Memo

Project Name:	Antigonish Lagoon Preliminary Aeration Evaluation	Project No.:	240820.00
Date:	October 4, 2024		
Subject:	Final Report		
To:	Ken Proctor, P.Eng.; Kyle Meisner, P.Eng., Town of Antigonish		
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Introduction

The Town of Antigonish is currently serviced by a lagoon-based Wastewater Treatment Plant (WWTP) which discharges to Wright River. Since Spring 2024, the WWTP has been experiencing ongoing odour problems which are caused by insufficient air supply within the system to maintain aerobic digestion of the organic load. The following memorandum report will include an assessment of current system conditions and aeration system design parameters to recommend modifications to the lagoon system in order to rectify the odour problems.

Lagoon Design & Influent Conditions

The WWTP consists of the following wastewater treatment components:

- Influent grinder *.
- Submersible pump system.
- Six (6) celled aerated lagoon.
- Seasonal sand filtration.
- UV disinfection.

* There is currently no front-end screening process.

The WWTP services approximately 4,364 permanent residents as well as approximately 2,500 residents of the County Fringe Area, and a seasonal population of approximately 4,500 university students. The loads to the treatment system are currently from two main sources: the domestic loads from the Town and the benthic loads resulting from the on-going decomposition of sludge solids in the bottom of the lagoon.

Aerated lagoons are long retention systems with the hydraulic retention time typically in the order of 30 days. Solids present in the influent flow will settle to the bottom of the lagoon and the organic fraction will degrade over a long period of time. As long as free oxygen is available in the water column, the solids will digest aerobically. The end products of the aerobic digestions are primarily carbon dioxide (CO_2), water, and inert solids. Design of lagoon systems typically includes a Dissolved Oxygen (DO) concentration of 1.0 to 3.0 mg/L maintained across the system. When oxygen is not available in sufficient amounts to facilitate aerobic digestion, the solids will degrade

anaerobically. The end products of anaerobic digestion are methane (CH_4), inert solids, hydrogen sulphide (H_2S), and possibly other malodorous gases. The Antigonish WWTP has been in operation since upgrades were last performed on the system in 1995. The lagoon has since been desludged via dredging in 2004 and 2015, with each process removing >200 BDT of material. Due to increased loading to the system, it is expected that there could be >200 BDT of partially digested sludge that has accumulated in the system since 2015.

The treatment efficiency achieved in an aerated lagoon is largely a function of Hydraulic Retention Time (HRT) and wastewater temperature. Other factors such as raw wastewater characteristics, toxicity, and number of lagoon cells will also affect performance. The system efficiency increases during summer operation when ambient temperatures are higher and decreases somewhat in the winter as the biological activity slows in the lagoon. The system is meant to operate aerobically therefore, sufficient air must be provided under all operating conditions to achieve the stated performance. Air requirements increase in the warmer summer months when biological activity accelerates.

The lagoon consists of six aerated lagoon cells separated by a concrete well and several floating baffles. Cells 1A, 1B, 2A , 2B, and 3A have an equal volume of approximately 33,000 m^3 each and the final cell, 3B, has a volume of 25,000 m^3. A site layout of the lagoon is provided in the attached appendices. The Influent domestic wastewater is typically characterized by Carbonaceous Biochemical Oxygen Demand (CBOD), Total Suspended Solids (TSS), and Ammonia (NH_3) loads to the system. The original design values are provided in Table 1. It is notable that the design of the system did not include an aeration requirement for ammonia removal (nitrification).

Current influent conditions were estimated based on influent sample data collected approximately weekly from April 2021 to June 2024 and the corresponding quarterly ADF reported for the system.

Table 1: Comparison of Design and Current Influent Conditions

Parameter	Design Value	Current Value
ADF (m^3/d)	6,826	7,942
CBOD Concentration (mg/L)	100	108
TSS Concentration (mg/L)	180	162
NH_3 Concentration (mg/L)	n.s.	11
CBOD Load (kg/d)	680	870
TSS Load (kg/d)	1,220	1,284
NH_3 Load (kg/d)	n.s.	86
Operating Depth (m)	4.70	5.36
Operating Volume (m3)	190,000	215,500
Hydraulic Retention Time (d)	28	27

The influent conditions summarized in Table 1 indicate the system is operating above design limits for several parameters. However, effluent quality is not significantly impacted as the system has an average effluent CBOD concentration of 9 mg/L and TSS concentration of 10 mg/L from 2021 to 2024. This is primarily due to the increased water level in the cells. Based on daily lagoon level measurements from May to July 2024, the lagoon is operating with an average freeboard of 0.22 m (8.7 in). With the bottom lagoon elevation at 0.74 m and top of wall elevation of 6.32 m, the lagoon is consistently operating at or near the maximum operating water level of 5.36 m as compared to the design level of 4.70 m. This has mitigated the reduction of HRT that would typically occur when influent flows increase effectively maintaining the hydraulic capacity of the site. While some mitigation of the increased organic loading through operation of all blowers simultaneously has been attempted, it has not been as effective resulting in the operational issues the plant is currently experiencing. It should also be noted that the influent conditions can vary daily, weekly, and seasonally resulting in periods when the organic loads are within the design conditions alleviating the operational issues, periodically.

Existing Aeration System

Process air is supplied to the lagoon cells via four blowers: two 50 HP (37.4 kW) and two 25 HP (18.7 kW) blowers. The blower building is located at the effluent end of the site with Cell 1A located the farthest cell from the blower building. Based on equipment blower curves, the 25 HP Blower Engineering Model RB80 blowers (Blower #1 and Blower #2) each have a capacity of approximately 400 scfm and the two 50 HP Blower Engineering Model TL 100 blowers (Blower #3 and Blower #4) have a capacity of 800 scfm and 950 scfm, respectively. Table 2 provides a summary of the individual blower capacities.

Table 2: Blower Capacity Summary

Parameter	Blower #1	Blower #2	Blower #3	Blower #4
Blower Power (HP)	25	25	50	50
Pulley Diameter Ratio	0.78	0.78	0.83	0.95
Avg Pressure (psi)	8	9	10	11
Motor Speed (RPM)	1,765	1,765	1,770	1,770
Blower Speed (RPM)	1,373	1,373	1,462	1,677
Inlet Air Flow (ACFM)	400	400	800	950

The compressed air is delivered to floating laterals across each lagoon cell which are connected to the main aeration header. Along each floating lateral (Figure 1) are drop assemblies with fine bubble diffusers which provide air to the lagoon cell. There are a total of 14 floating laterals across the cells. The number of drop assemblies per lateral vary based on the originally estimated design aeration requirements for each cell.

Figure 1: Floating Aeration Lateral No. 13 in Cell 3A

The majority of drop assemblies were installed in 1995 and are Parkson Biolac fine bubble diffuser assemblies, each supplied with two diffusers per drop assembly. However, drop assemblies on the first three laterals in Cell 1A were replaced with TriplePoint Aerators (MARS and ARES aerators) within the last five years. Currently, Chain 1 has four MARS aerators and Chain 2 and Chain 3 each have four ARES aerators. Figure 2, provided by the Town, shows the location of the TriplePoint aerators in Cell 1A.

Figure 2: Positions of TriplePoint Aerators Installed in Cell 1A

Consistent with typical lagoon aeration system design, the majority of air is supplied to Cell 1, with aeration requirements reduced in the final cells to promote settling for TSS removal. A summary of the aeration system layout is provided in Table 3.

Table 3: Aeration System Layout

Cell	Chain #	# of chains per cell	Drops Per Chain	Diffusers Per Drop	Total number of diffusers	Diffuser Type
1A	1	6	4	10	40	Mars
	2		4	10	40	Ares
	3		4	10	40	Ares
	4		10	2	20	Biolac
	5		10	2	20	Biolac
	6		10	2	20	Biolac
1B	7	3	10	2	20	Biolac
	8		10	2	20	Biolac
	9		10	2	20	Biolac
2A	10	2	9	2	18	Biolac
	11		9	2	18	Biolac
2B	12	1	8	2	16	Biolac
3A	13	1	3	2	6	Biolac
3B	14	1	1	2	2	Biolac

Current Operating Conditions

The aeration system currently operates with all four blowers operating continuously; however, the original design of the aeration system would allow for one 50 HP to be stand-by. As stated in the Parkson Biolac equipment manual, the aeration system was designed to maintain a DO concentration of 1.0 – 3.0 mg/L across the system. Table 4 provides a summary of the average DO levels within the lagoon cells based on samples collected daily from May to July 2024. All blowers were operating when samples were collected.

Table 4: Dissolved Oxygen Concentration by Lagoon Cell

Parameter	Dissolved Oxygen Concentration (mg/L)						
Sample Location	Front Wall	Cell 1A Line 2	Cell 1A Line 5	Cell 1B Line 7	Cell 1B Line 9	Cell 2A Line 11	Cell 3A Line 13
Average DO	0.25	0.23	0.21	0.62	0.67	2.68	2.85
Peak DO	0.46	0.55	0.52	3.80	3.83	8.60	8.81

As shown in Table 4, the design minimum DO concentration for the system of 1.0 - 3.0 mg/L is not maintained within Cells 1A and 1B, indicating there is insufficient air particularly at the front of the system. DO concentrations increase in Cell 2A and Cell 3A, indicating improved conditions in later cells.

Oxygen transfer to the lagoon decreases in warmer conditions (spring/summer) compared to colder conditions (winter). The design winter and summer operating temperatures for the system are 0.5°C and 20°C, respectively. Daily low and high temperature readings from May to September 2024 (Figure 3) show prolonged periods of lagoon temperatures above 20°C. The average temperatures during this period were 19.8°C (low temperature) and 22.4°C (high temperature) with a peak temperature of 27.1°C. Temperatures are sustained above 25°C for at least a month as evidenced in the following figure.

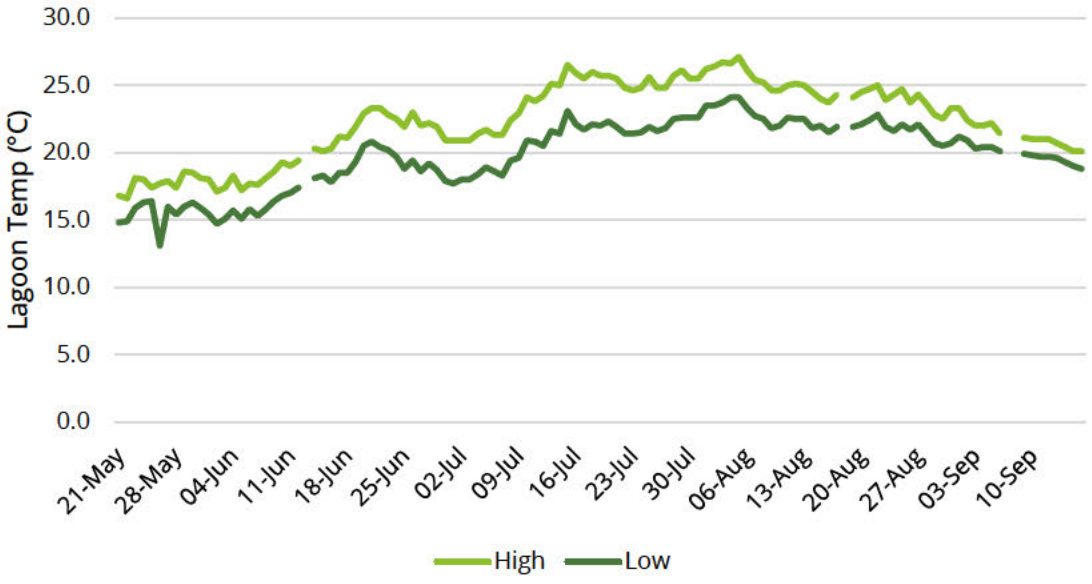

Figure 3: Lagoon Temperature Readings (May - September 2024)

Aeration System Assessment

An initial assessment of the aeration system was carried out by evaluating the design and actual conditions for the summer and winter conditions. The design conditions include the design organic load (680 kg/d) and air flow per cell as well as operating with one 50 HP blower on stand-by. The actual conditions reflect current influent, temperature and operating water level conditions as well as continuous operation of all four blowers. The Actual Oxygen Requirement (AOR) was estimated based on the current average influent CBOD loading and the theoretical oxygen requirements of 1.5 kg O_2/kg BOD removed. Additionally, benthic (sludge) loading was considered based on the approximate area of the lagoon (38,680 m^2) and a sludge oxygen demand of 8 g $O_2/m^2/d$ (Thomann and Mueller, 1987) resulting in a benthic demand of 390 kg O_2/d. A summary of the oxygen demand compared to the oxygen supplied for each of

these scenarios is provided in Figure 4. Details of the calculations are provided in the attached appendices.

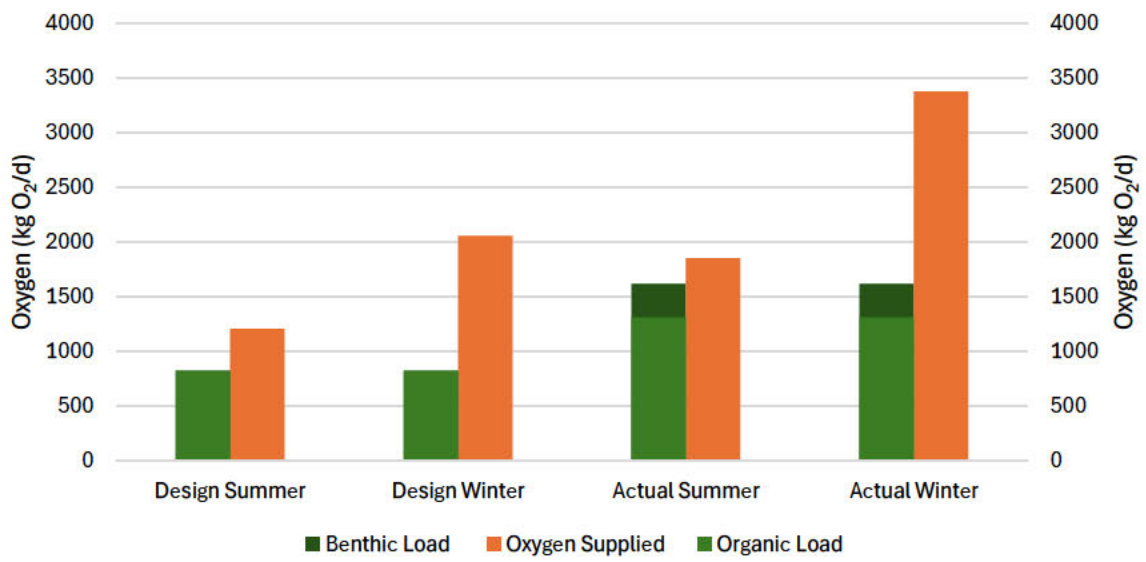

Figure 4: Evaluation of Design & Actual Conditions

In each of these scenarios, calculations suggest that sufficient air is available to treat the organic load within the system however, these scenarios do not account for any reduction in oxygen transfer that occurs as diffusers age, pores open, and bubble sizes increase. In addition, operational experience has shown an increased tendency for 'ragging' of the diffusers, primarily due to the non-biodegradable wipes, that can also impact diffuser airflow and bubble size. To account for these potential losses, a scenario was also carried out with a 15% reduced oxygen transfer efficiency. Additionally, increased operating temperatures will also influence the air supplied to the system so a scenario of the maximum recorded blower room temperature (54°C) and lagoon temperature (27°C) was also considered. A summary of the estimated oxygen demand compared to the estimated oxygen supplied for each of these scenarios is provided in Figure 5. Details of the calculations are provided in the attached appendices.

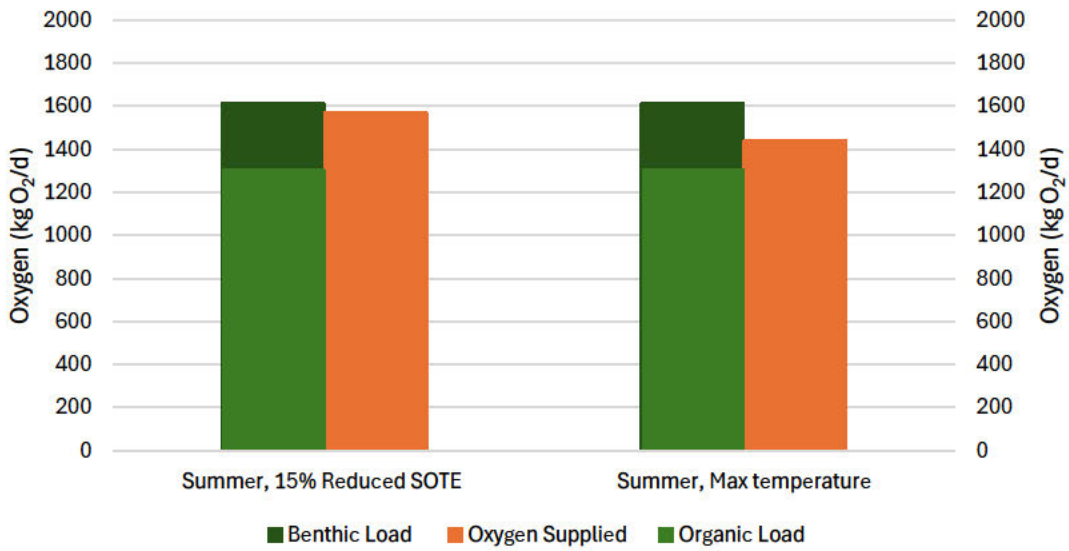

Figure 5: Actual Condition Scenarios with Additional Considerations

In the assessed scenarios, calculations indicate that at times there is potentially insufficient air available to treat the organic load within the system which could result in the odour conditions that are periodically present within the Town. These scenarios assume an average influent load and temperature. Fluctuations in the actual operating conditions will impact the oxygen demand and supply (i.e. high influent load and/or warmer temperatures will increase oxygen demand).

The TriplePoint Aerators have a design air flow of 35 scfm therefore, an assumption was made in all calculations that each TriplePoint aerator receives 35 scfm and that the remaining air supply is distributed evenly amongst the Biolac diffusers. Additional assumptions were included in the calculations such as the empirical factors (α, β & θ) and diffuser oxygen transfer efficiency (SOTE, %). It is important to note that these assumptions could result in the overestimation of the quantity of air provided to the system. Furthermore, the true distribution of air may not be as assumed and/or unidentified air leaks could also reduce air supply.

Mitigation Measures

The analysis above demonstrates that the aeration system does not have the capacity to meet the oxygen demand under all operating conditions. In general, when this occurs there are two approaches to rectify the situation including:

- Increase the amount of oxygen supplied (Increase supply).
- Decrease the amount of oxygen required (Decrease demand).

Oxygenation can be improved by either supplying more air or improving the oxygen transfer rate. Reducing the amount of oxygen required by the entire system can only be achieved by pre-

treatment. However, the amount of oxygen required in an individual cell can be reduced by redistributing the loading throughout the plant either by using multiple feed locations or by recirculation of effluent. Site specific actions to achieve these outcomes are described in the following sections.

Oxygen Supply Options

The oxygen supply is influenced by both the supply of air and the transfer of the oxygen contained in the air to the wastewater.

In order to increase the amount of air utilizing the existing equipment, the Town could consider increasing the motor size of the existing blowers to increase blower speed and therefore air supply. The blowers are rotary lobe, positive displacement units and the air delivery capability is closely proportional to blower speed. However, the line losses should be checked in the existing air distribution network to ensure that the resulting back pressure does not overload the blower motors or actuate the air release valves prematurely as well as to identify any potential leaks in the air supply. As well, speeding up the blowers will increase the electrical motor loads and therefore motor capacity and electrical distribution infrastructure will also need to be checked.

To increase air without using the existing equipment, additional blowers will be required. As the blowers are currently located at the back of the site, furthest from the inlet of Cell 1A, another option to be considered would be to install new blowers closer to the head of the facility to distribute air to Cell 1A and 1B. This would improve air flow and ensure sufficient air is provided to the head of the system, which has the most significant organic load and aeration requirements. This could be completed using temporary rental units in the short term or the construction of a new blower building in the longer term.

Oxygen transfer can be improved both through the installation of additional diffusers or the replacement of diffusers that are aged or damaged. As the flux rate per diffuser decreases, the oxygen transfer increases. The existing biolac drop legs have capacity to carry four diffusers however only two diffusers are installed as per the 1995 upgrade. Adding additional diffusers to the drop legs, particularly in the first few cells, could have a measurable impact especially if combined with additional aeration. The impact of ragging can also be reversed by pulling and cleaning the diffusers or installing screening ahead of the cells to prevent foreign materials from impacting the plant equipment. It is understood that the cleaning of the diffusers is very labour intensive such that the frequency of cleaning, while somewhat routine, cannot be performed to a level that would prevent any ragging issues. The proposed front end screening project will further assist in reducing the ragging and fouling of aeration and downstream process equipment.

It is more difficult to quantify the impact of the MARS/ARES units. While they do contain additional diffuser area, some of this air is in the form of coarse bubble aeration which is less efficient. In addition, by installing multiple diffuser systems on the same headers, the potential for distribution issues is greater. Therefore, if possible, isolation of these units with their own air supply is

recommended in the short term. A longer-term diffusion system upgrade should either utilize all of the same type of diffusers or contain separate air supply systems for the different types of diffusers.

Oxygen Demand Options

The oxygen demand is influenced by the amount of CBOD removal, nitrification, and aerobic digestion of solids that occurs in each cell. Demand can therefore be reduced by reducing the inputs to the various cells or by re-distributing where the loading is applied.

One of the more effective, short-term modifications that can be performed includes redistributing the load through effluent recirculation or step feeding. As there are higher concentrations of dissolved oxygen present in Cell 3B, flow from Cell 3B could be recirculated to the head of the system to increase oxygen to Cell 1 as well as dilute the influent wastewater. This will also decrease the HRT in the initial cells resulting in less CBOD removal and consequently less oxygen demand. Caution is required as this will push loading further downstream into the subsequent cells increasing the demand in those cells.

There is also an existing forcemain (designed for alternate maintenance feed main) from the influent PS to Cell 2A which could be utilized to step-feed the system for the short term, reducing the loading on Cell 1. This would improve the DO levels in Cell 1 but as with the technique above, increase the loading in subsequent cells, particularly Cell 2. In addition, as this force main is rarely if ever utilized, its condition is unknown and would require further investigation prior to implementing this recommendation.

Another way to decrease the oxygen demand is to remove the bottom sludge from the existing lagoon, particularly cell 1. Since individual cells cannot be isolated for cleaning, sludge removal will not be an easy task if the treatment system is to remain operational. One approach might involve the use of a section dredge to pump the material out of the system. Care would need to be exercised to avoid damage to the existing aeration system. Removal of the bottom deposits will further reduce the overall load on the treatment system and the potential for anaerobic decomposition.

Summary & Action Items

The Town of Antigonish wastewater treatment facility is currently seasonally overloaded with respect to the oxygen supply as compared to the oxygen demand. The hydraulic retention time appears adequate resulting in a plant that has sufficient capacity hydraulically but not organically, resulting in persistent odour issues within the Town. This report investigates the causes of this condition and identifies mitigation measures.

In summary, we recommend that the Town consider the following items to address the aeration system deficiencies:

- Increase the supply of air utilizing the existing blowers or installing additional blowers.
- Remove sludge from the lagoon cells.
- Recirculate flow from Cell 3B to the head of the lagoon.
- Activate forcemain to reduce loading on Cell 1.
- Install screening ahead of the first cell.
- Upgrade aeration system.

While some of these items can be implemented in the short term and help to contain the issue for now, more substantial modifications will be required to eliminate the odour issues in the long term. These modifications will require additional engineering related to the development of design parameters, selection of equipment, and the development of general arrangement and installation drawings. The design of these permanent longer-term upgrades will need to be informed by additional data. In addition to DO readings, further data collected across the system would provide additional insight into the conditions across the system.

Therefore, in terms of a prioritized action plan we recommend the following:

1. Recirculate Flow from Cell 3 to Cell 1 – Timeline: Immediate; Cost: [redacted]
    a. Maximize return flows from filter backwash line.
    b. Install temporary pumps.
2. Increase airflow from Existing Blowers – Timeline 2 – 6 weeks; Cost: [redacted]
    a. Check electrical capacity of blower starters/breakers.
    b. Determine increased loading from speeding up blowers.
    c. Increase speed of existing blowers where possible.
3. Remove Sludge from Lagoon – Timeline 2 – 3 months, Cost: [redacted]
    a. Circulate request for pricing to dewatering companies.
    b. Evaluate bids and select preferred service provider.
    c. Mobilize, dewater, tear down & re-instate.
4. Add new temporary additional air supply – Timeline 1-2 months, Cost: [redacted]
    a. Source temporary blower.
    b. Purchase and transport to site.
    c. Design electrical and piping modifications.
    d. Install and start-up.
5. Re-direct Influent to Cell 2 – Timeline 2 – 4 months, Cost: [redacted]
    a. Determine effectiveness of pervious implemented measures.
    b. Investigate loading/BOD removal of each cell.
    c. Model revised air supply vs current loading conditions.
    d. Assess Condition of forcemain.
    e. Utilize if deemed feasible and effective.

6. Install Influent Screens – Timeline 18 – 24 months, Cost: [redacted]
    a. Select Designer (1 – 2 months)
    b. Design New Screening Facility (4 – 6 months)
    c. Tender, Construct, & Commission (12 – 18 months)
7. Upgrade Aeration System – Timeline 18 – 36 months, Cost: [redacted]
    a. Investigate current/future loading conditions
    b. Determine Impact of Items above
    c. Develop necessary permanent upgrades for 20-year design life of new aeration system
    d. Design, tender, construct, commission.

APPENDIX

Scenario: Design Summer Conditions

Parameter	Value	Units
α	0.55	
β	0.95	
θ	1.024	
P atmospheric	14.7	psi
P site	14.8	psi
Ω	1.01	
Cs	9.17	mg/L
Csw	9.23	mg/L
T	20	°C
Co	2	mg/L
SWD	4.73	m

Design Organic Load (kg/d)	680
Design AOR (kg O_2/d)	816

Air Flow 1,347 scfm (from Biolac design)

Cell Number	Chain #	# of chains per cell	Air flow to cell	Drops Per Chain	Diffusers Per Drop	Total number of diffusers	Diffuser Type
1A	1	6	659	4	-	-	Mars
	2			4	-	-	Ares
	3		420	4	-	-	Ares
	4	3	239	10	2	20	Biolac
	5			10	2	20	Biolac
	6			10	2	20	Biolac
1B	7	3	340	10	2	20	Biolac
	8			10	2	20	Biolac
	9			10	2	20	Biolac
2A	10	2	206	9	2	18	Biolac
	11			9	2	18	Biolac
2B	12	1	94	8	2	16	Biolac
3A	13	1	32	3	2	6	Biolac
3B	14	1	16	1	2	2	Biolac

Chain #	Air Flow per Chain	Air flow per diffuser (scfm)	Air flow per diffuser (kg O_2/hr)	Diffuser SOTE (%)
1	140	35.0	16.6	28%
2	140	35.0	16.6	28%
3	140	35.0	16.6	28%
4	80	4.0	1.89	19%
5	80	4.0	1.89	19%
6	80	4.0	1.89	19%
7	113	5.7	2.69	19%
8	113	5.7	2.69	19%
9	113	5.7	2.69	19%
10	103	5.7	2.71	19%
11	103	5.7	2.71	19%
12	94	5.9	2.79	19%
13	32	5.3	2.53	19%
14	16	8.0	3.79	19%

Chain #	SOTR per diffuser (kg O_2/d)	Total SOTR (kg O_2/d)	α	AOR/SOR	AOTR (kg O_2/d)
1	111.6	446.2	0.55	0.37	163.3
2	111.6	446.2	0.55	0.37	163.3
3	111.6	446.2	0.55	0.37	163.3
4	8.4	167.8	0.55	0.37	61.4
5	8.4	167.8	0.55	0.37	61.4
6	8.4	167.8	0.55	0.37	61.4
7	11.9	238.7	0.55	0.37	87.4
8	11.9	238.7	0.55	0.37	87.4
9	11.9	238.7	0.55	0.37	87.4
10	12.1	216.9	0.55	0.37	79.4
11	12.1	216.9	0.55	0.37	79.4
12	12.4	198.0	0.55	0.37	72.5
13	11.2	67.4	0.55	0.37	24.7
14	16.8	33.7	0.55	0.37	12.3
					1,204 kg O_2/d
					2649.9 lbs O_2/d
					105.81 scfm

Scenario: Design Winter Conditions

Parameter	Value	Units
α	0.55	
β	0.95	
θ	1.024	
P atmospheric	14.7	psi
P site	14.8	psi
Ω	1.01	
Cs	9.17	mg/L
Csw	14.33	mg/L
T	1	°C
Co	2	mg/L
SWD	4.7	m

Design Organic Load (kg/d) 680

Design AOR (kg O_2/d) 816

Air Flow (scfm) 1,347 *from biolac design

Cell Number	Chain #	# of chains per cell	Air flow to cell	Drops Per Chain	Diffusers Per Drop
1A	1	6	659	4	-
	2			4	-
	3		420	4	-
	4	3	239	10	2
	5			10	2
	6			10	2
1B	7	3	340	10	2
	8			10	2
	9			10	2
2A	10	2	206	9	2
	11			9	2
2B	12	1	94	8	2
3A	13	1	32	3	2
3B	14	1	16	1	2

Chain #	Total number of diffusers	Diffuser Type	Air Flow per Chain	Air flow per diffuser (scfm)	Air flow per diffuser (kg O_2/hr)	Diffuser SOTE (%)
1	-	Mars	140	35.0	16.6	28%
2	-	Ares	140	35.0	16.6	28%
3	-	Ares	140	35.0	16.6	28%
4	20	Biolac	80	4.0	1.89	19%
5	20	Biolac	80	4.0	1.89	19%
6	20	Biolac	80	4.0	1.89	19%
7	20	Biolac	113	5.7	2.69	19%
8	20	Biolac	113	5.7	2.69	19%
9	20	Biolac	113	5.7	2.69	19%
10	18	Biolac	103	5.7	2.71	19%
11	18	Biolac	103	5.7	2.71	19%
12	16	Biolac	94	5.9	2.79	19%
13	6	Biolac	32	5.3	2.53	19%
14	2	Biolac	16	8.0	3.79	19%

Chain #	SOTR per diffuser (kg O_2/d)	Total SOTR (kg O_2/d)	α	AOR/SOR	AOTR (kg O_2/d)
1	111.6	446.2	0.55	0.62	278.4
2	111.6	446.2	0.55	0.62	278.4
3	111.6	446.2	0.55	0.62	278.4
4	8.4	167.8	0.55	0.62	104.7
5	8.4	167.8	0.55	0.62	104.7
6	8.4	167.8	0.55	0.62	104.7
7	11.9	238.7	0.55	0.62	148.9
8	11.9	238.7	0.55	0.62	148.9
9	11.9	238.7	0.55	0.62	148.9
10	12.1	216.9	0.55	0.62	135.3
11	12.1	216.9	0.55	0.62	135.3
12	12.4	198.0	0.55	0.62	123.5
13	11.2	67.4	0.55	0.62	42.0
14	16.8	33.7	0.55	0.62	21.0
					2,053 kg O_2/d
					4516.5 lbs O_2/d
					180.35 scfm

Scenario: Actual Winter Conditions

Blower	HP	Avg P (psi)	Pulley ratio	Motor RPM	Blower RPMs	ACFM
Blower #1	25	8	0.78	1765	1373	400
Blower #2	25	9	0.78	1765	1373	400
Blower #3	50	10.3	0.83	1770	1462	800
Blower #4	50	10.8	0.95	1770	1677	950

Standard Conditions: American Society of Mechanical Engineers (ASME)		
Ps	14.7	Standard Pressure (psi)
RHs	0.36	Standard Relative Humidity
PVs	0.3391	Saturated vapor pressure of water at standard temperature (psi)
Ts	528	Standard Temperature (^{o}R)
Site Conditions		
Pb	14.7	Atmospheric Temperature - Barometer (psi)
Pa	14.6	Actual Pressure (Suction Pressure)
RHa	1	Actual Relative Humidity
PVa	0.339	Saturated vapor pressure of water at actual temperature (psi)
Ta	528	Avg Room Temperature (^{o}R)

Air Flow	ICFM/SCFM	ICFM	SCFM
4 blowers running	1.02	2,550	2,495

Influent CBOD Load (kg/d)	870
CBOD O_2 Requirement (kg O2/kg BOD)	1.5
CBOD O_2 Requirement (kg O2/d)	1305
Lagoon Area (m^2)	39,680
O2 Demand (g O_2/m^2/d)	8
Benthic O_2 Demand (kg O_2/d)	309
Total AOR (kg O_2/d)	1,614

Lagoon Parameters

Parameter	Value	Units
β	0.9	
θ	1.024	
P atmospheric	14.7	psi
P site	14.8	psi
Ω	1.01	
Cs	9.17	mg/L
Csw	8.89	mg/L
T	22	^{o}C
C_o	2	mg/L
SWD	5.36	m

Air flow	2,371	scfm
MARS/ARES flow removed	1,951	scfm

Scenario: Actual Winter Conditions

Cell Number	Chain #	# of chains per cell	Drops Per Chain	Diffusers Per Drop	Total number of diffusers	Diffuser Type
1A	1	6	4	-	-	Mars
	2		4	-	-	Ares
	3		4	-	-	Ares
	4	3	10	2	20	Biolac
	5		10	2	20	Biolac
	6		10	2	20	Biolac
1B	7	3	10	2	20	Biolac
	8		10	2	20	Biolac
	9		10	2	20	Biolac
2A	10	2	9	2	18	Biolac
	11		9	2	18	Biolac
2B	12	1	8	2	16	Biolac
3A	13	1	3	2	6	Biolac
3B	14	1	1	2	2	Biolac

Chain #	Air Flow per Chain	Air flow per drop (scfm)	Air flow per diffuser (kg O_2/hr)	Diffuser SOTE (%)	SOTR per diffuser (kg O_2/d)
1	140	35.0	16.60	28%	111.6
2	140	35.0	16.60	28%	111.6
3	140	35.0	16.60	28%	111.6
4	231	23.1	5.47	19%	24.3
5	231	23.1	5.47	19%	24.3
6	231	23.1	5.47	19%	24.3
7	231	23.1	5.47	19%	24.3
8	231	23.1	5.47	19%	24.3
9	231	23.1	5.47	19%	24.3
10	207	23.1	5.47	19%	24.3
11	207	23.1	5.47	19%	24.3
12	184	23.1	5.47	19%	24.3
13	69	23.1	5.47	19%	24.3
14	23	23.1	5.47	19%	24.3

Chain #	Total SOTR (kg O_2/d)	α	AOR/SOR	AOTR (kg O_2/d)
1	446.2	0.55	0.59	263.7
2	446.2	0.55	0.59	263.7
3	446.2	0.55	0.59	263.7
4	485.5	0.55	0.59	286.9
5	485.5	0.55	0.59	286.9
6	485.5	0.55	0.59	286.9
7	485.5	0.60	0.64	313.0
8	485.5	0.60	0.64	313.0
9	485.5	0.60	0.64	313.0
10	437.0	0.65	0.70	305.2
11	437.0	0.65	0.70	305.2
12	388.4	0.70	0.75	292.2
13	145.7	0.75	0.81	117.4
14	48.6	0.80	0.86	41.7
				3,653 kg O_2/d
				8036.1 lbs O_2/d
				320.89 scfm

15% Reduced SOTE	3,105 kg O_2/d
20% Reduced SOTE	2,922 kg O_2/d

Scenario: Actual Summer Conditions

Blower	HP	Avg P (psi)	Pulley ratio	Motor RPM	Blower RPMs	ACFM
Blower #1	25	8	0.78	1765	1373	400
Blower #2	25	9	0.78	1765	1373	400
Blower #3	50	10.3	0.83	1770	1462	800
Blower #4	50	10.8	0.95	1770	1677	950

Standard Conditions: American Society of Mechanical Engineers (ASME)

Ps	14.7	Standard Pressure (psi)
RHs	0.36	Standard Relative Humidity
PVs	0.3391	Saturated vapor pressure of water at standard temperature (psi)
Ts	528	Standard Temperature (^oR)
Site Conditions		
Pb	14.7	Atmospheric Temperature - Barometer (psi)
Pa	14.6	Actual Pressure (Suction Pressure)
RHa	1	Actual Relative Humidity
PVa	0.616	Saturated vapor pressure of water at actual temperature (psi)
Ta	545	Avg Room Temperature (^oR)

Air Flow	ICFM/SCFM	ICFM	SCFM
4 blowers running	1.08	2,550	2,371

Influent CBOD Load (kg/d)	870
CBOD O_2 Requirement (kg O2/kg BOD)	1.5
CBOD O_2 Requirement (kg O2/d)	1,305
Lagoon Area (m^2)	39,680
O2 Demand (g $O_2/m^2/d$)	8
Benthic O_2 Demand (kg O_2/d)	309
Total AOR (kg O_2/d)	**1,614**

Lagoon Parameters

Parameter	Value	Units
β	0.9	
θ	1.024	
P atmospheric	14.7	psi
P site	14.8	psi
Ω	1.01	
Cs	9.17	mg/L
Csw	8.89	mg/L
T	23	^oC, lagoon temperature
C_o	2	mg/L
SWD	5.36	m

Scenario: Actual Summer Conditions

Air flow	2,371	scfm
MARS/ARES flow removed	1,951	scfm

Cell Number	Chain #	# of chains per cell	Drops Per Chain	Diffusers Per Drop	Total number of diffusers	Diffuser Type
1A	1	6	4	-	-	Mars
	2		4	-	-	Ares
	3		4	-	-	Ares
	4	3	10	2	20	Biolac
	5		10	2	20	Biolac
	6		10	2	20	Biolac
1B	7	3	10	2	20	Biolac
	8		10	2	20	Biolac
	9		10	2	20	Biolac
2A	10	2	9	2	18	Biolac
	11		9	2	18	Biolac
2B	12	1	8	2	16	Biolac
3A	13	1	3	2	6	Biolac
3B	14	1	1	2	2	Biolac

Chain #	Air Flow per Chain	Air flow per drop (scfm)	Air flow per diffuser (scfm)	Air flow per diffuser (kg O_2/hr)	Diffuser SOTE (%)	SOTR per diffuser (kg O_2/d)
1	140	35.0	-	16.60	28%	111.6
2	140	35.0	-	16.60	28%	111.6
3	140	35.0	-	16.60	28%	111.6
4	217	21.7	10.8	5.14	19%	22.8
5	217	21.7	10.8	5.14	19%	22.8
6	217	21.7	10.8	5.14	19%	22.8
7	217	21.7	10.8	5.14	19%	22.8
8	217	21.7	10.8	5.14	19%	22.8
9	217	21.7	10.8	5.14	19%	22.8
10	195	21.7	10.8	5.14	19%	22.8
11	195	21.7	10.8	5.14	19%	22.8
12	173	21.7	10.8	5.14	19%	22.8
13	65	21.7	10.8	5.14	19%	22.8
14	22	21.7	10.8	5.14	19%	22.8

Chain #	Total SOTR (kg O_2/d)	α	AOR/SOR	AOTR (kg O_2/d)
1	446.2	0.55	0.32	144.2
2	446.2	0.55	0.32	144.2
3	446.2	0.55	0.32	144.2
4	456.4	0.55	0.32	147.5
5	456.4	0.55	0.32	147.5
6	456.4	0.55	0.32	147.5
7	456.4	0.58	0.34	155.5
8	456.4	0.58	0.34	155.5
9	456.4	0.58	0.34	155.5
10	410.8	0.61	0.36	147.2
11	410.8	0.61	0.36	147.2
12	365.1	0.64	0.38	137.3
13	136.9	0.67	0.39	53.9
14	45.6	0.70	0.41	18.8
				1,846 kg O_2/d
				4060.7 lbs O_2/d
				162.15 scfm

15% Reduced SOTE	1,569 kg O_2/d
20% Reduced SOTE	1,477 kg O_2/d

Scenario: Maximum Summer Conditions

Blower	HP	Avg P (psi)	Pulley ratio	Motor RPM	Blower RPMs	ACFM
Blower #1	25	8	0.78	1765	1373	400
Blower #2	25	9	0.78	1765	1373	400
Blower #3	50	10.3	0.83	1770	1462	800
Blower #4	50	10.8	0.95	1770	1677	950

Standard Conditions: American Society of Mechanical Engineers (ASME)

Ps	14.7	Standard Pressure (psi)
RHs	0.36	Standard Relative Humidity
PVs	0.3391	Saturated vapor pressure of water at standard temperature (psi)
Ts	528	Standard Temperature (^oR)
Site Conditions		
Pb	14.7	Atmospheric Temperature - Barometer (psi)
Pa	14.6	Actual Pressure (Suction Pressure)
RHa	1	Actual Relative Humidity
PVa	1.7915	Saturated vapor pressure of water at actual temperature (psi)
Ta	589	Avg Room Temperature (^oR)

Air Flow	ICFM/SCFM	ICFM	SCFM
4 blowers running	1.27	2,550	2,010

Influent CBOD Load (kg/d)	870
CBOD O_2 Requirement (kg O2/kg BOD)	1.5
CBOD O_2 Requirement (kg O2/d)	1305
Lagoon Area (m^2)	39,680
O2 Demand (g $O_2/m^2/d$)	8
Benthic O_2 Demand (kg O_2/d)	309
Total AOR (kg O_2/d)	**1,614**

Lagoon Parameters

Parameter	Value	Units
β	0.9	
θ	1.024	
P atmospheric	14.7	psi
P site	14.8	psi
Ω	1.01	
Cs	9.17	mg/L
Csw	8.12	mg/L
T	27	^oC
C_o	2	mg/L
SWD	5.36	m

Scenario: Maximum Summer Conditions

Air flow	2,010	scfm
MARS/ARES flow removed	1,590	scfm

Cell Number	Chain #	# of chains per cell	Drops Per Chain	Diffusers Per Drop	Total number of diffusers	Diffuser Type
1A	1	6	4	-	-	Mars
	2		4	-	-	Ares
	3		4	-	-	Ares
	4	3	10	2	20	Biolac
	5		10	2	20	Biolac
	6		10	2	20	Biolac
1B	7	3	10	2	20	Biolac
	8		10	2	20	Biolac
	9		10	2	20	Biolac
2A	10	2	9	2	18	Biolac
	11		9	2	18	Biolac
2B	12	1	8	2	16	Biolac
3A	13	1	3	2	6	Biolac
3B	14	1	1	2	2	Biolac

Chain #	Air Flow per Chain	Air flow per drop (scfm)	Air flow per diffuser (scfm)	Air flow per diffuser (kg O_2/hr)	Diffuser SOTE (%)	SOTR per diffuser (kg O_2/d)
1	140	35.0	-	16.60	28%	111.6
2	140	35.0	-	16.60	28%	111.6
3	140	35.0	-	16.60	28%	111.6
4	177	17.7	8.8	4.19	19%	18.6
5	177	17.7	8.8	4.19	19%	18.6
6	177	17.7	8.8	4.19	19%	18.6
7	177	17.7	8.8	4.19	19%	18.6
8	177	17.7	8.8	4.19	19%	18.6
9	177	17.7	8.8	4.19	19%	18.6
10	159	17.7	8.8	4.19	19%	18.6
11	159	17.7	8.8	4.19	19%	18.6
12	141	17.7	8.8	4.19	19%	18.6
13	53	17.7	8.8	4.19	19%	18.6
14	18	17.7	8.8	4.19	19%	18.6

Chain #	Total SOTR (kg O_2/d)	α	AOR/SOR	AOTR (kg O_2/d)
1	446.2	0.55	0.29	131.0
2	446.2	0.55	0.29	131.0
3	446.2	0.55	0.29	131.0
4	372.1	0.55	0.29	109.3
5	372.1	0.55	0.29	109.3
6	372.1	0.55	0.29	109.3
7	372.1	0.58	0.31	115.2
8	372.1	0.58	0.31	115.2
9	372.1	0.58	0.31	115.2
10	334.9	0.61	0.33	109.1
11	334.9	0.61	0.33	109.1
12	297.7	0.64	0.34	101.7
13	111.6	0.67	0.36	39.9
14	37.2	0.70	0.37	13.9
				1,440 kg O_2/d
				3168.9 lbs O_2/d
				126.53 scfm

15% Reduced SOTE	1,224 kg O_2/d
20% Reduced SOTE	1,152 kg O_2/d