Lessons Learned from the Canadian Drought Years of 2001 and 2002:

Synthesis Report

for

Agriculture and Agri-Food Canada

by

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with the rest of the Canadian Drought Study Steering Committee,

P. Adkins, G. Bell, G. Brown, A. Howard, R. MacGregor

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Agriculture and Agri-Food Canada Agriculture et Agroalimentaire Canada

Canada

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HIGHLIGHTS

Drought is one of the world's most significant natural hazards. Droughts have major impacts on the economy, environment, health, and society. The droughts of 2001 and 2002 in Canada were no exception, covering massive areas, long-lasting, and bringing conditions unseen for at least a hundred years in some regions.

In general, droughts in Canada affect only one or two regions, are relatively short-lived (one or two seasons), and only impact a smaller number of sectors of the economy. In contrast, the drought years of 2001 and 2002 in Canada brought devastating impacts to many sectors of our economy, posed considerable adaptation challenges, and made history. The years 2001 and 2002 may have brought the first coast-to-coast droughts on record, and were rare as they struck areas that are less accustomed to dealing with droughts. These areas included parts of Eastern Canada and the northern agricultural prairies. The droughts were concentrated, however, in the West, with Saskatchewan and Alberta the hardest hit provinces.

> **"...the drought years of 2001 and 2002 in Canada brought devastating impacts to many sectors of our economy, posed considerable adaptation challenges, and made history."**

Repercussions were far-reaching:

- **Agricultural production** dropped an estimated $3.6 billion for the 2001 and 2002 drought years, with the largest loss in 2002 at more than $2 billion.
- The **Gross Domestic Product** fell some $5.8 billion for 2001 and 2002, again with the larger loss in 2002 at more than $3.6 billion.
- **Employment** losses exceeded 41,000 jobs, including nearly 24,000 jobs in 2002.
- **Net farm income** was negative or zero for several provinces for the first time in 25 years. A negative net farm income occurred in PEI for 2001, in Saskatchewan for 2002, and a zero net farm income was reported for Alberta in 2002.
- C**rop production losses** were devastating for a wide variety of crops across Canada, particularly in 2001.
- **Livestock production** was especially difficult due to the widespread scarcity of feed and water. Some livestock inventories decreased, especially in Alberta.
- **Water supplies** that were previously reliable were negatively affected, and several failed to meet the requirements. Water supplies considered included surface water such as streams, wetlands, dugouts, reservoirs and groundwater. Numerous adaptation measures were severely challenged.
- **Multi-sector effects** were associated with the 2001 and 2002 droughts, unlike many previous droughts that affected single to relatively few sectors. Impacts were felt in areas as wide-ranging as agricultural production and processing, water supplies, recreation, tourism, health, hydro-electric production, transportation, and forestry.
- **Long-lasting impacts** included soil and other damage by wind erosion, deterioration of grasslands, and herd reductions. Some of these systems can take decades and longer to recover.

- **Several government response** and safety net programs partially offset negative socio-economic impacts of the 2001 and 2002 drought years. Crop insurance payments were very high in 2001 and 2002, especially in Saskatchewan and Alberta. Saskatchewan saw a large increase in payments from $331 million in 2001, to $1.1 billion the following year. In Alberta, crop insurance payments jumped from $274 million in 2001, to $790 million in 2002.

While the 2001 and 2002 droughts would have likely been much worse without the lessons learned from previous droughts, recommendations stood out in a number of areas:

- Several **adaptation** measures were suggested and used, however many were costly and disruptive. Many adaptations proved insufficient to deal with such an intense, large-area, and persistent drought, underlining Canada's vulnerability to such events.
- **Wind erosion** and dust storms posed serious problems, particularly in Alberta and Saskatchewan in the spring of both 2001 and 2002. Blowing dust was associated with traffic accidents on the Prairies, and linked to some fatalities. Routine monitoring of wind erosion and dust storms - required to determine the effectiveness of adaptation measures - is now non-existent, contributing to increased risks.
- **Drought causal factors** are not well understood. The large-area atmospheric and oceanic patterns suspected to cause previous major droughts were distinctly different than those associated with these recent droughts. This suggests that a better understanding of the causal factors is needed to reduce our vulnerability by providing early warning.
- The **risk of drought** is greater than previously thought. Indicators of this increased likelihood include the recent knowledge of great decadal droughts before 1900, the increasing societal demands for water and food production, preliminary understanding of drought causal factors, and climate change. Evidence indicates that droughts may become worse as a result of climate change, requiring a far greater adaptive capacity in all areas.
- **Drought monitoring** and assessment of causes, impacts, adaptation and vulnerability research requires additional coordination, resources and expertise. A **national drought adaptation network** (DAN) should be implemented to advance these urgent requirements.

Photo 1 Visibility reduction due to blowing dust at Rosetown, Saskatchewan, about April 21, 2001 (photo provided courtesy of AAFC)

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WHY STUDY THE DROUGHT YEARS OF 2001 AND 2002?

The 2001 and 2002 events produced the worst droughts for at least a hundred years in parts of Canada, taking a widespread and devastating toll. These record to near-record droughts were preceded by dry to drought conditions and followed in some areas by persisting dry to drought conditions in 2003.

Multi-year droughts are much more severe and difficult to cope with than shorter droughts due to their increased intensity, compounding impacts, and the additional drain on adaptive resources. This multiple exposure effect, when combined with the extent and severity of the 2001 and 2002 drought years, produced a significant challenge to society.

> **"Multi-year droughts are much more severe and difficult to cope with than shorter droughts due to their increased intensity, compounding impacts, and the additional drain on adaptive resources."**

Droughts are a part of Canada's climate and are a concern, particularly in Alberta and Saskatchewan. However, droughts are generally more fragmented, less intense, and shorter than what was witnessed in 2001 and 2002. All the provinces experienced drought conditions in one or both years.

The 2001 and 2002 droughts were exceptional by many measures and extremely important to examine because they:

- were **unusually large in area, severe**, and embedded in a long dry period
- were associated with devastating **impacts**
- required considerable costly, disruptive, and problematic **adaptations** that still left losses
- led to residual and **longer-term impacts** that resisted adaptation, and
- provided **lessons** that can be a foundation for reducing Canada's vulnerability to future droughts, and enhancing adaptive capacity.

What did the project examine?

The primary purpose of the project was to document and evaluate the Canadian droughts of 2001 and 2002, and to determine the impacts, with emphasis on the agricultural and water sectors. Possible causes of these droughts were examined, including atmospheric general circulation and ocean patterns. Several climate variables were used to describe the droughts, including temperature, precipitation, wind, and the Palmer Drought Severity Index. The locations, severity, duration, and frequency of the droughts were determined. Physical and biological impacts explored included wind erosion, crop growth and yield, pastures and hay production, livestock, surface water (stream flows, dugouts, reservoirs, and wetlands), groundwater, and forest fires.

Economic impact variables examined included net income, bankruptcies, trade and value of production. Impacts on communities, as well as agriculture and non-agricultural sectors (e.g., forestry, water supplies, hydro-electricity, tourism, transportation) were also determined. The types and range of adaptation options suggested and undertaken were examined.

Some of the main questions examined by the study were:

- What were the possible causes of the droughts?
- How severe and unusual were these drought years? How did they evolve across Canada?
- How were physical and biological systems affected?
- What adaptation measures were advised and used? What residual impacts existed?
- What did the provincial and national economies lose during those years, and what sectors were damaged the most?

How did the project originate?

Recognizing the seriousness of the event, Agriculture and Agri-Food Canada (AAFC) began with an assessment of the 2001 drought and its impacts in Saskatchewan, one of the hardest hit areas. That study by Wittrock (2002) warned in February 2002 that the drought was not over and recommended that further monitoring and adaptation actions were needed. As the drought continued into 2002, the AAFC National Drought Study Steering Committee designed a research project focused on the 2001 and 2002 drought years across Canada.

How did the project evolve? What were its timelines and limitations?

The Drought Committee realized that it had to act quickly to document and assess the many aspects of this drought while information was readily available and events were fresh in memories. This rapid approach, although valuable, limited the availability of quality controlled data, especially for 2002, and restricted analyses, integration, and interpretations. This compressed timeline severely limited the comparisons of findings from one part of the Research Team to another, and restricted the ability to explore the findings for new insights. The adaptation research component was also very preliminary. Therefore, further in-depth assessments remain for future work.

> **"The Drought Committee realized that it had to act quickly to document and assess the many aspects of this drought…"**

The Drought Committee drew upon the cooperation of many agencies and people of many disciplines to support its work. The work has a strong interdisciplinary and integrated character as it was designed, facilitated and implemented by these many agencies. By fall 2002, the Drought Committee had developed a Research Team, objectives and terms of reference, work plans, and a research framework. The Research Team consisted of economists and climatologists with considerable expertise in droughts and their causes, integrated approaches, and drought impacts and adaptations across Canada.

What methods were used?

Because drought impacts most of society directly or indirectly, the methodology of the study required a comprehensive interdisciplinary and integrated research framework (Figure 1). A cause and effect integrated framework was used to explore several linkages: factors causing drought lead to droughts of various characteristics; droughts result in biological and physical impacts of various types; then these impacts lead to socio-economic consequences.

The adaptive responses to drought occur on two main time scales: as a short-term tactical response early in the drought, or as a longer-term strategic response planned before or after the drought to deal with future droughts (Figure 1). "Adaptation" is defined as adjustment in natural or human systems in response to actual or expected climatic stimuli (e.g. droughts) or their effects. The goal of adaptation is to moderate harm or to exploit beneficial opportunities (after Watson et al. 2001).

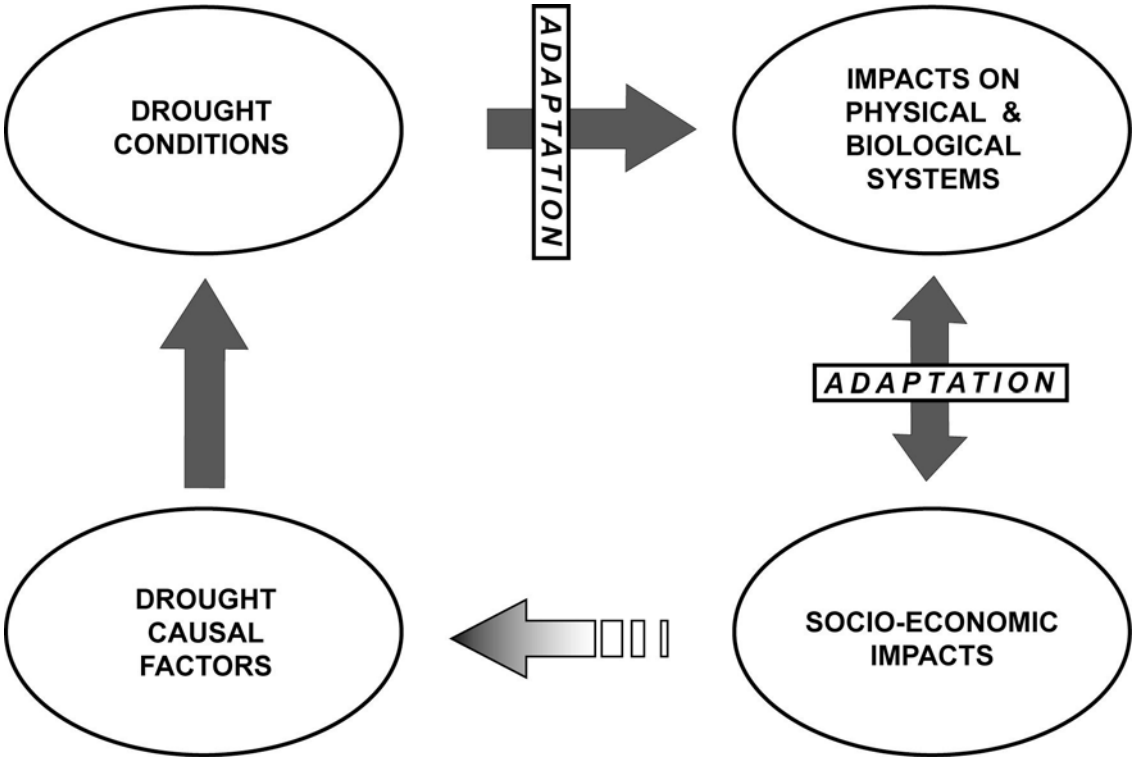

Figure 1 A Cause and Effect Research Framework Showing Drought Causes, Drought Characteristics, Impacts, and Adaptations

All components of the project were integrated through the adoption of common objectives and methods. A variety of methods were developed and used, including a literature review, composite maps of drought causal factors, time series analyses, crop growth and yield modeling, an interview questionnaire, an extensive set of phone interviews with agricultural producers and communities (140 producers, 19 extension workers, 97 community contacts), print media surveys, focus groups, expert opinions, and Statistics Canada's Inter-provincial Economic Input-Output Model. Numerous secondary data sources from public and semi-public sources were also used, including Environment Canada, Statistics Canada, Crop Insurance Corporations, and provincial governments. This wide variety of methods was valuable for several reasons including for comparisons and robustness of results.

More details on the economic sub-components of the methodology are supplied in Figure 2. Biophysical impacts of drought cause a wide range of social, environmental, and economic impacts. Evaluating economic effects involves assessing direct costs and benefits, regional level indirect and induced economic impacts, and trade-related economic impacts. These components combine to produce the total economic impacts of drought.

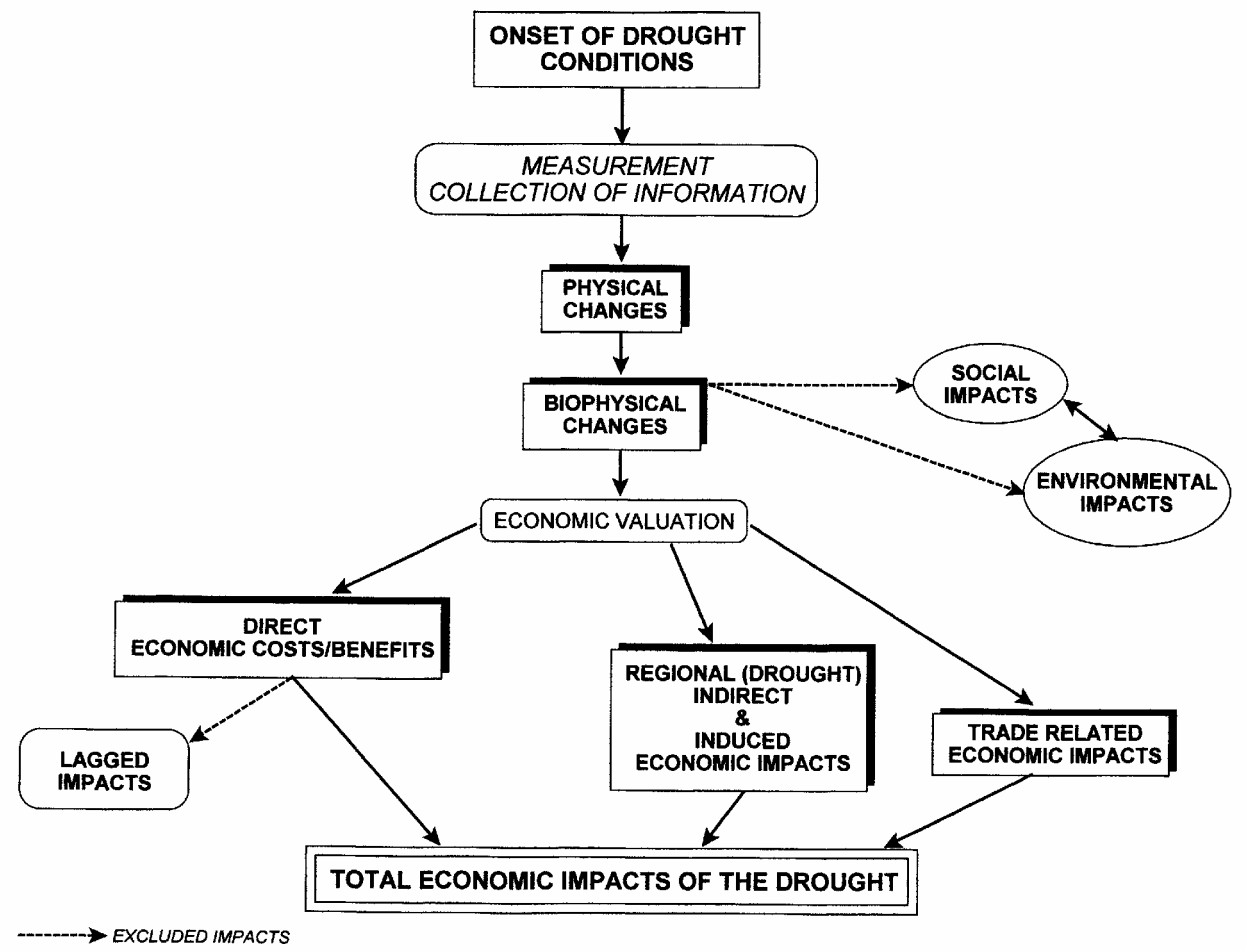

Figure 2 Overview of the Methodology, with further Economic Details (Kulshreshtha et al. 2003)

What are the results and implications of these results?

Findings are organized into several categories as guided by the cause and effect research framework: drought climatology, physical impacts, biological impacts, and economic impacts. Those regions unaffected by drought or dry conditions were not discussed in this report.

DROUGHT CLIMATOLOGY

How unusual were the droughts of 2001 and 2002?

The drought years of 2001 and 2002 easily rank among the major droughts of North America for the period of record (approximately one century in some areas). Also, these back-to-back droughts occurred as part of a much longer series of dry to drought conditions. Well below normal precipitation was reported in parts of Alberta and Saskatchewan for consecutive seasons for more than four years, extending from fall 1999 to the time of writing (November 2003). For example, Saskatoon's annual precipitation in 2001 was not only the lowest on record, it was a full 30 percent lower than the previous driest year in the 110-year record. Saskatoon was by no means unique, with many stations recording record or near-record dry years in 2001 or 2002. Even parts of Atlantic Canada experienced dry summers for four to five consecutive years.

"Saskatoon's annual precipitation in 2001 was not only the lowest on record, it was a full 30 percent lower than the previous driest year in the 110-year record."

Record to near-record drought, as indicated by the Palmer Drought Severity Index (PDSI), also occurred at several climate stations in 2001 (Figure 3). The time series of the Palmer Drought Severity Index was used to examine drought extremes, trends, variations, and spatial extent. Negative PDSI represent dry to drought conditions and positive PDSI indicate wetter conditions. Substantial variation is evident in these time series, with several climate stations exhibiting slight long-term trends toward drier conditions.

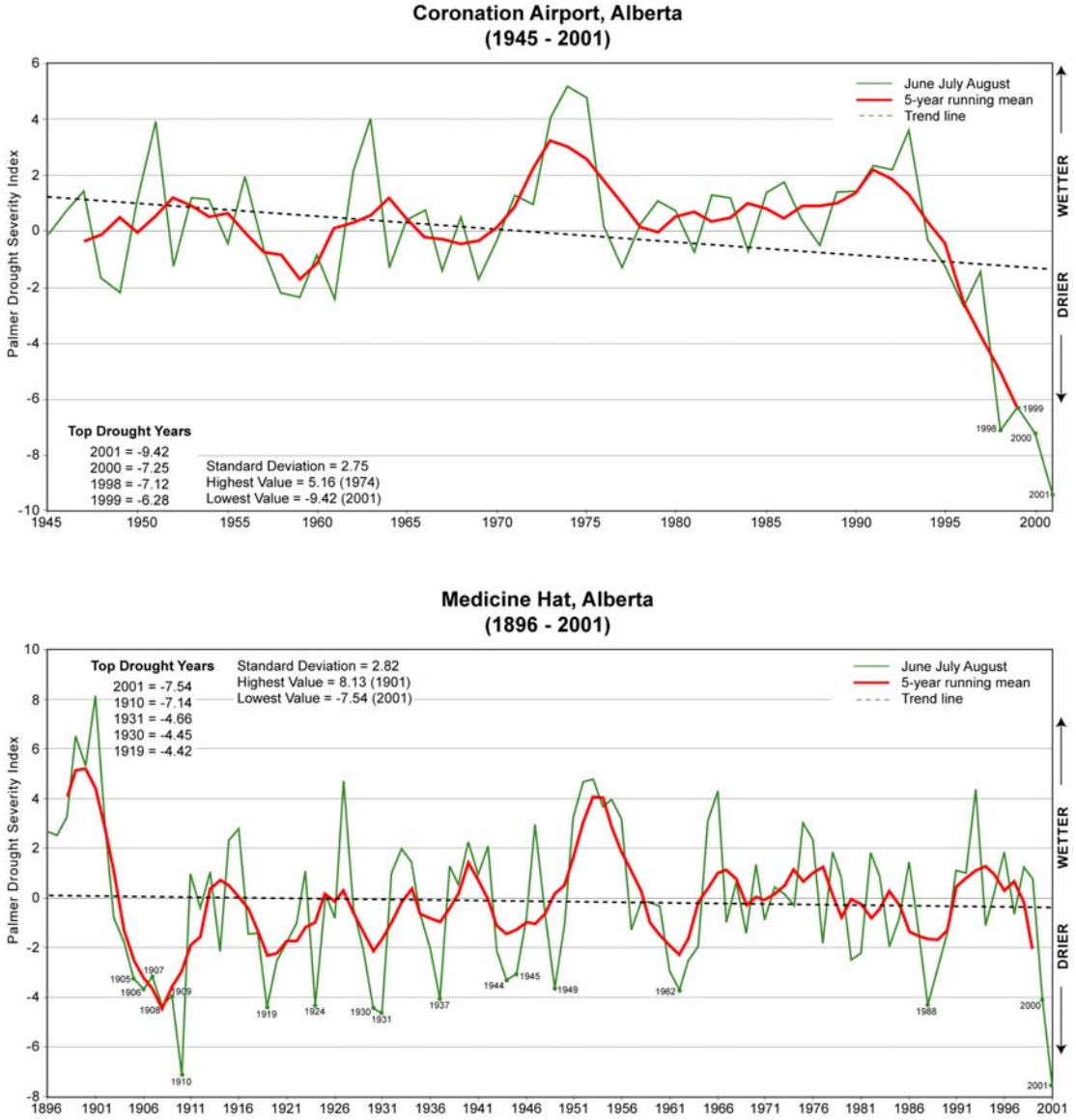

Figure 3a Time Series of Summer (June, July, August) Palmer Drought Severity Index (PDSI) for Coronation and Medicine Hat, Alberta (Dates are labelled for PDSI less than or equal to -3) (Data: Skinner, pers. comm. 2003)

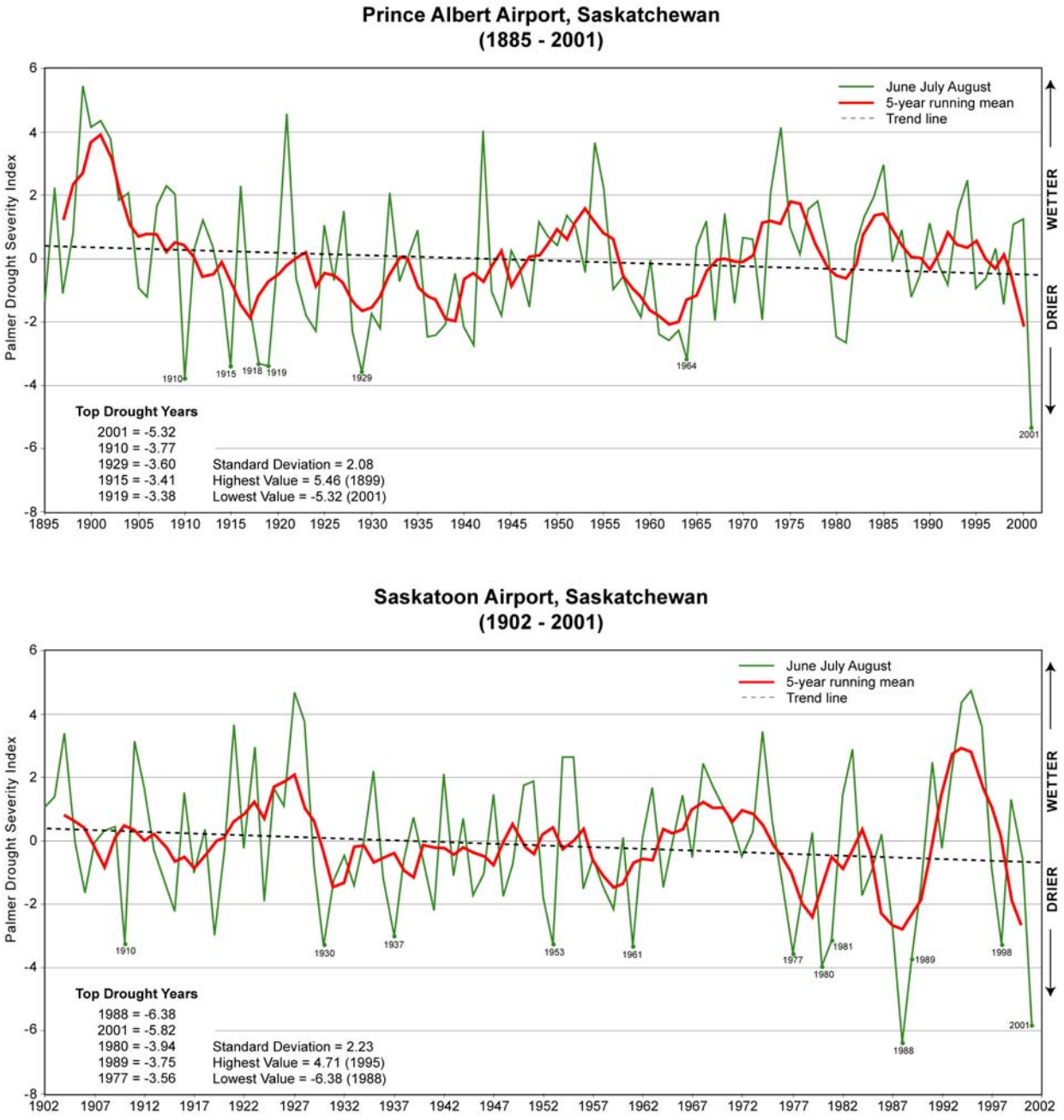

Figure 3b Time Series of Summer (June, July, August) Palmer Drought Severity Index (PDSI) for Prince Albert and Saskatoon, Saskatchewan (Dates are labelled for PDSI less than or equal to -3) (Data: Skinner, pers. comm. 2003)

Where were the droughts of 2001 and 2002 most severe, and what area did they cover?

The summer PDSI was used to compare the spatial extent of the drought years, as compared to other selected major North American drought years of 1931, 1961, and 1988 (Figure 4). This comparison was limited by the small number of climate stations and comparable drought years.

This composite map shows that:

- The 2001 and 2002 drought years were very extensive and appear to comprise a larger area across Canada than the other selected major droughts experienced in Canada.
- The 2001 and 2002 drought years occurred much farther northward and spread farther eastward and westward than the earlier major droughts depicted.
- Agricultural areas of Saskatchewan and Alberta were the most common locations of intense drought in Canada.
- The 2001 and 2002 droughts struck hardest in Saskatchewan and Alberta.

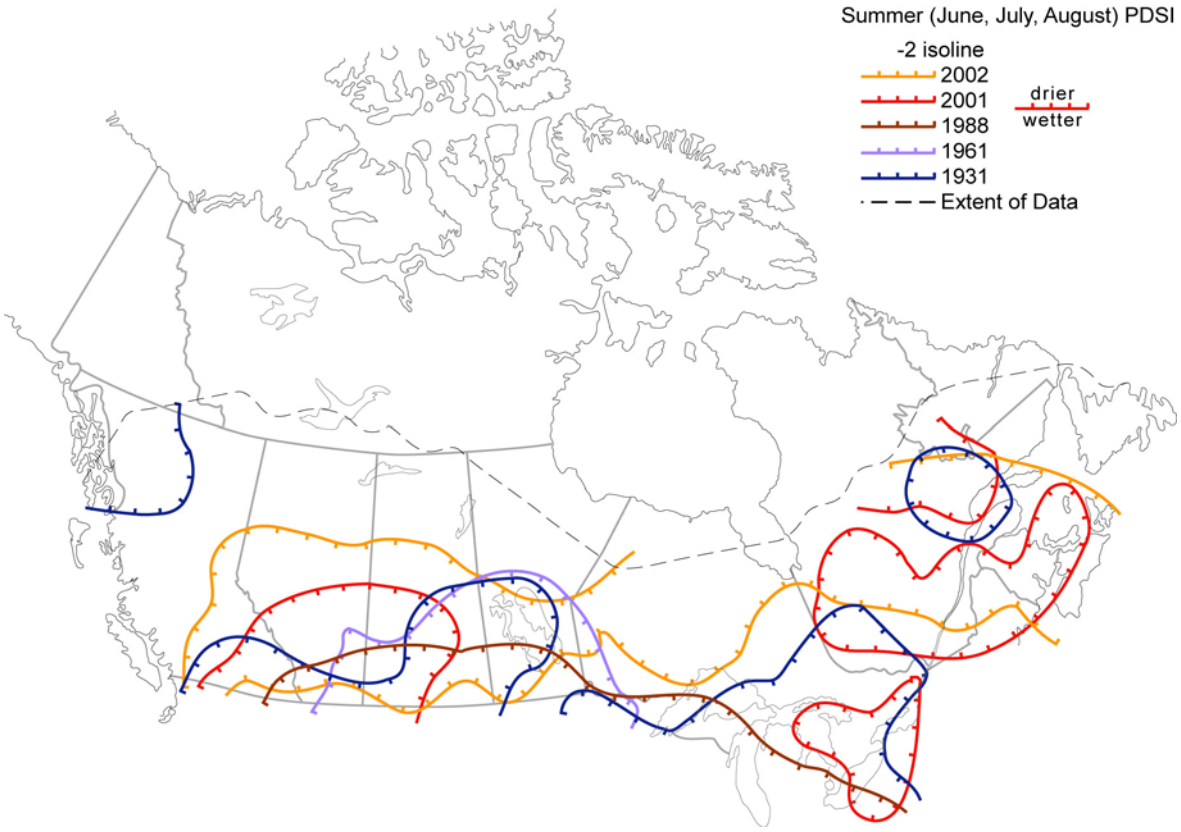

Figure 4 Spatial Comparison of Major Droughts of 2002, 2001, 1988, 1961, and 1931 using the Summer (June, July, August) Palmer Drought Severity Index Isoline of -2 (Data: Skinner, pers. comm. 2003)

How did the 2001 to 2002 droughts evolve?

Preceding dry conditions clearly set the stage for the drought of 2001. The winter of 2000-01 brought extremely low precipitation, with the largest deficits in Alberta and western Saskatchewan, and near normal temperatures to most of southern Canada. An extremely important source of moisture, prairie snow cover for the winter of 2000-01, was low.

Spring 2001 continued the dry trend over large parts of Canada, including interior British Columbia, southern Alberta, much of agricultural Saskatchewan, the Great Lakes area, and most of the Maritime Provinces. In contrast, well above normal precipitation occurred in Manitoba and northwestern Ontario.

The summer season brought increased demands for water supplies of all types, and severely dry conditions persisted through the summer and fall of 2001 over most of the already dry areas of the country. In summer 2001, very dry conditions encompassed most of southern Canada from central British Columbia to the Atlantic Provinces. Associated temperatures were above normal (Figure 5). Winter 2001-02 not only continued the dry trend over much of southern Canada, it also brought above normal temperatures. Again, Alberta and western Saskatchewan were the focus of drought conditions.

"…severely dry conditions persisted through the summer and fall of 2001 over most of the already dry areas of the country."

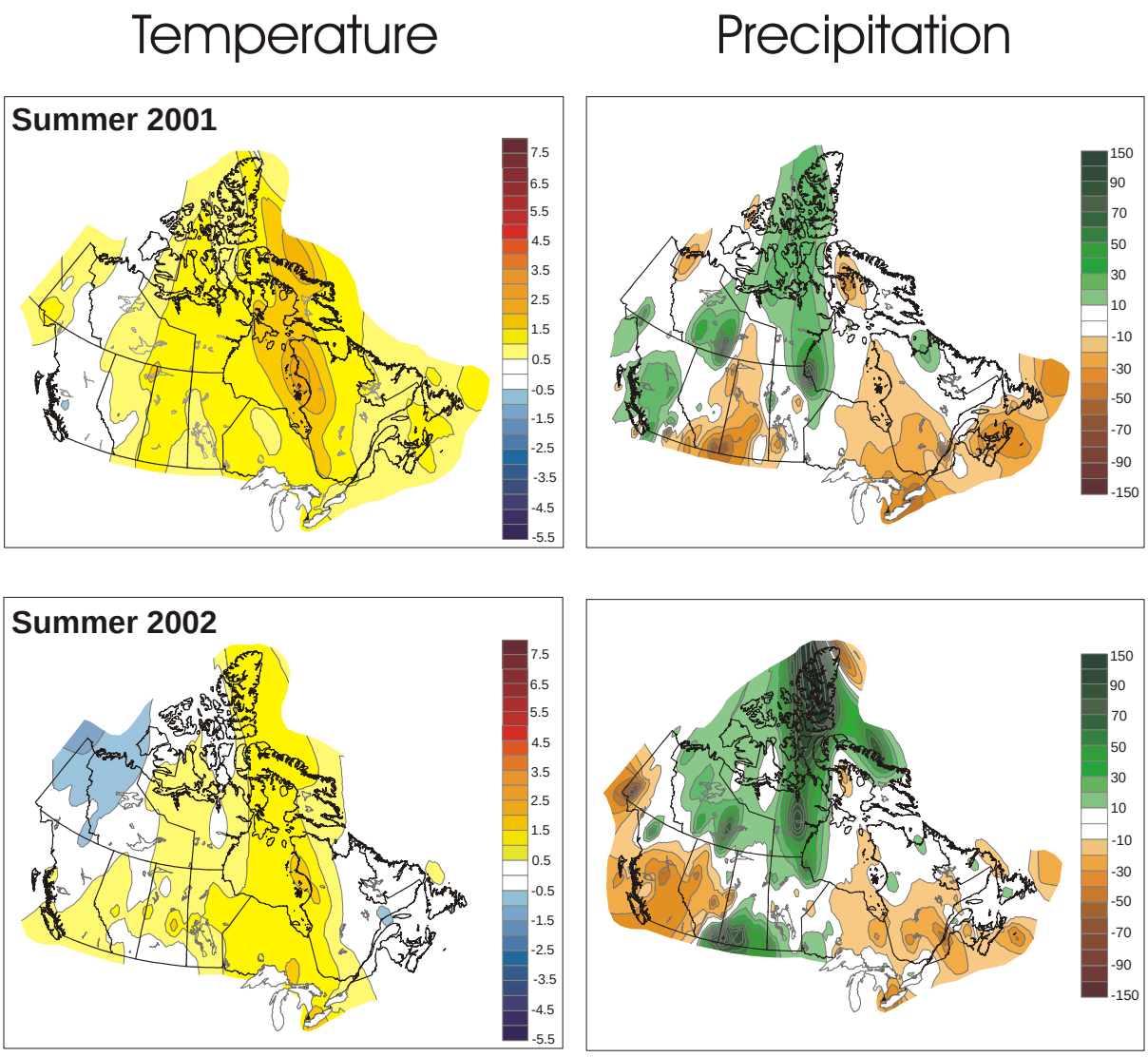

Figure 5 Precipitation and Temperature Departures from Normal (Percent) Across Canada for Summer (June, July, August) 2001 and 2002 (after Environment Canada 2002)

Spring 2002 saw highly unusual conditions in most of the country, characterized by unusually low temperatures and the still persistent well below normal precipitation. The very cold spring

was fortunate, as warmer temperatures would have increased demands on already limited water supplies. The dry trend eased in central BC, southern Ontario, and Quebec with the receipt of above normal precipitation.

Ontario was far less affected by drought than other parts of Canada, as the 2001 and 2002 droughts did not rate in that province's top 20 droughts in more than 100 years of record. In summer 2002, most of southern Canada again experienced well-below normal precipitation and above normal temperatures (Figure 5). An exception for summer 2002 was southern Alberta and southwestern Saskatchewan where precipitation was over 50% above average. Other areas in Saskatchewan and Alberta received above normal summer rainfall, but some of this rainfall was too late to aid agricultural production for that year. Wet conditions in the spring and fall of 2002 alleviated the drought in most of Atlantic Canada. In contrast, fall and winter 2002-03 brought lingering dry to drought conditions to areas of the central to northern agricultural region of the Prairies.

These results verify that the 2001 and 2002 droughts were indeed significant on continental and century length scales and clearly warrant considerable attention. An even more comprehensive assessment is urgently needed. Such an assessment can be used to further define our vulnerability and improve adaptation plans, adaptive capacity and understanding of the adaptation processes and their effectiveness.

What were the possible causes of drought in 2001 and 2002?

Previous major Western Canadian droughts have been associated with distinctive atmospheric circulation patterns over North America and persistent temperature patterns in the Pacific Ocean. This tendency was tested for the drought years of 2001 and 2002. Surprisingly, analyses of the associated atmospheric and oceanic patterns revealed no consistent or easily identifiable features. In fact, summer atmospheric pressure patterns during 2001 and 2002 were distinctly different from those associated with the major prairie droughts of 1961 and 1988, for example.

This suggests that the scientific understanding of the driving forces behind massive droughts may be less solid than expected, and further complicated by climate change factors. Additional research is needed to address the complexities of several other factors influencing drought, including large-area soil moisture patterns, vegetation, albedo (surface reflectance), and atmospheric dust interactions. This research is required to improve seasonal forecasting capabilities for major droughts.

> **"…the scientific understanding of the driving forces behind massive droughts may be less solid than expected, and further complicated by climate change factors."**

Will droughts occur in Canada in the future?

Drought is one of the major hazards affecting Canada and the risk of droughts will continue in the future. Drought is a normal part of the climate, especially on the Canadian Prairies. At least three main factors must be considered in determining the chances of future severe drought events: paleo-climatic evidence, increasing societal water requirements, and climate change. The drought pattern over the past hundreds of years (as determined by paleo-climatological

analysis of indicators such as tree growth ring formation) shows that major droughts were relatively rare in the 20th century. More severe, decade-long droughts occurred in the previous centuries and could recur. Secondly, society's increasing demand for good quality water will increase the stress on the water system in times of severe shortage that occur in a drought. These recent droughts clearly demonstrated that water needs can exceed supplies and that we must learn how to better manage water during these events. A third consideration is the enhanced probability of drought caused by climate change. Most global climate models project increased summer continental interior drying and, as a result, a greater risk of droughts is projected for the 21st century. The increased drought risk is described as likely and is a result of a combination of increased temperature and evaporation not being balanced by precipitation.

These three factors clearly point to the threat of increasing severity and frequency of future droughts. This trend means that further investments in activities such as monitoring, assessment, and adaptation are required. The increasing threat of drought risk to water availability in Canada is clearly critical to planning and policy at all levels and must be carefully considered.

WHAT WERE THE FINDINGS OF THE PRINT MEDIA SURVEY?

A new tool for drought assessment - a print media survey and review – was employed by this project. Media articles reflect the intensity, timing, and types of issues and concerns regarding hazards such as drought (Figure 6). For example, the first front-page national article on drought appeared in the August 14, 2001 issue of the *Globe and Mail* and identified drought as a "coast-to-coast" phenomenon affecting the entire country. The survey was used to provide information about the people and regions affected, as well as the nature of the impacts and adaptations. However, information on adaptation emphasized advice rather than actual measures used and their effectiveness.

This print media survey proved to be a valuable supplement, uncovering information that would otherwise be difficult or impossible to find as it reflects so many interviews and other information sources across Canada. For example, the survey clearly indicated the prominence of drought issues, particularly on the Prairies. Some 336 of the more than 2,400 Western Canadian articles regarding drought were on the front page, while 30 of the more than 160 Eastern Canadian articles were on the front page. A much wider range of impacts was noted through the survey than by using the other methods. Results were organized into four main categories: biophysical impacts, economic impacts, social and health impacts, and adaptation. Articles covering social and health issues were relatively sparse compared to those discussing biophysical and economic topics. Due to the large numbers of articles and topics, the review was only able to begin to organize and tap this wealth of information.

The majority of articles centred on drought effects and adaptations, with relatively few focused on climatological aspects of the drought. As a result, the number of articles peaked well after the onset of the drought and the peak occurred in summer for both drought years with a noticeable surge in August 2002 for Western Canada (Figure 7). Media coverage, especially in Western Canada, remained active even during the winters of 2001-02 and 2002-03, indicating continuing drought concerns.

Figure 6 Collage of Print Media Articles Demonstrating Drought Issues and Concerns

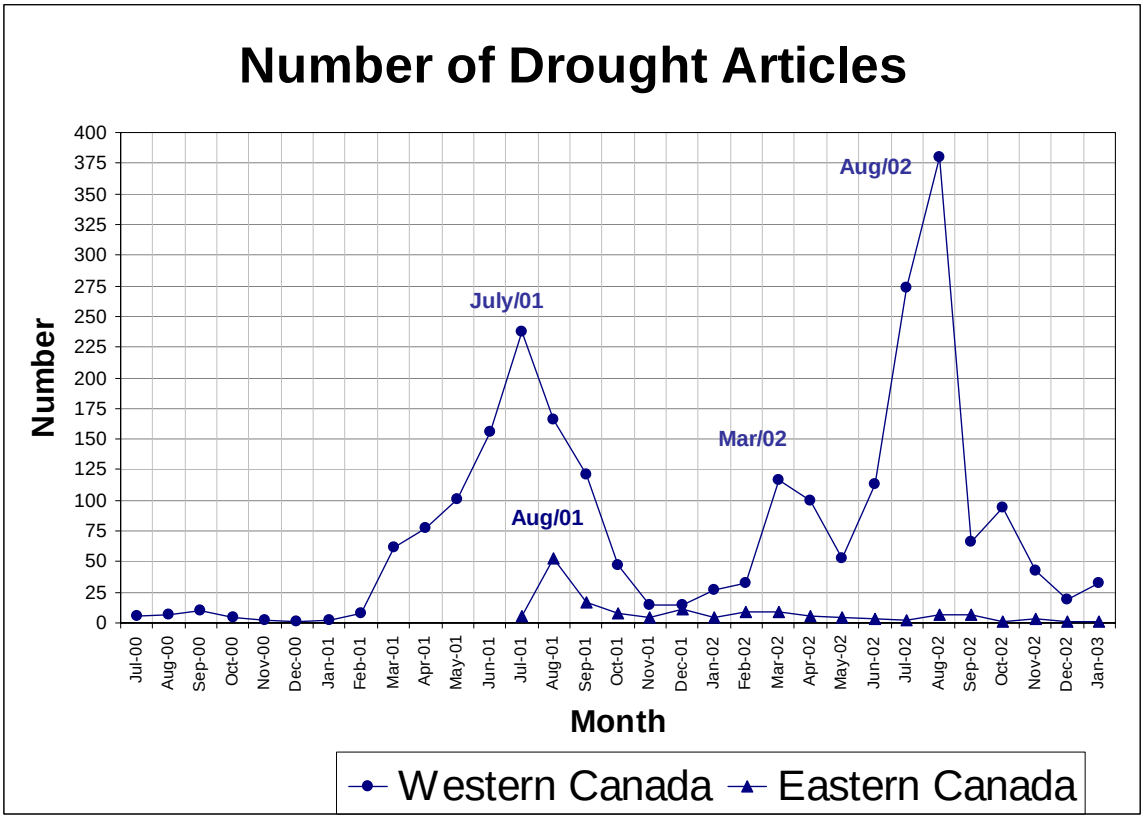

Figure 7 Time Series of the Monthly Number of Drought-Relevant Newspaper Articles, July 2000 to January 2003

In Eastern Canada, articles tended to appear about one month after the beginning of drought. The articles peaked in August 2001, as the drought was more severe that year (Figure 7). Many of the articles expressed surprise and concern about the seriousness of the drought.

PHYSICAL IMPACTS AND ADAPTATIONS

What were some drought impacts on surface and groundwater resources?

Good quality and reliable water supplies are crucial to plants, animals, people, and economic activities. The 2001 and 2002 droughts were strong reminders of the importance of water, and the challenges brought people together in many ways to deal with water scarcity issues. Drought impacts on several water supplies were described, including stream flows, wetlands, dugouts, reservoirs and groundwater. Secondary impacts of water scarcity affected irrigation and municipal water supplies.

Stream flow: In BC, stream flow records examined showed below average flows in 2001, but near normal flows in 2002. The worst situation appeared to be in Alberta and Saskatchewan, as many rivers and streams had well below average flows (or no flows) between 2000 and 2002. Mean annual flows of several rivers in Nova Scotia, New Brunswick, and Prince Edward Island were also at 20-year lows, and farmers in Nova Scotia reported that irrigation needs exceeded supplies. Adaptation was constrained by lack of knowledge concerning water needs, supplies,

and water management. These water shortages were significant as they restricted both livestock and crop production, as well as several other activities.

Dry conditions in southern Ontario resulted in requests to reduce water consumption in some watersheds. The Great Lakes-St. Lawrence River system experienced record low levels in 2001, part of a downward trend that began in the late 1990s. Navigation in the Great Lakes area slowed in 2001, causing an $11.25 million decrease in business volume, a portion of which could be attributed to low water levels.

Photo 2 Several years of drought have resulted in the lowest water levels in the Georgian Bay Region, Ontario, since the 1960s (photo by W. Leger, Environment Canada, Ontario Region)

Groundwater: Trend analyses were limited by the sparse groundwater level observation network, particularly in Eastern Canada. Preliminary trend analyses over the past 30 years indicate decreasing groundwater levels in several areas of Western Canada. Adaptive responses included improving well efficiency and increasing the numbers of new wells. For example, in PEI, the 2001 drought contributed to an increase in demand for new deep wells. This situation underscores the need to vastly improve groundwater monitoring, research, and assessment of long-term supply and demand.

> **"Preliminary trend analyses over the past 30 years indicate decreasing groundwater levels in several areas of Western Canada."**

Reservoirs and dugouts: In BC, reservoir levels were generally lower than normal in 2001, but returned to near normal in 2002. Many major reservoirs in Alberta and Saskatchewan had well-

below normal levels in 2001 and during the first five months of 2002. Some recovery occurred in southern locations in 2002. Manitoba's reservoir levels generally did not suffer in 2001 or 2002.

Dugouts, or constructed ponds, are often essential adaptations to water scarcity on Prairie farms, particularly for livestock and household use. By the fall of 2000, Prairie dugouts were drying out, and this trend became worse in 2001. Dugout water supplies rebounded somewhat in southern Alberta and Saskatchewan in 2002, as the dry pattern shifted northward. At the farm level, dugouts were the most negatively affected water supply source.

Photo 3 Dry dugout near Paradise Hill, Saskatchewan, August 2002 (photo provided courtesy of AAFC)

Ponds or wetlands: Wetlands in Prairie agricultural regions are particularly sensitive to drought, especially during multiple dry years. The number of natural Prairie ponds in May 2002 was the lowest on record, reflecting this sensitivity.

Rural community water supplies: Interviews with rural community leaders indicated water supply and/or quality problems in areas such as the Okanagan region of BC, central Alberta in 2002, and southwest Saskatchewan in 2001.

Adaptation overview: Although irrigation was considered an important adaptation option across Canada during the droughts, it incurred higher than average labour and energy costs, as well as management problems. For example, low water supply available for irrigation in the southeast Kelowna Irrigation District of BC led to water use restrictions imposed in April 2001. The unprecedented combination of high irrigation demand and low water supplies in Alberta resulted in unique voluntary approaches to irrigation water management. Irrigation needs also exceeded supplies in Nova Scotia and Ontario in 2001. In PEI, growers without irrigation experienced a 50 to 100 percent crop loss in 2001.

Individuals, municipalities, provincial and federal governments, and associations suggested and applied adaptation measures to deal with limited water supplies and water quality problems. These measures included water conservation and rationing, water sharing, water transfers, hauling water, drilling new wells, and using several other new sources of water, such as pipelines from more remote, secure sources. Restrictions were placed on watering of lawns, golf courses, and other non-essential water uses across Canada. In addition, water conservation measures were promoted through the distribution of public awareness materials and public service announcements.

What wind erosion impacts were observed?

Wind erosion tends to be more serious in Saskatchewan and Alberta than other provinces. This type of erosion results in environmental, health (including mortalities), and socio-economic costs. Soil lost by wind erosion is a long-term cost, often taking decades or longer to restore.

The most frequent wind erosion events on the Canadian Prairies in 2001 and 2002 occurred in Alberta and Saskatchewan. May of both 2001 and 2002 appeared to be the month with the greatest number of wind erosion events, including massive dust storms. No agency routinely monitors wind erosion or blowing dust events any longer, so only a few ad hoc observations compiled from field and media reports were available for assessment. This serious lack of monitoring makes it almost impossible to determine the nature of wind erosion events, confirm whether they are increasing or decreasing as a result of land management practices, or gauge the effectiveness of control measures.

Photo 4 Wind erosion and dust storms caused considerable soil and much other damage in a large area south of Saskatoon, Saskatchewan, in the summer of 2003 (photo by E. Wheaton, SRC)

A first attempt at using a proxy method of traffic accident data for evaluating wind erosion events was tested. At least 32 incidents of blowing dust with associated traffic accidents were reported in Saskatchewan between April and September 2001. This total is large as it was only exceeded once during the 1977 to 1988 period of dust storms documented by Wheaton (1990). Blowing dust may have been a contributing factor in two fatalities associated with these accidents.

> **"Soil lost by wind erosion is a long-term cost, often taking decades or longer to restore."**

The droughts of 2001 and 2002 were a stern test of farm management practices which reduce wind erosion. Although wind erosion was severe, it would probably have been much worse without the increase in soil conservation practices in the past several decades. However, these drought-related wind erosion events make it clear that the adaptation work is far from complete.

BIOLOGICAL AND ECONOMIC IMPACTS AND ADAPTATIONS

What crop production impacts were reported?

The 1990s saw many years of sufficient precipitation in Western Canada and increased production trends. This trend dramatically reversed in 2001, particularly in Alberta and Saskatchewan, where some regions reported record low crop production in 2001 and 2002 for a 25-year period. Several areas experienced consecutive years of very low crop yields. In contrast, crop production in BC and Manitoba was near normal.

Alberta and Saskatchewan crop yields and harvested areas were below average in both 2001 and 2002. This meant a reduction in the value of farm level crop production in both regions. The situation was worse in 2002 for both provinces, with almost all agricultural areas in Alberta suffering production losses. Alberta producers lost $413 million in 2001 and $1.33 billion in 2002 through value of lost crop production. In Saskatchewan, estimated value of reduced crop production accounted for losses of $925 million in 2001 and $1.49 billion in 2002. The farm cash receipts (a proxy for economic state of the farm economy) did not suffer by the same magnitude since withdrawals were made from farm inventories as an adaptation measure under drought conditions. Reduction in farm cash receipts in 2001 and 2002 were $267 and $920 million, respectively for Alberta, and $652 and $953 million, respectively for Saskatchewan.

Drought brought a host of other problems. Pests such as grasshoppers thrive in drought conditions, and massive outbreaks combined with drought to further cut crop production, especially in Alberta and Saskatchewan. Weeds can tolerate drought well and were a problem, even in grasslands. Shelterbelts designed to protect cropland and farmsteads were also severely affected by drought, to the point of dying out in some areas.

> **"Pests such as grasshoppers thrive in drought conditions, and massive outbreaks combined with drought to further cut crop production, especially in Alberta and Saskatchewan."**

In southern Ontario and Quebec, crop production impacts were widely dispersed and highly variable across locations and crop types. Production of two main field crops grown in Quebec

(soybeans and hay) ranged from slightly below to slightly above average. Quebec recorded crop losses, mostly in soybean and hay crops, estimated at $34 million in 2001 and $21 million in 2002. Drought damage to Quebec's apple crop was evident with scald, calcium deficiency, and early drop, as well as a 2001 production decline of 27 percent from the previous year.

In Ontario, 2001 field crop yields dropped significantly for grain corn, soybeans, and hay. Soybean, hay, and grain corn were the most affected crops in Ontario, with losses in production estimated at $295 million in 2001 and $140 million in 202. Grain corn and soybean yields recovered to near normal in 2002, but hay yields remained low in many areas. The hot, dry weather of 2001 led to improved grape quality and production, although the warm, dry winter reduced the ice-wine grape harvest. Ontario apple yields dropped by 8 percent in 2001, and plummeted further the following year when yields of popular varieties dropped 30 to 50 percent from 2001.

Ontario is Canada's largest vegetable growing region. Drought stress in 2001-02 saw vegetable yields drop significantly for many crops, including carrots, white onions, cabbages, and potatoes, especially where irrigation was not available. While irrigation was the main option used to deal with rainfall deficits, it was costly in terms of energy and labour. Wet conditions in the spring and early summer 2002 ended drought conditions. However, a record-dry spell occurred in August 2002 with parts of southwestern Ontario receiving less than 20% of normal precipitation. As a result, the effects of drought were not recognized until late summer 2002, taking many producers by surprise and allowing fewer adaptation measures. Earlier recognition may have enhanced adaptation capacities.

In Atlantic Canada, many crops were hit by the 2001 drought in particular, but again, drought impacts varied considerably from region-to-region and crop-to-crop. Severe impacts were felt in Nova Scotia, with 2001 crops such as wild blueberries suffering 50 to 75 percent production losses. Crop production losses in spring wheat, hay, potatoes, beans, apples, and blueberries totalled an estimated $27.5 million in 2001. The loss decreased to $16.5 million in 2002. Severe irrigation water shortages and water quality issues occurred. Even producers with access to irrigation suffered 20 to 25 percent yield losses - another example of the limits of current adaptation measures.

The southeastern and eastern portions of New Brunswick were most affected, reporting yield losses of horticultural crops of 30 to 60 percent in 2001. PEI experienced major potato production losses, with 2001 yields dropping 36 percent from the previous year. Soybean producers also incurred losses. Growers without irrigation lost 50 to 100 percent of their crops. The value of potato crop production was reduced by $52.7 million due to the drought. Newfoundland reported decreased cole crop production (e.g. cabbage, broccoli, cauliflower, and brussel sprouts) and decreased horticultural crop yields in 2001.

> **"Where possible, an increased reliance on irrigation was the primary adaptation to drought…"**

Where possible, an increased reliance on irrigation was the primary adaptation to drought, particularly for fruit and vegetable crops in Eastern Canada. However, increased irrigation resulted in higher energy and labour costs. Other adaptations included small reductions in fertilizer and herbicide applications, fuel, and labour. Adaptations were minor in Eastern Canada

because drought conditions were not recognized until well into the growing season, when most management decisions had been made and operating costs had already been incurred.

Photo 5 **St. Mary's Reservoir, Alberta, at 29% capacity, August 2000** (photo provided courtesy of AAFC) (Note the person [arrow] for scale)

Crop production effects of these droughts were devastating in many regions. Areas not commonly affected by drought were hit (e.g. northern agricultural Prairies and Eastern Canada), contributing to the vulnerability of producers and communities less experienced in dealing with drought.

What pasture and hay land impacts were found?

Massive areas of poor grass growth occurred in the spring to fall of both 2001 and 2002 on the Prairies. Alberta was the most severely affected, with Saskatchewan a close second in terms of both area and duration of poor grass growth. The poorest grass growth occurred in May 2002, with a close secondary peak the following month. Poor pasture growth encompassed all of Alberta, stretching in a wide swath across Saskatchewan into much of southwestern Manitoba. Only a narrow slice of southeastern Saskatchewan escaped the "poor growth" classification in that province. Hay production in Eastern Canada is discussed in the crop production section. Information about grass growth was not readily available for this region.

> **"Poor pasture growth encompassed all of Alberta, stretching in a wide swath across Saskatchewan into much of southwestern Manitoba."**

Several adaptation strategies were documented, including transporting hay, utilizing feed types not normally used, and using available public and private lands as well as cropland, also not normally used. Where adaptation was not successful, livestock lost weight, became sick from

drinking poor quality water, eating poor quality food or from overcrowding, or developed problems associated with eating unusual feed. When so much grazing and hay land is affected so severely for so long, limits to adaptation are reached. Adaptation action and planning are also extremely limited by sparse and ad hoc observational information and applied research, including grass growth forecasting.

Photo 6 Grasslands east of Vegreville, Alberta, during July 2002 (Note the yellow to brown color of the grasslands which indicates very low productivity) (photo by A. Howard, Alberta Food and Rural Development)

What livestock impacts were described?

The scarcity and high cost of feed and water supplies left drought-impacted livestock producers with many difficult decisions. Feed shortages were widespread, affecting pasture land, hay land, and feed grains. The timing and spatial extent of most droughts rarely affects so many sources of livestock feed.

> **"The scarcity and high cost of feed and water supplies left drought-impacted livestock producers with many difficult decisions. Feed shortages were widespread, affecting pasture land, hay land, and feed grains."**

Alberta's herd reduction in 2001 and 2002 resulted in two consecutive years of below normal cattle numbers. The 2002 decrease of more than 10 percent (600,000 head) saw record low cattle numbers since 1997. This drop is another example of an impact requiring a long-term recovery period. Saskatchewan's total livestock numbers did not appear to be affected. In BC, livestock sale receipts increased from 2000 to 2001, only to fall in 2002. Poor prices and herd inventory liquidations resulted in reduced income in 2002.

Some producers sold cattle early in anticipation of the continuation of the 2001 drought, leading to negligible economic impacts on producers in 2001. However, the 2002 drought had a significant impact, with an estimated loss to producers of $143.4 million, almost half in the province of Alberta.

NON-FARM DROUGHT IMPACTS

A variety of industries with ties to agriculture suffered across Canada. Farm input suppliers were hit by lower demand for their products, while food processors experienced local shortages of raw material. For example, in both 2001 and 2002, Ontario soybean crushers were forced to draw down carry-over stocks and increase imports at higher costs to maintain their crush levels. Vegetable producers saw their throughput reduced due to a lack of product in close proximity. Value-added processors in Prince Edward Island reported a downturn in business due to a lack of product. Access to long-term markets in the eastern United States for PEI cole products was threatened by the product shortfall.

In BC, hydro-electric power generation was curtailed, necessitating more purchases of power from neighbouring jurisdictions. While forest fires were not as prevalent in BC, the incidence of fires in Alberta in 2002 increased to five times the ten-year average.

Some recreational areas were also adversely affected due to low lake levels and intense fire risks. Saskatchewan's impacts were similar to Alberta's, including reduced hydroelectric power generation. Production shortfalls in 2001 were compensated for by purchases of power from other sources.

OVERVIEW OF ECONOMIC IMPACTS

What were the direct economic impacts on agriculture?

Drought impacts were more serious and widespread in Western than Eastern Canada, where impacts were more localized and variable (Table 1). In Western Canada, the total value of production dropped by about $930 million in 2001, doubled to $2.067 billion in 2002, and totalled some $3 billion for the two drought years. The hardest hit province in 2001 was Saskatchewan (48 percent of the Canadian drought-induced agricultural production losses), with Ontario and Alberta second and third (Figure 8). Drought contributed to a negative or zero net farm income for several provinces for the first time in 25 years. A negative net farm income occurred in PEI for 2001, in Saskatchewan for 2002, and a zero net farm income was reported for Alberta in 2002 (Statistics Canada 2003).

Saskatchewan and Alberta shared the bulk of 2002 agricultural production losses, with each accounting for 45 percent of the Canadian total (Figure 9). In Eastern Canada, the total value of production dropped by approximately $406 million in 2001 and $176 million in 2002. The total loss estimate was $583 million over the two year period. The total Canadian loss in value of agricultural production for both years is estimated at $3.6 billion.

Table 1 Summary of Agricultural Losses Due to 2001 and 2002 Droughts in Canada, by Province

Province	Reduction* in Value of Production in 2001 (000$)	Reduction* in Value of Production in 2002 (000$)
British Columbia	$0	$30,001
Alberta	$271,060	$1,008,500
Saskatchewan	$654,940	$1,000,980
Manitoba	$6,980	$27,770
Western Canada	**$932,980**	**$2,067,251**
Ontario	$294,730	$139,690
Quebec	$34,080	$20,550
Nova Scotia	$27,510	$16,510
Prince Edward Island	$50,230	$0
Eastern Canada	**$406,550**	**$176,750**
Total Canada	***$1,339,530***	***$2,244,001***

* Reduction in value of production was estimated as a sum of change (increase or decrease) in value of sales of crop and livestock products and in expenditures on farm inputs. If the change in the value of sales was positive, agricultural losses were equated to be nil. For crop production, analysis was done on a census agriculture region level while for livestock it was on a provincial level. Benchmark for crop products was previous 6 to 10 year level, while for livestock it was previous two years (on account of livestock cycles).

Note – data were not available for New Brunswick and Newfoundland.

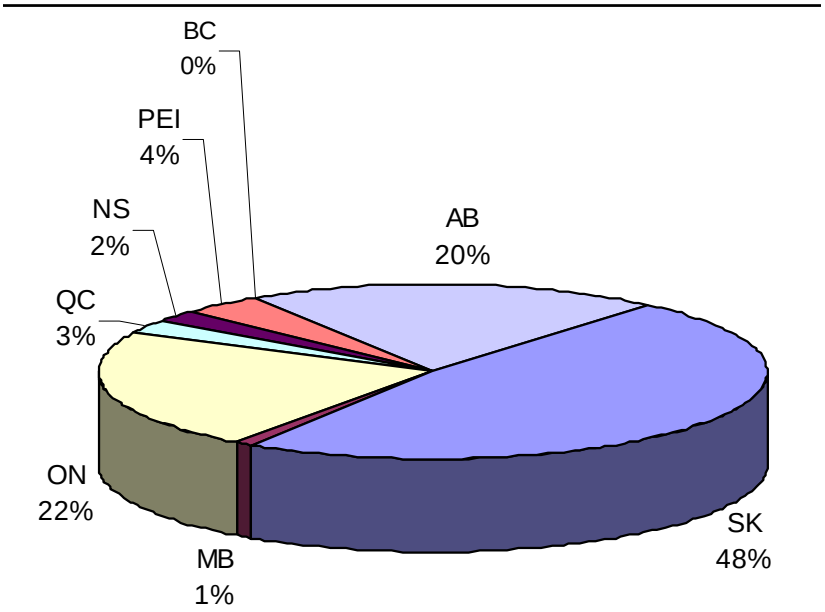

Figure 8 Provincial Distribution of 2001 Drought-Induced Agricultural Production Losses

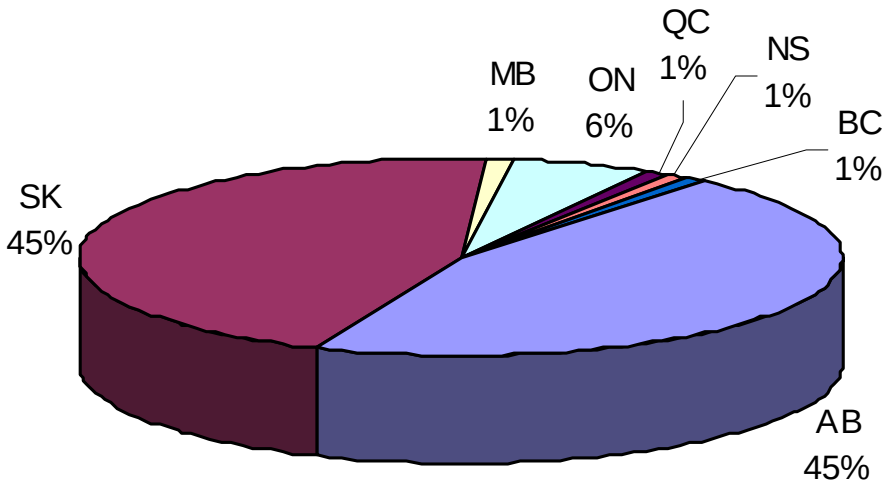

Figure 9 Provincial Distribution of 2002 Drought-Induced Agricultural Production Losses

Total economic impacts

In an economic system, actions taken by a group of individuals affect other individuals in the same region, as well as in other parts of the country. Actions of farmers as a result of drought are no exception. As farmers' incomes are reduced, so are their expenditures on farm and household needs. These changes then affect other industries and lead to a greater change in the economy. To measure the total change in the Canadian economy resulting from the 2001 and 2002 droughts, an input-output model of Canada was used.

The economic impact of the 2001-02 droughts rippled throughout the Canadian economy, as consumers spent less and demand for goods and services declined. Using Statistics Canada's Inter-provincial Input-Output Model, it is estimated that the 2001 drought resulted in a $2.1 billion drop in Canada's gross domestic product (GDP), and a loss of 17,637 jobs in various parts of the country (Table 2). The 2002 drought was more intense on the Prairies compared with the rest of Canada. The GDP loss in that year was approximately $3.6 billion, with the total loss estimate over the two drought years pegged at some $5.8 billion.

Table 2 Reduction in Gross Domestic Product and Loss in Employment Resulting from 2001 and 2002 Droughts in Canada, by Region**

Region	Loss** of G.D.P. (000$)		Loss** in Employment (No. of Workers)	
	2001	2002	2001	2002
British Columbia	$0	$42,955	0	224
Prairies	$1,434,619	$3,108,331	10,083	17,803
Central Canada	$412,886	$228,132	4,038	1,949
Maritimes	$115,122	$21,750	1,042	223
Trade-Related Impacts*	$164,031	$251,840	2,474	3,578
Total Canada	$2,126,658	$3,653,008	17,637	23,777

* Refers to those changes in non-drought regions created by inter-provincial trade
** Loss was based on estimated absolute change in the GDP or employment during the drought period.

OVERVIEW OF GOVERNMENT RESPONSE PROGRAMS

Negative economic and social impacts stemming from the 2001 and 2002 drought years were partially offset by government response and safety net programs. These include crop insurance, the Rural Water Development Program, the Net Income Stabilization Account (NISA), the Canadian Farm Income Program (CFIP), and the Tax Deferral Program.

The challenges posed by the 2001 and 2002 drought years were unusually severe, particularly for some sectors and regions. In severe drought years such as 2001 and 2002, the wide range of adaptation measures, including government programs, could not cope with the immensity of the losses.

> **"…the wide range of adaptation measures, including government programs, could not cope with the immensity of the losses."**

Under the crop insurance program, a federal/provincial/producer funded program, more than 102,000 Canadian farmers insured almost 56 million acres (22.7 million ha) in the 2001-02 crop year. The Canada wide payout for the 2001-02 crop year was over $1 billion. Saskatchewan, Alberta, and Ontario received the highest payments.

In the 2002-03 crop year, more than 100,000 farmers insured 68 million acres (27.5 million ha). Payments exceeded $2 billion, or more than 500 percent above the 10-year average in Canada. Again, the highest payments were made in Saskatchewan (over $1 billion), Alberta (almost $800 million), and Ontario (over $100 million). Unfortunately, the reasons for payments are not specified and problems other than drought were also included in these numbers. However, in the most severely affected areas, drought would clearly be a primary factor.

WHAT ACTIONS ARE NEEDED TO REDUCE VULNERABILITY TO DROUGHT?

Many research gaps were indicated by the study and only an overview is provided here. Limitations on the project were severe, including insufficient quality controlled data for 2002, analyses of cause-effect relations, implications and interpretations of findings, lag effects, and adaptation measures and processes. Highlights of required research include:

- Conduct a comprehensive sensitivity analyses of the **cause and effect relationships** of the research framework used here. The relationships include the drivers of drought; drought to biophysical impacts; and biophysical impacts to economic impacts. For example, crop modeling was found to be a useful tool that should be used for further understanding drought impacts on crop growth and yield as well as the effect of management alternatives.
- Test and decide upon an appropriate, flexible, and standardized suite of **methodologies** for assessing the impacts and adaptations to droughts. This will help ensure that lessons learned are properly documented and considered in policy development.
- Complete comprehensive **drought assessments** for each major drought. These assessments must be comparable to allow changes in sensitivity, adaptive capacity, and vulnerability to be determined.
- Expand and enhance Canada's current **drought and drought impact monitoring.** Monitoring is at a preliminary stage and requires considerable enhancement to become effective at a national level. Agriculture and Agri-Food Canada's National Agroclimate Information Service is a major step forward. To move toward this objective, more indices are needed, as well as a much-improved network of stations, and more communication vehicles. Far better monitoring, research, and adaptation testing for wind erosion is also needed, given the importance of this hazard.
- Make assessments of lag effects to determine the **nature of recovery** from drought and the resilience of each sector. Several drought impacts have time lags from the drought onset and will persist for years. These include soil degradation by wind erosion, grassland degradation, and numerous economic effects.
- Enhance research regarding **temporal and spatial patterns** of drought for both the past and future. The 2001 and 2002 droughts could be the first times in observational history that major droughts have been as extensive across Canada and as far north.
- Undertake research to separate drought impacts from other impacts. Crop production is one example as insects and diseases, frost, and excess moisture may have also contributed to decreased yields. Combinations of **monitoring and modeling** would achieve this objective.
- Conduct comprehensive research on the **climatological causes and prediction** of large-area droughts in consideration of climate change effects. A better understanding would permit seasonal forecasting of drought conditions and improve risk management before the event.
- Enhanced research is required to examine the process of **adaptation** and the effectiveness of adaptation in reducing vulnerability. Adaptation measures implemented by producers, communities, organizations, and government responses helped reduce the negative biophysical and socio-economic impacts of the 2001 and 2002 drought years in Canada. However, these droughts were of such magnitude, persistence, and intensity that severe hardship and residual impacts occurred regardless.
- Conduct **adaptation and vulnerability assessments** to determine who is at risk of impacts of further droughts and why.

The capacity required to better prepare for and deal with such droughts requires strengthening, and new capacity needs to be developed. For example, a **National Drought Adaptation Network** (DAN) should be considered. A critical mass of experts across many disciplines is required for drought monitoring, research, coordination, planning, and communication. National to local drought planning must be enhanced and accelerated, and must be supported by a strong foundation of monitoring and research knowledge.

WHAT DID THE PROJECT ACHIEVE?

This work was an immense undertaking, addressed critical knowledge gaps, and is one of the first assessments of its kind in North America. It was accomplished on a national scale and covered many drought climatology, impact and adaptation areas. This undertaking was pioneering in many respects, including time lines, research framework, set of research tools, new research tools, integration of disciplines, management, and review processes. As a result of this work, a comprehensive description of the nature of these extensive and severe droughts and their biophysical and economic impacts was achieved.

CONCLUSIONS

The Canadian droughts of 2001 and 2002 will long be remembered for their widespread and devastating toll – a toll that can be measured in increments of economic loss and environmental deterioration. While no region of the country escaped unscathed, the West was hardest hit. Billions of dollars were lost, along with tens of thousands of jobs. The impact on livestock production and the landscape will, in some cases, require years to decades before a full recovery can be contemplated. Drought continued taking its toll in 2003 in several parts of Canada.

A wide range of adaptation measures developed over the years did not fully deal with the impacts, underlining Canada's vulnerability to this natural hazard. It is also evident that much more needs to be learned about the phenomenon of drought and its impacts before we will be in a position to reduce our vulnerability.

Evidence indicates that the risk of drought is increasing as demands for food and water relentlessly climb, and the manifestations of climate change become ever more apparent. We must develop the capacity to predict droughts as part of seasonal forecasting efforts, and more detailed studies must be undertaken to better understand all aspects of Canadian droughts.

The key to better dealing with drought lies in taking the steps necessary to enhance our adaptive capacity, that is, the ability of a system to adjust to droughts, to moderate potential damages, and to take advantage of opportunities, or, in the absence of such adaptations, to cope with the consequences (adapted from Watson et al. 2001).

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APPENDIX 1: TERMINOLOGY

What is drought?

Droughts are natural hazards that can have devastating effects on the environment, society, and economics. However, as one of the most complex of weather hazards, droughts are very difficult to define. The comprehensive definition of drought is *a prolonged period of abnormally dry weather that depletes water resources for human and environmental needs* (Atmospheric Environment Service Drought Study Group 1986). Many definitions exist for each of the main types of drought, including meteorological, agricultural, hydrological, and socio-economic. For example, a meteorological drought applies to a long-term lack of precipitation that is frequently intensified by anomalously high temperatures that increase evapo-transpiration. This often leads to other types of droughts including agricultural (periods during which soil moisture is insufficient to support crops), hydrological (prolonged periods of unusually low surface run-off and shallow groundwater levels), and socio-economic droughts (an unusual shortage of water [including rainfall] that produces an adverse effect on society and the economy) (Maybank et al. 1995).

The character of drought depends on a wide range of factors, including the affected area, timing, duration, and antecedent conditions. For instance, a drought may affect crop growth or soil erosion, but may not be long enough to impact water supplies. The extent and character of drought impacts will depend on a region's sensitivity, vulnerability, and ability to adapt.

How is adaptation described?

"Adaptation" is defined as adjustment in natural or human systems in response to actual or expected climatic stimuli (e.g. droughts) or their effects. The goal of adaptation is to moderate harm or to exploit beneficial opportunities (after Watson et al. 2001).

Adaptive capacity is the ability of a system to adjust to droughts, to moderate potential damages, and to take advantage of opportunities, or cope with the consequences (after Watson et al. 2001). Some of the main questions to ask about the adaptation process include: who or what adapts, how do they adapt, what is the trigger for adaptation, and when do they adapt (Smit et al. 1999)? Drought adaptation decisions are made at a variety of levels including individuals, groups, institutions, and local to national governments. Drought adaptation processes or strategies include sharing and/or bearing the loss, modifying drought effects, research, education, behavioural changes, and avoidance (Burton et al. 1993).

How is vulnerability defined?

Vulnerability is the degree to which a system is susceptible to, or unable to cope with, the adverse effects of drought. Vulnerability is a function of exposure to the drought and capacity to adapt (after Watson et al. 2001).