July 16, 2012

Re: "Draft Site-Specific Water Quality Objectives for the Red Deer River Basin with Emphasis on the Mainstem."

Dear reader,

The Red Deer River Watershed Alliance gratefully acknowledges Dr Anne-Marie Anderson, PhD, who researched and wrote the appended report titled, "Draft Site-Specific Water Quality Objectives for the Red Deer River Basin with Emphasis on the Mainstem." Dr. Anderson's work benefited greatly from the assistance of the public and stakeholders, who took part in numerous consultation processes, and from the involvement of members of the Technical Advisory Committee, who contributed their time and advice at various stages in the preparation of this report. Alan Dolan, Alan Dolan & Associates, facilitated the community engagement process and chairs the Technical Advisory Committee.

The report is one in a series of Background Technical Reports that will be completed to provide critical information for the development of the Watershed Alliance's Integrated Watershed Management Plan.

During the public and stakeholder consultation process, a number of important concerns were raised related to surface water quality in the Red Deer River system. Dr Anderson and members of the Technical Advisory Committee reviewed all those concerns and made recommendations to the Watershed Alliance. The main concerns and rationales for including or not including them in the report are presented in the table below. A number of additional indicators were proposed, but, in many cases, water quality issues are addressed adequately by indicators already adopted in the report.

Concern	Rationale for including or not including in report
Industrial use of water in Reaches 1, 2 and 3 (oil and gas) and 6 (other industry)	Included
Need for water quality monitoring on Reaches 1 and 2 and at mouths of major tributaries	Included
Add surface water quality issues: chemicals used in hydraulic fracturing	Included
Add surface water quality issues: emerging contaminants including pharmaceuticals	Included
Add surface water quality issues: water temperature	Not included. Already monitored by provincial government at long-term river network sites.
Add indicator for nutrient enrichment: soluble reactive phosphorus, Biochemical	Not included. Total dissolved phosphorus (TDP) is an appropriate indicator; Dissolved

Concern	Rationale for including or not including in report
Oxygen Demand (BOD), and Chlorophyll-*a*	oxygen (DO) is a more relevant indicator for describing the quality of surface waters; chlorophyll-a is monitored by provincial government at long-term river network sites and is of more relevance in lakes.
Add indicators for erosion and sedimentation: colour, sediment deposition and turbidity	Not included. Colour is not a useful indicator because it can be an indicator of a host of different water conditions; it is unclear how sediment deposition could be incorporated into water quality monitoring; turbidity is already monitored by provincial government at long-term river network sites.
Add indicators for salinity: electrical conductivity, sodium and calcium	Not included. Provincial government already monitors electrical conductivity, sodium and calcium at long-term river network sites.
Add indicator for pathogen contamination: cyanobacteria, viruses	Not included. Cyanobacteria are of much more relevance in lakes than rivers. Viruses would require additional specialized research.
Inclusion of major lakes in IWMP	Will be included in the IWMP. Major lakes of the Red Deer River watershed are part of the IWMP. However, water quality targets/objectives will not be set for lakes, because these are being developed through a separate lake management planning process.
Need to indicate in the list of beneficial management practices (BMPs) that many organizations and individuals are already practising them	Included in report.

This report is available for downloading at RDRWA's website — www.rdrwa.ca.

Yours truly,

Gerard Aldridge
Chair, Project Management Unit,
Integrated Watershed Management Plan
cc: RDRWA Board of Directors, TAC

Draft Site-Specific Water Quality Objectives for the Red Deer River Basin with Emphasis on the Mainstem

July 2012

Prepared by

Anne-Marie Anderson Ph.D. P. Biol., Alan Dolan & Associates

EXECUTIVE SUMMARY

The Red Deer River Watershed Alliance (RDRWA) was formed to promote watershed health and the good use and proper management of water in the Red Deer River watershed. Good water quality is crucial to achieving the outcomes of *Water for Life- Alberta's Strategy for Sustainability*: safe, secure drinking water; healthy aquatic ecosystems; and quality water supplies for a sustainable economy.

The RDRWA has undertaken the development of an Integrated Watershed Management Plan (IWMP). Water quality is the first component to be addressed by the IWMP. The overall water quality management goal is defined as *"Maintain or Improve Water Quality in the Red Deer River Watershed,"* which is compatible with *Water for Life*, interprovincial agreements, and other water quality management initiatives in the province. Although the goal applies to all water bodies in the watershed, the process began with the development of draft site-specific water quality objectives (WQOs), or targets, for the mainstem of the Red Deer River. The river was segmented into four management reaches that were delineated by long-term river water quality monitoring sites between the Dickson Dam and the Alberta-Saskatchewan border.

The Technical Advisory Committee (TAC), which met monthly from October 2011 to March 2012, provided advice and reviews that greatly assisted in the drafting of site-specific WQOs. The TAC is composed of resource experts from a variety of disciplines, who provide advice to the RDRWA on the development of the IWMP.

In February and March 2012, the key points in this report were presented to public and stakeholders and input was solicited through a series of stakeholder workshops and an online response form.

Key water quality issues for the Red Deer River and associated water quality indicators were identified based on input from the public and stakeholders, and information contained in the State of the Watershed report. Draft WQOs were developed for 11 water quality indicators; dissolved oxygen, total phosphorus, dissolved phosphorus, total nitrogen, ammonia, nitrite, and (nitrite+nitrate)-nitrogen, total dissolved solids, total suspended solids, fecal coliform bacteria, and *E. coli*. Although the relevance of pathogens, pesticides and other man-made organic compounds as water quality indicators has been identified by public and stakeholder input and acknowledged by the TAC, the data and knowledge on these indicators are presently insufficient to draft objectives.

Ambient conditions at long-term river monitoring sites were compared to provincial and federal surface water quality guidelines designed to protect specific uses. If the most protective guideline was met by ambient data, or there were no relevant guidelines, then the 50^{th} percentile (median) and the 90^{th} percentile were adopted as objectives and the management goal was to maintain conditions, or improve them if river water quality was known to have been impacted by human activities. The 50^{th} and 90^{th} percentile represent average and extreme conditions to which the local aquatic ecosystem is adapted. If guidelines were exceeded by ambient conditions, then the most sensitive guideline was adopted as the objective and the management goal was to improve conditions and restore use protection. In keeping with the overall management intent, WQOs were recognized as limits, or thresholds, and trends indicative of deteriorating conditions would trigger remedial action.

WQOs are fundamental water quality management tools and the draft objectives presented here are intended to initiate discussion on the management of Red Deer River water quality. The objectives can

be used as: management tools to help determine the most practical and effective point or non-point source load reduction strategy; planning tools to help determine under what growth scenarios WQO will continue to be met; and assurance tools to demonstrate that with proper management of human activities in the basin, water quality can be maintained or improved.

There are currently insufficient water quality data for the Red Deer River upstream of Glennifer Lake and for major tributaries to draft water quality objectives. However, a summary of available data is provided to help confirm water quality issues, highlight data gaps and provide general guidance in the development of the IWMP.

This report provides recommendations with respect to monitoring needs, tool development, research and the general need for implementing beneficial management practices (BMPs).

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

ACKNOWLEDGEMENTS

The assistance, guidance and advice provided by the TAC during monthly meetings are gratefully acknowledged. Special thanks go to Carolyn Campbell, Chris Teichreb and Brock MacLeod for the active role they played as members of a working group and the valuable comments, information and insights they provided in the course of reviewing successive drafts.

Angus Schaffenburg (City of Red Deer) supplied information on the timing and nature of recent upgrades at the Red Deer Municipal Wastewater Treatment Plant.

Terry Chamulak (Alberta Environment and Water) provided generated flow data for water quality sampling sites on the Red Deer River that were not gauged by Water Survey of Canada.

Richard Casey (Alberta Environment and Water) supplied water quality data from the Prairie Provinces Water Board Station at Bindloss. As AEW's representative on the PPWB Committee on Water Quality, Mr. Casey was able to share information on the approach currently taken by PPWB to set draft Water Quality Objectives at interprovincial monitoring sites.

Doreen Leclair (Alberta Environment and Water) downloaded all water quality data for the Red Deer River and its tributaries from the provincial database.

Members of the public and stakeholder groups have been providing valuable input throughout the consultation process that began in January 2010 and will continue until the completion of the IWMP.

Associates from Alan Dolan and Associates are acknowledged for managing the IWMP project and chairing the TAC meetings (Alan Dolan) and compiling detailed minutes and taking care of logistics (Rene Michalak).

The RDRWA is also grateful for the project funds and in-kind support provided by Alberta Environment and Sustainable Resource Development (AESRD) as well as support from numerous provincial, municipal and other organizations.

1.0 INTRODUCTION

The Red Deer River Watershed Alliance (RDRWA) was formed to promote watershed health and the good use and proper management of water in the Red Deer River watershed. It was designated as the Watershed Planning and Advisory Council (WPAC) for the Red Deer River watershed under the Government of Alberta's Water for Life Strategy in September 2005.

The fundamental goal under the Water for Life Strategy (GOA 2003; 2008a) is to ensure the sustainable management of the province's water resources so that Albertans are assured of:

- Safe and secure drinking water supply
- Healthy aquatic ecosystems
- Reliable quality water supplies for a sustainable economy

As indicated in Alberta's Water for Life Strategy, WPACs are responsible for 'leading watershed planning, developing best management practices, fostering stewardship activities within the watershed, reporting on the state of the watershed, and educating users of the water resource.'

Phase 1 of the planning process was completed in 2009 when the RDRWA released its State of the Watershed Report. Phase 2 is to develop an integrated watershed management plan (IWMP) for the Red Deer River basin.

The terms of reference as approved by the board of the RDRWA state that the objectives of the IWMP are:

- To set targets and thresholds for water quality, land use, biological, and water quantity indicators as reported in the State of the Watershed Report.
  The process of identifying targets and thresholds allows stakeholders to work out mutually acceptable solutions for the protection, restoration, and/or maintenance of the health of the individual sub-watersheds as well as the Red Deer River watershed as a whole.
- To make recommendations such as best management practices, market-based instruments, monitoring strategies, future research priorities that may eventually be reflected in policies.
- To provide information and guidance to stakeholders in developing their action plans to implement recommendations of the IWMP.
- To provide decision-makers with the relevant information specific to the Red Deer River watershed essential for its effective protection, restoration, and/or maintenance as a healthy watershed.

Water quality (WQ) is the first component of the IWMP on which work has been initiated by the RDRWA.

Protecting water quality is important for all water bodies in the basin including rivers, streams, lakes, wetlands, and aquifers. However, it was not practical for the RDRWA to address the assigned tasks for all individual water bodies in the basin. Not only is this a massive undertaking that needs to occur in phases, but it also requires considerable information on ambient conditions, stressors and issues. The TAC undertook to focus on the mainstem of the Red Deer River. The Red Deer River is the largest water body in the basin and it is of critical environmental, economic and social importance. It is influenced by all activities in the watershed and defining water quality expectations for the Red Deer River has intrinsic implications on the management of the cumulative effects of these activities. Furthermore, its water quality and quantity are subject to Inter Provincial Agreements that must be respected.

The Technical Advisory Committee (TAC), which met monthly from October 2011 to March 2012, provided advice and reviews that greatly assisted in the drafting of site-specific WQOs. The TAC is composed of resource experts from a variety of disciplines, who provide advice to the RDRWA on the development of the IWMP.

The TAC is tasked with:

- Setting targets and limits for key water quality variables (i.e., indicators)
- Making recommendations on management, monitoring and research priorities
- Providing information and guidance to stakeholders
- Providing general guidance as to how WQ should be managed

The TAC included the following participants:

Table 1. List of TAC Members

Alphabetic list of TAC Members	Field of Expertise	Agency
Angus Schaffenburg (*)	Urban planning	City of Red Deer
Brad Dardis	Sustainable stormwater management; urban planning	Stantec, Red Deer
Brandon Leask (*)	Farm water quantity / quality	Alberta Agriculture and Rural Development
Brock McLeod (*)	Surface runoff modeling, water quality	Alberta Agriculture and Rural Development
Carolyn Campbell (*)	Wildlife and recreation	Alberta Wilderness Association
Chris Teichreb (*)	Aquatic ecology / water quality	Alberta Environment and Water
Dr. Mishka Lysack	Environmental ethics	University of Calgary
Dr. Peter Boxall	Market-based instruments and agricultural BMPs	University of Alberta
Jason Cooper (*)	Fisheries	Alberta Sustainable Resource Development
Jill Carlsen (*)	Hydrogeology	EnCana Corporation
Julie Pierce (*)	Wetlands	Ducks Unlimited Canada
Kevin Gagne	Forest management	Alberta Sustainable Resource Development
Kevin Warren	Cumulative air, water, soil conservation	Parkland Airshed Management Zone
Maggie Romuld (*)	Physical geography / geomorphology, stream ecology	University of Lethbridge
Michael A. Kitchen	Low impact development	Osprey Engineering
Quentin Schatz	Environmental public health	Alberta Health Services
Tennille Kupsch (*)	Rangelands and riparian areas	Alberta Sustainable Resource Development
Terry Chamulak	Hydrology	Alberta Environment and Water
Terry Krause	Parks planning	Alberta Tourism, Parks and Recreation
Trevor Wallace (*)	Nutrient / manure management	Alberta Agriculture and Rural Development

(*) TAC members who attended monthly meetings and provided input in the drafting of WQO's

This document summarizes the process adopted by the RDRWA and the progress to date in achieving the assigned tasks for the mainstem of the Red Deer River. This process is fundamentally transferable to other water bodies. Many recommendations regarding information needs, tool development, or enhanced management practices apply to the Red Deer River and smaller water bodies and their watersheds.

There are currently insufficient water quality data for the Red Deer River upstream of Glennifer Lake and for major tributaries to draft water quality objectives. However, a summary of available data is provided to help confirm water quality issues, highlight data gaps and provide general guidance in the development of the IWMP.

Of note is that lake management plans have been or are being developed for all large recreational lakes in the basin and many of these plans include the development of WQOs. These plans will be referenced in the RDRWA IWMP.

2.0 DEFINITIONS AND MANAGEMENT GOAL

2.1 Definitions

In order to minimize new terms and keep definitions as basic as possible, maximize consistency with existing terminology, and align terminology with acts, regulations, and guidance where available (e.g., GOA 2011, AEW 2012), the following terminology and definitions were adopted in this document.

Surface Water Quality Guideline (SWQG): a numerical concentration or narrative statement which is recommended to protect a specific use of water.

- Typically based on knowledge of species-specific tolerances (e.g., guidelines for the protection of aquatic life are based on toxicity testing).
- Generic (may be 'over-' or 'under-' protective); apply to any water body.
- Alberta (AENV 1999), Canadian Council Ministers of the Environment (CCME 1999), United States Environmental Protection Agency (USEPA 1986) have developed or adopted guidelines to protect specific uses.

Site-Specific Water Quality Objective (WQO): a numerical concentration or narrative statement which has been established for specified waters, at a specific site, and which has an action and/or a management commitment.

- Typically applicable to site-specific conditions and relying on ambient data. Natural variability is built into site-specific WQO.

Target: a concentration or narrative statement that management aims to achieve or do better than.

- Conceptually most akin to site-specific WQO: represents the desired water quality condition, at which management would be directed (e.g., would dictate the maximum allowable load) of a specific contaminant.
- Targets could be equal to or more stringent than a limit, but would not be less stringent.

Ambient limit: a level or condition beyond which the most sensitive use may not be protected (referred to as threshold in the IWMP terms of reference).

- Generally meant to define the boundary beyond which we do not want to go because the risk to aquatic ecosystem health and other water uses is considered too high.
- *Note when the most sensitive SWQG = WQO or target, then it is also = limit*

2.2 Management Goal for the Red Deer River Watershed

The RDRWA's vision is that the IWMP will achieve, or exceed requirements under government regulations.

In terms of water quality management this implies that, at a minimum, 'use protection' will be achieved. Moreover, management efforts will be directed towards maintaining current conditions where they are good, and improving conditions where they have deteriorated because of human activities.

This management goal is conceptually compatible with those incorporated in the development of water quality objectives for the Bow River (BRBC 2008), North Saskatchewan River (NSWA 2010), Battle River (Golder 2011) and the Prairie Provinces Water Board (PPWB in progress).

3.0 DEVELOPING SITE-SPECIFIC OBJECTIVES FOR THE MAINSTEM OF THE RED DEER RIVER

The development of site-specific WQO for the RDR IWMP relied on information presented in the State of the Watershed Report (Aquality 2009) and on input received through the public and stakeholder consultation process. Drafting of site-specific WQO is an evolving process and the RDRWA has benefitted from the experiences of other WPACs on this topic (e.g., Bow, North Saskatchewan, Oldman, South Saskatchewan and Battle rivers). In particular, the process for the South Saskatchewan River Basin planning (Golder 2009) included the Red Deer River Basin and was foundational for the present document.

The general approach that was adopted to draft site-specific WQO for the Red Deer River mainstem followed procedures outlined in a guidance document produced by Alberta Environment and Water (AEW 2012). Furthermore, the need to derive objectives that are compatible with those set by the Prairie Provinces Water Board for the Red Deer River at the Alberta-Saskatchewan border was of particular importance because of inter-provincial agreements (PPWB 1969; 1991).

The following steps were involved in the drafting of site-specific WQO for the Red Deer River:

1. Identify stressors and associated water quality issues
2. Identify water uses in the basin
3. Delineate reaches
4. Identify water uses applicable to each reach
5. Select key water quality indicators for each use
6. Draft site-specific WQO for each reach

3.1 Identify Stressors and associated Water Quality Issues

Any activity in the watershed has the potential to influence water quality by altering the chemical, physical and biological properties of the water and therefore can be regarded as a stressor. Typically, stressors are grouped into 'point sources' (PS), 'non-point sources' (NPS), and physical alterations.

For the Red Deer River Basin, point sources include municipal and industrial wastewater discharges, and storm water runoff conveyed to surface waters via storm sewers. Tributaries can also be regarded as point sources to the mainstem river. Non-point sources are diffuse sources of contaminants associated with overland runoff from rain or snowmelt, atmospheric deposition, and ground water infiltration. Although non-point sources occur naturally, contaminant loading can increase as a result of man-made land disturbances. Potential non-point sources of contaminants in the Red Deer River Basin include forestry, agriculture, municipal, urban and rural development and associated infrastructure, recreation and development, oil and gas development and riparian uses (e.g., unrestricted access to water by livestock and recreational vehicles).

Water quality issues typically associated with point and non-point sources involve nutrient enrichment, pathogen contamination, erosion and sedimentation, increases in salts or major ions, and contamination with pesticides and other man-made chemicals, such as pharmaceuticals (e.g., Stantec 2005, public and stakeholder consultation for the RDRWA IWMP).

Physical structures such as the Dickson Dam and the creation of Glennifer Lake have altered the hydrologic regime and several aspects of water quality downstream (e.g., dissolved oxygen and temperature fluctuation, and the delivery of suspended solids).

3.2 Identify Water Uses in the basin

Uses of Red Deer River water that depend on water quality, and associated high level outcomes of the Water for Life Strategy are listed in Table 2. In many instances, water quality guidelines have been established to describe the desirable state of water quality indicators that support these uses (AENV 1999, CCME 2003).

Table 2. Water Uses for the Red Deer River and Associated Water for Life Outcomes

Uses	Water for Life Outcomes
Protection of Aquatic Life	Healthy Aquatic Ecosystems
Raw Water for Drinking Water Supply	Safe, secure drinking water supply
Livestock Watering	Quality water supply for a sustainable economy
Irrigation	Quality water supply for a sustainable economy
Industry	Quality water supply for a sustainable economy
Aesthetics	Quality water supply for a sustainable economy; Healthy aquatic ecosystems
Recreation	Quality water supply for a sustainable economy; Healthy aquatic ecosystems

3.3 Delineate Reaches

The Red Deer River was segmented into reaches based on broad ecoregional changes, changes in land use and the location of long-tem water quality monitoring stations at the lower end of reaches 3 to 6 (i.e., Hwy 2, Nevis, Morrin, Bindloss and Jenner).

- Reach 1 - Headwaters to Hwy 22
- Reach 2 - Hwy 22 to upstream of Glennifer Lake
- Reach 3 - Glennifer Lake to Hwy 2
- Reach 4 - Hwy 2 to Nevis
- Reach 5 - Nevis to Morrin
- Reach 6a - Morrin to Jenner
- Reach 6b Jenner to Bindloss

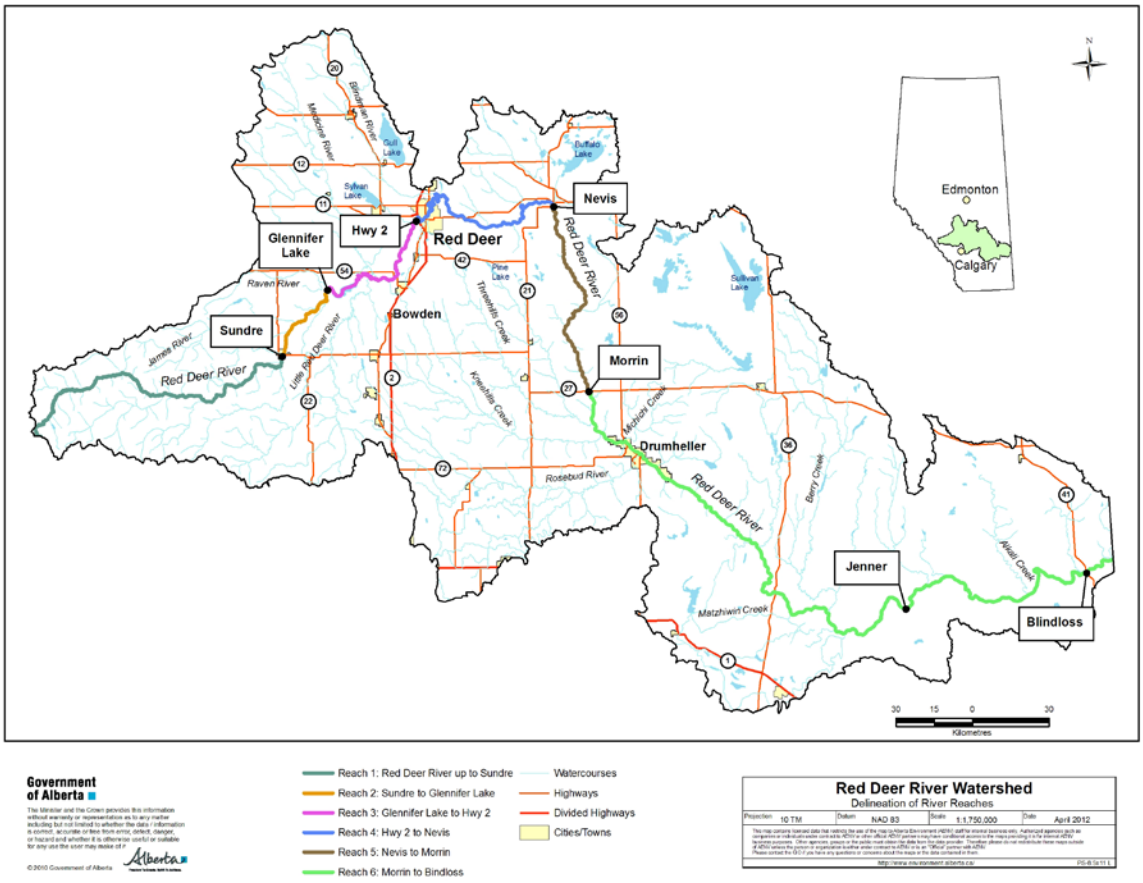


Figure 1. Delineation of Red Deer River Reaches

The reach definition was modified from what was originally proposed in Golder (2009):

- Reach 2 and 3 - Originally the Dickson Dam formed the lower portion of Reach 2. Defining reach-specific objectives would have required monitoring data from the dam site. That site was not considered representative of river conditions in Reach 2. Hence, Reach 2 was redefined and now ends upstream of Glennifer Lake. Glennifer Lake now forms the upper portion of Reach 3.
- Reach 6 is very long and the TAC recommended splitting it into two sub-reaches at Jenner, the site of a long-term water quality monitoring station recently established by AEW.

3.4 Identify Water Uses Applicable to Each Reach

Feedback received during the Stakeholder Workshops held in February 2012 indicated a strong desire to protect all uses identified in Table 2 now and in the future, whether they are currently relevant in a given reach or not.

This approach is consistent with the approach taken by the Prairie Provinces Water Board. It implies that if ambient concentrations are worse than the guidelines, reach management will at a minimum aim for compliance with surface water quality guidelines that protect the most sensitive use.

3.5 Select Key Water Quality Indicators for Each Use

Terms of reference for the RDR IWMP (RDRWA 2010) specify that draft targets and limits (initially referred to as thresholds) have to be defined for total nitrogen, total phosphorus, bacteria, parasites and pesticides. Following the review of water quality issues and uses in the basin and with the input provided through public and stakeholder consultation, and advice of the TAC, the RDRWA adopted a more comprehensive list of indicators that would be of greater practical use in the implementation of the water quality component of the IWMP.

- **Nutrient enrichment or eutrophication**

Potentially affected uses are the protection of aquatic life, drinking water supply, recreation, stock watering and aesthetics.

Key water quality indicators:

  - Total phosphorus (TP), dissolved phosphorus (TDP)
  - Total nitrogen (TN), nitrite and nitrate, nitrite, ammonia
  - Dissolved oxygen (DO)

- **Erosion and sedimentation (sediment transport)**

Potentially affected uses are protection of aquatic life, raw drinking water supplies, and industrial uses.

Key water quality indicator:

  - Total suspended solids (TSS)

- **Pathogen contamination**

Potentially affected uses are raw drinking water, recreation, irrigation and stock watering.

Key water quality indicators:

  - Fecal coliform bacteria. *E. coli*
  - *Cryptosporidium* and *Giardia*

- **Salinity**

Potentially affected uses are aquatic life, irrigation and industry.

Key water quality indicator:

  - Total dissolved solids (TDS)

- **Pesticide contamination**

Potentially affected uses are aquatic life, raw drinking water, irrigation and stock watering.

Key water quality indicators:

  - Pesticides (e.g., herbicides, insecticides, fungicides) in use in the basin

- **Contamination by other man-made contaminants**

Potentially affected uses are aquatic life, raw drinking water, irrigation and stock watering.

Key water quality indicators:

  - Pharmaceuticals and personal care products
  - Poly-brominated diphenyl ethers (flame retardants), nonylphenolethoxylates, phthalates, and other contaminants referred to as 'emerging contaminants'

A review of the long-term data sets for the Red Deer River (Reaches 3 to 6) showed that monthly data were available for most water quality variables of interest. However, some variables were sampled less frequently (e.g., pesticides: four times a year; other trace organics: twice a year). Pharmaceutical data were only collected as part of special projects and there were no *Giardia* or *Cryptosporidium* data in the AEW or PPWB data sets. Such data gaps combined with an incomplete understanding of the implications of these contaminants to various uses precluded the drafting of objectives for these variables.

3.6 Draft Site-Specific WQO for each Reach

Guidance provided by AEW (2012) was incorporated in the drafting of site-specific WQO for the Red Deer River mainstem. This relates to terminology used, the description of a management direction, the situation assessment, and specific approaches to derive objectives using background data.

The Prairie Provinces Water Board is in the process of developing site-specific WQO for its interprovincial monitoring sites. The RDRWA strived to develop compatible objectives by adopting some key steps from PPWB. More specifically this relates to:

- The derivation of site-specific WQO for open water (OW) and ice cover (IC) using fixed dates to define these two periods (OW: April 1 to and including October 31, and IC: November 1 to

and including March 31) . In practice, the IC period corresponds with lower flow open water conditions.

- The 90th percentile (or 10th percentile for some variables such as dissolved oxygen) was used to describe 'extreme' conditions instead of the 95th or 5th percentiles, which have been used elsewhere (e.g., NSWA 2010). In keeping with AEW (2012) and approaches taken for the South Saskatchewan River Basin and the Battle River, the 50th percentile, or median, is also proposed as an objective to describe 'average' conditions under ice or during open water. PPWB views trend assessment as a means of detecting departures from the median, but does not use the median as an objective.

- PPWB advocates the use of 10 years of data that represent the best water quality conditions. Statistical trend analysis was applied to the Red Deer River data sets to determine if water quality had changed over time.

3.6.1 Assemble Water Quality Data

Fully validated long-term monitoring data for the Red Deer River at Hwy 2 (Reach 3), Nevis (Reach 4), Morrin (Reach 5) and Jenner (Reach 6a) were downloaded from the Alberta Environment website in November 2011. In December 2011 AEW's Data Monitoring and Validation Branch, Edmonton, also provided a download of Red Deer River data that contained a longer period of record for the Morrin site. PPWB data for Bindloss (Reach 6 and 6b) were provided by Richard Casey, AEW's representative on the PPWB-Committee on Water Quality.

Monitoring at Alberta Environment's long-term river network sites started in the 1960s or 1970s depending on the water quality indicator. However, only data from 1987 to and including March 2010 were used to derive objectives. Step trends occurred for many water quality indicators when Alberta Environment took over the long-term monitoring program from Environment Canada in 1986-87 (e.g., Hebben 2005). These step trends are not due to changes in ambient conditions; they are artefacts of changes in analytical procedures and essentially break the continuity of the data sets.

Water quality data were available for the period 1987 to early 2010 for the monitoring sites at Hwy 2, Morrin and Bindloss, but the data records for Nevis and Jenner were shorter. Regular monthly sampling at Nevis started in 1999, yielding only a 10-year data record. Although trend analysis was carried out for this site, all data were used to derive objectives. Sampling at Jenner started in 1996, but has not been carried out consistently. Most samples were collected during the open water and it is only recently (2010) that regular monthly sampling has been carried out.

3.6.2 Conduct Trend Analysis and Calculate Percentiles

Trend analysis was carried out for each indicator and at each of the four long-term monitoring sites on the Red Deer River to determine if trends had occurred over time. If a trend was detected, the most recent (for improving trends), or oldest (for deteriorating trends) 10 years of data were used to generate percentiles. This is consistent with the approach used by PPWB.

Data were examined for two types of trends: step trends and monotonic trends. Step trends are generally the result of changes in methods (as mentioned above) or changes in point source loadings (e.g., reduction of loadings from municipal wastewater discharges). They are usually apparent in time series plots. Although improvements in municipal wastewater treatment did occur at Red Deer during the period 1989 to 2010, step trends were not apparent at Nevis. This is due to the fact that improvements at the Red Deer wastewater treatment plant preceded or coincided with the establishment of this sampling site and the most recent improvements (full tertiary treatment implemented in 2010) occurred beyond the period of record considered here for Nevis.

Testing for monotonic trends followed the approach outlined in Hebben (2005). Statistical analyses were performed using WQHydro (Aroner 2011), a DOS-based software package. Monthly data were tested for seasonality using the Kruskall-Wallis test. Seasonal data were then deseasonalized and tested for auto-correlation using the Kendall Tau and Spearman Rho tests. Water quality indicators that returned significant results for both seasonality and serial correlation were tested for trends over time using the Seasonal Kendall test that accounts for autocorrelation (seasonal Kendall with auto-correlation SKC). Indicators that were seasonal, but not auto-correlated were examined with a Seasonal Kendall test with auto-correlation (SK). Infrequently, variables did not exhibit seasonality and data were not auto-correlated; in such cases the Mann-Kendall analysis on monthly data (MK) was applied.

The trend analysis involved two steps: first the entire data set was tested. If a trend was detected then the analyses were repeated on data for open water (OW) and ice cover (IC), separately. The outcome of these analyses determined which data were used to derive site-specific WQOs.

Flow dependency was evaluated by regression analysis. If the regression coefficient was significant and greater than 0.3 then trend analysis was repeated on flow-adjusted data (i.e., residuals). Flow data from the Red Deer and Bindloss station were merged with water quality data from Hwy 2 and Bindloss, respectively. There are no active gauging stations in the immediate vicinity of Nevis and Morrin and modelled flow data were generated to evaluate flow dependency.

For the purposes of this report, trends that demonstrated a significant slope at a confidence interval of 90% or greater were considered meaningful.

Trend analysis was carried out for Nevis data, but since the sample record was only 10 years, all data were used to derive objectives, regardless of whether trends were observed or not.

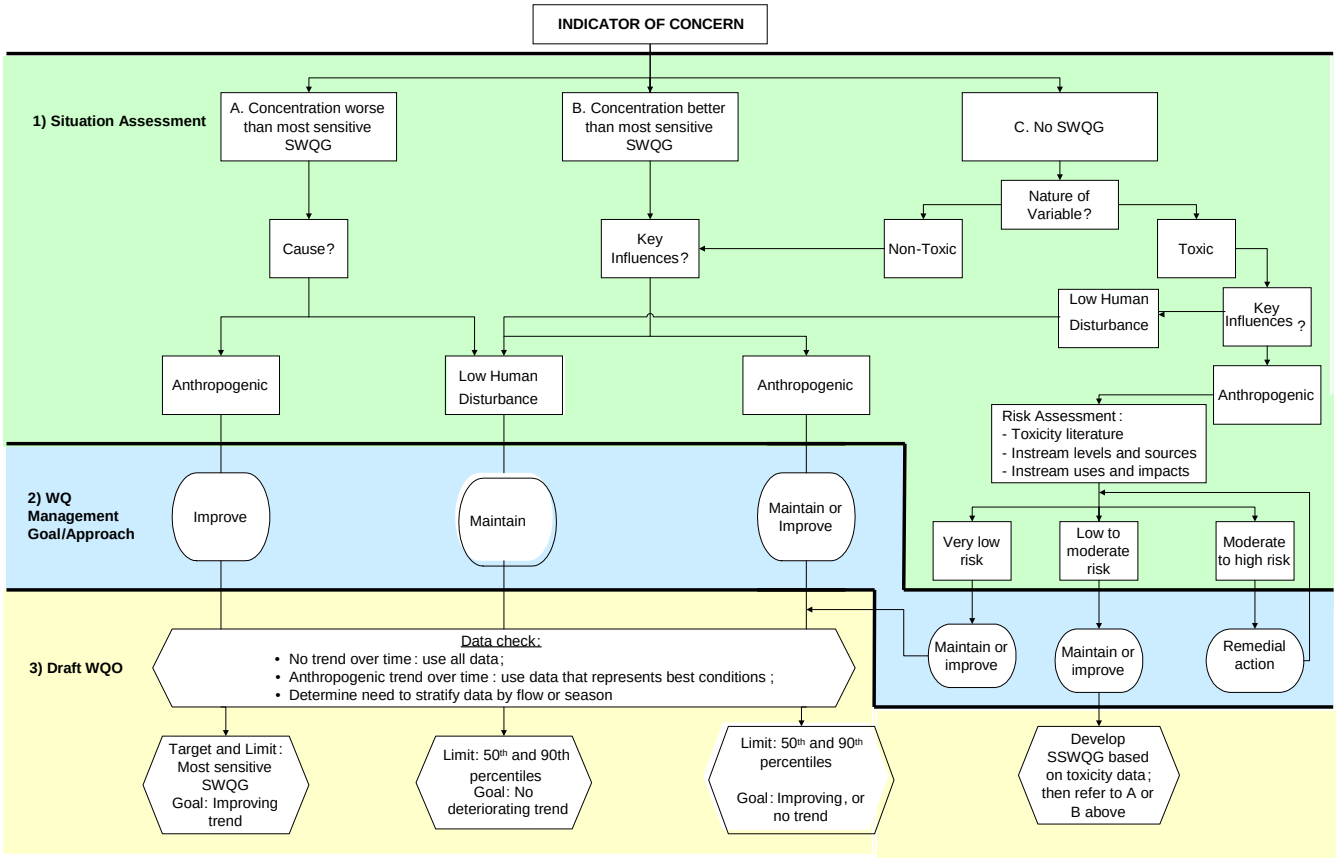
Censored data (less than the method detection limit, or MDL) were replaced by half the MDL. When, MDL's changed over time in the data series, censored data were replaced by the MDL that had been in effect most often.

Results of trend analyses on the four long-term monitoring sites are summarized in Appendix 1 (a to d). Percentiles for long-term monitoring sites on the Red Deer River are summarized in Appendix 2 (a to d).

3.6.3 Derive Draft Water Quality Objectives

The derivation of draft site-specific WQO followed two main decision steps as illustrated in Figure 2

Figure 2. Steps involved in deriving WQO (*diagram modified from AEW 2012*)



First, the Surface Water Quality Guideline that protects the most sensitive use (requires the best water quality) was identified. Main sources of guidelines considered here were CCME (1999) and AENV (1999). Then the guideline value was compared to ambient data. All indicators considered here are potentially influenced by anthropogenic activities in Reaches 3 to 6. The management goal is either to 'improve conditions' (if conditions are worse than the guideline) or to 'maintain or improve conditions' (if conditions are better than the guidelines, but enhanced management of human activities could result in improvements). Similarly, if no guideline is available water quality management would aim at *'maintaining or improving'* conditions.

Next the guideline is compared to the percentiles. The percentiles are adopted as draft objectives if they are indicative of better water quality than the guidelines, or if there is no guideline. If water quality conditions are worse than the guideline, the guideline becomes the objective.

In situations where human activities increase concentrations of variables that have toxic properties but no relevant guideline (C in Figure 2), AEW (2012) recommends that a risk assessment be carried out (i.e., review the literature pertaining to the toxicity of the variable, document instream levels and sources, and document uses and instream impacts). Such a process, which may lead to the derivation of Site-

Specific Water Quality Guidelines, was considered beyond the scope, timeframe and available resources. Variables of interest (section 2.5) potentially falling in this category include pesticides, pharmaceuticals and personal care products and other man-made contaminants. Water quality objectives were not developed for these contaminants.

Water quality objectives developed for the four long-term monitoring sites on the Red Deer River are shown in Table 2. Details about the rationale supporting their development are provided in Appendices 3 (a to d).

Table 2 Draft WQO for the Red Deer River (Reaches 3 to 6)

Fecal coliform bacteria	Draft WQO count/100mL			
Management Goal: improving trend[a] Guideline: Irrigation 100/100mL	Ice Cover		Open Water	
	percentile			
	50	90	50	90
Reach 3 - Hwy 2	[5b]	16[b]	18	100[c]
Reach 4 - Nevis	18	90	13	100
Reach 5 - Morrin	7	59	12	100[c]
Reach 6 Bindloss	5	20	34	100[c]

a. Fecal coliforms sometimes exceed the irrigation guideline; there are anthropogenic influences, hence desire for an improving trend

b. deteriorating trend (1987 - 2010) - used first 10 yrs of data (1987-1997)
investigate causes of trends

c. the 90th percentile >guideline, hence Irrigation guideline (100) = SSWQO

E.coli	Draft WQO count/100mL			
Management Goal: improving trend[a] Guideline: Recreation 400/100mL (as in ARWQI)	Ice Cover		Open Water	
	percentile			
	50	90	50	90
Reach 3 - Hwy 2	2[b]	[9b]	13[b]	62[b]
Reach 4 - Nevis	11[b]	67[b]	9[b]	78[b]
Reach 5 - Morrin	3	31	6	80
Reach 6 Bindloss	10	12	21	400[c]

a. Fecal coliforms sometimes exceed the recreational guideline used in the Alberta River Water Quality Index; there are anthropogenic influences, hence desire for an improving trend

b. Hwy 2. deteriorating trend (1987 - 2010) - used 1987-1997 data
Nevis deteriorating trend (1999- 2010) used all 10 years of data
investigate causes of trends

c. the 90th percentile >guideline, hence Recreation guideline (400) = SSWQO

Total Dissolved Solids	Draft WQO mg/L			
Management Goal: improving trend or no trend[a] Guideline: irrigation 500 mg/L	Ice Cover		Open Water	
	percentile			
	50	90	50	90
Reach 3 - Hwy 2	251	262	210	231
Reach 4 - Nevis	280	311	208	247
Reach 5 - Morrin	274[b]	292[b]	202[b]	234[b]
Reach 6 Bindloss	315[b]	369[b]	238[b]	310b

a. TDS complies with irrigation guideline; anthropogenic influences possible but not certain, hence desire for an improving trend or no trend

b. Morrin and Bindloss. deteriorating trend (1987 - 2010) - used 1987-1997 data
investigate cause(s) of trends

Total Suspended Solids	Draft WQO mg/L			
Management Goal: improving trend or no trend Assume no relevant guideline	Ice Cover		Open Water	
	percentile			
	50	90	50	90
Reach 3 - Hwy 2	4	5	4	51
Reach 4 - Nevis	4	4	4	120
Reach 5 - Morrin	L4[b]	14[b]	14	322
Reach 6 Bindloss	8	68	101	820

a. Anthropogenic influences, hence desire for an improving trend or no trend or improvement

b. Morrin (IC) - improving trend (1987-2010), used 2000-2010 data
investigate cause(s) of trends
'L" indicates value less than the method detection limit

Total Phosphorus	Draft WQO mg/L			
Management Goal: improving trend,or no trend Assumed no relevant guideline	Ice Cover		Open Water	
	percentile			
	50	90	50	90
Reach 3 - Hwy 2	0.005[b]	0016[b]	0.018	0.126
Reach 4 - Nevis	0.019	0.047	0.017	0.17
Reach 5 - Morrin	0.007[b]	0.033[b]	0.027[b]	0.182[b]
Reach 6 Bindloss	0.017	0.062	0.095	0.524

a. no guideline; anthropogenic influences, hence desire for an improving trend or no trend or improvement where deteriorating trend were observed

b. Hwy 2 (IC) and Morrin (IC and OW) - improving trend (1987-2010), used 2000-2010 data
investigate cause(s) of trends

Total Dissolved Phosphorus	Draft SWQO mg/L			
Management Goal: improving trend,or no trend Assumed no relevant guideline	Ice Cover		Open Water	
	percentile			
	50	90	50	90
Reach 3 - Hwy 2	0.003	0.0123	0.006	0.027
Reach 4 - Nevis	0.011	0.037	0.006	0.041
Reach 5 - Morrin	0.005[b]	0016[b]	0.009[b]	0.028[b]
Reach 6 Bindloss	0.005	0.02	0.01	0.034

a. no guideline; anthropogenic influences, hence desire for an improving trend or no trend or improvement where deteriorating trend were observed

b. Morrin - improving trend (1987-2010), used 2000-2010 data
investigate cause(s) of trends

Table 2 Draft WQO for the Red Deer River (Reaches 3 to 6) - continued

Total Nitrogen	Draft WQO mg/L			
Management Goal: improving trend or no trend Assumed no relevant guideline	Ice Cover		Open Water	
	percentile			
	50	90	50	90
Reach 3 - Hwy 2	0.248	0.637	0.341	0.848
Reach 4 - Nevis	0.626[b]	0.974[b]	0.381	1.066
Reach 5 - Morrin	0.69	0.979	0.458	1.279
Reach 6 Bindloss	0.490[b]	0.755[b]	0.530[b]	1.476[b]

a. no guideline; anthropogenic influences, hence desire for an improving trend or no trend or improvement where deteriorating trend were observed

b. Nevis - deteriorating trend (1999-2010), used all 10 yrs
Bindloss - deteriorating trend (1987 - 2010) - used 1987-1997 data
investigate cause(s) of trends

Nitrite+Nitrate-N	Draft WQO mg/L			
Management Goal: improving trendor no trend[a] Guideline: protection aquatic life 2.93 mg/L	Ice Cover		Open Water	
	percentile			
	50	90	50	90
Reach 3 - Hwy 2	0.085	0.186	0.008	0.097
Reach 4 - Nevis	0.366	0.474	0.003	0.157
Reach 5 - Morrin	0.340[b]	0.477[b]	L0.003[b]	0.194[b]
Reach 6 Bindloss	0.277[b]	0.463[b]	0.005	0.243

a. NO2+NO3 levels comply with guideline for the protection of aquatic life; anthropogenic influences, hence desire for an improving trend or no trend and improvement where deteriorating trend were observed

b. Morrin and Bindloss. deteriorating trend (1987 - 2010) - used 1987-1997 data
investigate cause(s) of trends

Ammonia-N	Draft WQO mg/L			
Management Goal: improving trendor no trend[a] Guideline: protection aquatic life pH and temperature dependent	Ice Cover		Open Water	
	percentile			
	50	90	50	90
Reach 3 - Hwy 2	0.02	0.06	0.01	0.01
Reach 4 - Nevis	0.05[b]	0.22[b]	0.02	0.09
Reach 5 - Morrin	0.05	0.22	0.01	0.09
Reach 6 Bindloss	0.02[b]	0.08[b]	0.01[b]	0.04[b]

a. ammonia levels comply with guideline for the protection of aquatic life; anthropogenic influences, hence desire for an improving trend or no trend or improvement where deteriorating trend were observed

b. Nevis - deteriorating trend (1999-2010), used all 10 yrs
Bindloss - deteriorating trend (1987 - 2010) - used 1987-1997 data
investigate cause(s) of trends

Nitrite-N	Draft WQO mg/L			
Management Goal: improving trendor no trend[a] Guideline: protection aquatic life 0.06 mg/L	Ice Cover		Open Water	
	percentile			
	50	90	50	90
Reach 3 - Hwy 2	L0.003	0.005	L0.003	0.004
Reach 4 - Nevis	0.005	0.012	L0.003	0.007
Reach 5 - Morrin	0.004	0.011	L0.003	0.005
Reach 6 Bindloss	no data		no data	

a. Nitrite-N levels comply with guideline for the protection of aquatic life; anthropogenic influences, hence desire for an improving trend or no trend or improvement where deteriorating trend were observed

All sites: insufficient non-censored data to assess trends
'L' indicates value less than the method detection limit

Dissolved Oxygen	Draft WQO mg/L			
Management Goal: improving trend or no trend Guideline: 9.5 sensitive life stages - coldwater fish (Hwy 2); 6.5 Protection Aquatic Life at all other sites	Ice Cover		Open Water	
	percentile			
	50	10	50	10
Reach 3 - Hwy 2	12.0[b]	10.9[b]	10.5[b]	9.5[b,c]
Reach 4 - Nevis	10.2	8.3	10.4	8.6
Reach 5 - Morrin	9.9	6.5[c]	10	8.3
Reach 6 Bindloss	9.9	6.5[c]	9	7.4

a. guideline exceeded; anthropogenic influences, hence desire for an improving trend or no trend or improvement where deteriorating trend were observed

b. HWY2 -deteriorating trend - used 1987-1997 data
investigate cause(s) of trends

c. the 10th percentile <guideline, hence guideline = SSWQO

4.0 IMPLICATIONS OF WATER QUALITY OBJECTIVES ON THE MANAGEMENT OF THE RED DEER RIVER

Proposing site-specific objectives to maintain or improve current water quality conditions has inherent implications for the future management of the river and activities within the basin.

Several water quality indicators show deteriorating trends (fecal coliform bacteria, *E. coli*, total nitrogen, (nitrite+nitrate)-nitrogen, ammonia, total dissolved solids and dissolved oxygen), or exceed the most sensitive guideline (fecal coliform bacteria, *E. coli* and dissolved oxygen) at one or more long-term monitoring sites.

There is a need to investigate the reasons why trends are occurring and why guidelines are exceeded. This involves understanding the relative influence of loadings from natural and man-made point and non-point sources on river water quality in each given reach and under a range of river flows. Once loading patterns are better understood it becomes possible to make informed decisions about selecting and implementing the most effective load reduction measures to correct deteriorating trends, and enable compliance with site-specific WQO at the long-term monitoring sites.

Understanding and managing loadings to maintain current water quality conditions also implies that best available technology and management practices such as offsets may be needed to allow future development, land use changes, or changes in flow regime.

5.0 EVALUATION OF DATA FROM REACHES 1 AND 2 AND MAJOR TRIBUTARIES

Much of the work presented in this report focuses on the four Red Deer River long-term monitoring sites. These sites have been sampled consistently for extensive periods of time and data were suitable to develop draft WQO for key indicators of interest in the RDR IWMP. However, it is recognized that to manage water quality in the basin WQOs will be needed at additional locations. Critical locations include the lower portion of reaches 1 and 2 and the mouth of major tributaries (i.e., tributaries designated as sub-watersheds in the IWMP). An initial evaluation of available data for these locations was carried out to determine if sufficient, suitable data existed to derive draft objectives.

AEW's Data Management and Monitoring Branch downloaded available data for the Red Deer River in Reaches 1 and 2, and major tributaries near the confluence with the Red Deer River.

Water quality data were available for the Red Deer River at Sundre and West of Bowden for the periods 1963 to 1997, and 1970 to 1994, respectively. The reason for sampling the river at these sites seems to have evolved over time: most sampling in earlier years occurred in winter under ice, while more recent samples have been collected during the open water.

Water quality data for tributaries near the confluence with the Red Deer River exist for the Raven River (1983-1988), the Little Red Deer River West of Innisfail (1974-2008), the Medicine River (1974-2008), the Blindman River (1974-2008), Kneehills and Threehills creeks (1983-1998) and the Rosebud River (1982-2001). Earlier sampling on the first four rivers focused on winter conditions whereas more recent sampling occurred on a flow-weighted basis during the open water. Other tributaries such as James River, Berry Creek and Matzihiwin Creek have fewer than 10 samples each and there were no water quality data near the mouth of the Panther River or Buffalo Creek. Although the period of record for some of the sites appears to be quite long, there are usually many years without data.

Data limitations for the Red Deer River at Sundre, West of Bowden and major tributaries were too severe to develop defensible draft objectives that followed procedures outlined in Section 3. These data limitations are a combination of; lack of current information; data sets that are too short and/or comprise periods with no data; and changes in sampling design (e.g., purpose of sampling, sampling frequency and timing, changes in indicators and analytical methods). This situation identifies serious data gaps and it is strongly advised that WQO development not be attempted until the data sets have been augmented with at least 5 years of regular sampling.

Although data sets for the Red Deer River at Sundre, West of Bowden and major tributaries are not suitable for WQO development at this time, they are of historical value and indicative of water quality issues that need to be addressed in an IWMP.

Appendix 2 e provides a summary of these data as well as a comparison with surface water quality guidelines. Similarly to the long-term monitoring sites on the Red Deer River (Section 3), relevant guidelines were not available for TSS, TN or TP. However, recent work by Chambers et al. (2012) provides nutrient thresholds, or limits, that are applicable to the Red Deer River tributaries. Based on an analysis of extensive stream nutrient (TN and TP) data, the authors proposed ecoregions-specific nutrient thresholds for streams across Canada. These thresholds are intended to protect 'good ecological conditions.' Thresholds for Mixedwood Plains were applied to the Raven, Medicine, and Little Red Deer river data and thresholds for Prairies were applied to the Blindman, Kneehills, Threehills and Rosebud creek data.

Guidelines or thresholds were exceeded for several indicators in the upper Red Deer River and major tributaries indicating use-impairment (Appendix 2e). In keeping with protocols outlined in Section 3, guidelines or thresholds were adopted as site-specific limits and management actions should be aimed at improving conditions so use-specific requirements are restored.

6.0 RECOMMENDATIONS

The following recommendations relate specifically to the development of water quality objectives, and to the implementation of the water quality component of the IWMP. They are organized into four broad categories which are listed in order of priority to meet the two stated objectives:

6.1 Monitoring and Data Acquisition

6.1.1 Implement Monitoring to Fill Apparent Data Gaps

This section identifies data gaps that became apparent during the drafting of site-specific WQO for the mainstem of the Red Deer River.

- Long-term water quality sampling stations need to be established for Reaches 1 and 2. AEW is intending to initiate sampling at Sundre (Reach 1) in fall 2012, but sampling of the lower portion of Reach 2 (e.g., Red Deer River West of Bowden) still needs to be approved and implemented.
- Major tributaries need to be sampled at the mouth to enable the drafting of objectives and the calculation of contaminant loads.

- Synoptic surveys need to be implemented on the Red Deer River to describe longitudinal changes in river quality and the influence from point sources and non-point sources on the aquatic ecosystem. Surveys need to capture critical seasonal and flow-related features such as spring and summer runoff, and winter and open water low flows.
- Easily accessible flow data are needed for all long-term water quality monitoring sites on the mainstem and tributaries.
- Pesticide use patterns in the Red Deer River Basin (Byrtus 2011) need to be compared to the list of pesticides commonly monitored by AEW to ensure that monitoring captures pesticides that are in high use and/or likely to enter surface waters and cause adverse effects.

It is of critical importance that monitoring at Hwy 2, Nevis, Morrin, Bindloss, and more recently at Jenner be continued as these data are fundamental to the use of the draft WQO and to the detection of trends over time.

6.1.2 Assemble existing Water and Effluent Quality and Flow Data

Integrated watershed and water quality models are important tools in the development and implementation of the water quality component of the IWMP. This section provides recommendations about steps that are needed to develop such models.

It is essential to identify, collect, and compile all the available data and knowledge that are useful for the development of integrated watershed and water quality models. This work needs to be followed by a critical evaluation of available data, the identification of data gaps and the implementation of a plan to fill these gaps. All information needs to be assembled in databases that can be readily accessed and updated.

The following provides some examples of critical information that needs to be assembled.

- All water quality, sediment quality and biological data for rivers, and tributaries.
- All flow data for rivers and tributaries.
- An inventory of point sources (municipal, industrial, storm water) including:
    - Location of discharge points
    - Timing of discharge (e.g., continuous, intermittent, seasonal)
    - Effluent quality and flow
    - Treatment process in place
- Land use infomation such as GIS-based information on the distribution of major land use types across the basin; soil classification; major crops, livestock, sources of irrigation water uses, and management practices.
- Information on groundwater-surface water interactions.

6.1.3 Develop an Integrated Monitoring and Reporting Framework

There is a need to develop and implement a framework to ensure that ongoing monitoring activities in the basin yield sufficient compatible information on ambient conditions, effluents, and non-point sources to support the IWMP. This would involve:

- Regular updates of load inventories to allow adaptive management and maintain the relevance and functionality of the predictive models
- Relevant and accurate loading and ambient quality information to justify treatment process upgrades, or other management measures
- Verification that the implementation of management measures is achieving the desired effect on aquatic conditions

In addition to monitoring (i.e., generating data), an evaluation and reporting framework needs to be implemented to document the progress and success of the RDR -IWMP at predetermined times**.** This would involve the evaluation and reporting on:

- Ambient conditions, point and non-point source loading and quality
- Progress in implementing management measures
- Success of management actions at eliciting the desired changes (e.g., PS and NPS load reductions, improvements in the aquatic environment)

The development, implementation, and maintenance of a monitoring and reporting framework are critical components of the IWMP. They require close and on-going cooperation among agencies, stakeholders and partners and a clear definition of roles and reponsibilities.

6.2 Tool Development and Maintenance

Surface water quality objectives are one of the first tools needed in water quality management. The focus, in this report has been on key water quality indicators. As more information becomes available on stressors and associated impacts on aquatic ecosystems it may be necessary to review and update existing objectives, or to expand the list of indicators to include additional water quality indicators, sediment quality indicators and biological indicators. The development of objectives for such indicators is evidently associated with ambient monitoring requirements.

There is a need to develop a framework with stakeholders that outlines a common understanding of when WQO are achieved and what management responses will take place when they are not achieved. This may include:

- Specifications about how and how often trend analysis and other relevant statistical testing should be performed to assess compliance
- The determination of triggers and associated management actions
- The investigation of the utility of a water quality index as a reporting tool for the RDRWA draft water quality objectives
- Similarly, the investigation of the utility of indices to report on the status of other ecosystem components (e.g., sediment quality, aquatic plants, invertebrates, and fish) for which the RDRWA may decide to develop site-specific objectives

As mentioned in section 5.1.2, integrated watershed and water quality models are important tools in the development and implementation of IWMP. Water quality models can range from relatively simple mass-balance approaches to more complex and more costly hydrodynamic water quality models. In either case the availability of current and comprehensive monitoring information is pivotal to successful management decisions.

6.3 Identification of Research Needs

Although the availability of baseline data was critical in the drafting of water quality objectives for the RDR IWMP, it was clear that in some cases there were critical information gaps or research needs that need to be filled before objectives can be drafted.

- Hydraulic fracturing for hydrocarbon recovery is a recent and intensifying activity, especially in the upper reaches. Research into the possible effects on surface and groundwater quantity and quality is needed.

- Research into the individual and cumulative effects of man-made chemicals, such as pharmaceuticals, personal care products, flame retardants and plasticizers on aquatic ecosystems and water uses is a topic of research worldwide. Although the development of water quality objectives for such contaminants is premature, it is recommended that the RDRWA remains informed about developments in ongoing research.

- Although some pesticides have guidelines for the protection of various uses, many pesticides that are detected in surface waters do not have guidelines, hence the significance of detections relative to the uses is difficult to assess. The Alberta Pesticide Toxicity Index (Anderson 2008) provides a measure of risk from cumulative pesticide toxicity to aquatic life. The potential application of this index as an indicator of pesticide contamination and a basis for deriving WQO for pesticides needs to be evaluated.

- There is a need to quantify the sources of TDS and TSS to determine the relative importance of natural and man-made disturbances.

- There is a need to clarify the application of recreational guidelines for fecal coliform and *E. coli,* which are based on geometric means of at least five samples taken over a 30-day period on monthly monitoring data.

- There is a need for research and monitoring of *Cryptosporidium* and *Giardia* to document occurrence, identify major sources, recommend BMPs and recommend objectives for use protection in the RDR basin.

6.4 Recommendations about BMPs

The implementation of water quality management in an IWMP is likely to be a lengthy and iterative process. However, there are many pro-active measures that can be taken in the watershed to maintain or improve surface water quality. Some of these measures have already been, or are being implemented, in some parts of the watershed as a result of improving technology, growing awareness of human impacts, and the recognition that water is a critical resource for all. Implementing these measures is part of the adaptive management process that strives for continuous improvement and reduction of the foot print from all human activities in the watershed.

An extensive review of beneficial management practices for potential application to the Red Deer River watershed has been carried out by the RDRWA (2009); the City of Red Deer (2010) provides a review and recommendations about riparian buffers. This document is a basic reference to BMPs for nutrient, bacteria and metals management by forestry, agriculture, municipalities and urban and suburban developers, oil and gas development and off-road vehicle use.

The selection and implementation of specific beneficial management practices needs to be tailored to site-specific conditions (e.g., climate, topography, specific land use, and targeted water quality issues and indicators). As mentioned earlier, it is important to have a good understanding of the relative importance of contaminant loading sources to surface waters in each management reach. Such knowledge and understanding is still being developed for the Red Deer River basin. This would allow applying load reduction measures to some of the larger sources that can be improved most cost effectively, first. The implementation of BMPs at a watershed scale is a long-term adaptive process that requires support and buy-in from all sectors. The effectiveness of education, incentives, and enforcement to bring about changes needs to be evaluated on a watershed, sub-watershed and case-by-case basis.

Following provides some examples of measures which apply to the management of point sources and non point sources and which are likely to be beneficial regardless of the sector or land use in improving water quality as it relates to issues identified in section 5.3. In many instances application of beneficial management practices aimed at reducing contaminant loadings to surface waters is likely to improve conditions for more than one water quality indicator.

- Some examples of measures that help reduce nutrient loading
    - Municipal and industrial effluents: implement nutrient removal technology
    - Enhance storm water management by using retention ponds, protecting or constructing wetlands
    - Apply inorganic and organic (manure, sewage sludge) fertilizers to meet and not exceed crop needs in fields and turf needs in urban or suburban settings
    - Ensure that septic systems are up-to-date and properly maintained and managed
    - Water and bed livestock away from water bodies, and manage runoff
    - Protect riparian areas: establish buffer crops that act as filters and can be harvested periodically; restrict all access that create scars, destroy vegetation, or expose soils
- Some examples of measures that help reduce suspended solids loading to surface waters
    - Protect riparian areas: establish buffer crops; restrict all access that create scars, destroy vegetation, or expose soils
    - Enhance storm water management by using retention ponds, and protecting or constructing wetlands
    - Implement erosion control measures (e.g., grassed waterways and other barriers that slow down the flow and allow particles to settle)

- Maintain bridge decks to avoid the washing of sand, gravel and soil into creeks; clean gravel and sand from urban and suburban roads

- Some examples of measures that help reduce bacteria (and pathogens) loading to surface waters
  - Implement UV treatment of municipal wastewater
  - Implement appropriate manure storage and application
  - Water and bed livestock away from water bodies, and manage runoff
  - Handle pet wastes responsibly (pick up, do not flush)
- Some examples of measures that help reduce pesticide loading to surface waters
  - Respect BMPs regarding application, disposal of containers and cleaning of tanks
  - Implement integrated pest management and environmental farm planning
  - Do not spray on windy or rainy days
  - Respect set back distances from surface waters
  - Avoid/eliminate cosmetic applications in urban and suburban settings
  - Consider alternative pest control methods
- Some examples of measures that help reduce loading of pharmaceuticals, personal care products and other man-made compounds to surface waters
  - Return unused medications to pharmacies for recycling
  - Use collection and recycling facilities to dispose of unused man-made products

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8.0 ACRONYMS AND DEFINITIONS

AENV: Alberta Environment

AEW: Alberta Environment and Water

Ambient limit: a level or condition beyond which the most sensitive use may not be protected (also referred to as 'threshold' in RDRWA terms of reference

CCME: Canadian Council of Ministers of the Environment

DO: Dissolved oxygen

LUF: **Land Use Framework**

NPS: Non-point source

Outcome: The result of an intervention, management, or other action; i.e., what is achieved or not.

PAL: Protection of Aquatic Life. Generally refers to the WQG for such.

PPWB: Prairie Provinces Water Board

PS: Point source

Site Specific: In surface water quality, applying to specified waters, such as a river reach, river location, or lake.

RDRWA IWMP: Red Deer River Watershed Alliance Integrated Watershed Management Plan

Site-Specific Water Quality Objective (WQO): a numerical concentration or narrative statement which has been established for specified waters, at a specific site, and which has an action and/or a management commitment.

Surface Water Quality Guideline (SWQG): a numerical concentration or narrative statement which is recommended to protect a specific use of water.

Target: a concentration or narrative statement that management aims to achieve or do better than.

Trigger: A condition which, if exceeded, results in some action being taken (e.g., intensified monitoring; risk assessment; point-source management).

USEPA: United States Environmental Protection Agency

Variable: In water quality, a substance in, or condition of, the water. Often referred to as a parameter, it may be physical, chemical, biologic, or radiological.

Appendix 1 a. Reach 3 - Summary of Trend Analysis and Implications on the development of WQO at Hwy 2

	seasonality	Autocorrelation		Trend analysis					Trend analysis on flow adjusted data		Ice Cover (IC)			Open Water (OW)			Implication on derivation of WQO
Variable	Kruskall Wallis Test Significance	Kendall Tau Significance	Spearman Rho Significance	Test	median	slope	%slope	significance	slope	significance	test	slope	significance	test	slope	significance	
Q	***	***	***	SKC	24.25	-0.118461	-0.48900	NS									
TP	***	***	***	SKC	0.0105	-0.00014	-1.36210	**↓	-0.01314	*	SK	-0.0001	**↓	SKC	-0.00017	NS	use 2000 to 2010 data for IC; all data for OW
TDP	***	***	***	SKC	0.004	0.00000	0.00000	NS	!!!								use all data (1987 to 2010)
TN	***	***	***	SKC	0.293	-0.00266	-0.90650	NS	!!!								use all data (1987 to 2010)
TSS	***	***	***	SKC	2.95	0.00277	0.09390	NS	0.01624	*↑	SK	0.00000	NS	SKC	0.10545	NS	use all data (1987 to 2010)
Fecal coliform	***	***	***	SKC	11.5	0.16674	1.44990	**↑	!!!		MK	0.17616	**↑	SKC	0.16636	NS	use 1987 to 1997 data for IC; all data for OW
E. coli	***	***	***	SKC	8	0.25000	3.12500	**↑	!!!		MK	0.16070	***↑	SKC	0.45534	**↑	use 1987 to 1997 data for IC and OW
TDS	***	***	***	SKC	223.5	0.55400	0.24790	*↑	0.00207	NS	SKC	0.62400	**↑	SKC	0.52420	NS	use 1987 to 1997 data for IC; all data for OW
(NO2+NO3)N	***	***	***	SKC	0.033	0.00000	0.00000	NS	!!1								use all data (1987 to 2010)
NO2-N	too many censored data; no trend analysis																use all data (1987 to 2010)
NO3-N	***	***	***	SKC	0.0395	0.00000	0.00000	NS	!!!								use all data (1987 to 2010)
Ammonia	***	***	***	SKC	0.01	0.00000	0.00000	(NS)	!!!								use all data (1987 to 2010)
DO	***	***	***	SKC	11.155	-0.01995	0.1789	*↓	-00159	NS	SK	-0.02867	***↓	SKC	-0.0287	**↓	use 1987 to 1997 for IC and OW

Seasonality, autocorrelation, trend analysis on deseasonalized and detrended data and flow adjusted data was carried out on the entire data set. If a trend was detected in data that had not been adjusted for flow, or that were flow adjusted, then trends were investigated in the data for ice-cover and open water. Seasonality and autocorrelation were tested on OW and IC data to determine the most appropriate trend test on these data

SK= seasonal Kendall test on data corrected for seasonality, SKC=seasonal Kendall test on data corrected for seasonality and autocorrelation; MK = Man Kendall test on data that are not seasonal or autocorrelated
slope - Sen slope estimator expressed as mg/L (or #/100mL for bacteria) change per year
% slope is annual % change relative to median
Significance is depicted as 99% (***), 95% (**), 90% (*) and not significant at 90% (NS) confidence intervals
ID = insufficient or no data
Significance placed in brackets indicates that the % of censored data > 30% - view results with caution
↑: increasing trend; ↓ decreasing trend
!!! Trend analysis on residuals was not attempted because regression of WQ variable against flow yielded r2< 0.3

Appendix 1 b. Reach 4 - Summary of Trend Analysis and Implications on the development of WQO at Nevis

	seasonality	Autocorrelation		Trend analysis					Trend analysis on flow adjusted data		Ice Cover (IC)			Open Water (OW)			Implication on derivation of WQO
Variable	Kruskall Wallis Test Significance	Kendall Tau Significance	Spearman Rho Significance	Test	median	slope	%slope	significance	slope	significance	test	slope	significance	test	slope	significance	
Q	***	***	***	SKC	23.55	1.75560	0.7455	NS									
TP	***	***	***	SKC	0.0175	-0.00043	-2.440	NS	-0.00122	NS							only 10 years of data (1999-2010); use all data
TDP	***	***	***	SKC	0.009	-0.000270	-2.9853	NS		!!!							only 10 years of data (1999-2010); use all data
TN	***	***	***	SKC	0.503	0.01557	3.09450	*↑	0.01361	*↑	SKC	0.02695	**↑	SK	0.01004	NS	only 10 years of data (1999-2010); use all data
TSS	***	***	***	SKC	2.35	0.04002	1.70300	NS	0.13868	NS							only 10 years of data (1999-2010); use all data
Fecal coliform	***	**	NS	SKC+SK	14	0.00000	0.00000	NS	0.1808	NS							only 10 years of data (1999-2010); use all data
E. coli	***	***	***	SKC	9	0.05080	5.57000	**↑	0.43905	NS	SKC	1.20550	**↑	SK	0.49891	**↑	only 10 years of data (1999-2010); use all data
TDS	***	***	***	SKC	239.5	1.49759	0.62530	NS	1.79815	NS							only 10 years of data (1999-2010); use all data
(NO2+NO3)N	***	***	***	SKC	0.1195	0.00000	0.00000	NS		!!!							only 10 years of data (1999-2010); use all data
NO2-N	too many censored data; no trend analysis				0.0015			NS		!!!							only 10 years of data (1999-2010); use all data
NO3-N	***	***	***	SKC	0.114	0.00000	0.00000	NS		!!!							only 10 years of data (1999-2010); use all data
Ammonia	***	***	***	SKC	0.02	0.00415	20.76150	(**↑)		!!!	SK	0.01009	***↑	SKC	0.00000	(NS)	only 10 years of data (1999-2010); use all data
DO	***	**	**	SKC	10.375	-0.01635	-0.1576	NS		!!!							only 10 years of data (1999-2010); use all data

Seasonality, autocorrelation, trend analysis on deseasonalized and detrended data and flow adjusted data was carried out on the entire data set. If a trend was detected in data that had not been adjusted for flow, or that were flow adjusted, then trends were investigated in the data for ice-cover and open water. Seasonality and autocorrelation were tested on OW and IC data to determine the most appropriate trend test on these data

SK= seasonal Kendall test on data corrected for seasonality, SKC=seasonal Kendall test on data corrected for seasonality and autocorrelation; MK = Man Kendall test on data that are not seasonal or autocorrelated

slope - Sen slope estimator expressed as mg/L (or #/100mL for bacteria) change per year
% slope is annual % change relative to median
Significance is depicted as 99% (***), 95% (**), 90% (*) and not significant at 90% (NS) confidence intervals
ID = insufficient or no data
significance' in brackets indicates that the percentage of censored data was > 30% - view results with caution
↑: increasing trend; ↓ decreasing trend
!!! Trend analysis on residuals was not attempted because regression of WQ variable against flow yielded r2< 0.3
Significance in brackets indicates that more than 30% of the data were censored

Appendix 1 c. Reach 5 - Summary of Trend Analysis and Implications on the development of WQO at Morrin

	seasonality	Autocorrelation		Trend analysis					Trend analysis on flow adjusted data		Ice Cover (IC)			Open Water (OW)			Implication on derivation of WQO
Variable	Kruskall Wallis Test Significance	Kendall Tau Significance	Spearman Rho Significance	Test	median	slope	%slope	significance	slope	significance	test	slope	significance	test	slope	significance	
Q	***	***	***	SKC	27.85	-0.04671	-0.1677	NS									
TP	***	***	***	SKC	0.026	-0.00100	-3.839	***↓	-0.00099	***↓	SKC	-0.00164	***↓	SKC	-0.00050	*↓	use 2000 to 2010 for IC and OW
TDP	***	***	***	SKC	0.008	-0.00031	-3.839	***↓		!!!	SKC	-0.00099	***↓	SKC	-0.00014	*↓	use 2000 to 2010 for IC and OW
TN	***	***	**	SKC	0.37	-0.00406	-1.0974	**↓		!!!	SKC	-0.00357	NS	SKC	-0.00498	NS	use all data (1987 to 2010) for IC and OW
TSS	***	NS	NS	SK	6	-0.09999	-1.6665	***↓	-0.07827	NS	SK	-0.11313	***↓	SK	-0.04998	NS	use 2000 to 2010 for IC, and 1987 to 2010 for OW
Fecal coliform	***	NS	NS	SK	10	0.00000	0.00000	NS		!!!							use all data (1987 to 2010) for IC and OW
E. coli	***	**	**	SKC	5	0.00000	0.00000	NS		!!!							use all data (1987 to 2010) for IC and OW
TDS	***	***	***	SKC	232	0.80220	0.34580	**↑	0.7649	NS	SKC	0.85990	**↑	SKC	0.77589	*↑	use 1987 to 1997 for IC and OW
(NO2+NO3)N	***	**	**	SKC	0.0475	0.00025	0.52780	***↑		!!!	SK	0.00583	***↑	SK	0.00067	(**↑)	use 1987 to 1997 for IC and OW
NO2-N	too many censored data; no trend analysis																use all data (1987 to 2010) for IC and OW
NO3-N	***	**	**	SKC	0.086	0.00030	0.30620	NS		!!!							use all data (1987 to 2010) for IC and OW
Ammonia	***	***	***	SKC	0.02	0.00000	0.00000	NS		!!!							use all data (1987 to 2010) for IC and OW
DO	***	**	**	SKC	10.05	0.01712	0.1703	NS		!!!							use all data (1987 to 2010) for IC and OW

Seasonality, autocorrelation, trend analysis on deseasonalized and detrended data and flow adjusted data was carried out on the entire data set. If a trend was detected in data that had not been adjusted for flow, or that were flow adjusted, then trends were investigated in the data for ice-cover and open water. Seasonality and autocorrelation were tested on OW and IC data to determine the most appropriate trend test on these data

SK= seasonal Kendall test on data corrected for seasonality, SKC=seasonal Kendall test on data corrected for seasonality and autocorrelation; MK = Man Kendall test on data that are not seasonal or autocorrelated

slope - Sen slope estimator expressed as mg/L (or #/100mL for bacteria) change per year
% slope is annual % change relative to median
Significance is depicted as 99% (***), 95% (**), 90% (*) and not significant at 90% (NS) confidence intervals
ID = insufficient or no data
significance' in brackets indicates that more than 30% of the data were censored - view results with caution
↑: increasing trend; ↓ decreasing trend
!!! Trend analysis on residuals was not attempted because regression of WQ variable against flow yielded r2< 0.3

Appendix 1 d. Reach 6 - Summary of Trend Analysis and Implications on the development of WQO at Bindloss

	seasonality	Autocorrelation		Trend analysis					Trend analysis on flow adjusted data		Ice Cover			Open Water			Implication on derivation of WQO
Variable	Kruskall Wallis Test Significance	Kendall Tau Significance	Spearman Rho Significance	Test	median	slope	%slope	significance	slope	significance		slope	significance		slope	significance	
Q	***	***	***	SKC	34.8	-0.1004	-0.0029	NS									
TP	***	***	***	SKC	0.008	-0.0001	-0.9629	NS	0.0151	***↑	SKC	0.00000	NS	SKC	0.00000	NS	use all data (1987 to 2010)
TDP	***	***	***	SKC	0.056	0.0002	0.3567	NS	-0.00733	NS							use all data (1987 to 2010)
TN	***	**	**	SKC	0.567	0.0100	1.7673	***↑	0.02197	***↑	SKC	0.01345	***↑	SK	0.00719	**↑	use 1987 to 1997 data for IC and OW
TSS	***	***	***	SKC	47.4	-0.00833	-0.0176	NS	!!!								use all data (1987 to 2010)
Fecal coliform	***	***	***	SKC	34	0.0000	0.0000	NS	!!!						open water data only		use all OW data (1987 to 2010) (too few IC for this site)
E. coli	**	NS	NS	SK	20.5	0.0000	0.0000	NS	!!!						open water data only		use all OW data (1987 to 2010) (too few IC for this site)
TDS	***	***	***	SKC	288	2.3290	0.8087	***↑	0.00742	***↑	SK	2.34790	***↑	SKC	2.30379	***↑	use 1987 to 1997 data for IC and OW
(NO2+NO3)N	***	***	***	SKC	0.039	0.0032	8.1573	(***)↑	!!!		SKC	0.00617	***↑	SKC	0.00000	(NS)	use 1987 to 1997 data for IC and all data for OW
NO2-N	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID							
NO3-N	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID							
Ammonia	***	**	**	SKC	0.014	0.0003	1.9645	**↑	!!!		SKC	0.00040	**↑	SK	0.00024	***↑	use 1987 to 1997 data for IC and OW
DO	***	***	***	SKC	9	-0.01215	-0.1350	NS	!!!								use all data (1987 to 2010)

Seasonality, autocorrelation, trend analysis on deseasonalized and detrended data and flow adjusted data was carried out on the entire data set. If a trend was detected in data that had not been adjusted for flow, or that were flow adjusted, then trends were investigated in the data for ice-cover and open water. Seasonality and autocorrelation were tested on OW and IC data to determine the most appropriate test on these data

SK= seasonal Kendall test on data corrected for seasonality, SKC=seasonal Kendall test on data corrected for seasonality and autocorrelation

slope - Sen slope estimator expressed as mg/L (or #/100mL for bacteria) change per year

% slope is annual % change relative to median

Significance is depicted as 99% (***), 95% (**), 90% (*) and not significant at 90% (NS) confidence intervals

ID = insufficient or no data

" significance" in brackets indicates that more than 30% of the data were censored; view trend analysis results with caution

↑: increasing trend

!!! Trend analysis on residuals was not attempted because regression of WQ variable against flow yielded r2< 0.3

Appendix 2 a. Reach 3. Summary Statistics for Water Quality Indicators from Hwy 2 (January 1987 - March 2010)

IC (November 1 to March 31) and OW (April 1 to October 31)

Ice Cover
(IC percentiles)

	Total Number of data points (N) 1987-2010	% censored data 1987-2010	IC - minimum 1987-2010	IC - 5 1987-2010	IC - 10 1987-2010	IC - 10 1987-1997	IC - 10 2000-2010	IC - 50 1987-2010	*IC - 50 1987-1997*	*IC - 50 2000-2010*	IC - 90 1987-2010	IC - 90 1987-1997	IC - 90 2000-2010	IC - 95 1987-2010	IC - maximum 1987-2010
Q at Red Deer in cms	118	0.000	9.410	13.300	14.270	14.930	14.100	17.600	19.100	17.100	23.550	27.650	19.300	26.525	74.000
Dissolved Oxygen mg/L[1]	118	0.0	10.3	10.8	11.0	10.9	11.3	12.0	12.0	12.1	13.5	13.5	13.5	13.6	14.2
Total Dissolved Solids (TDS) mg/L	117	0.0	192					250	251	250	270	262	278	278	294
Total Suspended Solids (TSS) mg/L	117	20.5	L0.4					4	2.8	2	5.1	8.0	4.4	9.4	61.0
Nitrate+Nitrite (NO3+NO2-N) mg/L	118	11.0	L0.003					0.085	0.092	0.080	0.186	0.148	0.196	0.224	1.080
Ammonia (NH3-N) mg/L	118	40.7	L0.01					0.02	0.01	0.02	0.06	0.12	0.05	0.14	0.41
Total Nitrogen (TN) mg/L	117	0.0	0.062					0.248	0.292	0.227	0.637	0.772	0.407	0.898	3.004
Total Phosphorus (TP) mg/L	118	11.0	0.002					0.006	0.008	0.005	0.023	0.034	0.016	0.045	0.350
Total Dissolved (TDP) mg/L	115	42.6	0.002					0.0030	0.0030	0.0030	0.0128	0.0256	0.0080	0.0280	0.2500
Fecal coliforms No/100 mL	94	17.0	L4					6	5	8	37	16	41	53	430
E. coli No/100 mL	79	19.0	L1					3	2	3	16	9	19	23	400
Nitrite (NO2-N) mg/L	58	72.4	L0.003					L0.003	0.002	0.002	0.005	0.005	0.005	0.007	0.038
Nitrate (NO3-N) mg/L	55	10.9	L0.003					0.080	#NUM!	0.080	0.191	ND	0.194	0.198	0.248

Open Water
(OW percentiles)

	Total Number of data points (N) 1987-2010	% censored data 1987-2010	OW - minimum 1987-2010	OW - 5 1987-2010	OW - 10 1987-2010	*OW- 10 1987-1997*	*OW - 10 2000-2010*	OW - 50 1987-2010	*OW- 50 1987-1997*	*OW - 50 2000-2010*	OW - 90 1987-2010	OW - 90 1987-1997	OW - 90 2000-2010	OW - 95 1987-2010	OW - maximum 1987-2010
Q at Red Deer in cms	162	0.0	15.800	20.005	21.820	24.110	14.100	43.650	50.900	39.600	116.700	*110.800*	*113.000*	200.000	818.000
Dissolved Oxygen mg/L	162	0.0	7.7	8.2	8.4	9.0	8.2	10.1	10.5	10.0	12.0	12.0	12.2	12.7	14.2
Total Dissolved Solids (TDS) mg/L	162	0.0	138					210	207	210	231	229	238	239	252
Total Suspended Solids (TSS) mg/L	160	10.0	L0.4					4.0	5.0	4.0	50.9	33.2	45.9	110.6	780.0
Nitrate+Nitrite (NO3+NO2-N) mg/L	162	36.4	L0.003					0.008	0.006	0.011	0.097	0.099	0.097	0.144	1.400
Ammonia (NH3-N) mg/L	162	42.0	L0.01					0.01	0.01	0.02	0.10	0.13	0.09	0.16	0.36
Total Nitrogen (TN) mg/L	161	0.0	0.027					0.341	0.338	0.341	0.848	1.033	0.825	1.510	3.520
Total Phosphorus (TP) mg/L	162	1.9	0.002					0.018	0.022	0.016	0.126	0.096	0.102	0.218	0.458
Total Dissolved (TDP) mg/L	162	17.3	0.002					0.0055	0.0070	0.0050	0.0268	0.0268	0.0180	0.0519	0.3580
Fecal coliforms No/100 mL	133	5.3	L4					18	20	16	126	102	110	314	5500
E. coli No/100 mL	108	7.4	L1					14	13	15	99	62	88	391	4600
Nitrite (NO2-N) mg/L	77	80.5	L0.003					L0.003	0.002	0.002	0.004	0.003	0.004	0.006	0.016
Nitrate (NO3-N) mg/L	75	36.0	L0.003					0.011	ND	0.011	0.096	ND	0.095	0.122	0.433

[1.] Variables identified by TAC as priority for the development of WQO

[2.] ND: no or insufficient data

Trend Analysis was used to determine what portion of the data set should be used to derive objectives (refer to Table 3 for Trend Analysis results)

no trend: use entire data set

improving trend: use most recent 10 years of data

deteriorating trend: used oldest 10 years of data

yellow highlights identify values used to set draft objectives

Appendix 2 b. Reach 4. Summary Statistics for Water Quality Indicators from Nevis (November 1999 - November 2009)

IC (November 1 to March 31) and OW (April 1 to October 31)

Ice cover
(IC percentiles)

	Total number of data points (N)	% censored data	IC - minimum	IC - 5	IC - 10	IC - 50	IC - 90	IC - 95	IC - maximum
Q at Red Deer in cms	55	0.0	12.74	13.85	14.48	17.23	21.01	25.02	38.20
Dissolved Oxygen mg/L[2]	55	0.0	5.6	8.1	8.3	10.2	13.8	14.6	16.7
Total Dissolved Solids (TDS) mg/L	55	0.0	230			280	311	323	376
Total Suspended Solids (TSS) mg/L	55	12.7	L0.4			4	4.0	4.7	44.4
Nitrate+Nitrite (NO3+NO2-N) mg/L	55	0.0	L0.003			0.366	0.474	0.492	0.570
Ammonia (NH3-N) mg/L	55	10.9	L0.010			0.05	0.22	0.24	0.28
Total Nitrogen (TN) mg/L	55	0.0	0.224			0.626	0.974	1.036	1.212
Total Phosphorus (TP) mg/L	55	1.8	L0.003			0.019	0.047	0.057	0.152
Total Dissolved (TDP) mg/L	55	3.6	L0.003			0.011	0.037	0.043	0.137
Fecal Coliforms No/100 mL	55	1.8	1			18	83	205	1300
E. Coli No/100 mL	55	10.9	1			11	67	126	1200
Nitrite (NO2-N) mg/L	55	23.6	L0.003			0.005	0.012	0.015	0.018
Nitrate (NO3-N) mg/L	55	0.0	L0.003			0.360	0.465	0.487	0.565

Open Water
(OW percentiles)

	Total number of data points (N)	% censored data	OW - minimum	OW - 5	OW - 10	OW - 50	OW - 90	OW - 95	OW - maximum
Q at Red Deer in cms	75	0.0	15.22	16.86	20.55	45.82	155.30	203.73	1001.80
Dissolved Oxygen mg/L	75	0.0	7.7	8.2	8.6	10.4	12.6	13.4	14.3
Total Dissolved Solids (TDS) mg/L	75	0.0	132			208	247	250	280
Total Suspended Solids (TSS) mg/L	75	4.0	L0.4			4.4	119.8	184.7	1560.0
Nitrate+Nitrite (NO3+NO2-N) mg/L	75	46.7	L0.003			0.003	0.156	0.206	0.396
Ammonia (NH3-N) mg/L	75	45.3	L0.010			0.02	0.09	0.13	0.28
Total Nitrogen (TN) mg/L	75	0.0	0.027			0.384	1.066	1.694	2.949
Total Phosphorus (TP) mg/L	75	4.0	L0.003			0.017	0.170	0.376	0.953
Total Dissolved (TDP) mg/L	75	13.3	L0.003			0.008	0.041	0.056	0.163
Fecal Coliforms No/100 mL	74	6.8	L2			13	100	307	3900
E. Coli No/100 mL	74	10.8	L2			9	78	307	3000
Nitrite (NO2-N) mg/L	74	77.0	L0.003			L0.003	0.007	0.008	0.014
Nitrate (NO3-N) mg/L	74	47.3	L0.003			0.003	0.149	0.188	0.285

[1.] Because the data set only covers 10 years, statistics for the oldest or most recent 10 years of data were not generated

values in highlighted in yellow were those used to derive objectives

[2.] Variable identified by TAC as priority for the development of WQO

Appendix 2 c. Reach 5. Summary Statistics for Water Quality Indicators from Morrin (March 1987 - March 2010)

IC (November 1 to March 31) and OW (April 1 to October 31)

Ice cover
(IC percentiles)

	Total number of data points (N) 1987-2010	% censored data 1987-2010	IC - minimum 1987-2010	IC - 5 1987-2010	IC - 10 1987-2010	IC - 10 1987-1997	IC - 10 2000-2010	IC - 50 1987-2010	IC - 50 1987-1997	IC - 50 2000-2010	IC - 90 1987-2010	IC - 90 1987-1997	IC - 90 2000-2010	IC - 95 1987-2010	IC - maximum 1987-2010
Q at Red Deer in cms	115	0.00	10.620	13.434	14.214	14.134	14.21	17.510	18.265	16.9	26.896	31.967	23.22	32.681	197.050
Dissolved Oxygen mg/L [1]	114	0.0	3.66	5.72	6.36	6.26	7.58	9.99	10.46	9.63	14.09	13.52	14.33	14.74	18.65
Total Dissolved Solids (TDS) mg/L	115	0.0	180					277	274	284	303	292	310	315	330
Total Suspended Solids (TSS) mg/L	115	14.8	L4					L4	4	L4	29	62	14	66	490
Nitrate+Nitrite (NO3+NO2-N) mg/L	115	5.2	L0.003					0.373	0.340	0.403	0.543	0.477	0.550	0.567	1.190
Ammonia (NH3-N) mg/L	115	22.6	L0.01					0.05	0.08	0.03	0.22	0.23	0.21	0.25	0.55
Total Nitrogen (TN) mg/L	115	0.0	0.093					0.690	0.707	0.690	0.979	1.702	0.955	1.658	3.290
Total Phosphorus (TP) mg/L	114	7.0	L0.003					0.016	0.051	0.007	0.073	0.193	0.033	0.193	0.590
Total Dissolved (TDP) mg/L	113	19.5	L0.003					0.008	0.043	0.005	0.065	0.103	0.016	0.102	0.320
Fecal Coliforms No/100 mL	95	11.6	L2					7	12	6	59	102	52	260	700
E. coli No/100 mL	78	20.5	L1					3	3	3	32	48	27	203	480
Nitrite (NO2-N) mg/L	56	33.9	L0.003					0.004	ID	0.004	0.011	ID	0.010	0.011	0.022
Nitrate (NO3-N) mg/L	55	1.8	L0.003					0.403	ID	0.403	0.549	ID	0.548	0.556	0.810

Open Water
(OW percentiles)

	Total number of data points (N) 1987-2010	% censored data 1987-2010	OW - minimum 1987-2010	OW - 5 1987-2010	OW - 10 1987-2010	OW - 10 1987-1997	OW - 10 1999-2009	OW - 50 1987-2010	OW - 50 1987-1997	OW - 50 1999-2009	OW - 90 1987-2010	OW- 90 1987-1997	OW - 90 1999-2009	OW - 95 1987-2010	OW - maximum 1987-2010
Q at Red Deer in cms	161.000	0.000	14.610	20.900	23.690	27.887	21.272	47.100	51.925	46.135	131.09	127.085	118.704	180.43	473.48
Dissolved Oxygen mg/L	159	0.0	4.96	7.96	8.28	8.31	12.55	10.04	10.02	10.19	12.03	11.76	12.55	12.53	13.82
Total Dissolved Solids (TDS) mg/L	161	0.0	127					204	202	208	243	234	250	250	266
Total Suspended Solids (TSS) mg/L	161	3.1	L4					14	19	12	322	450	170	549	3360
Nitrate+Nitrite (NO3+NO2-N) mg/L	161	49.7	L0.003					L0.003	L0.003	0.004	0.190	0.194	0.174	0.251	1.400
Ammonia (NH3-N) mg/L	161	40.4	L0.01					0.01	0.01	0.01	0.09	0.10	0.08	0.23	0.61
Total Nitrogen (TN) mg/L	158	0.0	0.027					0.458	0.522	0.404	1.279	1.452	1.012	2.260	3.825
Total Phosphorus (TP) mg/L	161	3.1	L0.003					0.034	0.050	0.027	0.341	0.350	0.181	0.420	1.850
Total Dissolved (TDP) mg/L	161	14.3	L0.003					0.008	0.010	0.006	0.045	0.055	0.028	0.066	0.154
Fecal Coliforms No/100 mL	132	12.9	L2					12	12	10	263	318	96	604	2500
E. coli No/100 mL	108	18.5	L1					6	5	6	80	61	79	265	2500
Nitrite (NO2-N) mg/L	80	75.0	L0.003					L0.003	ND [2]	0.002	0.005	ND	0.005	0.008	0.025
Nitrate (NO3-N) mg/L	76	46.1	L0.003					0.004	ND	0.004	0.169	ND	0.168	0.207	0.960

[1.] Variables identified by TAC as priority for the development of SSWQO
[2.] ND: no or insufficient data

Trend Analysis was used to determine what portion of the data set should be used to derive objectives (refer to Table 3 for Trend Analysis results)
no trend: use entire data set
improving trend: use most recent 10 years of data
deteriorating trend: used oldest 10 years of data
yellow highlights identify values used to set draft objectives

Appendix 2 d. Reach 6. Summary Statistics for Water Quality Indicators from Bindloss (January 1987 - June 2010)

IC (November 1 to March 31) and OW (April 1 to October 31)

Ice Cover
(IC percentiles)

	Total number of data points (N) 1987-2010	% censored data 1987-2010	IC - minimum 1987 -2010	IC - 5 1987 -2010	IC - 10 1987 -2010	IC - 10 1987 -1997	IC - 10 2000 -2010	IC - 50 1987 -2010	IC - 50 1987 -1997	IC - 50 2000 -2010	IC - 90 1987 -2010	IC - 90 1987 -1997	IC - 90 2000 -2010	IC - 95 1987 -2010	IC - maximum 1987 -2010
Q at Red Deer in cms	107	0.0	8.680	10.980	12.160	12.150	12.120	15.900	16.850	15.500	24.900	27.100	23.280	29.790	62.700
Dissolved Oxygen mg/L [1]	103	0.0	0.8	3.3	4.6	5.4	3.6	9.9	11.2	9.0	13.7	13.7	13.1	14.0	18.3
Total Dissolved Solids (TDS) mg/L	91	0.0	195					324	315	342	411	369	432	434	540
Total Suspended Solids (TSS) mg/L	106	0.0	1.8					7.6	8.0	5.6	67.6	76.6	52.0	124.5	229.0
Nitrate+Nitrite (NO3+NO2-N) mg/L	107	5.0	L0.01					0.380	0.277	0.404	0.530	0.463	0.530	0.550	0.980
Ammonia (NH3-N) mg/L	104	3.0	L0.005					0.017	0.017	0.020	0.123	0.078	0.120	0.161	0.284
Total Nitrogen (TN) mg/L	99	0.0	0.140					0.578	0.490	0.614	0.857	0.755	0.879	1.091	2.040
Total Phosphorus (TP) mg/L	107	0.0	0.006					0.017	0.019	0.015	0.0618	0.069	0.0376	0.121	0.285
Total Dissolved (TDP) mg/L	107	10.0	L0.002					0.005	0.0065	0.004	0.02	0.029	0.0132	0.0321	0.118
Fecal coliforms No/100 mL	20	8.0	L2					5.0	5.0	9.0	20.0	20.0	12.2	20.5	30.0
E. coli No/100 mL	3	0.0	3.0					10.0	ND	11.5	12.4	ND	12.7	12.7	13.0
Nitrite (NO2-N) mg/L	ND	ND	ND [2]					ND	ND	ND	ND	ND	ND	ND	ND
Nitrate (NO3-N) mg/L	ND	ND	ND					ND	ND	ND	ND	ND	ND	ND	ND

Open Water
(OW percentiles)

	Total number of data points (N) 1987-2010	% censored data 1987-2010	IC - minimum 1987 -2010	OW - 5 1987 -2010	OW - 10 1987 -2010	OW - 10 1987 -1997	OW - 10 2000 -2010	OW - 50 1987 -2010	OW - 50 1987 -1997	OW - 50 2000 -2010	OW - 90 1987 -2010	OW - 90 1987 -1997	OW - 90 2000 -2010	OW - 95 1987 -2010	IC - maximum 1987 -2010
Q at Red Deer in cms	174	0.0	12.700	21.640	25.740	29.500	21.580	46.800	53.450	41.6	152.200	138.000	177.200	271.000	620.000
Dissolved Oxygen mg/L	173	0.0	5.8	7.1	7.4	7.3	75.0	9.0	8.8	9.0	12.0	11.7	12.0	12.5	14.0
Total Dissolved Solids (TDS) mg/L	134	0.0	192					254	238	265	328	310	363	373	603
Total Suspended Solids (TSS) mg/L	175	0.0	8.6					101.0	115.0	96.8	819.8	622.0	1180.0	1628.5	5410.0
Nitrate+Nitrite (NO3+NO2-N) mg/L	174	62.6	L0.01					L0.01	0.005	0.005	0.413	0.243	0.463	0.609	1.210
Ammonia (NH3-N) mg/L	171	5.8	L0.005					0.012	0.010	0.014	0.043	0.038	0.049	0.127	0.625
Total Nitrogen (TN) mg/L	168	0.0	0.182					0.555	0.530	0.557	2.174	1.476	2.8876	3.501	16.490
Total Phosphorus (TP) mg/L	174	0.0	0.013					0.095	0.095	0.093	0.524	0.315	0.740	0.755	1.850
Total Dissolved (TDP) mg/L	174	0.6	L0.002					0.010	0.011	0.008	0.034	0.057	0.028	0.061	0.084
Fecal coliforms No/100 mL	161	14.9	L2					34.0	40.0	26.0	520.0	224.0	1228.0	1228.0	5833.0
E. coli No/100 mL	84	0.0	2.0					20.5	ND	19	488.9	ND	474.1	752.8	5067.0
Nitrite (NO2-N) mg/L	ND	ND	ND					ND	ND	ND	ND	ND	ND	ND	ND
Nitrate (NO3-N) mg/L	ND	ND	ND					ND	ND	ND	ND	ND	ND	ND	ND

[1] Variables identified by TAC as priority for the development of SSWQO

[2] ND: no data or insufficient data

Trend Analysis was used to determine what portion of the data set should be used to derive objectives (refer to Table 3 for Trend Analysis results)

no trend: use entire data set
improving trend: use most recent 10 years of data
deteriorating trend: used oldest 10 years of data
yellow highlights identify values used to set draft objectives

Appendix 2 e. Reach 1, Reach 2 and major tributaries - Summary of data and comparison to relevant guidelines. Note that these data are unsuitable for the derivation of defensible WQO (see section 5.0 for details)

Red Deer River at Sundre (January 1963 to October 1997)

	DO	TDS	TSS	NO2+NO3	Ammonia	NO2	TN	TP	TDP	Fecal coliforms	E. coli
ICE COVER											
N [1]	*15*	*3*	*1*	*15*	*15*	*5*	*2*	*14*	*0*	*12*	*0*
%<MDL	*0.0*	*0.0*	*0.0*	*13.3*	*20.0*	*80.0*	*0.0*	*14.3*		*0.0*	
minimum	8.7 [2]	268	28	0.050	0.004	0.001	0.225	0.004	ND	2	ND [1]
10th percentile	10.22	269	28	0.065	0.033	0.001	0.243	0.005	ND	4	ND
50th percentile	11.30	273	28	0.215	0.100	0.050	0.313	0.100	ND	8	ND
90th percentile	13.00	335	28	1.300	0.200	0.050	0.383	0.170	ND	51	ND
maximum	13.60	350	28	1.600	0.200	0.050	0.400	0.800	ND	95	ND
OPEN WATER											
N	*6*	*0*	*6*	*6*	*6*	*6*	*5*	*6*	*6*	*0*	*0*
%<MDL	*0.0*		*16.7*	*0.0*	*50.0*	*100.0*	*0.0*	*33.3*	*50.0*		
minimum	9.00	ND	1	0.089	0.003	0.003	0.173	0.001	0.001	ND	ND
10th percentile	9.08	ND	2	0.090	0.003	0.003	0.175	0.001	0.001	ND	ND
50th percentile	9.49	ND	4	0.105	0.004	0.003	0.212	0.006	0.002	ND	ND
90th percentile	10.56	ND	106	0.121	0.024	0.003	0.229	0.048	0.018	ND	ND
maximum	11.26	ND	148	0.129	0.041	0.003	0.230	0.065	0.030	ND	ND

Red Deer River West of Bowden (November 1970 to February 1994)

	DO	TDS	TSS	NO2+NO3	Ammonia	NO2	TN	TP	TDP	Fecal coliforms	E. coli
ICE COVER											
N	*55*	*18*	*27*	*55*	*56*	*20*	*22*	*55*	*17*	*41*	*0*
%<MDL	*0.0*	*0.0*	*3.7*	*20.0*	*32.1*	*90.0*	*0.0*	*20.0*	*41.2*	*14.6*	
minimum	10.10	217	0.4	0.050	0.005	0.001	0.180	0.003	0.002	1	ND
10th percentile	10.70	226	1	0.050	0.009	0.001	0.272	0.005	0.002	2	ND
50th percentile	11.70	255	9	0.155	0.100	0.050	0.343	0.075	0.003	9	ND
90th percentile	13.06	278	47	0.400	0.270	0.050	0.430	0.300	0.006	55	ND
maximum	14.20	316	54	0.600	0.600	0.050	0.509	1.500	0.014	130	ND
OPEN WATER											
N	51	20	50	54	47	21	46	51	46	40	0
%<MDL	0.0	0.0	2.0	9.3	46.8	90.5	0.0	7.8	8.7	2.5	
minimum	7.30	119	0.4	0.006	0.001	0.001	0.103	0.003	0.001	1	ND
10th percentile	8.60	164	2	0.023	0.002	0.001	0.125	0.005	0.002	2	ND
50th percentile	9.90	189	11	0.049	0.005	0.001	0.290	0.014	0.004	18	ND
90th percentile	11.80	226	90	0.074	0.100	0.050	1.155	0.100	0.015	88	ND
maximum	13.10	233	1517	0.440	0.600	0.050	5.150	1.400	0.042	370	ND

Red Deer River near Jenner (July 1996 to October 2002)

	DO	TDS	TSS	NO2+NO3	Ammonia	NO2	TN	TP	TDP	Fecal coliforms	E. coli
ICE COVER											
N	*15*	*0*	*7*	*0*	*0*	*7*	*7*	*7*	*7*	*14*	*14*
%<MDL	*0.0*		*0.0*			*14.3*	*0.0*	*0.0*	*42.9*	*28.6*	*50.0*
minimum	4.51	ND	2	ND	ND	0.002	0.470	0.005	0.002	1	1
10th percentile	4.88	ND	3	ND	ND	0.003	0.518	0.006	0.002	3	1
50th percentile	8.04	ND	4	ND	ND	0.008	0.610	0.010	0.003	8	5
90th percentile	10.83	ND	9	ND	ND	0.009	0.686	0.012	0.007	36	17
maximum	11.76	ND	10	ND	ND	0.011	0.710	0.013	0.011	220	88
OPEN WATER											
N	*34*	*0*	*18*	*0*	*0*	*0*	*18*	*18*	*18*	*34*	*34*
%<MDL	*0.0*		*0.0*				*5.6*	*0.0*	*5.6*	*5.9*	*14.7*
minimum	7.04	ND	25	ND	ND	ND	0.100	0.019	0.001	5	5
10th percentile	7.39	ND	50	ND	ND	ND	0.370	0.036	0.003	13	5
50th percentile	8.21	ND	147	ND	ND	ND	0.650	0.085	0.012	90	70
90th percentile	11.35	ND	829	ND	ND	ND	1.800	0.276	0.019	527	408
maximum	12.20	ND	1930	ND	ND	ND	3.100	0.337	0.027	890	780

Appendix 2 e. Reach 1, Reach 2 and major tributaries - Summary of Data and Comparison to relevant guidelines (continued) Note that these data are unsuitable for the derivation of defensible WQO (see section 5.0 for details)

Raven River near Mouth (Nov. 1983 to March 1988) (MWP[3])

	DO	TDS	TSS	NO2+NO3	Ammonia	NO2	TN	TP	TDP	Fecal coliforms	E. coli
ICE COVER											
N	*19*	*4*	*19*	*19*	*19*	*4*	*20*	*18*	*18*	*15*	*0*
%<MDL	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*100.0*	*0.0*	*0.0*	*0.0*	*20.0*	
minimum	7.20	272	2	0.095	0.01	0.001	0.000	0.012	0.003	0	ND
10th percentile	7.98	277	2	0.108	0.01	0.001	0.301	0.013	0.005	0	ND
50th percentile	10.10	288	5	0.179	0.03	0.001	0.427	0.015	0.008	4	ND
90th percentile	11.82	298	11	0.264	0.04	0.001	0.723	0.031	0.013	10	ND
maximum	12.30	302	18	0.480	0.08	0.001	0.846	0.073	0.055	24	ND
OPEN WATER											
N	*37*	*17*	*46*	*46*	*45*	*17*	*46*	*48*	*46*	*34*	*0*
%<MDL	*0.0*	*0.0*	*2.2*	*43.5*	*11.1*	*70.6*	*0.0*	*0.0*	*0.0*	*0.0*	
minimum	6.30	219	1	0.000	0.00	0.001	0.082	0.012	0.004	0	ND
10th percentile	7.36	229	3	0.000	0.01	0.001	0.190	0.016	0.008	5	ND
50th percentile	9.50	253	7	0.003	0.02	0.001	0.342	0.028	0.012	35	ND
90th percentile	11.14	272	21	0.040	0.05	0.004	0.794	0.057	0.021	222	ND
maximum	13.60	274	49	0.160	0.11	0.025	1.820	0.084	0.030	4500	ND

Little Red Deer West Of Innisfail (February 1974 to September 2008) (MWP[3])

	DO	TDS	TSS	NO2+NO3	Ammonia	NO2	TN	TP	TDP	Fecal coliforms	E. coli
ICE COVER											
N	*16*	*16*	*17*	*21*	*21*	*19*	*10*	*18*	*11*	*10*	*5*
%<MDL	*0.0*	*0.0*	*0.0*	*38.1*	*23.8*	*63.2*	*0.0*	*11.1*	*0.0*	*10.0*	*20.0*
minimum	3.60	236	1	0.002	0.01	0.001	0.291	0.008	0.003	0	5
10th percentile	7.05	258	3	0.020	0.01	0.002	0.397	0.011	0.004	0	5
50th percentile	9.15	322	15	0.050	0.10	0.035	0.781	0.115	0.028	3	10
90th percentile	12.34	436	56	0.830	0.30	0.050	3.598	0.416	0.196	70	23
maximum	13.60	469	60	1.900	0.66	0.050	3.760	0.700	0.478	70	27
OPEN WATER											
N	*95*	*45*	*107*	*112*	*112*	*73*	*109*	*110*	*108*	*106*	*86*
%<MDL	*0.0*	*0.0*	*15.0*	*42.9*	*19.6*	*57.5*	*0.0*	*0.9*	*0.9*	*19.8*	*37.2*
minimum	8.13	153	1	0.001	0.00	0.001	0.130	0.003	0.001	0	2
10th percentile	8.73	186	2	0.003	0.00	0.001	0.278	0.010	0.004	5	5
50th percentile	10.90	230	9	0.019	0.02	0.002	0.610	0.052	0.014	17	10
90th percentile	12.94	293	148	0.212	0.23	0.014	2.002	0.313	0.096	160	125
maximum	15.64	526	1294	0.499	1.00	0.050	5.180	1.300	0.164	11000	11000

Medicine River at Hwy58 (January 74 to September 2008) (MWP[3])

	DO	TDS	TSS	NO2+NO3	Ammonia	NO2	TN	TP	TDP	Fecal coliforms	E. coli
ICE COVER											
N	*18*	*18*	*18*	*25*	*25*	*18*	*18*	*22*	*14*	*6*	*4*
%<MDL	*0.0*	*0.0*	*0.0*	*36.0*	*16.0*	*33.3*	*0.0*	*9.1*	*7.1*	*0.0*	*0.0*
minimum	0.80	226	4	0.004	0.00	0.001	0.000	0.020	0.002	0	10
10th percentile	1.38	289	7	0.039	0.04	0.002	0.326	0.028	0.014	4	52
50th percentile	3.90	339	15	0.177	0.14	0.007	1.075	0.110	0.020	80	165
90th percentile	10.60	507	32	0.729	0.71	0.061	5.067	0.698	0.599	235	208
maximum	13.00	538	56	2.430	1.37	0.081	7.030	1.080	0.835	250	220
OPEN WATER											
N	*93*	*43*	*103*	*108*	*108*	*72*	*105*	*105*	*104*	*98*	*79*
%<MDL	*0.0*	*0.0*	*9.7*	*36.1*	*6.5*	*40.3*	*0.0*	*0.0*	*1.0*	*6.1*	*15.2*
minimum	3.62	163	1	0.000	0.00	0.001	0.020	0.016	0.001	0	1
10th percentile	7.33	182	3	0.003	0.01	0.001	0.672	0.037	0.017	6	1
50th percentile	9.70	229	10	0.019	0.03	0.004	1.060	0.091	0.050	40	30
90th percentile	12.39	301	86	0.404	0.23	0.019	2.228	0.310	0.173	160	168
maximum	17.05	396	284	1.430	0.90	0.050	3.882	0.880	0.397	5700	5700

Appendix 2 e. Reach 1, Reach 2 and major tributaries - Summary of Data and Comparison to Relevant Guidelines (continued) Note that these data are unsuitable for the derivation of defensible WQO (see section 5.0 for details)

Blindman River near the mouth at Hwy 2A and at Blackfalds (January 74 to September 2008) (P[3])

	DO	TDS	TSS	NO2+NO3	Ammonia	NO2	TN	TP	TDP	Fecal coliforms	E. coli
ICE COVER											
N	*21*	*17*	*13*	*24*	*18*	*23*	*15*	*19*	*8*	*11*	*0*
%<MDL	*0.0*	*0.0*	*7.7*	*37.5*	*0.0*	*52.2*	*0.0*	*5.3*	*0.0*	*0.0*	
minimum	1.67	279	3	0.003	0.01	0.001	0.012	0.025	0.018	0	ND
10th percentile	2.66	367	4	0.030	0.03	0.002	0.322	0.033	0.019	0	ND
50th percentile	7.20	499	10	0.055	0.27	0.007	0.999	0.046	0.020	4	ND
90th percentile	11.50	599	86	0.349	0.53	0.050	1.280	0.400	0.025	49	ND
maximum	13.00	620	141	0.930	0.60	0.050	1.430	0.500	0.025	49	ND
OPEN WATER											
N	*64*	*27*	*55*	*68*	*67*	*36*	*62*	*64*	*63*	*60*	*36*
%<MDL	*0.0*	*0.0*	*9.1*	*52.9*	*7.5*	*52.8*	*0.0*	*0.0*	*0.0*	*13.3*	*25.0*
minimum	6.50	175	2	0.001	0.00	0.001	0.030	0.042	0.012	0	5
10th percentile	8.16	201	3	0.002	0.01	0.001	0.664	0.067	0.034	4	5
50th percentile	9.78	289	7	0.004	0.03	0.002	1.054	0.122	0.081	20	20
90th percentile	11.85	358	46	0.289	0.30	0.025	1.994	0.300	0.228	190	80
maximum	13.44	454	361	1.570	1.60	0.050	4.800	0.554	0.409	2800	290

Kneehills Creek near the Mouth (April 1983 to August 1998) (P[3])

	DO	TDS	TSS	NO2+NO3	Ammonia	NO2	TN	TP	TDP	Fecal coliforms	E. coli
ICE COVER	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
OPEN WATER											
N	*33*	*9*	*32*	*34*	*34*	*14*	*34*	*34*	*13*	*30*	*6*
%<MDL	*0.0*	*0.0*	*0.0*	*23.5*	*2.9*	*21.4*	*0.0*	*0.0*	*0.0*	*10.0*	*0.0*
minimum	4.20	390	10	0.002	0.01	0.002	0.922	0.026	0.015	0	14
10th percentile	6.04	533	29	0.002	0.02	0.002	1.240	0.073	0.022	0	102
50th percentile	9.40	736	84	0.029	0.05	0.020	1.831	0.331	0.033	150	490
90th percentile	11.46	894	872	0.627	0.19	0.030	3.476	0.866	0.162	2000	1460
maximum	12.90	935	7200	1.950	0.50	0.056	4.850	2.400	0.705	13000	2000

Threehills Creek near the Mouth (April 1983 to August 1998) (P[3])

	DO	TDS	TSS	NO2+NO3	Ammonia	NO2	TN	TP	TDP	Fecal coliforms	E. coli
ICE COVER	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
OPEN WATER											
N	*18*	*4*	*18*	*13*	*17*	*5*	*18*	*18*	*6*	*16*	*4*
%<MDL	*0.0*	*0.0*	*0.0*	*27.8*	*5.6*	*16.7*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
minimum	4.20	569	10	0.002	0.01	0.003	1.280	0.070	0.029	4	14
10th percentile	6.58	644	27	0.003	0.02	0.003	1.330	0.133	0.031	12	136
50th percentile	9.70	852	73	0.023	0.05	0.017	1.694	0.331	0.113	250	490
90th percentile	11.45	920	563	0.466	0.18	0.028	3.754	1.011	0.435	1650	1568
maximum	12.60	935	7200	1.130	0.50	0.029	4.430	1.500	0.705	13000	2000

Rosebud River at Hwy 10 (August 82 to July 2001) (P[3])

	DO	TDS	TSS	NO2+NO3	Ammonia	NO2	TN	TP	TDP	Fecal coliforms	E. coli
ICE COVER	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
OPEN WATER											
N	*54.00*	*31*	*50*	*75.000*	*67.00*	*42.000*	*72.000*	*77.000*	*65.000*	*66*	*37*
%<MDL	*0.00*	*0*	*0*	*33.333*	*11.94*	*38.095*	*0.000*	*0.000*	*0.000*	*14*	*14*
minimum	7.60	219	10	0.001	0.00	0.001	0.065	0.018	0.010	0	1
10th percentile	8.04	299	36	0.002	0.01	0.001	0.526	0.078	0.015	1	1
50th percentile	8.90	701	183	0.022	0.02	0.003	1.175	0.210	0.042	68	80
90th percentile	12.27	1250	883	0.346	0.13	0.021	2.677	0.724	0.155	900	580
maximum	13.20	2530	5980	1.480	0.37	0.075	9.061	4.310	0.500	12000	10000

Appendix 2 e. Reach 1, Reach 2 and major tributaries - Summary of Data and Comparison to Relevant Guidelines (completed)

(1) **N**: total number of data points; **%<MDL**: percentage of values less than the method detection limit; **ND**: no data
(2) Guideline exceedences in red

DO guideline	9.5 mg/L for protection of early life stages cold water fishes (RDR and tributaries upstream of Red Deer) 6.5 mg/L for protection of all other life stages warm water fishes (RDR and tributaries downstream of Red Deer)
NO2-N	0.06 mg/L protection aquatic life
ammonia-N	pH and T dependent
fecal coliforms	100 cfu/100 mL irrigation guideline
E. coli	400 cfu/100mL contact recreation (resample)
TDS	500 mg/L irrigation guideline

(3) Threshold (limit) exceedence (as defined for TP and TN in Chambers et al. 2012) - applicable to streams only

	TP	TN
Mixedwood Plain (MWP)	0.03 mg/L	1.1 mg/L
Prairies (P)	0.10 mg/L	0.39-0.98 mg/L

note because TDP is an important indicator of eutrophication, the limits for TP have also been applied to TDP

Appendix 3 a. Draft WQO for Reach 3 - at Hwy 2

				Proposed draft Site Specific Water Quality Objectives
Water Quality Indicator	**Uses**	**Relevant Guidelines**	**Source**	**Based on:** **fixed dates for IC-OW** **comparison of the maximum to the guideline** **trend analysis to determine what portion of data set should be used to calculate percentiles**
Total suspended solids	Protection	background value + 10 mg/L	AENV [A]	Rationale 'Background' is difficult to define and there are insufficient data to define short-term or long-term exposure. Assumed no relevant guidelines, use percentiles as SSWQO, non-toxic, some man-made influences Trend analysis: no trend - use entire data set to derive objectives Proposed Objectives (in mg/L): Ice Cover = (4, 5.1) 50, 90 + improving trend, or no trend Open Water = (4, 50.9)50, 90 + improving trend, or no trend
		-during clear flow, background + 25 mg/L for any short-term exposure (e.g., 24-h period) and maximum average increase of 5 mg/L from background levels for longer term exposures (e.g., inputs lasting between 24 h and 30 d). -during high flow, maximum increase of 25 mg/L from background levels at any time when background levels are between 25 and 250 mg/L. -should not increase more than 10% of background levels when background is >250 mg/L.	CCME [B]	
		Settleable and suspended solids should not reduce the depth of the compensation point for photosynthetic activity by more than 10% from the seasonally established norm for aquatic life.	USEPA [C]	
Total phosphorus (TP)	Protection Aquatic Life	Chronic: 0.05 mg/L	AENV [A]	Rationale The phosphorus guideline may not be relevant to the RDR; assume no guideline, non-toxic substance, man-made influence. Trend analysis: IC - improving trend (drop in TP) use last 10 yrs OW: no trend; use all data Proposed Objectives (in mg/L): Ice Cover = (0.005, 0.016) $^{50, 90}$ + improving trend, or no trend Open Water = (0.018, 0.126)$^{50, 90}$ + improving trend, or no trend
		Phosphorus framework recommends staying within the trophic status of baseline conditions.	CCME [B]	
Total Dissolved Phosphorus (TDP)	Protection Aquatic Life	no guidelines		Rationale No TDP guideline, non-toxic substance, man-made influence. Trend analysis: no trend - use all data Proposed Objectives (in mg/L): Ice Cover = (0.003, 0.0128) $^{50, 90}$ + improving trend, or no trend Open Water = (0.006, 0.0268)$^{50, 90}$ + improving trend, or no trend
Total Nitrogen (TN)	Protection Aquatic Life	Chronic: 1mg/L	AENV [A]	Rationale Note guideline for TN may not be applicable for the Red Deer River Assume no guideline, non-toxic substance, man-made influence. Trend Analysis: no trend - use all data Proposed Objectives (in mg/L): Ice Cover = (0.248, 0.637) $^{50, 90}$ + improving trend, or no trend Open Water = (0.341, 0.848)$^{50, 90}$ + improving trend, or no trend

Appendix 3 a. Draft WQO for Reach 3 - at Hwy 2 (continued)

Total Ammonia	Protection Aquatic Life	0.019 for un-ionized ammonia There is a large range in guideline concentrations for total ammonia based on pH and temperature (e.g., guideline is 2.33 mg/L at a 0°C and pH of 8 and 0.125 mg/L at 25°C and pH of 8.5, representing typical ranges in water temperature	CCME[B]	Rationale Ammonia concentrations in the RDR are better (lower) than the guideline, man-made contributions Trend Analysis: no trend - use all data Proposed Objectives (in mg/L): Ice Cover = (0.02, 0.06) $^{50, 90}$ + improving trend, or no trend Open Water = (0.01, 0.1)$^{50, 90}$ + improving trend, or no trend
		There is an acute and chronic guideline for ammonia. One hour average and 30 day mean guidelines, respectively, are: 5.6 and 2.43 mg/L at a 0°C and pH of 8; and, 2.1 and 0.55 mg/L at 25°C and pH of 8.5 (representing typical ranges in water temperatures a	USEPA[C]	
Nitrate+Nitrite as N	Protection Aquatic Life	2.93 mg/L (the guideline is for nitrate as N but because nitrite values are low and nitrate values are not always available, it is reasonable to compare this guideline to nitrate+nitrite as N values in the NSR)	CCME[B]	Rationale: NO2+NO3 -N concentrations in the RDR are better (lower) than the guideline for the protection of aquatic life, man-made contributions Trend Analysis: no trend - use all data Proposed Objectives (in mg/L): Ice Cover = (0.085, 0.186) $^{50, 90}$ + improving trend, or no trend Open Water = (0.008, 0.097)$^{50, 90}$ + improving trend, or no trend
	Stock Watering	100 mg/L (for Nitrate+Nitrite as N)	CCME[B]	
Nitrite as N	PAL	0.06 mg/L	CCME[B]	Rationale Concentrations in the RDR are better (lower) than the guideline for the protection of aquatic life, man-made contributions Trend Analysis: was not performed because of large number of censored data. Use all data to derive percentiles Proposed Objectives (in mg/L): Ice Cover = (L0.003, 0.005) $^{50, 90}$ + improving trend, or no trend Open Water = (L0.003, 0.004)$^{50, 90}$ + improving trend, or no trend
	Stock Watering	10 mg/L	CCME [B]	
Total Dissolved Solids (TDS)	Stock Watering	3000 mg/L	CCME[B]	Rationale TDS levels are lower (better) than the irrigation guideline during IC and OW, relative importance of natural and man-made influences is unknown. Trend Analysis: IC: increasing (deteriorating) trend - use first 10 yrs of data OW: no trend - use all data Proposed Objectives: Ice Cover = (251, 262) $^{50, 90}$ *+ improving trend, or no deteriorating trend* Open Water = (210,231)$^{50, 90}$ *+ improving trend, or no deteriorating trend*
	Irrigation	500 to 3500 mg/L depending on the type of crop	CCME[B]	
Fecal coliforms **applied irr guideline as per TAC's agreement**	Irrigation	100/100 mL	CCME[B]	Rationale Some fecal coliform bacteria counts are above (worse than) the irrigation guideline, some man-made influence. Trend Analysis: IC: increasing (deteriorating) trend - use first 10 years of data OW: no trend - use all data Proposed Objectives (counts per 100mL): Ice Cover = (4, 19) $^{50, 90}$ + improving trend Open Water = (18,100)$^{50, \text{guideline}}$ + improving trend Because the OW 90th percentile exceeds the guideline, the guideline becomes the objective
	Recreation	When 90% of fecal coliforms are *E. coli* , the same recreational guideline for *E. coli* can be applied to fecal coliforms (i.e., the geometric mean of at least five samples collected within 30 days should be below 200 E. coli per litre).	CCME[B]	

Appendix 3 a. Draft WQO for Reach 3 - at Hwy 2 (continued)

E. coli	Recreation	Geometric mean of at least five samples collected within 30 days should be below 200 *E. coli* per 100mL. Resampling should be performed if any sample exceeds 400 E.coli per 100mL. The objective used int the ARWQI for E.coli is 400/100ml.	CCME[(B)]	Rationale Use of guideline based on geometric mean is questionable on monthly LTRN data. In line with the Alberta River Water Quality Index (ARWQI) a guideline of 400 E.coli/100mL is used. This is an actual value; it does not have the issues associated with the geometric mean which requires a minimum of 5 samples over a 30 day period. Some *E. coli* levels are *above (worse) than th*e guideline, some man-made influence. Trend Analysis: Deteriorating trend under IC and OW - use first 10 yrs of data Proposed Objectives (counts per 100mL): Ice Cover = (2, 10) $^{50, 90}$ + *improving trend* Open Water = (13,62)$^{50, 90}$ + improving trend
	Drinking Water Supply	There is no guideline for *E. coli* in source waters for drinking water supply. The treated drinking water guideline for *E. coli* is non-detectable per 100 mL.	HC [(D)]	
Giardia, Cryptosporidium	Drinking Water Supply	Treatment technologies in place should achieve at least a 3-log reduction in and/or inactivation of cysts and oocysts, unless source water quality requires a greater log reduction and/or inactivation.	HC [(D)]	No draft Site Specific Water Quality Objectives were derived for pathogens, because there are no data to describe current ambient conditions in the RDR. Pathogens are a concern for stakeholders because there are implications for drinking water quality. However there are no available data to derive objectives and there are no guidelines that apply to raw drinking water. The issue of drinking water safety is handled at drinking water treatment plant. Water treatment plants are required to treat raw (river) water so that pathogens represent a very low risk in treated drinking water. The public is advised never to consume raw (river, lake or stream) water. Recommendation: establish monitoring program to obtain data
Dissolved Oxygen (DO)	Protection Aquatic Life	Acute: 5 mg/L (1-day minimum), Chronic: 6.5 mg/L (7 day mean)	AENV [(A)]	Rationale There are coldwater fish between the Dickson Dam and Red Deer and 9.5 was adopted as a guideline for the HWY 2 site. Dissolved Oxygen levels are better (higher) than the guideline under IC, but sometimes lower during OW, man-made influences (regulated, nutrient enrichment). Trend Analysis: Deteriorating trend under IC and OW - use first 10 years of data Proposed Objectives (mg/L): Ice Cover = (12.00, 10.90) $^{50, 10}$ + improving trend, or no trend Open Water = (10.5, **9.5**)$^{50, \text{guideline}}$ + improving trend Note: because the 10th percentile (9.0) is lower than the guideline (9.5) during the OW,
		9.5 mg/L for early life stages and 6.5 mg/L for other life stages for coldwater fisheries	CCME [(B)]	
"Pesticides:"		Many pesticides used in AB, some have guidelines, others do not. Guidelines apply to single compounds and do not account for synergistic or antagonistic effects		It may not be justifiable at this stage to develop SSWQO for pesticides. Narrative statement such as 'decreasing trend, or no trend in pesticide detection frequency and concentrations' would be valid; so would 'Maintain a very low risk for toxicity at all time' (see Pesticide Toxicity Index). **Recommendation**: review pesticide data for the RDR, evaluate the current relevance of monitoring programs relative to pesticide use.

[(A)] Alberta Environment (AENV) 1999. Surface Water Quality Guidelines for Use in Alberta. November 1999. Environmental Service, Environmental Sciences Division. Edmonton, AB.
[(B)] CCME (Canadian Council of Ministers of the Environment). 1999. (with updates to 2007). Canadian Environmental Quality Guidelines. Winnipeg, MN.
[(C)] U.S. EPA. 2006. National Recommended Water Quality Criteria: 2006. Office of Water 4304T. United States Environmental Protection Agency. EPA 822-R-02-047. November, 2002.

[(D)] Health Canada (HC). 2008. Summary of Guidelines for Canadian Drinking Water Quality. Prepared by the Federal-Provincial-Territorial Committee on Drinking Water of the Federal-Provincial-Territorial Committee on Health and the Environment. March 20

Appendix 3 b. Draft WQO for Reach 4 - at Nevis

				Proposed draft Site Specific Water Quality Objectives
Water Quality Indicator	**Uses**	**Relevant Guidelines**	**Source**	**Based on:** **fixed dates for IC-OW** **comparison of the maximum to the guideline** **trend analysis to determine what portion of data set should be used to calculate percentiles**
Total suspended solids (TSS)	Protection Aquatic Life	background value + 10 mg/L	AENV [A]	Rationale Assumed no relevant guideline, use percentiles as SSWQO, non-toxic, some man-made influences Trend analysis: no trend - use entire data set to derive objectives Ice Cover = (4, 4) [50, 90] + improving trend, or no trend Open Water = (4.4, 120)[50,90] + improving trend, or no trend
		-during clear flow, background + 25 mg/L for any short-term exposure (e.g., 24-h period) and maximum average increase of 5 mg/L from background levels for longer term exposures (e.g., inputs lasting between 24 h and 30 d). -during high flow, maximum increase of 25 mg/L from background levels at any time when background levels are between 25 and 250 mg/L. -should not increase more than 10% of background levels when background is >250 mg/L.	CCME[B]	
		Settleable and suspended solids should not reduce the depth of the compensation point for photosynthetic activity by more than 10% from the seasonally established norm for aquatic life.	USEPA[C]	
Total phosphorus (TP)	Protection Aquatic Life	Chronic: 0.05 mg/L	AENV [A]	Rationale The phosphorus guideline may not be relevant for the RDR; assume no guideline, non-toxic substance, man-made influence. Trend analysis: IC - no trend; use all data OW: no trend; use all data Proposed Objectives (in mg/L): Ice Cover = (0.019, 0.047) [50, 90] + improving trend, or no trend Open Water = (0.017, 0.170)[50, 90] + improving trend, or no trend
		Phosphorus framework recommends staying within the trophic status of baseline conditions.	CCME[B]	
Total Dissolved Phosphorus (TDP)	Protection Aquatic Life	no guidelines		Rationale No TDP guideline, non-toxic substance, man-made influence. Trend analysis: no trend - use all data Proposed Objectives (in mg/L): Ice Cover = (0.011, 0.037) [50, 90] + improving trend, or no trend Open Water = (0.006, 0.041)[50, 90] + improving trend, or no trend
Total Nitrogen (TN)	Protection Aquatic Life	Chronic: 1mg/L	AENV [A]	Rationale Guideline for TN may not be applicable for the Red Deer River Assume no guideline, non-toxic substance, man-made influence. Trend Analysis: IC: increasing (deteriorating) trend - data set is only 10 years - all data were used, consider as draft interim and revise when more data available OW: no trend - use all data Proposed Objectives (in mg/L): Ice Cover = (0.626, 0.974) [50, 90] + improving trend Open Water = (0.381, 1.066)[50, 90] + improving trend or no trend

Appendix 3 b. Draft WQO for Reach 4 - at Nevis (continued)

Total Ammonia	Protection Aquatic Life	0.019 for un-ionized ammonia There is a large range in guideline concentrations for total ammonia based on pH and temperature (e.g., guideline is 2.33 mg/L at a 0°C and pH of 8 and 0.125 mg/L at 25°C and pH of 8.5, representing typical ranges in water temperature	CCME[B]	Rationale Ammonia concentrations in the RDR are better (lower) than the guideline, man-made contributions. Trend Analysis: IC: increasing (deteriorating) trend - data set is only 10 years - all data were used, consider as interim draft and revise when more data available. OW: no trend - use all data. Proposed Objectives (in mg/L): Ice Cover = (0.05, 0.22) $^{50, 90}$ + improving trend Open Water = (0.02, 0.09)$^{50, 90}$ + improving trend, or no trend
		There is an acute and chronic guideline for ammonia. One hour average and 30 day mean guidelines, respectively, are: 5.6 and 2.43 mg/L at a 0°C and pH of 8; and, 2.1 and 0.55 mg/L at 25°C and pH of 8.5 (representing typical ranges in water temperatures a	USEPA[C]	
Nitrate+Nitrite as N	Protection Aquatic Life	2.93 mg/L (the guideline is for nitrate as N but because nitrite values are low and nitrate values are not always available, it is reasonable to compare this guideline to nitrate+nitrite as N values in the NSR)	CCME[B]	Rationale: Nitrite+nitrate-N concentrations in the RDR are better (lower) than the guideline for the protection of aquatic life, man-made contributions Trend Analysis: no trend - use all data Proposed Objectives (in mg/L): Ice Cover = (0.366, 0.474) $^{50, 90}$ + improving trend, or no trend Open Water = (0.003, 0.157)$^{50, 90}$ + improving trend, or no trend
	Stock Waterin	100 mg/L (for Nitrate+Nitrite as N)	CCME[B]	
Nitrite as N	Protection Aquatic Life	0.06 mg/L	CCME[B]	Rationale Nitrite concentrations in the RDR are better (lower) than the guideline for the protection of aquatic life, man-made contributions. Trend Analysis: was not performed because of large number of censored data. Use all data to derive percentiles Proposed Objectives (in mg/L): Ice Cover = (0.005, 0.012) $^{50, 90}$ + improving trend, or no trend Open Water = (L0.003, 0.007)$^{50, 90}$ + improving trend, or no trend
	Stock Waterin	10 mg/L	CCME [B]	
Total Dissolved Solids (TDS)	Stock Watering	3000 mg/L	CCME[B]	Rationale TDS levels are below (better) than the irrigation guideline during IC and OW. Relative importance of man-made and natural influences is unclear. Trend Analysis: no trend Proposed Objectives: Ice Cover = (280, 311) $^{50, 90}$ + improving trend, no deteriorating trend Open Water = (208,247)$^{50, 90}$ + improving trend, no deteriorating trend
	Irrigation	500 to 3500 mg/L depending on the type of crop	CCME[B]	
Fecal coliforms **applied irr guideline as per TAC's agreement**	Irrigation	100/100 mL	CCME[B]	Rationale Some fecal coliform bacteria counts are above (worse than) the irrigation guideline, some man-made influence. Trend Analysis: no trend, use all data Proposed Objectives (counts per 100mL): Ice Cover = (18, 83) $^{50, 90}$ + improving trend Open Water = (13,100)$^{50, 90}$ + improving trend
	Recreation	When 90% of fecal coliforms are *E. coli*, the same recreational guideline for *E. coli* can be applied to fecal coliforms (i.e., the geometric mean of at least five samples collected within 30 days should be below 200 E. coli per litre).	CCME[B]	

Appendix 3 b. Draft WQO for Reach 4 - at Nevis (continued)

E. coli	Recreation	Geometric mean of at least five samples collected within 30 days should be below 200 *E. coli* per 100mL. Resampling should be performed if any sample exceeds 400 E.coli per 100mL. The objective used in the ARWQI for E. coli is 400 cfu/100mL	CCME[B]	The Alberta River Water Quality Index (ARWQI) use a guideline of 400 E.coli/100mL. It is adopted here as well. Rationale Some *E. coli* levels are a*bove (worse) than th*e guideline, some man-made influence. Trend Analysis: IC and OW: increasing (deteriorating) trend - because data set covers only 10 years all data were used. Consider as draft interim and update when more data available Proposed Objectives (counts per 100mL): Ice Cover = (11, 67) $^{50, 90}$ + improving trend Open Water = (9,78)$^{50, 90}$ + improving trend
	Drinking Water Supply	There is no guideline for *E. coli* in source waters for drinking water supply. The treated drinking water guideline for *E. coli* is non-detectable per 100 mL.	HC [D]	
Giardia, Cryptosporidium	Drinking Water Supply	Treatment technologies in place should achieve at least a 3-log reduction in and/or inactivation of cysts and oocysts, unless source water quality requires a greater log reduction and/or inactivation.	HC [D]	No draft Site Specific Water Quality Objectives were derived for pathogens, because there are no data to describe current ambient conditions in the RDR. Pathogens are a concern for stakeholders because there are implications for drinking water quality. However there are no available data to derive objectives and there are no guidelines that apply to raw drinking water. The issue of drinking water safety is handled at drinking water treatment plant. Water treatment plants are required to treat raw (river) water so that pathogens represent a very low risk in treated drinking water. The public is advised never to consume raw (river, lake or stream) water. Recommendation: establish monitoring program to obtain data
Dissolved Oxygen (DO)	Protection Aquatic Life	Acute: 5 mg/L (1-day minimum), Chronic: 6.5 mg/L (7 day mean)	AENV [A]	Downstream of Red Deer there are no coldwater fish, the AENV chronic guideline is adopted here. Rationale Dissolved oxygen levels comply with the guideline that applies to all life stages, man-made influences (nutrient enrichment). Trend Analysis: no trend Proposed Objectives (mg/L): IC = (10.2, 8.3) 50, 10 ; + improving trend or no trend OW = (10.4, 8.6)50, 10 ; + improving trend or no trend
		9.5 mg/L for early life stages and 6.5 mg/L for other life stages for coldwater fisheries	CCME [B]	
"Pesticides:"		Many pesticides used in AB, some have guidelines, others do not. Guidelines apply to single compounds and do not account for synergistic or antagonistic effects		It may not be justifiable at this stage to develop SSWQO for pesticides. Narrative statement such as 'decreasing trend, or no trend in pesticide detection frequency and concentrations' would be valid; so would 'Maintain a very low risk for toxicity at all time' (see Pesticide Toxicity Index). **Recommendation**: review pesticide data for the RDR, evaluate the current relevance of monitoring programs relative to pesticide use.

[A] Alberta Environment (AENV) 1999. Surface Water Quality Guidelines for Use in Alberta. November 1999. Environmental Service, Environmental Sciences Division. Edmonton, AB.

[B] CCME (Canadian Council of Ministers of the Environment). 1999. (with updates to 2007). Canadian Environmental Quality Guidelines. Winnipeg, MN.

[C] U.S. EPA. 2006. National Recommended Water Quality Criteria: 2006. Office of Water 4304T. United States Environmental Protection Agency. EPA 822-R-02-047. I

[D] Health Canada (HC). 2008. Summary of Guidelines for Canadian Drinking Water Quality. Prepared by the Federal-Provincial-Territorial Committee on Drinking Water of the Federal-Provincial-Territorial Committee on Health and the Environment. March 20

Appendix 3 c. Draft WQO for Reach 5 - at Morrin

				Proposed draft Site Specific Water Quality Objectives
Water Quality Indicator	**Uses**	**Relevant Guidelines**	**Source**	**Based on:** **fixed dates for IC-OW** **comparison of the maximum to the guideline** **trend analysis to determine what portion of data set should be used to calculate percentiles**
Total suspended solids (TSS)	Protection Aquatic Life	background value + 10 mg/L	AENV [A]	*Rationale* 'Background' is difficult to define and there are insufficient data to define short-term or long-term exposure. Assume no relevant guidelines, use percentiles as SSWQO, non-toxic, some man-made influences Trend analysis: IC: declining (improving) trend - used most recent 10 yrs of data to derive objectives OW: no trend - used all data to derive objectives Proposed Objectives (in mg/L): Ice Cover = (L4, 14) $^{50, 90}$ + improving trend, or no trend Open Water = (14, 322)$^{50, 90}$ + improving trend, or no trend
		-during clear flow, background + 25 mg/L for any short-term exposure (e.g., 24-h period) and maximum average increase of 5 mg/L from background levels for longer term exposures (e.g., inputs lasting between 24 h and 30 d). -during high flow, maximum increase of 25 mg/L from background levels at any time when background levels are between 25 and 250 mg/L. -should not increase more than 10% of background levels when background is >250 mg/L.	CCME [B]	
		Settleable and suspended solids should not reduce the depth of the compensation point for photosynthetic activity by more than 10% from the seasonally established norm for aquatic life.	USEPA [C]	
Total phosphorus (TP)	Protection Aquatic Life	Chronic: 0.05 mg/L	AENV [A]	Rationale The phosphorus guideline may not be relevant for the RDR; assume no guideline, non-toxic substance, man-made influence. Trend analysis: IC - declining (improving) trend; use last 10 yrs of data OW - declining (improving) trend; use last 10 yrs of data Proposed Objectives (in mg/L): Ice Cover = (0.007, 0.033) $^{50, 90}$ + improving trend, or no trend Open Water = (0.027, 0.181)$^{50, 90}$ + improving trend, or no trend
		Phosphorus framework recommends staying within the trophic status of baseline conditions.	CCME [B]	
Total Dissolved Phosphorus (TDP)	Protection Aquatic Life	no guidelines		Rationale No TDP guideline, non-toxic substance, man-made influence. Trend analysis: IC - declining trend; use last 10 yrs of data OW - declining trend; use last 10 yrs of data Proposed Objectives (in mg/L): Ice Cover = (0.005, 0.016) $^{50, 90}$ + improving trend, or no trend Open Water = (0.009, 0.028)$^{50, 90}$ + improving trend, or no trend

Appendix 3 c. Draft WQO for Reach 5 - at Morrin (continued)

Total Nitrogen (TN)	Protection Aquatic Life	Chronic: 1mg/L	AENV [A]	Rationale Guideline for TN may not be applicable for the Red Deer River; assume no guideline, non-toxic substance, man-made influence. Trend Analysis: no trend - use all data Proposed Objectives (in mg/L): Ice Cover = (0.690, 0.979) $^{50, 90}$ + improving trend, or no trend Open Water = (0.458, 1.279)$^{50, 90}$ + improving trend or no trend
Total Ammonia	Protection Aquatic Life	0.019 for un-ionized ammonia There is a large range in guideline concentrations for total ammonia based on pH and temperature (e.g., guideline is 2.33 mg/L at a 0°C and pH of 8 and 0.125 mg/L at 25°C and pH of 8.5, representing typical ranges in water tem	CCME [B]	Rationale Ammonia concentrations in the RDR are better (lower) than the guideline, man-made contributions. Trend Analysis: no trend - use all data Proposed Objectives (in mg/L): Ice Cover = (0.05, 0.22) $^{50, 90}$ + improving trend, or no trend Open Water = (0.01, 0.09)$^{50, 90}$ + improving trend, or no trend
		There is an acute and chronic guideline for ammonia. One hour average and 30 day mean guidelines, respectively, are: 5.6 and 2.43 mg/L at a 0°C and pH of 8; and, 2.1 and 0.55 mg/L at 25°C and pH of 8.5 (representing typical ranges in water temperatures a	USEPA [C]	
Nitrate+Nitrite as N	Protection Aquatic Life	2.93 mg/L (the guideline is for nitrate as N but because nitrite values are low and nitrate values are not always available, it is reasonable to compare this guideline to nitrate+nitrite as N values in the NSR)	CCME [B]	Rationale: (nitrite+ nitrate)-N concentrations in the RDR are better (lower) than the guideline for the protection of aquatic life, man-made contributions Trend Analysis: IC and open water: increasing trend - use first 10 years of data Proposed Objectives (in mg/L): Ice Cover = (0.340, 0.477) $^{50, 90}$ + improving trend Open Water = (L0.003, 0.194)$^{50, 90}$ + improving trend
	Stock Waterin	100 mg/L (for Nitrate+Nitrite as N)	CCME [B]	
Nitrite as N	Protection Aquatic Life	0.06 mg/L	CCME [B]	Rationale Nitrite concentrations in the RDR are better (lower) than the guideline for the protection of aquatic life, man-made contributions. Trend Analysis: was not performed because of large number of censored data. Use all data to derive percentiles Proposed Objectives (in mg/L): Ice Cover = (0.004, 0.011) $^{50, 90}$ + improving trend, or no trend Open Water = (L0.003, 0.005)$^{50, 90}$ + improving trend, or no trend
	Stock Waterin	10 mg/L	CCME [B]	
Total Dissolved Solids (TDS)	Stock Watering	3000 mg/L	CCME [B]	Rationale TDS levels are below (better) than the irrigation guideline during IC and OW; relative importance of man-made and natural influences is unclear. Trend Analysis: increasing (deteriorating) trend for IC and OW - use first 10 years of data Proposed Objectives: Ice Cover = (274, 292) $^{50, 90}$ + improving trend Open Water = (202,234)$^{50, 90}$ + improving trend
	Irrigation	500 to 3500 mg/L depending on the type of crop	CCME [B]	

Appendix 3 c. Draft WQO for Reach 5 - at Morrin (continued)

Fecal coliforms **applied irr guideline as per TAC's agreement**	Irrigation	100/100 mL	CCME[B]	Rationale Some fecal coliform bactera counts are above (worse than) the irrigation guideline, some man-made influence. Trend Analysis: no trend - use all data Proposed Objectives (counts per 100mL): Ice Cover = (7, 59) $^{50, 90}$ + improving trend Open Water = (12,100)^{50,guideline} + improving trend Because the 90th percentile (236) is over the guideline, the guideline becomes the objective
	Recreation	When 90% of fecal coliforms are *E. coli*, the same recreational guideline for *E. coli* can be applied to fecal coliforms (i.e., the geometric mean of at least five samples collected within 30 days should be below 200 E. coli per litre).	CCME[B]	
E. coli	Recreation	Geometric mean of at least five samples collected within 30 days should be below 200 *E. coli* per 100mL. Resampling should be performed if any sample exceeds 400 E.coli per 100mL. The objective used in the ARWQI is 400/100mL	CCME[B]	The Alberta River Water Quality Index (ARWQI) uses 400 E.coli/100mL as an objecitve. It is adopted here as well. This is an actual value; it does not have the issues associated with the geometric mean which requires a minimum of 5 samples over a 30 day period. Rationale Some *E. coli* levels are a*bove (worse) than th*e guideline, some man-made influence. Trend Analysis: no trend - use all data Proposed Objectives (counts per 100mL): Ice Cover = (3, 32) $^{50, 90}$ + improving trend Open Water = (6,80)$^{50, 90}$ + improving trend
	Drinking Water Supply	There is no guideline for *E. coli* in source waters for drinking water supply. The treated drinking water guideline for *E. coli* is non-detectable per 100 mL.	HC [D]	
Giardia, Cryptosporidium	Drinking Water Supply	Treatment technologies in place should achieve at least a 3-log reduction in and/or inactivation of cysts and oocysts, unless source water quality requires a greater log reduction and/or inactivation.	HC [D]	No draft Site Specific Water Quality Objectives were derived for pathogens, because there are no data to describe current ambient conditions in the RDR. Pathogens are a concern for stakeholders because there are implications for drinking water quality. However there are no available data to derive objectives and there are no guidelines that apply to raw drinking water. The issue of drinking water safety is handled at drinking water treatment plant. Water treatment plants are required to treat raw (river) water so that pathogens represent a very low risk in treated drinking water. The public is advised never to consume raw (river, lake or stream) water. Recommendation: establish monitoring program to obtain data
Dissolved Oxygen (DO)	Protection Aquatic Life	Acute: 5 mg/L (1-day minimum), Chronic: 6.5 mg/L (7 day mean)	AENV [A]	The chronic guideline of 6.5 mg/L is used here at this site. Rationale Dissolved oxygen levels are sometimes lower (worse) than the early life stage guideline during IC, man-made influences (nutrient enrichment). Trend Analysis: no trend - use all data Proposed Objectives (mg/L): Ice Cover = (9.99, 9.5) $^{50, guideline}$ + improving trend Open Water = (10.04, 8.28)$^{50, 10}$ + improving trend or no trend Note: because the 10th percentile (6.36 IC) is lower than the guideline (6.5), the guideline is used instead
		9.5 mg/L for early life stages and 6.5 mg/L for other life stages for coldwater fisheries	CCME [B]	
"Pesticides:"		Many pesticides used in AB, some have guidelines, others do not. Guidelines apply to single compounds and do not account for synergistic or antagonistic effects		It may not be justifiable at this stage to develop SSWQO for pesticides. Narrative statement such as 'decreasing trend, or no trend in pesticide detection frequency and concentrations' would be valid; so would 'Maintain a very low risk for toxicity at all time' (see Pesticide Toxicity Index). **Recommendation**: review pesticide data for the RDR, evaluate the current relevance of monitoring programs relative to pesticide use.

[A] Alberta Environment (AENV) 1999. Surface Water Quality Guidelines for Use in Alberta. November 1999. Environmental Service, Environmental Sciences Division. Edmonton, AB.
[B] CCME (Canadian Council of Ministers of the Environment). 1999. (with updates to 2007). Canadian Environmental Quality Guidelines. Winnipeg, MN.
[C] U.S. EPA. 2006. National Recommended Water Quality Criteria: 2006. Office of Water 4304T. United States Environmental Protection Agency. EPA 822-R-02-047.
[D] Health Canada (HC). 2008. Summary of Guidelines for Canadian Drinking Water Quality. Prepared by the Federal-Provincial-Territorial Committee on Drinking Water of the Federal-Provincial-Territorial Committee on Health and the Environment. March 20

Appendix 3 d. Draft WQO for Reach 6 - at Bindloss

				Proposed draft Site Specific Water Quality Objectives
Water Quality Indicator	**Uses**	**Relevant Guidelines**	**Source**	**Based on:** **fixed dates for IC-OW** **comparison of the maximum to the guideline** **trend analysis to determine what portion of data set should be used to calculate percentiles**
Total suspended solids (TSS)	Protection Aquatic Life	background value + 10 mg/L	AENV [A]	Rationale 'Background' is difficult to define and there are insufficient data to define short-term or long-term exposure. Assumed no relevant guidelines, used percentiles as SSWQO, non-toxic, some man-made influences Trend analysis: no trend - use all data Proposed Objectives (in mg/L): Ice Cover = (7.6, 68) 50, 90 + improving trend, or no trend Open Water = (101, 820)50, 90 + improving trend, or no trend
		-during clear flow, background + 25 mg/L for any short-term exposure (e.g., 24-h period) and maximum average increase of 5 mg/L from background levels for longer term exposures (e.g., inputs lasting between 24 h and 30 d). -during high flow, maximum increase of 25 mg/L from background levels at any time when background levels are between 25 and 250 mg/L. -should not increase more than 10% of background levels when background is >250 mg/L.	CCME [B]	
		Settleable and suspended solids should not reduce the depth of the compensation point for photosynthetic activity by more than 10% from the seasonally established norm for aquatic life.	USEPA [C]	
Total phosphorus (TP)	Protection Aquatic Life	Chronic: 0.05 mg/L	AENV [A]	Rationale The phosphorus guideline may not be relevant for the RDR; assume no guideline, non-toxic substance, man-made influence. Trend analysis: no trend - use all data Proposed Objectives (in mg/L): Ice Cover = (0.017, 0.062) $^{50, 90}$ + improving trend, or no trend Open Water = (0.095, 0.524)$^{50, 90}$ + improving trend, or no trend
		Phosphorus framework recommends staying within the trophic status of baseline conditions.	CCME [B]	
Total Dissolved Phosphorus (TDP)	Protection Aquatic Life	no guidelines		Rationale No TDP guideline, non-toxic substance, man-made influence. Trend analysis: no trend - use all data Proposed Objectives (in mg/L): Ice Cover = (0.005, 0.020) $^{50, 90}$ + improving trend, or no trend Open Water = (0.010, 0.034)$^{50, 90}$ + improving trend, or no trend
Total Nitrogen (TN)	Protection Aquatic Life	Chronic: 1mg/L	AENV [A]	Rationale Guideline for TN may not be applicable for the Red Deer River; assume no guideline, non-toxic substance, man-made influence. Trend Analysis: icreasing (deteriorating) trend for IC and OW - use oldest 10 years of data Proposed Objectives (in mg/L): Ice Cover = (0.490, 0.755) $^{50, 90}$ + improving trend Open Water = (0.530, 1.476)$^{50, 90}$ + improving trend
Total Ammonia	Protection Aquatic Life	0.019 for un-ionized ammonia There is a large range in guideline concentrations for total ammonia based on pH and temperature (e.g., guideline is 2.33 mg/L at a 0°C and pH of 8 and 0.125 mg/L at 25°C and pH of 8.5, representing typical ranges in water tem	CCME [B]	Rationale Ammonia concentrations are better (lower) than the guideline during IC and most of OW, but values between the 95 and 100 percentile may exceed the guideline during the OW. Man-made contributions. Trend Analysis: increasing (deteriorating) trend over time for IC and OW - use oldest 10 yrs of data Proposed Objectives (in mg/L): Ice Cover = (0.017, 0.078) $^{50, 90}$ + improving trend Open Water = (0.01, 0.038)$^{50, 90}$ + improving trend
		There is an acute and chronic guideline for ammonia. One hour average and 30 day mean guidelines, respectively, are: 5.6 and 2.43 mg/L at a 0°C and pH of 8; and, 2.1 and 0.55 mg/L at 25°C and pH of 8.5 (representing typical ranges in water temperatures a	USEPA [C]	

Appendix 3 d. Draft WQO for Reach 6 - at Bindloss (continued)

Nitrate+Nitrite as N	Protection Aquatic Life	2.93 mg/L (the guideline is for nitrate as N but because nitrite values are low and nitrate values are not always available, it is reasonable to compare this guideline to nitrate+nitrite as N values in the NSR)	CCME[B]	PAL guideline for (nitrite+ nitrate)-N is most restrictive. Rationale: Concentrations in the RDR are better (lower) than the guideline, man-made contributions Trend Analysis: IC: increasing trend - use first 10 years of data OW: no trend - use all data Proposed Objectives (in mg/L): Ice Cover = (0.277, 0.463) $^{50, 90}$ + improving trend Open Water = (0.005, 0.243)$^{50, 90}$ + improving trend, or no trend
	Stock Waterin	100 mg/L (for Nitrate+Nitrite as N)	CCME[B]	
Nitrite as N	Protection Aquatic Life	0.06 mg/L	CCME[B]	No nitrite data for this site
	Stock Waterin	10 mg/L	CCME [B]	
Total Dissolved Solids (TDS)	Stock Watering	3000 mg/L	CCME[B]	Rationale TDS levels are below (better) than the irrigation guideline during IC and OW; relative importance of man-made and natural influences is unclear. Trend Analysis: increasing trend for IC and OW - use first 10 years of data Proposed Objectives: Ice Cover = (315, 369) $^{50, 90}$ + improving trend Open Water = (238,310)$^{50, 90}$ + improving trend
	Irrigation	500 to 3500 mg/L depending on the type of crop	CCME[B]	
Fecal coliforms **applied irr guideline as per TAC's agreement**	Irrigation	100/100 mL	CCME[B]	Rationale Some fecal coliform bacteria counts are above (worse than) the irrigation guideline, some man-made influence. Trend Analysis: IC: very few data - no trend analysis - use all data and consider interim draft OW: data no trend - use all OW data Proposed Objectives (counts per 100mL): Ice Cover = (5, 20) $^{50, 90}$ + improving trend Open Water = (34,100)^{50,guideline} + improving trend Because the 90th percentile (520) is over the guideline, the guideline becomes the objective
	Recreation	When 90% of fecal coliforms are *E. coli*, the same recreational guideline for *E. coli* can be applied to fecal coliforms (i.e., the geometric mean of at least five samples collected within 30 days should be below 200 E. coli per litre).	CCME[B]	
E. coli	Recreation	Geometric mean of at least five samples collected within 30 days should be below 200 *E. coli* per 100mL. Resampling should be performed if any sample exceeds 400 E.coli per 100mL. The objective used in the ARWQI is 400/100ml.	CCME[B]	The Alberta River Water Quality Index (ARWQI) uses an objective of 400 E.coli/100mL. This is adopted here as well. Rationale Some *E. coli* levels are *above (worse) than th*e guideline, some man-made influence. Trend Analysis: IC: very few data, no trend analysis - use all data and consider objectives as interim draft OW: no trend - use all data Proposed Objectives (counts per 100mL): Ice Cover = (10, 12) $^{50, 90}$ + improving trend Open Water = (21,400)^{50,} guideline+ improving trend Because the OW 90th percentile (489) exceeds the guideline, the guideline becomes the objective
	Drinking Water Supply	There is no guideline for *E. coli* in source waters for drinking water supply. The treated drinking water guideline for *E. coli* is non-detectable per 100 mL.	HC [D]	

Appendix 3 d. Draft WQO for Reach 6 - at Bindloss (continued)

Giardia, Cryptosporidium	Drinking Water Supply	Treatment technologies in place should achieve at least a 3-log reduction in and/or inactivation of cysts and oocysts, unless source water quality requires a greater log reduction and/or inactivation.	HC [D]	No draft Site Specific Water Quality Objectives were derived for pathogens, because there are no data to describe current ambient conditions in the RDR. Pathogens are a concern for stakeholders because there are implications for drinking water quality. However there are no available data to derive objectives and there are no guidelines that apply to raw drinking water. The issue of drinking water safety is handled at drinking water treatment plant. Water treatment plants are required to treat raw (river) water so that pathogens represent a very low risk in treated drinking water. The public is advised never to consume raw (river, lake or stream) water. Recommendation: establish monitoring program to obtain data
Dissolved Oxygen (DO)	Protection Aquatic Life	Acute: 5 mg/L (1-day minimum), Chronic: 6.5 mg/L (7 day mean)	AENV [A]	Note: some difficulty in applying the chronic AEW guideline, unless data sonde in place Rationale Dissolved oxygen levels are sometimes lower (worse) than the early life stage guideline during IC and OW, man-made influences (nutrient enrichment). Trend Analysis: no trend - use all data Proposed Objectives (mg/L): Ice Cover = (9.9, 6.5) $^{50,\ guideline}$ + improving trend Open Water = (9, 7.4)$^{50,\ 10}$ + improving trend Note: because the 10th percentile (4.6 IC) is lower than the guideline (6.5), the guideline is used instead;
		9.5 mg/L for early life stages and 6.5 mg/L for other life stages for coldwater fisheries would reach 3 have cold water fish?	CCME [B]	
"Pesticides:"		Many pesticides used in AB, some have guidelines, others do not. Guidelines apply to single compounds and do not account for synergistic or antagonistic effects		It may not be justifiable at this stage to develop SSWQO for pesticides. Narrative statement such as 'decreasing trend, or no trend in pesticide detection frequency and concentrations' would be valid; so would 'Maintain a very low risk for toxicity at all time' (see Pesticide Toxicity Index). **Recommendation**: review pesticide data for the RDR, evaluate the current relevance of monitoring programs relative to pesticide use.

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[D] Health Canada (HC). 2008. Summary of Guidelines for Canadian Drinking Water Quality. Prepared by the Federal-Provincial-Territorial Committee on Drinking Water of the Federal-Provincial-Territorial Committee on Health and the Environment. March 20