Prairie Perspectives: Geographical Essays
Prairie Division
Canadian Association of Geographers
Association Canadienne des Géographes

Volume 20, 2018

PRAIRIE PERSPECTIVES: GEOGRAPHICAL ESSAYS

Edited by
Bernard D. Thraves
Lamberhurst, Kent
UNITED KINGDOM

# Contents

**Preface**
Bernard D. Thraves ii

## Research Articles

**Forced meanders and glaciofluvial deposits in an entrenched glacial spillway: The McFadden Valley-Polonia Trench, Riding Mountain Uplands, Manitoba**
Roderick A. McGinn 1

**An analytical comparison of flood zones derived from point cloud LiDAR data and historical flood data: A case study of Moose Jaw, Saskatchewan, Canada**
Yulu Peng, Abdul Raouf and Muhammad Almas 17

**Students' preceptions of clickers for enhancing student engagement and academic achievement**
Jamie Edwin Lee Spinney and Suzanne Elizabeth Kerr 26

## Reviews and Field Notes

**Historical precipitation characteristics in Palliser's Triangle region of the Canadian prairies**
Dustin M. Roussin and Jacqueline Binyamin 36

**Local communities and researchers working together for water security: A multi-actor dialogue in Saskatchewan, Canada**
Kenji Kitamura, Susan Carr, John Kindrachuk, Mark Johnston, and Maureen G. Reed 49

**Self and society: Using the cell phone images of northern Vietnamese university students to identify and share their environmental and cultural place-ness with their American peers**
Hồng Thị Hà and Aaron Kingsbury 54

**A field trip guide to selected settlements in the Red River Valley, Manitoba**
David McDowell 61

**Across the Division** 72

**About the Authors** 75

 ISSN 1911-5814

# Preface

The 41st annual conference and business meeting of the Prairie Division of the Canadian Association of Geographers (PCAG) was hosted by the Department of Geography and Geographic Information Science of the University of North Dakota over the weekend of September 29 to October 1, 2017. As in many previous years, the event was held off campus with a small prairie community serving as the venue. Morris, Manitoba was selected in preference to a location in North Dakota to avoid any impediments to cross-border travel caused by Executive Orders issued under the Trump presidency. Logistical support for the conference was provided by the geography departments at Brandon University and the University of Winnipeg, with financial assistance from the Association of North Dakota Geographers and the Virginia George Inheritance Fund. Meeting facilities were provided at the Morris Multiplex located in the Morris Stampede Grounds. Sixty-five attendees, including 30 students, and CAG President Dr. Dan Shrubsole of the University of Western Ontario, participated in the conference.

Friday evening was assigned to registration, an icebreaker reception, and the annual PCAG Executive Meeting. Those seeking further stimulus then ventured to one of Morris's fine hostelries for additional refreshments and intellectual discourse. Burke's Steak Pit Lounge was the most favoured establishment, presumably on the basis of its proximity to the conference site, but possibly because everywhere else seemed closed. On Saturday morning, 25 papers were presented in a series of three concurrent sessions either side of a mid-morning break during which delegates were invited to view a display of posters and partake of refreshments. Thirteen of the aforementioned papers and five of the posters were presented by students, each of whom was awarded a Paul Simpson-Housley/CAG Student Travel Award plus a one-year annual membership of the CAG. Saturday afternoon was devoted to a field trip of the Red River Valley led by David McDowell. With field notes in hand and under fair weather skies the field trip visited the communities of St. Jean Baptiste, Letellier, and St. Joseph where a refreshment break was taken while at the Musée St. Joseph and Parent Tourism Centre. The field trip then proceeded to the National Historic Site of Fort Dufferin, which for a short period in the late 19th century played an important role in asserting the Dominion government's claim to Canadian sovereignty and political control in the West. The field trip concluded in Emerson on the east bank of the Red River where CN and CP rail lines merge and cross into the USA, and where abandoned customs and immigration posts mark the former international boundary crossing point of Highway 75. An expanded version of McDowell's field notes are included in this volume as a record of the afternoon's activities and as a guide to those who might wish to explore this part of southern Manitoba under their own reconnaissance.

The traditional Saturday night banquet was held in Crocus Hall at the Morris Multiplex. After dining, PCAG president Dr. Derrek Eberts presented Dr. Jonathan Peyton of the University of Manitoba with the PCAG Early Career Award, which "recognizes early career appointees, normally within five years of graduation from a PhD, who have made significant scholarly contributions to the discipline and/or demonstrated exceptional achievement in teaching." Dr. Peyton's diverse research interests include energy politics and policies, the politics of environmental assessment, and environmental history. Dr. Randy Widdis of the University of Regina then delivered a keynote address titled The Northern Plains and Prairies as Frontier, Borderland and Bordered Land. Dr. Widdis' much appreciated presentation provided a historical geographic overview of the evolution of the interior plains both north and south of the 49th parallel. Saturday night's activities concluded with the Annual Slide Competition with Drs. Shrubsole and Widdis acting as judges of slides entered in five categories—physical geography, human geography, prairie, aesthetic, and humour. Sunday morning was devoted to the Annual General Meeting of PCAG at which the smooth running and sound financial status of the Division was confirmed. The AGM was also an occasion for celebration as Dr. Douglas Munski of the University of North Dakota and Dr. Laura Munski, Executive Director of the Science Center, Grand Forks, North Dakota were jointly awarded the PCAG President's Award in "recognition of their outstanding contribution to the Division having demonstrated exceptional dedication and commitment to Geography in the Prairie region, above and beyond the ordinary."

Three research articles, one review essay, two viewpoints, plus the aforementioned field trip guide are presented in this volume of *Prairie Perspectives: Geographical Essays*. In the first of the research articles, Roderick McGinn transports the reader to the Riding Mountain Uplands at the time of the late Wisconsinan glaciation to explain the formation of a pronounced landscape feature, the McFadden Valley-Polonia Trench. McGinn further explains how glacial meltwaters, ponding ice and differential geology combined to produce forced meanders and a range of glaciofluvial deposits. Continuing the aquatic theme but moving westward and to warmer climes of the present day, Yulu Peng, Abdul Raouf, and Muhammad Almas argue that regularly updated and accurate maps are essential to heighten public awareness of flood risks. They demonstrate the utility of remote sensing technologies including point cloud LiDAR data in producing improved flood zone maps for Moose Jaw, Saskatchewan. Jamie Spinney and Suzanne Kerr then conduct the reader to the safety of the classroom where they find students expressing strong positive attitudes toward the use of clickers for engaging and motivating them. Spinney and Kerr contend that students perceive clickers as effective tools for improving academic performance in an introductory geography class. In the review essay, Dustin Roussin and Jacqueline Binyamin venture to Palliser's Triangle to examine relationships between precipitation and ENSO, PDO, and PNA teleconnections. Of these, the PDO is shown to have the greatest influence over precipitation. Their study shows that winter values of teleconnection indices have a greater influence on spring and summer precipitation than spring and summer values of the same indices. The next section contains two 'viewpoint' contributions—short, peer-refereed essays examining a geographical problem or perspective.

In the first of these, Kenji Kitamura, Susan Carr, John Kindrachuk, Mark Johnston, and Maureen Reed report on the success of a workshop on community-researcher collaboration in water security. They stress the importance of drawing together multiple knowledge systems, diverse actors, Indigenous customs, and face to face dialogue in collaborative planning. Last but not least, Hồng Thị Hà and Aaron Kingsbury transport the reader to Thái Nguyên University of Agriculture and Forestry, Vietnam where students use self-taken photographs to express their cultural place-ness. These images are then exhibited at Mayville State University, North Dakota to challenge North American students' perceptions of contemporary Vietnam. Despite the great physical distance between the universities, their students are shown to share social worlds in common.

The volume includes two features that are new to *Prairie Perspectives: Geographical Essays*. First, news from the member departments in the Division is presented under the banner of 'Across the Division.' The intent of this section is to record significant news from each department such as appointments, retirements, major program initiatives, awards, faculty and student achievements, and other important events and milestones. Generally, the reporting period extends from mid-June, 2017 to mid-June, 2018. This period coincides with the year ending in the annual spring convocation cycle at all institutions in the Division, and recognizes that usually relatively little departmental business takes place over summer months. The second new feature provides brief biographical notes on contributing authors under the banner 'About the Authors.' The intent of the feature is to raise the profile of authors, especially those who are new faculty members or students, and to provide readers with a means by which they might more easily recognize or collaborate with the them.

Bernard D. Thraves
Lamberhurst, Kent
United Kingdom
October 2018

**Acknowledgements**

I would like to thank the authors for submitting their manuscripts to the double blind review process and meeting the challenges of revising them where deemed appropriate. Thanks are also extended to the reviewers for their efficient and critical assessments of the manuscripts. Their role has been pivotal to the success of this volume. As ever, a special thank you is extended to Weldon Hiebert at University of Winnipeg who as Dr. Munski notes "has done amazing things with the graphics for the volume be the item a map, a chart, or a photograph." Without Weldon's technical and production assistance, and great patience in dealing with the requests of the editor, publication of this volume would have been impossible. Last but not least, I am grateful to Dr. Munski for accepting my offer to serve as guest editor of this volume at a time when academic and personal commitments prevented him from performing this role.

Prairie Perspectives: Geographical Essays

Prairie Division
Canadian Association of Geographers
Association Canadienne des Géographes

# Forced meanders and glaciofluvial deposits in an entrenched glacial spillway: The McFadden Valley-Polonia Trench, Riding Mountain Uplands, Manitoba

Roderick A. McGinn
Department of Geography, Brandon University

**Key Messages**

- 14 ka –11 ka BP, a 30 km long, deeply entrenched glacial spillway.
- Parallels the crestline of the Manitoba Escarpment on Riding Mountain.
- Forced meander bends and a variety of glaciofluvial deposits.

*Approximately 13 to 14 ka BP an integrated network of supraglacial lakes drained over/through stagnating glacial ice on the Eastern Uplands of Riding Mountain. The meltwaters eroded a 30 km long channel into the local diamict and bedrock substrate. The McFadden Valley-Polonia Trench spillway is oriented north to south paralleling the crest line of the Riding Mountain Escarpment. Greatest entrenchment occurred in the northern McFadden Valley segment (60 m); down slope entrenchment is approximately 35 m in the southern Polonia Trench segment. In the McFadden Valley, meltwaters were diverted by active glacial ice and sub-cropping rock hummocks, creating valley-scale forced meanders and associated mega point bar deposits. Along the length of the Polonia Trench, remnant terminoglacial stream deposits near the valley rim, indicate a braided stream environment. Small, shallow and intermittent unpaired terraces are present along the steep valley sides of the Polonia Trench. The McFadden Valley-Polonia Trench drained into a terminoglacial (perhaps supraglacial) lake and the eroded material is deposited in a lake margin sandur plain/fan composed of braided stream deposits, which grade into subaqueous fan/delta/lacustrine sediments. Three recently published OSL ages effectively bracket a 4000-year period of operation from approximately 14 ka to 11 ka.*

Keywords: forced meanders, glacial spillway, glaciofluvial deposits, Riding Mountain

## Introduction

The Laurentide Ice Sheet covered the entire Riding Mountain Uplands during the late Wisconsinan (20,000 to 11,000 BP) with ice flow generally towards the southeast (Klassen 1966, 1979; McGinn 1991). Waning and downmelting of the last ice advance, named the Falconer Ice Advance (Fenton et al. 1983), resulted in the stagnation of glacial ice on the Riding Mountain Uplands and the division of the retreating Falconer ice into glacial sub-lobes (Figure 1). The retreating Souris Lobe (Elson 1956; Sun and Teller 1997) or Assiniboine Lobe (Klassen 1975, 1979), located west of the Riding Mountain Uplands, advanced



Correspondence to: Roderick A. McGinn, Department of Geography, Brandon University, Brandon, MB R7A 6A9
Email: mcginn@brandonu.ca

towards the southeast, terminating in an expanding glacial Lake Souris (Elson 1958; Klassen 1975; Sun and Teller 1997; Figure 1). At this time, glacial Lake Souris was draining by way of the Dand Valley into proto glacial Lake Hind, the Pembina Spillway, and eventually into early glacial Lake Agassiz (Sun and Teller 1997). East of the Riding Mountain Uplands, the Red River Lobe advanced southward, paralleling the Manitoba Escarpment with glacial sub-lobes pushing westward into the Valley River and Assiniboine re-entrants in the escarpment (Klassen 1975), an advancement phase referred to as the Arran Advance or in southeastern Manitoba as the Marchand Advance (Fenton et al. 1983; Figure 1).

Klassen (1966) proposes a two-stage ice stagnation model for the Riding Mountain Uplands; first on the higher Eastern Uplands and later on the Western Uplands (Figure 1). The Horod Moraine (HM on Figure 1) is believed to be the hinge point for this model. Meltwaters ponded over the stagnant ice on the Eastern Uplands, creating small thermokarst supraglacial lakes, and later, an integrated network of ice-walled supraglacial lakes (McGinn 1991). Klassen (1966) named the largest of these ice-walled lakes glacial Lake Proven (Figure 1). Glacial Lake Proven appears to have begun as an elongated shallow ice marginal supraglacial lake formed in a transitional zone between the stagnating ice of the Eastern Uplands and the active Assiniboine Lobe (Souris Lobe) to the southwest (McGinn 2002). The eastern ridge of the Horod Moraine was deposited at the northwestern extension of this transitional zone (Figure 1). Stratigraphic sections in the moraine indicate that this feature is an ice marginal ridge (Jurgaitis and Juozapavičius 1989) or kame moraine (Klassen 1979) characterized by stratified and unstratified sands and gravels, large till inclusions and slump features (McGinn 1997).

The glacigenic facies in glacial Lake Proven basin represent a continuum of supraglacial/terminoglacial lacustrine sedimentation throughout the history of the glacial lake. Five to eight metres of moderately deformed Quaternary sediments are exposed in road and river cuts at elevations above 615 m southeast of the Eastern Ridge of the Horod Moraine near Bottle Lake (Figures 1 and 2). The lithofacies and textural characteristics of the sediments suggest that they were deposited in a subaqueous environment and are supraglacial in nature. Some of the lacustrine deposits depict the characteristics of a supraglacial lacustrine complex (Brodzikowski and van Loon 1991), with alternating layers of sand and silt. There is some regular lamination of the finer sand and silt, evidence of coarse intercalations and dropstones (McGinn 2002). Most of the sequence, however, can be classified as supraglacial lacustrine bottomsets consisting of coarse sand and granules/silty-clay rhythmites that fine upwards to medium-fine sand/silty-clay rhythmites (McGinn 2002).

Five GeoProbe® cores extracted from the glacial Lake Proven basin (Figure 2) indicate that there was a rich supply of sediment into the lake in that up to 7.5 m of lacustrine material was deposited in the deeper regions of the terminoglacial lake. Sediments exposed in the cores represent a variety of terminoglacial lacustrine facies: lacustrine complexes, lacustrine bottomsets, and lacustrine complexes grading to shallow-water lake-margin deposits consisting of relatively thick units (> 1.0 m) of laminated medium to fine sand or fine sand and silt (McGinn et al. 2009). There is often evidence of coarse intercalations and material supplied by mass movement or wash-off and numerous dropstones (McGinn et al. 2009).

Four cores were extracted from the Otter Lake sub-basin (Figure 2). Sedimentary sequences exposed in the progressively up valley series of GeoProbe cores demonstrate that supraglacial Lake Otter extended northeast farther up the present-day Upper Rolling River Valley (Figure 2). The sediments represent a variety of supraglacial/terminoglacial lacustrine deposits; lacustrine complexes grading to shallow-water lake-margin deposits (Zaniewski et al. 2007). Thick units (2 m to 3 m) of Holocene fluvial

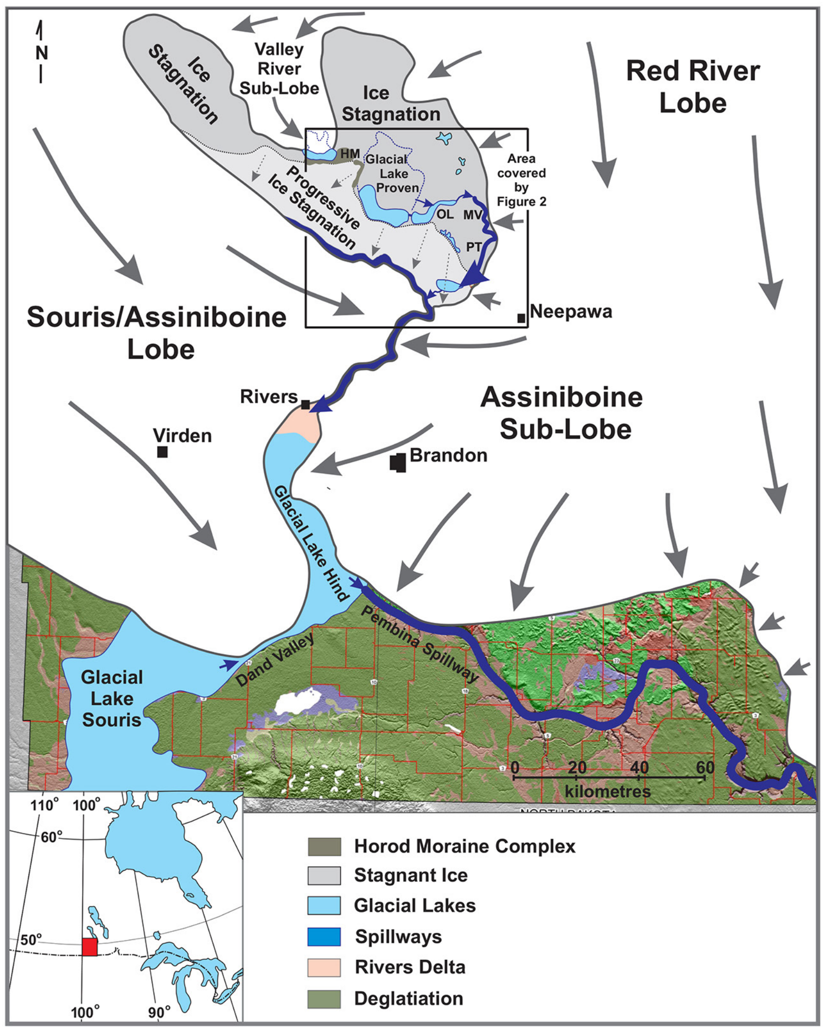



**Figure 1**
Glacial situation in southwestern Manitoba circa 14,000 BP
Cartography: R.A. McGinn

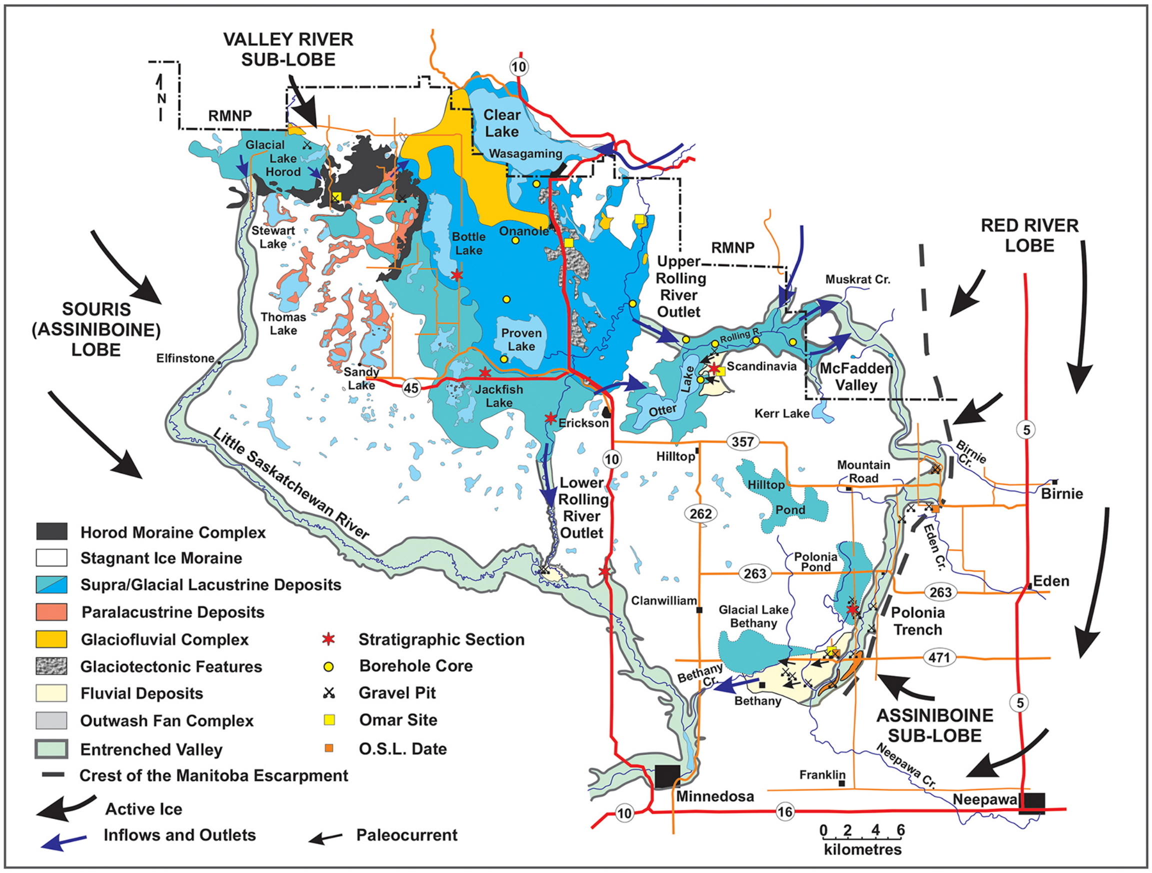



**Figure 2**
Surficial deposits in the glacial Lake Proven basin and the McFadden Valley and Polonia Trench
Cartography: R.A. McGinn

complexes and sheetflood deposits (Brodzikowski and van Loon 1991) overlay the glacial lacustrine deposits.

To date, diatoms, pollen, and other datable organics have not been found in the glacial Lake Proven basin deposits. Consequently, there is no absolute or relative chronology for the glacial Lake Proven stratigraphy or any estimates as to the longevity of the lake. To some extent this is not surprising, as the supraglacial subenvironment is located a significant distance from acknowledged ice margins. Stratigraphic position and interpretation become the default relative dating technique.

Early glacial Lake Proven drained over stagnant ice into the Otter Lake sub-basin (OL on Figures 1 and 2) and then eastward into the McFadden Valley-Polonia Trench (MVPT) spillway system (MV and PT on Figure 1). As glacial Lake Proven enlarged, transitioning from a supraglacial lake to a terminoglacial lake, the higher elevation ice marginal outlet channel was abandoned in favour of the relatively lower elevation Upper Rolling River outlet, which drained into the same eastern spillway system (McGinn 1991, 2002; Figures 1 and 2). It appears that the MVPT spillway system was in operation for a long period, probably throughout the history of glacial Lake Proven. At first, the supraglacial meltwaters flowed eastward down the ice sheet gradient to the edge of the Manitoba Escarpment and then paralleled the crest of the escarpment, draining southward (McGinn 1991). The meltwater channel rapidly entrenched into the substratum and a subaqueous fan/delta was deposited as the discharge entered a small supraglacial/terminoglacial lake southeast of glacial Lake Proven (McGinn 1991; Figures 1 and 2).

## Objective

This research examines the geomorphology and paleohydrology of the MVPT spillway system and the relationship to glacial Lake Proven.

## Glacigenic sediments

In 1989, the INQUA Commission on the Genesis and Lithology of Quaternary Deposits published a genetic classification of glacigenic deposits (Goldthwait and Matsch 1989). In this volume, Ashley (1989) reviews the sedimentary processes and lithofacies units in glacier-fed lakes and establishes lithofacies groups with commonly occurring lithofacies units. The lithologic criteria outlined in this publication are used in the current research.

Brodzikowski and van Loon (1991) present a synthesis of glacigenic sediments and establish a four-level systematic clas-

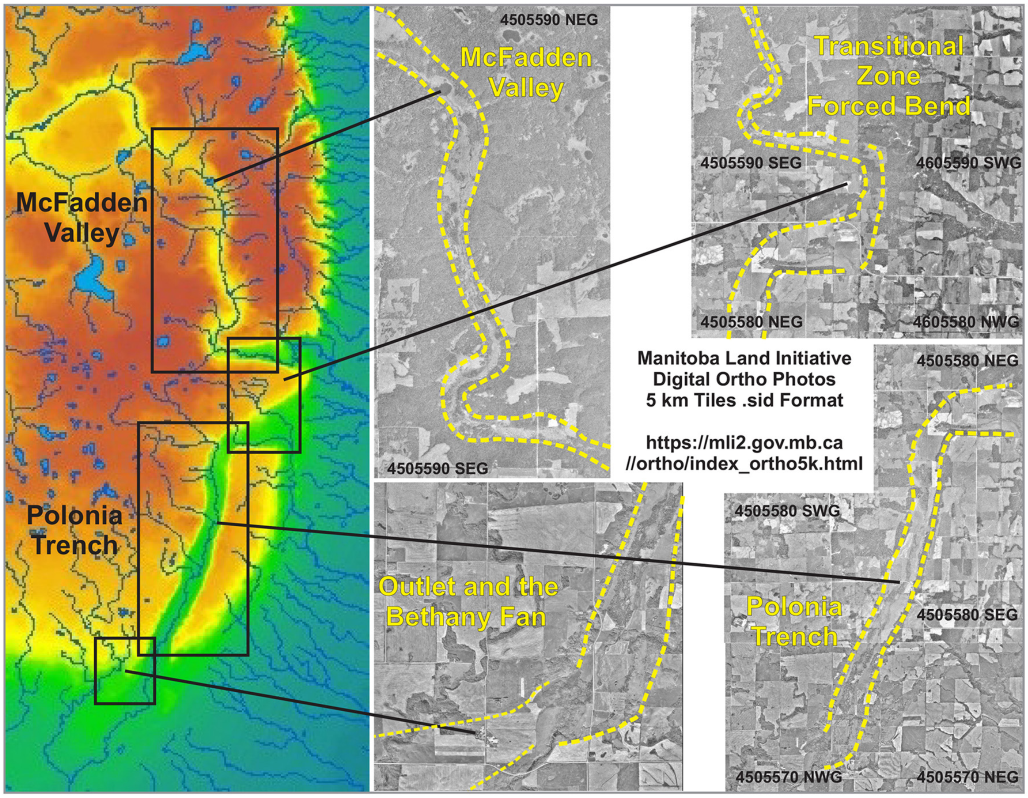



**Figure 3**
Physiographic components of the McFadden Valley-Polonia Trench spillway system
Cartography: R.A. McGinn

sification based on a general "glacial" or "periglacial" environment, the depositional subenvironment (e.g., supraglacial, englacial, subglacial), facies, and the characteristics of the deposits. The fourth level indicates the deposits associated with a specific depositional mechanism. For example, three types of deposits can be distinguished in the continental glacial, supraglacial, lacustrine facies: complexes, lake-margin deposits and bottomsets. The Brodzikowski and van Loon (1991) nomenclature is employed in this research.

## Procedures and methodology

Standard sedimentological observations were made (Stow 2005); specifically, site locality and lithofacies descriptions. Lithofacies observations include bed thickness, texture (use of comparator charts, hand lens and experience), and a description of sedimentary structures present: erosional, deformational, and bedding/lamination (parallel, wavy, cross, and graded). Observable paleocurrent indicators and fabric were measured with a conventional pocket transit (Brunton compass). Other lithofacies parameters recorded include Munsell colour, grain/clast morphology and lithology. Digital photographs were taken and sectional sketches, sketch logs and graphic logs constructed. GeoProbe and other cores are conventionally logged from the top down, whereas stratigraphic sections are described from the base unit upwards (Stow 2005). Lithofacies units identified in the stratigraphic section logs and core descriptions are compared to the characteristics of the Brodzikowski and van Loon (1991) four-level classification system derived for glacigenic sediments. Specifically, the characteristics of the "melting ice," "fluvial," "lacustrine," and "mass-transport" facies and the deposits associated with the "supraglacial" and "terminoglacial" subenvironments. The Brodzikowski and van Loon (1991) criteria formulate the basis used for all facies interpretations in this text.

## Physiography of the McFadden Valley-Polonia Trench

The MVPT spillway system can be subdivided into four physiographic regions; the McFadden Valley, a transitional zone, the Polonia Trench, and the spillway outlet/fan (Figure 3).

### McFadden Valley

Overflow from supraglacial Lake Otter drained eastward through two contemporaneous channels into the McFadden Valley ice-marginal channel (Figure 4). The late Wisconsinan McFadden channel drained south paralleling the active lateral margin of the Red River Lobe as it pressed up and over the Manitoba Escarpment. The McFadden Valley channel is approximately 14 km long, 0.75 km wide and deeply entrenched (45 m to 55 m) into the underlying Zelena Formation (Zelena Till) and the Odanah Member of the Pierre Shale Formation (Figure 5). The flat-bottomed valley floor is approximately 0.5 km wide and occupied by the Holocene Birnie Creek, several small ponds and numerous wetlands (Figure 4). While relatively straight, the ancestral McFadden Valley has three prominent meander bends; a limited meander bend in the north and two forced meanders in the south (Figure 4). Simons (1971) classifies entrenched stream morphological bends as "limited" and "forced" meanders based on the ratio of the length of radius of curvature (r) to the mean bankfull channel width in the bend (w), that is, r/w. The limited bend develops in consolidated material such as glacial diamict, which inhibits lateral erosion and mean r/w ratios exceed 7.0. Forced meander bends have a r/w ratio less than 3.0 indicating a sharp constricted bend often attributed to stream impingement at an angle of 60° to 100° on relatively consolidated and impermeable bank material.

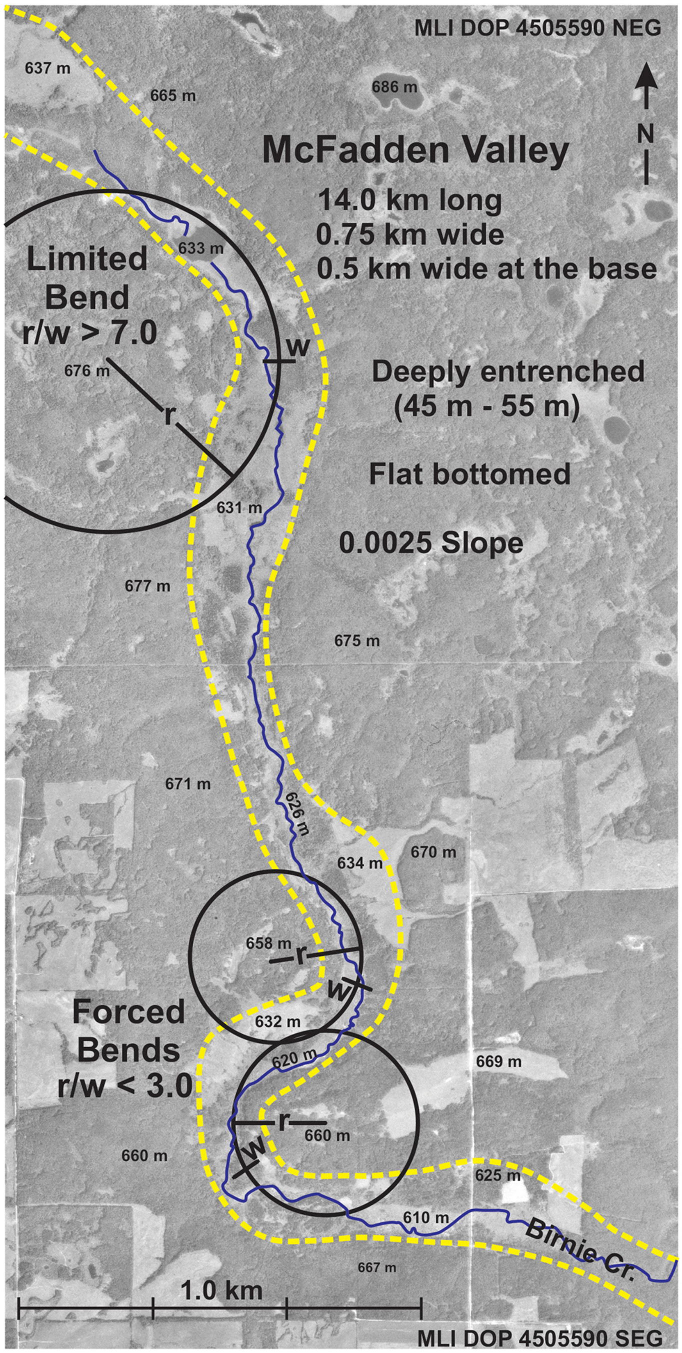



**Figure 4**
Physiography of the McFadden Valley
Cartography: R.A. McGinn

The McFadden Valley channel slopes at 2.5 m km$^{-1}$ (s = 0.0025). This segment of the spillway system is erosion dominated. There are no exposed sand and gravel deposits partly because most of the McFadden Valley is located in Riding Mountain National Park and there are few trails and no road access. There is some topographic evidence of terrace development in the southern region.

Based on the r/w ratios illustrated on Figure 4, the initial channel was a 100 m to 200 m wide braid plain coursing over debris-rich stagnant glacial ice and flowing parallel to the margin of active Red River ice to the east. As flow volumes increased, the anastomosing channel began to entrench into the subsurface Zelena diamict and eventually into the basement Odanah Member of the Pierre Shale Formation.

The Zelena Formation, on average, is 0.5 m to 5.0 m thick in the region and represents the uppermost tills (two) and inter-till sediments on the Riding Mountain Uplands deposited during the final stages of glacial stagnation (Klassen 1979; Figure 6). The Zelena Formation is composed of a supraglacial meltout complex, which overlies a slightly more compact supraglacial ablation till (McGinn 2000). The meltout complex is usually a typical diamict (38% sand, 31% silt, 31% clay), massive in appearance but with occasional concentrations of relatively coarse or fine material forming vague lenses (Klassen 1979). The ablation till is massive, and slightly more compact; 49% sand, 27% silt, 24% clay (Klassen 1979). Oxidized Zelena Till is usually yellowish brown or very dark grey brown in colour. Fresh (unoxidized) exposures are dark olive grey or very dark grey. The till is shale rich but since Odanah Shale clasts tend to disinte-

**Figure 5**
McFadden Valley: Deeply entrenched (55 m) into the underlying till and Cretaceous shale bedrock
Photography: R.A. McGinn

grate when removed from the matrix, it is difficult to determine a percentage composition. Interlake carbonates constitute approximately 26% to 36% of the clasts (Klassen 1979).

The Odonah Member of the Pierre Shale Formation is described as hard olive-grey siliceous shale with soft interbeds of darker olive-grey shale (McNeil and Caldwell 1981; Figure 7). The Cretaceous shales are composed of clay-sized siliceous particles, which show no sign of biogenic origin. The mineralogy is described as amorphous silica and illite with traces of quartz and organic carbon (Bannatyne 1970). Odanah Shale is jointed. Joints stain reddish to purplish brown and ironstone concretions are common. Dried out and weathered Odanah Shale is usually light olive grey in colour, non-calcareous, sub-fissile, siliceous and hard (McNeil and Caldwell 1981). Light brown to dark-yellowish-orange patches are common on some weathered fracture surfaces. Odanah Shales have high moisture absorption rates (approximately 20%) and air dry shrinkage rates of 4% to 8% (Bannatyne 1970). Consequently, theses shales are susceptible to hydration weathering, rapidly breaking down into small blade-like shapes over three to five wet/dry cycles (McGinn 2000; Figure 8). Mean ASCE (Corey) Shape Factor ($c/ab^{0.5}$) equals $0.296 \pm 0.064$. Mean relative density (specific gravity) is measured at 1.8 (Blais and McGinn 2011). It is speculated that sub-cropping Odanah Shale is responsible for the forced bends in south McFadden Valley.

### Transitional zone

The McFadden Valley transitions into the Polonia Trench through a 6 km long transitional zone featuring two spectacular forced meander bends (Figure 9). Eastward flow down the ancestral McFadden Valley was diverted by active glacial ice as the western margin of the Red River Lobe pressed westward, up and over the Manitoba Escarpment slope face (Figure 9). A 3 km long, 180° forced meander bend diverted the flow west. Active ice and sub-cropping Odanah Shale formed the cut bank (the left bank) of the forced bend, and on the right bank braid plain

**Figure 6**
Zelena Formation: Uppermost tills and intertill sediments on the Riding Mountain Uplands
Photography: R.A. McGinn

**Figure 7**
Odanah Member of the Pierre Shale Formation: A hard olive-grey siliceous shale with mean relative density (specific gravity) of 1.8
Photography: R.A. McGinn

**Figure 8**
Weathered Odanah Shales: Hydration weathering rapidly breaks down the shale into small blade like gravels
Photography: R.A. McGinn

(longitudinal bar) deposits evolved in a mega point bar deposit. Within 1 km, the westward flow impinged on sub-cropping hard olive-grey siliceous Odanah Shale and once again, a 90° forced meander diverted the flow south, paralleling the crest of the Manitoba Escarpment (Figure 9).

*Transitional zone deposits: The mega point bar.* Mega point bar deposits are exposed in four aggregate extraction pits (Figure 6; NTS 14U 459865.0 E, 5589784.0 N.). Stratigraphic sections in the mega point bar deposits suggest four zones of deposition. In the upper pit (A on Figure 10) coarse sand-sized shale exhibits parallel bedding and flow features characteristic of a longitudinal bar (Brodzikowski and van Loon 1991). Here, braid plain deposits predominately sand and fine gravel interfinger with a lateral accreting point bar deposit. The longitudinal bar deposits were sampled for optically stimulated luminescence (OSL), but since this sand is composed of predominantly Odanah shale and void of quartz and feldspar, the deposit is unsuitable for OSL dating.

The laterally accreting mid-bar deposits (B on Figure 10) are described as massive, horizontally bedded, clast supported gravel and cobbles with numerous boulder-sized clasts (Giles 1987; Figure 11). The slightly inclined, curved bedding generally fines upwards. Interlake carbonates and Shield-derived granitoids and metasedimentary rocks represent the predominate gravel and cobble lithologies; coarse sand and granule-sized shale fill the voids.

At a lower elevation (13 m below the laterally accreting surface), in an upstream position (C on Figure 10), a clast supported cobble and gravel deposit with a high boulder component is present. This deposit is interpreted as a combined channel lag deposit with infill fluvial sand and gravel. Large (up to 2 m in diameter) boulders are indicative of till washout and a channel lag or washover deposit (Giles 1987). Downstream from pit C, and only 10 m from the base of the modern day channel (D on Figure 10), a stratified sandy-pebbly gravel deposit fines upwards into a 20 cm thick silty-clay drape (Giles 1987). Overlying this overbank fill, a cross-bedded medium sand unit was sampled for OSL datable material (OSL sample B1, Table 1).

*Transitional zone stream piracy.* During the early Holocene, three steeply graded streams draining the escarpment slope, vigorously eroded headward into the Cretaceous shale scarp face and breached the eastern wall of the MVPT. Georgison (1988) describes several scenarios for a multiple stream piracy in the MVPT. The most probable sequence has Eden Creek captur-

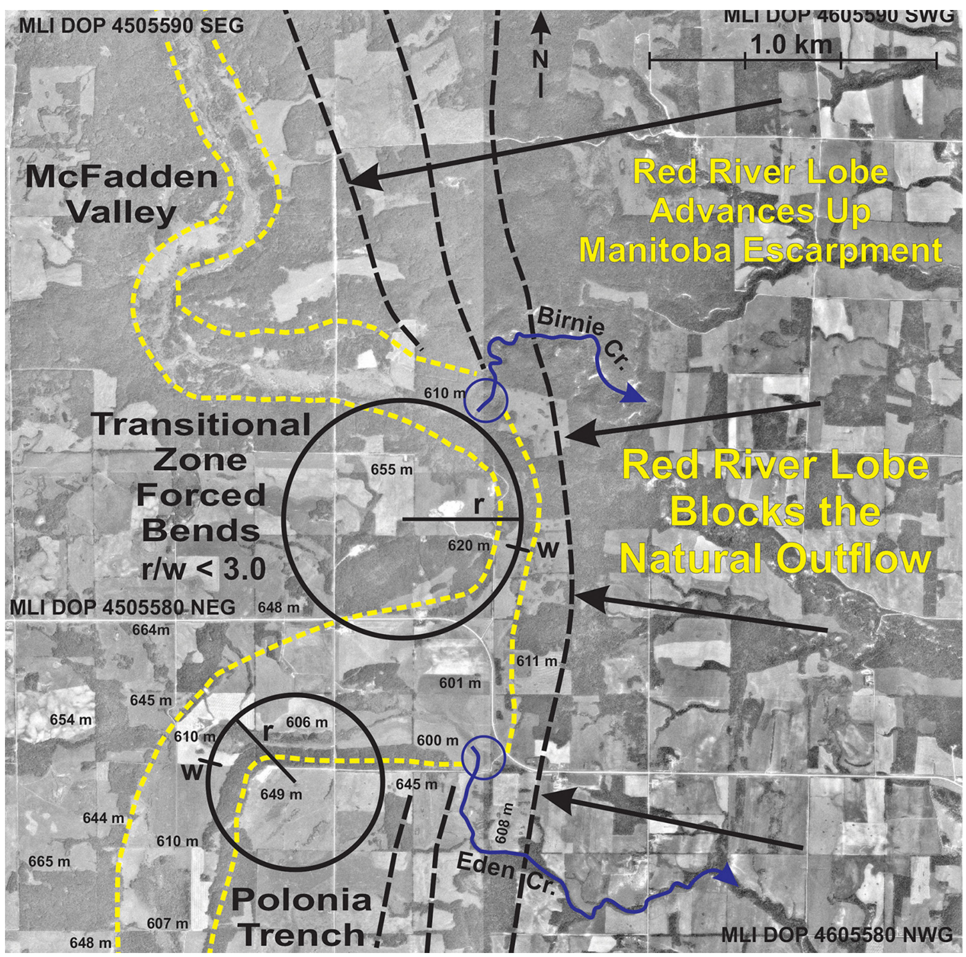



**Figure 9**
The transitional zone: McFadden Valley-Polonia Trench
Cartography: R.A. McGinn

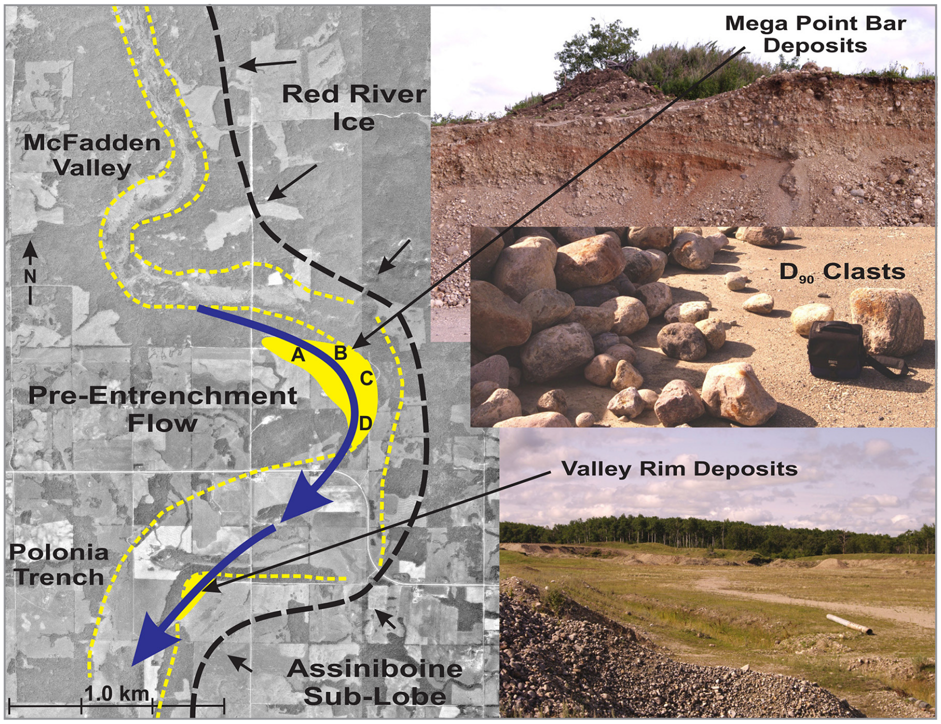



**Figure 10**
Mega point bar deposits and other sediments in the transition zone
Cartography and photography: R.A. McGinn

ing the ancestral McFadden Valley drainage (Figure 9). Shortly thereafter, Birnie Creek beheads the MV-Eden Creek flow approximately 3.0 km upstream of the Eden Creek elbow of capture. Some time later Neepawa Creek captures the Polonia Trench drainage.

## Polonia Trench

The Polonia Trench is a 13 km long straight channel exhibiting no meander bends (Figure 12). The ancestral channel, 1.2 km wide at the rim and 0.6 km wide at the base, is deeply entrenched, approximately 40 m to 50 m in the northern sections and 20 m to 30 m in the southern portion. For descriptive purposes, the Polonia Trench can be subdivided into two regions; North Polonia Trench (NPT), the entrenched valley north of the village of Polonia on Provincial Highway 357, and South Polonia Trench (SPT), the entrenched valley south of Polonia (Figure 12).

The general stratigraphy of the Polonia Trench is exposed in a road cut on the west side of the valley (NTS 14U 453545.0 E, 5577483.0 N; Figure 13). Here 4.5 m of stratified sand and gravel overlies approximately 5.0 m of diamict, which overlie Odanah Shale. The diamict exhibits the characteristic colour, texture, and structure of the Zelena ablation till, and the carbonate and Shield clasts have a weak north to south orientation (McGinn 2000). In-situ Odanah shale is exposed at the base of the 13 m deep road cut.

The Polonia Trench slopes at 2.3 m km$^{-1}$ (0.0023). The flat-bottomed channel is occupied by the Holocene Neepawa Creek and numerous wetland regions (Figure 12). There is sedimentological and topographic evidence of terrace development and valley rim deposits in both sub-regions. Unpaired terraces have been observed at elevations of 620 m and 601 m ASL on the east side of the valley and at 608 m and 600 m ASL on the west side (Figures 2 and 13). There are few exposures in these shallow deposits; typically, scoop pits which unearth shale rich gravel of little commercial value. These deposits are topographically distinct from remnant valley rim braid plain deposits located on the east side of the NPT at elevations of 642 m ASL (Figures 12 and

**Table 1**
Optically-stimulated luminescence dates from the Riding Mountain uplands and adjacent Lake Agassiz beaches

| Sample ID | Depth (cm) | Grain Size (µm) | Moisture Content (%) | Radio Activity Data U (ppm) | Th (ppm) | K (%) | Cosmic Radiation (CR µGy/a) | Dose Rate (Gy/ka) | Paleodose (De Gy) | Age (ka) |
|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 760 | 90–150 | 5 | 4.4 | 8.3 | 1.6 | 70±14 | 2.97±0.17 | 36.3±2.2 | 13.8±1.0 |
| A2 | 773 | 90–150 | 10 | 2.4 | 5.6 | 1.0 | 73±15 | 1.77±0.09 | 15.8±3.2 | 12.5±2.6 |
| B1 | 100 | 120–180 | 10 | 1.2 | 4.6 | 1.3 | 190±38 | 1.84±0.09 | 19.3±4.9 | 10.5±2.7 |
| C1 | 45 | 150–210 | 10 | 1.3 | 2.9 | 1.2 | 201±40 | 1.62±0.07 | 15.6±1.9 | 12.7±2.1 |
| C2 | 75 | 150–210 | 10 | 1.3 | 2.3 | 1.1 | 191±38 | 1.53±0.07 | 14.5±1.1 | 13.9±1.6 |
| D1 | 241 | 150–210 | 10 | 1.0 | 2.3 | 1.0 | 144±29 | 1.30±0.06 | 14.3±0.9 | 12.1±0.8 |

A1 Bethany Fan sample: NTS 14U 451908 N, 5575968 E, 602 m
A2 Bethany Fan sample: NTS 14U 451908 N, 5575968 E, 602 m
B1 Mega point bar sample: NTS 14U 460665 N, 5574953 E, 621 m
C1 Norcross beach sample: NTS 14U 467672 N, 5574927 E, 373 m
C2 Norcross beach sample: NTS 14U 467677 N, 5574899 E, 373 m
C3 Norcross beach sample: NTS 14U 468436 N, 5573840 E, 373 m

Source: Teller et al. 2018

**Figure 11**
Laterally accreting mega point bar deposits: Horizontally bedded, slightly inclined, massive clast supported gravels and cobbles
Photography: R.A. McGinn

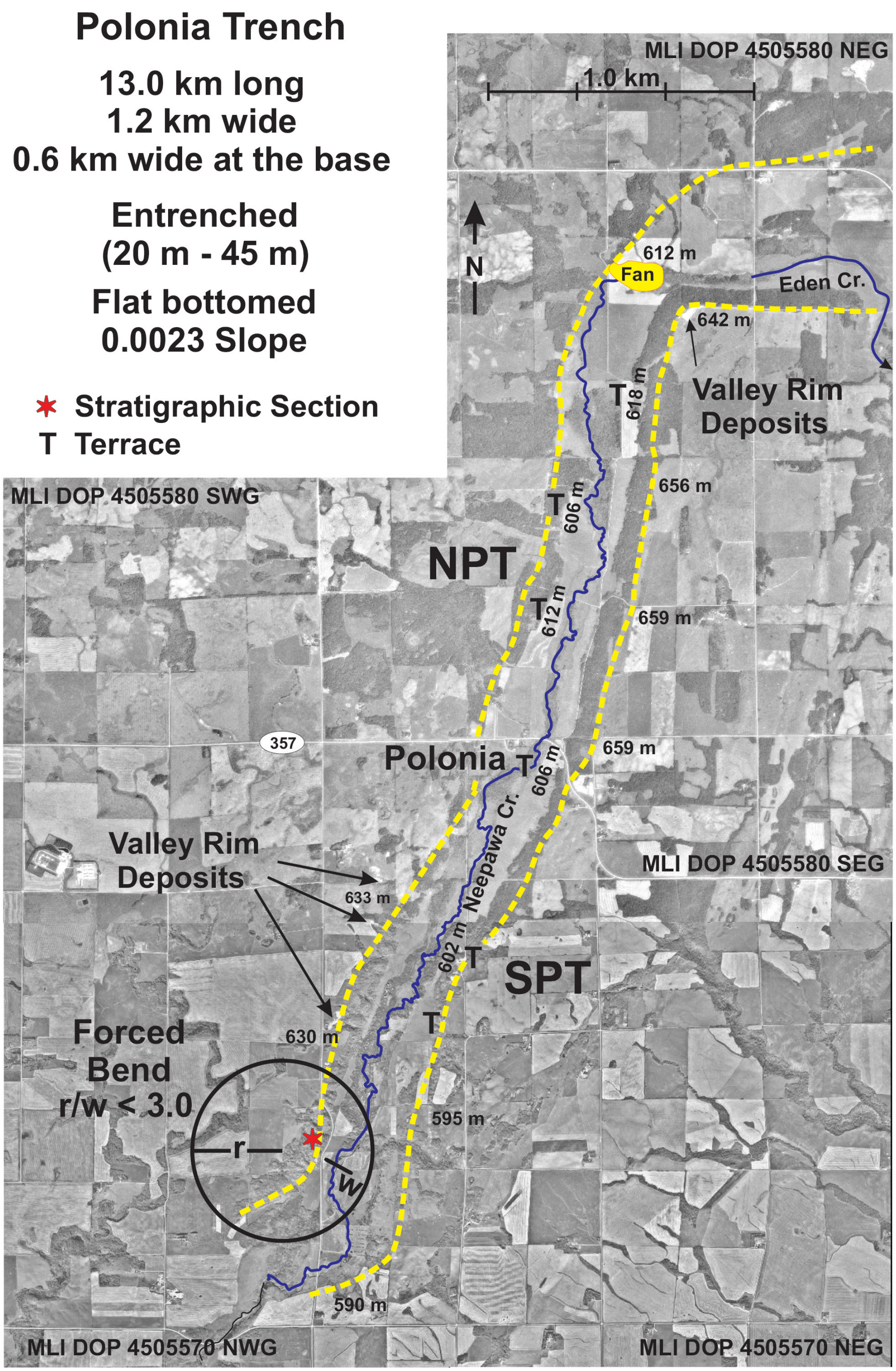



**Figure 12**
Physiography of the Polonia Trench
Cartography: R.A. McGinn

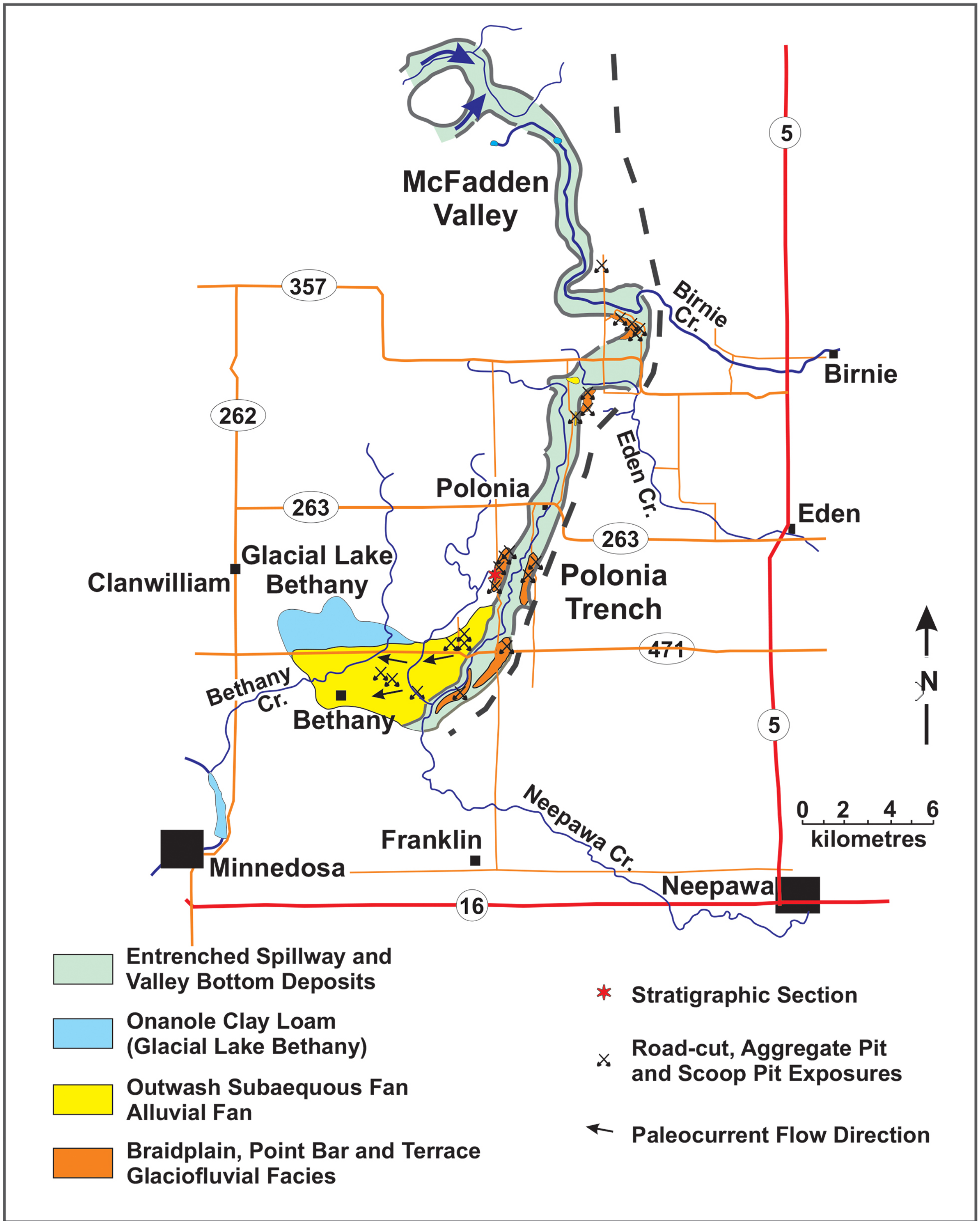



**Figure 13**
McFadden Valley-Polonia Trench – Bethany fan sediments
Cartography: R.A. McGinn

13). Similar valley rim deposits are found at lower elevations (630 m to 635 m ASL) on the western rim of the SPT sub-region. These thin (< 3 m) valley rim sediments composed of stratified sands and gravels are indicative of longitudinal bar, streamflood, and sheetflood deposits.

Streamflood and sheetflood deposits form during and following sudden outbursts of sediment rich meltwater (Brodzikowski and van Loon 1991). Deposits are of irregular thickness and commonly interfinger with fluvial/glaciofluvial deposits. Streamflood valley rim deposits consist of relatively coarse gravel fining upward to coarse sand. The sand grains are composed of local shale and considered unsuitable for OLS dating. Gravel-sized clasts are shale rich but appear to contain a disproportionate number of sub-angular to sub-rounded carbonates and Shield granitoids and metasedimentaries. The more numerous gravel to cobble-sized shale exposed in extraction pits rapidly weather to fine gravel and very coarse sand. Sheetflood deposits in the region are thinner, horizontally stratified, and poorly sorted shale sands and gravel with stringers of buff coloured carbonate pebbles.

There is little evidence of glaciofluvial gravel forming the base of the Polonia Trench. However, a small Holocene alluvial fan has spread shale rich alluvium across the floor of the NPT (Figure 13). These shale rich alluvial gravels are of little commercial value, used by locals for fill and farm lane grading.

The Polonia Trench ends in a 110° forced meander (Figure 12) exiting the entrenched channel towards the west and spreading across a 2.5 km wide, 7.0 km long deposit interpreted as a shallow water underflow fan/delta (Benn and Evans 2010).

Klassen (1979) speculates that a late glacial advance of the Red River Lobe east of the Manitoba Escarpment pushed westward into the Swan River, Valley River and Assiniboine re-entrants (Figure 1). Other authors (Nielson 1988; Groom 2006; Hodder and Trommelen 2015) refer to this late glacial advance in southern Manitoba as the Arran Advance depositing a carbonate rich till sheet in the re-entrants; the Arran Formation. Fenton et al. (1983) refer to this late Wisconsinan advance in the eastern Agassiz basin as the Marchand Advance, occurring approximately 11.2 ka BP. Along the northern edge of the Assiniboine re-entrant active glacial ice pressed up and over the 230 m high Manitoba Escarpment. A carbonate rich till (Arran Fm?), deposited over distorted sands and gravels, exposed in a small pit (NTS 14U 455346.00 E, 5579550.00 N 626 m) supports this hypothesis. Two and one half km to the southwest, the advancing Assiniboine sub-lobe blocked the natural outlet of the Polonia Trench and consequently, diverted flow westward across stagnant ice. MVPT meltwaters drained into a small supraglacial or terminoglacial Lake Bethany (McGinn 1991) depositing a braid plain/subaqueous fan/delta.

Arran Fm. Till is, on average, 2 m to 3 m thick, along the eastern margin of the Polonia Trench. The carbonate rich, yellow-brown ablation till is loose, similar in texture to the Zelena Till and the youngest diamict in the region (Klassen 1979). Interlake carbonates (34% to 65%), weathered Shield granitoids and metasediments (approximately 30%), and fractured shales constitute the typical clasts. Two dimensional fabric analyses of the carbonate and Shield clasts indicate a preferred east to west orientation (McGinn, unpublished data). The similar Zelena Till west of the Polonia Trench has a weak north-northwest to south-southeast preferred orientation (Klassen 1979; Groom 2008).

### Glacial Lake Bethany and associated underflow fan

Glacial Lake Bethany, a shallow glacial lake (possibly a supraglacial lake), was surrounded by wasting stagnant ice on the southern margin of the Eastern Uplands (Figures 2 and 13). The small lake was fed by local meltwaters and the meltwater discharge from the Polonia Trench. There are no exposures of glacial Lake Bethany deposits and no topographically defined shoreline. Consequently, mapping lake boundaries is speculative, relying on the distribution of fine-grained soils evolving over lacustrine parent material displayed on the Reconnaissance Soil Survey Map of the West-Lake Map Sheet Area (Ehrlich et al. 1958).

The Onanole Clay Loam is a degrading black meadow soil "developed on medium to coarse textured lacustrine deposits which lie over… till" (Ehrlich et al. 1958, 57). In the Bethany region, topographies associated with the Onanole Clay Loam are described as gently sloping to irregular gently sloping. This observation suggests that a relatively flat Lake Bethany lacustrine plain may have experienced post depositional deformation, associated with the meltout of the underlying stagnant ice. The same lacustrine-based soil series has developed on nearby glacial Lake Proven and glacial Lake Otter lacustrine deposits.

A significant portion of the Lake Bethany sediment is overlain by underflow fan/delta glaciofluvial deposits (Figure 13). Marringhurst soils are well-drained, weakly developed black soils composed of coarse sands and gravels, evolving on glaciofluvial deposits (Ehrlich et al. 1958). In the Bethany region, the Marringhurst shale variant soil has evolved over the subaqueous fan/delta deposit in glacial Lake Bethany (Figure 13). As discussed below, numerous active and depleted gravel extraction pits speckle the underflow fan/delta aggregate deposit. Lake Bethany appears to have drained westward into the ancestral Little Saskatchewan River drainage system (McGinn 1991).

Benn and Evans (2010) describe three general types of glacial fed deltas: the shallow water Hjulstrom-type or underflow fan/delta, the deeper water Gilbert-type delta, and the intermediate in character, Salisbury delta (Church and Gilbert 1975). Brodzikowski and van Loon (1991) subdivide the Hjulstrom-type delta into "fan-type" deltas and "braid-type" deltas. Fan deltas are formed by the progradation of a glaciofluvial fan into a terminoglacial lake whereas braid deltas are formed by a prograding sandur into a proglacial lake.

The Bethany underflow fan/delta appears to be a subaqueous shallow water Hjulstrom-type deposit in an ice-walled terminoglacial lake, constructed by the discharge of a steep to moderate gradient high energy inflow stream; the MVPT. The aggregate resource deposit appears on Mihychuk and Groom's (1979) preliminary map and the Manitoba Energy and Mines (1988) Aggregate Resources Map AR88 1-7. The resource is described as sandy coarse pebble gravel with high shale content (Young 1982).

Benn and Evans (2010) indicate that the Hjulstrom-type fan/delta has three depositional sub-regions: apex aerial sandur topsets, delta front foresets, and pro-delta bottomsets. Apex sandur topsets are characterized by coarse bedload, clast supported, braid plain streamflood deposits (Benn and Evans 2010). Delta front foresets are often massive, poorly sorted, class supported cobbles, pebbles, and gravels with a coarse sand matrix and/or graded bedded sands and gravels, commonly deposited by high-density turbulent underflows (Benn and Evans 2010). Foresets vary in inclination from 0° to 30° and are typically coarser in the upper slopes, fining down foreset. The distal pro-delta bottomsets are deposited by subaqueous traction currents, density flows and underflows, which frequently interfinger lacustrine sediments (Benn and Evans 2010).

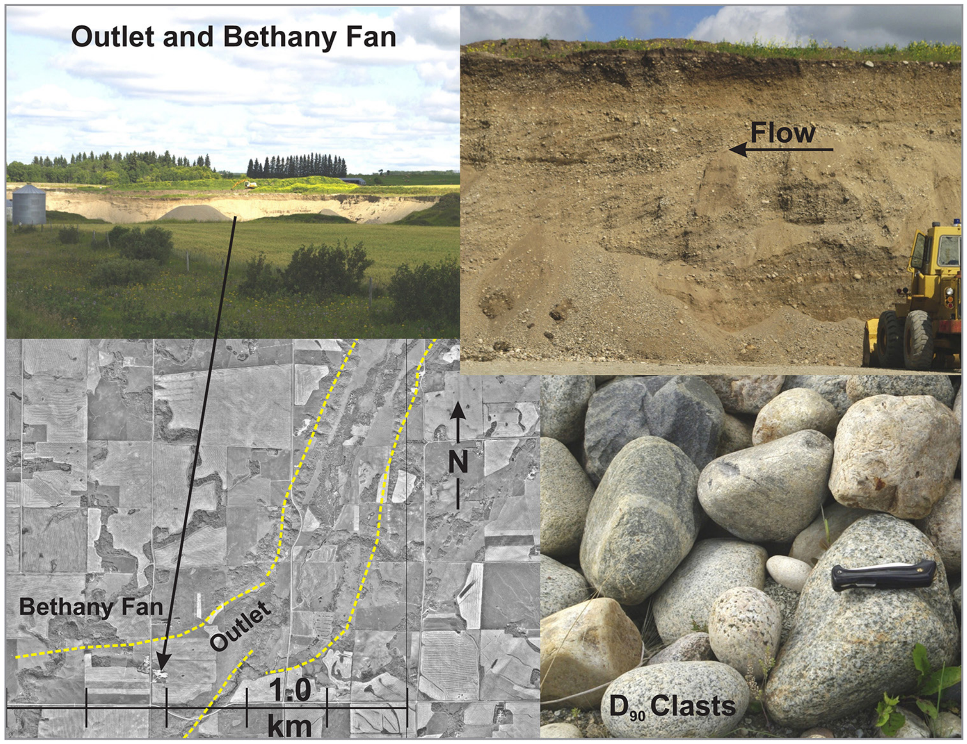



**Figure 14**
Bethany fan sediments
Cartography and photography: R.A. McGinn

Giles (1987) describes the Bethany fan apex delta/sandur topsets as stratified, horizontally laminated pebbly sand and gravel, grading upward into coarse to fine sands. The deposit is overlain by poorly sorted, moderately rounded, very coarse pebbly gravel with interchannel sands and gravels. Giles (1987) interprets the stratigraphic section to represents a transition or "wedging out" of streamflood deposits to "fan-type" deltaic topsets.

Delta foresets are exposed in a large, active extraction pit 5.9 km east-northeast of Bethany, (NTS 14U 451908 E, 5575968 N, 600 m asl., Figures 14 and 15). Coarse gravel foresets, dipping southwest are exposed at the base of the section. This unit is overlain by a 2 m thick sandy silt drape, coarsening upward into very coarse sand, granules, and fine gravel that dips west at 5°. Sand in the unit was sampled for OSL dating (OSL samples A1 and A2, Table 1). This sand unit is overlain by a 2 m thick gravel unit, which coarsens upward from a fine gravel-granule-sand, dipping west, to a matrix-supported gravel of mixed lithology (Figure 15). The matrix is predominantly sand and granule-sized clasts composed of shale. This unit is overlain by over 6 m of foreset beds composed of class supported, cobble-pebble gravels up to 20 cm in diameter and dipping 30° to the west. A detailed description of the Bethany fan stratigraphic section is found in Appendix 1. Samples collected from the delta front exhibit mean textural values of 74% cobbles/pebbles/granules, 23% sands, and 3% fines (Young 1982).

Several shallow exposure pits are found in the pro-delta region approximately 2 km east-northeast of Bethany, Manitoba (NTS 14U 4483577.0 E, 5574577.0 N, 574 m ASL.). Here stratified fine to medium texture shale gravel, interbedded with silt and clay, form the parent material for the Marringhurst shale variant soil. The predominance of shale gravel in the normally fine-grained pro-delta bottomsets is probably due to the low specific gravity of the Odanah Shale (1.8) and hydration weathering that produces a fluid dynamic blade shape that facilitates the transport of these fine gravels down low energy gradients. Pro-delta core and exposure samples record mean textural values of 55% pebbles/granules, 41% sands, and 3% fines (Young 1982).

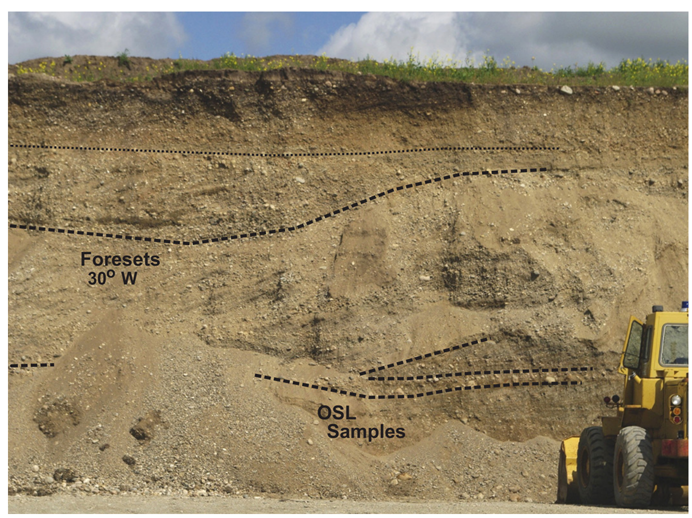



**Figure 15**
Bethany fan sediments: Inclined foresets of mixed lithology. OSL calibrated ages of 13.8 to 12.5 ka
Photography: R.A. McGinn

Omars

Omars, an abbreviated term proposed by Prest (1990) for clasts derived from the Omarolluk Formation, are distinctive glacial erratics composed of massive siliceous greywacke, characterized by buff-weathering sub-spherical calcareous concretions (Figure 16). The Omarolluk Formation is a thick Proterozoic turbidite-flysch deposit outcropping in the Belcher Islands, southeastern Hudson Bay (Ricketts and Donaldson 1981). Omars found in southern Manitoba have experienced a minimum of two episodes of Late Wisconsinan glacial dispersal; an early northwest to westward flow from the Belcher Islands source region (Labrador Sector ice flow), followed by the north to south-southeast dispersal by the Keewatin Sector ice flow (Prest et al. 2000). Their occurrence on the Riding Mountain Uplands are rare but have been found in the mega point bar deposit (Pit B), the Bethany fan, the Horod Moraine ice marginal ridge deposit, the Onanole Outwash (Beatty Pit #1 and the eastern outwash pit), and the Scandinavia Outwash fan (Figure 2). The occurrence of omars on the Riding Mountain Uplands supports ice flow directions proposed by Klassen (1975, 1979), Groom (1980, 2006, 2008), Nielsen (1988), McGinn (2000), and Hodder and Trommelen (2015).

**Figure 16**
Omar found in the Bethany fan. A massive siliceous greywacke, characterized by a buff-weathering spherical calcareous concretion.
Provenance: Belcher Island, Hudson Bay, Canada
Photography: R.A. McGinn

## Discussion

The MVPT formed shortly after stagnation and downwasting of the Laurentide Ice Sheet on the Eastern Uplands of Riding Mountain. Meltwaters, ponding in supraglacial Lake Proven and glacial Lake Otter, drained over stagnant ice towards the east. Active ice remained east of Riding Mountain. Here the Red River Lobe advanced south towards the current day American border and beyond, the lateral margin pressing westward against the Manitoba Escarpment along the eastern edge of Riding Mountain and occupying the Assiniboine re-entrant (Figure 1). Consequently, the natural drainage from the Eastern Uplands down the escarpment slope was blocked and meltwater drainage was diverted southward paralleling the western margin of the Red River Lobe. During this time, the MVPT entrenched 35 m to 60 m into the underlying stagnant ice, the Zelena Formation and the basement Odanah Member of the Pierre Shale Formation. Along the southern boundary of the Eastern Uplands, drainage over the escarpment crest into the Assiniboine re-entrant was blocked by glacial ice (the Assiniboine Sub-lobe) and meltwater flows were diverted westward, ponding in glacial Lake Bethany (Figure 2). Shale rich sediments derived from the MVPT were deposited in an underflow fan/delta building into the supra/terminoglacial lake (Figure 2). Glacial Lake Bethany drained west along the northern margin of the Assiniboine Sub-lobe to join the ancestral Little Saskatchewan River and drain into glacial Lake Hind (Figure 1).

Two sediment samples, extracted from foreset beds in the Bethany fan and dated at 13.8 ka and 12.5 ka, yield a mean age of 13.2 cal ka (Site A, Table 1; Teller et al. 2018). A third OSL age, derived from a sample taken near the base of the McFadden Valley is dated at 10.1 ka (Site B, Table 1). The three OSL ages effectively bracket a 4000-year period of flow and sediment deposition for the MVPT (Table 1).

The mean OSL age of 13.2 ka for a well-established, entrenched MVPT is older than the earliest radiocarbon age (13 cal ka BP) for Assiniboine River outwash near Brandon, Manitoba and consequently, an unobstructed Assiniboine River draining into glacial Lake Agassiz (Dyke and Prest 1987). New radiocarbon dates for the drainage of glacial Lake Hind confirm that the Assiniboine Sub-lobe was breached near Brandon approximately 13 cal ka BP (Teller et al. 2015).

Teller et al. (2018) published two dates from the Lake Agassiz Norcross beach series located on the Agassiz lake plain, near Eden, Manitoba; 10 km east and 230 m below the Bethany fan deposit (Site C, Table 1). A mean OSL age of 13.3 ka suggests that the LIS had vacated the Assiniboine re-entrant at this time and retreated north of present day Neepawa, Manitoba. Early glacial Lake Agassiz (Norcross phase) expanded into the area. The Norcross beach OSL ages (Teller et al 2018) are within the error estimates of the 13.6 ka mean OSL age for the Norcross strandline in the Lake Traverse, Minnesota area (Lepper et al. 2013) and a 13.4 ka OSL age for the Norcross beach series near Morden, Manitoba (Teller et al. 2018). However, a third OSL age of 12.1 for a Norcross beach sample taken 2.2 km north-northeast of Sample Site C (Site D, Table 1) changes the average OSL age for the Norcross beach in the Eden region to 12.9 ka, an age arguably in accordance with the lower elevation Tintah strandline (for discussion, see Teller et al. 2018). Further research with respect to the relative physiography and geomorphology of the Herman-Norcross-Tintah (HNT) strandline series and respective OSL dates in the Eden/Arden region is required.

## Summary and conclusion

During deglaciation of the Eastern Uplands on Riding Mountain, stagnating ice was bordered by ice marginal disintegration ridges (kame moraine) and supraglacial/terminoglacial lakes and ponds. Entrenched channels and spillways such as the MVPT, ancestral Little Saskatchewan River and the Rolling River drained meltwaters from the Eastern Uplands south into proto glacial Lake Hind and eventually into glacial Lake Agassiz. It is estimated that the MVPT spillway/channel draining glacial Lake Proven/glacial Lake Otter was active for approximately 4000 years from approximately 14 ka to 10 ka. During this time interval, MVPT sediments were deposited as valley rim deposits, in unpaired terraces and in a Hjulstorm-type underflow fan-type delta. Today, shale rich glaciofluvial sediments provide approximately 16 million $m^3$ of medium quality aggregate resources that are marginally suitable for asphalt, road base, sub-base, shoulders and traffic gravel, but are not suitable for concrete aggregate or cement (Young 1982).

## References


Ashley, G. M. 1989. Classification of glaciolacustrine deposits. In *Genetic classification of glacigenic deposits*, ed. R. P. Goldthwait, and C. L. Matsch. Rotterdam, Netherlands: Balkema, 243–360.

Bannatyne, B. B. 1970. The clays and shales of Manitoba. Manitoba Department of Mines and Natural Resources, Mines Branch, Publication 67(1): 1–104.

Benn, D. I., and D. J. A. Evans. 2010. *Glaciers and glaciation*. 5th ed. London, UK: Hodder Education.

Blais, E. L., and R. A. McGinn. 2011. Critical erosion velocity for natural shale gravels: An empirical study. *Prairie Perspectives: Geographical Essays* 14: 51–59.

Brodzikowski, K., and A. J. van Loon. 1991. Developments in sedimentology. *Glacigenic Sediments* 49. Amsterdam, Netherlands: Elsevier.

Church, M., and R. Gilbert. 1975. Proglacial fluvial and lacustrine sediments. In *Glaciofluvial and glaciolacustrine sedimentation*, Special Publication 23. ed. A. V. Jopling, and B. C. McDonald. Tulsa, OK: SEPM, Society for Sedimentary Geology, 22–100.

Dyke, A. S., and V. K. Prest. 1987. Late Wisconsinan and Holocene history of the Laurentide Ice Sheet. *Géographie Physique et Quaternaire* 41(2): 237–263.

Ehrlich, W. A., L. E. Pratt, E. A. Poyser, and F. P. Leclaire. 1958. Reconnaissance soil survey of West-Lake map sheet area. *Manitoba Soil Survey Soils Report* 8. Winnipeg, MB: Manitoba Department of Agriculture.

Elson. J. A. 1956. Surficial geology and stratigraphy of the Tiger Hills region. PhD thesis, Yale University, New Haven, Connecticut.

—. 1958. Pleistocene history of southwestern Manitoba. In *Guidebook, Ninth Annual Field Conference*, North Dakota Geological Survey Miscellaneous Set 10, ed. W. M. Laird, R. W. Lemke, and M. Hansen. Grand Forks, ND: North Dakota Geological Survey, 62–73.

Fenton, M. M., S. R. Moran, J. T. Teller, and L. Clayton. 1983. Quaternary stratigraphy and history in the southern part of the Lake Agassiz basin. In *Glacial Lake Agassiz*, Geological Association of Canada Special Paper 26, ed. J. T. Teller and L. Clayton. Toronto, ON: University of Toronto Press, 49–74.

Georgison, J. P. 1988. A comparative morphology of stream pirate watersheds along the Riding Mountain Escarpment to determine the occurrence of resulting impact of stream piracy. BSc thesis, Brandon University, Manitoba.

Giles, T. R. 1987. Glaciofluvial gravels of the Polonia Trench meltwater channel, Riding Mountain Uplands, Manitoba. Topics Research Paper, Brandon University, Manitoba.

Goldthwait, R. P., and C. L. Matsch, eds. 1989. *Genetic classification of glacigenic deposits: Final report of the Commission on Genesis and Lithology of Glacial Quaternary Deposits of the International Union for Quaternary Research (INQUA)*. Rotterdam, Netherlands: Balkema.

Groom, H. D. 1980. The surficial geology of the South Riding Mountain Planning District. In *Manitoba geological survey: Report of field activities, 1980*. Winnipeg, MB: Manitoba Mineral Resources Division, Manitoba Geological Survey, 82–83.

—. 2006. Aggregate resources in the Rural Municipality of Ste. Rose, Manitoba (NTS 62J 13, 14, 62O 3, 4). In *Manitoba geological survey: Report of activities 2006*. Winnipeg, MB: Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, 234–239.

—. 2008. Aggregate resources in the rural municipalities of Dauphin, Ethelbert, Gilbert Plains, Grandview and Mossey River, Manitoba (parts of NTS 62N 1, 2, 7, 8, 9, 10, 62O 4, 5, 12). In *Manitoba geological survey: Report of activities 2008*. Winnipeg, MB: Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, 159–170.

Hodder, T. J., and M. S. Trommelen. 2015. Quarternary geology of the Arden NTS area (62J6), southwestern Manitoba. In *Manitoba geological survey: Report of activities 2015*. Winnipeg, MB: Manitoba Mineral Resources, Manitoba Geological Survey, 115–123.

Jurgaitis, A., and G. Juozapavičius. 1989. Genetic classification of glaciofluvial deposits and criteria for their recognition. In *Genetic classification of glacigenic deposits*, ed. R. P. Goldthwait, and C. L. Matsch. Rotterdam, Netherlands: Balkema, 227–242.

Klassen, R. W. 1966. The surficial geology of the Riding Mountain area, Manitoba-Saskatchewan. PhD thesis, University of Saskatchewan, Saskatchewan.

—. 1975. Quaternary geology and geomorphology of Assiniboine and Qu'Appelle valleys of Manitoba and Saskatchewan. *Geological Survey of Canada Bulletin* 228. Hull, QC: Canadian Government Publishing Centre.

—. 1979. Pleistocene geology and geomorphology of the Riding Mountain and Duck Mountain areas, Manitoba-Saskatchewan. *Geological Survey of Canada Memoir* 396. Hull, QC: Canadian Government Publishing Centre.

Lepper, K., A. W. Buell, T. G. Fisher, and T. V. Lowell. 2013. A chronology for glacial Lake Agassiz shorelines along Upham's namesake transit. *Quaternary Research* 80(1): 88–98.

Manitoba Energy and Mines. 1988. Aggregate resources compilation map AR88 1–7, Neepawa: (NTS 62J) 1:250,000. Winnipeg, MB: Manitoba Mineral Resources Division.

McGinn, R. A. 1991. The formation and draining of late Wisconsinan superglacial lakes on the Riding Mountain Uplands, Manitoba. *Atlantic Geology* 27(3): 221–227.

—. 1997. The Horod Moraine: The facies and deposits of a supra-terminoglacial subenvironment. In *Estevan Papers, Regina Geographical Studies* 6, ed. B. D. Thraves, A. H. Paul, and R. W. Widdis.

Regina, SK: University of Regina, 100–112.
—. 2000. Ice-shoved hills and related glaciotectonic features in the glacial Lake Proven basin, Riding Mountain Uplands, Manitoba. *Prairie Perspectives: Geographical Essays* 3: 84–96.
—. 2002. A sedimentary sequence in the glacial Lake Proven basin: The Rolling River section, Riding Mountain, Manitoba. *Prairie Perspectives: Geographical Essays* 5: 111–126.
McGinn, R. A., D. J. Wiseman, and K. Zaniewski. 2009. Terminoglacial lacustrine sediments and other deposits in the glacial Lake Proven basin, Riding Mountain, Manitoba. *Prairie Perspectives: Geographical Essays* 12: 63–78.
McNeil, D. H., and W. G. E. Caldwell. 1981. *Cretaceous rocks and their foraminifera in the Manitoba Escarpment (Special Paper)* 21. Geological Association of Canada and Department of Earth Science, University of Waterloo.
Mihychuk, M. A., and H. Groom. 1979. Quaternary geology and aggregate resources of the Neepawa area–Arden (NTS 62J/5E and 62J/6W). *Preliminary Maps 1979 PN -1 and 2*, scale 1:50,000.Winnipeg, MB: Department of Mines, Natural Resources and Environment, Mineral Resources Division.
Nielsen, E. 1988. *Surficial geology of the Swan River area*. Report GR80-7, Winnipeg, MB: Manitoba Energy and Mines, Geological Services.
Prest, V. K. 1990. Laurentide ice-flow patterns: A historical review, and implications of the dispersal of Belcher Island erratics. *Géographie Physique et Quaternaire* 44(2): 113–136.
Prest, V. K., J. A. Donaldson, and H. D. Mooers. 2000. The omar story: The role of omars in assessing glacial history of west-central North America. *Géographie Physique et Quaternaire* 54(3): 257–270.
Ricketts, B. D., and J. A. Donaldson. 1981. Sedimentary history of the Belcher Group of Hudson Bay. In *Proterozoic basins of Canada*, Paper 81–10, ed. F. H. A. Campbell. Geological Survey of Canada, 235–254.
Simons, D. B. 1971. River and canal morphology. In *River mechanics Vol. II*, ed. H. W. Shen. Fort Collins, CO: H. W. Shen, 20/1–60.
Stow, D. A. V. 2005. *Sedimentary rocks in the field: A colour guide*. Burlington, MA: Elsevier Academic Press.
Sun, C. S., and J. T. Teller. 1997. Reconstruction of glacial Lake Hind in southwestern Manitoba, Canada. *Journal of Paleolimnology* 17(1): 9–21.
Teller, J. T., M. LeCompte, J. Kennett, A. Telka, M. Boyd, A. West, R. Garcia, D. Batchelor, and C. Mooney. 2015. A Younger Dryas sequence in the glacial Lake Hind basin of Manitoba, Canada. *Abstracts*. XIX International Quarternary Association Congress. Nagoya, Japan.
Teller, J. T., R. A. McGinn, H. M. Rajapara, A. D. Shukla, and A. K. Singhvi. 2018. Optically-stimulated luminescence ages from the Lake Agassiz basin in Manitoba. *Quaternary Research* 89(2): 478–493.
Young, R. V. 1982. Aggregate resource inventory of south Riding Mountain area. Open File Report OF83-1.Winnipeg, MB: Manitoba Department of Energy and Mines, Mineral Resources Division.
Zaniewski, K., R. A. McGinn, and D. J. Wiseman. 2007. The extent and characteristics of glaciolacustrine and other deposits in the Otter Lake basin, Riding Mountain Uplands, Manitoba. *Prairie Perspectives: Geographical Essays* 10: 173–190.

## APPENDIX 1

### Description of the Bethany fan/delta section, OSL sample sites A1 and A2 after Teller et al. (2018) and personal observations (2010).

| | |
|---|---|
| 0.5 m | Soil |
| 3 m | Cobbly bedded, clast supported, gravel (10 cm diameter, maximum 20 cm diameter). Fines upward to a pebbly gravel of mixed lithology. Distinct angular lower contact. |
| 3 m | Very coarse, matrix supported, pebbly sand and gravel (1 to 5 cm diameter). Thick cross-beds dipping 30° W. Distinct lower contact, undulating. |
| 0.1–1.5 m | Matrix supported gravel (2 to 5 cm diameter), sand and occasional cobbles. Mixed lithology, sub-rounded metasedimentaries and carbonates. Distinct undulating lower contact. |
| 0.1–0.4 m | Very coarse-fine gravel, granules and sand; Dipping W. Dune bedform with an overlying drape. Distinct lower contact. |
| 0.1–2.0 m | Silt, coarsening upwards. Sandy in upper part, clayey in lower part. Scour and fill structures throughout. Irregular but distinct lower contact. OSL Sample A1, 55 cm from top of the unit. OSL Sample A2, 28 cm from top of the unit. |
| 0.2 m | Sandy, pebbly gravel. |
| >2.0 m | Coarse gravel-fine gravely sand. |

### Description of the Bethany fan/delta section after Giles (1987) and personal observations (2010).

| | |
|---|---|
| Unit 1 | Unconsolidated clast supported poorly sorted gravel. Sub-rounded to round metasedimentaries and carbonate lithologies. Relic foreset structures, 18° NW; also 30° W. |
| Unit 2 | 0.5–1.0 m silt-clay drape. Small, well defined, cross beds and foresets dipping at 10° WNW. Occasional pebble. |
| Unit 3 | Gravel and cobbles, shallow foresets dipping 5° W. |
| Unit 4 | Pebbly sandy gravel beds 30 to 50 cm thick infilling in a shallow trough. Small foresets dipping 28° W. Unit pinches out to the west and, upstream is over 1.0 m thick in the east. |
| Base Unit | Interbedded but generally well sorted (25 cm thick) cobble, pebble and granules beds that dip 20° SW. |

Author's Note:
Comparing written descriptions of the same stratigraphic section, described at different times, for example Giles (1987), Teller et al. (2018), and personal observations (the 2010 photograph, Figure 15), is complicated. Gravel pit operations continually modify the pit face, exposing a slightly different perspective, thickness and position (depth) of described units, sub-units and contacts. The text on page 12 is a general summary of the stratigraphy of the collective observations and will not precisely match units illustrated in Figure 15.

Prairie Perspectives:
Geographical Essays

Prairie Division
Canadian Association of Geographers
Association Canadienne des Géographes

# An analytical comparison of flood zones derived from point cloud LiDAR data and historical flood data: A case study of Moose Jaw, Saskatchewan, Canada

Yulu Peng
Department of Geomatics and Surveying Engineering Technology, Saskatchewan Polytechnic, Moose Jaw Campus, Saskatchewan

Abdul Raouf
Department of Geomatics and Surveying Engineering Technology, Saskatchewan Polytechnic, Moose Jaw Campus, Saskatchewan

Muhammad Almas
Water Security Agency, Moose Jaw, Saskatchewan

**Key Messages**

- Regularly updated and accurate flood zone maps should be made publicly available to increase awareness of risks to personal property.
- Existing flood zone maps are based on historical flood recurrence data and are outdated as flood zones can change.
- The latest remote sensing technologies, such as aerial images and LiDAR, can be used to update existing flood zone maps and to estimate the volume of flooded waters.

*The high accuracies of point cloud data captured using light detection and ranging (LiDAR) offer an advantage over traditional surveying techniques that are used to extract elevation information in developing a digital elevation model (DEM) of an inaccessible area. This research demonstrates the use of point cloud LiDAR data for flood zone mapping in an urban environment, and specifically in Moose Jaw, Saskatchewan. Base flood signatures around water bodies were extracted from high resolution aerial photographs to establish base flood elevation (BFE) using 0.25 m elevation contours derived from LiDAR data. A surface elevation of 0.5 m above the BFE was classified as a flood zone. It was estimated that 787 ha of lands within Moose Jaw's boundaries fall within the flood zone. The developed flood zone was found to be 184 ha smaller than one developed using 500-year historical flood recurrence data. Spatial analysis techniques were then used to identify historical inaccuracies and changes in land cover as the possible causes for these changes. The study demonstrated the need for regular mapping of flood zones as they can change over time. Remote sensing technologies utilizing high resolution aerial photographs and point cloud LiDAR data can be used effectively for this purpose.*

Keywords: LiDAR, DEM, flood zones, remote sensing, GIS



Correspondence to: Abdul Raouf, Department of Geomatics and Surveying Engineering Technology, Saskatchewan Polytechnic, PO Box 1420, Moose Jaw, SK S6H 4R4     Email: raoufa@saskpolytech.ca

## Introduction

Floods are an important natural process and one of the most common and expensive natural hazards in Canada, where related losses to personal property are estimated to cost up to \$600 million per year (Thistlethwaite et al. 2017). The cost of flood related hazards is increasing due to climate change and continuous development in flood-prone areas. Poor maintenance of storm water and flood protection infrastructure may add to the risk of flooding (Thistlethwaite et al. 2017). Flood related damage is not limited to direct financial impacts, as a range of social (e.g., business failure, unemployment and population displacement) and public health (e.g., mold-related health effects, post-traumatic stress disorder, depression, and anxiety) related issues also follow floods (Levin et al. 2007; Lamond et al. 2015). Frequent occurrences of severe storms due to the warming atmosphere and slowing jet streams has created an urgent need for an awareness campaign, through information dissemination, for proper protection and management of floods. Homeowners can only play their part in reducing flood risks if they are aware of the options available to them. However, the majority of the population living in flood prone areas is unaware of its vulnerability. A national survey conducted by the University of Waterloo revealed that only 6% of participants (2300 home owners) knew that their property or home was located within a designated high-risk flood zone, and 89% of home owners did not have flood insurance for their property (Thistlethwaite et al. 2017). Outdated flood maps or unavailability of updated maps can be one of the many causes for this lack of information. Flood Damage Reduction (FDR), started in 1975, was a Canadian government initiative to produce high quality flood risk maps for all urban municipalities in the country. The program was also intended to coordinate federal and provincial strategies to discourage future development in flood zones. Zoning authorities were encouraged to zone on the basis of flood risks. Flood-related financial assessment and management is a difficult task for several reasons including population growth, asset value increase, and the vulnerability of infrastructure within flood prone areas. In a continuing effort to minimize the effects of flooding, the Government of Saskatchewan introduced the Development Act of 2007. The Act requires that all municipalities in Saskatchewan must identify areas prone to natural disaster before initiating any planning, rezoning, and development activities within municipal boundaries (Government of Saskatchewan 2007). Maps of these areas need to be updated on a regular basis to include the latest information as flood zones change over time.

Risk assessment, analysis, and mapping of areas prone to natural disasters comprises a complex set of processes. It may involve a combination of different geomatics technologies including remote sensing and geographic information systems (GIS). Some of the common reasons for flooding in Saskatchewan include snowmelt runoff, ice/snow jams, extreme rainfall, and structural failure (Sandink et al. 2010). Identification and continuous monitoring of possible snow jam areas can play a crucial role in flood prevention. These may include natural or artificial obstructions to water flow including river bends, decreased river slopes, tributary mouths, dams, and bridges. Water held back due to ice/snow jams can cause flash flooding. Though freeze-up ice/snow jams occurring in early winter are usually less damaging, break-ups occurring in early spring can cause significant damage to infrastructure and contribute to spring flooding in low lying areas. Spring thermal processes deteriorate ice cover causing it to fracture into large floating ice slabs which can accumulate into ice jams. Kinetic energy generated from floating ice can damage infrastructure and erode stream banks. Additionally, rain that falls on top of snow or snow melt due to increasing spring temperatures can trigger snow breakup and cause ice jams. The soil underneath a thick snowpack of a long prairie winter is saturated and cannot absorb water from snow melt or rain, adding it directly to the rivers and streams. Ice jams can create rapid increases in upstream water levels and consequent flooding. Additionally, sudden collapses of ice jams can violently increase downstream water levels and water velocities (Scrimgeour et al. 1994). The average annual cost associated with ice jam related damage in Canada is approximately \$20 million (Lawford et al. 1995).

Heavy summer rains are another common cause of flooding in areas where a large percentage of the surface is impermeable, or when prolonged wet periods have saturated the ground. Soil compression, paved roads, impermeable parking lots, and rooftops resulting from urbanization can greatly increase water runoff caused by precipitation, resulting in urban floods (Lawford et al. 1995). Heavy rainfall over a short period of time can significantly increase the water level in lakes. Fisheries and Environment Canada has recorded that heavy rainfall in June 1973 over Alberta caused the water level of Lake Winnipeg to rise by 1 m. A big river such as the St. Lawrence, with an average flow rate of 10,100 $m^3/s$, would take almost one month to drain this additional water (CNC/HID 1978; Lawford et al. 1995). The rainfall of early June 2002 brought major flooding to the Canadian prairies (Szeto et al. 2011). Four heavy rain events in June 2005 resulted in flooding in all provinces and caused property damage of approximately \$400 million (Shook 2016). The Alberta flood of June 2013, caused by above normal spring snowmelt in the Canadian Rockies and extreme rainfall, is one of the costliest natural disasters in Canadian history, with projected costs of up to \$6 billion (Pomeroy et al. 2016). Hence flooding is considered the most common and costly natural disaster for Canadians. Identification of flood prone areas and restriction of development within flood zones can significantly reduce damage caused by flooding and can also help to save lives.

There is a need for updated accurate flood zone maps of Moose Jaw to fulfill the requirements of Saskatchewan's Development Act of 2007. This study demonstrates the use of the latest remote sensing technologies (i.e., high resolution aerial photographs and point cloud LiDAR) for accurate flood zone mapping, its comparison with traditional flood zone delimitation generated from 500-year historical flood recurrence data, and temporal analysis of flood zones to emphasize the need for regular updates of flood zone maps within an urban environment.

## Study area

Southern Saskatchewan is an extension of the Great Plains of central North America. Much of the region consists of gently rolling hills separated by river valleys with trees largely confined to these valleys (Buttle et al. 2016). The region is primarily a grassland heavily altered by agricultural activities, and is sparsely populated. Moose Jaw is a medium-sized city, founded in 1882 and situated about 80 km west of Regina at the intersection of Highway 1 and Highway 2 (Figure 1). It is an important railway junction that connects with Chicago via the Soo Line and is a home to 33,890 people (Statistics Canada 2016). Downtown Moose Jaw is located in close proximity to the confluence of Thunder Creek and the Moose Jaw River, and has a high risk of flooding. Spring snow melt or heavy rain over a short period of time in the catchment area of Spring Creek also increases water levels and can cause flooding in some parts of the city. The city experienced its worst flooding in April 1974 when the Moose Jaw River, Thunder Creek, and Spring Creek all overflowed their banks. About 60 city blocks were flooded, forcing 1400 residents to evacuate (Ministry of Environment and Climate Change Canada 2013). Infrastructure within the flooded area was severely damaged and essential services were disrupted. This study focuses on flood zone mapping of Moose Jaw.

Moose Jaw River, Thunder Creek, and Spring Creek are the three main water channels flowing through the city boundaries and are potential sources of flooding. Some areas of the city are within the flood zones of these channels. Infrastructure here is under seasonal flood threat.

Traditionally, flood zone mapping in Saskatchewan has been based on 500-year historical flood recurrence data, referred to as 1:500 mapping having 0.2% (1 in 500) chance of flooding, with additional freeboard for hydrologic and hydraulic uncertainties (Government of Canada 2013). Hydrologic modeling is

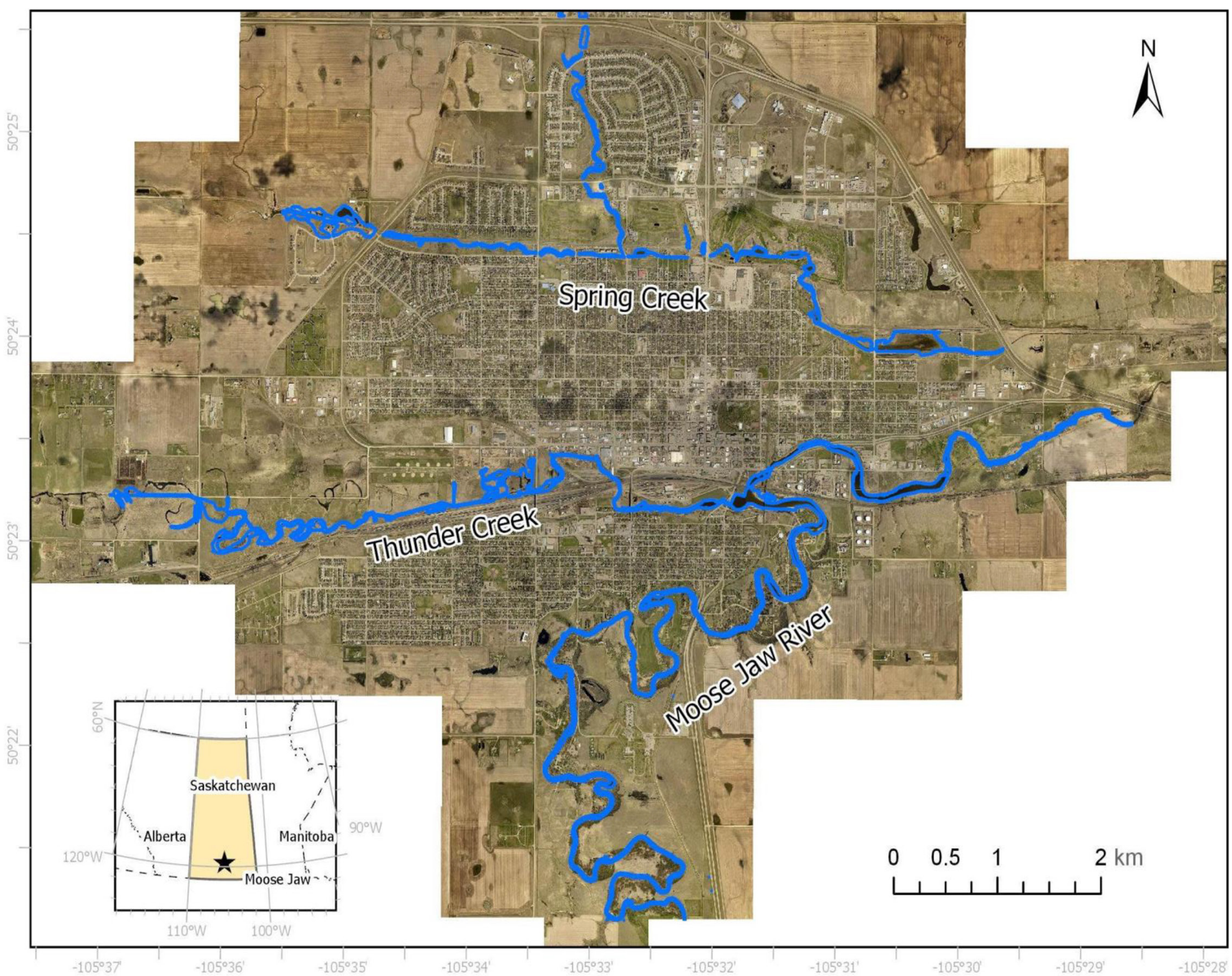



**Figure 1**
The study area
Cartography: Muhammad Almas

used to estimate peak flow from storm events whereas hydraulic modeling is used to estimate water surface elevations. Hydraulic analysis coupled with terrain analysis can be used to estimate the flood inundation area.

Alternatively, flood zones can be mapped through identification of base flood elevation (BFE) which is defined as a reference surface elevation beyond which water levels may be considered as flooded water. It can also be defined as the elevation marking the edges/boundaries of the floodway. Identification of an accurate BFE is a crucial and critical step in flood zone mapping using elevation data. Different regulatory authorities may provide guidelines for establishing BFE. Generally, it is a computed water surface elevation that flooded water has a 1% chance to reach or exceed during a regular base flood event (National Research Council 2007). However, depending upon the topography of an area, it can simply be an elevation of the river edges, floodway boundaries, or the extent of base flood events. Once BFE has been established, an area with a predefined elevation added to BFE can be classified as a floodplain (Merwade et al. 2008). Depending upon the general topography of an area, local governments may require different elevations to be added to the BFE for flood zone mapping. As per flood zone mapping guidelines provided by the Government of Saskatchewan, an area with a surface elevation of 0.3 m above the BFE is considered floodplain (Sandink et al. 2010).

The accuracy of the flood inundation maps based on elevation information depends upon accurate identification of BFE and the accuracy of the digital elevation model (DEM) (Merwade et al. 2008). Surface elevation for flood zone mapping is typically derived from historical contour maps which may not provide accurate elevation information for several reasons, notably the limited spatial and vertical accuracies of these maps. Highly accurate flood zone maps with improved spatial resolution can be created using a DEM. DEMs based on NASA's Shuttle Radar Topography Mission (SRTM3), with a spatial resolution of 3 arc seconds (≈ 90 m spatial resolution), are freely available from the United States Geological Survey (USGS) and have been used by many agencies for flood zone mapping (van de Sande et al. 2012). NASA has recently started offering DEMs (≈ 30 m spatial resolution) generated from SRTM Global 1 arc second (SRTMGL1) data (NASA 2017). The significant improvement of spatial resolution in the STRMGL1 data will allow users to update older flood zone maps. If available, point cloud LiDAR data can be used to derive more accurate DEMs, resulting in better quality flood zone maps.

Flood zone maps generated using historical data need to be updated not only to improve accuracies but also to include updated information as these maps can become obsolete due to topographic and land-use changes within the floodplain. The Federal Emergency Management Agency (FEMA) of the USA estimates that as of March 2004, nearly 70% of United States flood maps were more than 10 years old and were based on outdated data (GAO 2004). The situation in Canada is not very different. Most of the floodplain maps in Canada were produced between 1976 and 1997 under the federal Flood Damage Reduction Program (FDRP). In March 2017, the federal government announced its intention to restart the program (Insurance Business 2017; Natural Resources Canada and Public Safety Canada 2017). The guidelines provided under the new initiative encourage the use of point cloud LiDAR data for extraction of elevation information and flood zone mapping (Natural Resources Canada and Public Safety Canada 2017). LiDAR is one of several methods used to construct DEMs and to derive elevation data from them. Several studies have been published to support the use of LiDAR data for flood zone mapping (Webster 2010). However, no standard methodology has been reported in the literature to determine BFE as it is highly terrain dependent.

## Methodology

Elevation information was extracted from high density point cloud LiDAR data collected in 2014 and provided by the City of Moose Jaw to generate a DEM of the area. A typical airborne LiDAR system collecting 30 points/m$^2$ is capable of 5 to 9 cm lateral and 5 to 19 cm vertical accuracies depending upon the flight height. In addition to the flight height, accuracies of a LiDAR generated DEM also depend upon the topography and land cover of the area (Hodgson and Bresnahan 2004). Accuracy should be checked by using a sufficient number of ground control points (GCPs). The American Society for Photogrammetry and Remote Sensing (ASPRS) and the Inter-Governmental Committee on Surveying and Mapping (ACSM) have proposed the use of a minimum 30 GCPs for accurate assessment of LiDAR-derived elevation data (Pourali et al. 2014).

The combined use of high resolution aerial photographs and point cloud LiDAR data is employed in this study to identify river edges, floodway boundaries, and the signatures of base flood events. A combination of these features is then used to determine a river profile when establishing BFE. The proposed methodology adds a safe margin to the established BFE to determine a floodplain. This objective was achieved through extraction of elevation contours at regular interval from LiDAR-derived DEM. ArcMAP 10.4 offers a built in tool under Spatial Analyst and 3D Analyst extensions to generate elevation contours from a raster DEM image. This tool was used to extract elevation contours. Different vertical intervals for elevation contours were tried, however, contours of 0.25 vertical interval were found the most suitable as they could be related easily with BFE. The other contour intervals produced either too dense or too sparse contour lines and were deemed unsuitable. The vertical accuracy of these contours depends upon the accuracy of the LiDAR-derived DEM and was verified using 100 well defined GCPs collected using a survey grade Trimble 6000 series GeoXH GPS device having sub-cm 3D accuracy (Raouf et al. 2017).

The root mean square (RMS) error of the LiDAR-derived elevation contours is usually used to calculate for accuracy assessment of elevation data (Gianinetto and Fassi 2008). An RMS error of 0.15 m was observed in the elevation contours of the LiDAR-derived DEM. As indicated earlier, accuracy of LiDAR elevation data is highly terrain and land cover dependent (Hodgson and Bresnahan 2004). Considering the frequent eleva-

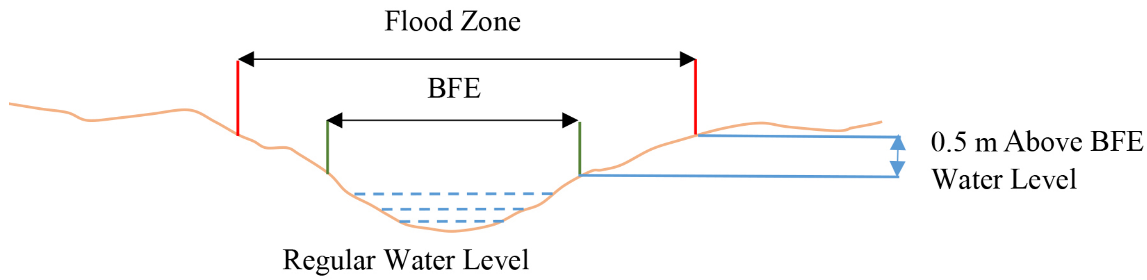



**Figure 2**
Adopted methodology for flood zone mapping using elevation data

tion changes and abundant vegetation within the area, a vertical RMS error of 0.15 m may be considered within acceptable limits. As per guidelines of the Government of Saskatchewan, a surface with elevation of 0.3 m higher than BFE can be classified as flood zone (Sandink et al. 2010). However, based on the accuracy assessment of the LiDAR-derived elevation contours, a safety allowance of 0.2 m was added to accommodate the RMS error of 0.15 m. Thus, a surface having an elevation of 0.5 m above BFE was classified as flood zone. Use of a 0.25 m contour interval also facilitated the addition of 0.5 m elevation to the BFE. The adopted methodology for flood zone mapping using elevation data is presented in Figure 2.

High resolution aerial imagery taken in 2014 with a spatial resolution of 14 cm, was used for mapping water bodies and other land use in Moose Jaw and the city's immediate environs. The three water channels within the city limits have distinctive sharply carved edges with steep slopes. Only a small portion of the Moose Jaw River has a wider channel where river edges are not sharply carved. However, regular base flood events has caused erosion and left permanent signatures, thus making it easy to identify in the high resolution aerial images. Different image classification techniques could have been applied to extract this information but research suggests that the use of hands-on digitization is a preferred technique for such features using high resolution aerial photographs (Brown and Young 2006; Raouf et al. 2017). Although time consuming, hands-on digitization provides superior and accurate results for river profile identification. Elevation contours of 0.25 vertical interval were superimposed on the classified aerial imagery to find elevation information for the three water channel profiles. This elevation information was used to determine the BFE.

Three dams are constructed on the Moose Jaw River to regulate the water discharge and to control flooding within the project area. The elevation of the river profile is considerably different in sections before and after each dam. The river was divided into three sections to accommodate these changes, and an average elevation value was used to determine the BFE for each section. Elevation contours with an elevation 0.5 m higher than BFE were used for flood zone mapping of each section. In addition to identifying the river profile, other infrastructure such as roads and bridges were identified in the aerial images. The elevations of these structures were recorded to determine their effect on flood zone delimitation. Recording these data recognized that elevated infrastructure can act as a protective boundary for floods and can change the flood zone pattern in the area. The overall methodology of the research is summarized in Figure 3.

## Results and discussion

Identification of BFE is a challenging process and is rarely cited in the literature. Aerial photographs acquired in 2014 with a spatial resolution of 14 cm were used for land-cover/land-use mapping of Moose jaw and its immediate environs. River profiles of the three water channels were identified using visual interpretation techniques and were used for flood zone mapping.

It was observed that the elevation contours of 0.25 m interval, superimposed on the river profiles, were not 100% coincident with them and a few gaps between the two were observed. These gaps were used to select observation points and the elevation of the river profile at these points was recorded using a handheld survey grade Trimble 6000 series GeoXH GPS device. No significant change was observed along downstream river profile elevations of Thunder Creek and Spring Creek. An average of all elevation change was used to determine the BFE of the respective creeks. However, river profile elevation

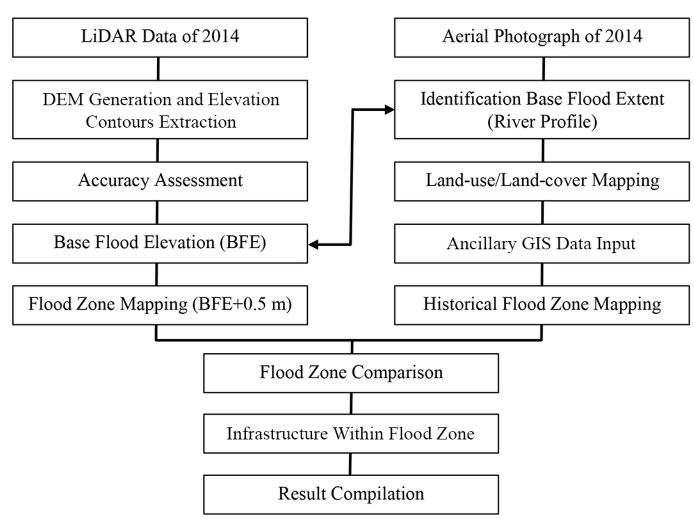



**Figure 3**
Overall methodology of the project

changed markedly before and after the three dams on the Moose Jaw River. Three different BFE values were used to accommodate these elevation changes in the river profile. The use of a different BFE value for each section allowed accurate floodplain mapping along different sections of the Moose Jaw River. While these dams can be used for flood prevention, they can also cause flash flooding downstream if the gates are opened suddenly to prevent the dam from collapsing because of excessive water. The inlets of the dams along with the bridges are potential areas for ice jam occurrences along the river. Ice jams at these points of flow constriction can cause local flooding and damage to the dams and bridges. The locations of the dams and bridges were extracted from the high resolution aerial photographs. Elevations of water clearances under the bridges and dam elevations were recorded using a handheld survey grade GPS device. The BFE value for each section of the river profile was adjusted to accommodate the clearance elevations of the bridges and dam elevations. The extent of the flood zone generated from LiDAR data was compared with the traditional flood zone based on 500-year historical flood recurrence data. A comparison of the two is shown in Figure 4.

Figure 4 shows that both zones were mostly similar in extent, however, a considerable difference between the two was observed at some locations. The LiDAR-derived flood zones are less extensive than those based on 500-year historical flood recurrence data due to their increased accuracy and ability to accommodate changes in land cover. These differences were most pronounced along Thunder Creek. Land-cover analysis of aerial imagery revealed that infrastructure development in the area is one of the main causes of these alterations to the floodplains. In particular, Highway 2, Highway 363, Manitoba Expressway, 9th Avenue SW and High Street West were raised considerably to higher elevations during construction and repaving. These roads act as flood protection barriers and have changed the flood zones within the city boundaries. However, not all the roads were raised to the higher elevations and are still at great risk of flood water inundation. It was calculated that 19.8 km of city roads lie within the flood zones, have a high risk of flooding, and should

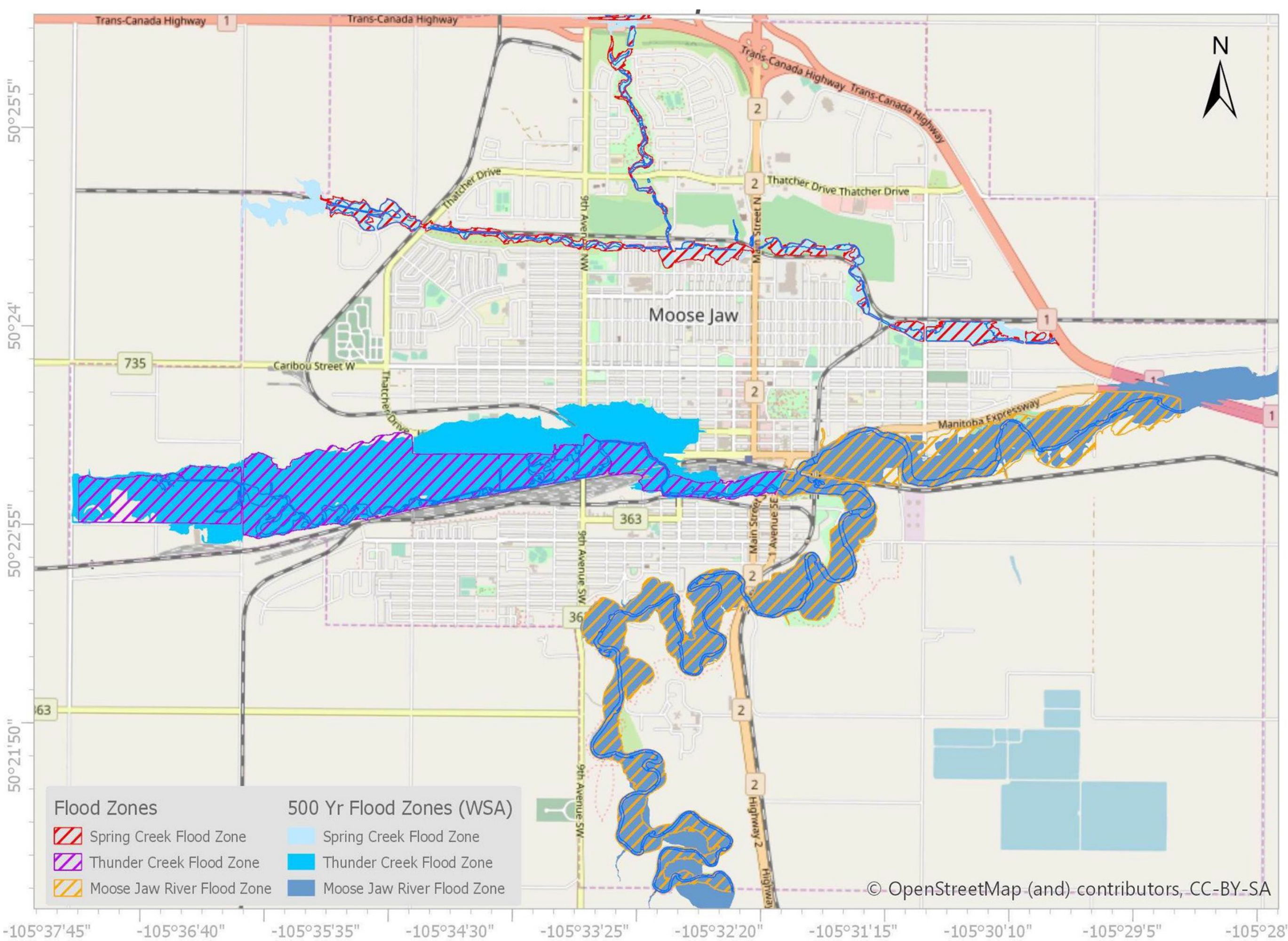



**Figure 4**
A comparison of flood zones generated from LiDAR data and 500-year flood recurrence data
Cartography: Muhammad Almas

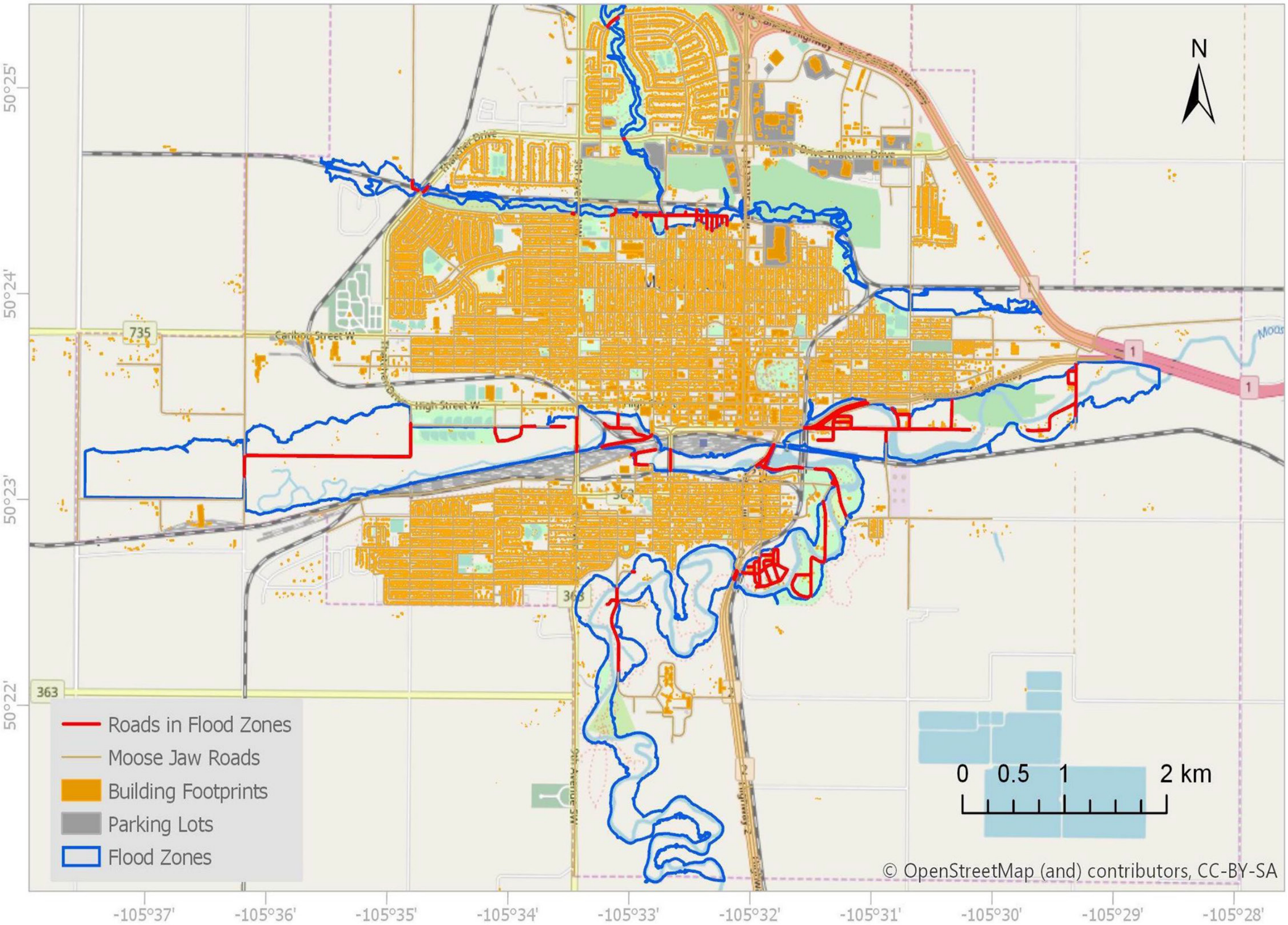



**Figure 5**
Infrastructure within the flood zones
Cartography: Muhammad Almas

be monitored closely during flooding season. All infrastructure within the flood zones was identified from high resolution aerial photographs and is shown in Figure 5.

Technological advancements in data collection and mapping techniques have contributed to recorded changes in floodplain geometry. Traditional flood zone maps are based on 500-year historical flood recurrence data. However, data collection and mapping techniques have changed drastically because of technological advancements. In addition, cartographic data collection scale and the digitization of historical maps can introduce errors. These are difficult to determine with precision because of missing information regarding data collection techniques and the equipment used when collecting the data. Inherent inaccuracies of historical data and infrastructure development within flood zones are the main causes of changes within the flood zones. A comparison of the two flood zones along the three water channels within the project area is summarized in Table 1.

Use of the latest remote sensing technologies such as LiDAR for flood zone mapping offers additional benefits. The LiDAR data combined with the high resolution aerial photographs can be used to calculate building footprints and impermeable surface area within the city limits. Since water cannot penetrate through these surfaces, almost 100% of the incident rainwater runs off into the city drainage system. This information can be used for hydrologic modeling and the designing of flood drainage systems for the city. A building footprint image generated from the LiDAR data is also shown in Figure 5.

The calculated area of the building footprints within city limits was 289.9 ha. Similarly, paved roads and parking lots were extracted from the high resolution aerial photographs. The calculated area of paved parking lots was 144.5 ha and the total

**Table 1**
Area comparison of flood zones

| Water Channel | 500-year flood zone (ha) | LiDAR-derived flood zone (ha) | Difference (ha) |
|---|---|---|---|
| Moose Jaw River | 460.8 | 393.3 | 67.5 |
| Spring Creek | 118.6 | 96.3 | 22.3 |
| Thunder Creek | 391.8 | 297.4 | 94.3 |
| Total | 971.0 | 787.0 | 184.1 |

length of paved roads was 284.5 km. This area can have a significant contribution to the accumulation of water during rain storms and requires adequate drainage systems to protect the city from inundations during intense rainfalls and consequent flash flooding.

## Conclusions

The study concluded that LiDAR data can be used successfully to generate DEMs in an urban environment and to derive elevation contours from the DEM using interpolation techniques. However, the accuracy of these elevation contours should be verified using well distributed GCPs before using them for flood zone mapping. It is also concluded that the information obtained only from LiDAR generated elevation contours is not sufficient for flood zone mapping and must be supplemented by high resolution aerial photographs to identify flood signatures and waterbodies which can provide a basis for determining BFE. These high resolution aerial photographs can help in the identification of flood barriers including dams and bridges. The BFE should be adjusted to accommodate the elevation information of these flood protection structures and potential flood barriers. This information is most useful in refining flood zones derived from elevation data. Flood zones generated from LiDAR data can be significantly different from the flood zones based on historical flood data, especially in an urban environment, as development of infrastructure can alter flood zones. This requires regular updating of flood zone maps and LiDAR data can be used successfully for this purpose. In addition to the flood zone mapping, LiDAR data can be used for mapping impermeable surfaces within an urban environment. This information can be used for hydrologic/hydraulic modeling to design effective and adequate flood drainage systems. The study has successfully demonstrated an integrated use of various remote sensing and GIS technologies to upgrade the flood zone maps of Moose Jaw. Similar techniques can also be used to upgrade the flood zone maps of other cities.

## Acknowledgments

The authors acknowledge the City of Moose Jaw for providing aerial photographs and LiDAR data. They also acknowledge the Water Security Agency of Saskatchewan for sharing information for flood zone mapping practices in Saskatchewan and providing the historical flood zone maps of the city.

## Conflicts of interest

The authors declare no conflict of interest. The funding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

## References

Brown, L., and K. L. Young. 2006. Assessment of three mapping techniques to delineate lakes and ponds in a Canadian High Arctic wetland complex. *Arctic* 59(3): 283–293.

Buttle, J. M., D. M. Allen, D. Caissie, B. Davison, M. Hayashi, D. L. Peters, J. W. Pomeroy, S. Simonovic, A. St-Hilaire, and P. H. Whitfield. 2016. Flood processes in Canada: Regional and special aspects. *Canadian Water Resources Journal* 41(1–2): 7–30.

CNC/HID (Canadian National Committee for the International Hydrological Decade). 1978. *Hydrological atlas of Canada*. Ottawa, ON: Fisheries and Environment Canada.

GAO. 2004. *Flood map modernization: Program strategy shows promise, but challenges remain*. Washington, DC: United States General Accountability Office. https://www.gao.gov/assets/ 250/241972.pdf.

Gianinetto, M., and F. Fassi. 2008. Validation of Cartosat-1 DTM generation for the Salon de Provence test site. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* 37(B1): 1369–1374.

Government of Canada. 2013. Flood Damage Reduction Program. Ottawa, ON: Environment and Climate Change Canada. https://ec.gc.ca/eau- water/default.asp?lang=En&n=0365F5C2-1.

Government of Saskatchewan. 2007. *The Planning and Development Act, 2007*. Regina, SK: The Queen's Printer. http://www.qp.gov.sk.ca/documents/english/statutes/statutes/p13-2.pdf.

Hodgson, M. E., and P. Bresnahan. 2004. Accuracy of airborne LiDAR-derived elevation: Empirical assessment and error budget. *Photogrammetric Engineering and Remote Sensing* 70(3): 331–339.

Insurance Business. 2017. Updated flood maps coming to Canada. http://www.insurancebusiness mag.com/ca/opinion/updated-flood-maps-coming-to-canada-78259.aspx.

Lamond, J. E., R. D. Joseph, and D. G. Proverbs. 2015. An exploration of factors affecting the long term psychological impact and deterioration of mental health in flooded households. *Environmental Research* 140: 325–334.

Lawford, R. G., T. D. Prowse, W. D. Hogg, A. A. Warkentin, and P. J. Pilon. 1995. Hydrometeorological aspects of flood hazards in Canada. *Atmosphere-Ocean* 33(2): 303–328. doi:10.1080/07055900.1995.9649535.

Levin, J. N., A-M. Esnard, and A. Sapat. 2007. Population displacement and housing dilemmas due to catastrophic disasters. *Journal of Planning Literature* 22(1): 3–15.

Merwade, V., F. Olivera, M. Arabi, and S. Edleman. 2008. Uncertainty in flood inundation mapping: Current issues and future directions. *Journal of Hydrologic Engineering* 13(7): 608–620.

Ministry of Environment and Climate Change Canada. 2013. Flooding events in Canada: Prairie Provinces. https://www.canada.ca/en/environment-climate-change/services/water-overview/quantity/floods/events-prairie-provinces.html.

NASA. 2017. NASA shuttle radar topography mission (SRTM) Version 3.0 Global 1 arc second data released over Asia and Australia. https://earthdata.nasa.gov/nasa-shuttle-radar-topography-mission-srtm-version-3-0-global-1-arc-second-data-released-over-asia-and-australia.

National Research Council. 2007. *Elevation data for floodplain map-*

*ping*, ed. Committee on Floodplain Mapping Technologies. Washington, DC: The National Academies Press. https://www.nap.edu/catalog/11829/elevation-data-for-floodplain-mapping.

Natural Resources Canada and Public Safety Canada. 2017. *Federal floodplain mapping framework*. Ottawa, ON: Natural Resources Canada. https://doi.org/10.4095/299806.

Pomeroy, J. W., R. E. Stewart, and P. H. Whitfield. 2016. The 2013 flood events in the South Saskatchewan and Elk River basins: Causes, assessment and damages. *Canadian Water Resources Journal* 41(1–2): 105–117.

Pourali, S., C. Arrowsmith, N. Chrisman, and A. Matkan. 2014. Vertical accuracy assessment of LiDAR ground points using minimum distance approach. In *Proceedings of Research at Locate'14*, ed. S. Winter, and C. Rizos. Canberra, Australia: Research@Locate'14: 86–96.

Raouf, A., Y. Peng, and T. I. Shah. 2017. Integrated use of aerial photographs and LiDAR images for landslide and soil erosion analysis: A case study of Wakamow Valley, Moose Jaw, Canada. *Urban Science* 1(2): 20.

Sandink, D., P. Kovacs, G. Oulahen, and G. McGillivray. 2010. Making flood insurable for Canadian homeowners: A discussion paper. Toronto. ON: Institute for Catastrophic Loss Reduction and Zurich, Switzerland: Swiss Reinsurance Company Ltd. https://www.iclr.org/images/Making_ Flood_Insurable_for_Canada.pdf.

Scrimgeour, G. J., T. D. Prowse, J. M. Culp, and P. A. Chambers. 1994. Ecological effects of river ice break-up: A review and perspective. *Freshwater Biology* 32(2): 261–275.

Shook, K. 2016. The 2005 flood events in the Saskatchewan River Basin: Causes, assessment and damages. *Canadian Water Resources Journal* 41(1–2): 94–104.

Statistics Canada. 2016. *Census Profile, 2016* Census. Ottawa, ON: Statistics Canada. https://www12.statcan.gc.ca/census-recensement/2016/.

Szeto, K., W. Henson, R. Stewart, and G. Gascon. 2011. The catastrophic June 2002 prairie rainstorm. *Atmosphere-Ocean* 49(4): 380–395.

Thistlethwaite, J., D. Henstra, S. Peddle, and D. Scott. 2017. *Canadian voices on changing flood risk: Findings from a national survey*. Waterloo, ON: Faculty of Environment, University of Waterloo. https://uwaterloo.ca/climate-centre/sites/ca.climate-centre/files/uploads/files/ canadian_voices_on_changing_flood_risk_fnl.pdf.

van de Sande, B., J. Lansen, and C. Hoyng. 2012. Sensitivity of coastal flood risk assessments to digital elevation models. *Water* 4(3): 568–579. doi:10.3390/w4030568.

Webster, T. L. 2010. Flood risk mapping using LiDAR for Annapolis Royal, Nova Scotia, Canada. *Remote Sensing* 2(9): 2060–2082. http://www.mdpi.com/2072-4292/2/9/2060.

Prairie Perspectives: Geographical Essays

Prairie Division
Canadian Association of Geographers
Association Canadienne des Géographes

# Students' perceptions of clickers for enhancing student engagement and academic achievement

Jamie Edwin Lee Spinney
Department of Geography, South Dakota State University

Suzanne Elizabeth Kerr
Faculty of Education, Brandon University

**Key Messages**

- Students expressed strong positive attitudes toward clickers for engaging and motivating them.
- Students perceive clickers as effective tools for improving academic performance.
- Students are enthusiastic about the use of clickers in an introductory physical geography classroom.

*The objective of this research is to summarize students' perceptions on the effectiveness of personal response systems or, more commonly, simply clickers for enhancing their level of engagement and academic achievement. Quantitative and qualitative data were collected from undergraduate university students regarding their perceptions of clickers in an introductory geography classroom. Results suggest a strong link between student engagement and academic achievement, but both engagement and achievement appear invariant to students' perceptions of clickers. Students expressed strong positive attitudes toward the use of clickers, especially their ability to improve the quality of learning experiences and to promote more engaging learning environments.*

Keywords: clickers, personal response systems, student engagement, academic achievement, higher education

## Introduction

Due to numerous direct and indirect benefits for students, teachers, and society, student engagement should be an important objective for all teachers. The importance of student engagement stems from its direct correlation with several positive student outcomes that include greater academic success (Crosnoe et al. 2004; Trotter 2005; Moredich and Moore 2007; Reyes et al. 2012; Zepke 2014), better health and well-being (Willms 2003; Murray and Zvoch 2011), and lower levels of misbehaviour (Crosnoe et al. 2004; Oelsner et al. 2011). However, student engagement is a complex and multi-dimensional concept (Fredricks and McColskey 2012), which makes it difficult to define (Harris 2008; Taylor and Parsons 2011; Saha 2014) and measure effectively. Student engagement is a function of a student's academic, intellectual, behavioural, social, emotional, cognitive, and psychological connections to their education or school (Harris 2008; Dunleavy and Milton 2009; Willms et al. 2009; Taylor and Parsons 2011; Fredricks and McColskey 2012; Saha 2014). Mostly a function of data availability, many different approaches



Correspondence to: Jamie Edwin Lee Spinney, Department of Geography, South Dakota State University, Wecota Annex 414, Box 506, Brookings, SD, USA, 57007 Email: jamie.spinney@sdstate.edu

have been used to measure various dimensions of student engagement. Three dimensions of student engagement are used herein: (i) behavioural, which is the dedication or persistence students apply toward participating in their learning; (ii) emotional, which is the emotion or feelings students have toward their learning; and (iii) cognitive, which is the mental strategies, processing, and self regulation skills students use when they are learning.

Unfortunately, however, student engagement can be an especially challenging task in large classes of undergraduate students, who are often reluctant to participate in class (Campbell and Monk 2015; Dong et al. 2017). Paradoxically, student engagement is particularly important in large undergraduate classes because students, especially those at an early stage in higher education, need to quickly engage with the material and their new learning environment. Graduation rates among Canadian undergraduate university students range from a high of almost 90% to a low of 44% at open enrolment universities (Maclean's 2018). This makes student engagement increasingly necessary and simultaneously more difficult, since university class sizes have been steadily increasing over the past 50 years (Huxley et al. 2018). The problems with larger class sizes, particularly as they relate to student engagement, include negative impacts on grades (Kokkelenberg et al. 2008), students' learning experience (Mulryan-Kyne 2010), student-rated outcomes of amount learned, and instructor and course ratings (Monks and Schmidt 2011). Moreover, research suggests that social interactions in the classroom with the teacher and fellow students can enhance student learning (Vygotsky 1978; Mayer and Wittrock 2006). Yet, such interactions, especially teacher-student interactions, are more difficult particularly in large classes.

Correa (1993) argues that many of the problems associated with larger class sizes stem from instructors tending to devote more effort to class-wide activities, such as increased use of lecture-style teaching, at the expense of individual attention. Consequently, there has been increased focus and urgency to find effective tools and techniques to enhance student participation (Campbell and Monk 2015) and to make lectures less passive and impersonal (Burnstein and Lederman 2001). Draper (1998) cautions that technology in the classroom is only worthwhile if it addresses a specific instructional shortcoming, which in this case is the passive, one-way communication that is inherent in lecture-style teaching and the consequent difficulty for students to maintain concentration. This sentiment is echoed by Kirkwood and Price (2005) who argue that it is not simply the introduction of technology that enables student learning, but teachers' pedagogical strategies that are supplemented by the technology.

Personal response systems (PRS), audience responses systems (ARS), student response systems (SRS), learner response systems (LRS), or simply 'clickers' are among the tools and techniques used to enhance student participation, and thereby, student engagement (Blood and Neel 2008; MacGeorge et al. 2008; Strasser 2010; Bachman and Bachman 2011). In fact, Bojinova and Oigara (2011) argue that clickers represent one of the most powerful interactive technologies available for promoting active learning in the classroom. The rationale behind clickers is not new (Caldwell 2007). Teachers have been using the Socratic method of interactive questioning for centuries, but this teaching method becomes progressively more difficult with increasing class size. In addition to the number of students, students in large classes are often reluctant to actively participate in class due to fear of embarrassment or making a mistake (Draper et al. 2002; Caldwell 2007; Bojinova and Oigara 2011; Dong et al. 2017; Katz et al. 2017). In response to these challenges, and in an attempt to foster greater student engagement in the classroom, there is a growing body of literature detailing the implementation and use of clickers in higher education (e.g., Barnett 2006; Caldwell 2007; Koenig 2010; Milner-Bolotin et al. 2010; Strasser 2010; Campbell and Monk 2015). This surge of interest, and of commercial vendors, is based on a mounting body of evidence that demonstrates the ability of clickers to promote an interactive classroom atmosphere (Draper et al. 2002; Roschelle et al. 2004a, 2004b; Johnson and Lillis 2010; Bojinova and Oigara 2011; Simelane and Skhosana 2012).

Clickers are being used increasingly in higher education because they provide a wide variety of potential benefits for both students and teachers alike. Draper et al. (2002) described five pedagogic uses for clickers: (i) formative and summative assessment; (ii) formative feedback for teaching and learning; (iii) peer assessment and community building; (iv) research on human responses; and (v) initiating discussion. These uses are echoed in other studies as well. For example, clickers enable a constructivist approach to learning by providing regular feedback to students during lectures (Barnett 2006; Beatty and Gerace 2009; White et al. 2011). Clickers also provide formative (i.e., diagnostic) assessment which allows teachers to immediately gauge the level of students' understanding of specific concepts (Halloran 1995; Poulis et al. 1998; Draper et al. 2002; Roschelle et al. 2004a; Wood 2004; Beatty and Gerace 2009) and further enables them to adapt lectures to either provide different examples (Mazur 1997; Jones et al. 2012; Lennox Terrion and Aceti 2012), to proceed more quickly, or possibly even eliminate content that students have already mastered (Anderson et al. 2011; White et al. 2011). Other benefits of clickers include higher exam and test scores (Beatty et al. 2006; Poirier and Feldman 2007; Morling et al. 2008; Shaffer and Collura 2009; Shapiro 2009; Shapiro and Gordon 2012; Katz et al. 2017), greater retention of information (Campbell and Mayer 2009; Anderson et al. 2011), more enjoyment of a given course (Barnett 2006; Caldwell 2007), elevated interaction and engagement of students (Jackson and Trees 2003; Blood and Neel 2008; Strasser 2010; Bachman and Bachman 2011; Heaslip et al. 2014; Katz et al. 2017), improved attendance, particularly when clicker responses contribute to participation grades (Burnstein and Lederman 2001; Jackson and Trees 2003; Wit 2003), as well as increased participation by allowing students to anonymously express their understanding of course content (Draper et al. 2002; Wood 2004; Heaslip et al. 2014; Katz et al. 2017), which encourages student risk-taking and lets them know they are not alone in their confusion (Knight and Wood 2005).

Despite a growing body of literature detailing the implementation and potential benefits of clickers in higher education, including several systematic literature reviews (e.g., McDermott and Redish 1999; Roschelle et al. 2004a; Duncan 2005; Fies and Marshall 2006; Caldwell 2007; MacArthur and Jones 2008; Kay and LeSage 2009; Hunsu et al. 2016), much less is known about students' personal experiences using clickers in the classroom (Laxman 2011). Moreover, Kay and LeSage (2009) as well as Barnett (2006) argue there has been a lack of research investigating the implementation and use of clickers in the social sciences, while targeted searches indicate this deficiency certainly applies to the use of clickers in large introductory geography classes. Therefore, the main objective of this research is to summarize undergraduate students' perceptions on the effectiveness of clickers, particularly as a tool to enhance student engagement and academic achievement in an introductory geography class. More specifically, the research aims to answer three questions: (i) do students perceive clickers as effective tools for engaging them; (ii) do students perceive clickers as effective tools for improving their academic performance; and (iii) to what extent do students perceive real value in the use of clickers in the classroom.

## What are clickers?

Clickers have been in existence since the 1960s (Judson and Sawada 2002) and generally consist of "a combination of software and hardware that allows students to deliver almost instantaneous feedback to their instructors" (Birdsall 2002, 1). These small wireless handheld devices are commonly referred to as clickers in North America and zappers in the United Kingdom (d'Inverno et al. 2003; Laxman 2011). Modern clickers are used by students to wirelessly transmit their answers (mainly radio-frequency signals), which are automatically collected, tabulated, and summarized by a computer and then displayed in chart form, usually a histogram, but some systems offer more sophisticated options (Roschelle et al. 2004b), such as word clouds for short-answer responses.

The clicker system chosen for this study was the iClicker® (www.iclicker.com), which is touted as the leading SRS in higher education and corporate spaces. The traditional iClicker remote uses a two-way radio frequency (RF), which ensures that there is no interference with Wi-Fi networks. This aspect is an important feature because the iClicker system is a hybrid product, meaning it also operates along with iClicker Cloud 4.3. The iClicker Cloud (formerly REEF Polling and iClicker GO) application is a mobile classroom response system that allows students in the same classroom to use their smartphone, tablet, laptop, or an iClicker remote. iClicker remotes and the iClicker Cloud application enable students to answer three question formats, namely multiple choice, numeric, and short-answer.

## Methods

This study received approval from the Brandon University Research Ethics Board (File 21789) on December 4, 2015. The target population for the study was the students enrolled in *Introduction to Physical Geography* (N= 68) at Brandon University during the fall semester of 2015. The sampling frame for the study was all students who attended the last class of the semester on December 7, 2015. These students were provided with a letter of information for implied consent, which described the purpose of the project and their rights as voluntary participants. Students were asked to voluntarily respond to a series of 13 closed-response and two open-response questions that were designed to measure their perceptions on the effectiveness of using clickers in the classroom.

The 15-question survey instrument used in the study was based on a modified version of the instrument used in Sartori's (2008) doctoral dissertation. Survey items were organized into three sections. The first section contained three demographic items, namely sex, year of study, and faculty major. The second section comprised ten items that addressed students' perceptions of using clickers. It employed a five-point Likert scale (5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree, and 1 = strongly disagree) to measure different behavioural, emotional, and cognitive dimensions of student engagement, while recognizing that these dimensions are often intertwined. The third section consisted of two free-response questions: (i) what do you "like most" about using clickers in the classroom; and (ii) what do you "like least" about using clickers in the classroom.

The closed-response questions were displayed on a screen at the front of the classroom and students answered them using their clickers (seven students used RF remotes and 38 used their smartphones). The two free-response survey questions were similarly displayed and students were asked to anonymously write their answers on a piece of loose-leaf paper regarding what they liked most and liked least about using the clickers. Their responses were subsequently transcribed into digital format and then independently categorized by the co-authors with the goal of creating mutually exclusive categories that maintained as much information as possible. The resulting categories and their content were remarkably similar, but a few categories were renamed (for clarity) and others were collapsed into existing categories.

Students' open and closed-responses were merged with objective measures of engagement (i.e., participation grades) and academic achievement (i.e., final grades on tests and assignments). Students' participation grades reflected both attendance and class participation by using the combined score of correct responses to clicker questions, which were worth two points, and incorrect responses that were worth one point and reflected attending class and actively participating. Participation grades were used to measure the emotional and behavioural dimensions of student engagement. Students' final grades reflected the combined score of fact-based and performance-based assessment tools used in the course and were used to measure the cognitive dimension of student engagement, recognizing that dimensions of student engagement often overlap.

Statistical analysis of the closed-response questions and contextual survey questions (i.e., sex, year of study, major) as well as the students' participation and final grades were performed using IBM SPSS version 22. Summary statistics were used to explore the frequency distributions as well as measure central tendency and dispersion of responses. Partial correlations were used to measure the bivariate statistical association between participation (i.e., engagement) and final grade (i.e., achievement) while controlling for both year of study and major. The assumption was that students who are science majors and/or in higher years of study would, *ceteris paribus*, perform better in this introductory science course.

The responses to the first six survey questions (1 to 6) were used to test whether clickers provide an effective tool for increasing the behavioural and emotional dimensions of student engagement and were analyzed against participation grades using Spearman's rank correlation to quantify the strength and significance of statistical associations. The responses to the next three questions (7 to 9) were used to test whether clickers provide an effective tool for enhancing the cognitive dimension of student engagement and were analyzed against measures of students' final grades using Spearman's rank correlation to quantify the strength and significance of statistical associations. The strength of associations is hereafter described as either very weak (0.00–0.19), weak (0.20–0.39), moderate (0.40–0.59), strong (0.60–0.79), or very strong (0.80–1.0) based on a guide proposed by Evans (1996). It is noteworthy that despite the implied one-tailed hypotheses associated with these analyses, a more rigorous two-tailed measure of significance was used in the correlation analyses. The last closed-response question (10) plus the two free-response questions were used primarily to investigate the students' perception of value in using clickers in the classroom. Finally, frequency analysis of the open-response questions was used to summarize and communicate what students liked most and liked least about using clickers in the classroom.

## Results and discussion

The participants for this study were the 45 undergraduate students who attended the last class of the semester. All of the students responded, which represents a response rate of 100% and a participation rate of 66.2%. The distribution of participants by sex was 22 males and 23 females. The participants represented several different majors; 23 were science majors, 16 were arts majors, five were education majors, and the remaining one reported "NIL" (non-degree credit). There were 14 freshman participants, 12 sophomores, ten juniors, and nine seniors. The response frequencies (in percent) to the closed-response questions are summarized in Table 1.

Responses to the closed-response questions are strongly skewed toward a strong positive perception of using clickers in the classroom (Table 1). Regarding whether clickers provide an effective tool for increasing the behavioural and emotional dimensions of student engagement (questions 1 to 6), the strongest support for clickers relates to their perceived ability to help students "pay attention in class," "gain confidence when correctly responding to the questions," "feeling more involved in the class material," and "contribute positively to my learning." These results accord with the findings of Jackson and Trees (2003), Blood and Neel (2008), Bachman and Bachman (2011), and Strasser (2010) who also found increased interaction and student engagement. Regarding whether clickers provide an effective tool for enhancing the cognitive dimension of student engagement (questions 7 to 9), the strongest support for clickers relates to their perceived benefits "when the teacher discusses the wrong answers as well as the right answers." Other studies have also reported that regular feedback is one of the most appreciated aspects of clickers (Barnett 2006; Beatty and Gerace 2009; White et al. 2011), while Tanner and Allen (2005) explain the value of discussing misinformation, that is, the wrong answers. It is also notable that few students (n = 2) either agreed or were neutral in their belief that "it is a waste of time to use the clickers" while the vast majority (96%) either disagreed or strongly disagreed that clickers are a waste of time. The free-response comments provide further insights into why a few students were less enthusiastic about the use of clickers in the classroom.

The partial correlation coefficients describe the linear relationship between participation grades and final grades while

**Table 1**
Frequency of student responses

| | Percent frequency of student responses | | | | |
|---|---|---|---|---|---|
| | Strongly agree | Agree | Neutral | Disagree | Strongly disagree |
| **Behavioural and emotional dimensions of engagement** | | | | | |
| 1 The clickers helped me pay attention in class | 64.4 | 31.1 | 4.4 | 0.0 | 0.0 |
| 2 I feel more involved in the class material when we use clickers | 55.6 | 35.6 | 8.9 | 0.0 | 0.0 |
| 3 When I am feeling confused the clicker results help me see that I am not the only person that does not understand | 35.6 | 46.7 | 17.8 | 0.0 | 0.0 |
| 4 I enjoy seeing the graphs of the class responses displayed on the screen | 35.6 | 44.4 | 20.0 | 0.0 | 0.0 |
| 5 I gain confidence when I correctly respond to the clicker questions | 62.2 | 33.3 | 4.4 | 0.0 | 0.0 |
| 6 Because the clickers are used to measure participation, I more regularly attend class than I would if there were no clickers | 31.1 | 37.8 | 15.6 | 13.3 | 2.2 |
| **Cognitive dimension of engagement** | | | | | |
| 7 I find it helpful when the teacher discusses the wrong answers as well as the right answers to the clicker questions | 62.2 | 33.3 | 4.4 | 0.0 | 0.0 |
| 8 Clicker questions contribute positively to my learning | 57.8 | 35.6 | 6.7 | 0.0 | 0.0 |
| 9 Clicker questions help me process what I just learned | 44.4 | 48.9 | 4.4 | 2.2 | 0.0 |
| **Perception of value in the use of clickers** | | | | | |
| 10 I believe it is a waste of time to use clickers | 0.0 | 2.2 | 2.2 | 40.0 | 55.6 |

controlling for the effects of year of study and major field of study variables. Based on rank correlation analysis using Kendall's tau-b, both year of study and the students' major field of study are significantly correlated with final grade ($\tau = 0.279$, $p = 0.013$ and $\tau = 0.294$, $p = 0.013$, respectively), while year of study is significantly associated with participation ($\tau = 0.289$, $p = 0.011$). Furthermore, visual inspection of a scattergram, and corroborated by a linear line of best fit ($R^2 = 0.360$), suggests that a linear measure of association appropriately represents the statistical relationship between participation and final grade. The partial correlation coefficient value of 0.567 and two-tailed p-value of <0.001 suggests a moderately strong and statistically significant association between student engagement and student achievement.

Responses to the first six survey questions (1 to 6) were used to test whether clickers provide an effective tool for increasing the behavioural and emotional dimensions of student engagement. Results in Table 2 indicate no statistically significant association between students' participation grade and any of the closed-response survey items. However, there are some associations among the closed-response survey questions themselves, which point toward the overlapping nature of behavioural, emotional, and cognitive dimensions of student engagement and the difficulty in disentangling them. For example, and not surprisingly, students who feel strongly that the clickers help them "pay attention in class" also reported that clickers (a) make them "feel more involved in the class material" ($\rho = 0.539$, $p = <0.001$), (b) help them see that they are "not the only person that does not understand" ($\rho = 0.313$, $p = 0.036$), and (c) help them "gain confidence when they correctly respond to the clicker questions" ($\rho = 0.604$, $p = <0.001$). Also, students who felt more involved in the class material tended to report "gaining confidence when they correctly respond to the clicker questions" ($\rho = 0.329$, $p = 0.028$) and they "more regularly attend class than they would if there were no clickers" ($\rho = 0.307$, $p = 0.040$). In fact, many others have found increased attendance when clicker responses contribute to participation grades (Burnstein and Lederman 2001; Jackson and Trees 2003; Wit 2003). Students who more strongly agree with the statement that they "enjoy seeing the graphs" are also more likely to feel strongly that the clicker "helps them see that I am not the only person that does not understand" ($\rho = 0.296$, $p = 0.048$) and "gain confidence when they correctly respond to the clicker questions" ($\rho = 0.325$, $p = 0.029$). Finally, students who feel strongly that the clickers "help them see that I am not the only person that does not understand" also report strong feelings of "gaining confidence when they correctly respond to the clicker questions" ($\rho = 0.357$, $p = 0.016$). This weak relationship suggests the two survey items are measuring similar yet, at the same time, different dimensions of student engagement.

The next three survey questions (7 to 9) were used to test whether clickers provide an effective tool for enhancing the cognitive dimension of student engagement. Results in Table 3 indicate there is no statistically significant association between academic achievement and any of the corresponding closed-response survey items. While it was hypothesised that there would be significant associations among the three closed-response questions, there is only one significant association between clicker questions, namely "contributing positively to my learning" and "helping me process what I just learned" ($\rho = 0.373$, $p = 0.012$). This weak relationship highlights the difficulties in disentangling the different dimensions of student engagement.

The final survey question (10) was used to investigate whether students perceive real value from the use of clickers in the classroom. While 55% of students strongly disagreed with the statement "it is a waste of time to use the clickers," another 40% disagreed, one student remained neutral, and another student agreed. These results suggest almost all students perceive real value in using clickers in the classroom.

The free-response questions garnered a wide variety of responses that provide further insights into what students liked most and least about using clickers. Allowing students' responses to include multiple 'meanings' and, thus be counted in multiple categories, text classification of the 45 students' comments regarding what they liked most about clickers yielded a total of 83 sentiments that were classified into ten mutually exclusive

**Table 2**
Spearman's rank correlation (ρ) of participation and engagement questions

| | Participation grade | Q 1 Pay attention | Q 2 Feel more involved | Q 3 Enjoy seeing graphs | Q 4 Not feeling alone | Q 5 Gain confidence | Q 6 More regularly attend |
|---|---|---|---|---|---|---|---|
| Participation grade | 1 | -0.217 | -0.192 | -0.170 | 0.094 | -0.077 | -0.022 |
| *Sig. (2-tailed)* | - | *0.151* | *0.206* | *0.264* | *0.538* | *0.617* | *0.886* |
| Q 1 Pay attention | -0.217 | 1 | 0.539 | 0.192 | 0.313 | 0.604 | 0.288 |
| *Sig. (2-tailed)* | *0.151* | - | *<0.001* | *0.206* | *0.036* | *<0.001* | *0.055* |
| Q 2 Feel more involved | -0.192 | 0.539 | 1 | 0.236 | 0.219 | 0.329 | 0.307 |
| *Sig. (2-tailed)* | *0.206* | *<0.001* | - | *0.118* | *0.149* | *0.028* | *0.040* |
| Q 3 Enjoy seeing graphs | -0.170 | 0.192 | 0.236 | 1 | 0.296 | 0.325 | -0.273 |
| *Sig. (2-tailed)* | *0.264* | *0.206* | *0.118* | - | *0.048* | *0.029* | *0.070* |
| Q 4 Not feeling alone | 0.094 | 0.313 | 0.219 | 0.296 | 1 | 0.357 | -0.212 |
| *Sig. (2-tailed)* | *0.538* | *0.036* | *0.149* | *0.048* | - | *0.016* | *0.161* |
| Q 5 Gain confidence | -0.077 | 0.604 | 0.329 | 0.325 | 0.357 | 1 | 0.207 |
| *Sig. (2-tailed)* | *0.617* | *<0.001* | *0.028* | *0.029* | *0.016* | - | *0.173* |
| Q 6 More regularly attend | -0.022 | 0.288 | 0.307 | -0.273 | -0.212 | 0.207 | 1 |
| *Sig. (2-tailed)* | *0.886* | *0.055* | *0.040* | *0.070* | *0.161* | *0.173* | - |

**Table 3**
Spearman's rank correlation (ρ) of final grades and achievement questions

| | Final grade | Q 7 Helps to discuss wrong answers | Q 8 Contribute to learning | Q 9 Help me process what I learn |
|---|---|---|---|---|
| Final grade | 1 | -0.006 | 0.006 | -0.146 |
| *Sig. (2-tailed)* | - | *0.969* | *0.968* | *0.339* |
| Q 7 Helps to discuss wrong answers | -0.006 | 1 | 0.275 | 0.249 |
| *Sig. (2-tailed)* | *0.969* | - | *0.067* | *0.099* |
| Q 8 Contribute to learning | 0.006 | 0.275 | 1 | 0.373 |
| *Sig. (2-tailed)* | *0.968* | *0.067* | - | *0.012* |
| Q 9 Help me process what I learn | -0.146 | 0.249 | 0.373 | 1 |
| *Sig. (2-tailed)* | *0.339* | *0.099* | *0.012* | - |

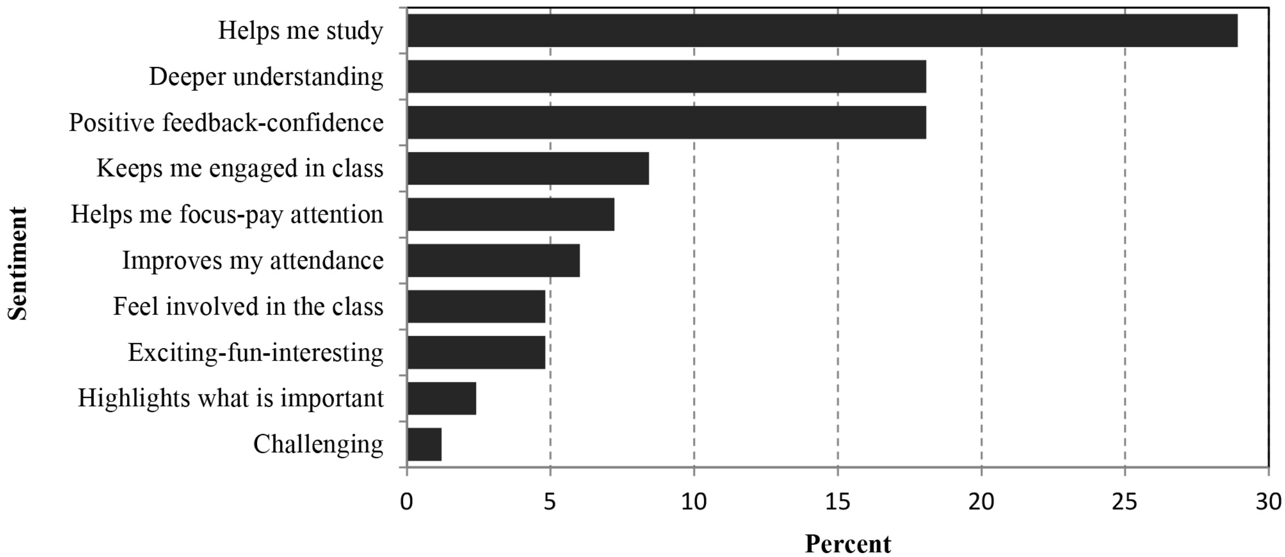



**Figure 1**
Open, responses to what students "liked most" about using clickers

categories. A similar process, however, yielded only 54 sentiments about what they liked least. These were classified into 12 mutually exclusive categories. The frequency distribution of sentiments about what students liked most is illustrated in Figure 1, while the frequency distribution of sentiments about what students liked least is illustrated in Figure 2.

The modal response regarding what students liked most about the clickers is that they "helped them study for exams," which represents almost one-third (28.9%) of all sentiments, and it was reported by more than half of the respondents. Similar findings have been widely reported in other studies (Beatty et al. 2006; Poirier and Feldman 2007; Morling et al. 2008; Shaffer and Collura 2009; Shapiro 2009; Shapiro and Gordon 2012). This response is directly influenced by the iClicker Cloud software, which saves a screen capture of the questions. Students are then able to review all the questions asked during each session, thus providing a great study guide for any student who uses the iClicker Cloud application on their mobile device. This option is not available to students who use the iClicker remote, but the questions were made available to those students in pdf format. The next two most common sentiments relate to clickers providing a "deeper understanding" of the material and the "positive feedback increasing their confidence" (both at 18.1%). Campbell and Mayer (2009), Milner-Bolotin et al. (2010), as well as Anderson et al. (2011) also indicated students reported greater retention of information. The belief that clickers provide a deeper understanding stems from the instructor reviewing not only an explanation of the correct answer, but also an explanation of why the other answers are incorrect. The positive feedback provided by answering correctly confirms the student's understanding and gives them confidence.

The next two responses in Figure 1 are related, but sufficiently different to be categorized separately. Responses suggest that the clickers help students "focus or pay attention" during the lecture (7.2%) and they indicate that students are kept "more engaged in class" (4.8%), likely because students know they will be asked to answer clicker questions related to the lecture topic. Similarly, responses indicate that students "feel more involved in the class" and suggest the atmosphere created by the clicker is "fun, exciting, and interesting." The enhanced two-way interaction and level of excitement generated by using clickers in the classroom has been widely reported by others (Laurillard 1993; Draper et al. 2002; Roschelle et al. 2004a, 2004b; Johnson and Lillis 2010; Bojinova and Oigara 2011; Simelane and Skhosana 2012). Other sentiments indicate that clickers lead to "improved attendance," presumably because students know their attendance is part of their final grade; a finding also reported by Draper et al. (2002) and Wood (2004). While similar attendance rates were reported by Burnstein and Lederman (2001) who reported 80 to 90% attendance in science classes where clickers were used, the class surveyed for this study averaged over 70% attendance for the semester. Students' sentiments corroborate the argument that clickers enhance the behavioural dimension of student engagement.

Comprising 22% of all sentiments, and reported by more then one-quarter of respondents, the modal response regarding what students liked least about the clickers was "the cost." On the one hand, this response is surprising given the cost of the iClicker Cloud application is only $10 and a used iClicker remote is about $25. On the other hand, if this is the most significant criticism of the clicker system, then it can be concluded that students have only minor negative perceptions about using clickers in the classroom. This is confirmed by one of the two second-most frequently reported concerns; 19% of sentiments indicate there was "nothing" that the students disliked about using clickers in the classroom. The other second-most frequently reported negative sentiment relates to the frequent dropping of the Wi-Fi signal in the lecture theatre, which necessitated restart-

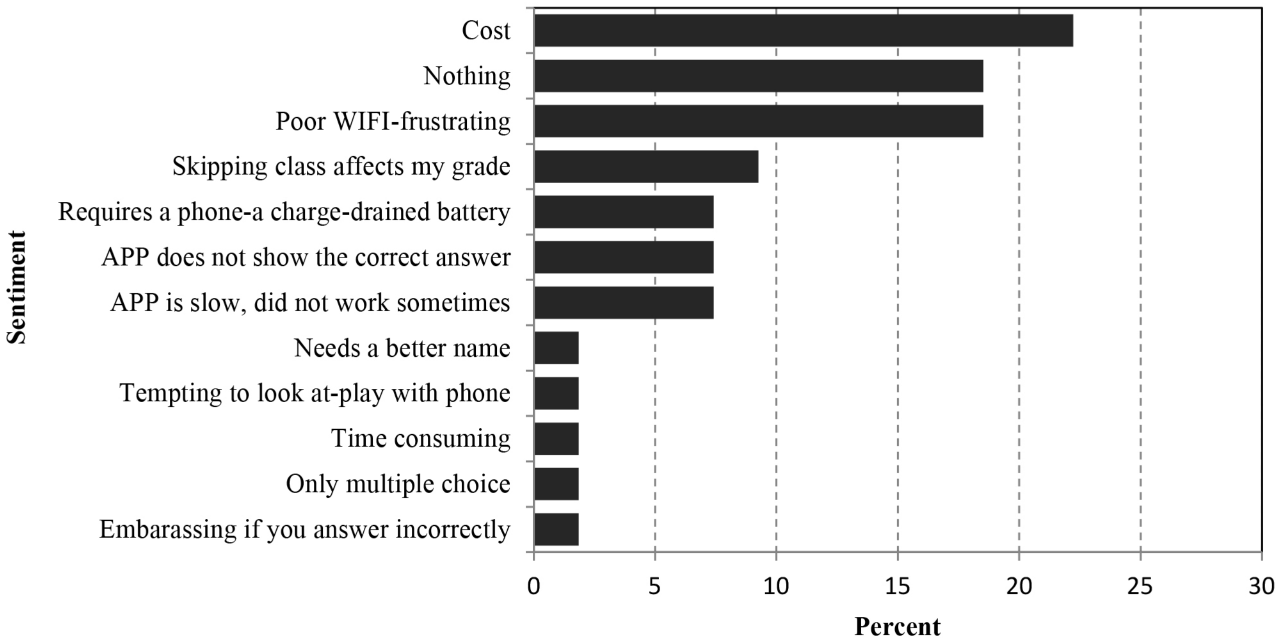



**Figure 2**
Open, responses to what students "liked least" about using clickers

ing the program and caused a considerable amount of frustration for many users of smart-device applications, but not the iClicker remote users. Again, this was not a criticism of the clicker itself, but rather the associated classroom infrastructure. Reports of clickers not always working properly are described in detail by Barnett (2006) while potential implementation problems are described by Hoekstra and Mollborn (2012). The third-most frequently reported concern surrounds students being disappointed that skipping class would affect their participation grade, a concern that was echoed when clickers were used only for attendance (Trees and Jackson 2007). This revelation may indicate that grade-oriented students may be more engaged by the participation grade than the use of clickers, which raises issues of disentangling the impact of clickers alone on either engagement or achievement. The next three most frequently reported concerns relate to the smart-device application, which drains the battery on their smartphone, was sometimes slow (presumably related to Wi-Fi issues), and the application did not record the correct answer (only a screen grab of the question, which was an intentional aspect of course design). There were four other individual responses that suggested the application might deserve a better name, using their phone in class tempted them to check their social media accounts, it was embarrassing to find out they were the only person to answer incorrectly, and perhaps the professor relied too heavily on multiple choice responses.

Overall, students' perceptions on the effectiveness of clickers to enhance student engagement and academic achievement appear overwhelmingly positive, which accords with previous findings. Students' perceptions also provide valuable insights into the perceived strengths and weaknesses of using clickers, which are particularly relevant to teaching large undergraduate classes. Large classes arguably provide the best forum for the pedagogical benefits of clickers, because the anonymity that clickers provide empowers all students to have a 'voice' (Giroux and McLaren 1986, 233) in the classroom without the fear of embarrassment or making a mistake, and by letting them know they are not alone in their confusion. Professors are also empowered by using clickers in the classroom, because the technology can be used to enhance their pedagogical strategies, such as promoting an interactive classroom atmosphere, and providing real-time feedback, which allows them to immediately gauge the level of students' understanding and then adapt the content and pace of instruction to reflect their students' needs. On this basis, and despite the possibility of operational issues as noted above, professors should be encouraged rather than dissuaded to adopt clickers in their classrooms.

This research has its limitations. For example, the cross-sectional nature of the sample raises attendant concerns over representativeness and generalizability, while the self-selection of students attending the last day of class raises concerns over potential biases, such as social desirability bias, especially within the power relations and semester-long positive relationship between the professor and the students. Another important limitation is the observed lack of a clear statistical association between the perceived benefits of using clickers and either the behavioural and emotional dimensions (participation) or the cognitive dimension (achievement) of student engagement. This may be due, for example, to the relatively small sample size for the study, the highly skewed opinions on the perceived benefits of clickers, the absence of an empirical relationship, or the manifest variables (i.e., participation grades and final grades) may not be good proxies for student engagement and academic achievement, respectively. Another consideration is that participation, and particularly as a measure for the behavioural dimension, may have been too narrowly defined in the study (attending class and correctly answering clicker questions). Appleton et al. (2006) suggest participation should include attendance, class participation, time spent on homework, and involvement in extra-curricular activities. Future research should employ a more nuanced measure of student engagement, and potentially academic achievement (perhaps according to fact-based and performance-based assessment items) to better understand the impact of clickers on different dimensions of student engagement. Rather than attempting to disentangle the multi-dimensional nature of student engagement, an alternate approach, perhaps using data reduction techniques such as principal component analysis, could capitalize on the overlapping nature of student engagement dimensions, but then this would raise issues of cumulative effects.

## Conclusion

Student engagement is an important goal for higher education, because there is a strong direct link between student engagement and several positive outcomes, including academic achievement. This research aimed to answer three questions, namely if students' perceptions provide convincing evidence that clickers: (i) are effective tools for engaging and motivating them inside and outside the classroom; (ii) are effective tools for improving academic performance; and (iii) provide real value in an introductory physical geography classroom. The results of this study demonstrate a significant association between student engagement and academic achievement. However, the results fail to demonstrate a statistical association between the students' perceptions on the effectiveness of clickers and measures of either student engagement or academic achievement. This research suggests that students believe clickers can help create an interactive, adaptive, and flexible learning environment that has the potential to enhance student engagement.

## Acknowledgements

We gratefully acknowledge the support of the students who attended class on the last day of the semester and who participated in this study. We also thank the anonymous reviewers and editor for their helpful comments.

## References

Anderson, L. S., A. F. Healy, J. A. Kole, and L. E. Bourne, Jr. 2011. Conserving time in the classroom: The clicker technique. *Quarterly Journal of Experimental Psychology* 64(8): 1457–1462.

Appleton, J. J., S. L. Christenson, D. Kim, and A. L. Reschly. 2006. Measuring cognitive and psychological engagement: Validation of the Student Engagement Instrument. *Journal of School Psychology* 44(5): 427–445.

Bachman, L., and C. Bachman. 2011. A study of classroom response system clickers: Increasing student engagement and performance in a large undergraduate lecture class on architectural research. *Journal of Interactive Learning Research* 22(1): 5–21.

Barnett, J. 2006. Implementation of personal response units in very large lecture classes: Student perceptions. *Australasian Journal of Educational Technology* 22(4): 474–494.

Beatty, I. D., and W. J. Gerace. 2009. Technology-enhanced formative assessment: A research-based pedagogy for teaching science with classroom response technology. *Journal of Science Education and Technology* 18(2): 146–162.

Beatty, I. D., W. J. Gerace, W. J. Leonar, and R. J. Dufresne. 2006. Designing effective questions for classroom response system teaching. *American Journal of Physics* 74(1): 31–39.

Birdsall, S. 2002. Assessment and student response systems. *The Teaching Exchange, Brown University* 7: 1–4.

Blood, E., and R. Neel. 2008. Using student response systems in lecture-based instruction: Does it change student engagement and learning? *Journal of Technology and Teacher Education* 16(3): 375–383.

Bojinova, E. D., and J. N. Oigara. 2011. Teaching and learning with clickers: Are clickers good for students? *Interdisciplinary Journal of E-Learning and Learning Objects* 7(1):169–184.

Burnstein, R. A., and L. M. Lederman. 2001. Using wireless keypads in lecture classes. *The Physics Teacher* 39(1): 8–11.

Caldwell, J. E. 2007. Clickers in the large classroom: Current research and best-practice tips. *CBE-Life Sciences Education* 6(1): 9–20.

Campbell, C., and S. Monk. 2015. Introducing a learner response system to pre-service education students: Increasing student engagement. *Active Learning in Higher Education* 16(1): 25–36.

Campbell, J., and R. E. Mayer. 2009. Questioning as an instructional method: Does it affect learning from lectures? *Applied Cognitive Psychology* 23(6): 747–759.

Correa, H. 1993. An economic analysis of class size and achievement in education. *Education Economics* 1(2): 129–135.

Crosnoe, R., M. K. Johnson, and G. H. Elder, Jr. 2004. Intergenerational bonding in school: The behavioral and contextual correlates of student-teacher relationships. *Sociology of Education* 77(1): 60–81.

d'Inverno, R., H. Davis, and S. White. 2003. Using a personal response system for promoting student interaction. *Teaching Mathematics and its Applications* 22(4): 163–169.

Dong, J-J., W-Y. Hwang, R. Shadiev, and G-Y. Chen. 2017. Pausing the classroom lecture: The use of clickers to facilitate student engagement. *Active Learning in Higher Education* 18(2): 157–172.

Draper, S. W. 1998. Niche-based success in CAL. *Computers & Education* 30(1–2): 5–8.

Draper, S. W., J. Cargill, and Q. Cutts. 2002. Electronically enhanced classroom interaction. *Australian Journal of Educational Technology* 18(1): 13–23.

Duncan, D. 2005. *Clickers in the classroom: How to enhance science teaching using classroom response systems*. San Francisco, CA: Pearson Education.

Dunleavy, J., and P. Milton. 2009. *What did you do in school today? Exploring the concept of student engagement and its implications for teaching and learning in Canada*. Toronto, ON: Canadian Education Association.

Evans, J. D. 1996. *Straightforward statistics for the behavioral sciences*. Pacific Grove, CA: Brooks/Cole Publishing.

Fies, C., and J. Marshall. 2006. Classroom response systems: A review of the literature. *Journal of Science Education and Technology* 15(1): 101–109.

Fredricks, J. A., and W. McColskey. 2012. The measurement of student engagement: A comparative analysis of various methods and student self-report instruments. In *Handbook of research on student engagement*, ed. S. L. Christenson, A. L. Reschly. and C. Wylie. New York, NY: Springer, 763–782.

Giroux, H. A., and P. McLaren. 1986. Teacher education and the politics of engagement: The case for democratic schooling. *Harvard Education Review* 56(3): 213–238.

Halloran, L. 1995. A comparison of two methods of teaching computer managed instruction and keypad questions versus traditional classroom lecture. *Computers in Nursing* 13(6): 285–288.

Harris, L. R. 2008. A phenomenographic investigation of teacher conceptions of student engagement in learning. *The Australian Educational Researcher* 35(1): 57–79.

Heaslip, G., P. Donovan, and J. G. Cullen. 2014. Student response systems and learner engagement in large classes. *Active Learning in Higher Education* 15(1): 11–24

Hoekstra, A., and S. Mollborn. 2012. How clicker use facilitates existing pedagogical practices in higher education: Data from interdisciplinary research on student response systems. *Learning, Media and Technology* 37(3): 303–320.

Hunsu, N. J., O. Adesope, and D. J. Bayly. 2016. A meta-analysis of the effects of audience response systems (clicker-based technologies) on cognition and affect. *Computers and Education* 94: 102–119.

Huxley, G., J. Mayo, M. W. Peacey, and M. Richardson. 2018. Class size at university. *Fiscal Studies* 39(2): 241–264.

Jackson, M. H., and A. R. Trees. 2003. Clicker implementation and assessment [Report]. Boulder, CO: Department of Communication, University of Colorado at Boulder.

Johnson, K., and C. Lillis. 2010. Clickers in the laboratory: Student thoughts and views. *Interdisciplinary Journal of Information, Knowledge, and Management* 5: 139–151.

Jones, M. E., P. D. Antonenko, and C. M. Greenwood. 2012. The impact of collaborative and individualized student response system strategies on learner motivation, metacognition, and knowledge transfer. *Journal of Computer Assisted Learning* 28(5): 477–487.

Judson, E., and D. Sawada. 2002. Learning from past and present: Electronic response systems in college lecture halls. *Journal of Computers in Mathematics and Science Teaching* 21(2): 167–181.

Katz, L., M. C. Hallam, M. M. Duvall, and Z. Polsky. 2017. Considerations for using personal Wi-Fi enabled devices as "clickers" in a large university class. *Active Learning in Higher Education* 18(1): 25–35.

Kay, R. H., and A. LeSage. 2009. Examining the benefits and challenges of using audience response systems: A review of the literature. *Computers & Education* 53(3): 819–827.

Kirkwood, A., and L. Price. 2005. Learners and learning in the twenty-first century: What do we know about students' attitudes towards and experiences of information and communication technologies that will help us design courses? *Studies in Higher Education* 30(3): 257–274.

Knight, J. K., and W. B. Wood. 2005. Teaching more by lecturing less. *Cell Biology Education* 4(4): 298–310.

Koenig, K. 2010. Building acceptance for pedagogical reform through wide-scale implementation of clickers. *Journal of College Science Teaching* 39(3): 46–50.

Kokkelenberg, E. C., M. Dillon, and S. M. Christy. 2008. The effects of class size on student grades at a public university. *Economics of Education Review* 27(2): 221–233.

Laurillard, D. 1993. *Rethinking university teaching: A framework for the effective use of educational technology*. London, UK: Routledge/Falmer.

Laxman, K. 2011. A study on the adoption of clickers in higher education. *Australasian Journal of Educational Technology* 27(8): 1291–1303.

Lennox Terrion, J., and V. Aceti. 2012. Perceptions of the effects of clicker technology on student learning and engagement: A study of freshmen chemistry students. *Research in Learning Technology* 20(2): 16150.

MacArthur, J. R., and L. L. Jones. 2008. A review of literature reports of clickers applicable to college chemistry classrooms. *Chemistry Education Research and Practice* 9(3): 187–195.

MacGeorge, E. L., S. R. Homan, J. B. Dunning, Jr., D. Elmore, G. D. Bodie, E. Evans, S. Khichadia, and S. M. Lichti. 2008. The influence of learning characteristics on evaluation of audience response technology. *Journal of Computing in Higher Education* 19(2): 25–46.

Maclean's. 2018. Canadian universities with the highest (and lowest) graduation rates. *Maclean's Magazine*. http://www.macleans.ca/education/canadian-universities-with-the-highest-and-lowest-graduation-rates/.

Mayer, R. E., and M. C. Wittrock. 2006. Problem solving. In *Handbook of educational psychology*, ed. P. A. Alexander, and P. H. Winne. 2nd ed. Mahwah, NJ: Lawrence Erlbaum, 287–304.

Mazur, E. 1997. *Peer instruction: A user's manual*. Upper Saddle River, NJ: Prentice-Hall.

McDermott, L. C., and E. F. Redish. 1999. Resource letter: PER-1: Physics education research. *American Journal of Physics* 67(9): 755–767.

Milner-Bolotin, M., T. Antimirova, and A. Petrov. 2010. Clickers beyond the first-year science classroom. *Journal of College Science Teaching* 40(2): 14–18.

Monks, J., and R. M. Schmidt. 2011. The impact of class size on outcomes in higher education. *The B.E. Journal of Economic Analysis & Policy* 11(1): Article 62.

Moredich, C., and E. Moore. 2007. Engaging students through the use of classroom response systems. *Nurse Educator* 32(3): 113–116.

Morling, B., M. McAuliffe, L. Cohen, and T. M. DiLorenzo. 2008. Efficacy of personal response systems ('clickers') in large, introductory psychology classes. *Teaching of Psychology* 35(1): 45–50.

Mulryan-Kyne, C. 2010. Teaching large classes at college and university level: Challenges and opportunities. *Teaching in Higher Education* 15(2): 175–185.

Murray, C., and K. Zvoch. 2011. Teacher-student relationships among behaviorally at-risk African American youth from low-income backgrounds: Student perceptions, teacher perceptions, and socioemotional adjustment correlates. *Journal of Emotional and Behavioral Disorders* 19(1): 41–54.

Oelsner, J., M. A. Lippold, and M. T. Greenberg. 2011. Factors influencing the development of school bonding among middle school students. *Journal of Early Adolescence* 31(3): 463–487.

Poirier, C. R., and R. S. Feldman. 2007. Technology and teaching: Promoting active learning using individual response technology in large introductory psychology classes. *Teaching of Psychology* 34(3): 194–196.

Poulis, J., C. Massen, E. Robens, and M. Gilbert. 1998. Physics lecturing with audience paced feedback. *American Journal of Physics* 66(5): 439–441.

Reyes, M. R., M. Brackett, S. E. Rivers, M. White, and P. Salovey. 2012. Classroom emotional climate, student engagement, and academic achievement. *Journal of Educational Psychology* 104(3): 700–712.

Roschelle, J., W. R. Penuel, and L. Abrahamson. 2004a. Classroom response and communication systems: Research review and theory. Paper presented at the Annual Meeting of the American Educational Research Association, April 12–16, San Diego, CA. http://www.humansphere.com.sg/pdf/an/Classroom%20Response%20and%20Communication%20Systems.pdf.

—. 2004b. The networked classroom. *Educational Leadership* 61(5): 50–54.

Saha, G. G. 2014. Student engagement: A strategic tool to reform the quality of management education. *The Standard International Journals Transactions on Industrial, Financial & Business Management (IFBM)* 2(3): 153–157.

Sartori, T. M. 2008. An empirical investigation of electronic student response systems in a K-12 school district: The relationship of ongoing assessment on student achievement. PhD thesis, Pepperdine University, California.

Shaffer, D. M., and M. J. Collura. 2009. Evaluating the effectiveness of a personal response system in the classroom. *Teaching of Psychology* 36(4): 273–277.

Shapiro, A. M. 2009. An empirical study of personal response technology for improving attendance and learning in a large class. *Journal of the Scholarship of Teaching and Learning* 9(1): 13–26.

Shapiro, A. M., and L. T. Gordon. 2012. A controlled study of clicker-assisted memory enhancement in college classrooms. *Applied Cognitive Psychology* 26(4): 635–643.

Simelane, S., and P. M. Skhosana. 2012. Impact of clicker technology in a mathematics course. *Knowledge Management & e-Learning: An International Journal* 4(3): 279–292.

Strasser, N. 2010. Who wants to pass math? Using clickers in calculus. *Journal of College Teaching & Learning* 7(3): 49–52.

Tanner, K., and D. Allen. 2005. Approaches to biology teaching and learning: Understanding the wrong answers—teaching toward conceptual change. *Cell Biology Education* 4(2): 112–117.

Taylor, L., and J. Parsons. 2011. Improving student engagement. *Current Issues in Education* 14(1): 1–32.

Trees, A. R., and M. H. Jackson. 2007. The learning environment in clicker classrooms: Student processes of learning and involvement in large university-level courses using student response systems. *Learning, Media and Technology* 32(1): 21–40.

Trotter, A. 2005. Technology turns test-prep into clicking experience. *Education Week* 24(36): 8.

Vygotsky, L. S. 1978. *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

White, P., D. J. Delaney, D. Syncox, O. A. Akerberg, and B. Alters. 2011. Clicker implementation models. *Educause Quarterly* 34(4): 1–4.

Willms, J. D. 2003. *Student engagement at school: A sense of belonging and participation: Results from PISA 2000*. Paris, France: Organisation for Economic Co-operation and Development.

Willms, J. D., S. Friesen, and P. Milton. 2009. *What did you do in school today? Transforming classrooms through social, academic, and intellectual engagement* (First National Report), Toronto, ON: Canadian Education Association.

Wit, E. 2003. Who wants to be… The use of a personal response system in statistics teaching. *MSOR Connections* 3(2): 14–20.

Wood, W. B. 2004. Clickers: A teaching gimmick that works. *Developmental Cell* 7(6): 796–798.

Zepke, N. 2014. Student engagement research in higher education: Questioning an academic orthodoxy. *Teaching in Higher Education* 19(6): 697–708.

Prairie Perspectives: Geographical Essays
Prairie Division
Canadian Association of Geographers
Association Canadienne des Géographes

# Historical precipitation characteristics in the Palliser's Triangle region of the Canadian prairies

Dustin M. Roussin
Department of Geography, University of Winnipeg

Jacqueline Binyamin
Department of Geography, University of Winnipeg

**Key Messages**

- Drought is a recurrent and spatially variable feature of Palliser's Triangle.
- Teleconnections (ENSO, PDO and PNA) affect seasonal and long-term variation in precipitation across the Canadian prairies.
- Among teleconnections, the PDO has the greatest effect on precipitation in Palliser's Triangle..

*The Palliser's Triangle region of the Canadian prairies is a drought prone area. The region's dry belt extending from Lethbridge, Alberta to Swift Current, Saskatchewan has variously expanded and shrunk over the course of the 20th century. Since1980, it has been expanding east and north towards Regina and Saskatoon, Saskatchewan. Teleconnections such as the El Niño/Southern Oscillation (ENSO), the Pacific North American (PNA) pattern, and the Pacific Decadal Oscillation (PDO) are known to have effects on the precipitation received in the region. The main purpose of this research is to understand how teleconnections alter the pattern of precipitation across Palliser's Triangle. The PDO was shown to have the greatest influence over precipitation. The study shows that winter values of a teleconnection index have a greater influence on spring and summer precipitation than the spring and summer values of the same index.*

Keywords: Palliser's Triangle region, Canadian prairies, teleconnections, ENSO, PDO, PNA

## Introduction

The Canadian prairies are noted for their agricultural production, however, there are areas of the region that are known for being more prone to drought than others. One such area, known as Palliser's Triangle, extends across southern Alberta and Saskatchewan to the southwest corner of Manitoba (Villmow 1956; Spry 1959; Gan 2000; Marchildon et al. 2009). Known for its dryness, there is, however, variability from year to year in the amount of precipitation received. Different teleconnections such as the El Niño/Southern Oscillation (ENSO), the Pacific Decadal Oscillation (PDO), and the Pacific North American (PNA) pattern, have been known to affect temperature and precipitation across the Canadian prairies and over the globe (Maybank et al. 1995: Bonsal and Lawford 1999; Gan 2000; Shabbar and Skinner 2004; Coulibaly 2006; St. George et al. 2009; Vicente-



Correspondence to: Jacqueline Binyamin, Department of Geography, University of Winnipeg, 515 Portage Avenue, Winnipeg, MB R3B 2E9
Email: j.binyamin@uwinnipeg.ca

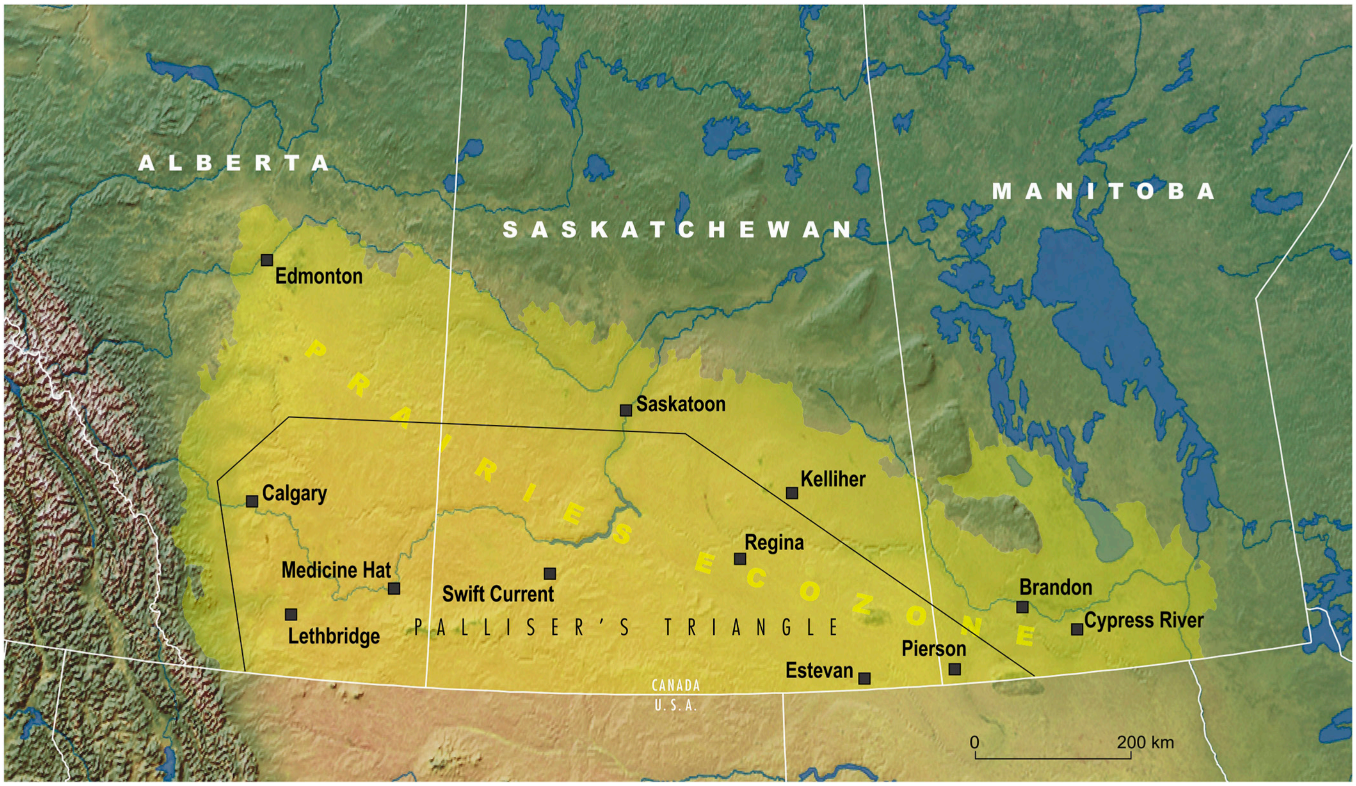



**Figure 1**
The study area
Cartography: Weldon Hiebert, base map from Natural Earth

Serrano et al. 2011; Dong and Dai 2015; Vincent et al. 2015). Interannual variations in precipitation in the Canadian prairies have been associated with ENSO and PDO variations (Shabbar et al. 1997; Bonsal and Lawford 1999; Bonsal et al. 2001; Shabbar and Skinner 2004; Shabbar and Yu 2012). The objectives of this research are to: i) investigate the amount of precipitation that Palliser's Triangle receives at different locations; ii) identify those areas within Palliser's Triangle that are the most variable in the amount of precipitation received; and iii) examine the correlations between climate modes (teleconnections) and precipitation in regions of Palliser's Triangle.

## Background

During John Palliser's 1857–1860 expedition into the heart of the central plains of North America, he observed that an area of the prairies was more arid than the land that bordered it to the north (Marchildon et al. 2009). This area became known as Palliser's Triangle. Its northern boundary is set at 52°N from where it extends south to the USA-Canada border between 100°W in southwestern Manitoba and 114°W in southeastern Alberta (Villmow 1956; Spry 1959; Marchildon et al. 2009) (Figure 1). There is a drier interior within the region around the Alberta-Saskatchewan border extending west to Medicine Hat, Alberta and east to Swift Current, Saskatchewan known as the dry belt (Villmow 1956; Maybank et al. 1995; Marchildon et al. 2008, 2009: Masud et al. 2015). The dry belt lies in the rain shadow of the Rocky Mountains, which restrict the flow of moisture from the Pacific Ocean and cause it to receive much lower precipitation (<350 mm per annum) than the average precipitation of Palliser's Triangle (Marchildon et al. 2008). Although the whole of Palliser's Triangle is vulnerable to drought, the precipitation record and pattern show a great deal of interannual variability (Marchildon et al. 2009; St. George et al. 2009). Neither is the amount of atmospheric moisture the only variable factor. The area experiences high moisture losses due to chinook winds. Also, the soils are typically of light texture and have low water retention capacity making the area more sensitive to drought (Marchildon et al. 2008). Not least, the size of the dry belt has also fluctuated over the 20th century, growing up to seven times larger during the 1930s than its present size (Marchildon et al. 2009).

Vincent et al. (2015) showed a significant increase in the annual mean temperature (1° to 2°C) of the southern parts of the Canadian prairies over the period 1948 to 2012, with the highest warming occurring in winter and spring. In contrast, annual and seasonal total precipitation amounts have decreased in the region (Vincent et al. 2015). Also the increase in temperature has triggered a decrease in the amount of precipitation falling as snow. Millet et al. (2009) showed that the prairie pothole region (PPR) varies greatly in atmospheric moisture by presenting a precipitation gradient from east to west. The PPR is prairie grassland, which occupies approximately 750,000 km$^2$ and covers parts of three Canadian provinces (Alberta, Saskatchewan, and Manitoba) and five U.S. states (Montana, North and South Dakota, Minnesota, and Iowa). Precipitation in the east of the region was nearly triple the amount received in the west (Millet et al. 2009). The Palmer Drought Severity Index and decadal analysis for the 20th century indicate that southeastern Alberta and southwestern Saskatchewan comprise the most drought prone area in the prairies (Millet et al. 2009). Millet et al. (2009) also determined that conditions across the western prairies in the 1980s were similar to those of the Dust Bowl of the 1930s, and that the 1990s was the wettest decade of the 20th century. Similar findings on the interdecadal variation of precipitation have been found by Chipanshi et al. (2006), Bonsal et al. (2013), and Masud et al. (2015). Bonsal et al. (2017) found that the region of the South Saskatchewan River Basin has experienced many interdecadal periods of variability changing from cool/wet to warm/dry throughout the 20th century. The interdecadal changes are attributed to variation in the 500 mb pressure height above the region, with ridging associated with warm/dry periods and troughing with cool/wet periods. Bonsal and Wheaton (2005) confirm that the 2001–2002 Canadian prairie drought was caused by anomalous persistent ridges over the USA and southern Canada that continued for several seasons. Bonsal and Regier (2007) investigated the 2001–2002 drought and found that the west-central Canadian prairies experienced severe precipitation deficit due to anomalous above average pressure heights which led to warmer and drier than normal surface conditions.

Masud et al. (2015) have shown that the southern parts of the Saskatchewan River Basin including the western part of the South Saskatchewan River watershed and regions around the Alberta-Saskatchewan border experience high drought risk. In contrast, moderate drought risk is characteristic of the North Saskatchewan River watershed with the exception of its eastern parts, which are at high risk. Still lesser but more frequent drought risk is associated with areas near the Saskatchewan-Manitoba border, and particularly in those parts of the border within the Saskatchewan River watershed. Masud et al. (2015) also identified an association between drought severity and drought duration, with areas recording highest drought severity being closely associated with areas of greatest drought duration.

## Climatic variability and drought

It has been known for many years that the ENSO has an effect on precipitation in many places across the globe and, in particular, western Canada (Maybank et al. 1995; Kumar and Hoerling 1997; Bonsal and Lawford 1999; Shabbar and Skinner 2004; Coulibaly 2006; St. George et al. 2009; Vicente-Serrano et al. 2011; Dong and Dai 2015). Sea surface temperatures (SSTs) in the equatorial Pacific have been shown to influence prairie precipitation (Shabbar et al. 1997; Bonsal and Lawford 1999; Shabbar and Skinner 2004). Colder than average SSTs in the equatorial Pacific in the previous winter tend to bring wetter summers to the Canadian prairies. These colder SSTs indicate the ENSO is in a cool phase, or La Niña, while warmer than average SSTs bring drier summers to the region. Shabbar and Skinner (2004) also connected the longer-term variability of moisture conditions in the Canadian prairies to the interdecadal pattern of the PDO. The PDO has been shown to be an important control on the variability of precipitation received, bringing more (or less) rain and snow during its negative (or positive) phases (Mantua and Hare 2002; Newman et al. 2003; Shabbar and Skinner 2004; Dong and Dai 2015). El-Niño and the positive phase of the PDO have been related to warm winter temperatures in western and central Canada (Shabbar and Khandekar 1996; Bonsal et al. 2001; Mantua and Hare 2002; Shabbar and Yu 2012).

St. George et al. (2009) have used tree-ring records to identify long-term drought periods, and have established that a few ‘megadroughts’ occurred in the 18th century. Bonsal et al. (2013) found similar results with events dating back to the 14th century, and noted that pre-instrumental droughts typically had longer durations than modern droughts. St. George et al. (2009) attempted to connect summer tree-ring records with the ENSO and the PDO but failed to find any significant results. Instead, they suggested that winter values of the ENSO and the PDO are more strongly related to summer drought conditions, but could not demonstrate the relationship because the tree-ring records only correlate to summer growing conditions (St. George et al. 2009). Bonsal and Lawford (1999) showed that more extended dry spells were recorded during the second summer after an El Niño event occurred, while the opposite was true following La Niña events when far fewer dry spells occurred.

The PNA in upper-atmosphere circulation has been shown to be an important factor affecting temperature and precipitation across North America (Coulibaly 2006), and most influentially in winter. Bonsal and Lawford (1999) showed that the PNA follows the patterns of the ENSO, meaning that the PNA index often shows strong positive (or negative) values during El Niño (or La Niña). The PNA is also associated with drought on the Canadian prairies (Hryciw et al. 2013). Positive PNA values have also been related to drier than normal springs and summers over the prairies (Knox and Lawford 1990; Bonsal et al. 1999).

## Data and methodology

Monthly precipitation totals for 12 stations were obtained from Environment and Climate Change Canada (2018). With the exception of Edmonton, all stations are located within an area bounded approximately by 49°N to 52°N, and 100°W to 114°W. Average annual precipitation was calculated for two time periods, 1950 to 1979 and 1980 to 2009. Average seasonal precipitation for spring (March to May) and summer (June to August) was calculated for both time periods. Using the long-term average precipitation, both annual and seasonal for the two time periods, the average deviation was calculated. With the aid of ArcGIS, data for each station was recorded, and several maps were created to display the average precipitation and average deviation data. Isohyets were used to show areas of equal precipitation and to identify locations that were most vulnerable to drought.

Teleconnection data for the ENSO and the PNA were taken from the US National Oceanic and Atmospheric Administration's Climate Prediction Center (NOAA 2018), and data for the PDO were retrieved from the University of Washington's Joint Institute for the Study of the Atmosphere and Oceans (JISAO 2018). Average annual index values were calculated, as well as seasonal averages for spring and summer (March to August). These values were then compared with the total annual and total spring and summer precipitation for each of the 12 stations using Pearson's correlation coefficients. The average winter (December to February) index value for the ENSO, the PDO, and the PNA were correlated with the spring and summer precipitation totals.

## Results and discussion

### Average precipitation

*Average annual precipitation.* The average precipitation from 1950 to 1979 across all 12 stations indicates that there was a dry belt (≤420 mm) extending from Medicine Hat towards Swift Current (Figure 2A). Between 1980 and 2009 the dry belt expanded from Lethbridge in the west towards Swift Current in the east, and also north towards Saskatoon (Figure 2B). Moving outwards from the core, the average annual precipitation increased. The driest station was Medicine Hat, then in decreasing order of dryness Swift Current, Saskatoon, and Lethbridge (Figure 3). Similar results were found by Maybank et al. (1995) and Marchildon et al. (2009), who found the area between Medicine Hat eastward towards Swift Current was more arid than the surrounding region. The wettest station was Cypress River, then in order of decreasing wetness Brandon, Edmonton, and Pierson (Figure 3). These wetter stations formed a band around the drier stations extending north and east of the core of dryness.

*Average seasonal precipitation.* Average spring precipitation had a pattern similar to the average annual precipitation from 1950 to 1979 with a dry belt (≤100 mm) from Edmonton in the northwest, Saskatoon in the east and Swift Current in the south (Figure 4A). Between 1980 and 2009, the dry area shifted westward slightly to include Medicine Hat but not Edmonton (Figure 4B). The driest spring station was Swift Current, then in order of decreasing dryness Saskatoon, Medicine Hat, and Edmonton (Figure 5). The wettest spring station was Cypress River, then in order of decreasing wetness Brandon, Pierson, and Lethbridge (Figure 5).

The Canadian prairies receive the majority of their precipitation during the summer season. Despite this, a dry belt extending from Lethbridge towards Swift Current and northwards towards Saskatoon existed between 1950 and 1979 (Figure 6A). Between 1980 and 2009 the dry belt was still evident (Figure 6B). Surrounding it, there was a band of moderate moisture, and finally a wet band was observed in the periphery. There was no significant change in summer precipitation between the two study periods. In both periods, the driest summer stations in order of decreasing dryness were Medicine Hat, Saskatoon, Lethbridge, and Swift Current (Figure 7). The wettest stations were Edmonton, Cypress River, Brandon, and Calgary (Figure 7).

### Average deviation of precipitation

*Average annual.* The average deviation of annual precipitation was more variable between 1950 and 1979 (Figure 8A) than between 1980 and 2009 (Figure 8B). For 1950 to 1979, the east was more variable than the west with the exception of Lethbridge (Figure 8A). The least variable stations were Saskatoon, Edmonton, Calgary, and Swift Current while between 1980 and 2009 the least variable stations were Calgary, Cypress River, Saskatoon, and Edmonton (Figure 8B). The most variable stations between 1950 and 1979 were Brandon, Estevan, Kelliher, and Lethbridge while between 1980 and 2009 Pierson, Kelliher, Estevan, and Medicine Hat were the most variable (Figure 9).

*Average seasonal.* The average deviation of spring precipitation showed that between 1950 and 1979, Calgary was the least variable. With the exception of Lethbridge, the western stations had less deviation than stations in Manitoba (Figure 10A). Between 1980 and 2009 Manitoba stations were more variable than the western stations. The least variable station was Medicine Hat (Figure 10B). The range of deviation was larger between 1950 and 1979 than between 1980 and 2009. The least variable stations in the earlier period were Calgary, Edmonton, Swift Current, and Saskatoon, while in the later period the least variable stations were Medicine Hat, Lethbridge, Saskatoon, and Swift Current (Figure 11). Between 1950 and 1979, the most variable stations were Cypress River, Lethbridge, Estevan, and Brandon, while between 1980 and 2009 the most variable stations were Brandon, Cypress River, Pierson, and Calgary (Figure 11).

The summer average deviation for 1950 to 1979 had a pattern similar to the spring of that period. Western stations were less variable than their eastern counterparts, with Saskatoon identified as the least variable station, and Brandon and Kelliher the most variable (Figure 12A). Between 1980 and 2009, there was greater overall variability in precipitation (Figure 12B). Over the 1950 to 1979 period the least variable stations were Saskatoon, Edmonton, Swift Current, and Lethbridge while in the later period the least variable stations were Saskatoon, Calgary, Cypress River, and Swift Current (Figure 13).The most variable stations between 1950 and 1979 were Brandon, Kelliher, Estevan, and Pierson, while between 1980 and 2009 the most variable were Lethbridge, Edmonton, Brandon, and Kelliher (Figure 13).

### Correlation between precipitation and teleconnections

*ENSO.* The Pearson correlation coefficients between average annual precipitation and average annual value of the Southern Oscillation Index (SOI) were significant at the 99% confidence level ($P < 0.01$) for Pierson, Brandon, Saskatoon, and Estevan (Table 1). The positive sign of the correlation coefficient suggests that these locations receive larger amounts of precipitation during the cold phase of the ENSO, La Niña. There also appears

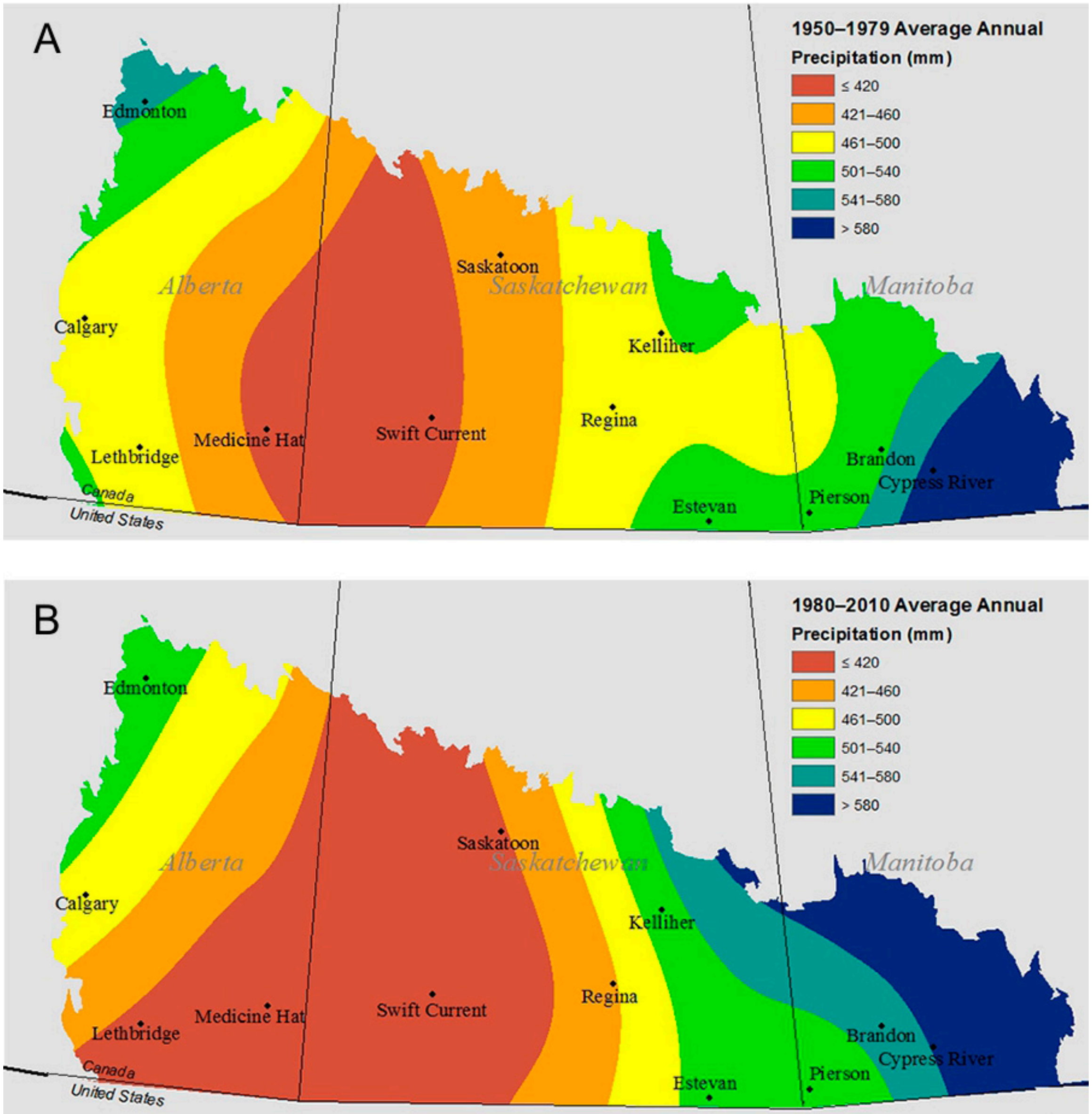



**Figure 2**
30-year average annual precipitation for 1950 to 1979 and 1980 to 2009 for Palliser's Triangle
Cartography: Dustin Rousin

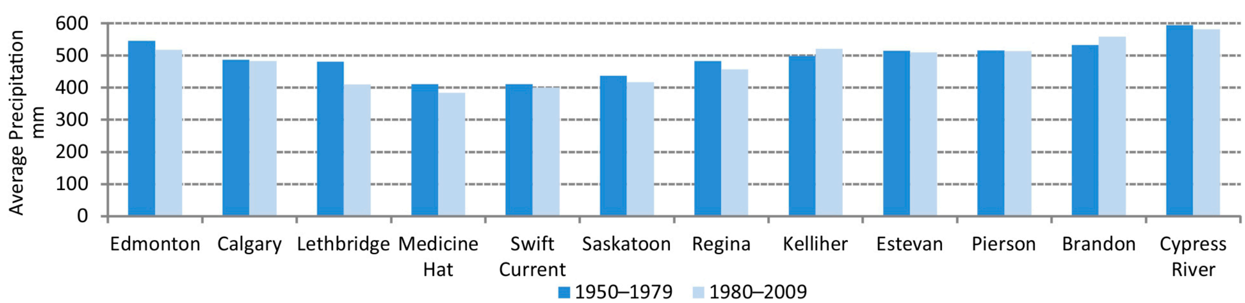
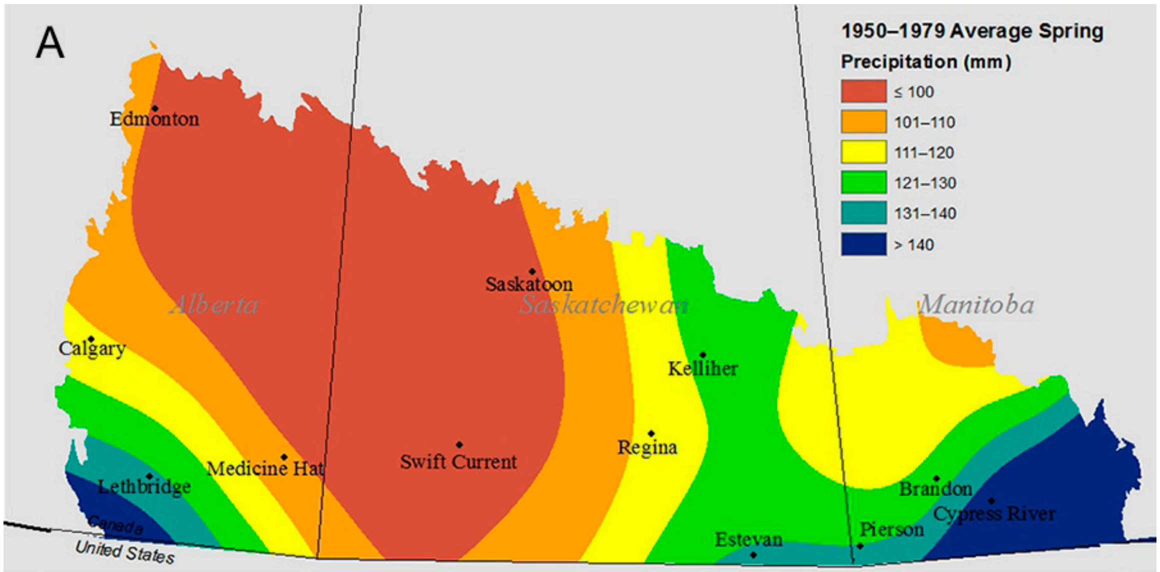



**Figure 3**
Average annual precipitation from 1950 to 2009 across Palliser's Triangle



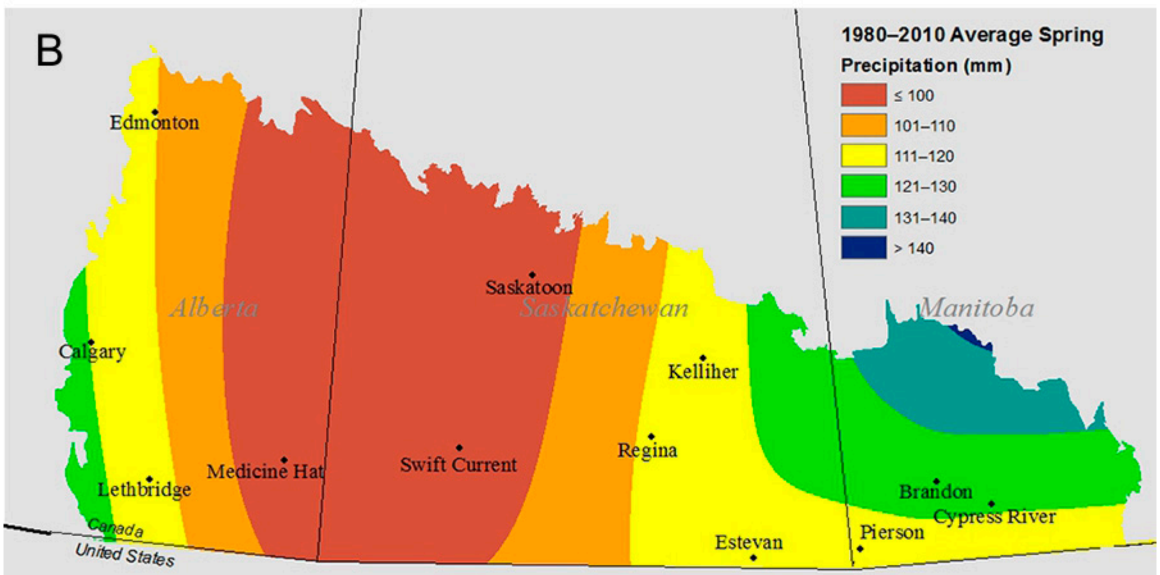




**Figure 4**
30-year average spring precipitation for 1950 to 1979 and 1980 to 2009 for Palliser's Triangle
Cartography: Dustin Rousin

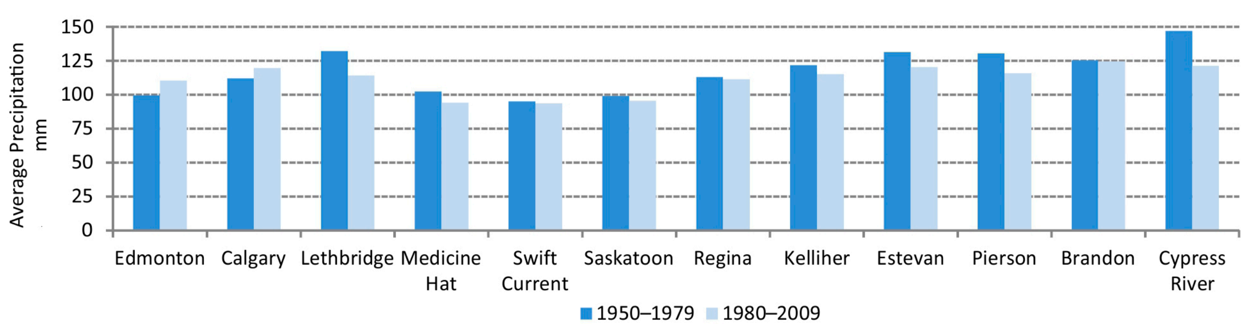



**Figure 5**
Average spring precipitation from 1950 to 2009 across Palliser's Triangle

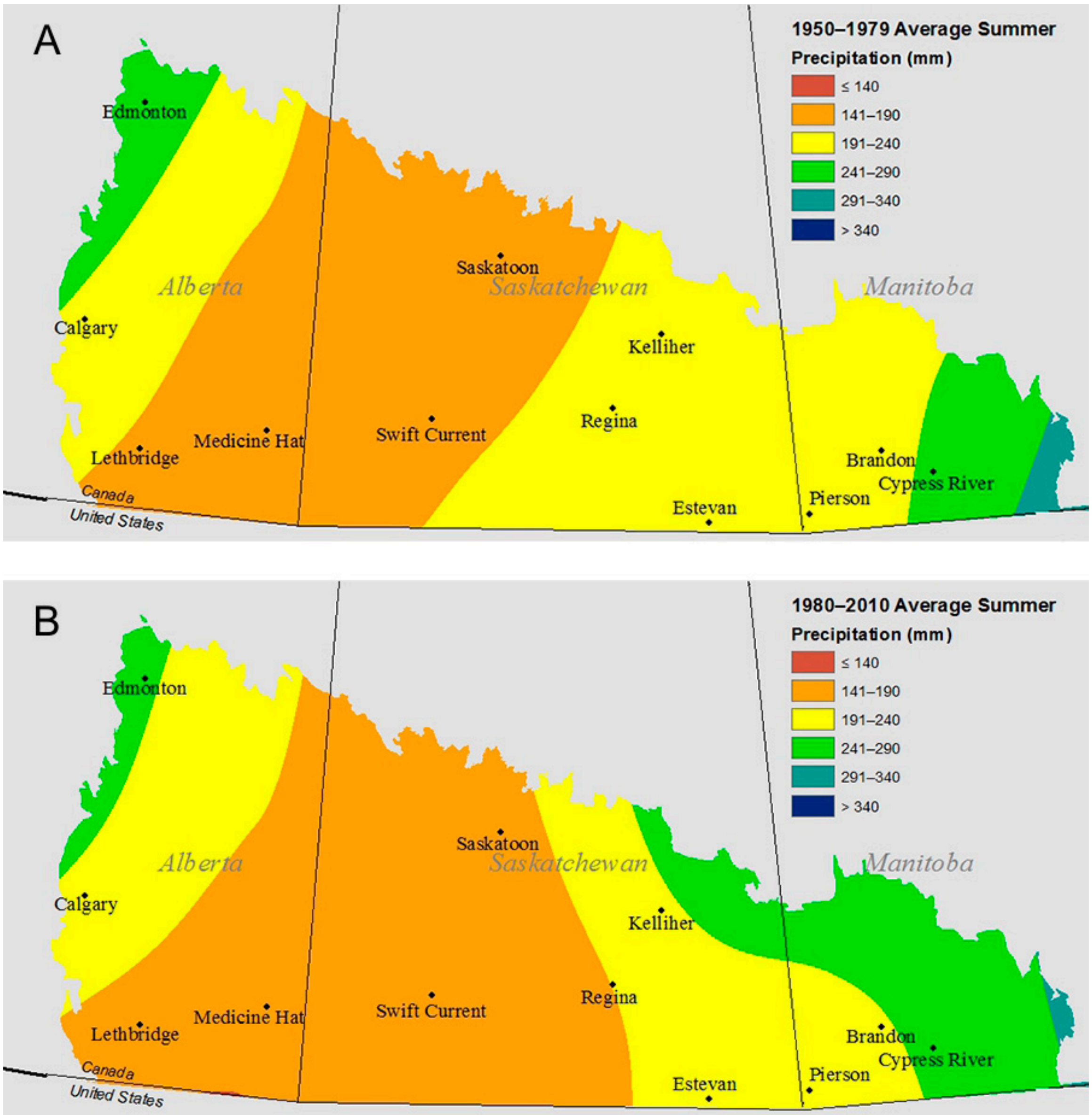



**Figure 6**
30-year average summer precipitation for 1950 to 1979 and 1980 to 2009 for Palliser's Triangle
Cartography: Dustin Rousin

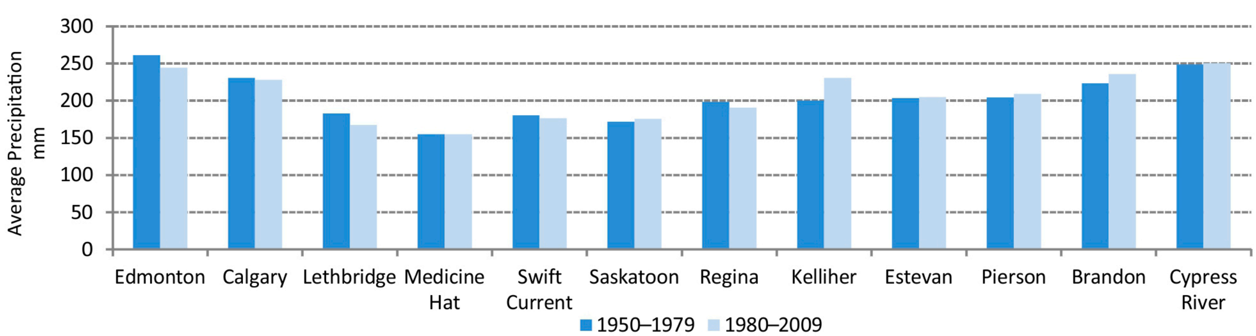



**Figure 7**
Average summer precipitation from 1950 to 2009 across Palliser's Triangle

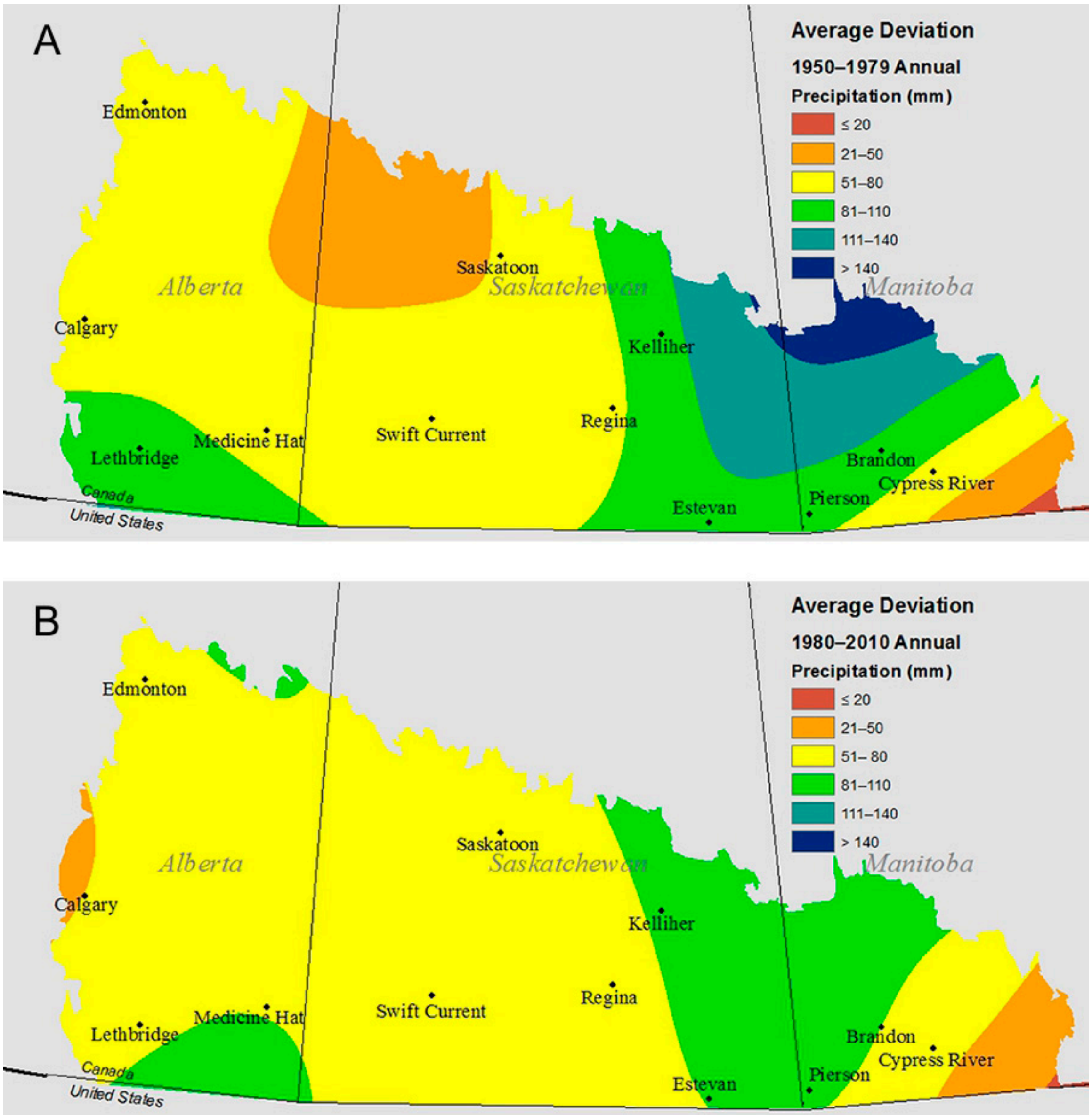



**Figure 8**
Average deviation from 30-year average annual precipitation for 1950 to 1979 and 1980 to 2009 for Palliser's Triangle
Cartography: Dustin Rousin

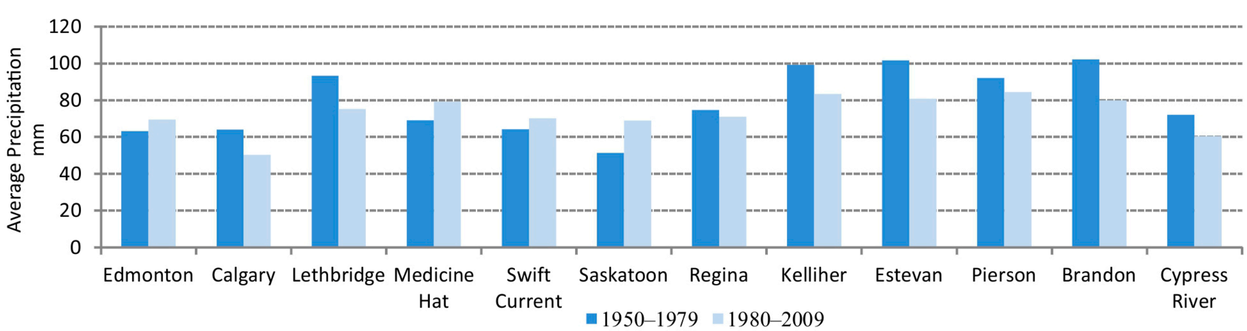



**Figure 9**
Average deviation of annual precipitation from 1950 to 2009 for Palliser's Triangle

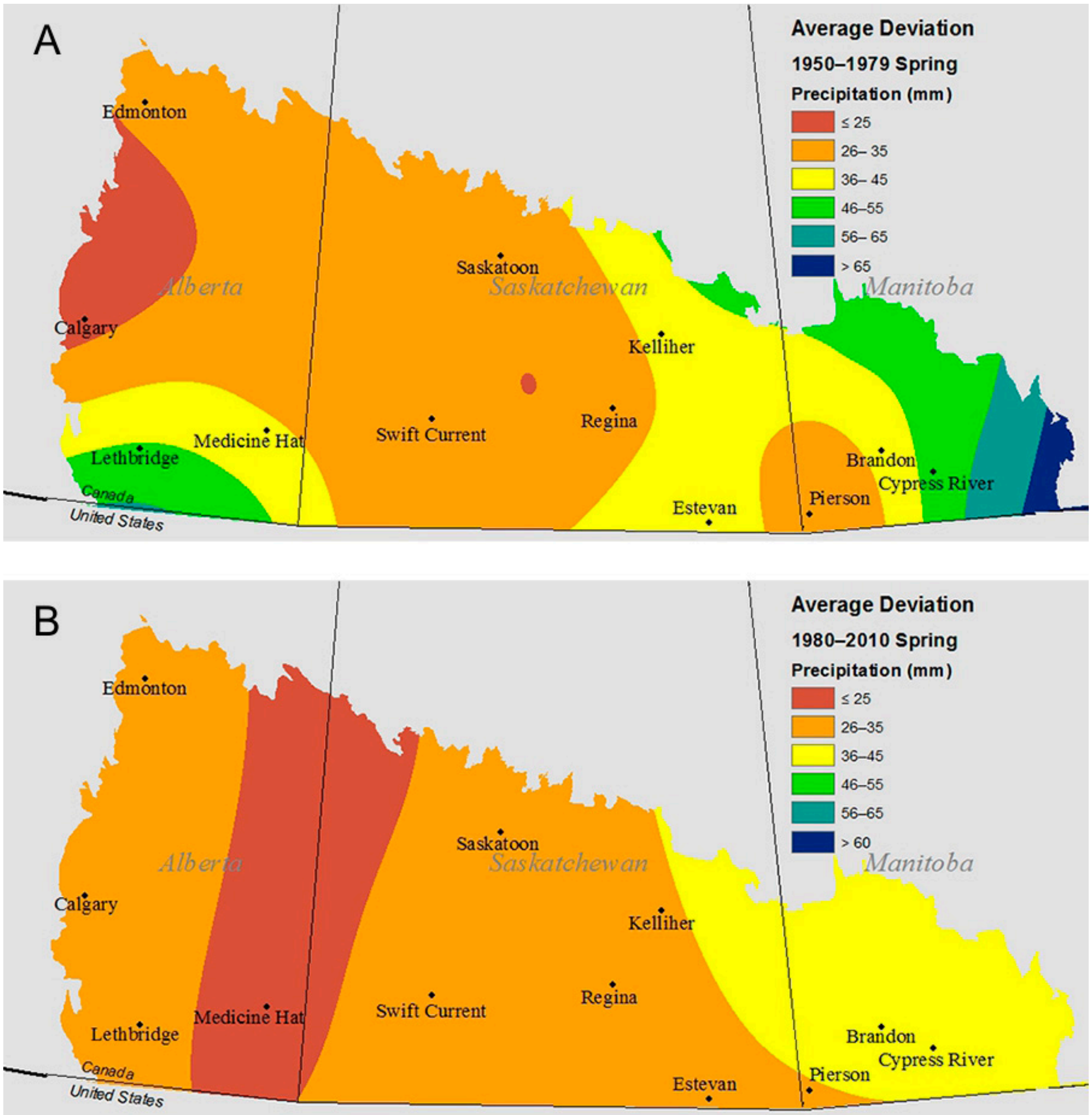



**Figure 10**
Average deviation from 30-year average spring precipitation for 1950–1979 and 1980–2009 for Palliser's Triangle
Cartography: Dustin Rousin

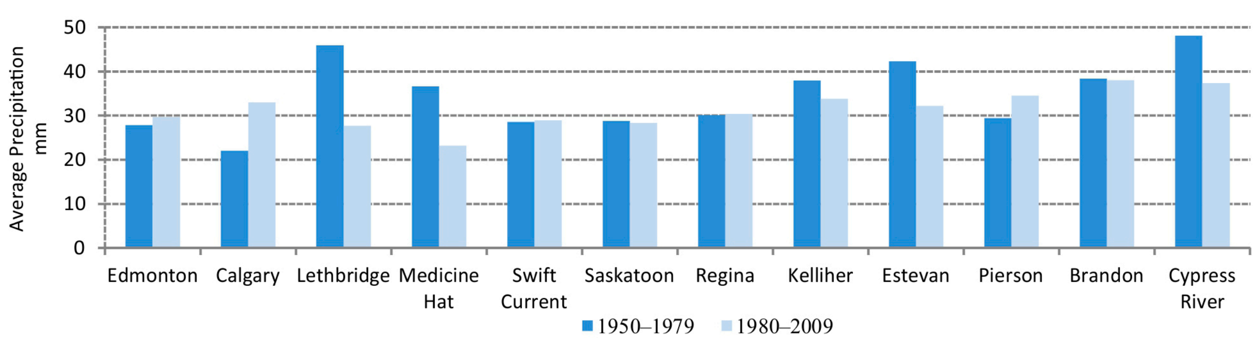



**Figure 11**
Average deviation of spring precipitation for the Palliser's Triangle, 1950 to 2009

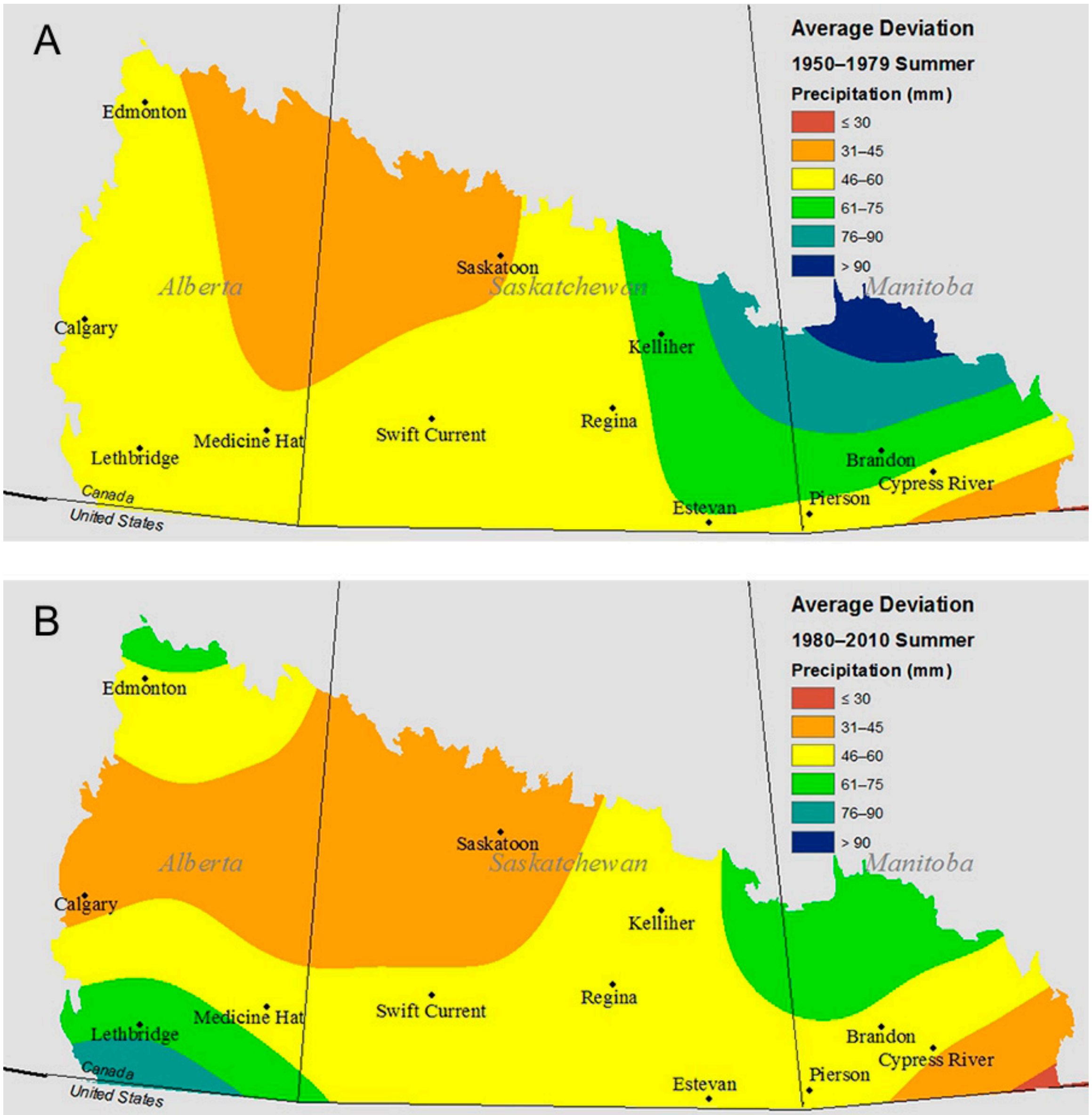



**Figure 12**
Average deviation from 30-year average summer precipitation for 1950 to 1979 and 1980 to 2009 for Palliser's Triangle
Cartography: Dustin Rousin

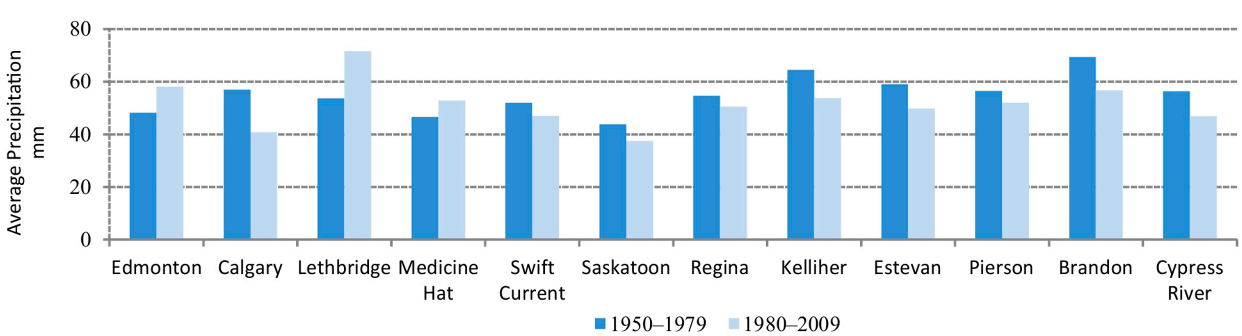



**Figure 13**
Average deviation of summer precipitation for Palliser's Triangle, 1950 to 2009

to be a relationship between precipitation at Lethbridge and El Niño, suggesting that it is wetter during this phase of the ENSO in spring and summer (Table 1). The area around Brandon had a significant result with the combined spring and summer values, suggesting that La Niña brings more precipitation to the region (Table 1). There were no significant results between the winter index value of the ENSO and the combined spring and summer precipitation totals (Table 2). These results conform with the majority of research conducted on the ENSO, where La Niña (El Niño) tends to bring with it wetter (drier) conditions across the Canadian prairies (Maybank et al. 1995; Bonsal et al. 1999; Shabbar and Skinner 2004; Coulibaly 2006: St. George et al. 2009; Vicente-Serrano et al. 2011; Dong and Dai 2015).

*PDO.* The PDO yielded a greater number of significant results than the other teleconnections (Table 1). The correlation between average annual precipitation and the average annual PDO index yielded significant results in all eastern stations bar Kelliher. The stations were in order of decreasing significance, Pierson, Brandon, Estevan, Regina, Saskatoon, and Cypress River (Table 1). The negative sign of the correlation coefficients suggests that the aforementioned stations received more precipitation during the negative or cool phase of the PDO. This relationship continues for the combined spring and summer values for Brandon and Estevan, where the coefficient is both significant and negative (Table 1). Kelliher had a coefficient that was positive and significant, suggesting that the region's precipitation is heavier during the positive phase of the PDO (Table 1). The correlation between the winter index value and combined spring and summer precipitation totals was both negative and significant for Estevan, Regina, Brandon, Swift Current, and Pierson, implying that the amount of precipitation received at these stations increases during the negative phase of the PDO (Table 2). This suggests that the winter values have a larger control on the precipitation received on the prairies than the spring and summer index values (Tables 1 and 2). The PDO appears to be the strongest variable in the interdecadal patterns of drought and precipitation variability, as presented by Shabbar and Skinner (2004), Dong and Dai (2015), and Vincent et al. (2015).

**Table 1**
Correlation between average annual and spring/summer teleconnection indices and average annual and spring/summer precipitation totals for stations within Palliser's Triangle, 1950 to 2009

| Weather Station | ENSO | | PDO | | PNA | |
|---|---|---|---|---|---|---|
| | Annual | Spring/ Summer | Annual | Spring/ Summer | Annual | Spring/ Summer |
| Edmonton | -0.07 | -0.09 | -0.03 | 0.07 | -0.07 | -0.05 |
| Calgary | -0.13 | -0.19 | -0.07 | 0.02 | **0.20*** | 0.15 |
| Lethbridge | -0.14 | **-0.21*** | -0.09 | 0.08 | 0.04 | -0.15 |
| Medicine Hat | -0.12 | -0.18 | -0.05 | 0.07 | 0.09 | -0.17 |
| Swift Current | 0.03 | -0.14 | -0.12 | 0.07 | 0.09 | -0.18 |
| Saskatoon | **0.21*** | 0.01 | **-0.23*** | 0.07 | -0.08 | -0.13 |
| Regina | 0.11 | -0.08 | **-0.26*** | -0.01 | 0.00 | **-0.22*** |
| Kelliher | 0.05 | -0.16 | -0.01 | **0.23*** | 0.15 | 0.07 |
| Estevan | **0.21*** | 0.12 | **-0.29*** | **-0.23*** | 0.03 | **-0.26*** |
| Pierson | **0.33*** | 0.05 | **-0.36*** | -0.10 | -0.10 | **-0.22*** |
| Brandon | **0.32*** | **0.23*** | **-0.32*** | **-0.24*** | 0.02 | 0.02 |
| Cypress River | 0.06 | -0.04 | **-0.23*** | -0.03 | -0.11 | -0.07 |

* Significant at 0.01

**Table 2**
Correlation between winter average teleconnection index (December to February) and combined spring and summer precipitation totals across Palliser's Triangle

| Weather Station | SOI | PDO | PNA |
|---|---|---|---|
| Edmonton | -0.04 | -0.03 | -0.03 |
| Calgary | -0.13 | -0.10 | 0.03 |
| Lethbridge | -0.16 | -0.07 | -0.14 |
| Medicine Hat | -0.13 | -0.12 | -0.12 |
| Swift Current | -0.04 | **-0.22*** | -0.09 |
| Saskatoon | -0.01 | -0.10 | -0.06 |
| Regina | -0.04 | **-0.26*** | -0.09 |
| Kelliher | -0.17 | 0.06 | 0.19 |
| Estevan | 0.04 | **-0.27*** | -0.06 |
| Pierson | -0.02 | **-0.22*** | -0.11 |
| Brandon | 0.00 | **-0.24*** | -0.05 |
| Cypress River | 0.07 | -0.19 | -0.19 |

* Significant at 0.01

*PNA.* Calgary recorded the only significant relationship between average annual precipitation and the average annual index of the PNA (Table 1). The positive sign of the correlation coefficient suggests that the positive phase of the PNA is an important control on the amount of precipitation received in the Calgary area. However, since the value is low and other surrounding areas were not significant, this result should be viewed with caution. The combined spring and summer values, however, yielded significant results for Estevan, Regina, and Pierson (Table 1). The negative value of the coefficient suggests that during the negative phase of the PNA the amount of precipitation received increases. There were no significant results between the winter index value of the PNA and the combined spring and summer precipitation totals (Table 2). These results corroborate other studies conducted for the region, which show that the PNA during the negative phase brings increased precipitation and fewer dry periods (Knox and Lawford 1990; Bonsal and Lawford 1999; Coulibaly 2006; Hryciw et al. 2013). Researchers have shown that the PNA is most influential during winter, but that there is also a relationship between the spring and summer values and the growing season precipitation in the more western stations.

## Conclusion

The climate of the Palliser's Triangle region of the Canadian prairies is dynamic exhibiting a large variability across the area. Precipitation varies both spatially and temporally and is affected by several teleconnections. It was shown that a core of dryness straddles the Alberta-Saskatchewan border from Lethbridge eastwards towards Swift Current as identified by other researchers. However, research reported here suggests that it now extends north to Saskatoon. Historically the dry region has expanded and contracted several times. The amount of precipitation varies from east to west with the east receiving up to three times as much precipitation over the year. The western region was shown to be less variable during both spring and summer than areas further east. Variation within the region was not only spatial, but also changed with time, with 1950 to 1979 showing less range but more variation between stations than the 1980 to 2009 period. The variation between 1980 and 2009 resulted from the fact the 1980s was a very dry decade while the 1990s was the wettest of the 20th century. The PDO was shown to have the most widespread influence on eastern stations during its negative phase. The eastern Saskatchewan and western Manitoba stations received more precipitation during the negative or cool phase of the PDO. The ENSO showed similar, but weaker results, in the same regions of eastern Saskatchewan and western Manitoba during La Niña (cold phase). The PNA only had significant results from the correlation between the combined spring and summer months. It has been proposed that the winter values of a teleconnection index could have a greater influence on spring and summer precipitation than the spring and summer values of the same index. This was the case with regards to the PDO, wherein most Saskatchewan and all Manitoba stations returned significant results, showing that the negative phase of the PDO in winter is related to a wetter growing season in the eastern Canadian prairies. Since drought is such a complicated phenomenon, and this research only focused on the meteorological aspect, further research is needed to examine the linkage between teleconnections, ground moisture conditions, and hydrologic runoff in these areas.

The preceding analysis has suggested that teleconnections affect the amount and pattern of precipitation across the Canadian prairies, and that recent decades have witnessed expansion of the drought prone area of Palliser's Triangle towards the east and northeast. This said, results of the analysis should be viewed with a degree of caution. While the observed changes in precipitation patterns between the two 30-year periods can be accepted as correct, in the sense that analysis for each period is based on the same number and distribution of weather stations, the limited number of those stations and their precise locations may impart spatial biases in the cartography that do not reflect the 'true' patterns of precipitation. The analysis reported here is based on just 12 weather stations. Their distribution leaves large areas of Palliser's Triangle and the wider prairie region without input into the maps showing precipitation patterns. To confirm existing findings and to minimize the risk of spatial biases in analysis, additional research is desirable based on a larger number of weather stations, which are evenly distributed across the prairies.

## Acknowledgements

The authors would like to thank the University of Winnipeg for financial support of this project. Thanks are also extended to Brian McGregor for his help with cartography and ArcGIS, and to Brad Russell for his assistance in recovering corrupted ArcGIS data. The authors are also grateful to Bernard Thraves, formerly of University of Regina, and the two anonymous reviewers for their insightful comments and suggestions.

## References

Bonsal, B. R., R. Aider, P. Gachon, and S. Lapp. 2013. An assessment of Canadian prairie drought: Past, present, and future. *Climate Dynamics* 41(2): 501–516.

Bonsal, B. R., C. Cuell, E. Wheaton, D. J. Sauchyn, and E. Barrow. 2017. An assessment of historical and projected future hydroclimatic variability and extremes over southern watersheds in the Canadian prairies. *International Journal of Climatology* 37(10): 3934–3948.

Bonsal, B. R., and E. E. Wheaton. 2005. Atmospheric circulation comparisons between the 2001 and 2002 and the 1961 and 1988 Canadian prairie droughts. *Atmosphere-Ocean* 43(2): 163–172.

Bonsal. B. R., and R. G. Lawford. 1999. Teleconnections between El Niño and La Niña events and summer extended dry spells on the Canadian prairies. *International Journal of Climatology* 19(13): 1445–1458.

Bonsal, B. R., and M. Regier. 2007. Historical comparison of the 2001/2002 drought in the Canadian prairies. *Climate Research* 33(3): 229–242.

Bonsal, B. R., A. Shabbar, and K. Higuchi. 2001. Impacts of low frequency variability modes on Canadian winter temperature. *International Journal of Climatology* 21(1): 95–108.

Bonsal, B. R., X. Zhang, and W. D. Hogg. 1999. Canadian prairie growing season precipitation variability and associated atmospheric circulation. *Climate Research* 11(3): 191–208.

Chipanshi A. C., K. M. Findlater, T. Hadwen, and E. G. O'Brien. 2006. Analysis of consecutive droughts on the Canadian prairies. *Climate Research* 30(3): 175–187.

Coulibaly, P. 2006. Spatial and temporal variabiltiy of Canadian seasonal precipitation (1900–2000). *Advances in Water Resources* 29(12): 1846–1865.

Dong, B., and A. Dai. 2015. The influence of the interdecadal Pacific Oscillation on temperature and precipitation over the globe. *Climate Dynamics* 45(9–10): 2667–2681.

Environment and Climate Change Canada. 2018. http://climate.weather.gc.ca/historical_data/search_historic_data_e.html.

Gan, T. Y. 2000. Reducing vulnerability of water resources of Canadian prairies to potential droughts and possible climatic warming. *Water Resources Management* 14(2): 111–135.

Hryciw, L. M., E. H. Atallah, S. M. Milrad, and J. R. Gyakum. 2013. A meteorological analysis of important contributors to the 1999–2005 Canadian prairie drought. *Monthly Weather Review* 141(10): 3593–3609.

JISAO. 2018. Joint Institute for the Study of the Atmosphere and

Oceans, University of Washington. https://jisao.uw.edu/research/atmosphere.

Knox, J. L., and R. G. Lawford. 1990. Relationship between Canadian prairie dry and wet months and circulation anomalies in the mid-troposphere. *Atmosphere-Ocean* 28(2): 189–215.

Kumar, A., and M. P. Hoerling. 1997. Interpretation and implications of the observed inter-El Niño variability. *Journal of Climate* 10(1): 83–91.

Mantua, N. J., and S. R. Hare. 2002. The Pacific Decadal Oscillation. *Journal of Oceanography* 58(1): 35–44.

Marchildon, G. P., S. Kulshreshtha, E. Wheaton, and D. Sauchyn. 2008. Drought and institutional adaptation in the Great Plains of Alberta and Saskatchewan, 1914–1939. *Natural Hazards* 45(3): 391–411.

Marchildon, G., J. Pittman, and D. Sauchyn. 2009. The Dry Belt and changing aridity in the Palliser Triangle. *Prairie Forum* 34(1): 31–44.

Masud, M. B., M. N. Khaliq, and H. S. Wheater. 2015. Analysis of meteorological droughts for the Saskatchewan River Basin using univariate and bivariate approaches. *Journal of Hydrology* 522: 452–466.

Maybank, J., B. Bonsia, K. Jones, R. Lawford, E. G. O'Brien, E. A. Ripley, and E. Wheaton. 1995. *Drought as a natural disaster. Atmosphere-Ocean* 33(2): 195–222.

Millet, B., W. C. Johnson, and G. Guntenspergen. 2009. Climate trends of the North American prairie pothole region 1906–2000. *Climate Change* 93(1–2): 243–267.

Newman, M., G. P. Compo, and M. A. Alexander. 2003. ENSO-forced variability of the Pacific Decadal Oscillation. *Journal of Climate* 16(23): 3853–3857.

NOAA (National Oceanic and Atmospheric Administration). 2018. http://www.cpc.noaa.gov.

Shabbar, A., and M. Khandekar. 1996. The impact of El Nino-Southern Oscillation on the temperature field over Canada: Research note. *Atmosphere–Ocean* 34(2): 401–416.

Shabbar A., B. Bonsal, and M. Khandekar. 1997. Canadian precipitation patterns associated with the Southern Oscillation. *Journal of Climate* 10(12): 3016–3027.

Shabbar, A., and W. Skinner. 2004. Summer drought patterns in Canada and the relationship to global sea surface temperatures. *Journal of Climate* 17(14): 2866–2880.

Shabbar, A., and B. Yu. 2012. Intraseasonal Canadian winter temperature responses to interannual and interdecadal Pacific SST modulations. Atmosphere–Ocean 50(1): 109–121.

Spry, I. M. 1959. Captain John Palliser and the exploration of western Canada. *Geographical Journal* 125(2): 149–184.

St. George. S, D. M. Meko, M. P. Girdarin, G. M. MacDonald, E. Nielsen, G. T. Pederson, D. J. Sauchyn, J. C. Tardif, and E. Watson. 2009. The tree-ring record of drought on the Canadian prairies. *Journal of Climate* 22(3): 689–710.

Vicente-Serrano, S. M., J. I. López-Moreno, L. Gimeno, R. Nieto, E. Morán-Tejeda, J. Lorenzo-Lacruz, S. Beguería, and C. Azorin-Molina. 2011. A multiscalar global evaluation of the impact of ENSO on droughts. *Journal of Geophysical Research-Atmospheres* 116(D20): 1–23.

Villmow, J. R. 1956. The nature and origin of the Canadian Dry Belt. *Annals of the Association of American Geographers* 46(2): 211–232.

Vincent, L. A., X. Zhang, R. D. Brown, Y. Feng, E. Mekis, E. J. Milewska, H. Wan, and X. L. Wang. 2015. Observed trends in Canada's climate and influence of low frequency variability modes. *Journal of Climate* 28(11): 4545–4560.

Prairie Perspectives: Geographical Essays
Prairie Division
Canadian Association of Geographers
Association Canadienne des Géographes

# Local communities and researchers working together for water security: A multi-actor dialogue in Saskatchewan, Canada

Kenji Kitamura
Research Institute for Humanity and Nature, Kyoto, Japan

Susan Carr
Prince Albert Model Forest

John Kindrachuk
Redberry Lake Biosphere Reserve

Mark Johnston
Saskatchewan Research Council

Maureen G. Reed
School of Environment and Sustainability, University of Saskatchewan

**Key Messages**

- Multiple knowledge systems, from local to global, can be integrated through collaborative planning and dialogue among diverse actors.
- Including local/Indigenous customs is important for meaningful collaboration.
- Face-to-face dialogue is essential; it both broadens and deepens collaboration among diverse actors.

*This article reports and reflects on the implementation of a workshop we jointly organized in Prince Albert, Saskatchewan in May 2016, with a theme of community-researcher collaboration in water security. Through the planning, implementation and reflection processes, several lessons were learned including the following three points. First, integration of knowledge at various scales was observed from the planning stage, where local actors provided knowledge on the severe issues at the local scale, while actors visiting from outside proposed a general framework for discussion. Both were important types of knowledge. Second, local customs adopted in the workshop played an important role in facilitating dialogue. They included respect to the Indigenous leaders and their perspectives, and the use of local foods catered for the lunch that were local products with connections to the workshop theme of water security. Third, a strong interest in the theme of the workshop helped to strengthen connections among participants. While there had been collaborations between some of the participating actors prior to the workshop, most of these had been indirect and/or bilateral. The workshop created one arena where a broader set of actors met in one room to have deep discussions to foster relationships for future work together.*

Keywords: collaborative planning, water security, integrated knowledge systems, participatory discussion



Correspondence to: Maureen G. Reed, School of Environment and Sustainability, University of Saskatchewan, 117 Science Place, Saskatoon, SK S7N 5C8 Email: m.reed@usask.ca

## Introduction

Thirty people participated in a one-day workshop, titled *Water Security Workshop: Interactions between Communities and Scientists*, on May 3, 2016 at the Saskatchewan Forest Centre in Prince Albert, Saskatchewan, Canada. The purpose of this workshop was to bring together people of different standpoints, allowing them to share their own experiences of society-science interaction with respect to water security, and to consider how actors in local communities and researchers could work together to address water security. The workshop had a good balance of participant composition in terms of age, gender, and occupation. Both academic researchers and practitioners participated.

The workshop was hosted jointly by Prince Albert Model Forest (PAMF; http://www.pamodelforest.sk.ca/), Redberry Lake Biosphere Reserve (RLBR; http://redberrylake.ca/), the North Saskatchewan River Basin Council (NSRBC; http://www.nsrbc.ca/), the University of Saskatchewan's School of Environment and Sustainability (SENS; http://www.usask.ca/sens/), and the Integrated Local Environmental Knowledge (ILEK) Project (http://en.ilekcrp.org/) of the Research Institute for Humanity and Nature located in Kyoto, Japan. The authors of this review represent these host organizations.

The ILEK Project worked together with PAMF, RLBR, and SENS in Canada, and with many other collaborators around the world, investigating the mechanisms of adaptive governance in complex social-ecological systems. The project aimed to produce a body of knowledge about governance for sustainability that is practical and innovative. It presumed the importance of "knowledge translators," who bridge gaps between multiple actors such as local residents, government officials, and researchers (Sato et al. 2018). In the processes of co-production and use of ILEK, new interpretations and meanings are added so that the knowledge is adapted, or translated, to the local contexts and becomes sharable by diverse actors. The project attempted to document and visualize the processes in which translated and shared knowledge promotes collaborative action against local issues (Kitamura et al. 2018). As part of its action-based research design, the ILEK Project organized similar workshops in Kyoto (Japan), Sarasota (USA), and Suva (Fiji), where local participants engaged in dialogue on society-science interactions in specific contexts, such as coastal restoration and resource management.

For the workshop in Saskatchewan, the local hosts proposed that water security and source water protection be the topic of discussion, because it is an on-going concern in the province. Many factors affect water security and source water protection, including increasingly variable precipitation patterns that can yield extreme impacts such as drought in one year and flood in the next. These are complex issues that require collaboration between diverse research and resource management organizations, including governments.

## The workshop program and highlights

The workshop started its morning segment with opening prayer and remarks by one of the Indigenous participants. This was followed by a round of quick self-introduction by everyone present. A keynote presentation by a water modelling scientist Zilefac Elvis Asong set the context for the workshop. Then, the participants moved to smaller rooms for their first round of breakout discussions, sharing past experiences of community-researcher interactions. After this session, lunch was provided by the hosts, featuring northern pike and wild rice. Both are produced in the watershed, making the participants not only enjoy the local delicacy but also think of the importance of clean water and sustainable social-ecological systems. After the lunch, the breakout discussions in the smaller groups continued, entering the second round to talk about how local communities and researchers can work together to address water security. Later in the afternoon, everyone gathered again in the larger room for the final plenary session to share the summaries of the four groups. The workshop concluded with closing remarks, and the participants filled in a questionnaire before leaving the venue. This was the program of the day.

In his keynote presentation, Asong first pointed out that water security is a global concern. The UNESCO's International Hydrological Programme defines water security as "the capacity of a population to safeguard access to adequate quantities of water of acceptable quality for sustaining human and ecosystem health on a watershed basis, and to ensure efficient protection of life and property against water related hazards—floods, landslides, land subsidence, and droughts" (UNESCO-IHP 2012, 1). An important message is that both quantity and quality of water matter to ensure that the needs of human consumption and well-being are fulfilled.

Asong then showed a list of water security issues in the Saskatchewan River Basin. It is reported that the health risk from drinking water contamination is being faced by 90% of the Indigenous people in the province. An example is tap water contamination with parasitic *Cryptosporidium* in North Battleford in central Saskatchewan in 2001, which reportedly caused health problems for up to 7000 people, including approximately 700 people who were eventually compensated by the provincial and municipal governments. Water security issues in the province also include floods and droughts (Figure 1), with the former occurring several times in the past destroying many properties, and the latter causing billions of dollars of damage to agriculture. The Canadian prairies have always been subject to extreme events related to water, but the threats have become greater due to socio-economic factors such as population growth and economic development, coupled with environmental factors such as warmer climate resulting in variable water supply from glaciers in the Rocky Mountains (Gober and Wheater 2014). The keynote talk concluded by pointing out the importance of communication between scientists and local communities, to which this workshop could contribute.

Breakout discussions in four groups of six to seven people were facilitated by graduate students of SENS who had received


**Figure 1**
Many roads in Saskatchewan, like this one in Hafford, were flooded in 2014
Photography: Kenji Kitamura, August 28, 2014

training in facilitation. All the groups had active discussions with diverse views expressed. For example, the issue of water allocation was raised in one group, emphasizing the complexity of water allocation mechanisms. In addition to the trade-offs between quantity available for farms, livestock or humans, the quality for one user group is affected by another. Cow droppings on the snow, for example, easily run into the river, causing water pollution which is hazardous for human consumption. With respect to the floods in recent years due to heavy rains, the elder of an Indigenous community represented many people in the entire watershed sharing the same sentiment by saying: “We took water for granted for quite some time until we had these different emergencies.”

There were also comments on community-science interactions. For example, it was pointed out that scientists should communicate better and more creatively to make the meaning of their research understandable; they should also target broader groups of people in the community. Another problem raised was insufficient cooperation between different agencies of the government. One participant also mentioned the different attitudes among municipal administrators towards environmental hazards that resulted in different levels of readiness and thus different levels of damage when a flood occurred. There were data available to describe the hazard but these had not informed policy. Another comment was that a facilitator is needed to promote interaction among different groups, one who can communicate in a language understandable and relatable to all groups. Scientists in this sense should have a responsibility of knowing the people and their needs, according to another group of breakout discussions. For reciprocal learning, skills such as trust building and listening were considered to be important. Because problems are complex in reality, no single scientific approach would solve them; practical and combined methods were considered necessary for problem solving.

“Community champions” and “community ambassadors” were the words that several people mentioned during the workshop. They can be dedicated leaders who connect scientists with community, and who understand the social issues that are often more severe than the environmental issues. Such leaders would also connect the communities with industries and government. All of these comments are just a few examples of the rich discussions during the workshop.

There was one elder from an Indigenous community, who acts usually as a listener rather than a speaker in official meetings. He started to draw a map on a white board during the breakout discussions, to describe the water issue in the area (Figure 2). It was about water regulation with a dam, a source of conflict between different groups of residents such as cabin owners and animal trappers. The facilitator of his group and the workshop organizers tried to have a computer connected to the Internet so that a digital map could be accessed online and used to assist the description. Unfortunately, the connection was not successful. However, his hand-drawn map worked as an effective tool, which showed his perspective on the area and its water issue. What was drawn (and what was not) indicated meanings in themselves, so the lack of Internet connection was a fortunate thing in a sense. The group facilitator noticed the value of this map, so the participant was invited to share the map and his explanation with the larger group. This was one moment that demonstrated the benefit of actually getting together to share diverse viewpoints.

## Quotes from the questionnaire

We asked all the participants to provide comments through the questionnaire, which we considered to be another round of learning mutual insights. Here are some examples. One participant listed key points for community-researcher collaboration: “Demonstrating success stories from other communities; good facilitators who can bridge gaps between people and bring them together; make sure to incorporate local knowledge and aspirations in selecting options with local participants.” Another pointed out: “Scientist must get to know the issue but also the community. Be upfront with what will be involved and what the community can expect with the research that will be done.”

There were suggestions about the processes and mechanisms of collaboration. One participant emphasized the importance of trust building by listing key points as: “Communication strategies; ‘connections,’ such as champions and enabling policies and approaches that bring people together; time to build relations; respectful communication.” With respect to the issue of how to sustain activities, particularly after a certain collaborative project comes to an end, one opinion was expressed from an Indigenous community’s perspective: “Local leader or community champion is critical for work to continue during and after field visits and after project completion.” The key point raised by one participant read: “Mechanisms in understandable language that

**Figure 2**
An Indigenous elder shared his view of the water security issue with his group members by hand-drawing a map
Photography: Kenji Kitamura, May 3, 2016

the community has helped develop and can take ownership of. Without ownership, you cannot expect uptake."

A comment was made about the local community's efforts that "if the issue is important to the community, one should hope the community would ensure that their message is effectively communicated," rather than just passively dependent on government support.

The types of scientists who would be helpful to local communities were defined by a local community member as "Scientists who familiarize themselves with community concerns and issues before proposing research or solutions. Scientists who advocate a collaborative approach to research with other scientists and members of the community." One participant mentioned the need to acknowledge diverse knowledge of diverse people: "Understand that everyone is expert in their own right."

There was a comment on the benefits of the workshop: "I think the various discussions and perspectives were very stimulating and engaging. Workshops like this do add a lot to our knowledge base." One undergraduate student commented from a perspective of a younger generation that "having knowledge from research 'elders,' members of the community, and liaisons from the community made this workshop incredibly valuable for future work and research."

## Reflections

A one-day workshop does not solve the problem of water security. Nor does it secure long-term collaboration. However, it is reasonable to conclude that one of our main purposes of connecting people from diverse standpoints was realized. This owes largely to existing networks of the local hosts. Prince Albert Model Forest has a board of directors represented by diverse groups in the area, which served as the basis of the invitees list. Redberry Lake Biosphere Reserve and the North Saskatchewan River Basin Council also work with important actors in the watershed, adding more names to the list.

The workshop discussed the local context of water issues in relation to a universal theme of community-researcher collaboration. It was both local and international, with the keynote speaker originally from Cameroon, and the first author of this paper a visiting researcher from Japan. The facilitators in breakout discussions were all international graduate students originally from Colombia, Ecuador, and Ghana. This diversity contributed to a broadening of perspectives.

There were valuable tips provided in the planning stage of the workshop by a researcher, who was absent from the workshop but had been working closely with many local communities, including Indigenous groups, to address water security issues. His tips for effective collaboration included: a need for local stories and traditional knowledge for water to be incorporated into planning; inclusion of both elders and youth in the planning process; adhering to local protocols in plan making such as opening prayers and meals; identification of a plan champion in the community to lead and coordinate the committee; early clarification of the plan's legitimacy; and sharing of the draft plan in a number of venues such as health centres, schools, and councils. Many of these points were actually mentioned by the workshop participants, and also adopted in the planning of the workshop itself. Because future action depends on younger generations, youth participation in the dialogue and knowledge translation is important (Garinger et al. 2016).

One conclusion we might all agree on is the important role played by a representative, or a champion, in each of the various groups involved in the specific local issues. This does not mean there is a single model for such a person. Each person can be a champion based on her/his unique talent (Reed et al. 2015). Where a process of collaboration by people with different talents receives skilful facilitation, knowledge from diverse sources can be translated, combined, and used to prompt action against the issues.

## Acknowledgements

The authors thank everyone who participated in the workshop, including the student facilitators: John Boakye-Danquah, Hardi Shahadu, Maria Mora Garces, Razak Abu, and Sandra Betancur. We also appreciate those who supported the workshop planning in various ways including Peter Kingsmill, Bob Patrick, Lalita Bharadwaj, and Graham Strickert. This research was conducted as part of the ILEK Project at Research Institute for Humanity and Nature (Project No. 14200085), with support by JSPS (KAKENHI Grant Number 15K00673), and Noto Satoyama Satoumi Research Program.

## References

Garinger, C. A., K. A. Reynolds, J. R. Walker, E. Firsten-Kaufman, A. S. Raimundo, P. C. Fogarty, M. W. Leonhart, and Mobilizing Minds Research Group. 2016. Mobilizing minds: Integrated knowledge translation and youth engagement in the development of mental health information resources. *Gateways: International Journal of Community Research and Engagement* 9(1): 172–185. doi: http://dx.doi.org/10.5130/ijcre.v9i1.4415.

Gober, P., and H. S. Wheater. 2014. Socio-hydrology and the science-policy interface: A case study of the Saskatchewan River Basin. *Hydrology and Earth System Sciences* 18(4): 1413–1422. doi: http://10.5194/hess-18-1413-2014.

Kitamura, K., C. Nakagawa, and T. Sato. 2018. Formation of a community of practice in the watershed scale, with integrated local environmental knowledge. *Sustainability* 10(2): 404. doi: https://doi.org/10.3390/su10020404.

Reed, M. G., H. Godmaire, M-A. Guertin, D. Potvin, and P. Abernethy. 2015. Engaged scholarship: Reflections from a multi-talented, national partnership seeking to strengthen capacity for sustainability. *Engaged Scholar Journal* 1(1): 167–183. doi: http://dx.doi.org/10.15402/esj.v1i1.28.

Sato, T., I. Chabay, and J. Helgeson. 2018. Introduction: Framing studies of knowledge co-production to tackle social-ecological challenges. In *Transformations of social-ecological systems: Studies in co-creating integrated knowledge toward sustainable futures*, ed. T. Sato, I. Chabay, and J. Helgeson. Singapore: Springer (forthcoming).

UNESCO-IHP. 2012. (Draft) Strategic plan of the eighth phase of IHP (IHP-VIII, 2014–2021). Paris, France: United Nations Educational, Scientific and Cultural Organization–International Hydrological Programme.

Prairie Perspectives:
Geographical Essays

Prairie Division
Canadian Association of Geographers
Association Canadienne des Géographes

# Self and society: Using the cell phone images of northern Vietnamese university students to identify and share their environmental and cultural place-ness with their American peers

Hồng Thị Hà
Thái Nguyên University of Agriculture and Forestry

Aaron Kingsbury
Maine Maritime Academy

**Key Messages**

- University students in northern Vietnam took photographs of their cultural place-ness that thematically focused on their love of sports, family, friends, video games, and pets.
- The photographs were framed and exhibited at a gallery on the campus of a rural university on the upper Great Plains of the United States to challenge lingering and/or inaccurate beliefs of contemporary Vietnam held by many Americans.
- Despite geographic distance, this project showed that university students share more universal loves, concerns, and aspirations.

*This article summarizes a multi-phase project which employed the tools of social media to encourage university students to identify, expand, and then cross-culturally share their environmental and cultural place-ness. Students at a university in northern Vietnam captured over 1000 images with GPS-enabled cell phones that best exemplified the social worlds they valued highest. Students then incorporated their images into self-styled ESRI StoryMaps to cartographically share the images and the myriad of stories they hold with their fellow classmates. Finally, a subset of images were selected by students for an exhibition at a university gallery on the Upper Great Plains of the United States to help challenge lingering, often incorrect, and occasionally racist stigmas/stereotypes from the 1960s and 1970s about Vietnamese people still held by many Americans. The reactions of small town American university students, staff, and community to the photographs of their peers is discussed. Overall, this project drew from the natural sciences, social sciences, geospatial technologies, and humanities to show that despite considerable geographic distance, university students share more proximate and universal loves, concerns, and aspirations.*

Keywords: social worlds, cell phone imagery, student life, Vietnam, Upper Great Plains



Correspondence to: Aaron Kingsbury, Maine Maritime Academy, 1 Pleasant Street, Castine, ME, USA, 04420
Email: aaron.kingsbury@mma.edu

## Introduction

Thái Nguyên University of Agriculture and Forestry (TUAF) is located in Thái Nguyên City about 80 km from Hanoi in the north of Vietnam (Figure 1). With over 12,000 students, TUAF provides a unique opportunity for undergraduates to complete a Bachelor of Science in Environmental Management in English through its Advanced Education Program. In the summer of 2017, teaching assistant (Hồng Thị Hà) and visiting scholar Dr. Aaron Kingsbury worked together to teach an intensive course entitled *The Earth: Linking Human and Physical Environments* as part of this program. Fifty two undergraduate students took part. This article describes a project that helped students identify and then share their social worlds with their American peers to help bridge longstanding divides between the people of these two countries.


**Figure 1**
Location of TUAF, Thái Nguyên City, Vietnam
Cartography: Muto-Kingsbury Emiko, redrawn by Weldon HIebert, made with Natural Earth

## Methods

Phase 1: Identifying the social worlds of university students in northern Vietnam

Geographers centre intellectual inquiry on the concepts of space and place. Indeed, locations reflect patterns of culture that include temporal elements characteristic of historical change. This project adds additional dimensions to these conceptualizations by teasing out the negotiated aesthetics and cultural constructions of landscapes with the aid of geospatial technologies.

Initially the project centred on providing students a solid foundation in the history of landscape studies. Drawing heavily from Sauer (1925), students first explored notions of a cultural landscape, or one that combines cultural and physical features. Landscapes were additionally shown to be not only a set of environmental characteristics, but also, in example, imagined, consumed, contested, constructed, fabricated, sanctified, or possibly even in existence as nothing more than notions only perceived through engaged attunement (For a review of the vast theoretical literature on the study of landscapes, see Wylie 2007). The semantics of concepts such as 'natural' and 'nature' were also debated both in terms of their actual existence as well as universal and culturally driven semantic constructions. Indeed, rather than perceiving the environment and culture as separate phenomena, they can be intrinsically linked in our conceptualization, definition, and interpretation of space and place. Students were encouraged to connect their views on their own position as university students in northern Vietnam with their physical environment to build conceptual notions of their own social worlds.

As camera-enabled cell phone usage is fairly universal among university students in Vietnam, each student was then required to take and submit a total of at least 20 geo-referenced photographs. The assignment required that these images best illustrate their personal understanding of their own social worlds. Students were asked not to modify the images they took, with the exception of four images where students were permitted to add designs to or use photo editors as they saw creatively fit. Selfies were encouraged. A total of over 1000 photographs were collected and uploaded to the course account on Flickr for storage and retrieval.

Geographers also employ a complex array of tools and technologies with which to document, explore, and interpret Earth and its myriad of landscapes. Having students gain experience with these tools means they will be better prepared to use them in their own professions. Indeed, the primary motivation for capturing images with cell phones links directly to storytelling. Students used the images to contextually analyze their own social worlds and tell the stories they see or do not see before them. Students incorporated their written texts with images and video to create ESRI ArcGIS StoryMaps (i.e., a format that combines cartography, narrative texts, and multimedia content). A selection of these was presented in class, on campus in Vietnam, and a link to an example is included at the end of this article. The use of stories and photographic images as tools to explore lived experiences and how various cultural narratives shape those experiences is common in a number of the social sciences (e.g.,


**Figure 2**
Location of Mayville State University, Mayville, North Dakota
Cartography: Muto-Kingsbury Emiko, redrawn by Wedon Hiebert, made with Natural Earth

Diversi 1998; Prosser 1998; Cahyanto 2009). This article approaches notions of reflexive photography from the perspective of international cross-cultural exchange, and seeks to expand cultural competence by allowing for reflection on images of social worlds selected specifically for sharing by the 'other.'

### Phase 2: To rural America: Sharing the cultural landscapes of northern Vietnam

The second phase of this project was to use the social worlds identified and photographed by TUAF students to share with a rural community in the United States. Dr. Kingsbury was an assistant professor of geography at Mayville State University, located in small town North Dakota in the Upper Great Plains (Figure 2). The city of Mayville has less than 2000 residents and only one traffic light. It is located in a county which is expansive 2235 km² in area, but has a population of only around 8000 residents. It provided an optimal setting to carry out the next phases of this project.

In this part of the United States, the study of contemporary Vietnam is rare. As a result, many Americans' perception of and possibly even engagement with the country concluded with the end of the Vietnam conflict in the 1970s. This lack of a basic understanding of contemporary Vietnamese culture and society is apparent and occasionally mixes with apathy (Silverman 2016; Taylor 2016). This has been exasperated by continued themes in the American mainstream popular cinema with storylines occurring in war-era Vietnam, starring American protagonists, yet void of likeable or even realistic Vietnamese characters (Silverman 2015). This has furthered the progression of negative stereotypes and left many rural Americans with apathetic (or worse), inaccurate, and hopelessly antiquated views of a country undergoing considerable economic development and social change (Taylor 2016). While former US President Obama's visit to Vietnam in 2016 did help to begin to change stereotypes, these enduring images, accurate and otherwise, linger in the American imagination (Gillespie 2000; Taylor 2016). As direct evidence of this, when Dr. Kingsbury explained to his students that he was going to work in northern Vietnam over the summer, students immediately inquired about the movie character Rambo and the possibility of being taken hostage. This is also particularly troublesome considering most Vietnamese were not even born until well after the conclusion of the war.

In the digital age, cell phone images are quickly taken, shared, and consumed. University students are familiar with these forms of social discourse and interact seamlessly between apps, software, and other tools of communication. Such familiarity with technology has become *de rigueur* for the youth of today. Indeed, as one student said, "If I did not post it (i.e., to social media), it did not happen." Within this milieu, this project sought to understand how students define themselves through

**Figure 3**
Basketball
Photography: TUAF students


**Figure 5**
Dinner out of class
Photography: TUAF students


**Figure 4**
Me and my friend
Photography: TUAF students

**Figure 6**
My passion
Photography: TUAF students

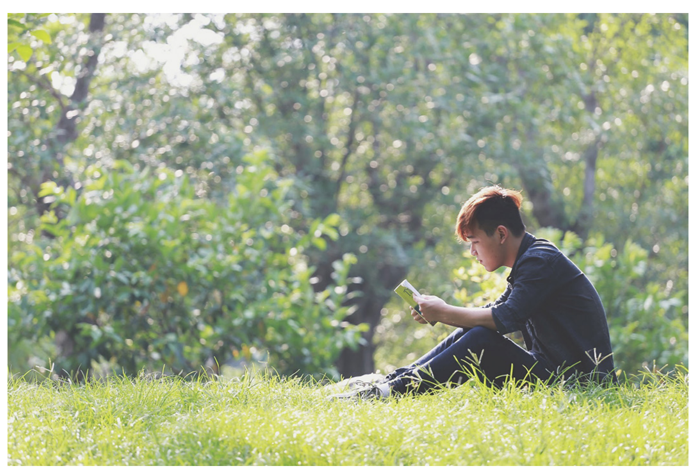


**Figure 7**
Studying
Photography: TUAF students

**Figure 8**
My poor dog
Photography: TUAF students

**Figure 9**
Friendship is forever
Photography: TUAF students

their chosen images, what they understand to mean by their sense of place in time and space, and most importantly what images would they choose to more statically express their lives and dreams as college students in contemporary Vietnam. The answers to these questions are found in the photographs of students, a selection of which are included as Figures 3 to 9.

As was expected, submissions varied in quality and content. Common themes that emerged centred on the use of technology (including a love of video games), the ritual importance of collective meals and group sporting activities, an interest in travel, a strong bond with pets, and the significance of spending time with family and friends. TUAF students then further selected a subset of 55 images they felt best represented their social worlds as university students in northern Vietnam for exhibition in a gallery in the United States. Vietnamese students also captioned their images.

Phase 3: The reactions of small town American university students to the Vietnamese images

Images were framed and exhibited in multiple high traffic locations around the Mayville State Campus. While one main room served as the gallery headquarters, American students were provided with maps to the various numbered images on campus. This meant that images were also visible to those not seeking a specific gallery related experience. The diffused nature of the exhibition is illustrated in Figure 10. In the gallery headquarters an explanation of the project, a map of Vietnam, and a set of questionnaires were located. The survey questionnaire asked the American students about their favourite image, what they found most surprising, and thoughts on Vietnamese culture before and after viewing the gallery. The exhibition was advertised on campus radio and monitors, in e-mail blasts, in a column in the local newspaper, and on the websites of both the university and the North Dakota Humanities Council.

A public event was also held on campus for students, faculty, staff, and the community. Nine students from the Advanced Education Program at TUAF were available via streaming internet to ask and answer questions (Figure 11). This event drew people from Mayville and nearby communities in North Dakota who averaged over 60 years of age. Typical comments from the audience following the event expressed surprise about how similar

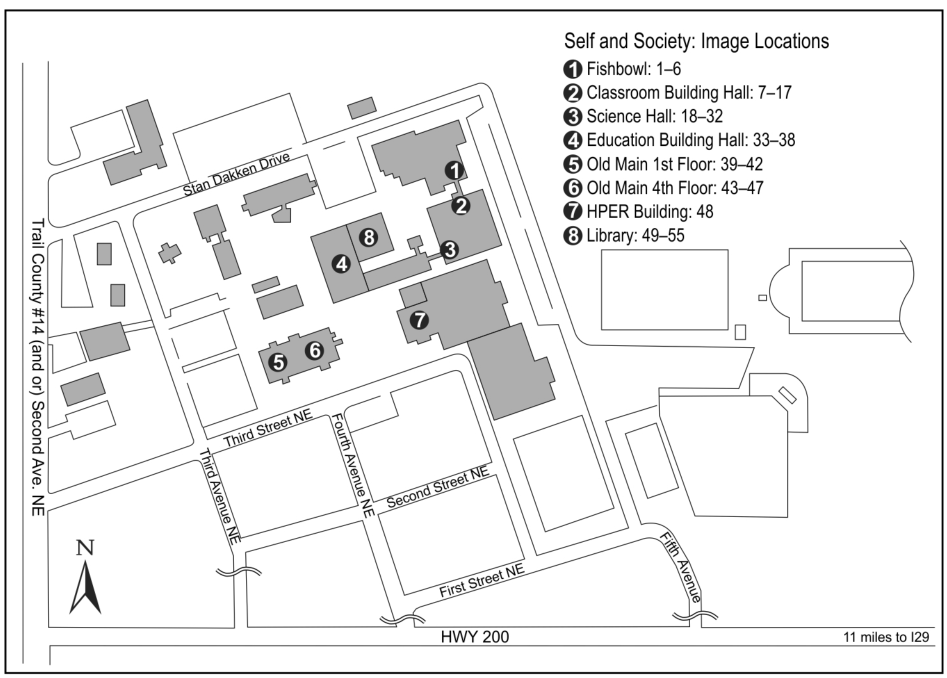



**Figure 10**
Image locations at Mayville State University Campus
Cartography: Muto-Kingsbury Emiko, redrawn by Weldon Hiebert

**Figure 11**
TUAF students answering questions from audience in Mayville, North Dakota
Photography: Beth Swenson

both student cultures were. As one respondent over 70 years of age noted "They are like Americans!" While the American-centric nature of the answer is slightly off-putting on the surface, the comment does speak to a newer depth of understanding of contemporary Vietnam. The realization that the social worlds of university students globally is often more similar than different meets one of the goals of this project.

Overall, 65 members of the student body, community, faculty, and staff completed the gallery survey. This was an incredible number when considering the size of the local community and campus. Interestingly, mirroring the opinions of those in attendance at the public program, over 95% of all surveys completed mentioned similarities between student culture in the USA and Vietnam. Most also expressed some element of surprise at this. American students in particular shared opinions of "Everything seemed so similar," "A lot of things look surprisingly similar to what we do in the USA," "I do the same things!" and "They are exactly like us!" Other American students were impressed with how modern and wealthy Vietnam looked in contrast to what they had imagined. The most popular images related to pets, with American students selecting images of cats and dogs as their favourites as they claimed to relate to them directly or appreciated how much the Vietnamese students also loved their pets. One American student expressed a thought shared in the comments of many others, which we feel also matches our goal for this project: "It is awesome to see how much I actually relate to them (i.e., the Vietnamese students) and the activities they do."

## Reflective critique

The ultimate goal of this project was to begin to challenge the perceptions of northern Vietnamese people held by members of a very conservative and rural American community. Overall, we feel this goal has been achieved. With that said, we offer the following critiques of our methods and the process. First, the authors recognize that the content and nature of our project meant that those Americans who participated in the public program and/or completed the questionnaires were more likely to be college educated (or be in the process of becoming college educated). It can also be said that attendance at our events signified an interest in learning about Vietnam or at least more willingness to engage with something new. It must be assumed that some members of the community dismissed this project simply on the basis of subject matter. With that said, we hope our efforts have at least brought Vietnam back into conversation and debate.

Next, the authors were careful to respect the opinions of locally-based American veterans of the Vietnam War. We even considered hosting a public program including both Vietnamese students and American veterans. However, after discussion with local members of that community, it was decided against collective participation. As one American veteran mentioned, "These images are from northern Vietnam, but they could be anywhere. It is amazing, but this is not about the war." The authors are happy that a number of veterans did participate in the public program and viewed the campus exhibition. Comments were overwhelmingly positive.

Without adding too many layers of complexity, the authors also note that there are some limitations on acceptable political and religious expression in contemporary Vietnam. While we wish to make no assumptions or comments on if or how this affected the selection of images by Vietnamese students, we do recognize this as a potential critique. We also established ground rules for the public event, forbidding questions on contemporary politics for either country.

The authors also recognize that regardless of nationality or culture, university students tend to live a somewhat similar existence globally. Without many of the pressures faced by those outside the university environment, students' lives become more centred on surviving on low budgets, attending classes, passing examinations, and negotiating their development as young adults. Vietnam and its people share a diversity of cultures far beyond university student life, and we recognize that images selected from this diversity may uncover an array of different social worlds.

With that noted, we feel the similarities between American and Vietnamese student cultures was the most pronounced and meaningful message of the series of events. These shared social worlds were also something that surprised both American students and members of our community. In turn, this helped to humanize the people of contemporary northern Vietnam in rural America.

## Conclusions

This article shared the experiences of a visiting scholar and teaching assistant in using the tools of social media to identify and share the diverse social worlds of university students at Thái Nguyên University of Agriculture and Forestry. This was a simple and inexpensive idea, but one that proved to ultimately have a meaningful impact for rural American students and a community in the Upper Great Plains. As a series of assignments, northern Vietnamese students photographed things important to them in their daily lives. These students then selected a subset of images for framing and exhibiting at the university campus of Mayville State University in Mayville, North Dakota. Images selected expressed values and interests easily relatable to Americans in the rural Upper Midwest, which surprised most. This article posits that while languages and beliefs may differ across cultures, some universals remain. Overall then, this project distilled some of these universals, and in doing so began the process of re-humanizing Vietnamese living in the north of their country by sharing an immensely personal glimpse of its next generation of social, economic, cultural, environmental, and political leaders. The project is now being reversed to explore what view contemporary society in northern Vietnam holds of young Americans. The cell phone images of rural American students are currently on exhibit in northern Vietnam throughout the summer of 2018. We hope to report on this new phase of the project in the 2019 issue of Prairie Perspectives.

## Acknowledgements

The authors would like to thank participating students from classes K45, K46, and K47 at the Advanced Education Program at TUAF and those students at Mayville State University for their contributions and enthusiasm. The gallery and public program on Mayville State Campus was funded by a grant from the North Dakota Humanities Council and the Mayville State University Office of Diversity and Inclusion. The authors would also like to thank Dr. Dina Zavala-Petherbridge for her logistical support and Dr. Erin Lord Kunz at the Mayville State University Writing Center for proofreading this paper. Finally, an earlier version of this paper was presented at the Prairie Division of the Canadian Association of Geographers Meeting in Morris, Manitoba, Canada. The authors would like to thank those in attendance for their comments and suggestions.

## ESRI ArcGIS StoryMap

An example of an ESRI ArcGIS StoryMap created by a TUAF student, in this case Luyến Nguyễn Kim, can be found at the following link:
https://mayvillestate.maps.arcgis.com/apps/MapTour/index.html?appid=3f4f7fe9fe834ef5895a8de46fc8d870.

## References

Cahyanto, I. 2009. Reflections from utilizing reflexive photography to develop rural tourism in Indonesia. *Tourism Analysis* 12(6): 721–736.

Diversi, M. 1998. Glimpses of street life: Representing lived experience through short stories. *Qualitative Inquiry* 4(2): 131–147.

Gillespie, M. 2000. American look back on the Vietnam War. *Gallup News*. November 17. http://news.gallup.com/poll/2299/americans-look-back-vietnam-war.aspx.

Prosser, J. ed. 1998. *Image-based research*. London, UK: Falmer Press.

Sauer, C. O. 1925. *The morphology of landscape*. Berkeley, CA: University of California.

Silverman, G. 2015. The US has forgotten about the Vietnamese: Americans tend to think only of what they suffered during the war. *Financial Times*, April 25. https://www.ft.com/content/c26c8af4-e846-11e4-baf0-00144feab7de.

Taylor, A. 2016. Vietnam and America's surprising turn from foes to friends. *The Washington Post*, May 23.

Wylie, J. 2007. *Landscape* (*key ideas in geography*). New York, NY: Routledge.

Prairie Perspectives:
Geographical Essays

Prairie Division
Canadian Association of Geographers
Association Canadienne des Géographes

# A field trip guide to selected settlements in the Red River Valley, Manitoba

David McDowell
Faculty of Education, University of Winnipeg (retired)

*This field trip guide represents a revised and expanded version of the guide provided for the field trip conducted during the 2017 PCAG conference. The original guide is available on request from the author.*

## Introduction

The Red River Valley has long been an area of challenges due to periodic flooding attributable in large part to its drainage basin occupying the near level bed of former Glacial Lake Agassiz (Rannie 1998; Bower 2011). This has necessitated the need to create drainage works and protection with ring dikes. Despite this, the fertile clay-loam soils have yielded their bounty, and successful harvests in most years have sustained a modest population.

The valley has been an Indigenous travel zone for thousands of years, an area of passage for fur traders moving between The Forks and the Pembina bison wintering grounds, the setting for the refugee journey of Selkirk Settlers in dispute with the North-West Company, and the home for countless settlers seeking a new start on the fertile prairies. An early railway on the east side of the Red River from St. Paul, Minnesota to Winnipeg, and subsequent rail lines to the west plus an extensive network of roads have facilitated communication and enabled the transport of grain, goods, and people.

The field trip focuses on the past and present geography and history of this portion of southern Manitoba. Special attention is placed on the changing composition of agricultural production, settlement origins and the area's francophone population, the economic structure of communities, and the importance of ring dikes in providing protection from periodic floods. The field trip progresses in a general southerly direction along Highway 75 towards the international border at Emerson (Figure 1). This journey passes through prairie farmland and small communities fringing the west bank of the Red River. It encompasses the most southerly reaches of the Rural Municipality (RM) of Morris, the entire north-south extent of the RM of Montcalm, before entering the RM of Emerson-Franklin approximately 4 km north of the international border. The straight-line distance from Morris to the border is 39 km. By road this distance increases slightly to 41 km. In contrast, because of its many meanders, the length of a similar journey by the Red River is 74 km.

## Agriculture

Agriculture has long been practised in the Red River Valley. The Aboriginal peoples supplemented their hunter-gathering diet by utilizing the staple plants of corn, beans, and squash—the 'Three Sisters'—an intercrop planting system that supplied easily stored plant-based food over long winter seasons (Figure 2). With the introduction of commercial agriculture in the late C19th, grains such as wheat and barley formed the mainstay of



Correspondence to: David McDowell, 260 Carpathia Road, Winnipeg, MB R3N 1S9
Email: clio1@mymts.net

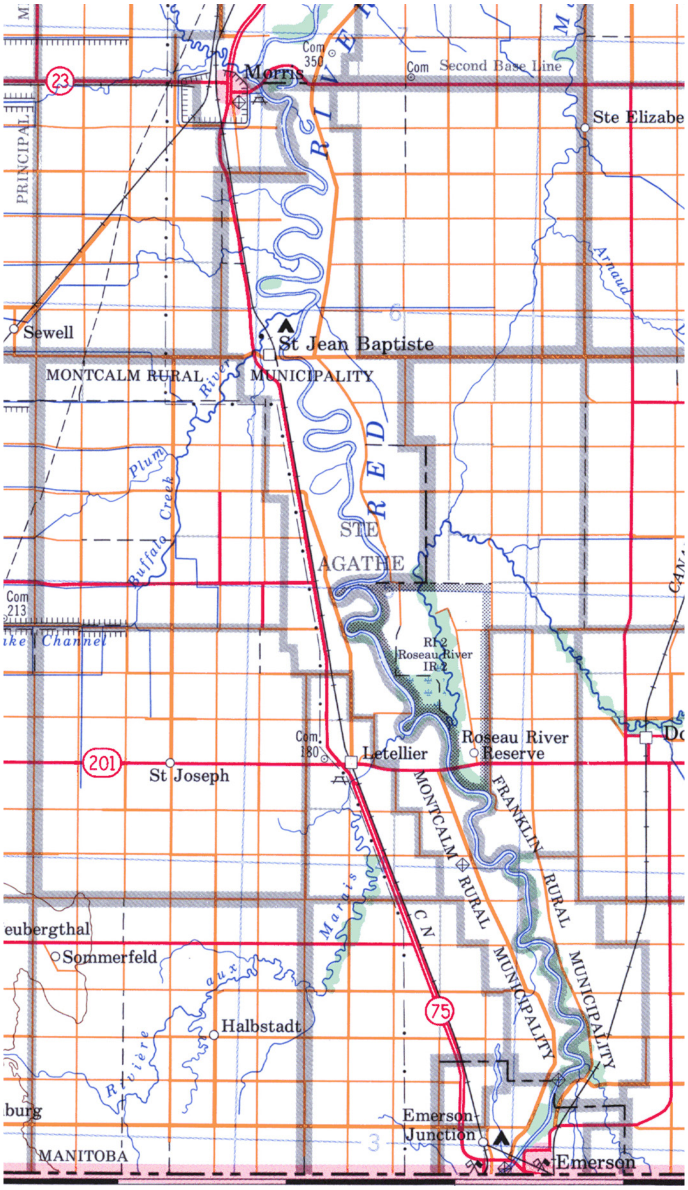



**Figure 1**
Regional setting of the field trip
Source: Canada Department of Energy, Mines and Resources

the agricultural economy in the RMs of Morris and Montcalm. This situation has changed somewhat in recent decades as wheat and barley have been pushed down the preferred crops chain by soybeans, canola, corn, and sunflowers. Interest in peas is also increasing with establishment of a new processing facility in Portage la Prairie, Manitoba. In 2017, a cool wet spring meant it was difficult to get seeding done, but subsequent slow drying of soils made for deep-rooted crops and high yields. Average crop yields in late September were reported as: soybeans 30 to 35 bu/acre, wheat 80 to 100 bu/acre, and oats 110 to 180 bu/acre (Province of Manitoba 2017).

Modern agriculture benefits from careful scientific work conducted at experimental farms such as Kelburn Farm, a 700 acre (283 ha) research farm located about 10 km south of Winnipeg in the RM of Ritchot (Figures 3 to 5), and nearby Bruce D. Campbell Farm and Discovery Centre which is affiliated with the University of Manitoba's Faculty of Agriculture and Food Sciences (Figure 6). Research at the farms advances information on plant varieties that can adapt to changing climate and the changing tastes of consumers. Their outreach also includes active support of education by organizations such as Agriculture in the Classroom, which encourages the next generation to be knowledgeable consumers and supporters of expenditures that seek improvement in nutrition and health. Visits to these experimental sites are strongly recommended.

**Figure 2**
The 'Three Sisters' of Indigenous agriculture—corn, beans, and squash—at Lower Fort Garry
Photography: D. McDowell

As in other parts of Canada, the number of farms in the valley has continued its long-term decline whilst average farm size has tended to increase. Between 2011 and 2016, the number of farms in the, RM of Morris declined from 218 to 201 (−7.8%), and those in the RM of Montcalm from 88 to 76 (−13.6%) (Statistics Canada 2017a). In the RM of Montcalm the modal class of farm increased from 1120 to 1599 acres, to 1600 to 2239 acres (Statistics Canada 2017b). At the same time, the number of very large farms equal to or greater than 2240 acres remained unchanged at 18, but increased from 20% to 24% of all farms. Of the 76 farms in the RM of Montcalm, 68 (89%) were engaged in oilseed and grain farming. Chicken and egg production, and hay farming each accounted for two (3%) farms, with beef cattle ranching, dairy cattle and milk production, goat farming, and horse and equine production, each accounting for one (1%) farm. Corresponding data for the RM of Morris suggest a slightly greater degree of diversification, possibly reflecting closer proximity to the Winnipeg market. Despite this, oilseed and grain farming still dominated and accounted for 153 of 201

**Figure 3**
Experimental plots of oats and soybeans at Kelburn Farm
Photography: D. McDowell

**Figure 5**
Experimental crop of flax at Kelburn Farm
Photography: D. McDowell

**Figure 4**
Experimental plots of wheat at Kelburn Farm
Photography: D. McDowell

**Figure 6**
Grain samples at Bruce D. Campbell Food and Development Centre
Photography: D. McDowell

(76%) farms. Other specializations included 14 (7%) hog and pig farms, nine (4%) beef cattle ranches, six (3%) poultry and egg farms, and five (2%) greenhouse, nursery and floriculture operations.

## Morris

Originally known as Scratching River, Morris was incorporated in 1883 and named after the Honourable Alexander Morris, the first Chief Justice in the Court of Queen's Bench and second Lieutenant Governor of Manitoba. The town was established at the river crossing of the Morris and Red rivers, following an era of fur trade and roaming Métis hunters. With the coming of the Red River Valley Railway in 1887–1888 (Joyal n.d.), the area prospered as a major trading centre mid-way between Winnipeg and the international border, and played a role as a major stop on the Great or Jefferson Highway extending from Winnipeg to New Orleans (Henry 2016). In Manitoba, this stretch of road was formerly designated as Highway 14, and is now identified as Highway 75.

Morris is the largest community visited on the field trip and functions as a service centre for smaller communities in the valley, such as St. Jean Baptiste and Rosenort. Canadian Pacific and Canadian National rail lines integrate the community into the wider North American trade network through linkage to Winnipeg's Centreport. Between 2011 and 2016, the population of the town increased from 1,797 to 1,885 (4.9%), an indication perhaps of a healthy local economy (Statistics Canada 2017c). This viewpoint is supported by the recent upgrading of Cargill's farm service centre, which features expanded rail capacity and grain handling facilities, and by the development of a new residential

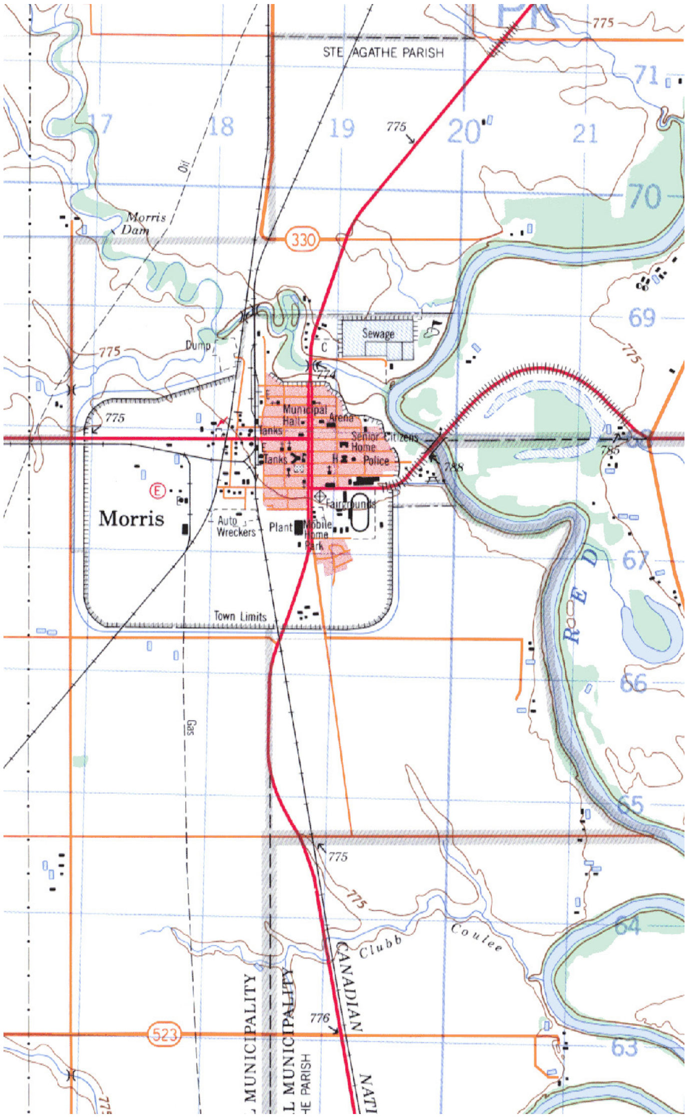



**Figure 7**
Morris and immediate environs showing encircling ring dike
Source: Canada Department of Energy, Mines and Resources

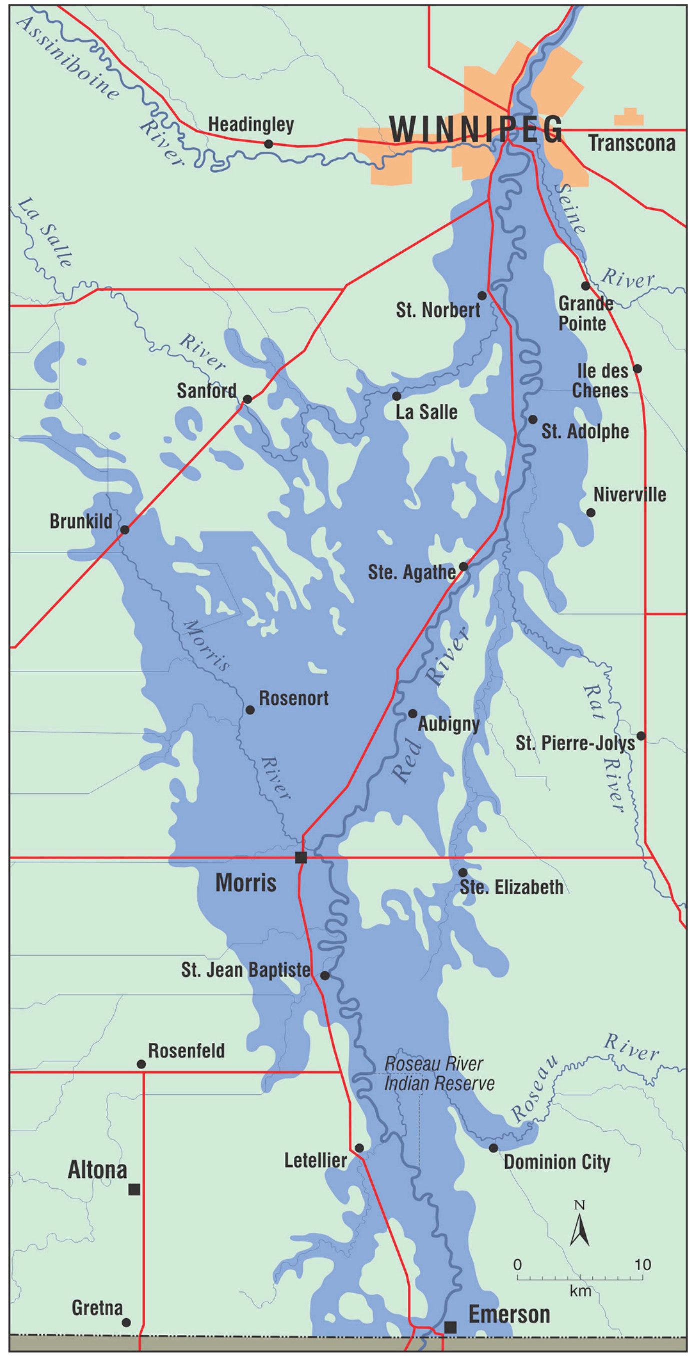



**Figure 8**
Extent of 1950 flood in the Red River Valley
Source: Manitoba Department of Natural Resources. Redrawn by Weldon Hiebert

subdivision southeast of the town (Figure 7). Next to employment in health care and social assistance (15%), employment in agriculture (12%) forms the mainstay of the community. Other prominent sectors are construction (11%), retailing (10%), and manufacturing (9%). The latter sector includes the manufacture of agricultural equipment and steel buildings. Important regional services include the 23-bed Morris General Hospital, offices of the Red River Valley School Division, a detachment of the RCMP, and the provision of services to the agricultural community. Local amenities include a six-sheet curling rink, which features coaching clinics using modern audio visual equipment. An important international service is provided by Wood Bay Turf Technologies whose ten employees serve North America golf course grooming from the former Andres Winery building. Not least, Morris is noted as the home of the Manitoba Stampede and Exhibition, an annual event which features the largest professional rodeo east of Calgary, Alberta.

The disastrous flood of 1950 inundated Morris and other communities throughout the length of the Red River Valley (Figures 8 to 10). The flood prompted excavation of the Red River Floodway and Portage Diversion channel to protect Winnipeg but small communities such as Morris were left unprotected. Following a lesser flood in 1966, a series of ring dikes was constructed to protect Morris and other vulnerable communities to

**Figure 9**
Inundation of Morris during 1950 flood
Source: RM of Morris (2018)

**Figure 10**
Main Street Morris during 1950 flood
Source: RM of Morris (2018)

**Figure 11**
Morris during 1997 'Flood of the Century'
Photography: Province of Manitoba

the south of Winnipeg. These measures, are credited with averting extensive property damage from the 1997 'Flood of the Century' when floodwaters far exceeded those of 1950 (Rannie 1998). Since 1997, additional dikes have been constructed and existing structures have been raised (Manitoba n.d.). Figure 11 presents a low level oblique view of Morris sitting snug and dry within its ring dike during the 1997 flood. The channel of the Red River is picked out by the parallel line of trees at the centre right margin of the image, with the confluence of the Red and Morris rivers identified by the arrow on the outside curve of the meander.

After a short loop out to the east of Morris on Highway 23 to view to an oxbow lake and to note the cottonwoods (*Populus deltoides*) forming a riverside forest (Figure 7), the field trip proceeds south on Highway 75. The near level or isotropic form of the Red River Valley is evident in all directions. Between the bridging points on Provincial Road 200 at Emerson and Highway 23 at Morris, the Red River drops approximately 2 m as it meanders in a general northerly direction. This virtually imperceptible change is evident in the topographic maps included in this guide, which show the 750 ft. (228.6 m) contour closely fringing the banks of the Red River and its tributaries for much of the distance from Emerson to Morris.

Before proceeding further 'up' the valley, a note on rural location numbering is of interest. The former section, township, and range survey system, out from the Prime Meridian, a north-south line 4.5 miles (7.2 km) west of Morris (Figure 7) and north from the USA border, needed clarification in the era of EMO vehicle responses. To this end, The Civic Addressing Standard for Manitoba provided a new numbering system, which gives addresses in 20 m intervals by road numbers north of the USA border, and east or west of the Prime Meridian, and thereby allows for more precise place-finding (Province of Manitoba n.d.; WikiProject Canada 2018).

## St. Jean Baptiste

St. Jean Baptiste is an unincorporated community in the RM of Montcalm (Figure 12). The community was first settled by Métis from St. Norbert, a suburb of present day Winnipeg. Originally founded as the settlement of Grosse Pointe near the confluence of Plum Creek with the Red River, it was renamed Mission de la Rivière aux Prunes. Following the arrival of 20 families from Quebec and the eastern USA, the community was given its current name by Bishop Taché in 1872 in honour of the patron saint of French-Canadians. Today, the cultural foundations of the community are reflected in its large Roman Catholic parish church, Église de Saint-Jean-Baptiste dating from 1877, the Roman Catholic cemetery consecrated in 1882, and the former Couvent des Soeurs des Saints Noms de Jésus et de Marie. The church features a prominent bell tower, and is constructed from Tyndall stone, the same highly fossiliferous Ordovician limestone used in the construction of the Canadian Parliament Buildings in Ottawa, and the Manitoba and Saskatchewan legislative buildings. The convent was built between 1897 and 1898 in the Second Empire architectural style featuring a mansard roof, dormer windows, and a central pavilion. It is designated a provincial historic site. Street names include Rue Fillion and Baie Valcourt, but also the seemingly linguistically confused Chemin du Park. Today, 43% of the community identify French as their mother tongue and first official language spoken (Statistics Canada 2017c). Other evidence of the continuing strength of the

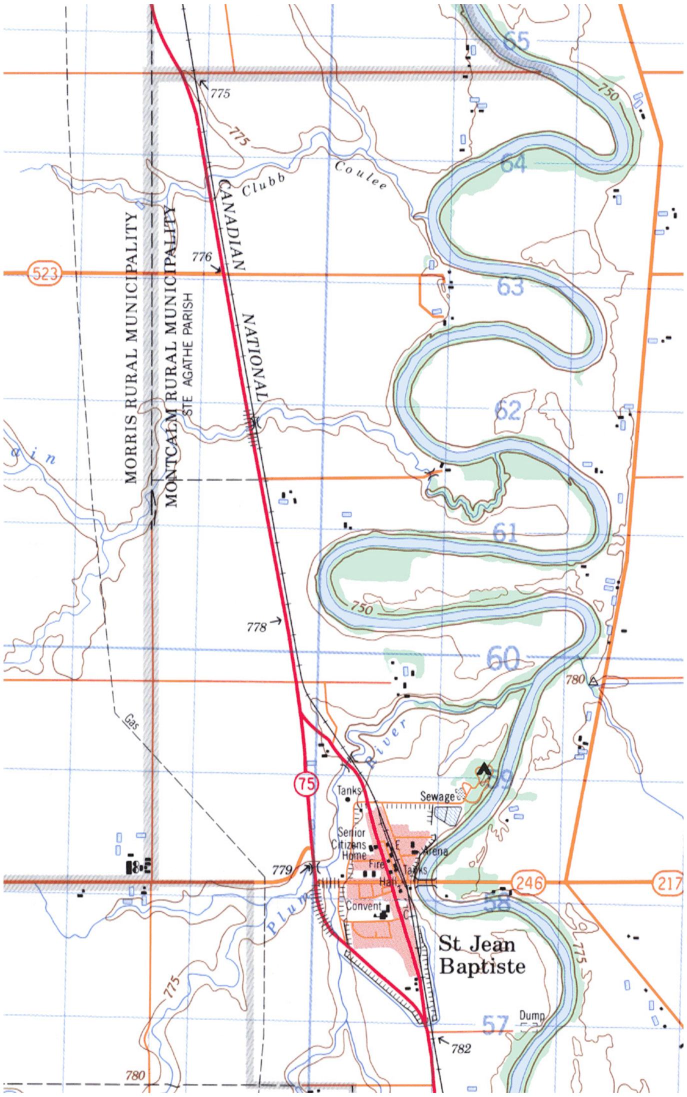



**Figure 12**
St. Jean Baptiste and regional environs showing the confluence of the Plum and Red rivers
Source: Canada Department of Energy, Mines and Resources

francophone community is reflected in the presence of a French language high school, École Régionale Saint-Jean-Baptitse.

Between 2011 and 2016, the population of St. Jean Baptiste increased from 552 to 563 (2.0%) (Statistics Canada 2017c). Employment in health care and social assistance (24%) constitutes the largest industrial sector. Other important sectors are retailing (13%), construction (13%), and agriculture and other primary industries (11%). In 2011, the Roy Legumex pulse handling facility amalgamated with Walker Seeds, and was then sold to Scoular, a USA-based grain handling company. This company originally worked with specialty crops, but now forms part of the company's handling facilities. Other agriculture related enterprises include NuVision Commodities Incorporated, a specialized grain and feed hauling and shipping company. NuVision operates a certified CN agricultural transload facility from two elevators including a former Manitoba Pool elevator dating from 1950. The latter features a traditional gable roof design and tall gabled cupola, an annex (1965), and three large steel storage bins. Today, the Co-op gas bar, and Caisse Popular provide a reminder of a major organizational feature found in many prairie towns, as farmers sought to gain control though mutual help. The town has the typical T-street layout with Railway Street paralleling the CN line and minor streets running off it at right angles. As with other communities in the valley, St. Jean Baptiste is protected by a ring dike, with potential flood water advancing down the Plum River from the west as well as the Red River from the south.

A bridge across the Red River replaced an earlier ferry service in 1947, and perhaps earlier. Here and elsewhere along the valley there is a constant battle to maintain bridges in the flood zone. At St. Jean Baptiste the 1947 bridge was demolished in 2013 when slumping of the river banks lead to its structural failure. To date, a replacement bridge has not been built. Residents wishing travel to the east bank must now either travel 10 km (6 mi) north to Morris or 16 km (10 mi) south to Letellier to cross the river. The loss of the bridge and the dislocation it continues to cause points to the lingering isolation and vulnerability of small communities in the valley, and more generally in rural Manitoba.

## Letellier

Letellier is an unincorporated settlement in the RM of Montcalm located approximately 26 km south of Morris and 15 km north of the international border (Figure 13). Originally identified as the Métis community of Saint Pie, it was renamed Letellier in 1879 upon the arrival of francophone immigrants from Quebec and the USA. A point of interest is provided by the Letellier Cairn, which describes the Roseau Route, or the war road of the Sioux leading from (to) the Lake of the Woods. It commemorates the earliest route to the West, first used in 1733 by the French explorer La Jemmeraye, who in 1736 was buried near the mouth of the Roseau River during the return trip. The plaque was unveiled in 1936 by the Historic Sites and Monuments Board of Canada.

Today, the population of around 440 persons remains predominantly francophone. Sadly, unlike in St. Jean Baptiste, none of the street names in Letellier appear to reflect anything of the community's Métis-Québécois heritage. The community is noted for its vernacular house styles, particularly the traditional Prairie cubic. In terms of function, Letellier serves as a centre for first responders and municipal government. Its continuing role in serving the agricultural community is expressed through the siting of Richardson Pioneer's modern grain elevator on the CN line approximately 2 km north of the community. As well as taking crop from the area, the elevator serves the Kelburn Farm research facility. It has a capacity of 16,300 tonnes and provision for over 100 grain cars.

Letellier is associated with Norbert Jutras (1856–1929), a cleric who is recognized as a 'Memorable Manitoban.' Jutras was born in Canada East, where he studied at Nicolet Seminary. In 1880, he came to Manitoba before being ordained to the

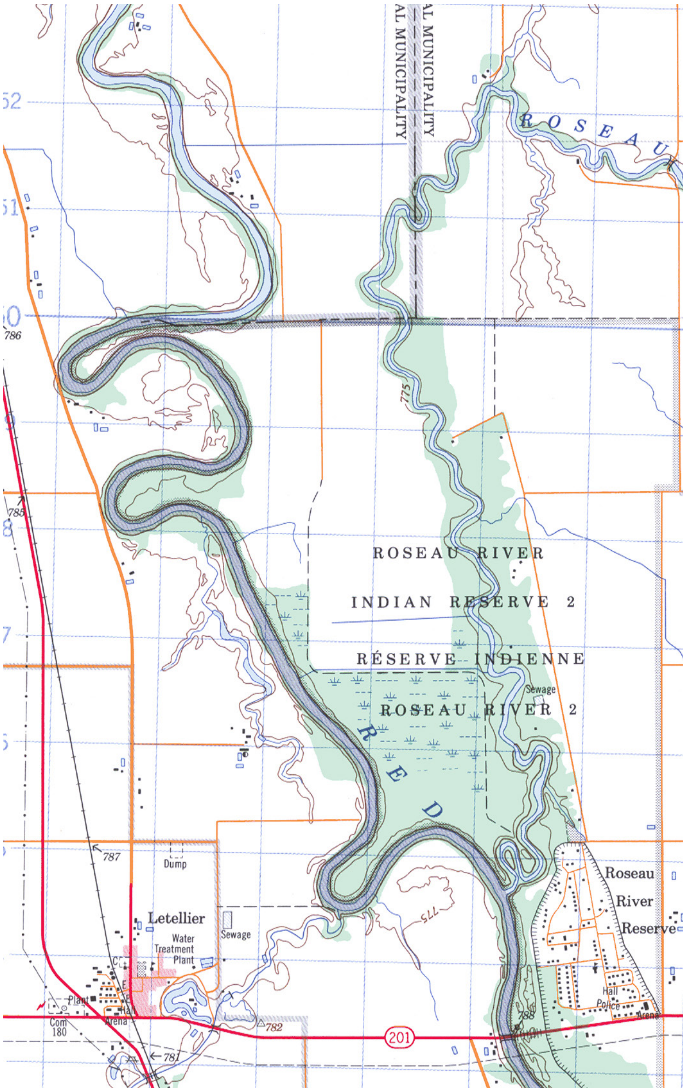



**Figure 13**
Regional setting of Letellier and the flood prone Roseau River Reserve 2
Source: Canada Department of Energy, Mines and Resources

priesthood in 1882. He began his ministry at St. Pie about 6 km southwest of Letellier, and in 1889 moved to the community, where he became known as the 'Apostle of Mixed Farming.' Jutras wrote on agricultural reform for many years, especially in the French-language journals of the province. He was a staunch advocate of modern machinery, and is celebrated as a member of the Manitoba Agricultural Hall of Fame.

## Roseau River Reserve 2

The reserve occupies a wedge-shaped 22.2 km$^2$ (8.6 mi$^2$) tract of land bordering the right bank of the Red River where it is bisected by the Roseau River (Figure 13). The river has an unusual configuration. From its source near Lake of the Woods in the USA the river flows in a general northwesterly direction to a point just north of its confluence with the Red River from where it takes a sharp turn to run south to the junction. Much of the reserve occupies land between the two rivers with a consequent heightened danger from flooding. The closely settled part of the reserve is located south of (i.e., above) the confluence of the rivers. Even so, this is a highly flood prone location and, in contrast to most communities in the valley, this area was not ring diked until after the 1997 flood.

Unlike other communities presented in this guide, the population of the reserve declined between 2011 and 2016 from 588 to 558 (−5.1%) (Statistics Canada 2017c). The reason for this decline is unknown but could be attributable to one or more of several factors including declining birth rate, economic outmigration, or simply under reporting in the census record. In 2015, the employed labour force comprised only 70 persons. Of this total, the greatest number was employed in construction (29%), with public administration (21%), health care and social assistance (21%), educational services (14%), and retailing (14%) accounting for the rest (Statistics Canada 2017c). In view of the small size of the numbers involved, the sample nature of the data, and rounding to a base of 5, these data should be viewed with caution.

## St. Joseph Museum

St. Joseph is a small francophone community with a population of about 200 located in the RM of Montcalm approximately 6.2 km directly west of Letellier along Provincial Road 201. On leaving Letellier the field trip passes the operations of Seed-Ex, a grains handling and exporting company which exports malting barley, soybean, and high protein wheat to the United States, and from where it imports corn and animal feeds including dried distillers grains (DDG) for Canadian livestock producers. Seed-Ex is a business success story founded in 1996 by local businessman Roger Barnabe.

Access to the St. Joseph Museum (Figure 14) is from the grandly named Brais Boulevard. The museum is constructed as a pioneer village, featuring an agricultural village, tourism centre, and campground. Buildings include the Perron House from


**Figure 14**
Bilingual signage at Musée St. Joseph Museum
Photography: D. McDowell

1850 (the collectors of many of the artifacts on display), Union Point School (from near Ste Agathe), a church, general store, typical farm buildings, exhibits of tractors and other agricultural machinery, a blacksmith's shop, leather workshop, woodworking shop, one of the largest collections of stationary engines in the Canadian West, and a heritage display of the once important Manitoba sugar beet industry (Friesen 1962). The latter industry collapsed in 1997 when the sugar processing plant in Fort Garry, Winnipeg closed with the loss of 82 full-time jobs (Robertson and Davis 2017). This action left 230 sugar beet growers with no buyer for their product. Closure was forced by the 1995 General Agreement on Tariffs and Trade, which allowed the USA government to restrict Canadian exports of sugar-containing products and to levy barriers on refined sugar from Canada.

## The Parent Tourism Centre

The Tourism Centre (Figure 15) is a timber-frame structure decorated with murals by Manitoba artist Hubert Théroux. It introduces highlights of the museum's collections. The museum's 45,000 artifacts are normally housed in the buildings of the historical and agricultural villages, which are open to the public during summer months. The centre has a gallery for artifacts and travelling exhibits, a meeting room, workshop, and gift shop. A permanent gallery is dedicated to the unique Laurent Fillion collection of cameras.

**Figure 15**
Parent Tourism Centre
Photography: D. McDowell

St. Joseph is also the location of Manitoba's second major wind farm, the first being the St. Leon Wind Farm located west of Miami. The St. Joseph Wind Farm was commissioned in March of 2011 by San Francisco-based Pattern Energy Group at a cost of $345 million. Originally planned as a 300 megawatt (MW) installation, the 138 MW project consists of 60 Siemens turbines, each with a nameplate capacity of 2.3 MW (Energy Manitoba n.d.). The turbines are set on towers that are 80 m high, or about the same height as a 20-storey office building (Figure 16). They generate enough power to serve the needs of 50,000 homes, an amount equivalent to 16% of households in Winnipeg. The project is distributed over an area of 125 km$^2$ (over 30,000 acres) of privately owned agricultural land in the RMs of Montcalm and Rhineland. Critical electrical equipment in each tower has been installed well above ground level. This

**Figure 16**
Turbines at Pattern Energy Group's St. Joseph Wind Farm
Photography: Weldon Hiebert

provision plus the siting of the towers on a low ridge is intended to avoid the risks associated with periodic floods of the Red River (Caulfield 2010). The turbine blades are positioned to maximize generation potential from prevailing northwesterly winds in winter and southerly winds in summer. During wind generation, water can be stored for hydro generation during calm wind times.

## Fort Dufferin

Fort Dufferin (Figure 17) is located on the west bank of the Red River approximately 3.4 km (2 mi) north of the international border. Approaching from the north, it can be accessed from Highway 75 by turning east along Road 3 North then south along Manchester Avenue. Alternatively, if travelling from the south, the fort can be reached from the community of West Lynne by proceeding east along Merrick Avenue then north on Manchester Avenue.

The fort asserted Canadian sovereignty in the region from 1873 to 1879, and was a major location for the British-Canadian contingent of the North American Border Commission from 1872 to 1874 (Manitoba Historical Society 1992). It was also the site of the famous assembly for the 1874 'March West' of

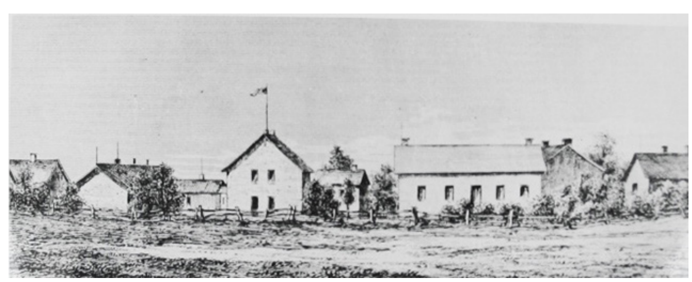


**Figure 17**
Fort Dufferin in 1874
Source: Archives of Manitoba

the newly formed North-West Mounted Police, and between 1875 and 1879 served as the immigration station for steamboats entering Canada via the Red River. The fort was abandoned in 1879 following the completion in 1878 of the rail line from St. Boniface—variously known as the Emerson Line or Pembina Branch—along the east side of the Red River. The railway forced closure of steamboat services and loss of the fort's function as an immigration and quarantine station. Following abandonment, the Canadian government sold the property.

Fort Dufferin was designated a National Historic Site in 1937. Despite this, many of the buildings are in a bad state of repair. Conservation and restoration initiatives are now evident with work being shared by local residents, the Canadian government, and the RCMP Veterans Association. Today, the site includes a worthy museum which is open to the public during summer months.

As a bonus, the site provides access to two trails—the Trans Canada Trail, and the Forgotten Forests Trail. The latter is a 1.6 km (1 mi) pathway through riparian forest skirting the Red River (Rivers West 2004). Interpretive signs explain the important features of the ecosystem as the trail descends to the river through three forested zones—terrace, floodplain, and channel shelf. Each zone is associated with different species such as bur oak (*Quercus macrocarpa*), American elm (*Ulmus americana*), and eastern cottonwood (*Populus deltoides*), the presence or absence of these being largely determined by seasonal flooding, variable erosion and deposition of sediments, and, historically at least, resistance to natural grass fires from the adjacent prairie. Walking the trail provides an opportunity for gentle exercise, enlightenment, and quiet reflection.

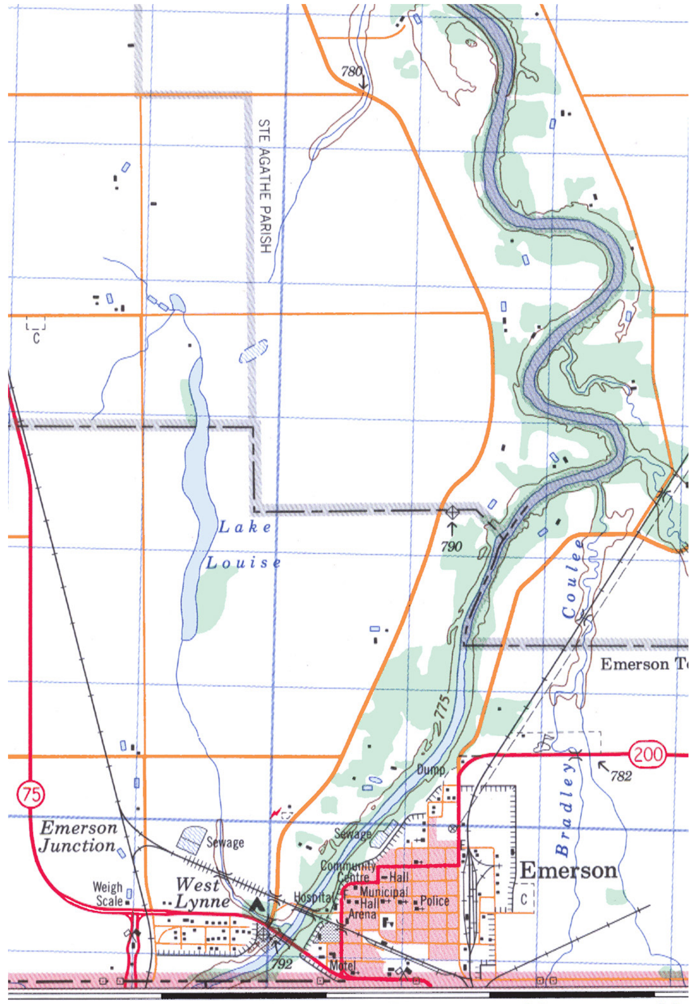



**Figure 18**
Convergence of water, road and rail routes at Emerson
Source: Canada Department of Energy, Mines and Resources

## Emerson

Emerson is located on the right-hand bank of the Red River in the RM of Emerson-Franklin (Figure 18). It is named after the writer Ralph Waldo Emerson. This small border community was once touted to become a major city. One factor in this optimism was the arrival in 1878 of the Saint Paul and Pacific Railroad from St. Paul, Minnesota, which joined with the Emerson Branch from St. Boniface, the last spike being driven at Dominion City 16 km northeast of Emerson. Between 1880 and 1883, the community boomed and grew quickly to reach a population of around 10,000. Many fine public buildings were built during this period and survived into the 1960s. Regrettably, all have been lost as a consequence of flood damage or fire (Ewens 1995). The neo-classical Court House and Town Hall on Church Street was built in 1917 to replace a building of similar function which had been destroyed by fire. Elsewhere several fine residential structures still survive from Emerson's boom years. They include Fairbanks Mansion located between Second and Third Streets, and Bryce House at 99 Assiniboine Street. Despite its very promising start, Emerson is now designated as a lowly local urban district. In 2016, it had a population of only 678 (Statistics Canada 2017c). Even so, this reflected a modest increase of 2% since 2011.

Today, an abandoned railway station reflects the long disappearance of passenger rail service, but Emerson is still the crossing point for CP and CN rail lines linking with Soo and BNSF rail lines in the USA. In 2003, the Emerson East Customs Port facilitating road crossings to Minnesota was closed. This location was the site of major unregulated refugee crossing from the USA in the winter of 2016–2017, with danger to life and limb and a cause of great concern to local residents.

Employment in retailing (19%) constitutes Emerson's largest industrial sector (Statistics Canada 2017c). Other important sectors are transportation and warehousing (15%), accommodation and food services (13%), and public administration (13%). Presumably, employment in the transportation sector reflects Emerson's function as a border crossing point to the USA, and the convergence of road and rail routes. Perhaps surprisingly, employment in agriculture and other primary industries accounts for a relatively modest 6% of total employment.

Like other communities in the valley, Emerson has experienced periodic setbacks caused by flooding of the Red River

**Figure 19**
Main Street Emerson during 1950 Flood
Source: RM of Morris (2018)

**Figure 20**
Looking south on Main Street, Emerson with the ring dyke at centre right of image
Photography: D. McDowell

(Figures 19), but is now protected by a ring dike (Figure 20). This ring dike is much like others in the valley with the important distinction that it crosses the international border to enclose the small community of Noyes, Minnesota, and the Port of Noyes Customs and Immigration Station. The latter was decommissioned in 2006 following the aforementioned closure of the Emerson East Customs Port. Border crossings by road are now restricted to the west side of the Red River where they are conducted through upgraded customs and immigration facilities at West Lynne on Highway 75 in Canada, and at a point approximately 4 km north of Pembina on Interstate 29 in the USA.

## Memorable Manitobans

Several 'Memorable Manitobans' are associated with the post-contact settlement of the area (MHS 2017). Alexandre 'Buffalo' Ayotte (1859–1932) was a noted bison conservationist. He reintroduced the prairie icon from Montana to Alberta and the rest of the West. Arthur Lucien Beaubien (1879–1971) was a hotelier, farmer, and Reeve of the RM of Montcalm. He served as the Member of Parliament for Provencher from 1921 to 1940 and as Senator for Provencher from 1940 to 1969 during which time he acted as a government (1951 to 1957 and 1964 to 1969) and opposition (1958 to 1962) whip. Today, the federal electoral districts of Portage-Lisgar and Provencher are served respectively by Hon. Candice Bergen and Ted Falk. In provincial politics, the electoral districts of Morris and Emerson are served by Shannon Martin and Cliff Graydon. All representatives are members of the Conservative Party of Canada or Progressive Conservative Party of Manitoba.

## Acknowledgements

The author would like to thank, Guy Robbins at St. Joseph Museum, the volunteers at Fort Dufferin, Ed Voth, Economic Development Officer, Town of Morris, Ingrid Kristjanson, Farm Production Extension Specialist, Manitoba Agriculture, and the PCAG organizing committee for providing information and otherwise assisting in the planning and conducting of the field trip. All maps presented in the guide contain information derived under the Open Government Licence – Canada.

## References

Bower, S. S. 2011. *Wet prairie: People, land and water in agricultural Manitoba*. Vancouver, BC: University of British Columbia Press.

Caulfield, P. 2010. Construction begins on 138-megawatt wind farm near St. Joseph, Manitoba. *Daily Commercial News,* May 11. https://canada.constructconnect.com/dcn/news/others/2010/5/Construction-begins-on-138-megawatt-wind-farm-near-St-Joseph-Manitoba-DCN038809W.

Energy Manitoba. n.d. Wind: St. Joseph wind project. http://www.energymanitoba.org/renewable_wind_stjoseph.htm.

Ewens, S. 1995. Historical tour – Emerson: Gateway to the West. *Manitoba History* 30.

Friesen, J. 1962. The Manitoba sugar beet industry: A geographical industry. MA thesis, University of Manitoba.

Henry, L. D., Jr. 2016 *The Jefferson Highway: Blazing the way from Winnipeg to New Orleans*. Iowa City, IA: University of Iowa Press.

Manitoba Historical Society. 1992. Fort Dufferin: Then and now. *Manitoba History* 23.

Joyal, P. n.d. The railway. http://www.rmofmorris.ca/history/the-railway-by-paul-joyal/.

Manitoba. n.d. Red River Valley ring dike communities and properties. https://www.gov.mb.ca/flooding/fighting/valley_ring_dike.html.

MHS. 2017. Memorable Manitobans. Manitoba Historical Society. http://www.mhs.mb.ca/docs/people/index.shtml.

Province of Manitoba. n.d. The Civic Addressing Standard for Manitoba. http://www.amm.mb.ca/download/reports/Report_Civic AddressingStandard.pdf.

—. 2017. Crop report: Issue 22, September 25. https://www.gov.mb.ca/agriculture/crops/seasonal-reports/crop-report-archive/crop-report-2017-09-25.html.

Rannie, W. F. 1998. The 1997 Red River flood in Manitoba, Canada. *Prairie Perspectives* 1: 1–24.

Rivers West. 2004. Forgotten forests of the prairies: Self-guiding interpretive trail. http://www.routesonthered.ca/media/documents/brochure-forests.pdf.

Robertson, B., and Davis, T. 1997. Sugar plant, trade killed. *Winnipeg Free Press*, 24 January, 1, 3. https://newspaperarchive.com/winnipeg-free-press-jan-24-1997-p-1/.

RM of Morris. 2018. 1950 flood pictures. http://www.rmofmorris.ca/community/flood/historical-floods/.

Statistics Canada. 2017a. Farms classified by farm type. Table 32-10-0403-01. https://www150.statcan.gc.ca/tl/tb11/en/tv.action?pid=3210040301.

—. 2017b. Farms classified by total farm area. Table 32-10-0404-01. https://www150.statcan.gc/t1/tb11/en/tv.action?pid=321004401.

—. 2017c. Census profile, 2016 census. https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/index.cfm?Lang=E.

WikiProject Canada. 2018. Addresses in Manitoba. https://wiki.openstreetmap.org/ wiki/Manitoba.

# Across the Division

**Brandon University**

During fall 2017, Brandon University Department of Geography welcomed Dr. Alex Koiter to its ranks. Alex completed his PhD at the University of Northern British Columbia and brings with him teaching and research expertise in geomorphology and watershed management. The fall also marked the first offering of a new unmanned aerial vehicle (UAV) certification course in compliance with Transport Canada. The course is one of the first of its kind in Canada and offers students instruction on everything from pilot navigation to map interpretation, to Canadian aviation regulations. More recently, Drs. Chris Malcolm and Doug Ramsey completed a report for the provincial government on the role of community museums in southwestern Manitoba. Their report outlines the importance of community museums in rural tourism and highlights the fact that they often suffer from a lack of funding and are dependent on an aging set of volunteers to run them. The department congratulates Dr. Rachel Herron on her appointment by the Canadian Institutes of Health Research as Canada Research Chair in Rural and Remote Mental Health. Further, Dr. Peter Whittington and colleagues from University of Alberta, University of Waterloo, and University of Laval were awarded an NSERC – Collaborative Research and Development (CRD) grant to investigate management and ecological restoration of peatlands to support a sustainable Canadian horticultural peat industry. Not least, the department extends big congratulations to Brandice Hollier (MSc candidate with Drs. Whittington and Malcolm) who was awarded a Manitoba Graduate Scholarship. Finally, the department has joined twitter. Please follow us @BU_Geog for the latest news and updates.

**Lakehead University**

Lakehead University's Department of Geography and the Environment embarked this year on a process of remodelling and updating its programs. At the graduate level, the Master of Environmental Studies in Northern Environments and Cultures program is being expanded to include a wider range of faculty and has been renamed to simply Master of Environmental Studies. At the undergraduate level, work is being done to define concentrations of study for particular student interests such as geoscience and climate change, and to add a co-operative education option. The department went through a cyclical undergraduate review in 2018, which reinforced the need for this remodelling in the context of challenges such as reduced enrollment and faculty. No staffing changes have taken place since Dr. Todd Randall was appointed Dean of Science and Environmental Studies in 2017. In September 2017, the department hosted an interdisciplinary Forum on Climate Change, but is hoping for no conflicts with the PCAG conference in Hecla this fall.

**University of Manitoba**

The reporting year in the Department of Environment and Geography has been busy with curriculum development, discussions of program restructuring and the successful applications for high-level research chair positions. Both the BA and BSc in Geography have moved to reinvigorate their undergraduate curriculums with streams and new course development, while the Environmental Studies and Sciences programs have begun discussions for strategic renewal of their programming. Dr. Mark Hanson has led these changes in his position as Acting Chair of the department. The department has also seen the recruitment of several chairs: A Canada 150 Chair and a Canada Excellence Research Chair, both of which come with additional chair positions granted at the university level.

The department is able to report a range of exciting research brought to completion or underway. Dr. Bruce Erickson was awarded a SSHRC grant to study polar bear tourism and neoliberal landscapes in Churchill. Dr. Jonathan Peyton published Unbuilt Environments (UBC Press 2017), a monograph that has won multiple awards. Jonathan also received the U of M/UMFA Merit Award for Excellence in Scholarly Research. Dr. Stephane McLachlan continued as the Chair of Wa Ni Ska Tan: Manitoba Hydro Alliance, a $2.5 million SSHRC grant. Dr. Feiyue Wang was awarded a Tier I Canada Research Chair in Arctic Environmental Chemistry. Dr. C.J. Mundy continued as Graduate Chair and received several major grants, as did Dr. Jens Ehn, relating to ongoing research on

Arctic oceanography. Dr. Tim Papakyriakou stepped down from his position as the Director of the Centre for Earth Observation Science to focus more directly on research. He was replaced in that position by Dr. John Iacozza, who also led a series of changes to the physical geography curriculum. Dr. Ronald Stewart and John Hanesiak continue to develop the undergraduate atmospheric science specialization. Lisa Ford (with Dr. Alan F. Arbogast, Michigan State University and Dr. Daryl Dagesse, Brock University) published *Discovering Physical Geography* (Wiley 2017). Dr. Janna Wilson continued her undergraduate teaching excellence, while Dr. Bonnie Hallman and Dr. Mary Benbow dedicated most their 2017 academic year to administrative positions at the faculty level.

Several other exciting research initiatives were delayed by extenuating circumstances: construction at the Churchill Marine Station was delayed by the conditions of the rail track to Churchill, while the summer research season on the Arctic Research Vessel HMSS Amundsen was interrupted by weather and the distress calls of other sailors.

**University of North Dakota**

During the reporting period, the Geography and GISc Department experienced both triumphs and tragedies. The department hosted the 2017 PCAG meeting in Morris, Manitoba in late September with the support of the Virginia George Inheritance Fund, the Dakota Science Center, the Association of North Dakota Geographers, as well as contributions of sweat equity from many colleagues across the division when the Trump Travel Ban prevented the program being held in conjunction with the AAG GP-RM regional meeting in Grand Forks during mid-October. Long-time departmental secretary, Cindy Purpur, retired. The department recognizes her strong efforts through the years to assist in the success of many undergraduates, graduates students, and faculty. Fortunately in the budget cuts at UND the department was able to have her position retained and filled by Valerie Bensley. Unfortunately, Dr. Michael Niedzielski elected not to return from his developmental leave and signed resignation papers effective 2019–2020. He will be teaching only online from Poland during 2018–2019 before ending his appointment at UND. Dr. Christopher Atkinson, a stalwart supporter of PCAG, has moved from Grand Forks to Melrose, Minnesota in order to be with his wife and children. Lisa Atkinson was selected to be the community development planner for this part of the North Star State, so Chris will be teaching online for UND in 2018–2019. Meanwhile, the department's graduate program has seen Brandon University alumnus Peter Brandt successfully defend his thesis in May of 2018. The department's graduate teaching assistantship roster was slashed by a third in the 2017–2018 'budgetary bloodletting,' the consequence of certain administrators thinking that the Bakken Boom would be lasting forever in the Williston Basin oilfields. However, there is optimism that there will be a rebound in the state's economy but it is guarded optimism tinged with pessimism in light of current global geopolitics. The decision to appoint Dr. Bradley Rundquist, a former chairperson of the department, to be Interim Dean of the College of Arts and Sciences for 2018–2019 is duly noted. Finally, there will be a delegation of folks from the Grand Forks campus and the Dakota Science Center coming to the 2018 PCAG meeting at Hecla Island which looks to be a bright spot on the horizon for the department's faculty, graduate students, and undergraduates.

**University of Regina**

The department celebrated the convocation of 19 undergraduates in our Environmental Studies, Geography and Geographic Information Science Major and Minor programs this past year. Two faculty members are on sabbatical this year: Dr. Randy Widdis and Dr. Julia Siemer. The department underwent its first Academic Unit Review since 2002, and we are excitedly working to apply the recommendations that will carry us into the future. We were also delighted to offer a summer field course exploring the history and geography of Berlin, Germany.

**University of Saskatchewan**

Last year the department welcomed Dr. Krystopher Chutko whose research focuses on isotope hydrology, lacustrine processes, and paleoenvironmental reconstruction. This year the department welcomed three new members. Dr. Corinne Schuster-Wallace combines research interests in water, health, and wellbeing. Corinne joins us from the Institute for Water, Environment and Health, part of the United Nations University at Hamilton, Ontario. Dr. Ehab Diab brings expertise in urban transportation and network planning. Ehab is a former NSERC post-doc scholar from the University of Toronto's Transportation Research Institute. The University has recruited NASA Jet Propulsion Laboratory senior water scientist Dr. Jay Famiglietti as Canada 150 Research Chair in Hydrology and Remote Sensing. Jay will hold a joint faculty appointment in the Department of Geography and Planning. After 10 years as Department Head, Dr. Dirk de Boer has stepped down to take on the role of acting Vice Dean Indigenous in the College of Arts and Science. Dr. Alec Aitken has replaced him as Department Head with Dr. Bram Noble serving as Acting Head in 2018–2019. This year has seen many personal accomplishments and honours. Dr. Chutko was honoured by University of Saskatchewan Students Union at the Experience in Excellence Awards Gala for his excellence in teaching, student involvement, leadership, and bettering the student experience. Dr. Bram Noble was awarded a SSHRC Insight Grant of $91,800 for researching Knowledge-based Impact Assessment for Renewable Energy Transition. Leigh Thomas, a third-year Regional and Urban Planning student, received the Academic Excellence Award during Indigenous Achievement Week. Thomas who is from the Cree First Nation community of Chitek Lake is particularly interested in Indigenous planning in the 21st century through community-led initiatives, traditional Indigenous governance systems and integrating Indigenous ways of knowing into planning practices. Last but not least, Dr. John Pomeroy was awarded the prestigious J. Tuzo Wilson Medal for outstanding contributions in the field of geophysical sciences at a ceremony in Vancouver during the annual meeting of the Canadian Geophysical Union.

**University of Winnipeg**

One highlight of this exciting academic year was the joint effort of the Departments of Geography and Environmental Studies and Sciences to successfully propose a new graduate program to the University with the next step being provincial approval. A range of research projects are ongoing in the department. Dr. Ed Cloutis continues to work with the NASA Mars Rover 2020 teams, including the ExoMars Trace Gas Orbiter NOMAD instrument science team preparing for analysis when the spacecraft settles into its final data acquisition orbit. Dr. Patricia Fitzpatrick is the Co-Principal Investigator of a High North Programme (Norway) funded collaboration between the University of Winnipeg and NTNU Gjovik. The Department of Geography along with broader support from the University hosted its first cohort of Norwegian exchange students in September 2017. The students spent the week learning about sustainability initiatives and energy research at UW and elsewhere in the province. Dr. Danny Blair and Dr. Ian Mauro are the co-directors of the Prairie Climate Centre that in 2017 received a $1M grant from Environment and Climate Change Canada to complete the online and bilingual Climate Atlas of Canada. Dr. Nora Casson was awarded the 2018 UW Chancellor's Research Chair to investigate relationships between water, landscape, and environmental stressors such as climate change. On sabbatical in Australia, Dr. Joni Storie collaborated with Dr. Neil Sims of Land and Water, Commonwealth Scientific and Industrial Research Organization (Melbourne), to examine the ability to extract forest biomass measures from synthetic aperture radar and optical remotely sensed datasets for areas in Queensland and Tasmania. The department is also appreciative for the commitment of Dr. Marc Vachon as the Department Head for six years, with Dr. Chris Storie now accepting a three-year term in the role. In addition, the department welcomes back Dr. Blair after his tenure as Associate Dean of Science and more recently the Acting Dean of Science. We are also pleased to report that 20 undergraduate Geography students were awarded UW scholarships totalling $15,000 during this academic year. Finally, the department will be hosting the Canadian Association of Geographers meeting in May of 2019 with Dr. Matt Dyce as the Conference Chair. We are looking forward to seeing many of you in Winnipeg.

# About the Authors

**Muhammad Almas** is a GIS expert currently working for the Water Security Agency of Saskatchewan. Previously he has worked for the United Nations World Food Program (UNWFP) and has over 22 years of post-graduate working experience. His expertise includes web mapping, computer programming, and GIS applications in water resource management.

**Jacqueline Binyamin** is a climatologist and an Associate Professor at the University of Winnipeg, Department of Geography. Her research interests include radiation climatology, climate change and variability, severe weather, surface-atmosphere interactions and boundary layer processes, and surface energy budget for northern lakes.

**Susan Carr** was General Manager of the Prince Albert Model Forest at the time of the water resources workshop reported in this volume, playing a leading role in making local arrangements as well as setting the theme suitable for discussion.

**Hồng Thị Hà** is a recent graduate of the Thái Nguyên University of Agriculture and Forestry (TUAF) in Vietnam. Her BSc was in Environmental Science and Management. She is now a program officer, researcher, and teaching assistant for the Advanced Education Program at TUAF.

**Mark Johnston** is Senior Research Scientist at the Saskatchewan Research Council in Saskatoon. His research interests include boreal forest ecology and the impacts of climate change. Mark works closely with forest managers on developing options for adapting to climate change. He is also an adjunct professor at the University of Saskatchewan, and since 2006 has been President of the Prince Albert Model Forest.

**Suzanne Elizabeth Kerr** is a graduate student in the Department of Education at Brandon University. She has two decades of experience teaching in the public school system, mostly as a resource teacher. Her teaching and research interests include student engagement, assessment of and for learning, and student voice.

**John Kindrachuk** is Executive Director of the Redberry Lake Biosphere Reserve, and also works with the North Saskatchewan River Basin Council. With his knowledge and experience in agriculture, John undertakes a number of activities in pursuit of sustainable communities.

**Aaron Kingsbury** is an Assistant Professor at Maine Maritime Academy, Castine, Maine, and a two-time visiting scholar at the Thái Nguyên University of Agriculture and Forestry (TUAF) in Vietnam.

**Kenji Kitamura** is Assistant Professor at Kanazawa University, Japan, and an adjunct faculty member at the University of Saskatchewan. At the time of the workshop reported in this volume he was Researcher at the Research Institute for Humanity and Nature in Kyoto, Japan. Kenji obtained his Ph.D. at Simon Fraser University, and continues his field research in various locations including Canada, Japan, and Costa Rica.

**David McDowell** is a historical geographer who trained at Brandon College and University of Manitoba. Following a career in high school geography and distance education, he served as a geography instructor at University of Winnipeg Teacher Education. Now retired, he enjoys keeping abreast of Manitoba history and geography.

**Roderick A. McGinn** is Professor Emeritus at the Department of Geography, Brandon University. During a 45-year academic career, Rod has conducted research studies on orographic enhanced rainfall, drought modelling, and climate warming scenarios for southwestern Manitoba and eastern Saskatchewan; surface water and snowpack hydrology, flood frequency, and limnological and macronutrient studies focusing on the Clear Lake watershed, pothole lakes, and Manitoba Escarpment. However, Rod is best known for a sequence of papers on the glacial history of the Eastern Uplands of Riding Mountain, Manitoba. Much of this research is published in Prairie Perspectives.

**Yulu Peng** was a Geomatics and Surveying Engineering Technology (GSET) diploma student at Saskatchewan Polytechnic who graduated in 2016. Research presented in this volume is based on her capstone project. Yulu is currently pursuing her graduate studies at the University of Lethbridge in the field in GIS.

**Abdul Raouf** is currently working as an instructor in the Geomatics Department of Saskatchewan Polytechnic, Moose Jaw Campus. He has over 27 years of post-PhD research and teaching experience. In the past, he has worked at the European Space Agency (ESA), and the Pakistan Space and Upper Atmosphere Research Commission (SUPARCO). His expertise includes integrated use of remote sensing and GIS for land-use planning, disaster monitoring/mitigation, and environmental management.

**Maureen G. Reed** is Professor and Assistant Director Academic in the School of Environment and Sustainability at the University of Saskatchewan. She also holds a UNESCO Chair in Biocultural Diversity, Sustainability, Reconciliation and Renewal. Maureen has worked in collaboration with model forests and biosphere reserves on issues related to sustainability and environmental governance.

**Dustin M. Roussin** is an honours physical geography student at University of Winnipeg and a member of the Métis Nation. His research interests include climate variability and extreme weather events on the Canadian prairies.

**Jamie Edwin Lee Spinney** is an Assistant Professor at South Dakota State University. He is a teacher-scholar whose interdisciplinary research interests include the scholarship of teaching and learning. He is actively investigating how to measure student engagement, the application of differentiated assessment, and best practices for incorporating technology in the classroom.