A Review of International Water Quality Objectives in the Souris, Red, Rainy-Lake of the Woods and St. Croix River Basins

Historical Perspectives, Recent Trends and Future Directions

A Report to the Governments of Canada and the United States

January 2017

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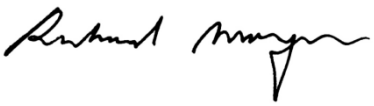

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Executive Summary

This report provides a review of the status of international water quality objectives (WQOs) and Alert Levels for the four International Joint Commission (IJC) boards with a water quality mandate that are located outside of the Great Lakes Basin. The boards that are the focus of this report are the International Souris River Board (ISRB), the International Red River Board (IRRB), the International Rainy-Lake of the Woods Watershed Board (IRLWWB) and the International St. Croix River Watershed Board (ISCRWB). The following two text boxes summarize the Key Messages and Findings from the report and list a series of Recommendations that are directed either to the IJC or to the governments.

Key Messages and Findings

- There are differences in the history, type and number of water quality objectives (WQOs) and, where applicable, Alert Levels used by the four IJC boards with a water quality mandate outside of the Great Lakes Basin. This is the result of the specific water quality needs of each board in each watershed. The use of Alerts Levels reflects some of the constraints placed on boards in obtaining government approval to modify or expand their sets of WQOs.
- These four boards depend on water quality monitoring data provided by federal agencies, notably Environment and Climate Change Canada (ECCC) and the United States Geological Survey (USGS), to report to the IJC at least annually on water quality trends and occurrences of WQO exceedances.
- For international monitoring stations on the Souris River and the Red River, exceedances in several water quality parameters have been observed over the past decade. For some parameters, concentrations appear to be increasing (i.e. chloride, sulfate and total dissolved solids) in both rivers. These observations are consistent with those made by the international Souris River and Red River boards and help support further investigation of the causes of these exceedances and advising appropriate agencies regarding potential response strategies.
- Setting water quality objectives for phosphorus and nitrogen is a priority of the International Red River Board (IRRB), and development of objectives for these parameters is a key deliverable of its nutrient management strategy. Although objectives for these nutrients are part of the set of WQOs under the purview of the International Souris River Board, they may require updating.
- Generally, WQO levels for the Souris and Red rivers are below or within the range of water quality standards, objectives or guidelines in place for participating jurisdictions

suggesting that further review should focus on reviewing the most current and best-available science as to whether the objectives are relevant to the particular river system, and whether there are other environmental factors that need to be considered.
- Based on narratives provided by each of the four boards, there is a commitment by the boards to review and, if necessary, recommend revisions to sets of WQOs on a periodic basis. Further, there is an expectation by these boards that the IJC will provide guidance and assistance with their WQO review processes and that processes for updating WQOs will be more efficient.

Recommendations

Directed to the IJC , its boards and its operations

- Direct boards with water quality mandates outside of the Great Lakes Basin to ensure that WQOs and Alert Levels are reviewed periodically (e.g. every 5 years) and, if warranted, provide recommendations to the IJC regarding changes in numerical values or in the addition or removal of WQOs. Then the IJC can provide such recommendations to governments for their consideration.
- For the International Rainy-Lake of the Woods Watershed Board, it is recommended that new WQOs and, where appropriate, Alert Levels be forwarded to the IJC as per the board's directive and submitted to the governments as recommendations for their consideration.
- It is recommended that these four boards assess whether appropriate processes are in place to interpret and, if warranted, respond to exceedances of WQOs and Alert Levels.
- In instances where sustained exceedances of WQOs are observed, boards are encouraged to investigate the factors responsible for the exceedances, which may be the result anthropogenic activities or natural system processes. If appropriate, boards should develop advice regarding potential mitigation and restoration solutions. Funding such as through the International Watersheds Initiative could be pursued. Collaborative proposals are recommended for those boards that share common water quality issues.
- As follow-up to this report, it is recommended that IJC staff collaborate with board members of these four boards responsible for water quality reporting in their respective basins located outside the Great Lakes on a review of current, best available processes used to review and update WQOs and Alert Levels. This review would provide a roadmap by which boards could more efficiently deliver on their water quality reporting mandates.

Directed to the governments of the United States and Canada

- As new scientific knowledge and understanding is made available and conditions change in shared waters along the border, it is recommended that the governments work with the IJC to make the process of WQO revision and updating more efficient for IJC boards working in basins located outside the Great Lakes with water quality mandates.
- Where exceedances of WQOs are documented and prioritized for follow up study by the

boards, it is recommended that there be in place an agreed-upon process between the governments and the IJC for notification and, if applicable, response and intervention by the appropriate agencies.

- Stemming from the Key Messages and Findings itemized in this report, it is recommended that governments assess the adequacy of water quality monitoring in all shared waters located outside of the Great Lakes Basin for the detection of trends in water quality and, where applicable, for comparison against existing water quality objectives, standards or guidelines.
- Where water quality issues are evident in any of the watersheds of the four boards discussed in this report or elsewhere in transboundary systems outside of the Great Lakes Basin, it is recommended that governments – in collaboration with the IJC – investigate the causes of those issues, especially in the context of climate change, towards improved management of shared waters.

For over a half century, in advising governments in accordance with the Article IX Reference function under the Boundary Waters Treaty (BWT), the International Joint Commission (IJC) has recommended Water Quality Objectives (WQOs) for several boundary and transboundary waters between the United States and Canada. Outside of the Great Lakes Basin there are four IJC boards that have mandates to monitor and report on water quality at select international border locations. These are the International Souris River Board (ISRB), the International Red River Board (IRRB), the International Rainy-Lake of the Woods Watershed Board (IRLWWB), and the International St. Croix River Watershed Board (ISCRWB). Each board tracks and reports on its own set of water quality parameters, although some parameters are common to multiple boards. Many of the internationally-agreed upon parameters and associated WQOs reflect historical concerns over polluted waters. WQOs and, in some instances, Alert Levels, for water quality parameters are used by the boards to characterize the water quality condition of transboundary waters, to enable a means by which boards can track improvement or deterioration of water quality, and to provide observational data that may support interpretations of factors responsible for changes in water quality.

This review arose from concerns expressed by boards, notably the ISRB and the IRRB, over the past several years regarding frequent or sustained exceedances of particular WQOs. As a result, the IJC felt it prudent to review the WQOs and Alert Levels reported on by all four boards

with water quality mandates and to develop guidelines regarding how boards might review and potentially revise their WQOs and Alert Levels. The objectives of this review are to (1) Detail the history and background behind the selection of current WQOs and, where applicable, associated Alert Levels, (2) Summarize information on data (e.g., station location, sampling time and frequency, data quality control) reported on at each monitoring station, (3) Conduct a preliminary evaluation of the modern relevancy of current WQO levels and (4) Provide recommendations and suggested next steps on how the IJC and its boards could proceed with advising governments on any recommended modification, discontinuation or addition of WQOs to better reflect current criteria, advances in analytical detection and precision, and contemporary sources of pollutants. This report is to be used as a foundational piece to aid the IJC and its boards as they look to potentially modernize WQOs and Alert Levels. Human activities and environmental conditions in each of the four international watersheds have led to different sets of WQOs that are monitored and reported on by the boards today.

- For the ISRB, WQOs are in place for border monitoring locations at Sherwood, North Dakota (ND), near the Saskatchewan-ND border and at Westhope, ND, near the ND-Manitoba (MB) border. The WQOs were adopted from what was established by the Souris River Bilateral Water Quality Monitoring Group in 1991 through a consensus building process. The current ISRB Directive states that its Water Quality Monitoring Program and WQOs be reviewed at least every five years and develop recommendations, as appropriate, to the IJC to improve the Program.
- For the IRRB, in 1969 the U.S. and Canadian governments authorized the IJC to establish continuous supervision over the quality of waters in the Red River crossing the International Boundary near Emerson, MB, and to recommend amendments or additions to the objectives when warranted to the IJC. In 1984, the board introduced the concept of Alert Levels in lieu of establishing additional WQOs. In 2010, the board modified one of its WQOs (replacing fecal coliforms with *Escherichia coli*), which is the most recent change to any of the WQOs or Alert Levels across the four boards in this

review.

- For the IRLWWB, the most recent set of WQOs were approved by U.S. and Canadian federal governments in 1965 for multiple pollution criteria in the Rainy River (e.g. sanitary sewerage, suspended solids, and "slime" bacteria). Despite successive efforts by the precursor to the IRLWWB, no additional WQOs have been approved by governments. However, a revised Directive from the IJC in 1992 introduced the ability for the previous board to establish and use water quality and/or aquatic ecosystem health alert levels for parameters for which water quality objectives had not been set, with particular focus on priority issues within the basin such as water quality, alien aquatic invasive species, climate change indicators and adaptation, and ground and surface water contamination. It is anticipated that as a result of the IRLWWB's most recent Directive in 2013, WQOs and Alert Levels will be reviewed and modernized.
- The WQO for the ISCRWB stems from a 1961 reference from the U.S. and Canadian governments to address industrial and municipal pollution and adopt WQOs. The monitoring stations along the river are located at Milltown, New Brunswick, and Forest City, Maine. Expansion of a monitoring plan for assessing changes in ecosystem quality and sampling protocols in 1984 was deemed by governments to be within the domain of the 1961 reference. Except for the addition of a composite measure of water quality, called a Water Quality Index (WQI), no changes have occurred to the ISCRWB's only WQO, dissolved oxygen.

Two of the four boards, the ISRB and the IRRB, have repeatedly reported on WQO exceedances for several parameters. For the ISRB, parameters that consistently exceed WQOs are total phosphorus (TP), sodium, sulfate, total dissolved solids (TDS) and total iron. The levels of these parameters at the two transboundary locations along the Souris River (Sherwood and Westhope) are consistent with widespread loading from across the watershed rather than from point sources or single releases of specific constituents. For the IRRB, WQOs for TDS, chloride and sulfate are frequently exceeded, as are iron, cadmium and manganese in relation to the

board's Alert Levels. Like the ISRB, these exceedances are consistent with widespread loading across the watershed. In addition, exceedances of sulfate and chloride at the border are likely linked to discharges from Devils Lake. Rare exceedances of jurisdictional guidelines or standards for phosphorus and some metals have been observed in the St. Croix River at the Milltown monitoring station, but because of local knowledge that can explain these exceedances they have not caused the ISCRWB to review its WQOs. In the absence of numerical WQOs or Alert Levels for the IRLWWB, trends in water quality exceedances cannot be assessed in a manner similar to the other boards.

As an initial investigation of exceedances, WQO thresholds at international monitoring locations can be compared to current state and provincial and, where applicable, federal water quality criteria. Such a comparison ought to be supplemented with a binational assessment as to whether the thresholds and criteria are based on the most current and best-available science, relevant to a particular river system, and if there are other environmental factors that need to be considered. Another potential complication is that objectives for specific parameters may differ between jurisdictions for a shared river.

Where exceedances are determined to be a concern, such as for those select parameters identified by the ISRB and the IRRB, follow-up study may be warranted to understand causal factors of the observed trends in water quality and make recommendations regarding WQO levels or mitigative measures. In prairie landscapes, such factors may include changes in water management as a result of floods or droughts, resource extraction industries, changes in land use, particularly agricultural land use, aging or outdated municipal infrastructure, including for wastewater treatment, and climate change, among others, as well as interactions between each of these.

The four boards considered in this review provided narratives that describe their perspectives on WQOs and any related water quality issues that they wish to highlight.

- The ISRB has determined that a comprehensive review of WQOs is a priority. In the short term, the board's Aquatic Ecosystem Health Committee (AEHC) will review sampling and analysis protocols, notification procedures, and any other monitoring issues, such as identifying and documenting what the current water quality objectives are meant to protect, be it human health, aquatic life, or some other beneficial use. A review of current provincial and state standards/objectives within the Agreement's jurisdiction will also be conducted. Over the medium to long term, there are plans to establish a mechanism for the periodic review of WQOs, assess the applicability of WQOs in use elsewhere for the Souris River, consider the addition of Alert Levels and composite measures, such as water quality indices, and investigate potential sources and causes of observed exceedances.
- As part of the IRRB nutrient management plan, the development of objectives for nutrients in the Red River is a top priority. The board also recognizes that the existing five water quality objectives (i.e. DO, TDS, chloride, sulfate, and *Escherichia coli*) have been in place for many years and that a review is warranted. The specific interest in reviewing TDS, chloride and sulfate stems from concerns over water management projects that appear to be affecting water quality. Furthermore, the addition of Red River phosphorus and nitrogen WQOs would supplement the IRRB's work in delivering its nutrient management strategy.
- For the IRLWWB, WQOs should be focused on a small number of key issues of relevance to the binational management of the boundary and transboundary waters of the drainage basin. Existing objectives only pertain to the Rainy River and do not reflect the broader geographic mandate of the current watershed board. The board intends to work towards recommending revised WQOs and a suitable and updated list of Alert Levels that reflect current issues and are measureable and realistic for the waters of the basin. The board is confident that any recommendations made regarding the revision of objectives will be welcomed given that governments have signaled that concerns over current water quality conditions in the Rainy-Lake of the Woods basin require

coordinated action.

- Over at least the past ten years, the St. Croix River has generally enjoyed good to excellent ecological condition, as expressed through its WQI, a composite measure based on several water quality parameters. However, the board recognizes that industrial development, aging infrastructure and climate change pose threats to the maintenance of this water quality, especially in the lower watershed. Hence, the board sees value in carrying out time-series analyses of select water quality parameters to establish baseline water quality levels and track changes over time. If problems are identified in the future then this may lead towards recommendations regarding changes to its WQOs.

While IJC boards are the primary instigators for any recommended changes to their respective WQOs and Alert Levels, there is a critical role for the IJC to help facilitate and coordinate board activities in the area of water quality and to provide guidance on the processes that may be involved.

Abbreviations and Acronyms:

AEHC – Aquatic Ecosystem Health Committee
BOD – Biological Oxygen Demand
BWT – Boundary Water Treaty
CCME - Canadian Council of Ministers of the Environment
DO – Dissolved oxygen
ECCC – Environment and Climate Change Canada
IJC – International Joint Commission
IRLWWB – International Rainy-Lake of the Woods Watershed Board
IRRB – International Red River Board
ISRB – International Souris River Board
ISCRWB – International St. Croix River Watershed Board
IRRWPB – International Red River Water Pollution Board
POR – Period of record
TDS – Total dissolved solids
USGS – U.S. Geological Survey
WQC – Water Quality Committee
WQI – Water quality index
WQO – Water Quality Objective

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1. Rationale for the Water Quality Objective Review

The protection and management of shared waters between international jurisdictions poses unique challenges for federal agencies. Between the United States and Canada, there is a mosaic of lakes and rivers that either form or traverse the international border. For over a half century, in advising governments in accordance with the Article IX Reference function under the Boundary Waters Treaty (BWT), the International Joint Commission (IJC) has recommended the adoption and use of Water Quality Objectives (WQOs) for several of these boundary and transboundary waters between the United States and Canada. The governments have, in some cases, accepted IJC recommendations to establish and maintain WQOs as part of the continuing supervision of water quality in certain transboundary and boundary waters, with the assistance of advisory boards. These boards keep the IJC informed of water quality conditions thereby enabling the IJC to report to governments on references under the BWT and other bilateral agreements. The federal government's concern over transboundary water quality dates back to Article IV of the Boundary Waters Treaty of 1909, which states "*It is further agreed that the waters herein defined as boundary waters and waters flowing across the boundary shall not be polluted on either side to the injury of health or property on the other*." This reflects the government's long-standing commitment, shared by the IJC, to protecting water quality across the boundary.

References under Article IX of the BWT requesting that the IJC investigate and report on water quality, water use and conservation, have been issued to the IJC for multiple boundary and transboundary waters since 1912. References have been issued on water quality at various times and for various geographies across the boundary over the history of the IJC, including: a multiple system pollution reference in 1912, the Great Lakes in 1946, the St. John River in 1972, the St. Croix River in 1955, the Lake of the Woods and Rainy River in 1959, the Red River in 1964, the Skagit River in 1971, the Saint John River in 1972, the Poplar River in 1977, the Flathead River in 1985 and Lake Champlain (Missisquoi Bay) in 2004 and 2008. References under the BWT regarding the bilateral Great Lakes Water Quality Agreement have been issued

to the IJC on Great Lakes water quality in 1972, 1978, 1983, 1987, and 2012. In a 2005 exchange of notes between the two governments, the IJC was provided with an Article IX reference to report on water quality monitoring in the Souris River basin in accordance with the 1989 Souris River Agreement.

Following the completion of reference reports, governments accepted IJC recommendations for the adoption of WQOs and authorized continuing monitoring and reporting on WQOs by the IJC in three boundary water or transboundary water areas located outside the Great Lakes: the St. Croix River, the Red River and the Rainy River. Through an exchange of notes between the governments under the bi-lateral 1989 Souris River Agreement, the IJC was assigned additional water quality reporting responsibilities in the Souris River basin. WQOs are currently in place and monitored for the IJC and governments by the International Souris River Board (ISRB), the International Red River Board (IRRB), the International Rainy Lake of the Woods Watershed Board (IRLWWB) and the International St. Croix River Watershed Board (ISCRWB).

1.1 What Are Water Quality Objectives?

WQOs recommended by the IJC and accepted by U.S. and Canadian governments are concentration levels, other measures, or narrative goals which are intended to support the designated uses of water at a specific site (*Twenty-Fifth IRRB Report, 1985*, *Halliday et al. 1991*). Such uses could include objectives for recreation, livestock, irrigation for agriculture, and protection of native species and other species of interest, among others. Specific objectives for a site typically define allowable levels of particular chemical or microbiological contaminants. Based on an early description, WQOs are viewed "*as a tool for effecting water quality management; Water quality objectives are concentration levels prescribed for water or biota which, if exceeded, may constitute a potential risk to one or more uses of that water; objectives therefore describe, in part, the poorest quality of water which will not only provide for, but also protect designated uses of that water*" (*Twenty-Fifth IRRB Report, 1985*). From the same

report, WQOs can also be regarded as a "*numerical concentration limit or narrative statement, based on scientific criteria, relevant socio-economic and other factors, which has been negotiated to support and protect the designated uses of water"*. By convention, a WQO for boundary water is a water quality target that is developed from scientific analysis, recommended by the IJC in a report, and accepted by the two federal governments in a response to the IJC. In responding to the IJC on a WQO recommendation, the two federal governments may solicit input or consent from state and provincial authorities or otherwise obtain jurisdictional consensus, but this is not required.

In the past, water quality constituents selected for inclusion on a board's recommended WQO list were agreed upon by Board members. Criteria used to select WQO constituents and associated target levels (i.e., concentration thresholds) have largely involved existing or predicted human activities, the nature of existing state/provincial monitoring programs and their water quality criteria, and the prevailing water quality. In some instances, regional flow patterns and seasonality are considered when selecting recommended WQO levels (*Twenty-Fifth IRRB Report, 1985*).

1.2 How Are Water Quality Objectives Used?

WQOs serve as benchmarks against which observational data can be compared. Many are meant to be protective of ecological condition, but some are intended to protect other uses (e.g., drinking water, livestock watering, irrigation, and recreation). An important outcome of using WQOs to guide water quality management is the actions taken if an exceedance occurs. An exceedance refers to a situation where a monitoring instrument or laboratory analysis of a collected water sample has a verified concentration level that is different (higher or lower depending on the type of parameter) than the WQO concentration or threshold. An exceedance should trigger a response mechanism; however, specific mechanisms will vary by board and by water quality parameter. In addition, as analytical results from accredited

laboratories undergo quality control procedures, they are often not available for many months after sample collection. This can impose a lag time on reporting, which may further affect selection of response mechanisms to exceedances. As an example, for the IRRB, exceedances may result in the following:

> "*- agencies will be notified that there has been an exceedance and that a specified use may be at risk so that they may be able to take appropriate action;*
> *"- depending upon the magnitude of the exceedance, or the duration of non-compliance, the Board may request, or any agency may initiate with the cooperation of others, special follow-up surveys to confirm the results or to further elucidate the potential problem;*
> *"- the Board will annually report or if it feels necessary on an event basis, to the IJC concerning noncompliance-much in the same way as it does at the moment with respect to the adopted and proposed objectives.*
> *"- the agency responsible for following up on the exceedance will report to the board on the nature of the problem and what remedial action has been taken. The Board will then advise the Commission either by letter or in the annual report depending on the gravity of the situation*" (*Twenty-Fifth IRRB Report, 1985*).

In conjunction with WQOs, the use of "Alert Levels" was introduced to provide additional information on water quality issues within the Red River and Rainy-Lake of the Woods basins. Details on the chronology of Alert Levels for these Boards are described in detail below. According to the IRRB's Twenty-fifth report (1985) "*Alert Levels are concentrations or narrative statements based on criteria, existing quality and other factors, which have been derived to trigger investigative action by the Board into the potential risks to water uses caused by contravention of these Levels".* Unlike WQOs, Alerts Levels do not have to be government approved. Alerts Levels go beyond the list of WQOs that are defined for a specific region and could be established for any parameter for which at least one of the agencies (such as

provinces, states or the federal governments) have domestic objectives, water quality standards or guidelines (or interim objectives, standards or guidelines) (*Clark and Sellers, 2014*). Alerts Levels have included several biological, physical and chemical constituents, such as trace and macro-metals, pesticides and organometallic contaminants. For the IRLWWB, Alert Levels are based on the most stringent value for any jurisdictional or regulatory party. As such, values which exceed Alert Levels would be of potential concern to one of the regulatory agencies and should trigger an appropriate response. Alert Levels can be viewed as pseudo-objectives but are clearly monitoring tools which, when exceeded, 'flag' a condition, which the Board should assess in terms of the magnitude of the problem, implications to water uses and possible resolutions.

1.3 Why Review These Water Quality Objectives?

The IJC has in its directives to those boards that oversee water quality that WQOs be periodically reviewed to ensure they reflect current criteria, advances in analytical detection and precision and modern pollution, among other considerations. For example, as stated in the IRRB's Twenty-Fifth report (1985) "*it is intended that the numerical objectives and the list of constituents [WQOs] be reviewed periodically and updated on the basis of new scientific and technological information. Ongoing evaluation, review and updating of today's water quality objectives must be an active administrative process and not simply a statement of intent. Numbers formulated today will be different than those formulated five years from now simply because our understanding of how systems respond to pollutants in the environment is increasing day by day*." Therefore, an understood responsibility to applying WQOs as a means to assess water quality condition is that they be periodically reviewed for accuracy and relevancy. Reviews may be initiated by boards for multiple reasons, including unresolved exceedances or new scientific and technological information. On the basis of reviews, changes may be recommended to governments, whose approval is required for the introduction of new WQOs or the modification of existing WQOs.

Over the last decade there have been consistent exceedances for several WQOs at Red and Souris river transboundary monitoring locations and occasional exceedances at the downstream St. Croix River monitoring location. These exceedances have caused particular concern for the ISRB and IRRB resulting in investigation by the boards, the IJC, and government agencies on both sides of the border. To better understand the context for these exceedances, it is necessary to first determine the set of criteria used to establish the original WQOs including any factors which may influence specific parameters. A second step is to compare current WQO levels to state, provincial, and where applicable federal quality standards or guidelines to establish expected ranges or quantitative values for each parameter. If WQO levels are found to reflect existing state and provincial water quality standards (or the equivalent), then the issue turns to the basin from which there could be numerous causes for the exceedances. Depending on the water quality parameter, exceedances could be the result of both outdated WQOs and water quality issues in the basin. In prairie landscapes, such factors may include changes in water management as a result of floods or droughts, resource extraction industries, changes in land use, particularly agricultural land use, aging or outdated municipal infrastructure, including for wastewater treatment, and climate change, among others, as well as interactions between each of these.

With the longstanding exceedances observed for several WQOs in the Red and Souris rivers and recognition that some WQOs may be overdue for review and revision, the IJC determined it is an appropriate time to complete a review of all criteria related to WQOs (past and present). This review will provide better handling and accountability of WQOs and an improved ability to track and respond to water quality issues along the U.S.-Canada transboundary region. To provide a collective synthesis of WQOs and Alert Level functions for each board, the objectives of this review are to (1) Detail the history and background behind the selection of current WQOs and, where applicable, associated Alert Levels, (2) Summarize information on data collected (e.g., station location, sampling time and frequency, data quality control) at each monitoring station, (3) Conduct a preliminary evaluation of the modern relevancy of current

WQO levels, and (4) Provide recommendations and suggested next steps on how the IJC and its boards could proceed with advising governments on a recommended modification, discontinuation or addition of WQOs to better reflect current criteria, advances in analytical detection and precision, and contemporary sources of pollution. This review is to be used as a foundational piece to aid future decision making by the IJC and its boards. The four IJC boards that are covered in this review include the International Souris River Board (ISRB), International Red River Board (IRRB), the International Rainy-Lake of the Woods Watershed Board (IRLWWB), and the International St. Croix River Watershed Board (ISCRWB) (Figure 1). It does not cover the water quality objectives for the Great Lakes as provisions for the establishment and revision of such objectives are covered through the Great Lakes Water Quality Agreement (GLWQA 2012).

2. History and Genesis of the WQOs

The following sections detail the history of WQO and Alert Level development for each of the boards mentioned above and what is currently in their mandate on water quality assessment.

2.1 WQOs: International Souris River Board

In May 1959 the International Souris River Board of Control (ISRBC) was formed by the IJC. The directive for this board charged it with the responsibility of ensuring compliance with Interim Measures set out in 1958. WQOs for the current ISRB were adopted from what was established by the Souris River Bilateral Water Quality Monitoring Group ("Group") on April 1, 1991. This Group was established pursuant to the October 26, 1989, *Agreement between the Governments of Canada and the U.S. for Water Supply and Flood Control in the Souris River Basin*. These WQOs were established from data at two transboundary locations: Saskatchewan/North Dakota and Manitoba/North Dakota and the WQOs were derived through a consensus building process. For each objective, the numerical value was derived by comparing the objectives, guidelines and/or standards from the appropriate jurisdictions, in this case: USEPA,

Environment Canada, ND Department of Health, Saskatchewan Department of Environment and Public Safety, and Manitoba Department of Environment (*Halliday et al. 1991*).

In 2000, the IJC directed the International Souris-Red Rivers Engineering Board to transfer its responsibilities to the ISRBC and the IJC changed the name to the ISRB. The federal governments, in a 2005 exchange of diplomatic notes, provided the IJC with a reference to assist with the implementation and review of a Joint Water Quality Monitoring Program pursuant to the 1989 Canada-U.S. Agreement for Water Supply and Flood Control in the Souris River basin. In 2006, the IJC changed the ISRB's mandate to provide a more encompassing watershed approach. The IJC's 2007 directive reflects the full range of the single board's new responsibilities, which include ensuring compliance with the apportionment measure, reporting on activities that could affect transboundary water flows, providing oversight of flood operations, reporting on compliance with water quality objectives, reviewing existing water quality objectives every five years, developing new recommendations regarding water quality objectives, reporting on aquatic ecosystem health issues and involving the public in its work. Unlike the IRRB, IRLWWB and the ISCRWB, the ISRB does not currently have Alert Levels in place. The current ISRB Directive states that its Water Quality Monitoring Program and WQOs be reviewed at least every five years and develop recommendations, as appropriate, to the IJC to improve the Program. Additional details on the formation of ISRB are provided in the historical section for the IRRB.

2.2 WQOs: International Red River Board

On October 1, 1964, the governments of Canada and the United States submitted a reference to the IJC requesting an investigation of pollution in the waters crossing the international boundary in the Red River. Following receipt of the reference, the IJC established the International Red River Water Pollution Board on December 2, 1964, and appointed technical experts to the Board from both countries. The IJC provided detailed instructions to the Board in

the form of a directive which asked that all relevant water quality information be examined, pollution sources identified and remedial measures determined. The International Red River Water Pollution Board conducted investigations from 1965 to 1966 and submitted a report to the IJC in October 1967. The IJC conducted public hearings on April 11, 1968 and reported to the governments on their findings, recommendations and conclusions. The key recommendation was that WQOs, as defined in the IJC report, be accepted by governments. In letters dated May 13 and 14, 1969, the governments informed the IJC that the recommendations contained in the IJC's report to governments were accepted and approved. The two governments specifically authorized the IJC to establish continuous supervision over the quality of waters in the Red River crossing the International Boundary and to recommend amendments or additions to the objectives when warranted by the IJC. The IJC recommended the establishment of WQOs for a limited number of variables at the international boundary on April 11, 1968 and the recommendation was approved by governments on May 4, 1969. Shortly after, the IJC established the International Red River Pollution Board (IRRPB) on June 10, 1969. The parameters included on its WQO list were: dissolved oxygen (DO), total dissolved solids (TDS), chloride, sulfate, and fecal coliforms (*Thirtieth IRRB Report, 1990*).

At the November 13, 1984 IJC semi-annual meeting held in Winnipeg, the Board introduced the concept of Alert Levels in lieu of establishing additional WQOs. Alert Levels for the most significant water chemistry variables were developed and approved by the Board at its January 14, 1986, meeting. A compendium of the analytical methods used was prepared in 1990 (*Thirty-Ninth IRRB Report, 1999*). After the reconfiguration of IRRPB and the International Souris-Red Engineering Boards, the IRRB and ISRB were created and its WQOs and Alert Levels were later transferred to the IRRB in 2000. *Escherichia coli* replaced fecal coliforms as a water quality objective on October 1, 2010. According to the 2001 IRRB Directive regarding transboundary water quality, the Board's duties shall be to: (1) Maintain an awareness of basin-wide development activities and conditions that may affect water levels and flows, water quality and the ecosystem health of the Red River and its transboundary tributaries and inform

the IJC on transboundary issues; (2) provide a continuing forum for the identification, discussion and resolution of existing and emerging water-related issues relevant to the Red River basin; and (3) recommend appropriate strategies to the IJC concerning water quality, quantity and aquatic ecosystem health objectives in the basin.

2.3 WQOs: International Rainy-Lake of the Woods Watershed Board

The IJC received a reference on water pollution in the Rainy River and Lake of the Woods in 1959. In its 1965 report to governments in accordance with this reference, The IJC recommended the establishment of WQOs for the Rainy River. Governments agreed with this recommendation, and asked the IJC to supervise water quality on a continuing basis, which led to the establishment of the International Rainy River Water Pollution Board (IRRWPB) on January 18, 1966. The 1965-approved WQOs set forth multiple criteria for several pollutants such as sanitary sewerage, suspended solids, and "slime" bacteria. These objectives were for the most part qualitative, seeking to reduce pollutants to a point where they were not conducive to undesirable conditions. Specific quantitative criteria were prescribed only for coliforms and dissolved oxygen concentrations. Over the ensuing decades, there were multiple initiatives by the IRRWPB to review and recommend revised and/or additional WQOs for the Rainy River. For example, a 1981 IRRWPB report provided details regarding the criteria for selecting specific objectives and provided a more comprehensive list of parameters and recommended WQOs for the Rainy River. Parameters included: bacteria, pH, TDS, ammonia, DO, polychlorinated biphenyls (PCBs), cadmium, copper, iron, lead, manganese, mercury, nickel, zinc, nitrates, pesticides, color, suspended solids, turbidity, odor, temperature, arsenic and organic compounds. By the early 1980s, the list of parameters of concern had expanded. Although recommendations were made by the IRRWPB for revised general and specific additional water quality objectives, no further WQOs were approved by the governments beyond what existed in the 1965 original list. Thus, the current IRLWWB does not have WQOs beyond those inherited from the former IRRWPB. Further, these historic objectives apply only

to the Rainy River and not to the expanded geographical mandate of the current IRLWWB. Therefore, there are no modern WQOs for the Rainy River and no international WQOs for Lake of the Woods or the rest of the boundary waters (*Clark and Sellers, 2014*).

In 1992, the IJC provided the IRRWPB with a revised Directive, which introduced the ability for the Board to establish and use Alert Levels; effectively advisory thresholds or triggers for guidance in identifying and dealing with water pollutants for which WQOs had not been established. Alert levels could be established by the IRRWPB for any parameter for which at least one of the "parties" (i.e., Ontario, Minnesota, Environment and Climate Change Canada, US Environmental Protection Agency) have objectives, water quality standards or guidelines (or interim objectives, standards or guidelines). Alert Levels were based on the most stringent value requirements for any of the parties. As such, values which exceed Alert Levels would be of potential concern to one of the regulatory agencies and should trigger an appropriate response. Alert Levels for the Rainy River were adopted for a long list of parameters by 1994. This list of parameters and adopted Alert Levels were presented to the IJC in the 44th progress report of the IRRWPB in 1994 (*Clark and Sellers, 2014*).

The IRLWWB has an expanded geographical mandate for Alert Levels to waters of the entire Rainy-Lake of the Woods (RLOW) basin. The IRLWWB also has an expanded Alert mandate that extends beyond traditional water quality parameters to include aquatic ecosystem health indicators. It is not clear at this time, given the recent formation of the IRLWWB, if the parameters in the 1994 Alert Levels list are those that the IRLWWB would still deem to be important. Considering this, Alert Levels do not yet substantively exist for the RLOW basin, outside of those established historically for the Rainy River (*Clark and Sellers, 2014*). Based on the current IRLWWB Directive, the board shall continue to carry out evaluations and assessments from time to time as the Board considers necessary or desirable to ascertain the extent to which existing WQOs, such as approved by the governments for the Rainy River in 1965, are being met. The board shall also notify the IJC of instances where existing WQO are

not being met and of actions being taken by those responsible for sources of pollution and by the regulatory agencies to meet these WQOs. Other responsibilities in the IRLWWB Directive include to select, determine, establish, and report on water quality and/or aquatic ecosystem health alert levels within the waters of the Lake of the Woods and Rainy River watershed in order to identify potential problems for boundary waters for which WQOs have not been established, with particular focus on priority issues within the basin such as water quality, alien aquatic invasive species, climate change indicators and adaptation, and surface and ground water contamination.

2.4 WQOs: International St. Croix River Watershed Board

Following a 1955 reference to study water resources for the St. Croix River basin, the IJC issued a report to governments in 1959 addressing a number of issues including water levels, flows and water quality. The IJC recommended that the WQOs specified in a 1950 Report on the Pollution of Boundary Waters of the St. Croix River be adopted by the governments of Canada, the United States, the Province of New Brunswick and the State of Maine (*Docket 71, 1959*). In 1961 the governments accepted the IJC recommendations to adopt WQOs and agreed that pollution abatement measures would be undertaken to meet those objectives. The governments also requested the IJC maintain continuing surveillance over boundary waters pollution in the river through a technical advisory board.

The IJC established a pollution advisory board in 1962 to implement the pollution surveillance requested by the governments. The IJC's directive stated the Board was to "*seek through the appropriate enforcement agency the implementation of adequate treatment measures for industrial wastes, domestic sewage and prevention of physical pollution by solid refuse such as coarse wood wastes and coal ash as would be required in order to improve the quality of the waters in both countries for domestic and municipal purposes, recreation and other uses, such as to reduce contamination of shellfish growing areas, and to aid in the restoration of*

anadromous fish runs in the St. Croix River."

From 1962 through the late 1970s, the St. Croix Pollution Board maintained a continuing water quality surveillance program in the St. Croix River Basin. In 1962, the Board reported that untreated domestic sewage was being discharged to the St. Croix River from sewage systems serving municipalities in both countries and that gross bacterial pollution was a condition in the stretch of the St. Croix River extending below Woodland, Maine, now known as Baileyville, to tidal water. The Board also reported in 1962 that industrial pollution was contributing to the degradation. At that time, the minimum objective for dissolved oxygen (DO) was not being met in a nine-mile section of the river below a paper mill at Woodland.

While subsequent progress in the abatement of both municipal and industrial waste discharges was slow, the St. Croix Pollution Board reported definite progress by the late 1960s with the construction of municipal secondary sewage treatment plants. The Pollution Board reported that waste treatment efforts at the paper mills were implemented in the mid-1960s with a conversion from coal to oil and with operational changes to reduce solid mill wastes from reaching the river. However, these practices did not result in any significant changes in the polluted state of the river. It was not until a secondary treatment of the paper mills' industrial wastes were constructed in the mid-1970s that dramatic improvement in water quality was reported. By the summer of 1977 effluent monitoring reports indicated a substantial reduction in biological oxygen demand (BOD) loading and suspended solid loadings to the river mainly due to secondary treatment systems for industrial wastes.

On the basis of substantial progress made in both municipal and industrial pollution abatement programs in the St. Croix River, in 1977 the IJC wrote the governments that insofar as water quality is concerned the restoration of an anadromous fishery would be possible. Continued improvement of water quality and a heightened awareness by industry and communities along the river produced further developments. In 1980, fishways were rehabilitated by dam owners

resulting in the return of upstream passage of fish. The Pollution Board reported in 1983 that municipal and industrial treatment facilities were operating well.

Considering these developments, in 1984 the IJC wrote the governments its conclusion that the Board's work under the 1955 reference had essentially been fulfilled. The IJC highlighted several important tasks that might continue to be undertaken by the Pollution board including a monitoring plan for assessing changes in the ecosystem quality and sampling protocols for measuring the health of the St. Croix River. The IJC asked whether an additional reference would be needed to carry out these additional tasks. The governments responded that the St. Croix reference was working well and that the modest and limited changes suggested by the IJC could be done under the current reference.

In 2000, the IJC formally combined the St. Croix Pollution Board with the St. Croix River Board of Control, which had been established to monitor compliance with water level and flow requirements issued by the IJC for the dams on the St. Croix River at Forest City, Vanceboro, Grand Falls and Milltown. Combining the boards was consistent with the International Watersheds Initiative's ecosystem approach adopted by the governments and the IJC in order to address water quantity and water quality together in a more comprehensive and inclusive manner. In April 2007, the IJC issued a new directive designating the board as its first international watershed board pursuant to the 1998 reference from governments relating to an integrated, ecosystem approach to transboundary environmental issues and international watershed boards.

The ISCRWB currently has one WQO: dissolved oxygen (DO). Along with DO, routine measurements for surface water temperature, pH and specific conductivity are reported. In addition, the board uses a Canadian Council of Ministers of the Environment (CCME) water quality index (WQI), which is a tool to summarize water quality at monitoring sites visited regularly. WQI measures the frequency and extent to which selected parameters exceed water

quality guidelines and reports the combined results as a single score. This allows for a quick assessment of the status of the water body and can be used as an indicator of overall aquatic health. The WQI is calculated for pH, DO, nutrients and several trace metals.

3. Current WQOs, Parameter Trends and Exceedance Issues

3.1 Monitoring for WQOs

Tables 1 to 4 and associated appendices list the WQOs and Alert levels for each of the four boards included in this review (ISRB, IRRB, ISCRWB and IRLWWB). There is variation in the array of parameters for which objectives exist largely due to differences in the selection of water quality parameters over time based on specific basin issues. For instance, some of the clearest differences are with the ISRB which has the largest number of WQOs (over 40) and the, ISCRWB which has one WQO, but tracks over 30 water quality parameters. There are differences in the number and type of pesticides between the ISRB and IRRB, and the ISCRWB uses a water quality index (WQI) along with its WQOs. Water quality monitoring for assessment of exceedances at the US/Canada border is conducted at a number of stations described below. Agencies involved in the various IJC boards also conduct water quality monitoring throughout the Red, Souris, Rainy-Lake of the Woods, and St. Croix watersheds. While these data are used by boards to understand general water quality throughout the watersheds, they are not used to assess compliance with objectives and alert levels. The following sections detail water quality monitoring procedures for each of the four boards in review.

ISRB: Routine water quality sampling for WQO assessment involves two primary sampling locations: a USGS hydrometric gauge near Westhope, ND and a USGS hydrometric gauge near Sherwood, ND (alternate sites are visited if there are safety concerns at these stations due to flow). Sampling is conducted seven to eight times per year; six times during open water and

twice under ice. USGS collects samples at Sherwood and Environment and Climate Change Canada (ECCC) collects at Westhope. The original ECCC monitoring site was at Coulter, MB (since 1960) which is downstream of the Westhope site. It was changed to Westhope in the early 1990s. Once a year both agencies sample at both sites to assess comparability. This sampling program has been in place since 1960 making it one of the most continuous water quality monitoring programs still in operation.

IRRB: Water quality data collected for compliance with WQOs for IRRB is obtained at an ECCC hydrometric gauge on the Red River at Emerson, Manitoba. ECCC samples the Red River at Emerson weekly during open water, semi-weekly during freshet/flood, and monthly under ice. ECCC also operates an automated continuous monitoring station at Emerson. The Red River station has been continuously active since 1960 and as with the stations on the Souris River, is one of the most continuous water quality monitoring programs in operation.

IRLWWB: The IRLWWB is currently working to identify an up-to-date list of water quality parameters for WQO assessment after which arrangements will be made to determine the logistics of where and when samples will be collected including which agencies will be employed to collect and analyze the data. Currently, no water quality monitoring in boundary waters is being conducted by this board. In its first annual water quality report from the in 2015, the board highlighted information for a limited set of parameters and geography in the basin, based on interpretive summaries of monitoring data supplied by jurisdictional agencies roughly from the 2009 to 2014 period. For the most part, the report was limited to highlights on phosphorus conditions on Lake of the Woods and Rainy River. The board has also completed the 2014 RLOW State of the Basin Report summarizing conditions and knowledge gaps in the basin (*Clark and Sellers, 2014*). A proposed International Monitoring Program for the Lake of the Woods Basin has been developed and included as the core foundational project in the Water Quality Plan of Study for the Lake of the Woods Basin (IJC 2015). These reports and the proposed monitoring program will be used by the IRLWWB's new Aquatic Ecosystem Health

Committee to better understand water quality issues in the basin and to help design future monitoring and assessment strategies for the IRLWWB. The WQOs in place for this board are listed in Table 4 and a complete list of the Alert Levels can be viewed in the RLOW State of the Basin Report (*Clark and Sellers, 2014*). These WQOs (dating to 1965) and Alert levels (dating to 1994) were inherited from the former IRRWPB, when the IRLWWB board was formed in 2013. The IRLWWB under its mandate is to establish WQOs and review them periodically.

ISCRWB: ECCC, in partnership with the New Brunswick Department of Environment and Local Government, maintains two automated real-time water quality monitoring stations on the St. Croix River system. The first station is located at the Milltown Dam in Milltown (St. Stephen), New Brunswick and the second station is located in Forest City, Maine. The Milltown station records hourly measurements of temperature, DO, pH, specific conductance and turbidity while the Forest City station records hourly measurements of temperature and conductivity. Six grab samples are collected per year during the ice free period at the Milltown and Forest City stations and analyzed for 38 water quality parameters, and are compared to Canadian Council of Ministers of the Environment guidelines. WQI ratings are calculated by the board each year using samples from the current year and the previous two years. In addition, IJC in partnership with United States Geological Survey maintains an automated real time water quality monitoring station about 0.5 miles above Milltown Dam. This station records hourly measurements of temperature, DO, pH and specific conductance. It has been in operation since 1972, providing a long term record over the last 40 years.

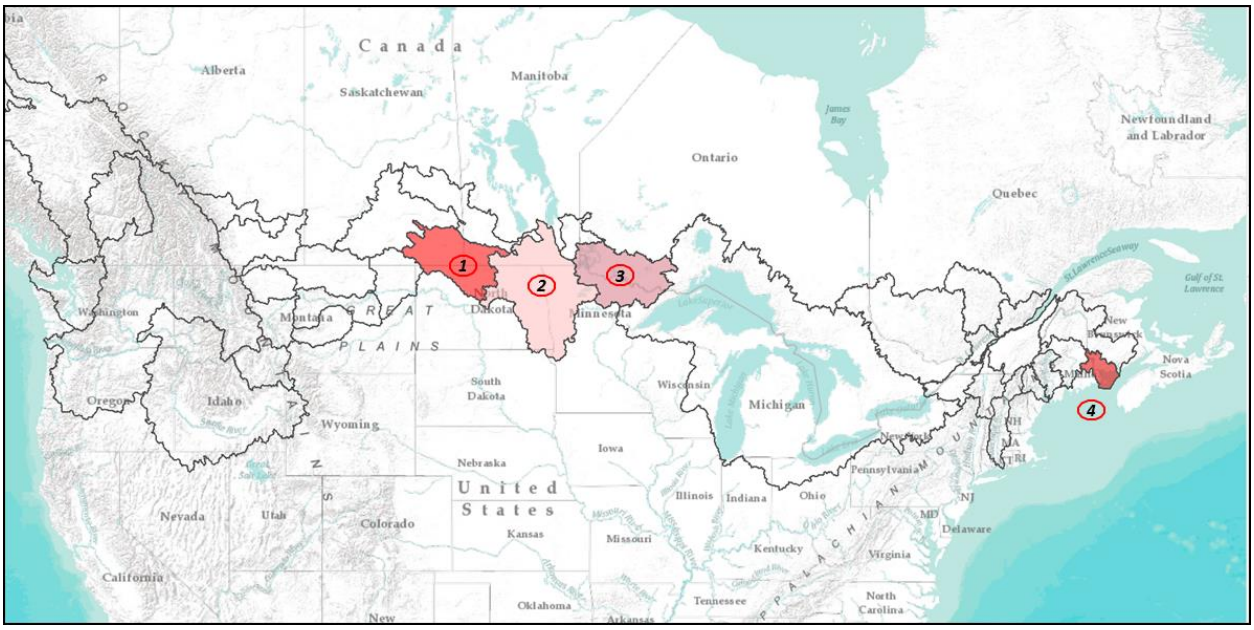

Figure 1. Map of the transboundary region showing locations for the Souris River Basin (1), the Red River Basin IRRB (2), the Rainy-Lake of the Woods Basin (3) and the St. Croix River Basin (4).

Table 1. Water Quality Objectives for the ISRB as listed in the ISRB Fifty Sixth Annual Report to IJC.

Water Quality Objectives		
Parameter	Units	Threshold Level
Nutrients		
Phosphorus (total[TP])	mg/l	0.1
Nitrate (NO_3^-) + Nitrite (NO_2^-)	mg/l	1
Major Ions		
Sodium (Na)	mg/l	100
Sulfate (SO_4^{2-})	mg/l	450
Fluoride (F^-)	mg/l	1.5
Chloride(Cl^-)	mg/l	100
Ammonia (unionized as N)	mg/l	***
Dissolved Oxygen (DO)	mg/l	>5
Biological		
Fecal coliforms	cells/ml	200/100 ml
Physical		
pH		6.5-8.5
Total dissolved solids (TDS)	mg/l	1000
Total Suspended Solids (TSS)	mg/l or %	lesser of 10 mg/l or 10% over ambient
Metals		
Iron (Fe)	µg/l	300
Arsenic (As)	µg/l	50
Barium (Ba)	µg/l	1000
Boron (B)	µg/l	500
Beryllium (Be)	µg/l	100
Cadmium (Cd)	µg/l	**27
Chromium(Cr)	µg/l	50
Cobalt (Co)	µg/l	50
Copper (Cu)	µg/l	**30
Lead (Pb)	µg/l	**13
Molybdenum (Mo)	µg/l	10
Nickel (Ni)	µg/l	**220
Selenium (Se)	µg/l	5
Zinc (Zn)	µg/l	30
Mercury (Hg)	µg/g tissue	0.5
Pesticides		
Atrazine	µg/l	2
Bromoxynil	µg/l	5
Carbaryl	µg/l	90
a-Chlordane	µg/l	0.0043

g-Chlordane	µg/l	0.0043
o,p-DDT	µg/l	0.001
Dieldrin	µg/l	0.0019
Dicamba	µg/l	TBD
Diclofop-methyl	µg/l	TBD
Heptachlor	µg/l	0.0038
MCPA	µg/l	0.2
Parathion	µg/l	0.04
Picloram	µg/l	0.05
Phenols (total)	µg/l	1
Polychlorinated biphenyl (total)	µg/l	0.001
Triallate	µg/l	0.57
Trifluralin	µg/l	0.1
2,4-D	µg/l	4

*****unionized ammonia is calculated using temperature and pH**

****based on a hardness of 300 mg/l**

Table 2. Water Quality Objectives and Alert Levels for the IRRB as listed in the Spring 2015 Status Report to IJC.

Water Quality Objectives		
Parameter	Units	Threshold Level
Major Ions		
Sulfate (SO_4^{2-})	mg/l	250
Chloride (Cl^-)	mg/l	100
Dissolved Oxygen (DO)	mg/l	>5
Physical		
Total dissolved solids (TDS)	mg/l	500
Biological		
Escherichia coli	cells/ml	>200/100
Alert Levels		
Metals		
Cadmium (Cd)	µg/l	Detection
Chromium (Cr)	µg/l	50
Iron (Fe[Total Fe])	µg/l	300
Manganese (Mn[Total Mn])	µg/l	50
Selenium	µg/l	10
Zinc	µg/l	47
Toxic Substances		
Arsenic (As[Total As])	µg/l	10
Boron (B[Total B])	µg/l	500
Total Poly Chlorinated Biphenyls (PCB)	ng/l	Detection
Pesticides		
2,4-D	ng/l	Detection
Bromoxynil	ng/l	Detection
Clopyralid	ng/l	Detection
Dicamba	ng/l	Detection
Imazamethabenz-methyl a	ng/l	Detection
Imazamethabenz-methyl b	ng/l	Detection
MCPA	ng/l	Detection
Mecoprop	ng/l	Detection
Picloram	ng/l	Detection
Aldrin	ng/l	Detection
g-Benzenehexachloride n	ng/l	Detection
Pentachloroanisole	ng/l	Detection
Atrazine	ng/l	Detection
Desethyl Atrazine	ng/l	Detection
Metolachlor	ng/l	Detection
P,P-DDE	ng/l	Detection
Alpha-Endosulfan	ng/l	Detection

Beta-Endosulfan	ng/l	Detection
Heptachlor Epoxide	ng/l	Detection
Metribuzin	ng/l	Detection

Table 3. Water Quality Objectives and Alert Levels for the IRLWWB as listed in the 2014 State of the Basin Report to IJC.

Water Quality Objectives		
Parameter	Units	Threshold Level
Coliforms (Most probable number [MPN])	ml	2400/100 (Max) 1000/100 (Median)
Dissolved oxygen (DO)	mg/l	>=5*
Suspended solids	"should be reduced to a point that they are not conducive to slime growths, formation of sludge islands and banks, and do not injure fish or wildlife or their habitats"	
Nutrients and wood sugars	"should be controlled to the extent that they do not promote the nuisance growths of Sphaerotilus and other slime bacteria in the river"	
1974 and 1981 Recommendations: See Appendix B and C respectively of the Clark and Sellers, 2014 State of the Basin Report		
Alert Levels (See Appendix D of the Clark and Sellers, 2014 State of the Basin Report)		

***The dissolved oxygen should not fall below 5 mg/l at the average monthly flow which is exceeded 95 percent of the time in the critical month, nor below 3 mg/l at the minimum daily flow that is exceeded 95 percent of the time in the critical month**

Table 4. Water Quality Objective, Routine Collections and Water Quality Indices for the ISCRWB as listed in the 2014 Annual Report to IJC.

Water Quality Objectives		
Parameter	Units	Threshold Level
Dissolved Oxygen (DO)	mg/l	>5
Routine Collections		
Water temperature	^{o}C	
pH		6.5
Specific conductivity	µS/cm	
Water Quality Index		
Arsenic (As)	µg/l	5
Chloride (Cl^-)	mg/l	120
Copper (Cu)	µg/l	2
Iron (Fe)	mg/l	0.3
Nitrate (NO_3^-)	mg/l as N	3
Dissolved Oxygen (DO)	mg/l	6.5
Phosphorus (P)	mg/l	0.03
pH		6.5-9
Turbidity	NTU	10
Zinc (Zn)	µg/l	calculated
Grab Samples (See Appendix 1)		

3.2 Recent WQO Threshold Exceedances

The following paragraphs discuss water quality parameters that have demonstrated consistent WQO exceedances over recent years. Investigating these exceedances is a valuable initial step towards understanding possible relationships between threshold level exceedances and point and non-point sources of pollutants. Results are only presented for the ISRB and IRRB parameters as these are the boards that have demonstrated frequent WQO exceedances.

For the Souris River, tables 5 and 6 detail exceedance criteria for WQOs for a specific year (2015) and Figures 2 to 5 display recent (2013-2016) trend characteristics for specific parameters of interest. As shown in the time series plots, the parameters that have demonstrated sustained exceedance over thresholds are TP, sodium, sulfate, TDS, and total iron. Also, there is similarity in exceedance percentages for both monitoring stations (Sherwood

and Westhope). It is not surprising that TDS is also showing exceedance along with the other constituents, which suggests large-scale natural system loading (e.g. weathering, surface water-ground water interactions, and increased flow) rather than point sources or singular release of specific constituents. Based on visual inspection of Figures 2 to 5, TP and total iron concentrations increase with discharge. In prairie river systems, total metal concentrations often increase with increasing flow. High flow conditions lead to elevated suspended solids which include particulate metals. A striking feature for iron is the difference in concentration at the two stations with iron concentrations consistently higher at Sherwood than at Westhope (Figure 4). Also, while iron concentrations are positively related to discharge at Sherwood, this relationship does not appear to exist at the Westhope site.

For the Red River, tables 7 and 8 detail recent exceedances (2015) for WQOs and Alert Levels and Figures 6 to 8 display longer-term (1998-2014) trend characteristics for other parameters of interest. The monitoring station used for WQO assessment is located in Emerson, Manitoba. This monitoring station shows increasing trends in concentrations for TDS and sulfate, which is believed to be related to outflows from the two Devils Lake discharges during relatively wet periods. The outlets have discharged since 2005 (west) and 2012 (east), respectively. Unlike the ISRB, IRRB has Alert Levels (Table 2) which include several metals and pesticides. Frequent exceedances of alert levels are shown for iron, cadmium and manganese (Table 8). For the exceedances shown for TDS and several metals that share similar physico-chemical transport properties, this also points to watershed-scale non-point source loading and Devils Lake discharges as the most likely primary sources. TDS, chloride and sulfate all show apparent increases since 1998.

For the ISCRWB there are no reported exceedances of its WQOs however, for the 2014 collection year, there were exceedances of CCME guidelines for a number of metals collected under grab sample analysis. These were for aluminum (4 cases), cadmium (1 case) and iron (1 case). Results are displayed in Appendix 1.

Table 5. Summary of Water Quality Objective Exceedances - Souris River at Sherwood 2015 (Adapted from the February 2015 meeting in Bismarck).

Parameter	Objective	Exceedance		Maximum Exceedance
		#(total)	Percent (%)	
Phosphorus (total [TP])	0.1 mg/l	8(8)	100	0.48
Sodium (Na)	100 mg/l	5(8)	62.5	259
Sulfate (SO_4^{2-})	450 mg/l	2(8)	25	623
Total dissolved solids (TDS)	1000 mg/l	3(8)	37.5	1360
Iron (total [TFe])	300 mg/l	8(9)	100	5870
pH	6.5-8.5	1(8)	12.5	8.6
Dissolved oxygen (DO)	>5 mg/l	0(8)	0	n/a
Fecal coliforms	<200/100 ml	ND	n/a	n/a
Escherichia coli	n/a	0(3)	0	n/a

Table 6. Summary of Water Quality Objective Exceedances - Souris River at Westhope 2015 (Adapted from February 2015 meeting in Bismarck)

Parameter	Objective	Exceedance		Maximum Exceedance
		#(total)	Percent (%)	
Phosphorus (total [TP])	0.1 mg/l	7(7)	100	0.328
Sodium (Na)	100 mg/l	5(7)	70	184
Sulfate (SO_4^{2-})	450 mg/l	4(7)	57	544
Total dissolved solids (TDS)	1000 mg/l	2(6)	33	1013
Iron (total [TFe])	300 mg/l	2(6)	29	602
pH	6.5-8.5	6(7)	86	9.71
Dissolved oxygen (DO)	>5 mg/l	1(7)	14	4.91
Fecal coliforms	<200/100 ml	0(7)	0	n/a
Escherichia coli	<200/100 ml	0(7)	0	n/a

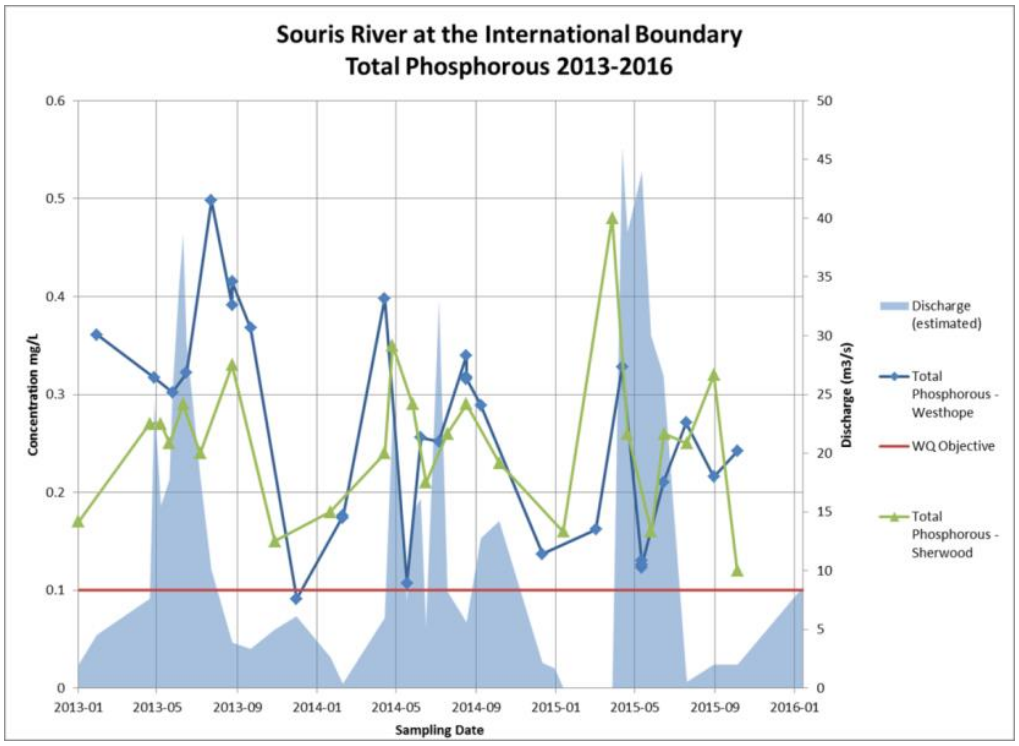

Figure 2. Observed total phosphorus concentrations for the Souris River at Sherwood and Westhope for 2013–16 (adapted from the February 2016 ISRB meeting).

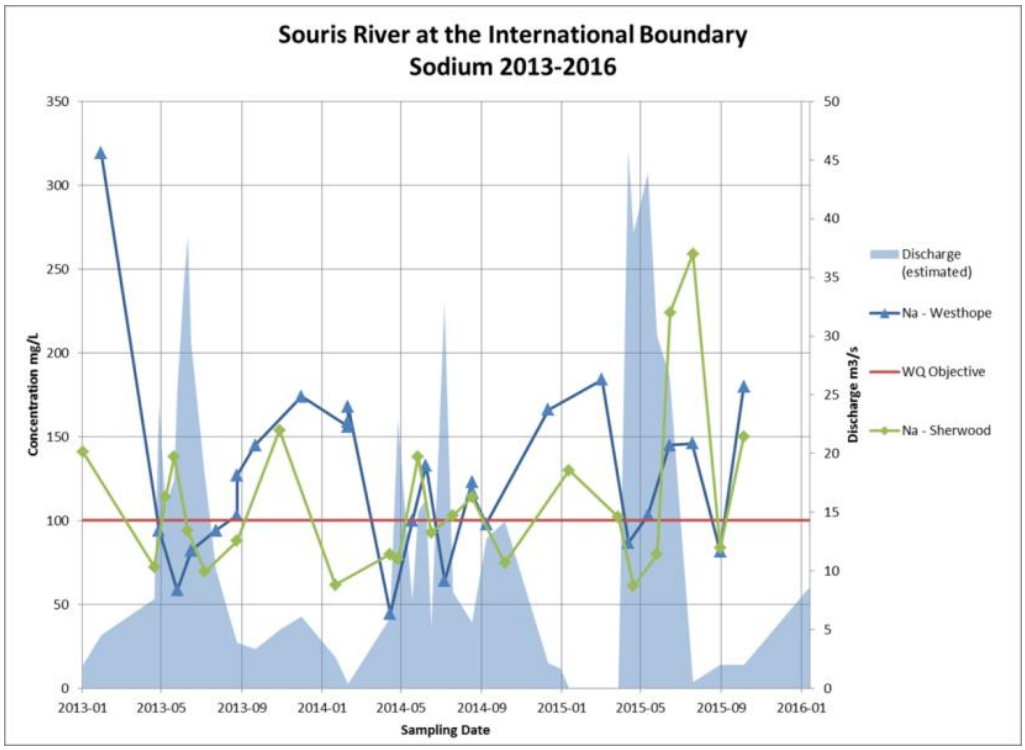

Figure 3. Observed sodium concentrations for the Souris River at Sherwood and Westhope for 2013–2016 (adapted from the February 2016 ISRB meeting).

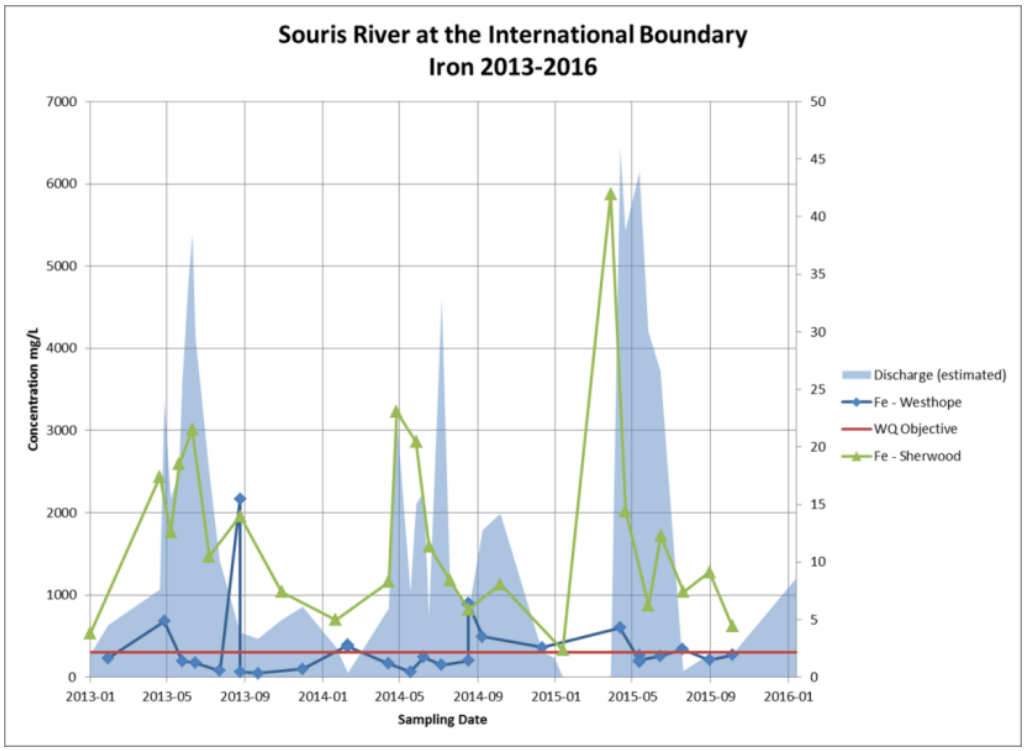

Figure 4. Observed total iron concentrations for the Souris River at Sherwood and Westhope for 2013–2016 (adapted from the February 2016 ISRB meeting).

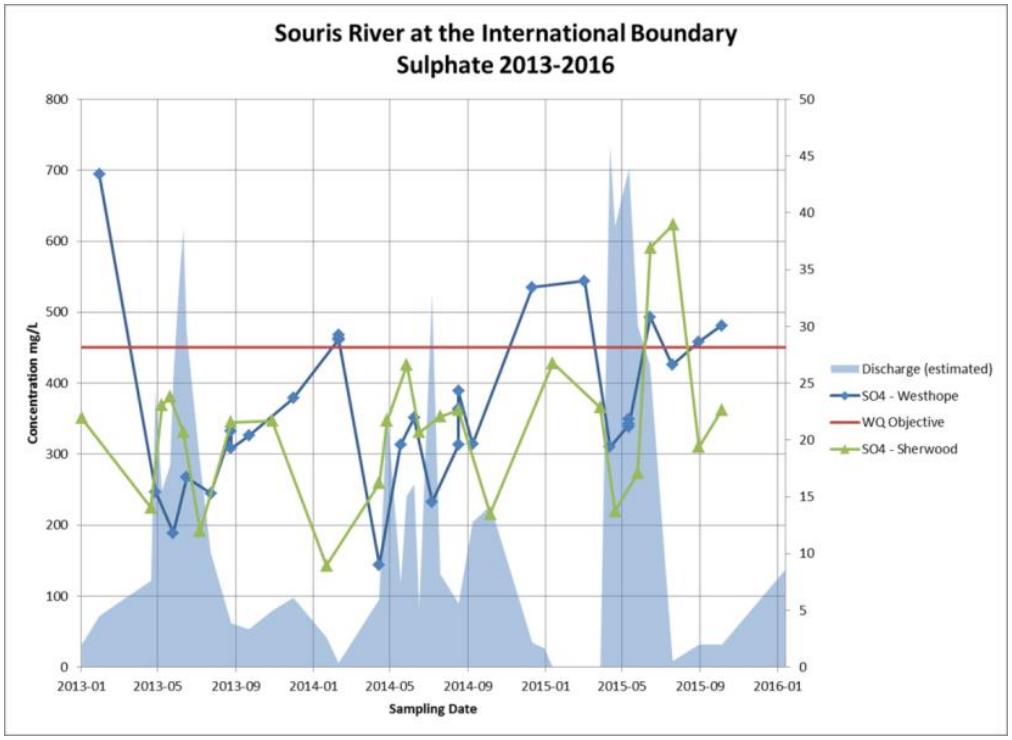

Figure 5. Observed sulfate concentrations for the Souris River at Sherwood and Westhope for 2013–2016 (adapted from the February 2016 ISRB meeting).

Table 7. IRRB Water Quality Objective Summary of Exceedances at the International Border for Water Year 2013-2014 (Adapted from the April 2015 IRRB Status report).

Parameter	Objective	Exceedance		Maximum Exceedance
		#(total)	%	
Dissolved Oxygen (DO)	>5 mg/l	0(44)	0	n/a
Total Dissolved Solids (TDS)	500 mg/l	32(43)	81	1045.2
Chloride (Cl^-)	100 mg/l	0(44)	0	n/a
Sulfate (SO_4^{2-})	250 mg/l	11(44)	23	441
Escherichia coli	<200 /100 ml	0(14)	0	n/a

Table 8. IRRB Alert Level Summary of Exceedances (Adapted from April 2015 Status report).

Parameter	Units	Alert Level	Number of Samples	Exceedance Number (# and %)	Maximum Exceedance Value	Canadian Environmental Quality Guideline
Metals						
Cadmium	µg/l	Detect	44	**44 (100%)**	0.359	0. 074 µg/l[1,3]
Chromium	µg/l	50	44	0	--	NG
Iron (total)	µg/l	300	44	**41 (93%)**	8120	300 µg/l[1]
Manganese (total)	µg/l	50	44	**42 (95%)**	827	200 µg/L[2]
Selenium	µg/l	10	44	0	--	1 µg/l[1]
Zinc	µg/l	47	44	0	--	30 µg/l[1]
Toxic Substances						
Arsenic (total)	µg/l	10	44	0	--	5 µg/l[1]
Boron (total)	µg/l	500	44	0	--	29 mg/l[1]
Total PCB	ng/l	Detect	4	0	--	NG
Pesticides						
2,4-D	ng/l	Detect	11	**11 (100%)**	137	4000 ng/l[1]
Bromoxynil	ng/l	Detect	11	**4 (36%)**	172	5000 ng/l[1]
Clopyralid	ng/l	Detect	11	**11 (100%)**	161	NG[5]
Dicamba	ng/l	Detect	11	**11 (100%)**	39.2	10000 ng/l[1]
Imazamethabenz-methyl a	ng/l	Detect	11	0	--	NG
Imazamethabenz-methyl b	ng/l	Detect	11	**2 (18%)**	14.6	NG
MCPA	ng/l	Detect	11	**11 (100%)**	404	2600 ng/l[1]
Mecoprop	ng/l	Detect	11	**9 (82%)**	21.9	NG
Picloram	ng/l	Detect	11	**11 (100%)**	59.7	29000 ng/l[1]
Aldrin	ng/l	Detect	11	0	--	NG
g-Benzenehexachloride	ng/l	Detect	11	0	--	NG
Pentachloroanisole	ng/l	Detect	11	0	--	NG
Atrazine	ng/l	Detect	6	**6 (100%)**	70.3	1800 ng/l[1]
Desethyl Atrazine	ng/l	Detect	6	**5 (83%)**	28.1	NG
Metolachlor	ng/l	Detect	6	**6 (100%)**	66.9	7800 ng/l[1]
P,P-DDE	ng/l	Detect	11	0	--	NG
Alpha-Endosulfan	ng/l	Detect	11	0	--	3 ng/l[1,4]
Beta-Endosulfan	ng/l	Detect	11	0	--	3 ng/l[1,4]
Heptachlor Epoxide	ng/l	Detect	11	0	--	NG
Metribuzin	ng/l	Detect	6	**1 (17%)**	16.4	1000 ng/l[1]

Notes:
1. Canadian Water Quality Guidelines for the Protection of Aquatic Life (http://st-ts. ccme. ca/)
2. Canadian Water Quality Guidelines for the Protection of Agriculture (http://st-ts. ccme. ca/)
3. Guideline value corrected for minimum value for hardness (mg/l CaCO3) in the reporting period (http://st-ts. ccme. ca/?lang=en&factsheet=93)
4. Guideline value is for technical grade Endosulfan, which is a mixture of the two biologically active isomers (α and β)
5. NG = No guideline established

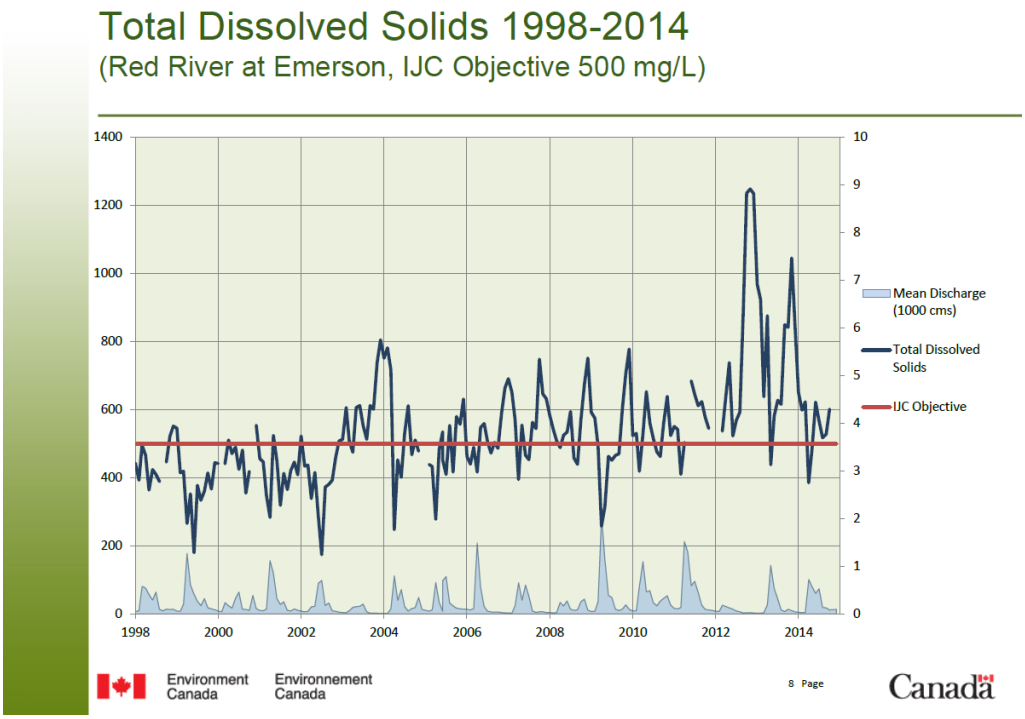

Figure 6. Observed TDS concentrations for the Red River at Emerson for 1998–2014 (adapted from the January 2016 IRRB meeting).

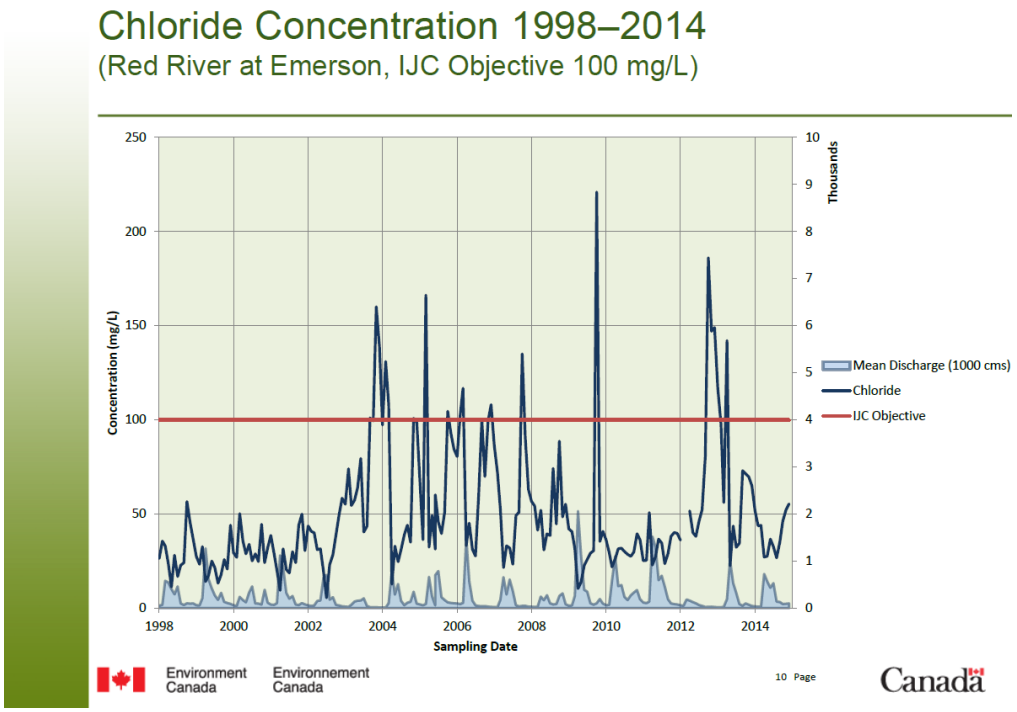

Figure 7. Observed chloride concentrations for the Red River at Emerson for 1998–2014 (adapted from the January 2016 IRRB meeting).

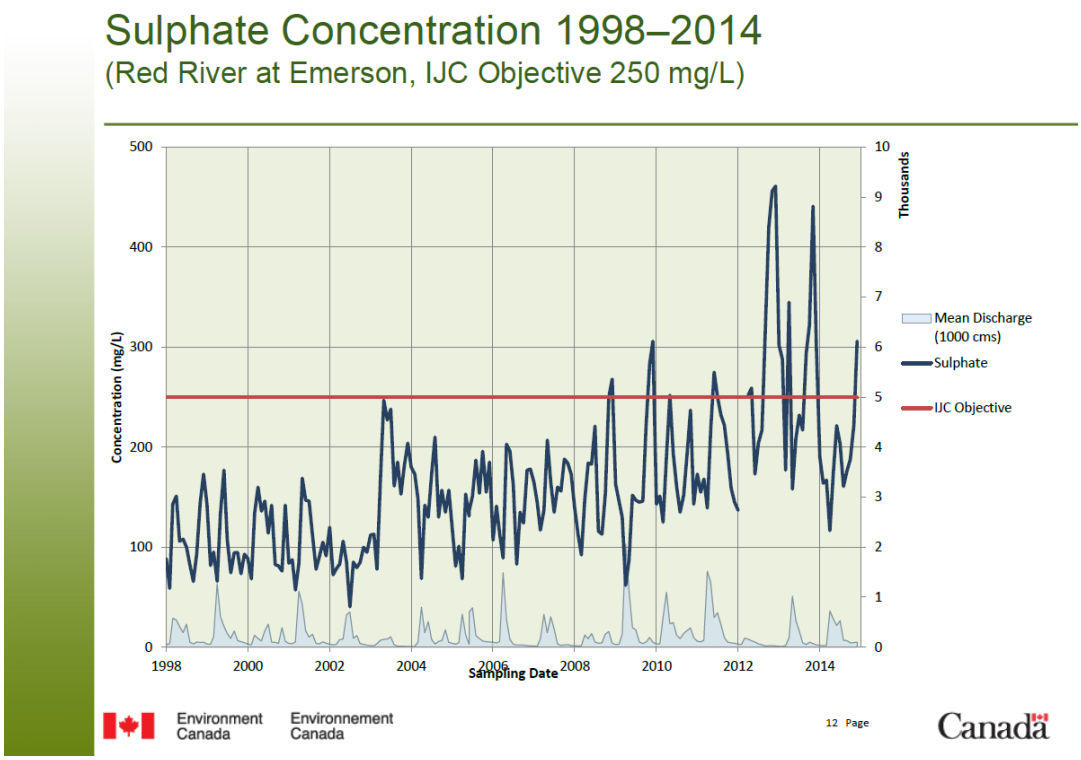

Figure 8. Observed sulfate concentrations for the Red River at Emerson for 1998–2014 (adapted from the January 2016 IRRB meeting).

4. Relevance of Current WQO Levels

As referenced in the introductory section of this report, one of the justifications for developing this review is to address the consistent WQO exceedances for iron, sulfate, TDS, and others WQOs that have been observed in the Souris and Red rivers at monitoring stations near the border. To gain a perspective on such exceedances of concern, as an initial investigation of exceedances, WQO thresholds at international monitoring locations can be compared to current state and provincial and, where applicable, federal water quality criteria. Such a comparison ought to be supplemented with a binational assessment as to whether the thresholds and criteria are based on the most current and best-available science, relevant to a particular river system, protective of various uses deemed important (e.g. aquatic life) and if other environmental factors need to be considered. Another potential complication is that objectives for specific parameters may differ between jurisdictions for a shared river.

Where exceedances are determined to be a concern and outside of an appropriate range, such as for those select parameters identified by the ISRB and the IRRB, follow-up study may be warranted to understand causal factors of the observed trends in water quality and make recommendations regarding WQO levels or mitigative measures. In prairie landscapes, such factors may include changes in water management as a result of floods or droughts, resource extraction industries, changes in land use, particularly agricultural land use, aging or outdated municipal infrastructure, including for wastewater treatment, and climate variation (i.e. the wet-dry cycle) and climate change (i.e. non-stationarity), among others, as well as interactions between each of these. Since water quality data collected from monitoring locations along the international border integrates the influence of factors from across a watershed, to fully assess trends in water quality, the suite of watershed and riverine processes that also influence concentrations of particular parameters need to be considered.

As an example of how initial comparisons can be made between IJC WQO threshold levels and

the levels of a relevant jurisdiction, Table 11 shows current ISRB and IRRB WQOs for parameters of most concern or that have exceeded objectives over the last five years. According to North Dakota standards (NDDoH, 2014), the main stem of the Red River is a class 1 water body and the Souris River is a class 1A. Data are not shown for the St. Croix River because the ISCRWB has not identified any water quality exceedance issues. For the IRLWWB, although water quality is monitored in the Rainy River and Lake of the Woods, there are no current WQOs to report against. According to values in the table, most IJC WQO thresholds fall within or below jurisdictional criteria, notably for sodium, iron, TDS, chloride, pH and DO. As a first test, this indicates that the current international WQO thresholds are consistent with those of jurisdictions in the region. The applicability of whether the WQOs are appropriate tests for desirable or acceptable water quality is however, complex to interpret. For example, water quality objectives can be broadly divided into those that are specifically designed to be protective of the aquatic environment and those that are defined by suitability of uses external to the aquatic environment. Such external use-suitability objectives (such as agricultural uses) are derived based on the independent use needs and have no direct relationship to the health of any particular ecosystem. Thus, it may be that a water source may be naturally unsuitable for a specific use (e.g. one does not irrigate or water livestock from a saline lake). For aquatic ecosystems/rivers that are suitable for such uses the desire is to maintain that suitability; however, an exceedance of such use-suitability objectives does not necessarily imply there is an environmental issue. Any detailed water quality objective review process needs to evaluate the various objectives within the context of the ecosystem and the use(s) being protected.

In this exercise, where exceedances are found for both sets of water quality thresholds (i.e. IJC WQO levels and jurisdictional standards), there is justification for investigation of causal factors and the potential recommendation of new WQOs. For the ISRB and the IRRB, the water quality parameters that have been shown to consistently exceed WQOs are sodium, iron, TDS, chloride and sulfate. Where exceedances are found for one set of thresholds, study may be warranted regarding the appropriateness of particular WQOs and why they may differ. Under these

circumstances, for the IRRB, the water quality parameters of interest might be *Escherichia coli* and sulfate. . Studies that result from such initial comparisons could be carried out by the boards as part of their ongoing responsibilities to review and possibly revise their WQO lists. The series of questions laid out by the IRRB (below) represents an approach that could be adopted by the boards to help frame their own reviews.

Table 11. ISRB and IRRB Water Quality Objectives and water quality criteria for bordering jurisdictions for a select set of parameters that generally show the consistent threshold exceedances.

Parameters of interest or concern	Current IJC WQO levels	Current ND Standard[1]: Class 1A,1	Current Manitoba Objective or Guideline[2]:	Current Sask. Objectives[3]	Current Minnesota water quality standards[4]
Total phosphorus (TP)	0.1 mg/l for ISRB	None[^]	0.05 mg/l narrative guideline to prevent the growth of nuisance algae (objective for rivers)	None	Not to exceed regional P std. and one response variable (e.g., chl. a); separate lake and river stds; also site-specific and narrative stds.
Sodium (Na)	100 mg/l for ISRB	60% of total cations as mEq/l (1A), 50% of total cations as mEq/l (1)	<-200 mg/l (guideline)	None	< 60% total cations as mEq/L for irrigation.
Sulfate (SO_4^{2-})	450 mg/l for ISRB and 250 mg/l for IRRB	450 mg/l, 250 mg/l	<-500 mg/l for drinking and 1000 mg/l for livestock (guideline)	1000 mg/l for livestock	10 mg/l in waters used for production of wild rice.
Total Iron (TFe)	0.3 mg/l for ISRB	None[δ]	<-0.3 mg/l for drinking, 0.3 mg/l for aquatic life and 5.0 mg/l for irrigation (guideline)	0.3 mg/l for aquatic life and 5.0 mg/l for irrigation	None
Total dissolved solids (TDS)	1000 mg/l for ISRB and 500 mg/l for IRRB	None	500 to 3500 mg/l (crop dependent)for irrigation, <- 500 mg/l for drinking and 3000 mg/l for livestock (objective)	500 to 3500 mg/l for irrigation, 3000 mg/l for livestock	700 mg/l for irrigation.
Fecal coliforms	200 cells/100 ml for ISRB	None	200 colony forming units/100 ml for recreation and irrigation and 0 colony forming units for drinking	100 cells/100 ml for irrigation	See *Escherichia coli*

			(objective)		
Chloride (Cl^-)	100 mg/l for ISRB and IRRB	250 mg/l,100 mg/l	<- 250 mg/l for drinking, 100 to 900 mg/l for irrigation (guideline)	100-700 mg/l for irrigation	230 mg/l as four day avg. for aquatic life.
pH	6.5-8.5 for ISRB	6.0-9.0, 7.0-9.0	6.5-8.5 for drinking and 6.5-9.0 for aquatic life (guideline)	None	6.5 – 9.0 for aquatic life.
Escherichia coli	200 cells/100 ml for IRRB and ISRB	126 cells/100 ml, same	200 colony forming units/cells/100 ml for recreation and irrigation and 0 colony forming units for drinking (objective)	200 cells /100 ml for recreation and aesthetics*	Two part std. of < 126 organisms/100 mL of sample mean; monthly maximum 1260 organisms/ 100 mL for aquatic recreation.
Dissolved oxygen (DO)	>5 mg/l for ISRB and IRRB	5 mg/l, same	3-6 mg/l (for cool water species) (objective)	5.5-9.5 mg/l for protection of aquatic biota	> 5 mg/l daily minimum for aquatic life; site-specific stds.

1 Standards of Quality for Water of the State, Chapter 33-16-02.1, North Dakota Administrative Code – Title 33 Article 16 Chapter 2.1
2 Manitoba Water Quality Standards, Objectives, and Guidelines, Manitoba Water Stewardship, November 28, 2011, Manitoba Water Stewardship Report 2011-01
3 Water Security Agency, Surface Water Quality Objectives, Interim Edition, EPB 356, June 2015, http://www.saskh2o.ca/pdf/epb356.pdf
4 Water Quality Standards for protection of waters of the state, MN rule chapter 7050; www.revisor.mn.gov/rules/?id=7050
^ ISRB uses a guideline of 0.02 mg/l identified in Standards that acts as a goal in lake and reservoir improvement projects (not rivers)
δ ISRB uses an EPA recommendation of 0.3 mg/l as a secondary drinking water standard
*based on a geometric mean of at least five samples taken during a period not to exceed 30 days. Resampling should be performed when any sample exceeds 400 cells/100 ml

5. Board Perspectives on Water Quality

The following section provides narratives developed by each of the four boards considered in this review. These narratives are used to provide any information the boards choose to communicate to IJC Commissioners and advisors on their respective water quality objectives, including any other information on water quality within their respective basins and future directions in WQO assessment.

International Souris River Board – "The ISRB recognizes the importance of water quality in coordination with water quantity issues at the two transboundary sites on the Souris River covered under the Agreement. Prior to the compilation of this document, the ISRB, with the assistance of the Aquatic Ecosystem Health Committee (AEHC) had determined a comprehensive review of water quality objectives was a priority. However, it is also recognized that this review, led by the AEHC, will require significant time, effort, and funds. It is likely that a funding proposal to the International Watersheds Initiative will be submitted to assist in this effort.

"In the short term, a review will be undertaken to review sampling and analysis protocols, notification procedures, and any other monitoring issues such as identifying and documenting what the current water quality objectives are meant to protect, be it human health, aquatic life, or some other beneficial use. A review of current provincial and state standards/objectives within the Agreement's jurisdiction will also be conducted.

"Moving forward, medium to long term goals will include establishing a mechanism/outline for water quality objectives review. Initial draft development of this process is just underway. It is believed that this process will allow the ISRB to identify where data and information gaps exists as well as identify where funding and assistance will be needed. Other longer term goals will be to identify objectives in use elsewhere and to assess the appropriateness of these objectives for

application to the Souris River. As part of the review, the AEHC will also consider historical data and background concentrations and will consider adding Alert Levels or using a water quality index. Water quality objectives are important but may not be the only tool that we rely on to identify water quality issues. The overall goal is to ensure that the ISRB has appropriate objectives designed to protect designated uses and meet its goals and objectives as outlined in the Agreement.

"Another long term goal would be research into potential sources/causes of the exceedances. Over time, the annual report will be expanded to include more information on possible sources related to the impairments, land use and land use changes, programs for improving water quality in the watershed, and a section on invasive species concerns and protection.

"Undertaking a comprehensive water quality objectives review and expansion of the annual report will be challenging, but will result in better information provided to the International Joint Commission and our respective agencies on water quality and aquatic health concerns throughout the international Souris River watershed."

International Red River Board – "The IRRB is developing a work plan to support a nutrient management strategy for the Red River. The strategy includes developing nutrient objectives for the Red River at the US/Canada border. The Water Quality Committee expects to recommend WQOs for nutrients to the board in the fall/winter of 2016/17. Completing the development of the nutrient objectives is a high priority for the IRRB and its Water Quality Committee. However, the board has recognized that the existing five water quality objectives (dissolved oxygen, total dissolved solids, chloride, sulfate, and *Escherichia coli*) have been in place for many years and a review is warranted. There is particular interest in total dissolved solids, chloride and sulfate given water delivery projects (i.e. Devils Lake) that are currently impacting water quality in the Red River. In addition, other parameters and contaminants of interest could be considered and added to the suite of water quality objectives for the Red

River at the US/Canada border. Once the nutrient objectives are developed, the board expects its Water Quality Committee to develop a proposal to review and update the water quality objectives at the US/Canada border." Some questions the board could ask when initiating a detailed WQO review are:

1. Is the objective based on current best science?
2. Is the WQO relevant for that ecosystem?
3. Does it need to be adjusted to reflect environmental factors specific to local/basin conditions?
4. Is there sufficient information available to facilitate an adjustment of the WQO?

International Rainy Lake of the Woods Watershed Board – "WQOs should be focused on a small number of key issues of relevance to the binational management of the boundary/transboundary waters of the drainage basin. They should be designed in such a manner as to provide value added to the management of boundary and transboundary waters by governments.

"The current WQO for the Rainy-Lake of the Woods basin (est. 1965) reflect issues that affected the river roughly 50 years ago such as pulp and paper mill and sanitary effluents that have largely been addressed. These objectives also pertain only to the Rainy River and do not reflect the broader geographic mandate of the current watershed board.

"The IRLWWB intends to work towards recommending revised WQO and a suitable and updated list of Alert Levels that reflect current issues and are measureable and realistic for the waters of the basin. The basin is complex, with large river and lake systems that have unique physical, hydrogeomorphic, and biogeochemical conditions and may require separate recommendations for different regions of the basin. The Board is confident that any recommendations developed for revising the objectives will be considered given that governments have signaled that current water quality conditions in the Rainy-Lake of the

Woods basin require coordinated action and providing recommendations on this issue is timely."

International St. Croix River Watershed Board – "Over at least the past ten years, the international St. Croix River has generally enjoyed good to excellent ecological condition, as expressed through the CCME water quality index (WQI), which is a composite index based on several water quality parameters. For the water quality monitoring station at Forest City in the headwaters of the watershed, no parameters exceeded applicable guidelines in 2015. Downstream, at the Milltown monitoring station near the head of the tide, exceedances are occasionally observed for phosphorus, nitrogen and a few metals (e.g. aluminum), which are attributed to discharges of municipal and industrial wastewater in more densely populated areas. However, the board recognizes that industrial development, aging infrastructure and climate change pose threats to the maintenance of this water quality. Hence, the board sees value in carrying out time-series analyses of select water quality parameters to establish baseline water quality levels and track changes over time."

6. Conclusions

This report provides a review of the IJC's history and current status of monitoring and reporting on water quality along the border between the US and Canada using government-approved WQOs and IJC board-developed water quality Alert Levels. The motivation for this report stems from consistent exceedances for several WQOs at the Red River and Souris River transboundary monitoring locations. Along with these exceedances, there are notable differences in water quality conditions across transboundary systems, including the type and number of WQOs and Alert Levels used by the ISRB, IRRB, IRLWWB and ISCRWB. This complex set of issues surrounding WQOs and Alert Levels, prompted this assessment of all boards' WQOs and Alert Levels. This report is intended as a foundational piece for developing a path forward as the IJC becomes more aware of and responsive to water quality concerns along the transboundary.

There is a wide variety of parameters, WQO threshold levels and Alert Levels across the four boards. This is in part due to the environmental context and the history of human activities in each of the transboundary systems, but also in part due to boards responding to specific water quality needs in each basin, including terms stated in references issued to the IJC by governments and limitations in obtaining government approval to modify WQO lists. The ISRB has a large, comprehensive WQO list with no Alert Levels and the IRRB has a small WQO list with several Alert Levels. The ISCRWB has one WQO, largely due to good water quality conditions, and an extensive list of parameters collected through grab sample monitoring. The IRLWWB intends to work towards recommending a modern list of WQOs and Alert Levels that better address Lake of the Woods basin water quality monitoring needs.

The last component of this review compared board WQO threshold levels to surrounding state, provincial and, where applicable, federal water guidelines for the ISRB and IRRB. Findings showed that many thresholds are comparable to water quality standards/objectives and guidelines for relevant jurisdictions, further substantiating the need to better understand the consistent WQO threshold exceedances for several of the parameters. In particular, board-led investigation of the environmental context, watershed processes and land use factors, as well as climate variability and change, responsible for elevated concentrations of select water quality parameters is warranted.

The final section of this report provided an opportunity for the four boards to communicate any issues or future directions related to WQOs and water quality in their basins. Overall, the resounding and consistent message delivered in this section of board narratives is that all boards plan to develop strategies to review their WQOs on a routine basis. This is encouraging since the IJC has in its directives that boards are to periodically review WQOs to ensure they reflect current criteria, advances in analytical detection and precision and modern pollution issues.

While IJC boards are the primary initiators for any changes to their respective lists and levels of WQOs and Alert Levels, there is a role for the IJC to help facilitate and coordinate board activities in the area of water quality and to provide guidance on the processes that may be involved.

7. References

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8. Appendices

Appendix 1

Parameter	Unit	Guide-Lines	St. Croix River at Forest City (NB01AR0151)					
			02/04/20	04/09/201	06/25/201	07/22/201	09/10/201	11/04/201
ALUMINUM	µg/L	100	113.2	157	100	106	43	205
ANTIMONY	µg/L		0.04	0.04	0.06	0.04	0.05	VNA
ARSENIC	µg/L	5	0.36	0.34	0.55	0.66	0.47	VNA
BARIUM	µg/L		7.5	5	7	6	7	7
BERYLLIUM	µg/L		0.02	0.01	<0.01	0.01	<0.01	VNA
CADMIUM	µg/L	calculated	0.03	0.02	0.04	0.02	0.03	VNA
CALCIUM	mg/l		4.05	3.64	4.1	3.95	4.07	4.04
CHLORIDE	mg/l	150	4.52	4.3	4.4	3.1	4.7	4.8
CHROMIUM	µg/l	8.9	0.19	0.27	0.23	0.21	0.14	VNA
COBALT	µg/l		0.04	0.14	0.05	0.05	0.01	VNA
COLOUR	Hazen Units		65	51	70	82	42	97
COPPER	µg/l	2	0.4	0.39	0.54	0.4	0.32	VNA
ANALKALINITY	mg/l ($CaCO_3$)		9.81	9	12	10	13	9
IRON	mg/l	0.3	0.16	0.27	0.25	0.28	0.16	0.36
LEAD	µg/l	1	0.11	0.22	0.16	0.06	0.14	VNA
MAGNESIUM	mg/l		0.71	0.69	0.66	0.63	0.64	0.81
MANGANESE	µg/l		31.8	53	55	62	44	42
MOLYBDENUM	µg/l	73	0.1	0.08	0.13	0.12	0.16	VNA
NICKEL	µg/l	25	0.29	0.45	0.41	0.34	0.23	VNA
NITRATE	mg/l as Nitrogen	2.9	0.06	0.07	0.05	0.07	0.05	0.06
pH - LAB	pH Units	6.5-9.0	7.08	7.13	7.2	7.13	7.28	6.98
PHOSPHOROUS	mg/l	0.03	0.017	0.018	0.018	0.019	0.02	0.02
POTASSIUM	mg/l		0.7	0.5	0.6	0.5	0.9	0.7
SELENIUM	µg/l		0.08	0.06	0.05	0.07	0.06	VNA
SILVER	µg/l	0.05	<0.01	<0.01	<0.01	<0.01	<0.01	VNA
SODIUM	mg/l		5.78	4.2	5.88	4.16	7.22	5.31
SPECIFIC CONDUCTANCE - LAB	µS/cm		54	44.8	51.7	41.8	58.9	50
STRONTIUM	µg/l		19.3	16	19	20	20	VNA
SULPHATE	mg/l		6.36	3.3	5.2	3.5	6.6	5.4
THALLIUM	µg/l		<0.01	<0.01	<0.01	<0.01	<0.01	VNA
TIN	µg/l		<0.05	<0.05	<0.05	<0.05	<0.05	VNA
TITANIUM	µg/l		1.28	2.81	1.42	1.21	0.88	VNA
TTL ALKALINITY	mg/l ($CaCO_3$)		<20	<20	<20	<20	<20	<20

TOTAL NITROGEN	mg/l		0.36	0.33	0.35	0.44	0.32	0.43
TOTAL ORGANIC CARBON	mg/l		8.8	6.4	9	10	6.9	11.4
TURBIDITY - LAB	NTU		1.2	3.3	1.9	1.4	1.7	4.1
URANIUM	µg/l		0.09	0.06	0.07	0.08	0.06	VNA
VANADIUM	µg/l		0.3	0.35	0.38	0.35	0.34	VNA
ZINC	µg/l	calculated	3.26	2.58	31.9	5	3.72	VNA

- Yellow highlights indicate an exceedance

Appendix 1 (Continued)

Parameter	Unit	Guide-Lines	St. Croix River at Forest City (NB01AR0151)					
			02/04/20	04/09/201	06/25/201	07/22/201	09/10/201	11/04/201
ALUMINUM	µg/l	100	8.4	8	15	17	10	18
ANTIMONY	µg/l		0.04	0.04	0.04	0.04	0.04	VNA
ARSENIC	µg/l	5	0.26	0.23	0.23	0.21	0.2	VNA
BARIUM	µg/l		2.2	2	2	2	2	2
BERYLLIUM	µg/l		<0.01	<0.01	<0.01	<0.01	<0.01	VNA
CADMIUM	µg/l	calculated	<0.02	<0.02	<0.02	<0.02	<0.02	VNA
CALCIUM	mg/l		4.54	4.7	4.36	4.38	4.4	4.4
CHLORIDE	mg/l	150	1.63	1.6	1.5	1.5	1.4	1.4
CHROMIUM	µg/l	8.9	0.07	0.07	0.06	0.05	0.06	VNA
COBALT	µg/l		<0.01	0.01	<0.01	<0.01	<0.01	VNA
COLOUR	Hazen Units		13	13	15	14	14	14
COPPER	µg/l	2	0.28	0.56	0.26	0.24	0.22	VNA
GRANALKALINIT	mg/l $CaCO_3$		11.33	12	12	12	12	12
IRON	mg/l	0.3	<0.02	<0.02	0.02	0.02	<0.02	0.03
LEAD	µg/l	1	<0.03	0.03	0.03	<0.03	<0.03	VNA
MAGNESIUM	mg/l		0.65	0.65	0.61	0.6	0.62	0.63
MANGANESE	µg/l		3.2	3	3	4	4	9
MOLYBDENUM	µg/l	73	0.06	0.06	0.06	0.07	0.06	VNA
NICKEL	µg/l	25	0.15	0.17	0.14	0.15	0.16	VNA
NITRATE	mg/l as Nitrogen	2.9	0.02	0.02	0.02	<0.01	<0.02	0.03
pH - LAB	pH Units	6.5-9.0	7.33	7.31	7.37	7.41	7.36	7.3
PHOSPHOROUS	mg/l	0.03	0.004	0.005	0.005	0.004	0.004	0.006
POTASSIUM	mg/l		<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
SELENIUM	µg/l		0.06	0.08	0.04	<0.03	0.07	VNA
SILVER	µg/l	0.05	<0.01	<0.01	<0.01	<0.01	<0.01	VNA
SODIUM	mg/l		1.49	1.55	1.46	1.39	1.42	1.41
SPECIFIC CONDUCTANCE - LAB	µS/cm		34.1	35.8	33.1	31.6	32.5	32.1
STRONTIUM	µg/l		24	24	23	23	23	23
SULPHATE	mg/l		1.68	1.6	2.3	1.4	1.6	1.9
THALLIUM	µg/l		<0.01	<0.01	<0.01	<0.01	<0.01	VNA
TIN	µg/l		<0.05	<0.05	<0.05	<0.05	<0.05	VNA
TITANIUM	µg/l		0.18	0.21	0.19	0.22	0.1	VNA
TOTAL ALKALINITY	mg/l $CaCO_3$		<20	<20	<20	<20	<20	<20
TOTAL NITROGEN	mg/l		0.17	0.2	0.17	0.17	0.17	0.17

TOTAL ORGANIC CARBON	mg/l		4.3	4.6	5.1	4.2	4	3.72
TURBIDITY - LAB	NTU		0.5	0.3	0.5	0.4	0.5	1.1
URANIUM	µg/l		0.03	0.03	0.03	0.03	0.03	VNA
VANADIUM	µg/l		0.06	0.06	0.06	0.06	0.08	VNA
ZINC	µg/l	calculated	0.19	1.09	0.18	0.18	0.14	VNA