Adapting to Impacts of Climatic Extremes:

Case Study of the Kainai Blood Indian Reserve, Alberta

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Prepared for the Institutional Adaptations to Climate Change Project,
Social Sciences and Humanities Research Council of Canada's
Major Collaborative Research Initiatives

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smart science solutions

LIMITED REPORT

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Cover Photo: **Kainai Blood Indian Reserve Signage** (V. Wittrock 2008)

Inside Cover Photo: **Community of Standoff** (V. Wittrock 2008)

Executive Summary

This report is part of the Institutional Adaptation to Climate Change (IACC) project. The IACC project is designed to "develop a systematic and comprehensive understanding of technical and social capacities of regional institutions to formulate and implement strategies of adaptation to climate change risks and the forecasted impacts of climate change on the supply and management of water resources in dryland environments". In order to facilitate meeting this objective, knowledge of the impacts on people and the communities' institutions is crucial. Past experience with the coping mechanisms and adaptation measures adapted to these changing climate regimes may also be useful in designing future climate change programs and policies.

One of the six Canadian communities chosen was the Kainai Blood Indian Reserve (KBIR). The Blood (Kainai) First Nation is one of five tribes of the Blackfoot Confederacy that entered into a peace agreement (Treaty Seven) in 1877 with the Canadian and British Governments. The KBIR is located in southern Alberta in the Palliser Triangle, the driest part of the Canadian Prairies, and therefore the people on the reserve are exposed to extreme climatic events such as floods and droughts.

The primary objective of this study was to investigate the impacts of the 2001 to 2002 drought, and the floods of 1995, 2002 and 2005 on the Kainai Blood Indian Reserve (KBIR) and its residents, with emphasis on water resources. An associated objective was to identify the nature of adaptation measures undertaken to deal with the impacts. These impacts were studied in the context of the entire KBIR which encompasses an area of just over 1400 km^2. Drought and flood impacts were assessed in terms of bio-physical and economic changes.

The impacts of the extreme weather events were serious for the people of the KBIR. The floods likely had the most immediate impacts on the residents, as homes and businesses were flooded. Also, the response capabilities of emergency services were stressed, infrastructure such as roads was damaged and the potable water sources were compromised. Many other impacts likely occurred, but we do not have information about them.

The droughts appeared to have little direct impact on the residents of the reserve because they obtain their potable water either directly from a well or via delivery by truck from a communal groundwater source. Some residents with individual wells reported that their wells went dry and they had to have water delivered by truck. The droughts did impact the irrigated land through reduction of available irrigation water, however, the amount of reduction is not known. While some conflicts over water availability were discussed, it is not known if the reduced water supply affected the crop yields. Reduced crop yields have little effect on the KBIR people because the majority of the agricultural land is cash-leased to non-natives.

Despite the many economic challenges, the Kainai Nation residents have undertaken some measures to adapt to the impacts of flooding, including the relocation of some homes to less risky areas and improved drainage for some of the other at-risk houses. Since the 2002 floods, the Department of Public Works has been upgrading some roads with more compaction and better drainage to prevent washouts during heavy precipitation events. Boil-water advisories were issued to Reserve residents because of possible contamination from flood waters.

Future adaptation measures by the Kainai Nation to climatic changes and extremes are a function of their current and future adaptive capacities. The economic limitations faced by the Kainai Nation members result from limited money transfers by the Federal government to the Nation, the lack of local economic opportunities, high unemployment rates, lack of insurance and relatively lower human capital (level of education and skills), and these limitations constrain their adaptive capacity. Moreover, future adaptation measures will continue to have less priority for the Nation if the stresses from more immediate socio-economic challenges persist. However, the stress of impacts of climate extremes is likely to continue to compound the other stresses.

The characteristics of the KBIR caused several challenges for the climate impact, adaptation and vulnerability assessment research. Main challenges included the lack of data and information including water usage, population, plus others. This work represents only a beginning to the required impact and adaptation assessment that is needed to improve preparation to climatic. Suggestions for additional research include:

- Water supply and demand should be monitored and trends determined to help increase the understanding of vulnerability to water scarcity. For example, a groundwater level monitoring network is needed.
- Recently, the Blood Tribe started to decrease the amount of cash-leased land on the reserve and is enlarging their farming practices. It is important to determine how they will be able to cope with the effects of droughts and excess moisture/flooding under these new arrangements. This is especially important because the climate change projections indicate more extended and severe droughts and floods.
- The vulnerability of the KBIR residents is already high because of other stressors. It is important to determine the limits to the vulnerabilities such as determining groundwater levels and quality, and the priorities for improving adaptive capacity. It is also critical to determine how climate change will exacerbate all the stressors on the KBIR residents. Increased knowledge of climate change impacts and the Kainai Nation Members' potential adaptive capacities and vulnerabilities would be beneficial for many, including the KBIR residents.

In conclusion, this report is an important foundation for the comparison of two important hazards, flood and drought, and for integrating biophysical and socio-economic aspects of impacts and adaptive capacity, which form the basis for vulnerability assessment. The KBIR residents are in a region that is already affected by drought and floods, and these hazards and others are expected to increase. Their adaptive capacities are constrained by many socio-economic factors, however, they are currently buffered from drought, and sometimes flood effects, by factors including their use of groundwater, irrigation, and by their cash-lease system for agricultural land. Others in the Prairies, in general, have less access to these adaptation measures. Key questions regarding their vulnerability to climate change and water scarcity include the sustainability of those measures and the complex interaction of socio-economic and biophysical stresses.

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ABBREVIATIONS AND ACRONYMS

°C – Degrees Celsius
AAFC – Agriculture and Agri-Food Canada
BIR – Blood Indian Reserve
BSE – Bovine Spongiform Encephalopathy
BT – Blood Tribe
BTAP – Blood Tribe Agricultural Project
BTAR – Blood Tribe Administrative Review
BTAS – Blood Tribe Agricultural Sector
Cert. – certificate
cm – centimetres
DJF – December, January February
ha – hectare
IACC – Institutional Adaptation to Climate Change
INAC – Indian and Northern Affairs Canada
IWGIA – International Work Group for Indigenous Affairs
IPCC – Intergovernmental Panel on Climate Change
JJA – June, July, August
KABC – Kainai Agricultural Business Corporation
KBIR – Kainai Blood Indian Reserve
km – kilometres
km^2 – square kilometres
m^3/s – cubic metres per second
MAM – March, April, May
MCRI – Major Collaborative Research Initiative
mm – millimetres
No. – number
p. comm. – Personal Communication
PDSI – Palmer Drought Severity Index
PET – potential evapo-transpiration
PFRA – Prairie Farm Rehabilitation Administration
SMRID – St Mary Reservoir Irrigation District
SON – September, October, November
SPI – Standardized Precipitation Index
SSHRC – Social Sciences and Humanities Research Council of Canada

"Water – you have to be thankful for it…
The water that comes from the mountains, the rain and also from Mother Earth.

You have to be thankful and understand the value of water…what water gives to us…for the plants, the animals and ourselves.

You have to understand water first
before it can work for you."

Quoted from a Blood Tribe Member (Magzul 2005).

St. Mary Reservoir (Photo: V. Wittrock 2008)

"*We [people on the Reserve] should be really concerned about water because we are surrounded by it…*

It should be up to us and the surrounding people that live along the rivers to realize the importance of the resource that they have in their backyard."

Quoted from a Blood Tribe Member (Magzul 2005).

"Right now, people [on the Reserve] don't care
if it's going to be a drought,
or if there is going to be a flood…
they don't care because they believe they have no stake in it."

Quoted from a Blood Tribe Member (Magzul 2005).

KBIR Water Truck (Photo: L. Magzul 2005)

"In the Kainai culture, there is a month referred to as "the Moon of the Geese"; but now duck and geese appear at other times of the year.

March storms also used to be very predictable, and a lot of people would prepare accordingly; but increasingly they are not coming on time.

Another concern is in the area of traditional medicine: there is a risk of a real shortage of the supply of roots and other vegetation used for traditional remedies."

Quoted from Andy Blackwater, Elder of the Kainai (Blood Tribe) Nation presentation to the Standing Senate Committee on Agriculture and Forestry (Oliver and Wiebe 2003)

"We learned from the 1995 flood.
This time around [2002 flood], we had more help.
People were aware of what their roles were."

Quoted from Narine 2002

1. INTRODUCTION

1.1 Background and Need for the Study

This report is part of the Institutional Adaptation to Climate Change (IACC) project, which is designed to "develop a systematic and comprehensive understanding of the technical and social capacities of regional institutions to formulate and implement strategies of adaptation to climate change risks and the forecasted impacts of climate change on the supply and management of water resources in dryland environments" (Diaz et al. 2003). In order to facilitate meeting this objective, knowledge of the impacts on people and the communities' institutions is crucial. Past experience with the coping mechanisms and adaptation measures adapted to these changing climate regimes is also needed for designing climate change programs and policies. This study provides information on the current physical and social vulnerabilities related to water resource scarcity and surplus and assesses the technical and social adaptive capacity of various institutions in the Kainai Blood Indian Reserve study region. It complements other project activities, such as adding to the work by Magzul (2007).

In this report, the reserve is referred to as the Kainai Blood Indian Reserve No. 148 (KBIR). However, members of the reserve are called "Kainai Nation Members". The official administrative units at the KBIR are called Blood Tribe Department. Statistics Canada refers to the KBIR as the Blood 148 community.

The IACC project identified the KBIR for an in-depth investigation (Figure 1.1). This reserve is located in the Palliser Triangle[1], the driest part of the Canadian Prairies. This area is characterized by its aridity and has a mixed grassland eco-region (Nemanishen 1998). Under a changing climate, the frequency of drought and severe flood events are expected to increase. More specifically, all Global Climate Models project future increases of summer continental interior drying and associated risk of droughts (Watson et al. 2001). The recently released Fourth Assessment Report from the Intergovernmental Panel on Climate Change (IPCC) stated that future increases in the area affected by drought are likely (i.e. 66% probability of occurrence) (IPCC 2007a). The area of very dry regions has doubled since the 1970s and much of the Canadian Prairie Provinces has exhibited drying since the 1970s (Dai et al. 2004). Global warming enhances the hydrological cycle, so floods as well as droughts could increase. The IPCC (2007b) writes that the frequency of heavy precipitation events will very likely increase in the future (90-99% probability).

Increasing occurrences of extreme events have the potential to bring a high cost to society, especially those areas that are under stress with current climatic and other conditions. Other vulnerable areas are those areas with low adaptive capacity, low ability to implement adaptation, and/or considerable property to damage. For indigenous peoples, climate change and extreme

[1] The Palliser Triangle is in the "rain-shadow" of the Rocky Mountains. It is north of the American border, bounded by Cartwright, Manitoba, Lloydminster, Saskatchewan and Calgary and Cardston Alberta. It was reported by Captain John Palliser that the land was not suitable for agricultural settlement (Nemanishen 1998)

events brings different kinds of risks, opportunities, threatens cultural survival and negatively impacts indigenous human rights (IWGIA 2008).

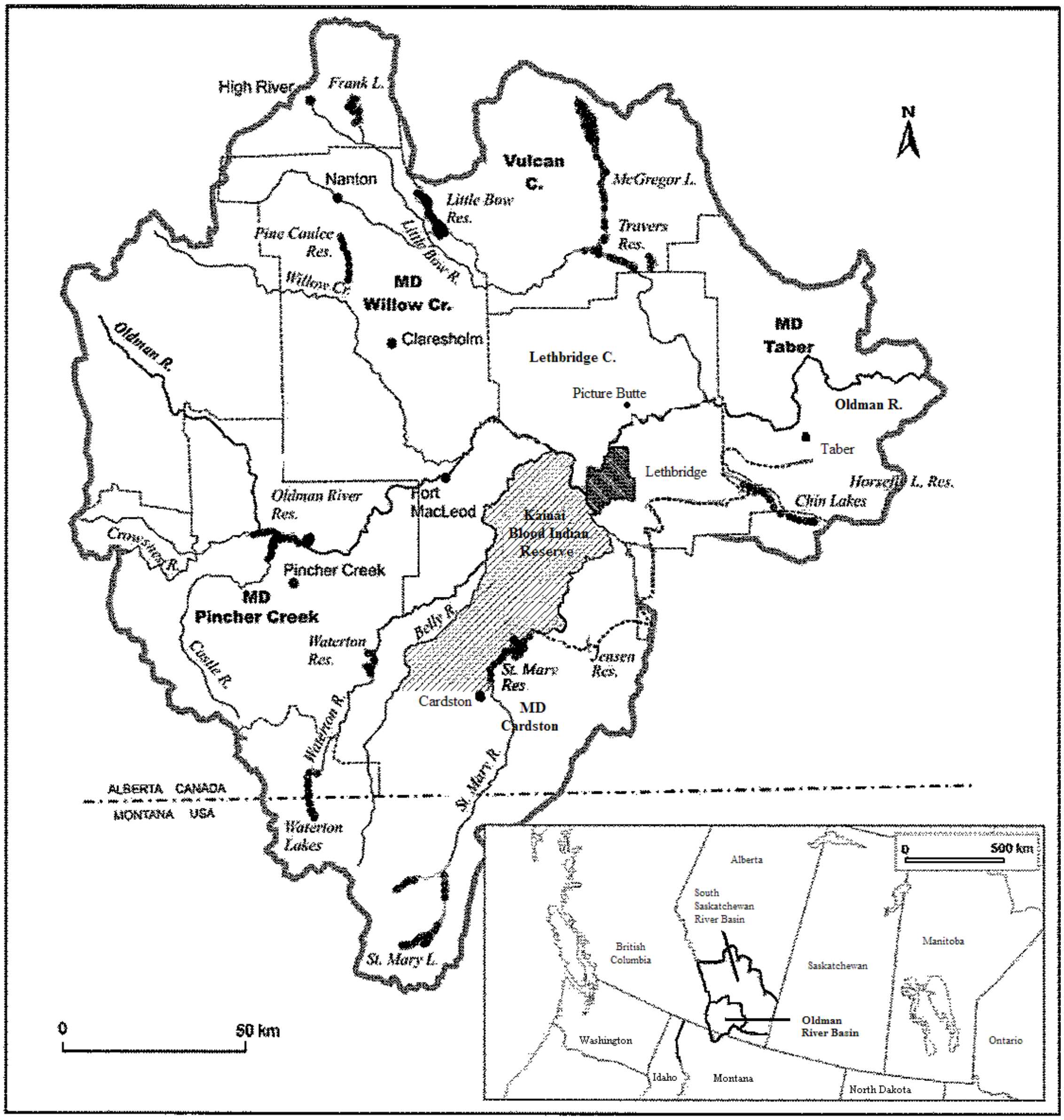

Figure 1.1 The Location of the Kanai Blood Indian Reserve and Surrounding Areas (adapted from Stratton 2005).

1.2 Objective and Scope of the Study

The primary objective of this study is to investigate the impacts of the 2001 to 2002 drought as well as the floods of 1995, 2002 and 2005 on the KBIR, with emphasis on water resources, where information is available. An associated objective is to identify the nature of adaptation measures undertaken.

1.3 Organization of the Report

In addition to this section, the Introduction, the report has six other sections. The first describes the study methodology, second describes the KBIR and the Kainai Nation Members, the third is an overview of the droughts and floods selected for the assessment, the fourth discusses adaptation measures and their effectiveness, and a summary and conclusion follow.

2. STUDY METHODOLOGY

The study methodology involved a combination of three types of techniques including:

1) Conceptual and descriptive tools as well as secondary literature relevant to this study.

2) Primary data-based research which included information on enterprise-specific and location specific data interpretation on impacts, vulnerability and adaptation measures used by the KBIR. These data were collected by a combination of focus group meetings and interviews conducted by Magzul during 2005 and a second set of informal meetings with KBIR officials during July 2008 by Kulshreshtha, Magzul and Wittrock.

3) Primary and secondary data-based research, which included an assessment of historical pattern of droughts and floods, features of the 1995, 2002 and 2005 floods, features of the 2001 to 2002 drought and associated bio-physical and economic impacts.

2.1 Method for Data and Information Collection at the Community Level

Interviews and a focus group were conducted in the Blood Tribe to gain insights of the community, stakeholders and institutions. They were semi-structured to allow respondents to discuss the difficulties they and their community faced and their ability to cope with various situations.

The 30 stakeholder interviews conducted by Magzul (2005) were based on the method developed by Wandel et al. (2005). The interviews addressed three main areas:

- General information to place the person being interviewed in the larger picture of the community;
- Open-ended questions to document exposure and sensitivities important to the people, and why and how adaptive strategies are implemented to deal with the exposures; and
- Guided interview to provide a systematic basis for assessing exposures, sensitivities[2] and adaptive capacity[3].

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[2] Exposure and sensitivities are those conditions that are important to people (Wandel et al. 2005).
[3] Adaptive capacity is the ability of a system to adjust to change, including climate, to minimize the damages, to take advantages of opportunities, or to cope with the consequences (IPCC 2007)

The meetings conducted by Kulshreshtha, Magzul and Wittrock were informal in nature. A set of questions was prepared (Appendix A), which was as a general guide to the discussion, as appropriate to the people attending the meeting. The general procedure was to let the spokesperson speak, and to record the gist of the conversation. Nine interviews were conducted; eight of these were with various officials of the Blood Tribe Administrative departments[4], and the ninth one with a Band Council Member.

2.2 Data Sources for the Bio-Physical Assessment

Several databases were obtained and processed for use in this analysis. These databases include information on climatic elements, climatic indices and various hydrologic elements including stream flow, reservoir levels, groundwater levels, and dugout levels. These data provide essential information for documenting the nature of the water supplies of the region. Data for grasshoppers were also utilized. Grasshoppers were selected as they are an import crop pest species in the prairies. Additional figures and tables for the bio-physical sections are in the appendices B and C.

2.2.1 Climatic Elements

Precipitation and temperature information for Cardston, Lethbridge and Blood Tribe was obtained from Environment Canada (2008a) (Table C2.1, Figure B3.1). The averages are for 1971-2000. Blood Tribe area's climate station (Blood Tribe AGDM) does not have averages because of its short duration (2004-2007). The data were imported into Microsoft Excel for analyses.

2.2.2 Stream Flow and Reservoir Levels

Stream flow and reservoir level data were obtained from Environment Canada (2008b) (Table C2.2). The averaging period for each stream and reservoir was the 1971-2000. The data were imported into Microsoft Excel for analyses.

The KBIR has three rivers as its borders: the St. Mary River on the east, the Belly River on the west and the Oldman River on the north (Figure 1.1). The Waterton River is also important because it drains into the Belly. Also, diversion canals join the Waterton River with the St. Mary River and one of the canals traverses the southern portion of the Reserve.

Drainage area is the total surface area, upstream of a point on the stream, where water from rain, snowmelt or irrigation, which is not absorbed into the ground, flows over the ground surface, back into the streams. Knowing the drainage area is important in extreme events such as rainfall as the bigger the drainage area, the more water the stream will have to accommodate. As indicated in Table C2.2, the Oldman River has the largest effective drainage area of 15,500 km^2 (Environment Canada 2008b) compared to the St Mary River at Lethbridge (3310 km^2). The

[4] The names of these individuals are not presented here on account of anonymity requested by these individuals at the time of their interview.

Belly River's effective drainage area is the lowest at 538 km^2. The Belly River, even with its small drainage area, is important to the KBIR because there are major settlements including Standoff that are located close to it.

2.2.3 Groundwater

Groundwater levels are monitored by a network of observation wells (Alberta Environment 2008). The observation wells were selected because of their proximity to the study area (Figure B3.1). Groundwater level data for these wells were obtained from Alberta Environment (2008) (Table C2.3). The data were imported into Microsoft Excel for analyses.

2.2.4 Dugout Levels

Dugout level data were obtained from the Prairie Farm Rehabilitation Administration – Agriculture and Agri-Food Canada (2006a) (Figures B5.16-B5.22).

2.2.5 Potential Evapo-transpiration

Potential evapo-transpiration (PET) data were obtained from Prairie Farm Rehabilitation Administration, Agriculture and Agri-Food Canada (2008a). PET was calculated using the Priestley-Taylor equation[5].

2.2.6 Palmer Drought Severity Index

Palmer Drought Severity Index (PDSI) was published monthly for the Canadian Prairies in map form for the 1995 to 2005 period. The maps indicate how the wet conditions and drought conditions evolved. The method used for Environment Canada's and Agriculture and Agri-Food Canada's PDSI is described in Hopkinson (2000).

2.2.7 Standardized Precipitation Index

The Standardized Precipitation Index (SPI) was calculated by Bonsal (p. comm. 2008) using Environment Canada's measured data as well as its gridded data set. SPI is an index based on the probability of precipitation for selected time scales. SPI values range from +2 (or more) indicating wet conditions to -2 (or less) indicating dry conditions. SPI values are another indication of drought severity.

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[5] Potential evapo-transpiration is a measure of the ability of the atmosphere to remove water from the surface through evaporation and plant transpiration, assuming no limit to the water supply (Ritter 2006). The Priestley-Taylor method is one of several ways to calculate potential evapo-transpiration.

2.2.8 Grasshopper Population

A grasshopper survey is carried out every year by Alberta Agriculture Food and Rural Development and other organisations including Agriculture and Agri-Food Canada, University of Lethbridge and Association of Alberta Agricultural Fieldmen (August to September) to determine the potential grasshopper density for the upcoming year. The forecasts for the coming year (e.g., 2002) indicate the grasshopper population for the current year (e.g., 2001) (Hartley, p. comm. 2006). For example, the forecast for 2002 made in 2001 was an indication of the grasshopper population in 2001. However, a limitation is that the forecasts do not distinguish between the pest and non-pest species of grasshoppers (Johnson, p. comm. 2006) (Figures B5.23-B5.24).

2.3 Data Sources for the Socio-Economic Assessment

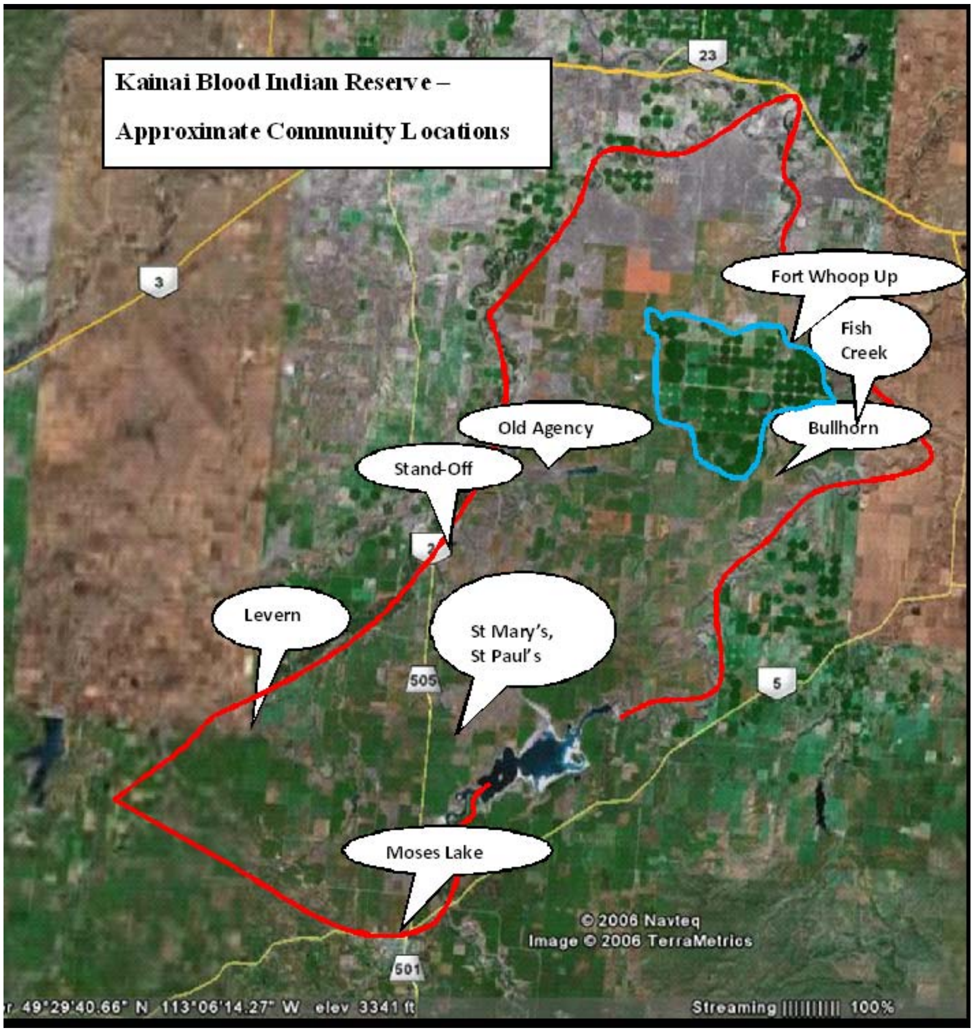
Collection of data on various socio-economic characteristics for the Kainai Blood Indian Reserve No. 148 (KBIR) was challenging. This is because much of the secondary data affecting the impact of extreme events are not collected for the local region (i.e., KBIR). To overcome this problem, an attempt was made to collect this information first hand through a visit to the KBIR in 2008. However, this also yielded very little success.

Although some of the secondary data on agricultural and other socio-economic characteristics are collected, these are typically for a larger region, such as a county, or a crop district. In spite of the challenges faced, data were collected from the following sources: (i) Population data from Statistics Canada, Community Profiles; (ii) Blood Tribe Web site; (iii) Information gathered through interviews of KBIR Administration officials; and (iv) Indian and Northern Affairs Canada.

3. DESCRIPTION OF THE KAINAI BLOOD INDIAN RESERVE REGION

3.1 Location of the Kainai Blood Indian Reserve

The Blood (Kainai) First Nation is one of five tribes of the Blackfoot Confederacy that entered into a peace agreement (Treaty Seven) in 1877 with the Canadian and British Governments. The KBIR with a land base of 1414.03 square kilometres, or 356,755 acres, is located in the southwest corner of Alberta, west of the St Mary River, east of the Belly River and south of the Oldman River (Figure 1.1). Its capital is Standoff with six other communities (Moses Lake, Levern, Old Agency, Fish Creek, Fort Whoop Up and Bullhorn) on the reserve (Figure 3.1) (Blood Tribe Web Page ND; Dempsey, 2007; MNP Mpact 2003; Schissel and Wilson 2005; Blood Tribe/Kanai 2004; Statistics Canada 2001; SouthGrow Regional Initiative 2008).



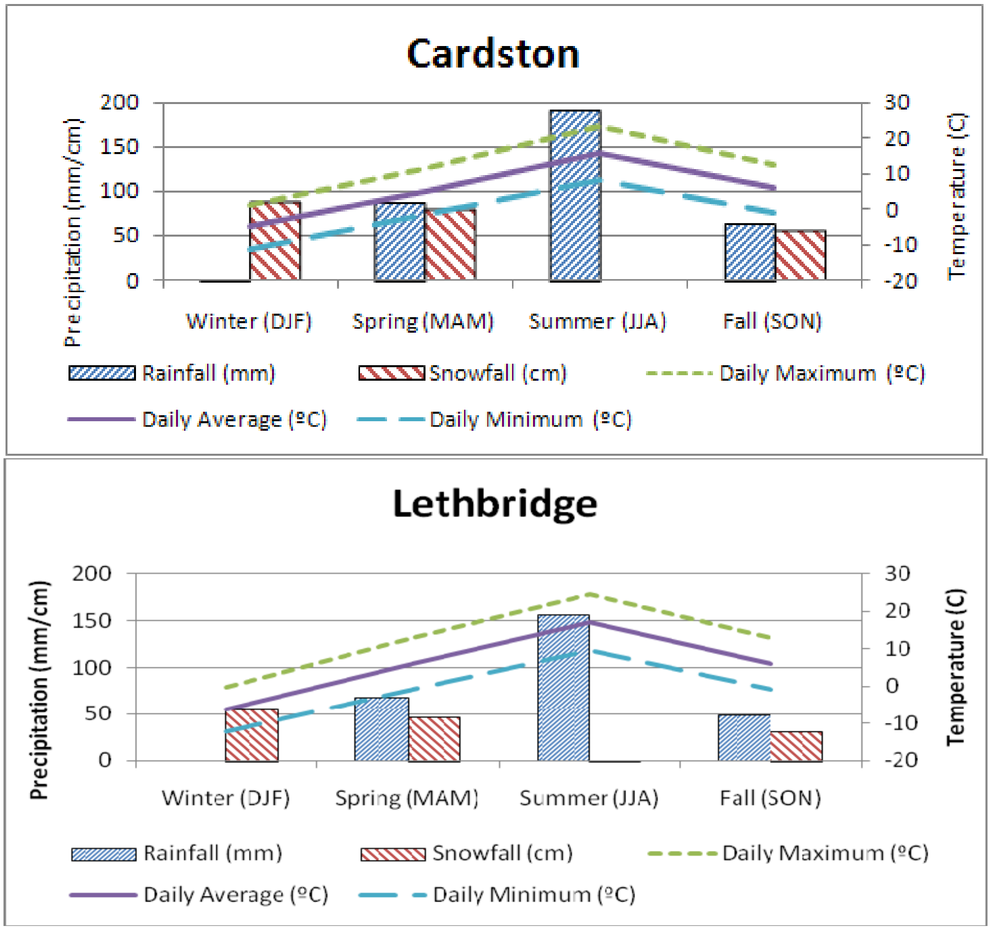
Base Map Source: Google Earth Pro 2007

Figure 3.1 Kainai Blood Indian Reserve's Approximate Community Locations.
Note: Reserve boundary is outlined in red.
Irrigation area is outlined in blue.

3.2 Physical Characteristics of the Kainai Blood Indian Reserve

3.2.1 Climatology of the Region

Two long term climate stations, Cardston and Lethbridge, are located relatively close to the KBIR (Figure B3.1). Cardston is located south of the Reserve and Lethbridge is located on the northeast corner of the Reserve. The two stations have slightly different climates. Cardston has a slightly lower annual temperature than Lethbridge and receives 170 mm more annual average precipitation than Lethbridge (Table C3.1). Both of the locations are located in the Chinook belt which helps moderate average temperatures. Cardston is warmer than Lethbridge in winter by 1.1ºC, but is 1.3ºC cooler in the summer and also cooler in the spring by 0.8ºC and 0.2ºC in the fall (Figure 3.2). The coldest month is usually January and the warmest month is usually July at both sites.



Data source: Environment Canada 2008a

Figure 3.2 Seasonal Average Temperature Levels and Precipitation Amounts for Cardston and Lethbridge for the 1971-2000 Averaging Period

The two sites have had severe weather events. For example, Cardston's extreme daily precipitation event occurred on June 6th, 1995 when 106 mm of rain fell. In Lethbridge the greatest one day precipitation event occurred on May 23, 1980 with 85.4 mm. Wind is also a factor in southern Alberta. At Lethbridge, the average annual wind speed is 18.2 km/h with December being the windiest month with an average wind speed of 21.2 km/h. Every month of the year has had peak wind gusts greater than 120 km/h. The maximum gust of 171 km/h was recorded on November 19, 1962 at Lethbridge.

As the KBIR is in the Chinook Belt of southern Alberta, daily temperatures fluctuate considerably, even in a matter of hours. Extreme high and low temperatures have been recorded in the area. For example, the highest temperature at Cardston was 39.0ºC in 2007, beating the previous record of 38.9ºC in 1939; Lethbridge's record high temperature was 39.4ºC in 1973. The extreme minimum temperatures for the two sites were −41.7ºC in Cardston in 1929 and −42.8ºC in Lethbridge in 1968 and 1950. Cardston has had below zero temperatures every month of the year, while in Lethbridge, only July has not had below zero temperatures.

3.2.2 Water Supply Characteristics

3.2.2.1 Stream Flow

The Oldman River Basin is an important water source for south western Alberta, including the KBIR. In Southern Alberta, the water is used for many services including irrigation, recreation, power generation ecosystems and drinking water. These rivers and canals were chosen for analyses to determine how they were affected by the drought of 2001 to 2002 and the high precipitation events of 1995, 2002 and 2005.

As stated earlier, the KBIR is bordered on three sides of the reserve by rivers. A hydro-electric generating plant is located on the Belly River near Glenwood. This generating plant diverts a portion of the flow through the Waterton-Belly Diversion Canal to a turbine (Canadian Hydro Developers, Inc. 2006). The Waterton River joins the Belly River on the west side of the reserve, just north of the community of Standoff. The Belly River joins the Old Man River on the north side of the Blood Tribe Reserve.

3.2.2.2 Groundwater

Groundwater levels in shallow, surficial aquifers overlain by permeable material fluctuate according to the seasonal and annual amounts of recharge. As a result, these aquifers are sensitive to drought and high soil moisture levels (Sketchell et al. 2000). Deeper wells are more resilient to most droughts, but they take longer to recharge. Groundwater recharge characteristics are not easy to determine because recharge depends on several variables including soil type, geology and hydrogeology, precipitation (e.g., amount, type, intensity, and snow melt rate), antecedent soil moisture conditions, runoff, topography and evapo-transpiration (Sketchell et al. 2000).

Approximately 90% of rural Canadian prairie residents obtain their water from wells (Martin et al. 2000). Groundwater is used by the KBIR residents for household potable water, and to a lesser water for livestock.

Groundwater accounts for only 4% of Alberta’s water needs because of the province’s proximity to high quality surface water from the mountains. In contrast, over 80% of the residents of the KBIR utilize groundwater supplies (Magzul 2005). This is of great benefit to buffer the residents from the immediate impact of inclement weather such as drought as it takes groundwater longer to react to decrease surface water levels. Only the people in Moses Lake use water supplied by Cardston (Magzul 2005).

3.2.2.3 Dugouts

Dugouts (excavated artificial ponds) are essential to most prairie agricultural community water supplies. Dugouts can be used in rural areas for many purposes including households, livestock and crop spraying. Dugouts are usually designed to have storage capacities for up to two years of drought conditions (Bell, p. comm. 2002 in Wittrock 2005).

From 1935 to 1999, approximately 49,100 dugouts were established in Alberta and the Dawson Creek region of British Columbia (PFRA-AAFC, 2006b). The KBIR has over 60 dugouts with the majority built prior to 1990 (PFRA-AAFC 2008b) (Figure B3.2). The authors could not find documentation on how the dugouts were utilized.

3.2.2.4 Domestic Water Supplies

Adequate water quantity is very important to communities. Relatively small changes in climate can cause or exacerbate water resource problems especially in arid to semi-arid regions (Wittrock et al. 2001). As mentioned, the domestic water source for the KBIR is mainly groundwater and all communities except Moses Lake obtain water from groundwater. Moses Lake obtains its potable water from the town of Cardston (Magzul 2005) likely because of the close proximity to Cardston. Cardston obtains its potable water from Lee Creek and St. Mary River (Town of Cardston 2008).

3.3 Socio-Economic Characteristics of Kainai Blood Indian Reserve and Its Communities

In this section, socio-economic characteristics of the KBIR are described using population, labour force, and employment, education, and housing as the major criteria. These characteristics were chosen as they are considered to be some of the generic determinants of the capacity to adapt to a changing climate (Smit and Pilifosova 2001). Of course, adaptation success is determined by the ability to effectively use these determinants. As noted above, all information is based on secondary sources with additional information obtained during interviews and field trips.

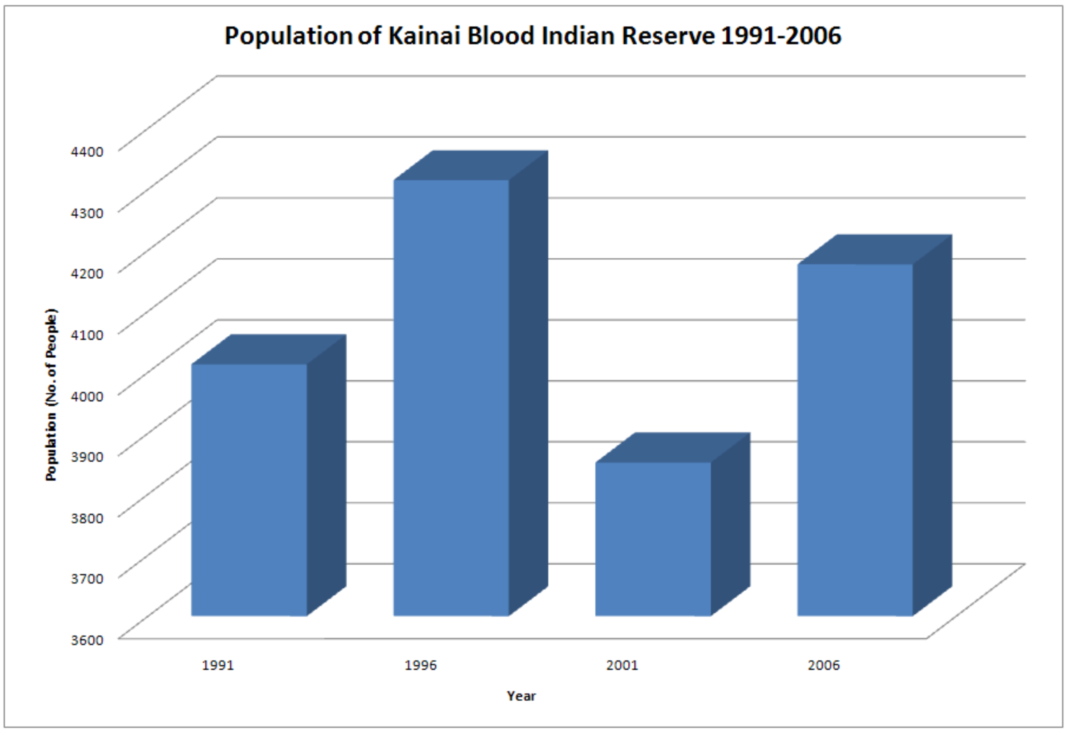
3.3.1 Population Base and Communities within the KBIR

Population of the KBIR is subject to the definition used. There are two major sources of population estimates: The Census of Population, and the KBIR Administration. According to Magzul (2007), the KBIR Administration estimates the current population of the Band to be 9,000 to 10,000 people. SouthGrow Regional Initiative (2008) confirms that 1996 population was 9,000, which grew to 10,006 by 2001. Latest estimate is that the membership of the Blood Tribe stands at 12,400 people[6]. However, Statistics Canada (2008) estimated the 2006 population for the reserve at 4,177 people. There are no official explanations for the discrepancy between the two estimates. One possible explanation might be that the estimates by the KBIR Administration refer to registered members of the Tribe, some of whom reside off the reservation. In contrast, general practice of Statistics Canada is to count the people who normally reside at a particular place. If one takes the 2006 estimate of KBIR population around 10,000 people, some 5,828 registered members of the KBIR must live outside the KBIR. Included here would be three types of families: (1) Kainai Nation members who live outside the reserve on account of shortage of housing on reserve; (2) Students and their dependents who live

[6] Based on information provided by the Blood Tribe Department of Works, Personal Communication, July 7 2008.

off-reserve; and (3) Kainai Nation members who live off-reserve for gainful employment but maintain their registration with the KBIR.

A time series over a longer period of time for the population of the KBIR is not available. Statistics Canada (2008) and data from Agriculture and Agri-Food Canada (undated) have provided data for 1996 to 2006 period (census periods only). Again it should be noted that this is based on the number of people who normally reside on the KBIR. A graph of this population trend is shown in Figure 3.3. On account of short period of time for the available data, a clear trend cannot be established. The reserve had a population of 4,315 in 1996. By the next census period (2001), it lost some 463 inhabitants, and population level of the reserve came down to 3,852. However, by 2006 there was a reversal in the decrease, as population grew to 4,177 people. Reasons for these changes are not available but are expected to be out- or in-migration in response to economic conditions.



Data Source: Compiled from Statistics Canada (2008) and Agriculture and Agri-Food Canada (Undated)

Figure 3.3 Population of Kainai Blood Indian Reserve, 1991-2006

The KBIR is relatively more sparsely populated than the province. In 2006 the population density was 3 people per square kilometer, as against 5.1 for Alberta. However, if we take the estimate of KBIR of 10,000 members of the Tribe, population density would be seven people per square kilometer, and is higher than that for the province of Alberta.

Total population of the KBIR is distributed in several communities and surrounding areas. Most of the population of the KBIR is concentrated around the Local Government (Band Council) Headquarter townsite, named Standoff. This is the center of the reserve and the hub of activity. However, as shown in Table 3.1, several other communities also exist in the KBIR. A map of location of these communities is shown in Figure 3.1.

Table 3.1 Estimated Population of KBIR Reserve Members by Community, 2008

Location or Name	Estimated Number of Members	Percent of the Total*
Standoff	1,800 – 2,400	28.0
Moses Lake	1,400	16.4
Levern	700	8.2
Old Agency Area**	2,000	23.4
Bullhorn / St. Mary's/ St. Paul's	1,500	17.5
Fort Whoop Up	200	2.3
Fish Creek	350	4.2
Estimated Total Population	7,950 -- 8,550	100.0
Population north of Standoff	3,000	
Population south of Standoff (including Standoff)	5,000	

* Estimated at the upper range of population

** Not a community concentrated in one place; most houses are in open area.

Data Source: Based on interviews of Blood Tribe Officials during the 2008 Field Trip

Almost two-thirds of the total population of the KBIR resides in the town of Standoff and areas to the south of it. Population of Standoff is somewhat transient and therefore, a precise estimate could not be made. The next larger community is Moses Lake, which is located on the very southern end of the reserve next to the town of Cardston[7].

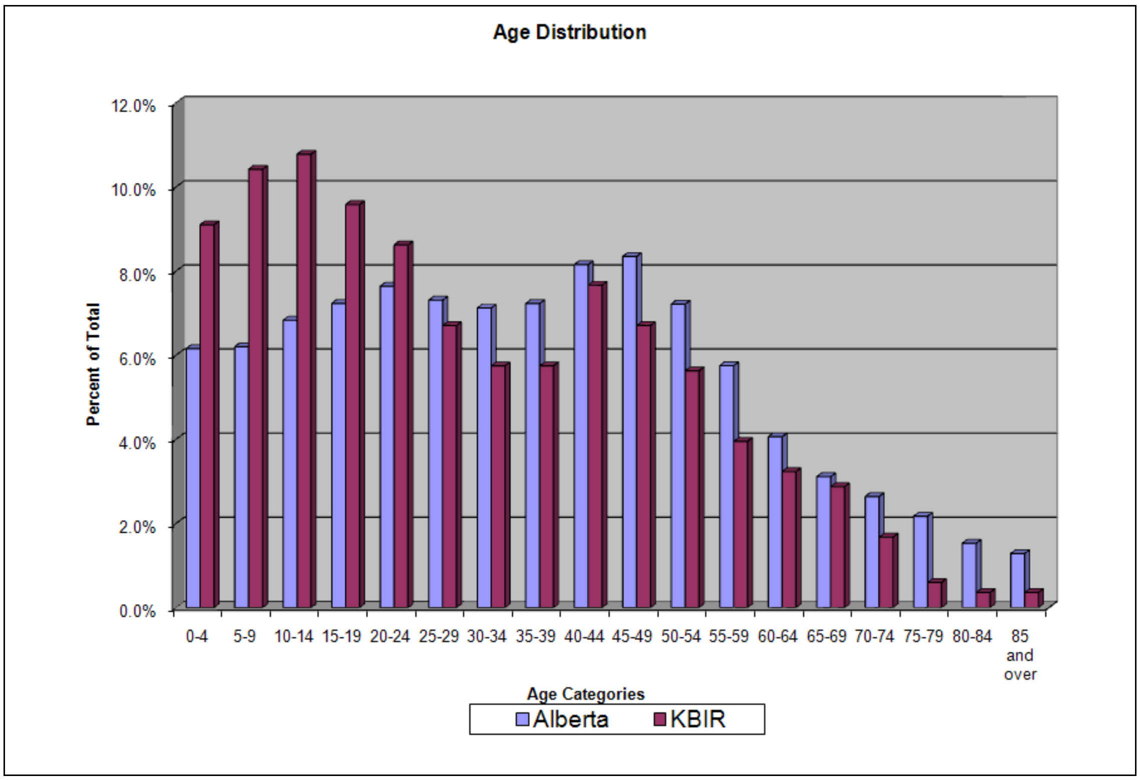
Standoff's Water Tower (Photo: E. Wheaton September 2008)

[7] The community of Moses Lake and Cardston are located very close to each other except that Cardston is outside the KBIR region, whereas the Moses Lake is within the KBIR.

3.3.2 Age Composition of KBIR Residents

Age distribution of the KBIR suggests that the population of younger (less than 15 year) and young adults (between 15 and 24 years of age) is relatively larger than for the province of Alberta (Figure 3.4). However, the proportion of people between the ages of 25 to 40 years is relatively smaller, and that over 75 years of age is even smaller.

A partial explanation of the lower proportion of 25-39 years might be that this age group is most likely to be in educational institutions off-reserve. The lower proportion of older people living at the reserve might be considered indicative of lower life expectancy[8] of KBIR people.



Data Source: Statistics Canada (2008)

Figure 3.4 Age Distribution of Population at Kainai Blood Tribe Indian Reservation and Province of Alberta, 2006

3.3.3 Dwellings on the KBIR

Similar to estimates of population, the data on dwellings varies somewhat depending on the source. Statistics Canada (2008) estimated that there were a total of 1,050 dwellings on the KBIR, of which 520 are owned (Table 3.2). According to the Blood Tribe Housing Department (2008), the KBIR has 1,218 homes, of which 903 are rural homes, and 165 are in the Standoff townsite. In addition, at the Standoff townsite, there are 14 special needs apartments. Also a total of 35 trailers are available for renting at the Kainai Manufactured Home Park.

[8] This conclusion is a pure conjecture at this time and requires further evidence on mortality of KBIR people.

Table 3.2 Selected Characteristics of Occupied Private Dwellings, Blood Indian Reserve, 2005

Selected Characteristic	Total No. of Dwellings	Percent distribution
Total Occupied Private Dwellings	1,050	
Single Detached Houses (% of Total)		95.2
Number of Owned Dwellings	520	
Number of Dwellings constructed before 1986	710	
Dwellings requiring major repairs (% of Total)		60.5
	Number	
Average Number of Rooms per Dwelling	5.7	
Dwellings with more than one person per room (% of Total)		15.7

Data Source: Statistics Canada (2008).

Many of the homes are in poor shape, perhaps in part due to flooding events. However, the most likely reasons for the poor housing conditions include an inadequate supply and an aging housing stock, overcrowding and lack of income for home repairs. The following excerpt from an interview in 2005 with an employee of the Blood Tribe Housing Department (Magzul 2005) provides a picture of the housing challenges faced by the Kainai Nation residents:

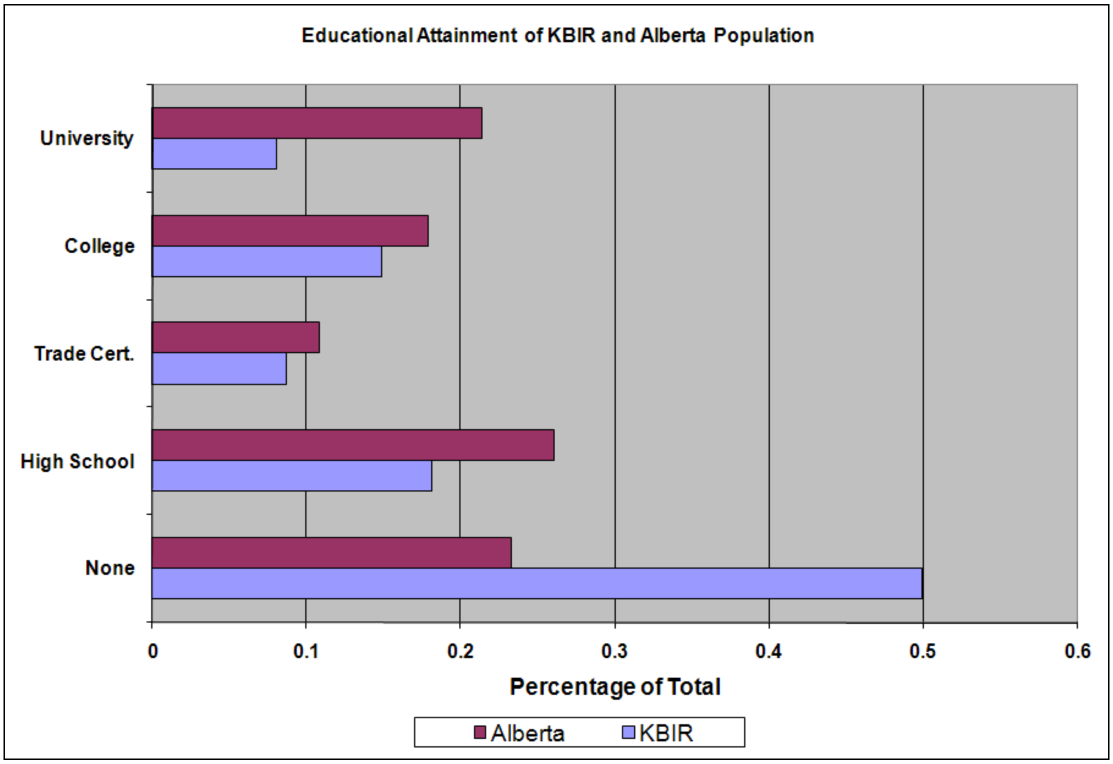
> "*In order to provide adequate housing for the community we need another 3,000 homes, and that's just to separate some of the families that are living 2 to 3 families per house, and that's for our future too. Our kids need a place to go. Right now our children are all moving to cities; we are losing them to the outside when this is their home, they should be able to stay, but we can't build houses fast enough because we don't have the money.*"
> (Blood Tribe Housing employee in Magzul 2005).

According to Statistics Canada (2008), 60.5% of all dwellings require major repairs. On-reserve occupancy rate is almost 6 members per home, compared to the national average of 2.5 people per home. Regardless of data source, the inescapable conclusion remains that dwellings on the KBIR are crowded and are in need of major repairs[9].

3.3.4 Educational Attainment

Relative to the province of Alberta, residents of the KBIR have not attained a similar level of education. As shown in Figure 3.5, half of the people over the age of 15 years have not had any formal education leading to a high school diploma or any other certificate or degree. The proportion of people with the same education status in Alberta was only 23%. Proportions of people at the KBIR in the other four categories of education attainment are lower than the same for the province. For example, only 8% of the members of the KBIR labour force had any university degrees, as against 21% for the province. One cannot escape that conclusion that the members of the KBIR are relatively less educated than a typical Albertan of age 15 years or over, and may not be as fully prepared for the workplace.

[9] This conclusion is supported both by the data in Table 3.2 as well by information provided by the Housing Department of the Blood Tribe Administration.



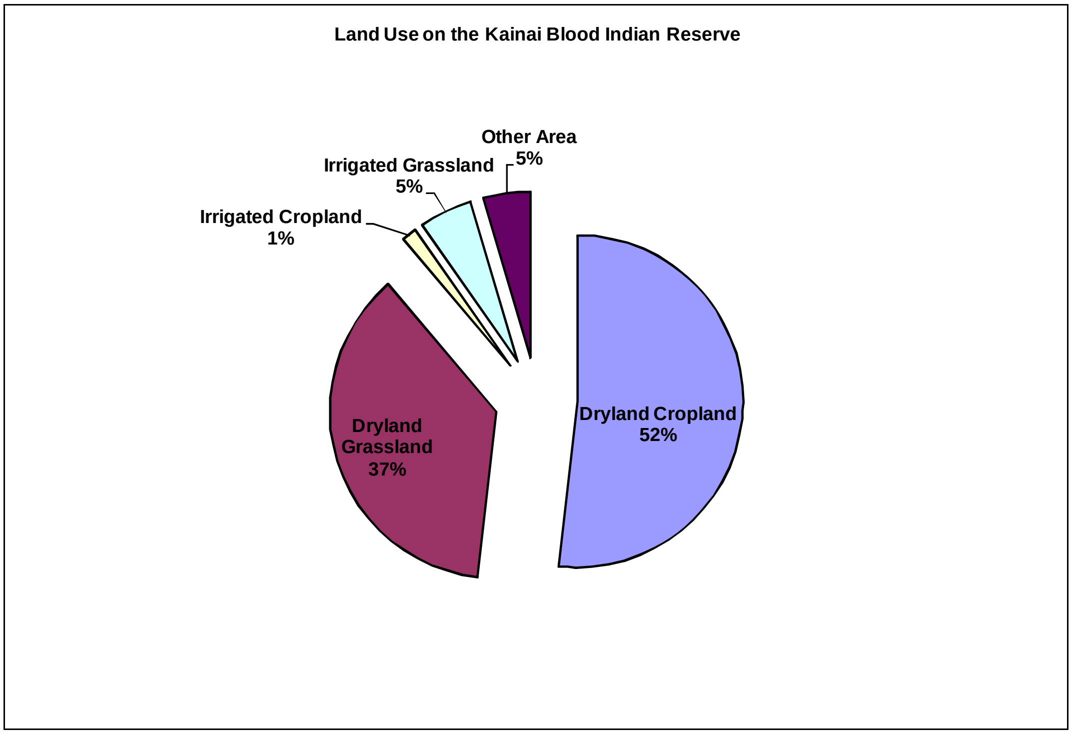
Data Source: Statistics Canada (2008)

Figure 3.5 Highest Educational Attainment of the Kainai Blood Indian Reserve and Alberta Population over 15 Years of Age

3.3.5 Economic Base of the KBIR

The KBIR has a limited resource base compared to the surrounding region or the province of Alberta. Although most of the KBIR lands are suitable for agricultural production, not much of any other type of economic activity is visible. Residents depend on the surrounding communities (such as Lethbridge or Fort Macleod in the north, and Cardston in the south) for meeting their day to day needs.

Although there is significant agricultural activity on the KBIR, only a small proportion is undertaken by the KBIR residents. Figure 3.6 shows that about 89% of the total area is suitable for dryland production. Relatively speaking, irrigation on the KBIR is limited to about 6% of the total land area.



Data Source: Blood Tribe Land Management Department (2006)

Figure 3.6 Land Use on the Kainai Blood Indian Reserve, 2006

On the KBIR, there are two types of land ownerships: Communal lands and Private lands. The former belong to the Kainai Nation and is under the control of the Band Council. The Band Council has created two organizations that hold the communal lands – Kainai Agricultural Business Corporation (KABC), and Blood Tribe Agricultural Project (BTAP). These two organizations hold 20% of the cultivable lands on the reserve, as shown in Table 3.3. The rest of the land is "owned" privately through occupancy rights.

Historically, some members of the KBIR were given occupancy rights. Individuals with occupancy rights have some control of the land. They can transfer, exchange or sell their land, but only to a member of the Band. Land "owned" through occupancy rights can be leased to neighbouring non-KBIR farmers, and the proceeds of the leasing arrangements are received by the "owners." These lands can remain in the family and are passed on from generation to generation.

Existence of occupancy rights is somewhat controversial since some members do not have such rights. It is estimated that 80% of the land is "owned" by 10-12% of the population[10]. Those, who do not have such lands, move to Standoff. This has created pressure on the infrastructure at the Standoff town-site. In addition, some of these members migrate to other places. This has created nucleus of Blood Tribe members in Northeast Calgary and North Lethbridge.

[10] Based on discussions with officials at the Blood Tribe Employment and Skill Training (BTEST), Levern.

Table 3.3 Major Types of Land Use by Ownership, Blood Indian Reserve

Land Use	Kainai Agricultural Business Corporation (Acres)	Blood Tribe Agricultural Project (Acres)	Occupants (Acres)	Total Area in Acres
Dryland Grassland	18,900		112,910	131,810
Irrigated Cropland	2,262	2,262	600	5,124
Dryland Cropland	20,354	6,496	156,926	183,776
Irrigated Grassland	18,380			18,380
Total Agricultural Area	59,896	8,758	270,436	339,090
Other Area				16,208
Total Area of the Reserve				355,298
	Percent			
Percent of Total Agricultural Area	17.7	2.6	79.7	100.0

Data Source: Blood Tribe Land Management (2006)

Another issue related to land is the decreasing per capita land availability. As the amount of land remains fixed, and population of the KBIR increases, more and more people do not have occupancy rights. Although communal lands (that owned by the Band) do exist, they constitute a very small proportion (20% of the total agricultural area) of the total.

The Blood Tribe Agricultural Project (BTAP) was initiated in 1991, but actual operations did not begin until 1995. At present, it manages Canada's largest irrigation project on the reserve (INAC 2004). This project came through a set of negotiations in 1989 among the three levels of governments – Federal, Province of Alberta[11], and the Tribal (Blood Tribe Band Council) government. It is the largest contiguous single owned irrigation project in Canada. Irrigated lands are cash-leased out to neighbouring farmers and are worth $370/ha/year, compared to leasing of dryland, which is cash-leased only at $76/ha/year. Included in the cash-lease charge for irrigated lands is the cost of delivering the water through center pivots. Currently the project has 104 center pivots that are owned and operated by the BTAP. The BTAP also owns a full fleet of heavy equipment and supplies[12]. The water rights assigned to the reserve are to irrigate 10,000 ha[13] of land when fully mature[14]. Currently it employs 7 people. Plans are underway to take over the leased irrigated land under the BTAP management[15].

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11 These rights were granted in return for relinquished land in 1947 for the expansion of the St. Mary's reservoir, which flooded a part of the KBIR land (INAC, 2004).

12 Based on information provided during the interview of BTAP officials, July 2008.

13 According to the BTAP officials, the target of 25,000 acres (or equivalent to 10,000 ha) has not yet been achieved.

14 Data on the actual irrigated area on the KBIR lands were not available. However, in 2004 there were 19,000 acres of land were developed for irrigation (Blood Tribe/Kainai, 2004). In 2007 only an area of 10,000 was reported to be irrigated (BTAR June 2007).

15 Based on discussions with BTAP officials during the field trip of July 2008.

The other major economic development institution within the KBIR is the Kainai Agribusiness Corporation (KABC). This institution was developed with the irrigation to capture value added opportunities by the Kainai Nation members. Partnerships were formed with Corporations in Japan to develop a hay processing plant on the Reserve. The Blood Tribe Forage Plant was built in 1997, and now has a capacity of producing 35,000 tonnes of compressed (or densified) hay for exports. This plant has created up to 75 permanent jobs for the Kainai Nation members. Neighbouring producers bring their hay for processing and sell it in the export market. The plant collects a processing fee from these producers.

Blood Tribe Agricultural Project Buildings (Photo: V. Wittrock July 2008)

The Blood Tribe Economic Development Department has designated commercial and industrial area zones on the reserve. However, manufacturing and commercial concerns are not too commonly found on the KBIR. The Blood Tribe Economic Development Department can provide 5,000 grants to Kainai Nation members for starting a new business; however some members of the Kainai Nation believe that these grants are insufficient for starting up viable businesses. In 2007, the KBIR did attempt to revive the manufacturing of affordable housing units (BTAR March 2007). Although no official reasons for this lack of manufacturing concerns are known, a combination of competitiveness of the KBIR firms, smaller size of the market on the reserve, and lack of local entrepreneurs are hypothesized to be some of the reasons for this situation.

In 2007, all agricultural activities were amalgamated into one umbrella organization – Blood Tribe Agriculture Sector (BTAS). This included Kainai Agri-Business Corporation, Blood Tribe Agricultural Project, Blood Band Ranch, Kainai Farming Initiative[16], and Blood Tribe Forage Plant (BTAR, June 2007). The BTAS has been reported to be purchasing 230 head of Black

[16] According to BTAR (August 2007), under this initiative, high-tech farming equipment is used which is monitored by a Global Positioning System. Typical examples of this equipment are tractors and combines.

Angus cows to build the cattle industry. These will be added to existing 150 head of cattle at the Blood Band Ranch (BTAR, February 2008).

Recently, the Kainai Resource Inc. Board has approved an initiative of the Buffalo Rock Mining Company to mine 25 acres of reserve land for ammolite fossils (BTAR, April 2008). This is expected to create employment[17] for the Blood Tribe members.

3.3.6 Labour Force and Employment

Data on labour force at the KBIR are available only from Statistics Canada (2008), are based on the 2006 Census of Population and therefore, have the same limitations as the population estimates. The KBIR was estimated to have a total of 2,915 workers over the age of 15 years (Table 3.4). These were almost equally divided into male and female workers. About 47.3% of these workers were active, with male workers with higher participation rate than female workers. According to this source, employment rate of all workers was very low at 36.2% of the total labour force. This is very low compared to the provincial average employment rate of 70.9% (Statistics Canada, 2008).

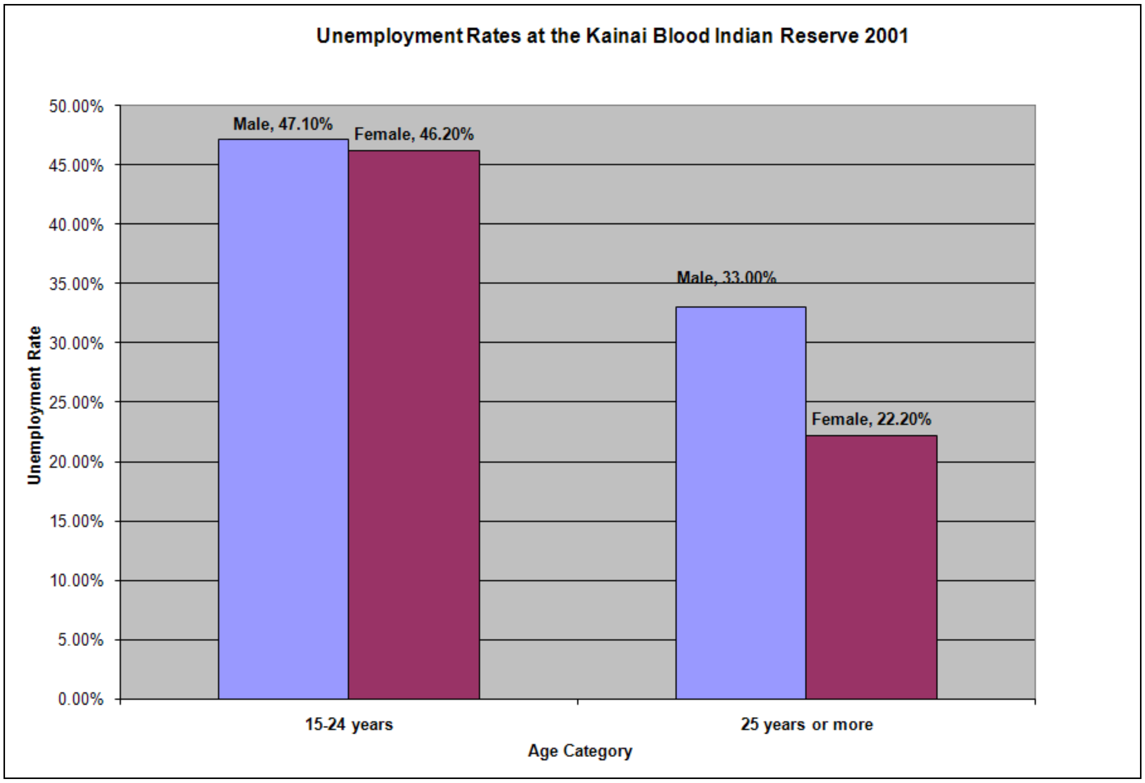
Table 3.4 Selected Characteristics of Labour Force at the Blood Indian Reserve

Characteristic	Total	Male	Female
Total Population 15 or over	2,915	1,435	1,480
In the Labour Force	1,380	745	635
Participation rate (% of the Total Population)	47.3	51.9	42.9
Employed	1,055	565	490
Employment Rate (% of Total Labour Force)	36.2	39.4	33.1
Unemployment Rate (% of Total Population)	23.6	24.2	23.6

Data Source: Statistics Canada (2008).

In 2005, the unemployment rate for the KBIR was estimated at 36.2%, with female workers being slightly lower at 33%. This is considerably higher than the unemployment rate of 4% for the province of Alberta. Although data were not available for 2006 Census of Population, based on 2001 data, unemployment rate for males over the age of 25 years or more was significantly higher than that for female in the same age category (Figure 3.7). However for the younger members (age less than 25 years), the unemployment rate was almost equal.

[17] Although precise estimates of additional employment are not available, according to the press release it was noted that a staff of ten people has been hired to operate the excavating machinery and other duties related to this operation (BTAR, April 2008).



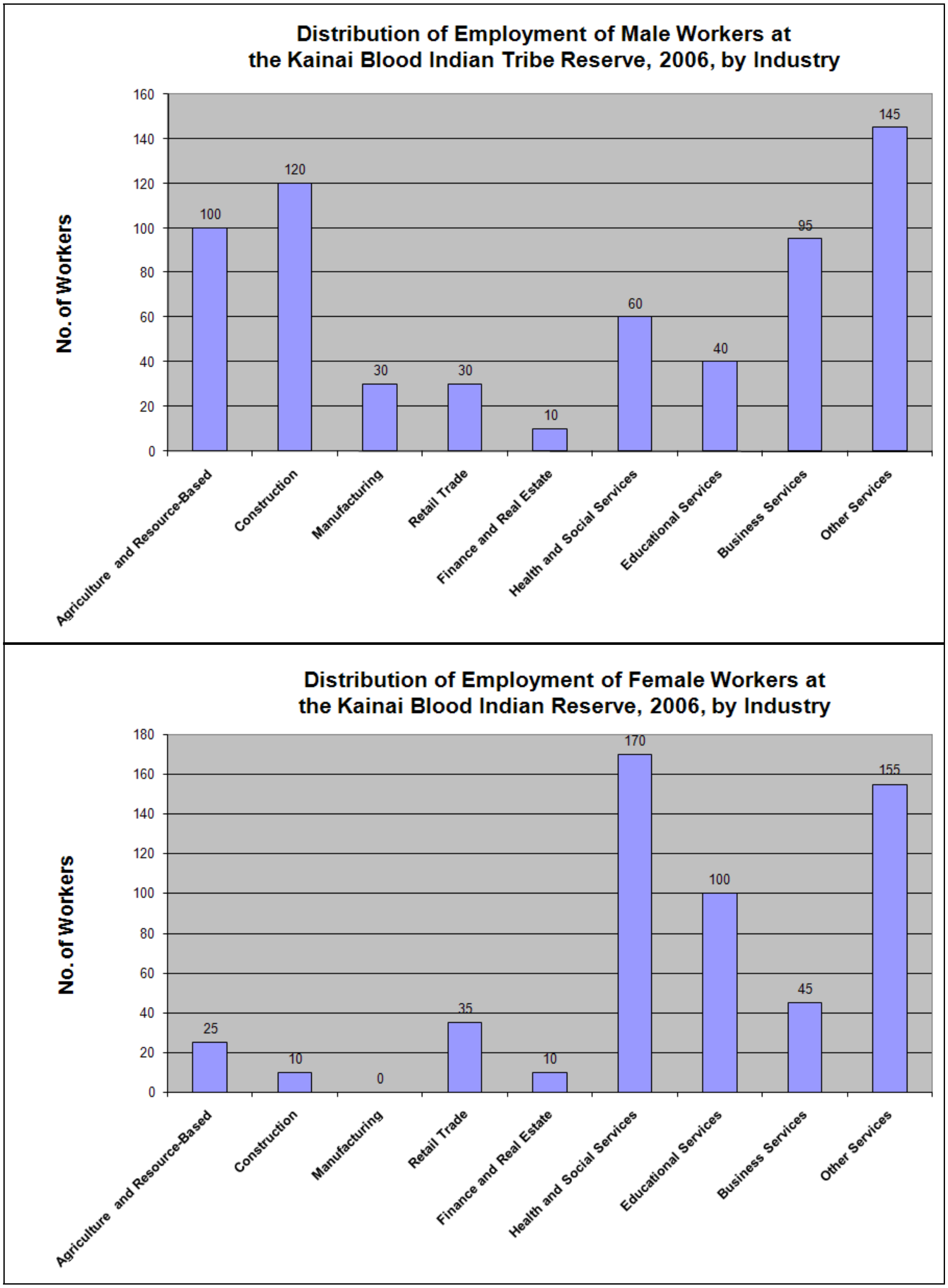
Data Source: AAFC (Undated).

Figure 3.7 Unemployment Rate for Kainai Blood Tribe Reserve 2001 by Age and Sex of Workers

The unemployment rate reported by Statistics Canada is significantly lower than those estimated by the KBIR officials. For example, one such estimate, according to the Blood Tribe Works Department, is around 60%. The discrepancy between the two estimates could be explained partly by a partial success by Statistics Canada to contact[18] people, and partly by the definition of the active labour force participant. However, the general conclusion remains that the KBIR has a high unemployment rate which perhaps shows lack of opportunity for people to work on the reserve.

Turning our attention to employment (Figure 3.8), KBIR residents are employed in various types of industries. However, there are differences in terms of male and female workers. Male workers tend to be in construction, agricultural and business services related jobs, whereas female workers are engaged more in the health and educational services.

[18] According to the KBIR Officials, Statistics Canada workers are not allowed to enter the KBIR land. Their contact perhaps is through telephone or some other means. It is speculated that the estimates may not be based on a total count of the people on the KBIR land.



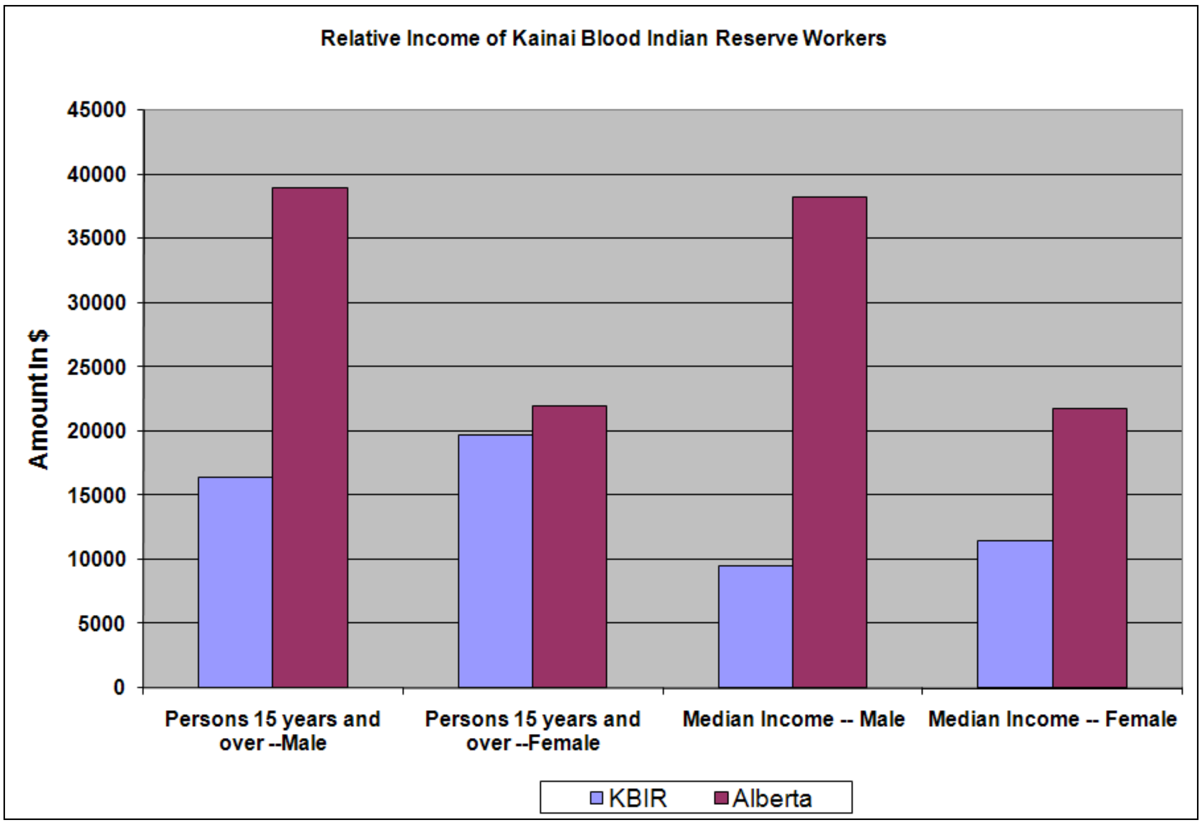
Data Source: Statistics Canada (2008)

Figure 3.8 Distribution of Male and Female Workers by Industry, Kainai Blood Tribe Reserve, 2006

The major employer at the KBIR is the 12 administrative departments of the Blood Tribe Band Council. Most of the employees are members of the Blood Tribe but some non-members are also employed[19].

3.3.7 Income Sources and Earnings

According to Statistics Canada (and confirmed by the KBIR officials) average income of workers at the reserve is significantly lower than that elsewhere in the province of Alberta. For example, in 2006, average income on the KBIR was estimated to be $16,387 per annum almost a third of the income of Alberta male workers (estimated at $39,965 per annum). For female workers at the KBIR average income was closer to that for the Alberta female workers. Using median income, both male and female workers at the KBIR earned significantly lower than an average Alberta worker (Figure 3.9).



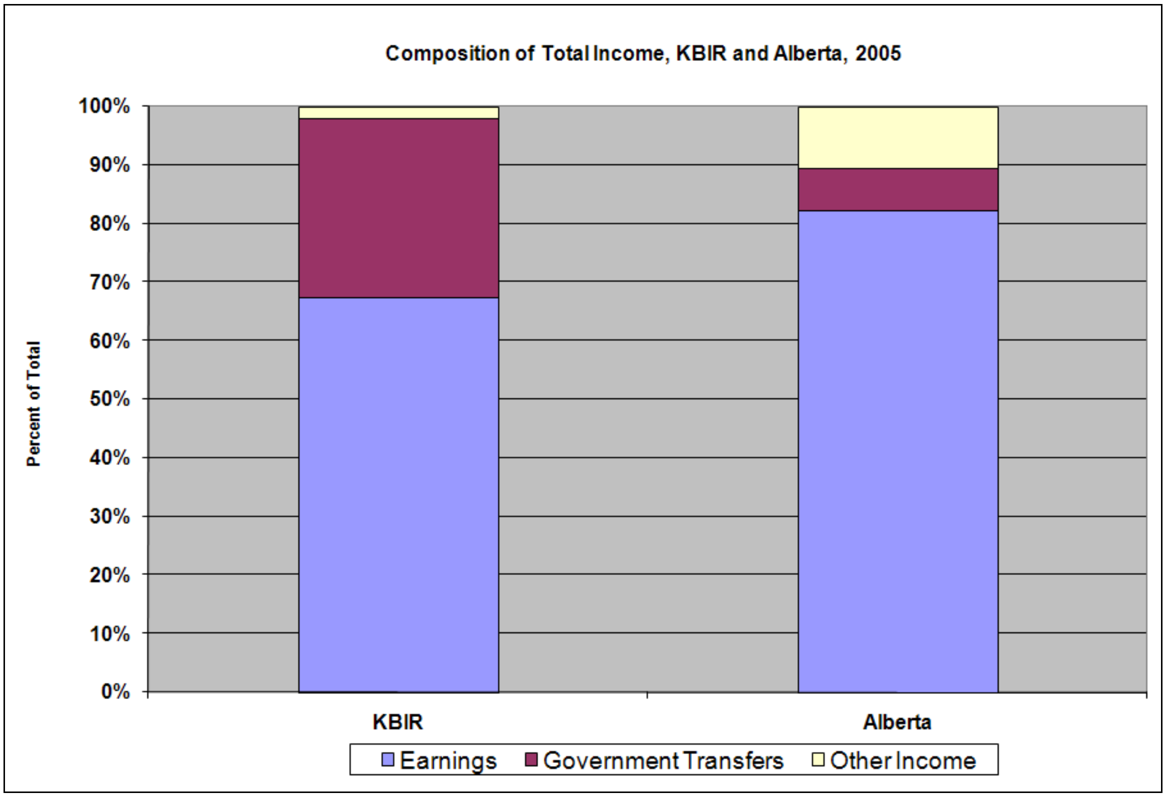
Data Source: Statistics Canada (2008)

Figure 3.9 Relative Income and Earnings of Kainai Blood Indian Reserve and Alberta Workers, by Category

The other significant difference in the income pattern of KBIR and Alberta is its composition. At the KBIR, a larger portion of the total income is through transfer payments from the Band Council. At the KBIR 31% of the total income of the people is through such transfers, as against only 7% for the Province of Alberta, as shown in Figure 3.10. Undoubtedly this is because of

[19] Exact number of non-Kanai Nation members employed on the KBIR is not available.

high unemployment, which is perhaps a result of lower skill set of the workers, and very few available jobs.



Data Source: Statistics Canada (2008)

Figure 3.10 Composition of Total Income by Source, KBIR and Alberta, 2005

3.3.8 Implications of Socio-Economic Characteristics for Adapting to Climate Change

A number of socio-economic characteristics of the KBIR make it less prepared for climate change. Included among these are:

- Low educational achievement of members of the KBIR;
- Lack of employment opportunities for KBIR workers, making them highly dependent on social assistance;
- Lower income relative to the neighbouring non-reserve regions;
- Relatively lower income potential of the Band Council. Limiting their capacity to assist people during period of extreme events, such as floods or droughts;
- Complex set of regulations and policies of the Indian and Northern Affairs Canada for dealing with the emergencies[20];
- Increasing population, making limited resources even more meagre over time.

[20] For example, during the flood of 2005 almost half of the homes were damaged. Requests made to the Indian and Northern Affairs Canada led to only a limited amount of funds available for repairs and / or reconstruction.

4. CLIMATOLOGICAL ASPECTS OF DROUGHTS AND FLOODS

4.1 Measurement of Floods and Droughts

The KBIR is subject to many extreme weather events including floods and droughts. Floods are an inundation of water of any land area not normally covered with water owing to a rapid change of the level of a particular water body. Floods may be due to several factors including a rapid rainfall event, rapid snowmelt, a combination and/or an obstruction of a water course (Whittow 1986). Floods can have very rapid and severe impacts on communities ranging from housing and agricultural damage, infrastructure damage and can significantly strain emergency services. Flood plain assessment has not been completed by either the provincial or federal governments for Reserve land (Mahabir p. comm. 2008).

Droughts are very complex so quantifying and defining them is difficult. Drought has been defined as a prolonged period of abnormally dry weather that depletes water resources for human and environmental needs (Atmospheric Environment Service Drought Study Group 1986). Various types of droughts can be categorized including meteorological, hydrologic, agricultural and socio-economic. The nature and severity of drought depends on many factors including area affected, timing, duration, antecedent conditions, and the region's sensitivity, vulnerability and adaptive capacity (Drought Steering Committee 2005).

4.2 Overview: Climate of 1995 to 2006

During 1995 to 2006, extreme precipitation and subsequent flooding, as well as droughts occurred in southern Alberta, and the KBIR was subjected to both. This section describes climatic conditions, nature and evolution of that period. The excessive moisture and droughts are described using information about temperature, precipitation and various indices.

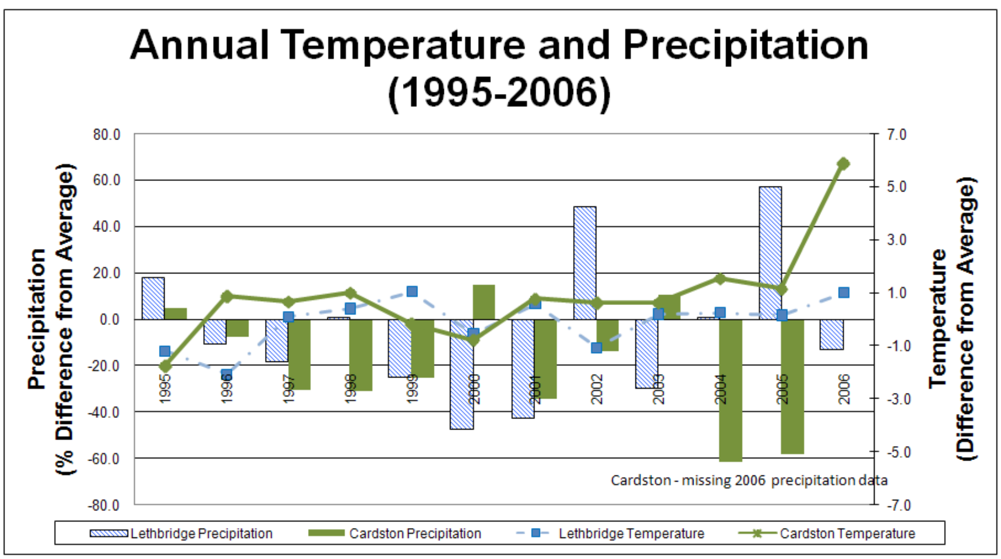
The winter of 1994/1995 had below average precipitation and above average temperatures. The spring and summer of 1995 were very wet. In Cardston, precipitation amounts were 80 and 72% difference from average (Figure B4.1). A total of 230.3 mm of precipitation fell in May in Cardston. This amount is almost 190% above the average amount for May. This amount probably would have saturated the soil. On June 6, Cardston received 106 mm of rain, 28% above the monthly average for June. Lethbridge had less precipitation than Cardston but spring and summer precipitation in 1995 were between 40 and 27% above the percent difference from average (Figure B4.2).

The extended dry period began in the fall of 1998 and continued through the winter of 2001/2002. During that period Lethbridge had above average precipitation only in the fall of 1999 and winter of 2000/2001. Cardston had below average precipitation 12 out of 14 months during that period. Temperatures were above average, except during the spring and summer of 1999 and fall and winter of 2000.

The spring of 2002 had a dramatic increase in precipitation and a dramatic decrease in temperature. The spring temperatures at both Lethbridge and Cardston were more than 5ºC below average. Cardston's precipitation was more than 40% above average and Lethbridge's precipitation was only slightly above average. Extreme precipitation events occurred in June 2002, when Lethbridge received more than 251 mm and Cardston received 181.7 mm, with 70 to 80% of the average rain for the month received over a three day period (June 8th to 10th inclusive). This precipitation event covered much of the southern prairies located south of Highway Number 1(Figure B4.3).

The precipitation in 2003 and 2004 fluctuated between well below to slightly above the percent difference from average as was the temperature (Figures B4.1 and B4.2). Then, in the summer and fall of 2005, precipitation was more than 100% difference from average in Lethbridge and 100 to 50% differences from average in Cardston consecutively for the two seasons. June was the extreme rainfall month for both sites. Cardston received measureable rain on 17 days totalling 256.4 mm compared to an average of 10.4 days averaging a total of 82.6 mm for the month. Lethbridge had 20 days with measurable rain in June, totalling 272 mm. The average number precipitation days is half that amount at Lethbridge when the total average precipitation is 63 mm. Lethbridge had 10 consecutive days of rain in early June, 2005, totalling 194 mm and during the same June 1 to 10th period, Cardston received 188 mm. The Blood Tribe, whose climate station started in June 2005, received 250 mm during the June 1 to 10th period, with the total monthly precipitation at 316.4 mm. Unfortunately, as stated previously, there is no averaging period for the Blood Tribe climate station due to shortness of record.

During 1995 to 2006, the extreme nature of the climate was well demonstrated. Cardston and Lethbridge fluctuated from having high amounts of precipitation to very little. In Cardston, only 1995 and 2000 had below average annual average temperatures, and only 1995, 2000 and 2003 had above average annual precipitation. At Lethbridge, 1995, 1996, 2000, and 2002 had below average temperatures. Precipitation was well above average in 2002 and 2005, nearly 20% above average in 1995 and only slightly above average in 1998 and 2004 (Figure 4.1).



Data Source: Environment Canada 2008a

Figure 4.1 Annual Temperature (Difference from Average) and Precipitation (Percent Difference from Average) for 1995 to 2006 for Lethbridge and Cardston

4.3 Potential Evapo-Transpiration

Evapo-transpiration is a major component of the water balance and of water consumption in the Canadian Prairies. Potential evapo-transpiration (PET) patterns for the 2000 to 2002 period for the Canadian Prairie Provinces were described by Wheaton and Wittrock (2005). They found that annual PET values were greater than 600 mm over a larger portion of the prairies in 2001 as compared with 2000. High PET values indicate greater water loss to the atmosphere, greater demands on water supplies, and less water available for vegetation and other purposes.

The closest station to the KBIR is at Lethbridge and its average (1995-2006) PET is 558 mm for the growing season and 747 mm for the year. The PET was above average for the growing season in 2000 and 2001 (Figure B4.4) and in 2001, it was above average by 2.2% (greater than 12 mm). July generally has the highest PET at 136 mm with July 2001 being near average. A dramatic decrease in PET occurred in 2002 primarily due to the cool wet April to June period. The PET in April was 28% below average with May being 5% below average. This low demand eased the stresses on water supplies that would have been much larger with higher temperatures. June 2002 was slightly above average (Figure B4.5). 1995 and 2005 had below or near average PET's.

4.4 Palmer Drought Severity Index

The Palmer Drought Severity Index (PDSI) is an indicator of drought and excess moisture. The PDSI is generally considered useful for agriculture and other activities sensitive to soil moisture. It is widely used in Canada and the United States and is available in map and tabular format. PDSI is based on precipitation, temperature and available water content of the soil. The index was developed by Palmer (1965) and is intended to measure the cumulative departure of moisture supply from a water balance viewpoint.

PDSI values usually range from -4 (or less) indicating extremely dry conditions to +4.0 (or more) indicating extreme drought conditions. Environment Canada published monthly PDSI information for the Canadian Prairies in map form. We focus on 1995, 1999-2002 and 2005, as they are considered to be of greatest impact to the Reserve as reported by the interviews by Magzul (2005). Also, 1995 and 2005 resulted in excess moisture, while 1999-2002 were generally dry years.

The spring and summer 1995 PDSI values for south western Alberta indicate near average to slightly wet conditions as shown by the May and July maps (Figures B4.6 and B4.7). The fall PDSI values started to indicate moderately wet conditions in the KBIR region as indicated by the October map (Figure B4.8). The high precipitation values of the summer of 1995 only had moderate influence on the PDSI.

As mentioned earlier, the extended dry period began in the fall of 1998. The PDSI values did not reflect this until the winter of 1999/2000 (e.g., January 2000 map Figure B4.9). By late spring (e.g., May 2000 Figure B4.10), the southwest corner of Alberta was in severe drought of between -3 and -4 category. By August, 2000 (Figure B4.11), the PDSI values had reached extreme drought conditions of -6. These extreme low PDSI values remained until June 2002. The extreme rainfall event of June 8 to 10 moved the very low PDSI values from dry in May 2002 (Figure B4.12) to near average conditions on the KBIR (Figure B4.13). In the summer and fall of 2002, the PDSI conditions became slightly to moderately wet and by the winter of 2002/2003 and spring 2003, PDSI values indicated average to slightly wet conditions.

2005 had extreme rainfall in June. This is indicated by the PDSI changing from extreme drought conditions in the KBIR region (Figure B4.14) to slightly wet in June (Figure B4.15).

4.5 Standardized Precipitation Index

The Standardized Precipitation Index (SPI) is a climatological index that allows for drought and excess water severity assessment, as discussed earlier. The closest two sites with available SPI values around the KBIR are Lethbridge and Carway, located approximately 23 km south of Cardston, just north of the Alberta/US border. Over the 1995 to 2003 period, there have been dramatic changes in the agricultural year SPI. An agricultural year is defined as the September to August period. SPI in 1995 was rated as neutral, that is, neither wet nor dry. 1996 is a good example of how different areas can receive different levels of precipitation in the same period with Carway being moderately moist and Lethbridge moderately dry. By 1998, Carway was moderately dry while Lethbridge remained near neutral. In 2000, Lethbridge was drier than Carway and this trend continued into 2001. The conditions reversed in 2002 with Carway being wetter than Lethbridge and in 2003, the two sites were back to slightly dry conditions (Figure B4.16).

The summer (June, July and August) SPI values show more significant wet and dry episodes. The wettest summers over the 1995 to 2003 period were 1995 and 2002 with Carway having larger SPI values than Lethbridge in 1995 but Lethbridge was wetter than Carway in 2002. The driest summers were 1996 and 2003 with Lethbridge being the most extreme of both years. In this analysis, the drought years of 2000 and 2001 do not appear to be excessively dry (Figure B4.17) but the PDSI values indicate the region was extremely dry (Figure B4.11 and B4.12). The difference between the two indices is because SPI responds to precipitation only while PDSI incorporates temperature, precipitation, and soil moisture and also has a built in lag effect (i.e., it is slow to change).

5. IMPACT OF EXTREME EVENTS ON THE KAINAI BLOOD INDIAN RESERVE

Floods and droughts have extensive and severe impacts on the economy, environment, and health of society. The excess moisture and floods of 1995, 2002 and 2005 and the drought of 2001 to 2002 were no exception. Both Magzul (2007) and Patino and Gauthier (2007) have examined the current exposures and constraints due to the floods and droughts. This section builds upon their findings by further examining the bio-physical and the socio-economic impacts on the KBIR.

5.1 Bio-Physical Impacts

Droughts and floods generally result in negative bio-physical impacts on human activities. In this section, various bio-physical areas are analyzed including water availability through trends analysis in stream flow, groundwater and dugout levels. Other bio-physical impacts include an exploration of insect infestation. The implications of these impacts on the KBIR are also examined.

5.1.1 Water Availability

5.1.1.1 Stream Flow

Rivers and streams are important for the Reserve. Water, either too much or too little, has potentially large ramifications for the people that live close to the rivers and streams. As shown in the previous section, the late 20th century and early 21st century had both major rainfall events plus drier than average conditions. The major rainfall events caused the waterways to have high flows. The dry conditions led to lower than average stream flows and lower than average reservoir levels throughout the South Saskatchewan River Basin (Wittrock 2005). This section examines the four rivers, two diversion canals and two reservoirs that are located in the KBIR region (Figures B5.1 to B5.12). The locations of these water ways are explained in Section 3.2.2.1

There are four river systems important to the KBIR: the St. Mary River, located on the east side of the Reserve, the Waterton River which feeds into the Belly River located on the west side of the Reserve and the Oldman River which runs along the north side of the reserve. All of these rivers are important to the reserve, especially when water levels fluctuate to the extreme. It has been noticed by various member of the Reserve (Magzul 2005) that the water levels in the St Mary River and Oldman River have been generally decreasing. These observations are corroborated with the measured flow data which show declines in water levels from the early 1900s to 2006 (Figure B5.1 and Figure B5.7)). While the period of record for the Waterton River (Figure B5.3) is shorter, it has also been decreasing over the 1967 to 2006 period. The Belly River has a much shorter period of record (1986-2006) and it is indicating a slight increase in mean annual stream flow.

The Belly-St Mary Diversion Canal crosses the Reserve and this canal is fed water from the Waterton-Belly Diversion Canal. These canals were built to help maintain a stable water supply in the St. Mary Reservoir (SMRID ND; Alberta Environment 2003). The water transfer has been increasing over their period of record (Figure B5.9) due in part to increasing irrigation water demands, increasing population in Taber, and increasing usage by industry. The highest water transfer year in the Waterton-Belly Diversion Canal was 1989 during the 1968 to 2006 period. In recent years the amount of water being diverted has not fluctuated as much as in the late 1970s to early 1980s (Figure B5.9 and Figure B5.10).

The Waterton, Belly and St Mary Rivers all have modified stream flows because of two reservoirs. The St. Mary Reservoir provides water needs for eight irrigation districts (565,809 acres) plus the Blood Tribe Irrigation Project (25,000 acres) and more than 21,000 acres of private irrigation (Alberta Agriculture, Food and Rural Development 2004). It obtains its water from the Waterton, Belly and St. Mary Rivers through the canal system mentioned earlier. As a result the St Mary Reservoir has an effective drainage area of 2170 km^2 (Environment Canada 2008b). The water levels were low in 1999 to 2001 due to the drought conditions, but also due to maintenance on the dam that required low water levels. The reservoir had its highest annual average level in 1993 at 1101.61 m, followed closely by 1982 (1101.26 m) and 2005 (1101.24 m) (Figure B5.11).

The Waterton Reservoir is important because it allows for a consistent supply of irrigation water through the reserve to the St Mary Reservoir, which supplies water to the KBIR as well as many other regions of southern Alberta. From 1971 to 2006, the lowest reservoir level was in the winter of 1998/1999 when water levels fell below 1170m or nine metres below the annual average (Figure B5.12). The highest water level of 1185.601m occurred on June 19, 2002, only 0.07m below full supply level.

5.1.1.2 Groundwater

As described earlier, groundwater is used both in the rural and urban regions of the study area. Persistent, severe and frequent droughts can have adverse effects on groundwater resources and can result in negative effects on various industries and communities. Alternatively, intense precipitation events may not be effective in recharging groundwater because much of the precipitation becomes runoff. However, if the water stays on the surface in a wetland, for example, groundwater levels will likely increase (Rivera et al. 2004).

As mentioned, groundwater is the main potable water source for the Blood Tribe, therefore monitoring of this vital resource is necessary for early warnings of problems. Unfortunately, all three groundwater observation wells are located off the Reserve and no observation wells are south of the reserve (Figure B3.1). These observation wells will give an indication of the groundwater levels on the reserve, especially the northern side of the reserve. The KBIR does not have their own groundwater monitoring wells so water levels are not known[21]. It is recommended observation wells be established and trends monitored.

The Lethbridge groundwater observation well is located northeast of the KBIR, by the city of Lethbridge. Mud Lake and Orton are northwest of the KBIR, close to Fort MacLeod (Figure B3.1). Only the Mud Lake well is considered to be unaffected by human influence, but it is also the furthest from the Reserve so data from all three are analyzed.

Lethbridge's observation well is a 21m deep well and has had fairly constant water levels from 1987 to 2006 (Figure B5.13) and the lowest recorded levels were in the 1988-1989 period. The water level slowly rebounded and remained relatively constant at 914 m above sea level. A slight decline occurred in late 2001 to early 2002 but the level quickly rebounded in mid 2002. Since then, the water level stayed consistently higher than 914 m above sea level.

[21] Based on information provided during the interviews of BTAP officials, July 2008

Orton's groundwater observation well is located approximately 9 km northwest of the Reserve. The well depth is approximately 50 m below ground and has recorded seasonal fluctuations in over the 1987 to 2006 period (Figure B5.14). The lowest water levels were in the drought years of 2000 and 2001 when water levels were at or below 951 m above sea level, approximate 4.5 m below the high water levels. The highest water levels were in the early 1990s when the highest levels were approximately 955.5 m above sea level. The draw-down of water is likely due to irrigation in the region (Simpson p. comm. 2008). Mud Lake's well is approximately 23 km northwest of the KBIR and has a well depth of about 34 m. This well also has seasonal fluctuations (Figure B5.15) and similar to Orton, its lowest water levels were in 2001 (during the drought), and highest water levels were in the early 1990s. Since a low water level in 2001, it appears that the seasonal variability of the aquifer has increased in recent years. For example, a low water level occurred in May 2005, with rapid rebounding in June and a second low water level in August resulting in a one metre fluctuation. The cause of this increased variability is not known to the authors.

As of 2002, 37 wells were located on the Reserve (Figure B3.2). In the drought years, some of the wells went dry. Also, the floods caused contamination and siltation. New wells were drilled because of these problems (Magzul 2005). It is very expensive to drill new wells, especially those that need to access water from deep aquifers. The number of dry wells and the extent of contamination problems are not known by the authors. It is recommended that this number be determined as it helps establish the sensitivity of the water supplies to droughts and floods.

Residents of the KBIR have noticed that some of the wells are "going bad". They have noticed the groundwater is "changing", that the aquifer is "moving around" and some of the wells are going dry where previously there was plenty of water. They have also noticed that the water quality of the groundwater has deteriorated (Magzul 2005). This adds credence to the recommendation that groundwater monitoring should be carried out because these statements indicate that a greater flexibility in types and amounts of water sources may be needed for improved adaptation to extreme climatic conditions.

5.1.1.3 Dugouts

Dugouts are an essential part of rural life, especially for livestock operations, domestic use, and crop spraying, for example. Over much of the Canadian Prairies agricultural region, water levels or lack thereof, in dugouts became a concern and a problem in 2001 and 2002 (Wittrock 2005). The authors were unable to determine the types of uses of the dugouts on the Reserve, although it is speculated that they are mainly used for livestock. It is recommended that dugout usage be determined to help determine the value of this water source and its contribution to resiliency during droughts.

In 1993, 63 dugouts were in the KBIR (Figure B3.2) (PFRA – AAFC 2008b), but is not known if more dugouts were established since then. Water levels in dugouts have fluctuated considerably from 1999 to 2005 (Figures B5.16 to B5.22). In 1999, the dugouts were half full for the May 1 to November 1 period and they remained half full to spring 2000. By fall 2000, the dugouts on the reserve were classified one quarter full to dry. This is a challenge as any activity that depended upon this water would have to cease or other sources would have to be found. These low water levels continued until 2002 when the early June precipitation event filled the dugouts. By the fall 2002, the dugouts were again half full. From 2003 to 2005 inclusive, dugouts on the Reserve had adequate water. It is not known what the impacts of low water levels in the dugouts were and it is recommended that this be determined for determining how to be better prepared for droughts.

5.1.1.4 Domestic Water Supply and Use

As mentioned previously, the majority of the people on the Reserve receive potable water from ground water sources. Only the community of Moses Lake obtains its water from Cardston. The floods of 1995, 2002 and 2005 resulted in boil water advisories for the Reserve residents because of possible contamination from flood waters. The droughts of 2000, 2001 and early 2002 resulted in some of the private wells becoming dry. Unfortunately, consumption rates are not known. This is an important data limitation in determining vulnerability of the people and their activities to drought impacts, and trends in vulnerability. It is recommended that consumption rates be measured to assist with establishing baseline information. Information about groundwater levels, trends and consumption rates is needed to help assess and reduce the vulnerability due to drought. Without this information, the sustainability of these important water supplies is not known or protected. Also, without early warning systems of water supply and quality problems, solutions are more difficult and expensive to find.

5.1.2 Grasshoppers

Grasshoppers can be a major pest in the Canadian Prairies as they are able to cause major damage to all types of vegetation both pasture and cropland. A moderate infestation of 10 grasshoppers per square metre can consume from 16 to 60% of the available forage (Saskatchewan Agriculture, Food and Rural Revitalization 2000). The effects of different types of grasshoppers, the ramifications of different types of weather on grasshopper sustainability and economic thresholds of the number of grasshoppers on a field and their impacts are explained in Wittrock et al. (2006).

The grasshopper forecast for the KBIR in 1999 was for none to very light infestation in 2000 and 2001. The forecast for 2002 indicated that the grasshopper numbers would increase to light to moderate infestation. The 2003 forecast was for moderate to severe infestation of grasshoppers on the Reserve. The forecast for 2004 was the severity to increase to very severe, especially on the south side of the Reserve. The projected infestation levels were expected to drop to light on the north side of the Reserve and be moderate on the south side in 2005 and very light to light in 2006 (Figures B5.23 and B5.24) (Data source: Saskatchewan Agriculture, Food and Rural Revitalization 2000, Johnson, 2002, Jones, 2000, Manitoba Agriculture and Food 2002, Saskatchewan Agriculture Food and Rural Revitalization 2002, Olfert et al. 2003, Johnson and Calpas 2003). Information on the agricultural impact of pests, such as this grasshopper example, was not readily available, but the moderate to severe infestations would likely have caused damage, depending on timing.

While grasshopper infestation is important for agriculture, it may not be considered to be as an important to the members of the KBIR. This is because very few of the residents are directly involved with farming and the leasing agreements between Reverse members and off-reserve farmers are on a cash rent per acre basis, not tied to crop production. This is important because it decreases the KBIR susceptibility to extreme weather events; residents receive income regardless of weather conditions.

5.1.3 Implications of Extreme Climatic Events for the Kainai Blood Indian Reserve

The impacts of the extreme weather events were serious for the people of the KBIR. The floods likely had the most immediate impacts on the residents as homes and businesses were flooded. Also, emergency services response capabilities were stressed, infrastructure such as roads was damaged and the potable water sources were compromised (Table 5.1). Many other impacts likely occurred that we do not have information about. Magzul (2005) fields notes and information from the July 2008 discussions were used to provide many examples of flood impacts to many categories of respondents. Examples of impacts are listed by types of impacts, such as physical, biological, economic and social. Adaptations are included along with the descriptions of the level of success of the solutions, as indicated in the field notes. The type of groups who were affected and who developed adaptive solutions included the residents of the reserve, local businesses, irrigators, and government.

The droughts appeared to have little direct impact on the residents of the reserve because most residents obtain their potable water either directly from a well or via delivery by truck from a communal groundwater source. Some residents with individual wells reported that their wells went dry and the residents had to have water delivered by truck (Magzul 2005). The droughts did have an impact on the irrigated land because of the reduced available irrigation water. However, it is not known how much it was reduced. While some conflicts over water availability were discussed (Stratton 2005), it is not known if the reduced water supply affected the crop yields (Table 5.2). Reduced crop yields was likely not be an issue for the KBIR, especially in the short term, because the majority of the agricultural land is cash-leased to non-natives.

There are many gaps in our analysis due to lack of data and information for the Reserve. For example, total number of dugouts and their uses are not known. Other data and information problems included the total number of people using private wells, the number of these wells that went dry, and the number of wells that were contaminated. One additional impact type mentioned in the interviews was the large number of grassfires on the Reserve (Magzul 2005), however, the total number, timing and impacts of these fires are not known.

Table 5.1 Examples of Flood Impacts and Adaptations of the Blood Tribe (Data source: Magzul 2005, Discussions July 2008)

Type of Respondent	**Impacts**				**Adaptations**		
	Physical	**Biological**	**Economic**	**Social**	**Successful**	**Not Successful**	**Comments**
Government	Flooding resulted in potable water being compromised Houses were flooded due to location and high water table Housing stock has deteriorated due to the floods.	Mold in basements	The 2002 floods caused $6.6 million in damage to infrastructure and housing The 2005 flood costs were $8.6 million.	80 people were displaced due to flooding	Installed water treatment facility New well for one of the communities Houses moved to higher ground in town site resulted in less damage in recent flood Attempting to more houses to higher ground Disaster plan exists Each new house built has soil test and proper drainage Imposed boil water advisory during flood events Tests water quality on regular basis Insurance Flood victims likely to be compensated by from Indian & Northern Affairs Have a general disaster plan but do not have an individual department disaster plan Better maintenance of road infrastructure	Houses built on flood plain. Some residents do not want to move; some do not have other property to move to Lack of housing Lack of funds Improperly installed weeping tiles Need to update disaster response plan Boil water advisories created problems for residents including cost, time and inconvenience	Reserve builds only 20 new houses per year but demand and need is much greater It is not known if the flood victims were compensated by Indian & Northern Affairs

Type of Respondent	Impacts				Adaptations		
	Physical	**Biological**	**Economic**	**Social**	**Successful**	**Not Successful**	**Comments**
Emergency Response Organizations (e.g, police, ambulance)				People stranded due to flood	Closed flooded roads Rescued stranded citizens Preparing for more frequent floods through acquisition of more equipment		
The Residents of KBIR		Contamination of potable water supplies from sewage septic tanks			Drank bottled water during flood events	Cost and inconvenience of bottled water. Cannot or do not want to move from flood prone regions.	
Local Businesses	Flooding of oil well sites				Have contingency flood plan		
Irrigation Land and Irrigation Farmers		Flooded fields	Flooded a couple of pump houses and damaged some of the pumps		Fixed the pumps Crop insurance	Crop insurance	Were able to recover costs through “disaster services” Minimize buying insurance due to high rates.
Livestock Producers		Lost livestock in the 1995 flood					

Table 5.2 Drought Impacts and Adaptations of the Blood Tribe (Data source: Magzul 2005, Discussions July 2008)

Type of Respondent	**Impacts**				**Adaptations**		
	Physical	**Biological**	**Economic**	**Social**	**Successful**	**Not Successful**	**Comments**
Government	Low groundwater levels. Hard packed roads.		Increased water delivery, resulted in increased costs. Equipment damage due to road conditions.		Boil water advisories		
Livestock Producers		Low feed supplies			Sold large number of cattle. Bought feed Obtained water for cattle via pipeline from river		
Dryland Farmers	Grass fires		Small returns due to drought.		Leased land Because of the drought in the 1980s, a large portion of land was turned back to the reserve from individual tribe members	Leased land	Changed the way the land was leased after the 1988 drought. While cash leases of land allow the band and various members to have guaranteed income, it results in lack of work for tribe members
The Residents of KBIR	Lack of water Water levels in wells were declining and some went dry			Hot weather may lead to more violence Hot weather causes distress of the elderly and those in poor health	Conserve water where possible. KBIR members with occupancy rights cash-lease their land to non-native farmers.		Water conservation is partly due to infrastructure difficulties

Type of Respondent	Impacts				Adaptations		
	Physical	Biological	Economic	Social	Successful	Not Successful	Comments
Irrigation farming and irrigation farmer	Low water levels				Decreased amount of water used for irrigation		Potential difficulty for irrigation in the future due to water rights.

5.2 Socio-Economic Impacts of Extreme Events

5.2.1 Conceptual Framework

A socio-economic assessment of the impacts of extreme events on the people of KBIR was challenging on account of two factors: 1) limitation of available data, and 2) a complex set of institutions[22] that govern economic performance of the people and the entire reservation. A representation of the interactions that may exist among various institutions is shown in Figure 5.1. On the first point, data that could be used for any socio-economic assessment are not routinely collected. Although some facts could be obtained from the officials of the KBIR, because of high turn-over of these staff members, responses tended to be more qualitative. In terms of the second factor, KBIR social structure is somewhat complex, and a complex set of institutions affects their social welfare. Various KBIR members could be divided into several categories, such as:

1. Kainai Nation Registered members residing on the KBIR with occupancy rights;
2. Kainai Nation Registered members residing on the KBIR without occupancy rights;
3. Kainai Nation Registered members not residing on the KBIR on account of housing shortage;
4. Kainai Nation members emigrated from the reserve;
5. Kainai Nation members in educational institutions.

Similarly in terms of institutions that affect social welfare of the Kainai Nation members may include:

1. Blood Tribe Agricultural operations -- Irrigation;
2. Blood Tribe Livestock operations;
3. Local farmers doing business with the Kainai Blood Tribe Band;
4. Blood Tribe Non-agricultural operations;
5. Kainai Resources Inc. (oil and gas);
6. Kainai Blood Tribe Band Council, and,
7. Government of Canada through Indian and Northern Affairs Canada.

The last institution governs the level of funding for operations and capital expenditures on the reserve, and thus affects the social well-being of the Band members through the Band Council. The Kainai Blood Tribe Band Council also affects the Band members through the creation of some local employment outlets, such as the BTAP and Kainai Agribusiness Corporation. However, most of the economic activities of the BTAP and land owners are through interaction with the local producers who lease the land and actually perform agricultural activities. The lease rate is negotiated though the Band Council Departments. A crude set of interrelationships among members and various institutions is shown in Figure 5.1.

[22] Institutions play an important role in adaptation to climate change. To what extent the current institutions are enhancing the adaptive capacity on the KBIR is not know and required further study.

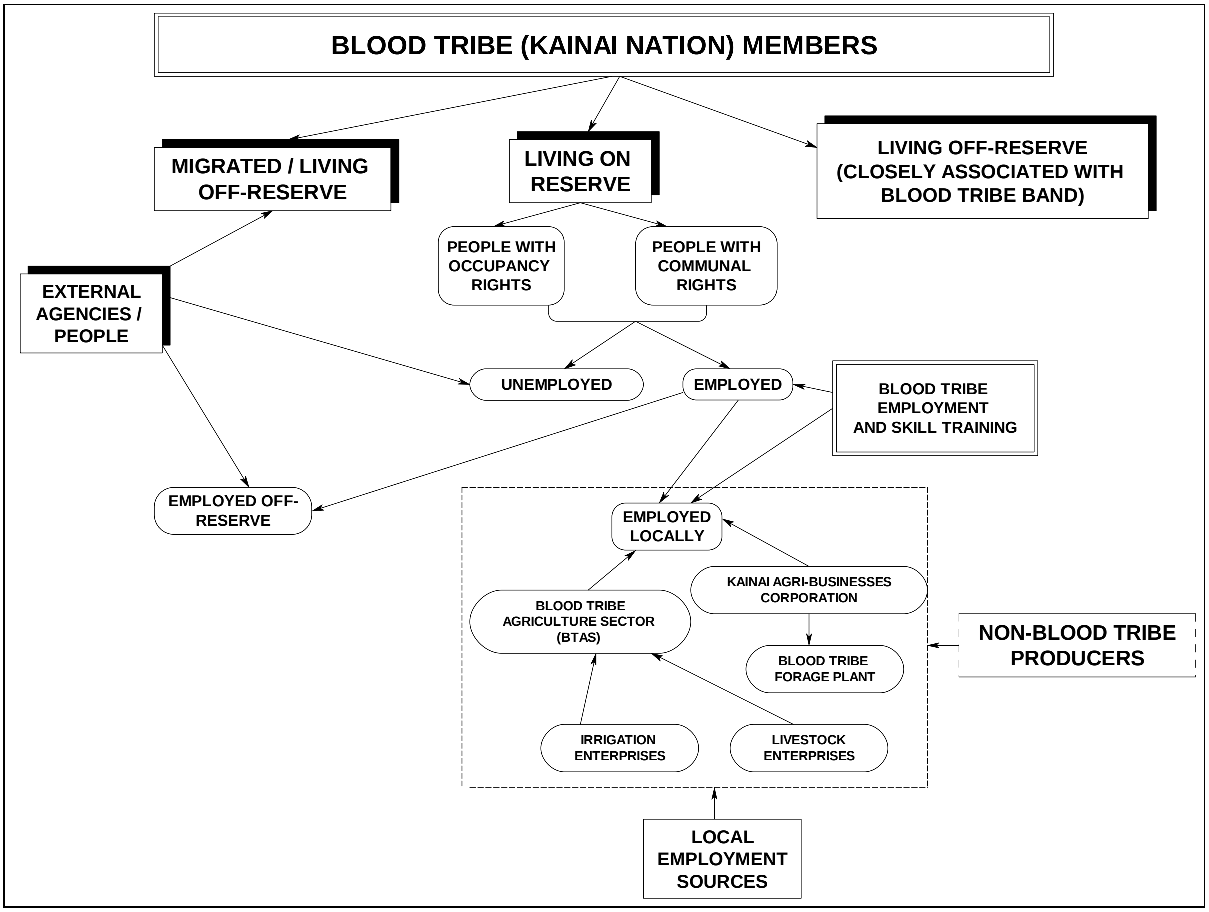


Figure 5.1 Interactions Among Various Groups affecting Socio-Economic Status of Blood Tribe Members

5.2.2 Socio-Economic Impacts of the 2001 – 2002 Drought

A main consideration for assessing the socio-economic impacts of the 2001 or 2002 drought on the Kainai Nation members is the fact that all land was cash-leased out to neighbouring producers. Typically these leases are for three years in duration. No consideration of a drought event is made in assessing the level of rent paid to the member of the Blood Tribe[23]. In this sense, the Kainai Nation members are shielded against drought events and are therefore currently less sensitive to the negative impacts of drought and the effects of other extreme events. Leasing of agricultural land in cash rent would appear to be a suitable way of avoiding the effects of events such as droughts (Table 5.2). The longer the rental agreement, the greater the chance of avoiding the effects of a longer term drought. However, if the frequency of droughts or incidence period of droughts increases, the neighbouring farmers who lease KBIR lands would demand some consideration of such events, which may make the KBIR more vulnerable to climate change. The dynamics of the drought occurrence and settlement of lease rates for dryland or irrigated lands is not known and requires further investigation.

[23] Based on information provided by BTAP officials during July 2008 interview.

5.2.2.1 Drought Impacts on Crop Production

Since land is leased out, no loss of income was noted for the Kainai Nation members. For the dryland area leased out, the impact may have been on the farmers who leased them. However, the land owners did not suffer any loss of income on account of the two years of drought. This is because lease rates were established by the Band Council before the onset of the drought season[24].

For the irrigated lands, since the BTAP is responsible for supplying water to the fields, it is conceivable that BTAP may have spent more money on pumping water. This cost may include the power cost and manpower costs. However, precise data on these changes could not be obtained from BTAP. Also, BTAP received less water than the amount that is normally allocated to BTAP (Magzul 2007). However, the amount was not documented[25].

During the drought of 2001, one of the costs to the Non-Kainai Nation farmers leasing the land included re-seeding of some lands. Although seeding was already done, but due to poor germination, some 3% of the irrigated area had to be re-seeded[26]. Again as noted above this cost was not borne by the Blood Tribe members or the BTAP and provided a means of shielding the members of the KBIR from effects of droughts.

5.2.2.2 Drought Impacts on Livestock Production

Since there are no major livestock operations on the KBIR involving Kainai Nation members, the impact of the drought through livestock enterprises was minimal. However, the KBIR Administration assisted livestock operations by securing feed[27], but the exact cost of this operation could not be ascertained. This is another example of a knowledge gap that constrains the assessment of the adaptive capacity and vulnerability of the KBIR and its members.

Another impact of the 2001 drought was on the Blood Ranch, which had to reduce number of cows on account of forage shortages[28]. Approximately 700 cattle were on the KBIR prior to 2001 but decreased to between 200 and 300 head due to the drought and the BSE (Bovine Spongiform Encephalopathy) crisis (Table 5.2) (Magzul 2005).

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[24] Based on information provided by BTAP officials, July 2008 interview

[25] Based on information provided by BTAP officials during July 2008 interview.

[26] Based on information provided by BTAP officials during July 2008 interview.

[27] Based on information provided by the BT and Department during interview of July 9 2008.

[28] Based on information provided by an interview with BTAP officials on July 8 2008.

Livestock on the KBIR (Photo: V. Wittrock, July 2008)

5.2.2.3 Other Socio-Economic Impacts of Droughts

The drought of 2001 to 2002 did have adverse effects on the operations of the Blood Tribe Works Department (Table 5.2). Examples of these impacts included[29]:

- Several grass fires were reported to have occurred during this period. These fires were costly (in terms of controlling them)[30]. In some cases, fire fighters from Lethbridge and Fort McLeod were brought to assist the local fire fighting crew.

- Ground was hard which affected machinery operations, particularly for road upkeep or repairs after flood damage. This resulted in higher labour costs for the KBIR Works Department.

- Groundwater was low and in cases wells went dry. Data on number of dry wells were not collected and therefore, not known at this time. This necessitated delivery of water by trucks to these properties by the BT Works Department from the wells at the Standoff. The destination of these trucks varied depending on locations of homes with dry wells. Exact details on the cost to the KBIR could not be estimated. However, homes that were affected the most were the ones without any cisterns.

- More water advisories were issued during the drought event of 2001, most of these involved boiling water

- During the 2001 drought event, some cisterns and septic tanks were cracked[31] and had to be repaired. Cost of replacing a cistern is estimated to be around $5,000 per cistern. This

[29] This set of information was provided by the Blood Tribe Works Department on July 7 2008.

[30] Based on information provided by the Blood Tribe Public Works Department. Much of this information was qualitative in nature and quantitative estimates of the actual cost borne by the KBIR were not available.

[31] Reasons for this problem were not provided and require further investigation.

indicates that the maintenance of such infrastructure is especially important to deal with droughts.

- In the northern part of the reserve, and near Fort Whoop Up, fields went very dry and created a dust problem. Information on the number of such events and their respective duration were not available. Although there were some minor health issues related to this, no major problems were encountered.

5.2.3 Socio-Economic Impacts of the Floods

The KBIR is surrounded by three rivers, and therefore, it is located in a natural flood zone. Flooding of parts of the KBIR has been a recurring problem, partly because of the topography[32] of the region. Although flooding is a very common regular occurrence in some parts of the reserve, major floods have been experienced in the region during 1995, 2002, and 2005[33].

One of the worst floods experienced on the KBIR lands was during 2005. It was caused by a heavy rainfall during a short period of time. Much of the flood damage occurred in the rural part of the KBIR. For some people with occupancy rights, their choice for building a house is limited to lands which may be subject to flood risk (Table 5.1). In addition, some people do not wish to relocate from the flood zone to the Standoff townsite due to its social problems (in particular, high crime rate)[34].

Major damages of the flood in 2005 included the following:

(i) Road washouts, including culverts;
(ii) Road damage;
(iii) Flooded basements;
(iv) Damaged personal belongings;
(v) Moving people from their houses, and the cost of lodging in hotels or other suitable accommodation during the flooding period;
(vi) Increased stress level among those affected;
(vii) Treatment of the well water at a cost of $4,000 per treatment[35];
(viii) Impact on the cropland, and
(ix) Reduced fishing in the river due to high river level.

However, on the positive side, although flooding is costly to the Blood Tribe Administration, it does increase number of people temporarily employed on the reserve, and brings income to the

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32 Based on information collected through July 2008 interviews

33 Based information provided by various officials during interviews at the KBIR in July 2008. A minor flood was also experienced during 2006. However, no significant impacts of this flood event were reported.

34 Based on information collected through July 2008 interviews.

35 Information on the nature of these treatments was not available.

people. In addition, contractors (people) undertaking flood damage repairs or selling carpets do better business due to these events.

During the flood of 2005 many homes were affected. According to Blood Tribe Housing Department[36], almost half of the homes were damaged by this flood. Of the almost 1,218 homes, some 600 of these were affected. Major damage came through flooded basements and sewer backups. Since these homes are not covered under an insurance policy, much of this cost had to be borne by the owners of the home or by the KBIR Band Council. Some assistance is provided by INAC for such repairs or reconstruction of homes. Lack of insurance appeared to be a source of vulnerability to flood impacts on housing. Drinking water was contaminated and several water advisories were issued.

The damage from the 2005 flood to the homes was estimated at $6.5 million[37]. However, a portion of this cost was reduced through some compensation received from insurance companies and the provincial government under the Alberta Emergency Program. Assistance for relocation of homes was also received from Indian and Northern Affairs Canada for relocated the homes away from the flood plain[38].

In general, flooding is experienced in virtually the entire KBIR area. It typically starts in the southern part of the reserve which has a larger concentration of homes and people, and moves north and east. During the 2002 flooding, more people were affected from flooded basements and damages to the homes. The least damage from flooding was reported from the flood of 2006[39].

Flooding also affected cropland managed by BTAP in the following manner (Table 5.1):

- In the 2002 flood event, many fields were under water, making crop production difficult, but information regarding the area affected was not available. In many cases, seeding was delayed, thereby affecting yield and possibly quality of various crops. The exact cost of this damage could not be estimated because of lack of data and information.

- The 2005 flood event was the worst, since during this year many acres were under water and could not be cultivated.

In the 1995 flood, two pump sites used for irrigation were flooded.
The reserve does not have any coverage for flood insurance[40]. However, crop losses are covered under the Alberta Crop Insurance program (Table 5.1). Effectiveness of this program was not reported to be investigated by the KBIR, and therefore, is not known.

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[36] Based on information collected through an interview of BT Housing Department on July 10 2008.

[37] Based on information collected through an interview of BT Housing Department official. .

[38] Although funding from INAC has been received, it does not cover the total cost of renovating these damaged homes. Funding trickles down in smaller amounts. Exact number of houses relocated was not provided.

[39] Based on information collected through an interview Blood Tribe Public Works Department
[40] Reasons for this lack are somewhat obscure. KBIR land being crown lands may be one of the reasons.

Mold is a big problem after any flood event, as it affects human health (Table 5.1). Although, no direct association was made between water supply, mold, and disease incidence during these periods[41] some respondents did associate flood events with mold incidences in various homes. The presence of mold in some homes added further stress and health risks for some of the households during and following flood periods because of potential implications for human health and disruptions and costs required to address the problem.

> *"When I was living there, during the flood of 2001…and then there was one in 1995–the one in 1995 was really bad–the water went right up to the back stairs…underneath all the insulation and everything was all wrecked and the house smelled really musty; they had to rip off all of the bottom of the trailer so that they could dry it; most of the houses on that end had [walls] ripped off to try them out…after several months then they put back the bottoms again, but you could still smell the must, the dampness…I was just glad to get out of there."*(Blood Tribe respondent quoted in Magzul 2005)

The researchers were unable to locate information on other health issues associated with extreme events such as post-traumatic stress disorder caused by the flooding events. It is important to determine health risks and impacts on health due to extreme events because health of people is considered to be one of the determinants of adaptive capacity in a community.

5.2.4 Socio-Economic Impacts of Other Climate Related Events

Besides drought and floods, strong winds are extreme weather events that can cause damage. Strong winds mostly affect the home, by causing damages to the roofs, and outside structures. Some parts of the reserve are more vulnerable to this than others. Rural homes, or those located in open areas, perhaps belong to this category. Severe windstorms can also cause other problems such as crop and soil damage.

Other extreme events that are likely to cause damage include hail, frost, lightning, and blizzards. They not only cause property damage, but may result in health problems and deaths. An examination of these events and their effects were beyond the scope of the study.

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[41] Based on information provided by Blood Trine Department of Health officials on July 9 2008.

6. ADAPTATION MEASURES AND THEIR EFFECTIVENESS

"Social and economic problems are our biggest factor…we are already in a state of depression, so climate wouldn't really affect us as much as someone from the outside. We would survive almost any kind of climate change."
(Blood Tribe respondent quoted in Magzul 2005)

The KBIR is a community trying to survive in the short-term but is looking at longer term necessities. For example, based on experience with the extreme events, KBIR administration and Kainai Nation members have adopted some measures to minimize the adverse effects of these events as described in this section.

6.1 Droughts

The KBIR adapted to previous droughts, specifically the 1988 drought by implementing a leasing policy (Table 5.2). This policy allows Reserve land to be leased on a cash basis to non-reserve farmers, allowing people with occupancy rights to have a stable yearly income and not be susceptible to changing climatic or economic conditions. In 2001 and 2002, BTAP was the major agricultural organization on the reserve, and since no major impacts of the drought were experienced due to the leasing of agricultural land to non-native farmers, no adaptation measures were reported by the Reserve. As noted above, this arrangement tends to reduce vulnerability to drought. However, it was felt that if there are more droughts in the future, the irrigated land may have to revert back to dry-land agriculture[42] due to possible lack of irrigation water (Magzul 2005). The exposure risk to drought on the KBIR may increase in the future because the KBIR administration is reducing the amount of lease land and opting to farm the land themselves.

The droughts affected management of the livestock herd because of decreased feed supplies and water supply. The result was a large number of cattle were culled, feed was purchased and water was brought to the cattle via pipeline from one of the rivers (Magzul 2005).

The droughts also resulted in some residents' wells going dry. This resulted in water being hauled to the supply water to these residents or new wells were established (Magzul 2005).

Dust and wind damage was an issue on the reserve in 2001 and 2002. Dust and wind damage was an issue on the reserve in 2001 and 2002. The result of this was Alberta Agriculture and Prairie farm Rehabilitation Administration undertook soil conservation activities[43].

High winds on the KBIR causes damages to homes and the result is housing construction guidelines have changed to better deal with the effects of high winds. In recently constructed

[42] Although amount of water allocated to the KBIR is adequate to irrigate 25,000 acres of crop land, problems may arise in the future during drought periods, particularly if droughts tend to be back-to-back or longer in duration. Furthermore, during these periods, the province may also impose restriction on amount of water that can be used. Both of these factors may suggest that some area in the future may have to revert back to dry-land production.

[43] Based on information gathered from KBIR officials during the July 2008 field trip.

homes, sidings have been replaced by stucco. Also, installation of shingles is done with more tar being used, although steel roofs are more appropriate (but not used because of the cost)[44].

6.2 Floods

Floods require adaptation measures to be implemented very quickly, including moving people to safe places (Table 5.1). Medium-term adaptation measures applied included checking water quality on a regular basis and imposing boil water advisories, as needed. Longer-term adaptation strategies include an emergency response task force and plan was put in place after the 1995 flood. The process and plan were tested and refined in 2002 and 2005. This task force brings in people from the various departments to assist with mitigating the flood impacts and protecting citizens (Magzul 2005). Other medium- and long-term adaptation strategies used included insurance and federal government compensation for some of the flood victims (Magzul 2005).

The Blood Tribe Works Department, in association with the Blood Tribe Housing Department, has begun to survey the reserve in order to locate the homes in less flood-prone areas. The same surveys will also be used for designing and locating roads to various homes on the reserve. It is reported that no new houses would be permitted to be built in the flood plain and each new house must have proper drainage (Magzul 2005). However, some Kanai Nation members have occupancy rights on land that is only on the flood prone land and may not have the option of locating their homes in areas with less risk of flooding. In summary, the many impediments to implementing adaptation measures include lack of funds, lack of housing, and inability to move houses due to occupancy rights (Magzul 2005).

7. SUMMARY AND CONCLUSIONS

7.1 Summary

The major objective of this study was to investigate the impacts of the 2001 to 2002 drought as well as the floods of 1995, 2002 and 2005 on the KBIR, with emphasis on water resources. Drought and flood impacts were assessed in terms of bio-physical and economic changes observed during and after the droughts and floods. An associated objective was to identify the nature of adaptation measures undertaken to deal with the impacts.

The KBIR is bordered on three sides by rivers which are used for irrigation and many other purposes. Residents obtain potable water from both community and private wells located throughout the Reserve. There was some concern over low water levels in the wells during the drought years, but alternative water supplies from other wells on the KBIR were available to the residents.

Flooding appears to have greater impacts on the KBIR and its members than droughts because many residents are impacted directly by flooding, whereas droughts do not directly impact as many people at this time, partially because they cash lease their agricultural land to non-native farmers. Also the effects of the recent floods were more evident to the people and more recent, and therefore, may have been emphasized to a greater extent.

[44] Based on information provided by the Blood Tribe Housing Department during July 2008 interview.

Despite the many economic challenges, the Kainai Nation residents have undertaken some measures to adapt to the impacts of flooding, including the relocation of some homes to less risky areas and improved drainage. Since the 2002 floods the Department of Public Works has upgraded some roads with more compaction and better drainage to prevent washouts during heavy precipitation events.

7.2 Conclusions

The Kainai Blood Indian Reserve and the Kainai Nation Members are facing many challenges, one of which is how best to adapt to severe weather events. These many challenges have the potential to decrease the adaptive capacity of the KBIR. The additional stress of the impacts of extreme weather events add to the many socio-economic stresses already being felt.

Future adaptation measures by the Kainai Nation members to climatic changes and extremes are a function of their current and future adaptive capacity. The economic limitations faced by the Blood Tribe people result from limited money transfers by the Federal government to the KBIR, the lack of local economic opportunities, high unemployment rates and relatively lower human capital (level of education and skills), and these limitations constrain their adaptive capacity. Moreover, future adaptation measures will continue to have less priority for the KBIR and its members if the stress from more immediate socio-economic challenges persists.

In conclusion, this report is an important foundation for the comparison of two important hazards, flood and drought, and for integrating biophysical and socio-economic aspects of impacts and adaptive capacity, which form the basis for vulnerability assessment. The KBIR residents are in a region that is already affected by drought and floods, and these hazards and others are expected to increase. Their adaptive capacities are constrained by many socio-economic factors, however, they are currently buffered from drought, and sometimes flood effects, by factors including their use of groundwater, irrigation, and by their cash-lease system for agricultural land. Others in the Prairies, in general, have less access to these adaptation measures. Key questions regarding their vulnerability to climate change and water scarcity include the sustainability of those measures and the complex interaction of socio-economic and biophysical stresses.

Horses on the KBIR (Photo: L. Magzul 2005)

7.3 Areas for Future Research

The characteristics of the KBIR caused several challenges for the climate impact, adaptation and vulnerability assessment research. Main challenges included the lack of data and information including water usage, population, plus others. This work represents only a beginning to the required impact and adaptation assessment that is needed to improve preparation to climatic. Suggestions for additional research include:

- Water supply and demand should be monitored and trends determined to help increase the understanding of vulnerability to water scarcity. For example, a groundwater level monitoring network is needed.
- Recently, the Blood Tribe started to decrease the amount of cash-leased land on the reserve and is enlarging their farming practices. It is important to determine how they will be able to cope with the effects of droughts and excess moisture/flooding under these new arrangements. This is especially important because the climate change projections indicate more extended and severe droughts and floods.
- The vulnerability of the KBIR residents is already high because of other stressors. It is important to determine the limits to the vulnerabilities such as determining groundwater levels and quality, and the priorities for improving adaptive capacity. It is also critical to determine how climate change will exacerbate all the stressors on the KBIR residents. Increased knowledge of climate change impacts and the Kainai Nation Members' potential adaptive capacities and vulnerabilities would be beneficial for many, including the KBIR residents.

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APPENDIX A

Discussion Questions for the July 2008 Meetings with Kainai Nation Members

This study is part of the Institutional Adaptation to Climate Change (IACC) project. The IACC project is designed to "develop a systematic and comprehensive understanding of technical and social capacities of regional institutions to formulate and implement strategies of adaptation to climate change risks and the forecasted impacts of climate change on the supply and management of water resources in dryland environments. In order to facilitate meeting this objective, knowledge of the impacts on people and the communities' institutions is crucial. Past experience with the coping mechanisms and adaptation measures adapted to these changing climate regimes may also be useful in designing future climate change programs and policies.

The primary objective of this study is to investigate the impacts of the 2001 and 2002 droughts plus the flood events of 1995, 2002 and 2005 on the Blood Tribe Reserve, with emphasis on water resources, where information is available. An associated objective is to identify the nature of adaptation measures undertaken.

Background

1. According to the Blood Tribe, the population of the community is around 10,000 people, but according to Statistics Canada and Indian and Northern Affairs Canada, it is only 4,500. What is the reason for the discrepancy?

2. Statistics Canada's unemployment rate for the Blood Tribe for 1996, 2001, 2006 were 29%, 45%, and 23.6% respectively. Some people in the community interviewed in 2005 gave estimates of 60-80% unemployment. What is the reason for the discrepancy?

3. The Kainai Blood Indian Reserve consists of six satellite communities along with headquarters for the Reserve at Standoff. What is the approximate population base of these communities?

Community	**Estimated population in 2008**	**Comments**
Standoff		
Moses Lake		
Levern		
North End		
Old Agency		
Fish Creek		
Fort Whoop Up		
Bullhorn		
Total		

4. Some residents of the Blood Tribe have occupancy rights. What is the origin of these rights?

5. What is the nature of these rights?

6. Do these rights create any conflict among the residents of the Blood Tribe?

7. What is the current land use on the Blood Tribe?

Type of Land	Area	Current Use
Irrigated		
Dryland Agriculture		
Others?		

Droughts of 2001 and 2002

Were there drought-like conditions faced during 2001 and 2002 on the KBIR lands?

If yes:

1. What areas of the KBIR were most affected in 2001 by the drought-like situation? How long did the drought conditions last?

2. What sectors were affected by the drought in these areas?

3. How would you characterize the economic impact of the drought conditions (limited, moderate, severe)?

4. Were there any government programs available in response to the drought? If yes, please describe their nature.

5. How effective were these programs in helping individuals cope with the drought situation?

6. What additional planning and coping measures are required if a drought occurs in the future?

7. Was the forestry sector affected? If yes, describe the nature of the impacts

8. Was the transportation sector (rail, trucks and shipping) impacted in any way by the drought? If yes, describe the nature of the impacts.

9. Was the tourism/recreation sector affected? If yes, describe the nature of the impacts.

10. Did the drought conditions result in increased personal stress, and if so, in what ways?

11. What other effects did you notice or hear about?

Same questions for drought of 2002.

<u>Flooding in 1995, 2002 and 2005</u>

Were areas of the KBIR affected by flood in 1995, 2001 or in 2002?

If yes:

1. How frequent is the flooding on the KBIR lands?

2. What parts of the KBIR are affected?

3. What sectors were affected by the flood on the KBIR?

4. How would you characterize the economic impact of the flood conditions (limited, moderate, severe)?

5. Were there any government programs available in response to the flood? If yes, please describe their nature.

6. How effective were these programs in helping individuals cope with the flooding situation?

7. What additional planning and coping measures are required if a flood occurs in the future?

8. Was the forest lands affected? If yes, describe the nature of the impacts.

9. Was the transportation sector (rail, trucks and shipping) impacted in any way by the flood? If yes, describe the nature of the impacts.

10. Was the tourism/recreation sector affected? If yes, describe the nature of the impacts.

11. Did the flood conditions result in increased personal stress, and if so, in what ways?

12. What other effects did you notice or hear about?

<u>Other Issues</u>

How did the community deal with the problem(s)? What was the role of the local government in dealing with these problems? Did the community receive help from public institutions such as INAC? How did people help each other in dealing with these problems?

APPENDIX B

Biophysical Figures

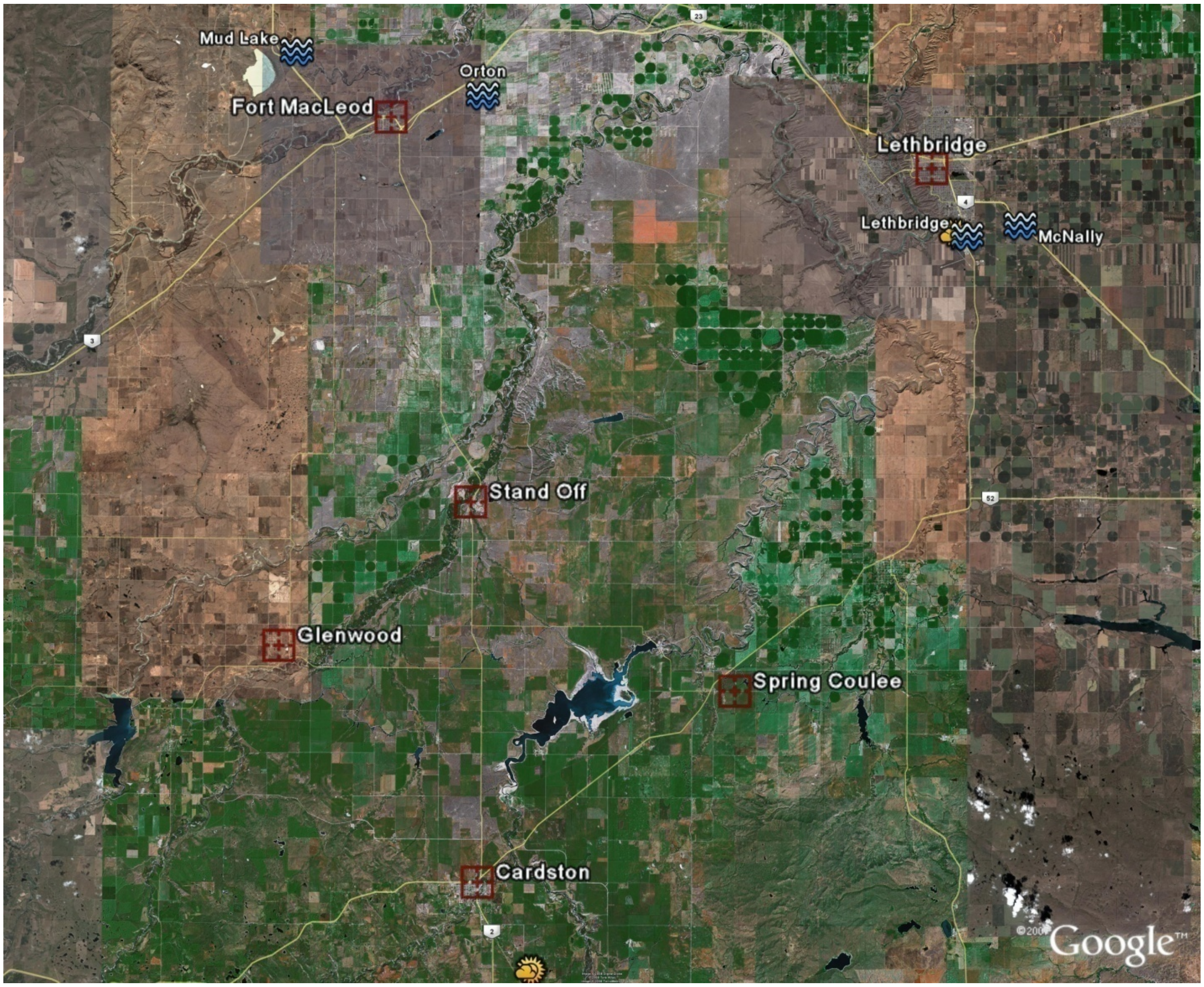


Figure B3.1 Locations of Groundwater and Climate Stations in the Study Area
(base map: Google Earth Pro 2007).
Sun/cloud – climate station locations (Cardston and Lethbridge)
Waves – groundwater well monitoring sites (Mud Lake, Orton, Lethbridge, McNally)

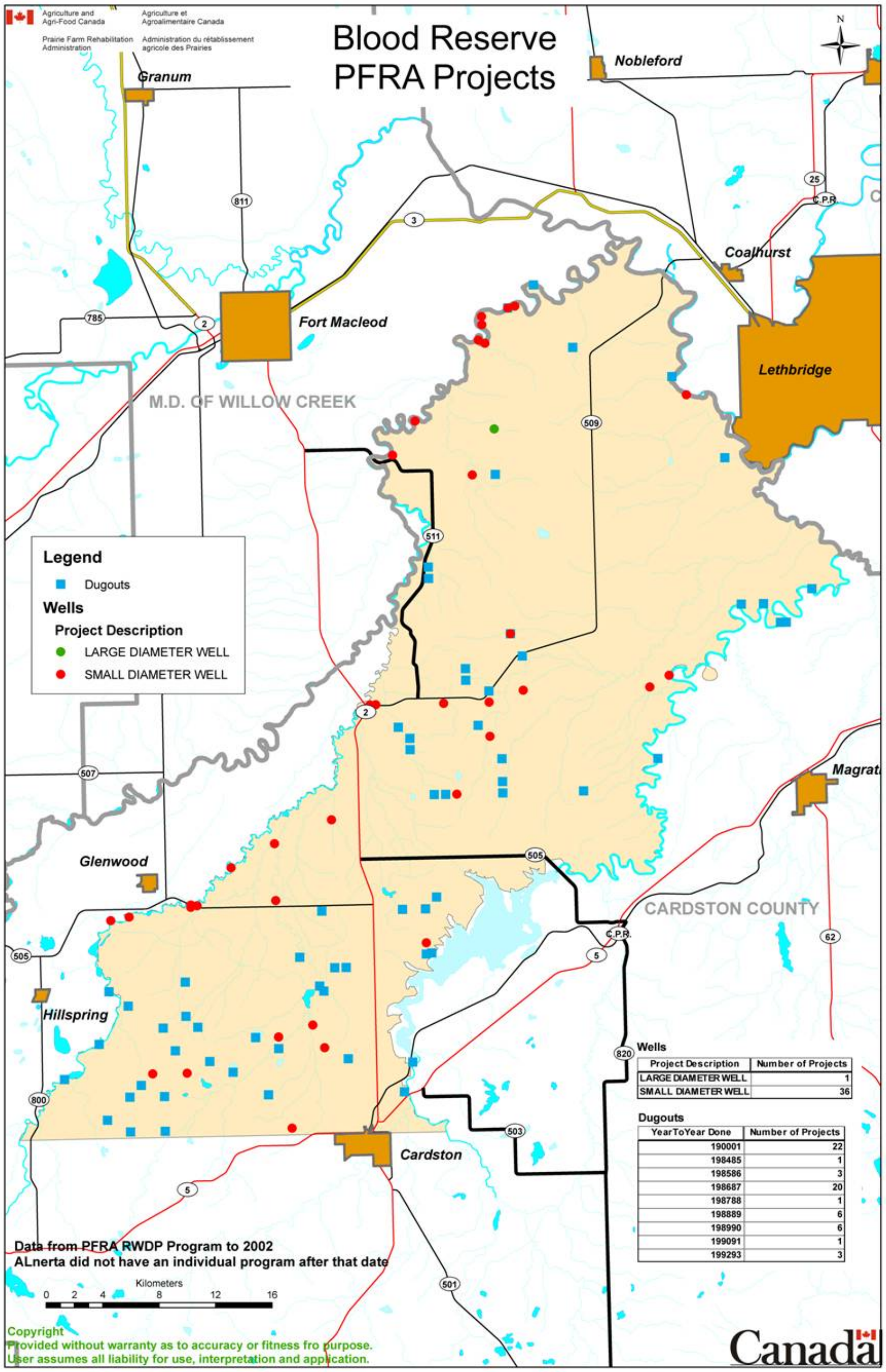


Figure B3.2 Historic (1900-1993) Dugout and Well Locations in the Kainai Blood Indian Reserve, Alberta (PFRA – Agriculture and Agri-Food Canada 2008)

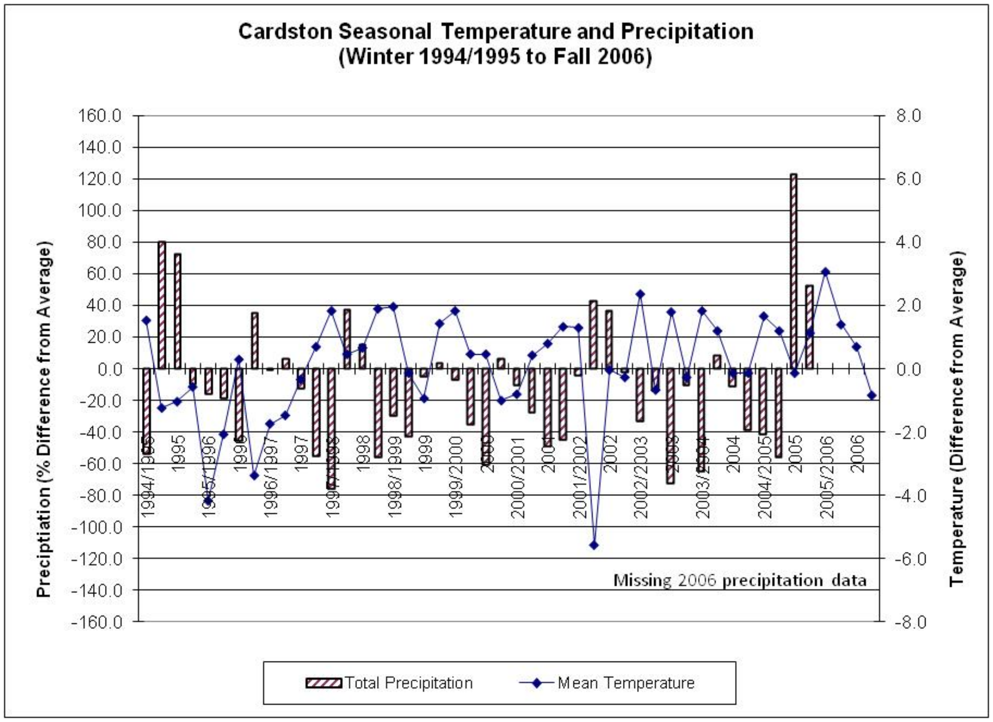


Figure B4.1 Cardston's Seasonal Climate for 1994 to 2006
(Data Source: Environment Canada 2008)

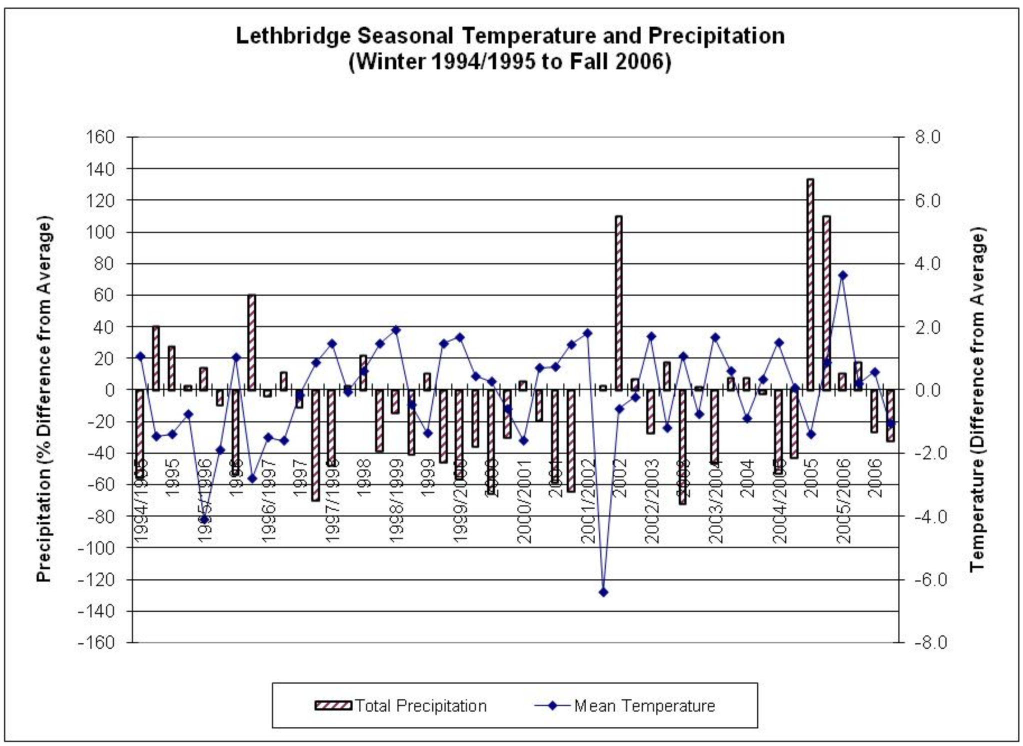


Figure B4.2 Lethbridge's Seasonal Climate for 1994 to 2006
(Data Source: Environment Canada 2008)

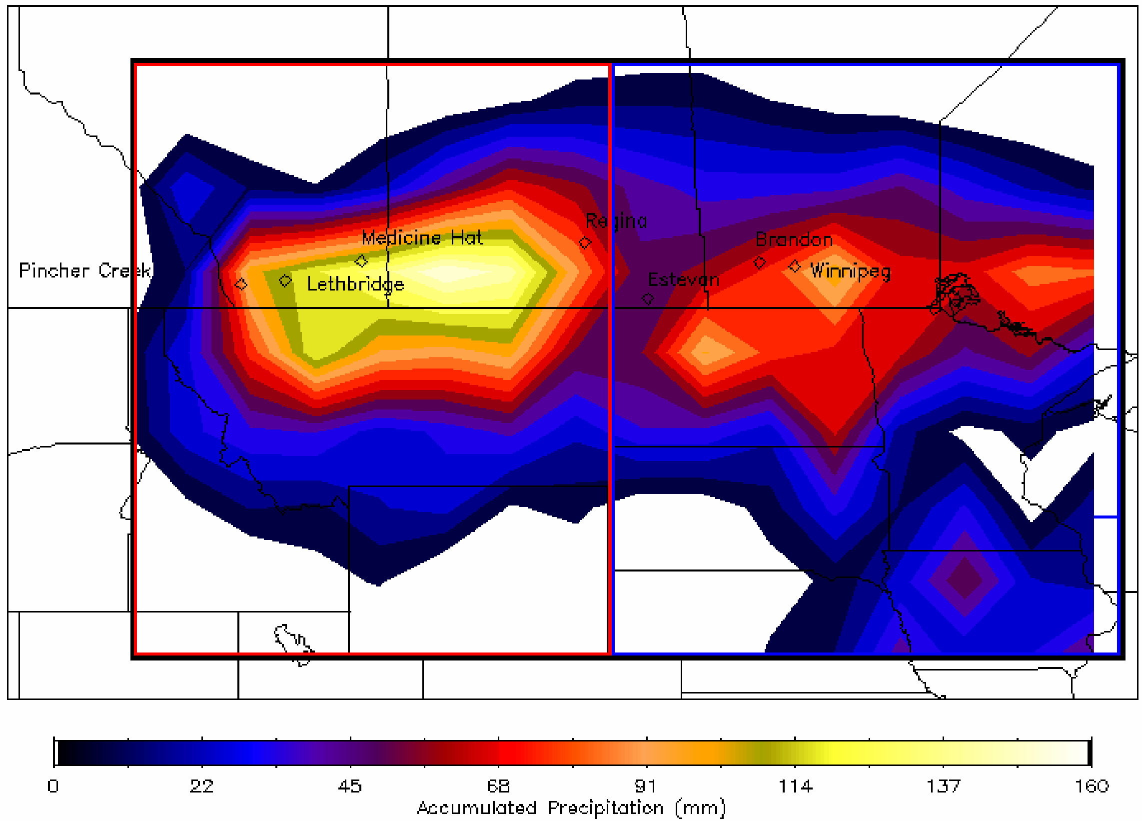


Figure B4.3 June 8-10th 2002 Precipitation Event (Stewart et al. 2007)

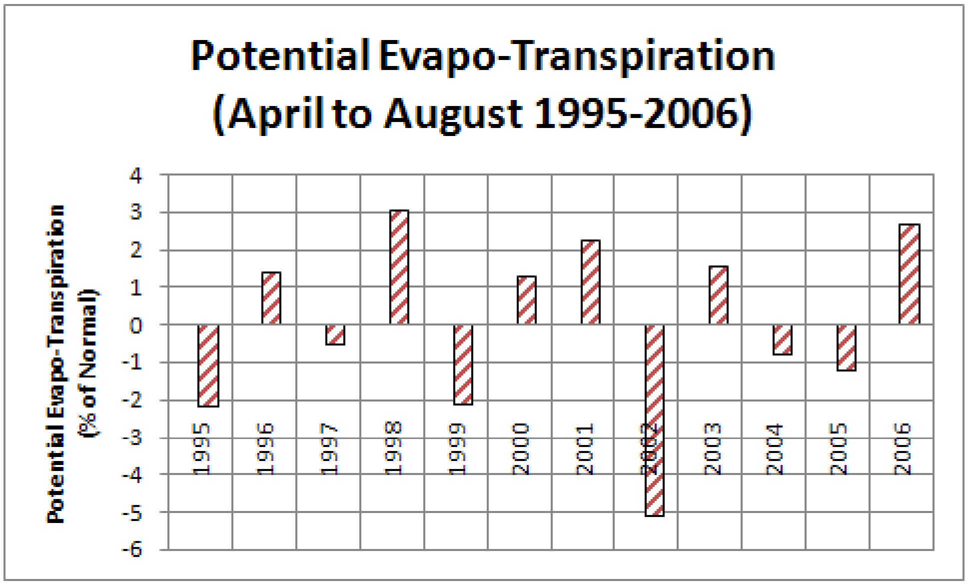


Figure B4.4 Potential Evapo-Transpiration for April to August 1995-2006 period for Lethbridge (Data Source: PFRA – AAFC 2008)

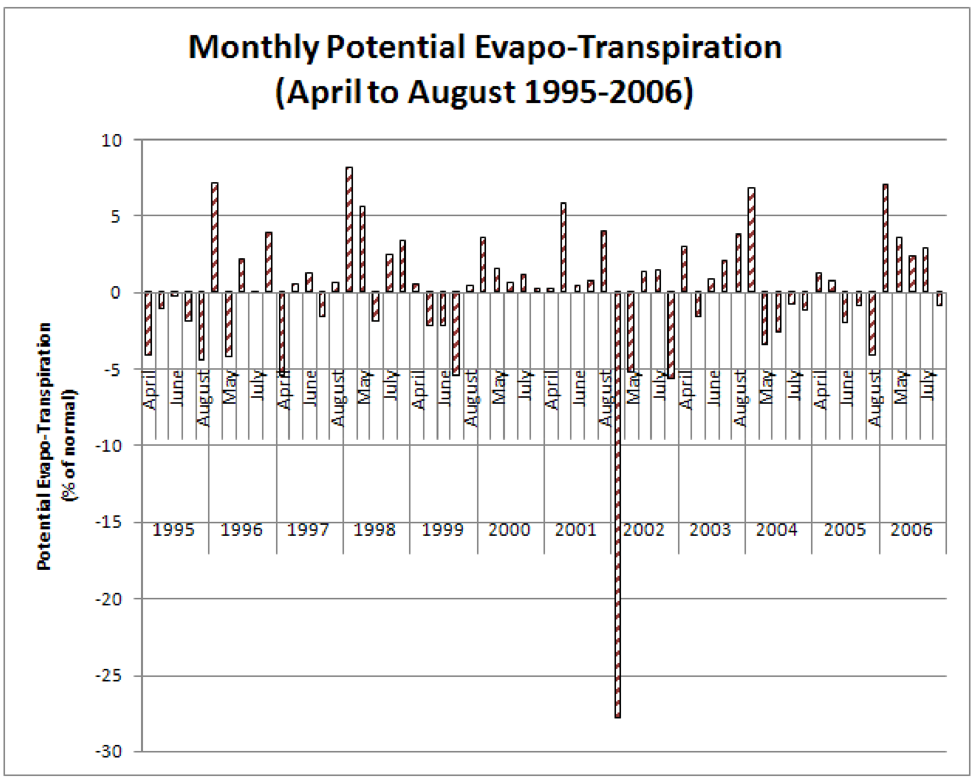


Figure B4.5 Monthly Potential Evapo-Transpiration for April to August 1995-2006 period for Lethbridge (Data Source: PFRA – AAFC 2008)

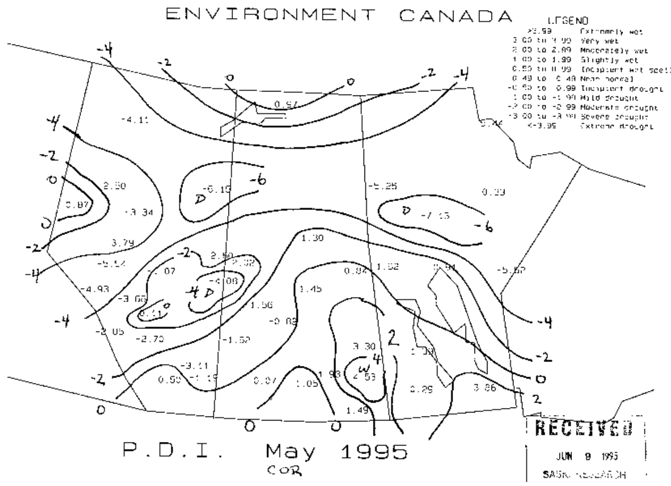


Figure B4.6 Palmer Drought Severity Index for the Canadian Prairie Provinces, May 1995 (Ryback, p. comm. 1995)

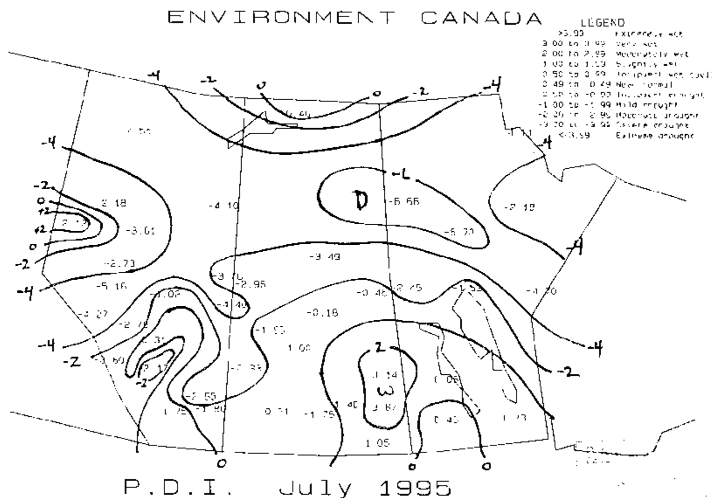


Figure B4.7 Palmer Drought Severity Index for the Canadian Prairie Provinces, July 1995 (Ryback, p. comm. 1995)

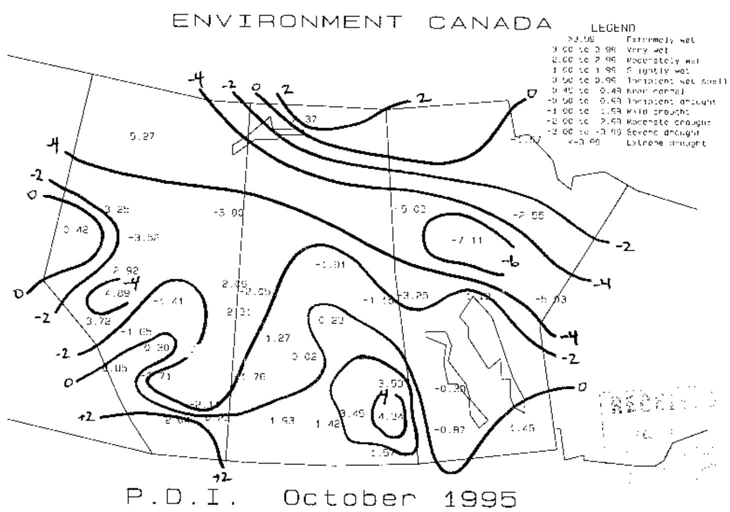


Figure B4.8 Palmer Drought Severity Index for the Canadian Prairie Provinces, October, 1995 (Ryback, p. comm. 1995)

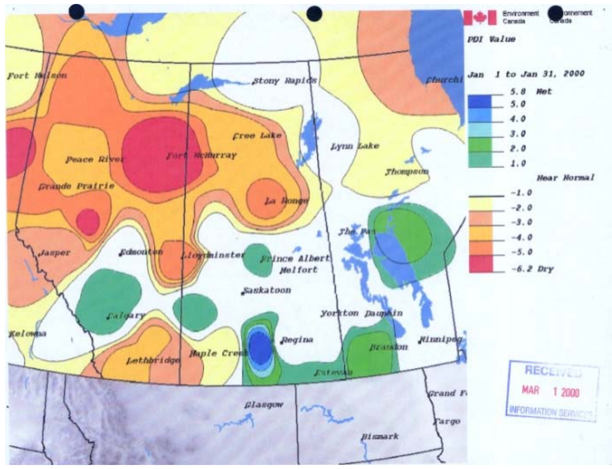


Figure B4.9 Palmer Drought Severity Index for the Canadian Prairie Provinces, January 2000 (Ryback, p. comm. 2000)

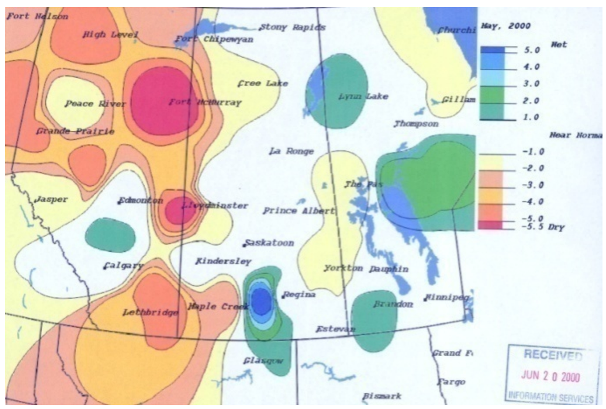


Figure B4.10 Palmer Drought Severity Index for the Canadian Prairie Provinces May 2000 (Ryback, p. comm. 2000)

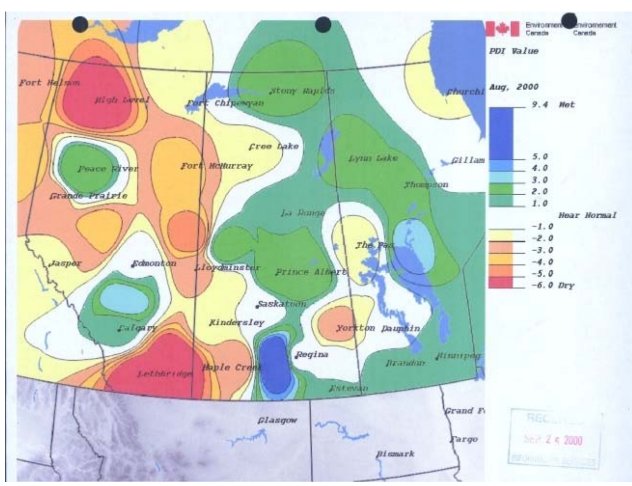


Figure B4.11 Palmer Drought Severity Index for the Canadian Prairie Provinces, August 2000 (Ryback, p. comm. 2000)

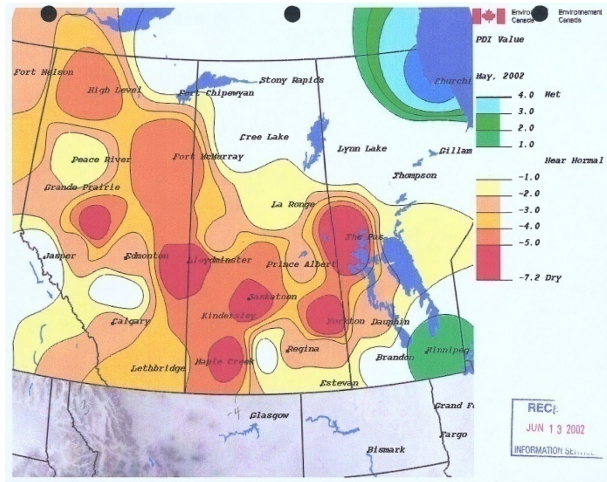


Figure B4.12 Palmer Drought Severity Index for the Canadian Prairie Provinces, May 2002 (Ryback, p. comm. 2002)

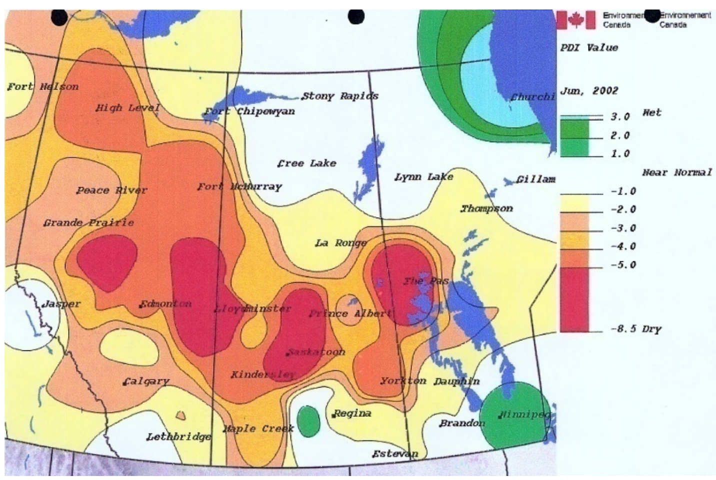


Figure B4.13 Palmer Drought Severity Index for the Canadian Prairie Provinces, June 2002 (Ryback, p. comm. 2002)

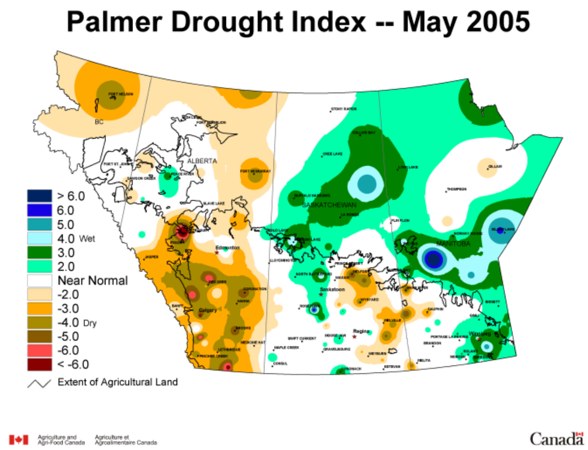


Figure B4.14 Palmer Drought Severity Index for the Canadian Prairie Provinces May 2005 (PFRA – Agriculture and Agri-Food Canada 2005)

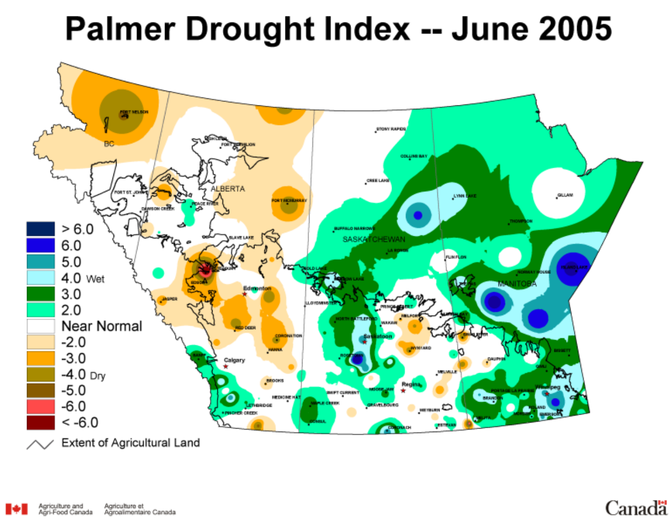


Figure B4.15 Palmer Drought Severity Index for the Canadian Prairie Provinces, June 2005 (PFRA – Agriculture and Agri-Food Canada 2005)

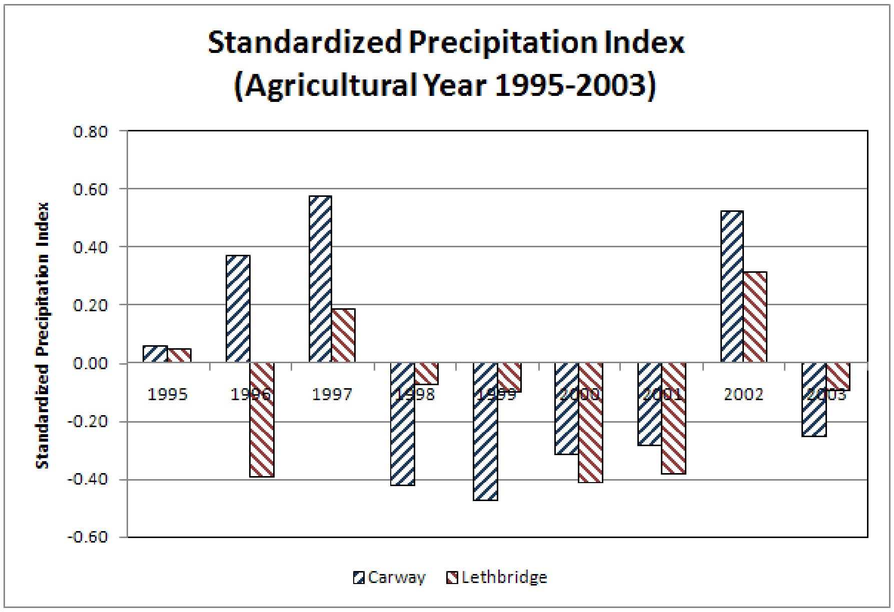


Figure B4.16 Standardized Precipitation Index Values for the Agricultural Year (April to August) for the Carway and Lethbridge, Alberta Region (1995-2005)
(Data Source: Bonsal, p. comm. 2008).

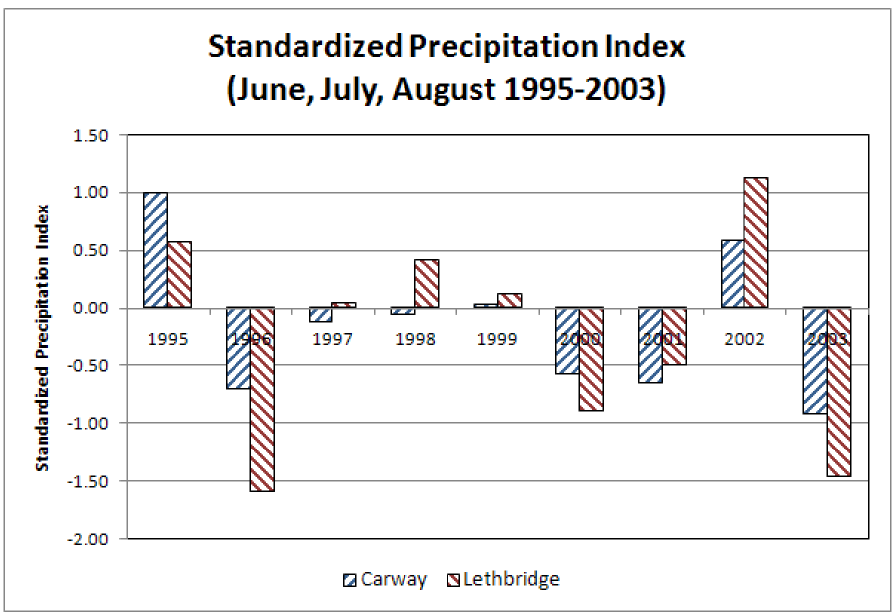


Figure B4.17 Standardized Precipitation Index Values for the Summer Month (June, July August) for the Carway and Lethbridge, Alberta Region (1995-2005)
(Data Source: Bonsal, p. comm. 2008).

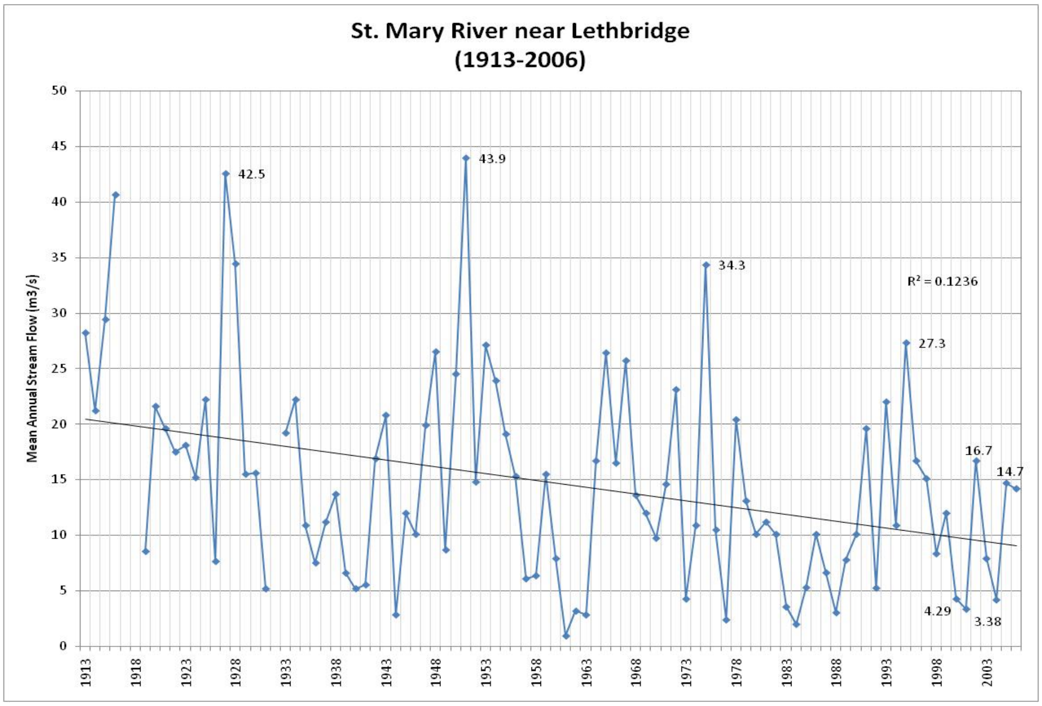


Figure B5.1 St. Mary River near Lethbridge Mean Annual Stream Flow (1913-2006) (Data Source: Environment Canada 2008)

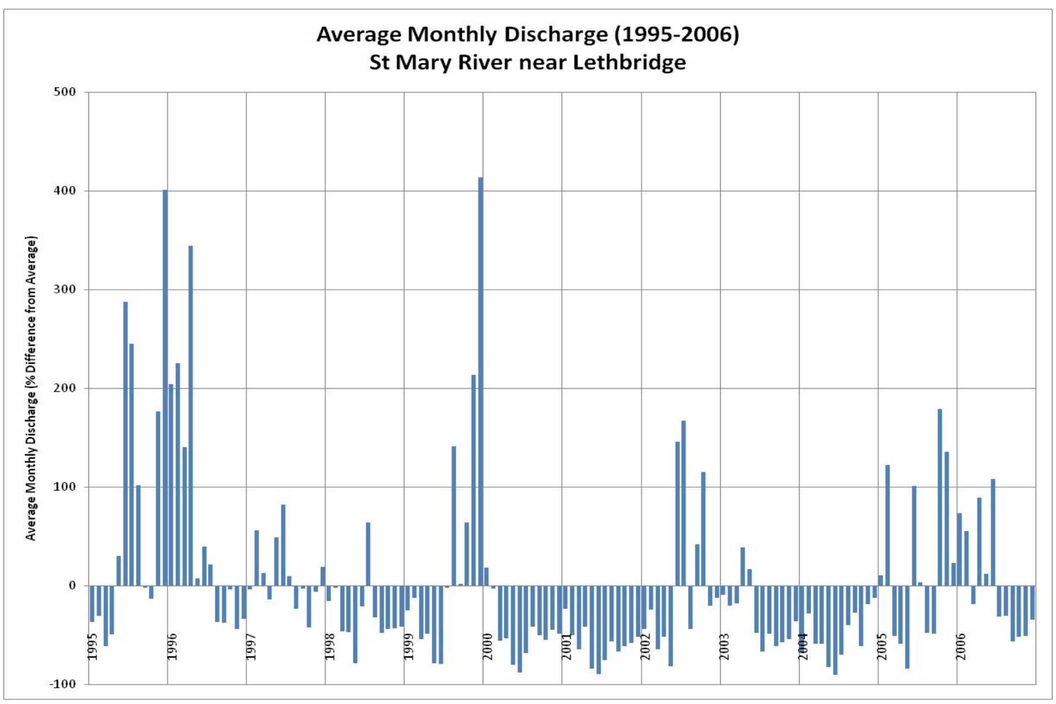


Figure B5.2 St. Mary River near Lethbridge Mean Annual Stream Flow (1995-2006) (Percent Difference from Average) (Data Source: Environment Canada 2008)

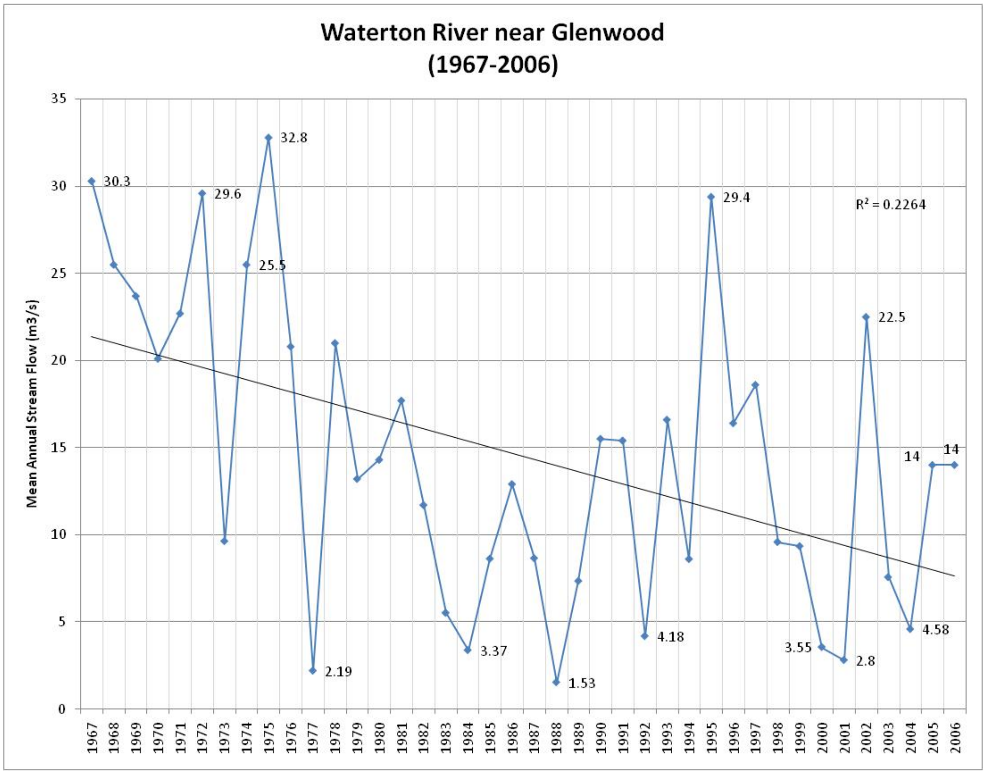


Figure B5.3 Waterton River near Glenwood Mean Annual Stream Flow (1967-2006) (Data Source: Environment Canada 2008)

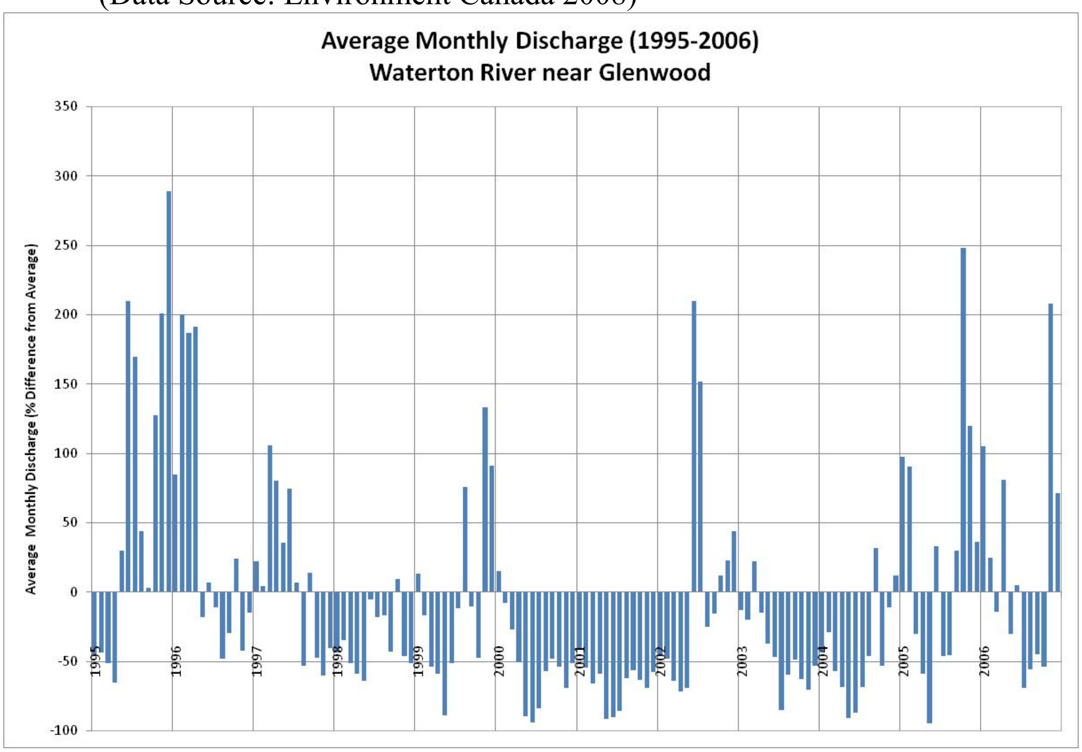


Figure B5.4 Waterton River near Glenwood Mean Annual Stream Flow (1995-2006) (Percent Difference from Average) (Data Source: Environment Canada 2008).

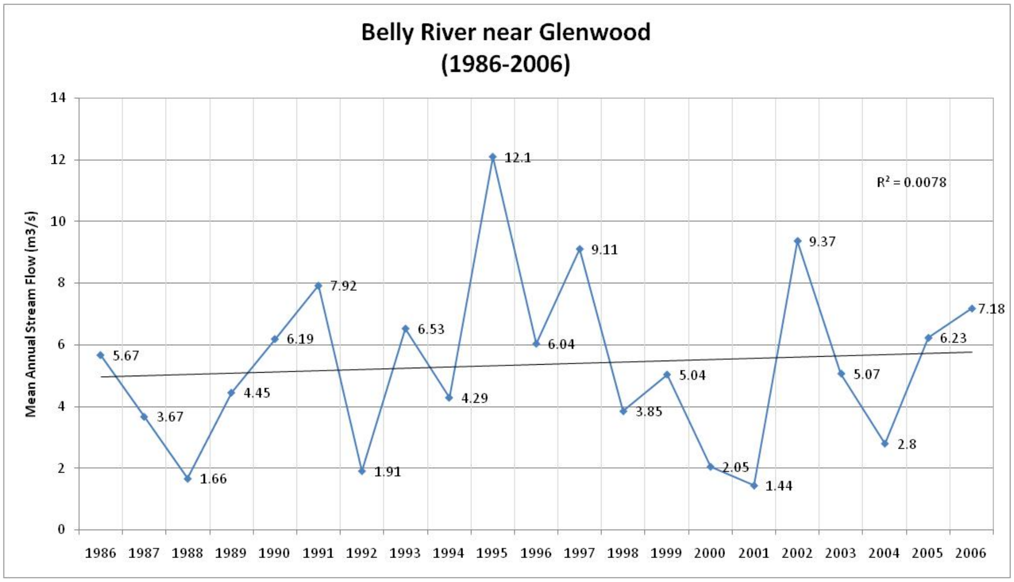


Figure B5.5 Belly River near Glenwood Mean Annual Stream Flow (1986-2006) (Data Source: Environment Canada 2008)

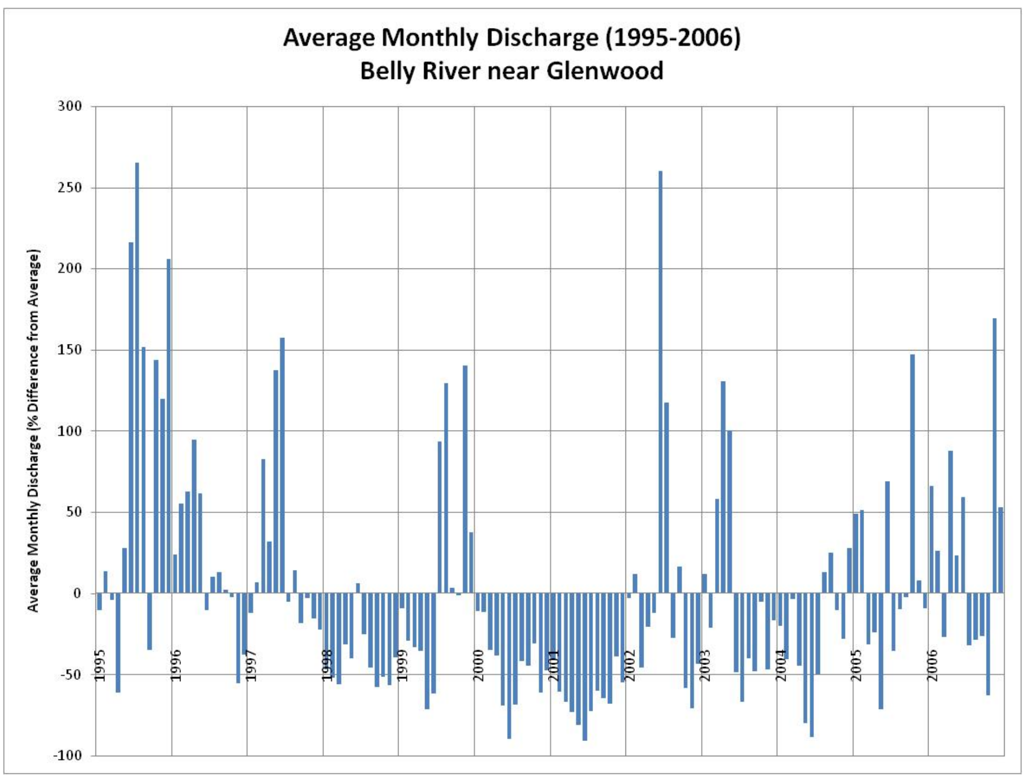


Figure B5.6 Belly River near Glenwood Mean Annual Stream Flow (1986-2006) (Percent Difference from Average) (Data Source: Environment Canada 2008)

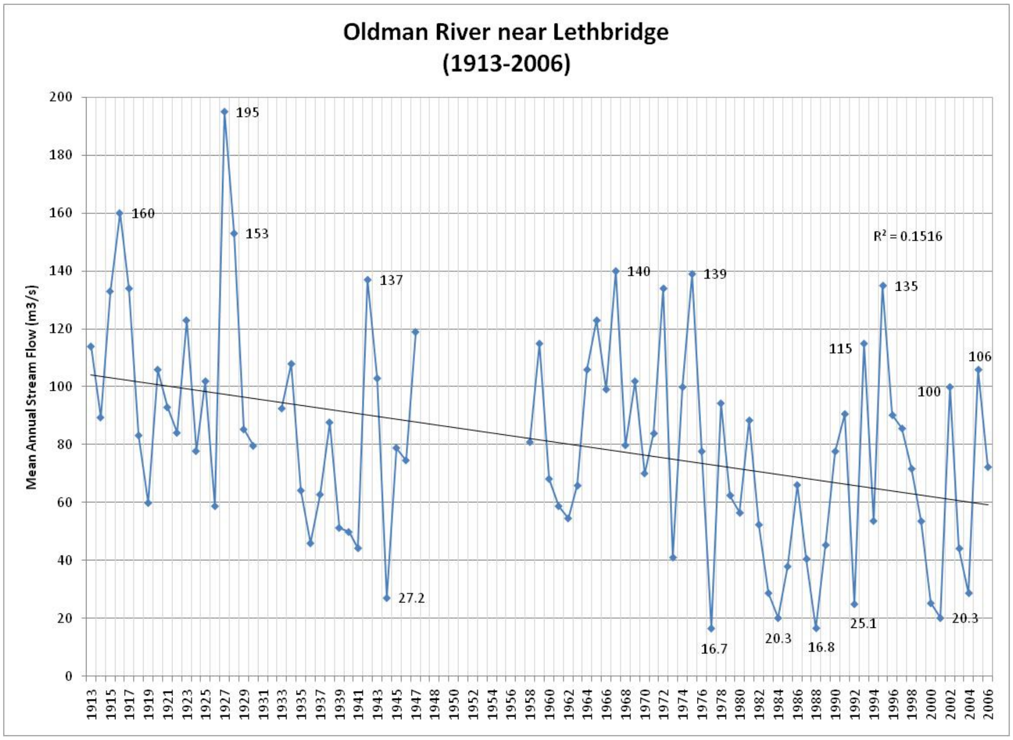


Figure B5.7 Oldman River near Lethbridge Mean Annual Stream Flow (1913-2006) (Data Source: Environment Canada 2008)

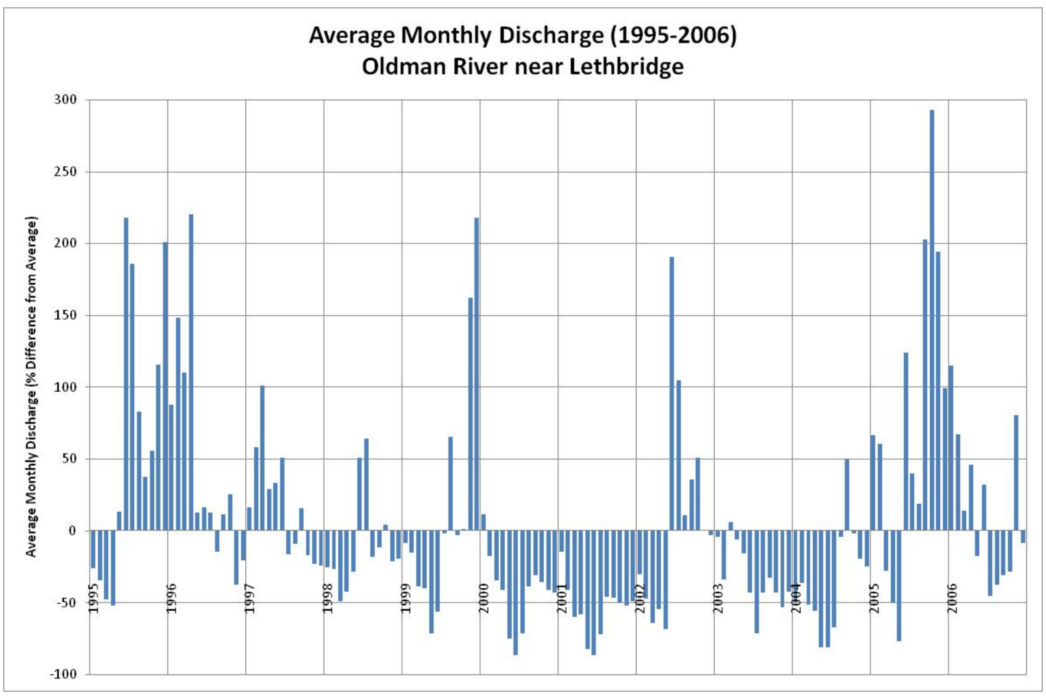


Figure B5.8 Oldman River near Lethbridge Mean Annual Stream Flow (1995-2006) (Percent Difference from Average) (Data Source: Environment Canada 2008)

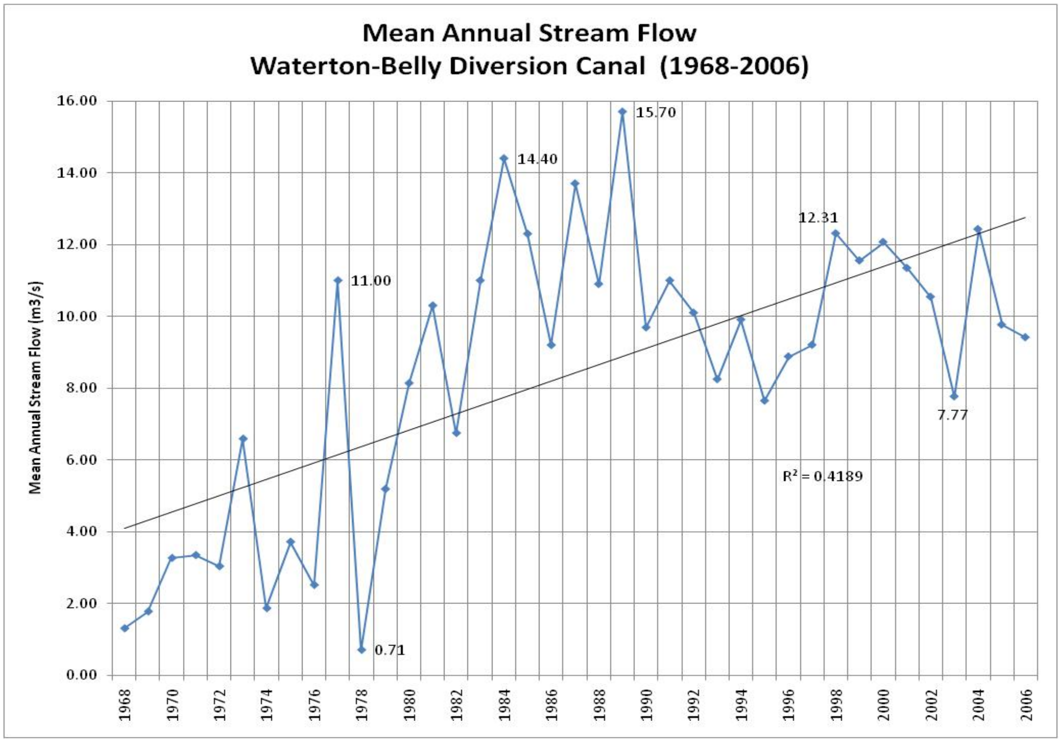


Figure B5.9 Waterton-Belly Diversion Canal Mean Annual Stream Flow (1968-2006) (Data Source: Environment Canada 2008)

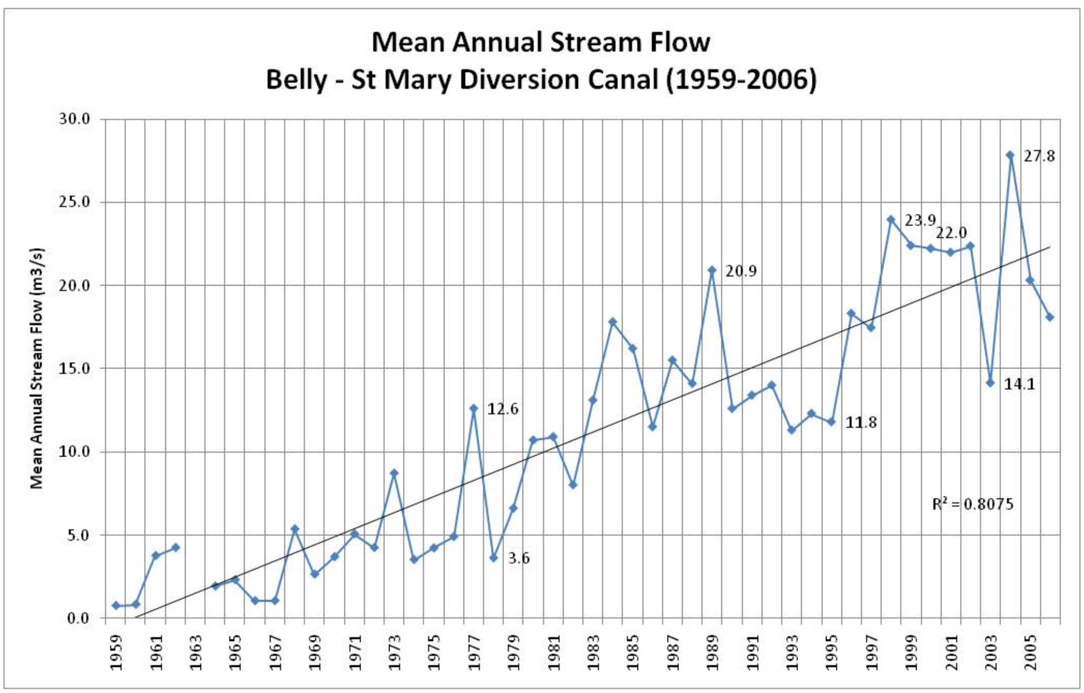


Figure B5.10 Belly – St. Mary Diversion Canal Mean Annual Atream Flow (1959-2006) (Data Source: Environment Canada 2008)

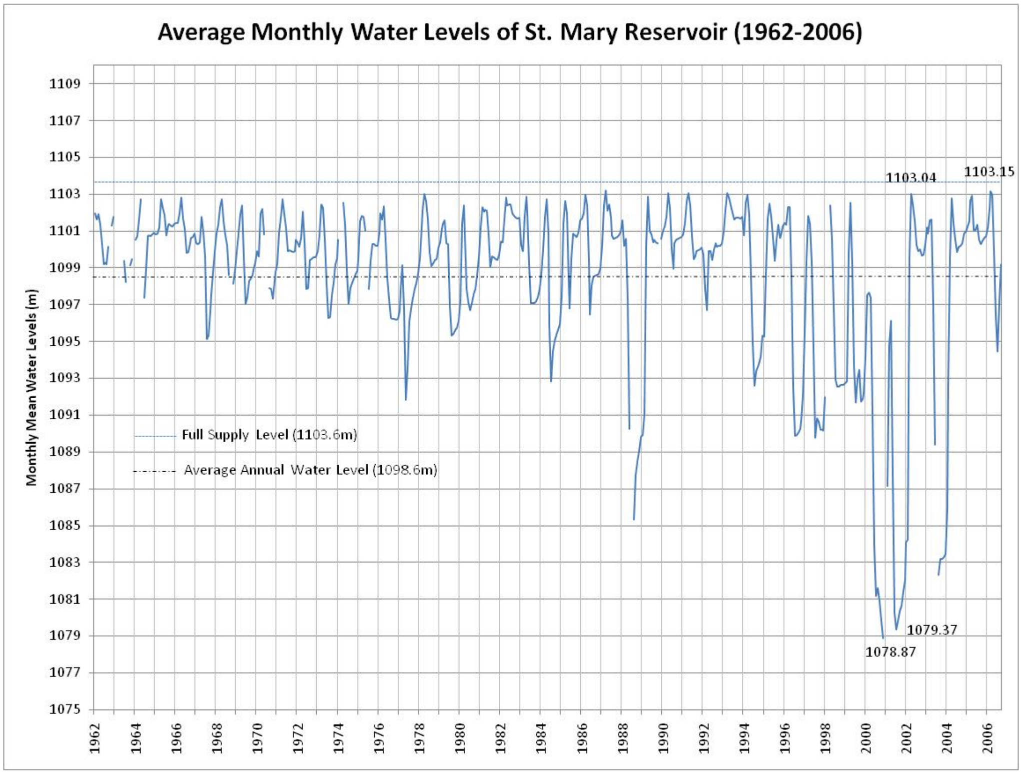


Figure B5.11 Monthly Mean Water Levels at St. Mary Reservoir (1962-2006)
(Data Source: Environment Canada 2008)

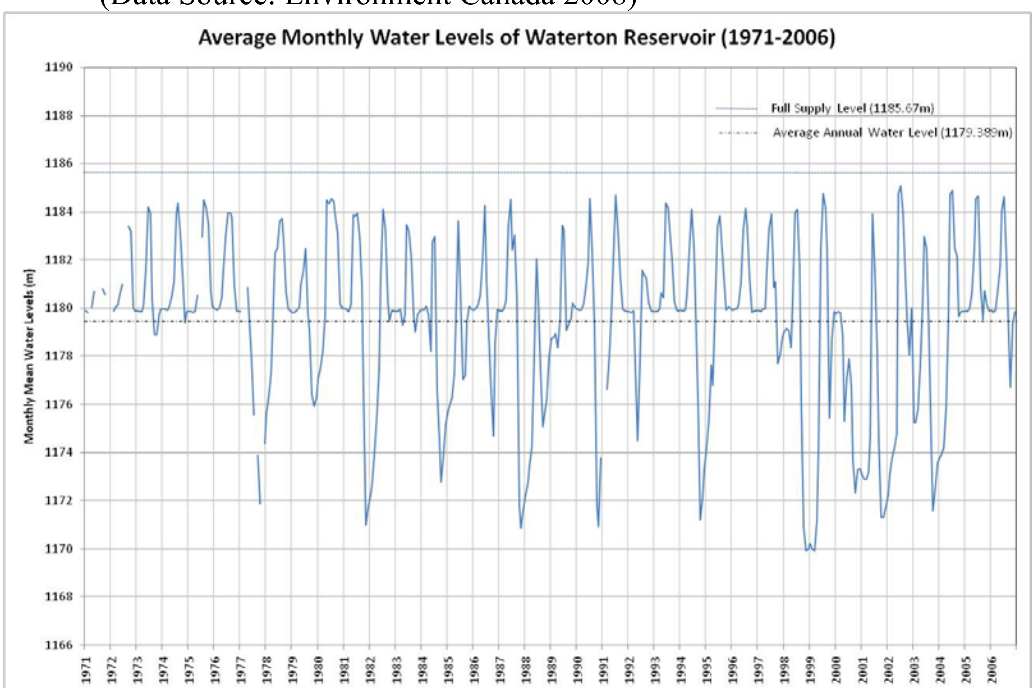


Figure B5.12 Monthly Mean Water Levels at Waterton Reservoir (1971-2006)
(Data Source: Environment Canada 2008)

Lethbridge Airport (Obs. Well #109)

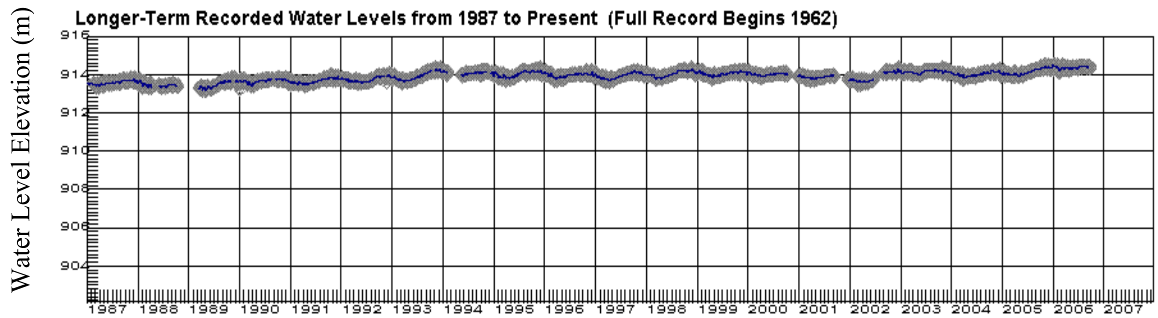


Figure B5.13 Groundwater Observation Well at Lethbridge Airport (Adapted fromAlberta Environment 2008)

Orton 1514E (Obs. Well #111)

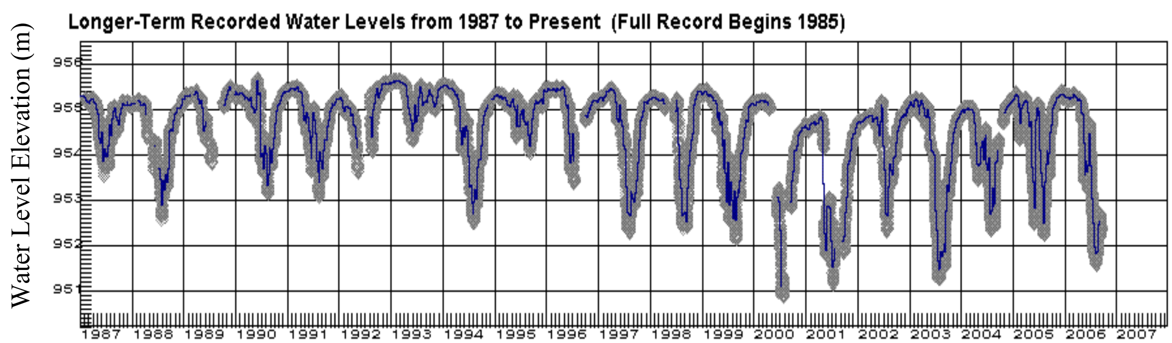


Figure B5.14 Groundwater Observation Well at Orton (Adapted from Alberta Environment 2008)

Mud Lake 1537E-1538E (Obs. Well #112)

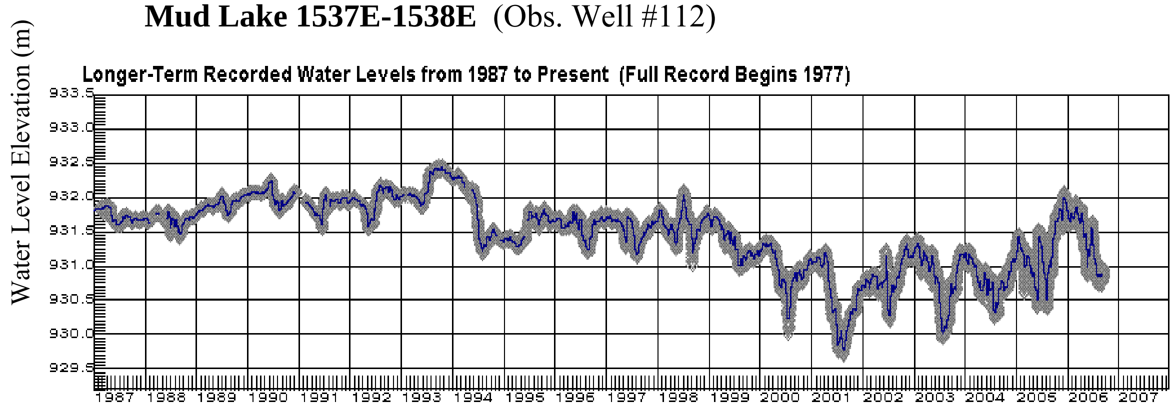


Figure B5.15 Groundwater Observation Well at Mud Lake (Adapted from Alberta Environment 2008)

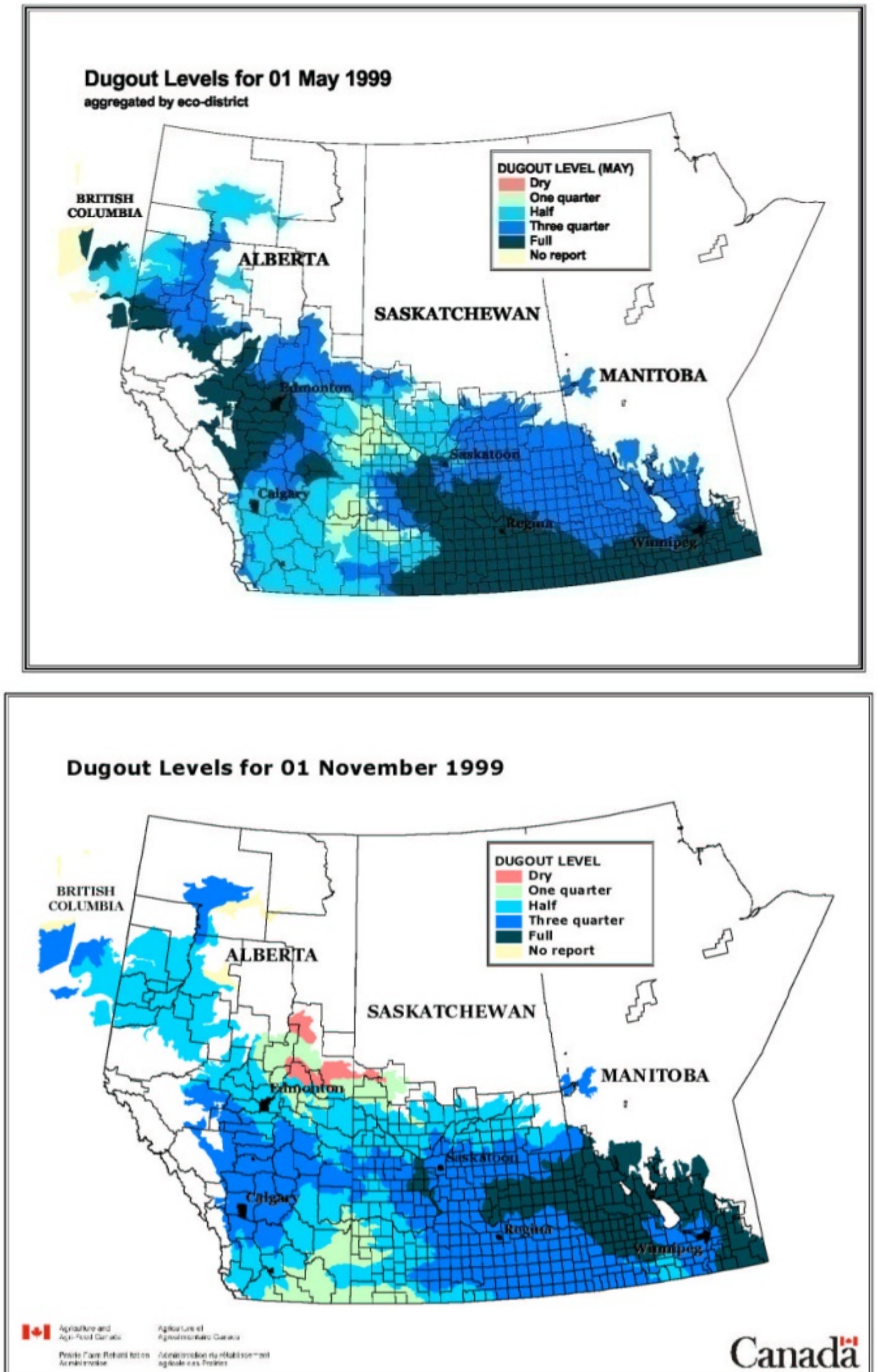
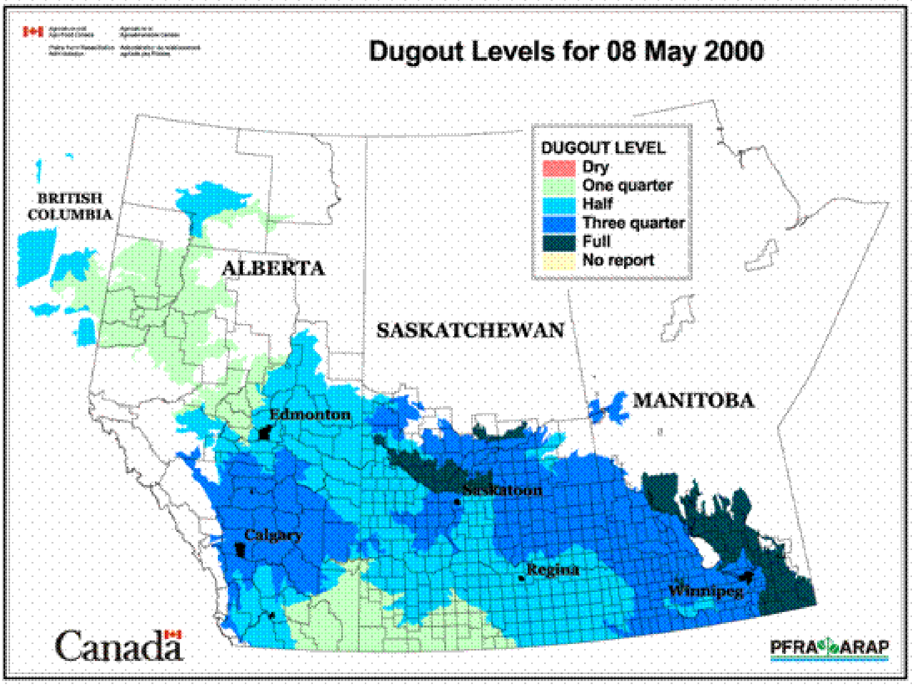


Figure B5.16 Dugout Levels across Canadian Prairies for May and November 1999
(PFRA - Agriculture and Agri-Food Canada 2006)



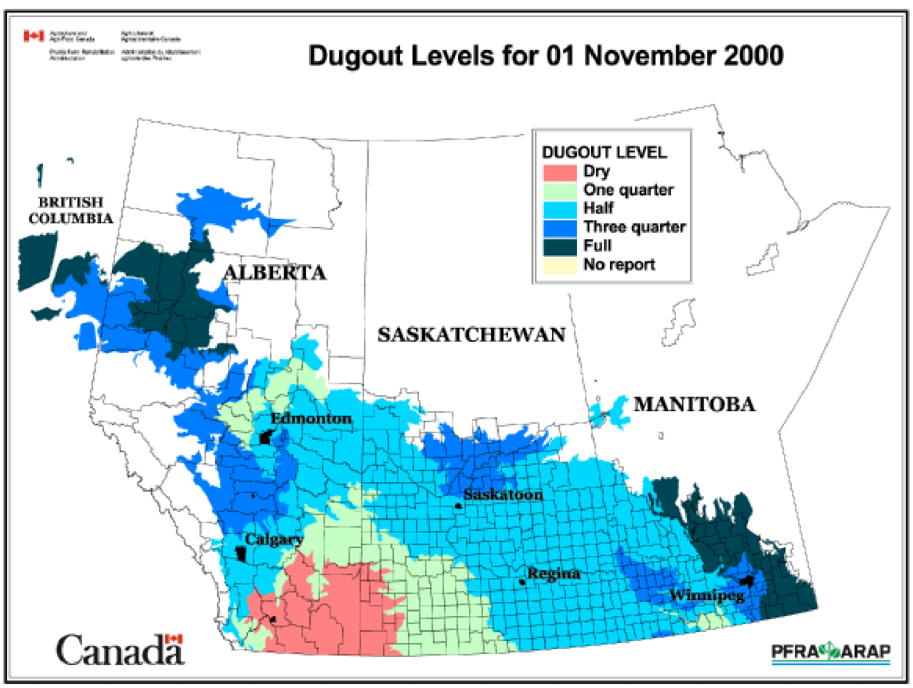
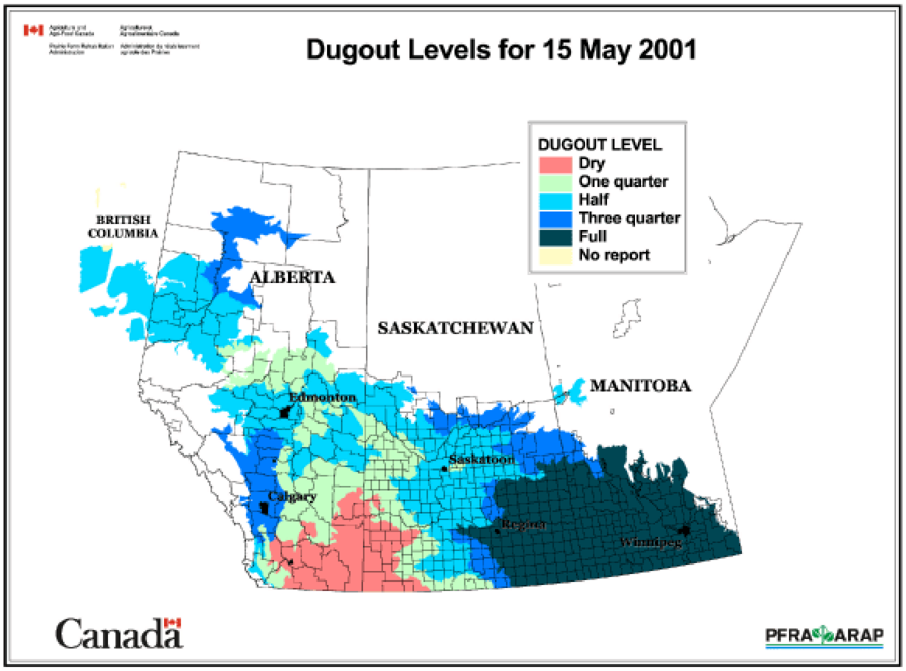


Figure B5.17 Dugout Levels across Canadian Prairies for May and November 2000
(PFRA - Agriculture and Agri-Food Canada 2006)



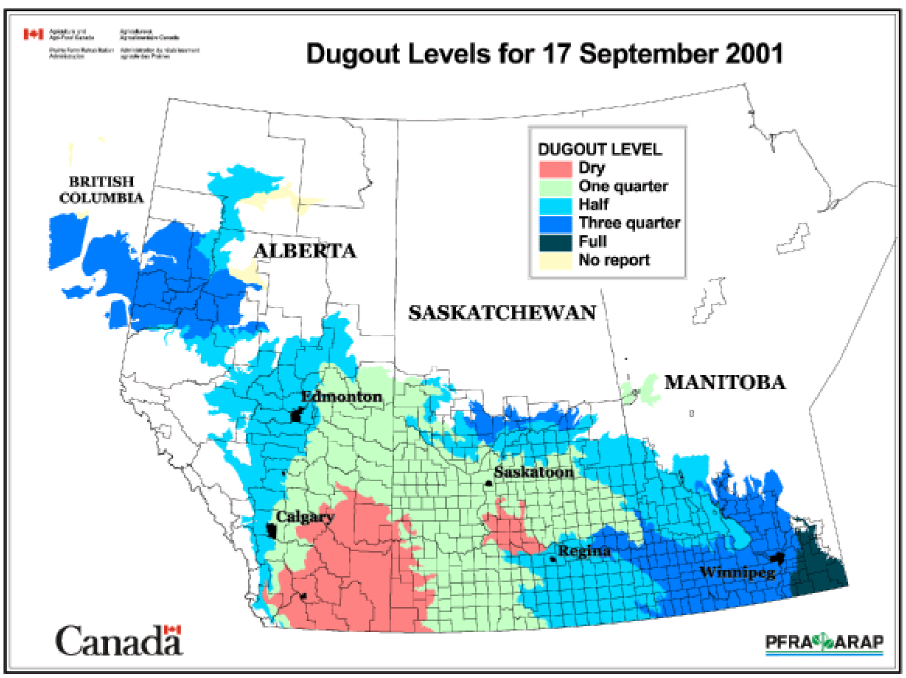


Figure B5.18 Dugout Levels across Canadian Prairies May and September 2001
(PFRA - Agriculture and Agri-Food Canada 2006)

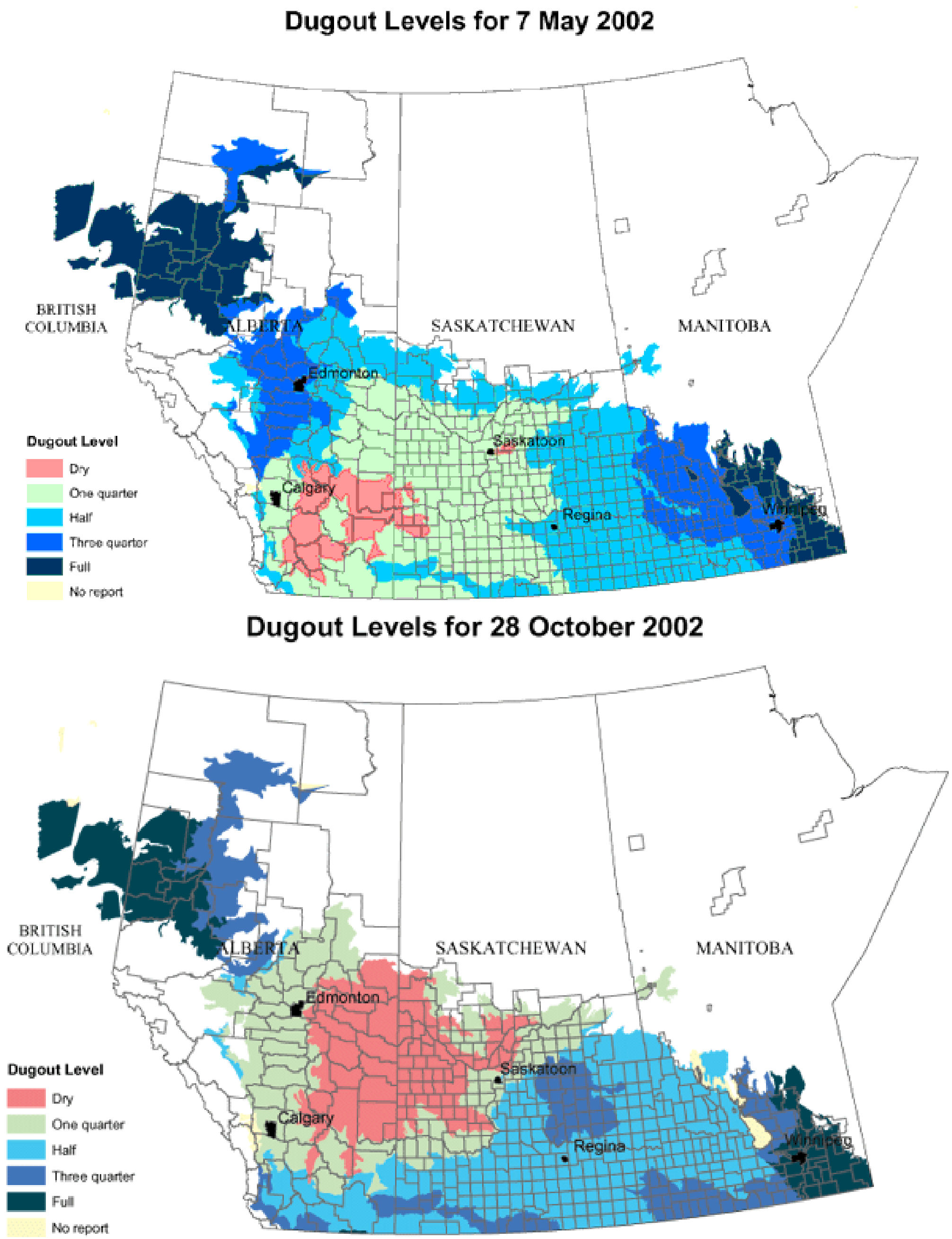


Figure B5.19 Dugout Levels across Canadian Prairies May and October 2002
(PFRA - Agriculture and Agri-Food Canada 2006)

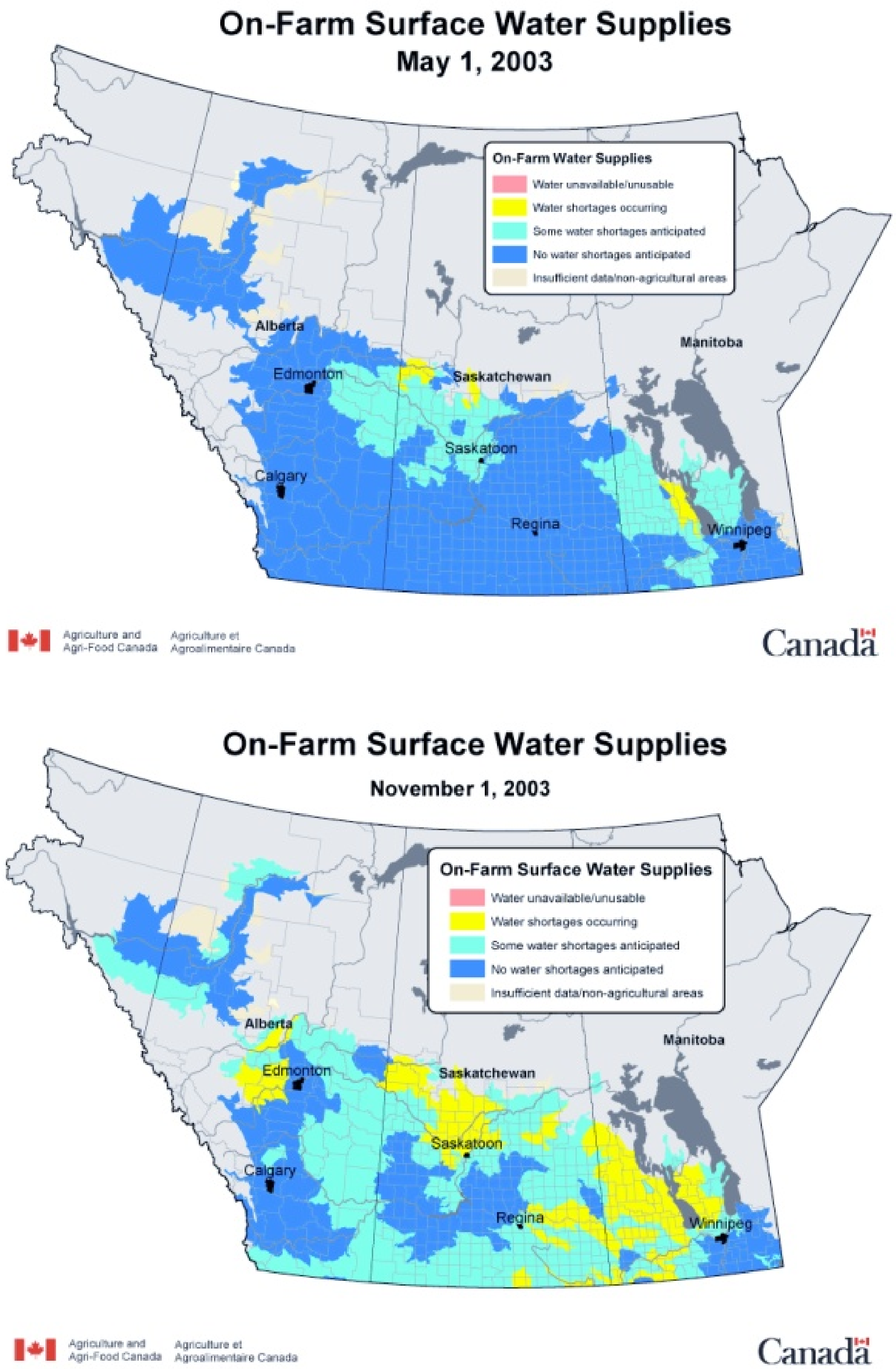


Figure B5.20 On-Farm Surface Water Supplies across Canadian Prairies May and November 2003 (PFRA - Agriculture and Agri-Food Canada 2006)

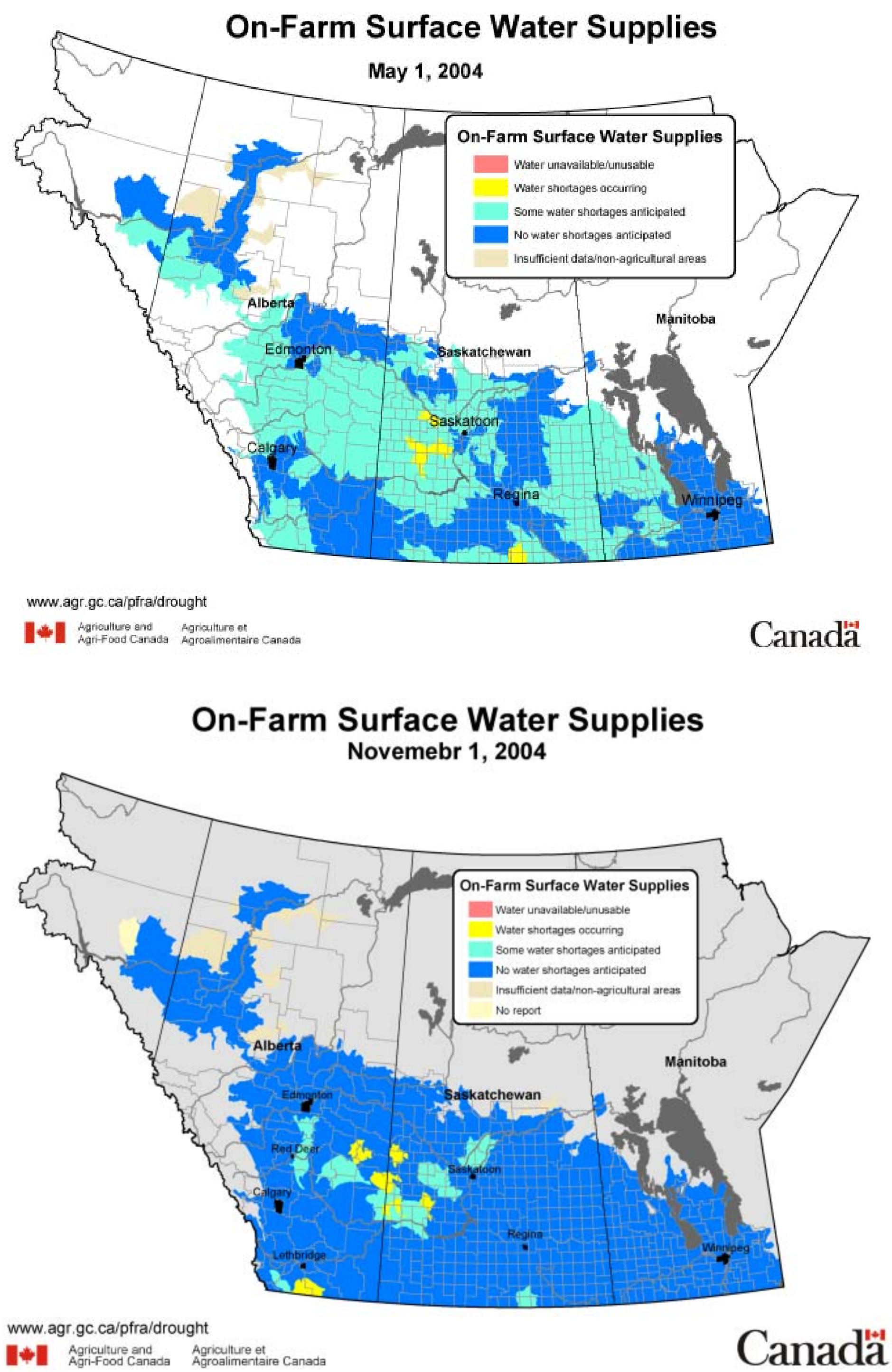


Figure B5.21 On-Farm Surface Water Supplies across Canadian Prairies May and November 2004
(PFRA - Agriculture and Agri-Food Canada 2006)

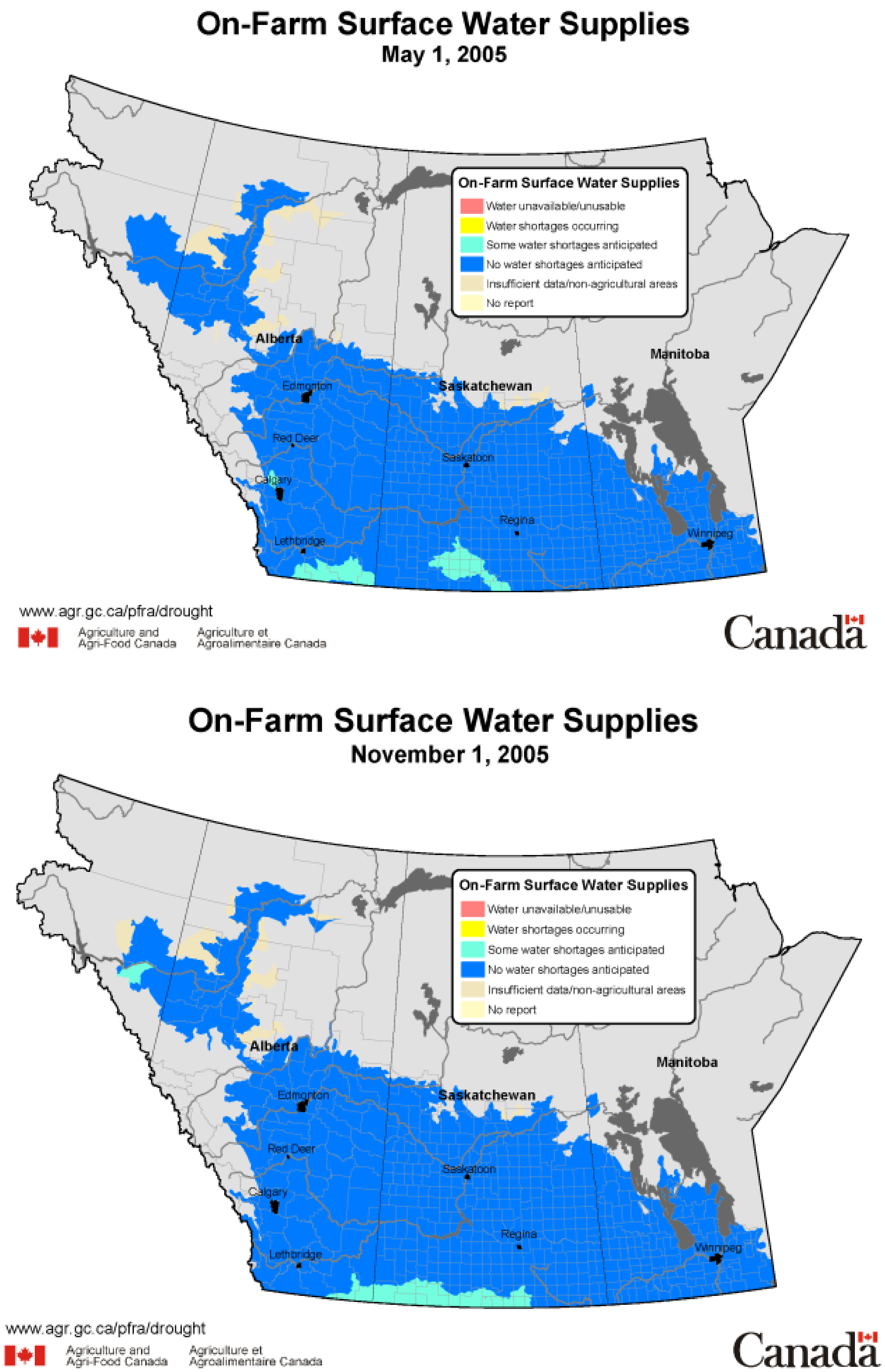


Figure B5.22 On-Farm Surface Water Supplies across Canadian Prairies for May and November 2005 (PFRA - Agriculture and Agri-Food Canada 2006)

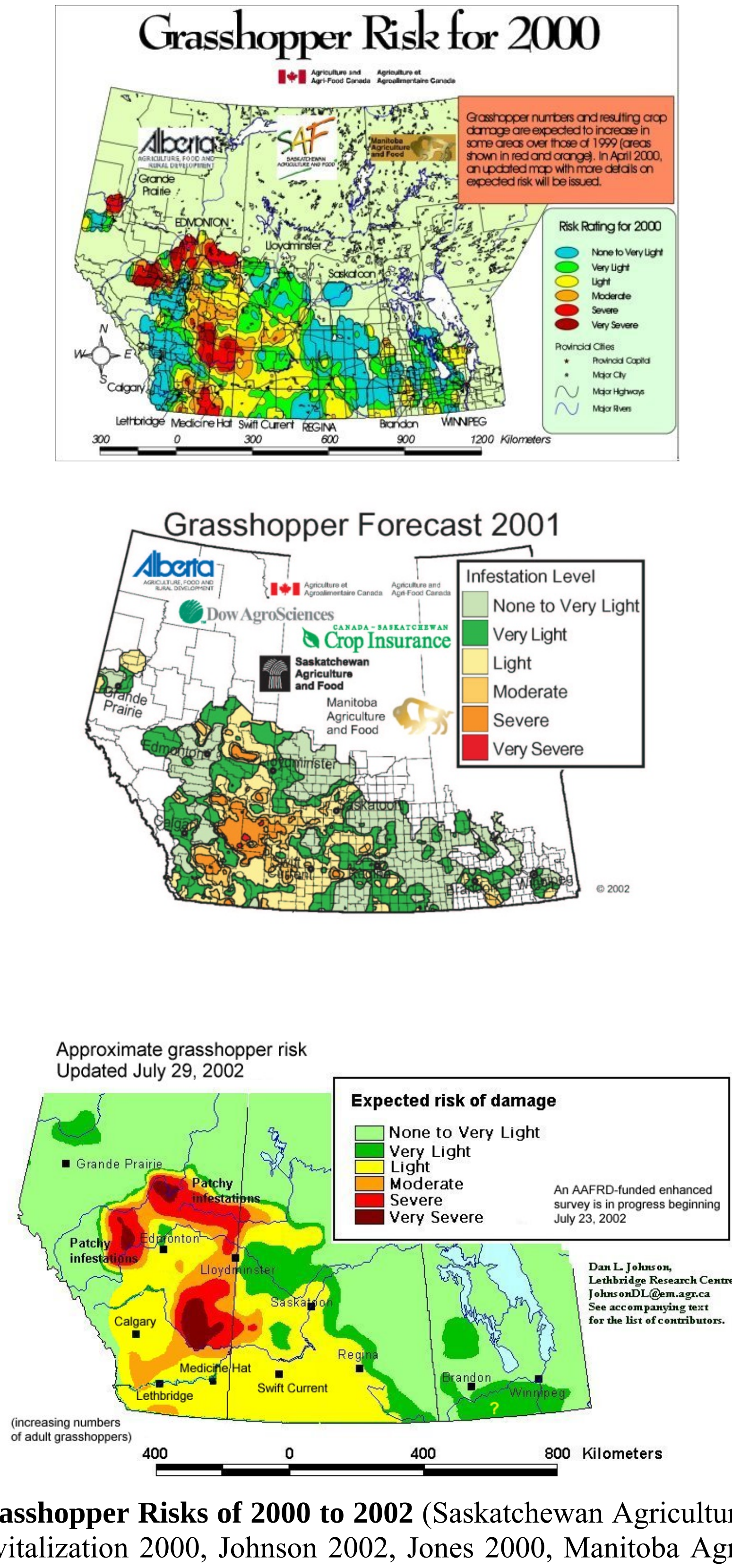


Figure B5.23 Grasshopper Risks of 2000 to 2002 (Saskatchewan Agriculture, Food and Rural Revitalization 2000, Johnson 2002, Jones 2000, Manitoba Agriculture and Food 2002, Saskatchewan Agriculture Food and Rural Revitalization 2002 and Olfert et al. 2003)

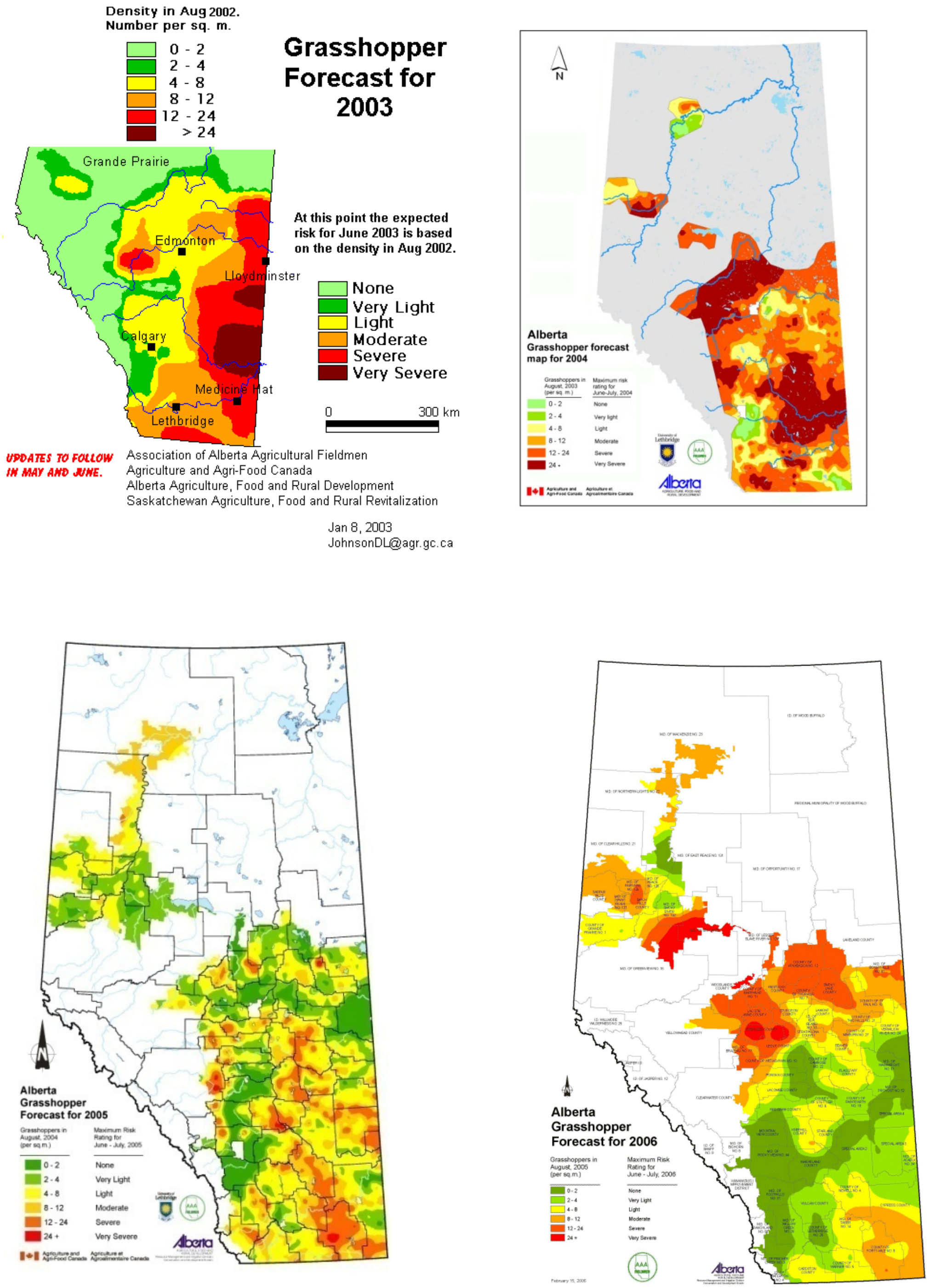


Figure B5.24 Grasshopper Risk for 2003. (Johnson and Calpas 2003, Agriculture and Agri-Food Canada et al. 2004, Agriculture and Agri-Food Canada et al. 2005, Alberta Agriculture and Rural Development and Association of Alberta Agricultural Fieldmen 2006)

APPENDIX C

Biophysical Tables

Table C2.1 Selected Climate Stations for the Study Area (Environment Canada 2008a)

Station Name	Station Number	Location (Latitude/Longitude)	Period of Record
Blood Tribe AGDM	3030720	49º 34'N 113º 3'W	2004-2007
Lethbridge A	3033880	49º 37.8'N 112º 48'W	1953-2007
Cardston	3031320	49º 7.8'N 113º 14.4'W	1918-2007

Table C2.2 Selected Hydrometric Gauging Stations for the Study Area (Environment Canada 2008b)

Station Name	Station Number	Location (Latitude/Longitude)	Period of Record	Effective Drainage Area (km^2)	Mean Annual Discharge (m^3/sec)
Waterton River near Waterton Park	05AD003	49º 6' 50"N 113º 50' 20"W	1908-2006	613	17.1
Waterton River near Glenwood	05AD028	49º 26' 35"N 113º 28' 10"W	1966-2006	1540	13.9
Belly River near Glenwood	05AD041	49º 21' 8"N 113º 28' 49"W	1985-2006	538	5.4
St Mary River near Lethbridge	05AE006	49º 34' 24"N 112º 50' 38"W	1911-2006	3310	11.8
Oldman River near Lethbridge	05AD007	49º 42' 30"N 112º 52' 30"W	1911-2006	15500	67.6
Waterton-Belly Diversion Canal	05AD027	49º 19' 20"N 113º 38' 10"W	1968-2006		8.7
Belly-St. Mary Diversion Canal	05AD021	49º 19' 20"N 113º 38' 10"W	1959-2007		12.4
Waterton Reservoir	05AD026	49º 19' 18"N 113º 40' 52"W	1965-2006	1200	
St. Mary Reservoir near Spring Coulee	05AE025	49º 19' 18"N 113º 40' 52"W	1951-2006	2170	

Table C2.3 Groundwater Observation Wells in the Blood Indian Reserve Region (Alberta Environment 2008).

Well Name	**Location (Latitude/Longitude)**	**Depth Class**	**Aquifer Name**	**Aquifer Type***	**Aquifer Composition**	**Affected by Human Activity**
Lethbridge Airport	49º 38' 4"N 112º 47' 13"W	Shallow (21.03 m)	Intertill	Confined	Sand	Yes
McNally	49º 38' 30"N 112º 43' 49"W	Intermediate (76.2 m)	Lethbridge Valley	Confined	Sand, Gravel	Yes
Orton 1514E	49º 43' 47"N 113º 18' 1"W	Intermediate (50.3 m)	Lethbridge Valley	Confined	Sand, Gravel	Yes
Mud Lake 1537E/1538E	49º 45' 32"N 113º 29' 53"W	Intermediate (33.8 m)	Mud Valley	Confined	Gravel	No

* A confined aquifer is bounded above and below by a low permeable confining layer, which tends to keep the water contained in the aquifer. Water levels and movement in confined aquifers tend to have constant pressure heads unless they are affected by human activity (Alberta Environment 2008).

Table C3.1 Average Temperature and Precipitation for Cardston and Lethbridge (Environment Canada 2008a).

Station	**Climate Parameter**	**Winter (DJF)***	**Spring (MAM)***	**Summer (JJA)***	**Fall (SON)***	**Yearly**
Cardston						
	Daily Average (ºC)	-5.1	4.9	15.8	5.8	5.4
	Daily Maximum (ºC)	1.0	11.4	23.2	12.5	12.0
	Daily Minimum (ºC)	-11.3	-1.5	8.3	-0.9	-1.3
	Rainfall (mm)	0.5	85.5	189.3	61.7	337.0
	Snowfall (cm)	86.7	78.4	0.0	54.6	219.8
	Total Precipitation (mm)	87.2	164.1	189.3	116.4	557.0
Lethbridge						
	Daily Average (ºC)	-6.2	5.7	17.1	6.0	5.7
	Daily Maximum (ºC)	-0.2	12.4	24.4	12.8	12.3
	Daily Minimum (ºC)	-12.2	-1.1	9.7	-0.7	-1.1
	Rainfall (mm)	1.0	66.9	155.6	47.6	271.1
	Snowfall (cm)	54.2	45.8	0.8	29.8	130.5
	Total Precipitation (mm)	45.9	108.8	156.3	75.4	386.3

*DJF = December, January February; MAM = March, April, May; JJA = June July August; SON = September, October, December.