RUSC149

City of Cold Lake

Cold Lake Regional Wastewater Treatment Feasibility Study

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Project Number:

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June 30, 2011

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Dear Mr. Khan:

Project No: 60157998

Regarding: Cold Lake Regional Wastewater Treatment Feasibility Study

We are pleased to submit an electronic copy of our report on the Cold Lake Regional Wastewater System Feasibility Study for the Cold Lake Regional Utility Services Commission.

Sincerely,
AECOM Canada Ltd.

Ryan Reich P.Eng.
Project Manager

vf:td
Encl.
cc:

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Executive Summary

The Cold Lake Regional Utility Services Commission (RUSC) retained AECOM Canada Ltd. to provide engineering services to conduct a nutrient control strategy study for municipal effluents discharging to the Beaver River. This study has been supported by the Green Municipal Fund.

The City's sanitary collection system and wastewater treatment system is owned and operated by the Cold Lake RUSC, and currently serves the City population and Cold Lake First Nation 149A located east of the City. Cold Lake First Nation 149B located north of the City and Cold Lake First Nation 149, the 4-Wing Air Base and the M.D. of Bonnyville operate separate wastewater systems. The existing WWTF was originally constructed in 1983 as a facultative lagoon system and includes wastewater stabilization and storage ponds, a septage receiving station, and a treated wastewater outfall. The treated effluent is discharged to the Beaver River. The plant has undergone several upgrades between 2005 and 2009

The 2006 Canadian Census reports a population of 11,991 for the City, including approximately 2,800 people at the 4-Wing Air Base. The 2006 Canadian Census reports a population of approximately 590 for Cold Lake First Nations 149, 149A and 149B. The immediate area surrounding the City boundary in the M.D. of Bonnyville, defined as the Plan Area, had a population of approximately 100 people in 2006.

The projected population of the areas being considered for inclusion in the regional wastewater treatment system is 30,000 in year 2037. The flows have been summarized in **Table ES.1**.

Table ES.1: Summary Cold Lake Flows

Summary	Design Parameter
Population	30,000
Per Capita Flow	475 L/capita/d
Average Flow	14.8 ML/d
Peak Flow	36.7 ML/d

To determine the target limits for the nutrient removal and effluent quality, this study included a receiving water assessment. . The monitoring and modeling conducted indicates that "worst case" conditions in the Beaver River often do not meet comparison guidelines under the existing treatment regime and sometimes exceed guideline values in absence of the RUSC discharge for various parameters. Although the water quality in the Beaver River downstream of the proposed RUSC WWTF upgrade is significantly affected by upstream concentrations of various parameters (such as total phosphorus) and the capabilities of the proposed WWTF technology, guidelines will be achieved under select conditions. The proposed WWTF upgrade is expected to result in a significant improvement in the water quality of the Beaver River under all but winter conditions in comparison to the existing WWTF.

Table ES.1, below summarizes the estimated effluent limits, which have yet to be confirmed by Alberta Environment.

Table ES.1.1: Proposed Effluent Limits for the Discharge to the Beaver River

Parameter	Limit	Sampling
CBOD	<10 mg/L	monthly arithmetic mean
TSS	<10 mg/L	monthly arithmetic mean
Total P	<0.15 mg/L	monthly arithmetic mean
NH_3-N	<6.0 mg/L (winter)	monthly arithmetic mean
NH_3-N	<3.0 mg/L (summer)	monthly arithmetic mean
E. Coli	<200 per 100 mL	monthly geometric mean
pH	6.5 to 9.5	-

Another option for the wastewater effluent that was reviewed as part of this study was the possibility of supply effluent water to local industries to reduce conventional freshwater demand. Unfortunately after some preliminary talks with the industries it was deemed cost prohibitive at this time considering the large distance to convey the water.

The study compared several process options for the new wastewater facility including, conventional activated sludge (CAS) with chemical and biological phosphorus removal, membrane bioreactors (MBR), sequencing batch reactors (SBR), moving bed biofilm reactors (MBBR), submerged attached growth reactors (SAGR), engineered treatment wetlands (ETW) and intermittent sand filters (ISF). These different options were evaluated based on economic, technical, operational, social and environmental factors as deemed appropriate by the RUSC. The analysis resulted in the MBBR being the most promising option. Other components of the proposed plant include screening, grit removal, effluent filtration, chemical dosing, and UV disinfection, as well as an administration building and workshop.

Once the wastewater treatment process was selected, solids handling requirements were considered. The sludge that settles and collects in the lagoons will need to be removed. This sludge can be dewatered using Geotubes as the facility is doing currently and then trucked for landfill disposal.

The MBBR technology should be built such that the media can be added as flows and population increase. The current estimates reflect a large MBBR tank split into two streams for some redundancy. Although it would be cost effective to build the entire system all at once, it is not necessary and funds are limited. In order to fund the project responsibly and affordably for the individual service user, it is advisable to build for half the treatment capacity of the design population and delay increasing the rest of the capacity until the proved necessary by the growth of the service area..

The capital cost for an upgraded WWTP that serves a population of 30,000 and uses the MBBR treatment process is estimated at approximately $33,700,000. If only half the capacity is constructed for the first phase of the new wastewater treatment plant, that minimizes the increase from $24.60/month to $67.50/month. The full system would be a monthly cost of $78.40 per service user. In the long run staging the wastewater treatment in two phases will cost the client more but will ease the burden on the smaller population for the short term. A breakdown of the user fees can be seen in **Table ES.2**.

Table ES.2: User Fees

Cost	MBBR Full System	MBBR 2 Stages
Construction Cost	$ 33,700,000	$ 22,700,000
Funding 35%	$ 11,865,000	$ 7,992,000
Yearly Interest Payment on New Treatment 4% over 20 years	$ 1,607,000	$ 1,082,000
Operation & Maintenance Treatment	$ 2,160,000	$ 1,080,000
User Rate	$ 78.40	$ 67.50

The RUSC must upgrade their wastewater treatment to meet stricter environmental limits and increase the capacity of their wastewater treatment to keep up with the projected population growth of the City and surrounding areas. The user rate increase is substantial and while there is not significant savings between the full construction and a staged approach ($78.40 versus $67.50 per month), it may still be worthwhile for the individual user.

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1. Introduction

1.1 Introduction

The Cold Lake Regional Utility Services Commission (RUSC) retained AECOM Canada Ltd. to provide engineering services to conduct a nutrient control strategy study for municipal effluents discharging to the Beaver River.

The RUSC received additional funding for this report from the Green Municipal Fund. There are many environmental issues involved with this study which made application to the Green Municipal Fund a good partnership.

1.2 Background

The City of Cold Lake (City) is located approximately 290 km northeast of Edmonton, adjacent to the Alberta/Saskatchewan border in the Municipal District (M.D.) of Bonnyville, Alberta. The City was integrated in 1996 through the merger of the 4-Wing Air Base (formerly Town of Medley), the Town of Grand Centre and the Town of Cold Lake. The area surrounding the City is comprised of Cold Lake First Nation lands to the north, south and east, undeveloped land to the west, and Cold Lake to the northeast.

The City collection system and WWTF currently serves the City population and Cold Lake First Nation 149A located east of the City. Cold Lake First Nation 149B located north of the City and Cold Lake First Nation 149 located south of the City operate with separate wastewater systems.

The 4-Wing Air Base currently operates a separate sanitary collection system and mechanical wastewater treatment facility on the base. The wastewater treatment facility discharges to Marie Creek (Municipal Development Plan 2007-2037), a tributary of the Beaver River.

To service the rural community, the M.D. of Bonnyville provides access to three sanitary wastewater lagoons in the hamlets of Ardmore, Fort Kent and Therien, which are located more than 25 km from the City.

The City's sanitary collection system and wastewater treatment system is owned and operated by the Cold Lake RUSC (Municipal Development Plan, 2007). Wastewater from the sanitary collection system is pumped from Building 9 Lift Station to the wastewater treatment facility (WWTF) located outside the city limits to the southeast. The existing WWTF consists of wastewater stabilization and storage ponds, a sludge drying cell and a treated wastewater outfall. Specifically, the City's WWTF includes the following components:

- Septage receiving station
- Aerated wastewater stabilization ponds:
  - One complete mix cell (15,600 m^3)
  - One partial mix cell (15,600 m^3)
  - One facultative pond (183,000 m^3)
- Storage ponds:
  - North pond – Storage Pond 1 (284,000 m^3)
  - South pond – Storage Pond 2 (584,000 m^3)

- Two anaerobic cells used to divert flow when de-sludging the aerobic cells or in an emergency
- One sludge drying cell (17,000 m^3)
- Effluent flow control and sampling
- Treated wastewater outfall discharging to the Beaver River

Septage is added to the forcemain that directs all the wastewater flow to the aerated cells. Wastewater flow is then directed from the aerated cells to the facultative pond, followed by the storage ponds. The treated effluent flows from Storage Pond 2 through the outfall line to the Beaver River.

The WWTF was originally constructed in 1983 as a facultative lagoon system. In 2005, the RUSC upgraded the system by converting two of the anaerobic cells to aerated cells to reduce biochemical oxygen demand (BOD). In 2005, the south storage pond volume was increased by raising the berm level. Also in 2005, effluent flow control was upgraded. In 2009, a septage receiving station was constructed west of the aerated lagoons. The WWTF currently operates under Alberta Environment Licence No. 1585-03-00.

Wastewater solids are removed periodically from the aerated cells. Historically the solids were pumped to a solids pit north of the facultative lagoon to decant and decompose. The City received approval to decant as much water as possible from the solids pit and permanently cap it (2007 Sludge Mitigation Study). In 2008, solids were removed from the aerated complete and partial mix cells and placed in Geotubes for dewatering. It is expected that the solids in the Geotubes will be disposed of off-site.

1.3 Project Objectives

The project objective is to develop a nutrient control strategy for the municipal effluent discharging to the Beaver River, as future quality-based effluent objectives will include nutrient limits. The RUSC has indicated that their ultimate goal is to build a wastewater collection, treatment and disposal system capable of reducing nutrient loading, preventing sewage contamination and protecting the Beaver River.

One of the options that will be investigated is the reuse of the wastewater effluent at surrounding industries as an alternative option to discharging it to the Beaver River.

2. Regulatory Requirements

2.1 Introduction

Alberta Environment (AENV) has recommended that the RUSC upgrade the existing WWTF. Future effluent limits will be based on the quality of the receiving water, the Beaver River, and will include nutrient limits. This section outlines the existing regulatory requirements and the estimated future requirements for a regional WWTF.

2.2 Existing Regulatory Requirements

The WWTF currently operates under AENV Approval No. 1585-03-00 issued to the Cold Lake RUSC for the construction, operation and reclamation of a wastewater system.

The WWTF is permitted to receive wastewater from the City, Cold Lake Provincial Park and other adjacent rural developments, and sewage from septic haulers operating in the Greater Cold Lake Area. The approval outlines requirements for record keeping, analytical testing, construction and upgrading requirements, operations, limits and decommissioning for the WWTF. The operational limits for treated wastewater include the following:

- CBOD < 25 mg/L monthly arithmetic mean of weekly samples.

The treated wastewater must be monitored for Carbonaceous Biochemical Oxygen Demand (CBOD), Total Suspended Solids (TSS), Total Phosphorus (TP), Total Dissolved Phosphorus, Total Kjeldahl Nitrogen (TKN), Ammonia-Nitrogen (NH_3-N), Fecal Coliforms (FC) and *E.coli* prior to the outfall. In addition, there are several conditions that apply to the treated wastewater from the WWTF.

- Treated effluent must be discharged continuously to the Beaver River from spring thaw to winter freeze up.
- The average daily Beaver River flow, as measured at Cold Lake Reserve and reported by AENV, must be a minimum of ten times the average daily discharge of treated effluent.
- There must be no appreciable water quality impacts on the Beaver River.

Since the 2005 facility upgrades including the aeration system, the effluent sampling and control system and the increased storage capacity for Storage Pond 2, the Annual Reports indicate that the WWTF is generally functioning well.

2.3 Future Regulatory Requirements

Future effluent limits will be based on the quality of the Beaver River and will include nutrient limits. Water quality data exists for the Beaver River upstream of the WWTF discharge point, but until now there has been no monitoring data downstream of the discharge and none of the current AENV monitoring stations can describe the effects of the effluent. A receiving water sampling program and assessment has been completed and is explained in more detail in **Section 5** of this report. **Table 2.1** summarizes the estimated effluent limits yet to be confirmed by AENV.

Table 2.1: Proposed Effluent Limits for the Beaver River

Parameter	Limit	Basis of Compliance
CBOD	<10 mg/L	monthly arithmetic mean
TSS	<10 mg/L	monthly arithmetic mean
Total P	<0.15 mg/L	monthly arithmetic mean
NH_3-N	<6.0 mg/L (winter)	monthly arithmetic mean
NH_3-N	<3.0 mg/L (summer)	monthly arithmetic mean
E. Coli	<200 per 100 mL	monthly geometric mean
pH	6.5 to 9.5	-

3. Design Criteria

3.1 Introduction

The City has experienced considerable growth in the past 15 years. If this trend continues, municipal services including the WWTF will require expansion and upgrades. A future regional WWTF may also include the addition of the 4-Wing Air Base, Cold Lake First Nations 149B and 149 and surrounding areas. This section outlines the population projections, and the current and future flow and load scenarios for the WWTF.

3.2 Population Projection

There are four populations which may contribute to the future Regional WWTF: The City, the Cold Lake First Nations, the 4-Wing Air Base and immediate surrounding areas in the M.D. of Bonnyville.

The 2006 Canadian Census reports a population of 11,991 for the City, including approximately 2,800 people at the 4-Wing Air Base. The 2006 Canadian Census reports a population of approximately 590 for Cold Lake First Nations 149, 149A and 149B. The immediate area surrounding the City boundary in the M.D. of Bonnyville, defined as the Plan Area, had a population of approximately 100 people in 2006.

The City and the M.D. of Bonnyville developed an Intermunicipal Development Plan (IDP) in 2009 to coordinate the management of urban expansion into the land immediate surrounding the City, the Plan Area. The Plan Area is comprised of approximately 5,120 hectares (12,675 acres) and has an estimated population of 100 people. Most of the growth in the IDP Area will be urban expansion from the City.

Based on the Cold Lake Municipal Development Plan 2007-2037 (MDP), the City has established a target population of 30,000 by 2037 including the 4-Wing Air Base, First Nations and areas of the of M.D of Bonnyville. The 2037 design of the WWTF is based on the MDP target population of 30,000 people.

3.3 Flows

The effluent flow discharged to the Beaver River in 2008 was 1,700 ML resulting in an average annual flow of 4.65 ML/d. This flow results in a per capita flow of 475 L/capita/d which is higher than would be expected assuming there is not excessive infiltration; see **Table 3.1** for comparative data. The City has a separate sanitary sewer system; stormwater should not be entering the sewer. City residents are required to discharge their weeping tile flow to their backyards during summer months rather than the sanitary sewer system. However, the City believes, on average, that the flow remains directed to the sanitary sewer year round.

Table 3.1: Flow Rate Comparison

Location	Flow rate (L/capita/d)
City of Cold Lake, AB	475
Lac la Biche, AB	474
Strathmore, AB	432
Grande Prairie, AB	349
Fort McMurray, AB	390
Pine Creek City of Calgary, AB	400

There is no information regarding the current wastewater flows for the Cold Lake First Nations or M.D. of Bonnyville and therefore, it is assumed, their per capita flows will be the same as the City. The 4-Wing Air Base experienced an average flow of 686 ML/d in 2008 resulting in a flow rate of 627 L/capita/d. This could be due to high consumption of water for non-residential uses.

For the purposes of this study it has been conservatively assumed that the flow for all communities except the 4-Wing Air Base will be 475 L/capita/d and with a 2037 population of 27,000 people and 627 L/capita/d for the 4-Wing Air Base population of 3,000. This will result in an average annual design flow (AAF) of 14.8 ML/d for the population of 30,000. The peak dry weather flow has been estimated using Harmon's Peaking Factor (HPF) where P is population in thousands.

$$1 + \frac{14}{4+P^{0.5}}$$ Equation 3.1 Harmon's Peaking Factor

Based on a future population of 30,000 people, the HPF is 2.477 resulting in a peak dry weather flow of 36.7 ML/d.

The existing sewer system in Cold Lake is reported to suffer from high inflow and infiltration. Historically flows of up to 480 L/s (equivalent to 41.5 ML/d), which is the capacity of Building 9 Lift Station. The Lift Station is currently being upgraded so that it can pump up to 650 L/s (equivalent to 56.2 ML/d)

It is proposed that the regional WWTF be designed to fully treat the peak diurnal flow of 36.7 ML/d. Flows above that flow would be directed to the existing lagoons for temporary storage. An alternative approach to lagoons for storage of wet weather flows might the use of wetlands.

In the absence of actual flow data, the peak flow is assumed to be the same as the peak dry weather flow. The flows have been summarized in **Table 3.2**.

Table 3.2: Summary Cold Lake Flows

Summary	Design Parameter
Population	30,000
Per Capita Flow	475 L/capita/d
Average Flow	14.8 ML/d
Maximum Flow to Full Treatment	36.7 ML/d

As the predicted flow has increased substantially from the existing flow and the winter storage ponds are close to maximum capacity with minimal room for expansion without the need to purchase new land, the new WWTF will need to discharge continuously throughout the year.

3.4 Loads

The pollution loads that are received by a WWTF, and the load variability, are a critical part of plant sizing. Typical wastewater loading for medium strength untreated domestic wastewater provided by Metcalf & Eddy 4th Edition compared to the average loading of the wastewater influent experienced from 2006 to 2009 are shown in **Table 3.3** below.

Table 3.3: Average Loading of the Wastewater Influent Experienced from 2006 to 2009

Loading Parameter	City of Cold Lake	Metcalf & Eddy 4th Edition
BOD mg/L	144	190
TSS mg/L	226	210
Total N mg/L	33.6	40
NH_3-N mg/L	21.3	25
Total P	4.5	7

The existing sewage treatment plant has weekly wastewater data for the BOD and TSS concentrations and monthly for the remaining parameters. With the exception of TSS, Metcalf & Eddy 4th Edition provides a more conservative approach to the loading values so the study will use these values for the design loads. Low sewage strength may be attributed to dilution of back wash water from the water treatment plant, a flow of approximately 1,000 m^3/d. This back wash can be reduced which has the potential of reducing some of the costs for the pumping stations and some areas of the WWTF but would increase the sewage strength resulting in other areas of the WWTF being increased. Removing the back wash would have to be evaluated in more detail the next stage of design.

It is recommended that RUSC increase frequency of its sampling program to improve the data available for the wastewater facility design. This will limit the cost associated with a conservative design approach due to lack of data.

The influent load estimate for the 2037 design has been summarized in **Table 3.4**.

Table 3.4: Design Influent Loads for 2037

Loading Parameter	Loading
BOD kg/d	2,800
TSS kg/d	3,100
Total N kg/d	590
NH_3-N kg/d	370
Total P kg/d	100

3.5 Water Reuse

The feasibility of implementing a water reuse strategy at the City's future wastewater treatment facility was investigated as a potential end use for the wastewater effluent. The water reuse program would supply effluent water to local industries to reduce conventional freshwater demand. Six oil and gas companies, CNRL, Husky Energy, OSUM Oil Sands Corporation, Cenovus Energy Incorporated, Shell Canada Energy and Imperial Oil, all located near Cold Lake were contacted to determine interest in participating in a water reuse program with the City. All six companies were oil and gas facilities, which typically require high volumes of water for activities such as cooling, boiler feed and process feed water.

Local industries could benefit from the reuse of water from the City's treatment facility through the reduction of freshwater withdrawal and the associated reduction of power consumption from pumping raw water. In addition to economic benefits, industries that reuse water could benefit from enhanced corporate images and public acceptance due to increased environmental responsibility.

Currently, the oil and gas industry is regulated by the Energy Resource Conservation Board to minimize the amount of freshwater used on site. Industries that produce bitumen are mandated to reuse 90% of all water received, and would be challenged to import a new source of water. Additionally, industry regulations are shifting to mandate the use of more saline water sources to replace fresh water sources. These mandates and regulations make the use of treated effluent water from the City difficult.

To date, two responses were received. OSUM Oil Sands Corporation and Cenovus Energy Incorporated were not in favour of partnering with the City to implement a Water Reuse program. The largest disadvantage expressed was that the distance between the City and the industrial sites is too far to make the construction of a pipeline economically feasible. Another concern was the ability of the City to provide a reliable and consistent supply of water (both quality and quantity). Information and responses received from local industry are attached as Appendix A.

Wastewater effluent reuse has been successfully applied at other WWTFs such as the Goldbar Wastewater Treatment Facility in Edmonton, AB. If the City of Cold Lake would like to investigate Water Reuse further it would need to conduct further research to determine if it would be economically feasible for both the City and industry. The City would need to consider economic and technical feasibility, cost and funding structure, responsibilities and liabilities, and approval by regulatory bodies such as the Energy Resource Conservation Board, Alberta Environment, and Alberta Sustainable Resource Development.

4. Condition Assessment

4.1 Introduction

This section summarizes the condition assessment of the WWTF done on July 5, 2010 by AECOM. The assessment results are based on visual inspection of above-grade structures and mechanical systems, and information provided by City personnel.

4.2 Existing Condition

In general, the WWTF lagoons appeared to be in good condition. The site is fenced with a gate in place. There was no evidence of berm settlement or leakage. The cells are constructed with compacted clay liner. The approximate sizes of the lagoon system cells are summarized in **Table 4.1**.

Table 4.1: Lagoon System Sizing

Name	Area	Maximum liquid Depth	Volume
Aerated Cells (2)	0.65 ha	4.22 m	15,600 m^3
Anaerobic Cells (2 - not in use)	0.65 ha	4.22 m	15,600 m^3
Facultative (Aerobic) Cell	13.4 ha	1.40 m	183,000 m^3
North Storage Pond	13.1 ha	2.35 m	284,000 m^3
South Storage Pond	15.7 ha	3.90 m	584,000 m^3

Note: The sizing taken from the 1983 Cold Lake sewage lagoon drawings and the Associated Engineering Design for facility upgrades that increased the size storage pond #2 in 2004.

There was no evidence of burrowing animals. The grass on the berms was long and some trees were observed at the aerated lagoon water level. The site had very little odour and the wastewater had little algae.

Figure 4.1: Lagoon Berms

The blower building and aeration system appeared to be in good condition. The building is constructed of metal on a concrete slab. There are two multistage centrifugal blowers that run alternately on a duty/standby operation. The blowers supply approximately 81 m^3/min (2850 cfm) air flow through two main header lines that connect to the lateral pipes along the bottom of the aerated cells. The aeration cells are connected in series, with the majority of the complete mix process occurs in the first aerated cell, followed by partial mixing in the second. The airflow from the blowers is controlled by an inlet butterfly valve that is manually set by an operator to achieve the desired flow rate. Power (600V, 3 phase) is supplied to the blower building from a nearby power line. It was reported that one of the blower lines froze in the winter of 2009/2010 and needed repair. In 2008, one blower was removed from service for re-build and re-installed.

Figure 4.2: Blower Building

Figure 4.3: Blowers

Figure 4.4: Aerated Lagoon

The sampling and effluent control building appeared to be in good condition. The building is metal on a concrete slab. It houses the effluent control PLC and the effluent sampler. The effluent flow control system was upgraded in 2005 to a magnetic flow meter and pinch valve complete with a remotely controlled actuator. A pre-cast concrete vault houses the flow meter and pinch valve. A simple PLC system controls the effluent flow rate. There is a heater and a ventilation system for the building to maintain appropriate temperatures inside. There is also a dial-out alarm system installed to indicate high/low temperature, illegal entry into the building and high water level in the meter vault. Power is supplied underground from the onsite power line to a transformer inside the building which supplies 120V/208V power. There were no chemicals observed on site.

Figure 4.5: Flow Control Building

The 630 mm outfall pipe appeared to be running with no evidence of obstruction. The outfall pipe was submerged at the outlet at the time of inspection. City personnel indicated that the outfall valve was in good condition and there were no apparent leaks.

Figure 4.6: Submerged Outfall Pipe

In 2008, settled wastewater sludge from the aeration cells was removed and placed into four Geotubes for dewatering. The Geotubes are located north of the facultative cell. The dewatering process is likely complete. It is expected that the dewatered sludge will be transported and disposed at the landfill facility.

Figure 4.7: Geotubes for Sludge Dewatering

The septage receiving station appeared to be in good condition. It consists of a camlock connection for truck access, and a line that connects to the influent manhole. An in-line grinder shreds large debris downstream of the station. Power to the septage hauling station is provided underground from the power line onsite to a transformer adjacent to the station, which supplies 120/208V power. It will be required to review the septage receiving station in more detail in the next phase of the project. The nitrification process for ammonia is very sensitive. If the hauled waste being received is from an industrial process or contains toxic chemicals, it may upset the future treatment process.

Figure 4.8: Septage Receiving Station

5. Receiving Water Assessment Summary

5.1 Introduction

A receiving stream analysis was completed in order to predict the effect of the proposed improved effluent treatment on the Beaver River receiving waterbody. The analysis was completed based on available water quality and quantity information upstream of the discharge location, existing and proposed effluent quality information for the RUSC discharge, a limited sampling program, and a modeling exercise. No representative discharge or nearfield water quality data was previously available in the immediate vicinity of the existing discharge. The field program was developed to provide information on conditions under different discharge scenarios, calibrate a water quality model, and to form a baseline against-which the performance of the proposed upgrade could be compared. An in depth technical memorandum with details on the program implemented including the modeling activities is included in **Appendix A**. The following subsections provide a summary of the technical report results and the implications for the Beaver River of the proposed treatment regime.

5.2 Current Conditions

Beaver River

The current, and proposed, receiving body is the Beaver River. Water in the Beaver River watershed (**Figure 5.1**) (including approximately 1/3 of available groundwater) is allocated for various uses including human consumption, oil and gas, and other industries. However, flows in the Beaver River are unregulated and annual fluctuations are considered natural. Typically Beaver River flows, as measured upstream of the site near the Highway 28 Bridge (“Beaver Crossing”), peak between April and August, fed by seasonal rains, surface runoff and groundwater sources.

Examination of water quality records for the Beaver River reveals the following issues:

- Concentrations of total phosphorus (TP), total nitrogen (TN), iron, manganese and phenols in river water have exceeded the Alberta Surface Water Quality Guidelines (ASWQG)
- Some flow-independent variables (DO, nitrate, sulphate) decreased between 1969 to 1989
- Some flow-dependent variables (conductivity, alkalinity, sodium, chloride) increased between 1969 to 1989
- Some flow-dependent variables (true colour, Chlorophyll *a*) decreased between 1969 to 1989
- The Beaver River at Beaver River crossing:
  - TP and TN frequently exceeded ASWQG during low flow periods between 1998 and 2003
  - DO concentrations were compliant 66% of the time and mainly fell below the guideline during winter
  - Pesticides have been detected but have not exceeded guidelines

Water quality upstream of the existing and proposed outfall location is summarized in **Table 5.1**.

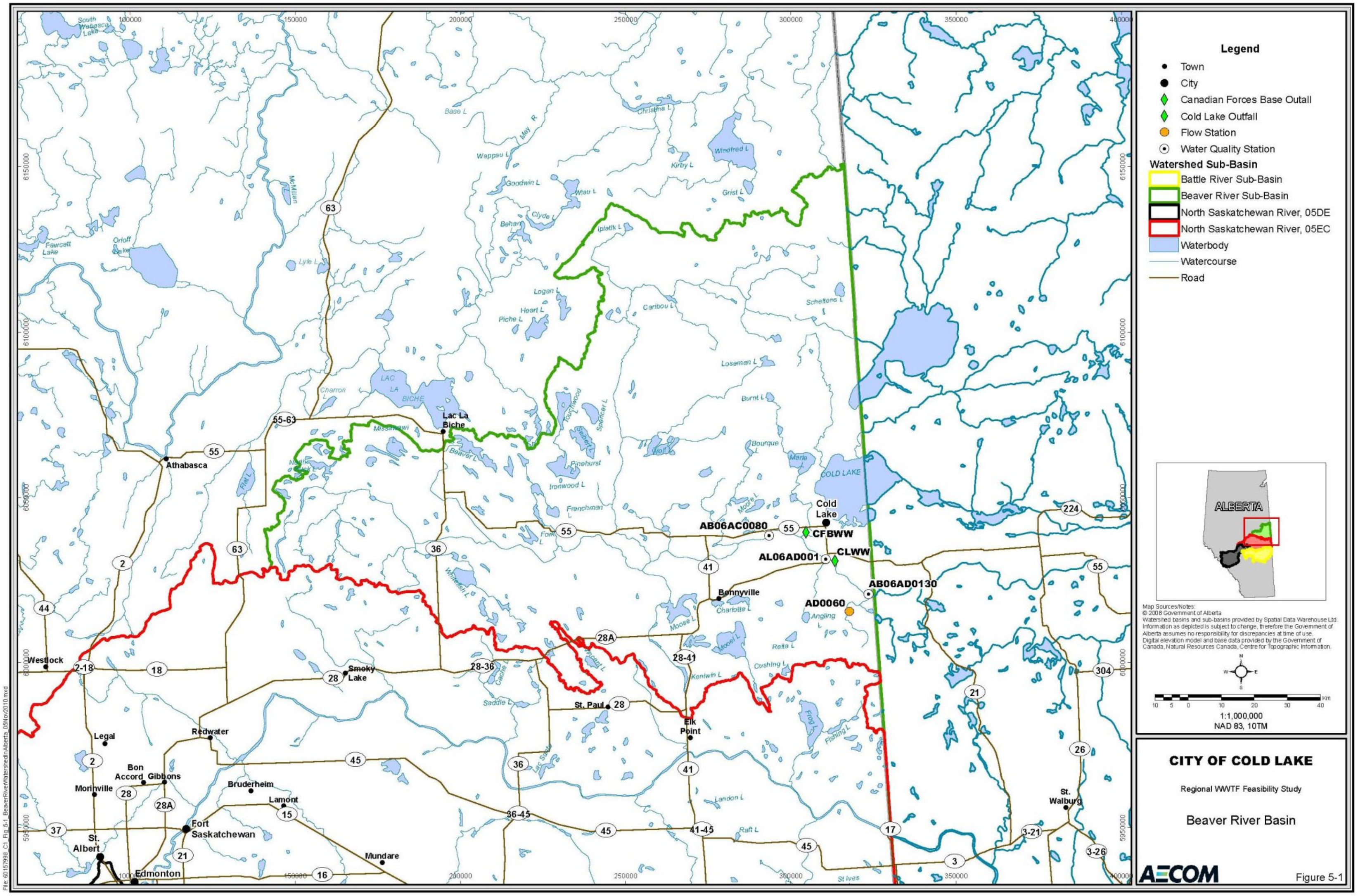


Figure 5.1: Beaver River Basin

Table 5.1: Summary of Water Quality in the Beaver River at Beaver Crossing (AL06AD0001)

	Ammonia (dissolved) (mg/L)	Ammonia (un-ionized) (mg/L)	Fecal Coliforms (no/100 mL)	Total Nitrogen (calc) (mg/L)	Total Dissolved Nitrogen (mg/L)	Total Phosphorus (mg/L)	Total Dissolved Phosphorus (mg/L)	Dissolved Oxygen (mg/L)
Guideline	*0.6*[a]	*0.019*[b]	*100*[b]	*1*[c]		*0.05*[c]		*5.0*[c]
pre-Oct 1993[d]								
# Samples	69	67	180	166	196	224	196	216
min	0.008	<0.001	0.0	0.17	0.12	0.026	0.009	**0** (**4.2**[e])
mean	0.193	<0.001	19.6	0.80	0.68	**0.103**	0.044	7.5
max	1.390	0.010	**345.0**	**2.09**	1.90	**0.720**	0.225	14.6
post-Oct 1993[d]								
# Samples	167	161	63	160	167	167	167	164
min	0.005	<0.001	2.0	0.27	0.04	0.027	0.010	**0.1** (**3.1**[e])
mean	0.210	0.001	34.9	**1.02**	0.86	**0.090**	0.033	7.14
max	2.780	**0.026**	**227**	**3.48**	3.11	**0.652**	0.540	14.2

Note: A – PPWB 1991; B – CCME 2007; C – AENV 1999; D – Due to changes in analytical technique, samples are grouped as pre and post October 1993; E – 25th Percentile Value

RUSC Effluent

Effluent discharge from RUSC is currently permitted to occur from spring until winter freeze-up as long as river flows exceed 10 times the RUSC discharge volume. Data on flow and quality from the existing RUSC discharge was obtained and is summarized in **Table 5.2**. The current effluent AENV license only limits the cBOD to be less than or equal to 25 mg/L (monthly arithmetic mean of weekly samples).

Table 5.2:. Final Effluent Quality Summary

Date	BOD (mg/L)	TSS (mg/L)	TKN (mg/L)	NO_X-N (mg/L)	NH_4-N (mg/L)	TP (mg/L)	TDP (mg/L)	*E. coli* (MPN)[a]	Total coliform (MPN)*
statistics for data collected in 2006-2009									
N	35	35	32	31	31	32	24	32	32
min	4.0	4.0	3.4	<0.02	2.0	0.86	0.61	0	0
mean	8.5	20.3	16.7	0.20	12.9	3.03	2.56	638	6,092
median	7.0	15.0	15.8	0.13	11.8	3.30	2.84	16	78
95th Percentile	18.0	45.2	25.4	0.47	21.9	3.79	3.44	1,960	33,950
Max	19.0	87.0	28.8	1.08	25.1	4.01	3.50	10,000	60,000
Summer (mid June to Sept)									
N	18	18	15	14	14	15	12	16	16
mean	7.4	13.1	13.2	0.26	9.8	3.08	2.87	156	3,217
median	5.0	12.0	14.0	0.26	10.3	3.26	2.92	10	18
95th Percentile	18.2	24.6	16.8	0.45	13.3	3.65	3.39	1,075	23,750
Max	19.0	28.0	17.1	0.50	13.3	3.70	3.50	1,300	29,000
Winter (October to early June)									
N	17	17	17	17	17	17	12	16	16
mean	9.6	28.0	19.8	0.15	15.5	2.98	2.26	1,120	8,967
median	9.0	24.0	20.2	0.06	16.0	3.40	2.34	110	1,115
95th Percentile	16.4	55.8	26.2	0.49	23.0	3.84	3.31	4,300	45,000
Max	18.0	87.0	28.8	1.08	25.1	4.01	3.46	10,000	60,000

Note: a - most probable number

5.3 Data Collection

To develop an understanding of water quality within the Beaver River and the effect of proposed changes in wastewater discharge on the river a field study was designed to collect samples for effluent quality, river water quality, benthic invertebrates and other supporting environmental data. The parameters included general chemistry, oxygen demand, nutrients, bacteria, and more. Data were collected from a number of sampling stations (as shown on **Figure 5.2**) established for data collection both upstream and downstream of the RUSC outfall with timing of sample collection varying over three sampling events as shown in **Table 5.3**.

RUSC149

Figure 5.2: Beaver River Receiving Water Study Area

Table 5.3: Collection of samples by Station and Month

Station	August 31, 2010	September 29, 2010	March 12-13, 2011
US Ardmore		Water	Water
US MC500-02			Water
US MC50-01			Water
DS MC50-01			Water
US100-02	Water	Water (replicate) + Invertebrates	Water
Effluent	Effluent	Effluent	
DS50-01	Water	Water + Invertebrates	Water
DS100-01	Water	Water	Water
DS200-01	Water	Water	Water
DS200-02	Water		
DS300-02		Water	Water (replicate)
DS500-02	Water	Water + Invertebrates	Water
DS500-03	Water		
DS1000-02	Water	Water + Invertebrates	Water
DS1000-03	Water		

5.4 Comparison of Existing Upstream and Downstream Conditions

Upon completion of the field data collection program, the results were analyzed to identify apparent relative changes in water quality resulting from the RUSC effluent discharge.

Overall the collected data appear to indicate that effects of the existing RUSC discharge are evident as expressed in concentrations of several parameters with some exceeding relevant guidelines and a general trend for concentrations in the river to be higher than background concentrations for a distance of 0 to 1000 m downstream of the outfall under the conditions experienced during monitoring events. The data also indicated that these effects do not identifiably persist in absence of the discharge, as demonstrated by monitoring in winter (non-discharge/ice covered) conditions. Comparisons of upstream and downstream conditions are provided in the subsections below in terms of general chemistry, total nitrogen, ammonia, total phosphorus, bacteria, and benthic parameters.

5.4.1 General Chemistry

As illustrated in **Figures 5.3 to 5.5**, general chemistry parameters indicated variable responses to the effluent input. Apparent increases downstream of the outfall were noted for conductivity, TDS, chloride, and sulphate that often returned to upstream concentrations within approximately 200 m of the outfall. Other parameters, such as TSS and DO, did not indicate substantial increases. Some parameters showed a higher concentration on the left bank (outfall side) of the channel, within the effluent plume.

Figure 5.3: Measured a) Conductivity and b) TDS in the Beaver River Study

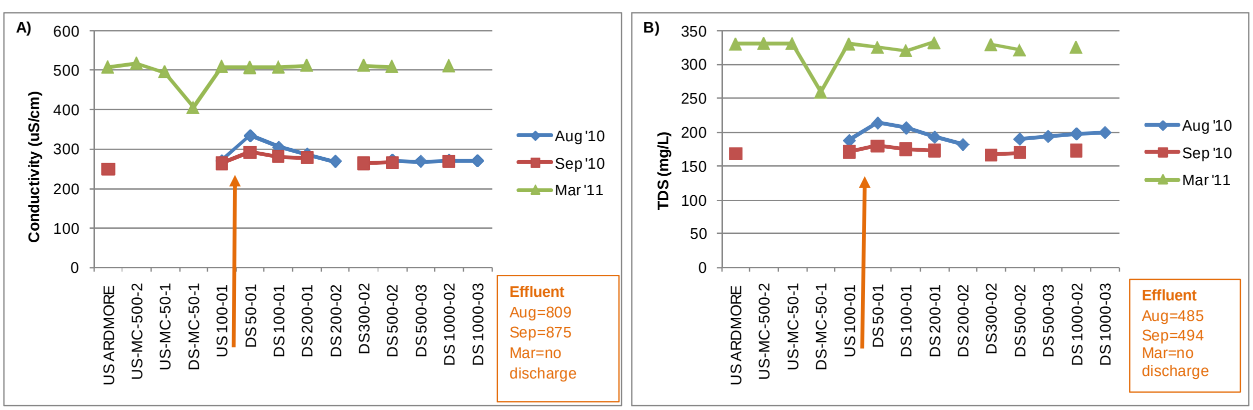


Figure 5.4: Measured a) Chloride and b) Sulphate in the Beaver River Study

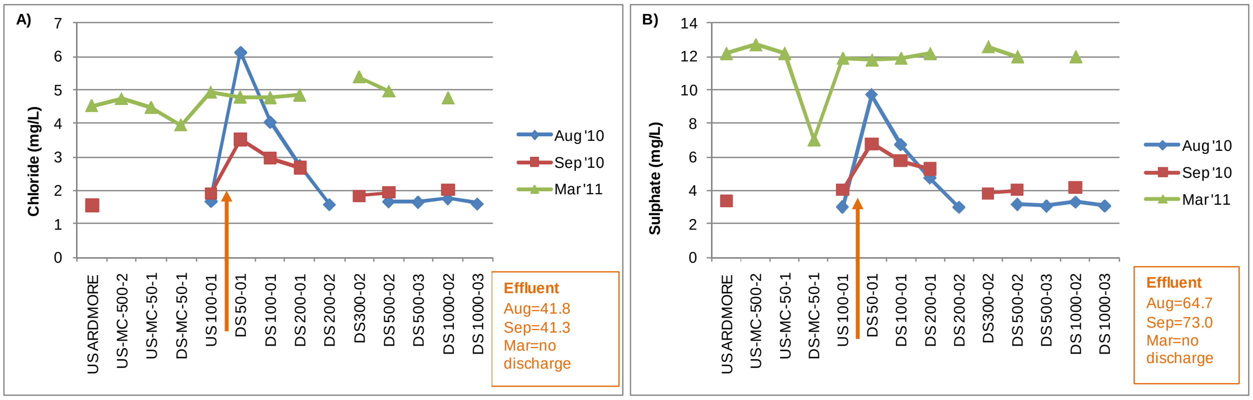
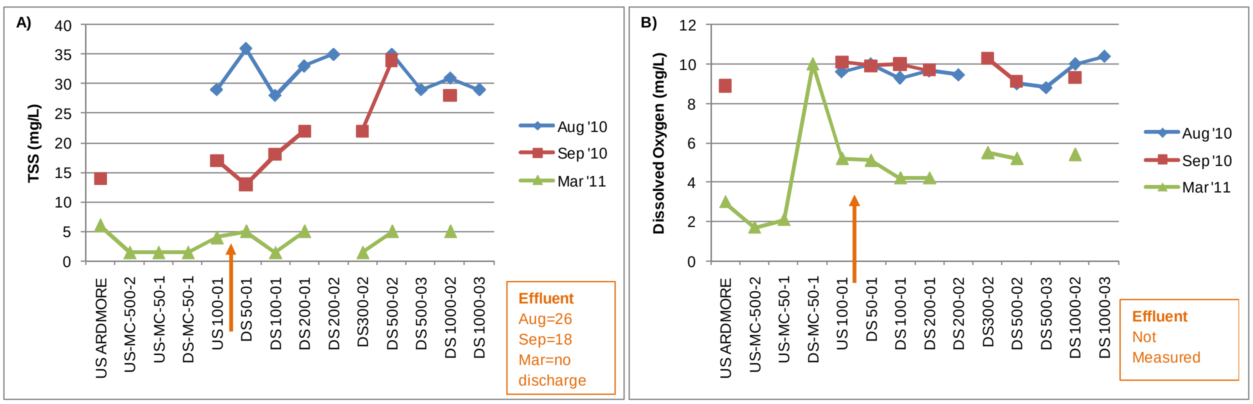


Figure 5.5: Measured a) TSS and b) Dissolved Oxygen in the Beaver River Study



5.4.2 Total Nitrogen

Total Nitrogen data collected from the river (illustrated in **Figure 5.6**) indicated concentrations in excess of Surface Water Quality Guidelines for Use in Alberta (SWQGUA) in summer, both up and downstream of the outfall, with elevated concentrations in the effluent plume returning to background concentrations within approximately 200 m of the outfall. The fall monitoring indicated a similar TN pattern but the concentrations were lower with exceedances limited to approximately 200 m downstream. The March (non-discharge event) indicated all sample concentrations (up and downstream stations) were in excess of SWQGUA guidelines.

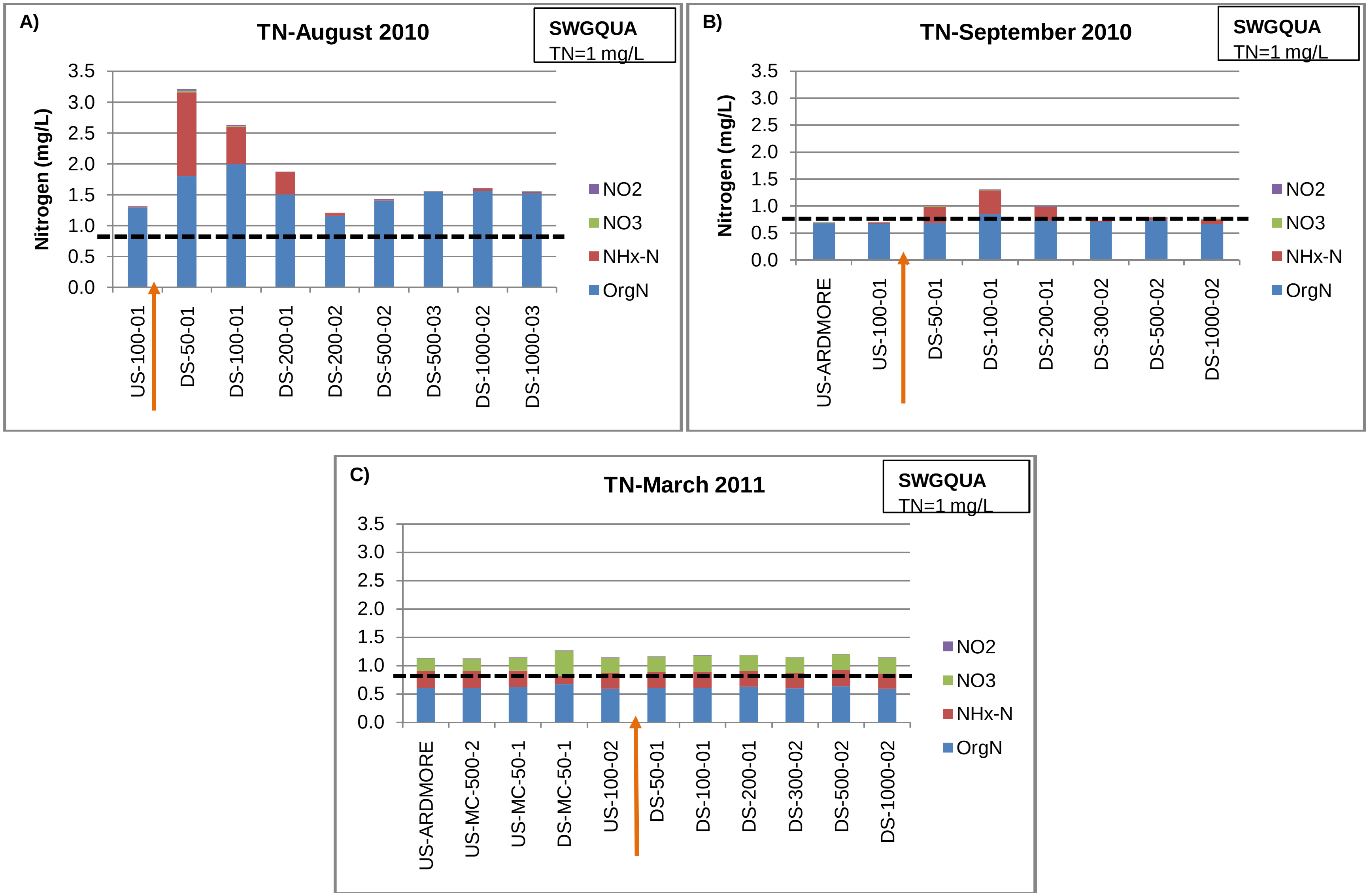


Figure 5.6: Concentration of Total Nitrogen by Nitrogen Form in River Samples in a) August 2010, b) September 2010 and c) March 2011

5.4.3 Ammonia

Total ammonia concentrations were analyzed and found to exceed the Prairie Provinces Water Board (PPWB) guideline value of 0.6 mg/L immediately downstream of the outfall and then dropped below the guideline within 200 m of the outfall for the August event. All analyzed samples for the September and March event were below the guideline. Unionized ammonia concentrations were also calculated for the effluent discharged and found to be less than the 1.25 mg/L limit (draft federal regulations) during both sampling events. Ammonia concentrations are indicated graphically in **Figure 5.7**.

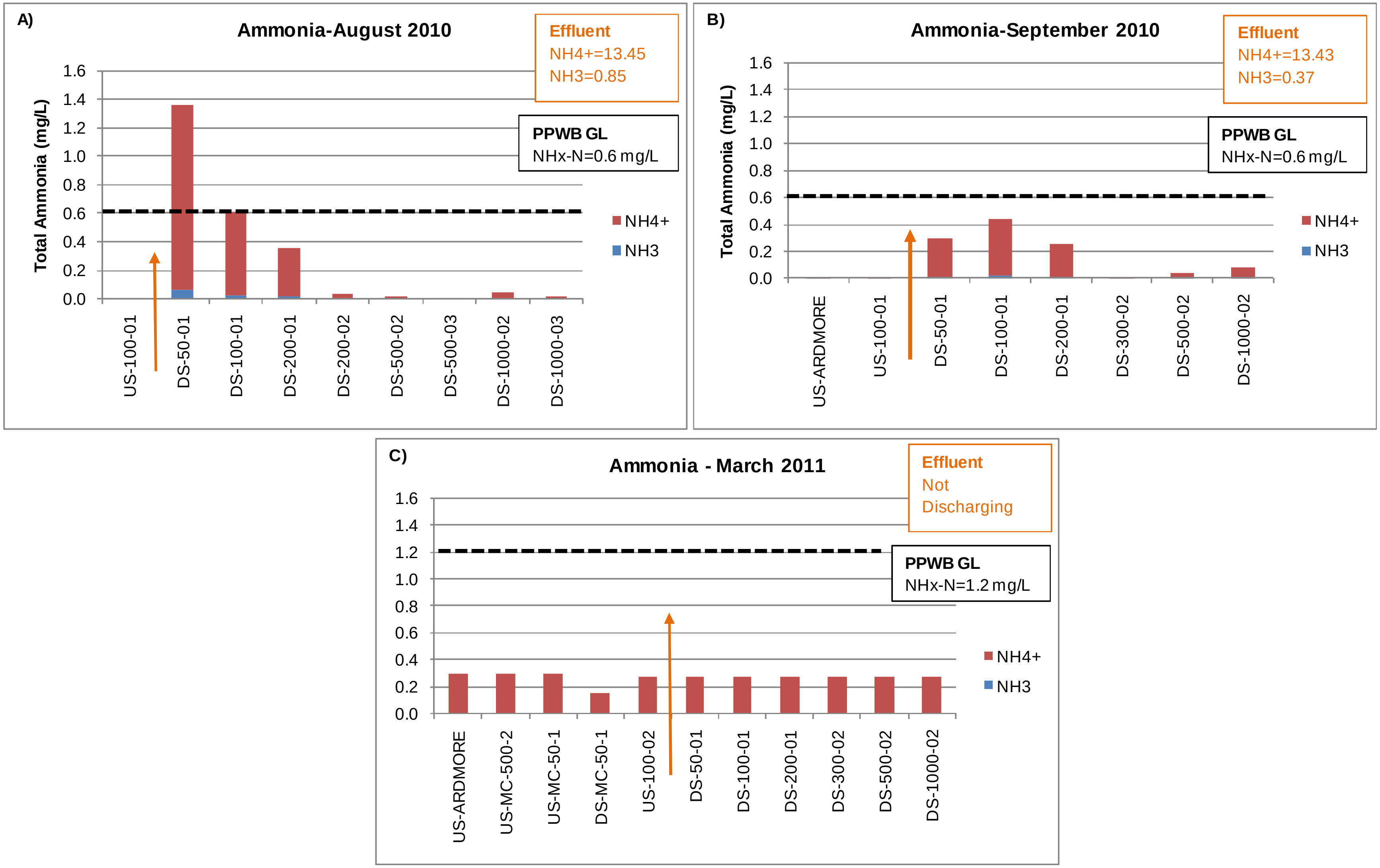


Figure 5.7: Total Ammonia (ionized plus unionized) in River and Effluent Samples in a) August 2010, b) September 2010 and c) March 2011

5.4.4 Total Phosphorus:

As indicated in **Figure 5.8**, total phosphorus (TP) data collected indicated concentrations above the 0.05 mg/L SWQGUA in all samples collected with an apparent increase immediately downstream of the outfall that decreased to upstream concentrations within approximately 200 m of the outfall during the August sampling event. The September event indicated concentrations below the ASWQG with the exception of exceeding values within 200 m downstream of the outfall. Most TP concentrations were below the ASWQG under ice conditions.

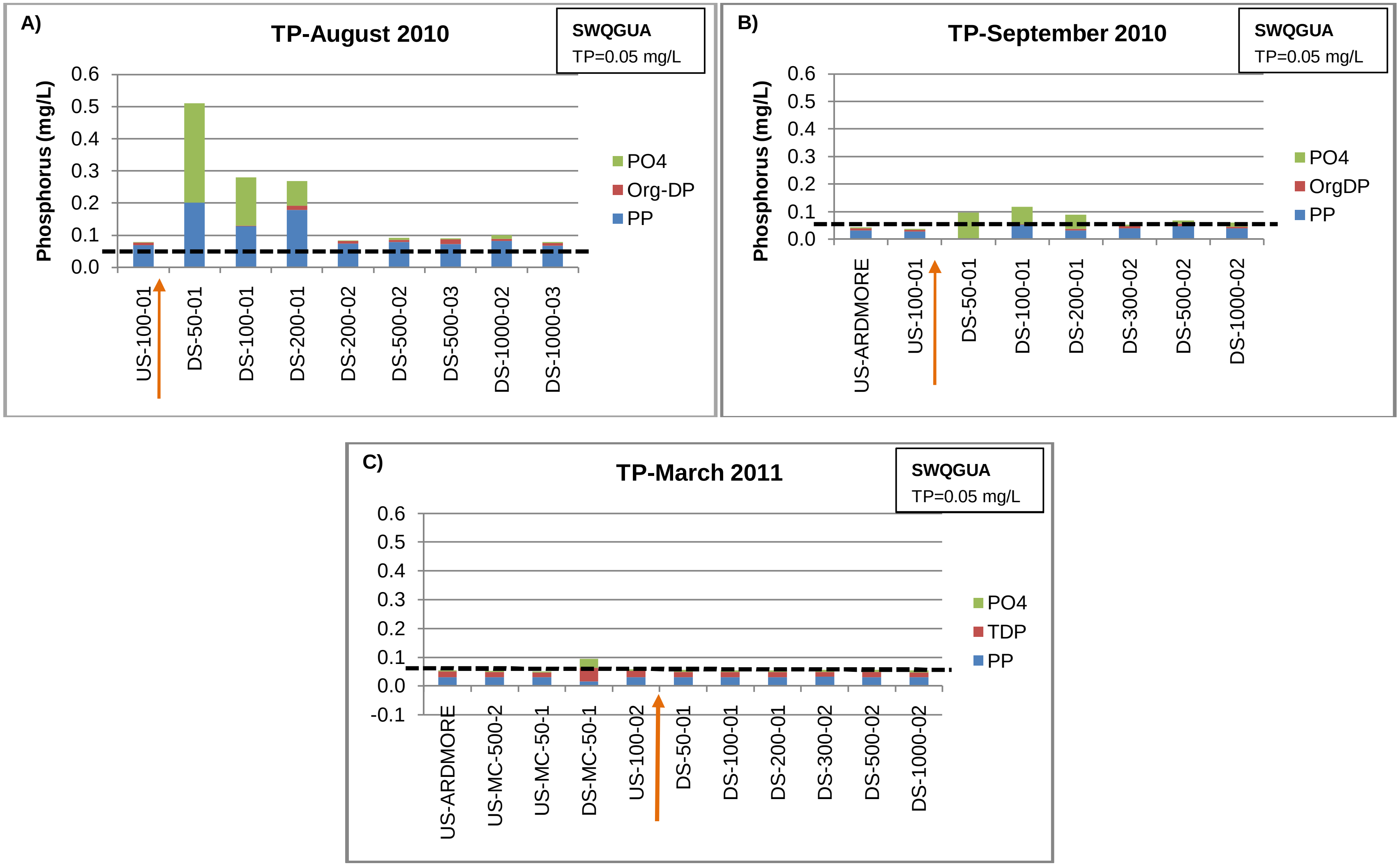
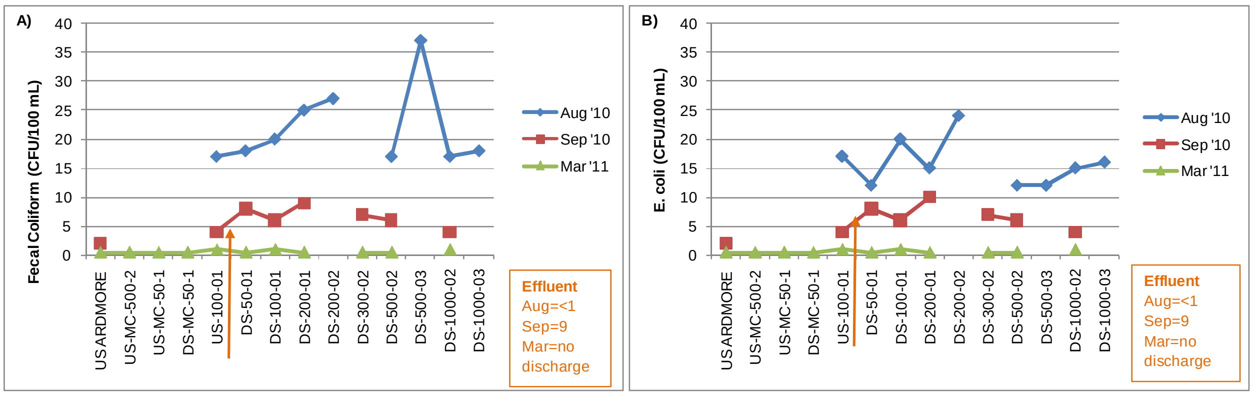


Figure 5.8: Concentration of Total Phosphorus by Phosphorus Form in River Samples in a) August 2010, b) September 2010 and c) March 2011

5.4.5 Bacteria:

Bacteria (*E. coli* and Fecal Coliforms) counts indicated concentrations higher than upstream conditions downstream of the outfall for a distance of approximately 1000 m in the August and September events while levels were near non-detectable during the March event. The data are represented graphically in **Figure 5.9**.

Figure 5.9: Measured a) Fecal Coliform b) *E. coli* in the Beaver River Study



5.4.6 Benthos:

Results from the benthic invertebrate sampling indicated that effects of the effluent discharge on the benthic invertebrate community in the river were overshadowed by differences in physical habitat (streambed substrate) between the reaches upstream and downstream of the effluent outfall.

5.5 Mixing Assessment

A mixing assessment was conducted using two alternative methods to characterize the effect on phosphorus and ammonia concentrations in the Beaver River. One method, a hydrodynamic model (CORMIX), was utilized to simulate river conditions under open-water measured conditions and then used to compare the effects of a change in the effluent treatment. The other method, a mass balance analysis, was utilized to identify changes in water quality as a result of the upgraded WWTF under flow conditions that would not be adequately represented by the hydrodynamic model with the collected information.

<u>CORMIX model:</u>

Using existing and collected data, a CORMIX model was built and calibrated with the flow measurements and water quality data collected during August and September 2010 field events. The model was then used to compare the resulting river water quality effects of the existing WWTF lagoon discharge to those of the proposed upgraded WWTF discharge under August 2010 conditions.

Applicable criteria referenced to provide context for the water quality model included:

- The Surface Water Quality Guidelines for Use in Alberta (SWQGUA) for TN of 1 mg/L and TP of 0.05 mg/L in surface water bodies.

- Canadian Council of Ministers of the Environment (CCME) Water Quality Guidelines for instream un-ionized ammonia concentrations of 0.019 mg/L.

- Canadian Council of Ministers of the Environment Wastewater Systems Effluent Regulations (CCME WSER) for unionized ammonia concentrations in effluent of 1.25 mg/L.

Upstream total phosphorus concentrations (0.0791 mg/L) exceeded the SWQGUA of 0.05 mg/L, therefore, all modeled downstream points also exceeded the SWQGUA.

The un-ionized ammonia concentration for the proposed WWTF effluent met the CCME regulation of 1.25 mg/L with a calculated value of 0.165 mg/L.

Calculated un-ionized ammonia concentrations in the Beaver River, downstream of the existing effluent discharge, met the CCME guideline of 0.019 mg/L within 500 m of the outfall in August 2010, while the proposed WWTF model-predicted concentration would meet the guideline within 100 m of the outfall.

The proposed WWTF upgrade would result in a predicted reduction of nutrient concentrations ranging from 51-80% for total phosphorus and 61-70% for total and unionized ammonia under August 2010 conditions within 1 km of the outfall. As the model was not calibrated to winter hydraulic conditions, prediction of winter water quality was not conducted using the CORMIX model.

<u>Mass Balance Analysis:</u>

Although the mass balance scenario analysis does not incorporate decay factors or other removal mechanisms in characterizing fully mixed concentrations in the Beaver River, it was used in the context of this study to provide a means of evaluating relative improvements as a result of the proposed WWTF upgrade. As the mass balance analyses do not require the change in hydraulics with flow that are brought about by low-flow conditions or ice-covered conditions, the analysis method provides a coarse level of relative comparison on the basis of concentration only. The derived concentrations would not be directly comparable to CCME or SWQGUA guidelines. In this case, five scenarios were analyzed to represent existing and proposed effluent regimes under "worst-case" summer and spring/fall conditions and to conservatively estimate the change in water quality under a winter scenario for the proposed WWTF upgrade.

- The "worst-case" scenarios were defined by low flows in the Beaver River, 95th percentile water quality in the existing WWTF discharge, limit concentrations for the proposed WWTF discharge, and 75th percentile upstream (background) water quality in the Beaver River.
- For all lagoon scenarios (Scenarios 1 and 2) and all proposed plant scenarios (Scenarios 3 to 5), the un-ionized ammonia effluent concentration in the outfall was below the CCME regulation of 1.25 mg/L.
- For all scenarios, the total phosphorus concentrations upstream of the outfall exceeded the SWQGUA guideline of 0.05 mg/L and therefore the mass balance analysis did not demonstrate that the WWTF upgrade would achieve this guideline.

Comparison of the Summer scenarios (scenarios 1 and 4) indicated that the proposed plant would reduce total phosphorus concentrations by 68% compared to the existing WWTF under worst case conditions. Similarly a reduction in the order of 56% would be realized for total and unionized ammonia concentrations.

Examination of the Spring/Fall scenarios (scenarios 2 and 5) revealed a potential total phosphorus reduction in the order of 73% with the implementation of the proposed WWTF upgrade compared to the existing WWTF lagoon. The total and unionized ammonia concentrations would be reduced by 64-65% with the upgraded WWTF.

The calculated fully mixed unionized ammonia concentration examined in scenario 3 (winter) indicated that the concentration may slightly exceed the 0.019 mg/L CCME guideline by approximately 10% under extreme conditions as a result of the proposed WWTF effluent. The total phosphorus concentration will continue to exceed the criteria under winter conditions owing to the upstream concentration of (0.088 mg/L).

5.6 Conclusion:

The RUSC must upgrade their wastewater treatment to accommodate the projected growth for the City of Cold Lake and surrounding areas. The monitoring and modeling conducted indicates that “worst case” conditions in the Beaver River often do not meet comparison guidelines under the existing treatment regime and sometimes exceed guideline values in absence of the RUSC discharge for various parameters.

Historical total phosphorus concentrations are greater than the SWQGUA of 0.05 mg/L upstream of the WWTF outfall and as such, total phosphorus concentrations downstream of the outfall will be greater than the guideline. However, final effluent TP concentrations should be as low as possible to prevent further deterioration of the Beaver River. Based on the analyses of this study, the proposed WWTF upgrade would reduce open-water total phosphorus concentrations by 68-73% under the worst case conditions and by 51-80% under more typical conditions, such as those measured in August 2010. As the existing WWTF lagoon does not discharge during ice-covered conditions, the proposed WWTF will result in the addition of up to 0.15 mg/L total phosphorus to the river in this period.

In terms of total and unionized ammonia, the proposed WWTF upgrade would reduce concentrations in the order of 56-65% under worst case conditions and by 61-70% under conditions typical of those monitored in August 2010.

Accordingly, although the water quality in the Beaver River downstream of the proposed RUSC WWTF upgrade is significantly affected by upstream concentrations of various parameters (such as total phosphorus) and the capabilities of the proposed WWTF technology, guidelines will be achieved under select conditions. The proposed WWTF upgrade is expected to result in a significant improvement in the water quality of the Beaver River under all but winter conditions in comparison to the existing WWTF.

6. Treatment Process and Nutrient Removal Options

6.1 Introduction

This section provides an overview of the treatment process and nutrient removal treatment technologies for the Cold Lake WWTF upgrade.

To select the most appropriate technology, they were evaluated based on their social, environmental and economic factors through a structured rating system.

When evaluating and costing each option, all estimates include a 30% estimating allowance (Class 5 estimate), 10% contractor mark-up, 15% engineering fee and a 250 m^2 staffing building equipped with a laboratory, showers, control room, lockers, and a lunch room. Process options that require mechanical pretreatment include 6 mm screening, followed by grit removal. Tertiary filtration is added where required. All options include UV disinfection of the final effluent. For simplicity, the figures for the following treatment options do not show the various internal recycle streams in the bioreactors

6.2 Nutrient Removal Options

In order to remove nutrients, nitrogen, and phosphorus, several different environments need to be provided to promote growth of the appropriate microorganisms. In general, a wastewater treatment system capable of removing nutrients requires a source of biodegradable organic material (i.e. BOD).

The basis of design assumes a future effluent limit for ammonia and phosphorus, but not nitrogen. However, nitrogen removal is sometimes required in order for phosphorus removal to be achieved.

Each option reviewed will need some ancillary components to complete the entire treatment process. Many will be the same for each option. All process components will be reviewed as part of the entire treatment process.

Ammonia Removal

Ammonia removal involves the biological conversion of ammonia (NH_3) to nitrate (NO_3) using the nitrification process. This conversion requires an aerobic environment i.e. air is supplied to the biomass in the reactor tanks. The nitrification process is very temperature dependent; the reaction rate reduces as the wastewater temperature drops. Little or no nitrification is achieved when the wastewater temperature is below about 5°C, which is why aerated lagoons cannot provide year-round ammonia removal in cold climate regions of the world.

Nitrogen Removal

Nitrogen removal is based on the biological conversion of NO_3 to nitrogen gas (N_2) using the denitrification process. The denitrification process requires an anoxic environment, i.e. nitrate present, but no oxygen (air) present. Biodegradable organic carbon in the wastewater is also required for the process to work. A benefit of anoxic denitrification is that it reduces the amount of oxygen (air) required in the downstream aerobic zones, thereby saving electrical energy. Anoxic zones can also improve the settling properties of the solids in the secondary clarifiers.

Phosphorus Removal

There are two methods available for phosphorus removal: chemical removal and biological removal.

Chemical phosphorus removal involves the addition of metal salts (e.g. ferric chloride or alum) to the primary clarifiers and/or the bioreactors to precipitate phosphorus.

Biological phosphorus removal takes place in the bioreactors, and requires an anaerobic zone i.e. no nitrate and no oxygen (air). Since nitrate cannot be present, a nitrogen removal process is required. This combined removal of phosphorus and nitrogen is called biological nutrient removal (BNR). The phosphorus removal process requires volatile fatty acids (VFA); these are typically provided by fermenting the primary solids, and directing the VFA-rich supernatant to the anaerobic zone. Since the phosphorus is removed and contained in the waste solids, careful attention must be given to subsequent solids processes to limit the amount of phosphorus released and returned to the WWTF via sidestreams (such as filtrate from solids dewatering processes).

6.2.1 Ancillary Treatment Process Components

Currently the site has an outdoor septage receiving station, a small blower building and an even smaller sampling and effluent control building. To increase the capacity of the plant, each option will require ancillary facilities including an onsite administration building complete with a small laboratory for onsite testing, staff facilities and a workshop for storage and onsite equipment repair.

Pretreatment

Each process described in this section will require some form of pretreatment. At the conceptual level for this report, a standard pretreatment system that includes influent screening and grit removal is applied to all options. The screen will be sized to remove material 6 mm and greater to prevent debris from damaging the process equipment. Grit causes significant wear and tear on mechanical wastewater treatment equipment and a typical grit removal system will use a classifier to dewater and remove the grit for disposal. For the purpose of this report a 6 mm bar screen and Eutek grit removal system have been included.

Figure 6.1: Typical 6 mm Bar Screen (Photo Courtesy of Headworks)

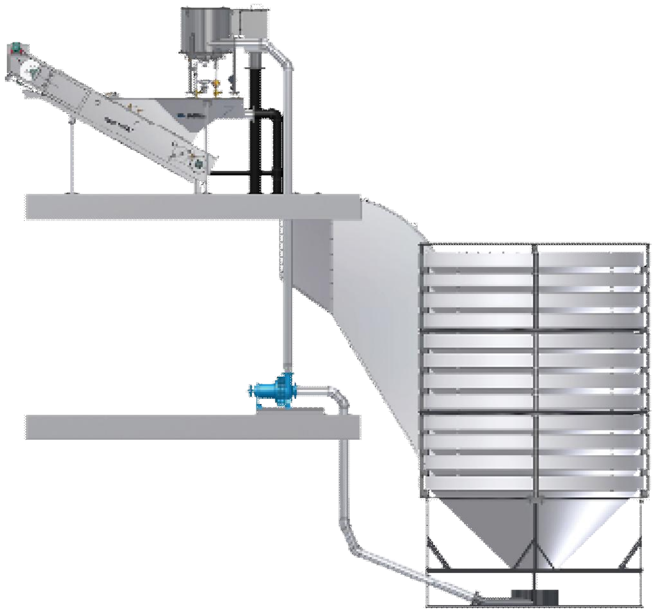


Figure 6.2: Typical Grit Removal System (Figure Courtesy of Eutek)

Primary Clarifiers

Primary clarification is often used in conventional activated sludge plants to remove the larger particles from the wastewater to decrease the suspended solids and BOD loads. This reduces the size of the bioreactors. Primary clarifiers also play an important role in supplying the feed sludge to fermenters that are required to produce the VFAs for biological phosphorus removal.

Fermenters

Fermenters are required in the biological phosphorus conventional activated sludge process only. The purpose of the fermenters is to provide an environment where primary sludge organic material can be fermented to short-chain VFAs without the concurrent production of sulphides or methane. The products of fermentation, when introduced to the bioreactor, initiate the biochemical reactions necessary for biological excess phosphorus removal. By piping the fermenter's VFA-rich supernatant to the anaerobic zone of the bioreactor, the proper environment for biological phosphorus removal can be maintained. Fermenters are not necessarily needed for every installation. If the collection system generates sufficient amount of VFAs, a fermenter would not be needed. As the RUSC collection system is large, it would be important to test for VFAs before deciding to build a fermenter.

Tertiary Filtration

All options, with the exception of the membrane bioreactors (MBR), will require chemical addition and tertiary filtration to meet the low phosphorus limit of 0.15 mg/L. Technologies available in tertiary treatment able to meet the low phosphorus limits include media filtration such as the Dynasand® filtration available from Parkson or the BluePro® phosphorus removal filter from Blue Water Technologies, as well as the Actiflo® high rate clarification process available from John Meunier. For the purpose of this report, the Dynasand® filter has been included for all with the exception of the suspended attached growth reactor (SAGR), which included its own proprietary tertiary filter system.

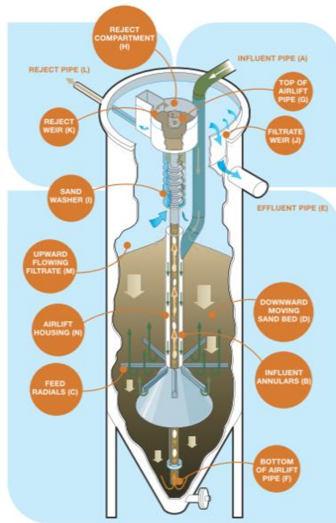


Figure 6.3: Dynasand Filtration Unit (Figure Courtesy of Parkson)

UV Disinfection

Regardless of which process is chosen, effluent disinfection is necessary to meet the effluent criteria. UV lamps disinfect wastewater by affecting genetic material so that bacteria can no longer reproduce. In UV disinfection systems, germicidal lamps submerged in channels produce the UV light which imparts a damaging dose of UV radiation to the cells' DNA as the wastewater flows through the reactor.

There are several types of UV disinfection systems, with the main differences being the lamp intensity, the lamp pressure, and the lamp configuration. The three systems currently available on the market are low pressure, low output (LPLO); low pressure, high output (LPHO); and medium pressure, high output (MPHO). A LPHO system is proposed for Cold Lake because of its energy efficiency and suitability for this size of plant. The other variable is based on configuration, or whether the lamps are set in a vertical or horizontal orientation. An example of a UV system is shown in **Figure 6.4**.

Figure 6.4: Typical UV System (Photo Courtesy of Trojan UV Systems)

UV disinfection equipment sizing depends on the flows and the characteristics of the wastewater to be disinfected. The most important wastewater characteristic that influences UV disinfection is UV transmissivity, which is a measure of the “transparency” of the wastewater to the passage of UV light. Others include iron concentration, the presence of complex soluble organics, water hardness, TSS, turbidity, and particle size distribution. The TSS concentration may determine the level to which UV can disinfect; solids can shield organisms from the effects of the UV light allowing them to pass through the system unaffected.

The effluent characteristics have to be assumed or estimated when considering a new wastewater treatment plant. A UV transmissivity of 70% has been assumed. The actual transmissivity in the existing wastewater treatment plant will need to be measured and confirmed prior to final detailed design of the system.

There will be two banks of UV modules to provide a redundant disinfection service. The channel hydraulics and UV equipment is designed to handle the peak flow.

6.2.2 Conventional Activated Sludge

The basic conventional activated sludge (CAS) process has existed for many years and has evolved into many different configurations for wastewater treatment. The basic design of an activated sludge treatment process is built on three main components:

- Reactors with microorganisms aerated in suspension to biologically degrade the organic matter and ammonia in the wastewater
- Clarifiers for liquid-solids separation
- Recycle process to return solids removed from the clarifier back to the reactor

The key process in the activated sludge process is to introduce oxygen (air) into the wastewater in combination with microorganisms to develop flocculated settleable solids that can be removed by gravity settling to reduce the BOD, ammonia and TSS of the effluent. In order for the process to function, most of the settled solids need to be returned to the bioreactor to seed the incoming wastewater with microbes. A small portion of the solids is removed and disposed of separately.

CAS systems can be configured in a variety of ways to remove nitrogen and phosphorus. If biological phosphorus removal is selected rather than chemical phosphorus removal then additional un-aerated zones must be incorporated into the bioreactor design. For biological phosphorus removal, the bioreactor is usually divided up into a pre-anoxic zone, anaerobic zone, anoxic zone, and aerobic zone. Selecting biological phosphorus removal has the added advantage of being a complete biological nutrient removal (BNR) facility which could be important if in the future nitrogen, not just ammonia, is limited in the effluent. **Figure 6.5** is a photograph of the West End Water Pollution Control Centre (WEWPCC) in Winnipeg that was a typical CAS plant with primary clarification, bioreactors and secondary clarification that has since been converted to a CAS-BNR plant with fermenters.

Figure 6.5: WEWPCC with CAS Treatment Process

If chemical phosphorus removal is selected then the treatment system can be simplified. A bioreactor with an anoxic zone (for energy efficiency) followed by an aerobic zone and return activated sludge (RAS) from the secondary clarifier will remove the ammonia, and chemicals such as alum or ferric chloride are added into the reactor to precipitate phosphorus. This precipitated phosphorus is removed through the daily wasting of waste activated solids (WAS) from the process. Since the phosphorus is chemically bound, there is no concern with the re-release of phosphorus during subsequent biosolids processing.

<u>**Conventional Activated Sludge with Biological Phosphorus Removal**</u>

Figure 6.6 shows the basic process and **Table 6.1** shows the design parameters for an activated sludge treatment process with biological phosphorus removal, followed by the cost estimate in **Table 6.2.** The pretreatment for this option will include a screen followed by grit removal system. This process technology will not be able to consistently meet the low 0.15 mg/L phosphorus limit even with the included backup chemical dosing system and will therefore require a tertiary filter. A UV system will also be required.

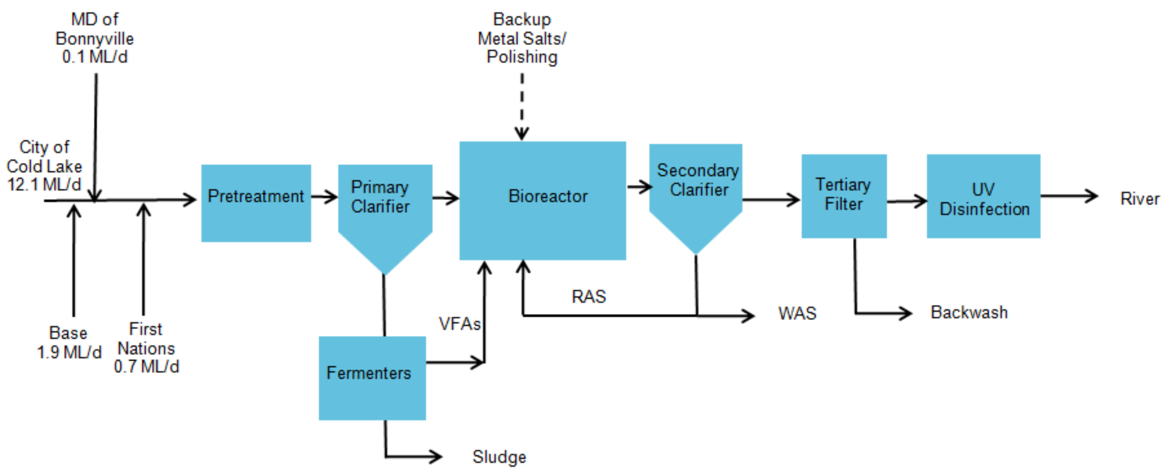


Figure 6.6: CAS with Biological Phosphorus Removal Process Flow Diagram

Table 6.1: Design Parameters for CAS with Biological Phosphorus Removal[1]

Parameter	Unit	Value
Primary Clarifiers		
Water Depth	m	4
Number	No.	2
Diameter	m	18
Surface Overflow, average	$m^3/m^2/d$	30
Surface Overflow, maximum	$m^3/m^2/d$	72
Fermenters		
Depth	m	3
Number	No.	2
Diameter	m	9
Bioreactors		
Solids Retention Time (SRT), average	d	15
Hydraulic Retention Time (HRT), average	hrs	10.4
Mixed Liquor Suspended Solids (MLSS), average	mg/L	2,400
Number of Bioreactor Trains		4
Water Depth	m	6
Anoxic Cell		
Number per Train		1
Length	m	9
Width	m	7.5
Anoxic Volume per Train	m^3	405
Aerobic Cell		
Number per Train		3
Length	m	10
Width	m	9
Total Aerobic Volume per Train	m^3	1,215
Reactor Volume per Train (anoxic +aerobic)	m^3	1,620
Total Reactor Volume	m^3	6,480
Clarifiers		
Solids Loading Rate, average	$kg/m^2/h$	2.8
Solids Loading Rate, maximum	$kg/m^2/h$	5.3
Surface Overflow Rate, average	m/hr	1.3
Surface Overflow Rate, maximum	m/hr	3.1
Number	No.	2
Water Depth	m	6
Diameter	m	25

Note 1: Ancillary structures and equipment e.g. RAS pumping station, blower building, are not included in this table

Table 6.2: Cost Estimate CAS with Biological Phosphorus Removal

Item	Cost
Contractor's Markup (10%)	$ 3,200,000
Siteworks	$ 2,900,000
Electrical Supply Distribution	$ 3,700,000
Staffing Building/Lab	$ 400,000
Pretreatment	$ 1,500,000
Chemical Dosing Building	$ 700,000
Primary Clarifiers	$ 2,100,000
Fermenters	$ 1,800,000
Bioreactors	$ 12,500,000
Secondary Clarifiers	$ 2,900,000
Tertiary Filter	$ 2,200,000
UV Disinfection	$ 1,100,000
Subtotal	$ 35,000,000
Est. Allowance (30%)	$ 10,500,000
Subtotal	$ 45,500,000
Engineering (15%)	$ 6,900,000
Total	**$ 52,400,000**

Conventional Activated Sludge with Chemical Phosphorus Removal

Table 6.7 shows the basic process and **Table 6.3** shows the design parameters for an activated sludge treatment process with chemical phosphorus removal. The pretreatment for this option will include a screen followed by grit removal system. This technology will not be able to consistently meet the low 0.15 mg/L phosphorus limit and will require the installation of a tertiary filter, and UV disinfection will be required for adequate disinfection.

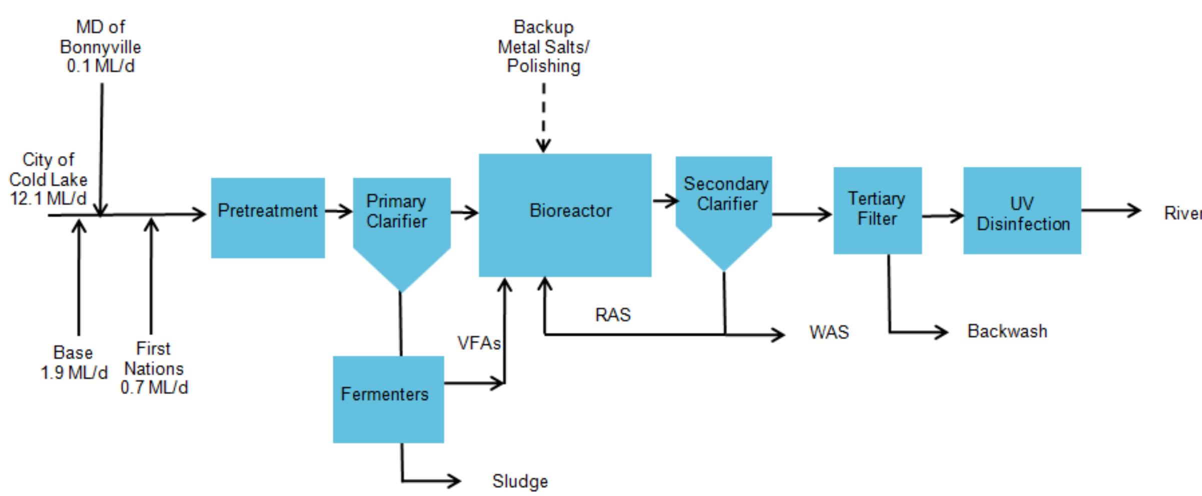


Figure 6.7: CAS with Chemical Phosphorus Removal Process Flow Diagram

Table 6.3: Main Design Parameters for CAS with Chemical Phosphorus Removal[1]

Parameter	Unit	Value
Primary Clarifiers		
Water Depth	m	4
Number	No.	2
Diameter	m	18
Surface Overflow, average	$m^3/m^2/d$	30
Surface Overflow, maximum	$m^3/m^2/d$	72
Bioreactors		
SRT, average	d	15
HRT, average	hrs	10.4
MLSS, average	mg/L	2,400
Number of Bioreactor Trains		4
Water Depth	m	6
Anoxic Cell		
Number per Train		1
Length	m	9
Width	m	7.5
Anoxic Volume per Train	m^3	405
Aerobic Cell		
Number per Train		3
Length	m	10
Width	m	9
Total Aerobic Volume per Train	m^3	1,215
Reactor Volume per Train (anoxic +aerobic)	m^3	1,620
Total Reactor Volume	m^3	6,480
Clarifiers		
Solids Loading Rate, average	$kg/m^2/h$	2.8
Solids Loading Rate, maximum	$kg/m^2/h$	5.3
Surface Overflow Rate, average	m/hr	1.3
Surface Overflow Rate, maximum	m/hr	3.1
Number	No.	2
Water Depth	m	6
Diameter	m	25

Note [1]: Ancilliary structures and equipment e.g. RAS pumping station, blower building, are not included in this table

Table 6.4: Cost Estimate for CAS with Chemical Phosphorus Removal

Item	Cost
Contractor's Markup (10%)	$ 3,300,000
Siteworks	$ 3,000,000
Electrical Supply Distribution	$ 3,800,000
Staffing Building/Lab	$ 400,000
Pretreatment	$ 1,500,000
Chemical Dosing Building	$ 2,600,000
Primary Clarifiers	$ 2,100,000
Bioreactors	$ 12,480,000
Secondary Clarifiers	$ 2,900,000
Tertiary Filter	$ 2,200,000
UV Disinfection	$ 1,100,000
Subtotal	$ 35,400,000
Est. Allowance (30%)	$ 10,700,000
Subtotal	$ 46,100,000
Engineering (15%)	$ 7,000,000
Total	**$ 53,100,000**

6.2.3 Membrane Bioreactor

The membrane bioreactor (MBR) process is a small footprint biological treatment process in which membranes rather than final clarifiers are used for solids separation as seen in **Figure 6.8**. The pore size of the membranes is in the ultra-filtration range of 0.04 to 0.08 um for hollow fibre membranes. Plate membranes can also be used instead of hollow fibres. **Figure 6.9** shows a hollow membrane filtration system.

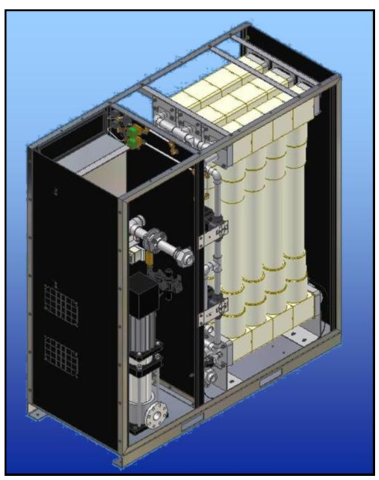


Figure 6.8: Typical Membrane System Configuration (Figure Courtesy of GE Water)

Figure 6.9: Hollow Membrane Filtration System (Photo Courtesy of GE Water)

In both plate membranes and hollow fibre membranes, clarified liquid is withdrawn from the space between the membranes. In some systems, pumps withdraw the effluent; while with others, the interstitial space between membranes drains by gravity. Membranes are scoured by an aeration system and routine cleaning with chlorine solution is required to control biofouling. Excellent TSS and BOD reductions are normally achieved (less than 1 mg/L TSS and 5 mg/L BOD). In addition, membranes remove a substantial fraction of the influent bacteria and disinfection requirements can be reduced.

Unlike secondary clarifiers, solids separation efficiency is not dependent on the mixed liquor suspended solids concentration or settling characteristics. Since elevated mixed liquor concentrations are possible, the aeration basin volume can be reduced, further reducing the plant footprint. Membrane systems require pretreatment screens generally less than 2 mm.

Normally a spare membrane train is provided to allow recovery cleans of the membranes every four to six months; each clean typically lasts approximately 24 hours. With the availability of the lagoons, flow could be diverted to a lagoon cell during the recovery clean process. This reduces the required redundancy and the necessary stand-by equipment. Budget quotation for the membrane bioreactor equipment was provided by GE Water & Process Technologies. **Figure 6.10** shows the basic process and **Table 6.5** shows the design parameters for an MBR treatment system followed by the cost estimate in **Table 6.6**.

The pretreatment for this option will include a 6 mm bar screen followed by grit removal system and 1 to 2 mm fine screen. A UV system will be required but it will be smaller than those used in other treatment options.

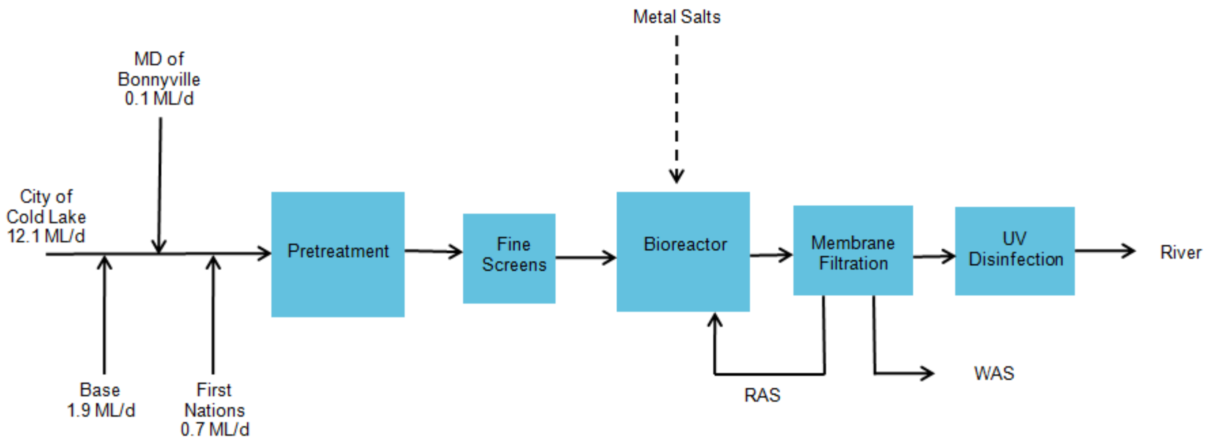


Figure 6.10: Membrane Bioreactor Process Flow Diagram

Table 6.5: Main Design Parameters for Membrane Bioreactor

Parameter	Unit	Value
Bioreactors		
SRT, average	d	20
HRT, average	hrs	7.4
MLSS, average	mg/L	8,000
Number of Trains		2
Depth	m	6.0
Anoxic Cell		
Number		1
Length	m	9.5
Width	m	10
Total Reactor Anoxic Volume	m^3	570
Aerobic Cell		
Number per reactor		3
Length	m	9.5
Width	m	10
Total Reactor Aerobic Volume	m^3	1,710
Total Reactor Volume	**m^3**	**4,560**
Cassettes		
Number of membrane trains		6
Number of cassettes per train (spare)		7 (1)
Number of modules per cassette		6 cassettes x 48 1 cassette x 24
Total number of installed modules (spare space)		312 (72)

The cost estimate in **Table 6.6** includes pretreatment of coarse screening, grit removal and fine screening.

Table 6.6: Membrane Bioreactor Cost Estimate

Item	Cost
Contractor's Markup (10%)	$ 3,200,000.0
Siteworks	$ 2,600,000.0
Electrical Supply Distribution	$ 3,800,000.0
Staffing Building/Lab	$ 400,000
Pretreatment	$ 2,100,000
Bioreactors	$ 7,200,000
Chemical Dosing	$ 630,000
Membrane Building	$ 13,600,000
UV Disinfection	$ 1,100,000
Subtotal	$ 34,630,000
Est. Allowance (30%)	$ 10,400,000
Subtotal	$ 45,030,000
Engineering (15%)	$ 6,800,000
Total	**$ 51,900,000**

6.2.4 Sequencing Batch Reactor

A sequencing batch reactor (SBR) is a fill and draw reactor involving a single reactor in which all steps of the activated-sludge process occur. In the basic SBR four major treatment steps occur in a sequence: fill, react, settle and decant. Variations in the SBR system are possible including the continuous fill SBR (**Figure 6.11**) which simplifies the process. Due to the intermittent discharge (decant) an equalization tank is typically provided. An operating SBR is shown in **Figure 6.12**. The biological reactions and the sedimentation and clarification are carried out sequentially in the same tank. Mixing is used during the anoxic fill cycle to facilitate the contact of the mixed liquor with the influent wastewater. Sufficient BOD and fill time is made available to allow much of the nitrate remaining in the mixed liquor to be removed after the settling and decant steps. Biomass is wasted either at the end of the react cycle or prior to the decant cycle. Since react and settle takes place in the same tank, there is no need for a return activated sludge (RAS) system. Chemical phosphorus removal rather than biological phosphorus removal is normally practiced with SBRs.

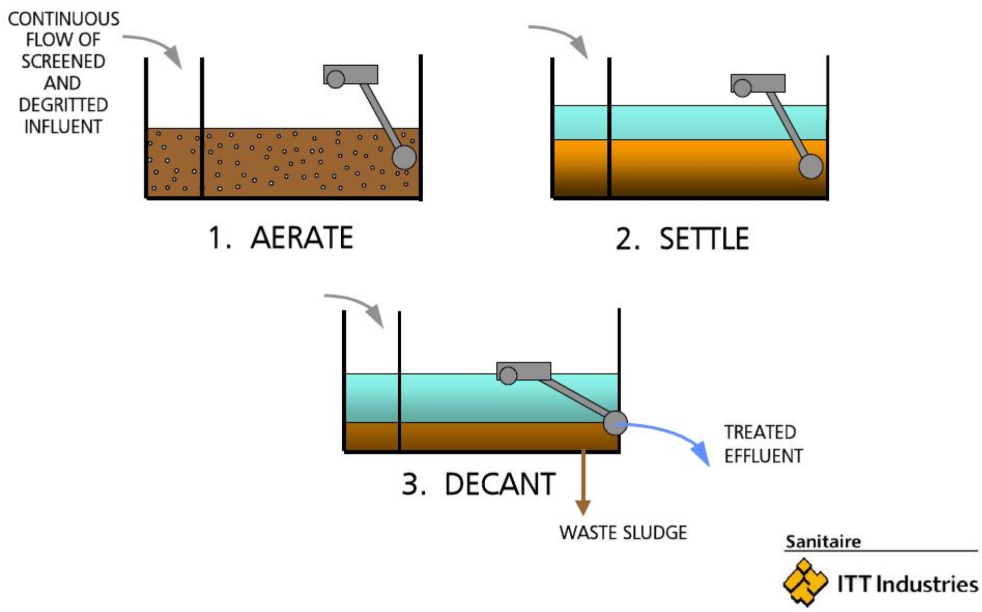


Figure 6.11: SBR System Schematic

Figure 6.12: SBR Treatment Facility in Operation

For wastewater treatment systems with continuous flow, at least two basins are typically needed so that one basin is in the fill mode while the other is undergoing the react, settle, and decant stages. Shorter cycle periods can be chosen to accommodate periods of high flow. The process can be readily expanded by adding additional SBR modules.

Figure 6.13 illustrates the SBR process flow diagram, **Table 6.7** shows the design parameters, and the cost estimate is in **Table 6.8**. Budget quotations were provided by ITT Sanitaire.

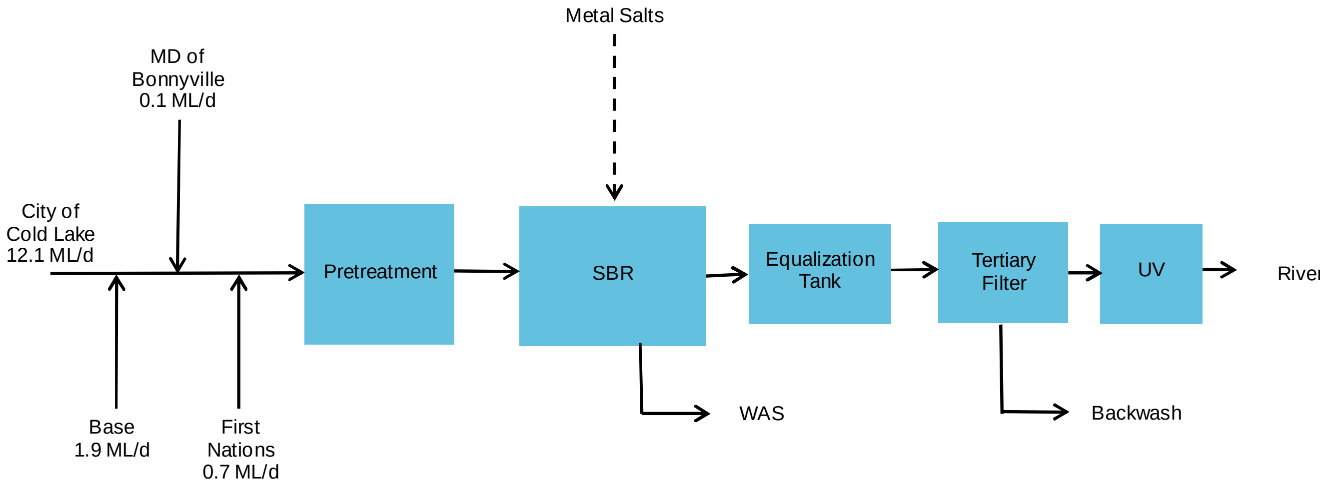


Figure 6.13: SBR Process Flow Diagram

Table 6.7: Main Design Parameters for SBR

Parameter	Unit	Value
Basins		
SRT, average	d	32.5
HRT, average	hrs	25.5
Temperature, average	ºC	8
Number of Basins		4
Depth		
Top water level	m	5.0
Bottom water level	m	4.0
Length	m	56.4
Width	m	19.2
Total Volume	m^3	5,414
Decanter Mechanism		
Number		4
Weir Length	m	12.2
Decant Rate		
Normal	m^3/min	22
Peak	m^3/min	31
Equalization Tank		
Depth	m	4
Volume	m^3	1,500

Table 6.8: SBR Cost Estimate

Item	Cost
Contractor's Markup (10%)	$ 2,900,000
Siteworks	$ 2,300,000
Electrical Supply Distribution	$ 3,400,000
Staffing Building/Lab	$ 400,000
Pretreatment	$ 1,500,000
Chemical Dosing Building	$ 2,000,000
SBR	$ 15,200,000
Tertiary Filter	$ 2,200,000
UV Disinfection	$ 1,100,000
Subtotal	$ 31,000,000
Est. Allowance (30%)	$ 9,300,000
Subtotal	$ 40,300,000
Engineering (15%)	$ 6,100,000
Total	**$ 46,400,000**

6.2.5 Moving Bed Biofilm Reactor

The moving bed biofilm reactor (MBBR) process can be used for BOD removal and nitrification, and has a relatively small footprint. The process utilizes millions of tiny, polyethylene biofilm carriers (biocarriers, **Figure 6.14**) that are specially designed to provide a high surface area. The MBBR tanks are filled to 30-60% capacity with the media. Active bacteria culture will then grow onto this media. The media is kept in suspension in the water by aeration and/or mixers. Excess biofilm sloughs off the biocarriers; a clarification stage is required to settle and remove these solids.

Figure 6.14: MBBR Biocarriers (Photo Courtesy of Veolia)

Figure 6.15 shows a typical MBBR basin installation.

Figure 6.15: A Typical MBBR Basin Installation with No Media Installed (Photo Courtesy of Veolia)

Figure 6.16 shows the process diagram for the proposed MBBR facility using the lagoon for clarification followed by a tertiary filter to remove the remaining TSS and phosphorus loading. The design parameters and cost for the facility follow respectively in **Table 6.9** and **Table 6.10**. Budget quotations for the MBBR components were provided by Veolia.

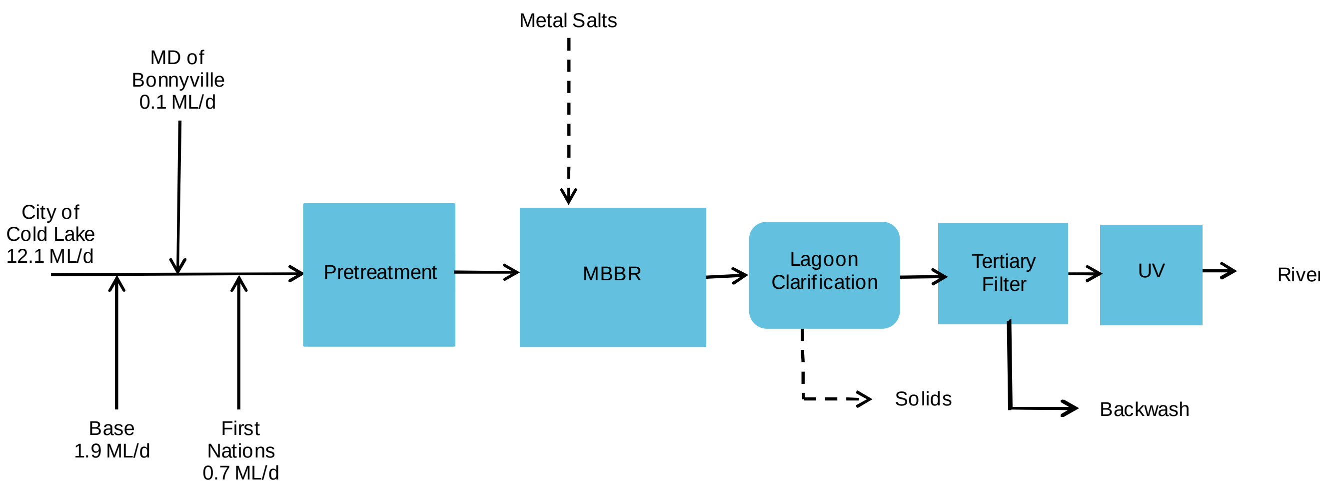


Figure 6.16: MBBR Process Flow Diagram

Table 6.9: Main Design Parameters for MBBR

Parameter	Unit	Value
Bioreactors		
Type: Moving Bed Bioreactor		
MBBR Reactor		
HRT, average	h	8.4
Number		3
Length	m	18
Width	m	16
Depth	m	5.0
Total Aerobic Reactor Volume	m^3	1,728
Carrier		
K3 Media	m^3	2,592
Clarification		
Type: Use existing lagoon cells for clarification		

Table 6.10: MBBR Cost Estimate

Item	Cost
Contractor's Markup (10%)	$ 2,100,000
Siteworks	$ 1,700,000
Electrical Supply Distribution	$ 2,500,000
Staffing Building/Lab	$ 400,000
Pretreatment	$ 1,500,000
MBBR Tank Construction	$ 8,400,000
MBBR Equipment Supply and Install	$ 3,100,000
Tertiary Filter	$ 1,700,000
UV Disinfection	$ 1,100,000
Subtotal	$22,500,000
Est. Allowance (30%)	$ 6,800,000
Subtotal	$29,300,000
Engineering (15%)	$ 4,400,000
Total	**$33,700,000**

An added advantage to the MBBR system is the ability to purchase media for the reactor as the population grows. As the loads for the system increase, media can be added to increase the performance of the reactor until a maximum number is reached. This allows some flexibility in cost for a growing population.

There is an alternative to the MBBR configuration and that would be to install the MBBR after one of the lagoons. This would help the process by removing excess TSS before the MBBR and the lagoons would help equalize the flow coming into the MBBR and the process could be optimized resulting in smaller MBBR tanks and less media, reducing the cost of the plant. Also it would eliminate grit removal and possibly the need for screens. This option would require further scrutiny as the lagoons would also reduce the temperature of the flow entering the MBBR tanks and lower temperatures could affect the performance of the MBBR.

6.2.6 Submerged Attached Growth Reactor

The Submerged Attached Growth Reactor (SAGR) is a relatively new technology aimed at removing ammonia from lagoon effluents. The lagoon effluent is directed through an influent header which distributes the effluent through a gravel media bed. Aeration grids provide oxygen for nitrification and are reported to minimize clogging of the media. A thick layer of mulch is spread on top of the gravel bed for insulation and heat retention. A schematic is shown in **Figure 6.17** and **Figure 6.18** shows an installation in summer and winter scenes after installation of a system in a cold weather climate.

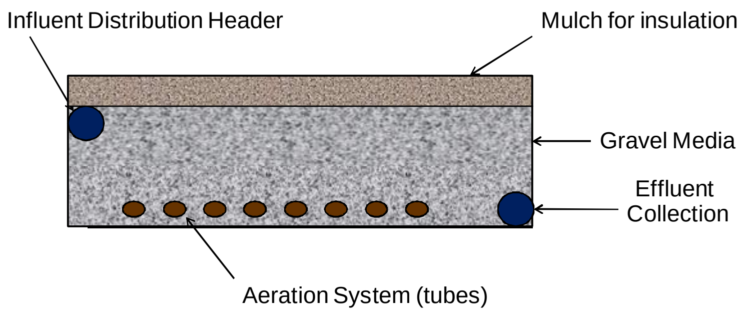


Figure 6.17: Simplified Schematic of the SAGR System

Figure 6.18: SAGR System Installation During Construction, and Summer and Winter after Construction

The SAGR system entails developing the existing aerated and facultative lagoon cells into fine bubble complete and partial mix aeration cells for BOD and TSS removal followed by the SAGR cells for ammonia removal. A sand filter has been proposed by the SAGR vendor as part of the system to remove phosphorus and TSS. Disadvantages to the SAGR system is the limited life span of the system and the space required for larger operations. The aeration diffuser membranes have a reported life span of 10 to 15 years and the SAGR cells must be dug out and reconstructed every 15 to 20 years due to solids build-up. The SAGR process flow diagram is illustrated in **Figure 6.19** and **Table 6.11** summarizes the design parameters, **Table 6.12** is a preliminary cost estimate.

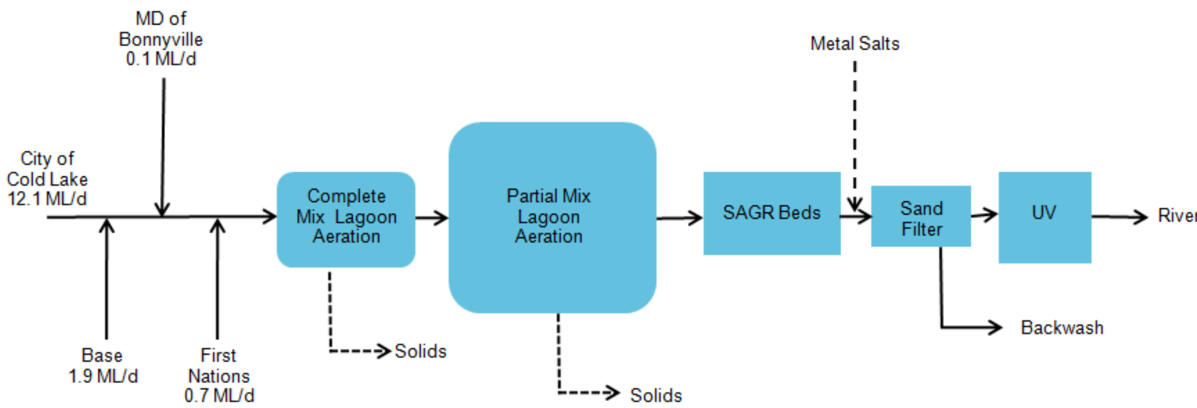


Figure 6.19: SAGR System Process Flow Diagram

Table 6.11: SAGR System Main Design Parameters

Parameter	Unit	Value
Lagoon Expansion		
Complete Mix Cell		3
Volume	m^3	15,600
Partial Mix Cell		1 (divided)
Volume	m^3	584,000
SAGR Cells		
Number of cells		8
Width of each cell	m	40
Length of each cell	m	87.5
Sand Filter		
Number		24
Length	m	2.2
Width	m	2.2

Table 6.12: SAGR System Cost Estimate

Item	Cost
Contractor's Markup (10%)	$ 3,100,000
Siteworks	$ 2,500,000
Electrical Supply Distribution	$ 3,800,000
Staffing Building/Lab	$ 400,000
System Equipment Supply and Install	$ 14,100,000
SAGR Construction	$ 6,400,000
Sand Filter	$ 3,600,000
UV Disinfection	$ 200,000
Subtotal	$ 34,100,000
Est. Allowance (30%)	$ 10,300,000
Subtotal	$ 44,400,000
Engineering (15%)	$ 6,700,000
Total	**$ 51,100,000**

6.2.7 Engineered Treatment Wetlands

Engineered treatment wetlands (ETW also known as constructed wetlands) are engineered structures in which the flow, water level and detention time is controlled. They resemble natural wetlands in appearance and are used for municipal wastewater, industrial wastewater and storm water treatment. Constructed wetlands are gaining popularity as they are perceived as both an environmentally conscious and cost effective treatment option. While there are cold climate installations there are challenges with this type of installation.

The RUSC, as part of the review of treatment technologies for the regional wastewater facility, have requested that AECOM consider engineered treatment wetlands as part of the feasibility study.

This section outlines the general application, capabilities and design criteria related to constructed treatment wetlands.

Wetland Categories

Regardless of the category, wetlands have the same characteristics. They generally consist of the following; one or more clay dyke-enclosed cells complete with clay liner, an inlet structure to regulate the influent throughout the cells (zones) for optimal treatment, combinations of fully vegetated (anaerobic) and open water (aerobic) zones for nitrification, and control structures at the outlet to regulate both discharge rates and operating levels throughout the wetlands.

Constructed wetlands are typically divided into two categories - free water surface (FWS) and vegetated submerged bed (VSB) wetlands.

Free Water Surface Wetlands

FWS wetlands closely resemble natural wetlands in that they contain aquatic plants that are rooted into the bottom soil while water flows through their submerged leaves and stems. A typical FWS wetland design is shown in **Figure 6.20**. Particulate matter settles in the primary cell before the flow is transferred into the wetland cells.

FWS wetlands attract birds, which can contribute to the fecal coliform levels in the effluent if large numbers gather; as well, they can become a breeding ground for insects (mosquitoes).

FWS typically have a higher capital cost (although competitive with other alternative treatment technologies), and lower operating cost than traditional treatment technologies. The higher capital cost can be attributed to material for the construction of the cells and the supply of emergent plants.

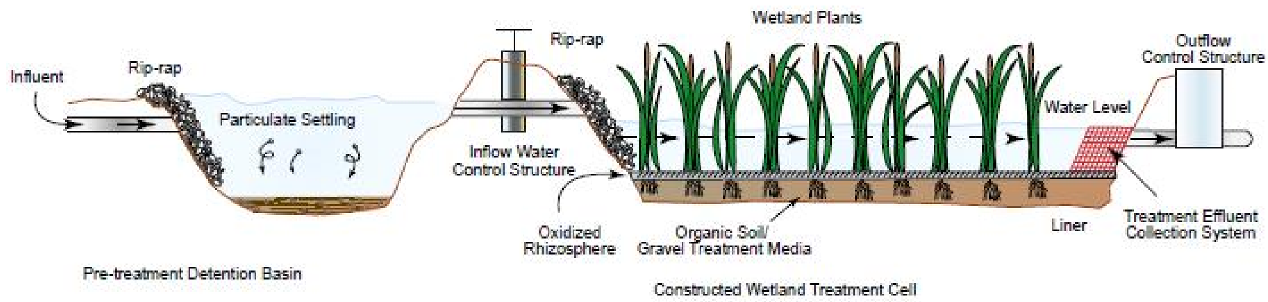


Figure 6.20: Free Water Surface Wetland Schematic

Source: An Overview of Constructed Treatment Wetlands, Carl E. Tammi, PWS, AECOM 2009

<u>Vegetated Submerged Bed Wetlands</u>

VSB wetlands do not resemble natural wetlands in that there is no standing water. They typically contain a bed of rock media in which aquatic plants have been planted. Flow is maintained below the media surface and flows across the roots of the plants. There are two types of VSB; horizontal flow, where the flow is introduced in a subsurface horizontal direction and vertical flow gravel or sand filter, where flow is either forced upward through the media or dosed on the surface of the planting substrate. **Figure 6.21** shows a typical horizontal flow VSB. If designed correctly, a VSB will not support wildlife, since the water level is maintained below the planting substrate.

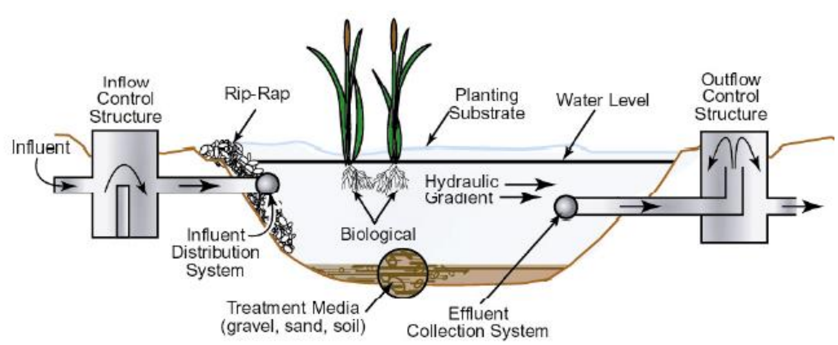


Figure 6.21: Vegetated Submerged Bed (Horizontal Flow) Schematic

Source: An Overview of Constructed Treatment Wetlands, presented by Carl E. Tammi, PWS, AECOM 2009

During cold weather, the plants can provide insulation for the effluent within the media bed.

When compared to FWS wetlands, VSB wetlands can cost more to construct, primarily due to the cost of the media. An advantage VSB wetlands have over FWS wetlands is the reduced odours as well as the control of insect larva and wildlife since there is no open water. The disadvantage to the VSB wetlands is their limited ammonia and phosphorus removal ability.

Wetlands Nutrient Removal Capability

There are physical, biological and chemical treatment processes at work in constructed wetlands for the removal of contaminants. Specific contaminant removal depends on the design, which is often dictated by the existing site conditions for size, complexity, operation and performance.

When wetland zones are fully vegetated, they are considered to be fully dominated by anaerobic conditions. Newer plants survive under these anaerobic conditions by transferring atmospheric oxygen to their roots. Since anaerobic zones dominate, aerobic zones must be specifically incorporated in the design in order for nitrification to occur. These are typically open water zones for aerobic treatment.

Phosphorus removal is limited to seasonal uptake by plants. Newer plants tend to uptake more phosphorus than mature fully vegetated wetlands as phosporus is a nutrient required for growth. Mature plants will in turn release phosphorus back into the wetland ecosystem as they decay, repeating this phosphorus uptake-release cycle every growing season. Mature fully vegetated wetlands, on average over time, have no net annual increase in phosphorus plant storage (Treatment Wetlands, Kadlec & Wallace, 2008).

Because of limited phosphorus removal in wetlands, it is considered the least efficient parameter for removal. If the influent phosphorus concentration is found to be high, then a large area of wetland would be required to reduce the concentration. Similarly, if the influent concentration is low, a smaller area would be required. The wetlands would have to be sized to meet the phosphorus limit of 0.15 mg/L which could require large amounts of area.

The nutrients are ultimately removed by harvesting un-decomposed plants from the wetlands. Typically harvesting is done during the peak growing period when phosphorus content is the highest. This makes harvesting the plants a significant effort due to the amount of mature floating aquatic plants. however, harvesting is typically infrequent, at intervals of 10 to 15 years (Treatment Wetlands, Kadlec & Wallace, 2008).

While VSB wetlands are less affected by winter as they can be insulated, FWS wetlands are more conducive to ammonia and phosphorus removal and will be the best option for the City. The basic process flow diagram for an ETW system following the lagoons is illustrated in **Figure 6.22**. The basic design parameters and cost estimate are shown in **Table 6.13** and **Table 6.14** respectively. The wetlands have been sized conservatively based on the highest proven achievable level of phosphorus removal and a tertiary filter is included to remove the remaining phosphorus. There is no mechanical pretreatment included in this option: the process will use the existing lagoons upstream of the wetlands.

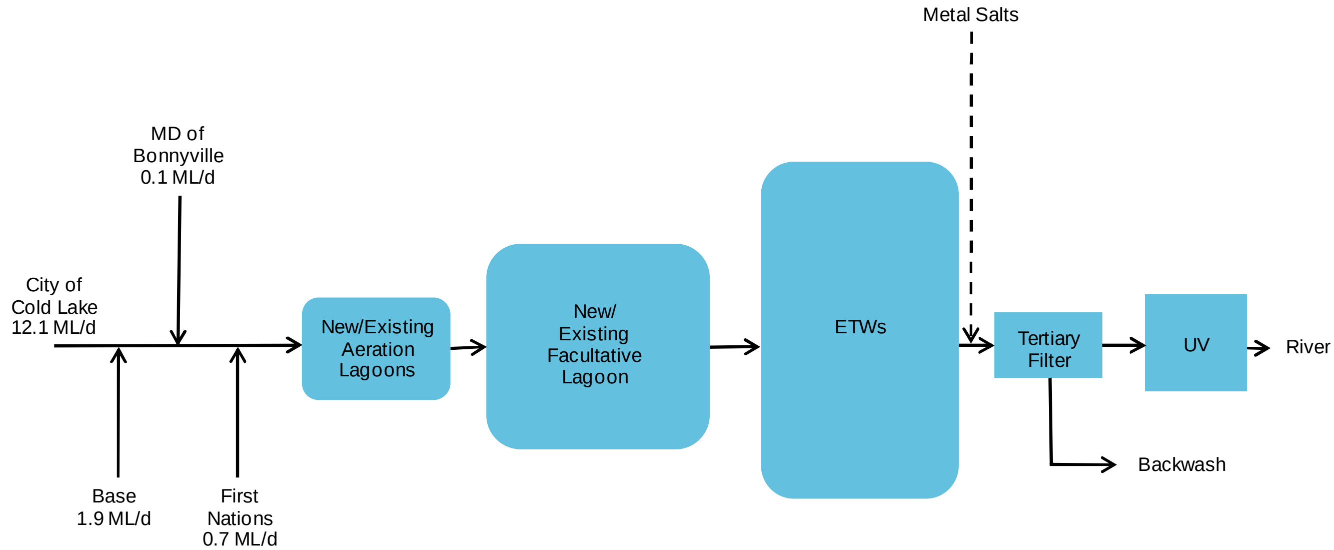


Figure 6.22: ETW Process Flow Diagram

Table 6.13: ETW Design Parameters

Parameter	Unit	Value
Lagoon Expansion		
Existing		
Aeration Complete Mix Cell		1
Volume	m^3	15,600
Aeration Partial Mix Cell		1
Volume	m^3	15,600
Facultative Cell		1
Volume	m^3	183,000
New		
Aeration Complete Mix Cell		2
Volume	m^3	15,600
Aeration Partial Mix Cell		2
Volume	m^3	15,600
Facultative Cell		2
Volume	m^3	183,000
ETW		
Type: FWS		
Depth	m	0.8
Volume	m^3	320,000
Area	ha	40

Table 6.14: ETW Cost Estimate

Item	Cost
Contractor's Markup (10%)	$ 2,400,000
Siteworks (10%)	$ 1,900,000
Electrical Supply Distribution	$ 2,900,000
Staffing Building/Lab	$ 400,000
Overall System Supply and Install	$ 15,900,000
Tertiary Filter	$ 2,000,000
UV Disinfection	$ 500,000
Subtotal	$ 26,000,000
Est. Allowance (30%)	$ 7,800,000
Subtotal	$ 33,800,000
Engineering (15%)	$ 5,100,000
Total	**$ 38,900,000**

The limited number of wastewater treatment wetlands operating year round in cold climates makes this option an unproven treatment system for Cold Lake. The winter freeze will impair ammonia volatilization/mineralization and conversion, and winter die back of emergent vegetation combined with freezing will also impair winter phosphorus removal. There are some process elements that can be incorporated into the design to improve the quality of the final effluent and overcome some of these limitations. Heating the water is an option but would be unfeasible for the size of wetlands required. The other option would be to cascade the effluent over rip rap or small drop channels which will assist in ammonia removal and limit freezing in the immediate location if the water is kept turbulent.

6.2.8 Intermittent Sand Filter

The intermittent sand filter technology for nutrient removal is not feasible for the effluent limits required and the cold climate. Industry consensus is that intermittent sand filters are not suitable for cold climate treatment locations so this technology is not considered for further analysis.

6.3 Process Treatment Selection

Each technology is evaluated against the triple bottom line including economic, environmental and social factors. Supplier quotes were obtained where possible and cost estimates developed to a feasibility stage. For this type of estimate an allowance of 30% is typically used to account for limited definition of scope. As the level of definition increases, the accuracy of the estimate will improve and the percent allocated to unknowns lowered. For technology screening only a qualitative view of the costs should be taken.

To assess the economic and non-economic criteria, a weighted decision matrix has been developed to aid in selecting the most appropriate technology for the City. Descriptions of the matrix factors can be found below.

6.3.1 Economic

Capital cost and operating cost have been estimated strictly for evaluation purposes. The comparison table of the costs for the different technologies is presented in **Table 6.15**. The life cycle cost is calculated over the next 26 year period to the year 2037.

Table 6.15: Cost Comparison

Technology	Capital Cost ($ million)	Operating Cost ($ million / ML/d)	Life Cycle Cost[1] ($ million)
CAS with Chemical P removal	53.1	2.2	89.1
CAS with Biological P removal	52.4	2.2	88.4
MBR	51.9	2.5	92.8
SBR	46.4	2.2	81.7
MBBR	33.7	2.2	69.7
SAGR	51.1	2.6	93.6
ETW	38.9	2.4	78.1

Note 1: Life cycle cost calculated using a 4% interest rate.

Operating costs have been estimated using a nation-wide benchmarking scale where wastewater treatment facilities report their capital and operating costs to the benchmarking group so the data can be used to estimate costs for facilities that will be using similar treatment methods.

6.3.2 Technical

If a technology has a verifiable record of meeting its process objectives and reliability consistently over the long term in comparable climates at plants of similar size, then it is considered to have proven applicability and proven reliability.

Expandability of the technology allows the City to decide if it would be more cost effective to build a portion of the plant and expand or modify at a future date as the population grows.

Constructability assesses how difficult the technology will be to construct on the existing site and how easily the existing facility can integrate the new technology. One of the key components is how to construct while keeping the existing plant operational. Processes that do not use the lagoons can be completed offline and are ranked the highest.

Space Requirements takes into account how much land area will be required to construct new facilities or will need to be made available based on the footprint of the treatment system selected.

6.3.3 Operational

Staffing Level assesses the number of operators that will be required in order to run the treatment facility and Staff Qualification assesses the amount of training the operators will require. The latter is a function of the plant complexity.

Ease of Maintenance assesses the effort will be required to maintain the treatment facility.

Operator Safety and Environment assesses the level of hazards associated with the technology including the chemicals used in the process and compromised working conditions.

6.3.4 Social

Odour and Visual Impact assesses the effect the technology would likely have on the community and surrounding neighbours.

6.3.5 Environmental

Effluent Quality weighs the ability to reliably and consistently meet or exceed the design effluent limits. This criteria would be important if water reuse being included. However as described above, the local industries have no interest in water reuse.

Public perception takes into account the opinions that Cold Lake residents may have about the choice of treatment type with regard to protecting the environment.

Green House Gases (GHG) take into account the overall carbon footprint for each technology including transportation of chemicals to site, energy consumption and future replacement.

Waste Streams takes into account the quality and quantity of solids produced and disposal options available.

6.3.6 Decision Matrix

Each treatment has been evaluated on a scale of 1 to 5, 1 being the worst and 5 being the best, for the factors described previously. Each factor has then been weighted on a scale of 1 to 10, 1 being the worst and 10 being the best, to award a numerical value to each treatment option. The Decision Matrix was provided to the RUSC to complete using its preferred weightings and scaling.

Table 6.16: Decision Matrix

Factors		Weighting (1-10)	Treatment Options						
			CAS		MBR	SBR	MBBR	SAGR	ETW
			ChemP	BioP					
Economic									
	Capital Cost	10	1	1	1	2	4	1	3
	Operating Cost	10	2	3	1	2	2	1	2
Technical									
	Proven Applicability	10	4	5	4	4	4	3	1
	Proven Reliability	10	5	4	4	5	4	1	1
	Expandability	5	3	3	5	5	5	2	4
	Constructability	4	5	5	5	5	5	1	3
	Space Requirements	1	4	3	5	4	3	2	1
Operational									
	Staffing Level	7	2	1	2	2	2	3	3
	Staff Qualification	7	2	1	2	2	2	3	3
	Ease of Maintenance	7	2	2	1	2	2	4	3
	Operator Safety/Environment	8	2	4	2	2	2	3	3
Social									
	Odour	1	2	2	2	2	2	2	2
	Visual Impact	1	1	1	2	1	2	4	3
Environmental									
Governed by AENV	Effluent Quality	0	3	3	5	3	3	3	1
	Public Perception	1	1	4	4	1	2	3	5
	GHG	0	2	2	1	2	2	2	4
	Waste Streams	0	3	2	3	3	3	2	2
TOTAL		**340**	**221**	**235**	**209**	**241**	**252**	**179**	**200**

6.4 Recommendation

The option best suited for the needs of the RUSC wastewater treatment facility is a combination of MBBR treatment and the lagoon process. This is one of the lowest cost options for the RUSC and has the highest value in the decision matrix. This system not only uses existing infrastructure but provides the RUSC with a system that would be easily integrated into their operation and does not require a huge learning curve for the operators and staff. This process is relatively new to North America. It is recommended that RUSC run a pilot plant to increase confidence in the process especially at low temperatures.

Appendix C includes a high level drawing of a possible process configuration for the new wastewater facility and a process diagram of the proposed WWTF.

7. Solids Handling

There will be three main sources of solids from the proposed MBBR and lagoon treatment system.

The first source is the screenings and grit collected in pretreatment. These solids will be trucked to the landfill for disposal.

The second source will be the sludge accumulated on the bottom of the aerated lagoons. These solids can be handled the same way as the City currently handles lagoon solids. When the sludge accumulation requires the lagoons to be emptied, the sludge can be collected and dewatered in geotextile tubes. From there the solids can be trucked for disposal at the landfill. The City can explore alternative uses for the solids such as composting or land application but ultimately it will depend on finding a source willing to receive the solids.

The third source is the chemical-rich solids contained in the backwash from the tertiary filter. Typically this stream is returned to the upstream of the treatment process if the option is an activated sludge plant. For the recommended MBBR option, to prevent recirculation of fine particulates through the system, the recommendation is to discharge these solids in the facultative lagoon that will no longer be in use. Solids separation will be through evaporation.

The approach described alone for management of the solids will need to be confirmed with AENV. The City will need to apply for a licence and obtain separate approval for the solids management approach.

8. Project Implementation

8.1 Introduction

Any large infrastructure project needs to consider the best approach for constructing the new facility for the existing and future population as well as maintaining service during construction to meet all effluent regulatory requirements.

8.2 Construction Delivery

An important consideration when designing a new wastewater treatment plant or upgrading an existing one is providing treatment during construction. The new system could be built around the lagoon operation. This will minimize the operational downtime of tying in the new system to the aeration lagoons and decommissioning some of the lagoons after the new system is operational.

8.3 Construction Staging Options

Depending on the available funding, there are two main options for construction of the regional system, one large contract or a two-phased construction approach. The MBBR provides a very easy transition to larger wastewater flows by the addition of media without having to increase the tank size. Currently the average annual flow is 4.65 ML/d with a peak dry weather flow (calculated using Harmon's Peak factor Equation 3.1) of 13.4 ML/d. With regionalization and a 3% population growth to 30,000, the average annual flow would be 14.8 ML/d with a peak flow of 36.7 ML/d by 2037.

The first option would be to build the full system including capacity for regionalization and the future design population of 30,000. All the tanks for the new WWTF would be built and media would be added on an as needed basis. The cost associated with a full capacity system will be very high and will need to be funded by the current service population (just under 12,000 if the system is regionalized or just over 9,000 without regionalization). Because the 2037 projected population of 30,000 for the new system design is more than double the existing population, it may be too onerous for the present population to bear the burden of the full cost.

The second option, although it may cost more in the long run, will reduce the cost for the individual service user. This option would divide the flow capacity in half and stage the construction in two phases. Although there may be some components that could be built for the full 30,000 capacity, this would mainly be a plant built for an average annual flow of 7.5 ML/d and a population of approximately 15,800., This approach allows the RUSC to grow into the system and defer some of the construction cost, and distribute it over a larger population. The MBBR option has the added advantage of being able to build the tank for a future population but installing only enough media to service for the existing population. Increased population can be accommodating merely by adding more media until the second MBBR tank is required.

8.4 Recommendations

The MBBR tanks should be built such that the media can be added as population and flow increase. The current estimates reflect a large MBBR tank split into two streams for some redundancy. Although it would be cost effective to build the entire system all at once, it is not necessary and funds are limited. In order to fund the project responsibly and affordably for the individual service user, it is advisable to build treatment capacity for half of the design population and delay increasing the rest of the capacity until the area grows into it.

9. Project Delivery

9.1 Introduction

The primary objective of this section is to review existing policies in Alberta for delivering infrastructure projects and services, review alternative approaches and delivery models, comparatively evaluate options against traditional approaches and recommend the best project delivery approach for the RUSC.

9.2 Understanding Project Delivery Options

The Province of Alberta has established a policy for involving the private sector in delivering strategic infrastructure and associated services and to that end in 2003 published a document titled "Public Private Partnerships – Alberta Infrastructure Guidance Document" (Guidance Document). The intent of the document is to provide a framework for evaluating and implementing infrastructure projects and services and originally was intended to focus on schools, health facilities, post-secondary institutions and government facilities. However, in recent years the scope of Public Private Partnerships (P3) has expanded to include major urban transportation highways in the Province and in 2006 two new guidance documents were issued: "Public Private Partnerships – Management Framework: Assessment Process" (Assessment Process) and "Public Private Partnerships – Procurement Process" (Procurement Process). These documents provide further details on assessing and procuring P3 projects in Alberta.

The Guidance Document defines a P3 as a cooperative venture between the public and private sectors, built on the expertise of each partner, that best meets clearly defined public needs through the appropriate allocation of resources, risks and rewards.

Figure 9.1 illustrates a continuum of P3 approaches with increasingly higher levels of private sector involvement from left to the right hand side of the bar. The lowest level of private sector involvement is on the left hand side of the bar with the conventional design/bid/build (DBB) approach and the highest level of involvement is on the right hand side with a fully privatized utility.

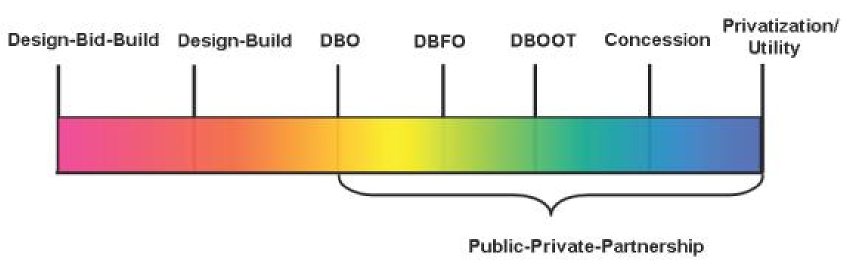


Figure 9.1: Continuum of Project Delivery

In the DBB approach it is most common for local government to retain responsibility for operations, maintenance and financing, while design and construction is contracted out to outside organizations. In the fully privatized utility, local government would have very little involvement in delivering the infrastructure or related services, as the utility would be regulated by provincial statute, as is common in the energy sector. In the middle of the continuum, approaches range from Design-Build , Design-Build-Operate-Transfer (DBOT), Design-Build-Operate (DBO), Design-Build-Finance-Operate (DBFO), Design-Build-Own-Operate-Transfer (DBOOT) and Concession.

However, the continuum is by no means all inclusive as there are delivery model variations not illustrated in **Figure 9.1**, including different ways of designing/constructing the asset and providing related services as well as different organizational models for the private sector proponent and local government. For example, construction management is an approach that, depending on which party assumes the risk for final costs, would fall somewhere between a conventional DBB and DB. **Table 9.1** summarizes the various delivery options.

Table 9.1: Procurement Opportunities and Challenges

Model	Definition	Opportunities	Challenges
Design – Bid – Build	Traditional delivery method where the design and construction of a project are carried out under separate contracts	-Owner and operators fully involved -Owner control -Project phasing -Public financing and borrowing costs are less and more efficient -Scope changes are easy to quantify and implement -There is no time constraint -Budget constraint	-Owner maintains most of the risk financially -Multiple points of accountability
Design/Build	Delivery method where one entity is responsible for both design and construction	-Opportunity to ‘fast track’ the project -Contractor assumes the risk -Single point of accountability -Early knowledge of the total costs -Incentive for cost innovation works well for large projects	-Loss of design control by the owner and operators -Loss of upfront planning -Limited time to respond to issues -Honoraria to unsuccessful bidders -Limits inspection of work -Profit oriented and could lead to impacts in the future to client infrastructure -Construction staging
Construction Management @ Risk	Two contracts managed by owner that involves both the construction manager and the engineer in the planning and design phases	-Provides more cost certainty -Project management expertise introduced early	-Final cost can still escalate -Does not eliminate finger pointing -Owner maintains the most risk -Construction staging
Design/Build/Operate	Delivery method where private entity is responsible for design, construction and operating the facility	-Using outside expertise and innovation -Limits the onus on the owner from training staff and operating a new, unknown system	-Very complex contracts -Locked in contract reduces flexibility for the owner -Limited flexibility in design changes -Few potential for competitors and out of reach for local competitors

Model	Definition	Opportunities	Challenges
Design/Build/Finance /Operate	Delivery method where one entity is responsible for design, construction, operating and financing the facility	-Innovative financing -Less onus on the owner	-High costs of private borrowing and financing, could end up costing more to the service user -Limited public oversight
Design/Build/Own/ Operate/Transfer	A private sector consortium is responsible for designing, constructing, operating, owning and financing a facility for the life of the project (normally 20–25 years). At the end of this period ownership of the facility is transferred to the owner	-Innovative financing -Less onus on the owner	-High costs of private borrowing and financing, could end up costing more to the service user -Limited public oversight
Concession	A private-sector company is responsible for operation and maintenance of the system, and capital investment required over the life of the concession, typically 20–30 years	-Innovative financing -No onus on the owner	-High costs of private borrowing and financing, could end up costing more to the service user -Limited public oversight
Private Utility	Built, owned and operated by a private company	-No onus on the owner	-Complete disassociation with the service

Sources: CRD Public Participation Summary Report: Procurement Delivery, Core Area Wastewater Treatment Project by J. Loveys February 2010.

The opportunities, location and size of the City likely limit the potential for high level P3 construction. The RUSC should focus on three main options, Design-Bid-Build, Design-Build and Construction Management @ Risk. The main issues to consider when choosing the project delivery method include:

- Size and complexity of project — as the size and complexity of a project increases, a greater opportunity exists to explore options for infrastructure delivery
- RUSC policies — the RUSC may wish to own and operate assets
- Finance — a higher level P3 delivery option including financing may be attractive where the RUSC wishes to avoid taking on additional debt but this may raise the individual service user rates with higher private interest financing
- Regulatory approvals — the need for a detailed conceptual design for regulatory approvals for certain projects may limit options to sequentially design and construction
- Timing — DB may lead to quicker project completion
- Design needs — DB and DBO may not be favoured if the contractor or operator do not possess the best design process skills
- Construction — DB and DBO may be favoured for a greenfield site with high project cost and some complexity and scope for innovation
- Risk management — Design-Bid-Build may be favoured where detailed site investigations are necessary to adequately develop and cost a concept design, or where there is considerable uncertainty in demand/load projections. DBO or DBFO would be favoured where the RUSC wishes to transfer management of design, construction and operation interface risk to the private sector

The most appropriate delivery method for the RUSC can only be determined once a careful review of the above issues is completed.

10. Financial Considerations

10.1 Background

The RUSC currently supplies wastewater treatment to the City and Cold Lake First Nations 149A. The expansion into a regional system may also include Cold Lake First Nations 149 and 149 B, immediate surrounding areas of the M.D. of Bonnyville as shown in the IDP and possibly the 4-Wing Air Base residential users.

10.2 Current Structure

The RUSC is dependent on the rates collected from service users to pay for capital infrastructure and the operations and maintenance required to provide wastewater treatment services. Currently the sewer charge to the 4,000 users is a flat rate of $24.60/month of which approximately 20-25% is wastewater treatment expenses (RUSC Public Works Budget).

10.3 Future System

As identified in **Section 6**, all options for a full scale wastewater treatment plant designed to remove nutrients for 30,000 people have a very significant capital cost and will need to be financed.

Funding sources available for capital costs of wastewater treatment can include federal funding, provincial funding and funding directly through the service rates. The current user rate for the sewer services covers all existing costs associated with the wastewater treatment and collection with no reserves for capital projects. One potential funding source that has been identified for this capital project include the Alberta Municipal Water/Wastewater Partnership that can cover 30% of the capital cost of the project. Currently there is no federal funding in place for this type of project (the stimulus program has expired) but it will be important to keep checking as this type of funding can become available at any time. There is also potential for funding from INAC by including the First Nations as part of the service users. If there are First Nations involved as part of the regional system, there is funding for 5% of the capital cost available for the project and is included in the estimate.

The capital cost for an upgraded WWTP that serves a population of 30,000 and uses the MBBR treatment process is estimated at approximately $33,700,000. If only half the capacity is constructed for the first phase of the new wastewater treatment plant, that minimizes the increase from $24.60/month to $67.50/month. The full system would be a monthly cost of $78.40 per service user. In the long run staging the wastewater treatment in two phases will cost the client more but will ease the burden on the smaller population for the short term. A breakdown of the user fees can be seen in **Table 10.1**.

Table 10.1: Estimated User Fees[1]

Cost	Full System	WWTF – Stage 1 only[2]
Estimated Construction Cost	$33,700,000	$22,700,000
Funding 35%	$11,865,000	$7,992,000
Yearly Interest Payment on New Treatment 4% over 20 years	$1,607,000	$1,082,000
Operation & Maintenance Treatment	$2,160,000	$1,080,000
User Rate	$78.40	$67.50

Note 1: The estimates are based on 2011 dollars, current labour and material rates, and are preliminary at this stage. The estimates will be refined during the next design stages.

Note 2: Additional costs and user fees will be required when Stage 2 is completed.

10.4 Recommendations

The RUSC must upgrade their wastewater treatment to meet stricter environmental limits and increase the capacity of its WWTF to keep up with the projected growth for the City and surrounding areas. The user rate increase is substantial and while there is not significant savings between the full construction and a staged approach ($78.40 versus $67.50 per month), it may still be worthwhile for the individual user.

Bibliography

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An Overview of Constructed Treatment Wetlands. PWS AECOM.

Appendix A

Please fax or email response to:

ATTN: Kristi Beckman, AECOM
Fax: 780-488-2121
Email: Kristi.Beckman@aecom.com

Name of Facility	Osum Oil Sands Corp., Taiga Project Central Processing Facility
Address of Facility	NW, Section 5, Township 066, Range 01, West of the 4^{th} Meridian
Contact Name	Jamie Carlson, Manager, Operations
Contact Phone Number	403-861-6302

Questions

1. Is your facility interested in participating in a Water Reuse Program with the City of Cold Lake? (yes/no)

Yes, although this depends on the technical & commercial aspects of the program.

2. What type of processes could reused water be used for at your facility?

Salt cavern washing process

Steam generation

Drilling mud preparation

3. Do you foresee there being any limitations on the application of reuse water at your facility?

Our facility is quite some distance from Cold Lake making the idea unlikely to be commercially viable.

Quantity of Water

4. What is the quantity of freshwater water used at your facility daily? (m^3/d)

Zero for steam generation, some freshwater use for domestic purposes – although we would not use effluent for this purpose, unless it had been appropriately treated first.

5. What is the quantity of reused water you estimate could be used at your facility daily? (m^3/d)

Our facility could use 100% of the available effluent from the City of Cold Lake.

6. Are there any seasonal variations in the water quality demand of your facility? Describe.

Our Taiga Central Processing Facility will operate 24 hours a day, 7 days a week so there are no seasonal variations anticipated.

Quality of Water

7. What would be the required quality of reuse water required by your facility? List all applicable parameters.

This is something we would need to investigate further, however, the reused water would have to be solids free, treated for bacteriological or viral agents, and low in treatment chemical composition.

From: Jamie Carlson
To: Beckman, Kristi
Cc: Stan Bergen; Justin Robinson
Subject: Cold Lake Water Reuse Strategy
Date: Thursday, May 26, 2011 11:14:49 AM
Attachments: Cold Lake Water Reuse Survey.docx

Hi Kristi,

Thank you for contacting Osum Oil Sands Corp. regarding a strategy for reusing Cold Lake effluent water.

Osum has not yet constructed our Taiga Project facilities so the answers to the survey are the best answers we can provide at this point and are subject to change. Osum has already taken considerable steps to make the Taiga Project something our shareholders, employees, consultants, vendors, and the local stakeholders can be proud of, we hope. We have committed to not use any fresh water in our steam generation processes, we will use water treatment technology that is more environmentally friendly than typical sized oil sands projects (we will not have any tailing ponds or lime sludge treatment ponds), we will have very low air emissions from our facility, we have made great strides in reducing the footprint of our Taiga Project, and are working hard to reduce the noise & light emissions a project of this size typically creates.

Reusing effluent water from the City of Cold Lake is a great idea, however, I do have some technical and commercial questions that relate to this strategy proposal:

1.) What is the time frame for the start of this project?
2.) Are you aware of the distance of our Taiga Project from the City of Cold Lake (~ 30-km)?
3.) What type of cost structure is associated with this project and how would it be funded?
4.) What sort of effluent water quality standards are you aiming for?
5.) Would this type of project be sanctioned by Alberta Government regulatory agencies (Energy Resources Conservation Board, Alberta Environment, Alberta Sustainable Resource Development) and have you discussed this with the appropriate agencies?
6.) Are you aware of your responsibilities for Aboriginal Consultations in proposing a project like this?
7.) Who would be responsible for liabilities related to this type of project (i.e. – a leak in a pipeline)?
8.) Does the City of Cold Lake have the expertise to enable a reliable and consistent supply, both in terms of quantity and quality, from a project such as this?

I look forward to discussing this strategy idea with your further.

Regards,

Jamie Carlson, P. Eng.
Manager, Operations

Suite 1900, 255 - 5th Avenue SW

Bow Valley Square 3
Calgary, Alberta, Canada T2P 3G6
D 403.270.4760 | M 403.861.6302 | F 403.283.3970

Osum Oil Sands Corp.
The time is right | www.osumcorp.com

From: Reid, Bryon
To: Beckman, Kristi
Cc: Mostoway, Boyd A.; Reid, Bryon
Subject: RE: Cold Lake Water Reuse Strategy
Date: Tuesday, May 24, 2011 11:44:57 AM

Kristi,

This certainly appears to be an opportunity worth perusing. Unfortunately, for a facility such as our Cenovus Foster Creek Production facility, we're located on the Cold Lake Air Weapons Range, the economics' and feasibility for a pipeline would be insurmountable. In addition, all of industry is mandated by the Alberta ERCB to reuse 90% of all water received in the production of bitumen. To meet this commitment, we would be really challenged to import a new water source, and meet our recycle limits. Our license to operate also mandates that we (industry) shift for raw (potable) water sources to more saline (brackish) water sources. In our case we've done so, our raw water silence allows for up to 3550 m3 / day annualized, we're taking < 800 m3 / day.

One thought that my be of consideration, is if the City of Cold Lake were to recycle their effluent streams, a significant user for this water might be the power plant on 4 Wing. The costs associated with pipelines and delivery to the base would be relatively small.

Regards,

Bryon

Cenovus Energy New Ideas. New Approaches.

From: Sander, Maureen
Sent: Friday, May 20, 2011 1:50 PM
To: 'Beckman, Kristi'
Cc: Mostoway, Boyd A.; Reid, Bryon
Subject: RE: Cold Lake Water Reuse Strategy

Hi Kristi:

I am forwarding your inquiry on to our Operations Coordinator for water in our operation and to our Plant Superintendent. They would be the appropriate contacts to answer your questions.

Maureen Sander
Cenovus Energy Inc.
Office: 780-815-6703
Cell: 780-201-3964

From: Beckman, Kristi [mailto:Kristi.Beckman@aecom.com]
Sent: Friday, May 20, 2011 1:45 PM
To: Sander, Maureen
Subject: Cold Lake Water Reuse Strategy

Good afternoon,

AECOM is a consulting firm currently working with the Town of Cold Lake on upgrading their wastewater treatment system. The city would like to investigate the potential for implementing a Water Reuse program. The program would involve utilizing treated effluent water produced by the City to reduce the freshwater demand of local industries.

Local industries who would benefit from the application of reused water from the City's treatment facility would be:

1. Industries consuming high volumes of water for activities such as cooling, boiler feed and process water (ie. oil and gas, pulp and paper)
2. Industries discharging highly toxic effluent to natural bodies of water
3. Industries with growing demands for water consumption

Local industries would benefit from the reuse of water from the treatment facility through the reduction of freshwater withdrawal and the associated reduction of power consumption from pumping raw water. In addition to economic benefits, industries that reuse water can benefit from enhanced corporate images and public acceptance due to increased environmental responsibility

I have attached a quick questionnaire to gauge the interest in a implementing a Water Reuse program at your facility. Please fill out this questionnaire and return your comments to myself. If my inquiry would be better posed to someone else at your facility, please let me know and I can redirect my questions accordingly.

Your timely response is appreciated.

Thank you,
Kristi

Kristi Beckman, E.I.T.
Engineer in Training, Water
D. 780.732.9451
kristi.beckman@aecom.com

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Appendix B

RUSC149

Water

Cold Lake Regional Utility Services Commission

Receiving Water Assessment Technical Memorandum

Prepared by:

AECOM
17203 103rd Avenue
Edmonton, AB T5S 1J4
www.aecom.com

780.488.6800 tel
780.488.2121 fax

Project Number:

60157998

Date:

June, 2011

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- was prepared for the specific purposes described in the Report and the Agreement
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- as required by law
- for use by governmental reviewing agencies

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Revision Log

Revision #	Revised By	Date	Issue / Revision Description
1	C. Prather	10-Nov-10	First draft
2	C. Prather	11-Mar-11	Edits to receiving water TM
3	S. Biswanger	28-Jun-11	Final Edits
4			

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Appendices

1. Receiving Water Assessment

1.1 Background

The City of Cold Lake (City) sanitary collection system and wastewater treatment system is owned and operated by the Cold Lake Regional Utilities Services Commission (RUSC) (Municipal Development Plan 2007). The RUSC wastewater treatment facility (WWTF), a facultative lagoon facility, is south of the City limits (**Figure 1.1** and **1.2**). Treated effluent is piped approximately 1 km and discharged directly to the Beaver River with a side bank outfall. The operation of the WWTF is covered under Alberta Environmental Protection and Enhancement Act (EPEA) approval 1585-03-00. As part of the licence, the RUSC is to develop a nutrient control strategy for discharge of municipal effluents to the Beaver River.

As a portion of this feasibility study, existing conditions within the Beaver River have been investigated and used to confirm design criteria for an upgraded municipal wastewater treatment facility.

1.2 Current Conditions

1.2.1 Beaver River

The Beaver River Basin, a sub-basin of the Churchill River Basin, covers a portion of east-central Alberta and west-central Saskatchewan (Mitchell and Prepas 1990). The Beaver River originates at Beaver Lake, near Lac La Biche, and drains eastward. In Alberta this is one of the smaller river basins, covering approximately 2% of the province and is contained entirely within the Boreal Forest Natural Region (AENV 2006) (**Figure 1.1**). Approximately 25% of the entire basin is located in Alberta. The catchment area in Alberta, approximately 15,500 km^2, contains numerous recreational lakes, wetlands and peatlands with peatland cover ranging between 26 to 50% of the land cover in some watersheds (Turchenek and Pigot 1988).

Water in the Beaver River Basin is allocated for various uses including human consumption, oil and gas, and other industries, however flows in the Beaver River are unregulated and annual fluctuations are considered natural. It has been estimated that the amount of water allocated for use (surface and groundwater) is equal to 10 to 20% of the natural flow of the Beaver River (AENV 2006). Of the total water allocations in this basin, approximately 33% are from groundwater sources. This is in sharp contrast to groundwater allocations in other river basins of the province which are typically less than 3% (AENV 2006).

Water Quantity

Daily flows of the Beaver River are measured at a Water Survey of Canada (WSC) station (06AD006) located near the Highway 28 Bridge across the river (Beaver Crossing). A previous study has identified a statistically significant declining trend in the annual volume of water in the Beaver River Basin over the period of 1956 to 2001 (Seneka and Figliuzzi 2004) (**Figure 1.3**). Mean annual daily flow was lowest in 1992 and highest in 1962. The Beaver River is primarily fed by naturally variable surface runoff rather than mountain snowpack, so the reported significant decrease in surface runoff cannot be confirmed at this time (Seneka and Figliuzzi 2004). However due to local melt, groundwater sources and seasonal rains, monthly average flows peak between April and August (**Figure 1.4**).

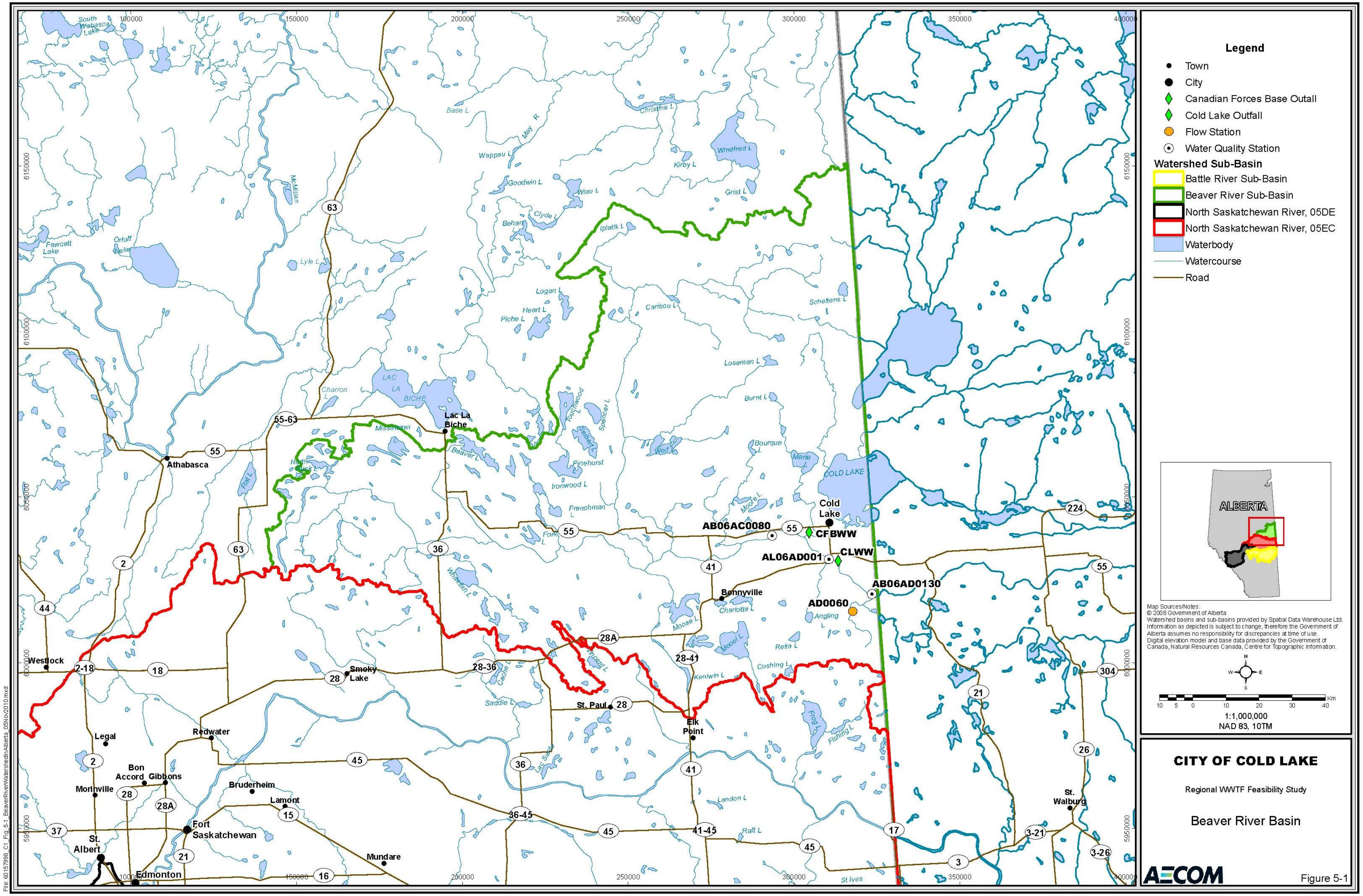

Figure 1.1: Beaver River Watershed in Alberta

Figure 1.2: Beaver River Receiving Water Study Area

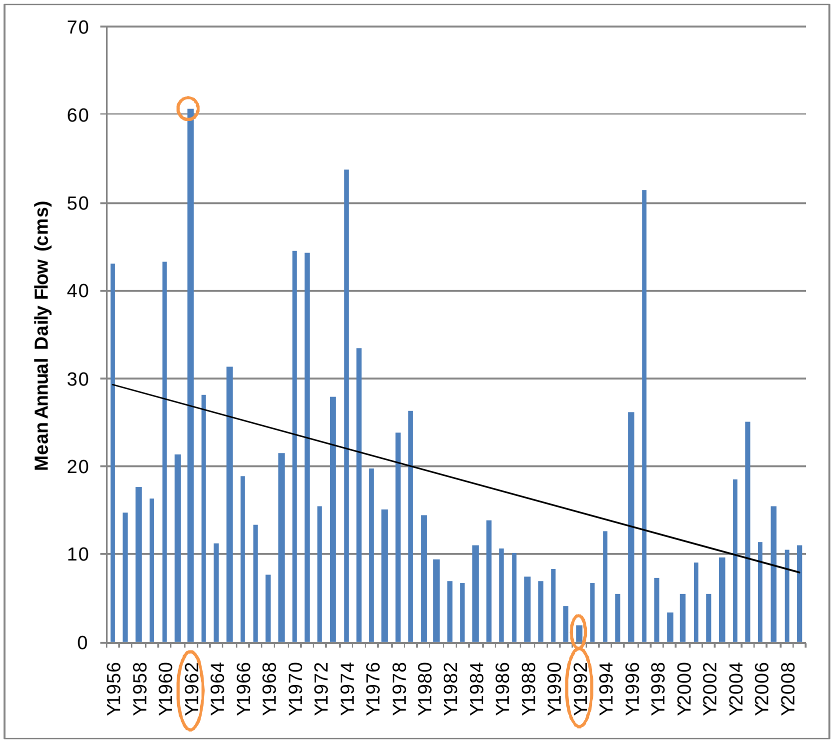

Figure 1.3: Mean Annual River Discharge in the Beaver River at Beaver Crossing (WSC 06AD006)

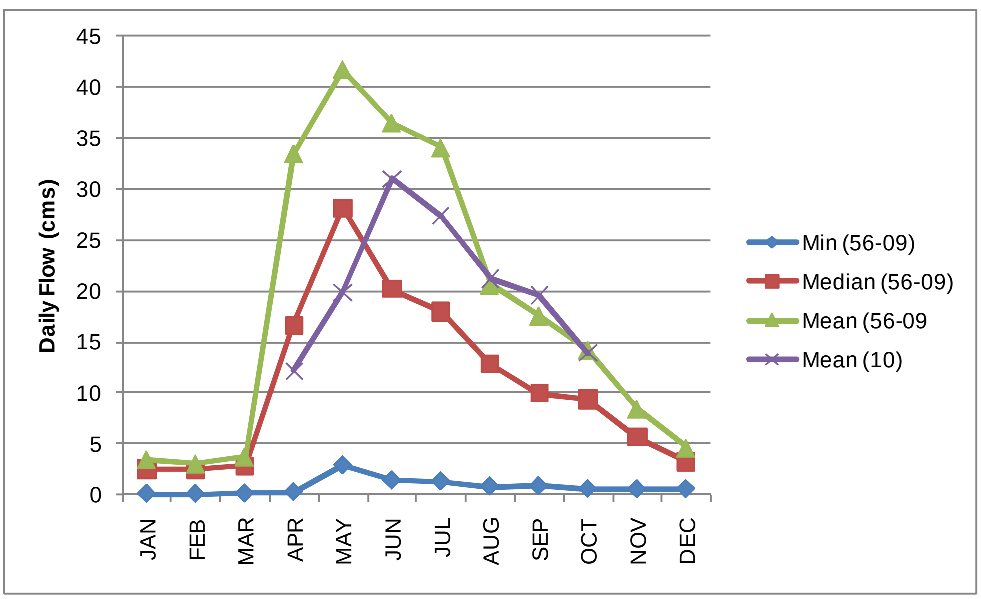

Figure 1.4: Minimum, Median and Mean Monthly Discharge in the Beaver River at WSC 06AD006 (1956-2009) Plus Mean Monthly Discharge in 2010

Water Quality

Water quality in the basin has been monitored at various stations on the main river. The closest water quality monitoring station to the RUSC discharge point is at Beaver Crossing on the Beaver River (Highway 28 bridge), located approximately 3 km upstream (AL06AD0001). The data at this station are maintained by Environment Canada as part of the Prairie Provinces Water Board (PPWB) group. The closest downstream monitoring station is approximately 21 km downstream of the RUSC discharge point (Cherry Grove). Currently, there are no monitoring data from immediately downstream of the sewage discharge and none of the current monitoring sites can describe the effects of regional sewage effluent discharge (Anderson 1994; North/South 2007).

Previous studies completed on the Beaver River identified the following water quality issues:

- concentrations of Total Phosphorus (TP), total nitrogen (TN), iron, manganese and phenols in river water exceed the Surface Water Quality Guidelines for Use in Alberta (SWQGUA)
- some flow independent variables (DO, nitrate, sulphate) decreased between 1969 to 1989
- some flow dependent variables (conductivity, alkalinity, sodium, chloride) increased between 1969 to 1989
- some flow dependent variables (true colour, Chlorophyll *a*) decreased between 1969 to 1989
- The Beaver River at Beaver River crossing:
    - is eutrophic
    - TP and TN frequently exceeded SWQGUA during low flow periods between 1998 and 2003
    - DO concentrations met SWQGUA guidelines 66% of the time and mainly fell below the guideline during winter
    - Pesticides have been detected but have not exceeded guidelines

Existing water quality data from the long-term monitoring station above the RUSC outfall has been summarized (**Table 1.1**). Of the four parameters presented in Table 1-1 with published guidelines, all of them have maximum recorded values that exceed current water quality guidelines. The exception is for Dissolved Oxygen where the minimum values are less than the guideline to support aquatic life. Current water quality guidelines that can be used for this location include:

- PPWB – Prairie Provinces Water Board guidelines (PPWB 1991)
- CCME – Canadian Council for Ministers of the Environment, Water Quality guidelines for protection of aquatic life (CCME 2007)
- SWQGUA –Surface Water Quality Guidelines for Use in Alberta (AENV 1999)

Data have been collected from the Beaver Crossing station since 1967 however in October 1993 the lab changed the method used to analyze dissolved nitrogen. This change resulted in better detection of nitrogen and consequently data in the post-October 1993 group have higher values. Comparison of dissolved and total nitrogen values in the pre-October 1993 period to the post-October 1993 period should be treated separately.

Table 1.1: Summary of Water Quality in the Beaver River at Beaver Crossing (AL06AD0001)

	Ammonia (dissolved) (mg/L)	Ammonia (un-ionized) (mg/L)	Fecal Coliforms (no/100mL)	Total Nitrogen (calc) (mg/L)	Total Dissolved Nitrogen (mg/L)	Total Phosphorus (mg/L)	Total Dissolved Phosphorus (mg/L)	Dissolved Oxygen (mg/L)
Guideline	*0.6*[a]	*0.019*[b]	*100*[b]	*1*[c]		*0.05*[c]		*5.0*[c]
Pre-Oct 1993[d]								
# Samples	69	67	180	166	196	224	196	216
Min	0.008	<0.001	0.0	0.17	0.12	0.026	0.009	0 (4.2[e])
Mean	0.193	<0.001	19.6	0.80	0.68	0.103	0.044	7.5
Max	1.390	0.010	345.0	2.09	1.90	0.720	0.225	14.6
Post-Oct 1993[d]								
# Samples	167	161	63	160	167	167	167	164
Min	0.005	<0.001	2.0	0.27	0.04	0.027	0.010	0.1 (3.1[e])
Mean	0.210	0.001	34.9	1.02	0.86	0.090	0.033	7.14
Max	2.780	0.026	227	3.48	3.11	0.652	0.540	14.2

Note: A – PPWB 1991; B – CCME 2007; C – AENV 1999; D – Due to changes in analytical technique, samples are grouped as pre and post October 1993; E – 25th Percentile Value

1.2.2 Existing Effluent

Existing Effluent Quantity

The current EPEA approval for this facility authorizes continuous discharges to the Beaver River from spring until winter freeze-up, when river flows are at least 10 times higher than the daily discharge rate and if there are no appreciable impacts on the water quality of the river. Discharge from the lagoon typically occurs from mid-April to late September. Available historical discharge data has been summarized in **Table 1.2**.

Table 1.2: Summary of Historic Effluent Quantity

Year	Number of Discharge Days	Total Discharge Volume (ML)	Average Daily Discharge Rate (m^3/s)
2006	205	1,184	0.067
2008	214	1,697	0.092
2010	201	1,872	0.108

Existing Effluent Quality

There is a requirement for monthly monitoring of treated effluent quality during the period of discharge to the river and daily recording of effluent flow rates. Treated effluent must be analyzed monthly for carbonaceous Biochemical Oxygen Demand (cBOD), Total Suspended Solids (TSS), Total Phosphorus (TP), Total Dissolved Phosphorus (TDP), Total Kjeldahl Nitrogen (TKN), Total Ammonia-Nitrogen (NH_X-N), Nitrate & Nitrite-Nitrogen (NO_X-N), Fecal Coliforms (FC) and *E. coli*. Treated effluent must meet the cBOD limit of 25 mg/L. A summary of treated effluent quality from 2006 to 2009 is provided in **Table 1.3**.

Through previous studies, the following is known about treated effluent quality from the Cold Lake WWTP:

- Spring effluent is very poor quality
- Effluent P and N concentrations are higher than concentrations in the river

- Ammonia nitrogen is the dominant form of nitrogen in the effluent (as compared to oxidized nitrogen)

Table 1.3: Existing Effluent Quality Summary

Date	BOD (mg/L)	TSS (mg/L)	TKN (mg/L)	NO_X-N (mg/L)	NH_4-N (mg/L)	TP (mg/L)	TDP (mg/L)	*E. coli* (MPN)*	Total coliform (MPN)*
statistics for data collected in 2006-2009									
N	35	35	32	31	31	32	24	32	32
min	4.0	4.0	3.4	<0.02	2.0	0.86	0.61	0	0
mean	8.5	20.3	16.7	0.20	12.9	3.03	2.56	638	6,092
median	7.0	15.0	15.8	0.13	11.8	3.30	2.84	16	78
95^{th} Percentile	18.0	45.2	25.4	0.47	21.9	3.79	3.44	1,960	33,950
Max	19.0	87.0	28.8	1.08	25.1	4.01	3.50	10,000	60,000
Summer (mid June to Sept)									
N	18	18	15	14	14	15	12	16	16
mean	7.4	13.1	13.2	0.26	9.8	3.08	2.87	156	3,217
median	5.0	12.0	14.0	0.26	10.3	3.26	2.92	10	18
95^{th} Percentile	18.2	24.6	16.8	0.45	13.3	3.65	3.39	1,075	23,750
Max	19.0	28.0	17.1	0.50	13.3	3.70	3.50	1,300	29,000
Winter (October to early June)									
N	17	17	17	17	17	17	12	16	16
mean	9.6	28.0	19.8	0.15	15.5	2.98	2.26	1,120	8,967
median	9.0	24.0	20.2	0.06	16.0	3.40	2.34	110	1,115
95^{th} Percentile	16.4	55.8	26.2	0.49	23.0	3.84	3.31	4,300	45,000
Max	18.0	87.0	28.8	1.08	25.1	4.01	3.46	10,000	60,000

*Note: * = most probable number*

1.3 Receiving Water Study Methods

To assess the potential impact of RUSC wastewater effluent on the Beaver River and to aid development of future effluent quality limits, a receiving water study was initiated. The purpose of the study was to develop an understanding of water quality within the Beaver River and the effect of proposed changes in wastewater discharge on the river. To facilitate model development and understanding a field study was designed to collect samples for effluent quality, river water quality, benthic invertebrates and supporting environmental data. Sampling was also planned for periphyton analysis but it was observed during the August site visit that there was minimal algal growth in the study area. A view of the outfall is provided in **Figure 1.5**.

Figure 1.5: Cold Lake wastewater outfall on the Beaver River (August 2010)

1.3.1 Water Quality Sampling Stations and Sample Collection

Sampling stations were established to assist with modeling and interpreting current and future impacts of wastewater discharge on the river. Stations were established upstream of the outfall to describe background conditions and at various distances downstream of the outfall to measure water quality downstream. In addition, samples of final effluent were collected to understand effluent loads during the field program.

There is a bank-side outfall on the left bank side (looking in a downstream direction). Transects were established at discrete distances upstream and downstream of the outfall. At each transect, 1 or 2 of three stations were selected for sampling. In each transect, station 1 was closest to the left bank (within 10 m of the shore), station 2 was in the centre and station 3 was closest to the right bank (within 10 m of the shore).

Sampling stations in relation to the outfall were established at:

- Upstream 100 m, centre – US100-02
- Downstream 50 m, left bank – DS50-01
- Downstream 100 m, left bank – DS100-01
- Downstream 200 m, left bank and centre – DS200-01, DS200-02
- Downstream 300 m, centre – DS300-02
- Downstream 500 m, centre and right bank – DS500-02, DS500-03
- Downstream 1000 m, centre and right bank – DS1000-02, DS1000-03
- Effluent, sampling manhole at lagoon – Effluent

The transects across the river at these distance intervals are illustrated in **Figure 1.2**.

Additional upstream stations were also established to aid interpretation of the impact of the Canadian Forces Base Cold Lake (CFB-CL) effluent on the Beaver River. Samples were collected from the Beaver River at Ardmore bridge which is approximately 30 km upstream of the RUSC outfall. The location of this station (AB06AC0080) is shown on **Figure1.2**. The Ardmore crossing station was chosen as a far upstream station because of accessibility and historical data from this location. CFB-CL discharges treated effluent into Marie Creek which enters the Beaver River upstream of the Beaver Crossing station. To evaluate water quality in the Beaver River at this location, samples were collected upstream and downstream of the Marie Creek confluence in March 2011.

Sampling stations were established at:

- Far-field Upstream
  - Ardmore (same as AB06AB0080)
- In relation to Marie Creek (discharge location for the CFB-CL)
  - Upstream 500 m, centre – US-MC500-02
  - Upstream 50 m, left bank – US-MC50-01
  - Downstream 50 m, left bank – DS-MC50-01

Samples were collected in August and September 2010 and March 2011. Samples were collected at the above identified stations as per the sample collection schedule in **Table 1.4**.

Table 1.4: Collection of samples by Station and Month

Station	August 2010	September 2010	March 2011
US Ardmore		Water	Water
US MC500-02			Water
US MC50-01			Water
DS MC50-01			Water
US100-01	Water	Water (replicate) + Invertebrates	Water
Effluent	Effluent	Effluent	
DS50-01	Water	Water + Invertebrates	Water
DS100-01	Water	Water	Water
DS200-01	Water	Water	Water
DS200-02	Water		
DS300-02		Water	Water (replicate)
DS500-02	Water	Water + Invertebrates	Water
DS500-03	Water		
DS1000-02	Water	Water + Invertebrates	Water
DS1000-03	Water		
Field Blank	Water	Water	Water

Water quality samples for laboratory analysis were collected by following recognized sampling protocols and appropriate measures were taken to avoid sample contamination such as wearing nitrile gloves during sample collection, not touching the inside of bottles and storing the samples in coolers. Sample bottles were provided by the laboratory (rinsed in triplicate, rinse water disposed of downstream of the sampling station). All river sampling was conducted from a boat by orienting the boat upstream and collecting samples by leaning safely over the edge facing upstream. Sample bottles were filled by placing them at least 10 cm below the water surface and plunging them in to avoid surface film. The effluent sample was collected by lowering a sample bottle into the sampling manhole at the lagoon facility.

For the March 2011 sampling event, samples were collected from under-ice conditions after drilling a hole through the ice with a gas powered auger. The sampling area was cleared of snow and debris prior to drilling and the sampling hole was cleared of ice, using a sieve, prior to collection of samples. Samples were collected by lowering the sampling bottle into the hole and allowing the bottle to fill.

When required, samples were preserved or filtered and preserved using the pre-measured preservative provided by the laboratory. All samples were stored in coolers and kept cool with ice. Chain of custodies were filled out and the samples were delivered to ALS Laboratory Group in Edmonton.

1.3.2 Water Quality Sample Parameters

At each station, field environmental parameters of pH, conductivity (µS/cm), temperature (°C), dissolved oxygen (DO) and water velocity (km/h) were measured by using an Oakton pH Testr 2, Oakton ECTestr Low, an OxyGuard Hand Polaris and a Global Water Flow Meter, respectively. Water depth, photographs and GPS coordinates were also collected at each station.

River and effluent samples were collected and submitted to ALS for analysis of a variety of water quality parameters including:

- General chemistry
  - pH, conductivity, alkalinity, cations, anions, sulphate, total suspended solids (TSS), total dissolved solids (TDS)
- Oxygen Demand
  - carbonaceous Biochemical Oxygen Demand (cBOD), Biochemical Oxygen Demand (BOD)
- Nutrients
  - Total Phosphorus (TP), Total Dissolved Phosphorus (TDP), orthophosphate (PO_4-P), nitrite (NO_2), nitrate (NO_3), total ammonia (NH_X-N), Total Kjeldahl Nitrogen (TKN), Total Organic Carbon (TOC), Dissolved Organic Carbon (DOC)
- Bacteria
  - *E. coli*
  - Fecal Coliforms

Samples were analyzed for general chemistry, cBOD, nutrients and bacteria in August and September. Total and dissolved metals were analyzed only in August and BOD was only analyzed in September.

1.3.3 River Flow

Daily discharge of the Beaver River is recorded at Environment Canada station 06AD006. Daily discharge (m^3/s) data from 1956 to 2009 was obtained from the Water Survey of Canada website (Environment Canada 2010). The data was evaluated and summarized to understand yearly and monthly variability in flows (**Figures 1.3** and **5.4**). The mean monthly flows in August, September and March are reported by Environment Canada as 20.6 m^3/s, 17.6 m^3/s, and 3.73 m^3/s respectively. Similarly, reported daily mean flows at the time of sampling in August and September were 17 m^3/s and 20 m^3/s respectively.

Historical, long-term data was also used to calculate a 7Q10 statistic (the lowest flow recorded over 7 continuous days in 10 years). The 7Q10 statistic was calculated using all data over the period from 1956 to 2009. The 7Q10 statistic was calculated as follows:

- The seven day mean time series for the daily flow time series data from January 1, 1956 to December 31, 2009 was reviewed and no data gaps were found within the original flow time series.
- For each year, the minimum seven day mean was extracted. This provided the annual minimum 7Q from 1956 to 2009

- A frequency analysis was performed on the annual minimum 7Q time series using a program called "Low Flow Frequency Analysis Package" or LFA. LFA is a software package developed by the Water Resources Branch of Environment Canada. The software fits a Gumbel III distribution to the time series data. In the event that the software cannot fit the Gumbel III distribution, a three-parameter lognormal distribution is fit to the time series.
- The 7Q10 estimated from the frequency analysis using the Gumbel III distribution was 0.468 m^3/s.

The 7Q10 statistic was also calculated for the dataset April 15 to October 15 for the years 1956 to 2009. April 15 to October 15 is the typical period of time when wastewater is discharged to the Beaver River. The 7Q10 statistic was calculated using the above procedure and was estimated to be 1.460 m^3/s for the April 15 to October 15 period.

1.3.4 Mixing Zone Models

The mixing of the Cold Lake WWTF discharge within the Beaver River was modeled using two separate methods, depending on the flow regime analyzed. For low flow Beaver River conditions a conservative mass balance model was used to indicate fully-mixed concentrations of ammonia and phosphorus in the stream assuming no uptake or degredation of model parameters within the mixing zone. This analysis provides a conservative estimate of parameter concentrations at the downstream end of the mixing zone (in line with the intent of the SWQGUAs). This was done as the hydraulic characteristics of the river at low flows were expected to be variable and substantially different compared to the characteristics at higher flows.

For the higher, more typical Beaver River flow conditions similar to those encountered during the monitoring program, the river was hydrodynamically modeled using CORMIX GT Version 6.0. CORMIX is a software system developed by Cornell University for the analysis, prediction and design of aqueous toxic or conventional pollutant discharges into diverse water bodies, (Doneker and Jirka 2007). CORMIX specializes in analyzing the effluent plume in the mixing zone region (i.e., the region between the lagoon outfall and the point of complete mixing of the plume in the Beaver River).

The basis of the CORMIX model is a flow classification system. Based on dimensionless length scales, the model classifies the discharge configuration into generic flow classifications (Gomm 1999). Once the flow has been classified, the model assembles and executes a sequence of sub-models to simulate the hydrodynamic behaviour of the discharge, and calculates the plume trajectory, dilution and maximum centerline concentration. CORMIX uses these different sub-models to predict mixing in both the near-field region and far-field region from the discharge point. Note that in the context of the CORMIX model, the terminology "near-field" and "far-field" have no relation to the point of complete mixing – the near-field region refers to the region where the initial jet characteristics (including momentum flux and buoyancy flux) and outfall geometry govern the plume mixing; the far-field region is representative of where conditions existing in the ambient environment (such as density, current buoyant spreading and passive diffusion) govern the trajectory and dilution of the plume. The distance to the boundary between the near-field to far-field regions is arbitrary and depends on the model input parameters (scenario).

The Cold Lake WWTF discharge to the Beaver River was modeled using CORMIX1, a subsystem which is used for single port discharges. This subsystem was chosen due to the fact that the lagoon discharges into the Beaver River via a culvert.

Model Input and Rationale

The CORMIX model was calibrated with the water quality data collected during the August 31, 2010 monitoring event on the Beaver River near the Cold Lake WWTF outfall and then validated with water quality data collected during the September 29, 2010 monitoring event. The model was used to predict the mixing zone dimensions and resulting water quality in the Beaver River downstream of the Cold Lake WWTF lagoon outfall during the summer and fall/spring scenarios with the current lagoon configuration, and during an open water scenario assuming the proposed wastewater treatment plant.

Model Set-up Using August 31 and September 29, 2010 Data

During both the August 31 and September 29 monitoring events, surface water samples were taken at various stations (**Table 1.4**) including 100 m upstream of the outfall and downstream of the outfall at 50 m, 100 m 200 m, 300 m 500 m and 1000 m.

CORMIX models were created based on the August and September 2010 field data to simulate total phosphorus concentrations and ammonia concentrations in the Beaver River. Un-ionized ammonia concentrations were calculated using modeled ammonia concentrations. The CORMIX model inputs for the ammonia and phosphorus scenarios are provided in **Table 1.5**.

Table 1.5: CORMIX Model Inputs – August 31 and September 29, 2010 Field Events

Input Parameter	August 31, 2010 Scenario Total Phosphorus/Ammonia	September 29, 2010 Scenario Total Phosphorus/Ammonia
Effluent Worksheet:		
Conservative/non-conservative pollutant	Conservative/ Non-conservative	Conservative/ Non-conservative
Decay rate (1/d) if non-conservative	n/a / 55	n/a / 55
Discharge excess concentration (mg/L)	3.58 / 14.29	2.57 / 13.79
Effluent flow rate (m^3/s)	0.108	0.100.108
Effluent density: temperature (°C)	16.2	12.3
Ambient Worksheet:		
Average channel depth (m)	0.85	1.0
Depth at discharge (m)	0.85	1.0
Wind speed 2 m above the water surface (m/s)	2	2
Ambient Beaver River flow rate (m^3/s)	17	17.5
Bounded width (m)	50	50
Bounded appearance	Slight Meander	Slight Meander
Manning's n	0.04	0.04
Fresh water temperature (deg.C)	14.6	13
Discharge Worksheet (CORMIX1):		
Nearest bank (as seen looking downstream)	Left	Left
Distance to nearest bank (m)	0	0
Port diameter (m)	0.63	0.63
Vertical angle of discharge pipe (degrees)	0	0
Horizontal angle of discharge pipe (degrees)	270	270
Port height above water surface (m)	0.1	0.1
Discharge configuration	Jet-like	Jet-like

Notes: na = No decay rate was used for phosphorus, as it was modeled as a conservative constituent.

Additional details on the data included in **Table 1.5** are described below.

Effluent Worksheet

Conservative/Non-Conservative Pollutant and Decay Rate:

Under the "effluent" worksheet, the parameter may be modeled as either conservative or non-conservative. Total phosphorus was modeled as a conservative parameter since it behaves conservatively in the mixing zone. Ammonia was modeled as a non-conservative parameter and the decay rate, determined through calibration with the August 31 and September 29, 2010 water quality data, was 55 (1/d). The calibration results are presented in **Section 1.4.3**.

Discharge Excess Concentration:

The discharge excess concentration refers to the excess concentration of the point source (WWTF discharge) above background (i.e., the 100 m upstream station in Beaver River) concentrations. For total phosphorus on August 31, 2010, the upstream (US100-01) concentration was 0.0791 mg/L and the effluent concentration was 3.66 mg/L. Therefore, the discharge excess total phosphorus concentration was 3.58 mg/L (i.e., 3.66 mg/L – 0.0791 mg/L). On September 29, 2010, the discharge excess total phosphorus concentration was 2.57 mg/L (i.e., 2.61 mg/L – 0.04 mg/L).

Excess concentrations were also calculated for ammonia. For August, the discharge excess concentration was 14.29 mg/L (14.3 – 0.0078 mg/L) and for September the excess ammonia concentration was 13.79 mg/L (13.8 mg/L – 0.0096 mg/L).

Effluent Flow Rate

The effluent flow rate was assumed to be 0.108 m^3/s on both days, which is the average daily discharge rate for the Cold Lake WWTF.

Effluent Density (Temperature)

The effluent temperature was measured to be 16.2°C on August 31, 2010, and 12.3°C September 29, 2010.

Ambient Worksheet

Ambient Beaver River Flow

The flow in Beaver River was determined based on data acquired from the WSC flow station located on Beaver River (at Beaver Crossing) near Cold Lake (06AD006). The flow at this station was approximately 17.2 m^3/s on August 31, 2010 and 17.5 m^3/s on September 29, 2010.

Average Channel Depth

For the river geometry, CORMIX requires that the cross-section of the river be "schematized" as a rectangular channel. Beaver River depths were estimated based on encountered depths at surface water stations sampled on August 31 and September 29, 2010. The resulting average depth was estimated to be 0.85 m and 1.0 m, respectively.

Depth at Discharge:

The depth of the Beaver River at the point in which the outfall channel meets the River was measured to be about 0.85 m during the August 2010 sampling event, and 1.0 m during the September 2010 sampling event.

Bounded Width:

From aerial photos, the channel was determined to be 50 m wide in the vicinity of the Cold Lake WWTF outfall.

Wind Speed 2 m Above The Water Surface:

A wind speed of 2 m/s was used for all scenarios. In the absence of field data, this is the velocity recommended by CORMIX for conservative design conditions.

Manning's n:

Manning's n was determined through calibration with the August and September 2010 field water quality data to be 0.04. The calibration results are presented in the following Section.

Bounded Appearance:

From aerial photos, it was seen that the river immediately downstream of the outfall contains some large meanders. As such, the appearance of the river in CORMIX was denoted as either "slight meander" or "highly irregular", and determined through calibration with the August and September data to be "slight meander".

Fresh Water Temperature:

The Beaver River water temperature was measured (at the 100 m upstream station) to be 14.6°C on August 31 and 13.0°C on September 29, 2010.

Discharge Worksheet

Discharge Bank Location:

Under the "discharge" worksheet, the discharge bank location is the location of the nearest bank to the outfall when facing downstream in the direction of the river flow. For the Cold Lake WWTF discharge, this is the left bank.

Distance to Nearest Bank:

This is the distance from the outfall location to the nearest bank. Since the outfall is at the Beaver River bank, this is 0 m.

Vertical Angle of Discharge Pipe:

This is the angle between the outfall pipe centreline and the horizontal plane, which was 0 degrees.

Horizontal Angle of Discharge Pipe:

This is the angle between the outfall pipe centreline and the direction of river flow, if the pipe is measured in a counter-clockwise direction from the point where the discharge pipe is pointing in the direction of the river flow. As such, the horizontal angle was 270 °.

Port Diameter and Height Above Water Surface:

The port diameter and the port height above the water surface were measured in-field and from photographs, and found to be 0.63 m and 0.1 m, respectively.

Discharge Configuration:

The discharge configuration can be described as jet-like, deflected jet-like, or spray-like. Jet-like was determined to be the configuration that best described the WWTF outfall.

1.3.4.1 CORMIX Model – Proposed WWTF Under 2010 Measured Conditions

Using the calibrated open water CORMIX model developed based on the 2010 measured conditions, a model of the predicted effluent impacts was generated to provide a direct comparison of the relative change in water quality due to the implementation of the proposed WWTF upgrade in open water conditions. A summary of the CORMIX model inputs is provided in **Table 1.6** below with rationale for the various parameters provided following the table.

Table 1.6: CORMIX Model Inputs – Proposed WWTF August 2010 Conditions

Input Parameter	August, 2010 Proposed WWTF Scenario Total Phosphorus/Ammonia
Effluent Worksheet:	
Conservative/non-conservative pollutant	Conservative/ Non-conservative
Decay rate (1/d) if non-conservative	n/a / 55
Discharge excess concentration (mg/L)	0.0709 / 2.992
Effluent flow rate (m^3/s)	0.171
Effluent density: temperature (°C)	16.2
Ambient Worksheet:	
Average channel depth (m)	0.85
Depth at discharge (m)	0.85
Wind speed 2 m above the water surface (m/s)	2
Ambient Beaver River flow rate (m^3/s)	17
Bounded width (m)	50
Bounded appearance	Slight Meander
Manning's n	0.04
Fresh water temperature (°C)	14.6
Discharge Worksheet (CORMIX1):	
Nearest bank (as seen looking downstream)	Left
Distance to nearest bank (m)	0
Port diameter (m)	0.63
Vertical angle of discharge pipe (degrees)	0
Horizontal angle of discharge pipe (degrees)	270
Port height above water surface (m)	0.1
Discharge configuration	Jet-like

Notes: na = No decay rate was used for phosphorus, as it was modeled as a conservative constituent.

With the exception of the following, all model inputs remained the same as the August 31, 2010 Scenario described in **Section 1.3.4.2**.

1.3.4.2 Effluent Worksheet

Discharge Excess Concentration:

For total phosphorus on August 31, 2010, the upstream (US100-01) concentration was 0.0791 mg/L and the proposed TP effluent concentration is 0.15 mg/L. Therefore, the discharge excess total phosphorus concentration was 0.0709 mg/L (i.e., 0.15 mg/L – 0.0791 mg/L). Excess concentrations were also calculated for ammonia. For August, the discharge excess concentration was 2.992 mg/L (3 – 0.0078 mg/L).

Effluent Flow Rate:

The effluent flow rate was modeled under the proposed average daily flow rate of 0.171 m^3/s.

Effluent Density (Temperature):

The effluent temperature for the proposed WWTF was estimated by the design team to be 20°C.

1.3.4.3 Mass Balance Model – Existing WWTF Lagoon and Proposed WWTF Worst Case Scenarios

As detailed previously, a mass balance approach was utilized in order to evaluate concentrations of total phosphorus and ammonia under worst case conditions for the existing and proposed WWTF effluents. The “worst-case” scenarios are defined by low flows in the Beaver River, 95th percentile water quality in the existing WWTF discharge, limit concentrations for the proposed WWTF discharge, and 75th percentile upstream (background) water quality in the Beaver River. The mass balance analysis indicates the fully-mixed concentration in the Beaver River assuming conservative pollutants as shown for each scenario below:

- **Scenario 1** – Existing lagoon discharge, “worst-case” summer flows and water quality;
- **Scenario 2** – Existing lagoon discharge, “worst-case” spring/fall flows and water quality;
- **Scenario 3** – Proposed WWTF discharge, “worst-case” winter flows and water quality;
- **Scenario 4** – Proposed WWTF discharge, “worst-case” summer flows and water quality;
- **Scenario 5** – Proposed WWTF discharge, “worst-case” spring/fall flows and water quality;

The Cold Lake WWTF currently discharges to the Beaver River between mid-April to late October each year. Scenario 1 includes effluent discharges occurring between mid-June and September, while Scenario 2 models effluent discharges occurring mid-April to mid-June and October. Currently the Cold Lake WWTF does not discharge during the winter months of November through mid-April however Scenario 3 determines the fully mixed concentration under winter conditions for the proposed WWTF discharge.

The mass balance inputs for Scenarios 1 through 3 are summarized in **Table 1.7** and the rationale for the inputs are provided below.

Table 1.7: Mass Balance Analysis Inputs - Scenarios 1 through 5

Input Parameter	Scenario 1 Lagoon - Summer	Scenario 2 Lagoon – Spring/Fall	Scenario 3 New WWTF – Winter	Scenario 4 New WWTF – Summer	Scenario 5 New WWTF – Spring/Fall
Effluent:	*Phosphorus / Ammonia*	*Phosphorus / Ammonia*	*Phosphorus / Ammonia*	*Phosphorus / Ammonia*	*Phosphorus / Ammonia*
Beaver River u/s concentration (mg/L)	0.106 / 0.21	0.088 / 0.437	0.088 / 0.437	0.106 / 0.21	0.088 / 0.437
Beaver River flow rate (m^3/s)	1.46	1.46	0.468	1.46	1.46
WWTF effluent concentration (mg/L)	3.67 / 13.9	3.84 / 23.02	0.15 / 6	0.15 / 3	0.15 / 3
WWTF effluent flow rate (m^3/s)	0.108	0.108	0.171	0.171	0.171
Beaver River temperature (°C)	19.4	13	3.15	19.4	13
Beaver River pH (at 1 km downstream)	8.3	8.24	8.02	8.3	8.24

Concentrations:

Beaver River upstream concentration:

For total phosphorus, the background concentration was the 75th percentile total phosphorus concentration recorded at the Beaver River (at Beaver Crossing) station near Cold Lake, located upstream of the Cold Lake WWTF. Data at this station was available from 1993 to 2009. The data was divided according to season – the summer 75th percentile total phosphorus concentration was 0.106 mg/L based on 58 measurements taken between the months of June and September; the winter 75th percentile was 0.088 mg/L based on 109 measurements taken between the months of October to May. The winter season 75th percentile background data was also applied to the lagoon – spring/fall scenario (Scenario 2).

The summer WWTF lagoon discharge 95th percentile total phosphorus concentration was 3.67 mg/L based on 17 measurements collected between 2006 and 2009 during the months of June to September. The spring/fall WWTF lagoon discharge 95th percentile total phosphorus concentration was 3.84 mg/L based on 17 measurements collected between 2006 and 2009 during the months of mid-April to June, and October. The spring/fall lagoon 95th percentile water quality was also used in the estimated winter lagoon scenario.

Similarly for ammonia, the background (Beaver River) concentration was 0.021 mg/L based on the summer 75th percentile value of the Beaver Crossing water quality station, and 0.437 mg/L based on the winter 75th percentile value. The winter season 75th percentile background data was also applied to the lagoon – spring/fall scenario (Scenario 2).

Existing WWTF Effluent Concentration:

The WWTF lagoon discharge 95th percentile ammonia concentration was 13.9 mg/L for the summer and 23.02 mg/L for the spring/fall. The spring/fall lagoon 95th percentile water quality was also used in the estimated winter lagoon scenario.

Proposed WWTF Effluent Concentration:

The proposed plant discharge limits for total phosphorus for summer and winter is 0.15 mg/L. Similarly for ammonia, the proposed plant summer and winter discharge limits for ammonia are 3 mg/L and 6 mg/L, respectively.

Flow rates:

Beaver River Flow:

The flow in Beaver River was determined based on data acquired from the WSC flow station located on Beaver River (at Beaver Crossing) near Cold Lake (06AD006). Data at this station was available from 1956 to 2010. The Beaver River flow for the summer and spring/fall scenarios (Scenarios 1 and 2) was set at the 7Q10 flow for the April 15 to October 15 period. The 7Q10 flow is the minimum 7-day average flow, with a recurrence period of 10 years, between April 15 and October 15. The 7Q10 flow was calculated to be 1.46 m^3/s. For the winter scenario (Scenario 3), the low flow was set at the 7Q10 flow for the entire year, which was calculated to be 0.468 m^3/s.

Existing WWTF Effluent Flow Rate:

The effluent flow rate used for the existing plant was 0.108 m^3/s, which was the average daily flow during discharge of the existing WWTF in 2010.

Proposed WWTF Effluent Flow Rate:

The effluent flow rate used for the proposed plant was 0.171 m^3/s, which was calculated based on population projections to 2037.

Temperature:

Beaver River water temperature:

The Beaver River water temperature for summer, spring/fall, and winter was estimated using the 75th percentile temperature calculated between 1993 and 2010 from the Beaver River (at Beaver Crossing) station near Cold Lake for the respective season. The Beaver River water temperatures were set at 19.4°C for the summer (Scenarios 1 & 4), 13.0°C for the spring/fall (Scenarios 2 & 5), and 3.15°C for the winter (Scenario 3).

1.3.5 Benthic Invertebrate Community

Sample Collection

Samples were collected from depositional areas for benthic invertebrates. Four sampling areas were identified (US100, DS50, DS300 and DS1000) and within each area, samples were collected from five stations. Samples were collected using a Petit Ponar dredge (6” x 6” x 6”). At each station, one sample was collected for that station for a total sample area of 0.0232 m^2.

Samples were sieved through a 200 µm mesh size sieve and gently rinsed with water. Samples were transferred to glass jars and preserved with ethanol.

Samples were packed in coolers and shipped to Tailwind Environmental Solutions Inc. (Tailwind) for taxonomic analysis.

Upon receipt at Tailwind, samples were washed over a sieve with a mesh size of 400 µm, washed, floated and decanted into a 400 µm sieve until no invertebrates were left in the substrate material. This process was repeated ten times.

Entire samples were picked, identified to family-level following Clifford (1991) and counted. Damaged specimens were only identified if the fragment included the head attached to the body. In the case of damaged Oligochaeta, a sufficient number of segments were required before one individual was recorded. Samples were transferred to vials and topped with 70% ethanol.

A second, independent analysis was completed on 10% of the samples to confirm sorting and taxonomy. For taxonomy audits, the invertebrates were re-identified, enumerated and compared to the original taxonomy. Identification precision was recorded as identification error rate and calculated as follows:

$$ID\ error\ rate = \frac{\#\ errors}{total\ \#\ organisms} \times 100$$

A sorting audit was also completed to detect the number of specimens remaining in the sample residue. For the second, independent analysis, the whole sample residue was resorted, animals were removed and placed in new labelled vials. Sorting precision was recorded as percent sorting efficiency and calculated as follows:

$$\%\ sorting\ efficiency = 1 - \frac{\#\ organisms\ missed}{total\ \#\ organisms} \times 100$$

Statistical Analysis

Taxonomic data were received in electronic format. Raw count data was converted to organisms per square metre. Converted results were used for the calculation of the following community descriptors and biotic indices:

- Total invertebrate density
- Taxon richness
- Simpson's Diversity Index (SDI)

Total invertebrate density was calculated as the total number of individuals in each sample per square meter. The mean (standard deviation and stand error), minimum and maximum are reported for each area. Richness was calculated as the total number of taxa in each sample. Simpson's Diversity Index (SDI) gives the probability that two individuals chosen at random and independently will belong to the same taxonomic group. A lower probability indicates a more diverse community. SDI was calculated for each sample using the following formula:

$$D = \sum_{i=1}^{s} \frac{n_i(n_i - 1)}{N(N-1)}$$

where: D = Simpson's index
n_i = the number individual of the i^{th} taxon
N = the total number of individuals

SDI = 1-D

where: SDI = Simpson's Diversity Index

1.4 Receiving Water Study Results

1.4.1 Upstream Data Comparisons

Field supporting environmental data was measured at each sampling station in August and September 2010 and March 2011. In August, all samples were collected on August 31. In September all samples were collected on September 29 except for samples from Ardmore and final effluent which were collected on September 28. River samples were collected on March 12 and 13, 2011. No effluent samples were collected in March 2011 as the facility is not currently approved for discharge between October and April. Summarized field data are provided in **Table 1.8** and complete field data and notes are provided in **Appendix A Table A-1**.

Table 1.8: Field data from the fall 2010 and winter 2011 field program

Transect	Month	pH (field)	Conductivity (µS/cm)	pH (lab)*	Dissolved Oxygen (mg/L)	Temperature (°C)	Water Depth (m)	Ice Thickness (m)
US Ardmore	September	9.56	234	8.22	8.90	12.90	1.20	
	March	*	482		3	0.1	1.06	0.63
US MC 500-02	March	9.49	252		1.7	0.9	1.28	0.67
US MC 50-02	March	9.94	551		2.1	0.1	0.94	0.77
DS MC 50-01	March	8.61	420		10	0.3	1.03	0.53
US100	August	8.93	261	8.28	9.50	14.40	1.40	
	September	10.52	244	8.25	10.10	13.00	2.00	
	March	10.6	498		5.2	1.6	0.71	0.21
DS50	August	9.11	278	8.26	9.63	14.47	0.71	
	September	10.39	257	8.25	9.90	12.60	0.87	
	March	10.29	495		5.1	1.2	0.85	0.55
DS100	August	8.96	270	8.27	9.31	14.80	0.76	
	September	10.45	276	8.25	10.00	12.30	1.20	
	March	10.25	505		4.2	1.4	0.93	0.50
DS200	August	8.96	263	8.30	9.55	14.73	0.85	
	September	10.74	264	8.25	9.70	12.10	1.40	
	March	10.03	484		4.2	2.4	0.65	0.33
DS300	September	10.30	248	8.25	10.30	11.90	1.50	
	March	9.82	470		5.5	0.9	1.65	0.50
DS500	August	9.14	266	8.28	8.91	15.13	0.98	
	September	10.16	251	8.24	9.10	11.60	1.40	
	March	10.01	520		5.2	0.9	1.60	0.53
DS1000	August	9.16	261	8.30	11.00	15.43	0.69	
	September	9.98	257	8.24	9.30	10.40	1.10	
	March	9.55	501		5.4	0.2	0.90	0.45
Effluent	August	9.19	780	8.33		16.20		
	September	8.13	863	8.10		12.30		
	March	not discharging						

*Note: * It is suspected that the pH meter was malfunctioning. For any calculations requiring pH, the lab value was used*

Water quality was sampled at the Ardmore station in September and March to evaluate river water quality above the CFB outfall. Water quality sampled at Ardmore in September 2010 and March 2011 was similar to water quality measured in 1991 to 1993 for most parameters (**Table 1.9**). Only concentrations of bicarbonate, chloride, sulphate and TDS from the September 2010 sample were less than the historical concentrations. Nitrogen compounds (NH_4-N, NO_3-N+NO_2-N, TKN) in the March 2011 sample were higher than historical values

Table 1.9: Water Quality in the Beaver River at Ardmore - Historical (1991 to 1993) versus Recent (September 2010 and March 2011)

	Units	Ardmore 1991 to 1993					Ardmore 2010	Ardmore 2011
		N Samples	Min	Median	Mean	Max		
Alkalinity	mg/L	14	164	387	321.57	435	121	263
Ammonia	mg/L	14	0.006	0.0595	0.06	0.163	0.01	0.295
Bicarbonate	mg/L	14	194	472	390.93	530	148	321
DOC	mg/L	14	8.7	14.8	14.05	19.5	16.9	15.6
Chloride	mg/L	14	2.3	10.75	8.94	13.5	1.55	4.52
Fecal Coliform	CFU/100 mL	14	2	2	4.71	12	2	<1
Nitrite	mg/L	14	0.00050	0.00100	0.00146	0.00300	<0.0020	0.0048
NO_3+NO_2	mg/L	14	0.0005	0.0120	0.0130	0.0320	<0.0063	0.228
TKN	mg/L	14	0.52	0.74	0.71	0.89	0.691	0.907
BOD	mg/L	14	0.7	1.2	1.50	3.8	<2.0	<2.0
DO	mg/L	40	1	8.65	7.84	11.9	8.9	3.0
pH	pH	14	7.82	8.10	8.13	8.5	8.22	7.94
TP	mg/L	14	0.026	0.0435	0.054	0.111	0.0432	0.0501
TDP	mg/L	14	0.008	0.0105	0.017	0.070	0.0109	0.0187
Conductivity	uS/cm	14	325	757	636.9	844	249	507
SO_4	mg/L	14	8	29	24.64	38	3.36	12.2
Water Temp	°C	43	0	0.2	4.75	17.3	12.9	0.1
TDS	mg/L	6	204	265	262.5	334	168	331

Water quality at the upstream 100 m station (considered a near-field reference for this study) was similar to, or better than, the quality at the Beaver Crossing station (**Table 1.10**). Specifically, improvements were noted for many parameters including DO, *E. coli*, Fecal coliforms, NH_4-N, NH_3, NO_3+NO_2, TKN, total nitrogen (TN), PO_4-P, particulate phosphorus (PP), TDP and TP. The Beaver Crossing station is downstream of the Marie Creek confluence (approximately 13 km downstream) but the dataset from Beaver Crossing is very large and likely represents expected variability in the river at this point.

Table 1.10: Water Quality in the Beaver River at Beaver Crossing - Historical (1993 to 2009) versus Recent from US100 (August and September 2010, March 2011)

	Historical Data Beaver Crossing (Nov 93-Aug 09)						Upstream 100 m from RUSC Outfall			
	Units	No. Samples	Min	Median	Mean	Max	31-Aug-10	29-Sep-10	29-Sep-10 (rep)	13-Mar-11
pH	pH	128	7.25	7.95	7.90	8.45	8.28	8.25	8.24	7.98
TSS	mg/L	167	2	6.8	18.96	273	29.0	50	17	4.0
DO	mg/L	164	0.06	8.28	7.14	14.2	9.6	10.1	10.1	5.2
Water Temp	°C	167	0	4.1	7.62	23.4	14.6	13	13	0.1
E. coli	CFU/100 mL	60	2	25	34	264	17	6	4	1
Fecal Coliforms	CFU/100 mL	63	2	25	35	227	17	6	4	1
NH_X-N	mg/L	167	0.005	0.031	0.21	2.78	0.0078	0.0096	0.0108	0.273
NH_3	mg/L	161	<0.001	0.001	0.001	0.026	0.0004	0.0004	0.0004	0.0024
NO_X-N	mg/L	167	0.01	0.04	0.086	0.473	<0.006	<0.0063	<0.0063	0.278
TKN	mg/L	167	0.039	0.739	0.86	3.11	1.30	0.702	0.685	0.864
TN	mg/L	160	0.27	0.923	1.022	3.48	1.304	0.706	0.689	1.142
PO_4-P	mg/L	167	0.002	0.012	0.017	0.426	0.0011	0.0035	0.0034	0.006
PP	mg/L	167	0.01	0.043	0.057	0.356	0.0691	0.0304	0.0284	0.0307
TDP	mg/L	167	0.01	0.024	0.033	0.54	0.0100	0.0096	0.0088	0.0221
TP	mg/L	167	0.027	0.068	0.09	0.652	0.0791	0.04	0.0372	0.0528

1.4.2 Comparison of Upstream to Downstream Conditions During Monitoring Program (Existing WWTF)

This section presents the results of the 2010 field study in comparison to upstream values and water quality objectives (WQO). Treated effluent was discharged during the August and September 2010 river sample collection programs but not during the March 2011 collection program because presently the lagoon does not discharge during winter months. Samples were collected in March 2011, during under-ice conditions, to understand current conditions during that season.

General Chemistry Parameters

Conductivity and TDS:

Specific conductivity and concentration of TDS at all stations sampled as part of this receiving water study have been plotted (**Figure 1.6 a** and **b**). Included on the figure are the values of these same parameters in the effluent for both August and September. The orange arrow graphically illustrates the effluent outfall in relation to the sampling stations. Conductivity of the effluent was approximately 3.2 times higher than upstream river conductivity in August and September (**Figure 1.6 a**). There was a minor increase in conductivity from 50 m to 200 m (left bank side) downstream of the outfall. In the August sample, at 200 m downstream in the centre of the river, conductivity had returned to upstream values. Conductivity during under-ice conditions was much higher than during open water conditions.

TDS is a measure of dissolved material in the water column and can include dissolved salts such as sodium, chlorides, magnesium and sulphate. TDS in the existing WWTF effluent was approximately 2.8 times higher than in the river water. There was a minor increase in TDS downstream of the outfall. TDS was also higher in the river under ice-covered conditions as compared to open water conditions. It is suggested that lower flows during winter conditions as compared to open water conditions contribute to these results. It is also noted that at station DS-MC-

50, both conductivity and TDS were lower than at all other stations. This anomaly may be due to site specific causes or potentially due to contamination of the sample by surface melt-water.

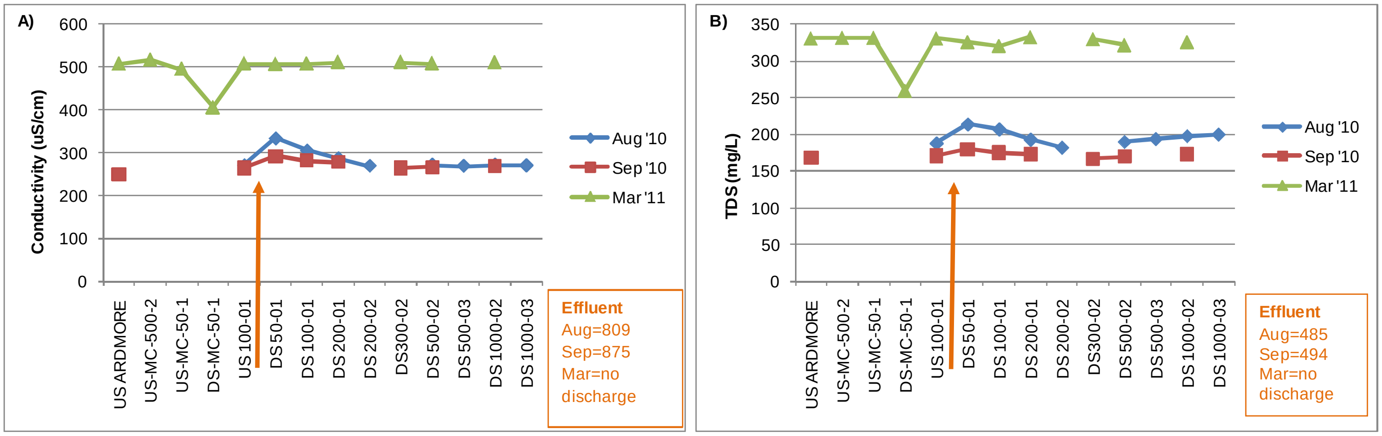

Figure 1.6: Measured a) Conductivity and b) TDS in the Beaver River Study

Chloride and Sulphate:

The Concentration of chloride and sulphate at all stations sampled as part of this receiving water study have been plotted (**Figure 1.7 a** and **b**). Included on the figure are the values of these same parameters in the effluent for both August and September. The orange arrow graphically illustrates the effluent outfall in relation to the sampling stations. Chloride in the existing WWTF effluent (August and September) was approximately 20 times higher than in the river water at the upstream stations and at 200 m downstream of the outfall. There was a distinct increase in chloride at the 50 m downstream station after which concentrations gradually decreased to background levels by around 200 m downstream. The same trend was observed in both August and September however the peak at 50 downstream was not as obvious in September as in August. There was only a minor chloride fluctuation in March and there was no increase in chloride at the 50 m DS station. Chloride also dropped slightly at the DS-MC-50 station in comparison to the upstream stations.

Sulphate concentrations in the existing WWTF effluent were also approximately 20 times higher than in the river at the upstream stations and at 200 m downstream of the outfall. Similar to the results for chloride, there was a distinct sulphate signature at 50 m downstream and this was more evident in the August event as compared to the September results. At 200 m downstream, sulphate was still elevated in the left bank sample as compared to the centre channel sample suggesting that the effluent plume hugs the left bank for a fair distance downstream of the outfall. In the samples collected in March, sulphate was approximately 12 mg/L in all samples except for the DS-MC-50 sample, which may have be misrepresentative as discussed previously.

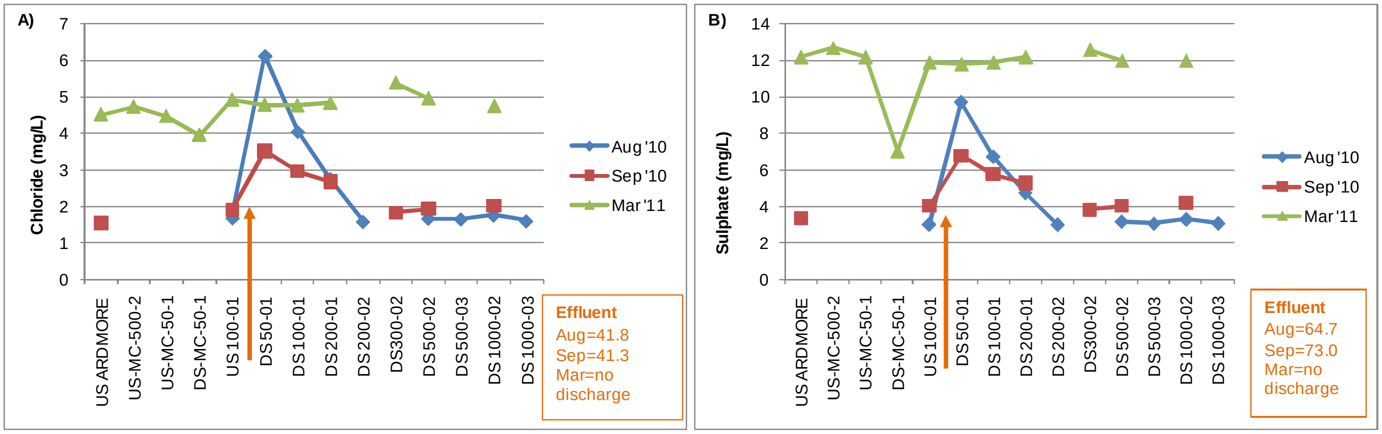

Figure 1.7: Measured a) Chloride and b) Sulphate in the Beaver River Study

<u>TSS and DO:</u>

Concentration of TSS and DO at all stations sampled as part of this receiving water study have been plotted (**Figure 1.8 a** and **b**). Included on the figure are the values of TSS in the effluent for both August and September. DO was not measured in the effluent. The orange arrow graphically illustrates the effluent outfall in relation to the sampling stations.

TSS in the existing WWTF effluent was comparable to upstream concentrations in the river in both August and September. TSS in the river and the effluent was higher in August as compared to September. Fluctuations in TSS downstream of the outfall are not necessarily related to discharge of effluent but may be related to the natural characteristics of the river itself. In March, TSS concentrations were very low in all samples.

Dissolved oxygen did not vary between sampling stations in either August or September. These values are comparable to the long-term statistics of DO at Beaver Crossing (**Figure 1.9**). There are expected DO sags in mid-summer but long-term concentrations of DO in August and September are on average between 8 and 10 mg/L. Concentrations from December through March have fallen below values required for aquatic life. DO concentrations in the under-ice samples were far lower than from the open water samples. At the station 50 m downstream of the outfall, DO was not noticeably lower than in stations either upstream or further down.

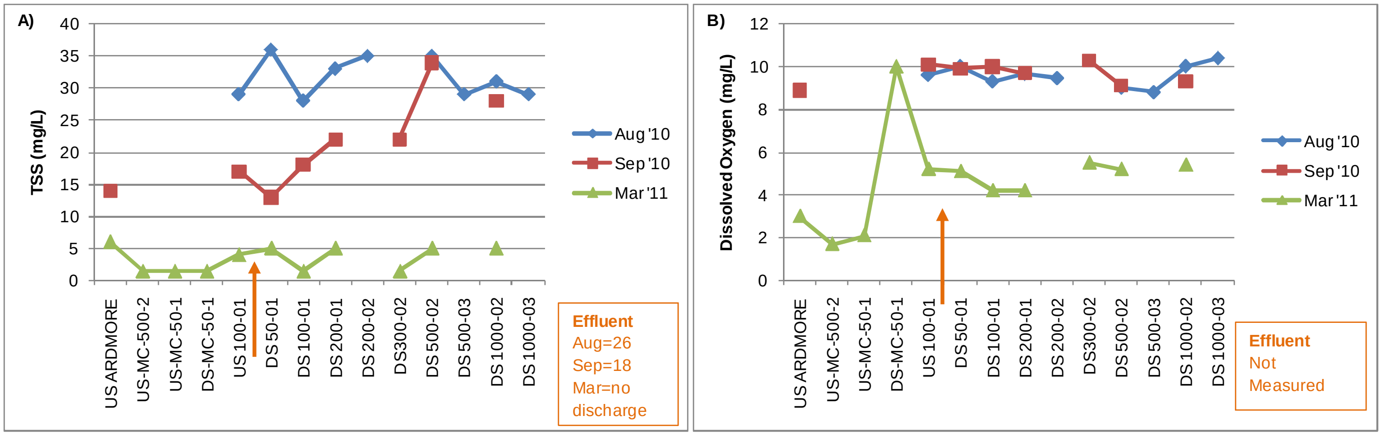

Figure 1.8: Measured a) TSS and b) Dissolved Oxygen in the Beaver River Study

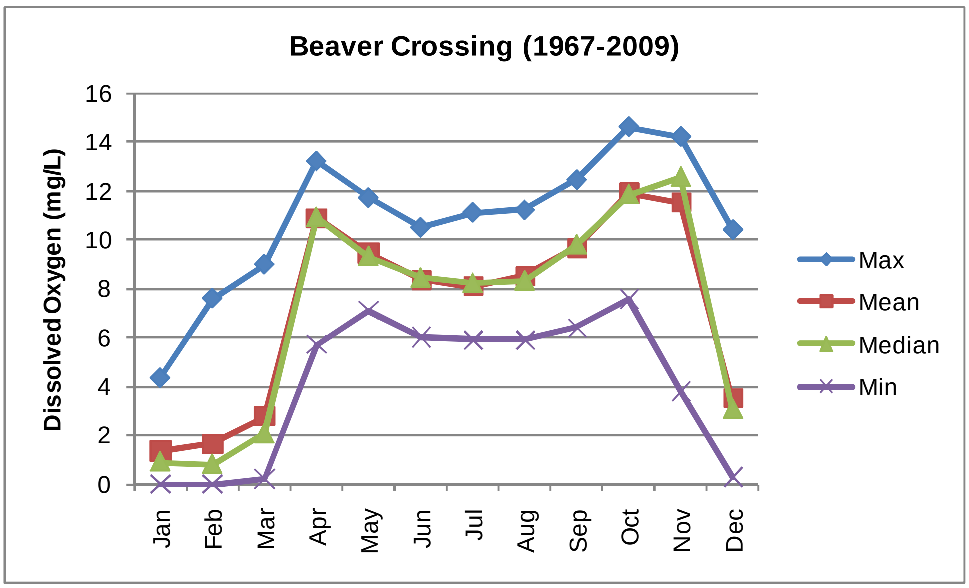

Figure 1.9: Monthly Statistics of Dissolved Oxygen at Beaver Crossing

Nitrogen

Various forms of nitrogen were measured in the river and existing WWTF effluent samples: TKN, NH_X-N, NO_3 and NO_2 were measured. From these values, organic nitrogen (NH_X-N subtracted from TKN) and total nitrogen (TKN plus NO_3 and NO_2) were calculated. Total nitrogen in the existing WWTF effluent (**Figure 1.10**) and river samples collected in August, September and March (**Figure 1.11 a**, **b** and **c**, respectively) have been presented as stacked bar graphs by nitrogen form. The SWQGUA for TN (1 mg/L) has been included in **Figures 1.11 a**, **b** and **c**. The orange arrow in **Figure 1.11** graphically illustrates the effluent outfall in relation to the sampling stations. The stacked bars graphically illustrate the different forms of nitrogen in the river upstream and downstream of the outfall.

The concentration of nitrogen in the existing WWTF effluent was higher in August compared to September but the relative proportion of ammonia was higher in the September effluent as compared to the August effluent (**Figure 1.10**). Nitrate and nitrite were very low in the effluent samples.

The concentration of total nitrogen was higher in the August river samples as compared to the September river samples (**Figure 1.11 a** and **b**). All samples in August exceeded the SWQGUA for TN while in September only the samples between DS50 and DS200 exceeded the guideline. The lower concentrations in the downstream stations in September as compared to August are partly due to the smaller nitrogen load from the outfall but also partly due to the lower loads coming from the upper portion of the watershed (Ardmore and US100). During the March sampling event, the concentration of TN was similar in all samples upstream and downstream of the outfall. All samples in March exceeded the 1 mg/L SWQGUA criteria for TN (**Figure 1.11 c**).

In both August and September, there was a clear trend of higher relative proportions of ammonia in the first 200 m downstream of the outfall (DS50, DS100, DS200) as compared to the other stations. In August, there was also a clear difference in water quality at the 200 m DS left bank sample (DS200-01) as compared to the 200 m DS centre channel sample (DS200-02) again suggesting that the effluent plume hugs the left bank past 200 m. Interestingly, TN at the DS-500-02 and DS-1000-02 were higher than at the DS-200-02 station in August but not in September. In September, TN concentration in the centre of the river was similar from 300 m to 1000 m downstream.

Nitrate and nitrite had minor concentrations in both the existing WWTF effluent and the river. In March there was a much higher concentration and overall proportion of nitrate in all river samples as compared to samples collected in August or September. The proportion of organic nitrogen, ammonia nitrogen and nitrate was similar in all river samples collected in March.

There was an identifiable nitrogen plume during the open water period while the existing WWTF lagoon was discharging but this was not evident during ice covered conditions while the lagoon was not discharging. There does not appear to be a residual nutrient signature during extended periods when the lagoon does not discharge.

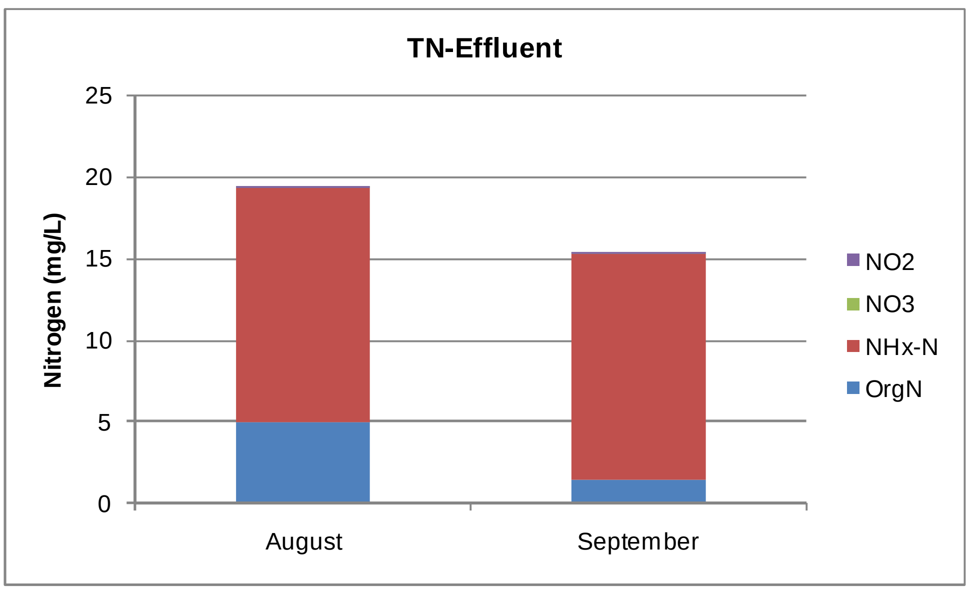

Figure 1.10: Concentration of Total Nitrogen by Nitrogen Form in Effluent Samples

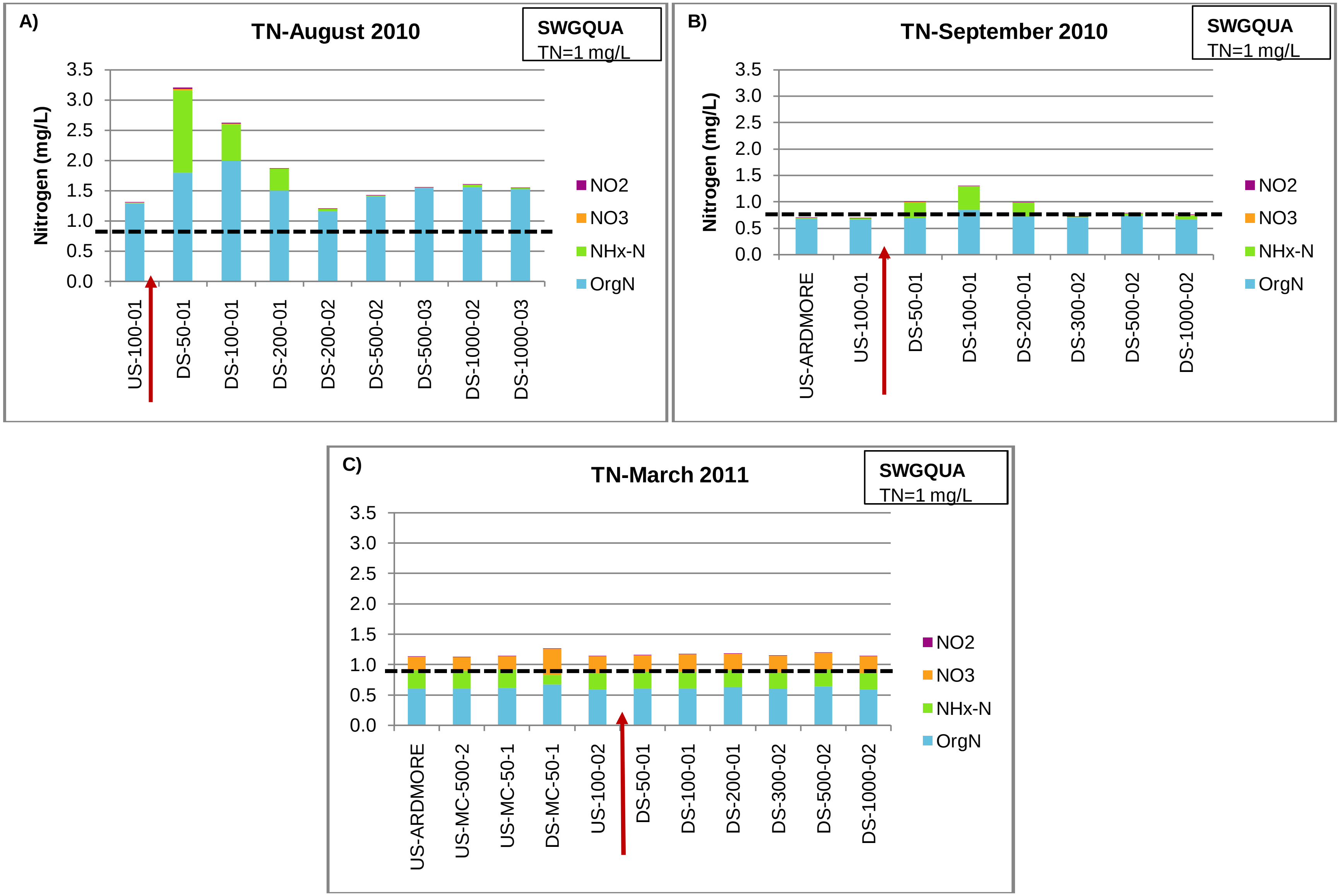

Figure 1.11: Concentration of Total Nitrogen by Nitrogen Form in River Samples in a) August 2010, b) September 2010 and c) March 2011

Inorganic nitrogen (nitrate, nitrite and ammonia) is the preferred nitrogen source for algae. Some studies suggest that ammonia is the preferred form while others suggest that any of the three forms will be used and the preference will depend upon concentration or availability of one form over another (Stolte and Riegman 1996). Abundant ammonia can stimulate primary producers and elevated concentrations of ammonia are toxic to invertebrates and fish. The CCME strategy document (CCME 2009) recommends considering the concentration of ammonia in municipal wastewater effluent as a potential toxicant since it is commonly associated with acute toxicity. The CCME document provides a formula to calculate the total ammonia acute toxicity threshold. Based on the CCME equation for toxicity threshold of total ammonia in effluent, the August effluent was calculated to likely be acutely toxic whereas the September effluent was calculated to not likely acutely toxic (**Table 1.11**). However, effluent samples collected in August and September were not tested for aquatic toxicity.

Table 1.11: CCME Total Ammonia Acute Toxicity Threshold of Effluent

Date Sampled	Measured in Effluent			Calculated	Result
	pH	**Temperature (°C)**	**NH_X-N (mg/L)**	**NH_X-N Acute Toxicity Threshold (mg/L)***	**Result**
31-Aug-10	8.33	16.2	14.3	12.37	**Fail** (exceed threshold)
28-Sep-10	8.1	12.3	13.8	19.80	**Pass** (lower than threshold)
13-Mar-11	Not measured because the lagoon was not discharging at this time.				

*Note: * Acutely Toxic Ammonia = 306132466.34 x (2.7183$^{(-2.0437 \times pH)}$)*

The PPWB put forward guidelines for total ammonia toxicity thresholds in the Beaver River (PPWB 1991). The toxicity threshold depends upon pH and temperature of the water. As shown in **Table 1.12**, the ammonia toxicity threshold for August and September was 0.63 while the ammonia toxicity threshold for March was 1.23.

Table 1.12: PPWB Total Ammonia Toxicity Thresholds by pH and Temperature for the Beaver River

		Water Temperature (°C)						
		0	**5**	**10**	**15**	**20**	**25**	**30**
pH	**6.50**	2.06	1.97	1.81	1.81	1.22	0.85	0.60
	6.75	2.06	1.97	1.81	1.81	1.22	0.85	0.61
	7.00	2.06	1.97	1.81	1.81	1.22	0.85	0.61
	7.25	2.06	1.97	1.81	1.81	1.23	0.86	0.61
	7.50	2.06	1.97	1.81	1.81	1.23	0.87	0.62
	7.75	1.89	1.81	1.73	1.64	1.15	0.81	0.58
	8.00	1.26	1.18	1.13	1.09	0.76	0.54	0.39
	8.25	0.72	0.67	0.64	0.62	0.44	0.32	0.23
	8.50	0.40	0.39	0.37	0.37	0.26	0.19	0.15
	8.75	0.23	0.22	0.21	0.22	0.16	0.12	0.09
	9.00	0.13	0.13	0.13	0.13	0.11	0.08	0.06

Note: From PPWB (1991); August and September 10 to 15 °C and pH 8.25; March 0°C and pH 7.9.

Un-ionized ammonia (NH_3) is a portion of the total ammonia in a sample, and is the form that is particularly toxic to fish and invertebrates. The proportion of total ammonia that is present as un-ionized ammonia is a function of temperature and pH. As these increase, the proportion of un-ionized ammonia in the sample also increases.
The expected fraction of un-ionized ammonia in the river and effluent samples was calculated. The concentration of total ammonia (unionized ammonia plus ionized ammonia) in the river samples has been illustrated (**Figure 1.12 a**, **b** and **c**). The total ammonia threshold, as based on Table 5-12, is indicated on the figures. The orange arrow in **Figure 1.12** graphically illustrates the effluent outfall in relation to the sampling stations.

Based on the PPWB guideline, total ammonia in the DS 50-1 and DS 100-01 samples were above the threshold in August (**Figure 1.12 a**). Total ammonia concentration in the August DS 200-01 m downstream sample was close to the threshold. In September, ammonia concentrations at 50 m, 100 m and 200 m downstream were close to, but less than, the threshold (**Figure 1.12 b**). All samples downstream of 200 m were less than the threshold in both open water events. For March, the toxicity threshold was 1.26 mg/L due to lower water temperature and slightly lower pH in comparison to the summer samples. None of the river samples collected in March had ammonia concentrations above the toxicity threshold limit (**Figure 1.13**).

The draft Federal regulations (Canada Gazette 2010) have identified that effluent can have a maximum concentration of un-ionized ammonia of 1.25 mg/L at a temperature of 15°C. The effluent samples analyzed for this project had less than 1.25 mg/L of un-ionized ammonia (**Figure 1.12 a**, **b** and **c**) and thus meet the draft effluent regulations.

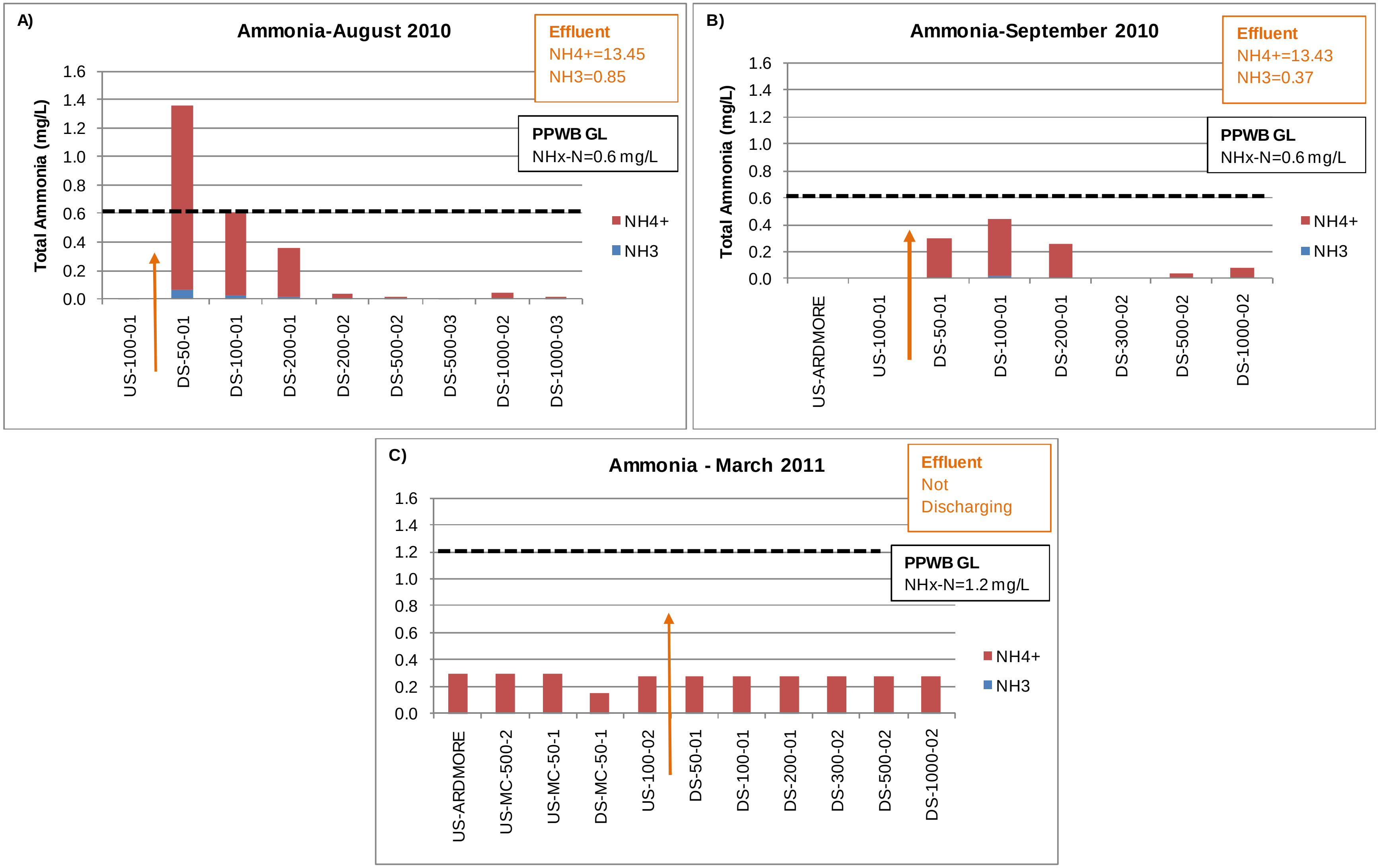

Figure 1.12: Total Ammonia (ionized plus unionized) in River and Effluent Samples in a) August 2010, b) September 2010 and c) March 2011

Phosphorus

Various forms of phosphorus were measured in the river and effluent samples: TP, TDP and PO_4-P. From these values, particulate phosphorus (TDP subtracted from TP) and organic phosphorus (PO_4-P subtracted from TDP) were calculated. Total phosphorus in the effluent (**Figure 1.13**) and river samples (**Figure 1.14 a, b** and **c**) have been presented as stacked bar graphs by station. This provides an illustration of the different forms of phosphorus in the river upstream and downstream of the outfall plus the forms of phosphorus added by the existing WWTF lagoon. The orange arrow in **Figure 1.14** graphically illustrates the effluent outfall in relation to the sampling stations.

The concentration of phosphorus in the effluent point source was higher in August as compared to September but the relative proportion of PO_4-P was similar between the effluents (both effluent samples had approximately 85% PO_4-P) (**Figure 1.14**).

The Concentration of the various forms of phosphorus (PO_4-P, TDP, TPP) in the river has been plotted along with the SWQGUA for TP (0.05 mg/L) (**Figure 1.14 a**, **b** and **c**). The concentration of TP below the outfall had a similar pattern to TN below the outfall. In August, the highest concentration was at 50 m downstream after which concentrations decreased. Concentrations approached upstream values within a distance of 1000 m downstream. In August, there was also a substantial difference in TP concentration at the 200 m downstream mark in the left bank sample (DS200-01) as compared to the centre channel sample (DS200-02) suggesting that the plume had not fully mixed across the river by this point. The concentrations in the middle of the river from 200 m to 1000 m downstream were similar. In September, the highest TP concentration was recorded at 100 m downstream of the outfall. This trend was only noticed in the nutrient parameters and TSS. In the general chemistry parameters (e.g, conductivity, chloride and sulphate) this trend was not observed.

The long-term mean concentrations of TP at Beaver Crossing for August, September and March were 0.08, 0.06 and 0.12 mg/L (above the SWQGUA of 0.05 mg/L), respectively (**Figure 1.15**). In both August and September, TP concentrations within the first 200 m of the outfall were greater than the long-term mean at Beaver Crossing. In March, TP concentrations at all stations were less than the long-term monthly mean at Beaver Crossing.

The stacked TP concentration bar graphs show the proportion of biologically available phosphorus (PO_4-P) to less biologically available forms (i.e., organic phosphorus and particulate phosphorus) in all samples (**Figure 1.14 a**, **b** and **c**). Unlike the trend in TN, there was more biologically available P downstream of the outfall in the September samples as compared to the August samples. Even though the actual concentrations were less in September, the proportion of PO_4-P in the river samples downstream of the outfall was higher in September as compared to August. The proportion of PO_4-P in the effluent was similar in August and September. The higher proportion of PO_4-P in the September river samples suggests reduced biological uptake. The zone of the river, from the outfall to approximately 200 m downstream, had higher proportions and total concentrations of inorganic phosphorus as compared to samples from upstream of the outfall and downstream of 300 m. This trend was very evident in both August and September and was not obvious in March.

TP was higher in the river in August as compared to September or March. Also, all samples in August exceeded the SWQGUA criteria of 0.05 mg/L for TP while in September only the samples downstream of the outfall exceeded the guideline. The concentration of TP in the river in March was similar across samples and close to the SWQGUA in all samples.

There was an identifiable phosphorus plume during the open water period (while the lagoon was discharging) within the first 200 m downstream of the outfall but this was not evident during ice covered conditions while the lagoon was not discharging. There does not appear to be a residual nutrient signature during extended periods when the lagoon does not discharge.

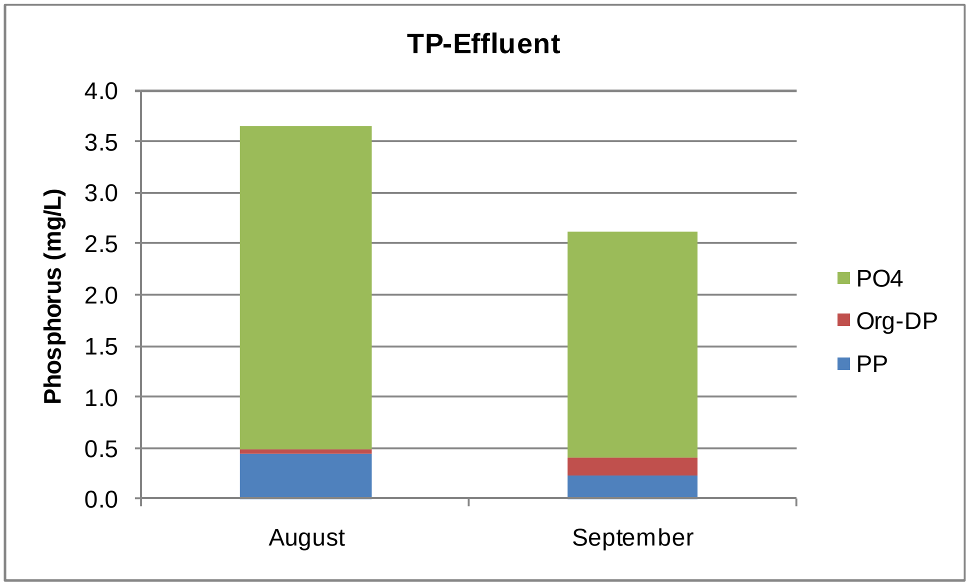

Figure 1.13: Concentration of Total Phosphorus by Phosphorus Form in Effluent Samples

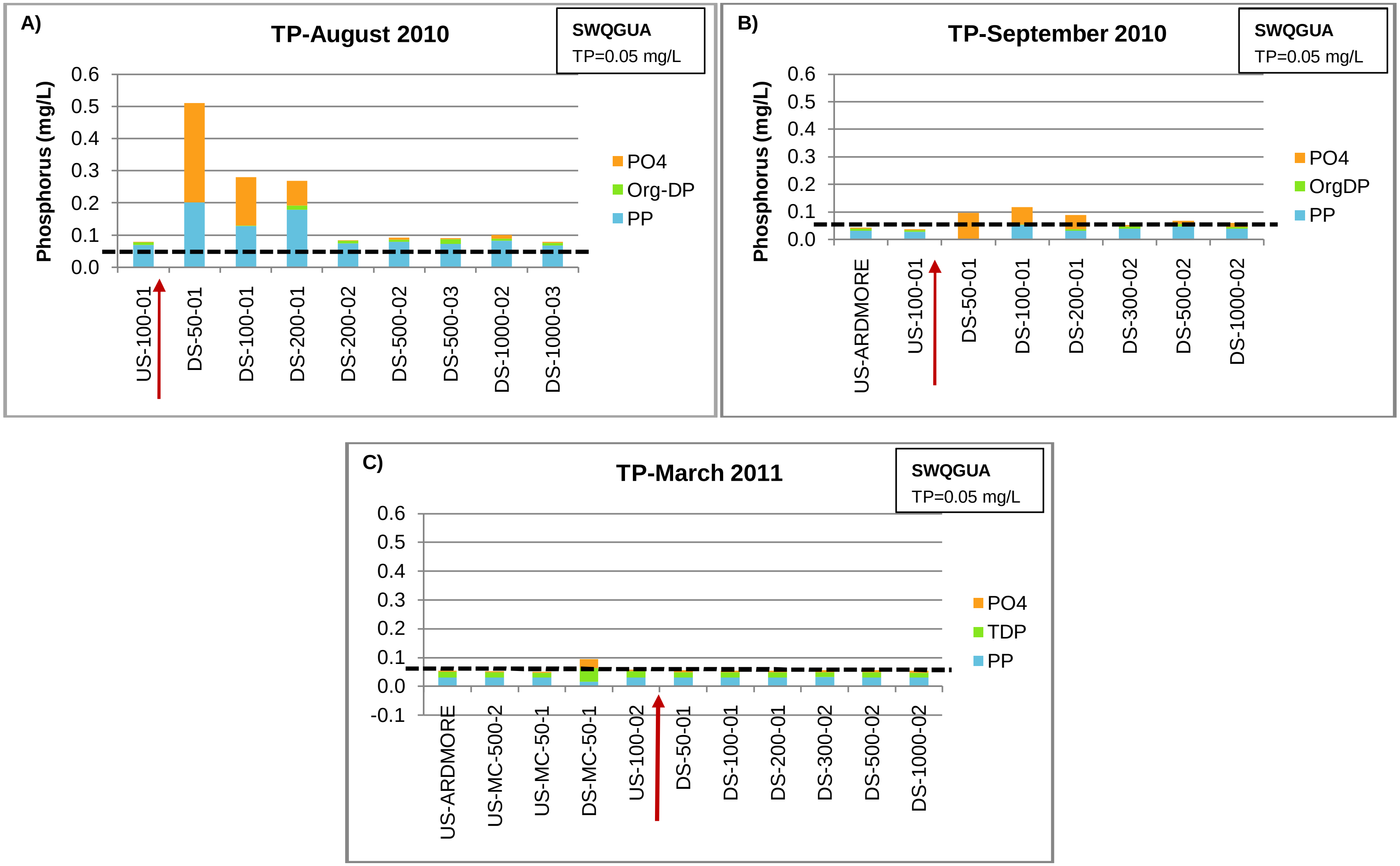

Figure 1.14: Concentration of Total Phosphorus by Phosphorus Form in River Samples in a) August 2010, b) September 2010 and c) March 2011

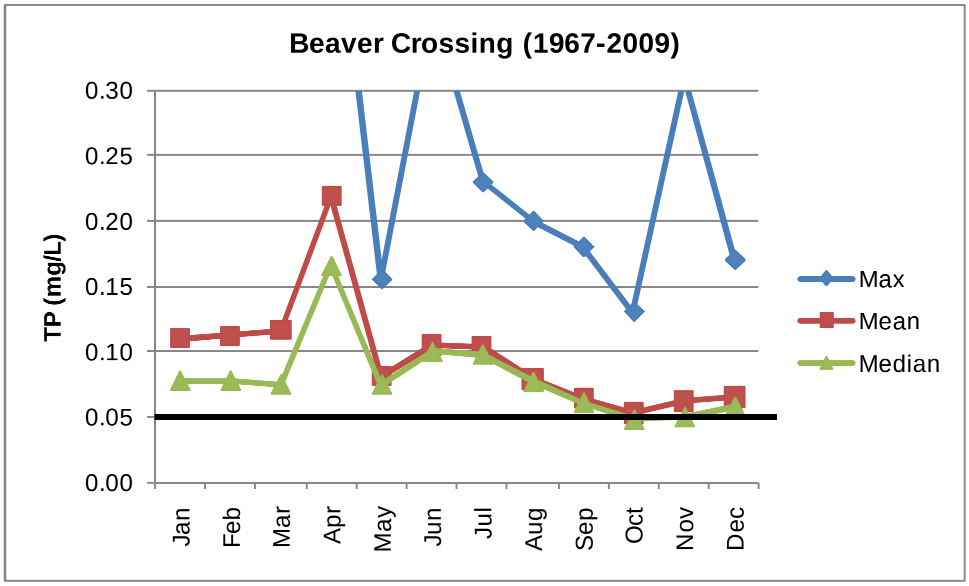

Figure 1.15: TP Concentration at Beaver Crossing (1967-2009)

Trophic Status:

Chlorophyll *a* concentrations (a primary photosynthetic pigment) has been measured at Beaver Crossing (**Figure 1.16**). This chlorophyll *a* data came from filtered whole water samples and represents the relative abundance of planktonic algae. As expected, concentrations vary seasonally with the highest concentrations when the river is open and temperatures are higher. Trophic status of surface waters are often described by the concentration of nutrients and planktonic algae (**Table 1.13**). The black line in **Figure 1.16** represents the 8 µg/L planktonic algae concentration threshold between oligotrophic and mesotrophic states. Based on this classification scheme, the river varies from oligotrophic to mesotrophic. Based on the measured maximum TP concentration, the river is eutrophic in any given month while median values indicate a variance between mesotrophic and eutrophic over the year. These data indicate that factors aside from available nutrients (ie. light penetration) limit the productivity of the stream in terms of algal growth.

Table 1.13. Trophic Status Classification by TP and Chlorophyll *a*

Trophic Status	Chla (µg/L)[a]	TP (mg/L)[b]
Oligotrophic	<8	<0.025
Mesotrophic	8-25	0.025-0.075
Eutrophic	26-75	>0.075
Hyper-eutrophic	>75	

Note: Mitchell and Prepas 1990; Dodds et al. 1998

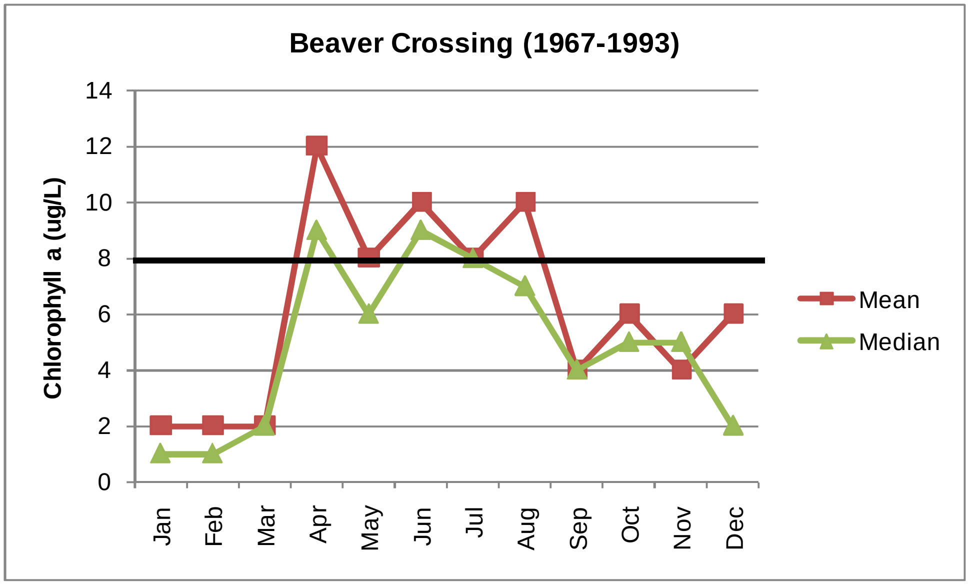

Figure 1.16: Chlorophyll a Concentration at Beaver Crossing (1974-1990)

Bacteria

The number of *E. coli* and Fecal Coliforms colony forming units (CFU) at all stations sampled as part of this receiving water study have been plotted (**Figure 1.17 a** and **b**). Included on the figure are the values of these same parameters in the effluent for both August and September. The orange arrow graphically illustrates the effluent outfall in relation to the sampling stations.

Fecal coliform bacteria include various types of gastroenteritis bacteria of which *E. coli* is one species. The fecal bacteria in the effluent samples in both August and September were all *E. coli* whereas, in the August river samples there were fecal bacteria other than *E. coli* present, and in September all of the fecal bacteria detected were *E. coli*.

The bacterial counts were higher at all stations in August as compared to September even though the concentration of bacteria in the effluent was higher in September. The background level of bacteria (US100 station) was higher in August as compared to September. In both months, the number of Fecal Coliform bacteria was higher in the DS50 sample as compared to the US100 sample. In August, the Fecal Coliform bacteria count continued to increase to the DS200-02 sample but the number of *E. coli* bacteria did not follow this trend and instead the numbers fluctuated between stations in the same stretch of the river (i.e., DS50 m to DS200 m). In September, the bacteria counts were higher at the DS200 station than at upstream stations. In both months, the bacteria counts at the DS1000 station were similar to the upstream station. Bacteria concentrations in March were non-detectable in most samples.

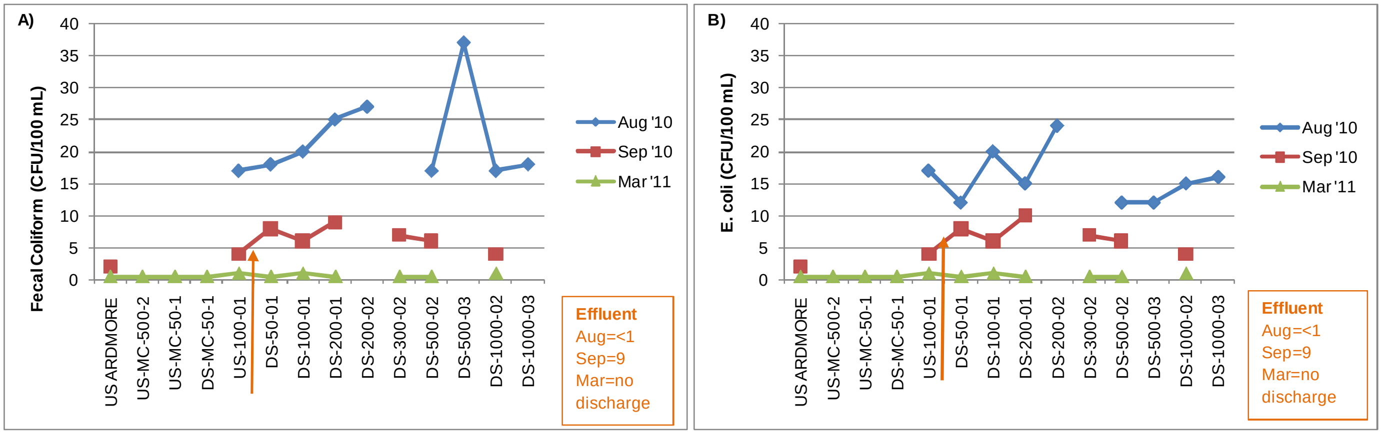

Figure 1.17: Measured a) Fecal Coliform b) *E. coli* in the Beaver River Study

1.4.3 Mixing Zone Model

CORMIX Model Calibration Results

The CORMIX model was built and calibrated with the water quality data collected during the August 31 and September 29, 2010 field events. The Manning's n value, river appearance, and ammonia decay rate were adjusted in CORMIX in order to best fit the model-predicted concentrations to the field concentrations from both monitoring events. Field measured TP was compared to CORMIX predicted TP for August and September (**Figure 1.18 a** and **b**). Field measured total ammonia was also compared to CORMIX predicted total ammonia for August and September (**Figure 1.19 a** and **b**).

Correlation between the modeled and measured phosphorus concentrations is strongest in the August data set. The September data trend was similar to the modeled concentration with the exception of the 50 m downstream station. During this monitoring event, water quality at the 100 m downstream station was poorer than at the 50 m downstream station. It is likely that the sample from DS-50 in September was collected at the edge of plume rather than the centre of the discharge plume.

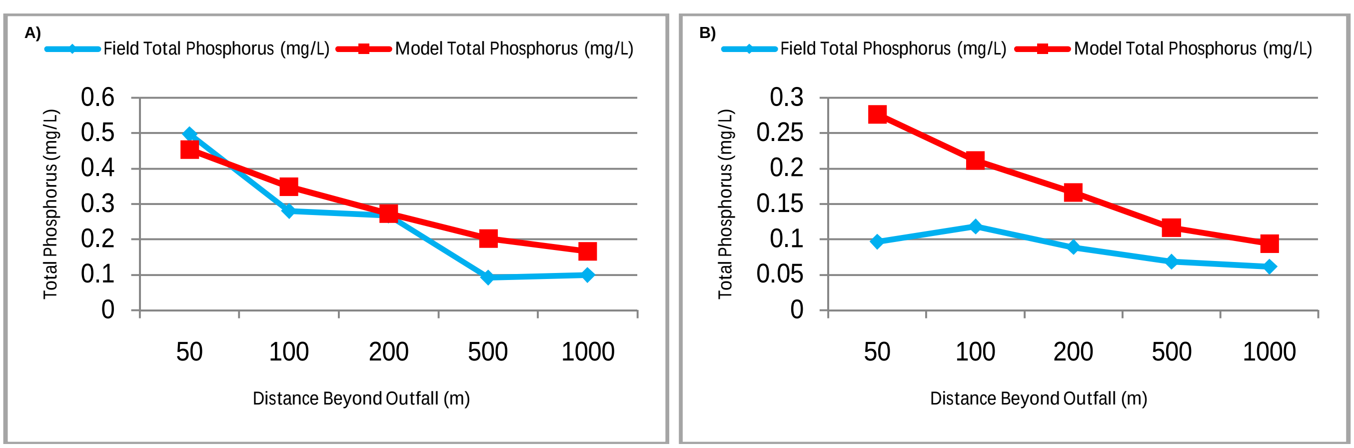

Figure 1.18: Measured versus Predicted Total Phosphorus in the Beaver River for A) August and B) September

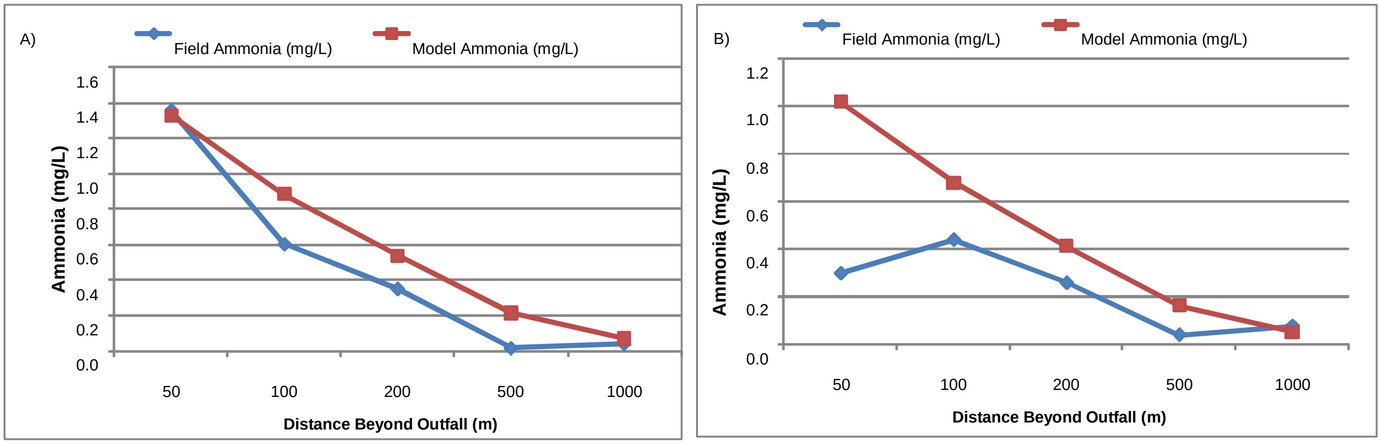

Figure 1.19: Measured versus Predicted Total Ammonia in the Beaver River for A) August and B) September

Model Results CORMIX Model – Proposed WWTF Under August 2010 Conditions

Predicted Water Quality – Total Phosphorus and Ammonia

The predicted total phosphorus, ammonia, and un-ionized ammonia concentrations for the Beaver River as a result of the proposed WWTF effluent, were determined within the plume at 50 m, 100 m, 500 m, and 1000 m downstream of the existing/proposed outfall. The results are summarized in **Table 1.14**.

Upstream total phosphorus concentrations (0.0791 mg/L) exceeded the SWQGUA of 0.05 mg/L, therefore, all modeled downstream points also exceeded the SWQGUA. However, a comparison of the total phosphorus concentrations between the existing and proposed WWTFs indicates that the proposed WWTF would result in total phosphorus concentration reductions in the river of 51-80% within 1 km of the outfall under August 2010 river conditions.

Under the upcoming CCME Wastewater Systems Effluent Regulations (WSER), un-ionized ammonia concentrations must be below 1.25 mg/L at 15°C in the effluent (i.e., prior to discharge to the river). The un-ionized ammonia concentration for the proposed WWTF effluent was calculated at 15°C and a pH of 8.1 to be 0.165 mg/L, a 63% reduction compared to that calculated for the effluent from the existing WWTF in August 2010 (0.455 mg/L).

Unionized ammonia concentrations were calculated based on the modeled total ammonia concentrations. Un-ionized ammonia concentrations in the Beaver River, downstream of the existing effluent discharge, met the CCME guideline of 0.019 mg/L within 500 m of the outfall in August 2010, while the proposed WWTF model-predicted concentration would meet the guideline within 100 m of the outfall. The modeled scenario indicates that the proposed WWTF would reduce total and unionized ammonia concentrations by 61-70% within 1 km of the outfall under August 2010 conditions.

Table 1.14: CORMIX Model Output – Proposed WWTF Under August 2010 Conditions

Parameter	Existing WWTF Modeled August, 2010 River Conc. (mg/L)	Proposed WWTF Modeled August 2010 River Conc. (mg/L)	Percent Difference
Total Phosphorus Concentrations:			
At 50 m downstream of outfall (mg/L)	0.454	0.090	-80%
At 100 m downstream of outfall (mg/L)	0.349	0.087	-75%
At 500 m downstream of outfall (mg/L)	0.202	0.083	-59%
At 1 km downstream of outfall (mg/L)	0.166	0.082	-51%
Total Ammonia Concentrations:			
At 50 m downstream of outfall (mg/L)	1.388	0.422	-70%
At 100 m downstream of outfall (mg/L)	0.927	0.296	-68%
At 500 m downstream of outfall (mg/L)	0.230	0.080	-65%
At 1 km downstream of outfall (mg/L)	0.079	0.031	-61%
Total Un-ionized Ammonia Concentrations :			
At 50 m downstream of outfall (mg/L)	0.065	0.020	-70%
At 100 m downstream of outfall (mg/L)	0.045	0.014	-68%
At 500 m downstream of outfall (mg/L)	0.012	0.004	-65%
At 1 km downstream of outfall (mg/L)	0.004	0.002	-61%
Un-ionized ammonia concentration in outfall (mg/L, @ 15°C):	**0.455**	**0.165**	**-63%**

Mass Balance Results

The mass balance method was used to determine the fully mixed concentrations of total phosphorus, total ammonia, and total unionized ammonia under each of the 5 worst case scenarios as indicated previously. This was done by multiplying the concentration and flow of each input (background river, proposed WWTF, and/or existing WWTF), adding them together, and then dividing by the total flow using the data in **Table 1.7**. The results are summarized below.

Summer Conditions:

As the upstream total phosphorus river concentration of 0.106 mg/L exceeds the SWQGUA guideline of 0.05 mg/L, the fully mixed concentration that includes the WWTF effluent would also exceed criteria. However, a comparison of scenario 1 to 4 indicates that the total phosphorus concentration under the worst case summer scenario would be reduced by 68% with the proposed WWTF as shown in **Table 1.15**.

Similarly, although the calculated un-ionized ammonia concentrations in the Beaver River, downstream of the existing effluent discharge, would exceed the CCME guideline of 0.019 mg/L under the summer worst case conditions, the proposed WWTF would result in a comparative reduction of 56% for both total and unionized ammonia concentrations as shown in **Table 1.15**.

Table 1.15: Scenario 1 vs Scenario 4 Summer Mass Balance Comparison

Beaver River Fully Mixed Parameter	Scenario 1 Lagoon - Summer	Scenario 4 New WWTF – Summer	Percent Change
Total Phosphorus (mg/L)	0.352	0.111	-68%
Total Ammonia (mg/L)	1.153	0.503	-56%
Total Unionized Ammonia (mg/L)	0.081	0.035	-56%

Spring/Fall Conditions:
As the upstream total phosphorus river concentration of 0.088 mg/L exceeds the SWQGUA guideline of 0.05 mg/L, the fully mixed concentration that includes the WWTF effluent also exceeds the criteria. However, a comparison of scenario 2 to 5 indicates that the total phosphorus concentration under the worst case summer scenario would be reduced by 73% with the proposed WWTF as shown in **Table 1.16**.

Similarly, although the calculated un-ionized ammonia concentrations in the Beaver River, downstream of the existing effluent discharge, would exceed the CCME guideline of 0.019 mg/L under the spring/fall worst case conditions, the proposed WWTF would result in a comparative reduction of 64-65% for both total and unionized ammonia concentrations as shown in **Table 1.16**.

Table 1.16: Scenario 2 vs Scenario 5 Spring/Fall Mass Balance Comparison

Beaver River Fully Mixed Parameter	Scenario 2 Lagoon – Spring/Fall	Scenario 5 New WWTF – Spring/Fall	Percent Change
Total Phosphorus (mg/L)	0.346	0.095	-73%
Total Ammonia (mg/L)	1.992	0.706	-65%
Total Unionized Ammonia (mg/L)	0.078	0.028	-64%

Winter Conditions:
As the upstream total phosphorus river concentration of 0.088 mg/L exceeds the SWQGUA guideline of 0.05 mg/L, the fully mixed concentration that includes the WWTF effluent also exceeds the criteria. The proposed WWTF would increase the concentration by 0.017 mg/L to 0.105 mg/L as the proposed WWTF would discharge year round whereas the existing WWTF is not permitted for winter discharge. Scenario 3 river water quality with the proposed WWTF discharge is shown in **Table 1.17**.

The fully mixed calculated un-ionized ammonia concentration in the Beaver River, downstream of the existing effluent discharge, would exceed the CCME guideline of 0.019 mg/L under the winter worst case conditions.

Table 1.17: Scenario 3 Winter Mass Balance

Beaver River Fully Mixed Parameter	Scenario 3 New WWTF – Winter
Total Phosphorus (mg/L)	0.105
Total Ammonia (mg/L)	1.926
Total Unionized Ammonia (mg/L)	0.021

1.4.4 Benthic Invertebrates

The benthic invertebrate community was very different upstream of the outfall as compared to downstream of the outfall but part of the difference is due to varied substrate types in the study area. The substrate upstream of the outfall is described as containing high quantities of detritus while the substrate downstream of the outfall is described as containing high quantities of sand. The density of invertebrates above the outfall is extremely high in comparison to the density at all three stations below the outfall (**Table 1.18, Figure 1.24**). Mean density is higher at DS50 as compared to DS300 or DS1000 and in 3 of the 5 samples collected at DS1000, no invertebrates were found. Statistics for DS1000 are based on results from 5 samples.

The effect of substrate type versus effluent on the benthic community cannot be determined at this time because quantitative samples for sediment quality were not collected. However it is suspected that differences in the benthic community are related more to substrate than effluent discharge.

Table 1.18. Summary Descriptive Statistics for Benthic Invertebrates

	Area	Total Density (#/m^2)	Family Richness (#)	Diptera (#/m^2)	Cladocera (#/m^2)	Insecta (#/m^2)	Oligochaeta (#/m^2)	Gastropoda (#/m^2)	Pelecypoda (#/m^2)
Min	US100	4,224.1	7.0	689.7	0.0	86.2	1,637.9	0.0	819.0
Median		16,034.5	8.0	948.3	43.1	215.5	13,275.9	0.0	1,293.1
Mean		15,689.7	8.0	974.1	86.2	215.5	12,793.1	8.6	1,413.8
Max		28,879.3	10.0	1,422.4	301.7	344.8	26,810.3	43.1	2,672.4
SE		4,304.0	0.5	123.9	56.2	40.9	4,397.0	8.6	335.9
Min	DS50	43.1	1.0	0.0	0.0	0.0	0.0	0.0	43.1
Median		301.7	2.0	0.0	0.0	0.0	0.0	0.0	43.1
Mean		258.6	2.0	43.1	8.6	0.0	0.0	17.2	172.4
Max		603.4	3.0	215.5	43.1	0.0	0.0	43.1	474.1
SE		103.8	0.4	43.1	8.6	0.0	0.0	10.6	86.2
Min	DS300	43.1	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Median		86.2	1.0	0.0	0.0	0.0	0.0	0.0	86.2
Mean		137.9	1.2	0.0	8.6	0.0	0.0	8.6	120.7
Max		387.9	2.0	0.0	43.1	0.0	0.0	43.1	387.9
SE		64.5	0.2	0.0	8.6	0.0	0.0	8.6	68.7
Min	DS1000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Median		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mean		103.4	0.6	0.0	0.0	0.0	0.0	8.6	94.8
Max		431.0	2.0	0.0	0.0	0.0	0.0	43.1	387.9
SE		83.6	0.4	0.0	0.0	0.0	0.0	8.6	75.2

Note: Five samples were collected from each area

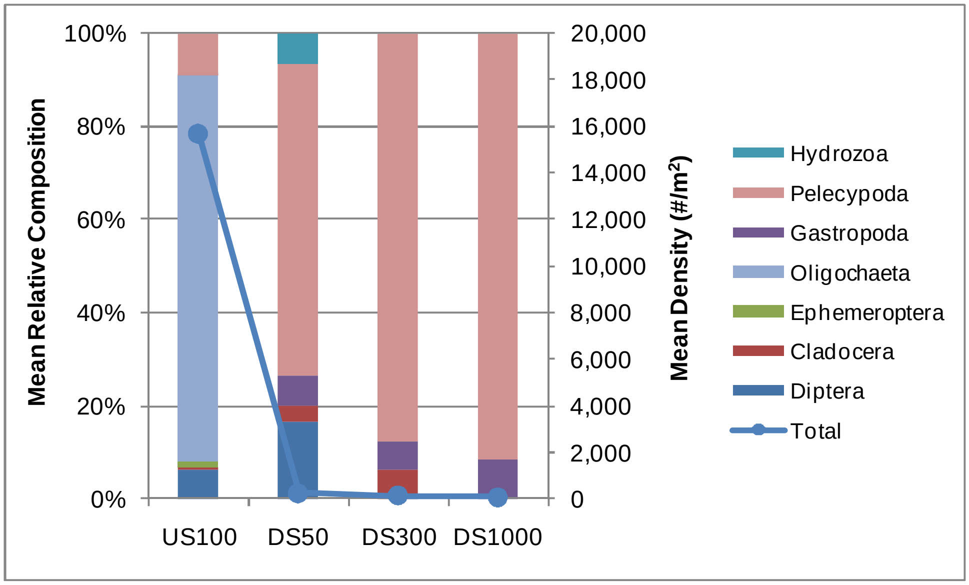

Figure 1.20: Mean Relative Invertebrate Composition and Total Density by Station in the Beaver River

1.5 Summary

1.5.1 Background

The City retained AECOM to conduct an assessment of the Beaver River (the receiving water body for treated municipal effluent) as part of the design for a new WWTF. The overall aim of the receiving water assessment study is to characterize the receiving water, identify sensitivities, and predict water quality changes as a result of the proposed WWTF upgrade. Based on previous studies, existing water quality issues of the Beaver River include:

- Concentrations of TP and TN above existing water quality guidelines
- Low concentrations of dissolved oxygen in the winter

A receiving water sampling program was established with stations immediately upstream of the outfall (US100) and downstream of the outfall at 50 m, 100 m, 200 m, 300 m, 500 m and 1000 m. Additional far-field upstream stations were established to understand variations in the river before the RUSC effluent discharge. These additional stations were established at Ardmore Bridge and near the confluence of Marie Creek (US500, US50 and DS50). Samples of final treated effluent were also collected. Samples were collected in August (2010), September (2010) and March (2011) and analyzed for a suite of general water quality parameters (e.g., TSS, pH, conductivity), nutrient parameters (e.g., ammonia, nitrate, TP, dissolved phosphorus), oxygen demand, and bacteria.

1.5.2 Existing Water Quality

This study represented the first investigation of the receiving environment downstream of the City WWTF outfall. Water quality data collected from stations upstream of the WWTF outfall were very similar to historical data upstream of the outfall.

Presently, final effluent is discharged from the lagoon to the Beaver River between April and October. River samples were collected when effluent was being discharged (August and September) and once when effluent was not being discharged under ice covered conditions (March). In the August and September samples, conductivity, TDS, chloride, sulphate and bacteria increased slightly in the first 50 m downstream of the outfall. Concentrations after 50 m downstream returned to near background values. In the March samples, upstream and downstream samples had similar concentrations of conductivity, TDS, chloride, sulphate and bacteria.

There was an identifiable nutrient effluent plume in the Beaver River from the outfall to approximately 200 m downstream. This was evident in the August and September samples but not in the March samples as the WWTF was not discharging. Additional cross-channel samples suggested that the effluent plume hugs the left bank (facing downstream) for approximately 200 m downstream of the outfall. In the winter, there was no effluent, and nutrient concentrations were similar in all samples from far upstream to far downstream.

In August and September, river samples in the plume from the outfall to 200 m DS had higher total concentrations of inorganic nitrogen and phosphorus in comparison to concentrations from upstream of the outfall and those further downstream of 200 m. The treated effluent contributes primarily inorganic nutrients and high concentrations of measureable inorganic nutrients in the river samples suggest that nutrients are being added to the surface waters in excess of immediate biological uptake. TN was above the SWQGUA in all samples in August and March but only in the near downstream samples (to 200 m DS) in September. TP was above the SWQGUA in all samples in August, only in the downstream samples in September and in a couple of upstream samples in March. Total ammonia was elevated in the near downstream samples in August (to 200 m DS) but effluent concentrations of un-ionized ammonia never exceeded the guidelines in any of the samples from August, September and March.

1.5.3 Mixing Assessment

A mixing assessment was conducted using two methods to characterize the effect on phosphorus and ammonia concentrations in the Beaver River. One method, a hydrodynamic model (CORMIX1), was utilized to simulate river conditions under measured open-water conditions and then used to compare the effects of a change in the effluent treatment. The other method, a mass balance analysis, was utilized to identify changes in water quality as a result of the upgraded WWTF under flow conditions that would not be adequately represented by the hydrodynamic model with the collected information.

CORMIX Model:

Using existing and collected data a CORMIX model was built and calibrated with the flow measurements and water quality data collected during August and September 2010 field events. The model was then used to compare the resulting river water quality effects of the existing WWTF lagoon discharge to those of the proposed upgraded WWTF discharge under August 2010 conditions (since the calibration was strongest with the August data set). The comparison indicated that the proposed WWTF upgrade would result in a predicted reduction of nutrient concentrations ranging from 51-80% for total phosphorus and 61-70% for total and unionized ammonia under August 2010 conditions within 1 km of the outfall. As the model was not calibrated to winter hydraulic conditions, prediction of winter water quality was not conducted using the CORMIX model.

Mass Balance Analysis:

Although the mass balance analysis does not incorporate decay factors or other removal mechanisms in characterizing fully mixed concentrations in the Beaver River, it was used in the context of this study to provide a means of evaluating relative improvements as a result of the proposed WWTF upgrade. As the mass balance analyses do not require the change in hydraulics with flow that are brought about by low-flow conditions or ice-covered conditions, the analysis method provides a coarse level of relative comparison on the basis of concentration only. The derived concentrations would not be directly comparable to CCME or SWQGUA guidelines. In this case five scenarios were analyzed to represent existing and proposed effluent regimes under “worst-case” summer and spring/fall conditions and to conservatively estimate the change in water quality under a winter scenario for the proposed WWTF upgrade.

- The “worst-case” scenario is described by low flows (7Q10) in the Beaver River and 75th percentile water quality concentrations for the Beaver River.

- For the lagoon models (Scenarios 1 and 2), 95th percentile effluent water quality concentrations were used.
- For all lagoon scenarios (Scenarios 1 and 2) and all proposed plant scenarios (Scenarios 3 to 5), the un-ionized ammonia effluent concentration in the outfall was below the CCME regulation of 1.25 mg/L.
- For all scenarios, the total phosphorus concentrations upstream of the outfall exceeded the SWQGUA guideline of 0.05 mg/L and therefore the mass balance analysis would not demonstrate that the WWTF upgrade would make compliance with this guideline possible.

Comparing the Summer scenarios (scenarios 1 and 4) indicated that the proposed plant would reduce total phosphorus concentrations by 68% compared to the existing WWTF under worst case conditions. Similarly a reduction in the order of 56% would be realized for total and unionized ammonia concentrations for the proposed WWTF compared to the existing WWTF.

Examination of the Spring/Fall scenarios (scenarios 2 and 5) revealed a potential total phosphorus reduction in the order of 73% with the implementation of the proposed WWTF upgrade compared to the existing WWTF lagoon. The total and unionized ammonia concentrations would be reduced by 64-65% with the upgraded WWTF.

The calculated fully mixed unionized ammonia concentration examined in scenario 3 indicated that the concentration may slightly exceed the 0.019 mg/L CCME guideline by approximately 10% under extreme conditions as a result of the proposed WWTF effluent. The total phosphorus concentration will continue to exceed the criteria under winter conditions owing to the upstream concentration of (0.088 mg/L).

1.5.4 Conclusion:

Historical total phosphorus concentrations are greater than the SWQGUA of 0.05 mg/L upstream of the WWTF outfall and as such, total phosphorus concentrations downstream of the outfall will be greater than the guideline. However, final effluent TP concentrations should be as low as possible to prevent further deterioration of the Beaver River. Based on the analyses of this study, the proposed WWTF upgrade would reduce open-water total phosphorus concentrations by 68-73% under the worst case conditions and by 51-80% under more typical conditions, such as those measured in August 2010. As the existing WWTF lagoon does not discharge during ice-covered conditions, the proposed WWTF will result in the addition of up to 0.15 mg/L to the river in this period.

In terms of total and unionized ammonia, the proposed WWTF upgrade would reduce concentrations in the order of 56-65% under worst case conditions and by 61-70% under conditions typical of those monitored in August 2010.

Accordingly, although the water quality in the Beaver River downstream of the proposed RUSC WWTF upgrade is significantly affected by upstream concentrations of various parameters (such as total phosphorus) and the capabilities of the proposed WWTF technology, guidelines will be achieved under select conditions, the proposed WWTF upgrade is expected to result in a significant improvement in the water quality of the Beaver River under all but winter conditions in comparison to the existing WWTF.

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1.6 Acronyms

Acronym	Definition
SWQGUA	Surface Water Quality Guidelines for Use in Alberta
CCME	Canadian Council for Ministers of the Environment
PPWB	Prairie Provinces Water Board
NO_X-N	Nitrate plus Nitrite
NH_4+	Ammonium Ion
NH_3	Unionized Ammonia
NH_x-N	Total Ammonia (ammonium and un-ionized ammonia)
RUSC	Cold Lake Regional Utility Services Commission
WWTF	Wastewater Treatment Facility
EPEA	Environmental Protection and Enhancement Act

Appendix A

RUSC149

Table A-1. Field Data for the Cold Lake WWTF Feasibility Study - Beaver River Sampling

Station Code	Date	pH	Conductivity (uS/cm)	DO (mg/L)	Temperature (oC)	Flow (km/hr) 5 cm depth	Flow (km/hr) 20 cm depth	Flow (km/hr) 50 cm depth	Water Depth (m)	Ice Thickness (m)	Turbidity (NTU)	Turbidity Rating	Macrophyte Cover	periphyton cover	Water Sample Collected	Invertebrates Collected
Ardmore	28-Sep-10	9.56	234	8.9	12.9	2.77	2.7	2.8	1.2	-	7.59	moderate	trace	trace	yes	
Ardmore	11-Mar-11	4.76	482	3	0.1	2.8	*	*	1.06	0.63	5.87					
US-MC-500-02	12-Mar-11	9.49	252	1.7	0.9	*	*	*	1.28	0.67	7.28					
US-MC-50-02	12-Mar-11	9.94	551	2.1	0.1	*	*	*	0.94	0.77	8.01					
DS-MC 50-01	12-Mar-11	8.61	420	10	0.3	*	*	*	1.03	0.53	4.76					
US-100-02	31-Aug-10	8.86	260	9.6	14.6	1	1.5	3.6		-	-	Turbid			yes	
US-100-03	31-Aug-10	8.99	261	9.4	14.2	2.4	4.5	2	1.4	-	-	Turbid				
US-100-02	29-Sep-10	10.52	244	10.1	13	10.12	9.55	9.95	2	-	4.06	moderate	abundant	trace	yes	yes
US-100-02	13-Mar-11	10.6	498	5.2	1.6	*	*	*	0.71	0.21	3.27					
DS-50-01	31-Aug-10	8.85	320	10	14.4	3	2.3	3.9	0.7	-	-	Turbid	Moderate, close to shore		yes	
DS-50-02	31-Aug-10	9.36	257	9.75	14	10.4	10	9.4	0.77	-	-	Turbid				
DS-50-03	31-Aug-10	9.12	258	9.14	15	9.9	6.2	4	0.65	-	-	Turbid	High, close to shore			
DS-50-01	29-Sep-10	10.39	257	9.9	12.6	6.36	5.95	5.56	0.87	-	6.89	moderate, visi	moderate (clum	none	yes	yes
DS-50-01	13-Mar-11	10.29	495	5.1	1.2	*	*	*	0.85	0.55	2.99					
DS-100-01	31-Aug-10	8.95	290	9.3	14.6	3.2	3.4	3.7	0.87	-	-	Turbid	None		yes	
DS-100-02	31-Aug-10	8.83	260	9.06	15	9.9	10.8	7.8	0.67	-	-	Turbid				
DS-100-03	31-Aug-10	9.09	259	9.58	14.8	10	8.6	7.6	0.75	-	-	Turbid	None			
DS-100-01	29-Sep-10	10.45	276	10	12.3	4.26	6.64	6.28	1.2	-	8.48	moderate	trace	none	yes	
DS-100-01	13-Mar-11	10.25	505	4.2	1.4	*	*	*	0.93	0.50	4.51					
DS-200-01	31-Aug-10	9.04	276	9.65	14.6	3.62	2.25	2.76	0.91	-	-	Turbid	None		yes	
DS-200-02	31-Aug-10	8.9	253	9.45	14.8	10.93	11.38	7.81	1.26	-	-	Turbid			yes	
DS-200-03	31-Aug-10	8.93	259	9.55	14.8	4.9	4.77	3.05	0.38	-	-	Turbid				
DS-200-01	29-Sep-10	10.74	264	9.7	12.1	7.95	7.46	6.31	1.4	-	8.29	moderate	none	none	yes	
DS-200-01	13-Mar-11	10.03	484	4.2	2.4	*	*	*	0.65	0.33	4.3					
DS-300-01	31-Aug-10	9.33	260	8.43	14.8	6.18	5.44	4.47	0.79	-	-	Moderate	None			
DS-300-02	31-Aug-10	9.25	259	8.84	14.9	11.87	9.34	8.66	0.71	-	-	Turbid				
DS-300-03	31-Aug-10	9.11	275	9.49	14.9	3.12	3.16	1.91	0.38	-	-	Turbid				
DS-300-02	29-Sep-10	10.3	248	10.3	11.9	9.93	9.76	8.21	1.5	-	10.12	moderate	moderate	none	yes	yes
DS-300-02	13-Mar-11	9.82	470	5.5	0.9	*	*	*	1.65	0.5	4.49					
DS-500-01	31-Aug-10	9.02	275	8.92	15.1	4.21	3.25	3.03	0.59	-	-					
DS-500-02	31-Aug-10	9.36	261	9	15.3	10.24	12	11.25	1.15	-	-				yes	
DS-500-03	31-Aug-10	9.05	261	8.8	15	6.52	5.86	3.34	1.2	-	-				yes	
DS-500-02	29-Sep-10	10.16	251	9.1	11.6	10.07	10.6	9.93	1.4	-	9.72	moderate	none	none	yes	
DS-500-02	13-Mar-11	10.01	520	5.2	0.9	*	*	*	1.60	0.53	6.42					
DS-750-01	31-Aug-10	9.06	268	9.11	15.3	3.98	2.84	1.68	0.58	-	-	Moderate	Trace			
DS-750-02	31-Aug-10	8.95	260	9.37	15	12.76	10.4	4.5	1	-	-	Turbid				
DS-750-03	31-Aug-10	9.02	260	9.11	15	4.78	2.72	2.65	0.34	-	-	Moderate	Trace			
DS-1000-01	31-Aug-10	9.08	266	12.61	15.5	3.97	1.96	1.4	0.34	-	-	Turbid	Trace, Lemna			
DS-1000-02	31-Aug-10	9.26	255	10	15.5	10.33	7.73	5.51	0.85	-	-	Turbid			yes	
DS-1000-03	31-Aug-10	9.15	262	10.38	15.3	6.75	5.39	5.22	0.89	-	-	Turbid	Trace		yes	
DS-1000-02	29-Sep-10	9.98	257	9.3	10.4	8.47	8.29	7.77	1.1	-	9.19	moderate	trace	none	yes	yes
DS-1000-02	13-Mar-11	9.55	501	5.4	0.2	*	*	*	0.90	0.45	5.34					
Effluent	31-Aug-10	9.19	780		16.2				-	-	-				yes	
Effluent	28-Sep-10	8.13	863	-	12.3				-	-	-	-	-	-	yes	
Effluent	13-Mar-11	no sample collected because lagoon does not discharge in the winter							-	-	-					

Table A-2. Analytical Data for the Cold Lake WWTF Feasibility Study - Beaver River Sampling - General Chemistry, Nutrients, Bacteria and BOD

Temperature (oC)

Sample ID	Units	DL	CCME Aquatic Life[a]	BC Aquatic Life[d]	Alberta SWQG[f]	PPWB[j]	US-100-01	DS-50-01	DS-100-01	DS-200-01	DS-200-02	DS-500-02	DS-500-03	DS-1000-02	DS-1000-03	Effluent	Field Blank
Project							60157998	60157998	60157998	60157998	60157998	60157998	60157998	60157998	60157998	60157998	60157998
ALS Sample ID							L926854-1	L926854-3	L926854-4	L926854-5	L926854-2	L926848-1	L926848-4	L926848-2	L926848-3	L926850-1	L926850-2
Date Sampled							31-Aug-10	31-Aug-10	31-Aug-10	31-Aug-10	31-Aug-10	31-Aug-10	31-Aug-10	31-Aug-10	31-Aug-10	31-Aug-10	31-Aug-10
Time Sampled							10:15	10:45	11:15	11:45	11:30	13:15	13:00	14:00	13:45	16:00	16:15
Field Data																	
pH			6.5-9.0	6.5 - 9.0	6.5-8.5[g]	6.5-9.0	8.86	8.85	8.95	*9.04*	8.9	*9.36*	*9.05*	*9.26*	*9.15*	9.19	
Temperature	°C						14.6	14.4	14.6	14.6	14.8	15.3	15	15.5	15.3	16.2	
Conductivity	µS/cm						260	320	290	276	253	261	261	255	262	780	
Dissolved Oxygen	mg/L		5.5 - 9.5[b]		5.0 to 6.5[h]	6	9.6	10	9.3	9.65	9.45	9	8.8	10	10.38		
Physical Tests																	
Total Suspended Solids	mg/L	3.0			narrative[i]		29.0	36.0	28.0	33.0	35.0	35.0	29.0	31.0	29.0	26.0	<3.0
Total Dissolved Solids	mg/L	5.0					188	214	207	193	182	190	194	198	200	485	236
TDS (Calculated)	mg/L	-					142	179	158	147	142	137	138	139	138	428	222
General Chemistry																	
Alkalinity, Total (as CaCO3)	mg/L	5.0					136	155	146	140	135	135	135	136	135	298	90.5
Bicarbonate (HCO3)	mg/L	5.0					166	189	178	170	165	164	156	157	156	352	104
Carbonate (CO3)	mg/L	5.0					<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	6.0	<5.0
Chloride (Cl)	mg/L	0.50		600		100	1.69	6.12	4.05	2.76	1.59	1.68	1.66	1.77	1.61	41.8	5.68
Conductivity (EC)	uS/cm	0.20					270	334	305	287	269	272	269	272	270	809	386
Hardness (as CaCO3)	mg/L	-					132	159	137	130	135	125	128	126	126	283	141
Hydroxide (OH)	mg/L	5.0					<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Ion Balance	%	-					108	114	104	104	111	102	110	107	109	102	93.8
pH	pH	0.10	6.5-9.0	6.5 - 9.0	6.5-8.5[g]	6.5-9.0	8.28	8.26	8.27	8.30	8.28	8.28	8.31	8.30	8.32	8.33	8.31
Sulfate (SO4)	mg/L	0.50		50 - 100[e]		500	3.05	9.69	6.73	4.76	3.03	3.20	3.09	3.33	3.10	64.7	93.0
Nutrients																	
Total Nitrogen (calculated)	mg/L				1		*1.3040*	*3.2059*	*2.6228*	*1.8705*	*1.2040*	*1.4240*	*1.5540*	*1.6040*	*1.5440*	19.4133	
Organic Nitrogen (calculated)	mg/L						1.29	1.80	1.99	1.51	1.16	1.40	1.54	1.56	1.53	5.00	
Total Kjeldahl Nitrogen	mg/L	0.050					1.30	3.16	2.60	1.86	1.20	1.42	1.55	1.60	1.54	19.3	<0.050
Ammonia-N	mg/L	0.0050				Table[k]	0.0078	*1.36*	*0.606*	*0.354*	0.0396	0.0194	0.0059	0.0433	0.0135	14.3	<0.0050
Un-ionized Ammonia (calculated)	mg/L	-	0.019				0.0012	*0.2098*	*0.1146*	*0.0789*	0.0069	0.0075	0.0014	0.0146	0.0038	4.4878	
Nitrate+Nitrite-N	mg/L	0.0060				10	<0.0060	0.0459	0.0228	0.0100	<0.0060	<0.0060	<0.0060	<0.0060	<0.0060	0.113	0.287
Nitrate-N	mg/L	0.0060	13	200			<0.0060	0.0216	0.0089	<0.0060	<0.0060	<0.0060	<0.0060	<0.0060	<0.0060	0.0321	0.287
Nitrite-N	mg/L	0.0020	0.06	0.06			<0.0020	0.0243	0.0139	0.0075	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	0.0812	<0.0020
Total Phosphorus	mg/L	0.0010			0.05		*0.0791*	*0.497*	*0.280*	*0.268*	*0.0826*	*0.0918*	*0.0898*	*0.0996*	*0.0789*	3.66	<0.0010
Particulate Phosphorus (calculated)	mg/L						0.0691	0.2010	0.1280	0.1793	0.0742	0.0782	0.0716	0.0823	0.0674	0.4500	
Total Dissolved Phosphorus	mg/L	0.0010					0.0100	0.296	0.152	0.0887	0.0084	0.0136	0.0182	0.0173	0.0115	3.21	-
Orthophosphate (PO4-P)	mg/L	0.0010					0.0011	0.310	0.151	0.0757	<0.0010	0.0064	0.0035	0.0106	0.0039	3.18	<0.0010
Organic / Inorganic Carbon																	
Dissolved Organic Carbon	mg/L	0.50					15.9	15.7	15.7	16.0	15.1	16.3	15.4	15.7	15.7	19.5	-
Total Organic Carbon	mg/L	0.50					16.8	17.4	17.2	17.3	17.0	17.3	17.8	18.0	17.8	23.8	-
Bacteria																	
E. Coli	CFU/100 mL	1					17	12	20	15	24	12	12	15	16	<1	-
Fecal Coliforms	CFU/100 mL	1	200[c]			100	17	18	20	25	27	17	37	17	18	<1	-
Aggregate Organics																	
BOD Carbonaceous	mg/L	2.0					<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	2.2	-
Biochemical Oxygen Demand	mg/L	2.0					n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a

Sample ID	Ardmore	US-100-01	US-100-02-Replicate	DS-50-01	DS-100-01	DS-200-01	DS-300-02	DS-500-02	DS-1000-02	Effluent	Field Blank
Project	60157998	60157998	60157998	60157998	60157998	60157998	60157998	60157998	60157998	60157998	60157998
ALS Sample ID	L937891-3	L937891-1	L937891-2	L937891-5	L937891-6	L937891-7	L937891-8	L937891-9	L937891-10	L937891-4	L937891-11
Date Sampled	29-Sep-10	29-Sep-10	29-Sep-10	29-Sep-10	29-Sep-10	29-Sep-10	29-Sep-10	29-Sep-10	29-Sep-10	29-Sep-10	29-Sep-10
Time Sampled	17:00	15:00	16:00	14:00	13:00	12:00	11:00	10:00	9:00	16:00	17:00
Field Data											
pH	9.56	10.52	10.52	10.39	10.45	10.74	10.3	10.16	9.98	8.13	-
Temperature	12.9	13	13	12.6	12.3	12.1	11.9	11.6	10.4	12.3	-
Conductivity	234	244	244	257	276	264	248	251	257	863	-
Dissolved Oxygen	8.9	10.1	10.1	9.9	10	9.7	10.3	9.1	9.3	-	-
Physical Tests											
Total Suspended Solids	14	50	17	13	18	22	22	34	28	18	<3.0
Total Dissolved Solids	168	170	171	180	175	173	167	170	173	494	<5.0
TDS (Calculated)											
General Chemistry											
Alkalinity, Total (as CaCO3)	121	128	127	137	133	132	128	129	130	319	<5.0
Bicarbonate (HCO3)	148	156	155	167	162	161	156	157	158	389	<5.0
Carbonate (CO3)	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Chloride (Cl)	1.55	2.4	1.9	3.52	2.96	2.68	1.84	1.94	2.02	41.3	<0.50
Conductivity (EC)	249	264	264	292	282	278	264	267	269	875	0.24
Hardness (as CaCO3)											
Hydroxide (OH)	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Ion Balance											
pH	8.22	8.25	8.24	8.25	8.25	8.25	8.25	8.24	8.24	8.1	6.08
Sulfate (SO4)	3.36	4.24	4.04	6.79	5.78	5.29	3.82	4.03	4.18	73	<0.50
Nutrients											
Total Nitrogen (calculated)	0.6950	0.7060	0.6890	*1.0011*	*1.3018*	0.9947	0.7190	0.7862	0.7565	15.2478	
Organic Nitrogen (calculated)	0.68	0.69	0.67	**0.69**	**0.85**	0.73	0.70	0.74	0.67	1.40	
Total Kjeldahl Nitrogen	0.691	0.702	0.685	0.986	1.29	0.984	0.715	0.778	0.745	15.2	<0.050
Ammonia-N	0.01	0.0096	0.0108	0.298	0.44	0.258	0.011	0.0399	0.0762	13.8	<0.0050 *
Un-ionized Ammonia (calculated)											
Nitrate+Nitrite-N	<0.0063	<0.0063	<0.0063	0.0151	0.0118	0.0107	<0.0063	0.0072	0.0105	0.0478	<0.0063
Nitrate-N	<0.0060	<0.0060	<0.0060	0.0097	0.0077	0.0067	<0.0060	0.0072	0.0105	0.0264	<0.0060
Nitrite-N	<0.0020	<0.0020	<0.0020	0.0054	0.0041	0.004	<0.0020	<0.0020	<0.0020	0.0214	<0.0020
Total Phosphorus	0.0432	0.04	0.0372	0.0967	0.118	0.0889	0.0528	0.0683	0.0614	2.61	<0.0010
Particulate Phosphorus (calculated)	0.0323	0.0304	0.0284	**0.0035**	**0.0527**	0.0318	0.0395	0.0468	0.0391	0.2400	
Total Dissolved Phosphorus	0.0109	0.0096	0.0088	0.0932	0.0653	0.0571	0.0133	0.0215	0.0223	2.37	<0.0010
Orthophosphate (PO4-P)	0.0031	0.0035	0.0034	0.094	0.0627	0.0503	0.0059	0.0123	0.0166	2.21	<0.0010
Organic / Inorganic Carbon											
Dissolved Organic Carbon	16.9	16.3	17.7	17	16.3	17.1	16.4	-	17.3 *	19.2	<0.50
Total Organic Carbon	20.4	17.3	16.9	17.1	17.1	19.4	17	-	16.5	21.6	<0.50
Bacteria											
E. Coli	2	6	4	8	6	10	7	6	4	9	<1
Fecal Coliforms	2	6	4	8	6	9	7	6	4	9	<1
Aggregate Organics											
BOD Carbonaceous	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	3.2	<2.0
Biochemical Oxygen Demand	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	6	<2.0

Sample ID	ARDMORE	US-MC-500-2	US-MC-50-1	DS-MC-50-1	US 100-02	DS 50-01	DS 100-01	DS 200-01	DS 300-02	DS 300-02-rep	DS 500-02	DS 1000-02	FIELD BLANK
Project													
ALS Sample ID	L985730-1	L985730-2	L985730-3	L985730-4	L985730-5	L985730-6	L985730-7	L985730-8	L985730-9	L985730-12	L985730-10	L985730-11	L985730-13
Date Sampled	11-Mar-11	12-Mar-11	12-Mar-11	12-Mar-11	13-Mar-11	13-Mar-11	13-Mar-11	13-Mar-11	13-Mar-11	13-Mar-11	13-Mar-11	13-Mar-11	12-Mar-11
Time Sampled	16:00	12:30	11:00	10:30	12:30	12:00	11:30	10:30	10:00	10:30	09:30	09:00	13:30
Field Data													
pH	4.76	9.49	9.94	8.61	10.60	10.29	10.25	10.03	9.82	-	10.01	9.55	-
Temperature	0.10	0.90	0.10	0.30	1.60	1.20	1.40	2.40	0.90	-	0.90	0.20	-
Conductivity	482	252	551	420	498	495	505	484	470	-	520	501	-
Dissolved Oxygen	*3.0*	*1.7*	*2.1*	10.0	*5.2*	*5.1*	*4.2*	*4.2*	5.5	-	*5.2*	*5.4*	-
Physical Tests													
Total Suspended Solids	6.0	<3.0	<3.0	<3.0	4.0	5.0	<3.0	5.0	<3.0	<3.0	5.0	5.0	<3.0
Total Dissolved Solids	331	332	332	259	331	326	321	333	330	326	322	326	<5.0
TDS (Calculated)	274	285	268	217	277	271	275	273	279	276	276	277	<1.0
General Chemistry													
Alkalinity, Total (as CaCO3)	263	265	256	209	261	262	260	261	261	261	259	260	<5.0
Bicarbonate (HCO3)	321	323	312	254	319	319	317	318	319	318	316	317	<5.0
Carbonate (CO3)	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Chloride (Cl)	4.52	4.73	4.47	3.95	4.92	4.78	4.76	4.84	5.39	4.80	4.96	4.75	<0.50
Conductivity (EC)	507	516	495	406	508	506	507	511	511	510	508	510	0.38
Hardness (as CaCO3)	211	231	210	186	225	208	220	215	225	222	223	226	<1.0
Hydroxide (OH)	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Ion Balance	94.6	102	95.9	97.7	99.7	92.8	98.4	95.2	99.2	98.3	99.6	101	Low TDS
pH	7.94	7.92	7.95	8.03	7.98	7.99	7.98	7.98	8.01	8.04	8.01	8.02	5.76
Sulfate (SO4)	12.2	12.7	12.2	7.04	11.9	11.8	11.9	12.2	12.6	12.0	12.0	12.0	<0.50
Nutrients													
Total Nitrogen (calculated)	1.1348	*1.126*	*1.141*	*1.269*	*1.142*	*1.162*	*1.178*	*1.184*	*1.147*	*1.109*	*1.198*	*1.141*	
Organic Nitrogen (calculated)	0.61	0.61	0.62	0.67	0.59	0.61	0.61	0.63	0.60	0.56	0.64	0.59	
Total Kjeldahl Nitrogen	0.907	0.902	0.916	0.825	0.864	0.882	0.884	0.907	0.872	0.833	0.918	0.860	<0.050
Ammonia-N	0.295	0.297	0.300	0.154	0.273	0.270	0.279	0.276	0.275	0.273	0.278	0.271	<0.0050
Un-ionized Ammonia (calculated)	0.0021	0.0022	0.0022	0.0014	0.0024	0.0024	0.0024	0.0026	0.0024	0.0026	0.0025	0.0023	
Nitrate+Nitrite-N	0.228	0.224	0.225	0.444	0.278	0.280	0.294	0.278	0.275	0.276	0.280	0.281	<0.0060
Nitrate-N	0.223	0.219	0.220	0.439	0.274	0.275	0.290	0.273	0.271	0.271	0.276	0.276	<0.0060
Nitrite-N	0.0048	0.0050	0.0046	0.0048	0.0044	0.0047	0.0042	0.0042	0.0042	0.0045	0.0043	0.0049	<0.0020
Total Phosphorus	0.0501	0.0484	0.0463	*0.0629*	*0.0528*	0.0492	0.0493	0.0492	0.0494	0.0498	0.0492	0.0480	<0.0010
Particulate Phosphorus (calculated)	0.0314	0.0306	0.0310	0.0157	0.0307	0.0307	0.0304	0.0300	0.0319	0.0296	0.0315	0.0300	
Total Dissolved Phosphorus	0.0187	0.0178	0.0153	0.0472	0.0221	0.0185	0.0189	0.0192	0.0175	0.0202	0.0177	0.0180	<0.0010
Orthophosphate (PO4-P)	0.0047	0.0037	0.0041	0.0322	0.0060	0.0064	0.0061	0.0062	0.0065	0.0069	0.0067	0.0061	<0.0010
Organic / Inorganic Carbon													
Dissolved Organic Carbon	15.6	14.4	14.2	13.6	15.0	14.5	14.3	13.7	14.6	14.0	14.5	14.5	0.56
Total Organic Carbon	15.4	14.3	14.2	12.7	13.9	13.1	14.4	14.0	13.8	14.0	14.1	14.1	<0.50
Bacteria													
E. Coli	<1	<1	<1	<1	1	<1	1	<1	<1	<1	<1	1	<1
Fecal Coliforms	<1	<1	<1	<1	1	<1	1	<1	<1	<1	<1	1	<1
Aggregate Organics													
BOD Carbonaceous													
Biochemical Oxygen Demand	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0

Notes

un-ionized ammonia calculated using
total ammonia
10^ (pKa-pH)
pKa=0.09018 + 2729/(273.15+temp)

a) Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 2007
b) early life stage 6.0 warm water, 9.5 cold water species; other life stages 5.5 for warm water and 6.5 for cold water
c) CCME guidelines for Canadian Recreational Water Quality
d) British Columbia Water Quality Guidelines (2006)
e) 50 mg/L Alert Level; 100 mg/L - Maximum Level
f) Surface water quality guidelines for Alberta, 1999
g) To be in the range of 6.5 to 8.5 but not altered by more than 0.5 pH units from background values.
h) acute 5.0 (1-day minimum); chronic 6.5 (7-day mean); chronic should increase to 8.3 for mid May to end of June for Mayfly emergence; increased to 9.5 embryonic and larval stages developing within gravel beds
i) Not to be increased by more than 10 mg/L over background value
j) PPWB Annual Report 2008
k) Table from PPWB 2008; ammonia guidelines dependent upon pH and temperature

italics exceeds most stringent guideline

RUSC149

Table A-3. Analytical Data for the Cold Lake WWTF Feasibility Study - Beaver River Sampling - Total and Dissolved Metals

					Temperature (oC)											
RESULTS OF ANALYSIS																
Project							60157998	60157998	60157998	60157998	60157998	60157998	60157998	60157998	60157998	60157998	60157998
ALS Sample ID							L926854-1	L926854-3	L926854-4	L926854-5	L926854-2	L926848-1	L926848-4	L926848-2	L926848-3	L926850-1	L926850-2
Sample ID	**Units**	**DL**	***CCME Aquatic Life*** [a]	**BC Aquatic Life** [g]	**Alberta SWQG** [m]	**PPWB** [o]	**US-100-01**	**DS-50-01**	**DS-100-01**	**DS-200-01**	**DS-200-02**	**DS-500-02**	**DS-500-03**	**DS-1000-02**	**DS-1000-03**	**Effluent**	**Field Blank**
Date Sampled							31-Aug-10	31-Aug-10	31-Aug-10	31-Aug-10	31-Aug-10	31-Aug-10	31-Aug-10	31-Aug-10	31-Aug-10	31-Aug-10	31-Aug-10
Time Sampled							10:15	10:45	11:15	11:45	11:30	13:15	13:00	14:00	13:45	16:00	16:15
Total Metals																	
Aluminum (Al)-Total	mg/L	0.020	0.005-0.1[b]				***0.289***	***0.261***	***0.230***	***0.249***	***0.315***	***0.305***	***0.296***	***0.317***	***0.263***	***0.272***	<0.020
Antimony (Sb)-Total	mg/L	0.00040					<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040
Arsenic (As)-Total	mg/L	0.00040	0.005	0.005			0.00124	0.00150	0.00134	0.00131	0.00134	0.00117	0.00116	0.00115	0.00117	0.00263	<0.00040
Barium (Ba)-Total	mg/L	0.00020				1	0.0445	0.0452	0.0449	0.0440	0.0444	0.0440	0.0438	0.0432	0.0432	0.0235	0.00136
Beryllium (Be)-Total	mg/L	0.0010					<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Bismuth (Bi)-Total	mg/L	0.00020					<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Boron (B)-Total	mg/L	0.020		1.2			0.029	0.043	0.037	0.034	0.028	0.027	0.027	0.027	0.027	0.186	<0.020
Cadmium (Cd)-Total	mg/L	0.00020	0.000017[c]			0.001	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Calcium (Ca)-Total	mg/L	0.50					36.6	37.5	36.8	35.1	34.7	25.9	28.6	27.2	30.7	70.2	40.7
Chromium (Cr)-Total	mg/L	0.00080	0.001			0.011	<0.00080	<0.00080	<0.00080	<0.00080	<0.00080	<0.00080	<0.00080	<0.00080	<0.00080	0.00132	<0.00080
Cobalt (Co)-Total	mg/L	0.00020		0.11			0.00033	0.00043	0.00035	0.00035	0.00036	0.00035	0.00034	0.00035	0.00033	0.00098	<0.00020
Copper (Cu)-Total	mg/L	0.0010	0.002-0.004[d]	0.011[h]	0.007[n]	0.004	0.0013	0.0014	0.0013	0.0011	0.0013	0.0012	0.0012	0.0013	0.0012	0.0042	0.0012
Iron (Fe)-Total	mg/L	0.010	0.3				***1.09***	***1.13***	***1.01***	***1.01***	***1.13***	***0.871***	***0.946***	***0.902***	***0.954***	***0.816***	<0.010
Lead (Pb)-Total	mg/L	0.00010	0.001-0.007[e]	0.003[i]		0.007	0.00035	0.00040	0.00036	0.00035	0.00037	0.00036	0.00037	0.00041	0.00035	0.00058	<0.00010
Magnesium (Mg)-Total	mg/L	0.10					13.4	14.8	13.9	13.1	12.8	10.9	9.95	11.2	12.6	37.9	11.9
Manganese (Mn)-Total	mg/L	0.0020		0.8 - 3.8[j]			0.0697	0.0975	0.0832	0.0750	0.0681	0.0555	0.0586	0.0567	0.0606	0.387	<0.0020
Mercury (Hg)-Total	mg/L	0.000020	0.000026	0.0001			<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020
Molybdenum (Mo)-Total	mg/L	0.00010	0.073	2			0.00039	0.00046	0.00040	0.00038	0.00038	0.00038	0.00038	0.00037	0.00042	0.00133	0.00047
Nickel (Ni)-Total	mg/L	0.00020	0.025-0.15[f]			0.1	0.00159	0.00190	0.00172	0.00170	0.00161	0.00190	0.00194	0.00198	0.00195	0.00462	0.00125
Potassium (K)-Total	mg/L	0.10					1.49	2.34	1.85	1.67	1.35	1.04	0.92	1.15	1.20	12.2	1.35
Selenium (Se)-Total	mg/L	0.00040	0.001	0.002			<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.0020	<0.00040
Silver (Ag)-Total	mg/L	0.00040	0.0001	0.0001 - 0.003[k]		0.0001	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040
Sodium (Na)-Total	mg/L	1.0					10.0	12.9	12.8	11.2	9.7	8.4	7.3	9.0	10.1	47.0	19.6
Strontium (Sr)-Total	mg/L	0.00020					0.0994	0.114	0.108	0.104	0.0975	0.0924	0.0947	0.0933	0.0946	0.263	0.385
Thallium (Tl)-Total	mg/L	0.00010					<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Tin (Sn)-Total	mg/L	0.00040					<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	0.00095
Titanium (Ti)-Total	mg/L	0.0050					0.0089	0.0087	0.0075	0.0086	0.0099	0.0098	0.0095	0.0102	0.0089	0.0127	<0.0050
Uranium (U)-Total	mg/L	0.00010				0.02	0.00016	0.00037	0.00029	0.00025	0.00016	0.00018	0.00017	0.00018	0.00017	0.00271	<0.00010
Vanadium (V)-Total	mg/L	0.00050					0.00126	0.00126	0.00114	0.00117	0.00134	0.00130	0.00125	0.00132	0.00118	0.00235	<0.00050
Zinc (Zn)-Total	mg/L	0.0040	0.03	0.04[l]		0.03	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	0.0046	0.0041	0.0041	0.0086	<0.0040
Dissolved Metals																	
Aluminum (Al)-Dissolved	mg/L	0.010					<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	-
Antimony (Sb)-Dissolved	mg/L	0.00040					<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	0.00061	-
Arsenic (As)-Dissolved	mg/L	0.00040				0.05	0.00099	0.00119	0.00107	0.00108	0.00096	0.00087	0.00082	0.00081	0.00085	0.00238	-
Barium (Ba)-Dissolved	mg/L	0.00010					0.0363	0.0326	0.0342	0.0355	0.0361	0.0373	0.0374	0.0372	0.0376	0.00564	-
Beryllium (Be)-Dissolved	mg/L	0.00050					<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	-
Bismuth (Bi)-Dissolved	mg/L	0.000050					<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	-
Boron (B)-Dissolved	mg/L	0.0020				5.00	0.0328	0.0465	0.0335	0.0327	0.0282	0.0306	0.0290	0.0300	0.0296	0.189	-
Cadmium (Cd)-Dissolved	mg/L	0.00010					<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	-
Calcium (Ca)-Dissolved	mg/L	0.50					33.0	38.2	33.7	31.8	33.7	30.9	31.7	31.0	31.2	60.0	37.8
Chromium (Cr)-Dissolved	mg/L	0.00040					<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.0020	-
Cobalt (Co)-Dissolved	mg/L	0.00010					<0.00010	0.00013	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00059	-
Copper (Cu)-Dissolved	mg/L	0.00060					<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	0.00208	-
Iron (Fe)-Dissolved	mg/L	0.010				1.00	0.051	0.020	0.022	0.025	0.047	0.027	0.029	0.029	0.035	0.048	-
Lead (Pb)-Dissolved	mg/L	0.00010					<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	-
Magnesium (Mg)-Dissolved	mg/L	0.10					12.1	15.5	12.9	12.2	12.3	11.5	11.8	11.7	11.7	32.4	11.3
Manganese (Mn)-Dissolved	mg/L	0.0020				0.20	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	0.0066	-
Mercury (Hg)-Dissolved	mg/L	0.000020					<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	-
Molybdenum (Mo)-Dissolved	mg/L	0.00010					0.00034	0.00043	0.00034	0.00034	0.00031	0.00035	0.00035	0.00034	0.00033	0.00147	-
Nickel (Ni)-Dissolved	mg/L	0.00010					0.00109	0.00149	0.00128	0.00125	0.00109	0.00085	0.00090	0.00091	0.00092	0.00373	-
Potassium (K)-Dissolved	mg/L	0.50					1.00	2.48	1.61	1.33	1.14	0.92	0.91	0.95	0.93	10.7	1.31
Selenium (Se)-Dissolved	mg/L	0.00040				0.001	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.0020	-
Silver (Ag)-Dissolved	mg/L	0.00020					<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	-
Sodium (Na)-Dissolved	mg/L	1.0					9.1	14.3	10.9	9.9	9.1	8.2	8.2	8.2	8.3	38.9	16.9
Strontium (Sr)-Dissolved	mg/L	0.00010					0.115	0.137	0.120	0.121	0.112	0.0906	0.0917	0.0912	0.0912	0.275	-
Thallium (Tl)-Dissolved	mg/L	0.000050					<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	-
Tin (Sn)-Dissolved	mg/L	0.00020					<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	-
Titanium (Ti)-Dissolved	mg/L	0.00030					0.00060	0.00120	0.00083	0.00071	0.00053	0.00036	0.00035	0.00039	0.00034	0.00275	-
Uranium (U)-Dissolved	mg/L	0.00010					0.00012	0.00038	0.00022	0.00020	0.00012	0.00015	0.00015	0.00016	0.00015	0.00275	-
Vanadium (V)-Dissolved	mg/L	0.00010					0.00033	0.00047	0.00038	0.00038	0.00033	0.00034	0.00032	0.00035	0.00034	0.00161	-
Zinc (Zn)-Dissolved	mg/L	0.0010					<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0011	<0.0010	<0.0010	0.0038	-

Notes

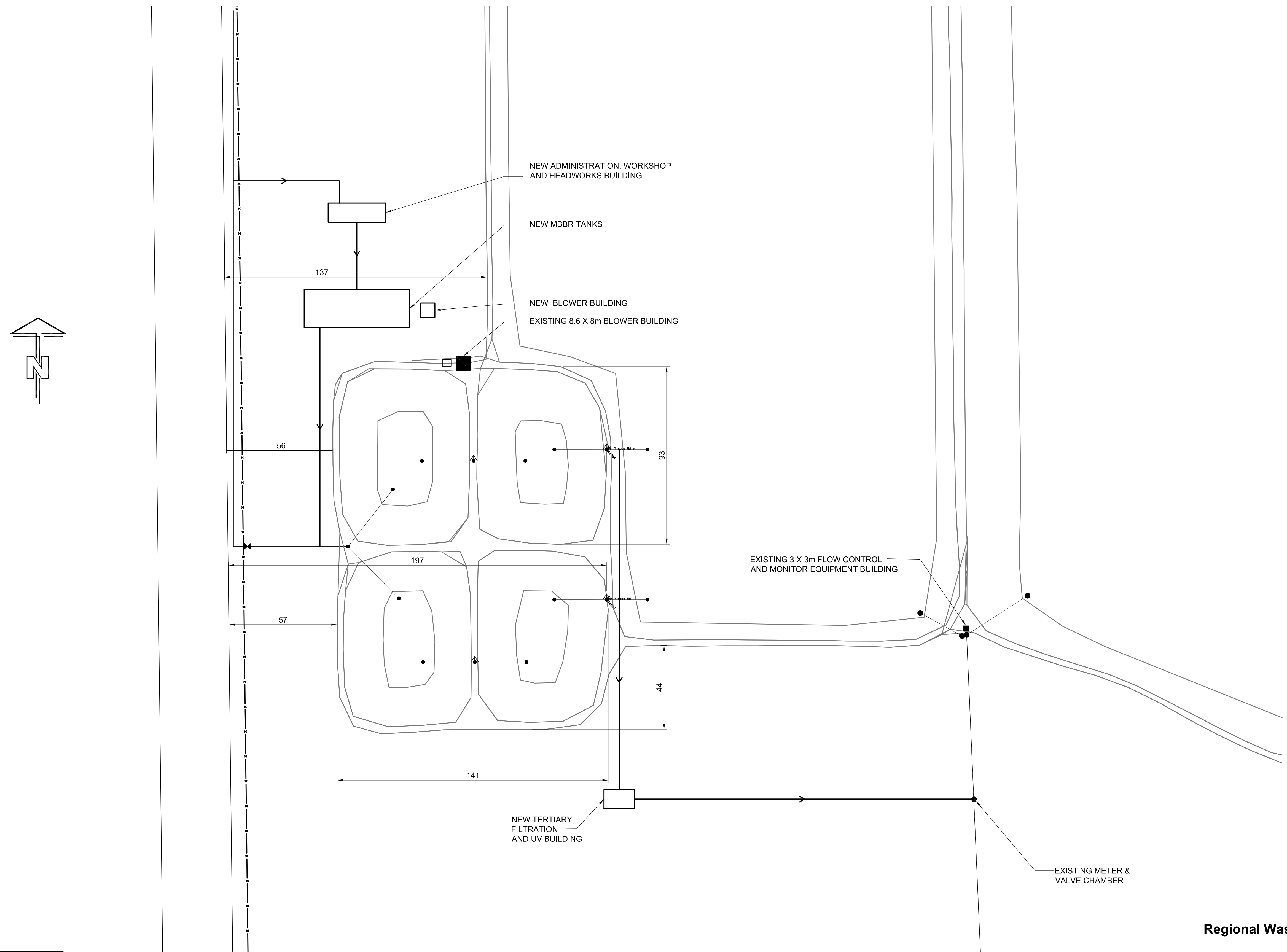
a) Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 2007
b) 0.005mg/L at pH < 6.5, [Ca2+] < 4 mg/L, DOC < 2 mg/L: 0.1 mg/L at pH > 6.5, [Ca2+] > 4 mg/L, DOC > 2 mg/L
c) Hardness based guideline = 10{0.86[log(hardness)]-3.2}
d) 0.002 mg/L at [hardness=CaCO3] = 0 - 120 mg/L; 0.003 mg/L at [CaCO3] =120 - 180 mg/L; 0.004 mg/L at [CaCO3] >180mg/L
e) 0.001 mg/L at [CaCO3] = 0 - 60 mg/L; 0.002 mg/L at [CaCO3] =60 - 120 mg/L; 0.004 mg/L at [CaCO3] =120 -180mg/L; 0.007 mg/L at [CaCO3] > 180mg/L
f) 0.025 mg/L at [CaCO3] = 0 - 60 mg/L; 0.065 mg/L at [CaCO3] =60 - 120 mg/L; 0.110 mg/L at [CaCO3] =120 -180mg/L; 0.150 mg/L at [CaCO3] > 180mg/L
g) British Columbia Water Quality Guidelines (2006)
h) Hardness based guideline (ug/L) = 0.094(hardness(mg/L)) + 2
i) 0.003 mg/L at [CaCO3] < 8 mg/L; e{1.273 ln(hardness) - 1.460 at [CaCO3] > 8 mg/L
j) 0.8 mg/L at [CaCO3] = 25 mg/L; 3.8 mg/L at [CaCO3] = 300 mg/L
k) 0.0001 mg/L at [CaCO3] < 100 mg/L; 0.003 mg/L at [CaCO3] > 100 mg/L
l) Hardness based guideline (ug/L) = 33 + 0.75(hardness(mg/L) - 90)
m)Surface water quality guidelines for Alberta, 1999
n) the chronic guideline can therefore only be applied at water hardness equal to or greater than 50 mg/L CaCO3. Guideline applies to acid-extractable copper concentrations
o) PPWB Annual Report 2008

italics exceeds most stringent guideline

<d.l. - less than the detection limit
n.a. - not analysed
CCME Drinking Water Guidelines

Appendix C

RUSC149



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Cold Lake
Regional Wastewater Treatment
Feasibility Study

Figure C.2

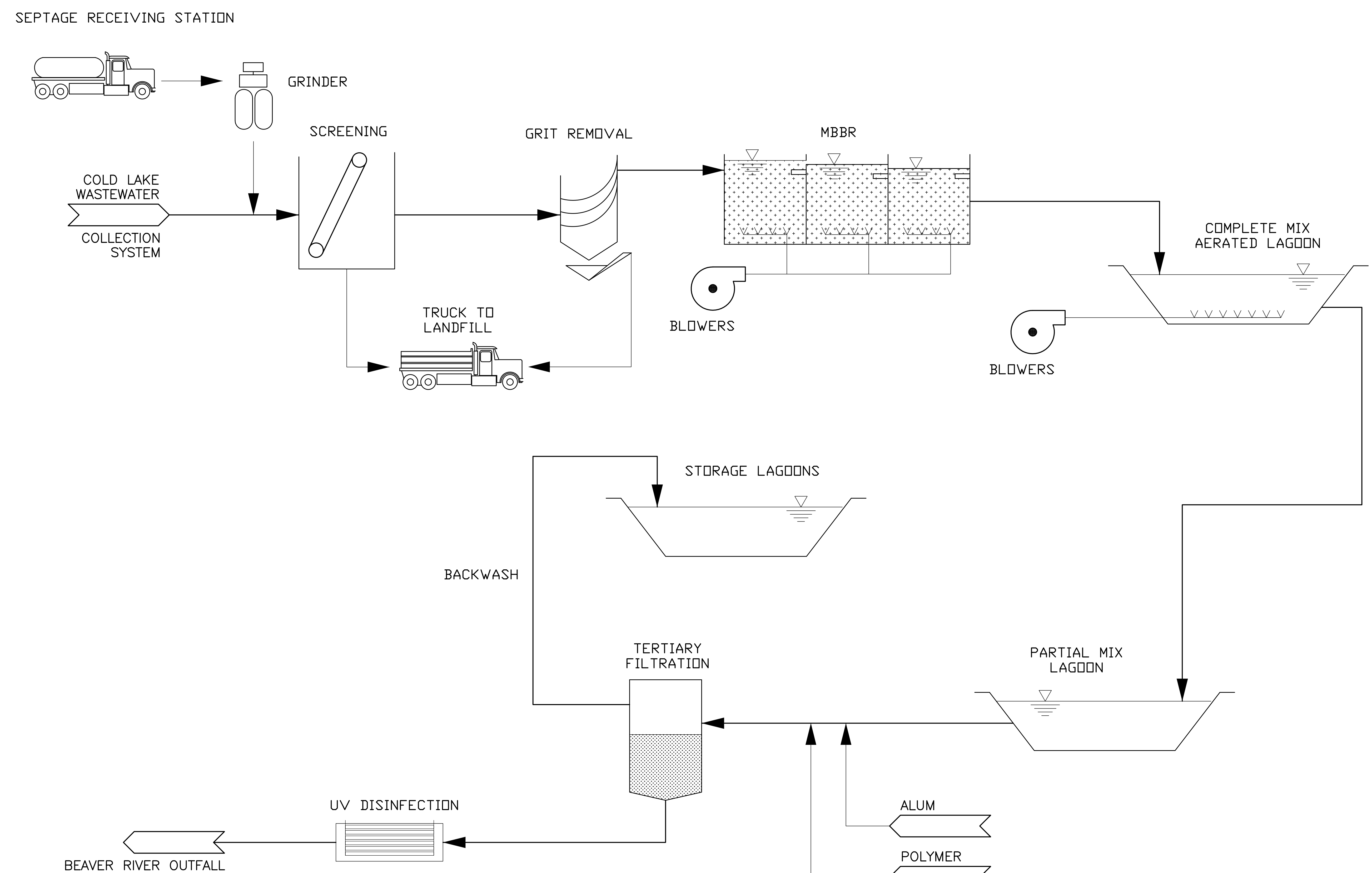

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Figure C.1