Manitoba Industry, Trade and Mines
Manitoba Geological Survey

University of Manitoba

Natural Resources Canada
Ressources naturelles Canada

PALEOENVIRONMENTAL EVIDENCE FOR HYDROCLIMATIC CHANGE AND EXTREME FLOODING IN THE RED RIVER BASIN OVER THE LAST 700 YEARS

Scott St. George
Geological Survey of Canada

Erik Nielsen
Manitoba Geological Survey

Grant Ferguson
University of Manitoba

Riparian forests in the RedRiver valley

TheoldestlivingburoakintheRedRivervalleywaslocatedin Kildonan Park and reachedanageof279yr.beforeitsdeathin 1999. However, small-scale logging in the early- to mid- 19th century deforested most of the Canadian portion of the Red River valley and, as a consequence, today there are few local trees older than140years.

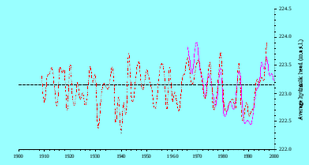
- A group of easternwhite cedars growingnearEasterville are the oldest known trees in Manitoba, with some individuals almost500yearsold.

The riparian forest in present-day Winnipeg (right) developed after extensive logging in the 19th century deforested much of the Red River valley. In 1875 (left), trees were completely absent near the Forks of the RedandAssiniboinerivers.

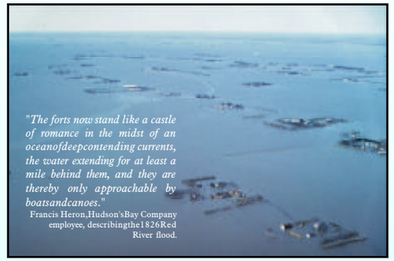
20th century groundwater levels inWinnipeg

Shallow monitoring wells in Winnipeg documented decreasing groundwater levels in the 1980s and early 1990s, followed by a recovery in the mid-1990s. Since regional groundwater levels are strongly related to changes in annual temperature and precipitation, combining these parameters with tree-ring records allowed us to estimate changes in average annual hydraulic head during the 20th century.

- Prior to the 1960s, climate-induced fluctuations in groundwater levels had a greater range, with lower levels in 1931 and 1940 than anyduringtheobservedrecord.
- Groundwater withdrawals had a much greater influence on groundwaterlevelsduringthe20th centurythanclimaticchange.



Observedgroundwater levelsinWinnipeg,whichbeganinthemid-1960s, are shown as a solid line, while estimated levels, derived fromclimatologicaland tree-ringdata, appear asadashedline.



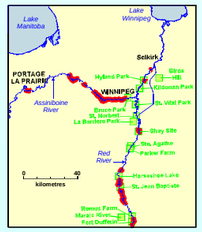
Extremespring flooding has been a recurring problemin the Red River valley since the establishmentofpermanentsettlement.

Trees record long-term changes

Instrumental records of temperature and precipitation from the Canadian prairies are rarely longer than 100 years. These short records can only provide a limited estimate of the natural range of climatic variability and cannot place recent or project climate changes within a long-termcontext.

Trees contain a record of past long- and short-term environmental changes withintheir annual growthrings, that canextend forhundredsorthousandsofyears. Inthis study, we use a network of bur oak growing in southern Manitobato make inferences about long-term changes in precipitation and groundwater levels near Winnipeg and patternsofextremefloodingintheRedRivervalley.

Tree-ring samples were collected throughout the CanadianportionoftheRedRiverbasinfromlivingtrees, historical buildings and river alluvium. The combined tree-ringrecordincludes398 treesandextendsbacktoAD 1286. Sincesomesubfossillogshaveradiocarbonagesthat range back to 4230±70 BP, collecting more material may extendtherecordtocoverthelastseveralthousandyears.



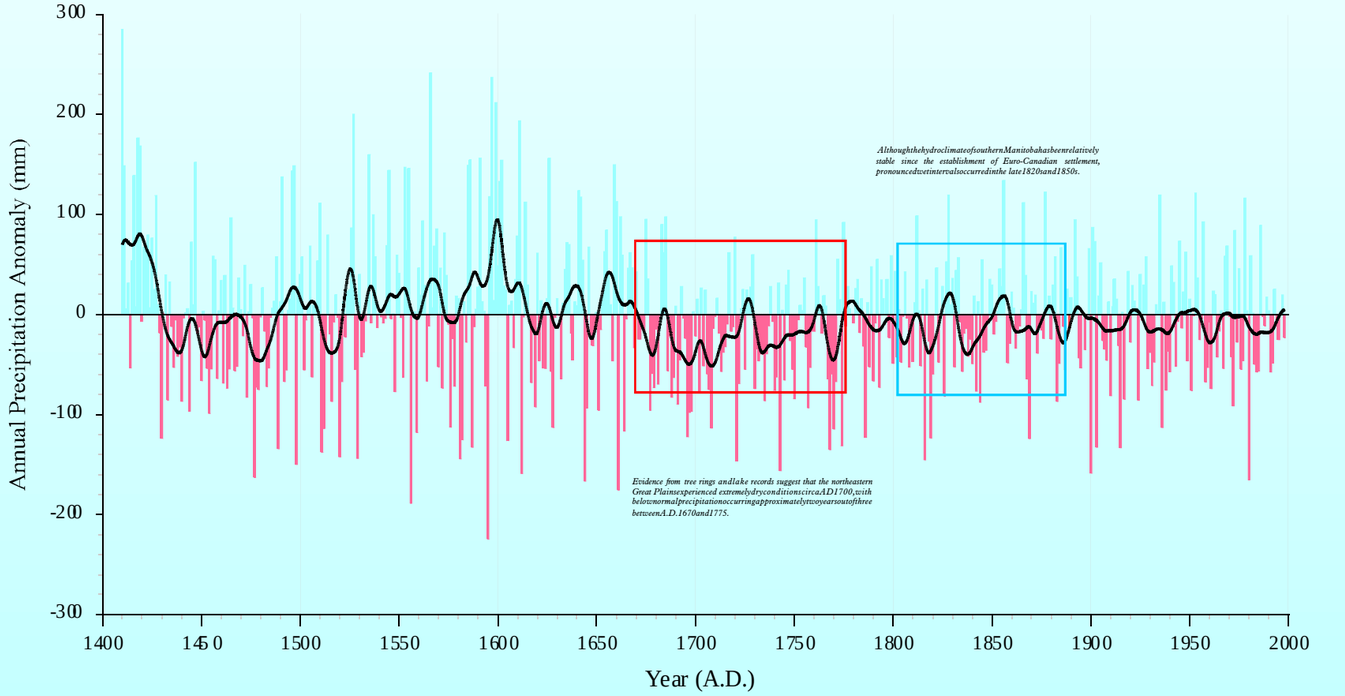
Sampling sites are concentrated along the RedRiverbetween WinnipegandEmerson and are derived from living trees (green squares), 19th century historical sites (not shown)andriverallluvium (shadedred).

Tree-ring samples were collected from live trees, timbers from historical buildings and logs recovered from river alluvium, todevelopa recordspanningthelastsevencenturies.

Past hydroclimatic changemore severe

Estimates of annual (prior August to current July) precipitation derived from regional bur oak ringwidthallowustomakethefollowinginferencesaboutpastclimatechangein southernManitoba:

- The hydroclimateofsouthernManitoba has beenrelativelystableoverthelasttwohundredyears butwasinterruptedbrieflybypronouncedwetintervals inthelate1820sand1850s.
- Conditionsweremuchmorevariableandpersistentpriorto A.D.1790.
- The Red River basin experienced extremely dry conditions between A.D. 1670 and 1775, with belownormal precipitation occurring approximately two years outof three. Lake records from NorthDakota and Minnesota also contain evidence of this dry event, which suggests that multi-decadal fluctuations in regional hydroclimate have been remarkably coherent across the northeasternGreat Plainsduringthelast600years.
- Individual dry years in the Red River basin were usually associated with larger-scale drought acrossmuchof theNorthAmerican interior.
- Although SaskatchewanandAlberta appear tohaveexperiencedsevere drought duringthe1790s, annual precipitationintheRedRivervalleywasonlyslightlybelowaveragedduringthisperiod.
- Hydroclimatic proxies from the northeastern Great Plains suggest that this area largely escaped theinfluenceofthe16th century'megadroughts'thataffectedmuchofwestern NorthAmerica.
- The mechanisms driving changes in regional aridity seem tovarydepending on the temporaland spatialscalesunderinvestigation.

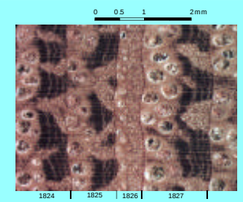


Extendedflood records

Flooding in the lower Red River valley since AD1648

Extreme floods, such as the 1950 floodor larger, cause bur oak growing along the river to develop distinctive anatomical markers, or 'flood rings', that can be used toidentifyolderandpreviouslyunknown Red River floods.

- Flood rings document seven high-magnitude RedRiverfloodssinceAD 1648: 1997, 1979, 1950, 1852, 1826, 1762 and 1747. Although the five most recentfloodringsarecoincident with known high-magnitude floods, signatures in 1747 and 1762 predate local instrumental and historical flood records and record previously unknownfloods.



'Flood' rings,suchasthoseformed duringthe1826 flood, are distinguished by obvious anatomical abnormalities, including shrunken earlywood vessels and disrupted latewood and flame parenchyma.

- The frequency and anatomical development offloodsignaturesin1826 suggestthattheRedRiverfloodofthatyearwasthemost severeeventinatleastthelast352years.
- Despitecommentsby anearlyfurtrapperthatsuggestsfloodingwasunusuallyextensivein 1776, thereisnotree-ringevidenceforsuchanevent.

AssiniboineandupperRedRiverfloodsduringthelast500years

Tree-ring samples collected from the Assiniboine River and the upper Red River (Minnesota and NorthDakota)alsocontainanatomicalevidenceofpastfloods.

- Althoughinformationfortheupper RedRiverisderivedfromrelativelyfewtrees,itsfloodrecord extendsfromAD1997to1448anddocumentsfloodinginAD 1510,1538,1658,1682,1726,1727, 1741,1747and1762.
- Flood signatures from the AssiniboineRiver suggest that the two basins, which have markedly differenthydroclimates,floodedsimultaneouslyin1510,1538and1826.
- The Assiniboine and Red River floods of 1826 also coincided with severe frost damage in the south-central United States, which implies that unusual spring weather extended throughout central NorthAmerica.

Changingflood risksovertime

The flood record for the lower Red River contains three periods with multiple high-magnitude floods:themid1700s,themid1800sandthelatterhalfofthe20th century.Conversely,thelowerRed experienced several prolonged intervals with little to no extreme flooding, particularly between 1648-1746,1763-1810and1862-1949.

Flood frequency analysis is based on the assumption that the flood flows are independent and identically distributed random variables. However, these 'high' and 'low' flood modes in the Red River record, which have extended from several decades to nearly a century, imply that the risk of flooding changes over time. Therefore, the risks of future flooding for Winnipeg and other communities in the Red River valley might be better estimated using techniques that account for non-stationairityand non-randomnessintroducedbyclimaticandlandscapechanges.

Acknowledgements

Thisresearchwassupportedby theManitobaGeologicalSurvey,the Red RiverFloodProtection Program, the Climate Change Action Fund and the Manitoba Hydro Forest Enhancement Program.For assistance in the field and/or laboratory, we wish to thank D. Bailey, C. Bater, R. Case,L.Friedrich,G.Gobert,J.Gutsell,G.MacDonald,D.McLeodandG.Matile.

Related papers

Ferguson, G. and St. George, S. (in prep.). Estimated changes in groundwater levels inasemi-confined aquiferinsoutheasternManitobaduring the20th century.

St. George,S.andNielsen,E.(submitted).Paleofloodrecordsforthe RedRivervalley,Manitoba, Canada derivedfromanatomicaltree-ringsignatures. *TheHolocene*.

St. George, S. and Nielsen, E. (in press). Hydroclimatic change in southernManitoba since AD 1409inferredfromtreerings. *Quaternary Research*.

St. George, S. and Nielsen,E. 2000. Signaturesofhigh-magnitude 19th century floods in *Quercus macrocarpa* treeringsalongtheRedRiver,Manitoba,Canada. *Geology* 28:899-902.

Contact information

Scott St. George
sstgeorg@nrcan.gc.ca

Erik Nielsen
ENielsen@gov.mb.ca

Grant Ferguson
umferg13@cc.umanitoba.ca

Manitoba Geological Survey
360-1395Ellice Avenue
Winnipeg, Manitoba
CANADA, R3G 3P2

www.gov.mb.ca/em/geoscience/geo-index.html