Executive Summary

Managing Water Supply and Flood Control in the Souris River Basin is the final report of the International Souris River Study Board (Study Board) to the International Joint Commission (IJC) on its evaluation of water management operations under the *1989 International Agreement between the Government of Canada and the Government of the United States of America for Water Supply and Flood Control in the Souris River Basin* (the 1989 Agreement).

The report presents the analysis, findings, conclusions, and recommendations of the Study Board regarding opportunities to improve the 1989 Agreement and strengthen the provision of flood control and water supply benefits to interests in the international basin.

The challenge

The Souris River basin covers about 61,900 km^2 (23,900 mi^2) in the provinces of Saskatchewan and Manitoba in Canada and the state of North Dakota in the United States (Figure A). With a total population of about 157,000, the basin's economy is relatively diversified, with a mix of agriculture, coal mining and energy production, service industries, and tourism.

Long, cold winters in the basin tend to retain snowfall until the spring melt, which provides most of the Souris River's annual flow. Much of the basin is part of the prairie pothole region, characterized by the presence of shallow potholes or kettle lakes that are remnants of the last period of continental glaciation in North America. The combination of climate and terrain contributes to highly variable flows in the basin, from season to season and from year to year.

Since 1940, Canada and the United States have worked together through the IJC to jointly manage the transboundary waters of the Souris River. Today, the waters of the Souris River basin are extensively managed for flood control and water supply by dams, diversion canals and other water resource infrastructure to meet the needs of communities, agriculture, industry, recreation, and ecosystems. The current operating plan has been in place since 1989, part of the 1989 Agreement.

In 2011, the Souris River basin experienced an unprecedented flood, far exceeding the scale of any other flood event in the more than 100 years for which instrumental data and records are available. Extremely wet conditions in the preceding years, combined with an above average snowmelt and heavy spring and substantial summer rainfall, resulted in a series of flooding events that significantly affected homeowners, businesses, and properties throughout the basin. Water management and control structures were severely tested as never before.

The 2011 flood focused renewed attention on the existing operating plan under the 1989 Agreement. Members of the public, as well as several government flood protection and water management agencies, requested that options for additional flood protection measures be evaluated. Across the basin, there were also emerging concerns related to security of water supply, water quality and environmental protection.

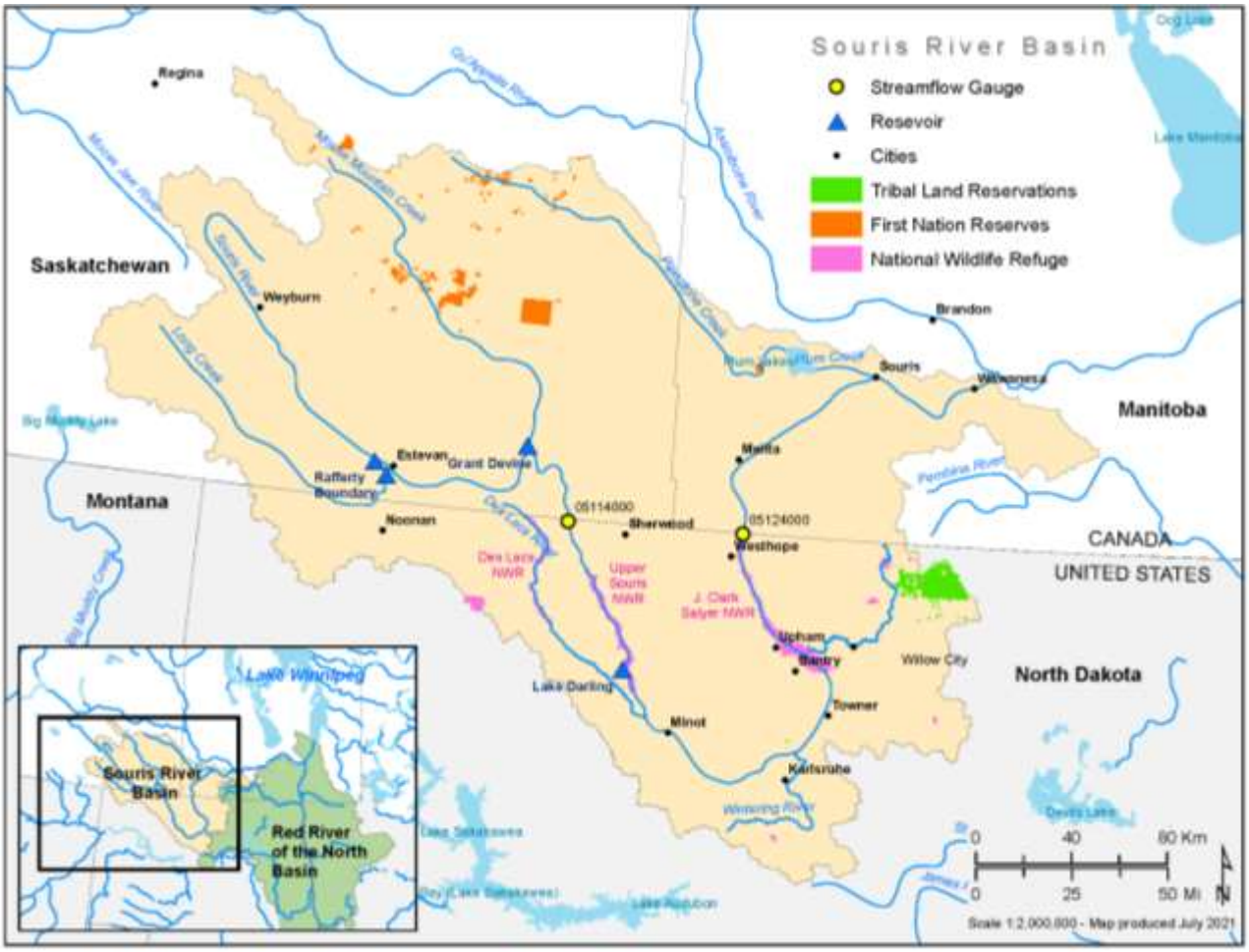

Figure A Souris River basin

The International Souris River Study

The International Souris River Study was a direct response of the Governments of Canada and the United States to the 2011 flooding event. In addition to the concerns expressed following the 2011 flooding, the 1989 Agreement requires that the Operating Plan be reviewed periodically to maximize the provision of flood control and water supply benefits that can be provided consistent with the terms of the Agreement. As a result, the International Souris River Board (ISRB), a permanent board established by the IJC responsible for oversight of transboundary water issues in the basin, including flood operations and apportionment of river flows, established the 2012 Souris River Basin Task Force to develop a Plan of Study (POS) proposing a review of the Operating Plan contained in Annex A for the consideration of the Governments of Canada and the United States. The Souris River Project includes three reservoirs in Saskatchewan and one in North Dakota (i.e., water storage reservoirs used for flood protection and water supply purposes.)

The Task Force's 2013 POS document describes the studies needed to review the existing Annex A of the 1989 Agreement's Operating Plan for the reservoirs in Saskatchewan and North Dakota, and to evaluate alternatives to maximize flood control and water supply benefits. The ISRB submitted the 2013 POS to the IJC in April 2013. The IJC submitted to governments a *Plan of Study: For the Review of the Operating Plan Contained in Annex A of the 1989 International Agreement Between the Government of Canada and the Government of the United States of America* on June 7, 2013. The IJC recommended the full scope of the POS be conducted.

On July 5, 2017, the Governments of Canada and the United States issued a reference for the IJC to undertake the Plan of Study. In accordance with Article IX of the *Boundary Waters Treaty of 1909*, the governments requested that the IJC examine and report on flooding and water supply in the Souris River Basin, and coordinate the completion of the full scope of the 2013 POS.

On September 5, 2017, the IJC issued a Directive to establish and direct the Study Board to examine and report to the IJC on matters raised by the Governments of Canada and the United States in the reference dated July 5, 2017.

Specifically, the Study was directed to undertake analysis and make recommendations regarding:

- the Operating Plan contained in Annex A to the 1989 Agreement; and,
- how the provision of flood control and water supply benefits in the basin might be maximized.

The Study organization (Figure B) consisted of:

- a Study Board of five members each from Canada and the United States responsible for providing overall direction and management of the Study, including reporting formally to the IJC on a regular basis;
- technical teams responsible for undertaking the extensive data collection, analysis and modelling that formed the basis of the Study's findings and recommendations;
- an independent binational Public Advisory Group (PAG), established by the IJC, responsible for helping plan and implement the Study's engagement and outreach plan;
- a binational Resource and Agency Advisory Group (RAAG), representing key resource management agencies and industry;
- a binational Climate Advisory Group (CAG) with expertise in hydrology and climate science was established; and,
- an Independent Review Group (IRG), established by the IJC, to provide independent scrutiny and guidance throughout the Study.

Brief summaries of the reports of the technical task teams are presented in Appendix 5. The reports are available on the Study's website: www.ijc.org/en/srsb

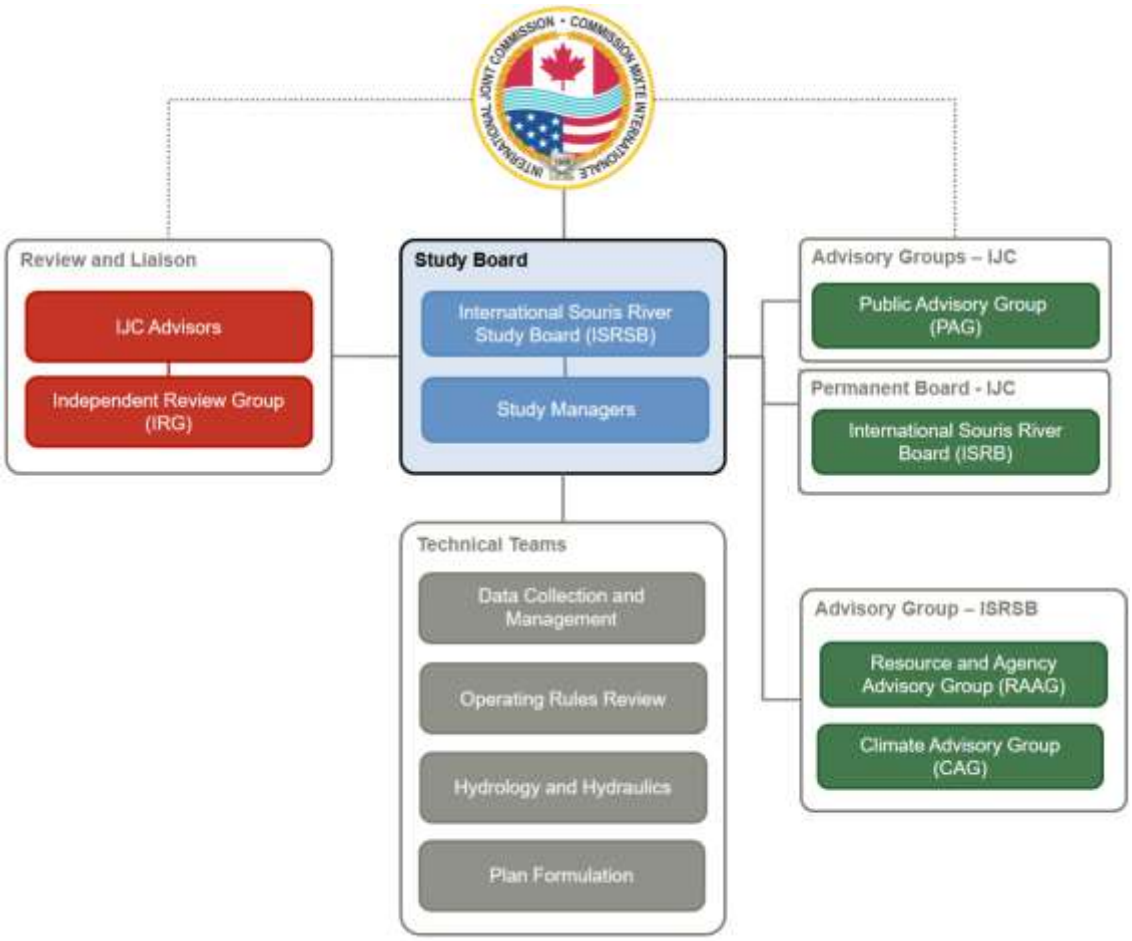

Figure B International Souris River Study organization

Engagement and outreach in the Study

The IJC was committed to ensuring that the Study process was open, inclusive, and fair, and that the public, stakeholders and Indigenous Nations in the region were aware of the Study and of the opportunities to participate. Over the course of the Study, Study Teams undertook a wide range of engagement and outreach activities with:

- the public;
- representatives of government resource and regulatory agencies and industry; and,
- Indigenous peoples with current and/or ancestral interests in the Souris River basin.

The binational PAG played a key role in helping develop and implement the Study's engagement and outreach activities. PAG members were responsible for:

- advising the Study Board on public consultation, involvement, and information exchange;

- involving the public by bringing information from the Study Board to their various networks throughout the community, as well as bringing back views from the community for consideration by the Study Board;
- reviewing and providing feedback on the Study's approaches, reports, products, findings, and recommendations; and,
- advising the Study Board on the responsiveness of the Study process to public concerns.

The RAAG was established by the Study Board early in the Study to act as a conduit for input from federal, provincial, state, and municipal agencies, and from the electric power industry over the course of the Study. The group worked to ensure that any recommendations made by the Study Board with respect to the existing operating plan or alternative measures would be compatible with the mandates and resources of the agencies. RAAG membership consisted of about 20 members from federal agencies and agencies in Saskatchewan, Manitoba, and North Dakota.

The Study Board recognized that Tribes, First Nations, and the Métis Nation have current and/or ancestral interests in the Souris River basin, and that their interests can be affected by the changes in water levels and flows in the basin. The Study worked to establish lines of communication and build relationships with these Indigenous Nations so that their interests could begin to be considered and the Study could benefit from Indigenous Knowledge. As this engagement has only started, continued engagement with Indigenous Nations is expected beyond the study, to determine how Indigenous interests can be included and addressed in management of the Souris River.

ISRSB Work Plan and Tasks

Based on the IJC Directive, the Study Team developed a work plan to guide the work of the Study Board and various task teams in the execution of the Study. The workplan identified key data requirements, tasks (Table A: ISRSB's main study tasks and task groups), and resources required to fulfill the directive. Stand-alone reports are available for most tasks at the Study website www.ijc.org/en/srsb.

Table A: ISRSB's main study tasks and task groups:

Core Activity	Technical Task Teams
Operating rules review	OR 1: 1989 Agreement Language Review
Data collection and management	DW 1: Projects and Report Progress since 2011 DW 2: Bathymetry and LiDAR Data DW 3: Hydro meteorological Network Review DW 4: Data Collection for Performance Indicators

Hydrology and hydraulics	HH 1: Regional and Reconstructed Hydrology HH 2: Stochastic Hydrology HH 3: Artificial Drainage Impacts Review HH 4: Flow Simulation Tools Development HH 5: Climate Change Analysis HH 6: Reservoir Flow Release Modelling (Res-Sim) HH 7: Reservoir Flow Release Modelling (HEC-RAS) HH 8: PRM Model Development (HEC-ResPRM) HH 9: Model System Integration HH 10: Flow Forecasting Assessment
Plan formulation	PF 1: Workshops and Engagement PF 2: Run and Evaluate Alternatives PF 3: Dam Safety PF 4: Apportionment, Water Quality and Ecosystem Health

Review of the 1989 Operating Plan Annex A language

The unprecedented flooding in the Souris River basin in 2011 challenged operations under the as never before. For the operators of the dams, the flooding highlighted long-standing language ambiguities in the 1989 Agreement and the need to clarify some provisions of the Agreement.

As a result, the operators commenced a cooperative review of the language used in the 1989 Agreement, with oversight from the ISRB. Their objective was to update provisions of the Agreement for clarity, relevancy, and completeness. In 2017, this work was brought into the Study as one of its primary objectives.

Building on the earlier work of the operating agencies' committee, a Study Team identified a range of issues that needed to be addressed to update and improve the clarity of the language of the 1989 Agreement. The team worked with reviewers from the dam operating agencies and the ISRB to find consensus on proposed changes. The team's proposals were then reviewed by the Study Board, the PAG and the RAAG.

Those areas that the Study Board reached consensus on revised language need to be submitted to the governments for legal review of the language and a decision made for implementation.

The Study Board identified six issues that need guidance, direction, and legal analysis from the Parties to the Agreement.

The review identified two sets of findings:

- specific proposed changes in language in the 1989 Agreement that will help improve the clarity and ongoing relevance of the Operating Plan and ensure consistency in its implementation; and,

- a set of six outstanding issues for which no consensus was reached among the operating agencies; resolution of these issues may involve policy considerations and require the attention of the IJC and the Governments of Canada and United States.

Table B summarizes these outstanding issues and the Study Board's conclusions regarding next steps.

Table B: Review of Operating Plan language: summary of outstanding concerns

1989 Operating Plan Item	Study Team Proposal	Outstanding Concerns	Study Board Conclusion (Possible Options)
1. Section 4.3.1 Flood operating plan	Revised language to address runoff during periods outside of spring snowmelt	Proposed revision could change the original intent of the 1989 Agreement	Retain existing language Reconsider if or when there are substantive updates to the 1989 Agreement
2. Section 4.3.3 Drawdown during spring freshet	New language proposed to address existing gap in Operating Plan procedures regarding drawdowns during the spring freshet	Proposed addition could be seen as a basic change to the 1989 Agreement	Proposed language should not be included as part of its recommended revisions to the 1989 Operating Plan Reconsider if or when there are substantive updates to the 1989 Agreement
3. Section 4.3.4 Drawdown after spring freshet	Revised language to clarify existing language regarding drawdowns after the spring freshet	The additional language assigns reservoir operating rules that are not in the original 1989 Operating Plan, and therefore, could be considered a change in the 1989 Agreement	Proposed language should not be included as part of its recommended revisions to the 1989 Operating Plan Reconsider if or when there are substantive updates to the 1989 Agreement
4. Section 4.3.5 Significant spring and summer rainfall	Revised text to provide more details on operational procedures during significant spring and summer rainfall events	Proposed text may add unintentional ambiguity	Revert to the 1989 Agreement language, given that the proposed new language could be viewed as a change in procedures of the 1989 Agreement
5. Section 4.3.6 Flood operation steps	Reviewed an editorial change to the 1989 Agreement made prior to 2017 that sought to simplify procedures during a flooding event	The 1989 Agreement language had been changed at some period prior to the study being established in 2017.	Retain the changed language Reconsider if or when there are substantive updates to the 1989 Agreement considered
6. Section 4.3.6 Flood operation steps - reporting	Reviewed an editorial change to the 1989 Agreement made prior to 2017 that sought to remove redundancy	The 1989 Agreement language had been changed at some period prior to the study being established in 2017.	Revert to the original language of the 1989 Agreement; that is, re-insert "part c" of section 4.3.6"

Evaluation of the performance of the 1989 Operating Plan

A key first step in considering the potential for improving water supply and flood control benefits in the basin was to first evaluate how well the existing Operating Plan has performed.

The Study analyzed and compared three hydrologic model simulations over a period from 1930 to 2017 to understand how the 1989 Agreement affects flood control, water supply and other key areas:

- a *baseline simulation*, incorporating the existing 1989 Agreement and its Annex A and Annex B, as if it had been in place the entire 1930-2017 period; this simulation includes Rafferty, Boundary, Grant Devine, and Darling reservoirs throughout the entire simulation;
- a *pre-Agreement simulation* that includes only the operational plans in place prior to 1989 for the Boundary and Darling reservoirs; the Rafferty and Grant Devine reservoirs were removed from the model for this simulation; and,
- an *unregulated simulation* representing a condition close to the "state-of-nature" for the Souris River basin from 1930 to 2017, with all four reservoirs removed from the model. It should be noted, however, this simulation is not truly a natural state, as J. Clark Salyer National Wildlife Refuge was not removed from the model, nor was all built infrastructure within the Souris River basin removed from the model (towns, cities, roads, rail, landscape/land use modifications, etc.).

The 1989 performance evaluation simulation runs included analysis for 13 key locations or reaches along the Souris River, to understand flow for all three regions (Saskatchewan, North Dakota and Manitoba).

Based on the analysis, the Study Board found that, overall, the 1989 Operating Plan has performed well in providing water supply and flood control benefits. In particular, the analysis showed:

- The baseline simulation reduces the number of bankfull overflows (exceedances) compared to the pre-Agreement and unregulated simulations at all locations downstream of the Rafferty and Grant Devine Reservoirs, with one exception at Bantry, North Dakota.

- The addition of Grant Devine, Rafferty and Boundary Reservoirs and Lake Darling to the Souris River System provided protection for the spring snowmelt in 2011; however, when high rainfall events occurred throughout the basin in May and June, all remaining flood storage was used, and basin-wide flooding occurred. Analysis showed that even if the reservoirs were empty before the flood (dry dam scenario), a flood of similar magnitude to the 2011 extreme summer flood could not be mitigated. The reservoirs do provide significant to modest flood protection from the Estevan, Saskatchewan reach to as far downstream as Westhope, North Dakota, and into Manitoba for floods similar in magnitude to the major floods experienced in1969 and 1976.

- Mean monthly streamflows in the baseline simulation generally were less during the spring and summer than in the pre-Agreement and unregulated simulations as a result of water being stored in each of the four reservoirs. Mean monthly streamflows in winter generally were greater in the baseline simulation as the result of water being released from storage, resulting in a more uniform distribution of streamflow throughout the year.

- In addition to the direct benefits to flood control and water supply, the presence of the Souris River Project reservoirs, as modelled under the baseline simulation, resulted in benefits and impacts on secondary effects on environmental resources, socio-economic components, historic and cultural sites, water quality and recreation.

Development of alternative operating plan measures

Alternatives are defined as a change or series of changes to how the basin's reservoir system is operated – that is, the levels of reservoirs and the timing of releases affecting flows, or a physical change to one of more of the reservoirs. By varying water levels and flow rates, reservoir operators can affect flood storage, outflow releases, water supply conditions and river and riparian conditions.

The Study addressed the need to develop a range of alternative operating plan measures through the integration of several key areas of work by the technical teams: data collection and management; development of runoff sequences; the application of performance indicators (PIs); and iterative rounds of modelling and evaluation. The evaluation of alternatives included engagement activities to obtain the input of the public, Indigenous Nations, government water and resource management agencies, and industry.

A first step was to review existing hydrological and meteorological studies and collect, update, and analyze key data on the basin's hydrology and meteorology needed to support the modelling of alternatives. This included physical data on the Souris River basin, data on each reservoir's elevation, storage, volume and outflow, and climate and bathymetric information (for reservoir depth and topography).

Study Teams also developed a set of runoff sequences as input to the modelling and testing of alternatives. These included scenarios of historical water supply conditions in the basin, going back to 1930.

The next step was to integrate the runoff sequences, basin data and PI data into models to formulate a range of alternative operating plan measures. The plan formulation process to investigate possible alternative operating plan measures was carried out over five phases. Each phase built on the findings of the previous phase, with new or modified alternatives being formulated at each phase. As this work advance to its later phases, a hydrological visualization tool allowed users to compare simulation results at specific locations in the Souris River basin.

Figure C illustrates how the initial ideas on the evaluation of operational changes in the early phases supported the formulation of new alternative operating plan measures in the subsequent

phases of analysis. Six of the initial set of operational changes were modelled primarily to provide insights into the limits and constraints to managing water supplies in the basin and thereby support additional modelling in subsequent phases. Some of these areas of operational change, such as those associated with minimum flows or spring drawdown, were rejected, as they failed to meet flood management and water supply criteria or resulted in unacceptable impacts on one or more PIs. Other operational changes, such as those associated with normal drawdown targets, spring maximum flow limits and summer operating rules, proved more promising and were refined through further modelling. They formed the basis of the final set of five alternative operating plan measures that have the potential to provide improved flood control and water supply benefits to the interests in the Souris River basin.

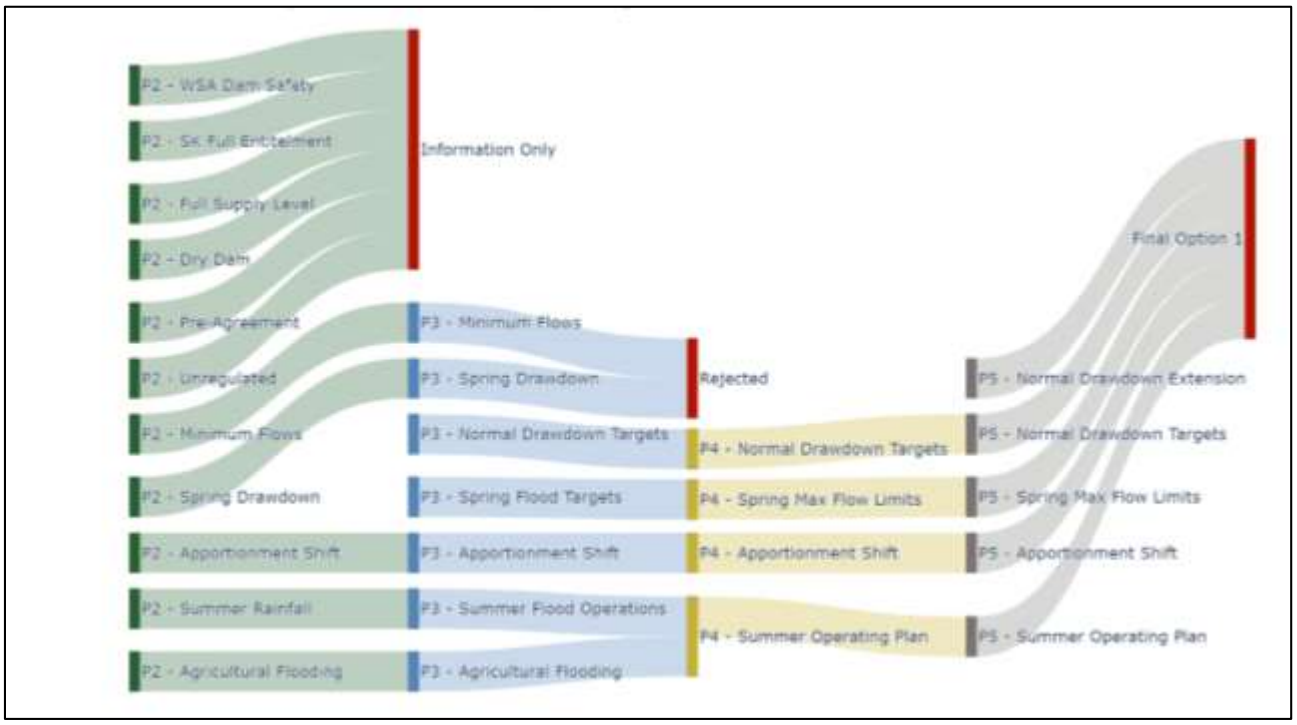

Figure C Overview of the development of alternative operating plans

Evaluation of alternative operating plan measures

The Study identified a short list of five operating plan measures that could be considered as viable alternatives to the existing provisions in the 1989 Operating Plan. These measures were largely developed as responses to specific seasonal conditions, (Table C).

Table C Summary of alternative operating plan measures

Alternative Operating Plan Measure	Objective
1. Winter Drawdown Elevation Targets (Two options)	Allows for changes in winter storage in reservoirs, for improved operations that account for antecedent soil moisture and watershed basin conditions
2. Winter Drawdown Extension to March 1st	Extends reservoir drawdown date from Feb 1 (1989 Agreement) to March 1, providing additional river flow for improved environmental benefits during February
3. Lower Spring Maximum Flow Limits	Reduced the spring flow limits during small/moderate flood years and non-flood years to reduce flood peaks and agricultural flood risk in riverine reaches in North Dakota
4. Summer Operations (Two options)	Provides operators guidance for reservoir storage and river flow to maintain lower flow limits during targeted summer flood events to mitigate flood risk
5. Apportionment Year Shift to a Water Year	Changes the apportionment calculations from a Calendar Year (Jan. 1 to Dec. 31) to a Water Year (Nov. 1 to Oct. 31) to ensure flood protection releases in Nov. and Dec. are credited towards apportionment

The alternative operating plan measures were evaluated in detail, through a series of workshops with members of the Study Board, the PAG and RAAG, using the visualization tool. The in-depth analysis and comparison included evaluating the alternative operating plan measures under a wide range of water supply conditions. Figure D shows how the most promising operating plan measures may be sequenced in comparison to the 1989 Agreement.

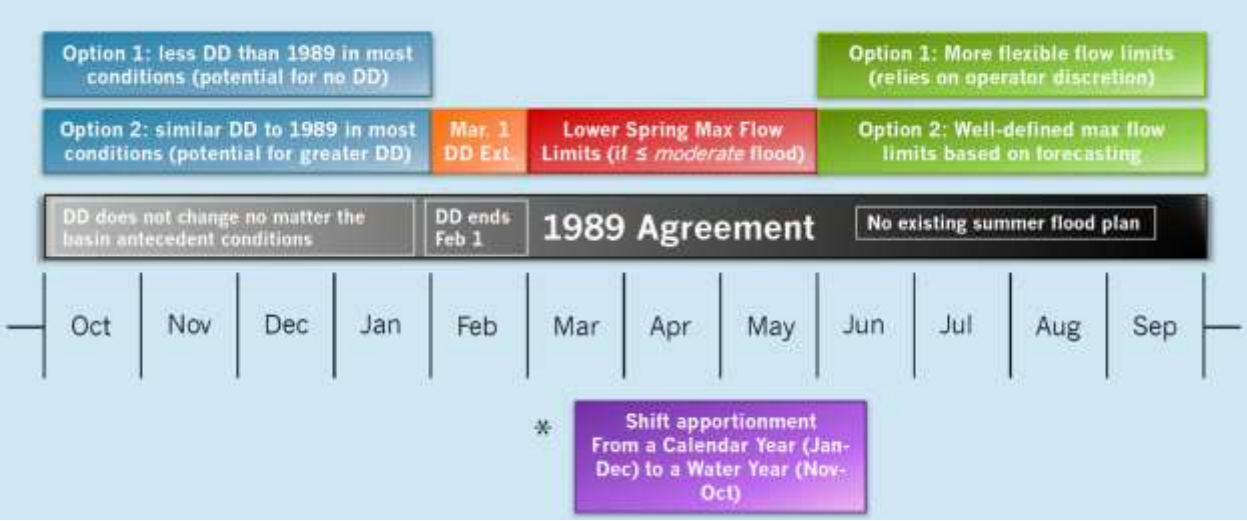

Figure D – Sequencing and timing of alternative measures compared to operations under the existing 1989 Agreement

Based on its evaluation of the alternatives, the Study Board made the following key findings:

Alternative Measure 1:
Winter Drawdown Targets – Options 1 and 2

The analysis of **Alternative Measure 1** showed that:

- Antecedent soil moisture conditions can be used for operational decisions on winter drawdown target elevations, adjusting for Dry, Normal or Wet basin conditions, with trade-offs to the amount of water stored in reservoirs
- Depending on the option selected, benefits could be accrued to water supply or to river water quality
- Reservoir storage would still require flood risk management

Alternative Measure 2:
Winter Drawdown Extension to March 1st

The analysis of **Alternative Measure 2** showed that:

- Extending the reservoir drawdown target date from February 1st to March 1st draws water down from the reservoirs over a longer winter period, improving river water quality and aquatic habit

Alternative Measure 3:
Lower Spring Maximum Flow Limits

The analysis of **Alternative Measure 3** showed that:

- Lowering of the spring maximum flow limits reduces flood risk of agricultural lands downstream of Minot with a trade-off of storing water at higher levels in the reservoirs
- This approach reduces flood risk for small to moderate flood events (peak flows of approximately 57-85 m^3/s (2,000-3,000 ft^3/s) at Minot, North Dakota).
- The trade-off is that storage used for these smaller floods may not be available should a larger flood event occur (i.e., increased risks could occur)

Alternative Measure 4:
Summer Operations - Options 1 and 2

The analysis of **Alternative Measure 4** showed that:

- Establishing a more robust summer flood operating plan that provides clearer operator guidance in managing summer floods
- Both options utilize reservoir storage and require careful management to reduce reservoir impacts and manage risk related to the passage of higher flood events should they occur
-

Alternative Measure 5:
Apportionment Year Shift to a Water Year (November to October)

The analysis of **Alternative Measure 5** showed that:

- Changing apportionment rules to be calculated from November to October ensures winter releases of water from Canadian reservoirs supporting flood risk management are credited to Canada as apportionment to the United States; this would result in more

gradual releasing of flood water and assist in water supply storage and management in Canada

- The volume of apportioned water is not changed. However, the trade-off in changing the apportionment rules to a Water Year from a Calendar Year (January to December) results in a shift of timing for the apportioned water delivered to the United States, and slightly decreases the storage at Lake Darling in the United States.

Climate variability and change in the basin

There is significant evidence pointing to a high degree of natural variability in the Souris River basin's hydrometeorology. Both natural climate variability and the potential future impacts of human-driven climate change poise a formidable challenge to formulating an enduring water management plan for the basin. To better understand and plan for climate variability and change, the Study team reviewed recently published, regionally relevant scientific research characterizing the effects of human driven climate change on hydrometeorology. As part of this literature review, the Study team also summarized studies which investigated naturally occurring climate variability, as apparent within paleo-flood records collected in the vicinity of the Souris River basin. After performing a literature review, the study team performed basic statistical analyses of observed, hydrometeorological records collected throughout the Souris River basin. In addition to evaluating observed records, the Study team also conducted a comparative analysis of global climate model (GCM) based historical simulations versus projected, climate changed simulations of precipitation and temperature.

It was found that although future climate change may fall within the historic natural variability experienced in the basin, it is also possible that climate change may have an effect on the timing/seasonality, variability, intensity, frequency and duration of streamflow events. There is evidence of increasing temperatures in both the historic record and projections of future meteorology. There is more uncertainty and less consensus in observed and projected precipitation trends, however, in general the frequency and intensity of extreme precipitation events and annual precipitation is anticipated to increase. There is little consensus in the literature reviewed or observed records analyzed concerning trends in observed or projected annual streamflow.

The Study team was originally scoped to model sequences of climate changed hydrology specific to the Souris River basin. Generating climate changed hydrology involves the development of a hydrologic model calibrated and configured for continuous simulation. To fulfil this need, a MESH model ("Modélisation Environnementale, Surface et Hydrologie") of the Souris River basin was produced. MESH was selected to model the basin because it is effectively able to capture distributed storage effects and the physical processes associated with snow accumulation and melt. To derive climate changed hydrology, outputs derived from GCMs are required to force the hydrologic model. Raw GCM outputs must be downscaled and bias corrected prior to being adopted in support of water resources modeling and decision making. This process is resource intensive. Only one off-the-shelf downscaled and bias corrected product is available for the Souris River basin. This product is derived using a single carbon emissions pathway and a single GCM. Due to the considerable uncertainty associated with the assumptions required to

produce climate changed hydrometeorology, to appropriately characterize the effects of climate change on hydrology, results must be based on an ensemble of GCMs. Thus, for the current Study, the team was limited to developing a work flow and conducting a proof of concept run demonstrating how GCM based meteorological outputs could be used to derive climate changed hydrology using MESH and HEC-ResSim. As new GCMs and mechanisms for downscaling and bias correction become available, these data sources can be used along with the workflow defined as part of this study effort to further improve the Study Board's understanding of future hydroclimatic conditions in the basin.

To further characterize how human driven climate change and natural climate variability will impact water management in the Souris River basin, it is suggested that resources be dedicated to continued monitoring of observed hydrometeorology, improving the MESH model and the generation of GCM based assessments of projected climate changed hydrology. To address the residual risk that climate variability and change poise to future water management as part of the Study, it is recommended that adaptive management be incorporated in the operating plan being proposed for the Souris River basin.

Other water management considerations in the basin

Over the course of the Study, the Study Board addressed a number of important emerging water management issues in the basin.

Impacts of artificial drainage

There are public concerns that the drainage of marshes, prairie potholes and other wetlands – undertaken to allow for increased or more efficient agricultural production – has increased the severity of flooding in the basin. As a result of these concerns, a review of the possible impacts of artificial drainage from the basin was added to the Study's work plan.

The Study concluded that artificial drainage has increased the basin's effective drainage area (the portion of the basin that may contribute runoff), although the change is not uniform throughout the basin. The Study was not able to quantify the extent of artificial drainage across the entire Souris River basin due to a lack of complete, comparable data sets. The existing wetland inventories in the three jurisdictions are incomplete, use different classifications and are based on different imagery dates. (For a more complete analysis, please see: HH3: Souris River Basin Artificial Impacts Review)

During extreme floods, such as in 2011, wetland drainage has a minor to insignificant impact, as all the wetlands are filling and spilling. However, based on the available data, it is likely that wetland drainage has the greatest impact in the basin in average to moderate runoff events and floods, resulting in more frequent occurrences of a 1:10-year flood.

Wetland drainage is potentially deteriorating water quality in the Souris River basin. However, it is not possible within the scope of the Study to separate out and quantify this impact, given the

ongoing impacts of other activities on water quality, such as changing land management practices.

Since post-European settlement, the Souris River basin continues to experience extensive modifications through land use changes (e.g., urban and rural development, agriculture and industrial development, road and rail transportation networks). While the natural variability of floods and droughts in the basin will continue, there is a need to better understand the impacts of land use changes and climate change in the region.

Water quality

Water quality of the Souris River was identified as an important issue during the Study's public engagement process. In response, the Study developed a series of water quality PIs to help evaluate potential alternative operating measures. The United States Geological Survey (USGS) undertook an analysis of the Souris River water quality in relation to flow under the guidance of the Study Board.

The analysis was conducted at three locations in North Dakota: Sherwood, Minot, and Westhope. The Study found that variability in concentration for chloride, sodium, sulfate, and total dissolved solids is largely explained by the variability in flow, and can be used to evaluate minimum flow thresholds for each season. The variability in other constituents such as total iron, total suspended solids and nutrients was explained largely by other factors, including seasonality. The implications of minimum flow thresholds were not possible to evaluate with limited data.

The ISRB has a mandate to report yearly on compliance with the established water quality objectives for the two international border crossings near Sherwood and Westhope, North Dakota. Under this mandate, the ISRB has developed a two-year International Watersheds Initiative (IWI) project for evaluating water quality trends for the entire Souris River basin. The ISRB IWI project has run in parallel to the Study. The findings of this project, which began in 2020, could be used to enhance the water quality PIs developed under the Study. The improved water quality PIs will help assess the effectiveness of the operational changes with respect to water quality conditions.

Given the public interest in water quality conditions in the basin, the Study Board concludes that water-quality monitoring should be continued as a basin-wide, long-term activity. It is expected that such an activity would capture a full range of hydrological conditions, including changes on the landscape and reservoir operations. The resulting long-term dataset will be critical for evaluating changes in water quality as well as improving knowledge of interconnections between hydrological conditions, landscape changes and reservoir operations on water quality.

Aquatic ecosystem health

Although the Study did not directly investigate aquatic ecosystem health, it did develop several PIs that provide a measure of the influence that a proposed operational change may have. Similar to the water quality trends analysis being conducted by the ISRB, the Study recognized that the

continuous dissolved oxygen (DO) monitoring investigation being conducted by the ISRB as an IWI project will contribute greatly to improving understanding of processes affecting DO concentrations in the Souris River.

The Study Board concludes that the findings of this continuous DO monitoring study will be useful in improving the aquatic ecosystem health PIs developed under the Study and in assessing the effectiveness of the operational changes with respect to aquatic ecosystem health conditions.

In addition to the improvements in the aquatic ecosystem health PIs developed under the Study, the Study Board believes that the potential for interconnecting water quantity and quality modelling should be explored. The additional data and knowledge gained from the efforts related to water quality trend analysis and continuous water quality monitoring will offer new insights into the possible interactions between hydrology, climate-driven flow conditions, aquatic ecosystem health and landscape changes.

Manitoba-based concerns raised by PAG

Throughout the Study's engagement process, Public Advisory Group members from Manitoba raised region-specific concerns related to the Souris River in Manitoba in the river's reach from Westhope (at the North Dakota border) to its discharge into the Assiniboine River near Wawanesa. They suggested that more analysis is needed to address the following priority items:

1. a better understanding of the reconstructed hydrology for the Souris River including the reach from Westhope to Wawanesa, for more complete knowledge of how the river in the Manitoba reach may have been influenced by upstream control structures;
2. a better understanding of the United States to Canada apportionment and minimum flow rules established in the current transboundary operating agreement; and,
3. a more comprehensive assessment of how the river's water quality in the Manitoba reach may be impacted or benefited by the operations of the Souris River, including structures not in the Study scope such as the J. Clark Salyer National Wildlife Refuge.

Dam Safety

Dam safety analysis was not originally included in the recommended scope as a task in the workplan for the study. The Study did, however, consider an alternative that used regulation of flows and reservoir pool levels that in extreme events would reduce overtopping dam risk. In a December 21, 2020 letter from Governments, the IJC was advised that issues with respect to dam safety were outside of the scope of the study. In addition, Governments stated that they had separately provided direction to the 'designated entities' under the 1989 Agreement to begin technical discussions on understanding the hydrology of the basin that would support further work related to dam safety.

Several considerations surrounding the implications of various dam safety operating scenarios were investigated within the Study. These concepts and potential options were not brought to a Study conclusion due to the complexity of the tasks, lack of study resources, and the revised

direction by the Governments. Some dam safety elements oriented towards extreme hydrologic events were initially formulated (pool restrictions, target flow changes, as examples) but the complexity could not be appropriately addressed within the study.

The study has produced most if not all of the tools that will be required to assess the implications of modifying operational rules to accommodate dam safety criteria. Once the issue of dam safety is satisfactorily resolved, these tools are available to assess and identify a plan that is consistent with the 1989 Agreement and the 1909 Boundary Waters Treaty.

Adaptive management

Adaptive management is a structured, iterative approach for improving decisions through long-term monitoring, modelling and evaluation. It is increasingly recognized as having an important role to play in water management, particularly at the scale of large basins such as the Souris River basin. It can assess the effectiveness of water management efforts in light of changing environmental and socioeconomic conditions. It also may help decision-makers deal with the uncertainty of water supplies associated with climate variability and change in the basin.

Regardless of the alternative operating plan measures that may be adopted under the 1989 Agreement, there will continue to be a need in the basin for ongoing efforts in communication, monitoring, modelling and research to assess risk, address uncertainties and changing conditions and identify appropriate adaptive actions.

There are several important challenges for strengthening adaptive management approaches in the Souris River basin. These include:

- the fact that the 1989 Agreement covering the Souris River basin is not an instrument of the IJC, but rather an international agreement between the United States and Canada and therefore not easily modified;
- the need for a long-term funding commitment; and,
- the need to engage multiple agencies in different jurisdictions.

There appear to be opportunities for building on several of the Study's initiatives and findings, and incorporating and strengthening adaptive management approaches for managing water levels and flows in the Souris River basin within the context of the 1989 Agreement. These opportunities include:

- modifying the 1989 Agreement by clarifying in the Agreement the organization or organizations responsible for conducting the tasks associated with successful adaptive management and extending the period of review from five to 15 years;
- strengthening the role of performance indicators and Indigenous science; and,
- establishing an adaptive management committee for the Souris River basin.

Study Board Findings and Recommendations

Based on the results of the analyses described in this report, the Study Board presents its summary of findings and recommendations. The Study Board acknowledges that the governance mechanism of the 1989 Agreement differs in both countries. Canada has designated the Province of Saskatchewan as the Canadian entity for the construction, operation, and maintenance of the improvements mentioned in the Agreement, whereas in the United States, these responsibilities have been designated to federal agencies – the US Army Corps of Engineers and the US Fish and Wildlife Services. It is important to acknowledge that the ISRB has an oversight responsibility and function, under the purview of the IJC which includes providing the Commission and the designated entities, under the 1989 Agreement, recommendations on how flood operations and coordination activities could be improved. Keeping this in mind, under the ISRSB's analysis, the Study Team has grouped its analyses under a series of 5 themes, outlining its findings and recommendations. **It is important to understand that some of these findings and recommendations may result in changes to the 1989 Agreement. The Parties to the Agreement (i.e., the governments) will need to determine a resolution framework for these recommendations.**

Theme 1. Reviewing the 1989 Agreement

a. Finding: 1989 Agreement Language review for Annex A

The Study Board completed its review of the language of the 1989 Agreement. The Study Board agreed on an updated 2020 plain language document to strengthen the language for clarity and improved understanding. Six items were unresolved in the review. Improved plain language of the Agreement is useful to guide the IJC and its jurisdictions which operate the water structures in the river system.

Therefore, the Study Board recommends that:

The IJC support the plain language revisions and clarifications to the 1989 Annex A recommended by the Study Board (revised language will need legal review and an implementation plan). The IJC consider advising the governments on the six issues that need guidance, direction, and legal analysis by the Parties to the Agreement.

b. Finding: Performance of the 1989 Operating Plan

The Study Board concluded that, overall, the 1989 Operating Plan has performed well in providing water supply and flood control benefits.

The addition of Grant Devine Lake, Rafferty Reservoir, Boundary Reservoir, and Lake Darling to the Souris River System provided flood protection for the spring snowmelt in

2011, but does not provide enough flood storage for protection from runoff similar in magnitude to the summer 2011 basin-wide rainfall runoff events. However, the reservoirs do provide significant to modest flood protection from the Estevan, Saskatchewan reach to as far downstream as Westhope, North Dakota and into Manitoba for floods similar in magnitude to the major floods experienced in1969 and 1976.

In addition to the direct benefits to flood control and water supply, the presence of the Souris River Project reservoirs, as modelled under the baseline simulation, also resulted in benefits and impacts to secondary effects on environmental resources, socio-economic components, historic and cultural sites, water quality and recreation.

The Study Board recommends that:

The modeling systems developed by the Study, and used to evaluate flow scenarios (including the effects and performance of the 1989 Agreement), continue to be used and updated to evaluate operational performance.

Theme 2. Strengthening water supply and flood control benefits

Finding:

The Study Team has documented, through extensive analyses, the merits and effectiveness of the 1989 Agreement, in providing flood protection and water supply, within the constraints of the natural systems and human-built water infrastructure systems of the Souris River. While the 1989 Agreement is functioning well, options for improvements exist, but will result in a need to balance performance trade-offs.

Therefore, the Study Board recommends that:

The following suite of alternative measures be considered for incremental or marginal improvements to the 1989 Agreement:

1. **Modify the Winter Drawdown Elevation Targets** to build greater flexibility into reservoir operations by varying reservoir elevation targets according to antecedent moisture conditions in the basin

2. **Extend the Winter Drawdown Date** from February 1st to March 1st to provide additional river flow for improved environmental benefits during February

3. **Lower the Spring Maximum Flow Limits** to reduce flood peaks and agricultural flood risk during small to moderate floods in riverine reaches in North Dakota (i.e., floods under 57-85 m^3/s or 2,000 to 3,000 ft^3/s)

4. **Establish a Summer Operating Plan** to provide more guidance to reservoir operators to better manage summer reservoir operations under all conditions

5. **Shift the Apportionment rule calculations to a Water Year (November to October)** from the current Calendar Year (January to December) to ensure flood protection releases in November and December are credited towards apportionment.

Selecting the best options will need to consider the full suite of alternative measures, options within the measures, and seasonal sequencing, culminating in choices to replace or remain within established 1989 rules. Careful analysis of trade-offs is required by the Governments of Canada and the United States to find the best and most balanced options for Canada, the United States, Saskatchewan, North Dakota, Manitoba, and the citizens in the basin, including Indigenous Nations, and diverse stakeholders who have vested interests in the Souris River.

Theme 3. Improving data collection and management

Finding: Precipitation gauges

The Study Board identified that gaps in precipitation gauging exist, affecting the meteorological data and risk analysis, which could impair data analysis and decision-making for flow management.

Therefore, the Study Board recommends that:

The IJC, through the International Souris River Board, engage with all the appropriate agencies, to report regularly on any efforts to reduce identified gaps in precipitation gauging stations within the Souris River watershed.

The IJC work with the International Souris River Board to determine an appropriate reporting interval.

Finding: Streamflow metering gauges

The Study Board identified gaps in flow gauging (also found in previous studies). These gaps impair analysis of river flow data and risk analysis, which could impair flow management decisions.

Therefore, the Study Board recommends that:

The IJC, through the International Souris River Board, engage with all the appropriate agencies, to report regularly on any efforts to reduce identified gaps in streamflow gauging stations within the Souris River Watershed.

The IJC work with the International Souris River Board to determine an appropriate reporting interval.

Finding: Collection of additional hydrologic data

The Study Board identified gaps in key hydrological data and data collection in the Souris River basin. These include gaps in:

- monitoring snow survey data for flood forecasting and water supply management;
- soil moisture data that affect knowledge of antecedent conditions affecting hydrology; and,
- low-flow and drought monitoring tools for water supply decision support, including methods and datasets to better estimate evapotranspiration data for reservoirs and throughout the basin.

In addition, there is a need for improved hydrologic models targeted to the Souris River prairie topography, frozen ground conditions and artificial drainage conditions within the basin.

Each of these gaps and needs influence effective decision-making for flood protection and water supply management.

Therefore, the Study Board recommends that:

The IJC, through the International Souris River Board, engage with the appropriate agencies, to prioritize and report regularly on any efforts to reduce identified gaps in other hydrologic data within the Souris River Watershed.

The IJC work with the International Souris River Board to determine an appropriate reporting interval.

Finding: Better dissemination of hydrologic data

Better dissemination of hydrologic data is necessary to incorporate real-time meteorological and hydrological data for the Souris River basin. Reinvigorating the IJC website would allow for improved awareness of actual basin conditions by the public and other users of the IJC website and promote better flood protection and water supply awareness to serve as an advance warning system to guide mitigation measures, as well as to improve public awareness of flow operations management.

Therefore, the Study Board recommends that:

The IJC, through the International Souris River Board, develop better methods to disseminate all hydrologic data (including flood forecasting, water flows, and flow operations) in the Souris River watershed, and that these efforts be reported on regularly.

Finding: LiDAR and bathymetry for reservoirs

Area-capacity curves are used to understand the volume of water stored in reservoirs. Data gaps need to be filled to develop more accurate area-capacity curves for Rafferty and Grant Devine reservoirs. Gathering these data will improve flood forecasting, water supply and operational flow management of these reservoirs.

Therefore, the Study Board recommends that:

> The IJC work with the Saskatchewan Water Security Agency (through the International Souris River Board) to provide updates on identifying and filling in data gaps in the Rafferty and Grant Devine area-capacity curves (for example, using LiDAR or bathymetry) for developing improved hydraulic models.

Theme 4. Addressing other water management challenges in the basin

Finding: Artificial drainage impacts review

Artificial drainage is practiced throughout the basin. Insufficient scientific data exist to fully understand its potential impacts on water supply, water quality and apportionment for flow management. The public and many stakeholders have expressed concerns about artificial drainage risks and impacts. Regulations and legal requirements are continually being reviewed as scientific understanding of artificial drainage increases. The IJC and the Souris River basin resource agencies and public need to be aware of the current knowledge and legal requirements of artificial drainage and its potential impacts on operations management of the Souris River.

It is recognized that artificial drainage may have linkages to the IJC's mandate through apportionment. Furthermore, there are also public concerns on drainage impacts to water quality, water quantity and wetlands.

Therefore, the Study Board recommends that:

> The International Souris River Board share scientific understanding of Souris River artificial drainage every two years, to advance evolving expert and public knowledge of the impacts, as well as the associated legal and regulatory requirements.

Finding: Adaptive management

Adaptive management approaches have been established in the 1989 Agreement (e.g., adjusting flows and reservoir levels to address climate and hydrologic variability). Building on several of the Study's initiatives and findings, there are opportunities to strengthen adaptive management approaches for managing water levels and flows in the Souris River basin within the context of the Agreement. Furthermore, adaptive management approaches would seek to continually adapt

to new knowledge, new science, and changing basin conditions for improved operations and decision-making.

Therefore, the Study Board recommends that:

The IJC (and, where necessary, the Parties to the Agreement) consider strengthening adaptive management approaches in managing water levels and flows of the Souris River, with the understanding that any changes to the 1989 Agreement will require government to government consensus. Strengthening adaptive management may include, among other things:

- clarifying roles and responsibilities for conducting adaptive management tasks (e.g., determine if the ISRB, a new adaptive management committee, or a different governance structure is best suited to assume adaptive management roles; support roles of operating and designated agencies participating in adaptive management, etc.);
- extending but formalizing the period of review of the Operating Plan from five years to potentially up to 15 years (a better time frame for adapting to new knowledge); and,
- clarifying the roles and responsibilities of the IJC and the International Souris River Board in adaptive management studies and periodic reviews.

Adaptive management should consider the on-going role of performance indicators and how they may be a useful tool in guiding new knowledge, studies and decisions. Adaptive management should consider the role of Indigenous Nations and Indigenous Science in the development of PIs for the Souris River, and how this knowledge can be incorporated and strengthened under the leadership of the International Souris River Board. The ISRB should be responsible for reviewing and updating the PIs developed in the Study and collaborating with Indigenous Nations to develop performance indicators that reflect their interests.

Adaptive management will require dedicated resources from many agencies. The IJC and Governments will need to work with the ISRB to consider options for establishing adaptive management governance processes and activities.

Moving forward, if adaptive management is to be formally enhanced for the Souris River basin – with its commitment to continuous monitoring and periodic review of the performance of the operations -- then it will need to have some foundation in an updated Agreement between the two countries.

Theme 5. Building on the Study's engagement and outreach

Finding: Continued engagement with the Public Advisory Group and the Resource and Agency Advisory Group

The Study Board has undertaken extensive public and resource agency engagement over the course of the Study. There are now increased interests and expectations for future engagement beyond the Study, and for an ongoing dialogue between these groups and the IJC into the future.

Therefore, the Study Board recommends that:

> The IJC and International Souris River Board consider continued engagement with the Study's Public Advisory Group and Resource and Agency Advisory Group.

Finding: Engagement with Indigenous Nations

The Study Board sought input from Indigenous Nations with current and ancestral interests in the Souris River basin. The increased awareness from Indigenous Nations has led to an interest in continued engagement beyond the Study, through an Indigenous Advisory Group and Indigenous representation on the International Souris River Board.

Therefore, the Study Board recommends that:

> The IJC continue to engage with Indigenous Nations. Indigenous Nations expressed interest in forming an Indigenous Advisory Group and participating as Board Members on the International Souris River Board.