City of Wasilla Wetland Wastewater Treatment Potential

City of Wasilla
Wastewater Outfall Feasibility Study

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Acronyms and Abbreviations

BOD_5	biological oxygen demand at 5 days
City	City of Wasilla
cm/day	centimeters per day
cm/m	centimeters per meter
deg C	degrees Celsius
Feasibility Study	*Wastewater Outfall Feasibility Study*
Gpd	gallons per day
Ha	hectares
HLR	hydraulic loading rate
Kg	kilograms
L	liters
LiDAR	Light Detection and Ranging
LiDAR	Light Detection and Ranging
M	meters
m^3/day	cubic meters per day
mg/L	milligrams per liter
MW	monitoring well
OLR	organic loading rate
S&W	Shannon and Wilson
Stantec	Stantec Consulting Services Inc.
TSS	total suspended solids
UNEP-IETC	United Nations Environmental Programme, International Environmental Technology Centre
WWTP	wastewater treatment plant

April 3, 2017

1.0 INTRODUCTION

To address the elevated levels of nitrate, and the capacity limitations of the wastewater treatment plant (WWTP) effluent disposal system, the City of Wasilla (City) has contracted with Stantec Consulting Services Inc. (Stantec) to examine the potential to use the 77-acre parcel adjacent to the existing WWTP for treatment and /or disposal of effluent the WWTP. This parcel, which consists primarily of wetlands, has been purchased by the City.

This *Wetland Wastewater Treatment Potential* report looks at the theoretical treatment potential of the wetlands and documents the calculations and modeling efforts referenced in the larger *City of Wasilla Wastewater Outfall Feasibility Study* (*Feasibility Study*).

2.0 WETLAND TREATMENT OVERVIEW

The intentional use of natural wetlands has been demonstrated to be effective in the treatment of municipal wastewater for a number of years (see references in Chouinard et al. 2014a), but examples have largely been focused in temperate climates (e.g. Cooke, 1994). Recent detailed studies in northern Canada also suggest that natural wetlands in cold climates can be effective in the treatment of municipal wastewater (Yates et al, 2012, 2013 and Chouinard et al. 2014b). Although these studies in northern Canada were focused on small villages with limited primary treatment, they nonetheless demonstrated that cold climate wetlands have surprising treatment capabilities.

To evaluate the treatment potential of the 37-acre wetland within the 77-acre parcel adjacent to the WWTP several methods were employed. Efforts focused on the removal of nitrate as it has been identified as the parameter of concern. First, common rules of thumb, namely hydraulic loading and organic loading rates were calculated. Finally, a SubWet 2.0 wetland model was utilized to estimate the treatment potential of the 37-acre wetland.

3.0 RULES OF THUMB

Common rules of thumb were calculated based on the guidance in Chouinard et al. (2014a) to provide an initial evaluation of the potential for the 37-acre wetland on the 77-acre parcel adjacent to the WWTP to further treat the effluent. These methods are based on observations from a broad range of climatic, vegetative, and physical conditions, and water quality types, but can provide an initial evaluation for the wetland size constraints and, more importantly, as a cross-reference to more detailed analyses.

3.1 HYDRAULIC LOADING RATE

Hydraulic loading rate (HLR) is a quick method to determine if flow through a wetland (distance/time) is within a broad range of values generally considered suitable for the treatment of municipal wastewater. HLR is simply effluent flow divided by wetland area and is a basic measure of effluent flow velocity, with the idea that a lower velocity facilitates greater settling of solids and other treatment processes (Chouinard et al. 2014a). HLRs for a variety of effluent flows being considered in the *Feasibility Study* were calculated as shown in Table 1. A suitable HLR normally ranges from 0.2 to 30 centimeters per day (cm/day) (Wood, 1995) and in arctic climates is has been suggested that a more appropriate range is 1 to 2 cm/day (Doku and Heinke, 1993). This simple calculation does suggest the wetland has sufficient volume for the treatment of effluent over a range of flow volumes, up to about 500,000 gallons, with only the effluent volume of 1,000,000 gallons per day (gpd) exceeding 2 cm/day (Table 1).

Table 1: Hydraulic Loading Rates for 37 Acres

Effluent Flow (gpd)	Hydraulic Loading Rate (cm/day)
350,000	0.88
400,000	1.01
500,000	1.26
1,000,000	2.53

3.2 ORGANIC LOADING RATE

Organic load refers to the soluble and particulate organic matter applied to a system. The organic loading rate (OLR) can have important influences on both biological and chemical treatment processes. Too low and organisms have no food, too high and aerobic organisms will consume the available oxygen, converting the system to an anaerobic environment with aerobic organisms dying and an increase in odors. Biological oxygen demand (BOD) is a measure of the organic loading and is the amount of oxygen consumed by microbes per liter of sample. Standard BOD testing is done for 5 days (BOD_5) to measure oxygen demand for 5 days of incubation at 20 degrees Celsius (deg C).

The following equation was used to calculate OLR:

$$Organic\ Loading\ Rate\ \left(\frac{kg\ BOD5}{ha \cdot d}\right) = \frac{\left(BOD5\ \frac{kg}{m3}\right)\ X\ Flow\ \left(\frac{m3}{d}\right)}{Area\ (ha)}$$

OLR was calculated for an effluent with BOD5 of 134.28 milligrams per liter (mg/L) (the 2015 annual average for effluent exiting the aeration lagoons) and a BOD_5 of 400 mg/L (maximum observed in 2015 exiting the aeration lagoons) at three different effluent flows. Table 2 displays the calculated results.

Table 2: Organic Loading Rates for 37 Acres

Effluent Flow (gpd)	Organic Loading Rate at 134.28 mg/L BOD_5 (kilogram [kg] BOD_5 / hectare [ha] /day)	Organic Loading Rate at 400.00 mg/L BOD_5 (kg BOD_5 / ha /day)
350,000	11.88	35.40
500,000	16.97	50.55
1,000,000	33.95	101.13

OLR values thought to be relevant to effective wetland wastewater treatment vary, and are largely based on constructed wetlands in temperate climates and not cold climate natural wetlands (Chouinard et al. 2014a). Kadlec and Wallace (2009) suggest that values not exceed 60 to 80 kg BOD_5 per hectare (ha) per day to achieve a treatment effluent less than 30 mg/L. Doku and Heinke (1993) suggest that arctic wetlands (e.g. tundra wetlands) not receive organic loading greater than 8 kg BOD_5/ha per day to ensure adequate aerobic conditions persist within the wetland. Again, this is a simplified calculation meant to provide an order of magnitude evaluation. The OLRs calculated exceed the Doku and Heinke (1993) ecological focused suggestion, but are well below water quality values suggested in Kadlec and Wallace (2009). It should be noted that Wasilla is sub-arctic and more temperate than the Canadian north. However, based on simple OLR further evaluation is warranted.

4.0 SUBWET

For a more sophisticated approach, a three-dimensional, horizontal subsurface flow modelling program, SubWet 2.0, was employed to evaluate the potential for the 37-acre wetland to treat the WWTP effluent. SubWet was originally developed for warm climate constructed wetland applications, but recent modifications allow for its application to cold climate natural wetlands (i.e., version SubWet 2.0). The model can be freely downloaded at the United Nations Environmental Programme, International Environmental Technology Centre (UNEP-IETC) website (http://web.unep.org/ietc/).

4.1 MODEL INPUTS

The SubWet model incorporates the influence of several factors simultaneously by employing 25 differential process equations and 16 parameters (e.g., rate coefficients such as temperature coefficient of nitrification). The model requires values describing the physical features of the wetland, including length, width, depth, slope, hydraulic conductivity, temperature etc. In addition, the model requires inputs on the expected influent, such as volume and water quality.

Table 3: SubWet 2.0 Design Parameters

Design Parameters	Value
Width (m)	175
Length (m)	166
Depth (m)	0.5
Precipitation factor	1.0
Slope - centimeters per meter (cm/m)	0.8
Average % Particular Matter (unitless)	0.0085
Hydraulic conductivity (m3/day)	0.3048
Selected flow (m^3/day)	Varies
Porosity (fraction)	0.275
Wetland Temperature (°C)	10
BOD5 (mg/L)	134 – 2015 average 400 – 2015 maximum value
Nitrate (mg/L)	26.7 – 1997-2015 average max 77 - max observed
Ammonium (mg/L)	0.1
Total Phosphorus (mg/L)	3.0

Table 3 displays the model design settings used for the City WWTP Outfall simulation. As explained below:

- **Width and Length:** The input dimensions for the wetland were chosen to approximate the irregular area of the 37 acres of wetland mapped within the larger 77-acre parcel.
- **Depth:** A depth of 0.5m is consistent with conservative estimations of the depth that influent will flow through in northern climate peat wetlands (Chouinard et al. 2014a), but is less than that assumed by Shannon and Wilson (S&W) (2016).
- **Precipitation Factor:** A precipitation factor of 1 indicates an assumption that the input of precipitation is balanced by the loss by evapotranspiration, over the duration of the model.
- **Slope:** The slope was estimated using light detection and ranging (LiDAR) data collected by the Matanuska-Susitna Borough in 2014 as shown on *Feasibility Study* figures.
- **Average Percent Particular Matter:** The Average Percent Particulate Matter is a measure of the material in the flow other than water and was taken from the annual average total suspended solids (TSS) observed in the effluent in 2015 (converted to percent by volume).

- **Hydraulic Conductivity:** Hydraulic conductivity was estimated based on empirical correlations with grain size test results from samples collected during S&W's 2008 and 2015/16 subsurface explorations at the site, 2008 slug test results, 2015 infiltration test results, and professional judgment (Shannon and Wilson, 2016).
- **Selected Flow:** The Selected Flow is the amount of effluent applied. This was varied by run at levels considered in the *Feasibility Study*.
- **Porosity:** The porosity of the wetland was estimated at 27.5 percent based on soil observations made across the site during at wetland delineation (Stantec 2016) and on hydrology work done by S&W (2016).
- **Wetland Temperature:** The average temperature of the wetland during the active growing season is unknown and estimated to be around 10 deg C.
- **BOD_5:** BOD_5 values were derived from the annual average and maximum observed exiting the aeration lagoons in 2015.
- **Nitrate:** Nitrate levels were derived from the annual maximum average observed in Monitoring Well (MW) MW-7 from 1997 through 2015, and the maximum value ever recorded.
- **Ammonium and Phosphorus:** Ammonium and phosphorus levels in the effluent are not routinely measured and thus are unknown, but were estimated at low levels resulting from the primary and secondary treatment processes.

4.2 MODEL RESULTS

Table 4: SubWet Model Results

	Influent Level (mg/L)	Effluent Level at 350,000 gpd 16.4 days HRT	Effluent Level at 400,000 gpd 14.4 days HRT	Effluent Level at 500,000 gpd 11.54 days HRT
Nitrate (mg/L) with BOD_5 at 134 mg/L	26.7	0.034	0.032	0.045
	77	0.040	0.050	0.072
BOD_5 (mg/L) with Nitrate at 26.7 mg/L	134.28	1.35	21.30	57.59
	400	unk	unk	unk
unk = unknown value, model failed to stabilize				

SubWet 2.0 estimated the hydraulic retention time (HRT) at 16.4 days for an effluent flow of 350,000 gal/day, 14.4 days for an effluent flow of 400,000 gal/day, and 11.5 days for an effluent flow of 500,000 gal/day. With the WWTP effluent BOD_5 set at 134.28 mg/L, which was the 2015 average value leaving the aeration lagoons, the simulations indicate that BOD_5 is expected to

be reduced to 1.35 mg/L. This suggests very good treatment of the average WWTP effluent up to flows of 500,000 gpd.

At an effluent of 400 mg/L BOD_5 the simulation fails to stabilize, suggesting the wetland lacks the capacity to treat this extreme value, for either of the three flow levels considered. At this extreme level of BOD_5 the wetland area near the discharge will quickly become depleted of oxygen and result in a biomass buildup until the water quality of the WWTP effluent improves. Without water quality improvements in this scenario there would likely be significant impacts to the wetland biota, such as loss of invertebrate and vegetation diversity.

SubWet 2.0 estimated that with WWTP effluent nitrate level set at 26.7 mg/L and a flow of 350,000 gpd the wetland would reduce the nitrate level to 0.034 mg/L. A very similar level of treatment is also achieved at the two higher flow rates. Even when the influent into the wetland is set with the highest level of nitrate observed the level of reduction is below 1.0 mg/L. Table 4 provides a summary of the simulation results observed.

Although not all permutations of the nitrate levels and BOD_5 levels are reported for simplicity, those additional results are consistent with the trends in Table 4. The results of the SubWet 2.0 simulations suggest that the 37-acre wetland adjacent to the WWTP has the capacity to reduce nitrate levels to meet project requirements at effluent flow volumes that exceed the current WWTP output. In addition, the simulation results suggest that this wetland also has the treatment capacity to reduce BOD_5 levels to meet permit requirements, but only to a certain extent. It is likely that the extreme levels of BOD_5 observed during some summer months in recent years would exceed the treatment capacity of this wetland. However, this would be typical of any process upset in a wastewater treatment system. It is important to note that these simulations assumed the conditions of the warmer summer months. Cooler temperatures and net gains of precipitation would have impacts on the treatment processes and potential treatment capacity of this wetland.

SubWet 2.0 does not specifically model the processes of soil and vegetation filtration, exposure to sunlight, temperature swings, or other abiotic or biotic conditions that remove fecal coliform. However, optimum removal of fecal coliform requires maximum contact with vegetation, and adequately warm soil or shallow wetland ponds. The EPA has published several case studies and guidance manuals; for this project EPA/625/1-88/022 Constructed Wetlands and Aquatic Plant Systems for Municipal Wastewater Treatment (it also covers natural wetlands) and EPA 625/1-81-013, Land Treatment of Wastewater are both applicable.

These manuals suggest that 7 to 10 days of wetland detention will remove about 90 percent of fecal coliform. The University of Minnesota, which has designed year-round wetlands, recommends 10 to 13 days for cold regions. Estimates of HRT provided by SubWet 2.0 exceed both of the estimates suggested as necessary for adequate fecal coliform removal.

4.3 MODEL REFINEMENT

One of the important aspects of the SubWet 2.0 modelling software is the ability to calibrate the model with empirical data (Chouinard et al. 2014b). Without calibration to the specific wetland, modeling the expected results are likely within 25 percent of potential observed values, but with calibration that can be reduced to 5 percent, or less. In addition, this model provides for the ability to alter parameters to account for seasonal changes in the wetland and in the influent. Empirical data gathered during a pilot study (being considered in conjunction with the Feasibility Study) can be used to calibrate the model and reduce variance around simulation results and provide a robust modelling tool for future decision making.

5.0 CONCLUSIONS

Rule of thumb analysis for hydraulic and organic loading rates, and SubWet 2.0 modeling all suggest the 37-acre wetland parcel is capable of treating as much as 500,000 gpd of typical WWTP effluent to a high level of BOD and nitrate removal.

The wetlands and subsurface ground water may have other limiting factors that govern the amount of effluent that can be accommodated in the wetlands. These factors are discussed separately in the *Feasibility Study* and the Shannon and Wilson *Hydrogeological Assessment.*

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