Memorandum

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To: **Robert Bolton, P.E., City of Vero Beach**
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From: **Jim Hagerty, P.E., Reiss Engineering, Inc.**
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QAQC: **Mark Burgess, P.E., BCEE, Reiss Engineering, Inc.**
Glenn Dunkelberger, P.E., BCEE, Reiss Engineering, Inc.

Date: **November 6, 2018**

RE: **TECHNICAL MEMORANDUM – FINAL**
Nutrient Management Study – Initial Evaluations and Alternatives Identification
REI Job# 129006

This report is intended for review by the City of Vero Beach and other parties as considered necessary by the City of Vero Beach and Reiss Engineering, Inc. This report has been prepared under the supervision of James Hagerty, FL P.E. Lic. 43969.

James Hagerty, P.E.

11/06/2018

Date

INTRODUCTION

The purpose of this memorandum is to summarize the data collection, plant operations review, existing process evaluation, initial process modeling, and the preliminary list of viable alternatives to be evaluated in Phase II for the City of Vero Beach (City) Wastewater Treatment Plant (WWTP) Phase I Nutrient Management Study. Reiss Engineering (REI) reviewed and analyzed historical plant operating and sampling data from the past 5 years (March 1, 2013 – May 31, 2018) and completed the Data Evaluation Memorandum. This Memorandum was submitted to the City on August 29, 2018 and addressed the following: Task 3: Data Collection, Influent Characterization, Historic Plant Data Review, Influent Loading and Biological Unit Process Loads; Task 4: Plant Operations Review; and Task 5: Existing Process Evaluation. No significant data gaps were identified and the preliminary development of the BioWin® Process Model (Model) began. A summary of the Data Evaluation Memorandum is presented in the following section, and the complete Memorandum can be found in **Attachment A**.

Since the submittal of the "Data Evaluation Memorandum", REI has completed the following work:

- Task 6: Process Modeling and Calibration – Includes the development and calibration of a process model to evaluate existing plant performance and effluent quality. The BioWin® process model was used based on having a complete set of data available from the City. The objective of this task was to gain insight on potentially viable nutrient reduction alternatives; and to identify modeling options and data requirements for more enhanced Phase II modeling of the selected alternatives.
- Task 7: Preliminary Process Alternatives – Based upon the data collection and review, site visit, and initial process modeling of the existing plant configuration, REI developed a list of potential process alternatives for achieving greater nutrient reduction. The list of alternatives is based on modifying existing plant operations and repurposing existing tankage (i.e. no new tankage).
- Task 8: Prepare Technical Memorandum and Workshop – A workshop was held on September 14, 2018 to review and discuss the six (6) alternatives developed by REI. A list of three (3) selected alternatives was developed, in collaboration with the City, that will be scoped and budgeted for evaluation in Phase II of the Nutrient Study from a benefit-cost perspective.

DATA EVALUATION MEMORANDUM SUMMARY

Task 3: Data Collection, Influent Characterization, Historic Plant Data Review, Influent Loading and Biological Unit Process Loads

REI reviewed historical plant operating and sampling data for the past 5 years and identified no significant data gaps for the development of a Model and alternatives analysis. The City has maintained excellent records of historical plant flows and loadings that were extremely helpful for this study.

From the review of the data, it was observed that influent flow to the plant is relatively stable throughout the 5-year review period.

Table 1 summarizes the yearly average day flow (ADF) for the data reviewed.

Table 1. Yearly ADF

Dates	ADF (MGD)
March 2013 to February 2014	3.152
March 2014 to February 2015	3.470
March 2015 to February 2016	3.584
March 2016 to February 2017	3.538
March 2017 to February 2018	3.621
March 2018 to May 2018	3.271

A graph was developed to compare influent ADF over the 5-year period to analyze variations in ADF and peaks. Based on the trendline developed from the influent flow graph, represented in **Figure 1** on the next page, annual average flow growth over the past 5 years is roughly 12%.

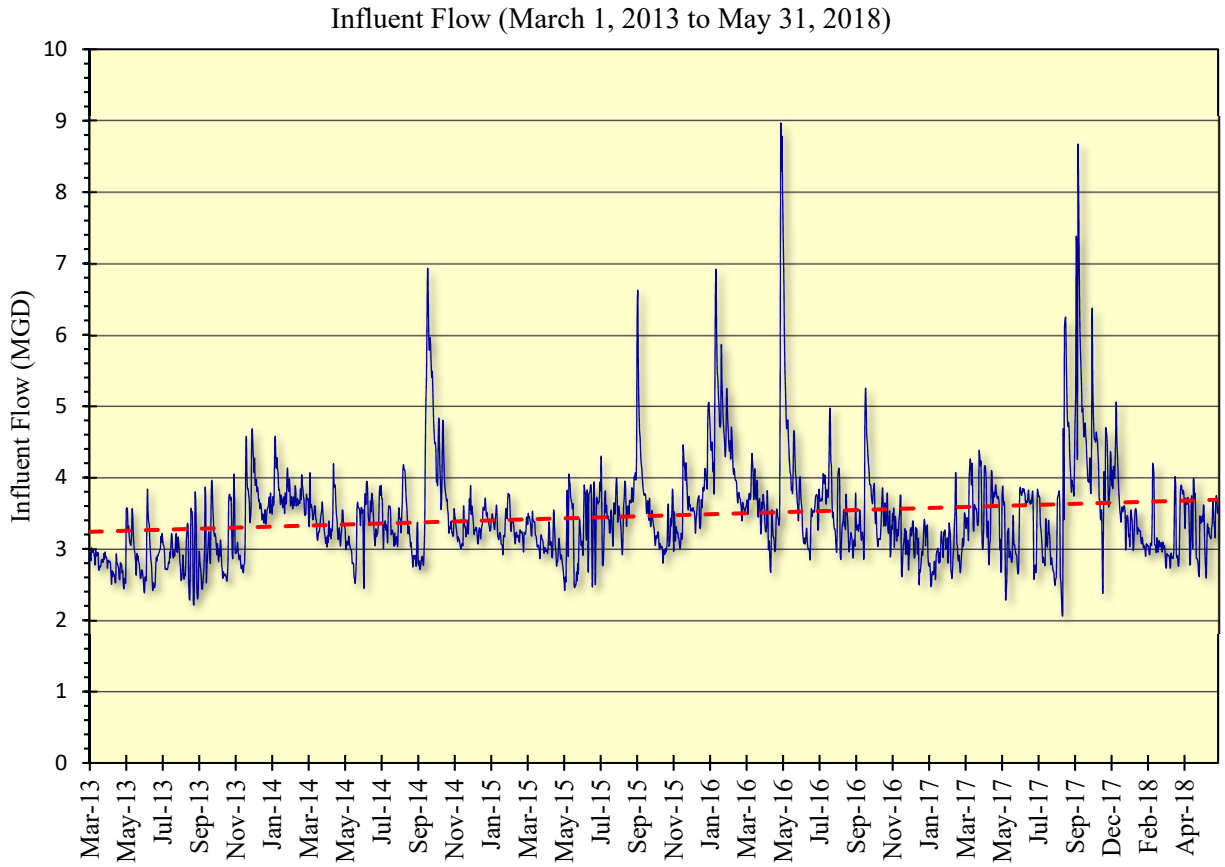

Figure 1. Five-Year Influent Flow

The subtle change in influent flow allowed REI to develop average loadings, influent flow, nutrient balances and effluent quality inputs that were used in the development and calibration of the Model. Average influent and effluent parameters from the data analyzed are presented in **Table 2**.

Table 2. Five-Year Average Wastewater Influent and Effluent Characteristics

Parameter	Influent		Effluent	
	mg/L	lbs.	mg/L	lbs.
cBOD	155	4,385	3	74
TSS	137	3,887	2	64
Total N	33	967	15	410
TKN	33	941	13	-
Nitrites - Nitrates	0	-	2	63
TP	5	134	2	51

Task 4: Plant Operations Review

REI performed a site visit and walk through with plant personnel to discuss operational procedures, operational flexibility, challenges, and constraints. Some major discoveries from this site visit and from other discussions with City staff include:

- Adjusting the air flow rate to the aeration basins based on alkalinity to maintain an operating range of 145 to 165 mg/L as $CaCO_3$.
- The plant has recently increased their aeration mixed liquor suspended solids (MLSS) concentration to 4,000 mg/L. Prior to this operational adjustment, the 5-year average MLSS concentration was about 2,500 mg/L.
- On January 1, 2018, the City commissioned their new CleanB® Chlorine Dioxide WAS treatment system. Since the start-up of this process, the plant has experienced an increase in net solids yield by about 0.30 lbs. per lbs. cBOD treated.

Task 5: Existing Process Evaluation

The major evaluations performed by REI under this task included developing nitrogen and alkalinity balances.

Nitrogen Balance

Results from the nitrogen mass balance indicated that denitrification is occurring in the completely mixed, fine bubble aeration basins. This phenomenon is not typically seen in completely mixed, fine bubble systems due to the wide availability of oxygen. The plant's operational and sampling data indicated that the complete mixed, fine bubble system nitrifies approximately 36 percent of the influent ammonia. Even though the plant is operating at an appropriate SRT to promote complete nitrification and experiencing higher wastewater temperatures (24 to 30 degrees Celsius), the system is not performing as expected. Typical nitrite/nitrate effluent concentrations range between 0.5 and 3.0 mg/L, even though there is no denitrification treatment process (i.e. anoxic zone), internal recycle, or any other process to promote denitrification. **Table 3** below presents the results from the nitrogen balance.

Table 3. Five-Year Average Plant Nitrogen Mass Balance Results

Parameter	Concentration (mg/L)
Nitrogen Removed	18
Nitrogen in WAS (Synthesis)	8
TKN Oxidized (Nitrification)	12
Nitrite/Nitrates Removed (Denitrification)	10

Alkalinity Balance

To further analyze the reasoning for the denitrification occurring in the aeration basins, REI evaluated alkalinity and its effects on the nitrification/denitrification process. Alkalinity plays a key role in the biological treatment process, as it provides a buffer for any sudden change in pH. A sufficient amount of alkalinity helps maintain a stable environment for microorganisms to grow and consume organics in the wastewater. Providing the microorganisms with a stable environment helps improve treatment performance and expands treatment capacity.

To nitrify, theoretical reaction values show that approximately 7.14 mg of alkalinity (as $CaCO_3$) is consumed for every mg of ammonia oxidized. In other words, for every mg/L of converted ammonia, alkalinity decreases by 7.14 mg/L. However, the process of denitrification allows for the ability to regain alkalinity through the removal of nitrates. During denitrification, 3.57 mg of Alkalinity is regained per mg of NO_3 reduced. **Table 4** presents the results of the alkalinity balance, which assumed nitrification of 13 mg/L of ammonia and denitrification of 10 mg/L of nitrates.

Table 4. Five-Year High and Low Average Alkalinity Balance Results

Parameter	Low Range	High Range
Influent Alkalinity	190 mg/L	232 mg/L
Nitrification Consumption (-)	86 mg/L Alkalinity Consumed for 12 mg/L Ammonia Oxidized	
Post-Nitrification Alkalinity	104 mg/L	146 mg/L
Denitrification Regain (+)	36 mg/L Alkalinity Regained for 10 mg/L Nitrate Reduced	
Final Alkalinity After Regain	140 mg/L	182 mg/L

The alkalinity balance presented above is simplified and does not consider the complexity of the reactions in the aeration basins or daily variation in influent and effluent nitrogen concentrations. It is provided to demonstrate that it would be difficult for the plant to be operating within their targeted alkalinity range of 145 to 165 mg/L on a consistent basis without alkalinity regain through denitrification. If no denitrification was occurring in the aeration basins, the predicted alkalinity would be within a 100 to 150 mg/L as $CaCO_3$ range.

TASK 6: INITIAL PROCESS MODELING AND CALIBRATION

REI is scoped to develop and calibrate a process model of the existing plant's biological process configuration to improve nutrient reduction. The process model development will identify modeling options and data requirements for Phase II modeling of the alternatives selected as part of Task 7, Preliminary Process Analysis, which is described later in this memorandum.

REI selected to develop a BioWin® model in lieu of the spreadsheet model due to the extensive plant operating data compiled by the City. The data evaluated was used to develop and calibrate the BioWin® Model outputs to match existing treatment and operational parameters.

Methodology

To determine the performance of the existing biological treatment process and to gain insight on potentially viable nutrient reduction alternatives, a model of the treatment process was employed. A computer based mathematical model of the activated sludge process was developed using BioWin® by EnviroSim, Inc.

Model Configuration

The model was built based on the equipment and unit process data given in the "*Vero Beach Wastewater Treatment Plant Capacity Upgrade and Future Biological Nutrient Removal Plan*" Basis of Design Report written by Hazen & Sawyer in April 2004. The model configuration is shown in **Figure 2** and component properties of the model are described in the following sections.

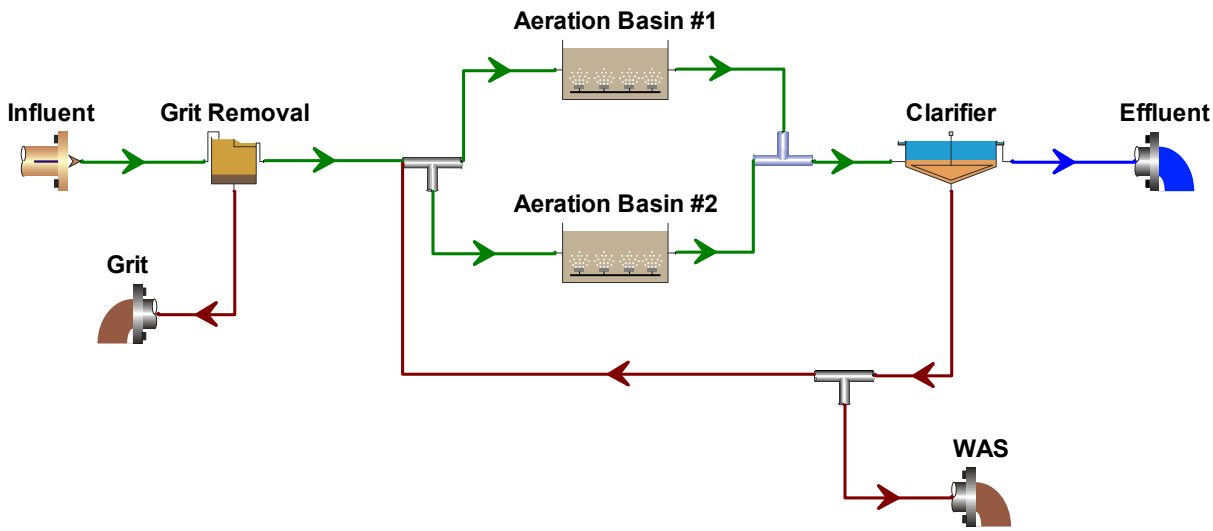

Figure 2. BioWin® Model Process Schematic

The BOD Influent Element (Influent) is used to control the wastewater flow/composition. The BOD Influent Element differs from the COD Influent Element in that its organic strength is specified in terms of BOD concentration, rather than COD concentration. BOD Influent Element characteristics put into the model are shown in **Table 5**.

Table 5. Wastewater Influent Characteristics

Element Name	Value
Flow (MGD)	3.4
Total Carbonaceous BOD (mgBOD/L)	155.0
Volatile Suspended Solids (mg/L)*	110.0*
Total Suspended Solids (mg/L)	137.0
Total Kjeldahl Nitrogen (mgN/L)	33.0
Total Phosphorus (mgP/L)	5.0
Nitrate N (mgN/L)	0.0
pH	7.30
Alkalinity (mg/L as $CaCO_3$)	205.0

**Volatile suspended solids concentration was assumed to be 80 percent of influent total suspended solids.*

The grit removal tank element was used to simulate the removal of sand and other inert solids in the influent wastewater. For this process model, it was assumed that the grit removal system at the Vero Beach WWTP removes 60% of inert solids. Grit removal percentage was assumed based on the MLSS concentration in the aeration basins.

The bioreactor element simulates the activated sludge process in a continuous stirred tank reactor (CSTR) with diffused air as its aeration method. Two (2) bioreactors, each with 0.405 MG of volume and a depth of 15 feet were used in the Model. A critical factor in the activated sludge process operation is the MLSS concentration. A value of 2,400 to 3,100 mg/L was targeted for this Model which is consistent with the plant's typical operating range. For dissolved oxygen setpoints, a value of 1.0 mg/L was used for the aeration zone to inhibit the amount of nitrification occurring within the basin.

The Ideal (secondary) clarifier element was used to model settlement of particulate material in a wastewater stream containing activated sludge mixed liquor based on an idealized solids separation model. For this Model, one (1) clarifier was used with a surface area equal to the total surface area of the two (2) existing clarifiers. The purpose of using one (1) clarifier was to provide reasonable Return Activated Sludge (RAS) and Waste Activated Sludge (WAS) conditions that could easily be modified by adjusting the clarifier's underflow rate. This clarifier was not intended to predict sludge settleability or actual clarifier performance, which can be very difficult to model. A surface area of 14,176 sq. feet and a depth of 12 feet were used in the Model element. The underflow of the clarifier was set at 1.15 MGD, which is the determining factor in setting the RAS (1.10 MGD) and WAS (0.05 MGD) flow rates. Clarifier removal efficiency was increased from 99.8 to 99.94 percent to accurately represent the effluent TSS concentration leaving the plant. The increased removal percentage simulates the additional removal of solids that would come from the sand filters downstream of the secondary clarifiers.

The RAS flow originates from the underflow of the clarifier and discharges to the beginning of the biological process into the wet well, where the RAS is blended with the degritted influent wastewater. The RAS flow rate was maintained at 1.10 MGD in the Model, which provided a RAS ratio comparable to the historical rates used by the plant.

WAS is also taken from the clarifier underflow and was maintained at the average WAS flow the plant typically operates at. Due to the variability in the plant's historical WAS flows and the steady-state nature of this Model, it is difficult to accurately match the plant's typical WAS solids concentrations with what the Model predicts. The WAS flow rate was maintained at 0.05 MGD, which provided a reasonable solids production and solids concentration of the wasted sludge stream.

Initial Model Calibration

Before process alternatives could be evaluated, historical data was utilized to calibrate the model. Influent wastewater fractions, kinetic parameters, and stoichiometric parameters were adjusted until the simulation output was within an acceptable range of the actual plant performance. Results from the Model simulation that were cross-checked with actual plant data include: effluent quality, aeration basin characteristics, and WAS characteristics.

The influent wastewater fractions define the composition of the influent wastewater and have a direct effect on the entire treatment process. Default and adjusted influent wastewater fractions used in this Model are shown in **Table 6**. In this table, F_{up} is the fraction of total influent COD which is particulate unbiodegradable, F_{nus} is the fraction of influent TKN which is soluble unbiodegradable, and F_{na} is the fraction of influent TKN which is ammonia. F_{na} was the only value that could be calculated directly from the data provided. Additional sampling would be required to confirm that the adjusted values are within actual influent composition.

Table 6. Default and Adjusted Influent Wastewater Fractions

Parameter	Default Value	Adjusted Value	Influent Fraction
F_{up}	0.1300	0.3000	Particulate Unbiodegradable COD
F_{nus}	0.0200	0.0350	Soluble Unbiodegradable TKN
F_{na}	0.6600	0.6700	Ammonia Fraction of TKN

The kinetic parameters include biological growth rates, half-saturation rates, and decay rates. The major kinetic parameters adjusted in the Model included Ammonia Oxidizing Biomass (AOB), Nitrite-Oxidizing Biomass (NOB), and Ordinary Heterotrophic Organisms (OHO). These three types of microorganisms control the amount of cBOD, ammonia oxidized, and nitrogen removed during the activated sludge process. Each type of microorganism is described below.

Ammonia Oxidizing Biomass (AOB)

This autotrophic biomass grows by oxidizing ammonia to nitrite or possibly nitrous oxide and using the energy to synthesize organic material from inorganic carbon (fixing CO_2). Nitrogen source for cell synthesis is ammonia. To account for the concentration of ammonia in the plant effluent, the maximum specific growth rate for AOBs was lowered from the default value of 0.90 $days^{-1}$ to 0.543 $days^{-1}$. By lowering the growth rate of such biomass, the model inhibits the conversion of ammonia to nitrite (nitrification). Aeration basin DO levels below 2.0 mg/L will have an impact on AOB growth rate and nitrification rates.

Nitrite Oxidizing Biomass (NOB)

This autotrophic biomass grows by oxidizing nitrite to nitrate and using the energy to synthesize organic material from inorganic carbon (fixing CO_2). Nitrogen source of cell synthesis is ammonia. NOB is found in most aerated systems, but their growth rate and utilization is limited due to the presence of oxygen. To represent the ratio of nitrate to nitrite in the plant's effluent, the maximum specific growth rate of NOBs was decreased from its default value of 0.70 $days^{-1}$ to 0.67 $days^{-1}$. This decreased growth rate allows for less conversion of nitrite to nitrate to occur. This adjustment was made to account for removal of total nitrogen in the aeration basin. However, the most probable reason for the denitrification is due to incomplete mixing and/or low DO zones in the aeration basins.

Ordinary Heterotrophic Organisms (OHO)

This heterotrophic biomass utilizes oxygen to uptake and remove organics from the wastewater stream. OHOs primary purpose is to remove cBOD from the wastewater. To account for the high percent removal of cBOD at the plant, the maximum specific growth rate of OHOs was increased from its default value of 3.2 $days^{-1}$ to 3.5 $days^{-1}$. Increasing the growth rate allows for more OHO biomass to grow in the reactor and to effectively remove more cBOD. Facultative OHO is also responsible for denitrification and the conversion of nitrates to nitrogen gas.

Stoichiometric parameters describe the yield rates for various microorganisms. The biomass volatile fraction is the volatile fraction of active biomass and was determined from the aeration basin MLVSS/MLSS concentration ratio. X_s COD:VSS Ratio is the conversion factor between particulate substrate measured as COD and its VSS content. X_i COD:VSS Ratio is the conversion factor between particulate inert material measured as COD and its VSS content. Both the X_s and X_i values were increased to reduce the TN in the effluent. OHO yield is the amount of biomass COD produced using one unit of readily biodegradable complex substrate COD, the remaining COD is oxidized. OHO yield was increased to account for the cBOD removal efficiency and to increase the amount of ammonia oxidized. The adjusted stoichiometric parameters are shown in **Table 7**.

Table 7. Default and Adjusted Stoichiometric Parameters

Parameter	Default Value	Adjusted Value
Biomass Volatile Fraction (VSS/TSS)	0.92	0.80
X_s (mgCOD/mgVSS)	1.6	1.7
X_i (mgCOD/mgVSS)	1.6	1.7
OHO Yield (aerobic)	0.666	0.720

Model Results

Model results were evaluated during calibration to ensure that the model was closely able to predict characteristics that the plant is currently operating at. Modeling results for effluent quality, aeration basin, and WAS characteristics are shown in **Table 8, Table 9**, and **Table 10**, respectively. To compare the model results with existing plant effluent quality, high and low ranges were established for each parameter. The high range represent values that are at or below the value 90 percent of the time (90th percentile). The low range represents values that are at or below the value 20 percent of the time (20th percentile).

Table 8. Five-Year Average Effluent Quality and Model Results

Parameter	5-Year Average Effluent Quality			Model Results
	Low Range	High Range	Average	
Total N (mg/L)	11	22	15	15.6
TKN (mg/L)	8	20	13	13.0
Nitrite/Nitrate (mg/L)	<1	5	2	2.6
Nitrite (mg/L)	<1	1	0.7	0.7
Ammonia N (mg/L)	6	16	10	10.6
cBOD (mg/L)	2	4	3	3.4
TSS (mg/L)	1	4	2	2.4
TP (mg/L)	1	4	2	1.7

Table 9. Aeration Basin and RAS Model Results

Parameter	5-Year Average Effluent Quality			Model Results
	Low Range	High Range	Average	
MLSS (mg/L)	2,000	3,100	2,400	2,900
MLVSS (mg/L)	1,600	2,300	1,900	2,500
Alkalinity (mg/L as $CaCO_3$)	145	165	155	149
RAS Flow (MGD)	0.85	1.25	1.05	1.10

Table 10. WAS Model Results

Parameter	5-Year Average Effluent Quality			Model Results
	Low Range	High Range	Average	
WAS Flow (MGD)	0.04	0.08	0.05	0.05
Solids Production (lbs.)	2,600	6,100	4,100	4,800

The solids retention time (SRT) for the existing plant is over 4.2 days, 70 percent of the time over the last 5 years, with an average SRT of about 5.2 days. The predicted model SRT was 5.35 days.

TASK 7: PRELIMINARY PROCESS ALTERNATIVES

On September 14, 2018 the City and REI collaborated in a workshop meeting to select the three process alternatives that are to be further evaluated in Phase II. Process alternatives were developed based on using existing aeration basins and the two existing sludge storage tanks that have become available since the City began stabilizing the waste solids using the CleanB® Chlorine Dioxide WAS treatment system and centrifugal dewatering unit. The two existing sludge tanks are designated as Sludge Tank No. 1 (existing aerobic digestor) and Sludge Tank No. 2 (existing sludge storage tank). Approximate tank volumes for the existing sludge storage tanks are as follows:

- Sludge Tank No. 1 = 0.50 MG
- Sludge Tank No. 2 = 0.65 MG

Alternatives were evaluated to provide the City options that could increase nutrient removal without additional tankage and were based on the following criteria:

- Potential reduction of total nitrogen
- Potential reduction of total phosphorus
- Demonstrated performance
- Capability to be retrofitted under existing tankage conditions
- Operational complexity
- Impact on other unit processes
- Potential for phased implementation
- Potential capital and operating costs

REI presented 6 alternatives to the City at the workshop and the options that were identified include:

1. Alternative One: Two-stage anoxic/aeration basin process utilizing additional volume from Sludge Tank No. 1
2. Alternative Two: Two-stage anoxic/aeration basin process utilizing additional volume from Sludge Tank No. 1 and No. 2.
3. Alternative Three: Four-stage nutrient treatment process utilizing additional volume from Sludge Tank No. 1 and No. 2.
4. Alternative Four: Two-stage anoxic/aeration basin process and replacing a portion of the DynaSand® filters with deep bed denitrification filters, utilizing Sludge Tank No. 1 for additional treatment volume.
5. Alternative Five: Multi-stage anoxic/aeration basin process membrane bioreactor system utilizing additional volume from Sludge Tank No. 1.
6. Alternative Six: Multi-stage anoxic/aeration basin process using a) integrated fixed film activated sludge (IFAS), or b) Aerobic Granular Sludge biological treatment technology utilizing Sludge Tank No. 1 for additional treatment volume.

Conceptual layouts and descriptions of each alternative were developed and can be found in **Attachment B**.

Selected Process Alternatives

The City and REI selected alternatives three, five, and six for further evaluation in Phase II. Alternative three involves adding a first anoxic basin to the process configuration. The Phase II analysis will be developed to determine the total nitrogen removal capacity of the first anoxic process and the additional total nitrogen removal achieved by adding on a second anoxic basin. Alternative 5 involves installation of a membrane bioreactor (MBR) process utilizing Sludge Tank No. 1, converting the clarifiers to equalization basins and modification of the headworks to incorporate fine screens. This alternative will provide a higher level of treatment at a significantly higher cost, but the City desires to analyze this alternative for comparison with a more advanced treatment process being evaluated as part of the City's Master Plan Update. Alternative six is to be evaluated for IFAS technology and is an independent process alternative.

Alternative Three: Four-Stage Anoxic, Aeration, Second Anoxic, Reaeration

This alternative proposes to modify and expand the existing aeration basins to a four-stage anoxic/aeration/anoxic/reaeration basin process. The new four stage system will require additional treatment volume and will be provided by re-purposing Sludge Tank No. 1 (existing aerobic digester) and Sludge Tank No. 2 (existing sludge storage tank). Sludge Tank No. 1 has a volume of approximately 0.5 MG and is directly connected to the west of the existing aeration basins. Sludge Tank No. 1 would be converted to an aeration basin, with part of the existing aeration basin being modified to an anoxic zone. The existing Sludge Tank No. 2 would be modified to a second anoxic/reaeration basin. Re-pumping of the existing aeration basin contents would be required, which will add additional pumps and operational costs. Sludge Tank No. 2 has an approximate volume of 0.65 MG.

Preliminary process modifications and tank volumes are listed below:

- Anoxic Basin No. 1 = 0.3 MG
- Aeration Basin No. 1 = 1.3 MG
- Internal Recycle Pumps = 3Q (13.5 MGD)
- Anoxic Basin No. 2 = 0.5 MG
- Reaeration Basin = 0.15 MG
- Anoxic Basin No. 2 Pump System = 5.5 MGD

Additional modifications would need to be evaluated including: changing the influent and effluent weirs on the aeration basins to introduce flow at a single point to the head of the basins and evaluating alternate operating scenarios such as step feed and/or sequenced aeration.

Alternative Five: Membrane Bioreactor System Utilizing Sludge Tank No. 1

Modify and expand the existing aeration basins system to a Multi-Stage Anoxic/Aeration Basin Process, adding membranes and sequencing operations of the aeration basins to achieve nutrient removal. The new multi-stage system will require additional treatment volume and will be provided by re-purposing Sludge Tank No. 1, which has a volume of approximately 0.5 MG and is directly connected to the west of the existing aeration basins. The clarifiers would be modified to operate as equalization basins, as the membrane bioreactor system eliminates the need for secondary clarification. The headworks screening system would need to be modified to provide fine screening of the raw wastewater for the membrane system to operate as designed.

Additional modifications that would need to be evaluated include changing the influent and effluent points to introduce flow at a single point at the head of the basins and evaluating alternate operating scenarios such as step feed and/or sequenced aeration. Some benefits of this more costly and advanced treatment system include:

- Full Nitrification of the Influent Ammonia
- Elimination of Secondary Clarifiers
- Potential to reduce TN to less than 5 mg/L at design capacity of 4.5 MGD
- TP reduction by BioP may be an option

Alternative Six: Integrated Fixed Film Activated Sludge

IFAS systems add fixed or free-floating media to an activated sludge process basin to encourage the growth of biomass and to enhance the treatment process. IFAS systems are currently being implemented at an increasing number of wastewater treatment facilities to expand the capacity of the activated sludge system while utilizing the existing tank volume. IFAS media is typically plastic or fabric and the amount of biomass that grows on the media surface depends on a host of factors, including: loading, dissolved oxygen concentration, temperature, mixing energy, suspended phase biomass concentration, and solids retention time. The attached biomass combined with the suspended biomass concentration allows for a much greater biomass population within the same reactor volume. A major benefit of IFAS systems is the increased MLSS without higher clarifier solids loading. Since some of the biomass grows and "lives" on the surface area of the media within the aeration basins, it does not make its way to the clarifiers.

The IFAS process will require additional volume and will be provided by re-purposing Sludge Tank No. 1, which has a volume of approximately 0.5 MG and is directly connected to the west of the existing aeration basins. Sludge Tank No. 1 would be converted to a second anoxic/reaeration basin, following the aerobic zone where the fixed film media will be stored.

Additional modifications that will need to be considered for an IFAS system include:

- Adequate mixing must be provided to ensure that the free-floating media remains uniformly distributed. The mixing energy provided is critical for sloughing of biomass and the creation of a thin biofilm.
- Increased DO concentrations, typically between 3.0 to 4.0 mg/L, are required in the suspended phase to ensure that the biofilm is completely aerobic.
- Effluent screens will have to be installed to contain the free-floating media within the reactors.
- Foam accumulation is a common issue with IFAS systems. Foam removal techniques should be considered for this alternative.

NEXT STEPS

This memorandum completes the scope of services authorized in Work Order No. 1 related to:

- Identifying influent loading characteristics
- Identifying existing operational flexibility and constraints
- Development of process modeling approaches
- Determination of data requirements, level of effort, and equipment needed to bridge the data gaps
- Performing a preliminary assessment of potential alternatives and operational changes that could reduce the total nutrients in the plant's effluent

The final work related to Work Order No. 1 is to receive comments and provide revisions to the draft memorandum; and to provide the City with a proposal for Work Order No. 2 that will include:

- Additional sampling data collection and recommended testing for modeling the nutrient removal alternatives selected for further analysis.
- Development of a BioWin® Model and/or recommendations from process equipment vendors for specialty IFAS and membrane bioreactor treatment systems.
- Evaluation of the alternatives including preliminary capital and operating costs, operational requirements, and process control strategies.
- Development of a phased implementation of the alternatives with preliminary costs.
- Workshop with the City to review the modeling work, alternatives, and implementation requirements.
- Development of the process analysis memorandum, memorandum review meeting, and submittal of a final memorandum.

Attachment A
Data Evaluation Memorandum

Memorandum

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Date: **August 3, 2018**

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James Hagerty, P.E.

8/29/2018

Date

INTRODUCTION

The purpose of this memorandum is to present the findings from Reiss Engineering, Inc.'s (REI) initial work related to Task 3: Data Collection, Influent Characterization, Historic Plant Data Review, Influent Loading and Biological Unit Process Loads, Task 4: Plant Operations Review, and Task 5: Existing Process Evaluation for the City of Vero Beach (City) Wastewater Treatment Plant (WWTP) Phase I Nutrient Management Study. REI reviewed and analyzed historical plant operating and sampling data from the past 5 years (March 1, 2013 – May 31, 2018) to determine if any data gaps were found that would hinder development of a process model.

City of Vero Beach WWTP

The City of Vero Beach WWTP is a secondary treatment plant permitted to treat 4.5 million gallons per day (MGD) annual average day flow and 5.44 MGD three-month average day flow. The treatment process includes influent screening, grit removal, biological nutrient removal, clarification, up flow sand filters, and chlorine disinfection. Treated effluent is beneficially reused in the City's public access reuse (PAR) system, and during periods when plant flow is greater than the reuse demand, excess effluent is disposed via a 9.72 MGD deep injection well.

Secondary Treatment System

Prior to the raw sewage entering the secondary treatment system, the wastewater influent is screened at the headworks. The headworks includes an aerated grit channel for removal of inorganic material, however the aeration system was taken out of service due to odor issues and equipment hydrogen sulfide corrosion. Grit is still collected and removed in the system without the assistance of air scouring.

The secondary biological treatment process is designed to remove carbonaceous biochemical oxygen demand (cBOD) and the secondary clarification process removes total suspended solids (TSS). In order to dispose of the secondary effluent to the deep injection well, the secondary treatment process must meet 20 mg/L cBOD and TSS.

High Level Clarification and Disinfection System

Beneficial use in the City's PAR water distribution system requires a higher level of treatment to protect public health. All reclaimed water is treated to high level clarification and disinfection standards via up flow sand filters and chlorination. The clarification system has consistently met required high-level clarification requirements of 5 mg/L TSS prior to chlorination.

TASK 3: DATA COLLECTION, INFLUENT CHARACTERIZATION, HISTORIC PLANT DATA REVIEW, INFLUENT LOADING AND BIOLOGICAL UNIT PROCESS LOADS

For Task 3 of the Study, REI reviewed historical plant operating and sampling data for the past 5 years and identified if additional data is needed to complete the process modeling and alternatives analysis. The City has maintained excellent records on historical plant flows and loadings that were very helpful for this Study.

Data Received from City of Vero Beach

Data received from the City included influent and effluent permit compliance data, nutrient loadings, alkalinity, pH, influent wastewater temperature, effluent quality data, sludge generation and plant operational data.

Process Control Reports from March 1, 2013 to May 31, 2018 were the primary source of data evaluation for the nutrient study. Data gaps found in the initial reports were identified and addressed by the City via providing data to fill the gaps. This Final Report's data analyses and findings have been updated based on a complete data set.

Process Flow Diagram

The Vero Beach WWTP's process flow diagram was updated during the project's kick-off meeting on June 26, 2018. Several items were adjusted on the process flow diagram and are listed below:

- The dechlorination process, after the Chlorine Contact Basins, was removed.
- The Wet Weather Discharge from the Chlorine Contact Basins was removed.
- Following the WAS Pumps, a new sludge treatment and disposal system was added. The CleanB® Chlorine Dioxide WAS treatment system, by BCR Environmental Corporation, was added. The new Sludge Treatment Facility disposes of residual biosolids to the landfill and returns collected centrate to the headworks.
- A centrate line from the rotary drum thickener to the headworks was added.

Once the updates were made, the City provided REI with the updated process flow diagram. Along with the process flow diagram, the City provided REI with updated AutoCAD drawings for the sampling and metering locations and the current hydraulic profile. All AutoCAD drawings provided from the City can be found in **Appendix A**.

Influent Characterization

Influent data from the City was reviewed and analyzed to develop distribution curves for influent wastewater parameters. Distribution curves were developed based on the plant's latest 5 years' worth of data from March 1, 2013 to May 31, 2018. The influent wastewater quality parameters that were reviewed are listed below, and their distribution graphs presented in **Appendix B**.

- Flow
- cBOD
- TSS
- Alkalinity
- pH (ranges were well within limits, no distribution curves were developed)
- Nitrogen (as TKN, NO_2, NO_3, and NH_3)
- Total Phosphorus (TP)
- Daily atmospheric maximum and minimum temperature
- Daily wastewater influent temperature

Influent Characterization Analysis

From the data collected, distribution graphs were constructed to determine concentrations and loadings the plant should expect to receive with a level of confidence of 85, 90 and 95 percent. From these graphs, the 85, 90, and 95 percentile concentrations and mass loadings are identified in **Table 1**.

Table 1. Influent Characterization

Percentile	cBOD	cBOD	TSS	TSS	TKN*	TKN*	TP	TP
	mg/L	lbs.	mg/L	lbs.	mg/L	lbs.	mg/L	lbs.
85%	204	5,886	172	4,897	43.3	1,134	7.0	188
90%	226	6,267	184	5,177	44.9	1,204	7.7	198
95%	248	6,814	198	5,556	48.7	1,293	8.2	209

*Average influent Organic-N to NH_3 ratio is 0.71. Influent nitrite and nitrate is negligible and the data is not shown on the table above.

Effluent Characteristics and Removal Efficiency

The biological process evaluation focused on removal efficiencies and process loadings for cBOD, TSS, TKN, Total N and TP. Average concentration and loadings were used to determine percent removal for each parameter based on the 5 years of data provided by the City. The results can be seen in **Table 2**. Distribution curves were also developed for effluent data and can be seen in **Appendix C**.

Table 2. Five Year Average Process Operating Efficiency

Parameter	Influent		Effluent		Percent Removal
	mg/L	lbs.	mg/L	lbs.	
cBOD	155	4,385	3	74	98%
TSS	137	3,887	2	64	99%
Total N	33	967	15	410	55%
TKN	33	941	13	-	61%
Nitrites - Nitrates	0	-	2	63	N/A
TP	5	134	2	51	60%

TASK 4: PLANT OPERATIONS REVIEW

During the project kick-off meeting on June 26, 2018, REI performed a site walk through the facility to review and discuss process operational procedures, operational flexibility, and plant challenges and constraints with operations personnel.

The City provided REI with a copy of the "*Vero Beach Wastewater Treatment Plant Capacity Upgrade and Future Biological Nutrient Removal Plan*" Basis of Design Report written by Hazen & Sawyer in April 2004. A summary of the existing unit process sizes is shown below in **Table 3**. Equipment and specifications for all unit processes, as described in the Hazen & Sawyer Report, are shown in **Appendix D**.

Table 3. Unit Processes and Specifications

Unit Process	Number	Specification
Wet Well	1	Volume = 4,800 gallons
Screens	2	Channel Width = 2.6 feet Bar Spacing = 1/8-inch
Aeration Basins	2	Volume= 405,000 gallons (each) Side Water Depth = 15 feet
Blowers	4	Capacity = 2,200 scfm (each)
Clarifiers	2	Diameter = 95 feet Side Water Depth = 12 feet
Sand Filters	10 Filter Cells, 4 Modules per Cell	Module Surface Area = 50 square feet Filter Media Depth = 3.33 feet
Chlorine Contact Basins	2	Volume = 123,000 gallons (each)

Biological Treatment System

Biological Treatment is achieved at the Vero Beach WWTP by a conventional activated sludge process. This method of treatment involves two components: the aeration tanks, which are used for biological degradation, and a secondary clarifier. Return Activated Sludge (RAS) is returned to the aeration basins from the secondary clarifiers to provide sufficient biomass for degradation of organics.

There are currently two existing aeration basins at the Vero Beach WWTP, each with a volume of 405,000 gallons and a side water depth of 15 feet. Process air is supplied to the basins via four (4) centrifugal blowers, each with a capacity of 2,200 standard cubic feet per minute (scfm). The plant operates with two (2) blowers in service and two (2) on standby, with room for a fifth.

Ceramic dome, fine bubble diffusers are used in the aeration basins to achieve oxygen transfer. The air flow rate to the diffusers is adjusted by plant operating staff based on alkalinity to maintain an operating range between 145 to 165 mg/L alkalinity, as $CaCO_3$. Influent flow is split between the two basins via a 2'-10" wide channel which tapers down to a width of 1'- 8". This tapered flow channel allows for flow to be evenly distributed between the three gates that allow influent to enter into the aeration basins. Flow is discharged from the aeration basins via three gates at the opposite end of the basin where the mixed liquor spills into a channel and is carried to the secondary clarifiers.

Key Biological Parameters

REI conducted a spreadsheet evaluation to review key operating parameters and to develop nitrogen and phosphorus mass balances, based on the operating data provided by the City. The purpose of this analysis was to provide process parameters that can be used for configuration and calibration of a process model that will be used in Phase II of the Nutrient Study. The key parameters that were developed based on review of the plant operations data are discussed in the following sections**.**

SRT

The solids retention time (SRT) for current operation is over 4.2 days, 70 percent of the time over the last 5 years, with an average SRT of 5.2 days. SRT values over 25 days were neglected as REI assumed these values are extreme outliers. When calculating SRT values, REI assumed no solids storage in the clarifiers.

MLSS/MLVSS Operating Ranges

Mixed Liquor Suspended Solids (MLSS) and Mixed Liquor Volatile Suspended Solids (MLVSS) data was relatively consistent based on the data provided by the City. Over the past several months, the City indicated they have increased their aeration MLSS operating concentration to 4,000 mg/L. Historic MLSS and MLVSS operating ranges for aeration basins #1 and #2 are presented below in **Table 4**.

Table 4. MLSS and MLVSS Operating Ranges

Parameter	Aeration Basin #1			Aeration Basin #2		
	Maximum	Minimum	Average	Maximum	Minimum	Average
MLSS (mg/L)	5,401	1,171	2,468	5,257	1,254	2,449
MLVSS (mg/L)	4,618	911	1,983	4,245	952	1,972

Net Solids Yield

Net Solids yield is defined as the mass of sludge produced per mass of cBOD removed; this parameter is important in understanding how the WWTP is operating and if it is efficiently converting substrate (cBOD) into biomass. Net yields were calculated based on the weekly cBOD influent strength, influent flow, and WAS wasted on the day of the cBOD sample and adjusted based on the change of mass in the aeration basins on the following day. For example, if 1,000 lbs. of solids are wasted and the mass in the aeration basins increases in the proceeding 24 hours by 200 lbs., the net yield is calculated by adding (1,000 lbs. + 200 lbs. = 1,200 lbs.) and dividing this number by the total cBOD lbs. treated.

Net solids yield at this plant has been at or above a value of 0.54 lbs. per lbs. cBOD treated 70 percent of the time over the last 5 years, with an average value of 0.80 lbs. per lbs. cBOD treated. This is lower than values referenced in literature for the operating SRT range. Literature values estimate new yield, without primary clarifiers, in the range of 0.80 to 1.0 lbs. per lbs. cBOD at wastewater temperatures between 20 and 30 degrees Celsius (68 and 86 degrees Fahrenheit), which is within range of the influent wastewater temperature at the Vero Beach WWTP. Typical high and low values for net solids yield seen at the plant are 1.45 lbs. per lbs. cBOD treated and 0.22 lbs. per lbs. cBOD treated, respectfully.

On January 1, 2018, the City commissioned their new CleanB® Chlorine Dioxide WAS treatment system. Prior to this date, the City was holding their WAS in storage tanks for several days to promote endogenous respiration and additional volatile solids reduction. This operational strategy can achieve significant solids reduction (up to an additional 30 percent), which may account for the lower net yield rates found from review of the plant operating data.

REI compared the net solids yield before and after the start-up of the CleanB® Chlorine Dioxide WAS treatment system and discovered an increase in net solids yield by about 0.30 lbs. per lbs. cBOD treated since January 1st. From March 1, 2013 to December 31, 2017, the average net solids yield was 0.80 lbs. per lbs. cBOD treated; this increased to 1.11 lbs. per lbs. cBOD treated from January 1, 2018 to May 31, 2018.

Nitrogen Mass Balance

A nitrogen mass balance was estimated based on the plant operating data provided to REI. The purpose of developing the nitrogen mass balance was to estimate the conversion and removal of influent nitrogen based on current plant operations. The nitrogen mass balance uses the plant data to estimate the following nitrogen states:

- Total nitrogen and its states in the influent raw wastewater
- TKN oxidized in the biological process to nitrites and nitrates (nitrification)
- Total nitrites and nitrates converted to nitrogen gas (denitrification)
- Total nitrogen removed in the WAS (biological synthesis)
- Total nitrogen in the plant effluent and its states

Table 5 shows the influent and effluent nitrogen as N concentrations for different states of nitrogen. From this data, the average nitrogen mass balance, over the 5-year data reviewed, was calculated and results are shown in **Table 6**.

Table 5. Influent and Effluent Nitrogen State Concentrations

Nitrogen State	Influent Nitrogen as N	Effluent Nitrogen as N
	mg/L	mg/L
Total Nitrogen	33	15
TKN	33	13
Nitrites/ Nitrates	0	2

Table 6. Five-Year Average Plant Nitrogen Mass Balance Results

Parameter	Concentration
	mg/L
Nitrogen Removed	18
Nitrogen in WAS (synthesis)	8
TKN Oxidized (nitrification)	12
Nitrites/ Nitrates Removed (denitrification)	10
Total Nitrogen in Effluent	15
TKN in Effluent	13
Nitrites/ Nitrates in Effluent	2

The existing plant is operated to reduce total nitrogen in the wastewater and based on the operating SRT, approximately 12 mg/L of TKN is oxidized to nitrites and nitrates with 10 mg/L of denitrification occurring. An additional 8 mg/L of total nitrogen is estimated to be synthesized and removed as waste activated sludge based on the typical nitrogen concentrations found in the WAS as reported in the EPA Land Application Annual Reports. From these reports, the average percent of nitrogen in the wasted solids was 6%. The nitrogen mass balance will provide initial values for calibrating the process model.

Phosphorus Mass Balance Ranges

The City of Vero Beach's FDEP permit does not have phosphorus effluent limits. The plant does remove a portion of the influent phosphorus through biological synthesis and land application of the WAS processed through the CleanB® Chlorine Dioxide WAS treatment system. The typical ranges for total phosphorus in the influent, effluent and WAS sludge are presented in **Table 7**. Percent phosphorus in the wasted solids was calculated assuming average net solids yield of 0.80 lbs. per lbs. cBOD treated and average influent of 3.463 MGD. EPA Land Application Annual Reports indicated a high of 4.8 percent and a low of 3.1 percent phosphorus.

Table 7. Typical Total Phosphorus Ranges

Parameter	Low Range	High Range
	mg/L	mg/L
Influent TP	2.0	8.7
TP in WAS	3.7	4.9
Effluent TP	1.1	5.0

Clarifiers

Two secondary clarifiers exist at the Vero Beach WWTP, each with a diameter of 95 feet and a side water depth of 12 feet. Mixed liquor from the aeration basins flows into the clarifiers where suspended solids settle to the bottom. The secondary effluent overflows a double-sided weir effluent launder and discharges into the clarifier drop box. The double-sided weirs increase the total weir length which results in a decreased weir loading rate.

Based on the 2006 Clarifiers Rehab drawings provided by the City, the clarifier's effluent weir has an inner diameter of 86'- 7" and an outer diameter of 90'- 1/2", this results in a total weir length of 564.5 feet. Historical flow data shows that the clarifiers are currently operating with an average weir overflow rate of 3,064 gpd/ft, over the last 5 years.

Typical clarifier design standards recommend that a clarifier should not exceed solids loading rate of 18 lbs./d/ft^2 at average day flow (ADF) and 35 lbs./d/ft^2 at peak hour flow. Recommended surface overflow rates are recommended to be below 600 gpd/ft^2 at average day flow and 1,000 gpd/ft^2 at peak hour flow. In addition, Class 1 Reliability for clarification states that with the largest unit out of service, the remaining units must handle 75% of total design capacity.

At ADF conditions, the existing clarifiers are estimated to experience a surface overflow rate of 317 gpd/ft^2 and a solids loading rate of 17 lbs./d/ft^2. These values were calculated with the assumption that the RAS recycle rate is 60 percent of influent flow at ADF and a MLSS concentration within the aeration basins of 4,000 mg/L.

During REI's site walk on June 26, 2018, an issue with the drop box was observed on the eastern-most clarifier. Secondary effluent, from the effluent launders, spills into the drop box where "burping" occurs. This burping is the result of air being pulled into the clarifier effluent pipes, causing a backup of secondary effluent.

ADDITIONAL DATA NEEDS

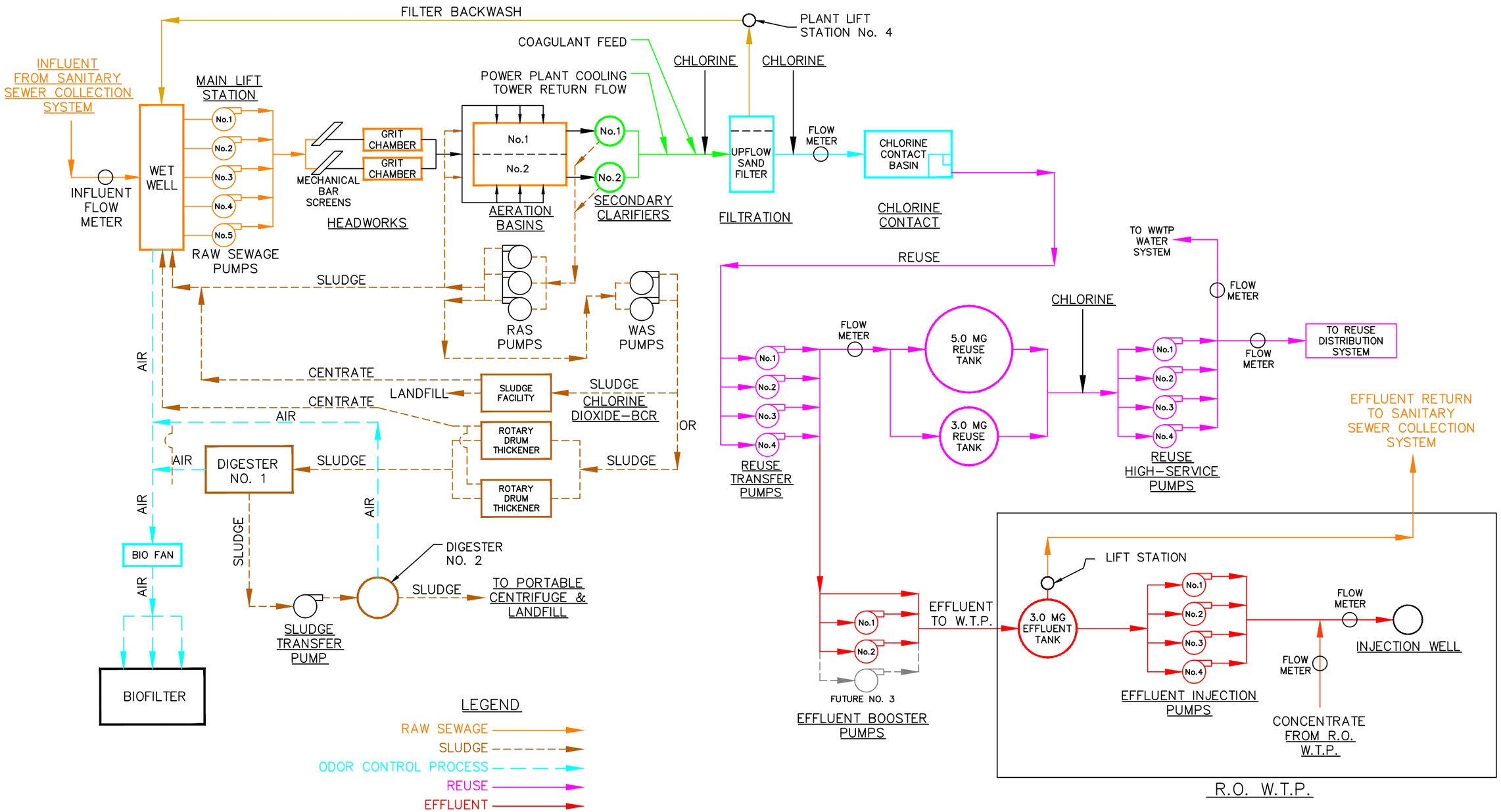
The plant operating data provided is extensive and provides a solid basis for developing and calibrating the process model. Providing influent chemical oxygen demand (COD) values would also be helpful to characterize the influent loadings but is not critical. Conducting COD tests on the weekly regulatory samples for the next year is recommended.

NEXT STEPS

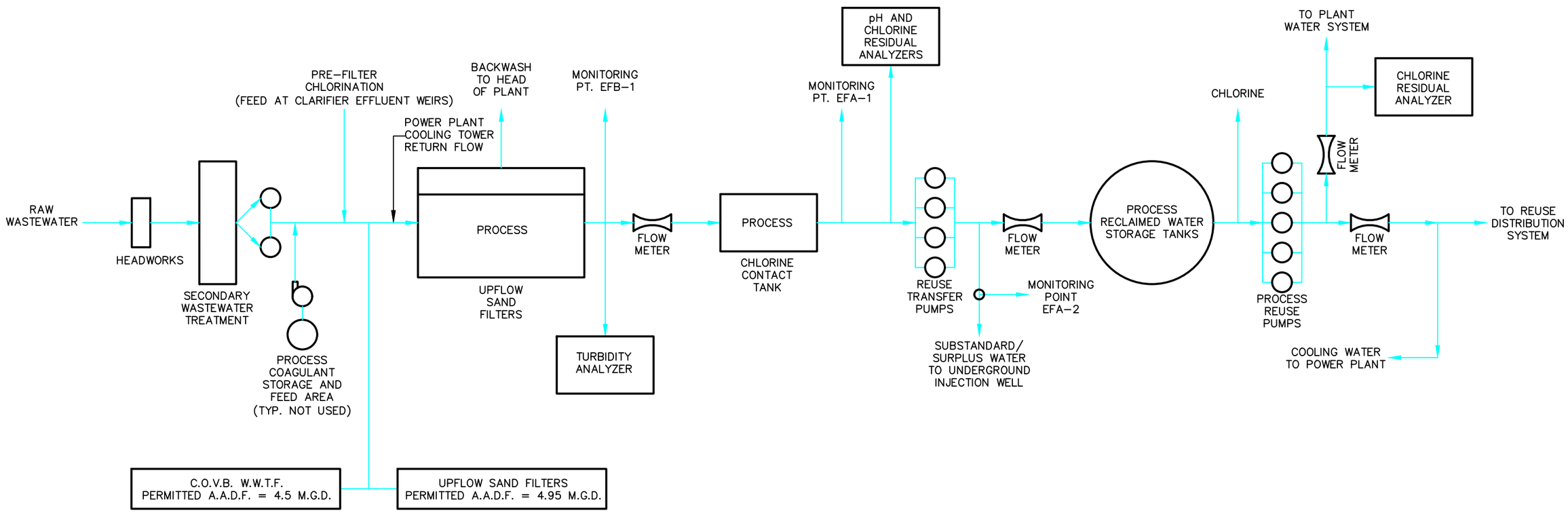
This report addresses scope of work items included in Tasks 3, 4, and a portion of Task 5. The next steps necessary to complete Phase I of the study include:

1. Obtain City review comments on this Draft Technical Memorandum via conference call. Revise the memo based on City comments and submit as final.
2. Evaluate existing process treatment capacities and constraints.
3. Review operational flexibility.
4. Develop and calibrate a process model of the existing plant.
5. Develop a list of process alternatives for achieving additional nutrient reduction without the addition of new tankage and collaborate with the City on those alternatives that will be evaluated in Phase II of the Study.

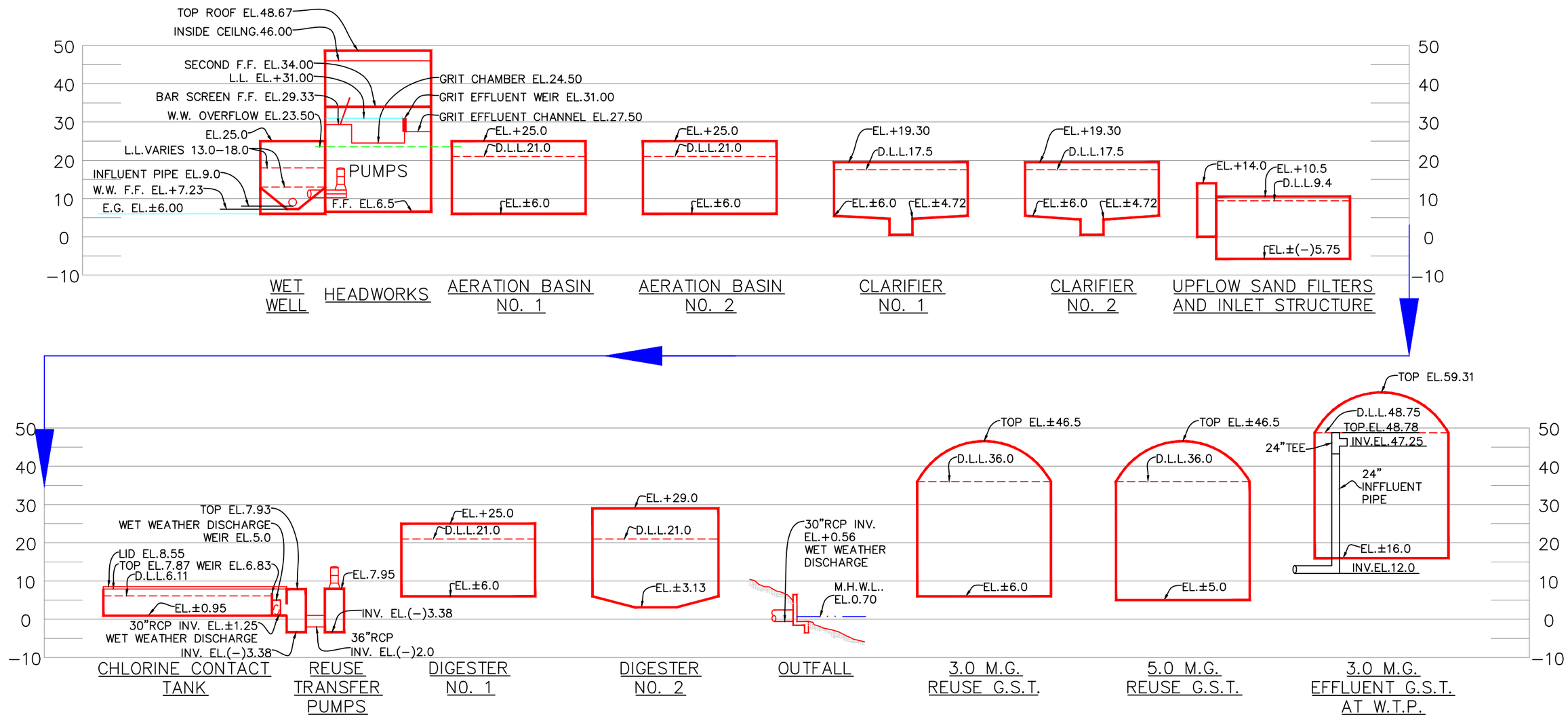
Appendix A
AutoCAD Drawings



CITY OF VERO BEACH NUTRIENT MANAGEMENT STUDY	CITY OF VERO BEACH WASTEWATER TREATMENT PLANT	EXISTING PROCESS FLOW DIAGRAM	FIGURE 1



CITY OF VERO BEACH NUTRIENT MANAGEMENT STUDY	CITY OF VERO BEACH WASTEWATER TREATMENT PLANT	SAMPLING AND METERING LOCATIONS	FIGURE 2



DESIGN ELEVATIONS

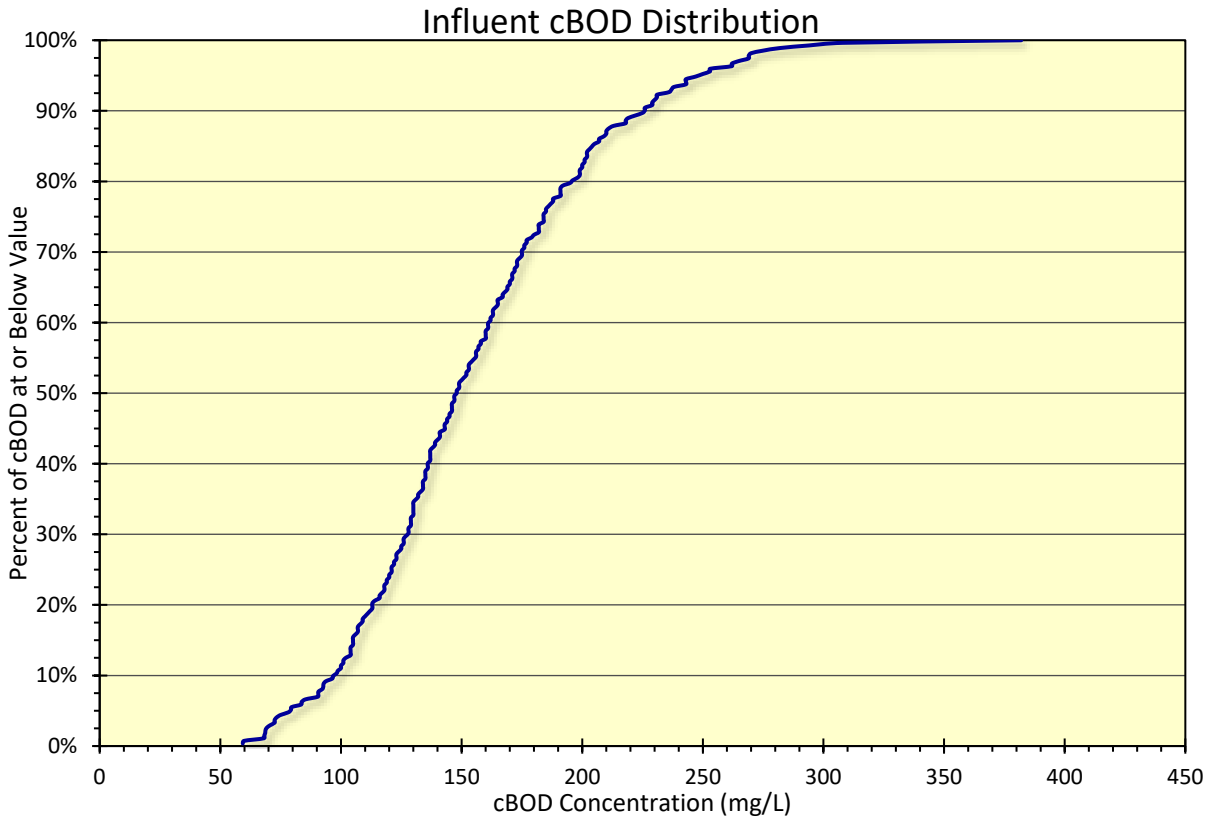
LEGEND

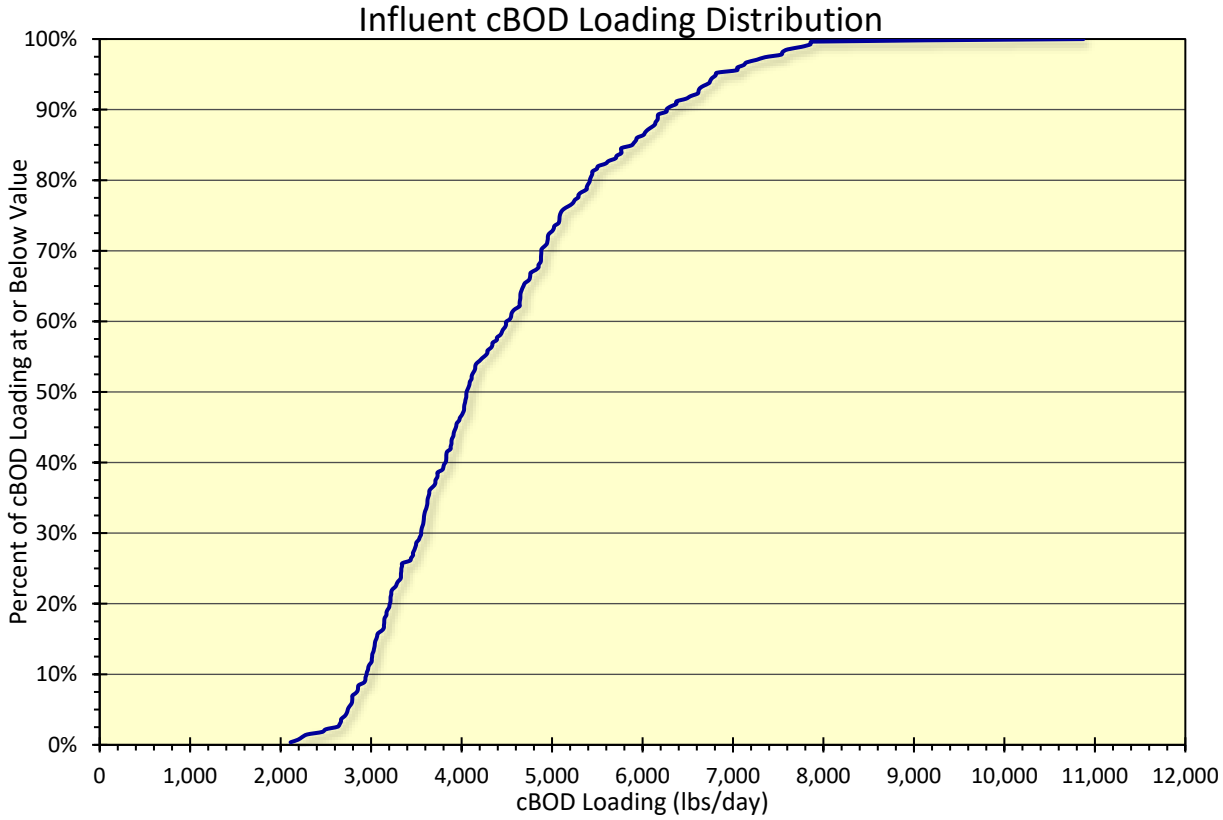
F.F. EL. = FINISH FLOOR ELEVATION
D.L.L. = DESIGN LIQUID LEVEL
E.G. = EXISTING GRADE

DATUM = N.G.V.D. 1929

CITY OF VERO BEACH NUTRIENT MANAGEMENT STUDY	CITY OF VERO BEACH WASTEWATER TREATMENT PLANT	EXISTING HYDRAULIC PROFILE	FIGURE 3

Appendix B
Influent Characterization
Distribution Graphs


Influent cBOD Distribution
Percent of cBOD at or Below Value
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
50
100
150
200
250
300
350
400
450
cBOD Concentration (mg/L)


Influent cBOD Loading Distribution
Percent of cBOD Loading at or Below Value
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90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1,000
2,000
3,000
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6,000
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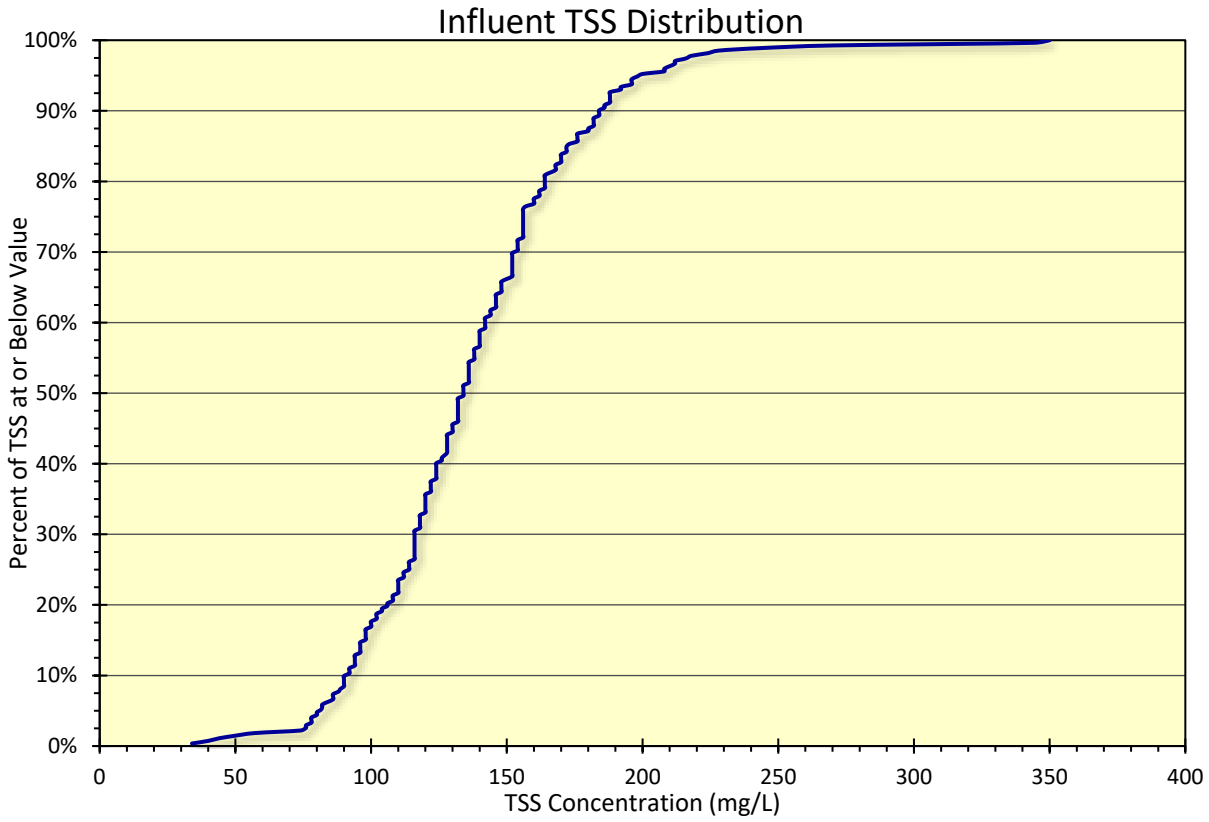
9,000
10,000
11,000
12,000
cBOD Loading (lbs/day)


Influent TSS Distribution
Percent of TSS at or Below Value
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60%
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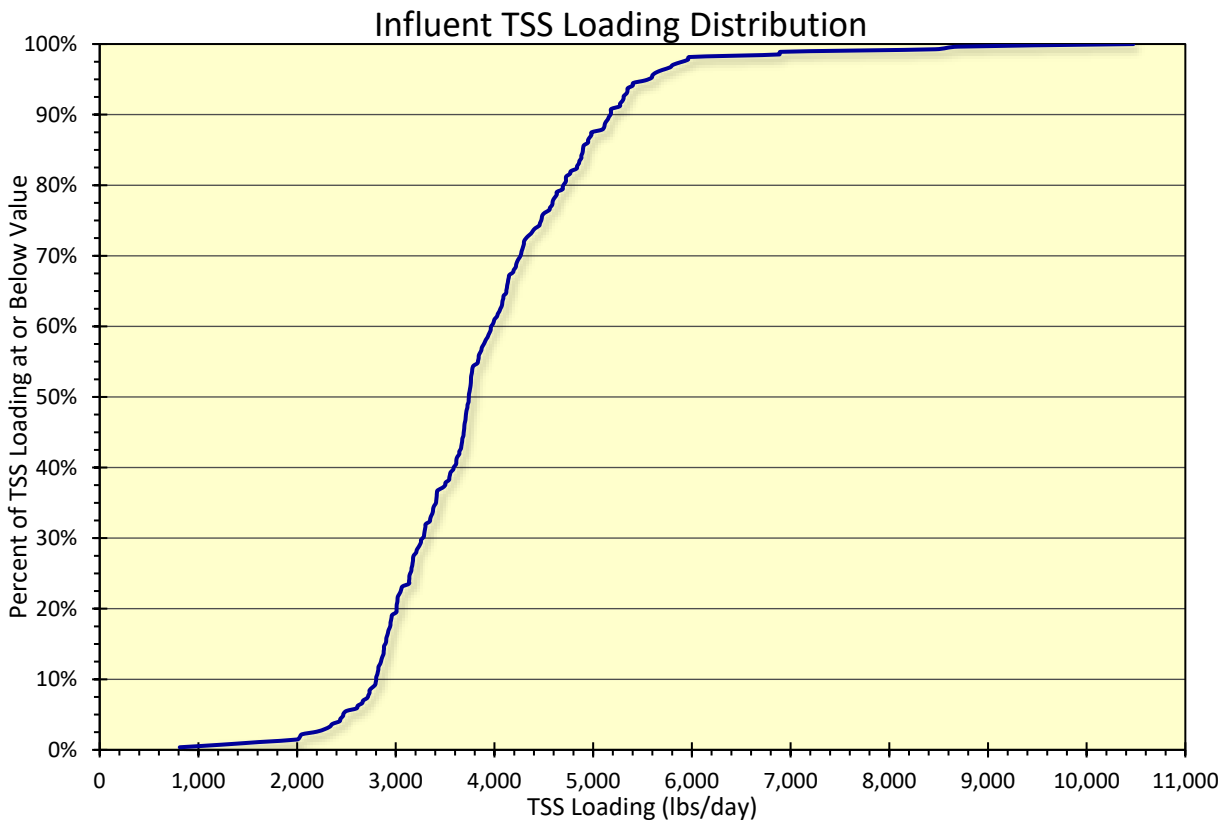
10%
0%
0
50
100
150
200
250
300
350
400
TSS Concentration (mg/L)


Influent TSS Loading Distribution
Percent of TSS Loading at or Below Value
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80%
70%
60%
50%
40%
30%
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0%
0
1,000
2,000
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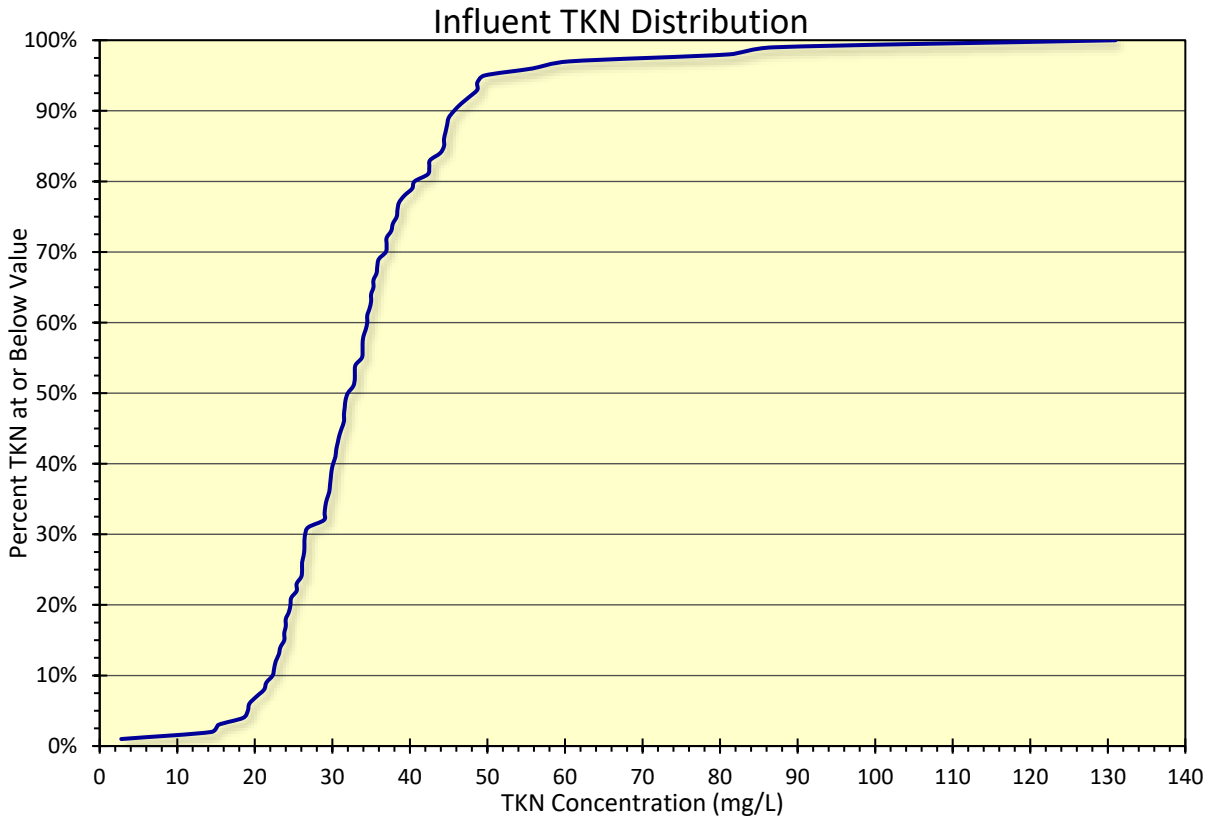
8,000
9,000
10,000
11,000
TSS Loading (lbs/day)


Influent TKN Distribution
Percent TKN at or Below Value
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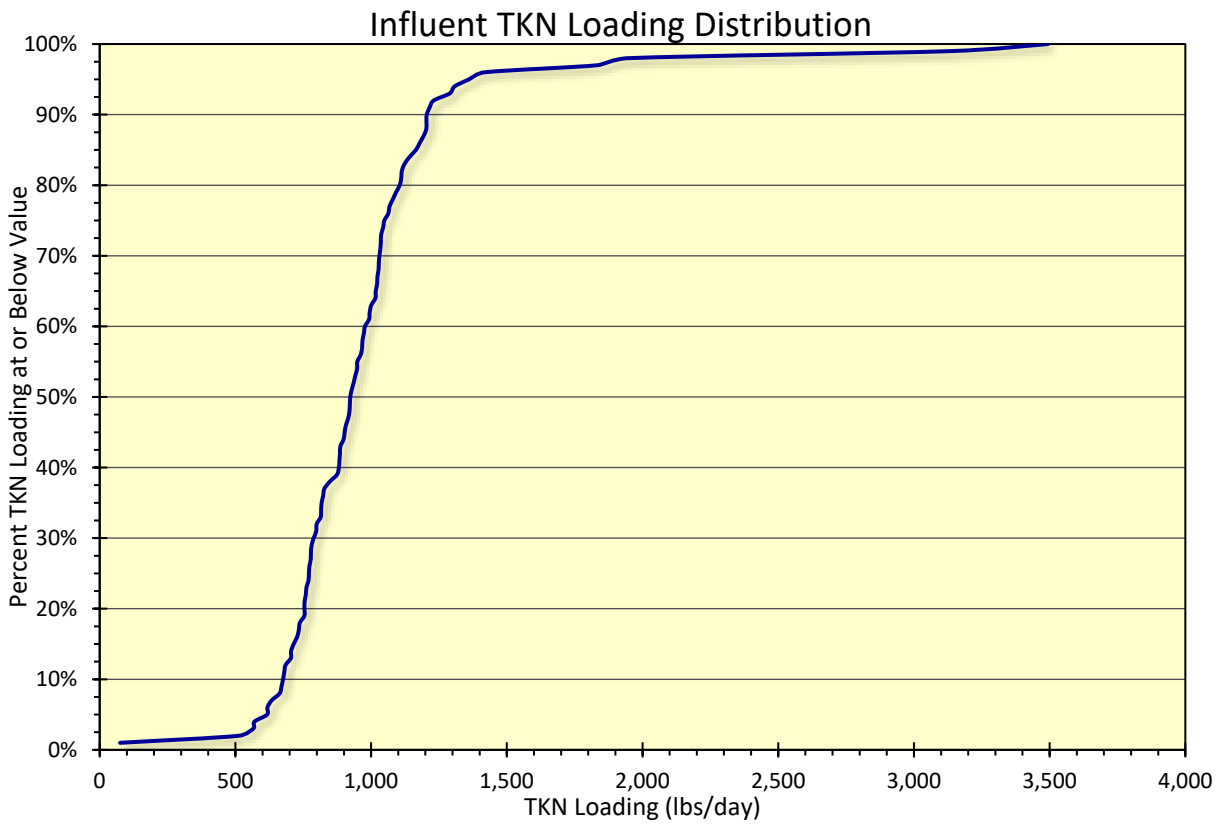
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
TKN Concentration (mg/L)


Influent TKN Loading Distribution
Percent TKN Loading at or Below Value
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
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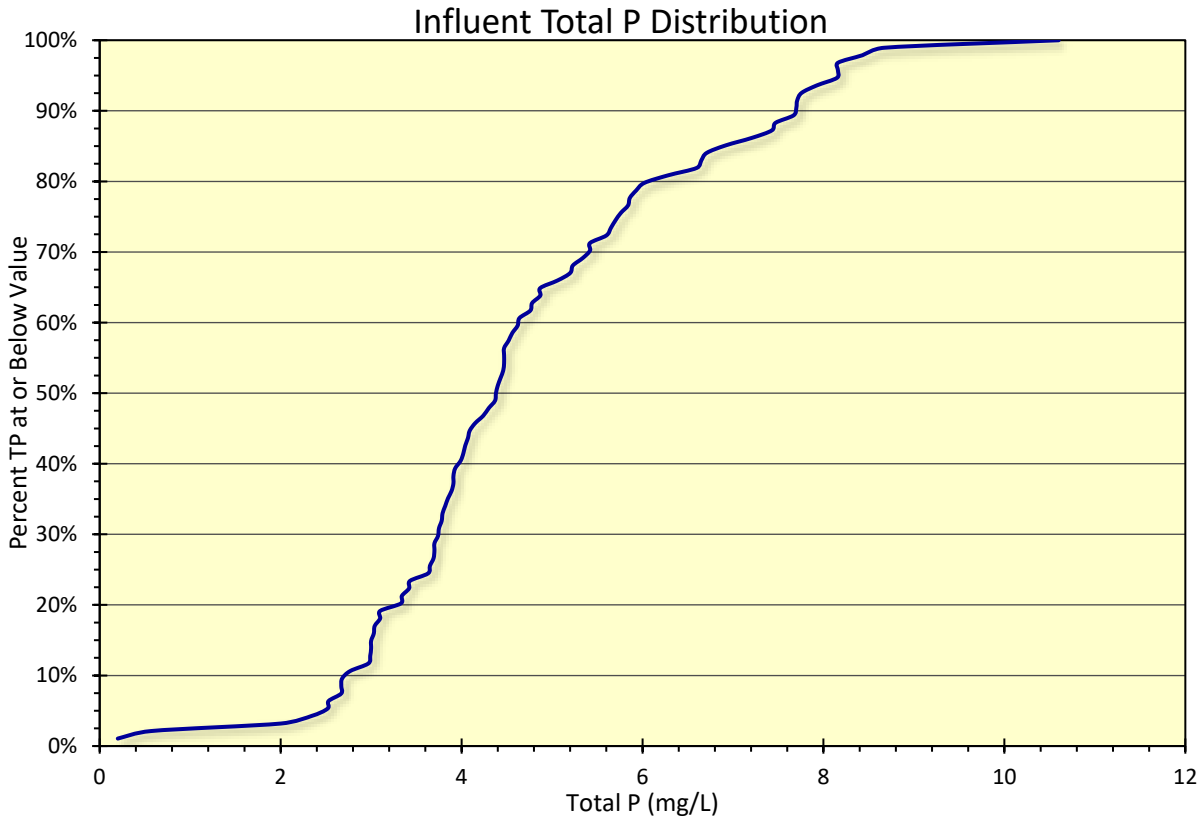
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
TKN Loading (lbs/day)


Influent Total P Distribution
Percent TP at or Below Value
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
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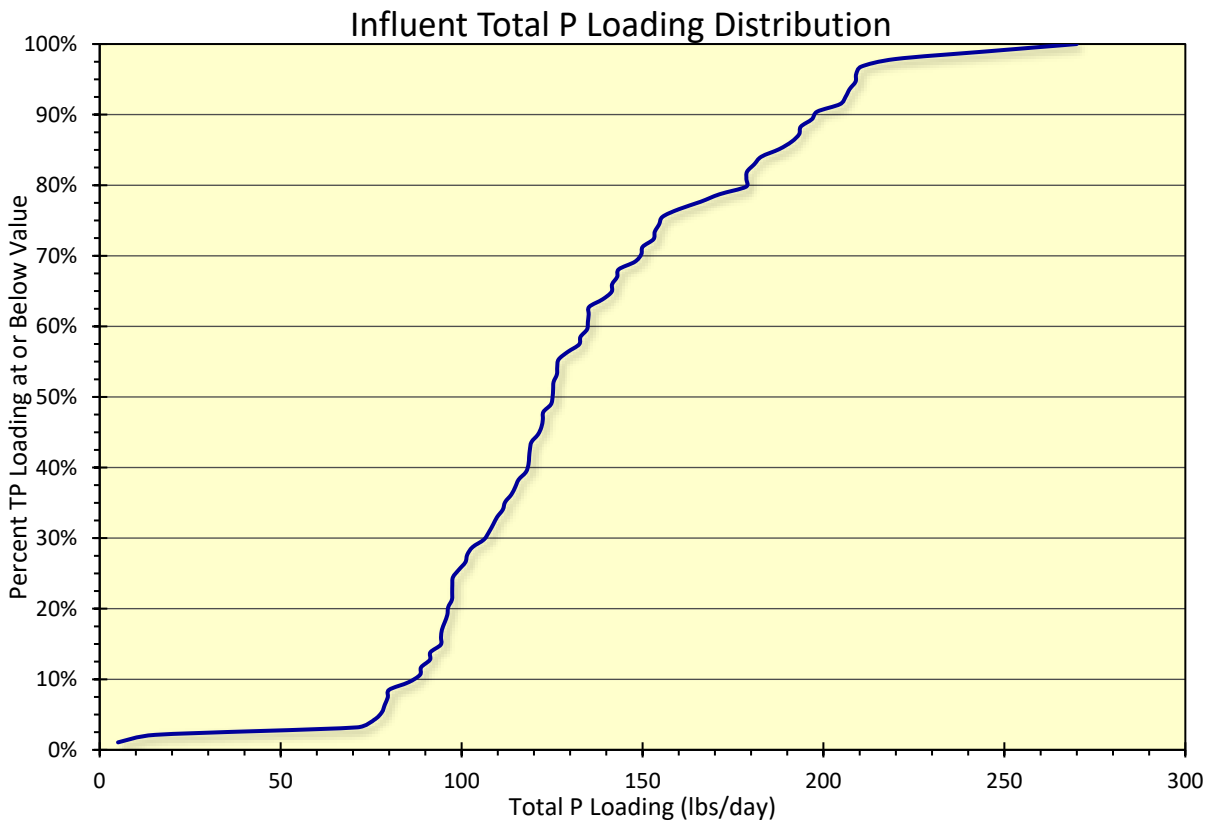
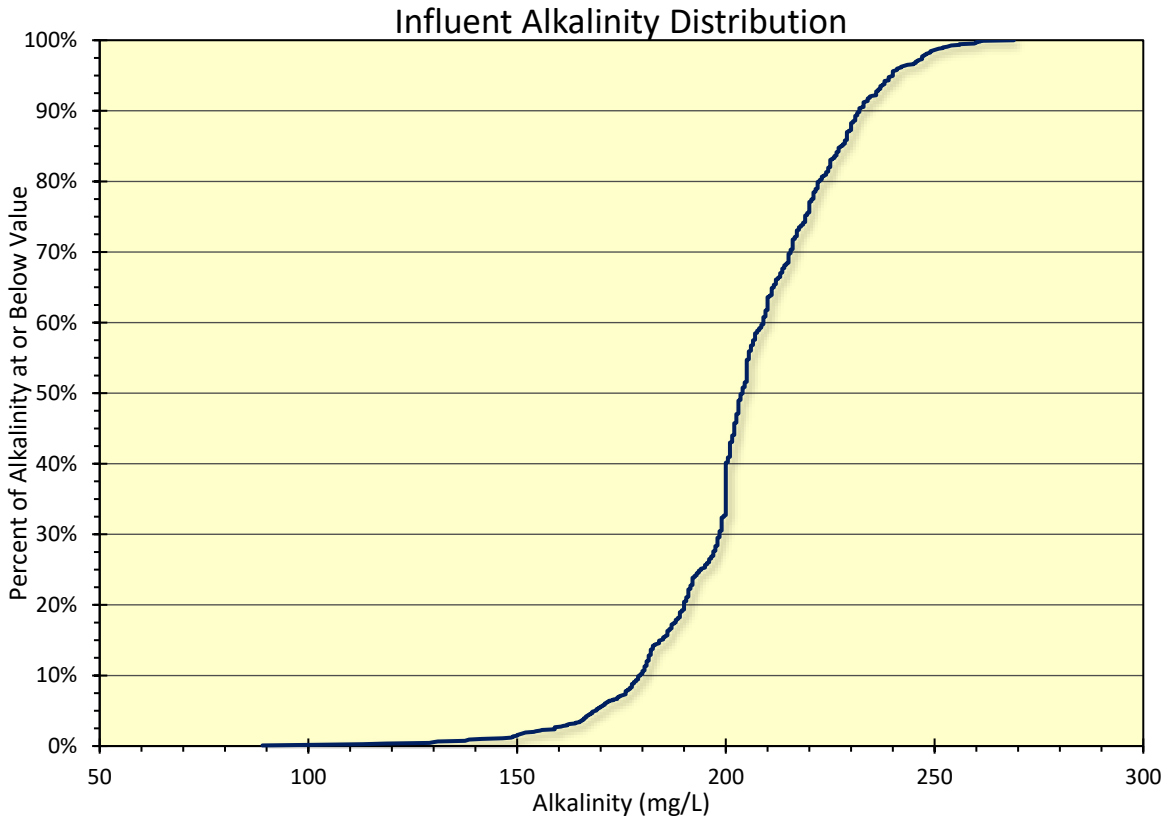
0
2
4
6
8
10
12
Total P (mg/L)


Influent Total P Loading Distribution
Percent TP Loading at or Below Value
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
50
100
150
200
250
300
Total P Loading (lbs/day)


Influent Alkalinity Distribution
Percent of Alkalinity at or Below Value
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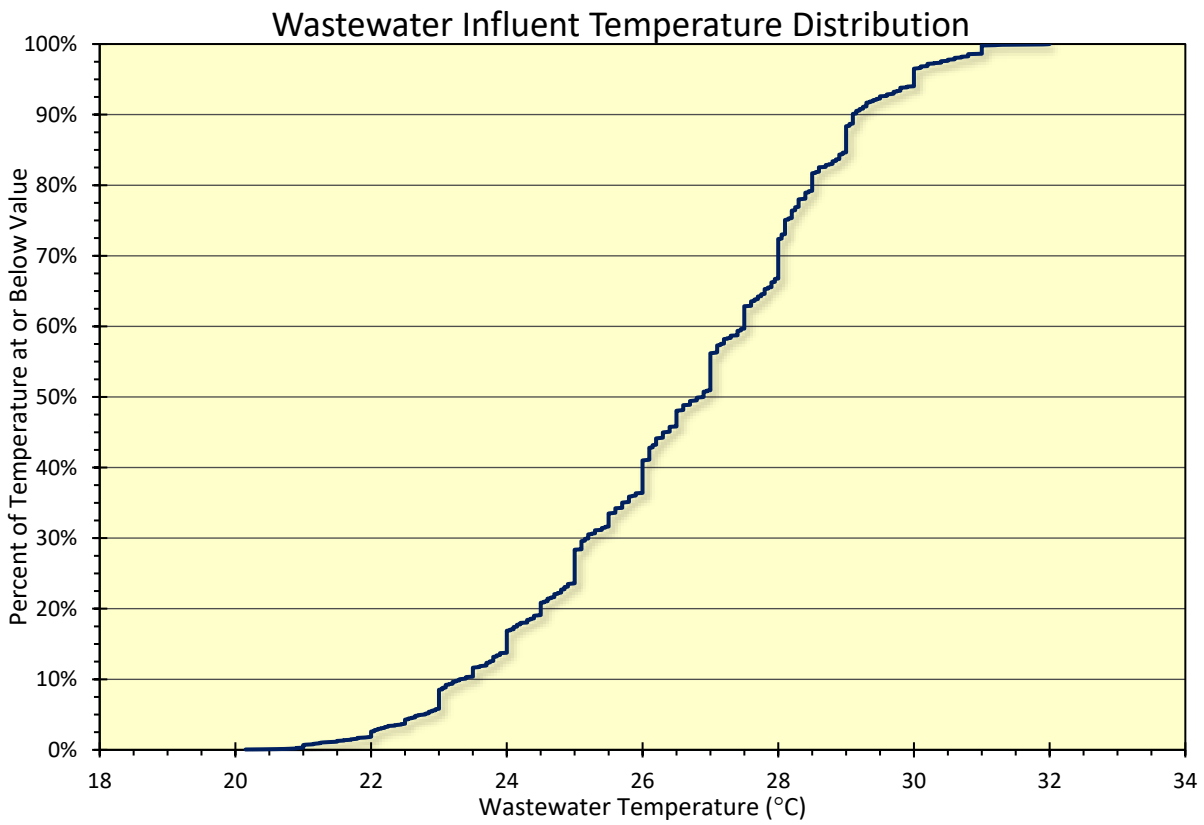
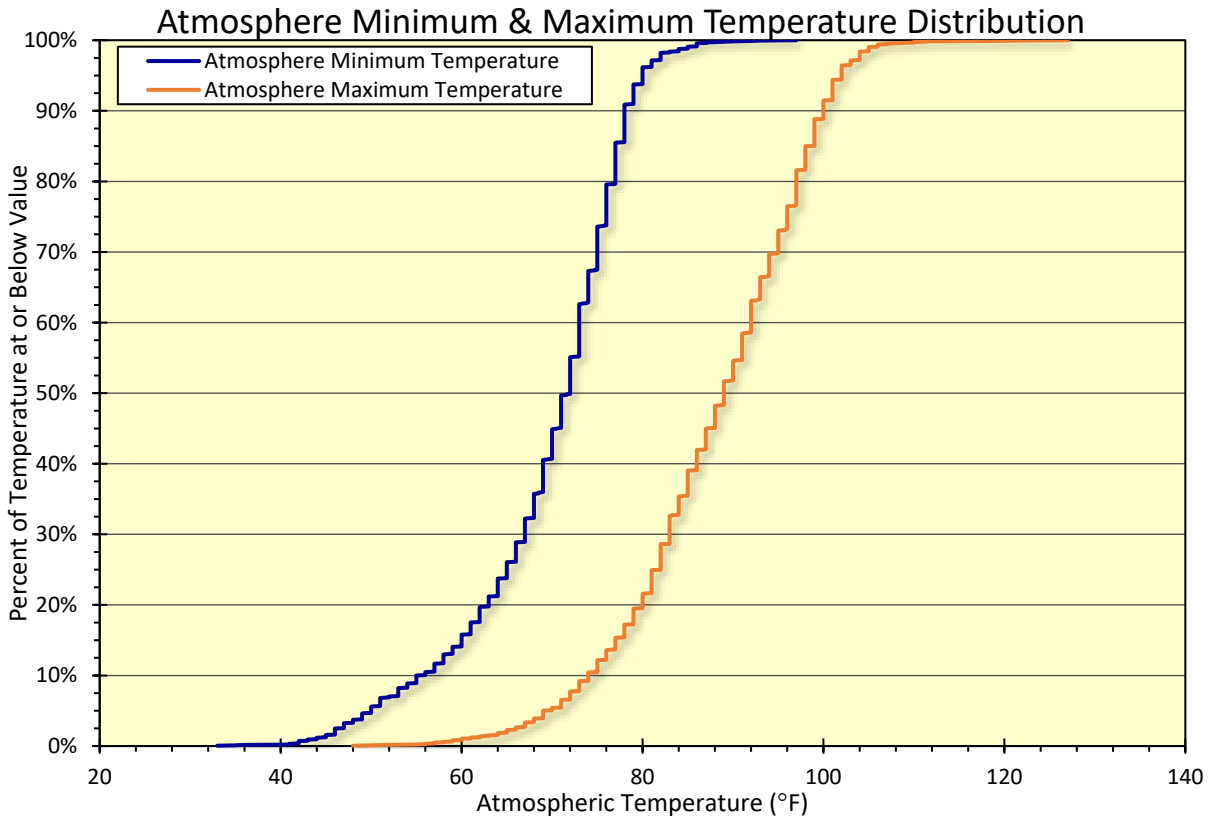
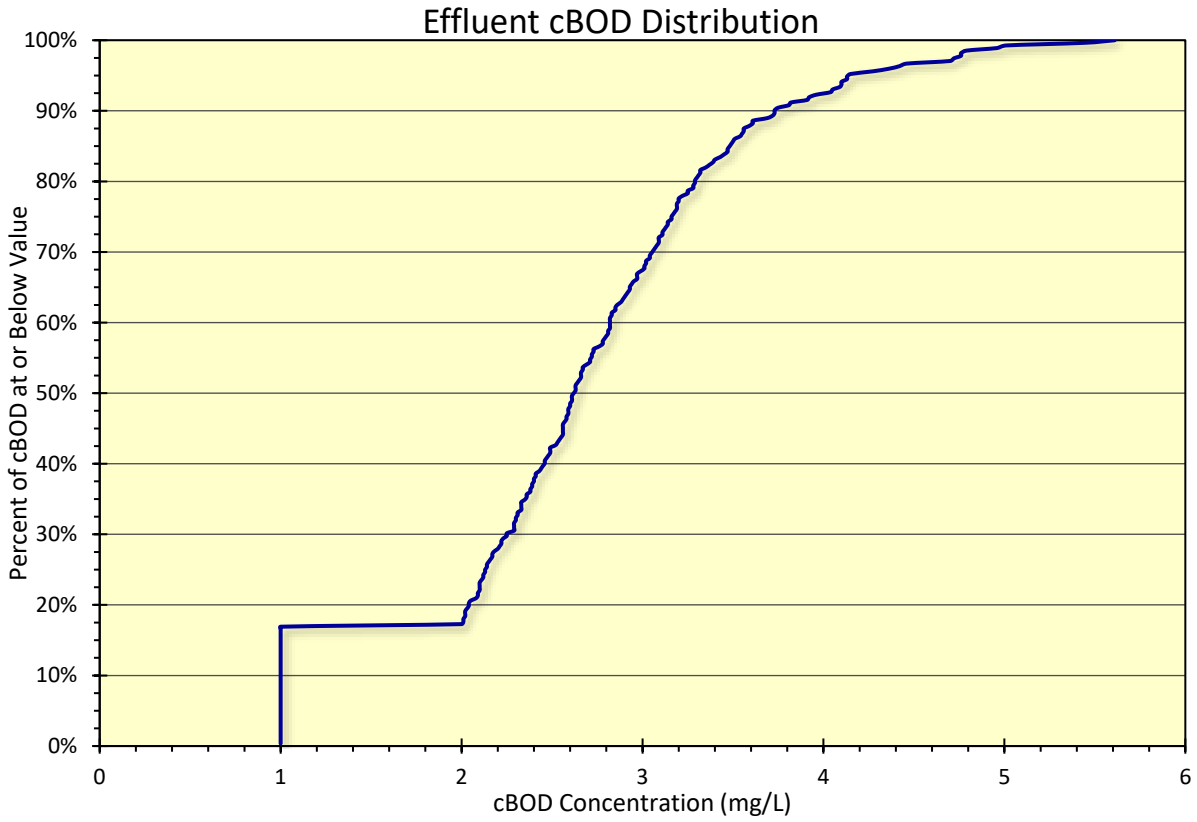
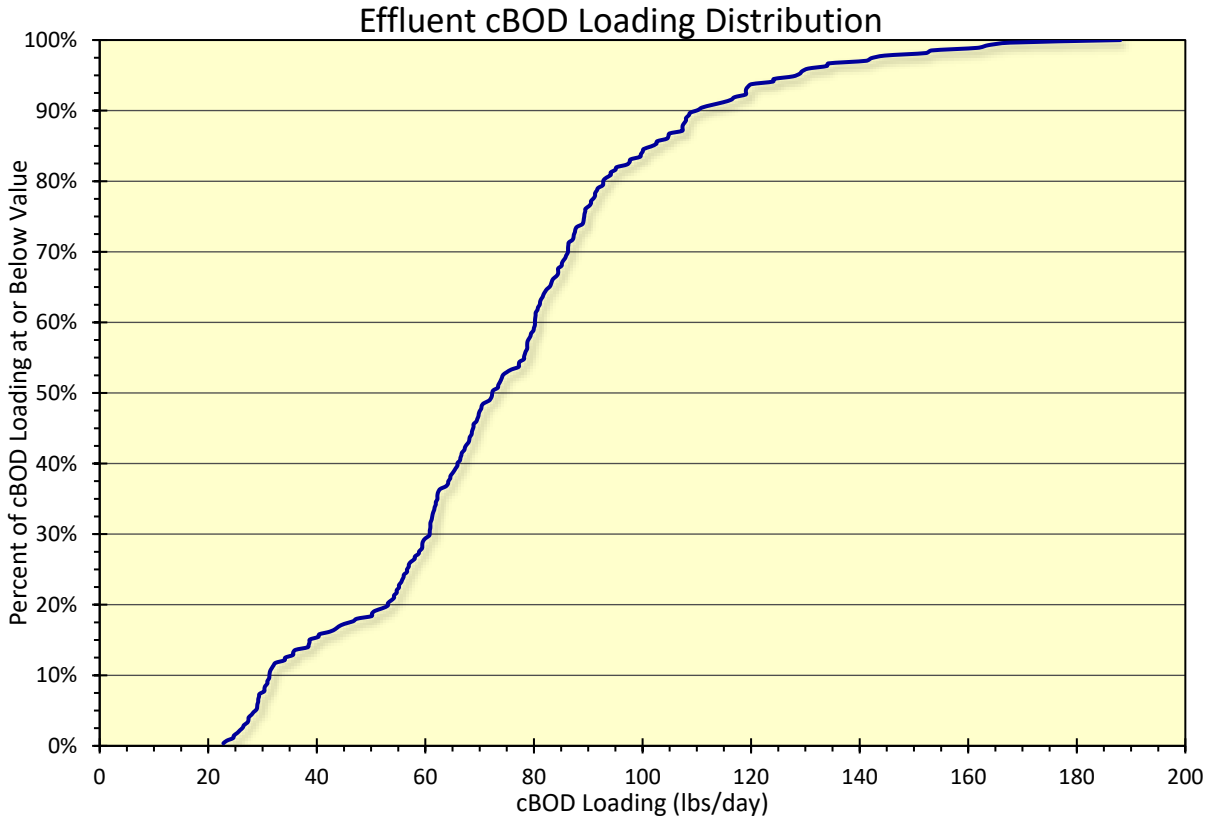
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
50
100
150
200
250
300
Alkalinity (mg/L)

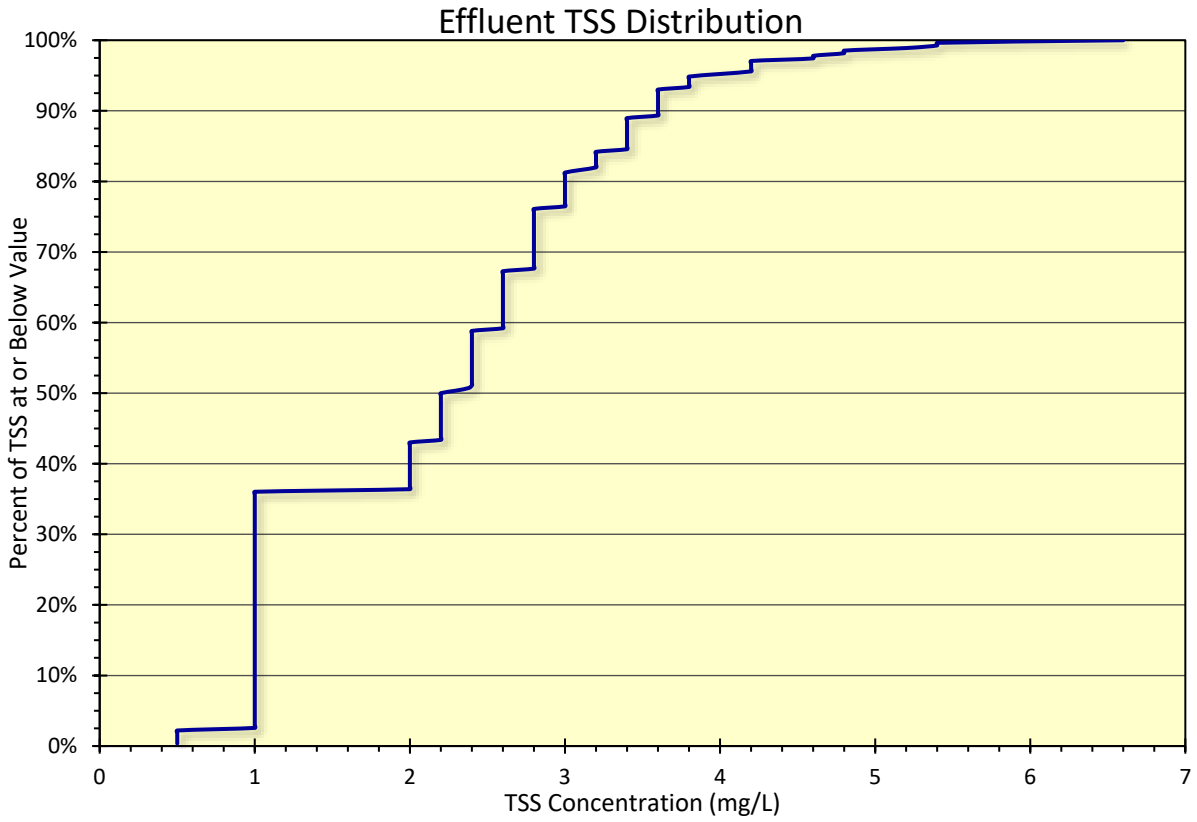

Wastewater Influent Temperature Distribution
Percent of Temperature at or Below Value
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
18
20
22
24
26
28
30
32
34
Wastewater Temperature (°C)

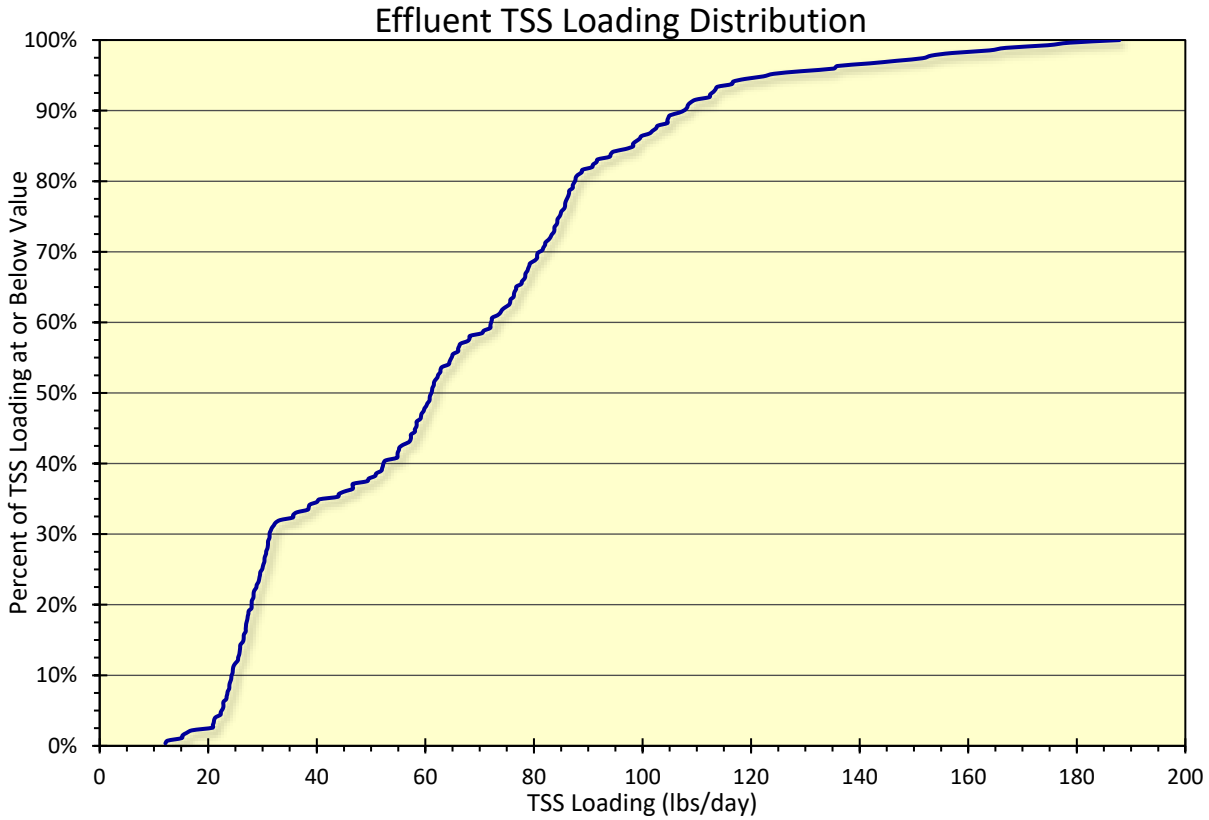

Atmosphere Minimum & Maximum Temperature Distribution
Atmosphere Minimum Temperature
Atmosphere Maximum Temperature
Percent of Temperature at or Below Value
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
20
40
60
80
100
120
140
Atmospheric Temperature (°F)

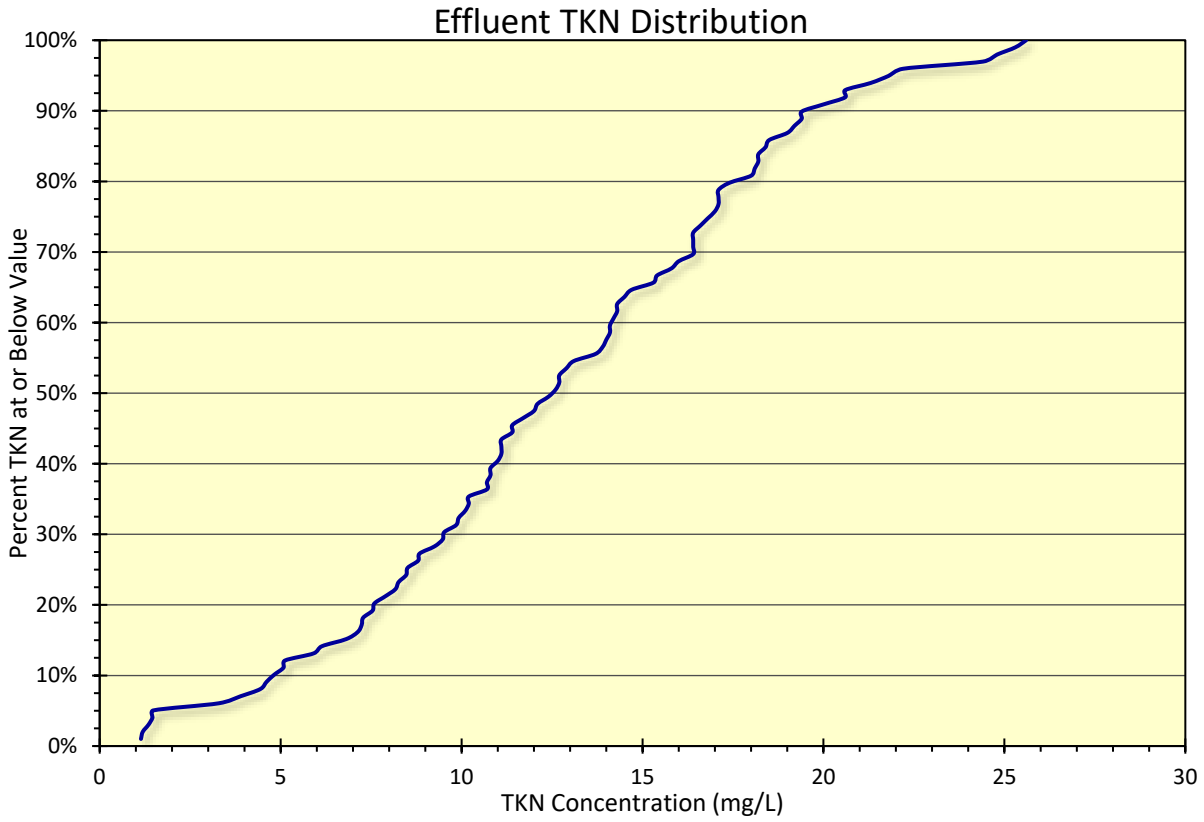
Appendix C
Effluent Characterization
Distribution Graphs

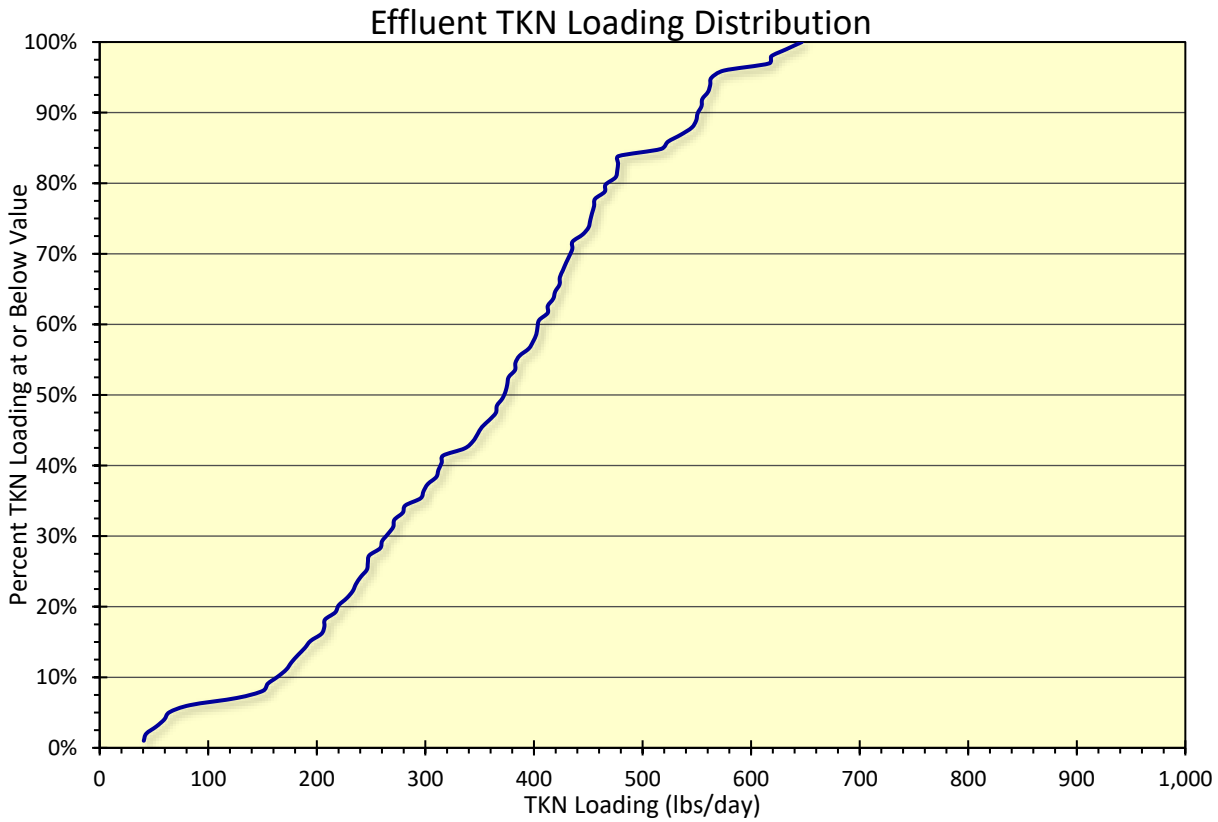

Effluent cBOD Distribution
Percent of cBOD at or Below Value
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
6
cBOD Concentration (mg/L)

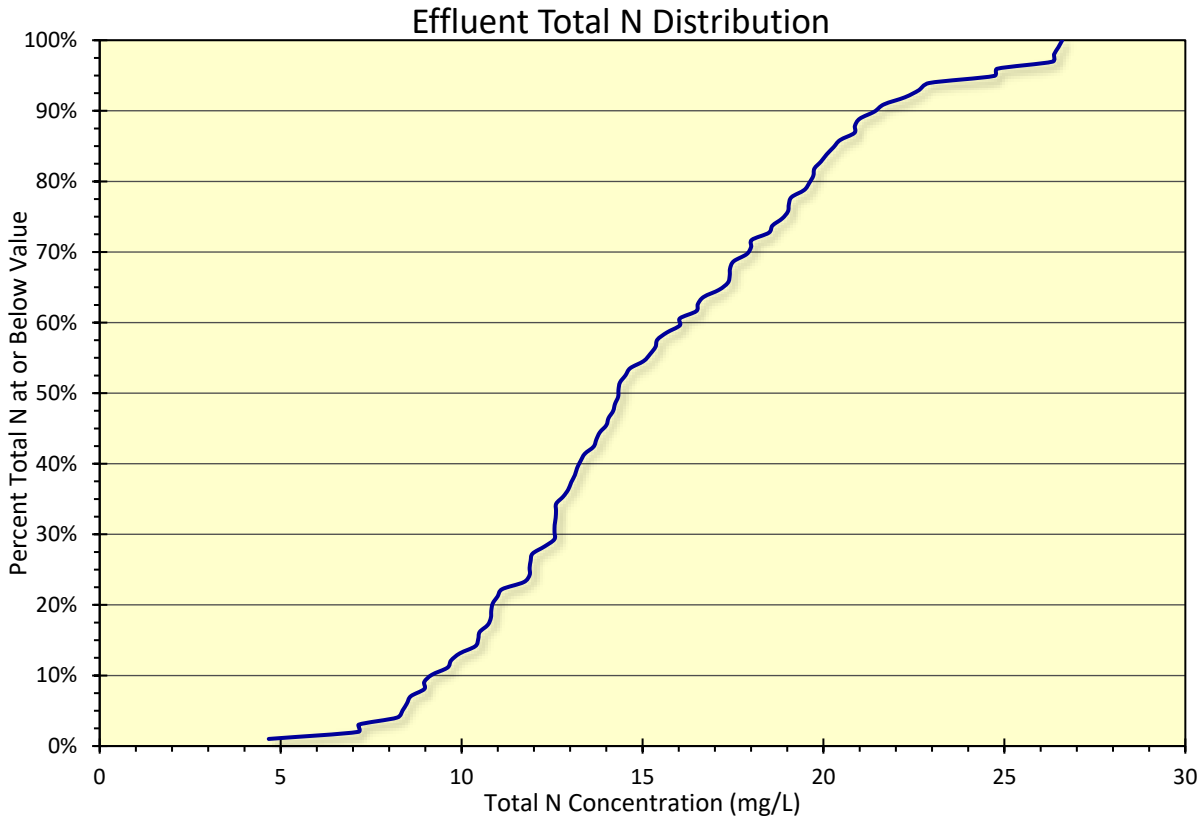

Effluent cBOD Loading Distribution
Percent of cBOD Loading at or Below Value
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
20
40
60
80
100
120
140
160
180
200
cBOD Loading (lbs/day)

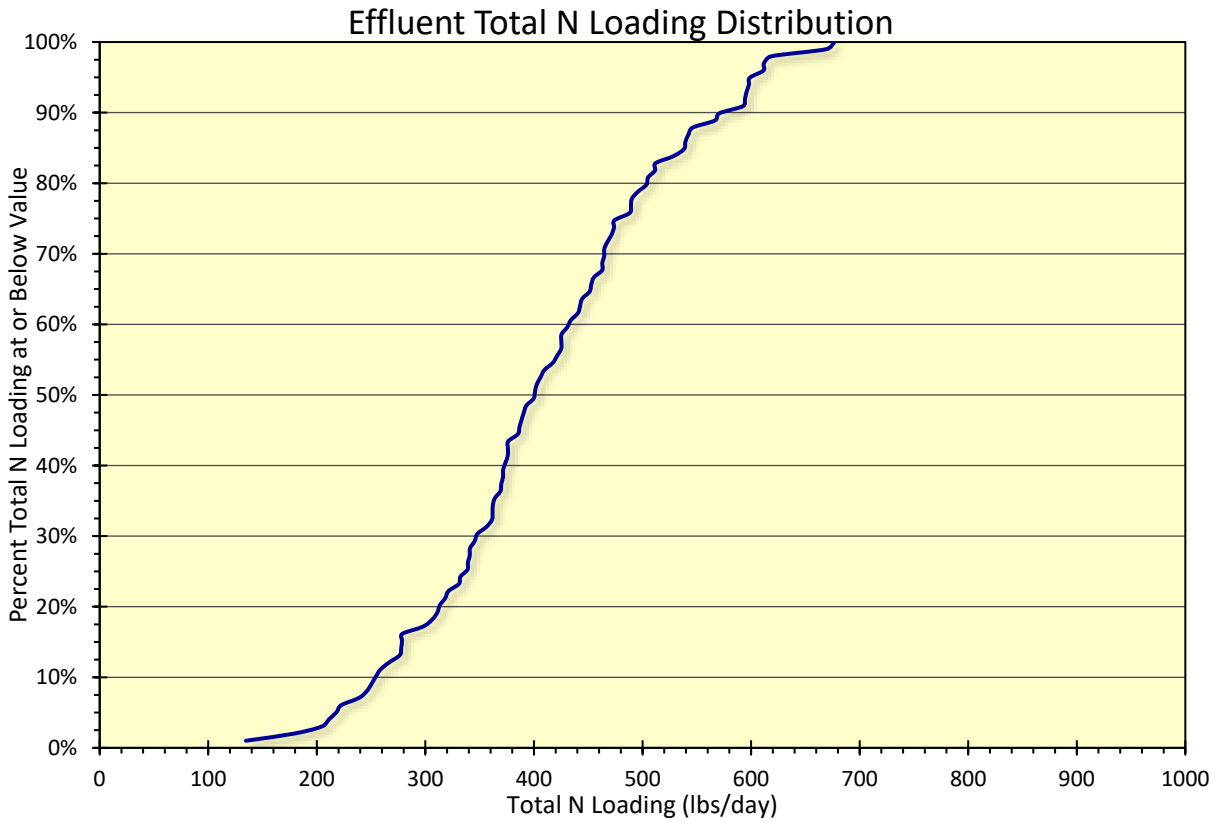

Effluent TSS Distribution
Percent of TSS at or Below Value
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
6
7
TSS Concentration (mg/L)

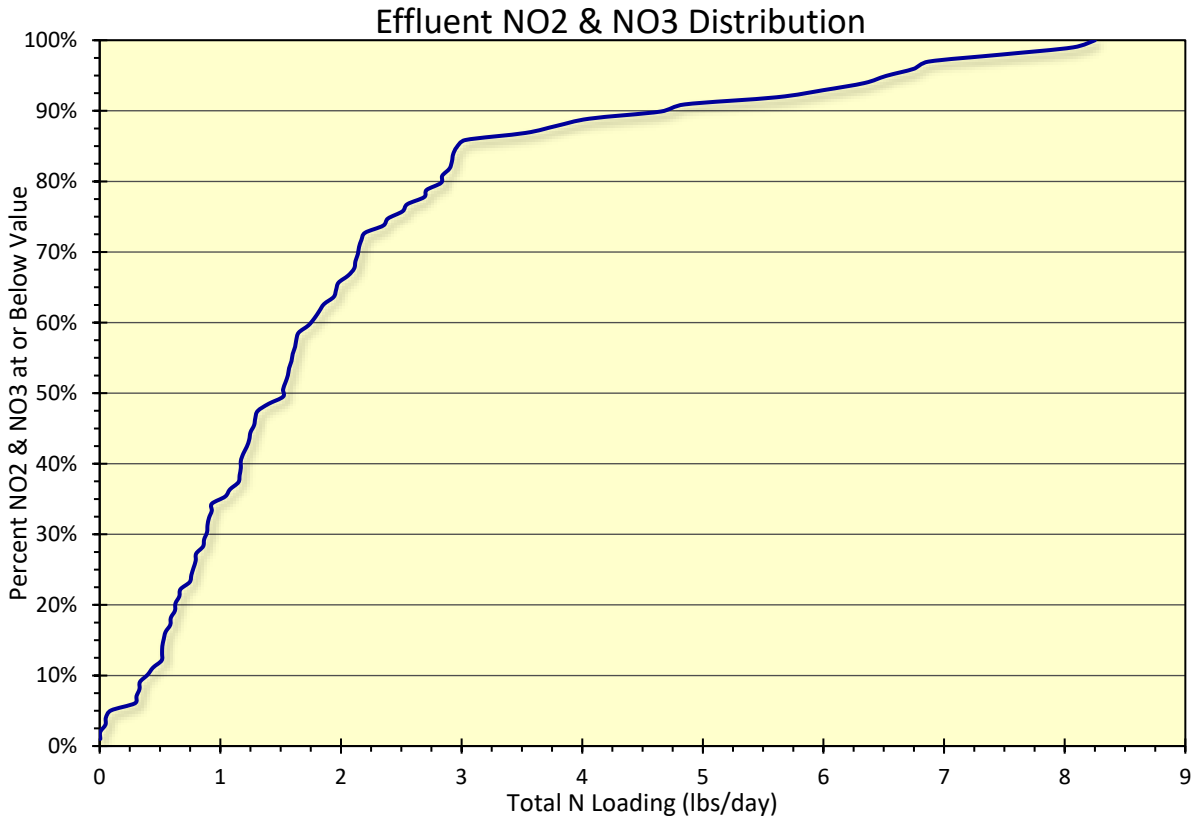

Effluent TSS Loading Distribution
Percent of TSS Loading at or Below Value
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
20
40
60
80
100
120
140
160
180
200
TSS Loading (lbs/day)

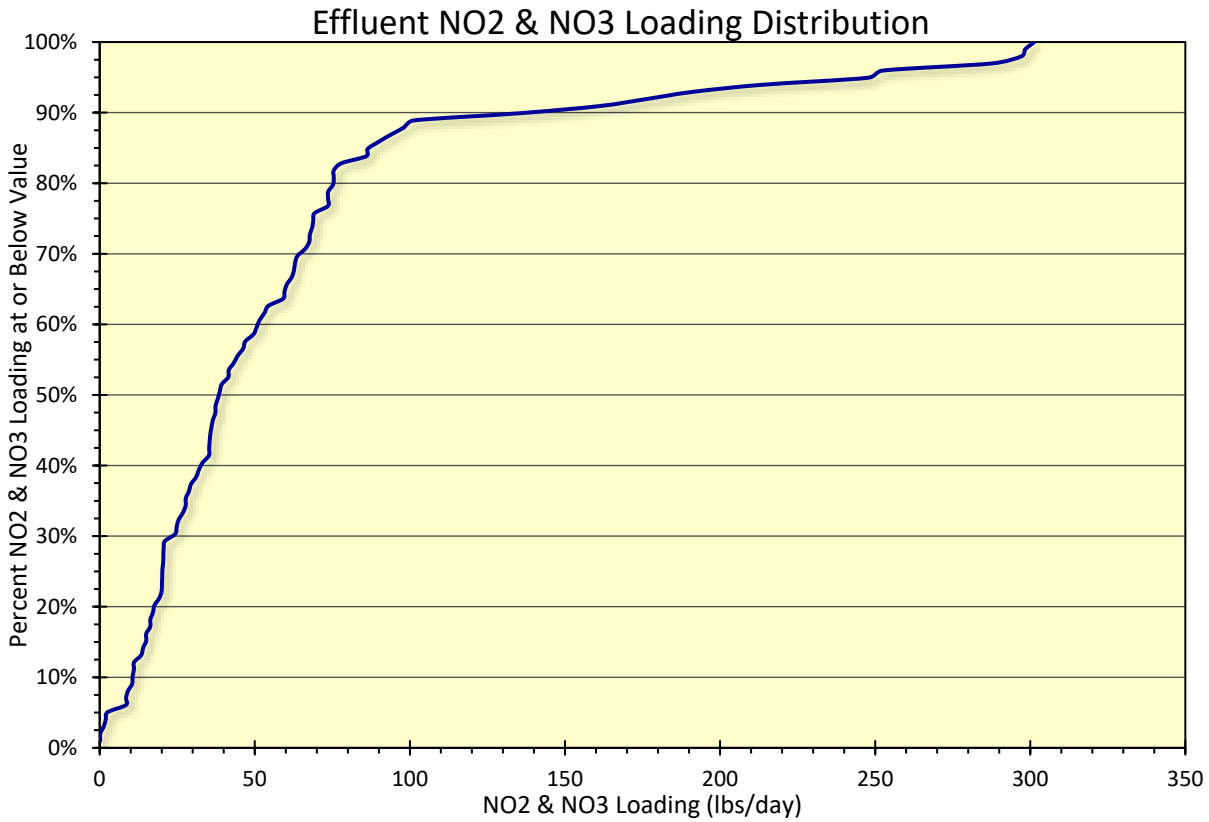

Effluent TKN Distribution
Percent TKN at or Below Value
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
5
10
15
20
25
30
TKN Concentration (mg/L)

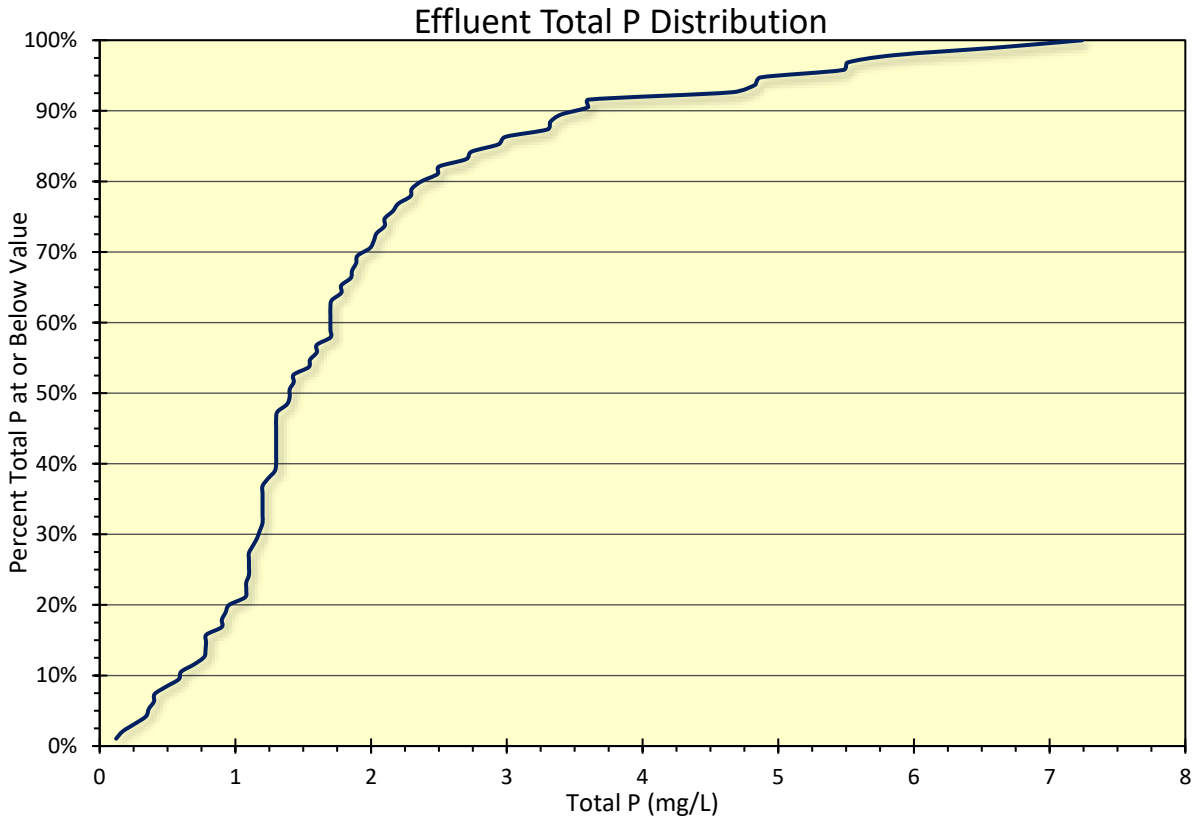

Effluent TKN Loading Distribution
Percent TKN Loading at or Below Value
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
100
200
300
400
500
600
700
800
900
1,000
TKN Loading (lbs/day)

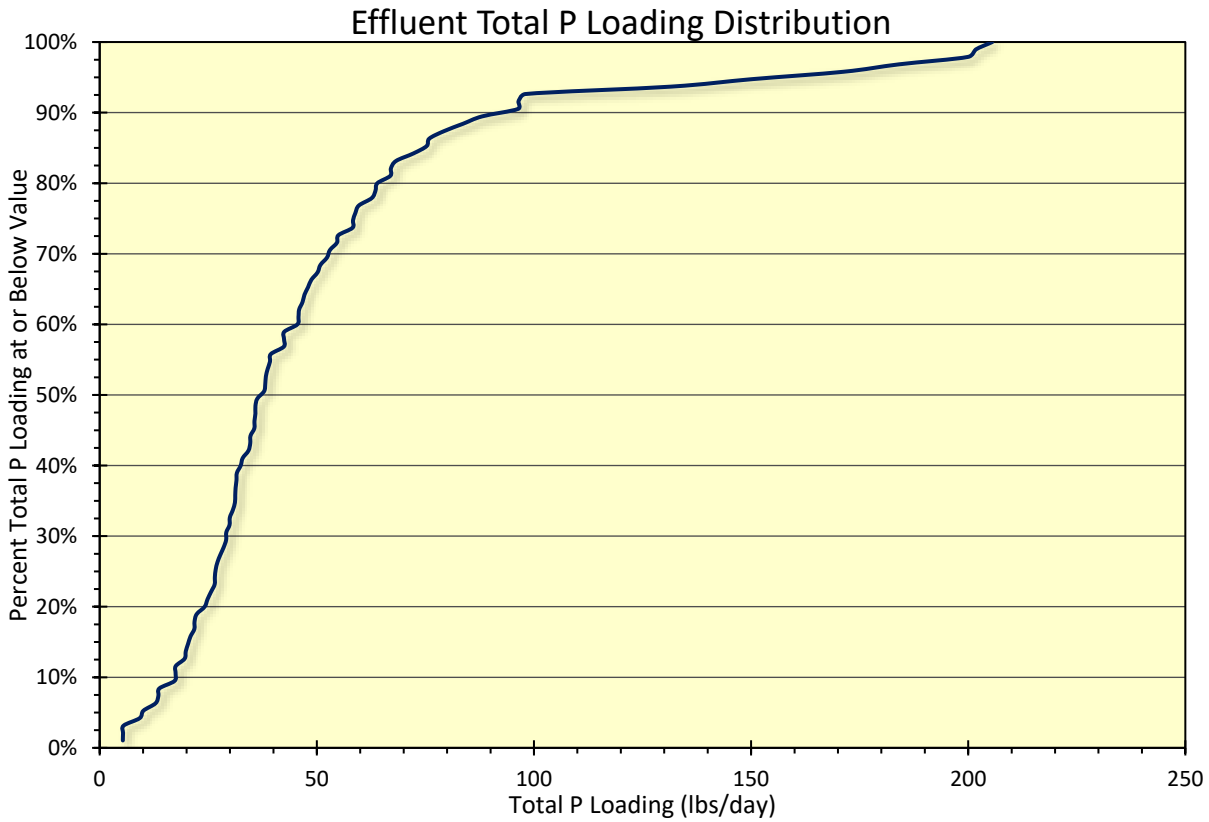

Effluent Total N Distribution
Percent Total N at or Below Value
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
5
10
15
20
25
30
Total N Concentration (mg/L)

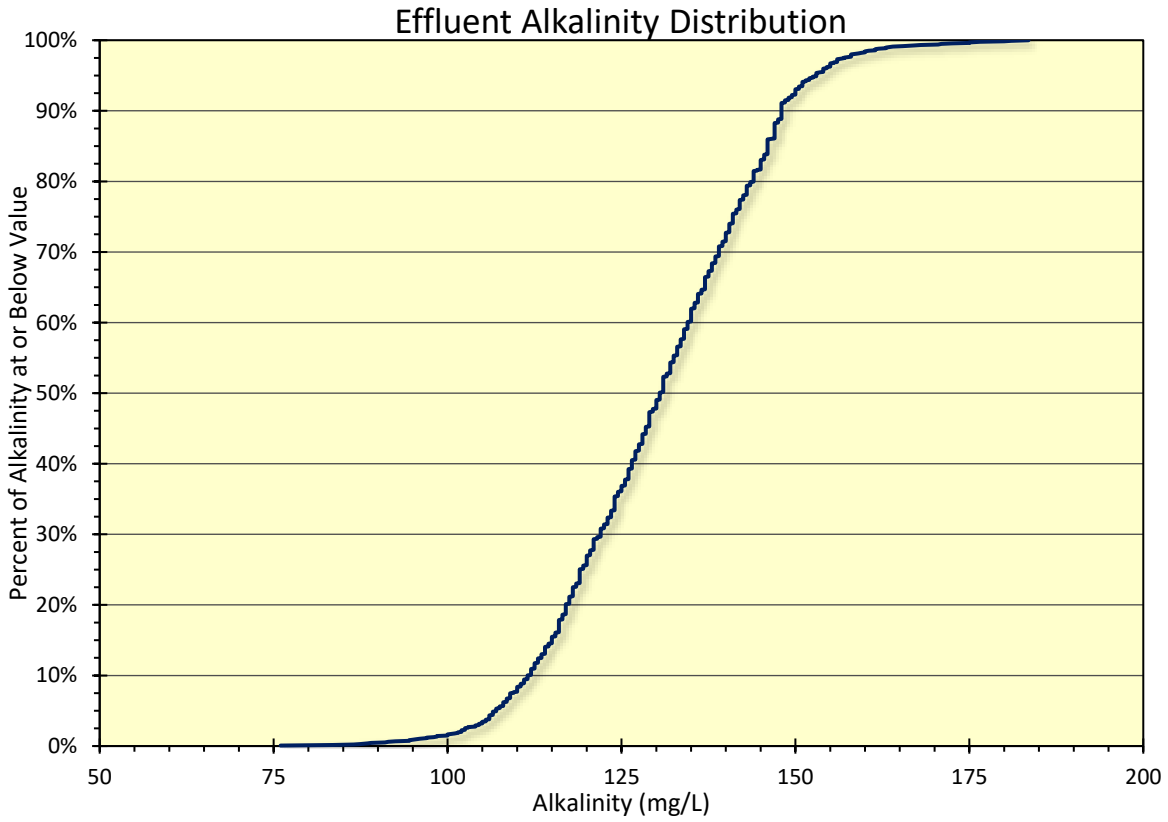

Effluent Total N Loading Distribution
Percent Total N Loading at or Below Value
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
100
200
300
400
500
600
700
800
900
1000
Total N Loading (lbs/day)

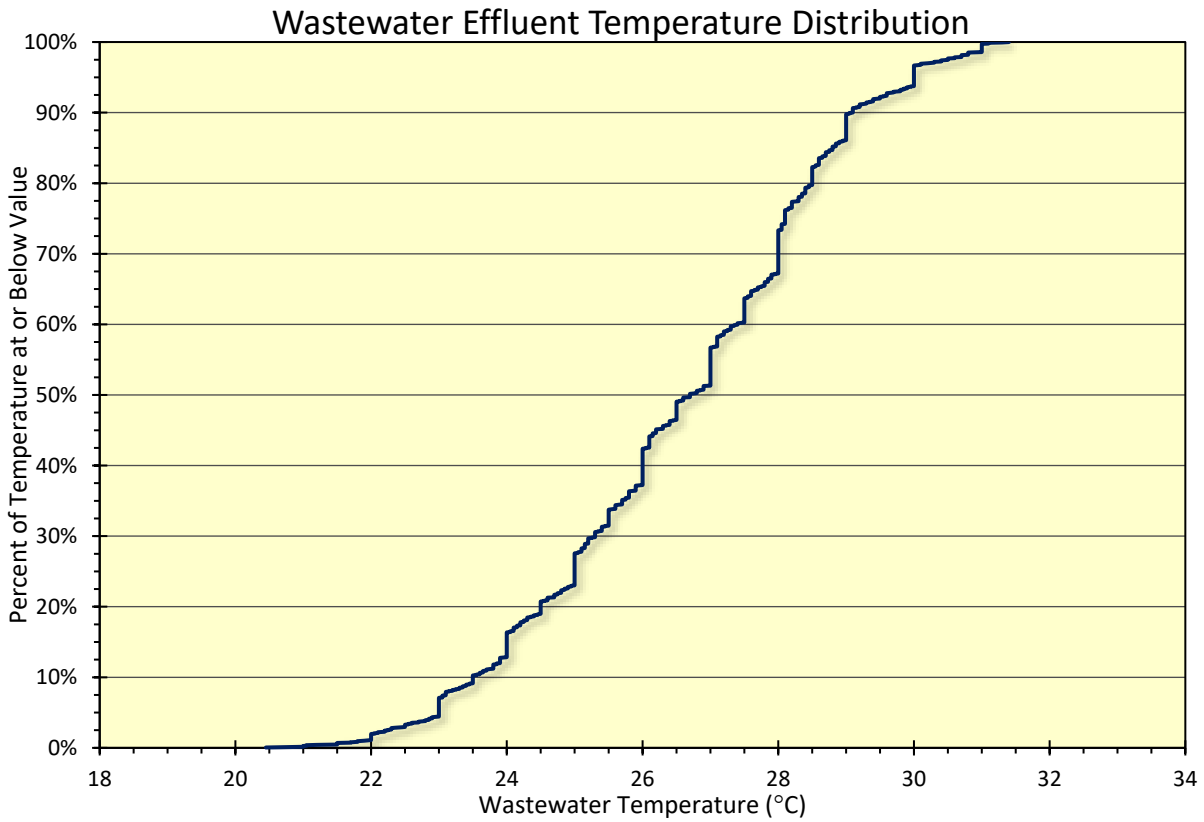

Effluent NO2 & NO3 Distribution
Percent NO2 & NO3 at or Below Value
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
6
7
8
9
Total N Loading (lbs/day)


Effluent NO2 & NO3 Loading Distribution
Percent NO2 & NO3 Loading at or Below Value
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
50
100
150
200
250
300
350
NO2 & NO3 Loading (lbs/day)


Effluent Total P Distribution
Percent Total P at or Below Value
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
6
7
8
Total P (mg/L)


Effluent Total P Loading Distribution
Percent Total P Loading at or Below Value
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
50
100
150
200
250
Total P Loading (lbs/day)


Effluent Alkalinity Distribution
Percent of Alkalinity at or Below Value
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
50
75
100
125
150
175
200
Alkalinity (mg/L)


Wastewater Effluent Temperature Distribution
Percent of Temperature at or Below Value
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
18
20
22
24
26
28
30
32
34
Wastewater Temperature (°C)

Appendix D
Existing Equipment and
Unit Process Specifications

Headworks

Wet Well

Influent Pipe Elevation	9 feet
Operational Depth	8 feet
Volume	640 cubic feet (4,800 gallons)

Raw Influent Pumps

Number	5
Manufacturer	Allis Chalmers
Model No.	300 F8H
Capacity (each)	3,800 gpm
Firm Capacity	15,200 gpm

Preliminary Treatment

Mechanical Bar Screens

Number	2
Type	Continuous screen
Manufacturer	Parkson AGMMA-75
Channel Width	2.6 feet
Bar Spacing	1/8 inch

Grit Chambers

Number	2
Construction	Concrete

Grit Classifier

Number	1
Type	Hydrocyclone
Manufacturer	Wemco
Capacity	0.316 MGD (Grit Slurry)

Grit Washer

Number	2
Type	Progressive Screw
Manufacturer	Wemco
Capacity (each)	0.316 MGD (Grit Slurry)

Secondary Treatment

Aeration Basins

Construction	Concrete
Total Number	2
Sidewater Depth	15 feet
Volume (each)	54,000 cubic feet (405,000 gallons)

Blowers

Number	5
Type	Centrifugal
Manufacturer	Hoffman

Operating Pressure	6.5 psi
Capacity	
Flow	2,200 scfm
Pressure	14 psi
Horsepower	100 HP
Secondary Clarification	
Construction	Concrete
Number	2
Diameter	95 feet
Side Water Depth	12 feet
Manufacturer	Dorr-Oliver/ EIMCO
Return Activated Sludge Pumping	
Total Number	3
Type	Centrifugal
Manufacturer	Wemco
Model	Hidrostal md#E8D-E2W
Capacity (each)	3.5 MGD

Tertiary Treatment

Sand Filters	2,430 gpm
Number of Filter Cells	10
No. of modules per cell	4
Manufacturer	Parkson
Model	Dynasand
Module Surface Area	50 sf
Filter Media Depth	3.33 feet
Average Loading Rate	2 gpm/sf
Peak Loading Rate	5 gpm/sf

Chlorination Facilities

Chlorine Contact Basin	
Number	2
Total Number	123,000 gallons
Chlorinator	
Number	4
Type	V-notch
Manufacturer	Wallace and Tierman
Dosage Rate	500 lbs./day
Concentration	3.6 mg/L (typical)
Chlorine Storage	
No. of Units in Service	
Type	
Capacity	

Dechlorination (Sulfur Dioxide) -Inactive

Number	2
Manufacturer	Wallace and Tierman
Dosage Rate Capacity	500 lbs./day (Maximum)
Concentration	2 mg/L
Storage	One Ton Cylinders

Reuse Water Transfer Pumps

Total Number	4
Manufacturer	Johnston
Type	Vertical
Capacity (each)	2,750 gpm
Firm Capacity	8,250 gpm
Total Capacity	11,000 gpm

Reuse Water Distribution Pumps

Total Number	4
Manufacturer	Johnston
Type	Vertical
Capacity (each)	2,250 gpm
Firm Capacity	6,750 gpm
Total Capacity	9,000 gpm

Storage Tanks

Type	Ground Storage
Construction	Circular Concrete
Total Capacity	8,000,000 gallons
Number	2

Residuals Handling Facilities

Waste Activated Sludge Pumps

Total Number	2
Manufacturer	Moyno
Model	1GO65G1CDQ
Type	Progressive Cavity
Capacity (each)	163 gpm

Rotary Drum Thickeners

Total Number	2
Manufacturer	Jones and Attwood
Model	MD#300RST
Capacity (each)	163 gpm

Aerobic Disgestors

Total Number of Tanks	2
Total Volume	1,000,000 gallons

Blowers

Total Number	2
Manufacturer	Hoffman
Capacity (each)	3,550 scfm

Sludge Transfer Pumps

Total Number	1
Manufacturer	Moyno
Model	MD#1G065G1 CDQ
Type	Progressive Cavity
Capacity (each)	192 gpm

Attachment B
Conceptual Process Alternative Descriptions and Site Layouts

CITY OF VERO BEACH, FLORIDA
WATER AND SEWER DEPARTMENT
PRELIMINARY NUTRIENT MANAGEMENT STUDY

Workshop No. 2
Existing Plant Process Review and Nutrient Removal Alternatives
September 14, 2018 1:30 pm

Agenda

1. Introductions

2. Meeting Purpose

3. Existing Process Evaluation

4. Process Modeling and Calibration of Existing Plant

5. Preliminary Process Alternatives

6. Screening of Process Alternatives for Phase II

7. Review of Action Items

8. Adjournment

REISS ENGINEERING
PLANNING · DESIGN · CONSTRUCTION

PROCESS IMPROVMENTS

Process Improvement: Increase Aeration Basin Mixed Liquor Volatile Suspended Solids

Description

This alternative proposes to improve the percentage of volatile solids in the aeration basin mix liquor suspended solids (MLVSS to MLSS ratio) by improving screening and grit removal. The proposed screening improvements would require replacing the existing two screens with new screens that would reduce the screening elements spacing and improve screening hydraulic performance. Conceptual grit system improvements could include covering the grit basins to contain odors, lining the grit basins with a PVC liner to protect the concrete, adding mixers and air to improve grit separation, adding a grit classifier and dewatering system to further separate the collected grit from biological solids and adding a new odor scrubbing system to treat odorous air from the process.

Benefits

- Improved Aeration Basins Treatment Efficiency
- Potential Reduction in Headworks Hydraulic Loses
- Improved Clarifier Performance – Reduced Solids Loading
- 5 to 15 Percent Decrease in WAS Solids

Required Improvements

- Adding or Replacing the existing screens
- Improve Grit Removal
- Screening and Degritting RAS
- Odor Control System
- Concrete Liners

Capital Costs

- Retrofit Aerated Grit Basins with Covers and Odor Control - $
- Install Second Screen - $
- Installing RAS Screening - $

Operations Impacts and Cost

- Increased Screening and Grit Disposal Costs
- Increased Odor Treatment Costs
- Reduced Wasting Solids Treatment and Disposal Costs

Process Improvement: Improve Aeration Basin Aeration and Mixing

Description

Calibration of the existing plant's BioWin model to the nutrient balance and performance summarized in the Data Evaluation Memorandum indicated that the oxygen transfer and mixing in the aeration basins may limit nitrification of ammonia and promotes denitrification of the formed nitrates to nitrogen gas. Current basins operation benefits the city by minimizing oxygen demand (by limiting nitrification) and improves alkalinity (denitrification adds alkalinity). However, to achieve additional nutrient removal, nitrification of the influent ammonia to levels of less than 3 mg/l will be required.

This alternative proposes to improve the oxygen transfer and mixing by modifying/replacing the diffused aeration system to improve oxygen transfer efficiency and mixing. Additional improvements to influent and effluent feed points should be evaluated.

Benefits

- Improved Aeration Basins Treatment Efficiency
- Full Nitrification of the Influent Ammonia
- Improved Aeration System Oxygen Transfer Efficiency
- Improved Aeration Basin Mixing

Required Improvements

- Modeling the aeration basins for mixing and diffused aeration
- Replacing existing diffused aeration system

Capital Costs

- CFD Modeling for the aeration basins - $
- Replacing existing diffused aeration system - $

Operations Impacts and Cost

- Improved Oxygen Transfer Efficiency and Lower Power Costs
- Increased Nitrification Oxygen Requirements
- Increased Nitrates Concentration
- Increased Alkalinity Demand

NUTRIENT REMOVAL ALTERNATIVES

Alternative No. 1 – Convert the Existing Process from Single Stage Aeration to a Two Stage Anoxic/Aeration Basin Process Utilizing Sludge Tank No. 1

Description

Modify and expand the existing aeration basins system to a Two Stage Anoxic/Aeration Basin Process. The new two stage system will require additional treatment volume. Additional treatment volume can be provided by re-purposing the existing aerobic digester/sludge holding tank that is directly connected to the west of the existing aeration basin. The existing sludge tank has an approximate volume of 0.5 MG. The preliminary process modifications and tank volumes are:

- Anoxic Basin – 0.3 MG
- Aeration Basin – 1.0 MG
- Internal Recycle Pumps – 3Q (13.5 GMD)

Additional modifications that would need to be evaluated include changing the influent and effluent points to introduce flow at a single point at the head of the basins and evaluating alternate operating scenarios such as step feed and/or sequenced aeration.

Benefits

- Improved Aeration Basins Treatment Efficiency
- Full Nitrification of the Influent Ammonia
- Improved Aeration System Oxygen Transfer Efficiency
- Improved Aeration Basin Mixing
- Potential to reduce TN to less than 10 mg/l at design capacity of 4.5 MGD. TP Requires Chemicals

Required Improvements

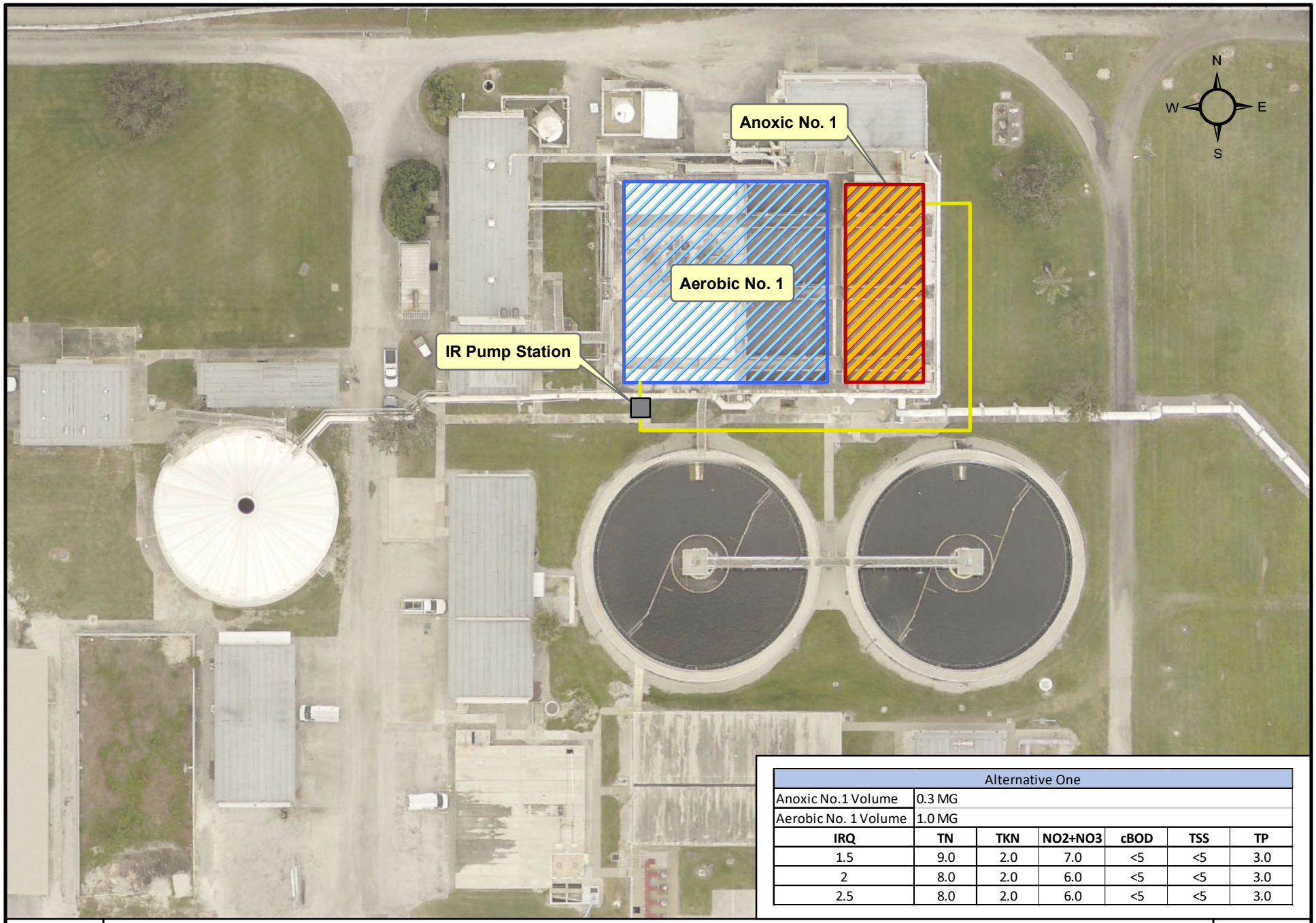
- Modeling the aeration basins for mixing and diffused aeration
- Replacing existing diffused aeration system
- Modifying the existing aeration system to a two-stage system
- Adding Anoxic Mixers
- New Internal Recycle Pump Station
- Changes to influent and effluent piping configuration

Capital Costs

- Modifying the aeration system to a two-stage system - $$

Operations Impacts and Cost

- Improved Oxygen Transfer Efficiency
- Increased Nitrification Oxygen Requirements
- Increased Denitrification Oxygen Credit
- Additional Pumping Costs for IR
- Improved Settleability of the Mixed Liquor and Clarifier Performance
- Provides more stable alkalinity
- More Stable Disinfection System Operation and Reduced Chlorine Demand
- Additional Sludge if TP Removed by Chemicals



Alternative One						
Anoxic No.1 Volume	0.3 MG					
Aerobic No. 1 Volume	1.0 MG					
IRQ	TN	TKN	NO2+NO3	cBOD	TSS	TP
1.5	9.0	2.0	7.0	<5	<5	3.0
2	8.0	2.0	6.0	<5	<5	3.0
2.5	8.0	2.0	6.0	<5	<5	3.0

City of Vero Beach WWTP Nutrient Management Study
Process Alternative No. 1

FIGURE 1

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Alternative No. 2 – Convert the Existing Process from Single Stage Aeration to a Two Stage Anoxic/Aeration Basin Process Utilizing Sludge Tank No. 1 and No. 2

Modify and expand the existing aeration basins system to a Two Stage Anoxic/Aeration Basin Process. The new two stage system will require additional treatment volume. Additional treatment volume can be provided by re-purposing the existing aerobic digester/sludge holding tanks No. 1 and 2. Sludge Tank No. 1 has a volume of approximately 0.5 MG and is directly connected to the west of the existing aeration basin. The existing Sludge Tank No. 2 would require re-pumping of the aeration basin contents or the raw sewage to the tank, adding additional pumps and costs. Existing Sludge Tank No. 2 has an approximate volume of 0.65 MG. The preliminary process modifications and tank volumes are:

- Anoxic Basin – 0.5 MG
- Aeration Basin – 1.3 MG
- Internal Recycle Pumps – 3Q (13.5 GMD)
- Sludge Tank No. 2 Pump System

Additional modifications that would need to be evaluated include changing the influent and effluent weirs on the aeration basins to introduce flow at a single point at the head of the basins and evaluating alternate operating scenarios such as step feed and/or phased sequenced aeration.

Benefits

- Improved Aeration Basins Treatment Efficiency
- Full Nitrification of the Influent Ammonia
- Improved Aeration System Oxygen Transfer Efficiency
- Improved Aeration Basin Mixing
- Potential to reduce TN to less than 10 mg/l at design capacity of 4.5 MGD
- Tankage Available for BioP Removal

Required Improvements

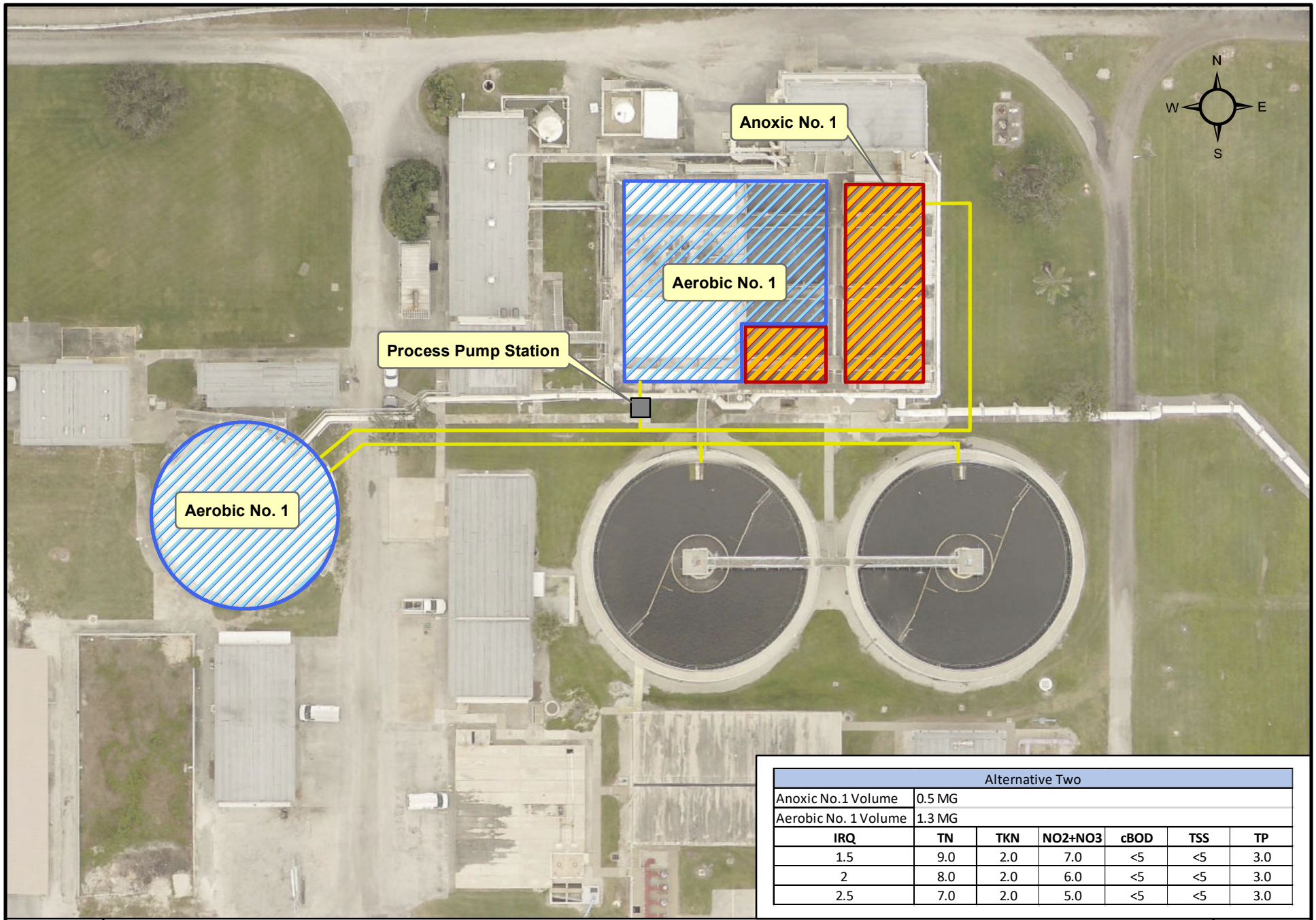
- Modeling the Aeration Basins for Mixing and Diffused Aeration
- Replacing existing Diffused Aeration System
- Modifying the existing Aeration System to a Two Stage System
- Add Anoxic Mixers
- New Internal Recycle and Sludge Tank No. 2 Pump Stations
- Changes to influent and effluent piping configuration
- Modifying Sludge Tank No. 2 to a process basin
- Add Anaerobic Basin if BioP removal is added, additional sludge if TP removed by chemicals
- Significant process piping Improvements

Capital Costs

- Modifying the aeration system to a two-stage system - $$+

Operations Impacts and Cost

- Improved Oxygen Transfer Efficiency
- Increased Nitrification Oxygen Requirements
- Increased Denitrifications Oxygen Credit
- Additional Pumping Costs for IR
- Improved settleability of the Mixed Liquor and Clarifiers Performance
- Provides more stable alkalinity
- More Stable Disinfection System Operations and Reduced Chlorine Demand
- Additional Sludge if TP removed by chemicals



Alternative Two						
Anoxic No.1 Volume	0.5 MG					
Aerobic No. 1 Volume	1.3 MG					
IRQ	TN	TKN	NO2+NO3	cBOD	TSS	TP
1.5	9.0	2.0	7.0	<5	<5	3.0
2	8.0	2.0	6.0	<5	<5	3.0
2.5	7.0	2.0	5.0	<5	<5	3.0

City of Vero Beach WWTP Nutrient Management Study
Process Alternative No. 2

FIGURE 2

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Alternative No. 3 – Convert the Existing Process from Single Stage Aeration to a Four Stage Nutrient Treatment Process Utilizing Sludge Tank No. 1 and No. 2

Description

Modify and expand the existing aeration basins to a Four Stage Anoxic/Aeration/Anoxic/Reaeration Basin Process. The new four stage system will require additional treatment volume. Additional treatment volume can be provided by re-purposing the existing aerobic digester/sludge holding tanks No. 1 and 2. Sludge Tank No. 1 has a volume of approximately 0.5 MG and is directly connected to the west of the existing aeration basin. The existing Sludge Tank No. 2 would require re-pumping of the aeration basin contents or the raw sewage to the tank, adding additional pumps and costs. Existing Sludge Tank No. 2 has an approximately volume of 0.65 MG. The preliminary process modifications and tank volumes are:

- Anoxic Basin – 0.3 MG
- Aeration Basin – 1.3 MG
- Internal Recycle Pumps – 3Q (13.5 MGD)
- Second Anoxic Tank - 0.5 MG
- Reaeration Tank – 0.15 MG
- Second Anoxic Tank Pump System – 5.5 MGD

Additional modifications that would need to be evaluated include changing the influent and effluent weirs on the aeration basins to introduce flow at a single point at the head of the basins and evaluating alternate operating scenarios such as step feed and/or phased sequenced aeration.

Benefits

- Improved Aeration Basins Treatment Efficiency
- Full Nitrification of the Influent Ammonia
- Improved Aeration System Oxygen Transfer Efficiency
- Improved Aeration Basin Mixing
- Potential to reduce TN less than 5 mg/l at design capacity of 4.5 MGD

Required Improvements

- Modeling the aeration basins for mixing and diffused aeration
- Replacing existing diffused aeration system
- Modifying the existing aeration system to a four-stage system
- Modifying Sludge Tank No. 2 to a Second Anoxic Tank
- Adding Anoxic Mixers
- New Internal Recycle Pump Station
- New Second Anoxic Pump Station
- Chemical addition system for TP removal

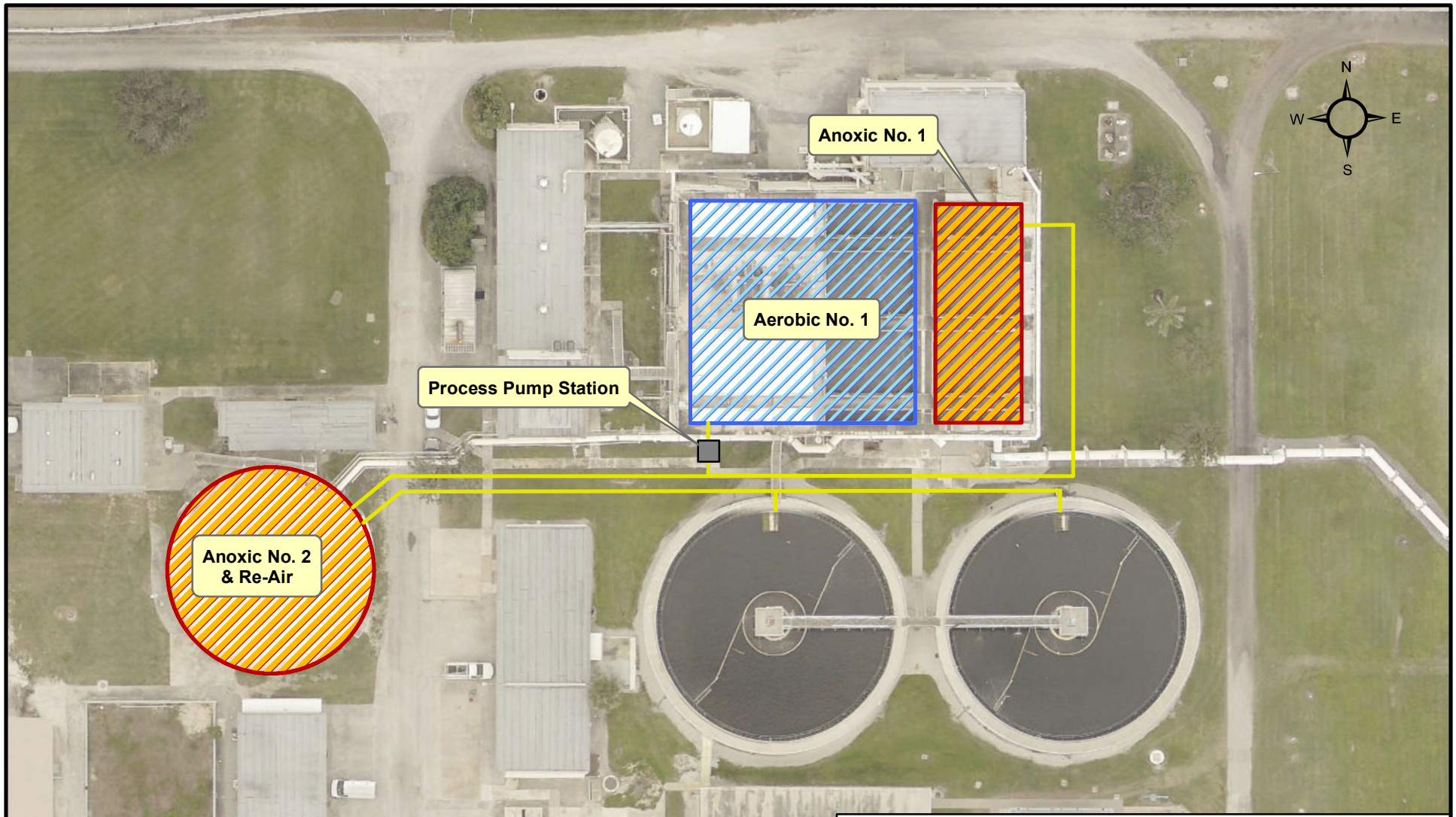
- Changes to influent and effluent piping configuration
- Significant Process Piping Improvements

Capital Costs

- Modifying the aeration system to a four-stage system - $$+

Operations Impacts and Cost

- Improved Oxygen Transfer Efficiency
- Increase Nitrification Oxygen Requirements
- Increases Denitrification Oxygen Credit
- Additional Pumping Costs for IR
- Additional sludge if TP removal by chemicals
- Improved settleability of the Mixed Liquor and Clarifier Performance
- Provides more stable alkalinity
- More Stable Disinfection System Operation and Reduced Chlorine Demand



Alternative Three						
Anoxic No.1 Volume	0.3 MG					
Aerobic No. 1 Volume	1.0 MG					
Anoxic No. 2 Volume	0.5 MG					
IRQ	**TN**	**TKN**	**NO2+NO3**	**cBOD**	**TSS**	**TP**
1.5	5.0	3.0	2.0	<5	<5	3.0
2	4.0	3.0	1.0	<5	<5	3.0
2.5	4.0	3.0	1.0	<5	<5	3.0

City of Vero Beach WWTP Nutrient Management Study
Process Alternative No. 3

FIGURE 3

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Alternative No. 4 – Convert the Existing Process from Single Stage Aeration to a Two Stage Anoxic/Aeration Basin Process and Replacing a Portion of the DynaSand® Filters with Denitrification Deep Bed Filters Utilizing Sludge Tank No. 1

Description

Modify and expand the existing aeration basins system to a Two Stage Anoxic/Aeration Basin Process and replacing a portion of the existing DynaSand® filters with new denitrification filter. The remaining DynaSand® filter (those not replaces with denitrification filters) would be replaced with new Disk Filters. The new two stage system will require additional treatment volume. Additional treatment volume can be provided by re-purposing the existing aerobic digester/sludge holding tank that is directly connected to the west of the existing aeration basin. The existing sludge tank has an approximate volume of 0.5 MG. The preliminary process modifications and tank volumes are:

- Anoxic Basin – 0.3 MG
- Aeration Basin – 1.0 MG
- Internal Recycle Pumps – 3Q (13.5 GMD)
- Deep Bed Filters - 3.2 MGD (900 – 1,000 square feet of filters at 2.5 gpm/sf loading)

Additional modifications that would need to be evaluated include changing the influent and effluent points to introduce flow at a single point at the head of the basins and evaluating alternate operating scenarios such as step feed and/or sequenced aeration.

Benefits

- Improved Aeration Basin Treatment Efficiency
- Full Nitrification of the Influent Ammonia
- Improved Aeration System Oxygen Transfer Efficiency
- Improved Aeration Basin Mixing
- Potential to reduce TN to less than 5 mg/l at design capacity of 4.5 MGD

Required Improvements

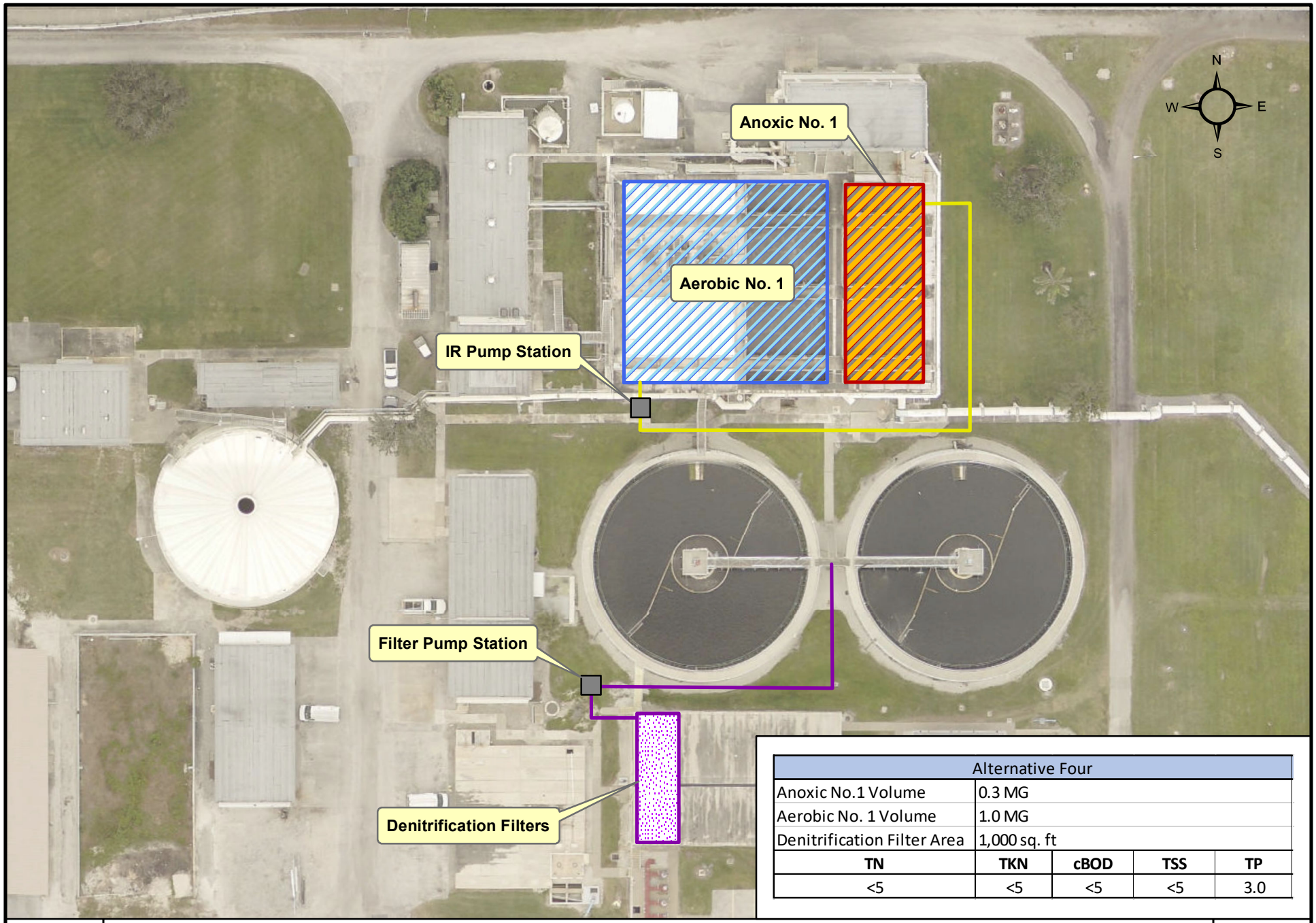
- Modeling the aeration basins for mixing and diffused aeration
- Replacing existing diffused aeration system
- Modifying the existing aeration system to a two-stage system
- Adding Anoxic Mixers
- New Internal Recycle Pump Station
- Addition of chemical feed system for TP removal
- Changes to influent and effluent piping configuration
- New Deep Bed Filter Pump Station
- New Deep Bed Denitrification Filters
- Methanol or other Carbon Source Chemical Feed System

Capital Costs

- Modifying aeration system to a two-stage system and New Deep Bed Filters - $$+

Operations Impacts and Cost

- Improved Oxygen Transfer Efficiency
- Increase Nitrification Oxygen Requirements
- Increases Denitrification Oxygen Credit
- Improved settleability of the Mixed Liquor and Clarifier Performance
- Additional Pumping Costs for IR and Filter Pump Stations
- Additional sludge if TP removal by chemicals
- Provides more stable alkalinity
- More Stable Disinfection System Operation and Reduced Chlorine Demand



Alternative Four				
Anoxic No.1 Volume	0.3 MG			
Aerobic No. 1 Volume	1.0 MG			
Denitrification Filter Area	1,000 sq. ft			
TN	**TKN**	**cBOD**	**TSS**	**TP**
<5	<5	<5	<5	3.0

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Process Alternative No. 4

FIGURE 4

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Alternative No. 5 – Convert the Existing Process from Single Stage Aeration to a Multi-Stage Anoxic/Aeration Basin Process Membrane Bioreactor System Utilizing Sludge Tank No. 1

Description

Modify and expand the existing aeration basins system to a Multi-Stage Anoxic/Aeration Basin Process, adding membranes and sequencing operations of the aeration basins to achieve nutrient removal. The new multi-stage system will require additional treatment volume. Additional treatment volume can be provided by re-purposing the existing aerobic digester/sludge holding tank that is directly connected to the west of the existing aeration basin. The clarifiers would be modified to operate as equalization basins. The headworks screening system would need to be modified to provide fine screening of the raw wastewater.

Additional modifications that would need to be evaluated include changing the influent and effluent points to introduce flow at a single point at the head of the basins and evaluating alternate operating scenarios such as step feed and/or sequenced aeration.

Benefits

- Full Nitrification of the Influent Ammonia
- Advanced Treatment
- Elimination of Clarifiers
- Potential to reduce TN to less than 5 mg/l at design capacity of 4.5 MGD
- TP reduction by BioP may be an option

Required Improvements

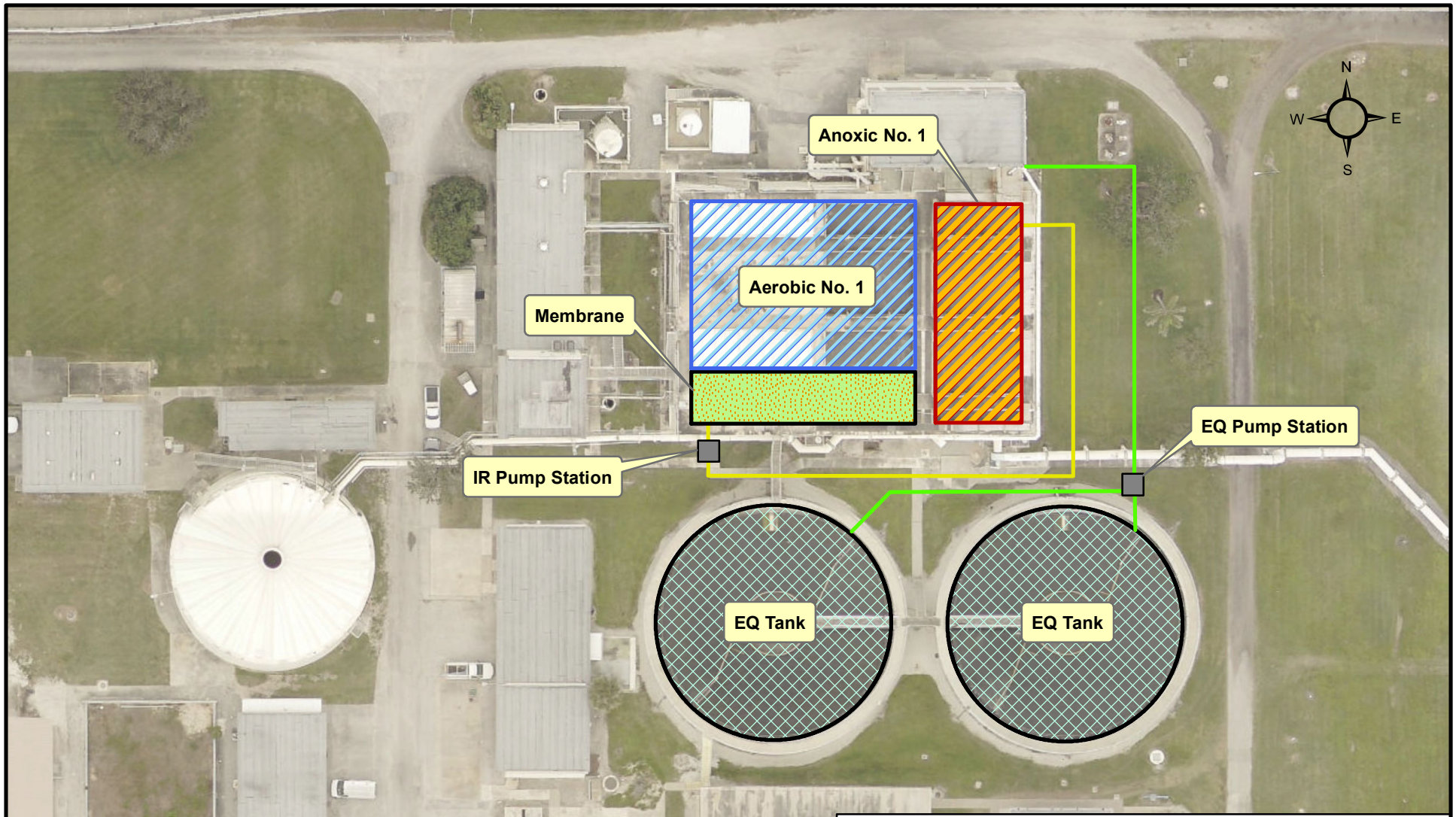
- New Fine Screening System and New Headworks Building
- Modeling the aeration basins for mixing and diffused aeration
- Replacing existing diffused aeration system
- Membrane Treatment System
- Process Monitoring and Control Systems for Sequenced Operations
- Adding Anoxic Mixers
- New Internal Recycle Pump Station
- Changes to influent and effluent piping configuration
- Chemical Cleaning System
- New EQ Pump Station
- Modify existing Clarifiers as EQ Tanks

Capital Costs

- Construction of the New Headworks, EQ Filters - $$$

Operations Impacts and Cost

- Operating and Maintenance of Membrane System
- Chemical Costs
- Increased Nitrification Oxygen Requirements
- Increased Denitrification Oxygen Credit
- Eliminates Clarifiers
- Additional Pumping Costs for IR and EQ Pump Stations
- More Stable Disinfection System Operation and Reduced Chlorine Demand



Alternative Five				
Anoxic No.1 Volume	0.3 MG			
Aerobic No. 1 Volume	1.0 MG			
TN	**TKN**	**cBOD**	**TSS**	**TP**
<5	<5	<5	<5	<3

City of Vero Beach WWTP Nutrient Management Study
Process Alternative No. 5

FIGURE 5

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Alternative No. 6 – Convert the Existing Process from Single Stage Aeration to a Multi-Stage Anoxic/Aeration Basin Process Using Suspended Growth Membrane Bioreactor System or Granular Sludge Bioreactor System Utilizing Sludge Tank No. 1

Description

Modify and expand the existing aeration basins system to a Multi-Stage Anoxic/Aeration Basin Process, adding Integrated Fixed Film Activated Sludge (IFAS) or Aerobic Granular Sludge biological treatment technologies. Operations would be sequenced to achieve nutrient removal. The new multi-stage system will require additional treatment volume. Additional treatment volume can be provided by re-purposing the existing aerobic digester/sludge holding tank that is directly connected to the west of the existing aeration basin. The clarifiers would be modified to operate as needed for the treatment system. Elimination of the clarifiers can be accomplished if aerobic granular sludge treatment systems are employed. The headworks screening system may need to be modified to provide fine screening of the raw wastewater. Screening of RAS may improve process performance and operations.

Additional modifications that would need to be evaluated include changing the influent and effluent points to introduce flow at a single point at the head of the basins and evaluating alternate operating scenarios such as step feed and/or sequenced aeration.

Benefits

- Full Nitrification of the Influent Ammonia
- Advanced Treatment
- Elimination of Clarifiers for some of the processes
- Potential to reduce TN to less than 5 mg/l at design capacity of 4.5 MGD
- TP reduction by BioP may be an option. If not, TP by chemicals may be needed

Required Improvements

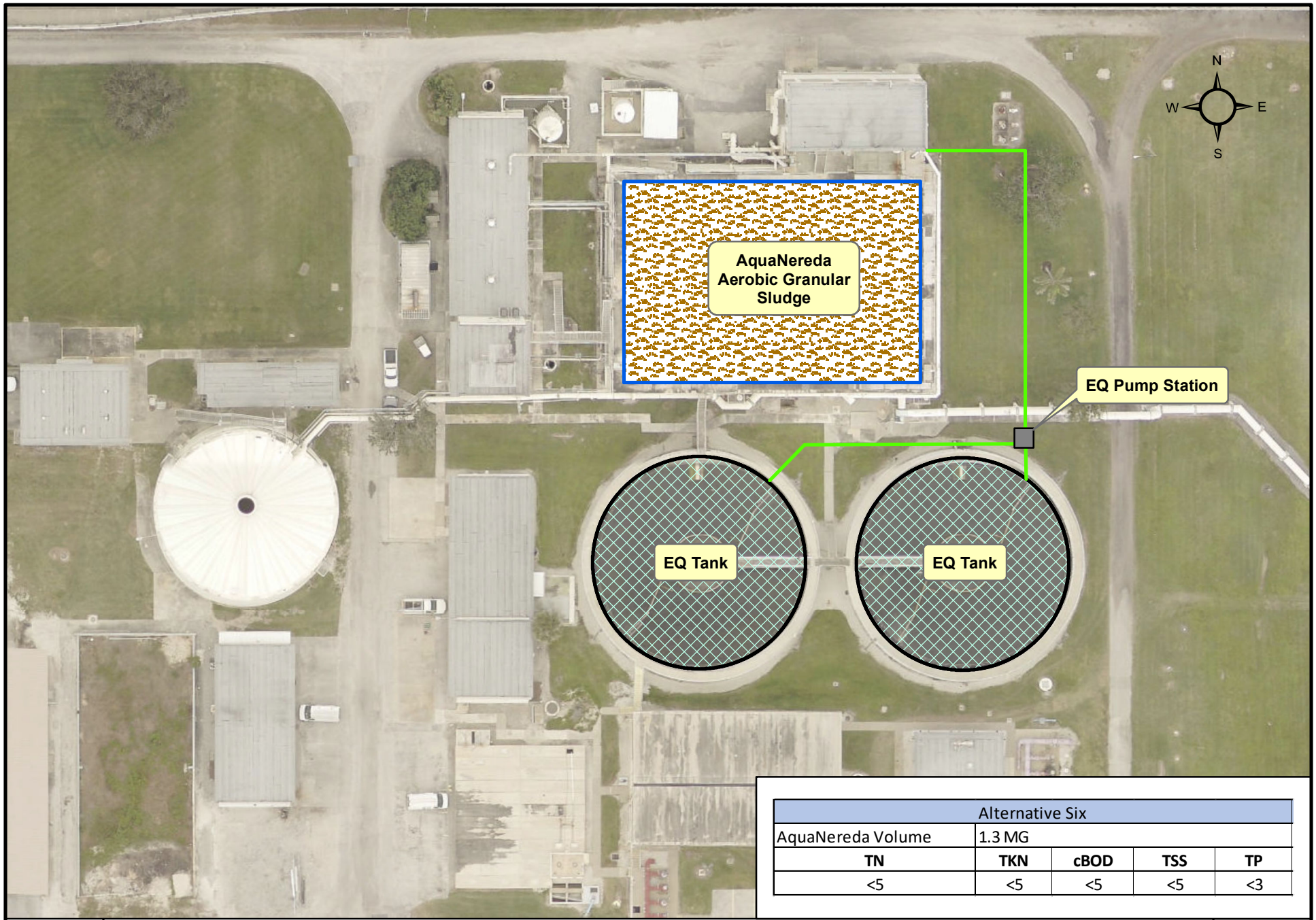
- New Fine Screening System
- New aeration system for mixing and diffused aeration
- Fixed Film or Granular Treatment System Retrofits
- Process Monitoring and Control Systems for Sequenced Operations
- Add Anoxic Mixers
- New Internal Recycle Pump Station may be required for some systems
- Changes to influent and effluent piping configuration

Capital Costs

- Construction of the New Headworks and Suspended Growth Systems $$ to $$$

Operations Impacts and Cost

- Operating and Maintenance of Membrane System
- Increase Nitrification Oxygen Requirements
- Increases Denitrification Oxygen Credit
- Eliminates Clarifiers in some cases
- Additional Pumping Costs for IR
- More Stable Disinfection System Operation and Reduced Chlorine Demand



Alternative Six				
AquaNereda Volume	1.3 MG			
TN	**TKN**	**cBOD**	**TSS**	**TP**
<5	<5	<5	<5	<3

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FIGURE 6a

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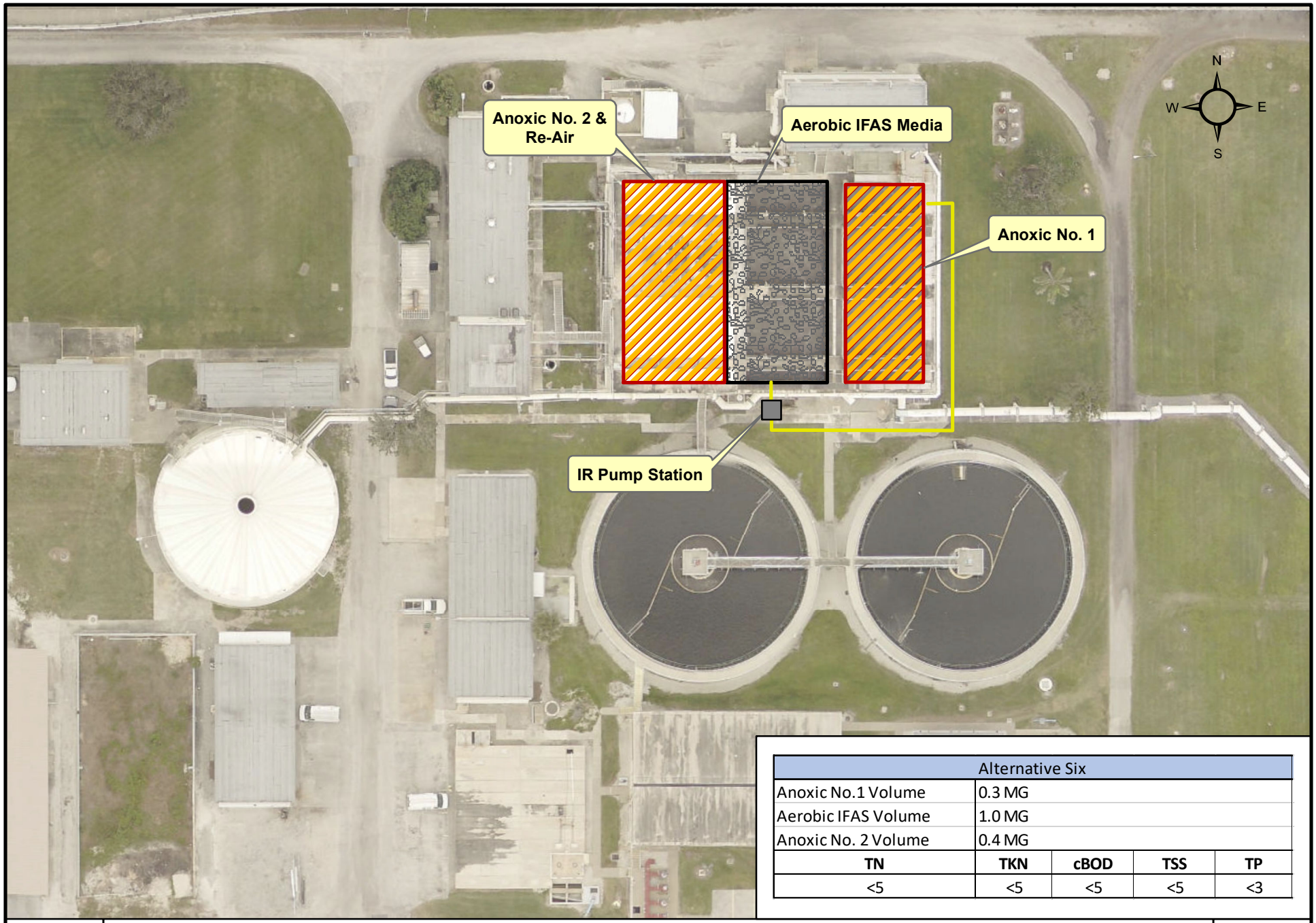

Alternative Six				
Anoxic No.1 Volume	0.3 MG			
Aerobic IFAS Volume	1.0 MG			
Anoxic No. 2 Volume	0.4 MG			
TN	**TKN**	**cBOD**	**TSS**	**TP**
<5	<5	<5	<5	<3

City of Vero Beach WWTP Nutrient Management Study
Process Alternative No. 6b

FIGURE 6b

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