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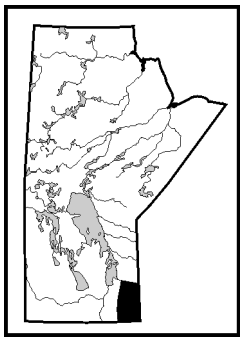
GS-27 Understanding drought in the Winnipeg River basin, Manitoba

by S. St. George[1, 2]



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Summary

This research will study the frequency, severity and causes of extreme droughts and low flows in the Winnipeg River basin (WRB). Because the Winnipeg River directly influences the production of approximately 4500 megawatts of hydropower, drought conditions affecting large portions of the WRB can have a serious impact on regional power supplies. This project will analyze streamflow records to determine if low flows occur in a predictable, periodic manner and establish if extreme low flows in the WRB are associated with specific atmospheric circulation patterns. Unfortunately, instrumental streamflow and climate records in the WRB are relatively short (less than 100 years), and may provide poor estimates of the frequency or severity of extreme low flow in the context of drought across the entire Manitoba Hydro system. To overcome this limitation, this project will also establish a new network of moisture-sensitive tree-ring sites within the WRB that will allow researchers to estimate hydroclimatic conditions in the basin during the past 200 to 500 years. These 'proxy' streamflow and/or precipitation records will be used to determine how the frequency and severity of low-flow events and droughts has changed over time, and evaluate the long-term variability of critical meteorological and climatological processes that control streamflow. This information will improve estimates of the risk of future low flows occurring in one of Manitoba's most important basins for hydroelectric power generation, and evaluate the accuracy of current worst-case scenarios for drought planning.

Introduction

Because more than 95% of Manitoba Hydro's current system supply is provided by hydroelectric generation, drought conditions affecting large areas can have a serious impact on power supply. The 'critical drought period', which is a central component of Manitoba Hydro's water management planning, is defined as the lowest observed inflows within Manitoba, and is determined from long-term historical records of precipitation and streamflow. Unfortunately, the frequency, severity and causes of severe droughts and low flows in the Nelson River system are not well understood. A number of researchers have suggested that the rhythm of drought in western North America is quasi-periodic and is driven by solar and lunar causes, but it is not known if similar cycles affect streamflow or precipitation in Canada. Also, although local climatic conditions are determined by the state of the atmospheric circulation system, the specific circulation patterns that cause extreme low flows in Manitoba have not been identified. Compounding these difficulties is the lack of long, continuous streamflow records. Most climate stations and stream gauges cover only the last 50 to 80 years, and even the longest records span little over 100 years. These data are not sufficient to estimate accurately the frequency or severity of system-wide drought under 'natural' climatic conditions, and cannot place recent or projected climatic change within a long-term context.

This project will improve our understanding of severe drought through the analysis of instrumental and paleoclimatic data from the Winnipeg River basin (Fig. GS-27-1). The Winnipeg River basin (WRB) is a major component of the Nelson River system, and supplies over 40% of the net inflow to Lake Winnipeg. This project will use climate, tree ring and derived proxy climate data to evaluate changes in hydroclimatic conditions in the Winnipeg River basin during the past several hundred years and to determine the frequency, severity and causes of droughts and low flows. This project began in August 2003 and will extend over four years.

Dendroclimatology

Dendroclimatology uses information obtained from the annual growth rings of trees to study climatic conditions prior to the period of instrumental monitoring. Within the last decade, dendroclimatology has made several major contributions to climate science, including estimates of global warming over the last thousand years that were featured prominently in the most recent report of the United Nations Intergovernmental Panel on Climate Change (Watson et al., 2001). Locally, tree-ring evidence has demonstrated that the northeastern Great Plains, including southern Manitoba, experienced prolonged arid conditions circa AD 1700 that lasted for nearly a century (St. George and

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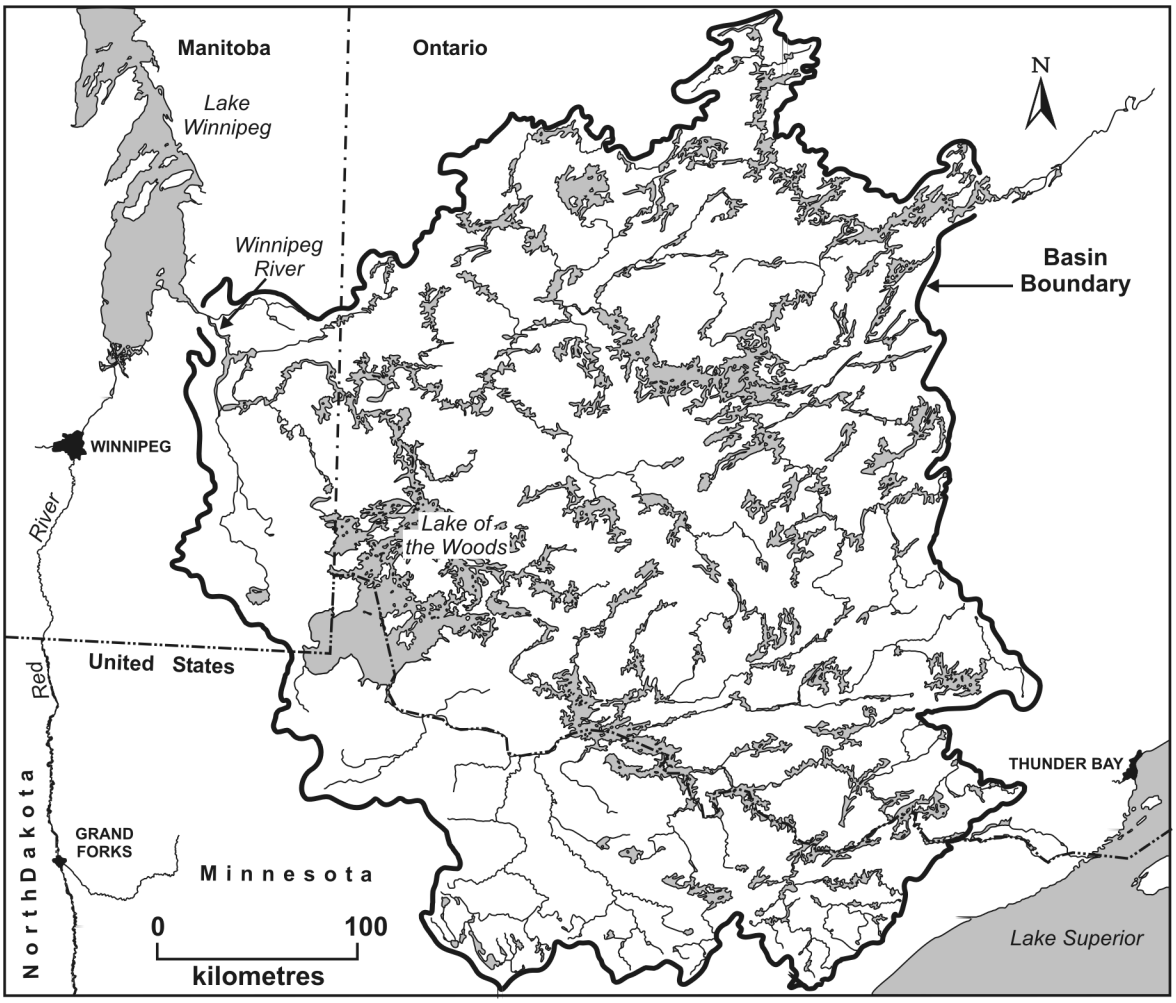

Figure GS-27-1. The Winnipeg River basin drains parts of southeastern Manitoba, northwestern Ontario and northern Minnesota. Drought conditions in the Winnipeg River can have a significant negative influence on tourism, fishing and hydroelectric production.

Nielsen, 2002). Tree-ring data is particularly well suited to provide information on past hydrological conditions in the WRB because of its wide distribution of suitable sites, fine temporal resolution and long records, as well as the clear relationship between tree growth and available moisture.

Specific objectives

1) Investigate the temporal and spatial variability in precipitation and streamflow.

This research will first evaluate the occurrence and extent of droughts and low-flow events in the Winnipeg River basin during the 20th century. A dataset of long climatic and hydrological records obtained from Environment Canada's Historical Adjusted Climate and HYDAT databases will be examined to determine the spatial extent of past low flows in the Winnipeg River system, and analyzed to identify potential periodicities that might be driven by external climatic or geophysical factors.

2) Link regional precipitation and streamflow to atmosphere-ocean circulation patterns.

Synoptic climatological techniques will be used to identify connections between the atmospheric circulation system and hydroclimatic conditions in the Winnipeg River basin. This approach will also determine if extreme low flows in the basin are associated with specific circulation patterns.

3) Establish a network of tree-ring sites within the Winnipeg River basin.

This research objective focuses on the collection of climate-sensitive tree-ring chronologies within the Winnipeg River basin. A new network of tree-ring sites will be developed within the basin, focusing primarily on locations close

to key stream gauges. Previous exploratory sampling in the Winnipeg River region indicates that records derived from these sites will, at minimum, span the last 200 years and may, in select locations, extend back 300 to 500 years (Fig. GS-27-2).

4) Develop extended streamflow records spanning the last 200 to 500 years.

The Winnipeg River tree-ring network will be examined to identify those species and environments (e.g., hydric, mesic or xeric) that are sensitive to changes in moisture conditions. Relationships between regional tree growth and streamflow/precipitation will be assessed using stochastic modelling techniques, and exploited to develop estimates of hydroclimatic conditions prior to the initiation of instrumental monitoring. At a minimum, "reconstructed" streamflow and precipitation records will span the last 200 years. If older, moisture-sensitive tree-ring records can be developed, these proxy data could document annual climatic changes in the WRB over the last five centuries.

5) Determine how the frequency and magnitude of low flows and droughts has changed over time and identify potential causes of those changes.

Proxy streamflow and/or precipitation records will be used to determine how the frequency and severity of low-flow events and droughts in the Winnipeg River basin has changed during the last 200 to 500 years. This information will provide valuable insight into the temporal evolution and spatial patterns of climate variation, and produce important knowledge about the long-term variability of critical meteorological and climatological processes that control streamflow.

Relationships with other projects

This project complements other research in the Nelson River basin that aims to improve our knowledge of the region's hydrology and climate. D. Sauchyn (University of Regina) has received funding to support a two-year dendrochronological project in the Saskatchewan River basin, while B. Cumming (Queen's University) is leading a three-year project developing paleoclimatic records from lakes in the Winnipeg River basin. Collectively, this research will add to our understanding of climate dynamics in the Nelson River basin, as well as provide valuable information that can be used to plan for future extremes in hydrologic conditions. This project will also complement the current expansion and integration of Canadian tree-ring records funded by the National Sciences and Engineering Research Council, the Canadian Foundation for Climate and Atmospheric Sciences and the Canadian Climate Change Action Fund, and contribute to ongoing attempts to extend existing drought and streamflow reconstructions for the coterminous United States into Canada (Cook et al., 1999).

Figure GS-27-2. Collecting tree-ring samples from Thuja occidentalis (Eastern white cedar) near Sprague, Manitoba, in 2000.

Economic considerations

Although hydroelectric production is a central tenant of the provincial government's policy on climate change, the impact of climate change on hydropower resources is unknown. The Winnipeg River currently supports six hydroelectric generating stations in Manitoba, which collectively produce 585 megawatts of electricity, roughly 11% of total provincial production. The river also provides the largest single contribution to Lake Winnipeg and thereby has an important influence on the production of nearly 4000 megawatts from the Jenpeg Generating Station and other stations on the Nelson River. Given the direct correlation between precipitation, runoff and hydro generation, an improved understanding of the frequency, magnitude and causes of past droughts and periods of low

streamflow across the basin will provide information critical to the management of hydroelectric facilities in Manitoba.

Acknowledgments

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