Wastewater Treatment Plant Upgrades Preliminary Design Report

December 11, 2019

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Executive Summary

Over the past several years, the capacity of the lagoon effluent disposal system for the City of Humboldt has not kept pace with its wastewater generation rates. This has resulted in storage levels within the existing lagoons exceeding the recommended design capacities. On several occasions, special permits have been required from the Water Security Agency (WSA) for discharge to Humboldt Lake. These discharges have been met with great opposition due to concerns about effluent quality and quantity. As a result, the WSA has strongly suggested that the City of Humboldt investigate and address the insufficient capacity of its effluent disposal system.

In December 2018, the City of Humboldt retained Stantec Consulting Ltd. to provide conceptual options and preliminary design for an upgrade to the Wastewater Treatment Plant (WWTP). The upgraded plant concept would retrofit the existing aerated lagoons and would be able to meet more stringent effluent limits than those set by the WSA because the vision of the City is to encourage sustainable development that is compatible with its vibrant agricultural base and critical ecological areas.

The Downstream Use and Impact Study (DUIS) completed by Stantec revealed that ammonia reduction is a reasonable goal for the City to achieve and proposed effluent discharge criteria for continuous discharge to Humboldt Lake. Proposed effluent discharge criteria for the Humboldt WWTP were discussed and confirmed by the WSA in a letter issued on December 31, 2018. Table 1 summarizes WSA proposed effluent limits for discharge of treated effluent to Humboldt Lake.

Table 1 Effluent Discharge Criteria

Parameter	Proposed Effluent Discharge Limit (1)	Design Target
Total Suspended Solids (TSS)	< 25 mg/L	< 20 mg/L
Carbonaceous Biochemical Oxygen Demand 5-day ($CBOD_5$)	< 25 mg/L	< 20 mg/L
Total Nitrogen (TN)	< 40 mg/L	< 28 mg/L(2)
Total Phosphorus (TP)	< 1 mg/L	< 0.75 mg/L
Ammonia-N Summer/Winter	< 4/10 mg/L	< 4/10 mg/L at 22°C / 1°C and pH of 8.0 < 1.6/7.5 mg/L at 22°C / 1°C and pH of 8.5
Unionized Ammonia-N	< 1.25 mg/L at 15°C ± 1°C	< 0.21 mg/L at 15°C ± 1°C
Total Chlorine Residual	< 0.02 mg/L	< 0.02 mg/L
E-Coli	< 200 orgs/100 mL	< 100 orgs/100 mL
Total Coliform	< 3,100 orgs/100 mL	< 3,100 orgs/100 mL

Note: (1) Sampling frequency has not been defined by WSA
(2) Total nitrogen target of 28 mg/L has been set to recover alkalinity through denitrification for secondary systems that can incorporate high recycle ratios of nitrifying mixed liquor (NML).

Population projections were updated as part of this Preliminary Design Report based on the analysis of historical records. The analysis indicates that the projected population by 2052 for Humboldt would reach 10,000 people using a 1.5 percent annual population increase. This preliminary design report was developed to serve the design population of 10,000 people with a maximum monthly flow of 7,235 m^3/d.

Liquid and sludge treatment process selection was conducted using a decision-making methodology which consisted of three phases. Phase 1 included identification of suitable liquid and sludge treatment options. Phase 2 further refined the options and provided a short listing of treatment processes. Phase 3 included evaluation of the short listed treatment processes and recommendation. Selection criteria and scoring of the various treatment processes were presented in technical memorandums for each phase. The implementation of the decision making methodology resulted in the selection of aerated lagoons followed by Submerged Aerated Growth Reactor (SAGR) with chemical precipitation of phosphorus as the preferred option for the City's WWTP upgrades.

The aerated lagoons / SAGR option provides the highest benefit cost ratio of all short listed options. The aerated lagoons / SAGR process is a proven technology in Western Canada, is very compatible with existing infrastructure and can be implemented in stages. The aerated lagoons / SAGR option provides the lowest opinion of probable capital cost (OPCC) of all short listed options, as it makes use of existing infrastructure (cells 1 to 6) and does not require headworks or filters. The aerated lagoons / SAGR option also provides the lowest Opinion of Probable Operating Cost (OPOC) of all short listed options, because it has fewer process units and equipment to operate and maintain.

The proposed liquid treatment train consists of two anoxic cells (cells 1 and 2), two complete mixed lagoons (cells 3 and 4) one partially mixed lagoon (cell 5), a series of mixing chambers for chemical precipitation of phosphorus in a settling cell (cell 6), SAGR cells for ammonia reduction, an ultraviolet disinfection reactor for pathogen reduction and pressurized effluent conveyance system and an outfall structure. The sludge management system consists of sludge thickening and stabilization in the non-aerated cells, partially mixed cell and settling cell. The sludge management option relies on periodical sludge removal to ensure that capacity will always be available to receive fresh sludge and to minimize odor emission by maintaining a water layer over the digested sludge. For this reason, two geotextile and one frac tank and Quadvac laydown areas are proposed. The WWTP also includes an Operations Building to house electrical and instrumentation panels for blowers, a chemical feed system a utility water system with sodium hypochlorite addition for disinfection. Figure 1 represents the proposed layout of the plant.

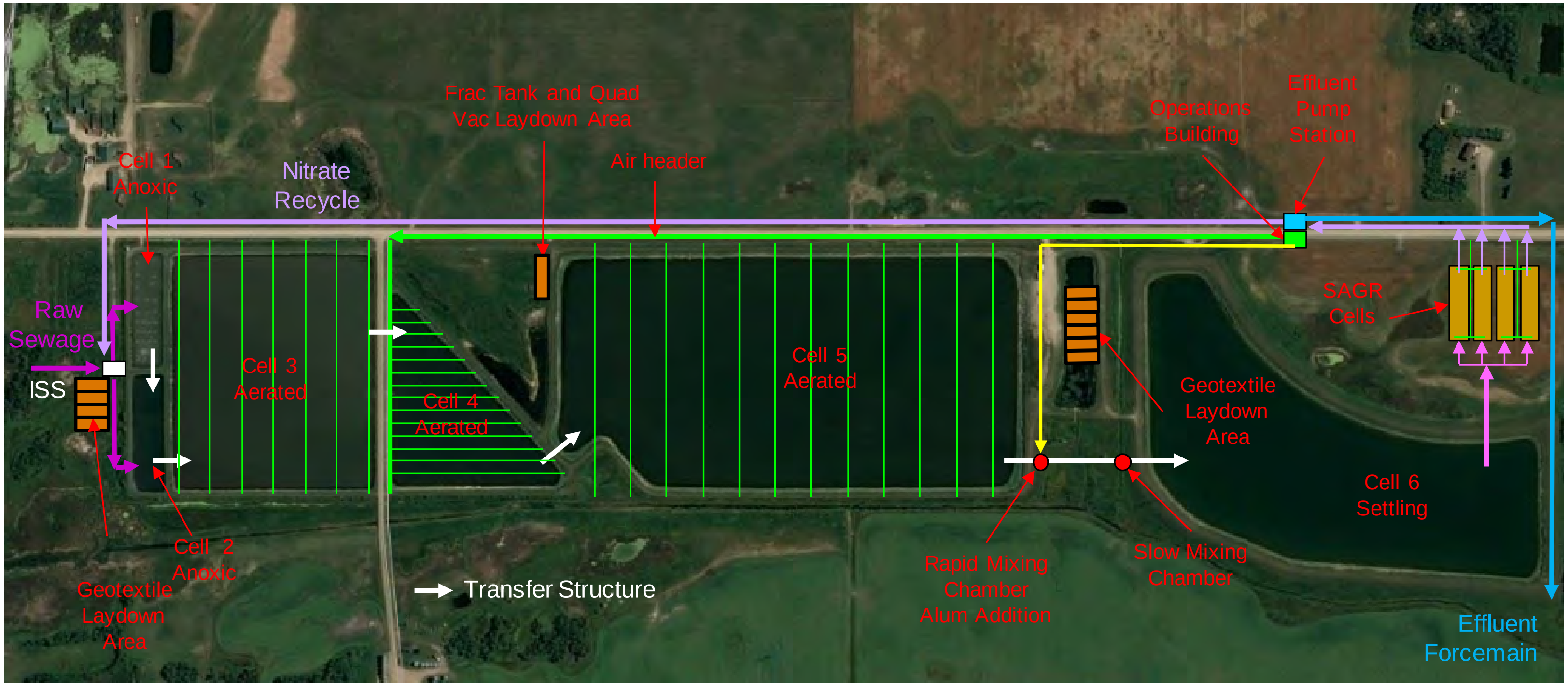

Figure 1 SAGR Process Configuration

The proposed aerated lagoon / SAGR plant is described below.

Process

a. Lift Stations: No modifications to the existing lift stations or pumps are required.

b. Influent Splitting Structure (ISS): ISS will be used to combine the influent from multiple lift stations and recycled Nitrified Mixed Liquor (NML). The ISS will be also used to direct flows to either anoxic cell 1 and/or anoxic cell 2.

c. Headworks: Screen and grit removal systems are not required for the aerated lagoons / SAGR process.

d. Anoxic Cells (cells 1 and 2): The existing cells will be used to settle grit and large solids as well as retain plastics. Nitrified rich effluent will be recycled to the ISS and directed to the anoxic cells to provide partial nitrogen reduction (denitrification) and odour control.

e. Partially Mixed Aerated Cells (cells 3 and 4): The existing cells will be retrofitted with 122 fine bubble diffusers for organic carbon reduction (BOD reduction for 8,000 population). An additional 28 fine bubble diffusers, for a total of 150 will be added for the 10,000 population (design year 2052).

f. Partially Mixed Aerated Cell (cell 5): The existing cell will be retrofitted with 56 fine bubble diffusers for additional organic carbon reduction (BOD reduction for 8,000 population). An additional 16 fine bubble diffusers for a total of 72 will be added for the 10,000 population (design year 2052).

g. Mixing Chambers: Two mixing chambers will be constructed between cells 5 and 6 for phosphorus reduction by mixing alum and phosphorus using mechanical mixers. The first chamber provides rapid mixing for coagulation and the second chamber provides slow mixing for flocculation.

h. Settling Cell (Cell 6): The existing cell will be used to settle chemical bound phosphorus before the effluent is conveyed to the SAGR cells.

i. SAGR Cells: Three SAGR cells will be constructed west of cell 6. An additional SAGR cell, for a total of four will be added for the 10,000 population (design year 2052). Each cell will have a surface area of 2,880 m^2 to provide ammonia, TSS and pathogen reduction. The SAGR cells consist of earthen basins with geomembrane liners, influent distribution laterals/chambers and a treated effluent collection chamber. Diffusers are secured to the bottom of the cell and covered with a layer of clean gravel. The gravel bed is covered with a layer of peat or mulch over a non-woven geotextile for insulation.

j. Secondary Effluent Tank: The tank will be designed to receive effluent from the SAGR cells and to split the secondary effluent in two streams. One stream is directed to the UV disinfection reactor the other is pumped back to the ISS as NML. This tank will be constructed in the substructure of the Operations Building. This tank also serves as a wet well for the nitrified mixed liquor pumps.

k. Ultraviolet (UV) Disinfection: UV reactor consisting of UV lamps, a power distribution system and flow control weir will be installed downstream of the SE tank in a stainless-steel channel and will be equipped with a self-cleaning mechanism to ensure that the disinfection is consistently achieved. This unit will be in the lower pump room.

l. Final Effluent Tank: This tank will be constructed in the substructure of the Operations Building and designed to receive effluent from the UV reactor. This tank also serves as a wet well for the final effluent pumps.

m. Nitrified Mixed Liquor (NML) Pumps: Two 5.5 kW (7.5 hp) pumps will be in the Secondary Effluent Tank, which will act as a wet well for these pumps. These pumps will be used to return nitrate rich effluent to cells 1 and 2.

n. Final Effluent Pumps: Two 18.7 kW (25 hp) and two 5.5 kW (7.5 hp) pumps will be located in the Final Effluent Tank, which will act as a wet well for these pumps used to pump the final effluent to Humboldt Lake through a 400 mm diameter 4.8 km long forcemain.

o. Plant Water Pumps: Two 7.5 kW (10 hp) centrifugal pumps will be in the pipe gallery of the operation building to convey UV disinfected effluent to process units that require flushing water and to the hose washdown stations.

p. Blower Room: This room will be in the Operations Building. The blower room will be sized for the design year 2052 with enough space to house two 37 kW (50 hp) blowers to serve the aerated lagoons and three 75 kW (100 hp) blowers to serve the SAGR cells (two duty and one standby).

q. Alum Feed System: The alum feed system consists of one tank capable of storing 16 m^3 of liquid alum and two metering pumps. This system will be installed in the Operations Building chemical room and will be used to chemically precipitate phosphorus.

r. Sodium Hypochlorite System: Sodium hypochlorite will be injected into the plant water system only when plant operators may be exposed to water sprays or minimize re-growth of pathogens. This system will be installed in the Operations Building chemical room.

s. Drain Pumps: These pumps will be in a sump inside of the Operations Building. These pumps are used to collect drain and wastewater from the building and convey the flow to aerated cells.

t. Sludge Stabilization: aerated cells will be used to stabilize sludge that settles between the rows of diffusers.

u. Sludge Dewatering: Two laydown areas are provided to deploy geotextile containers to dewater the sludge accumulated in cells 1, 2, 5 and 6. The purpose of the sludge dewatering system is to reduce the volume of water before the sludge is transported to the landfill to be used as intermediate cover.

v. Frac Tank and Quadvac Laydown Area: A laydown area will be provided to fill a frac tank and Quadvac to facilitate hauling of liquid biosolids from cells 5.

<u>Civil</u>

a. Site upgrades include excavation for the Influent Splitting Structure, SAGR cells, NML and final effluent force main pipes, outfall structure, geotextile laydown areas, drainage, access roads, parking lots, yard piping, berm seeding, and fencing.

b. Final effluent forcemain pipe and outfall structure: The final effluent will be directed from the WWTP to Humboldt Lake by a new 400 mm diameter 4.8 km long pressure pipe to allow year-round discharge of the effluent. A gravity pipe was also considered; however, the gravity pipe option carries a higher opinion of probable capital cost.

c. Discharge to Humboldt Lake will be through a submerged outfall pipe, outfall structure and diffuser which will extend an adequate distance offshore to achieve proper depth for mixing and dispersion.

d. Surface drainage will be accommodated in ditches along the roadways and parking areas and directed overland to the existing storm channel that runs west of the lagoons.

e. Access road and parking will consist of compacted gravel to reduce rutting and dust caused by trucks and B trains delivering chemicals and other consumables. The parking area will be in the vicinity of the Operations Building.

<u>Structural</u>

a. An Operations Building will be constructed, complete with a concrete substructure containing the secondary effluent and final effluent tanks. The superstructure will house the pump rooms, chemical room, blowers, laboratory, washroom, lunchroom, control room, electrical and mechanical rooms. The overall building footprint is anticipated to be approximately 34 m by 15.6 m. The foundation for the below-ground tanks will likely consist of a structural concrete slab on cast-in-place concrete piles, and the foundation below the remainder of the Operations Building will likely be designed as a cast-in-place concrete structural slab supported on concrete grade beams and piles (pending geotechnical analysis). For the purpose of the OPCC it was assumed that the raft slab will be 500 mm thick concrete, and that the main floor will be constructed as a 150 mm to 200 mm thick slab. The suspended main floor slab over the effluent tanks will be supported on concrete beams that span between the walls of the substructure. The above-grade walls will likely be constructed with 190 mm wide concrete masonry blocks, and the roof over the Operations Building will consist of hollow core concrete roof panels. The structural design is intended to ensure extended life expectancy of the structure, as concrete is the most durable construction material when exposed to corrosive environments.

b. There are various miscellaneous structures to be designed as part of the wastewater treatment process. The influent and SAGR splitting structures will be designed as concrete, either cast-in-place, precast concrete, or a combination of both. Due to the proposed significant depth of these structures, the foundation will likely be a raft-type foundation.

Architectural

a. The proposed building superstructure for process areas will be masonry block with rigid insulation, exterior metal cladding – both to be compliant to the requirements of NECB 2017 and painted interior finish. Interior dividing walls will be painted masonry block.

b. The proposed building superstructure for humidity and climate controlled administrative areas will be steel (no wood framed construction) with rigid insulation, metal cladding, and hollow-core concrete slab roofing to match the appearance of the other areas.

Mechanical

a. The Operations Building will contain two areas with distinctly different requirements, the process substructure, and the administration area. For process and equipment rooms, heating will be achieved by separate combustion gas-fired unit heaters. These areas include the mechanical room, chemical room, UV upper and lower pump room, blower room, and electrical room. Make up air for the process substructure will be provided by an indirect gas-fired makeup air unit complete with branch ductwork extending to the various areas. Individual exhaust fans c/w variable speed drives will maintain pressure and proper air movement in the UV and effluent tank areas. A mixed air ventilation system for both the mechanical and electrical rooms will provide ventilation and natural cooling. The blower room will be complete with intake louvers and exhaust fans for room cooling. Blower supply air will be connected directly to each blower, drawing air directly from outside. For the administration area, heating and cooling will be provided by two gas-fired heat/cool roof mounted air handling units serving the control and laboratory areas. Auxiliary electric baseboard radiation will be provided in the changeroom, laboratory, lunchroom, entrance and control room. A dedicated DX cooling unit will maintain space temperature in the server room. Additional exhaust fans include one common exhaust fan for the washroom and change room, and a dedicated fan for the chemical room. All mechanical systems will be controlled and monitored by a web based Direct Digital Control Building Management System.

Electrical

a. A new 600 V, 3-phase, 3-wire underground main service will be provided for the proposed Operations Building. SaskPower will provide a vault mounted 25 kV / 600 V 3-phase transformer, cables, protection equipment, and connections to the line-side of the service transformer located outside of the Operations Building. Underground power cables will supply 600 V 3-phase power to the switchgear located in the Electrical Room. The 600 V switchboard will provide normal power (through a 1000 A breaker) to a Motor Control Centre (MCC) for process mechanical equipment and building services loads. Preliminary sizing of plant electrical loads indicates a main service size of 1,000 Amps will be required. This service is sized to accommodate all required electrical loads including future process expansion.

b. A backup diesel or natural gas generator (skid mounted) will be installed in the Electrical Room and provide backup power for selected critical loads in the Operations Building. Preliminary sizing of the new wastewater treatment building's electrical loads indicates a 75 kVA generator will be required to maintain critical equipment operation during power outages.

<u>Instrumentation and Control</u>

a. A Supervisory Control and Data Acquisition (SCADA) system will be installed to automatically generate and transmit alarms of abnormal conditions to on-call personnel when the plant is not manned.

LIFE CYCLE COST

The life cycle costs for the aerated lagoons / SAGR process is presented in Table 2 along with the Net Present Value (NPV) for the design period. The NPV represents the value of all future costs over the design life of the capital investment. Opinions of probable cost for capital and operating costs are described in the following sections.

OPINION OF PROBABLE CAPITAL COST

Opinions of Probable Capital Cost (OPCC) are preliminary and subject to development of actual designs, loadings and any special requirements, but do provide an indication of relative cost differentials between design years. The attached spreadsheets provide a breakdown of the OPCCs for each design period.

OPPCs were developed using a combination of stochastic and deterministic factors as follows.

General requirements (stochastic): General requirements include the cost of mobilization/demobilization, start-up and commissioning, operation and maintenance manuals and record drawings. These costs are about 11.5% of the subtotal for all process areas.

Siteworks (deterministic and stochastic): Siteworks include the cost of excavation and backfill, roadways, yard piping, outfall structure, final effluent forcemain, seeding, fencing and dewatering allowance. The OPCC for excavation and compacted backfill are based on calculated volumes and rate of $24/m^3 of material.

Structural tank (deterministic): OPCC for concrete tanks is based on calculated concrete volumes priced at an average of $1,650/m^3 for slab and $1,400/m^3 for walls. Rebar cost is estimated based on a unit rate of $440/m^3 for concrete. Form work cost is estimated based on the surface area of tank wall at a unit rate of $280 for straight wall.

Structural building (deterministic): OPCC for structural buildings is based on lump sum prices for masonry, metals, wood, plastic, thermal and moisture protection, doors and windows for similar buildings.

Process (deterministic): OPCC for process is developed from vendor quotes (specifically requested for this project and provided by Nexom), plus a 50% installation cost. Nexom's proposal is attached.

Mechanical (stochastic): OPCC for HVAC mechanical is based on experience from previous projects, the mechanical costs are assumed to be 11% of the subtotal for the Operations Building for design year 2037.

Electrical, Instrumentation and Control (I&C) (deterministic): OPCC for electrical and I&C is based on lump sum prices from similar previous projects.

Table 2 Life Cycle Cost

Item	Description	Aerated Lagoons / SAGR Process Design year 2052 (10,000 population)
1.0	General requirements	$3,077,000
2.0	Siteworks	$4,783,400
4.0	Headworks	$0
5.0	Upgrades to cells 1, 2 3, 4, 5 and 6	$2,871,000
6.0	SAGR cells	$4,859,000
7.0	Operations Building	$9,085,000
8.0	Odour Control Building	$0
	Subtotal	$24,675,400
	Contingency (20%)	$4,936,000
	Engineering (10%)	$2,962,000
	Total Project Capital Cost	**$32,573,400**
	Annual Operation Costs (based on year 2020)	$505,000
	NPV O&M (33-yr for design year 2052)	$15,990,000
	NPV Life Cycle Cost (33-yr for design year 2052)	**$48,563,000**

OPINION OF PROBABLE OPERATING COST

Opinion of Probable Operating Cost (OPOC) is developed based on standard unit costs. The opinion of probable costs is tentative and subject to development of actual unit cost for the plant but do provide an indication of relative cost. The annual OPOC is approximately $505,000 (based on the first year of operation in 2020). Annual costs will fluctuate depending on sludge removal frequency. The annual operating costs and NPV are also included in Table 2.

Abbreviations

AS	Activated Sludge
ADF	Average Daily Flow
ADWF	Average Dry Weather Flow
BAF	Biological Aerated Filter
BOD_5	Biochemical Oxygen Demand 5-day
BNR	Biological Nutrient Removal
COD	Chemical Oxygen Demand
$CBOD_5$	5-day Carbonaceous Biochemical Oxygen Demand
DAF	Dissolved Air Floatation
d	Days
DNA	Deoxyribonucleic Acid
DO	Dissolved Oxygen
DUIS	Downstream Use and Impact Study
FOG	Fat Oil and Grease
FRP	Fibre Reinforced Plastic
FSL	Full Service Level
GSBR	Granular Sequencing Batch Reactor
h	Hours
ha	Hectares
H_2S	Hydrogen Sulfide
HP	Horse Power
IFAS	Integrated Fixed Film Activated Sludge
ISS	Inorganic Suspended Solids
ISS	Influent Splitting Structure
kW	Kilowatt
LPCD	Litres per capita day
m	Metre
m^3	Cubic Metres
MBBR	Moving Bed Biofilm Bioreactor
MBR	Membrane Bioreactor
MDF	Maximum Daily Flow
MLSS	Mixed Liquor Suspended Solids
MMF	Maximum Monthly Flow
MWF	Maximum Weekly Flow
MMF	Maximum Monthly Flow
MSBR	Modified Sequencing Batch Reactor

NML	Nitrified Mixed Liquour
NPV	Net Present Value
PDC	Power Distribution Center
PF	Peaking Factor
PHF	Peak Hourly Flow
OPCC	Opinion of Probable Capital Cost
OPOC	Opinion of Probable Operating Cost
RNA	Ribonucleic Acid
RAS	Return Activated Sludge
RBC	Rotating Biological Contactor
SAGR	Submerged Aerated Growth Reactor
SCFM	Standard Cubic Feet per Minute
SBR	Sequencing Batch Reactor
SS	Suspended Solids
TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
UV	Ultraviolet
VFD	Variable Frequency Drive
VSS	Volatile Suspended Solids
WW	Wastewater
WWTP	Wastewater Treatment Plant
WSA	Water Security Agency
W3	Non Potable Water (Final Effluent used as Utility Water)

1.0 INTRODUCTION

1.1 BACKGROUND

The City of Humboldt (City) is located approximately 112 km east of Saskatoon. The City has a wastewater treatment plant located southeast of the City along a storm water channel that discharges into Humboldt Lake. Wastewater is currently pumped from three lift stations directly to the WWTP through forcemains as shown in Figure 1-1.

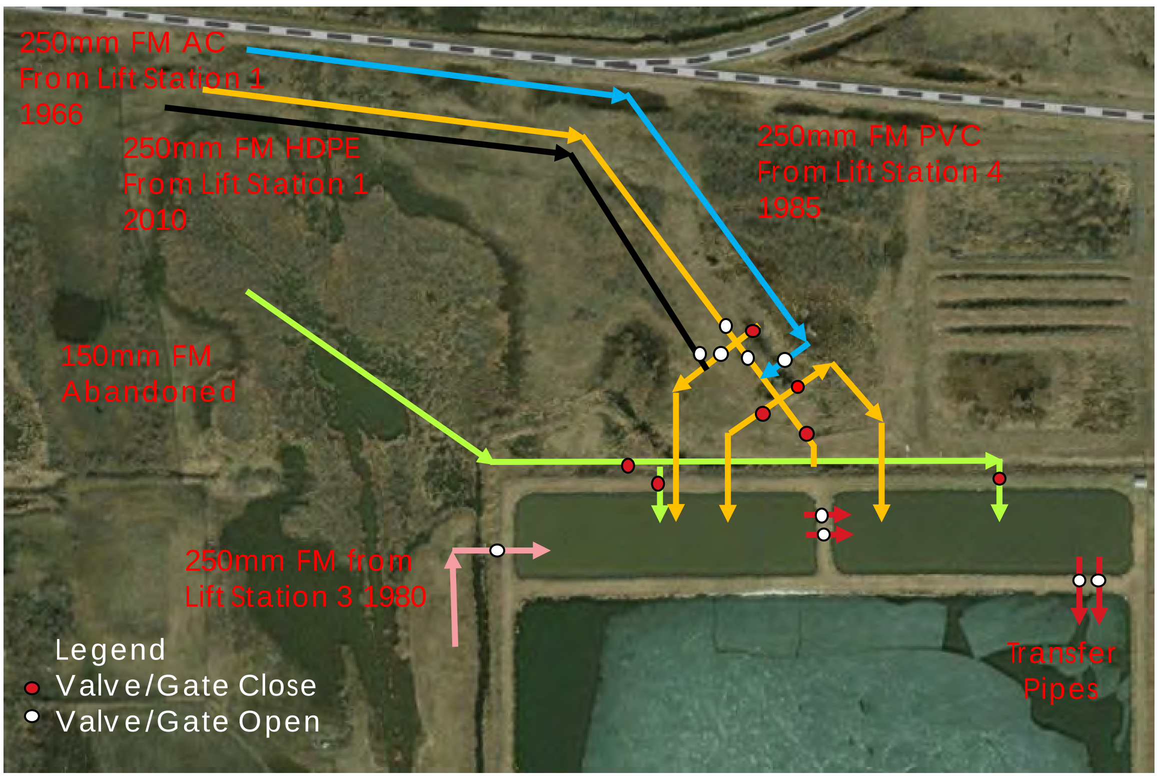

Figure 1-1 WWTP Forcemain Configurations at the Front End of the Lagoon System

The Humboldt WWTP consists of an anaerobic cell, an aerated cell, a facultative lagoon, three storage cells and a phosphorus removal system as described in Table 1-1 and presented in Figure 1-2. The lagoons are operated in series with all the flow from the three lift stations conveyed to the anaerobic cell. The phosphorus removal system consists of pumping secondary effluent from storage cells 2 and 3 through manholes where it is mixed with ferric sulfide before being discharged to the nutrient removal cell where phosphorus precipitates as ferric phosphate. Effluent from the nutrient removal cell is discharged to Humboldt Lake through a conveyance channel in May and October. The treatment lagoons were constructed in 1961, upgraded and expanded as listed in Table 1-1. The anaerobic lagoon has been de-sludged twice and the dewatered sludge applied to agricultural land (7,200 m^3 of sludge applied to 49 ha in 2002 and 7,563 m^3 of sludge applied to 55.6 ha in 2014). The aerated lagoon has not been de-sludged since the aeration system was installed in 1976. The facultative lagoon is operating at its maximum treatment capacity (WSA maximum design value of 30 kg BOD_5/ha-d). Although the current treatment system reduces the negative environmental impacts of the major pollutants in the wastewater, it cannot consistently meet the anticipated effluent discharge criteria in terms of total suspended solids (TSS), total phosphorus (TP) and ammonia. In addition, the storage lagoons have barely sufficient storage capacity to provide the previous standard of 180 days A new standard of 220 days retention time is required by Water Security Agency (WSA) and consequently, they are very frequently operated at high water levels, reducing the freeboard to 0.5 m in the front end cells during Maximum Monthly Flow (MMF) and causing erosion of the lagoon embankments. On several occasions, special permits have been required from WSA to allow for early discharge to Humboldt Lake. The maximum storage capacity of the cells is restricted by the size of the existing transfer structures and the need to maintain a minimum freeboard of 0.5 m in the front end cells.

Stantec Consulting Ltd. (Stantec) was retained by the City of Humboldt in 2018 to prepare a preliminary design report for the Wastewater Treatment Plant (WWTP) upgrades. As a part of the preliminary design, six (6) technical memoranda were prepared and are appended to this report (Appendix D).

Technical Memorandum 1 - Population, Wastewater Flow and Load Projections addresses the design criteria and provides discussion on population projections, wastewater flows, raw wastewater characteristics and associated plant loadings.

Technical Memorandum 2 - Wet Weather Management reviews alternatives to treat or store high flows.

Technical Memorandum 3 - Identification of Liquid Treatment Options and review of a long list of wastewater treatment options suitable for the City.

Technical Memorandum 4 - Identification of Sludge Management Options, review biosolids guidelines for disposal of municipal sludge onto land and a long list of sludge treatment options suitable for treatment of wastewater for the City.

Technical Memorandum 5 - Evaluation of Short Listed Treatment Options, detailed discussion of three preselected options for upgrading the WWTP. One of the key conclusions of this memorandum was to develop the City's WWTP upgrade project based on an aerated lagoons / SAGR process.

Technical Memorandum 6 - Opinion of Probable Capital Cost for Aerated Lagoons/SAGR System for two design periods: 2037 (8,000 population) and 2052 (10,000 population).

The information developed in the above noted technical memoranda and direct consultation with the City form the basis for the preliminary design report.

Table 1-1 Existing Wastewater System Description Based on Current ADF of 2,480 m^3/d and MMF of 4380 m^3/d

Parameter	Anaerobic Cell	Aerobic Cell	Facultative Cell	1st Storage Cell	2nd Storage Cell	3rd Storage Cell	Nutrient Removal Cell
Function	Sedimentation of solids and anaerobic treatment	Aerobic treatment using a 50 hp blower	Facultative treatment via algae growth	Storage of secondary effluent	Storage of secondary effluent	Storage of secondary effluent	Precipitation of phosphorus
BOD_5 Load at ADF, kg/d	395	280	166	N/A	N/A-	N/A	N/A
BOD_5 Loading at ADF, kg/ha-d	698	499	30	N/A	N/A	N/A	N/A
TSS Load, kg/d	481	241	N/A	N/A	N/A	N/A	N/A
Capacity at MMF, m^3	11,680	11,260	103,030	39,260	308,540	157,220	9,600
Operating Depth at MMF, m	3.21	3.13	1.79	1.69	2.4	2.1	2.00
Freeboard at MMF, m	0.52	0.6	0.56	0.65	0.84	2.35	0.82
Surface Area at MMF, ha	0.49	0.48	6.1	2.40	13.6	7.9	0.64
Floor Elevation, m	559.64	559.64	560.90	560.90	560.10	559.46	559.80
Full Service Level at MMF, m	562.85	562.77	562.69	562.59	562.50	561.56	561.80
Berm Elevation, m	563.38	563.38	563.24	563.24	563.34	563.91	562.62
Retention Time at ADF, d	4.71	4.5	41	15.8	111	63.4	3.70
Active storage at ADF, d	N/A	N/A	N/A	15	109.5	60.5	3.7
Slope	2.8:1 & 3.3:1	2.8:1 & 3.3:1	4:1	4:1	4:1	3.5:1	4:1
Construction Upgrade	1961 1971	1961 1973	1961	1961	1976	2001	1985

<table>
<tr><th>Parameter</th><th>Anaerobic Cell</th><th>Aerobic Cell</th><th>Facultative Cell</th><th>1st Storage Cell</th><th>2nd Storage Cell</th><th>3rd Storage Cell</th><th>Nutrient Removal Cell</th></tr>
<tr><td>Condition Assessment</td><td>Lagoon interior slopes may have been over excavated during dredging.</td><td>Sludge is encroaching on the diffusers; therefore the diffusers can only provide minimum BOD reduction</td><td>Facultative lagoon operating at maximum design load of 30 kg/ha-d</td><td colspan="3">Active storage is about 184 days (assuming 0.1 m of inactive water to protect the clay liner and average daily flow of 2,480 m^3/d). High water levels have reduced freeboard to less than 0.3 m, causing erosion of the lagoon embankments. Special permits have been frequently required from WSA for discharge.</td><td>No secondary containment for ferric sulfide tank</td></tr>
<tr><td>Recommendations</td><td>De-sludge the cell, which has an estimated 4255 m^3 of sludge</td><td>De-sludge the cell, which has an estimated 4340 m^3 of sludge</td><td>De-sludge the cell, which has an estimated 22,310 m^3 of sludge</td><td colspan="3">Proactive discussion with WSA is required to allow early effluent discharge to protect infrastructure until upgrades are implemented. Ongoing monitoring of slope stability. Repair berm as needed.</td><td>City to review Work safe practices in the event of spill</td></tr>
<tr><td colspan="8">Notes:
1. The lagoon description is based on top of berm survey conducted in August 2019 by Stantec. Floor and water elevations were calculated based on drawings provided to Stantec by the City of Humboldt.
2. Sludge quantities are based on the sludge survey provided to Stantec by the City of Humboldt.
3. The floor elevation of Cell 3 was not updated because the survey differed significantly from the information provided by the City (560.90 m - Catterall & Wright Drawing 024-11801-P). The sludge survey listed a water elevation of 561.85 m and a measured depth of 1.5 m, which corresponds to a floor level of 560.35 m. This elevation suggests that the floor elevation of Cell 3 is just slightly above the floor elevation of Cells 1 & 2, which is not consistent with the information provided previously. Further investigation is recommended.</td></tr>
</table>

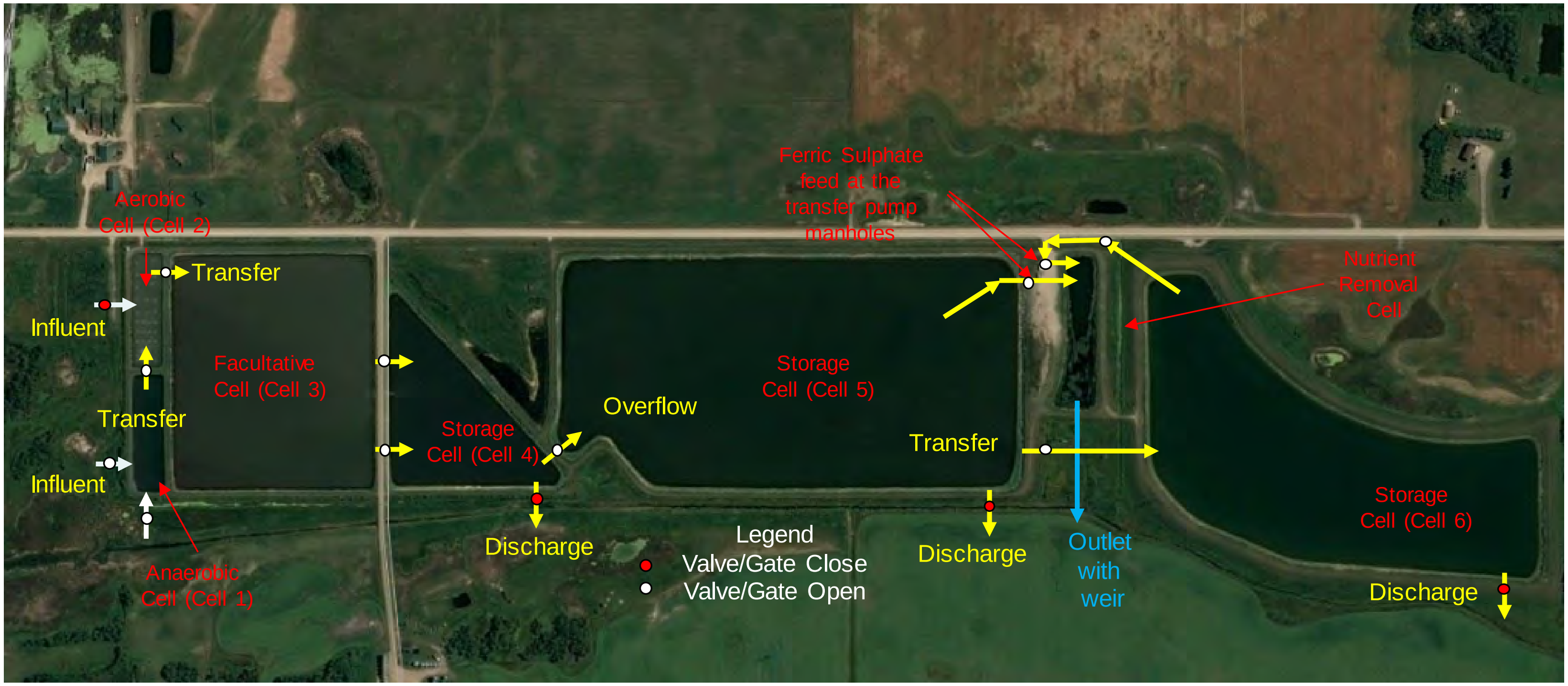

Figure 1-2 Wastewater Treatment System Flow Schematic

1.2 PURPOSE OF PRELIMINARY DESIGN

The purpose of the preliminary design is to further develop the concepts evaluated in the technical memorandums for the proposed WWTP facility. The report culminates with a detailed summary of the key components of the recommended WWTP upgrades, and includes establishing the design criteria basis for civil, structural, architectural, building mechanical, electrical, instrumentation and controls and site services components of the facility. Information developed in this report and feedback received from the City's engineering department during the technical memoranda reviews and project meetings form the basis for the preliminary design. The scope of work for the current assignment is summarized as follows.

- Update wastewater flows and loads
- Develop effluent discharge criteria for a new WWTP based on WSA review of the Downstream Use and Impact Study (DUIS)
- Evaluate various process options for the development of a new WWTP, developing capital and operational opinion of probable costs for three options, and recommending the preferred, cost efficient alternative
- Conduct a geotechnical study to enable a subsequent investigation
- Determine the necessary mechanical, electrical, instrumentation and control requirements to permit plant operation with a minimum of operation personnel
- Develop detailed capital and operation and maintenance costs for the WWTP upon selection of the recommended plant process
- Provide regular progress reporting to the City
- Submit a draft preliminary design report and receive review comments
- Provide bound copies of the final predesign report

Once feedback and funding are received, further work related to the detailed design of the proposed WWTP can proceed.

1.3 PRELIMINARY DESIGN REPORT CONTENT

The remainder of this report is comprised of six (6) sections which are summarized below.

Section 2 – Design Criteria: Presents an overview of the design objectives and treatment requirements for the WWTP upgrade.

Section 3 – Liquid and Sludge Treatment Processes Selection: Provides a summary of the liquid treatment and solids handling selection process.

Section 4 – Process Design: Presents a description of the selected process and provides information on process design such as mass balance and hydraulic profile.

Section 5 – Process Units: Defines the physical and engineering considerations for each of the key process units, including process design summaries.

Section 6 – Engineering Discipline Design Criteria: Outlines the discipline specific guidelines, standards, codes, materials and equipment used in the design.

Section 7 – Life Cycle Cost: Summarizes the preliminary opinion of probable cost for the project.

2.0 DESIGN CRITERIA

2.1 BACKGROUND

The following section summarizes the analysis of data related to the projected population and wastewater flows as well as the raw wastewater characteristics and effluent criteria. Although a majority of this information was presented as a part of Technical Memorandum No. 1, Population, Wastewater Flow and Load Projections; and Downstream Use and Impact Study, this information is summarized below.

2.2 DESIGN POPULATION

The City experienced a general decline in population from 2001 to 2006 followed by an increase from 2006 to 2016, as shown in Table 2-1. In 2006, the City had a reported population of 4,998 people. The latest census data from 2016 reported a population of 5,869 people, approximately 3.4 percent higher than the 2011 census data of 5,678 people. This trending seems to be in line with many communities near major centers who have experienced population growth since the 2006 census.

2.2.1 Population Projections

Based on population projections developed for three different growth scenarios and discussions with the City, it is recommended that adopting a medium growth rate of 1.5% for estimating the design population for this study is a reasonable expectation of growth for the City. Should there be substantial growth in the future; the plant capacity would be reached earlier than 33 years. On the other hand, if the growth is slower, the plant capacity would last longer than 33 years before a further expansion is warranted. As such, a design threshold population of 10,000 people is recommended. A summary of the projection is shown in Table 2-1.

Table 2-1 Population Projections

Year	Medium Growth at 1.5%
2018	6,047
2022	6,418
2027	6,914
2032	7,448
2037	8,024
2042	8,644
2047	9,312
2052	10,031

2.3 INFLUENT FLOWS

The City currently monitors daily flows to the WWTP via a dedicated flow meter located in lift station 1 and pump hours and assumed flowrates for lift stations 3 and 4. The flow meter displays the totalized flow, which is recorded daily by the plant operators.

The City does not allow septic truck discharge into the sewer collection system or the lagoons. The preliminary design report does not include provisions for receiving septic truck discharge at the upgraded WWTP. This is because septage can be 6 to 80 times more concentrated than typical municipal sewage and can be toxic to biological processes. The City indicated that a septage receiving station will not be incorporated into the proposed WWTP facility based on the impact of septage on the biological process. Further analysis of the impact of a septage receiving station on the upgraded WWTP is provided in Section 5.1.

2.4 WASTEWATER FLOW DATA ANALYSIS

Stantec requested historical flow data recorded at the lift stations for review. Daily flow data to the WWTP from January 01, 2010 to December 31, 2018 was supplied by the City and subsequently analyzed to determine average daily flow (ADF) and average dry weather flow (ADWF). Figure 2-1 presents the daily wastewater flows pumped from the lift stations to the lagoons over the 9-year period. The ADF is 2,748 m^3/d and the ADWF) is 2,138 m^3/d. The maximum day over the 9-year period plotted in Figure 2-1 was on July 28, 2015 with a flow of 16,780 m^3/d. Several other peak flows in the range of 8,000 m^3/d to 12,000 m^3/d were recorded. The City is in the process of implemented strategies to reduce inflow and infiltration to the sewer collection system and are not included in this report. These strategies are expected to reduce the impact that wet weather events have on undesirable inflow and infiltration to the sanitary sewer system.

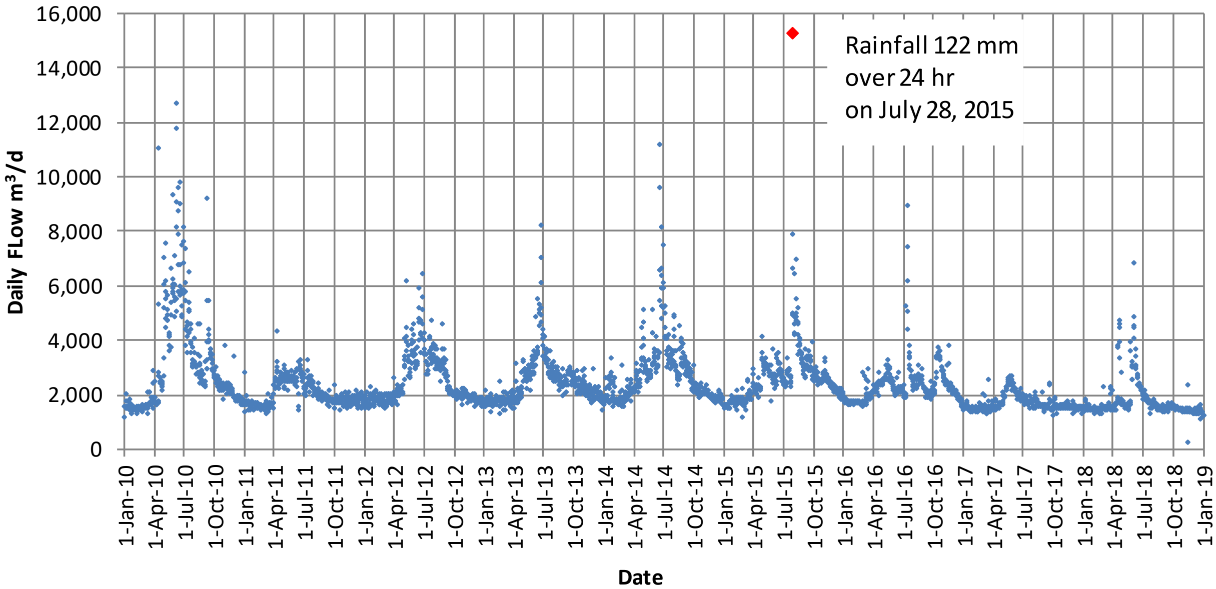

Figure 2-1 Daily Wastewater Flow Pumped from Lift Stations to Lagoons - 2010 to 2018

Table 2-2 summarizes annual average, maximum month, maximum week and maximum day flows and corresponding peaking factors (PF) over the 9 year period of record. The peaking factors in the left column of the table present the results in terms of percentiles: 91.8% (335/365 days), 98.1% (358/365 days) and 99.7% (364/365 days) to represent the maximum month, maximum week and peak day flows. The peaking factors in the right column summarize the 30-day and 7-day running averages and maximum day. The bottom of the table presents averages for peak factors over the 9-year period.

Table 2-2 Summary of Wastewater Flow Analysis

	Peak Factor (Percentile)	Average	Max. 30-day Running Average	Max. 7-day Running Average	Max. day Running Average	Peak Factor (Running Average)
	Unitless	m^3/d	m^3/d	m^3/d	m^3/d	Unitless
WW generation		410 LPCD				
ADF		2,373				
ADWF	0.78	1,804				
30-day PF	1.46		4,196.98			
7-day PF	1.98			5,766.84		
Max Day PF	2.74				8,533.06	
91.8 percentile		3,522				1.77
98.1 percentile		4,822				2.37
99.7 percentile		6,744				3.48
Minimum Flow	0.46	1,088				

2.5 WASTEWATER FLOW PROJECTIONS

Wastewater flow projections were developed under the assumption that the annual average per capita wastewater generation rate of 410 LPCD and peak factors are valid until 2052. Applying the year 2052 design population projection to these values results in the projected wastewater flow rates at the end of the planning period as presented Table 2-3. The values listed in Table 2-3 do not include in-plant generated flows from sludge management processes.

Table 2-3 Wastewater Flow Projections for Various Design Years

Parameter	Unit	Initial Year	Design Year
Design Year	year	2018	2052
Design Period	year	1	35
Design Population	capita	6,050	10,000
Annual Average per Capita Wastewater Generation Rate	LCPD	410	410
Annual Average Flow (AAF) (PF = 1.0)	m^3/d	2,479	4,098
Average Dry Weather Flow (ADWF) (PF = 0.78)	m^3/d	1,928	3,186
Maximum Monthly Flow (MMF) (PF = 1.77)	m^3/d	4,376	7,233
Maximum Weekly Flow (MWF) (PF = 2.37)	m^3/d	5,882	9,722
Maximum Daily Flow (MDF) (PF = 3.48)	m^3/d	8,618	14,244
Peak Hourly Flow (PHF) (PF = 6)	m^3/d	14,874	24,585
Minimum Day Flow (PF = 0.46)	m^3/d	1,140	1,883

2.6 INFLUENT CHARACTERISTICS

Historically, the City has not monitored the treatment system influent characteristics. In 2017, wastewater sampling programs were completed in September and October and additional sampling occurred during a period between June and July of 2019. 24-hour composite samples were collected at the lift stations. Grab samples were collected at lift station 1 and 3. Table 2-4 presents the average and 90 percentile influent characteristics for the short period of sampling conducted by the City. Outlier values were excluded from the analysis.

Table 2-4 Influent Wastewater Characterization

		Influent Wastewater Characteristics from Data Collected in 2017			**Lift Station 1 Composite Samples - Data Collected from June to July 2019**			**Lift Station 3 Composite Samples - Data Collected from June to July 2019**			**Typical WW Characteristics in Saskatchewan**
Parameter	Units	Min	Average	90 Percentile	Min	Average	90 Percentile	Min	Average	90 Percentile	
Chemical Oxygen Demand (COD)	mg/L	268	427	603	230	425	563	362	385	404	485
Biochemical Oxygen Demand (BOD_5)	mg/L	122	194	274	137	215	298	158	217	274	212
Total Suspended Solids (TSS)	mg/L	60	212	341	50	151	256	55	85	117	234
Inorganic Suspended Solids (ISS)	mg/L	7	39	56	8	19	18	16	16	17	34
Total Volatile Suspended Solids	mg/L	53	173	285	42	132	238	39	69	100	200
Ammonia-N	mg/L	38	**43**	46.5	25	32	38	30	**35**	38	25
Total Nitrogen	mg/L	40	**50**	55.8	35	**43**	52	45	**48**	53	35
Total Kjeldahl Nitrogen (TKN)	mg/L	40	**50**	57.6	35	**43**	52	45	**48**	53	35
Total Phosphorus (TP)	mg/L	5.7	**7.4**	8.4	3.8	4.8	5.4	5.4	6.0	6.6	6.5
Ortho Phosphorus	mg/L	NR	NR	NR	NR	NR	NR	NR	NR	NR	
Temperature	°C	NR	NR	NR	NR	NR	NR	NR	NR	NR	
pH Measured in Pumping Station		7.52	7.20	7.90	7.34	7.50	7.65	7.30	7.40	7.52	
Total Alkalinity (as $CaCO_3$)	mg/L	NR	NR	NR	362	376	388	351	374	392	
Bicarbonate	mg/L	NR	NR	NR	442	458	490	428	457	478	
Sulfate Dissolved	mg/L	NR	NR	NR	370	450	522	290	341	393	
Oil and Grease	mg/L	NR	NR	NR	13	37	60	12	18	21	100

Note: Values in bold exceed typical wastewater characteristics in Saskatchewan
Lift station 1 grab samples had high average oil and grease, COD and TSS concentration of 158 mg/L, 624 mg/L and 595 mg/L, respectively
Lift station 3 grab samples had high average oil and grease, COD and TSS concentration of 1,969 mg/L, 931 mg/L and 3,892 mg/L, respectively

2.7 DESIGN INFLUENT LOADS

The projected influent flow and loads for this Preliminary Design Report are listed in Table 2-5 and are based on wastewater concentration and projected flows listed in previous tables.

Table 2-5 Design Flows and Loads

Parameter	Unit	COD	BOD_5	TSS	ISS	TKN	TP
Annual Average Load	kg/d	1,845	882	869	160	205	30.3
Annual Wastewater per Capita Load	kg/c-d	0.185	0.088	0.087	0.016	0.021	0.003
Average Wastewater Concentration	mg/L	450	215	212	39	50	7.4
Annual Average Flow	m^3/d	4100					
Maximum Month Load	kg/d	2,491	1,190	1,173	216	242	34
Maximum Month Wastewater Concentration	mg/L	344.3	164.5	162.2	29.8	33.4	4.7
Maximum Month Flow	m^3/d	7,235					
Wastewater Temperature Used for Design	°C	8°C					

2.8 EFFLUENT DISCHARGE CRITERIA

Table 2-6 presents the WSA proposed effluent limits for discharge of treated effluent to Humboldt Lake. Detailed descriptions of these parameters and their relevance are presented in the Downstream Use and Impact Study (DUIS).

Table 2-6 Effluent Discharge Criteria for Humboldt

Parameter	Proposed Effluent Discharge Limit (1)	Design Target
Total Suspended Solids (TSS)	< 25 mg/L	< 20 mg/L
Carbonaceous Biochemical Oxygen Demand 5-day ($CBOD_5$)	< 25 mg/L	< 20 mg/L
Total Nitrogen (TN)	< 40 mg/L	< 32 mg/L(2)
Total Phosphorus (TP)	< 1 mg/L	< 0.75 mg/L
Ammonia-N Summer/Winter	< 4/10 mg/L	< 4/10 mg/L at 22°C / 1°C and pH of 8.0 < 1.6/7.5 mg/L at 22°C / 1°C and pH of 8.5
Unionized Ammonia-N	< 1.25 mg/L at 15°C ± 1°C	< 0.21 mg/L at 15°C ± 1°C
Total Chlorine Residual	< 0.02 mg/L	< 0.02 mg/L
E-Coli	< 200 orgs/100 mL	< 100 orgs/100 mL
Total Coliform	< 3,100 orgs/100 mL	< 3,100 orgs/100 mL

Note: (1) Sampling frequency has not been defined by WSA
(2) Total nitrogen target of 32 mg/L has been set to recover alkalinity through denitrification for secondary systems that can incorporate high recycle ratios of nitrifying mixed liquor (NML).

2.9 WET WEATHER FLOW MANAGEMENT

A review of options available for wet weather flow treatment processes was presented in the technical memorandum for wet weather flow management. This memorandum concluded that selection of an appropriate wet weather flow treatment process is based on several factors including water quality objectives, overall value of the process with respect to the City's operational goals, process flexibility, ease of operation and land area requirements. Based on the discussions presented and the relative advantages and disadvantages of each wet weather management option, the inline storage in the upgraded lagoon is recommended for further consideration since the existing lagoons will serve well for this purpose. This concept will consist of storing flows greater than the MWF of 9,720 m^3/d.

3.0 LIQUID AND SLUDGE TREATMENT PROCESS SELECTION

This section summarizes the decision methodology for the liquid and sludge treatment process selection. The methodology consisted of three phases. Phase 1 identified a long list of suitable liquid and sludge treatment options. Phase 2 short listed treatment processes and Phase 3 evaluated the various short listed treatment processes. Selection criteria and scoring of the various treatment processes for each phase were developed and discussed with the City's engineering department and presented to City Council.

The option to expand the existing lagoons was evaluated in detail in Technical Memorandum No. 3. Ammonia reduction in lagoons can be achieved by either ammonia volatilization or by nitrification (conversion of ammonia to nitrate by nitrifying bacteria). Ammonia volatilization can be attained in the storage lagoons if the effluent is stored over a full year and the water pH is greater than 8. For this to occur the City would require a new 17 ha facultative lagoon and a new 41 ha storage lagoon. Constructing these additional lagoons would be very expensive (approximately $20M depending on geotechnical conditions). An expanded lagoon system would not be able to consistently achieve the effluent quality listed in the DUIS response letter issued by WSA on December 31. 2018, specifically, TSS less than 25 mg/L, ammonia-N less than 3 mg/L and not acutely toxic. This is because the treatment capability of lagoons is significantly affected by climatic conditions (temperature, sunlight, icing days and rain). In addition, the plant operator has very limited control over the conditions that could lead to a non-compliance, such as water level in the storage lagoons, which can lead to excessive algae growth, responsible for high TSS (up to 100 mg/L) and pH spikes (up to 10). High pH in the final effluent may cause failure to pass the acute lethality test with rainbow trout since the ammonia toxicity test is pH dependent. Effluent with a residual ammonia concentration of 3 mg/L at pH of 10 and 15°C has a unionized ammonia of 2.2 mg/L, which is above the limit of 1.25 mg/L set by WSA.

WSA also requires a buffer zone of 300 m from an isolated residence and 550 m to a built-up residential area for facultative lagoons and 300 m for mechanical plants (EPB-503 Table 4.2). Currently, the City's lagoon system does not meet this set back requirement. The distance from the west berm is 250 m to a single residence and 513 m to the west built-up residential area (101 Street). The distance from the north berm is 500 m to the north built-up residential area (6 Avenue). It is unlikely that WSA would allow expansion of the lagoons which would continue to not meet the setback requirements.

Rather than lagoon expansion, a more feasible option is to add process units to provide nitrification in earthen basins or concrete basins with continuous discharge to Humboldt Lake. This is required for two reasons, first to ensure that treated effluent would not deteriorate in the storage lagoons due to algal growth or to the release of nutrients from decomposition of existing sediments in the lagoons, and second, expansion of the lagoons to provide enough storage time would be very expensive.

3.1 PHASE 1: IDENTIFICATION OF LIQUID AND SLUDGE TREATMENT OPTIONS

There are several treatment alternatives that can be used to meet the effluent criteria imposed by the WSA. Table 3-1 presents a list of potential liquid treatment processes, categorized by how the microorganisms grow. Table 3-2 presents a list of potential sludge treatment processes categorized by biosolids disposal methods.

The treatment processes listed in Table 3-1 are suitable for the scale of expected wastewater flows, and anticipated to meet the effluent quality requirements for discharge to Humboldt Lake. The treatment technologies listed in Table 3-2 are suitable for the expected sludge volumes, and expected to meet WSA requirements for disposal of biosolids.

Table 3-1 Long List of Liquid Treatment Processes

Category	Liquid Treatment Technology
In-pipe bioaugmentation	In-Pipe Technology
Suspended growth in earthen basins	Biolac process with chemical precipitation
Attached growth in earthen basins	Submerged Aerated Growth Reactor (SAGR) with chemical precipitation Bio2bloc and chemical precipitation
Attached growth in concrete tanks between earthen basins	LagoonGuard Moving Bed Biofilm Reactor (MBBR) with chemical precipitation
Suspended growth in concrete tanks	Activated sludge with nitrification with chemical precipitation Biological Nutrient Removal (BNR) Oxidation ditch Sequencing Batch Reactor (SBR) with chemical precipitation Continuous inflow and continuous decant SBR with chemical precipitation Modified Sequencing Batch Reactor (MSBR) Granular Sequencing Batch Reactor (GSBR) Membrane Bioreactors (MBR) with chemical precipitation Membrane Bioreactors (MBR) as BNR
Attached growth in concrete tanks	Biological Aerated Filter (BAF) with chemical precipitation Rotating Biological Contactor (RBC), with chemical precipitation Moving Bed Biofilm Reactor (MBBR), DAF with chemical precipitation
Integrated Fixed Film Activated Sludge (IFAS) in concrete tanks	IFAS with chemical precipitation (Bio-wheel)
Non-biological process	Electro-coagulation / Electro-flocculation

Table 3-2 Long List of Sludge Treatment Options

Biosolids Disposal	Sludge Treatment Technology
Liquid injection – Class A biosolids	Thickening / Alkaline Stabilization / Storage
Liquid injection – Class B biosolids Currently acceptable by WSA under more stringent considerations	Lagoon Thickening / Stabilization / Storage Thickening / Aerobic Digestion / Storage Thickening / Aerobic-Anoxic Digestion / Storage Thickening / Anaerobic Digestion / Storage Thickening / Alkaline Stabilization / Storage
Land spreading - Class A biosolids	Lagoon Thickening / Stabilization / Dewatering / Compost Aerobic Digestion / Dewatering / Compost Thickening / Aerobic Digestion / Dewatering / Compost Thickening / Aerobic-Anoxic Digestion / Dewatering / Compost Thickening / Anaerobic Digestion / Dewatering / Compost Dewatering / Alkaline Digestion / Stockpile Dewatering / Composting / Stockpile Dewatering / Dryer / Stockpile
Land spreading or landfill cover Class B biosolids	Lagoon Thickening / Stabilization / Dewatering / Stockpile Aerobic Digestion / Dewatering / Stockpile Thickening / Aerobic Digestion / Dewatering / Stockpile Thickening / Aerobic-Anoxic Digestion / Dewatering / Stockpile Thickening / Anaerobic Digestion / Dewatering / Stockpile Dewatering / Alkaline Digestion / Stockpile Dewatering / Composting / Stockpile

3.2 PHASE 2: SHORT LIST OF TREATMENT PROCESSES

The potential treatment processes were evaluated using a set of screening factors described below to establish a short list of options.

Proven Technology: The option must be in common use for waste activated sludge treatment in similar sized installations in Canada.

Reliability / Risk of Failure: The option must always provide reliable biosolids processing and disposal with little risk of failure due to mechanical or process breakdown.

Cost-Effectiveness: Based upon experiences at other locations, the technologies chosen should all be competitive with respect to both operating and capital costs. Therefore, processes fail this criterion when: they need to be conservatively designed to increase compliance under the City's operating conditions; or they have excessive operating costs because of power requirements or routine replacement of rapid-wearing components.

Easy Operation and Maintenance: The process should be capable of tolerating a range of sludge feeding conditions, and easy to operate with a minimum level of requirements for operator attention and specific process knowledge.

Based on this pass-fail comparison, the short listed treatment options identified in Technical Memorandum No. 3 - Identification of Liquid Treatment Options include.

- Option 1 – Aerated lagoons/ SAGR with chemical precipitation
- Option 2 – Moving Bed Biofilm Bioreactor (MBBR) with chemical precipitation
- Option 3 – Sequencing Batch Reactor (SBR) with chemical precipitation

The short listed treatment options identified in Technical Memorandum No. 4 - Identification of Sludge Management Options include.

- Option 1 – Lagoon thickening and stabilization, storage and land injection
- Option 2 – Lagoon thickening and stabilization, dewatering, stockpile and landfill cover

3.2.1 Option 1 – Aerated Lagoons / Submerged Attached Growth Reactor (SAGR)

The aerated lagoons / SAGR treatment process for lagoon retrofit is designed to carry out carbonaceous BOD reduction with suspended growth activated sludge, followed by the fixed-film growth media for nitrification in sequence, without internal solids recycle. The aerated lagoons operated in series are used to achieve biological reduction of carbonaceous BOD. Effluent from the aerated cells is directed to the settling cell through a pipe and a series of manholes where alum or ferric sulphate is injected for the removal of phosphorus. Effluent from the settling cells flows by gravity to a splitter box and into four SAGR cells operated in parallel. The SAGR process provides an alternative for lagoon upgrades, which consists of an aerated gravel media bed for nitrifying biomass growth, and a membrane diffuser aeration system for air supply and mixing. A fraction of the effluent from the SAGR cell is recycled to the front-end cells for denitrification and the rest flows through the UV reactor before being discharged to Humboldt Lake. A process schematic for the aerated lagoons / SAGR process is shown in Figure 3-1.

The development of this option consists of:

- Constructing an Influent Splitting Structure (ISS) to combine all the raw sewage and nitrified mixed liquor (NML). This recycle line would provide partial nitrogen reduction (denitrification)
- Dredging sludge from the two front-end cells for settling of grit and large settleable solids
- Converting the two front end cells to anoxic cells
- Dredging facultative cells to facilitate installation of new air diffusers
- Retrofitting cells 3, 4 and 5 with a fine bubble aeration system for BOD reduction
- Constructing an Operations Building to house pump rooms, blowers, chemical tanks, metering pumps and UV reactor
- Installing rapid mix and slow mix chambers between cells 5 and 6 for chemical precipitation of phosphorus
- Constructing four SAGR cells for ammonia, TSS and pathogen reduction
- Constructing a forcemain for NML from the secondary effluent tank to the ISS
- Constructing a forcemain effluent system from the final effluent tank to Humboldt Lake

- Installing instrumentation and control system for the blowers, chemical metering pumps, mixers and effluent pumps in the Operations Building
- Constructing a laydown area approximately 80 m by 30 m with a v-notch trench north of cell 1 to facilitate de-sludging using geotextile container
- Constructing a laydown area of approximately 115 m by 30 m with a v-notch trench inside the nutrient removal cell to facilitate de-sludging of cells 5 and 6 using geotextile container. Sludge dredging and raising the bottom of this cell by 1.4 m is required.
- Constructing a laydown area of 5 m by 40 m north of cell 5 to facilitate de-sludging using frac tanks and QuadVac

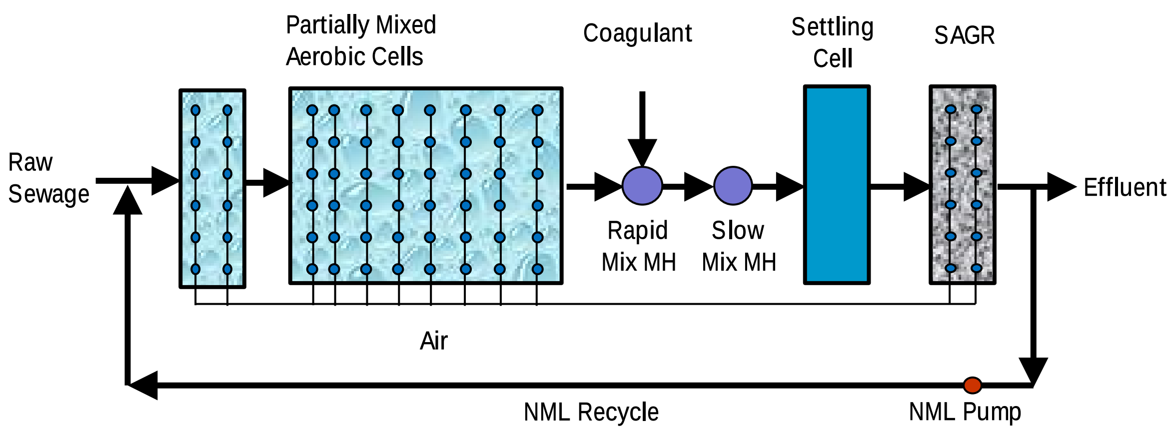

Figure 3-1 Process Schematic of Aerated Lagoons / SAGR with Chemical Precipitation

3.2.2 Option 2 – Moving Bed Biofilm Bioreactor (MBBR)

The Moving Bed Biofilm Bioreactor (MBBR), is based on buoyant plastic carriers that support growth of a high concentration of attached biomass. The carriers are made from HDPE media that have a very high surface to volume ratio in the range of 400 to 800 m^2/m^3. In the moving bed, plastic carriers are placed in the reactor in suspension with the activated sludge to support biofilm growth. Aeration or mechanical mixing circulates the packing material in the system to avoid packing accumulation at the reactor effluent. The packing material is retained in the reactor by media retention sieves. In large systems the plastic carriers are placed within cages to avoid the use of additional mixing equipment. Several packing materials have been developed for suspended attached growth processes, including Captor, Kaldnes and Hydroxyl-Pac media.

The process is unique in utilizing plastic biofilm carrier elements for BOD removal, nitrification, and denitrification. Since the biofilm carrier provides a relatively large surface area for growth, the system supports a much higher concentration of microorganisms as compared to other processes. This makes the process more spatially efficient. A single-stage reactor is presented in Figure 3-2. Sloughed solids are removed using Dissolved Air Floatation (DAF) or a disc filters. Disc filters are more appropriate for MBBR systems with estimated effluent TSS concentration below 160 mg/L and sludge stabilization in lagoons.

Multiple tanks or compartments can be set up to provide aerobic and anoxic zones for total nitrogen removal.

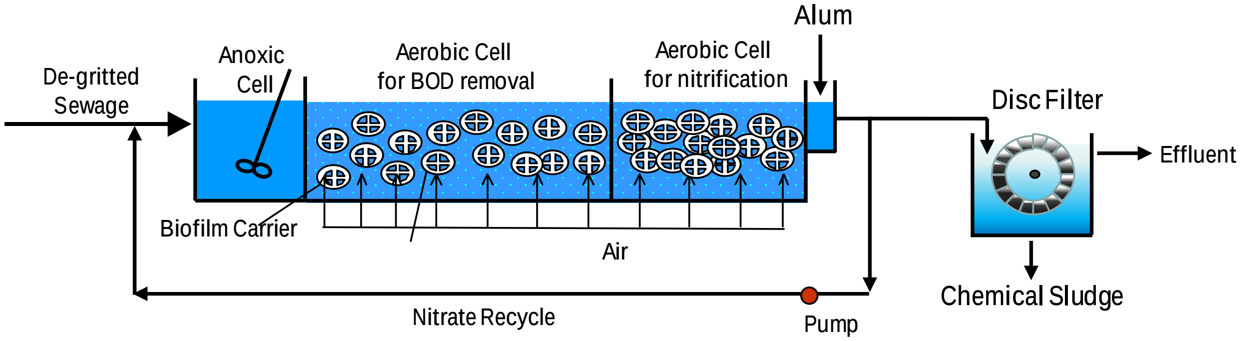

Figure 3-2 Process Schematic of MBBR with Chemical Precipitation

The development of this option consists of:

- Constructing a valve chamber to combine flows from all lift stations and re-direct the flow to the new headworks
- Constructing a headworks building to house screens and grit removal units
- Constructing a building to house blowers, cloth filters, UV disinfection units, chemical tanks and metering pumps
- Installing disc filters for solids separation
- Installing a UV disinfection system
- Installing pumps and forcemain to convey activated sludge to the existing lagoons or another sludge management system
- Retaining existing facultative cells for wet weather flow management through offline storage
- Constructing an effluent lift station and forcemain from the WWTP to Humboldt Lake
- Installing instrumentation and control systems for the MBBR, blowers, filtration, UV disinfection, sludge pump station and effluent lift station
- Constructing a laydown area of 115 m by 30 m with a v-notch trench south of cells 3 and 4 to facilitate de-sludging using geotextile containers
- Constructing a laydown area of 80 m by 30 m with a v-notch trench north of cell 1 to facilitate de-sludging using geotextile containers
- Constructing a laydown area of 5 m by 40 m south of cell 4 to facilitate de-sludging using frac tanks and QuadVac

3.2.3 Option 3 – Sequencing Batch Reactor (SBR)

The Sequencing Batch Reactor (SBR), is a fill-and-draw, non-steady state activated sludge type treatment system where the biological oxidation of organic matter, nitrification, denitrification and sedimentation (solid/liquid separation) are carried out in the same tank, typically in a timed sequence. As such, the SBR process does not require any secondary clarifiers and in most cases operates without primary sedimentation. Also, the SBR process does not require any return activated sludge (RAS) or any internal mixed liquor recycle streams. A schematic of this process is presented in Figure 3-3.

In general, a typical treatment cycle consists of filling the bioreactor with wastewater (FILL), aeration and/or mixing of the bioreactor contents (i.e., mixed liquor or biomass) (REACT), followed by settling (SETTLE) of the biomass. Aeration is provided by fine bubble diffusers and blowers. Treated effluent is then finally discharged by the decanter mechanism (DECANT). An IDLE stage may follow during which waste activated sludge is discharged and the SBR tank time sequence is adjusted prior to starting the next cycle.

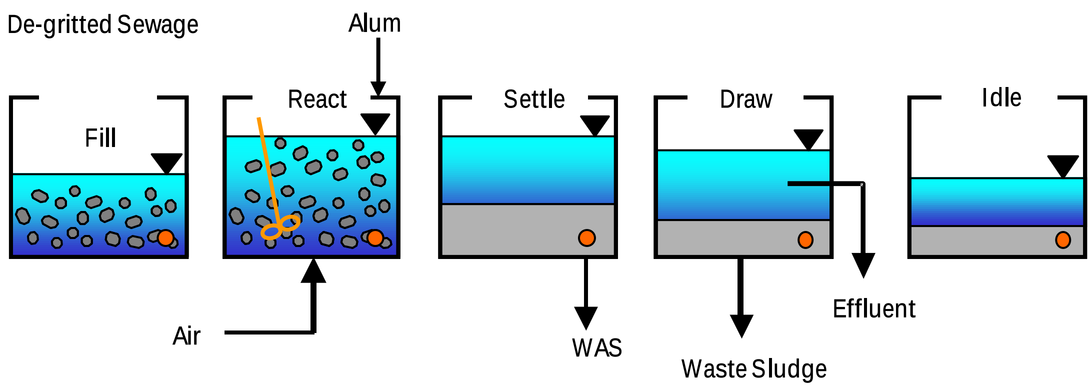

Figure 3-3 Schematic of the SBR Process with Chemical Precipitation

The development of this option consists of:

- Constructing a valve chamber to combine flows from all lift stations and re-direct the flow to the new headworks
- Constructing a headworks building to house screens and grit removal units
- Constructing a building to house blowers, post-equalization basin, UV disinfection units, chemical tanks and metering pumps
- Installing a UV disinfection system
- Installing pumps and forcemain to convey activated sludge to the existing lagoons or another sludge management system
- Retaining existing facultative cells for wet weather flow management through offline storage
- Constructing an effluent lift station and forcemain from the WWTP to Humboldt Lake
- Installing instrumentation and control systems for the SBR, blowers, filtration, UV disinfection, sludge pump station and effluent lift station
- Constructing a laydown area of 115 m by 30 m with a v-notch trench south of cells 3 and 4 to facilitate de-sludging using geotextile containers
- Constructing a laydown area of 80 m by 30 m with a v-notch trench north of cell 1 to facilitate de-sludging using geotextile containers
- Constructing a laydown area of 5 m by 40 m south of cell 4 to facilitate de-sludging using frac tanks and QuadVac

3.3 PHASE 3: EVALUATION OF SHORT LISTED TREATMENT OPTIONS

The short listed liquid treatment options were evaluated using the decision model presented in Table 3-3. The model organizes the decision factors by hierarchical level and gives a weighting corresponding to importance. Stantec completed preliminary scoring to facilitate discussions with the City. Weights for each factor were established by Stantec’s experience with other municipalities of similar size as Humboldt. The City was invited to undertake a similar exercise with the decision model, as weighting may be viewed differently by the City.

For each of the options (aerated lagoons / SAGR, MBBR, and SBR) a score of between 1 and 100 was assigned for each factor. The resulting points (weight x score) are totaled to determine the total for each of the options. For instance, Option 1 – aerated lagoon / SAGR process was given 4.5 points for operational robustness based on a net weight of 4.5% and a score of 100. The net weight was computed by multiplying the 30% weight factor for level 1 – operation times the 15% weight factor for level 2 – robustness. Option 2, the MBBR Process scored the highest overall score in the decision model, slightly edging out the SAGR and SBR options.

Table 3-3 Decision Model for the Evaluation of Short Listed Liquid Treatment Options

Weight	Level 1 Factor	Weight	Level 2 Factor	Description	Net Weight	Option 1 - Aerated Lagoons / SAGR Process		Option 2 - MBBR Process		Option 3 - SBR Process	
						Score	Points	Score	Points	Score	Points
30%	Operation	15%	Robustness	Ability to handle daily and seasonal wastewater flows and loading	4.5%	100	4.5	95	4.3	90	4.1
		15%	Reliability and Risk of Failure	Impact on effluent compliance due to process equipment malfunction (headworks, NML pump, PLC functioning)	4.5%	95	4.3	85	3.8	85	3.8
		10%	Flexibility	Adaptability to abnormal process conditions such as low food to mass ratio and high FOG	3.0%	95	2.9	90	2.7	95	2.9
		10%	Operational Complexity	Impact of process on plant operation and skill set of existing personnel (process with multiple tanks, pumps, blowers and recycle requires more operator attention)	3.0%	90	2.7	70	2.1	80	2.4
		10%	Operational Issues	Foaming, scum and bulking control	3.0%	90	2.7	80	2.4	70	2.1
		5%	Safety	Impact on operational safety (i.e. chemical handling, high H_2S, working near aerated cells)	1.5%	70	1.1	80	1.2	90	1.4
		5%	Track Record	Level of performance in Western Canada	1.5%	95	1.4	85	1.3	85	1.3
		15%	Level of Automation	Level of skills required for operation (PLC)	4.5%	90	4.1	75	3.4	75	3.4
		15%	Staffing	Level of certification requirements to attract and retain operators	4.5%	90	4.1	80	3.6	80	3.6
20%	Maintenance	25%	Safety	Ease of access for tank inspection and maintenance (i.e. diffuser in an aerated cell)	5.0%	60	3.0	90	4.5	90	4.5

Weight	Level 1 Factor	Weight	Level 2 Factor	Description	Net Weight	Option 1 - Aerated Lagoons / SAGR Process		Option 2 - MBBR Process		Option 3 - SBR Process	
						Score	Points	Score	Points	Score	Points
		30%	Maintenance Complexity	Impact of process selection on equipment maintenance (process with multiple tanks, pumps, blowers and recycle requires more maintenance)	6.0%	85	5.1	80	4.8	90	5.4
		15%	Warranty	Level of warranty required	3.0%	85	2.6	70	2.1	75	2.3
		15%	Proprietary Parts	Level of proprietary parts	3.0%	85	2.6	70	2.1	80	2.4
		15%	Availability of Parts	Easily available parts	3.0%	90	2.7	70	2.1	80	2.4
20%	Future Issues	20%	Compatibility with Future Liquid Process Expansion	Adaptability to future infrastructure	4.0%	80	3.2	100	4.0	80	3.2
		10%	Compatibility with Future Solids Process Expansion	Adaptability to future infrastructure	2.0%	90	1.8	90	1.8	90	1.8
		10%	Wet Weather Flow Management	Ability to treat high flows and effluent quality after blending	2.0%	95	1.9	70	1.4	70	1.4
		10%	Flexibility	Adaptability to more stringent effluent criteria	2.0%	50	1.0	90	1.8	80	1.6
		40%	Stage Development	Flexibility to be implemented or expanded in modular increments	8.0%	70	5.6	90	7.2	80	6.4
		10%	Future Cost	Cost of future expansions or upgrades	2.0%	50	1.0	100	2.0	50	1.0
10%	Constructability Issues	20%	Compatibility with Existing Infrastructure	Adaptability to the existing infrastructure or site conditions	2.0%	95	1.9	80	1.6	80	1.6

Weight	Level 1 Factor	Weight	Level 2 Factor	Description	Net Weight	Option 1 - Aerated Lagoons / SAGR Process		Option 2 - MBBR Process		Option 3 - SBR Process	
						Score	Points	Score	Points	Score	Points
		40%	Construction Schedule	Impact of long construction or late delivery	4.0%	60	2.4	90	3.6	70	2.8
		40%	Commissioning and Start-up	Impact of long commissioning or start-up	4.0%	90	3.6	80	3.2	90	3.6
10%	Public Acceptance	10%	Stakeholder Issues	Level of public support and positive opinion	1.0%	70	0.7	90	0.9	90	0.9
		40%	Odour Emissions	Level of nuisance odour emissions from septage discharge, sludge handling and disposal	4.0%	80	3.2	80	3.2	80	3.2
		5%	Impacts During Construction and Operation	Level of impact of construction and operation on nearby residential area	0.5%	80	0.4	70	0.4	70	0.4
		40%	Regional Growth	Support regional growth (septage receiving station)	4.0%	80	3.2	80	3.2	80	3.2
		5%	Land Use	Impact on property value	0.5%	70	0.4	80	0.4	80	0.4
10%	Environmental	17%	Enhanced Receiving Water	Ability to achieve higher water quality without excessively increasing capital cost	1.7%	60	1.0	90	1.5	80	1.4
		17%	Enhanced Solids Handling Train	Ability to achieve higher biosolids quality without excessively increasing capital cost	1.7%	70	1.2	70	1.2	75	1.3
		6%	Effluent Reuse	Effluent reuse potential	0.6%	80	0.5	90	0.5	70	0.4
		10%	Approvals / Regulatory	Proximity to residential area	1.0%	80	0.8	90	0.9	90	0.9
		20%	Sustainability	Long term commitment to maintain this treatment	2.0%	70	1.4	90	1.8	80	1.6

Weight	Level 1 Factor	Weight	Level 2 Factor	Description	Net Weight	Option 1 - Aerated Lagoons / SAGR Process		Option 2 - MBBR Process		Option 3 - SBR Process	
						Score	Points	Score	Points	Score	Points
		30%	Global Climate	Level of greenhouse gas generation during construction from the use of non-renewable fuels	3.0%	80	2.4	80	2.4	70	2.1
100%	Total Benefit				100 %		81.0		83.4		80.0

3.4 LIFE CYCLE COST FOR SHORT LISTED OPTIONS

A technical and financial evaluation has been completed for each option. Table 3-4 presents life cycle cost opinions and the benefit-cost ratio for the purpose of comparing the options.

Table 3-4 Life Cycle Cost for Short Listed Options

Item	Description	Option 1 Aerated Lagoons / SAGR Process	Option 2 MBBR Process	Option 3 SBR Process
1.0	General requirements	$2,352,000	$2,524,000	$2,518,000
2.0	Siteworks	$4,987,000	$4,648,200	$4,648,200
3.0	Headworks	$0	$1,760,000	$1,760,000
4.0	Upgrades to cells 1, 2 and 3	$1,698,000	$1,243,000	$1,243,000
5.0	SAGR cells	$4,693,000	$0	$0
6.0	Operations Building	$8,988,000	$13,564,500	$13,515,000
7.0	Odour Control Building	$0	$640,000	$640,000
8.0	**Subtotal**	**$22,718,000**	**$24,380,000**	**$24,324,000**
	Contingency (20%)	$4,544,000	$4,876,000	$4,865,000
	Engineering (10%)	$2,727,000	$2,926,000	$2,919,000
	Total Project Capital Cost	**$29,989,000**	**$32,182,000**	**$32,108,000**
	Annual Operation Cost for 2020	$495,000	$550,000	$533,000
	NPV O&M (33 years)	$15,870,000	$17,370,000	$16,930,000
	NPV Life Cycle Cost (33 years)	**$45,859,000***	**$49,552,000**	**$49,038,000**

Note:

1. Net Present Value developed based on a discount rate of 3.82% and an inflation rate of 2% per annum. Net present values were calculated using 2020 as the base year and extending to 2052.
2. Annual operating cost for 2020 does not include sludge disposal for the three options. The City should budget for sludge disposal, about $149,000 (landfilling) or $242,000 (land application) each year.
3. *Aerated lagoons / SAGR Process life cycle costs are reflective of the cost determined during preparation of Technical Memorandum 5 and have been updated in Table 7.1 of this report.
4. If the MBBR and SBR options were to be considered, a mixed equalization tank with a minimum active storage capacity of 800 m^3 (14 m x 14 m x 5 m) must be included. Addition of the equalization tank was not considered in the OPCC in previous technical memos as the flow patterns were not well understood until the City provided the diurnal flow pattern data (later stages of the analysis). Further discussion about this topic is presented in section 4.5.1. The addition of an equalization tank to the MBBR and SBR OPCC's will increase the capital cost by approximately $3,000,000. This change will impact the life cycle cost of each option by approximately $4,000,000.

3.4.1 Life Cycle Cost Results

The life cycle costs indicate that Option 1 - aerated lagoons / SAGR process provides the lowest capital cost, lowest operational cost and lowest Net Present Value (NPV) for the 33-year design life used in the calculation. The NPV represents the value of all future costs over the design life of the capital investment. Opinions of probable cost for capital and operating costs are described in Technical Memorandum No. 5.

The results of the decision model indicate that the MBBR option provides a slight benefit advantage to the City when compared to the aerated lagoons / SAGR or SBR options. The aerated lagoons / SAGR option provides the best NPV.

Final selection of the preferred option includes results from the decision model as well as evaluating life cycle costs, opinions of capital costs, opinions of operating costs, and opinions of consumable costs. The overall ranking of each option is presented below as a benefit to cost ratio.

Table 3-5 Overall Ranking for Each Liquid Treatment Option

Rank	Option	Benefit	Life Cycle Cost	Benefit - Cost Ratio
1	Option 1: aerated lagoons / SAGR process with chemical precipitation	81	$45.89M*	1.77
2	Option 2: MBBR with chemical precipitation	83.4	$49.55M	1.68
3	Option 3: SBR with chemical precipitation	80.0	$49.04M	1.63
*Aerated Lagoons/SAGR Process life cycle costs are reflective of the cost determined during preparation of Technical Memo 5 and have been updated in Table 7.1 of this report.				

The aerated lagoons / SAGR option has the highest benefit cost ratio because this option is very compatible with existing infrastructure and it can be expanded to meet population growth after 2052 by adding two more SAGR cells and installing additional blowers and diffusers, which would reduce future upgrade expenditures. This option has the lowest OPCC as it makes use of existing infrastructure (cells 1 to 6). In addition, the aerated lagoon / SAGR process does not require headworks, or solids separation equipment such as DAF or disc filters.

The main disadvantage of the aerated lagoons / SAGR option is that it cannot reduce the effluent Total Nitrogen (TN) concentration to less than 28 mg/L in summer and 31 mg/L in winter. This could be viewed by stakeholders near the WWTP as a significant issue since they may want a superior effluent quality discharged into the receiving environment even though WSA has not set stringent TN limits (typical TN limit has been between 10 and 15 mg/L for other WWTP in Saskatchewan). The MBBR option can provide a superior quality effluent with TN concentrations less than 12 mg/L. However, the MBBR option has a much higher OPCC. If WSA imposes more stringent TN limits in the future the aerated lagoons / SAGR option could be retrofitted with post denitrification cells and filters. This improvement would increase the capital and operating costs (not included in the NPV calculations). One other drawback with the aerated lagoons / SAGR option is that there is only one supplier (Nexom).

Both the aerated lagoons / SAGR and the MBBR processes are stable, efficient, reliable and flexible. These attributes are due to the inherent nature of the treatment processes coupled with reputable suppliers. These systems do not experience operational problems such as foaming, scum or bulking, which is very typical for suspended activated sludge processes.

Both the aerated lagoons / SAGR and the SBR processes have good track records in Western Canada. These processes have been widely used for small and medium size WWTPs that cannot re-use their existing facultative lagoons due to odour concerns and relatively proximity to residential areas. The MBBR and the SBR process have similar OPCC's, largely due to the premium cost of the MBBR propriety equipment even though it requires smaller bioreactors.

All short listed options support the City's objectives of implementing a mechanical WWTP without excessively increasing the level of certification and skills requirements to attract and retain operators since the facility most likely would be likely classified as Class II.

All options provide consistent sludge stabilization since the existing lagoons can be used for lagoon thickening and stabilization. The sludge management option relies on periodical sludge removal to ensure that space would always be available to receive fresh sludge and to minimize odor emission by maintaining a water layer over the digested sludge.

The aerated lagoons / SAGR option is operationally less complex than the MBBR and SBR options since it has fewer process units and equipment to operate or maintain. For this reason, it requires only two operators. The aerated lagoons / SAGR option will require a contract with Nexom for maintenance and repair of the aeration system. Although the aerated lagoons / SAGR system does not require daily supervision and routine maintenance, two operators are required to cover days off, holidays, sick days and to develop a successful training and succession plan as well as to establish a consistent biosolids disposal program that suits the needs of the City.

Option 1 - aerated lagoons / SAGR process provides the highest benefit to cost ratio, and therefore is the recommended option.

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4.0 PROCESS DESIGN

4.1 BACKGROUND

The following provides a list of the key process components of the proposed WWTP. The preliminary design of the proposed components is discussed in detail in the following sections. A WWTP Process Flow Diagram is provided in Appendix B - Figure D-601.

- Influent splitting structure (ISS)
- Secondary process based on aerated lagoons/SAGR cells
  - Blowers
- Ultraviolet disinfection system
- Effluent flow monitoring
- Lagoon thickening
- Lagoon stabilization
- Sludge dewatering
- Sludge storage and disposal to landfill/beneficial reuse as a landfill cover

4.2 LIQUID TREATMENT PROCESS DESCRIPTION

A brief description of each process unit is provided in the following paragraphs. This description should be read along with the WWTP Process Flow Diagram presented in Appendix B - Figure D-601.

4.2.1 Influent Splitting Structure (ISS)

The Influent Splitting Structure (ISS) will be used to combine the influent from multiple lift stations and the recycled Nitrified Mixed Liquor (NML) before being directed to the anoxic cells (cells 1 and 2). The ISS will be equipped with weirs to provide for equal flow split to each anoxic cell. Isolation of each anoxic influent pipe will be achieved by manually lifting the weir gates and closing buried plug valves.

4.2.2 Anoxic Cells

Raw sewage mixed with NML from the ISS will be conveyed by gravity to the anoxic cells (cell 1 and 2). These cells will be used to settle grit and large solids as well as retain plastics. These cells will not be mechanically mixed. The liquid in the cells will undergo denitrification (partial conversation of nitrate to nitrogen gas) since the NML recycle to the ISS is rich in nitrate. Denitrification in these cells will have the add-on benefit of reducing odour generation since microorganisms prefer using nitrates rather than sulfate for respiration.

4.2.3 Aerated Lagoons

Mixed liquor from cells 1 or 2 will be conveyed by gravity to the aerated cells (cells 3, 4 and 5 operated in series). The contents of the aerated cells will be continuously mixed by the aeration system. The aeration system consists of blowers and a network of fine bubble diffusers covering the lagoon floors for organic carbon reduction (BOD reduction). The diffused aeration system would be designed to maintain a dissolved oxygen concentration of 2 mg/L.

4.2.4 Phosphorus Precipitation System

Effluent from the aerated cells will be conveyed by gravity to the phosphorus precipitation system, which consists of two mixing chambers and a settling cell. The mixing chambers will be constructed between cells 5 and 6 to mix alum using mechanical mixers to precipitate phosphorus. The first chamber provides rapid mixing for coagulation and the second chamber provides slow mixing for flocculation. The settling cell will be used to settle chemical bound phosphorus before the effluent is conveyed to the SAGR cells for nitrification.

The alum feed system consists of one tank capable of storing 16 m^3 of liquid alum and two metering pumps. This system will be installed in the Operations Building and will pump alum to the rapid mix chamber.

4.2.5 SAGR Cells

Effluent from the settled cell will be conveyed by gravity to the SAGR influent splitting structure. This structure will be equipped with weirs to provide for equal flow split to each SAGR cell. Isolation of each SAGR influent pipe will be achieved by manual closing of weir gates and buried plug valves. Four SAGR cells will be constructed east of cell 6. The contents of the SAGR cells will be continuously mixed by the aeration system, which consist of blowers and a network of fine bubble diffusers for ammonia, TSS and pathogen reduction. The diffused aeration system will be designed to maintain a dissolved oxygen concentration of 2 mg/L.

Effluent from the SAGR cells will be conveyed by gravity to the SAGR effluent level control structures. These structures will be equipped with vertical pipes that will act as a weir to ensure that all the SAGR cells operate at the same water level. Effluent from each SAGR effluent level control structure is combined and directed to the secondary effluent tank.

4.2.6 Secondary Effluent Tank

This tank will be constructed in the substructure of the Operations Building and designed to receive effluent from the SAGR effluent level control structure. This tank will split the secondary effluent into two streams, one stream will be directed to the ISS as NML and the other directed to the UV disinfection reactor. This tank also serves as a wet well for the NML pumps. These pumps will be used to return nitrate rich effluent to the ISS and ultimately to the anoxic cells.

4.2.7 UV Disinfection

Secondary effluent will be conveyed by gravity from the secondary effluent tank to the UV disinfection channel. The UV disinfection system (horizontal lamp configuration) will automatically indicate lamp failure and low UV intensity. It will be equipped with an automatic lamp cleaning system. Disinfected effluent will flow by gravity to a final effluent tank. The UV disinfection system will be located over the final effluent tank and housed in the Operations Building.

4.2.8 Final Effluent Tank

This tank will be constructed in the substructure of the Operations Building and designed to receive disinfected effluent from the UV reactor. This tank also serves as a wet well for the final effluent pumps. The final effluent pumps will be used to convey UV disinfected effluent to Humboldt Lake through a 400 mm diameter forcemain. The non-potable water pumps will convey disinfected effluent to any place in the plant for internal use (i.e., flushing). These pumps will be in the pipe gallery. Sodium hypochlorite solution will be added to the non-potable water (W3) for additional disinfection.

4.2.9 Process Blowers

Process blowers will supply air at a rate and pressure sufficient to maintain the appropriate level of DO in the aerated lagoons and SAGR cells. Five positive displacement blowers will be provided to meet the total air flow demand (two blowers to serve the aerated lagoons, three blowers to serve the SAGR cells (two duty and one standby). Each blower will be equipped with a Variable Frequency Drive (VFD) to adjust the speed of the blower. Process air from the blowers will be conveyed to a main header and then split into dedicated air headers for each cell. Process air to each cell will be manually controlled by adjusting the VFD and air flow valves, based on dissolved oxygen level in the cell. The blowers will be in the Operations Building in a room located on the main level.

4.3 SLUDGE MANAGEMENT PROCESS DESCRIPTION

Sludge management consists of passive stabilization (non-assisted by mechanical aeration) of the sludge settled in the anoxic cells and chemical sludge settling cell and active stabilization (assisted by mechanical aeration) of the sludge settled in the aerated cells. The sludge management option relies on periodic sludge removal to ensure that space would always be available to receive fresh sludge and to minimize odor emission by maintaining a water layer over the digested sludge. It is expected that sludge thickening (increase of solids content from 1.2% to 4%) and passive stabilization will occur over time since the sludge is stored for a long period. Sludge dredging from the anoxic cells should be conducted initially every six years and progressively increased to every four years depending on sludge storage capacity and land availability. Sludge dredging from the aerated cells and settling cell should be conducted every twelve years. Three laydown areas are required with geotextile containers to dewater the sludge accumulated in the cells. The purpose of the sludge dewatering system is to reduce the volume of water before the sludge is transported to the landfill to be used as intermediate cover. Sludge could be transported in liquid form (4% solids) to be reused as Class B biosolids on agricultural land.

4.4 HYDRAULIC PROFILE

The hydraulic profile is governed by six constraints:

1. Maximum flood elevation of 553.00 m (1:500 year flood level for the City of Humboldt has not been defied)
2. The desire to have the building main floor level above the ground level of 561.00 m
3. The desire to reduce the earth excavated to build SAGR cells and concrete tanks
4. The desire to reduce the amount of clay to haul and place
5. The desire to install new 400 mm diameter transfer pipes below the frost level and ice level in the aerated lagoons while maintaining the existing system in operation
6. The desire to minimize hydraulic changes to the pumps at the lift stations

The hydraulic profile is shown in Appendix B Figure D-602.

4.5 PROCESS MODELING

Process modeling is typically completed using the BioWin modeling software package. This software is primarily used for mechanical plants and it is not suitable for modelling aerated lagoons followed by SAGR process. Process modeling for the aerated lagoons / SAGR process was carried out inhouse by Nexom, the supplier of the system, using their proprietary software. The objectives of completing the process modeling include determining the mass balances, air flow requirements, blower size and number of diffusers per cell.

4.5.1 Influent Flow and Characteristics

The influent element was specified with a wastewater flow rate as listed in Table 2-3 and wastewater characteristics as listed in Table 2-4. The diurnal influent pattern at Lift Station 1 was analyzed from June 2019 to September 2019. Figure 4-1 illustrates the diurnal flow pattern for August 25, 2019. This pattern shows that the lift station pumps approximately 66 L/s for 6 to 12 minutes, 17 times per day with long periods of no flow, ranging from 30 to 70 minutes (confirmed by diurnal flow pattern data). The cumulative flow pattern shows two very distinctive periods: low flow from 12:00 AM to 8:00 AM with a cumulative flow of 200 m^3 and high flow from 8:00 AM to 11:45 PM with a cumulative flow of 911 m^3. Lift Station 1 contributes 65% of the total sewage flow of the City.

The effluent quality of the aerated lagoons / SAGR system would not be affected by the affected by flow surges due to the large retention time in the lagoons. However, for other processes such as the SBR and MBBR effluent quality and process performance will be significantly affected by flow surges. Blowers will be frequently turning on and off during periods of no flow due to high dissolved oxygen in the tanks. Short-circuiting through the bioreactor zones will result in poor effluent quality. UV reactors components life will be shortened because lamps will be turned on and off very frequently (17 to 31 times per day based on the current pumping cycle).

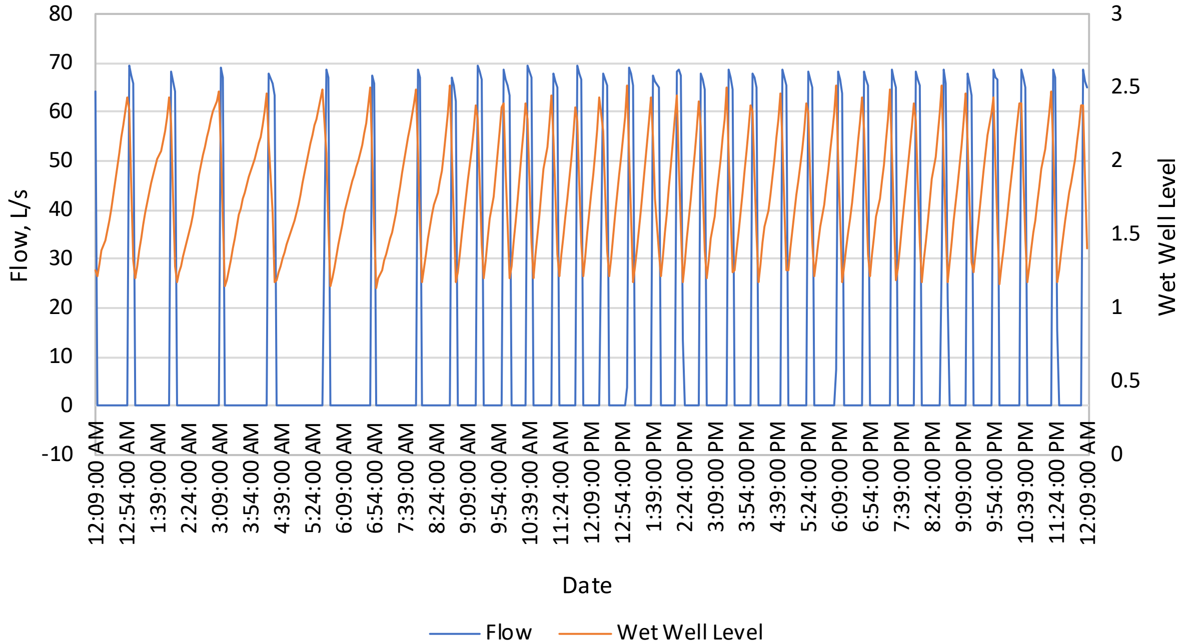


Figure 4-1 Lift Station 1 Diurnal Flow Pattern for August 25, 2019

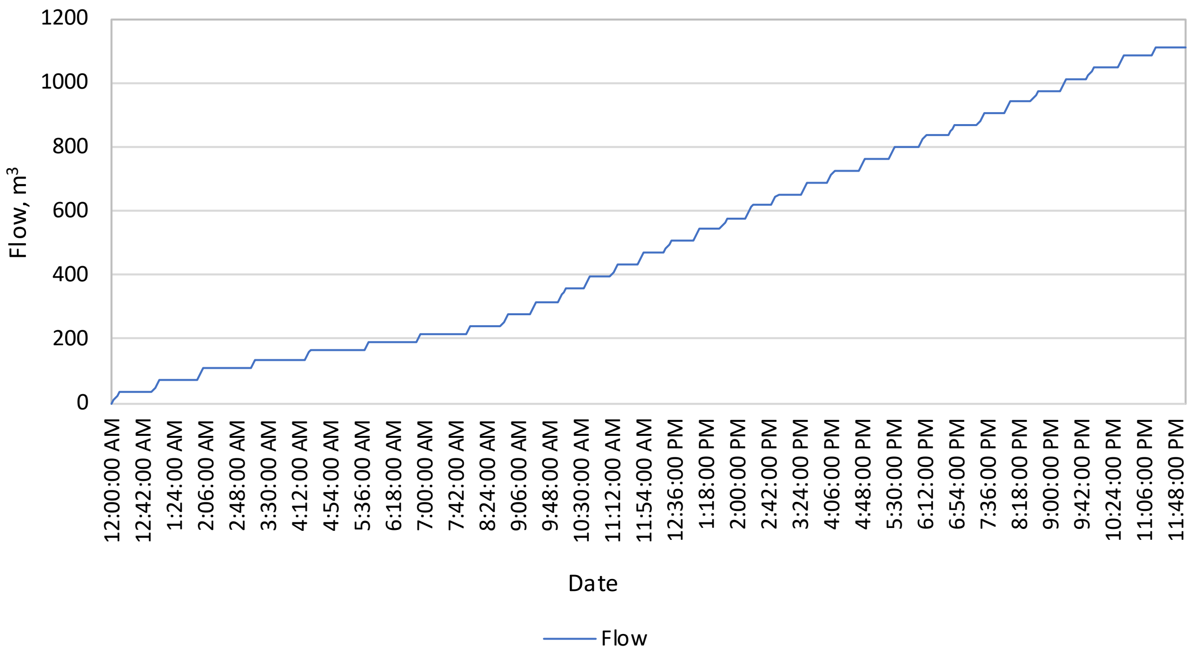


Figure 4-2 Lift Station 1 Cumulative Flow Pattern for August 25, 2019

4.6 MASS BALANCES

This section describes the mass balance for the WWTP. A mass balance model was developed based on a combination of assumptions and Nexom anticipated BOD_5 and TSS concentration throughout the process.

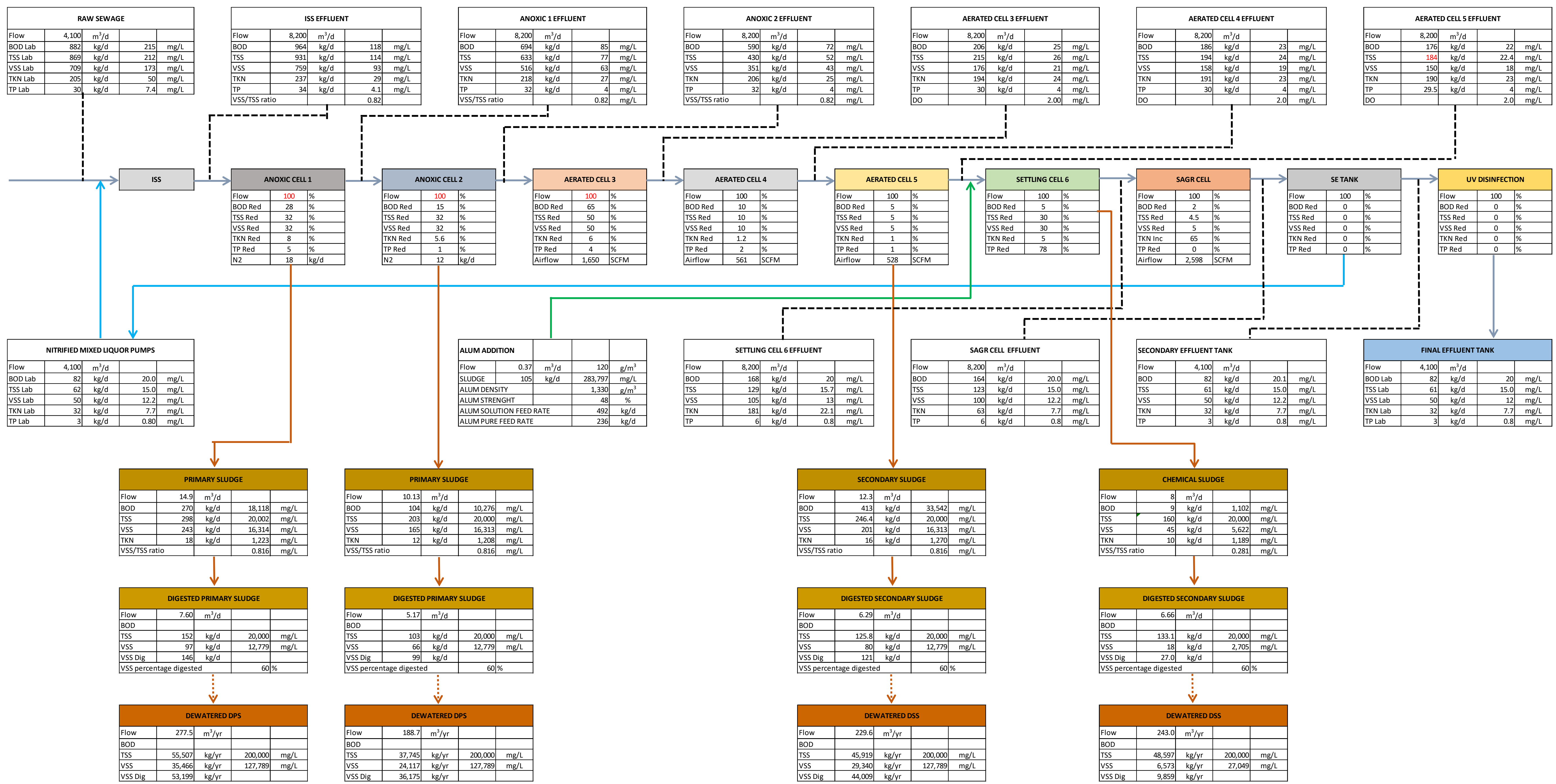
The objectives of completing a mass balance include establishing the solids mass flow rates to aid in sizing equipment, determining internal recycle flows, and understanding solids stream characterization. The mass balance provides a reasonable estimate of process performance in terms of BOD_5, TSS and VSS through the treatment plant. Figure 4-3 and 4-4 summarize the relevant stream flows and loadings results for the design year.

A mass balance for ammonia is not presented because its fate through the lagoons is not typically measured. It is most common to measure TKN. For this reason, Figure 4-3 presents a TKN mass balance. This balance has been revised to show an overall TKN reduction of 85% through the process. TKN reduction mainly occurs at the first anoxic cell, due to dilution with the NML, and the SAGR cells from a TKN concentration of 50 mg/L in the raw sewage to 7.5 mg/L in the effluent (4 mg/L of ammonia and 3.5 mg/L of recalcitrant TKN). Nitrogen leaves the plant in the biosolids, in the off-gas from the SAGR cells (as nitrogen gas) and the effluent (as total nitrogen, which includes nitrate, recalcitrant TKN and ammonia). In general, the fraction of ammonia to TKN in the raw sewage ranges between 73% and 86%. The anticipated fraction of ammonia to TKN in the influent to the SAGR cells is 83%.

In this mass balances, the NML pumps are designed for constant speed to provide a maximum flow of 4,100 m3/d. If the City wishes to adjust the flowrate, a variable frequency drive (VFD) must be provided. The reduction of the NML will cause an increase in the total nitrogen concentration (nitrate fraction will increase) and a decrease in alkalinity in the effluent, and it may lead to inhibition of nitrifying microorganisms due to an increase in the hydrogen ion toxicity (nitrification is sensitive at pH below 6.8). Stantec does not recommend increasing the NML recycle rate beyond the provided capacity since it affects the pumping capacity of the lift stations. If VFDs were to be incorporated, and the City turned down the pumping rate, odours from the unaerated cells and effluent pH should be monitored closely. If odours or low effluent pH were detected when the pumps were turned down, the pumping rate could be increased to mitigate odours and raise effluent pH.

It should be noted that aeration in Cells 4 and 5 is required for organic carbon reduction in winter and spring due to the low microbiological activity at temperatures below 1°C, as presented in Figure 4-4.

Strategies to reduce operating cost in summer consists of turning off laterals in cells 4 and 5 to reduce diffusers in service and resulting airflow. Any power cost reduction needs to be balanced against additional labor or capital cost. The best method to minimize power cost is to measure the dissolved oxygen periodically (every two weeks) and adjust the blowers speed accordingly. Alternatively, dissolved oxygen sensors could be installed in the lagoons to adjust the blowers speed automatically. Dissolved oxygen sensors require frequent calibration to ensure reliable readings for this reason they need a retrieval system when installed in lagoons. The City has the choice to increase the number of diffusers as presented in the table under question number 5.



Notes

BOD	5-day Biochemical Oxygen Demand
BOD Lab	5-day Biochemical Oxygen Demand measured by Lab
BOD Red	5-day Biochemical Oxygen Demand Reduction
DO	Dissolved Oxygen Measured by Laboratory
N2	Nitrogen Gas Generation
TKN	Total Kjeldahl Nitrogen
TKN Lab	Total Kjeldahl Nitrogen Measured by Lab
TKN Red	Total Kjeldahl Nitrogen Reduction
TP	Total Phosphorus
TP Lab	Total Phosphorus Measured by Lab
TP Red	Total Phosphorus Reduction
TSS	Total Suspended Solids
TSS Lab	Total Suspended Solids Measured by Lab
TSS Red	Total Suspended Solids Reduction
VSS	Volatile Suspended Solids
VSS Dig	Volatile Suspended Solids Digested percentage
VSS Lab	Volatile Suspended Solids Measured by Lab
VSS Red	Volatile Suspended Solids Reduction

Figure 4-3 Mass Balance for Summer at Average Day Flow

RAW SEWAGE				
Flow	3,186	m^3/d		
BOD Lab	883	kg/d	277	mg/L
TSS Lab	870	kg/d	273	mg/L
VSS Lab	710	kg/d	223	mg/L
TKN Lab	204	kg/d	64	mg/L
TP Lab	30	kg/d	9.5	mg/L

ISS EFFLUENT				
Flow	7,286	m^3/d		
BOD	979	kg/d	134	mg/L
TSS	945	kg/d	130	mg/L
VSS	771	kg/d	106	mg/L
TKN	250	kg/d	34	mg/L
TP	34	kg/d	4.6	mg/L
VSS/TSS ratio			0.82	

ANOXIC 1 EFFLUENT				
Flow	7,286	m^3/d		
BOD	832	kg/d	114	mg/L
TSS	666	kg/d	91	mg/L
VSS	544	kg/d	75	mg/L
TKN	234	kg/d	32	mg/L
TP	32	kg/d	4	mg/L
VSS/TSS ratio			0.82	mg/L

ANOXIC 2 EFFLUENT				
Flow	7,286	m^3/d		
BOD	782	kg/d	107	mg/L
TSS	466	kg/d	64	mg/L
VSS	381	kg/d	52	mg/L
TKN	222	kg/d	30	mg/L
TP	32	kg/d	4	mg/L
VSS/TSS ratio			0.82	mg/L

AERATED CELL 3 EFFLUENT				
Flow	7,286	m^3/d		
BOD	563	kg/d	77	mg/L
TSS	233	kg/d	32	mg/L
VSS	190	kg/d	26	mg/L
TKN	210	kg/d	29	mg/L
TP	30	kg/d	4	mg/L
DO			2.00	mg/L

AERATED CELL 4 EFFLUENT				
Flow	7,286	m^3/d		
BOD	462	kg/d	63	mg/L
TSS	210	kg/d	29	mg/L
VSS	171	kg/d	24	mg/L
TKN	208	kg/d	28	mg/L
TP	30	kg/d	4	mg/L
DO			2.0	mg/L

AERATED CELL 5 EFFLUENT				
Flow	7,286	m^3/d		
BOD	185	kg/d	25	mg/L
TSS	199	kg/d	27.4	mg/L
VSS	163	kg/d	22	mg/L
TKN	207	kg/d	28	mg/L
TP	29.5	kg/d	4	mg/L
DO			2.0	mg/L

ISS

ANOXIC CELL 1		
Flow	100	%
BOD Red	15	%
TSS Red	30	%
VSS Red	30	%
TKN Red	6.5	%
TP Red	5	%
N2	16	kg/d

ANOXIC CELL 2		
Flow	100	%
BOD Red	6	%
TSS Red	30	%
VSS Red	30	%
TKN Red	5	%
TP Red	1	%
N2	12	kg/d

AERATED CELL 3		
Flow	100	%
BOD Red	28	%
TSS Red	50	%
VSS Red	50	%
TKN Red	6	%
TP Red	4	%
Airflow	1,650	SCFM

AERATED CELL 4		
Flow	100	%
BOD Red	18	%
TSS Red	10	%
VSS Red	10	%
TKN Red	1	%
TP Red	2	%
Airflow	561	SCFM

AERATED CELL 5		
Flow	100	%
BOD Red	60	%
TSS Red	5	%
VSS Red	5	%
TKN Red	1	%
TP Red	1	%
Airflow	528	SCFM

SETTLING CELL 6		
Flow	100	%
BOD Red	5	%
TSS Red	30	%
VSS Red	30	%
TKN Red	4	%
TP Red	78	%

SAGR CELL		
Flow	100	%
BOD Red	2	%
TSS Red	4.5	%
VSS Red	5	%
TKN Inc	59	%
TP Red	0	%
Airflow	2,598	SCFM

SE TANK		
Flow	100	%
BOD Red	0	%
TSS Red	0	%
VSS Red	0	%
TKN Red	0	%
TP Red	0	%

UV DISINFECTION		
Flow	100	%
BOD Red	0	%
TSS Red	0	%
VSS Red	0	%
TKN Red	0	%
TP Red	0	%

NITRIFIED MIXED LIQUOR PUMPS				
Flow	4,100	m^3/d		
BOD Lab	97	kg/d	23.6	mg/L
TSS Lab	75	kg/d	18.3	mg/L
VSS Lab	61	kg/d	14.8	mg/L
TKN Lab	46	kg/d	11.2	mg/L
TP Lab	3	kg/d	0.80	mg/L

ALUM ADDITION				
Flow	0.29	m^3/d	120	g/m^3
SLUDGE	82	kg/d	283,797	mg/L
ALUM DENSITY			1,330	g/m^3
ALUM STRENGHT			48	%
ALUM SOLUTION FEED RATE			382.32	kg/d
ALUM PURE FEED RATE			184	kg/d

SETTLING CELL 6 EFFLUENT				
Flow	7,286	m^3/d		
BOD	176	kg/d	24	mg/L
TSS	140	kg/d	19.1	mg/L
VSS	114	kg/d	16	mg/L
TKN	198	kg/d	27.2	mg/L
TP	6	kg/d	0.9	mg/L

SAGR CELL EFFLUENT				
Flow	7,286	m^3/d		
BOD	172	kg/d	23.6	mg/L
TSS	133	kg/d	18.3	mg/L
VSS	108	kg/d	14.9	mg/L
TKN	81	kg/d	11.2	mg/L
TP	6	kg/d	0.9	mg/L

SECONDARY EFFLUENT TANK				
Flow	3,186	m^3/d		
BOD	75	kg/d	23.6	mg/L
TSS	58	kg/d	18.3	mg/L
VSS	47	kg/d	14.9	mg/L
TKN	35	kg/d	11.1	mg/L
TP	3	kg/d	1.0	mg/L

FINAL EFFLUENT TANK				
Flow	3,186	m^3/d		
BOD Lab	75	kg/d	23.6	mg/L
TSS Lab	58	kg/d	18.3	mg/L
VSS Lab	47	kg/d	14.9	mg/L
TKN Lab	35	kg/d	11.1	mg/L
TP Lab	3	kg/d	1.0	mg/L

PRIMARY SLUDGE				
Flow	13.9	m^3/d		
BOD	147	kg/d	10,545	mg/L
TSS	279	kg/d	20,008	mg/L
VSS	228	kg/d	16,333	mg/L
TKN	16	kg/d	1,166	mg/L
VSS/TSS ratio			0.816	mg/L

PRIMARY SLUDGE				
Flow	9.99	m^3/d		
BOD	50	kg/d	4,999	mg/L
TSS	200	kg/d	20,003	mg/L
VSS	163	kg/d	16,328	mg/L
TKN	12	kg/d	1,169	mg/L
VSS/TSS ratio			0.816	mg/L

SECONDARY SLUDGE				
Flow	13.3	m^3/d		
BOD	598	kg/d	44,780	mg/L
TSS	266.9	kg/d	20,000	mg/L
VSS	218	kg/d	16,326	mg/L
TKN	15	kg/d	1,149	mg/L
VSS/TSS ratio			0.816	mg/L

CHEMICAL SLUDGE				
Flow	7	m^3/d		
BOD	9	kg/d	1,307	mg/L
TSS	141	kg/d	20,000	mg/L
VSS	49	kg/d	6,906	mg/L
TKN	8	kg/d	1,169	mg/L
VSS/TSS ratio			0.345	mg/L

DIGESTED PRIMARY SLUDGE				
Flow	7.11	m^3/d		
BOD				
TSS	142	kg/d	20,000	mg/L
VSS	91	kg/d	12,799	mg/L
VSS Dig	137	kg/d		
VSS percentage digested			60	%

DIGESTED PRIMARY SLUDGE				
Flow	5.10	m^3/d		
BOD				
TSS	102	kg/d	20,000	mg/L
VSS	65	kg/d	12,799	mg/L
VSS Dig	98	kg/d		
VSS percentage digested			60	%

DIGESTED SECONDARY SLUDGE				
Flow	6.81	m^3/d		
BOD				
TSS	136.2	kg/d	20,000	mg/L
VSS	87	kg/d	12,799	mg/L
VSS Dig	131	kg/d		
VSS percentage digested			60	%

DIGESTED SECONDARY SLUDGE				
Flow	5.60	m^3/d		
BOD				
TSS	112.1	kg/d	20,000	mg/L
VSS	20	kg/d	3,484	mg/L
VSS Dig	29.3	kg/d		
VSS percentage digested			60	%

DEWATERED DPS				
Flow	259.5	m^3/yr		
BOD				
TSS	51,905	kg/yr	200,000	mg/L
VSS	33,218	kg/yr	127,994	mg/L
VSS Dig	49,827	kg/yr		

DEWATERED DPS				
Flow	186.1	m^3/yr		
BOD				
TSS	37,214	kg/yr	200,000	mg/L
VSS	23,815	kg/yr	127,994	mg/L
VSS Dig	35,723	kg/yr		

DEWATERED DSS				
Flow	248.6	m^3/yr		
BOD				
TSS	49,711	kg/yr	200,000	mg/L
VSS	31,814	kg/yr	127,994	mg/L
VSS Dig	47,720	kg/yr		

DEWATERED DSS				
Flow	204.5	m^3/yr		
BOD				
TSS	40,906	kg/yr	200,000	mg/L
VSS	7,127	kg/yr	34,845	mg/L
VSS Dig	10,690	kg/yr		

Notes

BOD	5-day Biochemical Oxygen Demand
BOD Lab	5-day Biochemical Oxygen Demand measured by Lab
BOD Red	5-day Biochemical Oxygen Demand Reduction
DO	Dissolved Oxygen Measured by Laboratory
N2	Nitrogen Gas Generation
TKN	Total Kjeldahl Nitrogen
TKN Lab	Total Kjeldahl Nitrogen Measured by Lab
TKN Red	Total Kjeldahl Nitrogen Reduction
TP	Total Phosphorus
TP Lab	Total Phosphorus Measured by Lab
TP Red	Total Phosphorus Reduction
TSS	Total Suspended Solids
TSS Lab	Total Suspended Solids Measured by Lab
TSS Red	Total Suspended Solids Reduction
VSS	Volatile Suspended Solids
VSS Dig	Volatile Suspended Solids Digested percentage
VSS Lab	Volatile Suspended Solids Measured by Lab
VSS Red	Volatile Suspended Solids Reduction

Figure 4-4 Mass Balance for Winter at Average Dry Weather Flow

5.0 PROCESS UNITS

This section defines the physical and engineering considerations for each of the key process units, including process design summaries. As part of the assessment of engineering considerations, staging of equipment capacity has been considered to facilitate future upgrades.

5.1 SEPTAGE RECEIVING STATION

The objective of this section is to evaluate septage characteristics and its impact on the proposed wastewater treatment plant in order to develop a strategy to deal with future septage loads.

The wastewater lagoons do not currently receive truck hauled septage from holding tanks from the surrounding area. Hauled septage is currently applied to land by either mixing the septage into the subsurface or applying the septage directly to the surface. This practice will be reviewed by the City and RM to determine the best course of action from a regional standpoint.

5.1.1 Hauled Waste

Hauled waste can be classified as heavy grit waste and septage. Heavy grit waste is material that has been gathered using a vacuum truck out of grit tanks, manholes, and sewers, and may contain heavy residual materials from a liquid waste pump out. Generally, heavy grit waste must be dumped and cannot flow by gravity through the decanting line.

Septage is a liquid or solids material removed and hauled from septic tanks, holding tanks, pit toilets, or similar systems that receives only domestic waste. Septage does not include process wastewater from commercial or industrial processes or wastes from grease traps. Septage contains water, settled organic and inorganics solids (rocks, silverware, phone, grease, grit, hair, rags, gloves, plastic, hypodermic needles, and sanitary hygiene products), scum, soluble inorganic materials and microorganisms (viruses, bacteria, and parasites). Septage is characterized by objectionable odour, a resistance to settling and dewatering, and the potential to foam. Wastewater from portable toilets has higher concentrations of pathogenic organisms and nutrients than wastewater from septic tanks. Wastewater from recreational vehicles and portable toilets might contain chemicals such us odour control, antibacterial and disinfectants.

This section of the report is developed to determine the feasibility of receiving septage at the WWTP. Heavy grit waste will not be accepted at the WWTP.

5.1.2 Septage Flow

The expected number of septic trucks to be received is unknown since the existing lagoon-based system does not receive septic haulers. For the purpose of this report, it is assumed that four trucks with an average load volume of 6 m^3 would be received per day.

5.1.3 Septage Characteristics and Loads

The expected septage characteristics to be received are unknown and typical values reported in textbooks vary depending on its source. However, two sources of information are provided in this report for the purpose of discussion. Table 5-1 lists typical septage characteristics for the City of Regina as reported in the “Final Report for Septage Dumping Facility Preliminary Investigation - 2001”. Table 5-1 lists typical septage characteristics for North America as reported in the “US EPA Handbook, Septage Treatment and Disposal”. These values are compared with average wastewater characteristics for Humboldt. These tables also present the pollutant load which was calculated by multiply the septage volume or the plant current average daily times the pollutant concentration. The ratio of septage to sewage load for each pollutant was calculated by dividing the septage load (column 2) by sewage load (column 4).

Table 5-1 Septage Characteristics and Load Based on City of Regina WWTP Data

Parameter	Septage Based on Typical Load Discharged at the Regina WWTP		City of Humboldt Sewage		Ratio of Septage to Sewage Load
	Concentration	Septage Load	Concentration	Sewage Load	
	mg/L	kg/d	mg/L	kg/d	% wt/wt
Column	(1)	(2)	(3)	(4)	(5)
Carbonaceous 5 day Biological Oxygen Demand ($CBOD_5$)	282	6.8	194	519	2
Suspended Solids	5,597	134.3	212	567	24
Chemical Oxygen Demand (COD)	5343	128.2	427	1,142	12
Phosphorus	15	0.4	7.4	20	2
Fat Oil and Grease (FOG)	108	2.6	100	268	1
Volume per day, m^3		24		2,675	0.9

Table 5-2 Septage Characteristics and Load Based on EPA Handbook, Septage Treatment and Disposal

Parameter	Septage Based on US EPA Handbook		City of Humboldt Sewage		Ratio of Septage to Sewage Load
	Concentration	Septage Load	Concentration	Sewage Load	
	mg/L	kg/d	mg/L	kg/d	% wt/wt
Column	(1)	(2)	(3)	(4)	(5)
Carbonaceous 5 day Biological Oxygen Demand ($CBOD_5$)	7,000	168	194	519	33
Suspended Solids	15,000	360	212	567	64
Chemical Oxygen Demand (COD)	15,000	360	427	1,142	32
Phosphorus	250	6	7.4	20	31
Fat Oil and Grease (FOG)	8,000	192	100	268	72
Volume per day, m^3		24		2,675	33

The results presented in these tables indicate that although a septic truck volume contribution to the City sewage flow is negligible (less than 1%, based on a septic truck hauling volume of 6 m^3 and the plant current average daily flow of 2,675 m^3/d), it can contribute significantly to the pollutant mass loading in the incoming sewage. This is because a single septic load has very high pollutant concentration in comparison to the City's sewage. For instance, suspended solids (SS) and Chemical Oxygen Demand (COD) mass loads entering the plant would be increased by a factor of 24 to 64% and 12 to 32%, respectively, after discharge of septage loads depending on its strength. If the septic load were to be discharged in a very short period (about 20 min) to the new WWTP, the process will not be able to handle such a high strength shock load because the pollutant load from the septage will overwhelm the treatment capacity of the biological process (dilution ratio of 16%, SS and COD mass loads increased by 426 to 1,143% and 200 to 570%, respectively). Consequently, if the septage load is to be discharged into the sewer collection system or at the WWTP, a septic flow balancing tank, a septage volume based standard and a sewer use by-law standard would be required to protect the biological process at the WWTP from high strength septage discharge.

5.1.4 Dedicated Septage Cell

A septage cell will be required to ensure that septage shock loadings would not negatively affect the plant performance. The septage cell should be designed to store 1% of the average daily design flow of the plant. The stored septage volume would then be blended with the plant influent over a 24-hour period.

5.1.5 Septage Volume Based Standard

Based on the presented analysis, it is suggested that a septage volume based standard be set based on Alberta Environment Recommended Standard and Guidelines for Construction, Operation and Monitoring of Septage Management Facilities - 2008. This guideline states: “The maximum daily volume of septage received for co-treatment by a WWTP without completion of a pre-treatment assessment shall not exceed 1% of the average daily design flow for that facility. In no case shall the quantity or quality of sewage received cause any design parameter or discharge license limit of that WWTP to be exceeded or have an adverse effect on sludge handling practices.”

5.1.6 Sewer Use Bylaw Standard

A sewer use by-law standard would be required to protect the new wastewater treatment plant from the discharge of high strength load from a septage pretreatment facility. Septic loads that should not be accepted at the new wastewater treatment plant include hydrovac, carwash and carpet cleaners due to their excessive concentrations of grit and surfactants. Sewage discharge quality from an independent septage receiving station should not exceed the limits imposed by a sewer use by-law standard. The following maximum concentration limits are suggested for Humboldt based on the 2008 - City of Saskatoon sewer use bylaw consultations.

Table 5-3 Suggested Sewer Use Bylaw Maximum Concentration Limits

Parameter	Unit	Maximum Concentration Limit
Carbonaceous 5 day Biological Oxygen Demand ($CBOD_5$)	mg/L	300
Suspended Solids	mg/L	300
Chemical Oxygen Demand (COD)	mg/L	600
Total Kjeldahl Nitrogen (TKN)	mg/L	100
Phosphorus	mg/L	10
Fat Oil and Grease (FOG)	mg/L	100
Oil and Grease (Petroleum)	mg/L	15
Sulphate	mg/L	2,000
Sulphide	mg/L	1
Aluminum	mg/L	50
Arsenic	mg/L	1
Boron	mg/L	50
Cadmium	mg/L	0.2
Chromium	mg/L	4
Cobalt	mg/L	5
Copper	mg/L	3
Iron	mg/L	10
Lead	mg/L	5
Manganese	mg/L	1
Mercury	mg/L	0.05
Molybdenum	mg/L	1
Nickel	mg/L	2
Silver	mg/L	1
Tin	mg/L	5
Zinc	mg/L	3
Benzene	mg/L	1
Cyanide	mg/L	1
Phenol Compounds	mg/L	0.1
Toluene	mg/L	1
Xylene	mg/L	1
pH range	unitless	5.5 to 9.5
Maximum Temperature	°C	65

Enforcement of a sewer use by-law standard can be challenging for a medium size WWTP. The City can include random sampling and analysis as part of the operating permit for the pre-treated effluent discharged by any user. A sampling and analysis program would hold any user accountable for the quality of wastewater discharged into the system. The implementation of a sewer bylaw standard would reduce the frequency and duration of potential plant upsets due to discharge of high strength loads.

5.1.7 Liquid Waste Pre-treatment

There are four basic options for pre-treatment of liquid wastes prior to discharge into the domestic wastewater flow upstream of the WWTP. These pre-treatment steps are as follows:

- Rock removal (using a separate rock trap which is easy to clean)
- Grinding (using a separate in-line grinder)
- Screening
- Grit removal

The use of one or more of these pre-treatment processes will depend on the typical characteristics of the liquid waste to be accepted and where the liquid waste will be discharge for treatment.

When the liquid waste received for disposal consists mainly of domestic septage pumped out of septic tanks, only screening is typically required. If open bottom cesspools are common in the pump-out service area, then a separate rock trap is beneficial. Rocks are trapped in the screen unit but are more difficult to remove versus a separate rock trap.

If portable toilet wastes will be accepted, the addition of a grinder prior to the screen should be considered to handle the vast array of material that can be in this waste (towels, cloths, blankets, etc).

Almost all liquid waste contains large solids (rock, silverware, screws, gloves, and phones) stringy materials (rags, hair, flushable wipes), smaller plastics, non-sanitary materials and sanitary hygiene products that accumulate prior to pump-outs. Without adequate pre-treatment, this material can overload downstream treatment processes, and has the potential to cause clogging of pipes, pumps and other equipment. A screening step is highly recommended for pre-treatment of liquid waste prior to discharge into the domestic wastewater flow upstream of the WWTP. Generally, a fine screen is used with 6 to 8 mm bar spacing or perforated plate openings.

Liquid wastes can contain heavy grit which can cause problems if it settles out in tanks and downstream sewer lines. Also, decant from heavy grit loads can contain some residual grit. Generally, grit removal should be provided if the pre-treated liquid waste will be held in a storage tank or discharged to an interceptor sewer with a flow velocity less than 1 m/s.

5.1.8 Septage Recommendations

A preliminary analysis of the projected septage loads indicates that the impact of the septage in the plant would be significant, particularly if the liquid waste is discharged in less than 20 minutes. For a system with a long hydraulic retention time such as the SAGR, the septage load would not affect its treatment performance. However, septage could affect its treatment performance if septage screening is not conducted.

Including a septage receiving station with the new WWTP would provide a valued service and help support regional growth. However, past experiences from other plants have shown that septic loads can upset wastewater biological treatment processes due to the high concentration of pollutants. The cost of building a septage screening station could range from $5M to $10M. Due to the added cost and operation challenges, the City decided that septage would not be received at the WWTP.

5.2 PRELIMINARY TREATMENT

The key components of the Preliminary Treatment include:

- Influent Splitting Structure (ISS)
- Influent flow monitoring

The following sections provide a brief discussion and design basis for each of the above components.

5.2.1 Influent Splitting Structure (ISS)

The proposed WWTP will combine influent wastewater from the lift stations and NML recycle pumps. This chamber will also split flows to the anoxic cells, if desired by operations. This will be accomplished with two weir gates installed in the chamber. The weirs will be manually operated to direct the flow to either anoxic cell 1 or 2 or to equalize flow to each anoxic cell.

A 5.1 m (L) x 5.1 m (W) x 5.8 m (H) chamber is required with two 1.5 m long weirs. Sizing of the ISS is based on keeping the water depth over the weir below 75 mm at MWF.

5.2.2 Influent Flow Monitoring

Influent flow measurement is critical to monitor the daily, hourly and instantaneous peak flows entering the plant. This information is required to issue alarms for plant operators to open the standby transfer pipes, should the freeboard in the lagoons be significantly reduced due a major storm event. Instantaneous and total daily flows will be measured by magnetic flow meters and recorded by the WWTP Supervisory Control and Data Acquisition (SCADA) system. These flow meters will be installed in the 400 mm diameter pipes that convey sewage from the ISS to the anoxic cells. Preliminary location of these chambers is shown in Appendix B Figure D-101.

5.2.3 Influent Sampling

Ideally wastewater sampling of the influent should be conducted prior to the introduction of any recycle flows produced by the plant that may influence the results of the sample. However, this is not possible without adding another structure upstream of the ISS. Therefore, it is suggested that a refrigerated composite sampler be located in the main lift station if the City wishes to monitor wastewater characteristics on a weekly or biweekly basis.

5.3 SECONDARY TREATMENT PROCESS

As discussed previously, the secondary process design would be based on the aerated lagoons followed by a SAGR process without the use of primary clarifiers to meet the effluent criteria presented in Section 2.8 of this report.

This process consists of anoxic cells, aerated cells, and SAGR cells to achieve biological reduction of organic carbon and nitrogen in the wastewater as shown in Figure 5-1. The cells will operate in series. Blowers convey air to the diffusers through an HDPE header buried along the aerated cells and floating laterals. The fine bubble diffusers are suspended near the bottom of the aerated cells with marine-grade rope directly under the lateral. The rope is attached to the floating header to facilitate diffuser retrieval. Each diffuser is attached to a small concrete weight, encased in HDPE pipe. Laterals are secured against wind action with stainless steel cables that will be fastened to anchors in the lagoon berm. Effluent from the aerated cells is directed to the settling cell through a pipe and a series of manholes where alum is injected for the removal of phosphorus. Effluent from the settling cell flows by gravity to a splitter box and into four SAGR cells operated in parallel. The SAGR cells consist of earthen cells with geomembrane liner, influent distribution laterals/chambers and a treated effluent collection chamber. The linear diffusers in the SAGR cells are spaced along the length of the cells. The diffusers are secured to the bottom of the cell and covered with a layer of clean gravel. The gravel bed is covered with a layer of peat or mulch over a non-woven geotextile for insulation as shown in Figure 5-2, Figure 5-3 and Figure 5-4.

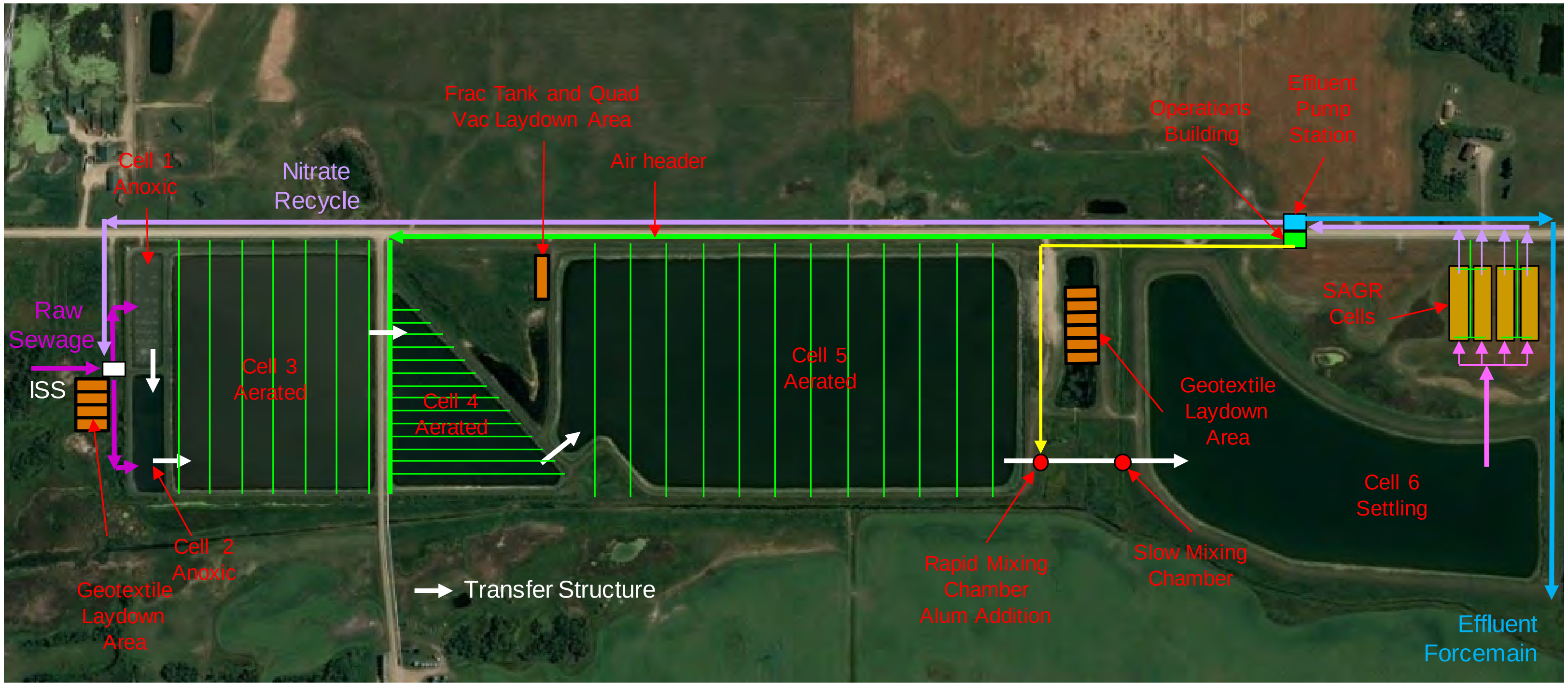


Figure 5-1 Aerated Lagoons / SAGR Process Configuration

Figure 5-2 Aerated Cells and SAGR (top left), Blowers (bottom left) and Fine Bubble Diffusers (right)

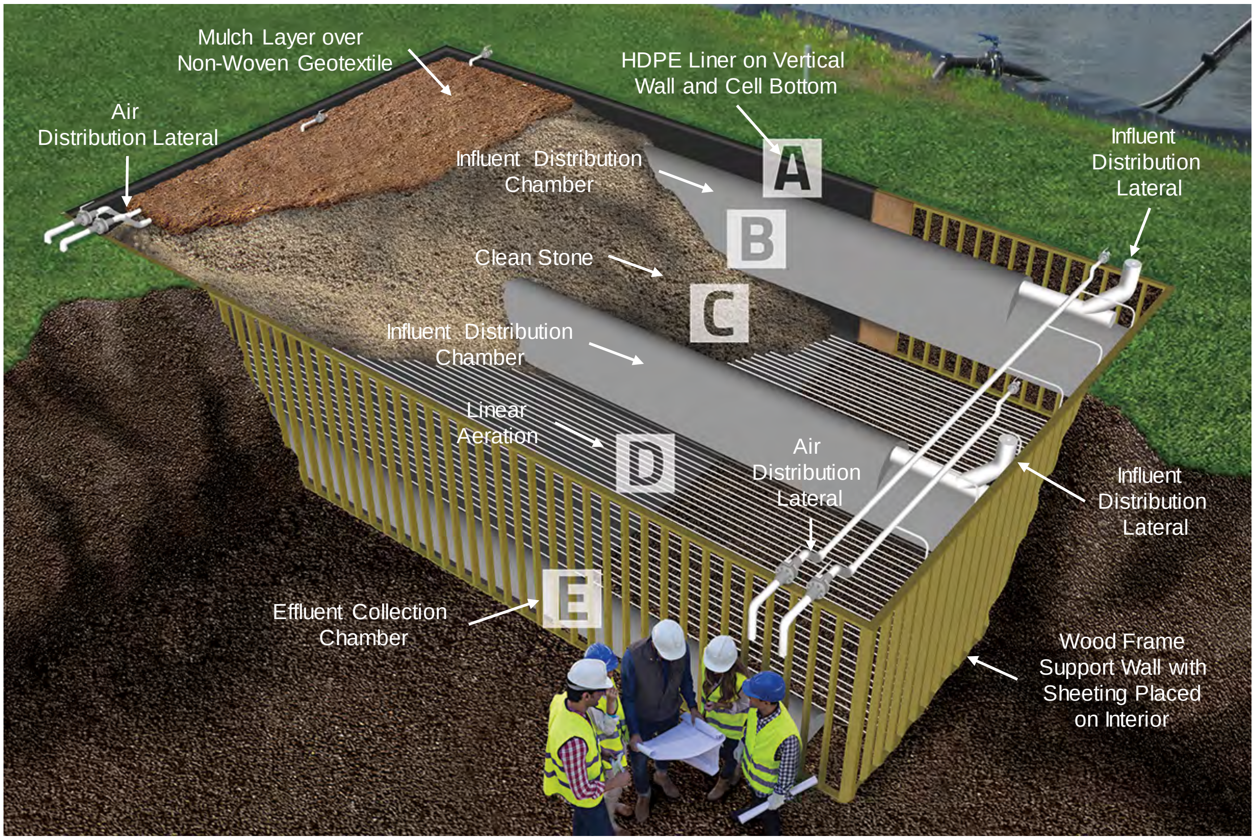


Figure 5-3 SAGR Cell 3D Rendering

The aerated lagoons / SAGR process will allow the City to retain the existing infrastructure but not without significant work such as sludge dredging and berm repairs. This process operates at low Mixed Liquor Suspended Solids (MLSS) to reduce BOD loads and requires large aerated lagoons. The SAGR cells used for nitrification require a large volume of stone fill and have a large footprint. The aerated lagoons / SAGR process also provides sludge digestion and the aerated cells are shallower than concrete tanks. One of the main advantages of the aerated lagoons / SAGR process is the ease of operation, the ability to adequately handle fluctuating flows and long sustained peak hourly flows due to high retention time in the cells.

This process is flexible enough for expansion beyond 2052 by the addition of two more SAGR cells and replacement of the blowers and diffusers with units that can provide more airflow. No additional earth work would be required. The proposed capacity of the aerated cells is sufficient to meet a population growth to 13,500 people.

Preliminary sizing of the aerated lagoons / SAGR system is based on Nexom Technologies and is summarized in Table 5-4.

Figure 5-4 SAGR Components

Sacrificial Frame Support (top left), Influent Laterals (top right), Linear Diffusers (middle left), Linear Diffusers and Effluent Collection Chamber (middle right), Chambers Being Covered with Stones (bottom left), and Non-Woven Geotextile over Air Distribution Laterals (bottom right)

Table 5-4 Aerated Lagoons / SAGR Design Summary

Parameter	Unit	Nexom Design
Design Summary		
Design flow rate (MMF)	m^3/d	7,235
Total lagoon volume	m^3	636,850
Cell 1 Anoxic, volume at 2.83 m FSL	m^3	9,740
Cell 2 Anoxic, volume at 2.81 m FSL	m^3	9,640
Cell 3 Aerobic, volume at 1.52 m FSL	m^3	88,360
Cell 4 Aerobic, volume at 1.50 m FSL	m^3	34,580
Cell 5 Aerobic, volume at 2.28 m FSL	m^3	280,010
Cell 6 Settling, volume at 2.81 m FSL	m^3	214,520
Lagoons Hydraulic Retention Time (HRT)	d	88
SAGR Cell, volume at 2.25 m FSL	m^3	26,035
SAGR number of trains	qty	2
SAGR number of cells per train	qty	2
SAGR cell dimensions (width, length, and side water depth)	m	32 x 90 x 2.26
SAGR cells HRT	d	3.6
Aerated Lagoon Blower Design Summary		
Total airflow requirements at 20°C, 101 kPa -Spring	m^3/h (SCFM)	4656 (2739)
Number of diffusers in cells 3, 4 and 5	qty	222
Number of blowers	qty	2 (2 duty / 0 standby)
Capacity per blower	m^3/h (SCFM)	2330 (1370)
Discharge pressure	kPa (psi)	28 to 37 (4.0 to 5.4)
Motor power	kW (HP)	37 (50)
SAGR Blower Design Summary		
Total airflow requirements	m^3/h (SCFM)	4416 (2598)
Total number of blowers	qty	3 (2 duty / 1 standby)
Capacity per blower	m^3/h (SCFM)	2265 (1332)
Discharge pressure	kPa (psi)	37 to 64 (5.4 to 9.4)
Power	kW (HP)	75 (100)
Lagoons standby aeration provided by SAGR blowers		

5.3.1 Aeration System

5.3.1.1 Blowers

Initially, five variable speed positive displacement blowers will be provided to supply air to the aerated lagoons and SAGR cells. Low pressure air from the blowers is discharged through aeration piping into the fine bubble diffuser system in each cell. Two 37 kW (50 HP) blowers can deliver 100% of the oxygen requirements for all the aerated lagoons for the design year of 2052. Two 56 kW (100 HP) blowers can deliver 100% of the oxygen requirements for all the SAGR cells. The third 56 kW (100HP) blower is a standby for either the aerated lagoons or the SAGR cells. The blowers will alternate duty and standby to evenly distribute the run time for each blower. Table 5-4 presents the design data for the aeration system. A process flow diagram for the process blowers is shown in Figures DI-601 in Appendix B.

Air flow requirements to the SAGR cells will be regulated by portable dissolved oxygen probes. The blower speed is entered in the logic control system interface by the operation’s staff to maintain a dissolved oxygen of 2 mg/L. As the dissolved oxygen level changes due to varying influent load seasonally, the operator will only need to change the blower speed setting four times per year to meet the new required air flow rate.

5.3.2 Rapid Mix and Slow Mix Chambers

The WWTP will utilize a 1.8 m diameter by 4.75 m high manhole as a rapid mix chamber and a 2.3 m diameter by 4.75 m high manhole as a slow mix chamber. The rapid mix chamber will be mixed with a 1.5 kW (2 HP) vertical mixer with two pitched blade turbines per shaft. The slow mix chamber will be mixed with a 0.56 kW (0.75 HP) vertical mixer with two blade hydrofoil type impellers per shaft.

5.3.3 SAGR Influent Splitting Structure

The WWTP will use a splitter box to evenly split the flow to the four SAGR cells. This will be accomplished with eight weir gates installed in the box. Isolation of each SAGR cell will be achieved by manually lifting the weir gates and closing the associated buried plug valves. A 6.2 m (L) x 6.2 m (W) x 3.13 m (H) chamber will be required with eight 0.9 m long weirs. Sizing of the SAGR influent splitting structure was based on keeping the water depth over the weirs below 75 mm at MWF.

5.3.4 SAGR Effluent Level Control Manholes

The WWTP will use four effluent level control manholes (1.5 m diameter by 2.64 m high) to maintain the water depth in the SAGR cells at about 2.1 m. This will be accomplished with a 0.3 m diameter standpipe installed inside the manhole. Isolation of each SAGR effluent level control manholes will be achieved by manually closing the associated buried plug valves. Sizing of the SAGR effluent level control manholes was based on keeping the water depth over the standpipe below 85 mm at MWF.

5.3.5 Secondary Effluent Tank

A secondary effluent tank will to serve as a wet well for the NML pumps and to provide flow to the UV reactor. Isolation of the SE tank will be achieved by manually closing the associated buried plug valves. A 4 m (L) x 4.75 m (W) x 6.9 m (H) tank will be required with one 600 mm pipe fed from the last SAGR effluent level control manhole and one 300 mm diameter pipe feeding the UV reactor.

The secondary effluent tank will be equipped with two 5.6 kW (7.5 hp) centrifugal pumps with built-in variable frequency drive to transfer NML from the tank to the ISS via a 250 mm HDPE forcemain with a total length of 1.5 km. The pumps will be operated on a duty-standby mode. The pumping rates would be adjusted by variable frequency drives up to a maximum of 4,050 m^3/d at a TDH of 8.0 m, which corresponds to the ADF for year 2052.

5.3.6 Ultraviolet Disinfection

UV disinfection involves the use of ultraviolet radiation to inactivate pathogens in the wastewater. UV radiation is a physical and not a chemical disinfectant. UV radiation between the wavelength of 235 and 270 nanometres (nm) has been found to be effective to inactivate the target pathogenic organisms found in wastewater effluents. A UV disinfection system transfers electromagnetic energy from a mercury arc lamp to an organism's genetic material (Deoxyribonucleic Acid (DNA) and Ribonucleic Acid (RNA)). When the UV radiation penetrates the cell wall of the microorganism, the microorganism is inactivated and rendered unable to reproduce or infect.

The main components of the UV disinfection system are UV lamps, UV channel, lamp ballasts and control panel. The UV lamps can be configured in a horizontal configuration. The UV channel will be designed to meet the requirements for design year 2052. The channel will be constructed with a width of 396 mm. Water level in the channel will be maintained by a 7 m long fixed finger weir. No inlet gate is required to isolate the channel since there are upstream manual valves that can be used for isolation.

Preliminary sizing of the UV system based on a horizontal low pressure high output lamp complete with chemical/mechanical cleaning is summarized in Table 5-5. The UV disinfection floor plan is shown in Figure D-103 and a process flow diagram shown in Figure D-601 in Appendix B.

Table 5-5 UV Disinfection Design Summary

Parameter	Unit	Stage 2
Number of units	qty	1
Maximum design flow	m^3/d	9,722
Fecal coliform disinfection target	E-coli/100mL	200
UV transmittance	%	50
Total suspended solids	mg/L	20
UV dosage	mWs/cm^2	30
Number of UV channels	qty	1
Channel length	mm	10,532
Channel width	mm	305
Channel depth	mm	1327
Channel water depth	mm	776
Number of banks	qty	2
Number of modules	qty	3
Number of lamps per module	qty	8
Total number of lamps	qty	48
Maximum power draw (2 PDC)	kVA	17.4

Parameter	Unit	Stage 2
Number of Power Distribution Centers (PDC)	qty	2
Number of system control centers	qty	2
Type of level controller		Weir
Weir length	m	7.265
Type of cleaning		Automatic chemical/mechanical cleaning
Inlet diameter	mm	300

5.3.7 Final Effluent Tank

A final effluent (FE) tank will serve as a wet well for the FE pumps and to receive flow from the UV disinfection reactor. Isolation of the FE tank will be achieved by manually closing the associated butterfly valves. A 14 m (L) x 4 m (W) x 6 m (H) tank will be required with one 300 mm pipe fed from the UV reactor and two 200 mm diameter pipes feeding the FE pumps.

5.3.8 Final Effluent Pump Station

The final effluent tank will be equipped with four centrifugal pumps with variable frequency drive to pump final effluent from the tank to the outfall at Humboldt Lake via a 400 mm diameter HDPE forcemain with a total length of 4.9 km. The pumps will be operated on a Lead 1 / Lag 2 / Lead 2 / Lag 2 mode and the pumping rates will be adjusted by variable frequency drives. It is estimated that one 5.5 kW pump will deliver 7,775 m^3/d (90 L/s) at a TDH of 3.15 m, two 5.5 kW pumps in parallel will deliver up to 9500 m^3/d (110 L/s) at a TDH of 7.8 m, and one 18.4 kW pump will deliver 9,720 m^3/d (112 L/s) at a TDH of 8.0 m

5.3.9 Non-Potable Water Pumps

Non-potable water (W3) is needed for process equipment demands throughout the facility, such as the hose washdown stations. The W3 pump station will be located over the FE tank and will pump disinfected plant effluent. The pump station consists of two close couple horizontal centrifugal pumps, an automatic backwash strainer, piping, valves, and other appurtenances. There will be a manual bypass around the strainer.

Pump station operation will be based on a pressure control loop with pumps in a duty/standby configuration. Each pump will have a maximum 5 L/s capacity at 470 kPa (68 psi) total dynamic head. Sodium hypochlorite will be injected into the W3 to minimize re-growth of pathogens.

5.3.10 Treated Effluent Flow Monitoring

An in-line magnetic flow meter will be provided on the discharge piping from the FE pumps to monitor the flow discharged to Humboldt Lake. Instantaneous and total flows will be recorded and tracked by the WWTP SCADA system.

5.3.11 Safety

Flotation rings will be provided along the lagoon berms. Davit bases for portable cranes will be installed to connect lifelines for access into chambers and tanks.

5.4 OUTFALL STRUCTURE

The outfall pipe and associated structure will discharge the projected maximum pump design flow of 112 L/s at the published safe building elevation of 553.00 m at Humboldt Lake. WSA advised that underwater discharge is generally more publicly acceptable than bank discharges. The details of the type of outfall structure will be determined during detailed design and after a topographical survey and geotechnical investigation of the site. Additional description of the outfall pipeline route is presented in the civil design criteria section.

5.4.1 Outfall Considerations

A water level elevation of 551.28 m was observed during the site survey work that took place in August 2019. The Humboldt Lake History - Lanigan Dellwood Brook - Saskatchewan Watershed Authority report provided by the City does not list the 1:500 flood level. It only states that “there is much development that has occurred below the safe building elevation of 1814.2 ft (553.0 m) that was established more recently by Saskatchewan Watershed Authority during the subdivision process for Humboldt Lake Resort.” The report also noted a water level reading of 1813.41 ft (552.7 m) during spring runoff in 2016 and 2017.

5.5 SLUDGE PROCESSING AND DISPOSAL

Sludge management consists of passive stabilization (non-assisted by mechanical aeration) of the sludge settled in the anoxic cells and chemical sludge settling cell; and active stabilization (assisted by mechanical aeration) of the sludge settled in aerated cells. The sludge treatment option involves thickening, passive or active stabilization and dewatering. A review of the different biosolids application options shows that biosolids produced by the aerated lagoons and SAGR cells are suitable for land application or landfilling. Refer to Technical Memorandum 4 - Identification of Sludge Management Options.

5.5.1 Sludge Processing Train

The sludge processing train will consist of the following units:

- Lagoon sludge thickening/stabilization and storage
- Sludge dewatering
- Final disposal/beneficial reuse as land application or intermediate landfill cover

A summary of the preliminary design is provided in the following sections.

5.5.2 WAS Generation and Pumping

The WWTP will generate three types of sludge: Primary Digested Sludge (PDS) from anoxic cells, Secondary Digested Sludge (SDS) from the aerated cells and Digested Chemical Sludge (DCS) from Cell 6. Sludge generation has been estimated and is listed in Table 5-6.

5.5.3 Sludge Thickening/Stabilization and Storage in Lagoons

For the liquid treatment (aerated lagoons / SAGR), lagoon thickening/stabilization consists of passive stabilization (non-assisted by mechanical aeration) of the sludge settled in the anoxic cells and active stabilization (assisted by mechanical aeration) of the sludge settled in cells 3, 4 and 5. In the anoxic and aerated cells, sludge settled at the bottom of the cells is thickened and stabilized simultaneously as the soluble organic matter in the sludge is either aerobically and anaerobically digested and the sludge compressed to reach a solids concentration in the range of 2% to 4%.

Passive stabilization can provide volatile solids destruction greater than 38% if sludge is left to digest for a year before dewatering. The degree of pathogen reduction achieved in the anoxic cells is a function of the time of sludge isolation and temperature. For this reason, incoming sewage should not be redirected to the sludge cell to be dewatered. After confirmation that the sludge has been stabilized, the digested sludge is ready for land application or landfilling.

Table 5-6 Anticipated Sludge Waste Generation

Year	Mass of PDS kg/yr	Volume of PDS m^3/yr	Volume of Dredged PDS m^3	Mass of SDS kg/yr	Volume of SDS m^3/yr	Volume of Dredged SDS m^3	Mass of DCS kg/yr	Volume of DCS m^3/yr	Volume of Dredged DCS m^3
2020	58,042	2,902		28,560	1,428		29,821	1,491	
2021	58,953	2,948		29,008	1,450		30,288	1,514	
2022	59,863	2,993		29,456	1,473		30,756	1,538	
2023	60,773	3,039		29,904	1,495		31,224	1,561	
2024	61,684	3,084	14,966	30,352	1,518		31,692	1,585	
2025	62,594	3,130		30,800	1,540		32,160	1,608	
2026	63,505	3,175		31,248	1,562		32,627	1,631	
2027	64,415	3,221		31,696	1,585		33,095	1,655	
2028	65,553	3,278		32,256	1,613		33,680	1,684	
2029	66,464	3,323	16,127	32,704	1,635		34,148	1,707	
2030	67,374	3,369		33,152	1,658		34,615	1,731	
2031	68,512	3,426		33,712	1,686		35,200	1,760	
2032	69,423	3,471		34,160	1,708		35,668	1,783	
2033	70,561	3,528		34,720	1,736		36,253	1,813	
2034	71,699	3,585	17,378	35,280	1,764		36,837	1,842	24,903

Year	Mass of PDS kg/yr	Volume of PDS m^3/yr	Volume of Dredged PDS m^3	Mass of SDS kg/yr	Volume of SDS m^3/yr	Volume of Dredged SDS m^3	Mass of DCS kg/yr	Volume of DCS m^3/yr	Volume of Dredged DCS m^3
2035	72,610	3,630		35,728	1,786		37,305	1,865	
2036	73,748	3,687		36,288	1,814	27,452	37,890	1,894	
2037	74,886	3,744		36,849	1,842		38,474	1,924	
2038	76,024	3,801	14,863	37,409	1,870		39,059	1,953	
2039	77,162	3,858		37,969	1,898		39,644	1,982	
2040	78,300	3,915		38,529	1,926		40,229	2,011	
2041	79,438	3,972		39,089	1,954		40,813	2,041	
2042	80,576	4,029	15,774	39,649	1,982		41,398	2,070	
2043	81,942	4,097		40,321	2,016		42,100	2,105	
2044	83,080	4,154		40,881	2,044		42,684	2,134	
2045	84,446	4,222		41,553	2,078		43,386	2,169	
2046	85,584	4,279	16,753	42,113	2,106		43,971	2,199	24,348
2047	86,949	4,347		42,785	2,139		44,672	2,234	
2048	88,315	4,416		43,457	2,173		45,374	2,269	
2049	89,453	4,473	13,236	44,017	2,201		45,959	2,298	
2050	90,819	4,541		44,689	2,234		46,661	2,333	
2051	92,185	4,609		45,361	2,268		47,362	2,368	
2052	93,323	4,666	13,816	45,921	2,296	33,029	48,039	2,402	13,903
Total	**2,458,254**	**122,913**	**122,913**	**1,209,617**	**60,481**	**60,481**	**1,263,084**	**63,154**	**63,154**

Active stabilization will occur in the aerated cells since the aeration system provides oxygen not only for degradation of organic matter but also for biodegradation of the sludge settled at the bottom of the lagoons between the diffusers. Active stabilization can provide volatile solids destruction greater than 38% if the aeration system is managed to always maintain a dissolved oxygen greater than 2.0 mg/L.

5.5.4 Dewatering

Dewatering is required to reduce the water content of the digested sludge from 2% to 20% to minimize transportation and disposal costs, to improve sludge handling, and to meet landfill disposal requirements. Sludge dewatering can be accomplished mechanically using centrifuges, or non-mechanically using geotextile containers. A centrifuge operates by allowing the polymer conditioned sludge to enter a stationary tube where it is fed into a rotating bowl that contains an accelerating inlet rotor. The rotor rotates at speeds up to 3,400 revolutions per minute, creating a centrifugal force that pushes solids to the outer wall of the bowl. Solids are conveyed out of the unit, and the separated liquid (centrate) is returned to the cell being dewatered. Geotextile containers are a high strength permeable bag where polymer conditioned sludge is pumped and filtrate escapes through the pores of the fabric while retaining the solids. Filtrate is typically collected and returned to the cell being dewatered.

The option of de-sludging the cells using geotextile containers provides flexibility to the City as the cake can be left in the geotextile containers during one freeze and thaw cycle to increase the cake dryness and provide the storage required before use. This in turn will allow the City to achieve better odour management since cake hauling can be conducted when the prevailing wind direction is away from the City. It is expected that the City will coordinate sludge dewatering during summer months.

It is estimated that six geotextile containers will be required to dewater 43,500 m^3 at 2% DS of digested sludge stored in the cells. Each geotextile container with a circumference of 36 m and a length of 30 m can be filled with approximately 723 m^3 of sludge. The resulting volume and mass of dewatered sludge retained in the geotextile containers at 20% solids would be 4,350 m^3 or 870 tonnes DS. A laydown area 115 m long by 30 m wide with a v-notch trench will be required to deploy the 6 containers, as shown in Figure 5-5.

Figure 5-5 Lagoon De-sludging Using Geotextile Containers

5.5.5 Final Disposal/Beneficial Reuse

Two biosolids disposal options are provided to ensure that biosolids are managed properly. These options are land injection and landfilling. WSA requires municipal sludge disposed on land to be in conformance with Saskatchewan Land Application of Municipal Sewage Sludge Guidelines (EPB-296). EPB-296's primary concern regarding biosolids application to agricultural land, are minimizing pathogens and heavy metals content. Further discussion of regulatory requirements is provided in Technical Memorandum No. 4 - Identification of Sludge Management Options.

5.5.6 Land Injection of Biosolids

The City can hire a contractor to dredge, transport and land inject liquid sludge at 2% solids from any of the cells using mobile sludge injection equipment (QuadVac), which would be loaded from the frac tank and travel from the lagoon to a farm, cross the field cutting a furrow, injecting the sludge, and then turning over the furrowed soil to cover the sludge. The QuadVacs are completely enclosed containers, designed to mitigate a potential sludge spill and odour emissions during transportation and injection, as shown in Figure 5-6.

Sludge dredging and land injection frequency varies depending on the capacity of the cells as listed in Table 5-6. Sludge should be dredged initially every 5 years from the anoxic cell, every 17 years from the aerated cells and every 15 years from the settled cell. Sludge sampling and soil analysis should be conducted prior to dredging to ensure regulatory requirements have been met. It is expected that the City will coordinate sludge dredging and pre and post application soil testing and reporting.

5.5.7 Landfilling of Biosolids

The City can also hire a contractor to dredge, dewater and transport sludge from the dewatering sites to the landfill, which is located 30 km from the WWTP. Sludge dredging and dewatering should be conducted with the same frequency described earlier. Dewatered biosolids should be stockpiled at the landfill and blended with native soil or other material if required to be applied as cover on the landfill. It is expected that the revenue generated by the biosolids sale as intermediate landfill cover offsets the solids management operating cost.

Figure 5-6 Frac Tank (top) Coarse Screen (bottom left), QuadVac (bottom right)

5.5.8 Laydown Areas

Construction of laydown areas is required for deployment of portable geotextiles or centrifuges.

- A laydown area of 80 m by 30 m with a v-notch trench north of cell 1 for de-sludging of anoxic cells

- A laydown area of 5 m by 40 m north of the cell 5 to facilitate de-sludging using Frac Tanks and QuadVacs
- Desludging nutrient removal cell to be reused as a laydown area for de-sludging of aerated cells or settling cells using geotextile containers. The floor level of nutrient removal cell will be raised by 1.4 m to increase the width of the lagoon from 21 m to 32 m and thus facilitate the laydown of the 30 m long geotextiles
- The existing road is not adequate to facilitate hauling liquid or solid biosolids to agricultural land or to the landfill and therefore will require upgrades to accommodate.

5.6 ODOUR CONTROL

The new WWTP has a potential for generation of hydrogen sulfide (H_2S) odours as well as lesser quantities of other organic odour compounds. In general, odour levels depend heavily on the levels of dissolved sulfides entering the plant within the influent raw wastewater, as well as turbulence at launder weirs and other hydraulic drops. The City has emphasized the need for odour control due to the proximity of the plant to residential areas, as such, the following four odour control strategies will be implemented. The first strategy is to recycle final effluent to the anoxic cells to reduce the potential of sulfide formation in these cells. The second strategy is to mechanically aerate cells 3, 4 and 5 to maintain a dissolved oxygen greater than 2.0 mg/L. The third strategy is to cover the SAGR cells to ensure that no offensive odour is perceived at 40 m from the edge of the cells. The fourth strategy is to set ventilation rates for pump wet wells, UV room, pipe gallery and chemical room at a rate of six air changes per hour (ACH) per the National Fire Protection Association (NFPA) and based on Stantec's past design experience for similar type facilities. This room may generate musty odours but they are not considered offensive and therefore exhaust gas can be vented to atmosphere without treatment.

5.7 CHEMICAL STORAGE AND PUMPING SYSTEM

The following chemical feed systems would be required for the WWTP:

- Alum (48.5%) for phosphorus removal
- Sodium hypochlorite for disinfection of non-potable water

A brief discussion on the proposed chemical feed system follows.

5.7.1 Alum Feed System

Alum addition is required to chemically precipitate the residual soluble phosphorus such that the total effluent phosphorus (TP) of $\leq$ 1.0 mg/L can be maintained on a 30-day rolling average. Alum will be added to the effluent of the aerated cell (cell 5) to precipitate phosphorus that is not biologically assimilated. Table 5-7 provides a summary of the alum design system. The alum feed system floor plan is shown in Figure D-103 and a process flow diagram shown in Figure D-601 in Appendix B.

Table 5-7 Alum Design Summary

Parameter	Unit	Value
Design year	m^3/d	2020
Sewage flow rate	m^3/d	2,550
Phosphorus concentration at the bioreactor inlet excluding phosphorus concentration in the recycle stream	mg/L	7.4
Phosphorus concentration at the final effluent	mg/L	0.5
Phosphorus concentration to be removed by microorganism assimilation	mg/L	2.0
Phosphorus concentration to be removed by alum addition	mg/L	5.4
Phosphorus mass to be removed by alum addition	kg/d	20
Alum solution dosage required (based on Al/P mole ratio of 1.2 required by other plants in Saskatchewan)	mg/L of sewage	120
Alum solution mass rate required	kg/d	492
Alum solution volume required	L/d	370
Alum solution price (48.18% strength)	$/kg	0.55
Alum solution annual cost, excluding taxes and freight charges	$/yr	61,400

Based on the above, approximately 492 kg/d of liquid alum will be needed for phosphorus precipitation with an estimated annual cost for alum of approximately $61,400 for the initial year. A chemical tank with 16 m^3 alum storage capacity will provide approximately 43 days storage capacity and will provide the most economic load that can be hauled from Fort Saskatchewan to Humboldt. Smaller quantities can be delivered; however, freight charge for a full load would apply.

5.7.2 Sodium Hypochlorite System

Sodium hypochlorite will be injected into the plant water system at a dose rate of 2 to 3 mg/L to minimize re-growth of pathogens using a chemical metering pump and a drum of sodium hypochlorite. An injection quill with isolation valve will be provided for sodium hypochlorite feed on the plant water pump discharge piping. The operator will utilize a supplier's chemical drum (typically 114 L or 210 L drum), eliminating the need to provide a sodium hypochlorite storage container or containment system.

6.0 ENGINEERING DISCIPLINE DESIGN CRITERIA

6.1 CIVIL DESIGN CRITERIA

6.1.1 Site Layout

There is only one building proposed at the site that is described in the following sections. The Operations Building will contain two areas with distinctly different requirements, the substructure, and the administration area. The substructure houses the secondary effluent tank and the final effluent tank. The super structure houses the UV room, chemical room, blower room, mechanical room, electrical room, control room, server room, laboratory, SCADA, lunch room, and washroom. The overall layout plan showing the proposed works is shown in Figures D-101 and D-102 in Appendix B. The proposed building layout is shown on drawing D-103.

6.1.2 Site Civil Works

New transfer structures, consisting of two 400 mm diameter pipes, will be built between the existing cells to convey up to 13,820 m^3/d (9,720 m^3/d of raw sewage and 4,100 m^3/d of NML), as shown on drawing D-101. These structures will be insulated and located 1.5 m below water level to prevent frost-jacking, as shown on drawing D-602. Aquadams will be used, as a small cofferdam to isolate the area in the vicinity of the proposed transfer structure location and to facilitate installation of the transfer structures while maintaining the lagoon in service. It is estimated that a total of four aquadams will be required for each transfer structure installation (two aquadams in each cell to form a “V” configuration down the center). A temporary dewatering pump will be provided to minimize the interference of water seepage into the work area. Aquadams can be deployed quickly and can be reused for isolation of the next transfer structure, if they are not damaged during the relocation process.

A preliminary estimate of the material quantity to be excavated for construction of the SAGR cells and the Operations Building is about 24,200 m^3, of which 15,100 m^3 will be used to fill the area within the SAGR cells, Cell 6 and the Operation Building. Additionally, 6,100 m^3 will be used to raise the bottom of the nutrient removal cell to facilitate deployment of geotextile containers and the remaining 3,000 m^3 will be used to repair the berms. Rip rap will be added to the berms in locations where they are considered susceptible to erosion due to wave action in the lagoons.

6.1.3 Land Ownership and Easements

To our knowledge most of the land required for the WWTP facility and the extension of the final effluent line is already owned by the City. The last quarter section encompassing the new final effluent line into Humboldt Lake is privately owned and will require a new easement. Easement acquisition should proceed as soon as the alignments are finalized in detailed design to minimize the impact to the construction schedule.

6.1.4 Utilities

SaskTel, SaskPower and SaskEnergy services are required at the Operations Building site.

Power is described in the electrical section.

Natural gas is described in the mechanical section.

Telephone, data lines, and communications are described in the instrumentation and control section.

6.1.5 Connections to Existing Infrastructure

6.1.5.1 Raw Wastewater Feed to Plant

Three lift stations pump wastewater to the lagoons via forcemains. The existing forcemain alignments follow a route southeast of the residential area to the existing lagoons.

The wastewater will be intercepted and directed to the WWTP by extending the forcemains to the new ISS. Two 400 mm HDPE pipes will connect the ISS to each anoxic cell. Each pipe will be fitted with a magnetic flow meter to measure the incoming sewage flow rate.

Instrumentation, cabling, and controls for the actuators are excluded from this discussion but are considered in the Instrumentation and Control section.

6.1.5.2 Plant Potable Water Supply

A potable water supply is required to meet the water requirements for process, bathrooms, kitchens and fire protection. The closest water supply main is located 2.0 km north from the plant and it would be very expensive to extend this line to the plant. Alternative water source such as groundwater, and treated effluent would be evaluated during detailed design.

6.1.5.3 Treated Effluent Outfall

Discharge from the WWTP will be via a 400 mm diameter forcemain from the WWTP to Humboldt Lake. The proposed forcemain route identified by the City follows a path along the existing drainage ditch to the municipal road between the NW quarter of 5-37-22-2 and the NE of 6-37-22-2 then west approximately 0.6 km and south approximately 0.5 km to Humboldt Lake. The forcemain will cross the storm channel that it is currently used to discharge lagoon effluent. The total length of the pipeline will be approximately 4.8 km. The open trench method of construction for pipe installation is feasible for this option. The new outfall will be located approximately 0.3 km west of the existing one.

WSA advised that underwater discharge is generally more publicly acceptable than bank discharges. The preliminary design assumes that the final effluent following UV disinfection will be discharged to Humboldt Lake via a new outfall structure. The outfall pipe will extend offshore and terminate at the outfall structure. The outfall will be provided with pre-cast concrete, bolt-on weights to keep it submerged. The outfall structure will be a pre-cast concrete construction with peripheral openings to allow dispersion of the effluent into the lake. As mandated by Fisheries and Oceans Canada, the construction of the outfall pipe and outfall structure must be carried out in a manner so that none of the following occurs:

- harm to fish or fish eggs
- destruction of fish or fish eggs
- harmful alteration, disruption or destruction of fish habitat

There may be a requirement to monitor flows prior to discharge. An in-line magnetic flow meter will be provided on the pump discharge header in the pump rooms. Instantaneous and total flows will be recorded and tracked by the SCADA system.

6.1.6 Stormwater Management

Ditches along the roadways and parking areas on site will direct runoff flow overland to a common low-lying area. Swales around the north side of the WWTP will direct overland flow to existing drainage runs.

6.1.7 Site Access and Roadways

6.1.7.1 Site Access and Security

Given the potential for access to the facility by the public or by wildlife and the likelihood of harm, restricted access to the site is recommended. A 1.8 m chain link fence topped with three strands of barbed wire is typically used in similar installations and is proposed.

Signage indicating only authorized personnel are permitted beyond that point at the intersection of the access road and lagoons, would serve to identify the site and provide an opportunity to restrict access at the road.

Access to the compound will be provided by a lockable gate. The gate will be manually or automatically actuated. Manual actuation will consist of a padlock, while automatic actuation could be via keypad or swipe card access. Automatic access would allow the opportunity to monitor the arrival and departure of authorized personnel and is recommended in conjunction with a pole mounted security camera at the gate.

6.1.7.2 Roadways

The WWTP will be accessed from 104th Street. The outfall at Humboldt Lake will be accessed by a graveled roadway paralleling the forcemain from the municipal road.

A parking area at the Operations Building will also be constructed.

6.1.8 Landscaping

Landscaping will primarily consist of reestablishing dryland seed mixtures along the forcemain route, slopes of the lagoon cells as well as in and around the Operations Building, SAGR cells and any other disturbed areas during the WWTP upgrades to minimize soil erosion and maintain soil stability of the lagoon cells. This provides a low maintenance option for operator personnel to maintain the WWTP site, the forcemain routing (where required) as well as at the outfall location.

6.1.9 Site and Worker Safety

6.1.9.1 Fire

Given the separation from the residential area and the sizing of the water main to provide fire flow, two hydrants will be provided at site, one near to the Operations Building adjacent to the access road and parking area and one to the east of the building. Threading and valve keys will be coordinated to match those of the local fire department.

Building fire suppression systems will be provided along with local and dial out alarms. The building mechanical section will cover the suppression system more fully while Instrumentation and Controls will describe the fire monitoring and alarm systems.

6.1.9.2 Gases

There are several locations in the site where potential hydrogen sulfide gasses may be present. These locations will be equipped with signage, warning personnel of potentially hazardous conditions.

6.1.9.3 Fall Prevention and Arrest

There are several structures that are considered confined spaces. In these locations, signage above the area indicating confined space entry procedures is required. Mounts for fall arrest devices and lifting davits will be provided at access hatches.

6.1.10 Permits

The following permits are believed to be required for the construction phase. Applications should be submitted as early as possible once the details are finalized.

Federal permits:

- Authorization under Wastewater Systems Effluent Regulations, 2014
- A Request for Project Review under Fisheries Act, 2013
- A Request for Authorization under Fisheries Act, 2013

Provincial permits:

- Permit to Construct, Extend or Alter a Sewage Works through Saskatchewan Water Security Agency (WSA) under the Environmental Management and Protection Act, 2012 (EMPA). Design report, drawings, and sludge management plan must accompany the application for permit
- Aquatic Habitat Protection Permit. Through WSA under EMPA
- Water Security Agency – Shoreline Alteration Permit
- Heritage Resource Impact Assessment

Municipal permits:

- Building permit from the RM of Humboldt, if required
- Building Permit from the City of Humboldt.

In addition to permit applications, it is recommended the following be addressed:

- Canadian Wildlife Service – should be consulted if clearing of trees, shrubs, grasses or marsh vegetation is to occur during nesting season (April 15 – August 31)
- Effluent discharge concentrations and habitat protection measures are to be addressed for endangered species, as identified as a Schedule 1 species under the Species at Risk Act, 2002
- Weed management plan should be developed with the goal of minimizing spread of weeds on the project area during construction and operations
- Duty to Consult First Nations and Metis Communities is the Province's responsibility. This is likely to take a minimum of one month to complete in Humboldt Lake area; therefore, project plans should take this time into consideration.

6.2 STRUCTURAL DESIGN CRITERIA

The structures for the WWTP will be designed and constructed to be durable with some maintenance requirements. Exposure to high moisture areas is one of the main criteria for the selection of construction material.

The structural design will be based on reasonable, economic methods of construction. The design will consider and accommodate future expansion with minimal interruption to the proposed building or structures. The following summarizes the design standards and criteria which will form the basis for the design of the structural systems.

6.2.1 Design Codes and Reference Standards

The structural design of buildings in Saskatchewan must meet the current requirements of the National Building Code of Canada 2015 together with associated design codes. Should the current edition of any of these publications be replaced or superseded by a new edition prior to the start of the design, the Designers will use the new publication.

The structural design of the WWTP will adhere to the following codes:

- The National Building Code of Canada 2015
- NBC 2015 Structural Commentaries (Part 4)
- CSA A23.3-19 Design of Concrete Structures
- CSA A23.1-19/A23.2-19 Concrete Materials and Methods of Concrete Construction / Test Methods and Standard Practices for Concrete
- CSA-S16.1-14 (R2019) Limit States Design of Steel Structures
- CSA S304.1-14 Design of Masonry Structures
- CSA O86-14 Engineering Design in Wood

- ACI 350 Manual of Concrete Practice for Water Containment Structures
- CAN/CSA-A3000-18 Cementitious Materials Compendium

6.2.2 Structural Design Considerations

The structural engineering work will involve designing the structural elements to satisfy code requirements under the following loading conditions. The structures will be classified as post-disaster, constructed with an importance factor of 1.25, and load combinations will be analyzed as described in the National Building Code of Canada.

6.2.2.1 Gravity Loads

This includes:

- Dead load of building and components (self-weight)
- The following live loads due to use and occupancy for the Operations Building:
  - Washrooms, change rooms, lunchroom, corridors and laboratory: 4.8 kPa (100 psf)
  - Mechanical and electrical rooms: 14.4 kPa (300 psf).
- Water pressure = 9.8 kN/m^3 (62.4 pcf)
- Earth pressure = 20 kN/m^3 (127 pcf)
- Hoist load = 2.0 Ton (4400 lbs)
- Roof = 2.23 kPa (46.5 psf) snow load plus drift loads as specified by the National Building Code
- Roof = 1.25 kPa (26 psf) for hanging mechanical loads

6.2.2.2 Wind load

Wind loading will be designed to NBC requirements, applied as a pressure or suction force on exterior wall and roof assemblies. The building interior may be subject to wind loading effects if there are large openings present in the building.

6.2.2.3 Seismic Load

Seismic forces will be determined according to NBC requirements for the soil classification determined by the geotechnical assessment of the subgrade conditions. It is anticipated that the seismic loads will be relatively minor and will not significantly influence the foundation requirements. The seismic design criteria may affect some of the detailing associated with the design and construction of the building foundations and superstructure.

6.2.2.4 Deflection, Settlement, and Vibration

The allowable deflection for each structural element will be based on the National Building Code of Canada. Settlement criteria will adhere to recommendations in the geotechnical report prepared for the project. Specific requirements for vibration tolerances will be provided by equipment manufacturers

6.2.2.5 Foundation

Foundation types, details, soil pressures frost penetration depth, design groundwater level, and lateral earth pressure coefficients will be based on recommendations made by the Geotechnical Consultant for the project. Design will be based on Limit states including ultimate and service limit states.

6.2.2.6 Construction Materials and Constructability

The materials chosen for construction of the Operations Building and other treatment facility elements are to be durable. Due to the high toxicity of the effluent that is processed, concrete and masonry block will be used to provide the highest corrosion resistance. Coatings or additives may also be added to extend the life of the concrete structural elements. Any exposed steel members or miscellaneous metals are to be hot-dip galvanized to provide corrosion protection. Fibre-reinforced polymer (FRP) components may be utilized for their durability.

6.2.3 Operations Building Structural Systems

The Operations Building includes a substructure containing the secondary and final effluent tanks. The superstructure houses the UV room, chemical room, blower room, SCADA, control room, lunchroom, laboratory, washrooms, and dedicated electrical and mechanical rooms and equipment. The overall building footprint is anticipated to be approximately 34 by 15.6 m.

6.2.3.1 Foundation

There will be a site-specific geotechnical investigation and report prepared for this project. The report will identify soil properties, seismic classification, water table, foundation types and design parameters, as well as concrete considerations. The foundation type and design parameters for the project will be based on recommendations provided in the geotechnical report.

It is assumed that the foundation for the Operations Building (which will form the bottom of the tanks) will consist of a structural concrete slab supported on cast-in-place (CIP) concrete piles. The slab will be approximately 500 mm thick and will be approximately 6.9 m below grade. A 50 mm topping would be added to the bottom of the tanks to provide required slope. The floor of the UV / Lower Pump Room will be a structural concrete slab 150 mm to 200 mm thick on reinforced concrete beams.

The remainder of the Operations Building will likely be a structural concrete slab supported on cast-in-place (CIP) concrete piles and grade beams. The pile design will depend on the soil friction, frost heave, and minimum pile depth as recommended in the geotechnical report. The width of the grade beams will be governed by the perimeter wall construction and design loading.

The main floor of the Operations Building could be a concrete slab-on-grade if differential movement in the building is acceptable. Settlement of approximately 25 to 30 mm can typically be expected with slab-on-grade construction, which can lead to cosmetic cracking and damage to architectural finishes. Foundation design will be governed by the recommendations presented in a site-specific geotechnical report.

Concrete strength for the foundation elements will be specified as 32 MPa minimum with type HS Sulphate Resistant Portland Cement.

6.2.3.2 Foundation Walls

The foundation concrete walls are proposed to be 500 mm thick to support the water pressure from the tank interior along with the exterior earth pressure.

The walls and the slab of the tanks for the Operations Building are designed according to the ACI 350 Code for Water Containment Structures to meet the requirements for crack control concrete to prevent any leakage. Water stops would be installed between concrete pours.

Interior concrete walls between tanks and maintenance areas will be designed to resist differential pressures exerted by one tank being empty, while the area on the other side of the common wall is at the maximum operating level. In most cases the maximum level would be considered as the underside of the main floor slab. The concrete design will be specified as 30 MPa minimum with an exposure class of A3 to protect from the corrosiveness of the effluent.

Access ladders will be attached to the foundation walls and connected to hatches in the main floor for maintenance access. Ladders, hatches, and other associated components may be FRP or hot-dip galvanized steel construction.

6.2.3.3 Main Floor

The main floor will consist of a 150 to 200 mm thick cast-in-place concrete suspended slab above the lower effluent tanks. The suspended slab will be supported by concrete beams spanning between the walls of the tanks. Floor hatches with an estimated size of 1200 mm x 1200 mm will be constructed in the slab for access to the piping gallery for maintenance and removal of large equipment. The remainder of the Operations Building main floor will also be a concrete slab, but the foundation will be designed based on the geotechnical report for the site (as noted above).

Hoist beams will be installed as required for future equipment maintenance and replacement. A protective coating, likely galvanized zinc, will be added to the structural steel to protect it from the potentially corrosive environment. Steel angles that frame any openings will also be galvanized.

Floor drains in the floor slab will be present in the chemical and pump rooms to limit the extent of leakage or spillage during operation and maintenance. Remaining rooms will include standard floor drains.

Concrete strength will be specified as 25 MPa minimum for interior slabs, and 35 MPa minimum for exterior slabs with type HS Sulphate Resistant Portland Cement. Due to the corrosive environment, epoxy rebar may be used to reinforce the slabs. These floors will be finished with a concrete hardener for impact resistance and easy cleaning.

6.2.3.4 Roof and Walls

The roof for the Operations Building will be a flat roof constructed with precast hollow core panels that span onto load-bearing masonry walls. Interior walls will also be constructed using concrete masonry block. Using concrete-based structural elements for construction will ensure that the structure can withstand exposure to excessive moisture, effluent, and other harmful chemicals.

The roof elevation will be 4.6 m above the blower, mechanical and electrical rooms. The roof structure will be designed to support the required snow, drift and mechanical loads.

6.2.3.5 Lateral Load Resisting Systems

Lateral loading on the Operations Building is caused by wind and seismic forces. The resistance to these loads will be provided by the exterior masonry walls and hollow core roof panels. Lateral loading from the walls is transferred into the foundation and roof systems. At the roof level, the lateral forces move from the roof diaphragm into the masonry walls, then down to the foundation level. The precast hollow core panels will likely be 200 mm or 250 mm thick, and design is delegated to manufacturers. The exterior masonry walls will be 190 mm thick and will contain vertical steel reinforcement in the cores.

6.2.3.6 Miscellaneous Structures

Miscellaneous structures such as exterior equipment foundations, will be designed for durability and will be steel reinforced cast-in-place concrete slabs-on-grade. For equipment or installations that cannot tolerate settlement or differential settlement, the slabs will be supported on a foundation based on the geotechnical report recommendations.

Exterior supporting frames, stairs and landings, and other exterior items will be specified to be either aluminum or galvanized steel unless otherwise supplied by equipment manufacturers.

Influent and SAGR Splitting structures are concrete structures that may be cast-in-place, precast, or a combination of both. The splitting structures may extend 6 to 7 m below grade and will be designed to prevent the structures from uplift due to buoyancy.

6.3 ARCHITECTURAL DESIGN CRITERIA

The proposed Operations Building would be constructed of durable, readily available, low maintenance materials to reduce operations and maintenance costs. Design and materials would meet or exceed the requirements of the applicable codes.

6.3.1 Operations Building

The substructure will be cast-in-place concrete and the super structure floor slab would be placed over the secondary and final effluent tanks. Access hatches to the tanks will be from within the structure.

The interior of process tanks will be treated with a crystalline waterproofing for the full length and width of surfaces facing the fluids. The substructure exterior facing the soil and groundwater will be dampproofed from the top of the wall to the bottom of the footing.

The superstructure will be masonry block with rigid insulation and air/vapour barrier and exterior metal cladding with thermal clips, rigid insulation, and air/vapour barrier. The assemblies of the superstructure exterior walls will be compliant to the requirements of the NECB 2017. Interior dividing walls will be painted masonry block except for the blower room which will employ unpainted sound absorbing acoustic block, and hollow-core concrete roof slab which have good sound insulation properties.

The east end of the Operations Building housing the UV and pump room equipment will require an elevated ceiling to house and maintain the pumps; however, the administrative areas will only require the standard 2.75 m ceiling. At present, a stepped roofline is envisioned, however a lower ceiling height in the administrative area can be achieved with suspended ceiling tile with recessed fluorescent lighting. Moisture-resistant gypsum board ceilings will be used in the washrooms & showers.

Access to the pump room for extraction of the submersible pumps will be via an insulated overhead door, large enough to pass equipment. A concrete slab on the exterior of the building in front of the double door will be sized to hold equipment for pick up.

Building superstructures above ground for process areas will be constructed in masonry with rigid insulation, metal cladding and a hollow-core concrete roof slab. Superstructures for humidity and climate controlled administrative areas will be steel (no wood framed construction) with rigid insulation, metal cladding and hollow-core concrete roof slab to match the appearance of the other areas.

The floor in the process areas will be coated with a non-slip polyurethane paint. The floors in the Chemical Room will be coated with an epoxy coating system resistant to the chemicals stored there. The floors in the admin areas, main corridor, office areas, washrooms, and showers will receive slip-resistant sheet vinyl flooring with welded seams and 100 mm-high rubber base. The floor in the laboratory will receive slip-resistant sheet vinyl flooring with chemical resistance and 100 mm-high rubber base.

Monorails over major items of equipment will be arranged to allow placement and removal of equipment on 100 mm high housekeeping pads as well as for maintenance and disassembly when required. Sizing of the lifts will incorporate commonly accepted factors of safety for lifting equipment. Where the equipment exceeds 200 kg, a chain wheel or electrically driven hoist and trolley will be considered.

6.3.2 Common Finishes and Hardware for Buildings

All interior partitions/walls, unless otherwise stated, are to be constructed of loadbearing concrete block walls to support the hollow core concrete slab. The masonry partitions/walls in the Operations Building's main corridor, office areas, laboratory, washrooms, & showers will be painted with block filler and two coats of alkyd paint.

Exterior doors will be insulated hollow metal with panic bars and kick plates while interior doors will be hollow metal with windows and lever handles, except the washroom doors which will not have glazing.

Where exterior double doors are present, they will include a removable mullion. Where interior double doors are present, both will be furnished with glazing without a mullion to separate them, while one of the doors will be furnished with cylinder flush bolts into the frame and floor on the interior side of the door. Weather-stripping will be provided on all exterior doors, doors in the Blower Room (for sound control), and for all doors in fire separations (for smoke control).

Exterior glazing will be double pane, sealed, argon filled, low E, with anodized aluminum frames to match the exterior, and an awning style opening with insect screens. Interior windows will be single pane with steel frames. In areas where there is risk of window breakage due to rotating, vibrating, or pressurized equipment such as the process, maintenance, or laboratory areas, the windows will be tempered, laminated, or shatterproof.

Access hatches to below grade tankage will be sealed, lockable aluminum hatches with pre-fabricated curbs. Hatches that are not within the building envelope in heated areas will include manufacturer-applied insulation to limit frost build-up and freezing.

In areas or rooms that will potentially be submerged or subject to gasses, fibre-reinforced plastic (FRP) ladders, railings and platforms are recommended for long term resistance to the aggressive environment. In areas where the humidity is controlled and there is sufficient air circulation, galvanized/stainless steel or epoxy-coated is adequate.

The design of ladders, railings, stairs, and platforms are subject to OH&S regulations.

6.4 MECHANICAL DESIGN CRITERIA

This section briefly describes building heating and ventilation, plumbing, fixtures and fire protection for the new WWTP.

6.4.1 Design Codes and Standards

The following codes and standards will form the basis for the mechanical design.

- NFPA 820, Standard for Fire Protection in Wastewater Treatment and Collection Facilities,
- NFPA Standard 45
- CSA Cross Connection Control Standard (for domestic water service piping) CAN/CSA-B64.10-94
- National Building Code of Canada, 2015
- National Fire Code of Canada
- The Uniform Building & Accessibility Standards Act (Sask.)
- CSA B149.1-00 Natural Gas and Propane Installation Code
- The Occupational Health & Safety Act & Regulations (Sask.)
- Saskatchewan Plumbing & Drainage Regulations
- Canadian Plumbing Code
- American Society of Heating, Refrigeration & Air Conditioning Engineers (ASHRAE), Fundamentals Handbook

- American Society of Heating, Refrigeration & Air Conditioning Engineers (ASHRAE), HVAC Applications Handbook
- American Society of Heating, Refrigeration & Air Conditioning Engineers (ASHRAE), Standard 62 – Addendum 62n, Ventilation for Acceptable Indoor Air Quality
- SMACNA HVAC Duct Construction Standards – Metal & Flexible, Second Edition

6.4.2 Climatic Data

The climatic conditions for Humboldt are as follows:

- Winter: January Design Temperature = -40.0ºC (-40.0ºF)
- Summer: July Design Temperature = Dry Bulb 30.5ºC (87ºF) and Wet Bulb 18.9ºC (66ºF)

6.4.3 HVAC Concept

6.4.3.1 Operations Building

The operations building comprises the process area and administration area, both with distinctly different requirements.

Heating in the process areas will be separated combustion gas-fired unit heaters with tempered make-up air supplied at room temperature. Heating and cooling for the administration areas will be rooftop heat/cool units and where required, secondary perimeter electric baseboard radiation. Make up air for the process area will be an indirect gas-fired makeup air unit. Dedicated exhaust fans c/w VFD modulation will provide the necessary air exchange in all process areas. An additional exhaust fan will serve the washroom and change room areas. A recirculating portable fume hood extractor will provide dedicated exhaust in the laboratory. The server room will have a dedicated DX split system cooling unit. The electrical and mechanical spaces will have mixed air systems, providing heating and free cooling as required to maintain space temperature. Ducting and equipment selection in the process areas will consider the corrosion potential of the area in which they are installed.

DDC (direct digital control) logic and web-based interface will control and monitor the mechanical systems. Individual heating thermostats will control the unit heaters and perimeter radiation. Programmable thermostats will control the rooftop units heating and cooling for the administration areas. A duct mounted temperature sensor in the make-up air unit will modulate the gas valve as required to maintain a constant supply air discharge temperature to the process areas. Pressure differential sensors will ensure all process areas remain negative in relation to adjacent corridors through modulation of exhaust air volume. All critical control, operating and alarm points associated with the HVAC systems will be monitored and controlled by the DDC (direct digital control) management system. These alarms can be monitored by an outside source (SCADA or alarm monitoring service) and monitored remotely through an internet connection.

6.4.4 Ventilation Criteria

Criteria for establishing the required ventilation rates for covered wastewater processes include:

- Ensure all process areas are negative in relation to administration areas, ensuring air migration is always from the administration areas into the process areas
- Maintain a safe work environment through monitoring of hydrogen sulfide (H_2S) concentration and alarming on levels above 10 ppm
- Control hydrogen sulfide levels and humidity to reduce corrosion
- Control corrosive liquids or vapors that have the potential to be present in quantities that are likely to interfere with the normal operation of electrical equipment

6.4.5 Area Requirements (HVAC)

Areas that contain open channels such as UV disinfection and pump rooms are very energy intensive to heat because treated effluent stored in these tanks are a heat sink. Consequently, winter indoor temperature will be maintained at approximately 10°C, which corresponds to 9°C above the treated effluent temperature in all process areas.

The HVAC design conditions and ventilation rates for the building rooms are presented in Table 6-1. Ventilation for the Operations Building will be as per NFPA 820, Standard for Fire Protection in Wastewater Treatment and Collection Facilities. Ventilation for the Operations Building will be as per ASHRAE ANSI/ASHRAE 62.1-2004, Ventilation for Acceptable Indoor Quality.

Table 6-1 HVAC Ventilation Requirements

Area	Temperature Range (C)	Class / Zone	ACH	Rate (m^3/h)	Heating	Cooling
Operations Building						
UV disinfection Room	min 10	none	6		Y	N
Chemical Room	min 10	none	6		Y	N
Blower Room	min 10	none	As required	As required	Y	Free Cooling
Laboratory	18-23	none	9		Y	Y
Control Room	18-23	none	6		Y	Y
Server Room	18-23	none	As Required		Y	Split System
Lunchroom	18-23	none	6		Y	Y
Washroom	18-23	none	10		Y	N
Electrical	15-20	none	As required	As required	Y	Mechanical Cooling
Mechanical	min 15	none	As required	As required	Y	Free Cooling
Process Tanks						
Secondary Effluent Tank	min 10	1/2	6		N	N

Area	Temperature Range (C)	Class / Zone	ACH	Rate (m^3/h)	Heating	Cooling
Final Effluent Tank	min 10	1/2	6		N	N

6.4.5.1 Operations Building-Administration Area

The entrances to the administration area will have electric wall heaters with integral temperature control for on demand heating. Hallways within the administration area will be heated and cooled with the common gas fired heating/DX cooling roof top air handling systems. Supply air will be ducted to the areas via ceiling diffusers and returned via a ceiling grille into a non-ducted ceiling plenum. Temperature control for the hallways will be tied to the control room thermostat.

6.4.5.2 Control Room

Supply air will be ducted to the room via ceiling diffusers and return air will be extracted via ceiling grilles. The air will be heated and cooled by a dedicated roof top unit. The thermostat to control the roof top unit will be in this room. Perimeter electric radiation will be located below the window.

6.4.5.3 Laboratory

Supply air will be ducted to the room via ceiling diffusers and return air will be extracted via ceiling grilles. The air will be heated and cooled by a dedicated roof top unit. Perimeter electric radiation will be located below the window. A portable fume extraction hood will capture toxic fumes from laboratory tests conducted by the operator.

6.4.5.4 Lunch Room

Supply air will be ducted to the room via ceiling diffusers and return air will be extracted via ceiling grilles. The air will be heated and cooled by the Laboratory roof top unit. Perimeter electric radiation will be located below the window.

6.4.5.5 Washroom and Change room

A common exhaust fan serving both areas will provide exhaust air from the washrooms. Perimeter electric radiation complete will provide heating for the Change room. Transfer air from the corridor will migrate below the undercut door into the Washroom and Changeroom areas.

6.4.5.6 Electrical

The electrical equipment and drives will generate heat and thus only minimal heating will be required via a gas fired unit heater. A dedicated mixed air fan system will mix recirculated air and outside air, providing free cooling as required to maintain space temperature. All outside air introduced through the fan will be filtered to ensure a clean environment within the electrical room. A relief damper will open as required to relieve air from the space. The resultant pressurization will minimize dust migration from adjacent spaces.

No mechanical cooling is contemplated. Dependent upon maximum allowable space temperature and electrical equipment heat rejection within the room, mechanical DX cooling may be required.

6.4.5.7 Mechanical

Internal heat generation within the mechanical room will be minimal. If required, a portion of the supply air from the Electrical room air handler can be directed to the Mechanical room to control space temperature. A gas-fired unit heater is proposed for this area.

6.4.5.8 Blower Room

There are five blowers located in the blower room. Each blower has a dedicated outside air connection, enabling the blower to draw air directly from outside, compress it and deliver it to the lagoons. In addition to the compressed air requirement, additional outside air is required to offset the heat rejected to the room from the blowers. Variable speed exhaust fans mounted above the blowers in combination with wall intake louvers complete with motorized dampers will exhaust warm air out of the room and introduce fresh ambient air into the room as required to maintain space temperature. A gas fired unit heater will heat the room when the blowers are idle.

6.4.5.9 Operations Building - Process Area

A large indirect gas-fired makeup air unit will provide tempered makeup air to all process areas. The makeup air unit will be located on the roof complete with make-up air duct branches to the various process areas. All ductwork will be stainless steel to maintain the integrity of the duct. A duct mounted temperature sensor will modulate the gas valve as required to maintain the required makeup air discharge air temperature. The unit will operate continuously.

Exhaust fans with appropriate protective coating and construction will provide continuous exhaust from all process areas. Duct construction will be stainless steel.

6.4.5.10 UV Disinfection Room

A thermostatically controlled gas-fired unit heater will provide supplemental heat to the area. High and low level supply air diffusers connected to the central makeup air unit will provide a constant volume of tempered makeup air to the area. A dedicated variable speed exhaust fan complete with high and low level exhaust will provide the necessary exhaust air exchange rate. A pressure differential monitor will monitor pressure differential between the corridor and UV area and modulate the exhaust fan air volume as required to ensure the required pressurization relationship is maintained.

6.4.5.11 Chemical Room

A thermostatically controlled gas-fired unit heater will provide supplemental heat to the area. Supply air diffusers connected to the central makeup air unit will provide tempered makeup air to the area. A dedicated exhaust fan complete with low level exhaust will provide the necessary exhaust air movement and ensure that the required pressurization relationship is maintained.

6.4.5.12 Secondary and Final Effluent Tanks

High and low supply air diffusers connected to the central makeup air unit will provide a constant volume of tempered makeup air to the area. A dedicated variable speed exhaust fan complete with high and low level exhaust will provide the necessary exhaust air movement and ensure that the required pressurization relationship is maintained. A pressure differential monitor will monitor pressure differential and modulate the exhaust fan air volume as required to ensure the required pressurization relationship is maintained.

6.4.5.13 Gas Sensing

Gas sensing in all critical areas will be interlocked with the operation of the dedicated exhaust fans. If not already operating, a high concentration alarm will signal the appropriate exhaust fan to energize as required to maintain air quality. The alarm will register on the BMS. Under normal operation, all exhaust fans and make-up air units are to operate on a continuous basis.

6.4.6 Heat Recovery

Adoption of the National Energy Code of Canada for Buildings requires heat recovery on all make-up air/exhaust systems. The make-up air and associated exhaust systems at this facility are candidates for heat recovery. There are however exemptions for specialized airstreams that are toxic, corrosive or dust laden which may negate the requirement for heat recovery. Heat recovery can be a viable investment dependent on several factors such as capital cost, hours of operation, room temperature requirements, physical arrangement of ductwork, special considerations for corrosive environments, etc. There are two aspects to implementing heat recovery that require further review. First, the Authority Having Jurisdiction will be consulted to determine if heat recovery is required and/or if the exemptions apply. Second, if heat recovery is not mandatory, the economics and available capital cost will be reviewed. The decision to implement heat recovery should be determined at the design stage of the project as the configuration of the make-up air unit, exhaust fans and associated ductwork differ if heat recovery is required. Implementing heat recovery at a future date is difficult and costly unless the infrastructure is already in place.

6.4.7 Plumbing

Potable water piping will extend to the site from the municipal system. Separate potable supply water mains will enter the mechanical room in the Operations Buildings. A separate fire line will feed fire hydrants on site in the vicinity of the building.

In the Operations building, a potable water system for the administration area will be fed through a reduced pressure backflow preventor on a separate parallel line to that supplying the process areas. A natural gas fired water heater located in the mechanical room will supply hot water to the administration area and tempered water to the emergency shower/eyewash stations.

All drainage in the Laboratory will be acid resistant and if required, directed to an acid neutralizing tank prior to being discharged into the sanitary main serving the building. Floor drains and general waste from plumbing fixtures will also be directed to the sanitary main system. All domestic waste from the will flow to the drain pumps wet well.

Plumbing fixtures in the Laboratory area will be 316 stainless steel with laboratory trim. All other plumbing fixtures will be standard commercial grade and hands-free accessible as required.

6.4.8 Fire Suppression

Fire protection for each of the facilities will include fire extinguishers mounted in all equipment rooms and other areas as required by code.

6.5 ELECTRICAL DESIGN CRITERIA

The following outlines the basis of design for the electrical, control and instrumentation systems which will be employed for the WWTP.

6.5.1 Referenced Standards

Applicable requirements from the following standards will be incorporated into the project design.

- National Building Code of Canada, 2015
- National Fire Code of Canada, 2010
- The Uniform Building & Accessibility Standards Act (Sask.)
- The Occupational Health & Safety Act & Regulations (Sask.)
- National Fire Protection Association (NFPA-72)
- CSA Standard C22.18 - Canadian Electrical Code, Part 1 (2018)
- Workplace Electrical Safety Z462-18
- CAN/CSA – C282-15 – 2015 Emergency Electrical Power Supply for Buildings
- ANSI Standard RP 12.06.01-2003 – Recommended Practice for Wiring Methods for Hazardous (Classified) Locations Instrumentation Part 1: Intrinsic Safety
- Illuminating Engineering Society of North America Lighting Handbook Standards
- Regulations of inspection, supply and regulatory authorities having jurisdiction

6.5.2 Electrical System Classification

The following area classifications will apply to the electrical, control and instrumentation systems.

The entire area within the Operations Building will be classified as general purpose, except the process area, which will be Class 1, Zone 1 and Class 1 Zone 2 area.

All areas exposed to open-vessel processes will be designated as “Category 1 - Humid” in accordance with the Canadian Electrical Code (CEC).

Where there is a presence of H_2S gas, these areas will be designated “Category 2- Corrosive” in accordance with the Canadian Electrical Code.

All electrical equipment will be supplied and installed in CSA-rated enclosures and using methods required to meet all Class and Category designations per the Canadian Electrical Code for the area in which the equipment will function. All electrical equipment wiring will be copper TECK cabling, except for building services which may be PVC conduit. Rigid and EMT conduit will not be used.

All other areas will be classified as ordinary dry service in accordance with the Canadian Electrical Code (CEC). Consequently, all electrical equipment will be installed in EEMAC 1 enclosures, and wiring will be copper conductors in either PVC raceways or TECK cable.

6.5.3 Electrical Service and Loading

The preliminary connected loading in the new facility will generally comprise of the following:

- Process equipment 457 kVA
- Illumination 5 kVA
- Convenience receptacles and miscellaneous 10 kVA
- Heating and ventilation 10 kVA
- Operations Building 10 kVA
- Total 492 kVA

The electrical supply to the site will be coordinated with SaskPower once final loading is confirmed. It is anticipated that SaskPower will provide an underground 25 kV supply feeder terminating at the line side of their 25 kV / 600 V vault mounted transformer. The Customer-owned service conductors will connect to the secondary of this transformer and run underground to the 600 V service entrance switchboard including the main service breaker and provisions for the utility revenue metering facilities.

6.5.4 Electrical Power Distribution Systems

A new 600 V, 3-phase, 3-wire underground entry service will be provided for the proposed new Operations Building. SaskPower will provide a vault mounted 25 kV / 600 V 3-phase transformer, cables, protection equipment, and connections to the line-side of the service transformer located outside of the Operations Building. Underground power cables will supply 600 V three-phase power to switchgear located in the Electrical Room of the Operations Building.

Stantec contacted and received from SaskPower an estimate for construction. The incoming service conductors, from the load-side of the service transformer, will be terminated on a main service entrance breaker (100% rated) mounted in Section 1 of switchgear located in the Electrical Room of the Operations Building. Preliminary sizing of plant electrical loads indicates a primary service size of 1,000 Amps would be required. This service is sized to accommodate all required electrical loads including future process expansion.

Outdoor metering will be provided, powered from utility transformers mounted in Section 1 of the MCC directly below the main breaker.

Electrical distribution systems will be designed with the capacity to supply future additions to the treatment facilities. The electrical service, power distribution and generation equipment will be in the Operations Building.

Power distribution transformers will be dry type, ventilated, with copper windings and configured as required. Panelboards will be surface mounted, circuit breaker type with flush hinged door, concealed hinges and a combination lock and latch.

6.5.4.1 Main Distribution Switchgear

The main distribution switchgear consists of a 600 V feed from the SaskPower distribution transformer via an underground power cable to a 1000 Amp rated switchgear lineup. The switchgear will be arc flash resistant rated. The switchgear will have two main sections: first section - the main service entrance breaker and SaskPower utility metering cubicle and second section – internal bus, cable connections and 600 V switchboard. The 600 V switchboard will provide regular power (through an 800 A adjustable main breaker) to a Smart Motor Control Centre for Operations building equipment and building services loads.

The 600 V Motor Control Centre (MCC) will be in the Electrical Room of the Operations Building. The MCC will employ smart technology so that the MCC can communicate electrical data and can be controlled over industrial networks. The smart technology will allow capturing of critical system data that can be used for preventative maintenance for increased plant reliability and reduced downtime.

Process and mechanical motors, as well as panels throughout the facility, will be supplied from the MCC. The MCC will also provide a power feeder to the Operations Building.

6.5.4.2 Backup Power

A backup diesel generator (skid mounted) will be installed outside the Electrical Room and provide backup power for selected critical loads in the Operations Building. The generator will operate in conjunction with the transfer switch in the MCC to automatically transfer from regular utility power to backup generator power during a power outage. The smart MCC will control the electrical loads considered critical in the event of a loss of power from the distribution system.

The generator system will be designed to automatically energize on utility failure, with a delayed shut-down on return to utility power. Preliminary sizing of the new Operations Building's electrical loads indicates that a 300 kVa generator is required to maintain critical equipment operation during power outages if the City intends to operate the aerated lagoons at fix water level. The generator size can be reduced to 75 kVa if the aerated lagoons are operated at variable water level. Additional provisions should be included during detailed design to ensure that higher water levels in the lagoons will not negatively impact the integrity of the SAGR cells or the pumping capacity of the lift stations (water level in the SAGR cells should not reach the mulch layer). The cells have enough spare capacity to store about 93,000 m^3 based on 0.3 m water level increase (nine days storage during maximum weekly flow of 9,720 m^3/d). The blowers and aeration equipment proposed by Nexom can handle variable water levels as the diffusers are suspended near the bottom of the cells.

It should be noted the size of the generator may increase if treated effluent is used for fire protection since it is a requirement by NFPA 20 – Standard for the Installation of Stationary Pumps for Fire Protection - that the fire protection pumps be on backup power.

The critical loads will generally comprise sump pumps, motorized process valves, control, instrumentation, essential lighting as well as the essential heating and ventilation requirements of the plant.

The backup power generation system is designed for standby service in an unattended mode and consists of a diesel- fueled engine, alternator, automatic transfer switch, battery charger, starting battery with rack stand enclosure, fuel supply system, engine exhaust system and engine cooling system.

An automatic transfer switch will be provided to monitor normal power supply voltage. On failure of normal power, the transfer switch will initiate cranking of the standby generator after a field adjustable time delay and transfer load from normal supply to the generating unit after the unit reaches rated voltage and frequency. Subsequently, after the restoration of normal power supply for a time, the transfer switch will automatically re-transfer load from the generating unit to the normal power supply and shut-down the engine generator.

6.5.4.3 Power Distribution

The MCC will house the automatic transfer switch, main surge protection device (SPD), active harmonic filter, process equipment direct motor starters and Variable Frequency Drives (VFD), equipment circuit breakers and a control section. From here, 600 V electrical power will be sub-distributed throughout the new building as required to feed all 3-phase motors and major electrical loads.

600 V, 3-phase power will be utilized for all motors over ½ hp and all primary HVAC equipment.

A 45 kVA, 600 V:120/208 V dry-type transformer will feed a power distribution panel board to provide for lighting, receptacles, small motors, miscellaneous 120-volt loads, etc., in the Operations Building.

Also, the 600 V switchboard will supply 3-phase power feeder to a 600/480 volt dry-type transformer for vendor equipment requiring 480 V power (e.g., UV System).

The normal power distribution equipment will consist of 600 V power panel(s), 600 V to 120/208 V, grounded-Y, transformer(s) and 120/208 V power panel(s).

6.5.4.4 Motor Control Centre

Full voltage non-reversing motor controllers will be magnetic and combination starters will be EEMAC standard NEMA rated and will generally be fitted with power and control terminal blocks, fused primary and secondary 120 V control transformer, solid-state overload protective device, with control station and auxiliaries as required.

Motor control centres (MCC’s) consisting of modular motor starters and feeder breakers will be provided for power supply to all 600 V process, mechanical equipment, motors, etc. The structure will be EEMAC 1 gasketed with top cable/conduit entries and provisions for future add-on sections to both sides. All control and ancillary devices associated to one drive will be installed in the unit compartment for that drive. Unused spaces will be arranged to accommodate standard starter/feeder unit compartments in the future. Motor control centre wiring will be EEMAC Class 2 Type B with track mounted terminals in each unit. Motor starter units will be motor circuit protector combination magnetic or microprocessor controlled, EEMAC type, sized and configured as required. Feeder breaker units will be mounted in unit compartments. Breakers will be moulded case thermal magnetic.

Variable Frequency Drives (VFD) will be of the Pulse-Width Modulated type and will incorporate a microprocessor to handle all logic functions. Electrical noise, (radio interference and AC line harmonics) will be limited to levels specified in the latest edition of IEEE 519 and the Radiocommunication Act of Canada. Equipment will be designed so that use of radio communication equipment adjacent to VFD units is possible. In addition, the VFD equipment is not to be susceptible to interference from radio equipment operated adjacent to it. Harmonics generated by the adjustable speed equipment are not to exceed the levels of distortion for voltage and current based on IEEE 519 latest edition. Input and output line reactors to be provided (approved to UL506), and harmonic compensated to carry full rated fundamental current plus 50% additional harmonic current continuously. Motor filters will be provided, if necessary, to limit the peak voltage at the motor terminals to less than 900 V with a maximum voltage rise of less than 300 V per microsecond. A line filter will be installed to the line side of the VFD. Filter characteristics will be as required to reduce the harmonic currents, as measured at the utility point of service, to below the limits established by electric utility service regulations.

6.5.4.5 Mechanical Equipment

The building services mechanical equipment will be provided with electrical services as required. Exact equipment sizes and locations will be coordinated with the mechanical engineering. Magnetic starters will be provided where required and housed in the MCCs to minimize space requirements and facilitate control wiring. All motor starters will be provided with HAND/OFF/AUTO selector switches, ammeters, elapsed-time meters and disconnects to code requirements. Local disconnects will be installed close to all main HVAC equipment, as per code requirements.

Motors will be TEFC or submersible rated, of the latest energy efficiency design and in conformance with Power Smart Program rating for energy efficiency where applicable. Motors on VFDs will be provided with individual Human Machine Interfaces (HMIs) for manual speed control.

6.5.4.6 Miscellaneous Electrical

Wiring in the building will be Teck90 in a cable tray or run in rigid PVC conduit and junction boxes, both in the wet; corrosive areas and in the regular dry areas. Branch circuit wiring will be a minimum of #12 RW90. All conductors will be copper. Feeders and major power circuits will be aluminum-sheathed PVC-jacketed copper cables or equivalent conductors in a conduit.

Receptacles and switches will be specification grade, installed in PVC boxes and covers, and weatherproof rated as required. Outdoor car block heater receptacles will be provided for employee parking.

A system of raceway, cabinets and outlets will be provided for telephone distribution. The SaskTel cost of service to the wastewater treatment plant will be included.

6.5.5 Grounding/Bonding

Substation ground grid will consist of 3/4" diameter × 20' copper clad steel ground rods connected by #2/0 bare stranded conductor with #4/0 bare stranded risers to equipment. Equipment will be grounded at two points. Grounding and bonding of equipment including fencing and gates will be as specified by the Canadian Electrical Code.

Building grounding will be accomplished by utilizing a building-perimeter ground grid consisting of 3/4" diameter × 20' copper clad structured steel ground rods connected by #4/0 bare stranded conductor – rods installed at the corners of the building will come complete with inspection well. Sufficient grounds rods will be utilized in the installation to maintain a minimum ground grid resistance. The main building ground bus bar(s) will be 6" x 48" x 1/4" wall mounted copper bar. #2/0 bare stranded conductors will rise from the main grid to the building structure. The building ground bus bars will be connected together with #4/0 bare stranded conductor. Connections from the interior building ground bus to the exterior building perimeter ground grid will be made at multiple points.

From the primary main perimeter ground ring, additional runs of primary ground grid conductors will be installed embedded in the building concrete. The building ground grid conductors will have connections available (pigtails) for bonding equipment. Grounding and bonding of equipment will be as specified by the Canadian Electrical Code.

A separate isolated grounding system will be created within the building for the incoming instrumentation signals. The isolated grounding system will be comprised of 6" x 48" x ¼" copper bus bars. These bus bars will be connected together with #4/0 bare stranded conductors. The isolated ground bus will be connected to the building ground bus system at two points externally. This configuration minimizes the effect of electromagnetic interference from large rotational mechanical loads on the instrumentation ground reference point.

6.5.5.1 Power Factor Correction

Automatic controlled power factor correction equipment will be provided at the 600 V level to maintain an overall system power factor at the plant of 90% or better.

6.5.6 Electrical Harmonic and Transient Suppression Techniques

The building contains a significant quantity of sensitive and high cost electrical equipment and associated wiring. The following design methods will be implemented to limit damaging harmonics and voltage transients to this equipment:

- A robust transient voltage surge suppression (TVSS) systems will be installed in the main MCC to protect against unwanted voltage transients and high frequency electrical noise
- All step-down transformers used within the design will incorporate harmonic mitigating technologies
- All neutral conductors for sensitive equipment connections will be sized at 200% of the feeder conductors – this will ensure sufficient conductor capacity to carry any harmonics or unbalanced currents within these circuits
- An isolated ground grid will be utilized for grounding sensitive equipment; this ground grid will be connected to the building ground grid externally to bypass building electrical noise
- Line reactor devices will be placed both upstream and downstream of any VFDs in order to limit total harmonic distortion to less than 5%

6.5.7 Lighting and Building Systems

6.5.7.1 Interior Building Lighting

The interior building lighting design will utilize LED moisture resistant light fixtures with moisture resistant task lighting were required. These will be controlled via occupancy sensors. Lighting levels will be 500 lux (50 foot-candles).

6.5.7.2 Building Lighting – Exterior

Exterior 150 W, LED, wall-mounted fixtures will be provided at all entrances and exits to the building (minimum illumination of 2 foot-candles), as well as along the exterior of the building to provide site exterior mechanical equipment. All exterior lighting fixtures will be controlled via integral photocells and will be weather-proof and vandal resistant.

6.5.7.3 Exit, Emergency and 24/7 Lighting

Exit lighting will be installed at all means of building egress, as well as other building areas as required to sufficiently indicate directions to a point of egress. This signage will be illuminated by two separate AC and DC LED arrays – the 120 VAC LEDs will be powered under normal building operation from essential power circuits and the DC LEDs will be powered from a self-contained battery unit, in the event of power interruption. The battery unit will be sized to provide at least 30 minutes of LED illumination in the absence of a 120 VAC power source.

As required by the National Building Code, a minimum of 1.0 foot-candles of emergency lighting illumination will be provided at all means of building egress, as well as along all paths to egress points from the building. This will consist of self-contained battery units.

In the event of a loss of utility power, the essential power feed may suffer a measurable period of interruption while the generator comes on-line. In order to ensure an uninterrupted emergency lighting service in the building the battery units will provide carry through for the generator start and transfer period or generator failure to start.

6.5.7.4 Fire Alarm System

Although the building by code is not required to have a fire alarm system because it would be unoccupied in normal operation it is recommend that a fire alarm system be installed. The system will be connected to the SCADA system to provide off site alarm and trouble monitoring. This system will consist of an intelligent, fully addressable Notifier fire alarm system, comprised of the following main devices:

- A Notifier main fire alarm control panel will be situated adjacent to the main entrance. The control panel will be powered under normal building operating conditions by a dedicated, essential power circuit complete with a locked-on circuit breaker; in the event of a prolonged main power service interruption, the system will have a self-contained battery unit capable of driving the fire alarm system for at least 24 hours in normal operation and 30 minutes in alarm mode
- Conventional technology heat detectors will be located as required
- Conventional technology smoke detectors will be located as required
- Duct type smoke detectors will be installed in the return and supply air ductwork of all main mechanical ventilation equipment
- Early detection laser smoke detectors will be located in high value electrical components. These specialty detectors can detect lower levels of smoke particulates per unit area as compared to conventional detectors. As such, they will offer improved fire protection to sensitive equipment in these areas by generating alarm signals before significant damage has occurred. All detectors will be 3-wire design
- Manual pull stations will be located adjacent to all building exits
- Alarm signaling devices (combined horn and strobe) will be located in appropriate number and orientation to provide sufficient audible and visual signals to building occupants
- Addressable fire alarm system control modules (relays) will be integrated into the starter circuits for all mechanical ventilation equipment to allow for shutdown in the appropriate fire alarm event

All detailed design related to the fire alarm system, including specifications related to fire alarm system devices spacing, quantity and coverage, will fully comply with the requirements of the NBC and relevant NFPA sections.

6.5.7.5 Toxic Gas Detection

Detection of toxic gas levels in the building will be addressed utilizing stand-alone detectors connected to the SCADA system.

6.5.8 Convenience Receptacles

Wiring devices will be specification grade housed within waterproof covers. Switches will be specification grade, side and back wiring, with conventional handle. Switch pole configuration will be as required and will be rated to conform to the system voltage and branch circuit size. Duplex receptacles will be nylon or lexan face, specification premium grade, CSA type 5-15R, 125 V, 3 wire, U grounded type.

All branch circuitry for luminaires, switches and convenience receptacles will be surface mounted utilizing copper conductors in PVC raceways and FS outlet boxes.

Special purpose or welding outlets will be provided in the general areas.

6.5.9 Security System

A multiple zone security system will be installed. A suitable arrangement of detection devices will be installed including door contact switches, motion sensors, etc. The security system will be connected to the SCADA system.

The capability for a Closed Circuit Television (CCTV) system for monitoring the interior and entrances of the building and site will be allowed as a future installation.

6.5.10 UPS Power System

Process-critical equipment (including racks, terminals and Control Panels) will be connected to a 10 kVA, redundant, 2-h UPS system, complete with internal maintenance bypass functionality in the Operations Building for the process critical equipment.

6.5.11 Telecommunications System

A system of empty raceways will be provided to facilitate telecommunication wiring throughout the plant. Telephone service will be provided by SaskTel. There may be impacts upon the exact nature of the communications services that are required, dependent upon the desired methods to be used to remotely access the automation system, and remotely transmit alarm conditions to off-site parties.

6.6 CONTROL AND INSTRUMENTATION DESIGN CRITERIA

6.6.1 General Approach to the Automation System

At this point in the development of the project, adequate time has not been available to systematically advance a control and instrumentation philosophy or system which would fully meet the needs of the City.

City staff would likely supervise the plant daily. During that time, they will respond to automatically generated alarms or pending alarm conditions within the plant as well as review process results in addition to their regular service and maintenance duties. City must be advised of all abnormal conditions within the plant, and to obtain this information will require a supervisory control and data acquisition system capable of transmitting those abnormal conditions to on-call personnel as designated by the City.

6.6.2 Basic Plant Operating Philosophy

A comprehensive approach to the operating philosophy initially considered for all process, mechanical and electrical equipment will be to provide a control mode selection at or near each piece of equipment to enable the operator to take control of that system or component manually.

The basic premise will be to have a control station installed adjacent to each controlled component. The “Local” control station will comprise a three-position (Local-Off-Remote) switch and two pushbuttons (Start - Stop). Typically, the selection will be the “Remote” position where all control originates from the programmable logic controller (PLC) for that area. Any selection other than “Remote” will initiate an alarm or equipment out-of-service status at the supervisory control and data acquisition (SCADA) system. When the operator selects the “Off” mode, the controlled component is mostly off-line or out-of-service for either maintenance or visual checking. When the mode selection is “Local”, the operator may start and stop that component via the pushbuttons.

There is no hard wiring between the local control station and the starter/controller, but rather all control is via the (PLC) hardware. Besides, all status, alarm, permissive, interlocks and safety element inputs will be processed by the (PLC) hardware.

6.6.2.1 Control and Instrumentation System Development

During the first stages of the detailed design phase, the following issues must be evaluated, reviewed and approved by the City:

- The process control requirements
- Operational philosophy
- Type of instrumentation and signal count
- Operator interface needs
- Anticipated analog signal manipulation
- The required database
- The relative physical location of the control system components
- Remote communications.
  - Typically, two dedicated analog phone lines are installed. One to be used for dial-in access for remote diagnostics and programming; and a second one to be used for alarms or critical operating conditions notification to the off-site personnel. If a digital phone system is contemplated, these analog lines may be able to be added as a function of the selected system. Otherwise, they would be separately installed when the overall service is brought to the site.
  - Alternatively, a web-based system could be considered. This system would require internet access and an associated security system that would need to meet the requirements of the City.

Once a process flow diagram has been established, the control system functional description will proceed with the development of the process and instrument diagram (P&ID) followed by the functional description (control philosophy). The functional description is a detailed description, at the equipment level, of the plant control operation to be used for the project. In turn, it is used to define the tasks to be performed by programmable devices.

At this stage, the control system that is best suited to the particular plant or system is defined. The criteria include the degree of automation required, client management and operator need, the size of the process being controlled, the reporting methods to be adopted, the response time required of the control system, and so forth.

An automatic/programmable control system will necessitate establishing the most appropriate system architecture taking into account the following:

- Type of operating system
- Local area network, extensive area network or other communication data transfer needs
- Connectivity needs of the system for various manufacturers equipment
- The control system hierarchy that may integrate several levels such as a field bus network, an operating system network and a management information system network
- The need to remotely transmit process signals or data
- System reliability and redundancy
- Diagnostics and maintenance
- Future expansion
- Ease of configuration and programming
- Expandability
- Local service, parts and technical support
- Cost

6.6.2.2 Equipment Selection

There are a number of programmable logic controller (PLC) manufacturers, each with their own SCADA software products to interface with the system PLCs. The SCADA packages are often able to communicate with other vendors' controllers. The following systems are recommended for evaluation based on the items listed in Basic Plant Operating Philosophy above:

- PLC platforms:
  - Rockwell/Allen-Bradley: Control Logix series
  - Schneider: Quantum series
- SCADA software:
  - Rockwell - FactoryTalk View SE
  - Schneider - Vijeo CITECT
  - Invensys – Wonderware

6.6.2.3 Instrumentation

All analog field instrumentation (e.g., flowmeters, level sensors, pressure transducers, etc.) will be provided with 4-20 mA analog signals to transmit process variables to the SCADA system. Flowmeters will additionally provide a configurable pulse output to the SCADA system to allow for accurate flow volume totalization.

7.0 LIFE CYCLE COST

A technical and financial evaluation has been completed for the design period. Table 7-1 presents life cycle cost estimates for the purpose of comparing the cost based upon two different design periods.

Table 7-1 Life Cycle Cost

Item	Description	Aerated Lagoons / SAGR Process Design year 2052 (10,000 population)
1.0	General Requirements	$3,077,000
2.0	Siteworks	$4,783,400
4.0	Headworks	$0
5.0	Upgrades to Cells 1, 2, 3, 4, 5 and 6	$2,871,000
6.0	SAGR Cells	$4,859,000
7.0	Operations Building	$9,085,000
8.0	Odour Control Building	$0
	Subtotal	$24,675,400
	Contingency (20%)	$4,936,000
	Engineering (10%)	$2,962,000
	Total Project Capital Cost	**$32,573,000**
	Annual Operation Costs (based on year 2020)	$505,000
	NPV O&M (33-yr for design year 2052)	$15,990,000
	NPV Life Cycle Cost (33-yr for design year 2052)	**$48,563,000**

7.1 LIFE CYCLE COST RESULTS

The life cycle costs for the aerated lagoons / SAGR process is presented in Table 7-1 along with the Net Present Value (NPV) for the design period. The NPV represents the value of all future costs over the design life of the capital investment. Opinions of probable cost for capital and operating costs are described in the following sections.

7.2 OPINION OF PROBABLE CAPITAL COST

Opinions of Probable Capital Cost (OPCC) are preliminary and subject to development of actual designs, loadings and any special requirements, but do provide an indication of relative cost differentials between design years. The attached spreadsheets in Appendix A provide a breakdown of the OPCCs for each design period.

OPPCs were developed using a combination of stochastic and deterministic factors as follows.

General requirements (stochastic): General requirements include the cost of mobilization/demobilization, start-up and commissioning, operation and maintenance manuals and record drawings. These costs are about 11.5% of the subtotal for all process areas.

Siteworks (deterministic and stochastic): Siteworks include the cost of excavation and backfill, roadways, yard piping, outfall structure, final effluent forcemain, fencing, landscaping and dewatering allowance. The OPPC for excavation and compacted backfill are based on calculated volumes and rate of $24/m^3 of material.

Structural tank (deterministic): OPCC for concrete tanks is based on calculated concrete volumes priced at an average of about $1,650/m^3 for slab and $1,400/m^3 for walls. Rebar cost is estimated based on a unit rate of $440/m^3 for concrete. Form work costs is estimated based on the surface area of tank wall at a unit rate of $280 for straight wall.

Structural building (deterministic): OPCC for structural buildings is based on lump sum prices for masonry, metals, wood, plastic, thermal and moisture protection, doors and windows for similar buildings.

Process (deterministic): OPCC for process is developed from vendor quotes (specifically requested for this project and provided by Nexom), plus a 50% installation cost. Nexom's proposal is attached.

Mechanical (stochastic): OPCC for HVAC mechanical is based on experience from previous projects, the mechanical costs are assumed to be 7% of the subtotal for the Operations Building.

Electrical, Instrumentation and Control (I&C) (deterministic): OPCC for electrical and I&C is based on lump sum prices from similar previous projects.

7.3 OPINION OF PROBABLE OPERATING COST

Opinions of Probable Operating Cost (OPOC) are developed based on standard unit costs. The opinions of probable costs are tentative and subject to development of actual unit cost for the plant but do provide an indication of relative cost differentials between design periods. The annual OPOC for the design year 2020 is approximately $459,000 annually. Annual costs will fluctuate depending on sludge removal frequency. For instance, the operating cost will increase to $816,000 due to additional sludge removal cost of $324,000 as presented in Table 7-2.

Table 7-2 Opinion of Probable Operating Cost

Item	O&M Components	Aerated Lagoons / SAGR Process Year 2020	Aerated Lagoons / SAGR Process Year 2024
1.0	Salaries with benefits	$141,000	$152,600
2.0	Administration (training, fleet, and fuel)	$35,000	$37,900
3.0	Insurances and legal fees	$35,000	$37,900
4.0	Monitoring and testing	$30,000	$32,500
5.0	Consumables (chemicals, UV lamps)	$71,000	$82,000
6.0	Electricity	$153,000	$166,000
7.0	Natural gas	$20,000	$22,000
8.0	Sludge disposal – land application (average 33-yr for design year 2052)	$0	$324,000
9.0	Contract operations (equipment maintenance)	$20,000	$21,600
	Total	**$505,000**	**$876,000**

Salary estimates are based on 2 full time employees (full time equivalents or FTE’s) for the aerated lagoons / SAGR option. Labor cost estimates are based on hourly rates for WWTP operators in Saskatchewan. Benefit costs were estimated using a 1.25 multiplier.

Natural gas costs were estimated based on the estimated footprint of the building.

Table 7-3 Consumables Cost Estimated for Chemical Precipitation (Initial Design Year)

Description	Qty/yr	Dose	Daily Chemical Usage	Annual Chemical Usage	Unit Consumable Costs	Annual Consumable Costs
		g/m³	kg/d	kg/yr	$/kg or $/unit	$
Alum		120	306	111,700	$0.55	$61,400
Polymer		N/A	N/A	N/A	N/A	N/A
Chlorine (for utility water)		3	7.65	2,792	$0.83	$2,300
UV lamps	17				$404.00	$7,100
Aerated Lagoons / SAGR Diffuser replacement (after 10 years of service)					$10,000 (in 2020)	$12,000 (in 2030)
Total Consumable Costs (chemical cost varies depending on the liquid treatment process)						$71,000

Sludge disposal costs were estimated based on $10/m^3$ for liquid land application and $20/m^3$ for dewatering and $0.72/tonne/km for transportation to landfill.

Consumables and chemical cost estimates are based on volume of chemical consumed and unit chemical costs as presented in Table 7-4.

Table 7-4 Consumable Cost Estimate for Chemical Precipitation

Year	Alum	Sodium Hypochlorite	UV Lamps	Diffuser Replacement	Total Consumable Cost
2020	61,400	2,300	7,100	0	71,000
2021	63,600	2,400	7,200	0	74,000
2022	65,900	2,500	7,400	0	76,000
2023	68,300	2,600	7,500	0	79,000
2024	70,700	2,700	7,700	0	82,000
2025	73,100	2,800	7,800	0	84,000
2026	75,700	2,900	8,000	0	87,000
2027	78,300	3,000	8,100	0	90,000
2028	81,300	3,100	8,300	0	93,000
2029	84,100	3,200	8,500	0	96,000
2030	86,900	3,300	8,600	12,000	111,000
2031	90,200	3,400	8,800	0	103,000
2032	93,200	3,500	9,000	0	106,000
2033	96,600	3,600	9,200	0	110,000
2034	100,100	3,800	9,300	0	114,000
2035	103,400	3,900	9,500	0	117,000
2036	107,100	4,000	9,700	0	121,000
2037	111,000	4,200	9,900	0	126,000
2038	114,900	4,300	10,100	0	130,000
2039	119,000	4,500	10,300	0	134,000
2040	123,100	4,600	10,500	15,000	154,000
2041	127,400	4,800	10,700	0	143,000
2042	131,800	5,000	10,900	0	148,000
2043	136,800	5,200	11,200	0	154,000
2044	141,400	5,300	11,400	0	159,000
2045	146,600	5,500	11,600	0	164,000
2046	151,600	5,700	11,800	0	170,000
2047	157,100	5,900	12,100	0	176,000
2048	162,700	6,100	12,300	0	182,000
2049	168,100	6,300	12,600	0	187,000
2050	174,100	6,600	12,800	18,000	212,000
2051	180,300	8,900	13,100	0	203,000
2052	186,600	11,400	13,300	0	212,000

Electricity costs were developed using motor power demand, and hours of service for expected equipment as presented in Table 7-5. For electrical power, a unit cost of $0.07/kWh was used for electricity. SaskPower utility bills include demand charges, peaking charges and other surcharges. For the sake of simplification, the average unit cost of $0.07/kWh was applied to all power cost calculations.

Table 7-5 Electricity Cost

Equipment Name	Connected Duty Load	Duty Factor	Power Consumption	Power Consumption	Power Cost
Type	kW	unitless	kWh/day	kWh/year	$/year
Aerated Lagoon Blower 1	37.3	0.4	393.8	143,724	$14,372
Aerated Lagoon Blower 2	37.3	0.4	393.8	143,724	$14,372
SAGR Blower 1	74.6	0.7	1,274.0	465,005	$46,501
SAGR Blower 2	74.6	0.7	1,274.0	465,005	$46,501
SAGR Blower 3 (standby)	74.6	0.0	0.0	0	$0
UV Disinfection	17.9	0.3	109.3	39,910	$3,991
Effluent Pump 1	18.7	0.1	22.4	8,169	$817
Effluent Pump 2	18.7	0.0	0.0	0	$0
Effluent Pump 3	5.6	0.6	73.9	26,957	$2,696
Effluent Pump 4	5.6	0.0	0.0	0	$0
Rapid Mixer	1.5	1.0	35.8	13,070	$1,307
Slow Mixer	0.6	1.0	13.4	4,901	$490
Alum Transfer Pump	0.75	0.1	0.9	327	$33
Alum Dosing System	0.09	1.0	2.1	784	$78
NML Pump 1	5.6	0.6	80.6	29,407	$2,941
NML Pump 2	5.6	0.0	0.0	0	$0
W3 Pump 1	4.8	1.0	116.4	42,477	$4,248
W3 Pump 2	4.8	0.0	0.0	0	$0
Hypochlorite Dosing System	0.09	0.5	1.1	392	$39
Compressor	11.2	0.0	0.7	272	$27
Drain Pump 1	3.7	0.3	29.5	10,783	$1,078
Drain Pump 2	3.7	0.3	29.5	10,783	$1,078
Laboratory rooftop unit	3.7	0.3	26.9	9,802	$980
Control room rooftop unit	2.6	0.3	18.8	6,862	$686
Server room cooling unit	1.5	0.5	17.9	6,535	$653
Electrical room air handler	2.2	1.0	53.7	19,605	$1,960
Makeup air unit	2.2	1.0	53.7	19,605	$1,960
UV exhaust fan	1.5	1.0	35.8	13,070	$1,307
Blower room exhaust fan	1.1	1.0	26.9	9,802	$980

Equipment Name	Connected Duty Load	Duty Factor	Power Consumption	Power Consumption	Power Cost
Type	kW	unitless	kWh/day	kWh/year	$/year
Blower room exhaust fan	1.1	1.0	26.9	9,802	$980
Washroom exhaust fan	0.2	0.5	2.2	817	$82
Electrical room exhaust fan	1.1	1.0	26.9	9,802	$980
Chemical room exhaust fan	0.4	1.0	9.0	3,267	$327
Entrance heaters	6.0	0.2	28.6	10,456	$1,046
DHW recirc pump	0.2	1.0	5.9	2,157	$216
Unit heaters (six)	1.1	0.3	6.7	2,451	$245
Total				1,534,952	**$153,000**

7.3.1 Limitations of Opinion of Probable Cost

The Project Team has agreed to basic design criteria, process and components. However, there are still many unknown details related to the WWTP project that could impact the opinion of probable costs presented in this section. Because the project is in the preliminary stage there will be design decisions made during detailed design that will affect the cost. Sufficient work has been undertaken on each of the components of the preliminary design for Stantec to make informed assumptions based on previous experience on similar treatment facilities. The OPCC includes a contingency allowance of 20 percent to account for facility changes made during detailed design. This allowance is not meant to cover design scope changes, capacity or quality modifications. The OPCC reflects our best judgment at this stage of the project. Stantec has no control of future construction market conditions, which could significantly impact construction costs. No inflation allowance during the construction period is included in these OPCCs.

The opinion of probable cost is prepared based on the preliminary design work completed to date, as outlined in the preceding technical sections. It reflects our best judgment at this stage of the project. Stantec has no control of future construction market conditions, which could significantly impact construction costs. No inflation allowance is included in these costs.

- Costs are based on 2019 Canadian Dollars
- Imported equipment exchange rate is based on US $1 = C $1.30
- Taxes are not included
- All Subtotal Costs are rounded to the nearest thousand dollars

Opinion of Probable Capital Cost Comments

The OPCC for the upgrade of the Humboldt WWTP has about $13.2M (including engineering and contingencies) related to other works that are not typical for aerated lagoons, without these additional components, the subtotal would be closer to $20M ($33.2M - $13.2M). These components include:

- A new influent structure to combine the influent from three lift stations
- A final effluent pump station with a 4.8 km forcemain and a new outfall
- A NML pump station with a 1.5 km forcemain so that alkalinity is recovered to ensure that nitrification inhibition will not occur
- A new outfall away from the residential area
- A small lake with limited assimilation capacity
- New transfer structures due to the hydraulic limitations of the existing structures
- Access road for a 40-tonne B-trains to deliver alum
- Site preparation for geotextile laydown area
- A building to house blower, chemical tanks, UV reactor, metering pumps, and electrical equipment

The OPCC does not defer components to the future. We are aware of Owners who defer items such as site preparation for geotextile dewatering. After some years they find themselves in a difficult and costly situation where they are facing sludge above the liquid level, odour emissions and now higher than normal sludge dewatering costs because they decided to defer site preparation during the initial construction. These costs now become operating costs and not eligible for grant funding.

The OPCC does not include applicable taxes (i.e. GST and PST) because some funding agencies require separate entries for eligible and ineligible costs.

APPENDIX

Appendix A OPINION OF PROBABLE CAPITAL COST

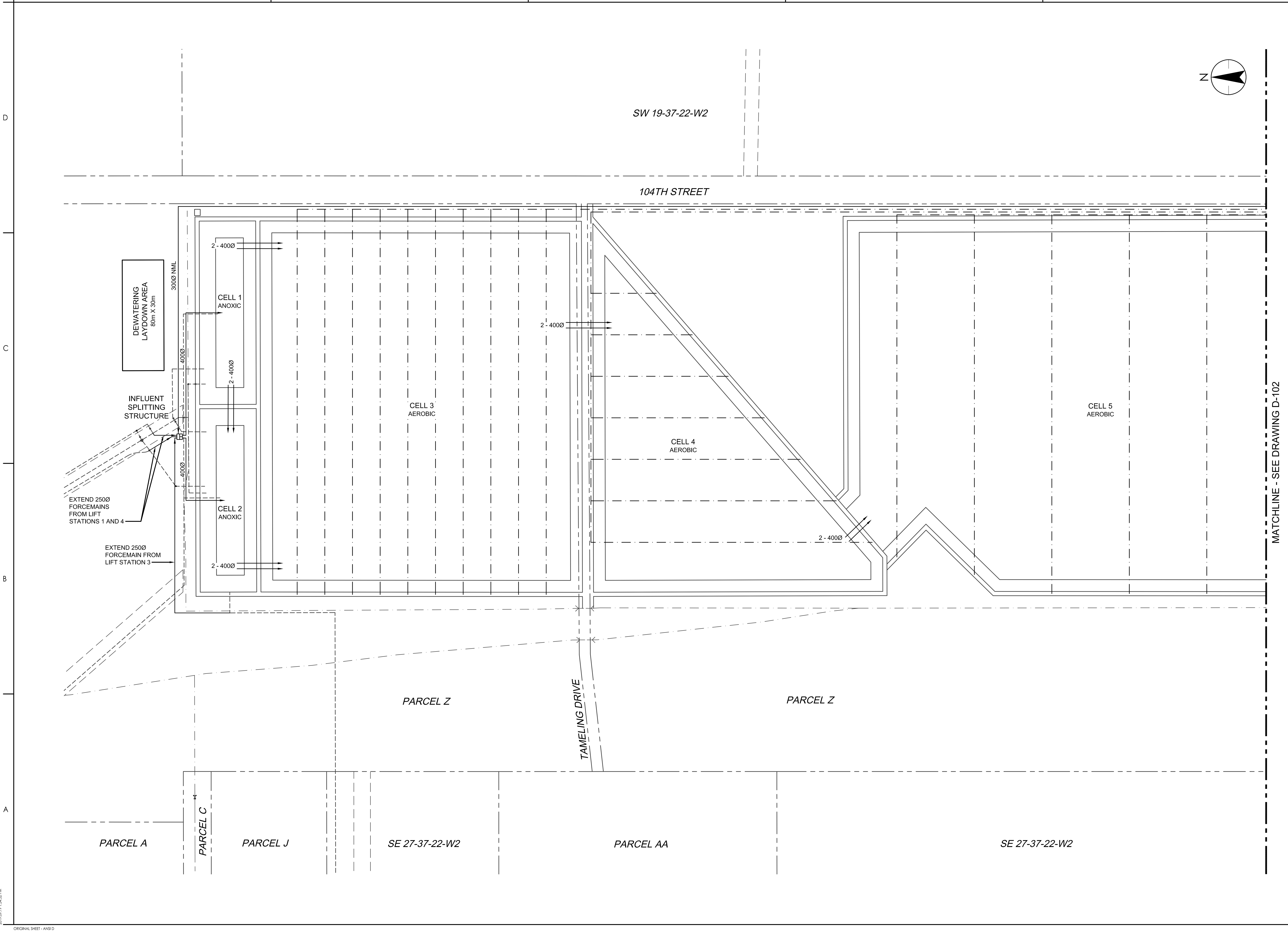
Opinion of Probable Capital Costs for Aerated Lagoons/SAGR for Design period 2052 to Serve 10,000 people
ADF = 4100 m^3/d, MMF = 7240 m^3/d, MDF = 14,252 m^3/d

Item No.	Description	Unit	Quantity	Material or Equipment Costs Unit Price	Material or Equipment Costs Total Price	Labour & Overhead	Total Costs
1.0	**General Requirements**						
1.1	Divisions 0 and 1						
	Mobilization / Demobilization	% Total	1	0.50%	$108,000		$108,000
	General Conditions	% Total	1	8.00%	$1,728,000		$1,728,000
	Performance Assurance	% Total	1	1.50%	$324,000		$324,000
	Insurance	% Total	1	1.70%	$367,000		$367,000
	Building Permit	% Total	1	0.75%	$162,000		$162,000
	Start-up and Commissioning	% Total	1	0.90%	$194,000		$194,000
	O&M Manuals and Record Drawings	% Total	1	0.90%	$194,000		$194,000
	Subtotal General Requirements			14.25%			**$3,077,000**
2.0	**Siteworks**						
2.1	Divisions 31 to 33 - Siteworks						
	Layout and Survey	LS	1	$30,000	$30,000	Included	$30,000
	Parking Lots and B train turn around	m^2	1,000	$87	$87,000	Included	$87,000
	Site Access Road to SAGR	LS	2,000	$87	$174,000	Included	$174,000
	Site Stripping and Grading	LS	1	$120,000	$120,000	Included	$120,000
	Yard Piping Allowance (Including underground services)	LS	1	$150,000	$150,000	Included	$150,000
	Influent Splitting Structure (ISS)	LS	1	$300,000	$300,000	Included	$300,000
	RS Pipe to Influent Splitting Structure	m	100	$500	$50,000	Included	$50,000
	RS Pipe from ISS to Cell 1 and 2	m	200	$500	$100,000	Included	$100,000
	Influent Flowmeters	LS	2	$9,000	$18,000	Included	$18,000
	Flowmeter chambers c/w access hatch, ladder, waterproof membrane and insulation	LS	2	$25,000	$50,000	$25,000	$75,000
	NML 250 mm dia. Forcemain to Front End Lagoon	m	1,500	$400	$600,000	Included	$600,000
	Outfall Structure	LS	1	$250,000	$250,000	Included	$250,000
	Effluent Forcemain 400 mm (including manholes, backfill and testing)	m	4,800	$500	$2,400,000	Included	$2,400,000
	WAS Pipe from Process Building to Lagoon 3	m	0	$0	$0	Included	$0
	Site Preparation for Geotextile Container North of Cell 1	m^2	2,400	$50	$120,000	Included	$120,000
	Site Preparation for Geotextile Container at Cell 6	m^3	5,720	$15	$86,000	Included	$86,000
	Site Preparation for Frac Tanks	m^2	200	$87	$17,400	Included	$17,400
	Generator Concrete Pad	LS	1	$75,000	$75,000	Included	$75,000
	Railway Crossing	LS	0	$0	$0	Included	$0
	Flood Protection (Berm and Sod)	LS	0	$0	$0	Included	$0
	Fencing (1800mm chain link fence)	m	4,000	$14	$56,000	Included	$56,000
	Berm Seeding Allowance	LS	1	$50,000	$50,000	Included	$50,000
	Dewatering Allowance	LS	1	$25,000	$25,000	Included	$25,000
	Subtotal Siteworks						**$4,783,400**
3.0	**Headworks**						
	Subtotal Headworks	N/A					**$0**
4.0	**Cells 1, 2, 3, 4, 5 and 6**						
4.1	Divisions 31 to 33 - Siteworks						
	Embankment Construction	m3	4,800	$24	$115,000	Included	$115,000
	Cells 1 and 2 Clay Liner (600 mm thick)	m2	9,500	$10	$95,000	Included	$95,000
	Liner Protection (300 mm thick)	m2	9,500	$5	$48,000	Included	$48,000
	Stripping and Compaction	m2	0	$0	$0	Included	$0
	Erosion Protection for 5300 m (L), 0.72 m (W), 0.3 m (T) for 0.3 m WL change	m3	250	$1,145	$286,000	Included	$286,000
	Rapid and Slow Mixing Manholes	LS	2	$75,000	$150,000	Included	$150,000
	Effluent Manholes	LS	1	$60,000	$60,000	Included	$60,000
	Excavation for Air Headers	m	1,300	$550	$715,000	Included	$715,000
	De-sludging Cells 1, 2 and 3	m3	30,900	$20	$618,000	Included	$618,000
	Supply of Aquadam (9 locations/15 dams)	unit	9	$10,000	$90,000	Included	$90,000
	Installation Aquadams & pumping (9 locations/15 dams)	unit	15	$20,000	$300,000	Included	$300,000
	Buried Plug Valves	unit	32	$9,500	$304,000	Included	$304,000
	Installation of Transfer Pipes x 2 (9 locations)	LS	9	$10,000	$90,000	Included	$90,000
	Subtotal Cells 1, 2, 3, 4, 5 and 6						**$2,871,000**
5.0	**SAGR Cells**						
5.1	Divisions 31 to 33 - Siteworks						
	Stripping and Compaction	m2	15,168	$2	$30,000	Included	$30,000
	Excavation	m3	22,917	$24	$550,000	Included	$550,000
	Hauling and Placing Excess Material	m3	10,800	$10	$108,000	Included	$108,000
	Wall Framing and Sheeting	m	976	$80	$78,000	Included	$78,000
	HDPE Liner (60 mil)	m2	15,104	$22	$332,000	Included	$332,000
	Clean Gravel/Rock	m3	27,878	$80	$2,230,000	Included	$2,230,000
	Insulating Wood Strips	m3	3,686	$20	$74,000	Included	$74,000
	Non-Woven Geotextile (8 oz)	m2	28,800	$3	$72,000	Included	$72,000
	SAGR Influent Flow Splitter Structure	l.s.	1	$300,000	$300,000	Included	$300,000
	Piping, Fittings, Valves from Splitter to SAGR	l.s.	1	$200,000	$200,000	Included	$200,000
	Piping, Fittings, Valves from Cell 7 to SAGR	m	200	$550	$110,000	Included	$110,000
	Piping, Fittings, Valves from SAGR to Effluent Lift Station	m	500	$550	$275,000	Included	$275,000
	Effluent Level Control Manhole	l.s.	4	$25,000	$100,000	Included	$100,000
	Inspection Manhole	l.s.	2	$25,000	$50,000	Included	$50,000
	Excavation for Air Headers	m	500	$700	$350,000	Included	$350,000
	Subtotal SAGR						**$4,859,000**

Item No.	Description	Unit	Quantity	Material or Equipment Costs Unit Price	Material or Equipment Costs Total Price	Labour & Overhead	Total Costs
6.0	**Operations Building**						
6.1	Divisions 31 to 33 - Siteworks						
	Excavation and Backfill	m^3	1,119	$24	$27,000	Included	$27,000
	Piling	each	55	$2,500	$138,000	Included	$138,000
6.2	Division 3 - Concrete Work						
	Structure - Slab	m^3	200	$1,650	$330,000	Included	$330,000
	Structure - Walls	m^3	172	$1,400	$241,000	Included	$241,000
	Form Work	m^2	688	$280	$193,000	Included	$193,000
	Rebar	m^3	372	$440	$164,000	Included	$164,000
	Void Form (200 mm)	m^2	109	$22	$2,000	Included	$2,000
	Precast Hollow Core	LS	1	$120,000	$120,000	Included	$120,000
6.3	Division 4 - Masonry	LS	1	$100,000	$100,000	Included	$100,000
6.4	Division 5 - Metals	LS	1	$100,000	$100,000	Included	$100,000
6.5	Division 6 - Wood and Plastic	LS	1	$10,000	$10,000	Included	$10,000
6.6	Division 7 - Thermal and Moisture Protection						
	Metal Cladding	LS	1	$80,000	$80,000	Included	$80,000
	Roofing	LS	1	$35,000	$35,000	Included	$35,000
6.7	Division 8 - Doors and Windows						
	Access Hatches	LS	6	$5,000	$30,000	Included	$30,000
	Doors / Overhead Doors / Frames / Hardware	LS	18	$1,500	$27,000	Included	$27,000
	Windows/Glazing	LS	4	$3,000	$12,000	Included	$12,000
6.8	Division 9 - Finishes						
	Painting	LS	1	$15,000	$15,000	Included	$15,000
	Special Coatings	LS	1	$75,000	$75,000	Included	$75,000
6.9	Division 10 - Specialties	LS	1	$7,000	$7,000	Included	$7,000
6.10	Division 12 - Furnishing	LS	1	$60,000	$60,000	Included	$60,000
6.11	Divisions 40, 43 and 46 - Process						
	Sluice and Slide Gates	LS	0	$8,000	$0	$0	$0
	Drain Pumps and Fittings	LS	1	$70,000	$70,000	$35,000	$105,000
	Equipment Supply by Nexom (air blowers, HDPE headers, laterals, diffusers, control panels, influent piping and chambers eng. and installation)	LS	1	$3,230,000	$3,230,000	$646,000	$3,876,000
	NML Pump and Fitting	each	1	$70,000	$70,000	$35,000	$105,000
	Filtration System	each	0	$0	$0	$0	$0
	UV Disinfection System including Davit	each	1	$350,000	$350,000	$175,000	$525,000
	Effluent Pump and Fitting	each	1	$170,000	$170,000	$85,000	$255,000
	Plant Water (W3) Pump and Fitting	each	1	$20,000	$20,000	$10,000	$30,000
	Polymer Blend System (Not Required)	LS	0	$40,000	$0	$0	$0
	Polymer Pumps (Not Required)	LS	0	$23,000	$0	$0	$0
	Alum Storage Tanks (reuse existing tank)	LS	0	$35,000	$0	$0	$0
	Alum Transfer Pumps and Feed Systems (reuse existing pumps)	LS	1	$20,000	$20,000	$10,000	$30,000
	Chlorination System with Chemical Piping	LS	2	$20,000	$40,000	$20,000	$60,000
	Laboratory Equipment Including Samplers	LS	1	$100,000	$100,000	$20,000	$120,000
6.12	Division 41 - Conveying Systems						
	Mobile Crane	LS	0	$65,000	$0	Included	$0
	Monorails (NML and FE pumps)	LS	1	$65,000	$65,000	$33,000	$98,000
6.13	Divisions 22 and 23 - Mechanical						
	HVAC and Exhaust-2RT units, MUA unit, vent unit, split system, exhaust fans and SS ductwork	LS	1	$400,000	$400,000	Included	$400,000
	Plumbing and Gas Service	LS	1	$105,000	$105,000	Included	$105,000
	Controls	LS	1	$75,000	$75,000	Included	$75,000
	Misc.	LS	1	$50,000	$50,000	Included	$50,000
6.14	Divisions 26, 28 and 40 - Electrical						
	Electrical Service						
	1000 Amp 25KV-600/347V	LS	1	$45,000	$45,000	Included	$45,000
	Service entrance switchgear, MCC's, panelboards etc.	LS	1	$410,000	$410,000	Included	$410,000
	LV Electrical Distribution (Switchgear, MCC & Transfer Switch) Install	LS	1	$150,000	$150,000	Included	$150,000
	Cabling, terminations & contractor commissioning	LS	1	$125,000	$125,000	Included	$125,000
	Telephone Service	LS	1	$30,000	$30,000	Included	$30,000
	Building Systems Electrical (lighting, power distribution, communications, fire, security, exit and emergency lighting & grounding systems)	LS	1	$300,000	$300,000	Included	$300,000
	Generator (Natural Gas)	LS					
	600V 75 KVA	LS	1	$80,000	$80,000	Included	$80,000
	Generator & Systems Installation	LS	1	$20,000	$20,000	Included	$20,000
	Controls/Instrumentation/Communications	LS					
	Control System & Programming	LS	1	$200,000	$200,000	Included	$200,000
	Control System (PLC and HMI Supply & Install)	LS	1	$125,000	$125,000	Included	$125,000
	Subtotal Operations Building						**$9,085,000**
7.0	**Odour Building**						
	Subtotal Odour Building	N/A					**$0**
	Subtotal						**$24,675,400**

Notes:
1. Costs are in 2019 Canadian Dollars.
2. Construction costs will vary depending on market conditions at the time of tender.
3. Stantec OPCC represents a Class IV/Class C estimate (+35% to -20%)

Appendix B PRELIMINARY DESIGN DRAWINGS



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Client/Project
CITY OF HUMBOLDT

WASTEWATER TREATMENT PLANT UPGRADES

Humboldt, Saskatchewan

Project No.: 113154831
File Name: 54831D101
Scale: NONE

Dwn.	Dsgn.	Chkd.	YYYY.MM.DD
MJS	AJM	JG	2019.08.11

Title
PROCESS
OVERALL LAYOUT

Revision: 0 Sheet: 1 of 5

Drawing No.
D-101

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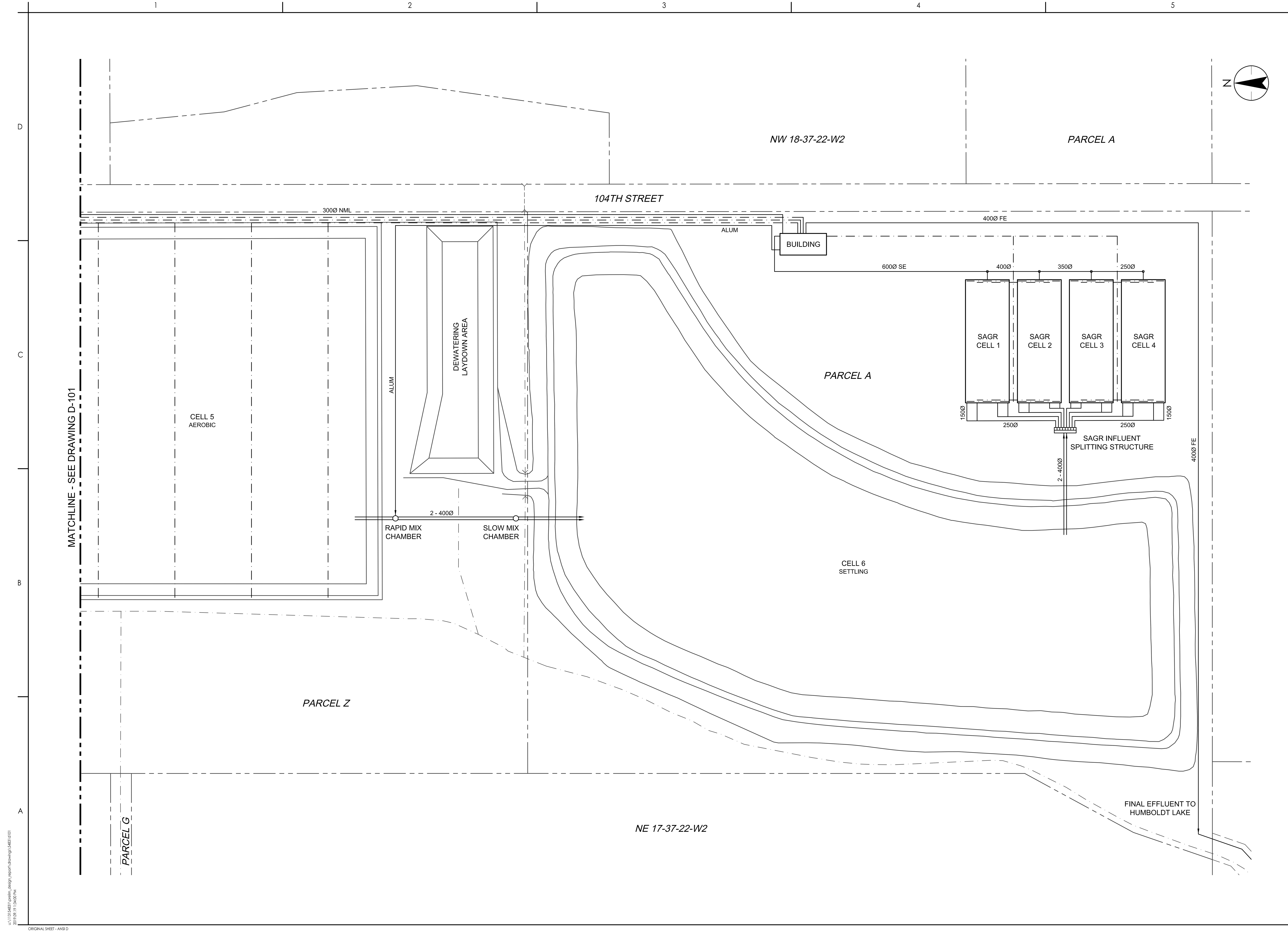

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WASTEWATER TREATMENT PLANT UPGRADES
Humboldt, Saskatchewan

Project No.: 113154831
File Name: 54831D101

Scale: NONE

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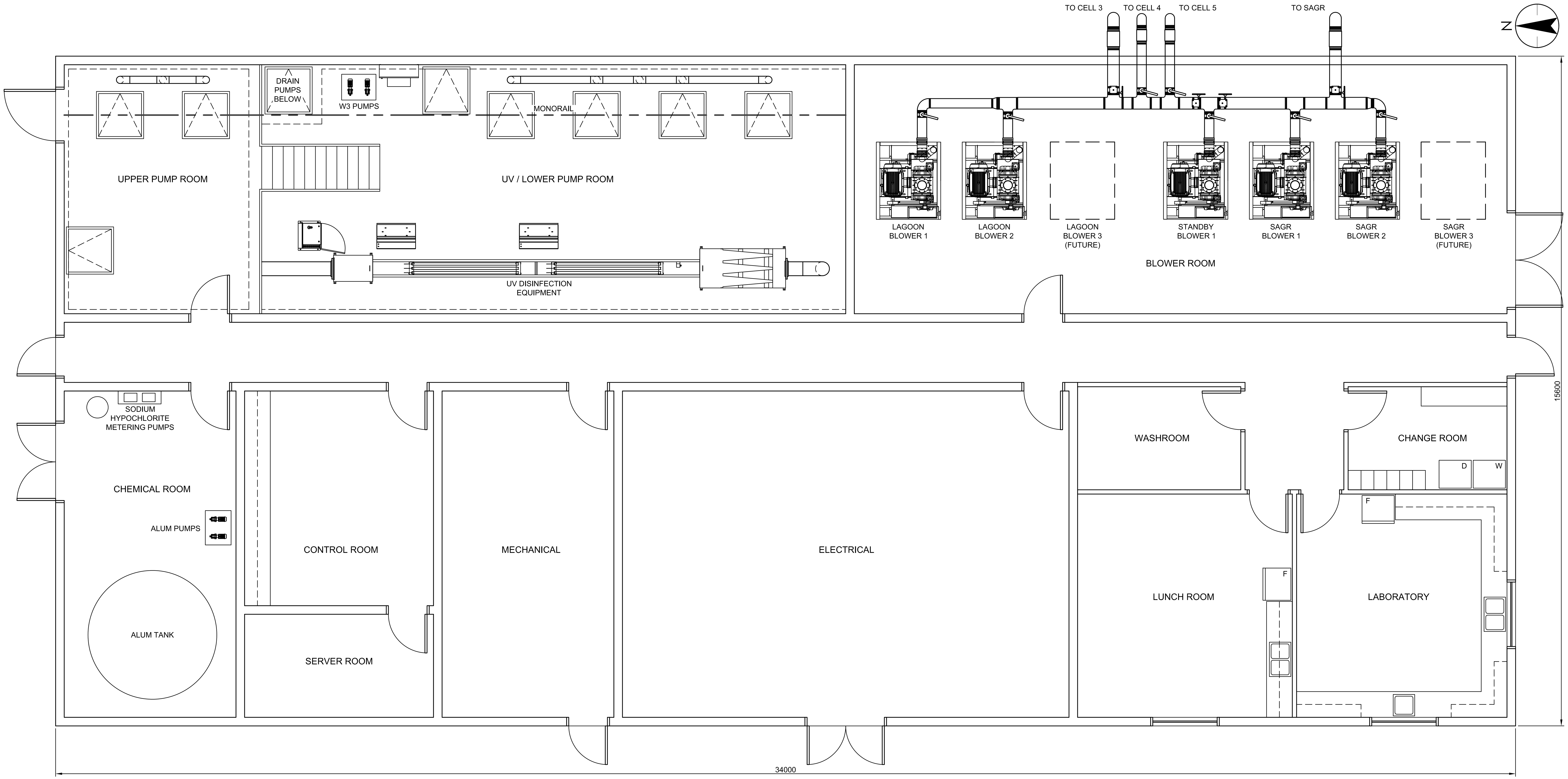
Title
PROCESS
OVERALL LAYOUT

Revision: 0 Sheet: 2 of 5

Drawing No.
D-102



FLOOR PLAN
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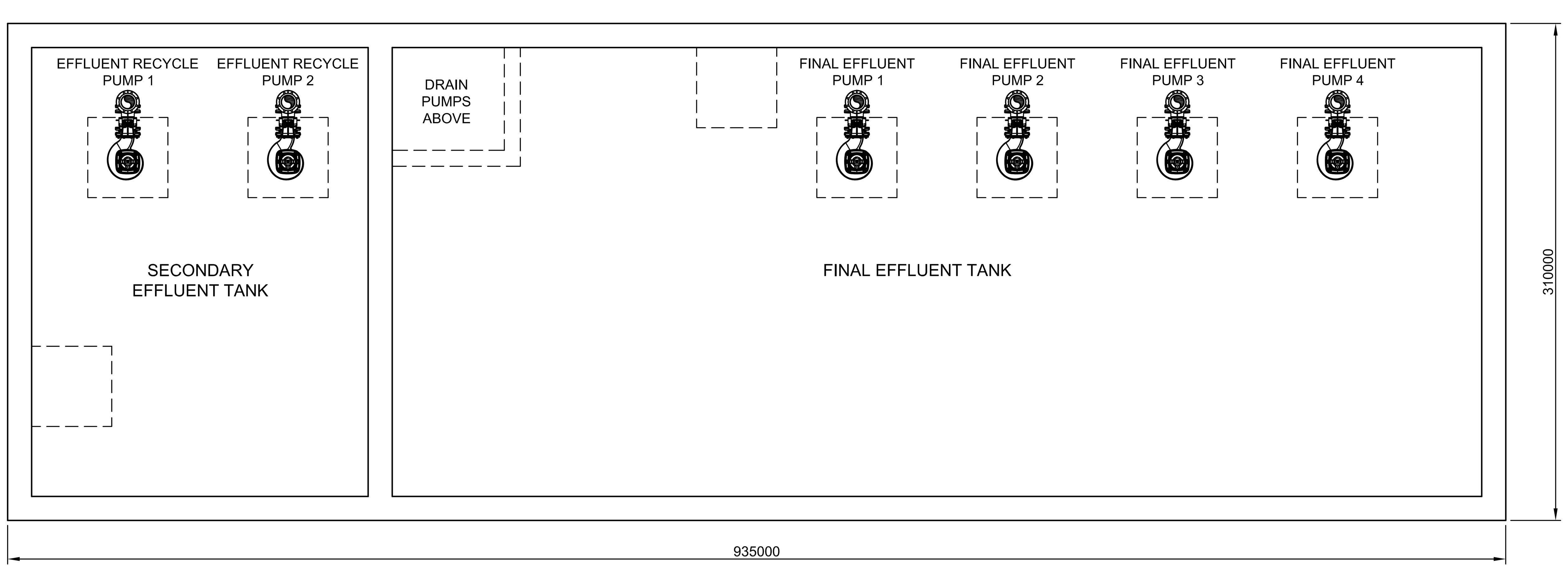

EFFLUENT TANK PLAN
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WASTEWATER TREATMENT PLANT UPGRADES
Humboldt, Saskatchewan

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File Name: 54831D103
Scale: NONE

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Title
PROCESS
BUIDING LAYOUT

Revision:0 Sheet: 3 of 5

Drawing No.
D-103

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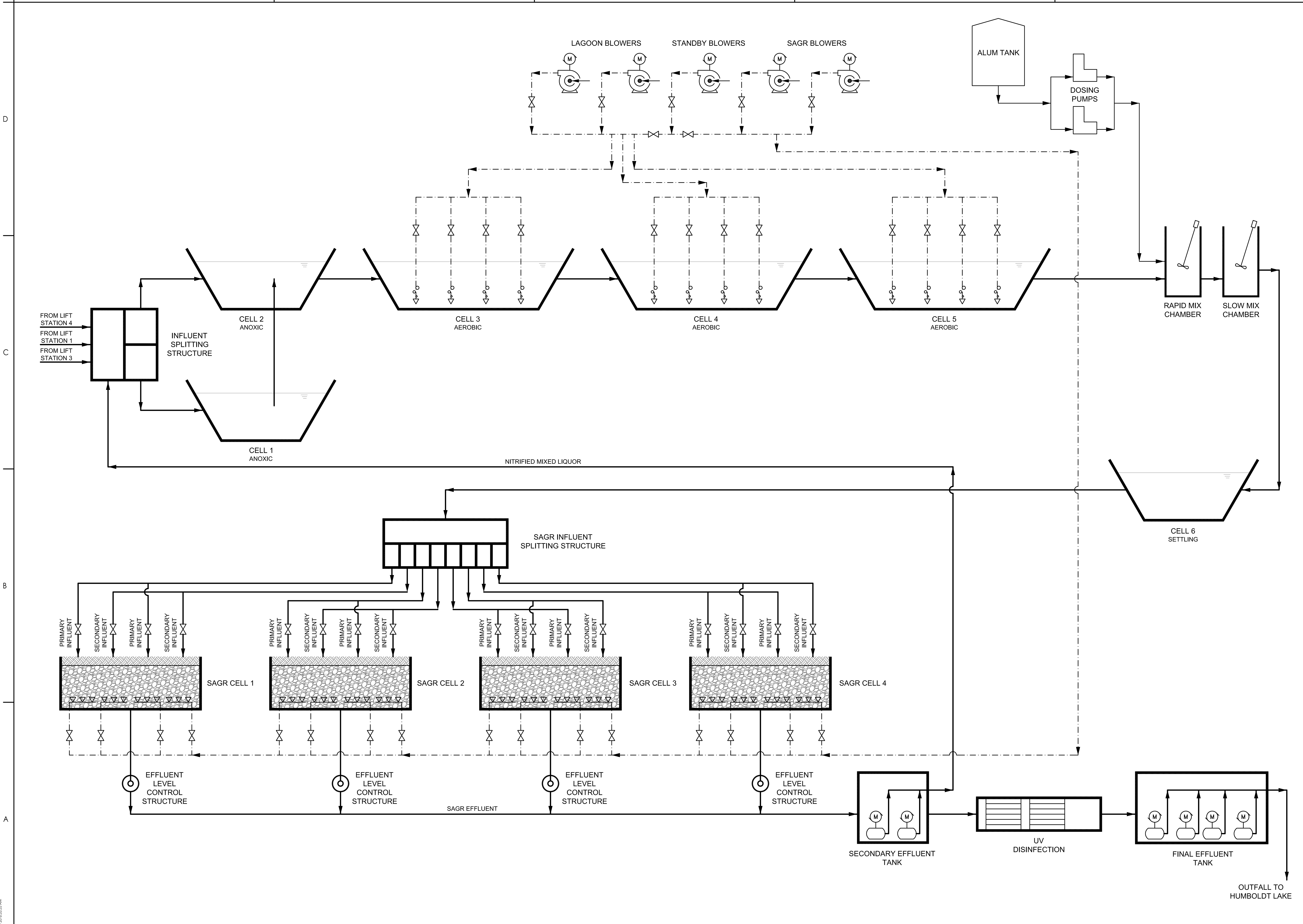

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WASTEWATER TREATMENT PLANT UPGRADES
Humboldt, Saskatchewan

Project No.: 113154831
File Name: 54831D601
Scale: NONE

MJS	AJM	JG	2019.08.11
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Title
PROCESS FLOW DIAGRAM

Revision: 0 Sheet: 4 of 5

Drawing No.
D-601

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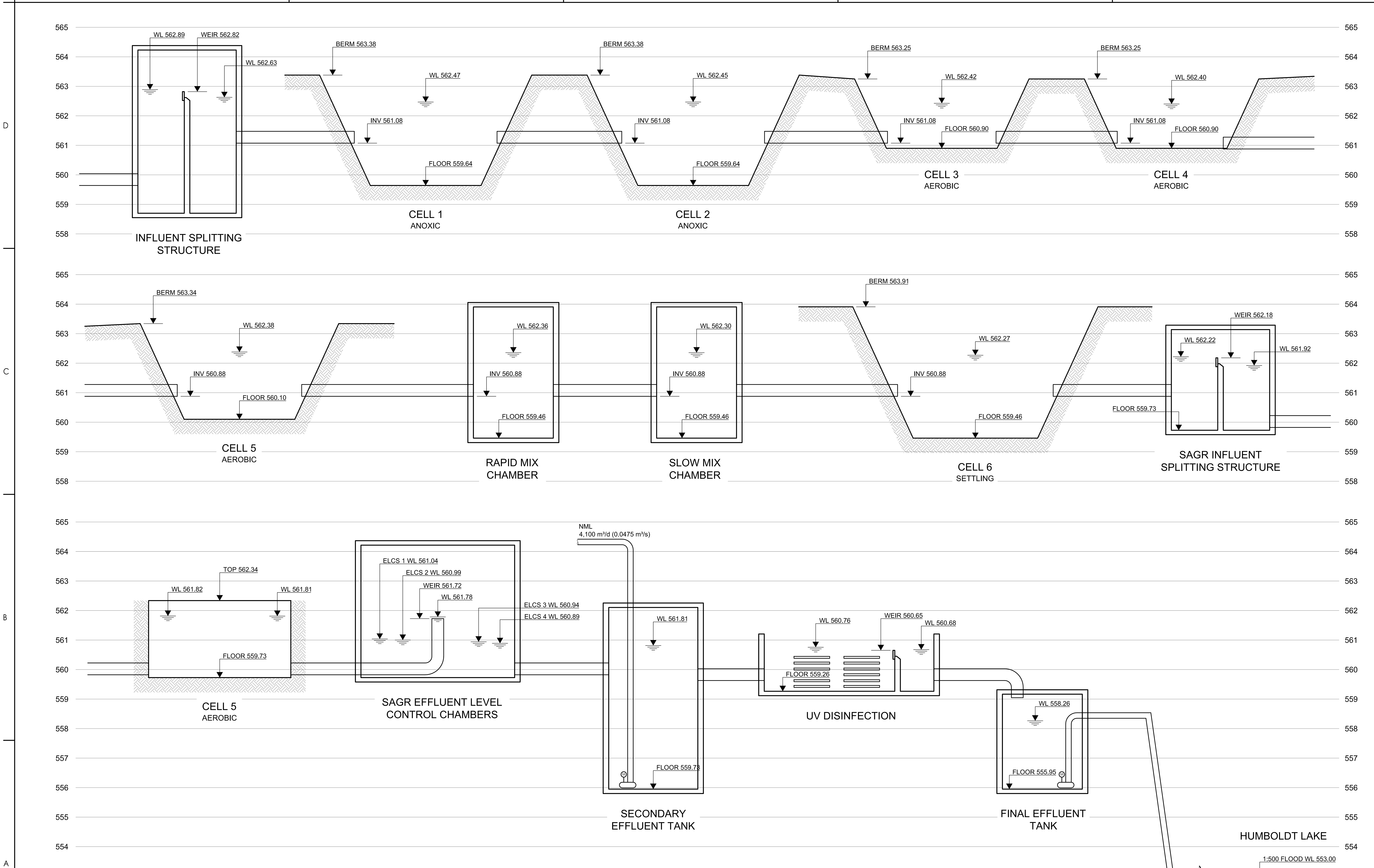

NOTE:
1 LIQUID LEVELS ARE FOR AVERAGE DAY FLOW OF 4,100 m³/d (0.0475 m³/s).
2 DURING AVERAGE DAY FLOW ONLY ONE TRANSFER VALVE PER CELL IS OPEN.
3 DURING MAXIMUM MONTH FLOW ALL TRANSFER VALVES ARE OPEN INCLUDING VALVES FROM ISS TO CELLS 1 AND 2.
4 DURING MAXIMUM WEEK FLOW THE ISS WEIR WILL BE SUBMERGED AND THE WATER LEVEL WILL INCREASE TO 563.25.
5 NITRIFIED MIXED LIQUOR (NML) PUMP MAY BE SHUT DOWN TO KEEP WATER LEVEL IN THE ISS AT 562.90.

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CITY OF HUMBOLDT

WASTEWATER TREATMENT PLANT UPGRADES

Humboldt, Saskatchewan

Project No.: 113154831
File Name: 54831D602

Scale: NONE

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Title
PROCESS HYDRAULIC PROFILE

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D-602

ORIGINAL SHEET - ANSI D

Appendix C EQUIPMENT QUOTES

Appendix D TECHNICAL MEMORANDUMS 1 TO 6

Technical Memorandum 1 - Population, Wastewater Flow and Load Projections

Technical Memorandum 2 - Wet Weather Management

Technical Memorandum 3 - Identification of Liquid Treatment Options

Technical Memorandum 4 - Identification of Sludge Management Options

Technical Memorandum 5 - Evaluation of Short Listed Treatment Options

Technical Memorandum 6 - Opinion of Probable Capital Cost – Aerated Lagoons/SAGR System Design Period 2037 (8,000 population) and 2052 (10,000 population)

City of Humboldt Wastewater Treatment Plant Upgrades

Technical Memorandum No. 1
Population Wastewater Flow and Load Projections

February 11, 2019

Prepared for:
City of Humboldt
715 Main Street, Box 2467
Humboldt, SK S0K 2A0

Prepared by:
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File: 113154831

Revision	Description	Author		Quality Check		Independent Review	
1		Alex Munoz		Jason Gaudet	J. Gaudet	Saibal Basu	

Sign-off Sheet

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(signature)

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Reviewed by ______________________________

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Saibal Basu, Ph.D., P.Eng.

Approved by ______________________________

(signature)

Jason Gaudet, P.Eng., ENV SP

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Abbreviations

AAF	Annual Average Day Flow
BOD_5	Biochemical Oxygen Demand-5 day
BNR	Biological Nutrient Removal
BWL	Bottom Water Level
COD	Chemical Oxygen Demand
$cBOD_5$	Carbonaceous Biochemical Oxygen Demand 5-day
DNA	Deoxyribonucleic Acid
FRP	Fibre Reinforced Plastic
MMF	Maximum Monthly Flow
H2S	Hydrogen Sulfide
ISS	Inorganic Suspended Solids
MBR	Membrane Bioreactor
MDF	Maximum Day Flow
PDC	Power Distribution Centers
RNA	Ribonucleic Acid
RAS	Return Activated Sludge
SBR	Sequencing Batch Reactor
SLR	Solids Loading Rate
SRT	Sludge Retention Time
SVI	Sludge Volume Index
TKN	Total Kjeldahl Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids.
TWAS	Thickened Waste Activated Sludge
TWL	Top Water Level
UV	Ultra Violet
VFD	Variable Frequency Drive
VSS	Volatile Suspended Solids
WAS	Waste Activated Sludge
WWTP	Wastewater Treatment Plant
WSA	Wastewater Security Agency

1.0 INTRODUCTION

Stantec Consulting Ltd. (Stantec) was retained by the City of Humboldt to prepare a pre-design report for the City of Humboldt Wastewater Treatment Plant (WWTP) Upgrade. This Technical Memorandum (TM) provides the design criteria and the basis for population projections, wastewater flows, raw wastewater characteristics and associated plant loadings. Following acceptance of the design criteria by the City and the Saskatchewan Water Security Agency (WSA), treatment options for the WWTP will be developed. This information will lead to the development of a pre-design report for presentation to the Council.

1.1 BACKGROUND

The City of Humboldt is located approximately 112 km east of Saskatoon. The City has a wastewater treatment plant located southeast of the City along a storm water channel that discharges into the Humboldt lake. Wastewater is currently pumped from three lift stations directly to the WWTP through dedicated forcemains as shown in Figure 1.

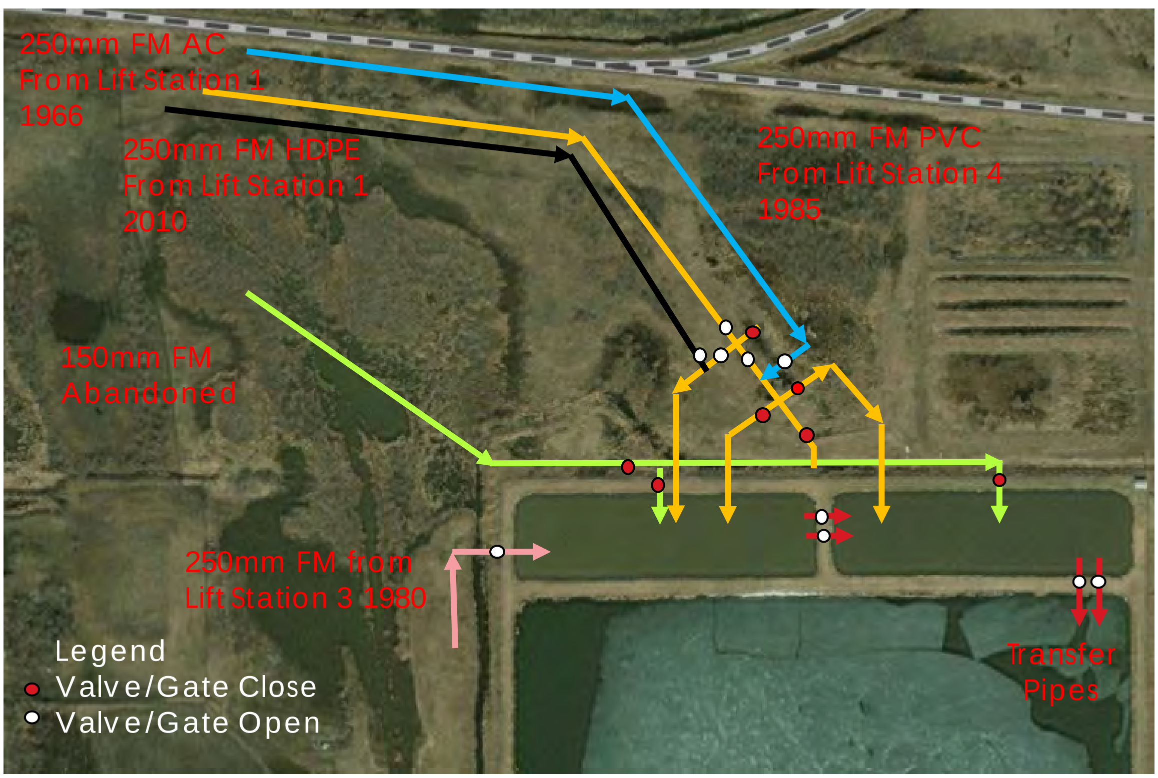

Figure 1 Humboldt WWTP Forcemains Configuration at the Front End of the Lagoon System

The Humboldt WWTP consists of an anaerobic cell, an aerated cell, a facultative lagoon, three storage cells and a phosphorus removal system as described in Table 1 and presented in Figure 2. The lagoons are operated in series with all the flow from the three lift stations conveyed to the anaerobic cell. The phosphorus removal system consists of pumping secondary effluent from storage cells 2 and 3 through manholes where it is mixed with ferric sulfide before being discharge to the phosphorus removal cell where phosphorus precipitates as ferric phosphate. Effluent from the phosphorus removal cells is discharged to the Humboldt lake through a conveyance channel in May and October. The treatment lagoons were constructed in 1961, upgraded and expanded as listed in Table 1. The anaerobic lagoon has been de-sludged twice and the dewatered sludge applied to agricultural land (7,200 m^3 of sludge applied to 49 hectares in 2002 and 7563m^3 of sludge applied to 55.6 hectares in 2014). The aerated lagoon has not been de-sludged since the aeration system was installed in 1976. The facultative lagoons is operating at its maximum treatment capacity (WSA maximum design value of 30 kg BOD_5/Ha-d). The storage lagoons have insufficient storage capacity to provide the 220 days required by Water Security Agency (WSA). The lagoons are very frequently operated at high water levels, reducing the freeboard to less than 300mm during high flow events and causing erosion of the lagoon embankments. On several occasions, special permits have been required from WSA for allow early discharge to the Humboldt Lake.

Table 1 Existing Wastewater System Description based on Current ADF of 2,480 m^3/d

Parameter	Anaerobic Cell	Aerobic Cell	Facultative Cell	1st Storage Cell	2nd Storage Cell	3th Storage Cell	P Removal Cell
Function	Sedimentation of suspended solids and anaerobic treatment	Aerobic treatment using a 50HP blower and 32 helixor diffusers	Facultative treatment via algae growth	Storage of secondary effluent	Storage of secondary effluent	Storage of secondary effluent	Precipitation of phosphorus
BOD5 Load, kg/d	395	280	166	N/A	N/A-	N/A	N/A
BOD5 Loading, kg/ha-d	698	499	30	N/A	N/A	N/A	N/A
TSS Load, kg/d	481	241	N/A	N/A	N/A	N/A	N/A
Capacity, m3	15,800	15,200	85,500	39,000	226,000	147,000	10,600
Operating Depth, m	3.95 (as per City emails)	3.85 as per City emails)	1.5	1.5	**2.1**	**2.1**	2
Freeboard, m	0.45	0.45	0.6	0.6	0.6	1.5	0.6
Surface Area, ha	0.567	0.556	5.99	2.58	14.5	7.4	0.75
Floor Elevation, m	558.90	559.00	560.90	560.90	560.30	560.30	559.8
Full Service Level, m	562.85	562.85	562.40	562.40	562.40	562.40	561.8
Berm Elevation, m	563.30	563.30	563.00	563.00	563.00	563.90	562.4
Retention Time, d	6.4	6.1	34	15.7	91	59	4.3
Active storage, d	N/A	N/A	N/A	15	86	56	4.0
Slope	2.8:1 & 3.3:1	2.8:1 & 3.3:1	4:1	4:1	4:1	3.5:1	4:1
Construction Upgrade	1961 1971	1961 1973	1961	1961 Rip rap repair	1976	2001	1985
Condition Assessment	Lagoon interior slopes may have been over excavated during dredging.	Sludge is encroaching the diffusers and thus diffusers provides minimum BOD reduction	Facultative lagoon operating at maximum design load of 30kg/ha-d	Active storage is about 161 days (assuming 100 mm of inactive water to protect the clay liner and average daily flow of 2,480 m^3/d). High water levels have reduced freeboard to less than 300mm, causing erosion of the lagoon embankments. Special permits have been frequently required from WSA for discharge to the Lake.			No secondary containment for ferric sulfide tank
Recommendations	Implement berm remediation strategy listed in previous reports.	De-sludge the cell	De-sludge the cell	Proactive discussion with WSA is required to allow early effluent discharge to protect infrastructure until upgraded are implemented. Ongoing monitoring of slope stability. Repair berm as needed.			City to review Work safe practices in the event of spill

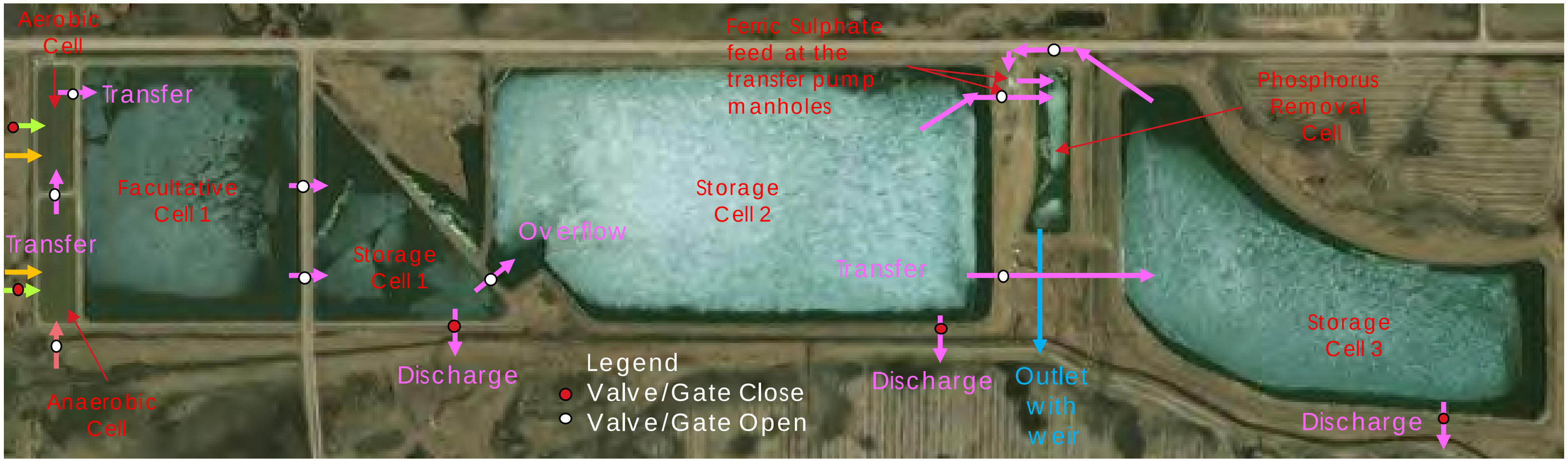

Figure 2 Humboldt Wastewater Treatment System Flow Schematic

1.2 POPULATION DATA ANALYSIS

According to Statistics Canada data, the City of Humboldt has experienced a general decline in population from 2001 to 2006 followed by an increase from 2006 to 2016, as shown in Table 2. In 2006, the City had a reported population of 4998 people. The latest census data from 2016 reported a population of 5869 people, approximately 3.4 percent higher than the 2011 census data of 5678 people. This trending seems to be in line with many communities near major centers who have experienced population growth since the 2006 census.

Population statistics compiled for the City based on Saskatchewan Health figures from 1994 to 2014 indicates an annual population increase of 1.5% with a standard error of the mean of 0.6%, as presented in Table 2. During the start-up meeting, the City advised Stantec that Statistics Canada 2016 census data of 5869 people is more representative of the actual population for the City of Humboldt and that this value should be utilized as the base population for future projection.

Table 2 Historical Population for Humboldt

Year	Statistics Canada	Saskatchewan Health	
	Population	Population	% Change
1996	5,074		
1997		5,343	
1998		5,456	2.1
1999		5,549	1.7
2000		5,524	-0.5
2001	5,161	5,572	0.9
2002		5,602	0.5
2003		5,562	-0.7
2004		5,602	0.7
2005		5,608	0.1
2006	4,998	5,511	-1.7
2007		5,577	1.2
2008		5,765	3.4
2009		5,940	3.0
2010		5,925	-0.3
2011	5,678	6,526	10.1
2012		6,644	1.8
2013		6,804	2.4
2014		6,850	0.7
2015			
2016	5,869		
Average			**1.5**
Standard Deviation			**2.6**
Standard Error			**0.6**

1.3 POPULATION PROJECTIONS

The proposed WWTP upgrades are anticipated to be completed by the summer of 2022 subject to availability of funding for this project and construction starting in the summer of 2020. As discussed in the project initiation meeting, the City suggested a design for a population growth of 8,000 and 12,000, which correspond to a design horizon of 20 to 48 years assuming a medium population growth of 1.5%. A design horizon of 48 years seems excessive. However, this wide range was provided by the City because potential potash development of the BHP Billinton Jasen Potash Mine could increase the population by 2,500 people. Crosby Hanna & Associates developed population projections for the City on Humboldt based on statistics Canada 2011 census data when the population growth by 13.6% since them population growth has been more moderate at less than 3.4%. Catterall & Wright Consulting Engineers used design population of 10,500 people for a design horizon of 20 years based on a population growth rate of 2.5% in the Lagoon Odour Issue Review Report. To assist the City to select the plant capacity, several growth scenarios were developed under different population growths.

1.4 GROWTH SCENARIOS

A statistical analysis on the Saskatchewan Health historical population records for the City from 1994 to 2014 indicates an annual population increase of 1.5% with a standard error of the mean of 0.6%. Therefore the low growth scenario (0.9%) and the high growth scenarios (2.1%) were developed by subtracting and adding the standard error to the annual percentage increase of population. Statistically, a standard error of the mean is the standard deviation of the sample mean and defines the interval around which the true mean will fall 68% of the time. A summary of these projections is shown in Table 3 and graphically in Figure 3. These projections indicate that a potential population increases of 2,500 people due to potash mine development will translate in a shift from a medium growth scenario to high growth scenario. Consequently, the plant upgrades should be designed for initial phase expansion to 10,000 people with flexibility to future expansion to 12,000 people. Thus, the design horizon could range from 25 to 35 years for a plant designed for 10,000 people.

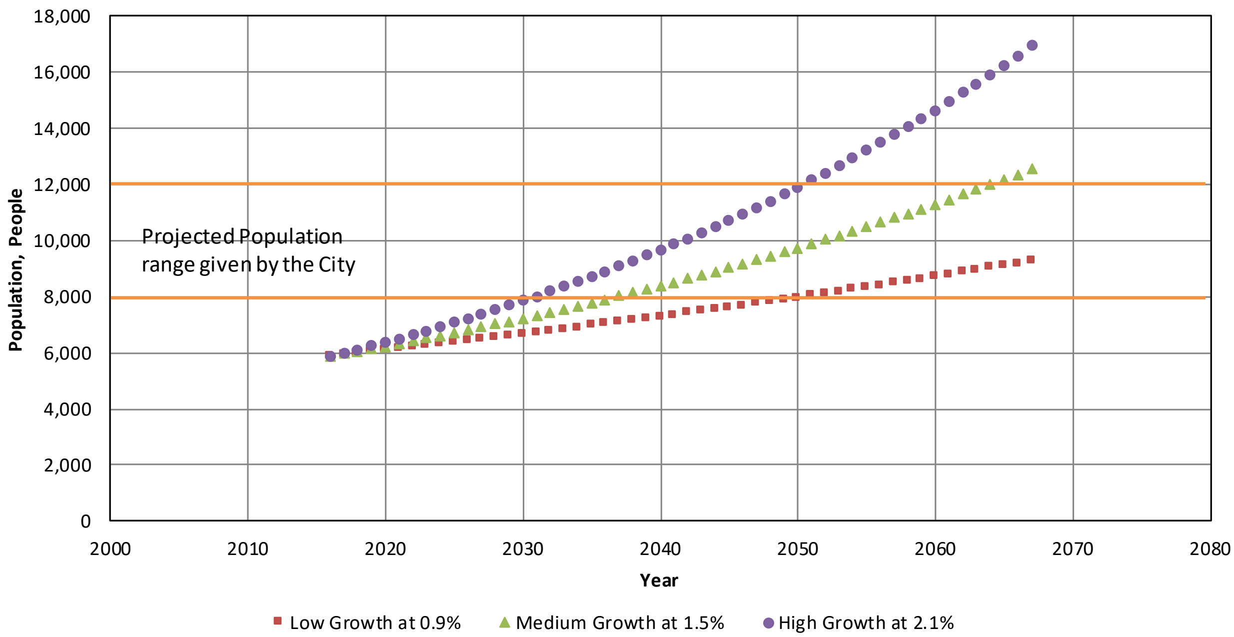

Figure 3 City of Humboldt Population Projections

Table 3 Population Projections for the City of Humboldt

Design Year	Calendar Year	Low Growth at 0.9%	Medium Growth at 1.5%	High Growth at 2.1%
1	2018	5,975	6,047	6,118
5	2022	6,193	6,418	6,649
10	2027	6,477	6,914	7,377
15	2032	6,774	7,448	8,185
20	2037	7,084	8,024	9,081
25	2042	7,409	8,644	10,075
30	2047	7,748	9,312	11,179
35	2052	8,103	10,031	12,403

1.5 RECOMMENDATION FOR DESIGN POPULATION

Based on analysis of the population growth under different scenarios, it is recommended that adopting a medium growth rate of 1.5% for estimating the future design population for this study provides a reasonable projection for the City. Should there be a substantial growth in the future; the plant capacity will be reached earlier than 35 years. On the other hand, if the growth is slower, the plant capacity will last longer than 35 years before a further expansion is warranted. As such, a future design population of 10,000 people is recommended.

2.0 WASTEWATER FLOWS

2.1 BACKGROUND

The City currently monitors daily flows to the WWTP via a dedicated flow meter located in lift station #1 and pump hours and assumed flowrates for lift stations #3 and #4. The flow meter displays the totalized flow, which is recorded daily by the plant operators. Based on our review of the existing flow data records, it is our understanding that the flow meter records the instantaneous peaks that are critical to sizing future process units. It is recommended that diurnal patterns be recorded for each season. This is required to properly size treatment components such as pumping stations, grit chambers and sedimentation tanks.

We also understand that, the City does not allow septic truck discharge into the sewer collection system or the lagoons. This memo does not include provisions for receiving septic truck discharge at the upgraded WWTP or the existing lagoons. This is because septage can be 6 to 80 times more concentrated than typical municipal sewage and can be toxic to biological processes. Septic receiving station would be discussed in a separate memo.

2.2 WASTEWATER FLOW DATA ANALYSIS

Stantec requested historical flow data recorded at the lift stations for review. Daily flow data to the WWTP from January 01, 2010 to September 29, 2017 was supplied by the City and subsequently analyzed to determine average daily flow (ADF) and average dry weather flow (ADWF). Figure 4 presents the daily wastewater flows pumped from the lift stations to the lagoons over the 8-year period. The average daily flow (ADF) is 2,748 m^3/d and the average dry weather flow (ADWF) is 2,138 m^3/d. The maximum day over the 8-year period plotted in Figure 4 was on July 28, 2015 with a flow of 16,780 m^3/d. Several other peak flows in the range of 8,000 m^3/d to 12,000 m^3/d were recorded. The City is in the process of implemented strategies to reduce inflow and infiltration to the sewer collection system. These strategies are expected to reduce the impact that wet weather events have on undesirable inflow and infiltration to the sanitary sewer system. These strategies are:

- Weeping tile disconnection program
- Removal of cross connections
- Replacing of cast iron water mains which are buried in a common trench with sewer (currently 15% of water main are common trench, 20% is cast iron/ductile iron in a separate trench, the remaining is PVC, HDPE and AC)
- Relining clay tile sewer trunk mains

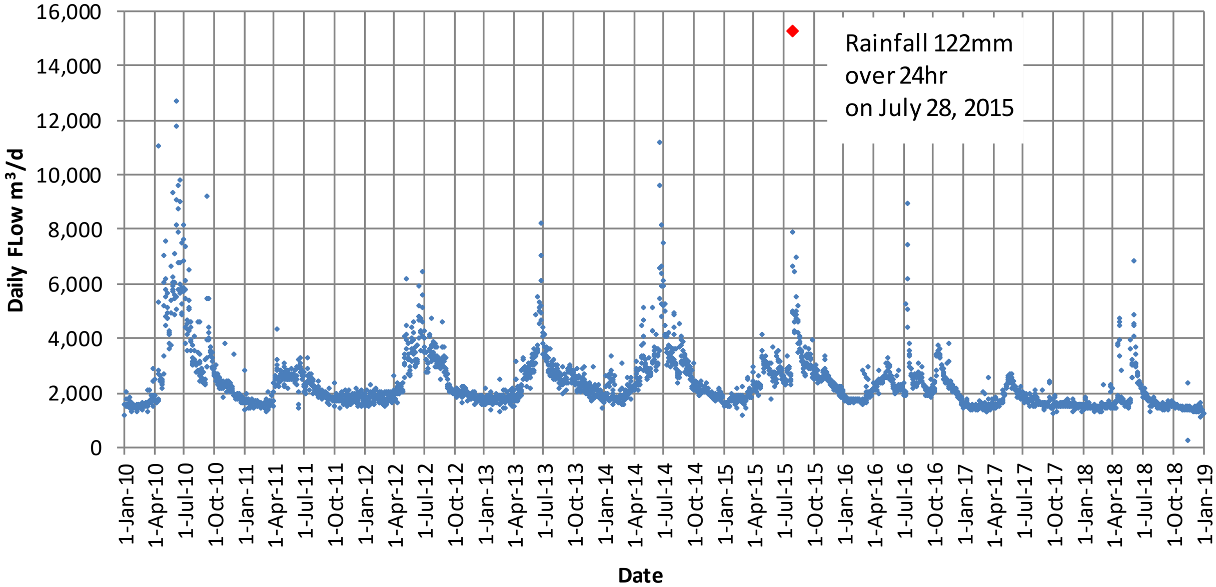

Figure 4 Daily Wastewater Flow Pumped from the Lift Stations to the Lagoons from 2010 to 2017

Table 4 summarizes annual average, maximum month, maximum week and maximum day flows and corresponding peaking factors for each year over the 8-year period of record.

The peaking factors in the left column of the table present the results in terms of percentiles: 91.8% (335/365 days), 98.1% (358/365 day) and 99.7% (364/365 day) to represent the maximum month, maximum week and peak day flows. The peaking factors in the right column summarize the 30-day and 7-day running averages and maximum day. The bottom of the table presents averages for peak factors over the 8-year period.

Table 4 Summary of Wastewater Flow Analysis

	Peak Factor (Percentile)	Average	Maximum 30-day Running Average	Maximum 7-day Running Average	Maximum day Running Average	Peak Factor (Running Average)
	Unitless	m3/d	m3/d	m3/d	m3/d	Unitless
2010						
AAF	1	3,146				
ADWF	0.59	1,846				
91.8 %tile	1.90	5,983	7201.71			2.29
98.1 %tile	2.89	9,078		9718.76		3.09
99.7 %tile	3.74	11,778			12684.60	4.03
Minimum Flow	0.38	1,201				
Population	5640	558LCP				
2011						
AAF	1	2,043				
ADWF	0.88	1,803				
91.8 %tile	1.33	2,727	2706.99			1.32
98.1 %tile	1.47	3,000		3073.62		1.50
99.7 %tile	1.60	3,268			4372.90	2.14
Minimum Flow	0.63	1,292				
Population	5678	360LCP				
2012						
AAF	1	2,512				
ADWF	0.72	1,808				
91.8 %tile	1.58	3,963	4203.36			1.67
98.1 %tile	1.91	4,796		4924.39		1.96
99.7 %tile	2.45	6,150			6475.79	2.58
Minimum Flow		1,512				
Population	5716	439LCP				
2013						
AAF	1	2,473				
ADWF	0.83	2,044				
91.8 %tile	1.39	3,428	4483.11			1.81
98.1 %tile	2.04	5,036		5940.71		2.40
99.7 %tile	2.85	7,057			8214.12	3.32
Minimum Flow		1,281				
Population	5754	430LPC				

Wastewater Flows
February 11, 2019

	Peak Factor (Percentile)	**Average**	**Maximum 30-day Running Average**	**Maximum 7-day Running Average**	**Maximum day Running Average**	**Peak Factor (Running Average)**
	Unitless	m3/d	m3/d	m3/d	m3/d	Unitless
2014						
AAF	1	2,754				
ADWF	0.66	1,824				
91.8 %tile	1.50	4,143	5325.03			1.93
98.1 %tile	2.22	6,114		7799.47		2.83
99.7 %tile	3.48	9,596			11198.25	4.07
Minimum Flow	0.56	1,552				
Population	5792	476LPC				
2015						
AAF	1	2,648				
ADWF	0.77	2,031				
91.8 %tile	1.36	3,604	5059.74			1.91
98.1 %tile	1.88	4,977		6956.28		2.63
99.7 %tile	2.98	7,899			15278.83	5.77
Minimum Flow	0.46	1,209				
Population	5831	454LPC				
2016						
AAF	1	2,330				
ADWF	0.79	1,833				
91.8 %tile	1.32	3,076	3434.54			1.47
98.1 %tile	1.62	3,784		5880.93		2.52
99.7 %tile	3.19	7,424			8985.98	3.86
Minimum Flow	0.11	253				
Population	5869	397				
2017						
AAF	1	1,692				
ADWF	0.90	1,522				
91.8 %tile	1.30	2,198	2369.15			1.40
98.1 %tile	1.48	2,506		3803.69		2.25
99.7 %tile	1.58	2,669			2727.58	1.61
Minimum Flow	0.73	1,237				
Population	5957	284				

Wastewater Flows
February 11, 2019

	Peak Factor (Percentile)	**Average**	**Maximum 30-day Running Average**	**Maximum 7-day Running Average**	**Maximum day Running Average**	**Peak Factor (Running Average)**
	Unitless	m3/d	m3/d	m3/d	m3/d	Unitless
2018						
AAF	1	1,754				
ADWF	0.87	1,522				
91.8 %tile	1.47	2,580	2989.16			1.70
98.1 %tile	2.34	4,110		3803.69		2.17
99.7 %tile	2.77	4,856			6859.53	3.91
Minimum Flow	0.14	253				
Population	6047	290				
Average						
WW generation		410				
ADF		2373				
ADWF	0.78	1804				
30-day PF	1.46		4196.98			
7-day PF	1.98			5766.84		
Max Day PF	2.74				8533.06	
91.8 %tile		3522				1.77
98.1 %tile		4822				2.37
99.7 %tile		6744				3.48
Minimum Flow	0.46	1088				

The annual average wastewater generation rate determined in this statistical analysis over the 8-year period of record is 410 L/cap/d, which is significantly higher than the annual average wastewater generation rate of 325 L/cap/day listed in the Catterall & Wright Consulting Engineers Lagoon Odour Issue Review Report (Note that the Catterall & Wright Consulting Engineers report used 375 L/cap/day for calculations). The implementation strategies to reduce inflow and infiltration to the sewer collection system may reduce the annual average wastewater generation rate but it is very unlikely that these strategies will reduce it to 325 L/cap/day, which corresponds to wastewater generation rate during dry weather (November to February).

Table 5 presents the flow unit rate and peak factors determined based on the statistical analysis presented above and their purpose for design.

Table 5 Annual Average Wastewater Generation Rate and Peak Factors to Be Used for Design

Average	Peak Factor	Purpose
Annual average wastewater generation rate, LPCD	410	Development of annual flow projections and power and chemical
ADWF/ADF	0.78	Development of dry flow projections.
Maximum Month 30 day running average or 91.8 percentile	1.46 1.77	Sizing of aeration equipment, chemical storage tanks and solids handling equipment.
Maximum Week 7 day running average or 98.1 percentile	1.98 2.37	Sizing of mechanical plant process units. Sizing of wet weather flow strategies.
Maximum Day 99.7 percentile	2.74 3.48	Sizing of equalization earthen basin.
Minimum Flow	0.46	Sizing turndown of pumps and influent channels.

2.2.1 Treated Effluent Release Flows

Treated effluent release flows were reviewed to determine the accuracy of influent data. However, it appears that there is a consistent effluent release increase over the 8-year period compared to the lagoon influent flows (up to 48% increase due to precipitation). This is inconsistent with expected slightly net gain due to precipitation based on the maps developed by Armstrong R.N et. Al. 2015 - variability in evaporation across the Canadian Prairie region during drought and non-drought periods-. The City should review method used to estimate effluent release flows.

2.2.2 Water Consumption

Water consumption data were used to determine the percentage of water that returns to the sewage system. Figure 5 presents water consumption data for the period of 1997 to 2017, as recorded in the Saskatchewan Community Water Use Records. Based on the ratio of water to wastewater average dry weather flow (average flow for the months of November, December, January and February), it was established that approximately 78% of the water returns to the sewage system which is well below typical value of 95% for cities in Saskatchewan. The City has estimated an average water loss of 20%, which increases the annual average wastewater generation by 53 LPCD, assuming that all water losses are directed to the sanitary sewer system.

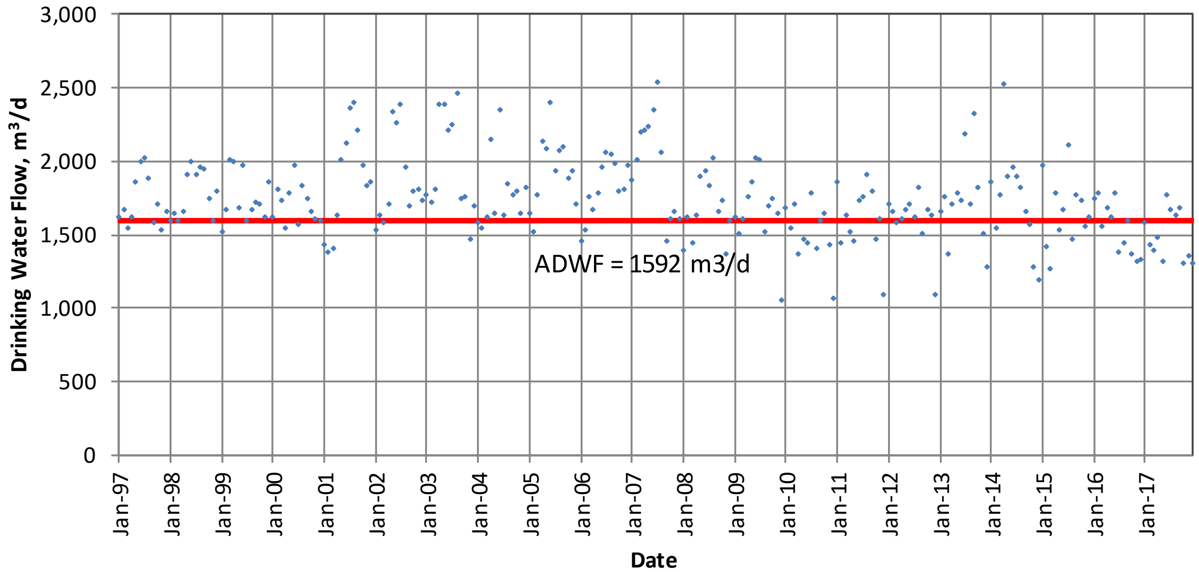

Figure 5 Humboldt Drinking Water Consumption based on Saskatchewan Community Water Use Records

2.3 WASTEWATER FLOW PROJECTIONS

Wastewater flow projections were developed under the assumption that the annual average per capita wastewater generation rate of 410 LCPD and peak factors are valid until 2052. Applying the year 2052 design population projection to these values results in the projected wastewater flow rates at the end of the planning period as presented in Table 6. The values listed in Table 6 do not include in-plant generated flows from sludge management processes.

Table 6 Wastewater Flow Projections for Various Design Years

Parameter	Unit	Initial Year	Design
Design Year	year	2018	2052
Design Period	year	1	35
Design Population	capita	6,050	10,000
Annual Average per Capita Wastewater Generation Rate	LCPD	410	410
Annual Average Flow (AAF) (PF =1.0)	(m^3/d)	2,479	4,098
Average Dry Weather Flow (ADWF) (PF =0.78)	(m^3/d)	1,928	3,186
Max Month Flow (MMF) (PF =1.77)	(m^3/d)	4,376	7,233
Max Week Flow (MMF) (PF =2.37)	(m^3/d)	5,882	9,722
Max Day Flow (MDF) (PF =3.48)	(m^3/d)	8,618	14,244
Peak Hourly Flow (PHF) (PF =6	(m^3/d)	14,874	24,585
Min Day Flow (PF =0.46)	(m^3/d)	1,140	1,883

Peak hourly flow of 6.0 was estimated based on maximum flow recorded in July 28, 2015. This is because diurnal flow variation is not recorded at the lift station. A peak hourly flow of 6.0 is not uncommon in Western Canada. The recommended design flows and loads will be discussed with the City and refined based on other considerations such as projected infiltration and inflow reduction that may reduce the annual average wastewater generation rate.

2.4 WASTEWATER LOADING CHARACTERISTICS

Historically, the City has not monitored the treatment system influent characteristics. In 2017, wastewater sampling program was completed in September and October. 24-hour composite samples were collected at the main lift station. Grab samples were collected at the lagoons. Table 7 presents the average, and 90 percentile influent characteristics for the short period of sampling conducted by the City. It should be noted that outlier values were excluded from the analysis.

2.4.1 DATA ANALYSIS

Table 7 indicates that the average influent wastewater concentrations are below typical concentrations for municipal WWTP in Saskatchewan for all the parameters, except for nutrients (ammonia, TKN and total phosphorus), comparing values between columns labeled Average and Typical WW Characteristics in Saskatchewan. This very unusual considering that inflow and infiltration will dilute the influent wastewater. High nutrient concentrations could be attributed to industrial discharge by Masterfeeds, Olymel pork processing, crop production services and CIM Metal manufacturing.

Table 8 shows that the wastewater loading rates for ammonia, TKN and total phosphorus are above the typical range for municipal wastewater in North America as presented in Tchobanoglous et al. 2003, comparing values between columns label Average and Typical WW per Capita Load in North America. Stantec suggests that additional sampling be taken to confirm TKN loads this is because the bioreactor volume required to reduce TKN increase by 40% for the measured TKN concentrations compared to typical municipal wastewater concentration. Due to the variability of the limited data presented in both tables, wastewater concentrations to be used for design were carefully selected as described below.

Table 7 Humboldt Wastewater Characterization (September - October 2017)

	Influent Wastewater Characteristics from Data Collected in 2017				Typical WW Characteristics in Saskatchewan
Parameters	**Units**	**Average**	**Min**	**90 Percentile**	
Chemical Oxygen Demand	mg/L	427	268	603	485
Biochemical Oxygen Demand	mg/L	194	122	274	212
Total Suspended Solids	mg/L	212	60	341	234
Inorganic Suspended Solids	mg/L	39	7	56	34
Total Volatile Suspended Solids	mg/L	173	53	285	200
Ammonia_N	mg/L	43	38	46.5	25
Total Nitrogen	mg/L	50	40	55.8	35
Total Kjeldahl Nitrogen	mg/L	56	40	57.6	35
Total Phosphorus	mg/L	7.4	5.7	8.41	6.5
Ortho Phosphorus	mg/L	NR	NR	NR	
Temperature measured in pumping station	°C	NR	NR	NR	
pH measured in pumping station	unitless	7.2	7.52	7.9	
Total alkalinity (as $CaCO_3$)	mg/L	NR	NR	NR	
Chloride dissolved	mg/L	NR	NR	NR	
Sulfate dissolved	mg/L	NR	NR	NR	
Calcium	mg/L	NR	NR	NR	
Magnesium	mg/L	NR	NR	NR	
Potassium	mg/L	NR	NR	NR	
Sodium	mg/L	NR	NR	NR	
Total dissolved solids	mg/L	NR	NR	NR	
Conductivity	dS/cm	NR	NR	NR	
Flow	m^3/d				
Note: Values in bold exceed typical wastewater characteristics in Saskatchewan					

Table 8 Calculated Wastewater per Capita Load for the Sampling Period 2017

		Calculated Wastewater per Capita Load from Data Collected in 2017		Typical WW per Capita Load in North America	
Parameter	Units	Average	90 percentile	Min	Max
Chemical Oxygen Demand	kg/capita-d	NR	NR	0.110	0.295
Biochemical Oxygen Demand	kg/capita-d	0.059	0.083	0.050	0.120
Total Suspended Solids	kg/capita-d	0.064	0.103	0.060	0.150
Ammonia_N	kg/capita-d	0.013	0.014	0.005	0.012
Total Kjeldahl Nitrogen	kg/capita-d	0.017	0.017	0.009	0.018
Total Phosphorus	kg/capita-d	0.0025	0.0025	0.0015	0.0045
Ortho Phosphorus	kg/capita-d	NR	NR	0.009	0.0018
Note: Values in bold exceed typical wastewater per capita load in North America					

2.4.2 Biological Oxygen Demand (BOD5) and Chemical Oxygen Demand (COD)

The average measured BOD_5 concentration of 194 mg/L is representative of the concentration experienced in other Saskatchewan communities and will be used in this design. The ratio of the COD/BOD5 is assumed to be 2.2, which is typical for raw municipal wastewater.

2.4.3 Inorganic Suspended Solids (ISS)

The typical ISS concentration of 35 mg/L, experienced in other Saskatchewan communities, was selected for this design because it ranges between the measured average and 90 percentile. The ISS concentration is a critical design parameter because it contributes to the mixed liquor suspended solids (MLSS) inventory in the bioreactors.

2.4.4 Total Suspended Solids (TSS)

The average measured TSS concentration of 212 mg/L, was selected for this design. This value is within typical values for municipal wastewater.

2.4.5 Total Kjehldahl Nitrogen (TKN) and Ammonia-N

The average measured TKN and ammonia-N concentrations of 50 mg/L and 35 mg/L (70% of the TKN) were selected for design, even though they are above concentrations experienced in other Saskatchewan communities. High concentrations could be attributed to industrial users.

2.4.6 Total Phosphorus (TP) and Ortho Phosphorus (OP)

The average measured TP concentrations of 7.4 mg/L was selected for design, even though it is above concentrations experienced in other Saskatchewan communities. High concentrations could be attributed to industrial users.

2.4.7 Wastewater Temperature

Wastewater temperature plays a major role in the design of biological nutrient removal plants. This is because the growth rate of bacteria responsible for converting ammonia to nitrate is significantly lower at colder temperatures. As a result, higher microorganism concentration is required to ensure that nitrification can be maintained during winter and early spring. For this design a minimum wastewater temperature of 8°C is assumed for design. Temperature was not measured by the City and should be measured to determine that process units are properly sized for the winter temperatures.

2.4.8 Seasonal Load Peaking Factors and Diurnal Load Pattern

In the absence of year-round wastewater characterization, it is assumed that the diurnal load patterns will be similar to the diurnal flow pattern.

2.5 OTHER IMPORTANT PARAMETERS

2.5.1 Alkalinity and pH

Alkalinity is required to maintain an acceptable pH for the biological conversion of ammonia to nitrates. For this process, an alkalinity between 300 and 350 mg/L (as $CaCO_3$) is required. Alkalinity was not measured by the City and should be measured to determine if there is sufficient alkalinity in the raw wastewater.

2.5.2 Volatile Fatty Acid (VFA)

Given the relatively small number of restaurants contributing to the sewer system, it is assumed that the VFA concentration in the raw wastewater will not sustain biological phosphorus removal. Therefore, a supplemental source VFA will be required as part of the process design of a biological nutrient removal process for the WWTP.

2.5.3 Conductivity, Total Dissolved Solids and Salinity

The most critical water parameter for effluent reuse is turfgrass tolerance to reclaimed water constituents, such as sodium, chloride, and boron. Most turfgrass is not affected significantly by soil water salinity that is less than 3 dS/m (approx. 1,920 mg/L of TDS). Typically, electrical conductivity of secondary effluent after conventional activated sludge is less than 1 dS/m. The electrical conductivity of the Humboldt treated effluent is unknown and should be measured if the City would like to be reuse the effluent.

2.6 RECOMMENDED DESIGN FLOWS AND LOADS

A summary of the loadings based on values discussed above are provided in Table 9 for the design year of 2052. The wastewater treatment plant would be sized to treat a maximum monthly flow of 7,235 m^3/d and capable of hydraulically accepting flow up to 8,200 m^3/d; however, at this high flow some effluent criteria would not be met. Flows greater than 8,200 m^3/d will be diverted to the wet weather flow management for storage or treatment. Table 9 also presents the design wastewater per capita loads, which are within the typical range for municipal wastewater in North America given in Table 8.

Table 9 Design Flows and Loads

Parameter	Unit	COD	BOD_5	TSS	ISS	TKN	TP
Annual Average Load	kg/d	1751	795	869	144	205	30.3
Annual Wastewater per Capita Load	kg/cap-d	1.751	0.795	0.869	0.144	0.205	0.0303
Average Wastewater Concentration	mg/L	427	194	212	35	50	7.4
Annual Average Flow	m^3/d	4100					
Maximum Month Load	kg/d	2363	1074	1173	194	242	34
Maximum Month Wastewater Concentration	mg/L	327	148	162	26.8	33.4	4.7
Maximum Month Flow	m^3/d	7,235					
Wastewater Temperature used for Design	°C	8°C					

It should be also noted that the recommended design flows and loads will be discussed with the City and refined based on other considerations such as additional sampling and projected infiltration and inflow reduction that may reduce the annual average wastewater generation rate. Additional sampling is suggested because the measured TKN concentration are 40% greater than typical wastewater concentrations. High TKN concentrations and annual average wastewater generation rates has a profound impact on the bioreactor volume and the associated cost of excavation, concrete tanks and mechanical equipment. At this point of time it is estimated that these two factors can increase the overall bioreactor volume by 40%. It is in the best interest of the City to address these design factors early in the design stage to reduce capital cost expenditure.

City of Humboldt – Wastewater Treatment Plant Upgrades

Technical Memorandum No. 2
Wet Weather Management

February 11, 2019

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Sign-off Sheet

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Abbreviations

AAF	Annual Average Day Flow
BOD_5	Biochemical Oxygen Demand-5 day
BNR	Biological Nutrient Removal
BWL	Bottom Water Level
COD	Chemical Oxygen Demand
$cBOD_5$	Carbonaceous Biochemical Oxygen Demand 5-day
DNA	Deoxyribonucleic Acid
FRP	Fibre Reinforced Plastic
MMF	Maximum Monthly Flow
H2S	Hydrogen Sulfide
ISS	Inorganic Suspended Solids
MBR	Membrane Bioreactor
MDF	Maximum Day Flow
PDC	Power Distribution Centers
RNA	Ribonucleic Acid
RAS	Return Activated Sludge
SBR	Sequencing Batch Reactor
SLR	Solids Loading Rate
SRT	Sludge Retention Time
SVI	Sludge Volume Index
TKN	Total Kjeldahl Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids.
TWAS	Thickened Waste Activated Sludge
TWL	Top Water Level
UV	Ultra Violet
VFD	Variable Frequency Drive
VSS	Volatile Suspended Solids
WAS	Waste Activated Sludge
WWTP	Wastewater Treatment Plant
WSA	Wastewater Security Agency

1.0 INTRODUCTION

Wet weather flows can have a significant impact on the treatment efficiency of a small wastewater treatment plant (WWTP) and it is particularly important to manage these high flows properly to ensure that the effluent criteria are met. This technical memo presents an analysis of the expected wet weather flows, an estimate of the size of the facility required to accommodate those flows and discussion of alternatives to reduce the cost of treating the expected flows.

Historically, Saskatchewan cities experience the highest wet weather flows during spring thaw and summer rainfall events. Figure 1 illustrates the daily flows pumped from the lift stations to the lagoon from 2010 to 2018 showing that wet weather flows in Humboldt are consistent with the provincial tendency.

Treatment of wet weather flows resulting from inflow and infiltration (I/I) to the sewer collection system is quite different from treatment of base flow during a dry weather period. For Humboldt, both rain events and snowmelt induced high flow events (flows two times greater than the annual dry weather flow) during spring can last for several days. Although the magnitude and duration of these snowmelt events can be somewhat predicted through knowledge of past occurrences and collection system limitations, the magnitude and duration of these peak events cannot be perfectly predicted. Flow event early spring can be exacerbated by rainfall event when catch basins and earth was still frozen, as it was the case in 2010; or when potable water pipes is bypasses to sewer collection system to prevent freezing of small potable pipes, as it was the case in 2014.

As seen from Figure 1, there is a need to provide some degree of treatment to all the flows conveyed to the plant regardless of the magnitude and duration. The strategies and feasible alternatives to control the magnitude of such wet weather events reaching the plant is discussed below. High wet weather flows through a rainfall and snowmelt induced I/I event can cause operational problems at a biological nitrogen removal facility by reducing process retention times and potentially washing out the biomass. This can result in compromised treatment efficiency for days or potentially weeks following an event. In addition, the dilute nature of wastewater resulting from these events is potentially more difficult to treat biologically. This potential occurrence at the plant presents an opportunity for the City to reduce the size of the biological process and divert part of the flow through a wet weather flow management process, producing a final effluent that is still within the effluent limits.

There are two important reasons the City should consider the use of wet weather flow management processes. First, since the plant experiences high wet weather flows relative to the average day flow, implementing a wet weather flow management system would protect the biological process from washout of the viable biomass, thereby maintaining adequate performance of the biological process under such conditions. The quality of the effluent can be restored immediately after the storm event. Secondly, the cost of a wet weather flow management system is approximately one-third the cost of a biological process and the entire treatment facilities need not be oversized to handle these unusual flow events. This could result in significant capital and operating cost savings for the City.

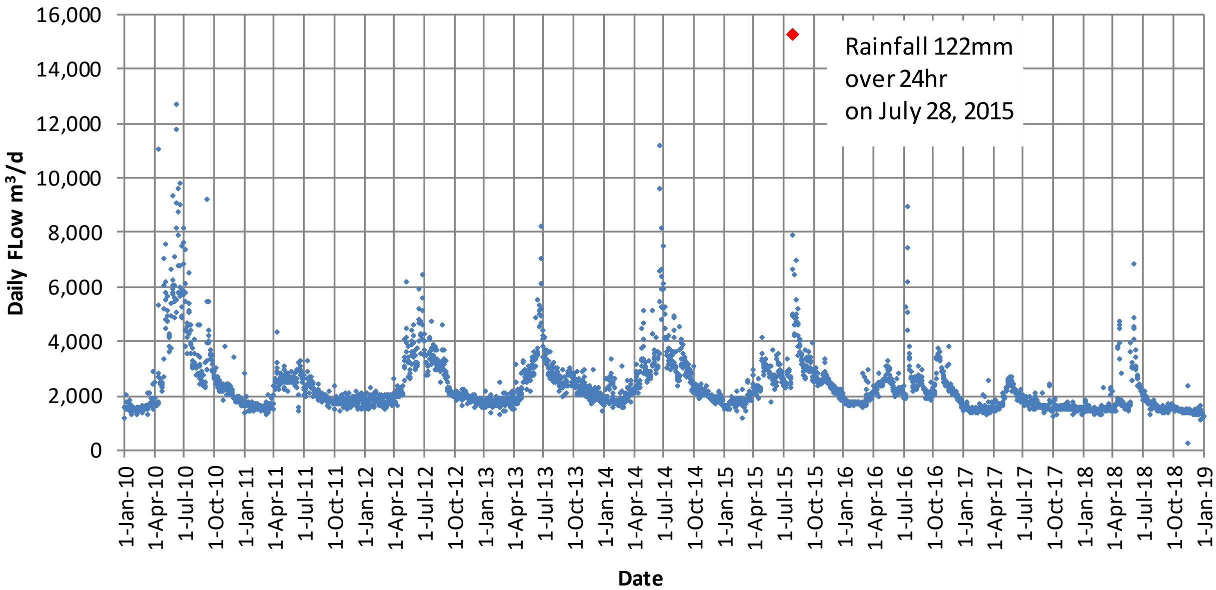

Figure 1 Daily Wastewater Flow Pumped from the Lift Stations to the Lagoons from 2010 to 2018

1.1 FLOW DATA ANALYSIS

Wet weather flow management requires an understanding of the interaction between the collection system and wastewater treatment, which are linked via the lift stations and forcemain. Collection systems and pumping stations are designed to handle peak flows in a manner that minimizes the possibility of basement flooding in wet weather events. Wastewater treatment plants are designed to handle peak flows in a manner that minimizes the potential of non-compliance with discharge limits. To develop cost-effective management of peak flows, sewer collection models are often developed to forecast the improvements required to accommodate future growth during inflow and infiltration response from rainfall events. Such a model would predict peak flows to the treatment plant and the period of time that the excess flows would be sustained in response to a design event. In the absence of such a sewer collection model only general comments can be made based on statistical analysis of the precipitation and flow handled by the lift stations.

1.1.1 Precipitation

Figure 2 shows the magnitude of wet weather events that occurred from 2012 to 2018. This indicates that the maximum monthly precipitations occurred in June 2013 and July 2015 for the City of Humboldt. Historical precipitation data for the City of Humboldt before 2012 was not available.

1.1.2 Wastewater Flows

Based on data presented in Figure 1, a probability graph was created to better visualize the daily flow magnitude and distribution for each year over the eight-year data period as presented in Figure 3.

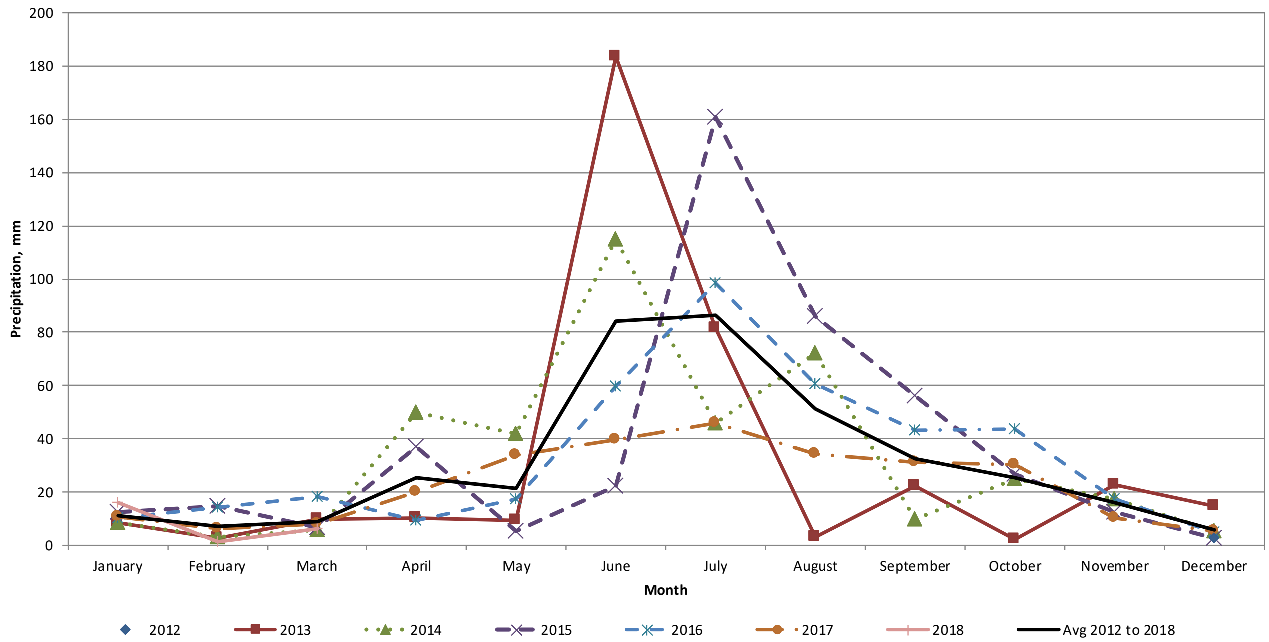

Figure 2 Historical Precipitation Data for Humboldt (Source: weatherstats.ca)

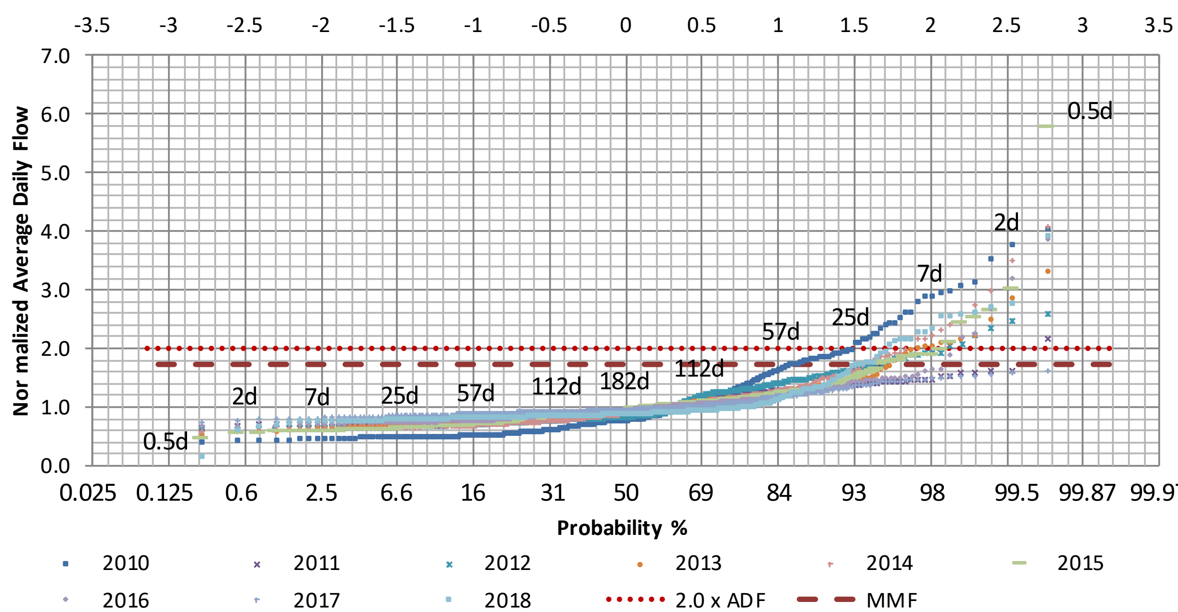

Figure 3 Probability of Daily Wastewater Flow, January 2010 to September 2017

The results of the analysis are summarized below:

- A wet weather management facility (WWMF) may be the best option when the magnitude of the peak factor is above 2.00 times the Average Daily Flow (ADF) based on probability analysis excluding data for 2010.
- Secondary treatment processes designed for a current Maximum Week Flow (MWF) of 9,722 m^3/d would have enough capacity to treat 98% of the flows during dry weather years. Seven days out of 365, flows would be diverted to the wet weather management system and would not be able to fully meet effluent discharge criteria.
- Secondary treatment processes designed for Maximum Month Flow (MMF) of 7235 m^3/d will have enough capacity to treat 98% of the high flows (flows above 7,235 m^3/d) as those experienced from 2013 to 2016. If the plant experiences wet weather events as in 2010, the secondary treatment process will have enough capacity to treat 94% of flows (25 days out of 365 days flows will be diverted to the wet weather management facility). Thus, a WWMF would be required during wet weather flows to deal with high flows if inflow and infiltration (I/I) is maintained at the same rate as was the case from 2010 to 2016.

The conclusion of this analysis is that high flows events have a profound impact on the sizing and operation of the secondary treatment process. Sizing of the secondary treatment based on flow data collected from 2010 to 2018 is reasonable considering that 2010 was a very wet year (the highest June rainfall on record) and can truly represent the flows to be received at the plant during extreme wet weather events. Thus, it is proposed that the secondary treatment process be designed to treat the maximum monthly flows of up to 7,235 m^3/d and to hydraulically handle the peak hourly flow. Flows in excess of the peak hourly flow will be diverted upstream of the secondary treatment process and blended with plant effluent before discharge to the Humboldt Lake.

1.1.3 Humboldt Lake Flows

Analysis of historical flows contributing to Humboldt Lake was not be conducted due to the absence of an active station listed in the Water Survey of Canada – Archived Hydrometric Data Online.

1.2 WASTEWATER CHARACTERISTICS

The influent wastewater characteristics and the resulting mass loads of key contaminants received at a WWTP during a wet weather flow event will be significantly different from the normal dry weather flow conditions. Although the presence of I/I usually means the measured concentrations of most constituents will be lower, significantly higher mass loads of contaminants such as suspended solids often occur during the initial first flush of a wet weather flow event. This is normally most prevalent after a long dry period. High and prolonged wet weather flows can re-suspend sediments that may have been deposited in the collection system or scour biomass from pipe walls and transport it to the WWTP. Additionally, the characteristics of contaminants during a wet weather flow event can be very different from a dry weather flow regime. These include the proportions of soluble and particulate fractions of five-day biochemical oxygen demand (BOD5), total suspended solids (TSS), fraction of particulates that can be removed by gravity settling, amounts of organic matter, particle size, and solids settling velocity and changes in temperature.

A detailed discussion of the wastewater characteristics during wet weather flow event cannot be presented as the City of Humboldt does not monitor influent characteristics. Generic observations from other city wastewater characterizations are summarized as follows:

- Bioreactor influent BOD concentration declines with increasing influent flow.
- Influent solids loadings are higher during higher flows. This suggests additional solids enter the system with I/I or solids settle during lower flows and are flushed from the system with increased flows.

2.0 WET WEATHER MANAGEMENT ALTERNATIVES

Selection of an appropriate wet weather treatment process requires careful consideration of the following factors.

Wet weather treatment is required only for a short duration of time compared to the operation of the overall main plant. Since significant capital investment is required, the feasibility of the selected wet weather management alternative to operate under normal flows should be considered. This alternative has the following benefits:

- Ability to respond to a quick start-up in response to wet weather events reaching the plant.
- Ease of operation and maintenance
- Successful track record of similar technologies
- Costs of associated infrastructure such as building envelope requirements (inside a covered building vs. covered tanks), building footprint etc.
- Capital cost and annual operation and maintenance costs

Based on this, the wet weather treatment alternatives that are considered appropriate for the City of Humboldt are listed below.

- Flow Blending
- Chemically Enhanced Primary Treatment (CEPT)
- High Rate Clarification (lamella plates, ballasted flocculation and dense sludge processes)
- Retention Treatment Basin (RTB)
- Off-line storage

Other processes such as vortex solid separators (VSS) and compressed media filtration (CMF) were not considered. Very limited operating experience exists for the VSS and CMF technologies. The CMF process requires no chemical addition and as the name suggests, it operates as a filter to accomplish removal of contaminants from wastewater. Extensive piloting of the CMF technology was carried out in parallel with a ballasted flocculation and dense sludge processes by the City of Akron. The study concluded that CMF did not provide the level of treatment comparable to the other high-rate processes (Frank and Smith, 2006).

The alternative processes considered feasible for the City of Humboldt are discussed in detail in the following sections.

2.1 FLOW BLENDING

Flow blending is a practice used at WWTPs that involves diverting a portion of the preliminary treated sewage around the biological treatment processes and re-combining the flow streams of the biological treatment process. Generally, the blended effluent must meet all effluent limits applicable to the WWTP discharge. Blending is used during periods of peak wet weather flow to allow peak flows to the WWTP to be maximized while protecting the biological treatment processes from adverse effects of high peak flows. Blending can be an effective means of mitigating the discharge of upstream, untreated overflows while providing effective pollutant removal at the WWTP. The key factor to consider in evaluating blending is whether the blended effluent can reliably meet required effluent limits.

2.2 CHEMICALLY ENHANCED PRIMARY TREATMENT (CEPT)

In simple terms, chemically enhanced primary treatment (CEPT) involves chemical coagulation of the influent wastewater to increase the efficiency and capacity of the conventional primary clarification. The additional removal efficiency is due to the improved floc structure and increased particle settling velocity thereby enhancing treatment efficiency, measured as removal of suspended solids, organic matter and nutrients (such as phosphorus) from the wastewater.

In addition, the colloidal fraction of the influent BOD5 that would otherwise not settle in a traditional clarification process tends to flocculate better and is removed from the wastewater stream.

CEPT technology can be implemented using dedicated CEPT tanks (e.g. for use during wet weather events). The use of chemical coagulants such as alum, ferric and ferrous salts in conjunction with flocculation aids such as polymer allows a higher overflow rate during the peak flow events (hence minimizing the clarifier surface area) while increasing system performance.

As applicable for conventional primary clarification, the system design of CEPT is still governed by the surface overflow rates (SOR) or rise rate. Rise rate is an important consideration in the evaluation of each side stream processes as it impacts the footprint requirement of the system tanks. Published value of peak SOR for CEPT ranges from 3.0 m/h to 5.0 m/h with removal efficiencies for TSS of 60% to 85%, BOD5 removals of 45% to 65% and up to 85% removal of total phosphorus (TP). A summary of advantages and disadvantages of CEPT are provided in Table 1.

Table 1 Summary of Advantages and Disadvantages of CEPT

Advantage	Disadvantage
Increased removal of BOD, TSS, TP and metals	Requires chemical addition, which increases sludge production and increases annual operating costs
Smaller footprint than conventional primary clarifiers	Addition of chemicals such as alum reduces alkalinity of the primary effluent causing a potential impact on the nitrification process
Improves performance of downstream biological process	Bigger footprint than high rate processes such as lamella plates, ballasted flocculation and dense sludge processes
CEPT tanks can be operated without chemicals during dry weather flows	More complex flow splitting and flow control as compared to conventional primary clarifiers

2.3 HIGH RATE CLARIFICATION PROCESS

Performance of all clarification devices is determined, in general, by the settling velocity of the suspended solids. The primary disadvantage of a conventional primary clarification process is the relatively low settling velocity of many wastewater particles which equates to a requirement for large surface areas and consequently high capital costs if they are only used for those occasional wet weather flow events.

High rate clarification processes use some combination of chemical coagulation, plate settlers such as lamella plates, ballasts or floc weighting agents and recycled sludge to achieve improved clarification performance while maintaining very high surface overflow rates. High rate clarification is very well suited for wet weather flow applications because of the reduced space requirements, fast start-up, short response time, relative insensitivity to fluctuations in the influent characteristics and high degree of removal of BOD, TSS, TP, metals and Total Kjehldahl nitrogen (TKN) (WEF, MOP FD-8, 2005).

Start-up and shut down of high rate clarification in wet weather applications requires careful consideration because of their intermittent operations, the use of chemicals, and the presence of sludge and sand in the process tanks (Keller et al., 2002). Since these wet weather events cannot be predicted, polymer solutions must be made up in advance and replaced as necessary. High rate clarification processes that are used include the following: lamella plate clarification; ballasted flocculation and the dense sludge process. Further discussions on these two systems are provided in the following sections.

2.3.1 Lamella Plate Clarification

A further enhancement of the CEPT process can be achieved by adding Lamella plate settlers to the clarifiers, allowing operation at peak SORs of 12 to 15 m/h at peak conditions (HDR Engineering, Black & Veatch, 2002) and better performance than conventional CEPT. Coagulation and flocculation units are usually added upstream to enable optimum system performance. The Lamella plate clarification system uses a series of inclined plates to increase the surface area over which particles can settle out. The most significant aspect of design is its available settling area. The effective gravity settling area of the inclined plate design equals each plate's area projected on a horizontal surface. Up to ten square meters of settling area become available for each square meter of land (or floor space) occupied by the unit allowing a higher peak flow to be handled in a given tank surface area. The surface area depends upon the angle of plate inclination, which is typically around 45 to 60 degrees and spaced at intervals of 40 ~ 120 mm. Because the plates are stacked at an incline, the depth from which they must settle is significantly less than those of traditional clarifiers.

The Lamella plate clarification system has similar efficiencies as observed for CEPT. The system can also be used for primary clarification under normal operations (without using chemicals) except that due to its unique design, influent wastewater may require pumping. Sludge flows are expected to be around 2.5%. Due to incorporation of lamella plates, this option would require additional cleaning effort compared to the CEPT process discussed before. This is due to potential plugging problems due to accumulation of settled solids in the plates as wells as development of biofilms in the large surface area available and resulting odour generation.

There is limited application of lamella plate clarification in North America although there are approximately 130 installations in Europe with France leading the way. The City of Edmonton Gold Bar WWTP has implemented a Lamella unit for dealing with high Combined Sewer Overflows (CSO). Some of the key design issues related to CEPT with Lamella plates include plate settler rise rate, tank hydraulics, flow modeling of the clarifiers under various flow regimes, end-feeding versus side feeding, spacing between lamella plates (minimum 75 mm recommended), and automatic plate cleaning systems to avoid plugging (combination of air scour and water jets). A summary of advantages and disadvantages of a lamella plate clarification system is provided in Table 2. A schematic of the lamella plate clarification is shown in Figure 4.

Table 2 Summary of Advantages and Disadvantages of Lamella Plate Clarification

Advantages	Disadvantages
Increased removal of BOD, TSS, TP and metals	Requires chemical addition which increases sludge production and reduces alkalinity
Smaller footprint than conventional clarifiers	Scum removal can be a problem and an in-place cleaning system is required to reduce clogging
Improves performance of downstream processes such as disinfection	Maintenance is required for cleaning of the Lamella plates
No additional thickening of primary sludge required	Bigger footprint than high rate processes such as ballasted flocculation and dense sludge
No additional fine screening required upstream of the CEPT clarifier	More complex flow splitting and flow control as compared to conventional primary clarifiers

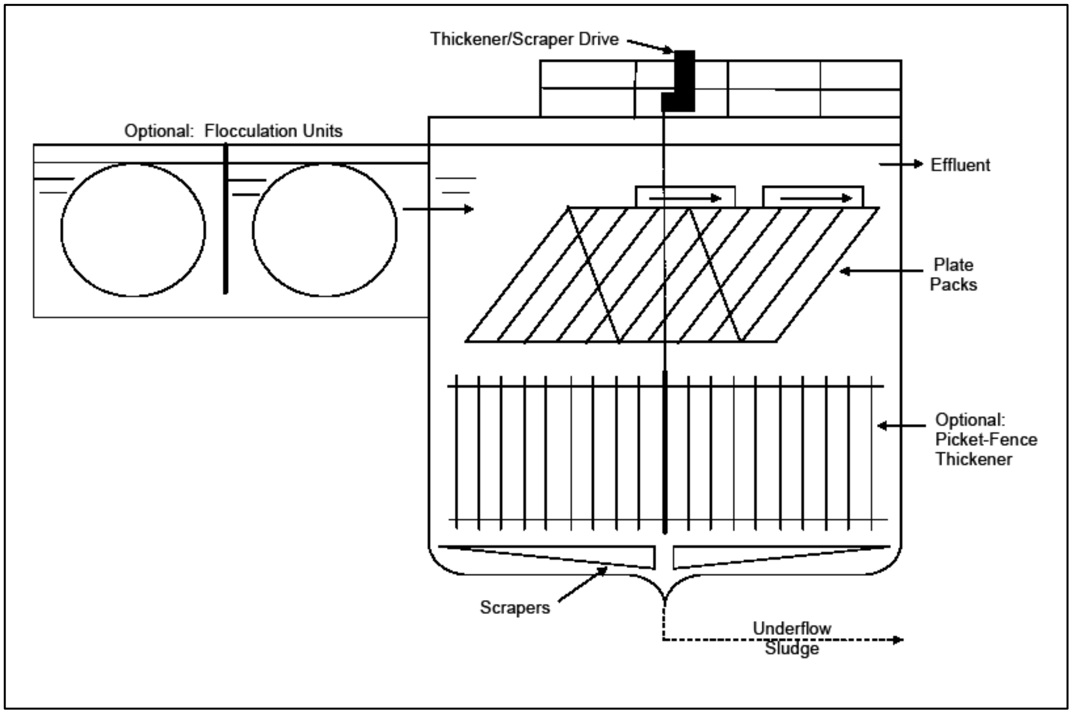

Figure 4 Schematic of Lamella Plate Clarification

2.3.2 Ballasted Flocculation

Ballasted flocculation refers to a high rate clarification process that utilizes micro-sand particles (45 to 100 µm in diameter) to enhance floc formation and increase floc settling rates in the presence of a chemical coagulant and polymer. This allows the system to be loaded with a very high SOR resulting in a small overall footprint. Actiflo is the most common ballasted flocculation process used in water and wastewater applications. The system was originally developed by Kruger, Inc. now a part of Veolia Water (Cary, North Carolina) and is marketed by John Meunier (St-Laurent, Quebec) in Canada. The process schematic is shown in Figure 5.

Actiflo is a three-stage process with the influent wastewater first screened and de-gritted to remove large particulates prior to entering the first stage. The first step is usually the addition of a coagulant such as alum or ferric salts prior to flash mixing followed by the addition of polymer and micro-sand. The second stage of the Actiflo process is maturation, where the ballast material serves to enhance the flocculation process, resulting in a much faster settling rate relative to traditional coagulants. The third stage of the Actiflo process is clarification. A majority of the solids settle to the bottom of the tank. However, the clarification zone is equipped with Lamella plates to further enhance the solid-liquid separation process. The settled solids are recycled back to a hydro-cyclone where the sludge is separated from the micro-sand. The sludge is wasted and the micro-sand is returned back into the process in the injection zone. Typical removal efficiencies for this process range as follows: TSS (70% to 90%); BOD5 (40% to 60%); TP (70% to 96%) and TKN (17% to 30%).

The Actiflo process can treat flows between 10 and 100 percent of its nominal design capacity, allowing systems to provide wet weather treatment for a range of design storm events. Typical start-up to steady-state time ranges from 15 to 30 minutes (to be confirmed by pilot testing). Typical peak surface overflow rates for the Actiflo process in the treatment of wet weather flows are in the range of 100 to 130 m/hr and produces thickened sludge of approximately 0.3% to 1% solids (HDR Engineering, Black & Veatch, 2002). A summary of the advantages and disadvantages of ballast flocculation are provided in Table 3.

Table 3 Summary of Advantages and Disadvantages of Ballasted Flocculation

Advantages	Disadvantages
Smallest footprint amongst all side-stream processes considered for Humboldt	Increased dosages of coagulants and polymers compared to CEPT
Fast start-up and shut down	Requires fine screening ahead of the process, which increases capital and operational costs
Very high degree of TSS, BOD, TP removal	Very low sludge concentrations, requires additional thickening of sludge
Process maintains stability even at high SORs	Micro-sand management issues during start-up and shut-down and higher wear rates for pumps and piping moving sludge and sand

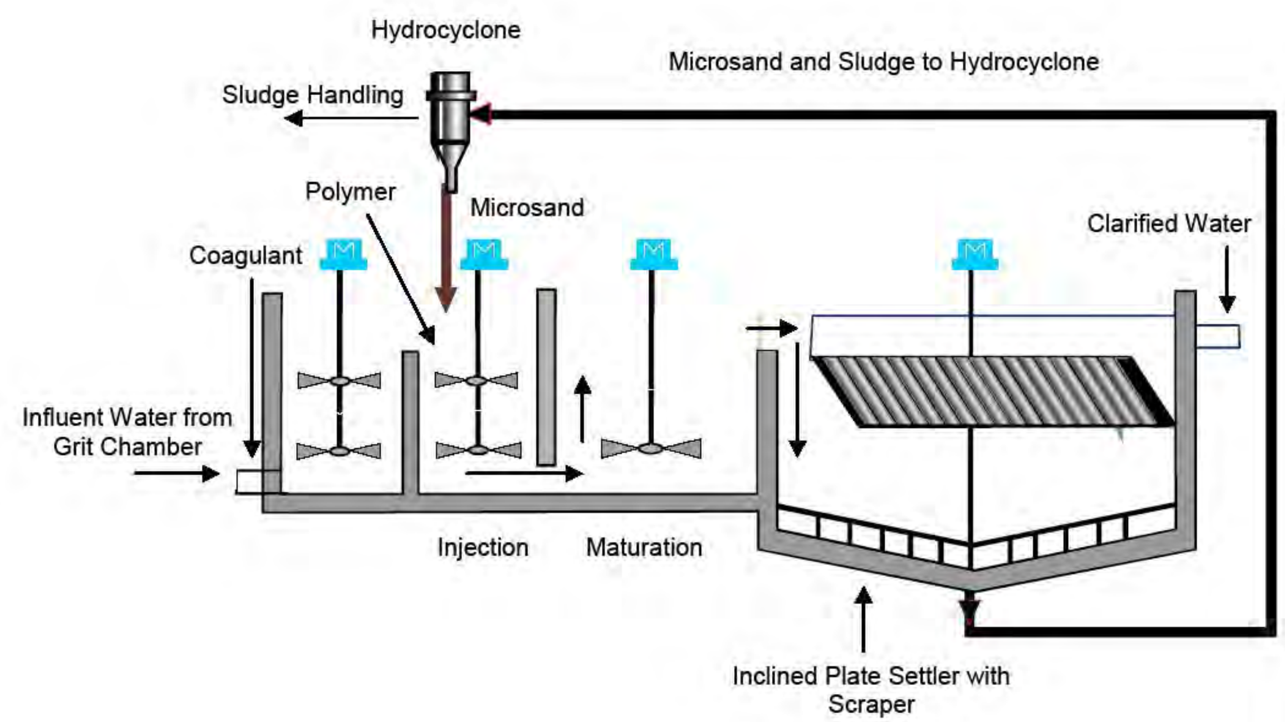

Figure 5 Schematic of Actiflo Process (Source USEPA 2003)

2.3.3 Dense Sludge Process

Dense sludge is a high rate clarification process that combines chemical coagulation, sludge recirculation, tube settling, thickening, and sludge recycling. Unlike the use of micro-sand in the ballasted flocculation process, a portion of the settled sludge (2% to 6% of flow) is recycled to the bottom of the flocculation tank resulting in a dense floc with high settling velocities. This technique allows for high removal efficiencies of TSS, particulate BOD and TP even under very high SORs. The dense sludge process is marketed under the trade name of DensaDeg by Infilco Degremont, Inc. (Richmond, Virginia). A schematic of the process is shown in Figure 6.

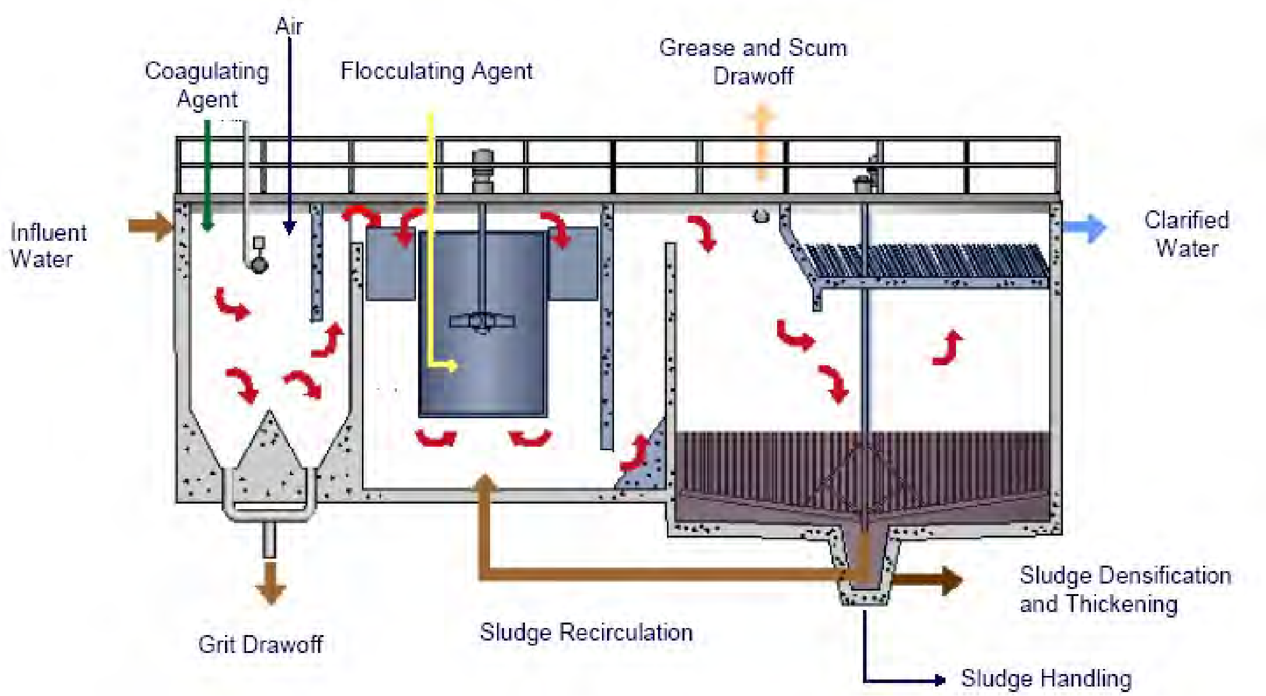

Figure 6 Schematic of a Densadeg Process (USEPA 2003)

2.3.4 Dense Sludge Process

The DensaDeg process is capable of the rapid start-up and shutdown which will typically be required for responding to wet weather flow situations. When this process is started dry, full efficiency is attained within 20 to 30 minutes and almost immediately during wet start-up (Westrelin and Bourdelot, 2001). Some of the unique features of the DensaDeg process are the use of air injection simultaneously with the coagulant and the use of a draft-tube mixer to enhance coagulant dispersion and mixing.

Coagulated wastewater enters the reactor where polymer is added with recycled settled sludge to help the flocculation process. In the reaction zone, wastewater enters a clarifier where grease and scum are drawn off the top. In the final step of the process, inclined tube settling or lamella plate settlers are used to remove residual floc particles. Settled sludge from the clarifier is thickened, and part of this sludge is re-circulated and added to the flocculate. Because this system uses entirely recycled sludge as a coagulant aid, it does not require separation techniques such as the hydro-cyclone in Actiflo system to recover micro-sand from the sludge. Typical peak surface overflow rates for the DensaDeg process are in the range of 30 to 100 m^3/m^2-hr with thickened sludge concentrations of approximately 4% solids or 40,000 mg/L, producing sludge almost 4 to 13 times thicker than Actiflo. This difference in sludge concentration is one of the important aspects for selecting an appropriate side-stream process for the City of Humboldt. Since the DensaDeg and the Actiflo process are expected to produce a similar mass of sludge (as they operate with similar coagulant dosages), the volume of sludge produced by the DensaDeg process would be significantly less than the Actiflo process. The treatment efficiencies of this process for the key contaminants such as BOD5, TSS, TKN and TP are comparable to the Actiflo process, although at comparatively lower SORs. A summary of advantages and disadvantages of DensaDeg process is provided in Table 4.

Table 4 Summary of Advantages and Disadvantages of DensaDeg Process

Advantages	Disadvantages
Footprint smaller than Lamella plate clarifier but slightly larger than Actiflo system	Requires fine screening ahead of the process
Produces sludge with highest concentration of solids that equates to lowest volume of sludge. No additional thickening of sludge is required	Requires longer time needed for startup because of the time required to build up re-circulating sludge from influent TSS
Very high degree of TSS, BOD, TP and TN removal (similar to Actiflo)	Potential for septic conditions and resulting in odours and corrosion if sludge is not properly managed in between start-up and shut down operations

2.4 RETENTION TREATMENT BASIN (RTB)

A Retention Treatment Basin (RTB) consists of a wet weather flow storage tank or a vessel that provides some storage and treatment in a flow-through mode. A typical RTB can resemble both a storage tank and clarifier and can operate in conjunction with chemical coagulation for enhanced treatment. During the flow-through treatment, influent solids are captured from the wastewater as settled sludge and floatable materials are removed. Both sludge and floating solids are typically returned to the mainstream process for further treatment and handling when capacity becomes available.

After a wet weather event has ended, the draining and flushing systems provide for draining the stored wet weather flow in the RTB to the outfall or interceptor sewer and for flushing out settled solids. Solids and flushing water are also discharged to the outfall pipe or interceptor sewer. Hence RTBs have flushing systems rather than sludge scrapers for diverting the solids back to the main treatment plant.

Rectangular basins are preferred as they are least expensive to construct and maintain. Baffles are generally used as a part of the inlet design to reduce inlet velocity and promote plug flow conditions to maximize sedimentation efficiency. Outlet structure design is critical to maintain a constant outlet flow rate to the downstream processes or structures. Fixed outlet orifices, flow restricting pipes, and overflow weirs are often chosen because they have predictable hydraulic characteristics and are simpler to design. A summary of advantages and disadvantages of RTBs is provided in Table 5.

Table 5 Summary of Advantages and Disadvantages of RTBs

Advantages	Disadvantages
Simple operation compared to other side-stream processes	Largest footprint amongst all side-stream processes
No additional fine screening required upstream of RTB	Odour control is required
No major mechanical parts	Contaminant removal efficiency is lower than that of other high rate clarification processes

2.5 OFF-LINE LAGOONS

An off-line lagoon is variation of the RTBs, with the exception that solids settled in the lagoons are not returned to the main stream process for further treatment, these solids remain at the bottom of the lagoons and solids removal is defer for many years. Stored flows in off-line lagoons can be returned to the head of the treatment plant once the wet weather event subsided or can be blended with final effluent prior to discharge to the Humboldt lake. Off-line storage can also be used when store raw sewage when the secondary treatment process is out of service for inspection or maintenance. Careful consideration should be given of how fill and drain the off-line lagoon. Odour control may be required if the off-line lagoon is located very close to residential areas. For Humboldt, this option is very attractive because it makes use of the existing lagoons. This option also justifies the need to maintain the lagoons rather than decommission the cells which is very expensive.

3.0 RECOMMENDED WET WEATHER FLOW MANAGEMENT

Selection of an appropriate wet weather flow treatment process for the City of Humboldt is based on several factors including: water quality objectives, overall value of the process with respect to the City's operational goals, process flexibility, ease of operation and land area requirements.

High rate clarification can achieve good effluent quality and requires a minimal foot print. However, it has a very high capital and operating cost in comparison to RTBs. High rate clarification requires a competent operating staff to operate and maintain the system. This is because the system relies heavily on chemicals (coagulant and polymer) in conjunction with ballasts (sand) or re-circulating sludge that is required to start-up on demand.

CEPT can be used under both dry and wet weather operations if primary clarifiers are to be constructed. Similar to high rate clarification, CEPT requires a competent operating staff to operate and maintain the system because the system relies heavily on chemicals.

RTBs have been implemented in several locations as a remote or satellite type facility primarily for wet weather flow management. RTBs present challenges with solids handling, odour potential and has the largest footprint. However, it has the lowest operating and capital cost of all the options. It is likely that WSA would require the basin design to follow the similar guidelines as in sewage lagoons. Off-line storage lagoons cannot be clay lined due to potential desiccation when the RTB is fully drained.

Based on the discussions presented and the relative advantages disadvantages of each wet weather management option, the off-line storage lagoon is recommended for further consideration since the existing lagoons will serve very well for this purpose.

City of Humboldt Wastewater Treatment Plant Upgrades

Technical Memorandum No. 3
Identification of Liquid Treatment Options

February 11, 2019

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Sign-off Sheet

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Abbreviations

AS	Activated Sludge
AAF	Annual Average Day Flow
BAF	Biological Aerated Filter
BOD_5	Biochemical Oxygen Demand 5-day
BNR	Biological Nutrient Removal
BWL	Bottom Water Level
COD	Chemical Oxygen Demand
$cBOD_5$	Carbonaceous Biochemical Oxygen Demand 5-day
DNA	Deoxyribonucleic Acid
FRP	Fibre Reinforced Plastic
GSBR	Granular Sequencing Batch Reactor
H2S	Hydrogen Sulfide
IFAS	Integrated Fixed Film Activated Sludge
ISS	Inorganic Suspended Solids
MBBR	Moving Bed Bioreactor
MBR	Membrane Bioreactor
MDF	Maximum Day Flow
MMF	Maximum Monthly Flow
MSBR	Modified Sequencing Batch Reactor
PDC	Power Distribution Centers
RNA	Ribonucleic Acid
RAS	Return Activated Sludge
RBC	Rotating Biological Contactor
SAGR	Submerged Aerated Growth Reactor
SBR	Sequencing Batch Reactor
SLR	Solids Loading Rate
SRT	Sludge Retention Time
SVI	Sludge Volume Index
TKN	Total Kjeldahl Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
TWAS	Thickened Waste Activated Sludge
TWL	Top Water Level
UV	Ultraviolet
VFD	Variable Frequency Drive
VSS	Volatile Suspended Solids
WAS	Waste Activated Sludge

WWTP	Wastewater Treatment Plant
WSA	Water Security Agency

1.0 INTRODUCTION

Stantec Consulting Ltd. (Stantec) was retained by the City of Humboldt to prepare a pre-design report for the City of Humboldt Wastewater Treatment Plant (WWTP) Upgrade. This Technical Memorandum (TM) provides a discussion of the existing treatment process and alternative liquid treatment technologies available. This information will lead to the short-listing of three options for further evaluation in technical memorandum No.5 - Evaluation of Treatment Options.

1.1 BACKGROUND

The City of Humboldt currently treats wastewater in a lagoon system consisting of an anaerobic cell, an aerated cell, a facultative cell, three storage cells and a phosphorus removal system as described in Table 1-1 and presented in Figure 1-1. The lagoons are operated in series with all the flow from the three lift stations conveyed to the anaerobic cell. The phosphorus removal system consists of pumping secondary effluent from storage cells 2 and 3 through manholes where it is mixed with ferric sulfide before being discharged to the phosphorus removal cell where phosphorus precipitates as ferric phosphate. Effluent from the phosphorus removal cells is seasonally discharged to Humboldt Lake through a conveyance channel in May and October. Although the current treatment system reduces the negative environmental impacts of the major pollutants in the wastewater, it cannot consistently meet the anticipated effluent discharge criteria in terms of total suspended solids (TSS), total phosphorus (TP) and ammonia. In addition, the storage lagoons have insufficient storage capacity to provide the old standard of 180 days (new standard of 220 days of retention time is required by Water Security Agency (WSA)) and consequently, they are very frequently operated at high water levels, reducing the freeboard to less than 300 millimetres during high flow events and causing erosion of the lagoon embankments.

Table 1-1 Existing Wastewater System Description based on Projected ADF of 4,100 m^3/d for 10,000 people

Parameter	Anaerobic Cell	Aerobic Cell	Facultative Cell	Storage Cell 1	Storage Cell 2	Storage Cell 3	Phosphorus Removal Cell
Function	Sedimentation of suspended solids and anaerobic treatment	Aerobic treatment using a 50 HP blower and 32 helixor diffusers	Facultative treatment via algae growth	Storage of secondary effluent	Storage of secondary effluent	Storage of secondary effluent	Precipitation of phosphorus
BOD_5 Load, kg/d	795	556	472	N/A	N/A	N/A	N/A
BOD_5 Loading, kg/ha/d	1,402	1,000	78	N/A	N/A	N/A	N/A
TSS Load, kg/d	869	435	N/A	N/A	N/A	N/A	N/A
Capacity, m^3	15,800	15,200	85,500	39,000	226,000	147,000	10,600
Operating Depth, m	3.95 (as per City emails)	3.85 as per City emails)	1.5	1.5	2.1	2.1	2
Freeboard, m	0.45	0.45	0.6	0.6	0.6	1.5	0.6
Surface Area, ha	0.567	0.556	5.99	2.58	14.5	7.4	0.75
Floor Elevation, m	558.90	559.00	560.90	560.90	560.30	560.30	559.80
Full Service Level, m	562.85	562.85	562.40	562.40	562.40	562.40	561.80
Berm Elevation, m	563.30	563.30	563.00	563.00	563.00	563.90	562.40
Retention Time, d	3.8	3.7	20.5	9.5	55	36	2.5
Active Storage, d	N/A	N/A	N/A	8.8	51	38	2.5
Slope	2.8:1 & 3.3:1	2.8:1 & 3.3:1	4:1	4:1	4:1	3.5:1	4:1
Construction Upgrades, year	1961 1971	1961 1973	1961	1961	1976	2001	1985
Total area required to meet WSA standards, ha	0	0	17 ha (415 m by 415 m berm to berm at FSL with slope 4:1)	41.4 ha (644 m by 644 m berm to berm at FSL with slope 4:1) to provide a total active storage volume of 1,613,300 m^3 assuming an operating depth of 3.0 m and cells completely drain after discharge.			
Comments		Current condition of diffusers provides minimum BOD reduction	Insufficient treatment capacity, BOD loading exceeds 30 kg/ha-d	Active storage is about 94 days (assuming 100 millimetres of inactive water to protect the clay liner and average daily flow of 4100 m^3/d for 10,000 people).			

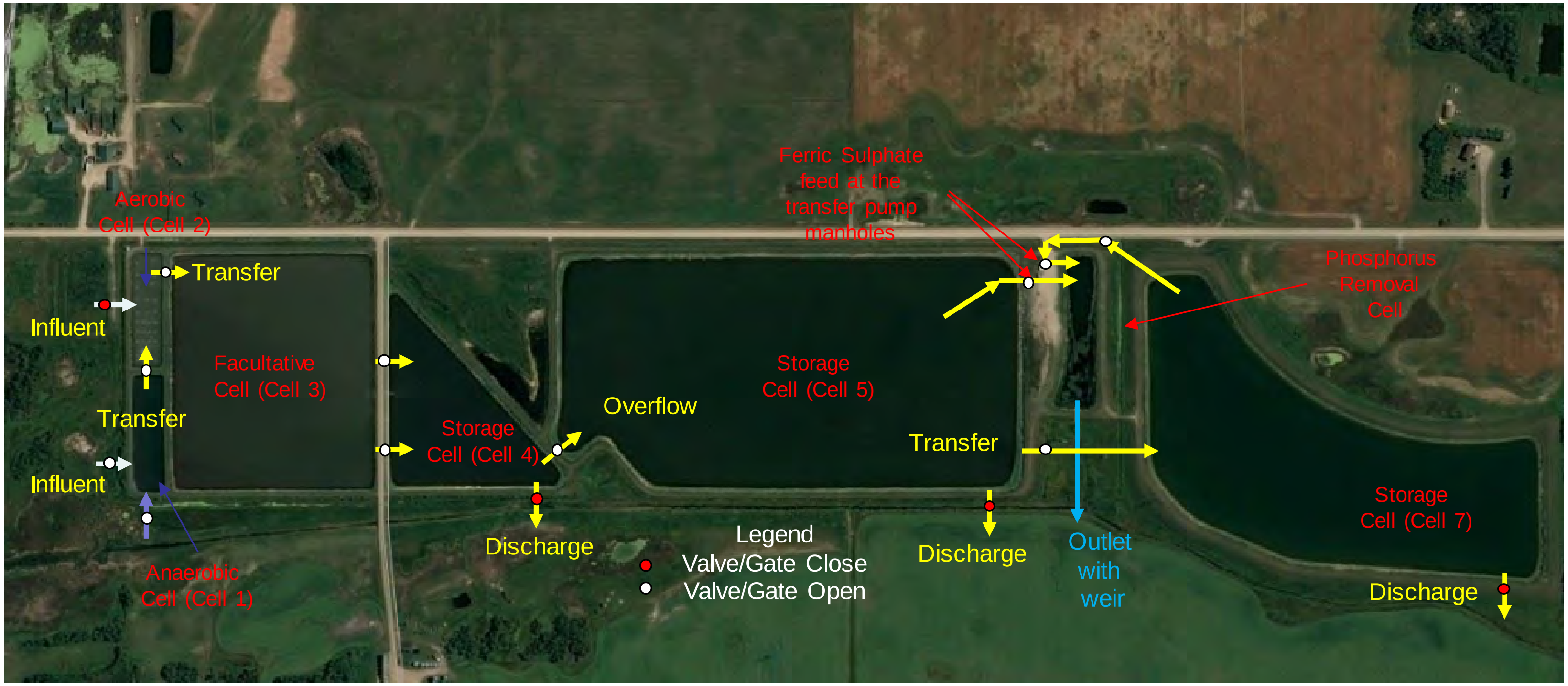

Figure 1-1 Humboldt Wastewater Treatment System Flow Schematic

Stantec's Downstream Use and Impact Study revealed that ammonia reduction is a reasonable goal for the City to achieve and proposed effluent discharge criteria for continuous discharge to Humboldt Lake, as listed in Table 1-2.

Table 1-2 Proposed Effluent Discharge Limits for Discharge to Humboldt Lake

Parameter	Proposed Effluent Discharge Limit (1)	Design Target
Total Suspended Solids (TSS)	< 25 mg/L	< 20 mg/L
Carbonaceous Biochemical Oxygen Demand 5-day ($CBOD_5$)	< 25 mg/L	< 20 mg/L
Total Nitrogen (TN)	< 40 mg/L	< 15 mg/L(2)
Total Phosphorus (TP)	< 1 mg/L	< 0.75 mg/L
Ammonia-N Summer/Winter	< 4/10 mg/L	< 4/10 mg/L at 22°C / 1°C and pH of 8.0 < 1.6/7.5 mg/L at 22°C / 1°C and pH of 8.5
Unionized Ammonia-N	< 1.25 mg/L at 15°C ± 1°C	< 0.21 mg/L at 15°C ± 1°C
Total Chlorine Residual	< 0.02 mg/L	< 0.02 mg/L
E-Coli	< 200 orgs/100 mL	< 100 orgs/100 mL
Total Coliform	< 3,100 orgs/100 mL	N/A(3)
Note: (1) Sampling frequency has not been defined by WSA (2) Total nitrogen target of 15 mg/L has been set to recover alkalinity through denitrification for secondary systems that can incorporate high recycle ratios of nitrifying mixed liquor (NML). For other options that cannot recycle high flows of NML, addition of sodium bicarbonate or sodium hydroxide would be considered if the effluent alkalinity is less than 50 mg/L. (3) N/A Not applicable		

Ammonia reduction can be achieved by either ammonia volatilization or by nitrification (conversion of ammonia to nitrate by nitrifying bacteria). Ammonia volatilization can be attained in the storage lagoons if the effluent is stored over a full year and the water pH is greater than 8. This would require a very large lagoon footprint as shown Figure 1-2, and would be very expensive (order of magnitude would be about $20M depending of geotechnical conditions). In addition, such a lagoon system would not be able to consistently achieve the effluent quality listed in the City of Humboldt Downstream Use and Impact Study (DUIS) letter issued by WSA on December 31, 2018, specifically, Total Suspended Solids (TSS) less than 25mg/L, ammonia-N less than 3 mg/L and not acutely toxic. This is because the treatment capability of lagoons is significantly affected by climatic conditions (temperature, sunlight and rain). In addition, the plant operator has very limited control over the conditions that could lead to a non-compliance such as water level in the storage lagoons that lead to excessive algae growth, responsible for high TSS (up to 100mg/L) and pH spikes (up to 10). High pH in the final effluent may cause failure to pass the acute lethality test with rainbow trout since ammonia toxicity test is pH dependant. Effluent with a residual ammonia concentration of 3 mg/L at pH of 10 and 15°C has an unionized ammonia of 2.2 mg/L, which is above the limit of 1.25 mg/L set by WSA.

It should be noted that WSA requires a buffer zone of 300 m from an isolated residence and 550 m to a built-up residential area for facultative lagoons and 300 m for mechanical plants (EPB-503 Table 4.2). Currently, the lagoon system does not meet this requirement. The distance from the west berm is 250 m to a single residence and 513 m to the west buildup residential area (101 St). The distance from the north berm is 500 m to the north build-up residential area (6Ave St). It is unlikely that WSA will allow and expansion of the lagoons not meeting set back requirements.

Figure 1-2 Humboldt Lagoon Expansion Minimum Required Area for 10,000 People

A more feasible option is to add process units to provide nitrification in earthen basins or concrete basins with continuous discharge to Humboldt Lake. This is required for two reasons: first to ensure that treated effluent would not deteriorate in the storage lagoons due to algal growth or to the release of nutrients from decomposition of existing sediments in the lagoons, and second, expansion of the lagoons to provide enough storage time would be very expensive.

This memorandum was developed based on the recommendations given in Technical Memorandum No. 1: Population, Wastewater Flows and Load Projections and summarized in Table 1-3 for the design year of 2052 with a projected population of 10,000 people

Table 1-3 Design Flows and Loads for the Design Year of 2052 (10,000 people)

Parameter	Unit	COD	BOD_5	TSS	ISS	TKN	TP
Annual Average Load	kg/d	1751	795	869	144	205	30.3
Average Wastewater Concentration	mg/L	427	194	212	35	50	7.4
Annual Average Flow	m^3/d	4100					
Maximum Month Load	kg/d	2363	1074	1173	194	242	34
Maximum Month Wastewater Concentration	mg/L	327	148	162	26.8	33.4	4.7
Maximum Month Flow	m^3/d	7,235					
Maximum Hydraulic Capacity	m^3/d	8,200 for mechanical plants					

2.0 IDENTIFICATION OF LIQUID TREATMENT OPTIONS

Typically, a WWTP comprises several process treatment units and two major waste streams: liquids and solids. Typical process treatment units that may be required for a liquid stream include: preliminary treatment, primary treatment, secondary treatment, filtration and disinfection. The process treatment units will included depend on the level of treatment required and the type of treatment. Some of the secondary treatment process does not require preliminary or primary treatment.

As a by-product of the liquid stream treatment, both primary and secondary sludge can be generated. Primary and secondary sludge need to be disposed of in a safe manner. Depending on the selected disposal of sludge, primary and secondary sludge may require storage and treatment.

A general discussion on the potential liquid treatment options for the City of Humboldt is provided in this section.

2.1 PRELIMINARY TREATMENT

Preliminary treatment prepares wastewater for further treatment by reducing or removing problem wastewater characteristics that could otherwise impede operation or increase maintenance of downstream processes and equipment. Typical problem wastewater characteristics include large solids, rags and abrasive grit.

Typical preliminary treatment processes are screening and grit removal. Other possible preliminary components include influent monitoring and septic receiving. The recommended components of preliminary treatment are usually common to all the secondary processes (except for lagoon based systems and electro-coagulation and electro-flocculation.

2.1.1 Screening

Screening at WWTPs is critical to remove large objects such as rags and debris that can damage influent pumps and block flow in piping systems. It is also necessary to remove smaller objects such leaves, hygiene and personal care products, and human hair to protect sensitive, downstream equipment including membrane systems or filters. The passage of rags and debris into downstream processes is one of the major causes for equipment maintenance and failure due to jammed pump impellers.

Most modern day WWTPs tend to employ some form of fine screens. Fine screens are typically considered to have openings of 6 millimetres or smaller and provide good capture of debris and larger particulate matter from raw wastewater streams. For the proposed WWTP upgrade, it is assumed that fine screens will be included. There are several fine screening technologies available on the market today. Based on our experience in similar plants in Western Canada, the degree of protection required for the downstream processes, the size of the proposed facility and the desired ease of operation, four types are considered: automatic multiple rake bar screen, perforated plate screen, step screen and spiral screen. A brief description and evaluation of each screen follows.

2.1.1.1 Automatic Multiple Rake Bar Screen

Bar screens are the most common screen type used in wastewater treatment facilities across North America. Due to their widespread use, operators are generally familiar with the design and operation of bar screens. As their name suggests, bars form the screen field to capture incoming solids. The captured solids are removed from the flow path by a mechanical rake, which moves the screenings onto a trough behind the screen, above the screen channel.

Multiple rake designs incorporate front-raking horizontal rake bars mounted on a heavy-duty chain to allow for shorter cleaning intervals; some screens are designed to clear the screen field every 10 seconds or less. The short cleaning cycle keeps the screen clear of obstructions and reduces blinding factors in hydraulic sizing. The use of a drive chain requires submerged sprockets and bearings. In earlier designs, these parts required regular replacement and maintenance, because the materials of construction selected were not suitable for the abrasive and corrosive environment of raw wastewater. New designs use corrosion-resistant stainless steel or synthetic materials, which reduce maintenance requirements. When the sprockets and bearings do require service, the units may be lifted out of the channel or, more simply, pivoted in place out of the channel. Multiple rake screens require less headroom than single rake screens because rakes are mounted onto chains, and hence, do not need to be lifted above the unit. With no reciprocating parts, multiple rake units are easily covered to contain odours. Multiple rake screens are illustrated in Figure 2-1.

Figure 2-1 Multiple Rake Bar Screens

The installation angle of the multiple rake bar screen is generally maintained between 70° and 75° to allow larger screenings to be conveyed up to the top of the screen. The captured screenings are transferred to a washer/compactor where the screenings are washed, dewatered and compacted to about 35% dry solids before final disposal to a landfill. The advantages and disadvantages of multiple rake screens are summarized in Table 2-1.

Table 2-1 Advantages and Disadvantages of Multiple Rake Bar Screens

Advantages	Disadvantages
Robust construction, proven reliable operation	Low screening capture rate about 40% compared to perforated plate
Simple design with few moving parts	In some design rakes can jam if a large or heavy object obstructs the channel
All moving parts can be serviced from the operating floor	Bottom sprockets require occasional inspection and maintenance (channel entry)

Advantages	Disadvantages
Efficiently retains captured screenings by minimizing carryover	Possibility of bottom jamming by unusual deposit of trash
Cleaning cycle can be adjusted based on water differential in the channel	Chain-driven mechanism consisting of submerged sprockets or other mechanical devices is subject to fouling by grit and rags
Low head room	Channel dewatering required for maintenance
Low head loss across the screen	

2.1.1.2 Perforated Plate Screen

Perforated plate type screens consist of a series of joined perforated plates mounted on chains at each end of the plate. The plates are pulled through the influent wastewater, collecting debris on the surface and lifting it out of the waste stream. Debris is removed from the plate by a brush a water spray, or both. A mechanical scraper cleans the brush, however additional periodic cleaning by plant staff is also required. Curved plates are recommended because they incorporate tines at set intervals between plates to lift large debris from the wastewater. Perforated plate screens are illustrated in Figure 2-2. As discussed in Section 2.1.1.1 captured screenings also require passage through a washer/compactor prior to landfill disposal. The advantages and disadvantages of perforated plate screens are summarized in Table 2-2.

Figure 2-2 Perforated Plate Screen

Table 2-2 Advantages and Disadvantages of Perforated Plate Screens

Advantages	Disadvantages
Higher capture rate about 80%, more solids removed	Higher headloss through the screens
Provides greater degree of protection for downstream equipment.	More complex system when compared to the traditional bar screen
Reduced maintenance of downstream equipment	More solids to handle at the screening's facility, and removal of more fecal and other organic
Improved performance, and potential for lower maintenance costs	If grease is an issue, the cleaning system will require hot water spray to remove grease and
Lower overhead clearance	Long screen result in several heavy plates that cause more wear on the chain
	Plugging that could lead to screen failure

	Perforated plates not as resilient as bars and are more susceptible to damage from large objects in wastewater flow
	Screen's blinding factor is higher than the reciprocating rake and chain-driven screens

2.1.1.3 Step Screen

Step screens consist of a stainless steel escalator that sits in the flow of the wastewater. One design approach incorporates perforations in the escalator that are typically 6 millimetres diameter or less. Once sufficient debris has collected on the face of the escalator, the screen revolves taking the blocked area to the top of the unit, where it is cleaned. This is accomplished by brushes and spray bars. In another design approach, a system of parallel stainless steel plates are assembled and cut in the shape of a staircase as viewed from the side. Alternate plates are connected to a rotating cam with the result that debris collected on the face of the step screen is eventually lifted out of the wastewater and over the top of the screening assembly to drop onto a conveyor. A step screen is illustrated in Figure 2-3. The advantages and disadvantages of step screens are summarized in Table 2-3.

Figure 2-3 Step Screen

Table 2-3 Advantages and Disadvantages of Step Screens

Advantages	Disadvantages
Simple cleaning method without any aids	Lower screening capture rate
Easy servicing	More complex system when compared to the traditional bar screen
Highest hydraulic capacity	If grease is an issue, the cleaning system will require hot water spray to remove grease and
	Accumulation of screenings on the bottom steps due to screenings roll back
	Regular maintenance of the chain and sprocket is required
	Poor performance in wastewater application that contains heavy grit or gravel loads
	A screening carpet must be formed on the surface of the screen to increase capture rate

2.1.1.4 Spiral Screen

Figure 2-4 Spiral Screen

Spiral screens are typically used to provide adequate screening for small WWTPs, with 6 millimetre diameter openings. Spiral screens are compact units and fully enclosed to contain vapours. The screen is mounted on an open channel. During operation, wastewater flows into the open end of the inclined screen basket where solids are captured, as presented in Figure 2-4. Screenings retained by the basket are used to create a filter mat. The basket starts to rotate when a certain upstream water level is exceeded due to screen surface blinding. The spiral screen moves the retained solids upward along the cylindrical transportation tube to the dewatering and compaction zone. Utility water (chlorinated final effluent) applied at this point washes accumulated filtrate and loose solids back to the influent side of the screen. The dewatered and compacted solids are then discharged to the screenings bagging system for disposal. The advantages and disadvantages of step screens are summarized in Table 2-4.

Table 2-4 Advantages and Disadvantages of Spiral Screens

Advantages	Disadvantages
Moderate capture rate about 60%	Moderate headloss through the screens
Provides a moderate degree of protection for downstream equipment.	More solids to handle at the screening's facility, and removal of more fecal and other organic
Reduced maintenance of downstream equipment	If grease is an issue, the cleaning system will require hot water spray to remove grease and solids
Improved performance, and potential for lower maintenance costs	Plugging that could lead to screen failure
Does not required separate washer/compactor	
Lower overhead clearance	
Unit motor provides double function, screening and dewatering	
Screen can be tilted out of channel for maintenance	

2.1.1.5 Screenings Handling

Pressing or compacting of the screenings can reduce the volume of material for disposal. Compactors typically utilize an inclined screw that compresses the screenings against a perforated drum.

Screenings can be directly discharged from the screen into a compactor. To minimize the odour and the nuisance potential of the compacted screenings the compactor unit can be fitted with a washer system. The washer unit sprays the screenings with wash water and removes a large portion of the organic matter, which is then returned to the wastewater stream.

Compacted screenings can be bagged for final disposal. Bagging of the screenings greatly reduces the odour. There are several systems available for bagging of screenings. For example, one system generates sausages of screenings that are produced with a continuous bag. A typical screenings washer and compactor unit is illustrated in Figure 2-5.

Figure 2-5 Screenings Washer and Compactor

2.1.1.6 Recommended Screening Option

Based on the review of the four alternative screening technologies presented in this section, their relative advantages and disadvantages, and our experience with similar systems in Canada, a spiral screen is recommended. Our recommendation is based on the following rationale:

- Significant track record in Western Canada for a wide range of WWTP sizes
- Automatic screens provide easier maintenance and have no wetted parts below the water surface
- These screens are less prone to plugging and jamming and can easily handle small to large debris
- The design of the screen is very robust which provides long-term performance and relatively low operating effort
- Relatively high capture rate at approximately 60%
- Relatively low headloss
- Similar capital cost to other technologies
- Several major manufacturers leading to competitive pricing

2.1.2 Grit Removal

Grit removal of heavier particles such as sand and gravel present in wastewater is critical to the protection of wastewater treatment equipment. The primary purpose of grit removal is to reduce abrasion and wear of downstream mechanical equipment, minimize deposition in pipelines and channels, and prevent grit from occupying valuable space in digesters, aeration basins and other process units. Grit removal is particularly critical for protection of dewatering centrifuges and high-pressure progressing cavity pumps. Grit is typically defined as particles larger than 0.2 mm (65 mesh) and with a specific gravity greater than 2.65. While there are several mainstream grit removal technologies available, the two alternatives considered for the Humboldt WWTP Upgrade project are: mechanically induced vortex grit removal and multi-tray vortex grit removal.

2.1.2.1 Mechanically Induced Vortex Grit Removal

This vortex grit removal system relies on a mechanically induced vortex to capture grit solids in the center hopper of a circular tank. The vortex forces are created by incoming tangential flow into a circular and conical upper chamber. Flow travels 270-degrees around the upper chamber before exiting while the grit is separated to the bottom of the grit collecting well. Partially submerged rotating paddles maintain a constant velocity in the chamber to achieve maximum efficiency. Grit pumps or airlift pumps can be provided to automate the process of grit removal. Flushing water or air is used to fluidize the settled grit prior to pumping for ease of removal. Grit pumped from the vortex grit chamber can be dewatered in a grit dewatering screw. The dewatered grit can then be transported to grit storage containers by screw conveyors.

Figure 2-6 Screen and Compactor

These systems are simple to cover to minimize odour emissions and can achieve greater removal efficiencies with a smaller footprint than conventional aerated grit chambers. For these reasons, they are less costly and have been used at increasing frequencies at larger wastewater plants. These systems are generally less efficient than multi-tray vortex systems at removing particles smaller than 200 microns but are comparable for particles larger than 200 microns. An example of a mechanically induced vortex grit removal system is illustrated in Figure 2-6. The advantages and disadvantages of mechanically induced vortex grit removal are summarized in Table 2-5.

Table 2-5 Advantages and Disadvantages of Mechanically Induced Vortex Grit Removal

Advantages	Disadvantages
Effective over a wide flow variation	Proprietary design
Simple design with no submerged bearings or parts	Paddles may collect rags
Minimal footprint	Grit sump may become compacted and clog; requires high pressure agitation water or air
Low headloss	Lower removal efficiency of grit particles less than 150 microns
Energy efficient	During inspection the flow will have to bypass the grit removal system

2.1.2.2 Multi-Tray Vortex Grit Removal

The multi-tray vortex grit removal system consists of a series of trays each receiving an equal share of the total flow. The unit is designed with a high inlet velocity so that a vortex is developed on each tray. This vortex flow combined with a steeply angled tray bottom results in the grit slurry efficiently flowing to the underflow outlet. By stacking trays, there is a significant increase in surface area which promotes grit settling. This increase in surface area increases the capacity of the unit and decreases the settling distance of the particles.

The settled grit is then sent to the center underflow collection chamber and removed by pumping, while the effluent flows out through the side of the trays to primary treatment. These hydraulically induced units rely solely on hydraulic energy and have no internal moving parts. As a result, they consume no additional power but introduce higher head losses than the traditional induced vortex grit systems. A multi-tray vortex grit removal system is illustrated in Figure 2-7. Multi- tray vortex units have been observed to work efficiently, achieving grit removal percentages around 95% of all the grit sized 100 microns. The advantages and disadvantages of multi-tray vortex are summarized in Table 2-6.

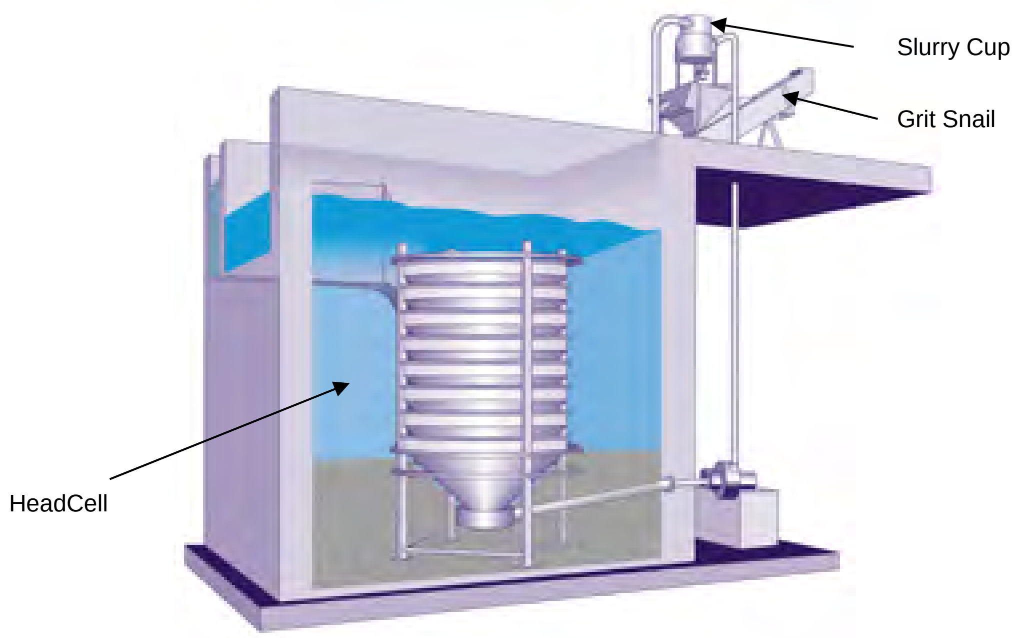

Figure 2-7 Multi-tray Grit Removal System

Table 2-6 Advantages and Disadvantages of Multi-tray Vortex Grit Removal

Advantages	Disadvantages
Effective grit removal over a wide flow variation	Proprietary design
No submerged bearings or parts	Higher capital cost
Minimal footprint	Higher headloss
Energy efficient	Difficult to access trays for cleaning
	For a small plant, it requires high flushing water flow

2.1.3 Grit Collection

Grit slurry removed from the grit removal system is typically washed using a hydrocyclone and compacted using a decanter. The hydrocyclone is used to separate organic material from the grit slurry. This is accomplished by pumping grit slurry into the hydrocyclone tangentially. The grit slurry flow then spirals inward and accelerates to the middle where it separates, and water exits through the discharge orifice. Centrifugal force captures the desired grit size at the specified flow while the organic solids are carried through with the water flow. The grit is then discharged into the decanter, which concentrates the grit even further and discharges it into a grit bin for disposal at the landfill.

2.1.4 Recommended Grit Removal Option

Based on the review of the two alternative grit removal technologies presented in this section, their relative advantages and disadvantages and our experience with similar systems in Canada, a mechanically induced vortex technology is recommended and is based on the following rationale:

- A self-priming pump can be used to pump grit from the bottom of the chamber, so no basement is required
- Significant track record in Western Canada for a wide range of WWTP sizes
- Efficient grit removal over a wide flow variation

2.2 INFLUENT FLOW EQUALIZATION

An in-line influent flow equalization basin is required for some secondary treatment options such as MBR or where the diurnal flow pattern has extensive periods of no flow. The equalization basin is required to dampen flow fluctuation due to the intermittent operation of the raw wastewater pumps in the pumping stations. Pumping stations are designed to handle peak flows in a manner that minimizes the possibility of basement flooding in wet weather events. Thus, raw sewage pumps in the three main stations would combine to provide a peak hourly flow of 282 L/s or 24,300 m^3/d. During low flows (~18 L/s) most of the pumps would shut down and the secondary treatment process would be underutilized. This would cause an increase in dissolved oxygen in the bioreactors and subsequently blowers would shut down. To minimize common alarms due to equipment shutdown during common low flows (i.e. early in the morning), an equalization tank would be proposed to store 885 m^3, which is equivalent to 20% of the average daily flow (ADF = 4100 m^3/d). The 20% volume is a typical equalization volume estimate for communities in Saskatchewan.

Equalization tanks are typically constructed adjacent to the bioreactor tanks and under the combined screen and grit removal unit. Stored flows would be pumped back to the secondary process tanks for treatment once the high-flow event is over.

2.3 PRIMARY TREATMENT

The principal form of primary treatment is primary sedimentation (clarification). The objectives of primary treatment are to produce a liquid effluent suitable for downstream biological treatment and achieve solids separation allowing convenient and economical treatment and disposal.

Primary treatment reduces suspended solids and biochemical oxygen demand (BOD) loading on downstream processes. Loading reductions minimize operational problems in downstream biological processes, lower the oxygen demand, decrease the rate of energy consumption for oxidation of particulate matter and reduce the waste activated sludge generation. Primary treatment also removes floating material and improves the plant's overall aesthetics.

2.3.1 Primary Sedimentation

Primary settling tanks (primary clarifiers) are designed to remove settleable suspended solids under quiescent conditions. Settled solids are removed from the bottom of the tank. Any scum and floatable solids are removed from the surface by a skimming device. Primary clarifiers (PC) can be rectangular or circular. The selection of the type of clarifier is governed by the size of the plant, local site conditions and economics.

For the WWTP, the primary clarifier could be designed as an activated primary clarifier, which incorporates both solids removal and fermentation in a single process to produce short chain volatile fatty acids (SCVFAs) for the biological phosphorus removal process. Depending on the wastewater temperature, a solids retention time of four to eight days results in optimum SCVFA production.

Projected primary effluent characteristics are summarized in Table 2-7.

Table 2-7 Projected Primary Effluent Characteristics

Parameter	Primary Influent (kg/d)	Primary Effluent (kg/d)	Primary Sludge (kg/d)	Removal Efficiency (%)
TSS	1,888	944	944	50
BOD_5	857	600	257	30
COD	937	600	257	30
TKN	221	200	21	10
TP	32.7	31	1.7	5

2.3.2 Primary Treatment Recommendations

It is recommended to exclude primary treatment for the new WWTP. The major advantage of this would be that the City would have to treat/dispose of only one type of sludge (secondary sludge).

2.4 SECONDARY TREATMENT

A list of secondary liquid and solids treatment options is presented in this section. Each treatment option was screened using a pass-fail ranking, based on its suitability for application at the WWTP as determined from the must meet criteria.

2.4.1 Biological Treatment

Biological treatment is directed toward removal of biodegradable organics and nutrients (colloidal and dissolved) and suspended solids. Biological treatment is achieved by growing a community of microorganisms in a bioreactor which utilize dissolved and colloidal matter as a food source to produce various end products and new cell tissue. Because cell tissue has a specific gravity slightly greater than that of water, the resulting cells can be removed from the treated liquid by gravity settling in the secondary clarifiers.

There are three main types of biological treatment defined by how the microorganisms are grown: suspended growth, attached growth and hybrid. In suspended growth systems, the microorganisms are held in suspension, usually by mixing. In attached growth systems, the microorganisms grow on a fixed media. Hybrid systems employ both suspended and attached growth components.

2.4.1.1 Suspended Growth Systems

Suspended growth processes with nitrification/denitrification require one aerobic and one anoxic zone. In the aerobic zone, microorganisms (activated sludge) consume the BOD and convert ammonia to nitrates (nitrification). Following the aerobic zone, secondary clarifiers are used to separate solids from the treated effluent. The activated sludge is returned to the nitrification cells to seed the process. The biological sludge concentrations, referred to as mixed liquor suspended solids (MLSS) would range from 3,000 to 4,000 mg/L and the solids retention time (SRT) would range from 10 to 20 days.

In suspended growth activated sludge treatment systems, a portion of the settled biomass is returned from the secondary clarifiers to the nitrification cells to maintain the microorganism concentration at an optimum level. That portion is called Return Activated Sludge (RAS). Excess microorganisms are removed from the treatment system as Waste Activated Sludge (WAS). Sludge can be wasted from mixed liquor or from RAS. The quantity of solids within the system divided by the quantity of wasted solids per day is defined as the Solids Retention Time (SRT). Thus, control of the SRT is governed by the daily wastage rate.

The contents of the bioreactor, referred to as Mixed Liquor (ML), consist of wastewater, microorganisms, and suspended and colloidal matter. The particulate fraction of the ML is referred to as Mixed Liquor Suspended Solids (MLSS).

Suspended growth systems typically operate in a continuous flow mode, but can also be operated as a batch process, such as sequencing batch reactor (SBR).

2.4.1.2 Attached Growth Systems

There are two basic types of attached growth systems – trickling filters (TF), and rotating biological contactors (RBC).

In this system, biomass attaches to a support media. Attached biomass periodically sloughs off from the support media and is settled in the secondary clarifiers. There is no return of the settled biomass from the clarifier to TF or RBC.

2.4.1.3 Hybrid Process

The Integrated Fixed Film Activated Sludge (IFAS) is a hybrid process that use both attached and suspended growth. The attached biomass periodically sloughs off from the support media and is settled in secondary clarifiers. Settled biomass from the clarifier is returned to the bioreactor.

One type of IFAS system utilizes a moving bed biofilm reactor (MBBR) which is based on mobile biomass carriers that support a high concentration of attached biomass. The biofilm carriers (or packing material) are frequently made from buoyant high density polyethylene (HDPE) media that have a very high surface to volume ratio in the range of 400 to 500 m^2/m^3. In the MBBR, packing material is placed in the reactor in suspension with the activated sludge to support biofilm growth. Mechanical mixing circulates the packing material in the system to avoid accumulation at the reactor outlet. The packing material is retained in the reactor by an effluent screen. In large systems the packing material is placed within cages to avoid the use of additional mixing equipment. Several packing materials have been developed for attached growth processes, including Captor, Linpor, Kaldnes and Hydroxyl-Pac media.

2.4.1.4 Basic Requirements for Nutrient Removal

Both attached and suspended growth systems can achieve excellent removal of organic matter. However, if biological removal of nutrients (nitrogen and phosphorus) is required, specific environmental conditions need to be provided for the microorganisms, as described below. In general, high efficiency of biological nutrient removal can only be achieved in a suspended growth system.

Nitrogen

Removal of nitrogen is a two-step process. In the first step, known as nitrification, ammonia is oxidized by nitrifying bacteria to nitrite and eventually to nitrate. This step requires oxygen and is carried out in an aerobic cell (presence of molecular oxygen) of the bioreactor. Nitrate is then converted to nitrogen gas in an anoxic zone of the bioreactor (no molecular oxygen; oxygen present in combined form, such as nitrate). This step is known as denitrification.

Phosphorus

Biological phosphorus removal is achieved by exposing the microorganisms to anaerobic and aerobic conditions. Two main conditions need to be satisfied for successful biological phosphorus removal: presence of an anaerobic zone in the bioreactor (no molecular or combined oxygen), and presence of VFAs in the anaerobic zone.

Alternatively, phosphorus can be removed by chemical precipitation.

2.4.2 Secondary Solids Separation

The separation of biomass from the liquid stream is vital in the operation and performance of the treatment systems. Secondary clarification is typically achieved using either clarifiers, dissolved air floatation, filter or membranes.

2.4.2.1 Secondary Clarifiers

Separation clarifiers are used to separate solids from the liquid by means of gravity settling of the biomass. Settling not only separates biomass but also thickens the settled sludge before it is returned to the bioreactor or wasted.

Secondary clarifiers vary in shape, depth and geometric detail. Circular clarifiers are most commonly used. Sludge settled at the bottom of the clarifier is collected by a rotating suction arm or a scraper mechanism. Sludge is then pumped by a variable frequency drive pump. Each clarifier has a dedicated pump. A standby pump is also provided. Most of the collected sludge is returned to the bioreactor as activated sludge which is ready to begin degrading the nutrients in the incoming wastewater. Two variable frequency drive pumps are provided for wasting of the secondary sludge. Alternatively, secondary sludge can be wasted directly from the bioreactor, as described in the previous section.

Each rotating secondary clarifier sludge mechanism is equipped with a surface skimmer arm. This arm collects scum from the surface of the clarifier. Scum is pumped for processing together with waste sludge, or it can be landfilled.

2.4.2.2 Dissolved Air Floatation

Dissolved air floatation (DAF) are used to remove solids from the secondary processes that use attached growth system when the TSS out of the bioreactors is greater than 200 mg/L. In the DAF process, air is introduced to the bioreactor effluent at a pressure in excess of atmospheric pressure. When the pressure is reduced to atmospheric pressure and turbulence is created, air in excess of that required for saturation leaves the solution as fine bubbles. These bubbles attach to the solids particles and raise them to the liquid surface. The floating solids are then collected by a skimmer and discharged into a trough. Typically, DAF requires addition of polymer to ensure high solids removal and high thickened solids concentration.

2.4.2.3 Filters

Filters are used to remove solids from the secondary processes that use attached growth system when the TSS out of bioreactors is less than 200 mg/L. Cloth media or membrane disk filtration are the preferred technology and are widely used in North America. Disc filters provide a large filtering area in a small footprint.

2.4.3 Identification of Liquid Treatment Options

There are several treatment alternatives that can be used to meet the effluent criteria required by the Water Security Agency (WSA). Table 2-8 presents a list of potential technologies, categorized according to how the microorganisms grow. The treatment technologies listed are ones that are consistent with the expected wastewater flows, and effluent quality requirements for discharge to Humboldt Lake, which are suitable for carbon ammonia and phosphorus removal and total nitrogen removal.

It is also considered that sludge generated by the liquid treatment process will be directed to the existing lagoons. Sludge storage in the lagoons would be stabilized over summer and removed periodically.

Table 2-8 Potential Liquid Treatment Processes

Category	Liquid Treatment Technology
In-pipe bioaugmentation	In-Pipe Technology
Suspended growth in earthen Basins	Biolac® process with Chemical Precipitation
Attached growth in earthen basins	Submerged Aerated Growth Reactor (SAGR) with Chemical Precipitation Bio2bloc and Chemical Precipitation
Attached growth in concrete tanks between earthen basins	LagoonGuard® Moving Bed Biofilm Reactor (MBBR) with Chemical Precipitation

Suspended growth in concrete tanks	Activated Sludge with Nitrification with Chemical Precipitation Biological Nutrient Removal (BNR) Oxidation Ditch Sequencing Batch Reactor (SBR) with Chemical Precipitation Continuous inflow and continuous decant SBR with Chemical Precipitation Modified Sequencing Batch Reactor (MSBR) Granular Sequencing Batch Reactor (GSBR) Membrane Bioreactors (MBR) with Chemical Precipitation Membrane Bioreactors (MBR) as BNR
Attached growth in concrete tanks	Biological Aerated Filters (BAFs) with Chemical Precipitation Rotating Biological Contactor (RBC), with Chemical Precipitation Moving Bed Biofilm Reactor (MBBR), DAF with Chemical Precipitation
Integrated Fixed Film Activated Sludge (IFAS) in concrete tanks	IFAS with Chemical Precipitation (Bio-wheel™)
Non-biological process	Electro-coagulation / Electro-flocculation

2.4.3.1 In-Pipe Bioaugmentation

In-pipe bioaugmentation consists of dosing either enzymes or microorganisms at multiple points of the sewer collection system. The addition of enzymes or microorganisms assists with the treatment process reducing the size of bioreactors or improving effluent quality. The in-pipe bioaugmentation process is marketed by In-pipe Technology. This process has not been used in cold climates.

2.4.3.2 Biolac Process with Chemical Precipitation

The Biolac treatment process for lagoon retrofit is marketed by Parkson Corporation in the US and Canada. Essentially, the Biolac process is similar to the suspended growth process but with extended aeration detention times. Aeration controls are designed to simulate multiple aerobic and anoxic zones in series. A floating lateral aeration system provides oxygen for carbonaceous BOD removal and nitrification and partial denitrification in each zone respectively. No fixed-film growth media are designed in the Biolac treatment process. A process schematic of the Biolac process is illustrated in Figure 2-8.

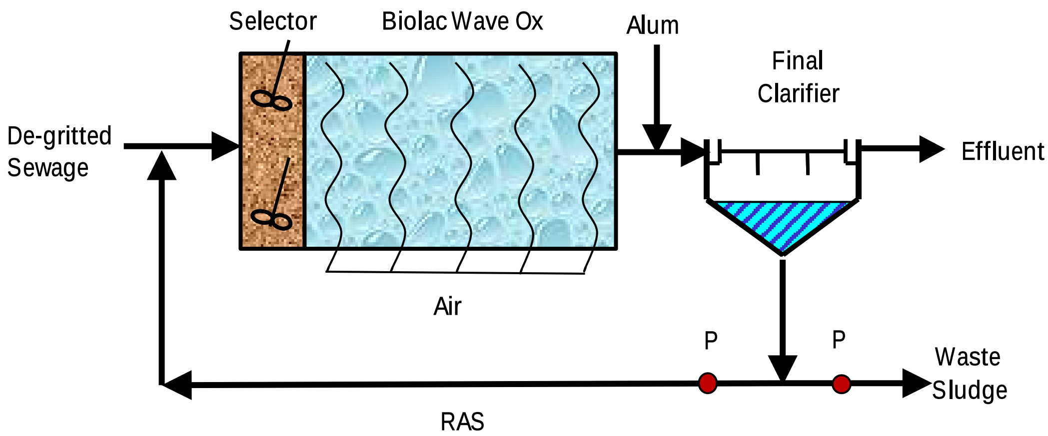

Figure 2-8 Process Schematic of Biolac System with Chemical Precipitation

The process characteristics are summarized as follows:

- The Biolac process includes the installation of floating lateral aeration chains and dissolved oxygen (DO control to alternate multiple stages of aerobic and anoxic conditions (Wave Oxidation Modification scheme). Carbonaceous BOD removal and nitrification and partial denitrification can be achieved in a sequence of alternating aerobic and anoxic zones.
- High MLSS concentrations and SRT is maintained to achieve nitrification. The MLSS concentrations are typically between 2,000 - 3,000 mg/L, and the SRT is between 40 - 70 days. Low sludge yield is expected due to long SRT in the lagoon system.
- Final clarifiers with covers are required to remove solids from the lagoon effluent, and the settled solids (return activated sludge, RAS) are recycled from the clarifiers to the inlet to the basin to mix with the primary effluent.
- Chemical precipitation could be applied as tertiary treatment or with alum addition to the effluent from the basin to meet the effluent phosphorus criteria.
- UV disinfection system would be required for continuous discharge.
- The largest installation in Canada is located at the Moose Jaw, Saskatchewan WWTP, with a design capacity of 24 ML/d, TN removal achieved by this plant is well above 16 mg/L.

2.4.3.3 SAGR with Chemical Precipitation

The Submerged Aerated Growth Reactor (SAGR) treatment process for lagoon retrofit is provided by Nexom in Canada. The process is designed to carry out carbonaceous BOD removal with suspended growth activated sludge, followed by chemical precipitation of phosphorus and fixed-film growth media for nitrification with or without internal solids recycle. The SAGR process provides an alternative for lagoon upgrades, which consists of an aerated gravel media bed for the nitrifying biomass growth, and a linear diffuser aeration system for air supply and mixing. A process schematic for the SAGR process is shown in Figure 2-9, and some process significances are summarized following the figure.

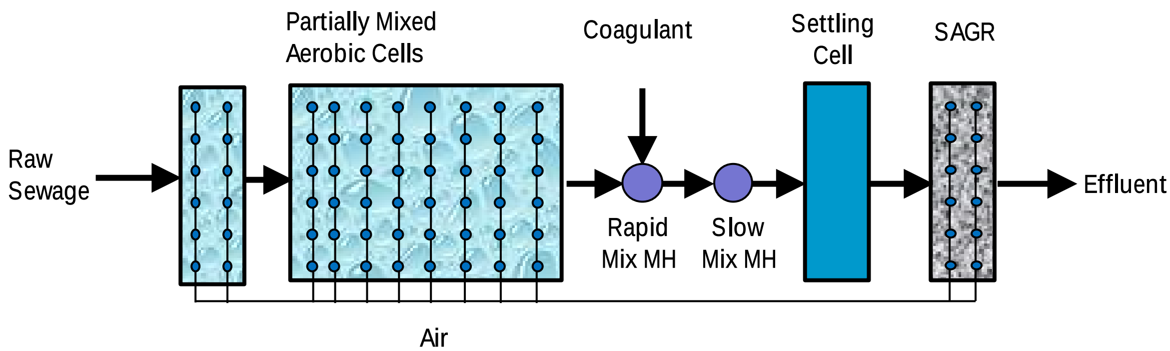

Figure 2-9 Process schematic of the SAGR with Chemical Precipitation

- Preliminary treatment using screen and vortex grit removal units is not required.
- Extended aeration lagoons are required for reduction of BOD and TSS.
- Aeration laterals provide oxygen for nitrification and to prevent clogging of the gravel media bed.
- A thick layer of mulch over the gravel bed provides insulation and heat retention.
- Chemical precipitation by addition of coagulant and settling cells is required for phosphorus reduction.
- UV disinfection system is not required for continuous discharge since the SGAR provides unfavorable conditions for survival of fecal coliforms.
- Several full-scale installations in Canada reported that nitrification could be achieved at cold temperatures as low as 0.5ºC.

2.4.3.4 Bio²Bloc with Chemical Precipitation

The Bio²Bloc treatment process is marketed by FBC Technologies and Hydro-Logic Environmental in the US and Canada, respectively. The Bio²Bloc is a modular product filled with bio-media and equipped with a fine bubble/coarse bubble aeration system, which can be used as add-on fixed-film treatment units in the aerobic wastewater earthen basin. With sufficient nitrifier microorganisms grown in the fixed-film biomass, it is claimed that nitrification can be achieved even at cold temperatures as low as 1ºC. A process schematic for lagoon retrofit using Bio²Bloc is illustrated in Figure 2-10, and some process significances are summarized as follows:

- The fixed-film growth of nitrifiers maintained in the Bio²Bloc modules can be optimized with low BOD/ammonia ratio in the wastewater.
- Each Bio²Bloc module is filled with thousands of pieces of plastic media for the fixed-film biomass growth. During normal operation, biomass is formed by a supply of air by the fine bubble membrane diffusers located on the bottom of each module for the autotrophic nitrifier growth.
- As with any fixed-film biological contactor, the units will tend to become overgrown with organisms after a period of time. The Bio²Bloc has a separate coarse bubble flush system to slough the media bed and clear the chamber for renewed growth.
- Chemical precipitation by addition of coagulant and settling cells are required for phosphorus reduction.
- UV disinfection system would be required for continuous discharge.
- Full-scale installations in US reported that nitrification could be achieved at cold temperatures as low as 4ºC.

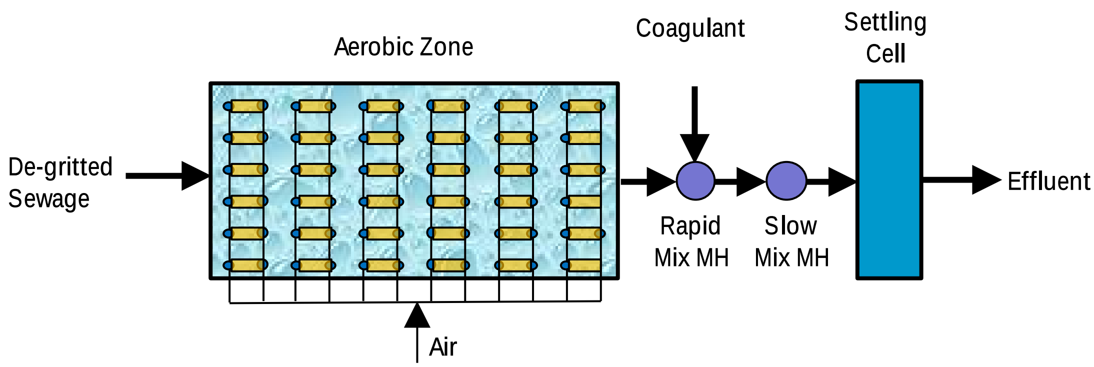

Figure 2-10 Process Schematic of Bio²Bloc with Chemical Precipitation

2.4.3.5 LagoonGuard® MBBR with Chemical Precipitation

The LagoonGuard® process for lagoon retrofits is provided by Veolia in Canada. The process is designed to carry out carbonaceous BOD removal in the existing facultative lagoons, followed by moving bed biofilm reactor (MBBR) process for nitrification in sequence, without internal solids recycle at low temperature as low as 5°C for extended periods of operation during winter months. The MBBR process provides an alternative for lagoon upgrade, which consists of the media carrier elements for the nitrifying biomass growth, and fine bubble diffuser aeration system for air supply and mixing. The MBBR is based on mobile biomass carriers that support a high concentration of attached biomass. The carriers are made from buoyant HDPE media that have a very high surface to volume ratio in the range of 400 to 500 m^2/m^3. In the moving bed, packing material is placed in the reactor in suspension with the activated sludge to support biofilm growth. Mechanical mixing circulates the packing material in the system to avoid packing accumulation at the reactor effluent. The packing material is retained in the reactor by an effluent screen. Sloughed solids from the media are settled out in the storage lagoons. Multiple tanks can be set up to provide aerobic and anoxic zones for total nitrogen removal. A process schematic for an MBBR retrofit is shown in Figure 2-11, and some process significances are summarized as follows:

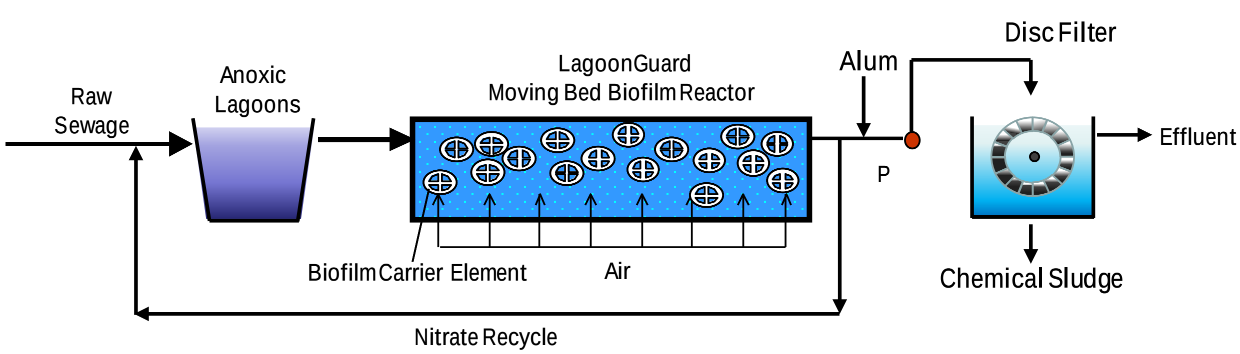

Figure 2-11 Process Schematic of the MBBR with Chemical Precipitation for Lagoon Retrofit

- The MBBR system would be implemented adjacent to the front-end lagoons (anoxic lagoons).
- A fraction of the nitrate rich treated effluent from the MBBR would be recycle back to the front-end cells to minimize odour generation from the anaerobic lagoons.
- The pretreated wastewater from the anoxic lagoons is conveyed by gravity to the MBBR.

- The MBBR reactors could be configurated with multiple tanks in series to provide BOD removal in the first cell and ammonia removal in the second cell.
- The MBBR concrete tanks that house the carrier elements and medium coarse bubble aeration system will be buried to match the hydraulic profile of the facultative lagoons and the storage lagoons.
- A disc filter is required for phosphorus reduction with alum addition.
- Full-scale installations in Quebec are reported under construction to achieve nitrification at temperatures as low as 5ºC. Full scale installations in Western Canada are currently under construction.

2.4.3.6 Activated Sludge (AS) with Nitrification and Chemical Precipitation

The activated sludge process with nitrification/denitrification is a biological nitrogen removal process, which utilizes anoxic and aerobic zones to achieve nitrogen reduction. In the activated sludge (AS) treatment process, de-gritted sewage is aerated in the presence of a mixed population of activated microorganisms (activated sludge). The activated sludge organisms utilize organics in wastewater as a food source and convert them to biomass, carbon dioxide and water. Compressed air is applied to the bioreactor to maintain the microorganisms in an aerobic condition. The activated sludge is settled out in the final clarifiers. Figure 2-12 shows a schematic of the most common AS process, the Modified Ludzack-Ettinger (MLE) process.

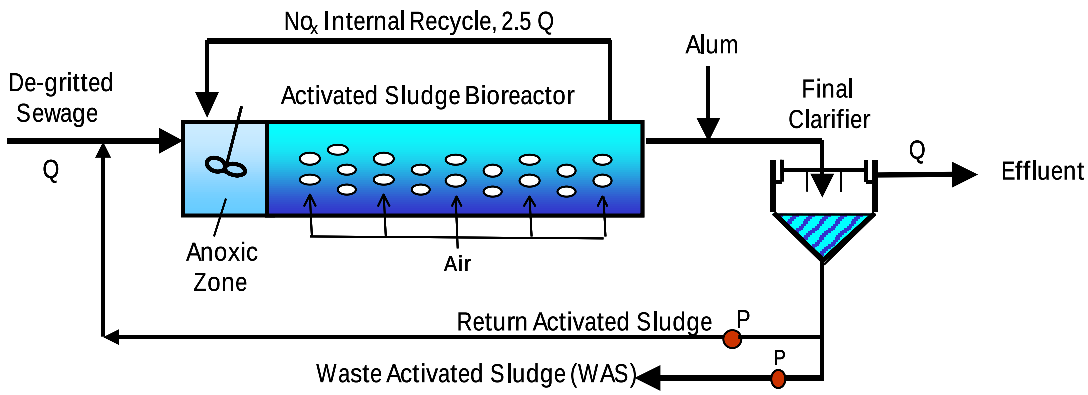

Figure 2-12 Process Schematic of the Activated Sludge Process with Nitrification and Chemical Precipitation (Modified Ludzack Ettinger Process)

A portion of the activated sludge is wasted, thickened and applied to sludge stabilization and the remainder is recycled as return activated sludge (RAS) to the bioreactor to seed the process. This process operates at a MLSS concentration (2,500 - 3,500 mg/L) and SRT (8-15 days) to sustain the growth of nitrifying bacteria which convert ammonia into nitrate. Under anoxic conditions (no oxygen) some facultative bacteria convert nitrates to elemental nitrogen gas using organics in the wastewater as a carbon source. To ensure significant nitrogen removal, a pre-anoxic zone would have to be added as well as an internal recycle of nitrified mixed liquor (NML) so that the BOD in the influent could maintain denitrification. The MLE process has frequently been designed and operated in many cold weather applications, including the North Battleford Saskatchewan WWTP.

For phosphorus removal, chemical (e.g. alum) is added to the bioreactor effluent prior to the final clarifier. The precipitates are settled out along with the solids in the final clarifier (co-precipitation).

2.4.3.7 Biological Nutrient Removal (BNR)

Biological nutrient removal (BNR), both nitrogen and phosphorus, can be achieved in a series of bioreactors with anoxic, anaerobic, and aerobic zones. In a BNR process, an aerobic zone is provided for carbonaceous BOD removal, nitrification and phosphorus uptake by microorganisms that concentrate phosphorus in their cells. The anoxic zones are used for denitrification of return activated sludge and nitrates recycled from the aerobic zone. In the anaerobic zone, acetate or volatile fatty acids in the wastewater, or through fermentation of primary clarifier sludge, enhances the growth of phosphorus accumulating organism microorganisms (Bio-P organisms). For bio-P organisms to reach a significant population, nitrates must be excluded from the anaerobic zone. In the sequential anoxic or aerobic zones, the bio-P microorganisms will utilize the energy stored during the anaerobic phase to complete phosphorus removal.

There are many different BNR process configurations for both nitrogen and phosphorus removals, including Bardenpho (4-stage), modified Bardenpho (5-stage), University of Cape City (UCT), modified UCT, and modified Johannesburg (MJ) process. A process schematic of the MJ process is illustrated in Figure 2-13.

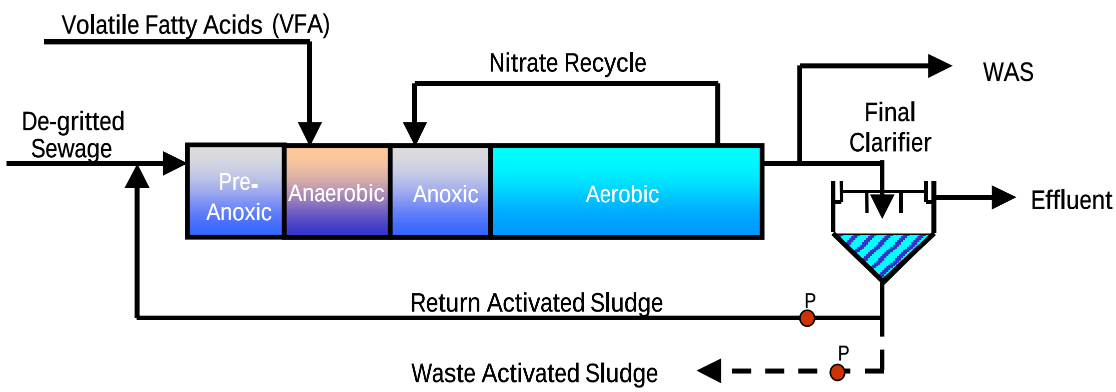

Figure 2-13 Process Schematic of the Modified Johannesburg BNR Process

Many of those configurations are designed to limit nitrate addition to the anaerobic zone. The MJ process has frequently been designed and operated in many cold weather applications, including the Regina and Swift Current WWTPs in Saskatchewan. The pre-anoxic zone ensures that nitrates in the return sludge are denitrified prior to the anaerobic zone.

A source of simple carbon compounds such as volatile fatty acids (VFA) is essential for biological phosphorus removal. This is usually provided by fermenting primary sludge. The fermentate is added directly to the anaerobic zone in the ratio of four parts VFA to one-part total phosphorus.

In the BNR process, phosphorus is removed with the waste sludge while nitrogen is removed as elemental nitrogen gas.

2.4.3.8 Sequencing Batch Reactor (SBR) with Chemical Precipitation

The sequencing batch reactor is a fill-and-draw activated-sludge treatment system carried out in a single tank, which serves as both a bioreactor and a settling tank. A process schematic of the operation cycle is illustrated in Figure 2-14.

Mixed liquor remains in the reactors during all cycles. The operation processes are carried out sequentially in the same tank and usually four or five steps are involved:

1. Fill – de-gritted sewage enters the bioreactor.
2. React – de-gritted sewage is mixed with activated sludge and aerated. Alum is injected at the end of the react phase to precipitate phosphorus.
3. Settle – mixed liquor is allowed to settle, thus separating solids.
4. Decant – treated clarified effluent is removed.
5. Idle (optional) – an idle period is provided for a multi-tank system (usually operated in parallel) to achieve continuous flow operation.

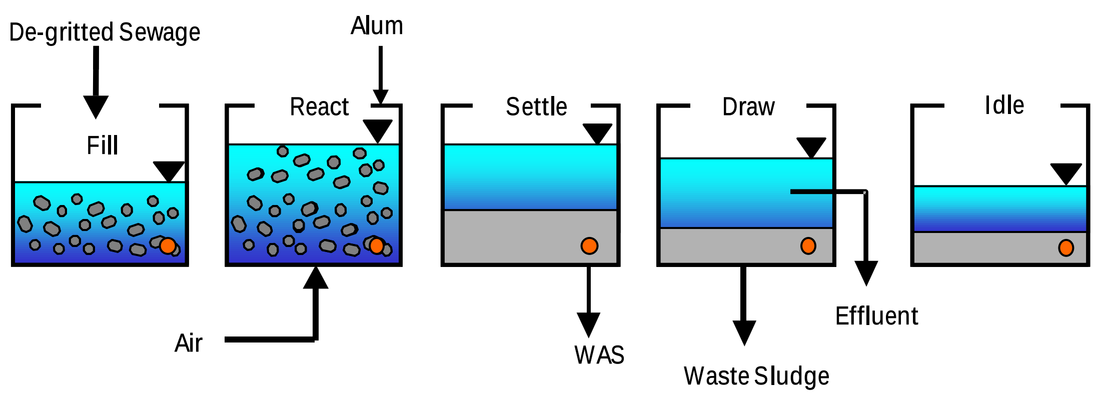

Figure 2-14 Process Schematic of Sequencing Batch Reactor (SBR) with Chemical Precipitation

Sludge can be wasted in the react phase or the decant phase. There is no return activated sludge, thus no separate secondary clarifier is needed.

The react phase can consist of an aerated period for BOD removal and nitrification to occur and a non-aerated period (with mixers retaining MLSS in suspension) for denitrification to occur.

SBRs can be configured to operate as intermittent flow variable level, intermittent flow constant level, continuous flow variable level, or continuous flow constant level systems. They can be constructed in concrete tanks. For SBRs to achieve nitrogen removal, they would be designed with a hydraulic retention time of 16 to 24 hours.

Several variations of the SBR are available which includes the following variations:

- Continuous inflow and intermittent decant.
- Intermittent or batch inflow and intermittent decant (also referred to as the true batch system).
- Continuous inflow and continuous decant (also referred to as the modified SBR or MSBR).

2.4.3.9 Continuous Inflow and Intermittent Decant SBR with Chemical Precipitation

In this process, the SBR receives continuous inflow of screened and de-gritted wastewater into the reactor basins during all phases of the cycle. One cycle consists of a react, settle, and decant phase. During the react phase, raw wastewater flows into the selector continuously to react with the mixed liquor suspended solids. Depending on the process scheme, the basin contents are aerated or mixed under anoxic conditions. As the basin continues to fill, biological oxidation/reduction reactions take place simultaneously to treat the wastewater. During the settle phase, basin agitation from the react phase (i.e. aeration or mixing) is stopped to allow the solids to settle to the bottom of the basin. Raw wastewater continues to flow into the pre-react zone as the main-react zone settles. As the solids settle, a clear layer of water would remain on top of the basin. During the decant phase, the decanter rotates downward into the liquid to draw off the clarified supernatant and discharge it to the post equalization tank. Raw wastewater continues to flow into the selector as the main-react zone is decanted. Sludge is typically wasted from the basin during this phase in the cycle.

2.4.3.10 Modified Sequencing Batch Reactor (MSBR)

The Modified Sequencing Batch Reactor (MSBR) process is similar to the SBR process except that anoxic and aeration zones are added prior to a constant level continuous flow SBR. This process can only be implemented in concrete tanks. A process diagram is shown in Figure 2-15.

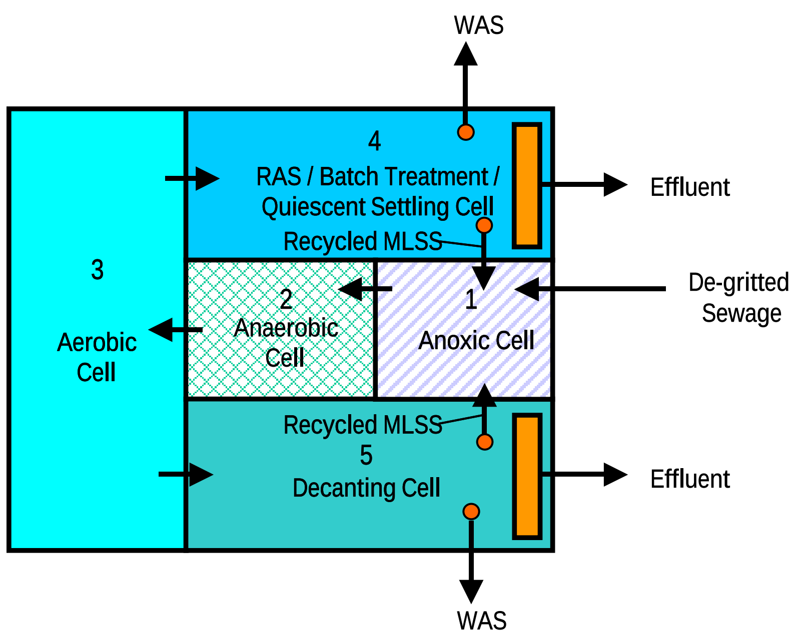

Figure 2-15 Process Schematic of Modified Sequencing Batch Reactor (MSBR)

The low dissolved oxygen level, high nitrate concentration, and carbon source in the screened wastewater provide the conditions for denitrification in the anoxic zone. De-gritted sewage is introduced to the anoxic Cell 1 along with nitrified effluent and return activated sludge from the final cells. The flow then passes to the anaerobic Cell 2 and then to the first aerobic cell, Cell 3. From this cell, the flow passes to either Cell 4 or Cell 5 which are also aerobic when operating in the react mode. Flow also passes to these cells while they operate in the settle mode and the decant mode during which final effluent is discharged. During the react mode, aerators are turned on in Cell 4 and BOD removal and nitrification occurs. After the react cycle in Cell 4 is complete, Cell 5 changes to the react mode and Cell 4 goes into the settle and decant mode. Alum could be added to the SBRs during the react cycle or tertiary chemical precipitation could be implemented. To improve biological phosphorus removal, VFA could be added to the anaerobic zone of the MSBR. The MSBR process has operated in cold weather at the WWTP in Estevan, Saskatchewan.

2.4.3.11 Granular SBR (GSBR)

The Granular SBR technology is based on granular biomass, is a special type of biofilm in which biomass grows in compact aggregates (granules with particle diameter ranging from 200 to 2000 µm) without any carrier material. Compared to flocculent biomass (particle diameter less than 200 µm), granular biomass presents several advantages that make it very attractive for wastewater treatment purposes. Granules are denser and have a stronger microbial structure than flocculent biomass. Thus, granular biomass settles five to ten times faster than flocculent biomass. Granular biomass also supports higher concentration of microorganisms (MLSS concentration of 8,000mg/L) as compared to flocculent biomass (MLSS of less than 4,000 mg/L). Therefore, SBRs using granular biomass are smaller than those using floc biomass.

From a microbiological point of view, granules consist of different layers where diverse microorganisms can be present as well as different reactions can take place. In conventional activated sludge processes with flocculent biomass, multiple tanks and recycling are required to perform the aerobic and anaerobic conversions. However, in granular biomass, anaerobic and aerobic reactions can occur at the same granule since each layer supports different conditions. For instance, in an aerobic system, the outer part of the granule, where oxygen is available, nitrifiers can grow, while in the inner part, denitrifiers, and phosphate accumulating organisms (PAOs) can develop themselves under anoxic and anaerobic conditions.

The granular biomass approach to wastewater treatment is a proprietary technology developed by Nereda Technology. This technology places granular biomass in an SBR which operates in three cycles as shown in Figure 2-16: draw/fill, react, and settling. In the draw/fill cycle, screened raw sewage is fed from the bottom of the reactor with a subsequent effluent withdrawal from the top. In the react cycle, the granules are kept in suspension by air introduced at the bottom of the tank and BOD, ammonia, nitrogen and phosphorus are removed simultaneously by the microorganism conglomerate of each granule. In the settling cycle, granules settle to the bottom of the tank and a fraction of the flocculent biomass is wasted from tank.

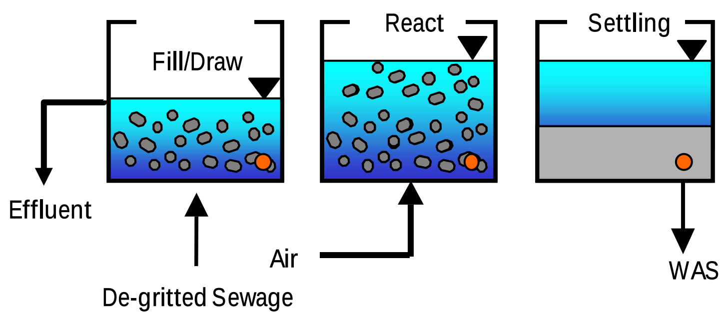

Figure 2-16 Process Schematic of the GSBR

The GSBR process shares the advantages of SBRs (i.e. no return activated sludge, and no separate secondary clarifiers) as well as the following advantages:

- Smaller tank size due to the rapid settling and high biomass concentrations characteristic to the process.
- Reduced energy consumption due to higher oxygen utilization rates and the absence of recycle pumps.

Disadvantages of GSBR include the following:

- Requires a larger equalization tank upstream of the SBR to store the screened raw sewage to feed during the short fill/draw cycle, slow startup to develop granular biomass (approximately 60 to 120 days).
- Requires careful control of operational conditions to favor the development of granular biomass over flocculent biomass (e.g. feed cycle, settling time, air bubble velocity). Once the granules are developed, control of the aeration rate and dissolved oxygen concentration is essential to maintain simultaneous nitrification and denitrification in a single tank.

2.4.3.12 Oxidation Ditch with Chemical Precipitation

The oxidation ditch treatment process is marketed by Xylem in the US and Canada. Essentially, the oxidation ditch process is similar to the suspended growth process but with extended aeration detention times. In this process, the mixed liquor is recirculated in a looped reactor using banana-type mixers. Aeration provides oxygen for carbonaceous BOD removal and nitrification. Non-aerated zones are provided for denitrification. The main advantages of this process are that it dampens flow and load fluctuations and achieves consistent quality effluent at variable flows and loads. Oxidation ditches have not been implemented in Western Canada due to the concerns of poor nitrification performance at low temperature and high capital cost due to large bioreactors and clarifier covers. A process schematic of the oxidation ditch process is illustrated in Figure 2-17. The process characteristics are summarized as follows:

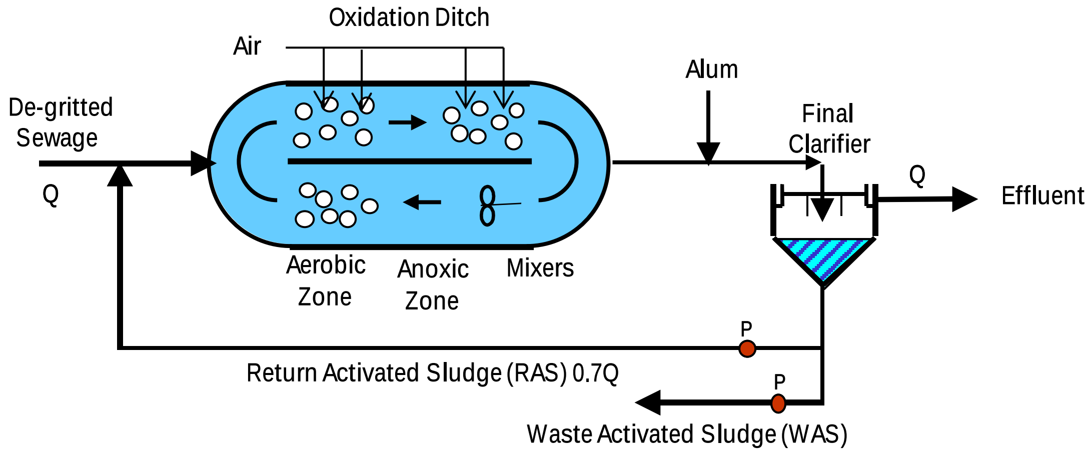

Figure 2-17 Oxidation Ditch with Chemical Precipitation

- The oxidation ditch process includes the installation of a submerged aeration system.
- High MLSS concentrations and SRT are maintained to achieve nitrification. The MLSS concentrations are typically 2,000 to 3,000 mg/L, and the SRTs are 40 to 70 days. Low sludge yield is expected due to long SRT in the system.
- Final clarifiers with covers are required to remove solids from the lagoon effluent, and the settled solids (RAS) are recycled from the clarifiers to the inlet to the basin to mix with the primary effluent.
- Chemical precipitation by addition of coagulant and settling in the secondary clarifiers are required for phosphorus reduction.
- UV disinfection system would be required for continuous discharge.
- Full-scale installations in US reported that nitrification could be achieved at temperatures as low as 4ºC.

2.4.3.13 Membrane Bioreactors (MBR) with Chemical Precipitation

This process is similar to the conventional activated sludge (CAS) process except that a membrane system (either ultrafiltration or microfiltration membrane) replaces the final clarifiers. The activated sludge organisms utilize organics in wastewater as a food source and convert them into biomass, carbon dioxide and water. Compressed air is applied to the bioreactor to maintain the micro-organisms in an aerobic condition. The bioreactor effluent is extracted through membrane filters and the biomass is retained in the bioreactors. The membranes are placed in series downstream of the bioreactor, as shown in Figure 2-18.

A high MLSS concentration (8,000 -10,000 mg/L) and SRT (10 - 20 days) is maintained in the reactors, which result in less sludge yield than CAS.

The drawbacks of the MBRs are high-energy consumption, membrane fouling problems and operational life of expensive membranes. However, these disadvantages will be eventually overcome as membrane technology suppliers develop more economical and durable products. To achieve denitrification, an upfront anoxic zone will have to be provided together with a nitrified effluent recycle stream. Tertiary chemical precipitation can be achieved by the addition of alum just prior to the membranes.

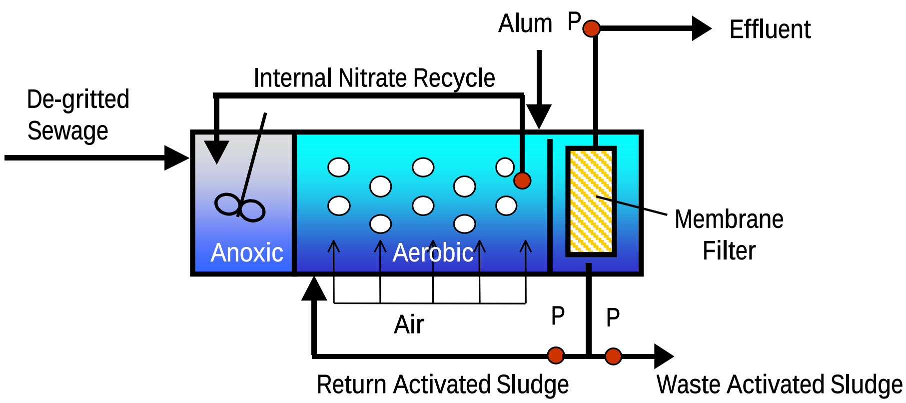

Figure 2-18 Process Schematic of the MBR with Chemical Precipitation

2.4.3.14 Membrane Bioreactors (MBR) as BNR

The membrane activated sludge process can be designed as part of any BNR system by replacing the final clarifier with a membrane filter. The modified University of Cape Town (UCT) process modified with the MBR system is shown as an example in Figure 2-19. The UCT configuration is a good choice because the second anoxic zone is a good way to remove high DO levels as well as nitrates prior to adding sludge to the anaerobic zone. The advantage of the MBR as BNR process is a reduced footprint by reducing the size of the bioreactor and eliminating the final clarifier. However, it requires multiple recycles.

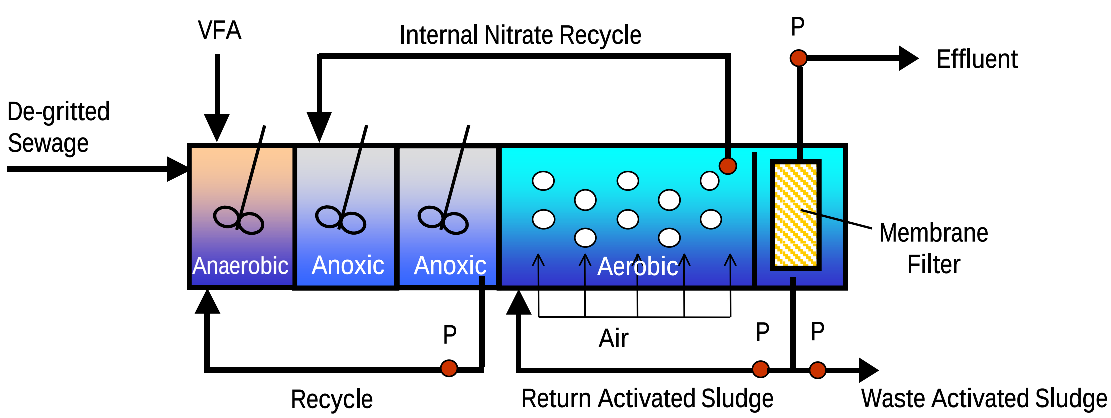

Figure 2-19 Process Schematic of the MBR as BNR

2.4.3.15 Biological Aerated Filters (BAFs) with Chemical Precipitation

A biological aerated filter (BAF) is a submerged aerated fixed film reactor. Figure 2-20 illustrates some common proprietary BAFs available in the market. Primary effluent is pumped upward or downward through a bioreactor containing fixed media on the surface of which biomass grows. Air is injected in the form of fine bubbles, 1-2 mm in diameter, near the base of the media in co-current flow with the primary effluent inlet stream. The biomass utilizes the organics in the wastewater as food and converts them to carbon dioxide, water and additional biomass. Nitrification and denitrification can be achieved by adding multiple BAF cells in series, with recirculation of nitrified effluent to a denitrification BAF operated without air addition.

The diagram shows a BAF process with the lower portion of the tank anoxic and the upper portion anaerobic to achieve organic removal, nitrification and denitrification in a single unit.

The media is approximately 3 to 4 m deep, has a high specific surface area, high porosity and is manufactured from materials which are resistant to attrition (e.g. Biofor media consists of an expanded clay material). Periodically the bio-filters are backwashed and simultaneously agitated by air scour to remove biosolids from the media. Filter effluent is stored to provide backwash water. The backwash cycle can be controlled by a timed cycle or head loss measurements. Multiple cells are utilized and can be cycled in and out of service to ensure generation at optimum flow rates for biological growth through a range of plant flows and load conditions. Alum can be added to the treated effluent from the bioreactor for phosphorus removal.

The BAF process is usually applied where there is a limited area to achieve treatment and there is a capital and operating cost premium to their application.

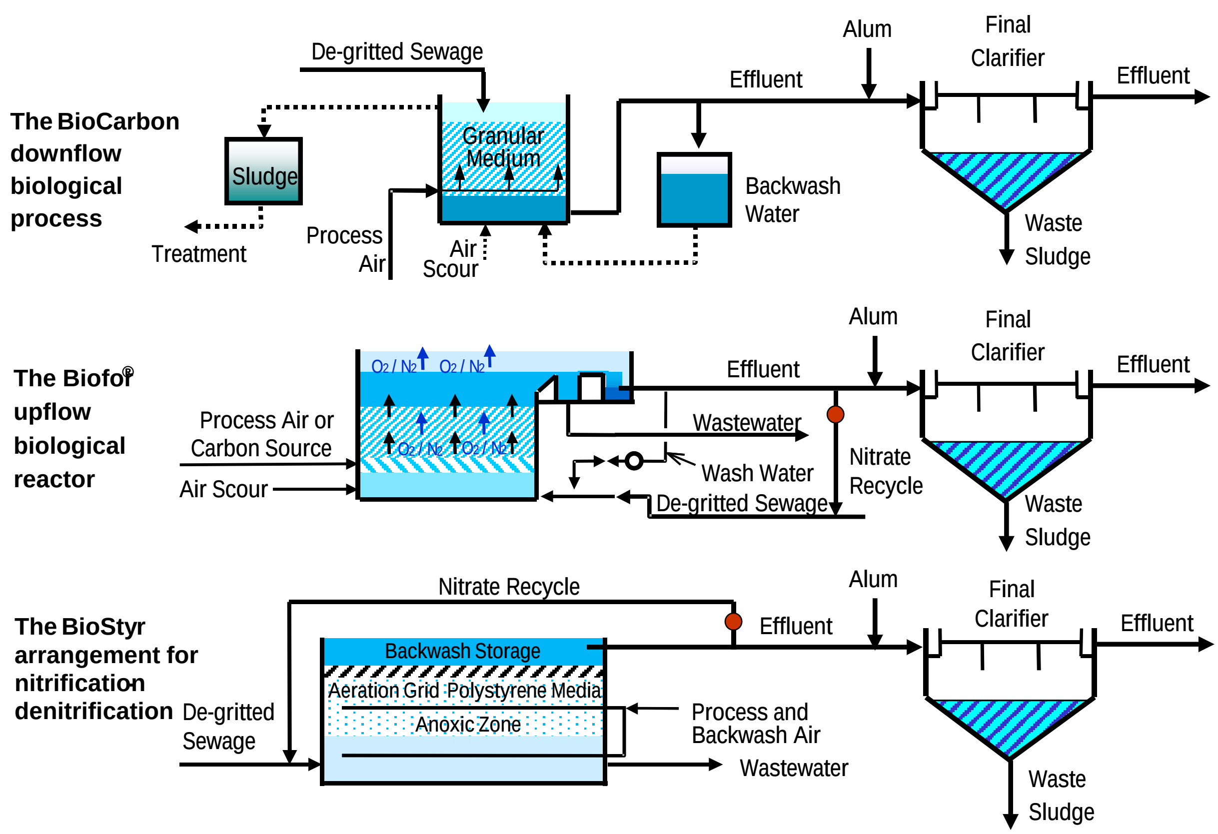

Figure 2-20 Process Schematic of Biological Aerated Filters with Chemical Precipitation

2.4.3.16 Rotating Biological Contactor (RBC) with Chemical Precipitation

The rotating biological contactor consists of a series of closely spaced circular disks made of polystyrene or polyvinyl chloride (PVC). Figure 2-21 presents a schematic of the process. The disks rotate around horizontal shafts and are partially submerged in wastewater. Bacteria attach to the surface of the disks and eventually form a slime layer over the entire wetted surface area of the disks. The rotation of the disks alternately contacts the biomass with the organic material in the wastewater and then with atmospheric oxygen. No mechanical aeration is required for the RBC process. Similar to the conventional activated sludge process, bacteria utilize the organics in the wastewater as food and convert BOD to carbon dioxide, water and cellular material. Nitrifying bacteria will become established on the disks following carbon removal.

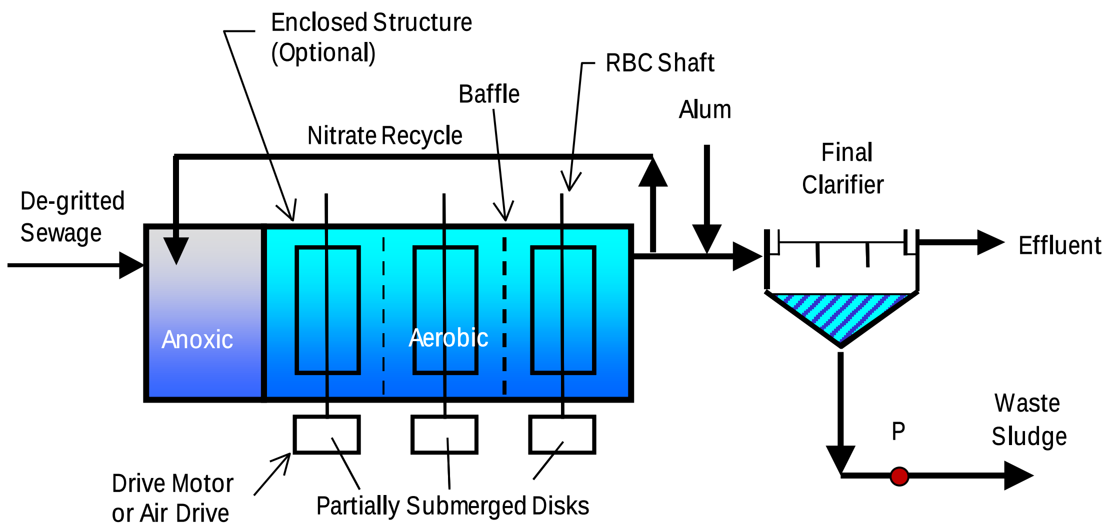

Figure 2-21 Process Schematic of RBC with Chemical Precipitation

To achieve denitrification the aerobic partially submerged disks can be preceded by a suspended growth anoxic zone or a fully submerged shaft with recycle of nitrified effluent.

The RBC can be arranged with several units operated in series. The rotating shafts can be oriented such that the direction of flow is either parallel or perpendicular to the shaft. The RBC units can be housed in an enclosed fiberglass structure to withstand cold temperatures.

2.4.3.17 Moving Bed Biofilm Reactor (MBBR) with Chemical Precipitation

The moving bed technology is based on mobile biomass carriers that support a high concentration of attached biomass. The carriers are made from buoyant HDPE media that have a very high surface to volume ratio in the range of 400 to 500 m^2/m^3. In the moving bed, packing material is placed in the reactor in suspension with the activated sludge to support biofilm growth. Mechanical mixing circulates the packing material in the system to avoid packing accumulation at the reactor outlet. The packing material is retained in the reactor by an effluent screen. In large systems the packing material is placed within cages to avoid the use of additional mixing equipment. Several packing materials have been developed for suspended attached growth processes, including Captor, Linpor, Kaldnes and Hydroxyl-Pac media.

The process is unique in utilizing plastic biofilm carrier elements for BOD removal, nitrification, and denitrification. Since the biofilm carrier provides a relatively large surface area for growth, the system supports a much higher concentration of microorganisms as compared to other processes. This makes the process more spatially efficient. A single-stage reactor is presented in Figure 2-24. Sloughed solids are floated out in the dissolved air floatation unit. Multiple tanks can be set up to provide aerobic and anoxic zones for total nitrogen removal. The process is typically applied to retrofit existing conventional activated sludge systems for nitrification where limited space is available.

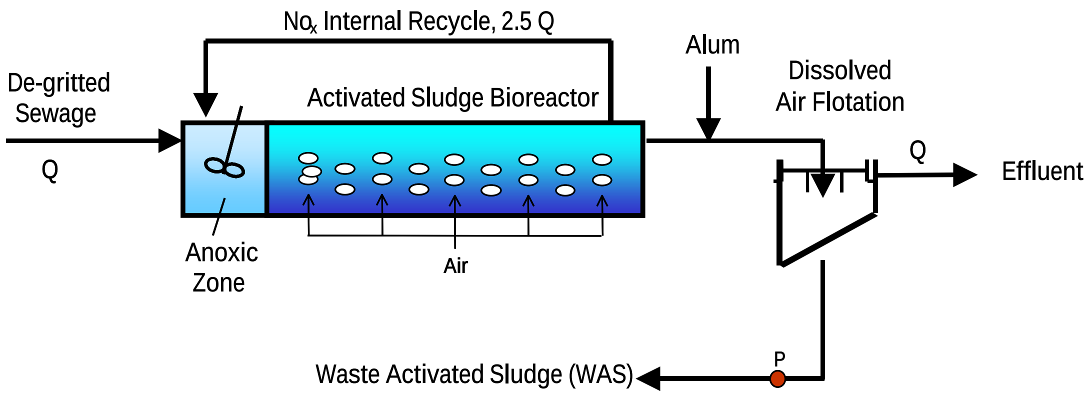

Figure 2-22 Process Schematic of the MBBR and Chemical Precipitation

2.4.3.18 IFAS and Chemical Precipitation (Bio-Wheel)

The Integrated Fixed Film Activated Sludge (IFAS) is a hybrid process that uses both attached and suspended growth. In this process suspended biomass is provided by the activated sludge process configuration involving the recycle of sludge from the secondary clarifier to the aeration tank and attached growth occurs on the biomass support media which are retained in the aeration tank. The addition of fixed film media increases biomass inventory and enhances nitrification performance. There are various suppliers of IFAS media; however, for small WWTPs the Bio-Wheel is gaining more support. A process schematic of the IFAS process using the Bio-Wheel technology is illustrated in Figure 2-25, and some process significances are summarized as follows:

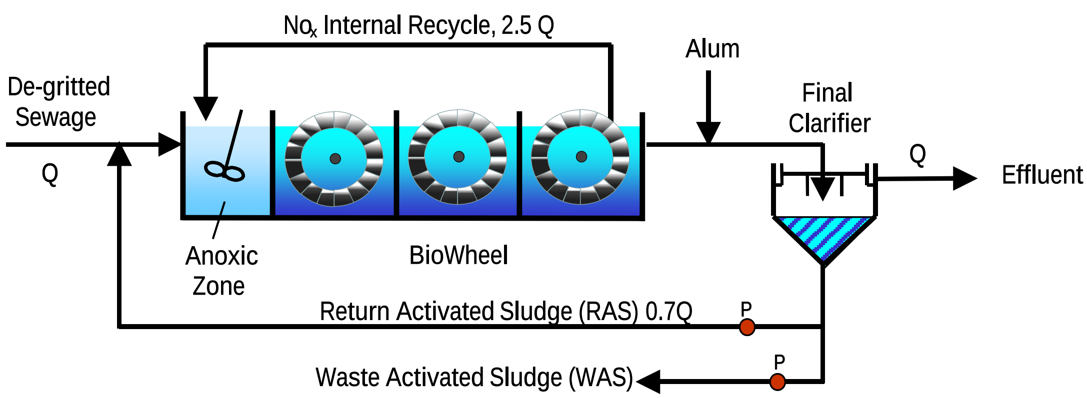

Figure 2-23 Process Schematic of IFAS (Bio-Wheel) and Chemical Precipitation

Two or three Bio-Wheels are added to the aerobic tanks. Each wheel is 80% submerged in the mixed liquor and rotates at a slow speed.

Aeration and mixing are provided by individual plastic plate cells with no external blowers or diffusers. The air contained in the cells arranged in a circular fashion is brought down to the mixed liquor where it escapes from the cells as fine to medium bubbles.

As with any fixed-film biological contactor, the units will tend to become overgrown with organisms after a period. Alum addition to the bioreactor effluent is required to meet the effluent phosphorus criteria.

2.4.3.19 Electrocoagulation/Electro-flocculation (EC/EF)

Electrocoagulation is widely used for treatment of mining wastewater and recently has been applied for treatment of wastewater from primary lagoons. Electrocoagulation is an electrochemical method to produce coagulants in-situ directly from sacrificial electrodes by passing direct current (DC) through aqueous media. Sacrificial anodes are dissolved in order to produce the coagulants (aluminum ions in the anodes and hydroxide ions in the cathode). These ions coagulate with pollutants in the water. The coagulated pollutants are floated to the surface by the gas bubbles generated during the process, known as electro-flocculation (hydrogen or oxygen gas is evolved from cathodes and oxygen or chloride gas may evolve from anode). The electrodes are usually made of aluminum, iron and titanium. The combination of electrocoagulation and electro-flocculation in one single step process with a retention time of 60 minutes has attracted a lot of attention due to the small foot print of the process.

The electro-coagulation/electro-flocculation (EC/EF) system uses a continuous flow reactor consisting of multiple flows through cells in series with electrode assemblies in each cell, feed pump, DC power supply (rectifier) and PLC controllers as shown in Figure 2-26. The electrode assembly consists of combination of aluminum and iron vertical plates spaced by more than 25 millimetres. The current density varied from 5 to 26 mA/cm^2. Floated solids are removed by a skimmer from the surface of the water while the water continuously flows through the subsequent cells. This technology combines multiple processes such as coagulation, floatation, disinfection and electrochemistry in a single tank.

Figure 2-24 Electrocoagulation Pilot Plant at Unity, SK

EC/EF has been pilot-tested twice in Saskatchewan: in the town of Unity by Tecvalco - Soneera Water Canada Ltd., and in the town of Pilot Butte by Living Sky Water Solutions. Also, in Saskatchewan, full-scale plants for the towns of Kerrobert and White City are under construction. The main advantages of this technology are that they defer lagoon expansion, eliminate the need to purchase coagulants such as alum or ferric chloride, remove a large fraction of dissolved solids, and have low capital cost due to the small footprint and lower sludge production. The main disadvantages of this technology are the uncertainty of the life of the sacrificial plates, and scaling of the electrodes. Tecvalco stated a plate life in the range of 90 days to 120 days for plates approximately 10 mm thick. Plate life decreases as the current density increases. The presence of chlorides also may reduce plate life as the chloride ion forms hydrogen chloride in the reactor, etching the plates. Although all suppliers claim a low operating cost due to the relatively low energy requirements, the long-term cost of electrode replacement is unknown. The current design allows easy cleaning and replacement of the plates with minimum operating down time.

Preliminary data for the operation of Unity and Pilot Butte electrocoagulation pilot plants indicates the technology can remove main pollutants of concern to low concentrations, as listed in the Table 2-9. However, the reactors were fed with partially treated wastewater from primary lagoons.

Table 2-9 Preliminary Operational Data for EC/EF Pilot Plants

Parameter	Unity		Pilot Butte	
	Primary Lagoon 6-month Average	Treated Effluent 6-month Average	Primary Lagoon 3-month Average	Treated Effluent 3-month Average
Biological Oxygen Demand-5 day (BOD_5), mg/L	140	11	20 to 76.4	< 3
Carbonaceous Biological Oxygen Demand (CBOD), mg/L	156	10	NR	NR

Total Suspended Solids, mg/L	55.9	< 3.0	149 - 161	< 3
Total Phosphorus, mg/L	7.11	0.3	3.9 to 6.8	< 0.47
Total Coliforms, Count/100 mL	8,660,000	0	< 613,100	10 to 565
Escherichia Coli, Count/100mL	3,870,000	0	< 461,100	< 10
Total Nitrogen, mg/L	42.5	1.61	15 - 40	1.4 - 7
Total Kjeldahl Nitrogen (TKN), mg/L	40	1.1	15 - 40	0.5 - 2.1
Ammonia Total (as N), mg/L	28	0.91	11 - 33	0.99 - 1.27
Un-ionized Ammonia as N @ 15°C, mg/L	0.0423	0.0016	NR	NR
Nitrate-N, mg/L	1.03	< 0.5	< 0.04	0.14 - 0.4
Nitrite-N, mg/L	0.941	0.218	NR	NR
Nitrate+Nitrite-N, mg/L	1.97	< 0.50	NR	NR
Note: NR Not Reported				

2.4.4 Screening of Liquid Treatment Options

As discussed above there are many potential alternatives which would be very time-consuming and impractical to review at a high level of detail. It's possible that all of them could achieve the treatment goals, but some are emerging technologies and others have not demonstrated cost effective success at the scale of operations and under the cold climate conditions required in Humboldt. A set of screening factors have been selected which are listed and described below to show their applicability to the WWTP.

Proven Technology: The treatment system must be in common use for secondary treatment and nitrogen and phosphorus removal in similar climatic conditions at a 2,000 to 8,000 m^3/d capacity range.

Reliability / Risk of Failure: The treatment system must be capable of compliance with all the required effluent quality parameters with little risk of failure due to mechanical or process breakdown.

Cost Effectiveness: The treatment technology chosen should be economical with respect to both operating and capital costs. Therefore, processes which need to be conservatively designed to increase compliance under the Humboldt operating conditions and effluent quality requirements or that have excessive operating costs because of power requirements or routine replacement of rapidly wearing components would fail this criterion.

Operational Control: Because of the relatively stringent effluent criteria for ammonia, the selected process should accommodate easy operator intervention so that trends in performance can be observed and process adjusted proactively to maintain effluent quality.

In Table 2-10, the process options were scored on a pass-fail basis for each of the above factors. To be considered for conceptual design and detailed cost evaluation the processes must pass all the criteria. Processes passing the pass-fail criteria are shown in bold.

Table 2-10 Screen Matrix - WWTP Liquid Treatment Options

Category	Liquid Treatment Process	Proven Technology	Reliability /Risk of Failure	Cost Effectiveness	Operational Control	Meet Pass-Fail Criteria
In-pipe bioaugmentation	In-Pipe Technology	NO	NO	NO	NO	NO
Suspended growth earthen basins	Biolac Process with Chemical Precipitation	YES	YES	NO	YES	No
Attached growth in earthen basins	**Submerged Aerated Growth Reactor (SAGR) post denitrification with Chemical Precipitation**	**YES**	**YES**	**YES**	**YES**	**YES**
	Bio2Bloc, Post Denitrification with Chemical Precipitation	YES	NO	YES	NO	NO
Attached growth in concrete tanks between earthen basins	LagoonGuard™ Moving Bed Biofilm Reactor (MBBR) with Chemical Precipitation	NO	YES	YES	YES	NO
Suspended growth in concrete tanks	AS with Nitrification with Chemical Precipitation	YES	YES	NO	YES	NO
	Biological Nitrogen and Phosphorus Removal (BNR)	YES	YES	NO	YES	NO
	Oxidation Ditch with Chemical Precipitation	NO	YES	NO	YES	NO
	Sequencing Batch Reactor (SBR) with Chemical Precipitation	YES	YES	NO	YES	NO
	Continuous Inflow and Intermittent Decant (SBR) with Chemical Precipitation	**YES**	**YES**	**YES**	**YES**	**YES**
	Modified Sequencing Batch Reactor (MSBR)	YES	NO	YES	YES	NO
	Granular Sequencing Batch Reactor (GSBR)	YES	YES	YES	NO	NO
	Membrane Bioreactors (MBR) with Chemical Precipitation	YES	YES	NO	YES	NO
	Membrane Bioreactors (MBR) as BNR	YES	NO	NO	YES	NO
Attached growth in concrete tanks	Biological Aerated Filters (BAFs) with Chemical Precipitation	YES	YES	NO	NO	NO
	RBC, Post Denitrification with Chemical Precipitation	NO	YES	YES	YES	NO
	Moving Bed Biofilm Reactor (MBBR) with Chemical Precipitation	**YES**	**YES**	**YES**	**YES**	**YES**

Category	Liquid Treatment Process	Proven Technology	Reliability /Risk of Failure	Cost Effectiveness	Operational Control	Meet Pass-Fail Criteria
IFAS	IFAS with Chemical Precipitation (Bio-wheel)	YES	YES	NO	YES	NO
Non-biological process	Electrocoagulation Electro-flocculation (EC/EF)	NO	YES	YES	YES	NO

Based on this pass-fail comparison, the following liquid treatment processes were chosen for further evaluation:

- Submerged Aerated Growth Reactor (SAGR) Post Denitrification and Chemical Precipitation.
- Continuous Inflow and Intermittent Decant (SBR) with Chemical Precipitation.
- Moving Bed Biofilm Reactor (MBBR) and Chemical Precipitation.

The Biolac process fails mainly because of poor quality of the equipment, specifically maintenance of the aeration system is complex and often deemed to be unsafe by plant operators. The aeration system tends to fail at the nipple that connects the air laterals to diffuser hoses. Reconnecting the hoses to the laterals requires a crew of four operators, two on the shore and two working at the edge of the boat while facing downward for a long period of time. In addition, due to the long sludge retention time that this process required, clarifiers need to be covered to ensure that ice would not form on the surface of the clarifiers.

The attached growth systems in earthen basins failed largely because of their susceptibility to reduced nitrification performance at low temperature or because the additional equipment required upstream and downstream of the secondary process (i.e. screens upstream and UV disinfection downstream). The only system that has proven performance with no requirement for screening and additional disinfection is the SGAR technology.

The Lagoonguard™ MBBR process failed because there is no long-term performance data to be able to determine if the system is a proven technology and reliable in cold weather conditions. Lagoonguard™ systems installed in Quebec and the USA do not experience the sudden lagoon effluent temperature decreases in fall that are common in Humboldt (22°C to 0.5°C). In addition, there is a concern of potential detachment of nitrifiers from the carriers during the prolonged starvation period, which occurs when the aerated lagoons nitrify in summer but not in fall.

The suspended growth processes in concrete tanks failed because the SBR is clearly more cost effective within this category given the effluent discharge objectives in the Downstream Users Impact Study. Other technologies listed under this category are usually selected to meet more stringent effluent or to retrofit existing mechanical plants.

The attached growth systems in earthen basins failed mostly because in order to ensure nitrification, the nitrifying trickling filters and RBC units become large and therefore would not be cost effective. A BAF system could be covered and operated at a high enough rate that cold climate operation would be effective. However, the cost premium in terms of operating and capital costs for this small footprint proprietary technology is significant. BAF also requires significant power because the primary effluent would need to be pumped through the expanded media.

EC/EF failed because there is no long-term performance data to show that the system is proven and reliable for municipal wastewater in the conditions that Humboldt experiences.

2.5 DISINFECTION

Wastewater disinfection is practiced for the purpose of providing protection to humans against exposure to waterborne pathogenic microorganisms. Disinfection is a common final step in most modern municipal wastewater treatment systems. Although conventional wastewater treatment can remove 2 to 3 log units of microorganisms from the waste stream, the final effluent still contains high numbers of microorganisms, including pathogens, which may affect the use of the receiving water body.

Microbial inactivation during disinfection is achieved by inducing biochemical changes within the microbial population. The nature of these biochemical changes is dependent upon the microbial population and the applied disinfectant.

The most universally practiced wastewater disinfection method since the late 1940s is chlorination. However, due to environmental concerns regarding chlorination, chlorination of secondary effluent has declined in recent years.

2.5.1 Disinfection Options

Options available for disinfection of the secondary effluent include:

- Chlorination/dechlorination
- Ultraviolet disinfection
- Ozone
- Chlorine dioxide

The use of ozone or chlorine dioxide is not considered in this evaluation because the amount of mechanical equipment required and associated high cost of equipment and manpower. In addition, the strong oxidizing power of these chemicals requires the use of stainless steel and safety equipment, which is costly.

2.5.1.1 Chlorination/Dechlorination

Four typical chlorine compounds used in wastewater disinfection include chlorine gas, chlorine dioxide, sodium hypochlorite and calcium hypochlorite. In recent years, there is a growing concern about the environmental impact of chlorine and its byproducts on the receiving environment and downstream water users. Under current provincial and federal regulations, chlorine is considered a deleterious substance contributing to effluent toxicity that would degrade the quality of water, potentially negatively impacting fish or fish habitat and the use of fish by people. In addition, Canadian Council of Ministers of the Environment (CCME) regulations (adopted by WSA) has adopted an average concentration of total residual chlorine in the effluent of less than or equal to 0.02 mg/L which is quite stringent. This limit has essentially necessitated a need for a complete dechlorination step using additional chemicals such as sodium metabisulfite or sulphur dioxide to limit the effluent chlorine levels to meet the CCME and WSA regulations.

As chlorine is toxic to the aquatic environment, the handling and infrastructure required to maintain and operate a chlorination/dechlorination system becomes more onerous and complicated. For this pre-design we therefore recommend that the disinfection process for upgraded WWTP will be based on ultraviolet light (UV). The technology is being promoted by both provincial and federal environmental authorities as the system of choice for most communities in Canada. A brief discussion of the technology is provided in the next section along with discussions on relative advantages and disadvantages with respect to chlorination/dechlorination.

2.5.1.2 Ultraviolet (UV) Disinfection

Ultraviolet (UV) disinfection utilizes short wavelength light (between x-rays and visible light) to inactivate waterborne pathogens. The UV region of the spectrum is divided into four sub-regions: vacuum UV, UV-A, UV-B and UV-C. The UV-A region (315 – 400 nm) is used for tanning lamps. UV-B (280 – 315 nm) and UV-C (200 – 280 nm) are the regions that contain the wavelengths most effective for germicidal treatment.

UV lamps are assembled in modules and installed into open channels. The position of the lamps can be horizontal or vertical. Several modules together form a bank. Wastewater flows through the banks of UV lamps, exposing the microorganisms to UV radiation. The main components of the UV disinfection system are UV lamps, UV channel, lamp ballasts and control panel. An example of a UV disinfection system is illustrated in Figure 2-25.

Figure 2-25 UV Disinfection System

The level of inactivation is directly related to the UV dose received by microorganisms that pass through the UV reactor system. The UV dose is determined by the special fluence rate distribution within the reactor and the hydrodynamic flow pattern. The resulting UV dose distribution is a complex function of several interacting variables including reactor geometry, the number, spacing and output of the lamps, lamp sleeve characteristics, baffle arrangements, water velocity and transmittance.

Upstream unit operations have a direct impact on effluent quality which subsequently affects the performance of the UV reactor. The effluent parameters that affect UV fluence rate include: UV transmittance, total suspended solids (TSS), particle size, chemical composition and bacterial density.

Transmittance decreases in the presence of UV absorbing substances and particles that either absorb or scatter the UV radiation. Wastewater transmittance depends on the type of treatment process and it has been shown that suspended growth processes have higher transmittance than attached growth systems. Another factor that may affect the transmittance is the use of metal salts for enhanced solids removal, phosphorus removal or odour control. While aluminum salts have no effect on UV transmittance, iron absorbs UV directly, fouls lamp sleeves and provides a protective shield for pathogens by adsorption onto suspended solids.

Reduced transmittance in wastewater effluent reduces the UV fluence rate, and therefore, the level of pathogen inactivation. Reduced UV fluence rate can be compensated for by decreasing the flow rate and increasing the individual lamp power or the number of lamps in operation.

Presence of TSS adversely affects UV disinfection. Solids tend to shield bacteria from exposure to UV (USEPA, 1992). Microorganisms inside the particles are protected from UV radiation, resulting in an increased UV dose demand. Any solids that are larger than approximately 40 microns will not be completely penetrated by UV radiation. A decrease in particle concentration and size results in decreased UV dose demand and more reliable performance.

Specific organic compounds and dyes will absorb UV energy when present in the wastewater stream reducing the efficiency of the disinfection process. Other parameters affecting the UV disinfection include: type of UV lamps, lamp age, sleeve cleanliness and total hardness.

Research carried out to date has not indicated harmful byproduct formation from UV disinfection of wastewater.

UV disinfection systems require safety glasses for use by visitors and operators during the regular checkup. Table 2-11 lists the advantages and disadvantages of UV disinfection.

Table 2-11 Advantages and Disadvantages of UV Disinfection

Advantages	Disadvantages
• Effective inactivation of bacteria and viruses • Effective inactivation of *Cryptosporidium* • Reliable • No toxic byproduct formation • UV irradiated wastewater is not toxic • No handling of chemicals • Simple operation, no special safety equipment required • Small footprint • Short retention time required	• High energy cost • Affected by TSS and absorbing substances in effluent • Possible pathogen reactivation • Affected by water hardness and scaling on the lamp sleeves • Disinfection can be compromised by poor effluent quality and lamp fouling • Disposal of burnt mercury lamps requires safe and proper handling techniques • Proper functioning and the design of the secondary clarifiers are critical to achieving consistently low effluent suspended solids

3.0 RECOMMENDED LIQUID TREATMENT OPTIONS

The following three liquid treatment options are recommended for further development because they are proven technologies, reliable, cost effective and easy to operate.

1. Submerged Aerated Growth Reactor (SAGR) with Chemical Precipitation. Implementation of this system requires:
   - Dredging sludge from the two front-end cells for settling of grit and large settleable solids.
   - Rebuild the embankment of cells 1 and 2. These cells are ideal to retain grit rags and plastics that otherwise get wear or wrapped around the diffusers.
   - Converting the two front-end cells to anoxic cells by installing a forcemain from the effluent lift station to the front-end cells (anoxic cells do not release odour because microorganisms prefer to use nitrate rather than sulphates).
   - Dredging facultative cells to facilitate installation of new air diffusers (conducted while the lagoon is active).
   - Retrofitting up to three cells with fine bubble aeration system.
   - Constructing a building to house blowers, chemical storage tanks and metering pumps. Alum of ferric can be used for phosphorus precipitation with this system.
   - Upgrading phosphorus chemical precipitation system with rapid mix and slow mixed manholes.
   - Retaining Cell 7 as settling cell for precipitation of phosphorus.
   - Constructing four earthen basins for the SGAR system.
   - Constructing an effluent lift station and forcemain from the WWTP to Humboldt Lake.
   - Installing an instrumentation and control system for the blowers, chemical metering pumps, mixers and effluent lift station.

   This system does not require preliminary treatment or disinfection equipment. Sludge generated by this system is stabilized in the earthen basin. Grit removal from the front-end cells is required every four to three years. Sludge removal from any other cells would be required after 10 to 12 years. The facility would be most likely classified as Class II.

2. Continuous Inflow and Intermittent Decant (SBR) with Chemical Precipitation. Implementation of this system requires:
   - Constructing a valve chamber to combine flows from all lift station and re-direct the flow to the new headworks.
   - Constructing a headworks building to house screens and grit removal units.
   - Constructing a concrete basin for the SBR and a building to house blowers, alum storage tanks and metering pumps. Alum is preferred over ferric sulfide because ferric foul the UV lamps quartz.
   - Installing a UV disinfection system.
   - Installing pumps and forcemain to convey chemical sludge to existing lagoons or another sludge management system.
   - Retaining existing cells for wet weather management.
   - Constructing an effluent lift station and forcemain from the WWTP to Humboldt Lake.
   - Installing an instrumentation and control system for the screen, grit removal unit, SBR, blowers, UV disinfection, sludge pump station and effluent lift station.

   This system may require pre-equalization if periods of zero flow are experienced frequently or are extended. This system would impact the maximum flow delivered by the existing lift stations since the headworks and SBR would be built at a higher elevation than the lagoons to reduce excavation volume. Sludge removal from facultative cells would be required after 10 to 20 years. Facility would be most likely classified as Class II.

3. Moving Bed Biofilm Reactor (MBBR) with Chemical Precipitation. Implementation of this system requires:
   - Constructing a valve chamber to combine flows from all lift stations and redirect the flow to the new headworks.
   - Constructing a headworks building to house screens and grit removal units.
   - Constructing a building to house blowers, dissolved air flotation units, UV disinfection units, chemical tanks and metering pumps.
   - Installing air floatation units.
   - Installing a UV disinfection system.
   - Installing pumps and forcemain to convey chemical sludge to existing lagoons or another sludge management system.
   - Retaining facultative cells for wet weather management.
   - Constructing an effluent lift station and forcemain from the WWTP to Humboldt Lake.
   - Installing an instrumentation and control system for the MBBR, blowers, filtration, UV disinfection, sludge pump station and effluent lift station.

   This system may require pre-equalization if periods of zero flow are experienced frequently or are extended. This system would affect the maximum flow delivered by the existing lift stations since the headworks and SBR would be built at a higher elevation than the lagoons to reduce excavation volume. Sludge removal from facultative cells would be required after 10 to 20 years. The facility would be most likely classified as Class II.

City of Humboldt Wastewater Treatment Plant Upgrades

Technical Memorandum No. 4
Identification of Sludge Management Options

February 1, 2019

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Sign-off Sheet

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Abbreviations

AAF	Annual Average Day Flow
BOD_5	Biochemical Oxygen Demand 5-day
BNR	Biological Nutrient Removal
BWL	Bottom Water Level
CCME	Canadian Council of Ministers of the Environment
CFIA	Canadian Food Inspection Agency
CFU	Colony Forming Units
COD	Chemical Oxygen Demand
$cBOD_5$	Carbonaceous Biochemical Oxygen Demand 5-day
DAF	Dissolved Air Flotation
DNA	Deoxyribonucleic Acid
FRP	Fibre Reinforced Plastic
HRT	Hydraulic Retention Time
H2S	Hydrogen Sulfide
ISS	Inorganic Suspended Solids
MBBR	Moving Bed Bioreactor
MDF	Maximum Day Flow
MMF	Maximum Monthly Flow
MPN	Most Probable Number
PFRP	Process to Further Reduce Pathogens
PDC	Power Distribution Centers
RNA	Ribonucleic Acid
RAS	Return Activated Sludge
SAGR	Submerged Attached Growth Reactor
SBR	Sequencing Batch Reactor
SLR	Solids Loading Rate
SRT	Sludge Retention Time
SVI	Sludge Volume Index
TKN	Total Kjeldahl Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
TWAS	Thickened Waste Activated Sludge
TWL	Top Water Level
UV	Ultraviolet
VFD	Variable Frequency Drive
VS	Volatile Solids
VSS	Volatile Suspended Solids

WAS	Waste Activated Sludge
WWTP	Wastewater Treatment Plant
WSA	Water Security Agency

1.0 INTRODUCTION

Stantec Consulting Ltd. (Stantec) was retained by the City of Humboldt to prepare a pre-design report for the City of Humboldt Wastewater Treatment Plant (WWTP) Upgrade. This Technical Memorandum (TM) provides a discussion of the sludge management options available. This information will lead to the 'screening' of one option for further evaluation in technical memorandum 5 – Evaluation of Treatment Options. The goal of the memo is to identify a Sludge Management Option (SMO) that is economically viable, meets regulatory requirements and can be maintained by the City. The identified SMO will provide a long-term sustainable strategy for handling, treatment, and disposal of the City's wastewater treatment solids.

1.1 BACKGROUND

The current operations consist of storing and stabilizing solids in the treatment lagoon. This practice has been in place for more than 55 years. Storage of sludge in the two front-end cells has generally been trouble free; however, odour complaints have arisen when accumulated solids significantly reduce the water layer. The anaerobic cell has been de-sludged twice, and the dewatered sludge has been applied to agricultural land. In 2002, 7,200 m3 of sludge was applied to 49 hectares, and 7,563 m3 of sludge was applied to 55.6 hectares in 2014, with an average cost of $20.83/m3. The aerated cell has not been de-sludged since the aeration system was installed in 1976. Similarly, the facultative cell has not been dewatered since it was constructed in 1961. It is recommended that a sludge survey be conducted to determine the quantity of sludge stored in these cells.

The projected Waste Activated Sludge (WAS) load for the design year 2052 is about 828 kg/d of solids based on a ratio of 0.95 kg WAS/kg Influent TSS mass and expected influent TSS mass of 869 kg/d of solids. This would correspond to about 102 m3/d at 0.85 % dry solids (DS). The projected digested WAS load for the year 2052 is 431 kg/d solids (21.5 m3/d at 2% DS), assuming a 60% volatile solids destruction. It is projected that about 870,000 kg (43500 m3 at 2% DS) of sludge would need to be land applied, if the sludge were to be stored in the facultative cell, and de-sludged initially every 6 year and progressively increased every 4 years when the population reaches 10,000 people. If the sludge were to be dewatered to 20% DS, the projected volume of sludge to landfill would decrease to 4350 m3. It should be note that although the landfill is 30 km from the WWTP, it is less expensive to landfill the sludge than to land apply it.

2.0 REGULATORY REQUIREMENT REVIEW

The purpose of this chapter is to familiarize stakeholders with current regulatory requirements for biosolids application to agricultural and non-agricultural land. New regulatory requirements have been issued by the Canadian Council of Ministers of the Environment (CCME) for the disposal of biosolids on a continuous basis. Consequently, the proposed solids management plan should comply with current regulatory requirements.

In Saskatchewan, the Water Security Agency (WSA) sets the regulatory requirements that govern both liquid and sludge treatment. The regulatory requirements that govern liquid treatment include the Permit to Operate and the Saskatchewan Sewage Works Design Standard (EPB 503). The regulatory requirements that govern sludge treatment include: the Saskatchewan Land Application of Municipal Sewage Sludge Guidelines (EPB 296); Canada's Fertilizer Act; CCME –Guidance Document for the Beneficial Use of Municipal Biosolids, Sludge and Treated Sewage; and CCME-Guidelines for Compost Quality; 2005. In Canada, consultants and suppliers usually refer to the US federal rule governing the land application of biosolids described here to familiarize the City with the multiple requirements related to biosolids application to agricultural land.

2.1 BIOSOLIDS MANAGEMENT REQUIREMENTS

The most common biosolids disposal method in Saskatchewan is agricultural land application, followed by landfilling (including use as a daily cover) and composting. Despite extensive experience with biosolids land application programs in North America, questions and concerns remain regarding the long-term safety of this practice, both to the environment and to human health. It is known that biosolids can contain numerous potentially harmful substances, and there is an ongoing debate on the relative risks. The US is currently reviewing its biosolids regulations, and it is expected that additional compounds, such as pharmaceuticals, flame retardants, and nanoparticles may be regulated under the new biosolids rule. The CCME recently issued a list of Emerging Substances of Concern in Biosolids. Pathogen reduction requirements, another area of concern, and demonstrations of compliance have been addressed in regulatory changes. Specifically, without a defined sludge treatment, the absence of specific organisms cannot be used to infer the absence of other potentially pathogenic organisms in the biosolids.

2.1.1 Saskatchewan Sewage Sludge Regulation Review

WSA requires municipal sludge disposed on land to be in conformance with Saskatchewan Land Application of Municipal Sewage Sludge Guidelines (EPB-296). The purpose of the guideline is the protection of human health, the environment, and groundwater.

EPB-296's primary concerns, regarding biosolids application to agricultural land, are minimizing pathogens and heavy metals content. The guidelines do not distinguish between Class A exceptional quality (EQ) and other biosolids. There are no limits to organic contamination in the guidelines. Key regulatory requirements listed in the guideline are discussed as follows.

2.1.1.1 Permit Requirements

A Permit to Operate Sewage Works is required that includes approval for biosolids land application. The following information supplements the application:

- An Environmental Impact Assessment (EIA) may be required under the Environmental Assessment Act (EAA).
- The guideline also requires information on:
  - Biosolids stabilization.
  - Biosolids quality.
  - Land information.
  - Including plans, topography, water courses, soil chemical and physical characterization, water table location, and water wells within a 1 km radius of the land.
  - Management practices.
  - Including application rate, intended crops, application system, operations considerations, sampling, contingency plans, etc.
  - Legal agreements.
  - Including land control agreements such as easements and liability.

2.1.1.2 Sludge Treatment

All biosolids must be stabilized prior to land application on agricultural or non-agricultural lands. Stabilization refers to the reduction of pathogenic organisms, odours, and putrescibility of the sludge. Acceptable stabilization methods include anaerobic digestion, aerobic digestion, composting, heat drying, heat treatment, and chemical stabilization. Sludge is considered stabilized if one of the following requirements is met:

- The mass of volatile solids in the sludge has been reduced to 38%.
- The specific oxygen uptake rate (SOUR) for the sludge is less than 1.5 mg of O2/g of solids-h at 20°C.
- Demonstration that volatile solids reduction for anaerobically digested sludge is less than 17% through additional anaerobic digestion in a bench scale unit.
- Demonstration that volatile solids reduction for aerobically digested sludge is less than 15% through additional aerobic digestion in a bench scale unit.
- Addition of alkaline materials to raise the pH of the sludge to ≥ 12 where it remains for two hours and remains at pH 11.5 or higher for an additional 22 hours.
- The sludge has been treated in an aerobic composting process for 14 days or longer at over 40ºC, with an average temperature above 45ºC.

2.1.1.3 Land Restrictions

- The land selected for biosolids application must meet several minimum separation distances from institutions such as hospitals, and public areas such as parks, residential areas, public roads, watercourses, water wells, and water bodies.
- Landowners who apply the biosolids for agricultural use must comply with specific harvesting and grazing times outlined in the guideline.

2.1.1.4 Biosolids Quality Criteria

- Biosolids must not exceed the specified Maximum Acceptable Concentration (MAC) for heavy metals, as presented in Table 2-1. These criteria are set in the Canada Fertilizer Act (2010), which is administered by the Canadian Food Inspection Agency (CFIA) which controls and regulates all agricultural fertilizers, specialty fertilizers, fertilizer/pesticide mixes, and supplements that are manufactured, sold, or imported. The primary purpose of this Act is to ensure that products are free of substances that are harmful to crops, animals, humans and the environment. It also ensures that they contain the necessary plant nutrients, are effective, and are labelled to avoid fraud.
- The soil onto which the biosolids are applied must not exceed the specified Maximum Acceptable Concentration (MAC) for metals in soil, as presented in Table 2-2. This is because some metals may accumulate to levels toxic to crops, humans, or animals that consume the crop.
- Biosolids must not exceed the specified Pathogen Reduction Requirements.
  - The density of fecal coliform in the sewage sludge must be less than 1,000 most probable number (MPN) per gram of total solids (dry weight basis), or
  - The density of salmonella in the sewage sludge must be less than three MPN per four grams of total solids (dry weight basis).
- Biosolids must not be applied onto frozen soil or soil that is covered with snow or ice.
- Biosolids must not be applied during a rainfall or immediately after.
- Compost must not exceed specified MAC for heavy metals as presented in Table 2-1. These criteria are set in the CCME-Guidelines for Compost Quality 2005.

Table 2-1 Maximum Acceptable Concentration of Metals in the Biosolids and Compost

Parameter	Saskatchewan Guidelines (1)	Canadian Federal Fertilizer Act (2)	US EPA (3) Class B	CCME Compost Class A	CCME Compost Class B
	MAC (4)	Pollutant Limit		MAC (4)	
Antimony (mg/kg)					
Arsenic (mg/kg)	75	75	75	13	75
Barium (mg/kg)					
Beryllium (mg/kg)					
Cadmium (mg/kg)	20	20	85	3	20
Chromium (mg/kg)	1,060	-	-	210	NR
Cobalt (mg/kg)	150	150		34	250
Copper (mg/kg)	760	-	4,300	400	NR
Iron (mg/kg)	-	-	-		
Lead (mg/kg)	500	500	840	150	500
Mercury (mg/kg)	5	5	57	0.8	5
Molybdenum (mg/kg)	20	20	75	5	20
Nickel (mg/kg)	180	180	420	62	180
Selenium (mg/kg)	14	14	100	2	14
Silver (mg/kg)	-	-	-		
Sulphur, Total (mg/kg)					

Thallium (mg/kg)					
Tin (mg/kg)					
Uranium (mg/kg)					
Vanadium (mg/kg)					
Zinc (mg/kg)	1,850	1,850	7,500	700	1,850

Notes:
(1) Land Application of Municipal Sewage Sludge Guidelines, EPB 296 (2004), Saskatchewan Environment
(2) Canada's Fertilizer Act (2010), administered by the Canadian Food Inspection Agency
(3) United States Environmental Protection Agency, EPA 503 Regulation
(4) Maximum Acceptable Concentration
(5) NR Not regulated

Table 2-2 Maximum Acceptable Concentration of Metals in Soils

Parameter	Agricultural Land Use	Commercial Land Use	Industrial Land use
	Maximum Acceptable Concentration (mg/kg)	Maximum Acceptable Concentration (mg/kg)	Maximum Acceptable Concentration (mg/kg)
Arsenic	12	12	12
Cadmium	1.4	22	22
Chromium	40	87	87
Cobalt	64	300	300
Copper	63	91	91
Mercury	6.6	24	50
Molybdenum	5	40	40
Nickel	50	50	50
Lead	70	260	600
Selenium	1	3.9	3.9
Zinc	200	360	360

2.1.1.5 Monitoring Requirements

Specific monitoring and sampling requirements are outlined for the biosolids, soils, and drinking water wells within 500 m. Records on biosolids quantity, application rate, soil and water analysis, crops grown, yield, etc., must be maintained and reported to the WSA once every two years. Monitoring wells may be required, depending on the results of the investigations.

2.1.2 US Federal Regulations Review

The US federal rule governing the land application of biosolids is included in 40 CFR Part 503. The rule governs the use and disposal of biosolids, and contains numerical limits for metals in biosolids, pathogen reduction standards, site restrictions, and record-keeping and reporting requirements for land-applied biosolids. This section includes a review of the federal requirements associated with biosolids land application.

2.1.2.1 Pathogen Criteria

The Environmental Protection Agency (EPA) defines two classes of biosolids that can be land applied: Class A and Class B. Class A biosolids must meet more stringent standards including no detectible levels of pathogens. Biosolids meet Class B requirements if pathogens are reduced to a level that does not pose a threat to the public if actions are taken to prevent exposure to biosolids after their use or disposal. Class A can be used with limited restrictions, while Class B biosolids are restricted to crops with limited human and animal exposure.

In the next sections, regulatory requirements for Class A and Class B biosolids are described. Since Class B has fewer restrictions than Class A, it is described first.

2.1.2.2 Class B Biosolids

Class B biosolids are the predominant class of biosolids produced in North America. Common treatment technologies, such as aerobic digestion, are used at many municipal wastewater treatment plants to inactivate the majority of potential pathogens in biosolids. However, the biosolids are not considered “pathogen-free”, and the EPA requires specific management practices to be employed to protect the public.

For Class B biosolids, the US EPA allows several options for pathogen reduction:

- Alternative 1: Meet monitoring requirements for fecal coliform – the geometric mean fecal coliform density must be less than 2 million colony forming units (CFU) or most probable number (MPN) per gram of biosolids.
- Alternative 2: Employ a Process to Significantly Reduce Pathogens (PSRP).
- Alternative 3: Employ a process equivalent to a PSRP.

PSRPs include the following:

- Anaerobic digestion between 15 days at 35ºC followed by 60 days at 20ºC.
- Aerobic digestion between 40 days at 20ºC and 60 days at 15ºC.
- Air drying for at least 3 months.
- Composting where the temperature of the sludge must be 40ºC or higher for at least five days, and the temperature must be 55ºC or higher for four hours of that period.

Biosolids treatment must also include a method for reduction of the attraction of vectors. Vector attraction requirements must be met for the biosolids to be considered Class A or Class B. Options for vector attraction requirements include:

- 38% reduction in volatile solids content.
- Dry biosolids with no unstabilized solids to at least 75% solids.
- Dry biosolids with unstabilized solids to at least 90% solids.

The final two biosolids disposal options are based on the treatment class defined by the US EPA. This classification requires a lesser degree of treatment, but it is also accompanied by more restrictive methods and locations for utilization.

The disposal options for future dewatered Class B biosolids include use as cover material at the Landfill or land application to agricultural sites. General management practices required for land application include: providing buffer zones around wells, surface water, and property boundaries; not causing any adverse impact to threatened or endangered species; and not applying biosolids to flooded, frozen, or snow-covered land. Biosolids must be applied at an agronomic rate; nitrogen is most commonly used to determine the agronomic rate for biosolids application. In some regions, the EPA requires evaluation of phosphorus loadings and phosphorus concentrations in soils. Some biosolids loading restrictions have been enforced based on phosphorus. Such restrictions have generally been associated with fields near surface water and at sites with a long history of high phosphorus loadings as determined by elevated phosphorus levels in soils. At this point, regulators have focused on nitrogen loadings, but future permits with some type of phosphorus criteria are possible.

Vector attraction reduction (VAR) requires the biosolids to be tilled into the soil within a specified period. In addition, Class B biosolids application is restricted to certain crop types and limited human and animal exposure. This could be a concern if biosolids are applied to hay fields or pasture areas where incorporation is limited. The general management requirements for Class B biosolids are summarized in Table 2-3.

Microbiological monitoring for either fecal coliforms or Salmonella Sp. are required at the time of biosolids use, when biosolids are prepared for sale or given away in a bag or other container for land application, or when the biosolids or material derived from the biosolids (e.g. compost) is prepared. Monitoring requirements vary by the size of the wastewater utility and the method of solids processing.

Table 2-3 Restrictions for Class B Biosolids Application

Land/Crop	Regulation
Land with a high potential for public exposure	Public access restricted for 1 year after biosolids application
Land with a low potential for public exposure	Public access restricted for 30 days after biosolids application
Food crops, feed crops or fiber crops	Not harvested for 30 days after biosolids application; in practice, 90 days is preferred if biosolids are incorporated due to cropping cycles
Food crops with harvested parts that touch the biosolids/soil mixture and are totally above the land surface (e.g. melons, cucumbers)	Not harvested for 14 months after biosolids application
Food crops with harvested parts below the land surface (e.g. root crops such as potatoes, carrots, radishes)	Not harvested for 20 months after biosolids application
Animal grazing on a site	Restricted for 30 days after biosolids application

Turf placed on land with high potential for public exposure or a lawn unless otherwise specified by the permitting authority	Restricted for 1 year after biosolids application

2.1.2.3 Class A Biosolids

Producing Class A biosolids may provide flexibility for biosolids management depending on the treatment process and the quality of the final product. For Class A, 40 CFR Part 503 requires either one of the following criteria be achieved to meet pathogen reduction requirements:

- Fecal coliform must be less than 1,000 MPN.
- Salmonella must be less than 3 MPN per 4 grams of total solids.

For Class A biosolids, 40 CFR Part 503 allows several options for meeting pathogen requirements:

- Alternative 1: Thermally treated.
- Alternative 2: High pH-high temperature.
- Alternative 3: “Other processes” – sampling required.
- Alternative 4: “Unknown processes” – sampling required.
- Alternative 5: Use of a Process to Further Reduce Pathogens (PFRP), such as composting.
- Alternative 6: Process equivalent to PFRP (requires approval of permitting authority).

Thermal treatment means that specific time-temperature requirements must be met as specified by the US EPA’s regulations. The time-temperature curves apply at different solids concentrations and contact times. All biosolids particles processed using this alternative method must be subjected to the EPA’s specified time-temperature regime.

A high pH-high temperature process is defined as the three following conditions:

- A pH greater than 12 for at least 72 hours.
- Maintaining the temperature of the biosolids above 52ºC for at least 12 hours while the pH is above 12.
- Air drying to achieve over 50% solids after the 72-hour period of elevated pH.

Class A biosolids Alternatives 3 and 4 rely on enteric virus or helminth ova testing, which can be expensive and time consuming. There are also a limited number of accredited laboratories capable of performing these analyses.

PFRPs produce Class A biosolids and include composting, heat drying, heat treatment, thermophilic aerobic digestion, beta ray irradiation, gamma ray irradiation, and pasteurization.

New processes not specified by US EPA can be considered equivalent to a PFRP. The permitting authority is responsible for determining if a process is equivalent, and this is generally the Pathogen Equivalency Committee of the US EPA.

The disposal options for Class A biosolids, on the other hand, have few restrictions due to the strict pathogen and metals standards described earlier. Class A biosolids meeting the criteria are considered exceptional quality and may be distributed to the public. Class A treatment methods generally require increased capital and operations and maintenance (O&M) costs including additional labor, power, and additional chemicals.

Table 2-4 provides a summary of pathogen reduction approaches for both PFRP and PSRP systems recognized to produce Class A and Class B biosolids.

Table 2-4 Pathogen Reduction Requirement(1)

Process	Class A Biosolids	Class B Biosolids
Alkaline Stabilization	pH > 12 for 72 hours with temperature at 52ºC for 12 hours of the high pH period Air dry to 50 percent solids	pH > 12 for 2 hours
Composting	3 days at 55ºC for in-vessel or aerated static pile 5 days at 55ºC for windrow, with five turnings	5 days at 40ºC for aerated pile and 4 hours at 55ºC for windrow
Aerobic Digestion	n/a	40-day SRT(2) at 20ºC, or 60-day SRT at 15ºC
Thermophilic Aerobic Digestion	10 days at 55ºC to 60ºC	n/a
Anaerobic Digestion	n/a	15-day SRT at 35ºC to 55ºC, or 60-day SRT at 20ºC
Air Drying	n/a	3 months total drying time, and 2 months at > 0ºC
Pasteurization	30 minutes at 70ºC	n/a
Heat Drying	Less than 10 percent solids	n/a
Heat Treatment	30 minutes at 180ºC	n/a
Beta Irradiation	1.0 megarad of beta irradiation	n/a
Gamma Irradiation	Gamma irradiation with Cobalt 60 and Cesium 137	n/a
Fecal Coliform Requirements	<1,000 MPN / gram of total solids	Geometric mean of 7 samples <2,000,000 MPN/g total dry solids
(1) Ref. Tables 4-2 and 5-1 (EPA, 2003). “n/a” = not applicable (2) Sludge Retention Time		

In addition to pathogen reduction requirements, vector-attraction reduction is required for beneficial reuse or disposal of both Class A and Class B biosolids.

Table 2-5 provides a summary of options applicable to land application or surface disposal of biosolids.

Table 2-5 Vector Attraction Reduction Options[1]

Option	Applicable to Class[1][2]	Description
1	A and B	Greater than 38% reduction in volatile solids during stabilization
2	A and B	Less than 17% additional volatile solids loss during bench scale anaerobic digestion of the sludge for 40 additional days at 30ºC to 37ºC
3	A and B	Less than 15% additional volatile solids reduction during bench scale aerobic batch digestion for 30 additional days at 20ºC
4	A and B	Standard oxygen uptake rate (SOUR) (at 20ºC is ≤1.5 mg O_2/h-g total solids)
5	A and B	Aerobic treatment of the sludge for at least 14 days at over 40ºC with an average temperature above 45ºC
6	A and B	Addition of sufficient alkali to raise the pH to at least 12 at 25ºC, and maintain a pH ≥12 for 2 hours and a pH≥11.5 for 22 more hours
7	A and B	Dry stabilized sludge to at least 75% solids content
8	A and B	Dry unstabilized sludge to at least 90% solids content
9	B	Biosolids are injected into soil so that no significant amount of biosolids is present on the land surface after 1 hour of injection
	A	Biosolids must be injected within 8 hours after PFRP
10	B	Biosolids are incorporated into the soil within 6 hours after application to land or placement on a surface disposal site
	A	Class A sewage sludge must be applied or placed within 8 hours after PFRP
11	B	Sewage sludge placed on a surface disposal site must be covered with soil or other material at the end of each operating day
12	N/A[3]	pH of domestic septage must be raised to ≥12 at 25ºC by alkali addition and maintained ≥12 for 30 minutes without adding more alkali

(1) Ref. 40 CFR Part 503, §503.33 – Vector attraction reduction
(2) Options applicable to disposal or beneficial reuse of wastewater sludge
(3) N/A = not applicable to disposal of wastewater sludge; only applies to domestic septage

2.1.2.4 Metals Criteria

Two approaches to meeting the 40 CFR Part 503 metals limits are allowed:

- The concentration in the biosolids must not exceed allowable values in Table 2-6.
  - This requires no record-keeping of cumulative loading to soils for land application.
  - If Class A pathogen reduction is also met, these biosolids may be distributed to the public.
- The cumulative amount of metals added to the soil from biosolids application must not exceed the two metrics in Table 2-7.
  - The maximum allowable metal concentrations in any biosolids applied to land.
  - The maximum allowable cumulative pollutant loading rates of metals applied to land.

Table 2-6 Pollutant Concentration in Biosolids

Pollutant	Allowable Concentration (mg/kg monthly average)
Arsenic	41
Cadmium	30
Copper	1,500
Lead	300
Mercury	17
Nickel	420
Selenium	100
Zinc	2,800

Table 2-7 Cumulative Pollutant Load Rate (CPLR) in Biosolids

Pollutant	Allowable Concentration (mg/kg dry wt.)	CPLR Loading	
		kg/ha	lb/ac
Arsenic	75	41	36.5
Cadmium	85	39	35
Copper	4,300	1,500	1,339
Lead	840	300	267
Mercury	57	17	15
Molybdenum	75	---	---
Nickel	420	420	375
Selenium	100	100	89
Zinc	7,500	2,800	2,500

Technologies to produce Class A and Class B biosolids generally do not decrease metals concentrations unless other materials are mixed with the biosolids, such as an amendment material for composting. An effective industrial pretreatment program is the key to complying with metals limits as industrial inputs into the collection system are a primary source of metals.

2.1.3 Issues of Potential Concern

Three issues have been raised that pose a potential concern for biosolids agricultural application: pathogen re-growth and reactivation, microconstituents, and public perception.

2.1.3.1 Pathogen Re-Growth and Reactivation

Recent research has shown that fecal coliform, the indicator organism commonly used for pathogens, sometimes reactivates and re-grows after mechanical dewatering of solids. This has occurred with a variety of anaerobic digestion processes for both Class B and Class A. Research is ongoing to further understand the mechanisms and causes of this phenomenon. Research to date has shown that high solids centrifuges have the greatest potential to reactivate and re-grow fecal coliform. This research could ultimately lead to changes in the regulatory requirements.

2.1.3.2 Microconstituents of Concern

The presence of trace organic chemicals (TOrCs) in municipal biosolids in the U.S. has received considerable attention by the public and scientific community over the last several years. The concern is whether the presence of TOrCs in biosolids results in significant risks to public health and the environment upon land application. While the US EPA has evaluated the risks associated with dioxins present in biosolids, there are other TOrCs of particular concern, such as steroid hormones, polybrominated diphenyl ethers, synthetic musks, steroidal chemicals, tetracycline antibiotics, antimicrobials, fluoroquinolones, brominated flame retardants, etc. Some of these TOrCs can accumulate in a variety of plants including grass, green onions, cabbage, corn, alfalfa, lettuce, radish, zucchini, and carrots. Studies have shown that bioaccumulation of TOrCs in animals, particularly invertebrates such as earthworms, is also possible.

2.1.3.3 Public Perception

Public perception can effectively impact management of biosolids in North America and regulations have been passed banning either Class B or all biosolids land application in some jurisdictions. Increasingly organized opposition to current biosolids management practices is compelling utilities to apply biosolids in more remote areas, process solids more extensively, and manage biosolids in alternative ways.

The future will likely bring substantial challenges to biosolids management. A continuation of substantial existing pressures, along with the emergence of new ones, presents serious challenges to biosolids management, likely resulting in severe restriction and increased cost of management options. This includes: the persistence of public perception and concerns, often substantially driven by odour, in combination with more emergent public health concerns (such as microconstituents) and the emergence of new regulatory actions such as managing the phosphorus component of biosolids consistent with agronomic rates.

2.2 SUMMARY

This section has provided a summary of the regulatory requirements for biosolids application to agricultural and non-agricultural land. This report was developed based on the sludge handling and treatment options target of biosolids application on non-agricultural land (landfill cover). If the City would like to explore a different biosolids application option, careful consideration should be given to the additional regulatory requirements as listed in section 2.1.1.4 and associated monitoring costs as listed in section 2.1.1.5.

3.0 IDENTIFICATION OF BIOSOLIDS DISPOSAL OPTIONS

To beneficially use biosolids, sludge must be stabilized and dewatered according to regulatory criteria as discussed in section 2.0. The most common methods in Saskatchewan for meeting the criteria of reducing pathogens and vector attraction is anaerobic digestion, alkaline digestion, or composting. This chapter identifies potential biosolids disposal options and sludge treatment options suitable for the City. The identified options are screened for further evaluation.

3.1 BIOSOLIDS DISPOSAL ALTERNATIVES

Table 3-1 presents the various biosolids disposal options along with the required biosolids quality and a relative comparison of costs. The most suitable biosolids disposal alternatives for the WWTP are land application and landfill cover due to their relative low cost. The following paragraphs provide a description of these biosolids disposal alternatives.

3.1.1 Landfill

The Humboldt landfill is located on the east side of the City, and approximately 30 km from the WWTP near Leroy. Direct landfilling of undigested sludge is feasible; however, the solids content must be increased above 20% to minimize leachate generation, spread in a thin layer, and covered immediately. WSA has requested WWTPs that directly landfill undigested sludge to upgrade their sludge handling system with a stabilization process because undigested sludge stockpiles at landfills are becoming a source of odour emissions.

3.1.2 Monofill (Class B)

A monofill is a dedicated site for surface disposal of Class B biosolids. Monofills are located, designed, and operated to assure that there will be no migration of any hazardous constituents into groundwater or surface water at any future time. Regina's WWTP includes a monofill inside one of the existing aerated lagoons.

3.1.3 Agricultural Land Application (Class B)

Agricultural land application is the placement of biosolids on land to use the biosolids' organic content and nutrients to support vegetative growth. Biosolids contain important nutrients for plant growth, such as phosphorus, nitrogen, and potassium (potash), but also contain trace inorganic chemical elements such as heavy metals which can be detrimental to soil quality and plant growth. Concentrations of heavy metals may limit the biosolids land application rate and life of the application site. Biosolids may be land applied in a liquid state or as dewatered cake. They may be spread on the soil surface, tilled into the soil, injected below the surface, or a combination of all three.

Agricultural land application of municipal biosolids is widely practiced in Canada, especially in Alberta and Manitoba. A few cities in Saskatchewan use this disposal option. It is more common for biosolids to be applied by liquid injection than by spreading as a dewatered cake. Key factors influencing farmer support of biosolids reuse are:

- Biosolids nutrient content, agronomic nitrogen requirement and application rate limit base on soil evaluation.
- Ease of application (Farmers prefer a liquid injection program to reduce solids handling, however, it increases storage and transportation costs).
- Availability of biosolids in late fall or early spring.

Table 3-1 Identification of Biosolids Disposal Options

Disposal Options	Biosolids Quality	Additional Processing after Aerobic or Anaerobic Digestion	Relative Cost
Landfill Disposal	Class B Dewatered Biosolids	None	Low
Monofill	Class B Dewatered Biosolids	None	Low
Agricultural Land Application	Class B Dewatered Biosolids	None	Low
Silviculture: Fertilizer	Class B Dewatered Biosolids	None	Moderate to High
Disturbed Land Reclamation/Rehabilitation	Class B Dewatered Biosolids	None	Low to Moderate
Alternative Intermediate Landfill Cover	Class B Dewatered Biosolids	None	Low
Alternative Final Landfill Cover	Class A/EQ Dewatered Biosolids	Pasteurization or Advanced Digestion	Moderate
Agriculture: Fertilizer	Class A/EQ Dewatered Biosolids	Pasteurization or Advanced Digestion	Moderate
Public Parks and Recreation Areas	Class A/EQ Compost or Dried Pellet	Composting or Thermal Drying Process	High
Horticulture	Class A/EQ Soil Amendment	Off-site contract composting	Moderate
Golf Course Fertilizer	Class A/EQ Dried	Thermal Drying Process	High
Biofuel Feedstock Fertilization	Class B Dewatered Biosolids	None	Low to Moderate
Direct Energy Production	Class A/EQ Dried	Thermal Drying Process	High
Direct Fuel Production	Coal-like Pellet	Proprietary Pyrolysis	Very High
Construction Materials	Glass Aggregate	Vitrification	Extremely High
Liquid Fuel	Char, Liquid Fuel	Pyrolysis	Very High
Syn Gas	Char, Syn Gas	Gasification	Very High
Incineration	Ash	Combustion/Incineration	High

3.1.4 Silvicultural Fertilization (Class B)

Similar to agriculture, forested lands can be fertilized with biosolids to increase tree yields and growth. The tree species used mostly in plantations are poplar and willows. Willows trees are used for fuel and as an amendment for composting. Typically, fertilization is limited to harvested land, new starts, and young trees due to difficulties with applying biosolids to more mature forests. Access, terrain, and slopes are key issues when applying biosolids in forests. However, this type of application is not used to a measurable degree in Saskatchewan. For facilities considering composting as a disposal option, development of a local willow plantation or a yard waste diversion program should be considered as an alternative to purchasing wood chips.

3.1.5 Disturbed Land Reclamation/Rehabilitation (Class B)

Disturbed lands include old mines and gravel pits that lack the topsoil to support vegetation. Land affected by other industrial activities or natural disasters can be rehabilitated using biosolids as well. Biosolids can provide topsoil to support vegetation, stabilize slopes, prevent erosion, and potentially restore ecosystems. Biosolids application in land reclamation is usually a one-time application, and therefore the rate of application (tonnes /hectare) is upwards of 10 to 20 times higher than in agricultural land use.

3.1.6 Intermediate/Final Landfill Cover Amendment (Class B)

Biosolids to be used as landfill cover should be dewatered to achieve soil-like characteristics. In the US, the Part 258 Landfill Rule requires that the daily landfill cover consist of 6 inches of earthen material (or alternative material or thickness approved by the state). Regulations do not establish standards for biosolids used as a landfill cover in municipal solid waste landfills.

Biosolids used as an intermediate landfill cover must comply with various requirements such as dryness (e.g., passing a paint filter test), granularity, spreadability, compactability, permeability, toxicity, odour, pathogen and vector attraction control.

Biosolids used as a final landfill cover are usually mixed with top soil to establish vegetation growth. Normally about 0.3 to 0.9 m of biosolids and top soil mixture (1:1) is applied.

Biosolids can be mixed with soil or sand and used as part of intermediate or final landfill cover material. The biosolids must be stabilized to prevent potential leachate issues and odour generation. The benefits of using biosolids in landfill cover include the reduction of landfill odours, minimizing litter, and enhancing and sustaining vegetation. This disposal option is typically considered to avoid the complexities of agricultural land application (finding farmland partners, monitoring and reporting requirements, and public support).

3.1.7 Agricultural Fertilization (Class A)

Humboldt could produce Class A biosolids for additional uses, and to open certain markets. Most metal concentrations are expected to be below the regulated pollutant concentration limits, thus providing an incentive to potential users, and thereby expanding local application opportunities.

3.1.8 Public Parks and Recreation Areas (Class A/EQ Compost or Dried Pellets/Granules)

Compost dried pellets have many benefits for soil amendment, including:

- Improves drainage and aeration of clay soils, preventing water-logged plants.
- Increases moisture and nutrient holding capacities of sandy soils, and reduced drought damage to plants.
- Keeps nutrients in the soil near plant roots, and it can immobilize and degrade pollutants.
- Prevents crusting on the top of the soil and helping seeds to sprout and water to percolate into the soil.

3.1.9 Composting

Compost can be used as organic mulch for residential or commercial gardening and landscaping. Additional processing steps such as screening and bagging may be required. If operated by the City, it would be necessary to construct a composting facility at the landfill site because of space requirements and potential generation of odours. In addition, a building may be required to house the compost equipment.

3.1.10 Dried Pellet / Granules

Dried biosolids pellets or granules are similar in particle size to commercial inorganic fertilizers. In the fertilizer industry, the drying process is called "prilling". Dried pellets are typically 90 to 95% solids with NPK (nitrogen: phosphorus: potassium) ratios similar to the cake biosolids from which they are derived (approximately 6:5:0).

The pellets are produced using a thermal drying process after stabilization of the solids (typically via anaerobic digestion). There are several commercially available systems. Systems that provide a method for particle size classification are preferred due to the market demand for homogeneous particle sizes and dust-free products.

Drying and composting are relatively common practices. Both result in products that are aesthetically acceptable to the public.

3.1.11 Horticulture (Class A/EQ Soil Amendment)

For the nursery and landscaping market, biosolids would be treated with a post-digestion process that achieves Class A standards and produces a soil amendment that appeals to the public and the landscaping industry. This would be expected to result in a product with salable value. Mulch and potting soil could be created by amending cake biosolids with sand, sawdust, wood chips, or other desirable materials.

3.1.12 Golf Course Fertilizer (Class A/EQ Dried Pellet)

Dried biosolid pellets are similar in particle size to commercial inorganic fertilizers. Dried pellets are well-suited to spreading by conventional golf course fertilizer application equipment. Particle size classification is critical for the golf course market.

3.1.13 Biofuel Feedstock Fertilization

Increased interest and demand for biofuels as an alternative to fossil fuels has led to production facilities all over North America. Some processes and production facilities use locally grown crops as a feedstock for producing biodiesel and ethanol. These crops could be fertilized with Class A or B cake biosolids.

3.1.14 Glass Aggregate Production

Vitrification is the process of melting waste materials at high temperatures. It was developed as an alternative for managing nuclear waste. Dried (>90%solids) biosolids are combusted in an oxygen-rich atmosphere at temperatures of 1315°C to 1482°C. This results in complete destruction of organic material, and the residue melts to form molten glass. The glass has several potential uses, such as sandblasting grit, asphalt paving, or roofing shingle granules. Besides total elimination of pathogens and toxic organics, the process is said to permanently immobilize potentially toxic metals. This is considered an "innovative" technology, and has been implemented in Zion, Illinois to generate about 6.8 tonnes/d of glass aggregate.

The process is a form of incineration, but there are technical differences from conventional systems. The obvious difference is the production of usable glass aggregate rather than a waste ash that is typically discarded in a landfill. This occurs because of the significantly higher temperatures in the combustion chamber. Another difference is the use of a closed loop gas system in which most exhaust is recycled back to the fluidized bed dryer. This reduces the system exhaust to a relatively low level. This is made possible using the oxygen injection system that provides the oxygen needed for combustion.

3.1.15 Solid Fuel (Coal Alternative) Production

This option includes various means of using the inherent heating value in biosolids to create usable energy. Several private firms have begun to offer biosolids management services through their proprietary biosolids-to-energy processes. Some offer management at their own facility, which eliminates the need to find a site for a facility and finance capital improvements. Two such vendors are EnerTech and Cement Kilns. These facilities have been implemented for wastewater plants producing large amounts of biosolids.

3.1.16 Liquid Fuel/Syn Gas Production

This option includes various means of using the inherent heating value in biosolids to create usable energy. There are two possible processes: Pyrolysis and Gasification.

3.1.16.1 Pyrolysis

Pyrolysis chemically converts complex organic molecules to simpler molecules using heat treatment in the absence of oxygen. Drying is a required pretreatment step for medium and high temperature pyrolysis, but not for low temperature pyrolysis. Depending on the type of pyrolysis, the biosolids convert to gas, liquid (or oil), and char. Recycling and waste streams contain high concentrations of contaminants which require industrial treatment systems. Some of the intrinsic heating value of the biosolids is lost in pyrolysis. For low temperature pyrolysis, the partial loss in heating value is partly or wholly recovered in improved mechanical dewaterability of the product. The product streams are rich with energy, however, and may be used in a burner or electricity generator. The net energy yield from pyrolysis varies from negative to slightly positive.

3.1.16.2 Gasification

Pyrolysis solids or char are amenable to further processing and conversion into a fuel gas or a syngas. Using starved air combustion, organic molecules are converted to hydrogen gas, carbon monoxide gas, and other minor gas constituents. Syngas typically has a heating value between 125 and 350 BTU per cubic foot. The gasification process relies on exothermic reactions, thus making the process self-sustaining. Post treatment of the syngas removes corrosive compounds and dries the gas prior to use in gas turbines, boilers, and internal combustion engines. Slag and other metals are residual waste products. Waste flue gas requires monitoring and treatment to control pollutant discharge. Wastewater treatment is necessary for scrubber blowdown if wet scrubbers are used for syngas treatment or waste gas pollution control.

3.1.17 Incineration

Incineration is combustion at high temperatures in the presence of oxygen. The organic portion of biosolids can be combusted. Organic matter, which is approximately 70 to 85% of the solids, is removed and the material left is inert inorganic ash. The ash is typically disposed in a landfill, but it can be recycled in construction materials such as concrete.

Typically, raw (undigested) solids are combusted as digestion reduces the heat energy value of the solids, decreases the dewaterability of the solids, and increases costs for processing.

Federal and provincial air emissions requirements for sewage sludge incinerators include limits on heavy metals, carbon monoxide or total hydrocarbons, and other organic compounds. There are also required management practices such as temperature and instrument maintenance and operating conditions for air pollution control equipment.

3.2 SCREENING OF BIOSOLIDS DISPOSAL OPTIONS

The most suitable biosolids disposal alternatives for the Humboldt WWTP are landfill disposal, agricultural land application, and intermediate landfill cover due to their relative low costs. Many of the biosolids management alternatives described above are not applicable to the City of Humboldt due to following reasons:

- Silvicultural fertilization and disturbed land reclamation options do not have a viable market near Humboldt.
- Public parks, horticulture, and golf course fertilizer options have permitting challenges, public perception of the alternatives may be negative, and they have high costs.
- Liquid/solid fuel, glass aggregate and incineration options are very expensive for a medium size WWTP due to their high level of complexity. These options are also highly susceptible to changes in market price and demand. In addition, public perception of these options may reduce the likelihood of implementing the option in a reasonable time frame.

4.0 SLUDGE MANAGEMENT ALTERNATIVES

There are several alternative processes and emerging technologies that can be used to thicken and stabilize the sludge generated by the liquid treatment process. Improvements in sludge quality and cost savings can be expected with some pre-treatment and process upgrades. Several post-stabilization processes can broaden the range of potential recycle/reuse options. Alternative sludge treatment processes can be classified in four categories:

- Sludge Thickening
- Sludge Stabilization
- Sludge Dewatering
- Sludge Storage

These sludge processing alternatives are illustrated in Figure 4-1 for their potential combinations.

Sludge Management Alternatives
February 1, 2019

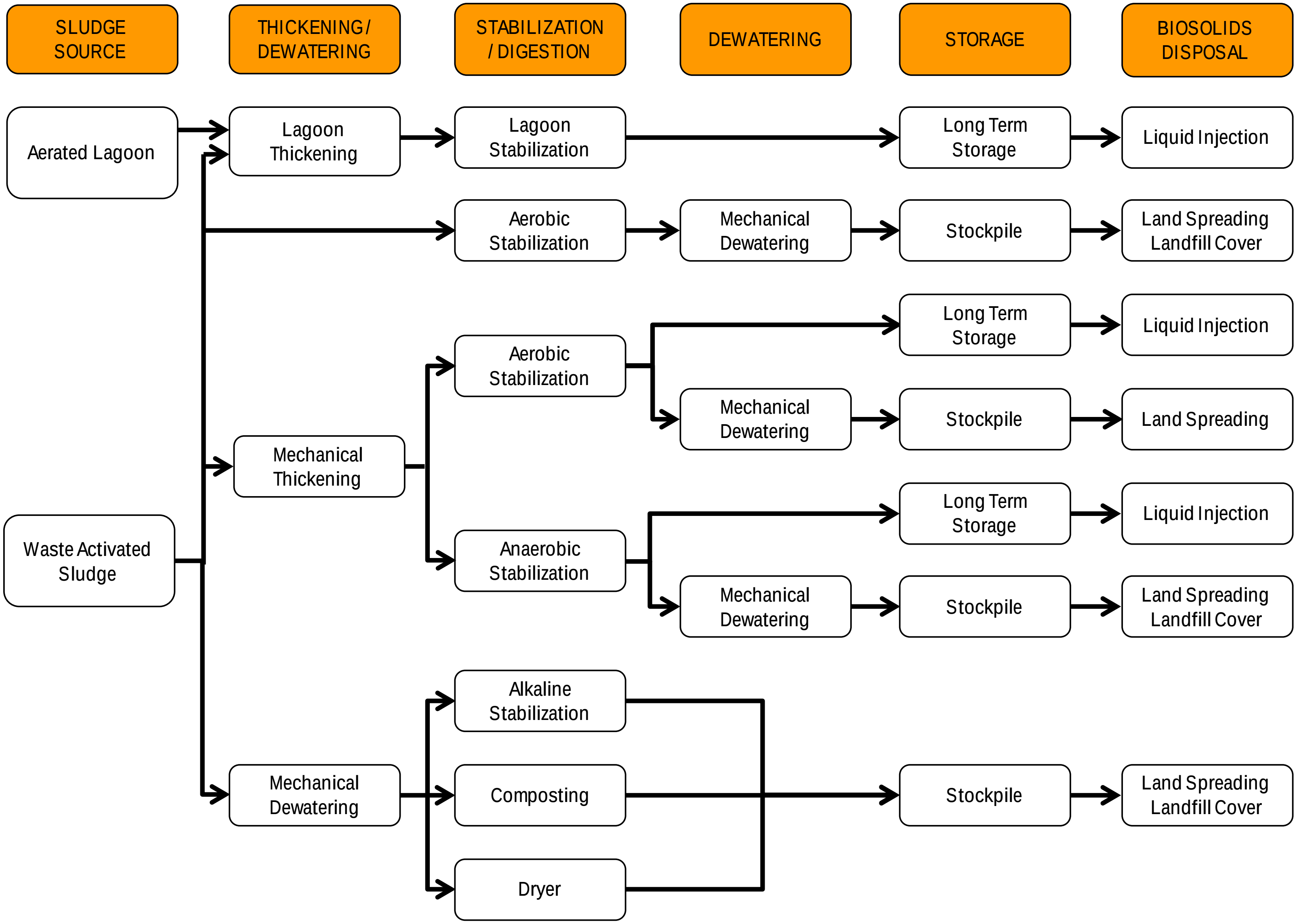

Figure 4-1 Sludge Processing Alternatives for Humboldt WWTP

4.1 WASTE ACTIVATED SLUDGE THICKENING

Waste activated sludge generated in the bioreactor is very diluted, with a total solids concentration less than 1% (10,000 mg/L). Thus, thickening is required to increase the solids content in the sludge above 3% solids, and to reduce the volume of sludge stabilization tanks and downstream processing equipment. Some stabilization processes require mechanical dewatering of the sludge, functioning properly at solids contents above 15%.

Technologies listed below can be also for dewatering except for dissolved air flotation and a rotary drum thickener.

4.1.1 Dissolved Air Flotation

In the dissolved air flotation (DAF) thickening process, air is introduced to the sludge at a pressure above atmospheric pressure. When the pressure is reduced to atmospheric pressure and turbulence is created, excess air (above saturation) leaves the solution as fine bubbles. These bubbles attach to the solid particles and raise them to the liquid’s surface. The floating solids are then collected by a skimmer and discharged into a trough. DAF is most commonly used for biological sludge thickening for medium and large sized WWTPs. The performance of DAF is subject to the sludge characteristics (e.g. Solids Volume Index, SVI) and operating conditions (e.g. air to solids ratio). Typically, DAF can achieve 85% solids capture for biological sludge thickening without adding polymer, and a solids concentration of 3.5%. The capture rate can be improved by polymer addition. The thickened biological sludge concentration can also be as high as 6% with polymer addition, which may result in bulk sludge volume reduction by about half compared to 3.5% thickened solids. Table 4-1 summarizes the advantages and disadvantages of DAF.

Table 4-1 Advantages and Disadvantages of DAF

Advantages	Disadvantages
Provide high solids concentration	Large footprint
Low speed process	Very odourous process
Low energy use	Complex start-up
Excellent performance	Air saturator fills with solids if subnatant is reintroduced into the process
Not impacted by grit	Moderate operator attention
Low polymer usage	
Relatively simple components	

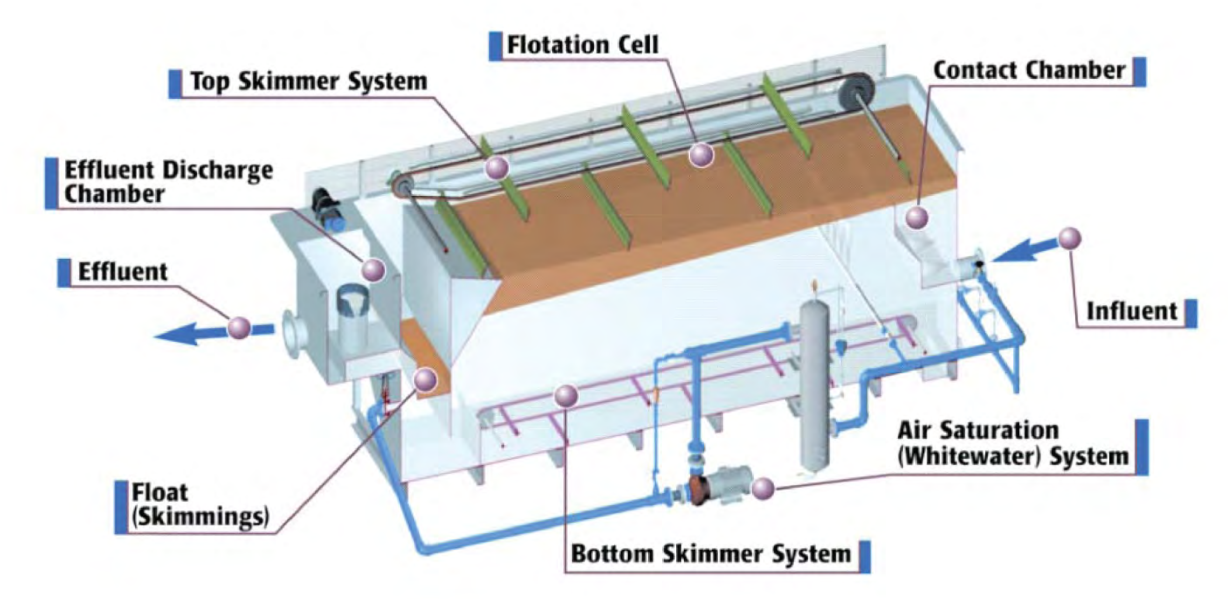

Figure 4-2 Dissolved Air Floatation Unit (adopted from ETS)

4.1.2 Rotary Drum Thickener

A rotary drum thickener (RDT) consists of a rotating drum and an external variable speed drive. A cylindrical screen inside the rotating drum captures solids as it rotates, allowing water to pass through the screen. An auger located inside the screen transports the remaining solids from the feed end of the drum to the outlet. Like other thickening processes, polymer addition is required to increase the solids capture rate and is added upstream of the drum in a flocculation tank. RDTs generally can handle moderate variations in flow and sludge consistency without adjustments to the drum or flocculator speeds. Washwater is required to periodically clean the drum to improve thickening.

RDTs have a small footprint, low horsepower, and few moving parts. The RDT is a slow-moving thickening unit that is simple to operate and maintain and has been used successfully in municipal plants to thicken WAS (no primary treatment) in Canada. Figure 4-3 shows a schematic of an RDT. Table 4-2 summarizes the advantages and disadvantages of RDTs.

Table 4-2 Advantages and Disadvantages of Rotary Drum Thickener

Advantages	Disadvantages
Low energy use	Large footprint
Low speed process	Performance highly dependent on sludge characteristics
Easy shutdown capabilities	Moderate to high polymer use
Few moving parts	Odour potential
Less impacted by grit	Moderate operator attention
Moderate noise level	

Figure 4-3 Rotating Drum Thickening (adopted from Vulcan Technologies)

4.1.3 Screw Thickener

Screw thickeners operate in a similar manner to RDTs by using a screen that allows water to pass while capturing solids. The screw thickener is oriented at an angle to allow an auger, located inside the screen, to transport solids from the bottom of the thickener to the top, while water flows through the screen and out the bottom of the thickener. Like the RDT, screw thickeners have minimal moving parts requiring maintenance. The motors required to operate the auger are small and require much less energy compared to a centrifuge. Table 4-3 summarizes the advantages and disadvantages of a screw thickener.

Table 4-3 Advantages and Disadvantages of Screw Thickener

Advantages	Disadvantages
Low energy use	Large footprint
Low speed process	Performance highly dependent on sludge characteristics
Easy shutdown capabilities	Moderate to high polymer use
Few moving parts	Odour potential
Less impacted by grit	Moderate operator attention
Moderate noise level	

4.1.4 Gravity Belt Thickener

Sludge is fed into a gravity belt thickener (GBT) over a porous serpentine belt that acts as a filter, allowing water to drain through while capturing solids on the belt. A polymer is mixed with the sludge prior to entering the GBT to increase the solids capture efficiency. A substantial volume of high-pressure wash water is required to clean the belts.

Typically, GBTs require a substantial amount of fine-tuning of the belt tension, which causes high operational costs compared to other thickening processes. GBT design considerations include curbs around the unit to capture the wash water. A schematic of a GBT is provided in Figure 4-4. Table 4-4 summarizes the advantages and disadvantages of a GBT.

Table 4-4 Advantages and Disadvantages of BFPs

Advantages	Disadvantages
Less impacted by grit	Dirty appearance, poor odour containment
Low speed process	Large footprint
Low energy use	Many moving parts
Low polymer use	High noise level
Easy shutdown capabilities	High volume of washwater
Easy to operate and maintain	Close supervision required

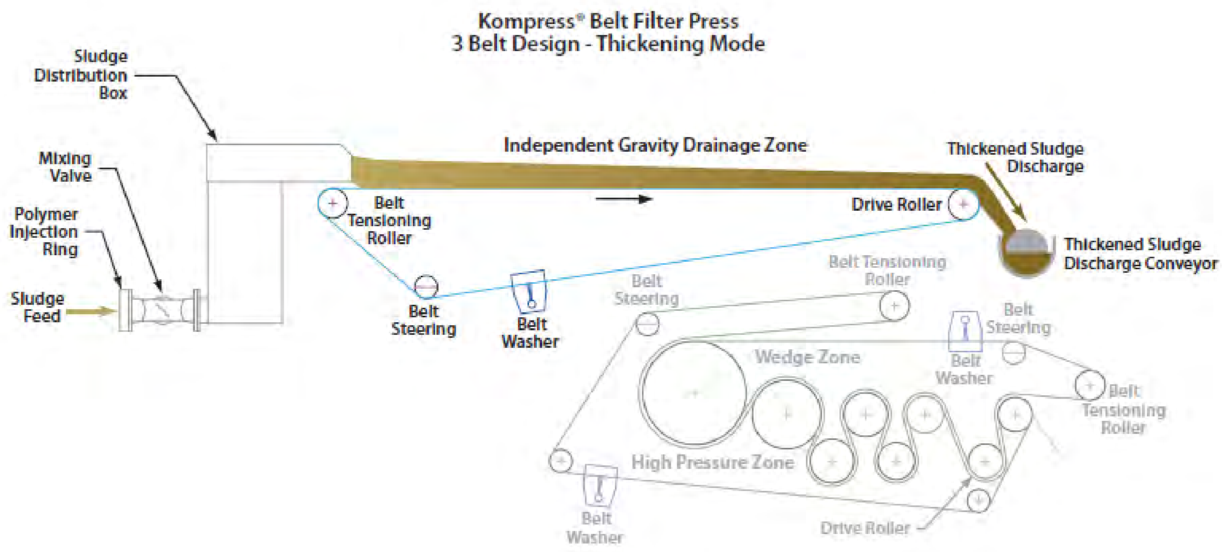

Figure 4-4 Schematic of a GBT (adopted from Komline-Sanderson Corp.)

4.1.5 Gravity Thickener

Gravity thickeners function in a similar manner to sedimentation basins where the solids settle via gravity and are compacted on the bottom while the decanted liquid flows over the weirs. Center drive mechanisms, like primary clarifiers, are used to scrape the settled and thickened sludge to a hopper for pumping to the digester.

Gravity thickeners operate best for primary and lime sludge but can also be effective for trickling filter solids or anaerobically digested solids (WEF MOP 8, 2010). Gravity thickening of biological solids (WAS) has lower capture rates, and the thickened sludge typically contains 2 to 3% solids. Polymer is not typically added to gravity thickeners. Table 4-5 summarizes the advantages and disadvantages of gravity thickeners.

Table 4-5 Advantages and Disadvantages of Gravity Thickeners

Advantages	Disadvantages
Low energy use	Large footprint
No polymer use	Odour potential
Easy shutdown capabilities	Erratic or poor solids concentrations for WAS
Less operator skill required	Floating solids
Less impacted by grit	
Reduced noise level	

4.1.6 Centrifuge

Centrifuges are a proven technology for thickening WAS. A centrifuge operates by allowing sludge to enter a stationary tube where it is fed into a rotating bowl that contains an accelerating inlet rotor. The rotor rotates at speeds up to 3,400 revolutions per minute, creating a centrifugal force that pushes solids to the outer wall of the bowl as shown in Figure 4-5. Solids are conveyed out of the unit, and the separated liquid (centrate) is returned to the headworks.

A centrifuge typically has a small footprint and can produce a more concentrated sludge than other technologies. Typical polymer dosage in a centrifuge is lower than other thickening technologies. Conversely, a significant amount of energy is required to create the centrifugal forces that separate the solids and liquids. High speed equipment like a centrifuge experiences wear on the equipment faster than other, slower rotating equipment. Table 4-6 summarizes the advantages and disadvantages of centrifuges.

Table 4-6 Advantages and Disadvantages of Centrifuges

Advantages	Disadvantages
Clean appearance, Good odour containment	Scroll wear, factory inspection required every 3 - 5 years
Fast start-up and shutdown capabilities	Grit removal is imperative
Small footprint	Skilled maintenance personnel required
Good odour containment	Energy intensive
	Moderate polymer use
	High noise level
	Worn items need to be refurbished at factory
	Slop produced at start up and shutdown

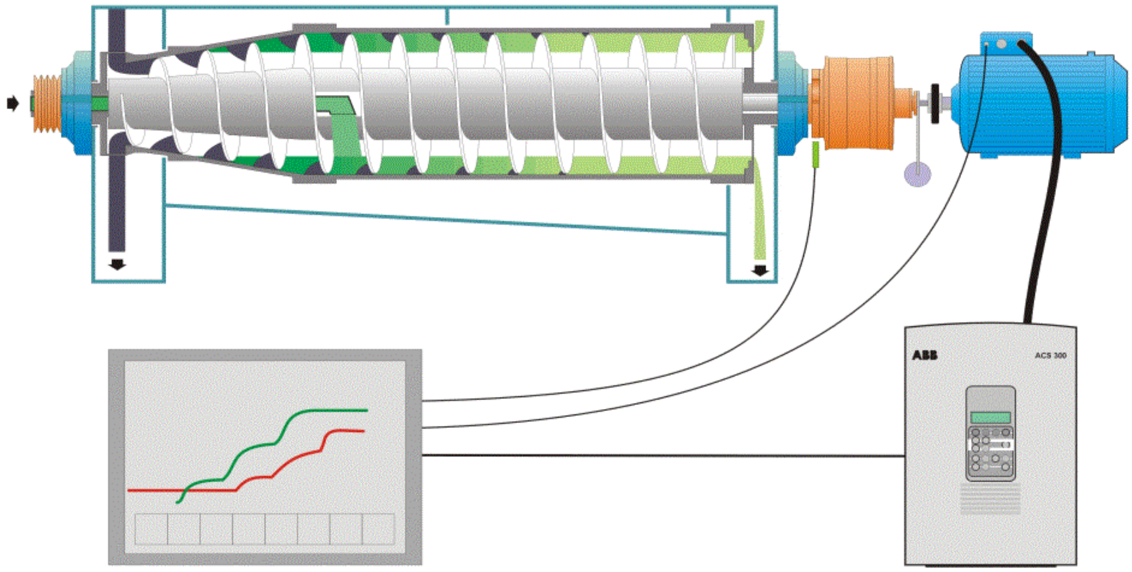

Figure 4-5 Schematic of a Centrifuge (adopted from Alfa Laval)

4.1.7 Recommended Thickening Option

The technologies that were screened as thickening alternatives each have proven track records at municipal installations. Since gravity thickening is not recommended for thickening biological solid waste, it was not considered further. Centrifuges and GBTs do not suit the City's interests related to maintenance and operator attention. The staff may prefer equipment that operates at slow speeds and is simple to operate and maintain, as well as requiring limited operator attention. For the thickening process, rotary screen thickeners are recommended.

4.2 SLUDGE STABILIZATION

Sludge stabilization is required to reduce aesthetic impacts of solids (e.g. odour generation and appearance), vector-attraction characteristics, waste volume and mass, and to improve dewaterability of the biosolids. There are various sludge stabilization processes including aerobic digestion, aerobic-anoxic digestion, anaerobic digestion, and alkaline digestion.

Two forms of solids digestion are commonly used for small wastewater treatment: anaerobic and aerobic. Anaerobic digestion is preferred when feasible as it produces a fuel (methane) and can lower plant energy costs. Anaerobic digestion, however, is more complex to operate, and the capital costs are greater than aerobic digestion. Typically, aerobic digestion is utilized for facilities with influent flows up to 20,000 m^3/d. For influent flows greater than that, anaerobic digestion becomes more economically feasible.

4.2.1 Aerobic Digestion

Aerobic digestion consists of oxidation of sludge in the presence of oxygen in a suspended growth environment. To meet Class B requirements, aerobic digestion requires longer detention times than anaerobic digestion, particularly in cold environments. The volatile solids reduction is typically much less in aerobic digestion compared with anaerobic digestion.

Aerobic digestion achieves a good volatile solids (VS) reduction, provides a return stream with low BOD and nutrient concentrations, provides a low-odour product, and recovers some of the nutrients which have a beneficial fertilizer use (WEF MOP 8, 2010). However, it requires high power consumption, and produces a digested sludge which is more difficult to dewater. In addition, the process is sensitive to water temperature changes, and its pathogen and solids reduction is significantly reduced at water temperatures below 15°C.

Conventional aerobic digestion can be used to produce a Class B biosolids product. Due to the cold-weather climate, the design will require a 60-day SRT at 15°C. The 60-day SRT was selected to meet the 40 CFR 503 regulations for Class B biosolids. An aerobic digester can be almost any shape. Table 4-7 summarizes the advantages and disadvantages of aerobic digestion.

Table 4-7 Advantages and Disadvantages of Aerobic Digestion

Advantages	Disadvantages
Substantial reduction of pathogens	No usable gas is produced
Simple operational control	Energy Intensive (high due to requirement for mixing and oxygen transfer)
Resulting biosolids generate low odour	Digestion performance is reduced by cold temperature
Low capital cost	Excessive foaming
Low strength supernatant	Poor sludge dewatering characteristics
Widely used	Lower VS reduction than anaerobic digestion
Reduce sludge mass	Reduce pH and alkalinity

4.2.2 Aerobic/Anoxic Digestion

Typical aerobic digester operation can provide both aeration and mixing through one process, like a pumped mixing system. With the increasingly stringent nutrient limits, the recycle load from the digester can be significant (i.e. BOD of 500 mg/L, TSS of 100 to 300 mg/L, TKN of 170 mg/L and Total Phosphorus of 98 mg/L) and can cause elevated nutrient concentrations in the plant effluent. One way to decrease the total nitrogen concentration in the recycle load is to operate the digester to achieve nitrification and denitrification. This will require the option of operating with cyclical aeration and the addition of a mixer for periods when the air is off.

Aerobic / Anoxic digestion is a more stable process than aerobic digestion since it maintains water pH and alkalinity above 6.8 and 80 mg/L, respectively. Aerobically digested sludge undergoes nitrification if excessive aeration is provided (DO above 0.5 mg/L) for an extended period. Cycling the aeration system reduces the DO content in the water and switches the microorganism metabolism to use nitrates as a source of energy instead of oxygen. Table 4-8 summarizes the advantages and disadvantages of aerobic-anoxic digestion.

Table 4-8 Advantages and Disadvantages of Aerobic-Anoxic Digestion

Advantages	Disadvantages
Substantial reduction of pathogens	No usable gas is produced
Better sludge dewatering characteristics than aerobic digestion	Digestion performance is reduced by cold temperatures
Resulting biosolids generate low odour	More complex operational control than aerobic digestion
Maintain pH and alkalinity	Not as common as an aerobic digestion
Less foam production than aerobic digestion	
Less energy intensive than aerobic digestion	
Low strength supernatant	
Low capital cost	

4.2.3 Anaerobic Digestion

The anaerobic digestion process involves three distinguishing reactions in sequence: hydrolysis, acidification, and gasification. Complex organic molecules in sludge, i.e. the biomass cells, are first hydrolyzed to soluble simple organic substrates. In the following acidification stage, these organic substrates are fermented to simple acids and hydrogen gas by fermentative microorganisms. Methanogenic bacteria will utilize these simple acids and hydrogen gas to produce methane and carbon dioxide in the gasification stage, thus accomplishing volatile solids (VS) reduction. In these sequential reactions, methane formation followed by hydrolysis is commonly the rate limiting stages in anaerobic digestion, particularly for biological sludge. Table 4-9 summarizes the advantages and disadvantages of anaerobic digestion.

Table 4-9 Advantages and Disadvantages of Anaerobic Digestion

Advantages	Disadvantages
Substantial reduction of pathogens	Complex process
Generation of methane gas	Slow start-up and recovery after upset
Resulting biosolids are suitable for land application	Requires skilled operators
Good VS destruction	Safety issues related to flammable gas and H_2S
Widely used for medium sized plants	High strength supernatant
Low net energy use	Difficult cleaning
Reduced sludge mass	Generate nuisance odours

4.2.4 Alkaline Stabilization

Alkaline stabilization is a well-established process to deodorize and stabilize night soil and manure. Lime treatment has recently gained popularity as an effective option for controlling pathogens in sludge. A dewatering system is the precursor to alkaline stabilization technology. An alkaline compound is added to the sludge before or after dewatering to raise the pH above 12 and to bring the temperature within a range of 52°C to 77°C for the period required by regulations. The most common alkaline compounds are hydrated lime ($Ca(OH)_2$, also known as calcium hydroxide or slaked lime), quicklime (CaO) and potassium hydroxide (KOH). Other alkaline compounds that have been used include cement kiln dust, lime kiln dust, Portland cement, and fly ash. The proper and thorough mixing of sludge and the alkaline compound has been considered critical for proper stabilization.

When lime is used, it may be added in either liquid or dry form. For dry lime alkaline stabilization, biosolids are dewatered prior to mixing with the lime. This mixture is then typically dried and cured, resulting in a product with a soil-like consistency (WEF, 1995). In liquid form, a lime slurry may be added to stabilize and thicken the biosolids prior to land application (e.g. by subsurface injection). Alternatively, lime slurry may be added to stabilize and condition the sludge prior to dewatering, in which case, other conditioners such as aluminum or iron salts would typically be added to enhance dewatering.

When quicklime (CaO) is used, it reacts with water in an exothermic reaction that can achieve temperatures above 700°C. This not only pasteurizes the biosolids but can convert it into a soil-like material. Additional heat needed to dry the treated biosolids may be supplied in a vessel such as a drum or rotary dryer. Moisture reduction may be achieved by air drying in windrows. If heat drying is applied, the final product may have a solids content of 50 to 60%, or greater (WEF, 1995).

Advanced alkaline stabilization methods involve the use of chemicals (in addition to lime), high chemical addition rates, and supplemental drying. The methods are designed to increase the stability of the product, decrease the odour potential, and further reduce pathogens. One such method involves the addition of “pozzolanic” materials, which are enriched in silica-based compounds (such as fly ash, cement kiln dust or pumice), which react with calcium hydroxide at normal temperatures to form compounds that have cement-like properties.

Long-term storage of lime-stabilized biosolids require either additional treatment to maintain elevated pH, drying, or future treatment to avoid problems with re-growth of pathogenic bacteria.

Lime-stabilized biosolids can be used for agriculture and reclamation. This product could be applied in parks and common areas but is not generally as desirable as compost for these applications due to increased potential for odour, and less desirable aesthetic properties.

A variety of proprietary lime stabilization systems are commercially available, and include the following:

- RDP EnVessel Pasteurization
- Schwing Bioset
- FKC Screw Press Dewatering and Pasteurization
- N-Viro Process
- Lystek

The Lystek process operates at ambient pressure and lower temperatures (70 °C), so high pressure steam is not required. Since it operates after dewatering, it does not generate a high strength centrate that requires further treatment. A high solid-liquid, Class A fertilizer is produced that is much less costly to land apply than dewatered biosolids. Table 4-10 summarizes the advantages and disadvantages of alkaline stabilization.

Table 4-10 Advantages and Disadvantages of Alkaline Digestion

Advantages	Disadvantages
Substantial reduction of pathogens	Requires the addition of chemicals
Capable of producing Class A biosolids	Sludge production increase with the addition of alkaline compound
Easy operation	No usable gas is produced
Low capital cost	Requires skilled operators
Small foot print	High operating costs if Potassium hydroxide is used
Resulting biosolids have reduced pathogens and odours	Excess lime is required to prevent a decrease in pH and pathogen regrowth
	Additional labor required to manage covered biosolids storage pond

4.2.5 Composting

Composting is a process that involves the decomposition of organic materials by microorganisms under aerobic conditions. It is a self-heating process that destroys pathogens and produces material similar to soil humus. Well stabilized compost can be stored for long periods of time and has minimal odour. The product is a dark, humus-like material, useful for soil amendments and other beneficial uses. The key factors influencing the process include carbon to nitrogen ratio, oxygen control, temperature control, and moisture content. In the presence of oxygen, the rate of composting is faster and odour is minimized. Composting takes place in three main stages: mixing with the bulking agent, active composting under elevated temperatures, and a period of curing which can take up to 6 months. During active composting, the compost is usually heated to 50-70°C for thermophilic composting. In the curing stage, the temperature drops, allowing a stable and mature compost to be formed. Sufficient moisture content is needed for microbial activities. However, too much moisture will decrease the void spaces of the compost, resulting in reduced oxygen transfer. A bulking agent or an amendment such as wood chips and saw dust is often adding to the compost to reduce moisture content and increase the porosity of compost for more efficient aeration. The composting process can be accomplished using aerated static piles, windrows, or by in-vessel methods. All three options follow three main stages. An aerated static pile composting operation would be suitable for the City. In addition, it provides better oxygen control, and is more compact. It is also typically less capital cost-intensive than in-vessel composting. Composting of dewatered undigested sludge can have significant odour issues and thus careful consideration should be given to air handling system to provide a safe working environment. In an aerated static pile system, the compost shall be maintained at 55°C for more than 3 days to meet pathogen kill requirements.

The City could also consider implementing a low-tech windrow composting, like the one used by the City of Medicine Hat, which operates year-round. During winter, temperatures of 55°C are achieved within the windrow piles although additional days of composting are required to achieve these internal temperatures. Odour management is achieved by ensuring the correct carbon to nitrogen ratio in the mix of one-part undigested dewatered sludge and three parts of amendment materials, which is a mix of straw and wood chips. Odour control is also achieved by turning rows to maintain aerobic conditions within the pile. Turning frequency depends on the rate of decomposition. During the beginning, high-rate phase, turning could be a daily requirement. As the process continues and nutrients are depleted, turning can be gradually reduced to once a week or less, depending on the temperature and oxygen levels. Rows are turned using a tractor-drawn turner or a self-propelled turner unit, as shown in Figure 4-6. Composting mainly takes place during summer and fall over a two to five-month period before moving to a curing pile for four to nine months. To meet pathogen kill requirements, the windrow system's compost shall be maintained at 55°C for more than 15 days and turned at least five times during this stage.

Recently, compost windrow fleece covers have been used to improve the quality of the compost. These covers are made from a breathable material which allows for air circulation, retains heats and humidity, and sheds excess rainwater. A 150 mm layer of finished compost has also been used to cover the pile to reduce dryness, heat loss, and flies. The finished compost also acts as a biofilter for odorous gases.

Figure 4-6 Self-Propelled Windrow Turner

Composting is a proven technology that requires moderate to high operator attention. Increased operator time will be required to move and mix the bulking agents and dewatered solids into the aerated static piles. Composting does not require chemical addition or natural gas, and it is assumed that a bulking agent is available in the area. The product typically has an earthy odour. Compost is typically not used for turf application. Table 4-11 summarizes the advantages and disadvantages of composting.

Table 4-11 Advantages and Disadvantages of Composting

Advantages	Disadvantages
Proven process for cold weather	Requires the addition of a bulking agents
Substantial reduction of pathogens	Requires a significant area
Capable of producing Class A biosolids	Requires 18 to 30% dewatered solids
Resulting biosolids have minimum pathogens and odours	Sludge production is increased by the addition of bulking agent
Can be combined with other stabilization	Requires skilled operators
Low capital cost	Potential for odour generation
	A building is required to house equipment during
	High operating cost

4.2.6 Drying

Sludge drying is typically used after stabilization to produce Class A Biosolids which are used on parks, golf courses, and general turf applications. Heat drying will reduce pathogenic viruses, bacteria, and helminth ova to below detectible levels, and also reduce the water content of the biosolids. Two basic types of sludge drying processes are used: indirect (auger screw, paddle), and direct (belt dryers, rotary drum dryers). Numerous manufacturers use these methods to increase the percent solids to at least 90%. Thus, the volume of biosolids produced by drying is much lower than any other sludge treatment methods.

Sludge drying is a proven technology that requires moderate to high operator attention. Drying requires no chemical addition; however, there are increased power and natural gas requirements. Due to the degree of dryness, there is limited odour in the end product. Dried biosolids are desirable for turf application if not too dusty, among other uses. Table 4-12 summarizes the advantages and disadvantages of drying. Figure 4-7 shows a picture of a sludge drying unit.

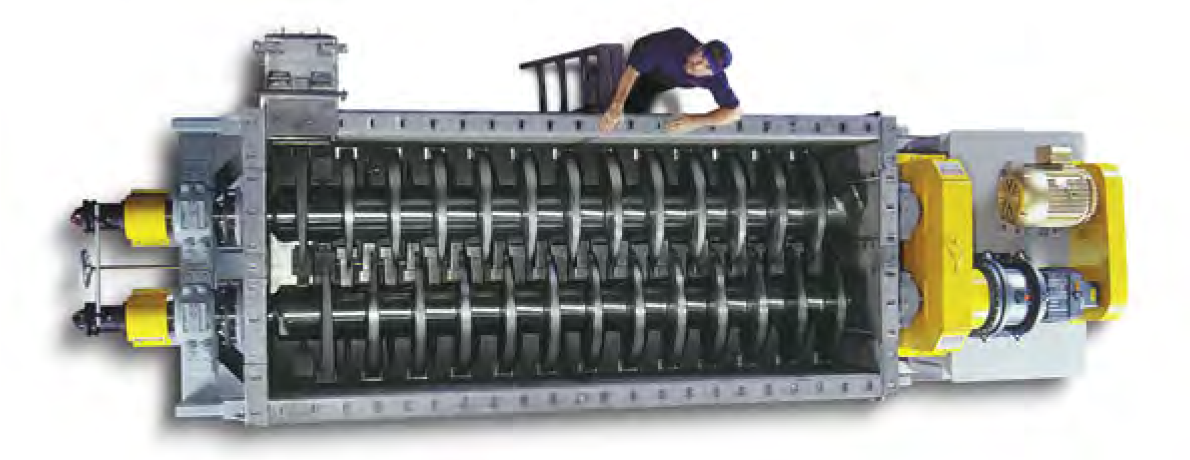

Figure 4-7 Sludge Drying (adopted from Komline-Sanderson Corp.)

Table 4-12 Advantages and Disadvantages of Drying

Advantages	Disadvantages
Substantial reduction of pathogens	Energy intensive
Substantially reduces volume	Produces an off gas that must be treated
Capable of producing Class A biosolids	Grease content in the sludge decreases heat transfer rate
Resulting biosolids have reduced pathogen and odours	Requires skilled operators
It can be started quickly	No usable gas is produced
Retain nutrients	High capital and operating costs

4.2.7 Sludge Thickening/Stabilization and Storage in Lagoons

In Western Canada, lagoons have been widely used to thicken or stabilize sludge, as well as for storage. Sludge lagoons can provide effective means for stabilization of waste activated sludge without excessive odour generation if designed and operated properly. Sludge lagoons are built to maintain an aerobic surface layer free of scum. The surface layer is usually 0.3 to 0.9 m in depth and supports a dense population of algae. Dissolved oxygen is supplied to this layer by algal photosynthesis by direct surface transfer from the atmosphere. To maintain the aerobic top layer, the organic loading rate to the lagoon should be carefully evaluated. The oxygen is used by microorganisms in the aerobic degradation of colloidal and soluble organic matter in the sludge, while the solids settle to the bottom of the lagoon, where they decompose anaerobically. Supernatant is returned periodically to the front end of the wastewater treatment plant. Decanting of supernatants allows an initial sludge feed concentration of about 1% solids to thicken to a concentration greater than 4%. Sludge removal should be conducted before the water layer over the sludge is less than 0.6 m. The left pictures in Figure 4-8 show a lagoon being de-sludged and sludge dewatering using a dredge and centrifuges, with temporary storage before final disposal. The bottom picture in Figure 4-8 shows a lagoon being de-sludged, and dewatering using a dredge and geotextiles. The top-right picture in Figure 4-8 shows a lagoon being de-sludged by a dredge, and the sludge being screened and stored in a temporary storage tank (Frac Tank) at the lagoon site for future use as agricultural fertilizer. The biosolids are then removed from the Frac Tank, and transported to a farm for land injection using mobile sludge injection equipment (QuadVac),

The existing lagoons could be reused for this purpose. However, periodic sludge removal will be required to minimize odour generation that may otherwise cause complaints from residences near the WWTP.

Table 4-13 Advantages and Disadvantages of Lagoon Thickening/Stabilization/Storage

Advantages	Disadvantages
Long term storage	Land use intensive
Sludge anaerobically stabilization in summer	May produce odours in early spring
Requires minimum operator attention or skill	High strength supernatant
Low operating cost (no chemicals if can be injected as a liquid)	No usable gas is produced
Low capital cost when there is an existing lagoon	High operating cost every three to four years

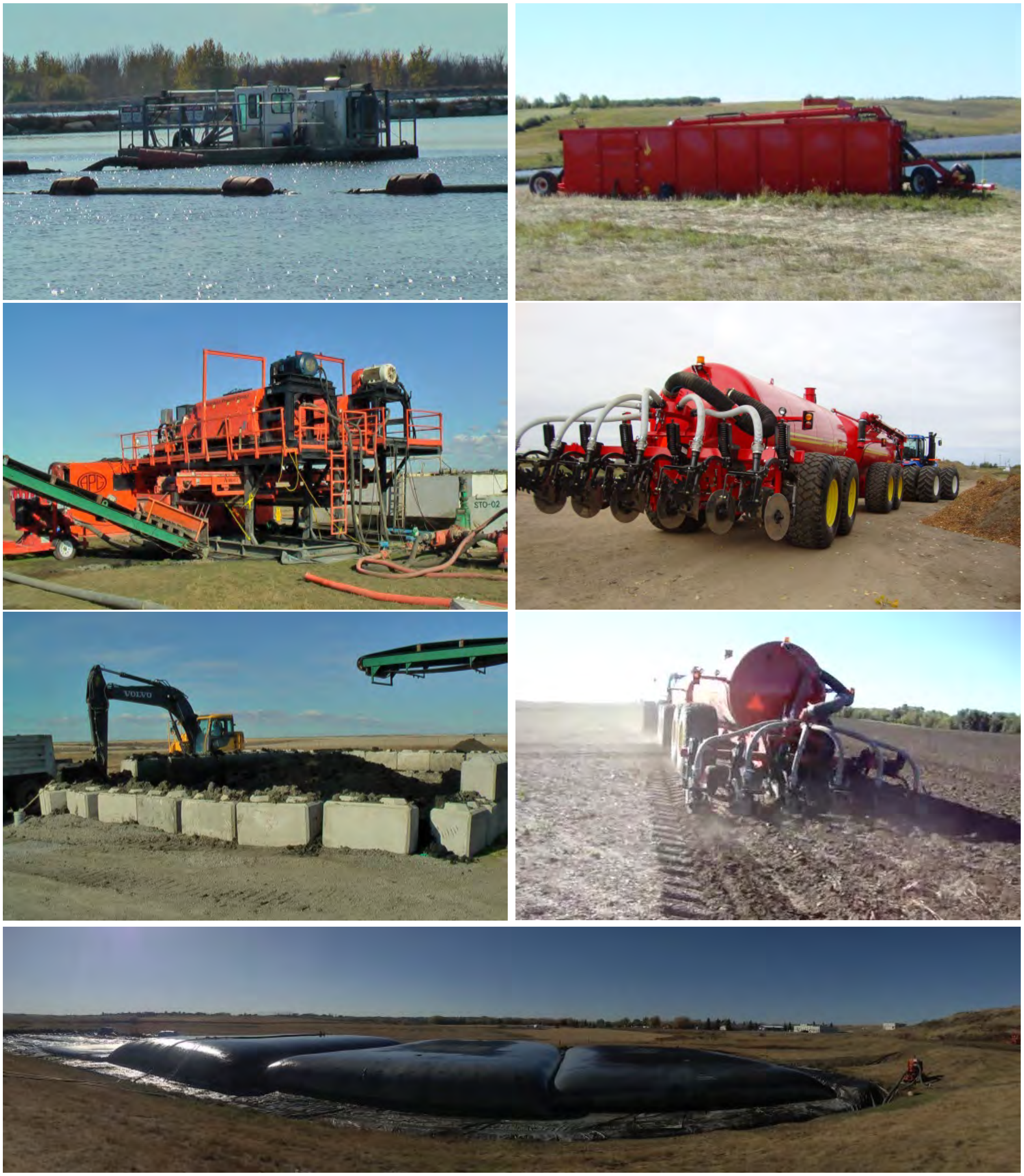

Figure 4-8 Lagoon De-sludging with Dredge and Centrifuge (left) Lagoon De-sludging with a Frac Tank and Quad-Vac (right)

4.2.8 Recommended Stabilization Option

Stabilization options will depend on the selected liquid treatment options. If the SAGR system is selected, sludge stabilization would occur in the aerated cells. If the MBBR or the SBR system is selected, sludge stabilization would occur in the lagoons by spatially distributing the sludge under passive conditions (no aeration). Alternative sludge stabilization from these mechanical systems can be using Aerobic/Anoxic digester. The technologies are most technically feasible for installation at the WWTP. Other options such as anaerobic digestion and drying will not be considered further because they are too complex or too expensive to operate. The staff may prefer processes that are simple to operate and maintain, as well as requiring limited operator attention.

4.2.9 Sludge Dewatering

Dewatering is the process to further reduce the water content of the digested sludge to minimize transportation and disposal costs, to improve sludge handling, or to meet the requirements of disposal such as landfilling. Sludge dewatering can be accomplished mechanically using equipment such as centrifuges, belt filter presses, screw presses, rotary presses, and volute presses, or non-mechanically by freeze and thaw lagoons and geotextile containers. Geotextile containers were reviewed since one of the solids management options is to thicken, stabilize, and store sludge in a lagoon followed by non-mechanical dewatering and composting.

4.2.10 Centrifuge

Centrifuges can be used for both dewatering and WAS thickening. An overview of centrifuge operation principles was described in Section 4.1.6, for WAS thickening. Centrifuges work in a similar manner for solids dewatering.

Centrifuges are an enclosed process, operate with a high hydraulic throughput, and have a small footprint when compared to other technologies. The energy use, however, is relatively high due to the rotational speed of the bowl. Because of this, the process must be monitored closely. Centrifuges have the potential to produce a thicker sludge concentration at a lower polymer use than other technologies.

4.2.11 Belt Filter Press

Belt filter presses (BFP) are widely used in North America for solids dewatering. The belt filter press uses two or more serpentine belts and a series of rollers to mechanically filter and separate moisture from stabilized solids. A simplified schematic of this unit is presented in Figure 4-9. The belt filter press is typically not enclosed to allow the operator to visually inspect the operation, as this is the basis for adjusting the speed of the machine and the incoming feed rate. This results in the need for increased operator attention and higher maintenance time and costs. Belt filter presses also require a large footprint and high ceiling due to their size. Additionally, these units have a high washwater demand and may have a difficult time achieving 18 to 20% solids for dewatering of WAS. Table 4-14 summarizes the advantages and disadvantages of BFPs.

Table 4-14 Advantages and Disadvantages of BFPs

Advantages	Disadvantages
Less impacted by grit	Dirty appearance, poor odour containment
Low speed process	Large footprint
Low energy use	Many moving parts
Low polymer use	High noise level
Easy shutdown capabilities	High volume of washwater
Easy to operate and maintain	Close supervision required

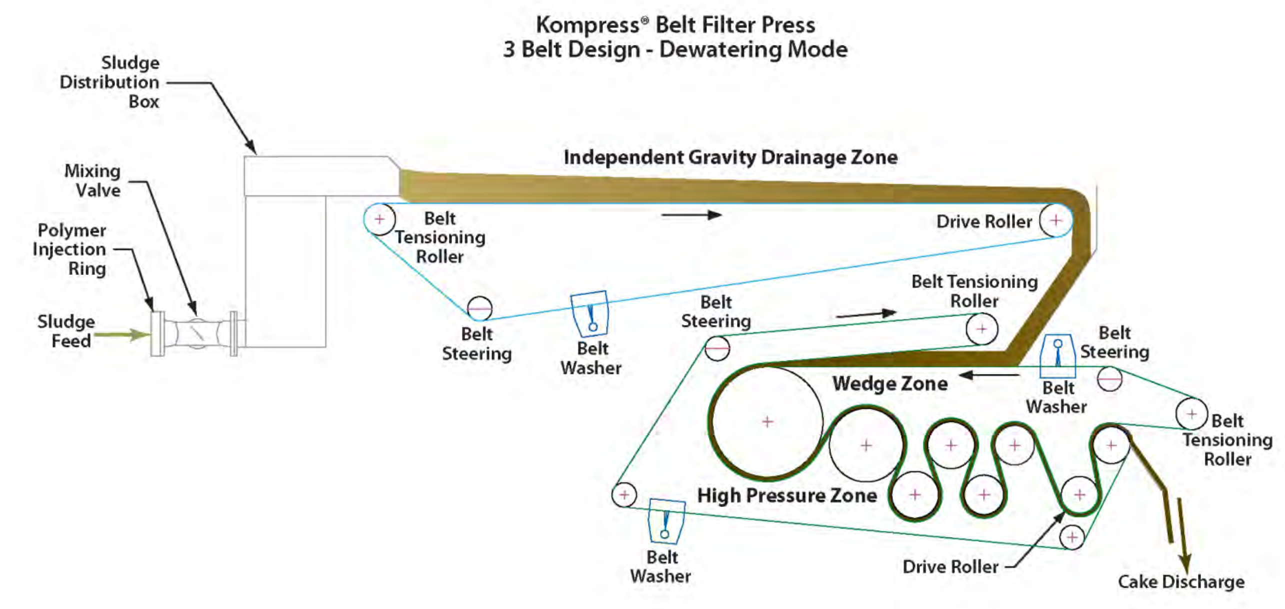

Figure 4-9 Schematic of a BFP (adopted from Komline-Sanderson Corp.)

4.2.12 Rotary Press

The rotary press consists of two round, porous metal discs that slowly rotate on a shaft. Solids are pumped between the discs and water is released through the pores as the discs rotate, compressing the sludge against a pressure bar. A simplified schematic of this unit is presented in Figure 4-10. Rotary presses have a low power requirement due to the slow rotational speed. The machine is simple in design, operates with few moving parts, and therefore can be operated unattended with automatic control systems. The hydraulic capacity of the rotary press is less than a centrifuge for the same footprint, which means that the units must run for a longer time to obtain the same throughput. These units have a difficult time achieving 16 to 18% solids for dewatering of WAS. Table 4-15 summarizes the advantages and disadvantages of rotary presses.

Table 4-15 Advantages and Disadvantages of Rotary Press

Advantages	Disadvantages
Less impacted by grit	Large footprint
Low speed process	Moderate to high polymer use
Low energy use	Sole source supplier
Easy shutdown capabilities	Performance depends on sludge characteristics
Easy to operate and maintain	
Good odour containment	
Few moving parts	
Low noise level	
Modular and expandable	

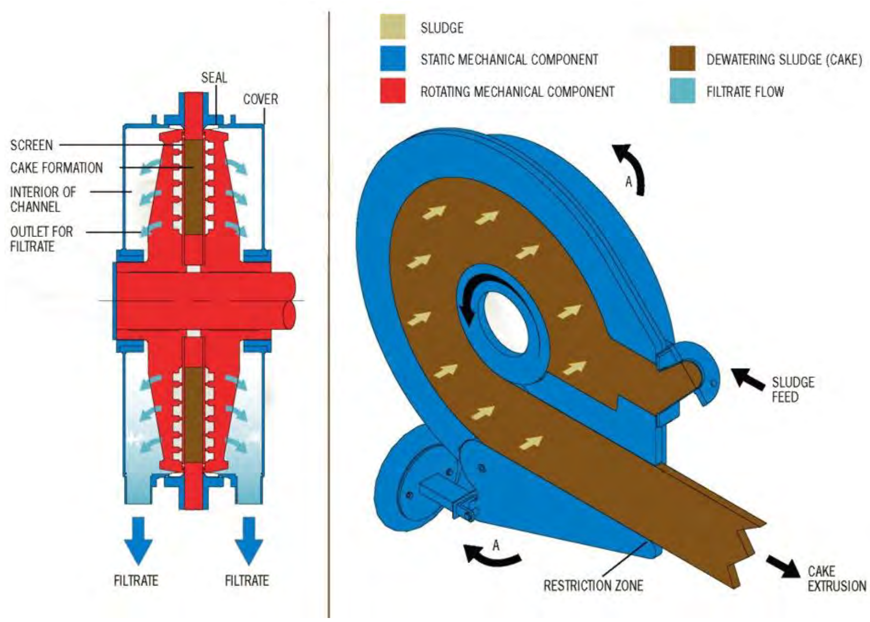

Figure 4-10 Schematic of a Rotary Press (adopted from Fourneir)

4.2.13 Screw Press

Screw presses use a slow-spinning auger inside a porous wire cage to compress solids and filter water. Water is released through the wire cage, and the dewatered cake is pushed out through the end of the unit. Screw presses operate at a low rotating speed and have low energy requirements. A simplified schematic of this unit is presented in Figure 4-11. These machines are capable of unattended operation due to their use of automated control systems. Screw presses have simple maintenance, abundant municipal installations, and consistently produce a cake with high percent solids. Table 4-16 summarizes the advantages and disadvantages of screw presses.

Table 4-16 Advantages and Disadvantages of Screw Presses

Advantages	Disadvantages
Less impacted by grit	Large footprint
Low speed process	Performance highly depends on sludge characteristics
Low energy use	Moderate to high polymer use
Easy shutdown capabilities	
Easy to operate and maintain	
Good odour containment	
Few moving parts	
Moderate noise level	

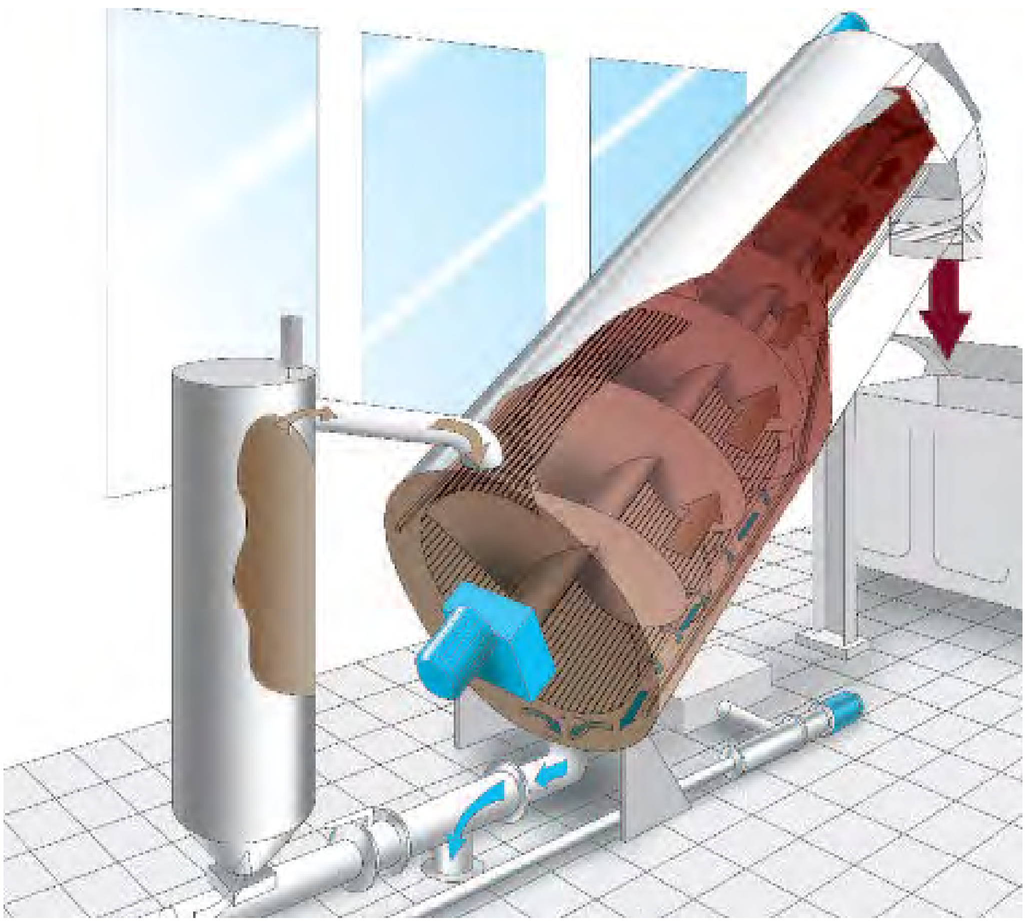

Figure 4-11 Schematic of a Screw Press (adopted from Huber Technology)

4.2.14 Volute Press

The volute dewatering press consists of a dewatering drum, which houses spacers, fixed rings, and moving rings. The initial section of the unit is the thickening zone where the threads are spaced further apart and the gaps between the rings are larger. A simplified schematic of this unit is presented in Figure 4-12. The distance between the screw threads decreases as the sludge is moved down the drum into the dewatering zone. This operation squeezes water from the sludge as it travels down toward the end-plate where the solids are discharged.

This system was piloted at the City of Estevan. While the pilot achieved substantial solids capture and produced a high percent solids cake, the polymer use was significantly greater than what is typical for municipal plants. The increased polymer use may be a function of the solids' characteristics or the dewatering capability of the unit. Therefore, it is difficult to draw any conclusions from this pilot. This is a relatively new technology compared to the screw press and belt press. Table 4-17 summarizes the advantages and disadvantages of volute presses.

Table 4-17 Advantages and Disadvantages of Volute Press

Advantages	Disadvantages
Less impacted by grit	Moderate footprint
Low speed process	Performance highly depends on sludge characteristics
Low energy use	Moderate to high polymer use
Easy shutdown capabilities	Many moving parts
Easy to operate and maintain	Limited track record in North America
Good odour containment	

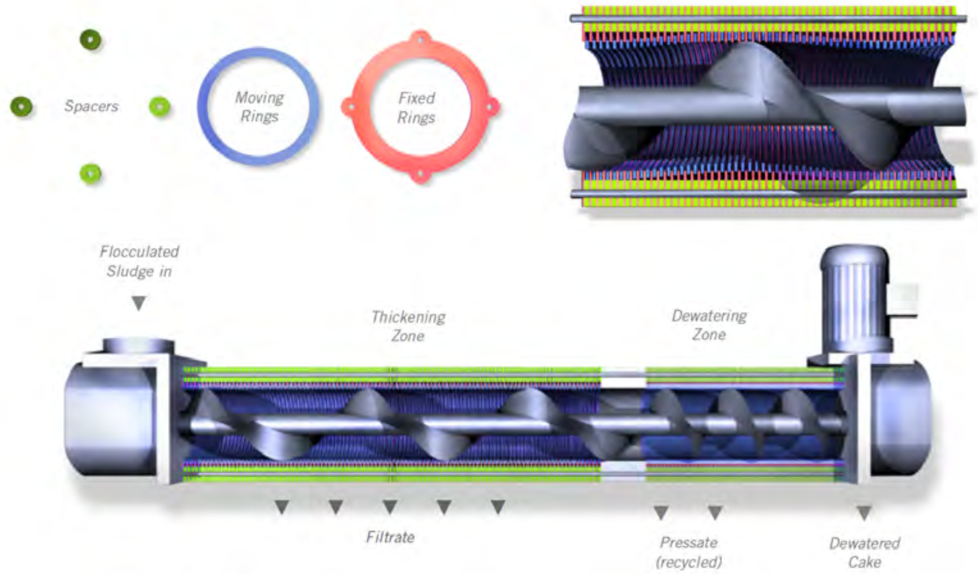

Figure 4-12 Schematic of a Volute Press (adopted from CDS Technologies)

4.2.15 Geotextile Containers

Geotextile containers are widely used in medium sized municipal sludge dewatering facilities. Polymer conditioned sludge is pumped into a geotextile container manufactured from high strength polypropylene fabric. The permeable textile allows filtrate to escape through the pores of the fabric while retaining the solids. Filtrate is typically collected and returned to the lagoon, as shown in Figure 4-13.

Volume reduction within the container allows for five or more repeated fillings of the geotextile containers. After the final cycle of filling and dewatering, retained solids continue to consolidate by desiccation as water evaporates through the geotextile. Solids can be removed from the geotextile after two to four weeks, once the retained solids meet the planned cake dryness. Solids retained in the geotextile are removed by cutting the container open and removing the cake with a front-end loader.

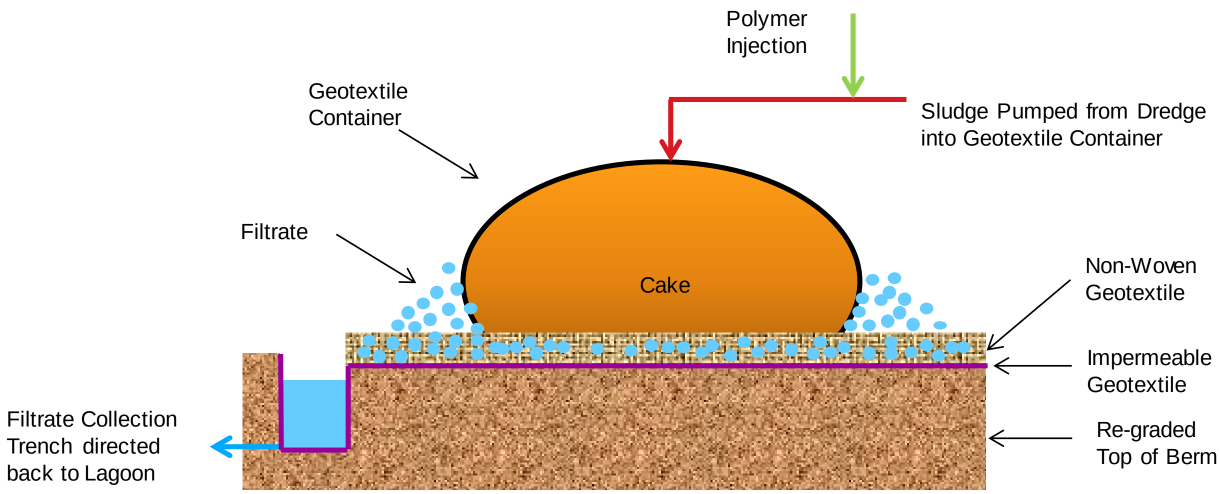

Figure 4-13 Geotextile Container Schematic

4.2.16 Recommended Dewatering Option

Most of the technologies that were screened as dewatering alternatives for the City have proven track records at municipal installations. Centrifuges are the preferred technology to dewater aerobically digested sludge, although they require daily operator attention and periodic maintenance. A geotextile container is the preferred technology to dewater sludge stabilized and stored in lagoons due to its simplicity and minimal operator attention. However, it requires proper planning, budget allocation at a rate of $500 per tonne of dry solids, and contractor coordination.

5.0 LONG LIST OF SLUDGE MANAGEMENT OPTIONS

There are several treatment alternatives that can be used to thicken and stabilize the sludge generated by the liquid treatment process. Table 5-1 presents a list of potential technologies categorized by Biosolids Disposal. The treatment technologies listed in Table 5-1 are consistent with the expected sludge volumes, and WSA requirements for disposal of biosolids.

Table 5-1 Long List of Sludge Treatment Options

Biosolids Disposal	Sludge Treatment Technology
Liquid Injection – Class A Biosolids	Thickening/Alkaline Stabilization/Storage
Liquid Injection – Class B Biosolids. Currently acceptable by WSA under more stringent considerations	Lagoon Thickening/Stabilization/Storage Thickening/Aerobic Digestion/Storage Thickening/Aerobic-Anoxic Digestion/Storage Thickening/Anaerobic Digestion/Storage Thickening/Alkaline Stabilization/Storage
Land Spreading - Class A Biosolids	Lagoon Thickening/Stabilization/Dewatering/Compost Aerobic Digestion/Dewatering/Compost Thickening/Aerobic Digestion/Dewatering/Compost Thickening/Aerobic-Anoxic Digestion/Dewatering/Compost Thickening/Anaerobic Digestion/Dewatering/Compost Dewatering/Alkaline Digestion/Stockpile Dewatering/Composting/Stockpile Dewatering/Dryer/Stockpile
Land Spreading or Landfill Cover Class B Biosolids	Lagoon Thickening/Stabilization/Dewatering/Stockpile Aerobic Digestion/Dewatering/Stockpile Thickening/Aerobic Digestion/Dewatering/Stockpile Thickening/Aerobic-Anoxic Digestion/Dewatering/Stockpile Thickening/Anaerobic Digestion/Dewatering/Stockpile Dewatering/Alkaline Digestion/Stockpile Dewatering/Composting/Stockpile

5.1 SCREENING OF SOLIDS TREATMENT OPTIONS

As shown on the list of potential sludge treatment processes, there are many potential alternatives, which would be very time-consuming and impractical to review at a high level of detail. All of them could achieve the treatment goals, but some have not demonstrated cost-effective success at the scale of operations and under the cold climate conditions required in Humboldt. A set of screening criteria have been selected and described below to gauge a technology's applicability to the WWTP.

Proven Technology: The option must be in common use for waste activated sludge treatment in similar sized installations in Canada.

Reliability / Risk of Failure: The option must always provide reliable biosolids processing and disposal with little risk of failure due to mechanical or process breakdown.

Cost-Effectiveness: Based upon experiences at other locations, the technologies chosen should all be competitive with respect to both operating and capital costs. Therefore, processes fail this criterion when: they need to be conservatively designed to increase compliance under the Humboldt operating conditions; or they have excessive operating costs because of power requirements or routine replacement of rapid-wearing components.

Easy Operation and Maintenance: The process should be capable of tolerating a range of sludge feeding conditions, and easy to operate with a minimum level of requirements for operator attention and specific process knowledge.

In Table 5-2, all the sludge treatment processes identified for potential application at Humboldt were scored on a pass-fail basis for each of the above criteria. To be considered for conceptual design and detailed cost evaluation, the processes must pass all the criteria.

Table 5-2 Screen Matrix - Sludge Treatment Options

Biosolids Disposal	Sludge Treatment Technology	Proven Technology	Reliability / Risk of Failure	Cost Effectiveness	Easy Operation & Maintenance	Meet Pass-Fail
Liquid Injection	**Thickening/Alkaline Stabilization/Storage**	**YES**	**YES**	**YES**	**YES**	**YES**
Liquid Injection	**Lagoon Thickening/Stabilization/Storage**	**YES**	**YES**	**YES**	**YES**	**YES**
Liquid Injection	Thickening/Aerobic Digestion/Storage	YES	NO	YES	YES	NO
Liquid Injection	Thickening/Aerobic-Anoxic Digestion/Storage	YES	YES	NO	YES	NO
Liquid Injection	Thickening/Anaerobic Digestion/Storage	YES	NO	NO	NO	NO
Land Spreading	Lagoon Thickening and Stabilization/ Dewatering/Composting/Stockpile	YES	YES	NO	YES	NO
Land Spreading	Aerobic Digestion/Dewatering/ Composting/Stockpile	YES	NO	NO	YES	NO
Land Spreading	Thickening/Aerobic Digestion /Dewatering/Stockpile	YES	NO	YES	YES	NO
Land Spreading	**Thickening/Aerobic-Anoxic Digestion/Dewatering/Stockpile**	**YES**	**YES**	**YES**	**YES**	**YES**
Land Spreading	Thickening/Anaerobic Digestion/ Dewatering/Composting/Stockpile	YES	YES	NO	NO	NO
Land Spreading	**Dewatering/Alkaline Digestion/Stockpile**	**YES**	**YES**	**YES**	**YES**	**YES**

Land Spreading	**Dewatering/Composting/Stockpile**	**YES**	**YES**	**YES**	**YES**	**YES**
Land Spreading	Dewatering/Dryer/Stockpile	YES	YES	NO	NO	NO
Landfill Cover	**Lagoon Thickening and Stabilization/ Dewatering/ Stockpile**	**YES**	**YES**	**YES**	**YES**	**YES**
Landfill Cover	Thickening/Aerobic Digestion/Lagoon Storage/Dewatering/Stockpile	YES	NO	YES	YES	NO
Options meeting all criteria are indicated in bold.						

Based on the must-meet criteria listed above, it was determined that the following sludge treatment processes should be further evaluated:

- Option 1 – Lystek: Thickening/Alkaline Stabilization/Storage/Land Injection.
- Option 2 – Lagoon Stabilization for Land Injection: Lagoon Thickening and Stabilization/Storage/Land Injection.
- Option 3 – Lagoon Stabilization for Landfill Cover: Lagoon Thickening and Stabilization/Dewatering/Stockpile/Landfill Cover.
- Option 4 – Aerobic-Anoxic Digestion: Thickening/Aerobic-Anoxic Digestion/Dewatering/Stockpile/Landfill Cover.
- Option 5 – Composting: Dewatering/Composting/Stockpile/Landfill Cover.
- Option 6 – Land Spreading: Dewatering/Alkaline Digestion/Stockpile.

The anaerobic stabilization options were dropped out mainly because of complexity of the process and the high level of operator attention and knowledge required. Dryers and composting options were dropped out due to high cost and risk associated with odour emissions. Alkaline stabilization has a higher capital and operating cost than any other stabilization option.

Preliminary screening of sludge management options for other facilities of similar size indicate that Option 1- Lystek, Option 4-Aerobic-Anoxic Digestion, and Option 5 have the highest net present value and consequently should not be further considered.

6.0 RECOMMENDATIONS

The following sludge management options are recommended for further development because they are proven alternatives, reliable, cost effective and easy to operate.

- Lagoon Stabilization for Land Injection: Lagoon Thickening and Stabilization/Storage/Land Injection.
- Lagoon Stabilization for Landfill Cover: Lagoon Thickening and Stabilization/Dewatering/Stockpile/ Landfill Cover.

These sludge management options are suitable for the “short-listed” liquid treatment options which are the SAGR, SBR and MBBR. For the SAGR system, the sludge produced is digested in the aerated cells along with the influent sewage as shown in Figure 6-1. For the SBR and MBBR sludge produced by these processes would be pumped to cells 3 and 4 for passive digestion (without aeration), as shown in Figure 6-2.

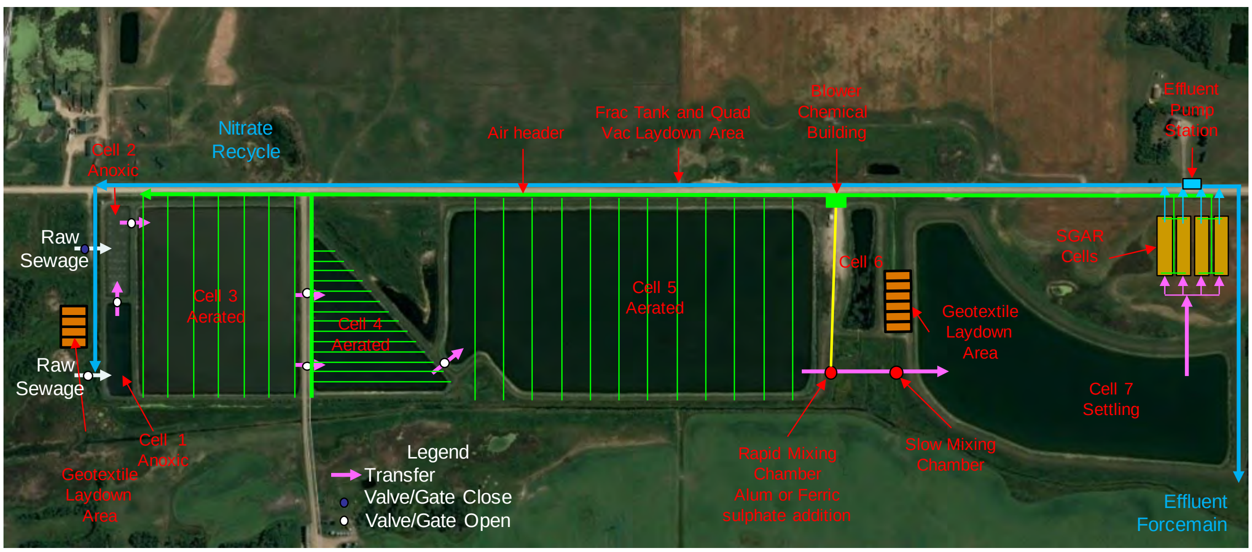

Figure 6-1 Schematic of Proposed Sludge Management Options for SAGR Process

The implementation of the sludge management options for the SAGR would require:

- Constructing a suitable road to facilitate hauling of liquid or solids biosolids to agricultural land or the landfill.
- Constructing a laydown area of 80 m by 30 m with a v-notch trench north of cell 1 to facilitate de-sludging of Cells 1 and 2 (front end cells where large solids would settle) using geotextile container.
- Constructing a laydown area of 115 m by 30 m with a v-notch trench south of cells 6 to facilitate de-sludging of cells 5 (partially aerated) and cell 7 (chemical sludge settling cell) using geotextile container.
- Constructing a laydown area of 5 m by 40 m east of cell 5 (partially aerated cell where suspended solids would settle) to facilitate de-sludging using Frac Tanks and QuadVac.
- Periodic sludge removal should be conducted to ensure the sustainability of the sludge management plan as follows:

  - Cells 1 and 2 de-sludged every four years initially and progressively increased to every three years by the end of the design life.
  - Cells 5 de-sludged every 17 years.
  - Cell 7 de-sludged every 15 years initially and then every 12 years.

The implementation of the sludge management options for the MBBR and SBR processes would require:

- Installing sludge discharge pipes along the east and south berms of cell 3 to provide spatial distribution of the sludge.
- Constructing a suitable road to facilitate hauling of liquid or solids biosolids to agricultural land or the landfill.
- Constructing a laydown area of 80 m by 30 m with a v-notch trench north of cell 1 to facilitate de-sludging using geotextile container, if septage is to be discharged to this cell.
- Constructing a laydown area of 115 m by 30 m with a v-notch trench south of cells 3 and 4 to facilitate de-sludging using geotextile container.
- Constructing a laydown area of 5 m by 40 m east of cell 3 to facilitate de-sludging using Frac Tanks and QuadVac.
- Periodic sludge removal should be conducted to ensure the sustainability of the sludge management plan as follows:
  - Cell 1 de-sludged as frequent as necessary to ensure sustainability of septage receiving station (if septage is to be received at this station).
  - Cells 3 or 4 de-sludged every six years initially and progressively increased to every three years by the end of the design life.

Installation of WAS discharge pipes along the east berm is required to convey sludge from the new liquid treatment process to the sludge stabilization cell and to better distribute the sludge along cells 3 and 4. It is expected that sludge thickening (increase of solids content from 1.2% to 4%) and stabilization would occur overtime since the sludge is stored for a long period of time. Lagoon stabilization can provide volatile solids destruction greater than 60% if sludge discharge lines are alternated every three to six months to ensure uniform spatial distribution of the sludge in the lagoon, and sludge is left to digest for a year before dewatering. The degree of pathogen reduction achieved in lagoons is a function of the time of sludge isolation and temperature. For this reason, incoming sewage should not be redirected to the sludge cell. During sludge stabilization in lagoons the sludge would thicken and stabilize in a period of a year. Digested sludge from this cell would be periodically dredged, screened and stored in a temporary storage tank (Frac Tank) at the lagoon site to be used as agricultural fertilizer or dewatered using geotextile containers.

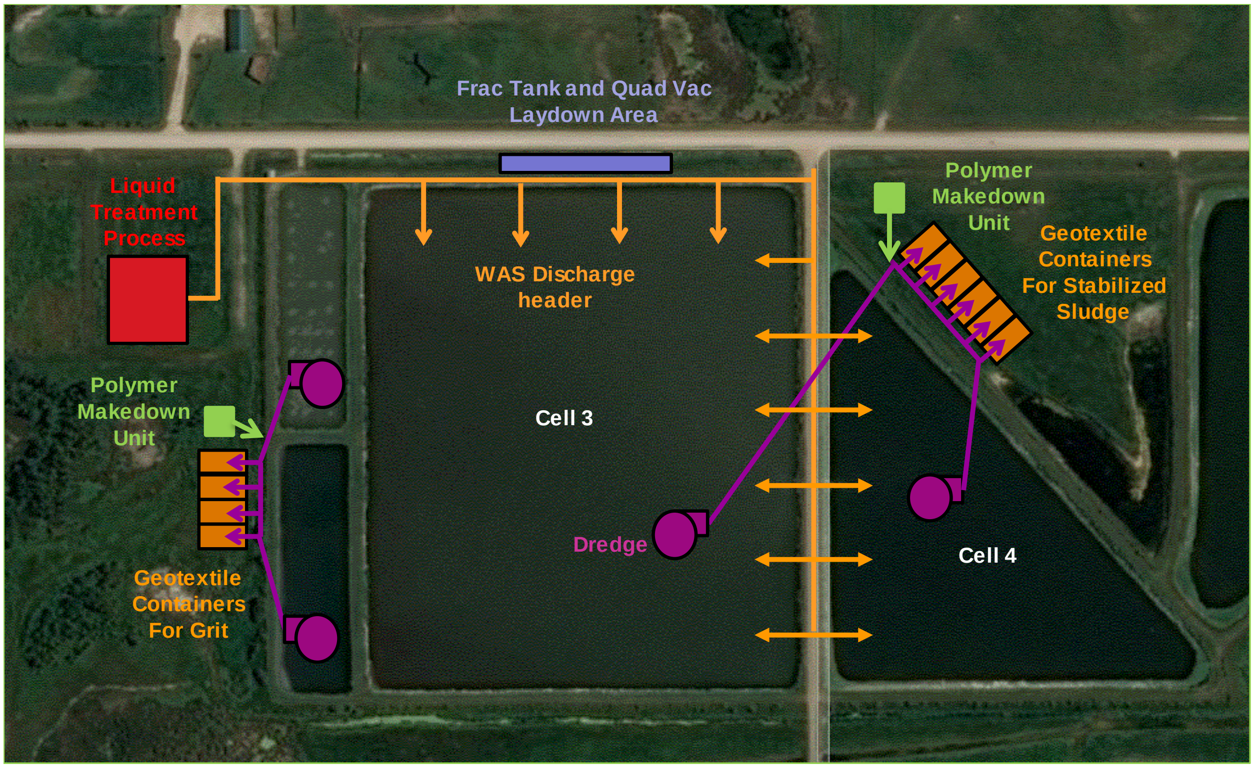

Figure 6-2 Schematic of Proposed Sludge Management Options for MBBR or SBR Processes

City of Humboldt Wastewater Treatment Plant Upgrades

Technical Memorandum No. 5
Evaluation of Short Listed Treatment Options

May 22, 2019

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Sign-off Sheet

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Abbreviations

AS	Activated Sludge
AAF	Annual Average Day Flow
BAF	Biological Aerated Filter
BOD_5	Biochemical Oxygen Demand 5-day
BNR	Biological Nutrient Removal
BWL	Bottom Water Level
COD	Chemical Oxygen Demand
$cBOD_5$	5-day Carbonaceous Biochemical Oxygen Demand
DAF	Dissolved Air Floatation
DNA	Deoxyribonucleic Acid
FOG	Fat Oil and Grease
FRP	Fibre Reinforced Plastic
FSL	Full Service Level
GSBR	Granular Sequencing Batch Reactor
H_2S	Hydrogen Sulfide
IFAS	Integrated Fixed Film Activated Sludge
ISS	Inorganic Suspended Solids
MBBR	Moving Bed Bioreactor
MBR	Membrane Bioreactor
MDF	Maximum Day Flow
MLSS	Mixed Liquor Suspended Solids
MLVS	Mixed Liquor Volatile Solids
MMF	Maximum Monthly Flow
MSBR	Modified Sequencing Batch Reactor
NML	Nitrified Mixed Liquour
NPV	Net Present Value
PDC	Power Distribution Centers
OPCC	Opinion of Capital Cost
OPOC	Opinion of Operating Cost
RNA	Ribonucleic Acid
RAS	Return Activated Sludge
RBC	Rotating Biological Contactor
SAGR	Submerged Aerated Growth Reactor
SCFM	Standard Cubic Feet per Minute
SBR	Sequencing Batch Reactor
SLR	Solids Loading Rate
SRT	Sludge Retention Time

SVI	Sludge Volume Index
TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
TWAS	Thickened Waste Activated Sludge
TWL	Top Water Level
UV	Ultraviolet
VFAs	Volatile Fatty Acids
VFD	Variable Frequency Drive
VSS	Volatile Suspended Solids
WAS	Waste Activated Sludge
WWTP	Wastewater Treatment Plant
WSA	Water Security Agency

1.0 INTRODUCTION

Stantec Consulting Ltd. (Stantec) was retained by the City of Humboldt to prepare a pre-design report for the Wastewater Treatment Plant (WWTP) Upgrade. This Technical Memorandum provides a detailed description of the short-listed treatment options and evaluates them based on multiple criteria including life cycle cost. The goal of the memo is to identify the Liquid Treatment and the Sludge Management Options that are economically viable, meet regulatory requirements and can be maintained by the City. The selected treatment option will be then further developed in the predesign report by other disciplines such as civil, structural, mechanical HVAC, electrical, instrumentation and controls to provide a detailed description of the scope of work to upgrade the wastewater treatment plant.

2.0 SHORT LISTED OF LIQUID TREATMENT OPTIONS

The short listed treatment options identified in Technical Memorandum No. 3 for liquid treatment include:

- Option 1 – Aerated Lagoons/SAGR with Chemical Precipitation.
- Option 2 – Moving Bed Bioreactor (MBBR) with Chemical Precipitation.
- Option 3 – Sequencing Batch Reactor (SBR) with Chemical Precipitation.

The short listed treatment options identified in Technical Memorandum No. 4 for sludge management include:

- Lagoon Stabilization for Land Injection: Lagoon Thickening and Stabilization/Storage/Land Injection.
- Lagoon Stabilization for Landfill Cover: Lagoon Thickening and Stabilization/Dewatering/Stockpile/Landfill Cover.

2.1 OPTION 1 – AERATED LAGOONS/SUBMERGED ATTACHED GROWTH REACTOR (SAGR)

The Aerated Lagoons/SAGR treatment process for lagoon retrofit is designed to carry out carbonaceous BOD removal with suspended growth activated sludge, followed by the fixed-film growth media for nitrification in sequence, without internal solids recycle. The Aerated Lagoons operated in series are used to achieve biological reduction of carbonaceous BOD removal. Effluent from the aerated cells is directed to the settling cell through a pipe and a series of manholes where alum or ferric sulphate is injected for the removal of phosphorus. Effluent from the settling cells flows by gravity to a splitter box and into four SAGR cells operated in parallel. The SAGR process provides an alternative for lagoon upgrades, which consists of an aerated gravel media bed for the nitrifying biomass growth, and a membrane diffuser aeration system for air supply and mixing. A fraction of the effluent from the SAGR cell is recycled to the front-end cells for denitrification and the rest flows through the UV reactor before being discharged to Humboldt Lake. A process schematic for the Aerated Lagoons/SAGR process is shown in Figure 2-1.

For the City of Humboldt, the development of this option is illustrated in Figure 2-2 and consists of:

- Dredging sludge from the two front-end cells for settling of grit and large settleable solids.
- Converting the two front end cells to anoxic cells by installing a forcemain from the effluent lift station to the front-end cells. This recycle line would provide partial nitrogen reduction (denitrification).
- Dredging facultative cells to facilitate installation of new air diffusers.
- Retrofitting cells 3, 4 and 5 with a fine bubble aeration system for BOD reduction.
- Constructing a building to house blowers, chemical tanks, metering pumps and UV reactor.
- Installing rapid mix and slow mix chambers between cells 5 and 7 for chemical precipitation of phosphorus.
- Retaining cell 7 as settling cell for precipitation of phosphorus.
- Constructing four SAGR cells for ammonia, TSS and pathogen reduction.

- Constructing a gravity effluent system from the WWTP to Humboldt Lake.
- Installing instrumentation and control system for the blowers, chemical metering pumps, mixers and effluent pump station.
- Constructing a laydown area of 80 m by 30 m with a v-notch trench north of cell 1 to facilitate de-sludging using geotextile container.
- Constructing a laydown area of 115 m by 30 m with a v-notch trench south of cell 6 to facilitate de-sludging of cells 5 and 7 using geotextile container.
- Constructing a laydown area of 5 m by 40 m east of cell 5 to facilitate de-sludging using frac tanks and QuadVac.

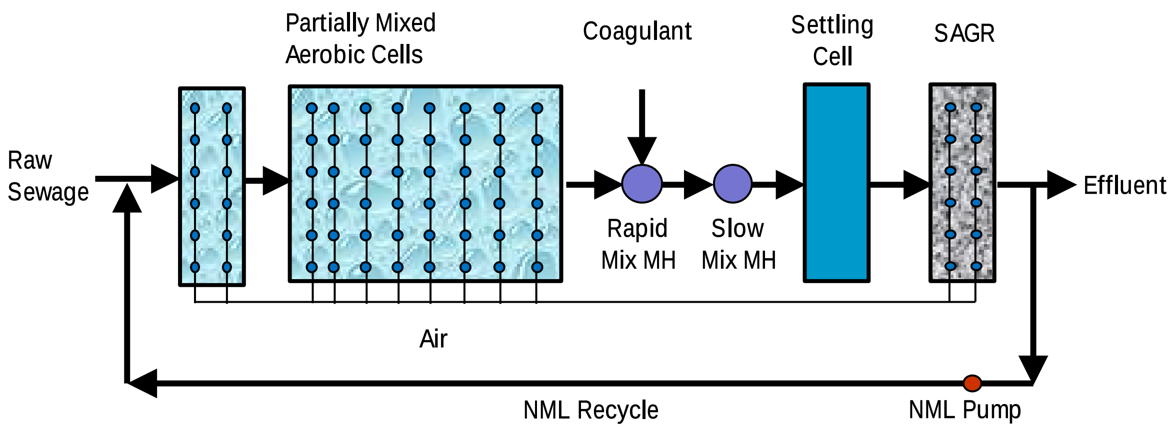

Figure 2-1 Process Schematic of Aerated Lagoons/SAGR with Chemical Precipitation

Option 1, Aerated Lagoons/SAGR, consists of anoxic cells, aerated cells, and SAGR to achieve biological reduction of organic carbon and nitrogen in the wastewater as shown in Figure 2-3. The aerated cells operate in series. Blowers convey air to the diffusers through an HDPE header buried along the aerated cells and floating laterals. The fine bubble diffusers are suspended near the bottom of the aerated cells with marine-grade rope directly under the lateral. The rope is attached to the floating header to facilitate diffuser retrieval. Each diffuser is attached to a small concrete weight, encased in HDPE pipe. Laterals are secured against wind action with stainless steel cables that would be fastened to anchors in the lagoon berm. Effluent from the aerated cells is directed to the settling cell through a pipe and a series of manholes where alum or ferric sulphate is injected for the removal of phosphorus. Effluent from the settling cells flows by gravity to a splitter box and into four SAGR cells operated in parallel. The SAGR cells consist of earthen cells with geomembrane liner, influent distribution laterals/chambers and a treated effluent collection chamber. The linear diffusers in the SAGR cells are spaced along the length of the cells. The diffusers are secured to the bottom of the cell and covered with a layer of clean gravel. The gravel bed is covered with a layer of peat or mulch over a non-woven geotextile for insulation as shown in Figure 2-4 and Figure 2-5.

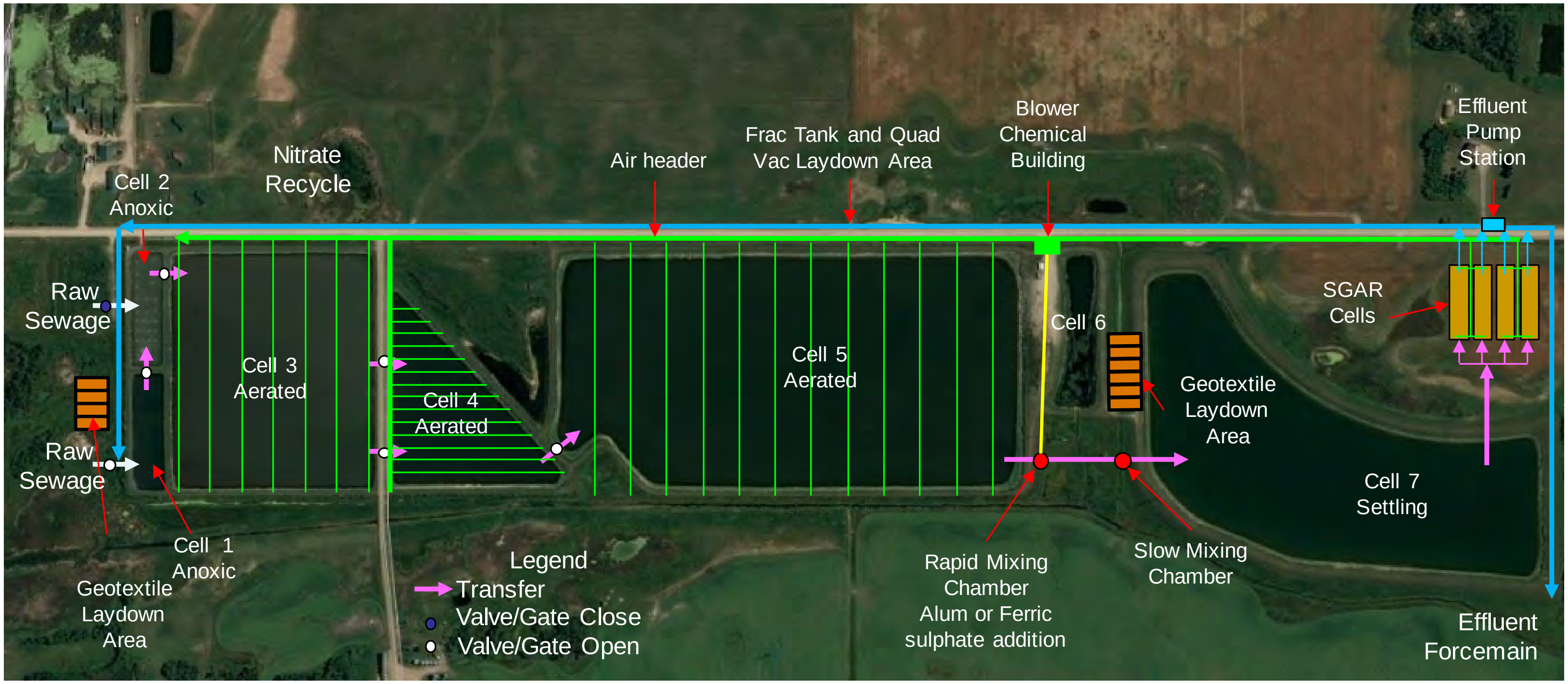

Figure 2-2 Aerated Lagoons/SAGR Process Configuration

Figure 2-3 Aerated cells and SAGR (top-left), blowers (bottom left) and fine bubble diffusers (right)

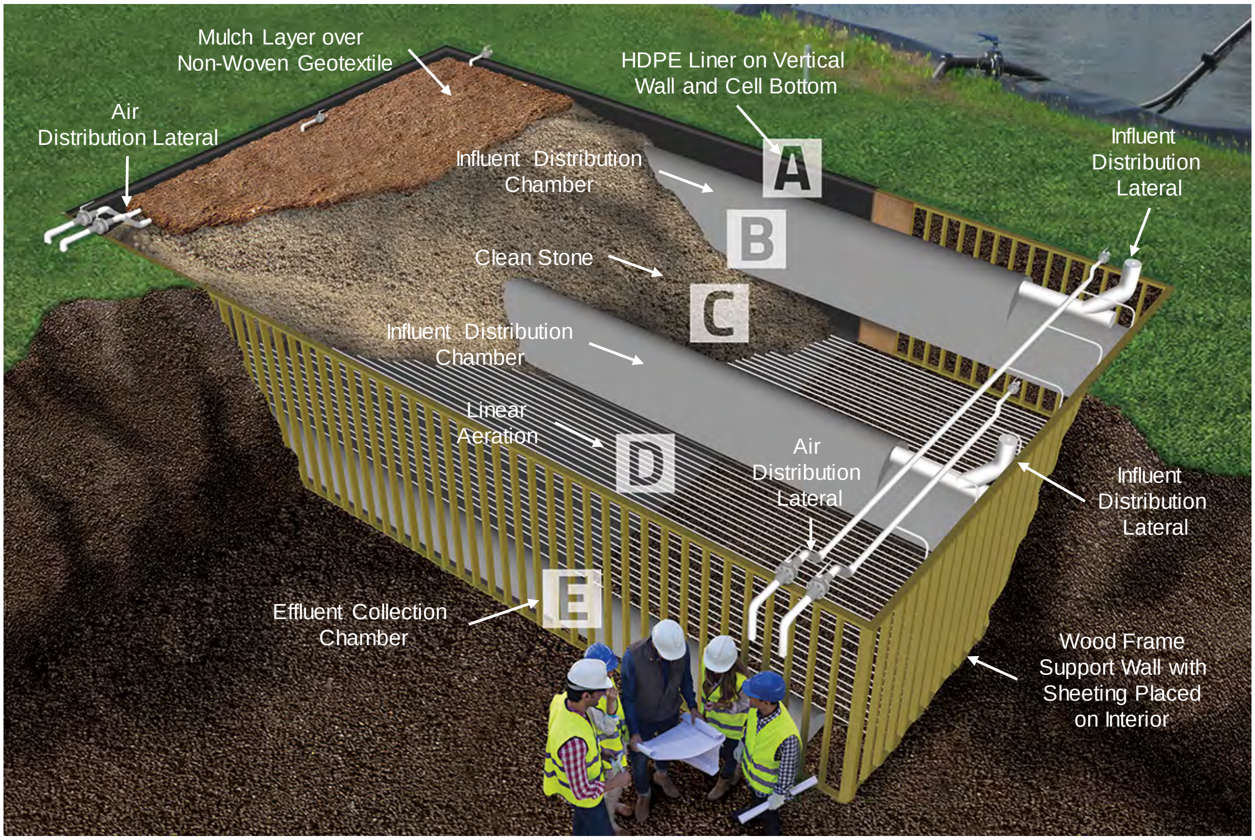

Figure 2-4 SAGR Cell 3D Rendering

The Aerated Lagoons/SAGR process will allow the City to retain the existing infrastructure but not without significant works such as sludge dredging and berm repairs. This process operates at low MLSS to reduce BOD loads and requires large Aerated Lagoons. The SAGR cells used for nitrification require a large volume of stone fill and have a large footprint. The Aerated Lagoons/SAGR process uses three times more air than SBRs or MBBR since this process provides sludge digestion and the aerated cells are shallower than concrete tanks. One of the main advantages of the Aerated Lagoons/SAGR process is the ease of operation, the ability to adequately handle fluctuating flows and long sustained peak hourly flows due to high retention time in the cells. The facility will most likely be classified as a Class II Wastewater Treatment Plant with these improvements. The advantages and disadvantages of the Aerated Lagoons/SAGR process are summarized in Table 2-1.

This process is flexible enough for expansion beyond 2052 by the addition of two more SAGR cells and replacement of the blowers and diffusers with units that can provide more airflow. No additional earth work would be required. The existing capacity of the aerated cells is sufficient to meet a population growth to 13,500 people.

Figure 2-5 SAGR Components

Sacrificial Frame Support (top left), Influent Laterals (top right), Linear Diffusers (middle left), Linear Diffusers and Effluent Collection Chamber (middle right), Chambers Being Covered with Stones (bottom left), and Non-Woven Geotextile over Air Distribution Laterals (bottom right)

Table 2-1 Advantages and Disadvantages of Aerated Lagoons/SAGR Process

Advantages	Disadvantages
• Good track record in cold weather condition in Western Canada. • High-quality effluent in terms of low bacteria, TSS, BOD and ammonia. • Lowest capital and operating costs. • Does not require a valve chamber and does not affect the hydraulic grade line of the pump stations. • Does not require headworks. • Does not require flow diversion of excessive wet weather flows. • Does not require pre or post equalization tanks. • Does not require sludge recirculation. • Does not require secondary clarifier or filters. • Performance not affected by solids settleability or bulking sludge. • Performance is not affected by Fat Oil and Grease (FOG) concentration in the raw sewage. • Simple process makes it easy to operate. • Reliable and robust due to the smaller number of mechanical components. • Low sludge production due to digestion in the cells. • No alkalinity limitation since aerated lagoons desorb carbon dioxide in the water which increases the water pH. • Minimum odour generation. • Long life of attached growth media (rocks).	• Installation of aeration requires dredging the lagoons. • Large footprint. • Higher overall power consumption due to higher oxygen consumption due to sludge digestion and shallow lagoons (about 50% higher than an SBR). • Separate blowers are required for aerobic cells, and SAGR. • Repair of aeration system is conducted from a boat and require four operators (two in the boat and two on the shore for safety). • Not an effective technology for denitrification, the process cannot reduce the Effluent Total Nitrogen concentration to less than 28 mg/L in summer and 31 mg/L in winter. • Only one supplier. However, Nexom has extensive and unparallel experience supplying and installing blowers and diffusers in WW lagoons.

2.1.1 Aerated Lagoons/SAGR Conceptual Design

Preliminary sizing of the Aerated Lagoons/SAGR system is based on Nexom Technologies and is summarized in Table 2-2.

Table 2-2 Aerated Lagoons/SAGR Design Summary

Parameter	Unit	Nexom Design
Design Summary		
Design flow rate	m^3/d	8,200
Total lagoon volume	m^3	529,133
Cell 1 Anoxic, volume at 3.95 m FSL	m^3	15,262
Cell 2 Anoxic, volume at 3.95 m FSL	m^3	14,692
Cell 3 Aerobic, volume at 1.5 m FSL	m^3	86,536
Cell 4 Aerobic, volume at 1.5 m FSL	m^3	39,131
Cell 5 Aerobic, volume at 1.8 m FSL	m^3	225,707
Cell 7 Settling, volume at 2.1 m FSL	m^3	147,805
SAGR Cell, volume at 2.25 m FSL	m^3	25,920
SAGR number of trains	qty	2
SAGR number of cells per train	qty	2
SAGR cell dimensions (width, length, and side water depth)	m	32 x 90 x 2.25
Hydraulic Retention Time SRT (Summer/Winter)	d	32 / 64
Aerated Lagoon Blower Design Summary		
Total airflow requirements at 20°C, 101 kPa (Summer)	m^3/h (SCFM)	4,529 (2,664)
Number of diffusers in cells 3, 4 and 5	qty	222
Number of blowers	qty	2 (2 duty / 0 standby)
Capacity per blower	m^3/h (SFCM)	2,265 (1332)
Discharge pressure	kPa (psi)	27 to 35 (3.9 to 5.2)
Motor Power	kW (HP)	37 (50)
SAGR Blower Design Summary		
Total airflow requirements	m^3/h (SCFM)	4,834 (2,844) 4,820 (2,835)
Total number of blowers	qty	3 (2 duty / 1 standby)
Capacity per blower	m^3/h (SCFM)	2,417 (1,422)
Discharge pressure	kPa (psi)	37 to 64 (5.4 to 9.4)
Power	kW (HP)	75 (100)
Lagoons standby aeration provided by SAGR blowers		

2.2 OPTION 2 – MOVING BED BIOREACTOR (MBBR)

Option 2, Moving Bed Bioreactor (MBBR), is based on buoyant plastic carriers that support growth of a high concentration of attached biomass. The carriers are made from HDPE media that have a very high surface to volume ratio in the range of 400 to 800 m^2/m^3. In the moving bed, plastic carriers are placed in the reactor in suspension with the activated sludge to support biofilm growth. Aeration or mechanical mixing circulates the packing material in the system to avoid packing accumulation at the reactor effluent. The packing material is retained in the reactor by media retention sieves. In large systems the plastic carriers are placed within cages to avoid the use of additional mixing equipment. Several packing materials have been developed for suspended attached growth processes, including Captor, Kaldnes and Hydroxyl-Pac media.

The process is unique in utilizing plastic biofilm carrier elements for BOD removal, nitrification, and denitrification. Since the biofilm carrier provides a relatively large surface area for growth, the system supports a much higher concentration of microorganisms as compared to other processes. This makes the process more spatially efficient. A single-stage reactor is presented in Figure 2-6. Sloughed solids are removed using Dissolved Air Floatation (DAF) or a disc filters. Disc filters are more appropriate for MBBR systems with estimated effluent TSS concentration below 160 mg/L and sludge stabilization in lagoons. Multiple tanks or compartments can be set up to provide aerobic and anoxic zones for total nitrogen removal.

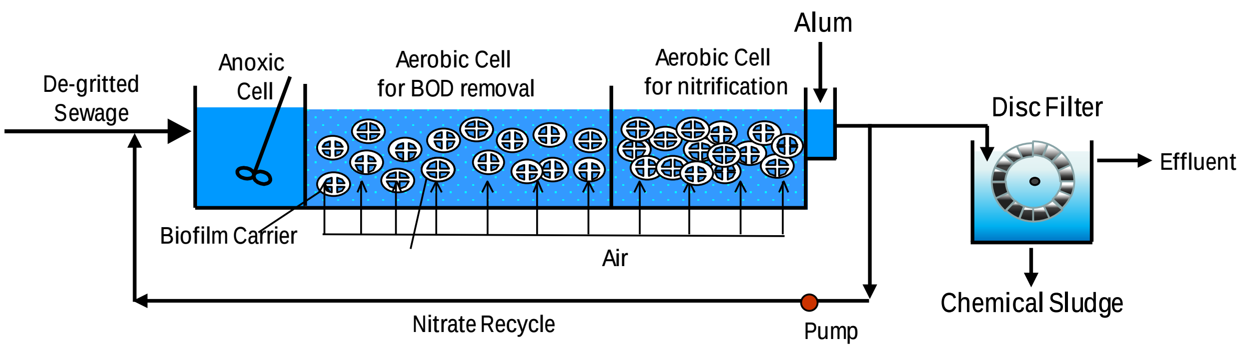

Figure 2-6 Process Schematic of the MBBR and Chemical Precipitation

The development of this option is illustrated in Figure 2-7 and consists of:

- Constructing a valve chamber to combine flows from all lift stations and re-direct the flow to the new headworks.
- Constructing a headworks building to house screens and grit removal units.
- Constructing a building to house blowers, cloth filters, UV disinfection units, chemical tanks and metering pumps.
- Installing disc filters for solids separation.
- Installing a UV disinfection system.
- Installing pumps and forcemain to convey activated sludge to the existing lagoons or another sludge management system.

- Retaining existing facultative cells for wet weather flow management through offline storage.
- Constructing an effluent lift station and forcemain from the WWTP to Humboldt Lake.
- Installing instrumentation and control systems for the MBBR, blowers, filtration, UV disinfection, sludge pump station and effluent lift station.
- Constructing a laydown area of 115 m by 30 m with a v-notch trench south of cells 3 and 4 to facilitate de-sludging using geotextile containers.
- Constructing a laydown area of 80 m by 30 m with a v-notch trench north of cell 1 to facilitate de-sludging using geotextile containers.
- Constructing a laydown area of 5 m by 40 m east of cell 3 to facilitate de-sludging using frac tanks and QuadVac.

The MBBR process consists of two process trains with two concrete tanks in series, blowers, air distribution laterals, diffusers, mixers, carriers and sieves to achieve biological reduction of organic carbon and nitrogen in the wastewater as shown in Figure 2-7. Blowers convey air to the diffusers through a stainless steel header along the aerated tanks. The coarse bubble diffusers are attached near the bottom of the aerated tanks. Effluent from the reactor is conditioned by polymer before filtration using disc filters as shown in Figure 2-8.

Effluent from the disc filters flows by gravity to two UV reactors operating in series in a single channel. Filter backwash is automated to start at a set water level. The disc rotates allowing the dirty panels to be exposed to high pressure spray. The clean panels rotate into the water to ensure continuous filtration with zero down time. Backwash water and waste sludge is directed to the lagoons.

This option may require pre-equalization if a period of zero flow is experienced frequently or for long periods. This will affect the maximum flow delivered by the existing lift stations since the headworks and MBBR tanks are built at a higher elevation than the lagoons to reduce excavation volume. Sludge removal from facultative cells will be required after 10 to 20 years. The facility will most likely be classified as a Class II Wastewater Treatment Plant with these improvements. The advantages and disadvantages of the MBBR process are summarized in Table 2-3.

This process is flexible enough for expansion beyond 2052 by the addition of more media in the bioreactors and one blower. The existing capacity of the bioreactors is sufficient for to meet a population growth to 13,500 people.

Table 2-3 Advantages and Disadvantages of MBBR

Advantages	Disadvantages
• High-quality effluent in terms of low bacteria, TSS, BOD and ammonia. • Reduce effluent Total Nitrogen concentration to less than 12 mg/L. • Does not require sludge recirculation. • Performance not affected by solids settleability or bulking sludge. • Simple process makes it easy to operate. • Reliable and robust due to the smaller number of mechanical components. • Minimum odour generation. • Long life of attached growth media (plastic). • Does not require dredging of the existing facultative lagoon. • Smallest footprint and compact design. • Low power cost due to low oxygen consumption since sludge digestion occurs in the lagoons and deep concrete tanks. • Requires fewer blowers than Aerated Lagoons / SAGR process. • Expandable by addition of more carriers up to 65% fill relative to the tank volume. • Does not require a post equalization tank. • Repair of aeration system is not frequently required (SS diffusers). • Final effluent can be easily reused since it has a TSS below 10 mg/L. • System is adaptable to more stringent effluent criteria.	• Higher capital and operating costs than Aerated Lagoons/SAGR process. • Requires a valve chamber to combine flows from various lift stations into one stream. • Hydraulic grade line of the pump stations will be affected (i.e. pumps will deliver less flow). • Requires headworks. • Requires flow diversion of excessive wet weather flows. • Requires a solids separation system: DAF or disc filters. • Requires UV disinfection. • Requires polymer for solids removal. • Performance may be affected by Fat Oil and Grease (FOG), if the FOG concentration in the raw sewage is greater than 100 mg/L. • Additional chemicals (polymer) required for proper operation of the disc-filters, hence higher chemical consumption costs. • Waste sludge is directed to lagoons for stabilization. • Alkalinity limitation may negatively affect the process (raw sewage alkalinity needs to be measured). • Limited track record in cold weather application in Western Canada.

Figure 2-7 MBBR Components

Anoxic Cell 3D Rendering (top left), Aerobic Cell Rendering (top right), Aerobic Cell Components (middle left), Sieves (middle right), Diffusers (bottom left), and Biofilm Carriers (bottom right)

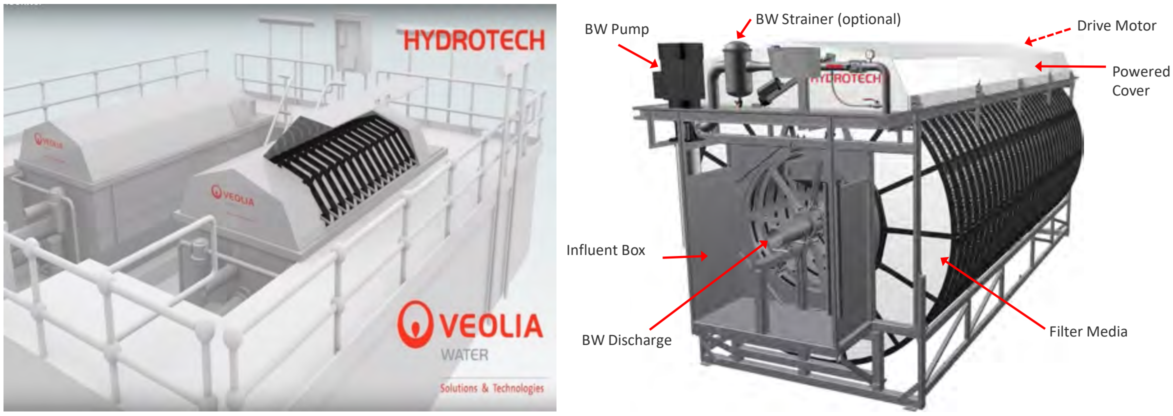

Figure 2-8 Disc Filter Layout and Description

2.2.1 MBBR Conceptual Design

For the MBBR concept, two bioreactor tanks are designed in a rectangular configuration and the tanks are placed adjacent to each other. Preliminary sizing of this bioreactor configuration is based on Veolia and is summarized in Table 2-4.

Table 2-4 MBBR Design Summary

Parameter	Unit	Value
Number of process trains	qty	2
Bioreactor Design Summary		
Maximum hydraulic flow	m^3/d	8,200
Design flow rate for treatment	m^3/d	7,235
Total bioreactor volume	m^3	2,350
Anoxic Cell 1 volume per train	m^3	425
Aerobic Cell 1 volume per train	m^3	200
Aerobic Cell 2 volume per train	m^3	500
Anoxic Cell 2 volume per train	m^3	50
Dimensions for each bioreactor (width, length, and side water depth)	m	7.0 x 33.6 x 5
Carrier surface area	m^2/m^3	800
Estimated sludge wasted flow rate	m^3/d	TBD
Estimated sludge wasted at design year	kg/d	900 to 1,000
Sludge Retention Time SRT (Summer/Winter)	d	TBD
Total number of mixers per train	qty	2
Mixer power	kW	TBD

Parameter	Unit	Value
Bioreactor Blower Design Summary		
Total airflow requirement at 20°C, 101 kPa	m^3/h	3,600 (2,120)
Number of blowers	qty	3 (2 Duty / 1 Standby)
Capacity per blower	m^3/h	TBD
Discharge pressure	kPa (psi)	54 (7.8)
Power	kW (HP)	40 (50)
Recirculation Pump Design Summary		
Number of Nitrified Mixed Liquour (NML) transfer pumps	qty	2
NML flow per pump	m^3/d	TBD
NML pump power	kW	TBD
Disc-Filter Design Summary		
Number of disc filters	qty	2
Flow per filter	m^3/d	3,750
TSS at the inlet	mg/L	160
Cloth openings	µm	40
Estimated headloss	mm of WC	300
Power	kW (HP)	TBD
Note: To be Determined (TBD)		

2.3 OPTION 3 – SEQUENCING BATCH REACTOR (SBR)

Option 3, Sequencing Batch Reactor (SBR), is a fill-and-draw, non-steady state activated sludge type treatment system where the biological oxidation of organic matter, nitrification, denitrification and sedimentation (solid/liquid separation) are carried out in the same tank, typically in a timed sequence. As such, the SBR process does not require any secondary clarifiers and in most cases operates without primary sedimentation. Also, the SBR process does not require any return activated sludge (RAS) or any internal mixed liquor recycle streams. A schematic of this process is presented in Figure 2-9.

In general, a typical treatment cycle consists of filling the bioreactor with wastewater (FILL), aeration and/or mixing of the bioreactor contents (i.e., mixed liquor or biomass) (REACT), followed by settling (SETTLE) of the biomass. Aeration is provided by fine bubble diffusers and blowers. Treated effluent is then finally discharged by the decanter mechanism (DECANT). An IDLE stage may follow during which waste activated sludge is discharged and the SBR tank time sequence is adjusted prior to starting the next cycle.

This process is flexible enough for expansion beyond 2052 by the addition of one bioreactor and one blower.

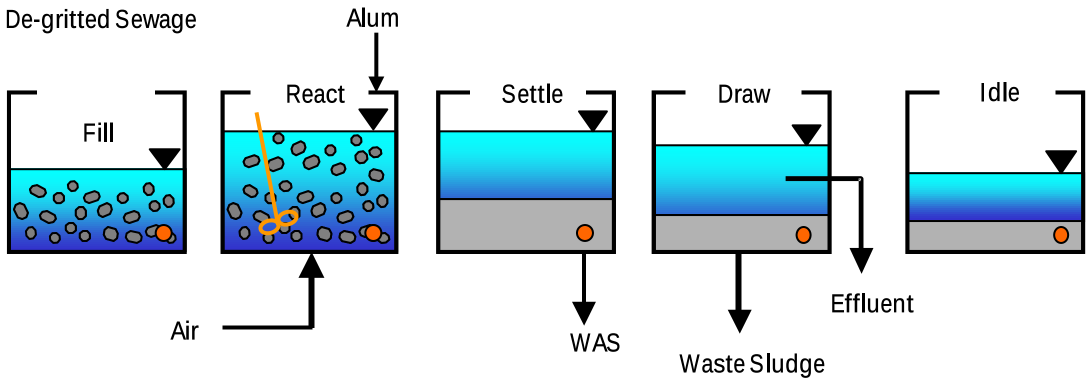

Figure 2-9 Schematic of the SBR Process

Several variations of the SBR process are available including the following:

- Continuous inflow and intermittent decant.
- Intermittent or batch inflow and intermittent decant (also referred to as the true batch system).
- Continuous inflow and continuous decant (also referred to as the modified SBR or MSBR).

Ammonia removal is achieved during the REACT phase by control of appropriate solids residence time (SRT) in the system. While most SBRs can be designed to remove some phosphorus biologically (depending on the raw wastewater characteristics), a chemical polishing system is necessary to consistently meet the effluent criteria of ≤ 1 mg/L of TP. Alum can be dosed into the tank at the end of the aeration cycle to precipitate phosphorus. The chemical complex precipitated is wasted during the normal sludge wasting process.

The SBR process for Humboldt consists of two process trains with two concrete tanks in series, blowers air distribution laterals, diffusers, mixers, and decanter as shown in Figure 2-10. Blowers convey air to the diffusers through a stainless steel header along the aerated tanks. The fine bubble diffusers are attached near the bottom of the aerated tanks. Mixers are required to provide independent mixing of the activated sludge for denitrification. Effluent from the SBR tanks is directed to the equalization tank. Effluent from the equalization tank is then pumped to two UV reactors operating in series.

This system may require pre-equalization if a period of zero flow is experienced frequently or for long periods. This system will affect the maximum flow delivered by the existing lift stations since the headworks and SBR tanks will be built at a higher elevation than the lagoons to reduce excavation volume. Sludge removal from facultative cells is required after 10 to 20 years. The facility will most likely be classified as a Class II Wastewater Treatment Plant with these improvements. The advantages and disadvantages of the SBR technology compared to the Aerated Lagoons/SAGR and the MBBR processes are summarized in Table 2-5.

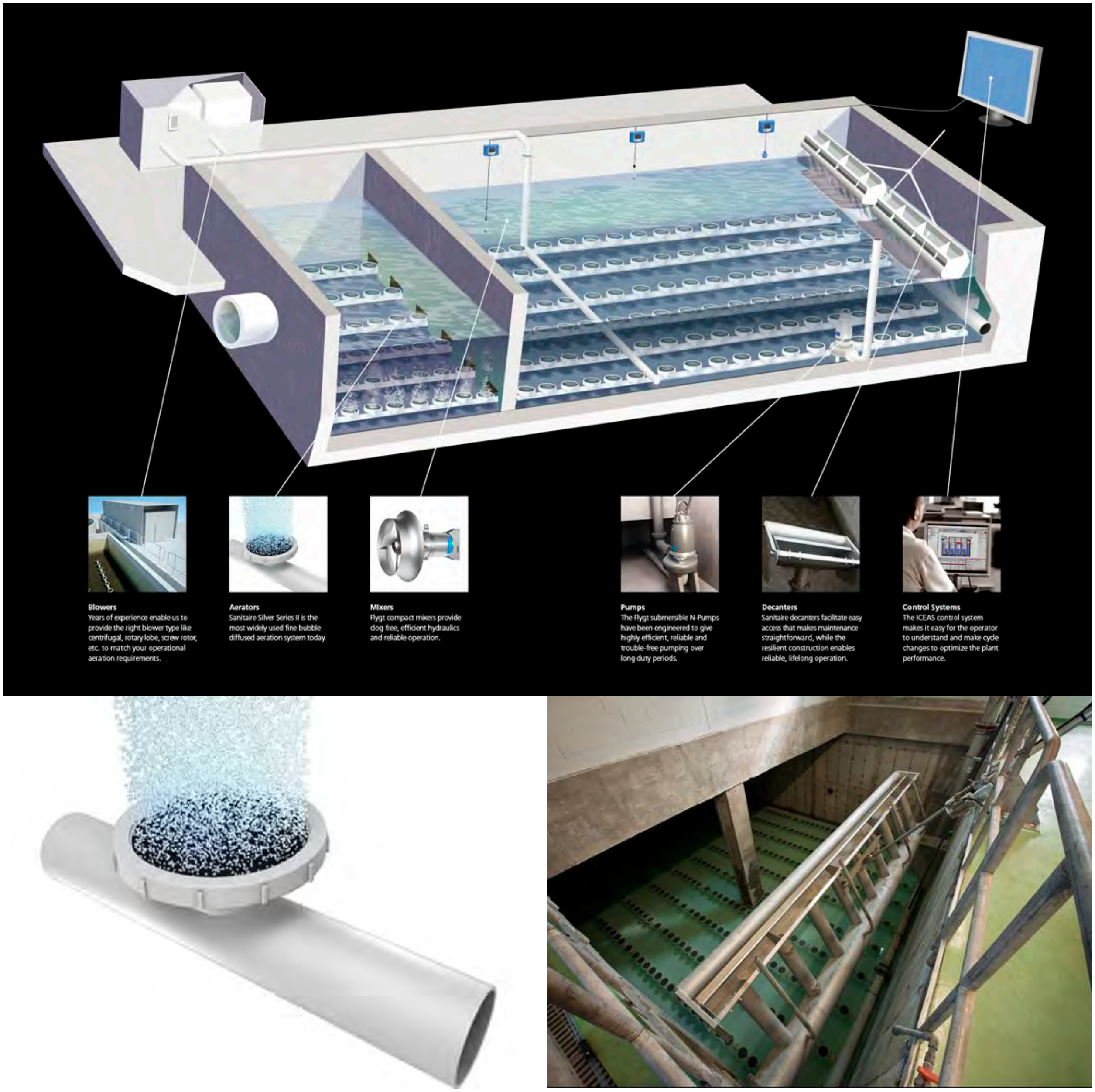

Figure 2-10 SBR Components

SBR 3D Rendering (Top), Fine Bubble Diffuser (Left), and Decanter (Right)

Table 2-5 Advantages and Disadvantages of SBR Process

Advantages	Disadvantages
• Good effluent quality achieved with existing installations. • Reduce effluent Total Nitrogen concentration to less than 12 mg/L. • Easier to operate and maintain. • No influent equalization required. • All treatment steps are performed in a single tank and secondary clarifiers are not required. • There is no need for either internal or return sludge recycle stream. • Several manufacturers available in the market. • Can be configured to any shape (square, rectangle, circle) to fit available space. • System can be easily expanded in a modular fashion. • System is easy to expand in modular increments. • Does not require filters like the MBBR process. • Requires smaller aeration blowers than Aerated Lagoons/SAGR or MBBR processes. • System is adaptable to more stringent effluent criteria. • Good track record in Western Canada.	• Proprietary systems. • Effluent equalization is typically required to limit size of downstream process units e.g., UV disinfection. • Proper functioning and the design of the decanter are critical to achieving consistently low effluent suspended solids. • Decanter area needs to be covered to avoid decanter freezing. • Larger bioreactor tanks compared to MBBR process. • Effluent TSS may not be as reliable as MBBR or Aerated Lagoons/SAGR process. • A WAS equalization tank may be required since SBR wasting step duration is less than 7 minutes. • Final effluent cannot be easily reused without the addition of filters to reduce the TSS concentration. • Process may experience foaming, scum or bulking.

2.3.1 SBR Conceptual Design

For the SBR concept, there will be two bioreactor tanks adjacent to each other designed in a rectangular configuration. Preliminary sizing of this bioreactor configuration is based on Xylem's Intermittent Cycling Extended Aeration System (ICEAS) and is summarized in Table 2-6.

Table 2-6 Preliminary SBR Bioreactor Sizing

Parameter	Unit	Value
Maximum hydraulic flow	m^3/d	8,200
Design flow rate for treatment	m^3/d	7,235
Number of process trains	qty	2
Number of normal batches per day per SBR	qty	5
Normal cycle time (total)	h	4.8
Air-off	min	72
Air on	min	96

Parameter	Unit	Value
Settle	min	60
Decant	min	60
Normal decant rate	m^3/min	12.5
Storm cycle time (total)	h	3.6
Air-off	min	54
Air on	min	72
Settle	min	45
Decant	min	45
Peak dry weather flow per tank	m^3/d	16.26
Bioreactor Design Summary		
Total basin volume	m^3	6,530
Basin volume per train	m^3	3,265
Dimensions per train (length, width and side water depth)	m	42.4 x 14 x 5.5
Hydraulic retention time (HRT)	d	1.33
Solids volume index	mL/g	150
Food to mass F/M ratio	kg BOD_5/kg SS-d	0.04
Estimated MLSS at bottom water level	mg/L	5,317
Estimated sludge waste flow rate	m^3/d	109
Estimated sludge wasted	kg/d	882
Sludge retention time SRT	d	30
Bioreactor airflow requirement per train at 20°C, 101 kPa	m^3/h (SCFM)	1,370 (806)
Total number of 225 mm (9”) diffusers per train	qty	1,104
Total number of mixers per train	qty	2
Mixer power	kW (HP)	9.4 (12.7)
WAS Pump Design Summary		
Number of WAS transfer pumps	qty	2
WAS flow per pump	L/min	416
WAS pump power	kW	1.7 (2.4)
Decanter Design Summary		
Number of decanters per train	qty	1
Decanter weir length	m	7.62
Decanter driver	kW (HP)	0.36 (0.5)
Blowers Design Summary		
Number of blowers	qty	3 (2 duty / 1 standby)

Parameter	Unit	Value
Capacity per blower	m^3/h (SCFM)	1,370 (806)
Discharge pressure	kPa (psi)	58.6 (8.5)
Power	kW (HP)	32 (44)

2.3.2 UV Conceptual Design

UV disinfection was selected as the preferred disinfection alternative. Preliminary sizing of the UV system is based on the Trojan 3000plus system with built-in chemical / mechanical cleaning as summarized in Table 2-7. Sizing of the UV system is based on Options 1 and 3. The UV system is slightly smaller for Option 2 since filtration increase the UV transmittance.

Table 2-7 UV Disinfection Design Parameter

Parameter	Units	Design Criteria
Number of trains	qty	1 (duty)
Number of banks	qty	2 (1 duty / 1 standby)
Peak Hour Flow (PHF)	m^3/d	9,936
Fecal coliform disinfection target	E-coli/100mL	200
UV transmittance	%	55
UV dosage	mWs/cm^2	TBD
Maximum power draw	kW (HP)	15.4 (20)
Average particle size	microns	TBD
Modules per bank	qty	4
Bulbs per module	qty	8
Total number of lamps	qty	64
Channel width with baffle	m	762
Water depth	m	TBD
Weir length	m	TBD
Note: To be determined (TBD)		

3.0 SLUDGE MANAGEMENT OPTIONS

The objective of this section is to provide a description of the selected sludge treatment options, which consists of thickening, lagoon stabilization, for land injection or landfilling as intermediate landfill cover. The description presented in this section will be used to develop an opinion of probable cost for each liquid treatment option.

3.1 WAS GENERATION

WAS generation will depend on the liquid treatment option, SRT, mixed liquor solids concentration and wastewater temperature. For the purpose of this memorandum, the WAS mass was estimated using the SBR process at a SRT of 20 days and MLSS of 3,500 mg/L. The WAS mass would range from 560 kg/d at the initial year to 900 kg/d at design year.

3.2 LAGOON STABILIZATION

For liquid treatment Option 1 (Aerated Lagoons/SAGR) sludge management consists of passive stabilization (non-assisted by mechanical aeration) of the sludge settled in in cells 1 and 2 and active stabilization (assisted by mechanical aeration) of the sludge settled in cell 3. For liquid treatment options 2 and 3 (MBBR and SBR) sludge management consists of installing WAS discharge pipes along the east berm to better distribute the sludge along cells 3 or 4 to convey sludge from the new liquid treatment process to the sludge stabilization cells (passive stabilization), as shown in Figure 3-1. It should be noted that pipes from the dredges to the geotextile are temporarily provided by the contractor hired by the City to dredge the cells.

It is expected that sludge thickening (increase of solids content from 1.2% to 4%) and passive stabilization will occur over time since the sludge is stored for a long period. Passive stabilization can provide volatile solids destruction greater than 38% if sludge discharge lines are alternated every three to six months to ensure uniform spatial distribution of the sludge in the lagoon, and sludge is left to digest for a year before dewatering. The degree of pathogen reduction achieved in lagoons is a function of the time of sludge isolation and temperature. For this reason, incoming sewage should not be redirected to the sludge cell. After confirmation that there has been stabilization, the digested sludge is ready for land application or landfilling.

If the biosolids are suitable for land injection, the City can hire a contractor to transport and land inject about 870 tonnes of DS (43,500 m^3 at 2% solids) from the sludge cells using mobile sludge injection equipment (QuadVac), which would be loaded from the frac tank and travel from the lagoon to a farm, cross the field cutting a furrow, injecting the sludge, and then turning over the furrowed soil to cover the sludge. The QuadVacs are completely enclosed containers, designed to mitigate a potential sludge spill and odour emissions during transportation and injection, as shown in Figure 3-2.

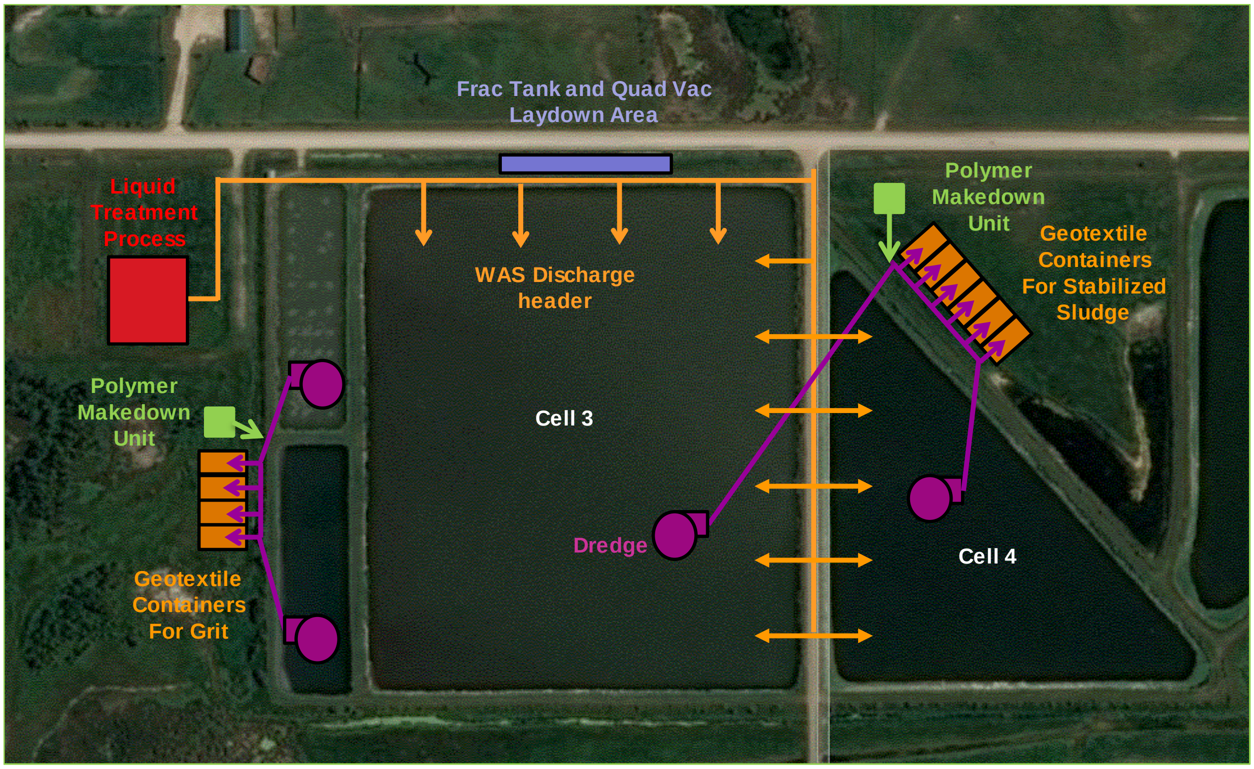

Figure 3-1 Lagoon Stabilization Layout

Figure 3-2 Frac Tank (top) Coarse Screen (bottom left), QuadVac (bottom right)

Land application of municipal sludge is a common method of sludge disposal in Western Canada and a methodology has been well developed to maximize its benefits and minimize its potential negative impacts. Benefits of land application include soil fertilization and conditioning. However, it could be cost prohibitive if the land application sites are relatively far from the WWTP.

Potential negative impacts with land application include contamination of crops, soil, surface water or groundwater. Proper precautions are required, which include understanding the sludge characteristics, rate of application of the sludge, monitoring of the soil, and selection of crops to be grown. Other potential negative impacts include variability of nutrients in the sludge, soil contamination with metals and toxic organic compounds, soil compaction during injection, contamination of surface or shallow groundwater by pathogens or nitrates, health concerns related to transmission of pathogens from soil to crops to animals and humans, odour emissions, road impacts and dust from tankers traveling on gravel roads. In some jurisdictions, reapplication is not allowed. Mitigation methods proposed to minimize potential environmental impacts include controlled application rates, proper site selection, sludge mixing, sub-surface injection, sludge and soil monitoring and crop restrictions.

Sludge dredging and land injection can be conducted initially every six years and progressively increased to every four years depending on sludge storage capacity and land availability. Sludge sampling and soil analysis should be conducted prior to dredging to ensure regulatory requirements have been met. It is expected that the City will coordinate sludge dredging and pre and post application soil testing and reporting.

If the biosolids are not suitable for land injection, the City can hire a contractor to dewater and transport about 870 tonnes of DS (4,350 m^3 at 20% solids) from the dewatering sites at the lagoons to the landfill, which is located 47 km from the WWTP. Sludge dewatering should be conducted initially every six years and progressively increased to every four years using geotextiles or skid mounted centrifuge rental units. Regardless of the selected dewatering method and frequency, sludge sampling should be conducted prior to dewatering to ensure regulatory requirements have been met. The section of sludge to be dewatered should be left to rest for a year to ensure that it has been stabilized and meets the regulatory requirements. Dewatered biosolids can be stockpiled at the landfill and blended with native soil or other material if required to be applied as cover on the landfill. It is expected that the revenue generated by the biosolids sale as intermediate landfill cover offsets the solids management operating cost.

The option of de-sludging the cells using geotextile containers provides flexibility to the City as the cake can be left in the geotextile containers during one freeze and thaw cycle to increase the cake dryness and provide the storage required before use. This in turn will allow the City to achieve better odour management since cake hauling can be conducted when the prevailing wind direction is away from the City. It is expected that the City will coordinate sludge dewatering during summer months.

It is estimated that six geotextile containers will be required to dewater 43,500m^3 at 2% DS of digested sludge stored in the cells. Each geotextile container with a circumference of 36 m and a length of 30 m can be filled with approximately 723 m^3 of sludge. The resulting volume and mass of dewatered sludge retained in the geotextile containers at 20% solids would be 4,350 m^3 or 870 tonnes DS. A laydown area 115 m long by 30 m wide with a v-notch trench will be required to deploy the 6 containers, as shown in Figure 3-3.

Figure 3-3 Lagoon De-sludging Using Geotextile Containers

4.0 CHEMICAL PRECIPITATION OF PHOSPHORUS

Chemicals such as alum or ferric chloride can be dosed into the tank at the end of the last aerobic zone to precipitate phosphorus. The precipitated chemical complex is wasted along with the waste activated sludge. The chemical complex increases the solids concentration in the bioreactor and needs to be accounted for in the design. In Saskatchewan, alum is the preferred chemical for phosphorus precipitation due to the relatively close supply from the Chemtrade alum production facility located at Fort Saskatchewan.

Alum is added after the bioreactors to remove the level of phosphorus that is not biologically removed due to a lack of sufficient VFAs. Annual alum costs were estimated using the assumptions listed in Table 4-1.

Table 4-1 Assumptions used to Estimate Annual Alum Cost

Parameter	Unit	Value
Design year	m^3/d	2020
Sewage flow rate	m^3/d	2,550
Phosphorus concentration at the bioreactor inlet excluding phosphorus concentration in the recycle stream	mg/L	7.4
Phosphorus concentration at the final effluent	mg/L	0.5
Phosphorus concentration to be removed by microorganism assimilation	mg/L	2.0
Phosphorus concentration to be removed by alum addition	mg/L	5.4
Phosphorus mass to be removed by alum addition	kg/d	20
Alum solution dosage required (based on Al/P mole ratio of 1.2 required by other plants in Saskatchewan)	mg/L of sewage	120
Alum solution mass rate required	kg/d	492
Alum solution volume required	L/d	370
Alum solution price (48.18% strength)	$/kg	0.55
Alum solution annual cost, excluding taxes and freight charges	$/yr	61,400

Based on the above, approximately 492 kg/d of liquid alum would be needed for phosphorus precipitation with an estimated annual cost for alum of approximately $61,400 for the initial year.

A 16 m^3 alum storage tank would provide approximately 43 days storage capacity. This is likely the most economic load that can be hauled from Fort Saskatchewan to Humboldt. Smaller quantities can be delivered; however, freight charges for a full load will apply.

5.0 TECHNICAL EVALUATION OF THE SHORT LISTED OPTIONS

The short listed liquid treatment options for the WWTP were evaluated using the decision model presented in Table 5-1. The model organizes the decision factors by hierarchical level and gives a weighting corresponding to its importance. Stantec completed preliminary scoring to facilitate discussions with the City. Weights for each factor were established by Stantec's experience with other municipalities of similar size as Humboldt. The City is invited to undertake a similar exercise with the decision model, as weighting may be viewed differently by the City.

For each of the options (i.e., Aerated Lagoons/SAGR, MBBR, and SBR) a score of between 1 and 100 was assigned for each factor. The resulting points (i.e., weight x score) are totaled to determine the total for each of the options. For instance, Option 1 – Aerated Lagoon/SAGR process was given a 4.5 point for operational robustness based on a net weight of 4.5% and a score of 100. The net weight was computed by multiplying the 30% weight factor for level 1 – operation times the 15% weight factor for level 2 – robustness. Option 2, the MBBR Process scored the highest overall score in the decision model, slightly edging out the SAGR and SBR options.

Table 5-1 Decision Model for the Evaluation of the Humboldt WWTP Short listed Liquid Treatment Options

Weight	Level 1 Factor	Weight	Level 2 Factor	Description	Net Weight	Option 1 - Aerated Lagoons / SAGR Process		Option 2 - MBBR Process		Option 3 - SBR Process	
						Score	Points	Score	Points	Score	Points
30%	Operation	15%	Robustness	Ability to handle daily and seasonal wastewater flows and loading	4.5%	100	4.5	95	4.3	90	4.1
		15%	Reliability and Risk of Failure	Impact on effluent compliance due to process equipment malfunction (headworks, NML pump, PLC functioning)	4.5%	95	4.3	85	3.8	85	3.8
		10%	Flexibility	Adaptability to abnormal process conditions such as low food to mass ratio and high FOG	3.0%	95	2.9	90	2.7	95	2.9
		10%	Operational Complexity	Impact of process on plant operation and skill set of existing personnel (process with multiple tanks, pumps, blowers and recycle requires more operator attention)	3.0%	90	2.7	70	2.1	80	2.4
		10%	Operational issues	Foaming, scum and bulking control	3.0%	90	2.7	80	2.4	70	2.1
		5%	Safety	Impact on operational safety (i.e. chemical handling, high H_2S, working near aerated cells)	1.5%	70	1.1	80	1.2	90	1.4
		5%	Track Record	Level of performance in Western Canada	1.5%	95	1.4	85	1.3	85	1.3
		15%	Level of Automation	Level of skills required for operation (PLC)	4.5%	90	4.1	75	3.4	75	3.4
		15%	Staffing	Level of certification requirements to attract and retain operators	4.5%	90	4.1	80	3.6	80	3.6
20%	Maintenance	25%	Safety	Ease of access for tank inspection and maintenance (i.e. diffuser in an aerated cell)	5.0%	60	3.0	90	4.5	90	4.5
		30%	Maintenance Complexity	Impact of process selection on equipment maintenance (process with multiple tanks, pumps, blowers and recycle requires more maintenance)	6.0%	85	5.1	80	4.8	90	5.4
		15%	Warranty	Level of warranty required	3.0%	85	2.6	70	2.1	75	2.3
		15%	Proprietary Parts	Level of proprietary parts	3.0%	85	2.6	70	2.1	80	2.4
		15%	Availability of Parts	Easily available parts	3.0%	90	2.7	70	2.1	80	2.4

Weight	Level 1 Factor	Weight	Level 2 Factor	Description	Net Weight	Option 1 - Aerated Lagoons / SAGR Process		Option 2 - MBBR Process		Option 3 - SBR Process	
						Score	Points	Score	Points	Score	Points
20%	Future Issues	20%	Compatibility with Future Liquid Process Expansion	Adaptability to future infrastructure	4.0%	80	3.2	100	4.0	80	3.2
		10%	Compatibility with Future Solids Process Expansion	Adaptability to future infrastructure	2.0%	90	1.8	90	1.8	90	1.8
		10%	Wet Weather Flow Management	Ability to treat high flows and effluent quality after blending	2.0%	95	1.9	70	1.4	70	1.4
		10%	Flexibility	Adaptability to more stringent effluent criteria	2.0%	50	1.0	90	1.8	80	1.6
		40%	Stage Development	Flexibility to be implemented or expanded in modular increments	8.0%	70	5.6	90	7.2	80	6.4
		10%	Future Cost	Cost of future expansions or upgrades	2.0%	50	1.0	100	2.0	50	1.0
10%	Constructability Issues	20%	Compatibility with Existing Infrastructure	Adaptability to the existing infrastructure or site conditions	2.0%	95	1.9	80	1.6	80	1.6
		40%	Construction Schedule	Impact of long construction or late delivery	4.0%	60	2.4	90	3.6	70	2.8
		40%	Commissioning and Start-up	Impact of long commissioning or start-up	4.0%	90	3.6	80	3.2	90	3.6
10%	Public Acceptance	10%	Stakeholder Issues	Level of public support and positive opinion	1.0%	70	0.7	90	0.9	90	0.9
		40%	Odour Emissions	Level of nuisance odour emissions from septage discharge, sludge handling and disposal	4.0%	80	3.2	80	3.2	80	3.2
		5%	Impacts During Construction and Operation	Level of impact of construction and operation on nearby residential area	0.5%	80	0.4	70	0.4	70	0.4
		40%	Regional Growth	Support regional growth (septage receiving station)	4.0%	80	3.2	80	3.2	80	3.2
		5%	Land Use	Impact on property value	0.5%	70	0.4	80	0.4	80	0.4

Technical Evaluation of the Short listed Options
May 22, 2019

Weight	Level 1 Factor	Weight	Level 2 Factor	Description	Net Weight	Option 1 - Aerated Lagoons / SAGR Process		Option 2 - MBBR Process		Option 3 - SBR Process	
						Score	Points	Score	Points	Score	Points
10%	Environmental	17%	Enhanced Receiving Water	Ability to achieve higher water quality without excessively increasing capital cost	1.7%	60	1.0	90	1.5	80	1.4
		17%	Enhanced Solids Handling Train	Ability to achieve higher biosolids quality without excessively increasing capital cost	1.7%	70	1.2	70	1.2	75	1.3
		6%	Effluent Reuse	Effluent reuse potential	0.6%	80	0.5	90	0.5	70	0.4
		10%	Approvals/Regulatory	Proximity to residential area	1.0%	80	0.8	90	0.9	90	0.9
		20%	Sustainability	Long term commitment to maintain this treatment	2.0%	70	1.4	90	1.8	80	1.6
		30%	Global Climate	Level of greenhouse gas generation during construction from the use of non-renewable fuels	3.0%	80	2.4	80	2.4	70	2.1
100%	Total Benefit				100%		81.0		83.4		80.0

5.1 LIFE CYCLE COST

A technical and financial evaluation has been completed for each option. Table 5-2 presents life cycle cost estimates and the benefit-cost ratio for the purpose of comparing the options.

Table 5-2 Life Cycle Cost

Item	Description	Option 1 Aerated Lagoons / SAGR Process	Option 2 MBBR Process	Option 3 SBR Process
1.0	General requirements	$2,352,000	$2,524,000	$2,518,000
2.0	Siteworks	$4,987,000	$4,648,200	$4,648,200
3.0	Headworks	$0	$1,760,000	$1,760,000
4.0	Upgrades to cells 1, 2 and 3	$1,698,000	$1,243,000	$1,243,000
5.0	SAGR cells	$4,693,000		
6.0	Process building	$8,988,000	$13,564,500	$13,515,000
7.0	Odour control building	$0	$640,000	$640,000
8.0	**Subtotal**	$22,718,000	$24,380,000	$24,324,000
	Contingency (20%)	$4,544,000	$4,876,000	$4,865,000
	Engineering (10%)	$2,727,000	$2,926,000	$2,919,000
	Total Project Capital Cost	$29,989,000	$32,182,000	$32,108,000
	Annual Operation Cost for 2020	$495,000	$550,000	$533,000
	NPV O&M (33 years)	$15,870,000	$17,370,000	$16,930,000
	NPV Life Cycle Cost (33 years)	$45,859,000	$49,552,000	$49,038,000

Note:

1. Net Present Value developed based on a discount rate of 3.82% and an inflation rate of 2% per annum. Net present values were calculated using 2020 as the base year and extending to 2052.
2. Annual operating cost for 2020 does not include sludge disposal. The City should budget for sludge disposal, about $149,000 (landfilling) or $242,000 (land application) each year.

5.1.1 Life Cycle Cost Results

The life cycle costs indicate that Option 1, Aerated Lagoons/SAGR process provides the lowest capital cost, lowest operational costs and lowest Net Present Value (NPV) for the 33-year design life used in the calculation. The NPV represents the value of all future costs over the design life of the capital investment. Opinions of probable cost for capital and operating costs are described in the following sections.

5.1.2 Opinion of Probable Capital Cost

Opinions of Probable Capital Cost (OPCC) are preliminary and subject to development of actual designs, loadings and any special requirements, but do provide an indication of relative cost differentials between the different options. Appendix A provides a breakdown of the OPCCs for each of the three options.

OPPCs were developed using a combination of stochastic and deterministic factors as follows:

General requirements (stochastic): General requirements include the cost of mobilization / demobilization, start-up and commissioning, O&M manuals and record drawings. These costs are about 11.5% of the subtotal for all process areas.

Siteworks (deterministic and stochastic): Siteworks include the cost of excavation and backfill, roadways, yard piping, outfall structure, outfall gravity piping, fencing, landscaping and dewatering allowance. The OPPC for excavation and compacted backfill were based on calculated volumes and rate of $\$24/m^3$ of material.

Structural tank (deterministic): OPCC for concrete tanks are based on calculated concrete volumes priced at an average of about $\$1,650/m^3$ for slab and $\$1,400/m^3$ for walls. Rebar cost are estimated based on a unit rate of $\$440/m^3$ for concrete. Form work costs are estimated based on the surface area of tank wall at a unit rate of $280 for straight wall and $330 for circular wall.

Structural building (deterministic): OPCC for structural buildings is based on lump sum prices for masonry, metals, wood, plastic, thermal and moisture protection, doors and windows for similar buildings.

Process (deterministic): OPCC for process is developed from vendor quotes (specifically requested for this project and provided in Appendix B) plus a 50% installation cost.

Mechanical (stochastic): OPCC for HVAC mechanical is based on experience from previous projects, the mechanical costs are assumed to be 10% of the subtotal for each process area.

Electrical, Instrumentation and Control (I&C) (stochastic): OPCC for electrical and I&C is based on experience from previous projects, these costs are assumed to be 17.5% of the subtotal for each process area.

5.1.3 Opinion of Probable Operating Cost

Opinions of Probable Operating Cost (OPOC) are developed based on standard unit costs. The opinions of probable costs are tentative and subject to development of actual unit cost for the plant but do provide an indication of relative cost differentials between the different options. Table 5-3 summarizes the OPOCs for the three options. The annual OPOC (Table 5-2) for each option is anticipated to be very similar, ranging from $480,000 to $550,000 annually (based on the first year of operation, without sludge disposal). Annual costs will fluctuate depending on sludge removal frequency. Item 8.0 in Table 5-3 below identifies the anticipated average sludge removal costs that the City should budget annually, for period sludge removal.

Table 5-3 Opinion of Probable Operating Cost

Item	O&M Components	Option 1 Aerated Lagoons / SAGR Process	Option 2 MBBR Process	Option 3 SBR Process
1.0	Salaries with benefits	$141,000	$211,000	$211,000
2.0	Administration (training, fleet, and fuel)	$35,000	$35,000	$35,000
3.0	Insurances and legal fees	$35,000	$35,000	$35,000
4.0	Monitoring and testing	$30,000	$40,000	$40,000
5.0	Consumables (chemicals, UV lamps)	$71,000	$80,000	$71,000
6.0	Electricity	$143,000	$94,000	$86,000
7.0	Natural gas	$20,000	$25,000	$25,000
8.0	Sludge disposal – land application (average over 33 years)	$242,000	$232,000	$232,000
9.0	Contract operations (equipment maintenance)	$20,000	$30,000	$30,000
	Total	**$737,000**	**$782,000**	**$765,000**

Salaries estimates are based on 2 full time employees (full time equivalents or FTE's) for the Aerated Lagoons/SAGR option and 3 FTE's for the MBBR and SBR options. Labor cost estimates are based on hourly rates for WWTP operators in Saskatchewan. Benefit costs were estimated using a 1.25 multiplier. WSA requires that owners of wastewater works ensure the responsibility for the overall day-to-day operation of the works is placed with operators holding the appropriate certificate. For this reason, two operators are required to cover days off, holidays, sick days and overtime exceeding 40 hours per week. Two or more operators are required to meet occupational health and safety regulations such as confined space entry, working alone or near open water without a safety watch. In addition, two or more operators are required to develop a successful training and succession planning as well as to establish a consistent biosolids disposal program that suits the needs of the City.

Power cost estimates were developed using motor power demand, and hours of service for expected equipment. For electrical power, a unit cost of $0.07/kWh was used for electricity consumed. It is understood the SaskPower utility bill includes demand charges, peaking charges and other surcharges. For the sake of simplification, the average unit cost of $0.07/kWh is applied to all power cost calculations.

Natural gas costs were estimated based on the estimated footprint of the building.

Sludge disposal costs were estimated based on $10/m3 for liquid land application and $20/m3 for dewatering and $0.72/tonne/km for transportation to landfill.

Consumables and chemical cost estimates are based on volume of chemical consumed and unit chemical costs as presented in Table 5-4:

Table 5-4 Consumables Cost Estimated for Chemical Precipitation (initial year)

Description	Qty	Dose	Daily Chemical Usage	Annual Chemical Usage	Unit Consumable Costs	Annual Consumable Costs
		g/m^3	kg/d	kg/yr	$/kg	$
Alum		120	306	111,700	$0.55	$61,400
Polymer		1	2.55	931	$9.25	$8,600
Chlorine (Final effluent disinfected to be used as utility water)		3	7.65	2,792	$0.83	$2,300
UV lamps	24				$404.00	$7,100
Aerated Lagoons/SAGR or SBR Diffuser replacement (after 10 years of service)					$10,000	$12,000
Total Consumable Costs (chemical cost varies depending of the liquid treatment process)						$71,000 to $80,000

5.2 CONCLUSION AND RECOMMENDATION

The results of the decision model indicate that the MBBR option scores the highest and provides a slight benefit advantage to the City of Humboldt when compared to the Aerated Lagoons/SAGR or SBR options. The Aerated Lagoons/SAGR option provides the best NPV.

Final selection of the preferred option includes results from the decision model as well as evaluating life cycle costs, opinions of capital costs, opinions of operating costs, and opinions of consumable costs. The overall ranking of each option is presented below as a benefit to cost ratio.

Table 5-5 Overall Ranking for Each Liquid Treatment Options

Rank	Option	Benefit	Life Cycle Cost	Benefit - Cost Ratio
1	Option 1: Aerated Lagoons/SAGR Process with Chemical Precipitation	81	$45.89M	1.77
2	Option 2: MBBR with Chemical Precipitation	83.4	$49.55M	1.68
3	Option 3: SBR with Chemical Precipitation	80.0	$49.04M	1.63

The Aerated Lagoons/SAGR option has the highest benefit cost ratio because this option is very compatible with existing infrastructure and it can be expanded to meet population growth after 2052 by adding two more SAGR cells and replacing blowers and diffusers, which would reduce future upgrade expenditures. This option has the lowest OPCC as it makes use of existing infrastructure (cells 1 to 7). In addition, the Aerated Lagoon/SAGR process does not required headworks, or solids separation equipment such as DAF or disc filters.

The main disadvantage of the Aerated Lagoons/SAGR option is that it cannot reduce the effluent Total Nitrogen concentration to less than 28 mg/L in summer and 31 mg/L in winter. This could be viewed by stakeholders near the WWTP as a significant issue since they may want a superior effluent quality discharged into the receiving environment even though WSA has not set stringent TN limits (typical TN limit has been between 10 and 15 mg/L for other WWTP in Saskatchewan). The MBBR option can provide a superior quality effluent with TN concentrations less than 12 mg/L. However, the MBBR option has a much higher OPCC. If WSA imposes more stringent TN limits in the future the Aerated Lagoons/SAGR option could be retrofitted with post-denitrification cells and filters. This improvement would increase the capital and operating costs (not included in the NPV calculations). One other drawback with the Aerated Lagoons/SAGR option is that there is only one supplier (Nexom).

Both the Aerated Lagoons/SAGR and the MBBR processes are stable, efficient, reliable and flexible. These attributes are due to the inherent nature of the treatment processes coupled with reputable suppliers. These systems do not experience operational problems such as foaming, scum or bulking, which is very typical for suspended activated sludge processes.

Both the Aerated Lagoons/SAGR and the SBR processes have good track records in Western Canada. These processes have been widely used for small and medium size WWTP’s that cannot re-use their existing facultative lagoons due to odour concerns and relatively proximity to residential areas. The MBBR and the SBR process have similar OPCC's, largely due to the premium cost of the MBBR propriety equipment even though it requires smaller bioreactors.

All short listed options support the City's objectives of implementing a mechanical wastewater treatment plant without excessively increasing the level of certification and skills requirements to attract and retain operators since the facility most likely would be likely classified as Class II.

All options provide consistent sludge stabilization since the existing lagoons can be used for lagoon thickening and stabilization. The sludge management option relies on periodical sludge removal to ensure that space would always be available to receive fresh sludge and to minimize odor emission by maintaining a water layer over the digested sludge.

The Aerated Lagoons/SAGR option is operationally less complex than the MBBR and SBR options since it has less process units and equipment to operate or maintain. For this reason, it requires only two operators. The Aerated Lagoons/SAGR option will require contract with Nexom for maintenance and repair of the aeration system. Any repair work near the cells would require three to four operators for safety reasons. Although the Aerated Lagoons/SAGR system does not require daily supervision and routine maintenance, two operators are required to cover days off, holidays, sick days and to develop a successful training and succession planning as well as to establish a consistent biosolids disposal program that suits the needs of the City.

Option 1, the Aerated Lagoons/SAGR process provides the highest benefit to cost ratio, and therefore is the recommended option to carry forward to predesign.

APPENDIX A

OPINION OF PROBABLE COST

Appendix A OPINION PROBABLE COST

Appendix A.1 – SAGR (2 pages)

Appendix A.2 – MBBR (3 pages)

Appendix A3. – SBR (3 pages)

Opinion of Probable Capital Costs for Aerated Lagoons/SAGR for Design period 2052 to Serve 10,000 people
ADF = 4100 m^3/d, MMF = 7240 m^3/d, MDF = 14,252 m^3/d

				Material or Equipment Costs		Labour &	
Item No.	**Description**	**Unit**	**Quantity**	**Unit Price**	**Total Price**	**Overhead**	**Total Costs**
1.0	**General Requirements**						
1.1	Divisions 0 and 1						
	Mobilization / Demobilization	% Total	1	0.30%	$61,000		$61,000
	General Conditions	% Total	1	7.50%	$1,527,000		$1,527,000
	Performance Assurance	% Total	1	1.20%	$244,000		$244,000
	Insurance	% Total	1	1.40%	$285,000		$285,000
	Building Permit	% Total	1	0.15%	$31,000		$31,000
	Start-up and Commissioning	% Total	1	0.50%	$102,000		$102,000
	O&M Manuals and Record Drawings	% Total	1	0.50%	$102,000		$102,000
	Subtotal						**$2,352,000**
2.0	**Siteworks**						
2.1	Divisions 31 to 33 - Siteworks						
	Layout and Survey	LS	1	$30,000	$30,000	Included	$30,000
	Parking Lots	m^2	4,500	$100	$450,000	Included	$450,000
	Site Access Road to SAGR	LS	2,000	$100	$200,000	Included	$200,000
	Site Stripping and Grading	LS	1	$120,000	$120,000	Included	$120,000
	Yard Piping Allowance (Including underground services)	LS	1	$150,000	$150,000	Included	$150,000
	Influent Valve Chamber	LS	1	$300,000	$300,000	Included	$300,000
	RS Pipe to Influent Valve Chamber	m	100	$500	$50,000	Included	$50,000
	RS Pipe from Valve Chamber to Headworks	m	5	$500	$3,000	Included	$3,000
	NML Forcemain to Front End Lagoon	m	1,300	$500	$650,000	Included	$650,000
	Outfall Structure	LS	1	$250,000	$250,000	Included	$250,000
	Effluent Forcemain 500 mm (including manholes, backfill and testing)	m	4,400	$500	$2,200,000	Included	$2,200,000
	WAS Pipe from Process Building to Lagoon 3	m	0	$0	$0	Included	$0
	Site Preparation for Geotextile Container for Grit	m^2	2,400	$75	$180,000	Included	$180,000
	Site Preparation for Geotextile Container for Stabilized Sludge	m^2	3,450	$75	$259,000	Included	$259,000
	Site Preparation for Frac Tanks	m^2	200	$75	$15,000	Included	$15,000
	Railway Crossing	LS	0	$1,000	$0	Included	$0
	Flood Protection (Berm and Sod)	LS	0	$0	$0	Included	$0
	Fencing (1800mm chain link fence)	m	0	$14	$0	Included	$0
	Landscaping Allowance	LS	1	$90,000	$90,000	Included	$90,000
	Dewatering Allowance	LS	1	$40,000	$40,000	Included	$40,000
	Subtotal Siteworks						**$4,987,000**
3.0	**Headworks**						
	Subtotal Headworks						**$0**
4.0	**Cells 1, 2 and 3**						
4.1	Divisions 31 to 33 - Siteworks						
	Embankment Construction	m3	4,800	24	$115,000	Included	$115,000
	Cells 1 and 2 Clay Liner (600 mm thick)	m2	9,500	10	$95,000	Included	$95,000
	Liner Protection (300 mm thick)	m2	9,500	5	$48,000	Included	$48,000
	Stripping and Compaction	m2	0	1900	$0	Included	$0
	Erosion Protection	m2	0	60	$0	Included	$0
	Rapid and Slow Mixing Manholes	LS	2	75,000	$150,000	Included	$150,000
	Effluent Manholes	LS	1	60,000	$60,000	Included	$60,000
	Excavation for Air Headers	m	1,300	$100	$130,000	Included	$130,000
	De-sludging Cells 1, 2 and 3	m3	55,000	20	$1,100,000	Included	$1,100,000
	Subtotal Cells 1, 2 and 3						**$1,698,000**
5.0	**SAGR Cells**						
5.1	Divisions 31 to 33 - Siteworks						
	Stripping and Compaction	m2	15,168	2	$30,000	Included	$30,000
	Excavation	m3	45,504	24	$1,092,000	Included	$1,092,000
	Wall Framing and Sheeting	m	976	80	$78,000	Included	$78,000
	HDPE Liner (60 mil)	m2	15,104	22	$332,000	Included	$332,000
	Clean Gravel/Rock	m3	27,878	80	$2,230,000	Included	$2,230,000
	Insulating Wood Strips	m3	3,686	20	$74,000	Included	$74,000
	Non-Woven Geotextile (8 oz)	m2	28,800	2.5	$72,000	Included	$72,000
	Influent Flow Splitter Structure	l.s.	1	75,000	$75,000	Included	$75,000
	Piping, Fittings, Valves from Splitter to SAGR	l.s.	1	200,000	$200,000	Included	$200,000
	Piping, Fittings, Valves from Cell 7 to SAGR	m	200	$550	$110,000	Included	$110,000
	Piping, Fittings, Valves from SAGR to Effluent Lift Station	m	500	$550	$275,000	Included	$275,000
	Effluent Manholes (provided by Nexom)	l.s.	4	0	$0	Included	$0
	Effluent Level Control Manhole	l.s.	1	75,000	$75,000	Included	$75,000
	Excavation for Air Headers	m	500	$100	$50,000	Included	$50,000
	Subtotal SAGR						**$4,693,000**

Item No.	Description	Unit	Quantity	Material or Equipment Costs Unit Price	Material or Equipment Costs Total Price	Labour & Overhead	Total Costs
6.0	**Process Building**						
6.1	Divisions 31 to 33 - Siteworks						
	Excavation and Backfill	m^3	1,136	$24	$27,000	Included	$27,000
	Piling	each	0	$2,500	$0	Included	$0
6.2	Division 3 - Concrete Work						
	Structure - Slab	m^3	135	$1,650	$223,000	Included	$223,000
	Structure - Walls	m^3	115	$1,400	$161,000	Included	$161,000
	Form Work	m^2	560	$280	$157,000	Included	$157,000
	Rebar	m^3	250	$440	$110,000	Included	$110,000
	Void Form (200 mm)	m^2	184	$22	$4,000	Included	$4,000
	Precast Hollow Core	LS	1	$60,000	$60,000	Included	$60,000
6.3	Division 4 - Masonry	LS	1	$100,000	$100,000	Included	$100,000
6.4	Division 5 - Metals	LS	1	$100,000	$100,000	Included	$100,000
6.5	Division 6 - Wood and Plastic	LS	1	$10,000	$10,000	Included	$10,000
6.6	Division 7 - Thermal and Moisture Protection						
	Metal Cladding	LS	1	$80,000	$80,000	Included	$80,000
	Roofing	LS	1	$35,000	$35,000	Included	$35,000
6.7	Division 8 - Doors and Windows						
	Access Hatches	LS	2	$5,000	$10,000	Included	$10,000
	Doors / Overhead Doors / Frames / Hardware	LS	16	$1,500	$24,000	Included	$24,000
	Windows/Glazing	LS	4	$3,000	$12,000	Included	$12,000
6.8	Division 9 - Finishes						
	Painting	LS	1	$15,000	$15,000	Included	$15,000
	Special Coatings	LS	1	$75,000	$75,000	Included	$75,000
6.9	Division 10 - Specialities	LS	1	$7,000	$7,000	Included	$7,000
6.10	Division 12 - Furnishing	LS	1	$60,000	$60,000	Included	$60,000
6.11	Divisions 40, 43 and 46 - Process						
	Sluice and Slide Gates	LS	2	$8,000	$16,000	$8,000	$24,000
	Drain Pumps	LS	2	$10,000	$20,000	$10,000	$30,000
	Equipment Supply by Nexom (air blowers, HDPE headers, laterals, diffusers, control panels, influent piping and chambers eng. and installation)	LS	1	$3,230,000	$3,230,000	$646,000	$3,876,000
	NML Pump and and Fitting	each	1	$150,000	$150,000	$75,000	$225,000
	Filtration System	each	0	$0	$0	$0	$0
	UV Disinfection System	each	1	$350,000	$350,000	$175,000	$525,000
	Effluent Pump and Fitting	each	1	$150,000	$150,000	$75,000	$225,000
	Plant Water (W3) Pump and Fiting	each	1	$15,000	$15,000	$8,000	$23,000
	Polymer Blend System	LS	0	$40,000	$0	$0	$0
	Polymer Pumps	LS	0	$23,000	$0	$0	$0
	Alum Storage Tanks (reuse existing tank)	LS	0	$35,000	$0	$0	$0
	Alum Transfer Pumps and Feed Systems (reuse existing pumps)	LS	0	$20,000	$0	$0	$0
	Chlorination System with Chemical Piping	LS	2	$20,000	$40,000	$20,000	$60,000
	Laboratory Equipment Including Samplers	LS	1	$100,000	$100,000	$20,000	$120,000
6.12	Division 41 - Conveying Systems						
	Mobile Crane	LS	1	$65,000	$65,000	Included	$65,000
	Monorails (polymer and filter)	LS	0	$0	$0	$0	$0
6.13	Divisions 22 and 23 - Mechanical	LS	1	$910,000	$910,000	Included	$910,000
6.14	Divisions 26, 28 and 40 - Electrical						
	Electrical Service	LS					
	1000 Amp 25KV-600/347V	LS	1	$45,000	$45,000	Included	$45,000
	Service entrance switchgear, MCC's, panelboards etc.	LS	1	$410,000	$410,000	Included	$410,000
	LV Electrical Distribution (Switchgear, MCC & Transfer Switch) Install	LS	1	$150,000	$150,000	Included	$150,000
	Cabling, terminations & contractor commissioning	LS	1	$125,000	$125,000	Included	$125,000
	Telephone Service	LS	1	$30,000	$30,000	Included	$30,000
	Building Systems Electrical (lighting, power distribution, communications, fire, security, exit and emergency lighting & grounding systems)	LS	1	$300,000	$300,000	Included	$300,000
	Generator	LS					
	600V 300 KVA	LS	1	$150,000	$150,000	Included	$150,000
	Exterior Diesel Fuel Tank	LS	1	$40,000	$40,000	Included	$40,000
	Generator & Systems Installation	LS	1	$60,000	$60,000	Included	$60,000
	Controls/Instrumentation/Communications	LS					
	Control System & Programming	LS	1	$200,000	$200,000	Included	$200,000
	Control System (PLC and HMI Supply & Install)	LS	1	$125,000	$125,000	Included	$125,000
	Subtotal Operations Building						**$8,988,000**
7.0	**Odour Building**						
	Subtotal Process Odour Building						**$0**
	Subtotal						**$22,718,000**

Notes:
1. Costs are in 2019 Canadian Dollars.
2. Construction costs will vary depending on market conditions at the time of tender. Stantec has no control over those conditions.

Opinion of Probable Capital Costs for MBBR with Chemical Precipitation

Bioreactor Volume 2350 m^3, Digester 0 m^3, ADF = 4420 m^3/d, PDF = 7500 m^3/d

				Material or Equipment Costs		Labour &	
Item No.	**Description**	**Unit**	**Quantity**	**Unit Price**	**Total Price**	**Overhead**	**Total Costs**
1.0	**General Requirements**						
1.1	Divisions 0 and 1						
	Mobilization / Demobilization	% Total	1	0.30%	$66,000		$66,000
	General Conditions	% Total	1	7.50%	$1,639,000		$1,639,000
	Performance Assurance	% Total	1	1.20%	$262,000		$262,000
	Insurance	% Total	1	1.40%	$306,000		$306,000
	Building Permit	% Total	1	0.15%	$33,000		$33,000
	Start-up and Commissioning	% Total	1	0.50%	$109,000		$109,000
	O&M Manuals and Record Drawings	% Total	1	0.50%	$109,000		$109,000
	Subtotal						**$2,524,000**
2.0	**Siteworks**						
2.1	Divisions 31 to 33 - Siteworks						
	Layout and Survey	LS	1	$30,000	$30,000	Included	$30,000
	Parking Lots	m^2	4,500	$100	$450,000	Included	$450,000
	Site Access Road to MBBR	m^2	2,000	$100	$200,000	Included	$200,000
	Site Stripping and Grading	LS	1	$120,000	$120,000	Included	$120,000
	Yard Piping Allowance (Including underground services)	LS	1	$150,000	$150,000	Included	$150,000
	Influent Valve Chamber	LS	1	$300,000	$300,000	Included	$300,000
	RS Pipe to Influent Valve Chamber	m	100	$500	$50,000	Included	$50,000
	RS Pipe from Valve Chamber to Headworks	m	5	$500	$3,000	Included	$3,000
	NML Forcemain to Front End Lagoon	m	0	$0	$0	Included	$0
	Outfall Structure	LS	1	$250,000	$250,000	Included	$250,000
	Effluent Forcemain 300 mm (including backfill and testing)	m	4,400	$500	$2,200,000	Included	$2,200,000
	WAS Pipe from Process Building to Lagoon 3	m	600	$500	$300,000	Included	$300,000
	Site Preparation for Geotextile Container for Grit	m^2	2,400	$75	$180,000	Included	$180,000
	Site Preparation for Geotextile Container for Stabilized Sludge	m^2	3,450	$75	$259,000	Included	$259,000
	Site Preparation for Frac Tanks	m^2	200	$75	$15,000	Included	$15,000
	Railway Crossing	LS	0	$1,000	$0	Included	$0
	Flood Protection (Berm and Sod)	LS	0	$0	$0	Included	$0
	Fencing (1800mm chain link fence)	m	800	$14	$11,200	Included	$11,200
	Landscaping Allowance	LS	1	$90,000	$90,000	Included	$90,000
	Dewatering Allowance	LS	1	$40,000	$40,000	Included	$40,000
	Subtotal Siteworks						**$4,648,200**
3.0	**Effluent Lift Station**						
	Subtotal Lift Station						**$0**
4.0	**Headworks**						
4.1	Divisions 31 to 33 - Siteworks						
	Excavation and Backfill	m^3	167	$24	$4,000	Included	$4,000
	Piling	each	21	$2,500	$53,000	Included	$53,000
4.2	Division 3 - Concrete Work						
	Structure - Slab	m^3	39	$1,650	$64,000	Included	$64,000
	Structure - Wall	m^3	98	$1,400	$137,000	Included	$137,000
	Form Work	m^2	145	$280	$41,000	Included	$41,000
	Rebar	m^3	137	$440	$60,000	Included	$60,000
	Void Form (200 mm)	m^2	252	$22	$6,000	Included	$6,000
	Precast Hollow Core	LS	1	$30,000	$30,000	Included	$30,000
4.3	Division 4 - Masonry	LS	1	$55,000	$55,000	Included	$55,000
4.4	Division 5 - Metals	LS	1	$100,000	$100,000	Included	$100,000
4.5	Division 6 - Wood and Plastic	LS	1	$10,000	$10,000	Included	$10,000
4.6	Division 7 - Thermal and Moisture Protection						
	Metal Cladding	LS	1	$70,000	$70,000	Included	$70,000
	Roofing	LS	1	$20,000	$20,000	Included	$20,000
4.7	Division 8 - Doors and Windows						
	Access Hatches	LS	0	$0	$0	Included	$0
	Doors / Overhead Doors / Frames / Hardware	LS	1	$7,000	$7,000	Included	$7,000
	Windows / Glazing	LS	1	$1,000	$1,000	Included	$1,000
4.8	Division 9 - Finishes	LS	1	$10,000	$10,000	Included	$10,000
4.9	Division 10 - Specialities	LS	1	$2,000	$2,000	Included	$2,000
4.10	Divisions 40, 43 and 46 - Process						
	Sluice and Slide Gates	LS	10	$8,000	$80,000	$40,000	$120,000
	Fine Screens	each	1	$140,000	$140,000	$70,000	$210,000
	Vortex Grit Removal System	each	1	$240,000	$240,000	$120,000	$360,000
4.11	Divisions 22 and 23 - Mechanical	LS	1	$300,000	$300,000	Included	$300,000
4.12	Divisions 26, 28 and 40 - Electrical	LS	1	$100,000	$100,000	Included	$100,000
	Subtotal Headworks						**$1,760,000**
5.0	**Cells 1, 2 and 3**						
5.1	Divisions 31 to 33 - Siteworks						
	Embankment Construction	m3	0	15	$0	Included	$0
	Cells 1 and 2 Clay Liner (600 mm thick)	m2	9,500	10	$95,000	Included	$95,000
	Liner Protection (300 mm thick)	m2	9,500	5	$48,000	Included	$48,000
	Stripping and Compaction	m2	0	1900	$0	Included	$0
	Erosion Protection	m2	0	60	$0	Included	$0
	Rapid and Slow Mixing Manholes	LS	0	75,000	$0	Included	$0
	Effluent Manholes	LS	0	60,000	$0	Included	$0
	Excavation for Air Headers	m	0	$100	$0	Included	$0
	De-sludging Cells 1, 2 and 3	m3	55,000	20	$1,100,000	Included	$1,100,000
	Subtotal Cells 1, 2 and 3						**$1,243,000**

Item No.	Description	Unit	Quantity	Material or Equipment Costs Unit Price	Material or Equipment Costs Total Price	Labour & Overhead	Total Costs
6.0	**Process Building**						
6.1	Divisions 31 to 33 - Siteworks						
	Excavation and Backfill	m^3	5,897	$24	$141,500	Included	$141,500
	Piling	each	0	$2,500	$0	Included	$0
6.2	Division 3 - Concrete Work						
	Structure - Slab	m^3	593	$1,650	$978,000	Included	$978,000
	Structure - Walls	m^3	484	$1,400	$678,000	Included	$678,000
	Form Work	m^2	2,376	$280	$665,000	Included	$665,000
	Rebar	m^3	1,077	$440	$474,000	Included	$474,000
	Void Form (200 mm)	m^2	740	$22	$16,000	Included	$16,000
	Precast Hollow Core	LS	1	$100,000	$100,000	Included	$100,000
6.3	Division 4 - Masonry	LS	1	$200,000	$200,000	Included	$200,000
6.4	Division 5 - Metals	LS	1	$210,000	$210,000	Included	$210,000
6.5	Division 6 - Wood and Plastic	LS	1	$20,000	$20,000	Included	$20,000
6.6	Division 7 - Thermal and Moisture Protection						
	Metal Cladding	LS	1	$180,000	$180,000	Included	$180,000
	Roofing	LS	1	$70,000	$70,000	Included	$70,000
6.7	Division 8 - Doors and Windows						
	Access Hatches	LS	5	$3,000	$15,000	Included	$15,000
	Doors / Overhead Doors / Frames / Hardware	LS	23	$1,500	$35,000	$17,500	$52,500
	Windows / Glazing	LS	4	$3,000	$12,000	$6,000	$18,000
6.8	Division 9 - Finishes						
	Painting	LS	1	$25,000	$25,000	Included	$25,000
	Special Coatings	LS	1	$200,000	$200,000	Included	$200,000
6.9	Division 10 - Specialities	LS	1	$6,000	$6,000	Included	$6,000
6.10	Division 12 - Furnishing	LS	1	$60,000	$60,000	Included	$60,000
6.11	Divisions 40, 43 and 46 - Process						
	Sluice and Slide Gates	LS	0	$8,000	$0	$0	$0
	Drain Pumps	LS	2	$10,000	$20,000	$10,000	$30,000
	Sludge Lagoon Feed Pumps	LS	2	$20,000	$40,000	$20,000	$60,000
	MBBR Equipment (air blowers, diffusers, mixers, media, sieves)	LS	1	$2,010,000	$2,010,000	$1,005,000	$3,015,000
	NML Pumps	each	2	$50,000	$100,000	$50,000	$150,000
	Disk Filter	LS	1	$740,000	$740,000	$370,000	$1,110,000
	UV Disinfection System	each	1	$350,000	$350,000	$175,000	$525,000
	Effluent Pump and Fitting	each	1	$150,000	$150,000	$75,000	$225,000
	Plant Water (W3) Pump Station	each	1	$15,000	$15,000	$8,000	$23,000
	Polymer Blend System	LS	1	$110,000	$110,000	$55,000	$165,000
	Polymer Pumps	LS	1	$25,000	$25,000	$12,500	$37,500
	Alum Storage Tanks (reuse existing tank)	LS	0	$35,000	$0	$0	$0
	Alum Transfer Pumps and Feed Systems (reuse existing pumps)	LS	0	$25,000	$0	$0	$0
	Chlorination System with Chemical Piping	LS	1	$20,000	$20,000	$10,000	$30,000
	Laboratory Equipment Including Samplers	LS	1	$100,000	$100,000	$20,000	$120,000
6.12	Division 41 - Conveying Systems						
	Mobile Crane	LS	1	$65,000	$65,000	Included	$65,000
	Dump Trailer	LS	0	$23,000	$0	Included	$0
	Monorails	LS	1	$40,000	$40,000	$20,000	$60,000
6.13	Divisions 22 and 23 - Mechanical	LS	1	$1,950,000	$1,950,000	Included	$1,950,000
6.14	Divisions 26, 28 and 40 - Electrical						
	Electrical Service	LS					
	1000 Amp 25KV-600/347V	LS	1	$45,000	$45,000	Included	$45,000
	Service entrance switchgear, MCC's, panelboards etc.	LS	1	$450,000	$450,000	Included	$450,000
	LV Electrical Distribution (Switchgear, MCC & Transfer Switch) Install	LS	1	$165,000	$165,000	Included	$165,000
	Cabling, terminations & contractor commissioning	LS	1	$135,000	$135,000	Included	$135,000
	Telephone Service	LS	1	$30,000	$30,000	Included	$30,000
	Building Systems Electrical (lighting, power distribution, communications, fire, security, exit and emergency lighting & grounding systems)	LS	1	$330,000	$330,000	Included	$330,000
	Generator	LS					
	600V 250 KVA	LS	1	$155,000	$155,000	Included	$155,000
	Exterior Diesel Fuel Tank	LS	1	$40,000	$40,000	Included	$40,000
	Generator & Systems Installation	LS	1	$55,000	$55,000	Included	$55,000
	Controls / Instrumentation / Communications	LS					
	Control System & Programming	LS	1	$320,000	$320,000	Included	$320,000
	Control System (PLC and HMI Supply & Install)	LS	1	$165,000	$165,000	Included	$165,000
	Subtotal Process building						**$13,564,500**
7.0	**Odour Building**						
7.1	Divisions 31 to 33 - Siteworks						
	Excavation and Backfill	m^3	0	$24	$0	Included	$0
	Piling	each	21	$2,500	$53,000	Included	$53,000
7.2	Division 3 - Concrete Work						
	Structure - Slab	m^3	18	$1,650	$30,000	Included	$30,000
	Structure - Walls	m^3		$1,400	$0	Included	$0
	Form Work	m^2		$280	$0	Included	$0
	Rebar	m^3	18	$440	$8,000	Included	$8,000
7.14	Division 44 - Odour Control	LS	0				
	Odour Control Unit	LS	1	$365,000	$365,000	$183,000	$548,000
	Subtotal Process Odour Building						**$640,000**
	Subtotal						**$24,379,700**

Notes:
1. Costs are in 2019 Canadian Dollars.
2. Construction costs will vary depending on market conditions at the time of tender. Stantec has no control over those conditions.

Opinion of Probable Capital Costs for SBR with Chemical Precipitation

Bioreactor Volume 6,530 m^3, Decanter 2 x 7.62 m, Digester 0 m^3, ADF = 4420m^3/d, PDF = 7500 m^3/d

Item No.	Description	Unit	Quantity	Material or Equipment Costs Unit Price	Material or Equipment Costs Total Price	Labour & Overhead	Total Costs
1.0	**General Requirements**						
1.1	Divisions 0 and 1						
	Mobilization / Demobilization	% Total	1	0.30%	$65,000		$65,000
	General Conditions	% Total	1	7.50%	$1,635,000		$1,635,000
	Performance Assurance	% Total	1	1.20%	$262,000		$262,000
	Insurance	% Total	1	1.40%	$305,000		$305,000
	Building Permit	% Total	1	0.15%	$33,000		$33,000
	Start-up and Commissioning	% Total	1	0.50%	$109,000		$109,000
	O&M Manuals and Record Drawings	% Total	1	0.50%	$109,000		$109,000
	Subtotal						**$2,518,000**
2.0	**Siteworks**						
2.1	Divisions 31 to 33 - Siteworks						
	Layout and Survey	LS	1	$30,000	$30,000	Included	$30,000
	Parking Lots	m^2	4,500	$100	$450,000	Included	$450,000
	Site Access Road to SAGR	m^2	2,000	$100	$200,000	Included	$200,000
	Site Stripping and Grading	LS	1	$120,000	$120,000	Included	$120,000
	Yard Piping Allowance (Including underground services)	LS	1	$150,000	$150,000	Included	$150,000
	Influent Valve Chamber	LS	1	$300,000	$300,000	Included	$300,000
	RS Pipe to Influent Valve Chamber	m	100	$500	$50,000	Included	$50,000
	RS Pipe from Valve Chamber to Headworks	m	5	$500	$3,000	Included	$3,000
	NML Forcemain to Front End Lagoon	m	0	$0	$0	Included	$0
	Outfall Structure	LS	1	$250,000	$250,000	Included	$250,000
	Effluent Forcemain 300 mm (including backfill and testing)	m	4,400	$500	$2,200,000	Included	$2,200,000
	WAS Pipe from Process Building to Lagoon 3	m	600	$500	$300,000	Included	$300,000
	Site Preparation for Geotextile Container for Grit	m^2	2,400	$75	$180,000	Included	$180,000
	Site Preparation for Geotextile Container for Stabilized Sludge	m^2	3,450	$75	$259,000	Included	$259,000
	Site Preparation for Frac Tanks	m^2	200	$75	$15,000	Included	$15,000
	Railway Crossing	LS	0	$1,000	$0	Included	$0
	Flood Protection (Berm and Sod)	LS	0	$0	$0	Included	$0
	Fencing (1800mm chain link fence)	m	800	$14	$11,200	Included	$11,200
	Landscaping Allowance	LS	1	$90,000	$90,000	Included	$90,000
	Dewatering Allowance	LS	1	$40,000	$40,000	Included	$40,000
	Subtotal Siteworks						**$4,648,200**
3.0	**Effluent Lift Station**						
	Subtotal Lift Station						**$0**
4.0	**Headworks**						
4.1	Divisions 31 to 33 - Siteworks						
	Excavation and Backfill	m^3	167	$24	$4,000	Included	$4,000
	Piling	each	21	$2,500	$53,000	Included	$53,000
4.2	Division 3 - Concrete Work						
	Structure - Slab	m^3	39	$1,650	$64,000	Included	$64,000
	Structure - Wall	m^3	98	$1,400	$137,000	Included	$137,000
	Form Work	m^2	145	$280	$41,000	Included	$41,000
	Rebar	m^3	137	$440	$60,000	Included	$60,000
	Void Form (200 mm)	m^2	252	$22	$6,000	Included	$6,000
	Precast Hollow Core	LS	1	$30,000	$30,000	Included	$30,000
4.3	Division 4 - Masonry	LS	1	$55,000	$55,000	Included	$55,000
4.4	Division 5 - Metals	LS	1	$100,000	$100,000	Included	$100,000
4.5	Division 6 - Wood and Plastic	LS	1	$10,000	$10,000	Included	$10,000
4.6	Division 7 - Thermal and Moisture Protection						
	Metal Cladding	LS	1	$70,000	$70,000	Included	$70,000
	Roofing	LS	1	$20,000	$20,000	Included	$20,000
4.7	Division 8 - Doors and Windows						
	Access Hatches	LS	0	$0	$0	Included	$0
	Doors / Overhead Doors / Frames / Hardware	LS	1	$7,000	$7,000	Included	$7,000
	Windows / Glazing	LS	1	$1,000	$1,000	Included	$1,000
4.8	Division 9 - Finishes	LS	1	$10,000	$10,000	Included	$10,000
4.9	Division 10 - Specialities	LS	1	$2,000	$2,000	Included	$2,000
4.10	Divisions 40, 43 and 46 - Process						
	Sluice and Slide Gates	LS	10	$8,000	$80,000	$40,000	$120,000
	Fine Screens	each	1	$140,000	$140,000	$70,000	$210,000
	Vortex Grit Removal System	each	1	$240,000	$240,000	$120,000	$360,000
4.11	Divisions 22 and 23 - Mechanical	LS	1	$300,000	$300,000	Included	$300,000
4.12	Divisions 26, 28 and 40 - Electrical	LS	1	$100,000	$100,000	Included	$100,000
	Subtotal Headworks						**$1,760,000**
5.0	**Cells 1, 2 and 3**						
5.1	Divisions 31 to 33 - Siteworks						
	Embankment Construction	m3	0	15	$0	Included	$0
	Cells 1 and 2 Clay Liner (600 mm thick)	m2	9,500	10	$95,000	Included	$95,000
	Liner Protection (300 mm thick)	m2	9,500	5	$48,000	Included	$48,000
	Stripping and Compaction	m2	0	1900	$0	Included	$0
	Erosion Protection	m2	0	60	$0	Included	$0
	Rapid and Slow Mixing Manholes	LS	0	75,000	$0	Included	$0
	Effluent Manholes	LS	0	60,000	$0	Included	$0
	Excavation for Air Headers	m	0	$100	$0	Included	$0
	De-sludging Cells 1, 2 and 3	m3	55,000	20	$1,100,000	Included	$1,100,000
	Subtotal Cells 1, 2 and 3						**$1,243,000**

Item No.	Description	Unit	Quantity	Material or Equipment Costs Unit Price	Total Price	Labour & Overhead	Total Costs
6.0	**Process Building**						
6.1	Divisions 31 to 33 - Siteworks						
	Excavation and Backfill	m^3	14,316	$24	$343,600	Included	$343,600
	Piling	each	0	$2,500	$0	Included	$0
6.2	Division 3 - Concrete Work						
	Structure - Slab	m^3	1,407	$1,650	$2,322,000	Included	$2,322,000
	Structure - Walls	m^3	810	$1,400	$1,134,000	Included	$1,134,000
	Form Work	m^2	3,968	$280	$1,111,000	Included	$1,111,000
	Rebar	m^3	2,217	$440	$975,000	Included	$975,000
	Void Form (200 mm)	m^2	1,818	$22	$40,000	Included	$40,000
	Precast Hollow Core	LS	1	$100,000	$100,000	Included	$100,000
6.3	Division 4 - Masonry	LS	1	$200,000	$200,000	Included	$200,000
6.4	Division 5 - Metals	LS	1	$210,000	$210,000	Included	$210,000
6.5	Division 6 - Wood and Plastic	LS	1	$20,000	$20,000	Included	$20,000
6.6	Division 7 - Thermal and Moisture Protection						
	Metal Cladding	LS	1	$180,000	$180,000	Included	$180,000
	Roofing	LS	1	$70,000	$70,000	Included	$70,000
6.7	Division 8 - Doors and Windows						
	Access Hatches	LS	5	$3,000	$15,000	Included	$15,000
	Doors / Overhead Doors / Frames / Hardware	LS	23	$1,500	$35,000	$17,500	$52,500
	Windows / Glazing	LS	4	$3,000	$12,000	$6,000	$18,000
6.8	Division 9 - Finishes						
	Painting	LS	1	$25,000	$25,000	Included	$25,000
	Special Coatings	LS	1	$200,000	$200,000	Included	$200,000
6.9	Division 10 - Specialities	LS	1	$6,000	$6,000	Included	$6,000
6.10	Division 12 - Furnishing	LS	1	$60,000	$60,000	Included	$60,000
6.11	Divisions 40, 43 and 46 - Process						
	Sluice and Slide Gates	LS	2	$8,000	$16,000	$8,000	$24,000
	WAS and Drain Pumps	LS	4	$10,000	$40,000	$20,000	$60,000
	Sludge Lagoon Feed Pumps	LS	2	$20,000	$40,000	$20,000	$60,000
	SBR Equipment (air blowers, diffusers, mixers, decanter)	LS	1	$910,000	$910,000	$455,000	$1,365,000
	UV Disinfection System	each	1	$350,000	$350,000	$175,000	$525,000
	Effluent Pump and Fitting	each	1	$150,000	$150,000	$75,000	$225,000
	Plant Water (W3) Pump Station	each	1	$15,000	$15,000	$8,000	$23,000
	Polymer Blend System	LS	0	$40,000	$0	$0	$0
	Polymer Pumps	LS	0	$23,000	$0	$0	$0
	Alum Storage Tanks (reuse existing tank)	LS	0	$35,000	$0	$0	$0
	Alum Transfer Pumps and Feed Systems (reuse existing pumps)	LS	0	$20,000	$0	$0	$0
	Chlorination System with Chemical Piping	LS	1	$20,000	$20,000	$10,000	$30,000
	Laboratory Equipment Including Samplers	LS	1	$100,000	$100,000	$20,000	$120,000
6.12	Division 41 - Conveying Systems						
	Mobile Crane	LS	1	$65,000	$65,000	Included	$65,000
	Dump Trailer	LS	0	$23,000	$0	Included	$0
	Monorails	LS	1	$40,000	$40,000	$20,000	$60,000
6.13	Divisions 22 and 23 - Mechanical	LS	1	$1,950,000	$1,950,000	Included	$1,950,000
6.14	Divisions 26, 28 and 40 - Electrical						
	Electrical Service	LS					
	800 Amp 25KV-600/347V	LS	1	$45,000	$45,000	Included	$45,000
	Service entrance switchgear, MCC's, panelboards etc.	LS	1	$450,000	$450,000	Included	$450,000
	LV Electrical Distribution (Switchgear, MCC & Transfer Switch) Install	LS	1	$165,000	$165,000	Included	$165,000
	Cabling , terminations & contractor commissioning	LS	1	$135,000	$135,000	Included	$135,000
	Telephone Service	LS	1	$65,000	$65,000	Included	$65,000
	Building Systems Electrical (lighting, power distribution, communications, fire, security, exit and emergency lighting & grounding systems)	LS	1	$330,000	$330,000	Included	$330,000
	Generator	LS					
	600V 250 KVA	LS	1	$155,000	$155,000	Included	$155,000
	Exterior Diesel Fuel Tank	LS	1	$40,000	$40,000	Included	$40,000
	Generator & Systems Installation	LS	1	$55,000	$55,000	Included	$55,000
	Controls/Instrumentation/Communications	LS					
	Control System & Programming	LS	1	$320,000	$320,000	Included	$320,000
	Control System (PLC and HMI Supply & Install)	LS	1	$165,000	$165,000	Included	$165,000
	Subtotal Process building						**$13,515,000**
7.0	**Odour Building**						
7.1	Divisions 31 to 33 - Siteworks						
	Excavation and Backfill	m^3	0	$24	$0	Included	$0
	Piling	each	21	$2,500	$53,000	Included	$53,000
7.2	Division 3 - Concrete Work						
	Structure - Slab	m^3	18	$1,650	$30,000	Included	$30,000
	Structure - Walls	m^3	0	$1,400	$0	Included	$0
	Form Work	m^2	0	$280	$0	Included	$0
	Rebar	m^3	18	$440	$8,000	Included	$8,000
	Void Form (200 mm)	m^2	60	$22	$1,000	Included	$1,000
7.14	Division 44 - Odour Control	LS	0				
	Odour Control Unit	LS	1	$365,000	$365,000	$183,000	$548,000
	Subtotal Process Odour Building						**$640,000**
	Subtotal						**$24,324,200**

Notes:
1. Costs are in 2019 Canadian Dollars.
2. Construction costs will vary depending on market conditions at the time of tender. Stantec has no control over those conditions.

APPENDIX B
BUDGET QUOTES

Appendix B BUDGET QUOTES

Stantec

Memo

To:	Peter Bergquist, A.Sc.T., Director, Public Works & Utilities	From:	Jason Gaudet, P.Eng., Senior Associate, Senior Civil Engineer
	City of Humboldt		Stantec Consulting Ltd.
File:	113154831	Date:	April 25, 2019

Reference: Humboldt WWTP Opinion of Probable Capital Cost – Aerated Lagoons / SAGR System Design Period 2037 (8,000 Population) and 2052 (10,000 Population)

BACKGROUND

The City of Humboldt (City) retained Stantec Consulting Ltd. (Stantec) to provide conceptual options and preliminary design for an upgrade to the Wastewater Treatment Plant (WWTP). Conceptual options were developed under the assumption that the upgraded WWTP will be developed to serve the 2052 design population of 10,000 people. Liquid and sludge treatment process selection was conducted using a decision-making methodology which consisted of three phases: Phase 1 included identification of suitable liquid and sludge treatment options. Phase 2 further refined the options and provided a short listing of treatment processes. Phase 3 included evaluation of the short listed treatment process and recommendation. Selection criteria and scoring of the various treatment processes were presented in technical memorandums for each phase. The implementation of the decision making methodology resulted in the selection of aerated lagoons followed by Submerged Aerated Growth Reactor (SAGR) with chemical precipitation of phosphorus as the preferred option the City's WWTP upgrades.

The Aerated Lagoons/SAGR option provides the highest benefit cost ratio of all short listed options. The Aerated Lagoons/SAGR process is a proven technology in Western Canada, is very compatible with existing infrastructure and it can be implemented in stages. The Aerated Lagoons/SAGR option provides the lowest opinion of probable capital cost (OPCC) of all short listed options, as it makes use of existing infrastructure (cells 1 to 7) and does not require headworks or filters. The Aerated Lagoons/SAGR option also provides the lowest Opinion of Probable Operating Cost (OPOC) of all short listed options, because it has less process units and equipment to operate and maintain.

The City, upon review of Technical Memorandum No. 5, Evaluation of Short Listed Treatment Options, requested Stantec to prepare opinion of probable costs for the Aerated Lagoons/SAGR option for two design periods:

- Design year 2037 to treat a maximum monthly flow of 5,790 m^3/d and serve a population of 8,000 people.
- Design year 2052 to treat a maximum monthly flow of 7,235 m^3/d and serve a population of 10,000 people.

Reference: Humboldt WWTP Opinion of Probable Capital Cost – Aerated Lagoons / SAGR System
Design Period 2037 (8,000 Population) and 2052 (10,000 Population)

PROPOSED WWTP PROCESS DESCRIPTION

The proposed liquid treatment train consists of two anoxic cells (cells 1 and 2), two complete mixed lagoons (cells 3 and 4) one partially mixed lagoon (cell 5), a series of mixing chambers for chemical precipitation of phosphorus in a settling cell (cell 7), SAGR cells for ammonia reduction, a ultraviolet disinfection reactor for pathogens reduction and pressurized effluent conveyance system and an outfall structure. The sludge management system consists of sludge thickening and stabilization in the non-aerated cells, partially mixed cell and settling cell. The sludge management option relies on periodical sludge removal to ensure that space will always be available to receive fresh sludge and to minimize odor emission by maintaining a water layer over the digested sludge. For this reason, two geotextile and one frac tank and Quadvac laydown areas are proposed. The WWTP also includes a process building to house electrical and instrumentation panels for blowers, chemical feed system, a utility water system with sodium hypochlorite addition for disinfection. Figure 1 presents the proposed layout of the plant.

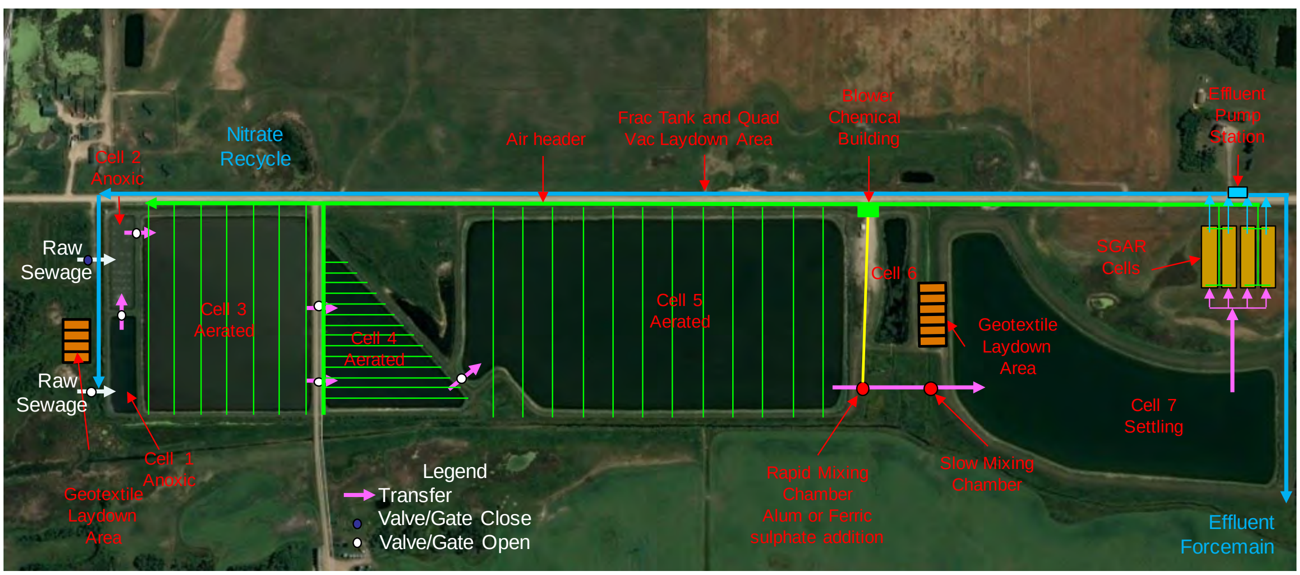

Figure 1 Aerated Lagoon/SAGR Process Configuration for Design period 2052 (10,000 population)

Note: The Aerated Lagoon/SAGR Process configuration for design period 2037 (8,000 population) has fewer diffusers in cells 3, 4 and 5 and one less SAGR cell.

The proposed Aerated Lagoon/SAGR plant consists of the following:

Process

a) Lift Stations: No modifications to the existing lift stations or pumps are required.
b) Influent Valve Chamber (IVC): IVC will be used to combine the influent from multiple lift stations and recycled nitrified mixed liquor.
c) Headworks: Screen and grit removal systems are not required.
d) Anoxic Cells (cells 1 and 2): The existing cells will be used to settle grit and large solids as well as retain plastics. Nitrified rich effluent will be recycled to the IVC and directed to the anoxic cells to provide partial nitrogen reduction (denitrification) and odour control.
e) Complete Mixed Aerated Cells (cells 3 and 4). The existing cells will be retrofitted with either 122 or 150 fine bubble diffusers for organic carbon reduction (BOD reduction) for design years 2037 or 2052, respectively.
f) Partially Mixed Aerated Cell (cell 5). The existing cell will be retrofitted with either 56 or 72 fine bubble diffusers for additional organic carbon reduction (BOD reduction) for design years 2037 or 2052, respectively.
g) Mixing Chambers: Two mixing chambers will be constructed between cells 5 and 7 to mix alum and phosphorus using mechanical mixers. The first chamber provides rapid mixing for coagulation and the second chamber provides slow mixing for flocculation.
h) Settling Cell (cell 7): The existing cell will be used to settle chemical sludge before the effluent is conveyed to the SAGR cells.
i) SAGR Cells: Three or four new SAGR cells will be constructed west of cell 7 for the design years 2037 or 2052, respectively. Each cell will have a surface area of 2,880 m^2 to provide ammonia, TSS and pathogen reduction. The SAGR cells consists of earthen basins with geomembrane liners, influent distribution laterals/chambers and a treated effluent collection chamber. Diffusers are secured to the bottom of the cell and covered with a layer of clean gravel. The gravel bed is covered with a layer of peat or mulch over a non-woven geotextile for insulation.
j) Secondary Effluent Splitter Box (SESB): The SESB box will be designed to receive effluent from the SAGR cells and to split the secondary effluent in two steams: one stream is directed to the SE tank the other is directed to the UV Reactor.
k) Ultraviolet (UV) Disinfection: UV reactor consisting of UV lamps, power distribution system and flow control weir will be installed downstream of the SESB in a stainless-steel channel and will be equipped with a self-cleaning mechanism to ensure that the disinfection is consistently achieved.
l) Secondary Effluent Tank: This tank will be constructed in the substructure of the operations building and designed to receive effluent from the SESB. This tank also serves as a wet well for the nitrified mixed liquor pumps.
m) Final Effluent Tank: This tank will be constructed in the substructure of the operations building and designed to receive effluent from the UV reactor. This tank also serves as a wet well for the final effluent pumps.
n) Nitrified Mixed Liquor (NML) Pumps: These 10 HP pumps will be located in the pipe gallery of the operations building and used to return nitrate rich effluent to cells 1 and 2.
o) Final Effluent Pumps: These 60 HP pumps will be located in the pipe gallery of the operations building and used to pump the final effluent to Humboldt Lake through a 300 mm diameter force main.
p) Plant Water Pumps: Two 6.5 HP centrifugal pumps will be located in the pipe gallery of the operation building to convey UV disinfected effluent to process units that require flushing water and to the hose washdown stations.

q) Blower Room: This room will be located in the operation building. The blower room will be sized for the design year 2052 with enough space to house two 50 HP blowers to serve the aerated lagoons and three 100 HP blowers to serve the SAGR cells (two duty and one standby).
r) Alum Feed System: The alum feed system consists of one tank capable of storing 16 m^3 of liquid alum and two metering pumps. This system will be installed in the pipe gallery and will be used to chemically precipitate phosphorus.
s) Sodium Hypochlorite System: Sodium hypochlorite will be injected into the plant water system only when plant operators may be exposed to water sprays or minimize re-growth of pathogens.
t) Drain Pumps: These pumps will be located in a sump in the pipe gallery of the operations building. These pumps are used to collect drain and wastewater from the building and convey the flow to aerated cells.
u) Sludge Stabilization: aerated cells will be used to stabilize sludge that settles between the rows of diffusers.
v) Sludge Dewatering: Three laydown areas are provided to deploy geotextile containers to dewater the sludge accumulated in cells 1, 2, 5 and 7. The purpose of the sludge dewatering system is to reduce the volume of water before the sludge is transported to the landfill to be used as intermediate cover.

Civil

a) Site upgrades include excavation for the influent valve chamber, SAGR cells, NML and final effluent force main pipe, outfall structure, geotextile laydown areas, drainage, access roads, parking lots, yard piping, landscaping and fencing. Note fencing is not included in the OPCC as fencing extents are not known.
b) Final effluent forcemain pipe and outfall structure: The final effluent will be directed from the WWTP to the Humboldt Lake by a new 300 mm diameter 4,400 m long pressure pipe to allow year-round discharge of the effluent. A gravity pipe was also considered; however, the gravity pipe option carries a higher OPCC.
c) Surface drainage will be accommodated in ditches along the roadways and parking areas and directed overland to the existing storm channel that runs west of the lagoons.
d) Access road and parking will consist of sealed compacted gravel to reduce rutting and dust caused by trucks and B trains delivering chemicals and other consumables. The parking area will be in the vicinity of the Operations Building.

Structural

a) An Operations Building will be constructed, complete with a substructure containing the piping gallery chemical tanks and pumps. The superstructure will house the blowers, laboratory, washrooms, lunchroom, control room, electrical and mechanical rooms. The overall building footprint is anticipated to be approximately 20 m by 16 m. The foundation for the building will likely consist of a raft type footing (pending geotechnical analysis). For the purpose of the OPCC it was assumed that the footing will be 500 mm thick concrete and that the main floor will consist of a 200 mm to 300 mm cast-in-place concrete suspended slab, supported on concrete beams that span between the walls of substructure.

Architectural

a) The proposed building superstructures for process areas will be masonry block with rigid insulation, exterior metal cladding, and painted interior finish. Interior dividing walls will be painted masonry block.
b) The proposed building superstructure for humidity and climate controlled administrative areas will be steel (no wood framed construction) with batt insulation, metal cladding and standing seam metal roofing to match the appearance of the other areas.

Mechanical

a) The Operations Building will contain two areas with distinctly different requirements, the substructure, and the administration area. For the substructure, heating will be achieved by separate combustion gas-fired unit heaters in the pipe gallery, chemical tanks, UV reactor, mechanical and electrical areas. Make up air for the substructure will be provided by an indirect gas-fired makeup air unit complete with branch ductwork extending to the various areas. Individual exhaust fans are included for these areas. A mixed air exhaust system for both the mechanical and electrical rooms will provide ventilation and natural cooling. The blower room will be complete with a large intake louver providing untreated make up air for the blowers. For the administration area, heating will be provided by a gas-fired heat/cool roof mounted air handling unit. Auxiliary electric baseboard radiation will be provided in the washrooms, laboratory, lunchroom, entrance and control room. Exhaust fans will include one common exhaust fan for the two washrooms, and mixed air exhaust systems for both the mechanical and electrical rooms.

Electrical

a) A new 600V, 3-phase, 3-wire underground main service will be provided for the proposed Operations Building. SaskPower will provide a vault mounted 25kV/600V 3-phase transformer, cables, protection equipment, and connections to the line-side of the service transformer located outside of the Operations Building. Underground power cables will supply 600V 3-phase power to the switchgear located in the Electrical Room. The 600V switchboard will provide normal power (through an 1000A breaker) to a Motor Control Centre (MCC) for process mechanical equipment and building services loads. Preliminary sizing of plant electrical loads indicates a main service size of 1,000 Amps will be required. This service is sized to accommodate all required electrical loads including future process expansion.
b) A backup diesel generator (skid mounted) will be installed in the Electrical Room and provide backup power for selected critical loads in the Operations Building. Preliminary sizing of the new wastewater treatment building's electrical loads indicates a 300 kW generator will be required to maintain critical equipment operation during power outages.

Instrumentation and Control

a) A Supervisory Control and Data Acquisition (SCADA) system will be installed to automatically generate and transmit alarms of abnormal conditions to on-call personnel when the plant is not manned.

LIFE CYCLE COST

A technical and financial evaluation has been completed for each design period. Table 1 presents life cycle cost estimates for the purpose of comparing the cost based upon two different design periods.

Table 1 Life Cycle Cost

Item	Description	Aerated Lagoons / SAGR Process Design year 2037 (8,000 population)	Aerated Lagoons / SAGR Process Design year 2052 (10,000 population)
1.0	General requirements	$2,153,000	$2,352,000
2.0	Siteworks	$4,972,000	$4,987,000
4.0	Headworks	N/A	N/A
5.0	Upgrades to cells 1, 2 and 3	$1,698,000	$1,698,000
6.0	SAGR cells	$3,682,000	$4,693,000
7.0	Process building	$8,291,000	$8,988,000
8.0	Odour control building	N/A	$0
	Subtotal	**$20,796,000**	**$22,718,000**
	Contingency (20%)	$4,160,000	$4,544,000
	Engineering (10%)	$2,496,000	$2,727,000
	Total Project Capital Cost	**$27,452,000**	**$29,989,000**
	Annual Operation Costs (based on year 2020)	$495,000	$495,000
	NPV O&M (18-yr for design year 2037 and 33-yr for design year 2052)	**$9,420,000**	**$15,870,000**
	NPV Life Cycle Cost (18-yr for design year 2037 and 33-yr for design year 2052)	**$36,872,000**	**$45,859,000**

Note:
1. Net Present Value developed based on a discount rate of 3.82% and an inflation rate of 2% per annum. Net present values were calculated using 2020 as the base year and extending to 2037 for design year 2037 and 2052 for design year 2052.
2. Final effluent pumps will be located in the pipe gallery of the operations building.

LIFE CYCLE COST RESULTS

The life cycle costs for the Aerated Lagoons/SAGR process is presented in Table 1 along with the Net Present Value (NPV) for both design periods. The NPV represents the value of all future costs over the design life of the capital investment. Opinions of probable cost for capital and operating costs are described in the following sections.

Reference: Humboldt WWTP Opinion of Probable Capital Cost – Aerated Lagoons / SAGR System
Design Period 2037 (8,000 Population) and 2052 (10,000 Population)

OPINION OF PROBABLE CAPITAL COST

Opinions of Probable Capital Cost (OPCC) are preliminary and subject to development of actual designs, loadings and any special requirements, but do provide an indication of relative cost differentials between design years. The attached spreadsheets provide a breakdown of the OPCCs for each design period.

OPPCs were developed using a combination of stochastic and deterministic factors as follows:

General requirements (stochastic): General requirements include the cost of mobilization/demobilization, start-up and commissioning, operation and maintenance manuals and record drawings. These costs are about 11.5% of the subtotal for all process areas.

Siteworks (deterministic and stochastic): Siteworks include the cost of excavation and backfill, roadways, yard piping, outfall structure, final effluent forcemain, fencing, landscaping and dewatering allowance. The OPPC for excavation and compacted backfill are based on calculated volumes and rate of $24/m^3$ of material.

Structural tank (deterministic): OPCC for concrete tanks are based on calculated concrete volumes priced at an average of about $1,650/m^3$ for slab and $1,400/m^3$ for walls. Rebar cost are estimated based on a unit rate of $440/m^3$ for concrete. Form work costs are estimated based on the surface area of tank wall at a unit rate of $280 for straight wall.

Structural building (deterministic): OPCC for structural buildings is based on lump sum prices for masonry, metals, wood, plastic, thermal and moisture protection, doors and windows for similar buildings.

Process (deterministic): OPCC for process is developed from vendor quotes (specifically requested for this project and provided by Nexom), plus a 50% installation cost. Nexom's proposal is attached.

Mechanical (stochastic): OPCC for HVAC mechanical is based on experience from previous projects, the mechanical costs are assumed to be 11% of the subtotal for the operations building for design year 2037.

Electrical, Instrumentation and Control (I&C) (deterministic): OPCC for electrical and I&C is based on lump sum prices from similar previous projects.

OPINION OF PROBABLE OPERATING COST

Opinions of Probable Operating Cost (OPOC) are developed based on standard unit costs. The opinions of probable costs are tentative and subject to development of actual unit cost for the plant but do provide an indication of relative cost differentials between design periods. The annual OPOC for the design years 2037 and 2052 are anticipated to be very similar, approximately $495,000 annually (based on the first year). Annual costs will fluctuate depending on sludge removal frequency. The annual operating costs and NPV for each design year are also presented in table 1.

Reference: Humboldt WWTP Opinion of Probable Capital Cost – Aerated Lagoons / SAGR System
Design Period 2037 (8,000 Population) and 2052 (10,000 Population)

CONCLUSION AND RECOMMENDATION

Comparison of the OPCC for construction of the WWTP based on the two distinctive design periods (8,000 and 10,000 populations) identifies a $2.54M difference in capital expenditure. Staging the construction of the plant will allow the City to bundle upgrades with the replacement of system components. In addition, it will allow the City to address future regulatory requirements. Overall Stantec recommends proceeding with the preliminary design based on the SAGR system for Design year 2037 (8,000 population).

Stantec Consulting Ltd.

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Attachment: OPCC for Aerated Lagoons/SAGR Cells (8,000 & 10,0000 populations)
Nexcom Proposal – April 1, 2019 (24 pages, including drawings for 8,000 & 10,000 populations)

Opinion of Probable Capital Costs for Aerated Lagoons/SAGR for Design period 2037 to Serve 8,000 people

ADF = 3280 m^3/d, MMF = 5790 m^3/d, PDF = 11,402 m^3/d

Item No.	Description	Unit	Quantity	Material or Equipment Costs Unit Price	Total Price	Labour & Overhead	Total Costs
1.0	**General Requirements**						
1.1	Divisions 0 and 1						
	Mobilization / Demobilization	% Total	1	0.30%	$56,000		$56,000
	General Conditions	% Total	1	7.50%	$1,398,000		$1,398,000
	Performance Assurance	% Total	1	1.20%	$224,000		$224,000
	Insurance	% Total	1	1.40%	$261,000		$261,000
	Building Permit	% Total	1	0.15%	$28,000		$28,000
	Start-up and Commissioning	% Total	1	0.50%	$93,000		$93,000
	O&M Manuals and Record Drawings	% Total	1	0.50%	$93,000		$93,000
	Subtotal						**$2,153,000**
2.0	**Siteworks**						
2.1	Divisions 31 to 33 - Siteworks						
	Layout and Survey	LS	1	$25,000	$25,000	Included	$25,000
	Parking Lots	m^2	4,500	$100	$450,000	Included	$450,000
	Site Access Road to SAGR	LS	2,000	$100	$200,000	Included	$200,000
	Site Stripping and Grading	LS	1	$110,000	$110,000	Included	$110,000
	Yard Piping Allowance (Including underground services)	LS	1	$150,000	$150,000	Included	$150,000
	Influent Valve Chamber	LS	1	$300,000	$300,000	Included	$300,000
	RS Pipe to Influent Valve Chamber	m	100	$500	$50,000	Included	$50,000
	RS Pipe from Valve Chamber to Headworks	m	5	$500	$3,000	Included	$3,000
	NML Forcemain to Front End Lagoon	m	1,300	$500	$650,000	Included	$650,000
	Outfall Structure	LS	1	$250,000	$250,000	Included	$250,000
	Effluent Forcemain Pipe 300 mm	m	4,400	$500	$2,200,000	Included	$2,200,000
	WAS Pipe from Process Building to Lagoon 3	m	0	$0	$0	Included	$0
	Site Preparation for Geotextile Container for Grit	m^2	2,400	$75	$180,000	Included	$180,000
	Site Preparation for Geotextile Container for Stabilized Sludge	m^2	3,450	$75	$259,000	Included	$259,000
	Site Preparation for Frac Tanks	m^2	200	$75	$15,000	Included	$15,000
	Railway Crossing	LS	0	$1,000	$0	Included	$0
	Flood Protection (Berm and Sod)	LS	0	$0	$0	Included	$0
	Fencing (1800mm chain link fence)	m	0	$14	$0	Included	$0
	Landscaping Allowance	LS	1	$90,000	$90,000	Included	$90,000
	Dewatering Allowance	LS	1	$40,000	$40,000	Included	$40,000
	Subtotal Siteworks						**$4,972,000**
3.0	**Headworks**						
	Subtotal Headworks						**$0**
4.0	**Cells 1, 2 and 3**						
4.1	Divisions 31 to 33 - Siteworks						
	Embankment Construction	m3	4,800	24	$115,000	Included	$115,000
	Cells 1 and 2 Clay Liner (600 mm thick)	m2	9,500	10	$95,000	Included	$95,000
	Liner Protection (300 mm thick)	m2	9,500	5	$48,000	Included	$48,000
	Stripping and Compaction	m2	0	1900	$0	Included	$0
	Erosion Protection	m2	0	60	$0	Included	$0
	Rapid and Slow Mixing Manholes	LS	2	75,000	$150,000	Included	$150,000
	Effluent Manholes	LS	1	60,000	$60,000	Included	$60,000
	Excavation for Air Headers	m	1,300	$100	$130,000	Included	$130,000
	De-sludging Cells 1, 2 and 3	m3	55,000	20	$1,100,000	Included	$1,100,000
	Subtotal Cells 1, 2 and 3						**$1,698,000**
5.0	**SAGR Cells**						
5.1	Divisions 31 to 33 - Siteworks						
	Stripping and Compaction	m2	11,520	2	$23,000	Included	$23,000
	Excavation	m3	34,560	24	$829,000	Included	$829,000
	Wall Framing and Sheeting	m	732	80	$59,000	Included	$59,000
	HDPE Liner (60 mil)	m2	11,568	22	$254,000	Included	$254,000
	Clean Gravel/Rock	m3	20,909	80	$1,673,000	Included	$1,673,000
	Insulating Wood Strips	m3	2,765	20	$55,000	Included	$55,000
	Non-Woven Geotextile (8 oz)	m2	21,600	2.5	$54,000	Included	$54,000
	Influent Flow Splitter Structure	l.s.	1	75,000	$75,000	Included	$75,000
	Piping, Fittings, Valves from Splitter to SAGR	l.s.	1	150,000	$150,000	Included	$150,000
	Piping, Fittings, Valves from Cell 7 to SAGR	m	200	$550	$110,000	Included	$110,000
	Piping, Fittings, Valves from SAGR to Effluent Lift Station	m	500	$550	$275,000	Included	$275,000
	Effluent Manholes (provided by Nexom)	l.s.	3	0	$0	Included	$0
	Effluent Level Control Manhole	l.s.	1	75,000	$75,000	Included	$75,000
	Excavation for Air Headers	m	500	$100	$50,000	Included	$50,000
	Subtotal SAGR						**$3,682,000**

Item No.	Description	Unit	Quantity	Material or Equipment Costs Unit Price	Material or Equipment Costs Total Price	Labour & Overhead	Total Costs
6.0	**Process Building**						
6.1	Divisions 31 to 33 - Siteworks						
	Excavation and Backfill	m^3	1,136	$24	$27,000	Included	$27,000
	Piling	each	0	$2,500	$0	Included	$0
6.2	Division 3 - Concrete Work						
	Structure - Slab	m^3	135	$1,650	$223,000	Included	$223,000
	Structure - Walls	m^3	115	$1,400	$161,000	Included	$161,000
	Form Work	m^2	560	$280	$157,000	Included	$157,000
	Rebar	m^3	250	$440	$110,000	Included	$110,000
	Void Form (200 mm)	m^2	184	$22	$4,000	Included	$4,000
	Precast Hollow Core	LS	1	$60,000	$60,000	Included	$60,000
6.3	Division 4 - Masonry	LS	1	$100,000	$100,000	Included	$100,000
6.4	Division 5 - Metals	LS	1	$100,000	$100,000	Included	$100,000
6.5	Division 6 - Wood and Plastic	LS	1	$10,000	$10,000	Included	$10,000
6.6	Division 7 - Thermal and Moisture Protection						
	Metal Cladding	LS	1	$80,000	$80,000	Included	$80,000
	Roofing	LS	1	$35,000	$35,000	Included	$35,000
6.7	Division 8 - Doors and Windows						
	Access Hatches	LS	2	$5,000	$10,000	Included	$10,000
	Doors / Overhead Doors / Frames / Hardware	LS	16	$1,500	$24,000	Included	$24,000
	Windows/Glazing	LS	4	$3,000	$12,000	Included	$12,000
6.8	Division 9 - Finishes						
	Painting	LS	1	$15,000	$15,000	Included	$15,000
	Special Coatings	LS	1	$75,000	$75,000	Included	$75,000
6.9	Division 10 - Specialities	LS	1	$7,000	$7,000	Included	$7,000
6.10	Division 12 - Furnishing	LS	1	$60,000	$60,000	Included	$60,000
6.11	Divisions 40, 43 and 46 - Process						
	Sluice and Slide Gates	LS	2	$8,000	$16,000	$8,000	$24,000
	Drain Pumps	LS	2	$10,000	$20,000	$10,000	$30,000
	Equipment Supply by Nexom (air blowers, HDPE headers, laterals, diffusers, control panels, influent piping and chambers eng. and installation)	LS	1	$2,649,000	$2,649,000	$530,000	$3,179,000
	NML Pump and and Fitting	each	1	$150,000	$150,000	$75,000	$225,000
	Filtration System	each	0	$0	$0	$0	$0
	UV Disinfection System	each	1	$350,000	$350,000	$175,000	$525,000
	Effluent Pump and Fitting	each	1	$150,000	$150,000	$75,000	$225,000
	Plant Water (W3) Pump and Fiting	each	1	$15,000	$15,000	$8,000	$23,000
	Polymer Blend System	LS	0	$40,000	$0	$0	$0
	Polymer Pumps	LS	0	$23,000	$0	$0	$0
	Alum Storage Tanks (reuse existing tank)	LS	0	$35,000	$0	$0	$0
	Alum Transfer Pumps and Feed Systems (reuse existing pumps)	LS	0	$20,000	$0	$0	$0
	Chlorination System with Chemical Piping	LS	2	$20,000	$40,000	$20,000	$60,000
	Laboratory Equipment Including Samplers	LS	1	$100,000	$100,000	$20,000	$120,000
6.12	Division 41 - Conveying Systems						
	Mobile Crane	LS	1	$65,000	$65,000	Included	$65,000
	Monorails (polymer and filter)	LS	0	$0	$0	$0	$0
6.13	Divisions 22 and 23 - Mechanical	LS	1	$910,000	$910,000	Included	$910,000
6.14	Divisions 26, 28 and 40 - Electrical						
	Electrical Service	LS					
	1000 Amp 25KV-600/347V	LS	1	$45,000	$45,000	Included	$45,000
	Service entrance switchgear, MCC's, panelboards etc.	LS	1	$410,000	$410,000	Included	$410,000
	LV Electrical Distribution (Switchgear, MCC & Transfer Switch) Install	LS	1	$150,000	$150,000	Included	$150,000
	Cabling, terminations & contractor commissioning	LS	1	$125,000	$125,000	Included	$125,000
	Telephone Service	LS	1	$30,000	$30,000	Included	$30,000
	Building Systems Electrical (lighting, power distribution, communications, fire, security, exit and emergency lighting & grounding systems)	LS	1	$300,000	$300,000	Included	$300,000
	Generator	LS					
	600V 300 KVA	LS	1	$150,000	$150,000	Included	$150,000
	Exterior Diesel Fuel Tank	LS	1	$40,000	$40,000	Included	$40,000
	Generator & Systems Installation	LS	1	$60,000	$60,000	Included	$60,000
	Controls/Instrumentation/Communications	LS					
	Control System & Programming	LS	1	$200,000	$200,000	Included	$200,000
	Control System (PLC and HMI Supply & Install)	LS	1	$125,000	$125,000	Included	$125,000
	Subtotal Operations Building						**$8,291,000**
7.0	**Odour Building**						
	Subtotal Process Odour Building						**$0**
	Subtotal						**$20,796,000**

Notes:
1. Costs are in 2019 Canadian Dollars.
2. Construction costs will vary depending on market conditions at the time of tender. Stantec has no control over those conditions.

Opinion of Probable Capital Costs for Aerated Lagoons/SAGR for Design period 2052 to Serve 10,000 people

ADF = 4100 m^3/d, MMF = 7240 m^3/d, MDF = 14,252 m^3/d

Item No.	Description	Unit	Quantity	Material or Equipment Costs Unit Price	Material or Equipment Costs Total Price	Labour & Overhead	Total Costs
1.0	**General Requirements**						
1.1	Divisions 0 and 1						
	Mobilization / Demobilization	% Total	1	0.30%	$61,000		$61,000
	General Conditions	% Total	1	7.50%	$1,527,000		$1,527,000
	Performance Assurance	% Total	1	1.20%	$244,000		$244,000
	Insurance	% Total	1	1.40%	$285,000		$285,000
	Building Permit	% Total	1	0.15%	$31,000		$31,000
	Start-up and Commissioning	% Total	1	0.50%	$102,000		$102,000
	O&M Manuals and Record Drawings	% Total	1	0.50%	$102,000		$102,000
	Subtotal						**$2,352,000**
2.0	**Siteworks**						
2.1	Divisions 31 to 33 - Siteworks						
	Layout and Survey	LS	1	$30,000	$30,000	Included	$30,000
	Parking Lots	m^2	4,500	$100	$450,000	Included	$450,000
	Site Access Road to SAGR	LS	2,000	$100	$200,000	Included	$200,000
	Site Stripping and Grading	LS	1	$120,000	$120,000	Included	$120,000
	Yard Piping Allowance (Including underground services)	LS	1	$150,000	$150,000	Included	$150,000
	Influent Valve Chamber	LS	1	$300,000	$300,000	Included	$300,000
	RS Pipe to Influent Valve Chamber	m	100	$500	$50,000	Included	$50,000
	RS Pipe from Valve Chamber to Headworks	m	5	$500	$3,000	Included	$3,000
	NML Forcemain to Front End Lagoon	m	1,300	$500	$650,000	Included	$650,000
	Outfall Structure	LS	1	$250,000	$250,000	Included	$250,000
	Effluent Gravity Pipe 500 mm (including manholes, backfill and testing)	m	4,400	$500	$2,200,000	Included	$2,200,000
	WAS Pipe from Process Building to Lagoon 3	m	0	$0	$0	Included	$0
	Site Preparation for Geotextile Container for Grit	m^2	2,400	$75	$180,000	Included	$180,000
	Site Preparation for Geotextile Container for Stabilized Sludge	m^2	3,450	$75	$259,000	Included	$259,000
	Site Preparation for Frac Tanks	m^2	200	$75	$15,000	Included	$15,000
	Railway Crossing	LS	0	$1,000	$0	Included	$0
	Flood Protection (Berm and Sod)	LS	0	$0	$0	Included	$0
	Fencing (1800mm chain link fence)	m	0	$14	$0	Included	$0
	Landscaping Allowance	LS	1	$90,000	$90,000	Included	$90,000
	Dewatering Allowance	LS	1	$40,000	$40,000	Included	$40,000
	Subtotal Siteworks						**$4,987,000**
3.0	**Headworks**						
	Subtotal Headworks						**$0**
4.0	**Cells 1, 2 and 3**						
4.1	Divisions 31 to 33 - Siteworks						
	Embankment Construction	m3	4,800	24	$115,000	Included	$115,000
	Cells 1 and 2 Clay Liner (600 mm thick)	m2	9,500	10	$95,000	Included	$95,000
	Liner Protection (300 mm thick)	m2	9,500	5	$48,000	Included	$48,000
	Stripping and Compaction	m2	0	1900	$0	Included	$0
	Erosion Protection	m2	0	60	$0	Included	$0
	Rapid and Slow Mixing Manholes	LS	2	75,000	$150,000	Included	$150,000
	Effluent Manholes	LS	1	60,000	$60,000	Included	$60,000
	Excavation for Air Headers	m	1,300	$100	$130,000	Included	$130,000
	De-sludging Cells 1, 2 and 3	m3	55,000	20	$1,100,000	Included	$1,100,000
	Subtotal Cells 1, 2 and 3						**$1,698,000**
5.0	**SAGR Cells**						
5.1	Divisions 31 to 33 - Siteworks						
	Stripping and Compaction	m2	15,168	2	$30,000	Included	$30,000
	Excavation	m3	45,504	24	$1,092,000	Included	$1,092,000
	Wall Framing and Sheeting	m	976	80	$78,000	Included	$78,000
	HDPE Liner (60 mil)	m2	15,104	22	$332,000	Included	$332,000
	Clean Gravel/Rock	m3	27,878	80	$2,230,000	Included	$2,230,000
	Insulating Wood Strips	m3	3,686	20	$74,000	Included	$74,000
	Non-Woven Geotextile (8 oz)	m2	28,800	2.5	$72,000	Included	$72,000
	Influent Flow Splitter Structure	l.s.	1	75,000	$75,000	Included	$75,000
	Piping, Fittings, Valves from Splitter to SAGR	l.s.	1	200,000	$200,000	Included	$200,000
	Piping, Fittings, Valves from Cell 7 to SAGR	m	200	$550	$110,000	Included	$110,000
	Piping, Fittings, Valves from SAGR to Effluent Lift Station	m	500	$550	$275,000	Included	$275,000
	Effluent Manholes (provided by Nexom)	l.s.	4	0	$0	Included	$0
	Effluent Level Control Manhole	l.s.	1	75,000	$75,000	Included	$75,000
	Excavation for Air Headers	m	500	$100	$50,000	Included	$50,000
	Subtotal SAGR						**$4,693,000**

Item No.	Description	Unit	Quantity	Material or Equipment Costs Unit Price	Material or Equipment Costs Total Price	Labour & Overhead	Total Costs
6.0	**Process Building**						
6.1	Divisions 31 to 33 - Siteworks						
	Excavation and Backfill	m^3	1,136	$24	$27,000	Included	$27,000
	Piling	each	0	$2,500	$0	Included	$0
6.2	Division 3 - Concrete Work						
	Structure - Slab	m^3	135	$1,650	$223,000	Included	$223,000
	Structure - Walls	m^3	115	$1,400	$161,000	Included	$161,000
	Form Work	m^2	560	$280	$157,000	Included	$157,000
	Rebar	m^3	250	$440	$110,000	Included	$110,000
	Void Form (200 mm)	m^2	184	$22	$4,000	Included	$4,000
	Precast Hollow Core	LS	1	$60,000	$60,000	Included	$60,000
6.3	Division 4 - Masonry	LS	1	$100,000	$100,000	Included	$100,000
6.4	Division 5 - Metals	LS	1	$100,000	$100,000	Included	$100,000
6.5	Division 6 - Wood and Plastic	LS	1	$10,000	$10,000	Included	$10,000
6.6	Division 7 - Thermal and Moisture Protection						
	Metal Cladding	LS	1	$80,000	$80,000	Included	$80,000
	Roofing	LS	1	$35,000	$35,000	Included	$35,000
6.7	Division 8 - Doors and Windows						
	Access Hatches	LS	2	$5,000	$10,000	Included	$10,000
	Doors / Overhead Doors / Frames / Hardware	LS	16	$1,500	$24,000	Included	$24,000
	Windows/Glazing	LS	4	$3,000	$12,000	Included	$12,000
6.8	Division 9 - Finishes						
	Painting	LS	1	$15,000	$15,000	Included	$15,000
	Special Coatings	LS	1	$75,000	$75,000	Included	$75,000
6.9	Division 10 - Specialities	LS	1	$7,000	$7,000	Included	$7,000
6.10	Division 12 - Furnishing	LS	1	$60,000	$60,000	Included	$60,000
6.11	Divisions 40, 43 and 46 - Process						
	Sluice and Slide Gates	LS	2	$8,000	$16,000	$8,000	$24,000
	Drain Pumps	LS	2	$10,000	$20,000	$10,000	$30,000
	Equipment Supply by Nexom (air blowers, HDPE headers, laterals, diffusers, control panels, influent piping and chambers eng. and installation)	LS	1	$3,230,000	$3,230,000	$646,000	$3,876,000
	NML Pump and and Fitting	each	1	$150,000	$150,000	$75,000	$225,000
	Filtration System	each	0	$0	$0	$0	$0
	UV Disinfection System	each	1	$350,000	$350,000	$175,000	$525,000
	Effluent Pump and Fitting	each	1	$150,000	$150,000	$75,000	$225,000
	Plant Water (W3) Pump and Fiting	each	1	$15,000	$15,000	$8,000	$23,000
	Polymer Blend System	LS	0	$40,000	$0	$0	$0
	Polymer Pumps	LS	0	$23,000	$0	$0	$0
	Alum Storage Tanks (reuse existing tank)	LS	0	$35,000	$0	$0	$0
	Alum Transfer Pumps and Feed Systems (reuse existing pumps)	LS	0	$20,000	$0	$0	$0
	Chlorination System with Chemical Piping	LS	2	$20,000	$40,000	$20,000	$60,000
	Laboratory Equipment Including Samplers	LS	1	$100,000	$100,000	$20,000	$120,000
6.12	Division 41 - Conveying Systems						
	Mobile Crane	LS	1	$65,000	$65,000	Included	$65,000
	Monorails (polymer and filter)	LS	0	$0	$0	$0	$0
6.13	Divisions 22 and 23 - Mechanical	LS	1	$910,000	$910,000	Included	$910,000
6.14	Divisions 26, 28 and 40 - Electrical						
	Electrical Service	LS					
	1000 Amp 25KV-600/347V	LS	1	$45,000	$45,000	Included	$45,000
	Service entrance switchgear, MCC's, panelboards etc.	LS	1	$410,000	$410,000	Included	$410,000
	LV Electrical Distribution (Switchgear, MCC & Transfer Switch) Install	LS	1	$150,000	$150,000	Included	$150,000
	Cabling, terminations & contractor commissioning	LS	1	$125,000	$125,000	Included	$125,000
	Telephone Service	LS	1	$30,000	$30,000	Included	$30,000
	Building Systems Electrical (lighting, power distribution, communications, fire, security, exit and emergency lighting & grounding systems)	LS	1	$300,000	$300,000	Included	$300,000
	Generator	LS					
	600V 300 KVA	LS	1	$150,000	$150,000	Included	$150,000
	Exterior Diesel Fuel Tank	LS	1	$40,000	$40,000	Included	$40,000
	Generator & Systems Installation	LS	1	$60,000	$60,000	Included	$60,000
	Controls/Instrumentation/Communications	LS					
	Control System & Programming	LS	1	$200,000	$200,000	Included	$200,000
	Control System (PLC and HMI Supply & Install)	LS	1	$125,000	$125,000	Included	$125,000
	Subtotal Operations Building						**$8,988,000**
7.0	**Odour Building**						
	Subtotal Process Odour Building						**$0**
	Subtotal						**$22,718,000**

Notes:
1. Costs are in 2019 Canadian Dollars.
2. Construction costs will vary depending on market conditions at the time of tender. Stantec has no control over those conditions.