Climate Change Impacts on Boundary and Transboundary Water Management

A Climate Change Action Fund Project
Natural Resources Canada

Project A458/402

June 30th, 2003

Authors

J.P. Bruce, H. Martin and P. Colucci
Global Change Strategies International

G. McBean,
Institute for Catastrophic Loss Reduction
J. McDougall, D. Shrubsole, J. Whalley
The University of Western Ontario
R. Halliday
R. Halliday& Associates

M. Alden, L. Mortsch and B. Mills
Meteorological Service, Environment Canada

Contributors

C. Coleman, Y. Zhang, J. Jia, M. Porco, S. Henstra

1.0 INTRODUCTION

This report, funded in part through the Climate Change Action Fund, Natural Resources Canada, deals with the climate-change related issues of water management in boundary and transboundary areas. Climate change is now happening and the projected climate change over this century is unprecedented in thousands of years. As part of climate change, there will be changes to the water cycles and increases, in some areas, and decreases, in others, in the flows in rivers in Canada and around the world. W\River flows natrally cross bondaries, both within Canada and between Canada and the United States. The management of these water resources is governed by a series of agreements between the provinces, territories and the federal government, within Canada and between Canada and the United States for international boundaries. Climate change will test these agreements and the management of water resources within the North American context. In recognition of these potential difficulties, a contract was let by the CCAF, Natural Resources Canada, to the partnership of Global Change Strategies International (GCSI) and the Institute for Catastrophic Loss Reduction. The Meteorological Service of Environment Canada became a partner in the project. Professors D. Shrubsole, J. McDougall and J. Whalley of The University of Western Ontario and R. Halliday of R Halliday & Associates became participants with the ICLR. The combined team held three meetings, in Burlington, Winnipeg and London, and several information meetings and discussions. An Advisory Board for the Project was created and met once formally to provide advice.

The following report was the result of this collaboration. The GSCI group, including the MSC participants, took responsibility for the preparation of sections 2, 3 and 4 (the climate scenarios and the Canada-US transboundary agreements) and the ICLR team took responsibility for the preparation of sections 5,6 and 7 (the interprovincial and federal provincial agreements and the international trade agreements). There are also three Annexes: the Annex "A": Analysis of Canada-U.S. Transboundary Water Instruments for Vulnerability to Climate Change (prepared by GCSI); Annex "B": Climate Change Scenarios prepared by the MSC; and Annex "C": Perceptions of Fairness in Allocating Water in the Saskatchewan River Basin, prepared by Shrubsole and Halliday.

The terms of existing Treaties and Agreements of 11 river basins between Canada and U.S.A. (see Figures 1.1 and 1.2) on boundary and transboundary waters were reviewed, and an initial assessment made of their possible sensitivity to climate change. At the same time, assessments were reviewed of a number of global climate model (GCM's) outputs on future temperature and precipitation by 2050, under a range of emission scenarios. These were then "downscaled" to each of the river or lake basins of interest.

Subsequently the available climate model results for two of the most recent greenhouse gas and aerosol IPCC emission scenarios, SRES A_2 and B_2 were selected for further use. These included ensemble results from the most recent atmosphere –ocean models of the Canadian Centre for Climate Modelling and Analysis, the Hadley Centre, United Kingdom, and the Commonwealth Scientific and Industrial Research Organization (CSIRO) of Australia.

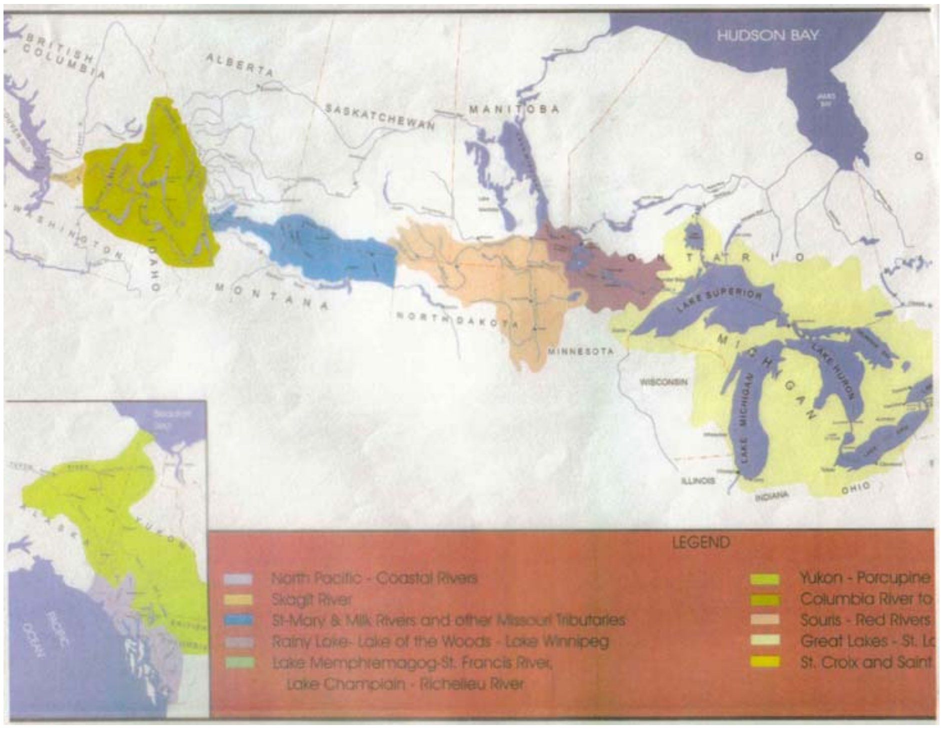


Figure 1.1 Basins in the western Canada-US boundary regions that were studied in this report.

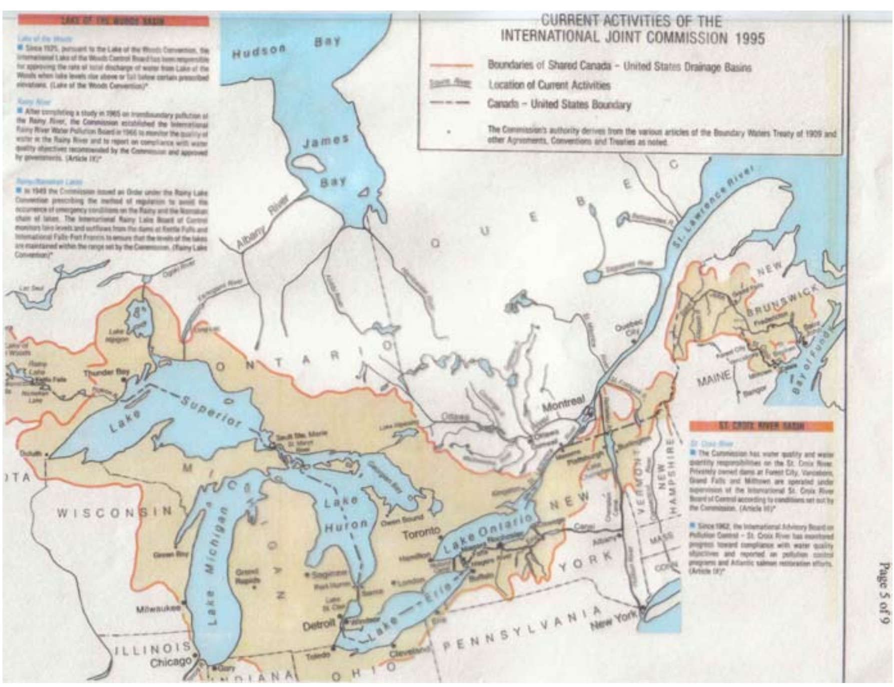


Figure 1.2 Basins in the eastern Canada-US boundary regions that were studied in this report.

In many studies of river basin responses to climate change, hydrologic models are combined with the output from GCM's. However, in this case it was decided to determine how the rivers or lakes actually responded to the observed changes in climate for the decades 1970-2000, and, using this experience as a base, extrapolate to the future. The last 30-year period was selected because global warming in that period was overwhelmingly due to anthropogenic forcing rather then natural factors (IPCC 2001) as is also the case with the projected changes to 2050. The projected "downscaled" changes were then used to provide projections of changes in flow regime likely to occur up to 2050. In cases where future flows have been modeled, results from this method were compared with published results.

Subsequently, the sensitivity to climate and flow changes of the various agreements of Annex "A" were examined, and suggestions made, in light of recent trends and probable future flow regime, of actions Canada might wish to consider in seeking modifications to Agreements, or the manner in which they are administered.

Within Canada, there is a general introduction followed by some comments on the Canadian Heritage Rivers Systems. The analyses then focused on 5 inter-provincial river systems (Ottawa, Mackenzie, Churchill (Nfld), Lake of the Woods, Churchill (MB)), the Canada-Ontario agreement vis-à-vis the Great Lakes, and two intra-provincial agreements (the Upper Thames River and the Ontario Permit to Take Water Program. A major analysis was undertaken for the Prairie Provinces Water Board, including an analysis of responses to a questionnaire vis-à-vis perception and fairness.

Because of the attention being given in the media and elsewhere to the importance of Canada-US trade agreements, in the context of water resources, a chapter analyzing the international trade agreements and bulk-water exports has been included.

The report ends with general recommendations.

2.0 CLIMATE CHANGE SCENARIOS

There is strong evidence of a general warming to date of the global climate with increasing greenhouse gases in the atmosphere due to human activities. However, there remain uncertainties about future regional distribution of rates of warming and related changes in precipitation. This is due to two main factors:

1. projections of future global greenhouse gas concentrations which are dependent on emissions related to population growth, economic development, energy consumption and mix, and government energy, forestry, agriculture and climate policies, all difficult to predict. The rates of removal of greenhouse gases from the atmosphere by the oceans and vegetation are also uncertain as the climate changes.
2. for a given emission scenario, there are somewhat different results from the various mathematical climate models (GCM'') which have been designed to simulate the complex natural system.

If the full range of possible future greenhouse gas emissions and the model responses are considered, a very wide range of climate outcomes are possible, although all outcomes on a global basis indicate a warming and slightly more precipitation on average. The way in which this wide range of possibilities manifests itself on the watersheds of concern is illustrated in the scatter plots of temperature increase vs. precipitation changes per watershed given in Annex B figures, with possible seasonal changes in Appendix I of Annex B.

The results shown in the scatterplots are from some 31-model runs with various input assumptions about future greenhouse gas emissions. However, many of the models cited have since been superceded by later, better models by the 6 modelling groups included. In addition, the emission scenarios have been updated by the Intergovernmental Panel on Climate Change. Each emission scenario in the new SRES series is driven by a number of explicit scenarios of future economic development, population, and technologies. These new emission scenarios have been used recently to drive GCM's from three modelling centres, Canadian CGCM2, British HadCM3 and Australian CSIROMK2b. In all, 12 model results were available for SRES scenarios A1, A2, B1 and B2. However, only the Australian model had used A1 and B1. Intercomparisons between all three model results were available for A2 and B2 scenarios. A description of the socio-economic assumptions in the 4 SRES scenarios is given in the attached box 2.1 and in Annex II.

A summary of the much smaller range of results using only SRES driven modelling runs for annual and seasonal values of temperature and precipitation for some of the basin is given the Table 2.1.

TABLE 2.1
PROJECTED TEMPERATURE AND PRECIPITATION CHANGES
to period 2040-2069 (centred on 2050s)
from 1961-1990 (centred on 70s)

		A1 (CSIRO only)		A2 (Average of 3)		B1 (CSIRO only)		B2 (average of 3)	
		Change T ^{0}C	% Precip.	Change T ^{0}C	% Precip.	Change T ^{0}C	% Precip.	Change T ^{0}C	% Precip.
Columbia to Chelan	**Annual**	2.9	6	2.4	4	2.7	8	2.2	3
	Winter (DJF)	3.3	15	2.9	11	3.5	15	2.1	8
	Spring (MAM)	1.8	13	1.9	6	1.6	9	1.8	6
	Summer(JJA)	3.3	-4	2.8	-5	2.7	-5	2.8	-10
	Autumn(SON)	3.4	-4	2.5	3	2.7	4	2.3	4
St. Mary/Milk	**Annual**	3.5	6	3.0	5	3.1	6	2.9	2
	Winter (DJF)	3.9	17	3.6	13	3.8	15	2.7	14
	Spring (MAM)	3.2	22	3.3	14	2.8	19	3.2	15
	Summer(JJA)	3.3	-8	3.2	-6	2.7	-8	3.0	-12
	Autumn(SON)	3.5	-5	2.5	6	3.0	2	2.7	-1
Souris/Red	**Annual**	3.9	0	3.2	3	3.2	0	2.9	0
	Winter (DJF)	4.1	17	3.6	11	3.6	11	2.8	7
	Spring (MAM)	3.9	24	3.5	16	2.9	20	3.4	17
	Summer(JJA)	4.0	-20	3.3	-9	3.2	-15	3.1	-12
	Autumn(SON)	3.6	-8	2.6	7	3.2	-4	2.7	-1

Rainy Lake/ Lake of the Woods, Lake Winnipeg	**Annual**	4.8	-4	3.3	4	3.7	0		
	Winter (DJF)	5.2	32	3.6	15	3.8	15	4.2	24
	Spring (MAM)	5.7	25	3.7	15	4.4	14	3.4	17
	Summer(JJA)	4.8	-30	3.3	-7	3.2	-11	3.0	-7
	Autumn(SON)	3.8	-13	2.6	4	3.4	-5	2.5	-2
Great Lakes – St. Lawrence	**Annual**	4.6	6	3.2	6	3.6	6	2.8	5
	Winter (DJF)	5.0	17	3.5	9	3.7	12	2.9	6
	Spring (MAM)	5.6	15	3.4	10	4.2	13	3.1	11
	Summer(JJA)	4.3	-2	3.3	-1	3.3	0	2.9	-1
	Autumn(SON)	3.6	-3	2.7	6	3.4	1	2.4	2

BOX 2.1

The Emissions Scenarios of the IPCC Special Report on Emissions Scenarios (SRES)	
A2. The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines.	B2. The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in A1 and B1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

A few consistencies and inconsistencies are evident from Table 2.1.

Consistencies:

a) Changes for B2 scenario are least
b) Precipitation in all basins is projected to increase in winter and spring and decrease in summer. The sign of change in autumn is mixed.

c) Temperature increases for A2 scenario (annual) range from 2.4^0C (Columbia) to 3.3^0C (Rainy) and for B2 scenario from 2.2^0C (Columbia) to 2.9^0C for other basins.
d) Seasonal temperature increases are greatest in winter and spring in all basins.

Inconsistencies:

a) The CSIRO results indicate consistently larger temperature increases than either the CGCM2 OR HadCM3 models, making comparisons inconsistent between A1 and B1 (CSIROonly) on the one hand and A2 and B2 (average of 3) on the other.

2.1 EVAPORATION

Evaporation losses tend to increase with higher temperatures and there has been an analysis in Europe at the latitude near the 49^{th} parallel, taking into account a small increase in cloudiness with a warming climate. This analysis indicates that for a warming of 2.8^0C, insolation would be reduced by 3%, but evaporation from shallow water bodies would increase by 11-24% (Jurak, 1989). Thus, to a first approximation, an increase in precipitation of this amount would be needed to maintain water levels, flows and soil moisture. In general, precipitation increases of this amount, on an annual basis seems unlikely from the recent model results, ranging from negative to +8%, from the most recent model outputs. (Table 2.1) It has been estimated that a 1^0C temperature increase reduces outflow from the Ocalla Aquifer to the Arkansas River, by 18-25% (Rivera, 2001). The work by Schindler in the Experimental Lakes area Northwest of Kenora, Ont., suggest that with a 2^oC rise in average air temperature the lake water temperature increased about 1.5 ^{o}C, suggesting a significant increase in evaporation losses.

On the other hand, increased cloudiness (up to 1990 but not after) may reduce evaporation changes with higher temperatures (Ohmusa and Wild 2002). The key for water bodies is how much the surface water temperature will rise for the saturation vapour pressure at that temperature to be higher than atmospheric vapour pressure. Observed evidence in Canada and elsewhere indicates clearly more evaporation with higher temperatures.

2.2 SOIL MOISTURE

Projections of soil moisture changes in boundary and transboundary water basins are, unfortunately not available from the recent, most reliable, modelling results. However, soil moisture change estimates from earlier runs by the Canadian CGCM1 model, using the older IS92a emission scenarios of IPCC for both greenhouse gases and aerosols are available. Fig. 2.1, shows these changes for Canada and adjacent U.S.A for autumn months. It will be noted that, with the exception of the Rainy Lake-River watershed, where an increase of 10-15% is shown, the projections for 2050 for Sept. through to November are all downward. Similar trends were evident in summer months (not shown). Average soil moisture losses are, at maximum, projected to exceed 20% in summer in the central Prairie watersheds. This is consistent with the excess of evaporation increases over precipitation cited above.

2.3 SPRING SNOWPACK AND GLACIERS

Spring snow cover extent over North America from 1993 to 1994 declined from 9 mill km^2 to 7.5 mill km^2 with a rate of change averaging –7.4 x 10^5 km^2 per decade (Groisman et al. 1994). Model projections of Northern Hemisphere Snow Cover >3cm in winter months (DJF) is expected to decline from 45 mill km^2 to 37 mill km^2 by 2050 and to 30 by 2100 with greenhouse and aerosol forcing (CGCM2-Boer et al. 2000).

Glaciers in the southern half of British Columbia and Alberta have been in retreat with warmer conditions. In the North, temperature effects appear to be offset by increased snowfall. When glaciers melt, there tends to be an initial increase in flow of glacier fed rivers, and then a decline as glacier size and influence shrinks. For southern Alberta, glacier fed streams appear to be already in a declining phase by 2001.

2.4 RAIN INTENSITY

Both recent data for some basins and model projections for all, indicate that frequencies of high intensity rainfalls in these basins will increase in a greenhouse gas enhanced world.

Analysis of carefully quality assured data for 1950-1995 for Southeastern Canada, (Great Lakes-St. Lawrence, St. Croix, St. John basins) suggests an upward trend averaging abut 8% per decade of frequency of heavy events in the May/June to Nov/Dec period. For Southwestern Canada, (including the southern Prairie basins, and southern British Columbia) increases in heavy event frequency average about 3% in May, June, July, and again in autumn (Sept. to Dec.). Heavy events in this analysis were defined as > (5+5n) mm/day where n is the highest integer that results in an average of at least five heavy precipitation events per year (160-1999). (Stone, Weaver and Zwiers, 2000). For Northwestern Canada including the Yukon River basin increases in frequency of heavy precipitation have been primarily in winter snow months, reaching a maximum average of 12% in Jan. Feb. March. Small increases in heavy rain events, of about 3% were also recorded over the summer and autumn season.

Studies for USA, indicate that for a 10% increase in rainfall, due to increased intensities, soil erosion would increase 24% on average (SWCS 2003). The main attempts to model future change in frequency of heavy precipitation events, has been undertaken with the Canadian model (Zwiers & Kharin 1998, Kharin & Zwiers 2000). The studies conclude that in a doubled CO2 world, about 2070, 20-year return period events will become more frequently 10-year events over most of Canada, and other one-day heavy rainfall return periods will be twice as frequent..

2.5 THAWING OF PERMAFROST

The observed and continuing thawing of the permafrost layer will have impacts on hydrology of the Yukon River and those in the Alaskan Panhandle. Effects are, however, difficult to predict as they involve slumping of lands and thus blocking or diverting of streams.

REFERENCES

Boer, G., G. Flato, M.C. Reader and D. Ramsden, 2000, CL transient climate change simulation with greenhouse gas and aerosol forcing, Climate Dynamics 16: 405-426.

Brown, R. and R. Broaten, 1997, Spatial and temporal variability of Canadian monthly snow depths 1946-1995, Atmosphere-Ocean 36.1: 37-54.

Bruce, J.P., I. Burton, H. Martin, B. Mills and L. Mortsch (2001), Water Sector: Vulnerability and Adaptation to Climate Change, Report to NR Can-CCAF, June 2000,141 pp. At: www.gcsi.ca

Intergovernmental Panel on Climate Change 2001, Climate Change 2001, The Scientific Basis, WG1. Model Evaluation, Chapter 8: 471-524, Cambridge.

Kharin, V.V. and F.W. Zwiers, 2000, Changes in the extremes in an ensemble of transient climate simulations with a coupled atmosphere-oceans GCM, Journal of Climate 13, 3760-3788.

Ohmura, A, and M. Wild, 2002, Is the hydrological cycle accelerating?, Science 298 (November 2002), 1345-1346.

Soil and Water Conservation Society, 2003. Conservation implications of climate change: Soil erosion and runoff from cropland, Report, Jan. 2003, SWCS, Ankeny, Iowa, 24 pp.

Stone, D.A., A.J. Weaver, F. W. Zwiers, 2000, Trends in Canadian precipitation intensity, Atmosphere-Ocean 38.2: 321-347.

Groisman, P. Y. and D. Easterling, 1994, Variability and trends of total precipitation and snowfall over U.S. and Canada, Journal of Climate 7: 184-205.

Natural Resources Canada, 1999, Sensitivities to climate change in Canada, Ottawa, 23 pp.

3.0 OVERVIEW OF CLIMATE CHANGE AND FLOWS ON RIVERS AND LAKES IN BORDER REGIONS

Observed changes in flow regimes have been analyzed by Zhang et al., 2001, and by Whitfield (2001). Among the most consistent and widespread effects of the warming have been earlier spring runoff (82% of basins in Canada), and in southern Canada greater total flow in winter but on average lower peaks, with winter melt periods more frequent, and declining minimum flows, usually late summer or autumn. Total annual flow changes over southern Canada are more mixed, depending on whether the winter discharges outweigh the late summer-autumn declines. However for some of the small transboundary rivers, e.g. Souris, Milk, St. Mary, minimum flows are often zero or a few CMS, making the trends there somewhat meaningless (see Sections 4.2 and 4.3).

TABLE 3.1
TRENDS IN ANNUAL FLOWS – 1970 to 2000, %

River	Mean	Minimum	Maximum
St. John (Fort Kent)	-13	71	-16
St. Croix	-21	-23	-26

Niagara (Queenston)	-7	-8	-9
Rainy (For Frances)	-22	-12	-27
Red (Emerson)	124	159	63
Souris (Sherwood)	-82	-74	-94
Souris (Westhope)	-42	100	-60
Milk (E. border)	-22	47	-6
Milk (W. border)	-26	59	-41
St. Mary (border)	-7	15	-29
Columbia (International Border)	4	37	-25
Yukon	1	-1	-12

Table 3.1 shows the observed % changes for the 1970:2000 period for major boundary and transboundary rivers at border crossings. The trend is fairly consistently downward with the notable exception of the Red River at Emerson, Manitoba. This is due to the much increased precipitation (21% in winter, 39% in summer) in the headwaters in Dakotas and Minnesota, in contrast to minor changes experienced North of the border in Manitoba areas.

These observed trends are partly due to changes, usually increases in upstream water uses and evaporation with more reservoir surfaces, but also to changes in climate factors. To assess the relative signification, calculated "natural flows" for Souris River and St. Mary River were examined. Remaining trends were still downward but not as steeply as for observed flows.

The observed trends in Table 3.1 have then been compared to observed climatic conditions over the same period to obtain an index of the responsiveness to the climatic trends.

Across southern Canada, major observed warming has been in winter and in spring. Warming in these two seasons are projected to continue more slowly, but the models also suggest significant summer and autumn warming, not yet evident in the record except for the Columbia basin. It may be that the conventional definition of the seasons – autumn (September, October, November), winter (December, January, February), etc. – may be providing misleading results if the seasons are shifting to later starts. That is if "autumn" really extends more into December, a small change or cooling in that season may result. Similarly spring may be encroaching on what we have traditionally classified "summer" i.e. June and recording significant warming..

Observed trends 1970-2000 indicate declining winter precipitation throughout (-3% in east to –12% in west), while in contrast, projections to 2050 indicate the largest precipitation increases in winter.

Observed precipitation increases of 10% or more over the 30 years occur in spring and summer, only in the east (St. John and St. Croix) and West (Columbia). More generally, changes in precipitation observed are small or negative from Spring through Autumn. Projections to 2050 are also negative in summer and in many cases autumn, but positive in spring.

In short, projected outcomes and observed trends both suggest little change or decline in warm season precipitation in most basins. Projected outcomes for winter snow are for increases, but observed trends to date are not consistent with this projection.

The general agreement in annual amounts, but differing seasonal distributions, between observed and projected changes to 2050 from the 1970 base, may be used in some cases to interpret the trends in flow regime of the past 30 years and project these, at least qualitatively, to the future. In other cases, flow projections are not possible by this approach because of conflicts between observations to date and projected future changes. These are discussed for individual basins in Chapters 4 to 12.

REFERENCES

Whitfield, P.H. and Cannon, A.J., 2000. Recent variations in climate and hydrology in Canada, Canadian Water Resources Journal V. 25 #1, 19-66.

Zhang, X, Harvey K.D., Hogg, W.D., Yuzyk, T.R., 2000. Trends in Canadian streamflow, Water Resources Research.

4.0 INTERNATIONAL BASINS

4.1 COLUMBIA RIVER BASIN

4.1.1 TRENDS OBSERVED

Increasing trends in mean (3.8%) and minimum (37%) flows have been observed at the International border (Fig. 4.1.1), with much increased air temperatures winter and spring, since 1970, even though winter precipitation has declined. Precipitation increases of 9-12% (mainly rain) have been observed in spring through autumn. Minimum flow months at the international border, since 1975 (last of major dams) have moved from mostly winter and early spring to mostly summer months. A trend from 1970 shows a movement from month 4 (April) to month 8 (August) for minimum flows. (Fig. 4.1.3)

Maximum flows have declined and moved from mainly June to be more frequently in winter, with major winter melt periods. (Fig. 4.1.4 The timings are, of course, strongly influenced by reservoir operations for minimum flows. It has been shown that earlier dates of maximum flows are also due in part to reservoir regulation (Volkman 1997).

Given the much warmer winters and spring but dryer winters in the basin for 3 decades, the small observed increases in mean annual flow and, particularly minimum flows, may be drawing on glaciers in the basin, with somewhat higher temperatures throughout the year resulting in glacier melt. If this is the case, the glacier contribution to flows in the basin is at an earlier stage than on the East Slopes of the Rockies, where it has been found that glaciers have now retreated to the stage that they contribute less melt water to the east flowing streams (Pietronio 2001).

4.1.2 PROJECTIONS: OUTLOOK WITH CLIMATE CHANGE

If the observed effects are combined with the projected more rapid warming in summer and autumn and thus greater evaporation losses from lakes and reservoirs, and a change to less summer rainfall (Table 4.1.1), and reduced glacier contribution eventually, it could be expected that recent trends in mean flow would be reversed. That is, the outlook for future decades is that mean annual flows of the Columbia at the international border are likely to be reduced. Unfortunately, it is difficult to quantify the magnitude of this reduction from analysis of the past record of a somewhat increasing trend and the many complexities in the natural and human operated system.

TABLE 4.1.1
COLUMBIA BASIN OBSERVED AND PROJECTED TEMPERATURE AND PRECIPITATION

	Temperatures ^{0}C					Precipitation %				
	Annual	W	Sp	Su	A	Annual	W	Sp	Su	A
1970-2000 observed	1.5	3	1.5	0.6	0.9	1	-12	12	12	9
1970-2050 Projections (A2 emissions)	2.4	2.9	1.9	2.8	2.5	4	11	6	-5	3
1970-2050 Projections (B2 emissions)	2.2	2.1	1.8	2.8	2.3	3	8	6	-10	4

Hydrologic modelling studies suggest a continuation of earlier and lower average peak flows, in May rather than June. An estimate of the reduction of mean annual flow at the Dalles in the U.S.A. is 16% by 2050 if the Max Planck Institute 1996 climate change scenario based on earlier emissions scenarios, were applied (Cohen et al 2000). For temperatures, this MPI climate scenario is very close to those more recent projections in Table 2.1 for SRES-A2 emissions scenario but for precipitation MPI is considerable drier in summer and fall than the more recent scenarios (Table 2.1). Minimum flow reductions of some 30% are projected by applying MPI results, but the recent climate scenarios suggest a lesser reduction.

A recent analysis by Lettenmaier, et al.[1] using a climate model providing more conservative climate changes than in Table 4.1 still showed that winter snowpack in Washington and Oregon Cascades would decline by 50% by 2050. Small temperature increases will give substantial changes in timing of runoff. The Lettenmaier modeling

[1] Lettenmaier, D. et al., *Climate Change* (in Press Dec. 2002).

suggests a reduction in average peak flow at The Dalles, by 2050, of 18%, from 1950-99-values. This model projects only a 3% decline in mean flow at The Dalles compared to 16% in the earlier study (Cohen et al., 2000). Storage for fishflow targets in that study would result in "severe losses in hydropower production", an estimated 15% by 2050.

However none of the climate modeling results has effectively simulated the very dry conditions of 2001 to early 2003. In the last few months of 2002 precipitation in the Canadian portion of the basin was only 57% of average. These warm-dry conditions are associated with El Nino related conditions in the Pacific. The linkage between El Nino episodes and greenhouse gas induced climate change is not well understood, but IPCC concluded in its 2001 report that conditions would be "more El Nino like" in a warmer world. If so then significant declines in flow would be experienced from the Canadian portion of the Columbia.

It should, however, be noted that while the average peak discharges will likely continue to decline, there is potential for very severe floods on occasions when heavy spring rains, increasingly likely, occur on the remaining snowpack.

4.1.3 IMPLICATIONS FOR TREATIES AND AGREEMENTS

The dominant provision of the Treaty (1961) (see Annex "A") requires Canada to provide for 15.5 mill acre-feet of reservoir storage, about 31% of the historic runoff from the Canadian portion of the basin. In exchange, an agreed portion of the U.S. hydroelectric power generated in the lower part of the basin is provided to Canada. This Treaty runs to Sept. 2024. Another major provision provides for Canadian storage to assist with control of floodwaters as needed. This is subject to short-term operational plans.

Other Agreements include those on Kootenay Lake (1938), and on Lake Osoyoos (1982) which refer to the Okanagan and Similkameen River. On Kootenay Lake, an extra 6 feet of storage was provided, and an IJC Board ensures operation of levels within a 1.83 metre (6 ft) range.

In considering the potential influence of climate change on administration of these Agreements, its importance relative to other stresses must be considered. Among these stresses are the fisheries needs in both countries and particularly for adequate flows for salmon in the U.S.A., and rising river and lake water temperatures which inhibit cold-water species. Some species fall under the powerful U.S. Endangered Species Act. For example in the Fraser River an average summer warming of water is estimated at 1.9^{o}C with climate change projected to late 21st century, resulting in a 10 fold increase in exposure of salmon to water temperatures above their estimated threshold. Similar experience is likely on the Columbia. The pressure will increase for greater diversion of waters for irrigation and domestic uses, such as air conditioning, as summer temperatures rise. Hydro-driven energy production will be at a premium, with attempts to curb consumption of fossil fuels for electricity production to limit greenhouse gas emissions.

It must be noted that declining flows would carry a large price in reduced hydropower production. BC Hydro reported a decline of earnings of $232 million in the quarter to June 30, 2001 due to "low snow pack and inflow to reservoirs" (Canadian Press Aug. 31, 2001).

Balancing these demands with projected lower mean and minimum flows, and the occasional very large flood will be major challenges.

4.1.4 SUGGESTED ACTIONS

The situation of the Columbia does not appear to require early adaptation actions. However:

i) Present operating procedures require that the countries, 5 years in advance, agree annually on operating plans and resulting downstream benefits for the sixth succeeding year of operation thereafter. With the situation volatile for all of the above reasons, a shorter time frame should be considered for these operational plans.

ii) While the Columbia Basin is a large system and response to changing climate factors has been slow and will continue to be, by 2024 when the main Treaty needs to be revisited, major changes and trends are likely to be evident. It is recommended that the BC and Canadian governments continue to keep a close watch on trends in the basin, and be prepared to make the needed adjustments for climate change and other factors in any new or renewed agreement.

REFERENCES

Cohen, S.J., Miller, K.A., Hamlet, A.F., Avis, W., 2000. Climate change and resource management in the Columbia River Basin, Water International 25:2:253-272.

Hamlet, A.F., Lettenmaier, Nijssen, B., 1997. Effects of Climate Shift on Water Resources Objectives in the Columbia Basin. JISAO Climate Impacts Group Report, University of Washington, Seattle, Washington, USA.

Lettenmaier, D.P. and Hamlet, A.F., 1998. Effects of Anthropogenic Climate Change on Water Resources Objectives in the Columbia Basin. JISAO Climate Impacts Group Report, University of Washington, Seattle, Washington, USA.

Morrison, G., M.C. Quick, M.G.C Foreman, 2002, Climate change in the Fraser River Watershed: flow and temperature projections, Journal of Hydrology 263, 10 June, 230-244.

Pietronio, A., 2001. Impact of climate change on the glaciers of the Canadian Rocky Mountain slopes and implications for water resources – related adaptation in the Canadian Prairies. CCAF Impacts and Adaptation Project, Natural Resources Canada, Ottawa.

Snover, A. 1997. Impacts of Global Climate Change on the Pacific Northwest. Prepared for the US Global Change Research Program and Office of Science and Technology Policy, Pacific Norwest Regional Climate Change Workshop, Seattle, Washington, July 14-15, 1997 Seattle, Washington, USA: University of Washington JISAO Climate Impacts Group.

Volkman, John N. 1997. A River in Common: The Columbia River, the Salmon Ecosystem, and Water Policy. Report to the Western Water Policy Review Advisory Commission.

FIGURE 4.1.1

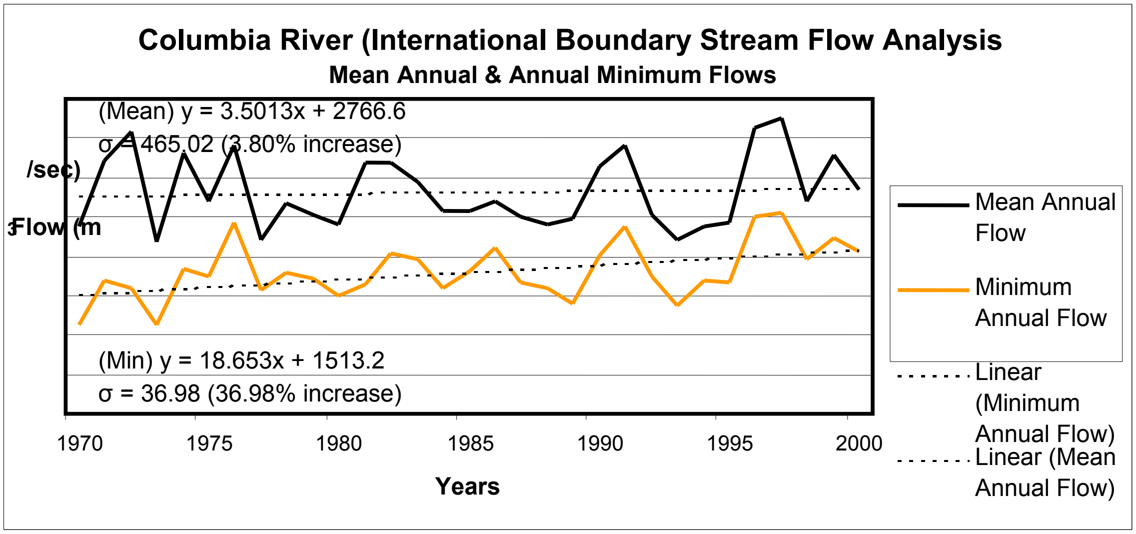


FIGURE 4.1.2

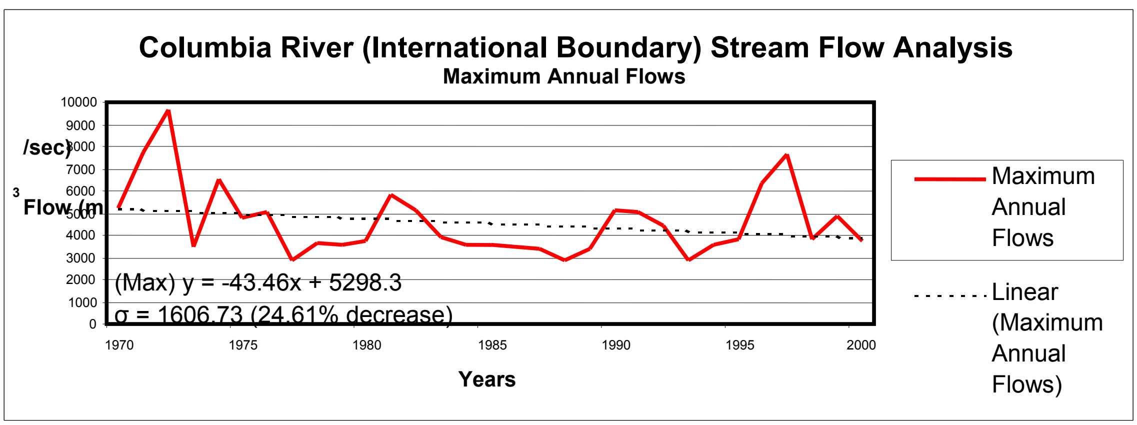


FIGURE 4.1.3

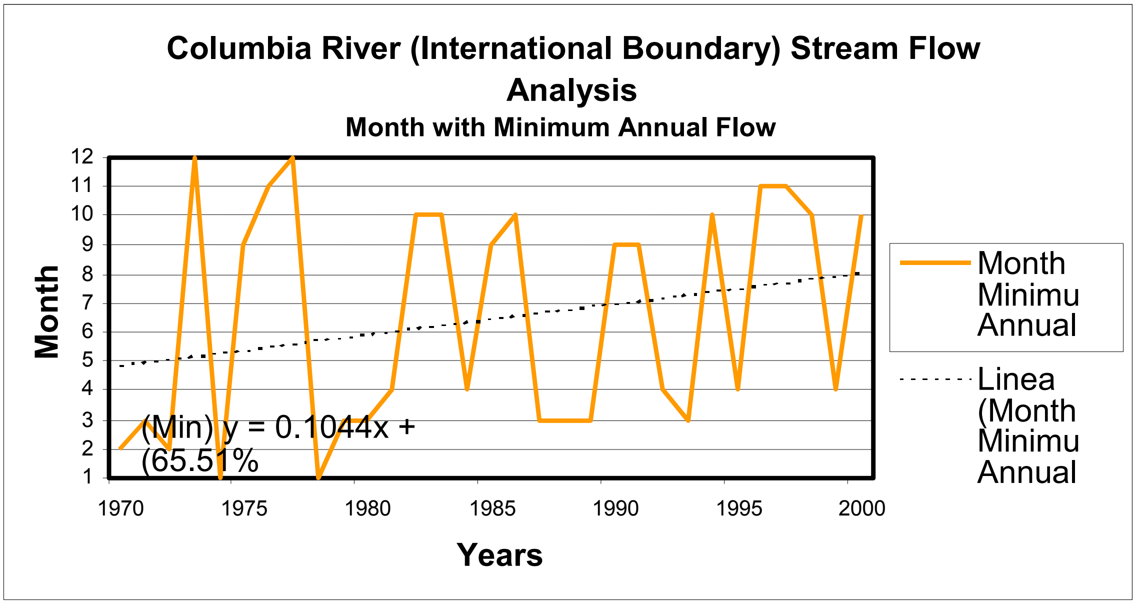
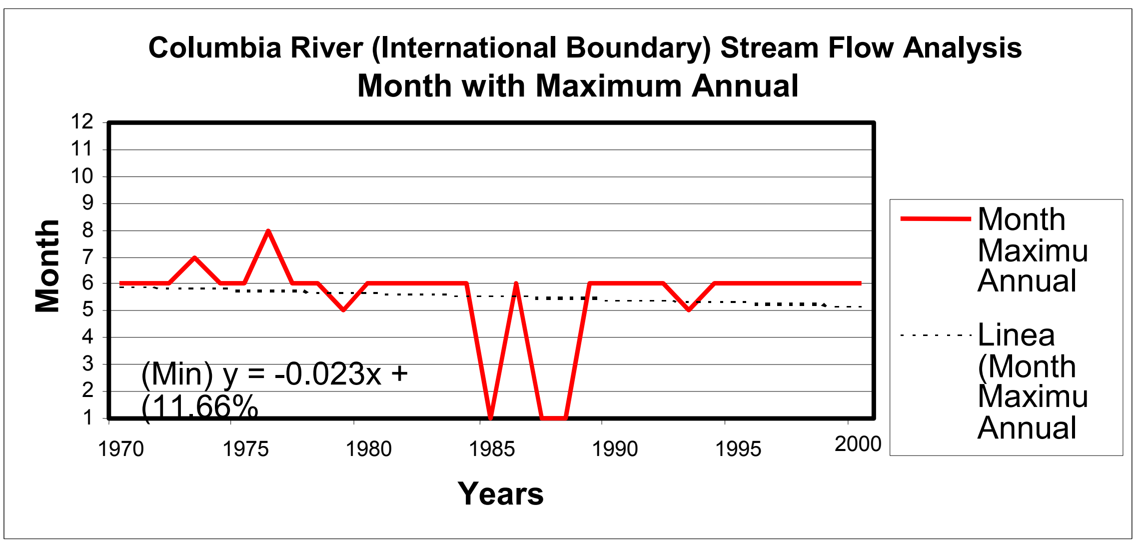


Figure 4.1.4



4.2 ST. MARY/MILK RIVERS

4.2.1 TRENDS OBSERVED

In the past 30 years, the mean flows of the Milk River at the border crossings have declined more than 20% at both West and East crossings, and the St. Mary has declined by 7%. (See Fig. 4.2.1 and 4.2.2) Minimum flows have increased substantially as a percentage, from earlier very low values (a few to less than 1 cms). Peak discharges have declined, on the Milk at the West border by 41%, and by lesser amounts at the east border and the St. Mary. These trends have undoubtedly been affected by changing patterns of water withdrawals and management for irrigation. Not much trend is evident in timing of peak and minimum flows on the St. Mary, which continue to be in May to June and late fall or winter months respectively. However, on the Milk at the Western Border Crossing, while minimum flows continue to be in autumn, maximum discharges are in recent years more frequently in March-April instead of April to June as in much of the period before 1920. Annual max and min flows tend to be a little later than at the West crossing on the Milk at the Eastern Border Crossing, as might be expected.

The mean flow decreases were due to a combination of increased consumption upstream as well as changes in climate. To assess the relative importance of these factors, an analysis was done of calculated "natural" flows (by the IJC Board of Control) for the St. Mary. The "natural" flows declined 3.8% while recorded mean annual flows were down 5.9%. Neither was significant at a 95% level.

These results, however, are reasonably consistent with expectations from observed climatic changes. Winter temperatures soared about 3^0C over the 1970-2000 period and precipitation (mostly snow) declined by about 10%. Spring and autumn temperatures rose by modest amounts (0.9 and 0.6^0C respectively) and little to no change occurred in summer months. There was little change in precipitation throughout the spring to autumn season.

Thus, with relatively little change in precipitation, and greater evaporation with higher temperatures, small declines in mean flow were not unexpected. While the daily minimum flows on the St. Mary and Milk have increased slightly from low values, the computed natural flows on the St. Mary at the border, from April through October (the irrigation season), have declined about 800, 000 Cubic Decametres (DAM^3), from around 1910 to about 720,00 DAM^3 in the 1990's.

4.2.2 PROJECTIONS: OUTLOOK WITH CLIMATE CHANGE

In the following Table 4.2.1, generalized climate changes for the St. Mary's/Milk's region for the 1970 to 2000 period are compared with projections of changes for the 1970-2050 period.

TABLE 4.2.1
ST. MARY/MILK RIVER BASINSOBSERVED AND PROJECTED TEMPERATURE AND PRECIPITATION CHANGES

	Temperatures ^{0}C					Precipitation %				
	Annual	W	Sp	Su	A	Annual	W	Sp	Su	A
1971-2000 observed	0.9	3.0	0.9	0	.6	0	-18	0	0	9
1971-2050 Projections (A2 emissions)	3.0	3.6	3.3	3.2	2.5	5	13	14	-6	6
1971-2050										

Projections (B2 emissions)	2.9	2.7	3.2	3.	2.7	2	14	15	-12	-1

Thus, the model projections for rate of temperature increase appear to be much lower for winter and higher for summer than the 1971-2000 period experience. For precipitation, the models project an increase in winter (mostly snow) in contrast to the decrease observed to 2000, and a decline in summer precipitation. For the transition seasons, in spring an increase over 1971-2000 amounts is projected and for autumn, projections are reasonably consistent with observations to date for both temperature and precipitation.

The implications for streamflow, if the modelled projections are accepted, are for stabilization of mean annual flows at about year 2000 levels. However, more would occur in the first half of the year, with more winter and spring precipitation, but less flow in the late summer and autumn with higher temperatures and lower precipitation than observed in the 1971-2000 period. Minimum flows in autumn would decline sharply in these scenarios. Peak discharges in spring would increase somewhat or at least stabilize from year 2000 levels. The occasional very large flood is likely, in the event of heavy early spring rains in the late snowmelt period.

4.2.3 IMPLICATIONS FOR TREATIES AND AGREEMENTS

The sharing of the waters of these basins was addressed in the original Boundary Waters Treaty of 1909, followed by an Order of the IJC in 1921. (See Annex “A”). The Treaty required the rivers to be “treated as one stream for the purposes of irrigation and power”, and for “equal apportionment” which can be juggled between the two river systems. However, between 1 April and 31 Oct. (irrigation season) U.S.A. can appropriate 500 cfs or ¾ of natural flow of the Milk and Canada has similar rights on the St. Mary. Needed balancing can occur between 1 Nov. and 31 March.

Pressures are greatest on waters of the Milk River where the mean annual flow at the Western Border Crossing has fallen to an average of about 2 cms (30cfs), (Fig. 4.2.1) and at the Eastern to just under 15 cms (525 cfs). (Fig.4.2.2) The lowest minimum flows, over the 3 decades occurred in late 1990s averaging about 0.3 cms (15 cfs) in the West and have at times dropped to zero, (1983, 84, 88, 2000) in Aug. Sept. and/or Oct.. At the Eastern Crossing, recent (late 1990s) minimums have averaged about 4 cms (~140 cfs) but with flows less than 1 cms (35 cfs) in 1983, 84, 88 and 2000.

The St. Mary delivers more water at the International border, averaging about 18 cms in the late 1990s, with minimum discharges of 3 cms (105 cfs) but in some years (e.g. 1982, 1987, 2000) dropping below 2 cms (70 cfs) in Nov., Dec, and Jan.

It can be seen that on the Milk the U.S. share of 500 cfs cannot be met at the Western Crossing and just barely so at the Eastern Crossing based on average annual flows. However, the minimum flows, at both locations in the latter part of the irrigation season, are hopelessly inadequate to permit 500 cfs withdrawal. This suggests that the ¾ of natural flow rule would frequently have to be used, but with irrigation water withdrawals and greater evaporation with climate change, the calculation of “natural flow” remains difficult.

On the other hand, Canada could obtain 500 cfs based on mean annual flows from the St. Mary, and the period of minimum flows at the border is outside the irrigation season although discharges from Sept. to March are usually much less than 500 cfs. However, a constant withdrawal of the 500 cfs would likely exceed ¾ of the "natural flow".

Under climate change scenarios A2 and B2, discharges from March through to mid summer are likely to be greater on both rivers, but with a more precipitous drop in flow in the latter part of the year, when evaporation losses are expected to be substantially higher by an estimated 11-24% (Jurak, 1989) and summer-autumn precipitation is projected to decline.

From the point of view of water quality, it should be noted that a "bimodal" distribution of high contaminant concentrations is likely. During very low discharge periods, return flows from agriculture and communities do not receive much dilution so stream pollutant concentrations are generally high. Also, with the projection of more frequent heavy rain events, surface run off with loss of soil, and contaminants attached to soil particles, can cause pollution episodes.

4.2.4 SUGGESTED ACTIONS

i) With the projected changes, U.S.A. may press for modification to the allocation rules and Canada should be prepared with a strategy.

ii) Procedures should be reviewed for calculating "natural flows" in a changed climate, allowing for increased evaporation from reservoirs and lakes in the basin, and to also allow for additional irrigation withdrawals in the expected warmer, drier, summer months.

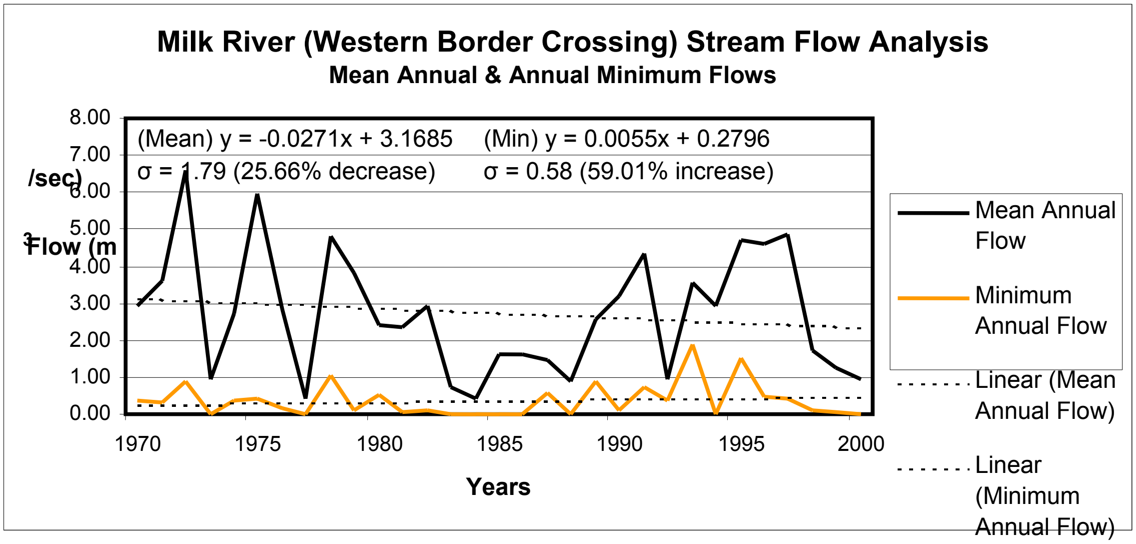
REFERENCES

Jurak, D., 1989. Effect of climate change on evaporation and water temperature. Proc. Conference on Climate and Water, Vol.1, 138-144, Helornki, Sept. 1989, Published by Academy of Finland.

Kharim, V.V. and Zwiers, F.W., 2000. Changes in extremes in an ensemble of climate simulations with coupled atmosphere-oceans GCM. J. of Climate 13(21), 3760-3788.

Pietronio, A., 2001. Impact of climate change on the glaciers of the Canadian Rocky Mountains slopes and implications for water resources – related adaptation in the Canadian Prairies, CCAF Impacts and Adaptation Project, Natural Resources Canada, Ottawa.

FIGURE 4.2.1


Milk River (Western Border Crossing) Stream Flow Analysis
Mean Annual & Annual Minimum Flows
(Mean) y = -0.0271x + 3.1685
σ = 1.79 (25.66% decrease)
(Min) y = 0.0055x + 0.2796
σ = 0.58 (59.01% increase)
Flow (m3/sec)
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
1970
1975
1980
1985
1990
1995
2000
Years
Mean Annual Flow
Minimum Annual Flow
Linear (Mean Annual Flow)
Linear (Minimum Annual Flow)

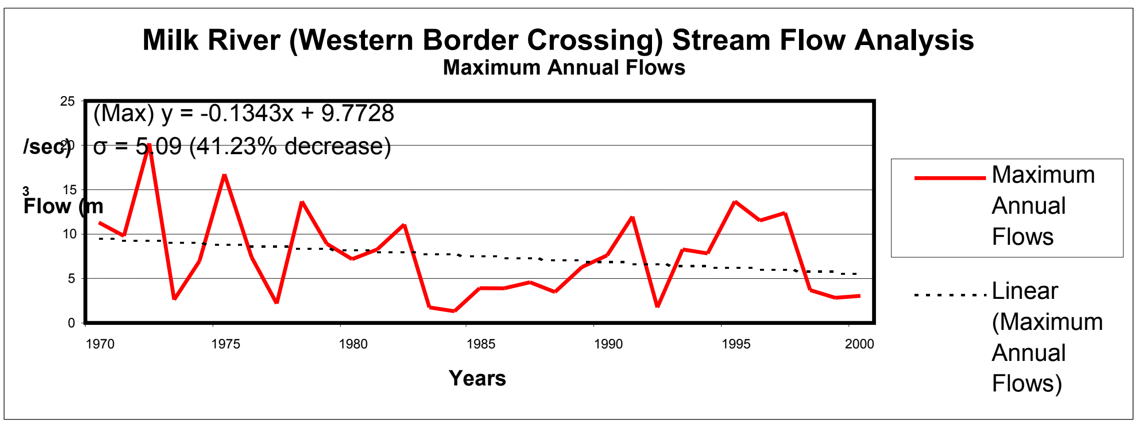
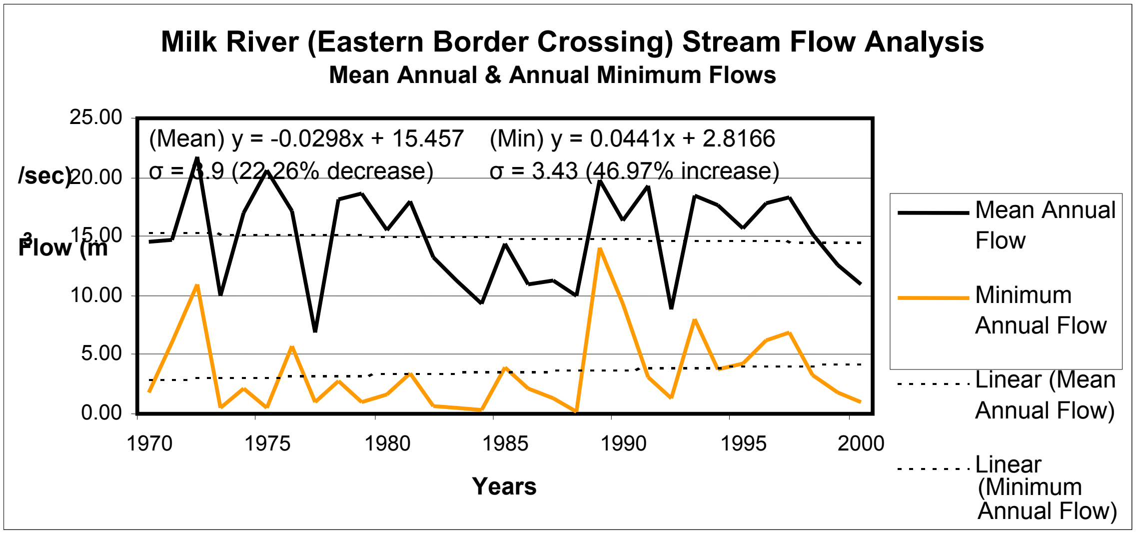

Milk River (Western Border Crossing) Stream Flow Analysis
Maximum Annual Flows
(Max) y = -0.1343x + 9.7728
σ = 5.09 (41.23% decrease)
Flow (m3/sec)
25
20
15
10
5
0
1970
1975
1980
1985
1990
1995
2000
Years
Maximum Annual Flows
Linear (Maximum Annual Flows)

FIGURE 4.2.2


Milk River (Eastern Border Crossing) Stream Flow Analysis
Mean Annual & Annual Minimum Flows
(Mean) y = -0.0298x + 15.457
σ = 3.9 (22.26% decrease)
(Min) y = 0.0441x + 2.8166
σ = 3.43 (46.97% increase)
Flow (m3/sec)
25.00
20.00
15.00
10.00
5.00
0.00
1970
1975
1980
1985
1990
1995
2000
Years
Mean Annual Flow
Minimum Annual Flow
Linear (Mean Annual Flow)
Linear (Minimum Annual Flow)

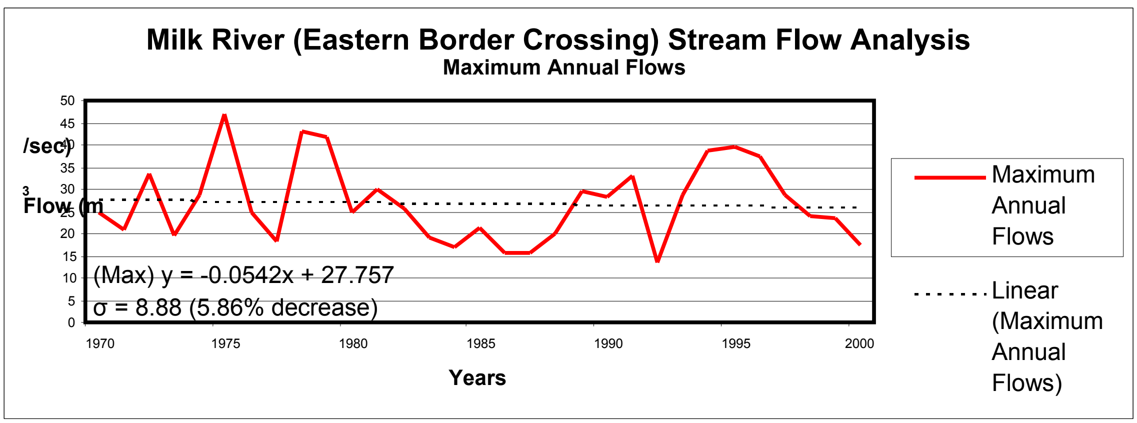
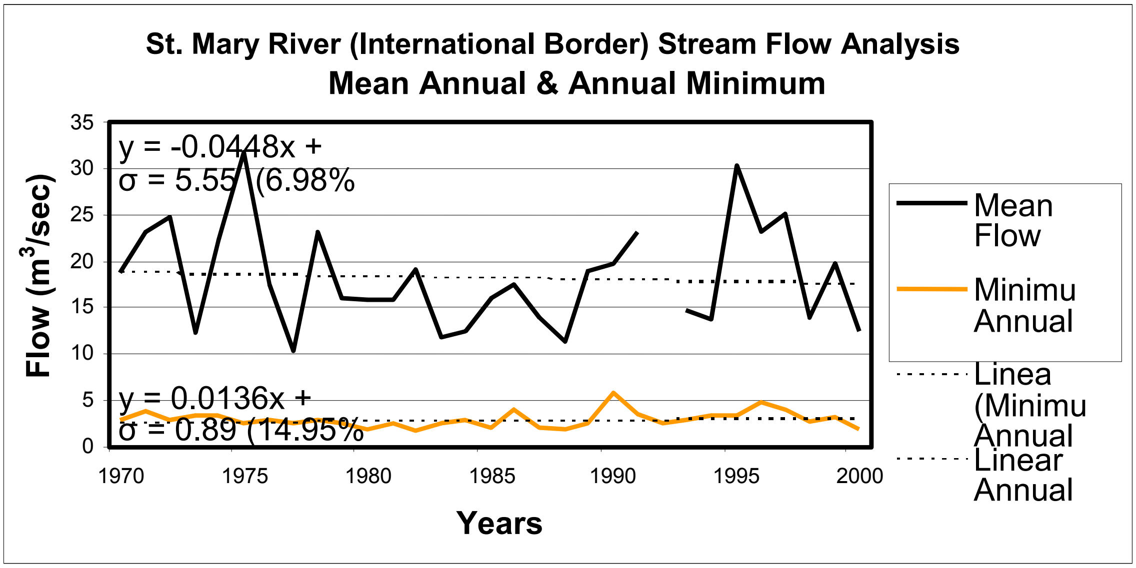

Milk River (Eastern Border Crossing) Stream Flow Analysis
Maximum Annual Flows
(Max) y = -0.0542x + 27.757
σ = 8.88 (5.86% decrease)
Flow (m3/sec)
50
45
40
35
30
25
20
15
10
5
0
1970
1975
1980
1985
1990
1995
2000
Years
Maximum Annual Flows
Linear (Maximum Annual Flows)

FIGURE 4.2.3


St. Mary River (International Border) Stream Flow Analysis
Mean Annual & Annual Minimum
y = -0.0448x +
σ = 5.55 (6.98%
y = 0.0136x +
σ = 0.89 (14.95%
Flow (m3/sec)
35
30
25
20
15
10
5
0
1970
1975
1980
1985
1990
1995
2000
Years
Mean Flow
Minimu Annual
Linea (Minimu Annual
Linear Annual

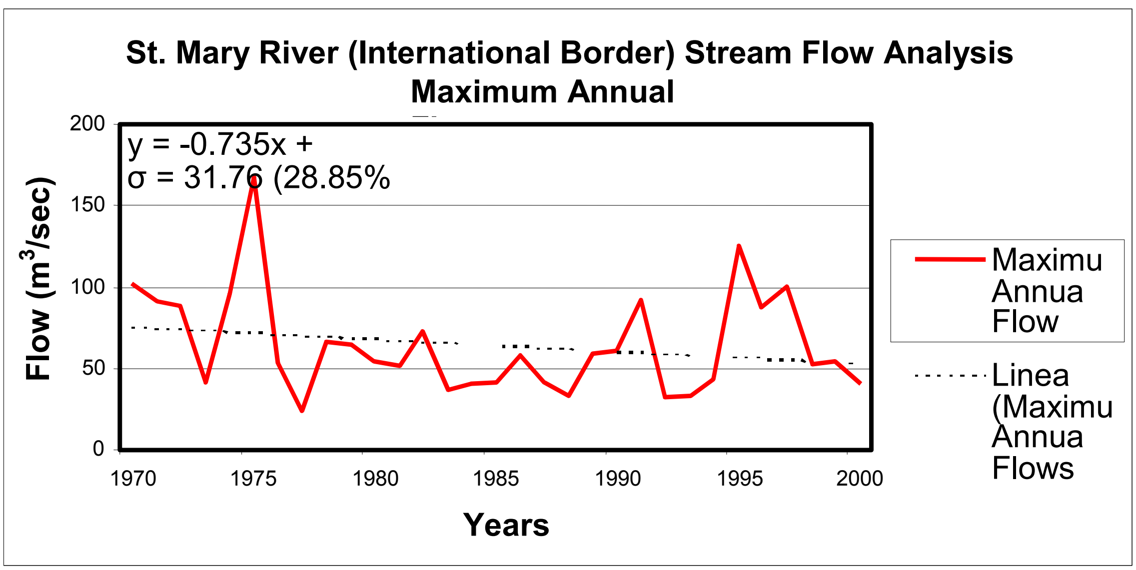
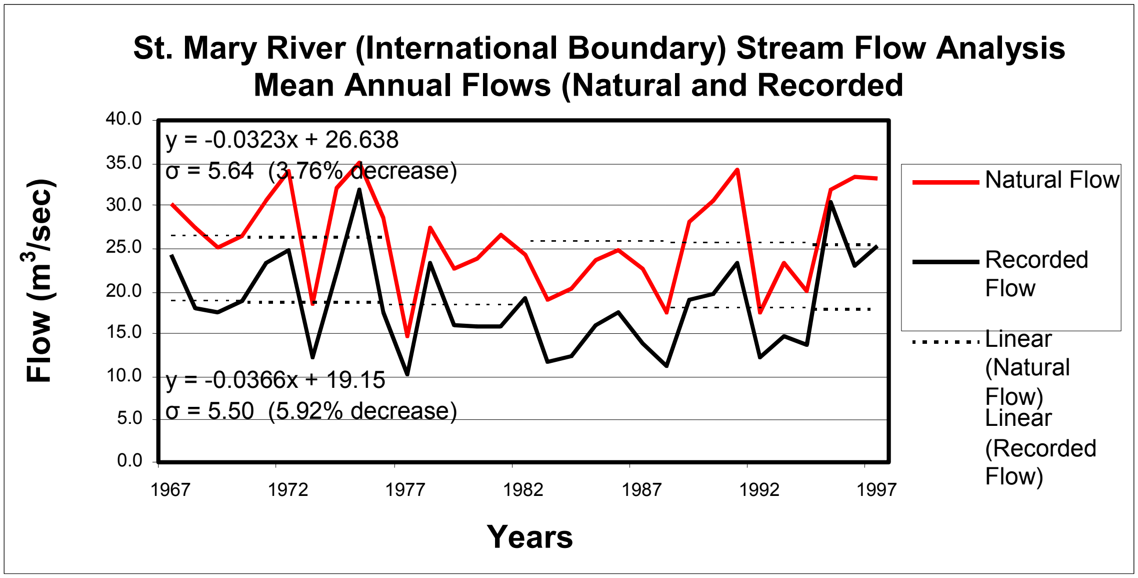

St. Mary River (International Border) Stream Flow Analysis
Maximum Annual
y = -0.735x +
σ = 31.76 (28.85%
Flow (m3/sec)
200
150
100
50
0
1970
1975
1980
1985
1990
1995
2000
Years
Maximu Annua Flow
Linea (Maximu Annua Flows

FIGURE 4.2.4



4.3 SOURIS RIVER

4.3.1 OBSERVED TRENDS

Observed trends for the past three decades are given in Fig. 4.3.1 and 4.3.2 for Sherwood, Saskatchewan near the location where the Souris enters U.S.A. and at Westhope, North Dakota near where the River returns to Canada (Manitoba) to join the Assiniboine-Red systems. The mean annual flow at Sherwood declined sharply (82%) between 1970 and 2000, partly due to upstream uses but also because of evaporation increases with higher temperatures in winter and spring, and because of declining winter precipitation with little change in the balance of the year. Peak discharges have declined by a similar amount. Average minimum flows have increased but in the 80s and 90s, were zero for extended periods in 5 of the years, and less than 0.1 cms (3.5cfs) in 12 other years. The zero or very low flow period in these decades often extended from September to October through to February. Similar zero or very low flows were also recorded in the 1930s.

The computed “natural flows” by the IJC Board showed similar trends to the recorded flows and averaged slightly more (about 1 cms) than the observed values (1973-98). (Fig. 4.3.3) Neither observed or “natural flow” trends were significant at the 95% level. Through mean “natural” streamflow regression analysis with annual temperatures and precipitation (Brandon, A.), it was found that the regression with temperature (evaporation) was significant at the 95% level, but with annual precipitation it was not.

At Westhope, after passage through North Dakota, the Souris produced mean annual flows which declined less (42%) over the 30 years and at the end of the 90s, were averaging about 8 cms (160 cfs). Minimum flows increased here on average but this still left 6 years of the 80s and 90s with zero flows and an additional 8 years with less than 1 cms. Annual peak discharges declines 60% over the 30 years. These observed trends in discharge at Westhope, are consistent with observed rises in winter and spring temperatures and evaporation, but with little change in summer and fall. Overall annual precipitation amounts were basically unchanged from 1971 to 2000.

4.3.2 PROJECTIONS: OUTLOOK WITH CLIMATE CHANGE

The following Table 4.3.1 gives observed temperature and precipitation trends 1971-2000, and projected changes 1971-2050, according to A2 and B2 scenario.

TABLE 4.3.1
SOURIS RIVER BASIN OBSERVED AND PROJECTED TEMPERATURE AND PRECIPITATION

	Temperatures ^{0}C					Precipitation %				
	Annual	W	Sp	Su	A	Annual	W	Sp	Su	A
1971-2000 observed	0.6	2.4	0.6	0	0	1	-9	3	3	6
1971-2050 Projections (A2 emission)	3.2	3.6	3.5	3.3	2.6	3	11	16	-9	7
1971-2050 Projections (B2 emissions)	2.9	2.8	3.4	3.1	2.7	0	7	17	-12	-1

In the case of the Souris basin, projected temperature changes are reasonably consistent with observed, expecially on an annual basis, although summer and autumn have yet to show any of the warming projected. For precipitation, the negative values in winter (snow) are projected to be replaced by increases in future decades and the reverse is true for summer rains.

If the projections are accepted, increased evaporation losses throughout the year (in the range 11 to 24%), would more than offset increased winter-spring precipitation and produce a further decline in mean flows. Combined with declining summer season rainfall, this would provide for many more years with zero or near zero discharge in autumn-winter months across the border in either direction. Annual average total discharges Jan. to May, may not change substantially if the projected increased spring-winter precipitation does occur.

4.3.3 IMPLICATIONS FOR TREATIES AND AGREEMENTS

The Canada-U.S. Agreement for Water Supply and Flood Control of 1989, and its amendment of 2000 provided for water apportionment and regulation. The principle is for equal sharing under “normal climate”, i.e. Canada (Saskatchewan) can use 50% of “natural flow” to the border. (See Annex A) Under drought conditions, at least 4 cfs (0.113 cms) must be passed to U.S.A. if that much “natural flow” could have occurred before the Boundary, Rafferty and Alameda dams in Saskatchewan were completed. However, in light of the potential value of these dams and reservoirs for flood protection in North Dakota, some of the U.S. share can be in the form of reservoir evaporation but the minimum flow passed through to North Dakota must still be 40% of the “natural volume”.

In addition, prior to 1 June, Saskatchewan is to deliver ½ of the first 50,000 decameters (40,500 acre ft.) of natural flow during the 1 Jan. to 31 May period. Flow releases from the reservoirs must be “in the pattern which would have occurred in a state of nature”.

As noted above, in dry years of the past two decades (before several of the reservoirs were constructed) minimum flows have been below 0.113 cms for long periods (late summer to winter months) and this is projected to worsen with climate change. Thus, the natural flow calculations must come into force increasingly frequently, to calculate the U.S. 40% share. Also, in drier years, e.g. 1988, 1989, 1990, 1998, 2000, the observed mean flows January to May have averaged:

January to May mean flows – averaged			
Year	Cms	Cfs	Acre feet
1988	.033	1.16	350
1989	1.48	52	15600
1990	0.43	15	4500
1998	0.84	29.5	8900
2000	0.31	10.9	3300

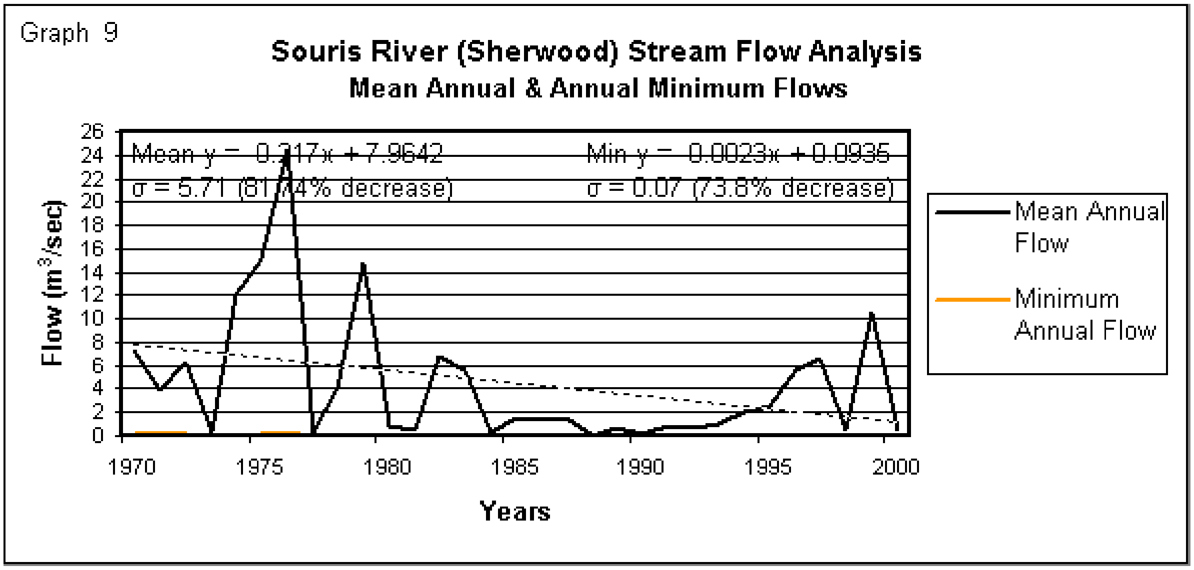
In brief, on a number of recent occasions and with likely similar frequency with climate change, the total discharge to U.S.A. in the 1 Jan. to 31 May period has been substantially less than the 20,000 acre-feet required by the Agreement. Adjustments would be required.

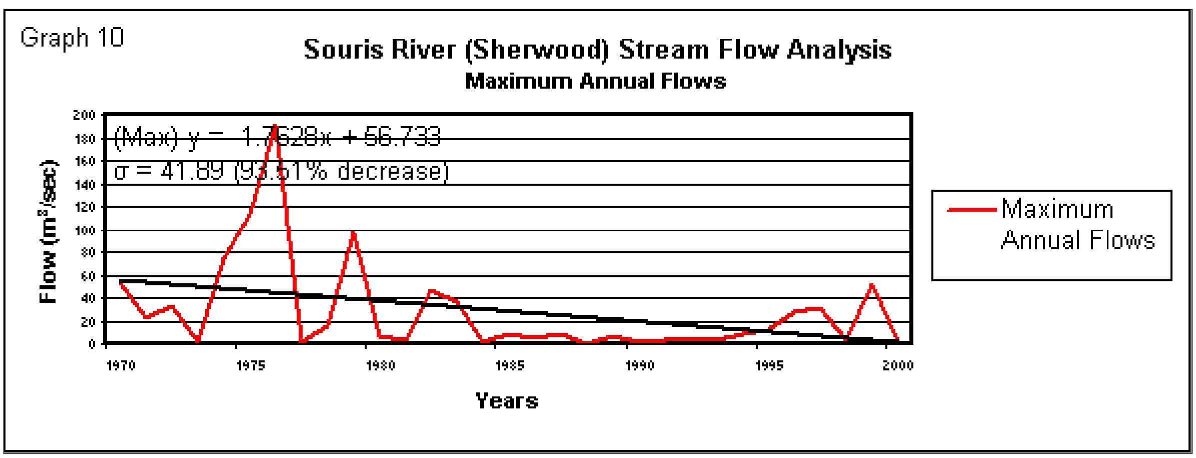
4.3.4 SUGGESTED ACTIONS

i) The terms of the Agreements should be reviewed in light of the recent experience and projections of more frequent very low or zero flows.

ii) Procedures for determining “natural flows” and calculating allowances for reservoir evaporation in a changing climate should be re-evaluated.

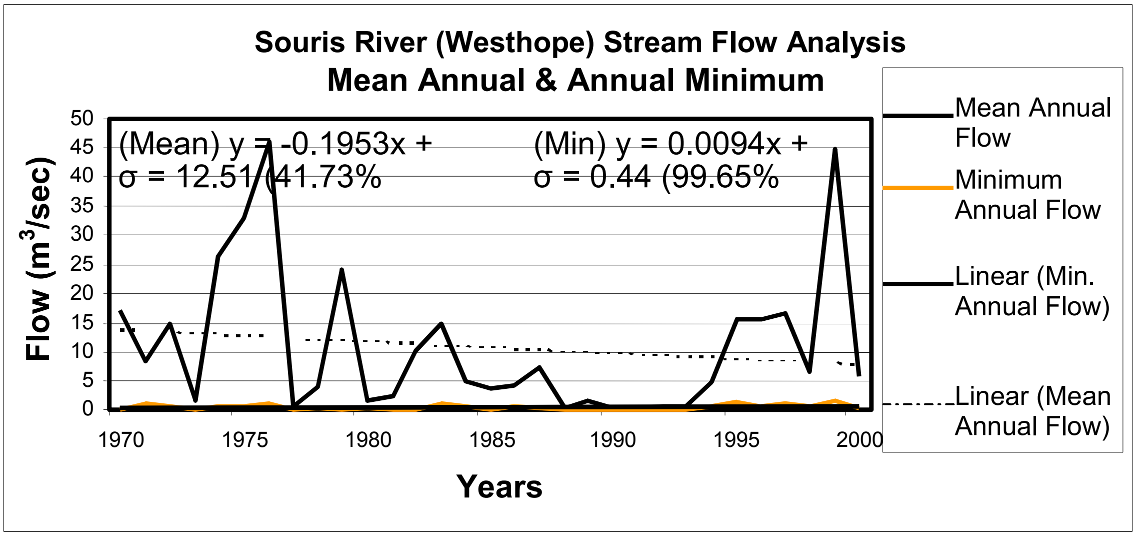
FIGURE 4.3.1



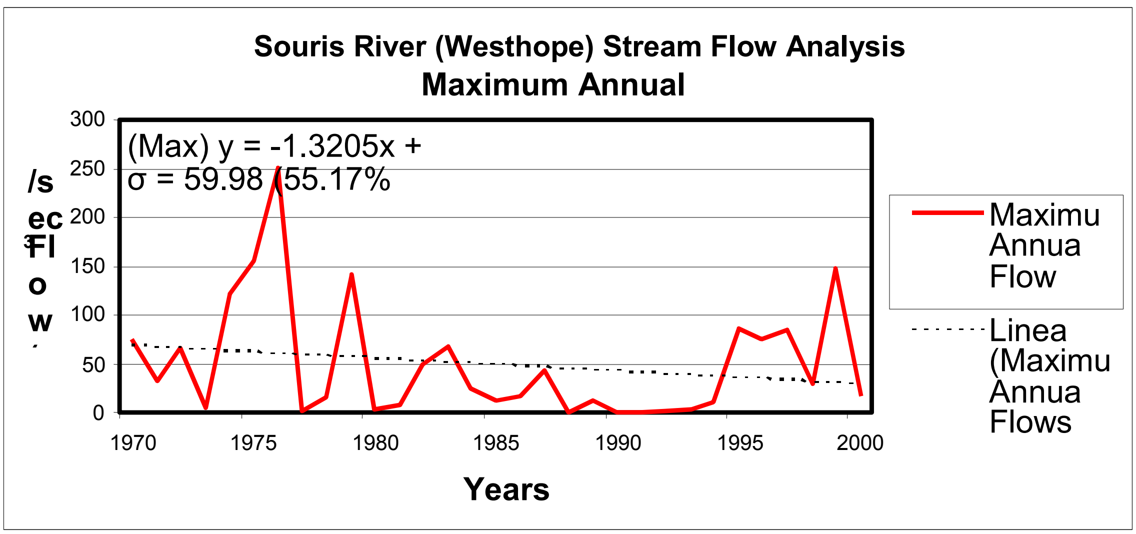


Average	7.9642	-0.217	30	-6.51	1.4542	18.25921	100	81.74
Minimum	0.0935	-0.0023	30	-0.069	0.0245	26.20321	100	73.80
Maximum	56.556	-1.7628	30	-52.884	3.672	6.49268	100	93.51

FIGURE 4.3.2

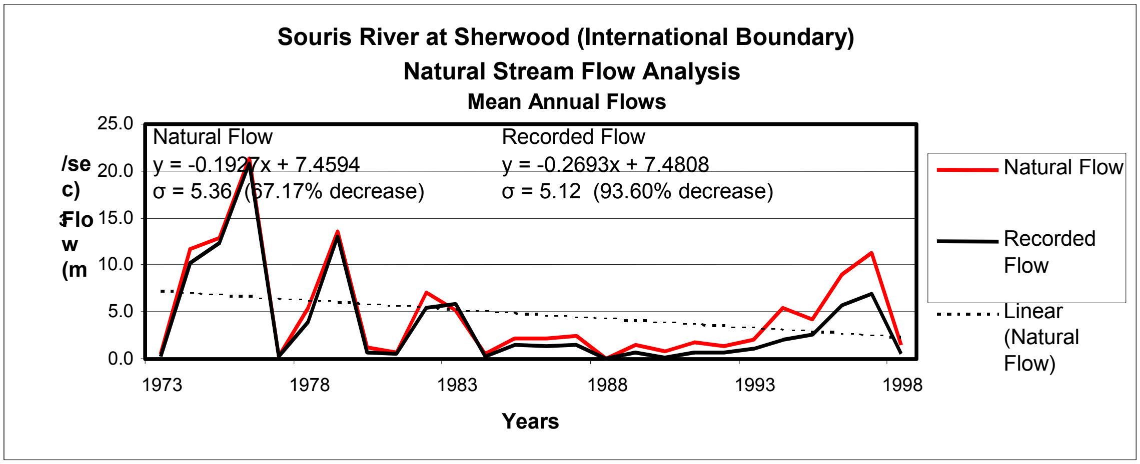


Souris River (Westhope) Stream Flow Analysis
Mean Annual & Annual Minimum
(Mean) y = -0.1953x +
σ = 12.51 (41.73%
(Min) y = 0.0094x +
σ = 0.44 (99.65%
Flow (m3/sec)
50
45
40
35
30
25
20
15
10
5
0
1970
1975
1980
1985
1990
1995
2000
Years
Mean Annual Flow
Minimum Annual Flow
Linear (Min. Annual Flow)
Linear (Mean Annual Flow)



Souris River (Westhope) Stream Flow Analysis
Maximum Annual
(Max) y = -1.3205x +
σ = 59.98 (55.17%
/s
ec
Fl
o
w
300
250
200
150
100
50
0
1970
1975
1980
1985
1990
1995
2000
Years
Maximu Annua Flow
Linea (Maximu Annua Flows

FIGURE 4.3.3



Souris River at Sherwood (International Boundary)
Natural Stream Flow Analysis
Mean Annual Flows
Natural Flow
y = -0.1927x + 7.4594
σ = 5.36 (67.17% decrease)
Recorded Flow
y = -0.2693x + 7.4808
σ = 5.12 (93.60% decrease)
25.0
20.0
15.0
10.0
5.0
0.0
1973
1978
1983
1988
1993
1998
Years
Flow (m³/sec)
Natural Flow
Recorded Flow
Linear (Natural Flow)

Natural Stream Flow

SUMMARY OUTPUT, Mean Annual Flows m3/s

The Regression is not significant at the 95% Confidence Level

Regression Statistics	
Multiple R	0.274869271
R Square	0.075553116
Adjusted R Square	0.037034496
Standard Error	5.260568558
Observations	26

ANOVA

	df	*SS*	*MS*	*F*	***Significance F***
Regression	1	54.28089862	54.28089862	1.96146995	**0.174153**
Residual	24	664.1659573	27.67358156		
Total	25	718.4468559			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	387.3709294	273.1226624	1.418303871	0.168957315	-176.326	951.0682835	-176.326	951.068283
X Variable 1	-0.192652912	0.13755765	-1.400524884	0.174152897	-0.47656	0.091252066	-0.47656	0.09125207

Recorded Stream Flow

SUMMARY OUTPUT, Mean Annual Flows m3/s

The Regression is significant at the 95% Confidence Level

Regression Statistics	
Multiple R	0.402554383
R Square	0.162050032
Adjusted R Square	0.12713545
Standard Error	4.781114903
Observations	26

ANOVA

	df	*SS*	*MS*	*F*	***Significance F***
Regression	1	106.0963969	106.0963969	4.641328128	**0.041464**
Residual	24	548.6174332	22.85905972		
Total	25	654.7138301			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	538.6211445	248.2299807	2.169847264	0.040142582	26.29975	1050.942539	26.29975	1050.94254
X Variable 1	-0.269340945	0.125020504	-2.154374185	0.041463596	-0.52737	-0.011311361	-0.52737	-0.0113114

4.4 RED RIVER

4.4.1 TRENDS OBSERVED

In contrast to most of the rivers in this investigation, the Red has exhibited substantial increases in flows over the 1970 to 2000 period. On a percentage basis, mean flows have increased 124% annual minima by 159% and annual maxima by 63% near the border crossing with Manitoba. (Fig. 4.4.1) In 1997, the largest flood of the 30-year period (Max 1550 cms) occurred and in the observed record was exceeded only by the flood of 1950 (2060 cms). The mean annual flow for 1997 at 372 cms was the largest in the 90-year record. Minimum flows of 5 cms or less occurred recently only in 1990 and 1991, but occurred in many years in the 1930's.

Temperatures since 1970 in the North Dakota portion of the basin have increased significantly in winter, and to a lesser extent in spring, but have declined or remained roughly constant in summer and autumn suggesting no change in evaporation losses. While spring precipitation has declined substantial increases have been observed in winter and summer. The amounts are shown in Table 4.4.1 and Fig. 4.4.1, 4.4.2 and 4.4.3).

It thus seems clear that greater amounts of precipitation and warmer conditions in winter and spring have resulted in substantially higher flows in the first half of the year. In summer, rainfall has increased substantially, but since little change has occurred in summer and autumn evaporation, the decline to low flow values in autumn and winter has been much less steep in recent years than in the early 1970's. It should be noted that summer precipitation in North Dakota represents nearly 40% of average annual precipitation, thus the large observed increase in summer has had a significant influence on flows.

4.4.2 PROJECTIONS: OUTLOOK WITH CLIMATE CHANGE

Observed trends in temperature and precipitation 1970 to 2000 and projections with A2 and B2 emission scenarios are given in the following Table 4.4.1.

TABLE 4.4.1
RED RIVER BASIN OBSERVED AND PROJECTED TEMPERATURE AND PRECIPITATION

	Temperatures ^{0}C					Precipitation %				
	Annual	W	Sp	Su	A	Annual	W	Sp	Su	A
1971-2000 observed	1	2.4	1.2	-0.3	0.4	14	21	-18	39	7
1971-2050 Projections (A2 emissions)	3.2	3.6	3.5	3.3	2.6	3	11	16	-9	7
1971-2050 Projections (B2 emissions)	2.9	2.8	3.4	3.1	2.7	0	7	17	-12	-1

If these projections are accepted, with significant warming insummer and autumn in future, a reversal in the upward trends in flows seems likely. Evaporation over the year could increase 10-15%, and with a switch to reduced precipitation in summer rather than increases, then a return to low minimum flows in the latter part of the year, such as those of the 1930's, is indicated. However, continued increased precipitation in winter and increased spring precipitation, combined with higher temperatures should maintain the 1990's experience of a higher flow season, March-July, with and following snowmelt, but with spring high discharges beginning in March rather than April. The pattern then suggested is for continued higher flows until late summer with an average lower flood peak due to more frequent winter melt, but the potential for the occasional very large flood with heavy rain on snow. Autumn and early winter flows are likely to decline due to greater evaporation losses. Concentration of pollutants in the low flow periods, autumn-winter, is likely to increase on average, with less dilution. Increased frequency of short duration heavy rains, as projected, would lead to flash floods on tributary streams and episodes of high concentrations of contaminants.

4.4.3 IMPLICATIONS FOR TREATIES AND AGREEMENTS

No formal Treaties or Agreements apply specifically to the Red River. However, a Reference to the IJC in 1948 resulted in establishment of the Souris-Red River Engineering Board to monitor water quantity and report on matters concerning apportionment, conservation and uses. (See Annex "A") The Red River Pollution Board of 1969 was provided with a further directive in 1995. Subsequently, quantity, quality, water conservation, invasive species and other matters were brought together in 2001 by the IJC in the Red River Board.

No apportionment agreement for the Red has been adopted. On water quality matters the Board in 1995 was required to report on "anticipated developments". This requirement was further elaborated and expanded in the 2001 IJC Directive to the Board to maintaining "an awareness of basin-wide development activities and conditions that may affect levels and flows, water quality and the ecosystem…." The new Board's focus so far has been on water quality and aquatic ecosystems as well as floods. Climate change implications have not been addressed by the Board. This is understandable in light of conditions in the basin since 1970. However, even changes outside the basin may increase pressure in U.S.A. for more diversion of water out of the basin. Drier conditions in autumn, as projected, would result in greater irrigation and other water demands from a small base flow.

5.4.4 SUGGESTED ACTIONS

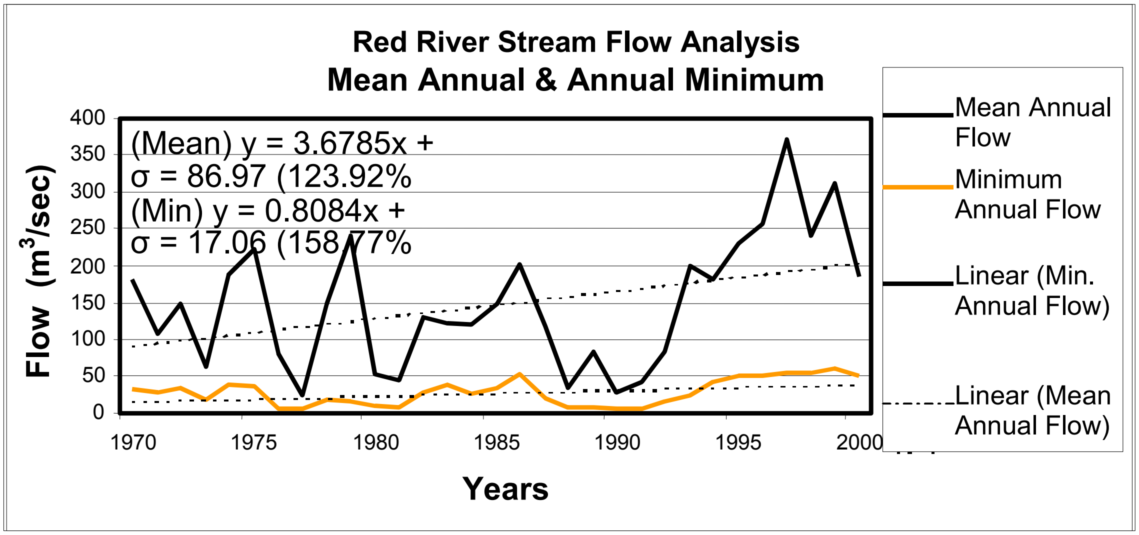
i) Seek a specific "equal share" apportionment agreement. The recently experienced good flow conditions, in the lowest annual flow period, should provide a better atmosphere for negotiation of apportionment, than the potential lower minimum flow conditions projected for future decades, i.e. do it now.

ii) Maintain some water quality monitoring stations with high frequency of sampling or measurements to assess short term pollution "spikes" which can be damaging to ecosystems and affect water supplies.

iii) Maintain adequate records of rising water temperatures and their potential impact on ecosystems and invasive species, which could affect the Red and subsequently Lake Winnipeg.

iv) Otherwise, it is suggest that until the recent trend towards slightly cooler, wetter summers begins to reverse, as projected, no major steps should be taken except those noted above.

FIGURE 4.4.1


Red River Stream Flow Analysis
Mean Annual & Annual Minimum
(Mean) y = 3.6785x +
σ = 86.97 (123.92%
(Min) y = 0.8084x +
σ = 17.06 (158.77%
Flow (m3/sec)
400
350
300
250
200
150
100
50
0
1970
1975
1980
1985
1990
1995
2000
Years
Mean Annual Flow
Minimum Annual Flow
Linear (Min. Annual Flow)
Linear (Mean Annual Flow)

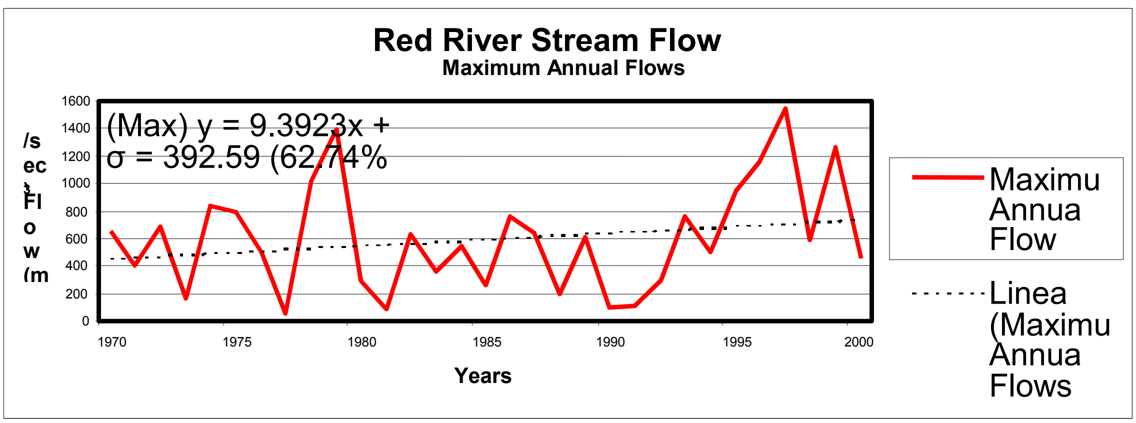
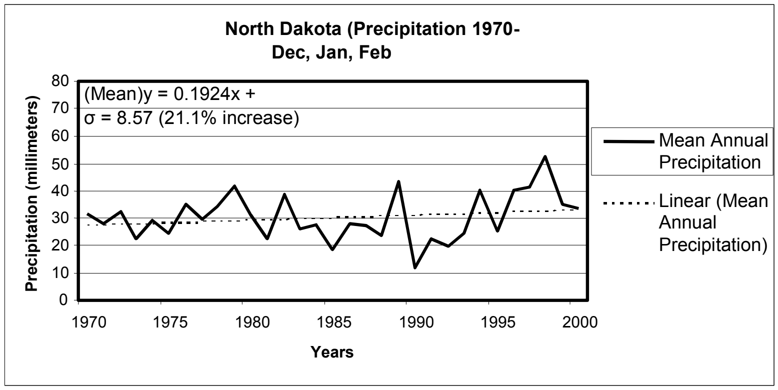
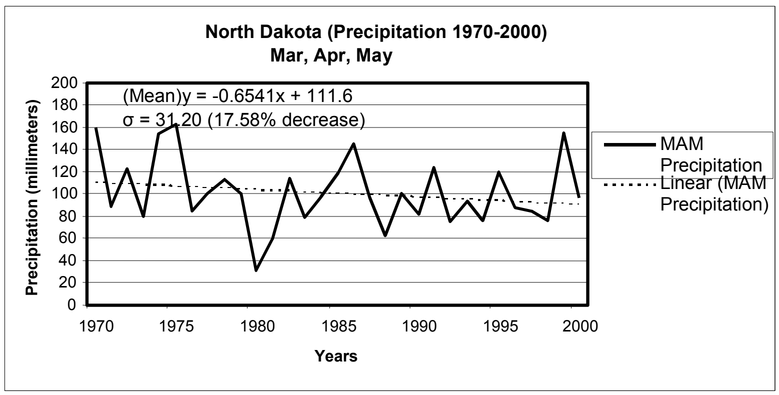
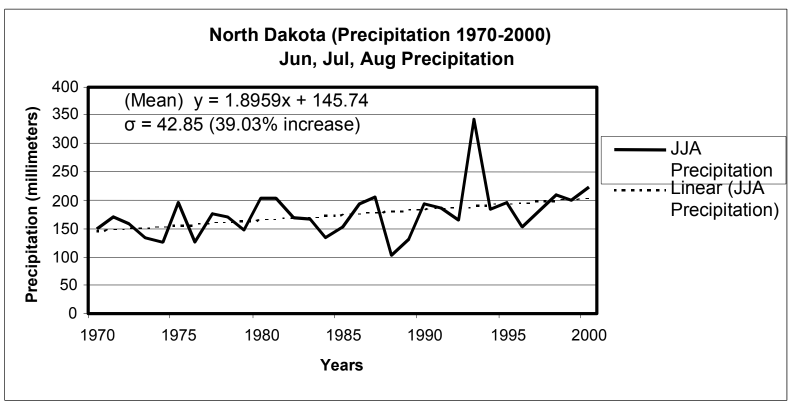

Red River Stream Flow
Maximum Annual Flows
(Max) y = 9.3923x +
σ = 392.59 (62.74%
1600
1400
1200
1000
800
600
400
200
0
1970
1975
1980
1985
1990
1995
2000
Years
Maximu Annua Flow
Linea (Maximu Annua Flows

FIGURE 4.4.2


North Dakota (Precipitation 1970-
Dec, Jan, Feb
(Mean)y = 0.1924x +
σ = 8.57 (21.1% increase)
Precipitation (millimeters)
Years
Mean Annual Precipitation
Linear (Mean Annual Precipitation)


North Dakota (Precipitation 1970-2000)
Mar, Apr, May
(Mean)y = -0.6541x + 111.6
σ = 31.20 (17.58% decrease)
Precipitation (millimeters)
Years
MAM Precipitation
Linear (MAM Precipitation)


North Dakota (Precipitation 1970-2000)
Jun, Jul, Aug Precipitation
(Mean) y = 1.8959x + 145.74
σ = 42.85 (39.03% increase)
Precipitation (millimeters)
Years
JJA Precipitation
Linear (JJA Precipitation)

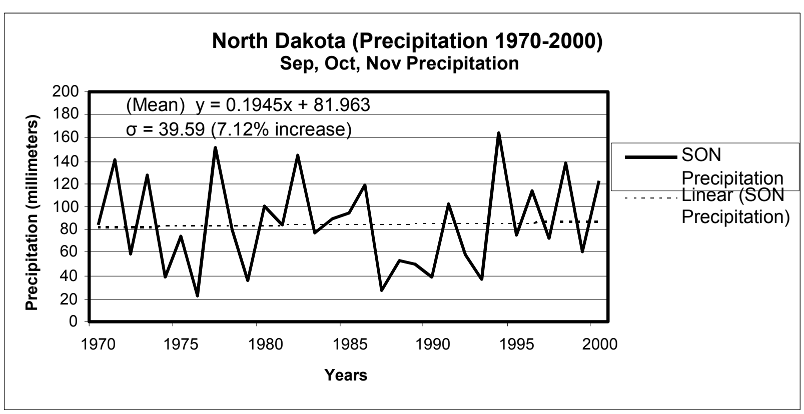
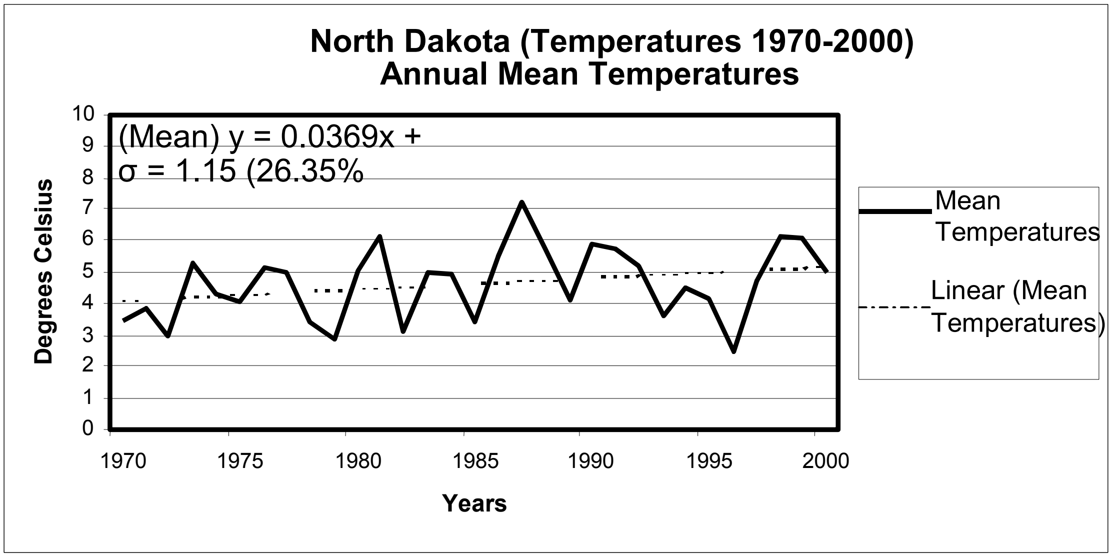

North Dakota (Precipitation 1970-2000)
Sep, Oct, Nov Precipitation
(Mean) y = 0.1945x + 81.963
σ = 39.59 (7.12% increase)
Precipitation (millimeters)
Years
SON Precipitation
Linear (SON Precipitation)

FIGURE 4.4.3



4.5 LAKES OF THE WOODS

4.5.1 TRENDS OBSERVED

The western outlet of the international Lake of the Woods is through an aqueduct supplying the city of Winnipeg via the Winnipeg River. In the period 1970 to 2000, the mean annual discharge declined from about 360 m^3/sec to 290 m^3/sec a 21% decrease. At the same time minimum annual flows declined 59% to about 120 m^3/sec, and peak discharges declined 29% on average. (Fig. 4.5.1)

The two Boards which regulate the outflow from Lake of the Woods are a Canadian Board, which oversees actions when levels are in a "normal' range, between 321.87m and 323.47m. When levels are higher or lower than that range, an International Board is invoked to deal with the US-Canada regulation agreement of 1925 (see Annex "A"). In spite of the observed overall decline in outflows to 2000, two recent periods, in 1985, and in 2001, saw levels higher than 323.47, requiring International Board consideration. On the latter occasion outflows rose to 1411.5 m^3/sec, higher than any flow since 1914, with a close second in the Red River flood year 1950.

TABLE 4.5.1
LAKE OF THE WOODS

	Temperature Changes ^{0}C					Precipitation Changes %				
	Ann.	W	Sp	Su	A	Ann	W	Sp	Su	A
1971-2000 Observed	**1.2**	**0.5**	**2.1**	**0.8**	**0**	**0**	**-6**	**-9**	**6**	**9**
1971-2050 Projections	**3.3**	**3.7**	**3.7**	**3.6**	**2.6**	**3.8**	**15**	**15**	**-11**	**2**

A2 Emissions										
1971-2050 Projections B2 Emissions	**2.9**	**2.8**	**3.4**	**2.8**	**2.5**	**2.3**	**10**	**16**	**-7**	**0**

In Table 4.5.1, the 1971-2000 temperature trends show marked springtime warming and significantly higher summer temperatures. These suggest greater evaporation losses. Precipitation was basically unchanged, with small increases in summer and autumn offset by winter and spring declines. The summer and autumn rainfalls probably contribute a lower proportion to runoff than do the winter and spring snow and rain amounts. Thus, both increased evaporation and the seasonal distribution of the modest precipitation shifts have contributed to the overall decline in outflows from Lake of the Woods. However, the very high levels and flows of 2001 and of 1985 make it clear that even in a declining flow regime, high water levels and the invoking of the International Board will still be required from time to time.

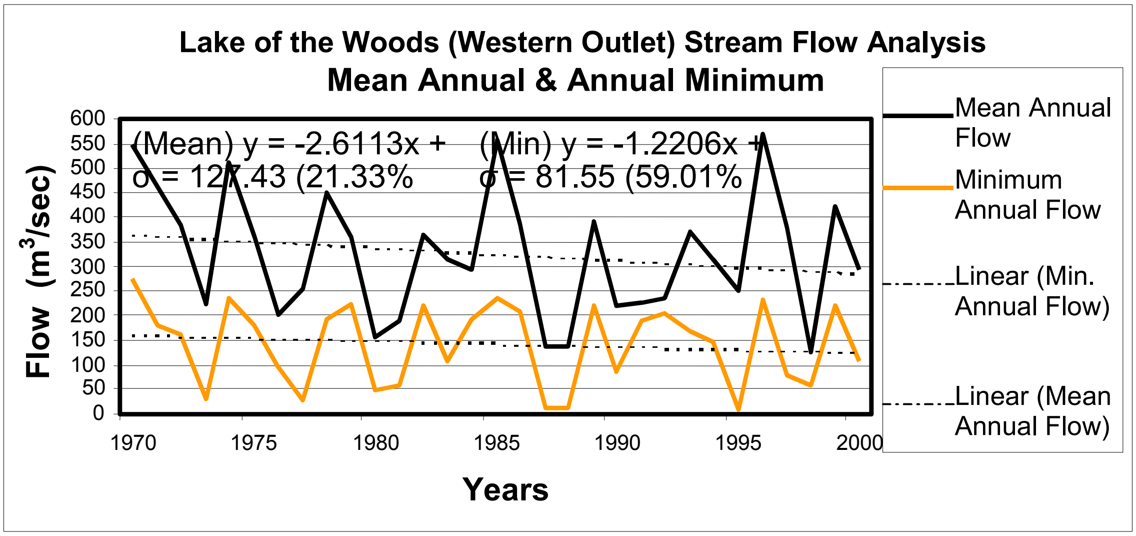
4.5.2 PROJECTED CHANGES

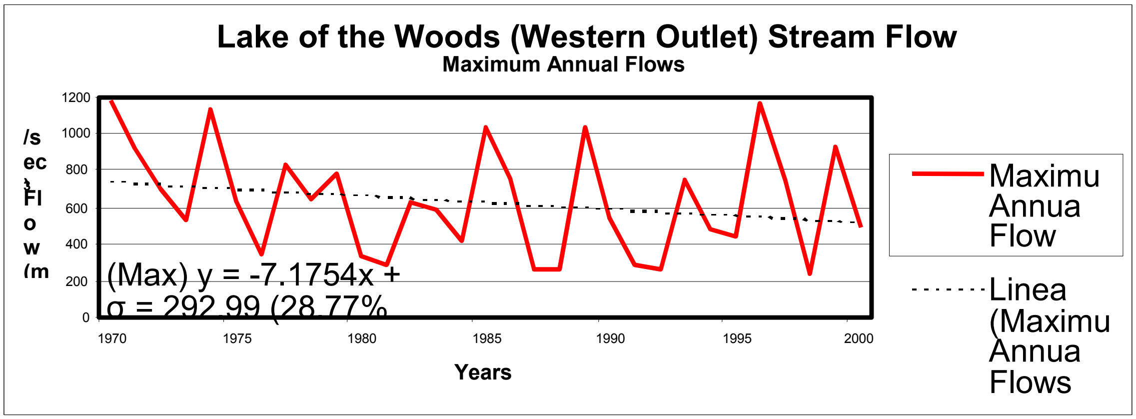
Model projections to 2050 (Table 4.5.1) suggest modest increases (about 15%) in winter and spring precipitation and increased summer and autumn evaporation with higher temperatures throughout the year. Comparing this with recent trends suggests a continuing small decline in mean annual flows, but a continuation of occasional episodes of high levels and flows.

4.5.3 IMPLICATIONS FOR TREATIES AND AGREEMENTS

1. Modest trends in decline in flow are unlikely to seriously impact Winnipeg water supplies to 2050.
2. With modest changes, the International Board of Control will need to be retained to respond to episodes outside the prescribed range of lake levels.

FIGURE 4.5.1





4.6 NIAGARA RIVER

4.6.1 TRENDS OBSERVED

Significant trends have been observed in the large flows of the Niagara River at Queenston. As seen in Fig. 4.6.1, mean annual flows from 1970 to 2000 have declined by about 7.4% (not significant at 95% level) and annual minimum flows by 8.3%. As well, the peak discharges or maximum annual flows have also declined an average of 9%.

Increases in consumptive uses upstream of Niagara-mainly from the U.S. side, on Lakes Erie, St. Clair, Michigan-Huron and Superior, have contributed to the decline of mean annual discharge. However, the decline 1970 to 2000 has been about 500 cms (17,600 cfs) and the increased upstream consumptive use over the 1970-2000 period is estimated at only 3,500 to 4,000 cfs. It is assumed that inflow to Lake Superior from the Long Lac-Ogoki diversion and outflow from Lake Michigan through the Chicago ship canal have been roughly constant over this 30-year period – with any adjustments being only for a few years at most.

Thus, a great portion (~80%) of the decline in Niagara flows must be attributed to the changing climate over the past 30 years. From Fig. 4.6.2, it will be noted that precipitation on the land areas of the basin (and to a first approximation over the whole basin) has increased slightly (<1%). This annual value balances increases in summer and autumn of 5 and 7% respectively against decreases in winter and spring of 6 and 6 ½ % respectively. It is probable that a higher percentage of winter and spring precipitation would run off than in summer and fall. Thus, small changes in the latter seasons are unlikely to have large effects. For temperature, the average of maxima and minima over the basin, has shown an increase of about 1 ½ ^{0}C. However, in winter the increase has been about 3 ^{0}C, for spring about 0.6^{0}C, and for summer and autumn, temperature increases have been under 1/2^{0}C. (Fig. 4.6.3)

What does this pattern suggest for evaporation losses? The Great Lakes have great heat storage and thus the experience with small water bodies elsewhere is not applicable. Because of this heat storage effect, evaporation from large lakes in the basin tends to be concentrated in winter (36%) and autumn (34%), with some months –April, May and June, often having more condensation than evaporation. (Bruce and Rogers, 1962). The higher temperatures year round affect evaporation by increasing surface water temperatures. Higher winter air and water temperatures also have reduced, and will continue to reduce, ice cover, permitting further increases in evaporation from the larger open water surfaces in winter. Thus even through annual precipitation has increased slightly over the period, flows at Niagara have declined. Mean annual surface water temperatures for the major Great Lakes have been projected to rise by 1^{0}C to as much as 7^{0}C by about 2070 for the lakes above Niagara from various climate and energy balance models. (Croley 2000). The highest of these estimates would result in soaring evaporation losses.

4.6.2 PROJECTIONS – OUTLOOK WITH CLIMATE CHANGE

The basin wide temperature and precipitation trends above Niagara to 2000 and projections to 2050 are given in the following Table 4.6.1.

TABLE 4.6.1

OBSERVED AND PROJECTED TEMPERATURE AND PRECIPITATION TRENDS

	Temperatures ^{0}C					Precipitation %				
	Annual	W	Sp	Su	A	Annual	W	Sp	Su	A
1970-2000 observed	1.5	3	0.6	0.4	0.1	0.7	-5.8	-6.6	5.1	7.2
1970-2050 Projections (A2 emissions)	3.2	3.5	3.4	3.3	2.7	6	15	15	-7	4
1970-2050 Projections (B2 emissions)	2.8	2.9	3.1	2.9	2.4	5	6	11	-1	2

It should be noted that the projected Annual and seasonal temperature changes are reasonably consistent with observed 30 year trends. The amounts of warming would continue to intensify but be spread more evenly over the year rather than having the major concentrations in winter.

For precipitation, the projections of change for the future are also reasonably consistent with observed trends on an annual basis, but a seasonal reversal is projected. That is, instead of decreased winter and spring precipitation and increases in summer and autumn as observed to date, the modelled future climate would see precipitation increases winter and spring, small declines in summer and small increases in autumn. If the assumption is correct that winter and spring precipitation are more likely to be reflected in discharges to the lakes, then this should contribute somewhat to increasing Niagara River flows.

On the other hand, further year-round increases in air temperatures, and thus water temperatures, would increase evaporation losses and tend to reduce flows. The balance between these opposing factors is difficult to determine, especially since evaporation is not a direct function of air temperature but is heavily dependent on water temperatures, vapour pressure, winds and changes in insolation. On the latter point, there has been an observed small increase in cloudiness over the basin, but that does not appear to have greatly influenced increased evaporation evident to 2000.

On balance, if one assumes that 80% of the reduced flow (about 500 cms) is due to increased evaporation in the warming climate, then a further warming as projected would probably increase the decline an additional 400-500 cms by 2050, since annual mean temperatures are projected to rise by an amount about equal to the increase observed to 2000. This assumes little further change in upstream consumption uses, although a warmer climate may provoke a greater use. This might be offset by a modest increase due to seasonal changes in precipitation. Thus, it is unlikely that further declines in Niagara flow based on these climate projections would exceed the 500 cms reduction experienced 1971 to 2000. This conclusion is in the same direction of declining levels and flows with climate change, as determined by many earlier assessments. It would, however, suggest a more modest decline than many of the earlier projections using hydrologic modelling techniques (e.g. Mortsch, 1998).

However, it must be recognized that the early 1970's (and 1985) were periods of high water on the Great Lakes and thus a decline in flow at Niagara since 1971 was not unexpected. Nevertheless the observed decline in flows are related to the climatic trends in the basin over the 1971-2000 period and should be a useful indication of trends with continuing changes, with projected climate continuing the trend.

4.6.3 IMPLICATIONS FOR TREATIES AND AGREEMENTS

As described in Annex "A", apportionment of the flows of the Niagara, is governed by the Niagara River Treaty of 1950. After 2000, this Treaty could be reopened by either Party. There was also an exchange of Notes (1940) between the governments concerning the waters of the Long Lac-Ogoki diversions from the Hudson Bay drainage into Lake Superior.

The Treaty provides for "preservation and enhancement of the scenic beauty of Niagara Falls" by mandating a certain flow over the Falls. The balance of the flow is diverted for power production on an equal basis between the two countries. Of course, these waters for power production return to the River below the Falls. The "scenic beauty" provision is for 100,000 cfs (2832 cms) in daytime and early evening from 1 April to 31 October, and 50,000 cfs (1416 cms) at night and in winter.

In addition to the equal division of the balance of water after aesthetic provisions, 5,000 cfs, approximately the amount of the Long Lac-Ogoki diversion, is also credited for power production at Niagara to Canada (Ontario), although not at Sault Ste. Marie or at plants on the St. Lawrence. It might also be noted that the diversion of water out of Lake Michigan in the Chicago ship canal is not debited to the U.S. side.

The main implication of the observed and projected decline in Niagara River flows is a reduction in the amount to be shared for hydro-electricity production – 500 cms to 2000 and perhaps 500 cms more by 2050. These reductions are coming at a time when a premium is being placed on clean hydropower.

4.6.4 SUGGESTED ACTIONS

i) In view of the increasing value of hydropower, Canada and Ontario may wish to consider* re-opening the Niagara River Treaty to negotiate an increasing share of the water for power in light of:

   a) declining flows due to consumptive uses upstream overwhelmingly by USA and likely to grow in a warming climate.

   b) recognition of the negative impact on water for hydropower of the Chicago diversion,

   c) consideration of Canada's use of Long Lac-Ogoki waters at hydro locations in addition to Niagara,

   d) reviewing allocations for "scenic beauty" in view of declining available flows for power production. Should "scenic beauty" take its fair share reduction, too?

Warning: While it is suggested that Canada and Ontario consider re-opening the Treaty, there are dangers in doing so. U.S. negotiators have often suggested that the Great Lakes waters be allocated on an equal per capita basis rather than equal shares by country, which would seriously work against Canada's interest.

REFERENCES

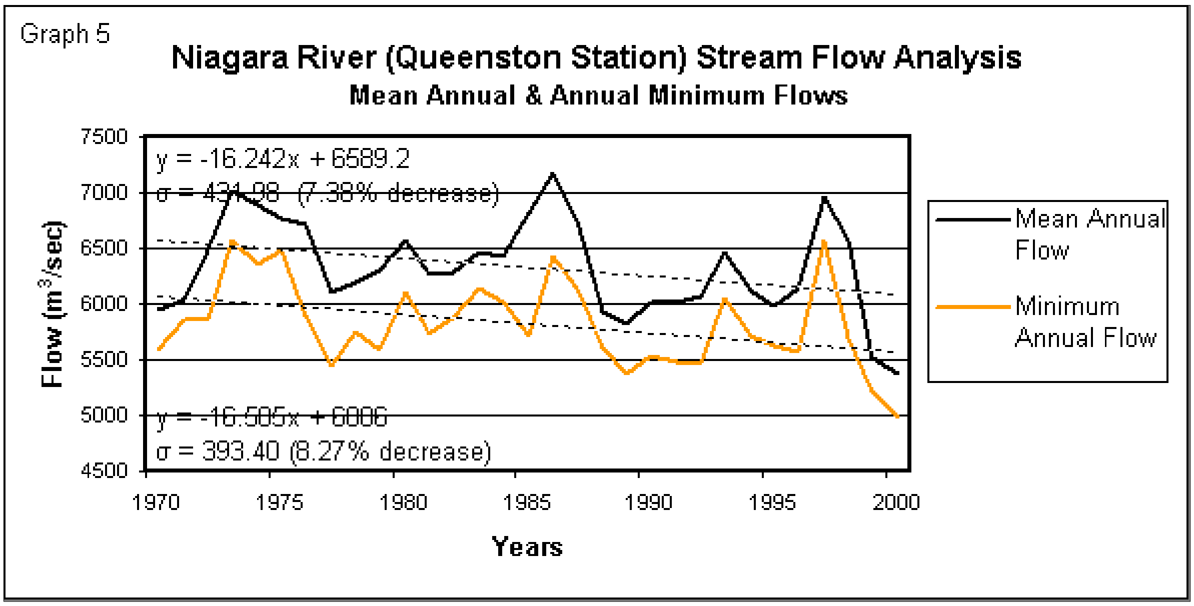
Bruce, J.P. and Rodgers. G.K., 1962. Water Balance of the Great Lakes System, in Great Lakes Basin, American Association for the Advancement of Science, 41-70.

Croley, T.H., Hunter, T.S., Martin, S.K., 2000. Great Lakes monthly hydrologic data, Great Lakes Environmental Research Laboratory #902, 13 pp.

International Joint Commission, 1997. The IJC and the 21st Century, 48 pp.

Mortsch, L., 1998. Assessing the impacts of climate change on Great Lakes shoreline wetlands, Climate Change 40: 391-416.

FIGURE 4.6.1



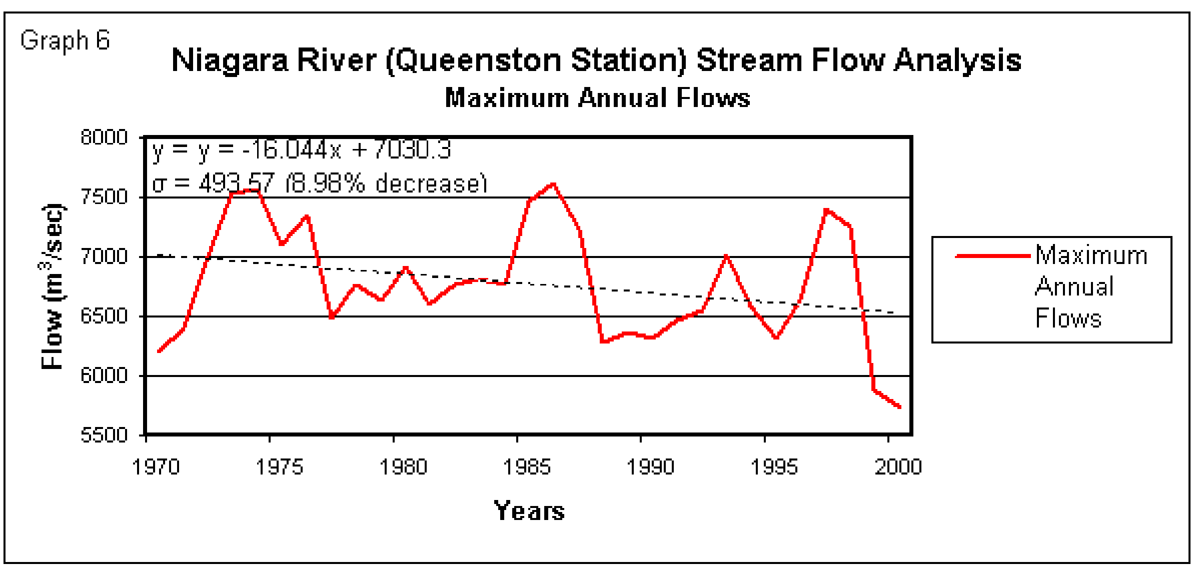
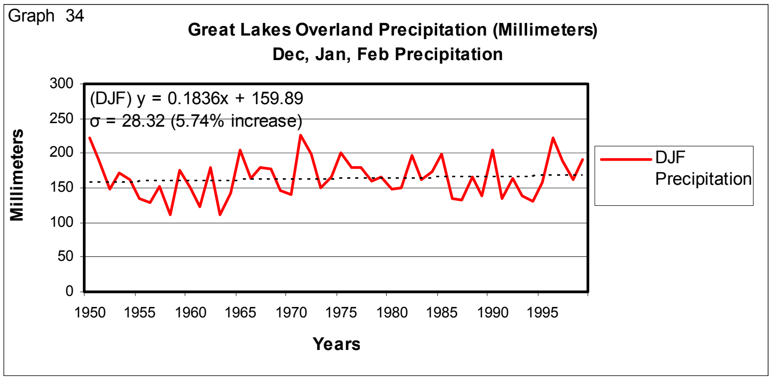
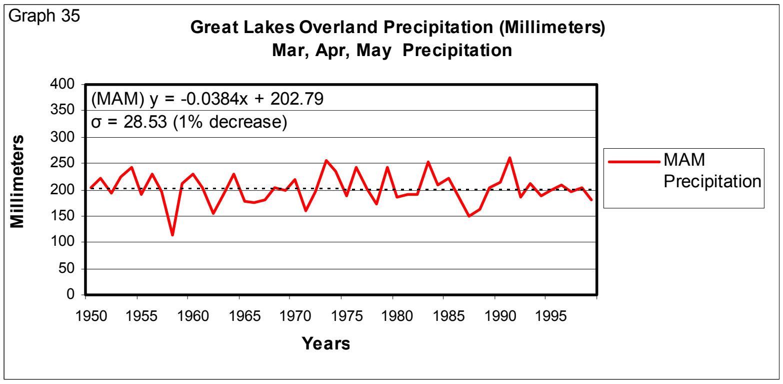


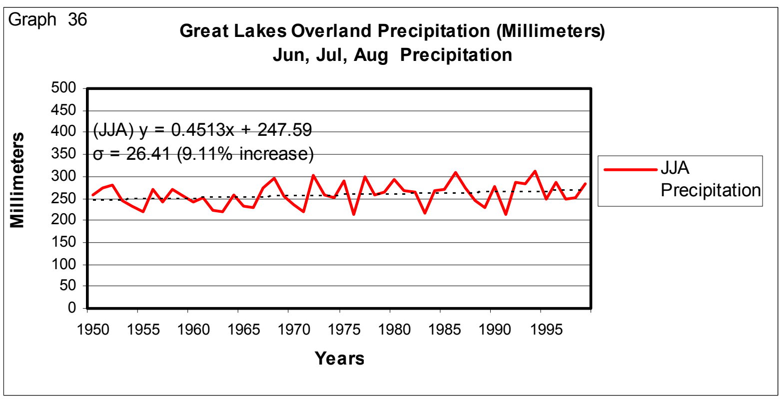
FIGURE 4.6.2



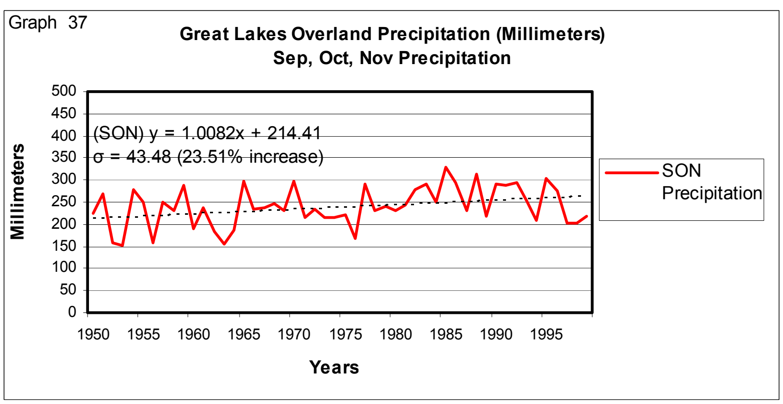
Graph 34
Great Lakes Overland Precipitation (Millimeters)
Dec, Jan, Feb Precipitation
(DJF) y = 0.1836x + 159.89
σ = 28.32 (5.74% increase)
Millimeters
Years
DJF Precipitation



Graph 35
Great Lakes Overland Precipitation (Millimeters)
Mar, Apr, May Precipitation
(MAM) y = -0.0384x + 202.79
σ = 28.53 (1% decrease)
Millimeters
Years
MAM Precipitation

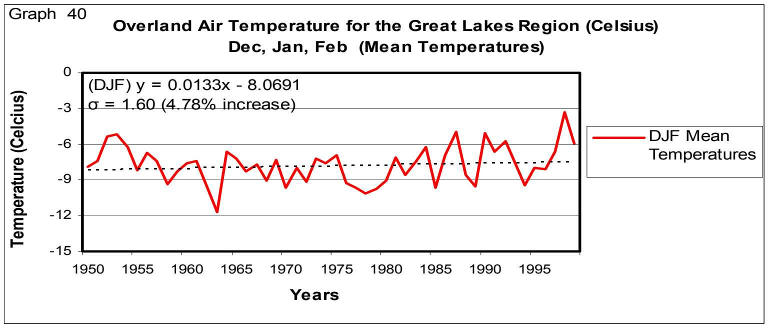


Graph 36
Great Lakes Overland Precipitation (Millimeters)
Jun, Jul, Aug Precipitation
(JJA) y = 0.4513x + 247.59
σ = 26.41 (9.11% increase)
Millimeters
Years
JJA Precipitation

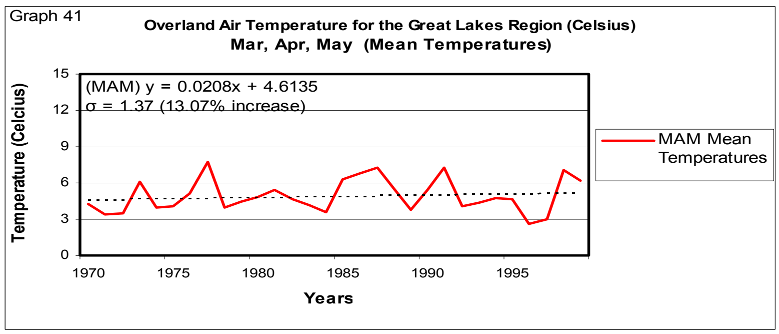


Graph 37
Great Lakes Overland Precipitation (Millimeters)
Sep, Oct, Nov Precipitation
(SON) y = 1.0082x + 214.41
σ = 43.48 (23.51% increase)
Millimeters
Years
SON Precipitation

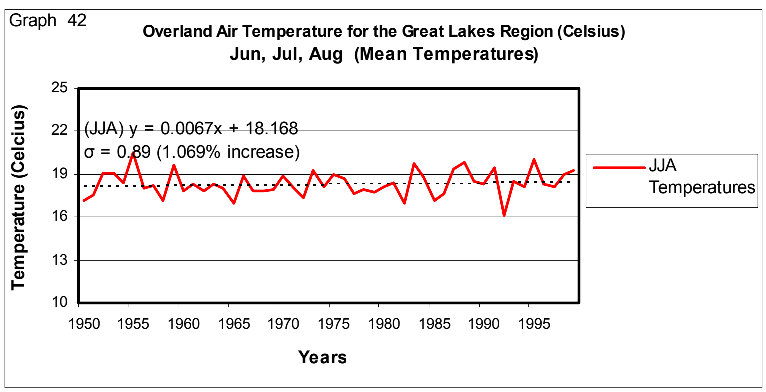
FIGURE 4.6.3



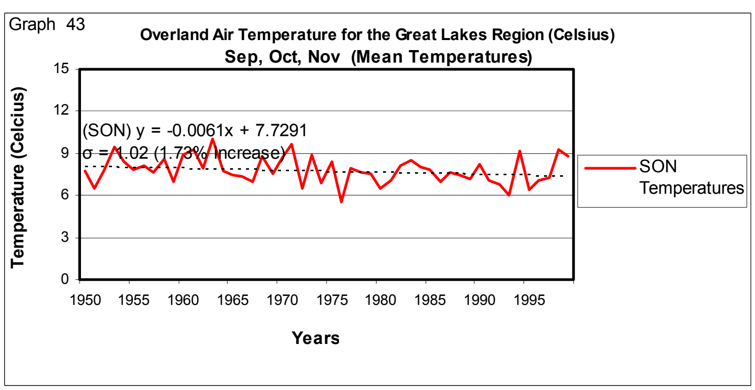
Graph 40
Overland Air Temperature for the Great Lakes Region (Celsius)
Dec, Jan, Feb (Mean Temperatures)
(DJF) y = 0.0133x - 8.0691
σ = 1.60 (4.78% increase)
DJF Mean Temperatures
Temperature (Celcius)
0
-3
-6
-9
-12
-15
1950 1955 1960 1965 1970 1975 1980 1985 1990 1995
Years



Graph 41
Overland Air Temperature for the Great Lakes Region (Celsius)
Mar, Apr, May (Mean Temperatures)
(MAM) y = 0.0208x + 4.6135
σ = 1.37 (13.07% increase)
MAM Mean Temperatures
Temperature (Celcius)
15
12
9
6
3
0
1970 1975 1980 1985 1990 1995
Years



Graph 42
Overland Air Temperature for the Great Lakes Region (Celsius)
Jun, Jul, Aug (Mean Temperatures)
(JJA) y = 0.0067x + 18.168
σ = 0.89 (1.069% increase)
JJA Temperatures
Temperature (Celcius)
25
22
19
16
13
10
1950 1955 1960 1965 1970 1975 1980 1985 1990 1995
Years



Graph 43
Overland Air Temperature for the Great Lakes Region (Celsius)
Sep, Oct, Nov (Mean Temperatures)
(SON) y = -0.0061x + 7.7291
σ = 1.02 (1.73% increase)
SON Temperatures
Temperature (Celcius)
15
12
9
6
3
0
1950 1955 1960 1965 1970 1975 1980 1985 1990 1995
Years

4.7 ST. CROIX RIVER AND ST. JOHNS RIVER

4.7.1 ST. CROIX RIVER

The St. Croix River forms a 185 km boundary between New Brunswick and Maine south of about 46^0N. Most of the 4230 km^2 drainage basin is in Maine. Pollution of the river by pulp and paper mills and other industries prompted the formation of IJC's International Advisory Board on Pollution Control in 1962. A previously instituted (1915) Board of Control dealt with dam and reservoir operation in relation to fisheries. In 2000, these were brought together into the International St. Croix River Board, following a 1997 review of existing Orders of Approval. (see Annex "A")

4.7.1.1 OBSERVED TRENDS

The mean annual flows at Baring near the mouth of the river have declined over the 1975-2000 period, by 16%. Over the same period, annual minimum flows dropped 26% and maximum annual flows by 4%. (Fig 4.7.1) However, there is obviously a major influence on the flow regime of a number of reservoirs operated in the basin in an attempt to even out the flows over the year to meet requirements for dilution of polluting discharges. However the reservoir operation has not been sufficient to maintain minimum and mean flows.

4.7.1.2 PROJECTIONS - OUTLOOK WITH CLIMATE CHANGE

With projected continued increases in temperature at a slightly more rapid rate, and rather little change in mean annual precipitation (~8%, Table 4.7.1), continued declines in flows are to be expected. While at Aroostook, Maine, for example, projected annual rainfall is expected to increase by about 9 mm, out of 106 (1961-1900), annual snowfall is projected to decline from 46 to 32 mm by the 2050's. (Fig. 4.7.2). These seasonal changes will likely increase the decline in flows.

4.7.1.3 IMPLICATIONS FOR TREATIES AND AGREEMENTS

The US EPA requires 750 cfs (21cms) at Baring in all seasons in order to safely dilute polluting discharges, mostly from the US side. This was to be achieved by judicious reservoir operation. However, analyses under the 1997 study over the flows of the period 1970-1989, revealed that at in least one dry year (1985), the required discharge could not be achieved. It will be noted from Fig. 10.1 that minimum discharges of 30 cms and under are the norm in the late 1990's. Thus, with projected further declines in mean and minimum flows with climate change, the discharge requirement at Baring would not be met much more frequently.

This suggests several possible options to pursue:

1. With reductions in polluting discharges, the flow requirements at Baring might be lowered.
2. Additional storage in the basin may be required if the 750 cfs target is to be met. However, the increased rated of evaporation losses with a warming climate, should be taken into account in considering the creation of greater reservoir surface area.

Table 4.7.1
St. Croix and St. John Basins

	Temperature Changes ^{0}C					Precipitation Changes %				
	Ann.	W	Sp	Su	A	Ann	W	Sp	Su	A
1971-2000 Observed	**0.8**	**1.4**	**.6**	**.3**	**.9**	**0**	**-3**	**9**	**6**	**0**
1971-2050 Projections A2 Emissions	**3.1**	**3.3**	**3.4**	**3.2**	**2.6**	**8**	**9**	**5**	**11**	**10**
1971-2050 Projections B2 Emissions	**2.7**	**3.0**	**2.8**	**2.7**	**2.2**	**8**	**10**	**7**	**14**	**6**

4.7.2 ST. JOHN RIVER:

The St. John River arises in Quebec, forms the border between Canada and USA between Edmunston and Grand Falls and thence flows southward through New Brunswick. The basin's 55,167 km^2 including some tributaries largely in USA, falls into 5 jurisdictions, 2 Canadian provinces, the State of Maine and the two federal governments. Approximately 35,500 km^2 of the basin is in Canada and 19,700 km^2 in Maine.

While an Agreement relating to the establishment of a Canada-USA committee on water quality in the St. John River and its tributary rivers and streams which cross the Canada-United States boundary was signed in 1972 (amended 1984), discussions take place through the St. Croix River International Board.

4.7.2.1 OBSERVED TRENDS

The average flow and the annual maximum flows at Fort Kent (near Grand Falls) declined from 1970 to 2000 by 13% and 16% respectively (not statistically significant at 95% level). However, minimum flows increased in this period from about 50 m^3/sec to about 85 m^3/sec (a 71% increase). (Fig. 4.7.3)

Minimum flows normally occur in February and March, with peak discharges in April-May. The St. John River basin experienced a warming trend averaging 1^{0}C over the 1900's much of that since 1970 (see also Table 4.7.1). From 1970 to 2000 there is a significant correlation between trends in both precipitation and temperature (at Fredericton A) (Fig. 4.7.4) and flows downstream at Mactaquac just above Fredericton. (Fig. 4.7.5) The warming trend in the St. John River basin is substantially greater than in regions further east in the Atlantic Provinces, in some areas of which cooling has occurred in the past 3 decades.

The decline in mean annual maximum flows should not lead to complacency about floods. The frequency of high intensity one-day rainfalls has been on the increase in the basin since 1950. And as one paper put it, "There have been several near misses in which intense rainfalls have almost coincided with the snowmelt freshet". (Hare, Dickison and Ismael, 1997). The increased frequency of heavy rains is projected to continue. In addition, spring flows have generally been earlier since 1972, with accompanied increases in frequency of flooding due to ice jams.

4.7.2.3 IMPLICATIONS FOR TREATIES AND AGREEMENTS

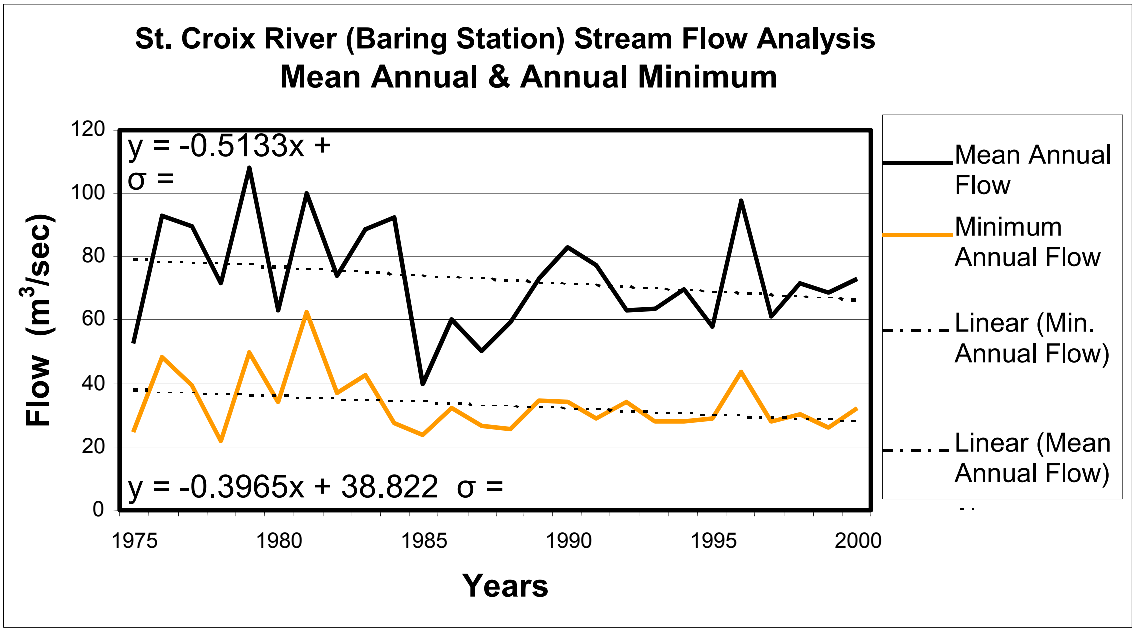
The trends to date probably do not warrant further intervention, but either through the International St. Croix River Board, or otherwise, the further trends in the St. John River system should be closely monitored. It may be that the 1984 Agreement related to water quality at boundary crossings should be reviewed in 10 years or so as flows continue to decline as projected and a water sharing agreement may be needed to protect hydro-power production and water supply in New Brunswick.

REFERENCES

Hare, F.K., R.B.B. Dickison, S. Ismael, 1997. Climatic variation over the St. John basin, Climate Change Digest, Environment Canada CCD97-02, 16 pp.

Karl, T.R., R. W. Knight, D.R. Easterling and R.G. Quayle, 1996. Indices of climate change for the United States, Bulletin of American Meteorological Society, 77, 279-292.

FIGURE 4.7.1


St. Croix River (Baring Station) Stream Flow Analysis
Mean Annual & Annual Minimum
y = -0.5133x +
σ =
y = -0.3965x + 38.822 σ =
Flow (m³/sec)
120
100
80
60
40
20
0
1975
1980
1985
1990
1995
2000
Years
Mean Annual Flow
Minimum Annual Flow
Linear (Min. Annual Flow)
Linear (Mean Annual Flow)

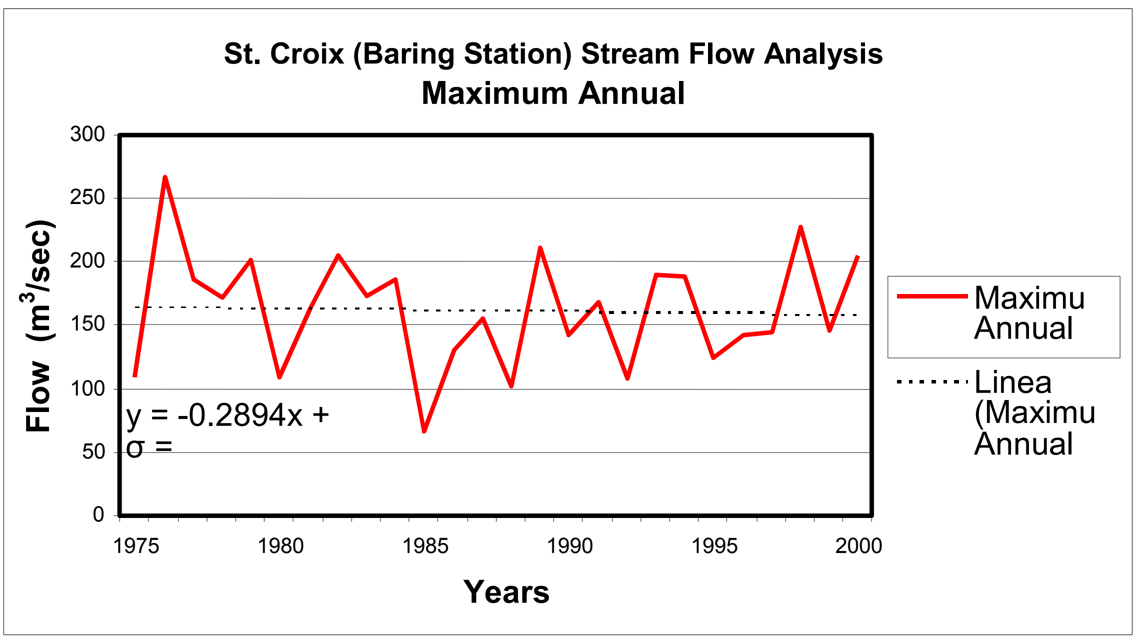
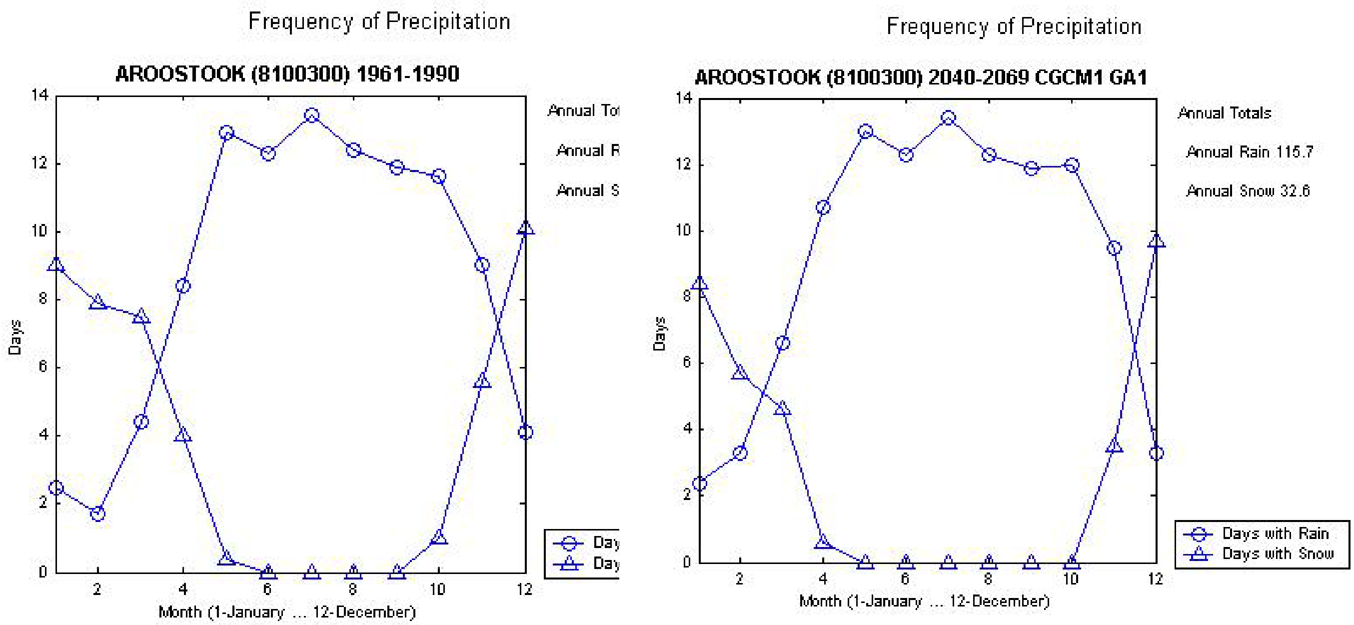
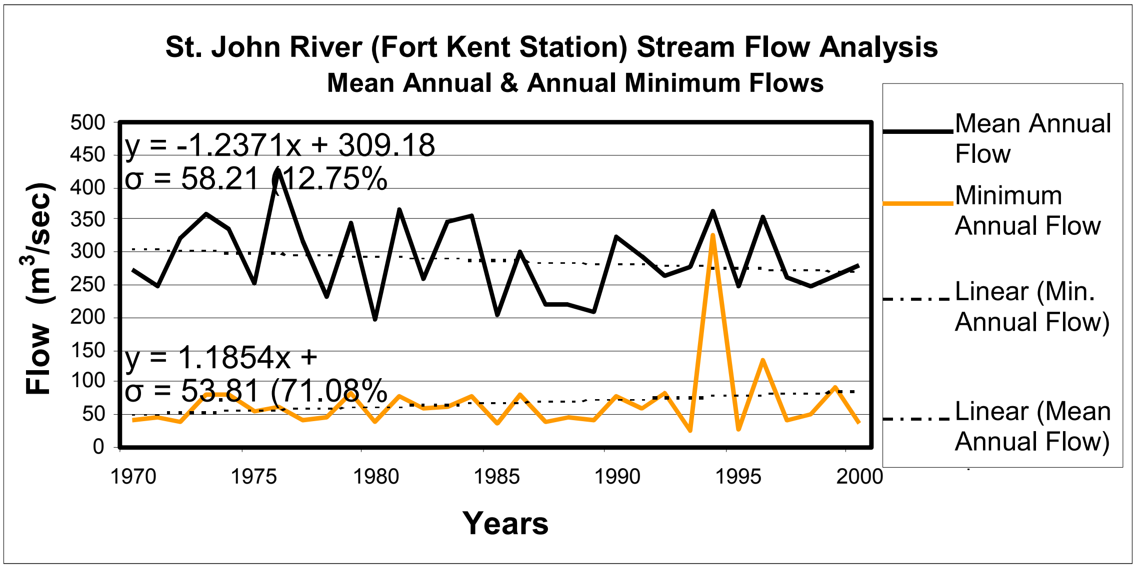

St. Croix (Baring Station) Stream Flow Analysis
Maximum Annual
y = -0.2894x +
σ =
Flow (m³/sec)
300
250
200
150
100
50
0
1975
1980
1985
1990
1995
2000
Years
Maximu Annual
Linea (Maximu Annual

FIGURE 4.7.2
St.Croix/St. John Watershed – Aroostook Station #8100300



Annual rainfall increased in 2040-2069 (115.7mm) from 1961-1990 (106.6mm). Annual snowfall decreased to 32.6cm in 2040-2069 from 46.1cm in 1961-1990. Winter snow days decreased in January for 2040-2069 compared with 1961-1990 (8 days from 9 days) and February (6 days from 8 days). Rain days did not increase for January, but did increase for February from 2 days to 3 days. Rain days increased in the early to mid-spring for the 2040-2069 periods and remained similar for both periods for the summer for the majority of the fall. November had a 1 snow day decrease in the fall for 2040-2069, and 1 rain day increase. The last snowfall for 1961-1990 for was May and April for 2040-2069. The first snowfall was October for 1961-1990 and November for 2040-2069. Of all of the study area watersheds, this one remained most constant for the rain and snow day profiles for both periods.

FIGURE 4.7.3


St. John River (Fort Kent Station) Stream Flow Analysis
Mean Annual & Annual Minimum Flows
y = -1.2371x + 309.18
σ = 58.21 (12.75%
y = 1.1854x +
σ = 53.81 (71.08%
Flow (m³/sec)
Years
500
450
400
350
300
250
200
150
100
50
0
1970
1975
1980
1985
1990
1995
2000
Mean Annual Flow
Minimum Annual Flow
Linear (Min. Annual Flow)
Linear (Mean Annual Flow)

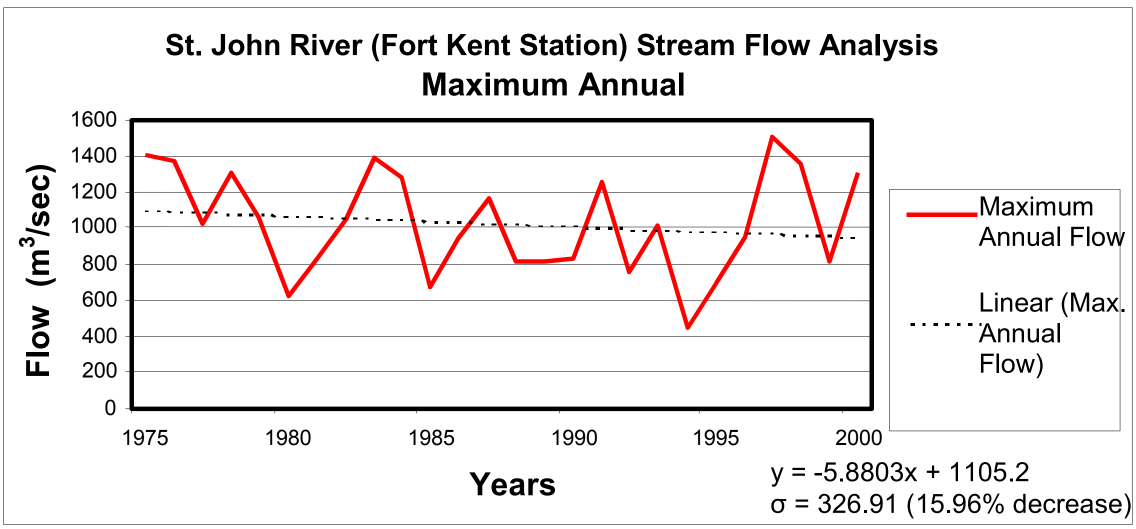
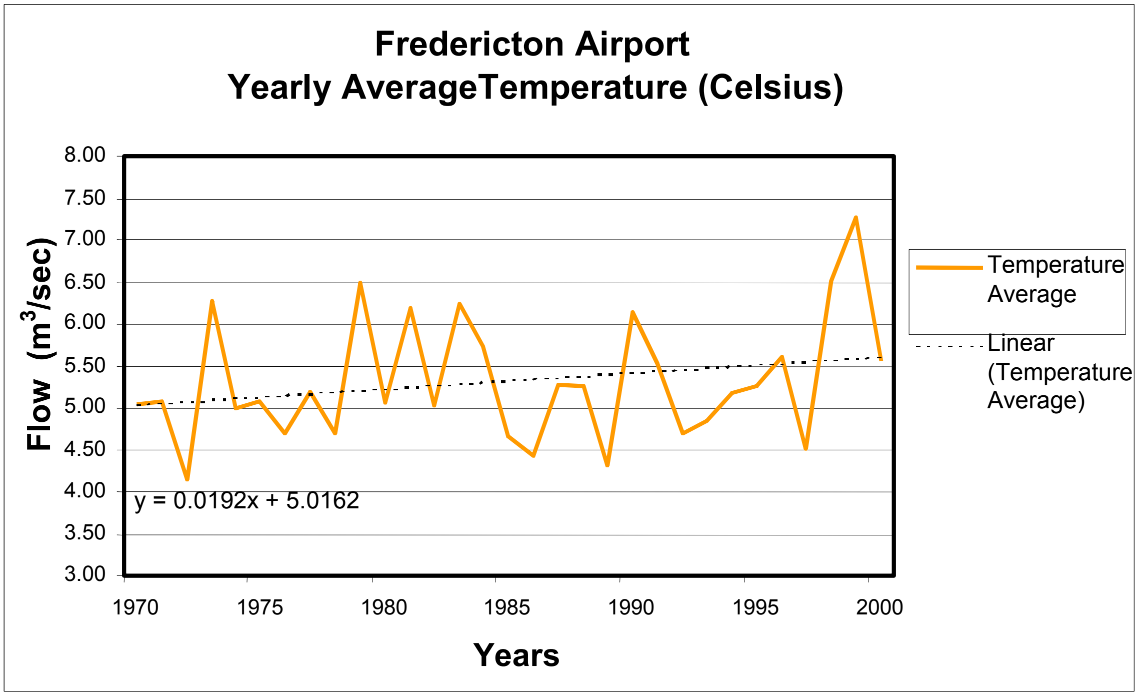
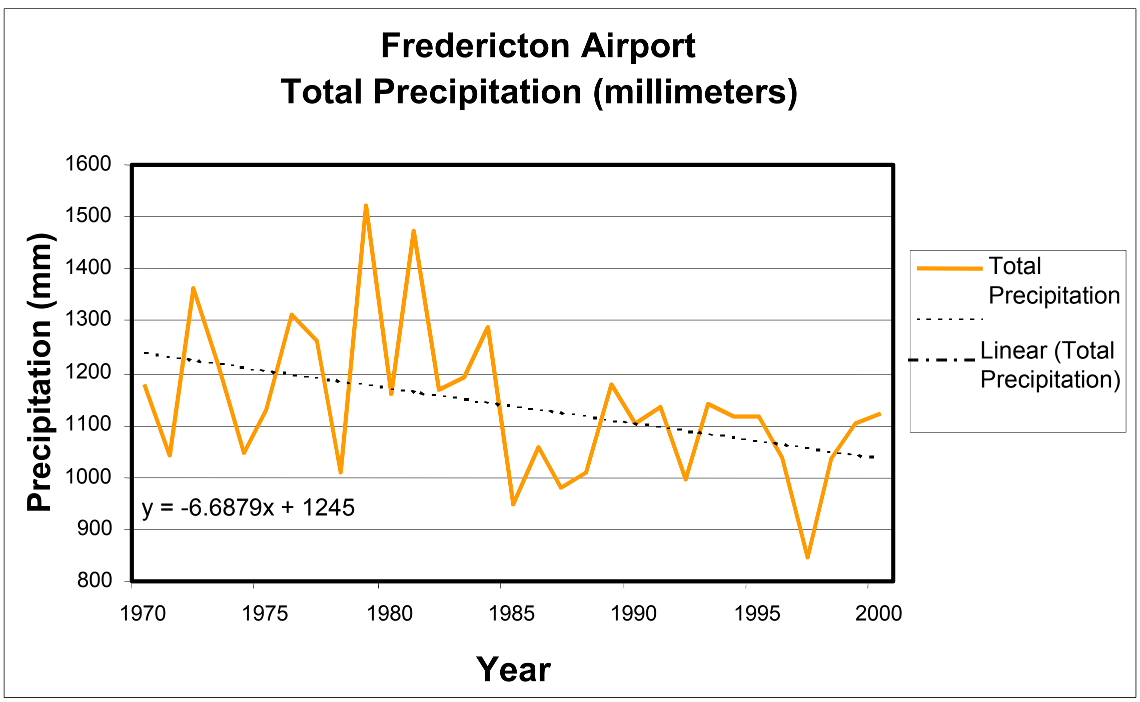

St. John River (Fort Kent Station) Stream Flow Analysis
Maximum Annual
Flow (m³/sec)
Years
1600
1400
1200
1000
800
600
400
200
0
1975
1980
1985
1990
1995
2000
Maximum Annual Flow
Linear (Max. Annual Flow)
y = -5.8803x + 1105.2
σ = 326.91 (15.96% decrease)

FIGURE 4.7.4



Fredericton Airport
Yearly AverageTemperature (Celsius)
Flow (m3/sec)
8.00
7.50
7.00
6.50
6.00
5.50
5.00
4.50
4.00
3.50
3.00
y = 0.0192x + 5.0162
1970
1975
1980
1985
1990
1995
2000
Years
Temperature Average
Linear (Temperature Average)



Fredericton Airport
Total Precipitation (millimeters)
Precipitation (mm)
1600
1500
1400
1300
1200
1100
1000
900
800
y = -6.6879x + 1245
1970
1975
1980
1985
1990
1995
2000
Year
Total Precipitation
Linear (Total Precipitation)

FIGURE 4.7.5

St. John River (South of Mactaqua)

	Yearly Mean Temperatures, Celsius	**Annual Precipitation**	**Average Monthly Flow (m^3/s) below Mactaqua**
1970	5.03	1178.4	756
1971	5.09	1041.5	657
1972	4.16	1364.3	879
1973	6.27	1211.8	1060
1974	4.99	1045.9	863
1975	5.08	1128.1	662
1976	4.69	1312.1	1170
1977	5.20	1261.1	951
1978	4.70	1009.7	700
1979	6.50	1520.7	1030
1980	5.06	1159.5	648
1981	6.18	1473.6	1040
1982	5.03	1167	785
1983	6.23	1191.3	988
1984	5.73	1288.3	966
1985	4.67	949.1	548
1986	4.43	1056.8	780
1987	5.28	979.9	638
1988	5.26	1008.7	621
1989	4.32	1177.3	626
1990	6.16	1102.4	927
1991	5.53	1137	902
1992	4.69	994.7	743
1993	4.85	1141.5	833
1994	5.18	1116.9	853
1995	5.26	1117.2	
1996	5.61	1035.8	
1997	4.51	844.8	
1998	6.51	1036.9	
1999	7.28	1103	
2000	5.55	1122	

SUMMARY OUTPUT
Regression is significant at 95% Confidence Interval
Y Variable (St. John River Flow)
X Variable (Temperature)

Regression Statistics	
Multiple R	**0.535760863**
R Square	0.287039702
Adjusted R Square	0.256041428

Standard Error	142.61548
Observations	25

ANOVA

	df	*SS*	*MS*	*F*	***Significance F***
Regression	1	188337.9317	188337.9317	9.259861	**0.005775**
Residual	23	467801.0283	20339.17514		
Total	24	656138.96			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	108.0100848	237.3524904	0.45506194	0.653331	-382.99	599.0105	-382.990282	599.0105
X Variable 1	137.5728924	45.20959722	3.043001948	0.005775	44.04984	231.0959	44.04984236	231.0959

SUMMARY OUTPUT

Regression is significant at 95% Confidence Interval

Y Variable (St. John River Flow)

X Variable (Precipitation)

Regression Statistics	
Multiple R	**0.719485394**
R Square	0.517659232
Adjusted R Square	0.496687894
Standard Error	117.3035027
Observations	25

ANOVA

	df	*SS*	*MS*	*F*	***Significance F***
Regression	1	339656.3899	339656.3899	24.68413	**5.05E-05**
Residual	23	316482.5701	13760.11174		

Total	24	656138.96

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-114.0892299	190.4741291	-0.598974939	0.555044	-508.114	279.936	-508.11445	279.936
X Variable 1	0.809103122	0.1628527	4.968312612	5.05E-05	0.472217	1.145989	0.472217104	1.145989

4.8 YUKON RIVER

4.8.1 OBSERVED TRENDS

With changes in climate being most intense in Canada in the Northwest it might be expected that flows experienced on the Yukon River (above White River near the Alaska border) would have shown significant trends. This has not occurred in the 1970-2000 period. Mean annual flows have increased about 1% and minimum flows have also declined about 1%. Maximum flood flows have declined 12%. None of these trends are significant at the 95% level. Winter (DJF) runoff has risen by 8% but summer flows (June to August) declined 13%.

With continued warming projected to 2050 but with greater increases in precipitation than those observed in the past 30 years (Table 4.8.1), annual flows should increase and average annual peak discharges would would continue to decline. Projections using CCCma model CGCMI with 1% increase in greenhouse gas and aerosol forcing per year suggest that by the period 2070-2100, annual flows should increase by 10% and mean annual flood flows decline by 20% (Arosa, V., Water News 21:5, March 2002).

TABLE 4.8.1
YUKON RIVER OBSERVED AND PROJECTED TEMPERATURE AND PRECIPITATION TRENDS

	Temperature Changes ^{0}C					Precipitation Changes %				
	Ann.	W	Sp	Su	A	Ann	W	Sp	Su	A
1971-2000 Observed	2.1	2	2.7	1.5	0	0	-12	0	+6	+5
1971-2050 Projections A2 Emissions	3.1	3.4	2.8	3.3	2.6	12	9	13	14	13
1971-2050 Projections B2 Emissions	2.7	2.8	2.5	2.8	2.6	13	14	13	13	12

No specific sharing agreement between USA and Canada exist on the Yukon River system, although general provisions of the Boundary Water Treaty apply. However fisheries agreements focused on salmon protection are under negotiation. An issue related to climate change is the extent to which waters may warm with climate change. Recent studies that indicate potential impacts of warm waters in the Fraser River system on salmon, suggest that this could become an issue. On the Fraser mean summer water temperatures are projected to increase by 1.9^{o}C by late this century bringing temperatures above estimated critical levels for Fraser River salmon 10 times more frequently. Air temperature and thus water temperature increases in the Yukon are projected to be even greater then the Fraser. However the cooler waters of the Yukon may not be as susceptible to future exceedance of critical levels. On the other hand the salmon of the Yukon may be less able to withstand higher temperatures than those of the Fraser. Further study is required.

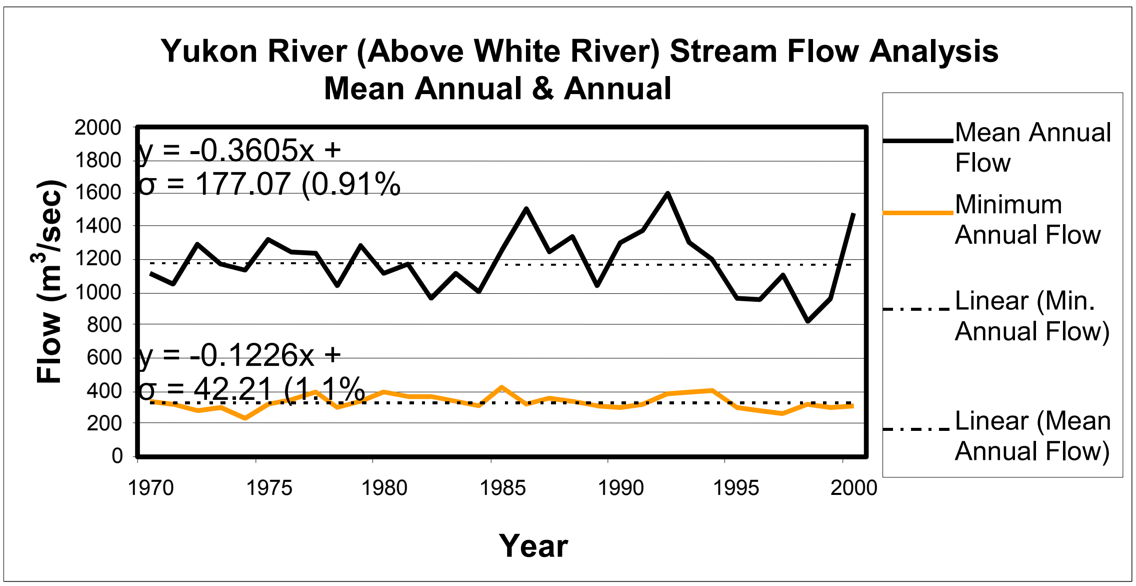
REFERENCES

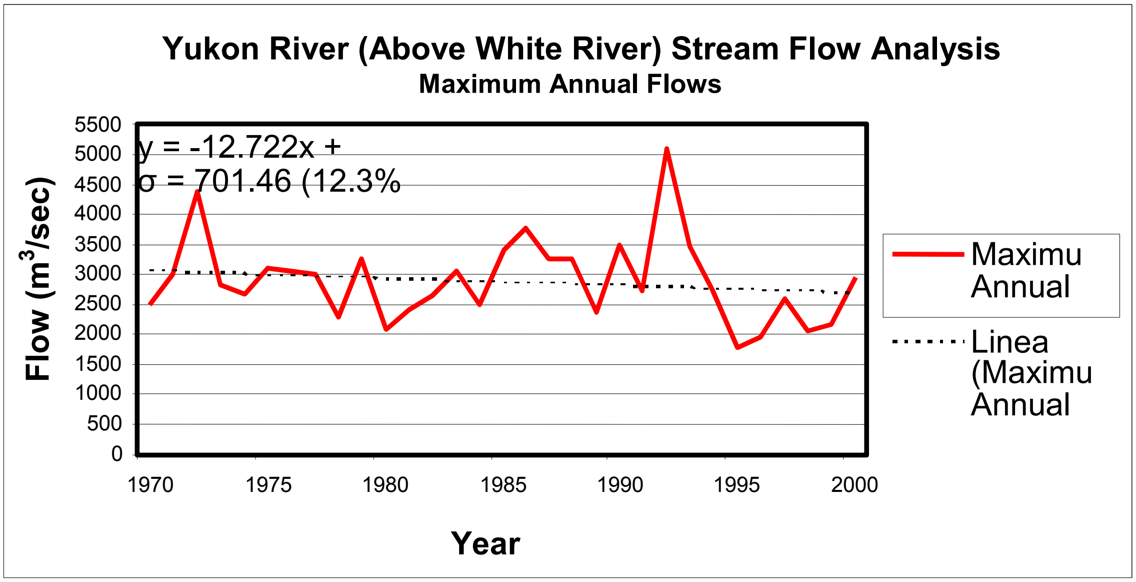
Arosa, V. (2002), Studying Climate Change Impact on Rivers Within the Framework of Global Climate Models, Tech. Bureau Supplement Water News, CWRA, 21:1, 19-25.

Arosa, V. And G.J. Boer (2001), Effects of simulated climate change on the hydrology of major river basins, Journal of Geophysics Research 106 (D4), 3335-3348.

Morrison, G., M.C. Quick and M.G.C. Foreman (2002), Climate change in the Fraser River watershed: flow and temperature projections, Journal of Hydrology 263, 10 June, 230-244.

FIGURE 4.8.1





5.0 OVERVIEW OF INTER-PROVINCIAL AND FEDERAL-PROVINCIAL AGREEMENTS

5.1 GENERAL INFORMATION

5.1.1 FEDERAL AND PROVINCIAL JURISDICTION

Water resources in Canada are subject to concurrent federal and provincial jurisdiction. There is no overall legislative framework for interjurisdictional water management in Canada. Responsibility for water is divided as follows:

- *Federal (Constitution Act 1867, section 91)*

  International waters, transboundary waters, the territories, protection of navigable waters, fisheries, management of water on federal (e.g. national parks) and Aboriginal lands, drinking water in areas of federal jurisdiction, some specific aspects of environmental protection.

- *Provincial Jurisdiction (Constitution Act 1867, section 92)*

  Surface and groundwater, flow regulation, authorization of water use development; and authority to legislate areas of water supply, pollution control, thermal and hydroelectric power development. Provinces have proprietary rights to water, which gives them more direct control over this resource. Consequently, they may legislate on many aspects, such as water supply, use, pollution control, hydroelectric power generation, irrigation, and recreation.[2]

Although environmental issues are not specifically enumerated in the 1867 Constitution Act, if conflict arises over an issue that is shared by both levels of government, the

---

[2] Environment Canada, "Jurisdictional responsibilities" [online] (Ottawa: Environment Canada, 2002, accessed 8 May 2002) available from www.ec.gc.ca/water/en/policy/coop/e_juris.htm; Internet.

federal government's interests take precedence (doctrine of paramountcy). The federal government also has claim to residual powers, i.e., aspects that are not clearly enumerated in the Constitution.[3]

In 1987, Environment Canada published its *Federal Water Policy*, which is a statement of the federal government's philosophy and goals for freshwater use in Canada. It has as its main objective "the use of freshwater in an efficient and equitable manner consistent with the social, economic and environmental needs of present and future generations."[4] It was not a legislative document but it was circulated to provinces for their feedback and then tabled in the House of Commons. The *Federal Water Policy* marks the first federal initiative to provide a federal policy framework for freshwater use and management, and its strategies are aimed at water pricing, science leadership, planning, legislation, and public awareness.

The *Federal Water Policy* briefly considers water use conflicts, interjurisdictional water conflicts within Canada, drought, and climate change. It states that existing interjurisdictional management bodies such as the Prairie Provinces Water Board ought to be encouraged, and describes such mechanisms as possessing the capacity to provide for "the ultimate resolution" to interjurisdictional disputes.[5] The federal government, according to the *Federal Water Policy* document, will develop "water demand management approaches" which will consider social and economic in areas of federal jurisdiction. The *Federal Water Policy* has not been updated or revised since its publication in 1987. However, changes in Environment Canada have changed the approach to water. The former Inland Waters Directorate was disbanded in 1993 and its functions assigned to different parts of Environment Canada (water policy to the Environmental Conservation Service and the Water Survey of Canada to the Meteorological Service of Canada). Further, Program Review budget reductions and program changes in the 1990's reduced the federal government's capacity and role in water monitoring, research and management.

Despite the provinces' direct control over many aspects of water resources, Environment Canada's *Canada Water Act* of 1970 contains some provisions that permit the federal government to be involved in the management of boundary or transboundary waters:

- Under Part I, "Comprehensive Water Resource Management," the federal environment minister may enter into an arrangement, with one or more provincial governments to establish on a national, provincial, regional, or river-basin basis, "to advise on the formulation of water policies and programs," and "to facilitate the coordination and implementation of water policies and programs…"[6]

[3] Kathryn Harrison, *Passing the Buck: Federalism and Canadian Environmental Policy* (Vancouver: UBC Press, 1996) 34-5.
[4] Environment Canada, *Federal Water Policy* [online] (Ottawa: Environment Canada, 1987, accessed 4 August 2002) available from http://www.ec.gc.ca/water/en/info/pubs/fedpol/e_fedpol.pdf; Internet.
[5] Environment Canada, *Federal Water Policy* 28.
[6] Department of Justice Canada, "Canada Water Act" section 4 [online] (Ottawa: Department of Justice Canada, 2001, accessed 10 July 2002) available from http://laws.justice.gc.ca/en/C-11/index.html; Internet.

- The federal environment minister can "formulate comprehensive water resource management plans… taking into account views expressed at public hearings and otherwise by persons likely to be affected by implementation of the plans" with respect to any waters where there is a significant national interest in the water resource management thereof, enter into agreements with one or more provincial governments…"[7]
- The federal environment minister may create a program with respect to any federal, international, transboundary, or boundary waters where there is "a significant national interest" in its management, provided that the Governor in Council is satisfied that the federal environment minister has made "all reasonable efforts" to reach agreement with the one or more provincial governments in question, and that those efforts have failed.[8]

5.1.2 WATER ALLOCATION AND USAGE IN CANADA

Canada is a country with a very low population density (31.4 ha per capita) compared to the United States (3.4) and the rest of world (2.1). Canada also has a relatively large amount of protected areas 3.0 ha per capita compared to the United States (0.6) and the rest of world (0.2). Worldwide water withdrawals from water bodies have risen from 250 cubic metres/person/year in 1900 to over 700 cubic metres today. Whereas most Canadians live in the southern part of the country near the United States' border, 60 per cent of Canadian water flows north. In Ontario, which has about one-third of the population, 85 per cent of residents draw their drinking water from the Great Lakes watershed.

The general principles for allocation of waters are different in the western Canadian provinces (and western U.S. states) are different from those in the eastern part. In the west, appropriation of water is based on economic, "out of stream" needs. The volumes of water flows are not considered.[9] East of 100th meridian in Canada and U.S. allocation generally "adhere to riparian or riparian-based permit systems of water law"

5.1.3 THE CANADIAN HERITAGE RIVERS SYSTEM

The Canadian Heritage Rivers System (CHRS) is a federal-provincial-territorial program that began in 1984. The goal of the CHRS program is "to establish a system that reflects the diversity of Canada's river environments and celebrates the role of rivers in Canada's history and society. The dream is to ensure that these rivers flow into the future with their heritage features protected for generations to come."[10] To be designated a Heritage River, "a river must have outstanding natural, cultural and/or recreational values, a high level of public support, and it must be demonstrated that sufficient measures will be put in place to ensure that those values will be maintained."[11] The CHRS is largely administered by Parks Canada. As the lead federal agency, Parks Canada provides

---

[7] Ibid., section 5(d).
[8] Ibid., section 6(1)(b,c).
[9] Intergovernmental Panel on Climate Change, Working Group II, *Climate Change 2001: Impacts, Adaptation, and Vulnerability* (New York: Cambridge University Press, 2001) 743.
[10] Canadian Heritage Rivers System, "About us," [online] (Ottawa: *Canadian Heritage Rivers System*, 2002, accessed 18 May 2002) available from www.chrs.ca/About_e.htm; Internet.
[11] Ibid.

financial and technical support. Parks Canada also has its own heritage rivers in national parks that it manages. As of 1994, all provinces and territories voluntarily participate in the CHRS. The Board of the CHRS is made up of one voting member from each jurisdiction with the chair elected annually.

Any individual or organization may submit a proposal. A river receives the Heritage designation once a heritage strategy or management plan to conserve its natural, cultural, or recreational features has been approved by the CHRS board, who then recommends it to the appropriate Ministers. Once a water basin has been designated as a Heritage River, the local authority with responsibility for its management must submit annual reports on the condition of the basin, and every ten years, a "State-of-the-River" report must be submitted to the Board. Local management is encouraged by the CHRS, and many of the benefits of designation rely on the voluntary efforts of the local community. No additional level of bureaucracy is created, and the water basin benefits from management by the local community. In 1997, the CHRS estimated that the annual economic benefits to Canada attributable to the CHRS program totaled $32 million.

The 2000-01 CHRS Annual Report lists the following Heritage Rivers, designated between 1986 and 2001 and each of which has a management plan outlining the river's heritage values:

River	**Province or Territory**
French	ON (French R. provincial park)
Alsek	Yukon (Kluane national park)
South Nahanni	NWT (Nahanni national park reserve)
Clearwater	Sask. (Clearwater River provincial wilderness park)
Mattawa	ON (Mattawa, Sam de Champlain provincial parks)
Athabasca	AB (Jasper national park)
N. Saskatchewan	AB (Banff national park)
Kicking Horse	BC (Yoho national park)
Kazan	Nunavut
Thelon	Nunavut
St. Croix	NB
Yukon – The Thirty Mile	Yukon
Seal	MB
Soper	Nunavut (Katannilik Terr. Park Reserve)
Arctic Red	NWT
Grand	ON
Boundary Waters/Voyageur Waterway	ON (La Verendrye/Quetico/Middle Falls provincial parks)
Hillsborough	PEI
Shelburne	NS
Bonnet Plume	Yukon
Upper Restigouche	NB
Bloodvein	MB, ON (Atikaki, Woodland Caribou prov'l parks)
Margaree	NS
Fraser	BC
Humber	ON

Rideau	ON (Rideau Waterway – Parks Canada)
Thames	ON
St. Marys	ON
Detroit	ON
Main	Nfld.

Total: 30 rivers, totalling 7368 km in length[12]

On 21 June 2002, the Minister of Canadian Heritage signed a ministerial proclamation declaring the second Sunday of June "Canadian Rivers Day," to promote the natural, cultural and recreational values of Canada's rivers. The day is similar to British Columbia's "Rivers Day," which has been celebrated for more than twenty years. The proclamation follows two unsuccessful motions tabled in the House of Commons in 1996 and 2001, which were deemed "unvotable," and so could not go forward for committee review or a third reading.[13]

5.1.3.1 ANALYSIS

The Canadian Heritage Rivers System cannot confer legal status on designated water basins, nor does it have legal status itself, and it cannot act as an intervener in legal matters. Management of designated water basins is the responsibility of local community organizations. Some of the potential benefits cited by the CHRS include a healthy ecosystem, a culturally rich community, outdoor recreation opportunities, and ecotourism. The CHRS claims that its rivers form "an elite group of the most historic and beautiful rivers in Canada" but that it is not an end in itself, and that a designation does not automatically bring major benefits. If the designation provides advantages to a local community, it is because of that community's concern for the water basin, which is invariably a pre-existing condition.

Despite the benefits that may or may not accrue to a local community because of the Heritage River designation, the CHRS designation has no legal or political standing. Thus, CHRS designation will not be a significant factor in an assessment of how the to manage issues arising from climate change effects on a river basin. Effects of climate change on a Heritage River would likely be mentioned in annual reports, but it is difficult to envisage that the designation would be in any way significant if governments or community organizations were considering potential responses to climatic changes. Strategies of adaptation to climate change would not be assisted nor harmed by the Heritage designation, and climate change-related decisions would occur outside of the Heritage designation.

[12] Canadian Heritage Rivers System, *Annual Report 2000-2001* [online] (Ottawa: Public Works and Government Services Canada, 2001, accessed 24 May 2002) available from www.chrs.ca/AnnualReports/2000-2001/AR2000-2001Eng.pdf; Internet.

[13] Canadian Heritage Rivers System, "Proclamation of Canadian Rivers Day" [online] (Ottawa: CHRS, 2002, accessed 16 October 2002) available http://www.chrs.ca/New_e.htm; Internet.

5.2 WATER AGREEMENTS

5.2.1 OTTAWA RIVER

The Ottawa River Basin is in a medium to heavily-populated area. Primary water uses are as a source for hydroelectric power generation, domestic water supply, effluent dilution (wastewater), recreational boating and a limited amount of log driving. Approximately 1130 km long, the Ottawa River forms the much of the boundary between Ontario and Quebec. The water basin area is 146,300 km^2, with approximately 65 per cent in Quebec and 35 per cent in Ontario. This division does not imply that each province has a corresponding degree of control or ownership of the basin's waters.

There are six main reservoirs in the Ottawa River Basin:

- Ottawa River – Dozois, Rapid VII, Quinze, Temiskaming, Des Joachims
- Montreal River – Lady Evelyn
- Kipawa River – Kipawa
- Madawaska River – Bark Lake
- Gatineau River – Cabonga, Baskatong
- Lievre R. – Mitchinamecus, Kiamika, Poisson Blanc

A total of 43 hydroelectric generating stations and dams are located in the Ottawa River basin, and these are important for the two provinces' economies. The generating stations are owned by Ontario Power Generation (a for-profit company, formerly Ontario Hydro), or by Hydro Quebec, or by Public Works and Government Services Canada, and one is jointly owned and operated by Ontario Power Generation and Hydro Quebec (Chats Falls, 56 km northwest of Ottawa).

An Act Respecting Ottawa River Basin Regulation was passed in March, 1983. It established the Ottawa River Regulation Planning Board, which has as its purpose the "integrated management of the principal reservoirs of the Ottawa River Basin" to "provide protection against flooding along the Ottawa River and its tributaries, particularly in the Montreal Region, and at the same time maintain the interests of the various users *particularly in hydro-electric energy production*" (italics added).[14]

The Board's membership is comprised of representatives from the governments of Canada (3 members), Quebec (2 members), and Ontario (2 members). The member agencies are the Ministere de l'Environnement du Quebec, Hydro-Quebec, Ontario Ministry of Natural Resources, Ontario Hydro, Environment Canada, Public Works and Government Services Canada, and Transport Canada. The Board is responsible for establishing and implementing general principles, priorities, and overall regulation policies for the principle reservoirs in the basin. It meets a minimum of three times each year and produces annual reports on its activities.

There is also a four-member regulating committee (each of the three governments are represented) that is responsible for operations, particularly the establishment of regulation practices and procedures within the policies set out by the Board. A secretariat lends

[14] Ottawa River Regulation Planning Board, "Organization and Purpose" [online] (Ottawa: Ottawa River Regulation Planning Board, 2002, accessed 6 July 2002) available from http://www.ottawariver.ca/emain.htm; Internet.

support to both the Board and the regulating committee. Funding for the Board and its activities is apportioned among the three governments, with the federal government contributing 50 per cent, and the two provinces each contributing 25 per cent.

The Ottawa River Regulation Planning Board is primarily an organization to coordinate the activities of generators of hydroelectricity in the Ottawa basin. Although it ostensibly looks out for all users in the Ottawa River basin, its primary concern is the hydro companies' use of the waters. Its statement of purpose includes mention of various users, but only hydroelectric generators are expressly identified. Its membership includes both Ontario and Quebec's hydroelectric power generators, and a reasonable inference is that these interests supercede other, possibly competing, interests. It is clear that the "integrated management of the principal reservoirs" concerns these companies, and the Board provides a source for coodinating activities and sharing information.

The Board is also responsible for gathering and publicizing data on water levels, a practice started at the behest of recreational water users. It updates its readings once each week, except in the spring, when data is published daily, and this information is accessible online or by phone. The Board's website also includes the minimum and maximum allowable water levels for each hydroelectric site. (Ontario Power Generation also monitors levels independently and publishes its information on its website.)

The hydroelectric companies under the terms of their licences set the water levels. Many of the dams and generating stations were built in the 1940s and '50s, and there was little concern about other users; nor were there opportunities for public input about these companies' activities. Consequently, they have considerable authority over water levels, so long as they operate within permitted ranges. Their needs are prioritized over those of other users, such as fisheries.

The hydroelectric companies are not insensitive to other users' needs; for example, Ontario Power Generation has developed several programs to promote environmental causes and to bolster its reputation. It has won eleven awards so far this year from a wide variety of organizations, such as the Forest Stewardship Recognition Program, the U.S. Environmental Protection Agency, the Conference Board of Canada, and the Canadian Electricity Association. There are programs for reforestation, voluntary watershed management with recreational users and conservation authorities, support for charities, and scholarship programs.[15] Hydro-Quebec has similar community outreach initiatives aimed at promoting social and environmental goals, and has the ISO 14000 standard. It publicly supports the federal government's desire to ratify the Kyoto Protocol.[16]

5.2.1.1 ANALYSIS

Given that the Ottawa River is the site of many hydroelectric power stations, climate change effects could cause less power to be generated due to lowering water levels

---

[15] Ontario Power Generation, "Environment and Community" [online] (Toronto: Ontario Power Generation Inc., 2002, accessed 14 October 2002) available http://www.opg.com/envComm/envcom.asp; Internet.
Ontario Power Generation, "Environment and Community" [online] (Toronto: Ontario Power Generation Inc., 2002, accessed 14 October 2002) available http://www.opg.com/envComm/envcom.asp; Internet.

[16] Hydro-Quebec, "Our Energy at Your Service" [online] (Montreal: Hydro-Quebec, 2002, accessed 14 October 2002) available http://www.hydro.qc.ca/en/index.shtml; Internet.

(resulting from increased surface water evaporation or less precipitation).[17] Secondary effects on recreational usage and domestic water supply are possible. Less water in southern Ontario is predicted to negatively influence ecosystem integrity and water quality due to a diminished dilution capacity.

There are no formal apportionment agreements for the Ottawa River, and the present availability of water has permitted the members of the Ottawa River Regulation Planning Board to achieve consensus whenever decisions have been made. If, however, water levels were to drop, at least two members of the Board – the Ontario and Quebec hydro generators – would likely be anxious to manage the resource so as to create the physical force necessary to generate electricity, especially during periods of high demand (e.g., summertime demand for air conditioning). Despite a majority of Board members representing government interests, it seems that there is little the Board could do to prevent downstream users from experiencing water shortages, if climatic changes caused water levels to drop. Hydroelectric companies' licences generally do not limit the amount of water they may take for power production but physical restrictions exist due to their structural limitations. To undertake modifications to dams would require government approval, which may or may not be granted.

There is a long-standing, but never used provision that could offer the federal government additional leverage, at least on the main stem of the Ottawa River. Under the 1870 *Act respecting certain Works on the Ottawa River*, administered by Public Works and Government Services Canada, the Ottawa River (but not its tributaries) is recognized as a navigable river and therefore subject to federal jurisdiction:

> … the navigation of the River Ottawa, as well as by vessels and boats as by rafts and cribs of timber and logs, is hereby declared to be subject to the exclusive legislative authority of the Parliament of Canada, and all canals or other cuttings for facilitating such navigation, and all dams, slides, piers, booms, embankments, and other works… shall be held to be works for the general advantage of Canada… and shall be under the control and management of the Department of Public Works…[18]

These works fall under the auspices of Public Works and Government Services Canada regardless of whether they are publicly or privately funded and/or operated. This provision has not been repealed.

Given the asymmetrical structure of water taking in favour of the hydroelectric power generators and their requirements for large quantities of water, they have the highest priority for water usage, and if the Ottawa River or its tributaries experience extremely low levels in the future, there is little that the Ottawa River Regulation Planning Board, or provincial or federal governments, can do to place limitations on hydroelectricity generators to protect downstream users. Governments' authority is largely confined to enforcement of adherence to maximum water levels and approvals of modifications to existing dam structures.

---

[17] Working Group II to the third assessment report of the Intergovernmental Panel on Climate Change, *Climate Change 2001: Impacts, Adaptation, and Vulnerability* (New York: IPCC, 2001) 746.

[18] "An Act respecting certain Works on the Ottawa River," cap.XXIV(1), *Statutes of Canada: Third Session of the First Parliament of Canada* (Ottawa: Brown Chamberlin, 1870) 77.

5.2.2 MACKENZIE RIVER BASIN

The Mackenzie River basin occupies 1,805,200 km^2 – more than one-sixth of the area of Canada – and encompasses parts of British Columbia, Alberta, Saskatchewan, the Northwest Territories, and the Yukon. It flows northward to Beaufort Sea, has seven major drainage basins: the main-stem Mackenzie River and several tributaries; Great Bear Lake and area; Liard River; Great Slave Lake and the Slave River; Lake Athabasca and the Fond du Lac River; Peace River; and Athabasca River. There are 87 minor transboundary sub-basins, three deltas (Mackenzie River delta, the world's tenth largest marine delta; Slave River delta on the south shore of Great Slave Lake; and the Peace/Athabasca delta on the western side of Lake Athabasca). The annual mean discharge is approximately 9000 m^3/s (compared with the St. Lawrence's 10,100m^3/s). A small population of 360,000 lives in the Mackenzie river basin area, and 88 per cent of this population lives upstream in British Columbia or Alberta. Aboriginal people living in the basin area speak eleven different languages.[19]

In 1977, a Memorandum of Understanding (MOU) Respecting the Water Resources of the Mackenzie River Basin was signed by Canada, British Columbia, Alberta, and Saskatchewan. The MOU established the intergovernmental Mackenzie River Basin Committee (MRBC) in order to conduct studies to improve understanding of natural processes occuring within the basin. A three-year, $1.6 million research project was submitted to Ministers in August 1981, and contained nine major recommendations that the MRBC was asked to implement.[20] Of these, a key recommendation was to develop an agreement among jurisdictions and establish a permanent board to implement the agreement. From 1991 to 1994, consultations regarding a master agreement and bi-lateral agreements among jurisdictions occurred.

The Mackenzie River Basin Transboundary Waters Master Agreement, based on the 1977 MOU, came into effect after being signed by the five provinces and territories, as well as the government of Canada on 24 July 1997. There are four components of the agreement:

1. principles for cooperative management of aquatic ecosystems, including water quality and quantity, seasonal variations, aquatic vegetation, fish, and invertebrates;
2. a dispute resolution mechanism;
3. an administrative mechanism and process that puts the agreement into motion; and
4. a provision for negotiation of bilateral water management agreements between neighbouring jurisdictions (to be added as schedules to the master agreement; these are to provide the substance and details of the agreement).

---

[19] Tom Cottrell, "Creating Intergovernmental Cooperation in the Mackenzie River Basin" [online] (Vancouver: Canadian Water Resources Association, 2000, accessed 8 June 2002) available from www.cwra.org/news/arts/mrbb.html; Internet.

[20] Mackenzie River Basin Board, "About us" [online] (2001, place unknown, accessed 7 June 2002) available from http://www.mrbb.ca/about.asp; Internet.

A key concept within the agreement is "equitable utilization" of resources, meaning that the use of water in one jurisdiction ought not unreasonably harm the ecological integrity of the aquatic ecosystem in another jurisdiction.

The Master Agreement provides for the Mackenzie River Basin Board (MRBB). Although the MRBB was appointed to address transboundary water management issues such as minimum flows, flow regulation and water quality; it does not have regulatory authority, nor does it have any legal or policy basis to regulate water resources of the provinces, territories, or the federal government.

The MRBB is composed of thirteen members – one representative each from the federal departments of Environment, Indian and Northern Affairs, and Health, and two representatives from each of the five provinces or territories (one of whom represents Aboriginal interests in each province or territory).[21] An independent secretariat is located in Edmonton within Environment Canada's Prairie and Northern Region and is headed by an executive director. One of the secretariat's main functions is to ensure that the provisions of the agreement are met. The MRBB is funded by contributions of all parties up to a maximum total annual budget of $280,000. Indian and Northern Affairs Canada has responsibility for water management in the territories, but according to one source, the Yukon Territorial Government is negotiating with Ottawa to devolve many water-related responsibilities.

5.2.2.1 THE YUKON-NWT TRANSBOUNDARY WATER MANAGEMENT AGREEMENT ANALYSIS

On 24 January 2002, the first of seven bilateral agreements was announced. The Yukon-NWT Transboundary Water Management Agreement is an agreement between the governments of the Yukon, NWT, and Canada and its purpose is to "cooperatively manage, protect and conserve the ecological integrity of the aquatic ecosystem of the Mackenzie River Basin common to the Yukon and the Northwest Territories while facilitating sustainable use of transboundary waters."[22]

The geographic scope of the agreement is limited to the Peel River Sub-Basin, the Rat River Sub-Basin, the Big Fish River Sub-Basin, and Moose Channel (and several rivers which are part of the sub-basins). Most of the rivers flow from the Yukon into the NWT.

Some of the bilateral agreement's objectives are as follows:

1. Protect the ecological integrity of the Peel River watershed, and any other transboundary waters between the two territories.
2. Ensure these transboundary waters are safe to drink, and the aquatic species taken from them are safe to eat.
3. Prohibit water transfer of the shared portion of the Mackenzie River Basin that could affect the ecological integrity of the aquatic resources"*

[21] Environment Canada, "Mackenzie River Basin Board" [online] (Ottawa: Environment Canada, 2002, accessed 8 May 2002) available from www.mb.ec.gc.ca/water/fa00s02.en.html; Internet.
[22] Indian and Northern Affairs Canada, "The Yukon-NWT Transboundary Water Management Agreement," section 1, "Purpose" [online] (Ottawa: Indian and Northern Affairs Canada, 2002, accessed 12 May 2002) available from www.ainc-inac.gc.ca/nr/prs/j-a2002/wate_e.html; Internet.

*Note: the Act does not specify who has the burden of proof to determine whether or not a water transfer would harm the basin's ecosystem.

"Aquatic ecosystem" is defined as including air, land, water, living organisms, including humans. "Water resources" includes "wetlands, deltas, tributaries to deltas, and groundwater, whether in a liquid or frozen state."

This master agreement meets the requirements of some land claim settlements – Metis, Dene, Gwich'in – which require that a body be established for environmental assessment and impact review. Note that this agreement "does not govern the actions of jurisdictions within their boundaries" and that "each jurisdiction retains licensing and regulatory control of water. The purpose of the bilateral and master agreements is to make cooperative management easier through information sharing."[23]

There are no timelines for the other six bilaterals to be negotiated.

Key aspects of the bilateral agreement are noted below with references to the corresponding section of the agreement in parentheses:

- The agreement is concerned with three ecological aspects: ecological indicators, water quality objectives, and water quantity objectives. Ecological indicators "provide early warning signs of environmental stress or quantify the magnitude of stress." These indicators have not yet been identified, but will eventually become part of the schedules appended to this agreement. (Schedule B.1)
- Water Quality Objectives are based on the CCME's 1999 Canadian Environmental Quality Guidelines, except where a specific parameter naturally exceeds the guidelines; then, the parameter objective will be amended for the purposes of this agreement. Any of the parameters can be changed based on monitoring programs, or a change in the CCME's parameters. There are approximately 80 parameters, or substances, included in the agreement. There are no parameters for temperature. (Schedule B.2)
- There is nothing in the agreement about specific water quantity objectives. Information and benchmark data regarding flow rates, seasonal variations, peaks and lows, etc. are yet to be developed. There is an interim water quantity objective that states that "there will be no significant change in the flow regime resulting from new human activity that could affect the aquatic regime." (Schedule B.3)
- If desired, an eight-member ad hoc committee may be formed to carry out specific tasks under this agreement. Members of the committee are to be appointed by their respective ministers or aboriginal organizations. Of the eight members, four must be from aboriginal organizations. (Section 6.4)
- Dispute Resolution: any disputes that cannot be resolved by the NWT, the Yukon, and Canada can be referred to the MRBB, who will examine and report on "facts and circumstances," and if necessary, will appoint experts to help with resolution.

[23] Mackenzie River Basin Board, "About us." Mackenzie River Basin Board, "About us."

Note that the agreement says nothing about what – if any – recourse is available to the parties if one or both are dissatisfied with the MRBB's conclusions. In addition, the wording of this agreement stops short of stating that the MRBB has the authority to decide or recommend; rather, its authority is limited to "examining," "reporting," and presenting "conclusions."

One of the responsibilities of the MRBB is to act as an intervener when required. There are no guidelines, however, about what issues may be referred to the MRBB. This problem recently came to light when the First Nations representative for Alberta asked the Board to become involved in the proposed Dunvagen Dam in Alberta. The proposal is not a transboundary issue; it is wholly contained in Alberta. The Master Agreement is silent on the conditions for requesting that the MRBB be an intervener in a dispute. Clear guidelines are needed for the Board, which has a limited budget.

- Within two years of signing this agreement, the parties must conduct a review to determine whether or not the agreement's objectives are being met. (Section 5.5) Any party can remove itself from this agreement by giving one year's notice. (Section 12.1)

5.2.2.2 ANALYSIS

A response to increasing climatic variability in the Yukon and NWT would rely heavily on the two territories' willingness to act cooperatively in an environmentally sensitive manner. It is too early to conduct an assessment of the 2002 Yukon-NWT bilateral agreement, but even at this early stage, it is worth noting some of the features that would likely inform the parties' response to climate change.

The bilateral agreement has no authority over the parties' jurisdiction, and each jurisdiction retains full control over its water resources. If conflicts between the parties arose, they could be referred to the MRBB, but the MRBB cannot compel a government that is a party to the Master Agreement to act or not act because it has no legal or policy authority. Nor could the MRBB regulate boundary or transboundary waters in a province or territory, because these sub-national governments have jurisdictional control (unless the federal government has jurisdiction, but the MRBB does not have authority over the federal government's activities, either).

The bilateral agreement, like the Master Agreement, is primarily a mechanism for communicating and coordinating information and activities of the signatories. The Master Agreement commits the MRBB to providing an annual report of its activities to the relevant Ministers, and every five years, the MRBB must report on the state of the aquatic ecosystem (Part D, Section 2(n,o)). These reporting requirements constitute a major strength of the Master Agreement.

The two territories' fragile ecosystem is particularly vulnerable to climate change and disputes may arise over degraded water basin ecosystems. The Water Quantity Objectives and Ecological Indicators have not yet been developed. These comprise two of the three ecosystem objectives, and would provide much-needed information about how this first bilateral agreement is to function. Development of detailed objectives and indicators may prove contentious. In addition, depending on when these are developed, climatic changes may influence the thresholds for parameters, and if climate change were to continuously affect the area, both water quality and ecological indicators would need to be frequently updated.

Development of water quality objectives specific to the Yukon and NWT may be difficult. For example, the Peel water basin is very pristine; so much so that naturally elevated levels of some parameters have been found, e.g., aluminum and copper. Similarly, it is anticipated that when the Laird River is monitored, some parameters will be naturally high. Schedule B of the agreement identifies the parameters that will be used, based on the CCME's 1999 guidelines. When naturally elevated levels occur and the Canadian Environmental Quality Guideline objective is exceeded, the agreement states that the water quality objective is to be amended to an agreed upon level based on the results of monitoring programs.[24] While the bilateral agreement is not bound by CCME guidelines and objectives, parties to the bilateral agreement may have differing views about what the objectives for parameters ought to be.

In Schedule B.3, the water quantity objectives are to include "parameters relating to changes in timing, frequency, and magnitude" of annual flow volumes, peak, seasonal, monthly, and daily flow rates. However, these have not been identified yet. The interim water quantity objective is that there should be "no significant change in the flow regime resulting from new human activity that could affect the aquatic system," but there could be many interpretations of what "significant" means. Jerome noted that there is data going back to the 1960s for annual averages, and standard deviations (for max. and min. levels), but this does not help with interpretation of non-specific language.

This first bilateral agreement was easy to negotiate because there is very little pressure to develop these areas. There are some coal deposits, and oil and gas interests are present, but overall, the territories are pristine. One former MRBB member anticipates that the Yukon-NWT bilateral agreement will prove the easiest to negotiate owing to the relatively pristine condition of the Yukon and NWT; in contrast, northern Alberta's oil sands near headwaters or B.C.'s Bennett Dam will present new difficulties. Development pressures are more intense in these areas, and difficult questions arise regarding how to best balance the goal of an ecologically healthy environment against development.

One problematic aspect of this bilateral agreement and others is that the boundaries used are political, not ecosystem-based, and if monitoring occurs at a jurisdictional boundary by one party, the data won't be as accurate as if it were collected at the source point, which may reside in another jurisdiction. However, the bilateral agreement provides for joint undertakings and for a water resources committee to be struck if needed (section 6.0); presumably, the committee would address this problem.

Both the Yukon-NWT bilateral agreement and the master agreement give strong consideration to aboriginal interests. The bilateral agreement complies with the Umbrella Final Agreement with Yukon First Nations, which states that the governments of Canada and the Yukon must try to negotiate water agreements between the Yukon and other jurisdictions. The bilateral agreement states in two places that it must not contravene existing Aboriginal treaties or land claims, and it defines "aboriginal organizations" for the purposes of this agreement, as being the Nacho Nyak Dun First Nation, the Vuntut

[24] "The Yukon-NWT Transboundary Water Management Agreement" Schedule B.2.

Gwitchin Tribal Council, and the Tr'on dek Hwech'in First Nation in the Yukon, and the Gwitch'in Tribal Council and the Inuvialuit Game Council in the NWT. If the parties decide to establish an ad hoc water resources committee, four of the eight members must be representatives of aboriginal groups.[25]

The bilateral agreement describes protocols for communication, notice of development, and reporting requirements. These provisions have been largely untested, and clarification is needed; for example, the section on notification and communication provides for "early consultation and notification of developments and activities that might affect another jurisdiction and share environmental assessment information in a timely and consistent manner" if developments or activities are being contemplated.[26] However, the protocols for "early notification" have not been worked out, and whether or not notification must be written or verbal will need to be determined. The terms "timely" and "a sufficient period of time" also need to be defined.

The provision for Notice of Development (section 7.2) requires that early notification of proposed development is required, but there is no provision for cumulative impacts of developments. Such a consideration is outside the scope of the agreement and could become an issue only if the parties agreed that cumulative effects ought to be examined.

One of the more problematic provisions of the bilateral agreement is described in Section 8.2, under which a party or aboriginal organization may:

> refer an unresolved dispute, difference or question to the Mackenzie River Basin Board and request the Board to examine and report upon the facts and circumstances. The Board may appoint one or more experts to assist with resolving the dispute.

The Master Agreement has a similar provision (Part E). This mechanism has proved problematic because there is nothing to give the MRBB's decisions "teeth"; its decisions can be ignored by any province or territory without legal consequence (although politically, public dissent or moral suasion may influence the actions of a sub-national government). One positive aspect is that the MRBB should be used as a last resort because parties to the Master Agreement are required to attempt to resolve issues as best they can before referring disputes to the MRBB.

As long as a province or territory is a signatory to the Master Agreement (and bilateral agreements, when they are developed), it is honour-bound to adhere to the objectives in principle and the detailed water quality, quantity, and ecosystem parameters (when they are developed). However, any party may release itself from these agreements by giving notice of its intent to withdraw.

Given that the Master Agreement and the bilateral agreement cede decision-making authority regarding water management to the provinces, territories, and federal government, responses to climate changes rely extensively on the will of these sub-national governments. Should the parties to the bilateral agreement, for example, decide against pursuing imitative or adaptive strategies to climate change, there is little in the

---

[25] Ibid., Section 6.4.
[26] Ibid., Section 7.0

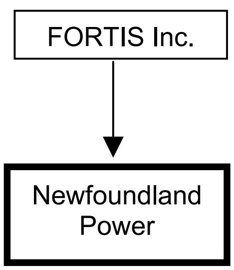
Master Agreement or in the Yukon-NWT bilateral agreement that would compel governments to address climate change effects.

5.2.3 CHURCHILL RIVER (NEWFOUNDLAND AND LABRADOR)

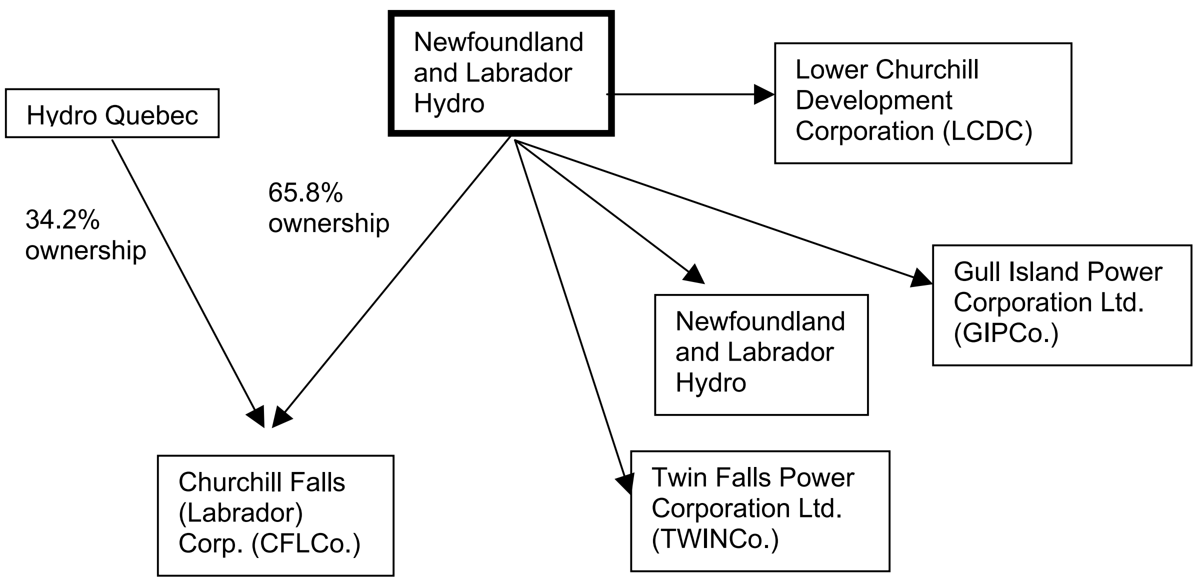
Originally named the Grand River, in 1939 its name was changed to the Hamilton River (after a Newfoundland Governor, Sir Charles Hamilton). In 1965, it was again renamed and became the Churchill River in honour of Sir Winston Churchill. With its tributaries, it drains most of the Labrador Plateau at an area of 79 800 km^2, and is the largest source of freshwater in Atlantic Canada. The Churchill River is 856 km in length to the head of Ashuanipi River, and it has a mean discharge rate of 1580 m^3/second.[27]

5.2.3.1 CHURCHILL FALLS (NEWFOUNDLAND AND LABRADOR)

Churchill Falls starts from Ashuanipi Lake, empties into Lake Melville. The Falls' vertical drop is 75 metres (245ft.), although the total drop over 32 km is more than 300 metres. Churchill Falls accounts for three-quarters of the province's total electricity generation (95 per cent of Newfoundland and Labrador's electric energy is generated by hydroelectric power plants). More than 70 per cent of this energy is exported.[28]



- FORTIS Inc. also owns Martime Electric, and 50% of Canadian Niagara Power Company, which distributes electricity to Fort Erie and Cornwall, ON, and upstate New York.
- Newfoundland Power is a subsidiary of FORTIS.
- Newfoundland Power is the main retailer of electricity in Newfoundland; distributes power to 85% of the population.
- Newfoundland Power buys 90% of its supply from NLH; the rest comes from its own smaller hydro generating facilities.



[27] Energy, Mines and Resources Canada, Surveys and Mapping Branch, "Drainage Basins" *The National Atlas of Canada* 5th ed. [online] (Ottawa: Environment Canada Inland Waters Branch, 1984, accessed 23 October 2002) available http://atlas.gc.ca/site/english/facts/rivers.html; Internet.
[28] Newfoundland Outport, "Newfoundland and Labrador – Energy" [online] (Newfoundland: Newfoundland Outport, 2002, accessed 20 October 2002) available http://www.durham.net/~kburt/index.html; Internet.

In Newfoundland and Labrador, electricity is generated and distributed by two utilities, Newfoundland Power and Newfoundland and Labrador Hydro (NLH). NLH is a crown corporation established by a 1961 statute and services most Labrador customers, while Newfoundland Power services mostly Newfoundland.[29]

Until 1996, Newfoundland and Labrador Hydro (NLH) was accountable only to the government for its capital expenditures and major decisions. The province's Hydro Act was amended that year to establish an "arm's length" relationship, and NLH became accountable both to the government, and to the Public Utilities Commission, which is an independent regulator.[30]

Construction on Churchill Falls (Labrador) Corp. (CFLCo.) began in the 1960s in Churchill Falls. Today, the turbines are located underground near the falls, and eight generators are located on the Upper Churchill portion of the river. Smallwood Reservoir feeds the power plant, and its area is 6462 km^2 (2% of the area of Labrador), making it the largest reservoir in Canada. The Smallwood Reservoir has a minimum 464-metre water level and a maximum level of 473 metres.

Large-scale hydro-electric projects usually emit minor pollutants but they flood large tracts of land, impairing ecosystems and in some cases, creating difficulties for aboriginal people. The Innu were especially upset at the prospect of hydro development contemplated by the Newfoundland and Labrador and Quebec governments.[31] Government officials had considered building additional facilities on the lower Churchill River, valued around $10 billion, but the economic merit of new development has not yet been proven.

Almost all power generated from the 5428 MW CFLCo. is sold to Hydro Quebec under a long-term, fixed price contract that expires in 2041. This power accounts for about one-fifth of Hydro Quebec's total electrical output, and this leaves Hydro Quebec with ample power to export to other provinces and states.[32] The former premier of Newfoundland and Labrador, Brian Tobin, has stated that the process which brought about this agreement "was arrived at in an unfair way" and described the considerable profits which

---

[29] Government of Newfoundland and Labrador, "Overview of the Electrical Power Industry in Newfoundland and Labrador" [online] (St. John's, NL: Government of Newfoundland and Labrador, 2000, accessed 26 May 2002) available http://www.gov.nf.ca/mines&en/ENERGY/OverviewofIndustry.htm; Internet.

[30] Department of Mines and Energy, Government of Newfoundland and Labrador, *An Electricity Policy for the 21st Century: Options and Opportunities* [online] (St. John's, NF: Government of Newfoundland and Labrador, 2002, accessed 28 September 2002) available from http://www.gov.nf.ca/mines&en/energy/policyreview/ep.pdf; Internet.

[31] CBC Newsworld, "Natives block signing of Churchill hydro deal" [online] (Toronto: CBC, 1998, accessed 26 May 2002) available from http://www.gov.nf.ca/mines&en/energy/policyreview/ep.pdf; Internet.

[32] BBC, H2G2 program, "Churchill Falls, Newfoundland and Labrador, Canada" [online] (London, UK: British Broadcasting Corp., 2001, accessed 22 October 2002) available http://www.bbc.co.uk/dna/h2g2/alabaster/A442865; Internet.

accrue from Quebec's resale to American states as "unconscionable" as part of his bid to renegotiate the agreement.[33]

In early 2002, the Newfoundland and Labrador Department of Mines and Energy undertook public consultations for Newfoundland and Labrador's electricity policy review. This review began in 1998 to look at the structure of the electricity industry, its role in the province's economy, its regulation, pricing, and future sources of electricity. One option not under consideration is privatizing Newfoundland and Labrador Hydro.

5.2.3.2 ANALYSIS

One constraint on potentially increased flooding if efforts are made to augment the force of Churchill Falls, or if development on the Lower Churchill becomes financially attractive, is physical one: the operation does not have dams, only earthen dykes, and operation above the maximum level would jeopardize the dykes' integrity. Smallwood Reservoir feeds the power plant, but permission would need to be sought from the Newfoundland and Labrador government for new construction to exceed maximum levels. Regardless of whether this change would warrant an amendment to the Lower Churchill Development Act, or simply an administrative change (i.e. an order-in-council), non-government organizations and aboriginal groups are likely to object because of damage caused by flooding. As a Department of Mines and Energy document published earlier this year states, "there is no incentive for a utility company to become more efficient or to encourage conservation."[34]

The NLH has an "environmental affairs" section, but there is little that can be done to protect a flooded ecosystem, or one which has been degraded because of flooding. Flooding is the most serious environmental problem, and this should be balanced against not only economic development considerations, but against other forms of power generation. As with other large-scale dams, the Churchill Falls is vulnerable to climatic change: more water would increase flooding, but less would prompt the NHL to find ways to compensate for lost power generation. In the latter case, this would likely mean expanded areas of flooding, and in a "business as usual" scenario, only the government's prioritization of environmental protection versus economic growth will determine whether or not climate change would exacerbate environmental degradation.

5.2.4 LAKE OF THE WOODS

Lake of the Woods is a domestic water with an international component, and responsibility for its management rests chiefly with the Lake of the Woods Control Board (LWCB). The LWCB was created under the Lake of the Woods Control Board Act of 1921, with amendments made in 1958, and is a Canadian board consisting of four members. Part of the lake is in Minnesota, that gives it an international dimension. The International Lake of the Woods Control Board (ILWCB) was created by a 1925 treaty

---

[33] Government of Newfoundland and Labrador, News Release, "Premier's address to Montreal Rotary Club" [online] (St. John's, NF: Government of Newfoundland and Labrador, 1996, accessed 26 May 2002) available from http://www.gov.nf.ca/releases/1996/exec/1015n06.htm; Internet.

[34] Department of Mines and Energy, Government of Newfoundland and Labrador, *An Electricity Policy for the 21st Century: Options and Opportunities*, 3

between Canadian and the U.S. that is made up of a convention and a protocol. The ILWCB falls under the aegis of the IJC.[35]

The LWCB is responsible for regulation of water levels in Lake of the Woods and Lac Seul, whose waters flow west into the English and Winnipeg Rivers. When the water level in Lac Seul exceeds a certain threshold, the LWCB also control the diversion of water from Lake St. Joseph into Lac Seul. The Winnipeg River drains into Lake Winnipeg. The LWCB regulates lake levels and river flows by operating dams located at the outlets of Lake of the Woods and Lac Seul. Approximately two-thirds of the inflow to Lake of the Woods is from Namakan and Rainy Lakes, which are both managed by the IJC.[36] The remainder comes from Rainy River tributaries and rivers and streams that flow directly into Lake of the Woods.

The four members who comprise the LWCB each report to the government that appoints them by order-in-council: Canada (one member), Ontario (two members), and Manitoba (one member).[37] Environment Canada appoints the federal government's member, the Ministry of Natural Resources appoints Ontario's two members, and Manitoba Conservation appoints the Manitoba member. Each appointee must be a professional engineer.[38] The ILWCB consists of one Canadian and one American member.

The LWCB's decision-making process is usually by consensus, and disagreements are rare. If necessary, decisions may be voted on, according to the LWCB's bylaws. Each member has one vote, the Chair may or may not vote at his discretion. The Chair rotates annually among the members.

Although the LWCB has primary jurisdiction, potential for conflict exists between the U.S. and Canadian governments and water users on either side of the international border. A key parameter for determining the circumstances under which the ILWCB has jurisdiction is based on water levels. The outflow of Lake of the Woods is subject to approval by the ILWCB whenever levels exceed or fall short of elevation parameters. The LWCB is charged with maintaining levels between 321.87 and 323.47 metres.[39]

The LWCB Act describes the Board's main responsibility:

> It shall be the duty of the Board to secure severally and at all times the most dependable flow and the most advantageous and beneficial use of the waters of the Winnipeg river and of the English river…[40]

---

[35] International Lake of the Woods Control Board, "Board responsibilities" (2002, accessed 4 September 2002) available from http://www.mvp-wc.usace.army.mil/ijc/low/low_board.html; Internet

[36] Lake of the Woods Control Board, "Balancing the Interests" (Ottawa: Lake of the Woods Control Board, 2002, accessed 11 July 2002) available from http://www.lwcb.ca/balancing.html; Internet.

[37] Lake of the Woods Control Board, "Board Description, Members & Staff" (Ottawa: Lake of the Woods Control Board, 2002, accessed 11 July 2002) available from http://www.lwcb.ca/BoardMembersAndStaff.html; Internet.

[38] Environment Canada, *An Act to Amend the Lake of the Woods Control Board Act*, Section 2 (Ottawa: Environment Canada, 2001, accessed 19 July 2002) available from http://www3.ec.gc.ca/EnviroRegs/Eng/SearchDetail.cfm?intAct=1008; Internet.

[39] Lake of the Woods Control Board, *Year 2001 High Water Levels on Lake of the Woods and the Winnipeg River* (Lake of the Woods Control Board, 2002, accessed 14 July 2002) available from http://www.lwcb.ca/permpdf/LW2001HighWaterReport30May2002.pdf; Internet.

[40] Environment Canada, *An Act to Amend the Lake of the Woods Control Board Act*, Section 3.

The LWCB recognizes that it "serves vastly diverse interests in the basin and it tries to produce conditions that are reasonably acceptable to all."[41] No one's interests are well-served when extremely high or low water levels occur, and for this reason, the LWCB strives to balance the multi-purpose Lake of the Woods basin so that competing interests are accorded priority at different times. For example, if water is needed in February so that a utility can provide heating and lighting, the utility will probably get it, but in April, a main priority is to meet fish spawning targets. The LWCB has not prioritized types of usage, but it has committed to meeting with "specific interest groups" no less than three times annually. Some of these interests are municipalities, cottagers and resort owners, aboriginal people, and hydroelectric power producers.

The LWCB states that it welcomes feedback from its American neighbours, and it recognizes that there are many commonalities regarding desirable water levels.[42] A greater problem stems from the challenge of regulation within strict parameters. The high water levels of 2001 and 2002 illustrate this problem.

The Lake of the Woods basin experienced very high levels due to the highest rainfall in 54 years between April and July 2001 in the area which flows into Lake of the Woods. This extreme weather event could not have been forecast; to the east and west of the basin, weather conditions were very dry during the same period. The level of the Lake of the Woods was above the upper threshold at which the ILWCB has final authority for 77 days. Similarly, June 2002 experienced very high levels of precipitation: approximately 12 inches of rain fell within a four-day period.

The ILWCB's authority is effective when levels exceed 323.39 metres, which is 8 centimetres less than the upper limit of the permitted operating range. Although the ILWCB has one Canadian and one American member, the ILWCB has generally made consensus-based decisions. One reason is that the Canadian member of the ILWCB must be the same individual that represents the Canadian government on the LWCB. Another reason is that during high water events, members are aware that dams have limits as to how far they may open, and they appreciate that precipitation is not easily forecast.

5.2.4.1 ANALYSIS

The Lake of the Woods and Lac Seul are well governed by the LWCB, and to a lesser extent, the ILWCB. The LWCB produces thoughtful and detailed publications about its management decisions and practices, and it has solicited public opinion and met with several special interest groups about its operations. Its handling of high water levels in 2001 and 2002, including its decision to update users more frequently than usual and to widen its list of media contacts in Canada and the U.S. (e.g. by making its toll-free number for water conditions more widely accessible, further to a suggestion made by water users) suggest that it is sensitive to users' needs and viewpoints, and committed to balancing interests as much as possible.

---

[41] Lake of the Woods Control Board, "Balancing the Interests"

[42] Lake of the Woods Control Board, *Year 2001 High Water Levels on Lake of the Woods and the Winnipeg River* 23.

Given the LWCB's detailed management practices which balance the needs of different user types, its careful monitoring of levels, and its awareness of both Canadian and American users' views, it is particularly well-equipped to handle climate-induced change. Its regular reports ("notice boards" which give water levels, outflow rates, and trends for Lake of the Woods, Lac Seul, Nutimik Lake, and the Winnipeg River) are highly informative. If temperature and precipitation changes were especially severe in this region, however, there may be increased concern expressed by Americans, particularly if water levels were to drop to a point where they felt their needs were being sacrificed to Canadian interests.

Water levels over the past several years have been less variable than normal; in the last two years, variability of levels has increased. Given that the LWCB has experience with managing fluctuating levels within 1.6 metres in wet and dry conditions, it is better equipped than most transboundary water boards to handle climate change-induced conditions. If the high levels of the past two years continue, the LWCB may need to consider enlarging the capacity of the Lake of the Woods outlet to accommodate the increased volume. If climate change effects produced highly variable water levels, the Board might also revisit the 1.6 metre gap and consider whether or not increasing this interval would allow it to retain control before the ILWCB becomes involved.

If the LWCB's decisions were to become less consensus-based, the voting structure is unlikely to favour any of the three parties to the Lake of the Woods Act (Ontario's two members' preferences could be negated by the two other votes). The rotating chair has discretionary authority as to whether or not it votes, but it would not be wise for a chair to take advantage of this temporary option.

Each of the governments of Canada, Manitoba, and Ontario have concurrent legislation for the Lake of the Woods Control Board (Manitoba was not represented until 1958, when it passed its own legislation, administered by its Department of Conservation, and replaced one of the two government of Canada representatives with its own[43]; in the same year, the governments of Canada and Ontario amended their legislation to reflect this development). None would be able to amend the structure of the LWCB without the consent of the others, since the membership is described in the legislation. The Canadian government, however, ought to be regarded as the senior partner of the Board because of its commitment to the international treaty.

It is difficult to envisage how the federal government might be able to increase its influence, if it chose, given that it possesses just one of four votes, and would require the provinces' consent to alter the Board's structure. The three governments each appoint a professional engineer and an alternate to the LWCB by an order-in-council and each member "holds office during the pleasure of the authority that appointed him."[44] Conceivably, an individual member could be replaced if he or she performed in a manner inconsistent with a government's expectations. A change in membership, however, would not alter the structure of the Board nor its decision-making process. Relations

[43] Manitoba Department of Conservation, *The Lake of theWoods Control Board Act* (Winnipeg: Queen's Printer for the Province of Manitoba, 1987, accessed 19 September 2002) available from http://www.gov.mb.ca/chc/statpub/free/pdf/l030.pdf; Internet.
[44] Environment Canada, *An Act to Amend the Lake of the Woods Control Board Act*, Section 2(4).

among the parties have been largely harmonious, as evidenced by consensus-based decisions to date.

Although the ILWCB has not experienced difficulties regarding decision-making, severe climatic change may create new problems. These problems would likely be due to disagreements about how to interpret the data, or they may be political in nature. It is less likely that disagreement would arise over the scientific data, because the ILWCB uses the detailed data collected by the LWCB as a basis for its decisions. Climate change-induced conditions may or may not result in greater variances of water levels, and if these variances become more pronounced, a greater number of decisions will fall under the jurisdiction of the ILWCB as the LWCB tries to maintain levels within a narrow range. If the two-member international body cannot achieve consensus, the dispute is to be referred to the IJC, and its decision is final.[45] The migration of issues from the domestic LWCB to the ILWCB presents a new set of variables for Canada as the IJC becomes the decision-making body, and the IJC's structure is also examined in this report.

5.2.5 CHURCHILL RIVER (SASKATCHEWAN)

The Churchill River is 487 km in length and originates in East Alberta, flows through Saskatchewan and Manitoba, and discharges into the Nelson River. In Saskatchewan, the river basin occupies 72,000km^2, or about one-half of Saskatchewan's northern boreal forest.[46] Several lakes are part of this river system, incl. Reindeer Lake, Wollaston Lake, and Lac La Ronge. The Churchill was a meeting ground for Plains, Swampy and Woodland Cree, and Dene. Today, the majority of aboriginal people living there are Cree, Dene, and Metis.

The amount of surface water in the Churchill River is highly variable and the Canadian Prairies are more prone to drought conditions than other parts of the country. Between the late 1970s and 1993, precipitation was below average and the Churchill had its lowest flow rates ever. The summers of 2001 and 2002 also saw very low water levels to the particular detriment of farmers. Over one-half of its runoff occurs between March and May and is supplemented in the summer months by precipitation or groundwater discharge from springs.[47] Although the Saskatchewan government considers the dams, wells, weirs, dugouts, and drainage channels in the province as "relatively minor,"[48] the Canadian Parks and Wilderness Society's chapter in that province is critical of the lack of integrated planning along the Churchill, and notes that "there are threats to this great river basin – threats from human developments such as mining, industrial logging, hydroelectric projects and water diversion projects."[49]

---

[45] International Water Law Project, Article 6 of the *Agreement Between the United States of America and Canada to Regulate the Level of Lake of the Woods* (2002, accessed 12 June 2002) available from http://www.internationalwaterlaw.org/RegionalDocs/Lake-Woods.htm; Internet.

[46] Canadian Parks and Wilderness Society - Saskatchewan, "Churchill River" [online] (Saskatoon, SK: CPAWS, 2001, accessed 19 May 2002) available http://www.cpaws-sask.org/campaign/forest/churchill.html; Internet

[47] Saskatchwan Environment, "Water Management Framework – Surface Water" [online] (Regina, SK: Government of Saskatchewan, 2002, accessed 19 May 2002) available

[48] Ibid.

[49] Canadian Parks and Wilderness Society - Saskatchewan, "Churchill River."

Like many prairie rivers, the Churchill River crosses several jurisdictions, and is subject to an inter-provincial sharing arrangement. The 1969 Master Agreement on Apportionment is an agreement among the provinces of Alberta (Alberta Environment), Saskatchewan (Sask Water), and Manitoba (Manitoba Conservation), and the government of Canada (Environment Canada and Agriculture and Agri-Food). Under the agreement, the waters that flow mostly west to east are shared so that each jurisdiction may take up to 50 per cent of the natural flow ("natural flow" refers to the flow of water that would occur in a river if it had never been affected by human activity), which is calculated over a twelve-month period.[50] The agreement established the Prairie Provinces Water Board (PPWB) to administer the agreement (established in 1948, the PPWB predates the Master Agreement but was re-established under the 1969 Master Agreement).

Located in Regina, Saskatchewan, the PPWB is comprised of one member from each of the three provinces and two members from the federal government. It has three permanent committees: a committee on hydrology, a committee on water quality, and a committee on groundwater. The committees provide analysis and advice to the Board, which is also supported by Environment Canada's Transboundary Waters Unit (before 1995, the PPWB had an executive director and secretariat, but these were folded into Environment Canada's operations). It relies on a consensus-based decision-making process and, according to Environment Canada, a spirit of cooperation and mutual respect.[51]

The Board consists of five members (each one has an alternate): two members from the federal government and one from each of the three provinces. All members are appointed by a governor general in council or a lieutenant governor in council. The PPWB is chaired by one of the federal members (if absent, the other federal member assumes chairmanship). The major decisions of the Board require unanimity, and only meetings of the Board where all members or their alternates are present are considered official.[52]

The PPWB's administration of quantitative aspects of inter-provincial water management is well-known. It strives to ensure a consistent water supply to meet the Master Agreement's requirement of an "equitable sharing" of prairie waters by recommending in some cases a minimum flow of water at provincial borders. It monitors stream flow at fourteen locations along the Alberta-Saskatchewan and Saskatchewan-Manitoba borders and its Committee on Hydrology estimates and reports flows. It also uses hydrometric data to calculate natural flow from more than 90 sites.[53]

Water quality issues are also part of the PPWB's mandate and it has twelve monitoring stations for this purpose. In 1992, the Agreement on Water Quality was signed and became part of the Master Agreement on Apportionment. It states that the PPWB will "foster and facilitate interprovincial water quality management among the parties that encourages the protection and restoration of the aquatic environment." The PPWB has

---

[50] Environment Canada, "Water Quantity Activities – The Master Agreement on Apportionment" [online] (Ottawa: Environment Canada, 2002, accessed 19 May 2002) available http://www.mb.ec.gc.ca/water/fa01/fa01s21.en.html; Internet.
[51] Environment Canada, "PPWB – Overview" [online] (Ottawa: Environment Canada, 2002, accessed 2 June 2002) available http://www.mb.ec.gc.ca/water/fa01/fa01s01.en.html; Internet.
[52] Master Agreement on Apportionment, "By-Laws," Part II, 70.
[53] Ibid.

moved toward integrated ecosystem and watershed management methods, and as part of its commitment to water quality, it is responsible for comparing the results of monitoring activities against PPWB objectives and trying to ensure that the provinces have compatible water quality objectives. Water quality objectives are based on provinces' objectives (in some cases, the objectives are basin-specific), and where these are not available, the PPWB uses the Canadian Council of Ministers of the Environment's surface water guidelines. Environment Canada contributes to monitoring activities through its 75 water quantity monitoring stations, 16 meteorological stations, as well as the twelve water quality monitoring sites along provincial borders.

The first major hydro development in Saskatchewan was Island Falls. Construction of Island Falls facilities by Hudson Bay Mining and Smelting Co. began in 1927 to provide power to its mining operation in Flin Flon, and until 1981, was operated by the Churchill River Power Co., a subsidiary of the Hudson Bay Mining and Smelting Co. SaskPower took over the operation after 1981, and today, the Island Falls plant is now remotely operated in Regina.

The Churchill River is subject to the PPWB and the Master Agreement on Apportionment, and its basin has been the site of various proposals to construct dams. In 1978, an Environmental Impact Assessment was performed by Saskatchewan Environment, and resulted in a decision to forbid a project to build a major hydro-electric power dam by the Sask. Power Corp. In the 1970s, SaskPower proposed the Wintego Dam, comprised of 3 potential power dam sites to bring the Churchill River's water level up to the level of Reindeer Lake, and was rejected by the Saskatchewan government. In 1998, the proposal was revived. The Cree Nation and many environmental groups are opposed to the plan.

The Churchill River was, as of 1995, nominated to be a Canadian Heritage River, but in the CHRS 2000-01 annual report and on its website, it is still listed as a "nominated river," and is the only such river to not have an anticipated designated date.

5.2.5.1 ANALYSIS

The PPWB has been hailed by Environment Canada as "a model for dealing with interjurisdictional issues," noting that "because of the PPWB's consensus approach, provincial governments, as the primary regulator of water supplies, have always complied with the Agreement."[54] A less sanguine outlook for the PPWB and the Master Agreement on Apportionment, however, quickly replaces rhetoric as the difficulties of recent summers due to extreme low flows are considered.

The IPCC's report *Impacts, Adaptation, and Vulnerability* also notes that annual streamflow in the Canadian Prairies and Midwest U.S. may increase or decrease, but that the region is particularly vulnerable to drought, and significant declines in summer streamflow are possible. There is a great deal of uncertainty, however, regarding climatic impacts on farming, groundwater levels, and water quality.[55]

---

[54] Ibid.
[55] IPCC 746.

The PPWB's role is limited to coordination, monitoring, and recommendations to its members' governments. If climate changes caused multi-year droughts, higher-than-usual springtime runoff, and unpredictable seasonal variations, the PPWB's consensus-building approach may be tested to the point where its members cannot find agreement. Each member is permitted to refer an issue to the federal court of Canada's trial division, but this has never occurred. Note that each province became a member of the PPWB by an order-in-council.

A party to the Master Agreement on Apportionment could pursue legal action against another member through the federal court of Canada, but this is highly unlikely because "all recommendations to government, all By-Laws and budgets-in-total shall require unanimous approval."[56] For other items, a simple majority is required. Each government has publicly stated its strong commitment to upholding the agreement, but political will is an insufficient substitute for a binding legal instrument, and orders-in-council can be rescinded. The PPWB's consensus-building skills will be more rigorously tested if summer drought conditions occur with greater frequency.

5.2.6 CANADA-ONTARIO AGREEMENT RESPECTING THE GREAT LAKES BASIN ECOSYSTEM

The Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem ("COA") allows the government of Canada to fulfill its obligations under the Canada-United States Great Lakes Water Quality Agreement. Effective 22 March 2002, after two years of negotiation, this federal-provincial agreement is for a five-year period. A six-month review will be conducted in the fifth year and must include public consultation, the findings and outcomes of which must be made public for 60 days after the consultation period. This agreement has been renegotiated four times since it was first passed in 1971, and like previous agreements, represents a wholly new agreement between the two levels of government, rather than an updated version of previous agreements, and identifies new priorities based on recent developments.[57]

The purpose of this shared agreement is to "restore, protect and conserve the Basin Ecosystem" and "work in a cooperative, coordinated and integrated fashion." The COA identifies twelve principles which are intended to guide the actions of the parties. Among these are an ecosystem approach, pollution reduction (with an emphasis on control at the source), the precautionary principle, sustainability, and conservation (energy and water should be conserved to sustain the physical, chemical, and biological integrity of the basin).[58]

The Parties to the Agreement are as follows:

Government of Canada	**Government of Ontario**
Minister of the Environment	Minister of the Environment
Minister of Natural Resources	Minister of Natural Resources
Minister of Agriculture and Agri-Food	Minister of Agriculture, Food and

[56] Master Agreement on Apportionment, "By-Laws," Part II, 70.

[57] Telephone conversation with Adele Iannantuono, Environment Canada, Ontario Region. 18 October 2002

[58] "The Principles of the Agreement," *Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem.*

Minister of Canadian Heritage
Minister of Fisheries and Oceans
Minister of Health
Minister of Public Works and Government Services
Minister of Transport

Rural Affairs

The lead agency for the government of Canada is Environment Canada; for the Ontario government, it is the Ministry of the Environment. In the language of the COA, a "party" refers to either the federal or Ontario government; it does not refer to individual departments or ministries. There is no mention within the COA text of financial commitments to the COA and its annexes, but it is assumed that each ministry or department will make available sufficient funds to carry out its responsibilities.

The agreement is administered by a Management Committee co-chaired by two representatives, one from Environment Canada and one from the Ontario Ministry of the Environment. In addition, each ministry or department has a representative at the levels of regional director-general and assistant deputy minister. The Management Committee came into force at the time the COA became effective, and it is responsible for setting priorities, establishing strategies, coordinating an annual internal assessment of the COA against the established objectives, and identifying gaps and coordinating the work of the Annex committees. At the time of writing, the Management Committee has had two meetings since the COA came into effect.

Although originally, there were plans to have an annex implementation committee for each of the four annexes, each with an "annex management lead" reporting to the Management Committee, the intent now is to establish only one annex committee. This proposed change is due in part to a recognition that in many cases, membership in these committees overlaps, and some mandarins would do little more than attend multiple meetings of annex committees. There are four annexes to the COA:

i) Areas of Concern (AOC)
ii) Harmful Pollutants
iii) Lakewide Management
iv) Monitoring and Information Management

The goals associated with each annex are qualitative in nature. For example, the annex for areas of concern identifies three goals: restoration of environmental quality in at least two of the sixteen AOCs; carrying out actions for Remedial Action Plans in at least six AOCs; and at least partial rehabilitation of ecological systems in the rest of the AOCs. The annex for harmful pollutants also has three broad goals, including progressing towards "virtual elimination" of persistent bioaccumulative toxic substances such as mercury, dioxins, furans, and PCBs, and reducing other harmful pollutants.

Each annex must specify "five-year societal goals for the Basin Ecosystem, specific to the environmental issue or component of environmental management, which is the subject of the Annex."[59] Annexes must also specify each party's commitment to realizing the goals of the Annex, describe the desired results, outline a management structure to ensure coordination of the parties' activities, and identify "quantitative and

[59] "Annexes to the Agreement," *Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem*

measurable environmental outcomes and the name of the Party responsible for specific actions and monitoring and reporting the results."[60]

The terms of reference for the annex implementation committee are not available at the time of writing. However, it is expected that they will include a decision-making process that is consensus-based, and that a dispute resolution mechanism will also be outlined. Regardless of what form dispute resolution will take, unresolved disputes will likely be referred to the Management Committee. There is no formal decision-making process, nor is one expected, but decision-making at this level would probably involve the representatives' consultation with their respective ministries or departments.

Finally, a stakeholder committee is to be established to make decisions about which parties, and representatives of the parties, will undertake specific tasks "on the ground"; it is hoped that this committee will be established by March 2003.

The parties' degree of commitment to the COA appears very strong politically, but legally, there are means of withdrawal before the five-year period expires which are built into the agreement. The first is the statement "The Agreement may be terminated earlier [than five years] by either Party giving the other at least twelve months written notice." Another means of reducing one's commitments is to terminate an annex, and either party may do so by giving three months' notice to the other. A party must, however, conduct public consultations if it intends to terminate an annex, or develop a new one. In addition, if either party cannot fulfill its obligations as described in the annexes, it must notify the other party twelve months in advance.[61]

5.2.6.1 ANALYSIS

Effects of climate change on the Great Lakes basin ecosystem are expected to result in increased surface water evaporation, decreased summer flows, and increased winter flows (due to more frequent mid-winter thaws and earlier snow melt). Possible qualitative effects include changes in phytoplankton or zooplankton biomass, northward migration of fish species, and possible extirpations of coldwater species.[62] The purpose of the COA is intended to address mostly qualitative issues in the Great Lakes ecosystem, and would therefore be of limited use if water quantities were severely affected by climate change, despite an established relationship between water quality and quantity. Concerning water levels, a more relevant transboundary agreement is the 1985 Great Lakes Charter and its 2001 annex. If qualitative changes in the basin were definitively established during the COA's five-year duration, its parties would be obliged to address them, but actions may be limited to further monitoring if the parties felt they were overburdened with existing commitments.

Politically, the COA is a highly visible federal-provincial agreement concerning a water basin that is home to a population that has the highest density in Canada. It describes an arrangement between the two levels of government that builds on previous cooperative agreements, and this thirty-year history gives it an element of stability and predictability. However, some groups have criticized previous COAs for falling short of their

---

[60] Ibid.
[61] "Amending Annexes," *Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem*
[62] Working Group II to the third assessment report of the Intergovernmental Panel on Climate Change, *Climate Change 2001: Impacts, Adaptation, and Vulnerability* (New York: IPCC, 2001) 746.

commitments, especially regarding AOCs, only one of which was restored during the 1994-2000 period. The 2002 COA's very modest goals for AOCs have been strongly criticized by groups such as the Canadian Institute for Environmental Law and Policy, which notes that the goal of restoring at least two AOCs over five years means that "if this goal is indeed met by the year 2006, the parties will be one-third of the way to the goal they originally committed themselves to achieving by 2000."[63]

The presence of myriad paths for either level of government to extricate itself from part or all of the agreement before the end of the five-year period presents a potential but significant weakness of the COA. While such options for withdrawal are based on recognition that each government has constitutional jurisdiction over various environmental features, it does not closely bind the parties to their commitments. This concern is not without precedent: the option for partial withdrawal was used while the 1994 COA was in effect, and allowed the government of Ontario, through its lead agency the Ministry of the Environment, to withdraw its support of some initiatives at a time when the government, and in particular the Ministry of the Environment, was undergoing a downsizing exercise.

Another concern regarding the COA is that at its highest level of decision-making, it is silent on how decisions are to be reached. If the annex implementation committee cannot resolve an issue, it is to refer it to the Management Committee. Presumably, the issue would be one which is particularly intractable, yet there are no formalized rules for how the Management Committee is to debate and decide the problem.

If climatic changes were manifest in the Great Lakes basin in ways which degrade its ecosystem and/or cause concern among citizens and non-government organizations, the COA is flexible enough that it could respond to by developing another annex, provided that there is sufficient political will to do so.

Climate change might also affect the COA because of a "Commitment to Notify" provision in the agreement:

> Canada will consult with Ontario regarding any changes to the Canada-United States Great Lakes Water Quality Agreement or on *any other international activities that may affect this Agreement.* [italics added]

If Canada ratifies the Kyoto Protocol to the United Nations Framework Convention on Climate Change, it would be obliged to consult the province before it implements programs or initiatives aimed at meeting its commitments under the Protocol. This explicit requirement to notify gives the province potential leverage and it might be able to change or even block the federal government's plans to reduce greenhouse gas emissions. However, a legal opinion would be useful to accurately forecast the degree of authority the notification section gives the government of Ontario. Either party still has the option of complete withdrawal from the COA, and this feature of the COA, more than any other, has the potential to undermine a Canadian response to climatic change in the Great Lakes basin.

---

[63] Canadian Institute for Environmental Law and Policy, *Walkerton: What Have We Learned?* [online] (Toronto: Canadian Institute for Environmental Law and Policy, 2001, accessed 13 October 2002) available http://www.cielap.org/waterspecialweb.pdf; Internet, 20.

5.2.7 ONTARIO PERMIT TO TAKE WATER (PTTW) PROGRAM

The PTTW program is administered by the Ontario Ministry of the Environment (MOE), and derives its authority from section 34 of the Ontario Water Resources Act. Under the PTTW program, users of water in Ontario who use more than 50,000 litres per day require a permit. All types of uses, and all types of sources of water (e.g. from a well, lake, stream, or storage pond) require a permit if over the 50,000 litre threshold.[64]

Approximately one-half of all municipal water supplies in Ontario are from groundwater sources, and Ontario municipal governments are subject to the PTTW program. Some exceptions to the requirement to obtain a permit include water for emergency fire fighting, water for livestock or poultry, and water for home gardens and lawns.

Applications are received and decisions are made at the Ministry's five regional offices. There is a thirty-day comment period, and the decision-maker is obliged to take any Ontario citizens' comments into account before deciding whether or not to grant a permit.[65] Permits have expiry dates, often between five and ten years, and usually have conditions attached; for example, the permit holder must perform certain monitoring functions, or maintain a record of water use, or for surface water permits, the holder may be restricted to a percentage of available stream flow.[66] Permit holders must renew to continue taking water. Applicants who are denied a PTTW may appeal under the Ontario Environmental Bill of Rights.

If the water is from a groundwater source, the applicant must provide a hydrogeological report, which will provide information about pump test results to ensure long-term sustainability. If the water is from a surface source, the applicant must provide information on stream flow, other uses of the water, and what the potential impact on the stream might be. The MOE evaluates PTTW applications "according to a fair-share concept."[67]

Currently, there are approximately 5540 active permits in Ontario. The bottled water industry accounts for about 10 per cent of the total volume of water taking permitted. Permits for bottled water are valid for one to two years; surface water permits are usually valid for a five-year period, and groundwater permits expire after ten years.[68]

In addition to the PTTW program, the Ontario regulation "Water Taking and Transfer" (regulation 285/99 under the Ontario Water Resources Act) ensures that large volumes of water cannot be taken from a water basin. The Ontario government claims that this regulation was passed as part of its obligations under the Great Lakes Charter. It

[64] Ontario Ministry of the Environment, *Review process for permits to take water* (Toronto: Queen's Printer for Ontario, 2000, accessed 24 July 2002) available from http://www.ene.gov.on.ca/programs/3930e.pdf; Internet, 1.
[65] Environmental Bill of Rights Office, Ontario Ministry of the Environment, *Environmental Registry* (Toronto: Queen's Printer for Ontario, 1994-2000, accessed 9 June 2002) available http://www.ene.gov.on.ca/envision/env_reg/er/registry.htm; Internet.
[66] Ibid., 2.
[67] Ibid.
[68] Ontario Ministry of the Environment, Public Information Centre, *Permit to Take Water Program* (Toronto: Ministry of the Environment, 30 June 2002) 1.

prohibits water transfers outside a basin in containers with a capacity greater than 20 litres. Ontario was the first province to pass a regulation to prevent the transfer of large volumes of water out of water basins (including the Great Lakes).

The OWRA reg. 285/99 contains a section on the PTTW program, and the wording is similar to that contained in the OWRA itself. However, there is one statement that appears only in the regulation. The purpose of the regulation is "to provide for the conservation, protection and wise use and management of Ontario's waters."[69] (section 1). The statement reads, "A Director who is considering an application [for a PTTW] *shall consider*... protection of the natural functions of the ecosystem" (section 2 of reg.285, italics added). This wording is stronger than section 34 of the Act because it refers to the ecosystem itself, and not simply to other users of water. Section 34 of the OWRA does not mention "ecosystem."

Another point of differentiation is that the regulation states that a director must consider "ground water that may affect or be affected by the proposed surface water taking, if the application is for a permit to take surface water."[70] This point suggests concern for aggregate effects of permits, and demonstrates a sensitivity regarding potential effects on ground water.

There are strong critics of the PTTW program. In a brief to the Walkerton Inquiry in January 2001, the Environmental Commissioner of Ontario (ECO) noted that the impetus for selecting the PTTW program for his office's review stemmed from public concern, complaints about the quality of information in permits and proposal and decision notices, and the Walkerton contaminated water incident in 2000, among other reasons.[71] In a detailed analysis of the program, particularly the permits themselves, the ECO review concluded that:

> Public accountability and transparency are threatened because of inaccuracies and omissions in the Registry notices for PTTWs, and because the actual PTTWs often omit or misrepresent crucial information… MOE's poor administration of the PTTW system poses real implications for ecosystem protection… MOE has admitted that it does not know how much water is available in the province for taking purposes.[72]

In a follow-up analysis of the program conducted several months later, the ECO found little improvement in the quality of information. The Canadian Institute for Environmental Law and Policy is just as critical, noting that in light of the MOE's decision to allow commercial bottlers to take 18 billion litres of water per year, perhaps

---

[69] Ontario Ministry of the Environment, "Regulation made under the Ontario Water Resources Act: Water Taking and Transfer" (Toronto: Queen's Printer for Ontario, 1999, accessed 18 July 2002); available from http://www.ene.gov.on.ca/envision/env_reg/documents/a/ra8e0037.pdf; Internet.
[70] Ibid.
[71] Environmental Commissioner of Ontario, *Ontario's Permit to Take Water Program and the Protection of Ontario's Water Resources* [online] (Toronto: Environmental Commissioner of Ontario, 2001, accessed 5 October 2002) available http://www.eco.on.ca/english/publicat/walker01.pdf; Internet, 3.
[72] Ibid., 25

the Ministry of Natural Resources (which demonstrated greater concern for ecosystem integrity), should investigate the MOE.[73]

5.2.7.1 Analysis

The PTTW program issues many permits for groundwater sources, and these types of permits usually valid for ten years, which is the maximum time permitted. Given that the recharge rates for groundwater in Canada (and groundwater dynamics generally) are poorly understood, permits for groundwater takings should be monitored carefully and frequently – especially shallow wells – as climate change effects become increasingly evident in Ontario.

The administration of the Ministry of the Environment's PTTW program has improved slightly in recent years; for example, ten years ago, decisions about granting permits and imposing conditions were often made by summer interns and students and this is no longer the case. However, permit decisions continue to be made at the Ministry's five regional offices, and this system does not allow for watershed concerns to be factored into the Ministry's decision-making process. Although more attention has been given to the PTTW program, its administration of PTTWs still requires broad changes. The problems identified by the COA suggest that the PTTW program is so poorly administered that its actions place ecosystems at risk, and climate change would exacerbate the level of risk to an already vulnerable environment.

Another concern is that the PTTW program does not appear to be coordinated with the government of Ontario's Low Water Response program. Although the Low Water Response program is relatively new, a closer relationship between the two programs would enable the Ministry of the Environment, which assists in the administration of the Low Water Response program, to make decisions based in part on data and observations from local conservation authorities. This additional information might form part of the terms of permits issued, so that permit holders' rights are circumscribed by any Level I, II, or III conditions in effect under the Low Water Response program.

If severe climate change were to cause decreased surface and groundwater, there is a possibility of legal implications as permits could be issued which fail to adequately consider "the protection of the natural functions of the ecosystem," under regulation 285/99. Conversely, if fewer permits were issued in the interest of protecting ecosystem functions, prospective users may argue that their right to access to water is harmed, and legal challenges may also arise under these circumstances.

5.2.8 UPPER THAMES RIVER (LONDON ON)

Upper Thames River watershed covers 3482 km^2 of mainly rural areas in Southwestern Ontario except for urban centres of London, Stratford, and Woodstock, and exists wholly within Ontario. It was designated a Canadian Heritage River in February 2000 by the CHRS. Responsibility for the Upper Thames River rests primarily with the Upper

[73] Canadian Institute for Environmental Law and Policy, *Walkerton: What Have We Learned?* [online] (Toronto: Canadian Institute for Environmental Law and Policy, 2001, accessed 13 October 2002) available http://www.cielap.org/waterspecialweb.pdf; Internet, 17.

Thames River Conservation Authority (UTRCA). It derives its authority from the 1946 Conservation Authorities Act.[74]

The UTRCA was formed in 1947 as a result of lobby efforts of local farmers and conservationists. However, responsibility is divided due to other provincial agencies' legislative authority; for example, the Ontario Water Resources Act and the Environmental Protection Act, both administered by the Ministry of the Environment; the Lakes and Rivers Improvement Act, administered by the Ministry of Natural Resources; and the Planning Act and the Municipal Act, both administered by the Ministry of Municipal Affairs and Housing.[75] Jurisdictional overlap is further complicated by the federal government's role: the Department of Fisheries (the Fisheries Act) and the Department of the Environment (Canada Water Act, Canadian Environmental Protection Act) both have legislative authority under certain circumstances.

There are four objectives which form its mandate:

- "to ensure that the upper Thames watershed's rivers, lakes and streams are properly safeguarded, managed and restored";
- "to protect, manage and restore watershed woodlands, wetlands and natural habitat";
- "to develop and maintain programs that will protect life and property from natural hazards such as flooding and erosion";
- "to provide opportunities for the public to enjoy, learn from and respect the watershed's natural environment."

The UTRCA recognizes that the Upper Thames River provides for a diverse range of activity, and that these activities may at times be in conflict, it has no policies regarding prioritization by water user type.

In 2001, the UTRCA's revenue was $6,365,693 from the following sources:

- 43% user fees
- 14% general levy from watershed municipalities
- 11% special project funding
- 9% other provincial sources
- 8% special benefiting municipality levy
- 5% MNR grant for flood control
- 5% federal sources
- 4% capital reserve
- 1% donations[76]

The UTRCA has no control over surface and groundwater takings, which are administered by the Ontario Ministry of the Environment's Permit to Take Water Program (see page 86, "Ontario Permit to Take Water Program"). If permits were issued

[74] Upper Thames River Conservation Authority, "The Conservation Movement in Ontario" (London, Ontario: UTRCA, 2002, accessed 26 June 2002) available from http://www.thamesriver.org/Home_Page/about_page2.htm#conservation%20movement; Internet
[75] Ministry of Natural Resources, *Ontario Low Water Response* (Toronto: MNR, 2002, accessed 4 September 2002) available from http://www.mnr.gov.on.ca/MNR/water2000/OLWR_opt.pdf; Internet
[76] Upper Thames River Conservation Authority, "Funding Sources" (London, Ontario: UTRCA, 2002, accessed 29 June 2002) available from http://www.thamesriver.org/Home_Page/about.htm; Internet.

which resulted in impaired water quantities, the conservation authorities in Ontario – including the UTRCA – would be unable to prevent or reverse the Ministry of the Environment's decision.

Nor is it clear whether or not the Permit to Take Water Program takes into consideration the modifications for which conservation authorities are responsible. For example, the Upper Thames River has two reservoirs, Wildwood Reservoir on Trout Creek and Pittock Reservoir on the South Thames, and the effects of these flood control structures on the river may or may not be a factor in the Ministry of the Environment's decision to issue permits, or attach conditions to permits.

Of the myriad pieces of legislation pertaining to water quality, water quantity, and water-related land management in Ontario, authority for short-term (i.e., 24 hour) drought management is derived from the Ontario Water Resources Act, the Environmental Protection Act (both administered by the MOE), and the Fisheries Act (administered by the Department of Fisheries and Oceans).[77] However, many other government ministries, departments, and agencies have control over related aspects of water management. The many levels of jurisdiction, coupled with overlapping legislative authority, create potential for interjursidictional dispute and mismanagement of water resources such as the Upper Thames River.

One tool recently developed to assist both provincial and local conservation authorities with water management is the Ontario Ministry of Natural Resources' "Ontario Low Water Response" program, which was developed in response to severe weather conditions in 1998 and 1999 that resulted in some of the lowest water levels and driest soils in several decades. The program, which began in 2000, is intended to offer short-term, low-water management strategies to mitigate effects of drought. It involves five provincial ministries, the Association of Municipalities of Ontario, and Conservation Ontario.

Operation of the Low Water Response program relies heavily on cooperation between provincial and local authorities, with the provincial government coordinating policies, science, and information systems, and providing overall direction, and the conservation authorities and local governments collecting information, interpreting policy, and delivering programs. Cooperation is essential: the program relies on a highly coordinated flow of information, from Environment Canada (weather and climate data), MNR (precipitation, streamflow, weather data), the Conservation Authority (precipitation, streamflow, weather data), and/or the MOE, to the MNR for analysis of reported conditions, and then to a Water Response Team (WRT) for confirmation.[78] WRTs are composed of local and provincial water managers and local water users, and are charged with coordinating local activities, which vary depending on the condition level.

Under the Ontario Low Water Response program, there are three levels which may be used, triggered by conditions based on precipitation and streamflow: Level I (Conservation), Level II (Conservation, Restriction), and Level III (Conservation, Restriction, Regulation).

---

[77] Ministry of Natural Resources 24-26.
[78] Ibid., 17.

Since Low Water Response came into effect, levels I and II have been used. Level III, which has been used only once, provides for legal action against users that contravene low flow regulations, and permits prioritization of types of water usage. A declaration of any condition level may cause economic loss, but municipal or provincial authorities are not responsible for compensation. The imposition of a Level III may be open to a challenge by water users who rely on access to water for economic purposes.

5.2.8.2 ANALYSIS

Although jurisdiction for the Upper Thames River is clouded by the many government agencies, departments, and ministries, it is primarily governed by the UTRCA, a provincial creation which is arguably the closest authority to water usage in the Upper Thames River. Its proximity gives it intimate knowledge of practices and trends, and other governments rely on the UTRCA's expertise. A considerable degree of overlap exists, but potential jurisdictional difficulties are minimized due to shared goals and a high degree of cooperation. If climatic changes caused water levels in the UTRCA's jurisdiction to drop significantly, the UTRCA would not have the authority to act on its own to prevent water takings.

To manage water resources such as the Upper Thames River, the Ontario Low Water Response program offers an excellent means of addressing low flow conditions through coordinated provincial and local efforts for a timely response to unanticipated conditions which produce low flow. The effectiveness of the program relies on coordination of information and activities among the many government ministries and departments and agencies. Fortunately, low water conditions build up over weeks and months, which allows all stakeholders sufficient time to generate a coordinated response.

The Ontario Low Water Response program has the potential to provide a highly effective and integrated response to extreme water conditions arising from extreme climatic or weather conditions. One cautionary note is warranted, however, concerning the implementation of Level III, which allows the program to implement regulatory measures which may prohibit some kinds of water use. Although the WRT must demonstrate that it has implemented and documented conservation and reduction efforts associated with Levels I and II before proceeding with a Level III condition, Level III gives considerable authority to the members of the Low Water Response program. In addition to prohibitive measures, priorities based on type of water usage can be established by the program using a basic model which divides usage into essential, important, and non-essential. These measures may impact the perceived rights of water users, and the Low Water Response program may be vulnerable to a legal challenge regarding its implementation of Level III conditions.

The Upper Thames River and similarly governed watersheds and basins in Ontario are well-served by the Ontario Low Water Response program, which has the capacity to provide an effective and timely set of response to changing water conditions due to severe climatic change effects. Assuming that adequate funding and staffing are allocated to the program, a coordinated effort from all levels of government, with input from local water users, should be sufficient to address future climate change-related conditions.

6.0 PERCEPTIONS OF CLIMATE CHANGE AND FAIRNESS IN APPORTIONING AND ALLOCATING WATER IN THE SASKATCHEWAN RIVER BASIN

6.1 INTRODUCTION AND OBJECTIVES

In many areas of the world, including Canada, the allocation of water has sometimes resulted in conflict between and within user groups. Presently in some regions of the world, water has been fully allocated or over allocated for withdrawal uses – municipal, agricultural and industrial. Allocation of fresh water for in-stream purposes – environmental and recreational – has become increasingly difficult. Anthropogenic climate change may significantly affect the temporal and spatial distribution of water availability.

Research has focused on the possible physical effects of climate change on hydrologic systems as well as on determining strategies to manage those impacts. With regards to the latter, management practice has focused on increasing water use efficiency through the use of economic instruments and technological innovation. Miller *et al*. (1997, 158) maintained that water was a

> multifaceted resource, and competing claimants to the resource value its various dimensions differently. Valuations of the quantity, reliability, quality, location and timing dimensions of the resource differ across competing user groups, and these relative values change over time. In addition, the degree to which there is direct competition among water users varies with the type of use and across the various dimensions of the resource…The increased potential for conflict warrants closer examination of the ways in which institutions may channel such competition to either facilitate or hinder [the implementation of management programs].

Institutions and institutional arrangements can be defined as both formal components (*e.g.* rules, laws, programs, administrative arrangements) and informal components (*e.g.* self-imposed codes of conduct, norms of behaviour), and their enforcement characteristics. "Together they define the incentive structure of societies and specifically economies" (North, 1994, 360). One aspect of this report focuses attention on an informal aspect of institutional arrangements that considers norms of behaviour. It desires to determine if the statements made by Miller *et al.* (1997) concerning the variety of views different water users have about water can be extended to their perceptions of fairness in its management. It adopts a case study approach using the Master Agreement on Apportionment as it applies to the Saskatchewan River.

The Master Agreement on Apportionment, administered by the Prairie Provinces Water Board, sets out the rights and duties of the federal and provincial governments pertaining to the sharing of the waters of eastward flowing streams that cross interprovincial boundaries. Under present streamflow conditions the apportionment needs of the Saskatchewan River at the Saskatchewan-Manitoba boundary and the North Saskatchewan River at the Alberta-Manitoba boundary are easily met. On account of significant water consumption related to irrigation development in southern Alberta, during low flow years that province delivers little more than the required flow of the

South Saskatchewan River to Saskatchewan. Under future water development projections and climate change scenarios, interprovincial water apportionment in that basin will present an increasing challenge.

This report has four objectives. First, to provide insight into how climate change may influence surface water flows in the Saskatchewan River Basin. Second, to briefly describe the manner in which waters in the Saskatchewan River Basin are apportioned among the three prairie provinces and allocated among users groups within each province. Third, to report on a survey that explored the perceptions of fairness among water users within the basin. Fourth, to provide recommendations for the future.

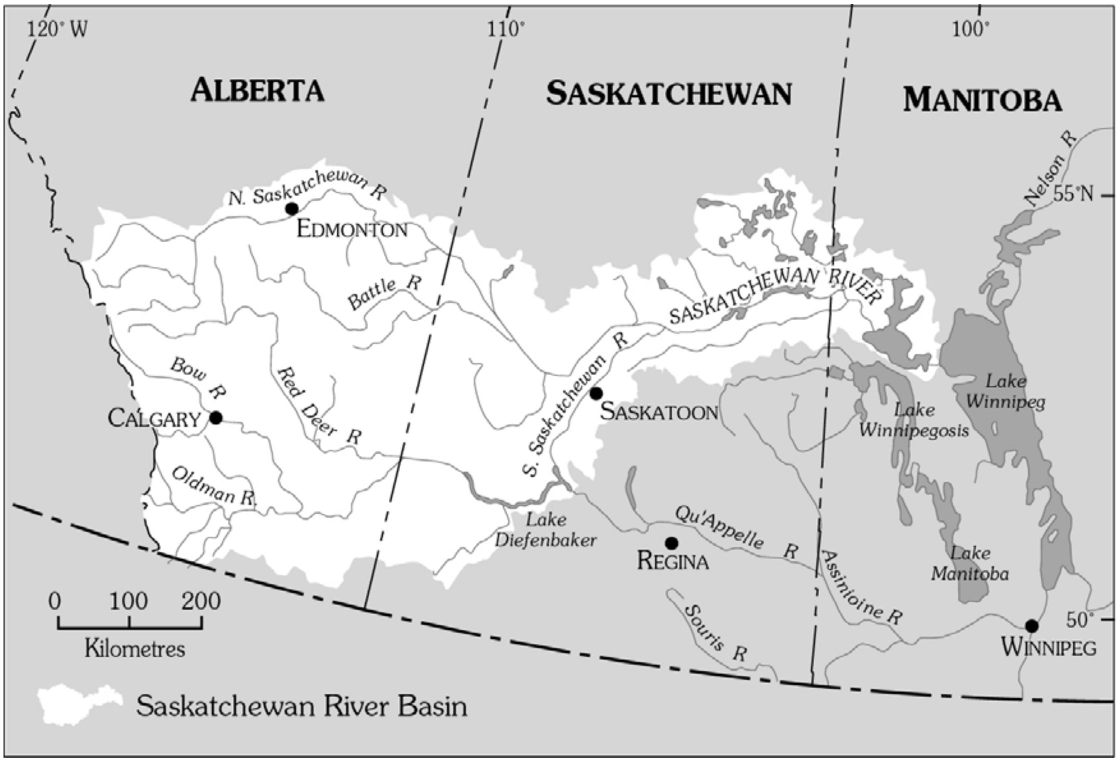
The report is organized around two major parts. Part 1, entitled "Physical Aspects of the Basin and Water Use" describes the physical setting, the Master Apportionment Agreement, and water uses. It then provides an analysis of streamflow trends, climate scenarios, and hydrology. Part 2 is entitled "Perceptions of Climate Change and Fairness in the Saskatchewan River Basin. It presents the questionnaire, the methods of analysis, and the results from the survey. Implications and recommendations are provided at the end of the report.

6.2 PHYSICAL ASPECTS OF THE BASIN AND WATER USE

6.2.1 PHYSICAL SETTING

The Saskatchewan River system (Figure 6.1) originates as several streams in the eastern slopes of the Rocky Mountains. It is the fourth longest in North America. The surface area of the basin is approximately 336,000 km^2, 70% of that being in Alberta (SNBB 1972, PFRA 1982, SSRBS 1989, Kellow 1989).

FIGURE 6.1 - Saskatchewan River Basin



The two principle tributaries, the North and South Saskatchewan Rivers originate close to one another in the Columbia Icefields. The North Saskatchewan River flows easterly through prairie parkland terrain joining the South Saskatchewan River near St. Louis, Saskatchewan. The Saskatchewan River continues to flow east into Manitoba joining Lake Winnipeg and thence to Hudson Bay via the Nelson River.

The 157,400 km^2 South Saskatchewan River is comprised of three major rivers: the Oldman and Bow, which meet near Bow Island to form the South Saskatchewan River, and the Red Deer, which joins the South Saskatchewan just east of the Alberta-Saskatchewan boundary. Notable tributaries include the St. Mary, Belly and Waterton Rivers that originate in Montana. The Bow River contributes about 43% of the flow at the Saskatchewan boundary, the Oldman, 36% and the Red Deer, the remaining 21%.

There are very few tributaries that originate in the plains portion of the basin and their contribution to the total flow is small. At the Manitoba boundary, on average, the North Saskatchewan and the South Saskatchewan Rivers each make up about half the flow of the Saskatchewan River.

The basin can be divided into two physiographic regions. At the western extremity at the continental divide is the Cordillera with mountains exceeding 3000 m in height descending to alpine forests at about 2000 m through foothills to open grassland at 1000 m. Streams in this zone are deeply incised.

The remainder of the basin, the Interior Plains, is rolling topography dominated by short-grass prairie in the south and tending to mixed prairie, parkland, and some evergreen forest in the north. The North and South Saskatchewan Rivers flow though valleys some 15 to 60 m deep (PFRA, 1982). The basin contains some poorly organized drainage, particularly in Saskatchewan, therefore about 14% of the total drainage area does not contribute to flow in a median year (Cohen, 1989).

The prairie portion of the basin is subject to a cold continental climate with short hot summers and cold winters. The region is semi-arid with annual precipitation being about 350 mm to 450 mm, the least amount of precipitation being where the South Saskatchewan River leaves Alberta. (This is a striking contrast to the average precipitation of 1800 mm in the Rockies.) Gross evaporation on the prairie ranges from 650 to 1100 mm leading to a significant annual moisture deficit (Martin, 2002).

Flow in the Saskatchewan River system is dominated by snowmelt runoff in May, June and July from the Rocky Mountains and foothills. The remaining runoff comes from summer and fall precipitation. Some 75% of the annual Alberta runoff originates as snowmelt runoff in the mountains and foothills (Kellow, 1989). Runoff in the plains is small and is dominated by spring snowmelt. In the irrigation districts of southern Alberta, less than 20% of the annual runoff is due to rain during the irrigation season (PPWB, 1974).

Initial European contact in the basin originated with the fur trade. While Captain John Palliser declared much of the basin unfit for agriculture in 1857, the building of the transcontinental railway in the 1880s promoted settlement and significant agricultural development. A drought in the 1890s led to the *Northwest Irrigation Act* of 1894 thus enabling corporate irrigation development, particularly in Alberta (PFRA, 1982).

Under the Act, riparian water rights were suppressed and the concepts of western water law developed in Australia and the United States were introduced to Canada. In particular, water was declared the property of the crown and rights to use water were assigned priorities of domestic, industrial (including irrigation) and other. Rights were granted on the basis of date of application thus beginning the administrative regime of "first in time, first in right" that is still in place in western Canada today (Lucas, 1990).

Large-scale irrigation development by railways and private entrepreneurs in Alberta proceeded with government support. A water dispute with the United States over irrigation development in the Milk and St. Mary's River basins was one of the factors leading to the *Boundary Waters Treaty* of 1909 and water apportionment in those basins. Further irrigation development in organized districts in the South Saskatchewan River basin, beginning in 1915, and water development following the 1930s drought led to increasing concerns about water sharing, particularly in the South Saskatchewan basin.

These concerns led to the establishment of the Prairie Provinces Water Board (PPWB) in 1948 (PPWB, 1965; Stutt, 1995). This board was mandated to provide advice to governments on the best use of interprovincial waters and on allocations between provinces (PPWB, 2000). Its weakness was an inability to examine long-term water planning (Saunders, 1988). As a result, the 1969 *Master Agreement on Apportionment* was negotiated and the PPWB reconstituted to administer the Agreement.

6.2.2 THE MASTER AGREEMENT ON APPORTIONMENT

The *Master Agreement on Apportionment* (Barton, 1984; Kellow, 1989; PPWB, 2000) sets out the rights and duties of the three prairie provinces concerning the apportionment of eastward flowing interprovincial streams. Often described as a Saskatchewan River basin Agreement, the Master Agreement applies to all streams that flow eastward across either the Alberta-Saskatchewan or Saskatchewan-Manitoba boundary, or both. (The Master Agreement also applies to transboundary lakes and ground water.)

The essence of the Master Agreement is that the province of Alberta is entitled to make a net depletion of one-half of the natural flow of the waters arising in that province, allowing the remainder to flow into Saskatchewan. Further, Saskatchewan is entitled to make a net depletion of one-half of the water flowing in from Alberta and of waters arising in Saskatchewan and must allow the remainder to flow into Manitoba. These entitlements are subject to certain exceptions. The specific arrangements concerning the Saskatchewan River will be discussed later in this section.

The Master Agreement defines natural flow as the quantity of water which would naturally flow in any watercourse had the flow not been affected by human interference or human intervention, excluding any water which is part of the natural flow that is not available for the use because of the provisions of any international treaty. From the early days of the Master Agreement, the difficulties of calculating a true natural flow were appreciated. The Board agreed in 1976 agreed that "effects on runoff of changing land use patterns are not considered in the computation of natural flow (changes in land use include land clearing for agriculture, drainage, forestry, industrial and urban development and other land uses). Changes in natural flow due to groundwater inflow or recharge are not considered in the computations" (Board Minute).

The natural flows calculated for Board purposes could best be described as flows subject to apportionment or apportionment flows. For the purpose of this study, therefore, 'natural flow' is used to indicate flows subject to apportionment.

The Master Agreement has five schedules. Schedules A and B pertain to the division of waters between Alberta and Saskatchewan and Saskatchewan and Manitoba, respectively.

Schedule C reconstitutes the PPWB to administer the Agreement with two members (including the chair) from the federal government, and one each from the three provincial governments. The schedule states that the members "shall be chosen from those engaged in the administration of water resources or related duties for Manitoba, Saskatchewan, Alberta or Canada". While its principle role relates to the administration of the Master Agreement, the Board does perform a variety of other water management related functions. The PPWB has a small secretariat based in Regina.

Schedule D concerns previous allocations of interprovincial waters and Schedule E concerns water quality. The latter schedule, signed in 1992, sets out the duties of the PPWB relating to water quality and establishes water quality objectives for specified transboundary river reaches. These objectives include the North Saskatchewan, Red Deer, and South Saskatchewan Rivers at the Alberta-Saskatchewan boundary, and the Saskatchewan River at the Saskatchewan-Manitoba boundary.

6.2.2.1 APPORTIONMENT OF THE SASKATCHEWAN RIVER

Calculating natural flows for apportionment involves identification and measurement or computation of depletions due to storage, diversion, evaporation and consumptive use, and routing these depletions to the point of apportionment where they are applied to the recorded flows at that point to produce natural flows.

Over the years several different conceptual methods have been reviewed for the determination of natural flow (PPWB, 1965; PPWB, 1976). By far the most commonly used is the Project Depletion Method and this is the method used in the Saskatchewan basin.

The method involves direct measurement of diversions into, and return flows from, individual projects treating the project area itself as a black box unless the project area is large enough to generate natural runoff. The method, while very dependent on hydrometric data, does not require the extensive meteorological, topographic and land use data of other methods. While conceptually simple, the calculations can be complicated by a number of factors such as the need to calculate evaporation, estimate natural runoff within a project, and determine the significance of minor diversions (ungauged diversions).

Determining natural flow for the North Saskatchewan River at the Alberta-Saskatchewan boundary is very straightforward as consumptive use is small (less than 35,000 ac-ft), live storage is around 25% of mean annual flow, and reservoir evaporation is less than 1% of natural flow. As a result, the calculation is carried out by determining the change in storage on two reservoirs and routing the effect to the Saskatchewan boundary. Natural flow is usually within one or two percentage points of recorded annual flow and the long-term average is a fraction of a percentage point below 100%. There is no formal apportionment of the Battle River, which rises on the Alberta plains and flows eastward to join the North Saskatchewan River in Saskatchewan.

On the other hand, the calculations for the South Saskatchewan River are very complex. There are about 1.3 million acres being irrigated in southern Alberta with over two million acre-feet of water annually. Evaporative losses from reservoirs is also a major consideration. Data from 57 hydrometric stations and 6 meteorological stations are used in the calculation of natural flow. Recorded flow on the South Saskatchewan River can be less than 60% of natural flow although the average is around 80%.

Natural flow calculations for the Saskatchewan River at the Saskatchewan-Manitoba boundary are relatively straightforward. The runoff arising in Saskatchewan is only 4% of the flow coming from Alberta (PPWB, 1976). The main components of the calculation are change in storage in reservoirs, withdrawals from Lake Diefenbaker and flow routing. Recorded annual flows are commonly only 10% lower than natural flows.

There are some additional apportionment concepts that must be considered. The first relates to the apportionment period. The PPWB apportions streams on an annual basis. That is, the agreement is met if the annual natural flow is not depleted by more than 50%. The Master Agreement however also speaks of "equitable apportionment". This implies consideration of the volume and timing of the water released to the downstream party. In the case of the South Saskatchewan River, there are two specific constraints related to equitable apportionment (Kellow, 1989).

- Alberta is entitled to a 2,100,000 million acre-ft minimum net annual depletion as long as the depletion does not reduce the flow at the boundary to less than 42.5 m^3/s.
- Alberta must maintain a minimum daily discharge at the boundary of 42.5 m^3/s or one-half the natural flow, whichever is less.

The result is that flows are apportioned annually based on the calendar year. Meeting the conditions of equitable apportionment however requires periodic audits. For the South Saskatchewan River, there are quarterly audit periods and when flows are low, monthly or shorter audit periods are employed. As streamflow conditions become more exigent, the monitoring grows more intensive. In effect, apportionment is carried out "on-the-fly".

In 2001, for example, recorded flows in May, June and July were less than 50% of the monthly natural flow. However, as the flow at the boundary did not drop below 42.5 m^3/s, there was no violation of the Master Agreement. In effect, excess deliveries had been "banked" earlier in the year; at the end of the year about 58% of the natural flow had been delivered.

In the case of both the North Saskatchewan and Saskatchewan Rivers, the audit period is the same as the apportionment period and there are no minimum flow requirements.

The apportionment procedures used by the PPWB have evolved over the years and are very thoroughly documented. The procedures are formally adopted by Board minute.

The annual historic natural flows and recorded flows of the North and South Saskatchewan Rivers are displayed in Figures 6.2 and 6.3. As mentioned earlier, only for the South Saskatchewan River are there significant differences in the two figures. As one would expect, when natural flows are low, recorded flows at the boundary as a percentage of natural flow are also low.

FIGURE 6.2: North Saskatchewan River Recorded VS. Natural Flows

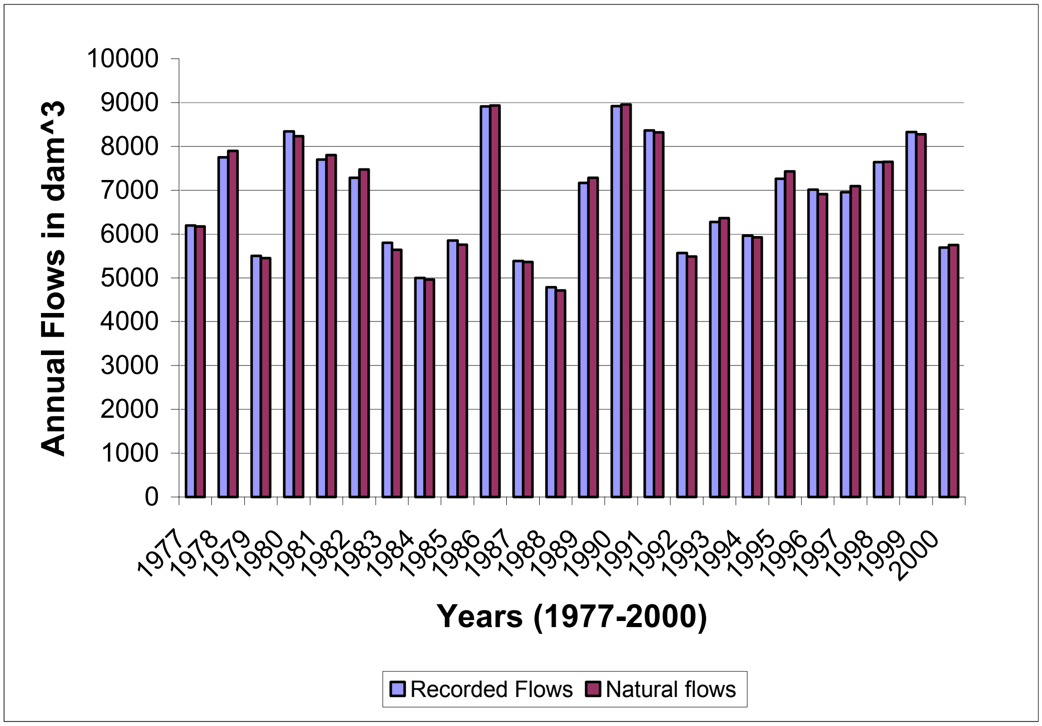
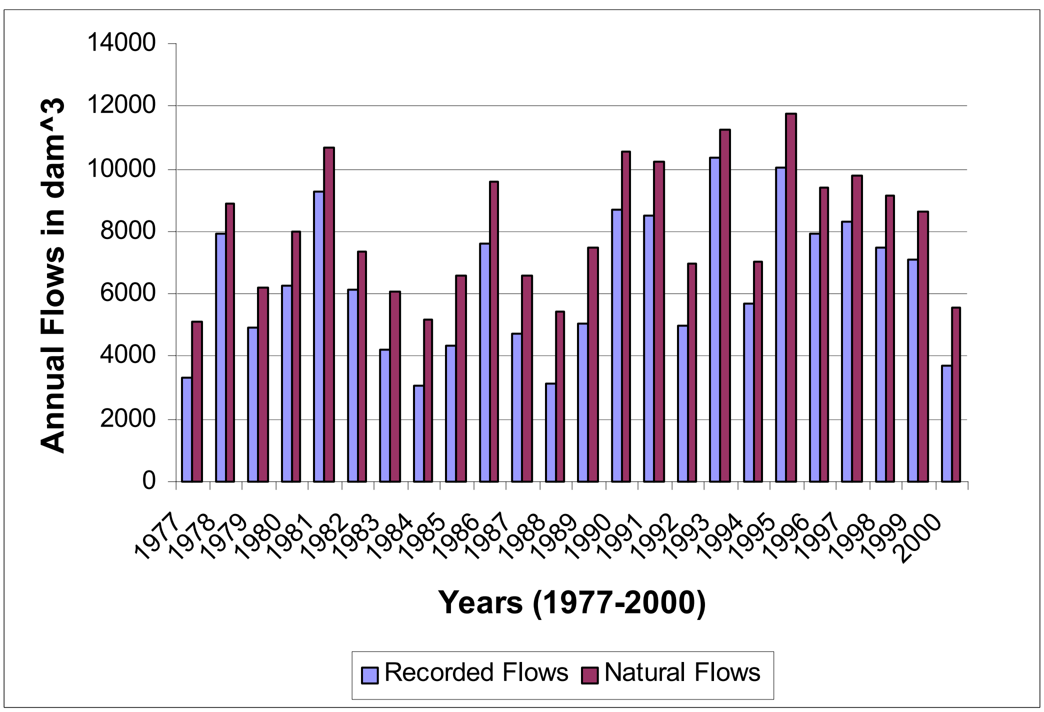


FIGURE 6.3: South Saskatchewan River Recorded VS Natural Flows



6.2.3 WATER USES

Water allocation in the Saskatchewan River basin is grounded in western water law rather than riparian rights, as is the case in eastern Canada. Western water law was adopted from Australia and the United States because water scarcity and the promotion of agricultural development required that water be conveyed away from riparian lands. Fundamental to western water law is the doctrine of prior appropriation or first-in-time, first-in-right (Percy, 1988; Lucas, 1990).

Under western water law, provinces issue a licence in perpetuity for the use of a specified quantity of water (at a certain rate and time) for a specified purpose. Licences are issued on the basis of a calculation of the reliable water supply in a stream and in terms of stated priorities for water use. The procedures for estimating reliable supply and priorities of use vary from jurisdiction to jurisdiction. Typical water use priorities were domestic, municipal, industrial and irrigation.

In law, the most senior water right must be satisfied in any given year before other more junior rights are satisfied. This approach does not promote conservation and favours early uses over more beneficial uses. As well, since it licenses withdrawals from a stream, it does not set aside flows for ecological needs or needs such as waste assimilation. Although current laws provide a little more flexibility and there is a tendency for licensees to "share the pain" during low flow conditions, problems with water shortages under the present water allocation system may lead to proposals to increase supply through importation from other basins, with potential environmental consequences to donor and recipient streams.

Another approach is to adjust water demand through a number of mechanisms. One such mechanism is the introduction of water allocation transfers from one water rights holder to another. Alberta, for example, has now provided for voluntary marketing of water licences within a river basin, subject to a hold-back of up to 10% of the transfer for in-stream needs (Alberta Environment, 2002).

Alberta has a *South Saskatchewan Basin Water Allocation Regulation*, 1991 that caps the number of acres set aside for irrigation in 13 irrigation districts and for other irrigation, including that on Indian reserve lands. The Regulation provides for an amount of water "sufficient for" the irrigation of the specified lands and reserves all water not subject to existing licences.

The Regulation affirms the rights of existing licensees, permits water allocation for other purposes and establishes in-stream flow requirements for the Waterton, Belly and St. Mary Rivers. The other purposes, while not specified as being in order of priority, are listed as domestic, municipal, agricultural (other than irrigation), industrial, water power, and other.

Irrigated agriculture in Alberta accounts for most of the consumptive water use in the basin. There are 13 irrigation districts in the South Saskatchewan River basin, the Oldman subbasin being the most highly developed, and 2786 individual irrigation projects irrigating approximately 272,000 acres. According to PPWB 1982, in 1978 some 1.47 million of the 1.69 million cubic decametres of water consumed in the basin was for agricultural purposes. In the South Saskatchewan basin alone, non-irrigation consumptive use had increased to 476,120 dam^3 by 1996 while irrigation use was 2,500,000 dam^3.

As part of a South Saskatchewan River Basin Water Management Review, Alberta has conducted a detailed study of long-term forecasts for population and non-irrigation water demand in the basin (Alberta Environment 2001). Water uses are categorized as municipal, industrial, stockwatering, other agricultural, and water management.

The basin was divided into 26 subbasins and, using 1996 as a baseline, forecasts were made 25 and 50 years into the future. Low, medium and high growth scenarios were used. Under these scenarios, non-irrigated consumptive water use is projected to increase by 34% to 67% by 2021 and by 62% to 132% by 2046. These projections include some modest reductions in per capita water demand.

The study recognizes the difficulty of making such long-term projections and of survey-based growth projections made, for the most part, on "business-as-usual" concepts. That said, even this increase in water demand in Alberta can be met in most years under the terms of the Master Agreement. However, in dry years water use would have to be curtailed. This presents an administrative challenge for Alberta as, legally, irrigation water rights are senior rights. In practice, however, irrigation water users accept the concept of "sharing the pain". This aspect will be discussed further in the second part of this report.

In 1984, Saskatchewan made extensive changes in its water rights legislation. Rights established before that time were affirmed but licences issued since then have been for specified periods and statutory water use priorities no longer exist (Percy 1988). Saskatchewan currently allocates water under the terms of the *Saskatchewan Watershed Authority Act.*

Considering the water use situation in Saskatchewan, there are no current detailed water use projections. A study of the South Saskatchewan basin in Saskatchewan (SSRBS, 1989) indicated that there was sufficient water available to meet all foreseeable needs, even if Alberta utilized all of its share under the Master Agreement on Apportionment. The only conceivable use that could put pressure on water allocation was irrigation development. Based on Cohen *et al.* (1989) and SSRBS (1989), one can speculate that the only conceivable water demand that might affect apportionment at the Manitoba boundary is a massive increase in irrigation development using Lake Diefenbaker as the source. Even under those circumstances, developments in Alberta will be as significant to Saskatchewan-Manitoba apportionment as those in Saskatchewan.

Water allocation in Manitoba is governed by the *Water Rights Act*. The Act is firmly rooted in western water law adhering to the prior appropriation doctrine and establishing water use priorities of domestic, municipal, agriculture, industrial, irrigation, and other. Regulations under the Act indicate that new licences may be issued for a period not exceeding 20 years. The Act itself allows the minister to reserve unlicensed water for future use.

6.2.4 STREAMFLOW TRENDS

6.2.4.1 INTRODUCTION

Several investigators have examined statistical trends in Canadian streamflow data. This research is important to climate change investigations as one hypothesis is that recent streamflow trends will provide insights into trends in the near term and hence into adaptive strategies that should be investigated.

The basis for much of this trend assessment research has been Environment Canada's Reference Basin Hydrometric Network (RBHN). This network (Harvey *et al.*, 1999) consists of 255 active hydrometric stations, 78 of which are in prairie and northern Canada. The network is comprised of stations having pristine of stable hydrologic conditions, minimal flow regulation, 20 years of good quality record, and stable operational funding. The stations were also selected to provide good stable and temporal resolution, and a wide range of basin scales and characteristics.

The methodology used in these trend analyses have become fairly standardized. As described by Hirsch *et al.* (1982), Lettenmaier (1994), Burn (1994) Zhang *et al.* (2001) and others, the non-parametric Mann-Kendall test is applied to a hydrological or climatological time series to detect trends in variables such as monthly seasonal or annual means and their level of significance. The null hypothesis is that there are no existing trends in the time series. The test provides a significance level (the strength of the trend) and a slope (the magnitude and direction of the trend). The analysis can be further extended by attempting to remove any serial correlation (persistence) from the time series through a technique known as "pre-whitening" (Zhang *et al.,* 2001; Burn and Elnur, 2002).

The results pertaining to Canada indicate a trend to warmer and wetter climate in the last half of the twentieth century (Zhang *et al*., 2001); a greater number of hydrologic trends (many decreasing) than can be accounted for by chance (Burn and Elnur, 2002); and a tendency to earlier spring freshets, decreased runoff and higher temperatures in prairies (Burn, 1994; Yulianti and Burn, 1998). DOE (2002) has applied this methodology to the RBHN stations in prairie Canada and has also found some statistically significant trends to larger winter flows and earlier spring freshets. Annual maximum and minimum flows appear to be decreasing. For the most part, however, stations having no trend tend to dominate the analysis.

For this current study, it was believed that a more detailed examination of trends in the Saskatchewan River basin would be useful. Such an analysis could include data to 2001. This examination could include mountain streams, the source of much of the basin's streamflow; plains streams, where water is consumed; seasonal trends; and several time series ranging from the entire period of record to the last 20 years, where anthropogenic effects might be most evident. Since the PPWB has a complete set of naturalized flows at interprovincial boundaries, this natural flow record and the RBHN stations could be used in the analysis.

6.2.4.2 METHODOLOGY

The natural flow time series described elsewhere in this report was a key dataset for this work. This is based on daily discharges for the period 1912-2001 for the North Saskatchewan and South Saskatchewan Rivers at the Alberta-Saskatchewan boundary and daily values for the period 1977-2001 for the Saskatchewan River at the Saskatchewan-Manitoba boundary.

The analysis examined trends in annual, monthly and seasonal flows. Trend testing was considered for 340 combinations of location, time period and variables. The seasonal flows were offset one month to coincide with climate seasons. That is, winter is December to February.

The 17 variables used were:

- Annual means
- Monthly means (Jan to Dec)
- Seasonal means (winter (DJF), spring (MAM), summer (JJA), autumn (SON)).

The following five time periods used were:

- 1912-2001 (90 years)
- 1947-1996 (50 years, period also used in Zhang *et al.*)
- 1957-1996 (40 years; period used in Zhang *et al*.)
- 1967-1996 (30 years; period used in Zhang *et al*.)
- 1977-2001 (25 years)

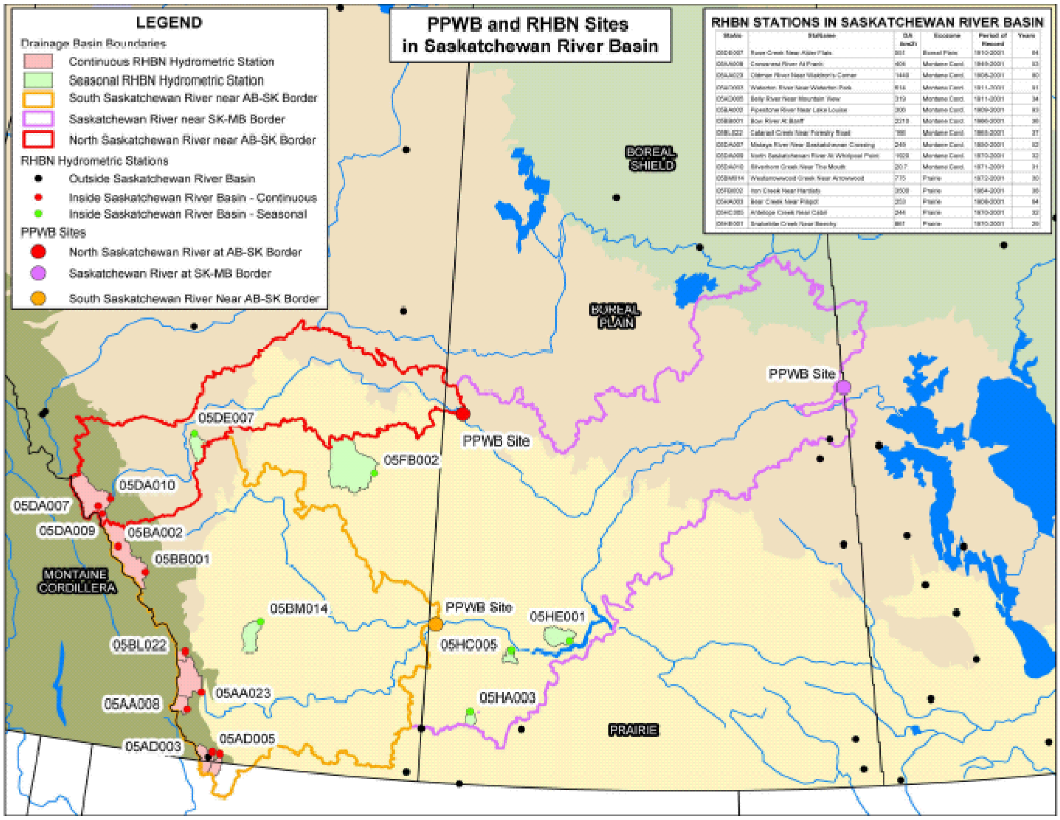
Due to insufficient data (greater than 20% missing years or greater than 10 years missing at end of time period) for many of the time periods under consideration, trend testing was possible on only 187 of the 340 combinations of location, time period and variables. In addition to the PPWB stations, 16 RHBN stations were used. These include ten Montane Cordillera stations, three in the North Saskatchewan River basin and the remainder in the South Saskatchewan, and six plains stations, three in each province. The sites are listed in Table 6.1 and displayed in Figure 6.4.

Table 6.1: RHBH Stations in Saskatchewan River Basin

Station Number	Name	Drainage Area km^2	Ecozone	Period of Record
05DA007	Mistaya River near Saskatchewan Crossing	249	Cordillera	1950-2001
05DA009	North Saskatachewan River at Whirlpool Point	1920	Cordillera	1970-2001
05DA010	Silverhorn Creek near the Mouth	20.7	Cordillera	1971-2001
05BM014	Westarrowwood Creek near Arrowwood	775	Prairie	1972-2001
05DE007	Rose Creek near Alder Flats	551	Boreal Plain	1910-2001
05AA008	Crowsnest River at Frank	404	Cordillera	1949-2001
05AA023	Oldman River near Waldron's Corner	1440	Cordillera	1908-2001
05AD003	Waterton River near Waterton Park	614	Cordillera	1911-2001
05AD005	Belly River near Mountain View	319	Cordillera	1911-2001
05BA002	Pipestone River near Lake Louise	306	Cordillera	1909-2001
05BB001	Bow River at Banff	2210	Cordillera	1966-2001
05BL022	Cataract Creek near Forestry Road	166	Cordillera	1965-2001
05FB002	Iron Creek near Hardisty	3500	Prairie	1964-2001
05HA003	Bear Creek near Piapot	253	Prairie	1908-2001
05HC005	Antelope Creek near Cabri	244	Prairie	1970-2001
05HE001	Snakebite Creek near Beechy	861	Prairie	1970-2001

The non-parametric, Mann-Kendall test, described earlier in this report, was used to determine whether a statistically significant trend existed for each PPWB streamflow time series. The WQHYDRO (Water Quality/Hydrology Graphics Analysis System) software program (licensed to Environment Canada from Eric Aroner, Environmental Engineer/Hydrologist) to carry out the test. The time series were not pre-whitened (*i.e.* removal of serial correlation) prior to trend testing. However, the time series which were examined should not have significant serial correlation and, therefore, ignoring serial correlation should not significantly affect the interpretation of the trend results.

Figure 6.4: Trend assessment stations in the Saskatchewan River Basin *(courtesy Environment Canada)*



6.2.4.3 RESULTS

Table 6.2 summarizes the trend significance results for the187 PPWB combinations. There are 32 significant trends (at 90%, 95%, or 99%) in the 187 time series of which 5 are increasing and 27 decreasing. The North Saskatchewan has 17 trends (14 decreasing and 3 increasing), while the South Saskatchewan has 14 (13 decreasing and 1 increasing) and the Saskatchewan (1977 - 2001) has 1 (increasing). The predominantly decreasing trends principally occur in the winter season (DJF) for the North Saskatchewan and the spring season (MAM) for the South Saskatchewan.

Table 6.2: Summary of Trend Test Results for PPWB Stations

Summary of Mann-Kendall Trend Test Results
- Locations, Time Periods and Variables with Significant Trend at 90%, 95% or 99%

Station Locations	Time Period	Dec	Jan	Feb	DJF	Mar	Apr	May	MAM	Jun	Jul	Aug	JJA	Sep	Oct	Nov	SON	Ann
North Saskatchewan (at AB border)	12-01		-Sig99 (-0.4) −		-Sig95 (-0.3) −	+Sig99 (+0.4) +	+Sig95 (+0.4) +			-Sig90 (-0.3) −				-Sig90 (-0.2) −				
	47-96		-Sig99 (-1.6) −	-Sig95 (-0.8) −	-Sig99 (-1.1) −	+Sig90 (+0.6) +		-Sig90 (-0.8) −										
	57-96		-Sig99 (-2.7) −	-Sig95 (-1.3) −	-Sig99 (-1.7) −													
	67-96		-Sig95 (-2.4) −		-Sig90 (-1.5) −													
	77-01							-Sig95 (-1.5) −										
South Saskatchewan (at AB border)	12-01	-Sig90 (-0.3) −					-Sig90 (-0.3) −		-Sig90 (-0.2) −									
	47-96		-Sig95 (-0.7) −				-Sig99 (-1.7) −	-Sig99 (-1.2) −	-Sig99 (-1.1) −	-Sig95 (-0.7) −			-Sig90 (-0.7) −					-Sig99 (-0.8) −
	57-96						-Sig90 (-1.2) −											
	67-96						-Sig90 (-1.7) −	-Sig90 (-1.0) −										
	77-01										+Sig90 (+1.7) +							
Saskatchewan (at MB border)	77-01											+Sig90 (+1.4) +						

Negative Trends	-Sig90 (*) −	-Sig95 (*) −	-Sig99 (*) −
Positive Trends	-Sig90 (*) +	-Sig95 (*) +	-Sig99 (*) +

Note: * is the trend slope as a % of the median volume

Assuming the natural flow calculations are reliable (*i.e.* they adequately account for regulation and land use change is not significant) the PPWB sites provide a more integrative, and potentially illuminating picture of overall streamflow variability (and trend) in the basin than the relatively small RHBN basins. As well, in the 40 and 50-year periods, the PPWB sites can provide important, additional insights.

There are significant differences in the trends identified for the North Saskatchewan River in comparison to the South. One possible explanation is that the Montane region of the former is very concentrated and therefore more likely to respond consistently to climate conditions. The headwaters of the South Saskatchewan River basin, on the other hand, comprise three main tributaries in a fairly large geographic region. Climate effects in one tributary could therefore counter effects in another.

Interpretation of the RHBN station streamflow statistics is somewhat less useful due to the much smaller basin coverage and associated variability of physio-climatic factors. Most of the RHBN stations had greater than the 20% missing data in these periods and could not be tested for trends. This made any spatial interpretation of trend difficult, especially during the longer time periods. The PPWB sites had a full record during the periods and indicate significant decreasing trends.

The PPWB trends results generally agree with those at the RHBN stations within and close to the Saskatchewan River basin. The RHBN Montane station monthly mean streamflow trends indicated generally higher (increasing trends) winter and early spring streamflows followed by lower (decreasing) summer and fall streamflows. One plains station that exhibits a trend shows decreasing spring flows. Some results for the RHBN stations are shown in Table 6.3.

Demuth and Pietronoro (2003), in their examination of climate change effects on glacier mass in the North Saskatchewan River basin, also conducted tests for trends in hydrometric and climate variables. The methodology was similar to that used in this report but the entire period of record to 1998 (approximately 20 to 50 years, depending on the site) was used in the analysis, which included three RHBN stations. The results confirmed the trends in the RHBN stations but analysis of the non-RHBN tributaries showed few statistically significant trends.

At first glance, the trends at the PPWB sites in the common time periods are negative even in the spring period. Closer examination, however, indicates increasing trends for the 30 year RHPN Montane record and decreasing trends for the 40 and 50-year records. This is reasonably consistent with the PPWB station trends.

Table 6.3: Summary of Trend Results for RHBN and Related Stations (1 = Results from non-standard time periods are taken from Demuth and Pietronio (2003))

Station Locations	Time Period[1]	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann.
***Siffleur River** near the Mouth*	1975-96													
Mistaya River near Saskatchewan Crossing	1950-98 1967-96								Sig 95 -		Sig 95 -			
***North Saskatchewan River** at Saskatchewan Crossing*	1951-70													Sig 95 -
North Saskatchewan River at Whirlpool Point	1970-98						Sig 99 +	Sig99 +						Sig 99 +
***North Saskatchewan River** at Bighorn Plant*	1972-98						Sig 99 +	Sig99 +						Sig 99 +
Silverhorn Creek near the Mouth														
***Ram River** near the Mouth*	1967-98													
***North Ram** River at Forestry Road*	1975-98													
Westarrowwood Creek near Arrowwood	1967-96				Sig 95 +				Sig 95 -					
Rose Creek near Alder Flats														
Crowsnest River at Frank														
Oldman River near Waldron's Corner														
Waterton River near Waterton Park	1947-96		Sig 95 -			Sig 95 -								
	1957-96						Sig 95 -							
Belly River near Mountain View	1947-96	Sig 90 -			Sig 90 +		Sig 95 -	Sig 90 -					Sig 90 -	Sig 95 -
	1957-96													
	1967-96			Sig 90 +										
Pipestone River near Lake Louise	1967-96										Sig 90 +			
Bow River at Banff														
Cataract Creek near Forestry Road	1967-96				Sig 95 +									
Iron Creek near Hardisty	1967-96									Sig 95 -	Sig 95 -			Sig 90 -
Bear Creek near Piapot														
Antelope Creek near Cabri														
Snakebite Creek near Beechy														
Pasquia River at Highway No. 9														

Negative Trends	Sig 90 -	Sig 95 -	Sig 99 -
Positive Trends	Sig 90 +	Sig 95+	Sig 99+

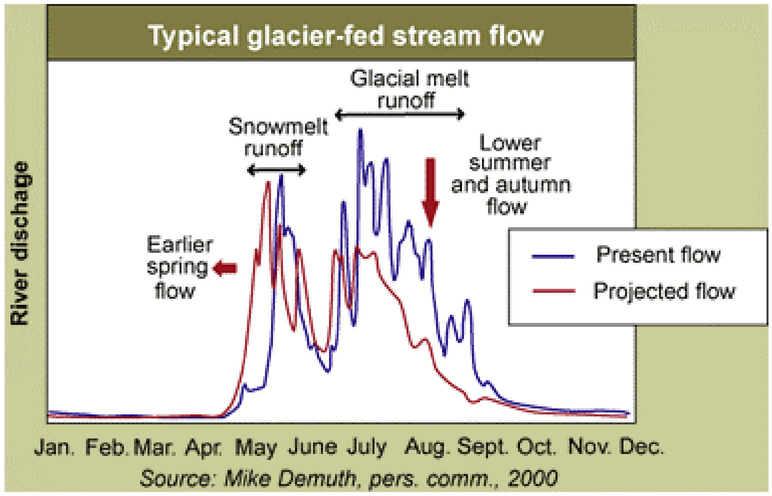


FIGURE 6.5: Typical Glacier-fed Streamflow

One hypothesis that would seem to explain negative trends in longer records and positive or no trend in shorter records is the influence of glacier melt. Figure 6.5 depicts typical glacier runoff under present and future climate conditions. In fact, Demuth *et al.* (2001) makes the case that the anticipated changes in glacier melt are already taking place with respect to glaciers in the North Saskatchewan River basin. There is a striking correlation between winter mass balance of Peyto and Place glaciers and the warm phase of the Pacific Decadal Oscillation (PDO), which extended from 1976 to 2001. Other researchers (Haeberli *et al*., 1999) have also identified significant losses in glacier mass throughout the world in the last few decades.

For the purpose of this report then, the working hypothesis is that long-term trend to declines in streamflows should be taken as an indicator of future decreased water availability in the Saskatchewan River basin. This overall trend may have been masked to some extent by increases in glacier melt in the last 25 years. The significant loss in glacier mass over that time, however, makes it unlikely that the 'bonus water' from glacier melt will persist. Further, the few trends in streamflows for plains RHBN sites are all negative. This may be an indicator that increased water demands under climate change scenarios will have to be met by increased reliance on mountain runoff. The trends detected in mountain runoff data imply, if anything, a decrease in water availability.

The trend analysis conducted for this report points to the need to maintain a national network of hydrometric stations such as the RHBN stations. Periodic examination of the flow records, say every five years, for trends is potentially very useful. The work also demonstrates that calculated natural flows for prairie streams is a useful adjunct to trend analysis.

6.2.5 CLIMATE SCENARIOS

The climate scenarios used in this study were based on work carried out by others. No new scenarios were developed. Prior to examining scenarios, however, a review of recent climate trends is in order. Lettenmaier (1994) shows consistent increasing temperature trends in the northern and western portions of the continental United States from 1948 to 1988. Precipitation trends were less pronounced but some statistically significant trends were identified, both increasing and decreasing. Zhang *et al*. (2000) indicates trends to wetter and warmer climate during the latter half of the 20th century. Burn (1997) attributes earlier spring freshets in the Churchill-Nelson basin to increasing temperatures.

For the Saskatchewan River basin, in the Montane ecozone, Demuth and Pietroniro (2003) examined meteorological trends over the last half of the 20th century at six climate stations in and adjacent to the headwaters of the North Saskatchewan River. They found statistically significant increasing trends in both seasonal (summer/fall) and annual minimum temperatures at several stations as well as increasing trends in mean temperatures at Banff, AB and Golden, BC. Only Banff indicated an increasing trend in maximum temperatures. The same study found no annual trends and virtually no seasonal trends in total precipitation.

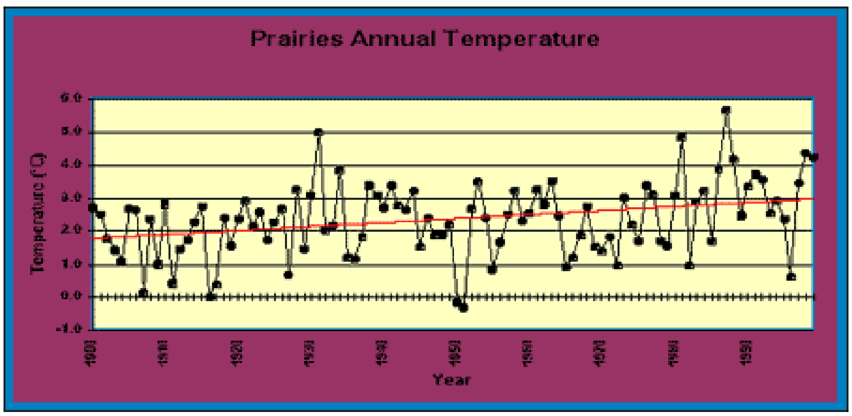


FIGURE 6.6: Annual Temperatures on the Prairies

Within the plains portion of the basin, increasing temperature trends have also been identified. This is illustrated by Figure 6.6 (courtesy of Environment Canada) for Swift Current, Saskatchewan.

Turning to future climates, it would appear reasonable to adopt a scenario that calls for increasing mean temperatures during all seasons. Precipitation scenarios are more complex. Based on GCM runs, winter-spring precipitation is anticipated to increase, summer precipitation to decrease and fall precipitation to remain about the same. There is considerably more uncertainty in the precipitation output from GCMs than for the temperature output. Figure 6.7 is a scatter plot of changes to annual precipitation versus temperature from 25 different GCMs from a 1961-90 baseline to 2020 provided by the Canadian Institute of Climate Studies, Canadian Climate and Impacts Scenarios Project, at the University of Victoria. The SRES emissions scenarios are used. The results are for the Medicine Hat area but are representative of scenarios for the plains portion of the basin. The results for subsequent decades are similar but tends to be more scattered.

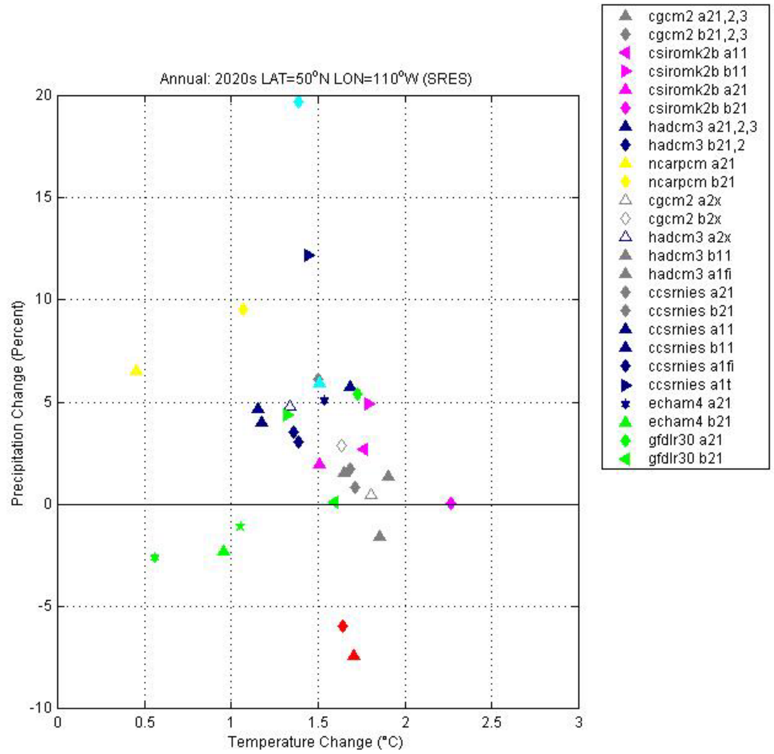


Figure 6.7: Scatter Plot of Change in Annual Temperature and Precipitation at Medicine Hat (*courtesy University of Victoria*)

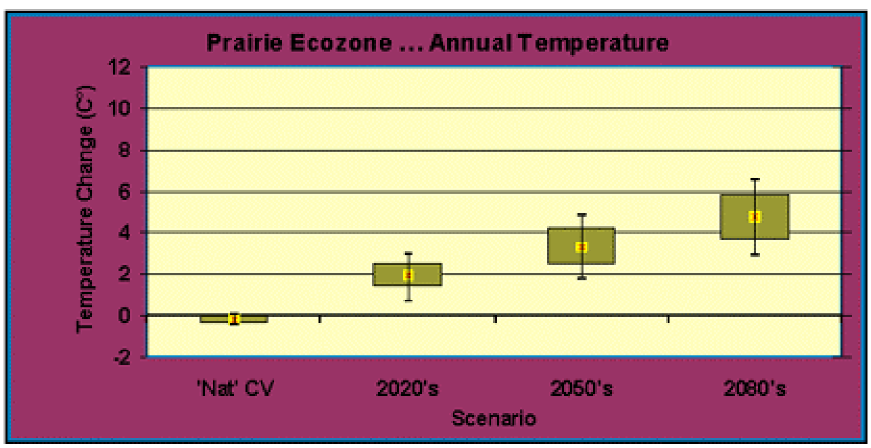


Figure 6.8: Prairie Ecozone – Annual Temperature Scenario

Figure 6.8 (courtesy Environment Canada) for the prairie ecozone illustrates the general scenario. That is, increases in mean annual temperature with greater uncertainty as time progresses. Based on observations of the recent past, these increases tend to be caused particularly by increases in minimum temperatures.

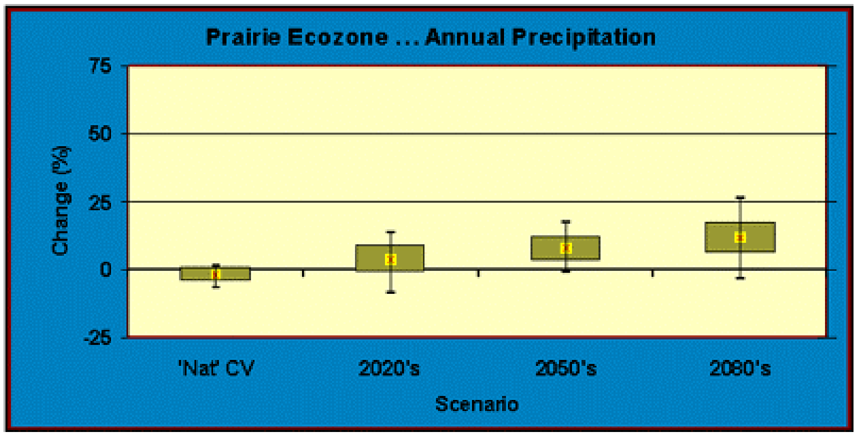


Figure 6.9: Prairie Ecozone – Annual Precipitation Scenario

The precipitation scenario is much more uncertain as indicated in Figure 6.9 (also courtesy of Environment Canada). While some annual and seasonal precipitation increases appear possible, these could be masked by interannual variability. For the purpose of this study, a no-change scenario is reasonable.

This temperature and precipitation scenario is entirely consistent with the work of many researchers and would be a good basis for considering future water availability in the plains portion of the Saskatchewan River basin. Thorpe *et al*. (2001) presents a good summary of the results of output from an ensemble of GCMs on temperature and precipitation in the prairie ecozone for the 2020s, 2050s and 2080s.

In the absence of other more detailed understanding, the scenario will also be applied to the montane portion of the basin. It is evident, however, that there is considerably more uncertainty in the montane scenario than the plains one. Demuth and Pietroniro (2003) used several GCMs to simulate the 1960-91 climatology in the montane portion of the North Saskatchewan River basin and found they could match the observed values reasonably well. Then they projected the temperature and precipitation regimes to the period 2040-2069. The five GCMs used all indicated increased temperatures, particularly for the winter-spring periods. Increases in precipitation were obtained as well in the winter-spring period, but results for summer and fall were mixed.

On the other hand, Byrne *et al*. (1999) examined anticipated changes in upper air circulation patterns that control winter precipitation in the Oldman River basin under 2 X CO_2 conditions, which will take place in about 2080 if present trends continue. A linkage was made between historical patterns and GCM patterns under current conditions and used in identifying changes under 2 X CO2. It was concluded that increases in winter precipitation were considerable and this increase was converted into a 64% increase in snowmelt runoff using regression analysis.

Pentland *et al*. (2002) discusses some of the challenges of determining precipitation in mountainous regions. There is a need to separate the convergence precipitation obtained from a climatologically homogeneous region from the orographic precipitation specific to a given basin. The use of GCM-based scenarios provides insights into the former but not the latter.

At present, more work is needed before a scenario implying large increases in mountain precipitation can be accepted. A more conservative approach is taken in this study. In summary, an assumption of increased temperatures and no increase in precipitation for both the plains and montane ecozones appears reasonable.

The spatially constrained montane headwaters of the North Saskatchewan River are a particularly good location to examine physical scenarios related to climate change. There is a continuing need to downscale climate scenarios to this area and to apply physically based distributed hydrologic models as a means of investigating effects on streamflow. The relative scientific 'purity' of working in this area must be balanced with the strong need to conduct similar work in the more complex South Saskatchewan basin to meet imminent water management requirements, however.

6.2.6 HYDROLOGY

Given the climate scenario described in the previous section, one can examine the effects on hydrological processes. In the absence of detailed modelling such as that carried out by Demuth and Pietroniro, one can still identify the likely consequences of warmer and perhaps, approximately, the same precipitation conditions. Considering that climate conditions on the plains will tend to govern water demand while climate conditions in the mountains will tend to govern supply, future hydrology should be discussed in two parts. These can further be subdivided into snowmelt processes and other hydrological processes.

6.2.6.1 PRAIRIE ECOZONE

Streamflow is the prairies is really the residual of precipitation and evapotranspiration. As indicated earlier in this report, annual precipitation is in the order of 350-450 mm and potential evapotranspiration is 650-1100 mm; under most circumstances runoff represents only 10-15 percent of incident precipitation.

Snowmelt runoff is the dominant factor governing water availability in most years in most basins in the prairie ecozone. Usually over half of the annual runoff occurs during the spring freshet. Modelling prairie runoff is confounded by precipitation measurement, infiltration into frozen soils, and determination of the contributing (or effective) drainage basin.

In general, snowmelt runoff begins with surface melt forming wetting fronts that percolate through the snowpack. Meltwater then moves laterally down hillslopes where it may infiltrate into soil, or continue to join the stream channel network (Quinton and Marsh, 1998). Under the previously identified climate scenario, the following effects are probable:

- Warmer temperatures will lead to greater snowpack loss through more frequent freeze-thaw cycles and increased sublimation. Depending on changes in winds, losses could also increase through redistribution of the snowpack.

- Infiltration into frozen soils plays a very significant role in determining runoff. Warmer temperatures and resulting decreased winter frost penetration will increase infiltration and hence runoff profoundly.
- Soil moisture has an effect on frost penetration. Drier pre-freeze-up soils caused by decreased summer rain and increased evaporation will therefore lead to reduced spring runoff.

Increased temperatures in the 'open water' season will also lead to increased evaporation. This will relate not only to the direct effect of increased air temperature but also to increased water temperatures in shallow impoundments. These effects are unlikely to be countered by increased cloudiness, or even increased precipitation.

While the overall outlook would tend to support drier conditions, increased moisture in the air column due to evaporation could lead to increased severe weather events, including severe rains. The Vangard storm (Hunter *et al*., 2002) could be an example of future intense rain activity.

In summary, the prairie ecozone on average will likely experience significantly reduced spring runoff and the possibility of more severe summer rains. It is conceivable that there will be a sufficient growing season and heat units in Saskatchewan to support the production of higher valued crops, such as soy beans or corn, using irrigation from the South Saskatchewan River. Increased agricultural water demands may also increase pressure for additional diversions from the North and South Saskatchewan Rivers to meet domestic and industrial demands.

6.2.6.2 MONTANE ECOZONE

The montane ecozone is the source of more than 80 percent of the water that flows in the Saskatchewan River basin (SNBB, 1972; Pentland *et al*., 2002). As for the prairie ecozone, snowmelt runoff is the dominant factor governing annual water availability. The challenges of modelling mountain runoff include determination of the nature (solid or liquid) and extent of precipitation on the basin, measurement of the energy available for snowmelt, and the response times of various sub-watersheds.

Under the climate change scenario the following snowmelt factors will come into play:

- Warmer temperatures will lead to greater snowpack loss through freeze-thaw cycles and increased sublimation. At present, some 40 percent of the snow intercepted by the forest canopy is sublimated and this will also increase.
- Early season melting may increase soil moisture but this may be countered by drier conditions in the fall.

In the ice-free period, late season streamflows will be affected by loss of glacier mass. According to Demuth and Pietroniro (2003), in the North Saskatchewan basin the time for increased flows due to glacier melt has already passed and in 20 years the contribution to streamflow from glacier melt will be minimal. The loss of glacier mass will tend to reduce late season flows and will also tend to make the basins more responsive to rain events, leading to sharper flood peaks in headwaters sub basins.

The eastern slopes of the Rockies may also be subject to larger rain events. Pentland *et al.* (2002) determined that the most significant floods in the South Saskatchewan basin will originate with summer rainstorms, not rain on snow events.

In summary, it can be expected that water supplies from the montane in an average year will decrease. However, the region may be subject to increased summer storms that could lead to increased streamflows.

6.3 PERCEPTIONS OF CLIMATE CHANGE AND FAIRNESS IN THE SASKATCHEWAN RIVER BASIN

6.3.1 INTRODUCTION

This portion of the report provides results from a questionnaire that was sent to federal, provincial and local government officials, and representatives from water user groups.

This portion of the research paper considers the following questions:

- How do different water user groups from the Saskatchewan River basin perceive the seriousness, impacts and causes of climate change? To what extent does the importance placed on different stakeholders in providing a diversity of views on this subject warranted? If not, what additional factors might be considered?
- How do different user groups perceive the fairness of existing arrangements for water apportionment among the prairie provinces and water allocation within each province?

Following these introductory remarks, the questionnaire is described. Some of the key findings are provided in the remaining sections are organized as follows: (i) the results from the questionnaire, (ii) perceptions of climate change, and (iii) perceptions of fairness in water apportionment and allocation.

6.3.2 THE QUESTIONNAIRE

The study was conducted by means of a survey of public and private water managers residing in the Saskatchewan River basin. A copy of the questionnaire is provided in Appendix I. It contained the following six sections which are described below.

Sections 1 & 2: General background information of the respondents who were asked to identify themselves as either a government official (Section 1) or an official from a water user group (Section 2). Similar questions were posed in both sections and concerned their province of residence, water user type (*i.e.* withdrawal, in-stream, water quality, public health, other), and length of residence in the province. The cover letter indicated that all respondents should answer questions as individuals and not on behalf of their employers or interest groups. Therefore, the results do not reflect government, agency or non-governmental organization policy.

Section 3: Questions concerning the status of water management issues within the entire Saskatchewan River basin, and the portion of the basin within their province were posed. Questions related to respondents' perceptions of fairness regarding water allocation were also asked. These questions were central to the research focus of the study.

Section 4: The fourth section pertained to respondents' views of the environment and technology. The intent was to apply the 5-point Likert Scale responses to an environmental values and technology index. These questions were patterned after the work of Mortsch (2002). Environmental values were assessed using 6 questions devised by Dunlap and Van Liere (1978). For analytical purposes, the 5 categories were reduced to three (i) strongly agree and agree, (ii) neutral, and (iii) disagree and strongly disagree.

Environmental problems have often been attributed to what has been called an "anthropocentric worldview" – the idea that humans measure the value of the environment and its natural resources by their ability to meet human needs and wants (Devall and Session, 1985; Nash, 1989). Dunlap and Van Liere (1978, 10) maintained that underlying this worldview was a "belief in abundance and progress, our devotion to growth and prosperity, our faith in science and technology, and our commitment to a laissez-faire economy, limited governmental planning and private property rights." In Mortsch's (2001, 12-13) view, writers in the 1970s and 1980s suggested that the

> dominant social paradigm (DSP) is society's dominant, though not universal, belief structure that organizes individuals or collectively, societies' perceptions and interpretations of the world…At times, [paradigms] shift because of crucial challenges in the worldview through an individual's conflicting cognitions – "dissonance" and disillusionment with the prevailing worldview's ability to explain and lead to fruitful interaction with the world.

Dunlap and Van Liere (1978) maintained that the dominant social paradigm was being challenged by a new environmental paradigm (NEP). According to Dunlap and Van Liere (1978), fundamental to the NEP is a belief on "limits to growth, the necessity of balancing economic growth with environmental protection, the need to preserve the balance of nature, and the need for humans to live in harmony with nature" (Scott and Willits, 1994, 240). In reviewing the literature on NEP, Mortsch (2001, 14) suggested that this worldview included "sustainable development, limits to growth, harmony with nature, scepticism toward scientific and technical fixes, finite natural resources, limits to substitution, and strong emphasis on public involvement in decision making."

The difference between DSP-NEP provides additional insights into how individuals and groups perceive water management issues in the Saskatchewan River basin.

For this study, six of the original questions from Dunlap and Van Liere (1978) were posed to respondents using a 5-point Likert scale (Table 4 and Appendix I). This approach has been used in other studies (Mortsch, 2001). There are three aspects to the statements – "Balance of Nature", "Limits to Growth", and "Humans over Nature".

Table 6.4: NEP-focused Statements

Statement	Dimension
1) The balance of nature is very delicate and easily upset by human activities.	Balance of Nature
2) The Earth is like a spaceship with only limited room and resources.	Limits to Growth
3) Plants and animals do not exist primarily for human use.	Humans over Nature
4) Modifying the environment for human use seldom causes serious problems.	Balance of Nature
5) There are no limits to growth for nations like Canada.	Limits to Growth
6) Humankind was created to rule over the rest of nature.	Humans over Nature

These statements cover some of the stated characteristics of DSP and NEP. However, they do not explicitly address issues related to the politics (*e.g.* role of government, experts and the public), equity (*e.g.* laissez faire approaches, private property rights based). The ability of the DSP/NEP to delineate these aspects will be considered in this study.

The six statements were scored according to the level of agreement (1, 3, 5 in Table 6.4) or disagreement (2, 4, 6 in Table 6.4). The use of the index was patterned after Mortsch (2001) who suggested that a "useful, albeit arbitrary division" would be:

- acceptance of the Dominant Social Paradigm (DSP) would score 6-15,
- a "Neutral View" would score 16-20, and
- acceptance of the New Ecological Paradigm (NEP) would score 21-30.

Science and technology have been important aspects in solving many human resource and environmental management problems. At times, however, science and technology can be seen as "band aid solutions" that address symptoms rather than causes, and exacerbate problems. Three statements addressed respondent's attitudes towards science and technology through a 5-point Likert scale (Table 5 and Appendix I). The answers were scored a 1-5 (with an inverse weighting to the first statement) in order to develop a scale of attitudes towards science and technology. Following the work of Mortsch (2001), three categories were used to classify these attitudes:

- scepticism for scores ranging from 11 to 15,
- moderate for scores between 8 and 10, and
- believer in science and technology for scores between 3 and 7.

Table 6.5: Statements focused on Attitudes towards Science and Technology

1) Technology will solve the problems from shortages of natural resources
2) People would be much better off of they lived a more simple life without so much technology
3) Future scientific research is more likely to cause problems than to find solutions

Section 5: It consisted of 33 statements covering a range of views concerning fairness of water allocation. Again, a 5-point response scale was applied. These questions were adapted from the work of Syme *et al*. (1999). Respondents were asked to rank their level of agreement with 33 statements that reflected selected perspectives on fairness. The intent was to identify which the respondent's level of agreement with each statement. The statements on fairness embraced a wide range of philosophies including:

- Water as a Common Good
- Free Market: Libertarianism
- Utilitarianism as Hedonism
- Procedural Justice (Rawls)
- Efficiency Principles
- Human Rights (Kant's Categorical Imperative, Positive Human Rights)
- Animal and Environmental Rights
- Distributive Justice
- Certainty and Forecasting
- Cost Benefit Approaches (Kaldor / Hicks formulation)

Syme *et al.* (1999) indicated that the essence of each philosophy was sometimes translated from its 'pure form' and expressed in 'lay terms'. Some statements were expressed as a negative form of a philosophy. The concepts of egalitarianism and proportionality formed the philosophies of fairness explored in the section. In a general sense, egalitarianism suggests that everyone should be treated equally, while proportionality present a view that people should be rewarded in proportion to the amount of effort they put forward. In relation to procedurally just decision making, "people subscribing to the proportionality view of equity would tend to be more concerned with procedural justice issues when judging the fairness of government allocations than would those with an egalitarian view. In contrast, those subscribing to an egalitarian viewpoint would tend to emphasize the distributive outcome of government decision making" (Syme *et al*., 1999, 54).

Section 6: The final section was completely open-ended, allowing respondents to comment on their perceptions concerning previous issues in the questionnaire.

The draft questionnaire was pretested with officials from the Partners FOR the Saskatchewan River Basin and the Prairie Provinces Water Board in October 2002. Based on their comments, the questionnaire was modified.

6.3.3 SAMPLING AND ANALYSIS

The Saskatchewan River basin provides at least two important regions for examination. The first is the basin itself. Its management efforts are guided by the previously described Master Agreement on Apportionment administered by the PPWB. The second region is the three prairie provinces – Alberta, Saskatchewan and Manitoba – which are members of the PPWB, and allocate water to users within their boundaries and are also responsible for other aspects of water management (*e.g.* water quality, public health, recreation). Since these two types of regions both are of interest in this study, an important aspect of the method is to obtain a list of water users who were reasonably familiar with both basin-wide and provincial water-based issues. Thus, it was desirable to obtain a mailing list which had the following characteristics:

- contained government officials and water users for the entire basin;
- contained a mix of in-stream and withdrawal users; and
- provided information to people about basin-wide and provincially-based water management activities.

In this way, the researchers would be reasonably assured that they were dealing with a relatively well-informed segment of the water user and management community that had both basin-wide and provincially based information.

Contact was made with the "Partners FOR the Saskatchewan River Basin" and they agreed to share their mailing list with the researchers. The Partners is a non-profit charitable organization. It is a network of partners who are committed to increasing stewardship of the river basin by developing:

- public awareness and education tools to teach the importance of the basin's biodiversity;
- partnerships and networks of organizations that cross political and sectoral boundaries; and
- action projects people can participate in.

Its mission is to promote awareness, linkages, stewardship, knowledge and respect for the basin's ecosystems and heritage that will encourage sustainable use of the basin's natural resources and nurture cultural values.

Thus, the desired characteristics have been achieved. However, the orientation of the Partners FOR the Saskatchewan River Basin suggests that individuals and groups on the mailing list are sensitive to ecosystem and heritage issues and problems. As members of this non-governmental organization, they may be a more vocal critic of water management issues and solutions. On this basis, the survey results do not claim to be representative of the provincial populations. However, responses from individuals on the mailing list reflect an excellent cross section of water users from the entire basin, and any items achieving a high-level of consensus may viewed as particularly significant.

The 1,350 name mailing list was screened in order that contact would limited to water users and government officials. Individuals without a clear affiliation to a water user group or agency (*e.g.* schools, museums, academics) were removed from the list. In November 2002, 794 questionnaires were mailed to government officials and individuals from water user groups and non-governmental organizations. By January 2003, 229 responses had been received and 30 surveys returned as "undeliverable". There were no follow-up notices sent to respondents. Responses were received from 144 government officials and 85 representatives from water users or non-governmental organizations. The response rate was 29%. Relative to other survey-based research, this was a very satisfactory rate of response.

Although Dunlap and Van Liere (1978) indicated that the scale was unidimensional, other researchers have reported multiple dimensions (Albrecht *et al.*, 1982; Arcury 1990). This characteristic is important if a meaningful index is to be calculated. An index based on a multidimensional scale would be prone to "adding apples and oranges" and be meaningless. For this study, the scale was indeed unidimensional as reflected in the Cronbachs alpha of 0.78. This suggests that it is feasible to sum the individual statement scores (Table 6.3). The Cronbach's alpha value of the science and technology statements was 0.56. This is relatively low and suggests that caution should be applied in summing the individual scores since differences based on this variable may be more imagined than real. For this reason, the analysis will not include aspects related to the science and technology index.

6.3.3.1 STATISTICAL METHODS FOR PAIRED COMPARISONS

In order to provide greater insight into perceptions of fairness, a number of paired comparisons were made. A chi-square test was used where more than 20% of the cells in the frequency table were above 5, and Fisher's exact test was used where more than 20% of cell entries were below 5. A reliability analysis and factor analysis were used to test whether the different environmental statements as well as the different science and technology views could be treated as internally consistent and measuring only one attitudinal domain. All statistical analysis was performed using the Statistical Analysis System (SAS). Only results that are statistically significant at the 5% confidence level are reported below. P-values less than a 0.05 level were considered statistically significant and were used as evidence against the hypothesis that claims there was no interaction between the cells of the frequency table. In other words, a p-value less than 0.05 implies that there is an association between the levels of the two variables in the frequency table or equivalently that the groups being tested perceive fairness differently.

Since there were very few respondents in the "New Environmental Paradigm" category, it was necessary to combine it with the "Neutral" category in order to meet the assumptions of subsequent statistical tests.

6.3.4 DEMOGRAPHIC SUMMARY OF RESPONDENTS

Table 6.6 displays some of the key characteristics of the respondents. A total of 223 indicated their affiliation with either governmental agencies (or no-governmental organizations with an interest in water. Most of the respondents (63%) were from government agencies. Of the government respondents, 38% (54) were from provincial government agencies, 27% (39) from federal agencies, 22% (31) from local governments, and 13% (19) from other government entities. A little over half of the respondents were from Saskatchewan (51% or 116 respondents). 87 respondents (38%) were from Alberta, while 20 (9%) were from Manitoba. The relatively low response from Manitoba is not surprising given the relatively small proportion of the Saskatchewan River basin that is located in the province. Most respondents have lived in their province of residence for more than five years. Therefore, the potential influence of being recently introduced to 'new' water management practices as a result of moving to a new province should be negligible. It was believed that a recent change in jurisdictional contexts might prompt some respondents to perceive these as 'unfair' rather than 'different'.

A reasonable mix of water management interests are represented from both government and non-government respondents (Table 6.6). Thus, the results will illustrate a wide range of perceptions about water quantity management in the Saskatchewan River basin.

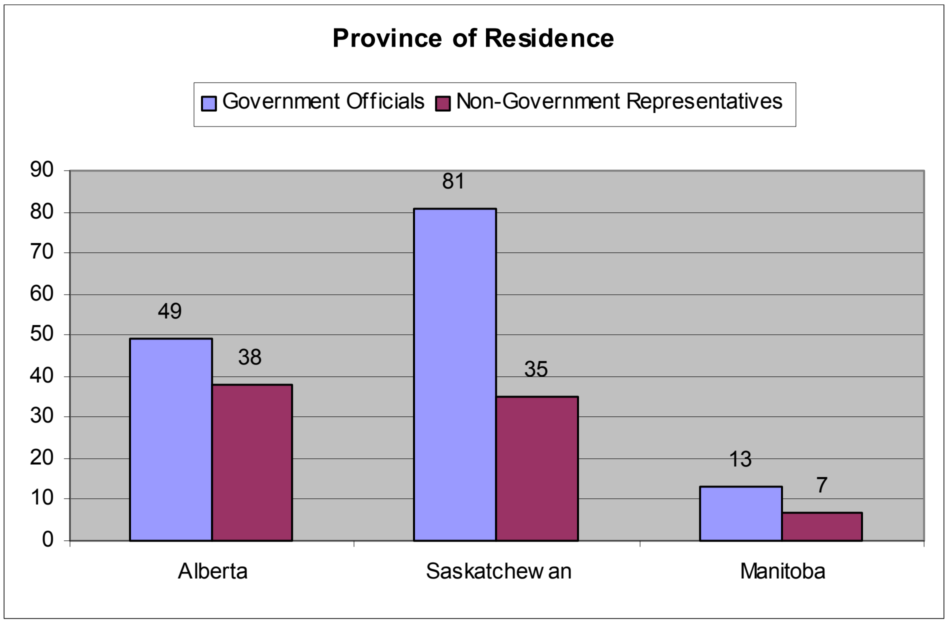


Figure 6.10: Distribution of Respondents by Province and Affiliation

Table 6.6: Type of Respondent and Water Management User/Interest (# of respondents)

	Non-Government Respondents	Non-Government Respondents
In-stream	38	39
Withdrawal	53	22
Water Quality	14	0
Other	31	17

(Government missing = 8; Non-government missing = 7)

The majority of respondents 116 (77.9%) were classified into the environmental values group that accepted the "Dominant Social Paradigm". 47 (22.1%) were neutral or accepted the "New Environmental Paradigm". An analysis was also completed to determine the relationship between government/non-government respondent and their environmental values; none was found. This suggests that although the majority of respondents accept the "Dominant Social Paradigm", it would be inappropriate to consider either government officials and/or non-government respondents as homogeneous groups. Some individuals from these groups reflect different values.

This point is also supported by Table 6.7. It considers the level of heterogeneity among water user groups according to environmental values. No statistically significant relationship was demonstrated. This suggests that it is inappropriate to consider that the four user groups – in-stream, withdrawal, water quality and other – as sets of homogeneous individuals. Not only will circumstances differ among individuals (*e.g.* location, income, culture), but their environmental values are different within the groups (Table 6.6).

Table 6.7: The Relationship between Water User Type and Environmental Values (# of respondents (%))

	In-stream	Withdrawal	Water Quality	Other	Total
Environmental Value Type					
- Dominant Social Paradigm	59 (27.7)	58 (27.2)	12 (5.6)	37 (17.4)	166 (77.9)
- New Environmental Paradigm	17 (8.0)	17 (8.0)	2 (0.9)	11 (5.2)	47 (22.1)

6.3.5 PERCEPTIONS OF CLIMATE CHANGE AND FAIRNESS IN WATER APPORTIONMENT AND ALLOCATION

The third assessment review completed by the Intergovernmental Panel on Climate Change (IPCC) maintained that research into the impacts of and responses to climate change were needed at regional scales (IPCC, 2001). It was believed that since many of the systems significantly affected by climate change are regional in scope, this geographic focus would have the most relevance for future actions. Another important element of regionally based studies concerns the belief that they offer a “better prospect for mobilizing stakeholder interest” (Shackley and Deanwood, 2002, 381). The focus of many public participation undertakings is to include as many different water users as possible in the belief that a diversity of perspectives will be provided to better inform decision makers and possibly ease the transition from planning to implementation. In the opinion of Miller *et al.*, (1997, 158), competing “claimants” to water value its “quantity, reliability, quality and timing dimensions” differently. In other words, the perception of the problem and its potential solutions should vary considerably among different stakeholders. In the next section, the perceptions of water users concerning the availability of water and climate change are presented. This discussion is followed by a description of the results pertaining to the perceptions of fairness on apportioning water among the prairie provinces and allocating water among water users within each province.

6.3.5.1 PERCEPTIONS ABOUT THE AVAILABILITY OF WATER IN THE SASKATCHEWAN RIVER BASIN

As noted in Part 1 of this report, there has been a general decline in the amount of flow in the Saskatchewan River and this trend is expected to continue in the future. A series of questions asked respondents to identify their perceptions regarding the seriousness of water quantity issues and the trend of issues in the portion of the Saskatchewan River basin within their province (Table 6.8). A clear majority of respondents (63.3%) maintained that water quantity issues were serious or very serious. 25 people (11.1%) indicated that the seriousness of problems was neutral, while 43 individuals (19%) indicated that problems were not serious or not very serious. 14 (6.6%) offered no opinion.

Table 6.8: Seriousness of Water Quantity Issues in the Saskatchewan River Basin (# of respondents (%))

	# (%) of respondents
No Opinion	15 (6.6)
Very/Not Serious	43 (19.0)
Neutral	25 (11.1)
Very/Serious	143 (63.3)

(missing = 3)

One hundred and forty six people (65.2%) believed the overall trend within their portion of the Saskatchewan River had gotten worse over the last 10 years, while 65 people (30.4%) perceived the situation had improved (Table 6.9). Ten people (4.5%) suggested that things had remained the same.

Table 6.9: Frequency of responses to the question -
'Over the past 10 years, or since you have lived in the province (whichever is shorter), what has been the overall trend for water quantity issues for the portion of the Saskatchewan River within your province?'

Perceived Trend	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Improved	68	30.4	68	30.4
Gotten Worse	146	65.2	214	95.5
Remained the Same	10	4.5	224	100.0

Missing = 5

Respondents who identified changes in the trend in water quantity issues were asked to rank three important contributing factors. Overall, a weighted score approach was used to score of the importance to each factor (Figure 6.11). This was done by summing the frequencies of that factor voted by the respondents as the top important factor, the second and the third important factor using weight 3, 2 and 1. Figures 6.11 and 6.12 indicate that overall the top three factors were *demand management* (*e.g.* pricing, conservation, introduction of new water users, regulation of water users), *climate/weather* (*e.g.* changing weather and climate, glaciers melting) and *supply management* (*e.g.* flow regulation, water supply) in the opinions of the respondents.

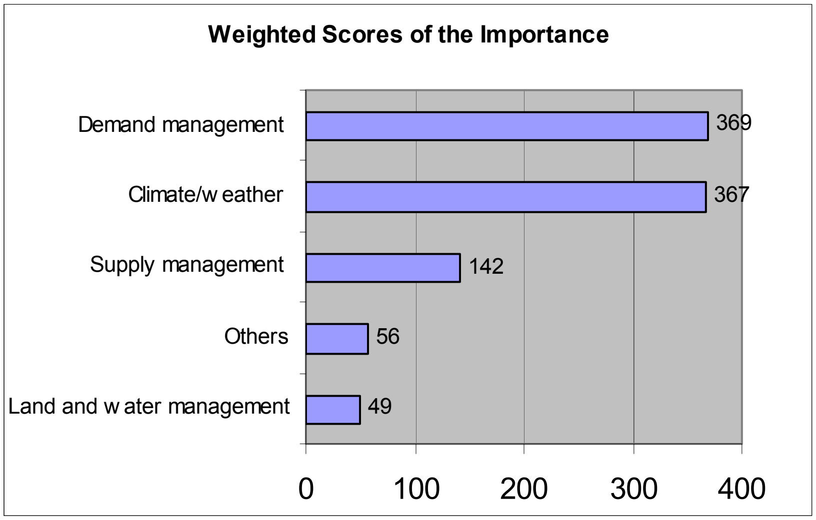


Figure 6.11: Weighted scores of the importance of the factors

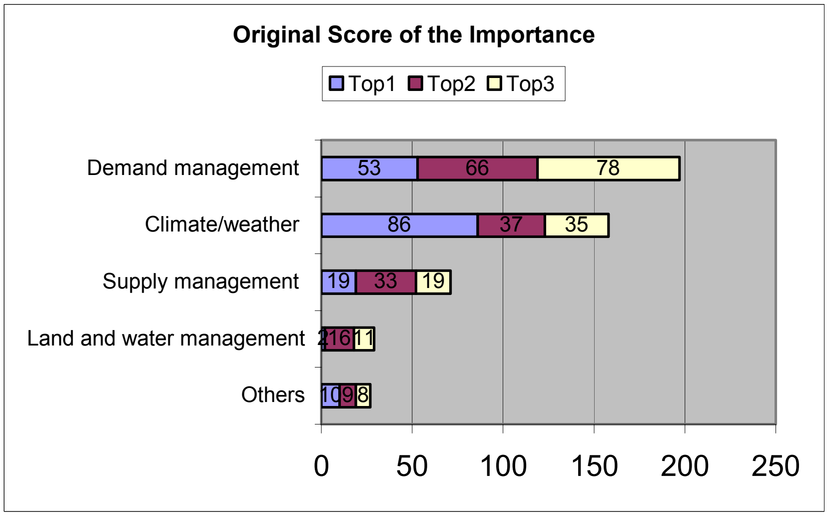


Figure 6.12: Original scores of the importance of the factors

What is interesting about the results from Figures 6.11 and 6.12 is that perceived shortcomings in water demand management approaches are believed to be more important or just as important in causing the apparent deterioration of water quantity conditions over the past 10 years as changing weather patterns. This finding has at least two implications.

First, it suggests that at least some changes in water allocation policies aimed at moving from water supply management to demand management are perceived negatively by water users. For example, water metering in Calgary remains controversial. However, there could be strong support by some people for greater efforts to improve fairness in instituting water demand policies or by other water users to move more quickly to demand management, for example, to increase the efficiency of water use. Further analysis of the data obtained in this survey may help clarify the precise opinions of government officials and water users. In any event, research focused on water demand management appears warranted.

This survey was carried out at the end of a two-year drought in the basin. Clearly, people's responses were influenced by that fact. Even under normal circumstances, the Saskatchewan River basin is subject to a considerable variability in water supplies, both within the year and between years. Further research into climate variability and change, and its link to perceptions and attitudes is also warranted.

The trend of water quantity issues was strongly associated with environmental values (Table 6.10). This was a statistically significant relationship. Somewhat surprising from perspective of the stereotypical characteristics of the two environmental paradigms, those who were more neutral or accepted the New Environmental Paradigm were more likely to believe that water quantity issues had improved over the past 10 years (25 of 48 NEP respondents (52.1%). Only 42 of 175 DSP respondents supported an improvement in conditions. DSP respondents were more likely to suggest that the situation had gotten worse (126 of 175 or 72.0%), while 20 of 28 (41.7%) NEP respondents supported this perspective (Table 6.9). This association might reflect the tendency for NEP respondents to be more inclined to believe in the demand management approaches that have been implemented over the past 10 years.

Table 6.10: Relationship between the Perceived Trend in Water Quantity Conditions over the Past 10 Years and Environmental Values (# of respondents (%))

	Gotten Worse	Remained the Same	Improved	Total
Accept the Dominant Social Paradigm	126 (56.5)	7 (3.1)	42 (18.8)	175 (78.5)
Neutral or Accept the New Environmental Paradigm	20 (9.0)	3 (1.4)	25 (11.2)	48 (21.5)
Total	67 (30.0)	146 (65.5)	10 (4.5)	223 (100)

(missing = 5) p = 3.571E-04

63.6% (143) of all respondents perceived current water quantity issues within their province as “serious” or “very serious” (Table 6.11). While individuals who were neutral or accepted the New Environmental Paradigm were more likely to perceive conditions as getting worse over the past 10 years, those who accepted the Dominant Social Paradigm were more likely to regard current conditions as "very serious" or "serious" (Table 6.10). This is a statistically significant relationship.

Table 6.11: Relationship between Seriousness of Water Quantity Issues within Respondent's Province and Environmental Value (# of respondents (%))

	No Opinion	Not (very) Serious	Neutral	(Very) Serious	Total
Accepts the Dominant Social Paradigm	14 (6.2)	25 (11.1)	17 (7.6)	121 (53.8)	177 (78.7)
Neutral or Accepts the New Environmental Paradigm	1 (0.44)	18 (8.0)	7 (3.1)	22 (9.8)	48 (21.3)
Total	15 (6.7)	43 (19.1)	24 (10.7)	143 (63.6)	225 (100)

Missing = 3; p = 0.0012

One set of questions asked respondents to identify their views on human-induced climate change and its impacts on droughts and floods. The majority of respondents (124 or 56.1%%) believed that the climate was changing (Table 12). 84 (38%) expressed the view that the climate would change, was likely to change or could change in the future. 8 (3.6%) suggested that climate change was unlikely or could not occur.

Table 6.12: Frequency of responses to the question –
'To what extent do you accept the possibility of human-induced climate change?'

Opinion Cumulative	Frequency	Percent	Cumulative Frequency	Percent
No Opinion	5	2.3	5	2.3
Climate is Changing	124	56.1	129	58.4
Climate certain/likely/may change	84	38.0	213	96.4
Unlikely/cannot Change	8	3.6	221	100.0

Missing = 8

This suggests that there is a consensus among water users and government officials that human-induced climate change has already been demonstrated and will continue to be in the future. It also suggests that respondents believe that there are potentially serious consequences to address. A large majority of respondents expected human-induced climate change to result in more droughts (214 respondents, 98.6%) while 3 respondents (1.4%) offered a different view. 181 respondents (87.9%) suggested that flooding would become more frequent, while 25 (12.1%) believed that flooding would become less frequent. A clear majority of respondents believe that climate change will result in more frequent extreme water-based events – droughts and floods.

6.3.5.2 PERCEPTIONS OF FAIRNESS IN WATER APPORTIONMENT

Fairness is part of the study of ethics. The latter is defined as the "study or discipline which concerns itself with judgements of approval or disapproval, judgements as to the rightness or wrongness, goodness or badness, virtue or vice, desirability or wisdom if actions, disposition, ends, objects, or states of affairs" (Runes, 1983, 113). This study does not suggest that any government action, past or present, has been or is "unfair", "wrong", or "bad". Instead, the intent is to describe and explain what groups perceive fairness in a similar manner, and what aspects of fairness are viewed differently.

Respondents were asked to comment on their familiarity with the Master Apportionment Agreement and their views of its fairness (Tables 6.13 and 6.14). 71 (31%) of all respondents indicated that they were not familiar with the agreement and 104 (45%) indicated some familiarity with it. 54 (24%) were very familiar with it.

Table 6.13: Frequency of responses to the question -
'How familiar are you with the Master Apportionment Agreement?'

	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Not Familiar	71	31.0	71	31.0
Somewhat Familiar	104	45.4	175	76.4
Very Familiar	54	23.6	229	100.0

When asked to comment on their perceptions of fairness of the Master Agreement, 95 respondents (41.7%) perceived it as fair. Almost 50% (111) of respondents offered no opinion or did not know. Only 23 (10%) perceived it differently (Table 6.14). Of those who offered an opinion 95 (80.5%) perceived the Master Apportionment Agreement as fair.

Table 6.14: Frequency of response to the question - 'Do you think the Master Agreement on Apportionment is fair in apportioning water among the prairie provinces?'

	Frequency	Percent	Cumulative Frequency	Cumulative Percent
No Opinion/Don't Know	110	48.2	110	48.2
No	23	10.1	133	58.3
Yes	95	41.7	228	100.0

Missing = 1

There was a statistically significant difference between how government officials and other individuals perceived fairness of the Master Agreement (Table 6.15). This result was not surprising. More government officials perceived management arrangements as fair (73 of 143 respondents or 51.0%) relative to non-government officials (22 of 85 respondents or 25.8%). Non-government officials provided relatively more responses in the "No opinion/Don't know" category (52 respondents or 61.2%) than government officials (58 respondents or 40.6%). For those non-government respondents who provided an opinion, there was a 66.7% (22 of 33 respondents) who perceived water apportionment as fair.

Table 6.15: Perceptions of fairness of the Master Agreement on Water Apportionment between Government and Non-government Officials (# of respondents (%))

	No Opinion/ Don't Know	No	Yes	Total
Government	58 (25.4%)	12 (5.3%)	73 (32.0%)	143 (62.7%)
Non-Government	52 (22.8%)	11 (4.8%)	22 (9.6%)	85 (37.3%)
Total	110 (48.2%)	23 (10.1%)	95 (41.7%)	228 (100%)

(missing = 1) P = 8.234E-04

There was also a statistically significant relationship between water user type and perceived fairness of the Master Agreement on Apportionment (Table 6.16). In-stream users are more likely to voice dissatisfaction with the Master Apportionment Agreement than others. 15 of 38 in-stream respondents (39.5%) perceived present arrangements as fair. This is much a much lower level of support than the other user groups – withdrawal (45.3%), water quality (57.1%), and other (73.3%). This pattern may reflect the longstanding efforts by PPWB members to meet the needs of withdrawal users, particularly farmers, and its recent initiatives to link water quantity and water quality considerations, as well as surface and groundwater considerations in their decision making. Since there has been implicit rather than explicit reference to the protection and enhancement of in-stream flow uses relative to the other uses by the PPWB, this group perceives itself in a relatively disadvantaged position.

Table 6.16: Perceptions of fairness of the Master Agreement on Water Apportionment by Government Respondents from Various Water Use Groups (# of respondents (%))

	No Opinion/ Don't Know	No	Yes	Total
In-stream	18 (13.3%)	5 (3.7%)	15 (11.1%)	38 (28.2%)
Withdrawal	26 (19.3%)	2 (2.2%)	24 (17.8%)	53 (39.3%)
Water Quality	5 (3.7%)	1 (0.7%)	8 (5.93%)	14 (10.4%)
Other	5 (3.7%)	3 (2.2%)	22 (16.3%)	30 (22.2%)
Total	54 (40%)	12 (8.9%)	69 (51.1%)	135 (100%)

(missing = 9) P = 0.0459

6.3.5.3 PERCEPTIONS OF FAIRNESS IN WATER ALLOCATION

Respondents were asked to comment on the process of allocating water within their province and its perceived fairness (Tables 6.17 and 6.18).

Table 6.17: Frequency of responses to the question - 'How familiar are you with the process of allocating water among users within your province?'

	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Not Familiar	78	34.4	78	34.4
Somewhat Familiar	100	44.0	178	78.4
Very Familiar	49	21.6	227	100.0

Missing = 2

Table 6.18: Frequency of responses to question – 'Do you think the current arrangement for allocating water among various users within your province is fair?'

	Frequency	Percent	Cumulative Frequency	Cumulative Percent
No Opinion/Don't Know	111	48.7	111	48.7
No	38	16.7	149	65.4
Yes	79	34.6	228	100.0

Missing = 1

A similar pattern seen with the Master Agreement is evident. There is a high level of respondents (78 or 34.4%) who are unfamiliar with water allocation procedures within the provinces. Regarding water allocation process within their provinces, 79 respondents (34.65%) believed in its fairness, 38 (16.67%) perceived it differently, while 111 (48.68%) showed no opinion/didn't know (Table 6.18). A relatively small proportion of respondents perceived the current practice of allocation among water uses and between users as unfair.

Although this is a lower level of approval than that associated with the Master Agreement, it is believed to be reasonably high. Differences in the level of perceived fairness between the two procedures relate to many factors including the nature of apportionment and allocation, and the means of participation and its ongoing nature.

Similar trends were seen between the perception of fairness by government and non-government officials of water allocation within provinces (Table 6.19). 61 of 143 government officials (42.6%) perceived water allocation within their province as fair while 18 of 85 non-government respondents (21.2%) shared this view. 49 of 85 non-government respondents (57.6%) provided no opinion or did not know how to perceive fairness, while 62 (43.3%) government respondents shared this perception. 50% (18 of 26 respondents) of non-government respondents who provided an opinion perceived that water allocation within their province was fair.

A large proportion of government officials were unable to provide a clear view of fairness. This suggests that the institutional arrangements for water management are organized along sectoral lines that focus attention on specific water uses. This is a reasonable and traditional approach to water management in Canada and the developed world. The high levels of no opinion/don't know could have implications for information and education programs.

Table 6.19: Perceptions of fairness of water allocation between government and non-government officials (# of respondents (%))

	No Opinion/ Don't Know	No	Yes	Total
Government	62 (27.2%)	20 (8.8%)	61 (26.8%)	143 (62.3%)
Non-Government	49 (21.5%)	18 (7.9%)	18 (7.9%)	85 (37.3%)
Total	111 (48.7%)	38 (16.7%)	79 (34.6%)	228 (100%)

missing = 1) P = 0.0034

Table 6.20 provides insight into how respondents from each province perceived fairness. There is a statically significant relationship between these two variables. Respondents from Alberta are more likely to perceive the Master Agreement on Apportionment as less than fair (25 of 87 respondents or 28.7%) relative to respondents from Saskatchewan (8 of 114 respondents or 7%) or Manitoba (4 of 20 respondents or 20%).

Table 6.20: Perception of Fairness of the Water Allocation by Province
(# of respondents (%))

	No Opinion/ Don't Know	No	Yes	Total
Alberta	30 (13.6)	25 (11.3)	32 (14.5)	87 (39.4)
Saskatchewan	66 (28.9)	8 (3.6)	40 (18.1)	114 (51.6)
Manitoba	11 (5.0)	4 (1.8)	5 (2.7)	20 (9.0)
Total	107 (48.4)	37 (16.7)	77 (34.8)	221 (100)

(missing = 7) p = 2.358E-04

This finding is explained by at least two factors. First, there have been recent and significant initiatives made by Alberta Environment to constrain water demand and provide allocations for in-stream needs. These initiatives have been made, in part, to allow Alberta to meet its commitments under the Master Agreement. There is likely some resentment by Alberta water managers and users that similar aggressive measures have not been undertaken in downstream provinces. Second, in the South Saskatchewan River at the Alberta-Saskatchewan border, the minimum flows noted in the Master Agreement on Apportionment have been met despite the recent periods of low precipitation. However if the period of low precipitation continues and runoff continued, these circumstances could prompt a desire by some to renegotiate the Master Agreement. Since there are no specific provisions for this, there could be some anxiety among water users, particularly in the upstream province, Alberta. Despite these comments, the majority of respondents from all provinces who offered an opinion perceive current arrangements associated with water apportionment among the prairie provinces as fair (Tables 6.14 and 6.19). This is a foundation to build upon for all circumstances – including any perceived need to change the minimum flow requirements under the agreement.

Tables 6.21 and 6.22 provide insight regarding how government and non-government respondents perceived the fairness of water allocation within their province. Earlier comments pertaining to the sectoral approach to management are supported in Table 6.20. Many government officials were unable to provide an opinion or did not know sufficient information about water allocation within their province. The high level of no opinion responses was shared by non-government respondents (Table 6.21). Government officials were encouraged to respond as individuals and not on behalf of their employers. This direction was apparently followed as evidenced by the lack of unanimity among government officials to endorse water allocation procedures within their province. 26 of

38 (68.4%) government officials who offered an opinion perceived procedures in Alberta as fair. Responses in Saskatchewan were 30 of 35 respondents (85.6%) and Manitoba 5 of 8 respondents (62.5%) (Table 6.20).

Response levels for non-government respondents who offered an opinion were Alberta - 6 of 19 (31.5%) who offered an opinion perceiving current arrangements as fair, Saskatchewan 10 of 13 (76.9%), and Manitoba 0 of 1 (0%) (Table 6.21).

The results shown in Tables 6.21 and 6.22 are statistically significant. No similar associations were found to exist between the Master Agreement on Apportionment and perceived fairness by government and non-government officials.

Table 6.21: Perceptions of fairness of water allocation within provinces by Government Officials from each Province (# of respondents (%))

	No Opinion/ Don't Know	No	Yes	Total
Alberta	11 (7.8%)	12 (8.4%)	26 (18.3%)	49 (34.5%)
Saskatchewan	45 (31.7%)	5 (3.5%)	30 (21.3%)	80 (56.3%)
Manitoba	5 (3.5%)	3 (2.1%)	5 (3.5%)	13 (9.2%)
Total	61 (42.3%)	20 (14.1%)	61 (42.3%)	142 (100%)

(missing = 2) P = 6.042E-04

Table 6.22: Perceptions of fairness of water allocation within provinces by Non-government Officials from each Province (# of respondents (%))

	No Opinion/ Don't Know	No	Yes	Total
Alberta	19 (23.8%)	13 (16.2%)	6 (7.5%)	38 (47.5%)
Saskatchewan	22 (27.5%)	3 (3.75%)	10 (12.5%)	35 (43.8%)
Manitoba	6 (7.5%)	1 (1.2%)	0 (0%)	7 (8.8%)
Total	47 (58.8%)	17 (21.2%)	16 (20%)	80 (100%)

(missing = 5) P = 0.0364

Perceptions of fairness of water allocation are also significantly associated with water user type (Table 6.23). Withdrawal and users are more likely to perceive practices within their province as fair relative to in-stream water users. This finding is consistent with the views and explanation provided for the perception of fairness of water apportionment.

Table 6.23: Perceptions of fairness of water allocation by Government Respondents from Various Water Use Groups (# of respondents (%))

	No Opinion/ Don't Know	No	Yes	Total
In-stream	24 (17.8%)	6 (4.4%)	8 (5.9%)	38 (28.2%)
Withdrawal	21 (15.6%)	8 (5.9%)	24 (17.8%)	53 (39.3%)
Water Quality	7 (5.2%)	2 (1.5%)	5 (3.7%)	14 (10.37%)

Other	5 (3.7%)	4 (3.0%)	21 (15.6%)	30 (22.2%)
Total	57 (42.2%)	20 (14.8%)	58 (43.0%)	135 (100%)

(missing = 9) P = 0.0029

Perceived fairness of water allocation was also significantly associated with a respondent's environmental values (Table 6.24). 57 of 91 (62.6%) respondents who offered an opinion from the DSP group perceived water allocation arrangements as fair. Those from the combined neutral and NEP perspective had a higher level of perceived fairness (22 of 26 or 84.6%). The higher level of satisfaction among NEP respondents might reflect initiatives taken by the PPWB members and the provinces, in particular Alberta, to better provide for environmental flows. From this perspective, the needs of the environment are, to some extent, now being addressed.

Table 6.24: Perceived Fairness of Water Allocation within Provinces and Environmental Values

	No	Yes	Total
Dominant Social Paradigm	34 (29.1%)	57 (48.7%)	91 (77.8%)
Neutral or New Environmental Paradigm	4 (3.4%)	22 (18.8%)	26 (22.2%)
Total	38 (32.4%)	79 (67.5%)	117 (100%)

(missing = 1) P = 0.0348

6.3.5.3 THE PERCEIVED ATTRIBUTES OF FAIRNESS

The analysis identified a statistically significant association between environmental values and perception of fairness in both the Master Agreement and water allocation within provinces. In order to determine how fairness was perceived, respondents were asked to rank their level of agreement with 33 statements that reflected the previously mentioned perspectives on fairness. The intent was to identify those statements that received high levels of agreement and disagreement. Two types of analysis are provided below. First, the level of agreement and disagreement is provided for all water users (Table 6.25, column 1). Second, statistically significant differences of the components of fairness based on environmental values is provided (Table 6.25, column 2). Each is discussed below.

6.3.5.3.1 OVERALL LEVELS OF AGREEMENT AND DISAGREEMENT

First, the level of agreement/disagreement with the statements is provided (Table 6.25). Following from the work of Syme *et al.* (1999), where greater than 80% of the sample agreed (strongly agree or agreed) or disagreed (strongly disagreed or disagreed) with the statement, this is indicated by HA (high agreement) or HD (high disagreement). Where

60% to 80% of the sample agreed or disagreed with the statement, this is indicated by GA (general agreement) or GD (general disagreement). Where there is a spread of opinion from strongly agree to strongly disagree, this is indicated by SO (split opinion). The statements shown in Table 6.25 are indicated by the previously mentioned philosophical categories (not the order in the questionnaire). The essence of each philosophy has been translated from its 'pure form' and expressed in 'lay terms'. Some statements are expressed as a negative form of a philosophy.

Table 6.25: Level of Agreement regarding Philosophies of Fairness among all Respondents

Legend:
HA = High Agreement. GA = General Agreement; SO = Split Opinion;
GD = General Disagreement; HD = High Disagreement

Philosophical Perspective and Individual Statement	(1) General Level of Agreement	(2) Significant Differences based on Environmental Values for perceived fairness of both the MAA and Water Allocation
Egalitarianism		
During times of drought all users should share the pain, irrespective of rights.	GA	Yes
If governments have to go into debt to provide enough water for everyone, they should.	SO	
In water allocation, everyone should be treated equally.	SO	
Proportionality		
All water users should pay the full cost of providing and treating water.	GA	Yes
Water should be allocated to those who work the hardest to use it most effectively.	SO	
Recreational users, such as anglers, boaters and canoeists and water skiers, should pay for costs of river and reservoir management.	SO	

Water as a Common Good		
Water is a community resource that cannot be owned by individuals.	HA	
Free Market: Liberarianism		
People who have been allocated water should retain this right only if they can show they are using it wisely.	HA	
Farmers should only be allocated water if they can demonstrate that it is being used efficiently on their property.	GA	
Landowners have a right to use water passing their property only if it does not have a negative effect on those downstream.	GA	
Those who have received water allocations in the past have a greater right to water than those who are relative newcomers.	SO	Yes
Water is a basic public good that is only "lent" to users.	GA	
Utilitarianism and Hedonism		
Water quality is an important issue in many water allocation decisions.	HA	
Water allocations should be used to maximize the overall economic development within a community.	SO	Yes
Recreational uses of water have important economic values.	GA	
Rawl's Procedural Justice		
Since the environment cannot defend itself, allocations should be specifically made to protect it.	HA	Yes
When a water licence is issued, provisions should be made for a periodic review.	HA	Yes

It is impossible to design a decision-making process which is fair to all water users.	SO	
Public involvement should not be used very often in water allocation as most people act out of self interest.	GD	
If the decision-making process is fair, people should accept the final allocation decision.	GA	Yes
Efficiency		
All water should be put on the market and allocated to those who will pay most, regardless of what it is used for.	HD	Yes
If you bought and sold water on the open market, the environment would not be allocated adequate quantities of water.	GA	Yes
Certainty and Forecasting		
It is important to set rules for how water should be allocated for the next generation.	HA	Yes
Human Rights		
Local people are best left to organize water allocation on rivers in rural areas.	GD	
Kant's Categorical Imperative		
Those upstream have a moral responsibility to look after the interests of those downstream.	HA	Yes
There should be no general rules about how to allocate water: it depends on the situation.	GD	Yes
All people of the basin have a right to have a say on water allocation.	HA	
Animal and Environmental Rights		
The natural environment has the same rights to water as people have.	GA	Yes

Environmental Pragmatism (Singer's Animal Rights) While some parts of the environment are valuable and should be preserved through water allocation, some are not so valuable and can be "let go". Any negative effects of irrigation on the land tend to be exaggerated.	SO SO	Yes

When examined thematically, a mix of philosophies concerning fairness rather than one single dominant perspective was selected by respondents (Table 6.25). There is high level of support for positions that: (i) water is a community resource that cannot be owned by individuals; (ii) people who have been allocated water should retain this right only if they can show they are using it wisely; (iii) water quality is an important issue in many water allocation decisions; (iv) since the environment cannot defend itself, allocations should be specifically made to protect it; (v) water should not be placed on the market and allocated to those who would pay the most, regardless of what it is used for; (vi) those upstream have a moral responsibility to look after the interests of those downstream; (vii) all people of the basin have a right to have a say on water allocation; and (viii) it is important to set rules for how water should be allocated for the next generation. Collectively, these statements suggest a strong role for government intervention in the allocation of water, including allocations for environmental considerations. This is also strong support for management to involve the public and consider the interests of upstream and downstream users. The basin-wide perspective provided by the Prairie Provinces Water Board reflects these attributes.

6.3.5.3.2 PERCEIVED FAIRNESS AND ENVIRONMENTAL VALUES

There are some clear distinctions between respondents who were classified as NEP versus DSP that support the traditional characteristics of each (Table 6.25, Column 2). There were statistically significant differences between the two groups with NEP more likely to suggest the following:

- The natural environment has the same rights to water as people have.
- Those upstream have a moral responsibility to look after the interests of those downstream.
- If you bought and sold water on the open market, the environment would not be allocated adequate quantities of water.
- All water should not be put on the market and allocated to those who will pay most, regardless of what it is used for.
- Since the environment cannot defend itself, allocations should be specifically

made to protect it.

What is less clear are the distinction between these two groups concerning public participation – there were no statistically significant differences between NEP and DSP respondents. This suggests that caution should be made in making comments based on the politics of the two groups. Given the orientation of the questions, comments should be limited to the three major factors – limits to growth, balance of nature, and humans over nature. Further analysis will be performed in order to determine what, if any, statistical associations exist between the statements of perception and (i) user groups, (ii) province of residence, and (ii) government and non-government officials. The desirability and feasibility of developing a predictive model based on these and other variables is an area for future research.

6.3.6 IMPLICATIONS AND RECOMMENDATIONS FOR WATER MANAGEMENT

The high level of no opinion/don't know prompts at least two interpretations. First, water users and government officials are not overly concerned about knowing the details of water allocation procedures because they place a high level of trust and confidence in the relevant government officials, agencies and the strength of the strength of the scientific basis that supports decision making. The authors have been and are positively impressed by the professionalism, competence and openness of officials with the PPWB and line provincial agencies. Second, more accessible information might be made available for low cost on the web. The PPWB and some provincial governments have already made steps in this direction.

The differences of opinion between government officials, water users, provinces, and those who have differing environmental values highlights some of the competition and protection that is often associated with water management. While water management is often characterized with terms such as "stakeholders", "partnerships", "participatory approaches", "information sharing" and "consensus building", its actual practice is often "characterized by competition and protection of interests" (Mitchell, 2003). If this view is true, then the institutional arrangements for water management should consider how this conflict can be used as a positive force to promote healthy dialogue among these competing groups and a search for new and effective decisions. The evolution of water management initiatives by the PPWB and the provinces indicate a willingness to explore new ideas and engage a wide range of groups – both government and non-government – in a meaningful debate. By better understanding how fairness is perceived in similar and different ways by different groups, these discussions might be enhanced in the future.

Although competition, protection and the promotion of self interest are important elements of the practice of water management, there is a strong consensus among respondents for basin-wide and collective approaches. This belief likely reflects the high level of regard provided to the Prairie Provinces Water Board and provincial water management agencies, and the reality of current circumstances. It also reflects the potential scale of human impacts on upstream and downstream users and the uncertainty of future water supplies which promote discussion among stakeholders.

The research has shown that water management stakeholders – government and non-government, water user types – in-stream, withdrawal, water quality, other, provinces – are heterogeneous not homogeneous. It is inappropriate to generalize across a user group because the environmental values of individuals as well as their individual circumstances are often different. This raises implications for practice of stakeholder involvement. Is it desirable to have representatives from various stakeholder groups who share the same basic environmental values or should a mix of values and stakeholders be consciously incorporated into relevant participatory approaches?

There are opportunities for further work arising from this study. These related to both the physical system and the social science or human response system. Each is considered below.

6.3.7 RECOMMENDATIONS FOR PHYSICAL SCIENCE

In the conduct of climate change research there is an ongoing need to relate the recent past to the probable future. For this reason, trend analysis using hydrometeorological variables is useful. It is therefore critical that Environment Canada continue to operate its RHBN hydrometric stations and long term climate stations. Trend analyses using the data obtained from these stations should be updated periodically, say every five years.

This study also demonstrated that natural flow arrays could also be used for trend analysis. The natural flow calculations performed for the PPWB, International Joint Commission boards and other bi-national organizations could contribute to a broader understanding of recent trends.

Beyond trend analysis, there are needs to continue to investigate climate scenarios and, in particular to downscale these scenarios to headwaters basins in mountainous regions. The use of coupled atmospheric-hydrologic models could be very important in this regard.

6.3.8 RECOMMENDATIONS FOR SOCIAL SCIENCE

Water apportionment and allocation are perceived as fair and provides a solid foundation from which to continue the development of appropriate management strategies. This study demonstrates that further study of demand management principles and practices is warranted. There seems to be a reasonable level of support across the basin for additional measures, In conducting public participation exercises, government officials should be sensitive to the diversity of values that are contained in any one user group. The desirability and feasibility of obtaining a range of values from user groups in public participation exercises should be considered.

ACKNOWLEDGEMENTS

The trend analysis in this report was performed by Mike Noonan, Environment Canada, Winnipeg. His contributions in performing the analysis and his insights in identifying the consequences of that analysis are gratefully acknowledged. We are also grateful to all respondents who completed questionnaires, and the Partners FOR the Saskatchewan River Basin for their cooperation.

REFERENCES

Alberta Environment 2001. *South Saskatchewan River Basin Non-Irrigation Water Use Forecasts.* Report prepared by Hydroconsult for Alberta Environment.

Alberta Environment 2002. *South Saskatchewan River Basin Water Management Plan - Phase One, Water Allocation Transfers.* Draft Report, Alberta Environment, Edmonton.

Albrecht, D., G. Bultena, E. Hoiberg abd P. Nowak. 1982. "The new environmental paradigm scale." *Journal of Environmental Education*. 13(3): 39-43.

Acurry, T.A. 1990. "Environmental attitude and environmental knowledge." *Human Organization*. 49(4): 300-304.

Barton, B. J. 1984. "The Prairie Provinces Water Board as a Model for the Mackenzie Basin". *Institutional Arrangements for Water Management in the Mackenzie River Basin,* Barry Sadler, ed. University of Calgary Press. Calgary

Burn, D. H. 1994. "Hydrologic Effects of Climate Change in West-Central Canada." *Journal of Hydrology*, 160: 53-70

Chen, A. J. and B. Godwin 1986. "Interprovincial Water Management in Drought Periods". Proceedings, Canadian Hydrology Symposium, National Research Council. Ottawa.

Cohen, S. J.. L. E. Welsh and P.Y. T. Louie 1989. *Possible Impacts of Climate Warming Scenarios on Water Resources in the Saskatchewan River Subbasin.* Canadian Climate Centre Report No. 89-9. Environment Canada, Saskatoon.

Demuth, Michael N., A Wallace, C. Hopkinson, B. H. Luckman and R Keller, 2001. *Recent Mass Wastage of Peyto Glacier in Relation to Past-century Variability and North Pacific Climate Indices.* Poster Paper, CGU National Conference.

Devall, B. and G. Sessions. 1985. *Deep Ecology*. Salt Lake City: Gibbs M. Smith.

DOE 2002. "Trends in Streamflow in Prairie and Northern Region". *Technical Report 2002-1.* Unpublished Manuscript, Environment Canada, Winnipeg.

Dunlap, R.E. and K.D. Van Liere.1978. "The New Environmental Paradigm." *Journal of Environmental Education*. 9: 10-19.

Dunlap, R.E. and K.D. Van Liere .1984. "Commitment to the Dominant Social Paradigm and Concern for Environmental Quality." *Social Science Quarterly.* 65(4): 1013-1028.

Haeberli, W., Frauenfelder, R., Hoelzle, M. and Maisch, M., 1999. "On rates and acceleration trends of global glacier mass changes." *Geografiska Annaler*, 81A(4), 585–591.

Hirsch, R. M., J. R. Slack and R. A. Smith 1982. "Techniques of Trend analysis for Monthly Water Quality Data." *Water Resources Research*, 18 (1): 107-121

IPCC. 2001. *Climate Change 2001: Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press.

Kellow, R. L. 1989. "The Prairie Provinces Water Board: A Working Partnership for Prairie Water Management". The International Coalition, 7th Annual Red River Basin Land and Water International Summit Conference.

Lettenmaier, Dennis P., Eric F. Wood, and James R. Wallis 1994. "Hydro-climatological Trends in the Continental United States, 1948-88." Journal of Climate, Vol. 7: 586-607

Lucas, Alastair R., 1990. *Security of title in Canadian Water Rights.* The Canadian Institute of Resources Law, Faculty of Law, The University of Calgary, Calgary.

Martin, F. R. J., 2002. *Gross Evaporation for the 30-Year Period 1871-2000 in the Canadian Prairies.* Hydrology Report #143. Agriculture and Agri-Food Canada, Prairie Farm Rehabilitation Administration, Regina

Miller, K.A., S. Rhodes and L.J. MacDonnell. 1997. "Water Allocation in a Changing Climate." *Climate Change.* 35: 157-177.

Mitchell, B. 2002. "Perspectives on Watershed Management and Protected Areas Management." Presentation to the Parks Research Forum of Ontario Annual Meeting 2003, London, Ontario.

Mortsch, L.D. 2001. *Framing the Issue of Climate Change: The Beliefs of Canadian Non-government Organizations and the Energy Industry.* Unpublished M.E.S. thesis, Department of Geography, University of Waterloo. Waterloo.

Nash, R. 1989. *The Rights of Nature.* Madison: University of Wisconsin Press.

North, D.C. 1994. "Economic Performance through Time." *American Economic Review*. 84(3): 359-368.

Pentland, R. S., W. D. Hogg, George H. Taylor and AMEC, 2002. *Probable Maximum Flood - South Saskatchewan River Project.* Report for Sask Water. Moose Jaw

Percy, David R., 1988. *The Framework of Water Rights Legislation in Canada.* The Canadian Institute of Resources Law, Faculty of Law, The University of Calgary, Calgary.

PFRA 1982. *History of Irrigation in Western Canada.* Prairie Farm Rehabilitation Administration. Regina.

PPWB 1965. *Apportionment of the Water of Interprovincial Streams.* Prairie Provinces Water Board. Regina

PPWB 1974. *Natural Flow: South Saskatchewan River below Red Deer River.* Prairie Provinces Water Board. Regina

PPWB 1975. *Natural Flow: North Saskatchewan River at the Alberta-Saskatchewan Boundary.* Prairie Provinces Water Board. Regina

PPWB 1976. *Natural Flow: Saskatchewan River at the Saskatchewan-Manitoba Boundary.* Prairie Provinces Water Board. Regina

PPWB 1982. "Historical and Current Water Uses in the Saskatchewan-Nelson Basin". *Water Demand Study.* Prairie Provinces Water Board. Regina

PPWB 1995. *Assessment of Natural Flow Computation procedures and Monitoring Network for Administering Apportionment of the South Saskatchewan River Basin at the Alberta-Saskatchewan Boundary.* PPWB Report No. 133, prepared by Alberta Environmental Protection. Edmonton

PPWB 2000. *The 1969 Master Agreement on Apportionment & Bylaws, rules and Procedures.* Prairie Provinces Water Board. Regina.

Quinton, W. L. and P. Marsh 1998. "Melt water Fluxes, Hillslope Runoff and Stream Flow in an Arctic Permafrost Basin". In *Proceedings, 7th International Conference on Permafrost, Yellowknife, Canada.* Centre d' etudes nordiques, Universite Laval, Laval, Canada. 921-926

Runes, D. 1983. *Dictionary of Philosophy*. New York: Philosophical Library.

Saunders, J. Owen 1988. *Interjurisdictional Issues in Canadian Water Management.* The Canadian Institute of Resources Law, Faculty of Law, The University of Calgary, Calgary.

SNBB 1972. "Water Supply for the Saskatchewan-Nelson Basin". *Report of the Saskatchewan-Nelson Basin Board.* Canada Alberta Saskatchewan Manitoba. Regina

SSRBS 1989. S*outh Saskatchewan River Basin Study.* Final Report. Environment Canada-Sask Water. Regina and Moose Jaw.

Scott, D. and F.K. Willits. 1994. “Environmental Attitudes and Behavior: A Pennsylvania Survey.” *Environment and Behavior*. 26(2): 239-260.

Shackley, S. and R. Deanwood. 2002. “Stakeholder Perceptions of Climate Change Impacts at the Regional Scale: Implications for the Effectiveness of Regional and Local Responses. *Journal of Environmental Planning and Management*. 45(3): 38-402.

Stutt, Roderick Irwin 1995. *Water Policy-Making in the Canadian Plains: Historical factors that Influenced the Work of the Prairie Provinces Water Board (1948-1969).* PhD Thesis, University of Regina. Regina

Syme, G.J., B.E. Nancarrow and J.A. McCreddin. 1999. “Defining the Components of Fairness in the Allocation of Water to Environmental and Human Uses.” *Journal of Environmental Management*. 57: 51-70.

Zhang, Xuebin, K. David Harvey, W. D. Hogg, and Ted R. Yuzyk 2001. "Trends in Canadian Streamflow." *Water Resources Research*, 37 (4): 987-998.

7.0 INTERNATIONAL TRADE AGREEMENTS AND BULK-WATER EXPORTS

From the earliest days of the debate over Canada-U.S. free trade, opponents of the idea have argued that Canada’s fresh water supplies might become subject to the new trade and investment rules and, hence, available for export to the United States. More recent developments surrounding bulk-water export proposals have added force to fears that free trade agreements may place in jeopardy Canada's management of its water resources. Meanwhile, climate change and the prospect of further global warming have raised widespread concerns that large areas of the United States may soon be without access to reliable supplies of usable water. In these circumstances, the eyes of some American entrepreneurs and government officials have turned northward to Canada.

All of these developments seem to call for a systematic assessment of how free trade agreements might bear on the large-scale export of water from Canada to the United States. The present study undertakes to do this through a review and summary of the literature on the NAFTA and water exports, along with a brief consideration of the international literature on cross-border agreements concerning freshwater management and bulk-water transfers. It concentrates on four primary areas of inquiry: first, an examination of the provisions of the North American Free Trade Agreement (NAFTA) and the World Trade Organization (WTO) that pertain to Canada-U.S. trade in water; second, an assessment of the political economy of capital projects aimed at the export/diversion of Canadian fresh water supplies into the United States, including a brief analysis of the so-called "Chicago Diversion"; third, a review of the NAFTA provisions that might apply to foreign direct investment in the provision of water services; and, finally, a summary of the literature on trans-jurisdictional conflicts over access to water resources and the role of international organizations, treaties and dispute resolution mechanisms in avoiding or settling such conflicts.

At its core, the argument constructed in what follows is that international trade in bulk-water is not likely to become a major issue in the near future. This is because the cost of transporting large volumes of fresh water from where it is more plentiful to where it is more scarce is likely to prove prohibitively high when compared with obvious alternatives, such as pricing water at its marginal cost. Nevertheless, closer inspection of the ways in which trade liberalization might affect North American markets for water is still warranted, given that transnational corporations (TNCs) and their investment strategies promise to play a part in the continental politics of water in the foreseeable future. To this extent, some preliminary attention to new or amended legal and institutional arrangements might help to avoid unnecessary conflicts and misguided policies in the future. However, the present discussion is not intended to make a case for changes in existing arrangements, but rather to clarify their implications for trade and investment in water and water services.

7.1 INTERNATIONAL BULK WATER TRANSFERS: THE POLITICAL ECONOMY OF WATER PIPELINES AND INTER-SHED DIVERSIONS

Since the mid-1980s, when the Canada-United States Free Trade Agreement (FTA) was first actively debated within Canada, there has been widespread and intense controversy over the linkages between "free trade" and "water exports", although precisely what these terms actually encompassed was rarely clear. If anything, the years since have amplified and further complicated this debate, partly because the issue of reliable access to fresh water is of increasing concern throughout North America and partly because the formal liberalization of markets has extended beyond the FTA to include the NAFTA and the WTO, both of which touch on various points in contention. Compounding this trend toward increasing controversy, just about all analytic work on the issue – whether ostensibly in the fields of economics, law, political science, or the environmental sciences

– is inextricably interwoven with political and ideological differences over the fundamental desirability trade in water (not to mention free trade in general). This political charge on most of the available literature makes it difficult to get to "the Truth" of the matter, or to even to a few "truths" about it.

The disputatious character of this issue begins with the seemingly elementary question of whether or not water qualifies as a "good" under the accepted norms of trade agreements. The phrases "bulk water", "water transfers"; "water export(s)" and "export(s) of water" do not appear anywhere in the text of the NAFTA.[79] Nevertheless, some opponents of water exports have made much of the fact that water has been designated the status of a "good" within the General Agreement on Tariffs and Trade (GATT), the predecessor of the WTO. By their argument, this GATT classification – which is cross-referenced in both the FTA and the NAFTA – means that signatories to the later trade agreements have made their water resources subject to all of the trade provisions they contain, including those concerning the "national treatment" of foreign producers, consumers and investors and the prohibition of bans on the export of goods.[80] In particular, a heading (22.01) of the Harmonized Commodity Coding System refers to "Waters, including natural or artificial mineral waters and aerated waters, not containing added sugar or other sweetening matter nor flavoured; ice and snow." A subsequent explanatory note for heading 22.01 states that it covers "ordinary natural water of all kinds (other than sea water)."[81]

The alleged legal implication of these interconnections among existing trade agreements is that Americans have access to Canadian natural waters at least as open and unfettered as Canadians do. Thus the Canadian Environmental Law Association asks us to

> ...consider the example of a diversion project hypothetically undertaken in southern Alberta to provide drought relief to Albertan farmers. The U.S. agricultural sector, under the National Treatment provisions of the FTA, is well within its rights to assert that if the United States pays for the capital works to bring the water from where we have it to where they need it, and to construct bigger dams to provide sufficiently large catchment basins, then under the National Treatment provisions of the deal, U.S. farmers have a right – equal to Canadian farmers – to access the benefits of the project...Americans can, indeed,

---

[79]The author has constructed a machine readable (WordPerfect) version of the entire NAFTA from the official text available on the web site of the Canadian Department of Foreign Affairs and International Trade. Computer searches of this file for all of the terms mentioned produced no results.

[80]See, for example, Canadian Environmental Law Association, *NAFTA and Water Exports*, Report prepared with financial assistance of the Ontario Ministry of Intergovernmental Affairs, 1993, mimeo, p. 2. (Hereafter cited as CELA, *NAFTA and Water Exports*.) Both Article 201.1 of the FTA and Article 201 of the NAFTA state that "goods of a party" are defined as understood in the GATT.

[81]Ibid., p. 3.

"turn on the taps" to Canadian water.[82]

In the light of cautions such as these, it is perhaps not surprising that the member governments of the FTA and the NAFTA have gone out of their way to provide frequent public assurances that these agreements in fact establish no obligation on any of them to export water. The chapter and verse of these repeated assurances will not be reviewed here. However, one recent study has presented a even-handed summary of both sides of this protracted debate, as follows:

> ...the three NAFTA countries clearly stated in their joint declaration of December 1993 that the NAFTA does not apply to water in its natural state in lakes, rivers, etc., since the water has not at that point "entered into commerce and become a good" for the purposes of the NAFTA. The [Canadian] federal government has taken this position all along with respect to the NAFTA and its predecessor, the FTA. Nevertheless, critics of the government position remain adamant that water in its natural state is covered by the NAFTA and that nothing short of an amendment to the agreement, accompanied by federal legislation banning large scale water exports, will protect our water resources adequately. Hence, the concerns of critics have not been appeased by the federal government's recent announcement of a strategy for seeking a commitment from all jurisdictions across Canada to prohibit the bulk removal of water, including water for export, from Canadian watersheds. Thus, the debate concerning water exports continues.[83]

More recently, the Government of Newfoundland and Labrador received an opinion on this matter that more closely resembles the federal government's position summarized in the preceding paragraph. According to this opinion,

> NAFTA and the WTO place obligations on Canada in respect of trade in goods and in respect of investment by the investors of NAFTA parties. These obligations apply to bulk water only if the sale of bulk water is permitted and bulk water is placed into commerce. Nothing in NAFTA or the WTO requires a state to exploit its natural resources. There is, thus, no obligation on Canada to

---

[82]Ibid. The national treatment provision cited by this source is Article 105 of the FTA, which states that, "Each Party shall, to the extent provided in the Agreement, accord national treatment with respect to investment and to trade in goods and services."

[83]David Johansen, "Water Exports and the NAFTA", Ottawa, Parliamentary Research Branch, March 8, 1999, p. 10. The joint federal-provincial strategy referred to did not succeed, owing to the reluctance of provincial governments to cede or compromise their constitutional jurisdiction over natural resources. However, all but one of the provinces (New Brunswick) subsequently passed unilateral legislation that effectively bans the "bulk removal" of water outside their borders or between their major watersheds. It is worth noting that, in framing such prohibitions, all governments in Canada seem careful to avoid the use of the term "water exports", apparently out of a concern that to do so would subject their attempts to regulate this matter to appeals under existing trade agreements. See B. Timothy Heinmiller, "Harmonization Through Emulation: Canadian Federalism and Water Export Policy", paper presented to a conference on "Questioning the Boundaries of Governance: A Graduate Workshop on the Theory and Practice of Federalism, Decentralisation and Multilevel Governance", Monk Centre for International Studies, University of Toronto, February 14-15, mimeo, p. 20.

> permit the sale of bulk water. It can do so if it chooses. Since natural resources, including fresh water, fall within provincial jurisdiction, any decision on the sale of bulk water is a matter for each province.[84]

This opinion goes on to make the case, however, that should a province authorize the sale of bulk water, then relevant rules of the NAFTA and WTO would apply, with two major consequences. First, barring legitimate environmental grounds for doing so, the sale of bulk water could not be restricted to the domestic market within Canada. Second, any subsequent decision to stop selling bulk water might involve liability to foreign investors for denying them expected commercial benefits of any investments they had made.[85]

7.2 INTERNATIONAL BULK WATER TRANSFERS: THE POLITICAL ECONOMY OF WATER PIPELINES AND INTER-SHED DIVERSIONS

The legalities of bulk water exports say nothing about the probability that any such projects will be undertaken in the foreseeable future. It is therefore the task of the present section to explore some of the economic considerations that might be expected to bear on this possibility. Of particular interest here are the economics of bulk water transfers, as well as the regulatory constraints – apart from international trade law – that are likely to affect the prospects for such developments.

The economics of international bulk-water transmission are not very attractive, a fact that can be substantiated by observing that very little of it takes place anywhere in the

---

[84]Donald M. McRae, Faculty of Law, Common Law Section, University of Ottawa, April 12, 2001, as reproduced in Government of Newfoundland and Labrador, *Report of the Ministerial Committee Examining the Export of Bulk Water*, October, 2001, p. 21. (Hereafter cited as Newfoundland and Labrador, *Report*.)

[85]Ibid. Export restrictions are prohibited under GATT Article XI and NAFTA Article 309, unless they can be justified under GATT Article XX or NAFTA Article 315. In addition, NAFTA includes a "proportionality clause" (Art. 315) which specifies that (subject to several qualifications) the government of a member country cannot reduce or restrict the export of a resource to another member country once the export flow has been established, and that any such reductions must be proportionate to reductions in deliveries to domestic markets. For further details, see Barry Appleton, *Navigating the NAFTA: A Concise User's Guide to the North American Free Trade Agreement* (Scarborough, Ont.: Carswell, 1994), pp. 204-5.

world.[86] The transmission of bulk water can be physically accomplished in only five known ways: by ocean-going tanker; by tanker trucks carried by barge; by pipeline; by huge floating bags towed by ship; and by water diversions.[87] The best-known and most fully-costed of these methods is that of bulk-water tankers (converted from their more conventional function of shipping crude oil), the economics of which are not promising. In fact, the lowest estimated cost of tanker shipments is approximately US$1.14 per cubic meter for a 15 day return trip, and the cost could easily run as high as US$3.60 per cubic meter.[88] Meanwhile, in 2001, the wholesale cost of treated water in California, for example, was reported to range from US$0.32 to US$0.49 per cubic meter.[89] In some of the driest regions of the United States, these prices can double. Nevertheless, even the highest of these prices is currently insufficient to cover the cost of tanker shipments.

Bulk-water pipelines have also been considered and, in a few instances, costed-out as a means of transmitting water. Again, the economics of such projects are not encouraging. For example, in 1971, the Libya pipeline project was conceived to pump water a distance of over 1,000 km from the southern Nubian desert to cities on the Mediterranean. At maximum scale, this project was anticipated to supply 730 million cubic meters per year, the equivalent of a good-sized river. However, the estimated cost was $25 billion, and the sources of ground-water involved were expected to run out in forty-to-sixty years, so the project was abandoned.[90] Meanwhile, at roughly the same time (and closer to home) it

---

[86]There are a few cases world-wide of international water transfers, generally on a very small scale. Within North America, a few delivery systems carry small volumes of Canadian municipal water to American towns a few miles across the border. An example is the sale of water by the town of Coutts, Alberta, to the nearby community of Sweetgrass, Montana. See Anthony Scott, John Olynyk and Steven Renzetti, "The Design of Water Export Policy" in John Whalley, Research Coordinator, *Canada's Resource Industries and Water Export Policy*, Volume 14 in a series of studies commissioned by the Royal Commission on the Economic Union and Development Prospects for Canada (Toronto: University of Toronto Press, 1986), p. 184. (Hereafter cited as Scott, "Water Export Policy".) It is worth noting, in the context of the discussion below of delivered water prices, that the price charged for these exports (in 1982) was Cdn$0.42 per cubic meter.

[87]See James Feehan, "Export of Bulk Water from Newfoundland and Labrador: A Preliminary Assessment of Economic Feasibility", Government of Newfoundland and Labrador, *Report,* Appendix III, p. 12.

[88]Costs depend on the capacity of the tanker, the number of days consumed by the return trips, and the state of the oil tanker market. The above estimates do not even include the cost of on- and off-loading facilities. See ibid., pp. 13-15.

[89]Ibid, p. 21. The present author converted the figures on water costs from US$/acre foot. These figures compare reasonably well with other sources on water prices in the western United States, such as CELA, *NAFTA and Water Exports*, p. 99. See also NUS Consulting Group, "Cost of water goes up worldwide, with larger increases expected", August 17, 2001, http://www.edie.net/news/Archive/4581.cfm This source records "national" (presumably average) prices (in US$/cubic meter) in selected countries, including 0.52 for the United States, 1.11 for the United Kingdom and 0.37 for Canada.

[90]O'Dean P. Judd, "A Future Basis for National Security and International Policy: Fresh Water" in Siegfried

was proposed to construct a pipeline to transport water from Alaska to Lake Shasta, in California, a distance of 2,200 km. The estimated cost here was US$110 billion, yielding unit costs of delivered water at an estimated US$2.40-3.25 per cubic meter.[91]

In light of these disparities between the cost of bulk-water transmission and current prices for water in major American markets, inter-watershed diversions may be the only economically viable mode of exporting water in the quantities envisaged by both the proponents and detractors of bulk-water exports in North America, especially in the absence of major modifications to the standard – and enormously subsidized – water-pricing regimes now in place throughout most of the United States.[92] However, even if the cost of creating and operating major diversion schemes were to prove more attractive than tanker or pipeline delivery of water, such projects would still involve huge initial outlays for construction, as well as major uncertainties generated by regulatory processes on both sides of the border.

In this respect, the history of large-scale, natural gas transmission systems may provide an indication of the probable economic, political and regulatory obstacles to comparable undertakings for the trans-shipment of water. During the 1950s and 1960s, the governments of Canada and the United States encountered significant difficulties in achieving the international regulatory coordination required to plan and efficiently complete major cross-border pipeline projects. Both countries had a system for approving "certificates of public convenience and necessity", which empowered the companies planning such trans-continental projects to prevail over the other economic and social interests they impinged upon. The difficulty was in getting the requisite authorities on opposite sides of the border to approve such certificates on the same, or

---

S. Hecker and Gian-Carlo Rota, eds., *Essays on the Future in Honor of Nick Metropolis* (Boston: Birkhauser, 2000), ch. 9, p. 113. It is worth noting that (allowing for their broad-brush character) these cost estimates work out over a fifty-year life-span to a unit cost of delivery of US$0.68 per cubic meter (based on calculations conducted by the present author on data provided by Judd).

[91]Ibid. The plausibility of this cost estimate may be measured against the cost projections in 1982 for a much more modest plan to transfer water from the Mississippi/Missouri drainage to the High Plains region stretching from Texas to Nebraska, which the U.S Army Corps of Engineers estimated could run as high as US$0.64 per cubic meter. See Scott, "Water Export Policy", p. 177. Meanwhile, Judd provided figures for the cost of agricultural water in the California market at at 5-to-10 times below the prevailing cost of urban water of only US$0.25-0.50 per cubic meter – in other words, less than 10 cents per cubic meter.

[92]A report of the North American Commission for Environmental Cooperation (CEC) has recently complained about how, "in many parts of North America, pricing schemes actively discourage water efficiency and conservation. These economic 'disincentives' include lack of water meters in homes, flat rates for water users, and subsidized rates for large industrial or agricultural users." See CEC Secretariat, *Draft Options for a CEC role in the Sustainable Use and Conservation of Freshwater in North America*, n.d. (probably February 28, 2003), p. 11. Accessed at http://www.cec.org/news/details/index.cfm?varlan=english&ID=2526. (Hereafter cited as CEC, *Draft Options*).

even compatible, terms and conditions.[93]

The promoters of such projects also encountered difficulty in matching available suppliers with eventual consumers on sufficiently favourable terms – and in sufficient time – to ensure the economic viability of specific pipeline ventures. The initial investments demanded by such undertakings are so large that their amortization becomes a significant component of fixed costs, and therefore adds substantially to the ultimate unit cost of delivery. These costs can become so high that the price the commodity would have to command in the designated market rises to a level that obviates the need for the deliveries in the first place. In other words, minimally-viable prices promise to be so high that they would both depress demand and promote alternative supply of the commodity to the extent that the projected market for the commodity to be delivered by the project disappears.[94]

Meanwhile, this basic economic obstacle is exacerbated by the required regulatory approval process already mentioned. This often entails the politically-charged allocation of burdens and benefits among suppliers, transmitters and consumers, which in turn can lead to long delays, uncertainties and financial risk that ultimately add to total cost. Nation-to-nation diplomacy – and issue linkages – are very likely to prove necessary to achieve resolution of these kinds of problems. In this context, it is worth noting that – despite all the attention paid to the pricing, marketing and security of energy supplies in the FTA and the NAFTA – scarcely a word was said in either agreement about the regulatory approval of cross-border transmission projects.[95] There is, therefore, no

---

[93]For a detailed history of cross-border pipeline development between Canada and the United States see John N. McDougall, *Fuels and the National Policy* (Toronto: Butterworths, 1982), chs. 4–6. In a similar vein, Scott points to the abortion of the Alaskan natural gas pipeline project over twenty years ago as an object lesson in the combination of regulatory and economic factors that can work to undermine the viability of large-scale, international transmission facilities: "This $40 billion project was half built when the U.S. importers belatedly discovered in the late 1970s that gas from contiguous states would be less expensive than Alaskan or Canadian supplies. This discovery has led to financing difficulties and project delays so that it is now [1986] uncertain when, or even if, the pipeline will be completed." See "Water Export Policy", p. 179.

[94]Scott, "Water Export Policy", pp. 205-24, contains a good overview of the cost-benefit calculations bearing on major water transmission systems. Elsewhere (pp.178-9) the study makes the point that "the delivery of Canadian water...would be a very unattractive alternative to developing the political will to make better use of the water supplies already available in the south and southwestern United States." It also supports the argument made above that most of the water "shortages" that part of the country are the result of fixed or non-existent pricing of the commodity in major markets, especially those for agricultural uses.

[95]See John N. McDougall, "The Canada-U.S. Free Trade Agreement and Canada's Energy Trade", *Canadian Public Policy*, 17, 1 (March, 1991): 1-13. The NAFTA's Article 606, titled "Energy Regulatory Measures", creates no precise legal obligation on the part of its members to extend the principle of national treatment into the regulation of energy facilities (although Section 1 of that article does explicitly extend it to government action with respect to exports and export taxes). Instead, Section 2 of the article stipulates

analogous "case law" under these trade agreements for large-scale projects for the transmission or redirection of water.

7.2.1 THE CHICAGO DIVERSION PROJECT

For all of the foregoing reasons, it seems likely that the only viable form of bulk-water export in the foreseeable future may be that of inter-basin diversions. Among these, the most plausible seems to an expansion of the Chicago Diversion project, more precisely known as the Chicago Sanitary and Ship Canal. This facility originated in the mid-19th century by reversing the Chicago River so that instead of flowing into Lake Michigan, it flows into the Illinois River and thence the Mississippi (thus relieving the City of Chicago of the problem of disposing of its sewage in Lake Michigan). More recently, in the early 1980s, drought conditions in the Mississippi and Missouri basins led to calls to utilize this system to divert water out of Lake Michigan to restore the water levels in these rivers so that barge traffic could be restored.[96]

There are increasing concerns in some quarters that potentially large amounts of Great Lakes water could one day be routed through an expanded version of the Chicago Diversion.[97] Indeed, in the early 1980s, it was identified as one of several schemes for major Great Lakes diversions, prompting the Council of Great Lakes Governors to create a Task Force on Water Diversion and Great Lakes Institutions. Its mandate was to "examine the existing institutional mechanisms to protect the Great Lakes from diversions and to recommend ways to strengthen the ability of the Great Lakes states and provinces to collectively and individually protect their shared water resources."[98] The task force drew up the Great Lakes Charter, a non-binding agreement, which was signed by the eight Great Lakes states, Ontario and Quebec on February 10, 1985.[99] However,

---

that each member must ensure that, in the application of any energy regulatory measure, "energy regulatory bodies within its territory avoid disruption of contractual relationships to the maximum extent practicable, and provide for orderly and equitable implementation appropriate to such measures." As NAFTA obligations go, this one seems far from a precise or firmly-binding commitment.

[96]See CELA, *NAFTA and Water Exports*, p. 33.

[97]See Stewart J. Cohen, “Impacts of CO2-induced climatic change on water resources

n the Great Lakes Basin”, *Climatic Change*, 8 (1986): 135-53. Cohen writes, "Small fluctuations in lake levels have caused significant damage in the past, including losses in hydro-electric power production, lake shipping, and shoreline erosion."

[98]See the "Fate" report, chapter 4: "The Great Lakes Charter" published February 1997: http://www.glu.org/publications/fate%20report/fate_c4.htm

[99]Binding or not, the Great Lakes Charter fostered the creation of the Great Lakes Commission, whose powers of publicity, if not legal veto, prevented at least one bid for water exports from the Great Lakes. See Kathie Canning and Kate Harrigan "Water export scheme scrapped" *Pollution Engineering* 31, (January, 1999), p. 3. According to this report, following protests by the Great Lakes Commission and a number of other organizations, "the Nova Group Ltd. of Sault Ste. Marie, Ontario, Canada, abandoned its controversial plan to export Great Lakes water to overseas customers."

because the Chicago Diversion has existed for such a long time, it is unclear whether the Charter would apply to plans to expand the amount of water diverted through the project. For example, in 1988, the U.S Army Corps of Engineers talked of tripling its size, and claimed that it had sufficient authority to proceed with the project without the approval of the Great Lakes states or provinces. However, it appears that this expansion did not proceed, and the recent average flow through the Diversion has remained within the limit of 3,200 cubic feet per second set by a U.S. Supreme Court decree in 1967.[100]

Nevertheless, the possibility persists that potentially large amounts of Great Lakes water could one day be routed through an expanded version of the Chicago Diversion and, as already suggested, economic considerations give this possible mode of water export greater economic feasibility than most others. Moreover, such an undertaking is plausible (though still not highly probable) precisely because it is free of many of the obstacles that stand in the way of other possible diversion and transmission schemes. For example, it:

- is already in existence, though on a minor scale.
- involves the southern end of Lake Michigan, which places it entirely within United States territory. This in turn means, most notably, that unlike all of the other Great Lakes it does not straddle the Canada-United States boundary. For both reasons, Canadian leverage on the issue of further development of the project, either directly or through the offices of the International Joint Commission (IJC), is significantly curtailed.[101]
- involves a potentially high ratio of volumes transferred per unit of scale of construction. Neither the distances nor the elevations involved are great, and facilities and capital expenditures would be modest compared with some mid-continent schemes that have been contemplated.

Nevertheless, any projected expansion of the facility would involve a reduction of fresh water available to Canadians in the Great Lakes/St. Lawrence basin, and thereby would constitute a bulk water export.

In sum, with the possible exception of an expanded Chicago Diversion, it does not seem very likely that any major project for the large-scale transmission of Canadian water into the United States (or any other form of cross-border transmission of any magnitude) is likely to come forward in the foreseeable future. In this sense, bulk water trade is a non-issue. However, as we shall see in the next section, this does not at all mean that there is no significant intersection between fresh water and international trade agreements. There are increasing signs of a major infusion of foreign direct investment in the provision of water services, and recent trade treaties such as NAFTA and the WTO are at least as

---

[100]See recent flow data provided in Frank H. Quinn, "Anthropogenic Changes to Great Lakes Water Levels" *Great Lakes Update*, US Army Corps of Engineers, Detroit District, Vol. 136, July 2, 1999.

[101]See ibid., which argues that the Diversion is of particular concern because, "unlike Lakes Superior, Huron, Erie and Ontario, Lake Michigan is not considered an international lake and does not fall under the jurisdiction of the International Joint Commission." The identical point is made in CELA, *NAFTA and Water Exports*, p. 33.

significantly involved in the liberalization of markets for investment and services as they are in the markets for goods.[102]

7.3 FOREIGN DIRECT INVESTMENT AND THE DELIVERY OF WATER SERVICES

TNCs with a growing global interest in water-service delivery have a strong financial interest in challenging existing Canadian restrictions on entry into the national market for such services. Meanwhile, a number of observers have pointed out that major TNCs are beginning to penetrate a number of other national markets in significant ways. One reason for their success in doing so is that, increasingly, municipal budgets are subject to combined pressures from their own property-tax payers and new demands for spending, and their governments have begun to look to foreign direct investment as a desirable (perhaps even necessary) substitute for increased municipal taxation.

This is not the place to debate the relative merits of public *versus* private ownership of municipal water services, but it is relevant to this discussion that the penetration of TNCs into the North American market for water services is likely to increase the political salience of the investment provisions of the NAFTA and the WTO. This is true for two reasons. First, there is the possibility that an increase in the foreign ownership of Canadian water services will over time increase the pressure on the Canadian governments to relax existing restrictions on the cross-border integration of water provision generally, thus improving the prospects for the international transfer of water resources. Second, there is the possibility that pressures from foreign investors will add fuel to the domestic Canadian debate about the privatization of water services, in their own right. Given the scope of the current discussion, only the first of these possibilities will receive direct attention here.

A recent Canadian study of water-service TNCs has attempted to alert Canadians to the fact that much is at stake in this contest between public and private priorities with respect to North American markets for water.[103] Barlow and Clark examine how economic globalization is driving what they depict as a world water crisis. They start by looking the World Water Forum in March 2000, where business organizations (such as the Global Water Partnership), the World Bank and leading water corporations discussed how companies could benefit from selling water in markets around the world.[104] Broadly

[102] It is worth noting in this connection that a recent planning document of the CEC, in a section titled "Emerging Issues", makes no mention of international water transfers of any kind. It does, however, refer to "globalization and privatization of water systems." See CEC, *Draft Options*, pp. 13-14.

[103] Barlow, Maude and Tony Clarke, *Blue Gold: The Fight to Stop the Corporate Theft of the World's Water* (New York: New York Press, 2002), esp. pp. 72-76.

[104] The major players in this expanding industry, dubbed "the lords of waters" by Barlow and Clark, are two largest water titans in the world, Vivendi Universal and Suez (formerly Suez-Lyonnaise des Eaux), both based in France. (Unlike most countries, which have traditionally entrusted the delivery of water services to their governments, France began to privatize water delivery as early as the middle of the 19th century.) A second tier of such firms consists of four corporations or consortiums with water service operations that are

speaking, this development has occurred in three different ways.

First, there is the complete sell-off by governments of public water delivery and treatment systems to corporations, as has happened in the UK. Second, there is the model developed in France, whereby water corporations are granted concessions or leases by governments to take over the delivery of the service and carry the cost of operating and maintaining the system, while collecting all the revenues for the water service and keeping the surplus as a profit. Third, there is a more restricted model, in which a corporation is contracted by the government to manage water services for an administrative fee, but doe not take over the collection of revenues or reap profits from surpluses. While all three forms contain seeds of privatization, the most common one is the second model, often referred to as "public-private partnerships".

Two international scholars have also focused on the increasing role of TNCs in the provision of water services and the accompanying growth in public service privatization.[105] They are particularly concerned about corporate concentration in the global water industry, which they claim constitutes a serious obstacle to managing global trade. This creates a strong need, they argue, for the adoption of appropriate legal instruments able to bind TNCs to fair conduct and consequently to better manage global trade in water services. At the same time, the growing prominence of TNCs in world markets for the provision of water services has increased the relevance of the "investment" and "services" provisions of recent trade agreements to issues surrounding the provision and consumption of fresh water, both nationally and internationally.

For instance, several observers have argued that the investor rights provisions of the NAFTA create more permissive conditions for the eventual export of bulk water from Canada than any of the trade provisions addressed in the previous section. For opponents of water exports, these concerns have been amplified over the past several years by decisions from NAFTA tribunals that seem to afford foreign investors open-ended protection against actions by governments to prevent or significantly constrain the commercial exploitation of water resources. Two cases can be cited to illustrate the potential capacity of Chapter 11 to curtail the effective application of domestic regulations with respect to water exports and associated environmental concerns.

Regarding the first of these cases, in October 1999, Sun Belt Water Inc. of California filed suit under Chapter 11 of the NAFTA demanding that an arbitration panel award it damages of between US$1.5 and US$10.5 billion in compensation for the loss of its alleged right to export bulk water from British Columbia. Because the B.C. government had refused to expand an existing licence to ship fresh water from the province by tanker and had later imposed a moratorium on all new or expanded licences, the company

---

best positioned to challenge the market monopoly of the two titans: Bouygues-SAUR, RWE-Thames Water, Bechel-United Utilities and Enron-Azurix (or not!).

[105]See Matthias Finger and Emanuele Lobina, "Managing Trade in a Globalizing World – Trade in Public Services and Transnational Corporations: The Case of the Global Water Industry" in Annie Taylor and Caroline Thomas (eds), *Global Trade and Global Social Issues (*Routledge: New York, 1999) ch. 9.

claimed that its long-term lost profits amounted to "expropriation" under the Article.[106] It also invoked Article 1105 in claiming that British Columbia had breached "minimum international standards" for treating a foreign investor.[107]

Regarding the second case, Ethyl Corporation of Virginia was able to use Chapter 11's "investor-state" provisions to protect itself from what it saw as discriminatory Canadian regulation, after the United States government had declined to do so under Chapter 20's "state-to-state" provisions. (That is, the company was able to circumvent its own government's reluctance to take up the matter directly with the Canadian government before a dispute resolution panel.) At issue was the Canadian government's attempt to ban the use in Canada of the gasoline additive MMT. The company claimed that this ban had cost it US$250 million in lost business and profits. Ottawa ultimately backed out of this dispute at a price of US$13 million in damages and a public apology.[108]

Finally, Chapter 11 also explicitly invokes the over-arching principle of national treatment in relation to investor-state disputes, and this principle can also play a role in protecting the rights of investors in relation to the possible export of water, potentially to the detriment planning and regulation in relation to Canada's water resources.[109] Specifically, there are two different scenarios under which Article 1102 can work to obligate Canadian governments to permit the export of water. One is a case where a Canadian and an American investor are seeking bulk water export licenses or water-diversion approvals. Here, the government in question is constrained by Article 1102

---

[106]Section 1 of Article 1110: Expropriation and Compensation reads as follows: "No Party may directly or indirectly nationalize or expropriate an investment of an investor of another Party in its territory or take measures tantamount to nationalization or expropriation of such an investment ("expropriation"), except: a) for a public purpose; b) on a nondiscriminatory basis; c) in accordance with due process of law and Article1105(1) ; and d) on payment of compensation in accordance with paragraphs 2 through 6."

[107]See Stephen Clarkson, *Uncle Sam and Us: Globalization, Neoconservatism and the Canadian State* (Toronto: University of Toronto Press, 2002), p. 348. According to Clarkson, the case was relegated to a state of "legal suspended animation." Regarding the relevant NAFTA provision, Section 1 of Article 1105, Minimum Standard of Treatment, reads as follows: "Each Party shall accord to investments of investors of another Party treatment in accordance with international law, including fair and equitable treatment and full protection and security."

[108]Ibid., p. 349. While this example has nothing directly to do with water exports, it helps to establish the point that potentially any government law or regulation that constrains a foreign investor's capacity to earn a profit through investing in a Canadian venture can be challenged under Chapter 11 – a confirmation of the "expansive terms" of the chapter identified by the Canadian Environmental Law Association (see fn. 33, below).

[109]Section 1 of Article 1102, National Treatment, reads as follows: "Each Party shall accord to investors of another Party treatment no less favorable than that it accords, in like circumstances, to its own investors with respect to the establishment, acquisition, expansion, management, conduct, operation, and sale or other disposition of investments." Section 2 extends the exact wording of Section 1 to "investments" (as opposed to investors).

from granting a license to a Canadian investor while denying one to an American investor – a denial to the latter of "national treatment". The implication of this is that Canadian governments retain the power to deny water export projects so long as such a prohibition applies to national as well as foreign investors.[110]

The other case is where one company (domestic or foreign) is seeking to provide domestic water services to Canadian municipal consumers from a watershed within in a Canadian province, and another company (domestic or foreign) seeks to do the same thing (from the same watershed) on behalf of municipal consumers in an American state. In other words, the comparison is not between licensing a domestic- versus a foreign-owned proposal for exports, but rather between licensing "in like circumstances" two very similar projects for the delivery of water services, with only national or locational differences between the beneficiaries of the investment. Here, the implication is that, once certain types of exploitation of Canadian water resources are permitted at all, their benefits cannot be restricted to Canadians.[111]

Neither of the possibilities referred to in the preceding two paragraphs is a legal or political certainty. However, this in itself may be a problem. Schrybman's opinion echoes a number of widely-shared concerns – including some on the part of American and Mexican commentators – about the open-ended and untested implications of Chapter 11. For example, he writes that the investment provisions of this Chapter

> represent a very significant innovation in the sphere of international trade agreements and many of the terms and concepts engendered by the provisions of this Chapter are entirely untested by trade dispute of (sic) judicial determination. Making predictions about the likely outcome of prospective litigation arising under these rules is a highly uncertain enterprise.[112]Worse still, the nature of the dispute resolution process contained within this chapter may not even produce clarification of key issues as time passes and cases proliferate, because there is no process of judicial precedent under these procedures that would bind any tribunal to adopting the same interpretation as another tribunal that had considered the same issues. For this reason, Shrybman writes, "it will be impossible in our view for Canada to develop water policy or regulatory initiatives with any certainty that these would withstand the rigours of investor-state litigation or for that matter, trade challenge."[113]

[110]See Steven Shrybman, "Legal Opinion Commissioned by the Council of Canadians Re: Water Export Controls and Canadian International Trade Obligations", Council of Canadians, June 18, 2002, p. 7.

[111]See ibid., p. 8. Shrybman cites the possibility that foreign investors holding riparian rights or licences under federal or provincial permits and attempting to exercise them for purposes of bulk water exports "might assert a claim that any denial of the opportunity to do so represents expropriation under the expansive terms of Article 1110. Alternatively, water use permits, which are silent with respect to the particular purpose for which the license was granted, might also give rise to claims under Chapter 11."

[112]Ibid.

[113]Ibid., p. 9.

7.4 NON-TRADE AGREEMENTS BEARING ON THE RESOLUTION OF WATER-ALLOCATION DISPUTES

The mandate for this study was to examine the provisions of international trade agreements that might have a bearing on possible cross-border trade in bulk water. However, this focus on international trade agreements is probably too narrow, if the fundamental purpose of the inquiry is to clarify what kinds of international legal constraints and opportunities might affect future continental trade in fresh-water resources. In fact, as the brief examination of the Chicago Diversion project suggested, there can be international dimensions to what are ostensibly domestic developments involving the use of shared international resources. For this reason, a wide range of bilateral and multilateral treaties and dispute resolution mechanisms, beyond existing trade agreements, might well become implicated in future conflict and/or cooperation among NAFTA parties with respect to water access, marketing and investments.

In fact, international water conflict resolution is emerging as a recognizable sub-field of international law, international relations and global environmentalism. These fields of study generally work from an assumption that shared water resources are at least as likely to occasion international cooperation as conflict, and that pre-existing international water treaties and other conflict resolution mechanisms can make a critical difference in resolving such conflicts more speedily and amicably. To quote one source on this point, "The key is establishing a process of cooperation early in the trajectory before serious hostilities erupt that make it difficult for nations to sit around a negotiating table together."[114] Similarly, "strong institutions make a difference. Treaties that provide for effective monitoring and enforcement are often remarkably resilient, holding even when the signatories are engaged in hostilities over non-water issues."[115] In sum, as Wolf has written elsewhere, "water rationality" tends to trump the tendency toward "water wars."[116]

At the same time, however, there has been a major shift of thinking in the field of international security analysis. The traditional focus of this field on political and military conflict has been replaced by a growing concern over more localized conflicts, including the connection between environmental degradation, scarcity of resources, and regional and international politics and disputes.[117] Resource scarcity and certain forms of environmental degradation are gaining recognition as important sources of political

---

[114]Sandra Postel and Aaron Wolf, "Tomorrow's Water Wars", *Foreign Policy* (September-October 2001), p. 66.

[115]Ibid.

[116]Aaron Wolf, "The Transboundary Freshwater Dispute Database Project", *Water International*, 24, 2 (June 1999), p. 160.

[117]Peter Gleick, "Conflict and Cooperation over Fresh Water", in *The World's Water 1998-1999: The Biennial Report on Fresh Water Resources* (Washington: Island Press, 1998), ch. 4, pp. 107-38 .

instability and potentially violent conflict at local, regional, and interstate levels. Where water resources and water-supply systems represent a strategic resource with economic, political, or military importance, they can become a focus of wars or significant diplomatic disputes. Thus, policymakers should be alert to the likelihood of disagreements over water resources and to possible changes in international water law, regional political arrangements, and patterns of use that could minimize the risk of conflict.

Fortunately, the late 1990s have seen an unusual amount of institutional reevaluation and reform at the international level, and this may provide both the inspiration and a model for comparable innovations for North America.[118] In 1996 and 1997, three new organizations and centres of activity were initiated at the international level: the Global Water Partnership (GWP), the World Water Council (WWC), and the World Commission on Dams(WCD). The WWC is a nonprofit independent forum to promote awareness on critical global water issues and is working on raising awareness of issues related to water-resource management. Meanwhile, the GWP is concerned with bringing sustainable water-resources management closer to the users in developing countries. Finally, the WCD has a mandate to review the effectiveness of the development of large dams in developing areas and to establish standards, criteria, and guidelines to advise future decision making.[119]

Canadian governments might consider asking their partners in the NAFTA to come together around an agenda of joint participation at these emerging global councils, and even to begin discussion of comparable legal and institutional structures among themselves. This is not to say that existing institutions and processes are manifest failures, or that there are not "enough" institutions to give adequate attention to existing and emerging water problems in North America. Certainly, with an almost one-hundred year old IJC and an increasingly active North American CEC operating as an adjunct to the NAFTA, it could be argued that significant institutional capacity already exists on the continent. However, it is not clear (at least to this observer) that anything like a coherent, coordinated North American water management regime exists.[120] Meanwhile, some of the issues raised in the present discussion suggest that there may be no time like the present for a comprehensive consideration of the ways in which the pre-free trade institutional order with respect to the management of water on the continent might be adapted to the emerging free trade regime.

---

118 Peter Gleick, "New Water Laws, New Institutions", ibid., ch. 6, pp. 156-83.

119 Sed Beach, L J. Hamner, J. Hewitt, E. Kaufman, A. Kurki, J. Oppenheimer, and A. Wolf, *Transboundary Freshwater Dispute Resolution: Theory, Practice and Annotated References* (New York: United Nations University Press, 2000).

120 Note that the CEC has recently complained that the "fragmentation" of jurisdiction is a major stumbling block to improving the management of North American freshwater resources , and by October 2002 had begun an attempt to overcome this problem through a series of consultations with member governments, the IJC, the International Boundary Water Commission and its own Joint Public Advisory Committee. See CEC, *Draft Options*, p. 9 and p. 2.

7.5 CONCLUSION

It does not appear to be possible to render a definitive verdict on whether or not international trade regimes such as the NAFTA or the WTO place significant constraints on Canadian governments with respect to their capacity to manage the country's water supplies. While some critics insist that these governments could do more – such as insisting on amendments to the NAFTA – to ensure that bulk-water exports are prohibited, neither does there seem to be anything within existing agreements that *requires* governments to approve water-export projects. Nevertheless, as large corporations become more and more heavily involved in the delivery of municipal water services, and as at the same time Canadian authorities increasingly undertake to privatize such services, pressure from TNCs for cross-border transmission or diversion of fresh water resources cannot be ruled out. It does seem clear from the text of the NAFTA, and from commentary upon it by trade lawyers, that *should* Canadian governments ever permit the export of water, one thing it cannot do is discriminate in favour of Canadians and against Americans (or other foreigners) in relation to any such projects. Further, once any such export commitments have been undertaken, trade treaties insist that rates of delivery to export markets cannot be substantially reduced thereafter, except in proportion to like deliveries to domestic consumers.

More clarity seems to surround the prospects for large-scale international shipment of water. It is – unequivocally – prohibitively expensive, and would seem to require either massive public subsidization in its own right, or revolutionary changes in the pricing regimes governing most water markets in North America, and especially in those parts of the United States that seem nearest to a crisis in water availability. Short of such measures, it is conceivable that small-scale, inter-shed diversions of water may become economically feasible, but even these are likely to encounter significant international regulatory obstacles, in addition to questionable economics. At the same time, however, an increasing number and intensity of inter-jurisdictional conflicts over the quality and availability of North America's water resources seems highly probable. All levels of government on the continent should work in advance of the outbreak of such conflicts to foster the practices, institutions and policies that can contribute to their smooth resolution, or to avoiding them altogether. To this end, more active consultation and coordination between the International Joint Commission and the North American Commission on Environmental Cooperation may provide some insurance against any such turns for the worse among the three NAFTA partners.

8.0 GENERAL RECOMMENDATIONS

This section contains some general recommendations based on an overview of the results of this study. As has been summarized in IPCC (2001), it is "very likely (90-99% chance) that there will be more intense precipitation events, over many areas", and "likely (66-90% chance) that there will be increased summer continental drying and associated risk of drought, over most mid-latitude continental interiors". Thus, we have the probability that much of Canada will see increased intense precipitation events while the interior regions will see summer drying and increased risk of drought. Both of these projections will have major implications for river flows and the management of water resources. Thus, while mean annual floods may be in decline, occasional very severe floods are very likely with observed and projected increased intensity of rainstorms.

In projecting climate change, there will always be an element of uncertainty and it is necessary to undertake risk management approaches. Hence, our systems, agreements or approaches for management of water resources need to be developed from a risk management point of view.

Our analysis indicates that our water management agreements are vulnerable to climate change. The agreements were not written with a changing climate and water flows in mind and there is a general need to revisit these agreements to address this vulnerability.

For example, the Master Agreement on Apportionment for the Saskatchewan River system, administered by the Prairie Provinces Water Board (PPWB), sets out the rights and duties of the three prairie provinces concerning the apportionment of eastward flowing interprovincial streams, in terms of natural flows. Recorded flows in the North Saskatchewan River are almost identical to natural flows. On the other hand, due to significant water use in irrigated agriculture, recorded flows are much less than natural flows in the South Saskatchewan River. In very dry years the quantity of water flowing in the South Saskatchewan River to the province of Saskatchewan is little more than that province's entitlement under the Master Agreement.

It is recognized that actions to renegotiate water agreements are sensitive. There will need to be careful considerations of the principal vulnerabilities and judgments made on how to address them. Some agreements are relatively robust. A major issue is the lack of dispute resolution methods within Canadian Mechanisms. Associated with this are the issues of longevity of the agreements which also have walk-out clauses. It is important to anticipate possible problems and have ongoing negotiation.

Part of this study was a survey to explore public attitudes to fairness in allocation of water. The majority of respondents to the survey perceive water quantity issues as serious or very serious, and a majority also believe that conditions have deteriorated over the past 10 years. Respondents indicated that the decline on conditions was the result of demand management and climate/weather considerations. There is high level of support for positions that: (i) water is a community resource that cannot be owned by individuals; (ii) people who have been allocated water should retain this right only if they can show they are using it wisely; (iii) water quality is an important issue in many water allocation decisions; (iv) since the environment cannot defend itself, allocations should be specifically made to protect it; (v) water should not be placed on the market and allocated to those who would pay the most, regardless of what it is used for; (vi) those upstream have a moral responsibility to look after the interests of those downstream; (vii) all people of the basin have a right to have a say on water allocation; and (viii) it is important to set rules for how water should be allocated for the next generation. Collectively, these statements suggest a strong role for government intervention in the allocation of water, including allocations for environmental considerations. This is also strong support for management to involve the public and consider the interests of upstream and downstream users. The basin-wide perspective provided by the Prairie Provinces Water Board reflects these attributes.

The findings of this study need to be combined with more extensive analyses of future water demands in these basins, including the effects of a changing climate. Unfortunately, the water use data systems for transboundary basins appear to be in decline and need to be increased through federal-provincial cooperation in light of increasing stresses on water availability. Better monitoring of water quality and quantity, precipitation, temperature, natural-flow is needed, recognizing the importance of intense events. More information is needed on water permits and allocation, as well as monitoring of water uses and water users. Water systems, as has often been shown, can lead to human health issues and we lack needed information to better quantify these relationships.

Recommendations:

1. Renewal of federal-provincial flood damage reduction agreements should be undertaken for transboundary basins.
2. Those transboundary agreements, which contain quantitative figures for the minimum flows to be passed to the downstream jurisdiction, are most vulnerable to observed and projected reductions in mean annual flows (e.g., South Saskatchewan, Milk, Souris) and require most urgent review by the International Joint Commission and the Prairie Provinces Water Board.
3. Bulk water exports from boundary and transboundary basins would be unwise in light of climate and other stresses on the resource. The federal action to prevent such exports should be effectively monitored and maintained.
4. Provincial governments should carefully review the technical basis for their permitting of water taking in light of the changing climate and other factors.
5. Design criteria for storm sewer systems and drainage facilities should be re-examined in light of observations and projections of increased frequencies of high intensity rainfalls, observed and projected.
6. Governments need to re-invest in monitoring and informational needs to provide a basis for decision making on these and related issues.
7. Research Needs:
   i. Quantitative estimates of the impact of changing flow regimes on water quality.
   ii. Impacts of increasing high-intensity short duration rainfalls on increasing erosion rates and pollution of watercourses – especially near the Canada-U.S. border where frequency of high intensity rainfalls have already increased.
   iii. The government of Canada should consult with government of USA with a view to proposing a Reference to the IJC to review and recommend (more completely than this study permitted), the actions that should be taken to reduce the vulnerability of the agreements to climate change.
   iv. The government of Canada should consult with the provinces and territories with a view to reviewing and recommending (more completely than this study permitted) the actions that should be taken to reduce the vulnerability of the agreements within Canada to climate change.

v. Agreements with a focus on one or two uses should be made more comprehensive in terms of requirements of multiple users, including preservation of ecosystem values.

vi. There is a need for further social-science analyses of peoples' perceptions, willingness to respond to measures to control water use and allocation and on optimum approaches for the further development of water management agreements, both within Canada and between Canada and the US, recognizing the needs for dispute resolution and management of risk.

vii. Federal and provincial governments should ensure strengthening of water monitoring networks, as well as climatic and precipitation intensity measurement programs in the transboundary and boundary basins.

ANNEX A – SUMMARY OF U.S.–CANADIAN WATER AGREEMENTS

COLUMBIA RIVER

Preamble

The River System
The Columbia River is a very complex and heavily utilized resource. There are three main transboundary rivers in the Columbia watershed; from east to west, the Kootenay (US portion called: Kootenai), the Columbia and the Okanagan. In addition, there are a number of lesser transboundary rivers, notably the Kettle, the Similkameen and the Flathead/ Pend d'Oreille River. The Flathead in the south east corner of British Columbia has received considerable attention and is mentioned briefly in the following discussion. The Pend d'Oreille River is part of the Skagit Agreement (not part of the Columbia), discussed elsewhere.

Uses
The Columbia River Basin is the most hydroelectrically developed river system in the world. On the US side, more than 400 dams -- 11 run-of-the-river dams on the mainstream -- and hundreds of major and modest structures on tributaries block river flows and tap a large portion of the Columbia's **electric power** generating capacity of more than 21 million kilowatts. On the Canadian side there are twelve major dams: Aberfeldie, Duncan, Elko, Keenleyside, Kootenay Canal, Mica, Revelstoke, Seven Mile, Shuswap, Spillimacheen, Walter Hardman and Whatshan.

The last dams built on the Columbia under the Columbia River treaty, came on line during the 1960s and 1970s. In 1973, Canada completed the last of the mainstream dams, Mica Dam on the upper river. The dams have created large reservoirs that provide **flood control** and water for vast **irrigation** systems on the Columbia Plateau. Already, in 1948, the Columbia Basin Project was transporting Columbia River water by canal to more than 600 thousand acres. With the completion of four dams on the lower Snake River during the 1970s, the US engineers strung together a series of slackwater lakes that allowed barge **navigation** for about 750 kilometers from the Pacific to the inland port of Lewiston, Idaho.

Fish
The river **fishery** is both an environmental and a commercial resource.
Between the 1860s and 1960s, commercial fisheries annually harvested millions of pounds of fish, especially five species of salmonids. Since the 1950s, the combined consequences of dams, increased ocean fishing, deterioration of stream and river habitats, and changing river conditions have made the Columbia less and less habitable for anadromous fish. The fish catch has dramatically declined. Today, hatchery-raised species making up more than 80 percent of commercially caught salmon in the river. Hatchery-raised stocks have become a major mitigation of dam-caused salmon declines during the late 20th century. In 1992, the US government listed the native Snake River

Sockeye salmon as endangered under the Endangered Species Act, and in 1998, the Willamette steelhead joined the list.

A: WATERSHED

Name: Columbia River Basin

Location: Southern British Columbia

Physical Description

A1: Columbia

Flowing Water Feature	Length (km)	Drainage Area (km^2)	Mean Discharge (m^3/s)
(Portion of the drainage area in the United States is shown in brackets)			
(mouth to head of Columbia Lake)	2 000	671 300	
(International Boundary to head of Columbia Lake)	801	102 800 (568 500)	2 790

Water area: 6 400 km^2

A2: Major Canadian Tributaries

Flowing Water Feature	Length (km)	Drainage Area (km^2)	Mean Discharge (m^3/s)
Kootenay River*	780	37 700	850
Okanagan River (to head of Okanagan Lake)	314	21 600	-
Similkameen River	251	9 300	65
Kettle River (to head of Holmes Lake)	336	4 700	-

*Called Kootenai in the US

B: BILATERAL MANAGEMNENT INSTRUMENTS*

In the following three boxes, the ‘a’s in each box refers to the same instrument, as do the ‘b’s, etc.

Title:

a) Columbia River Treaty (signed January 1961, ratified September 1964)**
b) Kootenay lake Order (1938)
c) The IJC Order of Approval concerning the construction a control structure near the outlet of Osoyoos Lake (1982, as revised in 1985)***

*An IJC Order (1950) concerning the levels of Duck Lake, Kootenay District, is not included here.
**The Treaty is in effect for 60 years, until September 2024.
***The Okanagan, Similkameen Rivers are mentioned in this Order.

Managing Authority:
a) The Governments of the USA and Canada
-Permanent Engineering Board
b) The IJC
- Kootenay Lake Board of Control (1938)
c) The IJC
- International Osoyoos Lake Board of Control

Nature of Instrument:
a) The treaty is concerned with water amounts and the production of electricity. It is a mechanism for the development , scheduling and management of hydro production, including ; dam construction(II, III, XII), Flood control (VI), Costs/Benefits sharing (V, VII, VIII, IX), Power transmission (X),Improved Stream Flow (XI), Diversions (XIII).
(I)Monitor the execution of the treaty and report to governments on deviations.

b) The Order is concerned with the construction and operation of Corra Linn dam at Granite, B.C. to store six feet of water in Kootenay Lake.

c) The Order is concerned with the levels of Osoyoos Lake as controlled by a new dam downstream from the outlet of Osoyoos Lake.
(I) Monitor the execution of the Order and report to the IJC on deviations.

C: CLIMATE SENSITIVITIES

Language Usage

As part of the evaluation of the climate-change sensitivity of agreements, the texts of the documents listed in Section B above, were subjected to a word search. The key search words used here were: climate, change, quality (water), fish, fishery, pollution, temperature, glacier, melt, drought, Kootenay, Okanagan, snow, allocation, precipitation, stream, flow, flood, environment, generation (power) and entitlement. The absence of some of these key words can be as important as their appearance in the text.

a) The following words appeared in the text of the Treaty: Kootenay (13), stream (22), flow (32), flood (72), generation (power) (24), entitlement (84), snow (1), allocation (1) and precipitation (1).

b) The following words appeared in the text of the Kootenay Order: power generations (10), flood (6) and flow (3).

c) The following words appeared in the text of the Osoyoos Order: flow (25), drought (8), flood (2) and Okanagan (5).

General

Issue Limitations

The Treaty is extremely focused. It deals with power production and floods on the Kootenay-Columbia water course. It considers no other tributaries or issues. The two basic obligations are:

> Canada has the obligation to manage the flow of the river throughout the year through a series of structures on the Canadian side. The Treaty discusses the management of floods in great detail while drought situations are not mentioned.
>
> The USA has the obligation to share with Canada the benefits of power production on the US side.

The Kootenay Order focuses on the maintenance of the Lake level within a range of 1.83 meters (six feet).

The Osoyoos Order deals with water levels only but does make reference to the Similkameen River or to drought.

Over the past decades environmental issues not treated by the Treaty or the Order have arisen. For example, nowhere in the Treaty are there formal provisions for the stewardship of fisheries (as suggested by the above word search).

Regional Limitations

The Treaty does not deal with the tributaries of the Columbia. This shortcoming has been corrected to some extent by more recent instruments. Some are discussed here.

The Treaty does not mention the Okanagan River. There is a rapidly increasing population in the Okanagan valley, a stark contrast to the empty wilderness character of the region just down river of the Canada-USA border. In 2002 it was reported the Okanagan sockeye spawned abundance had declined to record lows in three of the previous five years. Returns were recorded as high as 200,000 in 1967 and less than 5000 fish in 1994, 1995 and 1998. (Aboriginal Fisheries Journal, Newsletter of the BC Aboriginal Fisheries Commission Volume 6, No. 3 July 2000)

Climate-change-related changes in water quantity in the Canadian portion of the Okanagan catchment could have impacts in the USA, downstream. A shortage could put pressure on the Treaty management plans in the upper Columbia basin. Changes in water quantity could aggravate water quality problems in Canadian urban areas and downstream. Climate change could place further stress on the fish populations.

In contrast to the apparent neglect of the Okanagan basin, there has been considerable attention given to transboundary environmental issues in the relatively small Flathead basin near the British Columbia-Alberta border. The Flathead River is 390 km long and the transboundary catchment covers 2 574 km^2. The area is a wilderness. In 1983, the Flathead Basin Commission was established to bring the governments of Montana and BC together to define and implement compatible management strategies on both sides of the 49th parallel. In 1984, a reference was made to the IJC concerning the development of coal mines on the Canadian side. In 1988, the IJC recommended that the mine should not be developed because of its transboundary impacts. The IJC went further to advise that both countries develop a "creative, binational approach… for defining and implementing compatible, equitable and sustainable development activities and management activities in the upper Flathead River basin," in effect, endorsing the concept of an International Conservation Reserve. In 2000, the Flathead Basin Commission asked the International Joint Commission to establish an International Watershed Board to accomplish goals identified in the 1988 IJC referral, namely to create an International Conservation Reserve.

It might be argued that, as an International Conservation Reserve, the impacts of climate change on the Flathead watershed should not require intervention or adaptive interference by humans. With this notion in mind, the basin instruments were not analyzed for climate change implications.

Specific Obligations and Entitlements

Columbia River Treaty

The Treaty operates on the assumption that water quantities fluctuate within a known variability range. Treaty obligations and planning strategies could be challenged in the event that the amount of water increases or decreases in such a way as to exceed the customary or historical amount. Some examples follow.

Article II

Canada shall provide in the Columbia River basin in Canada 15,500,000 acre-feet of storage usable for improving the flow of the Columbia River. The necessary dams were built.

The Columbia has an average annual runoff at the mouth of about 198,000,000 acre-feet (275,000 cfs). The Canadian portion of the basin generally contributes about 50,200,000 acre-feet annually. Hence, the storage capacity (15,500,000 acre-feet) is equivalent to about 31% of the annual Canadian runoff. Climate change induced changes in the Canadian runoff may significantly alter these basic numbers.

Article III

The United States of America shall maintain and operate the hydroelectric facilities. In so doing, there are downstream power benefits to which Canada is entitled.

Climate change induced reduction in stream flow could impact of the US water availability far down stream. If Canada meets its Article II obligations then USA has the obligation to deliver the agreed power and will do so even if the water in the lower Columbia declines due to climate change, for example. The delivery of the power may/will require changes in USA usage, such as changes in levels of irrigation or local power usage.

Article VIII

Disposal of Entitlement to Downstream Power Benefits

(4) The bypassing at dams on the main stem of the Columbia River in the United States of Americas of an amount of water which could produce usable energy equal to the energy component of the downstream power benefits to which Canada is entitled but not delivered to Canada under Article V or disposed of in accordance with paragraphs (1) and (2) at the time the energy component was not so delivered or disposed of, is conclusive evidences that such energy component was not used in the United States of America and that the entitlement of Canada to such energy component is satisfied.

Does this mean that the USA is not obliged to deliver power commitments to Canada if the USA decides not to produce the power but rather to bypass the dam and send the water further downstream, for irrigation purposes, for example? This action could be an adaptation strategy to deal with drier conditions associated with climate change. Is this clause in conflict with Article III above?

Article XIII

Diversions

(1) Except as provided in this Article neither the United States of America nor Canada shall, without the consent of the other evidenced by an exchange of notes, divert for any use, other than a consumptive use, any water from its natural channel in a way that alters the flow of any water as it crosses the Canada-United States of America boundary within the Columbia River basin.

Definition---(e) "consumptive use" means use of water for domestic, municipal, stock-water, irrigation, mining or industrial purposes but does not include use for the generation of hydroelectric power;

1-Both countries can use water for irrigation without consultation. Note the River flows both into Canada from the USA and out of Canada to the USA.

2-There are important conditions attached to the introduction of diversions. A climate-change-driven reduction or increase in the water available may require diversions. Such adaptation measures should be examined in the light of the treaty, Article XIII. The treaty allows for such adaptations but does not seem to anticipate a major application.

Article XVIII

Liability for Damage

(1) The United States of America and Canada shall be liable to the other and shall make appropriate compensation to the other in respect of any act, failure to act, omission or delay amounting to a breach of the Treaty or of any of its provisions other than an act, failure to act, omission or delay occurring by reason of war, strike, major calamity, act of God, uncontrollable force or maintenance curtailment.

What is climate change? If the Treaty is in jeopardy because of lack of water, for example, is it "a breach of the Treaty ….occurring by reason of ….an uncontrollable force"?

Annex A

Principles of Operation:

For floods, the flow is managed through extra release and bypass at the generators. The schedules are prepared in advance and are complex. Under normal conditions, the Canadian reservoirs release specific amounts "Unless other-wise agreed by the entities".

Schedules of operation can be changed by agreement in order to adapt to unusual situations. Climate change scenarios may constitute sufficient reason to change operations.

Paragraphs 6, 7 and 8 suggest power production strategies can be implemented for occasions when there is too little water to run all facilities 'to achieve optimum power generation'.

The occurrence of wide-spread changes in climate is not addressed.

Five years in advance the countries 'agree annually on operating plans and the resulting downstream power benefits for the sixth succeeding year of operation thereafter.'

Climate change induced changes in precipitation patterns and amounts as well as changes in the supply of glacial water may be rapid enough to require that the five year planning horizon should be shortened.

Annex B

Determination Of Downstream Power Benefits

Paragraph 6: --'The critical stream flow period and the details of the assured plan of operation will be agreed upon by the entities at each determination. Unless otherwise agreed upon by the entities, the determination of the downstream power benefits shall be based upon flows for the twenty year period beginning with July 1928 as contained in the report entitled Modified Flows at Selected Power Sites-Columbia River Basin, dated June 1957. No reduction in the downstream power benefits will be made at any time during the period of the Treaty. '

The analysis of recent data and the predictions of the climate change scenarios used in this study may suggest that the historic data set is not relevant. Several data sets from the last 100 years are used in the Treaty.

The implications of the last quoted sentence, 'No-reduction-in-benefits…', above, are not clear and may require legal comment.

Kootenay Lake Order

Aside form details about the construction of the dam, the order deals with maintaining an annual cycle of lake levels required to deal with flooding and to accommodate land use activities (agriculture) up stream in both Canada and the USA. The levels clause states:

' after the high water of the spring and early summer flood and when the lake level at Nelson on its falling stage recedes to elevation 1743.32,…. the gates of the dam may be so operated as to retain it at said level until August 31st, and after said date the level of the main lake may be raised to elevation 1745.32, which shall be the maximum storage level until January 7, and thereafter it shall be lowered that shall not exceed elevation 1744 on February 1, elevation 1742.4 on March 1, and elevation 1739.32 (i.e., zero of the Nelson gauge) on or about April 1,…..'

with the caveat:

' except under extraordinary natural high inflow conditions, when sufficient gates shall be opened and remain open throughout such period of excess so as to lower the level of the main body of Kootenay Lake to the storage level at that time obtaining as above defined.'

Climate change scenarios may include situations where the levels required are not practical or desirable because of a change in the annual amount of water available and/or in the annual cycle of flow.

The caveat provides instruction under high flow conditions but not low flow conditions or a changed annual cycle. A change annual cycle of flow may impact on the total power produced over the year and hence, the financial returns from this enterprise.

Osoyoos Lake Order

Preamble text

In the introduction to the Order there are references to past climatological records. These are used to infer future climatic conditions. Examples are:

> "Whereas hydrological analyses indicate that the level of Osoyoos Lake has, and probably will again, exceed elevation 913.0 USCGS at least every other year and for a duration varying from two days to two months, that the probable recurrence interval of the lake level exceeding elevation 915.0 is 12 years and that in 1972 Osoyoos Lake level peaked at elevation 917.1 feet USCGS."

> "Whereas detailed analysis of recorded water levels of Osoyoos Lake from 1948 to 1981 inclusive indicates that for the period 1 April to 31 October in those years the levels have been 911.0 USCGS or above 82 percent of the time, 911.5 USCGS or above 50 percent of the time, 912.5 USCGS or above 11 percent of the time, and 913.0 USCGS or above 6 percent of the time. Moreover, the level of Osoyoos Lake has been maintained between elevation 911.0 and 911.5 USCGS 32 percent of the time."

Climate change scenarios may show that past records are no longer reliable predictors of future climates and therefore they should not be used as a basis for 'orders' concerning the future management of water resources.

Condition 7

"Washington State will maintain the Lake level "between elevation 911.0 and 911.5 feet USCGS to the extent possible from 1 April to 31 October each year except under drought conditions in the Okanogan Valley" and "between elevation 909.0 and 911.5 feet USCGS from 1 November to 31 March each year."

These mandatory levels should be examined in the light of the climate change scenarios.

Condition 8

"During a year of drought as determined by the Board of Control in accordance with the criteria set forth below, the levels of Osoyoos Lake may be raised to 913.0 feet USCGS and may be drawn down to 910.5 feet USCGS during the period 1 April to 31 October."

Under extreme or long-term change in the hydrological regime, in particular less water, higher evaporation and/or changes in diurnal patterns, the proposed levels, notably, the minimum drawdown level in the summer may not be practical or possible.

Condition 10

The proposed levels, discussed above, can be changed under a number of conditions including:

"In the event of circumstances including but not restricted to a prolonged drought coupled with high evaporation from Osoyoos Lake, …… the Commission upon written advice and recommendation from the Board of Control may allow a temporary deviation from the levels prescribed in Conditions 7 and 8."

This caveat may be sufficient to deal with climate change, depending on the magnitude of the change to the water supply.

D: REFERENECES

For links between The Flathead River and Pend D'Oreille River (Skagit Agreement) see map at: http://www.cbfwa.org/files/province/mtncol/geography.htm

Kootenay Lake Board of Control
http://www.nwd-wc.usace.army.mil/

ST. MARY'S AND MILK RIVERS

Preamble

Disputes involving Montana, Alberta and Saskatchewan over sharing the waters of the St. Mary and Milk Rivers were among the factors that led to the conclusion of the 1909 Boundary Waters Treaty. The treaty provided for equal apportionment of these waters, but it was left to the Commission to decide how this would be carried out in practice. The Commission issued an order in 1921 which put in place an apportionment regime that continues to be implemented effectively under the IJC (IJC 21ST C). In effect, the 1921 Order grants Canada a prior apportionment on the St. Mary River while the USA has a prior apportionment on the Milk. The Order also deals with the apportionment of the Eastern Tributaries of the Milk but is silent on the Southern Tributaries.

The St Mary flows into the Saskatchewan-Nelson system (Hudson Bay drainage) while the Milk flows into the Missouri-Mississippi system (Gulf of Mexico drainage). At their closest point they are only a few kilometers apart. The St. Mary is also the subject of interprovincial apportionment under the Prairie Provinces Water Board Master Agreement on Apportionment.

(In addition to the instruments concerning the St. Mary's and the Milk Rivers discussed below, there may also be instruments for the Poplar and Big Muddy, which flow south to the Missouri. These four catchments occur over a 600-kilometer long stretch of the international border, from the B. C. -Alberta border to halfway across Saskatchewan.)

A: WATERSHED

Name: St. Mary's River (South Saskatchewan Basin) Milk River (Missouri Basin)

Location: Southern Alberta and South-western Saskatchewan

Physical Description

Flowing Water Feature	Length (km)	Drainage Area (km^2)	Mean Discharge (m^3/s)
Milk River	1 005	Can.:21 600 US: 39 600 Total: 61 200	
St. Mary			

B: BILATERAL MANAGEMNENT INSTRUMENTS

In the following three boxes, the 'a's in each box refers to the same instrument, as do the 'b's.

Title:
a) Boundary Waters Treaty, 1909 : Article VI
b) International Joint Commission Order of 1921 (Not available)

Managing Authority:
a) International Joint Commission
b) Accredited Officers appointed in Canada by federal Order-in-Council and in the USA by the State Department.

Nature of Instrument:
a)

- Apportionment of waters of the St. Mary and Milk Rivers
- Diversion by USA of water from the St. Mary to the Milk
- Conveyance of St. Mary diversion water, via the Milk, though Canada and back to the USA.

b) Document not available.

- grants Canada a prior apportionment on the St. Mary River
- grants the USA a prior apportionment on the Milk

C: CLIMATE SENSITIVITIES

Language Usage
As part of the evaluation of the climate-change sensitivity of agreements, the text of the Boundary Waters Treaty was subjected to a word search. The search words were: climate, change, water quality, fisheries, pollute, temperature, glacier, melt , draught, Stikine, Yukon, Iskut, Taku, Skagit, division, snow, allocation, precipitation, stream, flow, flood, power (electrical), entitlement, diversion, Milk, Poplar, St. Mary, St. Laurence, irrigation, Great Lakes, St. Mary's river (Ontario), Sault Ste. Marie, Niagara and Commission. The absence of some of these key words can be as important as their appearance in the text.

Only the following words appeared in the text of the Treaty: Commission 50, flow 22, diversion 21, St. Mary 7, Milk 4, division 3, stream 5, power (electrical) 6, Niagara 6, irrigation 4, St. Mary's River (Ontario) 2, Sault Ste. Marie 2, pollute (1).

General

Boundary Waters Treaty

Article VI of the Boundary Waters Treaty (the St. Mary and Milk Rivers article) refers to irrigation and power production only:

> A-"The Rivers are to be treated as one stream for the purposes of irrigation and power, and the waters thereof shall be apportioned equally between the two countries….
>
> B-…but in making such equal apportionment more than half may be taken from one river and less than half from the other by either country so as to afford a more beneficial use to each."
>
> C-"It is further agreed that in the division of such waters during the irrigation season, between the 1st of April and 31st of October, inclusive, annually, the United States is entitled to a prior appropriation of 500 cubic feet per second of the waters of the Milk River, or so much of such amount as constitutes three-fourths of its natural flow, and that Canada is entitled to a prior appropriation of 500 cubic feet per second of the flow of St. Mary River, or so much of such amount as constitutes three-fourths of its natural flow."

These arrangements could work well in the event of inadequate water supplies.

In the event of water shortage, as may occur under climate change, a country may wish to take most of or all of its share of water out of one river and little or none out of the other. This could only be done during the period November 1 to March 31. In fact, there is little opportunity for swaps as it would have to be done by mutual agreement and both countries want more Milk River water.

In the event of water shortage, as may occur under climate change, decreased flows could lead to renewed pressure in Alberta to construct the Milk River Dam. This initiative could lead to an international disagreement.

The St. Mary-Milk River arrangement relates only to water quantity. Under climate change, water quality degradation due to increased, upstream, irrigation return flows could become an issue.

During the irrigation season, the respective prior apportionment may not be enough to satisfy the needs of existing Montana and Alberta water licenses. The situation may be aggravated by senior water rights and differences in the urgency-of-need along the full length of the rivers in the two countries.

Flexibility: The Treaty stipulates that: "The measurement and apportionment of the water to be used by each country shall from time to time be made jointly by the properly constituted ….officers" from each country under the direction of the International Joint Commission.

SOURIS RIVER

A: WATERSHED

Name: Souris River Basin (Assiniboine-Red)

Location: SE Saskatchewan-SW Manitoba and North Dakota

Flowing Water Feature	Length (km)	Drainage Area (km^2)	Mean Discharge (m^3/s)
Souris River	696		

B: BILATERAL MANAGEMNENT INSTRUMENTS

In the following three boxes, the 'a's in each box refers to the same instrument, as do the 'b's, etc.

Title:
a) Boundary Water Treaty* (1909)
b) Interim measures (1940, 1959 and 1992)
c) Canada-U.S. Agreement for Water Supply and Flood Control in the Souris River Basin (1989)
d) Amendments(December 2000) to: Canada-U.S. Agreement for Water Supply and Flood Control in the Souris River Basin (1989)

*The Boundary Water Treaty is the over-riding instrument

Managing Authority:
a) IJC through the International Souris-Red Rivers Engineering Board 1948
b) IJC through the International Souris River Board of Control (1959)
c) IJC through the International Souris River Board of Control (1959) supported by the Souris

River Bilateral Water Quality Monitoring Group
d) IJC through the International Souris River Board (2001)

Nature of Instrument:
a) Use and apportionment of boundary waters
b) Establish objectives and monitor storage and apportionment
c) Establish objectives and monitor storage, apportionment and quality(Article IV)
d) Establish objectives and monitor storage, apportionment and evaporation losses

C: CLIMATE SENSITIVITIES

Language Usage
The Treaty has been examined earlier in this report. The additional instruments noted above are very specific and were not screened for language use. One exception is noteworthy. The most recent instrument, 'Amendments to: Canada-U.S. Agreement for Water Supply and Flood Control in the Souris River Basin (December 2000)' makes no reference to climate change, as is the case for the other instruments.

General
The river valley is flat and shallow and its semi-arid prairie has been extensively cultivated.

The valley is vulnerable to floods and drought. Agriculture can require irrigation. The management of floods, droughts and irrigation could be challenging in the event that climate change alters the water regime.

Prairie Farm Rehabilitation Administration has determined that, at present, the net water availability in much of the Souris watershed (Canada Side), after accounting for allocations, is zero.
See: Rural Water Mapping Initiative (http://www.agr.gc.ca/pfra/pub/rwmi.htm)

Specific Obligations and Entitlements
Only the most recent instrument, 'December 2000 Amendment to the Agreement Between Canada and the United States for the Water Supply and Flood Control of the Souris River Basin', is considered here since it reflects current 'Obligations and Entitlements' and replaces, for the most part, earlier instruments. The December 2000 Amendment replaces several section of the Agreement with a section called 'Annex B'. This annex is the focus of the following analysis.

Annex B

The text covers a wide range of caveats, variations and options so that it is not a simple matter to extract the key points which might lead to difficulties in a new climate regime. Nor is it the intention of this analysis to probe all the nuances of the Amendment. In the following, several climate situations are listed along with sections of text which should be considered.

Simple, equal sharing – normal climate conditions (A Treaty Cornerstone)
'The Province of Saskatchewan shall have the right to divert, store, and use waters which originate in the Saskatchewan portion of the Souris River basin, provided that such diversion, storage, and use shall not diminish the annual flow of the river at the Sherwood Crossing more than 50 percent of that which would have occurred in a state of nature…' (Preamble in Annex B and Clause (a))

Quantitative Minimum flows - droughts
The flow at the boundary 'shall not be less than 0.113 cubic metres per second (4 cubic feet per second) when that much flow would have occurred under the conditions of water use development prevailing in the Saskatchewan portion of the Souris River basin prior to construction of the Boundary Dam, Rafferty Dam and Alameda Dam.' (Preamble in Annex B)

Evaporation Losses from Reservoirs
'Under certain conditions, a portion of the North Dakota share will be in the form of evaporation…' and in such as event 'the minimum amount of flow actually passed to North Dakota will be 40 percent of the annual natural flow volume' 'This lesser amount is in recognition of Saskatchewan's operation of Rafferty Dam and Alameda Dam for flood control in North Dakota and of evaporation as a result of the project.' (Preamble in Annex B) Evaporation is taken into account in international (and PPWB) apportionment calculations. The issue here is: since water is being held in Canada to provide flood control in the US, the Americans should bear some of the evaporative loss. At the moment, evaporation from Boundary Reservoir (including forced evaporation) is charged in its entirety to Canada.

High flow years – floods or US reservoir is high
'Saskatchewan will deliver a minimum of 40 percent of the annual natural flow volume' when 'The annual natural flow volume at Sherwood Crossing [the border] is greater than 50 000 cubic decameters and the current year June 1 elevation of Lake Darling [US reservoir] is greater than 486.095 metres (1594.8 feet) (Sub clause a (i))

Spring-delivery obligation
'Notwithstanding the annual division of flows that is described in (a), in each year Saskatchewan will, so far as is practicable as determined by the Board, deliver to North Dakota prior to June 1, 50 percent of the first 50 000 cubic decametres (40 500 acre-feet) of natural flow which occurs during the period January 1 to May 31.' (Clause (b))

The extracted texts contain quantitative commitments. Meeting these commitments may become more difficult with climate change. The climate scenarios should be examined for changes in total amount of water available, changes in evaporation rates from reservoirs, extreme water events such as floods and droughts and changes in the pattern of annual flow.

The meaning of the term 'a state of nature'
'Flow releases to the United States should occur (except in flood years) in the pattern which would have occurred in a state of nature.'

The terms 'natural flow' and 'state of nature' occur throughout the document and imply a condition in the past before the dams. However, would a new climate regime constitute a new 'state of nature', and therefore, a new reference point for the whole Amendment?

Generally in 'natural' flow calculations, the result is the flow in the absence of structures. Land use change, for example, is not considered. A better term would be 'apportionment flow', i.e. the flow subject to apportionment.

Flexibility in unusual situations
The text allows for flexibility in unusual situations.

Concerning the Spring-delivery obligation: '…as far as is practicable as determined by the Board.' (Clause (b))

Concerning the operational plans for refuges, 'Barring unforeseen circumstances, operations will follow said plans during each given year.' (Clause (c))

The Amendment is sensitive to unforeseen events. Climate change may require consideration and use of these flexibilities.

RED RIVER

Preamble
At Wahpeton, North Dakota, the river elevation is 287 meters above sea level. At Lake Winnipeg (the mouth), the elevation is 218 m, a difference of only 70 m over a distance of about 877 river km. In essence, the basin is completely flat with few natural features to slow water if there is a flood and that is, few natural places to store water. Consequently, lack of water supply can be as much of a problem as flooding.

There are no bilateral treaties or agreements relating directly to the basin. The basin has been examined and managed through a number of references to the IJC and subsequent directives from the IJC to standing boards and study boards. Some of these instruments are discussed here.

The important issues in the basin are: water quality, floods/droughts, diversions, allocations, aquifer utilization and ecosystem health.

These issues are currently receiving varying degrees of attention. Emphasis has changed over the years from allocations in the 50s, to water quality in the 60s and 70s, to diversions, to floods and ecosystem health more recently. All issues are sensitive to changes in climate.

A: WATERSHED

Name: Red River Basin

Location: Southern Manitoba

Physical Description

Flowing Water Feature	**Length (km)**	**Drainage Area (km^2)**	**Mean Discharge (m^3/s)**
Red River (Mouth at Lake Winnipeg to head at Wahpeton)	877	CAN-138 600 USA-148 900	

B: BILATERAL MANAGEMNENT INSTRUMENTS

In the following three boxes, the 'a)'s in each box refers to the same instrument, as do the 'b)'s, etc.

Title:

a) Governments' Reference Letter To The International Joint Commission (1948)
b) IJC Revised Directive To International Red River Pollution Board (1995)
c) IJC Directive to the International Red River Board (2001)

Managing Authority:

a) Federal Governments
   IJC - establishes International Souris-Red Rivers Engineering Board (1948)*
b) IJC
   IJC- through International Red River Pollution Board (1969)
c) IJC
   International Red River Board (an amalgamation of the International Souris-Red Rivers Engineering Board and the International Red River Pollution Board)

* The activities of The Board included investigations of the Souris River, Poplar River, Pembina River, Roseau River and the Garrison Diversion Unit.

Nature of Instrument:

a) Establishes International Souris-Red Rivers Engineering Board to monitor water quantity and report on all trans-boundary Prairie waters considering apportionment, conservation and utilization.
b) Focuses on water quality with monitoring, assessment and reporting. Replaces the directive of 1969 which established International Red River Pollution Board.
c) Replaces directives to former two boards. Provides general guidelines focusing on water quality, quantity, levels and ecological integrity. Places emphasis on flood management.

C: CLIMATE SENSITIVITIES

Language Usage

As part of the evaluation of the climate-change sensitivity of agreements, the texts of the documents listed in Section B above, were subjected to a word search. The key search words used here were : water quality, fisheries, pollution, temperature, climate, glacier, melt, drought, precipitation, snow, stream flow, flood, quantity, levels, power generation, utilization, allocation, apportionment, diversion and entitlement. The absence of some of these key words can be as important as their appearance in the text.

a) The following words appeared in the Governments' Reference Letter To The IJC: apportionment (3), conservation (1) and utilization (1).
b) The following words appeared in the IJC Directive To International Red River Pollution Board: water quality (6)
   (The word 'pollution' occurred but only in the Board's title.)
c) The following words appeared in the IJC Directive to the International Red River Board: water quality (6), flow (1), flood (17), water quantity (3), water levels (3), and aquifer (1).

General

Issue Limitations

The focus of the instruments has changed with time as demonstrated by the word search. The absence of allocations and diversions in the current focus is notable.

Regional Limitations

The geographical scope of the instruments has become narrower over the past 50 years.

Specific Obligations and Entitlements

Governments' Reference to the International Joint Commission (1948)-replaced

On receipt of this reference, the IJC established the International Souris-Red Rivers Engineering Board. This reference became the directive to the new board, which remained active until 1997.
The geographic scope of this reference was large, including,

> "…. the waters which are of common interest along, across, or in the vicinity of the international boundary from the eastern boundary of the Milk River drainage basin on the west up to and including the drainage basin of the Red River of the North on the east."

The focus of the reference was water quantity. The purpose was to investigate, to report and "to make advisory recommendations concerning the apportionment" of waters where needed and subsequently, "to prepare a comprehensive plan or plans…"

Today, even though there is a possibility of water shortages due to climate change, the notion of apportionment is not receiving a great deal of attention within the IJC framework. Only the Souris and Poplar rivers have apportionment instruments. The need for formal apportionment of the Red River basin as a whole will become increasing evident with the potential increase in irrigated agriculture and the US push for more flood control structures (e.g. the proposed Devils Lake project in northeastern North Dakota) .

IJC Directive to International Red River Pollution Board (1995)-replaced
In 1969, the IJC established this board. The boards was directed to assist the IJC in complying with its authorization concerning supervision over quality of waters in the Red River, as described in the IJC report of 1968. The 1969 directive was revised in 1995.

The 1995 Directives required that the Board maintain surveillance, carry out assessments and keep the IJC informed on matters related to water quality objectives. It required that the board report on "…developments, actual or anticipated, which have the potential to adversely affect the quality of the water and the health of the Red River trans-boundary aquatic ecosystem."

A significant change in climate could constitute such an 'anticipated development' if there was less water, due to less precipitation and/or higher evaporation, and hence, less dilution of water contaminants.

IJC Directive to the International Red River Board (2001)
This directive replaces the above two instruments and is intended to embrace the water quantity aspects of the 1948 reference and the water quality aspect of the 1995 directive.

The Directive Article 5. A. requires: 'Maintain an awareness of basin-wide development activities and conditions that may affect water levels and flows, water quality and the ecosystem…."

The 2001, 45-page first annual report of the Board does not mention the word 'climate' and gives scant reference to apportionment (11), conservation of water (0), snow (2), precipitation (3), evaporation (0), utilization (1), entitlement (0), diversion (0) and aquifers (0). Regarding the aquifers, the report does mention that it should report on aquifers but it does not do so.

On the other hand the report refers to water quality and flood extensively: water quality (157), fish (35), pollution (39), and flood (64).

Climate change implications have not been address by the Board though they could have significant impacts on the basin.

If the climate change scenarios predict important changes in the climate, then apportionment, diversion, entitlements and aquifers could become important. In addition, because of the link between water quality and quantity, due to dilution, changes in the climate could impact on the water quality.

Comment

The Dakota Water Resources Act 2000 concerns the large-scale inter-basin transfers (Garrison Diversion Unit) of Missouri River water into the Red River Valley. Canada and Manitoba have a longstanding policy of opposing such inter-basin transfers.

Climate change may increase the need for new sources of water in the upper Red River valley and thus put further pressure on the USA to implement the inter-basin transfer.

D: REFERENECES

International Red River Board: http://www.ijc.org/boards/irrb/irrb.html

International Red River Basin Task Force: http://www.ijc.org/boards/rrbtf.html

Basin wide: http://www.basinwide.org

Garrison Dam: http://www.gov.mb.ca/conservation/transboundary/maps/map2.html

The Dakota Water Resources Act 2000: http://www.garrisondiv.org/pdfs/dwrafinal.PDF

LAKE OF THE WOODS - RAINY RIVER

Preamble

Boards
For the past eighty years, the instruments developed for the Lake of the Woods and Rainy River basins have all dealt with one main issue, water levels. The two basins have been treated separately. An IJC Board of Control exists for each, the International Rainy Lake Board of Control (1941) and the International Lake of the Woods Board of Control (1925). In addition, there is a Canadian Lake of the Woods Board of Control (1925), which deals with the level of the Lake of the Woods and the flow into the Winnipeg River.

In the Lake of the Woods, the Canadian Board manages the levels when they are within a range of 321.87 to 323.47 m while the International Board manages those situations when the levels fall outside this range. With relatively few exceptions, such as the 1985 high water levels which slightly exceeded 323.47 m (1,061 ft.), the lake has remained within the water level range where it is under the full authority of the Canadian Board. In order to ensure the fullest measure of co-operation, the Government of Canada appoints one member of the Canadian Board as its representative on the International Board (Paragraph 4 of the Protocol attached to the 1925 Agreement on Level of Lake of the Woods).

Instruments
There has been a wide array of Conventions, Agreements, Acts, Orders and Directives. Only two instruments, one from each basin, will be analyzed in detail here.

- Agreement Between the United States of America and Canada to Regulate the Level of Lake of the Woods (July 1925). The Agreement had an attached Protocol which a) gives guidelines for initiating the Agreement and b) refers to the IJC some questions concerning the regulation of levels in the Rainy Lake Watershed.
- The IJC Order Prescribing Method of Regulating the Levels of Boundary Waters in the Rainy Lake Watershed (January 2001).

There is a third instrument of interest, the Convention between the United States of America and Canada Providing for Emergency Regulation of the Level of Rainy Lake and of Other Boundary Waters in the Rainy Lake Watershed (1938). This document was not available for analysis. In its stead the 2001 IJC Order, which provides the latest guidance on the Rainy River basin lake levels, is analyzed.

A: WATERSHED

Name: Lake of the Woods / Rainy River Basins

Location: NW Ontario

Physical Description

Flowing Water Feature	**Length (km)**	**Drainage Area (km^2)**	**Mean Discharge (m^3/s)**
Lake of the Woods and Rainy River system		70,400	460 (into Winnipeg River)

B: BILATERAL MANAGEMNENT INSTRUMENTS

In the following three boxes, the ‘a’s in each box refers to the same instrument, as do the ‘b’s.

Title:
a) Agreement Between the United States of America and Canada to Regulate the Level of Lake of the Woods (July 1925).*
b) The IJC Order Prescribing Method of Regulating the Levels of Boundary Waters in the Rainy Lake Watershed (January 2001).

*International Boundary Waters Treaty Act is the umbrella instrument

Managing Authority:
a) IJC
International Lake of the Woods Control Board (1925)
Canadian Lake of the Woods Control Board (1919)

b) IJC International Rainy Lake Board of Control – 1941

Nature of Instrument:

a) Regulates and controls the outflow of the waters of Lake of the Woods.
b) Regulates and controls levels controlled by private dams in Rainy River Basin

C: CLIMATE SENSITIVITIES

Language Usage

As part of the evaluation of the climate-change sensitivity of agreements, the texts of the documents listed in Section B above, were subjected to a word search. The key search words used here were: climate, change, quality (water), fish, fishery, pollution, temperature, glacier, melt, drought, snow, allocation, precipitation, stream, flow, flood, environment, generation (power), apportionment, conservation, utilization, diversion, trends, aquifer, levels, quantity and entitlement. The absence of some of these key words can be as important as their appearance in the text.

The following words appeared in the Agreement Between the United States of America and Canada to Regulate the Level of Lake of the Woods (1925): fish (2), precipitation (3),flow(amounts) (5), flood (1), power generation (1), diversion (1) and (water) levels (32).

The following words appeared in the IJC Order Prescribing Method of Regulating the Levels of Boundary Waters in the Rainy Lake Watershed (2001): water quality (1), drought (4), precipitation (1), flow (28), flood (5), power generation (6) and (water) levels (54).

Specific Obligations and Entitlements

Agreement between the United States of America and Canada to Regulate the Level of Lake of the Woods

Articles 3 and 4

The Canadian Board regulates and control the outflow of the waters of Lake of the Woods when the levels of the lake of the Woods falls between elevation 323.47 m (1061 ft.) sea level datum and 321.87 m (1056 ft.) sea level datum. Whenever the level of the lake rises above elevation 323.47 m sea level datum or falls below elevation 321.87 m sea level datum, the rate of total discharge shall be subject to the approval of the International Board, which has two members. This situation has occurred infrequently in the past.

If, because of climate change, the Lake levels fall outside the accepted range more frequently than in the past, the IJC might consider altering the reference levels. In addition, the IJC might consider augmenting the size of the International board so that a broader range of opinion and experience is available to the International Board.

Article 5

During periods of excessive precipitation an adjusted range of allowed levels on the Lake shall be permitted as prescribed by the International Board. Such flexibility might help to accommodate climate change effects.

Article 7

"The outflow capacity of the outlets of Lake of the Woods shall be so enlarged as to permit the discharge of not less than forty-seven thousand cubic feet of water per second (47,000 c.f.s.) when the level of the lake is at elevation 1061 sea level datum."

Climate change may be such that the flow out of the Lake of the Woods is far greater than in the past and the discharge capacity specified is insufficient. In such an event, the outlet may have to be further enlarged.

The IJC Order Prescribing Method of Regulating the Levels of Boundary Waters in the Rainy Lake Watershed (January 2001)

This Order takes account of the original 1938 convention between the two countries, the 1949 Order and subsequent Supplementary Orders of 1957, 1970 and 2002. The Order is directed to the two companies, Boise Cascade Corporation and Abitibi-Consolidated Inc., which currently own and operate the discharge facilities at the outlets of Rainy and Namakan lakes. They manage the dam at the outlet of Rainy Lake, the International Falls Dam and upstream, at the outlet from the Namakan string of lakes, Kettle Falls. They produce hydro power at the dams.

The Order provided extremely detail quantitative levels for the Lakes for up to seven different parts of the years. On those occasions when the levels cannot be maintain within the normal range, because there is too little water, the outflow from the lakes at the dams is reduce. If the levels of the lakes continue to fall to the level called the drought line, then the outflow is further restricted. No guidelines are provided for those cases where the amount of water greatly exceeds current experience.

Paragraphs 1(a), 1(b) and 1(c)

For example, the level of Namakan Lake must lies between 339.70 m and 340.00 m during the period January 1 to April 1. If the flow drops below 339.70 m, the outflow is reduced to 30 m^3/s. If the level continues to drop to what is called the drought line, 338.95 m in this case, then the outflow is further reduced to not less than 15 m^3/s.

Under extremely dry climate conditions, it may not be possible to operate the level control facilities in a manner which will maintain the lake levels within the prescribed ranges.

Paragraph 3

"… if extremely high or low inflows to Namakan Lake or Rainy Lake are anticipated, the … Board of Control,… may authorize the levels … be raised temporarily to greater than the maximum or lowered temporarily to less than the minimum elevations respectively prescribed in Paragraphs numbered 1(a) and 2(a) of this Order."

This flexibility is desirable given the uncertainty of future climates. In fact, it would appear that the prospect of climate change has been anticipated here, though the actual phenomenon is not mentioned.

Paragraph 5

"This Order shall be subject to review 15 years following adoption of the Commission's Supplementary Order of 5 January 2000, or as otherwise determined by the Commission."

Given the possible pace of climatic change, this 15 year review period may be too long.

Note:
In 2001 the water level exceeded 323.67 m for sevral days in June & July 2001. Earlier this year following a series of heavy rains in June 9-11 period, the entire system was subjected to high flows and elevations. For example, Lake of the Woods peaked at 323.676 m (0.206 m above bounds) on July 12 with a maximum outflow of 1411.5 cms on July 15. (Private communication from Syed M. A. Moin, Ph.D., P.Eng. Senior Hydrologic Engineer, Environment Canada.)

GREAT LAKES BASIN - NIAGARA RIVER

Preamble

The total generating capacity at Niagara is about 4.4 million kilowatts (5 million horsepower). The Niagara River Treaty stipulates that the river flow used for hydro-electric generation be shared equally by Canada and the United States. There is one exception to the equal sharing formula. The quantity of water diverted into the Great Lakes basin from the Albany River Basin as a consequence of the Long Lac-Ogoki diversions is governed by an "Exchange of Notes Between the United States of America and Canada Constituting an Agreement Regarding the Development of Certain Portion of the Great Lakes – St. Lawrence Basin Project" , 1940. This agreement is also examined here.

This treaty is unusual because it amends the fundamental Boundary Waters Treaty (1909) by terminating its third, fourth, and fifth paragraphs of Article V.

It was preceded by a number of agreements or notes, May 20 1941, October 27 1941, November 27 1941 and December 23 1948.

A: WATERSHED

Name: Great Lakes Basin - Niagara River

Location: Southern Ontario

Physical Description

Flowing Water Feature	Length (km)	Drainage Area (km^2)	Mean Discharge (m^3/s)
Niagara River	56	684,000	5,700 (variable)*

*The flow at Queenston for the period of record 1860 to present.

B: BILATERAL MANAGEMNENT INSTRUMENTS

In the following three boxes, the 'a's in each box refers to the same instrument, as do the 'b's, etc.

Title:

a) Niagara River Treaty* (1950) (formal title: Treaty Between the United States of America and Canada Relating to the Uses of the Waters of the Niagara River)
b) Exchange of Notes Between the United States of America and Canada Constituting an Agreement Regarding the Development of Certain Portion of the Great Lakes – St. Lawrence Basin Project (1940) also known as The Long Lac-Ogoki diversions

*The Treaty will remain in force for 50 years and thereafter until one of the parties notifies the other that it wishes to terminate the treaty.

Managing Authority:

a) The two federal governments through:
   i. International Niagara Committee (1950-Article VII) – inspecting plants, monitor water available and water used for power – report to Goverments
   ii. International Niagara Board of Control (1953 by the IJC) supervising water levels regulated by the operation of remedial works – reports to IJC
b) The two federal government with the support of the Government of Ontario

Nature of Instrument:

a) The preservation and enhancement the scenic beauty of the Niagara Falls and the production of hydro-electric power, including the construction of remedial works.
b) Enhance power production at Niagara Falls for the war effort

C: CLIMATE SENSITIVITIES

Language Usage

As part of the evaluation of the climate-change sensitivity of agreements, the text of the document listed in Section B above, was subjected to a word search. The key search words used were: climate , change, water quality , fisheries , pollution , temperature , glacier, melt , drought, snow , allocation , precipitation , stream , flow , flood , power (generation) , entitlement , apportionment, conservation, utilization, diversion, trends, aquifer, levels, and quantity (water). The absence of some of these key words can be as important as their appearance in the text.

The following words appeared in the text of the Treaty: power (generation) (12), diversion (8), flow (3) and quantity (water) (1).

The following words appeared in the text of the diversion agreement letters: flow (2), power (generation) (8), utilization (2), diversion (2) and quantity (2).

Specific Obligations and Entitlements

Niagara River Treaty

Article III

"Waters which are being diverted into the natural drainage of the Great Lakes System through the existing Long Lac-Ogoki works shall continue to be governed by the notes exchanged between the Government of the United States of America and the Government of Canada at Washington on October 14 and 31 and November 7, 1940 and shall not be included in the waters allocated under the provisions of this Treaty."

The Long Lac-Ogoki works divert 5,000 cubic feet per second into the Great Lakes Basin. (It has not been confirmed that this amount has remained constant since 1940.) At some times of day and for some months (see below) this water is equivalent to 10 % of the flow over Niagara Falls. The water is available to Canada for power production before apportioning of the water is done, 'off the top' so to speak.

Should the amount of water in the Niagara River become seriously reduced because of climate change, then this small fixed amount may become important and could be a point of renegotiation between the two countries.

Article IV

"In order to reserve sufficient amounts of water in the Niagara River for scenic purposes, no diversions of the water specified in Article III of this Treaty shall be made for power purposes which will reduce the flow over Niagara Falls to less than one hundred thousand cubic feet [2,826.2 cubic metres]* per second each day between the hours of eight a.m., E.S.T**., and ten p.m., E.S.T., during the period of each year beginning April 1 and ending September 15, both dates inclusive, or to less than one hundred thousand cubic feet per second each day between the hours of eight a.m., E.S.T., and eight p.m., E.S.T., during the period of each year beginning September 16 and ending October 31, both dates inclusive, or to less than fifty thousand cubic feet [1,413.1 cubic metres] per second at any other time;…"

*The Governemnts agreed that the metric conversions for the minimum Falls flows, are 2832 cubic metres per second for 100,000 cubic feet per second and 1416 cubic metres per second for 50,000 cubic feet per second.

** By an exchange of notes dated April 17, 1973, the Governments agreed the Treaty be interpreted to provide that Eastern Daylight Savings Time be utilized to determine the hours of flows specified in Article IV during the periods when EDST is legally in effect in the City of Niagara Falls New York or the city of Niagara Falls, Ontario.

These absolute flow requirements may be challenged should climate change result in a reduction in available water to the point where reduced power production becomes important.

Article VI

"The waters made available for power purposes by the provisions of this Treaty shall be divided equally between the United States of America and Canada."

The exception is the diversion water from the Long Lac-Ogoki works, in Article III.

Long Lac-Ogoki Diversions Agreement (done by the exchange of letters)
Formally called: Exchange of Notes Between the United States of America and Canada Constituting an Agreement Regarding the Development of Certain Portion of the Great Lakes – St. Lawrence Basin Project, Signed at Washington 14 and 31st October and 7th November 1940

October 14th 1940 – USA to Canada

"Meanwhile, to assist in providing an adequate supply to meet Canadian defense needs and contingent upon the Province of Ontario provide immediately for diversions into the Great Lakes System of waters of the Albany River Basin which normally flow into Hudson Bay, the Government of the United States will interpose no objection, pending the conclusion of a final Great Lakes-St. Lawrence Basin agreement between the two countries, to the immediate utilization for power at Niagara Falls by the Province of Ontario of additional waters equivalent in quantity to the diversions into the Great Lakes Basin above referred to."

Final exchange: November 7th, I940 – Canada to USA

"I note also that the Canadian Government is giving appropriate instructions to authorize the additional diversion of 5,000 cubic feet [141.58 cubic metres] per second of water at Niagara Falls by the Hydro-Electric Commission of Ontario."

Note: There is no mention of the exact amount of water which must be diverted at Long Lac-Ogoki, into the Great Lakes Basin. There is reference to 'utilization for power at

Niagara Falls by the Province of Ontario of additional waters equivalent in quantity to the diversions into the Great Lakes Basin …' The role of the Ontario Government has not been examined. The content of the Great Lakes-St. Lawrence Basin Agreement (March 1941) has not been examined.

Under certain climate change scenarios the relatively small quantity of equivalent water allowed for power production by Canada (Ontario) may become more important given the flow requirements of the Treaty.

Comments:

1--From: International Niagara Board of Control, Ninety-Eighth Semi-Annual Progress Report to the IJC, March 2002.

"For the months of September 2001 through February 2002, the level of Lake Erie continued below its long-term average but was nearly at average in February. Precipitation on the Lake Erie basin was above average during this period. This helped move the lake nearer to its long-term average as the period progressed. Lakes Michigan and Huron remain well below their long-term average levels, resulting in generally lower than average inflows to Lake Erie from upstream."

2-- The average combined LL/O diversion for Jan '44 to Dec 2001 is 153 cubic metres per second. (Private communication from Ralph Moulton, Water Issues Division, Environment Canada)

D: REFERENECES

Long Lac-Ogoki Diversions Agreement

http://www.internationalwaterlaw.org/RegionalDocs/St-Lawrence.htm

Niagara River Treaty

http://www.law.buffalo.edu/Academics/courses/775/Canada_Diversion_Treaty.htm

Information on the falls and the flow control plan.

http://www.infoniagara.com/d-att-river.html

ST. CROIX AND ST. JOHN RIVERS

Preamble

St. Croix River

The IJC Order of Approval for dams set the terms on which these works could be built and operated. The two IJC boards, the International St. Croix River Board of Control and the International Advisory Board on Pollution Control - St. Croix River, have assessed the need to modify the Commission's St. Croix Orders of Approval. The review report is examined here. The Review is not a legal instrument but it reveals issues of interest here.

In 2000, the International Joint Commission formally combined the two boards and established the International St. Croix River Board.

St. John River

Few instruments were identified and the one noted below could not be found.

A: WATERSHED

Name: St. Croix River and St. John River Basins

Location: Southern New Brunswick

Physical Description

Flowing Water Feature	Length (km)	Drainage Area (km^2)	Mean Discharge (m^3/s)
St. Croix River (length along boundary only)	185 km	4 230	
Saint John River	673	Can.: 35 500 US: 19 700 Total: 55 200	1 130

B: BILATERAL MANAGEMNENT INSTRUMENTS

In the following three boxes, the ‘a’s in each box refers to the same instrument, as do the ‘b’s.

Title:

a) Review of the Orders of Approval St. Croix River Basin Maine and New Brunswick (1997)
b) Agreement Relating to the Establishment of a Canada-United States Committee on Water Quality in the St. John River and its Tributary Rivers and Streams which cross the Canada-United States Boundary (with annex) (1972, amended 1984) *

*The text for this Agreement could not be found.

Managing Authority:

a) IJC through:
   - International St. Croix River Board of Control - oversees operation of dams and fisheries (1915 by IJC)
   - International Advisory Board on Pollution Control - monitors water quality (1962 by governments)

Nature of Instrument:

a) Assesses local concerns in context of Orders on river levels and flows

C: CLIMATE SENSITIVITIES

The "Review of the Orders of Approval St. Croix River Basin Maine and New Brunswick" is not a legal instrument. However, it provides some insight into potential climate change induced difficulties.

The Review received and analyzed proposals from a wide range of interested parties. The proposals were examined to see if they violated the existing Orders of Approval for the river. "…one of the most significant factors that caused violations in the analyses was a 750 cubic foot per second discharge requirement at Baring, Maine imposed by the United States Environmental Protection Agency. Since this discharge must be met year-round, the basin managers needed to utilize storage from the reservoirs during the summer periods when inflow was historically at its lowest." Baring is near the mouth of the river.

The climate change scenarios may indicate important change to the flow of the river. These changes may aggravate or remove the problems associated with the minimum flow requirement.

The analysis involved the application of a model, which determined the impact of each of the fourteen proposals on the flow record for the period 1970 to 1989. All produced violations of the Orders. The technical staff tried to develop a modified scenario from all the proposals submitted. "It was not possible to develop a scenario that was successful in all 20 years of record. However the Working Group did identify operating controls which could be attained for 19 years out of the 20 of record from 1970 to 1989. Only 1985, the driest year of record, showed violations." The Review concluded that the Orders should stand unchanged, for the moment.

The utilization of the period 1970 to 1989 may be unrealistic in the light of climate change scenarios.

The review further concluded that:
"No further work should be performed examining potential changes in the Orders of Approval until the 750 cfs discharge at Baring is reviewed by the St. Croix International Advisory Board on Pollution Control in conjunction with the United States Environmental Protection Agency and the Maine Department of Environmental Protection."

The climate change scenarios may indicate important future changes to the water resources. The examination of the Orders and the review of the USEPA discharge requirements should consider the implications of climate change.

D: REFERENECES

Review of the Orders of Approval St. Croix River Basin Maine and New Brunswick (1997), http://www.ijc.org/comm/stcroixrev.html

YUKON RIVER

A: WATERSHED

Name: Yukon River Basin

Location: Yukon Territories

Physical Description

Flowing Water Feature	Length (km)	Drainage Area (km^2)	Mean Discharge (m^3/s)
(Portion of the drainage area in the United States is shown in brackets)			
Yukon River (mouth to head of Nisutlin River)	3 185	-	-
(International Boundary to head of Nisutlin River)	1 149	323 800 (515 400)	2 300
Porcupine River*	721	61 400	-
White River	265	38 000 (12 500)	-

*Porcupine River: the drainage area in the USA is not available.

B: BILATERAL MANAGEMNENT INSTRUMENTS

In the following three boxes, the ‘a’s in each box refers to the same instrument, as do the ‘b’s, etc.

Title:
a) Yukon Waters Act* – 1992 (Replaced Northern Inland Waters Act - 1970)
b) Pacific Salmon Treaty** – signed/ratified June 1999 (replaces treaty of 1985)
c) Yukon River Treaty – signed, March, 2001 (also known as the Yukon River Salmon Treaty). The Yukon River Treaty is an annex to the Pacific Salmon Treaty.

*The Yukon Waters Act is unilateral. It sets the stage for further agreement development.

** Pacific Salmon Treaty will be in effect for ten years.

Managing Authority:
a) Canadian Federal Government
- Yukon Territory Water Board
b) Federal Governments of Canada and the USA
c) Federal Governments of the UASA and Canada
- Bilateral Yukon River Panel

Nature of Instrument:
a) The management of water use through the issuing of permits.
b) The management of Pacific salmon fisheries and the equitable harvest of salmon stocks
c) The management and allocation of salmon catches on the Yukon River

C: CLIMATE SENSITIVITIES

The Yukon River Treaty is not yet available for analysis.

Language Usage
As part of the evaluation of the climate-change sensitivity of agreements, the texts of the documents listed in Section B above, were subjected to a word search. The key search words used here were: water quality, fisheries, pollution, temperature, climate, glacier, melt, drought, precipitation, snow, allocation, stream flow, flood, power generation, and entitlement. The absence of some of these key words can be as important as their appearance in the text.

Only the following words appeared in the text of the Yukon Waters Act: water quality (9), fisheries (1), pollution (1) and flood (1).

The following key words appeared in the text of the Pacific Salmon Treaty Agreement: fisheries (123), allocation (4) and entitlement (1).

General
Issue Limitations
The Yukon Waters Act is limited to the management of water use through the issuing of permits. The act includes consideration for the pollution of water by local sources. It also provides for the alteration of water ways. "Water use" means a direct or indirect use of any kind, including, without limiting the generality of the foregoing,

(*a*) Any diversion or obstruction of waters,

(*b*) Any alteration of the flow of waters, and (*c*) Any alteration of the bed or banks of a river, stream, lake or other body of water, whether or not the body of water is seasonal,

The Act does not include a use connected with shipping activities.

Water use issues which might require attention in a climate change regime are not identified specifically in the act. However, the permitting process may provide the necessary mechanism for including climate change considerations.

The Pacific Salmon Treaty Agreement is concerned primarily with the maintenance of the fisheries resource.

Regional Limitation
The Yukon Waters Act is a Canadian Instrument. It is referenced here because it provides mechanisms for the compliance to bilateral instruments. Specific obligations and entitlements are not evaluated in this study.

This Pacific Salmon Treaty Agreement applies mainly to the Pacific coastal rivers, south of the Bering Sea. However, it includes Article 8: Yukon River. In addition, the Yukon River Treaty is an annex to the Agreement, and therefore is closely connected to the parent agreement.

Specific Obligations and Entitlements

The Pacific Salmon Treaty Agreement is discussed fully in the following sections dealing with the north-west river of British Columbia and the Skagit. However, specific details concerning allocations are contained in agreements for individual rivers, such as the Yukon River Treaty, below.

The signing of the Yukon River Treaty on March 26 2001, ended sixteen years of negotiations. The specific obligations and entitlements of this agreement are not yet available for assessment. Ratification is expected by the summer of 2002.

D: REFERENECES

Yukon Waters Act:
http://lois.justice.gc.ca/en/Y-4.6/

Pacific Salmon Treaty:
http://www.dfo-mpo.gc.ca/pst-tsp/main_e.htm

Yukon River Treaty - Interim information site:
http://www.landbigfish.com/articles/default.cfm?ID=20

ANNEX B – CLIMATE CHANGE SCENARIOS (MSC)

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

The objective of the CCAF-funded Project "Implications of Climate Change for Canada's Boundary and Transboundary Water Management" is to explore the vulnerability of bi-national and inter-provincial-territorial water resources and their respective water management institutional arrangements to climate change as well as assess capacity for and barriers to adaptation. This report provides the climate context for the project by describing plausible climate change scenarios.

Climate change scenario data for 2040–2069 (2050s) were obtained through the Canadian Climate Impacts Scenarios (CCIS) Project and were used to develop:

- scatterplots (seasonal and annual) of temperature and precipitation changes from Global Circulation Model (GCM) runs to illustrate the range of modeled changes and assist in selecting key scenarios for further analysis;
- maps of four climate change scenarios (CCSR-98 ga1, CGCM1 ga1, HadCM2 ga1 and HadCM2 ga4) that illustrate the spatial changes of temperature and precipitation (soil moisture is also represented by the CGCM1 ga1) across and between the watersheds;
- frequency of precipitation graphs to contrast the current (1961 to 1990) proportion of days with precipitation falling as rain and snow for each watershed with projections from one climate change scenario for 2050.

Recent climate change literature was surveyed to develop a summary of projected climate change impacts on the hydrologic cycle and water resources and to identify currently observed changes and trends that may be attributable to climate change.

1.1 Study Area Watersheds

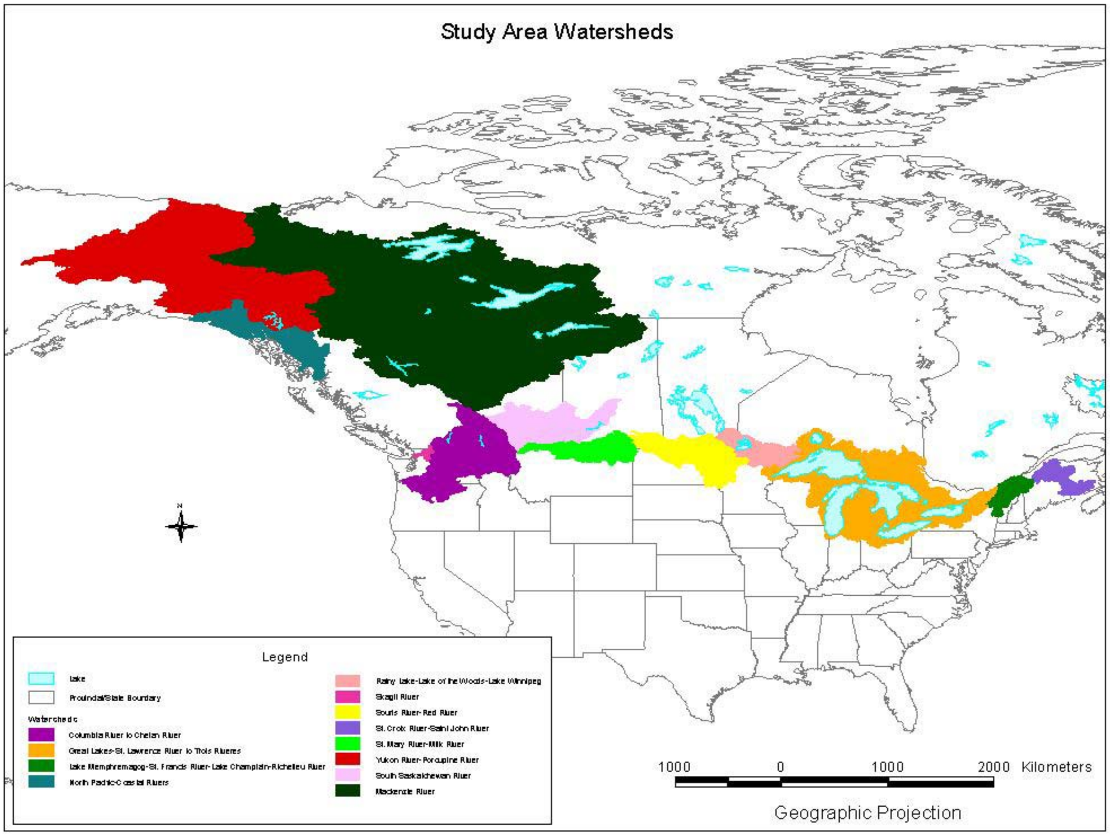
A map outlining the bi-national and inter-provincial-territorial watersheds is presented in Figure 1. The bi-national watersheds include those "boundary waters" identified by the International Joint Commission (IJC) (Fabien Lengelle, International Joint Commission, Personal Communication, 2002); several of the smaller watersheds have been amalgamated to ease analysis. The bi-national watersheds include:

1. Yukon River-Porcupine River
2. North Pacific-Coastal Rivers
3. Skagit River
4. Columbia River
5. St. Mary River-Milk River
6. Souris River-Red River
7. Rainy Lake-Lake of the Woods- Lake Winnipeg
8. Great Lakes-St. Lawrence
9. Lake Memphremagog-St. Francis River-Lake Champlain-Richelieu River

10. St. Croix River-Saint John River

The inter-provincial-territorial watersheds include:

1. Mackenzie River
2. South Saskatchewan River



3.

Figure 1: Map of Study Area Watersheds

3.0 CLIMATE CHANGE SCENARIOS

How the climate system responds to increasing concentrations of greenhouse gases and in turn impacts ecological and human systems and regions of the world is a complex process to understand. Confident predictions of the future state of the climate are not possible. However, climate change scenarios can indicate a range of plausible future climate states, which can be used in impact assessments to assess potential sensitivities, vulnerabilities and opportunities and develop mitigation and adaptation responses.

Various climate scenario-generating techniques have been used in climate change impact assessment. For example, scenarios from GCMs, analogues (spatial and temporal), statistical downscaling, regional climate models and systematic changes to observed climate data have been applied. The most commonly used scenario-generating technique, and the one adopted for this project, is GCM-based. Coupled general circulation models of the atmosphere and ocean (AOGCMs) provide the most credible quantitative estimate of the climate response to changing concentrations of greenhouse gases, sulphate aerosols and other elements that affect climate forcing (IPCC-TGCIA, 1999).

2.1 Climate Scenario Definition

The Task Group on Scenarios for Climate Impact Assessment (TGCIA) describes a climate scenario as:

> "A plausible representation of the future that are consistent with assumptions about future emissions of greenhouse gases and other pollutants and with our understanding of the effect of increased atmospheric concentrations of these gases on global climate." (IPCC-TGCIA, 1999).

The scenarios developed since 1992 also include social influences on possible climate outcomes related to assumptions concerning demographics, economics and technological advances (Leggett et al., 1992). The possibility that any single emissions path will occur as described in scenarios is highly uncertain (IPCC, 2001).

2.2 Description of Scenarios

The oldest GCM-based scenarios (and now obsolete for impact assessments) were developed from equilibrium-response climate change experiments where the atmospheric component was linked to highly simplified oceanic and sea-ice components. In these experiments, the global climate system is perturbed by an instantaneous increase in the atmospheric concentration of CO_2 (usually a doubling) and allowed to stabilize to a 'new' climate. This is known as a $2xCO_2$ run. In addition, a $1xCO_2$ control run of the GCM is produced with pre-industrial or current atmospheric greenhouse gas concentrations. The $2xCO_2$ climate change scenario is derived from the difference (temperature) or the ratio (precipitation) between the $2xCO_2$ and $1xCO_2$ results. The scenarios used in this project were the CCCII, GISS and the GFDL.

Current climate change research uses transient experiments in which AOGCMs simulate the response of the climate system to a gradual increase in CO_2 (the combined forcing of all the greenhouse gases as an equivalent CO_2 concentration) and sulphate aerosols. The AOGCM incorporates the ocean's important role in sequestering and distributing heat. In most cases, data are available depicting the evolution of the climate system to 2100 in response to historical and projected greenhouse gas and aerosol forcing described by the IS92 and Special Report on Emission Scenarios (SRES) emission scenarios (IPCC, 2000). In the scenario generating process, the 30-year simulation period from 1961-90 is used as the reference climate from which "change fields" for future periods including the 2020s (2010-2039), the 2050s (2040-2069) and the 2080s (2070-2099) are calculated. Climate change scenarios were developed from the IS92 and SRES emission scenarios used in GCM climate sensitivity experiments. The scenarios used in this project are described below.

IS92

Through the Intergovernmental Panel on Climate Change (IPCC), six (a to f) greenhouse gas and sulphate emission scenarios were developed using scenarios of economic development, population growth and energy mix (Leggett et al., 1992). The IS92a scenario is known as the "business as usual scenario" where emission scenarios are based on historical increases to 1990 and thereafter a 1% annum growth, compounded. The IS92a scenario was used by all GCM modeling centres in their climate sensitivity experiments.

SRES

The SRES emissions futures consist of a series of four scenario families, A1, A2, B1 and B2, which represent different demographic, social, economic and technological futures called 'storylines' (Carter et al, 1999). They differ from the IS92 by having lower population projections. The A1 and A2 families have more of an economic concentration and B1 and B2 are more environmental (CICS, 2002). The A1 and B1 focus is global and the A2 and B2 are more regional. The following description of the families is summarized from the IPCC (2000).

> ***The A1 storyline is a world of very rapid economic growth, low population increase and rapid introduction of new, more efficient technologies. The economy grows to approximately $550 trillion U.S. by 2100. Global populations reach 9 billion by 2050, and decrease to 7 billion by 2100. There are abundant energy and mineral resources available due to rapid technical progress.***
>
> ***The A2 storyline is a diverse world. There is a reliance and preservation of local identities and a high population growth, 15 billion by 2100. Economic development is regionally orientated. Economic growth and technological change are more uneven and slower than the***

other storylines. Global per capita income is low compared to the other scenarios. The GDP is $250 trillion U.S. by 2100.

The B1 storyline is a convergent world. There is low population growth, 9 billion by 2050 and a decrease to 7 billion by 2100. There are rapid changes in the economic organization through service, information economy and resource efficient technology. The GDP is $350 trillion U.S. by 2100.

The B2 storyline concentrates on local solutions to economic, social and environmental sustainability. There is moderate population growth, 10 billion and the GDP is $250 trillion by 2100. This storyline focuses on local and regional levels of environmental protection and social equity.

2.3 Scenarios Used in this Project

Four generations of GCM-based scenarios representing advances in the climate models, the greenhouse gas and sulphate emission scenarios or both were reviewed for the project. Table 1 lists the greenhouse gas emission scenarios, the vintage of the GCM models and the climate sensitivity experimental runs considered scatterplot analysis. Only IS92a and SRES-derived climate change scenarios were used. The SRES emission scenarios are now used in experiments with the most advanced GCMs and the results represent the current understanding of the climate response to these forcings. But, there are few climate impact assessments using SRES scenarios while many climate change impact assessments have used the IS92a-based scenarios from "warm start" transient GCM runs. An older equilibrium 2xCO_2 scenario and the GISS and GFDL "cold start" transient scenarios are included merely for reference in the scatter plots as they were used in early climate impact assessments that are still cited for hydrologic and water resource impacts.

Table 1 : Models and Scenarios used in the Scatterplots

Greenhouse Gas Emission Scenario	**GCM**	**Scenario**
SRES	CGCM2	A21,A22,A23,A2X, B21,B22,B23,B2X
	CSIROMK2b	A11,A21,B11,B21
	HadCM3	A21,B21
IS92a	CCSR-98	ga1
	CGCM1	ga1,ga2,ga3,gax
	GCCM2	ga1,ga2,ga3,gax
	CSIROMK2b	ga1
	HadCM2	ga1,ga2,ga3,ga4,gax
	HadCM3	ga1
Transient	GFDL	1991
	GISS	1995
Non-Equilibrium	CCCII	1 x CO_2, 2 x CO_2

CCC – Boer et al., 1992; CCSR-98 – Emori et al., 2000; CGCM1 – Flato et al., 1999; CGCM2 – Flato et al., 2001; CSIROMK2b – Hirst et al., 2000; GFDL – Taylor, 1996; GISS – Taylor, 1996; HadCM2 – Johns et al., 1997.

Warm start, transient AOGCM simulations were used to develop the climate change scenarios highlighted in this project and the future time period chosen was 2050s, which represents the years 2040-2069. For precipitation, the change is reported as a % change, while for temperature a difference in ^{o}C is calculated.

3.0 SCATTERPLOTS OF TEMPERATURE AND PRECIPITATION CHANGE FIELDS

Scatterplots are a simple tool used to compare temperature and precipitation changes for multiple scenarios. In this project, they were used to identify the GCM experiments that would depict warm-wet and warm-dry scenarios, which would be mapped. The scenarios presented in the scatterplots are listed in Table 3.1. Only the results of the IS92a and SRES scenarios are discussed. The older CCCII, GFDL and GISS scenarios, commonly used in the 1990s impact literature, are included for information and comparison with the newer GCM results that were based on the IS92a and SRES emission estimates.

3.1 Scatterplot Development

The data in the scatterplots represents average temperature and precipitation change fields associated with the GCM grid boxes within the watershed boundaries.

The data for the scatterplots were obtained using the following method. First, the areal extent of each watershed was defined by the latitude and longitude of 4 coordinates. The coordinates represented the northern, southern, eastern and western most corners of each watershed, which created a 'watershed box'. Then, the co-ordinates were sent to the CICS (Canadian Climate Impact Scenarios 2002 – http://www.cics.uvic.ca/scenarios/data/select.cgi) and superimposed onto grid boxes used by each GCM. Data from the grid boxes that overlapped any portion of the watershed box were averaged. A box (window) average of the grid boxes from the scenarios showing temperature and precipitation change, for the period of 2040-2069 (the 2050s), was compiled using this data. This process was repeated for several GCM data sets. Table 2 lists the number of grid boxes used for each model by watershed. Table 3 lists the resolution for each grid box by model. Finally, the scatterplots were created using Microsoft Excel.

	GCMs						
	Current Transient				Older		
Watershed	**CCSR-98**	**CGCM1, CGCM2**	**CSIROMK2b**	**HadCM2, HadCM3**	**CCCII**	**GFDL**	**GISS**
Yukon River-Porcupine River	15	28	20	35	20	12	15
North Pacific and Coastal Rivers	6	12	9	12	12	6	9
Mackenzie River	28	50	42	60	50	30	40
Skagit River	4	4	4	4	2	1	4
Columbia River	6	12	9	16	9	6	9
South Saskatchewan	3	8	6	12	8	2	3
St. Mary River-Milk River	2	6	2	6	6	3	6
Souris River-Red River	6	8	6	8	8	4	4
Rainy Lake-Lake of the Woods-Lake Winnipeg	4	6	2	6	6	1	4
Great Lakes-St. Lawrence River	16	18	15	24	18	12	15
Lake Memphremagog-St. Francis River-Lake Champlain-Richelieu River	2	4	2	4	4	2	2
St. Croix River-Saint John River	3	3	3	4	3	2	1

Table 2: Number grid boxes used for each watershed by GCM

	GCM – Model Resolution						
	CGCM1, CGCM2	**HadCM2, HadCM3**	**CCSR-98**	**CSIROMk2b**	**CCCII**	**GFDL**	**GISS**
ACGM Resolution (latitude x longitude)	**3.75° x 3.75°**	**2.5° x 3.75°**	**5.6° x 5.6°**	**3.2° x 5.6°**	**3.75° x 3.7°**	**7.5° x 4.5°**	**5.0° x 4.0°**

Table 3: Grid box dimensions of the models used in this project.

3.2 Summary of Scatterplots for the Study Area Watersheds

A summary of temperature and precipitation changes by watershed and scenario are listed in Table 4. Note that 'T' represents the temperature change field and 'P' is the precipitation change field. A more detailed summary by watershed is provided in the following section. The time-scale for the change fields were annual and seasonal. The annual timescale consists of the average of all the seasons. These maps are presented in Section 3.3. The seasonal timescale consist of the winter (December, January and February-DJF), the spring (March, April and May-MAM), the summer (June, July and August-JJA) and the fall (September, October and November-SON). Seasonal scatterplots are provided in Appendix 1.

An increase in temperature change was observed in every scenario for all time periods and watersheds (with the exception of the North Pacific and Coastal Rivers Watershed, where the HadCM3 B21 model showed a decrease in mean temperature by 0.1°C for the winter).

For the most part, the northwestern watersheds (Yukon River-Porcupine River, North Pacific and Coastal Rivers and Mackenzie River) showed an increase in precipitation for all seasons. The Yukon River-Porcupine River and the Mackenzie River watersheds had the greatest temperature increases for the winter months.

For the western watersheds, Skagit River and Columbia River, more than half of the scenarios showed a decrease in precipitation for the summer. This also occurred in the spring for Skagit River.

For the Prairie and the Great Lakes-St. Lawrence River watersheds, the majority of scenarios showed a decrease in precipitation change during the summer months. This was also the case for the fall, though not as many scenarios showed a decrease. However, there was general consensus between the scenarios that precipitation change would increase for the winter and spring.

The eastern watersheds, Lake Memphremagog-St. Francis River-Lake Champlain-Richelieu River and St. Croix River-Saint John River, the majority of the scenarios show an increase in precipitation change for all seasons.

Watershed	Annual	Winter (DJF)	Spring (MAM)	Summer (JJA)	Fall (SON)
Yukon River to Porcupine River	▪ T: +1.5 to +5°C ▪ P: +3 to +22%	▪ T: +1.5 to +7.5°C ▪ P: –4 to +28%	▪ T: 0 to +5°C ▪ P: +2 to +22%	▪ T: +2 to +4.5°C ▪ P: –3 to +22%	▪ T: +1.5 to +5.5°C ▪ P: + 2 to +24%.
North Pacific and Coastal Rivers	▪ T: +1 to +4°C ▪ P: 0 to +19%	▪ T: –0.1 to +5°C ▪ P: –4 to +26%	▪ T: +0.5 to +5°C ▪ P: –4 to +19%	▪ T: +2 to +3.5°C ▪ P: –7 to +18%	▪ T: +1 to +3.5°C ▪ P: –3 to +21%
Mackenzie River	▪ T: +1.5 to +4.5°C, ▪ P: +3 to +16%	▪ T: +1 to +7.5°C, ▪ P: 0 to +23%	▪ T: +1 to +5°C ▪ P: 0 to +24%	▪ T: +1.5 to +3.5°C ▪ P: 0 to -11%	▪ T: +1.5 to +4.5°C ▪ P: +4 to +16%
Skagit River	▪ T: +1.5 to 2.5°C ▪ P: –7 to +11%	▪ T: +0.5 to +3.5°C ▪ P: –10 to +16%	▪ T: +1 to +3°C ▪ P: –11 to +7%	▪ T: +1.5 to 4°C ▪ P: –32 to +19%	▪ T: +1.5 to +3.5°C ▪ P: –8 to +23%
Columbia River	▪ T: +2 to +3.5°C ▪ P: –1 to +13%	▪ T: +0.5 to +4.5°C ▪ P: 0 to +13%	▪ T: +1 to +4°C ▪ P: –1 to +15%	▪ T: +1.5 to +4°C ▪ P: –18 to +19%	▪ T: +1.5 to +3.5°C ▪ P: –5 to +18%
South Saskatchewan River	▪ T: +1.5 to +4.5°C ▪ P: +2 to +13%	▪ T: +0.5 to+ 6°C ▪ P: +2 to +13%	▪ T: +0.5 to +5.5°C ▪ P: +5 to +23%	▪ T: +1.5 to +3.5°C ▪ P: –8 to +12% ,	▪ T: +1.5 to +3.5°C ▪ P: –8 to +14%
St. Mary River – Milk River	▪ T: +1.5 to +4°C ▪ P: –2 to +16%	▪ T: +1 to +5°C ▪ P: –3 to +25%	▪ T: +1 to +6.5°C ▪ P: +3 to +25%	▪ T: +1 to +4°C ▪ P: –16 to +14%	▪ T: +1 to +3.5°C ▪ P: -6 to +25%
Souris River – Red River	▪ T: +1.5 to +4.5°C ▪ P: –3 to +11%	▪ T: +0.5 to +6°C ▪ P: –4 to +23%	▪ T: +0.5 to +6.5°C ▪ P: –4 to +28%	▪ T: +1 to +4°C ▪ P: –22 to +10%	▪ T: +1. to +3.5°C ▪ P: –12 to +25%
Rainy Lake-Lake of the Woods-Lake Winnipeg	▪ T: +1.5 to +4.5° ▪ P: –3 to +10%	▪ T: +1 to +6°C ▪ P: +0 to +32%	▪ T: +0.5 to +6°C ▪ P: –10 to +25%	▪ T: +1 to +3.5°C ▪ P: –30 to +10	▪ T: +1.5 to +4°C ▪ P: –14 to +22%
Great Lakes-St. Lawrence River	▪ T: +1.5 to +5°C ▪ P: +1 to +9%	▪ T: +1.5 to +5°C ▪ P: –2 to +18%	▪ T: +1.5 to 5.5°C ▪ P: –6 to +17%	▪ T: +1 to +4.5°C ▪ P: –5 to +10%	▪ T: +1.5 to +4°C ▪ P: –6 to +17%
Lake Memphremagog-St. Francis River-Lake Champlain-Richelieu River	▪ T: +1.5 to +4.5°C ▪ P: -2 to +14%	▪ T: +1.5 to +5°C ▪ P: –5 to +20%	▪ T: +0.5 to +6°C ▪ P: –7 to +15%	▪ T: +1.5 to +3.5°C ▪ P: -6 to +18%	▪ T: +1.25 to +3.5°C ▪ P: -7 to +16%
St. Croix River – Saint John River	▪ T: +1.5 to +4.5°C ▪ P: +2 to +8%	▪ T: +1.5 to +5°C ▪ T: +2 to +3.5°C	▪ T: +0.5 to +6°C ▪ P: –9 to +15%	▪ T: +1.5 to +3.5°C ▪ P: –8 to +26%	▪ T: +1.5 to +3.5°C ▪ P: –7 to +18%

Table 4: Summary of the range of temperature and precipitation changes, based on 30 scenarios per study area watershed.

3.3 Temperature and Precipitation Change Fields by Watershed

The following section describes the temperature and precipitation scatterplot results for each of the study area watersheds. Annual and seasonal results are discussed separately. Annual scatterplots are represented in Figures 2 – 13 and the seasonal scatterplots are in Appendix 1.

A total of 30 IS92a and SRES scenarios were used in the scatterplots. The scenarios are listed in a legend on the right-hand side of each scatterplot. Using the CCSR-98 ga1 as an example, deciphering the information in the legend will be clarified. The model name is listed first, in this case it is CCSR-98. Next is the emission scenario, which is ga. Finally, the run of the scenario is listed; in this situation it is 1. Some models have more than one run of a scenario, an example is the CGCM2 A21,A22, and A23. Scenarios with an 'x', instead of a number, represent an average of all the runs of the scenario.

For each watershed, a scenario may represent a 'warm-wet, warm-dry, cool-wet and cool-dry scenario'. The scenario that jointly had the greatest temperature increase, followed by the greatest precipitation increase, represented a 'warm-wet scenario'. A 'warm-dry scenario' was the greatest temperature increase and the least precipitation increase or greatest precipitation decrease. The 'cool-wet scenario' was the least temperature increase and the greatest precipitation increase. The 'cool-dry scenario' was the least temperature increase and least precipitation increase or greatest precipitation decrease.

Yukon River-Porcupine River Watershed

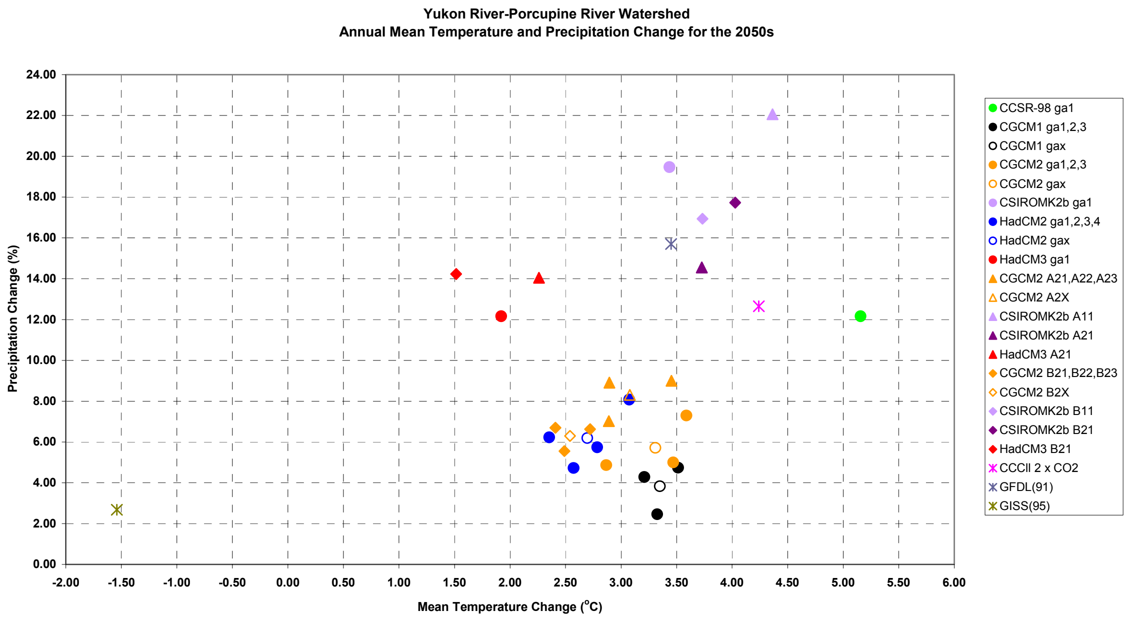


Figure 2: Yukon River-Porcupine River Watershed Annual Temperature and Precipitation Change Scatterplot

Annual

- **Temperature increases clustered between 2 and 4°C.**
- **All scenarios showed a precipitation increase, which clustered between 3 and 9%.**
- **The scenario with the greatest temperature increase was the CCSR-98 ga1, the least temperature increase was the HadCM3 B21, the greatest precipitation increase was the CSIROMK2b A11 and the least increase in precipitation was the CGCM1 ga2.**
- **The warm-wet scenario was the CSIROMK2b A11, the warm-dry scenario was the CGCM1 ga1, the cool-wet scenario was the HadCM3 B21 and the cool-dry scenario was the HadCM2 ga3.**

Seasonal

- **There was a large scatter of precipitation values for DJF and the majority of scenarios had a temperature increase between 3 and 5°C.**
- **Temperature increases for MAM were concentrated between 2 and 4°C, and precipitation between 3 and 11%.**
- **The JJA scenarios showed temperature and precipitation increases that clustered between 2 and 4°C and 3 and 18%, respectively.**
- **A majority of the scenarios for SON showed a temperature increase between 1 and 3°C and a precipitation increase, between 2 and 10%.**

North Pacific and Coastal Rivers Watershed

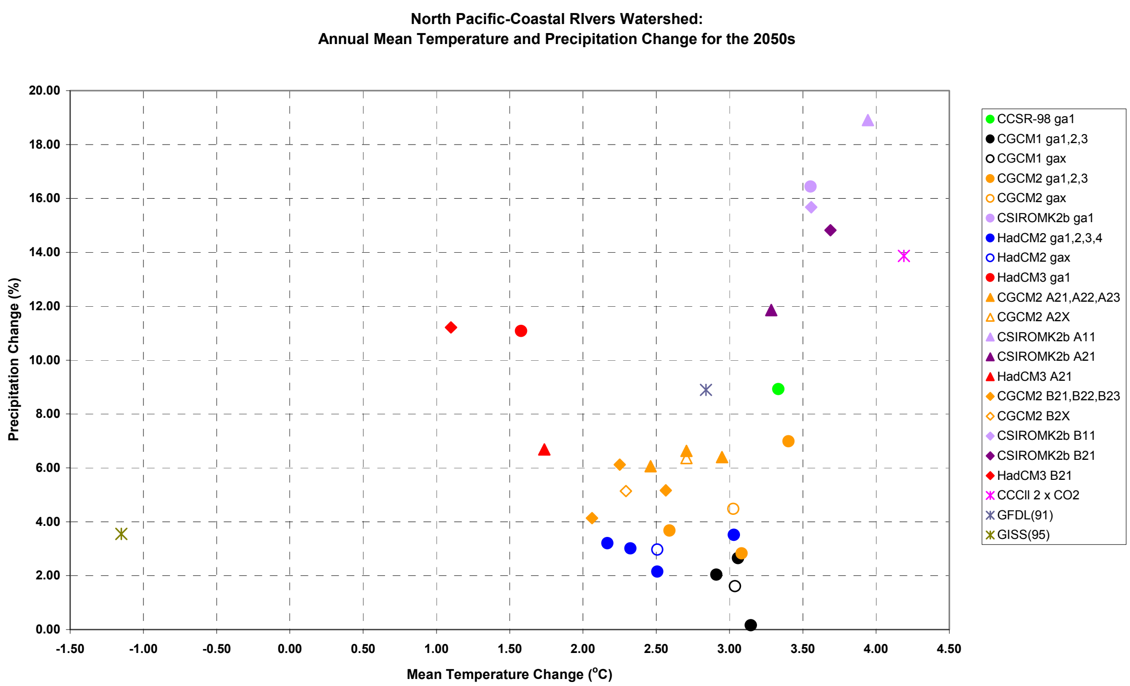


Figure 3: North Pacific and Coastal Rivers Watershed Annual Temperature and Precipitation Change Scatterplot

Annual

- **Temperature increases concentrated between 2 and 3.5°C**
- **All scenarios showed a precipitation increase, which clustered between 2 and 7%.**
- **The CSIROMK2b A11 scenario had the greatest temperature and precipitation increase. The HadCM3 B21 scenario had the least temperature increase and the CGCM1 ga1 had the least precipitation increase.**
- **The warm-wet scenario was the CSIROMK2b A11, the warm-dry scenario was the CGCM1 ga1, the cool-wet scenario was the HadCM3 B21 and the cool-dry scenario was the HadCM2 ga3.**

Seasonal

- **The majority of scenarios showed a temperature increase (except for HadCM3 B21 with a temperature decrease of –0.1°C in DJF) and a precipitation increase.**

Mackenzie River Watershed

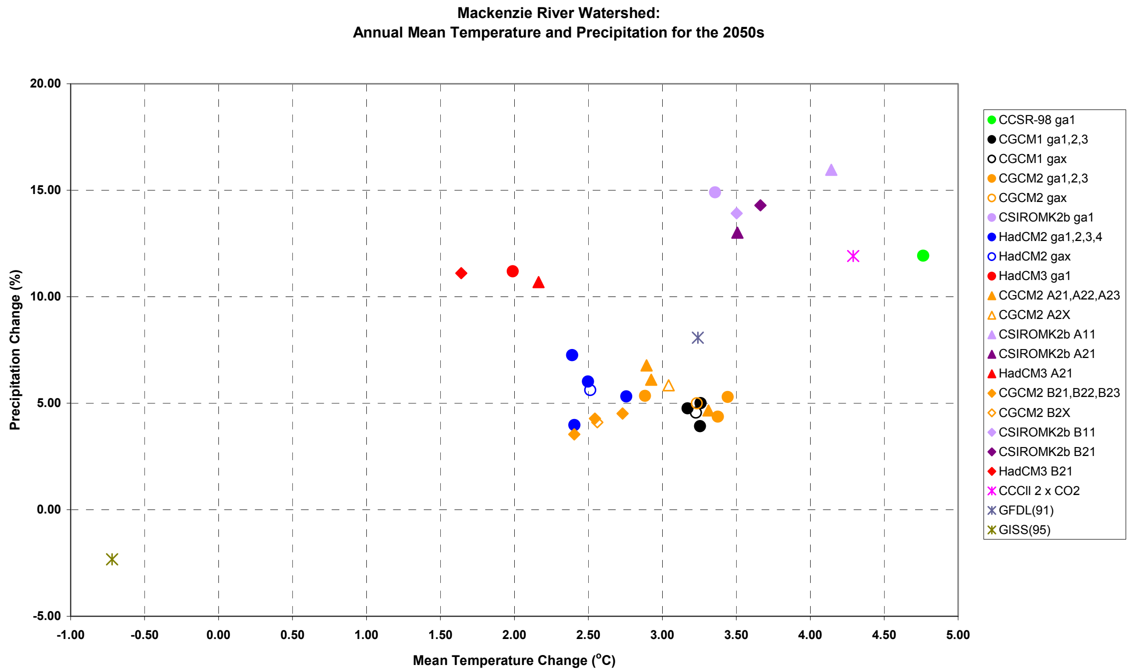


Figure 4: Mackenzie River Watershed Annual Temperature and Precipitation Change Scatterplot

Annual

- **Temperature increases clustered between 2 and 4°C.**
- **All scenarios showed a precipitation increase, which concentrated between 3 and 7%.**
- **The CCSR-98 ga1 had the greatest temperature increase, the HadCM3 B21 had the least temperature increase, the CSIROMK2b A11 the greatest precipitation increase, and the CGCM2 B21 had the least precipitation increase.**
- **The warm-wet scenario was the CSIROMK2b A11, the warm-dry scenario was the CGCM2 ga1, the cool-wet scenario was the HadCM3 B21 and the cool-dry scenario was the CGCM2 B21.**

Seasonal

- **For DJF and MAM, there was a large scatter of temperature and precipitation values and no defined clustering.**
- **Temperature changes for JJA were grouped between 2 and 3°C and for SON between 2.5 and 3.5°C.**
- **There was no decrease in precipitation for all seasons, precipitation increased in all scenarios.**

Skagit River Watershed

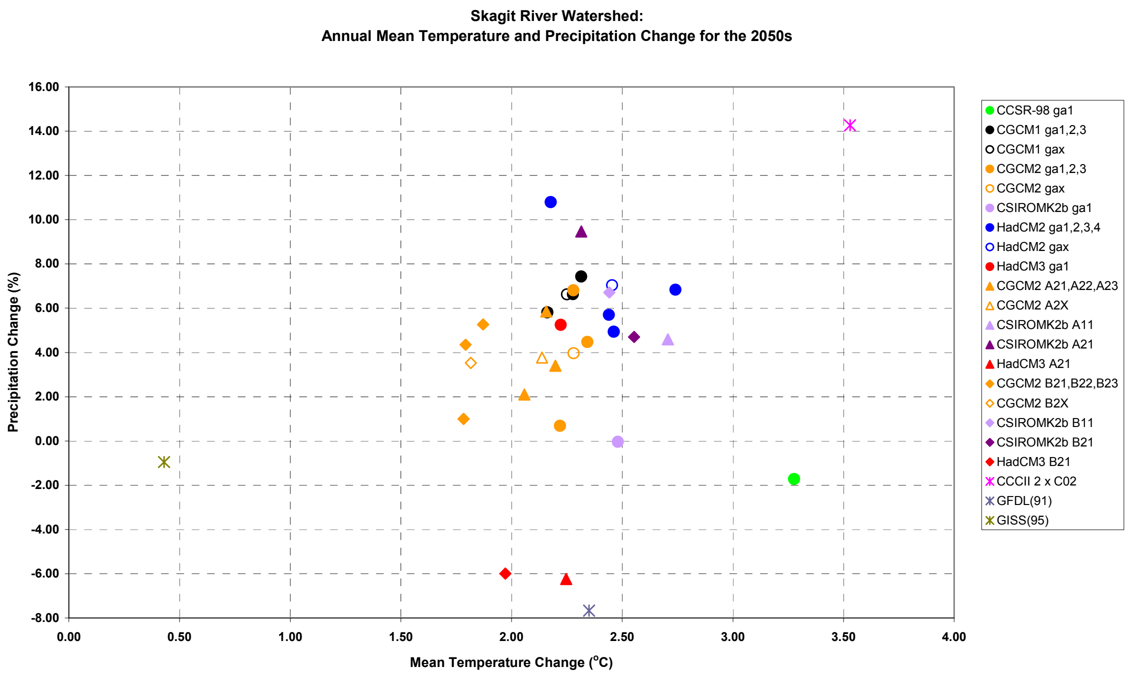


Figure 5: Skagit River Watershed Temperature and Precipitation Change Scatterplots

Annual

- **Temperature change clustered between 2 and 2.5°C.**
- **A majority of scenarios had a precipitation increase, which was concentrated between 2 and 6%.**
- **The CCSR-98 had the greatest temperature increase, the CGCM2 B21 the least temperature increase, the HadCM2 ga3 had the greatest precipitation increase and the HadCM3 A21 had the greatest decrease in precipitation.**
- **The warm-wet scenario was the HadCM2 ga2, the warm-dry scenario was the CCSR-98 ga1, the cool-wet scenario was the CGCM2 B21 and the cool-dry scenario was the HadCM3 B21.**

Seasonal

- **The majority of scenarios for the winter and fall showed a precipitation increase. More than half of the scenarios for the spring showed a precipitation decrease. In the summer, only 3 scenarios showed a precipitation increase.**

Columbia River to Chelan River Watershed

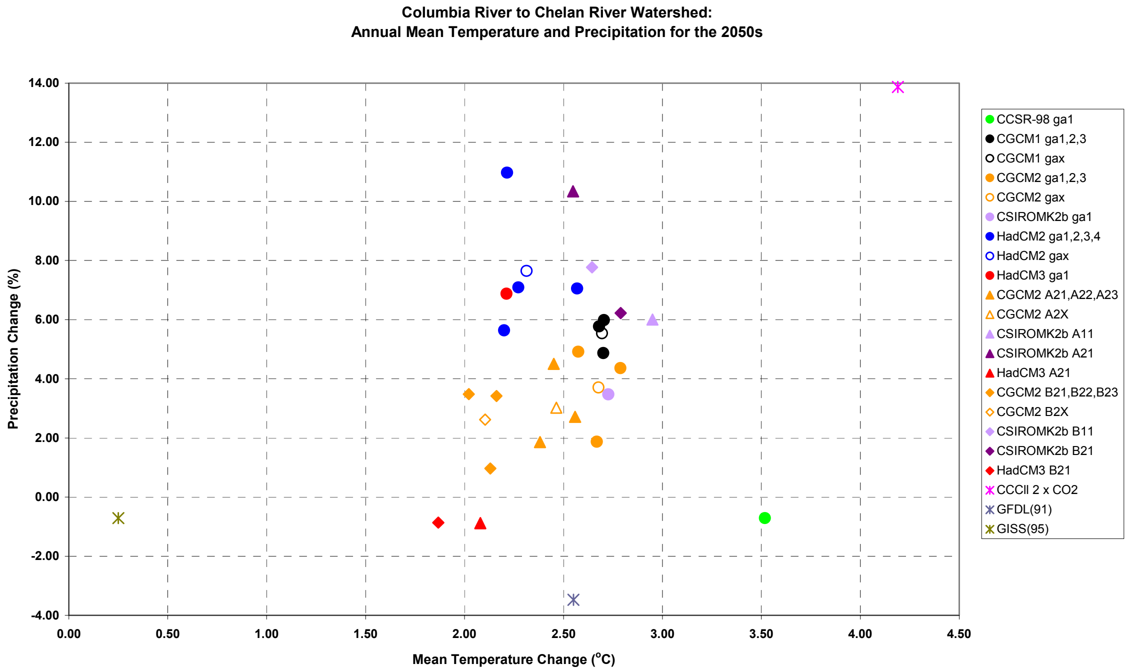


Figure 6: Columbia River to Chelan River Watershed Temperature and Precipitation Change Scatterplot

Annual

- **Temperature change for nearly every scenario (except the CCSR-98 ga1) ranged between 2 and 3°C.**
- **The majority of the scenarios showed an increase in precipitation, which clustered between 2 and 8%.**
- **The CCSR-98 scenario had the greatest temperature increase, the HadCM3 B21 had the least temperature increase, the HadCM2 ga3 had the greatest precipitation increase and the HadCM3 A21 had the greatest decrease in precipitation**
- **The warm-wet scenario was the CSIROMK2b A11, the warm-dry scenario was the CCSR-98 ga1, the cool-wet scenario was the HadCM2 ga3 and the cool-dry scenario was the HadCM3 B21.**

Seasonal

- **There were groupings of temperature change for DJF (2.5 to 3.5°C), JJA (1.75 to 2.75°C) and SON (1.5 to 2.5°C). Temperatures for MAM were spread out.**

- **All scenarios for DJF and the majority for MAM and SON showed a precipitation increase. The majority of scenarios for JJA had a precipitation decrease.**

South Saskatchewan River Watershed

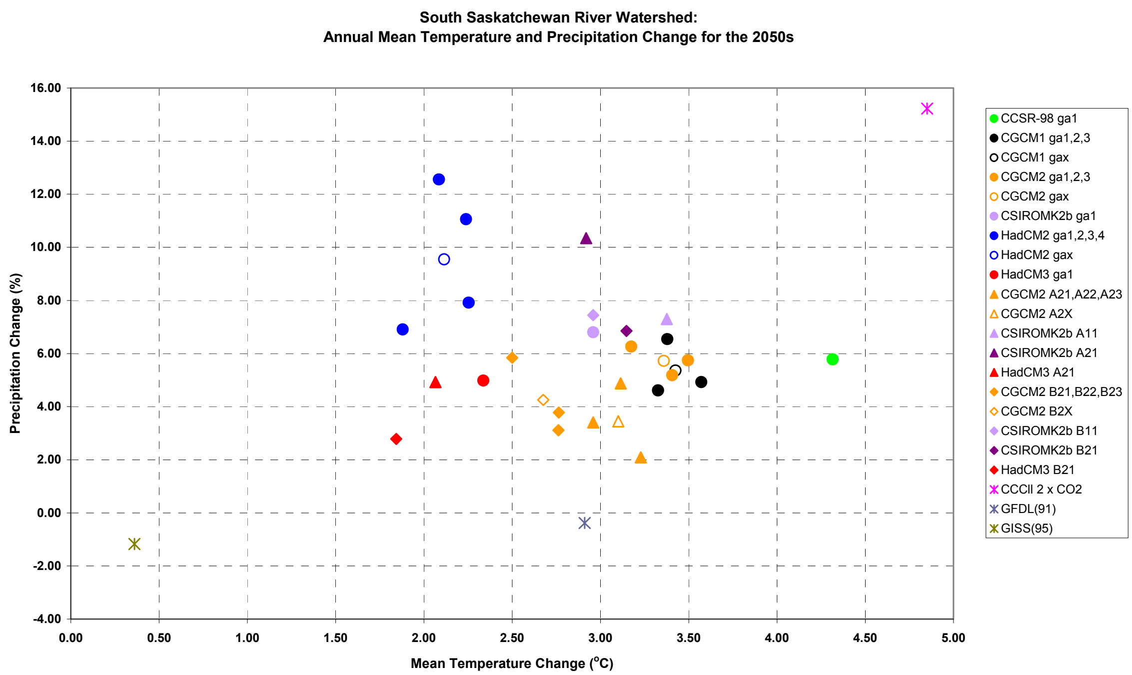


Figure 7: South Saskatchewan River Watershed Temperature and Precipitation Change Scatterplot

Annual

- **Temperature change clustered between 2 and 4°C. There was an increase in precipitation for all scenarios, which was concentrated between 3 and 18%.**
- **All scenarios showed a positive relationship between increased temperature and precipitation change.**
- **The scenario with the greatest increase in temperature was the CCSR-98 ga1, the least temperature increase was the HadCM3 B21, the greatest precipitation increase was the HadCM2 ga1 and the least precipitation increase was the CGCM2 A21.**
- **The warm-wet scenario was the CSROMK2b All, the warm-dry was the CGCM2 A2, the cool-wet was the HadCM2 ga1 and the cool-dry was the HadCM3 B21.**

Seasonal

- **All scenarios showed an increase in precipitation for DJF and MAM.**
- **For JJA, two-thirds of the scenarios showed a decreased in precipitation. Values clustered between –7 and +1%.**
- **In SON, all but one scenario showed a decrease in precipitation.**

St. Mary River-Milk River Watershed

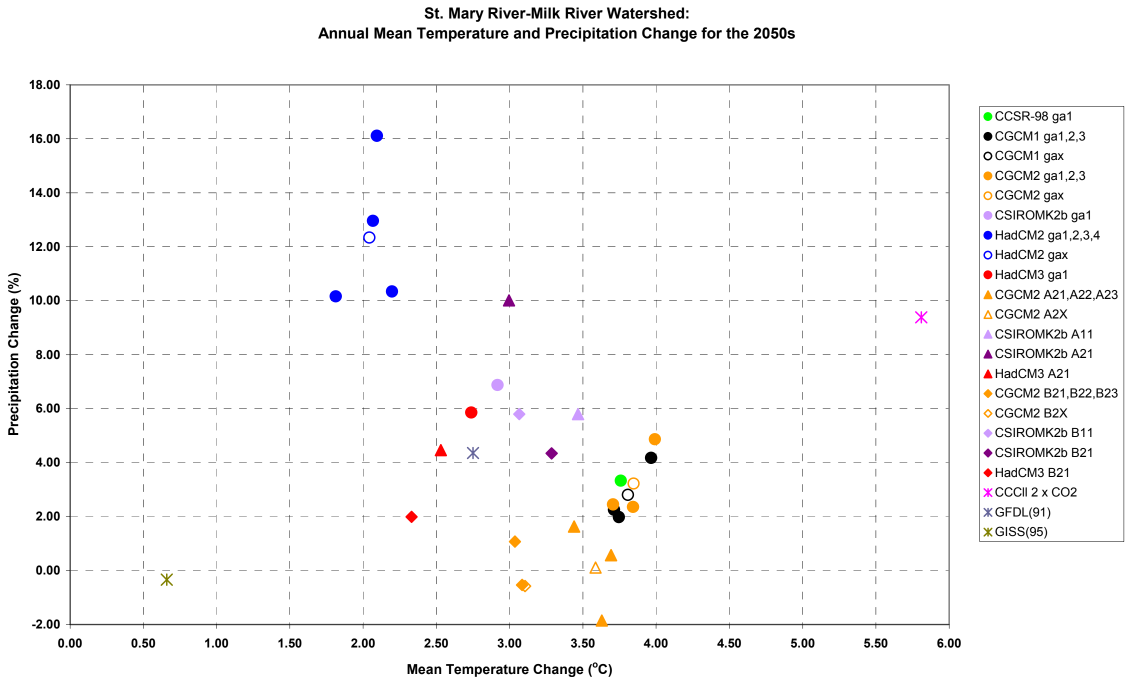


Figure 8: St. Mary River-Milk River Watershed Annual Temperature and Precipitation Change

Annual

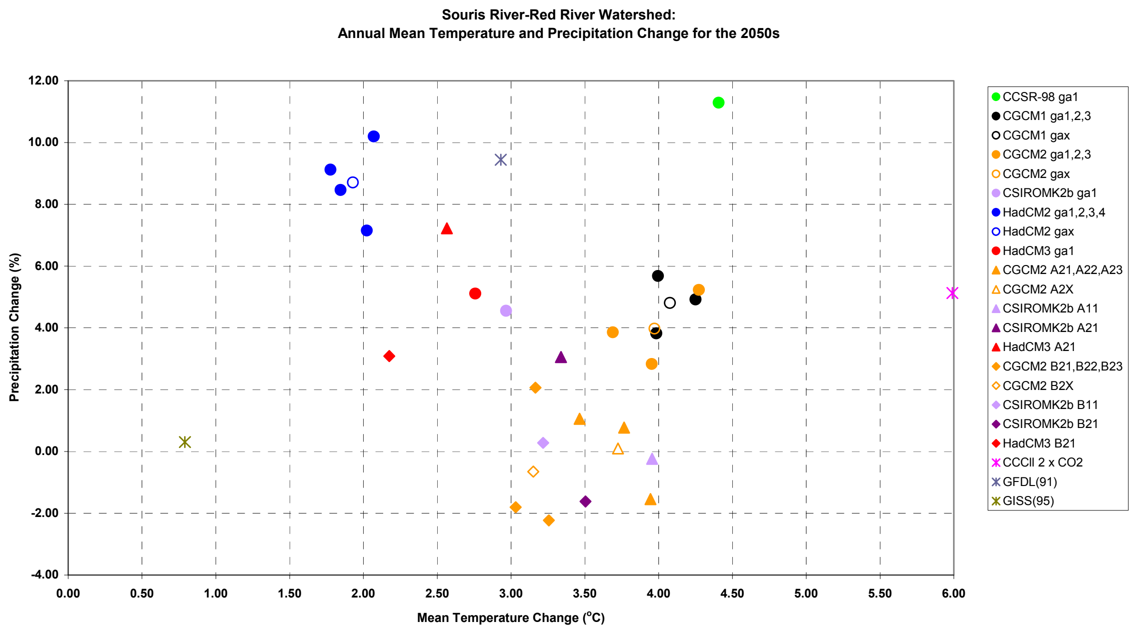
- **Temperature increases clustered between 2 and 4°C.**
- **Majority of scenarios had a precipitation increase, with most scenarios gathering between 0 and 6%.**
- **The greatest temperature increase was the CGCM2 ga1 scenario, the least temperature increase was the HadCM2 ga4, the largest precipitation increase was the HadCM2 ga3 scenario and the greatest precipitation decrease was the CGCM2 A22 scenario.**
- **The warm-wet scenario was the CGCM2 ga1, the warm-dry scenario was the CGCM2 A22, the cool-wet scenario was the HadCM2 ga3 and the cool-dry scenario was the HadCM3 B21.**

Seasonal

- **The majority of scenarios for DJF showed an increase in precipitation change. The values clustered into 2 groups, between 0 and 5% and between 15 and 22%.**
- **The MAM period was the sole season where all scenarios showed an increase in precipitation. Temperature change clustered into 2 groups. The first**

showed changes between 1 and 4°C and the second showed changes between 5 and 6°C.

- **For JJA, more than half of the scenarios showed a decrease in precipitation. The scenarios clustered between –2 and –15%. There was also a concentration of values for temperature increases, 2 and 3°C.**
- **Approximately two-thirds of scenarios showed a precipitation increase for SON. Temperature change clustered between 2 and 3°C.**



Souris River-Red River Watershed

Figure 9: Souris River-Red River Watershed Annual Temperature and Precipitation Change Scatterplot

Annual

- **Temperature increase clustered between 3 and 4°C.**
- **The majority of scenarios showed a precipitation increase and there was a spread in precipitation change values.**
- **The greatest temperature and precipitation change was the CCSR-98 ga1. The least temperature change was the HadCM2 ga4 and the greatest decrease in precipitation was the CGCM2 B22.**
- **The warm-wet scenario was the CCSR-98 ga1, the warm-dry scenario was the CGCM2 A21, the cool-wet scenario was the HadCM2 ga4 and the cool-dry scenario was the HadCM3 B21.**

Seasonal

- **There was a large distribution of precipitation values for all seasons.**
- **One-third of the DJF scenarios showed an increase in precipitation and there was a large spread in temperature change, between 1 and 6°C.**
- **Majority of precipitation values for MAM showed an increase.**
- **For JJA, more than two-thirds of the scenarios showed a decrease in precipitation. They clustered between –1 and –10%. Minimal increases (between 3 and 10%) were also evident for the remaining scenarios. Temperature values clustered between 2 and 4°C.**

- **SON temperature changes clustered between 2 and 4°C. One-third of scenarios showed a decrease in precipitation.**

Rainy Lake-Lake of the Woods-Lake Winnipeg Watershed

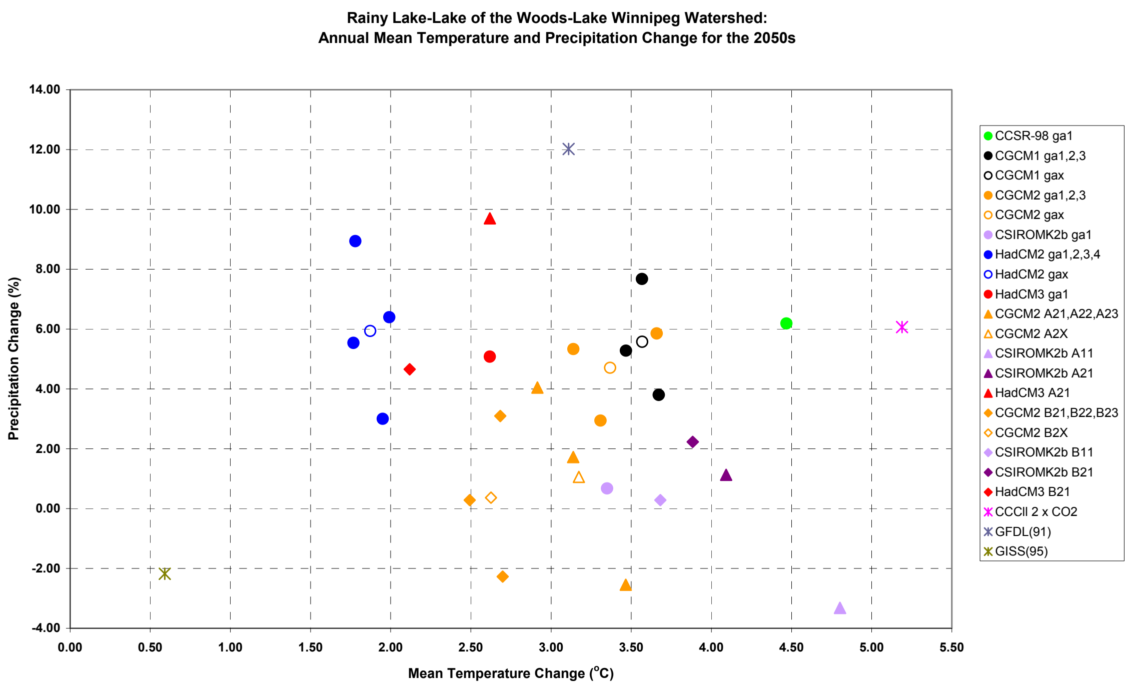


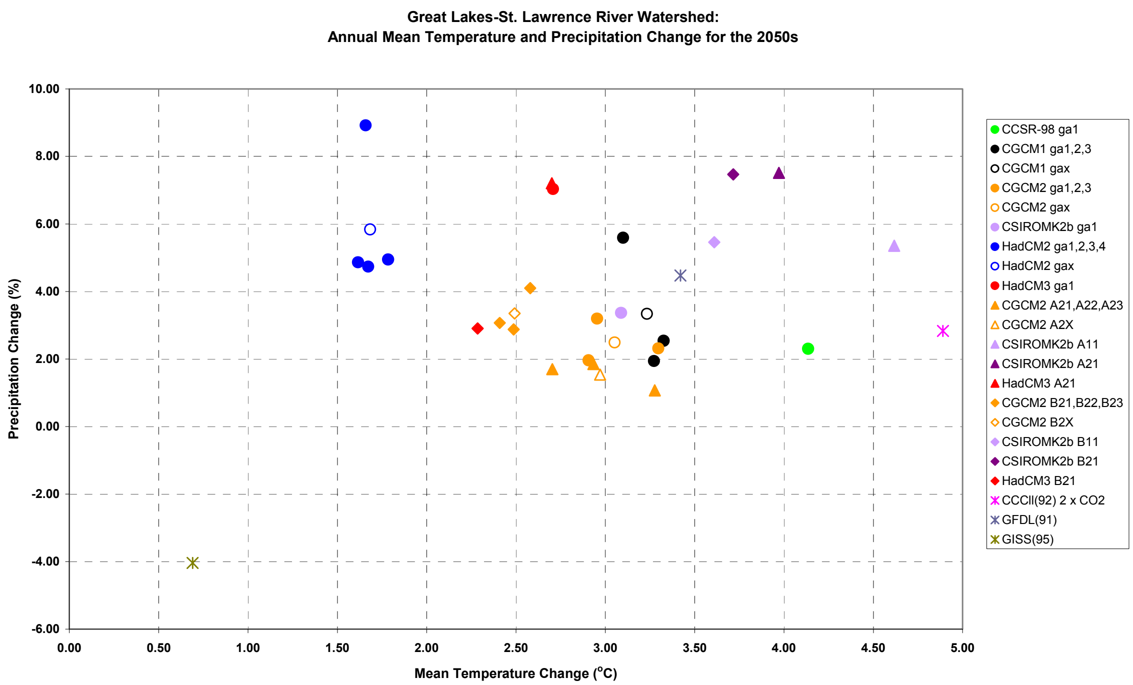
Figure 10: Rainy Lake-Lake of the Woods-Lake Winnipeg Watershed Temperature and Precipitation Change Scatterplots

Annual

- **Temperature change was very dispersed.**
- **Majority of scenarios showed a precipitation increase, which clustered between 0 and 6%.**
- **The scenario with the greatest change in temperature and greatest decrease in precipitation was the CSIROMK2b A11. The scenario with the least temperature change was the HadCM2 ga2 and greatest increase in precipitation was the HadCM2 A21. The warm-wet scenario was the CCSR-98 ga1, the warm-dry was the CSIROMK2b A11, the cool-wet scenario was the Had CM2 ga4, and the cool-dry was the CGCM2 B22.**

Seasonal

- **Majority of scenarios for DJF and MAM had an increase in precipitation. There was a wide dispersion of values for DJF, but for MAM there was clustering between 10 and 25%. The temperature increases for these two periods were the greatest of all the seasons.**
- **For JJA, two-thirds of the scenarios had a decrease in precipitation.**
- **Approximately half the scenarios for SON showed a decrease in precipitation. However, the values were widely dispersed, as was the case for temperature.**



Great Lakes-St. Lawrence River Watershed

Figure 11: Great Lakes-St. Lawrence River Watershed Annual Temperature and Precipitation Change Scatterplot

Annual

- **The majority of scenarios clustered between 2 and 4°C for temperature.**
- **All scenarios showed an increase in precipitation, which clustered between 2 and 6%.**
- **The scenario with the greatest temperature increase was the CSIROMK2b A11, the least temperature increase was the HadCM2 ga2, the greatest precipitation increase was the HadCM2 ga4 and the least precipitation increase was the CGCM2 B22.**
- **The warm-wet scenario was the CSIROMK2b A21, the warm-dry scenario was the CCSR-98 ga1, the cool-wet scenario was the HadCM2 ga4 and the cool-dry was the HadCM3 B21.**

Seasonal

- **The majority of scenarios for DJF and MAM had an increase in precipitation. They clustered between 0 and 6%, and between 10 and 18% for DJF, and between 5 and 15% for MAM.**

- **For JJA and SON half of the scenarios showed a decrease in precipitation. Temperature increase clustered between 2 and 4°C for JJA and between 1 and 3°C for SON.**

Lake Memphremagog-St. Francis River-Lake Champlain-Richelieu River Watershed

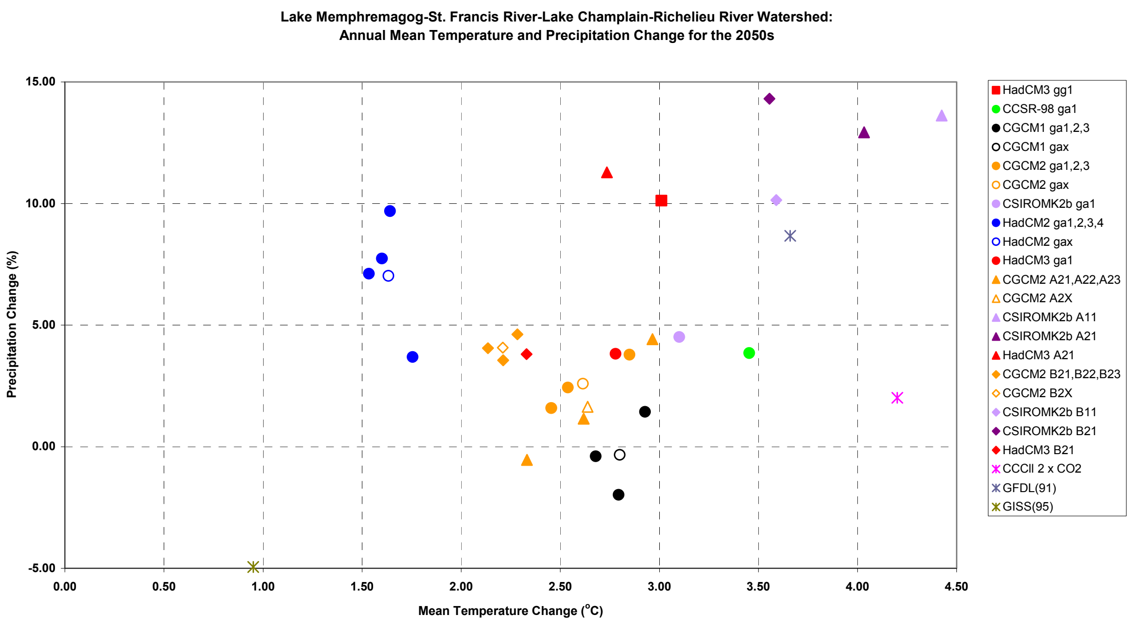


Figure 12: Lake Memphremagog-St. Francis River-Lake Champlain-Richelieu River Watershed Annual Temperature and Precipitation Change Scatterplots

Annual

- **Most temperature increases were grouped between 2 and 3°C.**
- **The majority of the scenarios showed an increase in precipitation, concentrating between –1 and +5%.**
- **The scenario with the greatest temperature increase was the CSIROMK2b A11, the least temperature increase was the HadCM2 ga1, the greatest precipitation increase was the CISROMK2b B21 and the greatest precipitation decrease was the CGCM1 ga3.**
- **The warm-wet scenario was the CSIROMK2b A11, the warm-dry scenario was the CCSR-98 ga1, the cool-wet scenario was the HadCM2 ga4 and the cool-dry scenario was the HadCM2 ga1.**

Seasonal

- **The majority of the scenarios showed an increase in precipitation.**
- **Temperature increases for DJF and MAM clustered between 2 and 4°C**
- **There was a lot of scatter for temperature and precipitation values for JJA and SON. Majority of temperature values were between 2 and 3°C for JJA, and between1 and 3°C for SON.**

St. Croix River-Saint John River Watershed

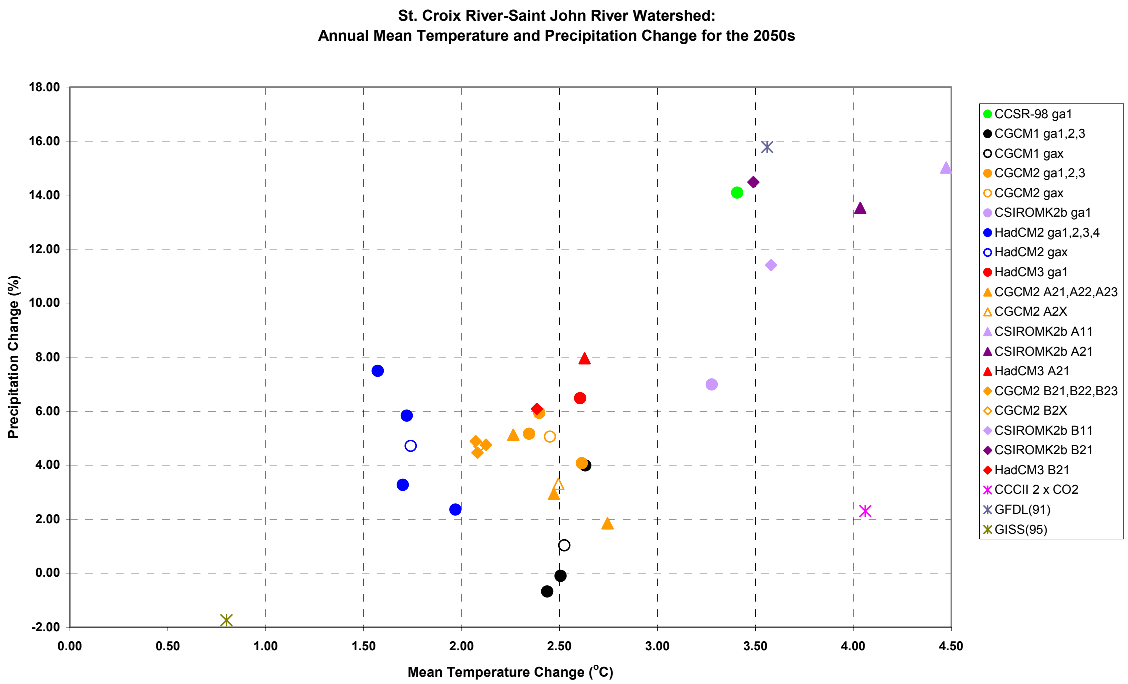


Figure 13: St. Croix River-Saint John River Watershed Annual Temperature and Precipitation Change Scatterplot

Annual

- **Temperature change clustered between 2 and 3°C.**
- **A majority of scenarios showed an increase in precipitation, with a concentration between 2 and 8%.**
- **The scenario with the greatest temperature and precipitation increase was the CSIROMK2b A11, the least temperature increase was the HadCM2 ga2 and the greatest decrease in precipitation was the CGCM1 ga1.**
- **The warm-wet scenario was the CSIROMK2b A11, the warm-dry scenario was the CGCM2 A21, the cool-wet scenario was the HadCM2 ga2 and the cool-dry scenario was the HadCM2 ga3.**

Seasonal

- **Most of the seasonal scenarios showed an increase in precipitation.**
- **Clusters of temperature change were apparent for DJF (2 - 4°C), MAM (2 - 3°C), JJA (1 - 3°C) and SON (1 - 3°C).**
- **There was a scatter of precipitation values for DJF, MAM and SON. For JJA, precipitation clustered between –5 and +10%.**

4.0 CLIMATE SCENARIO MAPS

4.1 Method for Construction of Watershed Area Boundaries

The study area watersheds were created using a combination of paper maps depicting the watershed boundaries and GIS ArcView shapefiles of second-order watersheds. The paper map for the transboundary watersheds was obtained from the International Joint Commission. The Mackenzie River study area boundary was obtained from the Mackenzie River Basin Board website (http://www.mrbb.ca/maps.asp). The South Saskatchewan boundary was obtained from the Cartographic department at the University of Western Ontario. The second order watershed shapefiles were downloaded from the Natural Resources Canada Geogratis website (http://geogratis.cgdi.gc.ca/) for Canadian watersheds and the United States Geological Survey website (http://water.usgs.gov/) for the US watersheds. The maps provided a general overview of the spatial distribution and shape of each watershed. Using this as a guide, the second order catchments that were part of each study area watershed were selected and converted into a shapefile. In instances where the boundary on the paper maps and the boundary of the second order watershed did not match, the second order watershed boundary was taken to be the correct boundary.

4.2 Method for Construction of Maps

The scenario maps were created using the GIS program ArcView. Provincial and state boundaries and lake shapefiles were downloaded from the Natural Resources Canada Geogratis website (http://geogratis.cgdi.gc.ca/) and the United States Geological Survey website (http://water.usgs.gov/). The General Circulation Model Grids were downloaded from the Canadian Climate Impacts Scenarios (CCIS) Project website (http://www.cics.uvic.ca/scenarios/data/select.cgi).

Using the scatterplots as a reference, frequencies for the coolest-wettest and warmest-driest model-scenarios were recorded for each watershed. The scenarios were chosen by determining those that had the greatest temperature increase/decrease, coupled with the greatest precipitation increase/decrease. The scenarios with the most occurrences were mapped. The HadCM2 ga4 was selected as the coolest-wettest scenario and the CCSR-98 ga1 for the warmest-driest scenario. The study team chose to map two additional scenarios, CGCM1 ga1 and HadCM2 ga1.

Maps were created showing temperature and precipitation changes for all scenarios; soil moisture was also mapped for the CGCM1 ga1 scenario (data was not available for the other scenarios). The presentation of the maps is in the Lambert Conical Projection.

4.3 Results

All of the scenarios showed an increase in average annual temperatures in every study area watershed, though the magnitude of warming varies. All scenarios agreed that the eastern watersheds would warm the least compared to the rest of the study area watersheds. The magnitude for warming was the least for the HadCM2

ga4 scenario and the greatest for the CCSR-98 ga1 scenario. There was agreement between the CCSR-98 ga1 and the CGCM1 ga1 scenarios concerning the increased warming in the Prairies and northern portions of the Yukon River-Porcupine River and Mackenzie River watersheds, compared to the rest of the watersheds, though the degree of increase was different, 1 to 2°C.

There was consensus among the CCSR-98 ga1, CGCM1 ga1 and the HadCM2 ga1, that the northern portion of the Great Lakes watershed (surrounding Lake Superior) would have a precipitation decrease between 0 and –5%. The majority of the scenarios (except for HadCM2 ga4) showed at least a 10% increase in the north of the Yukon River-Porcupine River and Mackenzie River watersheds. The HadCM2 ga4 showed a lesser increase, 0 to 5%, and even a decrease in the northern portion of the Mackenzie River watershed. For the Prairie watersheds, there was an increase in precipitation, except for the eastern portion of Rainy Lake-Lake of the Woods-Lake Winnipeg watershed, which had a decrease in the CCSR-98 ga1, CGCM1 ga1 and the HadCM2 ga1 scenarios.

The majority of the southern watersheds experienced a decrease in soil moisture. Soil moisture reduction, as depicted by the CGCM1 ga1, was most severe in the Prairie watersheds Canada. Only portions of the Great Lakes, Yukon River-Porcupine River and Mackenzie River watersheds had an increase.

The following sub-sections will describe the changes depicted by the scenarios in more detail. First, changes in temperature by scenario will be illustrated, followed by precipitation and then soil moisture.

4.3.1 Average Annual Temperature Change

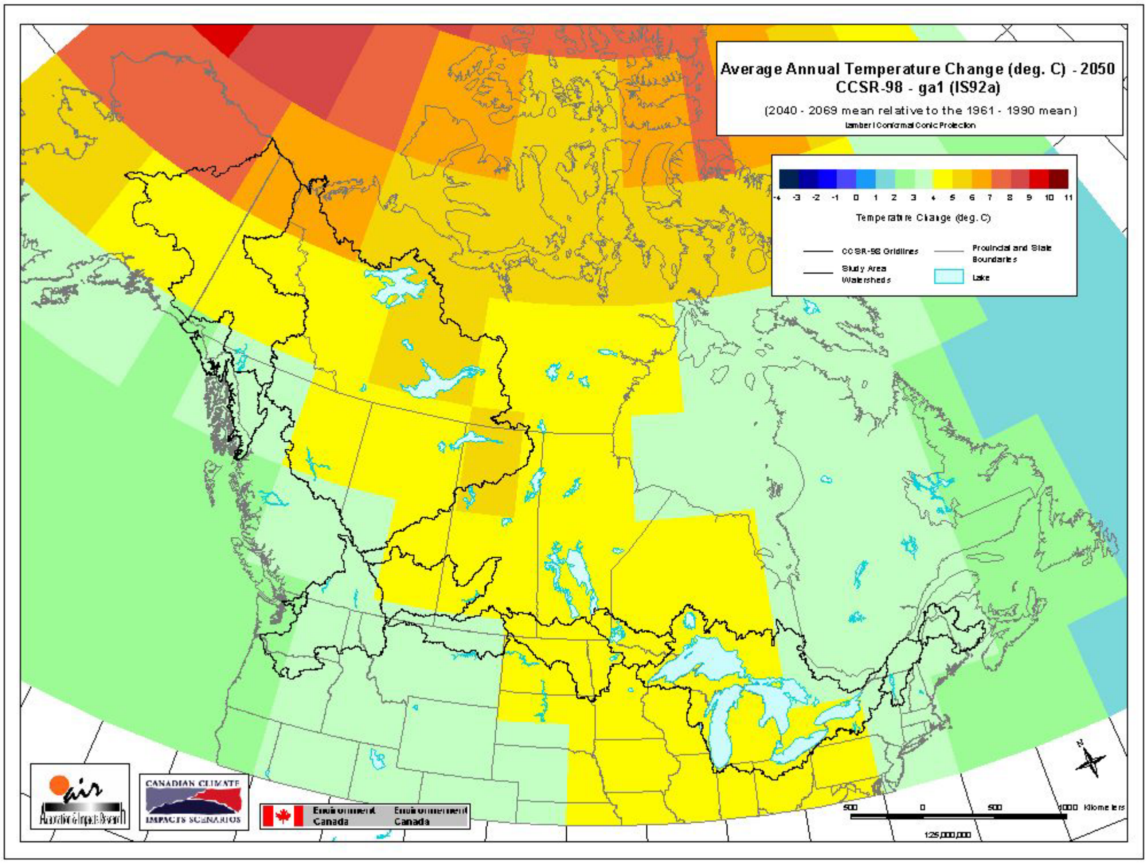


Figure 14: Map of Average Annual Temperature Change for the CCSR-98 ga1 scenario

CCSR-98 ga1

The CCSR-98 showed the greatest temperature change, 2 to 5°C for the majority of the watersheds (Figure 14). Temperature increased for the northern watersheds. The Yukon River-Porcupine River watershed had temperature changes that ranges between 3°C in the south and increased to 8°C in the north. The northern portion of the Mackenzie River watershed increased by 5 to 7°C and the western portion 5 to 6°C. The rest of the watershed showed a warming of 3 to 5°C. The Skagit and North Pacific and Coastal watersheds showed the least increase in temperature of the study area watersheds, 2 to 3°C. The Columbia River watershed had an increase of 3 to 4°C as well as the eastern watersheds (Lake Memphremagog-St. Francis River-Lake Champlain-Richelieu River Watershed and St. Croix-Saint John watersheds), the eastern portion of the Great Lakes-St. Lawrence watershed and St. Mary's River-Milk River watersheds. The majority of the Prairie watersheds (South Saskatchewan, Souris River-Red River and Rainy Lake-Lake of the Woods-Lake Winnipeg watersheds) and the western and mid portion of the Great Lakes-St. Lawrence watershed had an increase of 4 to 5°C.

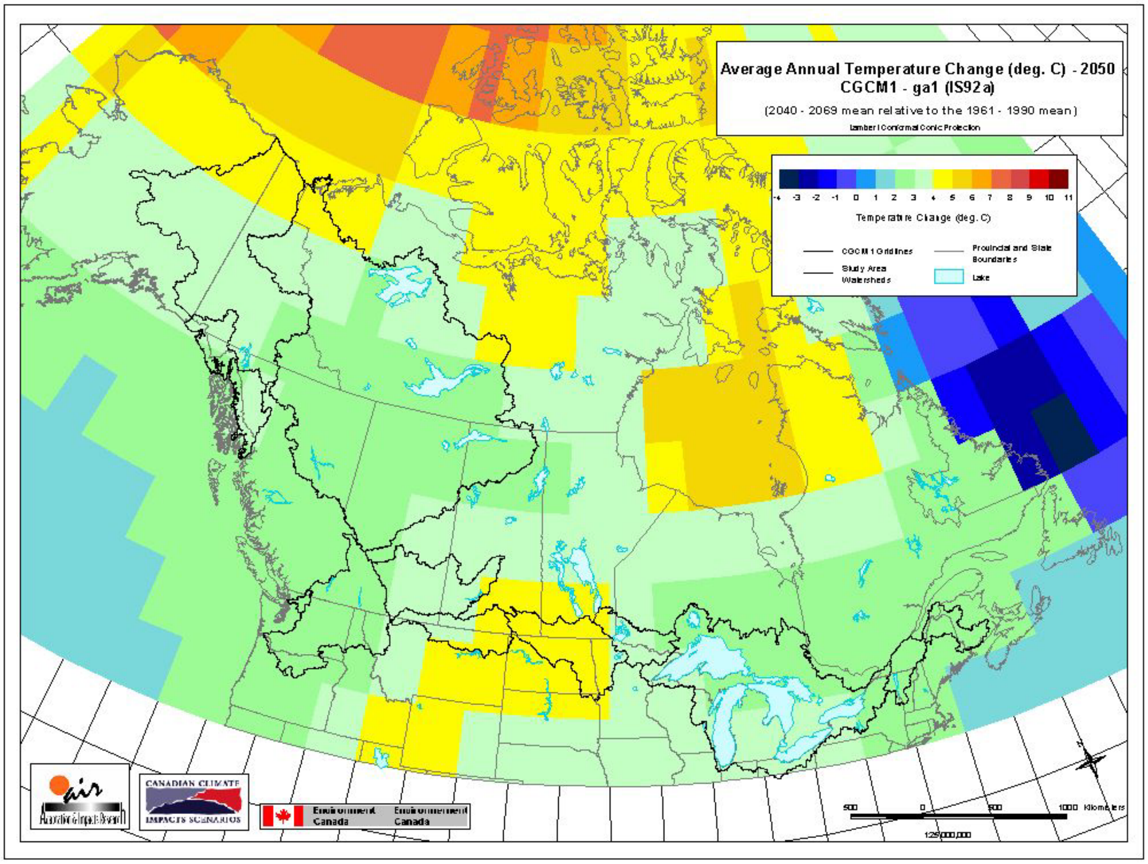


Figure 15: Map of Average Annual Temperature Change for the CGCM1 ga1 scenario

CGCM1 ga1

The CGCM1 ga1 showed an increase between 2 and 4°C (Figure 15) for the majority of the watersheds. The eastern half of St. Mary River-Milk River, the majority of Souris River-Red River and the northern portion of the Yukon River-Porcupine River and Mackenzie River watersheds showed a slightly higher increase (4 to 5°C). The western watersheds, majority of the remainder of the Mackenzie River watershed, the northern portion of the Great Lakes-St. Lawrence River and the eastern watersheds had the least increase for this scenario (2 to 3°C).

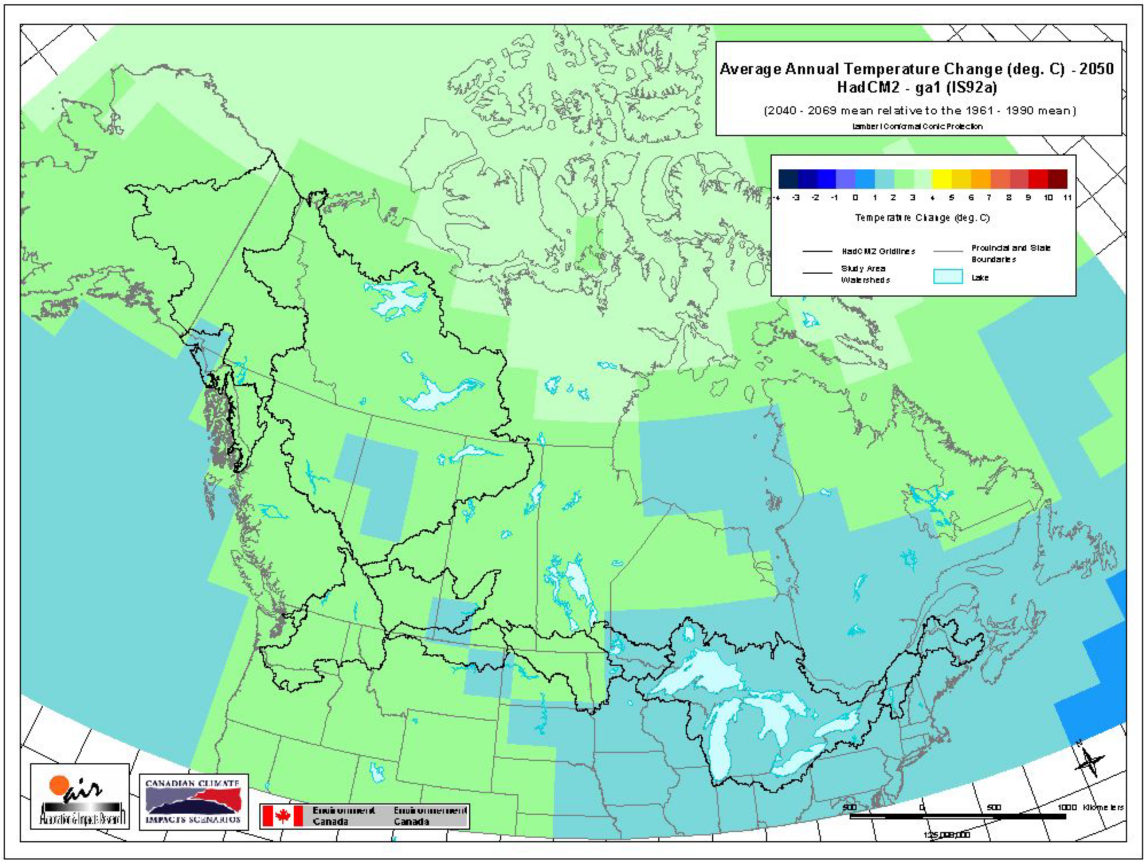


Figure 16: Map of Average Annual Temperature Change for the HadCM2 ga1 scenario

HadCM2 ga1

The HadCM2 ga1 scenario showed a temperature increase between 1 and 3°C for the study area watersheds (Figure 16). The least amount of warming (1 to 2°C) occurred eastward from the Rainy Lake-Lake of the Woods-Lake Winnipeg watershed. Less warming was also apparent for small areas in the South Saskatchewan River and St. Mary-Milk River, central Mackenzie River and the northern North Pacific and Coastal Rivers watersheds.

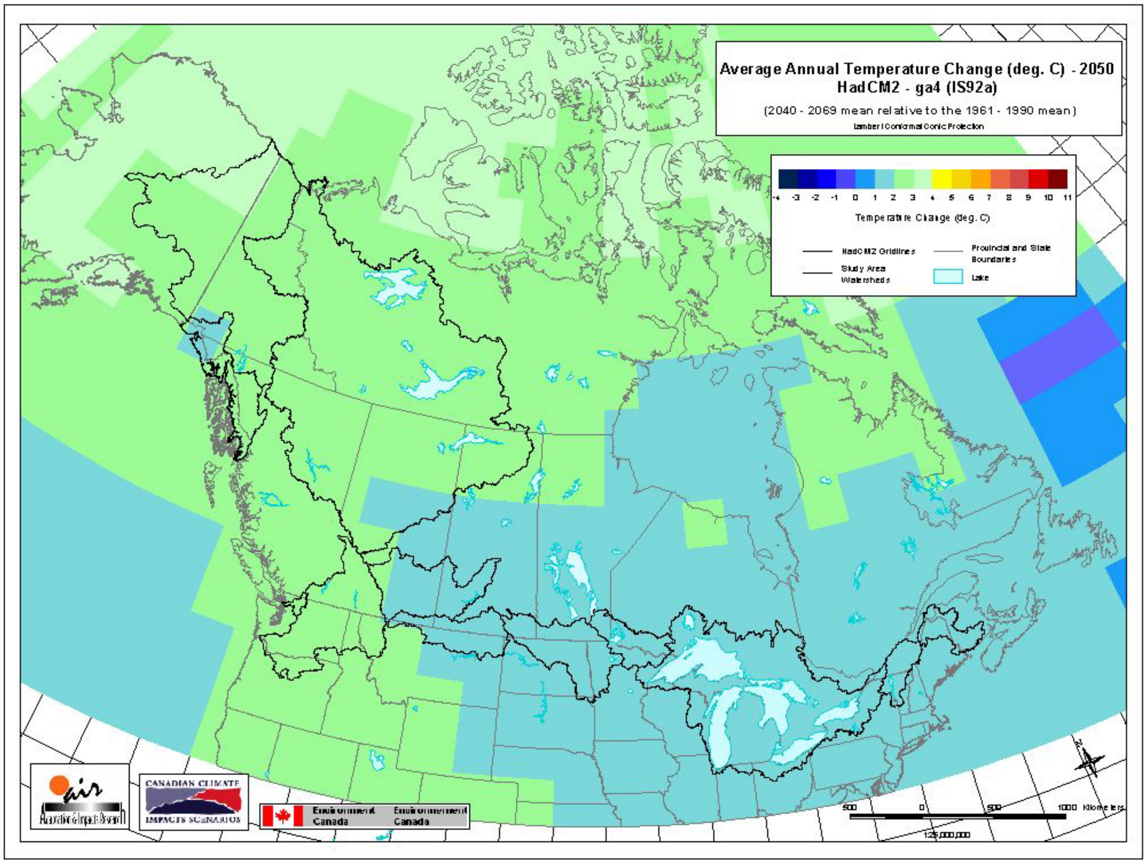


Figure 17: Map of Average Annual Temperature Change for the HadCM2 ga4 scenario

HadCM2 ga4

The HadCM2 ga4 scenario showed the least amount of warming of all the scenarios presented in this section (Figure 17). Temperature increases, for all the watersheds, were between 1 and 3°C. The least temperature increase (1 to 2°C) occurred from the southern tip of the Mackenzie River and South Saskatchewan River to the eastern watersheds. The western watersheds and the majority of the Mackenzie River watershed showed an increase between 2 and 3°C.

4.3.2 Average Annual Precipitation Change

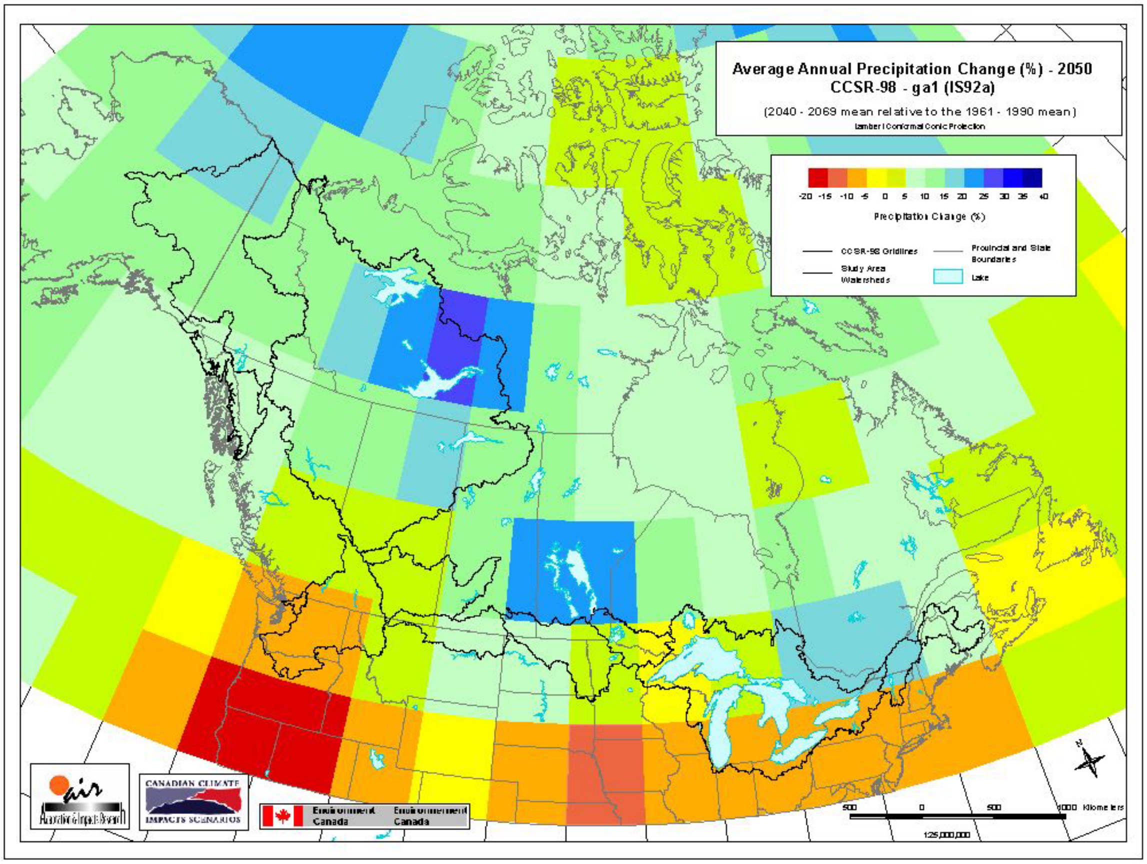


Figure 18: Map of Average Annual Precipitation Change for the CCSR-98 ga1 scenario

CCSR-98 ga1

Precipitation changes for the CCSR-98 ga1 scenario ranged between –10% and +30% for the study area watersheds (Figure 18). All of Yukon River-Porcupine River watershed showed an increase from 5% in the south to 20% in the north. The Mackenzie River watershed also had a south to north increase, 0 to up to 30% for some portions in the north. A most of the western watersheds showed a deficit, -5 to –15%. The northern area of the Columbia watershed showed a 0 to 5% increase. The Prairie watersheds, excluding Rainy Lake-Lake of the Woods-Lake Winnipeg

watershed, showed an increase in precipitation (0 to 15%). In the northern portions of Souris, this increased 20 to 25%. The Rainy Lake-Lake of the Woods-Lake Winnipeg watershed is noteworthy because the northern portion had a 20 to 25% increase, the middle had a 0 to 5% increase and the east decreased by up to –5. Most of the Great Lakes-St. Lawrence River watershed showed a precipitation decrease; the southern region had a –5 to –10% change, and the northern region had a 0 to –5% change. The mid portion of the watershed had a marginal increase between 0 to 5% and there was a greater increase in the eastern portion, 15 to 20%. The southern portion of Lake Memphremagog-St. Francis River-Lake Champlain-Richelieu River watershed showed a deficit between –5 to –10% while the rest had an increase of 15 to 20%. The St. Croix-Saint John watershed had an increase of 5 to 10%.

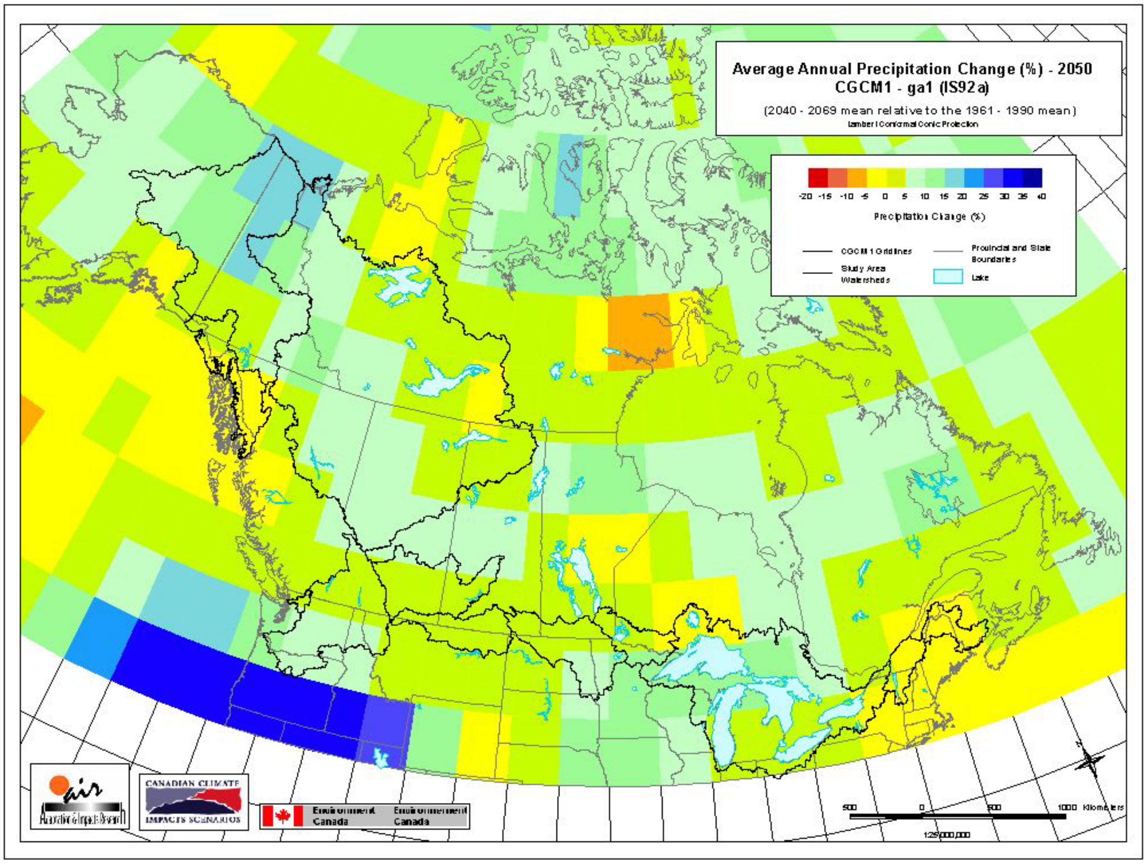


Figure 19: Map of Average Annual Precipitation Change for the CGCM1 ga1 scenario

CGCM1 ga1

Precipitation change for the study area watersheds for the CGCM1 ga1 scenario ranged between –5% and +20% (Figure 19). Reductions were observed in the eastern watersheds, the eastern and northern portion of the Great Lakes-St. Lawrence watershed, the southern North Pacific and Coastal Rivers Watershed, and a small eastern and northern portion of the Mackenzie River watershed. The Great Lakes-St. Lawrence River watershed showed minimal precipitation increase, 0 to 5% in the south and 5 to 15 % in the middle of the watershed. The Prairie watersheds and western watersheds, (excluding the southern portion of the Columbia showed minimal precipitation increase (0 to 5%). The majority of the Mackenzie River watershed had a precipitation increase between 0 and 10%.

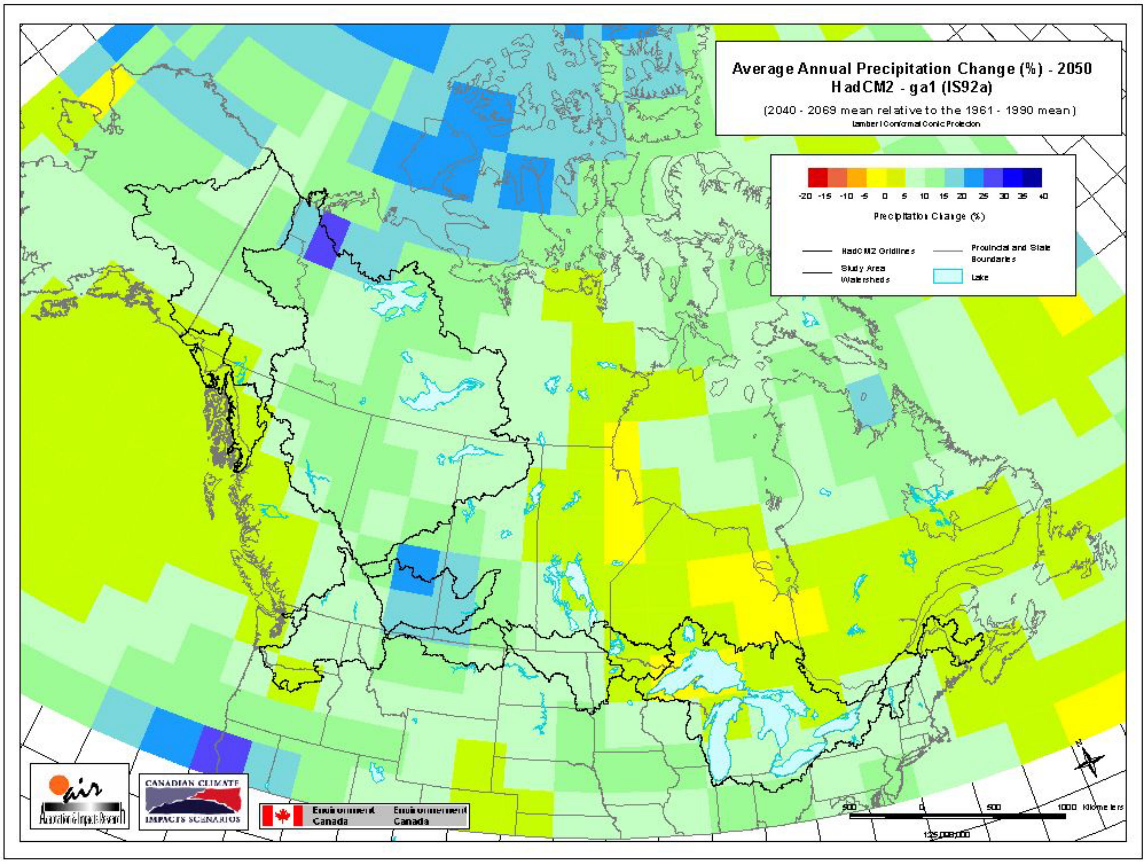


Figure 20: Map of Average Annual Precipitation Change for the HadCM2 ga1 scenario

HadCM2 ga1

Precipitation change for the HadCM2 ga1 scenario ranged between –5 and 30% (Figure 20). The only area to have a decrease was the Lake Superior region of the Great Lakes-St. Lawrence River watershed. The rest of the northern portion of this watershed had an increase between 0 to 5% and the southern portion had an increase of 5 to 10%. The Lake Memphremagog-St. Francis River-Lake Champlain-Richelieu River Watershed had an increase between 5 and 10% and the St. Croix-Saint John watershed had an increase between 0 and 5%. The northern, western and mid-western watersheds had the greatest precipitation increase, with the majority being between 5 and 15%. Some areas had a higher increase, the South Saskatchewan watershed was 10 to 25% and the northern portion of the Mackenzie River watershed was 20 to 30%.

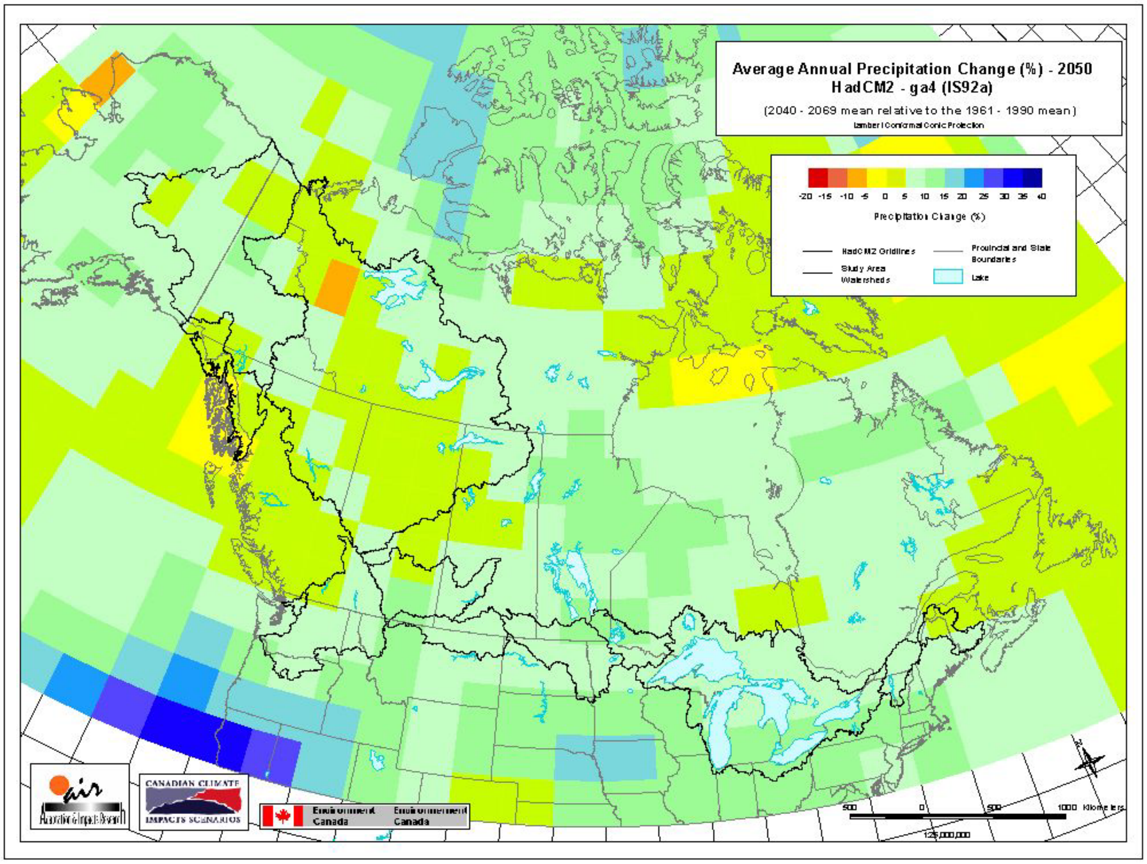


Figure 21: Map of Average Annual Precipitation Change for the HadCM2 ga4 scenario

HadCM2 ga4

Precipitation change for the HadCM2 ga4 scenario ranged between –10 and 15% (Figure 21). There were deficits in the northern portion of the Mackenzie River watershed (-5 to –10%) and the western portion of the North Pacific and Coastal Rivers Watershed (0 to 5%). The majority of the both watersheds showed a precipitation increase of 0 to 5% (with a 5 to 10% increase along the western and eastern boarder of the Mackenzie River watershed). The Yukon River-Porcupine River watershed had an increase of 0 to 10% for the most part. The Columbia River and Skagit River watersheds had a majority increase between 5 and 10%, with a 0 to 5% increase in the northwestern portion of the watersheds. The mid-western and Great Lakes-St. Lawrence River watersheds showed an increase between 5 to 15%.

4.3.3 Average Annual Soil Moisture Change

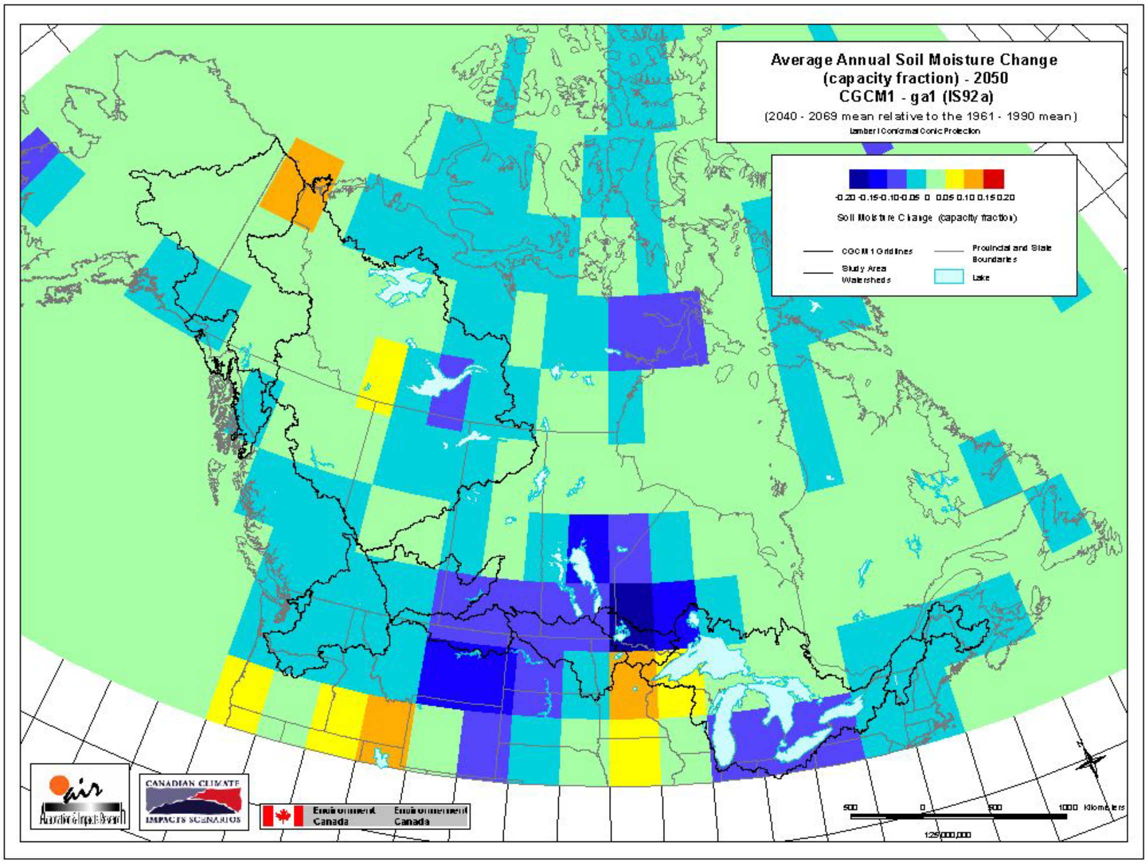


Figure 22: Map of Average Annual Soil Moisture Change for the CGCM1 ga1 scenario

CGCM1 ga1

Most watersheds show a spatially variable increase in soil moisture (Figure 22). Only a few areas suggest a decrease.

5.0 PROFILES OF FREQUENCY OF DAYS WITH RAIN AND SNOW

5.1 Method

This section compares the differences in days with rain and days with snow using bioclimate profiles for the time periods of 1961-1990 and the 2050s (2040-2069). The profiles are displayed in Figures 21 to 32. Annual rain totals are in mm and snow totals are in cm. This information was downloaded from the CCIS Project website (http://www.cics.uvic.ca/index.cgi?Climate_Data). The profiles were created by using actual observed precipitation data from 1961-1990 and then applying the 2050 change field data from the CGCM1 ga1 model to the 1961-1990 observed data to derive the future conditions. The climate stations for the watersheds were arbitrarily chosen to represent the watershed (locations are presented in Figure 20). This information was derived from Canadian climate stations.

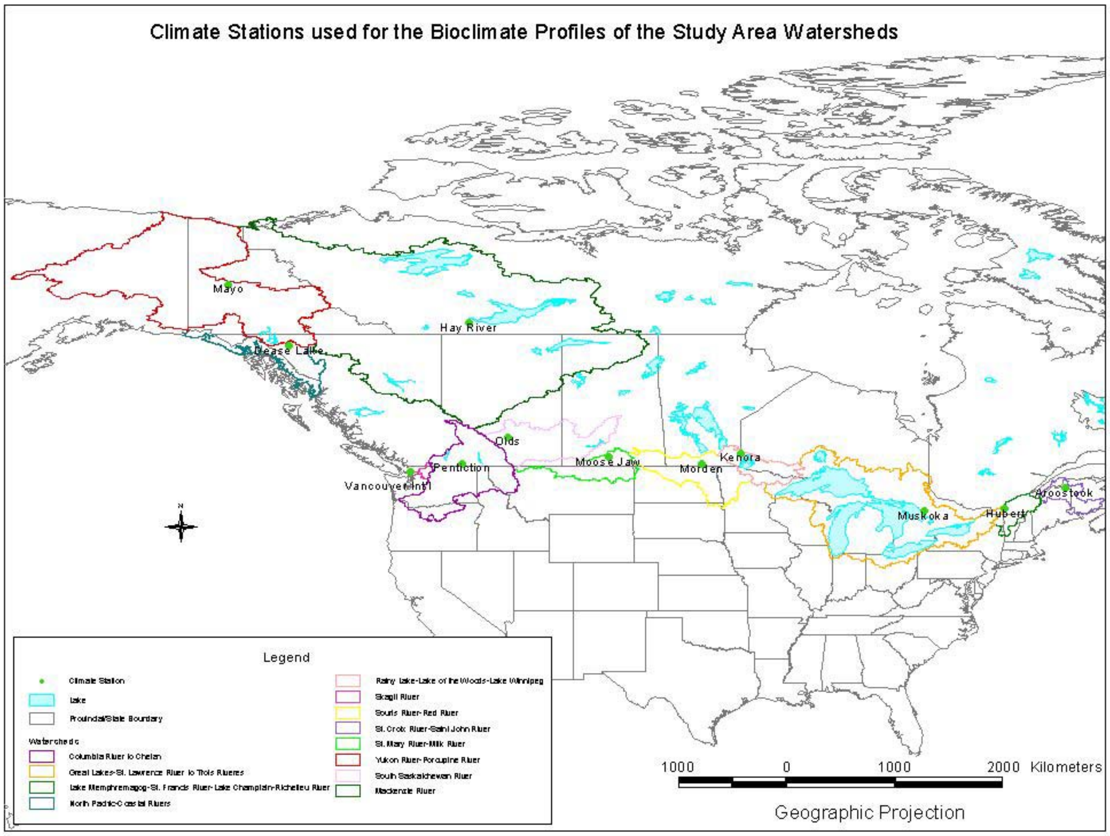
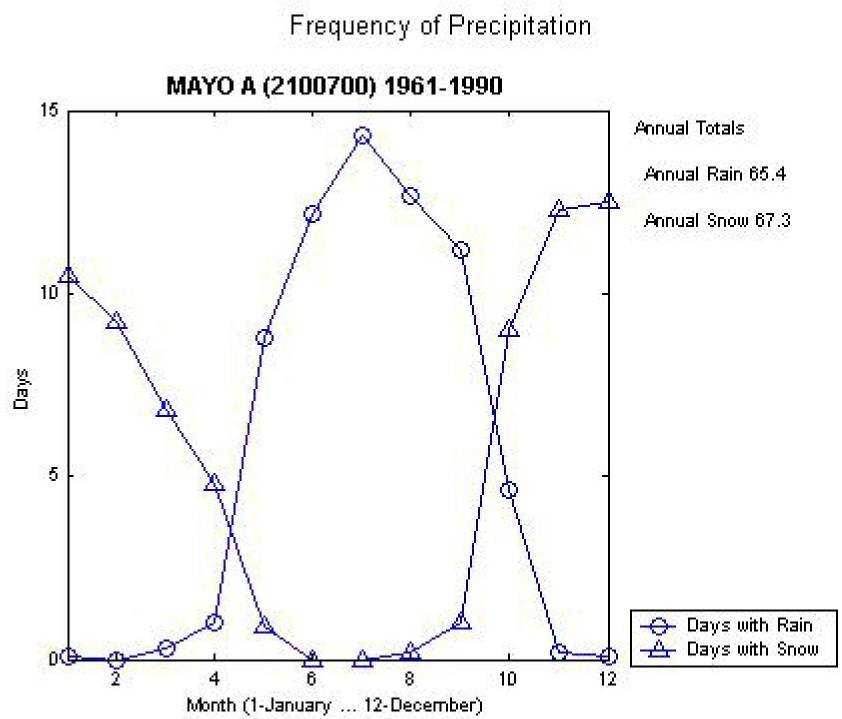


Figure 23: Climate stations used for bioclimate profiles for study area watersheds

5.2 Total Rain Days vs. Snow Days by Watershed

For all of the watersheds, the CGCM1 ga1 scenario suggest that the days with snow will decrease and the days with rain will increase for 2040-2069. In the late spring and summer, days with rain for both time periods are similar. The change is occurring in the late fall, winter and early spring. Snow days are decreasing during these periods and rain days are increasing. For many stations, the increase in rain days are not compensating for the decrease in snow days. The first snow fall occurrence is occurring a month earlier and last snow fall occurrence is occurring a month later in the 2040-2069. Results of specific watersheds are described below.



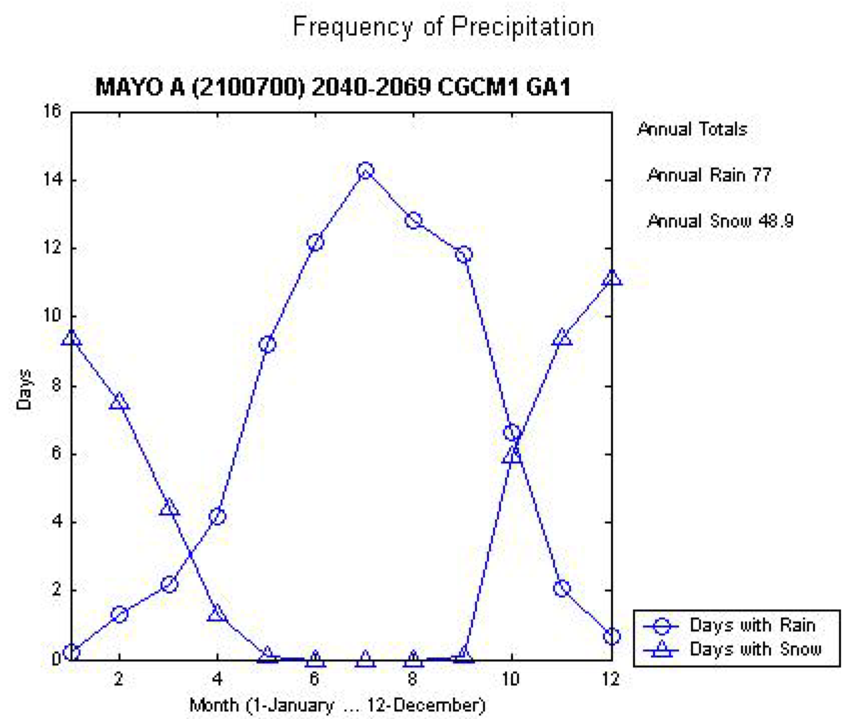
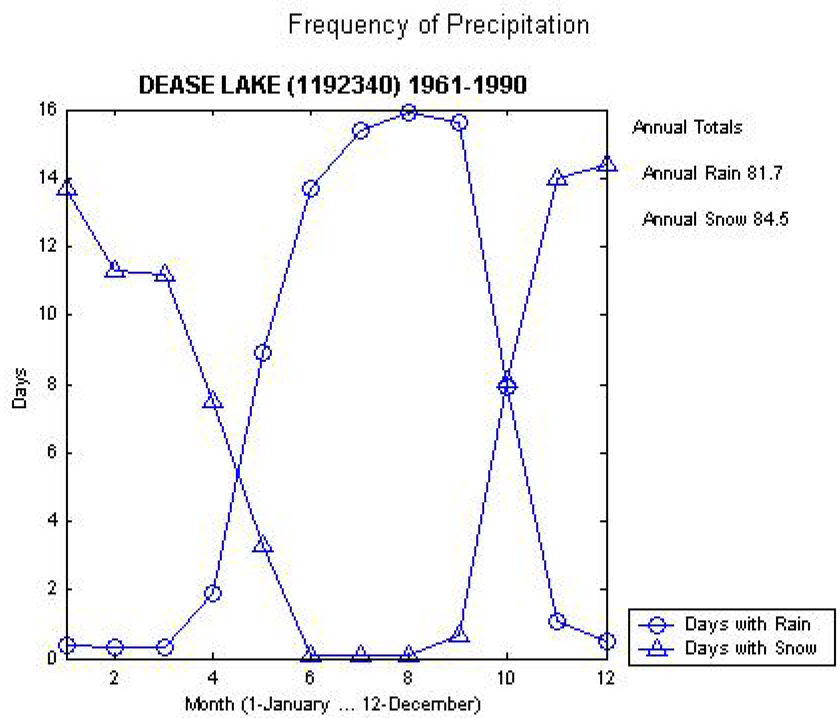


Figure 24: Yukon River/Porcupine River Watershed – Mayo Station #2100700

Overall, this scenario showed 2040-2069 receiving more annual rainfall (77mm) and less snowfall (48.cm) than 1961-1990 (65.4mm and 67.cm respectively). The profiles of both periods were similar. There were differences, however, in the first and last snowfall occurrences during the year. For the 1960-1991 period, the last snowfall occurred in May, and the first snowfall happened in August. For the 2040-2069 period, the last snowfall happened in April and in the first snowfall was in September. The winter months had a decrease of 2 days with snow for 2049-2060 compared to 1960-1991. However, there was more

rainfall during these months for this period as compared to the earlier period. This situation also occurred in the spring. Rainfall days remained similar for both time periods during the late spring and the summer.



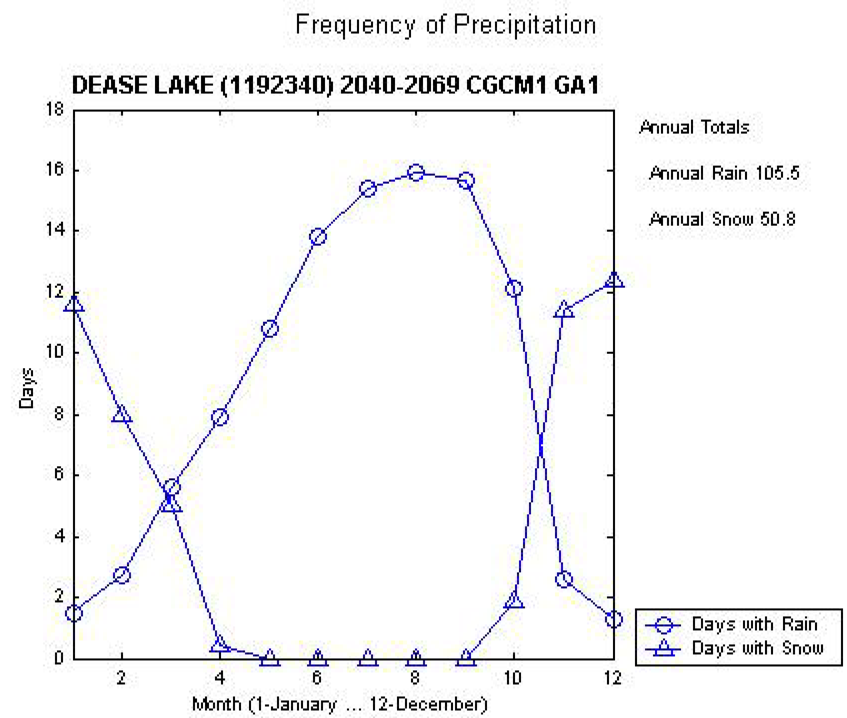


Figure 25: North Pacific and Coastal Rivers Watershed – Dease Lake Station #1192340

The 2040-2069 scenario showed an increase in annual rainfall (105.5mm) when compared to 1961-1990 (81.7mm). However, there was a decrease in snowfall during the former time period (50.8cm) when compared to the latter (84.5cm). There was a decrease in snowfall occurrences during the winter and spring months for 2049-2060. For 1961-1990, snowfall occurred the entire year. In 2049-2050 period the last snowfall was in April and the first snowfall was in October. Rainfall days for April increased for 2049-2060. Snowfall days in March for the 2040-2069 were lower and rain days were higher than 1961-1990.

Rainfall days during the spring were much higher for the 2049-2060. Summer rainfall days remained similar for both time periods.

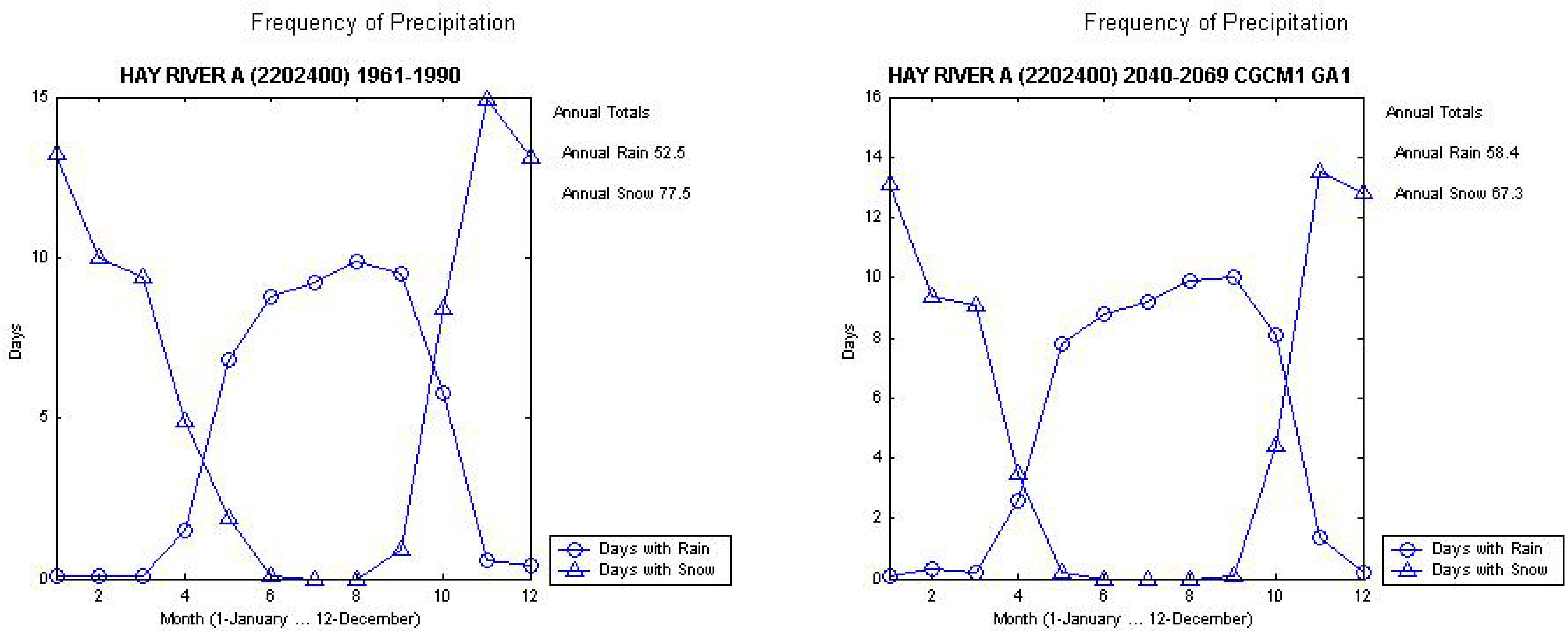
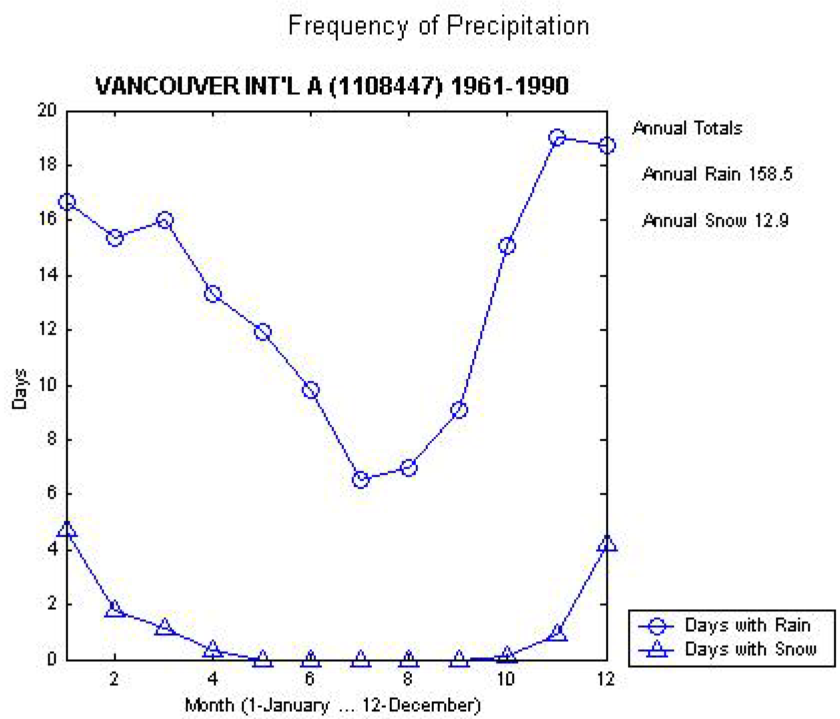


Figure 26: Mackenzie River Watershed-Hay River Station #2202400

Annual rainfall for 2040-2069 increased slightly (58.4mm compared to 52.5mm for 1961-1990) and snowfall decreased (67.3cm as compared to 77.5cm for 1961-1990). Days with snow for the late fall and winter dropped slightly by 1-2 days. Days with rain increased slightly for November for 2040-2069 (2 days compared to 0 days for 1961-1990), and remained close to negligible for the remaining winter months. The spring and summer days with rain were similar for both periods. Rain days for October were higher for 2040-2069 coupled with a decrease in snowfall occurrences for the same month. The first snowfall occurred in September for 1961-1990 and 2049-2060. The last snow fall was in June for 1961-1990 and May for 2049-2060.



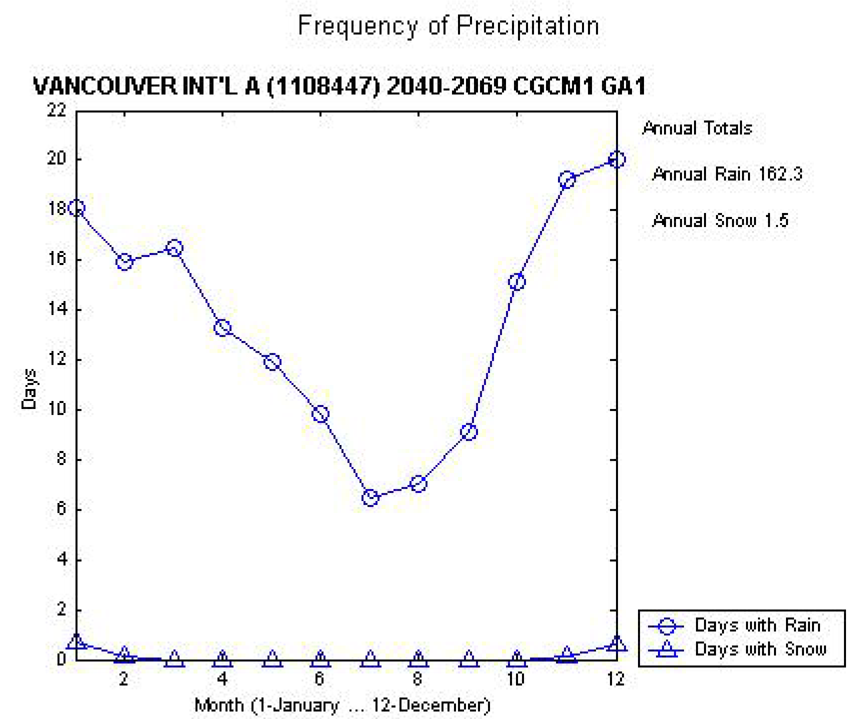


Figure 27: Skagit River Watershed - Vancouver International Airport Station #1108447

The 2040-2069 showed a minimal increase in annual rainfall (162.3mm as compared with 158.5mm for 1961-1990) and a large decrease in annual snowfall (1.5cm as compared with 12.9cm for 1961-1990). The profile for days with rain were similar for both periods. There was a small increase in rain days during the winter months for 2049-2060. However, snowfall days

decreased compared to 1961-1990. The late fall and winter months for 2040-2069 showed minimal snowfall occurrence. In 1961-1990, January and December received approximately 5 days of snow. The last snowfall occurred in April for 1961-1990 and February for 2049-2060. The first snowfall occurred in October for 1961-1990 and November for 2049-2060.

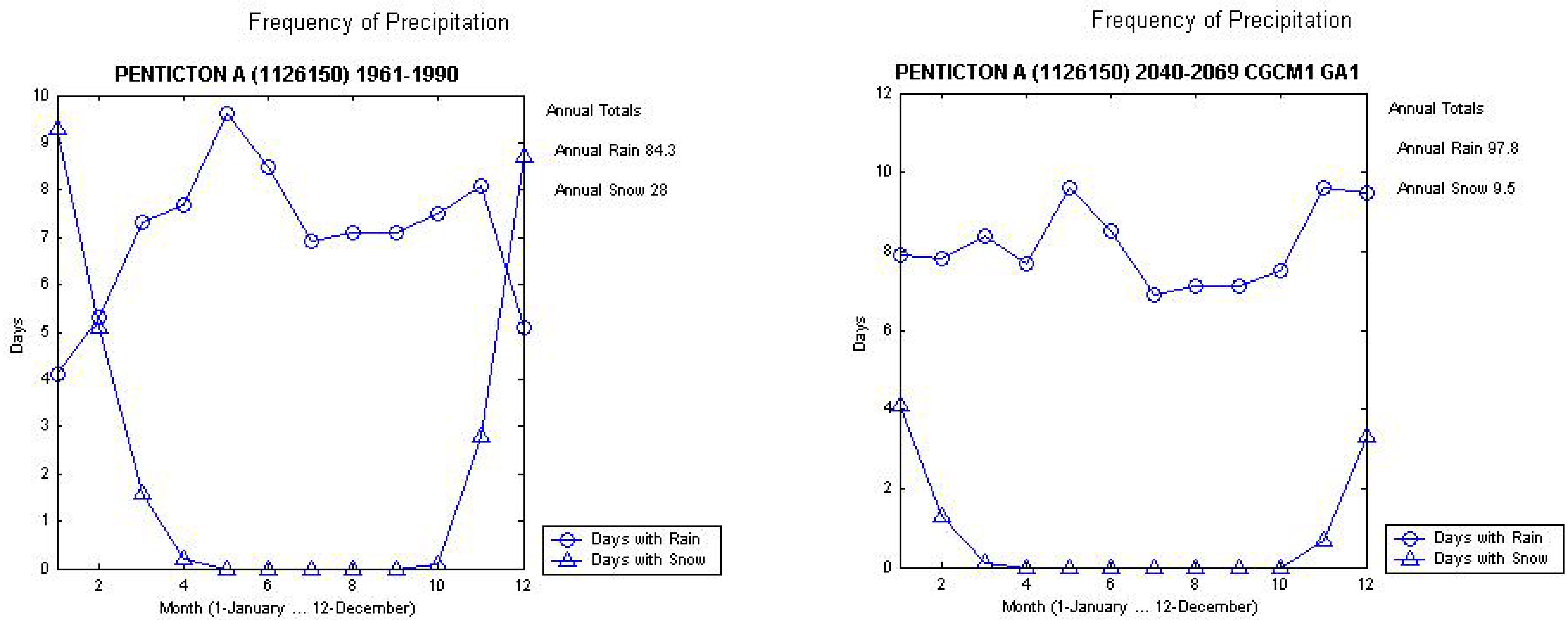
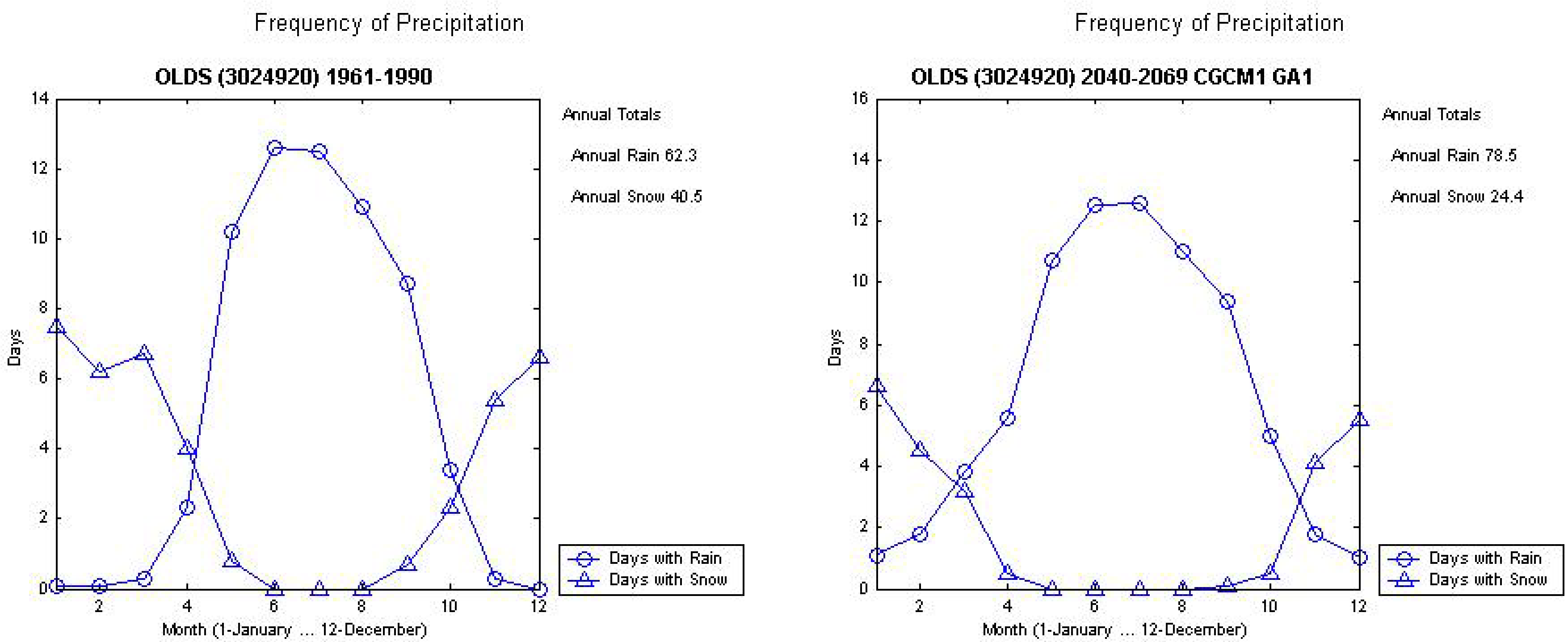


Figure 28: Columbia River Watershed – Pentiction Station #1126150

There was a marginal increase in annual rainfall for 2040-2069 (97.8mm compared with 84.3mm for 1961-1990). However, there was a significant decrease in annual snowfall, 9.5cm for 2040-2060 and 28cm 1961-1990. The decrease in snowfall days was most greatest for January (4 days for 2040-2069 compared to 9 days for 1961-1990) and December (3 days for 2040-2069 and 9 days for 1961-1990). Rain days increased for 2040-2069, 8 days in January as compared to 4 for 1961-1990 and 9 days for December compared to 5 days. Rain days also increased for February (8 days for 2040-2069 and 5 days for 1961-1990), coupling a decrease in snow days from 5 in 1961-1990 to 1 day in 2040-2069. For the spring, summer and fall, rain days

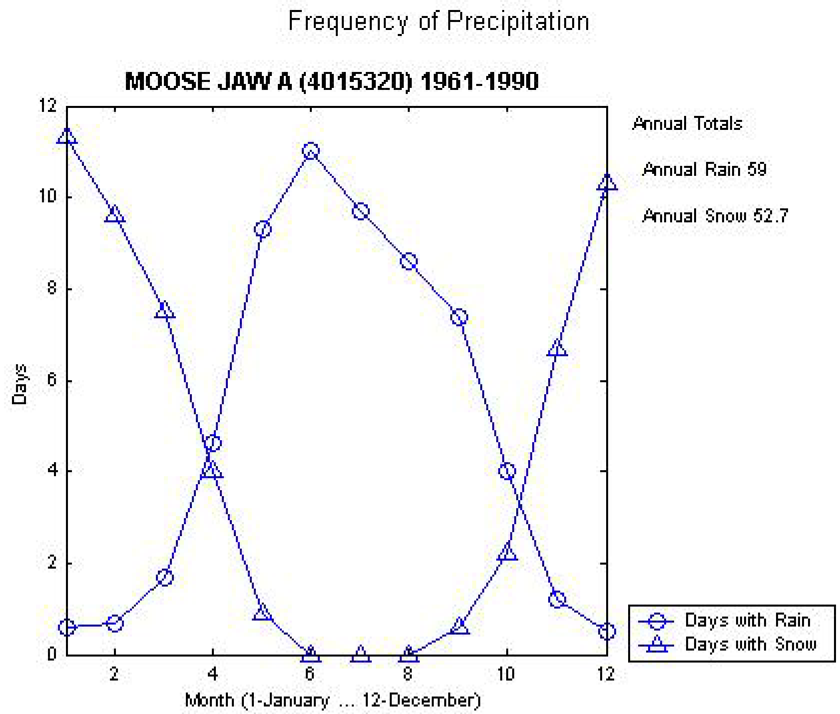
remained similar for both periods. The last snowfall incidence for 1961-1990 was in April and 2040-2069 for March. The first snowfall occurred in October for 1961-1990 and November for 2049-2060.

Figure 29: South Saskatchewan Watershed-Olds Station #3024920



Annual rainfall for this watershed increased for 2040-2069 (78.5mm compared to 62.3mm for 1961-1990) and annual snowfall decreased by almost half (24.4cm compared to 40.5cm for 1961-1990). The last snowfall incident for 1961-1990 was in May compared to April for 2040-2069. The first snowfall occurrence was September for 1961-1990 and October for 2040-2069. In the late fall and early winter, snow days were comparable for both periods. There was a decrease in snow days for the 1961-

1990 and 2040-2069 periods for October and from January to April. The greatest decrease was in March, where snow days dropped from 7 days to 3 days and in April, 4 days to negligible. Rain days during this period did increase by a couple days. Rain days from May to October were comparable.



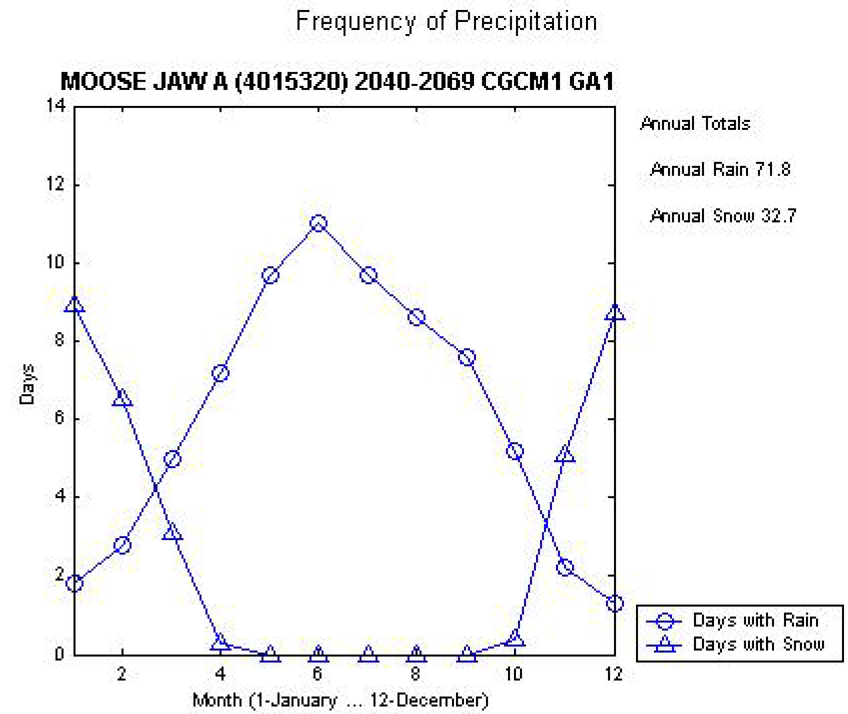


Figure 30: St. Mary River/Milk River – Moose Jaw Station #4015320

Annual rainfall increased for 2040-2069 (71.8mm compared with 59mm for 1961-1990) and annual snowfall decreased (32.7cm compared to 52.7cm). In 1961-1990 the last snowfall occurred in May and for 2040-2069 in April. The first snowfall was in September for 1961-1990 and October for 2040-2069. Snow days in the winter decreased for 2040-2069. Snow days in

December were reduced from 10 to 9 days, January 11 to 9 days, February 10 to 6 days and March 7 to 4 days. Rain days increased slightly for this period. The profile of rain days for the rest of the spring, summer and early fall were similar.

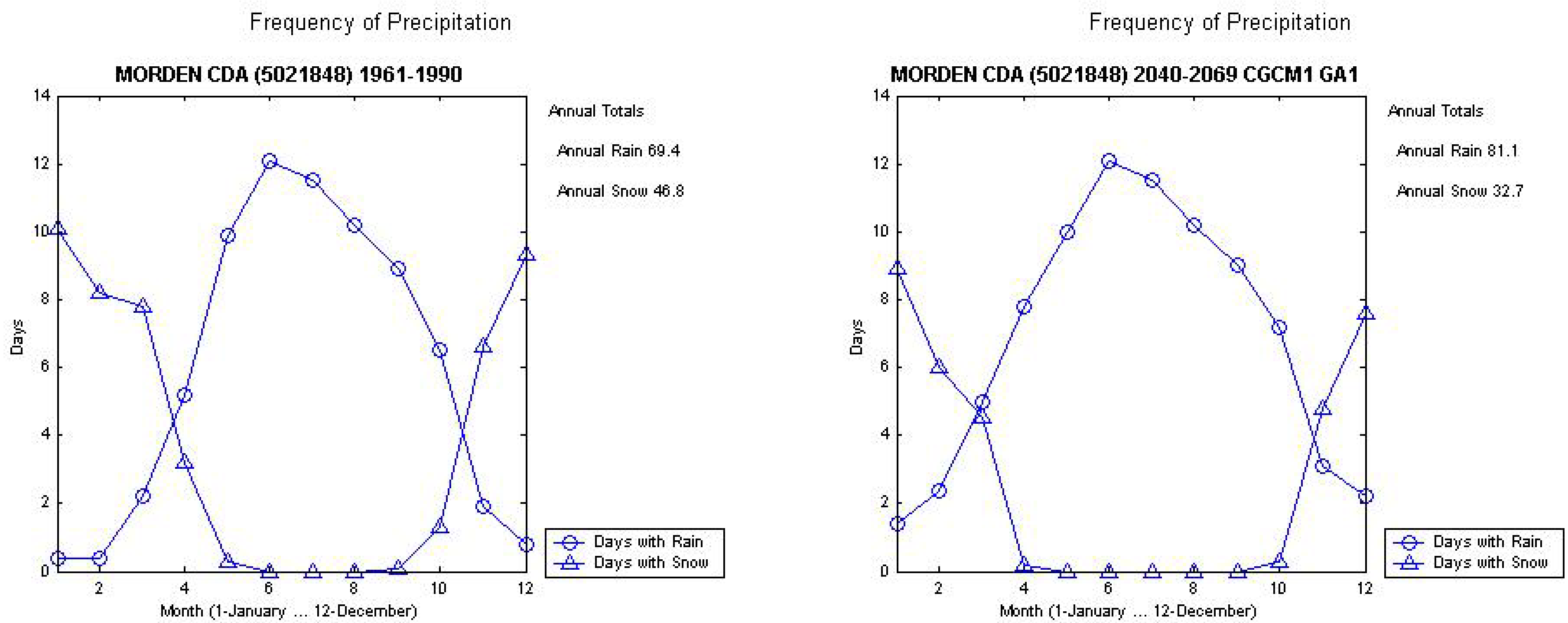


Figure 31: Souris River/Red River – Morden Station #5021848

Annual rainfall increased for 2040-2069 (81.1mm) compared to 1961-1990 (69.4mm). Annual snowfall decreased for 2040-2069 (32.7cm) compared to 1961-1990 (46.8cm). There was a decrease in snow days for February (8 days to 6 days), March (8 days to 5 days) and April (3 days to negligible). Rain days increased for February (negligible to 2 days), March (2 days to 5

days) and April remained the same. The last snowfall was in May for 1961-1990 and April for 2040-2069. The first snowfall was in September for 1961-1990 and October for 2040-2069. Rain days for the latter part of the spring, summer and early fall were similar for both periods. Rain days increased slightly in 2040-2069 for the late fall, early winter and snow days decreased by a couple days.

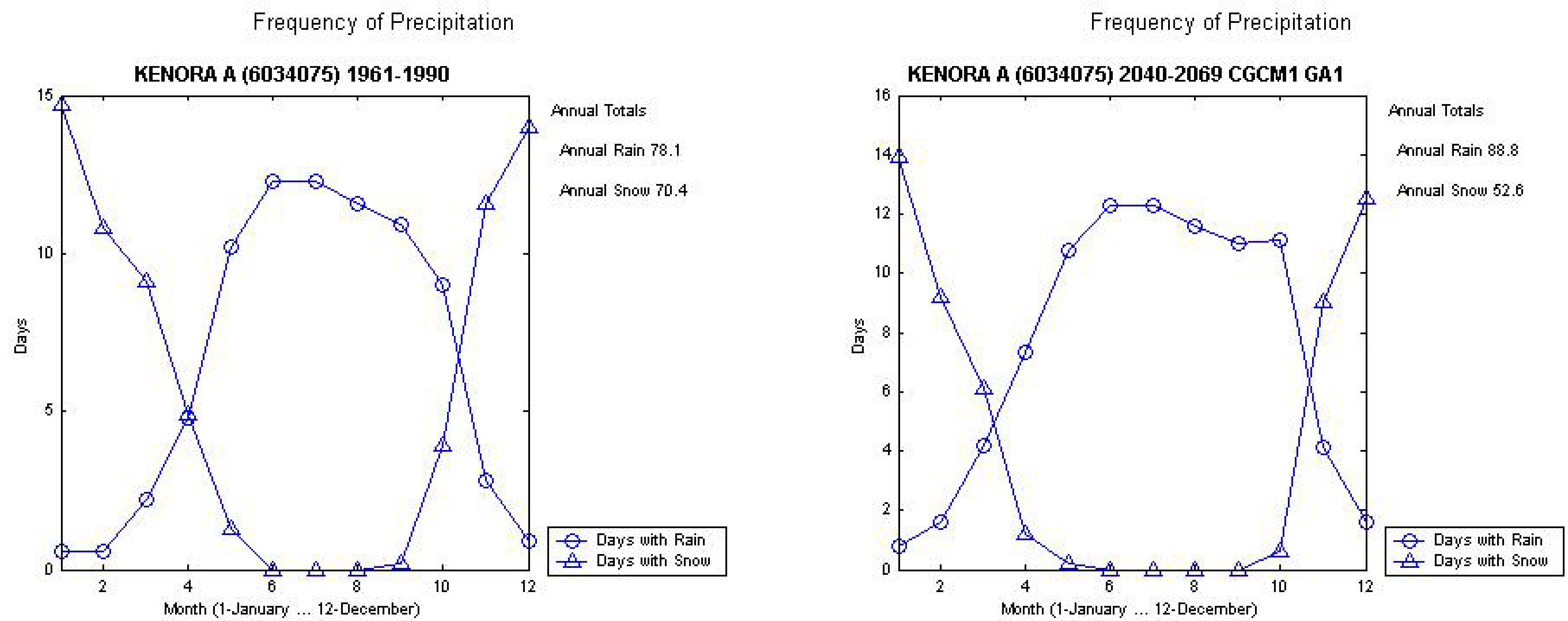


Figure 32: Rainy Lake-Lake of the Woods- Lake Winnipeg – Kenora Station #6034075

Annual rainfall increased for 2040-2069 (88.8mm) compared to 1961-1990 (78.1mm). Snowfall decreased, 52.6cm for 2040-2069 and 70.4cm for 1961-1990. The last snowfall was in May for both periods. The first snowfall was in September for 1961-1990 and September for 2040-2069. In 2040-2069, winter snow days decreased by a couple days. A larger reduction in snow days occurred from mid-late fall and early-mid spring (October 5 days to approximately 1 day, November 12 days to 9 days,

March 9 days to 6 and April 5 days to 1 day). Rain days increased slightly during this period, except for April where they rose from 5 days to 8 days and October 9 days to 12 days. The profile for rain days in the late spring to early fall remained similar for both periods.

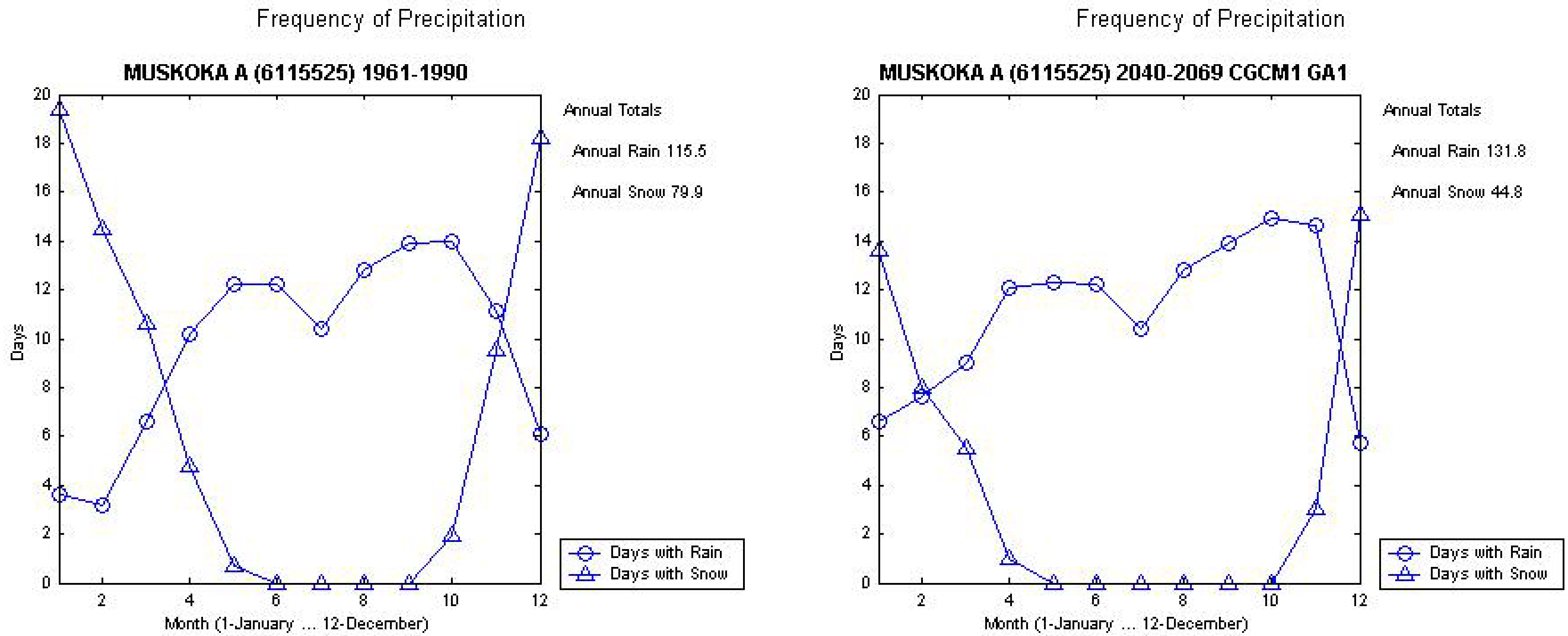
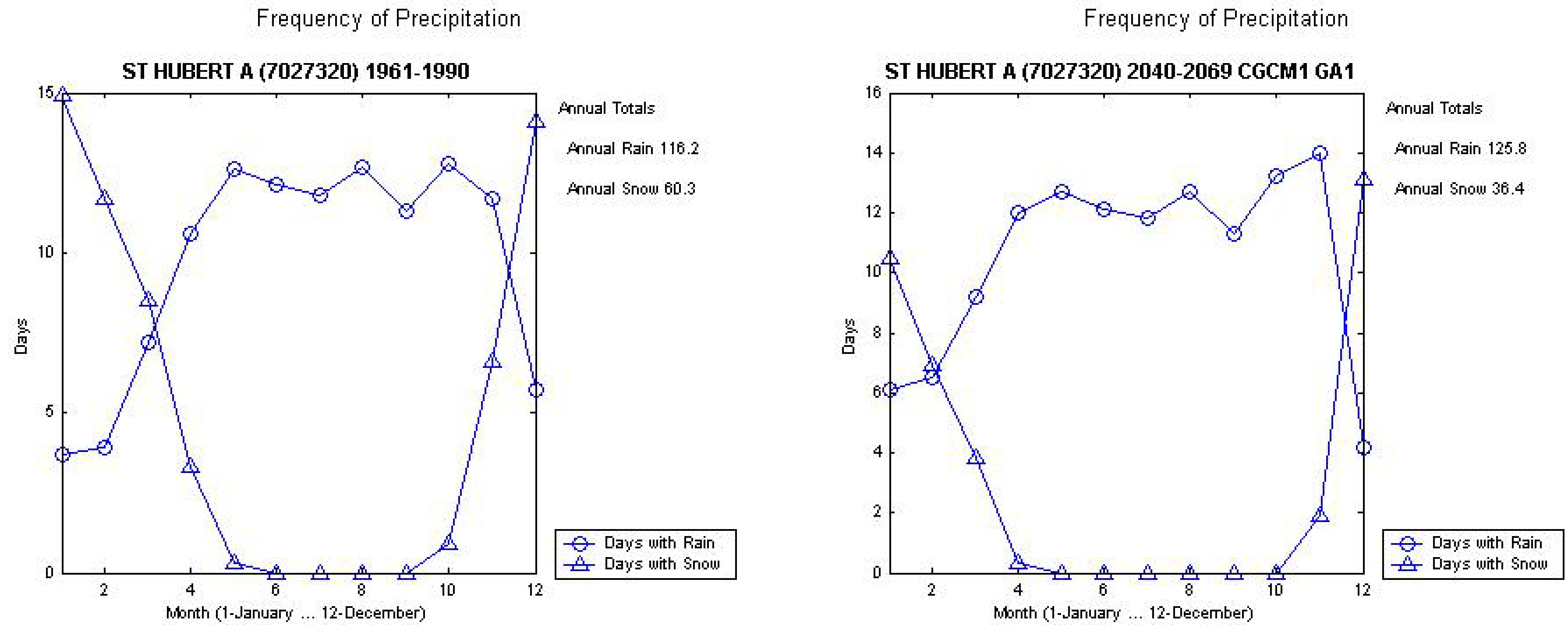


Figure 33: Great Lakes/St. Lawrence River Watershed – Muskoka Station #5115525

Annual rainfall increased for 2040-2069 (131.8mm) compared to 1961-1990 (115.5mm). Snowfall decreased by almost half, 44.8cm and 79.9cm respectively. There were differences in late fall, winter and early spring days with snow. In November, there was a decrease from 1961-1990 (10 days) to 2040-2069 (2 days), December (18 days to 14 days), January (20 days to 14 days), February (14 days to 8 days), and March (10 days to 5 days). Rain days for these months increased from 1961-1990 to 2040-2069. November had an increase from 12 to 14 days, December had no increase, January 4 to 6 days, February 3 to 8 days and March 3 to 6 days. The increase in rain days for 2040-2069 did not match the decrease in snow days. In April there was a increase of rain days, 12 days from 10 days, but there was also a decline in snow days, 2 days from 5 days. The late spring and summer rain day profile was similar for both periods. The last snowfall occurred in May for 1961-1990 and April for 2040-2069. The first snowfall occurred in October and November respectively.

Figure 34: Lake Memphremagog/St. Francis River/Lake Champlain/Richelieu River Watershed – St. Hubert



Station #7027320

Annual rainfall for this period increased from1961-1990 (116.2mm) to 2040-2069 (125.8mm). Annual snowfall decreased in 2040-2069 (36.4cm) from 1961-1990 (60.3cm). The last snowfall occurred in May for 1961-1990 and April for 2040-2069. The first snowfall began in October for 1961-1990 and November for 2040-2069. There was a decrease in late fall, winter and spring snow days in from 1961-1990 to 2040-2069. November had a decrease from 6 days to 2 days, December 14 days to 13 days, January 15 days to 10 days, February 12 days to 7 days, March 9 days to 3 days and April 4 days to negligible. Rain days during this period increased, on average, approximately 2 days per month. The rain day profile was similar for both time periods for the late spring and summer.

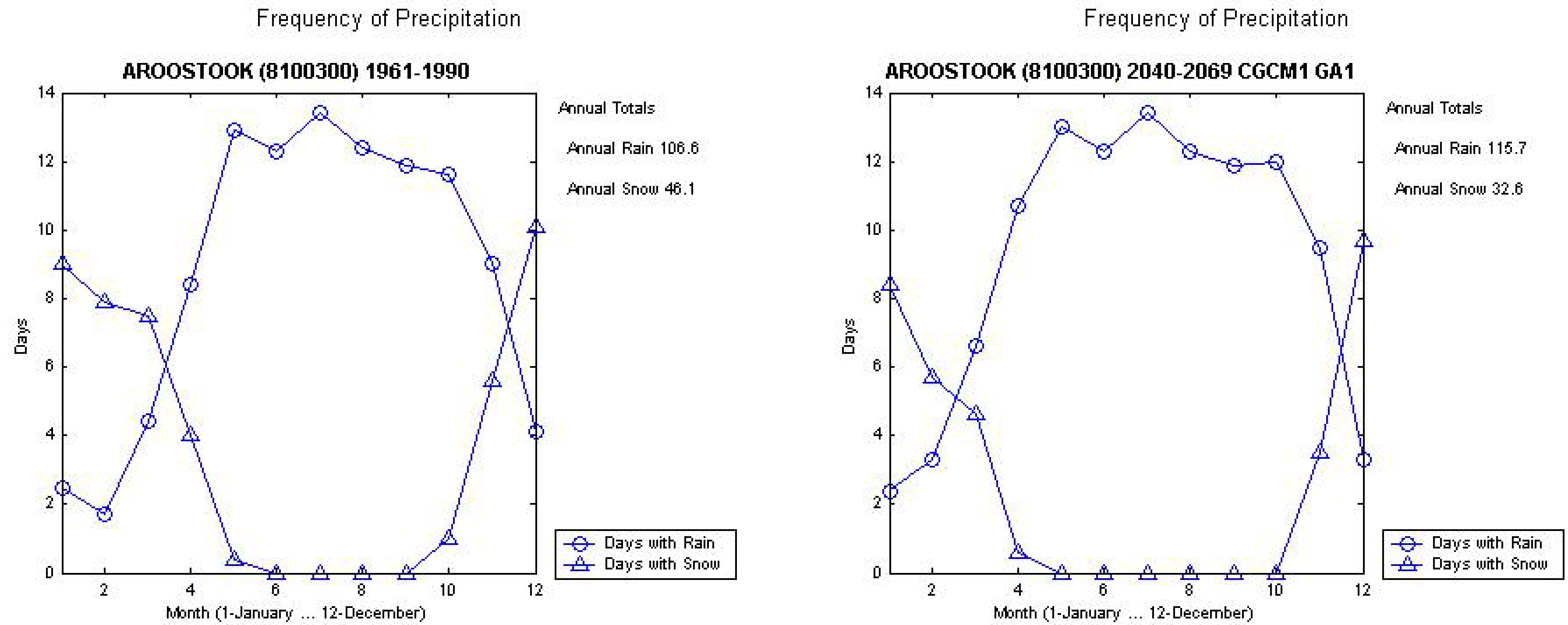


Figure 35: St. Croix/Saint John Watershed – Aroostook Station #8100300

Annual rainfall increased in 2040-2069 (115.7mm) from 1961-1990 (106.6mm). Annual snowfall decreased to 32.6cm in 2040-2069 from 46.1cm in 1961-1990. Winter snow days decreased in January for 2040-2069 compared with 1961-1990 (8 days from 9 days) and February (6 days from 8 days). Rain days did not increase for January, but did increase for February from 2 days to 3 days. Rain days increased in the early to mid-spring for the 2040-2069 periods and remained similar for both periods for the summer for the majority of the fall. November had a 1 snow day decrease in the fall for 2040-2069, and 1 rain day increase. The last snowfall for

1961-1990 for was May and April for 2040-2069. The first snowfall was October for 1961-1990 and November for 2040-2069. Of all of the study area watersheds, this one remained most constant for the rain and snow day profiles for both periods.

6.0 CLIMATE CHANGE – PROJECTED AND OBSERVED CHANGES

Climate change is projected to alter existing climate patterns within the study area watersheds. There is agreement among researches that warmer temperatures will ensue in the future (Cohen et al, 2001, Cohen et al., 1998, Clarke, et al., 2000, Hoffman, et al, 1998, Mortsch et al., 2000) and there will be different variations in seasonal precipitation patterns (Cohen et al, 1998; Hoffman et al, 1998; Bruce et al, 2000). The following table contains information on projected and observed changes in climate.

Table 5: Potential and Observed Trends in the Study Area Watersheds Associated With Climate Change

Variables Affected by Climate Change	Potential Impacts	Observed Impacts
Temperature	• Climate change scenarios include warmer temperatures[3,9,10,11,14,28], though cooling could occur in some parts of Canada[2] • Land areas will warm more than oceans[14] • Higher latitudes will warm more than the equatorial region[11,14] • Significant increases in temperature during the winter and spring[14]	• An annual increase of 1 °C in Canada over the past 100 years[1,2] • The largest increases have been in the central, northwest and northern regions. In the coastal areas of eastern Canada and over the waters of Labrador, cooling has been observed for the past 3 decades[2] • Temperature trends for southern Canada, from 1990-1998, show an overall increase of 0.9ºC[33] • There has been significant warming in the Prairies of 1.5ºC during the same period[25] • Diurnal temperature ranges are decreasing due to a more rapid increase in minimum temperatures as compared to maximum temperatures[26,27] • Maximum and minimum temperatures have increased except for eastern Canada[29] • The diurnal temperature range has increased, except for central Canada[29]
Precipitation	• Annual increase in some areas[2,9,11] and a decrease in others[2,11] • Precipitation could increase in high latitudes during the winter and dryer conditions could be experienced in the intercontinental regions of northern mid-latitudes[11,14] • Summer precipitation will decrease[10] • Changes in precipitation type (rain vs. snow)[9,10], mixed precipitation[5] and intensity[1] • Climate change due to GHG has the potential to change precipitation form, amount, timing, distribution, intensity, duration and extremes[14]	• Has been an overall increase in precipitation during the latter half of the 20th century[1,2,4] • In Southern Canada, there has been an increase in precipitation by 12% between 1900-1998[25] • Decrease in spring precipitation in southern Canada[4] • A significant trend in the frequency of precipitation events from light to heavy intensity for most of Canada. Since 1950, there has been a decrease in winter precipitation in south-western Canada. Lighter events are becoming less frequent, while heavier events are becoming more frequent[8] • Persistent high/low precipitation events over a period of several years are the main natural cause of extreme high/low water levels in the Great Lakes[23]

Evaporation & Evapotranspiration	• Will increase in intensity as a result of an increase in temperatures[7,9] • In Southern Alberta, the possibility of precipitation increasing from 2 –11% would not compensate for the increase in evaporation and evapotranspiration[16]	• Southern Alberta is very sensitive to climate change. Dry years are common with drought and crop failure[7] • In a 20 year study (1970-1990), in the Experimental Lakes Area of northwestern Ontario, it was found that an increase in temperature of 1.6°C and a decrease in precipitation caused annual evaporation to increase by 50%[9]

Variables Affected by Climate Change	Potential Impacts	Observed Impacts
Water Quantity	• Increase in flooding and runoff potential from extreme events[2] • Earlier onset of peak flow[3,9,10,11] • There will be lower total flow, lower minimum flows, longer average annual peak flow[1,2,9,11] • Winter flow will increase and summer flow will decrease[1,3,13] • Fall flow will decrease due to high evaporation and a reduction in groundwater base flow in the summer[1] • Groundwater recharge and levels may decline[9] • Shallow, unconfined aquifers will be impacted most significantly (causing wells to run dry during drought)[13] • An impact on the distribution and availability of water resources for social and economic uses [15] • In the northern areas of North America, the decrease in permafrost area could cause the summer water table to decrease[17]	• Observed changes in unregulated streams include earlier onset of annual spring peak, lower fall flows, higher early winter flows[3] • Annual mean flow for most of southern Canada has shown a downward trend[2,4] • Spring break up has occurred earlier most basins (82%), between 1967 – 1996[2] • In south-central BC, the spring freshet was 20 days earlier between 1984-1995 than 1971-1983, there were lower end of summer flows and increase in early winter streamflow[19] • Streams in Canada responded to different climate variations. When conditions were warmer, the hydrological spring occurred earlier in the more recent decade. When it was cooler, spring runoff was delayed [22] • Observation of hydrological stations for the past 30-50 years shows the annual hydrological cycle for most of Canada appears to be shifting to an earlier spring high flow season. There is also a decreasing trend for maximum daily streamflow, and BC and the Yukon showed a significant increase in minimum daily streamflow[4]
Soil Moisture	• Decrease in soil moisture during the summer in some parts of Canada[2], summer deficits in Southern Ontario, Saskatchewan and Alberta[9] • Less soil moisture in the interior regions at the northern mid-latitude[11,14] • Soil moisture can be expected to increase in high latitudes during the winter[11,14]	• In southern Alberta, dry years are common. Over 60% of irrigation in Canada occurs here[7]
Extreme Events	• Climate change could lead to more incidents of	• Frequency of Northern Hemisphere severe

	extreme events[9,15] • Short duration, heavy rain[2,11] • Severe thunderstorms[2,11] • Harsher winter storms[2,10] • Tornadoes[2,11] • Drought[2] • Flooding[2] • Forest Fires[17] • The darker landscape caused by burning could contribute to the climatic warming of the area. There could also be an increase in wind velocity and water temperatures (due to burning at the edges and the removal of the canopy)[24]	winter storms (central pressure lower than 970 kpa) nearly doubled since the mid 1970's[2] • In south-east Canada, an increase in frequency of heavy rainfall events between 1920 – 1970[8] • In north-western Canada, increase in the frequency of heavy rainfall events during December, January and February between 1950 - 1995[8]
Variables Affected by Climate Change	**Potential Impacts**	**Observed Impacts**
Oceans	• Mean sea levels may increase[2,11,12,14] • Rise would result in flooding, coastal erosion, and saltwater invasion on groundwater and estuaries[2]	• Sea level rose – 10 – 20cm (1900 – 1999)[2]
Permafrost	• Southern boundary is receding northward[2,9] • Total area is diminishing[2,5,9,17]	• Permafrost has been retreating, and more landslides are occurring as a result[2]
Ice Cover and Snow	• Warmer air and water temperatures will result in less duration of ice cover[13] • Larger open water fetch, increasing wave and storm surge effects on the coast of areas located in the north[12] • Fewer days with ice cover[5] • Less precipitation stored in snowpack[1,13,17] and ice[13] • Increased snowfall in some areas and a decrease in others[5] • Warmer temperatures will lead to an earlier spring breakup[5] • Lake ice cover could be reduced or eliminated on Great Lakes and smaller lakes[9]	• Frost-free days increased by 3.1 days/decade during the past 20th century[3] • Reduction in spring snow cover of 0.3 days/year since 1955[5] • Significant decrease in spring snow cover on most of western Canada, fall snow cover over BC, Alberta and northern Ontario and winter snow cover over Quebec[6] • Snow cover extent in North America has increased over most of the 20th century in response to increasing precipitation[5] • Between 1946-1995, there has been a decrease in snow depth for most of Canada, except the east coast where there has been an increase[6]

	• Warmer winters are projected to increase the frequency of mid-winter thaws and rain on snow events[13]	• In Lake Ontario during the winter of 1982-83, mean air temperature was 2.95ºC warmer than the 30-year mean. The duration of ice cover was 17 days with a maximum thickness of 13.5cm as compared with the average 71.7 days and a maximum thickness of 32 cm[21] • River freeze up is occurring earlier in the fall for most regions, but later in the Atlantic region. This results in the periods of ice cover to be longer[4] • There has been a decrease in snowcover since 1941 in many parts of Canada. These decreases were observed from January to March, with the largest decrease occurring in March. The only area experiencing an increase is in the Maritimes[6] • Glaciers in the Rocky Mountains are receding and thinning. The losses of ice are over 16 x 20^6 m^3 greater than is replaced each year [32]

REFERENCES

[1] Browne, J. et al, 1997
[2] Bruce, J. et al, 2000
[3] Cohen, S. et al, 2001
[4] Zhang et al, 2001
[5] SOCC, 2002
[6] Brown et al, 1997
[7] deLoe, R. et al, 1999
[8] Stone, D. et al, 1999
[9] Hoffman N. et al, 1998
[10] Cohen et al, 1998
[11] Clarke, A. et al, 2000
[12] Shaw, R. et al, 2001
[13] Water Resources Chapter, 2002
[14] Mortsch, L. et al, 2000
[15] Government of Canada, 2001
[16] deLoe, R. et al, 2001
[17] Poff, L. et al, 2002
[18] Environment Canada, 1995
[19] Leith et al, 1998
[20] Quinn, F., 1992
[21] Gilbert, R., 1991
[22] Whitfield, P. et al, 2000
[23] Bourget L. et al., 1998
[24] Schindler, D. et al, 1996
[25] Zhang et al, 2000
[26] Easterling et al, 1997
[27] Walther et al, 2002
[28] Murdoch et al, 2000
[29] Easterling et al, 1997
[30] Fee et al, 1996
[31] Murdoch P. et al, 2000
[32] Schindler D., 2001
[33] Zang, X. et al, 2000

7.0 SUMMARY

The scenarios used in this project show an increase in annual temperature and precipitation in the study area watersheds for the 2050s. The greatest temperature increases occurred in the northern watersheds and the least temperature increases occurred in the eastern watersheds. Precipitation changes vary season to season, with the least precipitation increase, and for the Prairies the greatest precipitation decrease, occurring during the summer months. All watersheds show changes in the number of snow and rainfall days and annual totals. The number of snow days are decreasing and rain days are increasing. Snowfall is also ending earlier in the spring and starting later in the fall. Annual rainfall totals are higher for 2040-2069 than 1961-1990 and annual snowfall totals
are lower.

8.0 REFERENCES

1. Boer, G. N. MacFarlane and M. Lazare. Greenhouse Gas-Induced Climate Change Simulated with the CCC Second-Generation General Circulation Model.". Journal of Climatology. 1992; 5:1045-1077.

2. Bourget, L. and M. Clamen. Managing Extremes: The IJC Experience. Canadian Water Resources Journal. 1998; 23(1):135-142.

3. Brown, R. and R. Braaten. Spatial and Temporal Variability of Canadian Monthly Snow Depths, 1946-1995. Atmosphere-Ocean . 1997; 36(1):37-54.

4. Browne, J. L. Mortsch S. Cohen K. Miller G. Larson H. Gilbert and L. Mearns. Climate Variability and Transboundary Freshwater Resources in North America: Vulnerability Assessment-U.S./Canadian Boundary Regions; 1997.

5. Bruce, J. P. I. Burton H. Martin B. Mills and L. Mortsch 2000. Water Sector: Vulnerability and Adaptation to Climate Change; 2000.

6. Canadian Climate Impact Scenarios (CCIS). Scenario Access [Web Page]. Accessed 2002. Available at: http://www.cics.uvic.ca/scenarios/data/select.cgi.

7. Canadian Institute for Climate Studies (CICS). The Climate Company [Web Page]. Accessed 2002. Available at: http://www.cics.uvic.ca/index.cgi?/About_Us/Canadian_Institute_for_Climate_Studies.

8. Carter, T. M. Hulme and M. Lai Intergovernmental Panel on Climate Change Task Group on Scenarios for Climate Impact Assessment. Guidelines on the Used of Scenario Data for Climate Impact and Adaptation AssessmentIPCC-TGCIA; 1999; Version 1.

9. Clarke, A. R. Pentland and J. Hougnon. Beyond the Great Lakes. Proposed Plan of Study for the Rest of the Canada-United States Boundary; 2000.

10. Cohen, S. and T. Kulkarni eds. Water Management and Climate Change in the Okanagan Basin; 2001.

11. Cohen, S. W. Avis K. Miller and L. Mearns. Implications of Climate Change for the Columbia River Basin. 1998.

12. de Loë, R. C. R. D. Kreutzwiser and L. Moraru. Adaptation options for the near term: climate change and the Canadian water sector. Global Environmental Change. 2001; 11(3):231-245.

13. --. Climate Change and the Canadian Water Sector: Impacts and Adaptations. 1999 Nov 1; Prepared for Natural Resources Canada.

14. Easterling, D. B. Horton P. Jones T. Peterson T. Karl D. Parker M. Salinger V. Razuvayev N. Plummer P. Jamason and C. Folland. Maximum and Minimum Temperature Trends for the Globe. *Science*. 1997; 277:364-367.

15. Environment Canada . Boundary Water Issues Compendium. Ottawa; 1995; Environmental Conservation Service.

16. Fee, E. J. R. E. Hecky S. E. M. Kasian and D. R. Cruikshank. Effects of lake size, water clarity, and climatic variability on mixing depths in Canadian Shield Lakes. . Limnol. Oceanogr. 1996; 41:912-920.

17. Flato, G. and G. Boer. Warming asymmetry in climate change simulations. Geophysical Research Letters. 2001; 28:195-198.

18. Flato, G. G. Boer W. Lee N. McFarlane D. Ramsden M. Reader and A. Weaver. The Canadian Centre for Climate Modelling and Analysis Global Coupled Model and its Climate. Climate Dynamics. 1999.

19. Gilbert, R. Ice on Lake Ontario at Kingston. Journal of Great Lake Research. 1991; 17(3):403-411.

20. Government of Canada . Canada's Third National Report on Climate Change . 2001.

21. Hirst, A. S. O'Farrell and H. Gordon. Comparison of a coupled ocean-atmosphere model with and without oceanic eddy-induced advection. 1: Ocean spin-up and control integrations. Journal of Climate. 2000.

22. Hoffman, N. L. Mortsch S. Donner K. Duncan R. Kreutzwiser S. Kulshreshtha A. Piggoot S. Schellenberg B. Schertzer and M. Silvitzky. Climate Change and Variability: Impacts on Canadian WaterEnvironment Canada. Responding to Global Climate Change. 1998.

23. IPCC. IPCC Emission Scenarios. 2000.

24. Leggett, J. W. J. Pepper R. J. Swart. Emission Scenarios for the IPCC: an Update. Houghton, J. T. B. A. Callander and S. K. Varney eds. Climate Change 1992: The Supplememtary Report to the IPCC Scientific Assessment. United Kingdom: Cambridge Univerity Press for IPCC; 1992.

25. Leith, R. and P. Whitfield. . Evidence of Climate Change Effects on the Hydrology of Streams in South-Central B.C. Canadian Water Resources Journal. 1998; 23(3):219-230.

26. Lengelle, F. 2002.

Note: Personal Communication.

27. Mortsch, L. H. Hengeveld M. Lister B. Lofgren F. Quinn M. Silvitzky and L. Wenger. Climate Change Impacts on the Hydrology of the Great Lakes-St. Lawerence System. Canadian Water Resources Journal. 2000; 25(2):153-179.

28. Murdoch, P. J. Baron and T. Miller. Potential Effects of Climate Change on Surface water Quality in North America. Journal of the American Water Resources Association. 2000; 36(2):347-367.

29. Natural Resources Canada . Geogratis site [Web Page]. Available at: http://geogratis.cgdi.gc.ca/.

30. Poff, L M. Brinson J. Day. Aquatic Ecosystems and Global Climate Change Potential Impacts on inland freshwater and Coastal Wetland Ecosystems in the United States; 2002.
Note: Prepared for the Pew Center on Global Climate Change.

31. Quinn, F. Hydraulic Residence Times for the Laurentian Great Lakes. Journal of Great Lakes Research. 1992; 18(1):22-28.

32. Schindler, D. The cumulative effects of climate warming and other human stresses on Canadian freshwaters in the new millennium. Canadian Journal of Fish Aquatic Science. 2001; 58:18-29.

33. Schindler, D. S. Bayley B. Parker K. Beaty D. Cruikshank E. Fee E. Schindler and M. Stainton. The Effects of Climatic Warming on the Properties of Boreal Lakes and Streams at the Experimental Lakes Area, Northwestern Ontario. Limnology and Oceanography. 1996; 41(5):1004-1017.

34. Shaw, R. and the CCAF A041 Project Team. Coastal Impacts of Climate Change and Sea-Levels Rise on Prince Edward Island; 2001.
Note: A Climate Change Action Fund Project CCAF A041A Climate Change Action Fund Project CCAF A041.

35. SOCC (State of the Canadian Cryosphere) . State of the Canadian Cryosphere [Web Page]. 2002; Accessed 2002 Apr 15. Available at: http://www.socc.ca/snow/snow_synopsis_e.cfm.

36. Stone, D. A. Weaver and F. Zwiers. Trends in Canadian Precipitation Intensity. Atmosphere-Ocean. 1999; 38(2):321-347.

37. Taylor, B. Aquatic and Atmospheric Sciences Division, Environmental Conservation Branch Pacific and Yukon Region Environment Canada. Climate Change Scenarios for Canada: A Users Guide for Climate Change Impact Studies. 1996.
Note: Prepared for the Canada Country Study.

38. United States Geological Survey . Water Resources of the United States [Web Page]. Accessed 2002. Available at: http://water.usgs.gov/.

39. Walther, G. E. Post P. Convey A. Menzel Camille Parmesan T. Beebee J. Fromentin O. Hoegh-Guldberg and F. Bairlein. Ecological Responses to Recent Climate Change. Nature. 2002; 416(389):395.

40. Water Resources Chapter . Climate Changes Impacts and Adaptation: a Canadian Perspective. 2002.

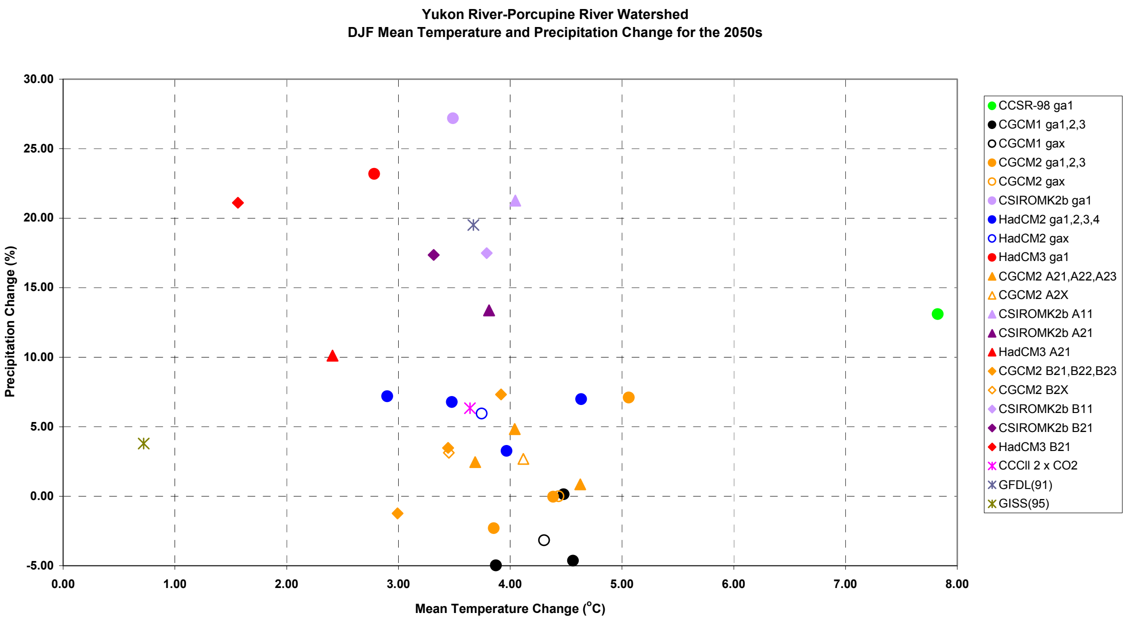
41. Whitfield, P. and A. Cannon. Recent Variations in Climate and Hydrology in Canada. Canadian Water Resources. 2000; 25(1):19-65.

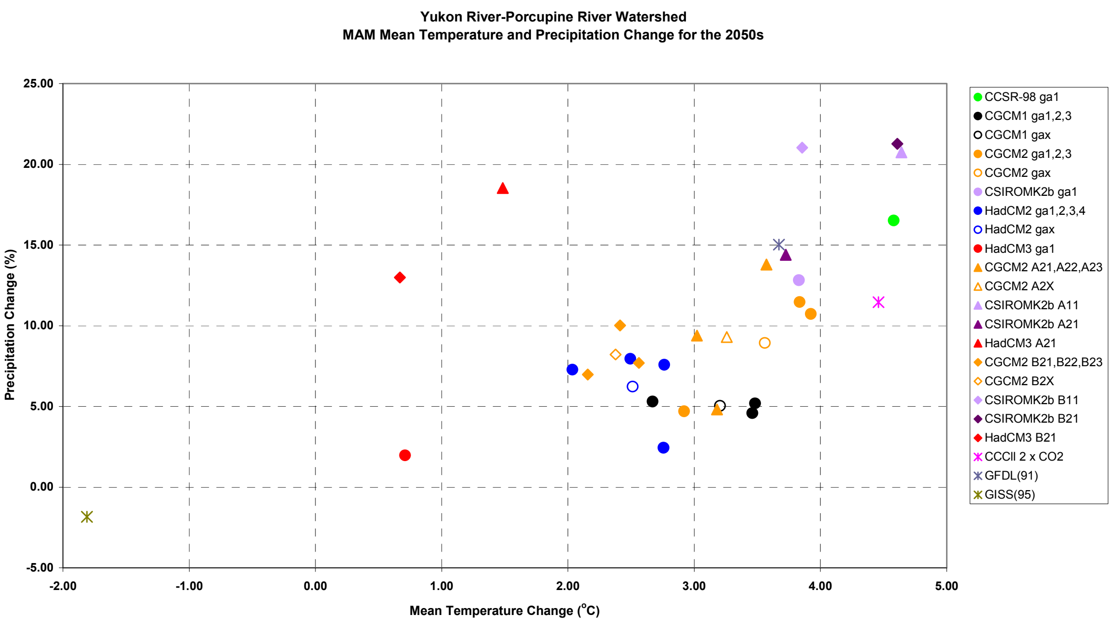
42. Zhang, X. K. Harvey W. Hogg and T. Yuzyk. Trends in Canadian Streamflow. Water Resources Research. 2001; 37(4):987-998.

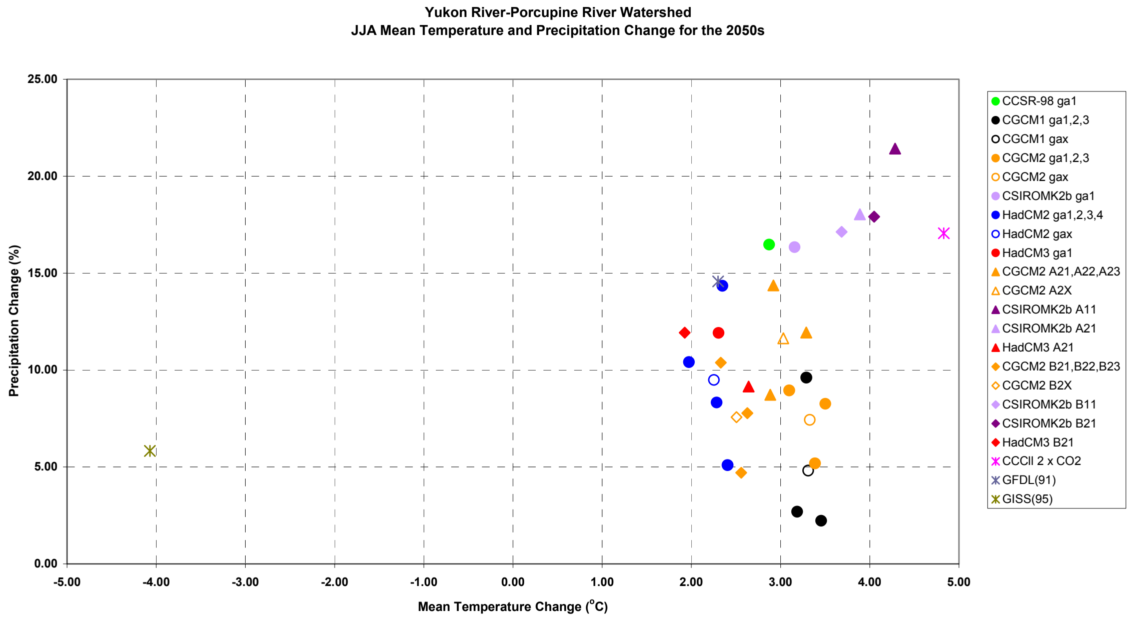
43. Zhang, X.; Vincent, L. A.; Hogg, W. D., and and Niitsoo, A. Temperature and precipitation trends in Canada during the 20th Century. Atmosphere-Ocean. 2000; 38(3):395-429.

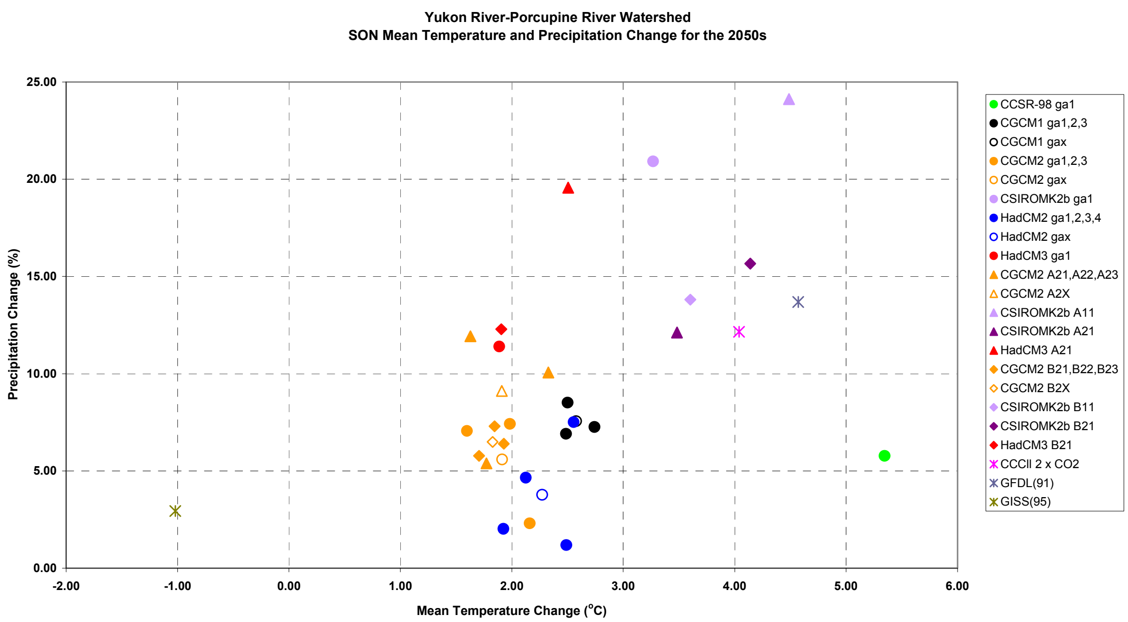
APPENDIX 1 - Seasonal Scatterplots

YUKON RIVER-PORCUPINE RIVER SEASONAL SCATTERPLOTS

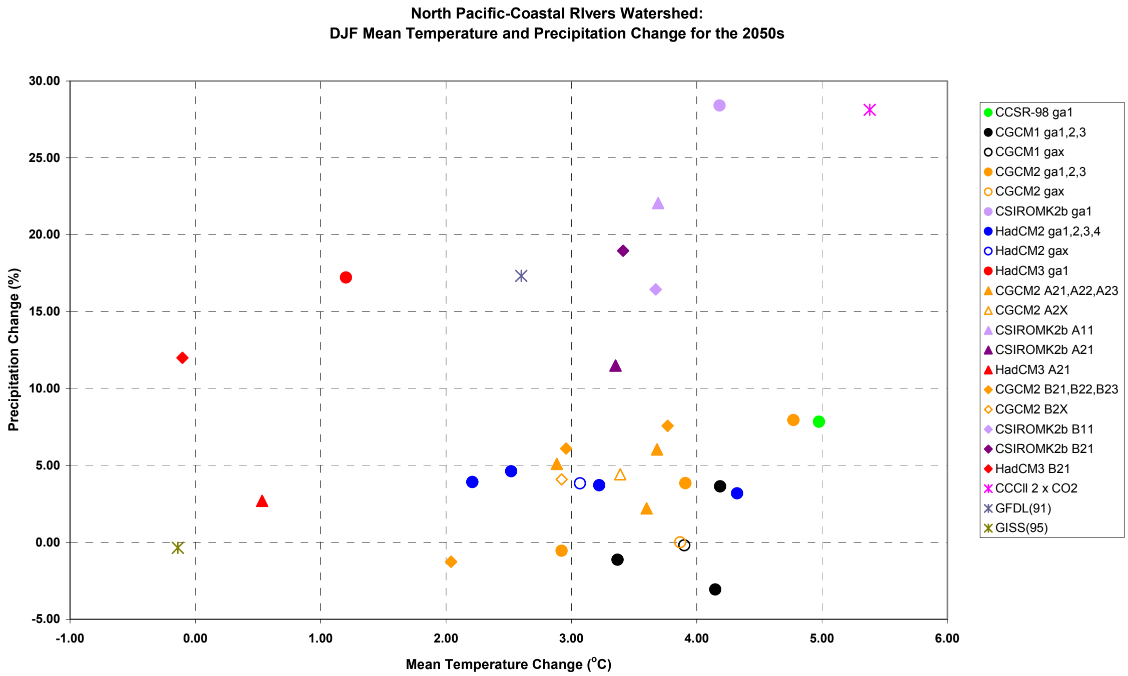

Yukon River-Porcupine River Watershed
DJF Mean Temperature and Precipitation Change for the 2050s
Precipitation Change (%)
Mean Temperature Change (°C)
30.00
25.00
20.00
15.00
10.00
5.00
0.00
-5.00
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
CCSR-98 ga1
CGCM1 ga1,2,3
CGCM1 gax
CGCM2 ga1,2,3
CGCM2 gax
CSIROMK2b ga1
HadCM2 ga1,2,3,4
HadCM2 gax
HadCM3 ga1
CGCM2 A21,A22,A23
CGCM2 A2X
CSIROMK2b A11
CSIROMK2b A21
HadCM3 A21
CGCM2 B21,B22,B23
CGCM2 B2X
CSIROMK2b B11
CSIROMK2b B21
HadCM3 B21
CCCII 2 x CO2
GFDL(91)
GISS(95)

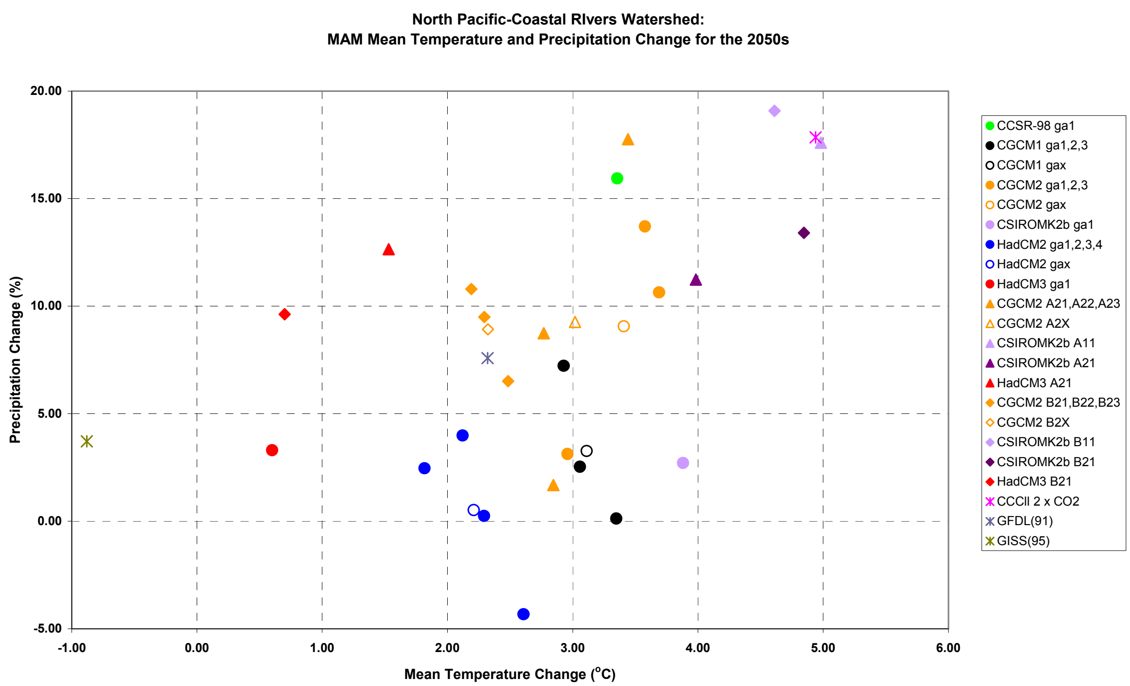

Yukon River-Porcupine River Watershed
MAM Mean Temperature and Precipitation Change for the 2050s
Precipitation Change (%)
Mean Temperature Change (°C)
25.00
20.00
15.00
10.00
5.00
0.00
-5.00
-2.00
-1.00
0.00
1.00
2.00
3.00
4.00
5.00
CCSR-98 ga1
CGCM1 ga1,2,3
CGCM1 gax
CGCM2 ga1,2,3
CGCM2 gax
CSIROMK2b ga1
HadCM2 ga1,2,3,4
HadCM2 gax
HadCM3 ga1
CGCM2 A21,A22,A23
CGCM2 A2X
CSIROMK2b A11
CSIROMK2b A21
HadCM3 A21
CGCM2 B21,B22,B23
CGCM2 B2X
CSIROMK2b B11
CSIROMK2b B21
HadCM3 B21
CCCII 2 x CO2
GFDL(91)
GISS(95)

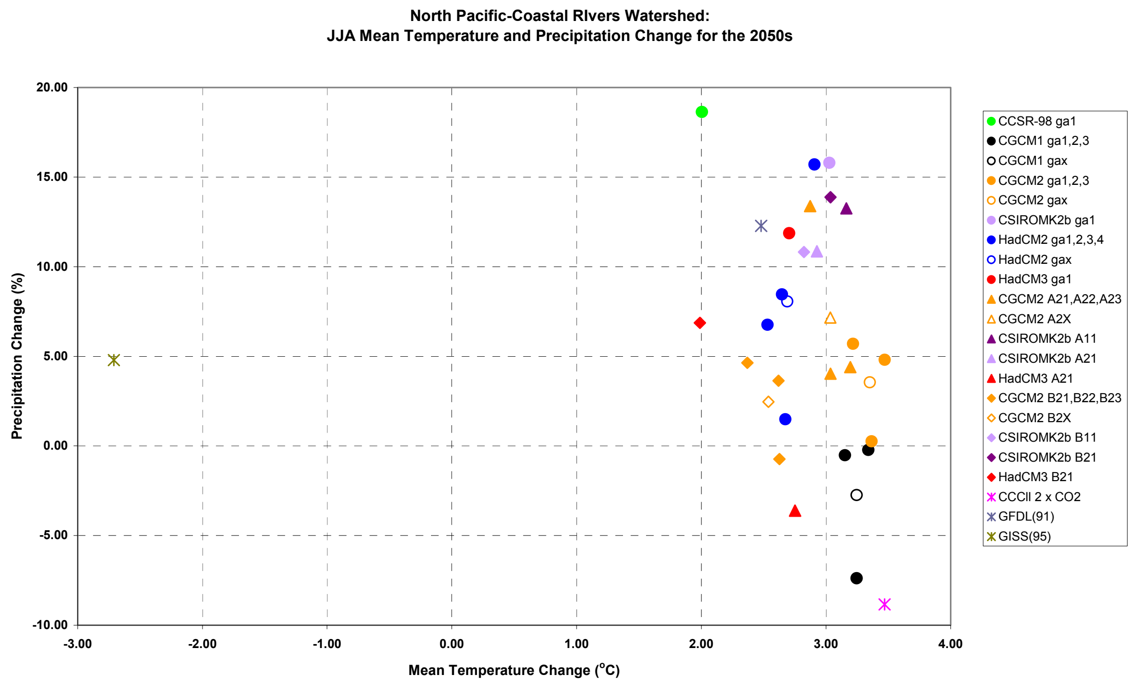

Yukon River-Porcupine River Watershed
JJA Mean Temperature and Precipitation Change for the 2050s
Precipitation Change (%)
Mean Temperature Change (°C)
25.00
20.00
15.00
10.00
5.00
0.00
-5.00
-4.00
-3.00
-2.00
-1.00
0.00
1.00
2.00
3.00
4.00
5.00
CCSR-98 ga1
CGCM1 ga1,2,3
CGCM1 gax
CGCM2 ga1,2,3
CGCM2 gax
CSIROMK2b ga1
HadCM2 ga1,2,3,4
HadCM2 gax
HadCM3 ga1
CGCM2 A21,A22,A23
CGCM2 A2X
CSIROMK2b A11
CSIROMK2b A21
HadCM3 A21
CGCM2 B21,B22,B23
CGCM2 B2X
CSIROMK2b B11
CSIROMK2b B21
HadCM3 B21
CCCII 2 x CO2
GFDL(91)
GISS(95)

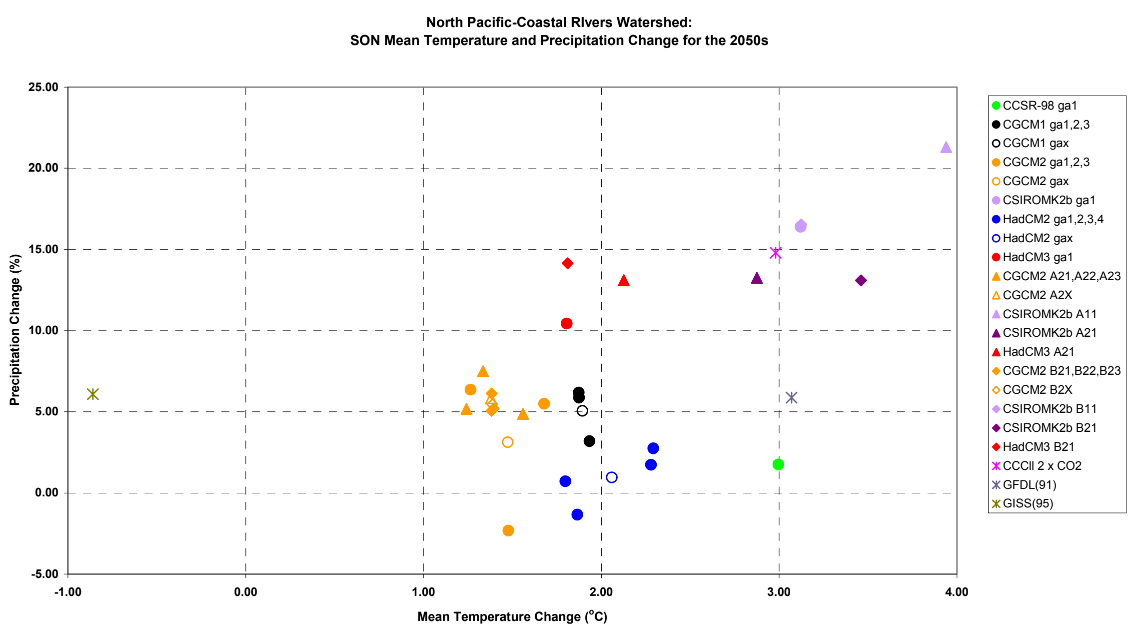

Yukon River-Porcupine River Watershed
SON Mean Temperature and Precipitation Change for the 2050s
Precipitation Change (%)
Mean Temperature Change (°C)
25.00
20.00
15.00
10.00
5.00
0.00
-2.00
-1.00
0.00
1.00
2.00
3.00
4.00
5.00
6.00
CCSR-98 ga1
CGCM1 ga1,2,3
CGCM1 gax
CGCM2 ga1,2,3
CGCM2 gax
CSIROMK2b ga1
HadCM2 ga1,2,3,4
HadCM2 gax
HadCM3 ga1
CGCM2 A21,A22,A23
CGCM2 A2X
CSIROMK2b A11
CSIROMK2b A21
HadCM3 A21
CGCM2 B21,B22,B23
CGCM2 B2X
CSIROMK2b B11
CSIROMK2b B21
HadCM3 B21
CCCII 2 x CO2
GFDL(91)
GISS(95)

North Pacific and Coastal Rivers Watershed Seasonal Scatterplots

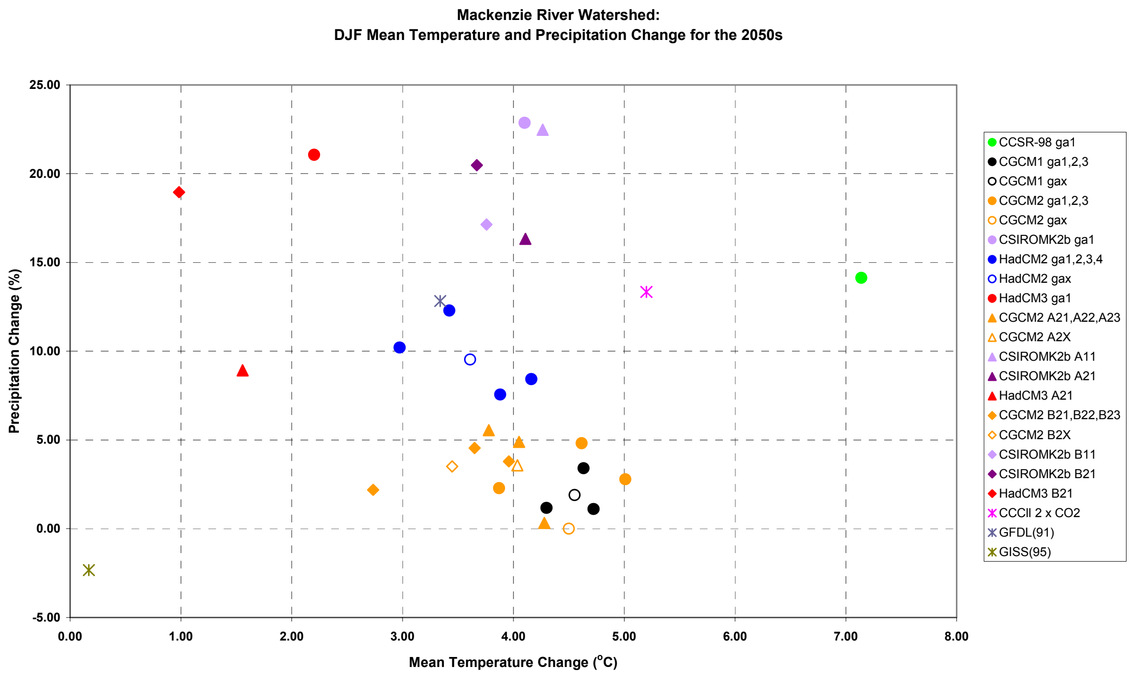


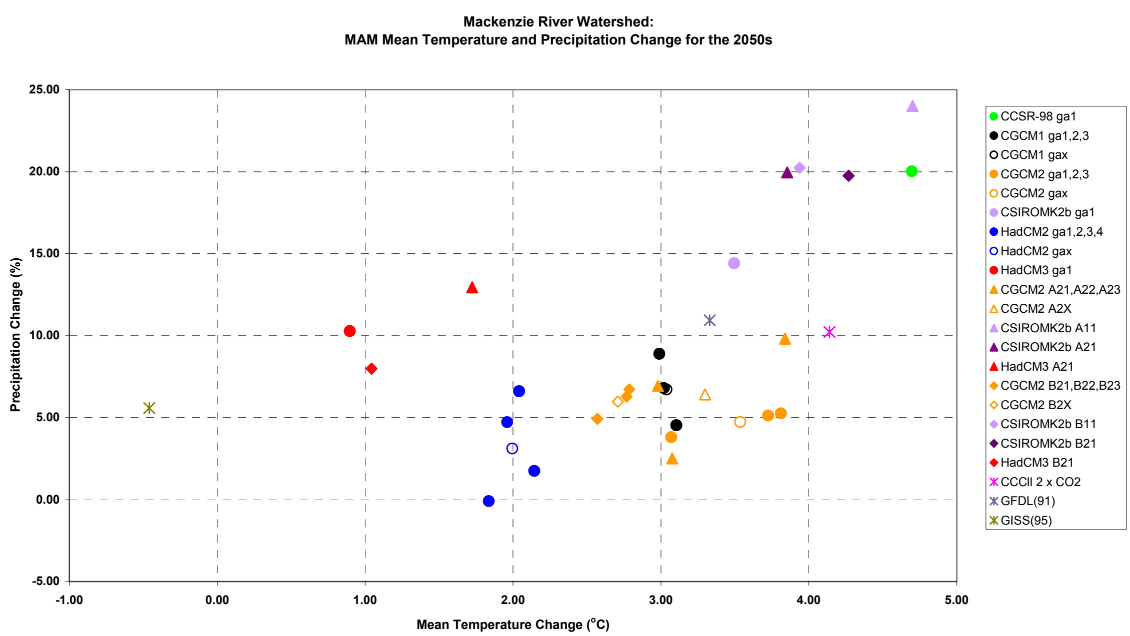


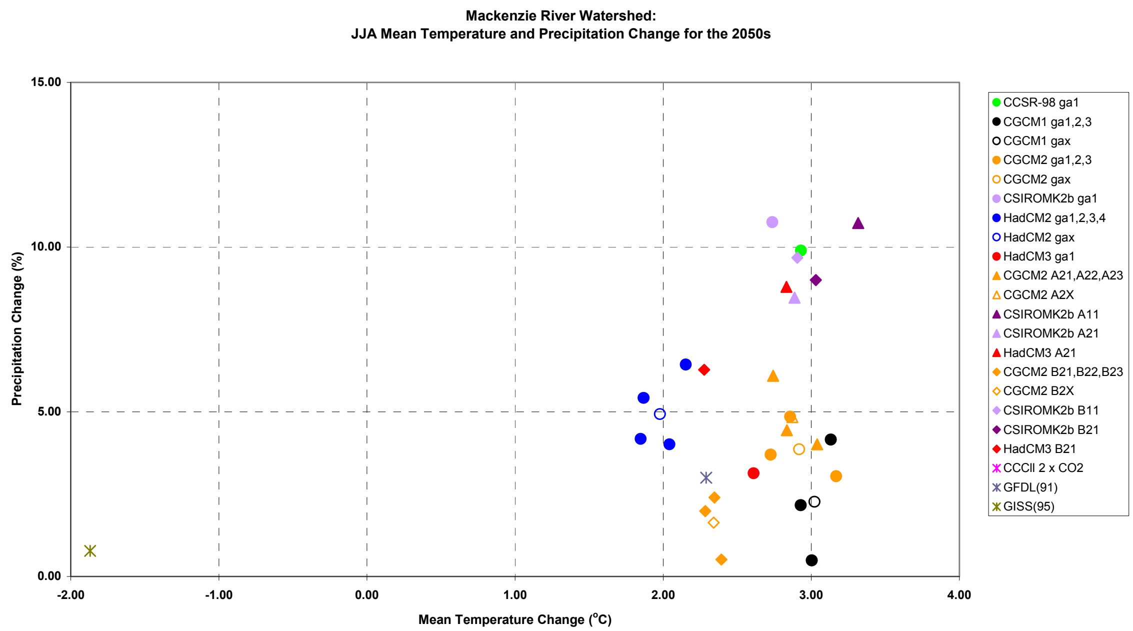

North Pacific-Coastal RIvers Watershed:
JJA Mean Temperature and Precipitation Change for the 2050s
Precipitation Change (%)
Mean Temperature Change (°C)
20.00
15.00
10.00
5.00
0.00
-5.00
-10.00
-3.00
-2.00
-1.00
0.00
1.00
2.00
3.00
4.00
CCSR-98 ga1
CGCM1 ga1,2,3
CGCM1 gax
CGCM2 ga1,2,3
CGCM2 gax
CSIROMK2b ga1
HadCM2 ga1,2,3,4
HadCM2 gax
HadCM3 ga1
CGCM2 A21,A22,A23
CGCM2 A2X
CSIROMK2b A11
CSIROMK2b A21
HadCM3 A21
CGCM2 B21,B22,B23
CGCM2 B2X
CSIROMK2b B11
CSIROMK2b B21
HadCM3 B21
CCCII 2 x CO2
GFDL(91)
GISS(95)


North Pacific-Coastal RIvers Watershed:
SON Mean Temperature and Precipitation Change for the 2050s
Precipitation Change (%)
Mean Temperature Change (°C)
25.00
20.00
15.00
10.00
5.00
0.00
-5.00
-1.00
0.00
1.00
2.00
3.00
4.00
CCSR-98 ga1
CGCM1 ga1,2,3
CGCM1 gax
CGCM2 ga1,2,3
CGCM2 gax
CSIROMK2b ga1
HadCM2 ga1,2,3,4
HadCM2 gax
HadCM3 ga1
CGCM2 A21,A22,A23
CGCM2 A2X
CSIROMK2b A11
CSIROMK2b A21
HadCM3 A21
CGCM2 B21,B22,B23
CGCM2 B2X
CSIROMK2b B11
CSIROMK2b B21
HadCM3 B21
CCCII 2 x CO2
GFDL(91)
GISS(95)

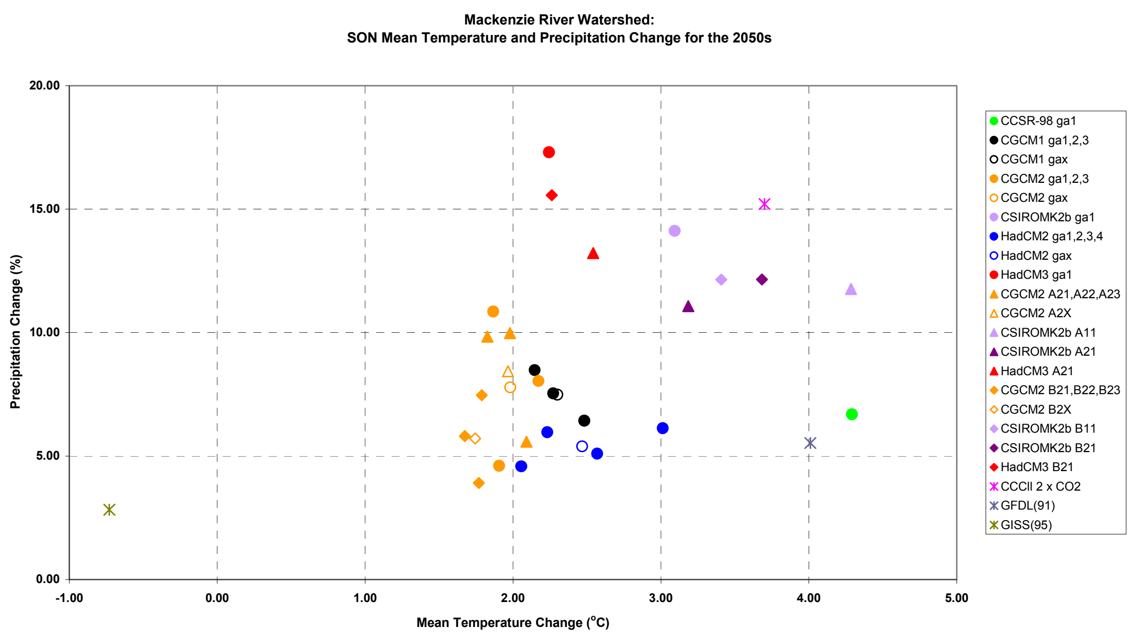
Mackenzie River Watershed Seasonal Scatterplots





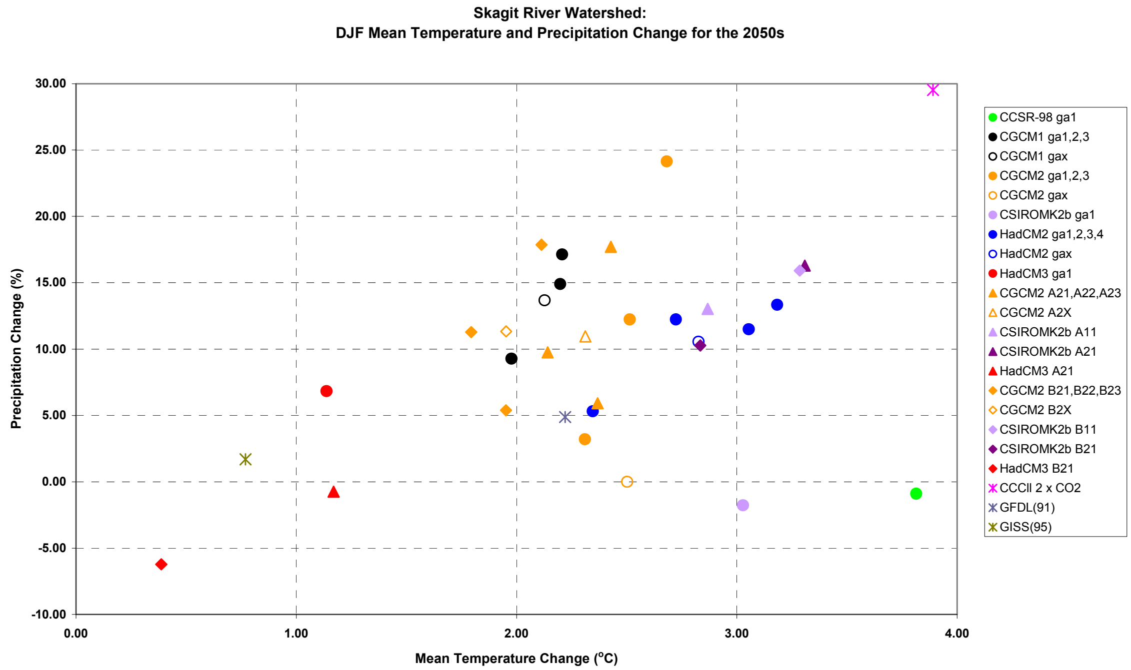


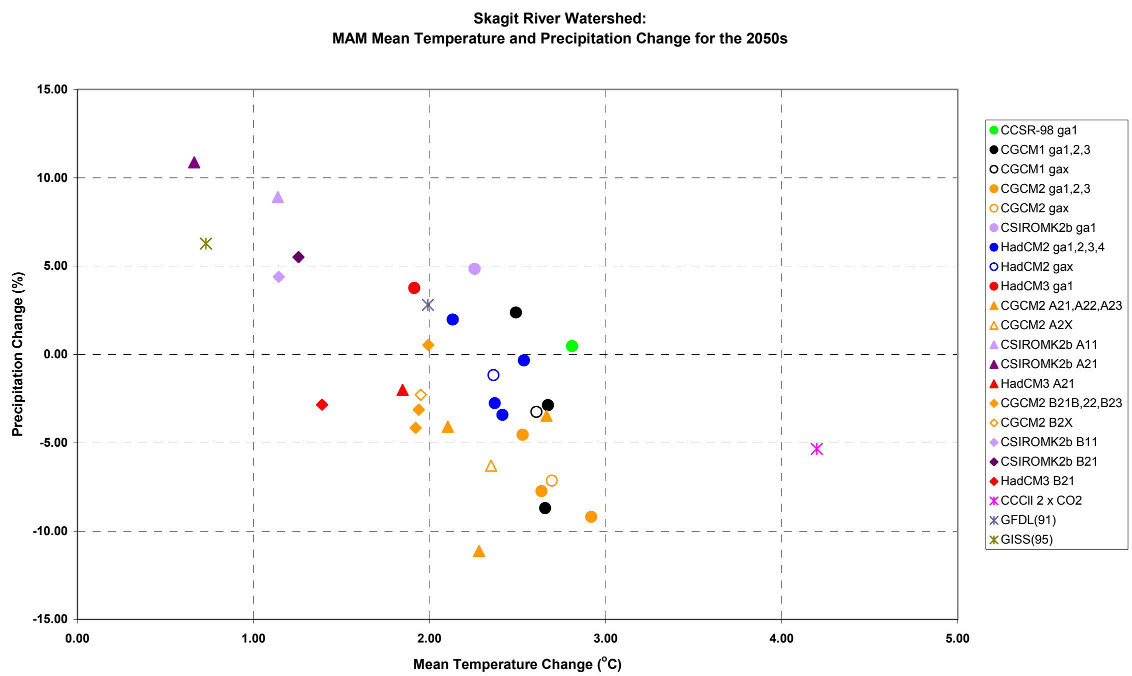
Mackenzie River Watershed:
JJA Mean Temperature and Precipitation Change for the 2050s
Precipitation Change (%)
15.00
10.00
5.00
0.00
-2.00
-1.00
0.00
1.00
2.00
3.00
4.00
Mean Temperature Change (°C)
CCSR-98 ga1
CGCM1 ga1,2,3
CGCM1 gax
CGCM2 ga1,2,3
CGCM2 gax
CSIROMK2b ga1
HadCM2 ga1,2,3,4
HadCM2 gax
HadCM3 ga1
CGCM2 A21,A22,A23
CGCM2 A2X
CSIROMK2b A11
CSIROMK2b A21
HadCM3 A21
CGCM2 B21,B22,B23
CGCM2 B2X
CSIROMK2b B11
CSIROMK2b B21
HadCM3 B21
CCCII 2 x CO2
GFDL(91)
GISS(95)

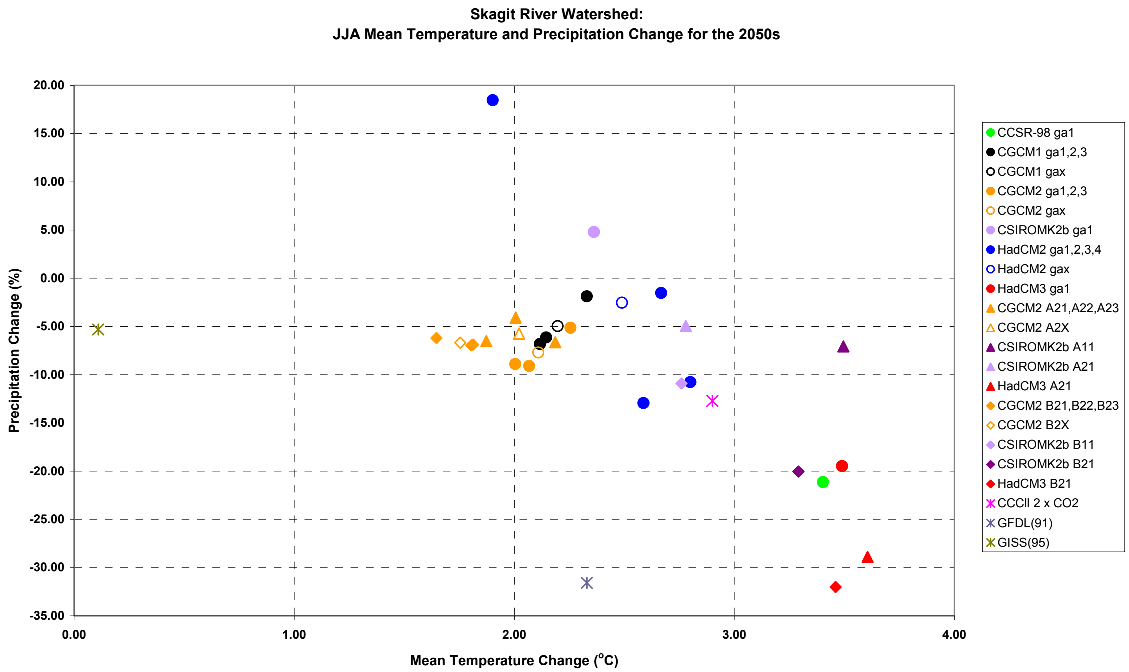


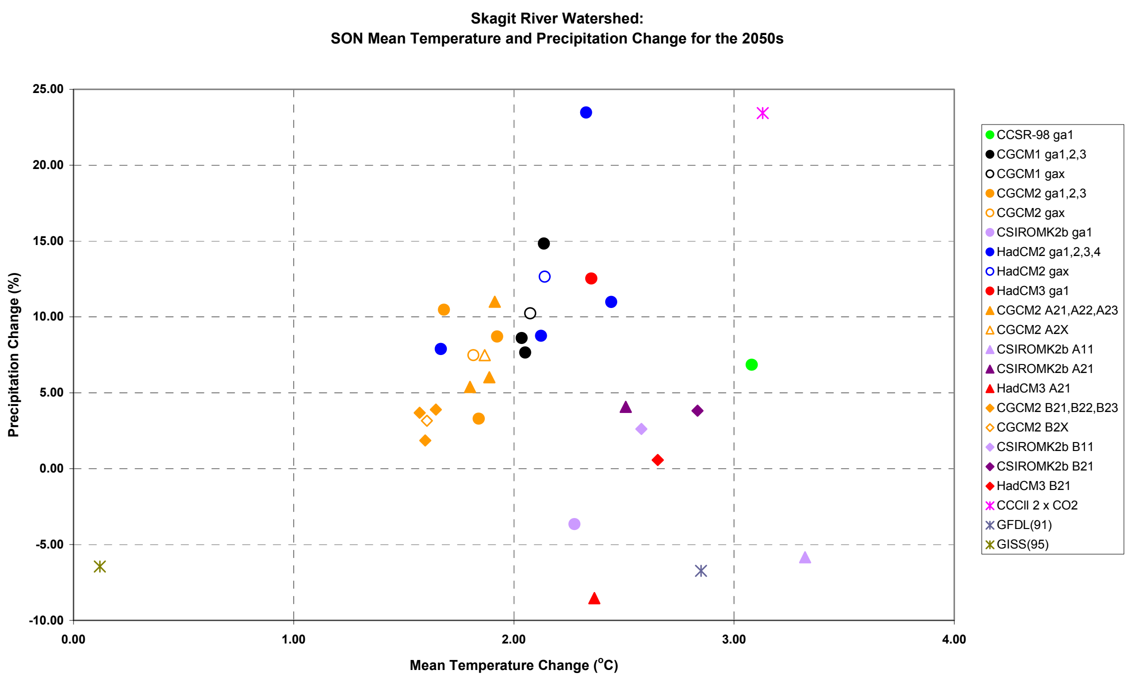
Mackenzie River Watershed:
SON Mean Temperature and Precipitation Change for the 2050s
Precipitation Change (%)
20.00
15.00
10.00
5.00
0.00
-1.00
0.00
1.00
2.00
3.00
4.00
5.00
Mean Temperature Change (°C)
CCSR-98 ga1
CGCM1 ga1,2,3
CGCM1 gax
CGCM2 ga1,2,3
CGCM2 gax
CSIROMK2b ga1
HadCM2 ga1,2,3,4
HadCM2 gax
HadCM3 ga1
CGCM2 A21,A22,A23
CGCM2 A2X
CSIROMK2b A11
CSIROMK2b A21
HadCM3 A21
CGCM2 B21,B22,B23
CGCM2 B2X
CSIROMK2b B11
CSIROMK2b B21
HadCM3 B21
CCCII 2 x CO2
GFDL(91)
GISS(95)

Skagit River Watershed Seasonal Scatterplots

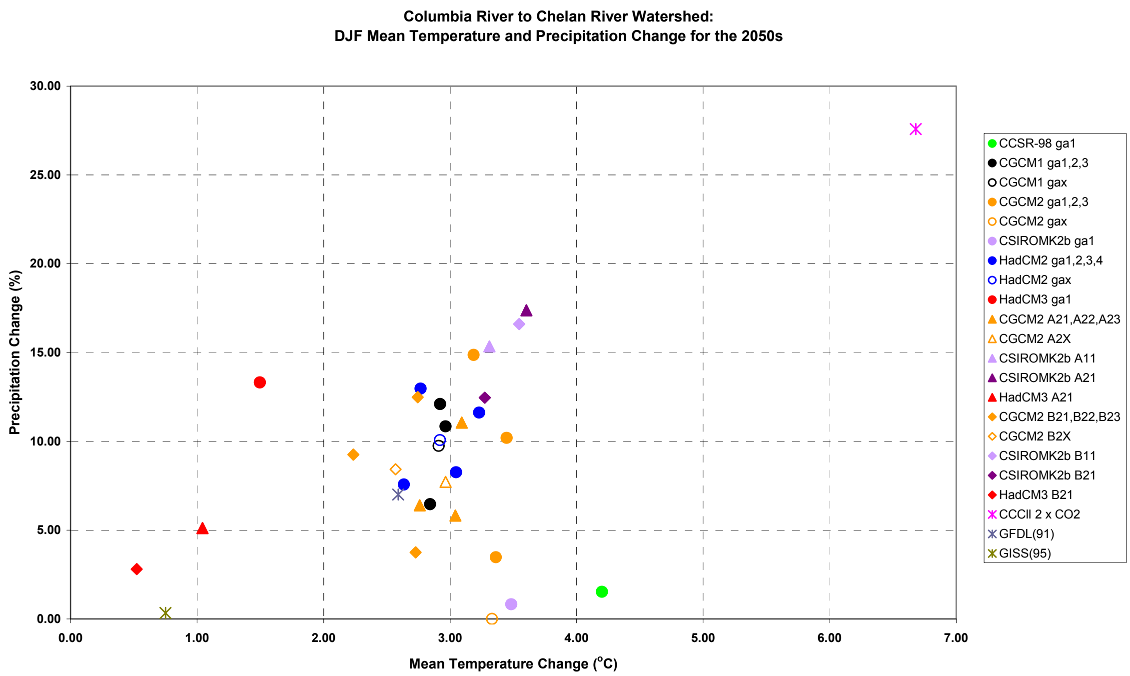


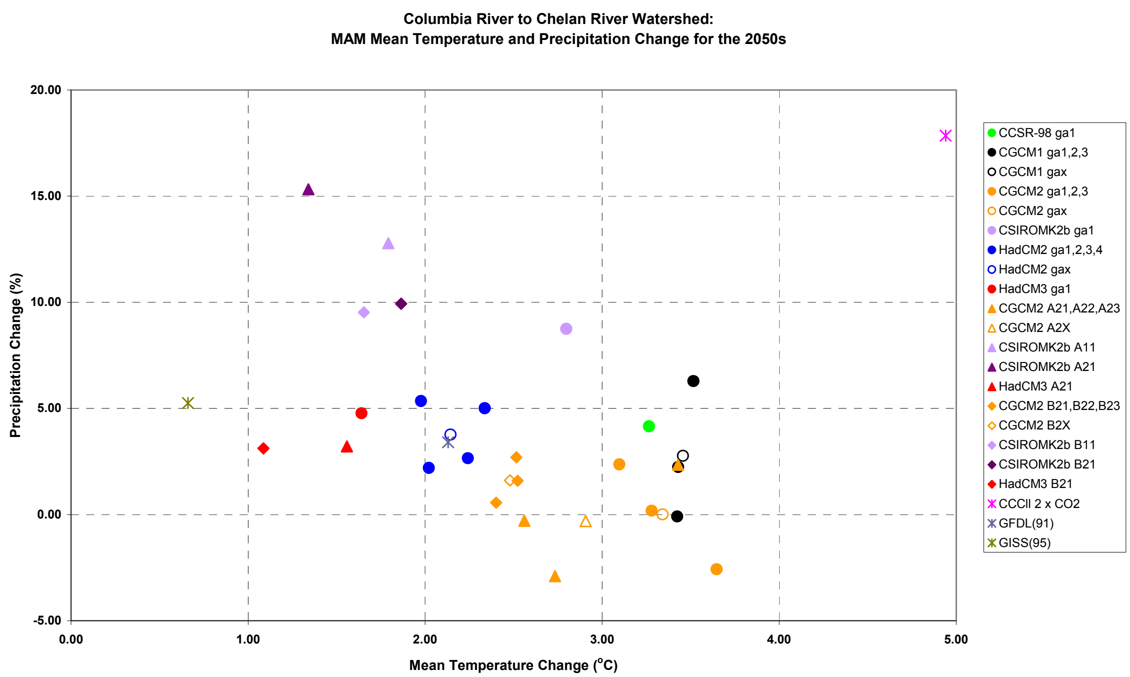



Skagit River Watershed:
JJA Mean Temperature and Precipitation Change for the 2050s
Precipitation Change (%)
Mean Temperature Change (°C)
20.00
15.00
10.00
5.00
0.00
-5.00
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
0.00
1.00
2.00
3.00
4.00
CCSR-98 ga1
CGCM1 ga1,2,3
CGCM1 gax
CGCM2 ga1,2,3
CGCM2 gax
CSIROMK2b ga1
HadCM2 ga1,2,3,4
HadCM2 gax
HadCM3 ga1
CGCM2 A21,A22,A23
CGCM2 A2X
CSIROMK2b A11
CSIROMK2b A21
HadCM3 A21
CGCM2 B21,B22,B23
CGCM2 B2X
CSIROMK2b B11
CSIROMK2b B21
HadCM3 B21
CCCII 2 x CO2
GFDL(91)
GISS(95)

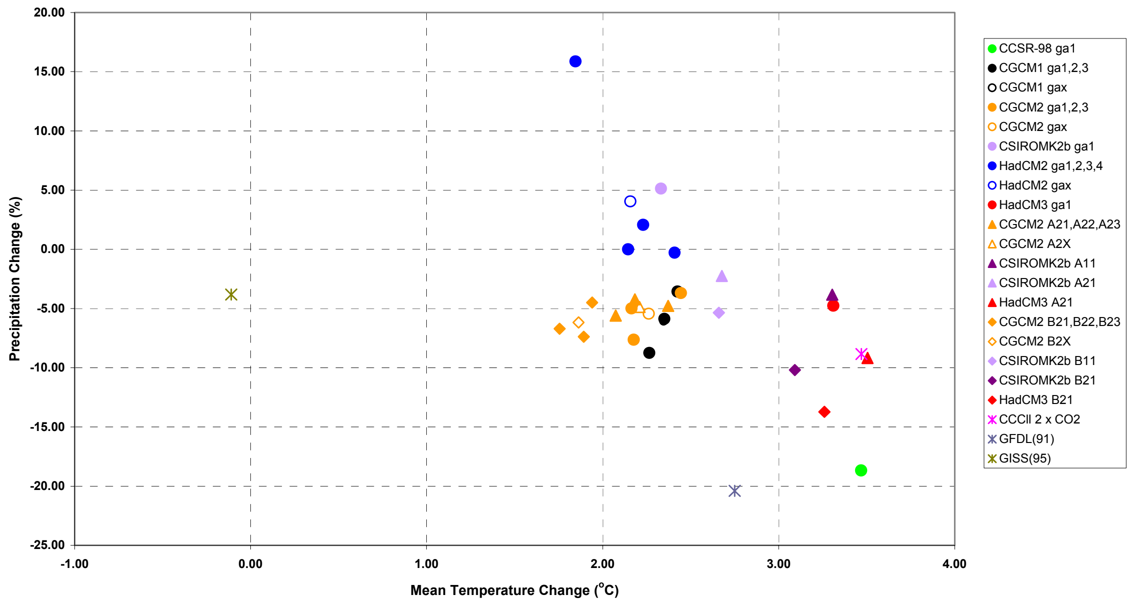

Skagit River Watershed:
SON Mean Temperature and Precipitation Change for the 2050s
Precipitation Change (%)
Mean Temperature Change (°C)
25.00
20.00
15.00
10.00
5.00
0.00
-5.00
-10.00
0.00
1.00
2.00
3.00
4.00
CCSR-98 ga1
CGCM1 ga1,2,3
CGCM1 gax
CGCM2 ga1,2,3
CGCM2 gax
CSIROMK2b ga1
HadCM2 ga1,2,3,4
HadCM2 gax
HadCM3 ga1
CGCM2 A21,A22,A23
CGCM2 A2X
CSIROMK2b A11
CSIROMK2b A21
HadCM3 A21
CGCM2 B21,B22,B23
CGCM2 B2X
CSIROMK2b B11
CSIROMK2b B21
HadCM3 B21
CCCII 2 x CO2
GFDL(91)
GISS(95)

Columbia River Watershed Seasonal Scatterplots

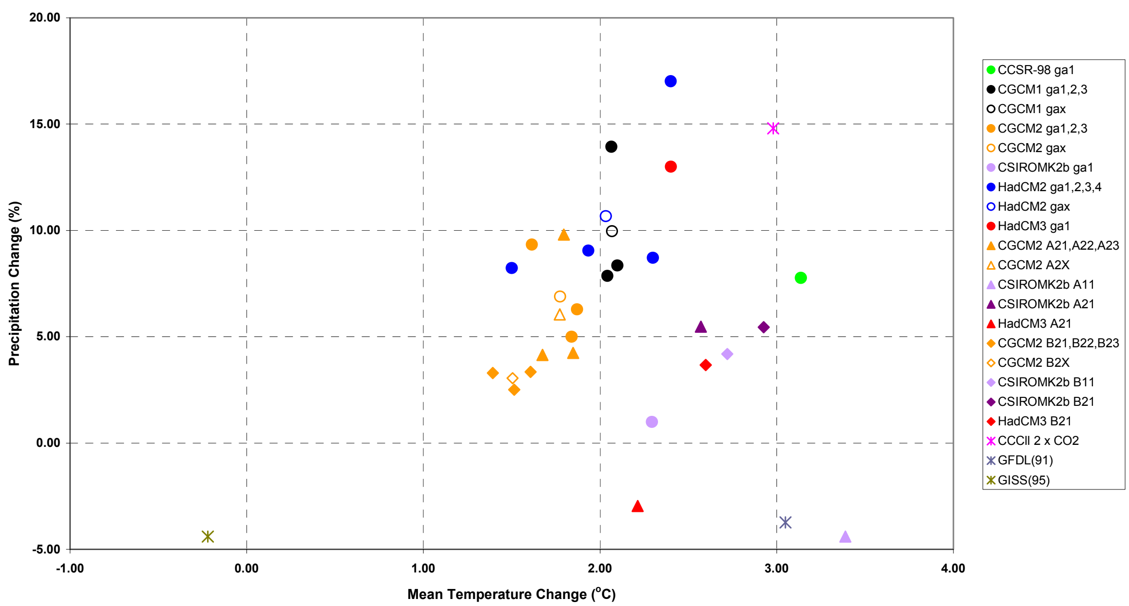




Columbia River to Chelan River Watershed:
JJA Mean Temperature and Precipitation Change for the 2050s

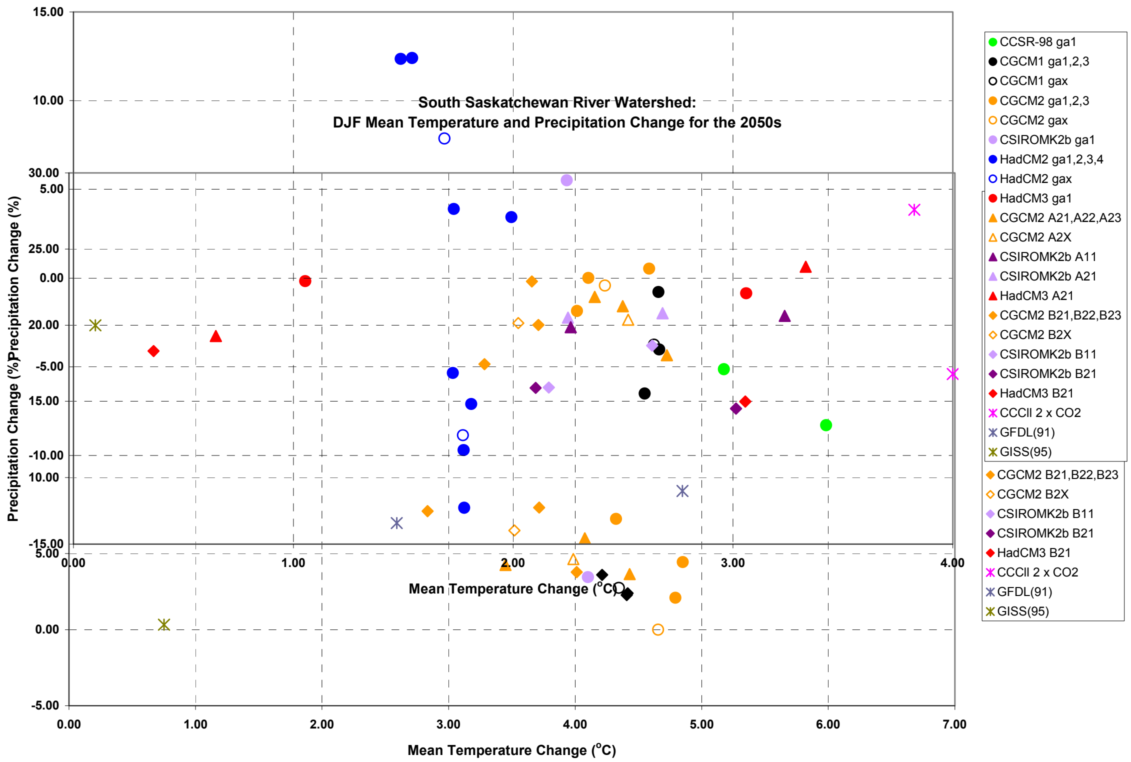


Columbia River to Chelan River Watershed:
SON Mean Temperature and Precipitation Change for the 2050s

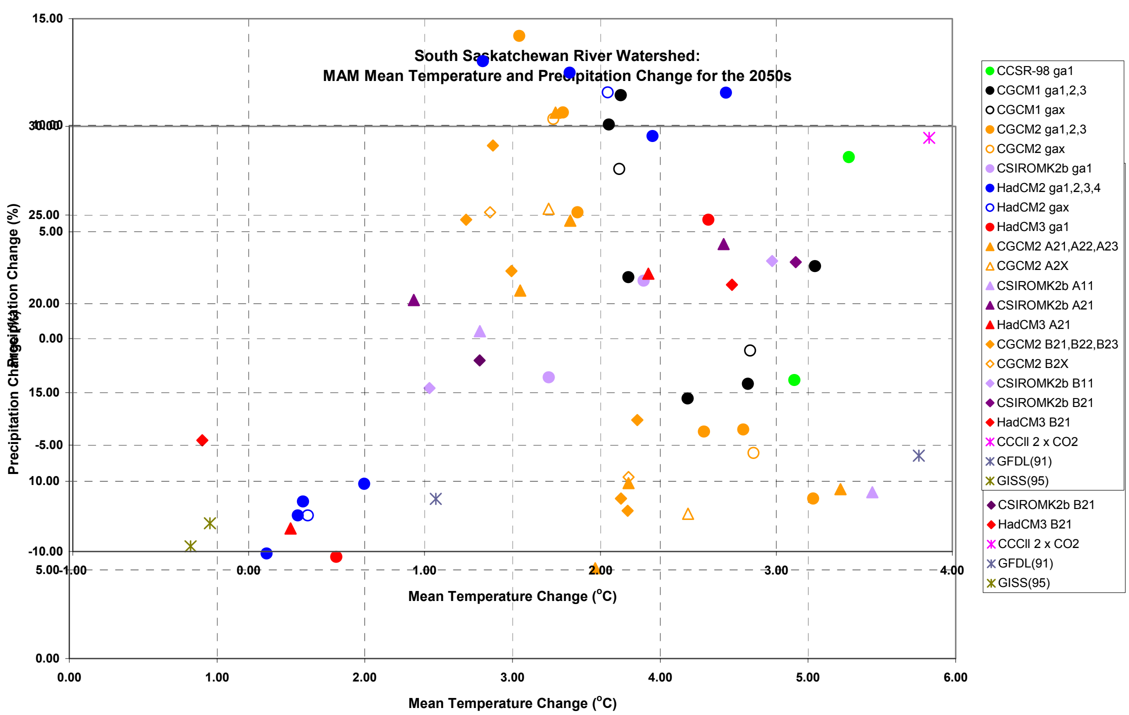


South Saskatchewan River Watershed Seasonal Scatterplots

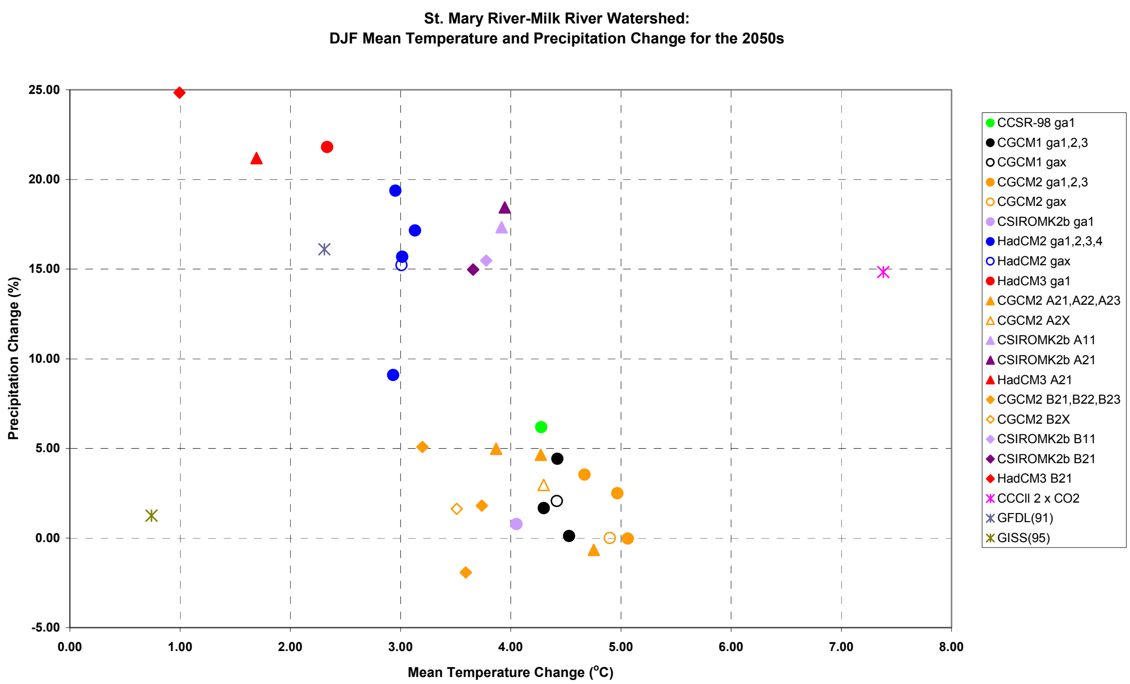
South Saskatchewan River Watershed:
JJA Mean Temperature and Precipitation Change for the 2050s

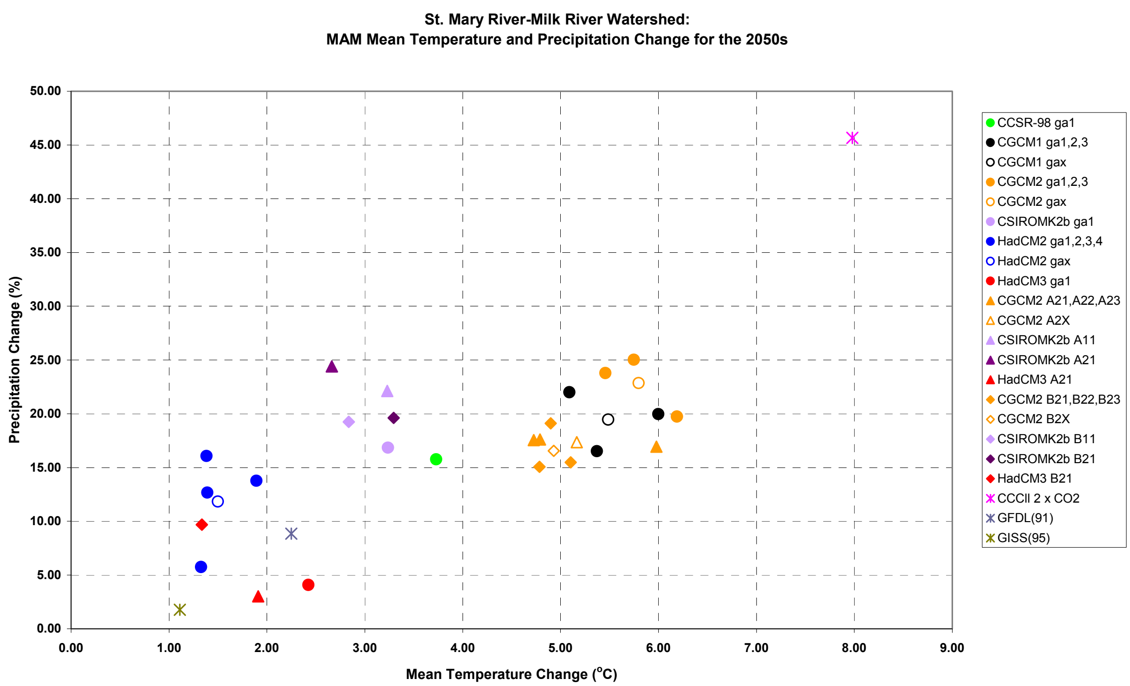


South Sakatchewan River Watershed:
SON Mean Temperature and Precipitation Change for the 2050s

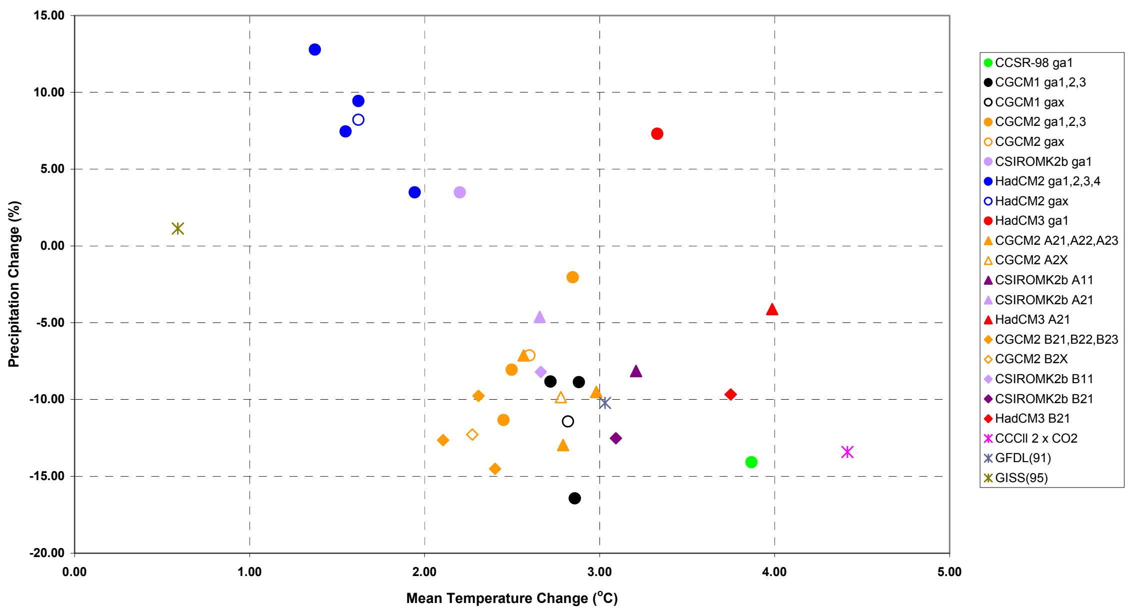


St. Mary River-Milk River Watershed Seasonal Scatterplots

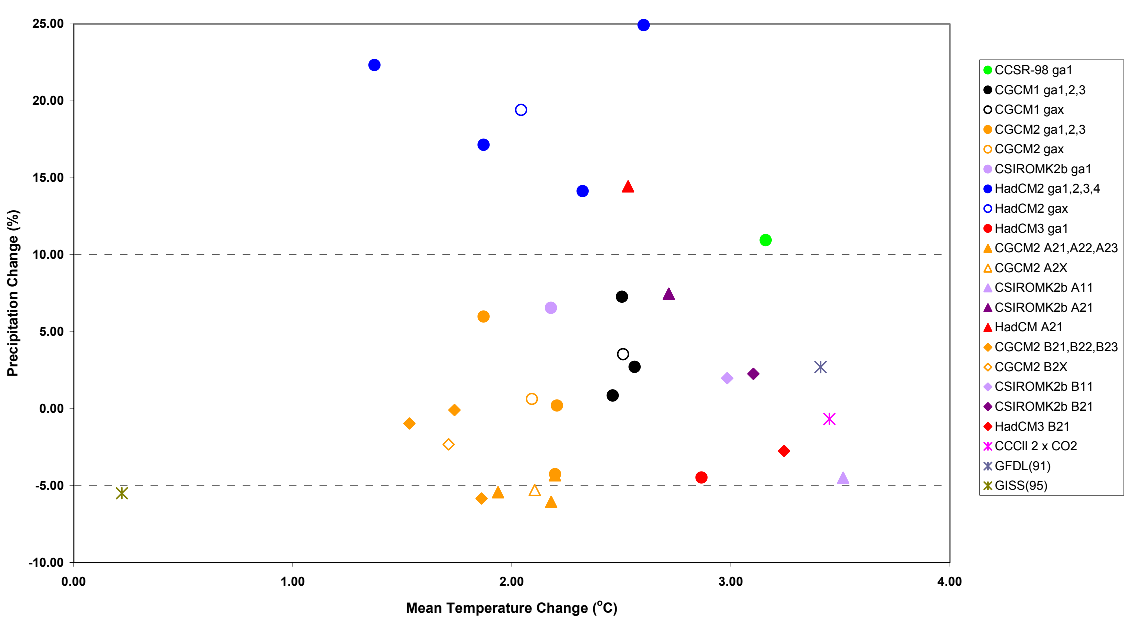




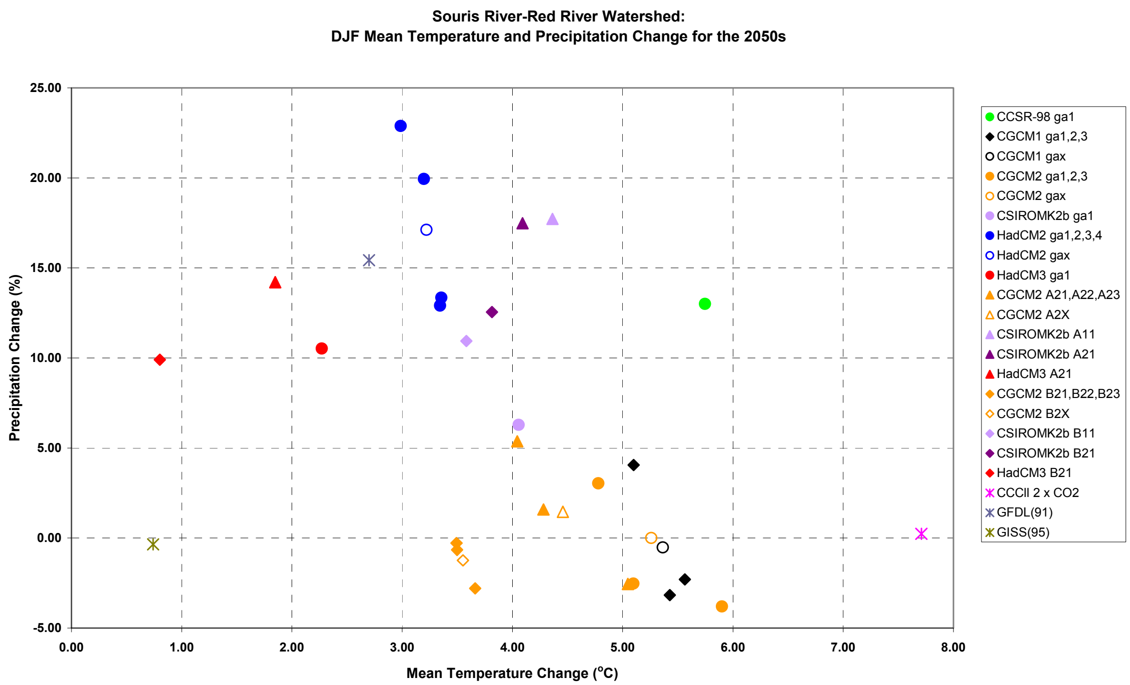
St. Mary River-Milk River Watershed:
JJA Mean Temperature and Precipitation Change for the 2050s

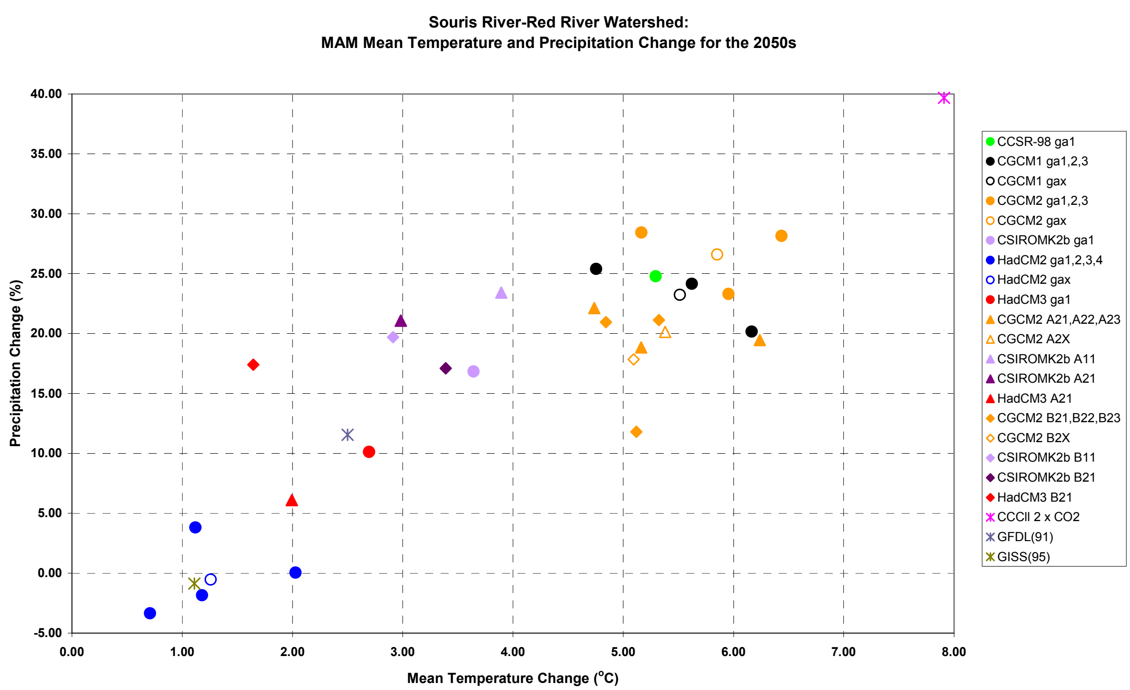


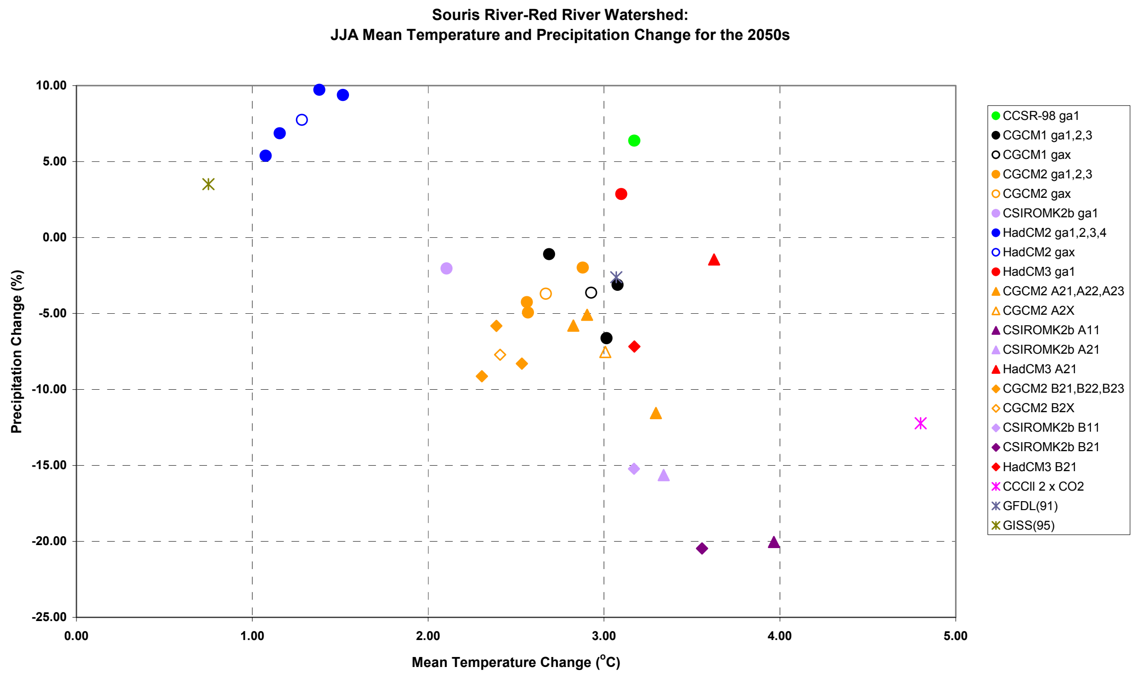
St. Mary River-Milk River Watershed:
SON Mean Temperature and Precipitation Change for the 2050s

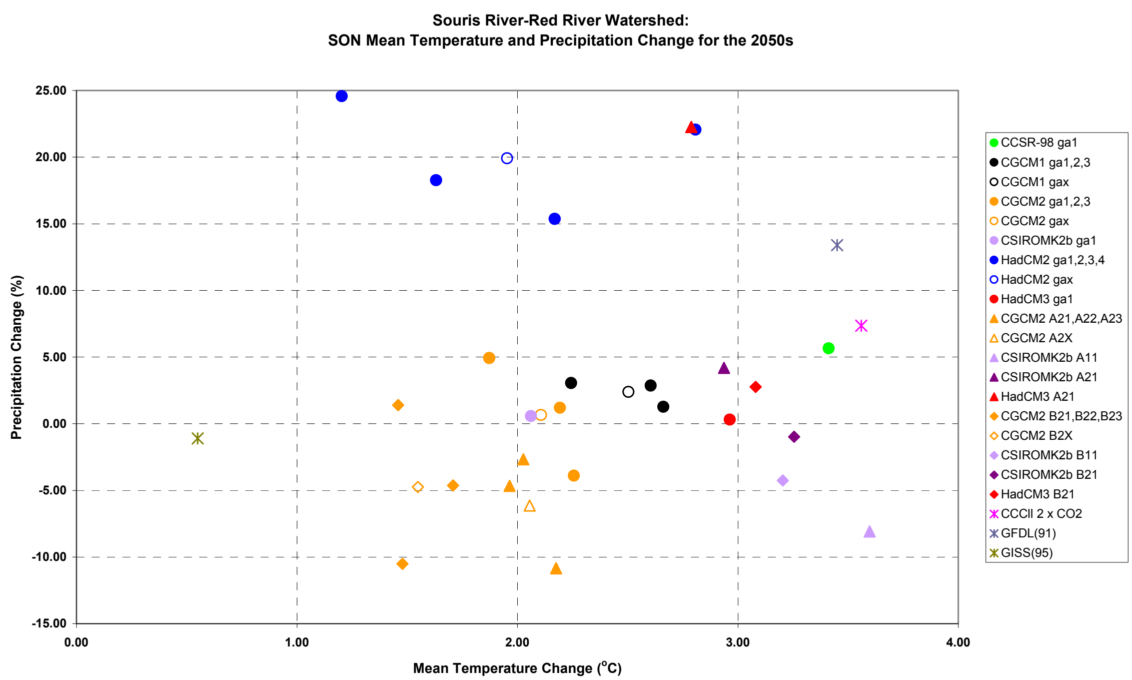


Souris River-Red River Watershed Seasonal Scatterplots

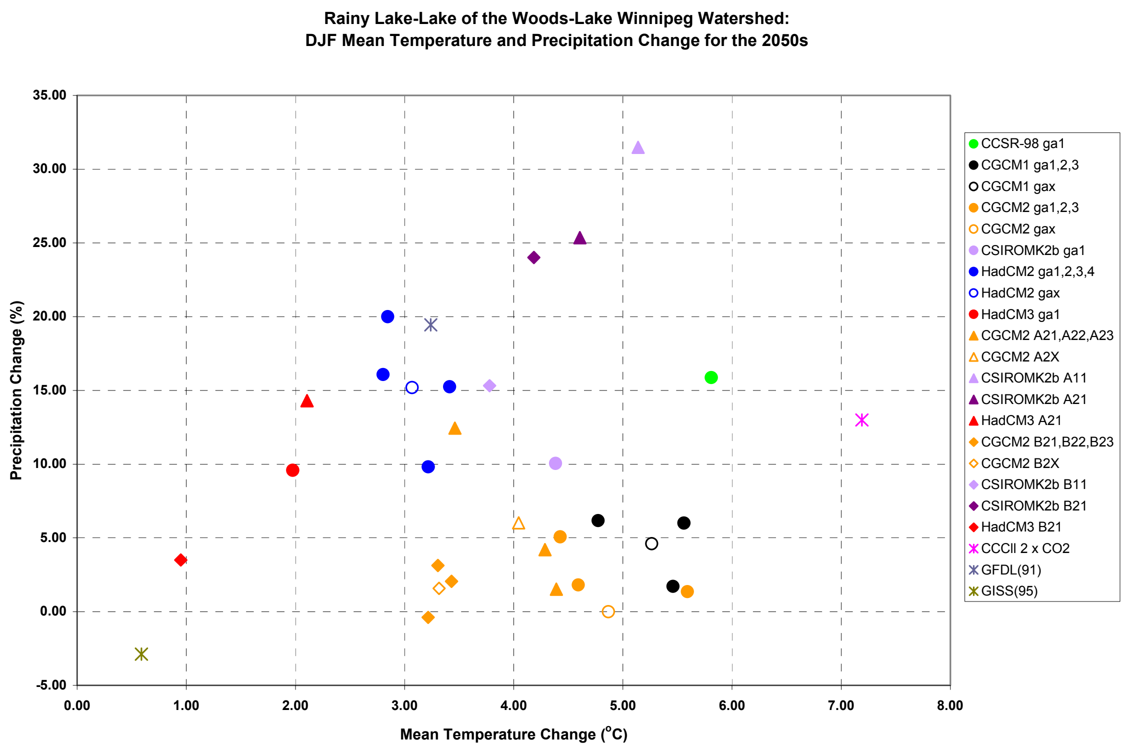


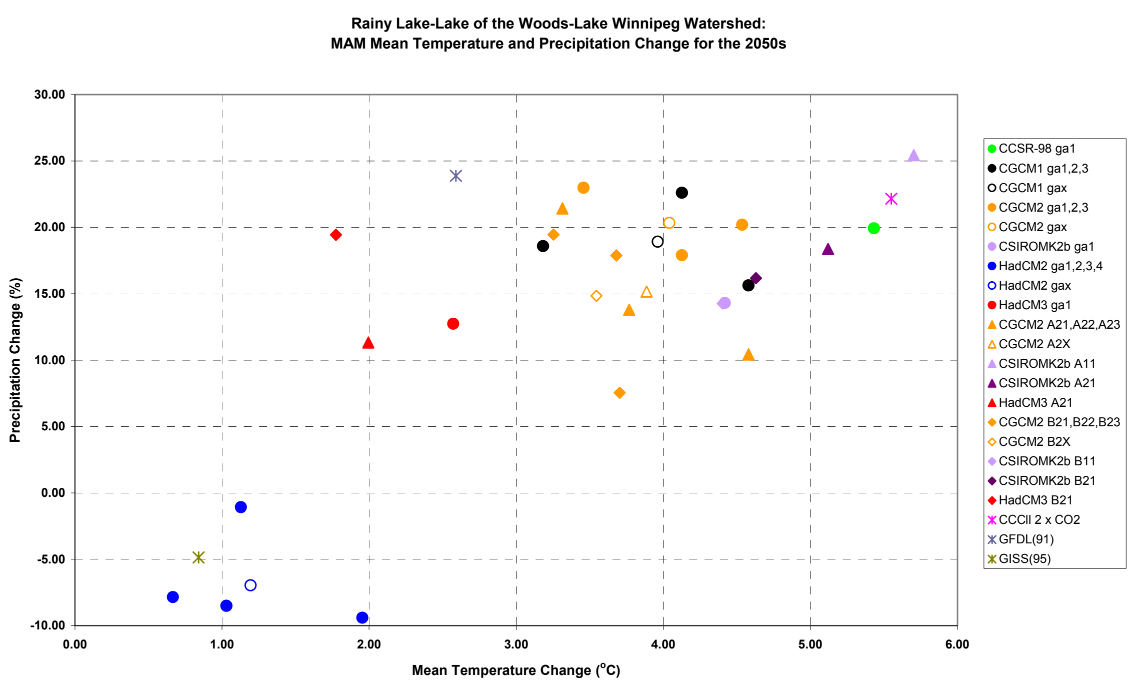


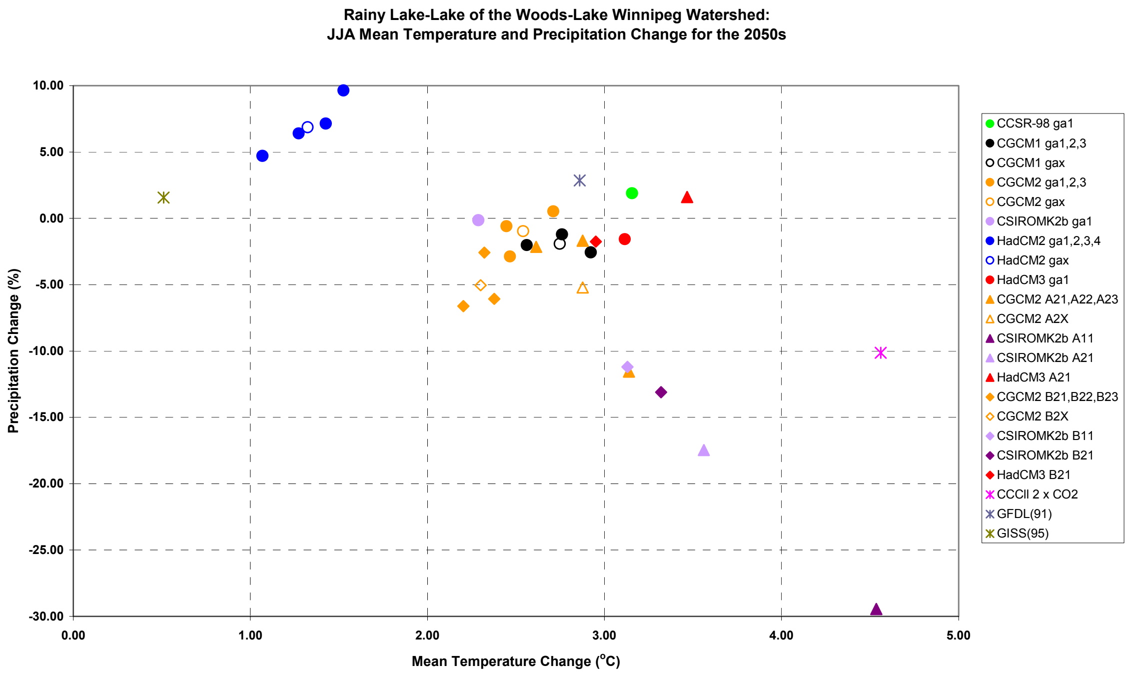

Souris River-Red River Watershed:
JJA Mean Temperature and Precipitation Change for the 2050s
Precipitation Change (%)
Mean Temperature Change (°C)
10.00
5.00
0.00
-5.00
-10.00
-15.00
-20.00
-25.00
0.00
1.00
2.00
3.00
4.00
5.00
CCSR-98 ga1
CGCM1 ga1,2,3
CGCM1 gax
CGCM2 ga1,2,3
CGCM2 gax
CSIROMK2b ga1
HadCM2 ga1,2,3,4
HadCM2 gax
HadCM3 ga1
CGCM2 A21,A22,A23
CGCM2 A2X
CSIROMK2b A11
CSIROMK2b A21
HadCM3 A21
CGCM2 B21,B22,B23
CGCM2 B2X
CSIROMK2b B11
CSIROMK2b B21
HadCM3 B21
CCCII 2 x CO2
GFDL(91)
GISS(95)

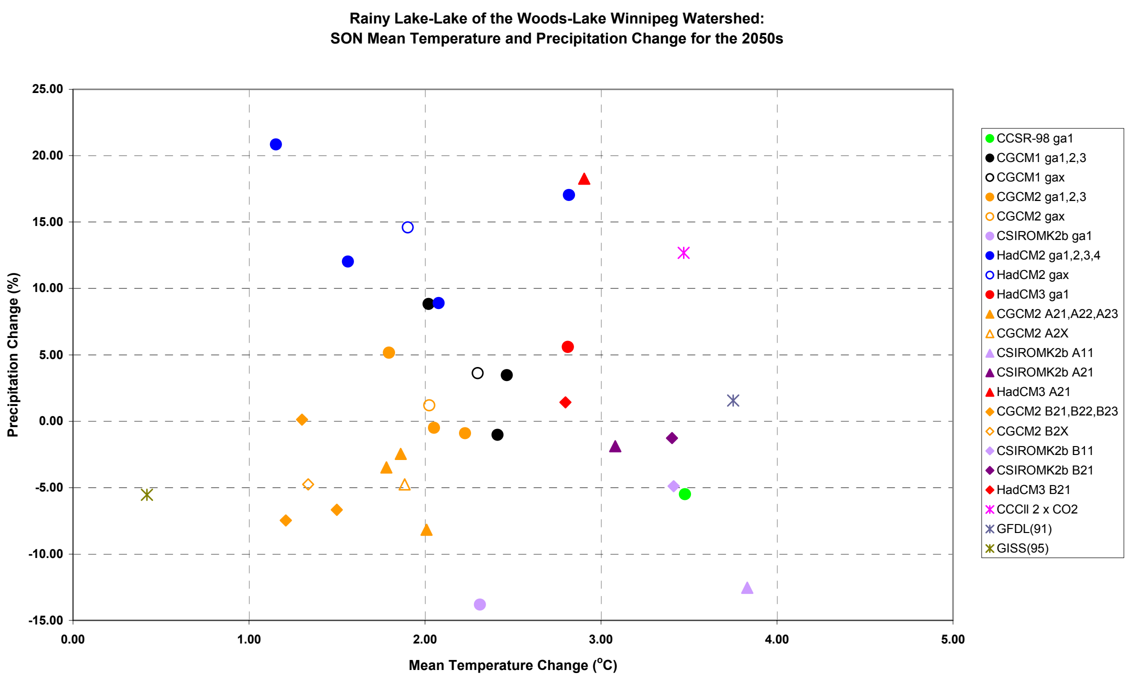

Souris River-Red River Watershed:
SON Mean Temperature and Precipitation Change for the 2050s
Precipitation Change (%)
Mean Temperature Change (°C)
25.00
20.00
15.00
10.00
5.00
0.00
-5.00
-10.00
-15.00
0.00
1.00
2.00
3.00
4.00
CCSR-98 ga1
CGCM1 ga1,2,3
CGCM1 gax
CGCM2 ga1,2,3
CGCM2 gax
CSIROMK2b ga1
HadCM2 ga1,2,3,4
HadCM2 gax
HadCM3 ga1
CGCM2 A21,A22,A23
CGCM2 A2X
CSIROMK2b A11
CSIROMK2b A21
HadCM3 A21
CGCM2 B21,B22,B23
CGCM2 B2X
CSIROMK2b B11
CSIROMK2b B21
HadCM3 B21
CCCII 2 x CO2
GFDL(91)
GISS(95)

Rainy Lake-Lake of the Woods-Lake Winnipeg Watershed Seasonal Scatterplots

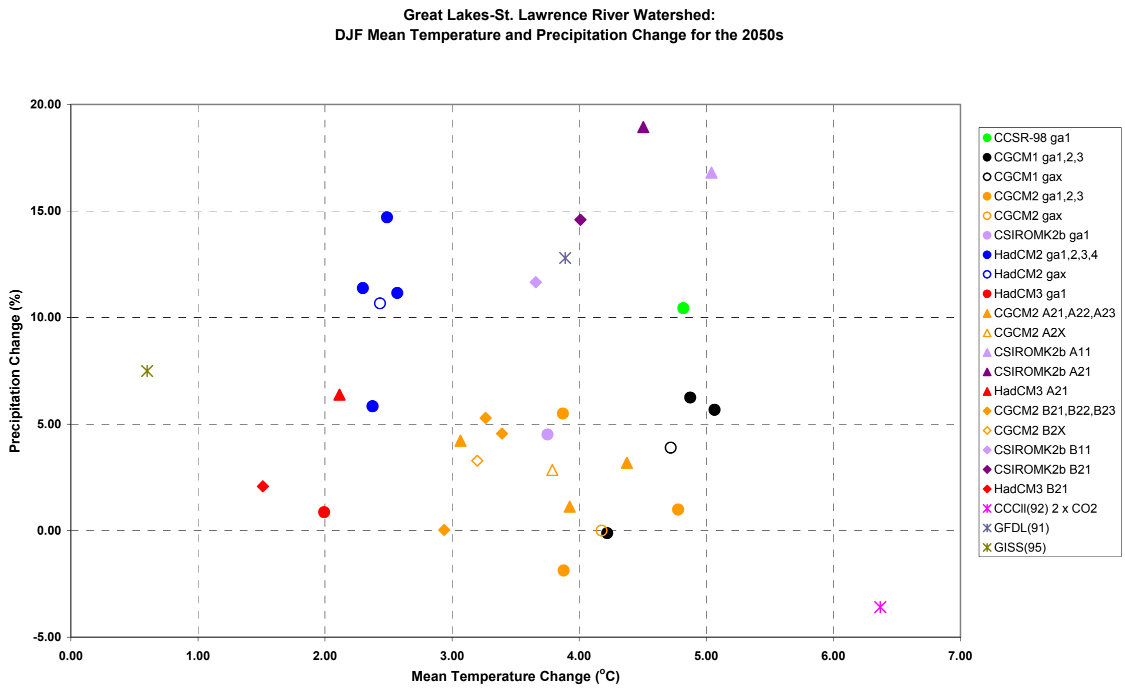


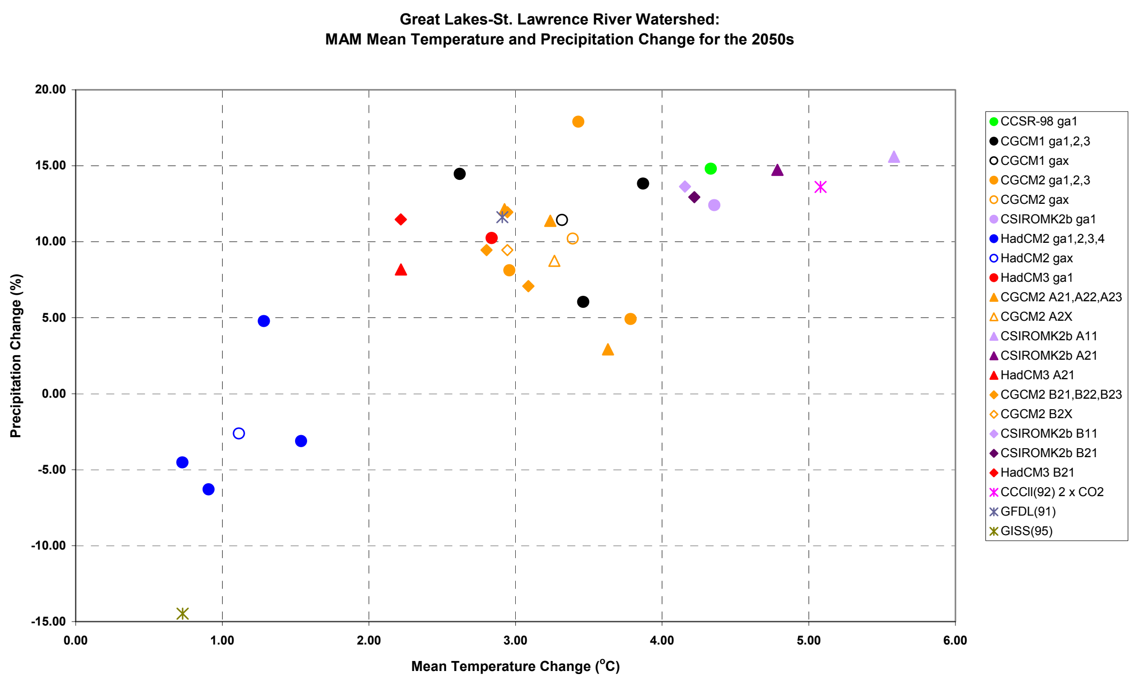


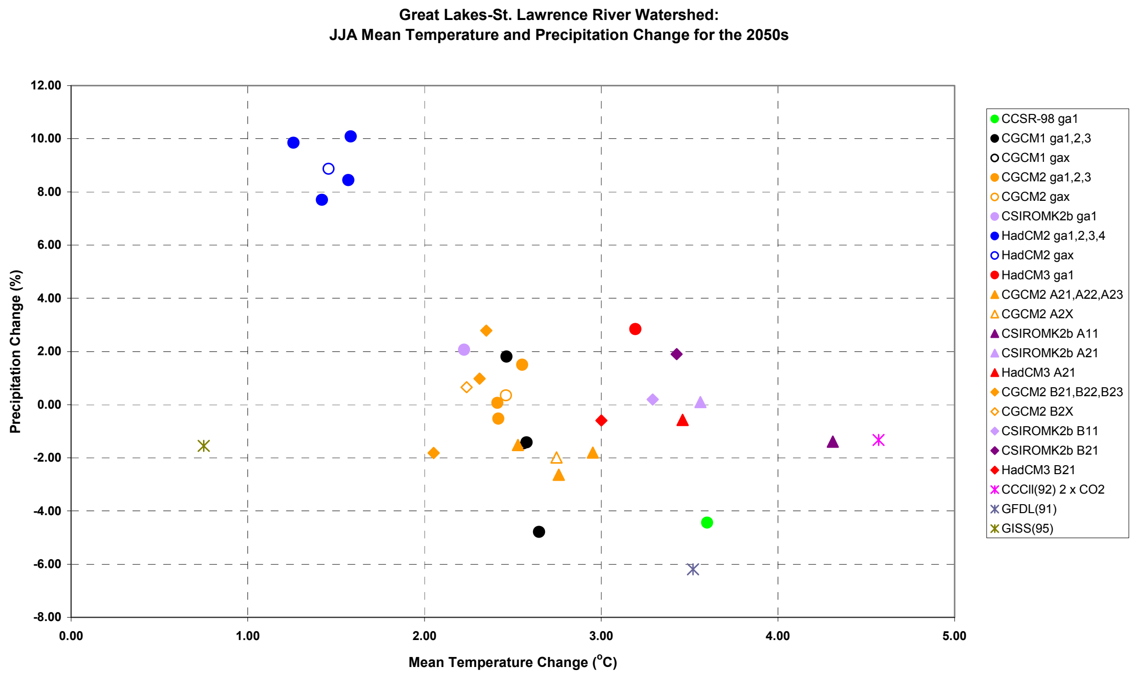

Rainy Lake-Lake of the Woods-Lake Winnipeg Watershed:
JJA Mean Temperature and Precipitation Change for the 2050s
Precipitation Change (%)
Mean Temperature Change (°C)
10.00
5.00
0.00
-5.00
-10.00
-15.00
-20.00
-25.00
-30.00
0.00
1.00
2.00
3.00
4.00
5.00
CCSR-98 ga1
CGCM1 ga1,2,3
CGCM1 gax
CGCM2 ga1,2,3
CGCM2 gax
CSIROMK2b ga1
HadCM2 ga1,2,3,4
HadCM2 gax
HadCM3 ga1
CGCM2 A21,A22,A23
CGCM2 A2X
CSIROMK2b A11
CSIROMK2b A21
HadCM3 A21
CGCM2 B21,B22,B23
CGCM2 B2X
CSIROMK2b B11
CSIROMK2b B21
HadCM3 B21
CCCII 2 x CO2
GFDL(91)
GISS(95)

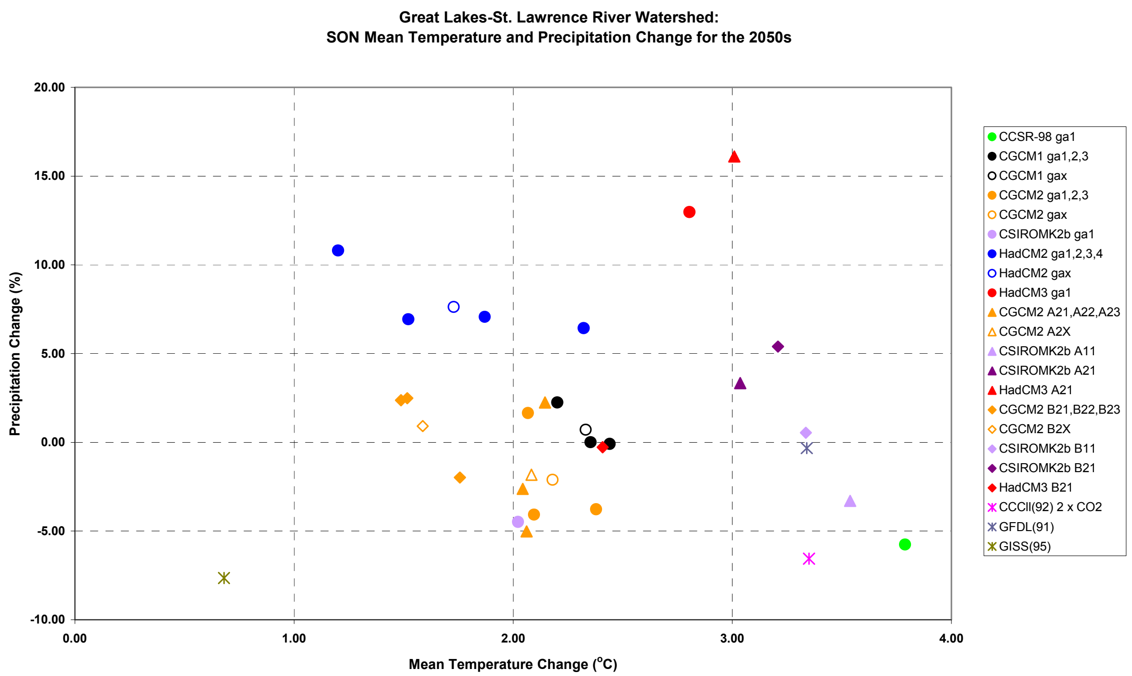

Rainy Lake-Lake of the Woods-Lake Winnipeg Watershed:
SON Mean Temperature and Precipitation Change for the 2050s
Precipitation Change (%)
Mean Temperature Change (°C)
25.00
20.00
15.00
10.00
5.00
0.00
-5.00
-10.00
-15.00
0.00
1.00
2.00
3.00
4.00
5.00
CCSR-98 ga1
CGCM1 ga1,2,3
CGCM1 gax
CGCM2 ga1,2,3
CGCM2 gax
CSIROMK2b ga1
HadCM2 ga1,2,3,4
HadCM2 gax
HadCM3 ga1
CGCM2 A21,A22,A23
CGCM2 A2X
CSIROMK2b A11
CSIROMK2b A21
HadCM3 A21
CGCM2 B21,B22,B23
CGCM2 B2X
CSIROMK2b B11
CSIROMK2b B21
HadCM3 B21
CCCII 2 x CO2
GFDL(91)
GISS(95)

Great Lakes-St. Lawrence River Watershed Seasonal Scatterplots

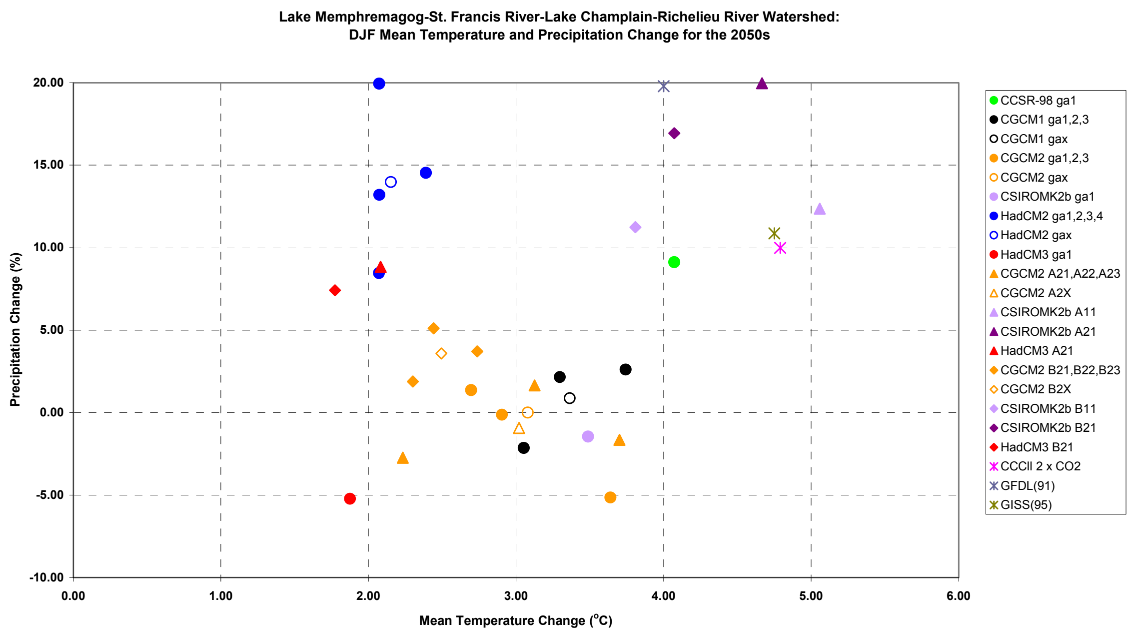


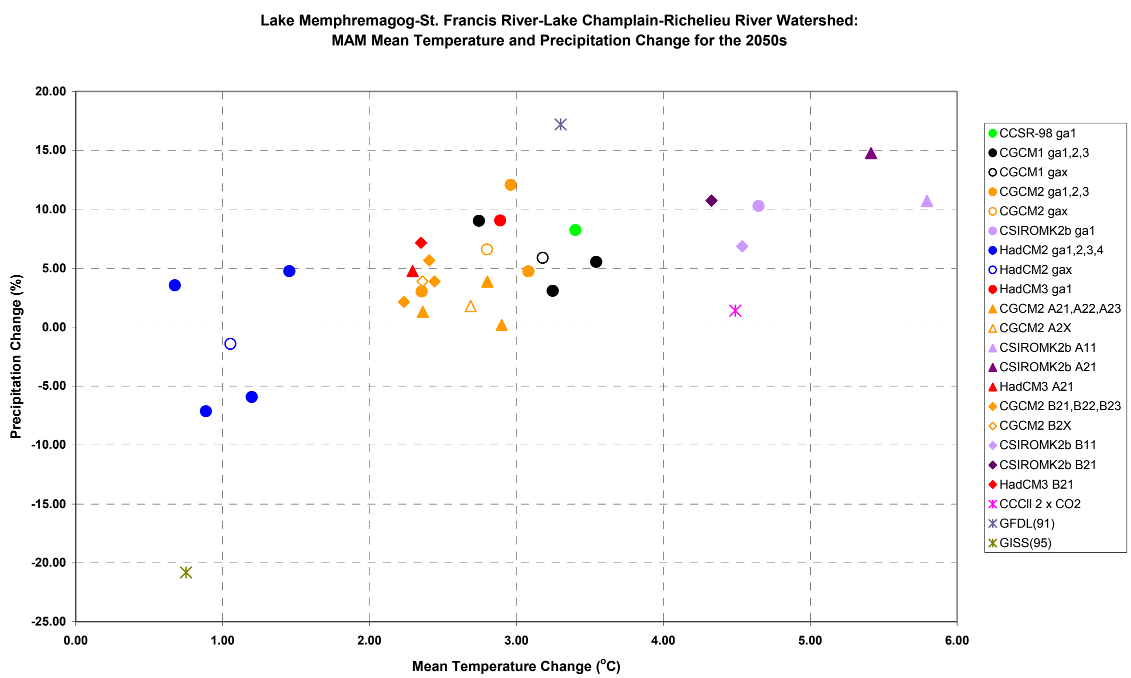



Great Lakes-St. Lawrence River Watershed:
JJA Mean Temperature and Precipitation Change for the 2050s
Precipitation Change (%)
Mean Temperature Change (°C)
12.00
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
-8.00
0.00
1.00
2.00
3.00
4.00
5.00
CCSR-98 ga1
CGCM1 ga1,2,3
CGCM1 gax
CGCM2 ga1,2,3
CGCM2 gax
CSIROMK2b ga1
HadCM2 ga1,2,3,4
HadCM2 gax
HadCM3 ga1
CGCM2 A21,A22,A23
CGCM2 A2X
CSIROMK2b A11
CSIROMK2b A21
HadCM3 A21
CGCM2 B21,B22,B23
CGCM2 B2X
CSIROMK2b B11
CSIROMK2b B21
HadCM3 B21
CCCII(92) 2 x CO2
GFDL(91)
GISS(95)

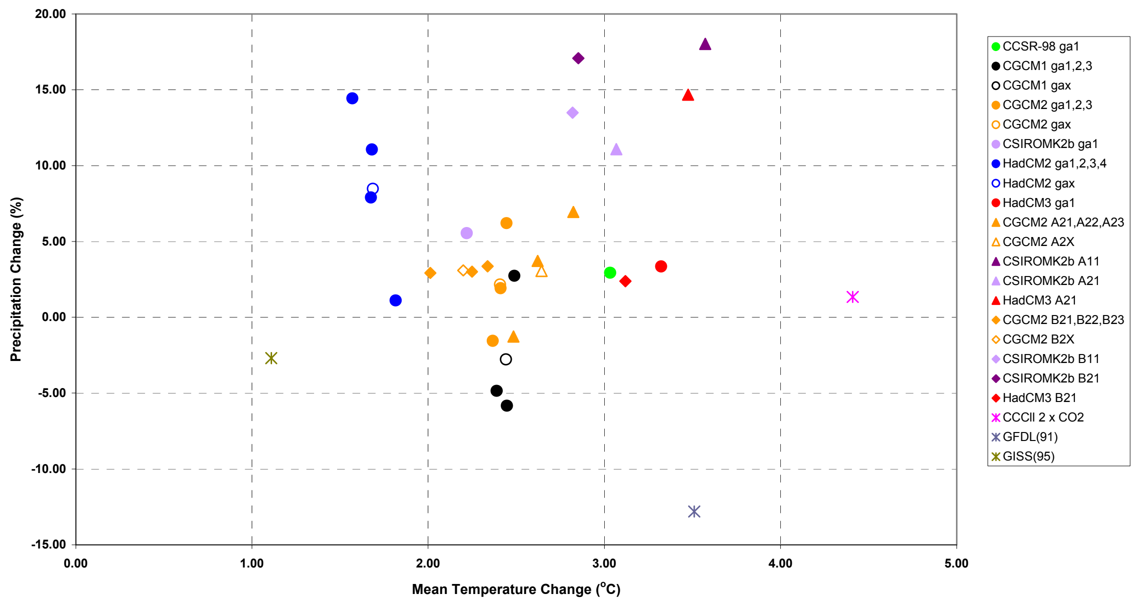

Great Lakes-St. Lawrence River Watershed:
SON Mean Temperature and Precipitation Change for the 2050s
Precipitation Change (%)
Mean Temperature Change (°C)
20.00
15.00
10.00
5.00
0.00
-5.00
-10.00
0.00
1.00
2.00
3.00
4.00
CCSR-98 ga1
CGCM1 ga1,2,3
CGCM1 gax
CGCM2 ga1,2,3
CGCM2 gax
CSIROMK2b ga1
HadCM2 ga1,2,3,4
HadCM2 gax
HadCM3 ga1
CGCM2 A21,A22,A23
CGCM2 A2X
CSIROMK2b A11
CSIROMK2b A21
HadCM3 A21
CGCM2 B21,B22,B23
CGCM2 B2X
CSIROMK2b B11
CSIROMK2b B21
HadCM3 B21
CCCII(92) 2 x CO2
GFDL(91)
GISS(95)

Lake Memphremagog-St. Francis River-Lake Champlain-Richelieu River Watershed Seasonal Scatterplots

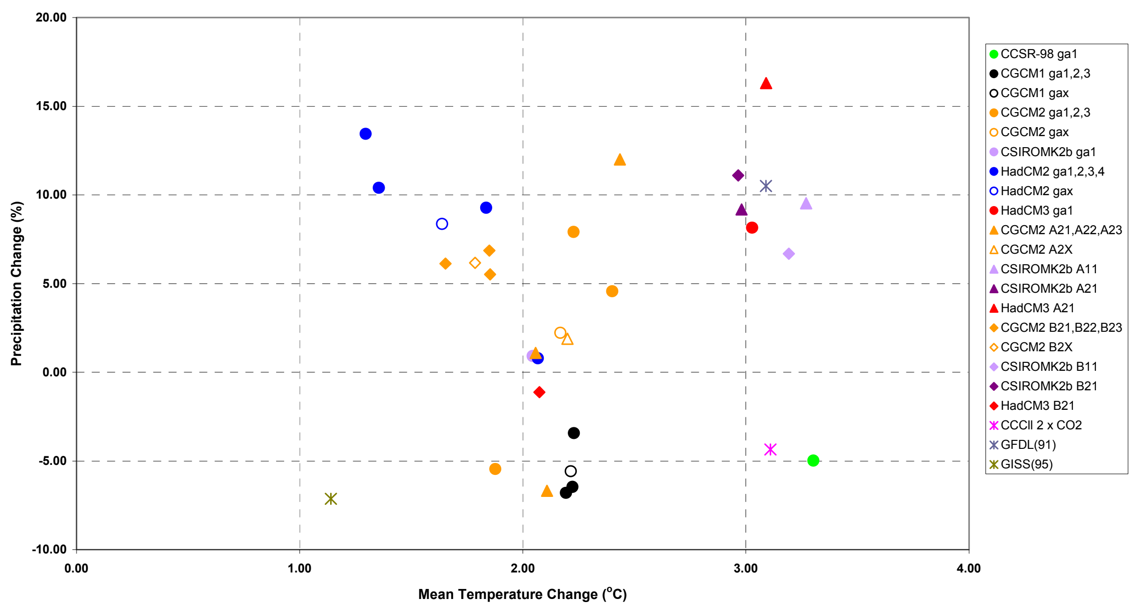




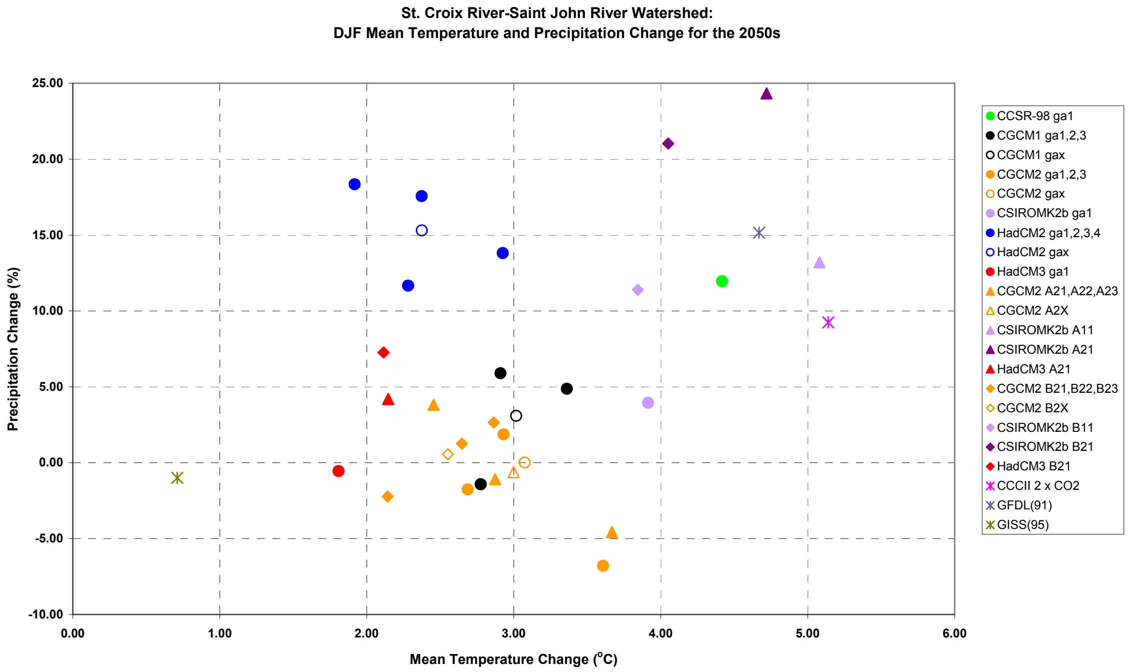
Lake Memphremagog-St. Francis River-Lake Champlain-Richelieu River Watershed:
JJA Mean Temperature and Precipitation Change for the 2050s

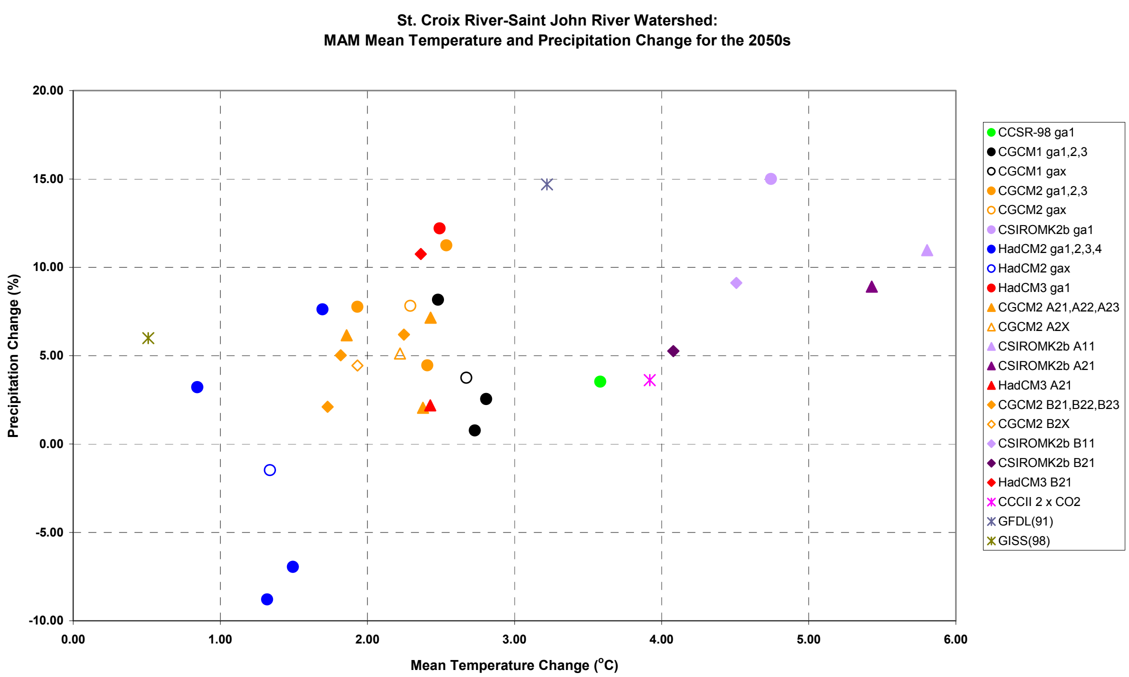


Lake Memphremagog-St. Francis River-Lake Champlain-Richelieu River Watershed:
SON Mean Temperature and Precipitation Change for the 2050s

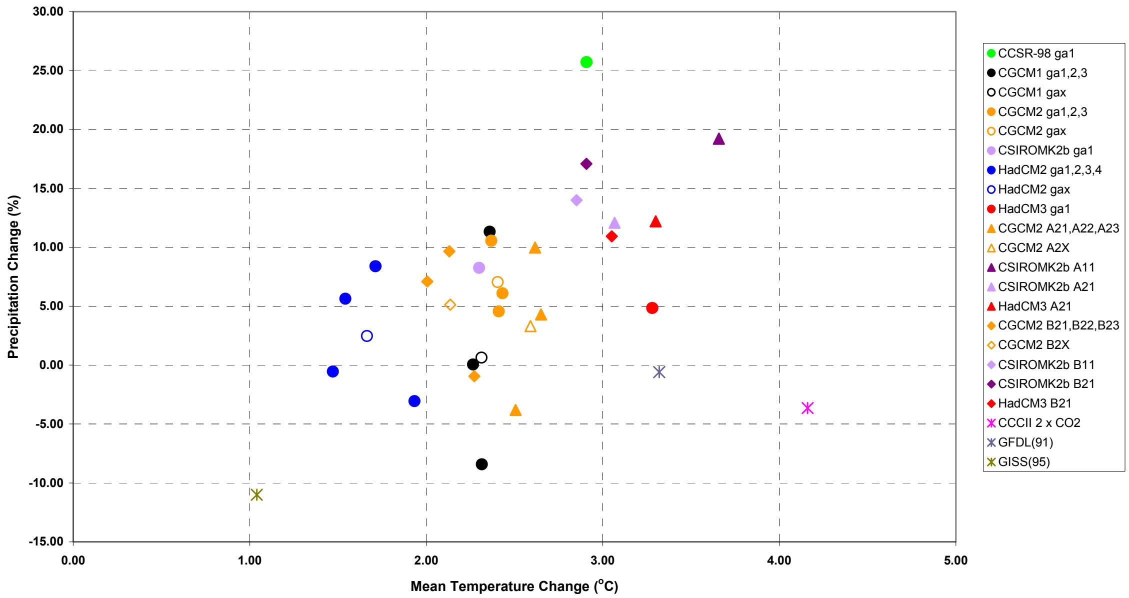


St. Croix River-Saint John River Watershed Seasonal Scatterplots

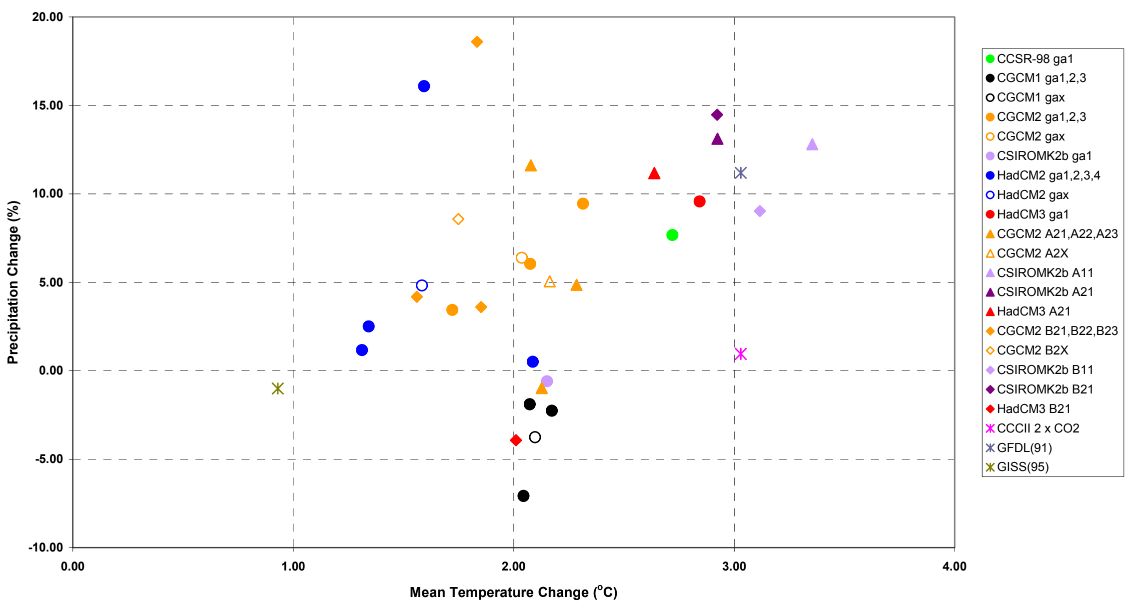




St. Croix River-Saint John River Watershed:
JJA Mean Temperature and Precipitation Change for the 2050s



St. Croix River-Saint John River Watershed:
SON Mean Temperature and Precipitation Change for the 2050s



Annex C
Perceptions of Fairness in

Allocating Water in the Saskatchewan River Basin

A Questionnaire to Government Officials Water Users and Representatives from Non-Governmental Organizations

Please mail the survey by December 16 to
Bob Halliday
R. Halliday & Associates
717 Sixth Avenue North
Saskatoon, SK, S7K 2S8

rhalliday@sk.sympatico.ca

Background

The Saskatchewan River is a very important resource to the social, economic and environmental well-being of prairie Canada. It provides for irrigation water. It is also used for domestic water supply, cooling water for thermal hydro plants, for recreation and supports hydroelectric power generation, including water power generation in the Nelson River. The ecosystem of the watershed also relies upon its ground and surface water resources. In recent years, a combination of decreasing water supply and increasing water demands have seen increased competition for water and the consideration of what might be done to solve this problem. Increased competition for water is happening in many places in Canada and provincial water managers are addressing the problem. The purpose of this survey is to examine ways what people think about water problems and ways that people think are fair in solving the complex problem of allocating a limited amount of water among diverse user groups. There is also a desire to determine their views about the relationship between environment and technology, and current and future water management efforts within the basin.

This survey is designed to explore the perceptions of fairness and the environmental values of government officials, water users and representatives from non-governmental organizations which have an interest in water. We have deliberately not mentioned how water allocations are currently made (*i.e.*, how it is decided, who or what gets the available water). We are interested in how you think it ought to be done. Although we ask you to give your affiliation, it is your personal views that we seek. We do not expect that the views expressed in this survey will reflect the official positions of your employer or organization.

Your answers will assist us in identifying the ideas we should study most closely, and how current practice might be improved. In the spring/summer of 2003, we will be providing a short synopsis of the research through regional newsletters. It will also provide information on how to obtain a copy of the final report.

To facilitate an efficient response, most of the answers are in the form of check boxes. **Please provide your initial responses to questions. Do not think about them for too long.**

If you are responding as an employee from any level of government, begin your responses in Section A. If you are responding as a major water user or a representative from a private water user or non-governmental organization, begin at Section B.

Part A – General Background of Government Officials
If you are not employed by a government agency, go to Section B.

1. Level of Government Affiliation (please check one):
   ______ Federal
   ______ Provincial
   ______ Local
   ______ Aboriginal Council
   ______ Crown Corporation
   ______ Basin Council/Valley Authority/Advisory Committee
   ______ Other (specify type of agency) ________________________

2. With respect to your government affiliation above, what is your department's/ agency's primary interest in water (please check one):
   ______ agricultural
   ______ community and/or economic development
   ______ electricity generating sector
   ______ fish, waterfowl, wildlife, or wetlands
   ______ forestry
   ______ manufacturing/industrial sector
   ______ municipal water use
   ______ oil/gas or mining sector
   ______ public health
   ______ tourism/recreation/cultural sector
   ______ water quality
   ______ water supply provider (municipal, agricultural, industrial)
   ______ other (specify)_______________________

3. Province of residence: (please check one)
   ______ Alberta
   ______ Saskatchewan
   ______ Manitoba
   How long have you lived in this province? ______________ years

GO TO SECTION C.

Section B: General Background of non-government responders

4. Affiliation (please check one):

______	Private Sector (e.g. farmer, oil company, electricity producer)
______	Non-governmental organization
______	Aboriginal Group
______	Other (specify) ________________________

5. With respect to your affiliation above, what is its primary interest in water? (please check one):

______ Agricultural producer

Primary type of agriculture (check one):

- ______ Irrigated crops
- ______ Non-irrigated crops
- ______ Livestock
- ______ Other (specify)___________________

______	community and/or economic development
______	electricity generating sector
______	fish, waterfowl, wildlife, or wetlands
______	forestry
______	manufacturing/industrial sector
______	municipal water use
______	oil/gas and mining sector
______	public health
______	tourism/recreation/cultural sector
______	water quality
______	water supply provider
______	other (specify)_______________________

6. Province of residence: (please check)

______	Alberta
______	Saskatchewan
______	Manitoba

How long have you lived in this province? ____________ Years

Section C: Basin Trends, Issues and Causes

7. How familiar are you aware of the Master Agreement on Apportionment (administered by the Prairie Provinces Water Board) that shares the waters of the Saskatchewan River among the three prairie provinces? (check one)

Very Familiar	Somewhat Familiar	Not at all Familair
☐	☐	☐

8. Do you think the Master Agreement on Apportionment is fair in apportioning water among the prairie provinces? (check one)

No	Yes	No Opinion/ Don't Know
☐	☐	☐

9. How familiar are you with the process of allocating water among users within your province?

Very Familiar	Somewhat Familiar	Not at all Familair
☐	☐	☐

10. Do you think the current arrangement for allocating water among various users within your province is fair?

No	Yes	No Opinion/ Don't Know
☐	☐	☐

11. How serious are the water quantity problems in the Saskatchewan River basin within your province?

Not Very Serious	Not Serious	Neutral	Serious	Very Serious	No Opinion
☐	☐	☐	☐	☐	☐

12. Over the past 10 years, or since you have lived in the province (which ever is shorter), what has been the overall trend for water quantity issues for the portion of the Saskatchewan River within your province?

☐ the situation has improved (go to Question 13)

☐ the situation has gotten worse (go to Question 13)

☐ the situation has remained about the same (go to Question 14)

13. Rank a maximum of three important factors that have contributed to the improving or declining trends in question 12. (1 = most important, 2 = second, 3 = third)

______ changing weather and climate (e.g. increase/decrease in rainfall, evaporation)

______ flow regulation (e.g. dam operations –effective/ineffective)

______ introduction of new water users (e.g. more people,industry)

______ water supply (e.g. new ones found/not found)

______ wetlands (e.g. have been preserved/filled in)

______ pricing (e.g. effective/ineffective)

______ regulation of uses (e.g. effective/ineffective)

______ conservation efforts (e.g. effective/ineffective)

______ glaciers (e.g. forming/dissipating)

______ others (specify)______________________________

______ ______________________________

______ ______________________________

14. To what extent do you accept the possibility of human-induced climate change?

☐ Climate change is occurring at the present time

☐ Climate change is certain to occur

☐ Climate change is likely to occur

☐ Climate change may occur

☐ Climate change is unlikely to occur

☐ Climate change will not or cannot occur

☐ No opinion

15. To what extent do you feel that more droughts and floods will be experienced in the Saskatchewan River Basin in the next 20 years (please check one in each column)

	More droughts are:	More floods are:
Certain to occur	_____	_____

Likely to occur	______	______
May occur	______	______
Unlikely to occur	______	______
Will not/cannot occur	______	______

Section D: Environmental Values

16. How an individual views the general environment influences their decision making. Your responses to the statements below will allow us to develop an index of environmental values. Using the check boxes below, please indicate your level of agreement or disagreement with each of the following statements. Check only one box per statement. Please do not take too long on each question. We are interested in your **first impressions only**.

Opinion	Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree
a) The balance of nature is very delicate and easily upset by human activities	☐	☐	☐	☐	☐
b) The Earth is like a spaceship with only limited room and resources	☐	☐	☐	☐	☐
c) Plants and animals do not exist primarily for human use	☐	☐	☐	☐	☐
d) Modifying the environment for human use seldom causes serious problems	☐	☐	☐	☐	☐
e) There are no limits to growth for nations like Canada	☐	☐	☐	☐	☐
f) Humankind was created to rule over the rest of nature	☐	☐	☐	☐	☐
g) Technology will solve problems resulting from shortages of natural resources	☐	☐	☐	☐	☐
h) People would be better off if they lived a simpler life without so much technology	☐	☐	☐	☐	☐
i) Scientific research is more likely to cause problems than to find solutions	☐	☐	☐	☐	☐

Part E: Components of Fairness in Water Allocation

17. There have been many theories and philosophies that have been put forward to guide water allocation decisions. In this section, we have put parts of these theories into statements. We would like to know the extent to which you agree or disagree with these statements. Using the check boxes below, could you indicate your level of agreement or disagreement with each of the statements below. Check only one box per statement. Again, do not take too long on each question. We are interested in your **first impressions only**.

Opinion	Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree
a) People who have been allocated water should retain this right only if they can show they are using it wisely	☐	☐	☐	☐	☐
b) All water users should pay the full cost of providing and treating water	☐	☐	☐	☐	☐
c) Water is a community resource that cannot be owned by individuals	☐	☐	☐	☐	☐
d) The natural environment has the same rights to water as people have	☐	☐	☐	☐	☐
e) Landowners have a right to use water passing their property only if it does not have a negative effect on those downstream	☐	☐	☐	☐	☐
f) There should be no general rules about how to allocate water: it depends on the situation	☐	☐	☐	☐	☐
g) All people of the basin have a right to have a say on water allocation	☐	☐	☐	☐	☐
h) Those who have received water allocations in the past have a greater right to water than those who are relative newcomers	☐	☐	☐	☐	☐
i) Water should be allocated to those who work the hardest to use it most effectively	☐	☐	☐	☐	☐

Opinion	Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree
j) If governments have to go into debt to provide enough water for everyone, they should	☐	☐	☐	☐	☐
k) While some parts of the environment are valuable and should be preserved through water allocation, some are not so valuable and can be "let go"	☐	☐	☐	☐	☐
l) Water is a basic public good that is only "lent" to users	☐	☐	☐	☐	☐
m) Water quality is an important issue in many water allocation decisions	☐	☐	☐	☐	☐
n) All water should be put on the market and allocated to those who will pay most, regardless of what it is used for	☐	☐	☐	☐	☐
o) It is impossible to design a decision-making process which is fair to all water users	☐	☐	☐	☐	☐
p) Water allocations should be used to maximize the overall economic development within a community	☐	☐	☐	☐	☐
q) Recreational uses of water have important economic values	☐	☐	☐	☐	☐
r) Public involvement should not be used very often in water allocation as most people act out of self interest	☐	☐	☐	☐	☐
s) If you bought and sold water on the open market, the environment would not be allocated adequate quantities of water	☐	☐	☐	☐	☐
t) Local people are best left to organize water allocation on rivers in rural areas	☐	☐	☐	☐	☐

Opinion	Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree
u) It is more important that water is used for the benefit of our way of life rather than to maximize our income	☐	☐	☐	☐	☐
v) It is important to set rules for how water should be allocated for the next generation	☐	☐	☐	☐	☐
w) Analyzing the monetary costs and benefits can't really solve allocation problem	☐	☐	☐	☐	☐
x) If the decision-making process is fair, people should accept the final allocation decision	☐	☐	☐	☐	☐
y) Farmers should only be allocated water if they can demonstrate that it is being used efficiently on their property	☐	☐	☐	☐	☐
z) Since the environment cannot defend itself, allocations should be specifically made to protect it	☐	☐	☐	☐	☐
aa) Those upstream have a moral responsibility to look after the interests of those downstream	☐	☐	☐	☐	☐
bb) In water allocation, everyone should be treated equally	☐	☐	☐	☐	☐
cc) Any negative effects of irrigation on the land tend to be exaggerated	☐	☐	☐	☐	☐
dd) Recreational users, such as anglers, boaters and canoeists and water skiers, should pay for costs of river and reservoir management.	☐	☐	☐	☐	☐
ee) During times of drought all users should share the pain, irrespective of rights	☐	☐	☐	☐	☐

Opinion	Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree
ff) During times of drought, more socially beneficial uses should have priority over less beneficial uses, irrespective of rights	☐	☐	☐	☐	☐
gg) When a water licence is issued, provisions should be made for a periodic review	☐	☐	☐	☐	☐

Part F: Other Comments

18. Feel free to elaborate on your perceptions concerning the fairness of water allocation in the Saskatchewan Rover Basin and/or within your province. You can also identify what, if anything, you believe could or should be done to improve water allocation management within the Saskatchewan River basin and/or within your province.

____

____

____

____

____

____

____

____

____

____

____

____

____

____

____

THANK YOU FOR YOUR ASSISTANCE