April 2012

REPORT

FINAL REPORT

Battle River Synoptic Water Quality Survey

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Executive Summary

The purpose of this study was to collect water quality data from the Battle River to further characterize spatial and temporal variation, and compare water chemistry to draft water quality objectives (WQO) in four previously defined reaches. Samples were collected from two stations in each of reaches 1, 3 and 4, and from five stations in Reach 2, where there is significantly more development pressure.

Discharge rates were measured at each station on each sampling event, and were used to calculate in-stream loads of key parameters. Discharge rates were also compared to data collected at the Water Survey of Canada stations to verify field measurements.

During winter (January) sampling, specific conductivity was highest and dissolved oxygen (DO) was lowest at all stations. Winter DO was lowest in Reach 2, but was still above the 10th percentile WQO. Most major ions and total dissolved solids (TDS) were higher in winter, compared to summer or fall, and concentrations were generally highest in Reach 2. Concentrations of calcium and chloride were more frequently above the 90th percentile WQO in the open-water period than during the ice-covered period.

Nutrient concentrations were highest in Reach 2. Ammonia concentrations were the highest in this reach during winter, nitrate and nitrite concentrations were highest in late summer, and phosphorus concentrations were higher in summer and winter than in fall. Nutrient concentrations were less than 90th percentile WQOs in Reach 1 during the open-water period, and were usually less than the 90th percentile WQO during the ice-covered period. In Reach 2, concentrations of nutrients were above the 50th percentile WQO in about 50% of the open-water samples, and occasionally above the 90th percentile WQO at the upstream end of the reach. During the ice-covered period in Reach 2, concentrations were mostly below the 90th percentile WQO except for nitrate at the upper end of the reach. Concentrations of nutrients in Reach 3 were generally lower than concentrations in Reach 2, except in the fall; during the period of municipal wastewater to the river. During the fall, elevated concentrations of dissolved nitrogen were detectable from below Camrose (end of Reach 2) through Reach 3. In Reach 4, concentrations of nutrients were often above the 50th percentile WQO, but usually below the 90th percentile WQO.

In-stream loads for most parameters were highest in September. Loads for most parameters were low in Reach 1, increased substantially in Reach 2, and continued to increase through Reaches 3 and 4.

Data collected for this project have provided an updated seasonal snapshot of water quality conditions in the Alberta section of the Battle River. Recommended future work includes collecting additional samples for the same parameters during one or two more sampling events (e.g., spring and early summer), characterizing water quality in major tributaries, reviewing existing information on land use in the watershed to understand non-point source stressors, and comparing 2011/2012 data to historical data.

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LIST OF ACRONYMS AND ABBREVIATIONS

%	percent
<	less than
>	more than
AEW	Alberta Environment and Water
CCME	Canadian Council of Ministers of the Environment
e.g.	for example
Golder	Golder Associates Ltd.
i.e.	that is
n	sample size
NO_2	nitrite
NO_3	nitrate
NO_3+NO_2	nitrate and nitrite
QA	quality assurance
QC	quality control
DP	dissolved phosphorus
TDS	total dissolved solids
TKN	total Kjeldahl nitrogen
TN	total nitrogen
TP	total phosphorus
TSS	total suspended solids

LIST OF UNITS

m^3/s	cubic metres per second
L	litre
kg/d	kilograms per day
mg/L	milligrams per litre
mL	millilitre
NTU	nephelometric turbidity unit

1.0 INTRODUCTION

The Land Use Framework developed by the Government of Alberta identified the need to develop environmental objectives (GoA 2008). Since the Battle River is part of the North Saskatchewan watershed, and because of pressures on the water resources within the Battle River sub-basin, development of scientifically defensible water quality objectives (WQO) for this basin was recommended by Alberta Environment and Water (AEW), along with collection of data for comparison to the draft WQO. Draft WQO for the Battle River were developed during 2010 to 2011 by Golder (2011).

The objectives of this project were to collect water quality from the mainstem of the Battle River during different flow and discharge periods, compare the data to the draft WQO, and further characterize water quality in the Battle River. In addition to water quality samples, river discharge rates were also measured at all stations and during all sampling events, and in-stream loads of key parameters were calculated.

1.1 Basin Characteristics

The Battle River originates at Battle Lake in central Alberta and flows through the central parkland region to the Saskatchewan border. Once in Saskatchewan, the Battle River enters the North Saskatchewan River near North Battleford. Surface water runoff and groundwater sources dominate source water in this sub-basin (Anderson 1999). The majority of the population is in the upper portion of this basin, with the majority of point source loads being municipal wastewater from the larger municipal centres (Lacombe, Ponoka, Wetaskiwin, Camrose, and Wainwright). Treated municipal wastewater is typically discharged from these municipalities in the fall. During periods of discharge, loads of phosphorus, chloride, sodium, biochemical oxygen demand (BOD) and ammonia increase measurably in the river (Anderson 1999). Agricultural activities can also influence surface water quality through direct or indirect runoff. Livestock farming predominates in the upper basin (considered a high intensity agriculture area), with cropland and minor livestock farming in the middle basin below Camrose (considered a low to moderate intensity agriculture area) (North/South 2007).

2.0 METHODS

The collection of water quality and quantity data in the Battle River was designed as a synoptic survey to provide a “snapshot” of water quality in the river throughout the basin. The synoptic survey was restricted to the Battle River mainstem and thus did not include sampling of major tributaries. The survey was not designed for sampling along river time-of-travel, because time-of-travel in the Battle River from Ponoka to the provincial border has been estimated to take 19 days (PPWB 2008). Given the slow natural flow of the river, this study was structured to characterize water quality conditions over a short period. A previous synoptic survey on the Battle River followed a similar approach (Anderson 1999).

The general study design is based on collecting at least one water sample per river reach, but with more intensive sampling in the upper reaches, as this is the area of higher population density. In addition, the WQO study report recommended increased monitoring effort in Reach 3, because at present insufficient data exist to propose WQOs for this reach (Golder 2011).

2.1 Sampling Stations

The selection of sampling stations along the Battle River was done taking into consideration the following:

- river reaches defined in Golder (2011);
- need for at least two stations in each reach, but more stations in the upper reaches, given that most of the water quality pressures are in the upper portion of the watershed;
- understanding of known major point sources, and need for sampling from upstream and downstream of these sources; and
- locations of existing AEW monitoring locations, to allow comparisons of 2011/2012 data to historical data.

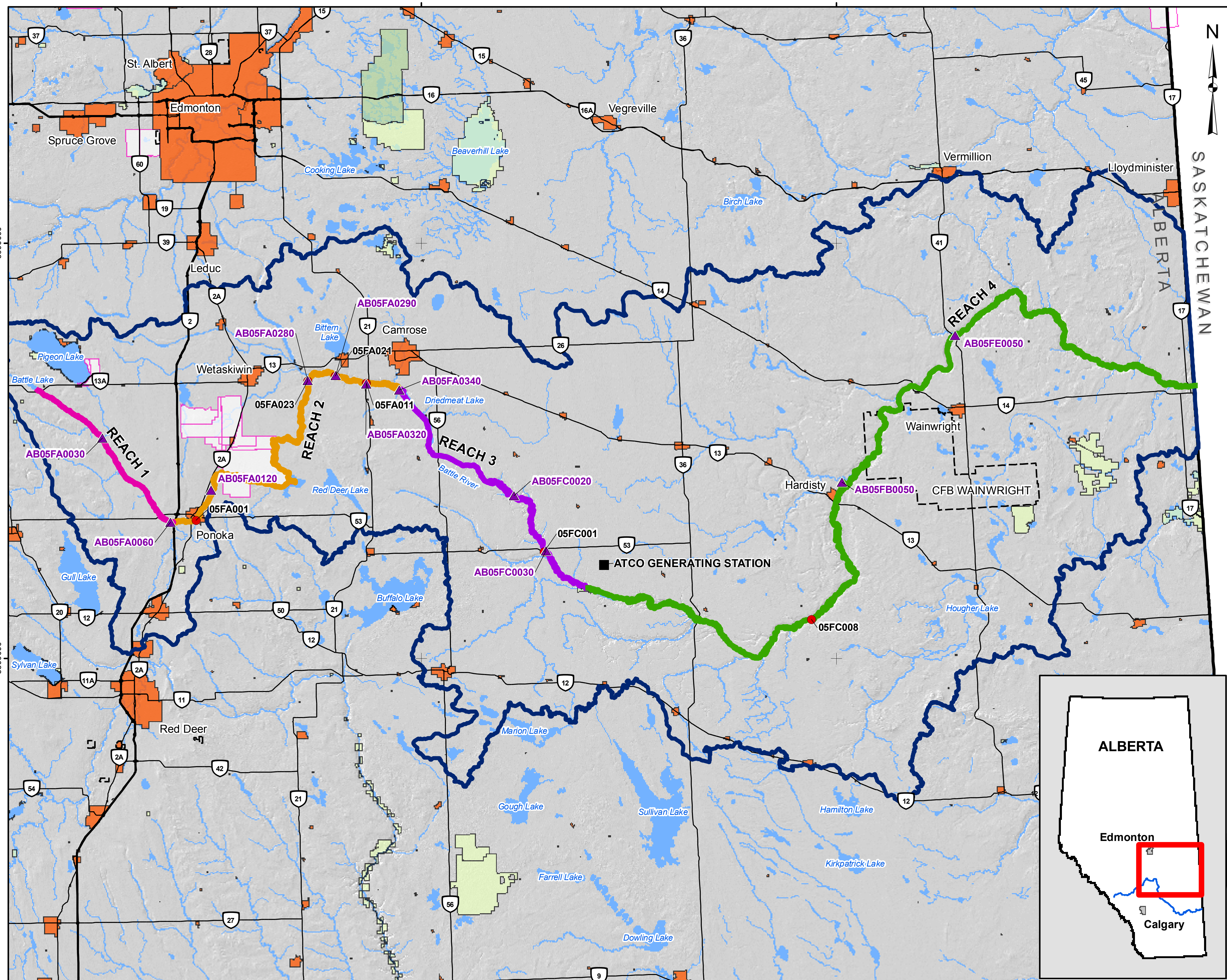
For this study, 11 sampling locations were selected in the Battle River mainstem (Table 2-1; Figure 2-1). Water samples were collected in late summer (September 6 to 9, 2011), fall (October 17 to 20, 2011), and winter (January 23 to 27, 2012).

Two stations were selected in Reach 1 (Figure 2-1). Both were located above the Highway 2 crossing, and both were above a discharge point of municipal wastewater. Five stations were selected in Reach 2, as this reach receives municipal wastewater from three municipalities (Ponoka, Wetaskiwin, and Camrose). Stations were established downstream of the municipal wastewater discharge location for the city of Ponoka, upstream and downstream of the municipal wastewater discharge location for the city of Wetaskiwin, and upstream and downstream of the municipal wastewater discharge location for the city of Camrose. Two stations were established in Reach 3, which has minimal historical data. Data collected in this reach can be used to better characterize the river downstream of the three major municipal discharges. One station was located in the upper portion of the reach, while the second station was in the lower portion of the reach, but above the Forestburg Reservoir. Finally, two stations were established in Reach 4. The first station is downstream of the municipal wastewater discharge location for the city of Hardisty and the second is downstream of the municipal wastewater discharge location for the city of Wainwright.

Table 2-1: Surface Water Quality Stations Sampled in the Battle River during the 2011/2012 Synoptic Survey

River Reach	Station ID	Station Description	Station Coordinates (12U NAD 83)		Sampling Dates		
			Easting	Northing	Late Summer	Fall	Winter
1	AB05FA0030	Battle River at HWY 611	303746	5858941	6-Sep-11	17-Oct-11	23-Jan-12
1	AB05FA0060	Battle River at Range Road 263 (d/s HWY 53; u/s Ponoka)	319073	5837707	6-Sep-11	17-Oct-11	23-Jan-12
2	AB05FA0120	Battle River at Diamond 5 Road (d/s Ponoka)	329230	5844847	6-Sep-11	17-Oct-11	27-Jan-12
2	AB05FA0280	Battle River u/s of Pipestone Creek (u/s Wetaskiwin)	354039	5869958	7-Sep-11	17-Oct-11	24-Jan-12
2	AB05FA0290	Battle River d/s of Pipestone Creek (d/s Wetaskiwin)	360767	5870852	7-Sep-11	18-Oct-11	24-Jan-12
2	AB05FA0320	Battle River at HWY 21 (u/s Camrose)	368036	5868388	7-Sep-11	18-Oct-11	24-Jan-12
2	AB05FA0340	Battle River at north end of Driedmeat Lake (d/s Camrose)	375965	5866517	8-Sep-11	18-Oct-11	25-Jan-12
3	AB05FC0020	Battle River u/s of HWY 854	402068	5839513	8-Sep-11	18-Oct-11	26-Jan-12
3	AB05FC0030	Battle River u/s Meeting Creek at HWY 53	409070	5825773	9-Sep-11	19-Oct-11	27-Jan-12
4	AB05FB0050	Battle River on HWY 881 (d/s of Hardisty)	481134	5838434	8-Sep-11	20-Oct-11	25-Jan-12
4	AB05FE0050	Battle River at HWY 41 Bridge (d/s Wainwright)	510335	5872160	9-Sep-11	19-Oct-11	26-Jan-12

Note: HWY = highway.
u/s = upstream.
d/s = downstream.



LEGEND

- ▲ WATER QUALITY AND RIVER DISCHARGE MONITORING STATION
- ● HYDROMETRIC STATION
- DIVIDED HIGHWAY
- PRIMARY HIGHWAY
- RIVER OR STREAM
- BATTLE RIVER BASIN
- INDIAN RESERVE
- MILITARY BOUNDARY
- NATIONAL PARK
- PROTECTED AREA
- POPULATED PLACE
- WATERBODY

BATTLE RIVER RIVER REACHES

- REACH 1 – BATTLE RIVER HEADWATER TO UPSTREAM HIGHWAY 2
- REACH 2 – UPSTREAM HIGHWAY 2 TO UPSTREAM DRIEDMEAT LAKE
- REACH 3 – UPSTREAM DRIEDMEAT LAKE TO UPSTREAM ATCO GENERATING STATION
- REACH 4 – UPSTREAM ATCO GENERATING STATION TO PROVINCIAL BORDER

REFERENCE

Road network obtained from © 2010 DMTI Spatial Inc. Digital Elevation data obtained from GeoBase®. Parks and protected areas obtained from Alberta Tourism, Parks and Recreation. Hydrographic data obtained from NTDB. Other base data obtained from IHS Energy Inc.
Projection: 10TM AEP Forest Datum: NAD 83

25 0 25

SCALE 1:950,000 KILOMETRES

PROJECT

BATTLE RIVER WATER QUALITY SYNOPTIC SURVEY

TITLE

RIVER REACHES AND SAMPLING STATIONS ON THE BATTLE RIVER

Golder Associates
Calgary, Alberta

PROJECT No. 11-1373-0040.5000			SCALE AS SHOWN	REV. 0
DESIGN	CC	06 Mar. 2012		
GIS	JH	06 Mar. 2012		
CHECK	CC	04 Apr. 2012		
REVIEW	CP	04 Apr. 2012		

FIGURE: 2.1

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2.2 Discharge Measurement

During open-water sampling in September and October 2011, depth and velocity were measured at a minimum of 20 equally spaced stations along a transect positioned perpendicular to the flow. Velocities were measured using a Swoffer Model 2100 current velocity meter.

For measurements under-ice in January 2012, total depth (i.e., depth of flowing water plus ice thickness), ice thickness and velocity were measured at a minimum of 8 equally spaced holes, along a transect positioned perpendicular to the flow. At several stations, fewer holes were drilled because ice extended to the channel bed; therefore, discharge estimates based on January 2012 data are less accurate than those based on open-water estimates. Under-ice water velocities were measured using a Marsh McBirney Flo-Mate Model 2000 velocity meter. For each measured velocity, a correction factor of 0.92 was applied, as required for under-ice measurements at a depth of 60% of the effective depth.

When direct flow measurements were not possible, discharges were estimated using available concurrent hydrometric data from the nearest Water Survey of Canada stations (Table 2-2), supplemented by field observations.

Table 2-2: Survey Locations and Relevant Water Survey of Canada Stations

Survey Location (Station ID)	Water Survey of Canada Station	Approximate Valley Distance from Survey Location (km)	Position Relative to Survey Location	Status	Data Type
AB05FA0030	-	-	-	-	-
AB05FA0060	05FA001	7.7	downstream	active	continuous[a]
AB05FA0120	05FA001	9.9	upstream	active	continuous[a]
AB05FA0280	05FA023	0	at location	discontinued	seasonal
AB05FA0290	05FA021	0	at location	discontinued	seasonal
AB05FA0320	05FA011	0	at location	active	continuous[a]
AB05FA0340	05FA011	13.6	upstream	active	continuous[a]
AB05FC0020	-	-	-	-	-
AB05FC0030	05FC001	0	at location	active	seasonal
AB05FB0050	05FC008	50.0	upstream	active	seasonal
AB05FE0050	05FE003	0	at location	-	-

Note: "-" no data
[a] Although data are recorded year-round, under-ice data were not available at the time of reporting

2.3 Water Quality

2.3.1 Sample Collection

Field measurements of water quality parameters were made using hand-held field meters and included a YSI 650 MDS (September only), an Oxyguard Handy Polaris dissolved oxygen (DO) meter, a Hanna Combo Pen pH and conductivity meter, and a LaMotte 2020WE turbidity meter. To ensure correct DO concentrations under-ice, a Hach Titration kit was used for DO measurements in January.

Measurements were taken as close to the middle of the channel as possible, below the surface at each station. The UTM coordinates for each measurement location were recorded in September, and used in October and January to sample from the same location. The following field parameters were measured at each station:

- water temperature (°C);
- pH;
- specific conductivity (µS/cm);
- DO concentration (mg/L) and percent saturation (%); and
- turbidity (NTU).

Grab samples for laboratory analysis were collected at each site using a plastic bottle attached to a telescopic pole. Water was then transferred into bottles provided by the laboratory. The bottle attached to the telescopic pole and the sample bottles were triple-rinsed at the sampling station. Samples were collected from as close to the middle of the channel as possible, approximately 10 cm below the water surface.

Samples to be analyzed for dissolved constituents were filtered in the field as soon as possible after sample collection. Water samples were filtered using a Geopump and a 0.45 µm pore size filter. If preservative was required, it was added in the field as soon as possible after collection. Preservation of a sample is required to reduce loss of components due to biological reactions, hydrolysis, volatilization, or adsorption. This is usually required for those samples (e.g., total nutrients, total metals) that will be analyzed for concentration of the total component (i.e., both dissolved and particulate fractions).

Sample bottles were labelled with the station ID code (Table 2-1), sampling date, and the required analysis. Samples were stored in coolers and packed with ice to keep them at 4 ± 2°C. Samples were delivered to Maxxam Analytics Inc. in Edmonton following completion of each sampling program.

2.3.2 Parameters

Water samples were analyzed for a suite of parameters grouped into conventional parameters, major ions, nutrients, total and dissolved metals, and selected organic compounds (Table 2-3).

Table 2-3. Water Quality Parameter List

Group Name	Parameters
Field Measurements	Water temperature, DO, pH, specific conductivity, turbidity
Inorganics	Total dissolved solids (TDS), total suspended solids (TSS), hardness
Major Ions	Dissolved calcium, dissolved chloride, dissolved fluoride, dissolved magnesium, dissolved sodium, dissolved sulphate, sodium adsorption ratio (SAR)
Nutrients – Nitrogen	Total nitrogen (TN), total Kjeldahl nitrogen (TKN), total ammonia, nitrate + nitrite, dissolved nitrate, dissolved nitrite
Nutrients – Phosphorus	Total phosphorus (TP), dissolved phosphorus (DP)
Nutrients – Carbon	Total organic carbon (TOC)

2.4 In-stream Load Calculations

To assess in-stream loads of each parameter in the Battle River during each sampling program, concentrations (mg/L) were converted to loads (kg/day) by multiplying concentration by discharge as follows:

$$Discharge\left(\frac{m^3}{d}\right) = discharge\left(\frac{m}{s}\right) x\ 60\left(\frac{s}{\min}\right) x\left(60\frac{min}{h}\right) x\ (24\frac{h}{d})$$

$$Load\ of\ Parameter\left(\frac{kg}{d}\right) = concentration\left(\frac{mg}{L}\right) x\left(\frac{1g}{1000mg}\right) x\left(\frac{1kg}{1000g}\right) x\left(\frac{1000l}{m^3}\right) x\ discharge\ (\frac{m^3}{d})$$

2.5 Quality Assurance and Quality Control

Quality assurance and quality control (QA/QC) practices determine data integrity and are relevant to all aspects of a study, from sample collection to data analysis and reporting. Quality assurance encompasses management and technical practices designed to ensure that the data generated are of consistent high quality. Quality control is an aspect of QA and includes the procedures used to measure and evaluate data quality, and the corrective actions to be taken when data quality objectives are not met. Appendix B describes QA/QC practices applied during this study, evaluates QC data, and describes the implications of QC results to the interpretation of study results.

QC samples were collected during each sampling event. In total, four blanks and three duplicate samples were collected. Detectable concentrations were found in three of the blank samples, but concentrations were less than the practical quantitation limit (PQL; i.e., 5 times the method detection limit) and were not considered further. One parameter in each of the duplicate sample sets exceeded the QC criteria. TP differed between duplicate samples in September, and TSS differed between duplicate samples in October and January. The relative difference between duplicates was more than 20%, and as high as 83%. While these parameters differed greatly between the duplicate samples, all other parameters were within the QC criteria; therefore, analytical precision is considered high, and data are used with confidence.

2.6 Water Quality Objectives and Guidelines

Water quality data were compared to the draft WQO developed for the Battle River (Table 2-4). Draft objectives and targets were available for the water quality parameters examined in this study, with targets specific to each reach for both open-water and ice-cover conditions. As there are currently no targets or objectives for Reach 3, concentrations from the two stations in Reach 3 were compared to upstream concentrations, and compared to generic guidelines.

Table 2-4. Water Quality Objectives for Reaches 1, 2 and 4 of the Battle River

Indicator	Units	Reach 1	Reach 2	Reach 3	Reach 4
Water temperature	°Celsius	**Objectives based on observed data:** IC ≤ (0, 1)[50, 90] OW ≤ (13, 21)[50, 90] Trend: ✋↗ and ✋↘	**Objectives based on observed data:** IC ≤ (1, 2)[50, 90] OW ≤ (14, 21)[50, 90] Trend: ✋↗ and ✋↘	-	**Objectives based on observed data:** IC ≤ (0, 1)[50, 90] OW ≤ (15, 21)[50, 90] Trend: ✋↗ and ✋↘
pH	-	**Objectives based on guidelines:** ≥6.5 ≤9 IC = (6.9, 7.4, 7.9)[10, 50, 90] OW = (7.9, 8.2, 8.9)[10, 50, 90] OW: ↘	**Objectives based on guidelines:** ≥6.5 ≤9 IC = (7.2, 7.5, 8.3)[10, 50, 90] OW = (7.9, 8.4, 9.1)[10, 50, 90] OW: ↘	**Guideline:** ≥6.5 ≤9	**Objectives based on guidelines:** ≥6.5 ≤9 IC = (7.4, 7.8, 8.5)[10, 50, 90] OW = (8.1, 8.5, 8.8)[10, 50, 90] IC & OW: ↘
Specific conductivity	µS/cm	**Objectives based on guidelines:** <1000 (where irrigation occurs) **Targets based on observed data:** IC ≤ (819, 1251)[50, 90] OW ≤ (515, 619)[50, 90] Trend: IC↘; OW✋↗	**Objectives based on guidelines:** <1000 (where irrigation occurs) **Targets based on observed data:** IC ≤ (1264, 2229)[50, 90] OW ≤ (663, 943)[50, 90] Trend: IC↘; OW✋↗	**Guideline:** <1000 (where irrigation occurs)	**Objectives based on guidelines:** <1000 (where irrigation occurs) **Targets based on observed data:** IC ≤ (1190, 1477)[50, 90] OW ≤ (816, 1130)[50, 90] IC & OW: ↘
Dissolved oxygen	mg/L	**Objectives based on guidelines:** Daily minimum > 5 7-day mean > 6.5 7-day mean > 8.3 (mid May to the end of June) **Targets based on observed data:** IC ≥ (0.2, 3.3)[10, 50] OW ≥ (7.8, 9.4)[10, 50] Trend: ✋↘	**Objectives based on guidelines:** Daily minimum > 5 7-day mean > 6.5 7-day mean > 8.3 (mid May to the end of June) **Targets based on observed data:** IC ≥ (0.36, 3.3)[10, 50] OW ≥ (6.7, 9.4)[10, 50] Trend: ✋↘	**Guideline:** Daily minimum > 5 7-day mean > 6.5 7-day mean > 8.3 (mid May to the end of June)	**Objectives based on guidelines:** Daily minimum > 5 7-day mean > 6.5 7-day mean > 8.3 (mid May to the end of June) **Targets based on observed data:** IC ≥ (0.4, 3.6)[10, 50] OW ≥ (7.2, 9.1)[10, 50] Trend: ✋↘
Turbidity	NTU	**Objectives based on observed data:** IC ≤ (6, 55)[50, 90] OW ≤ (7, 15)[50, 90] Trend: ✋↗	**Objectives based on observed data:** IC ≤ (26, 42)[50, 90] OW ≤ (16, 60)[50, 90] Trend: ✋↗	-	**Objectives based on observed data:** IC ≤ (5, 13)[50, 90] OW ≤ (17, 140)[50, 90] Trend: ✋↗
Total suspended solids	mg/L	**Objectives based on observed data:** IC ≤ (7, 22)[50, 90] OW ≤ (7, 39)[50, 90] Trend: ✋↗	**Objectives based on observed data:** IC ≤ (19, 40)[50, 90] OW ≤ (23, 81)[50, 90] Trend: ✋↗	-	**Objectives based on observed data:** IC ≤ (6, 22)[50, 90] OW ≤ (27, 288)[50, 90] Trend: ✋↗
Total dissolved solids	mg/L	**Objectives based on guidelines:** <3000 (where stock watering occurs) <500 (where irrigation occurs) **Targets based on observed data:** IC ≤ (498, 818)[50, 90] OW ≤ (322, 381)[50, 90] IC & OW: ✋↗	**Objectives based on guidelines:** <3000 (where stock watering occurs) <500 (where irrigation occurs) IC ≤ (834, 1460)[50, 90] OW ≤ (418, 589)[50, 90] IC & OW: ↘	**Guideline:** <3000 (where stock watering occurs) <500 (where irrigation occurs)	**Objectives based on guidelines:** <3000 (where stock watering occurs) <500 (where irrigation occurs) IC ≤ (702, 750)[50, 90] OW ≤ (536, 616)[50, 90] IC & OW: ↘
Hardness	mg/L	**Objectives based on observed data:** IC ≤ (280, 409)[50, 90] OW ≤ (170, 213)[50, 90] Trend: ✋↗	**Objectives based on observed data:** IC ≤ (360, 610)[50, 90] OW ≤ (190, 236)[50, 90] Trend: ✋↗	-	**Objectives based on observed data:** IC ≤ (349, 434)[50, 90] OW ≤ (213, 267)[50, 90] Trend: ✋↗

Table 2-4. Water Quality Objectives for Reaches 1, 2 and 4 of the Battle River (continued)

Indicator	Units	Reach 1	Reach 2	Reach 3	Reach 4
Calcium	mg/L	**Objectives based on guidelines:** <1000 (where stock watering occurs) **Targets based on observed data:** IC ≤ (69, 102) $^{50, 90}$ OW ≤ (42, 52) $^{50, 90}$ Trend: ✋↗	**Objectives based on guidelines:** <1000 (where stock watering occurs) **Targets based on observed data:** IC ≤ (78, 143) $^{50, 90}$ OW ≤ (42, 59) $^{50, 90}$ Trend: ✋↗	**Guideline:** <1000 (where stock watering occurs)	**Objectives based on guidelines:** <1000 (where stock watering occurs) **Targets based on observed data:** IC ≤ (81, 100) $^{50, 90}$ OW ≤ (45, 61) $^{50, 90}$ Trend: ✋↗
Chloride	mg/L	**Objectives based on guidelines:** <100 (where irrigation occurs) <230 **Targets based on observed data:** IC ≤ (7, 12) $^{50, 90}$ OW ≤ (5, 9) $^{50, 90}$ Trend: ✋↗	**Objectives based on guidelines:** <100 (where irrigation occurs) <230 **Targets based on observed data:** IC ≤ (61, 160) $^{50, 90}$ OW ≤ (26, 48) $^{50, 90}$ Trend: ✋↗	**Guideline:** <100 (where irrigation occurs) <230	**Objectives based on guidelines:** <100 (where irrigation occurs) <230 **Targets based on observed data:** IC ≤ (26, 37) $^{50, 90}$ OW ≤ (17, 38) $^{50, 90}$ Trend: ✋↗
Fluoride	mg/L	**Objectives based on guidelines:** <0.12 (for aquatic life) IC ≤ (0.22, 0.34) $^{50, 90}$ OW ≤ (0.15, 0.21) $^{50, 90}$ IC & OW: ↘	**Objectives based on guidelines:** <0.12 (for aquatic life) IC ≤ (0.37, 0.73) $^{50, 90}$ OW ≤ (0.22, 0.37) $^{50, 90}$ IC & OW: ↘	**Guideline:** <0.12 (for aquatic life)	**Objectives based on guidelines:** <0.12 (for aquatic life) IC ≤ (0.25, 0.32) $^{50, 90}$ OW ≤ (0.23, 0.28) $^{50, 90}$ IC & OW: ↘
Sulphate	mg/L	**Objectives based on guidelines:** <1000 (where irrigation occurs) **Targets based on observed data:** IC ≤ (25, 38) $^{50, 90}$ OW ≤ (19, 28) $^{50, 90}$ Trend: ✋↗	**Objectives based on guidelines:** <1000 (where irrigation occurs) **Targets based on observed data:** IC ≤ (186, 403) $^{50, 90}$ OW ≤ (75, 136) $^{50, 90}$ Trend: ✋↗	**Guideline:** <1000 (where irrigation occurs)	**Objectives based on guidelines:** <500 **Targets based on observed data:** IC ≤ (164, 214) $^{50, 90}$ OW ≤ (118, 179) $^{50, 90}$ Trend: ✋↗
Sodium adsorption ratio	-	**Objectives based on guidelines:** <5 (where irrigation occurs) **Targets based on observed data:** IC ≤ (2, 3.2) $^{50, 90}$ OW ≤ (1.3, 2.6) $^{50, 90}$ Trend: ✋↗	**Objectives based on guidelines:** <5 (where irrigation occurs) **Targets based on observed data:** IC ≤ (4, 5.1) $^{50, 90}$ OW ≤ (2.4, 3.6) $^{50, 90}$ Trend: IC↘; OW✋↗	**Guideline:** <5 (where irrigation occurs)	**Objectives based on guidelines:** <5 (where irrigation occurs) OW: ↘ **Targets based on observed data:** IC ≤ (3.5, 4.2) $^{50, 90}$ OW ≤ (5, 5.5) $^{50, 90}$ Trend: IC✋↗; OW↘
Total nitrogen	mg-N/L	**Objectives based on guidelines:** average < 1 IC ≤ (1.1, 3.4) $^{50, 90}$ OW ≤ (1, 1.6) $^{50, 90}$ IC & OW: ↘	**Objectives based on guidelines:** average < 1 IC ≤ (3.8, 10.1) $^{50, 90}$ OW ≤ (1.8, 5) $^{50, 90}$ IC & OW: ↘	**Guideline:** average < 1	**Objectives based on guidelines:** average < 1 IC ≤ (1, 1.3) $^{50, 90}$ OW ≤ (1, 2.4) $^{50, 90}$ IC & OW: ↘

Table 2-4. Water Quality Objectives for Reaches 1, 2 and 4 of the Battle River (continued)

Indicator	Units	Reach 1	Reach 2	Reach 3	Reach 4
Total ammonia	mg-N/L	**Objectives based on guidelines:** Ammonia concentrations should remain below the U.S. EPA criteria of the 30-day mean for total ammonia (temperature and pH dependent). **Targets based on observed data:** IC ≤ (0.28, 1.26) $^{50, 90}$ OW ≤ (0.04, 0.12) $^{50, 90}$ Trend: ✋↗	**Objectives based on guidelines:** Ammonia concentrations should remain below the U.S. EPA criteria of the 30-day mean for total ammonia (temperature and pH dependent). **Targets based on observed data:** IC ≤ (1.81, 9.19) $^{50, 90}$ OW ≤ (0.1, 1.99) $^{50, 90}$ IC & OW: ↘	**Guideline:** Ammonia concentrations should remain below the U.S. EPA criteria of the 30-day mean for total ammonia (temperature and pH dependent).	**Objectives based on guidelines:** Ammonia concentrations should remain below the U.S. EPA criteria of the 30-day mean for total ammonia (temperature and pH dependent). **Targets based on observed data:** IC ≤ (0.15, 0.4) $^{50, 90}$ OW ≤ (<0.01, 0.06) $^{50, 90}$ Trend: ✋↗
Nitrate + nitrite-N	mg-N/L	**Objectives based on guidelines:** <2.93 **Targets based on observed data:** IC ≤ (0.022, 0.213) $^{50, 90}$ OW ≤ (0.004, 0.066) $^{50, 90}$ Trend: ✋↗	**Objectives based on guidelines:** <2.93 **Targets based on observed data:** IC ≤ (0.253, 0.555) $^{50, 90}$ OW ≤ (0.007, 0.511) $^{50, 90}$ Trend: ✋↗	**Guideline:** <2.93	**Objectives based on guidelines:** <2.93 **Targets based on observed data:** IC ≤ (0.06, 0.48) $^{50, 90}$ OW ≤ (<0.01, 0.33) $^{50, 90}$ Trend: ✋↗
Nitrite-N	mg-N/L	**Objectives based on guidelines:** <0.06 **Targets based on observed data:** IC ≤ (0.003, 0.006) $^{50, 90}$ OW ≤ (0.003, 0.007) $^{50, 90}$ Trend: ✋↗	**Objectives based on guidelines:** <0.06 **Targets based on observed data:** IC ≤ (0.008, 0.032) $^{50, 90}$ OW ≤ (0.001, 0.038) $^{50, 90}$ Trend: ✋↗	**Guideline:** <0.06	Increase monitoring to obtain sufficient information to develop water quality objectives and target.
Nitrate-N	mg-N/L	**Objectives based on guidelines:** <2.93 **Targets based on observed data:** IC ≤ (0.019, 0.158) $^{50, 90}$ OW ≤ (0.003, 0.046) $^{50, 90}$ Trend: ✋↗	**Objectives based on guidelines:** <2.93 **Targets based on observed data:** IC ≤ (0.22, 0.561) $^{50, 90}$ OW ≤ (0.005, 0.483) $^{50, 90}$ Trend: ✋↗	**Guideline:** <2.93	Increase monitoring to obtain sufficient information to develop water quality objectives and target.
Total phosphorus	mg-P/L	**Objectives based on guidelines:** ≤0.05 IC ≤ (0.09, 0.98) $^{50, 90}$ OW ≤ (0.16, 0.41) $^{50, 90}$ IC & OW: ↘	**Objectives based on guidelines:** ≤0.05 IC ≤ (0.27, 0.92) $^{50, 90}$ OW ≤ (0.26, 0.59) $^{50, 90}$ IC & OW: ↘	**Guideline:** ≤0.05	**Objectives based on guidelines:** ≤0.05 IC ≤ (0.04, 0.09) $^{50, 90}$ OW ≤ (0.09, 0.33) $^{50, 90}$ IC & OW: ↘
Dissolved phosphorus	mg-P/L	**Targets based on observed data:** IC ≤ (0.03, 0.11) $^{50, 90}$ OW ≤ (0.09, 0.33) $^{50, 90}$ Trend: ✋↗	**Targets based on observed data:** IC ≤ (0.07, 0.31) $^{50, 90}$ OW ≤ (0.09, 0.3) $^{50, 90}$ Trend: ✋↗	-	**Targets based on observed data:** IC ≤ (0.02, 0.04) $^{50, 90}$ OW ≤ (0.03, 0.05) $^{50, 90}$ Trend: ✋↗
Total organic carbon	mg/L	**Targets based on observed data:** IC ≤ (18, 28) $^{50, 90}$ OW ≤ (15, 23) $^{50, 90}$ Trend: ✋↗	**Targets based on observed data:** IC ≤ (26, 32) $^{50, 90}$ OW ≤ (19, 23) $^{50, 90}$ Trend: ✋↗	-	**Targets based on observed data:** IC ≤ (12, 18) $^{50, 90}$ OW ≤ (16, 26) $^{50, 90}$ Trend: ✋↗

Notes:

Abbreviations used in describing objectives: IC = ice-covered conditions; OW = open-water conditions; ✋↗ = no increasing trend; ✋↘ = no decreasing trend; ↘ = decreasing trend; ≥ = greater than or equal to; ≤ = less than equal to; < = less than; > = greater than; geomean = geometric mean; "-" no generic guideline available.

Example: OW ≤ (7, 39) $^{50, 90}$ for TSS (in mg/L) in Reach 1 means that during open-water conditions, TSS concentrations should be at or below 7 mg/L 50 percent of the time and at or below 39 mg/L 90 percent of the time (based on a 90^{th} percentile).

Units: mg/L = milligrams per litre; NTU = nephelometric turbidity units, µS/cm = microSiemens per centimetre; No/100 mL = number of organisms per 100 millilitres; °C = degrees Celsius; N = as nitrogen; P = phosphorus.

3.0 RESULTS AND DISCUSSION

3.1 Discharge

Details of the discharge results are provided in Appendix A, which includes a summary of the measured results at each station in comparison to measured results from the nearest Water Survey of Canada station. Discharge measured at each station for each field event is summarized in Table 3-1. Measured discharge at station AB05FA0340 was high during the January field program, and was estimated at 0.348 m3/s (Appendix A).

Table 3-1. Measured Discharge at 11 Locations along the Battle River

Survey Location	Effective Drainage Area (km^2)[a]	Trip #1 – September 2011		Trip #2 – October 2011		Trip #3 – January 2012	
		Date	Measured Discharge (m^3/s)	Date	Measured Discharge (m^3/s)	Date	Measured Discharge (m^3/s)
AB05FA0030	-	6-Sep-11	0.1	17-Oct-11	0.04	23-Jan-12	0.455
AB05FA0060	1550	6-Sep-11	0.208	17-Oct-11	0.086	23-Jan-12	0.936
AB05FA0120	1550	6-Sep-11	0.639	17-Oct-11	0.249	27-Jan-12	0.338
Samson Lake							
AB05FA0280	2140	7-Sep-11	4.82	17-Oct-11	1.04	24-Jan-12	0.25
AB05FA0290	3270	7-Sep-11	5.46	18-Oct-11	1.28	24-Jan-12	0.279
AB05FA0320	2920	7-Sep-11	5.54	18-Oct-11	1.35	24-Jan-12	0.290 [d]
AB05FA0340	3510[e]	8-Sep-11	4.93	18-Oct-11	1.62 [c]	25-Jan-12	0.348
Driedmeat Lake							
AB05FC0020	-	8-Sep-11	8.25	18-Oct-11	1.63	26-Jan-12	0.335
AB05FC0030	3620	9-Sep-11	7.72 [b]	19-Oct-11	1.54	27-Jan-12	0.468
Forestburg Reservoir							
AB05FB0050	6010	8-Sep-11	10.5 [b]	20-Oct-11	2.24	25-Jan-12	0.584
AB05FE0050	8230	9-Sep-11	12.1	19-Oct-11	2.45	26-Jan-12	1.414

Notes: a= Effective drainage area from closest representative Water Survey of Canada Station (additional details in Appendix A).
b= Estimate based on Water Survey of Canada station 05FC008 (additional details in Appendix A).
c= Estimate based on prorated discharge from Survey Location AB05FA0320. Measurements were not possible with available equipment (additional details in Appendix A).
d= Estimate based on partial measurements and discharge at survey location AB05FA0290 (additional details in Appendix A).
e= Estimated from closest representative Water Survey of Canada Station and GIS (additional details in Appendix A).).

3.2 Water Quality

Descriptive water quality statistics for all parameters are provided below and the complete data set is provided in Appendix C (Tables C-1 to C-3). Data in Appendix C are sorted by sampling month and then by reach. The following discussion summarizes the chemistry of the four sampled reaches of the Battle River. Results are discussed by reach with reported averages and ranges for the various water quality parameters. Values that are higher than guidelines and objectives are identified. These data provide information on seasonal variation in water quality in the Battle River reaches. For all parameters except pH and dissolved oxygen, valus above the 90th percentile WQO are of concern. For pH, values less than the 10th percentile or more than the 90th percentile are of concern; for DO, values less than the 10th percentile WQO are of concern.

Summary statistics were generated for all samples collected during the open-water period (September and October) and all samples collected during the ice-covered period (January) (Table 3-2). In general, some parameters had higher concentrations during open-water conditions compared to ice-covered conditions. These included pH, DO, TSS, TP, and DP. Some parameters had higher concentrations during ice-covered conditions. These included TDS, hardness, and major ions. Finally, parameters including turbidity, nitrogen parameters, and TOC, had similar ranges and averages during both sampling seasons.

Table 3-2: Descriptive Statistics for all Reaches in September, October, and January, 2011-2012

Water Quality Parameters	Units	September (n=11)				October (n=11)				January (n=11)			
		Min	Median	Mean	Max	Min	Median	Mean	Max	Min	Median	Mean	Max
Physical Parameters													
Water temperature (field)	°C	15.1	17.9	18.3	21.3	3.6	5.7	5.7	8.1	0.0	0.2	0.2	0.5
pH (field)	-	8.0	8.2	8.2	8.6	8.0	8.5	8.5	9.0	6.6	7.6	7.5	7.9
Specific conductivity (field)	µS/cm	535	629	644	896	620	797	788	1027	649	1250	1291	1718
Dissolved oxygen (field)	mg/L	6.8	8.1	8.5	12.5	9.4	12.2	12.3	14.7	0.9	4.2	3.9	7.1
Dissolved oxygen (% saturation) (field)	%	82.0	96.0[a]	94.3[a]	111.0[a]	75.0	102.0	101.5	122.0	1.0	29.0	27.0	63.0
Turbidity	NTU	3.2	16.3	17.0	35.2	3.4	9.7	13.6	42.1	4.7	7.0	14.3	42.0
Inorganics													
Total dissolved solids	mg/L	380	420	423	510	320	410	432	610	360	720	781	1100
Total suspended solids	mg/L	4	46	44	87	5	24	29	87	3	5	9	24
Hardness ($CaCO_3$)	mg/L	200	220	222	300	230	260	266	360	230	420	458	640
Major Ions													
Dissolved calcium	mg/L	47	54	56	78	50	64	65	96	55	110	116	160
Dissolved chloride	mg/L	8.0	20.0	23.1	52.0	6.0	26.0	26.0	55.0	5.6	39.0	37.4	55.0
Dissolved fluoride	mg/L	0.16	0.22	0.23	0.30	0.14	0.21	0.21	0.31	0.20	0.31	0.30	0.35
Dissolved magnesium	mg/L	18	20	20	26	21	25	25	30	22	38	41	56
Dissolved sodium	mg/L	36	46	46	68	45	58	63	110	49	110	104	160
Dissolved sulphate	mg/L	21	45	44	56	18	58	74	180	22	160	132	210
Sodium adsorption ratio	N/A	1.1	1.3	1.3	1.7	1.3	1.7	1.7	2.7	1.4	2.1	2.1	3.1

Table 3-2: Descriptive Statistics for all Reaches in September, October, and January, 2011-2012(continued)

Water Quality Parameters	Units	September (n=11)				October (n=11)				January (n=11)			
		Min	Median	Mean	Max	Min	Median	Mean	Max	Min	Median	Mean	Max
Nutrients-Nitrogen													
Total nitrogen	mg-N/L	1.3	2.2	2.2	3.1	1.1	2.1	2.0	3.7	1.0	2.1	2.0	2.7
Total Kjeldahl nitrogen	mg-N/L	1.30	2.00	1.96	2.30	1.10	2.10	1.93	3.30	0.84	2.00	1.83	2.70
Total ammonia	mg-N/L	<0.05	<0.05	0.14	0.37	<0.05	<0.05	0.50	0.72	0.07	0.31	0.39	0.84
Nitrate plus nitrite	mg-N/L	<0.003	0.065	0.314	0.870	<0.003	<0.003	0.215	0.420	<0.003	0.180	0.273	0.700
Dissolved nitrate	mg-N/L	<0.003	0.330	0.269	0.660	<0.003	<0.003	0.197	0.400	<0.003	0.180	0.271	0.690
Dissolved nitrite	mg-N/L	<0.003	0.003	0.052	0.210	<0.003	<0.003	0.030	0.046	<0.003	<0.003	0.005	0.008
Nutrients-Phosphorus													
Total phosphorus	mg-P/L	0.075	0.230	0.260	0.840	0.041	0.170	0.146	0.310	0.038	0.062	0.172	0.480
Dissolved phosphorus	mg-P/L	0.028	0.140	0.181	0.840	0.013	0.037	0.038	0.099	0.011	0.021	0.025	0.047
Nutrients-Carbon													
Total organic carbon	mg/L	18.0	21.0	20.9	24.0	12.0	18.0	18.3	24.0	8.9	26.0	20.7	31.0

Note: median and mean values were calculated using only data above the analytical detection limit.

[a] unusual outlier was removed from the descriptive statistics.

Concentrations of water quality parameters are discussed in more detail below. Data are compared to guidelines and objectives in Table 2-4. A full set of figures showing variation in concentration along the length of the Battle River is provided for all parameters in Appendix D.

3.2.1 Field Measurements

This section summarizes field measured parameters (water temperature, DO, pH, and specific conductivity) by reach and by season (open-water and ice-covered).

3.2.1.1 pH

In the Battle River, pH was generally slightly basic (Figure 3-1), and values were between the 10th and 90th percentile in all samples except from one winter sample in Reach 4. Generally, pH was higher in October than in September. During the ice-covered sampling event, pH was closer to neutral at most stations along the river. Some values were still above the 10th percentile WQO, while most were above the 50th percentile WQO. In Reach 3, all pH values were within the CCME and ASWQG ranges (Table 2-4), and were similar to the pH in reaches 2 and 4 during both open-water and ice-covered conditions.

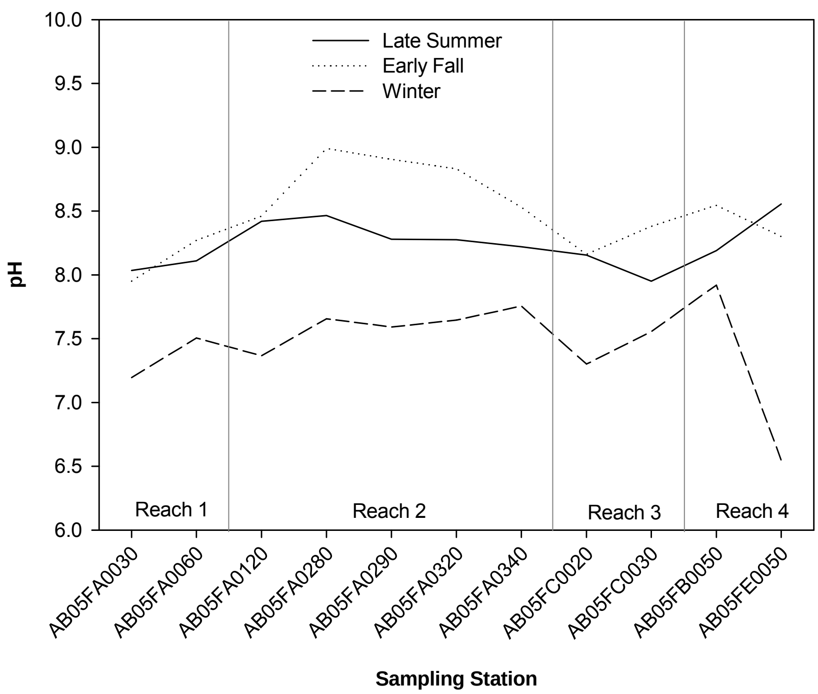

Figure 3-1: pH at Sampling Stations Along the Battle River

3.2.1.2 Specific Conductivity

Specific conductivity ranged from 571 to 1027 µS/cm during the open-water period, and from 649 to 1718 µS/cm during the ice-covered period (Figure 3-2). Many samples had values above the 90th percentile WQO within a reach, but specific conductivity was less than the irrigation guideline during the open-water period in all samples except one from Reach 2 in October. Specific conductivity was higher during the ice-cover period relative to the open-water period in all reaches, but the difference was greater in reaches 2 and 4 compared to reaches 1 and 3 (Figure 3-2). Higher conductivities were found in samples downstream of Ponoka, Camrose, and Hardisty.

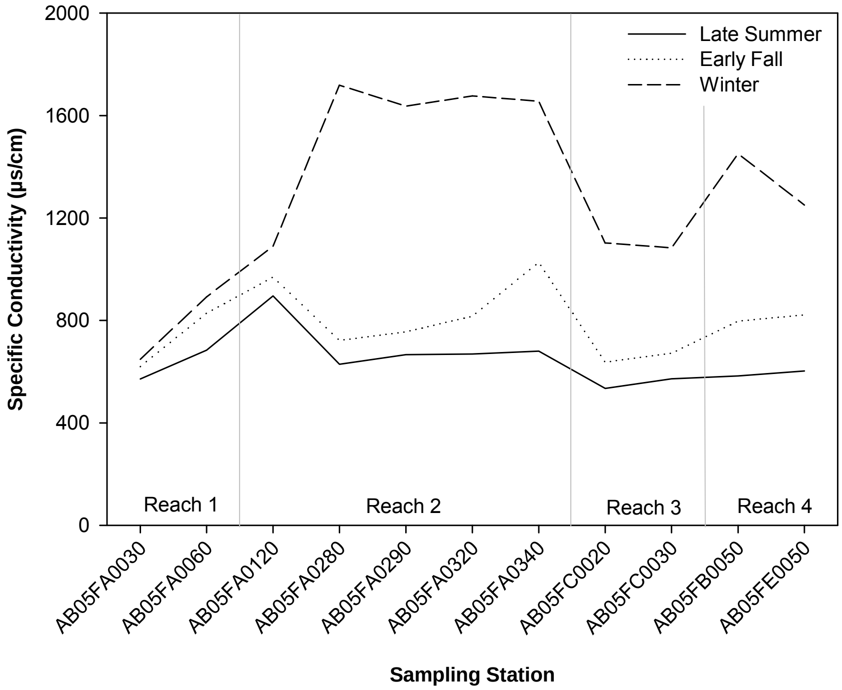

Figure 3-2: Specific Conductivity (µS/cm) at Sampling Stations Along the Battle River

3.2.1.3 Dissolved Oxygen

Evaluation of DO results is somewhat different than evaluation of results for other parameters. DO concentrations are compared against the guidelines and targets, and are flagged if they are less than the 10^{th} percentile WQO or less than the generic guideline for Reach 3. For DO, low concentrations negatively affect aquatic life.

All reaches were well oxygenated during the open-water period (September and October), but poorly oxygenated during the ice-covered period (Figure 3-3). Although DO concentrations were low in all reaches during the winter, it was especially low in Reach 2.

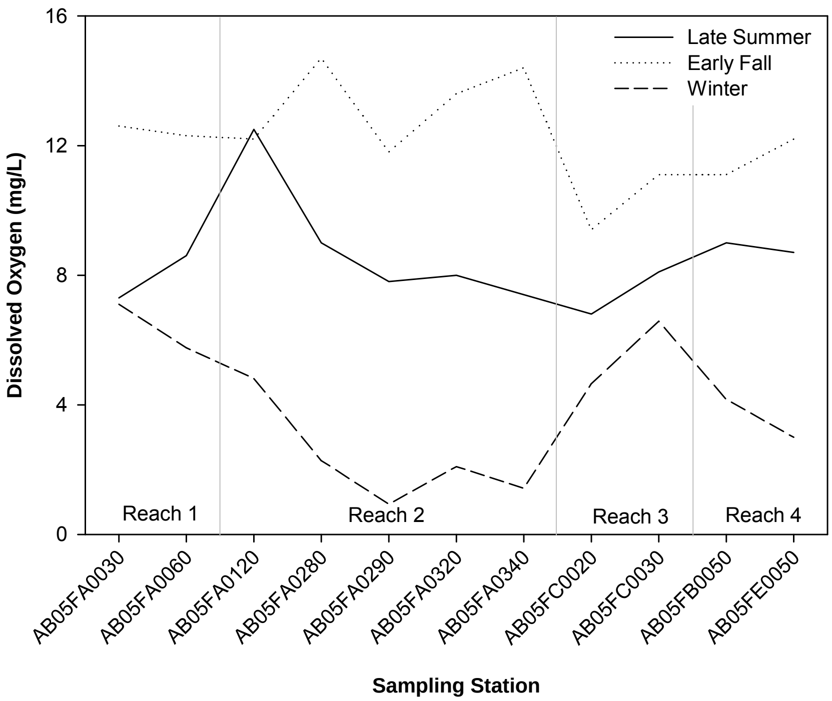

Figure 3-3: Dissolved Oxygen (mg/L) at Sampling Stations Along the Battle River

DO ranged from 6.8 mg/L to 12.5 mg/L in September, from 9.4 mg/L to 14.7 mg/L in October, and from 0.9 mg/L to 7.1 mg/L in January. DO was more than the 10^{th} percentile WQO in all reaches in all months. In Reach 3, DO was less than the generic guideline in one sample during January. During the ice-covered period, DO in the other reaches was low, but concentrations were still above the 10^{th} percentile WQO.

3.2.1.4 Turbidity

Turbidity in Reach 1 ranged from 3.4 to 8.6 NTU. Concentrations were generally above the 50^{th} percentile WQO during open-water conditions (with the exception of one October sample), and below the 50^{th} percentile during the ice-covered period. Turbidity was generally higher in Reach 2, ranging from 3.2 NTU (AB05FA0120, September) to 24.0 NTU (AB05FA0290, September) during the open-water period and from 6.3 NTU (AB05FA0120) to 42.0 NTU (AB05FA0290) during the ice-covered period. In September and October, turbidity peaked downstream of Wetaskiwin, while in January, turbidity peaked immediately downstream of Wetaskiwin and Camrose (Figure 3-4).

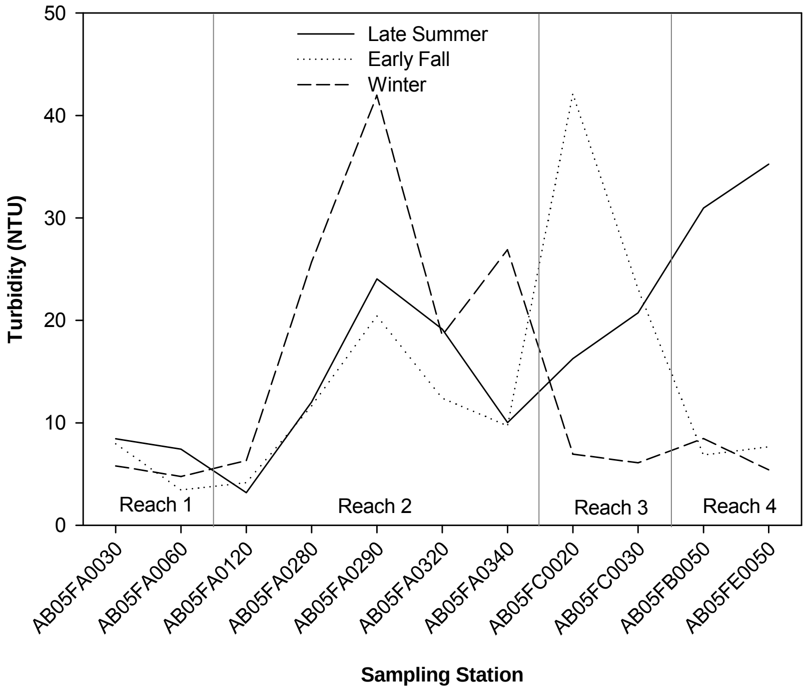

Figure 3-4: Turbidity (NTU) at Sampling Stations Along the Battle River

In Reach 3, turbidity ranged from 16 to 42 NTU, and was higher during the open-water period compared to the ice-covered period. Turbidity was higher in October than September. Turbidity was highest at the first station in Reach 3 (downstream of Camrose). Turbidity was similar in Reach 4 and Reach 3, and ranged from 5.4 to 35.2 NTU.

3.2.2 Inorganics

3.2.2.1 Total Dissolved Solids

During the open-water sampling events in Reach 1, TDS ranged from 320 mg/L (AB05FA0030, September) to 420 mg/L (AB05FA0060, September and October), and during the ice-covered period, TDS ranged from 360 mg/L (AB05FA00630) to 500 mg/L (AB05FA0060) (Figure 3-5). Concentrations were slightly above the 50th percentile WQO at station AB05FA0030, and above the 90th percentile WQO at station AB05FA0060. All concentrations were below the irrigation and stock watering guidelines.

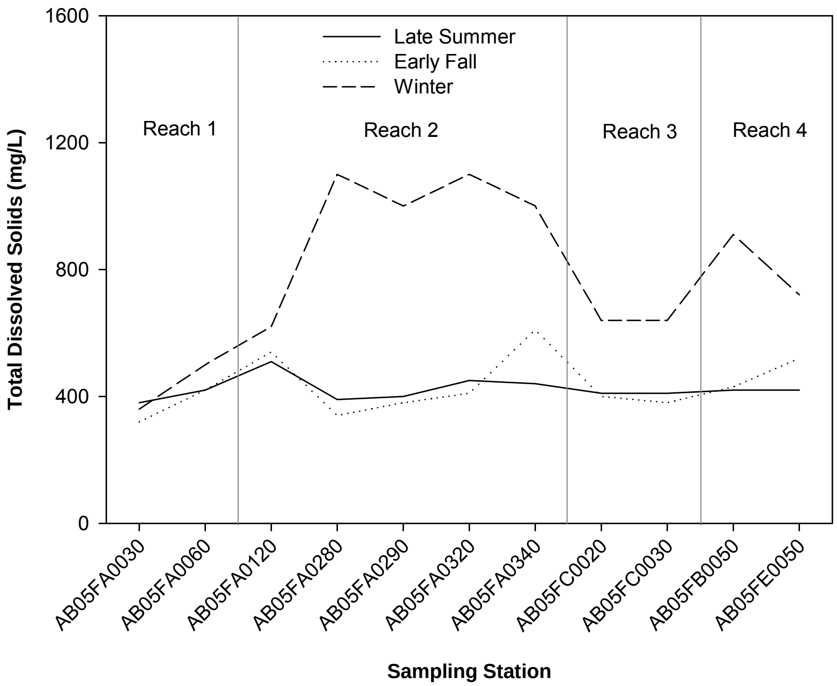

Figure 3-5: Total Dissolved Solids (mg/L) at Sampling Stations Along the Battle River

In Reach 2, TDS concentrations ranged from 340 mg/L (AB05FA0280, October) to 610 mg/L (AB05FA0350, October) during open-water, and from 620 mg/L (AB05FA0120) to 1100 mg/L (AB05FA0280 and AB05FA0320) during the ice-covered period.

In September, TDS was less than the 90th percentile WQO in all samples from Reach 2; in October, the concentration of TDS was greater than the 90th percentile WQO in two samples. The irrigation guideline was exceeded in three samples from Reach 2 (AB05FA0120 September and October and AB05FA0340, October). In January, TDS concentrations were less than the 90th percentile WQO.

In September, TDS peaked downstream of Ponoka. In October, TDS peaked downstream of both Ponoka and Camrose. In January, TDS peaked downstream of Wetaskiwin and continued to stay elevated through the remaining portion of Reach 2.

In Reach 3, TDS concentrations ranged from 380 mg/L (AB05FC0030, October) to 410 mg/L (AB05FC0020 and AB05FC0030, both in September) in the open-water season. During the ice-covered period, TDS was the same at both stations (640 mg/L). TDS in this reach was generally half of concentrations measured in Reach 2.

TDS concentrations in Reach 4 ranged from 420 mg/L (AB05FB0050 and AB05FE0050, both in September) to 520 mg/L (AB05FE0050, October) during the open-water season and from 720 mg/L (AB05FE0050) to 910 mg/L (AB05FB0050) during the ice-covered season.

3.2.2.2 Total Suspended Solids

TSS concentrations reflected the seasonal change in flow regime, with concentrations generally decreasing from September to October and from October to January (Figure 3-6). TSS concentrations increase during periods of higher runoff as suspended matter from the surrounding watershed is washed into watercourses and waterbodies. As well, higher flowing waters are capable of carrying increased suspended sediment loads.

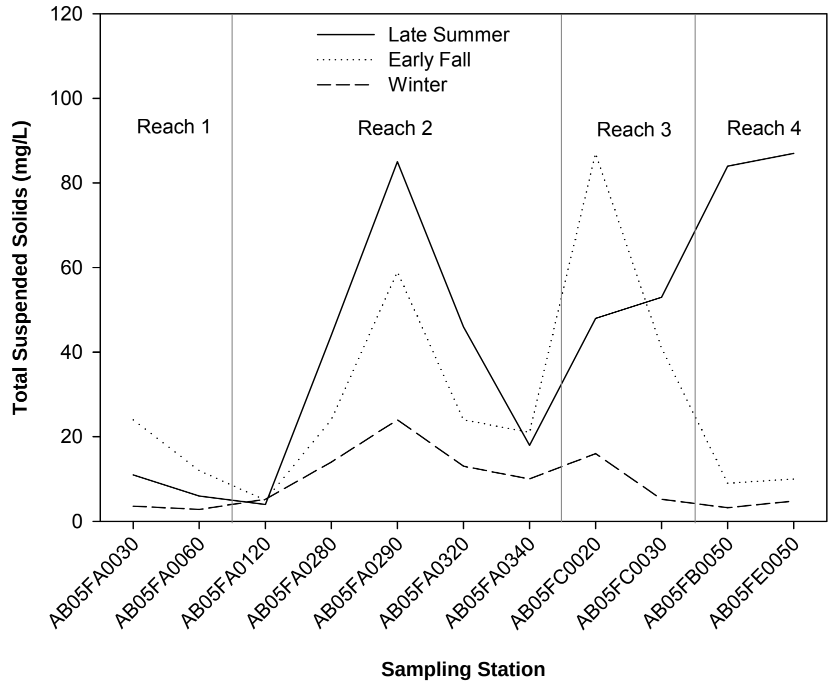

Figure 3-6: Total Suspended Solids (mg/L) at Sampling Stations Along the Battle River

TSS in Reach 1 ranged from 6 mg/L to 24 mg/L in open-water, and 2.8 mg/L to 3.6 mg/L during the ice-covered period. All concentrations of TSS in Reach 1 were less than the 90th percentile WQO.

In Reach 2, during the open-water period, TSS concentrations ranged from 4 mg/L to 85 mg/L in September. TSS was above the 90th percentile WQO in one sample from Reach 2 in September. All other samples from Reach 2 had TSS concentrations less than the 90th percentile WQO. In September and October, TSS peaked downstream of Wetaskiwin. In January, TSS concentrations ranged from 5.2 mg/L (AB05FA0120) to 24 mg/L (AB05FA0290), with the latter sample above the 50th percentile WQO.

In Reach 3, the concentration of TSS ranged from 41 mg/L to 87 mg/L in the open-water season, and 5.2 mg/L to 16 mg/L in the winter. TSS in Reach 3 was generally within the TSS range observed in reaches 2 and 4.

TSS concentrations in Reach 4 ranged from 9 mg/L to 87 mg/L in the open-water season, and from 3.2 mg/L to 4.8 mg/L in the ice-covered season. TSS concentrations in Reach 4 were higher than in the other 3 reaches.

3.2.2.3 Hardness

Hardness was similar across stations in September and October (though slightly higher in October), and was generally higher in January than during the open-water period at all stations (Figure 3-7). Hardness was highest at Reach 2 in January compared to the other reaches and sampling periods. Hardness was above the 90th percentile WQO at the downstream end of Reach 1 and upstream end of Reach 2 in September. In October, hardness was more than the 90th percentile WQO in most samples from Reaches 1, 2 and 4. In January, hardness was above the 90th percentile WQO in samples from Reaches 2 and 4, but not Reach 1.

In September, hardness peaked downstream of Ponoka and Camrose, and in October, hardness peaked downstream of Ponoka. Concentrations in Reach 3 were similar to concentrations in Reach 4.

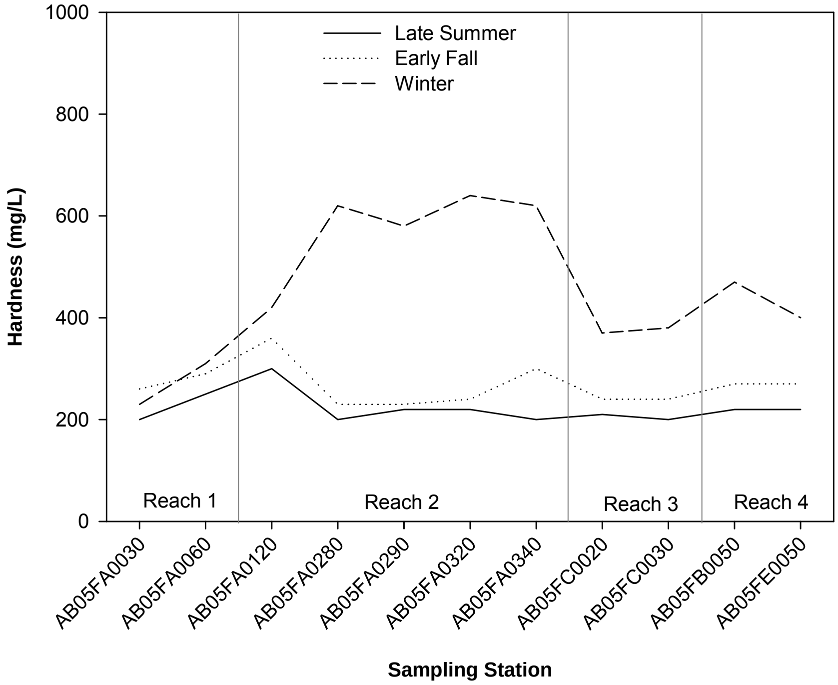

Figure 3-7: Hardness (mg/L) at Sampling Stations Along the Battle River

3.2.3 Major Ions

This section summarizes major ion data (calcium, chloride, fluoride, sulphate, and sodium adsorption ratio) by reach and season.

Calcium concentrations in Reach 1 were similar during open-water and ice-covered conditions (ranged from 51 mg/L to 75 mg/L) (Figure 3-8). Concentrations were above the 90th percentile WQO in 3 samples (AB05FA0030 October, and AB05FA0060 September and October) during open-water conditions only. Concentrations were below the stock watering guideline.

Calcium in Reach 2 was higher in the ice-covered period compared to the open-water period; calcium was also higher in Reach 2 as compared to Reach 1. Calcium ranged from 47 mg/L to 96 mg/L in the open-water period, and from 110 mg/L to 160 mg/L in the ice-covered period. Concentrations were generally above the 50th percentile WQO and occasionally above the 90th percentile WQO. All concentrations were below the CCME stock watering guideline. In Reach 3, dissolved calcium was lower than in Reach 2 (52 mg/L [September] to 94 mg/L [January], based on all samples). Calcium in Reach 4 was slightly lower than in Reach 3 (open-water: 54 mg/L [September] to 68 mg/L [October]; ice-covered: 96 mg/L to 120 mg/L). Calcium concentrations in the open-water and ice-covered periods were above the 50th percentile WQO, and occasionally above the 90th percentile WQO, and were below the stock watering guideline.

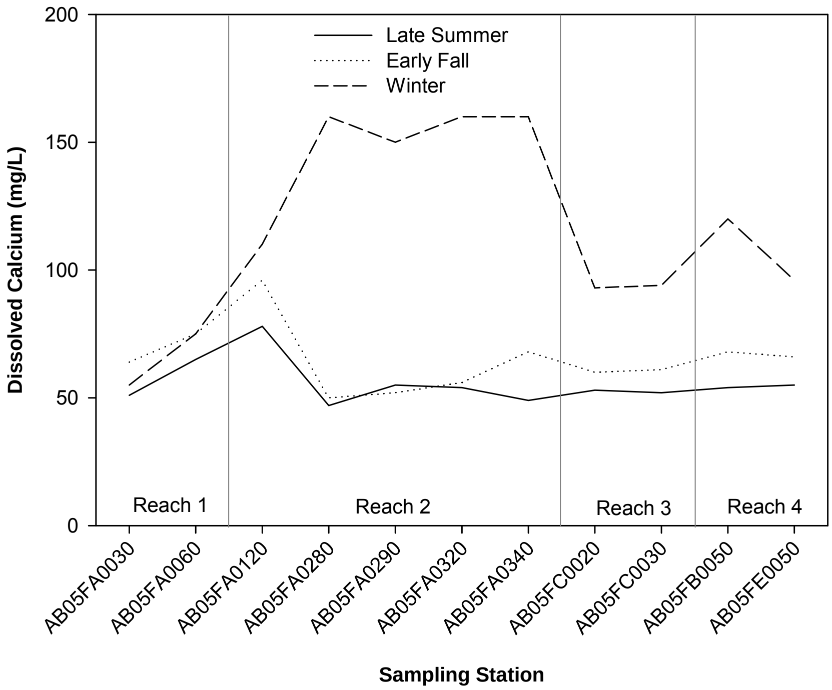

Figure 3-8: Calcium Concentrations (mg/L) at Sampling Stations Along the Battle River

Chloride concentrations in Reach 1 were similar during the open-water and ice-covered conditions (range for both open-water and ice-covered conditions: 5.6 mg/L to 15 mg/L (Figure 3-9). Concentrations were below the irrigation guidelines, but were above the 90th percentile WQO in one sample. Chloride in Reach 2 was also similar during the open-water and ice-covered conditions, but was higher than in Reach 1 (range for both open-water and ice-covered conditions was 23 mg/L to 55 mg/L). Concentrations were less than the irrigation guideline, and were less than the 90th percentile WQO in most samples. Chloride concentrations in Reach 3 ranged from 19 mg/L to 39 mg/L (across all samples) were higher than in Reach 1, but lower than in Reach 2, and were below the guideline for irrigation. Chloride was slightly higher in Reach 4 (20 mg/L to 50 mg/L) than in Reach 3, and concentrations from both the open-water and ice-covered periods were less than the irrigation guideline.

Chloride concentrations were above the 90th percentile WQO in September, but only in Reach 1, in October, at the furthest downstream stations in Reaches 1 and 2, and in January, but only in Reach 4.

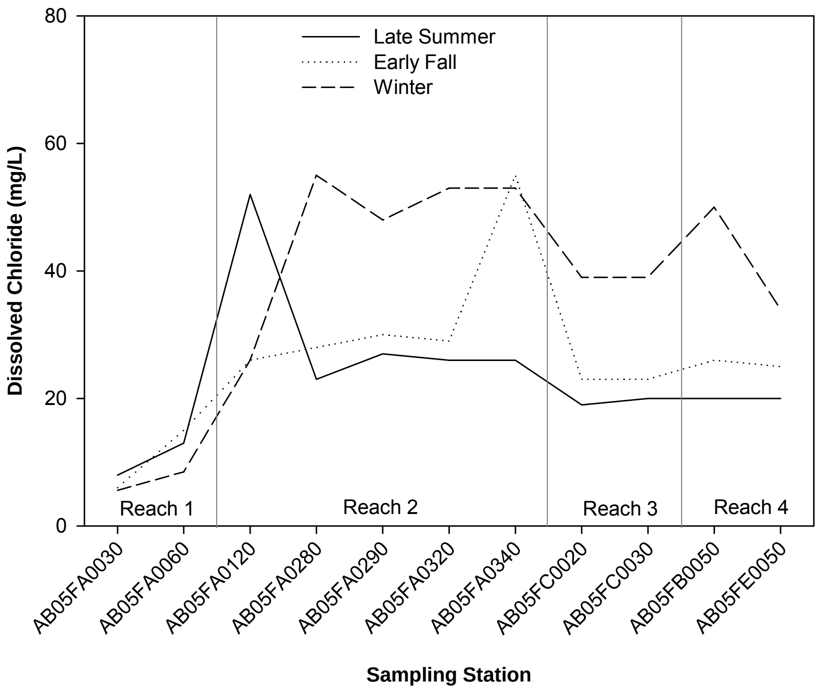

Figure 3-9: Chloride Concentrations (mg/L) at Sampling Stations Along the Battle River

Fluoride concentrations ranged from 0.14 mg/L to 0.24 mg/L in Reach 1 across all sampling months (Figure 3-10). During open-water conditions, one sample in September was above the 90th percentile WQO; during October and January, concentrations were less than the 90th percentile WQO. Fluoride concentrations were above the Alberta chronic aquatic life guideline in Reach 1.

Fluoride concentration in Reach 2 ranged from 0.18 mg/L to 0.35 mg/L across all sampling months, and only one sample in October was above the 90th percentile WQO. Similar to Reach 1, all concentrations were above the chronic aquatic life guideline.

Concentrations of fluoride in Reach 3 ranged from 0.18 mg/L to 0.21 mg/L across all sampling months. In the open-water period concentrations were similar to those in Reach 1, but concentrations during the ice-covered period, concentrations were more similar to those in Reach 2. All concentrations were above the generic chronic guideline for fluoride.

Fluoride concentrations in Reach 4 were comparable to concentrations in Reach 3. In September and October, all measured concentrations were less than the 90th percentile WQO, but in January, one sample was above the 90th percentile WQO. All concentrations were above the Alberta aquatic life guideline.

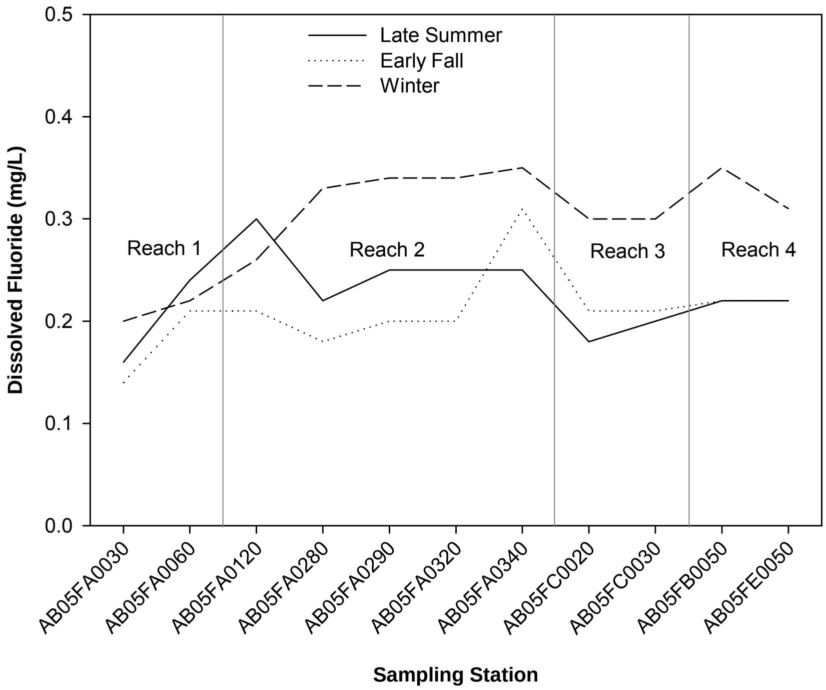

Figure 3-10: Fluoride Concentrations (mg/L) at Sampling Stations Along the Battle River

Sulphate concentrations in Reach 1 ranged from 18 mg/L to 36 mg/L across all sampling months, were above the 90th percentile WQO in September and October at the downstream station, and were below the irrigation guideline (Figure 3-11). Sulphate was higher in Reach 2 than in Reach 1 and ranged from 45 mg/L to 180 mg/L in open-water conditions, and 96 mg/L to 190 mg/L in ice-covered conditions. Concentrations were generally less than the 90th percentile WQO in September, October and January except for two samples in October (AB05FA0280 and AB05FA0340). All concentrations were also below the stock watering guidelines.

Sulphate concentrations in Reach 3 (41 mg/L to 110 mg/L), during both open-water and ice-covered periods, were generally lower than those in Reach 2, but higher than those in Reach 1. Sulphate concentrations in Reach 4 were higher than in Reach 3, and were more similar to concentrations found in Reach 2 (open-water: 49 mg/L to 100 mg/L; ice-covered: 180 mg/L to 210 mg/L). Sulphate was below the 50th percentile WQO in September and October, above it in January, and always below the irrigation guideline.

The major ions (calcium, chloride, fluoride, and sulphate) generally peaked downstream of Ponoka, and stayed elevated throughout the reach.

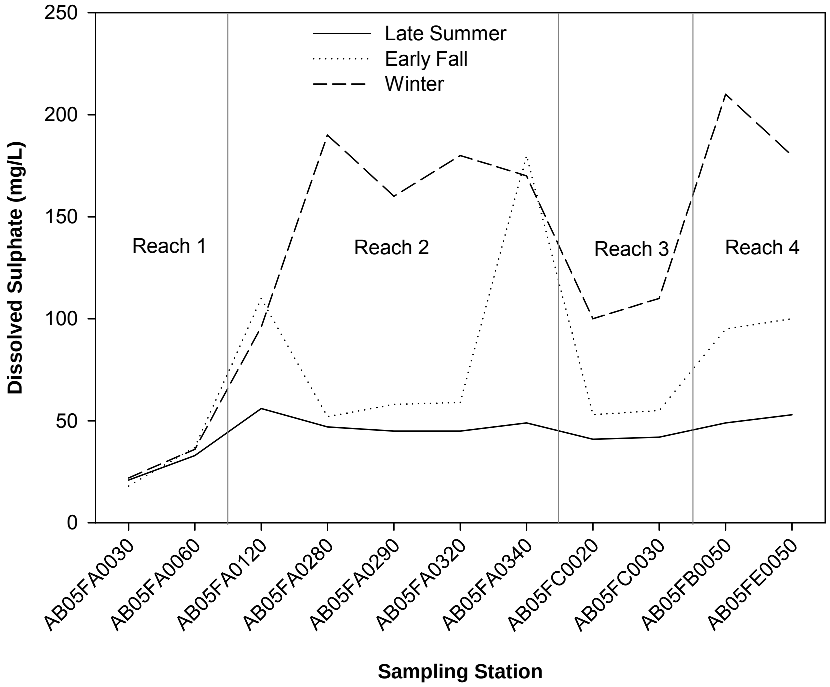

Figure 3-11: Sulphate Concentrations (mg/L) at Sampling Stations Along the Battle River

SAR values ranged from 1.2 mg/L to 1.8 mg/L across all sampling months in Reach 1 and were less than the 90th percentile WQO (Figure 3-12). SAR was slightly higher in Reach 2 (ranged from 1.3 mg/L to 2.7 mg/L), and was below the 90th percentile WQO. SAR in Reach 3 was higher in the ice-covered period (1.9 mg/L to 2.1 mg/L) and lower in the open-water period (1.1 mg/L to 1.4 mg/L), and lower than SAR in Reach 2. SAR in Reach 4 during the open-water period (1.3 mg/L to 2.1 mg/L) was similar to SAR in Reach 3 during the open-water period, but was higher than Reach 3 during the ice-covered period (2.9 mg/L to 3.1 mg/L).

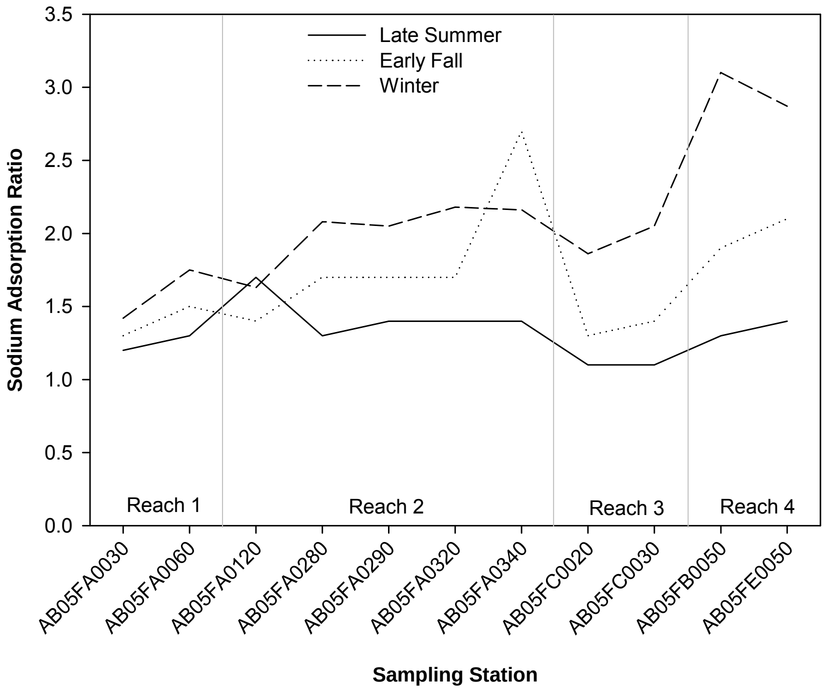

Figure 3-12: Sodium Adsorption Ratios at Sampling Stations Along the Battle River

3.2.4 Nitrogen

This section summarizes nitrogen parameters (TN, TKN, total ammonia, nitrate+nitrite, dissolved nitrate, and dissolved nitrite) by reach and season. TN is a measure of all forms of nitrogen in a water sample (i.e., dissolved and particulate, organic and inorganic). TKN is a measure of organic nitrogen and ammonia, and TN is the sum of TKN plus nitrate and nitrite. In some samples, TKN was equivalent to TN; thus, nitrate and nitrite contributed relatively little to TN in those samples.

3.2.4.1 Total Nitrogen

There was a distinct spatial trend for TN and TKN, but the seasonal trend as less distinct (Figures 3-13 and 3-14). TN, and TKN, were lowest in Reach 1, highest in reaches 2 and 3, and slightly lower in Reach 4.

During the open-water sampling events, TKN was the only nitrogen parameter detected in Reach 1. Concentrations of TN were less than the 90th percentile WQO in Reach 1 in both open-water and under-ice conditions. September and October concentrations were similar in Reach 1. All concentrations were above the generic guideline for TN.

TN was less than the 90th percentile WQO in all samples from Reach 2, but was above the objective guideline in all samples. In the upper parts of Reach 2, September concentrations were higher than October concentrations; whereas, in the lower pats of Reach 2, October concentrations were higher than September concentrations.

TN concentrations in Reach 3 were above the guideline in all three months, were similar to concentrations in Reach 2, and were higher than concentrations in Reach 4. In Reach 3, concentrations were highest during the October sampling event. In Reach 4, concentrations of TN were generally lower than in Reach 3, but values were still above the guideline and all concentrations were above the 50th percentile objective.

Overall, TN concentrations were highest in Reach 2, and were generally similar at stations regardless of sampling event (Figure 3-13). The highest TN, 3.7 mg/L, was recorded in October at station AB05FA0340 (Reach 2). In September, the highest TN concentrations were recorded downstream of Ponoka; in October, highest TN was recorded downstream of Camrose; and in January, highest TN was recorded in Reach 2 between downstream of Wetaskiwin to downstream of Camrose.

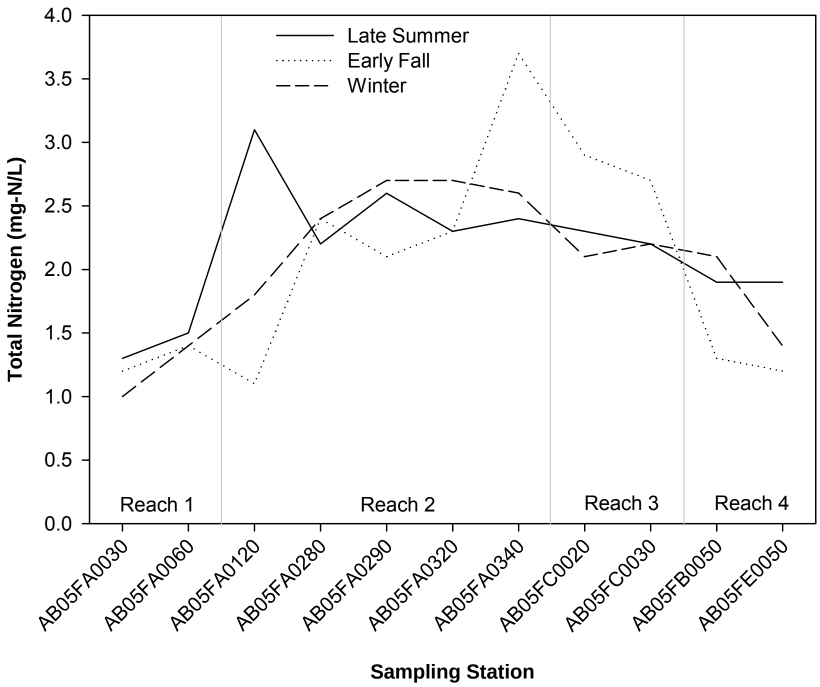

Figure 3-13: Total Nitrogen (mg-N/L) at Sampling Stations Along the Battle River

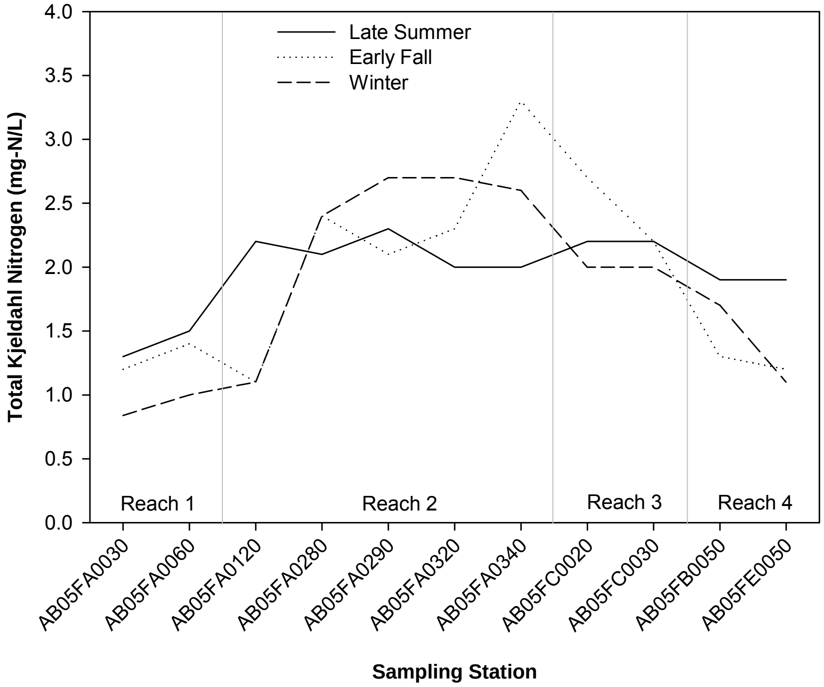

Figure 3-14: Total Kjeldahl Nitrogen (mg-N/L) at Sampling Stations Along the Battle River

3.2.4.2 Ammonia

There were clear spatial and temporal trends in ammonia concentration (Figure 3-6). TN, TKN and total ammonia concentrations generally increased throughout most of Reach 2. Ammonia was highest in Reach 2 in the winter, was only detected in Reach 3 in the fall (i.e., during municipal wastewater discharge), and was only detected in reaches 1 and 4 in the winter (Figure 3-15). When ammonia was detected, it was less than the 90^{th} percentile WQO in reaches 1, 2, and 4. In Reach 3, ammonia was higher than concentrations in reaches 2 and 4 in the open-water period, and below concentrations in reaches 2 and 4 in the ice-covered period.

In September, ammonia was highest downstream of Ponoka and concentrations were higher those in October in Reach 1 and the upper half of Reach 2; in October, ammonia was highest immediately downstream of Camrose and concentrations were higher than those in September in the lower half of Reach 2 and Reach 3; and in January, ammonia was highest upstream of Camrose.

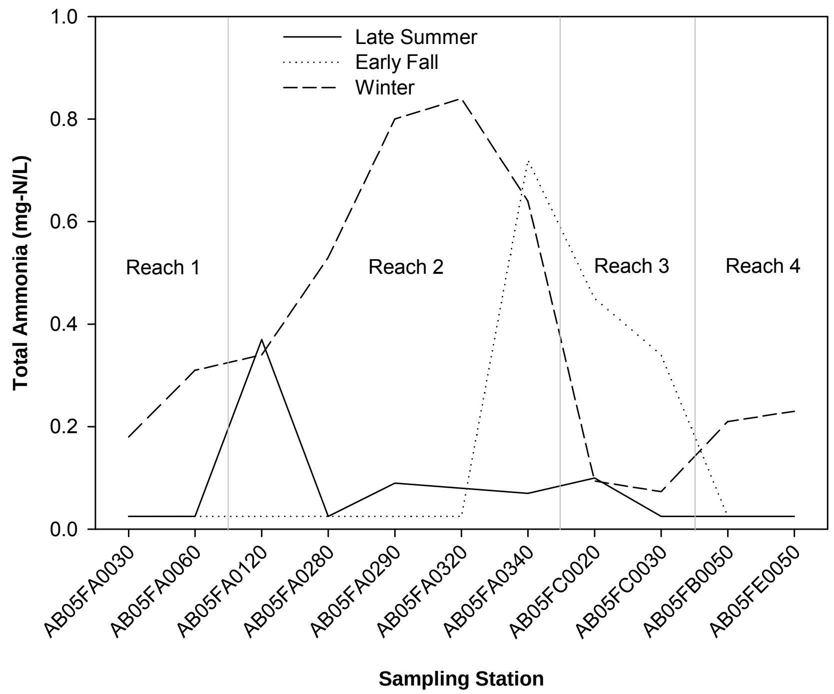

Figure 3-15: Total Ammonia (mg-N/L) at Sampling Stations Along the Battle River

3.2.4.3 Nitrate and Nitrite

Detectable concentrations of nitrate and nitrite also varied spatially and temporally (Figures 3-16, 3-17, and 3-18). Nitrite was detected less frequently than nitrate, and was highest in Reach 2.

During open-water conditions, nitrite was detected in reaches 2 and 3 (Figure 3-17). In Reach 2, nitrite was detected in five samples in September (AB05FA0120, AB05FA0280, AB05FA0290, AB05FA0320 and AB05FA0340) and in one sample in October (AB05FA0340). Concentrations were above the 90th percentile WQO at station AB05FA0120 in September and station AB05FA0340 in October, and above the 50th percentile at the remaining stations. At AB05FA0340, nitrite concentration in October was above the 90th percentile WQO. During ice-covered conditions, nitrite was only detected in one sample from Reach 2 (AB05FA0280), and at two stations in Reach 4 (AB05FE0050 and AB05FB0050), but all were less than the 90th percentile WQO.

Nitrate was detected more often in the samples, but in Reach 1, it was only detected in under-ice samples 1 (Figure 3-18). It was also not detected in some of the under-ice samples in Reach 2, and was detected at higher concentrations in the winter than in summer or fall in Reach 4.

In Reach 1, nitrate concentrations were above the 90th percentile WQO in the under-ice samples. In Reach 2, during the open-water sampling events, nitrate ranged from below detection (AB05FA0280, AB05FA0290, and AB05FA0320 in October) to 0.66 mg/L (AB05FA120). Detectable nitrate concentration was above the 90th percentile WQO at station AB05FA0120 in September and January.

In Reach 3, nitrate concentrations ranged from 0.037 mg/L to 0.40 mg/L in the open-water conditions, and 0.056 mg/L to 0.22 mg/L in the ice-covered conditions. Concentrations were within the range of the majority of the concentration in Reach 2, but greater than the concentrations in Reach 4. These concentrations peaked at the last station in Reach 3 (upstream of Hardisty).

In Reach 4, nitrate was detectable in only one open-water sample (AB05FB0050, October), and in both samples from January. In Reach 4, nitrate in open-water conditions was less than in Reach 3, but during ice-covered conditions, nitrate in Reach 4 was higher than in Reach 3, and on average, higher than in Reach 2, but concentrations were less than the 90th percentile WQO.

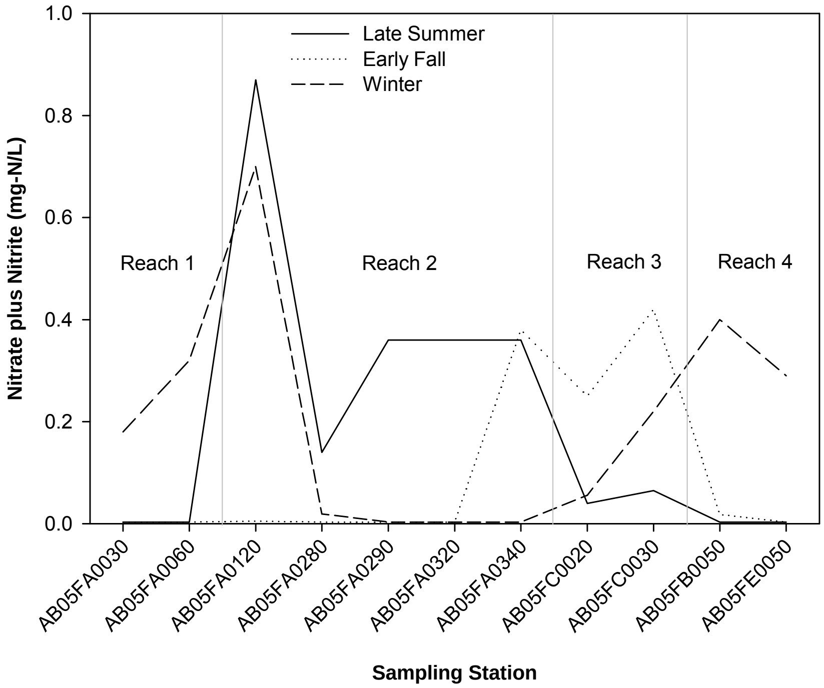

Figure 3-16: Nitrate plus Nitrite (mg-N/L) at Sampling Stations Along the Battle River

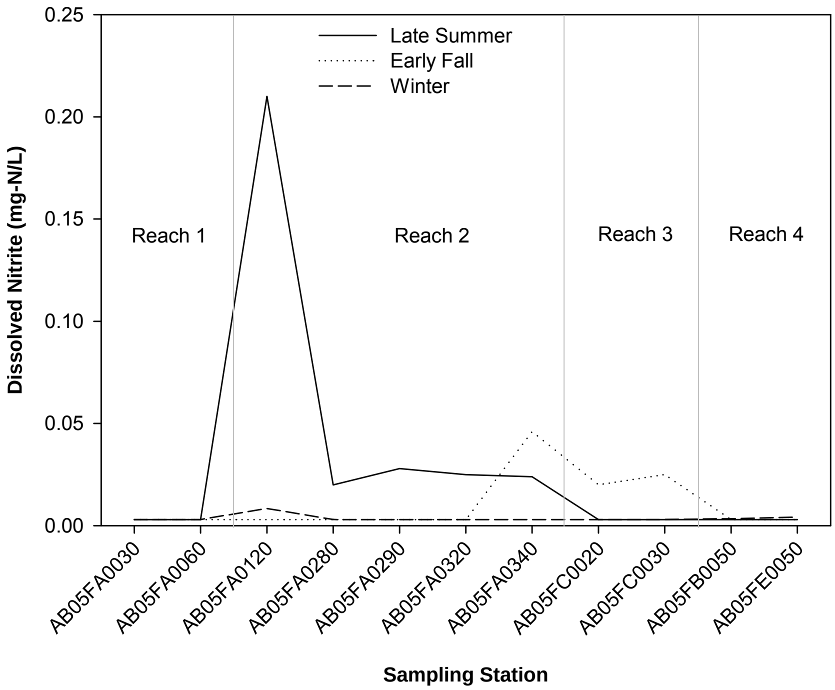

Figure 3-17: Dissolved Nitrite (mg-N/L) at Sampling Stations Along the Battle River

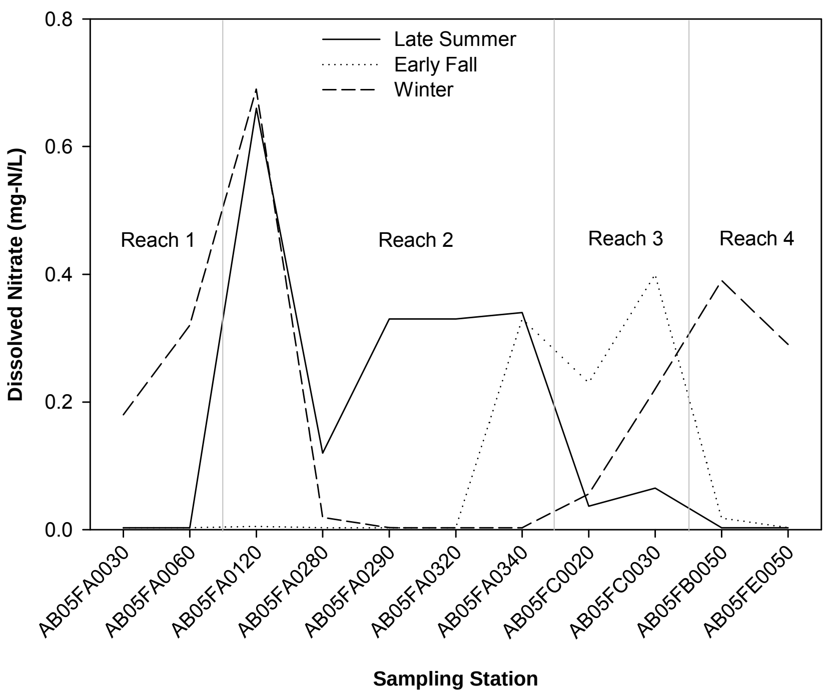

Figure 3-18: Dissolved Nitrate (mg-N/L) at Sampling Stations Along the Battle River

3.2.5 Phosphorus

This section summarizes phosphorus parameters (TP and DP) by reach and season. TP concentration varied both spatially and seasonally (Figure 3-19), with the highest seasonal variability in Reach 2 and the lowest in Reach 1.

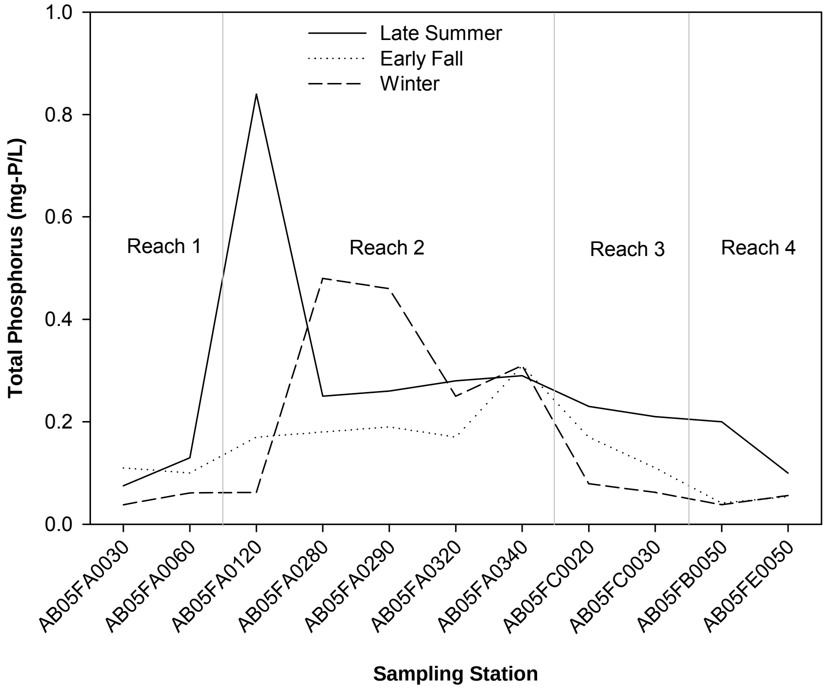

Figure 3-19: Total Phosphorus (mg-P/L) at Sampling Stations Along the Battle River

During the open-water season, TP concentrations ranged from 0.075 mg/L to 0.13 mg/L in Reach 1, from 0.17 mg/L to 0.84 mg/L in Reach 2, from 0.11 mg/L to 0.23 mg/L in Reach 3, and from 0.041 mg/L to 0.2 mg/L in Reach 4. The highest under-ice TP concentrations in each reach were 0.061 mg/L (AB05FA0060, Reach 1), 0.48 mg/L (AB05FA0280, Reach 2 upstream of Wetaskiwin), 0.23 mg/L (AB05FC0020, Reach 3), and 0.2 mg/L (AB05FB0050, Reach 4 downstream of Wainwright). TP in the under-ice samples was generally lower than in the open-water samples, except at some stations in Reach 2 where concentrations in January were higher than those in either September or October. TP concentrations were less than the 90th percentile WQO in all samples except for one (AB05FA0120, September). Concentrations in Reach 3 were above the generic objective guideline.

The proportion of phosphorus in the dissolved fraction varied between samples, but generally, DP represented approximately 40% of TP. DP was higher in September as compared to October and January, and was highest in Reach 2 (Figure 3-20). The concentration of DP was above the 90th percentile objective in Reach 2 (AB05FA0120) and Reach 4 (both stations) in September. All other concentrations of DP were less than the 90th percentile WQO.

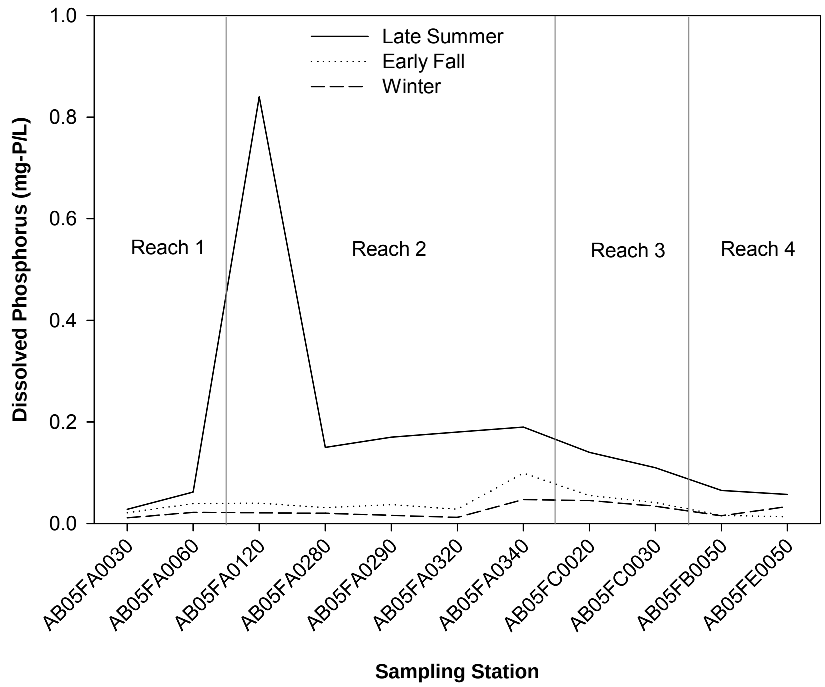

Figure 3-20: Dissolved Phosphorus (mg/L) at Sampling Stations Along the Battle River

3.2.6 Carbon

This section summarizes variation in TOC by reach and by season.

During the open-water sampling events in Reach 1, TOC ranged from 16 mg/L to 19 mg/L, and from 8.9 mg/L to 11 mg/L in the ice-covered period (Figure 3-21). All concentrations were less than the 90th percentile WQO.

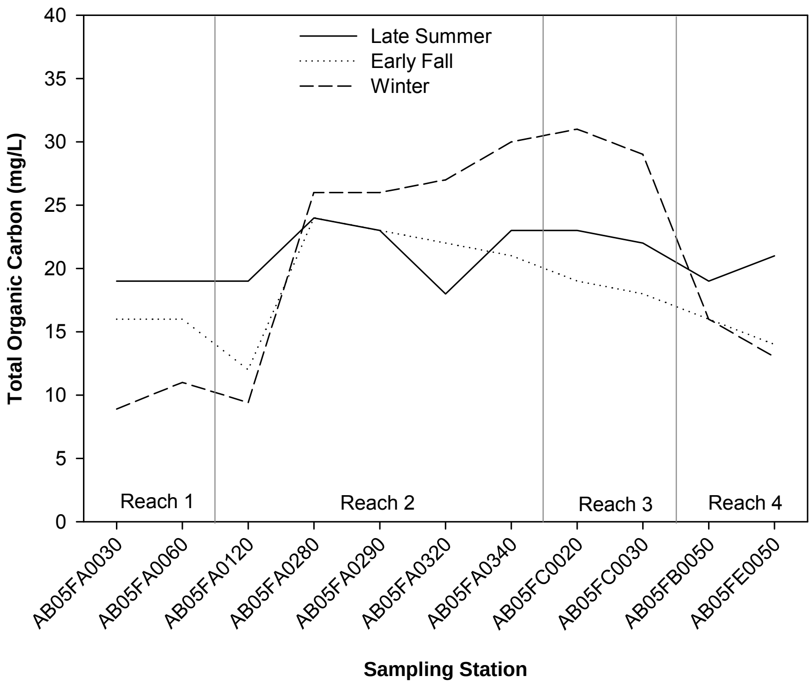

Figure 3-21: Total Organic Carbon(mg/L) at Sampling Stations Along the Battle River

In Reach 2, during the open-water sampling events, TOC concentrations ranged from 12 mg/L to 24 mg/L (AB05FA0280). TOC was above the 90th percentile WQO at one station (AB05FA0280) in both September and October. In both September and October, TOC concentrations were highest downstream of Ponoka.

During the under-ice sampling event in Reach 2, TOC ranged from 9.4 mg/L to 30 mg/L, but all concentrations were less than the 90th percentile WQO. During the winter, TOC concentrations were highest downstream of Ponoka, and continued to increase into Reach 3.

In Reach 3, TOC concentrations ranged from 18 mg/L to 23 mg/L during open-water conditions, and 29 mg/L to 31 mg/L during ice-cover conditions. TOC concentrations during open-water conditions were within the range of concentrations in Reach 2, but above some of the concentrations in Reach 4, while TOC concentrations during ice-covered conditions were higher than the majority of concentrations in reaches 2 and 4.

TOC ranged from 14 mg/L to 21 mg/L in open-water conditions, and 13 mg/L to 16 mg/L in ice-covered conditions in Reach 4. All concentrations were less than the 90th percentile WQO. TOC was generally lower in Reach 4 as compared to Reach 3.

3.3 In-stream Load Estimates

3.3.1 Inorganics

There was a distinct seasonal trend in in-stream TSS load, but a less distinct spatial trend except during the late summer (September) sampling event (Figure 3-22). During all three sampling events, TSS load was similar in Reach 1 (range: 83 kg/d to 226 kg/d). In late summer, load increased substantially in Reach 2 and was highest downstream of Wetaskiwin (station AB05FA0290), and continued to decrease throughout the remainder of Reach 2. Station AB05FA0340 is upstream of Driedmeat Lake, so it is possible that the lake slowed water flows and allowed for settling of particles. In addition, TSS concentrations in Reach 2 were lowest at the downstream station compared to the upper four stations. TSS load increased throughout reaches 3 and 4 to maximum load downstream of Wainwright. In early fall, TSS load was higher in Reach 2 than Reach 1, with the highest load value immediately downstream of Wetaskiwin. In October the load increased again in Reach 3 at station AB05FC0020, downstream of Camrose, and then decreased gradually throughout reaches 3 and 4. Winter load was very low, with the highest value immediately downstream of Camrose.

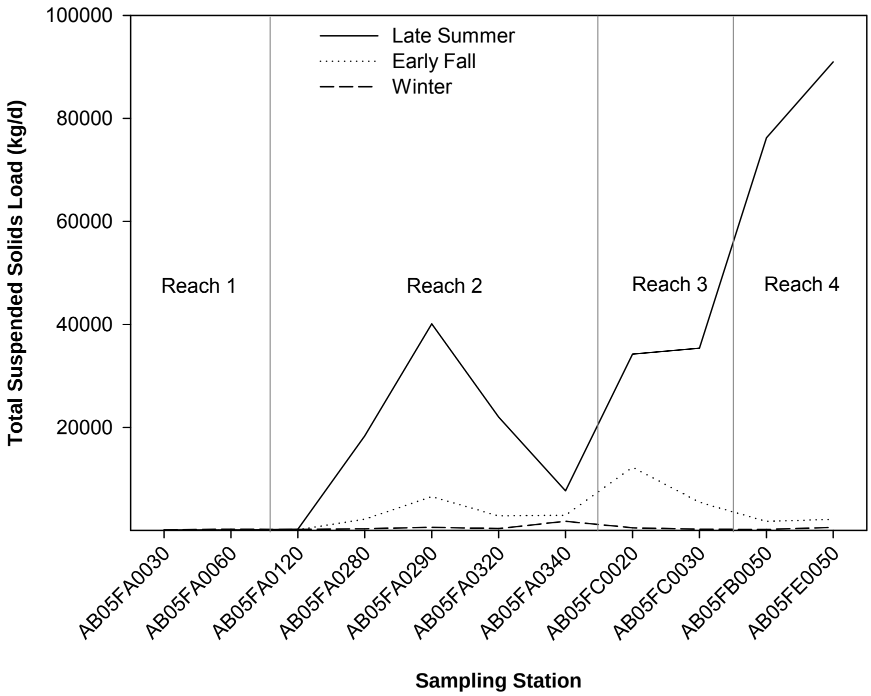

Figure 3-22: Total Suspended Solids Load (kg/d) at Sampling Stations Along the Battle River

In-stream TDS load increased in a downstream direction, but the estimated load was highest in September (Figure 3-23). In September, there was also a large increase in load from Reach 1 to Reach 2, and continued increasing load through Reaches 3 and 4. The increase in in-stream load was very gradual in October and January, with noticeable peaks downstream of Camrose.

The in-stream load for hardness was very similar to the in-stream load for TDS (Figure 3-24) with higher loads in September than in October and January, and peaks downstream of Camrose in October and January.

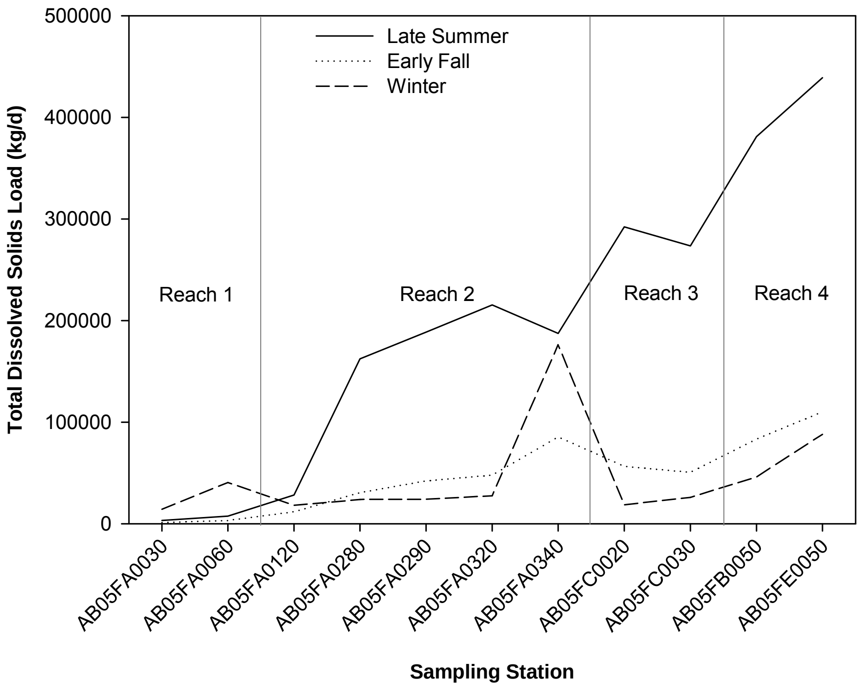

Figure 3-23: Total Dissolved Solids Load (kg/d) at Sampling Stations Along the Battle River

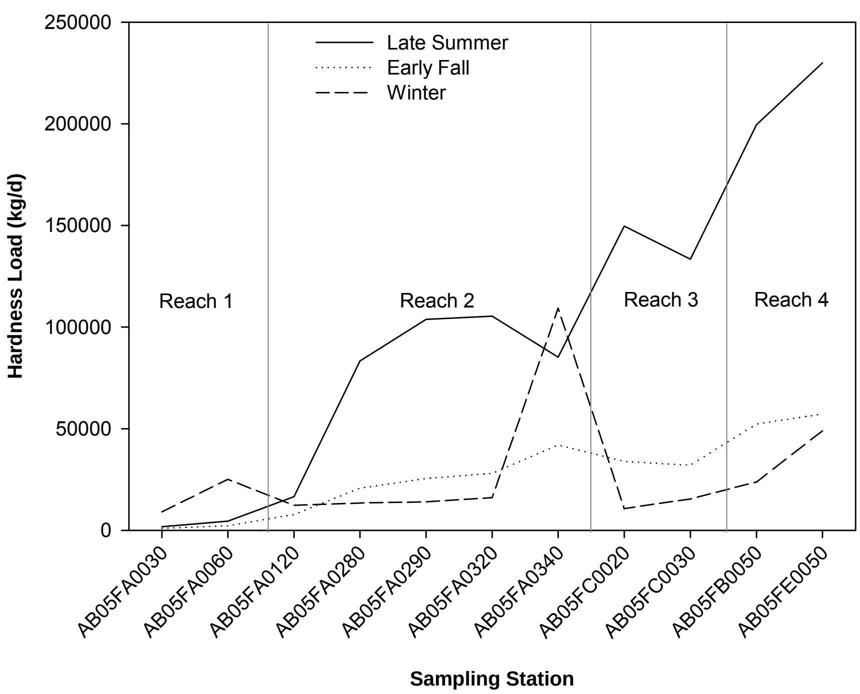

Figure 3-24: Total Hardness Load as $CaCO_3$ (kg/d) at Sampling Stations Along the Battle River

3.3.2 Major Ions

The in-stream load for calcium (Figure 3-25), sulphate (Figure 3-26), were similar to the load for hardness, and the in-stream load for chloride (Figure 3-27) and fluoride (Figure 3-28) were similar to the load for TDS. For all of these major ions, in-stream load was highest in September. In September, the in-stream load was much higher in Reach 2 than in Reach 1, and continued to increase throughout the river. The increase in load in a downstream direction was not as distinct in October and January.

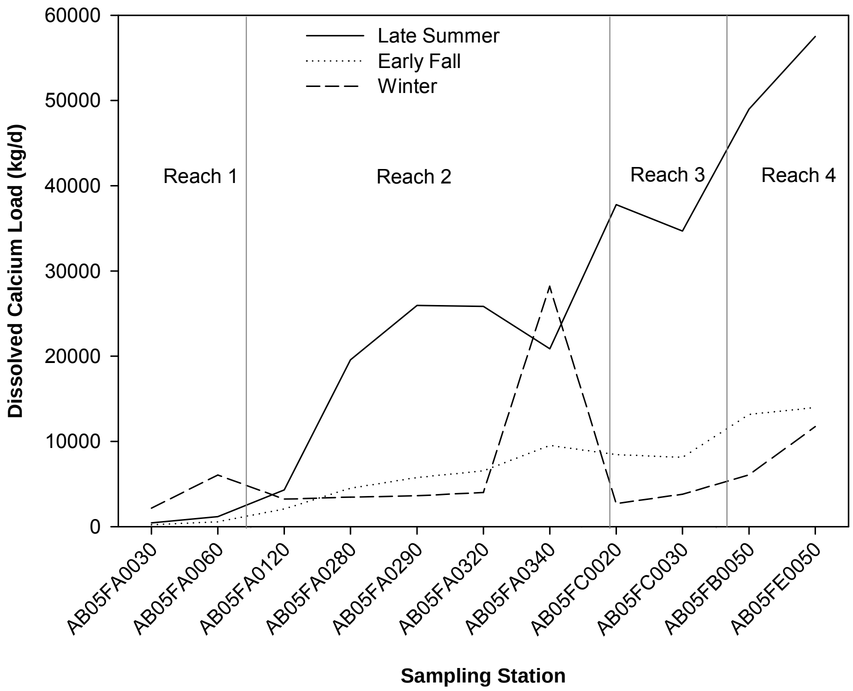

Figure 3-25: Dissolved Calcium Load (kg/d) at Sampling Stations Along the Battle River

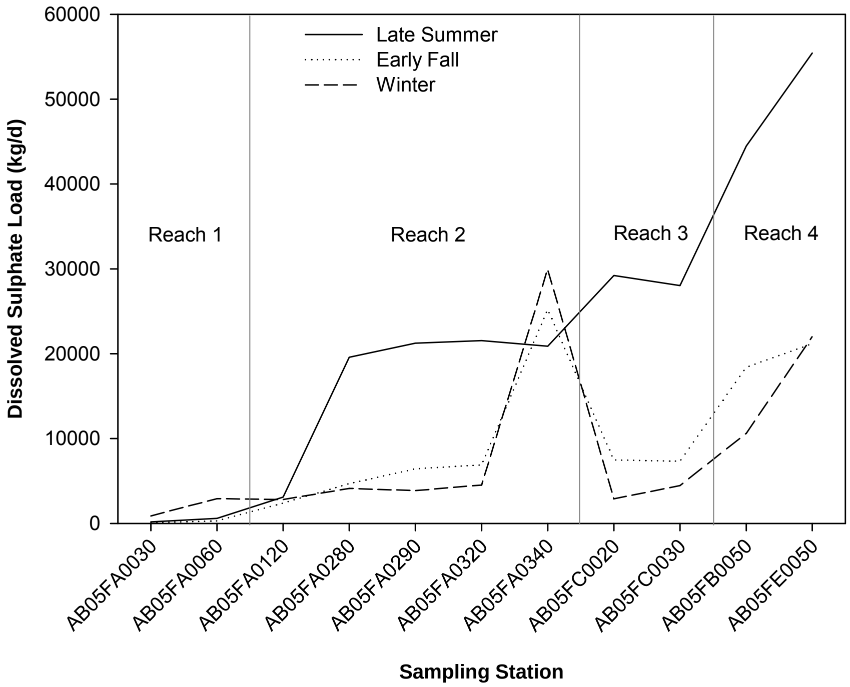

Figure 3-26: Dissolved Sulphate Load (kg/d) at Sampling Stations Along the Battle River

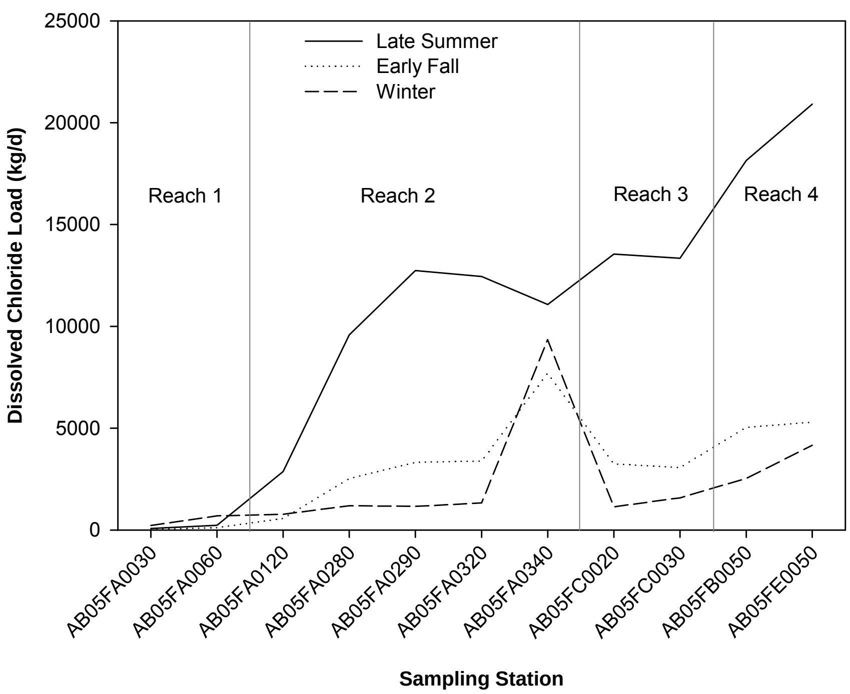

Figure 3-27: Dissolved Chloride Load (kg/d) at Sampling Stations Along the Battle River

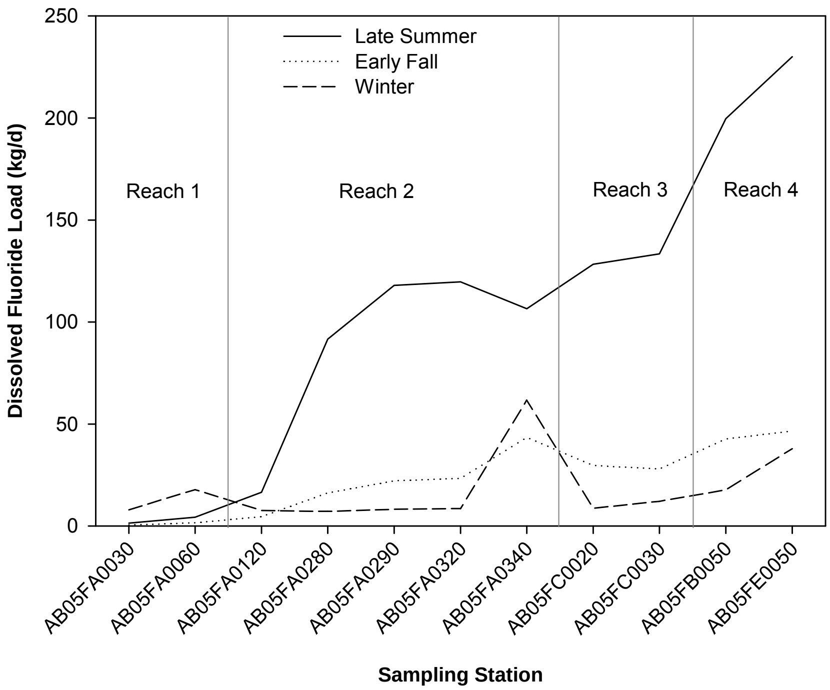

Figure 3-28: Dissolved Fluoride Load (kg/d) at Sampling Stations Along the Battle River

3.3.3 Nitrogen

Similar to TSS load, there was a distinct seasonal trend in in-stream TN load, but a less distinct spatial trend (Figure 3-29). During all three sampling events, TN load was similar in Reach 1. In late summer, the load increased drastically in Reach 2 and was highest downstream of Wetaskiwin (station AB05FA0290). TN load in Reach 3 was higher than in Reach 2, and was highest downstream of Camrose at station AB05FC0020. In Reach 4, TN load continued to increase with the highest value in the Battle River measured immediately downstream of Wainwright (station AB05FE0050). In early fall, TN load increased gradually in Reach 2 and peaked immediately downstream of Camrose (station AB05FA0340). The load decreased gradually in reaches 3 and 4. Winter load was similar to that in early fall; however, the peak immediately downstream of Camrose was more pronounced.

In-stream load estimates for TKN were similar to TN (Figure 3-30) indicating that most of the in-stream load was organic nitrogen, rather than inorganic nitrogen.

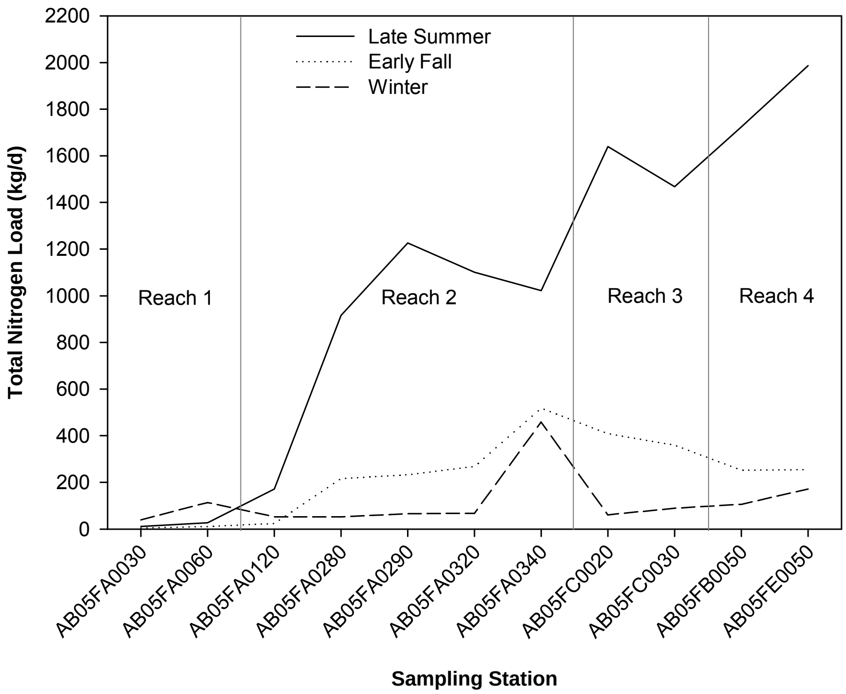

Figure 3-29: Total Nitrogen Load (kg/d) at Sampling Stations Along the Battle River

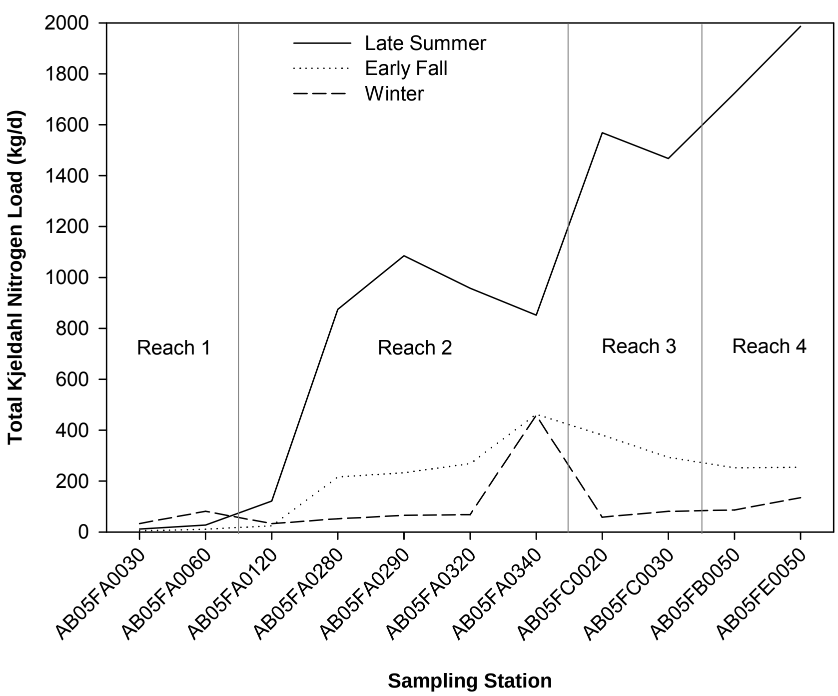

Figure 3-30: Total Kjeldahl Nitrogen Load (kg/d) at Sampling Stations Along the Battle River

In-stream total ammonia load trends were not as distinct as those in TP and TN (Figure 3-31). In late summer, the spatial trend in total ammonia load was similar to those in TP and TN loads, though the increases were not as pronounced. In late summer, peak ammonia load was in Reach 3, two stations downstream of Camrose (AB05FC0020); in early fall and winter, peak ammonia load was in Reach 2, immediately downstream of Camrose (AB05FA0340).

In late summer, the total ammonia load was low in Reach 1, and increased through reaches 2 and 3, peaking downstream of Camrose. The load decreased at the last station in Reach 3, but increased in Reach 4. In early fall, total ammonia load was low in Reach 1 and the majority of Reach 2, and peaked downstream of Camrose. Load decreased gradually throughout Reach 3 to low levels in Reach 4. Finally, in winter, total ammonia load increased through Reach 1 and was higher near the lower end of Reach 1 compared to the upper end of Reach 2. Through Reach 2, total ammonia load increased gradually until downstream of Camrose, where it increased sharply. Downstream of Camrose, ammonia load was very low in Reach 3 and gradually increased through Reach 4.

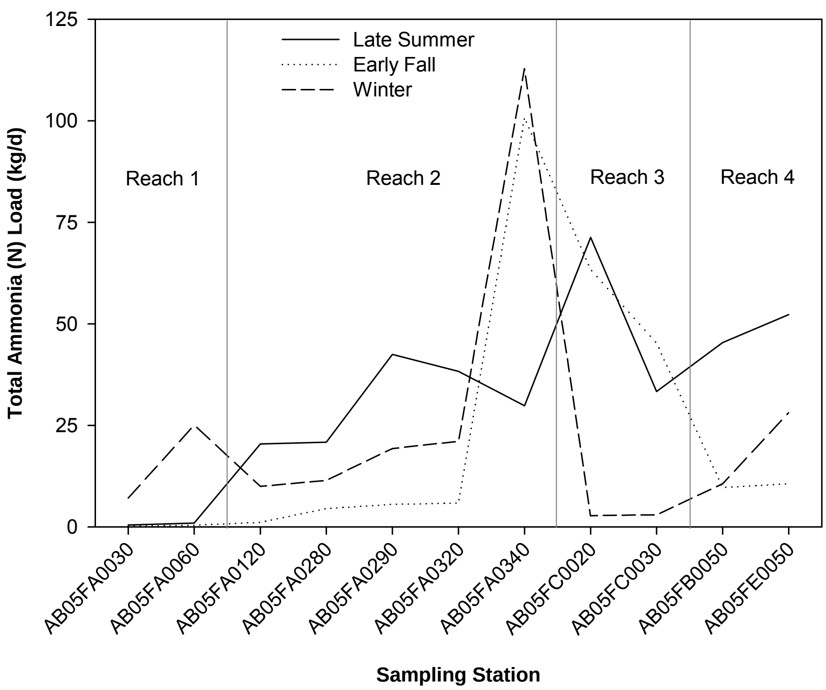

Figure 3-31: Total Ammonia Load (kg/d) at Sampling Stations Along the Battle River

The figures of inorganic nitrogen in-load estimates (Figures 3-32, 3-33, and 3-34) clearly show that the in-stream load of nitrate and nitrite was highest in September, and in Reach 2. This trend is in contrast to those observed for other parameters, where in-stream load increases in a downstream direction. For nitrate and nitrite, in-stream load did not increase in a downstream direction, indicating potential assimilation or denitrification of nitrogen in Reaches 3 and 4.

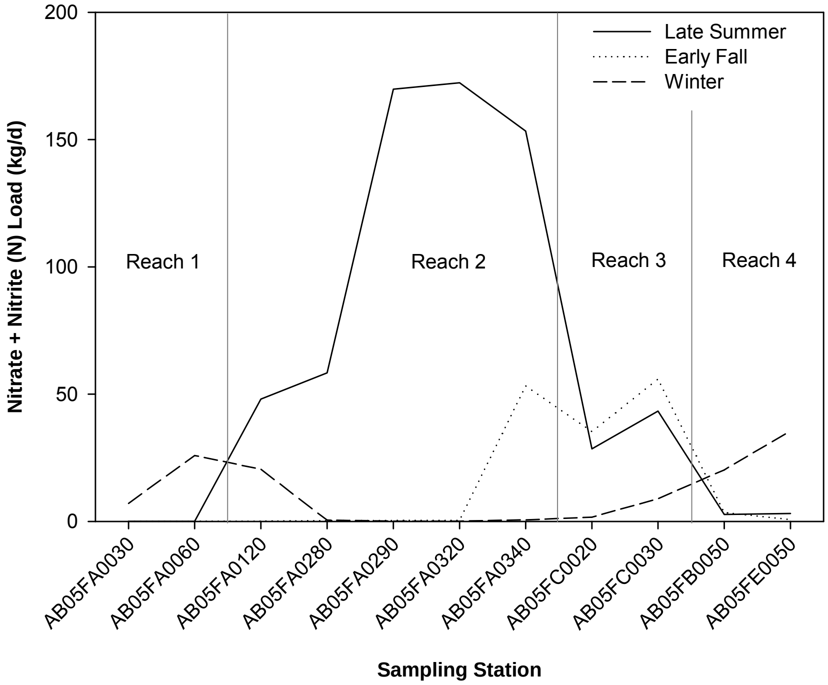

Figure 3-32: Nitrate + Nitrite (N) Load (kg/d) at Sampling Stations Along the Battle River

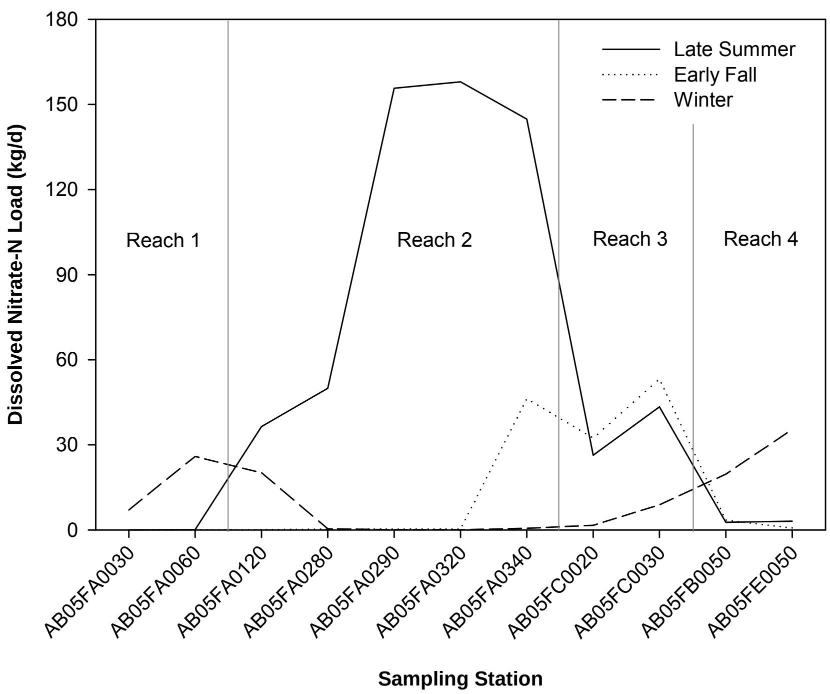

Figure 3-33: Dissolved Nitrate-N Load (kg/d) at Sampling Stations Along the Battle River

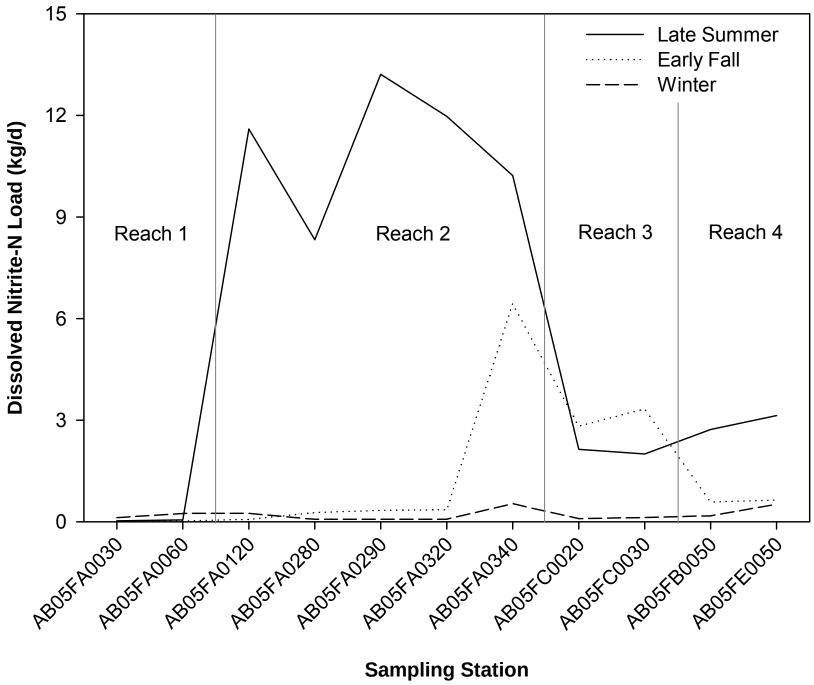

Figure 3-34: Dissolved Nitrite-N Load (kg/d) at Sampling Stations Along the Battle River

3.3.4 Phosphorus

In-stream TP load was similar to TN load; there was a distinct seasonal trend in TP load, but a less distinct spatial trend during early winter and fall (Figure 3-35). During all three sampling events, TP load was generally similar in Reach 1. In late summer, load increased substantially in Reach 2, and was highest at the station downstream of Wetaskiwin (AB05FA0290). TP load in Reach 3 was higher than in Reach 2, with the highest estimated load downstream of Camrose (station AB05FC0020). In Reach 4, TP load continued to increase with the highest value measured downstream of Hardisty (station AB05FB0050), followed by a decline. Load of TP was similar in early fall and winter. During both of these sampling periods, TP load increased gradually in Reach 2, peaked downstream of Camrose, and then decreased gradually in reaches 3 and 4. Downstream of Camrose, the peak was more pronounced during winter than in fall.

The in-stream load estimate for TDP (Figure 3-36) was similar to TP except that the peaks downstream of Camrose were less distinct, and there was a distinct decrease in load from Reach 3 through Reach 4.

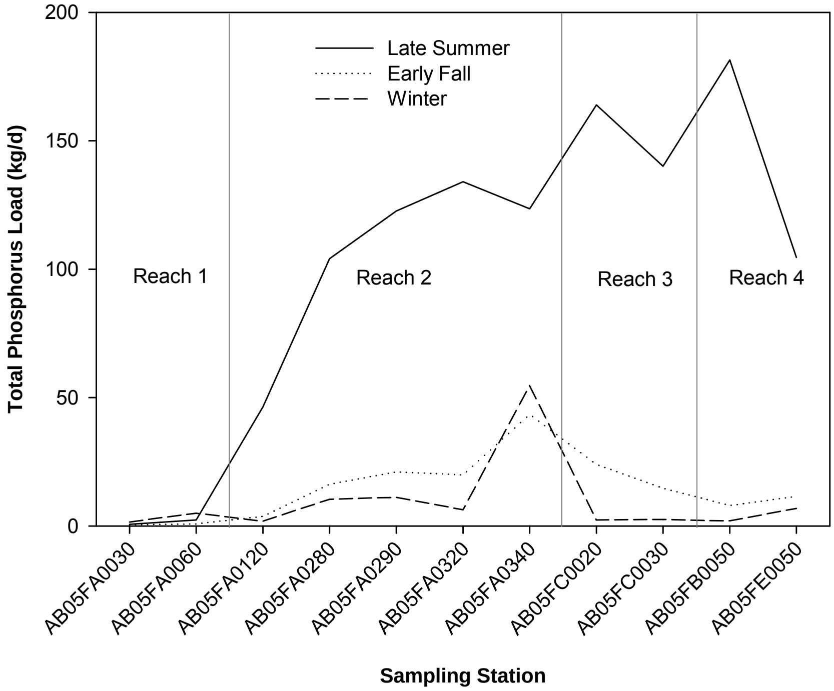

Figure 3-35: Total Phosphorus Load (kg/d) at Sampling Stations Along the Battle River

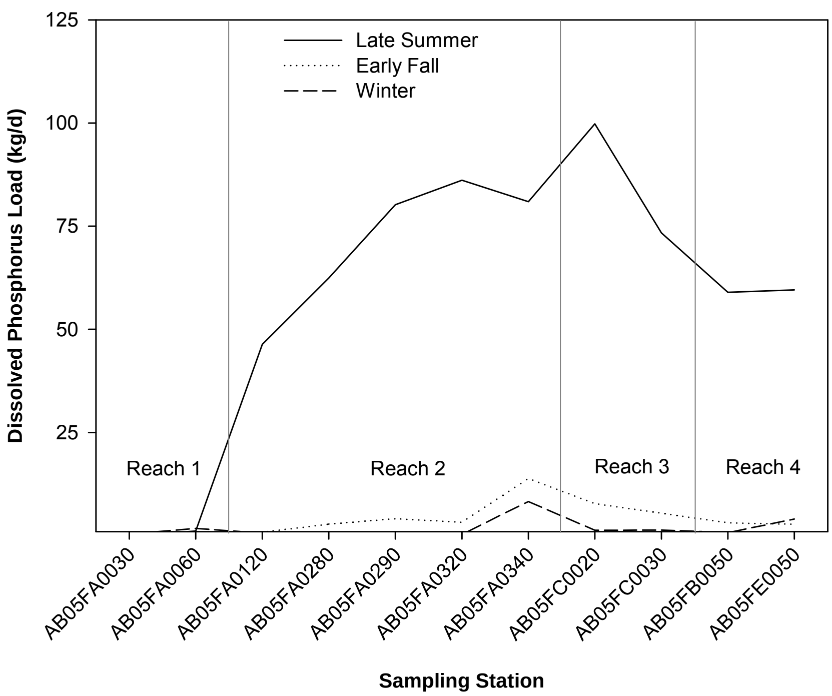

Figure 3-36: Dissolved Phosphorus Load (kg/d) at Sampling Stations Along the Battle River

3.3.5 Carbon

In-stream load for carbon (Figure 3-37) was similar to in-stream load for TN. Loads were highest in September, when there was a large increase in load from Reach 1 through Reach 4. In October, there was also an increase in load from Reach 1 to Reach 2, but loads remained similar from Reach 2 through Reach 4. In January, loads were lowest, and overall there was very little change in load, except for a peak downstream of Camrose.

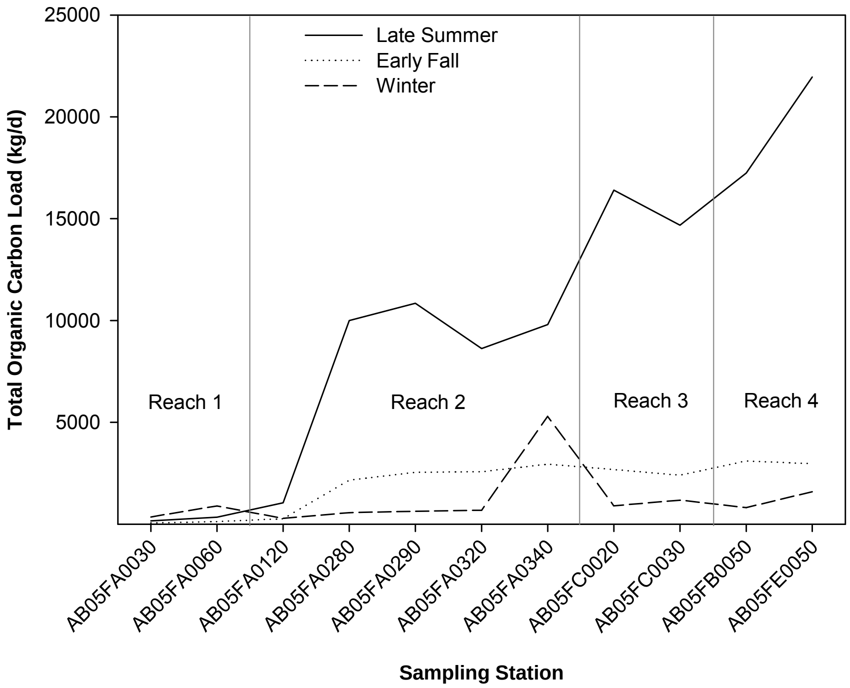

Figure 3-37: Total Organic Carbon Load (kg/d) at Sampling Stations Along the Battle River

4.0 CONCLUSIONS

Water quality data collected in the Battle River during open-water and ice-covered season sampling events in 2011/2012 were reviewed for spatial and temporal trends. In general, some parameters (e.g., TDS, hardness, and major ions) were higher during the ice-covered season, others (e.g., DO, TSS, and TP) were higher in the open-water season, and some (e.g., TN, ammonia, TOC) had similar ranges in both seasons.

For many parameters, concentrations were lowest in Reach 1, increased substantially in Reach 2, and either remained high in Reach 3, or gradually decreased through reaches 3 and 4. The highest concentrations of many parameters were usually detected downstream of Ponoka or Camrose wastewater discharge locations (either at the last station in Reach 2 or the first station in Reach 3). This suggests that for many of the parameters measured, increases are related to point and non-point source inputs in Reach 2.

Data were compared to reach specific 90th percentile WQO, for the open-water and under-ice periods, in Reaches 1, 2 and 4, and to generic WQO in Reach 3. In September, major ions, nitrogen and phosphorus were generally above WQO in lower Reach 1 and upper Reach 2; TDP was above WQO in Reach 4; fluoride, TN and TP were above generic guidelines in Reach 3. In October, conductivity was above WQO in Reaches 1 and 2, while TDS and major ions were above WQO in Reach 1. In Reach 3, fluoride was above generic guidelines. Nutrients were generally below WQO in October except for nitrite at the end of Reach 2, and TN and TP, as compared to generic guidelines in Reach 3. Finally, in January, nitrate was above WQO in Reach 1 and upper Reach 2, calcium and hardness were above WQO in Reach 2, and TDS, hardness, major ions, and TN were above WQO in Reach 4. In Reach 3 in January, fluoride, TN and TP were above generic guidelines.

In-stream loads for most parameters were lowest in Reach 1, increased substantially in Reach 2, and then continued to increase gradually through Reaches 3 and 4. For most parameters (e.g., TSS, TN, TP), loads were highest in late summer as compared to either fall or winter. Ammonia loads were an exception, and had more varied spatial and seasonal trends. In late summer, ammonia concentration was very low in Reach 1, and generally increased through Reaches 2 through 4, but fluctuated among stations. In early fall and winter, ammonia loads were lower than in late summer, but peaks downstream of Camrose were higher in fall and winter as compared to summer.

The general spatial and seasonal trend in loads of TSS and TDS can be characterized as much higher loads in summer compared to fall and winter, continued increasing loads in Reaches 3 and 4 during summer, compared to Reach 2, where there was either a spike mid-reach (TSS) or an increase in load in the upstream section of the reach followed by sustained loads through the remainder of the reach (TDS). The general spatial and seasonal trend for loading of nutrients in the Battle River is higher loads in late summer than in fall or winter, and highest loads of dissolved nitrogen in Reach 2.

5.0 RECOMMENDATIONS

The main objective of this project was to collect water quality data from the Battle River at representative stations in 4 reaches, over 3 different flow and discharge periods. This program focused on sampling of the mainstem of the river, and did not include sampling from major tributaries and point sources (e.g., municipal discharges). Results from this program have provided updated snapshots of water quality in the Battle River during late summer, early fall and winter. In addition, the early fall sampling program coincided with the municipal wastewater discharge period and provides an update on the effect of seasonal wastewater discharges on water quality in the river. Discharge rates were also estimated at each station during each sampling event, to allow estimation of in-stream loads.

Recommendations for future work include the following:

- Conduct two more sampling events (e.g., spring and early summer) to allow characterization of the full range of seasonal variability for this river;
- Collect samples and estimate discharge rates from major tributaries and municipal wastewater treatment plants during the fall discharge period to quantify point source loads to the river;
- Review existing information on land use in the watershed to identify areas where non-point source loading is highest; and
- Compare historical data to the recently collected data to evaluate changes over time since the last synoptic survey.

6.0 REFERENCES

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Report Signature Page

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APPENDIX A

Discharge

A.1 INTRODUCTION

Discharge was measured at 11 locations along the Battle River during three field programs, in September 2011, October 2011 and January 2012. Measured data were supplemented by concurrent data available from the Water Survey of Canada at four hydrometric stations.

A.2 METHOD

For open water measurements in September and October 2011, depth and velocity were measured at a minimum of 20 equally spaced stations perpendicular to the flow. Velocities were measured using a Swoffer Model 2100 current velocity meter.

For measurements under ice in January 2012, total depth (i.e., depth of flowing water plus ice thickness), ice thickness and velocity were measured at a minimum of 8 equally spaced holes perpendicular to the flow (as such, discharge estimates in January 2012 are less accurate than open water estimates). At several stations, fewer holes were augered when ice was found to extend to the channel bed, to avoid damaging the ice auger. Velocities were measured using a Marsh McBirney Flo-Mate Model 2000 velocity meter. For each measured velocity, a correction factor of 0.92 was applied as required for under ice measurements at a depth of 60% of the effective depth.

When direct flow measurements were not possible, discharges were estimated using available concurrent hydrometric data from the Water Survey of Canada, supplemented by observations.

A.2.1 Survey Locations

Survey Locations and relevant Water Survey of Canada stations are presented in Table A-1 and Figure A-1. Only active Water Survey of Canada stations are included on Figure A2-1. Data from other Water Survey of Canada stations along tributaries of the Battle River were either not available (most of these stations are not equipped with radio telemetry equipment, as advised by Alberta Environment and Water) or not reliable (data with negative values that have not yet been corrected) and could not be included in the analysis.

Table A-1: Survey Locations and Relevant Water Survey of Canada Stations

Survey Location	Water Survey of Canada Station	Approximate Valley Distance from Survey Location (km)	Position Relative to Survey Location	Status	Data Type
AB05FA0030	-	-	-	-	-
AB05FA0060	05FA001	7.7	downstream	Active	Continuous[1]
AB05FA0120	05FA001	9.9	upstream	Active	Continuous[1]
AB05FA0280	05FA023	0	at location	Discontinued	Seasonal
AB05FA0290	05FA021	0	at location	Discontinued	Seasonal
AB05FA0320	05FA011	0	at location	Active	Continuous[1]
AB05FA0340	05FA011	13.6	upstream	Active	Continuous[1]
AB05FC0020	-	-	-	-	-
AB05FC0030	05FC001	0	at location	Active	Seasonal
AB05FB0050	05FC008	50.0	upstream	Active	Seasonal
AB05FE0050	05FE003	0	at location	-	-

1- Although data are recorded all year long, under ice data were not available from Alberta Environment and Water at the time of reporting

- = no data.

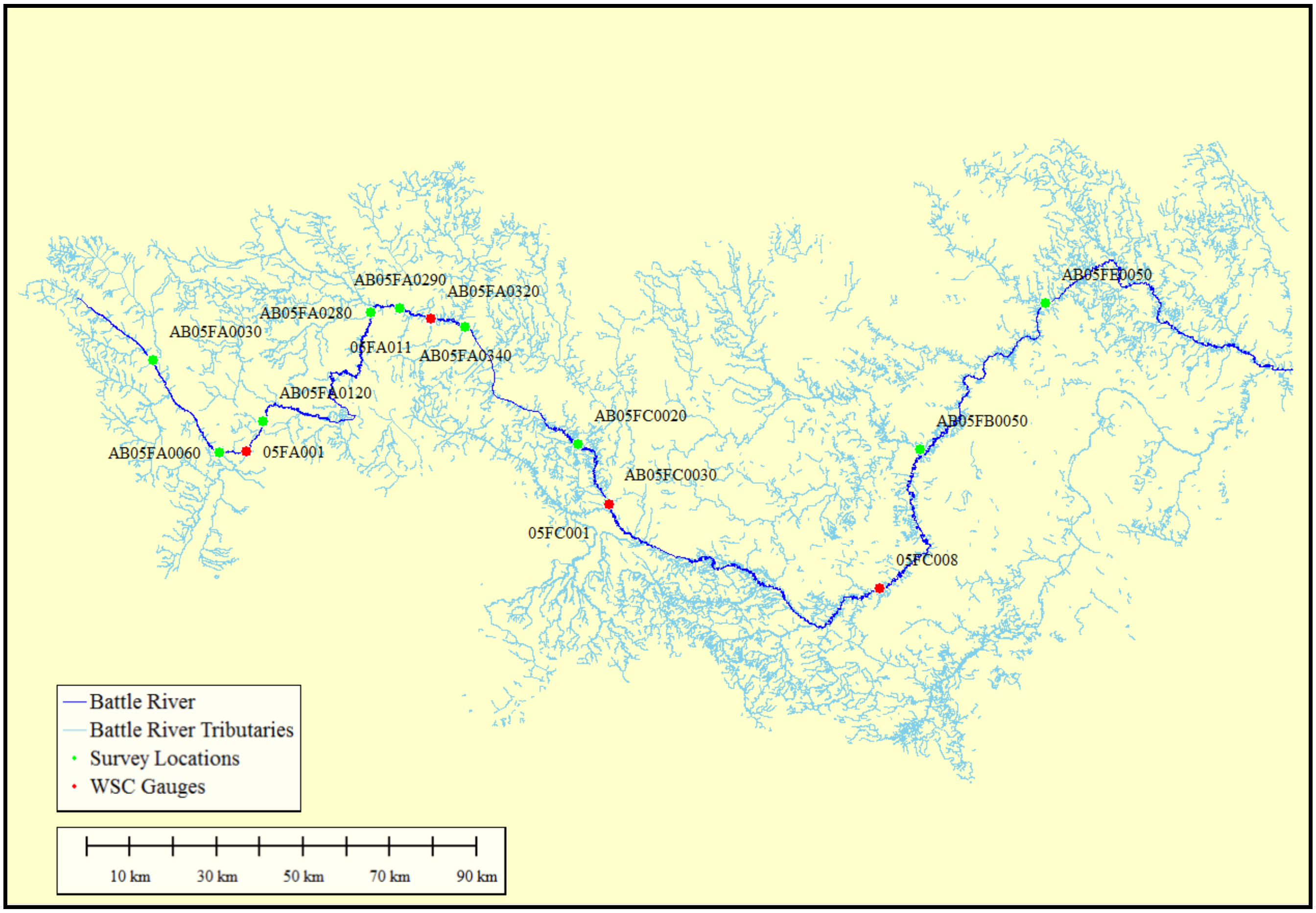


Figure A-1: Survey Locations and Active Water Survey of Canada Stations in the Battle River

A.3 RESULTS

Measured discharges for September 2011, October 2011 and January 2012 are presented in Table A-1 along with locations of storage, such as lakes and reservoirs, that control flow downstream. Measured discharges and concurrent data from the Water Survey of Canada along the Battle River for September 2011, October 2011 and January 2012 are presented in Figure A-2, Figure A-3 and Figure A-4, along with gauged tributaries. Municipalities discharged treated effluent into the Battle River or its major tributaries during the fall. The discharge period coincided with the October field survey. The locations of the municipal effluent discharge are indicated in relation to the monitoring stations (Figure A-3). Additional details on discharge measurements and field observations are provided in Section A3.1.

Table A-1: Measured Discharges along 11 Locations on the Battle River

Survey Location	Effective Drainage Area (km^2)[a]	Trip #1 – September 2011		Trip #2 – October 2011		Trip #3 – January 2012	
		Measured Discharge (m^3/s)	Date	Measured Discharge (m^3/s)	Date	Measured Discharge (m^3/s)	Date
AB05FA0030	-	0.100	6-Sep-11	0.040	17-Oct-11	0.455	23-Jan-12
AB05FA0060	1550	0.208	6-Sep-11	0.086	17-Oct-11	0.936	23-Jan-12
AB05FA0120	1550	0.639	6-Sep-11	0.249	17-Oct-11	0.338	27-Jan-12
Samson Lake							
AB05FA0280	2140	4.82	7-Sep-11	1.04	17-Oct-11	0.250	24-Jan-12
AB05FA0290	3270	5.46	7-Sep-11	1.28	18-Oct-11	0.279	24-Jan-12
AB05FA0320	2920	5.54	7-Sep-11	1.35	18-Oct-11	0.290 [d]	24-Jan-12
AB05FA0340	3510[e]	4.93	8-Sep-11	1.62 [c]	18-Oct-11	2.04	25-Jan-12
Driedmeat Lake							
AB05FC0020	-	8.25	8-Sep-11	1.63	18-Oct-11	0.335	26-Jan-12
AB05FC0030	3620	7.72 [b]	9-Sep-11	1.54	19-Oct-11	0.468	27-Jan-12
Forestburg Reservoir							
AB05FB0050	6010	10.5 [b]	8-Sep-11	2.24	20-Oct-11	0.584	25-Jan-12
AB05FE0050	8230	12.1	9-Sep-11	2.45	19-Oct-11	1.414	26-Jan-12

Notes: a= Effective drainage area from closest representative Water Survey of Canada Station (additional details in Section A3.1).
b= Estimate based on Water Survey of Canada station 05FC008 (additional details in Section A3.1).
c= Estimate based on prorated discharge from Survey Location AB05FA0320. Measurements were not possible with available equipment (additional details in Section A3.1).
d= Estimate based on partial measurements and discharge at survey location AB05FA0290 (additional details in Section A3.1).
e= Estimated from closest representative Water Survey of Canada station and GIS (additional details in Section A3.1).

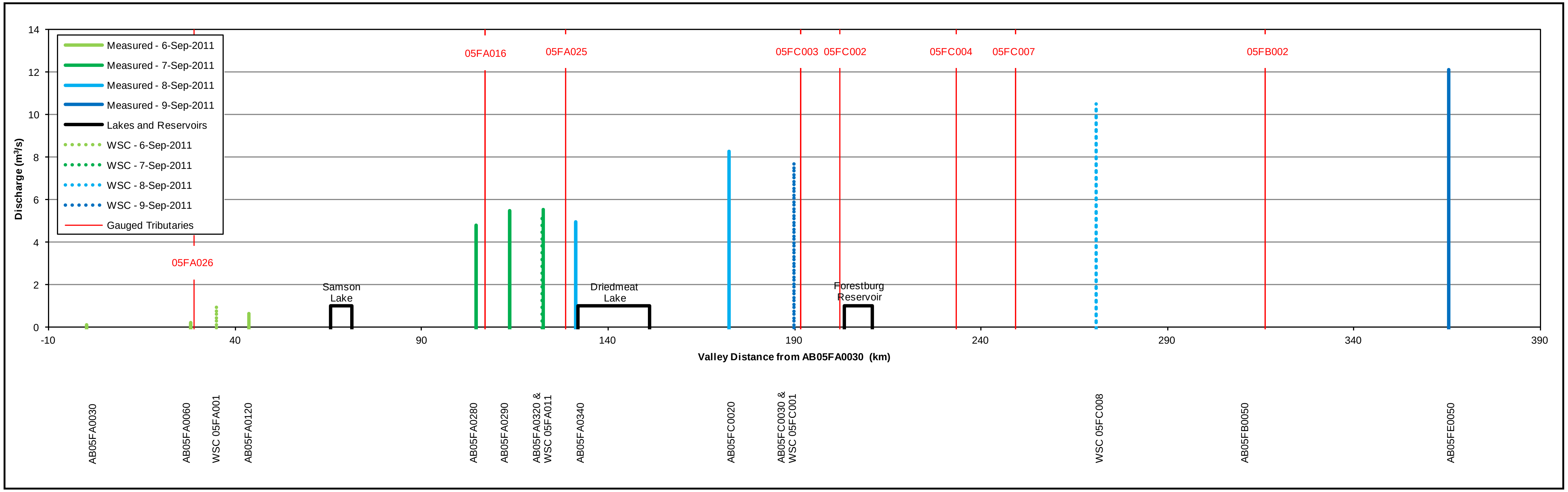


Figure A-2: Measured Discharge and Reported Discharge from the Water Survey of Canada, September 2011

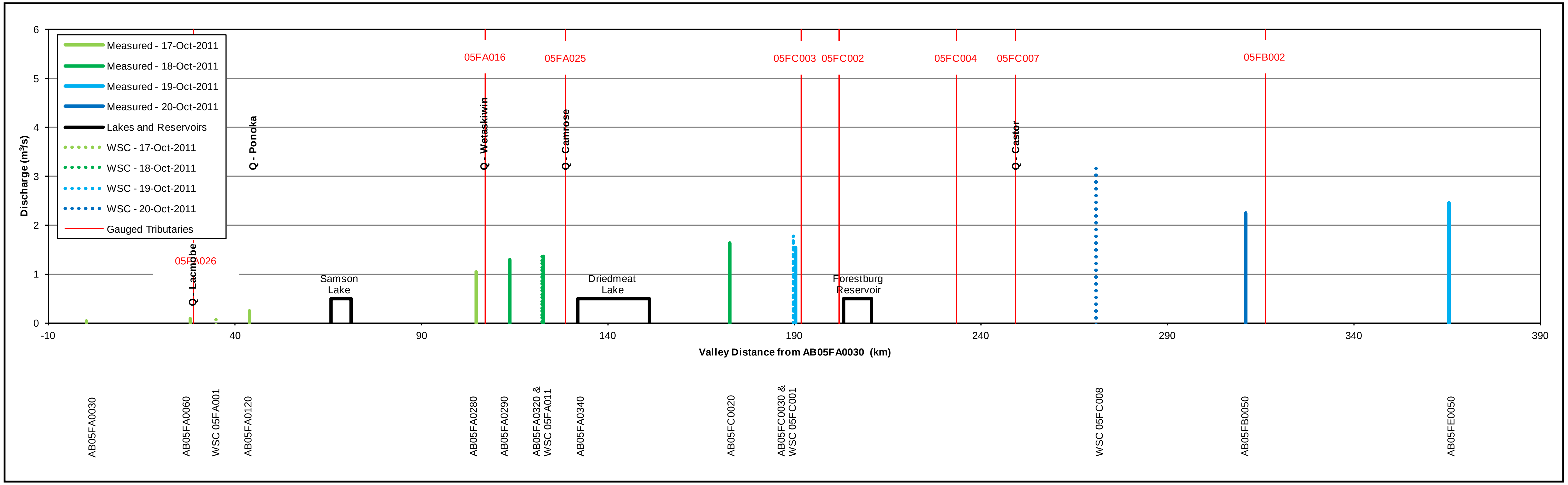


Figure A-3: Measured Discharge and Reported Discharge from the Water Survey of Canada, October 2011

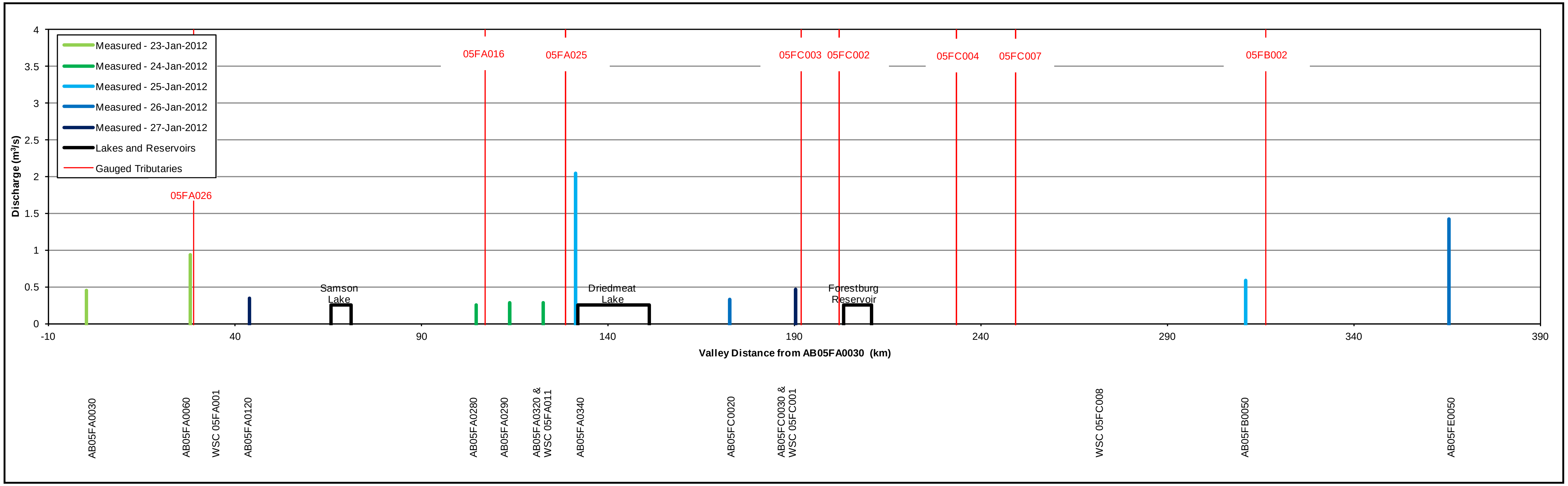


Figure A-4: Measured Discharge and Reported Discharge from the Water Survey of Canada, January 2012

A.3.1 Discharge Measurements and Field Observations by Station

AB05FA0030

Discharges were estimated based on observations in September 2011 and October 2011 because of low velocities that could not be measured using the available equipment. Estimates agree with measured discharges at Survey Location AB05FA0060 (next survey location downstream) with a drainage area of approximately twice the area of Survey Location AB05FA0030. Based on drainage areas and measured discharges in January 2012, discharges at Survey Location AB05FA0030 are expected to be approximately half of the discharges at Survey Location AB05FA0060 downstream. Summaries of discharge measurements and additional information are presented in Tables A-2 and A-3.

Table A-2: Summary of Discharge Measurements

Date	Measured Discharge (m^3/s)	Water Survey of Canada Mean Daily Discharge (m^3/s)	Average Measured Ice Thickness (m)
6-Sep-2011	0.100 [a]	-	-
17-Oct-2011	0.040 [a]	-	-
23-Jan-2012	0.455	-	0.35

Note: a= Estimated.

Table A-3: Information and Observations of Survey Location

Parameters	Value			Comment
ID	AB05FA0030			-
Name	Battle River at Hwy 611; upstream of Muskeg Creek			-
UTM (Easting m, Northing m, Zone)	303746	5858941	12	-
Gross Drainage Area (km^2)	745			Estimated from GIS
Effective Drainage Area (km^2)	-			Not available
Water Survey of Canada Station ID	-			-
Water Survey of Canada Station Location (km)	-			-
Additional Notes	Beaver dam present at survey location. Beaver dams also observed upstream and downstream of survey location. Discharges estimated in September 2011 and October 2011 because of very low velocities.			

6 September 2011 – View Upstream of Survey of Location

6 September 2011 – View Downstream of Survey of Location

AB05FA0060

The measured discharge in September 2011 is much smaller than the mean daily discharge reported by the Water Survey of Canada 7.7 km downstream. A major tributary (Wolf Creek, shown as 05FA026 on Figure A3-1) is located between Survey Location AB05FA0060 and Water Survey of Canada Station 05FA001. As such, flows reported at Station 05FA001 are expected to be greater than at Survey Location AB05FA0060. However, the discharge measured at Survey Location AB05FA0120 (next Survey Location downstream) was also smaller than that reported at Station 05FA001, indicating that reported discharges from Station 05FA001 may have been overestimated. The measured discharge in October 2011 was comparable to that reported by Station 05FA001. Measured discharge in January was greater than that measured at the previous station. Summaries of discharge measurements and additional information are presented in Tables A-4 and A-5.

Table A-4: Summary of Discharge Measurements

Date	Measured Discharge (m^3/s)	Water Survey of Canada Mean Daily Discharge (m^3/s)	Average Measured Ice Thickness (m)
6-Sep-2011	0.208	0.995	-
17-Oct-2011	0.086	0.087	-
23-Jan-2012	0.936	-	0.47

Table A-5: Information and Observations of Survey Location

Parameters	Value			Comment
ID	AB05FA0060			-
Name	Battle River at Highway 53			-
UTM (Easting m, Northing m, Zone)	319073	5837707	12	-
Gross Drainage Area (km^2)	1820			From Water Survey of Canada Station
Effective Drainage Area (km^2)	1550			From Water Survey of Canada Station
Water Survey of Canada Station ID	05FA001			-
Water Survey of Canada Station Location (km)	7.7			Downstream of Survey Location
Additional Notes	Beaver dam noted upstream of surveyed location in September 2011. Beaver dam noted downstream of surveyed location in October 2011.			

6 September 2011 – View Upstream of Survey of Location

6 September 2011 – View Downstream of Survey of Location

AB05FA0120

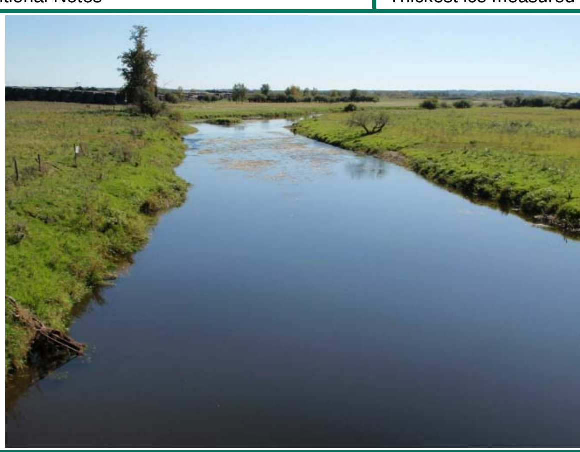
Survey Location AB05FA0120 is located downstream of the Ponoka wastewater outfall, which was discharging effluent during the field program in October 2011. The measured discharge in September 2011 is much smaller than the mean daily discharge reported by the Water Survey of Canada 7.7 km upstream. As noted previously, it is possible that the discharge reported by the Water Survey of Canada in September 2011 may be overestimated. The measured discharge in October 2011 is greater than the mean daily discharge reported by the Water Survey of Canada 10.0 km upstream, as expected from an increase in drainage area, and supplemental flow from the Ponoka wastewater outfall. In January 2012, the discharge was measured four days later than at Survey Locations AB05FA0060 and AB05FA0120 located upstream, and cannot be directly compared. Summaries of discharge measurements and additional information are presented in Tables A-6 and A-7.

Table A-6: Summary of Discharge Measurements

Date	Measured Discharge (m^3/s)	Water Survey of Canada Mean Daily Discharge (m^3/s)	Average Measured Ice Thickness (m)
6-Sep-2011	0.639	0.995	-
17-Oct-2011	0.249	0.087	-
27-Jan-2012	0.338	-	0.70

Table A-7: Information and Observations of Survey Location

Parameters	Value			Comment
ID	AB05FA0120			-
Name	Battle River at Diamond 5; Downstream of Ponoka Wastewater Outfall			-
UTM (Easting m, Northing m, Zone)	329230	5844847	12	-
Gross Drainage Area (km^2)	1820			From Water Survey of Canada Station
Effective Drainage Area (km^2)	1550			From Water Survey of Canada Station
Water Survey of Canada Station ID	05FA001			-
Water Survey of Canada Station Location (km)	10.0			Upstream of Survey Location
Additional Notes	Thickest ice measured in January 2012.			



6 September 2011 – View Upstream of Survey of Location

6 September 2011 – View Downstream of Survey of Location

AB05FA0280

Survey Location AB050280 is located downstream of Samson Lake and cannot be compared to other upstream Survey Locations. All measured discharges agree with discharges measured at nearby Survey Locations AB05FA0290 and AB05FA320 located downstream, and therefore seem plausible. Summaries of discharge measurements and additional information are presented in Tables A-8 and A-9.

Table A-8: Summary of Discharge Measurements

Date	Measured Discharge (m^3/s)	Water Survey of Canada Mean Daily Discharge (m^3/s)	Average Measured Ice Thickness (m)
7-Sep-2011	4.82	-	-
17-Oct-2011	1.04	-	-
24-Jan-2012	0.250	-	0.53

Table A-9: Information and Observations of Survey Location

Parameters	Value			Comment
ID	AB05FA0280			-
Name	Battle River; Upstream about 5 km from Confluence with Pipestone Creek; Township Road 462			-
UTM (Easting m, Northing m, Zone)	354039	5869958	12	-
Gross Drainage Area (km^2)	2800			From Water Survey of Canada Station
Effective Drainage Area (km^2)	2140			From Water Survey of Canada Station
Water Survey of Canada Station ID	05FA023			Discontinued
Water Survey of Canada Station Location (km)	0			At Location
Additional Notes	This station is located downstream of Samson Lake			

7 September 2011 – View Upstream of Survey of Location

7 September 2011 – View Downstream of Survey of Location

AB05FA0290

All measured discharges are plausible. Summaries of discharge measurements and additional information are presented in Tables A-10 and A-11.

Table A-10: Summary of Discharge Measurements

Date	Measured Discharge (m^3/s)	Water Survey of Canada Mean Daily Discharge (m^3/s)	Average Measured Ice Thickness (m)
7-Sep-2011	5.46	-	-
18-Oct-2011	1.28	-	-
24-Jan-2012	0.279	-	0.46

Table A-11: Information and Observations of Survey Location

Parameters	Value	Comment
ID	AB05FA0290	-
Name	Battle River Downstream of Confluence with Pipestone Creek; Township Road 462A	-
UTM (Easting m, Northing m, Zone)	360767 5870852 12	-
Gross Drainage Area (km^2)	4870	From Water Survey of Canada Station
Effective Drainage Area (km^2)	3270	From Water Survey of Canada Station
Water Survey of Canada Station ID	05FA021	Discontinued
Water Survey of Canada Station Location (km)	0	At Location
Additional Notes	Recently installed riprap and silt fences were noted under the bridge. Effective Drainage Area of 05FA021 is reported as greater than that of 05FA011, which appears incorrect.	

7 September 2011 – View Upstream of Survey of Location

7 September 2011 – View Downstream of Survey of Location

AB05FA0320

Discharges measured in September and October 2011 agree with reported discharges from the Water Survey of Canada Station 05FA011 at the same location. Discharge could only be partially measured in January 2012 because of shallow depth of free water in several holes limiting readings. The estimated discharge was therefore based on partial measurements and the ratio of discharges measured in September 2011 and October 2011 at this location and at the previous location AB05FA0290 (ratios of 1.05 and 1.01 were averaged). Summaries of discharge measurements and additional information are presented in Tables A-12 and A-13.

Table A-12: Summary of Discharge Measurements

Date	Measured Discharge (m^3/s)	Water Survey of Canada Mean Daily Discharge (m^3/s)	Average Measured Ice Thickness (m)
7-Sep-2011	5.54	5.27	-
18-Oct-2011	1.35	1.39	-
24-Jan-2012	0.290	-	0.34

Table A-13: Information and Observations of Survey Location

Parameters	Value			Comment
ID	AB05FA0320			-
Name	Battle River at Highway 21; Upstream of Camrose Creek			-
UTM (Easting m, Northing m, Zone)	368036	5868388	12	-
Gross Drainage Area (km^2)	5000			From Water Survey of Canada Station
Effective Drainage Area (km^2)	2920			From Water Survey of Canada Station
Water Survey of Canada Station ID	05FA011			Discontinued
Water Survey of Canada Station Location (km)	0			On Location
Additional Notes	Difficult to survey in January 2012. Depth of free water was shallow underneath the ice making it difficult for the meter to fit. Ice was also present all the way to the bottom at several holes. Effective Drainage Area of 05FA021 is reported as greater than that of 05FA011, which appears incorrect.			

7 September 2011 – View Upstream of Survey of Location

7 September 2011 – View Downstream of Survey of Location

AB05FA0340

AB05FA0340 is located on the north end of Driedmeat Lake and may be subject to backwater effects as suggested by its very high water levels compared to other survey locations. It is also located downstream of Camrose Creek, used to discharge effluent by the City of Camrose. Flooding was noted upstream of the survey location in September 2011, which may explain why the measured discharge was less than that of the upstream Survey Location AB05FA0320, from storage (5.56 m^3/s compared to 4.93 m^3/s). Depths greater than 2 m in several sections made the measurements difficult and may have resulted in inaccurate measurements. The confidence of the estimate in September 2011 is therefore poor.

The discharge could not be measured in October 2011 because of very low velocities. Discharge data may be available from Alberta Environment and Water, controlling the outlet of Driedmeat Lake, though none were found. The discharge was therefore estimated by pro-rating the measured discharge from Survey Location AB05FA0320 upstream, based on relative drainage areas. Potential backwater effects are not accounted for in the estimate, and the estimate is associated with a high level of uncertainty.

In January 2012, the measured discharge was much greater than that estimated the previous day at Survey Location AB05FA0320 upstream (2.04 m^3/s compared to 0.290 m^3/s). Alberta Environment and Water advised that the City of Camrose was not discharging effluent during the January 2012 field program. It is possible that some flow may have been discharged from Driedmeat Lake on the day of survey, although this was not confirmed, and such increase was not noticed at the following Survey Location AB05FC0020 downstream of Driedmeat Lake measured the following day (0.335 m^3/s). The discharges were measured directly under the bridge which may have contributed to errors in measurement because of potential eddies associated with flow constrictions. Pro-rating of the estimated discharge from Survey Location AB05FA0320 upstream, results in a more plausible discharge estimate of 0.348 m^3/s, recommended over the estimate of 2.04 m^3/s. Confidence of results for this survey location is low. Summaries of discharge measurements and additional information are presented in Tables A-14 and A-15.

Table A-14: Summary of Discharge Measurements

Date	Measured Discharge (m^3/s)	Water Survey of Canada Mean Daily Discharge (m^3/s)	Average Measured Ice Thickness (m)
8-Sep-2011	4.93	5.27	-
18-Oct-2011	-	1.39	-
25-Jan-2012	-	-	0.63

Table A-15: Information and Observations of Survey Location

Parameters	Value			Comment
ID	AB05FA0340			-
Name	Battle River at North End of Driedmeat Lake			-
UTM (Easting m, Northing m, Zone)	375965	5866517	12	-
Gross Drainage Area (km^2)	-			-
Effective Drainage Area (km^2)	3510			Derived from GIS
Water Survey of Canada Station ID	05FA011			Discontinued
Water Survey of Canada Station Location (km)	13.6			Upstream of Survey Location
Additional Notes	Flooding was noted upstream of survey location in September 2011. Difficult to survey in September 2011 because of depths greater than 2 m in several sections. Velocities were too low in October 2011 for measurements. Water Survey of Canada Station 05FA020 has continuous water level data available, and located approximately 20 km downstream of survey location, though was not used in discharge estimates.			


8 September 2011 – View Upstream of Survey of Location


8 September 2011 – View Downstream of Survey of Location

AB05FC0020

AB05DC0020 is located approximately 12 km downstream of Driedmeat Lake. In both September 2011 and October 2011, the maximum velocities were measured at this location (0.91 m/s in September and 0.55 m/s in October). All measured discharges agree with those measured at the next downstream Survey Location AB05FC0030 equipped with a Water Survey of Canada hydrometric gauge. Summaries of discharge measurements and additional information are presented in Tables A-16 and A-17.

Table A-16: Summary of Discharge Measurements

Date	Measured Discharge (m^3/s)	Water Survey of Canada Mean Daily Discharge (m^3/s)	Average Measured Ice Thickness (m)
8-Sep-2011	8.24	-	-
18-Oct-2011	1.63	-	-
26-Jan-2012	0.335	-	0.51

Table A-17: Information and Observations of Survey Location

Parameters	Value			Comment
ID	AB05FC0020			-
Name	Battle River Upstream of Highway 854			-
UTM (Easting m, Northing m, Zone)	402068	5839513	12	-
Gross Drainage Area (km^2)	7500			Estimated From Water Survey of Canada Station 05FA020 and GIS Analysis
Effective Drainage Area (km^2)	-			
Water Survey of Canada Station ID	-			-
Water Survey of Canada Station Location (km)	-			-
Additional Notes	Highest recorded velocities (0.91 m/s in September 2011). Woody debris in stream. Located downstream of Driedmeat Lake.			

8 September 2011 – View Upstream of Survey of Location

8 September 2011 – View Downstream of Survey of Location

AB05FC0030

The discharge was not measured in September 2011 because of scheduling issues; therefore, discharge was based on mean daily records of the Water Survey of Canada Station 05FC001 located on site. Although the reported discharge is less than that measured at the previous station (8.25 m^3/s compared to 7.72 m^3/s), they were not measured on the same day and are similar. The measured discharge in October 2011 appeared to be within acceptable daily fluctuations. The measured discharge in January 2012 agrees with that of the upstream Survey Location AB05FC0020, measured the previous day. Summaries of discharge measurements and additional information are presented in Tables A-18 and A-19.

Table A-18: Summary of Discharge Measurements

Date	Measured Discharge (m^3/s)	Water Survey of Canada Mean Daily Discharge (m^3/s)	Average Measured Ice Thickness (m)
9-Sep-2011	-	7.72	-
19-Oct-2011	1.54	1.78	-
27-Jan-2012	0.468	-	0.51

Table A-19: Information and Observations of Survey Location

Parameters	Value			Comment
ID	AB05FC0030			-
Name	Battle River at Highway 53 Bridge; Upstream of Meeting Creek			-
UTM (Easting m, Northing m, Zone)	409070	5825773	12	-
Gross Drainage Area (km^2)	7680			From Water Survey of Canada Station
Effective Drainage Area (km^2)	3620			
Water Survey of Canada Station ID	05FC001			-
Water Survey of Canada Station Location (km)	0			At Location
Additional Notes	Not measured in September 2011 because of scheduling issues. September 2011 estimate based on Water Survey of Canada data.			

9 September 2011 – View Upstream of Survey of Location

9 September 2011 – View Downstream of Survey of Location

AB05FB0050

Survey Location AB05FB0050 is located downstream of the Forestburg Reservoir. Discharge was not measured in September 2011 because of high water levels and high observed velocities, and was therefore based on mean daily records of the Water Survey of Canada Station 05FC008 located 50 km upstream. Although the discharge at AB05FB0050 is expected to be greater than that reported from Station 05FC008, the reported discharge agrees with the discharge at the next downstream Survey Location AB05FE0050, measured the following day, and was not pro-rated based on drainage area. In October 2011, the measured discharge was less than that reported at Water Survey of Canada Station 05FC008, although within possible daily fluctuations caused by the reservoir, and slightly less than that of Survey Location AB05FE0050 downstream measured a day apart. In January 2012, the measured discharge was less than that at Survey Location AB05FE0050 downstream measured a day apart. Both measurements in October 2011 and January 2012 are plausible. Summaries of discharge measurements and additional information are presented in Tables A-20 and A-21.

Table A-20: Summary of Discharge Measurements

Date	Measured Discharge (m^3/s)	Water Survey of Canada Mean Daily Discharge (m^3/s)	Average Measured Ice Thickness (m)
8-Sep-2011	-	10.5	-
20-Oct-2011	2.24	3.16	-
25-Jan-2012	0.584	-	0.45

Table A-21: Information and Observations of Survey Location

Parameters	Value			Comment
ID	AB05FB0050			-
Name	Battle River; Parallel to Highway 881; Downstream of Hardisty			-
UTM (Easting m, Northing m, Zone)	481134	5838434	12	-
Gross Drainage Area (km^2)	12200			Estimated From Water Survey of Canada Station 05FC008 and GIS Analysis
Effective Drainage Area (km^2)	6000			Effective Drainage Area at Water Survey of Canada Station 05FC008
Water Survey of Canada Station ID	05FC008			-
Water Survey of Canada Station Location (km)	50			Upstream of Survey Location
Additional Notes	Not measured in September 2011 because of unsafe depth and difficult access. September 2011 estimate based on Water Survey of Canada data.			

8 September 2011 – View Upstream of Survey of Location

8 September 2011 – View Downstream of Survey of Location

AB05FE0050

All measured discharges were greater than those from the previous station and are plausible. Summaries of discharge measurements and additional information are presented in Tables A-22 and A-23.

Table A-22: Summary of Discharge Measurements

Date	Measured Discharge (m^3/s)	Water Survey of Canada Mean Daily Discharge (m^3/s)	Average Measured Ice Thickness (m)
9-Sep-2011	12.1	-	-
19-Oct-2011	2.45	-	-
26-Jan-2012	1.41	-	0.62

Table A-23: Information and Observations of Survey Location

Parameters	Value			Comment
ID	AB05FE0050			-
Name	Battle River; Downstream Highway 41 Bridge			-
UTM (Easting m, Northing m, Zone)	510335	5872160	12	-
Gross Drainage Area (km^2)	17800			From Water Survey of Canada
Effective Drainage Area (km^2)	8230			From Water Survey of Canada
Water Survey of Canada Station ID	05FE003			Discontinued
Water Survey of Canada Station Location (km)	0			At Location
Additional Notes	Beaver lodge near survey location.			

9 September 2011 – View Upstream of Survey of Location

9 September 2011 – View Downstream of Survey of Location

APPENDIX B

Quality Assurance and Quality Control

B.1 INTRODUCTION

Quality assurance and quality control (QA/QC) practices determine data integrity and are relevant to all aspects of a study, from sample collection to data analysis and reporting. Quality assurance encompasses management and technical practices designed to ensure that the data generated are of consistent high quality. Quality control is an aspect of QA and includes the procedures used to measure and evaluate data quality, and the corrective actions to be taken when data quality objectives are not met. This appendix describes QA/QC practices applied during this study, evaluates QC data, and describes the implications of QC results to the interpretation of study results.

B.2 QUALITY ASSURANCE

Quality assurance applicable to this study cover three areas of internal and external management, as described below.

Field Staff Training and Operations

Golder field staff are trained to be proficient in standardized field sampling procedures, data recording, and equipment operations applicable to water quality sampling. Field work was completed according to approved specific work instructions and established Golder technical procedures. Specific work instructions are standardized forms that describe exact sampling locations and provide specific sampling instructions, equipment needs and calibration requirements, required technical procedures, sample labelling and shipping protocols, and laboratory contacts. They also provide specific guidelines for field record keeping and sample tracking. Technical procedures are consistent with standard field methods described in the relevant scientific literature (e.g., Environment Canada 1993; American Public Health Association (APHA) 2005), and outline sample collection, preservation, handling, storage, and shipping protocols.

Field work was preceded by a pre-field meeting by the field crew and the project manager, during which the purpose of the field program was discussed, roles of crew members were specified, questions regarding the specific work instruction were addressed, and equipment needs, field logistics and contingency plans were discussed. During field work, field data were recorded on Alberta Environment field data sheets. In addition, field crews checked-in with task managers regularly to provide an update on work completed. Samples were documented and tracked using chain-of-custody (COC) forms.

One field crew member was responsible for ensuring that:

- all required samples were collected;
- COC and analytical request forms were completed and correct;
- proper labelling and documentation procedures were followed; and
- samples were delivered to the appropriate locations in a timely manner.

Laboratory

The Project Manager was designated as the lab liaison. To ensure that high quality data were generated, laboratories used for the sample analysis are accredited by the Canadian Association for Laboratory

Accreditation Inc. (CALA). Under CALA's accreditation program, performance evaluation assessments are conducted annually for laboratory procedures, methods and internal quality control.

Office Operations

Office-related QA included use of appropriately trained personnel for each task and senior review of work products at appropriate milestones, use of standardized data manipulation/summary tools, filing of data and project information according to standardized protocols and establishment of a data management system to ensure an organized consistent system of data storage, QC and retrieval.

B.3 QUALITY CONTROL

B3.1 Field Quality Control Procedures

The water quality field QC program consisted of the collection and analysis of field equipment blanks, and duplicate samples. Each QC sample type is described below:

- Field equipment blanks consist of de-ionized water provided by the analytical laboratory, which is exposed to the sampling environment at the sample station and handled in the same manner as the surface water samples collected during the field program (e.g., preserved, filtered). Field equipment blanks are used to detect potential sample contamination during sample collection, handling, shipping and analysis.
- Duplicate samples (or replicate samples, depending on the number collected) are additional samples collected at the same time and location as surface water or sediment samples collected during a field program, using the sample sampling methods. They are used to check within-station variation, and the precision of field sampling methods and laboratory analysis.

Quality control samples collected during the field program accounted for approximately 15% of the total number of samples submitted for analysis. These samples were handled, stored and shipped along with field-collected surface water samples, and were submitted "blind" to the analytical laboratories. Quality control samples were analyzed for the same set of parameters as the samples collected from surface waters.

B3.2 Office Quality Control Procedures

Relevant elements of office-based QC included the following:

- creating scanned back-up copies of all field notes;
- creating backup files before each major operation as data were being manipulated; and
- verifying the accuracy of calculations performed to generate summary statistics.

B3.3 Initial Laboratory Data Screening

Upon receipt of water quality data from the analytical laboratory, a series of standard checks were performed to screen for potential data quality issues. These allowed potential re-analysis of samples to verify questionable data, or generate data for missing parameters. The following data checks were performed:

- verification that all required parameters and samples were analyzed;

- verification that data are reported using the appropriate units;
- verification that analyses were done with the appropriate detection limit;
- checking for outliers using graphical methods, and based on expected concentration ranges in the sampled waters;
- checking blanks for evidence of contamination (see next section);
- checking duplicate samples for evidence of unacceptable variation (see next section);
- checking laboratory QC data (sample temperature and integrity of containers upon receipt, review laboratory qualifiers, holding times, internal duplicates); and
- checking field-collected data for completeness, and unexpected values and trends.

If results of initial data screening indicated that there were deficiencies or potential data quality issues, the analytical laboratory was contacted and re-analysis of the parameters in question in the affected samples was requested. If data were verified by the analytical laboratory, but remained questionable based on the above evaluation, qualifiers were added to affected concentrations in the project data set for consideration during data summary and analysis, or data were excluded from further analysis (and identified in the report as excluded, with the corresponding reasons).

B3.4 Field Quality Control Data Evaluation

B3.4.1 Water Quality

Field Blanks

Concentrations in field blanks were considered notable if they were greater than or equal to five times the corresponding Reportable Detection Limit (RDL). A value of five times the RDL is considered the Practical Quantitation Limit (PQL). This threshold is based on the PQL defined by the United States Environmental Protection Agency (U.S. EPA 1985), and takes into account the potential for reduced accuracy when concentrations approach or are below RDLs.

The implications of notable results in blanks to data quality were evaluated relative to concentrations observed in surface waters sampled during the field program. The aim of this evaluation was to determine: (i) whether contamination was limited to a blank or was apparent in the corresponding water samples as well; (ii) whether it resulted in a consistent bias; and (iii) whether it was severe enough to warrant invalidating the affected data.

To address these questions, notable concentrations in blanks were interpreted as follows:

- If the blank had a detectable concentration of a parameter that was higher than those in the corresponding surface water samples, it was assumed that the concentration in the blank was the result of an isolated field or lab error. In this case, the corresponding water samples were considered uncontaminated.
- If the detectable concentration in the blank was less than 10% of the typical surface water concentration, the data for the corresponding water samples were considered acceptable for the parameter in question and were included in further analysis.

- If the detectable concentration in a single blank was greater than 10% of the typical surface water concentration, but below those in the corresponding water samples, the water samples were considered potentially contaminated and were qualified in the data tables and the project database. Affected data were excluded from further analysis.
- If two or more blanks had similar notable concentrations of a parameter, which was greater than 10% of the typical surface water concentration, but below those in the corresponding water samples, the results were considered to indicate a consistent analytical bias for that parameter. In this case, the data for the corresponding water samples were adjusted by subtracting the mean concentration in the blanks and the analytical laboratory was contacted to request development of corrective actions.

Duplicate Samples

Differences between concentrations measured in duplicate water samples were calculated as the relative percent difference (RPD) for each parameter. Before calculating the RPD, concentrations below the MDL were replaced with the MDL value in cases when only one of the concentrations for a given parameter was detectable. The RPD was calculated using the following formula:

RPD = (|difference in concentration between duplicate samples| / mean concentration) x 100

The RPD value for a given parameter was considered notable if:

- it was greater than 20%; and
- concentrations in one or both samples were greater than or equal to five times the MDL.

These criteria are consistent with those used by analytical laboratories as part of internal QC procedures for duplicate samples.

The number of parameters with exceedances of the assessment criteria was compared with the total number of parameters analyzed to evaluate analytical precision. Analytical precision was rated as follows:

- high, if less than 10% of the total number of parameters were notably different from one another;
- moderate, if 10 to 30% of the total number of parameters were notably different from one another; or
- low, if more than 30% of the total number of parameters were notably different from one another.

QUALITY CONTROL RESULTS

B4.1 Water Quality

B4.1.1 Field Blanks

Four blank samples were collected for this study (two during the late summer field campaign and one during each of the fall and winter field campaigns). One of the blanks collected in September was a trip blank and one was a field blank. In the fall and winter sampling events, field blanks were collected. No parameters were detected in the field blank from the September trip. In the trip blank from the late summer sampling trip and the field blanks from both the fall and winter sampling trips, one or two parameters were detected in each sample;

however, all detected concentrations were less than the PQL (Table B-1). The parameters detected in the blanks included the following:

- late summer – total organic carbon;
- fall – dissolved sodium and dissolved phosphorus; and
- winter – dissolved sodium and total organic carbon.

Since concentrations in the field blank samples were less than the PQL, they are not considered further.

Table B-1: Quality Control Results for Field Blanks with Detectable Parameters

Analyte	Unit	DL	PQL	Trip Blank 7-Sep-2011	Field Blank 20-Oct-2011	Field Blank 26-Jan-2012
Dissolved sulphate	mg/L	0.5	2.5	-	2.1	0.53
Dissolved phosphorus	mg/L	0.003	0.015	-	0.004	-
Total organic carbon	mg/L	0.5	2.5	1.0	-	0.55

Notes: - = not applicable.
DL = detection limit.
PQL = practical quantitation limit.

B4.1.2 Duplicate Samples

Duplicate samples were also collected during each field campaign. Duplicate samples were collected from Reach 4 (AB05FE0050) in the late summer, from Reach 1 (AB05FA0060) in the fall, and from Reach 3 (AB05FC0030) in the winter. A summary of the comparison of duplicates from the three field campaigns is provided in Table B-2. Three measurements in the duplicate samples were considered notable (i.e., more than 20% difference in concentration and both values more than the PQL) and included the following:

- late summer – TP;
- fall – TSS; and
- winter – TSS.

In total, three measurements (two parameters) were considered notable (Table B-2). The difference in concentration between replicates was between 33% and 83% for these parameters.

The reported concentrations for the duplicate samples were within the reported variation for all samples collected during the particular season; therefore, results for duplicate samples do not alter the interpretation of the data.

Analytical precision is rated as high as less than 10% of the total number of parameters were notably different from one another.

Table B-2: Quality Control Results for Notable Parameters

Analyte	DL/ Alternate DL	PQL/ Alternate PQL	AB05FE0050 Sample 9-Sep-2011	AB05FE0050 Duplicate 9-Sep-2011	RPD	AB05FA0060 Sample 17-Oct-2011	AB05FA0060 Duplicate 17-Oct-2011	RPD	AB05FC0030 Sample 27-Jan-2012	AB05FC0030 Duplicate 27-Jan-2012	RPD
Total suspended solids	0.003/ 0.02	0.015/ 0.1	-	-	-	12	29	**83%**	5.2	2.4	**74%**
Total phosphorus	0.003/ 0.02	0.015/ 0.1	0.1*	0.14	**33%**	-	-	-	-	-	-

Notes: Units are mg/L; - = not applicable.

DL = detection limit.
PQL = practical quantitation limit.
* =alternate DL and PQL were used.

Complete results for the duplicate samples are provided in Appendix B, Table B-3. The results are sorted by type of QC collection (duplicate and then blanks), and by date of collection.

Table B-3: QA/QC Results (Duplicates and Blanks)

Analyte	Unit	RDL	PQL	RDL (alternate) (1)	PQL (alternate) (1)	Reach 4			Reach 1			Reach 3			Trip Blank	Field Blank	Field Blank	Field Blank
						AB05FE0050			AB05FA0060			AB05FC0030						
						9-Sep-11			17-Oct-11			27-Jan-12			7-Sep-11	7-Sep-11	20-Oct-11	26-Jan-12
						Sample		*RPD*	Sample	Duplicate	*RPD*	Sample	Duplicate	*RPD*				
Inorganics																		
Total dissolved solids	mg/L	10	50	-	-	420	410	*2*	420	420	*0*	640	730	*13*	<10	<10	<10	<10
Total suspended solids	mg/L	1	5	3	15	87 (2)	91 (2)	*5*	12	29	*83*	5.2	2.4	*74*	<1	<1	<1	<1.0
Hardness ($CaCO_3$)	mg/L	0.5	2.5	-	-	220	220	*0*	290	290	*0*	380	380	*0*	<0.5	<0.5	<0.5	<0.50
Major Ions																		
Dissolved calcium	mg/L	0.3	1.5	-	-	55	54	*2*	75	74	*1*	94	94	*0*	<0.3	<0.3	<0.3	<0.30
Dissolved chloride	mg/L	1	5	-	-	20	20	*0*	15	15	*0*	39	34 (1)	*14*	1	<1	<1	<1.0
Dissolved fluoride	mg/L	0.05	0.25	-	-	0.22	0.21	*5*	0.21	0.21	*0*	0.30	0.30	*0*	<0.05	<0.05	<0.05	<0.050
Dissolved magnesium	mg/L	0.2	1	-	-	21	21	*0*	25	25	*0*	35	35	*0*	<0.2	<0.2	<0.2	<0.20
Dissolved sodium	mg/L	0.5	2.5	-	-	48	48	*0*	57	57	*0*	92	92	*0*	<0.5	<0.5	2.1	0.53
Dissolved sulphate	mg/L	1	5	2	10	53	50	*6*	37 (1)	38 (1)	*3*	110	110	*0*	<1	<1	<1	<1.0
Sodium adsorption ratio	N/A	0.1	0.5	-	-	1.4	1.4	*0*	1.5	1.5	*0*	2.05	2.06	*<1*	NC	NC	NC	NC
Nutrients-Nitrogen																		
Total nitrogen	mg-N/L	0.05	0.25	-	-	1.9	1.8	*5*	1.4	1.2	*15*	2.2	2.2	*0*	<0.05	<0.05	<0.05	<0.050
Total Kjeldahl nitrogen	mg-N/L	0.05	0.25	0.3	1.5	1.9 (3)	1.8	*5*	1.4	1.2	*15*	2.0	2.0	*0*	<0.05	<0.05	<0.05	<0.050
Total ammonia	mg-N/L	0.05	0.25	-	-	<0.05	<0.05	*0*	<0.05	<0.05	*0*	0.073	0.079	*8*	<0.05	<0.05	<0.05	<0.050
Nitrate plus nitrite-N	mg-N/L	0.003	0.015	-	-	<0.003	<0.003	*0*	<0.003	<0.003	*0*	0.22	0.22	*0*	<0.003	<0.003	<0.003	0.003
Dissolved nitrate-N	mg-N/L	0.003	0.015	-	-	<0.003	<0.003	*0*	<0.003	<0.003	*0*	0.22	0.22	*0*	<0.003	<0.003	<0.003	0.003
Dissolved nitrite-N	mg-N/L	0.003	0.015	-	-	<0.003	<0.003	*0*	<0.003	<0.003	*0*	<0.0030	<0.0030	*0*	<0.003	<0.003	<0.003	<0.003
Nutrients-Phosphorus																		
Total phosphorus	mg-P/L	0.003	0.015	0.02	0.1	0.1 (3)	0.14	*33*	0.100	0.092	*8*	0.062	0.065	*5*	<0.003	<0.003	<0.003	0.003
Dissolved phosphorus	mg-P/L	0.003	0.015	0.02	0.1	0.057	0.060	*5*	0.039	0.044	*12*	0.034	0.038	*11*	<0.003	<0.003	0.004	0.003
Nutrients-Carbon																		
Total organic carbon	mg/L	0.5	2.5	1	5	21 (1)	21 (1)	*0*	16	14	*13*	29 (1)	29 (1)	*0*	1.0	<0.5	<0.5	0.55

- = not applicable.
RDL = reportable detection limit.
PQL = practical quantitation limit.
(1) Detection limits raised due to dilution to bring analyte within the calibrated range.
(2) Detection limit raised based on sample volume used for analysis.

[orange] = >20% difference between replicates and values > PQL
[green] = value detected in blank, but value not greater than the PQL

APPENDIX C

Water Quality Results

Table C-1. Water Quality Results for September (all stations and reaches)

Water Quality Parameters	Units	RDL	RDL (alternate) (1)	Open-Water				Reach 1		Reach 2					Reach 3		Reach 4	
				90th Percentile WQO	90th Percentile WQO	Generic Guidelines	90th Percentile WQO	BR at HWY 611	BR at RR 263	BR at Diamond 5 Road	BR U/S of Pipestone Creek	BR D/S of Pipestone Creek	BR at HWY 21	BR at North end of Driedmeat Lake	BR U/S of HWY 854	BR above Meeting Creek	BR D/S of Hardisty	BR at HWY 41 Bridge
								AB05FA0030	AB05FA0060	AB05FA0120	AB05FA0280	AB05FA0290	AB05FA0320	AB05FA0340	AB05FC0020	AB05FC0030	AB05FB0050	AB05FE0050
				Reach 1	Reach 2	Reach 3	Reach 4	6-Sep-11	6-Sep-11	6-Sep-11	7-Sep-11	7-Sep-11	7-Sep-11	8-Sep-11	9-Sep-11	9-Sep-11	8-Sep-11	9-Sep-11
Physical Parameters																		
Water temperature (field)	°C	-	-	21	21	-	21	16.0	17.8	**21.0**	15.1	17.9	19.1	17.2	19.5	19.9	**21.3**	16.9
pH (field)	-	-	-	<7.9 or >8.9	<7.9 or >9.1	6.5 to 9.0	<8.1 or >8.8	8.0	8.1	8.4	8.5	8.3	8.3	8.2	8.2	8.0	8.2	8.6
Specific conductivity (field)	µS/cm	-	-	619	943	<1000	1130	571	**684**	896	629	667	669	681	535	572	583	603
Dissolved oxygen (field)	mg/L	-	-	9.4	9.4	5.5 to 9.5	9.1	7.3	8.6	12.5	9.0	7.8	8.0	7.4	6.8	8.1	9.0	8.7
Dissolved oxygen (field)	%	-	-	-	-	-	-	83	103	161.0	97.0	92.0	98.0	84.0	82	98	111	95
Turbidity (field)	NTU	-	-	15	60	-	140	8.4	7.4	3.2	12.0	24.0	19.1	10.0	16	21	31.0	35.2
Inorganics																		
Total dissolved solids	mg/L	10	-	381	589	<3000	616	380	**420**	510	390	400	450	440	410	410	420	420
Total suspended solids	mg/L	1	3	39	81	-	288	11	6	4	44	**85**	46	18	48	53 (2)	84	87 (2)
Hardness ($CaCO_3$)	mg/L	0.5	-	213	236	-	267	200	**250**	**300**	200	220	220	200	210	200	220	220
Major Ions																		
Dissolved calcium	mg/L	0.3	-	52	59	<1000	61	51	**65**	**78**	47	55	54	49	53	52	54	55
Dissolved chloride	mg/L	1	-	9	48	<100	38	8	**13**	**52**	23	27	26	26	19	20	20	20
Dissolved fluoride	mg/L	0.05	-	0.21	0.37	0.12	0.28	0.16	**0.24**	0.30	0.22	0.25	0.25	0.25	**0.18**	**0.20**	0.22	0.22
Dissolved magnesium	mg/L	0.2	-	-	-	-	-	18	21	26	20	20	20	18	18	18	20	21
Dissolved sodium	mg/L	0.5	-	-	-	-	-	39	47	68	41	48	48	46	36	36	44	48
Dissolved sulphate	mg/L	1	2	28	136	<1000	179	21	**33**	56	47 (1)	45	45	49	41	42	49	53
Sodium adsorption ratio	N/A	0.1	-	2.6	3.6	<5	5.5	1.2	1.3	1.7	1.3	1.4	1.4	1.4	1.1	1.1	1.3	1.4
Nutrients-Nitrogen																		
Total nitrogen	mg-N/L	0.05	-	1.6	5	<1	2.4	1.3	1.5	3.1	2.2	2.6	2.3	2.4	**2.3**	**2.2**	1.9	1.9
Total Kjeldahl nitrogen	mg-N/L	0.05	0.3	-	-	-	-	1.3	1.5	2.2 (1)	2.1 (1)	2.3 (1)	2.0	2.0 (1)	2.2 (1)	2.2 (1)	1.9	1.9
Total ammonia	mg-N/L	0.05	-	0.12	1.99	-	0.06	<0.05	<0.05	0.37	<0.05	0.09	0.08	0.07	0.10	<0.05	<0.05	<0.05 (3)
Unionized ammonia	mg-N/L	-	-	0.019	0.019	0.019	0.019	-	-	0.0369	-	0.0054	0.0052	0.0035	0.0051	-	-	-
Nitrate plus nitrite	mg-N/L	0.003	-	0.066	0.051	2.93	0.33	<0.003	<0.003	**0.87**	0.14	0.36	0.36	0.36	0.040	0.065	<0.003	<0.003
Dissolved nitrate	mg-N/L	0.003	-	0.046	0.483	2.93	-	<0.003	<0.003	**0.66**	0.12	0.33	0.33	0.34	0.037	0.065	<0.003	<0.003
Dissolved nitrite	mg-N/L	0.003	-	0.007	0.038	0.06	-	<0.003	<0.003	**0.21**	0.020	0.028	0.025	0.024	0.003	<0.003	<0.003	<0.003
Nutrients-Phosphorus																		
Total phosphorus	mg-P/L	0.003	0.02	0.41	0.59	<0.05	0.33	0.075	0.13	**0.84 (1)**	0.25	0.26	0.28	0.29	**0.23**	**0.21**	0.20	0.10 (3)
Dissolved phosphorus	mg-P/L	0.003	0.02	0.33	0.3	-	0.05	0.028	0.062	**0.84 (1)**	0.15	0.17	0.18	0.19	0.14	0.11	**0.065**	**0.057**
Nutrients-Carbon																		
Total organic carbon	mg/L	0.5	1	23	23	-	26	19	19 (1)	19	**24 (1)**	23 (1)	18	23 (1)	23 (1)	22 (1)	19	21 (1)

- = not applicable.
RDL = reportable detection limit.
(1) Detection limits raised due to dilution to bring analyte within the calibrated range.
(2) Detection limit raised based on sample volume used for analysis
(3) Sample was received unpreserved.

(blue)	above the 90th percentile objectives/targets for pH, values less than the 10th percentile or more than the 90th percentile for DO, values less than the 10th percentile for Reach 3, values above generic guidelines
(yellow)	unusually high value; instrument reading error expected

Table C-2. Water Quality Results for October (all stations and reaches)

Water Quality Parameters	Units	RDL	RDL (alternate) (1)	Open-Water				Reach 1		Reach 2					Reach 3		Reach 4	
				90th Percentile WQO	90th Percentile WQO	Generic Guidelines	90th Percentile WQO	BR at HWY 611	BR at RR 263	BR at Diamond 5 Road	BR U/S of Pipestone Creek	BR D/S of Pipestone Creek	BR at HWY 21	BR at North end of Driedmeat Lake	BR U/S of HWY 854	BR above Meeting Creek	BR D/S of Hardisty	BR at HWY 41 Bridge
								AB05FA0030	AB05FA0060	AB05FA0120	AB05FA0280	AB05FA0290	AB05FA0320	AB05FA0340	AB05FC0020	AB05FC0030	AB05FB0050	AB05FE0050
				Reach 1	Reach 2	Reach 3	Reach 4	17-Oct-11	17-Oct-11	17-Oct-11	17-Oct-11	18-Oct-11	18-Oct-11	18-Oct-11	18-Oct-11	19-Oct-11	20-Oct-11	19-Oct-11
Physical Parameters																		
Water temperature (field)	°C	-	-	21	21	-	21	4.3	6.1	8.1	5.8	3.6	5.0	7.4	5.7	4.3	5.2	7.2
pH (field)	-	-	-	<7.9 or >8.9	<7.9 or >9.1	6.5 to 9.0	<8.1 or >8.8	8.0	8.3	8.5	9.0	8.9	8.8	8.5	8.2	8.4	8.5	8.3
Specific conductivity (field)	µS/cm	-	-	619	943	<1000	1130	**620**	**828**	**969**	722	755	817	**1027**	637	672	797	822
Dissolved oxygen (field)	mg/L	-	-	9.4	9.4	5.5 to 9.5	9.1	12.6	12.3	12.2	14.7	11.8	13.6	14.4	9.4	11.1	11.1	12.2
Dissolved oxygen (field)	%	-	-	-	-	-	-	103	100	107.0	121.0	97.0	109.0	122.0	75	87	94	102
Turbidity (field)	NTU	-	-	15	60	-	140	8.0	3.4	4.2	11.6	20.4	12.4	9.7	42	23	6.9	7.6
Inorganics																		
Total dissolved solids	mg/L	10	-	381	589	<3000	616	320	**420**	540	340	380	410	**610**	400	380	430	520
Total suspended solids	mg/L	1	3	39	81	-	288	24	12	5	24	59 (1)	24	21	87 (1)	41	9	10
Hardness ($CaCO_3$)	mg/L	0.5	-	213	236	-	267	**260**	**290**	**360**	230	230	**240**	**300**	240	240	**270**	**270**
Major Ions																		
Dissolved calcium	mg/L	0.3	-	52	59	<1000	61	**64**	**75**	**96**	50	52	56	**68**	60	61	**68**	**66**
Dissolved chloride	mg/L	1	-	9	48	<100	38	6	**15**	26	28	30	29	**55**	23	23	26	25
Dissolved fluoride	mg/L	0.05	-	0.21	0.37	0.12	0.28	0.14	0.21	0.21	0.18	0.20	0.20	0.31	**0.21**	**0.21**	0.22	0.22
Dissolved magnesium	mg/L	0.2	-	-	-	-	-	23	25	29	25	24	25	30	21	21	24	25
Dissolved sodium	mg/L	0.5	-	-	-	-	-	48	57	61	58	58	60	110	45	48	71	79
Dissolved sulphate	mg/L	1	2	28	136	<1000	179	18	**37 (1)**	110	52	58	59	180	53	55	95	100
Sodium adsorption ratio	N/A	0.1	-	2.6	3.6	<5	5.5	1.3	1.5	1.4	1.7	1.7	1.7	2.7	1.3	1.4	1.9	2.1
Nutrients-Nitrogen																		
Total nitrogen	mg-N/L	0.05	-	1.6	5	<1	2.4	1.2	1.4	1.1	2.4	2.1	2.3	3.7	**2.9**	**2.7**	1.3	1.2
Total Kjeldahl nitrogen	mg-N/L	0.05	0.3	-	-	-	-	1.2	1.4	1.1	2.4 (1)	2.1 (1)	2.3 (1)	3.3 (1)	2.7 (1)	2.2 (1)	1.3	1.2
Total ammonia	mg-N/L	0.05	-	0.12	1.99	-	0.06	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.72	0.45	0.34	<0.05	<0.05
Unionized ammonia	mg-N/L	-	-	0.019	0.019	0.019	0.019	-	-	-	-	-	-	0.0347	0.0083	0.0092	-	-
Nitrate plus nitrite	mg-N/L	0.003	-	0.066	0.051	2.93	0.33	<0.003	<0.003	0.005	<0.003	<0.003	<0.003	0.38	0.25	0.42	0.018	<0.003
Dissolved nitrate	mg-N/L	0.003	-	0.046	0.483	2.93	-	<0.003	<0.003	0.005	<0.003	<0.003	<0.003	0.33	0.23	0.40	0.018	<0.003
Dissolved nitrite	mg-N/L	0.003	-	0.007	0.038	0.06	-	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	**0.046**	0.020	0.025	<0.003	<0.003
Nutrients-Phosphorus																		
Total phosphorus	mg-P/L	0.003	0.02	0.41	0.59	<0.05	0.33	0.11	0.100	0.17	0.18	0.19	0.17	0.31	**0.17**	**0.11**	0.041	0.054
Dissolved phosphorus	mg-P/L	0.003	0.02	0.33	0.3	-	0.05	0.021	0.039	0.040	0.031	0.037	0.028	0.099	0.055	0.041	0.016	0.013
Nutrients-Carbon																		
Total organic carbon	mg/L	0.5	1	23	23	-	26	16	16	12	**24 (1)**	23 (1)	22 (1)	21 (1)	19	18	16	14

- = not applicable.
RDL = reportable detection limit.
(1) Detection limits raised due to dilution to bring analyte within the calibrated range.

[shaded] above the 90th percentile objectives/targets
for pH, values less than the 10th percentile or more than the 90th percentile
for DO, values less than the 10th percentile
for Reach 3, values above generic guidelines

Table C-3. Water Quality Results for January (all stations and reaches)

Water Quality Parameters	Units	RDL	RDL (alternate) (1)	Ice-Covered				Reach 1		Reach 2					Reach 3		Reach 4	
				90th Percentile	90th Percentile	Generic Guidelines	90th Percentile	BR at HWY 611	BR at RR 263	BR at Diamond 5 Road	BR U/S of Pipestone Creek	BR D/S of Pipestone Creek	BR at HWY 21	BR at North end of Driedmeat Lake	BR U/S of HWY 854	BR above Meeting Creek	BR D/S of Hardisty	BR at HWY 41 Bridge
								AB05FA0030	AB05FA0060	AB05FA0120	AB05FA0280	AB05FA0290	AB05FA0320	AB05FA0340	AB05FC0020	AB05FC0030	AB05FB0050	AB05FE0050
				Reach 1	Reach 2	Reach 3	Reach 4	23-Jan-12	23-Jan-12	27-Jan-12	24-Jan-12	24-Jan-12	24-Jan-12	25-Jan-12	26-Jan-12	27-Jan-12	25-Jan-12	26-Jan-12
Physical Parameters																		
Water temperature (field)	°C	-	-	1	2	-	1	0.4	0.4	0.1	0.0	0.0	0.0	0.5	0.3	0.2	0.1	0.2
pH (field)	-	-	-	<6.9 or >7.9	<7.2 or >8.3	6.5 to 9.0	<7.4 or >8.5	7.2	7.5	7.4	7.7	7.6	7.6	7.8	7.3	7.6	7.9	6.6
Specific conductivity (field)	µS/cm	-	-	1251	2229	<1000	1477	649	892	1090	1718	1637	1677	1655	1102	1083	1451	1250
Dissolved oxygen (field)	mg/L	-	-	3.3	3.3	5.5 to 9.5	3.6	7.1	5.8	4.8	2.3	0.9	2.1	1.4	**4.6**	6.6	4.2	3.0
Dissolved oxygen (field)	%	-	-	-	-	-	-	63	46	29.0	9.0	1.0	2.0	2.0	38	49	41	17
Turbidity (field)	NTU	-	-	55	42	-	13	5.8	4.7	6.3	25.7	42.0	18.5	26.9	7	6	8.5	5.4
Inorganics																		
Total dissolved solids	mg/L	10	-	818	1460	<3000	750	360	500	620	1100	1000	1100	1000	640	640	**910**	720
Total suspended solids	mg/L	1	3	22	40	-	22	3.6	2.8	5.2	14	24	13	10	16	5.2	3.2	4.8
Hardness ($CaCO_3$)	mg/L	0.5	-	409	610	-	434	230	310	420	**620**	580	**640**	**620**	370	380	**470**	400
Major Ions																		
Dissolved calcium	mg/L	0.3	-	102	143	<1000	100	55	75	110	**160**	**150**	**160**	**160**	93	94	**120**	96
Dissolved chloride	mg/L	1	-	12	160	<100	37	5.6	8.5	26	55	48	53	53	39	39	**50**	34
Dissolved fluoride	mg/L	0.05	-	0.34	0.73	0.12	0.32	0.20	0.22	0.26	0.33	0.34	0.34	0.35	**0.30**	**0.30**	**0.35**	0.31
Dissolved magnesium	mg/L	0.2	-	-	-	-	-	22	30	36	52	49	56	54	34	35	44	38
Dissolved sodium	mg/L	0.5	-	-	-	-	-	49	71	77	120	110	130	120	82	92	160	130
Dissolved sulphate	mg/L	1	2	38	403	<1000	214	22	36	96	**190 (1)**	160	180	170	100	110	210 (1)	180
Sodium adsorption ratio	N/A	0.1	-	3.2	5.1	<5	4.2	1.42	1.75	1.63	2.08	2.05	2.18	2.16	1.86	2.05	3.10	2.87
Nutrients-Nitrogen																		
Total nitrogen	mg-N/L	0.05	-	3.4	10.1	<1	1.3	1.0	1.4	1.8	2.4	2.7	2.7	2.6	**2.1**	**2.2**	**2.1**	**1.4**
Total Kjeldahl nitrogen	mg-N/L	0.05	0.3	-	-	-	-	0.84	1.0	1.1	2.4 (1)	2.7 (1)	2.7 (1)	2.6 (1)	2.0 (1)	2.0	1.7	1.1
Total ammonia	mg-N/L	0.05	-	1.26	9.19	-	0.4	0.18	0.31	0.34	0.53	0.80	0.84	0.64	0.094	0.073	0.21	0.23
Unionized ammonia	mg-N/L	-	-	0.019	0.019	0.019	0.019	0.0002	0.0008	0.0006	0.0019	0.0025	0.0030	0.0031	0.0002	0.0002	0.0014	0.0001
Nitrate plus nitrite	mg-N/L	0.003	-	0.213	0.555	2.93	0.48	0.18	**0.32**	**0.70**	0.019	<0.0030	<0.0030	<0.0030	0.056	0.22	0.40	0.29
Dissolved nitrate	mg-N/L	0.003	-	0.158	0.561	2.93	-	**0.18**	**0.32**	**0.69**	0.019	<0.0030	<0.0030	<0.0030	0.056	0.22	0.39	0.29
Dissolved nitrite	mg-N/L	0.003	-	0.006	0.032	0.06	-	<0.0030	<0.0030	0.0084	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	0.0034	0.0042
Nutrients-Phosphorus																		
Total phosphorus	mg-P/L	0.003	0.02	0.98	0.92	<0.05	0.09	0.038	0.061	0.062	0.48	0.46	0.25	0.31	**0.079**	**0.062**	0.038	0.056
Dissolved phosphorus	mg-P/L	0.003	0.02	0.11	0.31	-	0.04	0.011	0.022	0.021	0.020	0.016	0.012	0.047	0.045	0.034	0.015	0.033
Nutrients-Carbon																		
Total organic carbon	mg/L	0.5	1	28	32	-	18	8.9	11	9.4	26 (1)	26 (1)	27 (1)	30 (1)	31 (1)	29 (1)	16	13

- = not applicable.
RDL = reportable detection limit.
(1) Detection limits raised due to dilution to bring analyte within the calibrated range.

[shaded] above the 90th percentile objectives/targets
for pH, values less than the 10th percentile or more than the 90th percentile
for DO, values less than the 10th percentile
for Reach 3, values above generic guidelines

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