Vulnerability of Prairie Communities During the 2001 and 2002 Droughts:

Case Studies of Taber and Hanna, Alberta and Outlook, Saskatchewan

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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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LIMITED REPORT

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Cover Photo Captions:

Left: Oil well on rangeland in Special Area #2. (Photo: Wandel and Young 2006)

Center: Irrigation system in Southern Alberta. (Photo: Stratton)

Right: South Saskatchewan River at Outlook. (Photo: Wittrock 2006)

EXECUTIVE SUMMARY

The major objective of this study was to investigate the impacts of the 2001 and 2002 droughts on the communities of Taber, Hanna and Outlook with emphasis on water resources. These impacts were studied with a focus on the communities as well as on the larger regions – Municipal District of Taber, Special Area #2 and the Rural Municipality of Rudy, respectively. Drought impacts were assessed in terms of bio-physical and socio-economic changes during these years.

The vulnerability of the three communities to drought differed among the communities. Typically low water levels impacts the initial water users first such as the agricultural community, municipal water supplies and other non-farm activities. These then have community level economic impacts and community level socio-economic impacts. How well a community adapts to low water levels influences the level of impacts.

Included among various bio-physical impacts of the drought were decreased stream flows, minimal recharge to groundwater and dry dugouts. In Special Area #2 (surrounding Hanna), the high numbers of grasshoppers were a severe secondary impact of the drought.

Lack of water impacted the community of Taber to the greatest extent during the drought. This resulted in water restrictions being imposed on both the residents of Taber and the surrounding irrigation districts. The towns of Hanna and Outlook were less affected due to their adequate water supplies.

The major conclusions of the study include:

- Taber and the Municipal District of Taber were negatively impacted due to low water levels in 2001. Water supply rebounded in 2002 because of increased rainfall in June. Water restrictions were the adaptation measure utilized for both the MD of Taber and the town of Taber. The irrigation community initiated several innovative adaptation strategies including transferring water from one irrigator to another, planting less water needy crops, and/or allowing processors access to more water than their water rights would allow, for example.

- Special Area #2 was severely affected by grasshoppers and low water levels which left their dugouts dry and shortage of forage. This resulted in secondary impacts on the livestock population and many adaptation measures were used including filling dugouts by installing temporary pipelines, moving cattle to other less drought stressed locations, and/or importing forage from outside the drought zone for example. The town of Hanna had an adequate supply of potable water because it obtains its water via a pipeline from the Red Deer River.

- Agricultural crop output was severely reduced in the Special Area #2, yielding large losses for producers than in the other two regions.

- Outlook had an adequate supply of potable water as did many in the agriculture community around Outlook due its access to the South Saskatchewan River and the network of water pipelines.

- Socio-economic impacts were a result of reduced crop production in the region. Lack of irrigation was a major factor affecting the magnitude of these impacts. Relative magnitude of irrigation was lowest in the Special Area #2 (surrounding Hanna), followed by Outlook and Taber. As a result, loss in value of crop production in the three communities was different. In the Hanna region, losses of $88 to $171 per ha were estimated, while those for the Taber region were from $35 to $38 per ha, and those for the Outlook region from $63 to $77 per ha. Thus, irrigation did help these regions to cope with the drought conditions.

Many agricultural producers thought that irrigation was a good adaptation measure. However, some problems arose with its usage including lack of water in the Municipal District of Taber causing several problems and resulting in inventive solutions to those problems. These solutions included sharing and trading water rights, changing cropping practices and using greater water conservation measures. Special Area #2 had difficulty with water availability in those areas that depended on dugout water for irrigation and other purposes. As a future adaptation strategy to drought, producers in Special Area #2 would like to expand their use of irrigation, but they need provincial approval to build a second pipeline from the Red Deer River to the community. The Rural Municipality of Rudy did not appear to have many difficulties with their irrigation during the drought years, although wind speeds were cited as a factor in being able to apply the correct amount of moisture. Outlook has limited irrigation because of the cost of irrigation equipment. Furthermore, in some instances, the higher age of the producers results in some reluctance to buy the equipment because they will be retiring in 5 to 10 years. In addition, infrastructure accessibility is seen as a difficulty.

In all three communities, producers would like more information to help them adapt to drought situations. For example, if producers had early warnings that a drought was very possible for the coming crop year, changes in the crop mix because of rotational requirements may be possible. The cost of production during a drought year does not change significantly unless drought conditions are predicted well in advance of seeding the crops. Even then, some producers hope for normal weather conditions later on and do not make appropriate adjustments.

The three communities already had many adaptation strategies in place for droughts. However, these strategies were at their limits with the multi-year drought. If droughts become more frequent, severe and extended as projected by the global climate models, current adaptation strategies may not be adequate.

Recommendations for further research include:

- Assessment of drought impacts on livestock production could not be done in this study due to lack of data. These impacts could be significant and therefore, need to be estimated.

- Effect of the drought on irrigation farmers is also a knowledge gap. How do these producers cope with drought conditions particularly when water availability is rationed requires further study.

- Impact of the drought on local businesses was not estimated in this study. These and related issues could be addressed by future studies.

- Economic efficacy assessment of various adaptation measures was not attempted in this study because of data limitations.

- Examination of the effectiveness of current adaptive strategies to cope with more extensive and extended drought situations.

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ABBREVIATIONS

$ - dollar
% - percentage
< - less than
> - greater than
°C – Degrees Celsius
AAFC – Agriculture and Agri-Food Canada
BSE – Bovine spongiform encephalopathy
bu/ac – bushels per acre
CCFDC – Chinook Community Futures Development Corporation
CD – Census Division
GDP – gross domestic product
ha – hectare
km – kilometres
km^2 – square kilometres
lbs/ac – pounds per acre
LDDA – Lake Diefenbaker Development Area
m^3 – cubic metres
m^3/s – cubic metres per second
MD – municipal district
N.A. – not available
No. – number
p. comm. - Personal Communication
PDSI – Palmer Drought Severity Index
PET – potential evapo-transpiration
PFRA – Prairie Farm Rehabilitation Administration
RM – rural municipality
SPI – Standardized Precipitation Index
US – United States of America

1. INTRODUCTION

1.1 Need for the Study

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 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 environment" (Diaz et al. 2003). In order to facilitate meeting this objective, knowledge of such impacts on people and their institutions is crucial. Past experience with the coping mechanisms and adaptation measures adopted to these changing climate regimes may also be helpful in designing future climate change programs and policies. A study looking at providing information on the current physical and social vulnerabilities related to water resource scarcity and to assess the technical and social adaptive capacity of various institutions in the study region was considered to be complimentary to other project activities.

The IACC project identified three communities[1] – Taber and Hanna, Alberta and Outlook, Saskatchewan – for an in-depth investigation (Figure 1.1). All three communities are located in the Palliser Triangle with Hanna in the "Dry Belt" and Taber and Outlook located in a slightly less arid region. Droughts are frequent events in all three locations. Under a changing climate, it is projected that the frequency of drought and other extreme events is expected to increase. Such occurrences may bring a high cost to society through impacts on those directly affected by them, but also through other linkages that exist within the economy.

1.2 Relationship between Water Supply and Droughts

Droughts are a natural hazard that can have severe negative effects on the environment, society, and economic activities. Droughts are 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). There are four main types of drought including meteorological, agricultural, hydrological and socio-economic. A meteorological drought applies to a long-term lack of precipitation usually accompanied by high temperatures and resultant increase in evapo-transpiration. A meteorological drought often leads to the others including agricultural (periods when soil moisture is insufficient to support crops), hydrological (extended periods of unusually low surface run-off and shallow groundwater levels) and socio-economic (the shortage of water results in an adverse effect on society and the economy) (Maybank et al. 1995).

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[1] In addition to these three communities, the project has identified three other communities for further study. These are: Cabri and Stewart Valley in Saskatchewan, and the Blood Tribe Reserve in Alberta. The first two communities were studied in 2005. A report of this investigation can be found in Wittrock et al. (2006). The third community is currently being studied.

Figure 1.1 Study Area Map (Google Earth 2007)

Droughts are recurring events in the Prairies where over 40 severe droughts have occurred in the past 200 years (Bonsal et al. 2004). Adequate water supplies are crucial to agriculture, communities and industries. The droughts of 2001 and 2002 caused severe strain on the water supplies in western Canada (Wittrock 2005). Although the extent and severity of low water levels varied from community to community and affected the economic and social activities differently, the general consensus remains that these droughts had a devastating effect on the prairie economy.

Water is essential to life as well as to most economic and social activities in a community. If a community is defined to include the hinterland, the impacts are even more devastating, in part because of linkages that exists between them. Shortages of water can take place in a variety of forms. Lack or shortage of rain will first be realized by agricultural producers, which may trigger their reaction in terms of cultural practices or choice of crops. Surface and groundwater may also be affected under a drought situation. These may directly affect community residents in terms of water available for regular activities as well as for some industrial activities. To cope with these shortages, community residents and their institutions may undertake necessary adjustments in their water use.

Under climate change, among other changes, frequency of extreme events is predicted to increase in the future (IPCC, 2001). These generally include drought and flood events caused by changing weather conditions. To understand climate change from the standpoint of a community, obtaining knowledge of how a community is vulnerable to an event such as a drought, and choice of adaptation measures, if any, that could be made, is imperative.

1.3 Realization of Droughts by Community Members

Realization of drought varies from community to community. This realization depends on the onset of drought and the impacts (if any) that develop. Typically these drought events are first realized by agricultural producers. Depending upon the lead time in terms of drought occurrence, producers may implement adaptation measures. Lower stream flows may also be an early warning of droughts. However, here the complicating factor is flow of water from upstream regions. For example, in the case of prairie communities, much of the stream flows originates either through snow melt in the eastern slope of the Rockies Mountains, or from local precipitation (both snow and rain). Change in the groundwater availability is perhaps the last type of water body that is affected under a drought condition. This is not to say that a prolong drought conditions would not deplete this type of water availability. However, the amount of time it takes for aquifers to react to climate changes is generally longer than that for the surface water bodies[2].

Members of the study communities reported that the 2001 and 2002 droughts were of some significance to them. This is because of the devastating effect they had on them and the region as a whole.

1.4 Potential Impacts of Droughts and Possible Adaptation Measures

Droughts result in a variety of impacts on a community. Availability of water manifests itself in many forms. For the community residents, this may translate into amount available for performing various social activities. For agricultural producers impacts are felt on crop and livestock enterprises. Wheaton et al. (2005) have reported that the 2001 and 2002 droughts inflicted a loss of $2 billion in the Prairie Provinces through losses in various agricultural activities. This cost is somewhat underestimated since total impacts on producers through changes in the livestock enterprise were not included. In addition, droughts can also bring devastating effect on other sectors of an economy. For example, forestry sector may be effected through a higher incidence of forest fires. Industries using a larger quantity of water may have to make adjustments either in terms of procuring water from other sources or reduce production levels.

Potential impact of droughts will vary from community to community depending upon its economic activities and dependence on water. In addition, type of droughts would also have a different impact on the community and surrounding region. For example, a one-year drought may not pose as large of hardship on people as a two-year (back-to-back) drought can. Coping mechanisms for these droughts would also be different.

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[2] Although impact of droughts on groundwater recharge has not been studies for the study region, according to Arnell and Liu (2001), an unconfined aquifer is recharged by local rainfall, rivers and lakes. As climate change affects these surface water bodies, recharge of these aquifers will be affected. The same situation is observed for the shallow aquifer that is found in semi-arid and arid environment.

1.5 Objective and Scope of the Study

The primary objective of this study is to investigate the impacts of the 2001 and 2002 droughts on the rural communities of Taber, Hanna and Outlook with emphasis on water resources. An associated objective of the study is to identify the nature of adaptation measures undertaken, and their efficacy, by individuals and institutions in response to or to cope with these droughts.

1.6 Organization of the Report

In addition to this section, the Introduction, the report has 6 other sections.

- Study Methodology (section 2)
- Description of the Study Region Communities (section 3)
- Climatological Description of Droughts (section 4)
- Drought Impacts on the Selected Communities (section 5)
- Adaptation Measures and Their Effectiveness (section 6)
- Summary and Conclusions (section 7).

Section 2 includes a description of the conceptual relationship between water supply and community vulnerability as well as the method of data and information collection at the community level. Also included is the list of sources of the bio-physical and socio-economic data. Section 3 describes the location, physical and socio-economic characteristics of the communities. Section 4 provides the climatological description of the 2001 and 2002 droughts. Section 5 describes the impacts each of the communities encountered because of the 2001 and 2002 droughts. This section examined both the bio-physical and socio-economic impacts. Section 6 examines the adaptation measures various sectors of the community utilized and their effectiveness. The last section of the report summarizes major findings of the study and conclusions.

2. STUDY METHODOLOGY

Water is essential for human existence as well as for most economic and social activities. When an external factor affects water availability to a community and its residents, they become vulnerable, unless they can adapt to the changed conditions. Under drought situation, water availability is threatened which may then affect the community in several ways.

A community in this context is defined in a wider context. According to Shaffer (1989) most definitions of communities contain some reference to area, commonality, and social interaction. In this study, a community is defined a group of people in a physical setting with geographic, political, economic and social boundaries and related communication linkages. These communication links ensure that people or groups interact in the defined area. Impact of droughts, in general, is more widespread and therefore requires a wider scope of the community region / community groups.

In this chapter, conceptual linkages among droughts, water availability and the manner in which these could affect a community are discussed. In addition, sources of data for the analysis of drought impacts on the three communities selected in this study are also listed, including those for physical and climatological as well as socio-economic impacts.

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

1) Conceptual and descriptive tools, which included a review of previous drought studies (e.g., Wheaton et al. 2005) as well as other 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 attempted by members of the three communities. These data were collected by a combination of focus group meetings, summarized by Hadarits (2007a, b, c), and interviews conducted by Pittman and Jeanes (2006), Prado (2006), and Wandel and Young (2006).
3) Primary and secondary data-based research, which included an assessment of historical pattern of the droughts in the regions, features of 2001 and 2002 drought, and the associated bio-physical and economic impacts.

2.1 Conceptual Relationship between Water Supply and Community Vulnerability

2.1.1 Concept of Vulnerability

Vulnerability is a complex term. A multitude of definitions exist in the literature[3]. In the context of climate change, vulnerability is the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes (McCarthy et al. 2001). The elements referred to above could be physical elements or human

[3] An excellent compendium of such definitions can be found at www.VulnerabilityNet.Org/home.

elements. The natural phenomenon of interest in this study is drought, which can affect both the bio-physical / ecological system as well as the human system directly. However, human systems are also affected, perhaps more indirectly, through the impacts on the bio-physical systems. Thus, the human systems are affected both directly as well as indirectly during periods of droughts.

2.1.2 Factors Affecting Community Vulnerability

Community vulnerability from droughts results from a combination of bio-physical and human system impacts, both directly and indirectly. In addition, several other factors also affect a community's degree of vulnerability to a natural phenomenon. The most important determinants of this are: (1) Degree of exposure to the natural phenomenon; and (2) Community's capacity to adapt to the exposure. The latter is a combination of at least two types of factors: One, those related to institutions governing the community affairs, and Two, factors related to characteristics of the community itself. According to Diaz and Rojas (2006), institutions can be broadly defined as the rules, social norms and organizations that facilitate the co-ordination of human actions. Marchildon et al. (2007) have suggested that institutions have been critical to local, regional, national and international efforts in reshaping agriculture in drought-prone environments. Institutions also influence resource availability through property rights, taxation policies, general and vocational education and distribution of information. All these actions in turn affect community growth and development (Shaffer 1989). Similarly many characteristics of the community could determine the adaptive capacity, including the size of the community, economic status of the people, demographics, population dependency patterns, among others. Future vulnerability of a community to any change caused by natural phenomenon is also related to past experience related to manner in which it was dealt with[4].

2.1.3 Relationship between Vulnerability and Water Supply

The natural phenomenon of interest in this study is droughts. These were selected, as stated earlier, in light of increasing frequency of such phenomenon in the future as a result of climate change. A community can be exposed to various types of droughts, but the one of interest to this study is an agricultural drought coupled with a hydrological drought. Under this type of drought(s), water supply (availability) is affected in one of three forms. Lower rainfall during the agricultural crop growing season results in lower soil moisture inadequate to meet the crop requirements. Lack of rainfall and other related factors may also result in lower stream flows which may also have some implications for the community. Persistent and frequent drought situations could also affect groundwater resources, and thus reduce water availability from alternative sources for a given community. All these three changes in water supply, as shown in Figure 2.1, have impacts on the community, and may lead to its vulnerability.

Let us start with the impact of the drought in terms of lower soil moisture. This will undoubtedly lead to lower crop yields, directly through lack of germination and / or wilting of plants under heat stress, for example. A typical crop mix on the prairies includes forage crops. Reduction in

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4 Figure 3 in Marchildon et al. (2007) illustrates this point.

the availability of forage has other repercussions on farms. Generally speaking, shortage of forage for winter feeding, coupled with poor pasture carrying capacity over the summer, would result in higher costs to the producers for maintaining livestock (e.g., beef herds, sheep and lamb enterprises, and some dairy enterprises). These costs may include higher cost of importing feed from other parts of the region or even from outside the region. Lack of water in the dugouts (or other sources for stockwatering) may also necessitate hauling of water from other sources. The combination of lower revenue from crop production and higher costs of livestock operations would result in lower farm income.

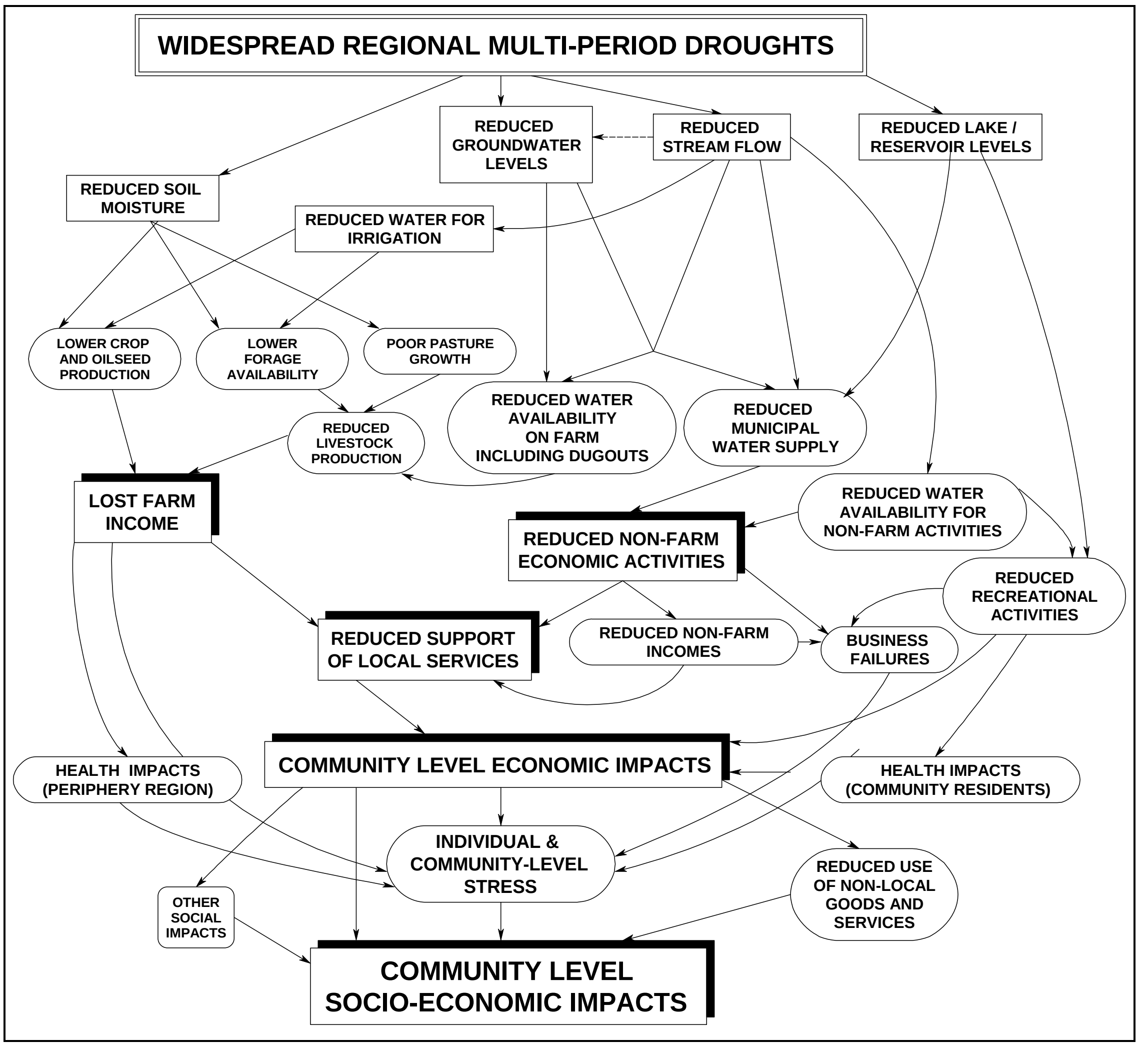

Figure 2.1 Overview of Pathways for Community's Vulnerability to Water Supply under Drought Conditions

Change in precipitation and higher evaporation (under higher temperatures, typical of drought periods) resulting in reduced stream flow would have impacts on local residents and business. Reduced amount of water available to community businesses (including agricultural producers) may result in several related impacts: One, if agricultural producers have converted a part of their farm operations from dryland to irrigation to supplement reduced soil moisture, there may be several impacts. One, if availability of water is not adequate to meet normal level irrigation activities, some areas may not be irrigated. It may also result in a need for water rationing or temporary transfer of water rights to other users[5], which may result in reduced irrigation and reduced crop production. However, if such shortages do not occur, irrigation may provide a boost to the crop yield and may result in higher farm incomes.

Reduced water supply for the community would affect residents and local businesses. In some cases, normal level of economic activity may not be possible. However, such an outcome is very improbable in the short-run. A more likely outcome is that the water authority (either in the region or from the community) may have to make arrangements to procure water from other sources. These actions may increase the cost of operations of the water utility and thus cost to the water users. Alternatively a situation of water rationing may prevail. In addition, droughts may also bring forth other impacts on the people. For example, health of individuals may be affected directly by a prolonged drought in a region. Drought can bring a sense of helplessness, irrepressible worry and apprehension to feelings of powerlessness, anger, deep sadness and grief. These feelings can lead to or aggravate health problems (Imhoff p. comm. 2003). Economic hardships caused by the droughts may also cause some stress-related ailments among the community and peripheral region residents. Lack of water may result in cancellation of many water-related recreational activities. All these changes affect the community level socio-economic impacts of the droughts.

Reduced farm incomes and reduced economic activity for the non-farm businesses will have major spin-off impacts on the community. It is conceivable that some workers may be laid off (albeit temporarily) which may bring further stress on the community residents. Lower incomes could reduce social and related activities in the community, leading to further socio-economic impacts.

2.2 Method of Data and Information Collection at the Community Level

Interviews and focus groups were carried out in each of the communities to gain insights of the community, institutions and stakeholders. The interviews and focus groups were semi-structured to allow respondents to discuss the difficulties they and their communities faced and their ability to cope with various situations.

The stakeholder interviews 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.
- Guided interview to provide a systematic basis for assessing exposure-sensitivity and adaptive capacity.

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5 In southern Alberta, according to Nicol and Klein (2006), during the 2001 drought period in Southern Alberta, water was transferred from producers to other users and from low value crops to high value crops.

A variety of stakeholders were invited to the focus groups including representatives from federal, provincial, regional and municipal governments and industry, as well as irrigators, farmers, mixed farmers and ranchers. The focus group sessions involved various presentations including presentations by Dr. Dave Sauchyn that provided insights into future climate and its effects on the water resources in the regions (Hadarits 2007b).

The focus group in Hanna for Special Area 2 (Hadarits DRAFT 2007a), Alberta was held in February 2007. The following questions were addressed:

- The morning session examined the implications of the climate change impacts and adaptation presentation for day to day and longer-term management and planning in individual operations and organizations.
    - What are the implications of the climate change scenarios for your operation?
        - With lower baseflow in the Red Deer River, do you anticipate problems?
        - Higher evapotranspiration/less moisture during growing season?
        - Warmer winters? Winters with little to no snow?
    - At what point would the climate scenarios become a problem? How? What actions would likely be undertaken as things get warmer and dryer?
    - What needs to change to put your operation in a better position of meeting these challenges? What is needed from Special Areas? From the Province? From the Federal Government/PFRA? From other organizations?
    - Considering past water shortages and poor growing seasons, what did you do and what would you do differently. Would what you did in the past work given the climate change scenarios?
- The afternoon session was focused on institutions and drought management
    - What happened during the last drought? What did you do to handle it and what is different now?
    - What other factors affected you during those years?
    - What institutions did you contact for help? Why? How was it effective? How could it have been better?
    - What additional support (in the context of drought and daily operation) is needed from institutions now and in the future?
    - Given the climate change scenarios presentation, what do you look for from institutions in the future?

The focus group held in Outlook in January 2007 was split into two sessions (Hadarits 2007b). The first session included the following questions:

- What are the issues your business/group sees with water availability? How is water used (day-to-day and seasonally)?
- What are the implications of the climate change and hydrologic scenarios for your business/group?
    - Lower baseflow in rivers?
    - Higher evaporation/less moisture during growing season?
    - Warmer winters?
- Would the climate change and hydrologic scenarios become a problem? How? What actions would your business/group likely undertake? Are the climate change scenarios within the coping range using existing actions?

- What needs to change to put you in a better position of meeting these challenges?
- What are the main types of water-related problems that have affected you in the past? What did you do to resolve these? In hindsight, what would you do differently?

The afternoon session at Outlook dealt with these questions:

- What types of future planning (with respect to water) does your institution do?
- With whom (other institution, etc) do you collaborate/draw upon for information?
- What are the constraints to more effective planning?
- In the past (e.g., 2001-2003 drought), how were things managed at the institutional level (i.e., within your institution)? What worked? What could have been done better, and how? Were there long-term changes within your agency as a result of this dry period?

The questions asked at the Lethbridge/Taber focus group, held in December 2006 were very similar but designed for that region (Hadarits 2007c). The questions were:

- "Outline the day-to-day management of water (and climate) involved in your organization.
- What information inputs are used to make decisions? Who makes the decisions?
- What agencies do you need to collaborate with to make these decisions?
- What sort of information would improve decision-making? What are the barriers to acquiring this?
- What sorts of actions are done at the institutional levels which reduce exposure at the regional/community / individual level?
- What (if any) planning for future conditions occurs? What are the constraints to future planning?
- Use the case 2001-2003: how was the drought felt in your institution? What was done about it? What could have been done better? What changes as a result of this stress? If the same three years happened again now, how would they be handled/ what is different now? Were there long-term changes as a result of this dry period?
- What are the implications of the climate change scenarios for your institution? Are they within the coping range using existing processes? What needs to change?"

2.3 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, dugout levels, and municipal water supplies. Insects and pests as well as wind erosion databases were also utilized. Many of the figures and tables are located in the appendices with the designation of A or B.

2.3.1 Climatic Elements

Precipitation and temperature information for Taber, Craigmyle, Scotfield and Outlook was obtained from Environment Canada (2007a) (Table B2.1). Craigmyle and Scotfield were used for the Hanna region because there is no climate station located at Hanna. The normals (i.e. averages) are for the 1971-2000 period. Scotfield does not have normals calculated. The data was imported into Microsoft Excel for analysis.

2.3.2 Stream Flow and Reservoir Levels

Stream flow and reservoir levels data were obtained from Environment Canada (2007b). The averaging period for each stream and reservoir was the period of record (Table B2.2). These locations were chosen to determine if the drought of 2001 and 2002 had an influence on the flows in the study region.

2.3.2.1 Taber

Taber is located approximately 10 km south of the Oldman River and approximately 85 km from the mouth of the Little Bow River and Oldman River. The Bow River runs along the north eastern border of the Municipal District of Taber and joins the Oldman River on the eastern edge of the Municipal District (MD). The Oldman River and the Little Bow River join on the western borders of the MD. The Oldman River dissects the MD in approximately the middle. There are two gauging hydrometric stations utilized including the one located on the Oldman River and the other on the Bow River (Table B2.2).

2.3.2.2 Hanna

Hanna is located close to Bullpound Creek. Unfortunately, it does not have discharge monitoring station. The closest surface water monitoring stations are located on Sounding Creek (east of Hanna), Monitor Creek (northeast of Hanna), Red Deer River at Drumheller (west southwest of Hanna), Kneehills Creek near Drumheller (west southwest of Hanna) and Michichi Creek near Drumheller (west southwest of Hanna) (Table B2.2).

2.3.2.3 Outlook

Lake Diefenbaker is an important reservoir to Saskatchewan and to the Rural Municipality of Rudy. This reservoir is used for hydro-electric generation, water level control, irrigation and recreation. The reservoir is subject to water fluctuations. This reservoir has an effective drainage area of 86,900 km^2 (Environment Canada 2007b), The Red Deer River near Bindloss and the South Saskatchewan River at Medicine Hat are important hydrometric gauging stations for the South Saskatchewan River. A third gauging station is located at Saskatoon (Table B2.2).

2.3.3 Groundwater

Groundwater levels data were obtained from the Saskatchewan Watershed Authority (2007) and Alberta Environment (2007) (Tables B3.1 to B3.3). The observation well sites were selected because of their proximity to the study areas. The observation wells selected for the analysis are generally surficial aquifers, thus responding fairly well to weather.

Groundwater levels in shallow, surfical aquifers overlain by permeable material fluctuate according to the seasonal and annual amounts of recharge. As a result, these aquifers are sensitive to drought situations (Sketchell et al. 2000) whereas deeper wells are more resilient to drought conditions and if they are affected by drought will likely have a lag effect. The reason for groundwater recharge is not easy to determine because recharge depends on several variable including soil type, geology and hydrogeology, precipitation (amount, type and snow melt rate), prior soil moisture conditions, runoff, topography and evapotranspiration (Sketchell et al. 2000).

<u>2.3.3.1 Taber</u>

Four groundwater observation wells are in the region around Taber (Figure 3.4 and Table B3.1). However, only the Pakowki 85-1 well has not been affected by human activity. It is classified as an intermediate depth and was established in 1985. The other three wells are considered to be affected by human activity (Alberta Environment 2007).

<u>2.3.3.2 Hanna</u>

Several groundwater monitoring sites located in the Special Area regions of Alberta (Figure 3.5 and Table B3.2). Two groundwater monitoring stations Hand Hills #1 and Hand Hills #2, are located approximately 30 km southwest of Hanna. Hand Hills #1 is located in a deep aquifer called Horseshoe Canyon. It is a confined aquifer and is made up of coal and shale. Hand Hills #2 is considered to be intermediate in depth and measures the Paskapoo aquifer. It is a confined aquifer in sandstone. Neither of these aquifers is considered to be affected by human activity (Alberta Environment 2007).

<u>2.3.3.3 Outlook</u>

There are four observation wells set up in the Conquest region approximately 15 km west of the Rural Municipality of Rudy (Figure 3.6 and Table B3.3). Conquest 500, 501 and 503 are shallow wells (less than 20 m) and Conquest 504 is an intermediate depth well (between 20 and 100 m) (Maathuis et al. 2002).

2.3.4 Dugout Levels

Dugout levels data for both Alberta and Saskatchewan were obtained from the Prairie Farm Rehabilitation Administration – Agriculture and Agri-Food Canada (2006) (Figures A5.25 to A5.28).

2.3.5 Municipal Water Supply

Municipal water supply information was obtained from the Saskatchewan Watershed Authority (Anderson, p. comm. 2007) and the towns of Hanna (Burgemeister, p. comm. 2007) and Taber (Cressman, p. comm. 2007).

2.3.6 Potential Evapo-transpiration

Potential evapo-transpiration (PET) data were obtained from the Prairie Farm Rehabilitation Administration, Agriculture and Agri-Food Canada (2007a). PET was calculated using the Priestley-Taylor equation[6] for the three study regions.

2.3.7 Palmer Drought Severity Index and Standardized Precipitation Index

Palmer Drought Severity Index (PDSI) was published monthly for the Canadian Prairies in map form during the 1999 to 2003 period (Figure A4.7 to A4.17). The maps indicate how the drought conditions evolved in the prairies. The method used for Environment Canada's PDSI is described in Hopkinson (2000).

2.3.8 Standardized Precipitation Index

Standardized Precipitation Index (SPI) was calculated by Bonsal (p. comm. 2006) using Environment Canada's measured data as well as it's gridded data set. SPI is an index based on the probability of precipitation for any time scale. 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.

2.3.9 Grasshopper Population

A grasshopper survey is carried out every year by Alberta Agriculture Food and Rural Development and Saskatchewan Agriculture (August to September) to determine the potential grasshopper density for the upcoming year for both provinces (Figures 5.32 and 5.33). The forecasts for the coming year (e.g, 2002) give an indication of 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, the forecasts do not distinguish between the pest and non-pest species of grasshoppers (Johnson, p. comm. 2006).

2.3.10 Wind Erosion

Environment Canada ended its observation of blowing dust events in 2000 and previous to that date, collected information at select locations. This resulted in other sources of wind erosion information having to be obtained including print media and traffic accident reports. Agriculture and Agri-Food Canada, PFRA staff documented wind erosion events across the prairies in 2001 and 2002 (Black, p. comm. 2003).

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[6] 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.

2.4 Data Sources for the Socio-economic Assessment

Data utilized for analysis presented in this study were obtained from two sources: One, primary data collection through ethnographic study of the community residents and other officials; and Two, secondary sources, including various government publications. Information on the community perception and other details were collected from reports by Pittman and Jeanes (2006), Prado (2006) and by Wandel and Young (2006). In addition special focus groups on droughts were organized in Lethbridge and Outlook, and respective reports were prepared (see Hadarits (2007 b and c) for details). These were used as source of information on perception, impacts, and adoption of adaptation measures in these communities.

For both provinces, much of the socio-economic analysis was based on secondary data sources. Reference to these sources is made in Chapter 3.

3. DESCRIPTION OF THE STUDY REGION COMMUNITIES

3.1 Location of Communities

3.1.1 Taber, Alberta

Taber is a town located in central-southern Alberta, in the municipal district (MD) of Taber, about 108 km (67.5 miles) southwest of Medicine Hat and 98 km (60 miles) north of Coutts/Sweetgrass US Border crossing. It is located in Census Division[7] (CD) 2 which is centered on Lethbridge. The area of this division is 18,038 km^2. Besides Taber, two main cities located in the division are Lethbridge and Brooks (Figure 3.1).

Source: http://en.wikipedia.org/wiki/Image:Taber%2C_Alberta_Location.png, accessed Feb 2007 and google map for Taber

Note: Insert on the lower right-hand part is the Map of Alberta showing the general location of the region enlarged.

Figure 3.1 Map of South-eastern Alberta showing Location of Taber

Taber is located at the crossing of two main highways -- Crowsnest Highway # 3 and Highway # 36. The main railway line -- Medicine Hat - Lethbridge Canadian Pacific Railway line, is another

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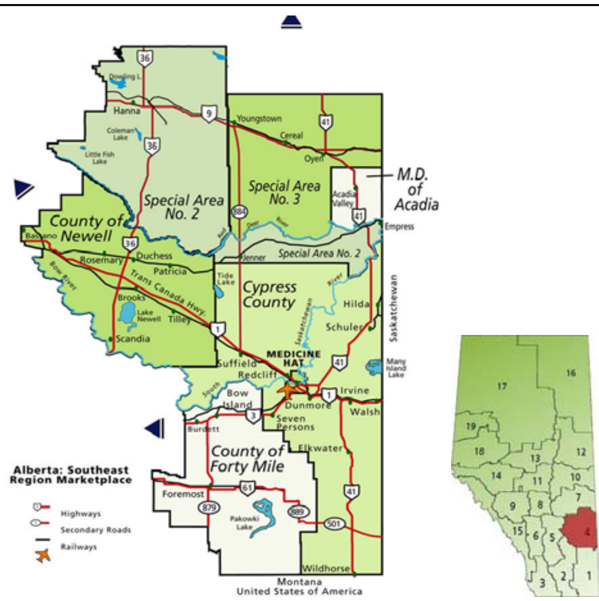
[7] A census division (CD) is a general term applied to areas established by provincial law which are intermediate between counties or rural municipalities (census subdivisions) and the provincial level (Statistics Canada, 1997). In Saskatchewan these areas are created by Statistics Canada since they are not legislated by provincial law.

link between the town and surrounding region. On account of the large amount of sunshine, the region is known for corn production.

In terms of history of the community, Taber was settled by homesteaders in the late 1890s (Town of Taber 2007). Initially it was a coal-mining town, which was mined locally and then shipped to Medicine Hat, first in the Oldman River steamers and, later by narrow gauge railway. However, coal mining declined in the late 1920s, but picked up in the 1930's after extensive irrigation in the area occurred (Town of Taber 2007). Irrigation helped the community and surrounding farmers through the production of sugar beets – a major cash crop in the region. Processing of sugar beets and several other agricultural commodities was attracted to the region on account of being centrally located in the irrigation region.

3.1.2 Hanna, Alberta

Hanna is located in east-central part of the province of Alberta. It is about 221 km north-east of Calgary. It is strategically located at the junction of Highway 36 and Highway 9. It is the centre of a large trading area called 'short grass country' (Town of Hanna, 2007). More details are shown in Figure 3.2. Administratively Hanna is located in the Census division (CD) 4, and in Alberta's Special Area # 2. These Special Areas were created following the economic hardships caused by the droughts in the 1930s with spill-over effects on the local municipal governments in the regions surrounding Hanna over the decade that followed[8]. Hanna is the headquarters for the Special Area # 2 administration.



Source: http://www.albertafirst.com/profiles/
Note : Insert at the lower right-hand is the map of Alberta showing the general location of the area enlarged.

Figure 3.2 Map of Central-east Alberta Showing Location of Town of Hanna and Special Area No. 2

8 More details on the creation of Special Areas in Alberta, see Marchildon et al. (2007).

The town came into existence in 1912 as divisional point on the Great Northern Railway, which was gobbled up by the Canadian National Railways later on. It gets its name from D.B. Hanna who was the president of the railway at that time. Historically, Hanna was the main service town in East Central Alberta for farmers and ranchers seeking banking services, professional services, medical care and a wide range of other shopping needs.

3.1.3 Outlook, Saskatchewan

Similar to the two Alberta communities (Taber and Hanna), Outlook is an agriculture community. It is located in the Rural Municipality of Rudy (RM # 284), and in terms of Statistics Canada's regional framework is in the Census Division # 11 in Saskatchewan. The town of Outlook is seated on the bank of South Saskatchewan River and close to Lake Diefenbaker – a man-made reservoir built for developing irrigation in the province. The town is located in the west central part of Saskatchewan, about 90 km southwest of Saskatoon on Highway 15. It is the headquarters for the Regional Economic Development Authority (Figure 3.3).

Source: Google Maps

Figure 3.3 Map of the Central-west part of Saskatchewan showing the location of Outlook

Settlement in the Outlook area began in 1900s. Auctioning of lots began in August 1908. Accessibility of water and power derived from the South Saskatchewan River and the rich soil and railroad provided all growing necessities for the region. On November 1 1910, Outlook officially became a town. The area was named "Outlook" by Native American Indians because of the beautiful scenic outlook from the bank of the South Saskatchewan River Valley (Town of Outlook 2007, and Wikipedia 2007).

3.2 Physical Characteristics of Communities

All three communities are located within "Palliser's Triangle". This term is used to describe the driest part of the Canadian prairies. This area is characterized by its aridity and has a mixed grassland eco-region with an annual water deficit of 524 mm (Nemanishen 1998; Dale-Burnett 2007). This section examines the average physical characteristics including climatology, and water supply characteristics of the communities.

3.2.1 Climatology of the Region

Of the three locations, Taber has the highest average annual temperature at 5.8°C while Craigmyle has the lowest at 3.1°C. Craigmyle, the closest climate station to Hanna, generally receives more precipitation than the other two sites (Table 3.1). The coldest month is generally January and the warmest one is July for all locations.

Table 3.1 Average Temperature and Precipitation for Taber, Craigmyle and Outlook (Environment Canada 2007a)

Station	Maximum Temperature (°C)	Average Temperature (°C)	Minimum Temperature (°C)	Total Precipitation (mm)
Taber	12.4	5.8	-0.7	368.5
Craigmyle	9.5	3.1	-3.3	407.0
Outlook	9.2	3.4	-2.4	337.8

3.2.1.1 Taber

The Municipal District (MD) of Taber is located in southern Alberta. The town of Taber is located in this District. Taber is approximate 5 km southeast of the Oldman River. Taber is located in Southern Alberta's Chinook belt (Figure 3.4). The result is temperatures, especially in winter, fluctuate to the extreme and can do so in the matter of hours. Extreme high and low temperatures have been recorded at Taber. The highest temperature recorded at Taber was 40.6°C in 1936 and the extreme low was January 23, 1969 at -43.3°C. Also, temperatures greater than 20°C have been recorded in 10 out of 12 months over the period of record while freezing temperatures have occurred 11 out of 12 months. Only July has not had below zero temperatures.

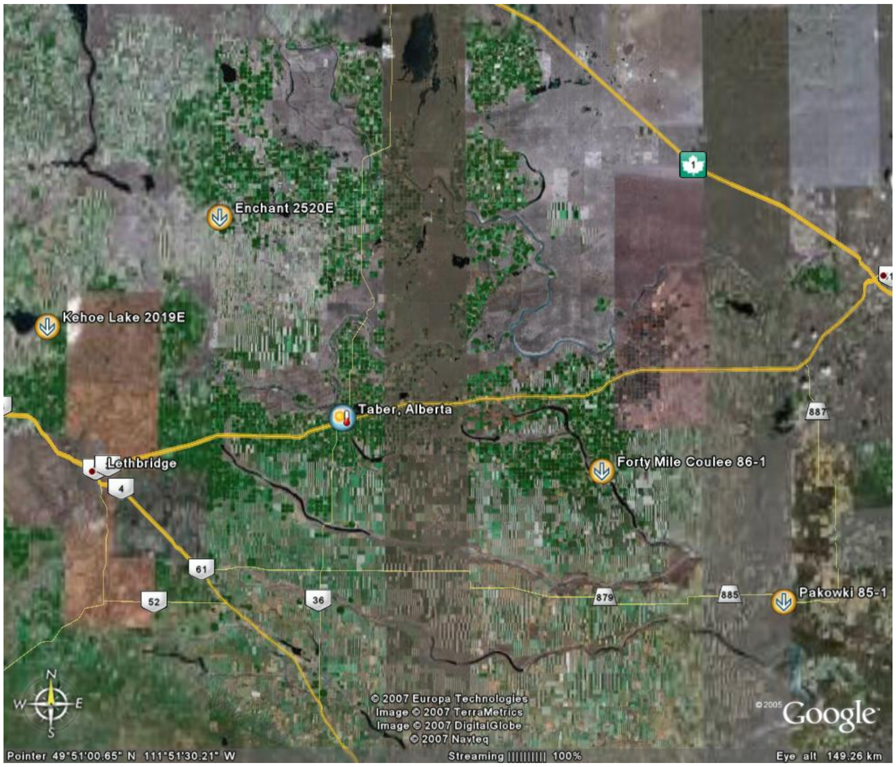


Figure 3.4 Location of Climate Stations (sun and temperature symbols) and Groundwater Observation Wells (down arrows) in the Taber, Alberta region (Map source: Google Earth 2007).

<u>3.2.1.2 Hanna</u>

Special Area # 2 is located in east central agricultural region of Alberta. Hanna is located on the western side of the Special Area # 2. Hanna is located on the edge of the Chinook belt therefore, similar to Taber, there are extremes in seasonal temperature and precipitation. The closest climate station to Hanna is Craigmyle (Figure 3.5). Craigmyle's extreme maximum temperature occurred in June 1975 (37.2°C) and two years later in December 1977 the extreme minimum was recorded (-45°C). Every month for the period of record has had temperatures zero or below as well as temperatures 14°C or above.

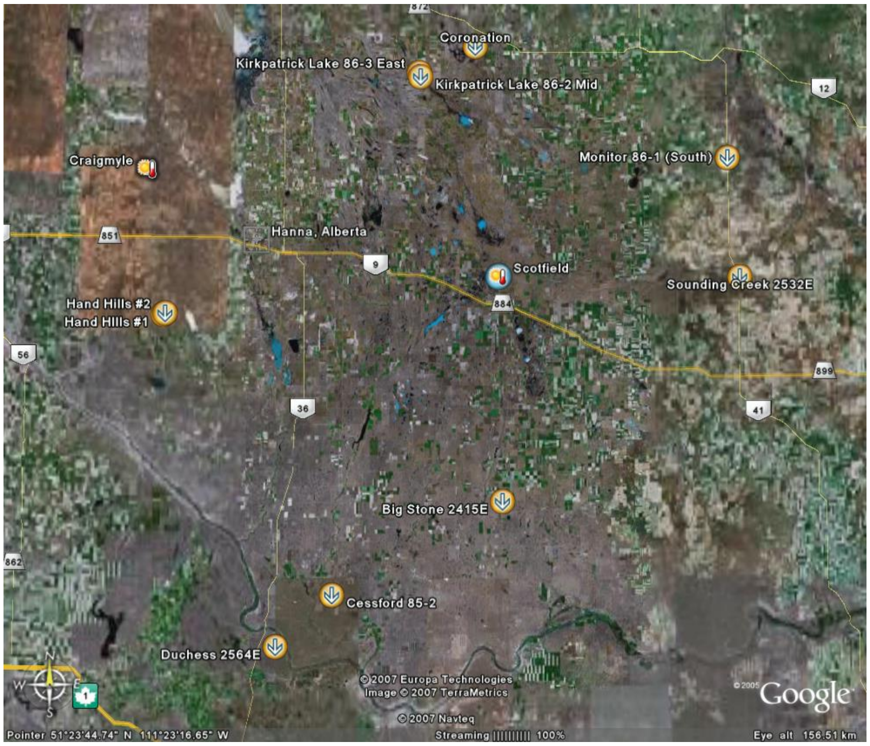


Figure 3.5 Location of Climate Stations (sun and temperature symbols) and Groundwater Observation Wells (down arrows) in the Hanna, Alberta region (Map source: Google Earth 2007).

3.2.1.3 Outlook

Outlook is in the RM of Rudy which is located south of Saskatoon. The town and much of the RM are located on the banks of the South Saskatchewan River (Figure 3.6). As with the other locations in the study area, the RM of Rudy has extreme high and low temperatures as well as extreme precipitation and drought events. For example, the highest temperature recorded at Outlook was 40°C in June 1987 and -42°C in February 1994. For the period of record, temperatures have not gone below zero in either July or August.

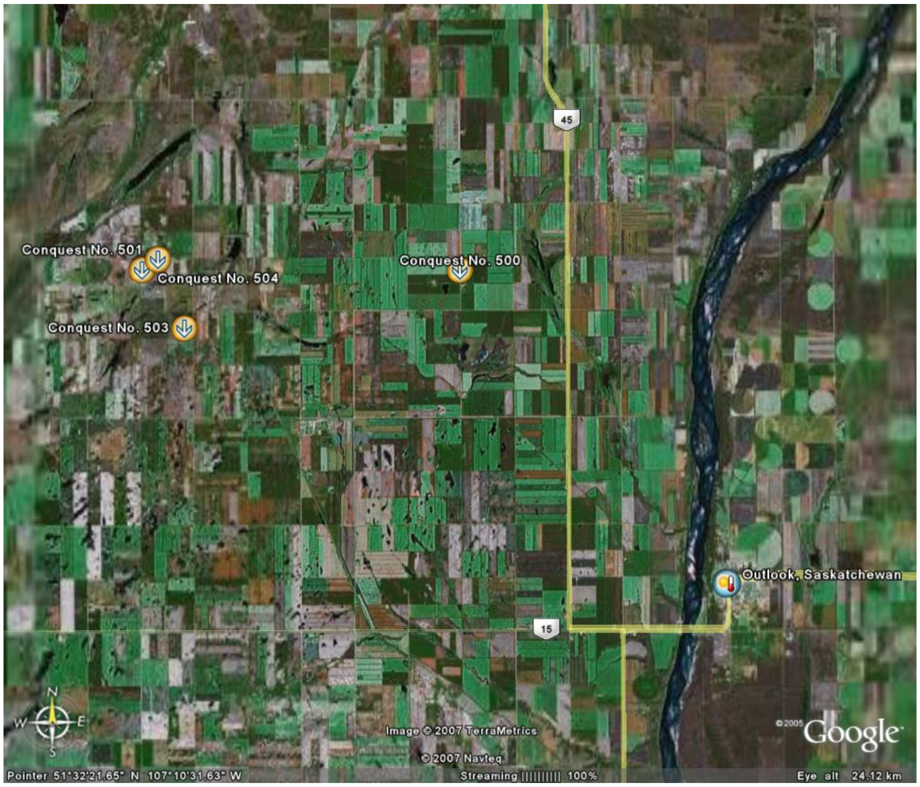


Figure 3.6 Location of Climate Stations (sun and temperature symbols) and Groundwater Observation Wells (down arrows) in the Outlook, Saskatchewan region (Map source: Google Earth 2007).

3.2.2 Water Supply Characteristics

3.2.2.1 Stream Flow

The South Saskatchewan River and its tributaries (Oldman and Red Deer Rivers) are an important water source for the three regions including being a water source for irrigation, recreation and potable water. All three communities are dependent upon adequate surface water supplies for their municipal water.

3.2.2.2 Groundwater

The prairies have many aquifers located in glacial deposits. These glacial materials are underlain by shale, sandstone and limestone bedrock formations in which many contain extractable groundwater. Approximately 90% of rural Canadian prairie residents obtain their water from wells (Martin et al. 2000). Groundwater is used by rural residents of the study area for multiple uses including rural residents' household potable water, water for livestock and water used for agricultural spraying.

Groundwater accounts for only 4% of Alberta's water needs because of the province's proximity to high quality surface water from the mountains. Saskatchewan's use of groundwater is slightly higher at 9% for its water needs. Only 1% of groundwater is used for irrigation in both Alberta and Saskatchewan (Martin et al. 2000).

Of the three regions, the Municipal District of Taber has the least number of groundwater wells at 69 up to 1999 (Figure A5.20) (PFRA-AAFC 2007c). Special Area 2 has the greatest number at 1,555 (Figure A5.19) (PFRA-AAFC 2007b). Rural Municipality of Rudy had 85 wells located on farmland up to 1999 (Figure A5.21) (PFRA-AAFC, 2007d).

3.2.2.3 Dugouts

Dugouts (excavated artificial ponds) are an essential part of the agricultural community. Dugouts are used by farmers for household usage, livestock and crop spraying. Dugouts are generally designed to withstand two years of drought conditions (Bell, p. comm. 2002 in Wittrock 2005).

From 1935 to 1999, over 75,119 dugouts were established in Saskatchewan and 49,100 in Alberta and the Dawson Creek region of British Columbia (PFRA-AAFC, 2006a). Of the three regions, Special Area 2 has the largest number of dugouts with 2,366 dugouts established between 1935 and 1972. Another 3,400 were built between 1973 and 1999 (Figure A5.19). MD of Taber had 821 dugouts established between 1935 and 1972 and another 416 built between 1973 and 1999 (Figure A5.20). The Rural Municipality of Rudy had 122 dugouts built between 1935 and 1972 with another 57 established between 1973 and 1999 (Figure A5.21).

3.2.2.4 Municipal 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. Water usage in a river basin involves many users including urban centres, rural populations, wildlife and other stakeholders that share a water body, as well as other provinces and other countries (Wittrock et al. 2001).

3.2.2.4.1 Taber

Taber's potable water supply is the St. Mary's River Irrigation District's canal system in the summer and the Taber Irrigation District through the Chin Reservoir (Figure A3.1) and a reservoir south of Barnwell in the winter months (Prado 2006). The reservoir capacity is 9,946 m^3 in measured treated water (AlbertaFirst 2007c). Based on a ten year averaging period (1994 to 2003), Taber uses 2,966,391 m^3 of potable water per year. The highest water consumption months are usually July and August (Figure A3.2).

3.2.2.4.2 Hanna

Hanna is located in an area with no reliable water supply therefore the source of potable water for Hanna is the Red Deer River. In 1985, a raw water pipeline was constructed from the Sheerness Power Generating Station to Hanna (AlbertaFirst 2007a). A water treatment plant in Hanna serves Hanna and many of the surrounding smaller communities along the number 9 Highway including Delia, approximately 30 km west of Hanna, and Oyen, approximately 110 km east of Hanna (Figure A3.3) (Burgemeister, p. comm. 2007). The town of Hanna has an average water usage of 437,762 m^3 per year over the 1990 to 2006 averaging period. July, August and June are generally the highest water usage months (Figure A3.2).

3.2.2.4.3 Outlook

Outlook's water supply is from the South Saskatchewan River. The water quality is generally good and requires a fairly simple treatment process. The plant is capable of treating 3.6 m^3 per minute and has a storage facility of 2,910 m^3. There are 32 subscribers for treated water to the east of town (Pittman and Jeanes 2006). Outlook consumes on average (1984-2006) 494,840 m^3per year. The greatest consumption period is May to September (Figure A3.2).

3.3 Socio-Economic Characteristics of Communities

Selected socio-economic characteristics of three study communities are described in this section. These include: population, economic base, and employment profile. The description includes not only the communities (towns) but also the trading area (hinterland or periphery region) for the community. The latter is demarcated as either the Rural Municipality (or Municipal District) or the entire Census Division, depending on availability of data.

3.3.1 Population Base

3.3.1.1 Taber

Alberta's economy has boomed during the past two decades, and so has its population. As shown in the top-left quadrangle of Figure 3.7, there has been a rapid population increase in the province. There were 2.5 million inhabitants in the province in 1991, which increased by 31.4% by 2006 – a population of 3.29 million. These trends will likely continue in the near future.

Like the growth in provincial population, most of the regions related to Taber have also shown an increase in their respective populations, although at different rates. As noted earlier, the town of Taber is located in Alberta's CD #2. In 1991, this CD had a population of 119 thousands, and increased to 145 thousand by 2006 – an increase of 22.1% over the 1991 level. The trend in the population for this region is shown in the top-right quadrangle of Figure 3.7. As for the province the area is showing an increasing population rate, although the increase is much smaller than that observed over the province for the same period.

The MD of Taber is located within the Alberta Census Division #2, and surrounds the town of Taber. There were some 6,280 people housed in the region in 2006. Population has also grown here from about 5,317 people in 1991 – a growth of 18% over the period. The trend is shown in the bottom-left quadrangle of Figure 3.7.

The bottom-right quadrangle of Figure 3.7 shows the population trend in the town of Taber. This town has shown an increasing population during the 1991-2001 period. However, the 2006 population showed a drop of some 80 people. This type of change is contrary to that observed for other parts of region and the province, and reasons for this change are not clear. The population of the town according to the 2006 census was 7,591 people. Although this level of population is still higher than that in 1991, the rate of growth has slowed down in the more recent period.

Growth rates in different regions related to Taber are shown in Table 3.2. Three five-year periods are compared – 1991 to 1996, 1996 to 2001, and 2001 to 2006. During the first period, the community of Taber grew very rapidly, even outpacing the province. The population growth of 8.32% during 1991 - 1996 period was the highest over these observed periods. During the second period, the province of Alberta grew very fast (13.3% during 1996 – 2001 period), primarily because of growth in the oil sands industry in Northern Alberta. The other regions' growth was slightly lower, but still a positive rate.

Source: Statistics Canada (2001, 2002, 2005a, and 2007a).

Figure 3.7 Population Trend in Alberta, Alberta CD 2, Municipal District of Taber and Town of Taber, 1991-2006

Table 3.2 Change in the Population in Alberta, by Jurisdiction, 1991-2006

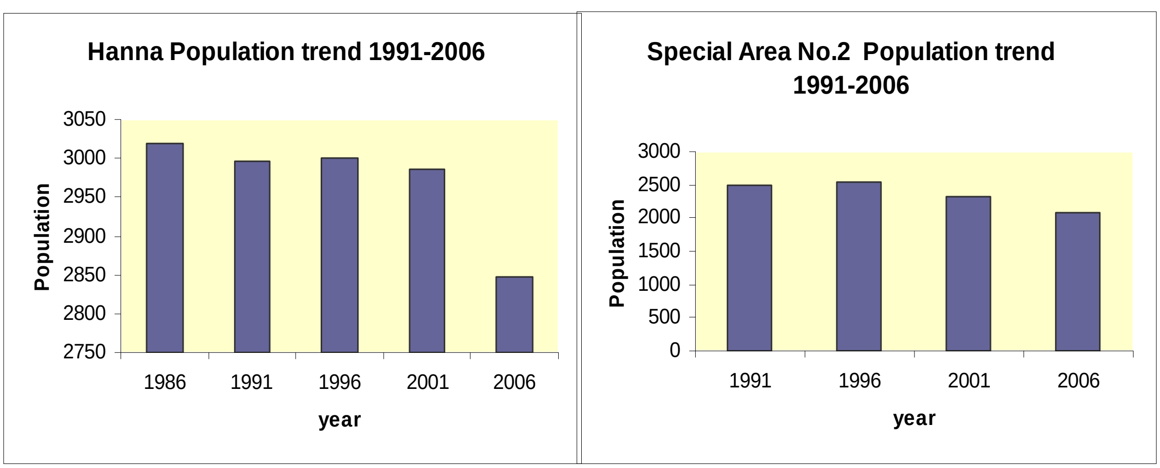
Particulars	Alberta	Alberta CD #2	Taber MD*	Taber
Population % change 1991-1996	4.87%	5.10%	6.15%	8.32%
Population % change 1996-2001	13.26%	6.98%	6.52%	6.33%
Population % change 2001-2006	10.61%	8.60%	4.46%	-1.04%

* Municipal District

During the next five-year period (2001 to 2006), although the population growth in Alberta did slow down from the second period, that for other regions slowed considerably. The population of Taber itself decreased by 1% over this time period. Reasons for this drop remains to be investigated. However, during this period, rate of population change for the CD was higher than that in the previous period.

3.3.1.2 Hanna

The community of Hanna is located in predominantly dryland area. In this respect, it is somewhat different from the Taber community, where irrigated production is a major boost to the community's economy. Hanna is located in the Special Area[9] #2, and as the head quarters of the Special Area program holds a prominent place in the region. This Special Area was formed in April 07, 1959, and contains an area of 9,342 km^2 with a rural population of 2,074 based on Census 2006 (Statistics Canada 2007a). The population of the Special Area #2 increased during 1991 to 1996 but since then has been declining (Right hand box in Figure 3.8).



Source: Statistics Canada (2001, 2002, 2005a, and 2007a).

Figure 3.8 Population Trends in Hanna, and Alberta's Special Area # 2, Selected Years

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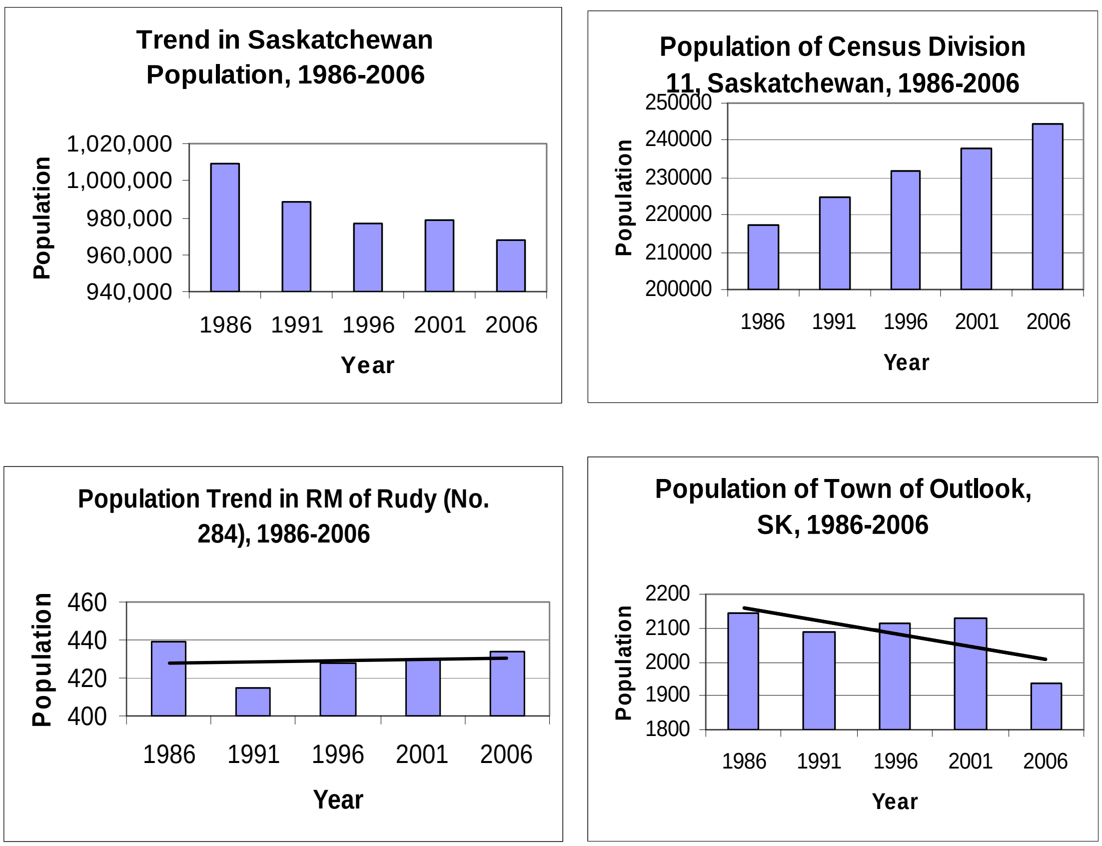
[9] Special Areas in Alberta were created by the provincial government in the mid-thirties in response to the severe drought conditions. For details see Marchildon et al. (2007).

Hanna is one of two larger communities in the Area – Oyen being the other community. In 2005, the community housed 2,847 people, which was a decline of 4.7% from 2001. As shown in the left-part of Figure 3.8, town population increased slightly during 1991 to 1996, but otherwise has been declining overall.

3.3.1.3 Outlook

The town of Outlook is located in Saskatchewan's CD # 11, which also houses the city of Saskatoon. The town is located in the RM of Rudy (# 284). Population trends in these areas are shown in Figure 3.9.



Source: Statistics Canada (2001, 2002, 2005a, and 2007a).

Figure 3.9 Comparison of Population Trend for Saskatchewan, CD 11, Rural Municipality of Rudy (# 284) and Town of Outlook

The population trends in the province of Saskatchewan are not as positive in terms of growth as the neighboring province of Alberta, as shown in the top left quadrangle in Figure 3.9. The province has a little over one million people in 1986, but has been losing them almost steadily since that time, with the exception of 1996-2001 where a small increase was observed. In 2006, the population of the province stood at 968,157 people, which is 1.1% lower than that five years ago (in 2001).

The 2006 population of the CD was 244,273 people, most of which resided in the city of Saskatoon – the largest center in the province. The trend in the population of the CD is that of increasing, mostly because of Saskatoon's population, which over the 2001 to 2006 period grew by 2.8% for the city itself and by 3.5% for the Census Metropolitan Area. This trend is shown in the top-right quadrangle of Figure 3.9.

The population trend in RM of Rudy # 284 is shown in the bottom-left quadrangle of Figure 3.9. Here the population has not followed a steady path during the 1991 – 2006 period. It decreased from 1986 to 1991 with a noticeable rate of -5.5%, followed by an increase of 3.1% from 1991 to 1996 and a quite slower increase rate of 0.5% to 2001. Based on the 2006 census, RM of Rudy had a population of 434 inhabitants.

Based on the 2006 census, Outlook has a population of 1,938 people, which registered a 9% decline since 2001. The trend, as shown in the right-bottom quadrangle of Figure 3.9, is mixed. There was a 2.5% decline in the population of the Outlook in 1991 compared to 1986, but it increased by 1.2 % in 1996 and again it rose in 2001 by 0.6%. However, a large decline in the population of the town was observed in 2006.

3.3.2 Economic Base

3.3.2.1 Taber

Initially Taber was famous primarily for its coal mining (although more recently oil and gas has replaced it), and now its economy is largely based on agriculture and related processing industries. Major agricultural products originating from the Taber area include: hogs, beef, sheep, poultry, sugar beets, potato, peas, carrots, and wheat. This is a reason that several food processing companies have located in this town. Irrigation brought with it the production of sugar beets to Taber and by 1950, a sugar beet processing plant, named Roger's Sugar Ltd. (formerly, the Alberta Sugar Company), had been built. This is the only sugar factory operating in Alberta and it is the largest employer in Taber. The following list shows the main agriculturally-based businesses and the products in the town:

- Lucerne Foods Inc. - Processed Foods and Canning
- Frito-Lay Products Ltd. - Potato Chips
- New-Way Irrigation Ltd. - Sprinkler Irrigation Equipment
- Masterfeeds Ltd. - Feeds, Poultry Feeds
- Roger's Sugar Ltd. - Granulated Sugar, Icing Sugar, Molasses
- Sunland Foods - Produce
- Alberta Pool Bean Business Unit - Bean Contracting & Production
- Select Turkey Ltd. - Poultry Processing
- Lamb Weston - Potato Processing (French Fries)
- Gouw Quality Onions Ltd. - Vegetable Production
- Chin Ridge Seed Producers - Seed Sales, Full Line Retail
- Greenley Trading (Canadian Bean Division)- Contract Bean Broker

Taber is a member of South-grow regional initiative in regional economic development alliances[10] located through Alberta and is a part of Marketplace # 2 in southwest of Alberta. The town is also a member of The Chinook Community Futures Development Corporation (CCFDC), which is funded by the Western Economic Diversification (Government of Canada). The goal of the CCFDC is to help build and maintain the economies of the region in order to provide a better quality of life for all. To accomplish this, the CCFDC provides economic development assistance to member towns (such as Taber) and villages[11].

3.3.2.2 Hanna

Hanna is well-known as the main market, educational, medical and administrative centre of a large trading area known as the "short grass country". Based on the information provided in town profile, there is a blend of over 200 industrial, retail, hospitality and service businesses in the town. While Hanna was initially known as an agricultural service centre in the past, oil and gas activity and the construction of a coal-powered electricity generating station in the area have had a huge beneficial impact on the community[12].

Agricultural products in Hanna include wheat, barley, rye, tame hay, oats, flax, canola, beef cattle, hogs, poultry, sheep, and lamb. As an agricultural centre, Hanna is home to: Hanna Farm Equipment/Heartland Equipment Group, Greenslades Northern Welding Ltd., UFA Farm Supply, Prairie Seeds Inc., the Agricultural Financial Services Corporation, and Agricultural and Agri-Food Canada PFRA.[13]

Hanna is the agricultural service centre for a trading area population estimated at over 11,000 people[14]. This is the area which is called regional market place # 1 or the south east market place. Hanna trading area includes areas East along Highway 9 to the Saskatchewan border, South to the Red Deer River, North to the Halkirk Area and West to Drumheller (for details see Figure 3.2). Electricity generation (ATCO Electric), mining (Luscar Ltd., Sheerness Mines), and oil and gas are other major industry in the area. Natural resources in the area include thermal coal, clay, sand/gravel, oil, natural gas, and bentonite (Town of Hanna 2007).

Hanna and Special Area # 2 are members of Palliser Economic Partnership (See Palliser-Alberta 2007). This is a regional alliance of 16 communities, rural municipalities and Special Areas

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10 For details see Alberta Regional Economic Development Alliance (2007).

11 The Corporation also helps people who own a business or who are contemplating starting a business with technical and financial assistance. It is also interested in attracting new businesses to the region through activities such as assisting local town and village councils or economic development committees in providing information about the area to interested parties.

12 For details see AlbertaFirst (2007a) and Town of Hanna (2007).

13 For details see AlbertaFirst (2007a).

14 For details see AlbertaFirst (2007b).

committed to improving and expanding economic development in Southeast Alberta. It is a not-for-profit company working with Alberta Economic Development, Alberta Municipal Affairs and Crop Business Development Center. This Partnership supports balanced, sustainable growth in member communities and encourages investment and business growth in the area.

Oil & gas activity is another major component of Hanna's economy. A number of businesses related to the energy extraction and businesses that service the sector exist in Hanna including: Bonavista Petroleum Ltd., Canadian Natural Resources Ltd. (head offices), Cononco Phillips Canada, Enerplus, EOG Resources Inc., Exlco Oilfield Service, Fluid Experts, Karg's Oilfield Services, KellAlta Fencing Oilfield Services, Quinn's Big Country Oilfield Services Ltd., Reacharound Controls Ltd., SIG Contracting, and Tranco (AlbertaFirst 2007a).

Hanna has a strong commercial and retail sector for a town of its size. Some key commercial/retail businesses in Hanna include: A&W, Best Western, The Brick, IGA, Pharmasave, Pizza Hut, MacLeods True Value Hardware, Value Drug Mart, and Warwick's Home Hardware Building Centre (AlbertaFirst 2007a). There is a very small manufacturing presence in the town. The main manufactured goods in Hanna include agricultural products, manufactured homes and absorbants. Hanna's key manufacturers include Exlco, an oilfield stackable fence manufacturer, and SorbitAll, a manufacturer of absorbents, headquartered in Hanna. Other manufacturers and fabricators in the area include: Big County Construction, Blake's Welding, Greenslades Welding, Hanna Sheet Metal & Insulation, Hanna Weldingrods, and Venture Fabrication (AlbertaFirst 2007b).

Hanna has also been known as the Home of the Canada Grey Goose, and it is still a favorite spot for hunters from all over North America. Therefore, the tourism and its dependent services constitute another active industry in the area. The town also offers numerous recreational opportunities to suit any taste including a 9-hole golf course and water sports on nearby lakes (Town of Hanna, 2007).

The financial institutions in the area are: Royal Bank, TD Canada Trust, ATB Financial and Hanna Savings (a division of Chinook Credit Union). Hanna and District Health Services boasts an 18 bed active facility that accommodates minor surgical/dental procedures, medical, obstetric for low risk mothers and babies, and palliative care. Twenty-four hour emergency care is staffed with a registered nurse. Hanna Continuing Care has 65 beds one of which is dedicated for respite care. The Hanna Community also boasts a medical clinic, optometrist, denturist, chiropractor, two dentists, and a registered massage therapist (Town of Hanna, 2007).

Hanna is part of the Prairie Land Regional School Division #25, headquartered in Hanna.
Schools in Hanna include Hanna Primary School [K-3], and J.C. Charyk School [4-12]. Post-secondary education is available at Red Deer Community College, Olds Agricultural College or Calgary-based institutions.

The Hanna Learning Center offers the Community Adult Learning Program and a wide variety of courses and programs to the community including: workplace safety, health, fitness, computer, personal, and career related courses. They also offer distance learning opportunities. A number of universities offer some services, including administering courses, supervising examinations and helping distance learners apply for education at several colleges and universities throughout Alberta. The Learning Centre also delivers the Registered Apprentice Program (RAP) for citizens interested in a career in the trades.

Hanna has a good transportation sector for a town of its size. Airport, rail services, highways, trucking firms, bus services and couriers and taxis are among the different transportation services available in the town. It has an airport with 3,500 foot runway, a non-directional beacon and all weather facilities. The town is served by Canadian National Railway. The main east-west route is Highway 9, and the main north-south route is Highway 36. These Highways are primary routes for both east/west and north/south trucking and transport.

3.3.2.3 Outlook

Saskatchewan is known as an agriculture based province. In 2006, agriculture, forestry, fishing and hunting together made up 7.4% of the province's GDP (gross domestic product) in constant dollars (Government of Saskatchewan 2007). Wheat, canola, flax, rye, peas, lentils, canary seed, and barley are main crops produced in the region. The livestock sector is active in the region too and the beef cattle production in Saskatchewan is only exceeded by Alberta. Mining and oil and gas are also important industries in the province. Saskatchewan is one of the world's main potash and uranium exporters.

The CD # 11 is known as the most populated and largest division in Saskatchewan. With Saskatoon, the largest city in the province, located in this division, the importance of the division in the provincial economy needs no emphasis. This CD also houses world's leading Agricultural Biotechnology Center with the researchers in the University of Saskatchewan and Innovation Place Research Park. In the mining sector, nearly two thirds of the world's recoverable potash reserves are located in this division. CD 11 is home to several manufacturers, information technology and telecom fields companies and food processing companies, and is a major center for education.

Outlook is an agriculturally-focused town has a reputation as the irrigation capital of Saskatchewan. Since 1949, when the pre-development farm to demonstrate irrigation methods was established at Outlook, it has became the service center for the largest irrigation project in the Saskatchewan in more recent years[15]. Plentiful water resources around Outlook and its rich dark brown sandy loam soil have turned agriculture as the base business here. As a result, it is also a potential place for food processing companies and related support industries. The main active businesses of the town are, therefore, related to agriculture and irrigation. At the present time, hay is processed at a dehydration plant, along with a local facility which extracts essential oil from mint and dill for use in food industry. There are large hog barns in the area that provide a market for the feed grains grown under irrigation. Cattle industry also is an active business in the agriculture sector of the area.

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[15] Much of the irrigation development in the region took place under the joint federal and provincial authority. The federal government institution was of PFRA. A brief history of this institution is presented in PFRA (2005). The surrounding region, called the Lake Diefenbaker Development Area, contains 87% of the total provincial irrigated area in 2004 (Kulshreshtha 2006).

Outlook community is a member of Mid Saskatchewan Regional Economic Development Authority (REDA).The economic development offices of the Mid Sask REDA/CFDC (Regional Economic Development Authority /Community Futures Development Corporation) are located in Outlook. These provide assistance to entrepreneurs in the area of financing, business plan assistance or developing community projects.

3.3.3 Employment Sources

3.3.3.1 Taber

Employment data for the Taber and its respective surrounding regions were acquired from Statistics Canada (special tabulations). However, it should be noted that the quality of the data for small centers, released for public use, leaves something to be desired in terms of its accuracy. This is because for preserving confidentiality, some of the employment data categories are rounded up to a higher round number (such as a 10 or a 20). On account of this rounding, the sum of reported data does not always add up to the total number of workers in the region (or community). In spite of this limitation, these data are presented in Table 3.3 for Taber and Taber MD As it can be observed from these data, Taber labor force has been engaged in all sectors. However, the main sector of employment is the manufacturing sector as 12.5% of the total labor force is engaged in these industries. This is followed by the mining sector, which accounts for 11.9%, and the retail sales sector with 10.5% of the total labor force. Agriculture labor force constitutes only 4.9% of the total employment in the town itself. Thus, manufacturing (primarily agricultural processing industries) and mining (oil and gas production) are the major employers in the town of Taber. Being a regional service center, the retail sector is also a very healthy employer in the town.

The Taber MD, the surrounding rural area (or the periphery region), is oriented more to agricultural production. More than 50% of the labor force is occupied in pursuing agricultural production related activities, followed by retail trade that only accounts for 5.3% of the labor force. Thus, the Taber MD has predominantly an agricultural based economy.

Over the last two census periods (1996 and 2001)[16], the Town of Taber has witnessed a larger increase in the service, mining and manufacturing industries, as shown in Figure 3.10. In contrast, agriculture, trade (wholesale and retail) and transportation/utilities sectors have declined, relatively speaking. A distribution of major employment groups in the Town is shown in Figure 3.11. Service industries, manufacturing and mining sectors emerge as the major industries in the town.

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[16] The 2006 census data was not available at the time of writing this report.

Table 3.3 Employment by Industry Division in Taber, and MD of Taber. Alberta, 2001

Industry Group	Town of Taber		MD of Taber	
	# of Workers*	% of Total	# of Workers*	% of Total
11 Agriculture, forestry, fishing and hunting	185	4.89	1,575	50.64
21 Mining and oil and gas extraction	450	11.90	120	3.86
22 Utilities	10	0.26	15	0.48
23 Construction	260	6.88	140	4.50
31-33 Manufacturing	470	12.43	145	4.66
41 Wholesale trade	215	5.69	125	4.02
44-45 Retail trade	395	10.45	165	5.31
48-49 Transportation and warehousing	315	8.33	165	5.31
51 Information and cultural industries	15	0.40	10	0.32
52 Finance and insurance	95	2.51	55	1.77
53 Real estate and rental and leasing	65	1.72	15	0.48
54 Professional, scientific and technical services	90	2.38	30	0.96
56 Administration, support, waste management, & remediation services	120	3.17	30	0.96
61 Educational services	225	5.95	170	5.47
62 Health care and social assistance	265	7.01	75	2.41
71 Arts, entertainment and recreation	30	0.79	35	1.13
72 Accommodation and food services	205	5.42	80	2.57
81 Other services (except public administration)	225	5.95	80	2.57
91 Public administration	145	3.84	80	2.57
Total Industry	3,780	100.00	3,110	100.00

* The quality of the data released for public use leaves something to be desired in terms of its accuracy. This is because for preserving confidentiality, some of the employment data categories are rounded up to a higher round number (such as a 10 or a 20). On account of this rounding, the sum of reported data does not add up to the total number of workers in the community to total.

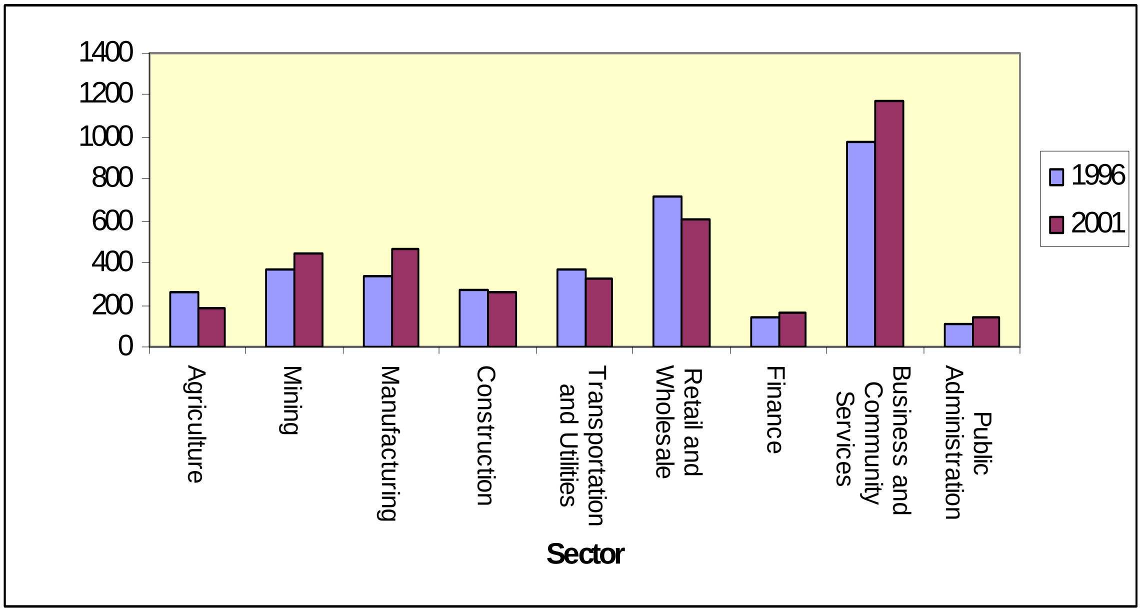


Figure 3.10 Change in Relative Share of Total Employment, Town of Taber, 1996 and 2001

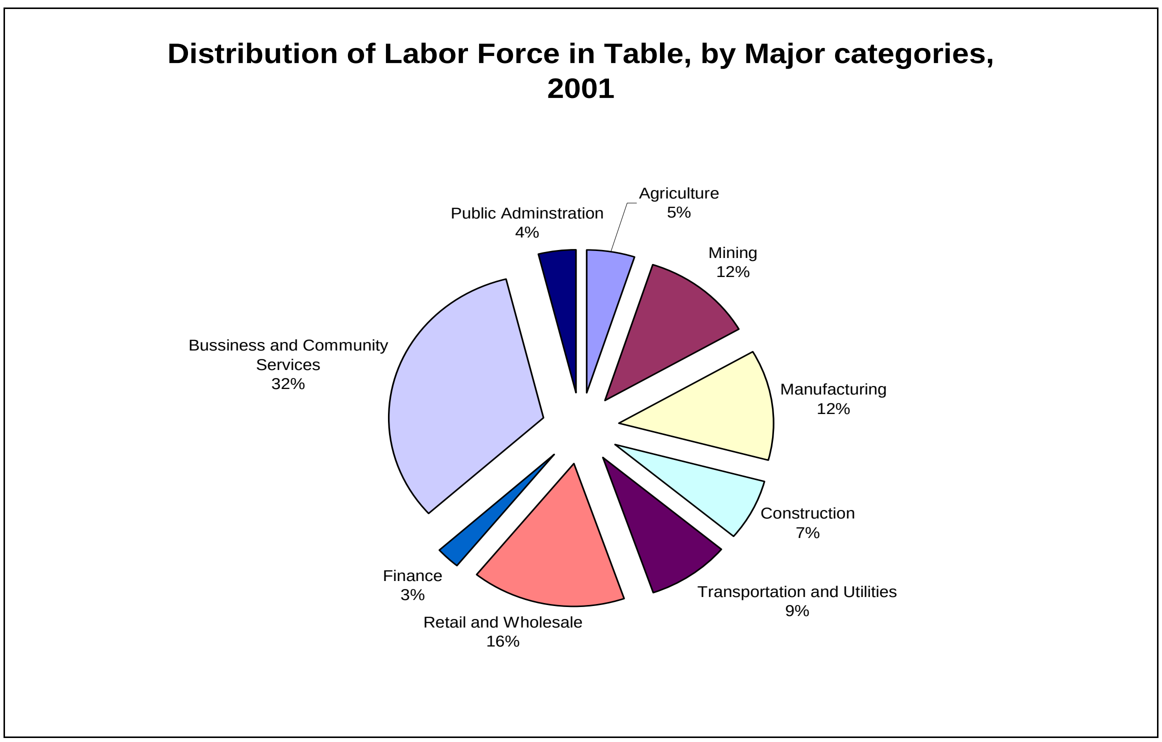


Figure 3.11 Distribution of Labor Force by Major Industry Groups, Town of Taber, 2001

3.3.3.2 Hanna

Employment data for Hanna and its respective surrounding regions were acquired from Statistics Canada (special tabulations), and suffered from the same rounding problem as noted earlier. In spite of this limitation, these data are presented in Table 3.4 for Hanna and for Special Area #2.

Table 3.4 Employment by industry division in Hanna, and in Special Area #2, 2001

Industry Group	Town of Hanna		Special Area # 2	
	Total*	Percent of Total	Total*	Percent of Total
11 Agriculture, forestry, fishing and hunting	95	6.07	860	56.39
21 Mining and oil and gas extraction	125	7.99	135	8.85
22 Utilities	90	5.75	15	0.98
23 Construction	140	8.95	30	1.97
31-33 Manufacturing	0	0	0	0
41 Wholesale trade	50	3.19	10	0.66
44-45 Retail trade	305	19.49	50	3.28
48-49 Transportation and warehousing	55	3.51	65	4.26
51 Information and cultural industries	15	0.96	10	0.66
52 Finance and insurance	20	1.28	20	1.31
53 Real estate and rental and leasing	25	1.60	10	0.66
54 Professional, scientific and technical services	60	3.83	20	1.31
56 Administrative and support, waste management and remediation services	40	2.56	45	2.95
61 Educational services	105	6.71	95	6.23
62 Health care and social assistance	130	8.31	65	4.26
71 Arts, entertainment and recreation	10	0.64	10	0.66
72 Accommodation and food services	160	10.22	45	2.95
81 Other services (except public administration)	55	3.51	15	0.98
91 Public administration	85	5.43	25	1.64
Total Industry	1,565	100.00	1,525	100.00

* The quality of the data released for public use leaves something to be desired in terms of its accuracy. This is because for preserving confidentiality, some of the employment data categories are rounded up to a higher round number (such as a 10 or a 20). On account of this rounding, the sum of reported data does not add up to the total number of workers in the community to total.

As it can be observed in the Table 3.4, in the Town of Hanna, the main employment sector is retail trade, followed by the accommodation and food sector. The community is a major retail center for the region, thereby serving most of the Special Area # 2 and other surrounding regions. Agriculture labor force constitutes only 6% of the labor force in the area.

The Special Area # 2, like any other periphery region, is primarily agricultural oriented. More than 56% of the labor force is occupied in agriculture sector. The mining (including oil and gas) is the second largest sector in the area with 9% of the total labor force employed in it.

Distribution of employment by major employment groups is shown in Figure 3.12. Being a major trading center for the region, wholesale and retail trade industries are the largest employment sectors, followed by other services (other than business services) and primary industries (agriculture, forestry, fishing and hunting).

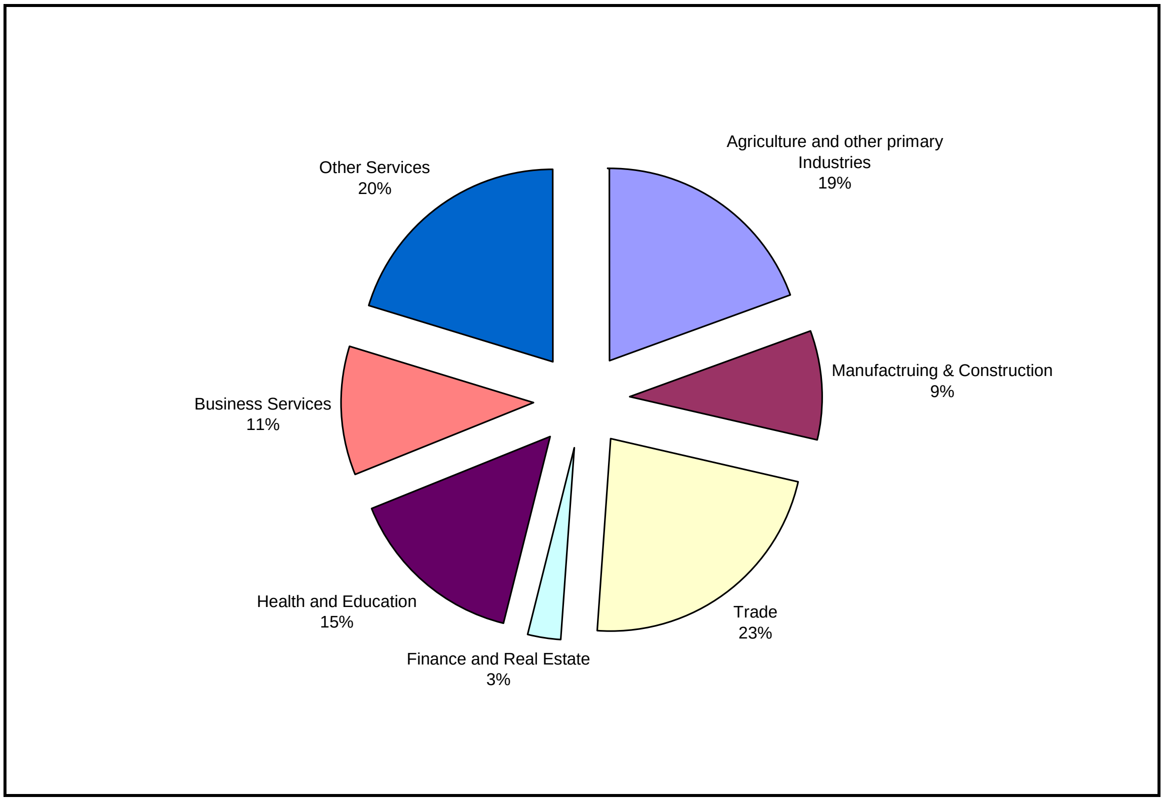


Figure 3.12 Distribution of Employment in Town of Hanna by Major Industry Groups, 2001

<u>3.3.3.3 Outlook</u>

Employment data for Outlook and its respective surrounding region, RM of Rudy # 284, were obtained from Statistics Canada (special tabulations). These data suffer from the same limitations as for the Alberta data set. These are presented in Table 3.5 both for Outlook and Rudy # 284.

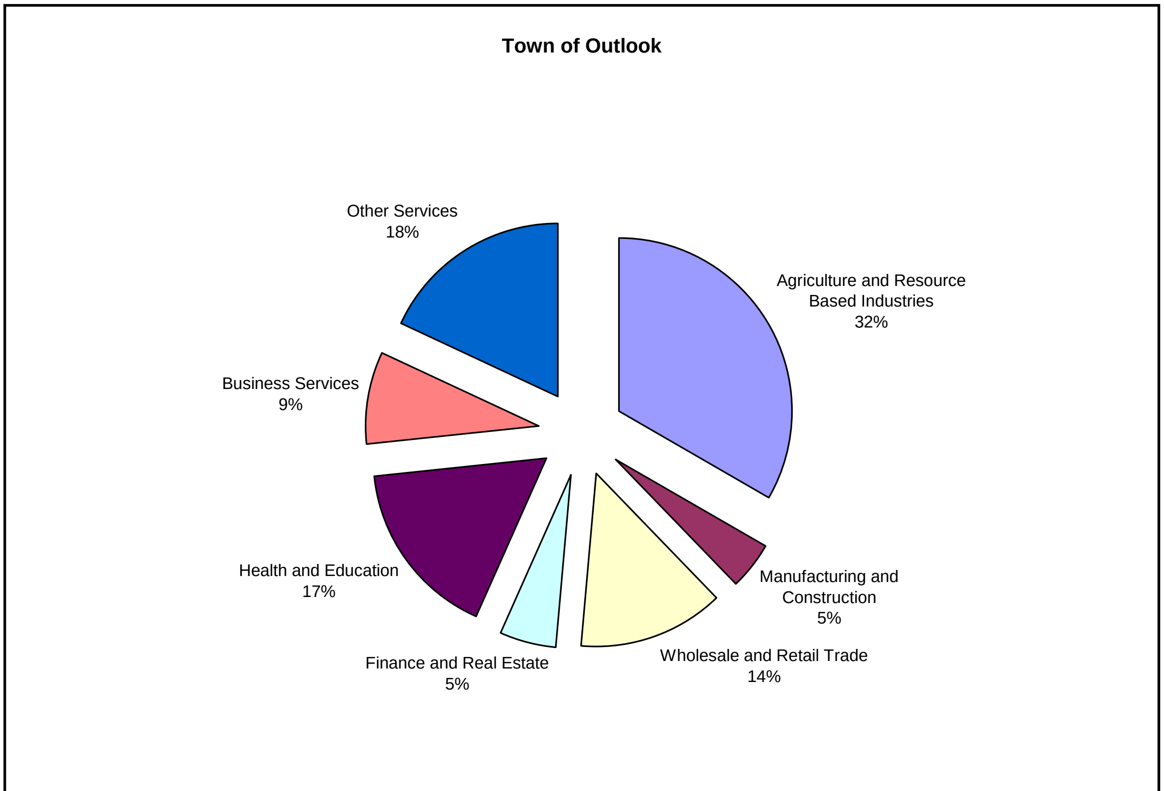
In the community of Outlook, major employment is in the agriculture and other resource base sectors. As shown in Figure 3.13, the town has a heavy dependency on primary industries as some 32% of the workers are employed in these industries. One of the features in the employment pattern distributed by sex of the worker is that more female workers are employed in the community in health care and education services.

In the periphery region – RM of Rudy, agriculture and other primary (resource) industries play an important part through employing 57% of the workers. The other major sectors are the business services and trade (wholesale and retail). Thus, Outlook and RM of Rudy # 284 are predominantly agriculture base regions and most of the businesses in the region are affected directly or indirectly by the factors that may affect the agriculture sector in the region.

Table 3.5 Employment by industry in Outlook and Rudy # 284, 2001

Industry group	Outlook			Rudy # 284		
	Total*	Male*	Female*	Total*	Male*	Female*
Total industry	990	525	470	265	155	115
Agriculture and Resource Based Industries	330	250	80	155	105	50
Manufacturing and Construction	45	40	10	15	10	0
Wholesale and Retail Trade	135	70	65	30	15	20
Finance and Real Estate	50	10	35	0	0	0
Health and Education	165	20	150	25	0	20
Business Services	85	50	35	30	15	10
Other Services	180	85	95	20	10	0

* The quality of the data released for public use leaves something to be desired in terms of its accuracy. This is because for preserving confidentiality, some of the employment data categories are rounded up to a higher round number (such as a 10 or a 20). On account of this rounding, the sum of reported data does not add up to the total number of workers in the community or the sum of male and female to Total.



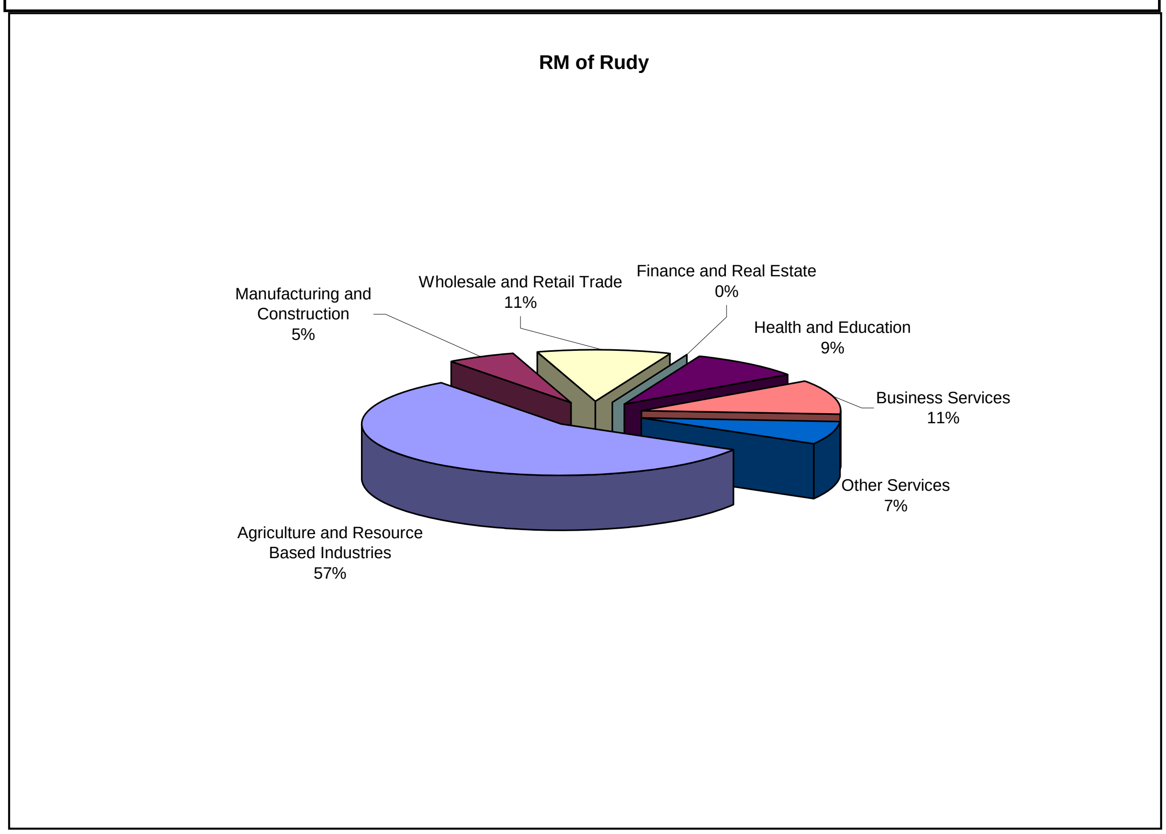


Figure 3.13 Distribution of Total Employment by Major Industry Groups, 2001, Town of Outlook, and Rural Municipality of Rudy, Saskatchewan

4. CLIMATOLOGICAL DESCRIPTION OF DROUGHTS

4.1 Measurement of Droughts

Droughts are unlike any other weather disasters such as floods and hurricanes. Droughts are more complex resulting in quantifying and defining them difficult. A 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). There are various types of droughts categorized: 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 of Droughts

Extreme drought conditions of 2001 and 2002 were experienced across Canada. By December 31, 2001, portions of Canada had experienced 4.5 years of consecutive seasons of warmer than average temperatures beginning in the summer of 1997 (Wheaton and Wittrock 2005). This section describes the antecedent conditions, nature and evolution of the 2001 and 2002 drought in the Taber, Hanna and Outlook regions. The droughts are described using temperature, precipitation, drought indices and other parameters.

4.2.1 Taber

Taber started having consecutive above normal temperatures in the summer of 1997 and persistent below normal precipitation amounts in the fall (September, October, November) of 1998. The extended dry and warm spell continued until the spring (March, April, May) of 2002 with a cool wet spring and summer (June, July, and August). Beginning in the winter (November, December, January) of 1996/1997 and ending spring 2002, Taber had 17 out of 22 seasons of above normal temperature and 16 out of 22 seasons of below normal precipitation, nine of which were consecutive (fall 1999 to fall 2001 inclusive) (Figure A4.1).

The meteorologic drought appears to have ended in 2002 with a cold spring (temperature was 5.9°C below normal) and wet summer (132 percent above normal). Extreme precipitation events occurred June 2002, when Taber received 248.2 mm of rain. Taber received 162.0 mm of precipitation between June 9 and 11th. This precipitation event occurred over much of the southern prairies located south of the Number 1 Highway (Figure A4.2).

Annually, 2000 and 2001 were the driest years between 1990 and 2005. The above normal annual temperatures began in 1997 and continued through to include 2001. A switch occurred in 2002 to an extremely high annual precipitation amount of 625.2 mm (70% above normal) and an annual temperature that was 0.5°C below normal (Figure 4.1).

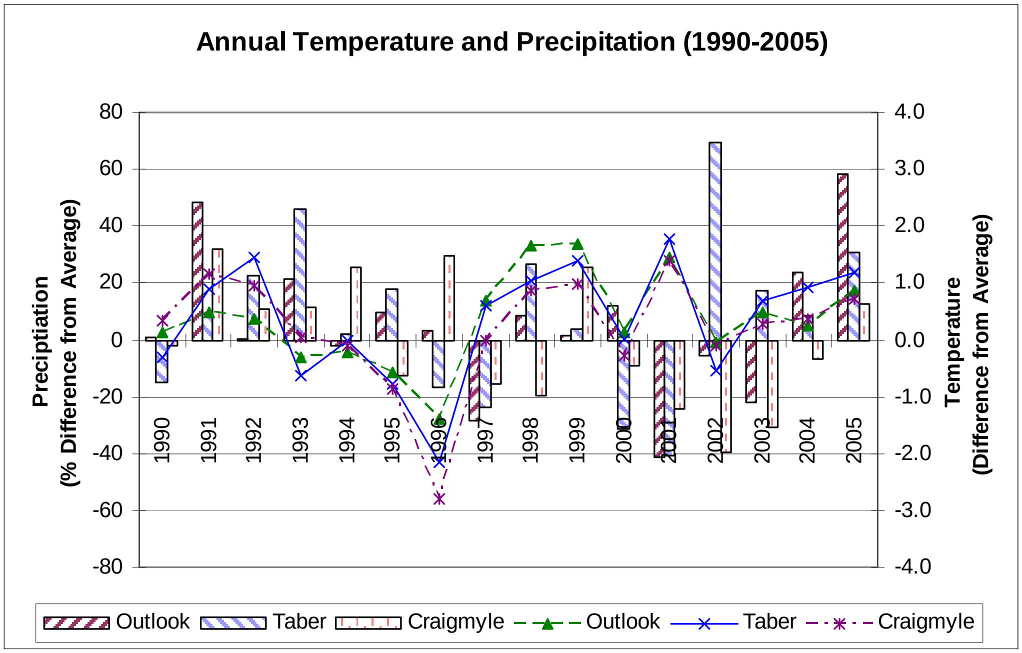


Figure 4.1 Annual Temperature (Difference from Average) and Precipitation (Percent Difference from Average) for 1990 to 2005 for Outlook, Taber and Craigmyle (Data Source: Environment Canada 2007a)

4.2.2 Hanna

The dry conditions also started early in the Hanna region. The dry conditions began in the winter of 1996/1997 and continued to the fall of 2005. This resulted in 27 out of 36 seasons between 1996 and 2005 with above normal temperature and 26 out of 36 had below normal precipitation. Between the winter of 1996/1997 and fall 2003, 21 out of 28 seasons had above normal temperature and below normal precipitation. The dry conditions were interrupted in the spring and summer of 1999 which had above normal precipitation and below normal temperature. The dry warm conditions resumed in the fall of 1999 and have generally continued to the fall of 2005 (Figure A4.3).

Annually, 2001, 2002 and 2003 were the driest years at Craigmyle between 1990 and 2005. Below normal precipitation occurred from 2000 to 2004 inclusive. Between 1990 and 2005, 2001 was the warmest year in that 16-year period. Above normal annual mean temperatures have been recorded at Craigmyle from 1997 to 2005 with slightly below normal temperatures in 2000 (Figure 4.1).

The spring of 2002 was cold with the mean temperature 5.9°C below normal. The Hanna region did not have the extreme precipitation that Taber had. During that June 9 to 11 period, Craigmyle received only 2.8 mm of precipitation resulting in continued drought conditions (Figure A4.2).

4.2.3 Outlook

The extreme dry conditions started later in Outlook than the Taber or Hanna regions. Below normal annual precipitation did not occur until 2001 and continued until 2003. Above normal annual average temperatures occurred at Outlook from 1997 to 2005 (Figure 4.1). This is mainly due to the winter season temperatures generally being well above normal.

Six consecutive seasons of below normal precipitation occurred from spring 2001 to summer 2002 inclusive. The fall of 2002 and the winter and spring of 2003 had above normal precipitation. Outlook had above normal temperatures starting in the spring of 2002 and continued through the winter of 2001/2002. Spring 2002 was very cold with nearly 5°C below normal temperatures. The summer of 2002 returned to above normal temperature but the fall of 2002 was below normal (Figure A4.4).

Outlook received 27.4 mm of precipitation from the June 9 to 11, 2002 storm system (Figure A4.2) helping alleviate some of the drought conditions.

4.3 Potential Evapo-transpiration

Evapo-transpiration is a major component of the water balance and of water “usage” in the Canadian Prairies. Potential evapo-transpiration (PET) patterns for the 2000 to 2002 period for the 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 than 2000. High PET values indicate less water available to the plants.

4.3.1 Taber

The Taber region has an average (1971-2000) PET of 740 mm for the year and 568 mm for the growing season (April to August inclusive). The PET was above normal in both 2000 and 2001 (Figure A4.5). In 2001, it was above normal for the growing season by more than 3% (approximately 18 mm). July generally has the highest PET (approximately 136 mm). July 2001 was 6 mm higher than normal. A dramatic decrease in the PET occurred in 2002 primarily due to the cool wet April to June period. The PET in April 2002 was 25% below normal with May being 11% below normal. June 2002 was only slightly below normal (Figure A4.6).

4.3.2 Hanna

The Hanna region has an average PET value of 664 mm for the year and 539 mm for the growing season based on the 1971-2000 averaging period. The PET was above normal in 2000 and 2001 with 2001 being nearly 3 percent (15mm) above normal for the growing season (Figure A4.5). The cool spring of 2002 also had an impact in Craigmyle with April’s PET being nearly 35% below normal. However, unlike Taber, June PET returned to being above normal by 4% and July by 5%. Craigmyle’s PET went back to being more than 2% (12mm) above normal in 2003 with April and August having strong influence (Figure A4.6).

4.3.3 Outlook

Outlook has a normal annual PET value of 686 mm and a growing season value of 558 mm. Higher than normal PET values occurred during the growing season in 2000 (0.3%) and 2001 (2.5%) (Figure A4.5). The PET dropped to being more than 4% below normal or more than 25 mm in 2002. This was due in large part to the low values in April and May. 2003 had above normal PET due mostly to the above normal values in August (Figure A4.6).

4.4 Palmer Drought Severity Index

The Palmer Drought Severity Index (PDSI) is a meteorological drought index and responds to weather conditions that have been abnormally dry or abnormally wet. It 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.

The PDSI is generally considered useful for agriculture and other activities sensitive to soil moisture and is widely used in Canada and the United States, and available to map and data format. PDSI values usually range from -4 (or less) indicating extremely dry conditions to +4.0 (or more) indicating extreme drought conditions. It is possible for these values to be exceeded indicating possible near record wet or dry conditions. Environment Canada published monthly PDSI information for the Canadian Prairies in map form during the 1999 to 2003 period (Figure A4.7 to A4.17). The maps indicate how the drought conditions evolved in the prairies. The method used for Environment Canada's PDSI is described in Hopkinson (2000).

4.4.1 Taber

The fall of 2000 PDSI indicates that dry conditions were already present in the Taber region. The winter of 2000/2001 PDSI did not improve, and spring 2001 conditions ranged from -4.0 in March to -6 in May. These extreme dry conditions worsened in June through August of 2001 and remained extreme until March of 2002. The PDSI returned to normal in the June to August period of 2002 with positive (wetter conditions) PDSI occurring in the fall of 2002 and staying moist to normal through to the summer of 2003 (Figure A4.7 to A4.17).

4.4.2 Hanna

The PDSI indicates that Hanna was on the edge of the extreme low (or dry) PDSI values but much of Special Area #2 was in the extreme drought zone. The fall of 2000 PDSI ranged from being just below normal to values below -3. The winter of 2000/2001 had more of Special Area #2 with more severe drought conditions. The spring of 2001 continued this level of drought conditions with the summer entering the severe drought. By August, 2001, much of Special Area #2 had PDSI values below -5 to -8 indicated extreme drought conditions. These extremely dry conditions continued into the fall and winter of 2001/2002. The spring of 2002 was not quite as extreme but Special Area #2 was still in severe drought. The summer of 2002 resulted in a variety of PSDI values throughout the Special Area including near normal conditions on the southern edge in August to severe drought conditions on the northern regions. This gradient continued into the fall and winter of 2002/2003. The PDSI values in the spring of 2003 returned to normal values (Figure A4.7 to A4.17).

4.4.3 Outlook

The Outlook and RM of Rudy did not have below normal PDSI values until the spring of 2001. The PDSI values decreased quickly through the summer of 2001 and remained extremely low through the fall 2001, winter 2001/2002, spring 2002, and summer 2002 indicating moderate drought conditions. The fall of 2002 had the northern portions of the RM of Rudy with below normal PDSI and the southern portion near normal. This spatial difference in PDSI continued through winter 2002/2003, and the spring 2003 (Figure A4.7 to 4.17).

4.5 Standardized Precipitation Index

The Standardized Precipitation Index is another climatological index that allows for drought severity assessment as discussed earlier.

4.5.1 Taber

The grid square center point is 12 km west of Taber. Below zero SPI values began in 1999 indicating slight drought conditions were present in the area. The SPI values were the lowest in 2000 for both the summer and agricultural year showing the extreme drought conditions were already underway in the Taber region. In 2001, the SPI values were still strongly negative indicating continued drought condition. By 2002, the SPI was above zero during both the agricultural year (April to August) and the summer indicating wet conditions (Table 4.1).

Table 4.1 Standardized Precipitation Index (SPI) Values for the Taber Region (1999-2000) Grid Square (49° 47’ 45.6”N, 112° 19’ 1.2”W) (Data source: Bonsal, p. comm. 2006)

	SPI (JJA)	SPI (Agriculture Year)
1999	-0.18	-0.77
2000	-1.53	-1.99
2001	-1.13	-1.70
2002	2.35	1.45

Agriculture Year = September to August e.g., September 1998 to August 1999
JJA = June, July, August

4.5.2 Hanna

The grid square centre point is 100 km north of Hanna. The SPI shows that a mild drought had started in the summer of 1999 with it becoming more severe in 2000 and slightly less severe in 2001. The area, according to the summer SPI values, was out of drought and into moist conditions by the summer of 2002. The agricultural year SPI reflect these summer values (Table 4.2).

Table 4.2 Standardized Precipitation Index (SPI) Values for the Hanna Region (1999-2000) Grid Square (52° 30'45.8"N 111° 41' 24"W) (Data source: Bonsal, p. comm. 2006)

	SPI (JJA)	SPI (Agriculture Year)
1999	-0.18	-0.77
2000	-1.53	-1.99
2001	-1.13	-1.70
2002	2.35	1.45

Agriculture Year = September to August e.g., September 1998 to August 1999
JJA = June, July, August

4.5.3 Outlook

The grid square is approximately 15 km southeast of Outlook. The summer SPI values for the summer indicate that drought conditions did not begin in the Outlook region until 2001 and moist conditions returned in 2002. However, the agricultural year SPI show that 2000/2001 and 2001/2002 were dry.with 2001/2002 having the worst drought conditions and 2002/2003 continued with drought (Table 4.3).

Table 4.3 Standardized Precipitation Index (SPI) Values for the Outlook Region (1999-2000) Grid Square (51° 25' 19.2" N 106° 51' 54" W) (Data source: Bonsal, p. comm. 2006)

	SPI (JJA)	SPI (Agriculture Year)
1999	0.06	1.29
2000	0.34	-0.04
2001	-1.24	-2.17
2002	1.13	-0.88

Agriculture Year = September to August e.g., September 1998 to August 1999
JJA = June, July, August

4.6 Summary and Comparison to Previous Droughts

The droughts of 2001 and 2002 were extreme and affected all three communities with warm and dry condition. The dry conditions started earlier in southern Alberta as indicated by the low SPI in 1999 and then migrated north and eastward. The drought also ended sooner in Taber than the other communities. The community of Outlook appeared to have not been less extreme drought conditions than the other two communities.

The atmospheric circulation patterns of 2001 and 2002 were unique. Bonsal and Wheaton (2005) compared them to the multi-season drought years of 1961 and 1988. They found the drought of 2001 and 2002 atmospheric circulation patterns were different from the other drought years. The circulation during 2001 and 2002 lacked the distinct meridional flow over the North Pacific and North America that was previously associated with dry periods over western Canada.

There was also no evident relationship with large-scale teleconnection patterns such as El Nino, that have influenced historic climatic extremes over western Canada.

The PDSI for the Canadian Prairies was compared to previous droughts by Bonsal and Regier (2006). They found that 2002 ranked high in terms of drought extent and severity on a summer and one-year time frame. 2002 was the 4th worst one year drought based on percentage area and 3rd worst drought based on average PDSI for the1915-2002 period. The majority of extreme dry periods were in the 1920s and 1930s with individual drought years occurring in 1961 and 1988. There was spatial variability between the 1961, 1988 and 2001 and 2002 droughts. Based on the PDSI values, the centre of the 1961 and 1988 droughts was over eastern Saskatchewan and southern Manitoba while the 2001 had the droughts in Alberta and Western Saskatchewan and 2002 the droughts moved northward in both provinces (Bonsal and Regier 2007).

PDSI results are similar to the historical examination of SPI (Richards and Burridge 2006). They found over the March to August for the 1950 to 2004 period that 2001 ranked 4th driest and 2002 was 7th driest.

5. DROUGHT IMPACTS ON THE SELECTED COMMUNITIES

Droughts have extensive impacts on the economy, environment, health and society. The droughts of 2001 and 2002 were no exception for the three communities. This section examines the bio-physical and socio-economic impacts to Taber, Hanna and Outlook.

5.1 Bio-Physical Impacts

Meteorological droughts generally result in negative bio-physical impacts. In this section, various bio-physical areas are analyzed including water availability through trends analysis in stream flow, groundwater, and dugouts levels, as well as an examination of municipal water supply and usage. Other bio-physical impacts included an exploration of insect infestation, and the extent of wind erosion. Also examined are the implications these impacts had on the communities.

5.1.1 Water Availability

5.1.1.1 Stream Flow

Rivers and creeks are an important water source for communities, agriculture and industry. When water supply decreases, there are potentially large ramifications for users. As shown in the previous section, the early portion of 21st century had drier than average conditions. 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 streams and reservoirs in three communities regions.

5.1.1.1.1 Taber

The Bow River had a slight decrease in stream flow over its 1965 to 2005 recording period as indicated by the trend line. The flow was the lowest in recorded history in 2001 with a mean annual flow rate of 32.8 m^3/s. The flow rate in 2000 was the fourth lowest at 46.7 m^3/s (Figure A5.1). The monthly flow rates were below normal in March 2000 and remained below normal for the next 26 months, until June of 2002. During that period there were 13 months with less than 50% of the normal stream flow with four of those months with less than 80% of the normal stream flow. July, 2001 was 86% below average with a mean monthly flow rate of 19.9 m^3/s compared to the average of 146 m^3/s (Figure A5.2).

The Oldman River had a slight increase in flow in its 1983 to 2005 mean annual stream flow as indicated by the trend line (Figure A5.3). The lowest mean annual stream flow occurred in 1988 followed closely in 2001 with 22.1 m^3/s. Similar to the Bow River, the 2000 mean annual flow in the Oldman River was the fourth lowest at 28.7 m^3/s. The monthly flows started to drop below normal in February of 2000 and stayed below normal until June of 2002 when extreme precipitation events occurred in Southern Alberta (Figure A5.4 and Figure A4.2). That period (February 2000 to June 2002) had 16 months with stream flows at or below 50% of normal. June, 2001 was the extreme low flow month with 87% below the June monthly average flow of 36.2m^3/s compared with the average of 276 m^3/s.

5.1.1.1.2 Hanna

The Red Deer River is the largest river in the Special Area #2. It has a mean annual discharge at Drumheller of 52.6 m^3/s. Over the 1960 to 2005 period of record, the river's flow rates have been highly variable as indicated by the flat line of the trend line (Figure A5.5). The lowest flow year was in 1984 (24.0 m^3/s) but 2002 and 2001 were a close second and third with 24.8 m^3/s and 28.7 m^3/s respectively (Figure A5.5). Below normal annual flows from 2000 to 2004 inclusively were recorded – two/thirds of the months. Of those 40 months, 17 had less than 50% of the average flow and 4 out of the 5 years, this occurred in the spring and early summer (Figure A5.6). In general, the winter months in those years had above normal flows.

The Michichi Creek and Kneehills Creek flow into the Red Deer River at Drumheller. These streams have highly variable flows because they are seasonal with normally the highest flows occurring in the spring with snow melt. April mean discharge for Kneehills Creek is, on average, 5.3 m^3/s but in 2001 it was 0.458 m^3/s and 2002 it was 0.084 m^3/s. The creeks stream flow varies annually as well. Kneehills Creek had high flows of 7.4 m^3/s in 1997 to almost no flow in 2001 and 2002 (0.06 m^3/s and 0.03 m^3/s). Michichi Creek has lower flows than Kneehills Creek, but Michichi Creek had 30 months out of 32 in the 2000 to 2003 period with below average stream flow. Kneehills Creek had 24 consecutive months with below normal stream flow during the 2000 to 2002 inclusive period (Figures A5.7 to A5.10).

5.1.1.1.3 Outlook

The South Saskatchewan River had a decrease in mean annual stream flow for the 1911 to 2005 period at Medicine Hat as indicated by the trend line. The lowest flow in recorded history was in 2001. Low flow also occurred in 2000 (Figure A5.11). Below average stream flow was recorded for 27 consecutive months on the South Saskatchewan River at Medicine Hat from March 2000 to May 2002, inclusive (Figure A5.12).

The Red Deer River near Bindloss had a slight decrease in mean annual stream flow for the 1961 to 2005 period. The river had below normal stream flows from 2000 to 2004 inclusive. The record lowest annual stream flows occurred in 2001 and 2002. The Red Deer River did not have an increase in flow in June 2002 as the South Saskatchewan River did (Figures A5.13 and A5.14).

The South Saskatchewan River has modified flow through Saskatoon due to the Gardiner Dam near Outlook. Even with this modified flow, 2001 had third lowest flow recorded at Saskatoon since 1912 (Figure A5.15). Nineteen months had below average stream flow for the March 2001 to September 2002 period at Saskatoon (Figure A5.16).

Lake Diefenbaker was 1.7 m below its average water level in 2001, the lowest level since 1984. The 2001 monthly mean water levels of October to December were the lowest since 1967. The reservoir water level was approximately 3 m below average during this period. The water levels remained below average until June/July 2002. The water level rebounded due to mountain snowmelt and mid-June extreme precipitation events in Southern Alberta and Southern Saskatchewan (Figures A5.17, A5.18 and Figure A4.2).

5.1.1.2 Groundwater

As described earlier, groundwater is used in the agricultural regions of the study areas. Persistent and frequent droughts can over time affect groundwater resources and have an adverse effect on various industries and communities. Groundwater levels are monitored by a network of observation wells.

5.1.1.2.1 Taber

Four groundwater observation wells are located in the Municipal District of Taber and region (Figure 3.4 and A5.22). Keho Lake 2019E, Enchant 2520E and Pakowki 85-1 have all been increasing in water levels. Forty Mile Coulee 86-1 had a relatively stable water level except for the 2000 to 2003 period. This observation well is known to be affected by human activity and may have contributed to the draw down during the drought period. Extensive draw down of water began in mid-2000. The draw continued until mid-2002 when a dramatic increase in the water table occurred and leveled out in 2004.

Municipal District of Taber has 69 water wells (Figure A5.19) with no known new water wells established in the Municipal District of Taber between 1999 and 2006 (Bell, p. comm. 2007). This lack of new establishment may indicate that the agricultural community utilizing groundwater has sufficient access and most may utilize surface water supplies.

5.1.1.2.2 Hanna

Special Area #2 and adjacent areas have a large number of observation wells. The closest ones to Hanna are Hand Hills #1 and #2 (Figure 3.5). Hand Hills #1 is a deep well in a confined aquifer and is not considered to be affected by human activity. This has had a general decline in water levels since 1985. The water level elevation reached its lowest level in the winter and spring of 2003 (Figure A5.23). It is not known why this aquifer has been in decline because deep aquifers are usually less affected by drought conditions.

Hand Hills #2 is an intermediate depth well in a confined aquifer and is not considered to be affected by human activity. This observation well is opposite of Hand Hills #1 in that the water levels were increasing from 1993 and reaching its maximum in 2001 and declining until end of recording (Figure A5.23). The decline occurring after 2001 maybe due to the delayed influence from the drought as aquifers closer to the surface respond quicker to drought conditions.

The observation wells north of Hanna are Kirkpatrick Lake 86-3 East, Kirkpatrick lake 86-2 Mid and Coronation. Kirkpatrick Lake 86-3 East is a shallow well in a confined aquifer. The result is that the water levels show seasonal fluctuations of increases in late spring with snow melt. The water levels of this aquifer were generally increasing from 1987 to 2004 when the water levels decreases. Dramatic decreases in water levels occurred from 1999 to 2003 with little to no seasonal recharge in the aquifer. The lowest level of the aquifer occurred in 2003. Kirkpatrick Lake 86-2 Mid is located in an intermediate depth. This observation well is very similar to that of Kirkpatrick Lake 86-3 East in term of trends in water levels. The lowest level of this aquifer occurred in 2003 as well. Coronation is also an intermediate well. This well is classified has having influence from human activity. The graph indicates that this aquifer has stable water levels even with human activity (Figure A5.23).

Sounding Creek 2532E and Monitor 86-1 (South) are the two observation wells east of Special Area #2 (Figure A5.23). Both of these observation wells are classified as being influenced by human activity. These wells are deep in a confined aquifer and both have decreasing water levels since observations began. Monitor 86-1 indicates there was increased usage of the aquifer during the growing season between 2000 and 2003 inclusive with 2003 having the lowest water levels in the period of record. The drop in aquifer levels indicates these aquifers may be used more during the extreme drought conditions.

Big Stone 2415E, Cessford 85-2 and Duchess 2564E are groundwater observation wells located in the southern reaches of Special Area #2. Duchess 2454E is the most southerly well. It is a shallow observation well located in a confined or semi-confined aquifer that is influenced by human activity. This well has been decreasing in water levels since observations began in 1990. The lowest water levels were recorded in 2003 and 2004. Cessford 85-2 and Big Stone 2415E are both intermediate wells located in confined aquifers. Neither is considered to be affected by human activity. Cessford's water levels increased from 1996 to 2001 and have been declining since. Big Stone's water levels reached a maximum in the fall of 2000 but have been decreasing since with the lowest levels occurring in fall of 2004 (Figure A5.23).

Special Area #2 has the greatest number of wells at 1,555 thus indicates high dependence on having adequate groundwater supply (Figure A5.20). At least four new water wells were established for agricultural use in 2000 and 2001 in Special Area #2 (Bell, p. comm. 2007). The large number of groundwater wells in Special Area #2 illustrates a historic adaptation to insufficient surface water supplies.

5.1.1.2.3 Outlook

Four observation wells are located relatively close to the Rural Municipality of Rudy (Figure 3.6). Conquest 500 and 501 are shallow aquifers. Conquest No, 500 is located in an intertill aquifer and Conquest # 501 in a surficial aquifer. Neither is considered to be affected by human activity. Conquest 500 has had increasing water levels since 1972. Water levels decreased during the 2001 to mid-2005 period but have rebounded to the highest level recorded in mid-2006. Conquest # 501 has strong seasonal fluctuations. This observation well had its lowest water level in the spring of 2002, the second lowest was in the spring of 1990 and its third lowest in the spring of 2005. The highest water levels were in 1994, 1996 and 1999. A dramatic decrease in water levels occurred between 1999 and 2005. The years 2001 and 2002 had very little spring recharge (Figure A5.24).

Conquest # 503 is located in a shallow surficial aquifer and is influenced by human activity. This aquifer has seasonal fluctuations. Its peak water level occurred in 1997 and its lowest level was in 1972. Between 2000 and 2005, water level declined with little to no seasonal recharge in 2001 and 2002. 2005 had the lowest water level since 1991. The water levels rebounded by approximately one metre by 2006 (Figure A5.24).

Conquest # 504 is an immediate depth intertill aquifer and is influenced by human activity. This well has seasonal recharge. This well had a dramatic decline in water levels between 1980 and 1990. The levels increased slightly by approximately 0.5 m between 1990 and 2000 but then declined until the fall of 2004 (Figure A5.24).

The Rural Municipality of Rudy had 85 groundwater wells established during the 1935 to 1999 period (figure A5.21). At least 3 new wells were established for agricultural use between 2000 and 2006 in the RM of Rudy (Bell, p. comm. 2007). This relatively low number of groundwater wells may indicate that most of the agricultural community in the RM of Rudy relies on surface water supplies.

5.1.1.3 Dugouts

Dugouts are an essential part of the agricultural community, especially for the producers with livestock operations. Dugouts are mainly used to supply rural domestic and livestock water needs as well as water for crop spraying. Over much of the Canadian Prairies agricultural region, water level or lack there of in dugouts became a concern in 2001 and 2002 (Wittrock 2005).

5.1.1.3.1 Taber

In 1999, there were 1237 dugouts in the MD of Taber (Figure A5.20) (PFRA – AAFC 2007c). In the spring of 2000, the dugout levels were only one quarter full. The dugouts were dry by the fall of 2000 and remained there through 2001. The spring of 2002 had the dugouts in the southern half of the municipal district with one quarter full of water and the northern half, the dugouts remained dry. The June 20th, 2002 survey indicated that the dugouts were full, the August 6th survey had the dugouts three quarter's full and the October 28th, 2002 dugout showed that most of the Municipal District's dugouts were only one quarter full (Figures A5.25 to A5.28). For 2003, the dugouts were classified as "no water shortages anticipated".

5.1.1.3.2 Hanna

Of the three study regions, in 1999, Special Area #2 had the greatest number of dugouts at 5766 (Figure A5.19) (PFRA – AAFC 2007b). The April 2000 dugout survey indicated the majority of Special Area #2 dugouts were classified as one quarter full, although the eastern edge of the area was dry and the northern edge dugouts were classified as full. The May 2000 survey showed the majority of the dugouts were full. By the fall of 2000, the majority of the dugouts were only one quarter full with the eastern portion of the area dry and the northern region half full. In November 2000 the number of dry dugouts was increasing in the south and east and the number of half full dugouts composed the rest of the area (Figures A5.25 to A5.28).

The May 15th, 2001 survey indicated that most of the Special Area had dugouts with only one quarter full and the eastern portion had dry dugouts. By the summer of 2001, the majority of the Special Area had no water in the dugouts. This trend continued through 2002 although some of the dugouts in the southern and western portions of the area had water for the June survey.

The May, July and September 2003 dugout surveys indicated that "no water shortages were anticipated". The November 2003 survey indicated that "some water shortages were anticipated".

5.1.1.3.3 Outlook

The Rural Municipality of Rudy had the lowest number of dugouts of the three study regions at 179 (Figure A5.21). The dugout survey of 2000 indicates that the Rural Municipality of Rudy had dugouts that were three quarter full in the spring and early fall to half full in November. The dugout levels in spring and summer of 2001 remained at half full but by August in the east central portion of the RM was about one quarter full with the rest of the RM classified as having dugouts half full. By mid-September 2001, most of the dugouts were only one quarter full with some on the southern edge classified as dry (Figures A5.25 to A5.28).

The May 2002 survey indicates that the dugouts were only one quarter full and completely dry by June 20th, 2002. The water levels rebounded a bit by August when the dugouts were classified as one quarter full and by October 2002, the dugouts were one quarter to half full.

The spring of 2003, indicated that some water shortages were expected in the western half of the Municipality and no water shortages on the eastern half. This pattern continued through the growing season.

5.1.1.4 Municipal Water Supply and Use

5.1.1.4.1 Taber

Taber's potable water supply source is the St. Mary's Reservoir and canal system in the summer and the Chin Reservoir and a reservoir south of Barnwell in the winter (Prado 2006). Water usage in Taber has generally been declining between the 1994 and 2003 (Figure A5.29). This observation may be skewed because of the extreme low water usage in 2002, due in part to low water levels prior to June and from June onwards; there were high amounts of precipitation. Below normal water usage occurred in 2001 because water rationing was implemented due to the extremely low water levels in southern Alberta. Prior to 2001, water usage was at or above average.

5.1.1.4.2 Hanna

Hanna's potable water supply is the Red Deer River via the Sheerness Power Generating Station to Hanna (AlbertaFirst 2007a). Water consumption in Hanna for the 1990 to 2006 period was highest in 2001 at 490,422 m^3, 12% above average. The 2000 to 2003 inclusive period had above average water consumption (Figure A5.30). The growing season months had the greatest above average consumption with August 2001 having the extreme of 42% above average followed closely by August 2003 with 41% above average water consumption.

5.1.1.4.3 Outlook

Outlook's potable water supply source is the South Saskatchewan River. Water consumption for the 1984 to 2006 period of record was the highest in 2003 followed closely by 2001 and 2002 (Figure A5.31). Water consumption follows a seasonal cycle with the greatest occurring during the May to October period.

5.1.2 Insects and Pests

Grasshoppers can be a major pest in the Canadian Prairies. They are able to cause major damage to all types of vegetation both pasture and cropland. It has been documented that a moderate infestation of 10 grasshoppers per square metre can consume 16 to 60% of the available forage depending on stand (Saskatchewan Agriculture, Food and Rural Revitalization 2000). Wittrock et al. (2006) explain 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 to make an impact. The drought stressed crops and pasture land negatively impacted by grasshoppers.

5.1.2.1 Taber

The grasshopper forecast for the Municipal District of Taber in 1999 was light to very light. In 2000, the forecast ranged from light on the eastern edge to severe on the western edge of the District. The 2001 forecast indicated that grasshopper infestation would range from moderate in the south and east to severe in the northwest. Grasshopper numbers were projected to be light in 2002 and moderate in 2003. The decrease in grasshopper numbers in 2002 was related to the cool, wet spring in southern Alberta (Figures A5.32 to A5.33).

5.1.2.2 Hanna

Special Area #2 grasshopper infestation level forecast for 1999 was to have severe levels in the south to light levels in the north. By 2000, the majority of the Special Area had severe to very severe levels of grasshoppers. This level of infestation was projected to remain for 2001 and 2002. The cooler and somewhat moister weather in 2002 decreased the population slightly resulting in the levels projected for 2003 to be somewhat less severe but they were still expected to have moderate to very severe numbers (Figures A5.32 to A5.33).

5.1.2.3 Outlook

The Rural Municipality of Rudy was projected to have very light to light levels of grasshoppers for 1999 to 2003. The exact reason for the low numbers is not known by the authors but may have to do with slightly moister conditions than Special Area #2, different soil types and different crop types (Figures A5.32 to A5.33).

5.1.3 Wind Erosion

Wind erosion is a serious hazard in the Canadian Prairies because of impacts including the loss of topsoil, plant damage, air pollution, traffic accidents and clean-up costs (Wheaton 1992). The Science Council of Canada (1986) found that the average annual on-farm costs of wind erosion in the Prairie Provinces are approximately $249 million Wind erosion has been a very common occurrence in this area during dry periods.

5.1.3.1 Taber

Southern Alberta had many wind erosion observations but due to data limitations, it is unclear whether these were in the Municipal District of Taber. Many news articles discussed wind erosion events quite frequently (eight articles) in May, 2001 in southern Alberta. There were three articles in June of 2001, one in August of 2001, and one in September 2001. Only one article appeared in spring of 2002 but the dust storm was a contributing factor in a 10-car pile up (Williamson and MacGillivray 2002).

5.1.3.2 Hanna

No newspaper articles or Agriculture and Agri-Food Canada staff wind erosion observations were reported in Special Area #2. This was also the observation from producers. The producers did mention that previous wind erosion episodes (1930s and more recently 1970s) resulted in less summer fallow and more minimum tillage (Wandel and Young 2006).

5.1.3.3 Outlook

There were no newspaper articles or AAFC staff wind erosion observations reported in the Rural Municipality of Rudy. There was no mention of wind erosion issues in the producer interviews from the RM of Rudy (Pittman and Jeanes 2006).

5.1.4 Implications for Communities

The bio-physical impacts of the droughts had implications for the communities ranging from poor quantity pasture and crops, to lack of water, to crop and pasture land devoured by grasshoppers (Table 5.1 to 5.3). Many of the measured bio-physical impacts were noted by the agricultural producers and communities.

Table 5.1 Drought Impacts and Adaptations of Taber and Area Residents

Type of Respondents	Impacts				Adaptations		
	Physical	Biological	Economic	Social	Successful	Not Successful	Reason
The Community	-low water supplies		-In Alberta, the rich get richer and the poor are getting poorer	-The city people think the rural community should be doing more to conserve and the rural people think the city people should be doing more to conserve	-some people try to reduce their overall water consumption	-urban vs rural water users in who should be conserving more water	
Local Businesses	-Grain producers had low yields		-Poor crop year results in lower fertilizer acquisitions -Poor agricultural year impacted the local newspaper in that not as many advertisements were bought.				-Fertilizer industry recommended that farmers need to pre-plan and not put all their fertilizer on first thing in spring. They need put a little on in the spring then when the crop looks good put more on when they spray for weeds.
Water Utility	-2001 – extremely low water levels				-three different sources of potable water are utilized throughout the year. May to October water from the Saint Mary's Reservoir via the canal system, October to April, from a large reservoir south of Barnwell and from the Chin Reservoir. These are normally adequate. -water restrictions were imposed on town residents		Water levels were low because the St. Mary's Reservoir had undergone maintenance and the expected spring recharge did not occur resulting in inadequate water supplies.
Tourism Industry	No data available	No data available	No data available	No data available	No data available	No data available	No data available

Type of Respondents	Impacts				Adaptations		
	Physical	Biological	Economic	Social	Successful	Not Successful	Reason
Livestock Producers	-2001 – extremely low water levels	Native grass did not grow during dry years			-many moved cattle to foothills or to Saskatchewan for the summer months. -Grow own feed for winter. -more efficient irrigation system -dugouts, wells, access to river -off farm income -stopped raising cattle after drought and BSE crisis -fill dugouts once or twice a year from either irrigation canals or river -while irrigation water allocation water was reduced, water allocation for livestock remained unaffected		
Grain Producers	-2001 – extremely low water levels	-higher quality crops -fewer plant diseases in drought years	-increased energy costs due to increased irrigation		-extensive irrigation network -water allocation levels were reduced due to the low water levels in 2001 -moved water allocation amounts to higher commodity priced crops (e.g., sugar beets). -transferred (sold) water allocation to neighbouring farmers -examining ways to increase on-farm storage -technological improvements to the irrigation systems (converting canals to pipeline, low flow pivots etc) have increased water conservation and improved water usage -irrigation district ditch riders check to make sure only the amount of water allocated is the amount of water used	-crop insurance – called disaster “act of god” so would not pay compensation	

Type of Respondents	Impacts				Adaptations		
	Physical	Biological	Economic	Social	Successful	Not Successful	Reason
					-fill dugouts once or twice a year from either irrigation canals or river -crop insurance and other government programs -off-farm income		
Mixed Farms	-shortage of water	-higher quality crops -fewer plant diseases in drought years	-increased energy costs due to increased irrigation -borrow more money from financial institution		-off-farm income -irrigation -fill dugouts once or twice a year from either irrigation canals or river -fill below ground cisterns with treated potable water from Taber. -crop insurance, and other government programs	-government programs do not help a diversified farm because they look at total income	
Local Governments	-2001 – extremely low water levels				-sent out information on water conservation measures in utility bills	-water conservation is an ongoing challenge	
Large Businesses	-2001 – extremely low water levels	-decreased acreage of sugar beet production			-water allocation levels were reduced due to the low water levels in 2001 -company imported more sugar can for refining -through water conservation measures and installing own water treatment plant have reduced water consumption to 1/3 of allocated water rights.		

Table 5.2 Drought Impacts and Adaptations of Hanna and Area Residents

Type of Respondents	Impacts				Adaptations		
	Physical	Biological	Economic	Social	Successful	Not Successful	Reason
The Residents of Hanna	-no water usage restrictions were imposed	-grasshoppers			-many residents conserved water on their own		-have a reliable supply of water
Local Businesses	No data available	No data available	No data available	No data available	No data available	No data available	No data available
Water Utility	-adequate water supply via pipeline from Red Deer River		-potential increase in town revenue through increased water usage		- Accessed stable water supply via pipeline from the Sheerness Power Generating Station which pipes in its water from Red Deer River. It was in place for the drought period. - potable water pipeline from Hanna to outlying communities -water reservoir would be viable for approximately 1 year without recharge		-pipeline was built because Hanna and other communities did not have a reliable source of potable water in the past
Tourism Industry	Golf course – low water levels but is able to access stable water supply		-increased costs through increased usage of town water		-Golf Course has obtained access to Hanna's reliable water source		
Livestock Producers	-low water levels in dugouts -found that ground water table has risen since irrigation systems were installed	-grasshoppers -little grass, hay, pasture -low quantity of grass and hay -calves and cattle getting sick (pneumonia) because they had to walk	-off-farm income -many producers receive 5 to 15 % of income from oil and gas wells on their land	-conflicts between producers due to water allocation issues	-Large number of dugouts, dams and wells -re-excavate dugouts to make them larger and less prone to water losses due to evaporation -installed shallow and deep (8 feet) pipelines to move water to where it was required. The pipelines were either bought by individual producers or the Special Areas allowed the pipelines to be rented -limit livestock access to dugouts	-grasshopper management -government programs – crop insurance, CAIS, -irrigation – ran out of water -irrigation – water conflicts between users -irrigation – expensive	-government programs do not always allow for the best / most appropriate adaptation measures to be implemented -community pastures were only allowed for a shortened

Type of Respondents	Impacts				Adaptations		
	Physical	Biological	Economic	Social	Successful	Not Successful	Reason
		long way to get water -dugout water gets stale, calves will not drink it and get sick due to dehydration			-hauled water to dugouts -install "water on demand" watering systems for cattle to decrease wastage -some producers were able to access reliable water for irrigation through pipeline utilized by the Sheerness Electric Power Generating Station -irrigation for hay crops -want another pipeline from the Red Deer River installed to increase stable water supply for agricultural community but there is a moratorium on expanding water transfers -carry at least one years worth of feed -bought feed -culled cattle – the older ones went first -re-located cattle - some went to Saskatchewan -multiple land bases in different micro-climates -utilized good rangeland management practices to decrease the negative impacts that can result due to over grazing -split pasture around water source so can move cattle to where feed is available as well as water -expand land area -stock fields at drought tolerance levels -fed later into year -keep cattle off native pasture until later into year to allow for longer fall grazing	-irrigation – expansion limited due to limited access to water sources -low water levels did not allow for irrigation to be utilized to the largest extend -irrigation – converted to water efficient nozzles	(breading season) grazing period to minimize negative impact on pasture - water conflicts arose when producers would utilize water for irrigation that wasn't allotted to them resulting in downstream producers not having water for their irrigation requirements -BSE did not have as big of impact as it might have due to many older cows had already been culled -grasshopper management did not work very well because there were too many

Type of Respondents	Impacts				Adaptations		
	Physical	**Biological**	**Economic**	**Social**	**Successful**	**Not Successful**	**Reason**
					-utilize tame grass in early spring to feed cattle -pasture insurance -government programs -utilize community pastures (managed by Special Areas) -green cover program – converted marginal cultivated land back to tame and native pasture -government assistance (PFRA) in designing pipeline systems, irrigation systems -utilizing Farm Environmental Program -getting out of ranching		
Grain Producers	-limited or no surface water -little precipitation	-grasshoppers -low crop yields	-off-farm income -did not harvest in 2002		-more Chemical Fallow in region -seeded more drought tolerant crops -crop insurance -getting out of grain production -want another pipeline from the Red Deer River installed to increase stable water supply for agricultural community but there is a moratorium on expanding water transfers -irrigation – converted to water efficient nozzles	-government programs -irrigation – expensive -irrigation – expansion limited due to limited access to water sources -grasshopper management	-Historically soils would erode due to wind or water erosion. In the droughts of 2001 to 2003 there was little soil erosion -grasshopper management did not work very well because there were too many

Type of Respondents	Impacts				Adaptations		
	Physical	Biological	Economic	Social	Successful	Not Successful	Reason
Mixed Farms	-low quantity of grass and hay -irrigation – converted to water efficient nozzles	-grasshoppers	-off-farm income		-turned cattle into low yielding crops -seeding crop land back to native and tame pasture -getting out of farming altogether (retire) -want another pipeline from the Red Deer River installed to increase stable water supply for agricultural community but there is a moratorium on expanding water transfers	-government programs -irrigation - expensive -irrigation – expansion limited due to limited access to water sources -grasshopper management	-grasshopper management did not work very well because there were too many
Large Businesses			-oil and gas companies had to pay more for accessing and using water during the drought years		- Oil and gas companies – allow farmers to access water from pipelines - Sheerness Power Generating Station – pipeline from Red Deer River – allows agricultural producers to access it if the pipeline crosses their land – pipeline allows Hanna and other communities to access a reliable potable water source		
Local Government		-Community Pastures grassland suffered due to drought and grasshoppers		-had implications on livestock community that rely on community pastures but producers understood	-shortened grazing season to breeding period -sent yearlings home first then the breeding cattle -have water lines to fill dugouts from Sheerness Electric generating station -rotational grazing -decreased the number of cattle accepted in 2003 to allow pasture to regenerate -stock community pastures to carrying capacity -dug deeper dugouts so are now catching 80% o median flow and	-grasshopper management	-grasshopper management did not work very well because there were too many

Type of Respondents	Impacts				Adaptations		
	Physical	Biological	Economic	Social	Successful	Not Successful	Reason
					decreasing the amount of water loss due to evaporation -Chemical fallow has decreased the number of dust storms in the Special areas. -large amounts of land has been converted back into grass		
Federal Government					-have mapped the groundwater systems in most counties of Alberta giving producers knowledge of what groundwater resources are available to them -have assisted the agricultural community with advise and money on permanent water structures, irrigation strategies, pipeline strategies -various assistance programs	-various assistance programs	-assistance programs do not always allow for the best adaptation measure to be implemented
Non-government Organizations	-70% of the Ducks Unlimited Canada projects (water retention projects) were dry by 2003				-Ducks Unlimited Canada water retention projects are usually good for a 2-3 year drought -DU allows landowners to pump water from their reservoirs for domestic use and watering cattle but not for irrigation purposes		

Table 5.3 Drought Impacts and Adaptations of Outlook and Area Residents.

Type of Respondents	Impacts				Adaptations		
	Physical	**Biological**	**Economic**	**Social**	**Successful**	**Not Successful**	**Reason**
The Community	-No municipal water restrictions imposed						
Local Businesses		-Poor crop	-Crop broker had to go find work where there was a crop in 2001 -the drought affected implement dealers later when farmers would have normally bought new equipment. -low yield and commodity prices resulted in farmers not buying new equipment -irrigation companies do more business when commodity prices are high. They also do more business during drought years when farmers buy irrigation equipment by borrowing money.		-Crop Broker has maintained client base in the area established in 2001. -Large corporate farms being formed.		
Water Utility	-extended droughts puts stress on infrastructure to keep up with demand for water		-drought years are good revenue for the town. Higher consumptions results in surpluses.		-try to encourage conservation.	-conservation is bad because of the potential decrease in town revenue	
Tourism Industry					-Diefenbaker Lake allows for tourism and economic benefits to Outlook		
Livestock Producers		-poor yields where irrigation is not utilized			-Borrowed money -pulled cattle off dryland pastures in 2001 and 2002 and put them on irrigated pasture.		

Type of Respondents	Impacts				Adaptations		
	Physical	Biological	Economic	Social	Successful	Not Successful	Reason
Market Garden Producers		-Insects (cabbage moths, root maggot, flea beetle)	- did not hire on farm labour		-Irrigation -Off-farm income -Use Outlook potable water supply	-irrigation –high labour requirements, -water rationing in 1988 but Broderick reservoir had capacity upgrades	-do not use crop insurance. Are self insured for 1 year
Grain Producers		-dry conditions usually result in better quality crops but the fall of 2002 was a wet harvest decreasing quality -grasshoppers	-did not hire on farm labour -high input costs with no payback -decreased the amount of fertilizer. -slight increase in chemical fallow. -planted more wheat and those crops that had lower input costs	-Some producers thought the1930s had a better social network as everyone was in the same predicament therefore better able to relate to one another.	-purchases of new equipment and other items are kept to a minimum -use minimum tillage -got off farm income when drought of 1988 occurred -crop insurance -hail insurance -off farm income -potable water distribution system -irrigation is worth the money as it makes a crop yield level reliable. Irrigation removes much of the risk. -had converted to centre pivot irrigation from the original flood irrigation because it improves water conservation and eliminated some of the salinity problem. -previous to the 2001/2002 drought, irrigation district upgraded the water distribution system by	-Irrigation – "no one appears to be making a fortune irrigating so why go into it?" -spot hail insurance -older farmers may not want to upgrade or expand irrigation if they are thinking of retiring in the next 5 to 10 years because of the expense. -some irrigated land becomes too saline to grow high value crops so land is turned into forage crops. -producers were more self sufficient 30 years ago	-economics of irrigating are not apparent -crop insurance removed spot hail insurance resulting in change in the way producers could claim hail insurance. -Irrigation farmers not allowed to claim dryland crops only. They have to incorporate their irrigation yield. -Broderick reservoir was upgraded after the 1988 drought -many farmers are on the Outlook potable water distribution system making them less susceptible to poor quality

Type of Respondents	Impacts				Adaptations		
	Physical	Biological	Economic	Social	Successful	Not Successful	Reason
					installing lining to conserve water. -off farm income -crop diversification -dryland farming – much of it is minimum till or chemical fallow -Borrowed money -after 1988, seeded highly erodible land to grass to stop wind erosion -got out of farming or rented out their land	because now there are higher input costs and a higher cost of living.	groundwater or low quantity surface water. -Irrigation District #1 increased acreage by 15% during 2001 and 2002.
Mixed Farms	-Wind in 2001, 2002 and 2003 resulted in not enough irrigation water being applied to crops	-grasshoppers -poor yields	-didn't hire on-farm labour		-crop insurance -fill dugout with water from irrigation wells and is used as potable water supply -Irrigation -off-farm income -trying to expand the irrigation land base -use minimum tillage -purchases of new equipment and other items are kept to a minimum -off farm income -Borrowed money	Irrigation – labour intensive, costly	-crop and hail insurance is not liked because they took away spot hail insurance, increased the premiums and guaranteed coverage has dropped -problems with irrigated acres and crop insurance
Local Governments	No data available	No data available	No data available	No data available	No data available	No data available	No data available
Large Businesses	No data available	No data available	No data available	No data available	No data available	No data available	No data available

5.1.4.1 Taber

The bio-physical impacts of the 2001 and 2002 droughts on Taber and the Municipal District of Taber were exacerbated by the low water supply provided by the St. Mary's Reservoir. This region is dependent upon irrigation and water supplied from the extensive canal system. The low water levels affected agriculture, industry, municipal government and individuals (Prado 2006). The low water supply resulted in several adaptation measures being implemented in the region. These are discussed in section 6.

The dry conditions resulted in grain producers having lower than average yields but generally higher quality. Producers also found fewer plant diseases in the drought years (Prado 2006). The dry conditions lead to native grass not growing well in the dry years (Prado 2006).

5.1.4.2 Hanna

The drought years impacted Hanna and Special Area #2 with lower than normal water supplies with a large number of dugouts being classified as dry (PFRA-AAFC 2006b) and the majority of the Ducks Unlimited Canada water retention projects were dry by 2003 (Wandel and Young 2006). The low water levels did not allow for irrigation to be utilized as much as normal (Wandel and Young 2006). The situation became even worse with the high number of insects, especially grasshoppers (Alberta Environment 2001 and Wandel and Young 2006). The dry conditions resulted in low quantity of grass and hay for livestock producers both privately and in the community pastures (Wandel and Young 2006). The dry conditions also resulted in low crop yields for grain producers (Wandel and Young 2006). The result is both ranchers and farmers were severely impacted.

The dry conditions negatively impacted livestock in several ways. Impacts included cattle having to walk long distance to obtain water and this resulted in a high potential for illness. Illness also occurred because of poor quality dugout water and dehydration (Wandel and Young 2006).

Adequate potable water was available to the town of Hanna and those communities and farmers located on the water pipeline. There were also adequate water supplies for the golf courses able to access the pipeline water (Wandel and Young 2006).

5.1.4.3 Outlook

Outlook and the Rural Municipality of Rudy's physical impacts of the droughts were minimized due adequate water supply from the South Saskatchewan River and to the extensive irrigation and pipeline networks in the RM. However, if a farmer was a dryland farmer, the droughts had serious implications including dry dugouts (Pittman and Jeanes 2006). Some producers said that the strong winds during the drought years resulted in not enough irrigation water being applied to the crops due to drift (Pittman and Jeanes 2006). Most of the summer in 2001 and 2002 had average wind speed except for May 2001 and 2002. These months had above average wind speed at Saskatoon (the closest available climate station with wind speed information). May

2001 had 15 days when wind speeds were greater than 51 km/h. May 2002 had 13 days when wind speeds were greater than 51 km/h (Beaulieu and Wittrock 2002 and 2003). The producers in the RM of Rudy had trouble with grasshoppers during the drought years (Pittman and Jeanes 2006) even though the 1999 to 2003 were supposed to have had light grasshoppers numbers.

5.2 Socio-Economic Impacts

Socio-economic impacts of the 2001 and 2002 droughts on the communities of Taber, Hanna and Outlook are reported in this section. Although the original intent was to estimate these impacts in a quantitative manner for all concerns (producers, residents, businesses, and governments), available data limited this investigation to an estimation of cost of the droughts on agricultural producers. These impacts on agricultural producers in the region (Municipal District, Special Area, or Rural Municipality) are based on a quantitative assessment of the farming situation during these years vs. other (non-drought) years. Investigation was attempted to cover all major enterprises in the region surrounding the communities. Here, two complications arose: One, information on impact of the droughts on livestock enterprises was not easily available. Two, in all three communities / regions, agricultural production is a result of both irrigated and dryland production systems. The droughts may affect irrigated production differently than that under the dryland production system. These needed to be taken into account in estimating the overall economic cost of the droughts to the three communities through changes in income level in the surrounding region. No attempt is made here to estimate the income of the people residing within the communities since this data required primary surveys.

The impacts of the two drought years in this section are presented in two parts: Part one (Section 5.2.1) describes the farm income level impacts. These are sub-divided into two sub-parts: Crop production related and livestock production related. To the extent possible (subject to data availability), these impacts are estimated in a quantitative manner. The other part of impacts deal with other impacts (on local business, residents of the communities, and local governments), and are presented in Section 5.2.2. These latter types of impacts tend to be qualitative in nature.

5.2.1 Impact on Farm Incomes

Following the conceptual framework presented in Chapter 2, it was stipulated that loss of agricultural income will be instrumental in increasing the vulnerability of the community. Thus, knowledge of change in the farm income situation during the drought years was considered important and therefore, examined in this section.

Most of the farm income in the study region is derived from the sale of crop and livestock products. Droughts can adversely affect crop production resulting in lower sales, and thus lower income to the farm business. Reduction in the availability of some crop products may also have implications for livestock production on farms during these periods. For example, reduced availability of home-grown feed grains may force the producers either to purchase more feed grains (adding to the cost of the operations of these enterprises) or dispose off some livestock. Same effect would be hypothesized for forage availability (reduced pasture carrying capacity or availability of forage for winter feeding). Selling a part of the cattle or calves herd would result in higher income in the short-run but could have serious adverse income effect in the future years.

In this section, farm income impacts of the 2001 and 2002 drought are examined individually for crop and livestock production. It is assumed that other products do not change as a result of drought[17]. However, typically disaster payments from the governments may increase, which will cushion the fall of income somewhat. However, the estimates shown in this study, effect of government payment have been excluded. Discussion of farm income from crops is described in Section 5.2.1.1, which is followed by those on livestock production in Section 5.2.1.2.

5.2.1.1 Crop Production

Crop production in the study regions comes from a combination of dryland (rainfed) and irrigation production systems. However, this situation varies from community (region) to community (region). As noted above, during a drought period, crops under these systems perform differently. Typically under the dryland production system, crops depend on natural precipitation over and above evaporation. During the drought period, precipitation is lower and evaporation increases, resulting in lower soil moisture. Even if soil moisture at the seeding time is adequate for germination, plants may wilt under heat stress if sufficient precipitation does not occur during the growing season. All these climate events may lead to lower yields. Unless price of their products increases due to lower supplies, farm income would be lower. However, since producers in Canada (and in these regions) face an international market, a change in regional production does not lead to an adjustment in market prices. Thus, farm income change is primarily as a result of change in production level available for sale[18].

Under irrigated production systems, supplementary irrigation is used for providing water at the time it is needed by plants. Therefore, yield of crops does not suffer, and conceptually could increase. However, the cost of providing the water may be high. Higher demand for irrigation water may also have implications for other water users, particularly those that are being serviced from a common pool (reservoir). However, it is hypothesized that farm income under irrigated conditions may be higher for some crops.

The economic impact of the droughts on agricultural producers was measured as a change in producer surplus during a drought year relative to some normal period which is considered as the base year. Producer surplus is the difference between gross returns from agricultural production and respective cost of producing the same goods. Total gross return from agricultural crop production is simply a weighted product of area under a crop and its respective value per unit of land area. Cost of production, in this context, is a sum of all variable and fixed costs, again weighted by land ares under different crops.

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[17] This assumption is based on the land use data where area under orchards, vinyards, or other perennial crops is very small.

[18] Typically, producers in the Prairie Provinces also deplete past inventory of gains and oilseeds during period of lean production. This adds to the current income of producers.

5.2.1.1.1 Taber

Since the town of Taber is a service center and a place for agricultural processing industries, much of the drought impacts would be felt through those on the surrounding area – MD of Taber. Total cropland area in the MD of Taber for the 2001 year was reported to be 489,655 acres. This area is about 26.4% of the total cropland area in Alberta CD 2, which was reported to be 1,857,530 acres[19]. Table 5.4 illustrates the land use trend in the past 20 years in Taber MD

Table 5.4 Land Use in the MD of Taber, 1981-2001

Land Use Type	Area in Acres during				
	1981	1986	1991	1996	2001
Total Area of Farms	779,306	892,168	968,771	995,398	997,569
Total Area under Crops	422,586	452,872	437,467	482,402	489,655
Total Summerfallow	149,406	132,104	124,743	122,733	107,948
Tame or seeded pasture	48,396	33,904	52,597	51,403	61,292
Natural Pasture	--	254,800	329,989	319,307	320,978
Other land	10,113	8,976	23,975	19,553	17,696

Source: Statistics Canada (2002)

Within the MD of Taber there is an increasing trend in total farm area and in area under crops. However, there was a slight drop in the cropped area in the MD during 1986 to 1991, but it recovered in the next census period and has been increasing ever since. Consistent with increase in farm area, that under tame and native pastures has also increased. However, practice of summerfallowing is on a decline in the MD, which is a trend in all Prairie Provinces.

Table 5.5 shows a summary of distribution of total crop area by crops during 1981 to 2001 in MD of Taber. Durum wheat area represented the largest share of the total cropped area in this region in 2001. However, in all the other years, spring wheat was the dominant crop in the region. Other crops in order of importance in 2001 were barley, alfalfa, potatoes and dry beans.

Total cropped area shown in Table 5.5 is a composite of dryland and irrigated areas under each crop. To show the overall impact of the droughts, these needed to be disaggregated by the two production systems. This proved to be somewhat more challenging. The reason for this was lack of data on irrigation for the MD of Taber. As a poor substitute, data for Alberta CD 2 were collected. In this CD, irrigated area in 2001 was reported to be 811,907 acres, which was 43.7% of the total cropped area.

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19 All data obtained from Statistics Canada (2002).

Table 5.5 Distribution of Total Crop Area by Crops, Taber MD, Alberta, 1981-2001

Crops	Area in Acres During				
	1981	1985	1991	1996	2001
Total wheat	244,597	278,559	250,280	258,982	215,826
Durum wheat	53,799	69,940	--	92,367	106,691
Spring wheat (excluding durum)	158,998	180,886**	169,929	163,798	105,961
Barley	63,969	46,899	43,455	68,619	62,074
Alfalfa and alfalfa mixtures	31,797	--	50,909	35,803	47,434
Potatoes	8,702	12,379	15,674	18,153	37,309
Total dry field beans	2,215	3,862	10,206	11,530	34,850
Sugar beets for sugar	1,043	5,688	--	29,636	18,732
Other dry beans	--	3,732	--	11,530#	16,337
Dry field peas	3,008	3,572	2,975	4,388	15,044
Canola (rapeseed)	5,455	11,865	15,697	29,636	13,992
Chick peas	--	--	--	--	12,529
All other tame hay and fodder crops	1,492	--	3,435	7,284	11,947
Corn for silage	7,505	5,688	2,844	3,193	6,314
Dry white beans	--	--	0	1,169	5,984
Oats	6,221*	4,014*	3,624	4,385	5,087
Winter wheat	12,920	27,733	--	2,817	3,174
Forage seed for seed	--	414	680	927	2,619
Mixed grains	299	578	1,920	x	2,510
Lentils	195	445	435	2,540	1,846
Mustard seed	7,062	6,463	2,611	4,355	1,640
Corn for grain	1,043	1,709	2,481	786	1,624
Total, rye	10,662	3,604	1,185	635	1,309
Fall rye	9,812	3,042	940	635	1,164
Flaxseed	4,801	4,280	4,850	2,899	618
Sunflowers	0	2,650	937	0	399
Triticale	230	0	--	260	150
Spring rye	850	562	245	0	145

-- Data not reported
X Data not available
* Oat for fodder and oat for grain were added together in 1981 and 1985.
** To calculate the spring wheat total spring wheat and durum wheat were subtracted in 1985
# Total white beans and other colored beans were added together to calculate other dried beans in 1996.

In order to estimate the drought impacts, a number of simplifying assumptions were made:

1. It was assumed that irrigation is distributed ubiquitously within the CD. Thus, the irrigated area in the MD of Taber would also be 43.7% of the total cropped area.

2. Irrigated crop patterns in the MD of Taber follow closely those in the Oldman River Sub-basin of the South Saskatchewan Basin. These data are shown in Table 5.6.

3. These data are for 2001, and an assumption that these parameters have not changed during 2002 was made.

It was assumed that the appropriate accounting stance for this analysis is that of producers. Thus, a private accounting stance was used. All impacts are those that are realized by the producers themselves with no spill-over effects on the rest of the society included here. Furthermore, not having appropriate information and data, it was assumed that availability of water for irrigation has not been affected by the drought conditions[20].

Applying the first assumption, area irrigated in the MD of Taber was estimated at 214,023 acres (or 86,614 ha). The crop mix under irrigation, as shown in Table 5.6 for the Oldman River sub-basin, was applied to this region. Major crops under irrigation according these data include forages (alfalfa hay, alfalfa silage, timothy hay, triticale silage, barley silage, corn silage, grass hay, green feed, tame grass, and pastures), and cereals (barley, durum wheat, spring wheat, winter wheat, oats, and Canada Prairie Spring wheat). Forages commanded almost half of the total area under irrigation (49.5% of the total), whereas cereals and oilseeds claimed another third of the total (37.4%) under irrigation. Of the remaining area, specialty crops (sugar beets, potatoes, beans, and peas) comprised of 12.5% of the total cropped area in the MD of Taber.

Estimated irrigated area for the MD of Taber for a given crop was deducted from the total cropped area as shown in Table 5.5 for the year 2001. Furthermore, as noted earlier, it was assumed that this cropping pattern did not alter during 2002.

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[20] It is realized that it may be an unrealistic assumption, since in the South Saskatchewan River Basin, there are reports that drought affected water availability as some reservoirs were not filled to the full safe level. As a result, some irrigation districts in Alberta may not have been provided with enough water to sustain irrigation at historical levels. In some of these areas, water trading may have taken place as a result, which could affect the magnitude of drought impacts shown in this study.

Table 5.6 Irrigated Cropped Area (in ha.) in The Oldman and Red Deer Sub-basins of the South Saskatchewan River Basin, Alberta, 2001

CROPS	OLDMAN	RED DEER
Alfalfa Hay	35,783	29,311
Alfalfa Silage	2,955	1,263
Timothy	9,763	3,233
Triticale Silage	2,330	747
Barley	28,497	13,106
Barley Silage	21,287	5,450
Corn Silage	9,672	2,022
Grass Hay	6,697	2,660
Green Feed	2,041	2,880
Native Pasture	2,130	187
Canola	15,150	8,012
Flax	1,210	909
Fresh Peas	1,429	315
Dry Beans	9,209	3,260
Tame Grass	13,935	18,095
HRS Wheat	13,833	8,241
CPS Wheat	1,248	3,276
SWS Wheat	6,912	5,169
Durum	12,781	3,387
Winter Wheat	914	291
Potatoes	9,815	2,900
Sugar Beets	6,541	2,670
Oats	1,052	1,397
Summerfallow	307	1,007
Total	215,491	119,790

Source: AAFRD (2003)

Next step in the estimation of cost of the two droughts was to assemble information on the following items:

- Cost of production of various crops grown under irrigated production system in the region;
- Cost of production of various crops grown under dryland production system in the region;
- Yield of crop(s) under normal and drought conditions of 2001 and 2002 in the region;
- Farm level price of crop products in the region; and,
- Increased cost of production under drought conditions.

The first set of data (Cost of production of various crops grown under irrigated production system in the region) were obtained from AAFRD (2003) and adjusted for year 2001 and 2002 using Farm Input Price Index obtained from Saskatchewan Agriculture and Food (2007a)[21].

The second set of data (Cost of production of various crops grown under dryland production system in the region) were also obtained from AAFRD (2003) and adjusted for year 2001 and 2002 using Farm Input Price Index obtained from Saskatchewan Agriculture and Food (2007a).

The third set of data (Yield of crops under normal and drought conditions of 2001 and 2002 in the region) was obtained from Kulshreshtha (2006). These estimates were based on a water production function for ten important crops[22] grown in the Prairie Provinces. These production functions were developed by Heikkila et al. (2002). It was assumed that for other crops not specifically included in this set, a proxy crop included in this set can be used. This proxy was set to the crop fairly similar in nature to the crop included in the water production data set.

The fourth set of data (Farm level price of crop products in the region) was obtained from Kulshreshtha (2006). It was assumed that price of a given crop would not change as a result of the drought conditions. This is based on the perfectly elastic demand function for all Canada crops. Dryland yields were obtained from Statistics Canada (2005a and 2005b).

The fifth set of data (Increased cost of production under drought conditions) could not be collected as this information is not routinely reported. Although estimation of this cost could be made if water requirements by crops under normal and drought conditions are known, unfortunately such data are not available either. This remains to be a major weakness of the approach used to estimate the economic cost of the drought in the region. However, it should be noted that the drought impacts, as reported here, are a little optimistic (on account of additional costs are excluded). Actual impact would likely be lower than the values shown here.

Using the above methodology, estimated of the impact of the droughts of 2001 and 2002 on value of crop production and resulting net farm income were made. These estimates are shown in Table 5.7.

According to the estimated impacts, the two droughts in the MD of Taber were equally devastating. Cost of the drought in the MD of Taber in 2001 was $7.48 million, whereas in 2002 it was slightly lower at $6.84 million. In both the years, the damage was cushioned because a large part of the area is under irrigation. If irrigation did not exist, for every acre, producers would have lost $39.57 in 2001 and $36.76 in 2006. Thus, irrigation is a successful adaptation to drought since it can cushion the adverse impact which could have resulted otherwise. In fact, as shown by the positive value of $46.37 per acre for irrigation farms, yields of various crops are higher during drought conditions. Thus, irrigation helps producers increase their net cash income

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[21] Since the Farm Input Price Index is for western Canada, it applies equally to Alberta and Saskatchewan.

[22] Crops included here were: alfalfa, barley, barley silage, canola, dry beans, tame grass, spring wheat, soft while wheat, potato, and sugar beet.

position during the drought periods unless availability of water for irrigation is in short supply and irrigation of certain crops cannot take place.

Table 5.7 Economic Impact of the 2001 and 2002 Droughts on Crop Production in the MD of Taber

PARTICULARS	2001 DROUGHT		2002 DROUGHT	
	Irrigated Crop Production	Dryland Crop Production	Irrigated Crop Production	Dryland Crop Production
Change in Farm Net Income (Million $)	$6.05	-$13.53	$6.05	-$12.89
Total Change in Farm Net Income (Million $)	-$7.48		-$6.84	
Impact in $ per Acre	$46.37	-$38.57	$46.37	-$36.76
Impact in $ per ha	$114.58	-$95.31	$114.58	-$90.83
Overall Impact of Drought $ per acre	-$15.53		-$14.21	
Overall Impact of Drought $ per ha	-$38.37		-$35.11	

5.2.1.1.2 Hanna

Economic impacts of the drought on crop production for Hanna were made following the same methodology as followed for the MD of Taber. A private accounting stance was assumed. Thus, the costs of the two droughts are those borne by the agricultural producers in the region. The region selected for analysis was the Special Area #2. This surrounding region of Hanna is predominantly agricultural, and production is mostly under dryland production systems. The exact magnitude of irrigation is not known, although it is reported that some producers near water courses do withdraw water for irrigation in this region.

The Special Area #2 is located within the Census Division # 4 of Alberta. The total area in cropland within the Special Area # 2, for the 2001 year was reported to be 355,880 acres out of a total cropland in the Census Division 4 of 1,148,371 acres. Thus around 31% of total cropland in the CD 4 is within the Special Area # 2, as shown in Table 5.8.

While total cropped area and total area of farms in the CD 4 and the Special area # 2 were increasing from 1981 to 1996, there was a 7.4% decrease in total area of farms in Special Area # 2 by 2001. It appears that this decrease may have been as a result of increased area under tame or seeded pasture.

Data on irrigated area in the Special Area # 2 are not available, although it has been suggested that some producer do irrigate their crops. Lacking this data, a surrogate method was developed. Data on irrigated area for the Alberta CD # 4 were obtained. This area was reported to be 24,808 acres, of the total area under crops of 1,148,371 acres (per Table 5.8). Thus, 2.16% of the area in the CD is irrigated. Using this proportion, irrigated area for the Special Area # 2 was estimated at 7,688 acres. Crop mix for the Red Deer sub-basin of the South Saskatchewan River Basin was used to estimate area under various crops in the Special Area # 2. This crop mix is shown in Table 5.6.

Table 5.8 Land Use in the Special Area # 2 and CD 4, Alberta: 1981-2001

Land Use	Special Area #2				
	1981	1986	1991	1996	2001
Total Area of Farms	2,022,848	2,140,246	2,187,781	2,232,517	2,067,350
Total Area under Crops	310,345	367,682	345,545	364,322	355,880
Total Summerfallow	183,303	195,579	179,775	153,407	130,290
Tame or seeded pasture	83,880	67,493	148,065	159,358	164,858
Natural Pasture	--	1,468,948	1,450,386	1,524,040	1,352,669
Other land	11,889	14,695	64,010	31,390	63,653
	CD # 4				
Total Area of Farms	4,804,592	4,994,310	5,016,535	4,968,599	4,790,253
Total Area under Crops	963,779	1,127,039	1,129,558	1,119,148	1,148,371
Total Summerfallow	652,183	682,452	623,629	559,511	494,358
Tame or seeded pasture	298,672	199,031	337,793	360,446	386,145
Natural Pasture	--	2,875,915	2,780,612	2,815,120	2,634,926
Other land	28,902	32,682	144,943	114,374	126,453

Table 5.9 shows the distribution of the total crop area by major crops in 2001 in the Special Area # 2. These data were obtained from Agriculture Census years for the region (Statistics Canada, 2005a and 2005b). As shown in the Table 5.9, area of spring wheat represents the largest portion of the crop acreage at 81,183 acres, which counts for 22.8% of total crop land. However, the area under this crop showed a significant drop in 2001 compared to 1996.

In order to assess the impact of drought, data on crop yields are needed. These were obtained from the Statistics Canada (2005a and 2005b). The 2001 winter and spring were one of the driest winters and spring with limited precipitation on record in Alberta and the dryness continued through most of the 2001 crop season, particularly in the Southern Region which includes the area surrounding Hanna and the eastern areas of the Central Region. As a result crop season began with dry conditions.

Cost of production for various crops was the same as used for the MD of Taber, since these data area available only at the soil type level for the province as a whole. Using all these sets of information, impact of the drought was estimated. Results are presented in Table 5.10.

Table 5.9 Distribution of Total Crop Area by Crops, Special Area # 2, Alberta, 1981-2001

Crops	1981	1986	1991	1996	2001
Total wheat	169,418	204,426	178,666	143,521	104,061
Spring wheat (excluding durum)	152,377	185,387**	153,953	119,335	81,183
Alfalfa and alfalfa mixtures	27,936	-	32,772	61,625	78,152
Oats	49,269*	48,498***	46,039	44,937	44,010
Barley	14,247	26,063	26,890	35,237	43,490
All other tame hay and fodder crops	19,471	60,358	21,589	25,925	39,091
Mixed grains	2,458	2,499	12,025	4,581	13,896
Total, rye	16,877	17,240	17,371	11,055	10,868
Canola (rapeseed)	840	4,594	5,637	23,625	8,740
Fall rye	10,641	11,496	7,587	6,956	5,991
Spring rye	6,236	5,744	9,784	4,099	4,877
Triticale	3,383	643	660	1,345	4,534
Dry field peas	0	0	0	675	3,163
Mustard seed	190	788	x	6,920	2,232
Total, dry field beans	0	0	0	0	1,832
Chick peas	--	--	--	--	1,832

- Data not reported
x Data not available
* and *** Oat for fodder and oat for grain were added together in 1981 and 1985.
** To calculate the spring wheat area in 1985, drum wheat area was subtracted from the total.

Table 5.10 Economic Impact of the 2001 and 2002 Droughts on Crop Production in the Special Area # 2, Alberta

PARTICULARS	2001 DROUGHT		2002 DROUGHT	
	Irrigated Crop Production	Dryland Crop Production	Irrigated Crop Production	Dryland Crop Production
Change in Farm Net Income (Million $)	$284,011	-$12,948,163	$284,011	-$24,924,197
Total Change in Farm Net Income (Million $)	-$12,664,152		-$24,640,185	
Impact per Acre ($)	$36.94	-$36.37	$36.84	-$71.58
Impact per ha ($)	$91.28	-$89.87	$91.28	-$176.88
Overall Impact of Drought per acre ($)	-$35.59		-$69.24	
Overall Impact of Drought per ha ($)	-$87.93		-$171.09	

The overall cost of the drought in the Special Area # 2 of Alberta was higher during 2002 than in 2001. On average, every acre of cropland lost $35.59 in 2001 as against $69.24 in 2002. Total loss in 2001 was $12.66 million, which increased to $24.64 million in 2002. Irrigation was not much of a cushion in the region on account of being relatively very small. Thus, drought had a more devastating impact on crop production in the region, and more so in 2002 than in 2001.

5.2.1.1.3 Outlook

Since the Outlook and its surrounding regions, RM of Rudy (# 284), are predominantly agricultural regions, drought impacts on crop production were estimated using a methodology similar to that followed for the other two regions. Again, as with the previous analyses, impact of the droughts did not include any spill-over effects on other industries.

Looking at the agricultural base of the region, both the RM and the Saskatchewan Census Division 11 were included. The total area in crops in the RM of Rudy, which houses the community of Outlook, for the 2001 Census year was 136,552 acres which is almost 5% of total cropland in Census Division 11 in Saskatchewan. Table 5.11 illustrates the land use trend in the past 20 years in the CD 11 and in the RM of Rudy (No 284). Here, crop acreage consistently represents the largest portion of land use. However, summerfallow area is less common than in the 1990s which reflects improved soil conservation practices. Tame or seeded pasture has increased slightly. Natural pasture has also increased.

Table 5.11 Land Use in Acres, Rural Municipality of Rudy and CD 11, 1981–2001

Land Use	**CD 11**				
	1981	1986	1991	1996	2001
Total Area of Farms	3,954,372	3,954,080	3,943,477	4,019,224	4,008,530
Total Area under Crops	1,943,526	2,236,079	2,245,409	2,523,951	2,763,090
Total Summerfallow	1,249,074	972,132	988,458	686,111	430,524
Tame or seeded pasture	117,874	691	123,666	159,257	189,692
Natural Pasture	N.A.	470,631	438,838	451,363	460,244
Other land	39,979	26,025	147,106	198,542	164,980
	R. M. of Rudy (# 284)				
Total Area of Farms	203,094	195,689	192,090	196,434	210,189
Total Area under Crops	104,825	109,383	105,701	119,753	136,552
Total Summerfallow	52,363	44,694	42,621	31,875	23,321
Tame or seeded pasture	4,426	11,782	14,115	15,758	17,818
Natural Pasture	N.A.	26,506	25,879	21,398	27,613
Other land	2,600	1,808	3,774	7,650	4,885

Outlook is called the 'Irrigation Capital' of Saskatchewan. This is because it serves the irrigation industry in the Lake Diefenbaker Development Area (LDDA). Most of the irrigation in this area was developed following the construction of the South Saskatchewan River Project[23]. According to Statistics Canada (2002), the RM of Rudy has 60,066 acres irrigated cropland. This constitutes almost 44% of the total cropped area in the RM.

23 For a description of the South Saskatchewan River Project, see Kulshreshtha et al. (1988).

As shown in Table 5.12, the dominant crops in the RM of Rudy (# 284) in 2001 were wheat, alfalfa and alfalfa mixture, lentils, canola, and barley. While total crop land had increased from 1996 to 2001, the land area under some crops like spring wheat, canola, and rye has decreased. At the same time, increases in area under alfalfa and alfalfa mixture, lentils, dry field peas, dry field beans, oat and potato were noted.

Table 5.12 Distribution of Total Crop Area by Crops, Rudy # 284-SK, 1981 – 2001

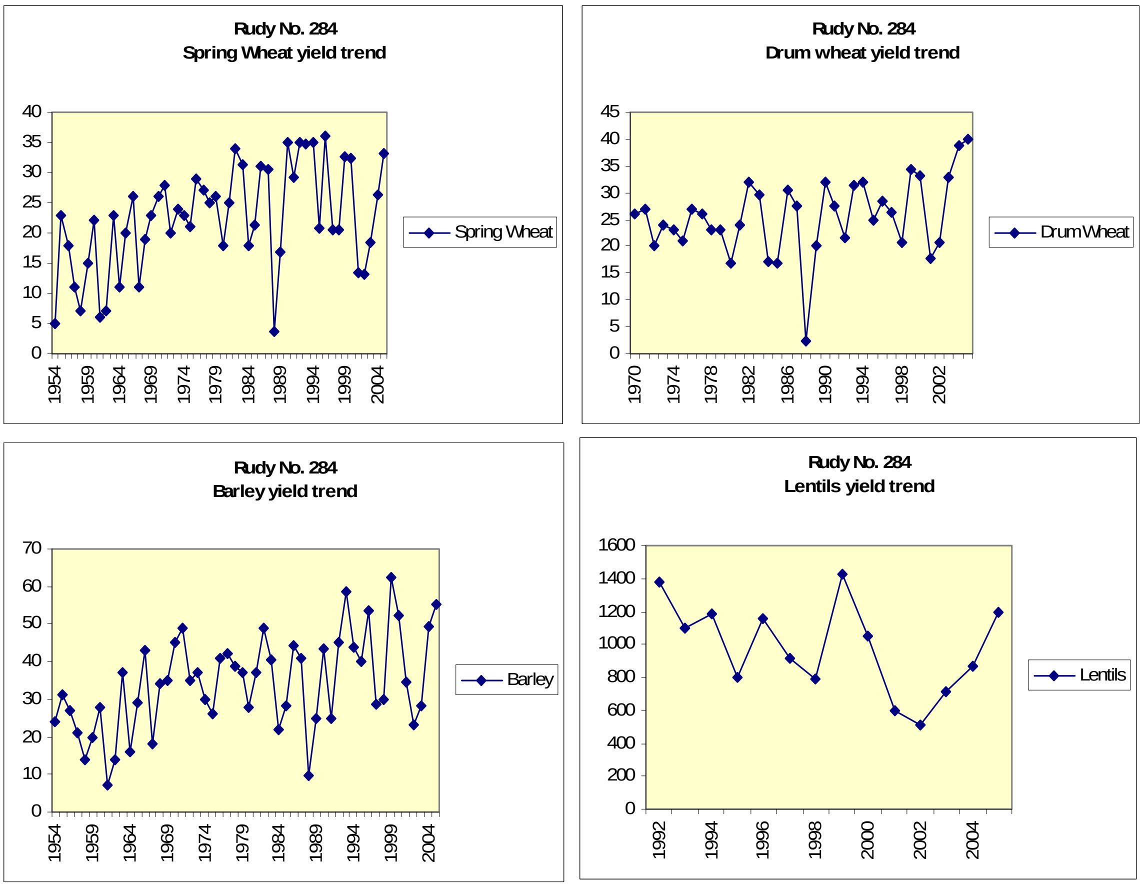
CROP	Area in Acres during				
	1981	**1986**	**1991**	**1996**	**2001**
Spring wheat (excluding durum)	65,006	67,691*	58,098	56,801	41,132
Alfalfa and alfalfa mixtures	8,718	N.A.	13,024	9,750	15,311
Lentils	505	2,291	4,889	6,587	12,518
Canola (rapeseed)	480	3,317	4,976	12,782	11,542
Barley	10,136**	5,891**	5,699	9,139	10,510
Dry field peas	117	N.A.	436	3,677	9,741
Durum wheat	6,423	5,371	N.A.	N.A.	8,947
Total dry field beans	305	638	1,099	1,310	5,516
Oats	2,425**	1,489**	1,802	1,780	4,683
Potatoes	730	N.A.	N.A.	791	4,668
All other tame hay and fodder crops	936	13,814	2,729	1,867	3,767
Flaxseed	2,560	3,044	1,591	1,365	2,608
Mustard seed	140	687	935	1,757	2,094
Winter wheat	10	1,750	N.A.	N.A.	1,566
All other field crops	N.A.	N.A.	N.A.	1,380	364
Total, rye	2,751	2,076	1,134	420	359
Fall rye	2,135	N.A.	N.A.	N.A.	359
Mixed grains	60	N.A.	93	0	275

N.A Not available
Source: Statistics Canada (Various issues of Census of Agriculture)
* To calculate the spring wheat total spring wheat and drum were subtracted 1986.
** Barley and oat for fodder and grain are added together for 1981 and 1986.

In 2001, the main crop in the region was spring wheat, which has been the main crop in the region for the last 20 years. This is followed by alfalfa and alfalfa mixture as the second largest crop area. Total area under spring wheat in 2001 is around 20% of total crop land in the region. Since the 2001 Census of Agriculture reports area under various crops for the year 2001, it was taken as that under a drought situation. Unless producers have an early warning of droughts, changes in the crop mix, on account of rotational requirements, is unlikely. Furthermore, the same area reported in Table 5.12 was taken as the area for the year 2002.

In order to identify / assess the impact of drought on crop yields, a long-term perspective was taken. Crop yields for major crops were collected for the 1954-2004 period from Saskatchewan

Agriculture and Food data sources. However, data for this period were limited to major crops only. Figure 5.1 displays yield of major crops in the RM of Rudy over the 1954-2004 period. Crops included here are spring wheat, drum wheat, lentil and barley. Over this period for the Rudy # 284, production varies from year to year; however, 2001 and 2002 had depressed yields for all crops.



Source: Saskatchewan Agriculture and Food (2007b).

Figure 5.1 Trend in the Yield of Major Crops in the RM of Rudy (# 284), Saskatchewan, 1954-2004

Spring wheat yields in the RM in 1999 were estimated to be 32.7 bu/ac. This increased to 32.4 bu/ac in 2000 but dramatically fell to 13.5 bu/ac in 2001 and 13.1 in 2002. The average yield rose slightly in 2003 to 18.4 bu/ac and more increase were noted in 2004 to 26.4 bu/ac.

Durum yields dropped from a 33.2 bu/ac in 2000 to 17.7 bu/ac in 2001. In 2002, the average yield slightly rose to 20.7 bu/ac, and again in 2003, it rose to 33 bu/ac. Finally, in 2004, yields exceeded the pre-drought level (to 38.8 bu/ac).

Barley yields also dropped during the drought years of 2001 and 2002. However it started its decreasing trend in 2000 where the yield dropped from 62.2 bu/ac to 52.2 bu/ac and registered a further decrease to 34.6 bu/ac in 2001 and 23 bu/ac in 2002. These latter period yields were significantly lower than the average in the neighboring period.

Lentils is another main crop in the region with the average yields of 1,049.8 lbs/ac which significantly dropped to 602 lbs/ac in 2001 and 515 lbs/ac in 2002.The average yield of this crop started to rise in 2003, but it did not reached to its pre-drought average until 2005.

The methodology of estimation followed the same steps as followed for the Alberta communities. This required the crop mix under irrigated conditions. Such data are not available at the RM level, but have been reported or the entire LDDA. These are shown in Table 5.13. Crops of higher importance (in terms of area seeded) include alfalfa and alfalfa mix, canola, and spring wheat. These crops make up 58% of the total irrigation area in the LDDA region. Lacking specific data for the RM, those for the LDDA were taken as a good representation of the RM irrigated crop mix.

Table 5.13 Irrigated Crop Cropped Area, LDDA Saskatchewan, 2004

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

Source: Kulshreshtha (2006)

As noted above, the economic cost of the droughts was measured as a change in producer surplus, which was estimated as the change in net farm income of the producers after all (fixed and variable) costs have been paid for. Cost of production budgets for this study were obtained from Wittrock et al. (2006). However, as reported by Kulshreshtha and Marleau (2005a), and the same methodology adopted by Wittrock et al. (2006), the cost of production during a drought year does not change significantly unless drought conditions are predicted well in advance of seeding the crops. In this study, it was therefore, assumed that the cost of production for various crops in the Rudy # 284 will not change on account of the drought conditions. Based on this logic, change in the producer surplus during a drought year is simply a change in the gross revenue from crop production, although in this study it was estimated as a net return to producers.

Results of the impact of the droughts on crop production are shown in Table 5.14. Since slightly less than half of the total area in the RM is irrigated, impacts are lower than under a no irrigation situation. These estimates also suggest that the 2002 drought was slightly less severe in the RM of Rudy than the 2001 drought. Total loss in terms of crop production was $3.48 million in 2002 as against $4.23 million in 2001. This translates into per ha loss of $76.61 for 2001 and $62.91 for 2002. It should be noted that without irrigation, losses would have amounted to $177.83 per ha in 2001 and $153.37 in 2002. Thus, the irrigation in the RM has reduced the adverse impact of the droughts.

Table 5.14 Economic Impact of the 2001 and 2002 Droughts on Crop Production in the Rural Municipality of Rudy, Saskatchewan

PARTICULARS	2001 DROUGHT		2002 DROUGHT	
	Irrigated Crop Production	Dryland Crop Production	Irrigated Crop Production	Dryland Crop Production
Change in Farm Net Income (Million $)	$1,270,941	-$5,504,562	$1,270,941	-$4,747,493
Total Change in Farm Net Income (Million $)	-$4,233,621		-$3,476,552	
Impact per Acre ($)	$21.16	-$71.97	$21.16	-$62.07
Impact per ha ($)	$52.28	-$177.83	$52.28	-$153.37
Overall Impact of Drought per acre ($)	-$31.00		-$25.46	
Overall Impact of Drought per ha ($)	-$76.61		-$62.91	

In summary, droughts of 2001 and 2002 did have an adverse impact on the three communities (as measured by change in the value of crop production in the surrounding region). These impacts were more pronounced, as shown in Table 5.15, in regions where dryland farming dominates. For example, in the Hanna community losses of $88 and $171 per ha were estimated for the 2001 and 2002 droughts, respectively, were estimated. In contrast, for Taber and Outlook, where a significantly larger area is under irrigation, losses ranged from $35 to $77 per ha. Thus, these data suggest that irrigation is a successful adaptation to drought conditions in the Prairies.

Table 5.15 Summary of Cost of 2001 and 2002 Drought through Loss of Crop Production, Taber, Hanna and Outlook Regions

Year	Value in $ per ha		
	Taber Region	Hanna Region	Outlook Region
2001	-$38.38	-$87.93	-$76.61
2002	-$35.12	-$171.08	-$62.91

5.2.1.2 Livestock Production

Livestock production is also affected during a drought period. Perhaps an appropriate way to investigate the impact of drought on the livestock production in a given region is to look at the cost and impacts of changes in livestock feeding comparing to the regular (normal weather) years. But data availability is a major constraint to estimation of exact drought impacts at the small region (Rural Municipality, Municipal District, or Special Area) level.

Conceptually, drought impacts on livestock production systems could be a result of the following types of changes:

1) Availability of forage may be reduced due to lower yields (unless producer have access to water for irrigation and that water is applied to forage crops for cattle enterprises);

2) Native and tame pastures are affected by the drought condition as grass growth is poor. This reduces the carrying capacity of the pastures;

3) Availability of feed grains is also reduced, thereby forcing the producers either to purchase more feed or reduce the herd size; and,

4) Since water availability on some farms may be limited, as shown by the dugout water supplies in Section 3.1.2.3, producers may have to incur additional cost of obtaining water to meet stockwatering needs.

Actual impact of the droughts on livestock production systems depends on two sets of conditions: One, how producers cope with the drought conditions, and Two, changes in the market conditions during a drought period as a result of drought.

With respect to the first change, Kulshreshtha and Marleau (2005b) reported that producers may undertake the following measures during a period of droughts:

- They may sell a part of their breeding herd;
- Hay fields may be grazed, rather than harvested;
- Hay may be transported over a longer distance (from surplus areas); and,
- Producer may ship their feeder cattle to areas with higher feed and forage availability[24].

If producers were to pursue the first option (i.e., selling a part of their herd), market prices play an important role in determining the impact. Figure 5.2 displays the price of cattle and calves over the 1995 – 2004 period. One would note that the prices until 2000 were strong. However, the 2001 and 2002 prices started weakening, perhaps because of heavy selling of cattle and calves. Unfortunately market continued weakening in the wake of Bovine Spongiform

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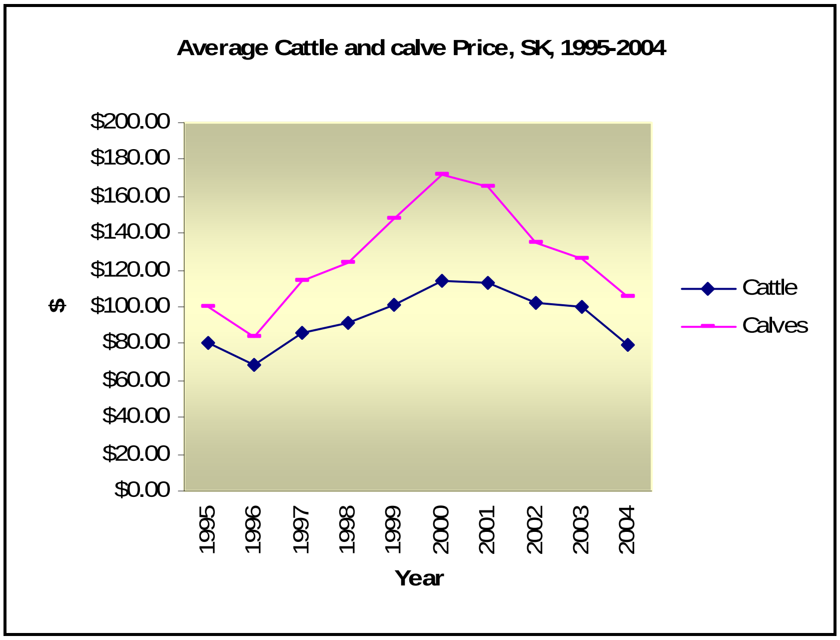
[24] According to Statistics Canada (2003), Alberta's beef ranchers have been hit hard by two years of drought. As of January 1, 2003, the province's cattle herd was 10.4% below year-earlier levels, in the wake of dwindling feed supplies and soaring feed prices. Alberta accounts for over 40.0% of the national cattle herd. More feeder cattle were shipped to Ontario, where feed supplies were plentiful; as a result, Ontario's inventories increased 6.6%.

Encephalopathy (BSE), commonly known as mad-cow disease, in Canada, reducing the demand for cattle due to restrictions placed by the US government on importation of Canadian cattle.



Source: Saskatchewan Agriculture and Food (2007a)

Figure 5.2 Average Cattle and Calf Prices Trend, Saskatchewan, $/cwt, Cattle and Calves, 1995-2004

Selling a part of the breeding herd has a mixed impact on producers. During the drought year, this would result in higher cash income. However, since the reduced in that year would also result in lower animals to market in subsequent, during the period it might take for the herd to come back to the pre-drought herd level, income from livestock operations would be reduced. Back-to-back droughts have more severe impacts on the livestock industry. Here, coping mechanisms and adaptation measures are more limited. However, very little is known about these for the communities included in this study. In the following discussion, review is limited to inventory of livestock and marketings of cattle (if available).

5.2.1.2.1 Taber

Alberta has the largest cattle industry in Canada. In 2001, 40% of national cattle inventories and 60% of slaughters were produced in Alberta. That is the reason that the Province (and MD of Taber is no exception to it) could be so sensitive to droughts which could affect livestock sector adversely. Drought conditions, lower cattle prices and rising feed costs did push the inventories down in the province during the 2001 and later years. Furthermore, the drought on the Prairies in 2001 resulted in increased marketing and bulls exported to the United States. With the continuation of drought in 2002, the cow herd continued to be reduced. In 2002, cow and heifer slaughter has increased 12.3 and 6.5 percent, respectively, compared to 2001.

When one looks at a regional (sub-provincial data), impact of the drought is almost impossible to decipher. This is because the only data that were found for the Municipal District of Taber was the cattle and calves inventory over the 1981 to 2006 period, but only on a 5-year interval. Even here, the 2006 data were more aggregate than that for the other years. These data are shown in Table 5.16.

Table 5.16 Historical Cattle Inventories in the Taber, 1981-2006

Year	Total Cattle and Calves	Total Cows	Total Heifers >1 year old	Calves <1 year old
1981	88,885	25,644	15,927	24,302
1986	70,653	23,393	13,191	20,652
1991	73,569	25,995	11,772	23,908
1996	111,380	31,772	21,665	35,683
2001	157,923	27,488	59,064	45,265
2006*	151,043	N.A.	N.A.	N.A.

* 2006 data from Statistics Canada (2007b)

Since cattle inventory follow a certain cycle, deciphering the impact of the droughts of 2001 and 2002 is difficult. One observation that could be made using the above set of data is that cattle numbers in the MD of Taber in 2001 were lower than previous estimate (for 1996). The 2006 inventory numbers also show a little decline in cattle and calves numbers on farms, which could be a result of the two drought years. However, this topic requires a fresh investigation using some primary survey of producers in the region.

Although the above set of data is inconclusive as to the impact of the drought on livestock producers, focus groups meetings and other interviews have provided evidence to the effect that the impacts were adverse. The following are selected statements made at these meetings (Prado, 2006):

- Drought made our hay production less, so we could not produce enough hay for the winter for our cattle; so we had to go out and purchase hay grass and cut our cow numbers down.
- When there is a drought, we have to bring cows home with the calves early, and start feeding early, or we could haul some feed out to pasture.
- 2001 and 2002 were really dry. They rationed our water for irrigating. You have to buy hay or you use more of your own hay that you have stored. But either way, it costs the same amount of money to raise it. So it is kind of an emergency measure because you do not want your cattle to die.

Statements such these show that the community of Taber (and the surrounding region) was affected by the droughts of 2001 and 2002, although precise estimation of this cost requires further investigation.

5.2.1.2.2 Hanna

The livestock sector within the Special Area # 2 consists primarily of cow-calf and on-farm feeder operations. As a result, production of tame hay and alfalfa is a big share of crop production in the area. As a result this sector of the local agriculture industry is mostly supported by forage production on farms. Unfortunately the data set for the Special Area # 2 suffered from the same limitations as noted for MD of Taber. Inventory of cows and calves in this Area is shown in Table 5.17 over the 1981 to 2006 period. As evident from these data, total number of cattle within the Area has experienced an increasing trend in cattle inventory. Whether the drought had no effect on this industry in the region cannot be stated with any degree of confidence. Like MD of Taber this issue requires a fresh look as well.

Table 5.17 Historical Cattle Inventories in Special Area #2, 1981-2006

Year	Total Cattle and Calves	Total Cows	Total Heifers >1 year old	Calves <1 year old
1981	107,072	45,049	11,419	39,440
1986	114,339	46,231	15,604	42,276
1991	116,138	48,597	12,325	44,783
1996	139,399	61,053	15,551	51,312
2001	190,127	59,455	17,431	90,356
2006*	184,927	N.A.	N.A.	N.A.

* 2006 data from Statistics Canada (2007b)

Statements made at various focus group meetings and interviews do indicate the severity of the drought impacts in the Hanna and surrounding region[25]. The following ones illustrate the impact on livestock producers in the region:

- … a lot of fellas just put their cattle on the market and got out.
- In 2001, the dugouts were dry. I had to pipe some water over from the oil company. But without that I would have to haul water with a truck or I do not know.
- The third year of the droughts guys started to ship cattle out, so that was the big change.
- They started to buy land in Manitoba and they started to find other solutions.
- During droughts, dugouts are low. … By then, of course, the quality is not as good. You get more algae growing. It can affect especially the calves' weight gain and I think may be pregnancy rates too if it is bad enough. And they are in the mud more and stuff and it is not nearly as good.
- During the drought I had to haul some water to fill some dugouts.
- In 2002, I … sold half of my cow herd that year because I had no carry over hay so I sold half of my cow herd off. … I guess got them in and trucked them out. Took what I could get.

[25] The comments are based on written comments of interviews of community of Hanna people and were provide by the IACC Study Office, University of Regina.

- We really had a horrible drought here in 2001 and 2002. In fact, they shipped feed from Ontario to Alberta. We did have to sell some (older cattle) because of the drought.
- We re-did several thousands of acres of native prairie which had been depleted during the drought years and was virtually producing nothing. That was broken down and regrassed ….
- … when we bought hay during the drought, the cost of trucking is very high so we wanted to get something more secure in our feed.

Judging from the above statements, the 2001 and 2002 droughts did have a devastating effect on some livestock producers. Estimation of the actual cost is not possible on account of paucity of appropriate data.

5.2.1.2.3 Outlook

While Saskatchewan is known as the bread-basket of Canada and much of the agricultural orientation is towards production of cereals and oilseeds, some mixed grain, livestock operations also exist in the region. Based on the average of 1997 to 2001, livestock products contributed about 27% of the total cash farm receipts. Saskatchewan's herd of cattle is about half that of Alberta in terms of size, but still higher than that in other regions of Canada. Saskatchewan cattle herd does not always follow a similar trend over time with Alberta. For example, the Alberta herd has been increasing consistently since 1997, while that in Saskatchewan has shown a consistent decline except for the year 2001.

As noted above, annual and RM level data on inventory and marketings of cattle are not available. The lowest level data available for this purpose is the data for the Census Agricultural Region (CAR) level. This CAR houses the Town of Outlook and the RM of Rudy. Where data for the RM were unavailable, data for CAR 6B were used as a poor substitute.

Table 5.18 provides historical data on the total number of cattle within the RM. As evident from these numbers, in the region, there is an increasing trend in cattle and calves inventory. Since 1981, these numbers have almost tripled.

Examining annual change in inventory in the CAR 6B, as shown in Table 5.19, suggested that various categories of animals (beef cows, heifers, steers and calves) numbers decreased from 2001 to 2002, suggesting a larger than normal selling of these animals. As a substitute, emphasis was placed on change in the number of cows and replacements in the CAR 6B. The same conclusion is supported by the Figure 5.3, where total cattle and calve numbers for CAR 6B peaked at 174,009 head in 2001 but began declining in 2002 to 152,270 head and again rising to 185,165 in 2003. The later period increase was a result of the export ban imposed by the US on Canadian cattle and calves on May 20, 2003, in reaction to the outbreak of BSE.

Table 5.18 Historical Cattle Inventories in the Rudy # 284, 1981-2006

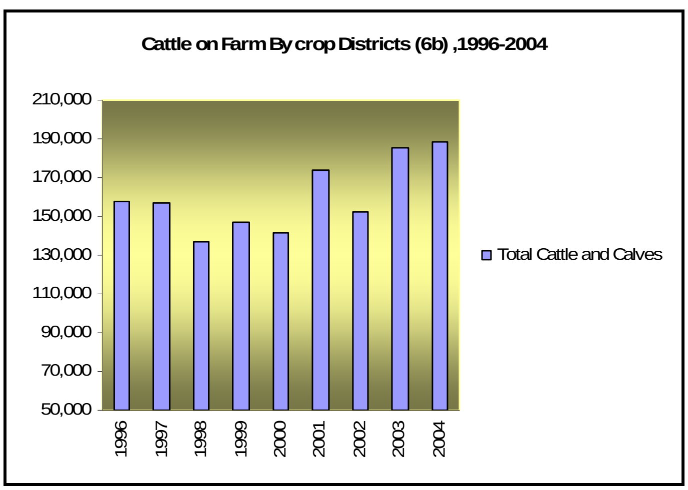
Year	Total Cattle and Calves	Total Cows	Total Heifers >1 year old	Calves <1 year old
1981	5,322	2,348	557	1,907
1986	4,297	1,866	581	1,564
1991	5,627	2,132	1,058	1,770
1996	8,114	3,346	1,190	2,832
2001	9,591	3,605	1,429	3,527
2006*	14,754	N.A.	N.A.	N.A.

* 2006 data from Statistics Canada (2007b)

Table 5.19 Cattle on Farm in Census Agriculture District 6B), 1996-2004

Year	Date	Calves	Steers	Slaughter heifers	Beef replacement Heifers	Milk Heifers	Beef Cows	Milk Cows	Bulls
1996	14-May	51,208	14,489	N.A.	N.A.	N.A.	54,438	10,013	3,569
1997	1-Jul	56,100	8,300	12,900	11,300	2,600	55,700	7,100	3,300
1998	1-Jul	49,129	6,505	5,901	7,866	6,530	47,344	13,698	2,601
1999	1-Jul	51,000	10,800	6,700	9,000	6,200	47,400	12,800	3,000
2000	1-Jul	53,200	6,000	1,200	10,200	5,400	49,900	12,780	3,000
2001	15-May	63,867	13,370	6,794	11,892	4,909	59,660	10,097	3,420
2002	1-Jul	58,700	6,000	3,700	11,400	4,720	55,900	8,750	3,100
2003	1-Jul	67,919	6,022	7,816	14,318	4,560	68,480	12,729	3,321
2004	1-Jul	62,300	16,600	9,800	11,800	5,600	67,300	N.A.	N.A.

Source: Saskatchewan Agriculture and Food (2005)



Source: Saskatchewan Agriculture and Food (2007a)
Note: Crop District 6B is the same as the CAR 6B.

Figure 5.3 Total Number of Cattle and Calves in CAR 6B Region, 1996 -2004

The change in the inventory of cattle and calves was also supported by increased marketing of various type of animals in the CAR 6B. These data are shown in Table 5.20. In fact, marketings of cattle and calves in 2002 were the highest during the 1995-2004 period.

Table 5.20 Cattle Marketing by Crop District (CAR 6B), 1995-2004

Year	Steers	Heifers	Cows	Bulls	Calves	Total Cattle and Calves
1995	39,200	25,820	12,270	1,850	8,640	87,780
1996	37,780	29,890	12,720	2,230	5,960	88,580
1997	43,770	36,580	19,320	2,530	3,870	106,070
1998	41,440	35,460	16,490	2,420	2,580	92,320
1999	42,430	32,370	10,680	2,480	7,260	96,260
2000	43,040	33,710	10,830	2,390	6,780	96,750
2001	41,380	36,950	13,000	2,520	7,550	101,400
2002	48,730	39,220	16,190	2,800	8,770	115,710
2003	37,820	31,070	11,320	1,360	8,290	89,860
2004	42,520	33,240	7,540	1,390	7,490	92,180

In summary, the drought years of 2001 and 2002 created a need to sell-off cattle and calves in Saskatchewan to meet feed and water availability constraints. This is supported by a decreasing trend in the number of cattle and calves on farms in 2001 and 2002, and increased marketing of cows during 2001 and 2002. Since exact nature of coping measures undertaken by the livestock producers in the RM of Rudy are not known, a precise estimation of the cost of the two droughts cannot be made at this time.

One of the statement made by local producers, as shown below, suggests the severity of the drought in the region (based on Pittman and Jeanes, 2006):

- The dryland pastures were suffering in 2001 and 2002, but I have the irrigated pastures too. So when I could see that the dryland pastures were hurting, instead of leaving the cattle there and graze it off to nothing, I pulled the cattle from there and put them on the irrigated pastures …

Like the case with Taber and Hanna, exact cost of the droughts of 2001 and 2002 requires a separate and more comprehensive investigation than was possible in this study.

5.2.1.3 Other Socio-Economic Impacts of the Droughts

Droughts can conceptually generate many other impacts, over and above those for crop and livestock producers. In this study, such impacts were identified during focus groups or interviews of the local people. These are listed in this section. No claim is made these being comprehensive or exhaustive for all sectors / agents[26].

5.2.1.3.1 Taber

Many impacts were noted (based on Prado 2006). These are listed below:

- The Town of Taber realized that water conservation is one way to cope with the adverse impacts of the droughts. Rationing was imposed to some 60% of what is normally taken. This may have affected the production of some industries or required them to invest in water conservation technology.

- Sale of fertilizer (and perhaps other farm inputs) was also reduced particularly in regions where drought occurrence was back-to-back droughts (happened in both 2001 and 2002).

- Local newspaper also suffered economically since there were fewer advertisements placed by people.

- Demand for borrowing rose significantly, making higher profits for the financial institutions.

5.2.1.3.2 Hanna

In the community of Hanna, impacts were also identified by focus group participants and other interviewees[27]. These included:

- Many agricultural producers, facing a bleak prospect for farm income, decided to take off-farm jobs. This was true for all farms, but more so for the grain farmers.

- Oil and gas companies were affected by the drought since they had to pay more for accessing water during drought years.

- During period of droughts there are all kinds of winter kill. Some respondent in Hanna indicated that "trees are dying now (during the drought period)". They take a lot more water if there is a drought.

- Temporary transfer of water rights to the neighbours was another practice that was noted in the region. Producers wishing to grow potatoes required more water and had to get it through water right transfers.

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[26] These comments were obtained from text of various interviews undertaken for the three communities.

[27] These comments are based on Town of Hanna interviews, provided by the Study Office, University of Regina.

5.2.1.3.3 Outlook

Information on other impacts of the droughts of 2001 and 2002 were collected in manner similar to those for the other two communities (Based on Pittman and Jeanes, 2006). These included:

- For water utilities droughts are a good event. As noted in the Outlook interviews, the water utility manager suggested that “droughts are good revenue years for us. We actually run surplus in our utilities, like in our sewer and water utilities because of more consumption. Our utilities, like our water treatments plant, are a money maker because the water quality is good coming out of the river, so it is not real expensive to make it, and even though our water rates are some of the best in Saskatchewan, we still make money at it”.

- Another impact of the droughts is on the equity status of the producers, particularly those with dryland production systems. One option for these producers is to “try to live off the equity”. Other option is that “you do not buy what you should and just keep upgrading your equipment”. These types of measures have an adverse impact on the new farm machinery sales.

- Market gardens are also hard hit since water requirements increase during the drought period, and if there is rationing, less water is available. Furthermore, there is also a higher incidence of insects creating damage.

- Grain brokers started doing business south of the # 1 highway because there was not enough grain available in the local region.

In summary, impacts of the droughts extend much beyond the farm boundaries. Many of these are directly related to water availability whereas others are related to a much direr weather pattern during these periods. Availability of data is a major constraint in identifying the magnitude of these costs. Tables 5.1 to 5.3 provide a summary of the physical, biological, economic and social impacts the communities of Taber, Hanna and Outlook experienced during the droughts of 2001 and 2002.

6. ADAPTATION MEASURES AND THEIR EFFECTIVENESS

Adaptation to the drought conditions varies depending on location, time and sector, for example. Adaptation is most effective if it is implemented properly, facilitated and has few barriers. This section examines adaptation measures implemented by five different sectors and undertakes a preliminary analysis of their effectiveness. As Wittrock and Wheaton (2007) point out, adaptation effectiveness is difficult to assess. They analyzed Canadian Prairie agricultural adaptation effectiveness by using the criteria suggested by Wheaton et al. (2004). These criteria are based on the concepts of barriers to adaptation, mal-adaptation, residual negative effects and innovation. A summary of the adaptation strategies by each of the communities is provided in Table 5.18.

6.1 Adaptation Measures by Farmers

"*You just keep plugging away and you don't spend money…you don't buy what you should… you don't upgrade equipment and that's basically what we've been doing for 10 years… you keep living off your equity hoping that things will get better someday*"
Farmer from R.M of Rudy (Pittman and Jeanes 2006).

The agricultural community is usually the first sector impacted by drought conditions, and therefore it also is one of the first sectors to attempt to implement adaptation strategies. The adaptation strategies depend on the severity of the situation. Table 5.18 provides an overview of the impacts of the drought and adaptation measures implemented. Many producers remembered the impacts the droughts of the 1930s, 1961, 1980 and 1988 had on them as well as the adaptation measures implemented because of these previous droughts (Pittman and Jeanes 2006). The adaptation measures implemented because of previous droughts influenced the extent the 2001 and 2002 drought impacted the agricultural community.

6.1.1 Taber

Southern Alberta has adapted to dry conditions by establishing an extensive irrigation network. As documented in previous sections, the years 2000 and 2001 had extremely low flow years for the Oldman River system. The low water levels were the result of drought and scheduled maintenance on the St. Mary's Reservoir. The Reservoir did not fill in the spring of 2001 due to lack of spring snowmelt (Wittrock 2005). As the result, the agricultural community in the municipal district of Taber was severely impacted because of the limited amount of irrigation water available. This prompted producers to develop and implement adaptation strategies for both crops and livestock (Prado 2006).

Livestock producers moved cattle to the foothills or to Saskatchewan for the summer months, many grew their own feed for winter, filled their dugouts using water from irrigation canals or the river and/or culled their herd. It is not known how the filling of dugouts impacted the dugout water level surveys. Livestock producers did not get a reduction in their water allocation from the irrigation districts because lack of water would result on undo stress to the livestock (Prado 2006). Another source of reliable water supply is the groundwater wells in the region (Figure A5.19).

If livestock producers sold part of their breeding herd it would have a mixed impact on them. During the drought year it would raise their income but it would lower the number of cattle the producers could sell in subsequent years. The coping mechanisms of back to back droughts is more limited (Section 5.2.1.2).

There is an extensive irrigation network in the MD of Taber resulting in the area already being partly adapted to drought situations. There have been technological improvements to the irrigation systems including low flow pivots to increase water conservation and improved water usage. There was, however, a reduction in water allocation because of low water levels resulting in many irrigation farmers having to think of new adaptation strategies. Some producers moved their water allocation to concentrate on higher commodity priced crops such as sugar beets. Some producers also sold their water allocation to neighbouring farmers. Farmers are also examining ways of increasing their on-farm water storage capability (Prado 2006; Wittrock and Wheaton 2007). Four new dugouts were established in the MD of Taber between 1999 and 2006 (Bell, p. comm. 2007) to offset future drought situations. Water sharing agreements were signed by private irrigators, industrial users and municipal governments in the several irrigation districts. This allowed those who may not have been entitled to water in low flow years access to sufficient levels (Wittrock and Wheaton 2007). Irrigation cushioned the cost of the drought by irrigation by helping producers increase their net cash income during drought periods (section 5.2.1.1.1).

The MD of Taber had wind erosion events growing season (April to September) of 2001 (section 5.1.3.1). It is not known if this was uncharacteristic of this region because of lack of data.

Many producers utilized crop insurance and other government programs and also have off-farm income (Prado 2006). Wittrock and Koshida (2005) examined the government safety net programs across Canada. There were several programs specific to Alberta including Alberta Disaster Assistance Loan program, Emergency Water Pumping Program plus others. To the authors' knowledge, while these programs were utilized by the agriculture community, the full extent of usage has not been determined.

6.1.2 Hanna

Special Area #2 was set up to help local producers cope with droughts (Marchildon 2007). Several historic adaptation measures to droughts are already in place in the Special Areas including having converted much crop land back to grassland (section 5.2.1.1.2). As a result, the droughts of 2001 to 2003 did not result in extensive soil erosion (Wandel and Young 2006). Over the years producers established more than 2,000 dugouts (PFRA-AAFC 2006a), and many dams and wells (Wandel and Young 2006) allowing for a certain amount of stability in water supply. However, many of these water bodies became unusable (both because of quantity and quality) by cattle, and producers were forced to find ways of getting adequate water to their cattle. Many producers installed shallow (seasonal) and deep (permanent) pipelines to move water to where it is most needed. The seasonal pipelines could be rented from Special Areas. Even though Special Area #2 has a large number of dugouts, the majority of these went dry during the droughts of 2001 and 2002. This resulted in livestock producers hauling water to the dugouts, limiting livestock access to dugouts and installing "water on demand" watering systems for cattle to decrease water wastage (Wandel and Young 2006). No known new dugouts were established in Special Area #2 between 1999 and 2006 (Bell, p. comm. 2007). Some ranchers have access to a reliable water supply via the pipeline utilized by the Sheerness Electric Power Generating Station. Many of these ranchers utilize this water to irrigate their hay crops. However, there are problems with irrigation including water conflicts between users, irrigation is expensive, and if irrigators were not on the Sheerness pipeline system, many ran out of water (Wandel and Young 2006). Another source of reliable water supply in the Hanna region is the large number of groundwater wells (Figure A5.20).

Longer term adaptation strategies were also carried out. For example, many of the dugouts became dry. It was a good time to refurbish the dugouts and make them deeper, thus making the dugouts less prone to evaporative water losses and able to hold more water. The exact number of refurbished dugouts is not known. A second longer term adaptation strategy that is wanted by the producers in the region is a second pipeline from Red Deer River to be installed to increase the stable water supply and thus expand the ability to irrigate (Wandel and Young 2006).

Limited water was only one issue facing ranchers. A second was lack of feed related to the drought. Many of the same adaptation measures that were utilized in Taber were also used in Special Area 2. Some livestock producers carry at least one year worth of feed, or they bought feed. Producers culled cattle with the older ones being sold first. They also re-located cattle with some moving to Saskatchewan. Some producers have multiple land holdings so that they are able to move cattle to where there are better conditions. A positive outcome for culling cattle in 2001 and 2002 was it lessened the impact of the BSE crisis in 2003 (Wandel and Young 2006).

As indicated earlier, there was an extreme grasshopper infestation in Special Area #2. The result was any grasshopper control measures undertaken were ineffective in either cropland or grassland and caused devastation to crop and grassland (Wandel and Young 2006). Producers in Special Area #2 stated (Wandel and Young 2006):

"…between the grasshoppers and drought, there was nothing left"

"…if it wouldn't have been for the grasshoppers,
we had drought but it wouldn't have been as bad."

Livestock producers utilized good rangeland management practices in an attempt to decrease the negative impacts that can result from over grazing. This was done in several ways including:

- Stocking the fields at drought tolerant levels (not allowing over grazing)
- Feed cattle later into the year to allow pasture to become established
- Kept cattle off native pasture until later in the year to allow longer fall grazing
- Utilize tame grass in early spring
- Split a pasture around a water source so that cattle could be moved to where feed was available as well as water
- Mixed farmers turned cattle onto low yielding crops
- Mixed farmers converted crop land back to grass (Wandel and Young 2006).

Producers used several government programs including community pastures, pasture insurance, crop insurance, government assistance programs (PFRA helped design pipeline systems and irrigation systems) and had Farm Environment Plans completed. Many producers did not feel the government programs were adequate because they do not always allow for the best or most appropriate adaptation measures to be implemented. Another limited adaptation was with the community pastures. Because of poor pasture conditions, livestock was allowed on them for a shortened period of time (the breeding season) to minimize the negative impact on the pasture (Wandel and Young 2006).

Farmers have tried to adapt to the Special Area's dry conditions by utilizing more chemical fallow. They also seeded more drought tolerant crops. Also, a historic adaptation was to convert cropland to grassland (Wandel and Young 2006). Both of these measures helped reduce the amount of soil erosion in the region (Section 5.1.3.2).

Many producers help support their lifestyle by having off-farm income and by allowing oil wells on their property. The final adaptation strategy for both grain and livestock producers was to get out of the industry completely (Wandel and Young 2006) although the actual number is not known.

Even with all the adaptation strategies Special Area #2 has in place, the droughts of 2001 and 2002 were extremely detrimental to the region. Also, the cost of the drought was higher during 2002 than 2001 (Section 5.2.1.1.2).

6.1.3 Outlook

As indicated in Section 5.2.1.1.3, the Rural Municipality of Rudy is a major irrigation region in Saskatchewan because of its location on the South Saskatchewan River. Irrigation farmers believe irrigation provides stability to agriculture because it allows the producer to apply water to the land when it is required thus removing some of the risk of farming. Irrigation farmers can benefit from drought, as long as they have adequate water because it allows for more control over water application – applying water when the crops need it. The irrigation district increased its area by 15% in 2001/2002 (Pittman and Jeanes 2006). It was found that the 2002 drought was slightly less severe in the RM of Rudy than the 2001 drought. Also, without irrigation, the losses would have been much greater (Section 5.2.1.1.3).

Irrigation in the RM has undergone some changes including (Pittman and Jeanes 2006):

- Conversion of irrigation equipment to center pivot from the original flood irrigation over several years. This has improved water conservation and has eliminated some of the salinity problems.
- Irrigation district installed pipeline lining over the last 10 to 15 years in order to conserve water by reducing seepage.

The RM of Rudy has the lowest number of groundwater wells (Figure A5.21) of the three communities. This may indicate that the RM depends and utilizes the South Saskatchewan River for most of its water needs.

Dryland farmers were able to adapt to the drought by becoming mixed farmers, increased use of minimum till and less summerfallow and after the 1988 drought some of the highly erodible land was seeded to grass to minimize soil erosion (Pittman and Jeanes 2006). This may have contributed to the RM having no observed wind erosion events (Section 5.1.3.3 and Section 5.2.1.1.3).

Some adaptation strategies that were utilized were delaying the purchase of new equipment, not hiring on-farm help, borrowed money or used money saved from the "good years", had off farm income and buying crop and hail insurance. Many farmers do not like crop and hail insurance because of the high cost of premiums, the reduction in coverage and the problems with having both irrigated and non-irrigated crops (Pittman and Jeanes 2006).

Longer-term adaptation strategies include examining ways to expand irrigation in the region. However, questions arise concerning whether irrigation is financially viable (Pittman and Jeanes 2006).

Livestock producers used various adaptive strategies including culling their cattle or removing cattle from dryland pastures and putting them on irrigated pastures (Pittman and Jeanes 2006). There were 12 new dugouts built in the RM of Rudy between 1999 and 2006 (Bell, p. comm. 2007) to offset future drought situations.

Many of the farmers that were interviewed were on the potable water supply pipeline from Outlook therefore they always had enough water to drink. Farmers not on the pipeline obtained their potable water from bottled water or wells (Pittman and Jeanes 2006).

The adaptation strategies implemented by farmers in the three regions are similar to what Wittrock and Wheaton (2007) found. They found many of the adaptation measures were effective but were at times limited due to lack of funds, lack of research and difficulty in making changes.

6.2 Adaptation Measures by Community Members

"We've noticed a lot of extreme weather here in the last five years"
Taber community member (Prado 2006).

6.2.1 Taber

The low water supply impacted Taber resulting in some adaptation measures being implemented. Water conservation measures were implemented, partly due to the imposed water restrictions and partly because the some people in Taber thought it was a good idea. However, in some cases, water usage conflicts arose between rural and urban residents. Some urban people thought the agricultural community was wasting water and vice versa (Prado 2006).

6.2.2 Hanna

As stated earlier, the town of Hanna adapted to its limited water supply by accessing Red Deer River water through a pipeline from the Sheerness Power Generating Station. The result was the town of Hanna did not have a water shortage and did not impose water usage restrictions. However, many residents conserved water on their own (Wandel and Young 2006).

Recreational facilities such as golf courses were able to access Hanna's water source after their own water storage became depleted (Wandel and Young 2006).

Special Areas have several Ducks Unlimited Canada projects. They were designed to remain viable for a two to three year drought but by 2003, all of the projects were dry. Ducks Unlimited Canada allows land owners to pump water from their reservoirs for domestic use and for watering cattle but do not allow water in the projects to be used for irrigation purposes (Wandel and Young 2006).

6.2.3 Outlook

Residents of Outlook were not concerned about the droughts of 2001 and 2002 because they had ample water supplies from the South Saskatchewan River and no watering restrictions were imposed (Pittman and Jeanes 2006).

Small business involved in the agricultural industry had to do business on a larger geographical area because the drought conditions limited commodity amounts. This expansion remained after the drought conditions had passed because of now established client base (Pittman and Jeanes 2006).

6.3 Adaptation Measures by Local Government

6.3.1 Adaptation Measures by Water Utility

6.3.1.1 Taber

Taber had increased its municipal water supply reliability previous to the droughts of 2001 and 2002 by utilizing water from two different water sources (Section 3.2.2.4.1). The drought of 2001 and 2002 resulted in below normal water supplies available for communities in southern Alberta resulting in many, including Taber, to impose water restrictions (Prado 2006). The imposed restrictions at Taber resulted in water consumption being 7% below average in 2001 (Table 6.1) even though the population was at its highest point in 2001 (Figure 3.7) compared to the other census years (1991, 1996 and 2006).

Table 6.1 Difference from Average* for Water Consumption, Temperature and Precipitation (2000 to 2003).

	Water Consumption (m^3)			Temperature (°C)			Precipitation (mm)		
	Taber	**Hanna**	**Outlook**	**Taber**	**Craigmyle**	**Outlook**	**Taber**	**Craigmyle**	**Outlook**
2000	4%	4%	-7%	0.0	-0.3	0.5	-31%	-9%	12%
2001	-7%	12%	16%	1.8	1.4	1.4	-40%	-25%	-41%
2002	-20%	10%	9%	-0.5	-0.1	-0.1	70%	-40%	-5%
2003	-9%	9%	27%	0.7	0.3	0.5	17%	-31%	-22%
Average	2,955,391	36,480	494,840	5.8	3.1	3.4	368.5	407.0	337.8

*Averaging Periods
Water Consumption Average
- Outlook (1984-2006, missing 1987 Data Source: Anderson p. comm. 2007)
- Taber (1994-2003, Data Source: Cressman p. comm. 2007)
- Hanna (1990-2006, Data Source: Burgemeister p. comm. 2007)

Temperature and Precipitation Average (1971-2000) (Data Source: Environment Canada 2007a).

6.3.1.2 Hanna

Due in part to previous droughts, Hanna accessed a stable water supply via a pipeline from the Sheerness Power Generating Station which pipes water from the Red Deer River. Hanna then pipes water to outlying communities. Hanna did not have to place water restrictions on any town people or those in outlying communities. Hanna has a water reservoir that would have enough water for approximately one year without recharge (Wandel and Young 2006). The result is the 2001 and 2002 droughts appeared to have no negative impacts on the potable water supply in Hanna because water consumption increased by 12 % in 2001 (Table 6.1) even though the population remained similar to previous census years (Figure 3.8).

6.3.1.3 Outlook

Outlook is located on the South Saskatchewan River. The result of this is water quantity is rarely an issue, especially with the increase in storage facility. Water quality is a problem when the river is running high resulting in high turbidity. The three years of drought (2001 to 2003) had no effect on accessibility to river water because the intakes are in the main channel (Pittman and Jeanes 2006). Water consumption increased by 16% in 2001 and 9% in 2002 (Table 6.1) even though the population was similar to previous census year (Figure 3.9).

Outlook changed the way it charges for water usage. There is now a base price and an extra cost for water that is used above a certain fixed level to encourage people to conserve water (Pittman and Jeanes 2006).

6.3.2 Adaptation Measures by Town / Municipal Governments

"In 2001, we had a drought situation and so we had to go into water rationing…you could only water on certain days and actually you could only water once a week" Taber community member (Prado 2006).

6.3.2.1 Taber

The extremely low water levels in southern Alberta resulted in the town of Taber imposing water restrictions on the town residents. The town sent out information on water conservation strategies with the utility bills. It was noted that water conservation is an ongoing challenge in Taber (Prado 2006). The water restrictions appear to have worked as there was a 7% decline in the amount water consumed in 2001 even though the average annual temperature was 1.8°C higher and 40% less precipitation than normal (Table 5.18) and an increase in population (Figure 3.7).

6.3.2.2 Hanna

The town of Hanna did not impose any water restrictions during the drought years as they had a reliable source of potable water (Wandel and Young 2006). There was an increased level of water consumption during the 2001 to 2003 period (Table 5.18) and a decrease in population (Figure 3.8).

Special Areas land management is in charge of several community pastures. These pastures suffered due to drought and grasshoppers and as the result many adaptation measures had to be undertaken to ensure the pastures future viability. Adaptation measures utilized included:

- Shortened grazing season to the breeding season
- Sent yearlings home first then the breeding cattle
- Implemented rotational grazing
- Stocked the pasture to carrying capacity
- Limited the number of cattle accepted in 2003 to allow pastures to regenerate
- Deepened the dugouts so that they catch 80% of the median flow and decrease the amount of water loss due to evaporation (Wandel and Young 2006).

The adaptation measures utilized by the Special Areas land management are similar to what was found by Wittrock and Wheaton (2007). They discovered across the drought affected region of the prairies that many of the community pastures utilized these measures. However, when the Special Areas land management and other community pastures implemented some of these measures, such as limiting number of cattle and shortened grazing season, the result was livestock producers were forced to find other arrangements for their cattle and further financial hardship for the producer.

Special Area land management had similar problems to the local farmers and ranchers with respect to grasshopper management. Similar to individual producers, the Special Area Land Management found any management strategies attempted at stopping the grasshoppers had little effect (Wandel and Young 2006).

6.3.2.3 Outlook

Drought years are generally considered to be good revenue years for the town of Outlook because of the higher water consumption. Outlook did not impose water rationing but did circulate flyers on how to conserve water (Pittman and Jeanes 2006). As with Hanna, Outlook's potable water consumption increased in the drought years (Table 5.18) with the population in 2001 similar to that in 1996 (Figure 3.9).

6.4 Adaptation Measures / Assistance by Provincial and Federal Governments

The provincial and federal governments had several programs and support strategies available to the agriculture sector including crop insurance, the Net Income Stabilization Program, the Canadian Farm Income Program, PFRA Community Pastures, Provincial Community Pastures, plus others. These programs were assessed in Wittrock and Koshida (2005) but they did not assess the magnitude of support the programs offered to producers nor did they differentiate between programs that were set up specifically in response to the drought situation. They did find the programs' impacts and successfulness varied by province and by region. The Alberta Government supplied more support to producers than the Saskatchewan Government was able to do. Difficulties with many of the programs were noted when multi-year droughts affected a region (Wittrock and Wheaton 2007). All three regions had access and utilized the various government programs however, to the authors' knowledge, the exact utilization of the government programs is not known.

One unique program is the federal government helped the Special Areas by mapping the groundwater systems. It has also assisted the agricultural community of Special Area #2 with advice and money for establishing permanent water structures, irrigation and pipeline strategies (Wandel and Young 2006).

7. SUMMARY AND CONCLUSIONS

7.1 Summary

The major objective of this study was to investigate the impacts of the 2001 and 2002 droughts on the communities of Taber, Hanna and Outlook with emphasis on water resources. These impacts were studied with a focus on the communities as well as on the larger region – Municipal District of Taber, Special Area #2 and the Rural Municipality of Rudy, respectively. Drought impacts were assessed in terms of bio-physical and socio-economic changes during these years.

The vulnerability of the three communities to drought differed among the communities. Typically low water levels impacts the initial water users first such as the agricultural community, municipal water supplies and other non-farm activities. These then have community level economic impacts and community level socio-economic impacts. How well a community adapts to low water levels influences the level of impacts.

Included among various bio-physical impacts of the drought were decreased stream flows, minimal recharge to groundwater and dry dugouts. In Special Area #2 (surrounding Hanna), the high numbers of grasshoppers were a severe secondary impact of the drought.

Lack of water impacted the community of Taber to the greatest extent during the drought. This resulted in water restrictions being imposed on both the residents of Taber and the surrounding irrigation districts. The towns of Hanna and Outlook were less affected due to their adequate water supplies.

Socio-economic impacts were a result of reduced crop production in the region. Lack of irrigation was a major factor affecting the magnitude of these impacts. Relative magnitude of irrigation was lowest in the Special Area #2 (surrounding Hanna), followed by Outlook and Taber. As a result, loss in value of crop production in the three communities was different. In the Hanna region, losses of $88 to $171 per ha were estimated, while those for the Taber region were from $35 to $38 per ha, and those for the Outlook region from $63 to $77 per ha. Thus, irrigation did help these regions to cope with the drought conditions.

Many agricultural producers thought that irrigation was a good adaptation measure. However, some problems arose with its usage including lack of water in the Municipal District of Taber causing several problems and resulting in inventive solutions to those problems. These solutions included sharing and trading water rights, changing cropping practices and using greater water conservation measures. Special Area #2 had difficulty with water availability in those areas that depended on dugout water for irrigation and other purposes. As a future adaptation strategy to drought, producers in Special Area #2 would like to expand their use of irrigation but need provincial approval to build a second pipeline from the Red Deer River to the community. The Rural Municipality of Rudy did not appear to have many difficulties with their irrigation during the drought years, although wind speeds were cited as a factor in being able to apply the correct amount of moisture. Outlook has limited irrigation because of the cost of the irrigation equipment. Furthermore, in some instances, the higher age of the producers' results in some reluctance to buy the equipment because they will be retiring in 5 to 10 years. In addition, infrastructure accessibility is seen as a difficulty.

In all three communities, producers would like more information to help them adapt to drought situations. For example, if producers had early warning that a drought was very possible for the coming crop year, changes in the crop mix because of rotational requirements may be possible. The cost of production during a drought year does not change significantly unless drought conditions are predicted well in advance of seeding the crops (Section 5.2.1.1.3). Even then, some producers hope for normal weather conditions later on and do not make appropriate adjustments.

The three communities already had many adaptation strategies in place for droughts. However, these strategies were at their limits with the multi-year drought. If droughts become more frequent, severe and extended as projected by the global climate models, current adaptation strategies may not be adequate.

7.2 Conclusions

The communities of Taber, Hanna and Outlook and surrounding areas were shown to have various adaptation strategies to droughts. However, the multi-year drought resulted in the communities' adaptive capacity being tested. As indicated in Figure 2.1, the impacts of the droughts would first impact the agricultural community but then extended beyond farm boundaries. Many of these impacts are directly related to water availability while others are related to drier weather patterns.

- Taber and the Municipal District of Taber were negatively impacted due to low water levels in 2001. Water supply rebounded in 2002 because of increased rainfall in June. Water restrictions were the adaptation measure utilized for both the MD of Taber and in the town of Taber. The irrigation community initiated several innovative adaptation strategies including transferring water from one irrigator to another, planting less water needy crops, and/or allowing processors access to more water than their water rights would allow, for example.

- Special Area #2 was severely affected by grasshoppers and low water levels which left their dugouts dry and very little forage. This resulted in secondary impacts on the livestock population and many adaptation measures being used including filling dugouts by installing temporary pipelines, moving cattle to other less drought stressed locations, and/or importing forage from outside the drought zone for example. The town of Hanna had an adequate supply of potable water because it obtains its water via a pipeline from the Red Deer River.

- Agricultural crop output was severely reduced in the Special Area #2, yielding large losses for producers than in the other two regions.

- Outlook had an adequate supply of potable water as did many in the agriculture community around Outlook due its access to the South Saskatchewan River and the network of water pipelines.

7.3 Areas for Future Research

- Assessment of drought impacts on livestock production could not be done in this study due to lack of data. These impacts could be significant and therefore, need to be estimated.

- Effect of the drought on irrigation farmers is also a knowledge gap. How do these producers cope with drought conditions particularly when water availability is rationed requires further study.

- Impact of the drought on local businesses was not estimated in this study. These and related issues could be addressed by future studies.

- Economic efficacy assessment of various adaptation measures was not attempted in this study because of data limitations.

- Examination of the effectiveness of current adaptive strategies to cope with more extensive and extended drought situations.

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Appendix A

Bio-Physical Figures

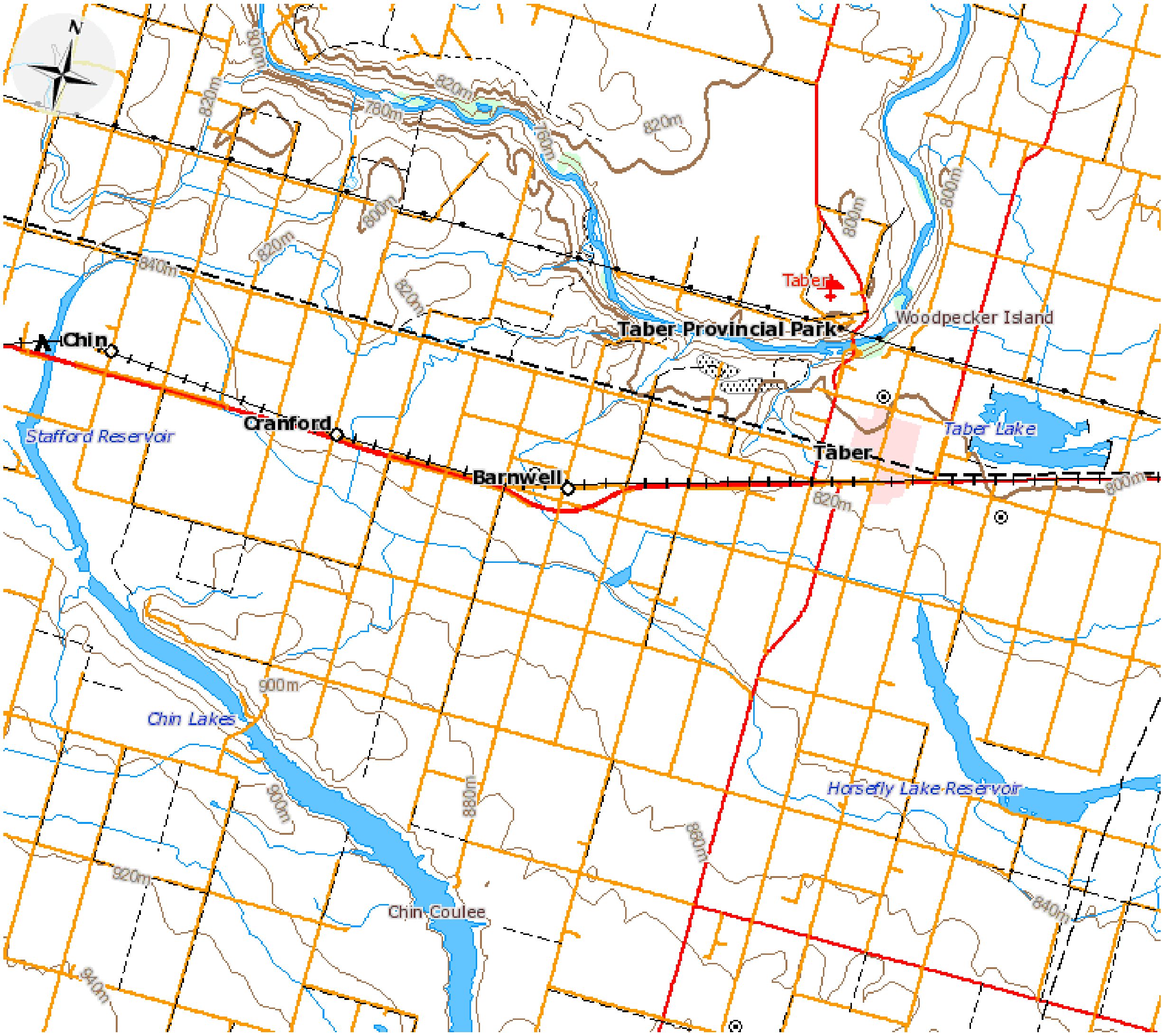


Figure A3.1 Taber's Potable Water Reservoir (Chin Lakes) (Natural Resources Canada 2007)

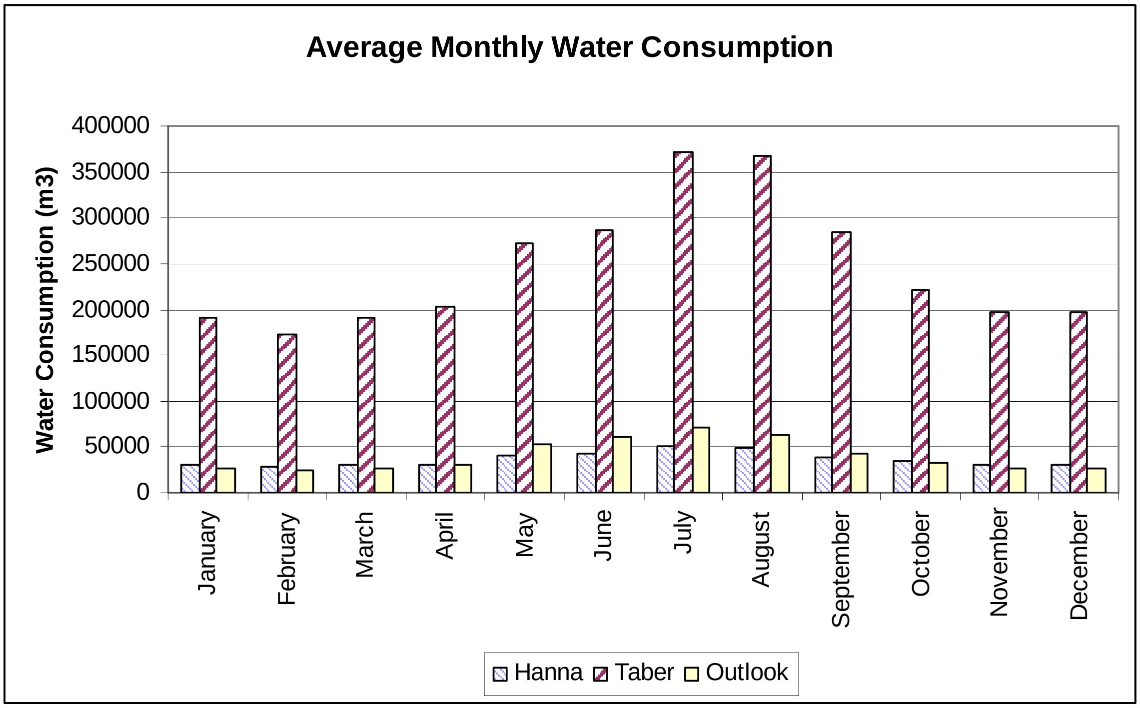


Figure A3.2 Average Monthly Water Consumption (m^3) for Hanna Taber and Outlook (Data Source: Anderson p. comm. 2007; Burgemeister p. comm. 2007; Cressman p. comm. 2007)

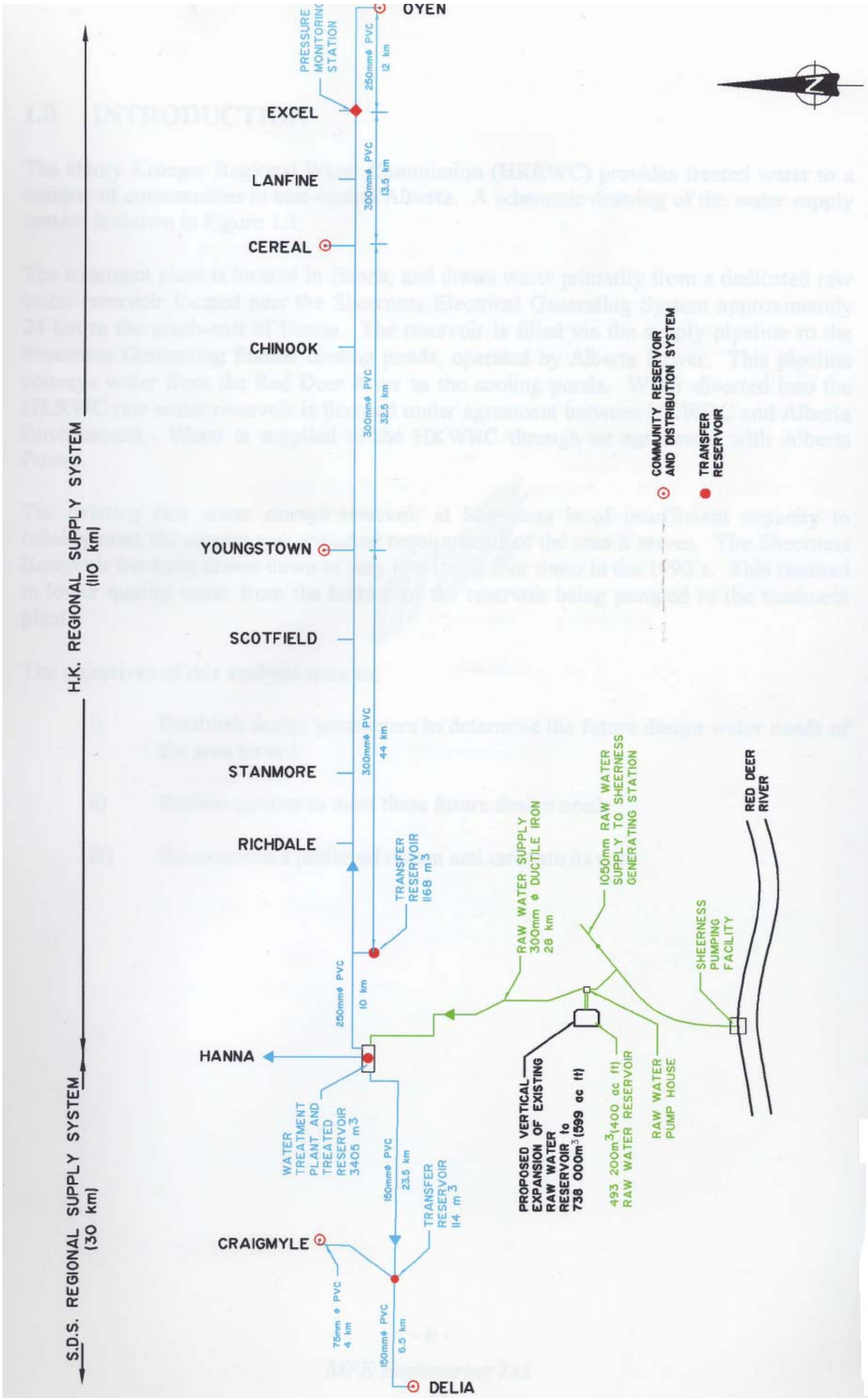


Figure A3.3 Water Distribution System for Hanna, Alberta and Area (Burgemeister p. comm. 2007)

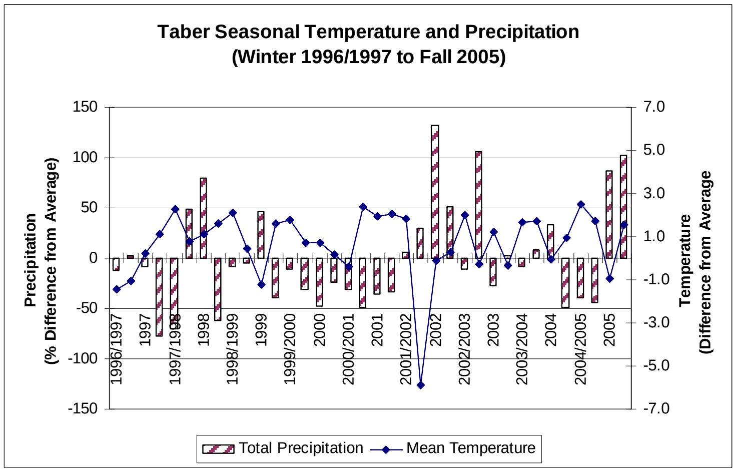


Figure A4.1 Taber's Seasonal Climate for 1996 to 2005 (Data Source: Environment Canada 2007a)

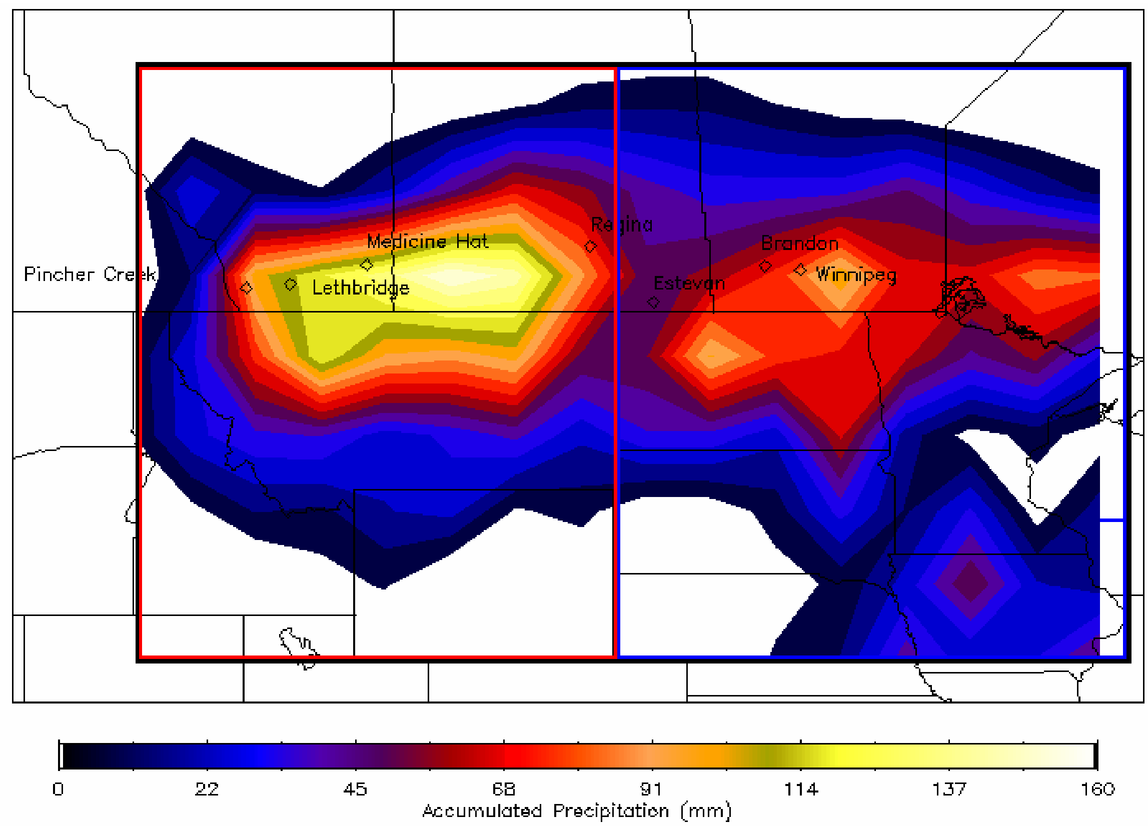


Figure A4.2 June 2002 Precipitation Event (Stewart et al. 2007)

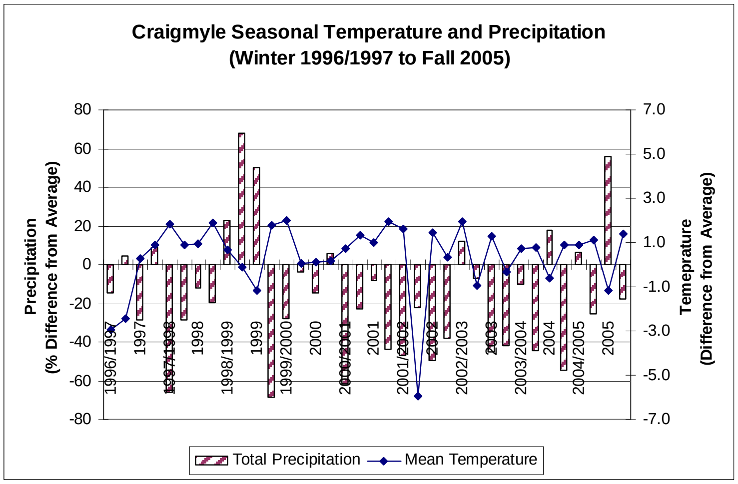


Figure A4.3 Craigmyle's Seasonal Climate for 1996 to 2005 (Data Source: Environment Canada 2006)

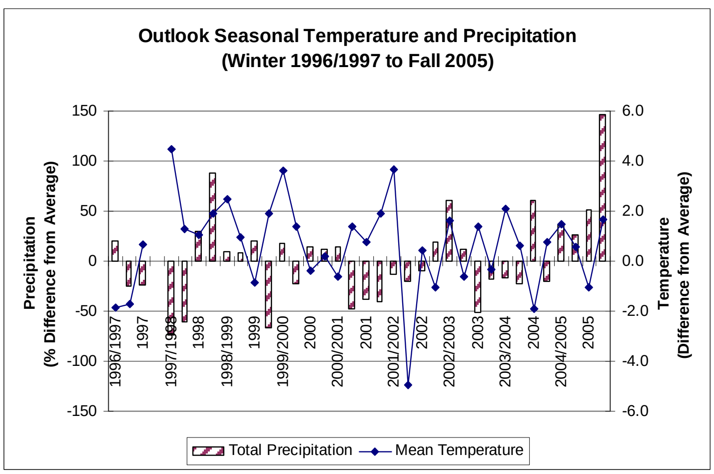


Figure A4.4 Outlook's Seasonal Climate for 1996 to 2005 (Data Source: Environment Canada 2006)

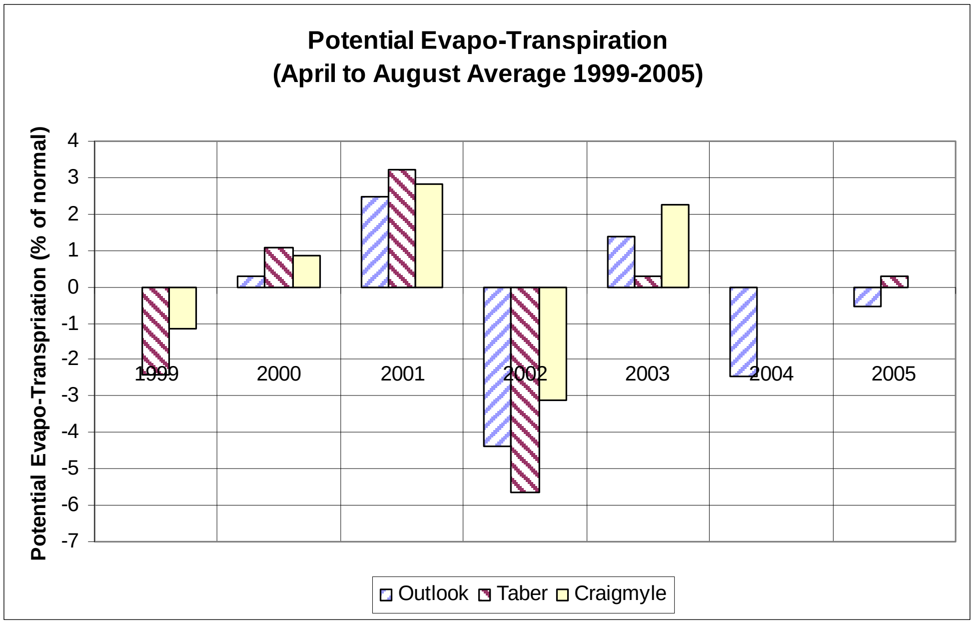


Figure A4.5 Potential Evapo-Transpiration for the April to August 1999-2005 period for Outlook, Taber and Craigmyle (Data Source: PFRA – AAFC 2007a)

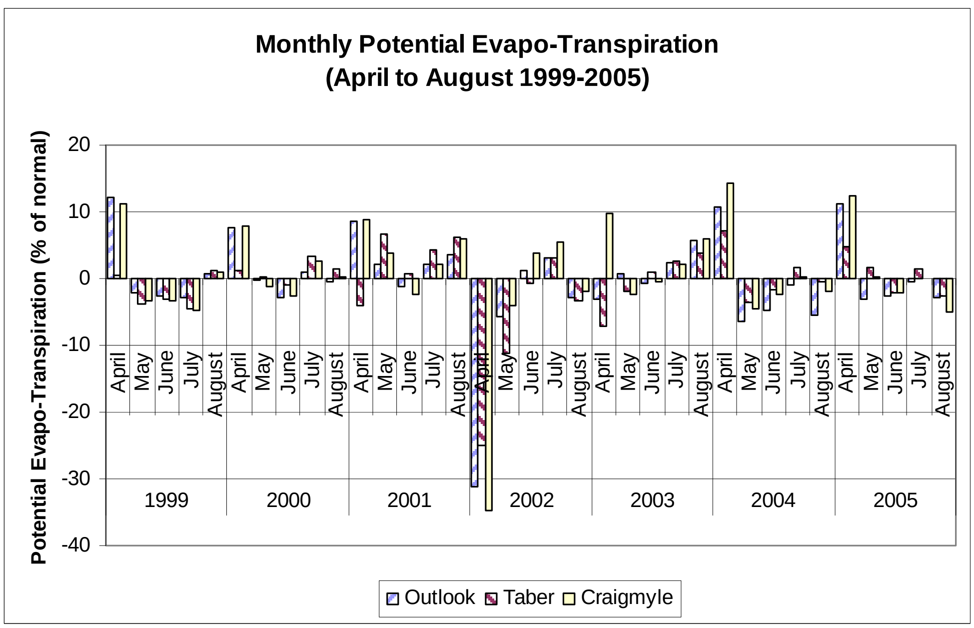


Figure A4.6 Monthly Potential Evapo-Transpiration for the April to August 1999-2005 period for Outlook, Taber and Craigmyle (Data Source: PFRA – AAFC 2007a)

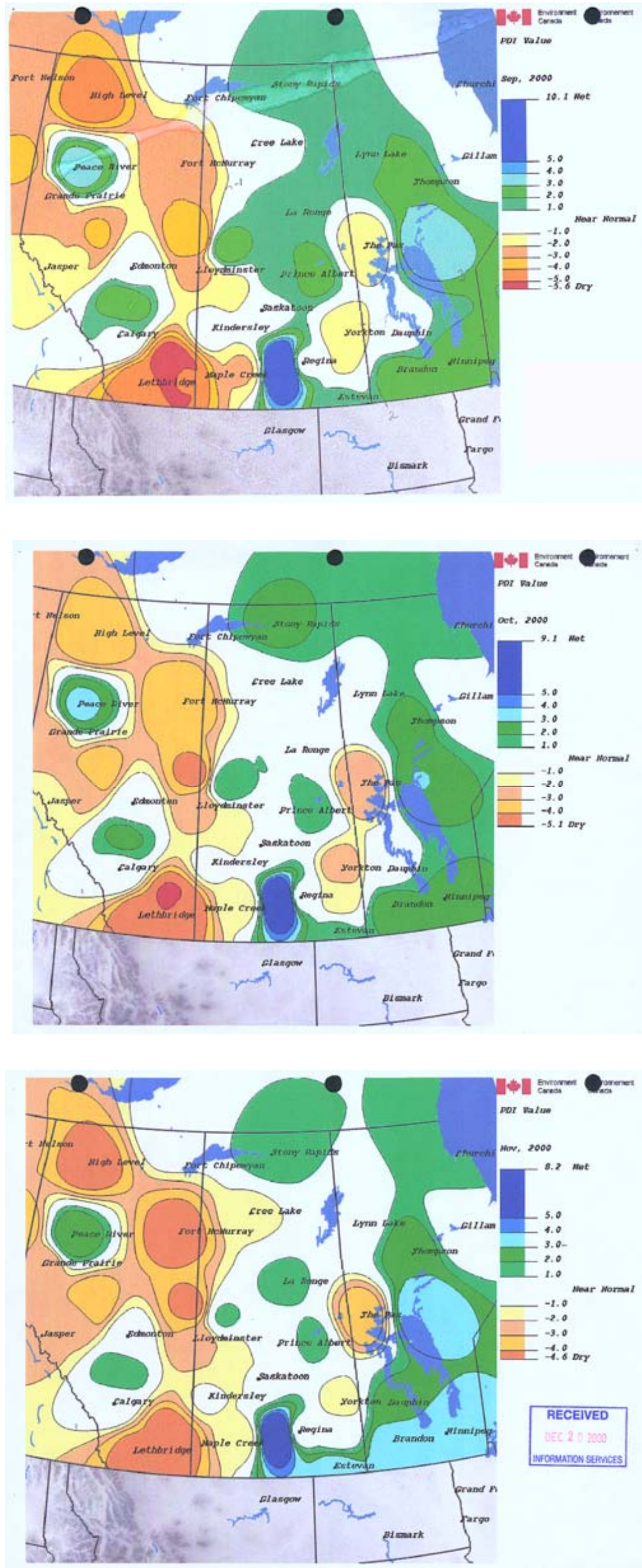


Figure A4.7 Palmer Drought Severity Index for the Canadian Prairie Provinces, Fall (September, October, November) 2000 (Ryback, p. comm. 2000)

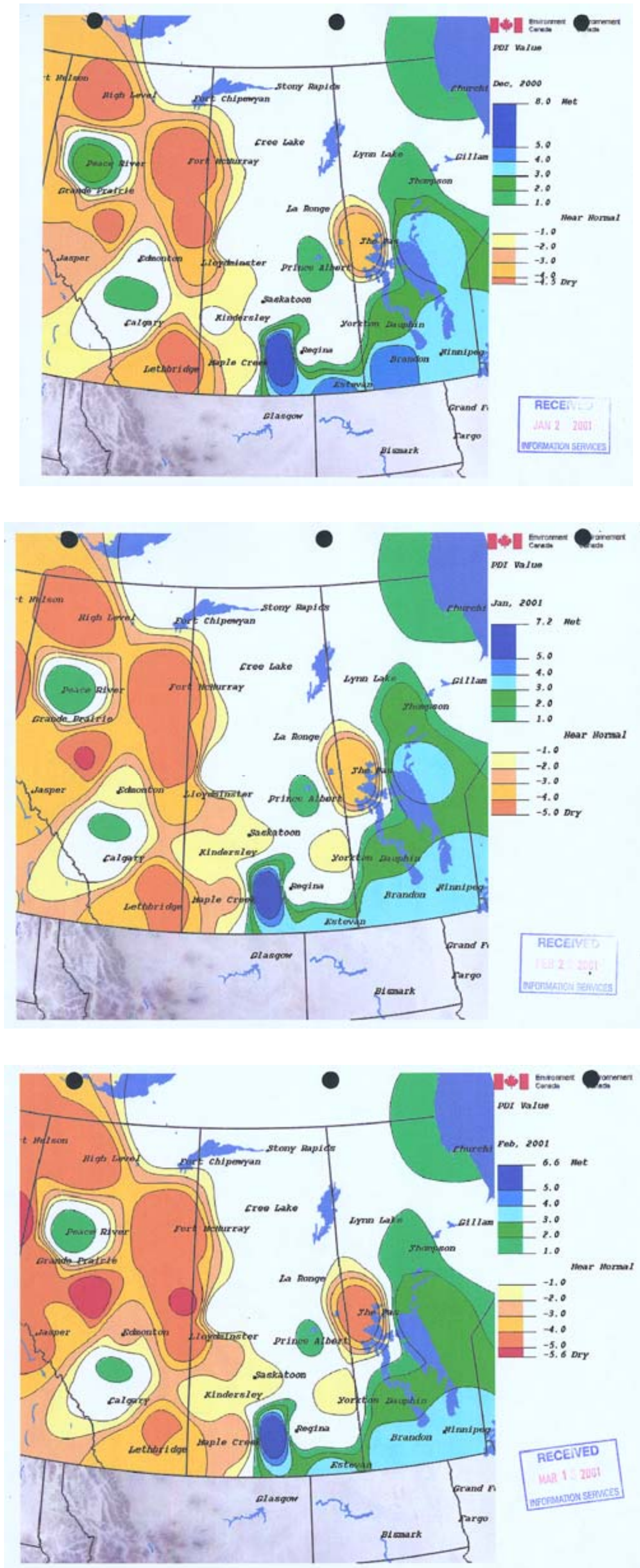


Figure A4.8 Palmer Drought Severity Index for the Canadian Prairie Provinces, Winter (December, January, February) 2000/2001 (Ryback, p. comm. 2000 and 2001)

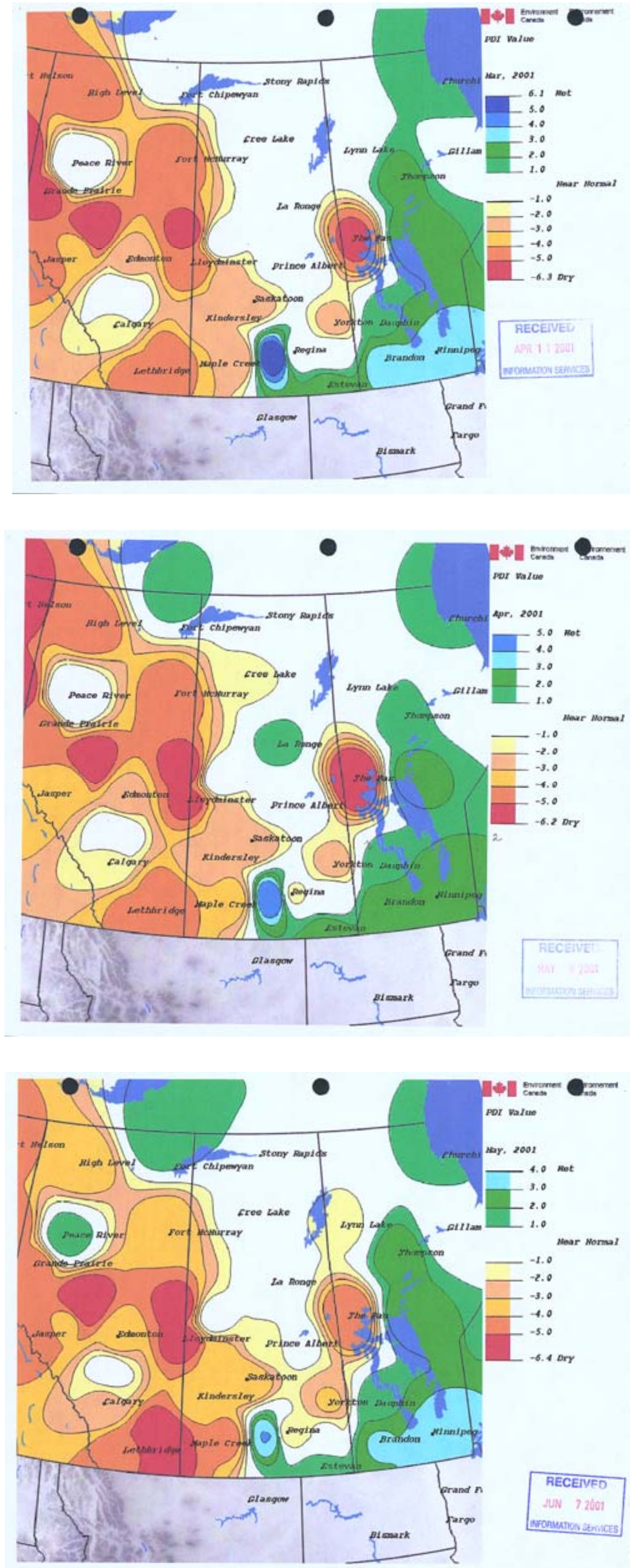


Figure A4.9 Palmer Drought Severity Index for the Canadian Prairie Provinces, Spring (March, April, May) 2001 (Ryback, p. comm. 2001)

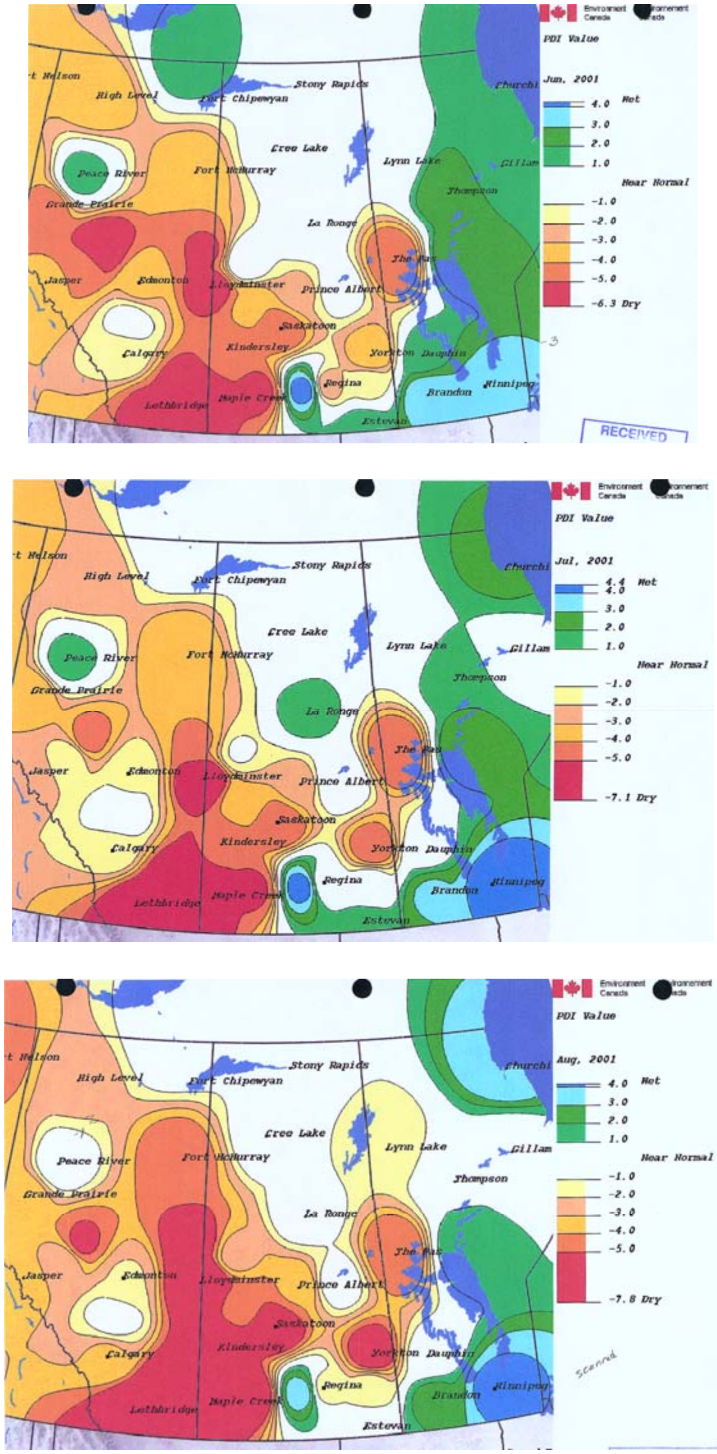


Figure A4.10 Palmer Drought Severity Index for the Canadian Prairie Provinces, Summer (June, July, August) 2001 (Ryback, p. comm. 2001)

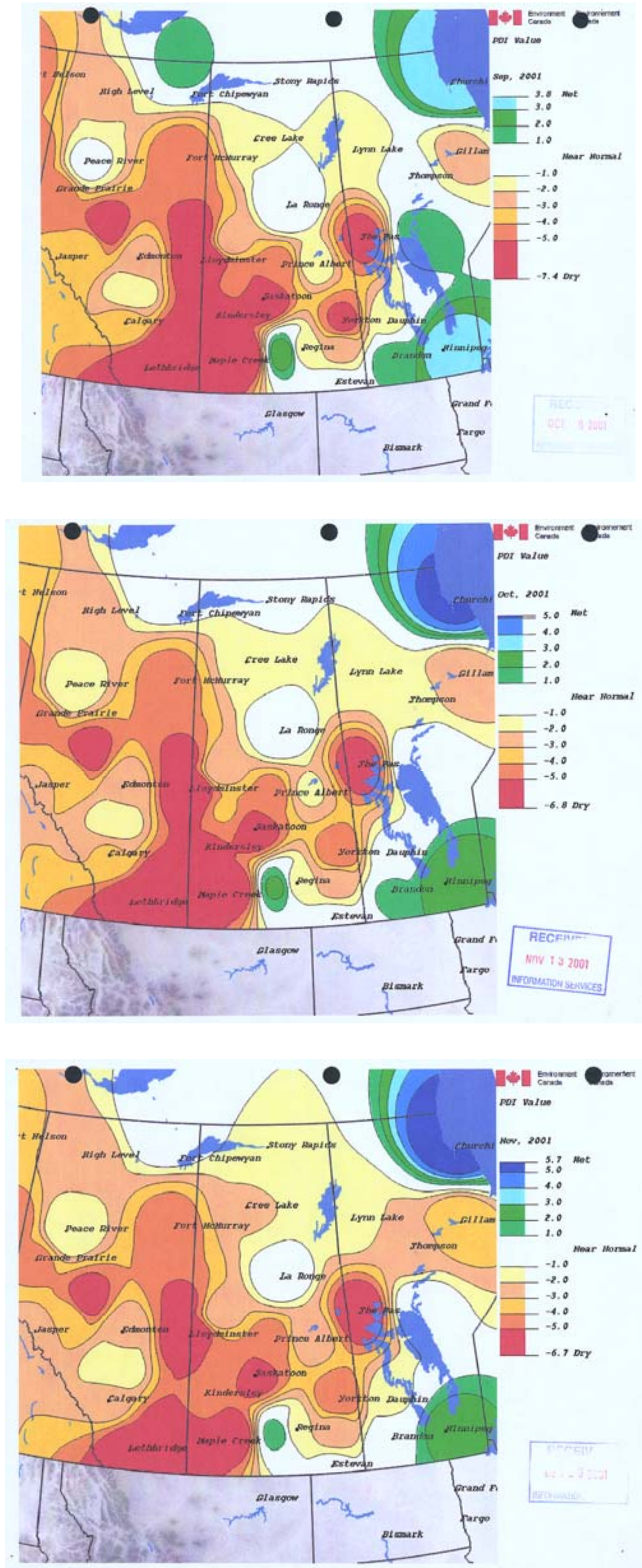


Figure A4.11 Palmer Drought Severity Index for the Canadian Prairie Provinces, Fall (September, October, November) 2001 (Ryback, p. comm. 2001)

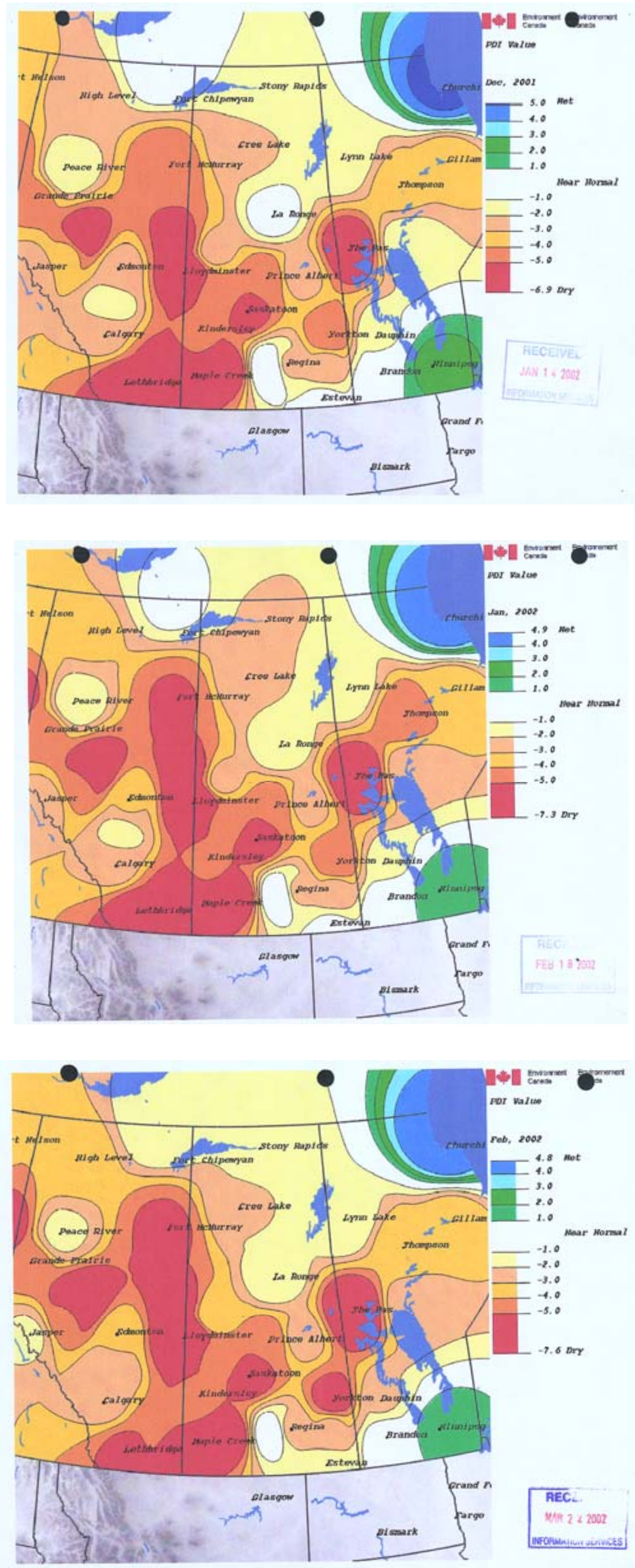


Figure A4.12 Palmer Drought Severity Index for the Canadian Prairie Provinces, Winter (December, January, February) 2001/2002 (Ryback, p. comm. 2001 and 2002)

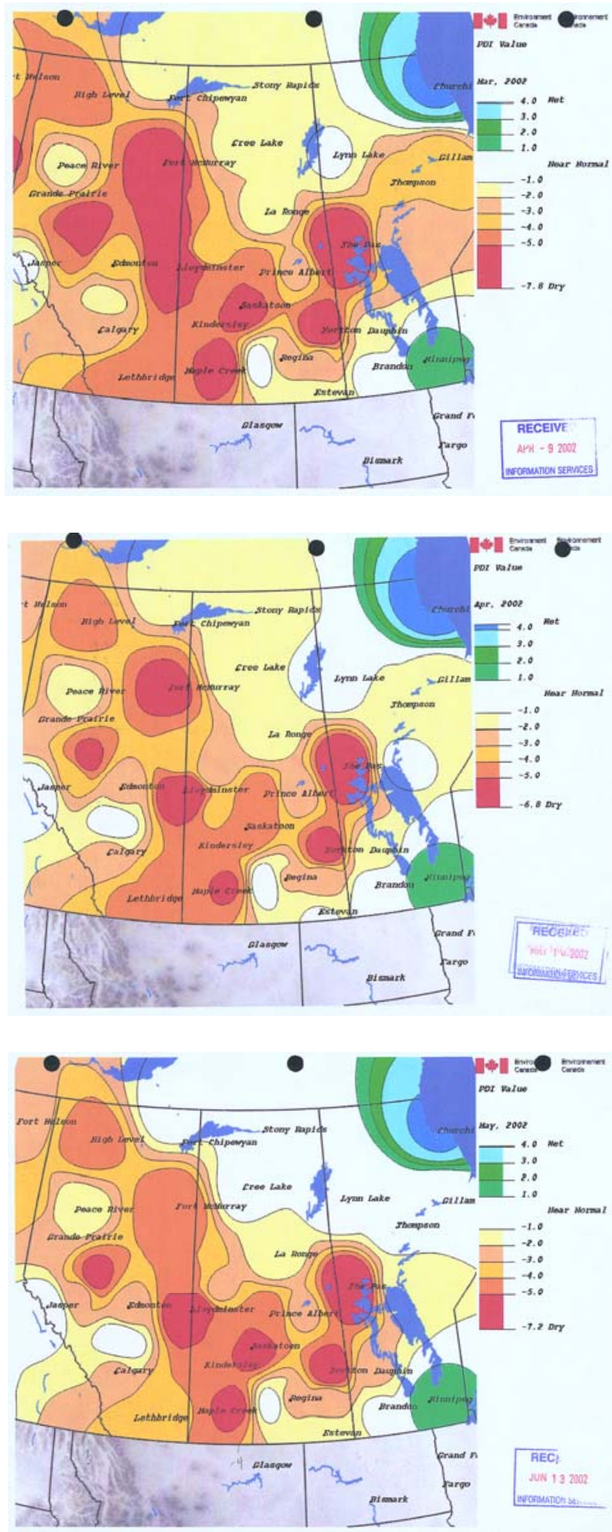


Figure A4.13 Palmer Drought Severity Index for the Canadian Prairie Provinces, Spring (March, April, May) 2002 (Ryback, p. comm. 2002)

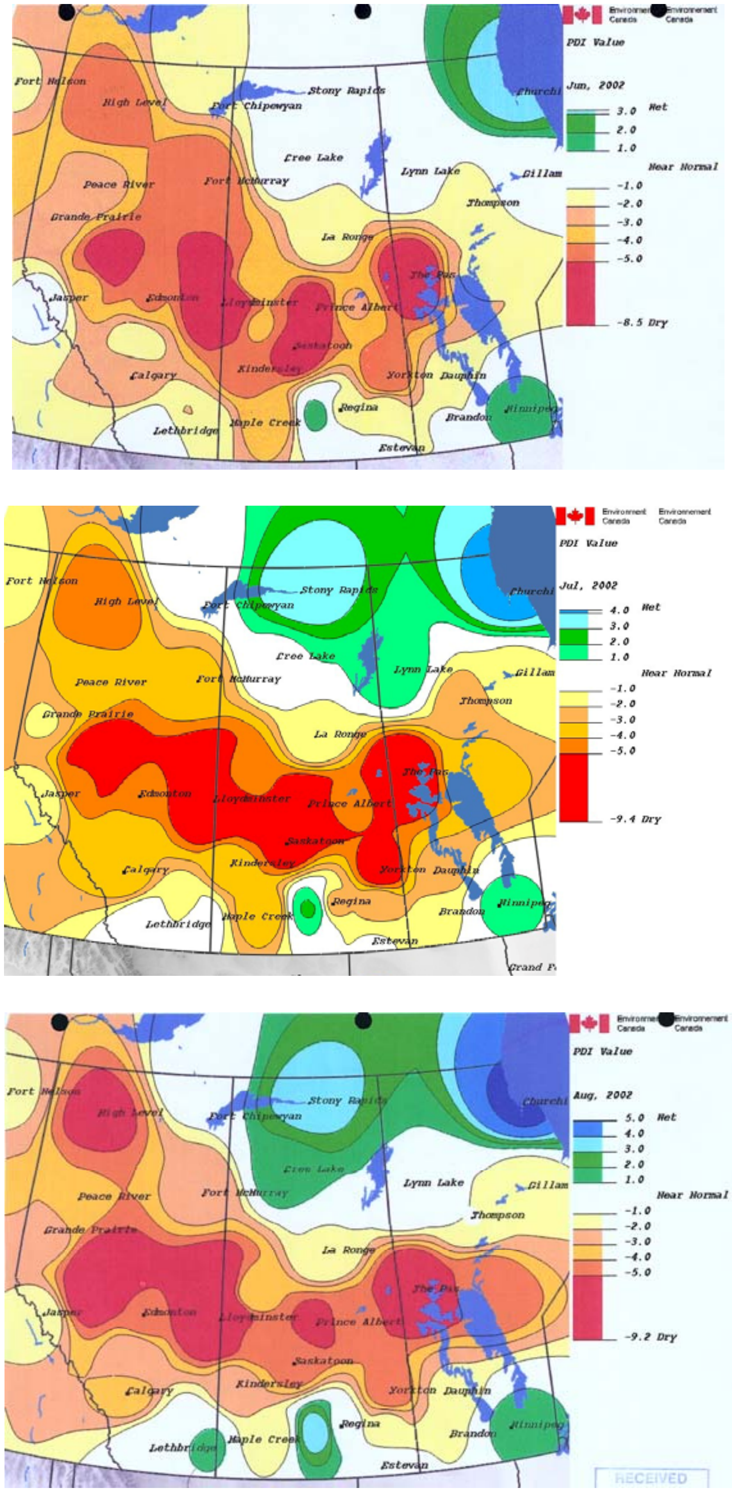


Figure A4.14 Palmer Drought Severity Index for the Canadian Prairie Provinces, Summer (June, July, August) 2002 (Ryback, p. comm. 2002)

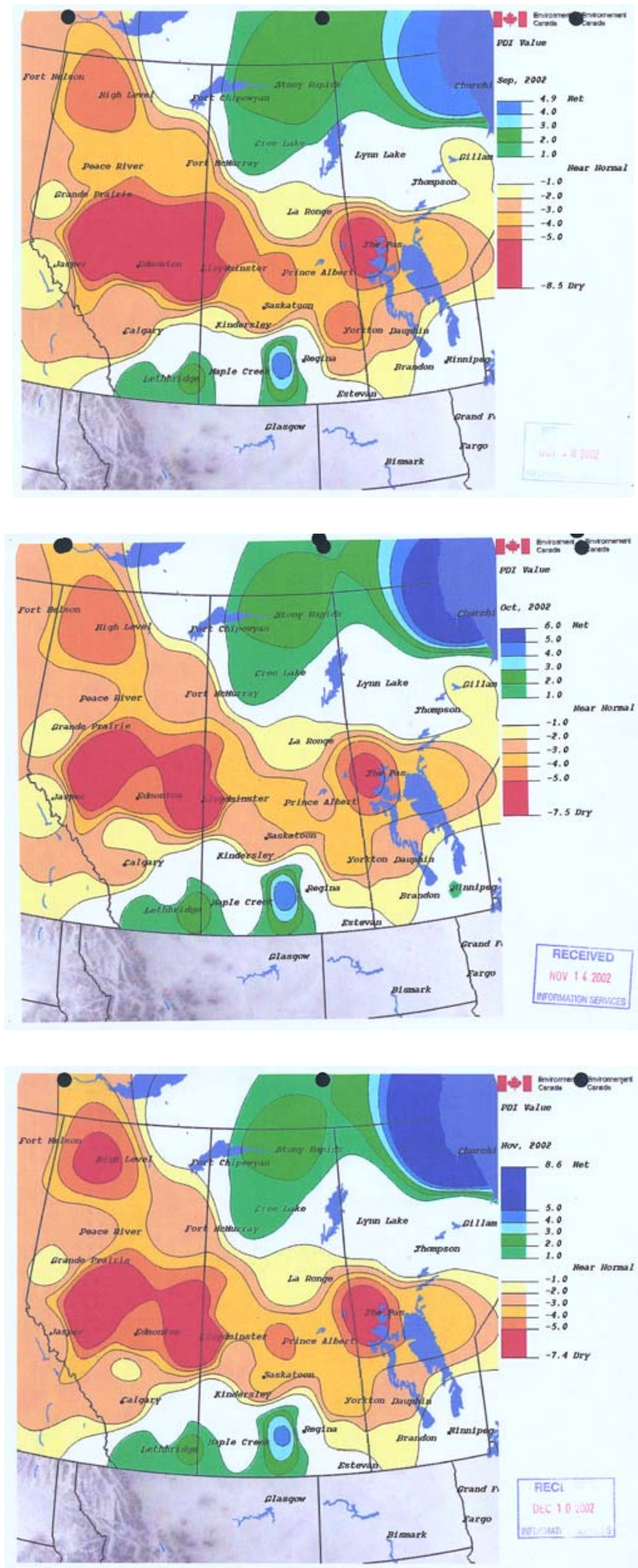


Figure A4.15 Palmer Drought Severity Index for the Canadian Prairie Provinces, Fall (September, October, November) 2002 (Ryback, p. comm. 2002)

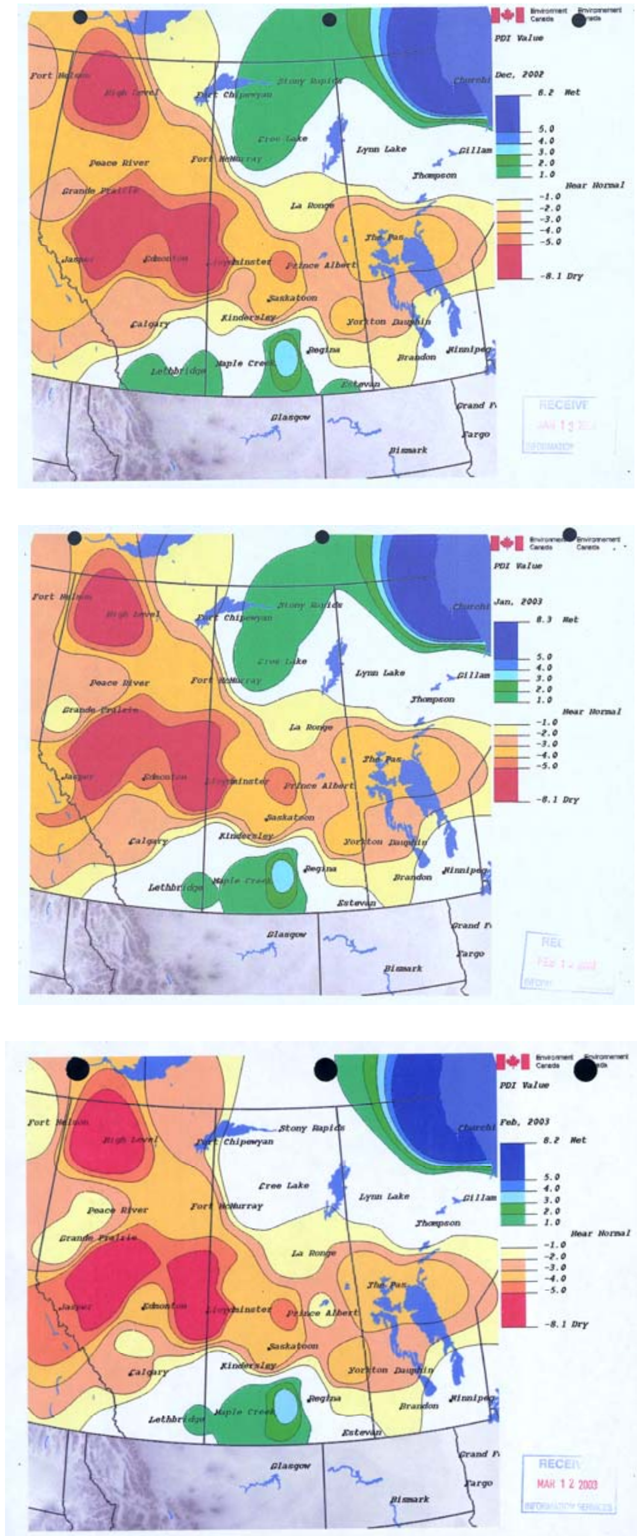


Figure A4.16 Palmer Drought Severity Index for the Canadian Prairie Provinces, Winter (December, January, February) 2002/2003 (Ryback, p. comm. 2002 and 2003)

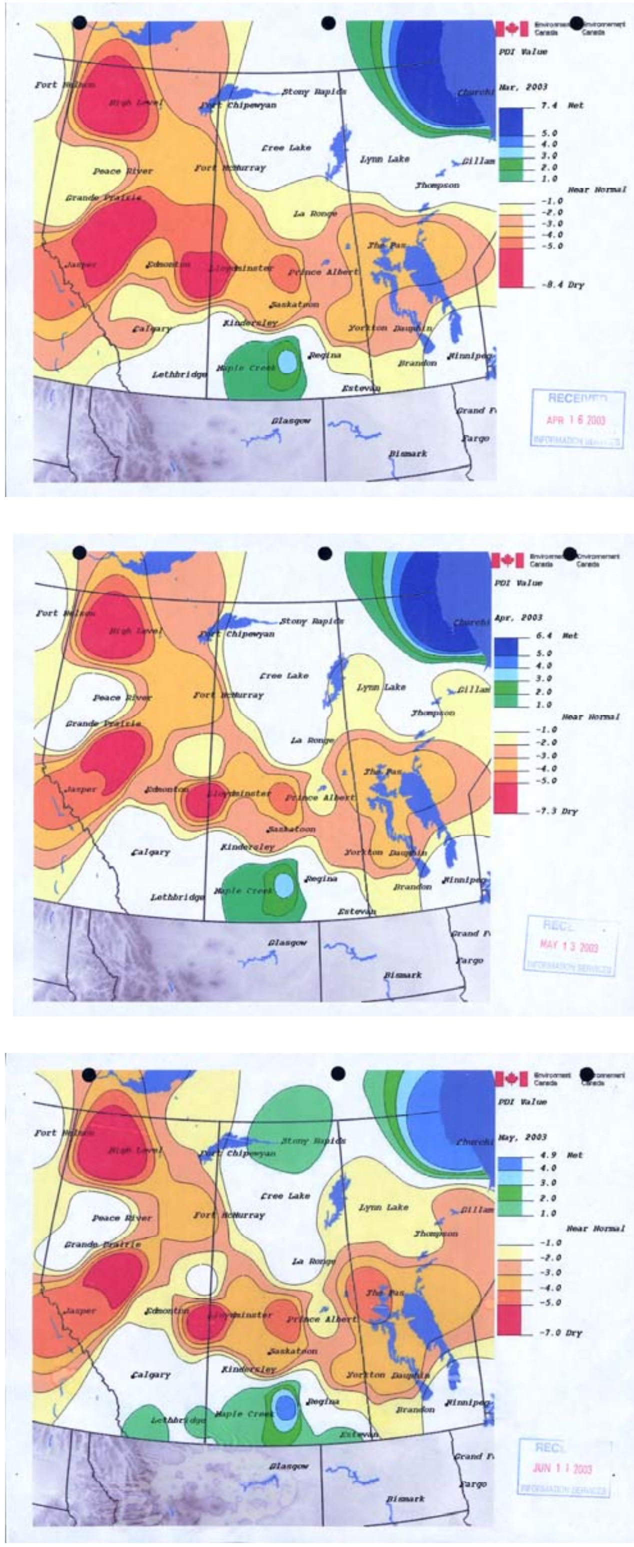


Figure A4.17 Palmer Drought Severity Index for the Canadian Prairie Provinces, Spring (March, April, May) 2003 (Ryback, p. comm. 2003)

Stream Flow in the Taber Area

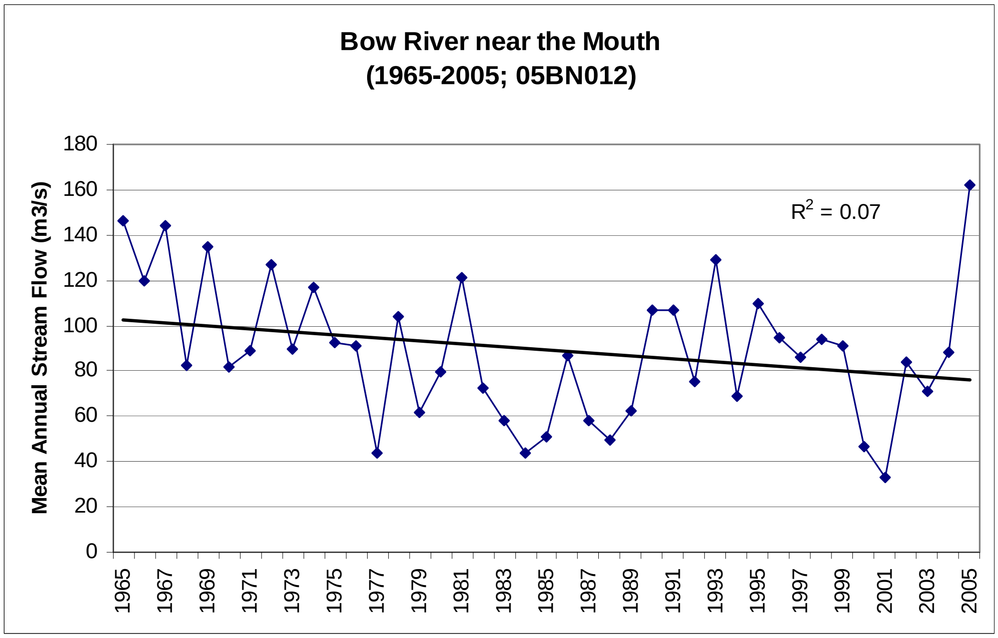


Figure A5.1 Bow River near the Mouth Mean Annual Discharge (1965-2005) (Data Source: Environment Canada 2007b)

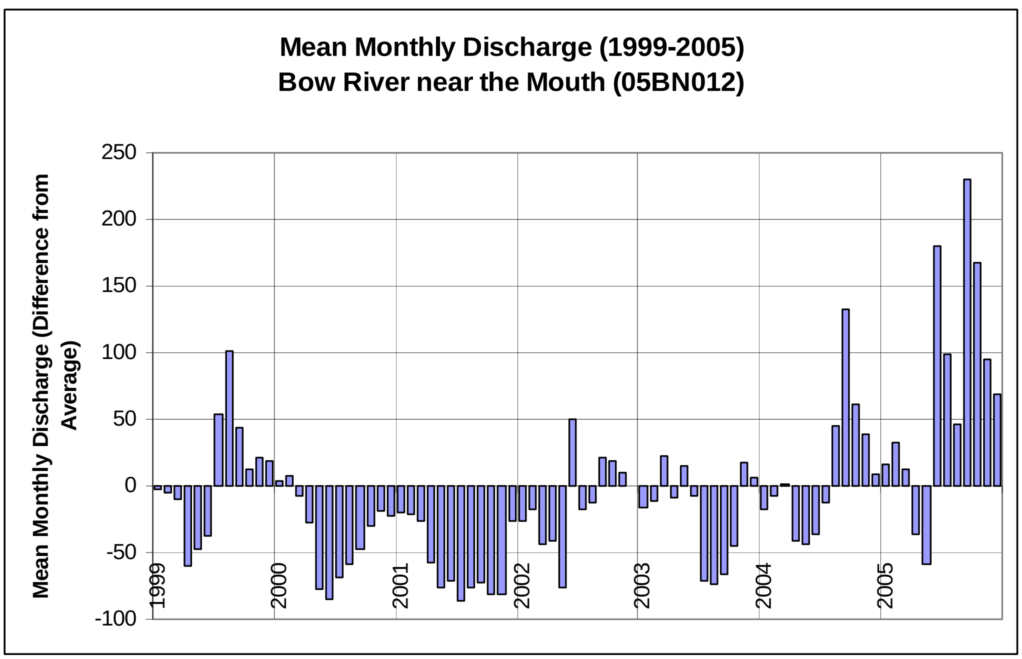


Figure A5.2 Bow River near the Mouth Mean Monthly Discharge 1999-2005 (Percent Difference from Average) (Data Source: Environment Canada, 2007b)

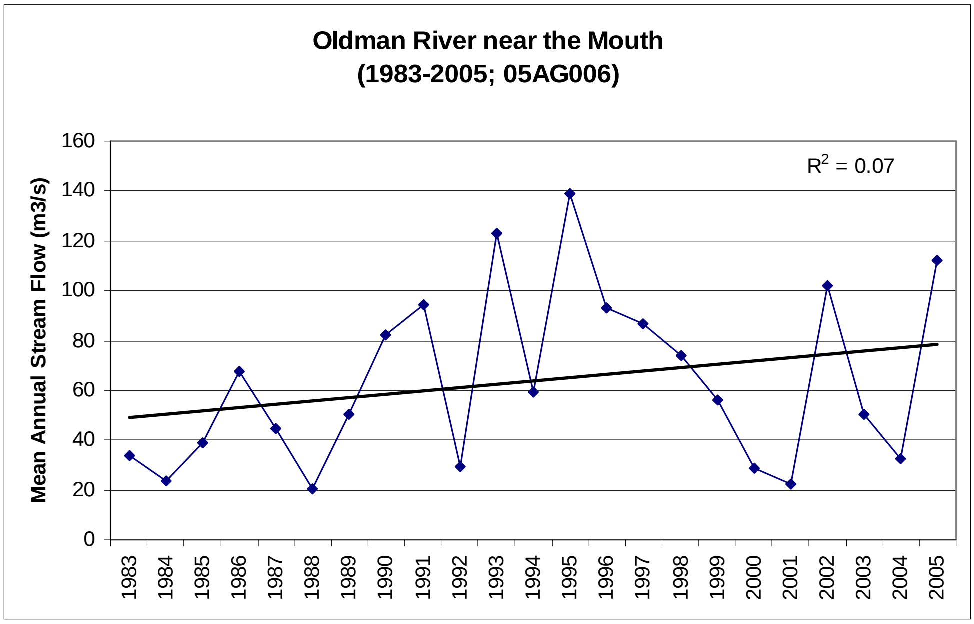


Figure A5.3 Oldman River near the Mouth Mean Annual Discharge (1983-2005) (Data Source: Environment Canada 2007b)

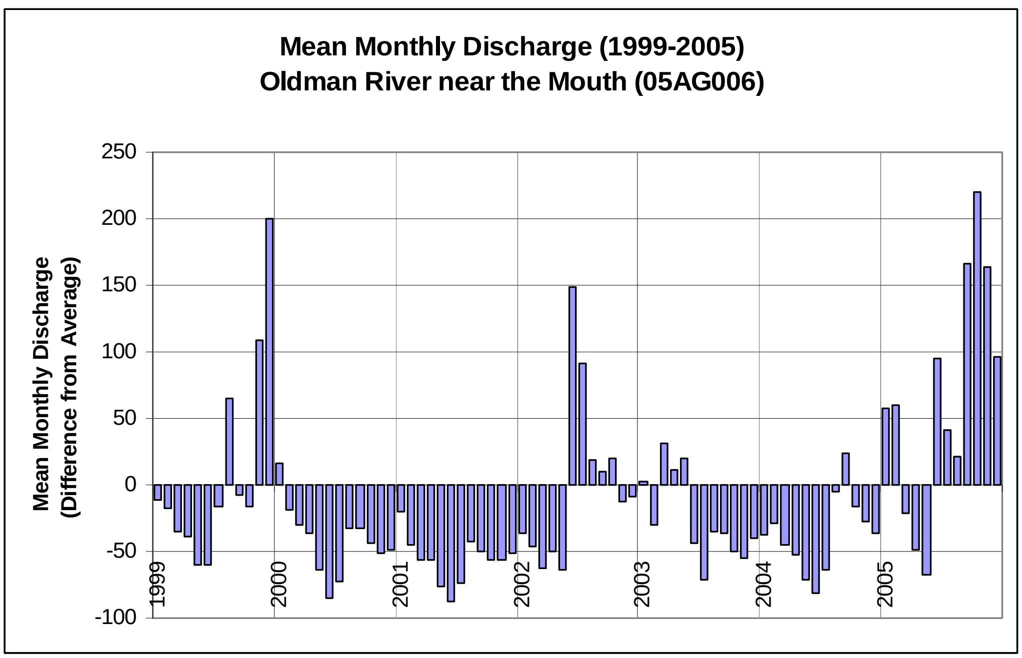


Figure A5.4 Oldman River near the Mouth Mean Monthly Discharge 1999-2005 (Percent Difference from Average) (Data Source: Environment Canada 2007b)

Stream Flow in the Hanna Region

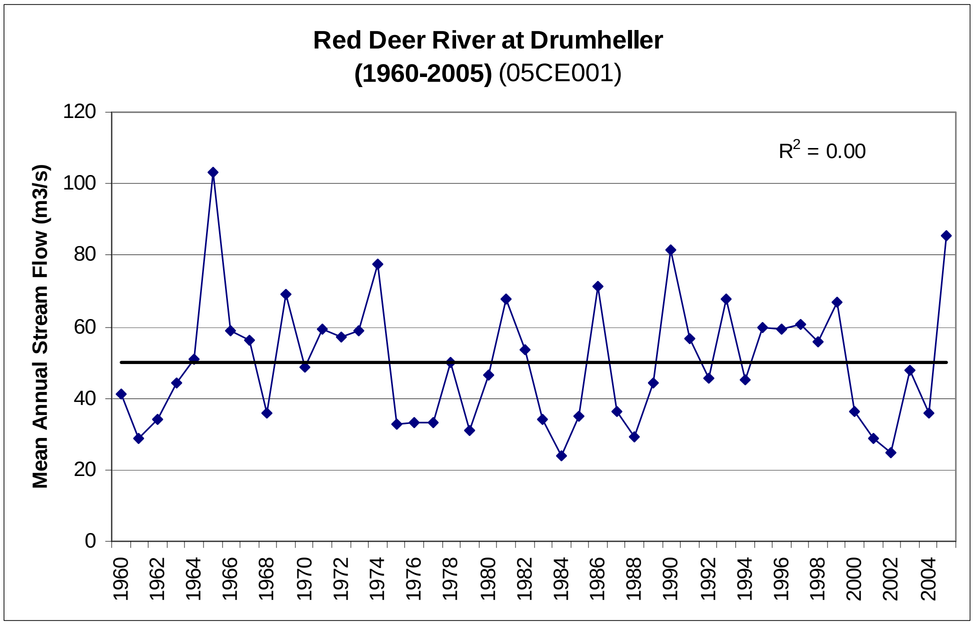


Figure A5.5 Red Deer River at Drumheller Mean Annual Discharge (1960-2005) (Data Source: Environment Canada 2007b)

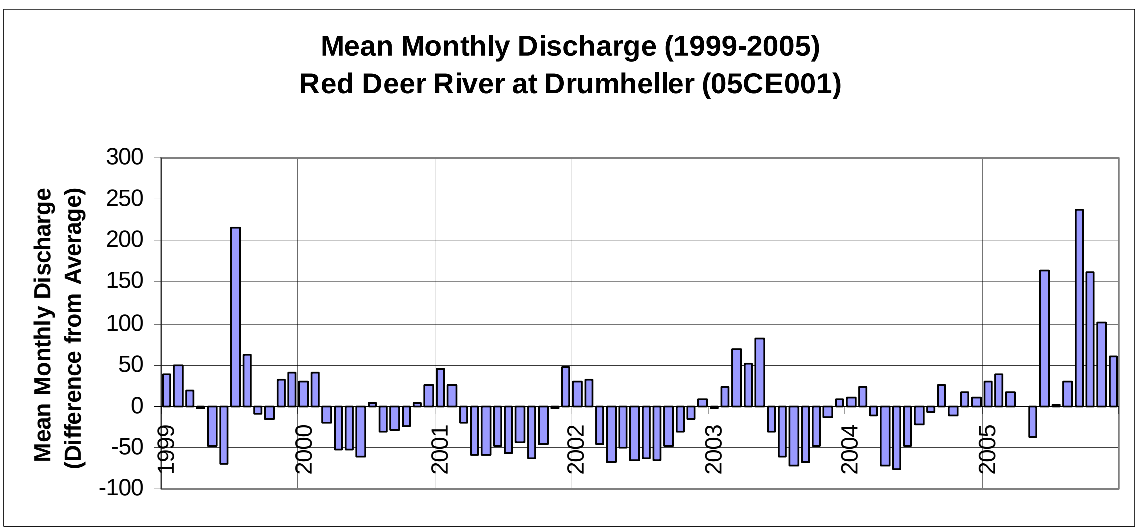


Figure A5.6 Red Deer River at Drumheller Mean Monthly Discharge 1999-2005 (Percent Difference from Average) (Data Source Environment Canada 2007b)

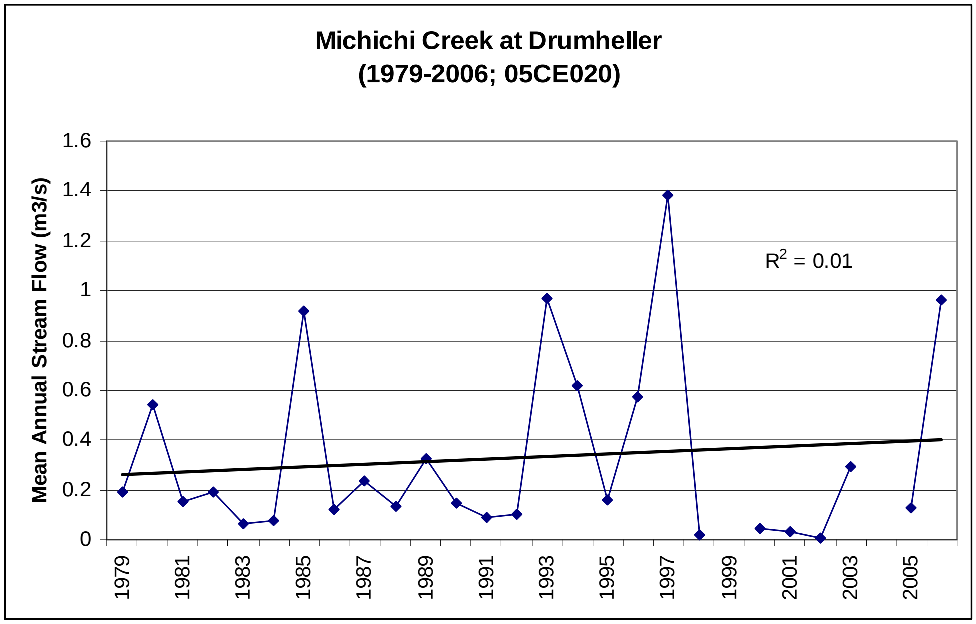


Figure A5.7 Michichi Creek near Drumheller Mean Annual Discharge (1979-2006) (Data Source: Environment Canada 2007b)

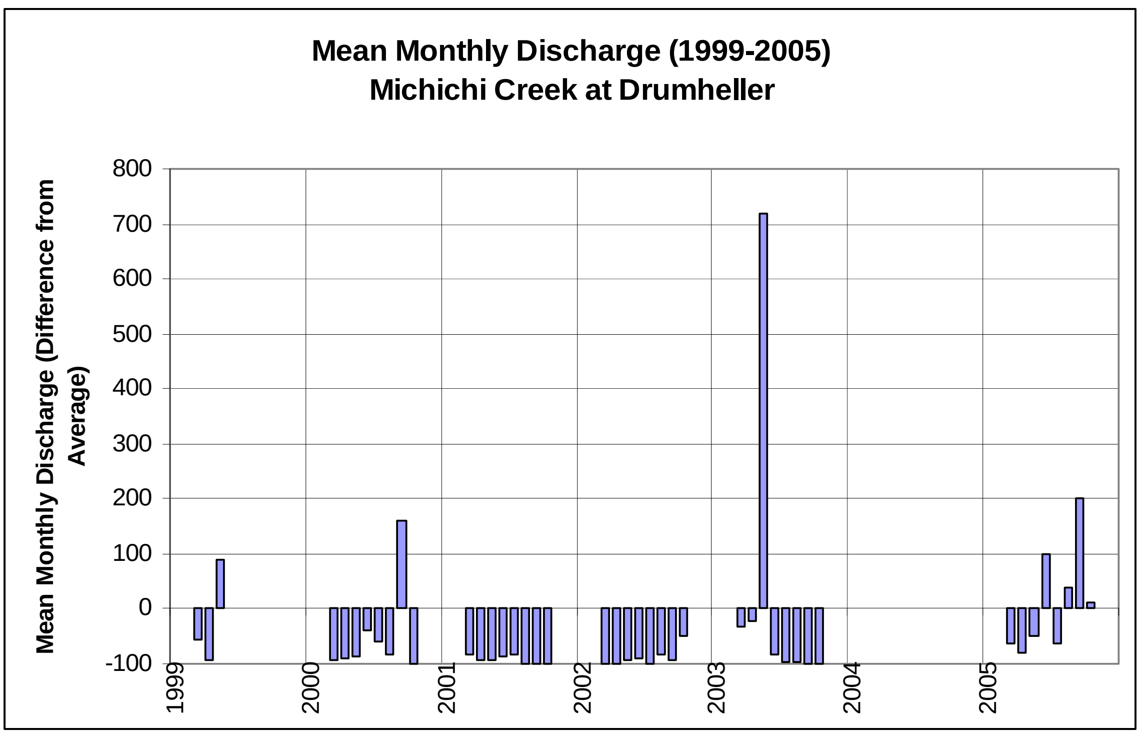


Figure A5.8 Michichi Creek near Drumheller Mean Monthly Discharge 1999-2005 (Percent Difference from Average) (Data Source: Environment Canada 2007b)

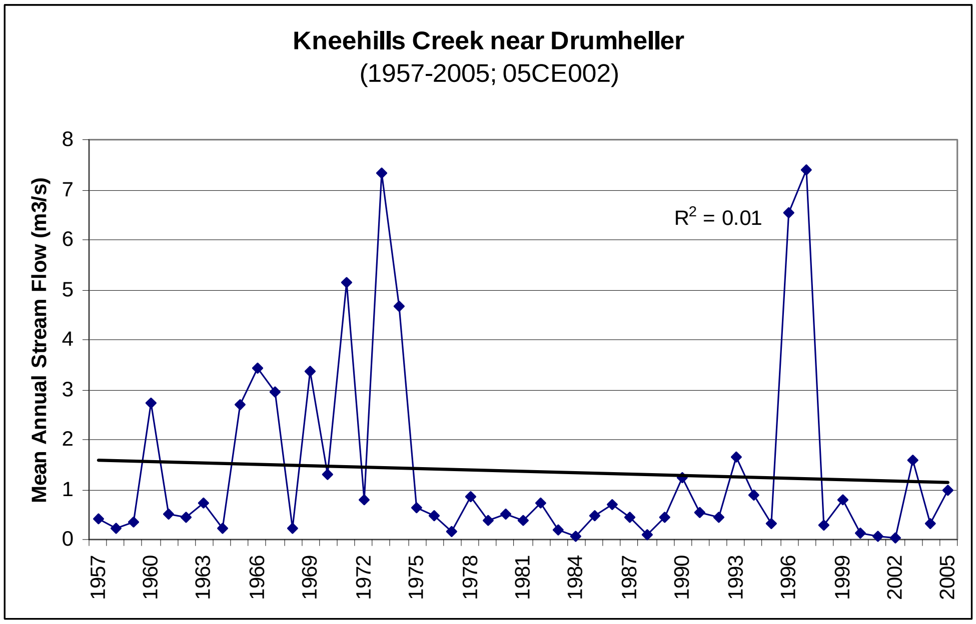


Figure A5.9 Kneehills Creek near Drumheller Mean Annual Discharge (1957-2005) (Data Source: Environment Canada 2007b)

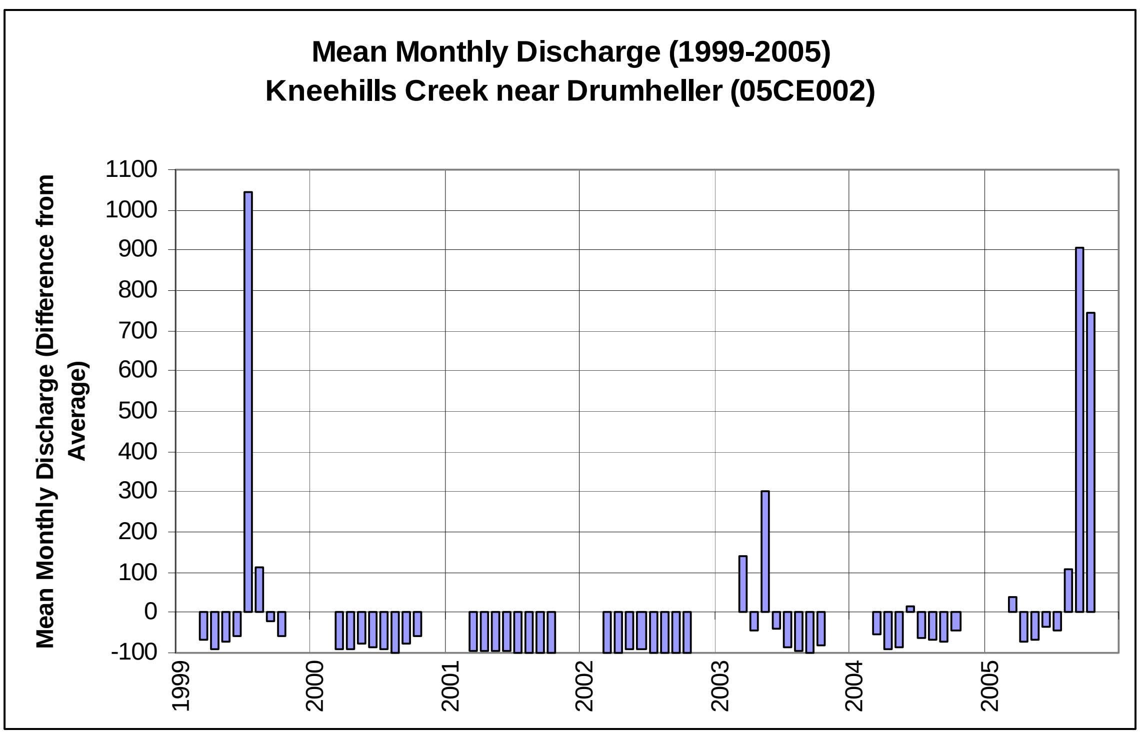


Figure A5.10 Kneehills Creek near Drumheller Mean Monthly Discharge 1999-2005 (Percent Difference from Average) (Data Source: Environment Canada 2007b)

Stream Flow in the Outlook Region

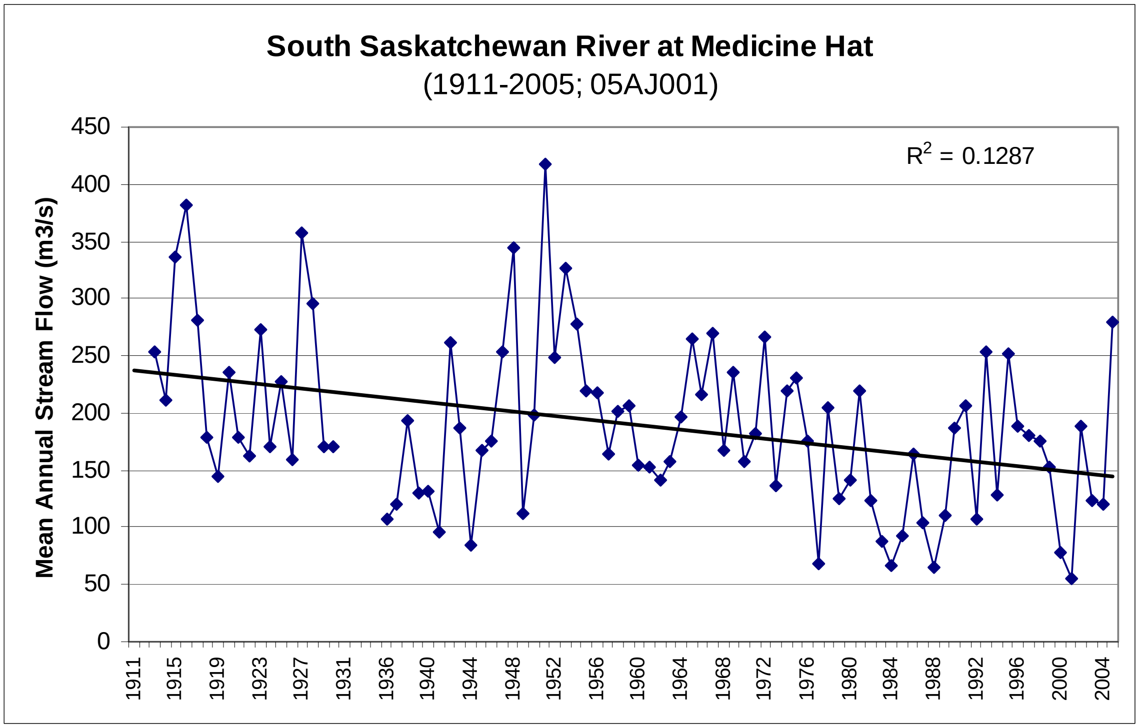


Figure A5.11 South Saskatchewan River Mean Annual Discharge at Medicine Hat (1911-2005) (Data Source: Environment Canada 2007b)

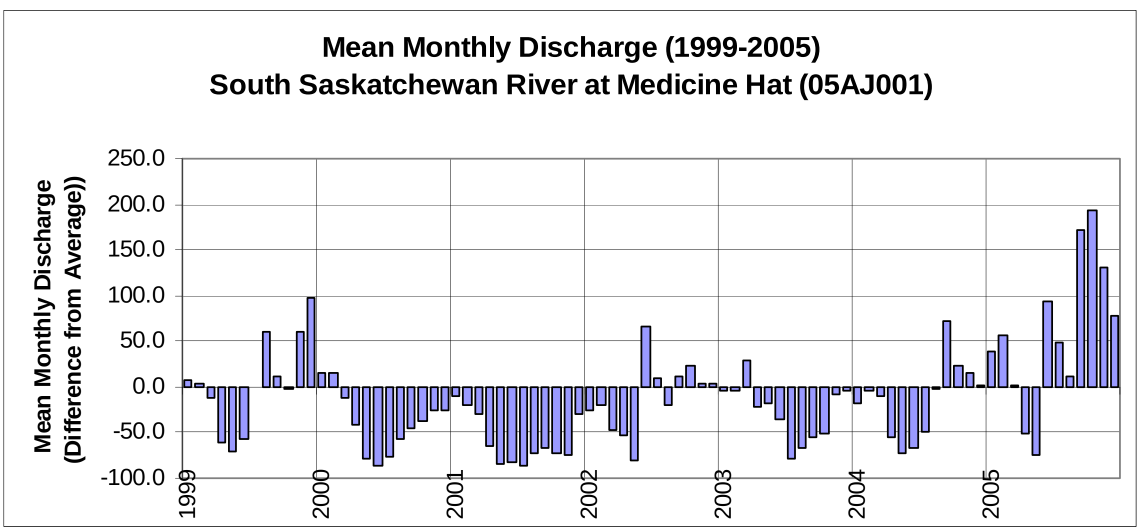


Figure A5.12 South Saskatchewan River at Medicine Hat Mean Monthly Discharge 1999-2005 (Percent Difference from Average) (Data Source: Environment Canada 2007b)

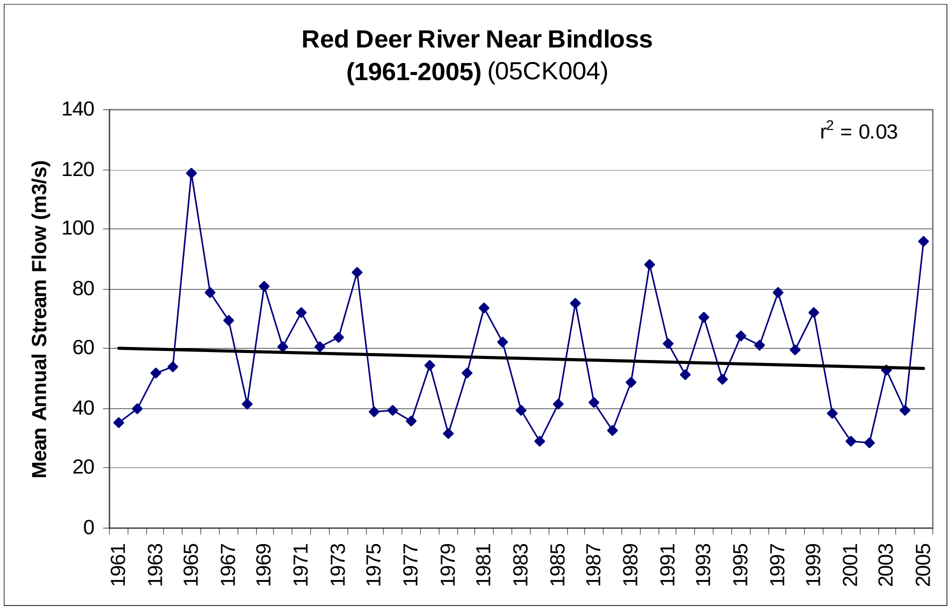


Figure A5.13 Red Deer River near Bindloss Mean Annual Discharge (1961-2005) (Data Source: Environment Canada 2007b)

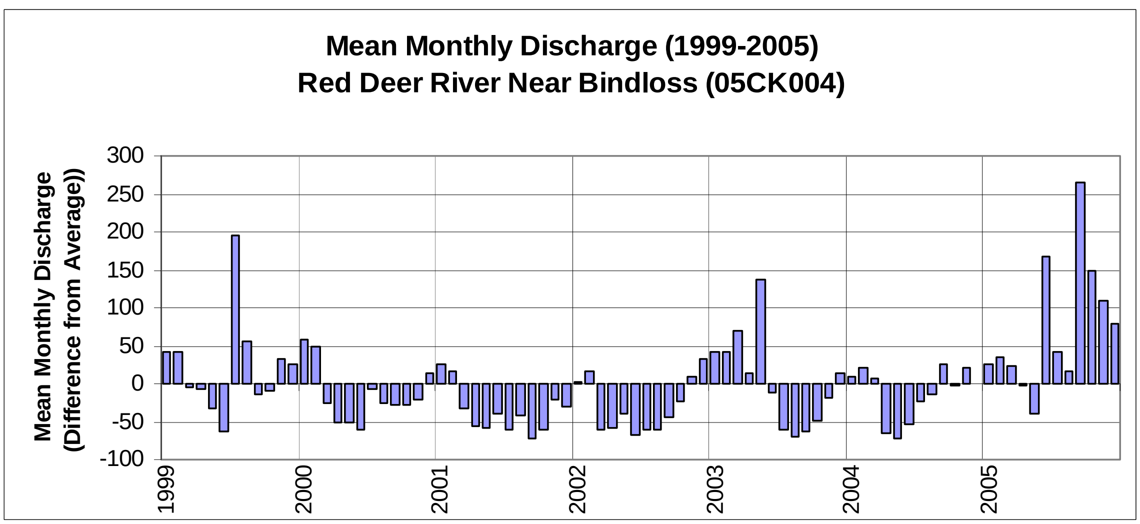


Figure A5.14 Red Deer River near Bindloss Mean Monthly Discharge 1999-2005 (Percent Difference from Average) (Data Source: Environment Canada 2007b)

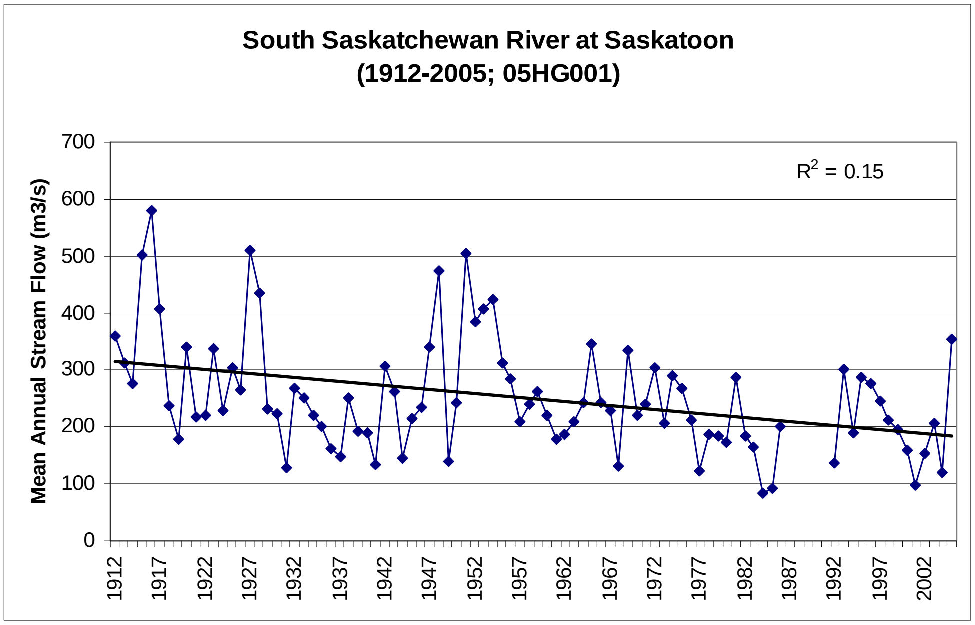


Figure A5.15 South Saskatchewan River Mean Annual Discharge at Saskatoon (1912-2005) (Data Source: Environment Canada 2007b)

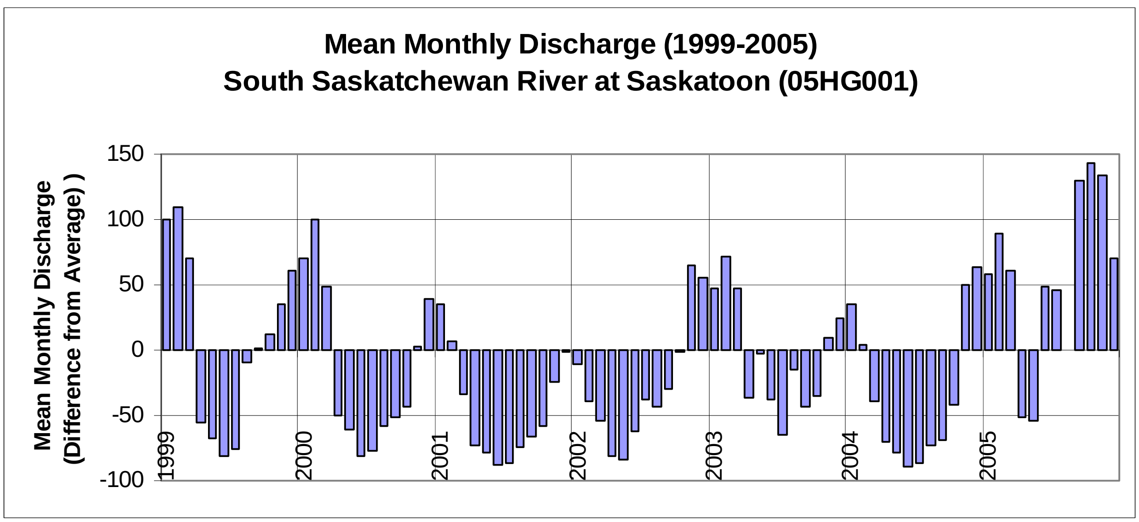


Figure A5.16 South Saskatchewan River at Saskatoon Mean Monthly Discharge 1999-2004 (Percent Difference from Average) (Data Source: Environment Canada 2007b)

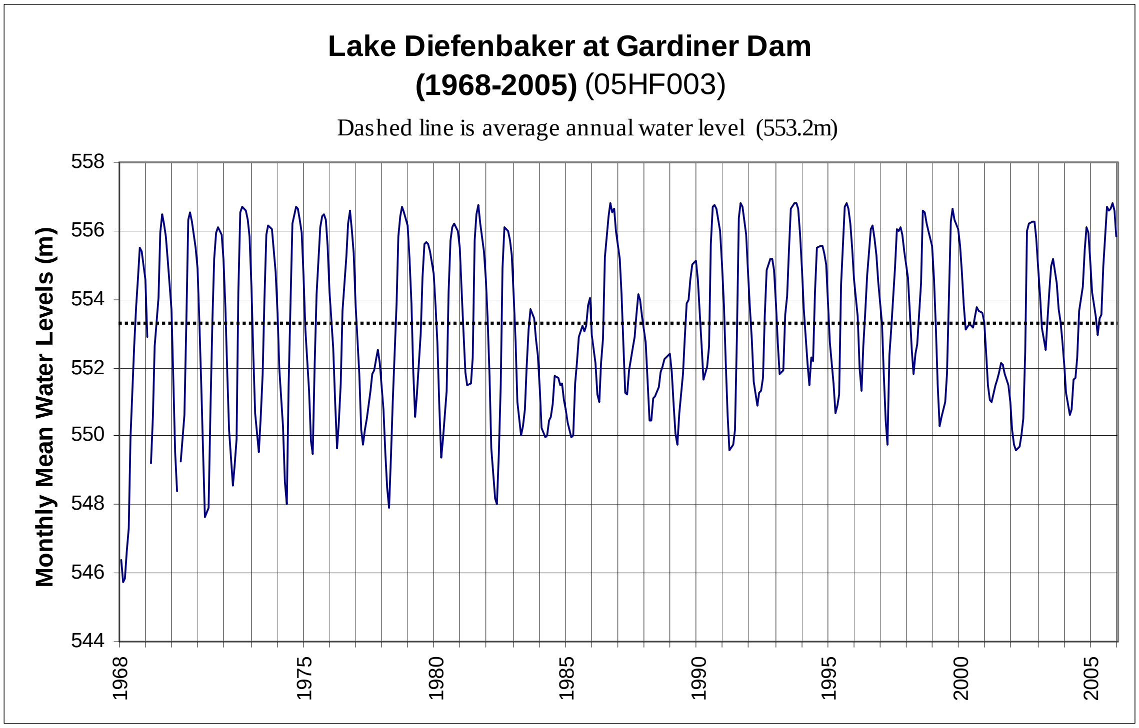


Figure A5.17 Monthly Mean Water Levels at Lake Diefenbaker (1968-2005) (Data Source Environment Canada 2007b)

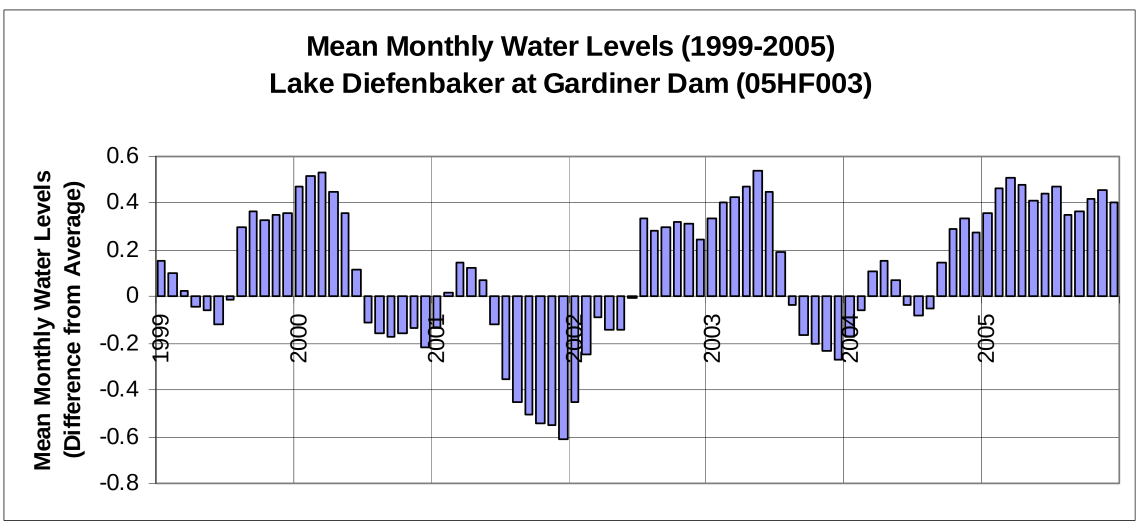


Figure A5.18 Lake Diefenbaker at Gardiner Dam Mean Monthly Water Levels 1999-2005 (Percent Difference from Average) (Data Source: Environment Canada 2007b)

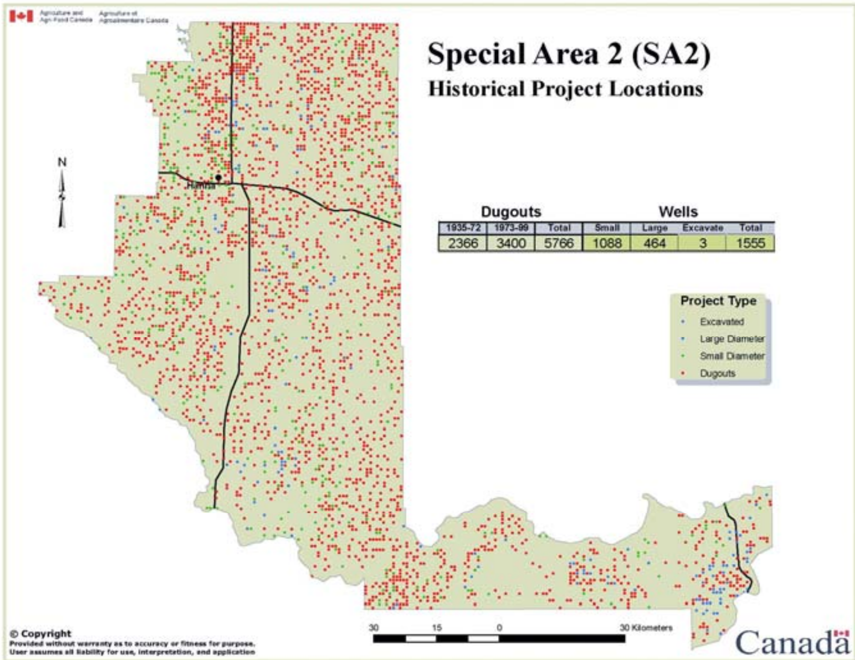


Figure A5.19 Historic Dugout and Well Locations in Special Area 2, Alberta (PFRA – Agriculture and Agri-Food Canada 2007b)

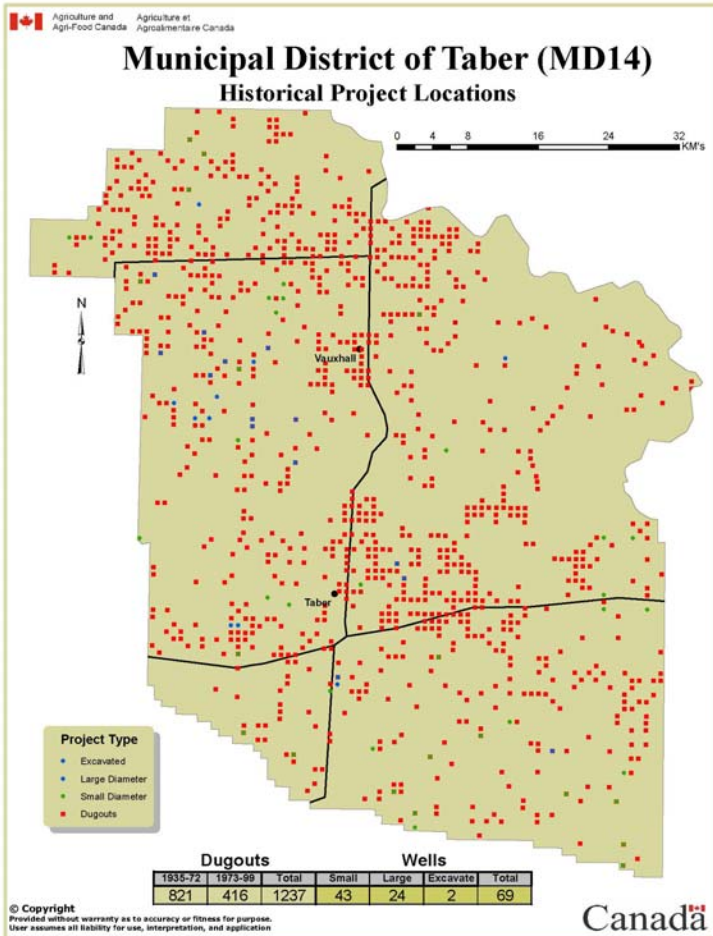


Figure A5.20 Historic Dugout and Well Locations in Municipal District of Taber, Alberta
(PFRA – Agriculture and Agri-Food Canada 2007c)

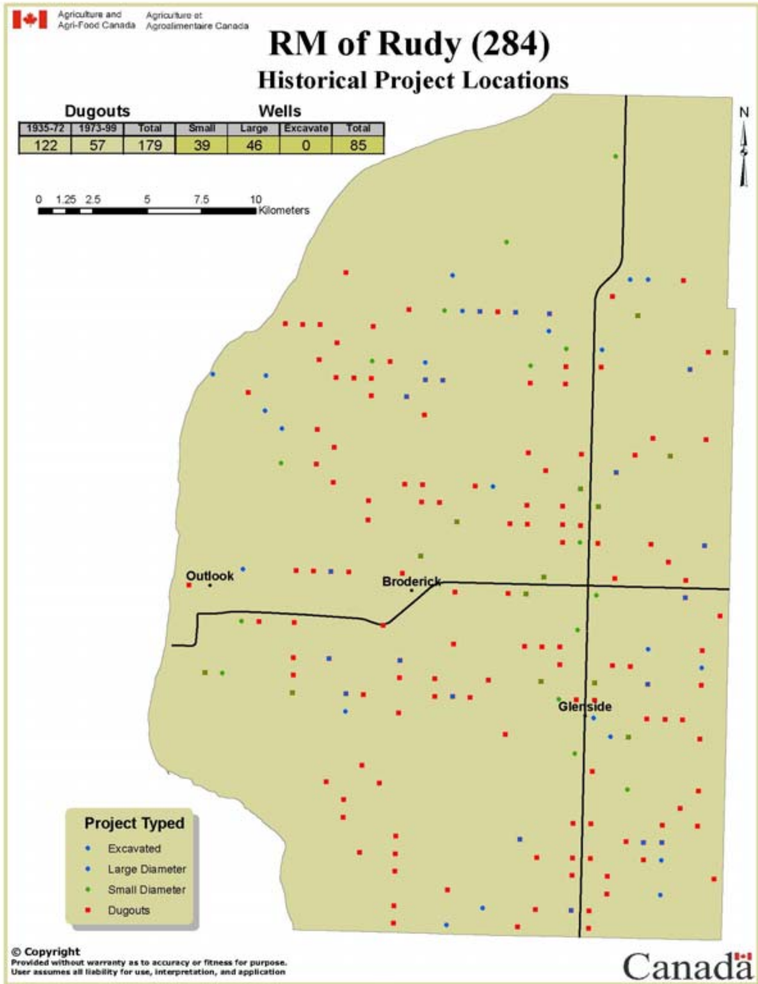
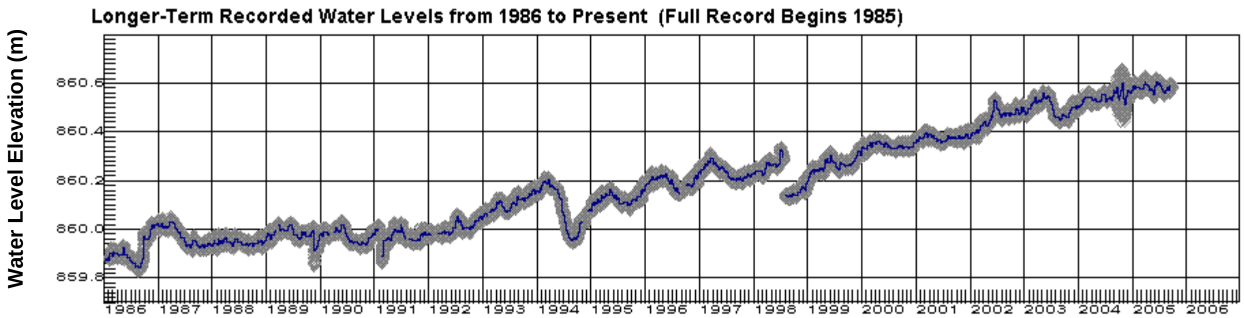


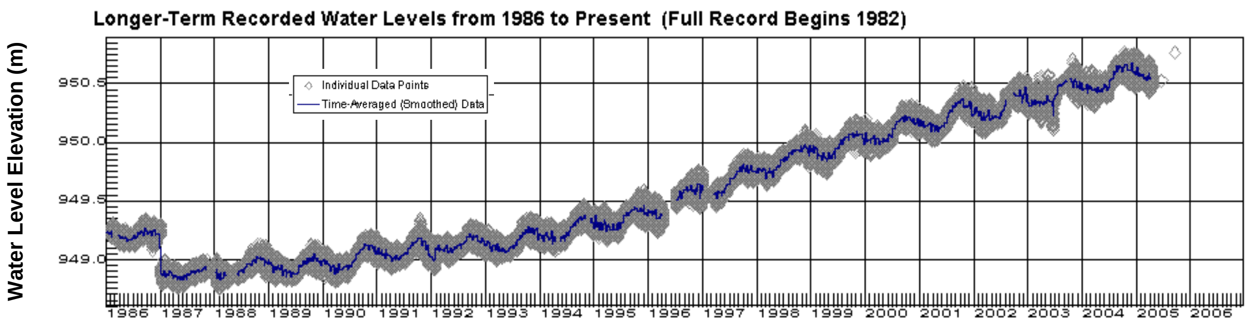
Figure A5.21 Historic Dugout and Well Locations in the Rural Municipality of Rudy, Saskatchewan (PFRA – Agriculture and Agri-Food Canada 2007d)

Figure A5.22 Groundwater Observation Wells in the Taber Region (Adapted from Alberta Environment 2007)

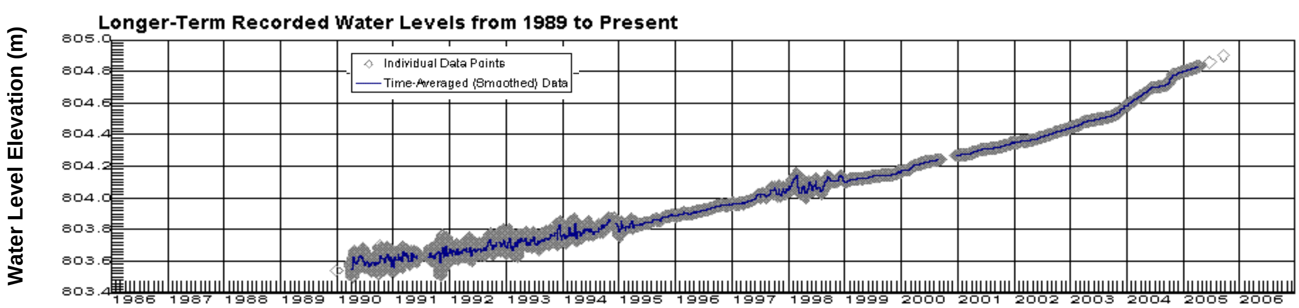
Pakowki 85-1 (Observation Well #104)



Keho Lake 2019E (Observation Well #113)



Enchant 2520E (Observation Well #278)



Forty Mile Coulee 86-1 (Observation Well #286)

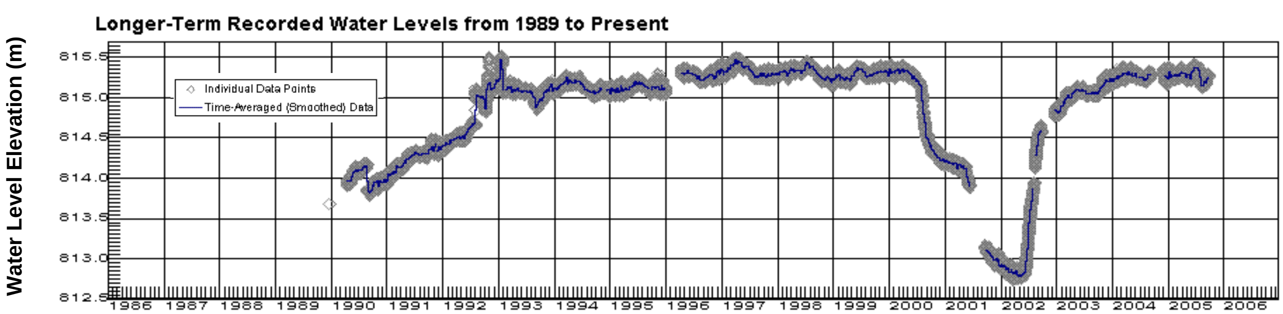
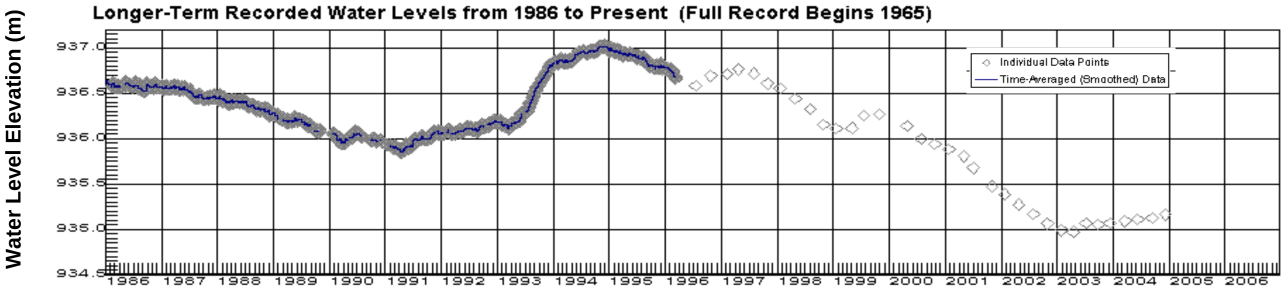
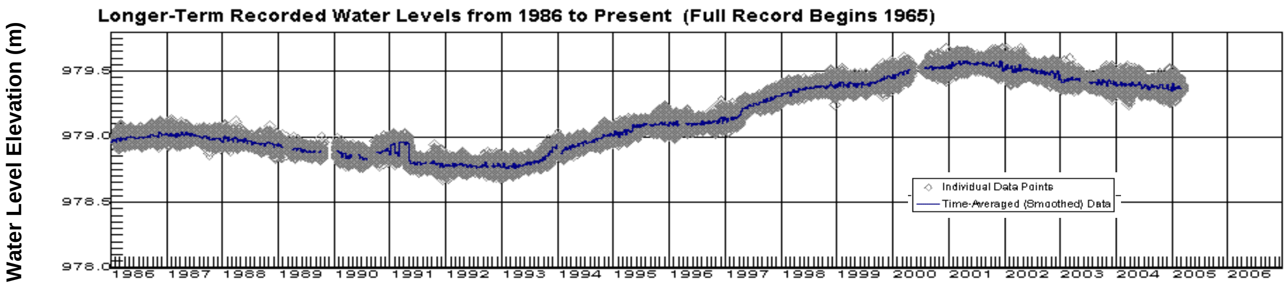


Figure A5.23 Groundwater Observation Wells in the Hanna Region (Adapted from Alberta Environment 2007)

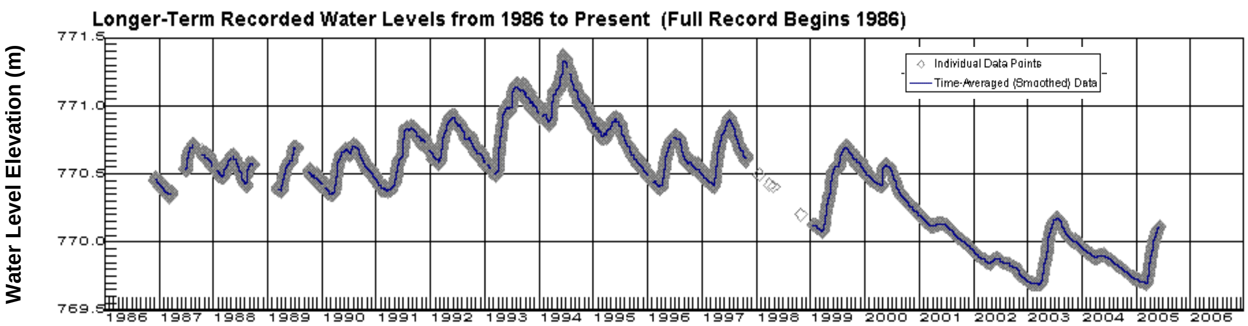
Hand Hills #1 (Observation Well #124)



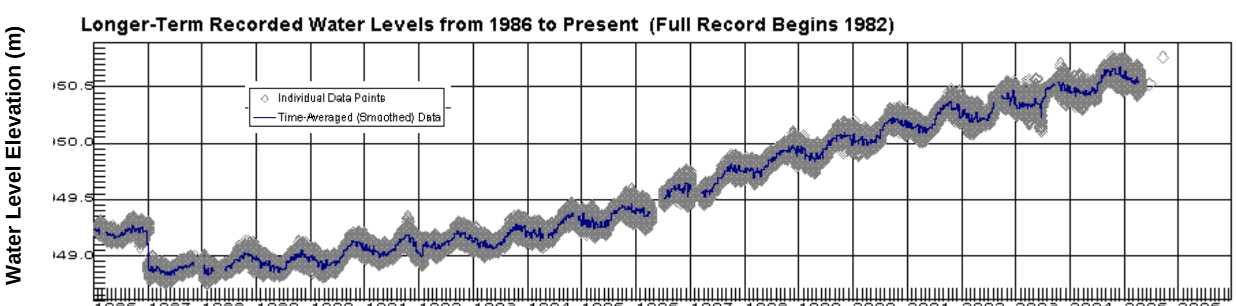
Hand Hills #2 (Observation Well #125)



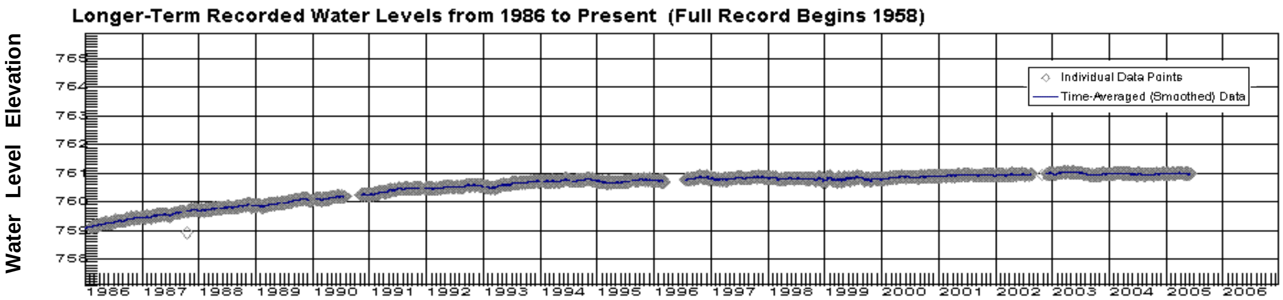
Kirkpatrick Lake 86-3 East (Observation Well #230)



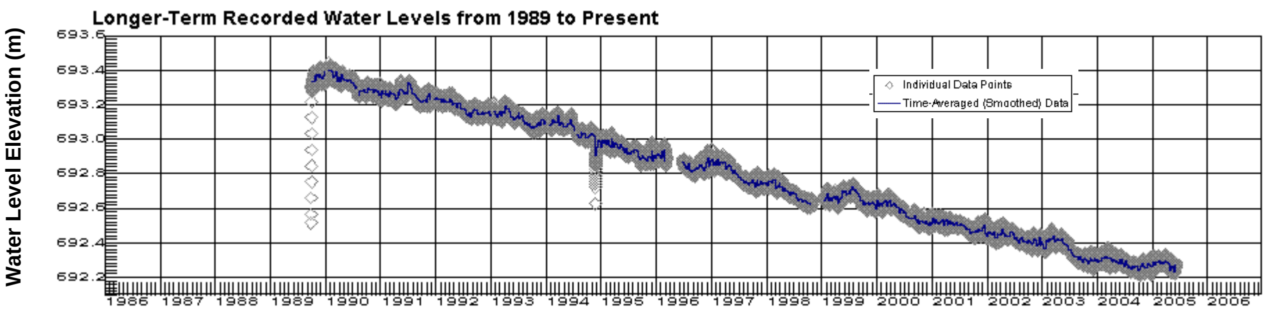
Kirkpatrick Lake 86-2 Mid (Observation Well #229)



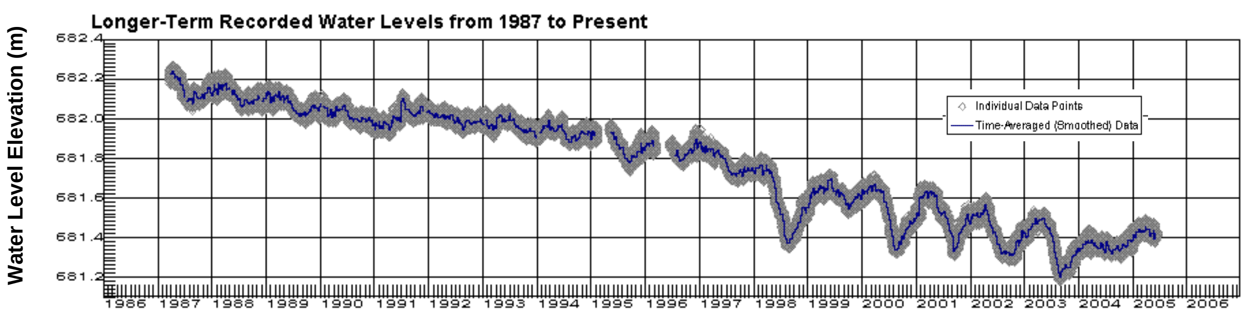
Coronation (Observation Well #130)



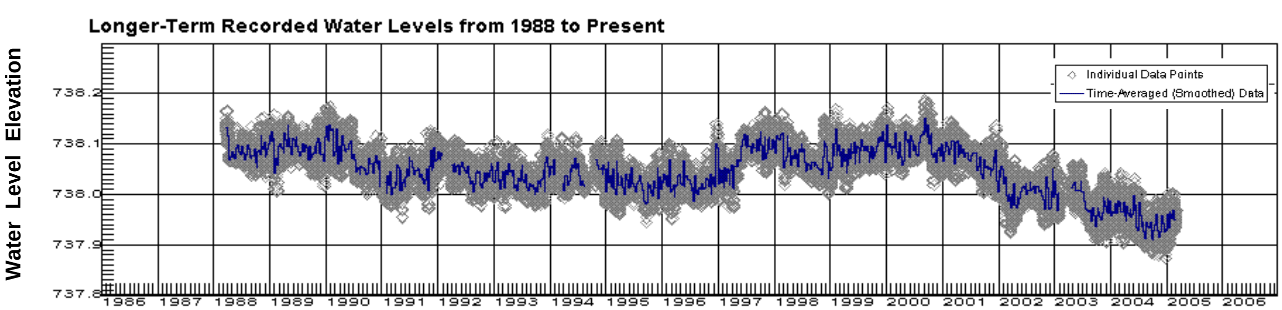
Sounding Creek 2532E (Observation Well #274)



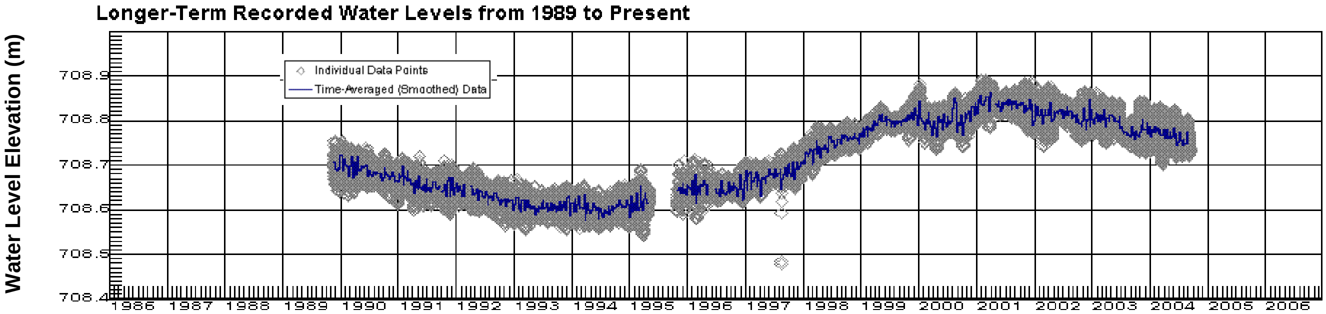
Monitor 86-1 (South) (Observation Well #225)



Big Stone 2415E (Observation Well #222)



Cessford 85-2 (Observation Well #258)



Duchess 2564E (Observation Well #289)

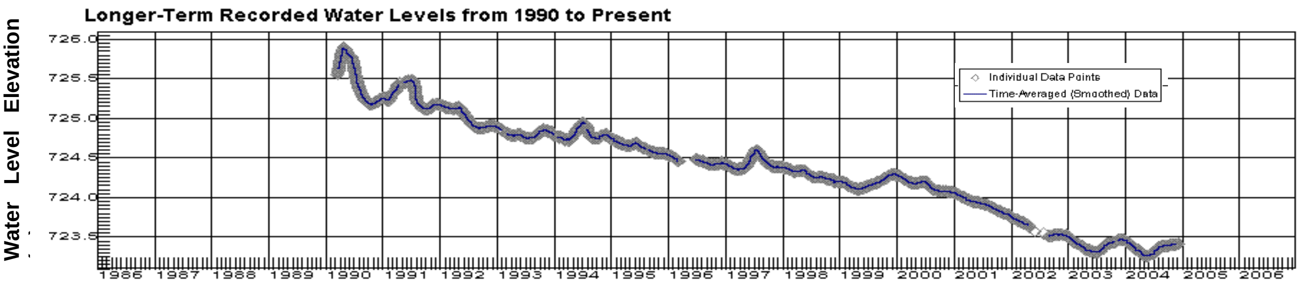
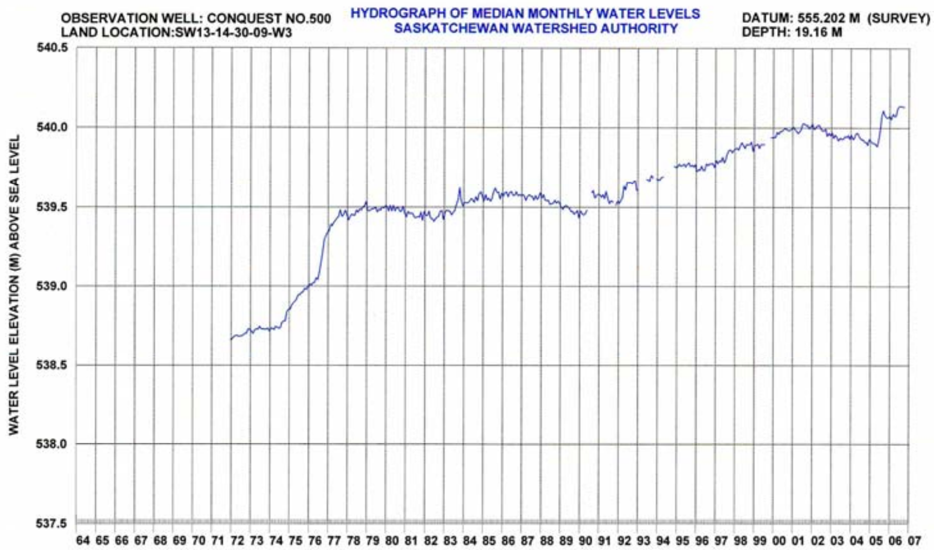
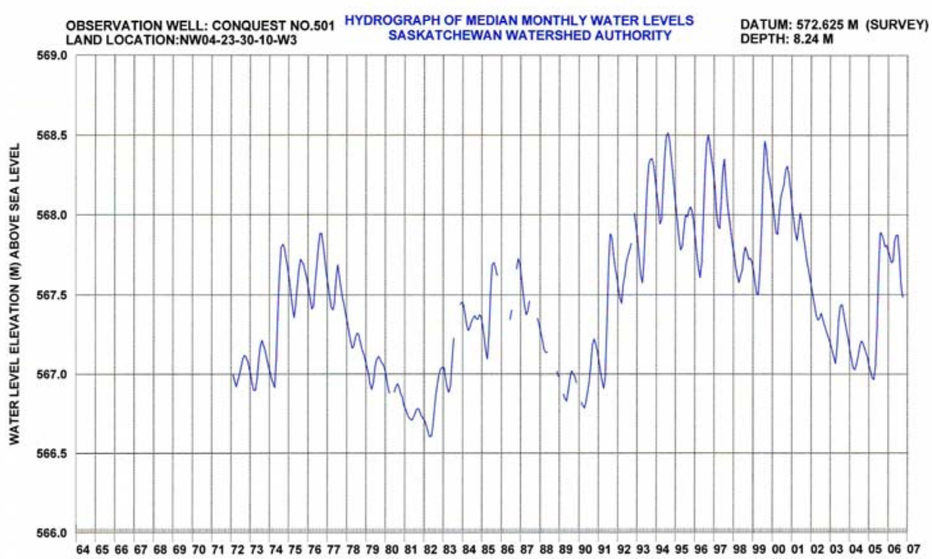
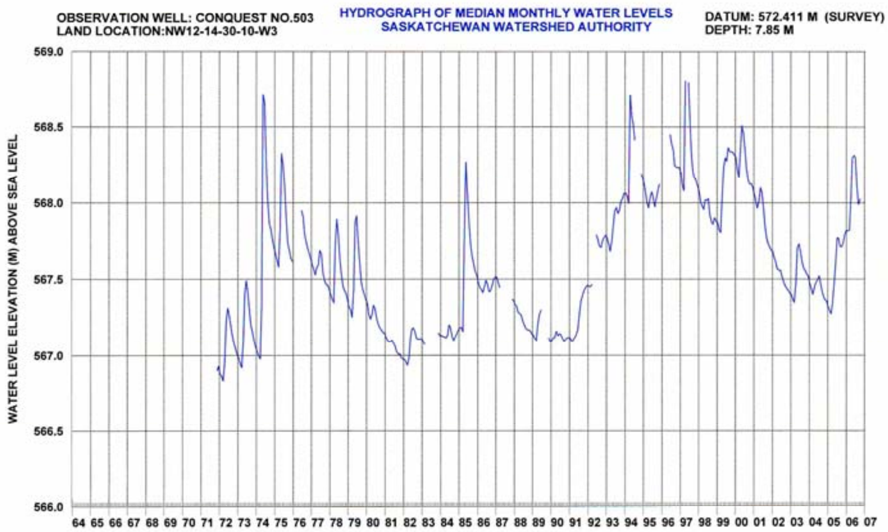
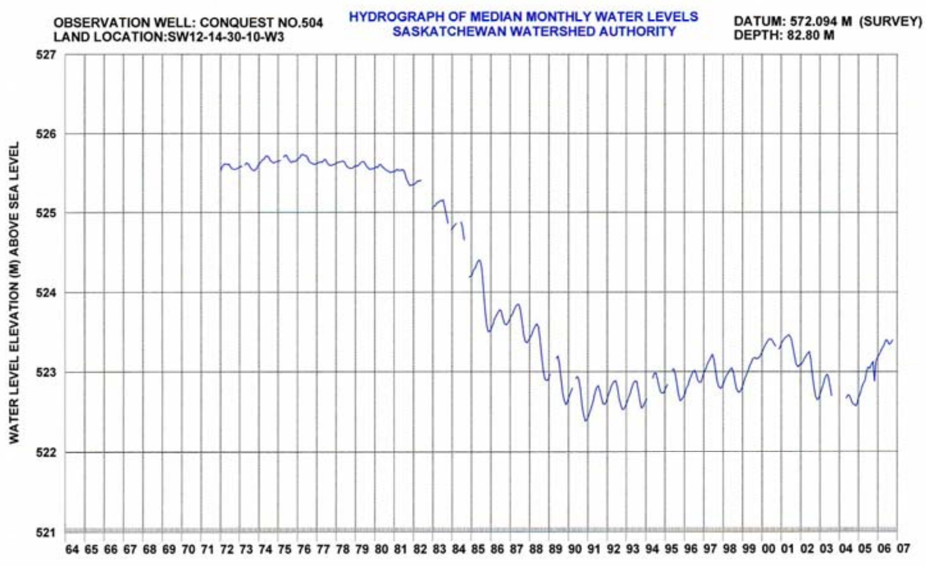


Figure A5.24 Groundwater Observation Wells in the Outlook Region (Adapted from Saskatchewan Watershed Authority 2007)






OBSERVATION WELL: CONQUEST NO.503
LAND LOCATION:NW12-14-30-10-W3
HYDROGRAPH OF MEDIAN MONTHLY WATER LEVELS
SASKATCHEWAN WATERSHED AUTHORITY
DATUM: 572.411 M (SURVEY)
DEPTH: 7.85 M
WATER LEVEL ELEVATION (M) ABOVE SEA LEVEL
569.0
568.5
568.0
567.5
567.0
566.5
566.0
64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07


OBSERVATION WELL: CONQUEST NO.504
LAND LOCATION:SW12-14-30-10-W3
HYDROGRAPH OF MEDIAN MONTHLY WATER LEVELS
SASKATCHEWAN WATERSHED AUTHORITY
DATUM: 572.094 M (SURVEY)
DEPTH: 82.80 M
WATER LEVEL ELEVATION (M) ABOVE SEA LEVEL
527
526
525
524
523
522
521
64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07

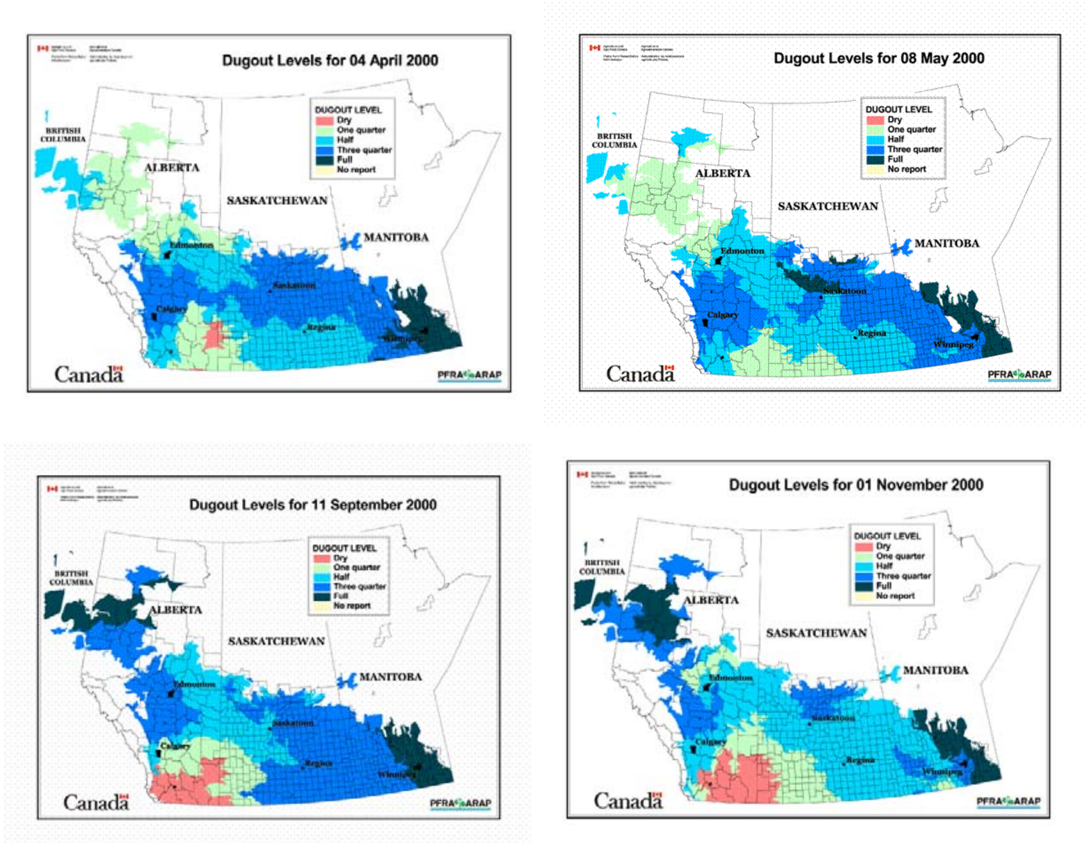


Figure A5.25 Dugout Levels across Canadian Prairies 2000 (PFRA - Agriculture and Agri-Food Canada 2006b)

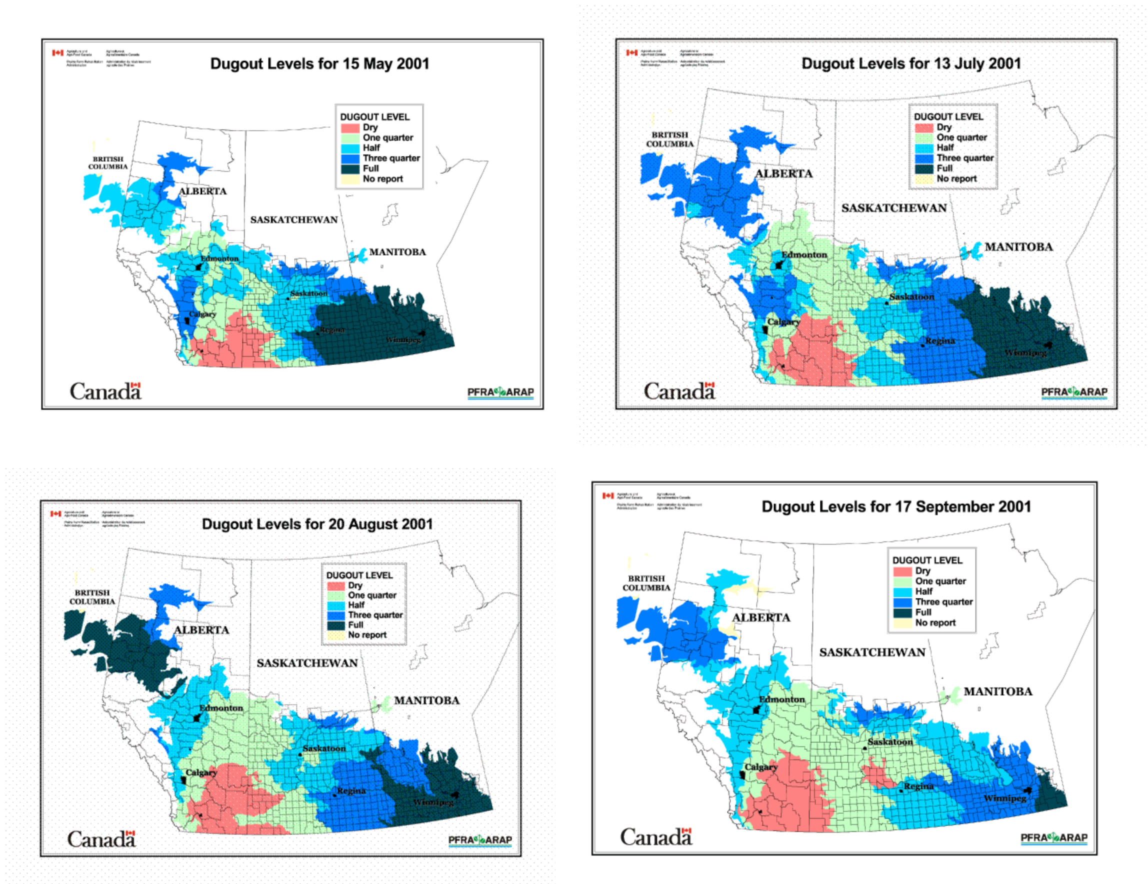


Figure A5.26 Dugout Levels across Canadian Prairies 2001 (PFRA - Agriculture and Agri-Food Canada 2006b)

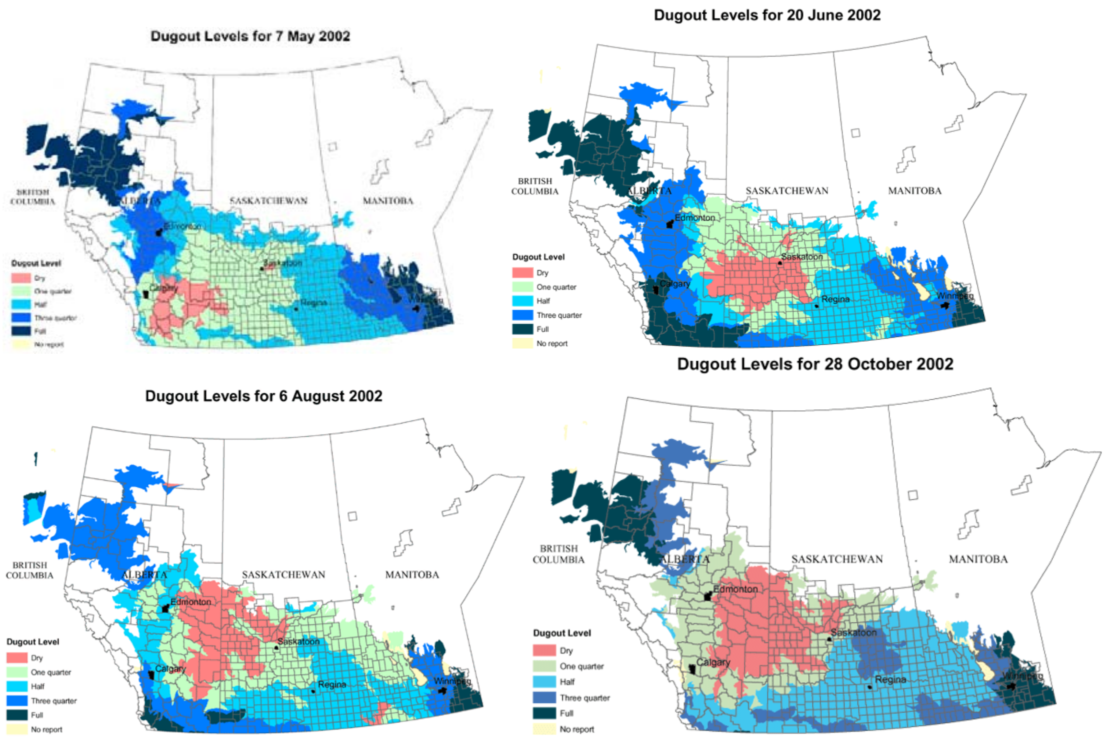


Figure A5.27 Dugout Levels across Canadian Prairies 2002 (PFRA - Agriculture and Agri-Food Canada 2006b)

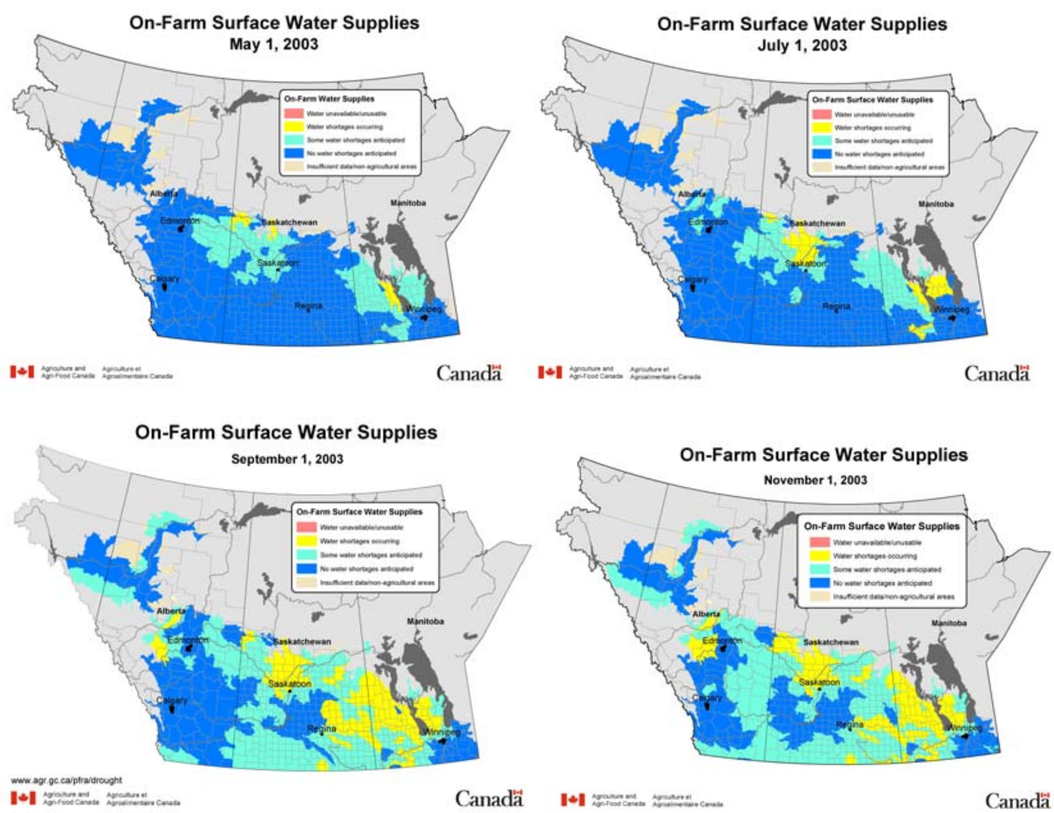


Figure A5.28 On-Farm Surface Water Supplies across Canadian Prairies 2003 (PFRA - Agriculture and Agri-Food Canada 2006b)

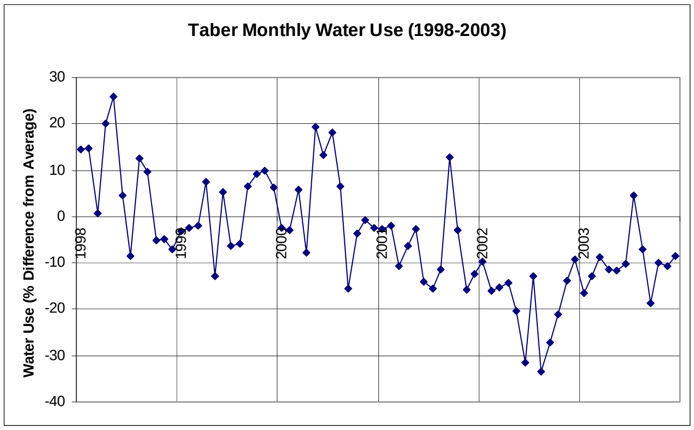


Figure A5.29 Taber's Potable Monthly Water Consumption (1998-2003) (Data: Cressman p. comm. 2007)

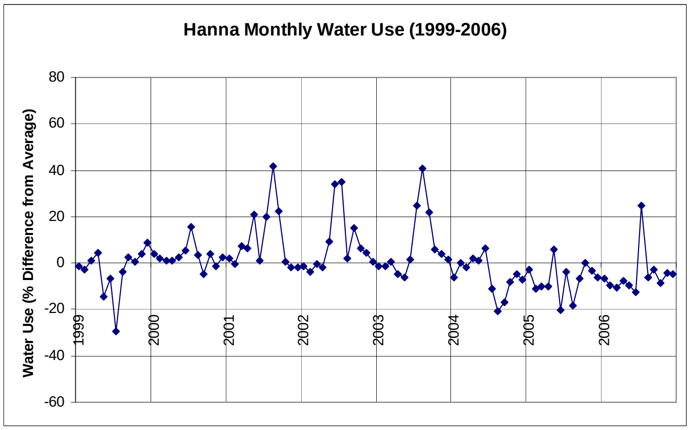


Figure A5.30 Hanna's Potable Monthly Water Consumption (1999-2006) (Data: Burgemeister p. comm. 2007)

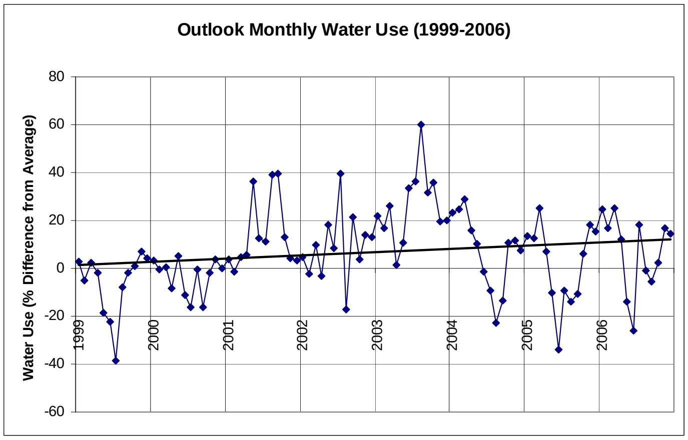


Figure A5.31 Outlook's Potable Monthly Water Consumption (1999-2006) (Data: Anderson p. comm. 2007)

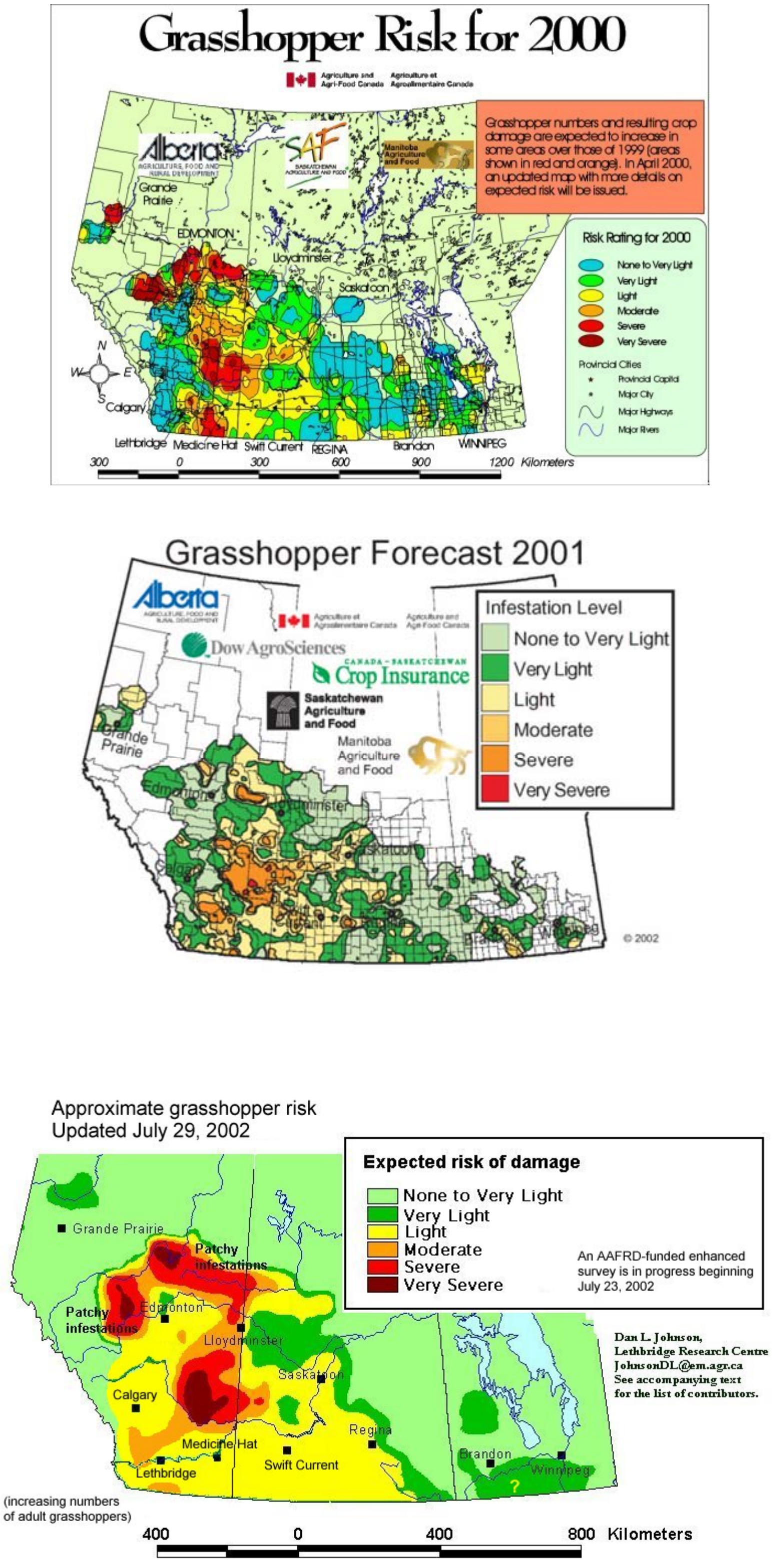
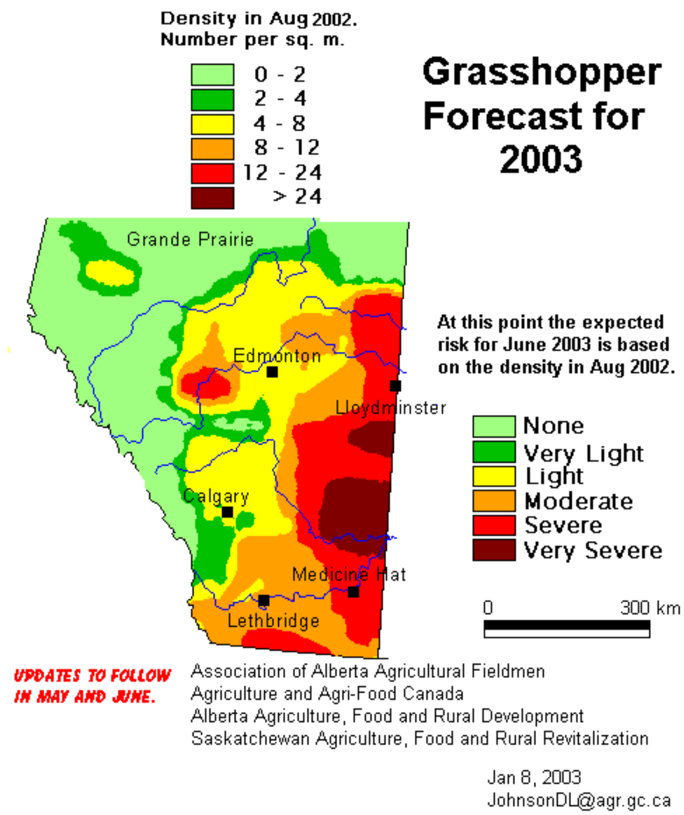


Figure A5.32 Grasshopper Risks of 2000 to 2002 (Saskatchewan Agriculture, Food and Rural Revitalization 2000, Johnson 2002, Jones 2000, Manitoba Agriculture and Food 2002, Saskatchewan Agriculture Food and Rural Revitalization 2002 and Olfert et al. 2003)



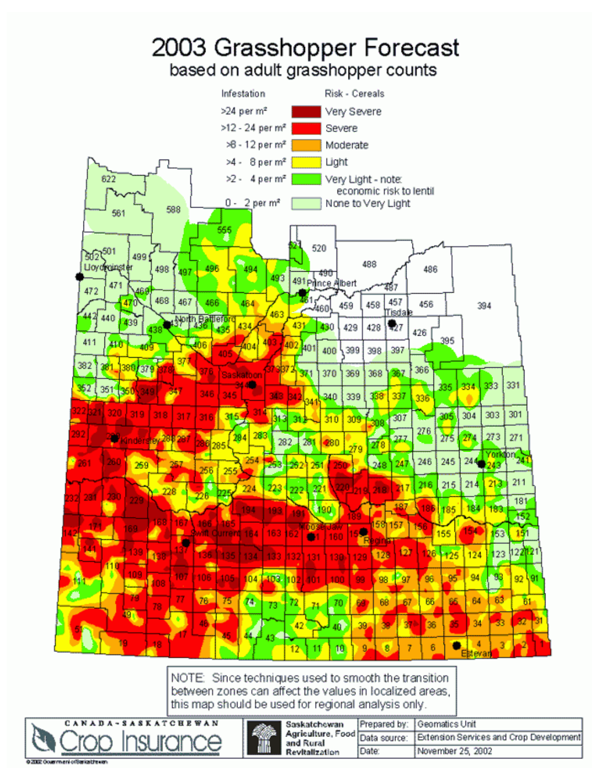


Figure A5.33 Grasshopper Risk for 2003 (Johnson and Calpas 2003 and Saskatchewan Agriculture, Food and Rural Revitalization 2002)

APPENDIX B

Bio-Physical Tables

Table B2.1 Selected Climate Stations for the Study Area (Environment Canada 2007a)

Station Name	Station Number	Location (Latitude/Longitude)	Period of Record
Taber	3036360	49° 47’N 112° 7’W	1907-2005
Craigmyle	3021940	51° 46’N 112° 16’W	1962-2005
Scotfield	3025770	51° 34’N 111° 21’W	1966-2005 (intermittent)
Outlook PFRA	4055736	51° 28’N 107° 3’W	1954-2005

Table B2.2 Selected Hydrometric Gauging Stations for the Study Area (Environment Canada 2007b)

Station Name	Station Number	Location (Latitude/Longitude)	Period of Record	Effective Drainage Area (km^2)	Mean Annual Discharge (m^3/sec)
Monitor Creek near Consort	05GA011	51° 52’26”N 110° 45’37”W	1983-2005	65.3	0.34 (8 months)
Monitor Creek near Monitor	05GA003	51° 58’10”N 110° 34’30”W	1954-2005	326	0.09 (8 months)
Sounding Creek near Chinook	05GA012	51° 32’52”N 110° 55’11”W	1984-2005	518	0.03 (8 months)
Sounding Creek near Oyen	05GA008	51° 33’55”N 110° 28’25”W	1968-2005	868	0.09 (8 months)
South Saskatchewan River at Saskatoon	05HG001	52° 8’25”N 106° 38’36”W	1911-2005	88,100	251
Red Deer River near Bindloss	05CK004	50° 54’10”N 110° 17’50”W	1960-2005	31,700	56.7
South Saskatchewan River at Medicine Hat	05AJ001	50° 2’35”N 110° 40’40”W	1911-2005	43,300	189
Oldman River near the Mouth	05AG006	49° 55’8”N 111° 48’0”W	1964-2005	20,900	70.6
Bow River near the Mouth	05BN012	50° 2’47”N 111° 35’28”W	1964-2005	19,200	89.2
Michichi Creek at Drumheller	05CE020	51° 28’17”N 112° 43’1”W	1979-2006	637	0.32 (8 months)
Kneehills Creek near Drumheller	05CE002	51° 28’12”N 112° 58’37”W	1921-2005	1,970	1.23 (8 months)
Red Deer River at Drumheller	05CE001	51° 28’2”N 112° 42’38”W	1915-2005	19,200	52.6
Lake Diefenbaker at Gardiner Dam	05HF003	51° 16’40”N 106° 50’18”W	1965-2005		

Table B3.1 Groundwater Observation Wells in the Taber Region (Alberta Environment 2007)

Well Name	Location		Depth Class	Aquifer Name	Aquifer Type	Aquifer Composition	Affected by Human Activity
	Latitude	Longitude					
Pakowki 85-1	49° 28’	110° 57’	Intermediate	Medicine Hat Valley	Confined	Sand and Gravel	No
Keho Lake 2019E	49° 57’	112° 56’	Intermediate	Keho Valley	Confined	Gravel	Yes
Enchant 2520E	50° 8’	112° 29’	Intermediate	Surficial	Confined	Sand and Gravel	Yes
Forty Mile Coulee 86-1	49° 41’	111° 26’	Deep	Milk River	Confined	Sandstone	Yes

Table B3.2 Groundwater Observation Wells in the Hanna Region (Alberta Environment 2007)

Well Name	Location		Depth Class	Aquifer Name	Aquifer Type	Aquifer Composition	Affected by Human Activity
	Latitude	Longitude					
Hand Hills #1	51° 30’	112° 12’	Deep	Horseshoe Canyon	Confined	Coal and Shale	No
Hand Hills #2	51° 30’	112° 12’	Intermediate	Paskapoo	Confined	Sandstone	No
Kirkpatrick Lake 86-3 East	51° 57’	111° 26’	Shallow	Surficial, water table	Confined	Sand and Gravel	No
Kirkpatrick Lake 86-2 Mid	51° 57’	111° 26’	Intermediate	Bulwark	Semi-confined	Sandstone	No
Big Stone 2415E	51° 9’	111° 11’	Intermediate	Surficial	Confined	Sand	No
Cessford 85-2	50° 58’	111° 41’	Intermediate	Calgary Valley	Confined	Sand and Till	No
Coronation	52° 0’	111° 16’	Intermediate	U. Bulwark	Confined	Sandstone	Yes
Monitor 86-1	51° 47’	110° 30’	Deep	Oldman F.	Confined	Sandstone	Yes
Sounding Creek 2532E	51° 34’	110° 28’	Deep	Oldman F.	Confined	Sandstone	Yes
Duchess 2564E	50° 52’	111° 72’	Shallow	Surficial	Confined or Semi-Confined	Sand	Yes

Table B3.3 Groundwater Observation Wells in the Outlook Region (Maathuis et al. 2002)

Well Name	Location		Depth Class	Formation	Aquifer Type	Aquifer Composition	Affected by Human Activity
	Latitude	Longitude					
Conquest No. 500	51° 34’	107° 10’	Shallow	Intertill Undefined	Intertill	Sand	No
Conquest No. 501	51° 34’	107° 18’	Shallow	Surficial Stratefied Drift	Surficial	Sand and Silt	No
Conquest No. 503	51° 33’	107° 17’	Shallow	Surficial Stratified Drift	Surficial	Sand and Silt	Yes
Conquest No. 504	51° 34’	107° 18’	Intermediate	Intertill Undefined	Intertill	Sand, Silt and Till	Yes