Water quality of the North Saskatchewan River and its four tributaries in Alberta's Industrial Heartland

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Table of Abbreviations

ANOVA	Analysis of Variance
DO	Dissolved Oxygen
CEQG	Canadian Environmental quality guidelines
CSOs	Combined Sewer Outfalls
CUCA	Concordia University College of Alberta
NSR	North Saskatchewan River
SSOs	Storm Sewer Outfalls
USEPA	United States Environmental Protection Agency
WTP	Water Treatment Plant
WWTP	Wastewater Treatment Plant

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Abstract

Monitoring the quality of the water in the North Saskatchewan River and its tributaries is critical to ensure compliance with provincial and federal guidelines related to water quality; for the benefit of humans, other animals and the ecosystems surrounding these areas. The human population and urban development is escalating at an unprecedented rate, creating tremendous stress on local and regional water quality within Alberta's Industrial Heartland. Twenty-three different parameters were studied from Wedgewood Creek, Horsehills Creek, Sturgeon River and Redwater River, as well as, upstream and downstream in the North Saskatchewan River at each location in the spring and summer of 2014. These samples were collected to investigate seasonal changes, differences between the tributary and the North Saskatchewan River water quality, differences between upstream and downstream water quality in the North Saskatchewan River, and differences between the types of tributaries studied. Comparisons showed that: 1) North Saskatchewan River water quality variables upstream of Horsehills Creek were the most diverse between seasons; 2) the water quality variables at Wedgewood Creek and North Saskatchewan River downstream of the tributary were the most different; 3) North Saskatchewan River water quality variables upstream and downstream of Horsehills Creek were the most varied; 4) Conductivity at Horsehills Creek and Wedgewood Creek was the most significantly different compared to the other water quality variables. By following the guidelines and regulations provided by the government, individuals can help protect the quality of the limited water resource for future generations to come.

Keywords

Downstream, Horsehills, Redwater, Sturgeon, Upstream, Wedgewood Creek

Introduction

The North Saskatchewan River (NSR) is the seventh largest river in Canada, starting in the Saskatchewan Glacier region in the Columbian Icefields in Banff National Park and emptying into Lake Winnipeg (Environment Canada 2013; Neufeld 2010; North Saskatchewan Watershed Alliance 2005; Alberta Environment 2008; Water for Life 2010). For many years, the NSR has been contaminated by natural and anthropogenic impurities (Environment Canada 2010; Environment Canada 2014). The number of physical, biological and chemical factors that enter the waterway determine the health of humans, other animals, and the ecosystems that depend on this resource to survive. Physical characteristics include: water temperature, turbidity, water colour, and suspended solids. Biological characteristics include: bacteria, animals and plants in the water body. Faecal pollution for example, is regulated by standards provided by protection agencies to help mitigate poor water quality associated to coliform present in water bodies (Schulz and Childers 2001). Lastly, chemical characteristics include: organic compounds, metals, minerals, dissolved oxygen (DO) and nutrients (Stantec Consulting Ltd. 2005; Water for Life 2010; Environment Canada 2013). DO is a vital chemical characteristic because it is a necessity for the survival of living organisms in water; however oxygen levels can be influenced by different aspects in the NSR. Industrial activities can increase concentrations of metals, chemicals, and water temperature which lower the dissolved oxygen level. These factors put the health of the water, the aquatic life, and the ecosystem as a whole at risk (Environment Canada 2010). Conductivity is defined as the waters' aptitude to conduct an electrical current through its waterway (Stantec Consulting Ltd. 2005; Mitchell 1994). This current is reflected by the geographical components of the watershed and can be influenced by anthropogenic impacts (Kney and Brandes 2007). These currents also offer a hint of the concentration of dissolved substances present in the water (Stantec Consulting Ltd. 2005; Mitchell 1994). Alkalinity is defined as the buffering capacity of a water body, which can be a major concern because of the increased run-off from urban development zones and agricultural practices. Also, as stated by Valdez-Aguilar and Reed (2007) and Stets and others (2014), there is a positive correlation between alkalinity and pH levels in these areas.

As the province's population has increased over the decades, the impact humans have had on water quality has also increased (Water for Life 2010). Extraction of resources, timber harvesting, agricultural/farming practices, urban centres, and human recreational activities take place along the NSR (Environment Canada 2014; Neufeld 2010; Stantec Consulting Ltd. 2005; North Saskatchewan Watershed Alliance 2005; Mitchell 1994). Humans have altered water flow, landscape health and the volume of water withdrawal; affecting the overall health of the NSR (Government of Alberta 2012; Government Law Centre 2003).

The main contributor to the health of the NSR is Alberta's Industrial Heartland, which encompasses 582 km^2 of Alberta's land mass, covering 5 municipalities: Edmonton, Fort Saskatchewan, Lamont, Strathcona and Sturgeon. To date, there are over 40 companies that call Alberta's Industrial Heartland home (See Appendix C: Figure 16), making this region Canada's largest hydrocarbon processing area (Alberta's Industrial Heartland Association 2014).

The Canadian Environmental Protection Act states water pollution as a condition that can endanger the health and safety of society including: humans, animals and the ecosystem as a whole (Environment Canada 1999). Pollutants can occur from two sources: point and non-point sources (North Saskatchewan River Basin Council 2008). Point source pollutants (See Appendix C: Figure 17) are in general manufactured by industrial, or municipal discharge, causing a drastic change in the river system by increasing its nutrient levels (North Saskatchewan Watershed

Alliance 2005). Municipal effluent discharge can be a mixture of debris, human waste, and suspended solids with an array of chemical contaminants, that is released directly into the NSR (Stantec Consulting Ltd. 2005). There are also 238 storm sewer outfalls (SSOs), 19 combined sewer outfalls (CSOs), 2 water treatment plants (WTP), 2 wastewater treatment plants (WWTP), and 26 petrochemical plants that discharge impurities into the NSR, and its tributaries daily (North Saskatchewan Watershed Alliance 2013; Alberta Environment 2008; Anderson and AECOM 2011). Non-point source pollutants are generally manufactured by land use runoff (Neufeld 2010). As urban run-off increases, the concentrations of nutrients such as phosphorus, nitrogen, sediment, animal waste, petroleum products, and road salts will also increase, altering the quality of the water (Environment Canada 2010). Approximately 33% of Alberta's land is used for agricultural/farming practices, where nitrate and phosphate fertilizers and pesticides are used to increasing its yields (Neufeld 2010; Stantec Consulting Ltd. 2005). Nitrates from fertilizers promote algae growth and strengthen aquatic plants, which harms the quality of the river's water (Environment Canada 2010). Nitrate and phosphate fertilizers are found in relatively high concentration in water bodies surrounding cultivated lands, and consequently DO levels are found to be decreased in these areas (North Saskatchewan Watershed Alliance 2005; North Saskatchewan River Basin Council 2008). Livestock can also increase nitrate and phosphate levels in the NSR, via livestock excrement (Stantec Consulting Ltd. 2005). Therefore, agricultural developments have modified the landscape, affecting the physical, chemical and biological resources (Alberta Environment 2008; Alberta Environment 2009). As a result, the recommended concentrations of nitrate and phosphate by the Canadian Environmental quality guidelines (CEQG) are low enough to prevent stimulation of weed growth (Alberta Environment 1999).

The objectives of this study were to investigate the water quality difference between seasons, the water quality difference between the tributaries and the NSR, the water quality differences between NSR upstream and downstream of each tributary at each location, and the water quality differences between the creek and river tributaries.

Materials and Methods

General Information

This study consisted of sampling the NSR and its four tributaries which includes: Wedgewood Creek, which is upstream of Alberta's Industrial Heartland, Horsehills Creek, Sturgeon River, and Redwater River located downstream of Alberta's Industrial Heartland (See Appendix A: Figure 3). A boat was used to travel from two boat launches for water quality testing. The first boat launch was the Fort Saskatchewan, Alberta, Canada boat launch; this boat launch allowed access to Horsehills Creek, Sturgeon River, and Redwater River. The second boat launch was at 50th street in Edmonton, Alberta, Canada; this boat launch allowed access to Wedgewood Creek. The tests were conducted with identical procedures, which increased the internal validity of the project by controlling extraneous variables and sources of error.

Sampling and Test Procedures

Samples were collected in: spring (end of June 2014), summer (end of August 2014), and fall (end of October 2014). The water quality samples were collected at the mouth of each tributary, 10 feet upstream, and 10 feet downstream of each tributary in the middle of the NSR, using 23 different water quality measures in both wet-day and dry-day weather conditions. However, due to low water levels and weather conditions, fall measurements were only recorded for Sturgeon River, Sturgeon upstream, Redwater River, Redwater upstream and Redwater downstream. Therefore, only spring and summer results were used in the statistical analysis of this study.

At each location, general observations were recorded, including: date, time, water depth, creek/river width, wave height, water colour, topography, sediments present, organisms/animals present, steepness of banks, and weather conditions (See Appendix D). The PASCO Xplorer GLX [1] was used to record a variety of information. The GPS position attachment was used to record the GPS coordinates of the tributary mouth, 10 feet upstream, and 10 feet downstream in the middle of the NSR. The light sensor and weather/anemometer sensor was used to record the air temperature, wind speed, and light intensity at each location. The flow meter was used to indicate the flow rate and the temperature of the water. Lastly, the water quality multi-measure sensor attachment was used to test the conductivity, DO, and pH of the water. These readings were taken from a 50mL centrifuge tube filled with water, sampled 14 inches below the water surface. Additionally, three 50 mL centrifuge tubes were used to collect water samples, from 14 inches below the water surface, at the mouth of each of the four tributaries, 10 feet upstream, and 10 feet downstream in the middle of the NSR. These samples were brought back to Concordia University College of Alberta (CUCA) for further testing.

The samples were collected, transported to CUCA, and analyzed using a variety of water quality equipment. The HACH ecology test kit [2] was used to test the free acidity, total acidity, alkalinity, carbon dioxide, and total hardness at each location; the instructions for these tests were provided by HACH. The phosphate and nitrate ezSample test kits were used to indicate the phosphate and nitrate levels at each location by using the water quality colorimeter, and the PASCO Xplorer GLX; the instructions of these tests were provided by PASCO. The PASCO Xplorer GLX with the attached turbidimeter used to measure the turbidity of the water. The

[1] **PASCO:** http://www.pasco.com/prodCatalog/PS/PS-2002_xplorer-glx/
[2] **HACH:** http://www.hach.com/water-ecology-test-kit-model-al-36dt/product?id=7640217323

operation of the PASCO Xplorer GLX and attachments were illustrated in the user guide provided by PASCO and CUCA. The LaMotte iron test kit was used to test the total iron and ferrous iron of each location; the instructions were provided by LaMotte. The LaMotte lead solder screening colour comparison kit was used to test the presence of lead in the water; these tests were illustrated by the instructional booklet provided by LaMotte. Lastly, Lauryl Tryptose broth and Bresmol Purple (0.04%) Indicator Test was used to test the presence or absence of coliform in the water at each location; these procedures will be provided by CUCA.

Statistical Analysis

Graph Pad Prism 6 was used to represent the total hardness, flow rate, conductivity, dissolved oxygen and turbidity values in the spring and summer, including standard error means for each variable. The wet-day and dry-day readings were averaged for each spring and summer value represented on each graph.

A one-way and two-way analysis of variance (ANOVA) with replication in Microsoft Excel 2007 was used to analyze the data. Post-hoc analysis was performed using SPSS to analyze the significant variables of four ANOVA two-way with replication tests that had sufficient amount of replication.

Fourteen variables, including water temperature, conductivity, pH, DO, flow rate, turbidity, phosphate (low & high), nitrate (low & high), total acidity, alkalinity, carbon dioxide, total hardness, depth of water, and total iron, were in the two-way ANOVA with replication and SPSS post-hoc tests. A one-way ANOVA was used to determine the significance of coliform present within the NSR and its four tributaries.

In the statistical analysis, seasons were used as a factor in the first objective which determined the differences in water quality between the spring and summer seasons. In all other analyses, the season values and the wet-day and dry-day values were included as replications in this study.

Results

Water quality differences between seasons

As shown in Table 1, seasonal differences ($p \leq 0.05$) in water quality variables were found in four locations including, NSR upstream and downstream of Horsehills Creek, and at the mouths of Redwater River and Sturgeon River

Table 1. Summary of ANOVA one-way and two-way analysis comparing the water quality differences of the North Saskatchewan River and its tributaries between seasons.

Sources of Variance	**df 1**	**df 2**	**F-value**	**P-value**
Horsehills upstream	1	32	68.287	1.933x10-09
Horsehills downstream	1	32	34.254	1.66x10-06
Redwater River	1	32	15.846	0.000370
Sturgeon River	1	32	7.999	0.000801

A one-way ANOVA was also conducted which demonstrated a seasonal difference ($p \leq 0.05$) of coliform within the NSR and its 4 tributaries [$F(1,22)=7.333, p=0.0128$].

Water quality differences between tributaries and the North Saskatchewan River

As shown in Table 2, there was a significant difference ($p \leq 0.05$) in the water quality variables of each tributary (Wedgewood Creek, Sturgeon River, Redwater River and Horsehills Creek), and the water quality variables of the NSR upstream and downstream at each tributary location.

Table 2. Summary of ANOVA two-way analysis comparing the tributary and the North Saskatchewan River upstream and downstream water quality variables at each location.

Sources of Variance	**df 1**	**df 2**	**Upstream F-value**	**Upstream P-value**	**Downstream F-value**	**Downstream P-value**
Wedgewood Creek	3	64	11.409	4.357x10-06	11.149	5.588x10-06
Sturgeon River	3	64	4.0135	0.0111	10.260	1.324x10-05
Redwater River	3	64	3.470	0.0211	6.679	0.000541
Horsehills Creek	3	64	2.840	0.0448	3.274	0.0267

Water quality differences between upstream and downstream at each location in the North Saskatchewan River

As shown in Table 3, there was a significant difference ($p \leq 0.05$) between the NSR upstream and downstream water qualities at the Horsehills Creek and Sturgeon River locations.

Table 3. Summary of ANOVA two-way analysis comparing North Saskatchewan River upstream and downstream water qualities at each location.

Sources of Variance	**df1**	**df2**	**F-value**	**P-value**
Horsehills Creek	3	64	29.410	4.509x10-12
Sturgeon River	3	64	10.260	0.0361

A one-way ANOVA was also conducted which demonstrated a significant difference ($p \leq 0.05$) in coliform between the NSR upstream and downstream water qualities at each location [$F(3,28)=3.813$, $p=0.0208$].

Water quality differences between the creek and river tributaries

A two-way ANOVA with replication was conducted which demonstrated a significant difference ($p \leq 0.05$) between the creek and river tributaries [$F(3,192)=11.788$, $p=4.021x10\text{-}07$].

As shown in Table 4, a post-hoc comparison using the LSD test indicated that water temperature, conductivity and alkalinity were significantly different ($p \leq 0.05$) between Redwater River and Wedgewood Creek. Water temperature, conductivity, flow rate, alkalinity total hardness and carbon dioxide were significantly different ($p \leq 0.05$) between Sturgeon River and Wedgewood Creek. Conductivity, flow rate, alkalinity and total hardness were significantly different ($p \leq 0.05$) between Horsehills Creek and Sturgeon River. Lastly, conductivity and pH were significantly different ($p \leq 0.05$) between Horsehills Creek and Sturgeon River.

Table 4. Summary of ANOVA two-way analysis and SPSS post-hoc tests comparing the water quality difference between the creek and river tributaries.

Water Quality Variable	**Sites**	**d*f***	**F-value**	**P-value**	**Post-hoc significance**
Water Temperature	Redwater River & Wedgewood Creek	1	15.164	0.000197	0.023
Water Temperature	Sturgeon River & Wedgewood Creek	1	24.178	4.300x10-06	0.032
Conductivity	Horsehills Creek & Wedgewood Creek	1	37.550	2.773x10-08	0.000
Conductivity	Redwater River & Wedgewood Creek	1	15.164	0.000197	0.001
Conductivity	Sturgeon River & Wedgewood Creek	1	24.178	4.300x10-06	0.008
Conductivity	Horsehills Creek & Sturgeon River	1	5.160	0.0257	0.044
Flow Rate	Horsehills Creek & Wedgewood Creek	1	37.550	2.773x10-08	0.043
Flow Rate	Sturgeon River & Wedgewood Creek	1	24.178	4.300x10-06	0.043
Alkalinity	Horsehills Creek & Wedgewood Creek	1	37.550	2.773x10-08	0.001
Alkalinity	Redwater River & Wedgewood Creek	1	15.164	0.000197	0.003
Alkalinity	Sturgeon River & Wedgewood Creek	1	24.178	4.300x10-06	0.004
Total Hardness	Horsehills Creek & Wedgewood Creek	1	37.550	2.773x10-08	0.003
Total Hardness	Sturgeon River & Wedgewood Creek	1	24.178	4.300x10-06	0.005
pH	Horsehills Creek & Sturgeon River	1	5.160	0.0257	0.053
Carbon Dioxide	Sturgeon River & Wedgewood Creek	1	24.178	4.300x10-06	0.051

As shown in Figure 1, in graph A, total hardness values were minimal in spring and summer, but Wedgewood Creek had the overall highest total hardness. In graph B, the flow rate was the highest in Wedgewood Creek summer season. In graph C, the conductivity was the lowest in Horsehills Creek spring. Lastly, in graph D, DO levels were the lowest in Redwater River summer season.

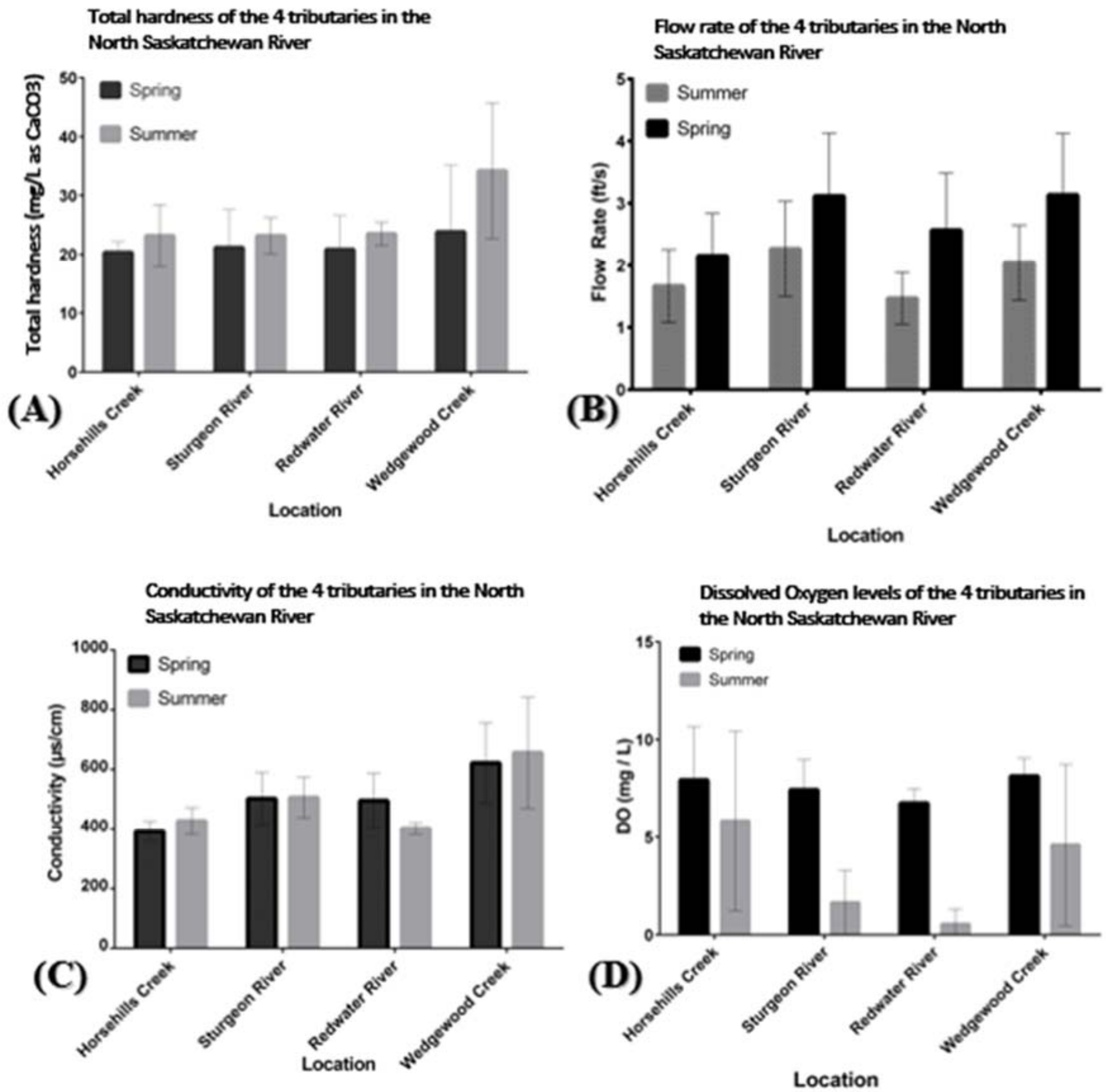

Figure 1. **(A) Total Hardness (mg/L as $CaCO_3$)** for the 4 tributaries: Horsehills Creek, Sturgeon River, Redwater River and Wedgewood Creek. The sample means for spring were: 20.33, 21.17, 20.83, 23.83, respectively. The sample means for summer were: 23.17, 23.17, 23.50, 34.20, respectively. Error bars represent one standard error mean (SEM) [Horsehills Creek spring SEM=0.76, Horsehills Creek summer SEM= 2.15, Sturgeon River spring SEM=2.64, Sturgeon River summer SEM= 1.25, Redwater River spring SEM=2.36, Redwater

River summer SEM=0.81, Wedgewood Creek spring SEM=4.65, Wedgewood Creek summer SEM=5.15]. **(B) Flow rate (ft/s)** for the 4 tributaries: Horsehills Creek, Sturgeon River, Redwater River and Wedgewood Creek. The sample means for spring were: 1.67, 2.27, 1.47, 2.04, respectively. The sample means for summer were: 2.15, 3.12, 2.56, 3.13, respectively. Error bars represent one standard error mean (SEM) [Horsehills Creek spring SEM=0.59, Horsehills Creek summer SEM= 0.69, Sturgeon River spring SEM=0.77, Sturgeon River summer SEM= 1.01, Redwater River spring SEM=0.42, Redwater River summer SEM=0.92, Wedgewood Creek spring SEM=0.60, Wedgewood Creek summer SEM=0.99]. **(C) Conductivity (µs/cm)** for the 4 tributaries: Horsehills Creek, Sturgeon River, Redwater River and Wedgewood Creek. The sample means for spring were: 391.50, 502.33, 4.95.50, 621,83, respectively. The sample means for summer were: 427.00, 506.00, 401.50, 656.40, respectively. Error bars represent one standard error mean (SEM) [Horsehills Creek spring SEM=33.17, Horsehills Creek summer SEM= 44.10, Sturgeon River spring SEM=87.98, Sturgeon River summer SEM= 68.10, Redwater River spring SEM=92.15, Redwater River summer SEM=19.25, Wedgewood Creek spring SEM=135.15, Wedgewood Creek summer SEM=187.00]. **(D) DO (mg/L)** for the 4 tributaries: Horsehills Creek, Sturgeon River, Redwater River and Wedgewood Creek. The sample means for spring were: 7.93, 7.43, 6.75, 8.13, respectively. The sample means for summer were: 5.83, 1.65, 0.55, 4.60, respectively. Error bars represent one standard error mean (SEM) [Horsehills Creek spring SEM=1.11, Horsehills Creek summer SEM= 1.88, Sturgeon River spring SEM=0.63, Sturgeon River summer SEM= 0.67, Redwater River spring SEM=0.30, Redwater River summer SEM=0.31, Wedgewood Creek spring SEM=0.37, Wedgewood Creek summer SEM=1.85].

As shown in Figure 2, Redwater River had the highest turbidity in the spring, while Wedgewood Creek had the lowest turbidity in the summer.

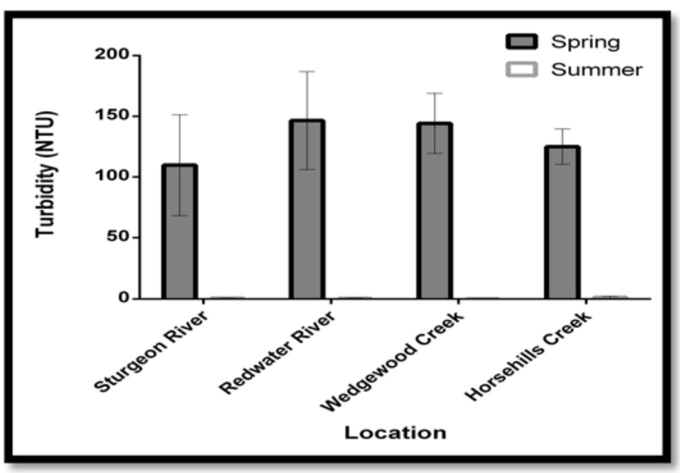

Figure 2. Turbidity (NTU) for the 4 tributaries: Horsehills Creek, Sturgeon River, Redwater River and Wedgewood Creek. The sample means for spring were: 125.05, 109.82, 146.52, 144.23, respectively. The sample means for summer were: 1.47, 0.75, 0.60, 0.25, respectively. Error bars represent one standard error mean (SEM) [Horsehills Creek spring SEM=14.62, Horsehills Creek summer SEM= 0.76, Sturgeon River spring SEM=41.55, Sturgeon River summer SEM= 0.25, Redwater River spring SEM=40.33, Redwater River summer SEM=0.40, Wedgewood Creek spring SEM=24.76, Wedgewood Creek summer SEM=0.14].

Discussion and Conclusion

This analysis of water quality of four tributaries (Wedgewood Creek, Horsehills Creek, Sturgeon River, and Redwater River), and the NSR upstream and downstream of Alberta's Industrial Heartland showed seasonal changes in the water quality variables of the NSR and its tributaries, differences between the tributaries and the NSR water quality variables at each location, differences between the upstream and downstream water quality variables of the NSR at each location, and differences between the water quality variables of the creek and river tributaries.

As shown in Table 1, the NSR upstream of Horsehills Creek water quality variables were the most different between the spring and summer seasons. Thus, according to Anderson and AECOM (2011), seasonal changes can influence the quality of the water within a water body. Neufeld (2010) acknowledges there to be differences in upstream and downstream water quality; this is seen in Tables 1 and 3, where the water quality variables are significantly different. The NSR water quality variables upstream and downstream at Horsehills Creek and Sturgeon River locations were significantly different. As shown in Table 2, the water quality variables are the most different between Wedgewood Creek and the NSR upstream and downstream water quality variables at this location. At the Wedgewood Creek location (See letter A in ArcMap - Appendix A: Figure 3), the tributary is located upstream of the City of Edmonton. Therefore, according to Neufeld (2010), the NSR quality of water upstream of the City of Edmonton is considered to have relatively good quality of water compared to downstream; therefore, as shown in the results, the NSR upstream and downstream water quality variables at the Wedgewood Creek location are the most significantly different. These differences in Table 2 are expected to be due to the water quality differences between the tributary and the water quality of the NSR, which results in the degree of significance that occurred. However, further testing is needed to recognize which variable is most different. According to the North Saskatchewan Watershed Alliance (2005) and Alberta Environment (2008), downstream of the City of Edmonton water quality is degraded in response to many point and non-point sources. Thus, seen in Appendix A: Figure 3- Horsehills (letter B), Sturgeon (letter C), and Redwater River (letter D), these tributaries are located downstream of the City of Edmonton and many point source discharges (See Appendix C: Figure 17). These significances shown in Tables 1, 2, and 3 are hypothesized to be related to the changes in the physical, chemical and biological factors in the tributaries and the NSR (Stantec Consulting Ltd. 2005; Water for Life 2010; Environment Canada 2013). Even though there is a change in the water quality upstream and downstream of Alberta's Industrial Heartland, the overall quality of the NSR is considered in good standing, and improvements in the downstream quality has increased in the last few decades (Neufeld 2010).

The coliform tests demonstrated a significant difference between the seasons and between the NSR upstream and downstream water quality variables at each location. Stantec Consulting Ltd. (2005) has outlined that the presence of the microbial organisms within these water bodies, such as prokaryotes, like bacteria, and unicellular eukaryotes, such as protists, can be caused by farming practices which increase the coliform and bacteria levels in the NSR via livestock waste. Thus, with the increasing population (Water for Life 2010), humans are impacting the quality of the NSR in a dramatic way. The significant differences shown in the results are due to the changes in the water quality variables, causing a difference in coliform within season. In addition, the input of water from the tributaries into the NSR, causes a difference between the upstream and downstream water quality variables at each location (Neufeld 2010; North Saskatchewan Watershed Alliance 2013; Anderson and AECOM 2011;

Aquality Environmental Consulting Ltd. 2012); however, with further research, these assumptions may be verified.

As shown in Table 4, water temperature between Redwater River and Wedgewood Creek, and Sturgeon River and Wedgewood Creek had statistically different water temperatures. These differences in the water temperature are expected to be influenced by the different season, time of day, flow of water, and weather conditions; which participates in the assortment of physical, biological and chemical processes within the river (Mitchell 1994). The flow rate of a river is most diverse when it transports large amounts of suspended soils, and contaminants, which include metals, pathogens, total organic carbon, and bacteria (Anderson and AECOM 2011). Thus, as shown in the results, the flow rate of both Horsehills Creek and Sturgeon River were significantly different than Wedgewood Creek. The flow rate at these locations may have been influenced by the other factors that Mitchell (1994), Anderson and AECOM (2011) had previously stated.

According to the results in Table 4, Horsehills Creek and Wedgewood Creek, Redwater River and Wedgewood Creek, Sturgeon River and Wedgewood Creek, Horsehills Creek and Sturgeon River were statistically different between their conductivity readings. Stantec Consulting Ltd. (2005) and Mitchell (1994) state that conductivity can be connected to two other conditions: flow rate and DO. As the flow rate increases in the NSR, the conductivity levels decrease, usually occurring in the summer; as seen in Figure 1, the results from this study conflict with the predicted relationship. When the flow rate was relatively high at each location, the conductivity was also relatively high. From these results, further testing is needed, with increased replication, to verify these results. Also, according to Stantec Consulting Ltd. (2005) and Mitchell (1994), conductivity and DO show a positive correlation; high DO levels predict high conductivity measurements. This was affirmed by the results shown in Figure 1, where the spring values at each location had high conductivity and DO levels. It is also hypothesized that this may have been the reason why only a few conductivity results (See Table 4) were significant in this study, but further research is needed to confirm this observation.

Alkalinity refers to the acid-neutralizing capability of the water; the concentration of alkalinity is lowest in the spring and summer months, and increases downstream (Mitchell 1994). Consistent with this, in Table 4, the alkalinity levels are statistically significant for Horsehills Creek and Wedgewood Creek, Redwater River and Wedgewood Creek, and Sturgeon River and Wedgewood Creek. As shown in Appendix D: Table 19, the alkalinity levels were relatively low according to Kney and Brandes (2007). However, the results showed alkalinity concentrations to be higher in the tributary mouths than downstream in the NSR at these locations; thus, further testing is needed to verify these results with the predicts.

Table 4 shows that Horsehills Creek pH was significantly different than Sturgeon River pH when determining if there was a water quality variable difference between each tributary. Mitchell (1994) explains that pH levels can affect the distribution of substances and the health of living organisms in the NSR. Typically the pH range in the NSR is beneficial to aquatic life (Mitchell 1994). The results revealed that Horsehills Creek was significantly different than Sturgeon River; these differences in the variables could affect the aquatic life in these tributaries. Lastly, as shown in Appendix D: Table 23, the pH ranges are between 6.5 and 9.0, which is where the United States Environmental Protection Agency (USEPA) deems the pH levels in rivers as safe (Alberta Environment 1999).

The hardness of the water can affect the quality of the NSR (Mitchell 1994). In Table 5, the results verified that there was a significant difference between Horsehills Creek and

Wedgewood Creek total hardness, Redwater River and Wedgewood Creek total hardness, and Sturgeon River and Wedgewood Creek total hardness. Also, as stated by Mitchell (1994), as the flow increased, the hardness of the water decreased in the NSR. Lastly, the hardness levels were minimal, as shown in Figure 1 (A) and in Appendix D: Table 20, during spring and summer months, which were also confirmed by Mitchell (1994).

As shown in Figure 1 (D) and in Appendix D: Table 17, even though there was no statistical difference in the DO levels, there still was a difference between each reading depending on the time of day and season. According to Anderson and AECOM (2011), the levels of DO are low in the summer in response to the higher water temperature present. This is seen in the summer dry-day values where they are vastly lower than the spring wet-day/dry-day and fall wet-day/dry-day values. It is recommended by Alberta Environment that the DO levels should be between 5.5 to 9.5 mg/L depending on the season and the optimal life stages of aquatic life (Alberta Environment 1999). From the results of this study, these DO levels were relatively on par with the guidelines recommended by Alberta Environment. However, further study needs to be conducted to verify these results. Carbon dioxide and dissolved oxygen can become entrapped in rain and deposited into the river stream, in turn changing the water quality in a water body (Environment Canada 2010). From the results shown in Table 4, the carbon dioxide levels were statistically different between Sturgeon River and Wedgewood Creek water quality variables.

As shown in Figure 2, even though there was no statistical difference within the four variables, there was however, a difference within each variable depending on the time of day and season. The varying turbidity readings are due to what Mitchell (1994) alludes to by stating that turbidity quantifies the cloudiness of the water by measurement of existence of organic matter, living organisms, silt, and clay particles in the water, via spectroscopy. A high turbidity reading demonstrates less transferable light penetrating below the water surface, thereby reducing the photosynthetic processes in the aquatic plants. These readings can be seen in the spring wet-day and spring dry-day variables. In this fashion, Mitchell (1994) expresses that high turbidity is usually present in spring and early summer. Also illustrated by Mitchell (1994), turbidity is at its lowest in late summer throughout winter. These readings can be seen in the summer wet-day/dry-day and fall wet-day/dry-day variables (See Appendix D: Table 18).

It has been stated that the quality of the NSR relies on the quality of its tributaries because they directly release their water into the river (Neufeld 2010; North Saskatchewan Watershed Alliance 2013; Anderson and AECOM 2011; Aquality Environmental Consulting Ltd. 2012). Therefore, within Tables 2 and 3, it showed there was significant variance between the water quality of Wedgewood Creek upstream and downstream, Sturgeon upstream and downstream, Redwater upstream and downstream, and Horsehills upstream and downstream.

Overall, it was determined that the NSR water quality variables upstream of Horsehills Creek was the most diverse within the spring and summer seasons. The Wedgewood Creek water quality variables and the NSR water quality variables downstream of the tributary were the most varied. The NSR water quality variables upstream and downstream of Horsehills Creek were the most significantly different. Lastly, the conductivity of Horsehills Creek and Wedgewood Creek were the most different. With the Earth’s overwhelming environmental problems, we as individuals can help protect the waters quality. Individual actions make a difference in protecting the environment (Environment Canada 2010).

In this study, the experimental error may have influenced the results obtained. The sampling procedures were performed as directed, and in replicate, but the equipment may have been dysfunctional. Better statistical analysis methods exist, but were unavailable due to the lack of replicated samples. Additionally, the environmental factors were not identical between replicates, with the inclusion of wet-day/dry-day, and seasonal samples into singular groups.

For future research, statistical testing on the results that have 90% confidence intervals should be explored. Also, greater replication at each location is required, rather than having the replicates feature the different seasons and weather conditions.

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Appendix A: ArcGIS ArcMap

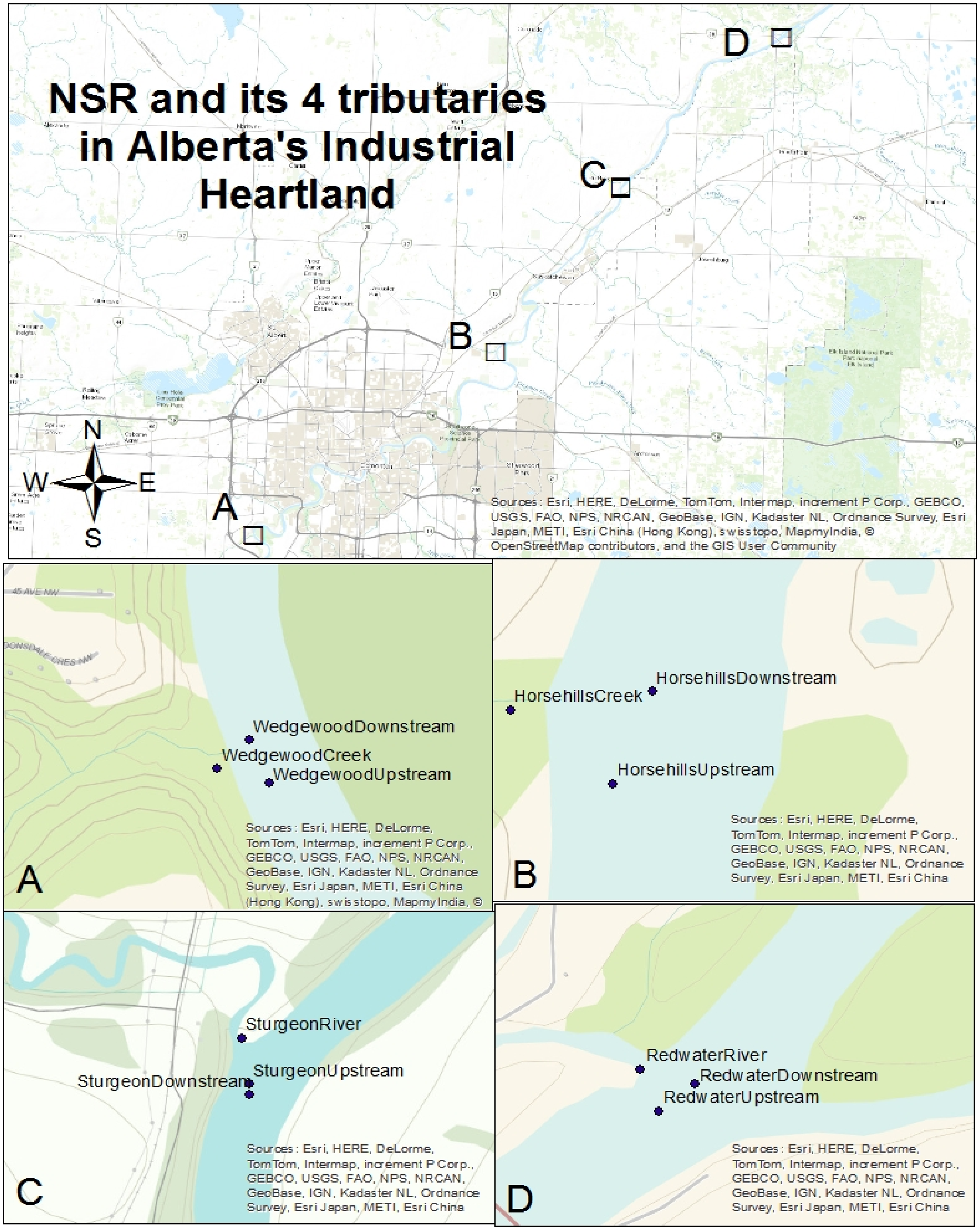

Figure 3. ArcMap of the sample sites located on the North Saskatchewan River in Alberta's Industrial Heartland (ArcGIS 2014).

Appendix B: Photography

Photography Credit: Breanne Bell

Figure 4. Wedgewood Creek (Letter A in ArcMap – Appendix A)

Figure 5. Wedgewood Creek Upstream (Letter A in ArcMap – Appendix A)

Figure 6. Wedgewood Creek Downstream (Letter A in ArcMap – Appendix A)

Figure 7. Horsehills Creek (Letter B in ArcMap – Appendix A)

Figure 8. Horsehills Upstream (Letter B in ArcMap – Appendix A)

Figure 9. Horsehills Downstream (Letter B in ArcMap – Appendix A)

Figure 10. Sturgeon River (Letter C in ArcMap – Appendix A)

Figure 11. Sturgeon River Upstream (Letter C in ArcMap – Appendix A)

Figure 12. Sturgeon River Downstream (Letter C in ArcMap – Appendix A)

Figure 13. Redwater River (Letter D in ArcMap – Appendix A)

Figure 14. Redwater River Upstream (Letter D in ArcMap – Appendix A)

Figure 15. Redwater River Downstream (Letter D in ArcMap – Appendix A)

Appendix C: Maps of Alberta's Industrial Heartland

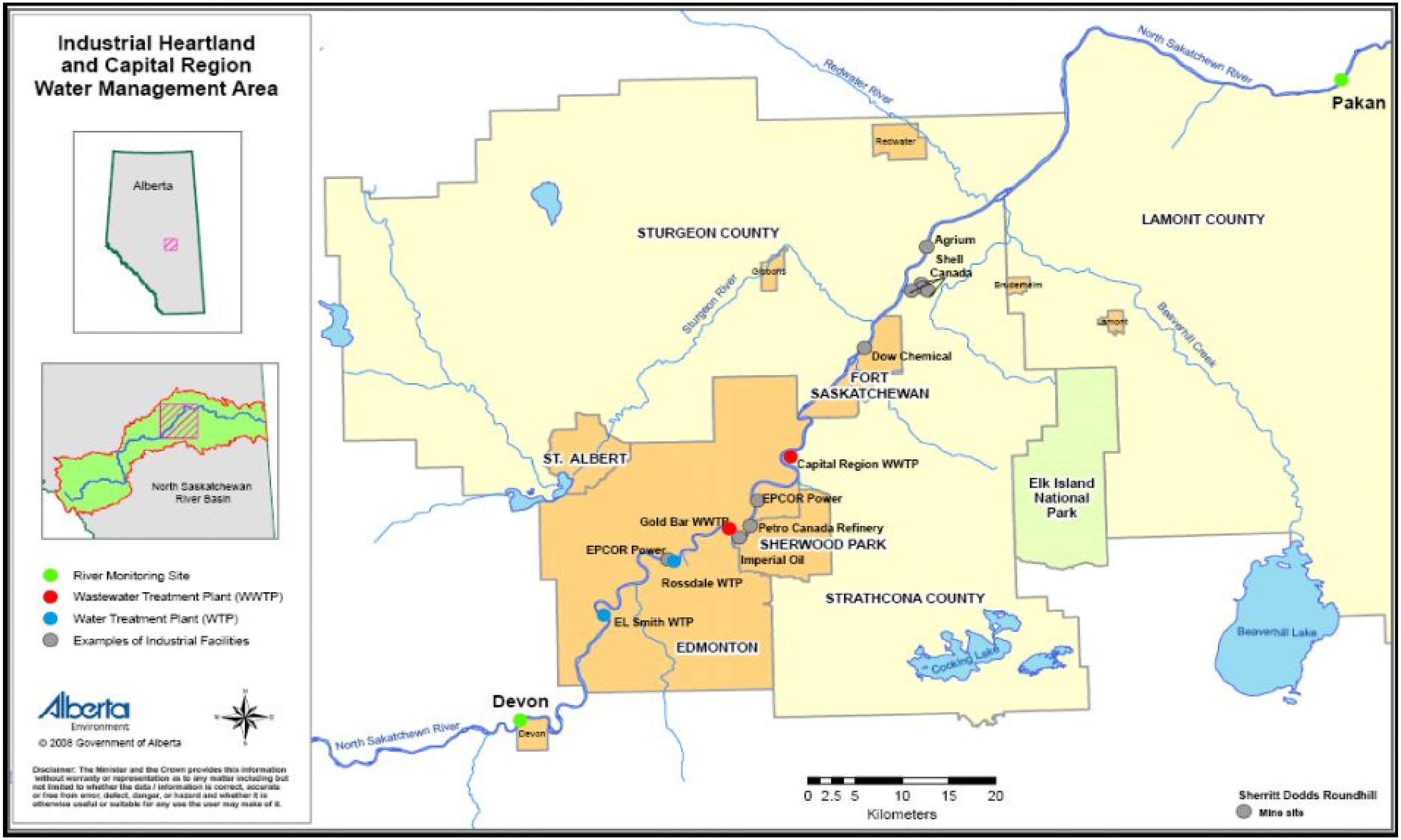

Figure 16. General map of the North Saskatchewan River in the Industrial Heartland (McDonald 2013).

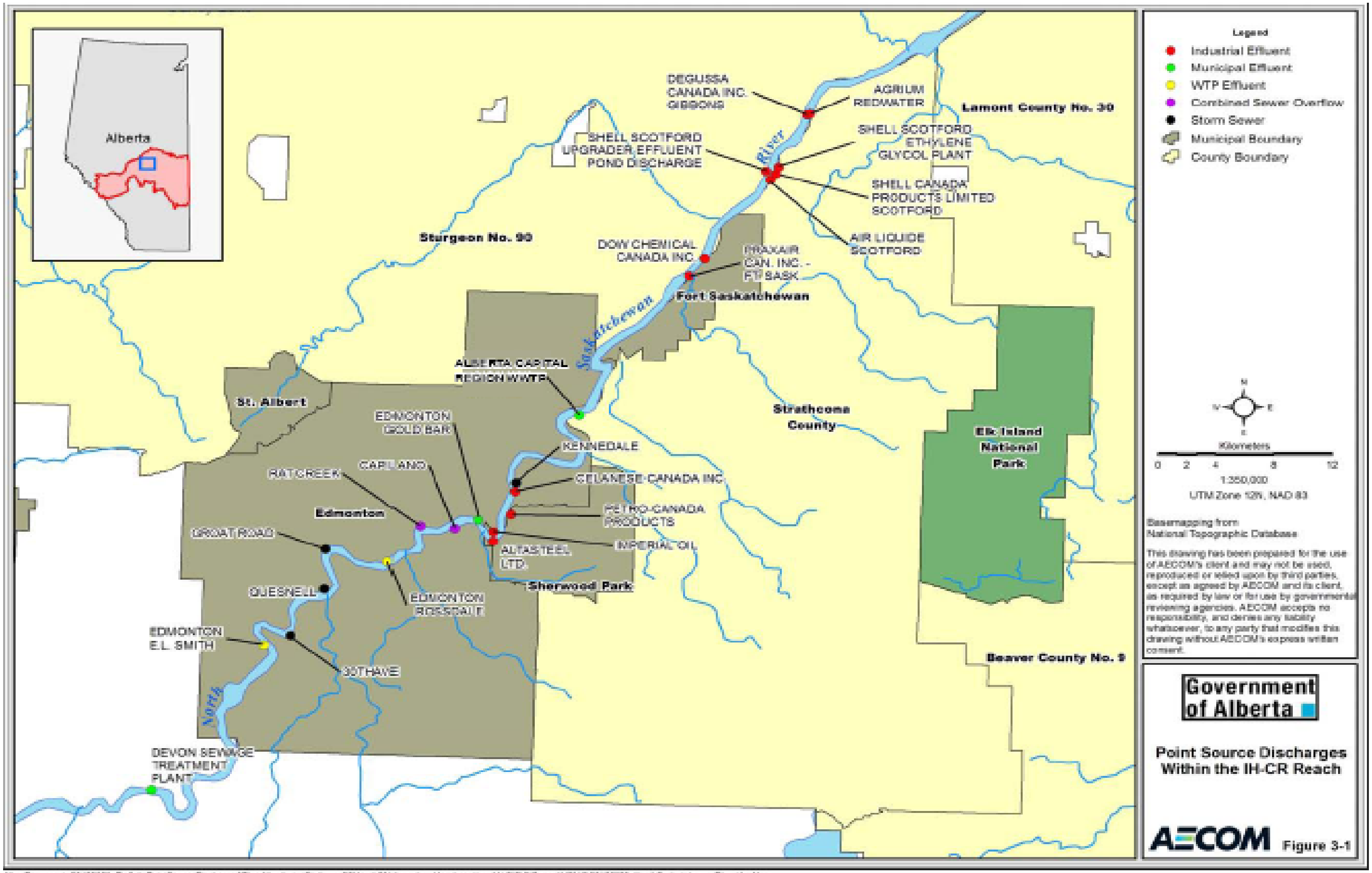

Figure 17.The point source discharges in the North Saskatchewan River within the Industrial Heartland (Anderson and AECOM 2011).

Appendix D: Additional Raw Data

Table 5. Wedgewood Creek, North Saskatchewan River upstream, and North Saskatchewan River downstream general observations for spring and summer.

Location	GPS Coordinates	Date	Time	Water Width (Feet)	Wave Height	Water Color	Topography	Sediment	Organisms/ Animals Present	Steepness of banks (Feet)	Weather Conditions
Creek (Dry)	Lat: 53.480438 Long: -113. 627792	June 22, 2014	16:05	19	None	Murky Brown	Forest, Dead trees falling into water	Sandy Clay	Flies & Mosquito	5	Sunny
Creek (Dry)	Lat: 53.480438 Long: -113. 627792	Aug 29, 2014	18:49	19	None	Clear	Rocks, twigs & branches	Sandy Clay	Flies & Bugs	5	Sunny
Creek (Wet)	Lat: 53.480438 Long: -113. 627792	June 19, 2014	19:35	19	None	Light Brown	Forest, Dead trees falling into water	Sandy Clay	Flies & Mosquito	5	Light Rain
Creek (Wet)	Lat: 53.480438 Long: -113. 627792	Aug 22, 2014	18:30	19	None	Clear	Rocks, twigs & branches	Sandy Clay	Flies	5	Overcast
Upstream (Dry)	Lat: 53.480240 Long: - 113.626465	June 22, 2014	16:30	65	Small Ripples	Murky Brown	Forest, Grasses, Shrubs	Sandy Clay	Flies & Mosquito	10-12	Sunny
Upstream (Dry)	Lat: 53.480240 Long: - 113.626465	Aug 29, 2014	19:03	65	Small to Medium Ripples	Clear to Light Brown	Forest, Grasses, Shrubs	Sandy Clay	Flies & Bugs	10-12	Sunny
Upstream (Wet)	Lat: 53.480240 Long: - 113.626465	June 19, 2014	20:30	65	Small Ripples	Murky Brown	Forest, Grasses, Shrubs	Sandy Clay	Ducks, Flies& Mosquito	10-12	Light Rain
Upstream (Wet)	Lat: 53.480240 Long: - 113.626465	Aug 22, 2014	18:45	65	Small to Medium Ripples	Clear to Light Brown	Forest, Grasses, Shrubs	Sandy Clay	Flies& Bugs	10-12	Overcast
Downstream (Dry)	Lat: 53.480911 Long: - 113.627014	June 22, 2014	16:41	65	Small Ripples	Murky Brown	Forest, Grasses, Shrubs	Sandy Clay	Flies	10-12	Sunny
Downstream (Dry)	Lat: 53.480911 Long: - 113.627014	Aug 29, 2014	19:10	65	Small to Medium Ripples	Clear to Light Brown	Forest, Grasses, Shrubs	Sandy Clay	Flies & Bugs	10-12	Sunny
Downstream (Wet)	Lat: 53.480911 Long: - 113.627014	June 19, 2014	21:00	65	Small Ripples	Murky Brown	Forest, Grasses, Shrubs	Sandy Clay	Flies	10-12	Light Rain/ Overcast
Downstream (Wet)	Lat: 53.480911 Long: - 113.627014	Aug 22, 2014	18:49	65	Small to Medium Ripples	Clear to Light Brown	Forest, Grasses, Shrubs	Sandy Clay	Flies & Bugs	10-12	Overcast

Table 6. Horsehills Creek, North Saskatchewan River upstream, and North Saskatchewan River downstream general observations for spring and summer.

Location	**GPS Coordinates**	**Date**	**Time**	**Water Width (Feet)**	**Wave Height**	**Water Color**	**Topography**	**Sediment**	**Organisms/ Animals Present**	**Steepness of banks (Feet)**	**Weather Conditions**
Creek (Dry)	Lat: 53.632980 Long: -113.325729	June 23, 2014	20:30	20	Small Ripples	Murky Brown	Forest, Dead trees falling into water	Sandy Clay	Flies	10-12	Clear
Creek (Dry)	Lat: 53.632980 Long: -113.325729	Aug 30, 2014	18:54	20	Small Ripples	Clear	Rocks, twigs & branches	Sandy Clay	Flies & Bugs	10-12	Clear
Creek (Wet)	Lat: 53.632980 Long: -113.325729	June 20, 2014	21:40	20	Small Ripples	Murky Brown	Forest, Dead trees falling into water	Sandy Clay	Crickets & Flies	10-12	Overcast
Creek (Wet)	Lat: 53.632980 Long: -113.325729	Aug 23, 2014	18:22	20	Small Ripples	Clear	Rocks, twigs & branches	Sandy Clay	Flies	10-12	Overcast
Upstream (Dry)	Lat: 53.632416 Long: -113.324371	June 23, 2014	21:00	65	Small to Medium Ripples	Clear to Light Brown	Forest, Grasses, Shrubs	Sandy Clay	Flies & Bugs	10-12	Clear
Upstream (Dry)	Lat: 53.632416 Long: -113.324371	Aug 30, 2014	19:01	65	Small to Medium Ripples	Clear to Light Brown	Forest, Grasses, Shrubs	Sandy Clay	Flies & Bugs	10-12	Clear
Upstream (Wet)	Lat: 53.632416 Long: -113.324371	June 20, 2014	22:00	65	Small to Medium Ripples	Clear to Light Brown	Forest, Grasses, Shrubs	Sandy Clay	Flies& Bugs	10-12	Overcast
Upstream (Wet)	Lat: 53.632416 Long: -113.324371	Aug 23, 2014	19:01	65	Small to Medium Ripples	Clear to Light Brown	Forest, Grasses, Shrubs	Sandy Clay	Flies& Bugs	10-12	Overcast
Downstream (Dry)	Lat: 53.633163 Long: -113.322914	June 23, 2014	21:20	65	Small to Medium Ripples	Clear to Light Brown	Forest, Grasses, Shrubs	Sandy Clay	Flies & Bugs	10-12	Clear
Downstream (Dry)	Lat: 53.633163 Long: -113.322914	Aug 30, 2014	19:08	65	Small to Medium Ripples	Clear to Light Brown	Forest, Grasses, Shrubs	Sandy Clay	Flies & Bugs	10-12	Clear
Downstream (Wet)	Lat: 53.633163 Long: -113.322914	June 20, 2014	22:30	65	Small to Medium Ripples	Clear to Light Brown	Forest, Grasses, Shrubs	Sandy Clay	Flies & Bugs	10-12	Overcast
Downstream (Wet)	Lat: 53.633163 Long: -113.322914	Aug 23, 2014	19:09	65	Small to Medium Ripples	Clear to Light Brown	Forest, Grasses, Shrubs	Sandy Clay	Flies & Bugs	10-12	Overcast

Table 7. Sturgeon River, North Saskatchewan River upstream, and North Saskatchewan River downstream general observations for spring, summer and fall.

Location	GPS Coordinates	Date	Time	Water Width (Feet)	Wave Height	Water Color	Topography	Sediment	Organisms/ Animals Present	Steepness of banks (Feet)	Weather Conditions
River (Dry)	Lat: 53.768051 Long: -113.170761	June 22, 2014	20:55	35	Small Ripples	Clear	Forest, Grasses, Shrubs	Sandy Clay	Mosquitoes	20-30	Clear
River (Dry)	Lat: 53.768051 Long: -113.170761	Aug 28, 2014	19:52	35	None	Clear to Light Brown	Forest, Grasses, Shrubs	Sandy Clay	Flies	20-30	Sunny
River (Dry)	Lat: 53.768051 Long: -113.170761	Oct 19, 2014	15:10	20	None	Light Brown	Seaweed & Forest	Sandy Clay	None	20-30	Sunny
River (Wet)	Lat: 53.768051 Long: -113.170761	June 20, 2014	19:08	35	Small Ripples	Clear	Forest, Grasses, Shrubs	Sandy Clay	Fish	20-30	Rain
River (Wet)	Lat: 53.768051 Long: -113.170761	Aug 21, 2014	20:38	35	None	Clear to Light Brown	Forest, Grasses, Shrubs	Sandy Clay	Flies	20-30	Overcast
River (Wet)	Lat: 53.768051 Long: -113.170761	Oct 25, 2014	17:34	20	None	Light Brown	Seaweed &Forest	Sandy Clay	None	20-30	Overcast
Upstream (Dry)	Lat: 53.766693 Long:-113.170303	June 22, 2014	21:05	65	Small to Medium Ripples	Murky Brown	Forest, Grasses, Shrubs	Sandy Clay	Flies & Mosquitoes	10-12	Clear
Upstream (Dry)	Lat: 53.766693 Long:-113.170303	Aug 28, 2014	20:01	65	Small to Medium Ripples	Clear to Light Brown	Forest, Grasses, Shrubs	Sandy Clay	Flies	10-12	Sunny
Upstream (Dry)	Lat: 53.766693 Long:-113.170303	Oct 19, 2014	15:00	55	Small Ripples	Light Brown	Dying Forest, Grasses, Shrubs	Sandy Clay	None	10-12	Sunny
Upstream (Wet)	Lat: 53.766693 Long:-113.170303	June 20, 2014	21:38	65	Small to Medium Ripples	Murky Brown	Forest, Grasses, Shrubs	Sandy Clay	None	10-12	Rain
Upstream (Wet)	Lat: 53.766693 Long:-113.170303	Aug 21, 2014	20:45	65	Small to Medium Ripples	Clear to Light Brown	Forest, Grasses, Shrubs	Sandy Clay	Flies	10-12	Overcast
Upstream (Wet)	Lat: 53.766693 Long:-113.170303	Oct 25, 2014	17:50	55	Medium Ripples	Light Brown	Dying Forest, Grasses, Shrubs	Sandy Clay	None	10-12	Overcast
Downstream (Dry)	Lat: 53.766373 Long: -113.170273	June 22, 2014	21:15	65	Small to Medium Ripples	Murky Brown	Forest, Grasses, Shrubs	Sandy Clay	Flies & Mosquitoes	10-12	Clear
Downstream (Dry)	Lat: 53.766373 Long: -113.170273	Aug 28, 2014	20:07	65	Small to Medium Ripples	Clear to Light Brown	Forest, Grasses, Shrubs	Sandy Clay	Flies	10-12	Sunny
Downstream (Wet)	Lat: 53.766373 Long: -113.170273	June 20, 2014	20:48	65	Small to Medium Ripples	Murky Brown	Forest, Grasses, Shrubs	Sandy Clay	None	10-12	Overcast
Downstream (Wet)	Lat: 53.766373 Long: -113.170273	Aug 21, 2014	21:51	65	Small to Medium Ripples	Clear to Light Brown	Forest, Grasses, Shrubs	Sandy Clay	Flies & Bugs	10-12	Overcast

Table 8. Redwater River, North Saskatchewan River upstream, and North Saskatchewan River downstream general observations for spring, summer and fall.

Location	GPS Coordinates	Date	Time	Water Width (Feet)	Wave Height	Water Color	Topography	Sediment	Organisms/ Animals Present	Steepness of banks (Feet)	Weather Conditions
River (Dry)	Lat: 53.768051 Long: -113.170761	June 22, 2014	19:16	51	None	Light to Dark Brown	Forest, Grasses, Shrubs	Sandy Clay	Flies & Mosquitoes	2-5	Clear
River (Dry)	Lat: 53.768051 Long: -113.170761	Aug 28, 2014	18:58	51	None	Light Brown	Forest, Grasses, Shrubs	Sandy Clay	Flies	2-5	Sunny
River (Dry)	Lat: 53.768051 Long: -113.170761	Oct 19, 2014	15:10	30	Small Ripples	Light Brown	Dying Forest, Grasses, Shrubs	Sandy Clay	Birds	2-5	Clear/ Windy
River (Wet)	Lat: 53.768051 Long: -113.170761	June 20, 2014	17:18	51	None	Light to Dark Brown	Forest, Grasses, Shrubs	Sandy Clay	Flies & Mosquitoes	2-5	Overcast
River (Wet)	Lat: 53.768051 Long: -113.170761	Aug 21, 2014	19:30	51	None	Light Brown	Forest, Grasses, Shrubs	Sandy Clay	Flies	2-5	Overcast
River (Wet)	Lat: 53.768051 Long: -113.170761	Oct 25, 2014	17:34	30	Small Ripples	Light Brown	Dying Forest, Grasses, Shrubs	Sandy Clay	None	2-5	Overcast
Upstream (Dry)	Lat: 53.766693 Long:-113.170303	June 22, 2014	19:50	65	Small Ripples	Murky Brown	Forest, Grasses, Shrubs	Sandy Clay	Flies & Mosquitoes	10-12	Clear
Upstream (Dry)	Lat: 53.766693 Long:-113.170303	Aug 28, 2014	19:07	65	Small to Medium Ripples	Clear to Light Brown	Forest, Grasses, Shrubs	Sandy Clay	Flies & Bugs	10-12	Sunny
Upstream (Dry)	Lat: 53.766693 Long:-113.170303	Oct 19, 2014	15:00	55	Medium Ripples	Light Brown	Dying Forest, Grasses, Shrubs	Sandy Clay	None	10-12	Clear/ Windy
Upstream (Wet)	Lat: 53.766693 Long:-113.170303	June 20, 2014	18:00	65	None	Murky Brown	Forest, Grasses, Shrubs	Sandy Clay	None	10-12	Rain
Upstream (Wet)	Lat: 53.766693 Long:-113.170303	Aug 21, 2014	19:50	65	Small to Medium Ripples	Clear to Light Brown	Forest, Grasses, Shrubs	Sandy Clay	Flies & Bugs	10-12	Overcast
Upstream (Wet)	Lat: 53.766693 Long:-113.170303	Oct 25, 2014	17:50	55	Medium Ripples	Light Brown	Dying Forest, Grasses, Shrubs	Sandy Clay	None	10-12	Overcast
Downstream (Dry)	Lat: 53.766373 Long: -113.170273	June 22, 2014	20:00	65	Small Ripples	Murky Brown	Forest, Grasses, Shrubs	Sandy Clay	Flies & Mosquitoes	10-12	Clear
Downstream (Dry)	Lat: 53.766373 Long: -113.170273	Aug 28, 2014	19:12	65	Small to Med. Ripples	Clear to Light Brown	Forest, Grasses, Shrubs	Sandy Clay	Flies & Bugs	10-12	Sunny
Downstream (Dry)	Lat: 53.766373 Long: -113.170273	Oct 17, 2014	18:50	55	Medium Ripples	Light Brown	Dying Forest, Grasses, Shrubs	Sandy Clay	None	10-12	Clear/ Windy
Downstream (Wet)	Lat: 53.766373 Long: -113.170273	June 20, 2014	18:26	65	None	Murky Brown	Forest, Grasses, Shrubs	Sandy Clay	None	10-12	Rain
Downstream (Wet)	Lat: 53.766373 Long: -113.170273	Aug 21, 2014	19:44	65	Small to Medium Ripples	Clear to Light Brown	Forest, Grasses, Shrubs	Sandy Clay	Flies & Bugs	10-12	Overcast
Downstream (Wet)	Lat: 53.766373 Long: -113.170273	Oct 25, 2014	16:35	55	Medium Ripples	Light Brown	Dying Forest, Grasses, Shrubs	Sandy Clay	None	10-12	Overcast

Table 9. Free Acidity, Lead in Solder, and Ferrous Test at the mouth of each tributary, 10 feet upstream, and 10 feet downstream of each tributary in the middle of the North Saskatchewan River.

	Wedgewood Creek, NSR Upstream & NSR Downstream	Horsehills Creek, NSR Upstream & NSR Downstream	Sturgeon River, NSR Upstream & NSR Downstream	Redwater River, NSR Upstream &NSR Downstream
Free Acidity	0	0	0	0
Lead in Solder	Negative	Negative	Negative	Negative
Ferrous Test (ppm)	0	0	0	0

Table 10. Air temperature (˚C) at the mouth of each tributary, 10 feet upstream, and 10 feet downstream of each tributary in the middle of the North Saskatchewan River.

	Spring Dry	Spring Wet	Summer Dry	Summer Wet	Fall Dry	Fall Wet
Wedgewood Creek	22.9	18.7	19.7	17.4	N/A	N/A
Wedgewood Upstream	19.1	17.5	16.3	18	N/A	N/A
Wedgewood Downstream	20.4	17.4	16.3	17.1	N/A	N/A
Horsehills Creek	20.7	14.6	15.9	19.8	N/A	N/A
Horsehills Upstream	20.5	14.3	18.3	17.4	N/A	N/A
Horsehills Downstream	19.6	14.3	18.7	17.1	N/A	N/A
Sturgeon River	18.4	18.8	16.9	11.8	17.5	7.1
Sturgeon Upstream	18.2	19.2	16.2	12	19.1	6.8
Sturgeon Downstream	18.6	19.1	15.7	13.9	N/A	N/A
Redwater River	27.3	19.3	18.3	14.8	13.7	6.9
Redwater Upstream	28	19.7	18.7	14.3	10.2	7.2
Redwater Downstream	25.4	18.7	19.4	12.9	10.5	8.5

Table 11. Wind speed (m/s) at the mouth of each tributary, 10 feet upstream, and 10 feet downstream of each tributary in the middle of the North Saskatchewan River.

	Spring Dry	**Spring Wet**	**Summer Dry**	**Summer Wet**	**Fall Dry**	**Fall Wet**
Wedgewood Creek	0.3	0.5	2.4	0.1	N/A	N/A
Wedgewood Upstream	1.7	0.6	2.6	0	N/A	N/A
Wedgewood Downstream	0.4	0.4	2.3	1.3	N/A	N/A
Horsehills Creek	1.1	0.6	0.9	2.2	N/A	N/A
Horsehills Upstream	0.3	0.6	2.6	0.6	N/A	N/A
Horsehills Downstream	0.2	0.6	0.4	0.5	N/A	N/A
Sturgeon River	0.4	2.1	0	0.5	4.4	2.4
Sturgeon Upstream	0.3	0.9	0	0	4.3	3.8
Sturgeon Downstream	0.2	0.9	0	0	N/A	N/A
Redwater River	0.5	1.0	0	2.2	1.4	2.5
Redwater Upstream	0.6	0.3	0	2.3	0	3.1
Redwater Downstream	0.8	0.5	0	0.6	0	4.2

Table 12. Light intensity (Lux) at the mouth of each tributary, 10 feet upstream, and 10 feet downstream of each tributary in the middle of the North Saskatchewan River.

	Spring Dry	**Spring Wet**	**Summer Dry**	**Summer Wet**	**Fall Dry**	**Fall Wet**
Wedgewood Creek	2262.44	224.30	157.14	27.60	N/A	N/A
Wedgewood Upstream	213.44	57.68	115.18	190.01	N/A	N/A
Wedgewood Downstream	23.7	44.86	155.78	107.09	N/A	N/A
Horsehills Creek	3.78	2.63	60.64	61.20	N/A	N/A
Horsehills Upstream	24.67	200.00	74.58	130.44	N/A	N/A
Horsehills Downstream	112.69	199.00	78.58	69.41	N/A	N/A
Sturgeon River	20.57	249.54	32.38	12.50	189.07	6.41
Sturgeon Upstream	102.08	108.95	30.95	4.50	125.17	12.69
Sturgeon Downstream	126.51	217.90	27.81	5.51	N/A	N/A
Redwater River	169.25	435.79	54.66	122.82	5.26	65.24
Redwater Upstream	157.44	326.84	77.1	100.46	0.11	57.68
Redwater Downstream	225.33	211.49	74.38	131.08	0.38	92.32

Table 13. Nitrate low (mg/L) at the mouth of each tributary, 10 feet upstream, and 10 feet downstream of each tributary in the middle of the North Saskatchewan River.

	Spring Dry	**Spring Wet**	**Summer Dry**	**Summer Wet**	**Fall Dry**	**Fall Wet**
Wedgewood Creek	0.09	0.18	0.31	0.38	N/A	N/A
Wedgewood Upstream	0.11	0.32	0.07	1.6	N/A	N/A
Wedgewood Downstream	0.11	0.14	0.18	0.27	N/A	N/A
Horsehills Creek	0.09	0.39	1.26	0.46	N/A	N/A
Horsehills Upstream	0.09	0.41	0.91	0.40	N/A	N/A
Horsehills Downstream	0.05	0.38	0.71	0.32	N/A	N/A
Sturgeon River	0.02	0.02	0.30	0.40	0.56	0.17
Sturgeon Upstream	0.07	0.32	5.02	0.45	0.02	0.02
Sturgeon Downstream	0.10	0.29	1.41	0.47	N/A	N/A
Redwater River	0.02	0.09	1.28	1.89	1.89	0.92
Redwater Upstream	0.11	0.35	0.41	3.05	0.02	0.02
Redwater Downstream	0.13	0.23	0.37	0.03	0.02	0.02

Table 14. Nitrate high (mg/L) at the mouth of each tributary, 10 feet upstream, and 10 feet downstream of each tributary in the middle of the North Saskatchewan River.

	Spring Dry	**Spring Wet**	**Summer Dry**	**Summer Wet**	**Fall Dry**	**Fall Wet**
Wedgewood Creek	0.14	0.23	0.35	0.42	N/A	N/A
Wedgewood Upstream	0.16	0.36	0.13	1.57	N/A	N/A
Wedgewood Downstream	0.16	0.19	0.23	0.32	N/A	N/A
Horsehills Creek	0.15	0.43	1.25	0.50	N/A	N/A
Horsehills Upstream	0.14	0.45	0.92	0.43	N/A	N/A
Horsehills Downstream	0.11	0.42	0.73	0.36	N/A	N/A
Sturgeon River	0.08	0.08	0.35	0.44	0.59	0.23
Sturgeon Upstream	0.12	0.36	4.8	0.49	0.08	0.08
Sturgeon Downstream	0.16	0.33	1.39	0.51	N/A	N/A
Redwater River	0.08	0.15	1.27	1.84	1.84	0.08
Redwater Upstream	0.16	0.39	0.45	2.94	0.08	0.08
Redwater Downstream	0.18	0.28	0.41	0.09	0.08	0.08

Table 15. Phosphate low (mg/L) at the mouth of each tributary, 10 feet upstream, and 10 feet downstream of each tributary in the middle of the North Saskatchewan River.

	Spring Dry	**Spring Wet**	**Summer Dry**	**Summer Wet**	**Fall Dry**	**Fall Wet**
Wedgewood Creek	0.15	-0.05	2.08	-0.09	N/A	N/A
Wedgewood Upstream	0.28	9.22	0.80	-0.07	N/A	N/A
Wedgewood Downstream	0.38	0.87	1.57	-0.09	N/A	N/A
Horsehills Creek	0.22	0.45	2.22	-0.08	N/A	N/A
Horsehills Upstream	0.38	0.59	1.20	-0.09	N/A	N/A
Horsehills Downstream	0.38	0.52	0.40	-0.09	N/A	N/A
Sturgeon River	0.16	1.87	0.65	0.49	0.12	-0.11
Sturgeon Upstream	0.19	0.72	0.81	-0.08	0.07	-0.04
Sturgeon Downstream	0.54	0.81	2.29	-0.08	N/A	N/A
Redwater River	0.18	0.26	0.10	-0.08	-0.08	-0.05
Redwater Upstream	0.40	0.78	0.63	-0.09	0.06	0.07
Redwater Downstream	0.42	0.69	0.42	-0.06	-0.06	0.03

Table 16. Phosphate high (mg/L) at the mouth of each tributary, 10 feet upstream, and 10 feet downstream of each tributary in the middle of the North Saskatchewan River.

	Spring Dry	**Spring Wet**	**Summer Dry**	**Summer Wet**	**Fall Dry**	**Fall Wet**
Wedgewood Creek	0	-0.20	2.2	-0.30	N/A	N/A
Wedgewood Upstream	0.20	10.3	0.70	-0.20	N/A	N/A
Wedgewood Downstream	0.20	0.80	1.6	-0.30	N/A	N/A
Horsehills Creek	0.10	0.40	2.16	-0.20	N/A	N/A
Horsehills Upstream	0.30	0.50	1.20	-0.30	N/A	N/A
Horsehills Downstream	0.30	0.40	0.30	-0.30	N/A	N/A
Sturgeon River	0	1.9	0.60	0.40	0	0
Sturgeon Upstream	0.10	0.7	0.80	-0.20	-0.10	-0.10
Sturgeon Downstream	0.50	0.80	2.4	-0.20	N/A	N/A
Redwater River	0.10	0.10	0	-0.20	-0.20	-0.10
Redwater Upstream	0.30	0.70	1.7	-0.30	-0.10	0.10
Redwater Downstream	0.30	0.60	0.30	-0.20	-0.20	-0.10

Table 17. DO (mg/L) at the mouth of each tributary, 10 feet upstream, and 10 feet downstream of each tributary in the middle of the North Saskatchewan River.

	Spring Dry	**Spring Wet**	**Summer Dry**	**Summer Wet**	**Fall Dry**	**Fall Wet**
Wedgewood Creek	7.8	8.9	0	8.7	N/A	N/A
Wedgewood Upstream	7.3	9.6	0.3	7.4	N/A	N/A
Wedgewood Downstream	7.4	7.8	0.9	6.6	N/A	N/A
Horsehills Creek	5.3	7.7	1.1	10.7	N/A	N/A
Horsehills Upstream	4.8	8.8	2.2	10.6	N/A	N/A
Horsehills Downstream	12.3	8.7	1.8	8.6	N/A	N/A
Sturgeon River	6.0	6.4	0	1.0	10.2	10.9
Sturgeon Upstream	9.7	7.1	0.9	2.2	7.3	14.0
Sturgeon Downstream	9.0	6.4	1.1	4.7	N/A	N/A
Redwater River	7.4	7.7	0	0.4	6.8	15.1
Redwater Upstream	5.7	6.7	0.3	2.1	9.0	10.0
Redwater Downstream	6.2	6.8	0.3	0.2	8.2	8.3

Table 18. Turbidity (NTU) at the mouth of each tributary, 10 feet upstream, and 10 feet downstream of each tributary in the middle of the North Saskatchewan River.

	Spring Dry	**Spring Wet**	**Summer Dry**	**Summer Wet**	**Fall Dry**	**Fall Wet**
Wedgewood Creek	67.1	78.7	0.20	0.50	N/A	N/A
Wedgewood Upstream	148.8	205.4	0.80	0	N/A	N/A
Wedgewood Downstream	156.2	209.4	0	0	N/A	N/A
Horsehills Creek	89.2	155.6	0	0	N/A	N/A
Horsehills Upstream	109.9	109.9	4.6	0	N/A	N/A
Horsehills Downstream	103.5	182.2	2.5	1.7	N/A	N/A
Sturgeon River	0	0	1.8	0.40	0.70	1.2
Sturgeon Upstream	97.8	227.4	0.70	0.70	2.8	0.9
Sturgeon Downstream	106.9	226.8	0	0.90	N/A	N/A
Redwater River	48.8	63.8	1.3	0	16.2	1.5
Redwater Upstream	126.3	211.90	0	2.3	1.30	1.6
Redwater Downstream	117.8	310.5	0	0	0	0.30

Table 19. Alkalinity (mg/L as $CaCO_3$) at the mouth of each tributary, 10 feet upstream, and 10 feet downstream of each tributary in the middle of the North Saskatchewan River.

	Spring Dry	**Spring Wet**	**Summer Dry**	**Summer Wet**	**Fall Dry**	**Fall Wet**
Wedgewood Creek	11	13	16	13	N/A	N/A
Wedgewood Upstream	5	6	8	8	N/A	N/A
Wedgewood Downstream	6	5	8	8	N/A	N/A
Horsehills Creek	7	6	9	8	N/A	N/A
Horsehills Upstream	6	6	10	8	N/A	N/A
Horsehills Downstream	6	6	6	6	N/A	N/A
Sturgeon River	8	9	10	8	10	8
Sturgeon Upstream	6	5	6	6	5	7
Sturgeon Downstream	6	5	5	4	N/A	N/A
Redwater River	8	7	12	7	7	13
Redwater Upstream	5	5	6	8	4	6
Redwater Downstream	6	5	5	7	4	5

Table 20. Total Hardness (mg/L as $CaCO_3$) at the mouth of each tributary, 10 feet upstream, and 10 feet downstream of each tributary in the middle of the North Saskatchewan River.

	Spring Dry	**Spring Wet**	**Summer Dry**	**Summer Wet**	**Fall Dry**	**Fall Wet**
Wedgewood Creek	46	26	44	49	N/A	N/A
Wedgewood Upstream	18	16	24	25	N/A	N/A
Wedgewood Downstream	18	19	26	29	N/A	N/A
Horsehills Creek	22	18	28	28	N/A	N/A
Horsehills Upstream	21	22	19	23	N/A	N/A
Horsehills Downstream	21	18	15	26	N/A	N/A
Sturgeon River	30	23	21	28	25	17
Sturgeon Upstream	20	14	21	22	14	15
Sturgeon Downstream	26	14	26	21	N/A	N/A
Redwater River	31	22	23	22	22	21
Redwater Upstream	20	17	26	22	11	18
Redwater Downstream	21	14	22	26	11	17

Table 21. Conductivity (µs/cm) at the mouth of each tributary, 10 feet upstream, and 10 feet downstream of each tributary in the middle of the North Saskatchewan River.

	Spring Dry	**Spring Wet**	**Summer Dry**	**Summer Wet**	**Fall Dry**	**Fall Wet**
Wedgewood Creek	1152	893	1167	1056	N/A	N/A
Wedgewood Upstream	387	397	336	327	N/A	N/A
Wedgewood Downstream	330	572	371	396	N/A	N/A
Horsehills Creek	391	554	453	629	N/A	N/A
Horsehills Upstream	352	350	403	341	N/A	N/A
Horsehills Downstream	347	355	399	337	N/A	N/A
Sturgeon River	840	707	641	771	716	343
Sturgeon Upstream	366	409	380	490	323	600
Sturgeon Downstream	338	354	402	352	N/A	N/A
Redwater River	877	666	381	444	475	746
Redwater Upstream	410	354	414	453	353	347
Redwater Downstream	333	333	393	324	382	343

Table 22. Water Temperature (ºC) at the mouth of each tributary, 10 feet upstream, and 10 feet downstream of each tributary in the middle of the North Saskatchewan River.

	Spring Dry	**Spring Wet**	**Summer Dry**	**Summer Wet**	**Fall Dry**	**Fall Wet**
Wedgewood Creek	19.8	16.4	16.3	15.1	N/A	N/A
Wedgewood Upstream	18.3	15.6	17.8	17.5	N/A	N/A
Wedgewood Downstream	18.4	15.6	17.8	17.5	N/A	N/A
Horsehills Creek	19.3	16.6	17.7	15.8	N/A	N/A
Horsehills Upstream	18.5	16.1	17.9	15.3	N/A	N/A
Horsehills Downstream	18.5	16.1	18.2	17.8	N/A	N/A
Sturgeon River	21.2	29.9	19.1	17.5	8.3	4.9
Sturgeon Upstream	18.3	17.9	18.7	18.2	10.1	6.5
Sturgeon Downstream	18.2	16.4	18.8	18.4	N/A	N/A
Redwater River	20.8	19.4	20.7	18.6	8.7	4.3
Redwater Upstream	19.2	17.3	19.2	18.5	9.1	5.8
Redwater Downstream	18.4	17.2	19.2	18.4	9.1	6.2

Table 23.pH at the mouth of each tributary, 10 feet upstream, and 10 feet downstream of each tributary in the middle of the North Saskatchewan River.

	Spring Dry	**Spring Wet**	**Summer Dry**	**Summer Wet**	**Fall Dry**	**Fall Wet**
Wedgewood Creek	8.17	8.03	8.08	7.99	N/A	N/A
Wedgewood Upstream	8.03	7.13	8.14	7.64	N/A	N/A
Wedgewood Downstream	8.18	8.03	8.20	7.84	N/A	N/A
Horsehills Creek	8.11	7.83	8.15	7.74	N/A	N/A
Horsehills Upstream	8.38	7.90	8.01	7.91	N/A	N/A
Horsehills Downstream	8.22	7.91	8.07	7.93	N/A	N/A
Sturgeon River	8.32	8.23	8.31	8.12	8.08	7.89
Sturgeon Upstream	7.96	7.93	8.04	7.65	7.62	7.92
Sturgeon Downstream	8.01	7.95	8.08	8.03	N/A	N/A
Redwater River	8.25	8.09	8.51	7.80	7.13	8.15
Redwater Upstream	8.30	7.96	8.16	7.76	7.22	7.97
Redwater Downstream	8.16	7.82	7.88	7.64	6.72	8.50