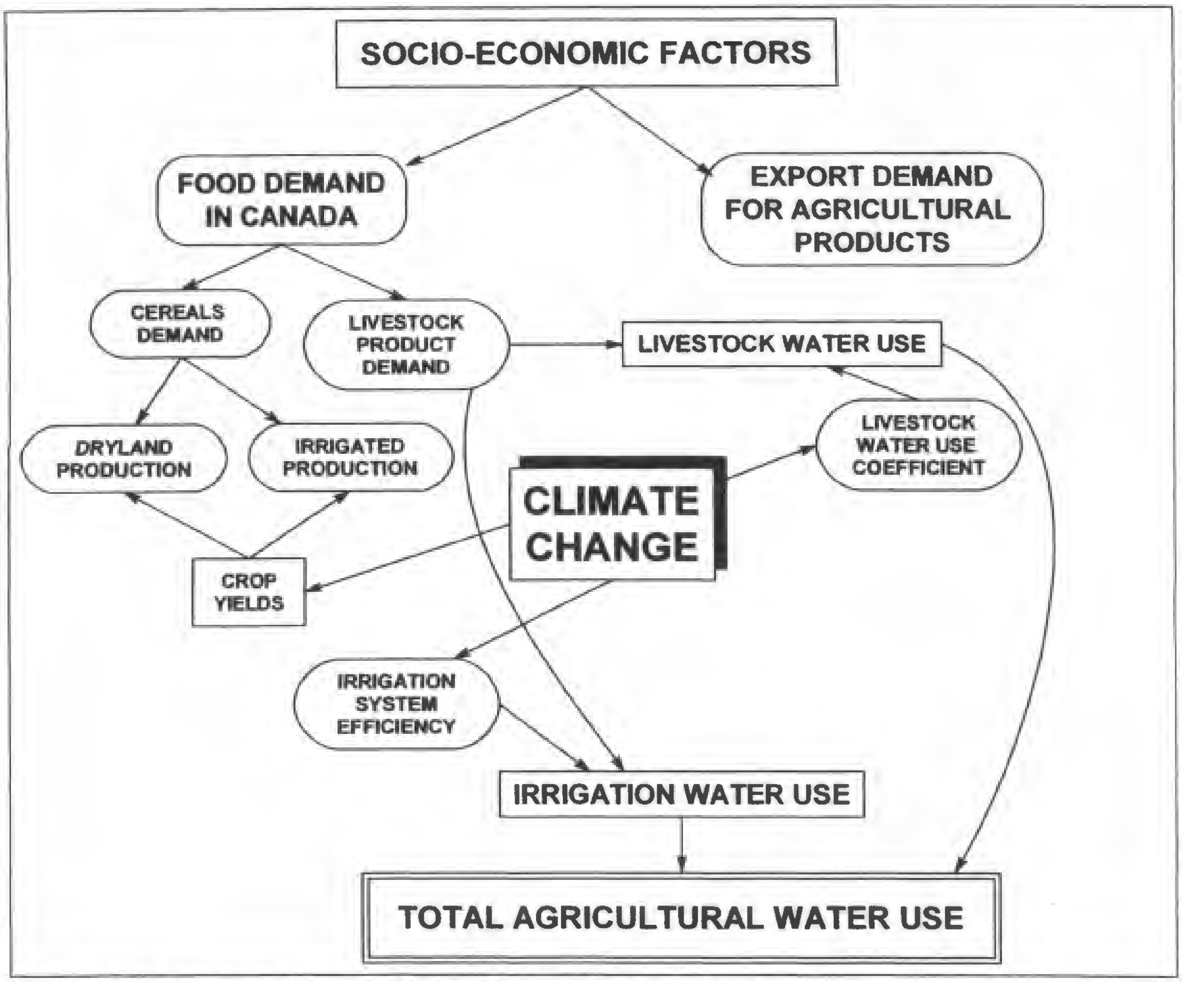


**Figure 11.3. Agricultural Water Use under Climate Change**

Under a warming climate scenario, more irrigation water may be required on account of decreased dryland production, increased requirements for forage and cereals for livestock, and on account of increased demand (domestic as well as international) for food in general. All these effects would lead to larger area under irrigation. The climate change would also have another indirect effect on the irrigation water requirements; this effect would be through decrease in the efficiency of the water delivery system.

The third round of effect -- policy-induced impact under climate change, is even more indirect. Here, the motivation for more irrigation may be imparted by the need for adoption of irrigation by producers. If dryland agriculture is affected to the point that irrigated production is more economically efficient, there may be more incentives for the farmers to increase the irrigated area. The final product of this type of change would be a larger agricultural water use in the region.

As a result of these three types of changes, the expected changes in climate and their consequent impacts will profoundly affect agricultural water use. However, precise results on many of these changes are still subject to empirical scrutiny. There is an urgent need to set these studies within a framework of water management, agriculture policy management, and economic analysis.

Under a changing climate, one of the most obvious changes in agricultural water use will come through increased crop requirements. However, this would not be the only reason for a change in the level of agricultural water use; there may be other contributing factors, as described below:

(i) Relationship of Irrigation Water Demand to Meteorological Data: The impact of climate changes on water requirements is an important issue of water and irrigation systems planning. The change in crop yields due to climatic change depends on other factors such as the species, farm technology, but it mainly depends on the soil moisture. For optimal yield, soil moisture should not decrease below a critical value. This condition can be expressed as the water balance in the soil (see Seuna, 1977). Since many of these variables would be altered under the climate change scenario, the model has an obvious application to the situation of climate change.

(ii) Model of Irrigation Water Requirements under Climate Change: The model of irrigation water requirements should be based on understanding the relationship between soil moisture (i.e., on the water balance in the soil of the root zone), potential evapotranspiration, and actual evapotranspiration. The model of climate-induced irrigation water requirements can be created by assuming that the present relation of temperature to other meteorological factors will be maintained under the changed climate, and that a relationship between these variables and temperature, based on a linear regression, is an adequate proxy for the future. In hydrologic analysis of watershed or in derivation of irrigation water requirements of large irrigation areas (i.e., 1000 ha or more), a more precise estimate is based on complementary responses of potential evapotranspiration to changes in water available for areal evapotranspiration.

(iii) Impact of Precipitation Change: Some climatic change scenarios indicate that the annual total precipitation will not change significantly, but its distribution during the year may change, thereby affecting the precipitation available during the vegetation period. Some estimates have put this decrease at 20%. Furthermore, some hydrologists predict that the pattern of precipitation could also change and decrease further the effective precipitation[36].

[36] For instance, the changes of synoptical situation may be more abrupt (e.g., after a long period of drought a severe storm with high runoff might follow and a new period of drought might appear) resulting in lower effective precipitation.

(iv) Evidence on Other Factors Affecting Agricultural Water Use: In addition to changing the irrigation water requirements, climate change may affect agricultural water use through the following changes, which are discussed below:

(a) Effect on Agriculturally Suitable Area
(b) Indirect Effects of Sea Level Rise,
(c) Effect on the dryland crop yields,
(d) Effect on Agricultural Pests and Diseases, and,
(e) Impact of Drought and other Extreme Events

According to the Second World Climate Conference (see Parry and Jiachen, 1991), increase in temperature can be expected to lengthen the growing season in areas where agricultural potential is currently limited by insufficient warmth, resulting in a poleward shift of thermal limits to agriculture. The major implication of this change would be an increased ability for cereal production for the region, which may indirectly change the need for irrigation to meet the gap between demand and supply.

Increased $CO_2$ in the atmosphere would lead to somewhat higher yields for certain crops. According to Cure and Acock (1986), this would lead to an increase in the rate of plant growth. However, crops such as wheat, rice, and soybeans would fair much better than maize, sorghum, millet, and sugarcane. The implications of such changes would be both in terms of global food security of many nations (limiting or opening opportunities for Canadian exports), as well as in terms of the land use.

The effect on the dryland agriculture should be viewed together with other changes (non-climate change related) that are happening at the same time. Some studies have suggested that temperature increase may be associated with extending the range of some pests, which are currently being limited by temperature. In addition, there may be more occurrences of livestock diseases (EPA, 1989). This may translate into, under warmer climate at mid-latitudes, an increase in the overwintering range and population density of some agricultural pests, while in cool temperate regions there will be more insect pests and diseases which are not present currently. These events would lead to decreased crop yields in some regions, as well a lowering of profitability from livestock operations.

With changing climate, the probability of extreme events, such as the droughts, storms, heat stress, and severe frosts, increases. Although crop yields exhibit a non-linear response to heat or cold stress, as suggested by Mearns, Katz and Schneider (1984), very little is known about such changes in the probabilities (Rind, Goldberg and Reudy, 1989).

The above noted impacts of the climatic variability would have serious implications for current food production, and through that for the future food security. However, the biggest unknown is the technological change, which may override any negative effects of climatic change. All these factors would have significant socio-economic implications for many countries.

### 11.3.4 Recreation, Navigation, and Ecosystem Water Use

The water related recreation represents an important function in the modern society. Its importance will grow with the increase in leisure time, through the need to satisfy basic functions of human life, i.e. rest, entertainment, personal development etc. Water quantity and quality requirements for water related recreation differ according to the type of recreation, such as direct or indirect contact with human body (Baumann, 1969). Various types of water related recreation and sports will be, in some way, influenced by the climate change. The increasing temperature will increase the number of days suitable for activities such as bathing and swimming, boating and sailing etc. This would result in overcrowding of existing facilities as well as in higher public demand for planning new recreational facilities. In some cases, it may lead to changed minimum flow requirements for rivers. In many cities, particularly those without any natural water-adjacent recreation areas, need for large recreational facilities may be overwhelming, which would lead to higher water use at the municipal level.

The evaluation of the recreation value of some reach of the river or of the lake has to take into account the fact that the environmental quality and the recreational use are closely connected. Both of these objectives can be expressed in terms of the alternative use in the multipurpose water resources system and can be reflected in the shadow prices (Cicchetti et al., 1972; and David, 1968).

The economic evaluation of the effect of the climatic changes on the recreational activities and ecosystems is relatively difficult, but possible. Using the Contingency Valuation methods, the willingness-to-pay[37] for recreational services can be estimated. These values can be used for planning of new recreational sites or bringing qualitative changes aesthetically pleasing to site users. One must be cognizant of the fact that the recreational use is a function of many socio-economic variables, like personal income, change in social behavior, availability of leisure time, and preference for water related sports, many of these may also be related to the climatic variability.

## 11.4 Climate Change, Water Quality, and Water Use

Climate change may also affect water quality in certain parts of the SSRB. This is an important ingredient in the determination of water use. If the quality of water goes below some critical level, and the cost of upgrading this quality increases, the demand for this water would likely approach to zero as well. Water quality impacts of climate change are dependent on society's response for quality management. Without such measures a number of impacts can be foreseen. For the rivers and streams, quality of water is generally defined in terms of concentration of pollutants at the time of critical low flow level. With the climate change, there may be a change in the stream flow, which is more important in terms of critical low flow. This will result in a decrease in the river and stream water

[37] Such willingness-to-pay studies have been carried out for the North American recreational sites. For a review of such studies see, Kulshreshtha (1991), and Gibbons (1986).

quality. If the climate change brings about a different seasonal distribution of precipitation, as suggested by Gleick (1987b), this may also result in deterioration of river water quality during the drier periods.

Climate warming would also create water quality problems in estuaries and bays similar to that in rivers and streams. According to Jacoby (1990, p. 314), the greenhouse-induced climate change will affect quality of water in lakes through three mechanisms: changes in throughput and volume, higher water temperature, and reduction in ice cover. The change in temperature will affect the rate of bacteriological activity and the amount of oxygen to support it. Problems of water quality would also emerge in coastal areas through saline water intrusion. Some of the groundwater may be particularly vulnerable.

Change in water quality has significant implications for all types of water uses. More significant will be the water use for human consumption, which has health implications. Change in the water temperature through a change in the atmospheric temperature may further enhance the occurrence of water-borne diseases (Nemec, 1988). Cost of water treatment would also be affected by the use of poor quality source water.

Tourism and recreation are particularly vulnerable to changes in the water quality. If the temperature of the stream increases, the dissolved oxygen content in the water may drop below the level necessary for some kind of fish survival and an ecological water quality accident may be the result (Edinger, Duttweiler and Geyer, 1968; O'Connor, 1967). The impact of the temperature rise on sport fishing may be negative, as it may decrease the dissolved oxygen content under the value necessary for fish ecology.

## 11.5 Non-Use Related Factors Affecting Value of Water

In addition to changes in the water use and its productivity under climate change, value of water may also be affected by other set of factors. Included here are two major factors: one, cost of developing new water supplies, and two, reducing water use through conservation measures or demand management measures. In addition, in-stream water needs may also affect the value of water (through its availability). These factors are discussed below.

### 11.5.1 Cost of Water Development

Value of water will certainly be determined by cost of developing new water sources when existing supplies dwindle. These costs are very site-specific. In relatively lower value uses, such as stockwatering, irrigation, and hydropower generation, cost of water may be an important determinant of its use, unless policies are designed in a manner that the users do not pay the full-cost of the new development. Frederick and Schwarz (1999) have reported costs if new water development according the level of water scarcity. These costs are shown in Table 11.1. The cost increases almost exponentially as the scarcity index for water in a given region increases.

Recycling municipal and industrial wastewater is assumed to be the lowest cost source of new supply. It is assumed that up to 10 percent of these uses can be recycled at an average cost of US$400/acre-foot (C$678 per $dam^3$ in 2004 dollars). Only part of this recycled water would represent new supply, using 70 percent in California, recycling produces new supplies at US$570/acre-foot (C$966 per $dam^3$). If supplies are still not in balance, it is assumed that an unlimited quantity of new water can be developed at US$1,000/acre-feet (C$1,695 per $dam^3$).

**Table 11.1. Cost of Developing Water for Non-Irrigation Uses**

| Cost of Development (in 1995 US$) | Scarcity Index[1] |
|---|---|
| $300/af (921/mg) | <80 |
| $400/af (1,228/mg) | >80 and < 90 |
| $500/af (1,534/mg) | >90 and < 100 |
| $1,000/af (3,069/mg) | >100 |

Source: Frederick and Schwarz (1999)

### 11.5.2 Cost of Water Conservation

For various water users, there exist alternatives to conserve water use and thus, to reduce the stress on water resources. Opportunities for such conservation are very industry-specific. For example, in irrigation, scheduling to deliver water when the plants can use it most effectively and switching to crops and varieties that require less water or provide higher returns per unit of water are such alternatives. Adoption of alternative technology in reducing water application rates (such as drip irrigation) is also an effective water conservation measures. Opportunities for curtailing consumptive use of irrigation water through conservation measures are small. Estimates by the USDA suggest that the maximum saving in consumptive use likely to be achieved through irrigation conservation measures is about five percent of the 1995 irrigation baseline (Frederick and Schwarz, 1999).

In power generation, dry tower cooling virtually eliminates both withdrawal and consumptive water uses in the production of thermoelectric power. But this system is about twice as expensive as wet tower cooling and it results in a loss of thermal efficiency. Taking these factors into account, reducing consumptive use through dry tower systems is assumed to cost US$440/acre-feet (C$746 per $dam^3$).

The costs and opportunities for conserving domestic, industrial, and commercial water in the climate change scenarios depend on how much the region has already invested in conservation. For a region that conserved only five percent in the no-climate-change scenario, it is assumed that an additional five percent can be saved at an average cost of US$110/af (US$337/mg). And regions can go from 10 to 16 percent reductions at an average cost of US$542/acre-feet(C$920 per $dam^3$)

### 11.5.3 Value of Change in Stream Flows

The benefits of increased flows and the costs of decreased flows are assumed to depend on the relation between mean stream flow and the desired[38] instream flow or the relationship between mean stream flow and critical[39] instream flows in each water resource region. The assumed benefits and costs of changes in stream flows are an average of all the estimated values for fish and wildlife habitat and recreation use. The estimated values are not available. Using data for the US, as shown in (Table 11.2), stream flows values may be as high as U$597 per acre-feet in 1995 dollars (equivalent to C$1,010 per dam3 in 2004 dollars). Much of this would depend on how scarcity category at a given location changes as a result of the projected changes in water use from 1995 to 2030.

**Table 11.2. Estimated Costs and Benefits of Stream flow Changes**

| Water Scarcity | Value of water (1995 US$) |
|---|---|
| Mean flow≥ desired flow | 4/af (12/mg) in the East;<br>21/af (64/mg) in the West |
| Desired flow≥ mean≥ critical flow | 205/af (629/mg) |
| Mean flow≤ critical flow | 597/af (1,832/mg) |

Source: Frederick and Schwarz (1999)

## 11.6 Implications of Climate-Induced Water Use

Future climate change would affect the socio-economic conditions facing many regions and sub-regions in the SSRB. Although each situation warrants an examination on its own merit, some generic implications of climate-induced water use can be drawn. Some of these implications would be relatively more obvious, while others, more diverse. In this section, major implications of such a change are outlined.

### 11.6.1 Increased Competition for Water

Climate change will worsen the competition for water in the SSRB. Competition for freshwater between cities and rural areas is intensifying in many parts of the basin. Evidence of such competition can be found in southwestern U.S.A., where increasing urban domestic water use has forced some municipalities to bid for water rights from the agricultural water users. The end result of these changes will be more disputes among water users within the same region. In some regions, there may arise a need for inter-regional transfers of water, which would demand a special handling in the wake of uncertainty created by the climate change.

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38 "Desired" instream flows are defined as the higher of the flow required to maintain fish and wildlife populations or navigation.

39 "Critical" instream flow is defined as 50 percent of the "desired" flow.

### 11.6.2 Development of Information on Present Water Use Levels and Patterns

Collection of adequate and comprehensive information is essential for sound decision-making. If the society is to make such decisions in anticipation of the climate change, we need to have a better handle on the existing situation first. However, much of the past data collection process related to water resources has concentrated on the water supply aspects -- its hydrology, and to a more limited extent and only during more recent period, on water quality monitoring. Collection of data on water use levels and its pattern of use have not attracted the attention of many water management agencies in the Basin. This deficiency was recognized by the International Conference on Water and the Environment, held in Dublin (see WMO, 1992), that recommended that "...the public to have best feasible access to ...water use data and information for those concerned in, or affected by, that water and their likely developments and demands" (p.5).

### 11.6.3 Vulnerability of Regions to Water Availability

Climate-induced changes in availability of water coupled with changes in water use/demand may make some regions more vulnerable in a sustainable context (Nemec and Schaake, 1982, and Nemec, 1982). Depending upon the relative water supply and availability, a region may be surplus in water, or may face severe water shortages. Under climate change, when both water availability as well as its use is affected, some regions now facing surplus may become under water stress or even face water scarcity.

### 11.6.4 Socio-Economic Impacts

The various degrees of vulnerability of various countries to climate change would have significant socio-economic-political implications on the countries. Climate change would affect all sectors of the society. Some of these changes would be as a direct result of climate change. For example, Dudek (1989) has reported that in California, the net economic well-being produced from agricultural operations under climate change between 14-17%. Other economic impacts will be felt through the impact on agricultural production firms, through economic linkages. Extreme events, such as the drought or floods, would decrease the economic profitability of production in all sectors, but more so for the agricultural production. This may eventually affect the competitive position of one region to other, and may lead to inter-regional shifts in economic activity, followed by massive migration of people. The adjustments in regional pattern for agriculture in many countries could be triggered by the climate change and the agricultural and economic prospects at the farm, regional or state level can be affected.

The climate change, through adjustment in various types of water uses, would have other impacts that may be of high social significance. For example, the vulnerability of domestic water use to climatic change will be different in various parts of the Basin. In some parts, increased water requirements can be met through technological change, such as by building new water reservoirs or by reduction of leakage and conveyance losses through reconstruction of water supply network. In other locations, such activity may not be feasible.

In assessing the potential impact of future climate changes on human activities, the fundamental subject of concern is the adaptive capacity of social and economic systems. Society in the past has adopted to similar changes. As climate change modifies the human action, feedbacks will again occur as society adapts in a dynamic fashion (Warrick, 1989).

### 11.6.5 Integrated Water Management

The attitude of water management planners should be such so as to be aware of the forthcoming challenge posed by the climate change, and to project and plan water resources in an appropriate manner. Such planning should be adaptable, robust and resilient to withstand the possible future changes of climate. As demand for dependable water supplies increases and its supplies dwindle, the type of water resources development that would be needed under climate change will be different. Simple withdrawal of water from streams or rivers would be replaced by provision of water reservoirs to smooth out the irregularity in stream flow on one side, and inter-year variability in its use on the other. Measures will also have to be developed for proper management of groundwater resources. According to Cook (1976), the cycle of groundwater is often so long that the groundwater can be taken as a non-renewable resource; mining it at an increasing rate may leave future generations with water shortages. According to Williams (1989), possible water management responses under climate change may also include reallocation of water supply from less valuable irrigated agriculture to municipal uses, changes in agricultural methods, increasing incentives for integrated flood management, increasing incentives for watershed management, integrating ecosystem needs in water resources planning, and the need to redesigning the operation of the existing water projects. Kos (1986) has also suggested that in a multipurpose water resources system, a transfer among the objectives may also react positively to climate change induced impact, and, thus, may reduce the possible economic losses to minimum.

Most of the past assessment of climate change has concentrated on physical and biological aspects. The results of these studies need to be set within a framework of water management, agriculture, and economic analysis (Orlovsky, 1984). The adjustment in regional pattern for agriculture may also take place in response to climate change, impacts of which should be linked to more general approaches to developing optimal water management policies in the future (Skogerboe, 1982; and Heady et al., 1973).

The price of water due to reduction of water resources may increase and as the consequence of these components, the water demand may be reduced causing further socio-economic problems. This situation in water supply is complicated by the decreasing quality of water and the increasing need for water treatment. Under these conditions, water quality management may have to be given a top priority in water policy making. It may be cheaper to solve the problem before it happens than to wait until it has major impacts on the society.

Meo (1991) has distinguished three types of strategies for adapting to the potential climate change: no-action, stand-and-defend, and strategic-retreats strategies. If water management in the future is based on `no-action' strategies, the outcome of impacts would be as described here. The `stand-and-defend' strategies include structural and non-structural measures to counter the impact of climate change. The last set of strategies includes measures for adapting to climate change impacts while not directly countering them. A pertinent question is which of these strategies would make the most sense from water management point-of-view? Complications are brought about by the fact that the environmental and socio-economic systems are also closely interrelated at the local and regional level, as suggested by Kairiukstis et al. (1989), and such linkages should be considered in the development of the water management policies.

### 11.6.6 Demand Management

Under climate change, with the water supplies dwindling, and its use level increasing, there would be a need for a properly developed demand management system which can improve the efficiency of water use on one side, and reduce the need for massive investments in water supply infrastructure without bringing undue hardship on the users. The nature of this plan cannot be generic, since measures need to be evaluated on their own merits for a given situation.

Under the looming fear of global warming, demand management measures would have to be devised to ensure: (1) balancing the water use with water availability; (2) maintenance of acceptable quality of water; (3) management of water use during periods of Drought; (4) matching seasonal water availability with use, and (5) management of inter-year variability in supply through adjustments in water use levels. Each of these may require different strategies, and therefore, should be considered on a site-specific basis.

Water demand management is based on the premise that the behavior of the individual can be modified. Economic incentives or penalties can be provided to induce the desired behavior. However, one should note that economic instruments are not the only means by which individuals' behavior can be changed. Through communications with the users, one may also be able to persuade the users to alter their water use levels. Among various economic instruments, use of tariffs (price) for water use is the predominant one. Tariffs can be at a uniform rate, or at a block rate[40]. Tariffs can also be devised on a seasonal basis to induce more water conservation during certain times of a year. However, before these tariffs can be effective, measurement of use of water is a very important prerequisite.

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[40] Under the uniform rate tariffs, all water is charged the same. Under the block rate system, however, increasing quantities of water may cost more or less. The first system is called the increasing block rates, whereas the second one, decreasing block rates. Based on analysis of households in Saskatchewan under these three pricing structures, increasing block rate pricing is the most consistent with water conservation. For details, see Brockman, Kulshreshtha and O'Grady (1987).

Although management of withdrawal demand for water is obvious, under climate change in-situ water use management may be just as important. Since under a warmer climate, recreational activities are expected to increase, there may also be several environmental impacts. The overcrowded beaches decrease their environmental value and the value of recreation. Some recreation water uses, e.g. boating can be considered as part of the pollution in the system, e.g. for noise generation and escaping oil and gas. These sources of pollution may in some regions increase due to the increased number participants on water related recreation activities. All these negative environmental impacts can grow in number and frequency with the expected climatic change.

With dwindling water supplies, and an increased competition for its use, management of direct water use may not be sufficient. These measures may need to be supplemented by management of indirect water use. One of the relatively larger water users is electric power generation. Some of this wasted energy can be reduced by measures that increase the efficiency of this use through heat recovery and better insulation of houses. As the climatic change may increase the temperature, the summer cooling requirements may also grow. In the future, we may approach the situation where the seasonal demand for heating and cooling is balanced at a low level, to be supplied by other alternative means. Since in conventional heat production, the real efficiency is extremely low, one could make a strong case for the introduction of thermodynamic heating in some form, e.g., use of industrial waste heat, combination of generation of power and heat, and thermally driven heat pumps.

### 11.6.7 Inter-Regional Conflicts

Global climate change appears to be the most likely change that would affect international politics because of its wide scope and management (Gleick, 1989). However, such conflict may also arise within a basin. Situation will be worse for regions (such as Alberta and Saskatchewan) that share water resources, such as the lakes and rivers, and for those where a large part of the water supply is obtained through flow from other regions.

### 11.6.8 Legal and Institutional Development

Climate change would require changes in legal and administrative structure, both nationally as well as regionally. There would emerge, under climate change, a need in various regions to develop a clear and concise water management policy, and appropriate legal structures. Climate change may also bring about a major challenge for human resources development. To implement the new mandate of water management, training of water managers, researchers, and policy makers would be required. Strengthening of the training program to meet the need of many developing countries will be a mammoth effort.

# Chapter 12

# SUMMARY AND CONCLUSIONS

The South Saskatchewan River Basin (SSRB) is an area of high activity in the southern prairies. It is home to a large population, thriving industry, and strong agricultural development. Water is a vital requirement for the survival and success of life in the SSRB. In order to ensure efficient allocation of water now and in the future, it is important to understand the economic value of water. The aspects of water supply and demand both play a role in the valuation of water.

The major objectives of this study were as follows:

1) To estimate the value of water in major withdrawal uses within the South Saskatchewan River Basin (SSRB);
2) To review previous studies on value of water in other water uses in the SSRB; and,
3) to conceptualize the relationship between the value of water and climate change.

In this document, the values of water in some uses were estimated and the results of a review of values from other studies were reported. The withdrawal use values are summarized in Table 12.1, whereas the in-situ water use values in Table 12.2. Some water uses were not investigated for value due to a lack of available data.

In arid and semi-arid climates, irrigation is a vital necessity. Without such application of water, many agricultural areas of Southern Alberta and western Saskatchewan may not be economically viable. However, under a climate change scenario, it is predicted that water supply will diminish. Under a situation of shortages, water allocation may need to be changed. Water resource managers may require some knowledge of the consequences of their decision.

The value of water in irrigation and other agricultural uses were examined more, in part, because irrigation is the largest water user in the basin. Two types of values were estimated: one, marginal value of water, and two, average value of water. The first type of value measures the contribution made / costs incurred on the producers if a small quantity of water was not provided. The second type of value illustrates the contribution made by water allocation to the welfare of the regional society through producers. All values were estimated for the two provinces – Alberta and Saskatchewan separately. In the case of marginal value of water, analysis was further extended to various sub-basins within each of these provinces.

Furthermore, it was hypothesized that these value would not be uniform for the entire basin, and thus, a disaggregated approach was preferable. Results suggest that indeed value of water in irrigation is highly variable. In Alberta long-run value ranged from a low of \$26.15 per dam$^3$ in the Red Deer River Sub-basin to \$38.60 per dam$^3$ in the Oldman River Sub-basin. A partial explanation for the differences is the crop mixes in various sub-basins, and the water withdrawals. In Saskatchewan, value of water in irrigation was found to be different for the two regions within the SSRB. In the southwest portion of the basin, where irrigation is practiced on a small-plot basis, water was valued at \$23.09 per dam$^3$, whereas in the Lake Diefenbaker Development Area the long-run value was \$201.82 per dam$^3$. This value is significantly higher than that in Alberta by almost a margin of six times. This is, in part, explained by the differences in the water use per unit of land in the two regions, and also by the proportion of seed potatoes in the crop mix in Saskatchewan. Irrigation water use also generates protection from droughts. This estimated value ranged from \$8 to \$29 per dam$^3$ for various sub-basins. In addition to irrigation, agricultural water use includes livestock water use. This value was estimated to be lower than that for irrigation.

**Table 12.1. Value of Water in Agricultural Uses, SSRB, 2004**

| Sub-Basin | Short-run Value per Dam$^3$ | Long-run Value per Dam$^3$ |
|---|---|---|
| **Irrigation** | | |
| | *Alberta Portion of SSRB* | |
| Oldman | \$78.13 | \$38.60 |
| Bow | \$48.01 | \$26.68 |
| Red Deer | \$52.24 | \$26.15 |
| SSRB-AB | \$72.64 | \$30.41 |
| | *Saskatchewan Portion of the SSRB* | |
| LDDA | \$272.75 | \$201.82 |
| SWDA | \$36.22 | \$23.09 |
| Average SSRB- Saskatchewan | \$235.81 | \$173.91 |
| **Non-Irrigation** | | |
| Drought Proofing -- Saskatchewan | | \$7.68 to \$11.05 |
| Drought Proofing -- Alberta | | \$11.05 to \$28.87 |
| Livestock (this Study) | | \$9.22 |
| Livestock (Bruneau 2004) | | \$46,330 |
| **Non-Agricultural Uses** | | |
| Municipal – Residential | Bruneau (2004) | \$1,270 to \$2,040 |
| Municipal – Commercial and Industrial | Bruneau (2004) | \$1,410 to \$2,170 |
| Industrial | Bruneau (2004) | \$80 to \$49,000 |
| Mining (Saskatchewan potash mining) | Kulshreshtha et al. (1988) | \$347.47 |
| Thermal Power Generation | Bruneau (2004) | \$1.12 to \$627 |

**Table 12.2. Value of Water in Non-Agricultural In-Situ Water Uses**

| Type of Use | Author | Location of Study | Value per dam$^3$ in 2004 Canadian Dollars |
|---|---|---|---|
| Hydroelectric Power Generation | Bruneau (2004) | SSRB | \$0.11 to \$0.24 |
| | Kulshreshtha et al. (1988) | Saskatchewan<br>Short-run Base<br>Short-run Peak<br>Long-run | <br>\$1.57<br>\$15.31<br>\$0.27 |
| Recreation | Kulshreshtha et al. (1988) | Saskatchewan | \$2.90 to \$1,139.42 |
| Waste Assimilation | Kulshreshtha and Gillies (1991) | Saskatoon (South Saskatchewan River) | \$15.92 to \$21.71 million * |

* Total value for waste assimilation. Value per unit of water not estimated.

Relatively lower marginal values were estimated for traditional crops such as cereals and oilseeds. Various sub-basins had a very similar marginal value of water, since cost of production budgets for these crops were based on an average for the province. Differences between the two provinces in the distribution of marginal value of water were noted. Although both provinces started with the same higher marginal value of water, it declined sharply in Saskatchewan for most of the irrigated area. The most likely cause of these differences was the differences in crop mix. One should note that these values are direct crop production based values. Forages are utilized on farm for other cattle enterprises. A true marginal value of water should take these linkages into account. However, this was not done in this study.

Non-use values were based on a review of literature. A general conclusion is that there are very few comparable values of such uses that can be applied to the SSRB.

As pertinent as it is to know the value of water in its different uses in the SSRB, it is also very important to estimate how that value will rise or fall in response to environmental changes. Climate change is one such environmental factor that is predicted to have an impact on the value of water. As global temperatures rise, the supply and demand of freshwater in the SSRB will be affected. Thus, the value of water will be altered as well. Estimates of the predicted value of water are essential in preparation for the uncertain and perhaps life-altering consequences resulting from climate change. However, based on a review of available study, no particular conclusions could be drawn as to how this value of water would change under climate change.

This study is based on available literature and data, and as a result has suffered through many limitations. The most important ones of these include:

1. Data on water use for irrigation is poor, particularly for the SWDA and LDDA regions of Saskatchewan.

2. For neither Alberta nor Saskatchewan data could be found on the actual water used for various crops. Although it is recognized that this may change from year to year due to climatic variability, an attempt should be made for collecting this information.

3. Data on actual area irrigated is also a major stumbling block in the estimation of value of water. A lack of knowledge of irrigation scale affects the marginal values as well as average value of water.

4. Cost of production budget data are poor on three counts: one, such budgets are not available for some regions such as SWDA; two, separate cost of production budgets are not available for various sub-basins of the SSRB; and, three, comparability of data from one province to the other is questionable.

5. There is a need to assess the value of water in alternative uses by location since value is highly variable from location to location.

6. Assessment of value of water quality is a relatively unstudied area of research. Although most studies concentrate on quantity of water, water is not a homogenous entity. It must be distinguished by quality of water for any meaningful analysis of scarcity and trade-offs.

7. Impact of climate change on value of water remains to be a mystery. Further attention to this aspect is required.

It is hoped that future studies in this area would make an attempt to improve on these major limitations for estimation of water value in the South Saskatchewan River Basin of Alberta and Saskatchewan.

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# APPENDICES

# APPENDIX A

# POPULATION DATA

## Table A.1. Urban, rural and farm population statistics by sub-basin

| | | Population[1] | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB-BASIN | CLASSIF-ICATION | 1951 | 1956 | 1961 | 1966 | 1971 | 1976 | 1981 | 1986 | 1991 | 1996[2] | 2001[2] |
| RDR | URBAN | 24,326 | 31,743 | 41,737 | 49,842 | 54,756 | 64,308 | 90,350 | 102,908 | 109,304 | 115,056 | 138,810 |
| | RURAL | 72,766 | 69,959 | 69,791 | 65,622 | 61,893 | 63,440 | 66,967 | 80,347 | 68,688 | | 92,240 |
| | FARM | 55,616 | | 46,790 | | 39,318 | 32,487 | 31,513 | | 30,940 | | 41,549 |
| BR | URBAN | 142,453 | 203,910 | 286,423 | 339,912 | 414,317 | 483,842 | 628,240 | 671,710 | 753,647 | 822,122 | 950,004 |
| | RURAL | 29,347 | 27,601 | 27,111 | 24,533 | 26,381 | 30,764 | 36,841 | 41,016 | 38,432 | | 49,489 |
| | FARM | 18,580 | | 20,305 | | 16,885 | 14,438 | 13,777 | | 13,484 | | 17,363 |
| OR | URBAN | 46,424 | 56,634 | 65,306 | 67,503 | 73,445 | 83,211 | 88,355 | 104,267 | 108,097 | 121,785 | 129,807 |
| | RURAL | 42,145 | 40,667 | 39,699 | 35,297 | 35,288 | 36,421 | 39,070 | 39,285 | 33,988 | | 55,104 |
| | FARM | 32,095 | | 24,828 | | 20,116 | 16,913 | 16,356 | | 14,120 | | 22,893 |
| SSR-alta | URBAN | 20,834 | 26,227 | 30,189 | 30,825 | 32,088 | 39,403 | 47,425 | 50,245 | 52,007 | 54,337 | 59,000 |
| | RURAL | 9,572 | 10,077 | 10,667 | 9,357 | 8,415 | 8,726 | 9,771 | 11,584 | 8,251 | | 16,584 |
| | FARM | 10,578 | | 7,545 | | 5,934 | 5,244 | 5,810 | | 5,044 | | 10,138 |
| SSR-sk | URBAN | 71,053 | 94,671 | 120,338 | 143,743 | 155,043 | 161,533 | 183,275 | 213,195 | 220,385 | 227,586 | 231,919 |
| | RURAL | 59,168 | 55,206 | 52,811 | 47,525 | 40,460 | 35,839 | 51,811 | 57,620 | 32,923 | | 53,280 |
| | FARM | 48,653 | | 39,657 | | 30,577 | 26,204 | 29,187 | | 24,196 | | 39,157 |

[1] Sobool and Kulshreshtha (2003)

[2] Urban population estimated communities with a population of 1,000 or more

Farm population estimated using 1991 percentage of rural population located on farms

## Table A.2. Price elasticities for residential consumption

| Municipality Population | Price Elasticity |
|---|---|
| < 500 persons | -0.17 |
| < 5,000 persons | -0.28 |
| 500 – 1,000 persons | -0.35 |
| 1,000 – 5,000 persons | -0.42 |
| 5,000- 10,000 persons | -0.48 |
| > 10,000 persons | -0.53 |

Source: Kulshrestha (1992)

# APPENDIX B

# LIVESTOCK WATER USE

**Table B.1. Annual Livestock Water Use based on Province and Sub – Basin**

| | | | Water Use ($m^3$/year/animal) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **PROVINCE** | **SUB-BASIN** | **ANIMAL** | **1951** | **1961** | **1971** | **1976** | **1986** | **1991** | **1996** | **2001** |
| Alberta | RD | Bulls | 259130 | 412102 | 549422 | 655297 | 572096 | 690161 | 854910 | 839548 |
| | | Calves | 941334 | 1947242 | 2388089 | 2759140 | 2391418 | 2928788 | 3445482 | 4229707 |
| | | Steers | 723927 | 1810032 | 2476050 | 3405170 | 1905481 | 2305644 | 2926543 | 3191357 |
| | | Milk cows | 2815053 | 2538387 | 1618511 | 1491308 | 1259793 | 1184214 | 1267494 | 1206908 |
| | | Beef cows | 3618464 | 6763631 | 9302022 | 11139707 | 6266972 | 7520823 | 9371693 | 10341836 |
| | | Hens and Chickens | 151231 | 154293 | 134345 | 143615 | 130920 | 129734 | 126789 | 190737 |
| | | Other poultry | 14131 | 39838 | 34588 | 32664 | 6290 | 6600 | 6527 | 5462 |
| | | Sheep | 74367 | 100745 | 48529 | 37667 | 36210 | 83357 | 52252 | 63866 |
| | | Horses | 1127821 | 568229 | 498659 | 497641 | 705384 | 577686 | 708657 | 769337 |
| | | Pigs | 390668 | 504438 | 709641 | 391158 | 902103 | 986310 | 925136 | 1237382 |
| | BR | Bulls | 94226 | 187283 | 247303 | 274428 | 230668 | 265924 | 324830 | 290826 |
| | | Calves | 335886 | 803146 | 973277 | 1068509 | 811822 | 1000225 | 1313196 | 1605809 |
| | | Steers | 347040 | 981442 | 1258880 | 1551512 | 643531 | 920609 | 1194968 | 1815396 |
| | | Milk cows | 754844 | 1002505 | 607799 | 550689 | 359367 | 334711 | 320358 | 204354 |
| | | Beef cows | 1517746 | 3002905 | 3937562 | 4434873 | 2143188 | 2607297 | 3293895 | 3286847 |
| | | Hens and Chickens | 54514 | 91967 | 90933 | 97582 | 99097 | 107494 | 95280 | 107722 |
| | | Other poultry | 5603 | 25967 | 24916 | 22589 | 3557 | 3616 | 3432 | 3045 |
| | | Sheep | 36465 | 52108 | 26662 | 19116 | 18419 | 33961 | 26400 | 26838 |
| | | Horses | 304293 | 249143 | 228294 | 221444 | 270960 | 235368 | 322465 | 357407 |
| | | Pigs | 106482 | 193964 | 269131 | 156471 | 170220 | 329794 | 186382 | 364853 |
| | OR | Bulls | 144614 | 248861 | 335333 | 367591 | 402312 | 441768 | 564114 | 469888 |
| | | Calves | 512674 | 1026502 | 1375478 | 1474415 | 1570055 | 1878549 | 2514154 | 2974963 |
| | | | Water Use ($m^3$/year/animal) | | | | | | | |
| **PROVINCE** | **SUB-BASIN** | **ANIMAL** | **1951** | **1961** | **1971** | **1976** | **1986** | **1991** | **1996** | **2001** |
| | | Steers | 685961 | 1157456 | 1619586 | 2470353 | 1941314 | 3156356 | 4835008 | 6720204 |
| | | Milk cows | 873953 | 881654 | 614263 | 583685 | 1006483 | 916442 | 959939 | 889881 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Beef cows | 2567941 | 4011543 | 5556410 | 6285849 | 4067768 | 4843335 | 6136588 | 5742730 |
| | | Hens and Chickens | 73029 | 77875 | 78252 | 86730 | 152498 | 165447 | 171850 | 233429 |
| | | Other poultry | 10364 | 28052 | 27332 | 25334 | 7853 | 12709 | 10627 | 11952 |
| | | Sheep | 103493 | 206819 | 106294 | 68657 | 73143 | 52301 | 78228 | 75795 |
| | | Horses | 498808 | 318068 | 265698 | 251178 | 404318 | 362446 | 611867 | 387023 |
| | | Pigs | 126137 | 196874 | 307837 | 212412 | 440304 | 495413 | 695532 | 880623 |
| | SSR | Bulls | 46529 | 106761 | 136895 | 161151 | 184713 | 195670 | 245784 | 210730 |
| | | Calves | 216011 | 502377 | 576224 | 628667 | 742234 | 822950 | 945947 | 1095453 |
| | | Steers | 192531 | 301421 | 360744 | 516407 | 661409 | 913089 | 1511814 | 1977927 |
| | | Milk cows | 329503 | 268796 | 144797 | 109216 | 305510 | 283214 | 274628 | 276680 |
| | | Beef cows | 980606 | 1851560 | 2318223 | 2434135 | 1949038 | 2138612 | 2537903 | 2411168 |
| | | Hens and Chickens | 24092 | 20881 | 15995 | 16755 | 44243 | 43928 | 44724 | 59526 |
| | | Other poultry | 3019 | 5716 | 4551 | 3256 | 3512 | 5041 | 5322 | 6176 |
| | | Sheep | 65766 | 52831 | 10287 | 7610 | 8579 | 15066 | 16499 | 19308 |
| | | Horses | 176818 | 89476 | 78406 | 78183 | 86870 | 104418 | 90661 | 92611 |
| | | Pigs | 0 | 33993 | 53011 | 34098 | 120930 | 137066 | 241850 | 298997 |
| Saskatchewan | SSR | Bulls | 87427 | 163276 | 214832 | 280766 | 273027 | 314023 | 401137 | 397476 |
| | | Calves | 348697 | 755693 | 925507 | 1082129 | 1144157 | 1297676 | 1583265 | 1841408 |
| | | Steers | 253977 | 551711 | 563181 | 794404 | 637399 | 776941 | 797108 | 555628 |
| | | Milk cows | 1529643 | 1173890 | 641412 | 542876 | 623476 | 576111 | 496131 | 441357 |
| | | Beef cows | 1246583 | 2627299 | 3515773 | 4240097 | 2999457 | 3466524 | 4497603 | 4780225 |
| | | Hens and Chickens | 95360 | 77689 | 58467 | 53163 | 72045 | 73428 | 74658 | 109309 |
| | | Other poultry | 10562 | 28292 | 22661 | 17772 | 4864 | 7070 | 3542 | 4496 |
| | | Sheep | 45637 | 43464 | 33114 | 22564 | 15282 | 18280 | 22158 | 33422 |
| | | Horses | 649837 | 262298 | 170240 | 131273 | 257855 | 207048 | 212438 | 238800 |
| | | Pigs | 150858 | 176343 | 340906 | 177657 | 306506 | 395705 | 430598 | 504247 |

Source: Sobool and Kulshreshtha (2003)

# APPENDIX C

# PARK VISITATION DATA

**Table C.1. Alberta Provincial Visitation Statistics (Fiscal Year: April 1 to March 31)**

| | 1993/94 | 1994/95 | 1995/96 | 1996/97 | 1997/98 | 1998/99 | 1999/00 | 2000/01 | 2001/02 | 2002/03 |
|---|---|---|---|---|---|---|---|---|---|---|
| **CAMPING** | | | | | | | | | | |
| Occupied campsite nights | 453,176 | 498,533 | 483,667 | 489,739 | 512,301 | 522,940 | 517,671 | 450,692 | 488,972 | 473,940 |
| Campers | 1,486,690 | 1,621,043 | 1,559,081 | 1,581,681 | 1,650,133 | 1,682,987 | 1,658,784 | 1,451,906 | 1,570,768 | 1,517,067 |
| Number of campsites | 13,251 | 12,775 | 12,789 | 12,471 | 13,079 | 13,320 | 13,383 | 13,110 | 13,124 | 13,248 |
| Average camping party size | 3.2 | 3.2 | 3.0 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 |
| **GROUP CAMPING** | | | | | | | | | | |
| Group unit nights | 28,244 | 27,830 | 37,108 | 28,309 | 28,058 | 24,550 | 21,546 | 22,227 | 20,888 | 28,780 |
| Group campers | 93,161 | 92,823 | 123,768 | 94,443 | 93,220 | 84,287 | 73,459 | 76,038 | 72,022 | 97,301 |
| Average group camping party size | 3.3 | 3.3 | 3.3 | 3.3 | 3.4 | 3.4 | 3.3 | 3.4 | 3.4 | 3.4 |
| **DAY USE** | | | | | | | | | | |
| Day use party visits | 2,838,818 | 2,780,349 | 2,552,280 | 2,723,050 | 2,555,300 | 2,617,790 | 2,610,063 | 2,571,904 | 2,457,908 | 2,434,465 |
| Day use visitors | 7,258,239 | 6,987,767 | 6,598,503 | 7,101,787 | 6,575,563 | 6,705,994 | 6,656,029 | 6,968,480 | 6,704,861 | 6,628,354 |
| Average day use party size | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.7 | 2.7 | 2.7 |
| **SUB-TOTAL VISITATION** | | | | | | | | | | |
| Parties | 3,320,238 | 3,306,712 | 3,073,055 | 3,241,098 | 3,095,659 | 3,165,280 | 3,149,280 | 3,044,823 | 2,967,768 | 2,937,185 |
| Visitors | 8,838,090 | 8,701,633 | 8,281,352 | 8,777,911 | 8,318,916 | 8,463,268 | 8,388,272 | 8,496,424 | 8,347,651 | 8,242,722 |
| **FIXED ROOF** | | | | | | | | | | |
| Occupied room nights | 102,032 | 106,300 | 103,562 | 82,825 | 41,093 | 97,035 | 95,686 | 116,909 | 116,776 | 3,815 |
| Guests | 204,374 | 213,485 | 204,107 | 174,832 | 170,189 | 198,717 | 193,571 | 233,818 | 238,032 | 15,641 |
| **TOTAL VISITATION** | | | | | | | | | | |
| Parties | 3,442,270 | 3,413,012 | 3,176,617 | 3323923 | 3,136,752 | 3,262,315 | 3,244,966 | 3,161,732 | 3,084,544 | 2,941,000 |
| Visitors | 9,042,464 | 8,915,118 | 8,485,459 | 8952748 | 8,489,105 | 8,661,985 | 8,581,843 | 8,730,241 | 8,585,682 | 8,258,363 |

**Source: Saskatchewan Parks Outdoor Recreation and Visitation Statistical Use Report (2004). Only the parks Along the SSRB are listed.**

**Table C.2. Visitation Summary by Alberta Provincial Park-April 1, 2002 to October 31, 2002.**

| Provincial Park - Campground, Group use area, or Day use area | Number of Campsites | Occupied Campsite Nights | Overflow Unit Nights | Campers | Group Unit Nights | Group Campers | Day Use Party Visits | Day Use Visitors | Total Parties | Total Visitors |
|---|---|---|---|---|---|---|---|---|---|---|
| **Aspen Beach** | | | | | | | | | | |
| -Lakeview | 280 | 12,846 | | 44,274 | | | | | | |
| -Brewers Beach | 306 | 14,725 | | 50,996 | | | | | | |
| -Ebeling Beach | | | | | | | 55,780 | 168,986 | | |
| -Aspen Beach A | | | | | 314 | 973 | | | | |
| -Aspen Beach B | | | | | 227 | 704 | | | | |
| -Aspen Beach C | | | | | 292 | 905 | | | | |
| -Aspen Beach D | | | | | 112 | 347 | | | | |
| -Aspen Beach E | | | | | 199 | 617 | | | | |
| -Aspen Beach F | | | | | 167 | 518 | | | | |
| **TOTAL** | **586** | **27,571** | | **95,270** | **1,311** | **4,064** | **55,780** | **169,986** | **84,662** | **268,320** |
| **Beauvais Lake** | **85** | **3,098** | | **9,448** | **191** | **688** | **ND** | **ND** | **3,289** | **10,136** |
| **Bow Valley** | | | | | | | | | | |
| -Willow Rock | 124 | 4,277 | | 11,482 | | | | | | |
| -Bow Valley | 169 | 19,684 | | 58,241 | | | | | | |
| -Jewel Bay Backcountry | 9 | 241 | | 1,068 | | | | | | |
| -Elk Flats | | | | | | | | | | |
| -Canoe Meadows | | | | | 317 | 1,242 | | | | |
| -Porcupine | | | | | 1,700 | 5,270 | | | | |
| -Grouse | | | | | 759 | 2,976 | | | | |
| -Old Church Camp: | | | | | 691 | 2,695 | | | | |
| Owl | | | | | 673 | 2,221 | | | | |
| **TOTAL** | **302** | **24,202** | | **70,791** | **4,140** | **14,404** | **62,620** | **156,550** | **90,962** | **241,745** |
| **Bow Valley Wildland** | | | | | | | | | | |
| -Quaite Valley Backcountry | 20 | 345 | | 1,188 | | | | | | |
| **TOTAL** | **20** | **345** | | **1,188** | | | **3,250** | **8,125** | **3,595** | **9,313** |
| **Kinbrook Island** | **166** | **11,361** | | **38,627** | **365** | **1,424** | **ND** | **ND** | **11,726** | **40,051** |
| **Little Bow** | | | | | | | | | | |
| -Deer Coulee | | | | | ND | ND | | | | |
| -Little Bow | | | | | ND | ND | | | | |
| **TOTAL** | **205** | **ND** | | **ND** | **ND** | **ND** | **ND** | **ND** | **ND** | **ND** |

| Provincial Park - Campground, Group use area, or Day use area | Number of Campsites | Occupied Campsite Nights | Overflow Unit Nights | Campers | Group Unit Nights | Group Campers | Day Use Party Visits | Day Use Visitors | Total Parties | Total Visitors |
|---|---|---|---|---|---|---|---|---|---|---|
| **Little Fish Lake** | 14 | 197 | | 689 | | | 400 | 1,148 | 597 | 1,837 |
| **Park Lake** | | | | | | | | | | |
| -Park Lake: A | | | | | 162 | 437 | | | | |
| -Park Lake: B | | | | | 130 | 312 | | | | |
| -Park Lake: Main Area | | | | | | | | | | |
| -Park Lake: Boat Launch | | | | | | | | | | |
| TOTAL | 48 | 892 | | 3,131 | 292 | 749 | ND | ND | 1,184 | 3,880 |
| **Pembina River** | 132 | 3,647 | | 10,738 | 159 | 493 | 6,250 | 17,209 | 10,056 | 28,440 |
| **Peter Lougheed Park** | | | | | | | | | | |
| -Canyon | 52 | 2,019 | | 6,270 | | | | | | |
| -William Watson | 20 | 421 | | 1,176 | | | | | | |
| -Elkwood | 130 | 7,211 | | 24,517 | | | | | | |
| -Boulton Creek | 118 | 7,036 | | 22,971 | | | | | | |
| -Lower Lake | 104 | 2,955 | | 9,829 | 895 | 2,596 | | | | |
| -Mount Sarrail | 44 | 1,165 | | 3,231 | | | | | | |
| -Interlakes | 48 | 4,100 | | 12,883 | | | | | | |
| -Elbow Lake Backcountry | 15 | 380 | | 1,381 | | | | | | |
| -Point Backcountry | 20 | 880 | | 3,568 | | | | | | |
| -Forks Backcountry | 15 | 533 | | 2,108 | | | | | | |
| -Three Island Lake Backcountry | 16 | 373 | | 1,308 | | | | | | |
| -Turbine Canyon Backcountry | 12 | 301 | | 1,086 | | | | | | |
| -Aster Lake Backcountry | 5 | 186 | | 732 | | | | | | |
| -Pocaterra | | | | | 580 | 1,566 | | | | |
| TOTAL | 601 | 27,560 | | 91,060 | 1,475 | 4,162 | 45,390 | 118,014 | 74,425 | 213,236 |
| **Red Lodge** | 120 | 4,312 | | 15,047 | | | 4,020 | 15,412 | 8,332 | 30,459 |
| **Tilebrook** | 120 | 5,998 | | 14,936 | | | ND | ND | 5,998 | 14,936 |
| **Willow Creek** | 40 | 1,637 | | 5,575 | | | ND | ND | 1,637 | 5,575 |
| **Woolford** | 30 | 130 | | 447 | 59 | 230 | ND | ND | 189 | 677 |

| Provincial Park - Campground, Group use area, or Day use area | Number of Campsites | Occupied Campsite Nights | Overflow Unit Nights | Campers | Group Unit Nights | Group Campers | Day Use Party Visits | Day Use Visitors | Total Parties | Total Visitors |
|---|---|---|---|---|---|---|---|---|---|---|
| **Wyndham-Carseland** | | | | | | | | | | |
| **-Carseland: A** | | | | | 484 | 1,888 | | | | |
| **-Carseland: B** | | | | | ND | ND | | | | |
| **-Carseland: C** | | | | | ND | ND | | | | |
| **-Wyndham: Main** | | | | | | | ND | ND | | |
| **-Wyndham: Johnson Island** | | | | | | | ND | ND | | |
| **-Wyndham: Weir** | | | | | | | ND | ND | | |
| **TOTAL** | **196** | **3,580** | | **11,495** | **484** | **1,888** | **ND** | **ND** | **4,064** | **13,383** |

Source: Saskatchewan Parks Outdoor Recreation and Visitation Statistical Use Report (2004). Only the parks Along the SSRB are listed.

**Table C.3. Camping Permit Days by Park Classification in Saskatchewan SSRB**

| Location and Permit | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|
| **Douglas** | | | | | | |
| Regular | 7,210 | 6,936 | 6,750 | 6,692 | 7,220 | 4,075 |
| Reservation | | | | | | 2,696 |
| Monthly | | 210 | 210 | 450 | 570 | 1,470 |
| Seasonal | 4,070 | 3,850 | 3,465 | 3,300 | 3,245 | 0 |
| Self-Registration | 145 | 159 | 210 | 140 | 250 | 167 |
| School/youth group | 218 | 343 | 233 | 272 | 200 | 168 |
| Total Permit Days | **11,644** | **11,498** | **10,868** | **10,854** | **11,485** | **8,576** |
| | | | | | | |
| **Saskatchewan Landing** | | | | | | |
| Regular | 6,627 | 6,196 | 7,091 | 6,601 | 9,144 | 7,440 |
| Reservation | | | | | | 1,097 |
| Monthly | | 180 | 450 | 960 | 360 | 810 |
| Seasonal | 7,590 | 7,370 | 7,700 | 6,490 | 5,610 | 5,555 |
| Self-Registration | 228 | 431 | 387 | 321 | 375 | 219 |
| School/youth group | 191 | 73 | 307 | 138 | 57 | 108 |
| Total Permit Days | **14,636** | **14,252** | **15,935** | **14,510** | **15,546** | **15,229** |
| | | | | | | |
| **Blackstrap** | | | | | | |
| Regular | | | | | 2 | -4 |
| Monthly | | | 90 | 30 | | 240 |
| Seasonal | 220 | 220 | 440 | 110 | 605 | 440 |
| Self-Registration | 1,448 | 1,389 | 1,455 | 1,656 | 1,779 | 1,311 |
| School/youth group | 30 | | | | | 0 |
| Total Permit Days | **1,698** | **1,609** | **1,985** | **1,796** | **2,386** | **1,987** |
| | | | | | | |
| **Danielson** | | | | | | |
| Regular | | | 646 | 1,311 | 1,328 | 1,240 |
| Monthly | | | 60 | 90 | 60 | 0 |
| Seasonal | 1,045 | 990 | 2,090 | 2,035 | 2,640 | 2,695 |
| Self-Registration | 2,201 | 2,168 | 1,612 | 635 | 880 | 608 |
| School/youth group | | 50 | | 53 | 50 | 42 |
| Total Permit Days | **3,246** | **3,208** | **4,408** | **4,124** | **4,964** | **4,585** |

Source: Saskatchewan Parks Outdoor Recreation and Visitation Statistical Use Report (2004).

**Table C.4. Economic impact multipliers for recreation site visits in Saskatchewan**

| Location | 1990 Multiplier | 2003 Multiplier | % Change from 1990 to 2003 |
|---|---|---|---|
| Blackstrap | 3.7 | 3.7 | 0.0% |
| Buffalo Pound | 3.6 | 3.6 | 0.0% |
| Candle Lake | 3.6 | 3.6 | 0.0% |
| Cypress Hills | 3.4 | 3.2 | -5.9% |
| Douglas | 3.4 | 3.4 | 0.0% |
| Duck Mountain | 3.3 | 3.6 | 9.1% |
| Echo Valley | 3.8 | 3.2 | -15.8% |
| Good Spirit Lake | 3.7 | 3.5 | -5.4% |
| Greenwater Lake | 3.6 | 3.5 | -2.8% |
| Makwa Lake | 3.7 | 3.5 | -5.4% |
| Meadow Lake | 4.4 | 3.6 | -18.2% |
| Moose Mountain | 3.6 | 4.0 | 11.1% |
| Pike Lake | 3.8 | 3.8 | 0.0% |
| Rowan's Ravine | 3.4 | 3.4 | 0.0% |
| Saskatchewan Landing | 3.2 | 2.9 | -9.4% |
| The Battlefords | 3.7 | 3.4 | -8.1% |
| Emma Lake Rec. Site | 3.5 | 3.5 | 0.0% |
| Chitek Lake Rec. Site | - | 3.2 | 0.0% |
| **Overall Average/Totals** | **3.6** | **3.5** | **-3.7%** |

Source: Saskatchewan Parks Outdoor Recreation and Visitation Statistical Use Report (2004). Not all sites could be accounted for with the data available.

**Table C.5. Expenditure on Nature Based Activities for Residents of Alberta (1996)**

| Category of Expenditure | Outdoor Activities | | Wildlife Viewing | | Recreational Fishing | | Hunting Wildlife | | Other Nature Related Activities |
|---|---|---|---|---|---|---|---|---|---|
| | $ Million | % | $ Million | % | $ Million | % | $ Million | % | $ Million |
| Accommodation | 135.3 | 15.0 | 4.4 | 2.6 | 7.4 | 5.0 | 1.8 | 2.5 | |
| Transportation | 229.0 | 25.4 | 15.8 | 9.2 | 35.0 | 23.7 | 20.2 | 28.5 | |
| Food | 183.2 | 20.3 | 9.5 | 5.5 | 23.5 | 15.9 | 7.2 | 10.1 | |
| Equipment | 293.6 | 32.6 | } 142 | 82.7 | 50.9 | 34.4 | 29.0 | 40.8 | |
| Other Items | 60.5 | 7.7 | | | 31.0 | 21.0 | 13.0 | 18.3 | |
| Costs for Other Activities | | | | | | | | | 70.2 |
| Total ($) | 901 | 100 | 171.6 | 100 | 147.8 | 100 | 71.0 | 100 | 70.2 |
| Average Yearly | $836 | | $433 | | $409 | | $843 | | |
| Average Daily | $56 | | $23 | | $22 | | $51 | | |

Source: Statistics Canada. *The Importance of Nature to Canadians: The Economic Significance of Nature Related Activities*. 2000. P. 32

## Table C.6. Expenditure on Nature Based Activities by Residence of Saskatchewan (1996)

<table>
<tr><th rowspan="2">Category of Expenditure</th><th colspan="2">Outdoor Activities</th><th colspan="2">Wildlife Viewing</th><th colspan="2">Recreational Fishing</th><th colspan="2">Hunting Wildlife</th><th>Other Nature Related Activities</th></tr>
<tr><th>$ Million</th><th>%</th><th>$ Million</th><th>%</th><th>$ Million</th><th>%</th><th>$ Million</th><th>%</th><th>$ Million</th></tr>
<tr><td>Accommodation</td><td>37.3</td><td>14.1</td><td rowspan="2">}6.7</td><td rowspan="2">17.0</td><td>5.7</td><td>6.0</td><td>1.0</td><td></td><td></td></tr>
<tr><td>Transportation</td><td>63.3</td><td>24.0</td><td>15.5</td><td>16.2</td><td>9.0</td><td></td><td></td></tr>
<tr><td>Food</td><td>50.8</td><td>19.3</td><td rowspan="3">}32.6</td><td rowspan="3">83.0</td><td>9.2</td><td>9.6</td><td>4.4</td><td></td><td></td></tr>
<tr><td>Equipment</td><td>97.0</td><td>36.8</td><td rowspan="2">}65.0</td><td rowspan="2">68.2</td><td rowspan="2">}19.3</td><td rowspan="2">57.2</td><td></td></tr>
<tr><td>Other Items</td><td>15.3</td><td>5.8</td><td></td></tr>
<tr><td>Costs for Other Activities</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>22.2</td></tr>
<tr><td>Total ($)</td><td>263.7</td><td>100.0</td><td>39.3</td><td>100.0</td><td>95.4</td><td>100.0</td><td>33.7</td><td>100.0</td><td>22.2</td></tr>
<tr><td>Average Yearly</td><td>763</td><td></td><td>344</td><td></td><td>557</td><td></td><td>723</td><td></td><td></td></tr>
<tr><td>Average Daily</td><td>49</td><td></td><td>17</td><td></td><td>29</td><td></td><td>45</td><td></td><td></td></tr>
</table>

Source: Statistics Canada. *The Importance of Nature to Canadians: The Economic Significance of Nature Related Activities*. 2000. P. 30