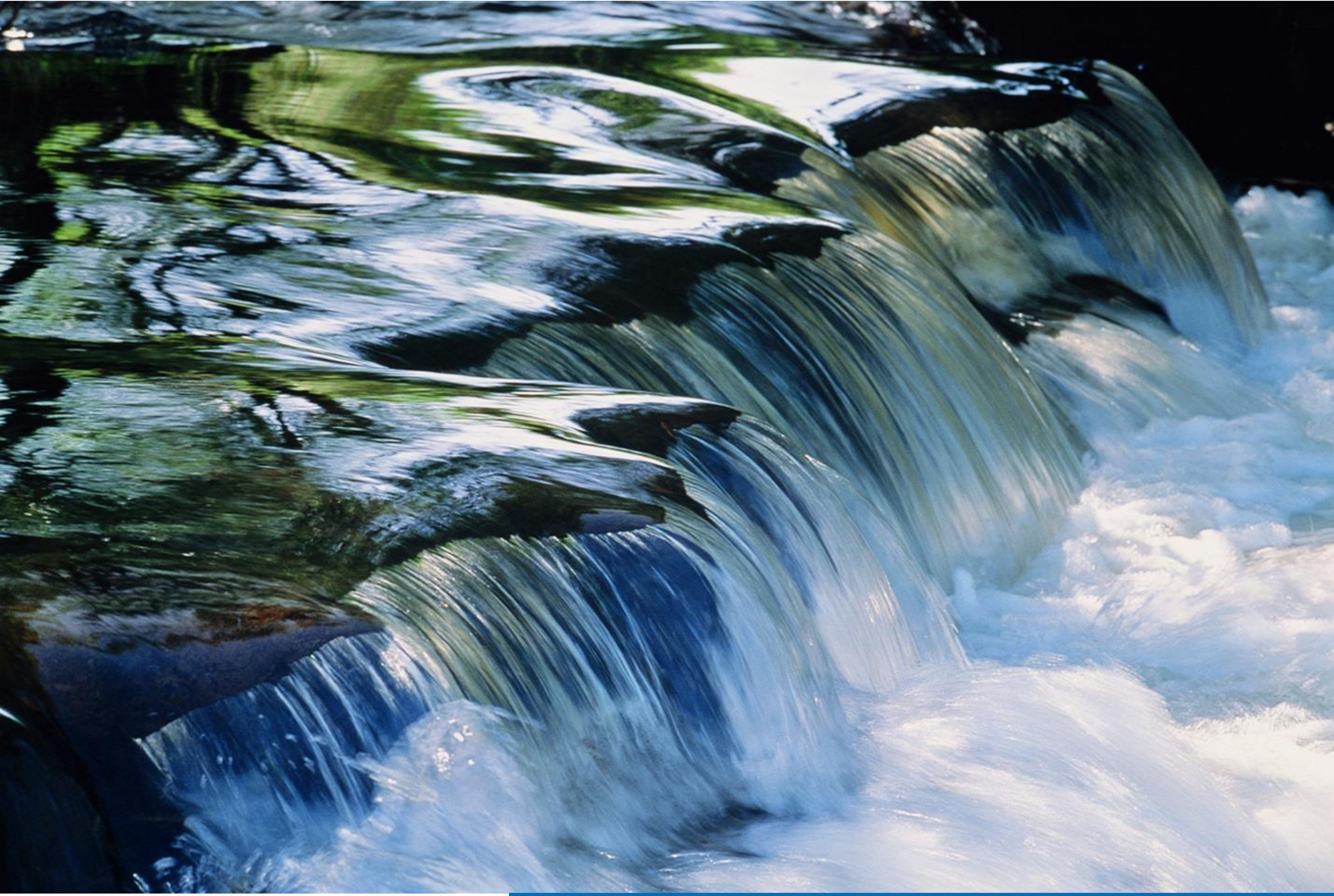

Metropolitan Water Reclamation District of
Greater Chicago
Phosphorus Removal Feasibility Study

Technical Memorandum A.1
PHOSPHORUS REMOVAL OPTIMIZATION OPPORTUNITIES FOR THE KIRIE WATER RECLAMATION PLANT

April 2022

Illinois Design Firm Professional
Registration No. 184.006021

Metropolitan Water Reclamation District of Greater Chicago
Phosphorus Removal Feasibility Study

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April 2022

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Abbreviations

AADF	Annual Average Day Flow
AADL	Annual Average Day Load
AOB	Ammonia Oxidizing Bacteria
ADM 1	Anaerobic Digestion Model No. 1
ASM 2D	Activated Sludge Model No. 2d
Bio P	Biological Phosphorus Removal
BOD	Biological Oxygen Demand
BOD_5	5 Day Biological Oxygen Demand
BNR	Biological Nutrient Removal
COD	Chemical Oxygen Demand
Chem P	Chemical Phosphorus Removal
Carollo	Carollo Engineers, Inc.
CUP	Chicagoland Underflow Plan
D	Depth
DO	Dissolved Oxygen
DAF	Design Average Flow
deg. C	Degrees Celsius
Dia.	Diameter
District	Metropolitan Water Reclamation District of Greater Chicago
DMF	Design Maximum Flow
ft	Feet
FRP	Fiberglass Reinforced Plastic
GAOs	Glycogen Accumulating Organisms
GPS-X	Process simulation model used to predict WRP performance
gpm	Gallons Per Minute
gph	Gallons Per Hour
gpd	Gallons Per Day
H	Height
hp	Horsepower
HRT	hydraulic retention time
IEPA	Illinois Environmental Protection Agency
in.	Inches
IWD	Industrial Waste Division
L	Length
LCIUs	Large Commercial-Industrial Users
M&O	Maintenance and Operations
mgd	Million Gallons Per Day

mg/L	Milligrams Per Liter
mL/g	Milliliters Per Gram
MLSS	Mixed Liquor Suspended Solids
MMADF	Maximum Month Average Day Flow
MMADL	Maximum Month Average Day Load
mV	Millivolt
NAS	Nitrifying Activated Sludge
NH_3-N	Ammonia Nitrogen
NO_3	Nitrate
NPDES	National Pollutant Discharge Elimination System
O&M	Operation and Maintenance
P	Phosphorus
PHA	Polyhydroxyalkanoate
PAO	Polyphosphate Accumulating Organism
ORP	Oxidization Reduction Potential
RAS	Return Activated Sludge
scfm	Standard Cubic Feet per Minute
SIC	Standard Industrial Classification
SRT	Solids Retention Time
SPA	State Point Analysis
SVI	Sludge Volume Index
TARP	Tunnel and Reservoir Plan
TDH	Total Dynamic Head
TKN	Total Kjeldahl Nitrogen
TM	Technical Memorandum
TP	Total Phosphorus
TSS	Total Suspended Solids
USEPA	United States Environmental Protection Agency
VFAs	Volatile Fatty Acids
W	Width
WAS	Waste Activated Sludge
WRP	Water Reclamation Plant

Technical Memorandum A.1

PHOSPHORUS REMOVAL OPTIMIZATION OPPORTUNITIES FOR THE KIRIE WATER RECLAMATION PLANT

A.1.1 Introduction

The Metropolitan Water Reclamation District of Greater Chicago (District) is an independent government and taxing body, encompassing 91 percent of the land area and 98 percent of the assessed valuation of Cook County, Illinois. The District owns and operates seven water reclamation plants (WRPs). The District treats an average of 1.4 billion gallons of wastewater each day with a total wastewater treatment capacity of 2.0 billion gallons per day (gpd). Figure A.1.1 gives an overview of the District's service area and seven WRPs.

The District has recently received a total phosphorus (TP) concentration limit of 1.0 milligrams per liter (mg/L) as a monthly average with associated load limits in the newly reissued National Pollutant Discharge Elimination System (NPDES) permits for the Kirie and Egan WRPs. The District retained Carollo Engineers, Inc. (Carollo) to prepare phosphorus (P) removal optimization plans and P removal feasibility studies for the Kirie and Egan WRPs (Groups A and B, 16-RFP-21).

The Phosphorus Removal Feasibility Study at the Kirie WRP (Group A) and Egan WRP (Group B) was conducted in two main engineering tasks. Task 1 evaluated P removal optimization opportunities with the primary goal of predicting effluent P concentrations through optimized use of the existing facilities with reasonable operational adjustments and minor facility modifications. Task 2 evaluated the recommended facility improvements, estimated capital costs, and estimated operation and maintenance (O&M) costs to meet potential NPDES permit effluent TP limits of 1.0 mg/L, 0.5 mg/L, and 0.1 mg/L.

The purpose of Technical Memorandum (TM) A.1 is to summarize the P removal optimization opportunities at the Kirie WRP (Group A, Task 1). Analysis of the anticipated effluent P concentrations resulting from operational adjustments for P removal optimization are presented in TM A.1.

Subsequent TMs will summarize the P removal optimization strategies for the Egan WRP (TM B.1), and P removal feasibility studies for the Kirie and Egan WRPs (TM A.2 and TM B.2).

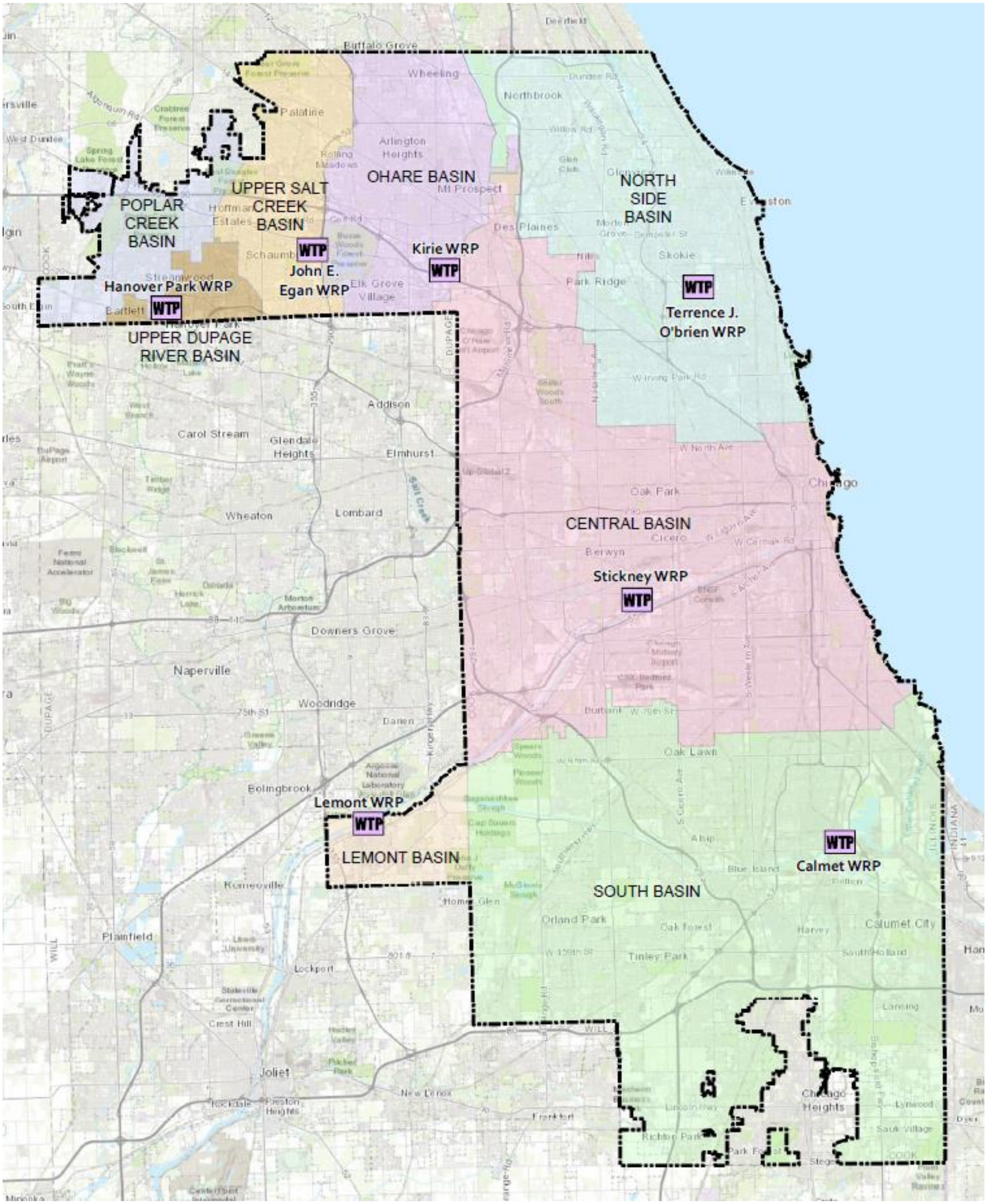

Figure A.1.1 Overview of the District's Service Area and Seven WRPs

TM A.1 is organized into 8 sections, structured as follows:

Section A.1.1 describes the purpose, basis of optimization, and objectives of this TM.

Section A.1.2 provides a background of the existing facility and summarizes findings of previous P removal testing conducted at the Kirie WRP.

Section A.1.3 evaluates the potential for capital and O&M cost savings due to influent P reduction through source control of tributary industrial dischargers.

Section A.1.4 describes the design criteria for biological phosphorus removal (Bio P) and provides an overview of the GPS-X process simulation modeling conducted to predict facility performance.

Section A.1.5 discusses the potential for implementation of Bio P while maintaining complete nitrification in the existing Kirie WRP as required to comply with current effluent ammonia NPDES permit limits.

Section A.1.6 describes optimization and control techniques to support efficient and effective Bio P.

Section A.1.7 discusses the potential unintended consequences of Bio P optimization.

Section A.1.8 summarizes the conclusions and recommendations of the P removal optimization analysis for Kirie WRP.

A.1.1.1 Purpose and Basis of P Removal Optimization Analysis

The newly reissued NPDES permit for the Kirie WRP requires a Phosphorus Removal Feasibility Study, which is consistent with the requirements in renewed permits for municipal dischargers throughout the State of Illinois. The basic scope elements of the Phosphorus Removal Feasibility Study as required in the NPDES permit are:

- P source reduction assessment.
- P removal optimization opportunities analysis.
- P feasibility study to identify facilities and costs required to meet numeric permit limits for effluent TP of 1.0 mg/L, 0.5 mg/L, and 0.1 mg/L on a monthly, seasonal, and annual average basis.

As part of the optimization analysis portion of the Phosphorus Removal Feasibility Study, the NPDES permit calls for evaluation of specific phosphorus reduction measures, both for the influent and effluent, under Special Condition 24. The influent reduction measures are as follows, which were evaluated and discussed as part of Section A.1.3:

- Evaluate the phosphorus reduction potential of users.
- Determine which sources have the greatest opportunity for reducing phosphorus (e.g., industrial, commercial, institutional, municipal, and others).
  - Determine whether known sources (e.g., restaurant and food preparation) can adopt phosphorus minimization and water conservation plans.
  - Evaluate implementation of local limits on influent sources of excessive phosphorus.

The effluent reduction measures include the following, which were evaluated, where applicable:

- Adjust the solids retention time (SRT) for either nitrification, denitrification, or Bio P.
  - See discussion herein (Section A.1.5) for an evaluation of SRT and available aeration tank capacity to achieve full nitrification, while converting some portion to anaerobic to promote Bio P according to process simulation modeling.
- Adjust aeration rates to reduce dissolved oxygen and promote simultaneous nitrification-denitrification.
  - This reduction measure was not specifically evaluated due to the results of full-scale testing in combination with process modeling which demonstrated that simultaneous nitrification-denitrification is not necessary for Bio P.
- Add baffles to existing units to improve microorganism conditions by creating divided anaerobic, anoxic, and aerobic zones.
  - See discussion herein (Section A.1.6) for an evaluation of the impact of baffles and in turn, defined zones on promoting Bio P and their level of necessity.
- Change aeration settings in plug flow basins by turning off air or mixers at the inlet side of the basin system.
  - See discussion herein (Section A.1.5) for an evaluation of the impact of strategically cutting off aeration air to portions of the aeration tanks on promoting Bio P according to full-scale testing results.
- Minimize the impact on recycle streams by improving aeration within holding tanks.
  - This reduction measure was not specifically evaluated as Kirie WRPbiosolids are sent offsite and handled at Egan WRP. As a result, no recycle streams are handled at Kirie WRP.
- Reconfigure flow through existing basins to enhance biological nutrient removal.
  - This reduction measure was not specifically evaluated due to full-scale testing demonstrating that the existing flow path is acceptable to support Bio P and does not require adjustment.
- Increase VFAs for Bio P.
  - See discussion herein (Section A.1.5) for an evaluation of the historical influent Carbon:TP ratio and its sufficiency to support Bio P.

In addition to satisfying the NPDES requirement to prepare a Phosphorus Removal Feasibility Study, the District wishes to assess the required modifications and costs associated with increasingly more stringent numeric limits for TP. Understanding the required plant modifications and the costs associated with optimization and compliance over a range of numeric effluent TP limits allows the District to better plan for and manage potential future impacts. The District also seeks to understand the ramifications of unintended consequences of P removal.

A.1.1.1.1 Optimization of Existing Facilities

For purposes of this TM, optimization has been defined as the anticipated effluent TP removal that can be achieved using the existing Kirie WRP processes and equipment through operational adjustments and minor facility modifications. Simply put; optimization suggests the District will do the best it can with what it has at the Kirie WRP. Therefore, optimization strategies are focused on the Bio P process generally consistent with the current WRP operations.

Chemical phosphorus removal (Chem P) was not considered for optimization because there are no numeric TP limits being targeted as part of the optimization measures; effluent P reduction is only a goal. As Chem P will increase the cost of treatment it is evaluated only as part of the feasibility study where Bio P is incapable of reaching the anticipated numeric limits or as required for treatment of peak flows and loads or for process reliability and redundancy. Similarly, high-rate treatment processes and other methods that require significant capital improvement or will significantly increase O&M costs were not evaluated as part of optimization.

A.1.1.1.2 Optimization at Existing Flows and Loads

The design average flow (DAF) of the Kirie WRP is 52.0 million gallons per day (mgd). An optimization analysis was performed at the current average annual day flow (AADF) of 35.8 mgd. Current flows as opposed to design flows were used in the optimization analysis because significant additional future flow is not anticipated at Kirie WRP in the near term.

A.1.1.1.3 Optimization to Achieve Approximately 1.0 mg/L TP

In general, with the appropriate influent wastewater characteristics and plant configuration, Carollo often finds that existing biological nutrient removal (BNR) activated sludge plants designed for nitrification can achieve a 30-day average effluent TP of approximately 1.0 mg/L through operational optimization of Bio P. Therefore, the optimization strategies in this TM were developed with a goal of approximately 1.0 mg/L TP in mind. Under some operational conditions the optimized plant may perform better than 1.0 mg/L effluent TP and under some operational conditions the optimized plant may exceed 1.0 mg/L effluent TP.

A.1.1.2 Specific Objectives

The specific objectives of this TM are to:

- Evaluate the potential impact of influent P reduction measures for industrial dischargers contributing to the Kirie WRP.
- Evaluate operational adjustments and minor facility modifications to optimize effluent P removal using existing processes and equipment at the Kirie WRP.
- Evaluate potential unintended consequences associated with P removal optimization at the Kirie WRP.

A.1.2 Background

The following sections provide a summary of the existing Kirie WRP, review of Bio P testing at the Kirie WRP, and effluent TP performance before and after Bio P testing.

A.1.2.1 Summary of Existing Kirie WRP

NPDES Permit No. IL0047741, Kirie WRP establishes a DAF of 52.0 mgd and design maximum flow (DMF) of 110 mgd. Figure A.1.2 illustrates the process flow diagram for the Kirie WRP. The unit processes at Kirie WRP include:

- Primary Screening (Debris Baskets, Coarse Screens, Fine Screens).
- Grit Removal.
- 1st Stage Aeration.
- 1st Stage Settling.
- 2nd Stage Aeration (currently operated as pass-through).
- 2nd Stage Settling.
- Tertiary Filtration.
- Disinfection.
- Post-Aeration.

The Kirie WRP was designed as a two-stage nitrification facility with the 1st stage activated sludge aeration tanks and clarifiers (Battery A) configured for 5 Day Biological Oxygen Demand (BOD_5) removal and the 2nd stage activated sludge aeration tanks and clarifiers (Battery B) configured for nitrification. At present, the 2nd stage aeration tanks (Battery B) at the Kirie WRP are not operated as aeration basins, as both BOD_5 removal and nitrification to meet the respective permit limits are accomplished in the 1st stage aeration tanks via SRT management. Therefore, the 2nd stage aeration tanks are used to convey the secondary effluent from Battery A to the 2nd stage settling tanks for additional polishing. Historically, the polished secondary effluent has met the effluent total suspended solids (TSS) criteria. Therefore, the tertiary filters at the Kirie WRP are no longer in service, and the flow is bypassed directly to the disinfection/post-aeration facility. Treated effluent is discharged to Higgins Creek. Waste activated sludge (WAS) is transported via a dedicated pipeline for processing at the Egan WRP.

The aeration tanks in both Battery A and Battery B are configured as 3 pass aeration basins originally designed for BOD_5 removal and nitrification with all three passes aerated.

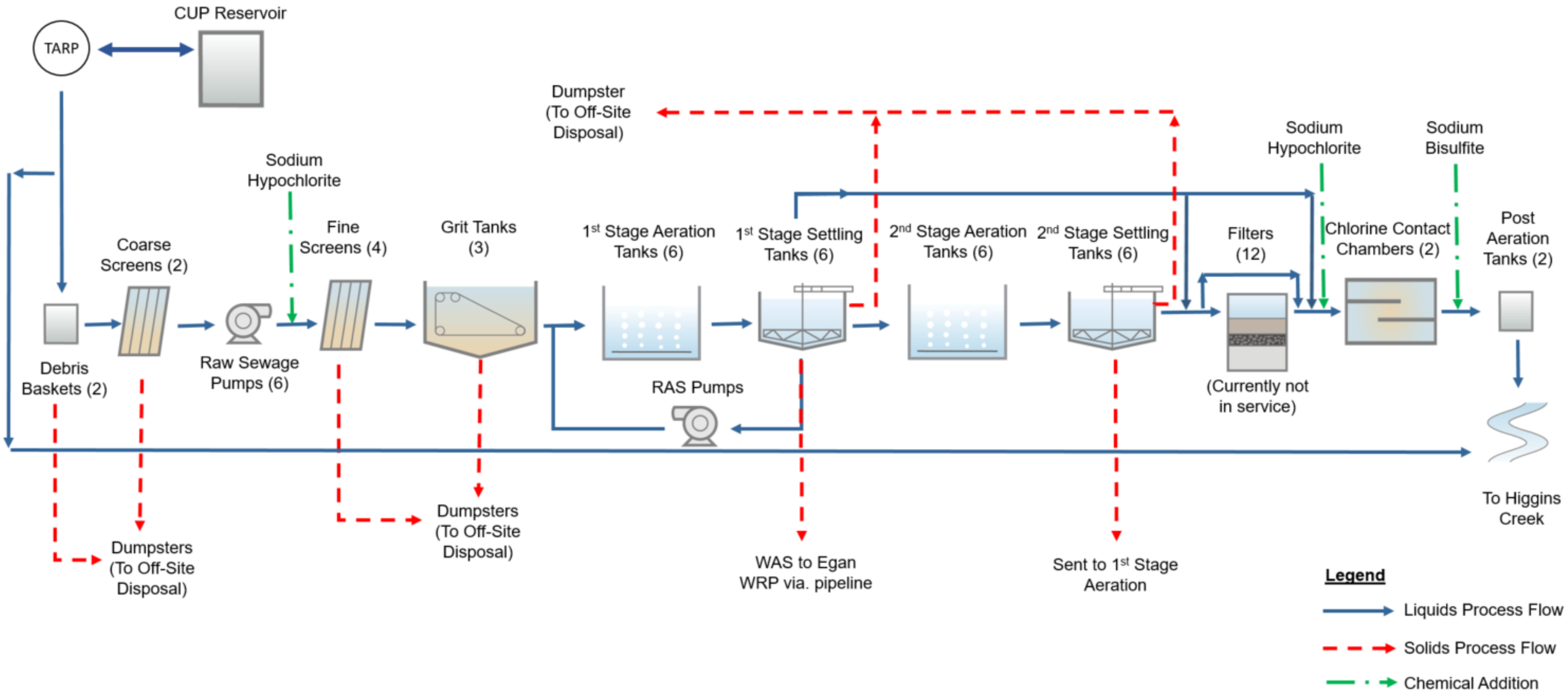

Figure A.1.2 Process Flow Diagram for Kirie WRP

A summary of existing process equipment and infrastructure at the Kirie WRP is presented in Table A.1.1.

Table A.1.1 Summary of Existing Process Equipment and Infrastructure at the Kirie WRP

Process	Number of Units	Type	Capacity/Dimensions
Debris Removal	2	Basket	6.5 ft L x 6.8 ft W x 15 ft H
Coarse Screens	2	-	6 ft W, 3 in. clear opening
Raw Sewage Pumps	6	Centrifugal	3 at 38 mgd at 190 ft TDH, 2,250 hp motor; 3 at 56 mgd at 190 ft TDH, 2,250 hp motor
Fine Screens	4	Multi-Rake	8 ft W, 3/16 in. clear opening
Grit Tanks	3	Gravity Detritus Tanks	55 ft L x 55 ft W x 4 ft 6 in. water depth
Blowers	5	Single Stage Centrifugal	37,770 scfm; 2,500 hp
Aeration Tanks	12	Conventional or Step Feed, Three-Pass	1st & 2nd Stage – 6 ea at 250 ft L x 25.5 ft W x 16 ft water depth
Return Sludge Pumps	36	Air Lift	1st & 2nd Stage – 18 ea at 24 in. Dia., 40 mgd per stage
Settling Tanks	12	Circular	1st & 2nd Stage – 6 ea at 153 ft Dia., 15 ft water depth
Scum Pumps	4	Positive Displacement	25 gpm, 5 hp motor
Low Lift Pumps	5	Centrifugal	30,000 gpm at 35 ft TDH, 350 hp motor
Filters	12	Dual Media-Anthracite and Sand	2 beds ea at 54 ft L x 13.5 ft W x 12.5 ft water depth
Sodium Hypochlorite Feed Pumps	10	Positive Displacement	8 diaphragm – variable rate up to 75 gph 2 peristaltic – variable rate up to 158.5 gph
Chlorine Contact Chambers	2	Eight-pass	each pass 64 ft 2 in. L x 15.5 ft W x 13 ft 8 in. water depth
Sodium Bisulfite Feed Pumps	2	Positive Displacement	variable rate up to 15.58 gph
Post Aeration Tank	2	2 cells each	each cell 61.5 ft L x 18 ft W x 13 ft 7 in. water depth

Abbreviations:

D	Depth
Dia	diameter
ft	feet
gph	gallons per hour
gpm	gallons per minute
H	Height
hp	horsepower
in.	inches
L	Length
scfm	standard cubic feet per minute
TDH	total dynamic head
W	Width

A.1.2.2 Review of Bio P Testing at Kirie WRP

The District started conducting full-scale Bio P testing at Kirie WRP in April 2015. The objective of the testing was to evaluate the potential for Bio P using existing infrastructure at Kirie WRP and to assess unaerated zone mixing requirements. The testing was divided into the following phases:

- Phase IA – Baseline testing to establish effluent TP performance without operational adjustments using the nitrifying BNR plant configuration of the 1st stage aeration tanks.
- Phase IB – Isolated Bio P testing in one aeration tank to evaluate P removal potential by turning off aeration air in the first 1/3 of the first pass. Using periodic air bump mixing of the anaerobic zone.
- Phase II – Evaluate the performance of Bio P by adding baffle walls in the first 2/3 and large bubble mixers in the first 1/3 of the first pass of the two aeration tanks to provide isolated and mixed anaerobic zones. Supplemental testing of the overall plant performance by running two aeration tanks in Bio P mode described above and turning off the air to the diffusers in the first 1/3 of the first pass of the remaining 4 aeration tanks.

During Phase IB and supplemental testing of aeration tanks 1-4 in Phase II, the anaerobic zones of the 1st stage aeration tanks were mixed using periodic aeration air bumping[1]. During Phase II temporary wood baffle walls were installed in aeration tanks 5 and 6 at approximately 1/3 and 2/3 of the first pass to create a defined anaerobic zone and followed by a swing zone (operated as anaerobic) and encourage sludge settling and fermentation in the first zone. Large bubble mixing devices were installed in the first 1/3 of the first pass of the two test aeration tanks. While testing has been completed, operation in the temporary Bio P mode is still ongoing in 2021. Certain operational modifications have been made, those being the removal of the temporary baffle walls in aeration tank 6 due to failure and converting operation of the swing zones in aeration tanks 5 and 6 from anaerobic to exclusively aerobic mode due to plugging of the ceramic plate diffusers. The wooden baffle walls were not reinstalled since permanent baffle walls will be installed to meet the upcoming 1.0 mg/L permit limit. Despite this change, effluent TP concentrations are in line with treatment levels achieved during Bio P testing, as highlighted in the following section, and continue to demonstrate improved removal of TP from the final effluent at Kirie WRP.

A.1.2.3 Effluent TP Performance Before and After Bio P Testing

Figure A.1.3 presents historical performance data on influent and effluent TP concentrations from 2014 through 2017 at the Kirie WRP. During this time period, influent TP ranged from about 3 to 6 mg/L with minimum and maximum values of approximately 1 mg/L and 13 mg/L, respectively. The average influent TP concentration was approximately 3.8 mg/L. During this time period, effluent TP ranged from about 0.2 to 2.0 mg/L with minimum and maximum values of approximately 0.1 mg/L and 2.1 mg/L, respectively. The average effluent TP concentration was approximately 0.74 mg/L.

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[1] Air bump mixing is turning on aeration intermittently for physical mixing versus aeration to diffuse oxygen for biological treatment.

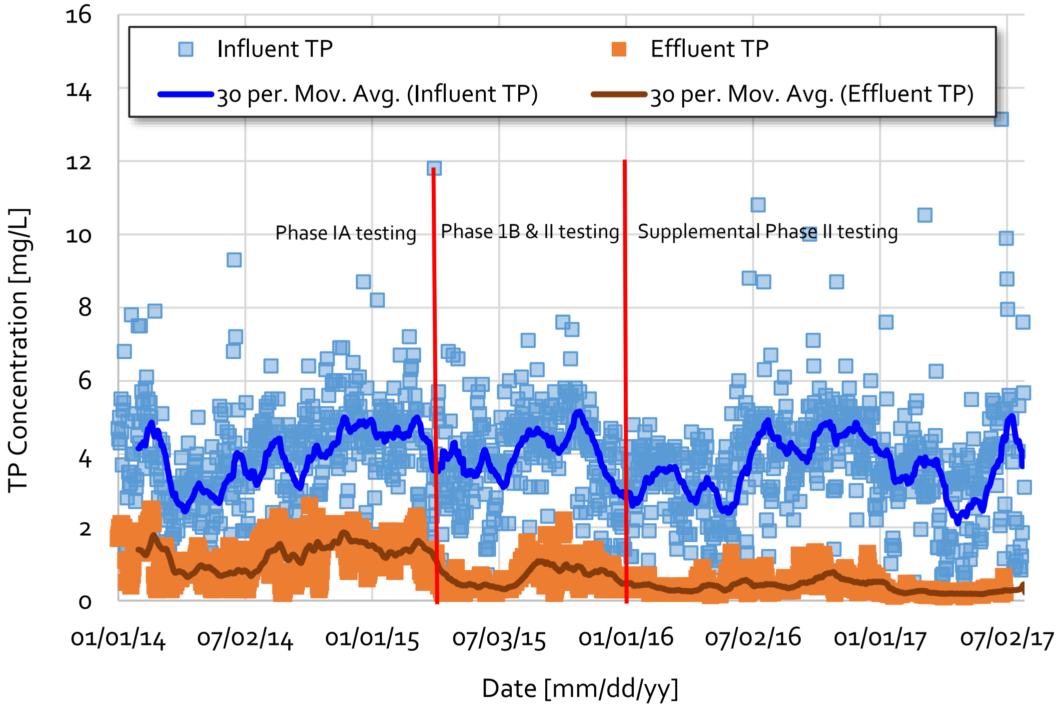


Figure A.1.3 Kirie WRP Historical TP Concentrations and Bio P Testing Program

Prior to Bio P testing from January 2014 through April 2015, the influent TP concentration averaged approximately 4 mg/L with an effluent concentration of approximately 1.2 mg/L. This indicates that baseline P removal in the unmodified aeration tanks and channels was approximately 70 percent.

The initial phase of testing with 2 test aeration tanks online, each with 2/3 of the first pass anaerobic (~7.4 percent of the total 1st stage aeration tank volume), was conducted between April 2015 and January 2016. During this initial test period the influent TP concentration averaged approximately 3.8 mg/L with an effluent concentration of approximately 1.0 mg/L. The effluent TP concentrations exhibited some seasonal variations between approximately 0.5 mg/L and 1.0 mg/L. This indicates a P removal due to initial Bio P operation of approximately 74 percent P removal.

Supplemental Phase II testing with 2 test tanks online and four aeration tanks each having 1/3 of the first pass anaerobic (~14.6 percent of the total 1st stage aeration tank volume) was conducted from January 2016 through July 2017. During this supplemental test period the influent TP concentration averaged approximately 3.0 mg/L with an effluent concentration of approximately 0.3 mg/L. This indicates improved P removal under test case conditions of approximately 90 percent P removal. During this test period the effluent TP concentrations were more stable without significant seasonal variations with only periodic excursions of approximately 1.5 mg/L.

Since the District began conducting Bio P pilot studies in April 2015, there has been a significant decrease in effluent TP concentrations and improvement of effluent quality, as seen in Figure A.1.3. This suggests that the facility has potential to meet or exceed a 30-day average of 1.0 mg/L optimized effluent P goal with full-scale implementation of Bio P process configurations.

A.1.3 Source Reduction through Industrial Discharge Management

This section evaluates the potential for capital and O&M costs savings due to influent P reduction through source control of tributary industrial dischargers. Evaluation of the viability and reduction opportunities of such influent optimization measures as specified under Special Condition 24 is a necessary exercise in accordance with the permit. Phosphorus discharge from industrial sources can occur in the following industrial categories:

- Food manufacturing of various types.
- Metal finishing and electroplating.
- Pharmaceutical manufacturing.
- Large commercial hotels or entertainment centers where food is served and laundry is washed.

The service area tributary to the Kirie WRP has several industrial dischargers in these categories. In some cases, influent P source reduction from industrial dischargers in these categories can reduce influent P loads to levels that would impact the capital and operating costs associated with treatment. Based on experience and professional judgment the following cost impact scale represents a conservative view of the potential cost impacts associated with industrial P source reduction at the Kirie WRP.

- Industrial contribution < 5 percent of the overall P load = Source control will not significantly reduce capital and O&M costs for P removal.
- Industrial contribution between 5 percent and 10 percent of overall P load = Source control may slightly reduce capital and O&M costs for P removal.
- Industrial contribution >10 percent of the overall P load = Source control may noticeably reduce capital and O&M costs for P removal. The cost reduction impact is assumed to increase as the percent contribution increases.

To determine the percentage contribution of the influent P load associated with industrial and commercial dischargers, potential industrial P sources were identified and their contribution estimated and compared to the overall influent P loads to the Kirie WRP. For purpose of this TM, industrial and commercial dischargers are considered as industrial sources.

A.1.3.1 Source Reduction Analysis Methodology

The following methodology was used to estimate the total industrial percent contribution to the influent P load at the Kirie WRP.

Step 1 - Identify average influent TP load to the Kirie WRP.

Step 2 - Identify Large Commercial-Industrial Users (LCIUs) tributary to the Kirie WRP.

Step 3 - Identify industrial category and Standard Industrial Classification (SIC) numbers.

Step 4 - Identify daily flow from each LCIU as available through District's Monitoring and Research Department's Industrial Waste Division (IWD) records.

Step 5 - Collect available minimum, mean, and max TP concentration data where site specific sampling was conducted by IWD.

Step 6 - Where site specific TP concentration data were not available, use a combination of published estimated minimum, mean, and maximum TP concentrations from the United States Environmental Protection Agency (USEPA) and other information sources based on SIC numbers from step 3.

Step 7 - Estimate each LCIUs mass and percent TP contribution using flow data from step 4 and concentration data from steps 5 and 6.

A.1.3.2 Assessment of LCIU P Load Contribution

Table 1 of Appendix A.1-A summarizes the data used to analyze the TP discharge contribution from LCIUs.

In Table 1 of Appendix A.1-A, the first four columns present information on 54 LCIUs tributary to the Kirie WRP including name, location, industrial category, and SIC number. The 5th and 6th columns present average daily flow discharges and the percentages of the total Kirie WRP flow for each LCIU as provided by the IWD. For this analysis, 2016 industrial and Kirie WRP plant flows were used to determine the percentage industrial contribution. The average daily flow to Kirie WRP in 2016 was approximately 34.5 mgd. The average daily flow from the industrial dischargers in 2016 was approximately 1.35 mgd or 3.92 percent of the total plant influent flow.

In Table 1 of Appendix A.1-A, columns 7, 8, and 9 present the minimum, mean, and maximum TP concentrations, respectively, as measured during a selected facility specific sampling program conducted by IWD in 2001. Facility specific TP concentration sampling data was available for 5 of the 54 LCIUs.

Where facility specific TP concentration data were not available, USEPA or other information sources reporting TP concentration ranges based on SIC classification were used. SIC is a system of classifying industry types using a four-digit code. The first two digits of the SIC code indicates a major industrial group (e.g., industrial and commercial machinery and computer equipment, electronic equipment and components, health services, etc.). The last 2 digits of the SIC code indicates a specific industry group (e.g., printed circuit boards, enameled iron and metal sanitary wire, industrial laundry, etc.).

In Table 1 of Appendix A.1-A, columns 10 through 15 present USEPA TP concentration data by SIC code as published in 2015.

In Table 1 of Appendix A.1-A, columns 16, 17, and 18 present TP concentration data from other information sources. Other information sources include industry specific research reports and studies. The other information sources were selected based on:

- Industry type studied.
- Location of the studies.
- Date of the studies.

Only studies conducted in the United States after 1970 were included due to US detergent manufacturer's agreement to reduce phosphorus content to 8.7 percent in 1970. In addition, phosphorus containing fertilizers for lawns and turf were banned in Illinois in 2011.

In Table 1 of Appendix A.1-A, columns 19/20, 21/22, and 23/24 represent the estimated total daily TP load and the percentage of the influent TP load to the Kirie WRP under minimum, mean, and maximum conditions, respectively. The phosphorus concentrations chosen to determine the daily phosphorous loads for each LCIU were based on facility specific sampling data, USEPA data based on SIC codes, and other information sources. Where available, facility specific sampling data were used to calculate the minimum, mean, and maximum industrial discharge contribution. Where facility specific sampling data were unavailable, TP concentrations from either USEPA data based on SIC codes or other information sources were selected based on engineering judgement.

A.1.3.3 Industrial Source P Contribution

Figure A.1.4 presents the data from Table 1 of Appendix A.1-A, columns 20, 22, and 24 showing the percent contribution of daily TP load to the Kirie WRP from individual LCIUs, on a minimum, mean, and maximum basis.

The mean values for LCIU percentage TP load contribution to the Kirie WRP were considered to be the most appropriate for assessment of the total industrial TP contribution. It is reasonable to assume that different LCIUs will discharge various concentrations of TP ranging from minimum to maximum at any point in time. However, it is unlikely that all of the industries tributary to the Kirie WRP will discharge either minimum or maximum concentrations simultaneously. Therefore, minimum and maximum values do not reflect a reasonable load contribution percentage scenario.

The total sum of the mean value industrial contribution as indicated at the bottom of column 22 on Table 1 of Appendix A.1-A is 7.27 percent. Figure A.1.5 shows a pie chart of the percentage of the mean TP load to the Kirie WRP from all combined industrial dischargers and from all non-industrial (domestic) dischargers. This analysis estimates that approximately 7.3 percent of the daily influent TP load to the Kirie WRP is attributed to industry. Approximately 92.7 percent of the daily influent TP load to the Kirie WRP is from non-industrial domestic users.

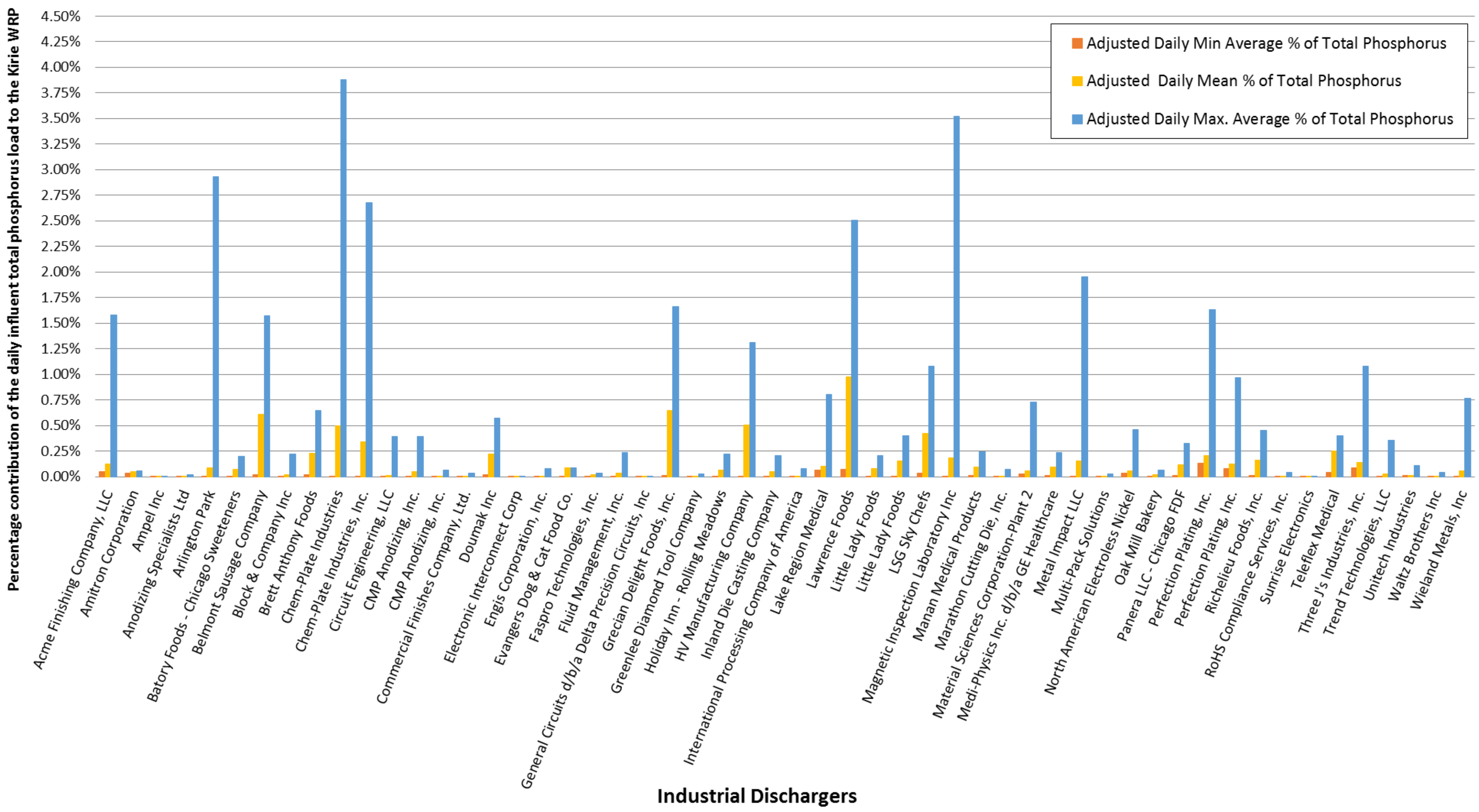


Figure A.1.4 Percent Contribution of Influent TP Load at Kirie WRP for Tributary LCIUs on a Minimum, Mean, and Maximum Basis

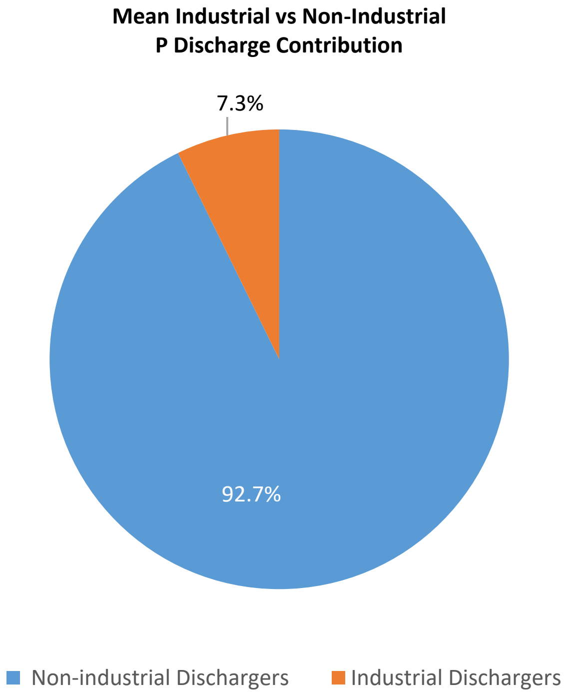


Figure A.1.5 Estimated Mean Percentage Distribution of Influent TP Load at Kirie WRP Attributed to Industrial and Non-Industrial Dischargers

A.1.3.4 Phosphorus Reduction Potential

The analysis indicates that the highest maximum TP contribution potential generally coincides with food manufacturers and metal finishing industries. This impact can be seen in Figure A.1.4 where the blue bars (corresponding to the maximum concentration assumptions) for select LCIUs are greater than 1 percent of the total TP load to the Kirie WRP.

The analysis indicates that approximately 14 LCIUs may have peak concentration potential to discharge a high percentage of the Kirie WRP phosphorus load on any given day. The IWD may elect to further investigate or conduct site specific sampling at industries with the potential to contribute TP in excess of 1 percent of the Kirie WRP influent TP load. The IWD may also elect to work collaboratively with certain LCIUs to increase awareness of P discharges and implement voluntary measures to prevent or reduce frequency and magnitude of P discharge.

Some of the phosphorus reduction measures which these industries can take include:

Food manufacturing facilities:

- Using dry cleaning practices prior to wet cleaning.
- Using low or non-phosphorus sanitizers.
- Providing wash down flow equalization or storage to reduce peak loads.
- Pretreating wastewater prior to discharging to the WRP.

Metal finishing facilities:

- Using solvents instead of phosphate-containing detergents to clean equipment.
- Recycling process water when possible.
- Improving efficiencies to reduce the amount of phosphorus used.
- Pretreating wastewater prior to discharging to WRPs.

A.1.3.5 Conclusions Related to Source Reduction for the Phosphorus Removal Feasibility Study

As indicated above a total industrial contribution < 5 percent of the overall P load to the Kirie WRP is not expected to significantly impact capital and O&M costs for P removal. Furthermore, an industrial contribution between 5 percent and 10 percent of overall P load to the Kirie WRP may only slightly impact capital and O&M costs for P removal. The overall industrial load contribution at the Kirie WRP is estimated at approximately 7.3 percent and falls in between a "no impact" and a "slight impact" potential. Considering the challenges associated with implementing District-wide industrial TP discharge limitations or phosphorus surcharges, it is recommended that the Phosphorus Removal Feasibility Study be completed assuming that all of the industrial TP loads will be treated at the Kirie WRP and that no reduction of influent TP load will be considered.

A.1.4 Bio P Evaluation Criteria and Process Simulation Modeling Overview

This section describes the evaluation criteria for Bio P and provides an overview of the GPS-X process simulation modeling conducted to predict facility performance.

A.1.4.1 Criteria Used for Optimization Opportunities Analysis

NPDES Permit No. IL0047741 establishes the effluent discharge criteria for the Kirie WRP. These criteria are used as the basis of the P removal optimization opportunities analysis.

A.1.4.1.1 Current NPDES Effluent Discharge Criteria

Table A.1.2 summarizes key secondary treatment effluent criteria that must be achieved in conjunction with optimized P removal at the Kirie WRP.

Table A.1.2 Key Effluent Discharge Criteria at the Kirie WRP

Parameter	Units	Criteria	Averaging Period (4)
$CBOD_5$	mg/L	4	Monthly Average
TSS	mg/L	5	Monthly Average
Ammonia-N (1)	mg/L - N	1.6	Monthly Average
Ammonia-N (2)	mg/L - N	2.1	Monthly Average
Ammonia-N (3)	mg/L - N	4.0	Monthly Average

Notes:

(1) The Kirie WRP permit contains revised ammonia limits for June through August of 1.6 mg/L as a maximum monthly average.

(2) The Kirie WRP permit contains revised ammonia limits for March through May and September through October of 2.1 mg/L as a maximum monthly average.

(3) The Kirie WRP permit contains revised ammonia limits for November through February of 4.0 mg/L as a maximum monthly average.

(4) Process simulation modeling of P removal based on static conditions that represent daily average values. Monthly average permit limits on effluent parameters provide additional performance safety factor.

Effluent ammonia concentrations are regulated seasonally. The 2.1 mg/L effluent ammonia requirement shown in Table A.1.2 is the lowest effluent concentration associated with cold weather operation which dictates nitrification capacity.

A.1.4.1.2 Raw Wastewater Characteristics

Historical records from July 2015 through July 2017 were used to develop influent raw wastewater characteristics for process simulation modeling at the Kirie WRP. The selected time range for this analysis corresponds with the Kirie WRP Bio P testing and allows for improved calibration of the process simulation models for Bio P. More recent influent flow and load data (2017 – 2019) has been reviewed and is consistent with the original influent characteristics used in the model, such that updates or adjustments to the data were deemed not necessary. Optimization analysis has been performed for current annual average day load (AADL) conditions and average water temperatures, current AADL and winter temperatures, as well as current maximum monthly average day load (MMADL) conditions and winter temperatures. This approach verifies that the Kirie WRP can meet the effluent discharge criteria under average conditions, periods of high loading, and periods of cold temperature winter conditions. It should be noted that periods of low flow present an additional variable and challenge, forcing operators to take tanks out of service to improve phosphorus removal when periods of low flow are extended.

Table A.1.3 presents the current flow and load peaking factors used for the P optimization opportunities analysis.

Table A.1.3 Kirie WRP Flow and Load Peaking Factors

Parameter	Value
Flow Peaking Factors	
Current MMADF / AADF	1.68
Design DMF / AADF	2.11
Load Peaking Factors, MMADL / AADL	
BOD_5	1.30
TSS	1.58
TKN	1.21
NH_3-N	1.16
TP	1.34

Notes:
(1) Peak hourly flow and peak instantaneous flow were not used in the optimization analysis.
(2) AADF = Average flow for a rolling 365 consecutive day period from July 2015 through July 2017.
(3) AADL = Average load for a rolling 365 consecutive day period from July 2015 through July 2017.
(4) Maximum Month Average Day Flow (MMADF) = Highest 30 day running average flow.
(5) MMADL = Highest 30 day running average load.

Abbreviations:

TKN	Total Kjeldahl Nitrogen
NH_3-N	Ammonia Nitrogen

Table A.1.4 presents the influent criteria used to evaluate P removal optimization opportunities and performance under current conditions at the Kirie WRP.

Table A.1.4 Kirie WRP Influent Evaluation Criteria

Influent Parameter	Value
Current Flows	
AADF, mgd	35.8
MMADF, mgd	60.1
DMF, mgd	110 (1)
Influent Concentrations at AADF	
BOD_5, mg/L	133
TSS, mg/L	166
TKN, mg/L	26.3
NH_3-N, mg/L	15.1
TP, mg/L	3.8
Influent Load at AADL	
BOD_5, lb/day	39,710
TSS, lb/day	49,563
TKN, lb/day	7,852
NH_3-N, lb/day	4,508
TP, lb/day	1,135
Influent Concentrations at MMADF	
BOD_5, mg/L	103
TSS, mg/L	156
TKN, mg/L	18.9
NH_3-N, mg/L	10.4
TP, mg/L	3.0
Influent Load at MMADL	
BOD_5, lb/day	51,627
TSS, lb/day	78,193
TKN, lb/day	9,473
NH_3-N, lb/day	5,213
TP, lb/day	1,504

Notes:

(1) DMF per NPDES Permit No. IL0047741.
(2) AADF = Average flow for a 365 consecutive day period.
(3) MMADF = Highest 30 day running average flow.
(4) AADL = Average load for a 365 consecutive day period.
(5) MMADL = Highest 30 day running average load.

A.1.4.1.3 Water Temperature Criteria

Historical daily influent temperature data was used to establish the winter, average, and maximum temperatures used for the analysis of secondary treatment. Average temperatures are used to estimate average capacity and treatment performance and winter temperatures are used to predict a worst-case scenario for nitrification performance. Table A.1.5 shows influent temperatures used for Kirie WRP P optimization opportunities analysis.

Table A.1.5 Influent Wastewater Temperatures

Criteria	Value (1)
Minimum Temperature, deg. C	10.0
Average Temperature, deg. C	17.9
Maximum Temperature, deg. C	23.2

Notes:
(1) Based on historical daily raw wastewater temperature recorded from Jan 2014 to July 2017.
Abbreviations:
deg. C degrees Celsius

The minimum influent wastewater temperature represents the weekly average value measured during the lowest temperature week of the year. The maximum influent wastewater temperature represents the weekly average value measured during the highest temperature week of the year.

A.1.4.2 Process Simulation Model Development

GPS-X (Hydromantis Environmental Solutions, Inc.: Hamilton, Ontario), a commercially available biological and physical treatment simulation software, was used to predict process performance for the P optimization opportunities analysis. GPS-X incorporates carbon, nitrogen, and phosphorus models based on the Activated Sludge Model No. 2d (ASM 2d) and the Anaerobic Digestion Model No. 1 (ADM 1). Key aspects of a modeling evaluation include:

- Data collection and reconciliation.
- Kirie WRP configuration model setup.
- Calibration and validation.
- Simulation of Bio P optimization and interpretation of results.

Historical performance data and operational parameters were collected during normal operations, during the Bio P test period, and as part of other special sampling campaigns. This data was used in model setup, calibration, and validation. Key historical operations information is presented in Appendix A.1-B. Data reconciliation, plant model setup, and calibration procedures are also described in Appendix A.1-B.

A.1.4.2.1 Kirie WRP Model Configuration

As indicated in Section 1.2.1 the Kirie WRP is currently operated as a single stage nitrification process with only Battery A aeration tanks and clarifiers operating as activated sludge. Within Battery A, as part of the past Bio P testing program, some aeration basins were configured differently. Aeration Tank Nos. 5 and 6 were operated with approximately 2/3 of the first pass as unaerated anaerobic zones. Aeration Tank Nos. 1 through 4 were operated with approximately 1/3 of the first pass as unaerated anaerobic zones. Therefore, approximately 15 percent of the total Battery A tank volume was operating as anaerobic to promote the growth of polyphosphate accumulating organisms (PAOs) and facilitate P release and subsequent P uptake in the aerobic zones.

The process simulation model that follows is configured according to the Bio P testing program setup, though operation has been adjusted in response to observed issues that resulted from that mode of operation, namely with respect to the swing zones. During the Bio P testing program, the swing zone was left unaerated to allow for 2/3 of the first pass to be anaerobic in Aeration Tank Nos. 5 and 6. While the additional anaerobic volume served to further support Bio P performance, it was also discovered to cause issues with plugging of the ceramic plate diffusers which was detrimental to overall aeration system performance. As a result, the swing zones are now only operated aerobically, so while the process simulation model reflects the Bio P testing mode of operation, given the observed fouling issues, such a configuration will not be replicated at the plant in the future unless there are significant modifications made to the aeration system.

Because the aeration tanks in Battery A were configured differently during the Bio P testing program, the process simulation model for Battery A is represented as two parallel systems with Aeration Tank Nos. 1-4 having 1/3 of the first pass anaerobic and Aeration Tank Nos. 5-6 having 2/3 of the first pass anaerobic.

Figure A.1.6 illustrates the configuration of the Kirie WRP process simulation model calibrated against existing operating data, including the Bio P testing period, and used for P removal optimization analysis.

Additional detail on the process simulation model calibration/validation is included in Appendix A.1-B.

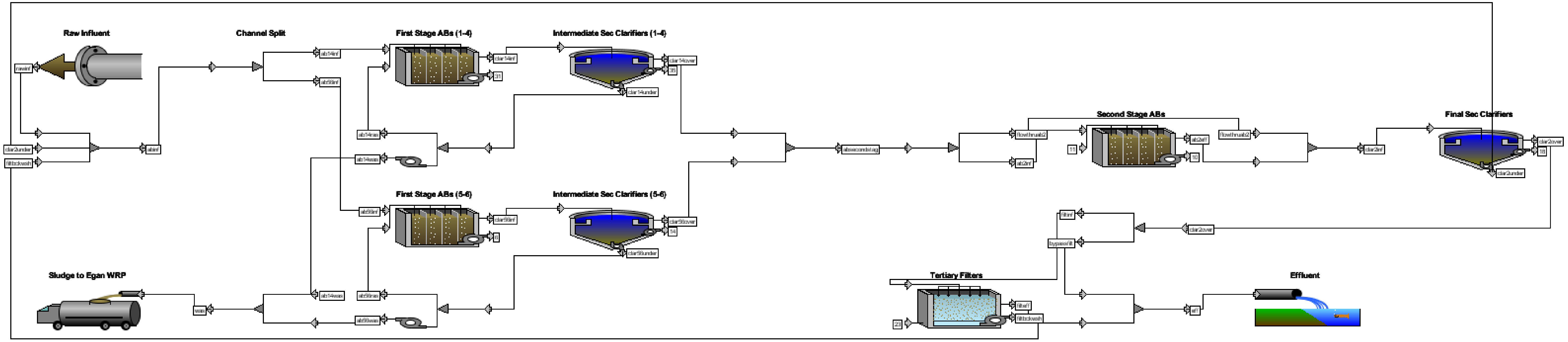


Figure A.1.6 Kirie WRP Process Simulation Model Configuration

A.1.4.2.2 Process Simulation Model Calibration

Process simulation model calibration at average day conditions (AADF, AADL) was performed to verify adequate prediction of key operating parameters and effluent quality. Figure A.1.7 and Figure A.1.8 present historical and model simulated operating parameters for Battery A Tank Nos. 1-4 and Tank Nos. 5-6, respectively. Figure A.1.9 shows historical and simulated effluent criteria.

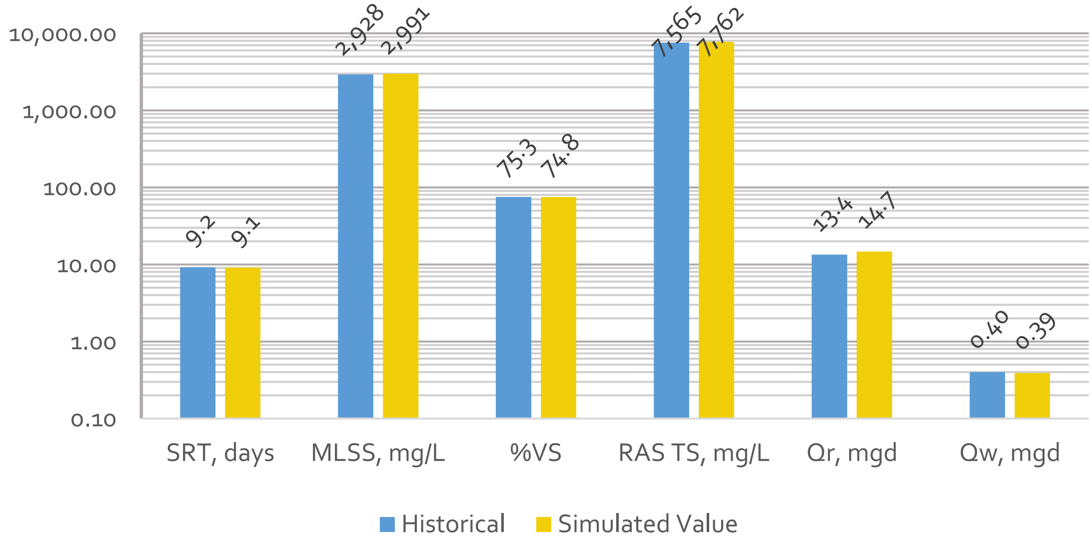


Figure A.1.7 Comparison of Calibrated Model's Simulated Operating Parameter Values to Historical Measured Operating Parameter Values in Kirie WRP Battery A Aeration Tank Nos. 1-4

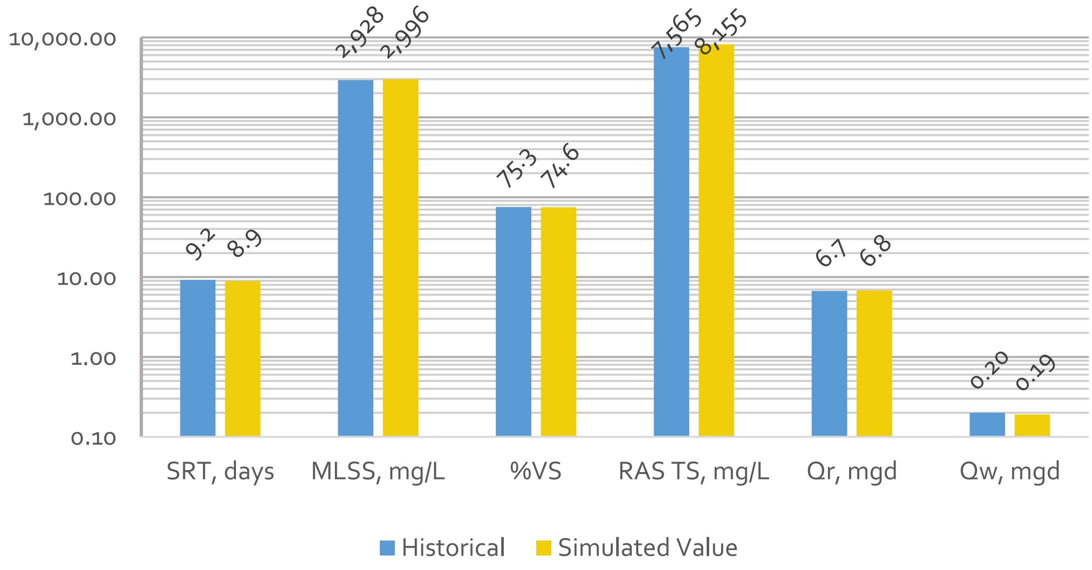


Figure A.1.8 Comparison of Calibrated Model's Simulated Operating Parameter Values to Historical Measured Operating Parameter Values in Kirie WRP Battery A Aeration Tank Nos. 5 & 6

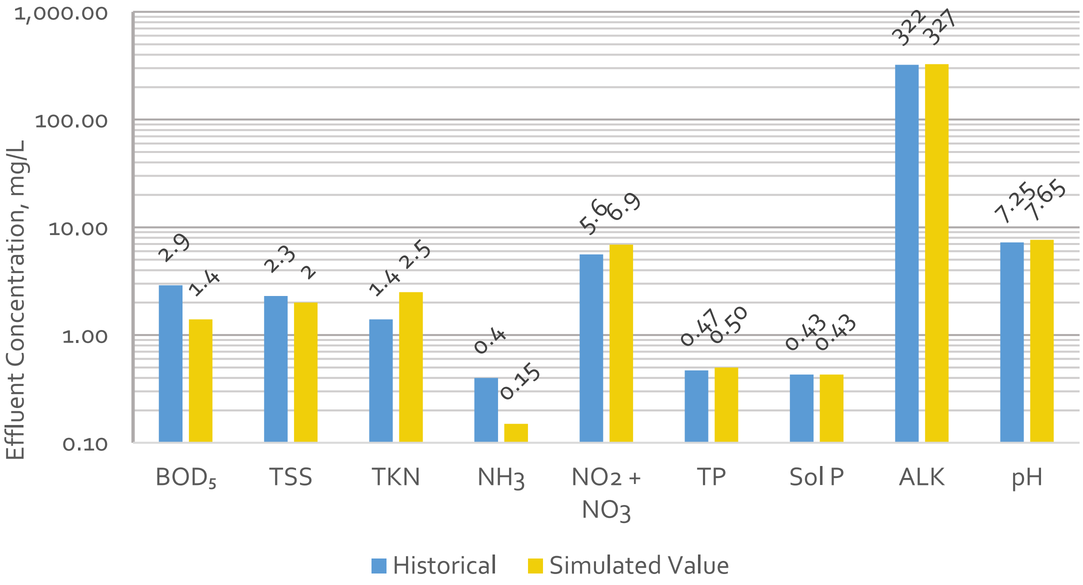


Figure A.1.9 Model Predicted Final Effluent Quality Compared to Historical Effluent Quality at the Kirie WRP

After calibration, all simulated operating parameter values agreed well with historical data. The resulting simulated average effluent values also compared reasonably well with measured average values with some effluent parameters predicted to be slightly higher than measured and some effluent parameters predicted to be slightly lower than measured. For purposes of this planning level model, the correlation between predicted and measured ammonia and phosphorus are the most important. The average effluent ammonia value was predicted to be less than measured average effluent ammonia. We believe that this is due to periodic ammonia excursions that are not captured in the steady-state simulations. Both predicted and actual effluent ammonia values are well below the effluent discharge criteria. The average effluent TP and Sol P was predicted within 10 percent of the measured average effluent values.

In order to achieve the calibration indicated in Figures A.1.7, A.1.8, and A.1.9, only a few default parameters required adjustment. All key operating parameters (e.g. SRT, MLSS, VS%) agreement within 10 percent. Predicted effluent values for TP and Sol P were also within 10 percent. This calibration is considered adequate for P optimization and feasibility planning level purposes

A winter validation was performed to ensure adequate model calibration during winter months when nitrification requires higher solids retention time (SRT) and mixed liquor suspended solids (MLSS) concentrations. All operating parameters were found to be within 10 percent of historical winter values and the effluent pollutant concentrations predicted within acceptable margins.

A.1.4.3 1st Stage Clarifier Maximum Capacity Analysis

The treatment capacity and performance for BOD_5 and ammonia removal and P removal is determined through a combination of aeration basin volume and clarifier capacity. The clarifier capacity is limited by MLSS settling characteristics, solids loading, and hydraulic loading. Clarifier solids loading is determined by the activated sludge MLSS concentration and the influent flow and return activated sludge (RAS) flow rates. A clarifier state point analysis (SPA) is a steady-state mathematical clarifier model that compares MLSS settling rates, represented by a solids flux curve, to the influent solids loading rates and solids removal rates through RAS. SPAs are frequently used to establish clarifier and RAS pump capacity based on several inputs derived from operating data.

As part of the P removal optimization analysis, a SPA was performed to determine the maximum MLSS concentrations of the aeration basins without overloading the clarifiers.

Table A.1.6 presents the assumptions used in the SPA to establish a Kirie WRP Battery A maximum MLSS concentration of 5,300 mg/L. The required MLSS concentrations to achieve both nitrification and P removal under various loading and temperature conditions are compared to the maximum MLSS value in subsequent sections for each model run.

Table A.1.6 SPA Analysis Assumptions and Maximum MLSS Value

Parameter	Units	Value
AADF	mgd	35.8
Peaking Factor (Max Flow/AADF) (1)	-	2.11
Maximum Flow	mgd	75.5
Number of Clarifiers in Service (2)	No.	6
Clarifier Diameter	ft	153
RAS Flow (3)	mgd	52
SVI (4)	mL/g	96
Minimum Clarifier Safety Factor	-	1.1
Correlation Model	-	Pitman
Kirie WRP Battery A Maximum MLSS (5)	**mg/L**	**5,300**

Notes:
(1) DMF/AADF per Table A.1.3.
(2) All Battery A clarifiers are assumed to be in service.
(3) RAS pump max capacity assumed to be 100% of the rated AADF per Illinois Environmental Protection Agency (IEPA) requirements.
(4) Developed from the 92nd percentile of historical Battery A sludge volume index (SVI) values from Jan 2014 to July 2017.
(5) The MLSS at which the clarifiers become critically loaded given the other SPA assumptions.
Abbreviations:
mL/g milliliters per gram

If effluent flow, SVI, or MLSS values exceed those presented in Table A.1.6, it is possible that solids will be washed out of the clarifiers. Additional discussion of SPA is presented in Appendix A.1-B.

A.1.5 Implementation of Biological Phosphorus Removal

Phosphorus can be removed from the influent wastewater either biologically (Bio P), chemically (Chem P), or through a combination of Bio P and Chem P. For this analysis only Bio P optimization opportunities were evaluated. Only Bio P was considered due to the high operating cost associated with Chem P.

Bio P is achieved by exposing the activated sludge biomass to anaerobic environmental conditions in the presence of short-chain volatile fatty acids (VFAs). The anaerobic zones favor the growth of PAOs that uptake and store VFA carbon within their cells as polyhydroxyalkanoate (PHA) while releasing P. The PAOs are subsequently exposed to aerobic environmental conditions where they take up both the released P and the P in the influent wastewater for biogrowth. The PAOs can uptake and store more P than necessary for biogrowth known as "luxury P uptake." The biomass rich with phosphorus is separated during sedimentation, and the phosphorus is removed from the system as WAS. The WAS from a conventional activated sludge process contains approximately 2 percent phosphorus, while the WAS in a Bio P activated sludge process contains between 3 to 8 percent phosphorus.

The Kirie WRP is designed to remove ammonia using nitrifying activated sludge (NAS). The NAS process is one of several BNR processes that can remove nutrients including ammonia, nitrogen, and phosphorus. BNR processes remove different nutrients to different levels by creating and managing specific biomass populations in anaerobic, anoxic, and aerobic environmental conditions within the aeration tanks. The NAS process designed at the Kirie WRP operates entirely in aerobic conditions.

A common configuration for P removal in a BNR activated sludge plant includes an anaerobic zone for P release followed by aerobic zones for both P uptake and nitrification of ammonia. This configuration is known as an A/O process. When using an A/O process with nitrification the anaerobic zone sizing is often extended to allow initial denitrification of nitrate contained in the RAS prior to establishing true anaerobic conditions required for PAO growth. The A/O process is the simplest configuration for Bio P and nitrification. There are more complex configurations with multiple anaerobic or anoxic zones for various levels of nitrogen and P removal.

As discussed in Section A.1.2.2, the District has successfully tested Bio P using the A/O process configuration with an extended anaerobic zone. Other more complex Bio P configurations require additional tankage and higher capital investment and operating costs. The A/O process was used for P optimization analysis as it has already shown good performance during testing by the District and requires the least cost to construct, operate, and maintain.

Complete nitrification is required at the Kirie WRP to meet current and future discharge criteria. Therefore, optimization of Bio P was evaluated at conditions that allow complete nitrification. In order to create an A/O process, some volume in the existing aeration tanks will be converted from aerobic to anaerobic conditions. This will decrease the aerobic volume available for nitrification. Therefore, the initial step in the Bio P optimization analysis is to evaluate the aerobic SRT and nitrification capacity followed by an assessment of Bio P performance.

Some of the critical elements for P optimization are:

- Maintaining sufficient aerobic SRT for complete nitrification under all temperatures and loads.
- Providing adequate anaerobic contact time (zone volume) to promote P release.
- Verifying adequate carbon, in readily available form, is available to support P release.

Optimization of Bio P in the existing aeration tanks requires that these elements are present, consistent, and controllable.

A.1.5.1 Nitrification Performance with Bio P

Nitrification is the aerobic oxidation of ammonia to nitrite by ammonia oxidizing bacteria (AOBs) and nitrite to nitrate by nitrite oxidizing bacteria (NOBs). Complete nitrification requires oxygen, sufficient alkalinity, and adequate aerobic SRT.

The Kirie WRP has historically operated at an aerobic SRT between 7 and 15 days while meeting effluent ammonia requirements (operating data presented in Appendix A.1-B). The corresponding MLSS concentrations range is between 2,500 and 3,500 mg/L. In general, prior to Bio P testing the SRTs were on the high side of the range near 15 days with MLSS concentrations on the low side of the range near 2,500 mg/L. As the District implemented Bio P at the Kirie WRP the SRTs trended to the low side of the range near 7 days with MLSS concentrations on the high side of the range near 3,500 mg/L. The Kirie WRP was able to provide full nitrification during the Bio P testing at approximately 7 days aerobic SRT.

Bio P optimization process simulation modeling was performed under a variety of load, temperature, effluent ammonia requirements, and anaerobic volume conditions. For average temperature conditions, the aerobic SRT required to achieve an effluent ammonia concentration of 1.5 mg/L was used. This limit was established according to the draft NPDES permit that was used for guidance when the process simulation modeling was originally performed and corresponds to the lowest monthly average ammonia limit during the summer months. For winter temperature conditions, the aerobic SRT required to achieve an effluent ammonia concentration of 1.5 mg/L was used. This limit was similarly set with guidance from the draft NPDES permit and corresponds to the monthly average ammonia limit in the coldest month of the year, March. The actual permitted limit for March is 2.1 mg/L, therefore, the following analysis for winter temperature conditions is slightly conservative, but the recommendations still apply.

The process simulation modeling runs were combined with SPA analysis to confirm adequate clarifier capacity under a range of predicted MLSS operating conditions. Process simulation model runs to establish MLSS, and clarifier capacity for nitrification under the A/O configuration were as shown in Table A.1.7 below.

Table A.1.7 Different Process Simulation Model Run Scenarios to Evaluate Nitrification under A/O Configuration

Run	Condition	Temperature (deg. C)	Effluent Ammonia Permit Limit (mg/L-N)	Anaerobic Zone
1	AADF, AADL	Average Temperature = 17.9 deg. C	1.5	2/3 of the first pass of 1st Stage Aeration Tanks
2	AADF, AADL	Winter Temperature = 10.0 deg. C	1.5	2/3 of the first pass of 1st Stage Aeration Tanks
3	MMADF, MMADL	Winter Temperature = 10.0 deg. C	1.5	2/3 of the first pass of 1st Stage Aeration Tanks
4	MMADF, MMADL	Winter Temperature = 10.0 deg. C	1.5	1/3 of the first pass of 1st Stage Aeration Tanks

A.1.5.1.1 Run 1 Nitrification Results - AADF, AADL; Average Temperature = 17.9 deg. C, Effluent Ammonia Requirement = 1.5 mg/L, 2/3 of the First Pass of 1st Stage Aeration Tanks is Anaerobic

The process performance was evaluated at average day flows and loads and an average influent temperature of 17.9 deg. C with 2/3 of the first pass of each aeration tank being converted into anaerobic zone. This represents approximately 22 percent of the total 1st stage aeration basin volume in anaerobic conditions. This anaerobic zone volume is consistent with the Kirie Bio P testing program that resulted in good Bio P performance and complete nitrification.

The model predicted a minimum aerobic SRT of 2.6 days to achieve effluent ammonia concentrations of 1.5 mg/L during the summer months. Nitrification processes typically include a safety factor applied to the minimum SRT to assure the plant continues to nitrify under dynamic operating conditions. Using an aerobic SRT safety factor of 1.4, based on historical daily average TKN peaking factors, the recommended operating aerobic SRT is 3.6 days. Daily average TKN peaking factors were developed by dividing the daily 24-hour composite influent TKN values by the average daily TKN for each day in the data set. The 92nd percentile of these peaking factors was used as the nitrification safety factor to account for daily average influent TKN variability.

Figure A.1.10 presents the Run 1 nitrification curves with predicted effluent ammonia versus aerobic SRT. The minimum recommended aerobic SRT is less than the aerobic SRT of approximately 7 days used during Bio P testing. Operating in an aerobic SRT range between 3.6 days and 7 days will result in adequate plant performance. At a median operating aerobic SRT of 5.3 days the predicted MLSS concentration is 2,300 mg/L. For average day loading and average wastewater temperature, at a 5.3 day aerobic SRT and 2,300 mg/L MLSS there are no anticipated clarifier capacity limitations.

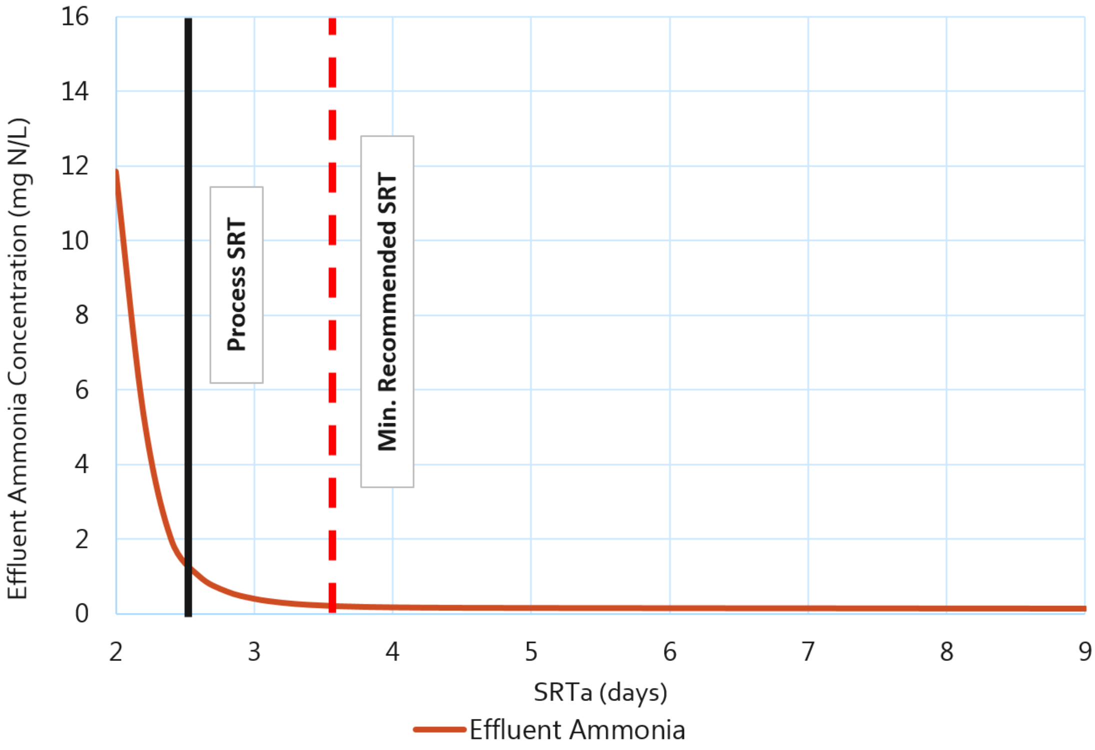


Figure A.1.10 Run 1 - Average Day (AADF, AADL) and Average Temperature Nitrification Curves

A.1.5.1.2 Run 2 Nitrification Results - AADF, AADL; Winter Temperature = 10.0 deg. C, Effluent Ammonia Requirement = 1.5 mg/L, 2/3 of the First Pass of 1st Stage Aeration Tanks is Anaerobic

To achieve effluent ammonia concentrations of 1.5 mg/L during average day flow and load conditions and winter temperatures, modeling predicted a minimum aerobic process SRT of 5.0 days. Using a safety factor of 1.4, based on historical TKN peaking factors, the recommended operating aerobic SRT is 7.0 days. Figure A.1.11 presents the Run 2 nitrification curves with predicted effluent ammonia versus aerobic SRT. Operating at an aerobic SRT of 7 days will result in adequate plant performance. At an operating aerobic SRT of 7 days, the predicted MLSS concentration is 3,100 mg/L. For average day loading and winter wastewater temperature, at a

7 day aerobic SRT and 3,100 mg/L MLSS there are no anticipated clarifier capacity limitations.

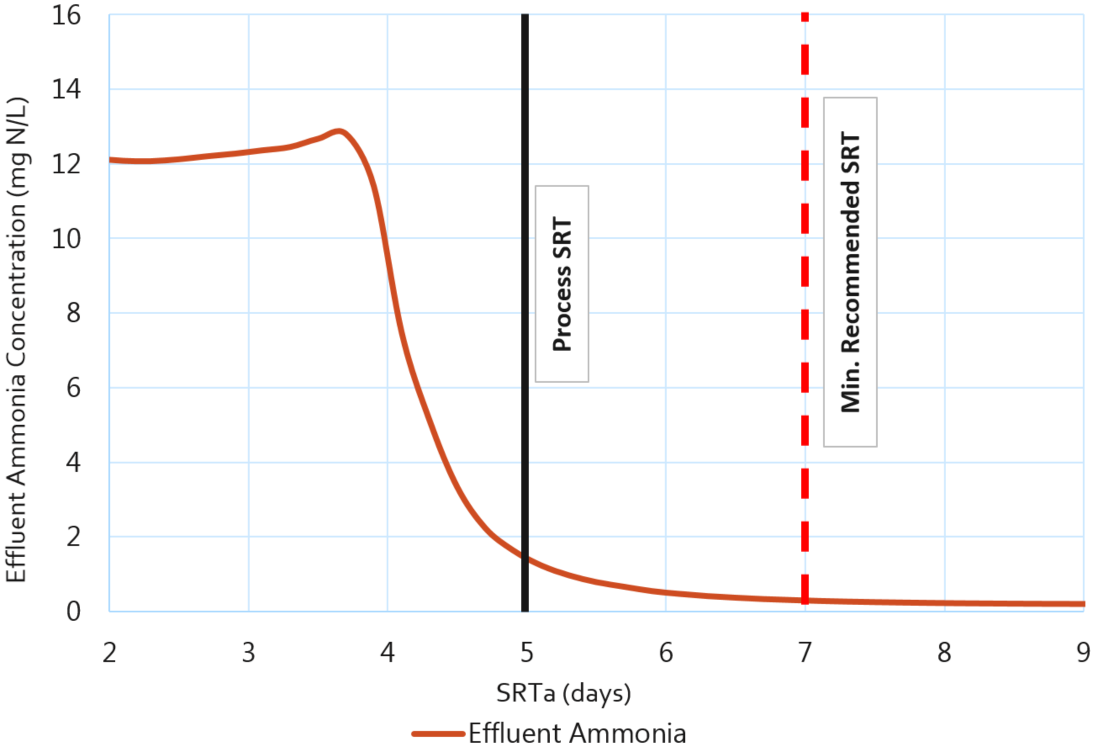


Figure A.1.11 Run 2 - Average Day (AADF, AADL) and Winter Temperature Nitrification Curves

A.1.5.1.3 Run 3 Nitrification Results - MMADF, MMADL; Winter Temperature = 10.0 deg. C, Effluent Ammonia Requirement = 1.5 mg/L, 2/3 of the First Pass of 1st Stage Aeration Tanks is Anaerobic

To achieve effluent ammonia concentrations of 1.5 mg/L during maximum month flow and load conditions, and winter temperatures, the minimum aerobic process SRT is 5.0 days. Using a safety factor of 1.4, based on historical TKN peaking factors, the recommended operating aerobic SRT is 7.0 days. This aerobic SRT is consistent with Run 2 as the winter temperatures have not changed.

Figure A.1.12 presents the Run 3 nitrification curves with predicted effluent ammonia versus aerobic SRT. For the MMADF and MMADL conditions a higher BOD_5 load results in additional solids yield and a higher MLSS concentration. Note in Figure A.1.12 that the initial MMADF/MMADL influent ammonia concentration is about half the concentration compared to AADF/AADL due to the high flow peaking factor.

Operating at an aerobic SRT of 7 days under maximum loading conditions the predicted MLSS concentration is 5,200 mg/L. The increase in MLSS concentration during maximum month conditions, compared to average day conditions, is associated with the higher BOD and ammonia loads. As indicated in Table A.1.6, an MLSS concentration of 5,200 mg/L is near the maximum capacity of the clarifiers.

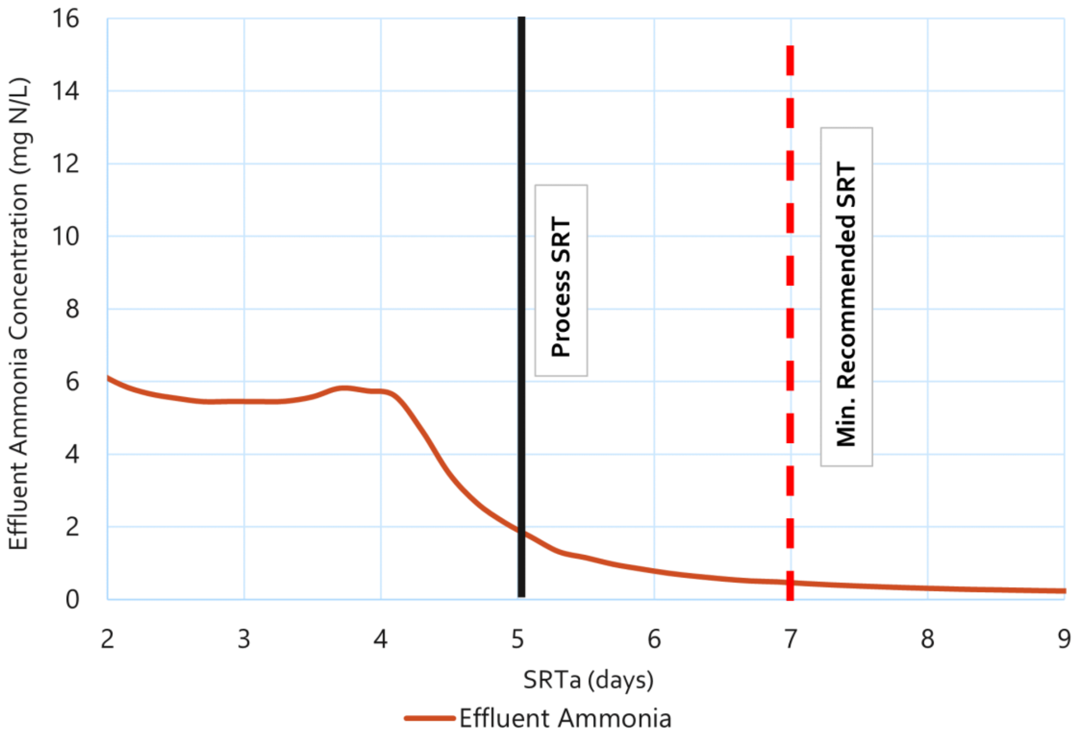


Figure A.1.12 Run 3 - Maximum Month (MMADF, MMADL) and Winter Temperature Nitrification Curves

Under normal operating conditions most WRPs operate aeration basins at MLSS between 2,500 and 3,500 mg/L. Under peak loading conditions some plants can operate with MLSS concentrations in excess of 4,000 mg/L if adequate clarifier capacity is available. Due to the extremely high MLSS concentration of 5,200 mg/L a SPA was performed to determine if adequate clarifier capacity is available for short periods of time when high loads and cold temperatures coincide. The SPA for maximum month flow and load and winter temperatures is illustrated in Figure A.1.13. The SPA indicates that the state point of the clarifier (circle where the solids overflow and solids underflow lines cross) is just below the flux curve indicating the clarifiers are near capacity.

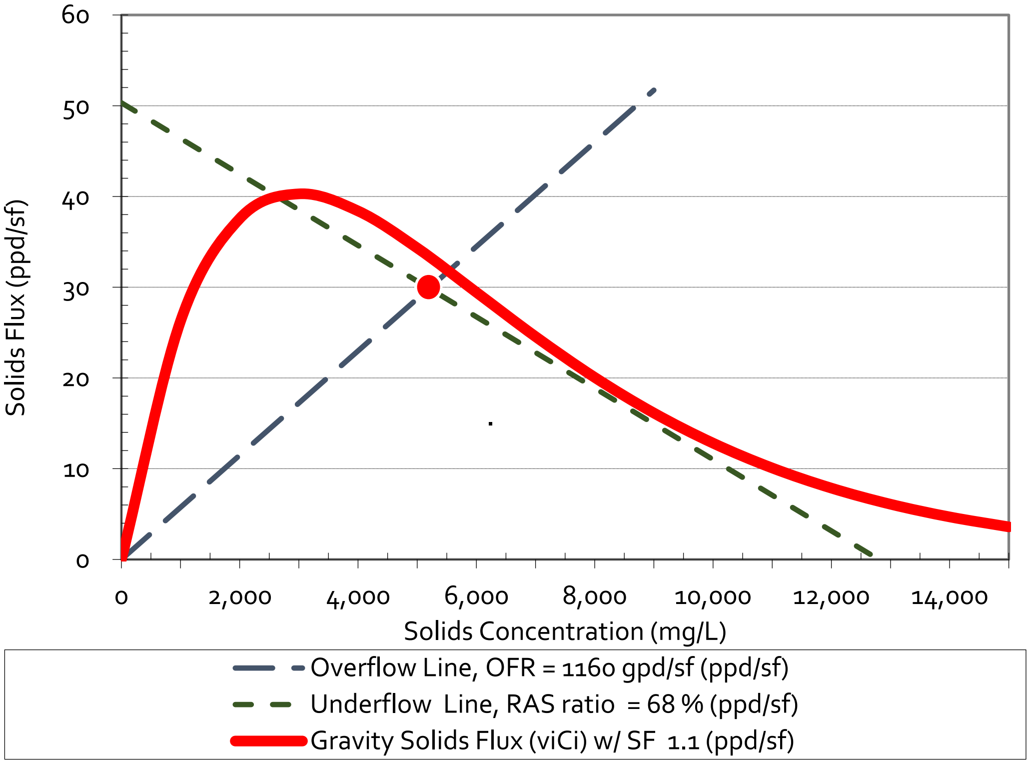


Figure A.1.13 Run 3 SPA Analysis at Maximum Month Condition (MMADF, MMADL), Winter Temperatures, and 2/3 of the First Pass of 1st Stage Aeration Tanks is Anaerobic

Operating the clarifiers under the conditions indicated in Figure A.1.13 for extended periods of time is not recommended. However, the probability of maximum month flows and loads and cold temperatures occurring simultaneously is low. Figure A.1.14 presents Kirie WRP influent BOD_5 load and wastewater temperatures from 2014 through mid-2017. The figure indicates that peak loads shown rarely if ever coincide exactly with low temperatures. Therefore, the likelihood or the duration of operating conditions that would require 5,200 mg/L MLSS concentrations is low.

If worst case conditions occur simultaneously, the District has limited operational flexibility to accommodate the occurrence. For example, the following mitigation is available:

- 30 day or longer averaging period to accommodate temporary excursions of ammonia or P.

Process simulation modelling Run 4 was performed to evaluate the drop in MLSS that occurs when the 2/3 of the first pass of each aeration basin (aerating the swing zone) is operated under aerobic conditions with only 1/3 operating under anaerobic conditions.

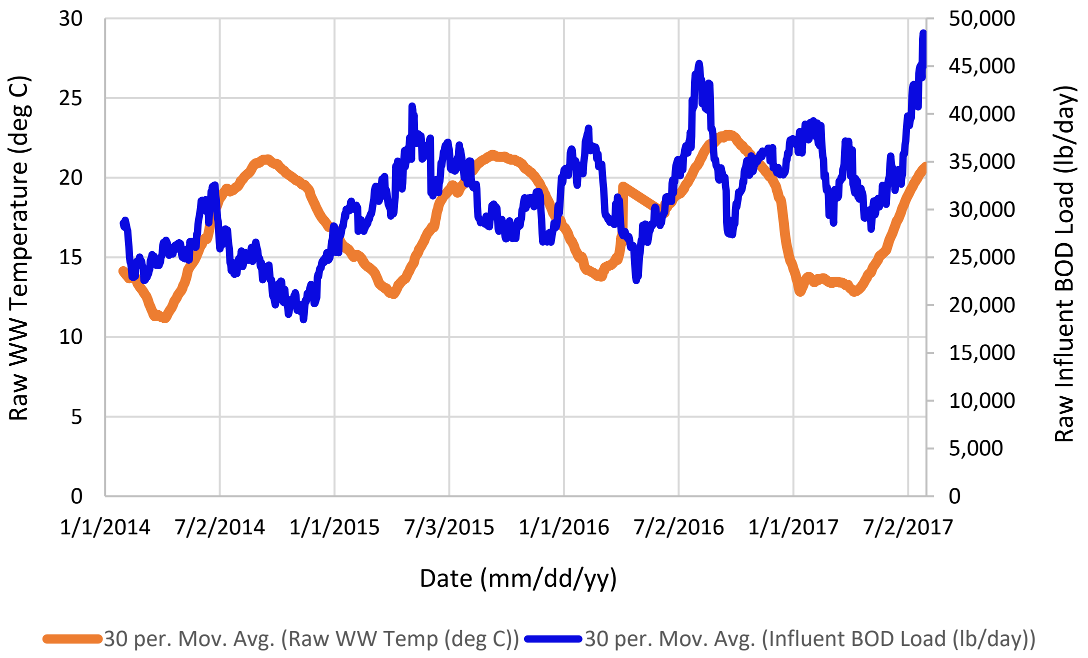


Figure A.1.14 Historical Record of Kirie WRP Influent BOD_5 Load and Influent Temperature

A.1.5.1.4 Run 4 Nitrification Results - MMADF, MMADL; Winter Temperature = 10.0 deg. C, Effluent Ammonia Requirement = 1.5 mg/L, 1/3 of the First Pass of 1st Stage Aeration Tanks is Anaerobic

As with model Run 2 and 3, the operating aerobic SRT to achieve effluent ammonia concentrations of 1.5 mg/L during maximum month flow and load conditions, and winter temperatures is 7 days. At an operating aerobic SRT of 7 days under maximum loading conditions and only 1/3 of the 1st pass under anaerobic conditions the predicted MLSS concentration drops to 4,800 mg/L.

The SPA for maximum month flow and load and winter temperatures with only 1/3 of the first pass anaerobic is illustrated in Figure A.1.15. The SPA indicates that the state point of the clarifier (circle where the solids overflow and solids underflow lines cross) has dropped further below the flux curve due to reduced MLSS concentrations indicating the clarifiers are not operating as close to capacity as indicated in Run 3. When MLSS is anticipated to be very high, RAS rates may have to be managed to prevent solids transfer limitations.

Designing the first pass of the aeration tanks with 1/3 anaerobic zone, 1/3 swing zone (either aerobic or anaerobic), and 1/3 aerobic zone provides the flexibility to balance nitrification SRT, P removal performance, and MLSS concentrations that accommodate a wide range of operating conditions. Providing a swing zone in the first pass of 1st stage aeration tanks, following an anaerobic zone, will make nitrification process more robust, flexible, and reliable during the critical winter conditions.

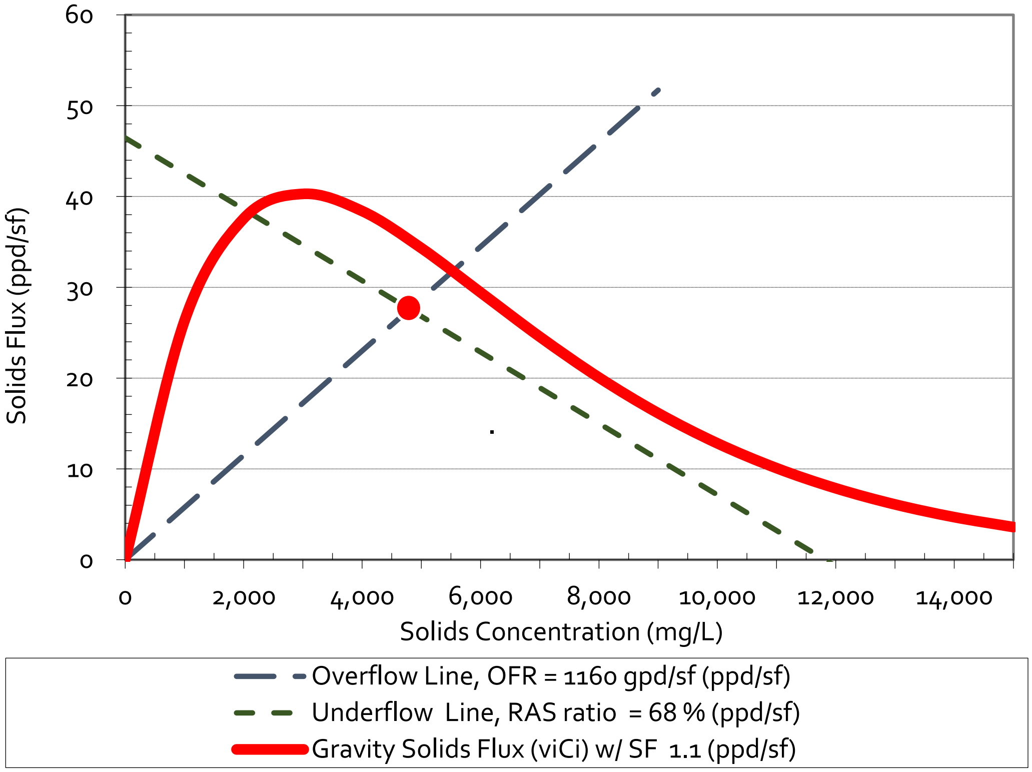


Figure A.1.15 Run 3 SPA Analysis at Maximum Month Condition (MMADF, MMADL), Winter Temperatures, and 1/3 of the First Pass of 1st Stage Aeration Tanks is Anaerobic

A.1.5.2 Alkalinity and Denitrification

The nitrification reaction consumes alkalinity in the wastewater. As alkalinity drops, the buffering capacity to prevent pH reduction is lost. AOBs are sensitive to inhibition at lower pH. As AOBs are inhibited, the nitrifier growth rate drops, and the nitrification efficiency decreases. Therefore, adequate alkalinity is also essential for efficient nitrification. The NAS process can become alkalinity limited when the residual effluent alkalinity reaches between 75 mg/L and 100 mg/L. If the NAS process is alkalinity limited, either supplemental alkalinity addition using lime (or similar chemical) or alkalinity recovery is required.

Denitrification in a BNR process can recover some of the alkalinity that is consumed during nitrification. The Kirie WRP, has a historical average effluent alkalinity of 322 mg/L and exhibits sufficient alkalinity to support complete nitrification. Therefore, more complex BNR configurations that incorporate denitrification are not required and were not evaluated.

A.1.5.3 Optimization for Bio P

The analysis of nitrification performance with Bio P described in Section A.1.5.1 indicated that the Kirie WRP can maintain nitrification under most loading and temperature conditions with 2/3 of the first pass of the 1st stage aeration tanks operating under anaerobic conditions. Reducing the anaerobic zone to 1/3 of the first pass of the 1st stage aeration tanks is recommended in the event that additional aeration volume is temporarily required to accommodate elevated loading or abnormally low temperatures.

Bio P performance was evaluated as a function of the size of the anaerobic zone within the first pass of 1st stage aeration tanks. The calibrated process simulation model was configured with two equal sized anaerobic zones in series. Each zone was approximately 11 percent of the total tank volume. The second anaerobic zone can be operated as a swing zone either under aerobic or anaerobic conditions. The remaining aeration tank volume is operated as aerobic zone. The anticipated Bio P performance expressed as effluent soluble P and total P was predicted using the process simulation model at AADF with AADL conditions. The process simulation model was also used to predict the corresponding concentration of PAO biomass within the anaerobic zone.

The model predicted effluent P concentrations at varying amounts of anaerobic volume in the first pass of the 1st stage aeration tanks as shown in Figure A.1.16. The x-axis of the figure shows the length along the first pass as indicated by the number of aeration header drop legs. During Bio P testing temporary baffle walls were placed between drop legs 4 and 5 and 8 and 9 in test tanks Nos. 5 and 6. This created an anaerobic zone in the first 2/3 of the first pass upstream of the baffle walls. During Bio P testing, test tanks Nos. 1-4 had the air turned off in drop legs 1-4. This created anaerobic zone upstream of drop leg 5. The primary y-axis of Figure A.1.16 indicates model predicted effluent soluble P and TP concentrations. The secondary y-axis indicates the PAO concentration at the end of the aerobic zone of the 1st stage aeration tanks.

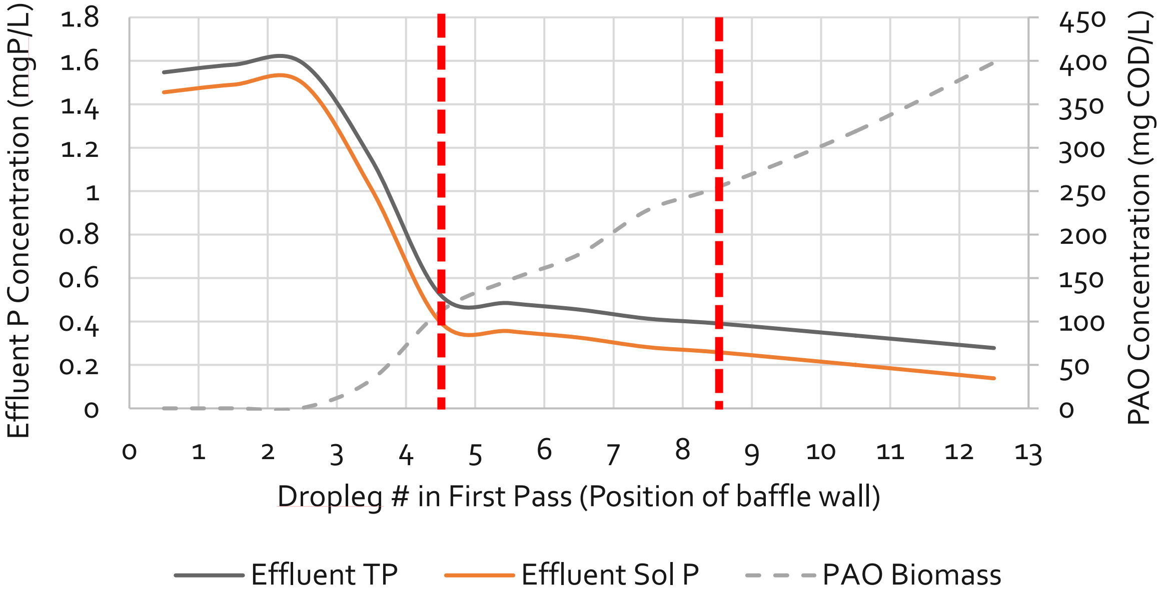


Figure A.1.16 Predicted Bio P Process Performance at Average Day Conditions

A.1.5.3.1 Critical Mass of PAOs

Figure A.1.16 indicates several important factors associated with Bio P removal optimization. The figure indicates that there is a critical mass of PAOs required before Bio P begins. This occurs at about drop leg 3 where PAO concentrations begin to increase and P concentration begins to decrease. At the average operating SRT and MLSS concentrations critical PAO mass occurs at an anaerobic zone volume of approximately 7 percent of the total aeration tank volume.

A.1.5.3.2 The Drop in Bio P Rate is Related to Carbon Limitations

The model shows the Bio P system reaches a linear breakpoint between drop legs 4 and 5 at the location of the recommended first baffle wall location with an anaerobic zone volume of approximately 11 percent of the total aeration tank volume. The Bio P reaction rate drops significantly at this point through the second anaerobic zone up to approximately 22 percent of the total aeration tank volume. The drop in Bio P rate is related to carbon limitations. The analysis indicates that beyond 11 percent anaerobic zone only slowly degradable carbon is available and that carbon is released through in-basin fermentation. Fine tuning of the baffle wall location of the first anaerobic zone will provide little benefit as it was located during testing at the model predicted rate change location. Reducing the first anaerobic zone size may risk incomplete Bio P reduction in the first zone under varying conditions.

A.1.5.3.3 Diminishing Return on Bio P

Bio P is predicted to continue at the slower rate of diminishing returns beyond the second anaerobic zone. As previously stated, the analysis of nitrification performance with Bio P described in Section A.1.5.1 indicated that no more than 2/3 of the first pass of the 1st stage aeration tanks can be dedicated to anaerobic conditions and still maintain nitrification at current average conditions.

A.1.5.3.4 Kirie Bio P Process Performance

The analysis of Bio P process performance indicates that most P release occurs in the first anaerobic zone at approximately 11 percent of the total aeration tank volume. The model predicts an effluent soluble P concentration of approximately 0.4 mg/L and a TP concentration between 0.5 mg/L and 0.6 mg/L through the first anaerobic zone. The model predicts additional P removal to a soluble P concentration between 0.2 mg/L and 0.3 mg/L and a TP concentration of approximately 0.4 mg/L through the second anaerobic zone at approximately 22 percent of the total aeration tank volume. The model predictions were performed at average conditions. Under varying operating and loading conditions that are expected at any WRP, it is prudent to provide anaerobic zone volume beyond the rate change location shown at the first baffle wall due to the risk of loss of adequate PAO population and rapidly declining Bio P performance. Therefore, we recommend that two anaerobic zones, each approximately 11 percent of the total aeration tank volume (or 2/3 of the first pass) be incorporated into the optimization strategy.

A.1.5.4 Carbon Requirements for Bio P

Adequate carbon is a critical component of the Bio P process. In general, facilities that do not use primary treatment such as the Kirie WRP have more carbon available to support Bio P. Treatment facilities in warm climates and with long and flat collection systems typically treat raw wastewater with more readily degradable VFA concentrations to support Bio P.

The amount of available carbon for Bio P is commonly expressed as the BOD_5:TP ratio entering the activated sludge aeration tanks. A BOD_5:TP ratio ranging from 20:1 to 30:1 is typically required for effective Bio P. Figure A.1.17 shows the measured BOD_5:TP ratios at the Kirie WRP. The 30 day moving average influent BOD_5:TP ratio typically ranges between 30 to 40, with high values approaching 50:1. Although the BOD_5:TP ratio is variable with influent flow conditions the ratio rarely drops below 20:1.

The BOD_5:TP ratio data at the Kirie WRP suggests that there is adequate carbon available for efficient Bio P. The modeling results (and Bio P demonstration testing) indicate that the carbon in the raw wastewater contains adequate VFAs to support Bio P down to about 0.5 mg/L without the need for supplemental carbon. Furthermore, the modeling suggests that additional VFA production through in-basin fermentation of MLSS in an extended anaerobic zone can reduce effluent P by an additional 0.1 to 0.2 mg/L. In addition, during periods where VFA may be limited intermittent mixing of the first and second anaerobic zones can also provide MLSS fermentation and increased VFA production. Based on these results supplemental carbon addition or advanced carbon management is not required and was not evaluated for the optimization analysis.

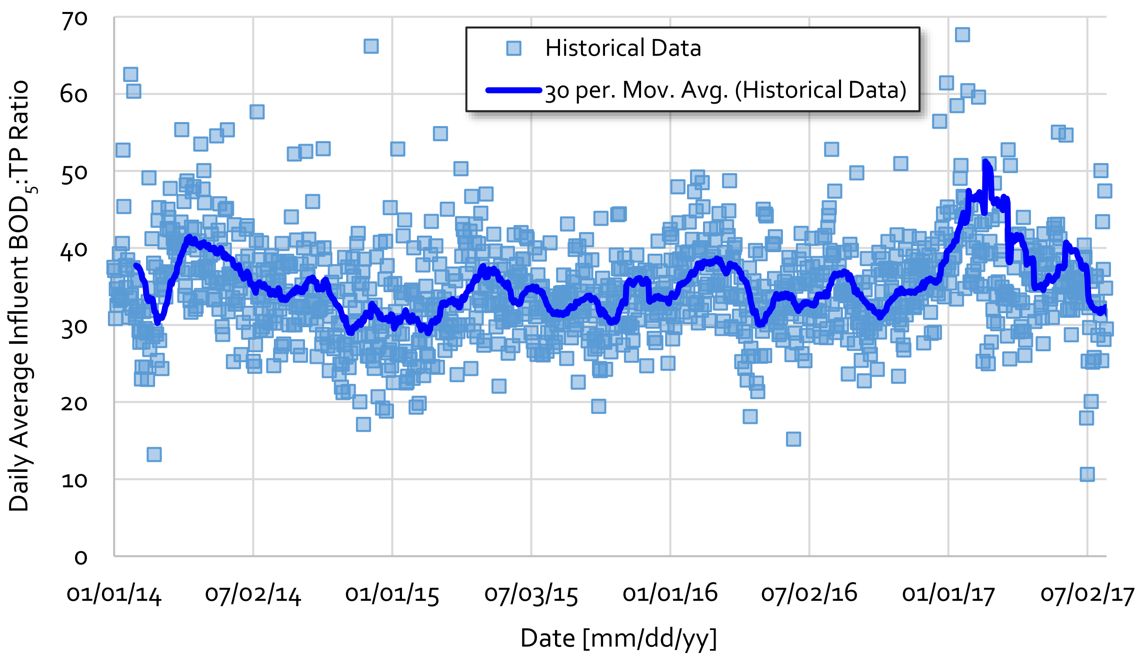


Figure A.1.17 Daily Average Influent BOD_5:TP Ratio at Kirie WRP

A.1.6 Bio P Process Optimization and Control

This section describes optimization and control techniques recommended to support efficient and effective Bio P.

As part of the P removal optimization improvements at the Kirie WRP several elements that impact the efficiency and performance of Bio P should be considered and addressed, as necessary. These include:

- Zone Baffle Wall Design - to create distinct zone boundaries, avoid scum trapping, and minimize back mixing.
- Anaerobic Zone Mixing - to provide adequate mixing, minimize physical obstructions, and prevent excess introduction of dissolved oxygen (DO) into anaerobic zones.
- Aeration Diffuser and Drop Leg in Swing Zones - to allow reactivation and cleaning of diffusers.

Two additional items to be considered when evaluating Bio P include:

- Minimizing the Impact of RAS Recycle - to provide efficient Bio P.
- Provision for Appropriate Data Monitoring and Instrumentation and Control - to improve monitoring and operation of an optimized Bio P process.

The following sections discuss each of these elements as related to the Kirie WRP and how each has been addressed as part of the improvements from the Bio P testing program, where applicable. The P removal optimization measures that have already been implemented represent all practical measures available at this time and they have been proven to be effective at achieving desirable levels of P removal. As such, additional optimization measures will not be pursued as part of this effort. There are diminishing performance returns with additional measures and since they are not necessary at this time, the potential performance improvements do not outweigh the additional infrastructure expenditure that would be required.

A.1.6.1 Baffle Walls, Mixers, and Aeration Diffusers

The P removal optimization analysis indicates that the Kirie WRP can achieve effluent TP concentrations of less than 1 mg/L using a simple A/O process while retaining adequate capacity for nitrification under current flows and loads. Therefore, more complex Bio P configurations that might require changes in the flow pattern through the aeration tanks are unnecessary.

A.1.6.1.1 Baffle Wall Recommendations

Baffle walls are important for creating a permanent and well-designed A/O process configuration. Baffle walls should generally be placed between drop legs 4 and 5 and between drop legs 8 and 9 to create three first pass zones operated under anaerobic, swing (anaerobic or aerobic), and aerobic conditions. With baffle walls placed in these locations the first pass zone sizes are 10.3 percent, 10.3 percent, and 12.7 percent of the total aeration tank volume, respectively.

Baffle walls are beneficial to minimize back mixing between aerobic and anaerobic zone and to help reduce filament growth that can occur in extended transitional zones between anaerobic and aerobic conditions. Figure A.1.18 shows the recommended zone layout and baffle wall position in the first pass of an aeration tank at the Kirie WRP. The blue dots represent the location of the existing air header drop legs. The red lines indicate location of zone baffle walls in the first pass.

Figure A.1.18 Recommended Zone Layout for the Number and Location of Baffle Walls in the First Pass of the 1st Stage Aeration Tank

Permanent baffle walls can be constructed of either concrete, wood, or fiberglass reinforced plastic (FRP). Occasionally, fabric curtains are used as more temporary baffle walls. The selected material for baffle walls depends upon the desired capital and O&M cost tradeoff and whether or not the best position for the walls is clear based on modeling, testing, or experience. For the Kirie WRP the optimal wall location has been verified through modeling and full-scale testing. There is little risk that baffle walls will have to be moved in the future. Concrete walls are the most permanent and robust material but require higher capital cost for construction. Wood, FRP, and curtain walls must be replaced more frequently and are generally less expensive to construct. Temporary wooden baffle walls were installed in aeration tanks 5 and 6 for the Bio P testing program and testing results demonstrated improved P removal as expected. The baffle walls in aeration tank 6 have since been removed due to failure, but P removal performance has held steady. As such, given the continued improved treatment performance that has been observed, baffle walls are considered complementary, but not critical for effective Bio P.

A 1.0 mg/L monthly average TP permit limit goes into effect on August 1, 2026, and a 0.5 mg/L annual geometric mean on January 1, 2030. Creating permanent anaerobic zones sized as indicated above will support the ability to use Bio P as part of the process to meet these future limits. However, until then, the remaining temporary baffle walls in aeration tank 5 in combination with the other optimization measures already in place from Bio P testing have proven to be sufficient in achieving P removal. As such, additional measures related to baffle wall installation are not recommended to be pursued at this time.

A.1.6.1.2 Anaerobic and Swing Zone Mixer Recommendations

Several types of anaerobic/anoxic zone mixers are available on the market today. These include:

- Large bubble intermittent burst mixers.
- Vertical top entry bladed mixers.
- Top mounted hyperboloid-type mixers.
- Wall mounted impeller mixers.
- Banana blade mixers.

Different mixers have a range of costs and mechanical advantages and disadvantages. The selection of the mixer type and manufacturer often depends upon the existing aeration diffuser type, grid layout, and drop leg configuration. Providing adequate access, bridges, and power and control conduit routing that does not create an obstruction can be challenging with electric motor driven mixers. For this reason, the large bubble mixers are gaining popularity in the industry.

Large bubble mixers can use air supply from aeration air systems, other existing air supply (instrument air or channel air), or dedicated compressors. Although adding oxygen to anaerobic zones in a Bio P process should be avoided to maintain process efficiency, the oxygen transfer associated with a large bubble is relatively low. In addition, bubble release for mixing is infrequent. For the Kirie WRP with extended anaerobic zones the impact of large bubble mixing on the performance efficiency is anticipated to be minor. The Kirie WRP installed large bubble mixers in a portion of the anaerobic zones in aeration tanks 5 and 6 during the Bio P testing program. The large bubble mixing air is supplied from the instrument air system. The mixers performed well and continue to be in use to great effect.

For the time being, given the Bio P performance with the large bubble mixers already installed in aeration tanks 5 and 6 along with the other optimization measures in place to achieve a Bio P operation mode, additional large bubble mixers are not considered necessary and therefore not recommended. As such, to avoid unnecessary capital expenditure, they will be tabled until permanent infrastructure is installed to meet the upcoming limits.

A.1.6.1.3 Aeration Air Diffuser Recommendations

The existing aeration tanks at the Kirie WRP use ceramic plate diffusers embedded in the floor of each pass. Ceramic diffusers are commonly used for swing and aerobic zones in a BNR facility. As part of the P removal optimization and to minimize capital investment, there is no need to modify the existing aeration air diffuser system.

Permanent removal or replacement of existing ceramic diffusers in the anaerobic and swing zones will be evaluated as part of the P Removal Feasibility analysis presented in TM A.2.

If the existing ceramic diffusers are left in place in the anaerobic and swing zones, it should be noted that periodic cleaning to prevent permanent plugging may be required. Some cleaning could be accomplished through regular air bumping and operation of diffusers to dislodge accumulated biomass. In addition, periodic high pressure washing or chemical cleaning may be required to maintain the ability to reactivate diffusers in the swing zones when needed.

While these are viable cleaning strategies to prevent plugging and maintain effective operation of swing zones with ceramic plate diffusers, in the case of the Kirie WRP, when the swing zone was operated anaerobically during Bio P testing, the District discovered excessive and irreversible fouling. Plugging of the ceramic plate diffusers was found to be debilitating to overall aeration system performance. As a result of this experience and to avoid similar issues in the future, the District has elected to operate the swing zone exclusively in aerobic mode.

A.1.6.2 Minimizing Impacts of Recycle Stream

The presence of DO and nitrate (NO_3) in anaerobic zones of a Bio P process impact environmental conditions that support growth of PAOs and P release therefore reducing process efficiency. Process simulation modeling and demonstration testing of Bio P indicates effective performance at Kirie WRP under the current raw wastewater feed, channel aeration, RAS rates, and temporary baffle wall configuration. The District staff has reported a decrease in Bio P performance and efficiency when very high DO concentrations are measured in the final pass of the aeration tanks. For purposes of P removal optimization and considering the recommendation for extended anaerobic zones, significant operational adjustments or capital investments are not necessary to address the impact of recycle streams. However, best management practices to limit DO and nitrate in the anaerobic zones without compromising other treatment processes are recommended.

Best management practices might include:

- Management of aeration tank DO in the last pass to reduce oxygen concentration returned to the anaerobic zones in the RAS. Tapering the aeration and DO from the head to the tail of the aerated zone generally allows adequate nitrification performance while limiting last-pass DO. In the future if DO is found to impact the Bio P performance, and a high DO in the aeration tanks is required to meet effluent permit DO requirements, it is recommended that the District consider reducing the DO setpoints in the aeration tanks and activating the post-aeration facility to increase DO just prior to discharge.
- Designing zone baffle walls to limit the amount of back mixing of high DO MLSS from aerated to anaerobic zones.
- Manage RAS rates to minimize unnecessary DO and nitrate return to the anaerobic zone.
- Avoid over aeration of wastewater feed channels and RAS return channels.
- Provide adequate instrumentation and control to evaluate the operating conditions and performance of the Bio P system.

A.1.6.3 Data Monitoring and Instrumentation and Control

Additional data monitoring and instrumentation can assist in improved Bio P control. Additional instrumentation beyond oxidation reduction potential (ORP) (optional) is not required for optimization but can be installed later if necessary to improve performance.

A.1.6.3.1 Data Collection and Monitoring

The Kirie WRP staff currently collects sufficient data for plant operations. As part of Bio P optimization, the staff may wish to consider preparing additional trending charts for the following information:

- Influent and effluent TP (Daily and 30 day moving average).
- Influent BOD_5 to TP ratios (Daily and 30 day moving average).
- Number of anaerobic zones in service.
- End of aeration tank DO vs. effluent TP.
- Aeration tank MLSS vs effluent TP.
- RAS rate vs. effluent TP.
- Anaerobic zone ORP vs. effluent TP.
- Anaerobic Zone ORP vs. end of aeration tank DO.

A.1.6.3.2 Instrumentation and Control Systems

Some agencies that operate Bio P facilities use online ORP meters to monitor the condition of the anaerobic zones. The anaerobic zone should operate in highly reducing conditions. The proper environment for phosphorus release in an anaerobic zone is indicated by a negative ORP value typically ranging from - 100 mV to - 250 mV. An ORP on the high side of the range can indicate inefficient P release due to nitrate or oxygen poisoning of the zone. It is typically not necessary to monitor ORP in every anaerobic zone in every aeration tank where multiple parallel trains exist and plant operations are generally consistent throughout.

A.1.7 Evaluation of Potential Unintended Consequences

Operational or process adjustments made in one area of the plant can lead to ramifications that were not anticipated in other areas of the plant. These unforeseen ramifications or unintended consequences can occur when either Chem P or Bio P is implemented. The risks, side effects, and unintentional consequences of Bio P can add significant capital and operating costs. We recommend that all of the cost and O&M impacts of Bio P be considered before making the recommended operational changes. Some of the common unintended consequences associated with Bio P include:

- Biosolids handling impacts:
  - A reduction of dewatered cake solids percentage.
  - An increase in thickening and dewatering polymer use.
  - An increase in biosolids processing and disposal costs.
- An increase in formation of struvite or other scale causing compounds.
- An increase in power costs for zone mixing or associated with activating additional aeration basins to make up for lost volume of anaerobic zones.
- Potential generation of odors.
- Plant operational difficulties and additional O&M challenges.
- Increased process monitoring, laboratory analysis, and data management costs.

The unintended consequences identified above are noted to help improve the transition to Bio P operations. Mitigation measures will be addressed in the feasibility study TM A.2, if deemed necessary.

A.1.7.1 Biosolids Handling Impacts

Implementation of Bio P at the Kirie WRP may lead to a minor increase in sludge production associated with additional PAO biomass in the MLSS. Model predictions estimate sludge production increases of approximately 2 percent or less. Wasted solids from the Bio P process have different characteristics than non-Bio P solids. In general, the industry has noted a 3 to 5 percent reduction in cake solids percentage points when dewatering Bio P sludge as compared to non-Bio P sludge. At typical dewatered cake solids percentages of 25 percent, a 5 percentage point drop in cake dryness results in a 25 percent increase in cake volume for hauling, disposal, or reuse.

In addition to the decrease in cake dryness and solids content, the polymer demand for thickening and dewatering also increases. In general, the industry has noted a 10 to 20 percent increase in polymer use when dewatering Bio P sludge as compared to non-Bio P sludge.

Biosolids produced at Kirie WRP are transferred to Egan WRP for processing and disposal or reuse. Therefore, impacts due to the implementation of Bio P associated with solids handling will occur at the Egan WRP. These impacts will be discussed as part of the Egan WRP P removal optimization and P removal feasibility study TMs.

A.1.7.2 Scale and Struvite Formation Potential

Potential compounds that cause scaling or precipitation in a Bio P process include brushite ($CaHPO_4$), newberyite ($MgHPO_4$), and struvite ($MgNH_4PO_4$). Of these compounds struvite (or magnesium ammonium phosphate) is the most prevalent when operating BNR facilities that change the chemical ratios of ammonium and phosphate through biological conversion. Scaling at WRPs often occurs where high concentrations of nutrients are present or chemical changes including heat, pH, and pressure occur. Scaling and struvite formation in mainstream tanks or piping is less frequent as these conditions do not exist. However, scaling and struvite formation is more prevalent in solids handling systems and side-streams like centrate. In general, there is less risk of scaling or struvite formation with Bio P at the Kirie WRP because there is limited solids handling, chemical changes in the process, and facility side-streams return to the plant. Scaling or struvite formation is possible in the waste sludge pipeline from Kirie WRP to Egan WRP.

In general, with or without Bio P, struvite formation potential in the WAS sludge from the Kirie WRP is low because both liquid phosphate and ammonia concentrations are low as these nutrients are bound in the solids. However, it is possible that the biosolids from the Kirie WRP will decay in the sludge transfer pipe and release ammonia and soluble BOD. If the conditions in the pipeline become anaerobic, PAOs will release stored phosphorus which creates conditions for struvite formation or calcium phosphate scale. The probability of scale formation in the sludge transfer piping to the Egan WRP is dependent on the travel time, the anaerobic conditions, and the rate of decay to release ammonia.

The calibrated process model was used to estimate the release of nutrients in the pipeline and the potential for scale formation. The optimization study does not consider the addition of metal salts for phosphorus removal (i.e. ferric chloride, alum). If the solids transferred to the Egan WRP contain metal salts there is a potential for other scale types to form.

At an average continuous Kirie WRP waste sludge flow of 0.6 mgd, the estimated retention time in the 18-inch, 7-mile length pipe from Kirie to Egan is approximately 1.6 days. Initial calcium and magnesium concentrations in the pipe are assumed to be equivalent to the effluent concentrations, which are routinely sampled at Kirie WRP. Simulations show that over a 1.6 day transit time nearly all polyphosphate is released under anaerobic conditions, however decay of the biosolids and ammonia release is limited. The mineral availability is also low. As such, the scaling and formation potential for calcium phosphate, newberyite, and struvite in the transfer pipeline is considered to be low.

A.1.7.3 Impacts on Aeration Power Costs and Energy Neutrality Goals

Some facilities that implement Bio P experience higher power cost despite the anaerobic nature of the process. Higher power costs are primarily associated with four factors. None of these factors are anticipated to result in significant additional power cost for Bio P optimization at the Kirie WRP.

- Mixing of anaerobic zones.
- Makeup of lost nitrification capacity due to incorporation of anaerobic zones to a degree that requires activation of additional unused aeration tanks.
- Need to reduce the DO setpoints in the aeration tanks to support efficient Bio P to the degree that post aeration must be used to meet effluent DO requirements.
- Chemical feed systems for ferric or supplemental carbon to overcome carbon limitations.

The P removal optimization recommendations include anaerobic zone mixing using large bubble mixers. These mixers are not powered by electric motors. Therefore, mixing will require little additional power over the existing configuration.

P removal optimization does not require the activation of the 2nd stage aeration tanks in order to make up for lost nitrification capacity. The amount of aeration required in the A/O process is driven by the ammonia load and nitrification. Nitrification air demand does not change with Bio P despite a reduced aerobic zone volume. Therefore, no additional power cost for aeration air is anticipated.

The DO in the final pass of the aeration tanks is sometimes high. District staff has noted the potential impact in Bio P efficiency when the final pass DO is elevated. However, due to the optimization recommendation to use "extended anaerobic zones" we anticipate little if any impact in performance with normal operating DO setpoints. Therefore, there is no need for activation of the post aeration process at the Kirie WRP. No additional power is anticipated to meet effluent DO requirements.

As indicated in Section A.1.5.4, the Kirie WRP does not use primary treatment. Therefore, adequate carbon to support the Bio P process is available for optimization of TP less than 1.0 mg/L. Supplemental carbon feed or advanced carbon management practices are not necessary. In addition, optimization is defined as optimization of Bio P only without Chem P implementation. Therefore, there is no additional power cost associated with carbon or other chemical feed demands.

In summary, the existing Kirie WRP energy use and power cost profile is not expected to increase due to implementation of optimized Bio P.

A.1.7.4 Generation of Odors

Anaerobic conditions within a wastewater facility can result in odor generation. Odorous anaerobic conditions often occur where solids are held in anaerobic conditions long enough to break down carbons to shorter chain acidic compounds. This generally requires solids and hydraulic retention times in excess of 1 or more days.

In general, anaerobic zones within Bio P aeration tanks are sized to provide hydraulic retention times (HRTs) ranging from 30 to 60 minutes or less. As such, under normal operations, odor generation from anaerobic zones is not significant. However, if the anaerobic zone volume size is extended beyond a few hours to promote fermentation and VFA production noticeable odors can occur. If the mixing systems are used intermittently or do not provide adequate mixing to keep solids in suspension, pockets of settled solids can occur. Whereas pockets of settled solids can be beneficial for carbon fermentation and P release, additional odors are generated in pockets of scum or solids. Odorous gasses can escape from the surface of the anaerobic zones especially immediately after intermittent mixing systems are activated. In general, we observe that the conditions that lead to odor generation in Bio P anoxic zones are transient and can be mitigated through proper timing of the zone mixing and use of swing zones.

Based on the location of the Kirie WRP and distance to local neighbors, we do not anticipate significant odors associated with Bio P operations that will require covering, ventilation, and off gas scrubbing of the anaerobic zones.

A.1.7.5 Operational Difficulties and Challenges

Some facilities that implement Bio P experience operational challenges despite the similarities with nitrification and other BNR plant configurations. The District staff should be aware of the following potential operational difficulties and challenges that can result from full scale Bio P process operations:

- Higher degree of process monitoring and control may be required to maintain the effectiveness of Bio P process, and avert potential plant upsets.
- Over-optimization for P removal with Bio P has the potential for compromising other plant process performance goals. Optimization for P removal should be carried out in balance with other processes performance considerations.
- Recovery from upsets when optimizing for Bio P can be more challenging. It may become harder to mitigate foaming episodes, filament growth, and high SVI while operating for optimized Bio P.
- Competition from glycogen accumulating organisms (GAOs) must be managed. GAOs consume VFAs (inhibiting PAO growth), but do not uptake, store, and release phosphorus like the PAOs.
- PAOs uptake P under aerobic conditions and release P under anaerobic conditions. Operational caution must be taken to avoid "secondary P release" from phosphorus rich PAOs. Secondary P release can occur in channels, clarifiers, and piping and equipment having anaerobic conditions.

- Effluent TP is a combination of effluent soluble P (ortho-phosphate) and the P bound in the effluent total suspended solids (TSS). If a plant upset episode occurs that increases effluent TSS, the effluent TP may also increase. Currently the Kirie WRP uses dual final clarifiers in series without filtration. Dual clarification results in low effluent TSS. If dual clarification is compromised and effluent TSS rises, it will impact P optimization.
- For some facilities, additional data collection, laboratory analysis, and/or instrumentation control is required for improved operational control of Bio P. Online instrumentation to monitor ORP, sludge blanket levels may be desirable. Lab analysis and monitoring of data relating to VFAs, ortho-P at several places in the process including MLSS, clarified effluent, filtered effluent etc. may be important. Trending of P vs. other operating parameters such as DO, aerobic SRT, total SRT, MLSS concentration, and BOD_5:TP ratios can help support improved operations. Additional microscopic analysis may also be helpful for better process control.
- Additional monitoring of DO and management of setpoints may be warranted to optimize DO control. Management of DO concentrations in the last pass of aeration tanks may improve Bio P performance and efficiency.
- If calcium nitrate or other oxidizing compounds are added to the raw wastewater for odor and corrosion control, monitoring of the calcium nitrate dosage and effluent soluble P concentration may be required. These oxidizing agents can reduce the BOD_5 in the wastewater. Significant decrease in BOD_5 concentrations can decrease the BOD_5:TP ratio and the amount of carbon available for Bio P. The residual nitrate can also impact the P release efficiency in the anaerobic zones affecting Bio P process performance.

A.1.8 Summary of Bio P Removal Optimization Conclusions and Recommendations

The following summarizes the major conclusions and recommendations of the P optimization study for Kirie WRP:

- Industrial dischargers contribute an average of 7.3 percent of the daily influent total P load to the Kirie WRP. A combined industrial TP contribution between 5 percent and 10 percent of the daily influent load is considered to have only a "slight impact" or "no impact" on the capital or O&M costs associated with P removal. Therefore, the P optimization analysis was performed assuming no reduction in industrial TP load.
- Food manufacturers and metal finishing facilities have a potential to contribute higher percentage of the daily average P load compared to other industries. The District's IWD may wish to conduct additional P monitoring or work with select industries with the potential for high peak P discharges to emphasize the importance of effluent P management.
- A calibrated GPS-X process simulation model was prepared to evaluate Bio P performance under various A/O process configurations and plant loading conditions. The model correlated well with the performance and operating parameters during the Kirie WRP Bio P testing program.
- The Kirie WRP can be optimized for Bio P at current AADF wastewater flows of 35.8 mgd while maintaining complete nitrification under winter temperatures and MMADL.
- Bio P optimization is predicted to result in average effluent TP concentrations between 0.4 mg/L and 0.6 mg/L.
- There is adequate carbon available in the wastewater to support Bio-P to the levels indicated above.

- A few optimization measures were implemented as part of the Bio P testing program which achieved a partial Bio P optimization mode of operation at Kirie WRP. These measures included temporary wooden baffle walls and large bubble mixers in aeration tanks 5 and 6, as well as the air being shut off in the first 1/3 of the first pass of aeration tanks 1 – 4 to create anaerobic zones.
- Testing is complete, but operation in the temporary Bio P mode is still ongoing in 2021. Certain operational modifications have been made, those being the removal of the temporary baffle walls in aeration tank 6 due to failure and converting operation of the swing zones in aeration tanks 5 and 6 from anaerobic to exclusively aerobic mode due to plugging of the ceramic plate diffusers. Even so, since implementation of these measures in January 2016, average effluent concentration has been held steady at less than 0.4 mg/L with approximately 90 percent P removal.
- Given the performance of Bio P with the optimization measures already in place, further implementation of additional measures is not recommended to be pursued as part of this effort. Any practical measures are already active and proving effective at achieving desired levels of P removal. There are diminishing performance returns with additional measures and since they are not necessary at this time, the potential performance improvements do not outweigh the additional infrastructure expenditure that would be required.
- As part of the optimization analysis, the effluent reduction measures specified under Special Condition 24 of the newly reissued NPDES permit were reviewed and incorporated into the overall evaluation, where applicable. Like the other optimization measures evaluated, the applicable effluent reduction measures from Special Condition 24 were generally deemed unnecessary or already implemented in some form as part of the measures still in place from the Bio P testing program. These include the following:
  - Adjust the solids retention time (SRT) for either nitrification, denitrification, or Bio P.
    - Process simulation modeling indicated that sufficient capacity is available within the existing aeration tanks to dedicate the necessary portion as anaerobic to support Bio P, while also achieving full nitrification under all temperature and loading conditions.
  - Add baffles to existing units to improve microorganism conditions by creating divided anaerobic, anoxic, and aerobic zones.
    - Baffles are recommended to create defined zones to enhance Bio P and limit filamentous growth. But given the continued improved treatment performance that has been observed with only the temporary baffle walls remaining in aeration tank 6, they are considered complementary and not critical for effective Bio P removal.
  - Change aeration settings in plug flow basins by turning off air or mixers at the inlet side of the basin system.
    - Full-scale testing with air shut off in the first 1/3 or 2/3 of the first pass of the aeration tanks has proven sufficient in achieving effective Bio P.

  - Increase VFAs for Bio P.
    - Full-scale testing, further supported by process modeling, indicate that the historical influent Carbon:TP ratio at Kirie WRP is adequate to support efficient Bio P without the need for additional measures to increase carbon/VFA availability.
- Some unintended consequences and operational challenges associated with implementation of optimized Bio P may occur at the Kirie WRP. Based on several years of operations under a Bio P test mode, we do not anticipate that these consequences and challenges will be significant under a process optimization scenario. However, the District's M&O staff should be aware of potential impacts of operating the Kirie WRP as a Bio P process and manage those as necessary for success. Some of the impacts of Bio P operations may be transferred to the Egan WRP through the combined solids handling systems.

Appendix A.1-A

SOURCE CONTROL ANALYSIS

TM A.1 Appendix Table 1
Summary Table for Discharger's Total P Contribution to the Kirie WRP

						Facility Specific Sampling Data (2001)[1]			USEPA Effluent Data Based on SIC Code (2015)[2]						Concentrations from Outside Studies[3]			Adjusted Minimum Discharge (lb/d)	Adjusted Daily Min Average % of Total Phosphorus	Adjusted Mean Discharge (lb/d)	Adjusted Daily Mean % of Total Phosphorus	Adjusted Maximum Discharge (lb/d)	Adjusted Daily Max. Average % of Total Phosphorus
Facility Name	**Address**	**Industry Category**	**Primary SIC Code**	**Average Flow Rate (GPD)**	**% of Daily Influent Flow Rate to Kirie**	**Min (mg/L)**	**Geometric Mean (mg/L)**	**Max (mg/L)**	**Min for 4 digit SIC code (mg/L)**	**Mean for 4 digit SIC code (mg/L)**	**Max for 4 digit SIC code (mg/L)**	**Min for 2 digit SIC code (mg/L)**	**Mean for 2 digit SIC code (mg/L)**	**Max for 2 digit SIC code (mg/L)**	**Min (mg/L)**	**Mean (mg/L)**	**Max (mg/L)**						
Acme Finishing Company, LLC	1595 E Oakton Street, Elk Grove Village, IL 60007	Electroplating (metal coating and engraving)	3479	32,821	0.10%	---	---	---	**1.91**	1.91	1.91	0.01	**4.47**	546.83	0.09	**56.86**	318.01	0.52	0.05%	1.22	0.12%	15.56	1.58%
Amitron Corporation	2001 Landmeier Road, Elk Grove Village, IL 60007	Electronic Manufacturing (Printed circuit board manufacturing)	3672	84,980	0.25%	**0.44**	**0.65**	**0.8**	---	---	---	0.00	2.27	4.59	0.09	56.86	318.01	0.31	0.03%	0.46	0.05%	0.57	0.06%
Ampel Inc	925 Estes Avenue, Elk Grove Village, IL 60007	Electronic Manufacturing (Printed circuit board manufacturing)	3672	10,450	0.03%	**0.43**	**0.48**	**0.52**	---	---	---	0.00	2.27	4.59	0.09	56.86	318.01	0.04	0.00%	0.04	0.00%	0.05	0.00%
Anodizing Specialists Ltd	210 Crossen Avenue, Elk Grove Village, IL 60007	Electroplating	3471	455	0.00%	---	---	---	0.01	**7.25**	546.83	0.01	4.47	546.83	**0.09**	**56.86**	318.01	0.00	0.00%	0.03	0.00%	0.22	0.02%
Arlington Park	2200 W Euclid Avenue, Arlington Heights, IL 60006	Horse Race Track	0219	125,144	0.36%	---	---	---	---	---	---	**0.00**	**0.84**	**27.74**	---	---	---	0.00	0.00%	0.88	0.09%	28.95	2.93%
Batory Foods - Chicago Sweeteners	1881 Touhy Avenue, Elk Grove Village, IL 60007	Food Manufacturing	2099	7,027	0.02%	---	---	---	0.05	**11.76**	25.90	0.00	13.03	1562.30	**0.98**	**33.59**	177.00	0.06	0.01%	0.69	0.07%	1.97	0.20%
Belmont Sausage Company	2201 Estes Avenue, Elk Grove Village, IL 60007	Meat Processing	2013	55,427	0.16%	---	---	---	0.01	**0.41**	1.83	0.00	**13.03**	1562.30	0.98	**33.59**	177.00	0.19	0.02%	6.02	0.61%	15.53	1.57%
Block & Company Inc	1111 S Wheeling Road, Wheeling, IL 60090	Metal Finishing	3499	4,534	0.01%	---	---	---	0.07	0.07	0.07	0.01	**4.47**	546.83	**0.09**	**56.86**	318.01	0.00	0.00%	0.17	0.02%	2.15	0.22%
Brett Anthony Foods	1350 Greenleaf Avenue, Elk Grove Village, IL 60007	Food Manufacturing	2099	22,917	0.07%	---	---	---	0.05	**11.76**	25.90	0.00	13.03	1562.30	**0.98**	**33.59**	177.00	0.19	0.02%	2.25	0.23%	6.42	0.65%
Chem-Plate Industries	1250 Morse Avenue, Elk Grove Village, IL 60007	Metal Finishing	3471	80,702	0.23%	---	---	---	0.01	**7.25**	546.83	0.01	4.47	546.83	**0.09**	**56.86**	318.01	0.06	0.01%	4.88	0.49%	38.27	3.88%
Chem-Plate Industries, Inc.	1990 E Devon Avenue, Elk Grove Village, IL 60007	Electroplating	3471	55,805	0.16%	---	---	---	0.01	**7.25**	546.83	0.01	4.47	546.83	**0.09**	**56.86**	318.01	0.04	0.00%	3.37	0.34%	26.46	2.68%
Circuit Engineering, LLC	1390 Lunt Avenue, Elk Grove Village, IL 60007	Metal Finishing	3672	8,121	0.02%	---	---	---	---	---	---	0.00	**2.27**	4.59	**0.09**	**56.86**	318.01	0.01	0.00%	0.15	0.02%	3.85	0.39%
CMP Anodizing, Inc.	1340 Howard Street, Elk Grove Village, IL 60007	Metal Finishing	3471	8,140	0.02%	---	---	---	0.01	**7.25**	546.83	0.01	4.47	546.83	**0.09**	**56.86**	318.01	0.01	0.00%	0.49	0.05%	3.86	0.39%
CMP Anodizing, Inc.	1530 Louis Avenue, Elk Grove Village, IL 60007	Metal Finishing	3471	1,367	0.00%	---	---	---	0.01	**7.25**	546.83	0.01	4.47	546.83	**0.09**	**56.86**	318.01	0.00	0.00%	0.08	0.01%	0.65	0.07%
Commercial Finishes Company, Ltd.	540 Lively Blvd, Elk Grove Village, IL 60007	Metal Finishing	3479	666	0.00%	---	---	---	**1.91**	1.91	1.91	0.01	**4.47**	546.83	0.09	**56.86**	318.01	0.01	0.00%	0.02	0.00%	0.32	0.03%
Doumak Inc	2491 Estes Avenue, Elk Grove Village, IL 60007	Candy Manufacturing	2064	20,205	0.06%	---	---	---	---	---	---	0.00	**13.03**	1562.30	**0.98**	**33.59**	177.00	0.17	0.02%	2.20	0.22%	5.66	0.57%
Electronic Interconnect Corp	2700 W Touhy Avenue, Elk Grove Village, IL 60007	Electronic Manufacturing (Printed circuit board manufacturing)	3672	27,211	0.08%	**0.36**	**0.36**	**0.37**	---	---	---	0.00	2.27	4.59	0.09	56.86	318.01	0.08	0.01%	0.08	0.01%	0.08	0.01%
Engis Corporation, Inc.	105 W Hintz Road, Wheeling, IL 60090	Adhesive Manufacturing	3291	8,428	0.02%	---	---	---	---	---	---	**0.01**	**0.65**	**10.75**	---	---	---	0.00	0.00%	0.05	0.00%	0.76	0.08%
Evangers Dog & Cat Food Co.	221 Wheeling Road, Wheeling, IL 60090	Dog & Cat Food Manufacturing	2047	8,126	0.02%	---	---	---	**0.05**	**46.07**	298.46	0.00	**13.03**	1562.30	---	---	---	0.00	0.00%	0.88	0.09%	0.88	0.09%
Faspro Technologies, Inc.	165 King Street, Elk Grove Village, IL 60007	Metal Finishing	3471	1,507	0.00%	**1.77**	**13.41**	**25.04**	0.01	7.25	546.83	0.01	4.47	546.83	0.09	56.86	318.01	0.02	0.00%	0.17	0.02%	0.31	0.03%
Fluid Management, Inc.	1023 Wheeling Road, Wheeling, IL 60090	Metal Finishing	3559	4,902	0.01%	---	---	---	---	---	---	0.01	**8.07**	281.00	**0.09**	**56.86**	318.01	0.00	0.00%	0.33	0.03%	2.32	0.24%
General Circuits d/b/a Delta Precision Circuits, Inc	1370 Lively Blvd, Elk Grove Village, IL 60007	Electronic Manufacturing (Printed circuit board manufacturing)	3672	16,409	0.05%	**0.29**	**0.39**	**0.5**	---	---	---	0.00	2.27	4.59	0.09	56.86	318.01	0.04	0.00%	0.05	0.01%	0.07	0.01%
Grecian Delight Foods, Inc.	1201 Tonne Road, Elk Grove Village, IL 60007	Food Manufacturing	2035	58,464	0.17%	---	---	---	0.06	**0.22**	0.44	0.00	**13.03**	1562.30	0.98	**33.59**	177.00	0.11	0.01%	6.35	0.64%	16.38	1.66%
Greenlee Diamond Tool Company	2375 W Touhy Avenue, Elk Grove Village, IL 60007	Metal Finishing	3545	552	0.00%	---	---	---	---	---	---	0.01	**8.07**	281.00	**0.09**	**56.86**	318.01	0.00	0.00%	0.04	0.00%	0.26	0.03%
Holiday Inn - Rolling Meadows	3405 Algonquin Road, Rolling Meadows, IL 60008	Hotel	7011	43,915	0.13%	---	---	---	**0.06**	**1.66**	16.00	0.00	**5.90**	186.39	---	---	---	0.02	0.00%	0.61	0.06%	2.16	0.22%
HV Manufacturing Company	1197 Willis Avenue, Wheeling, IL 60090	Food Manufacturing	2035	46,222	0.13%	---	---	---	0.06	**0.22**	0.44	0.00	**13.03**	1562.30	0.98	**33.59**	177.00	0.08	0.01%	5.02	0.51%	12.95	1.31%
Inland Die Casting Company	161 Carpenter Avenue, Wheeling, IL 60090	Metal Molding and Casting	3363	15,036	0.04%	---	---	---	0.03	0.06	0.09	0.00	**4.06**	280.26	**0.34**	**15.99**	41.94	0.04	0.00%	0.51	0.05%	2.01	0.20%
International Processing Company of America	1485 Lively Blvd, Elk Grove Village, IL 60007	Electroplating	3479	1,627	0.00%	---	---	---	1.91	**1.91**	1.91	0.01	**4.47**	546.83	0.09	**56.86**	318.01	0.03	0.00%	0.06	0.01%	0.77	0.08%
Lake Region Medical	140 E Hintz Road, Wheeling, IL 60090	Metal Finishing	3471/3843	16,660	0.05%	---	---	---	0.01	**7.25**	546.83	0.01	**4.47**	546.83	0.09	**56.86**	318.01	0.62	0.06%	1.01	0.10%	7.90	0.80%
Lawrence Foods	2200 Lunt Avenue, Elk Grove Village, IL 60007	Food Manufacturing	2099	88,329	0.26%	---	---	---	0.05	**11.76**	25.90	0.00	13.03	1562.30	**0.98**	**33.59**	177.00	0.72	0.07%	9.60	0.97%	24.74	2.51%
Little Lady Foods	2323 Pratt Blvd, Elk Grove Village, IL 60007	Food Manufacturing	2038	7,330	0.02%	---	---	---	0.41	**0.62**	1.13	0.00	**13.03**	1562.30	0.98	**33.59**	177.00	0.04	0.00%	0.80	0.08%	2.05	0.21%
Little Lady Foods	2241 Pratt Blvd, Elk Grove Village, IL 60007	Food Manufacturing	2038	14,091	0.04%	---	---	---	0.41	**0.62**	1.13	0.00	**13.03**	1562.30	0.98	**33.59**	177.00	0.07	0.01%	1.53	0.16%	3.95	0.40%
LSG Sky Chefs	200 E Touhy Avenue, Des Plaines, IL 60018	Food Manufacturing	2099	38,187	0.11%	---	---	---	0.05	11.76	25.90	0.00	**13.03**	1562.30	**0.98**	**33.59**	177.00	0.31	0.03%	4.15	0.42%	10.70	1.08%
Magnetic Inspection Laboratory Inc	1401 Greenleaf Avenue, Elk Grove Village, IL 60007	Metal Finishing	8734	73,240	0.21%	---	---	---	---	---	---	0.03	**2.95**	31.00	**0.09**	**56.86**	318.01	0.05	0.01%	1.80	0.18%	34.73	3.52%

TM A.1 Appendix Table 1

Summary Table for Discharger's Total P Contribution to the Kirie WRP

						Facility Specific Sampling Data (2001)(1)			USEPA Effluent Data Based on SIC Code (2015)(2)						Concentrations from Outside Studies(3)			Adjusted Minimum Discharge (lb/d)	Adjusted Daily Min Average % of Total Phosphorus	Adjusted Mean Discharge (lb/d)	Adjusted Daily Mean % of Total Phosphorus	Adjusted Maximum Discharge (lb/d)	Adjusted Daily Max. Average % of Total Phosphorus
Facility Name	**Address**	**Industry Category**	**Primary SIC Code**	**Average Flow Rate (GPD)**	**% of Daily Influent Flow Rate to Kirie**	**Min (mg/L)**	**Geometric Mean (mg/L)**	**Max (mg/L)**	**Min for 4 digit SIC code (mg/L)**	**Mean for 4 digit SIC code (mg/L)**	**Max for 4 digit SIC code (mg/L)**	**Min for 2 digit SIC code (mg/L)**	**Mean for 2 digit SIC code (mg/L)**	**Max for 2 digit SIC code (mg/L)**	**Min (mg/L)**	**Mean (mg/L)**	**Max (mg/L)**						
Manan Medical Products	241 W Palatine Road, Wheeling, IL 60090	Pharmaceutical Manufacturing	2835	22,151	0.06%	---	---	---	---	---	---	0.00	**12.94**	4420.00	**0.62**	**5.11**	8.09	0.11	0.01%	0.94	0.10%	2.39	0.24%
Marathon Cutting Die, Inc.	2340 S Foster Avenue, Wheeling, IL 60090	Electronic Manufacturing (Printed circuit board manufacturing)	3672	1,575	0.00%	---	---	---	---	---	---	0.00	**2.27**	4.59	**0.09**	**56.86**	318.01	0.00	0.00%	0.03	0.00%	0.75	0.08%
Material Sciences Corporation-Plant 2	2300 E Pratt Blvd, Elk Grove Village, IL 60007	Coil Coating	3479	15,135	0.04%	---	---	---	**1.91**	1.91	1.91	0.01	**4.47**	546.83	0.09	**56.86**	318.01	0.24	0.02%	0.56	0.06%	7.18	0.73%
Medi-Physics Inc. d/b/a GE Healthcare	3350 N Ridge Avenue, Arlington Heights, IL 60004	Pharmaceutical Manufacturing	2835	21,356	0.06%	---	---	---	---	---	---	0.00	**12.94**	4430.00	**0.62**	**5.11**	8.09	0.11	0.01%	0.91	0.09%	2.30	0.23%
Metal Impact LLC	1501 Oakton Street, Elk Grove Village, IL 60007	Metal Finishing	3499	40,614	0.12%	---	---	---	0.07	0.07	0.07	0.01	**4.47**	546.83	**0.09**	**56.86**	318.01	0.03	0.00%	1.51	0.15%	19.26	1.95%
Multi-Pack Solutions	1804 W Central Road, Mount Prospect, IL 60056	Labeling and Manufacturing	7389	44,183	0.13%	---	---	---	**0.02**	**0.13**	**0.64**	0.02	0.13	0.64	---	---	---	0.01	0.00%	0.05	0.00%	0.24	0.02%
North American Electroless Nickel	776 W Lunt Avenue, Elk Grove Village, IL 60007	Electroplating	3471	9,608	0.03%	---	---	---	0.01	**7.25**	546.83	0.01	**4.47**	546.83	0.09	**56.86**	318.01	0.36	0.04%	0.58	0.06%	4.56	0.46%
Oak Mill Bakery	2480 S Wolf Road, Des Plaines, IL 60018	Food Manufacturing	2099	2,322	0.01%	---	---	---	0.05	**11.76**	25.90	0.00	13.03	1562.30	**0.98**	**33.59**	177.00	0.02	0.00%	0.23	0.02%	0.65	0.07%
Panera LLC - Chicago FDF	1490 Chase Avenue, Elk Grove Village, IL 60007	Food Manufacturing	2099	11,495	0.03%	---	---	---	0.05	**11.76**	25.90	0.00	13.03	1562.30	**0.98**	**33.59**	177.00	0.09	0.01%	1.13	0.11%	3.22	0.33%
Perfection Plating, Inc.	775 Morse Avenue, Elk Grove Village, IL 60007	Electroplating	3471	33,967	0.10%	---	---	---	0.01	**7.25**	546.83	0.01	**4.47**	546.83	0.09	**56.86**	318.01	1.27	0.13%	2.05	0.21%	16.11	1.63%
Perfection Plating, Inc.	1521 Morse Avenue, Elk Grove Village, IL 60007	Electroplating	3471	20,192	0.06%	---	---	---	0.01	**7.25**	546.83	0.01	**4.47**	546.83	0.09	**56.86**	318.01	0.75	0.08%	1.22	0.12%	9.58	0.97%
Richelieu Foods, Inc.	1325 Chase Avenue, Elk Grove Village, IL 60007	Food Manufacturing	2099	15,923	0.05%	---	---	---	0.05	**11.76**	25.90	0.00	13.03	1562.30	**0.98**	**33.59**	177.00	0.13	0.01%	1.56	0.16%	4.46	0.45%
RoHS Compliance Services, Inc.	1260 Howard Street, Elk Grove Village, IL 60007	Electronic Manufacturing (Printed circuit board manufacturing)	3672	819	0.00%	---	---	---	---	---	---	0.00	**2.27**	4.59	**0.09**	**56.86**	318.01	0.00	0.00%	0.02	0.00%	0.39	0.04%
Sunrise Electronics	130 Martin Ln, Elk Grove Village, IL 60007	Electronic Manufacturing (Printed circuit board manufacturing)	3672	16,003	0.05%	**0.37**	**0.44**	**0.5**	---	---	---	0.00	2.27	4.59	0.09	56.86	318.01	0.05	0.01%	0.06	0.01%	0.07	0.01%
Teleflex Medical	900 W University Drv, Arlington Heights, IL 60004	Pharmaceutical Manufacturing	3842	58,291	0.17%	---	---	---	---	---	---	0.20	**0.89**	4.60	0.62	**5.11**	**8.09**	0.43	0.04%	2.48	0.25%	3.93	0.40%
Three J's Industries, Inc.	701 Landmeier Road, Elk Grove Village, IL 60007	Electroplating	3471	22,478	0.07%	---	---	---	0.01	**7.25**	546.83	0.01	**4.47**	546.83	0.09	**56.86**	318.01	0.84	0.08%	1.36	0.14%	10.66	1.08%
Trend Technologies, LLC	737 Fargo Avenue, Elk Grove Village, IL 60007	Metal Finishing	3469	7,405	0.02%	---	---	---	---	---	---	0.01	**4.47**	546.83	**0.09**	**56.86**	318.01	0.01	0.00%	0.28	0.03%	3.51	0.36%
Unitech Industries	1461 Elmhurst Road, Elk Grove Village, IL 60007	Metal Finishing	3471	2,337	0.01%	---	---	---	0.01	**7.25**	546.83	0.01	**4.47**	546.83	0.09	**56.86**	318.01	0.09	0.01%	0.14	0.01%	1.11	0.11%
Waltz Brothers Inc	10 W Waltz Drv, Wheeling, IL 60090	Metal Finishing	3471	830	0.00%	---	---	---	0.01	**7.25**	546.83	0.01	**4.47**	546.83	0.09	**56.86**	318.01	0.03	0.00%	0.05	0.01%	0.39	0.04%
Wieland Metals, Inc	567 Northgate Parkway, Wheeling, IL 60090	Copper Forming	3351	15,960	0.05%	---	---	---	---	---	---	0.00	**4.23**	280.26	**0.09**	**56.86**	318.01	0.01	0.00%	0.56	0.06%	7.57	0.77%
	Average Daily Flow Rate From Industries			**1,351,640**	**3.92%**								**Phosphorus Discharged to Egan from Listed Facilities (lb/d)**					**8.44**	**0.85%**	**71.73**	**7.27%**	**371.82**	**37.66%**
	Average Daily Influent Flow Rate to Kirie			**34,469,727**									**Total Phosphorus Discharged to Kirie WRP from all waste streams (lb/d)(4)**					**987.3**					

Notes:

Bold & Underlined = Concentration used to calculate estimated discharge

(1) Facility specific sampling data is summarized in "Sampling Data" tab

(2) USEPA wastewater effluent data is summarized in "SIC codes" tab

(3) Wastewater effluent data from outside studies and sampling events is summarized in "Studies" tab

(4) The total amount of phosphorus entering the Kirie WRP through waste streams was 987.3 lb/d in 2016

Appendix A.1-B

PROCESS SIMULATION MODEL DEVELOPMENT

Appendix A.1-B

PROCESS SIMULATION MODEL DEVELOPMENT

B.1. Process Simulation Modeling Approach

Process simulation modeling was used to conduct a fundamental evaluation of the necessary modifications and predicted performance of the Kirie WRP as part of the Phosphorus Removal Feasibility Study. The approach used for process simulation modeling follows the Unified Protocol proposed by Rieger et. al (2013). The steps used to develop the model and evaluate alternatives are:

- Project Definition.
- Data Collection and Reconciliation.
- Plant Model Setup.
- Calibration and Validation.
- Simulation and Results Interpretation.

B.2. Project Definition

From a modeling perspective, the Phosphorus Removal Feasibility Study is a planning-level effort to identify and evaluate measures to reduce effluent phosphorus from the facility. The first task of the study is to identify operational improvements and minor facility modifications ($1 to $2 million capital expenditure) to meet a target effluent TP of 1.0 mg/L or less at existing plant flows and loads. The second task of the study is to identify facility modifications to meet each of three potential future permit limit tiers for TP (1.0 mg/L, 0.5 mg/L, 0.1 mg/L) at current flows and rated capacity. Consideration is given to other process and operational aspects affected by P reduction, such as nitrification performance, air demand, solids production, and other unintended consequences detailed in TM A.1.

B.3. Data Collection and Reconciliation

Historical plant operating and performance data from Jan 2014 through July 2017 was provided by MWRDGC. Influent flows and loads presented in TM A.1 - Table 1.4 are based on average annual and maximum month values from July 2014 through July 2017. Carollo did not project future flows and loads. Future flows and loads are not expected to exceed the current WRP's design rated capacity.

Graphs of historical data for key influent constituents and operating parameters at the Kirie WRP are shown below. Data outside the 99.7th percentile for BOD_5 and TSS was removed from the analysis.

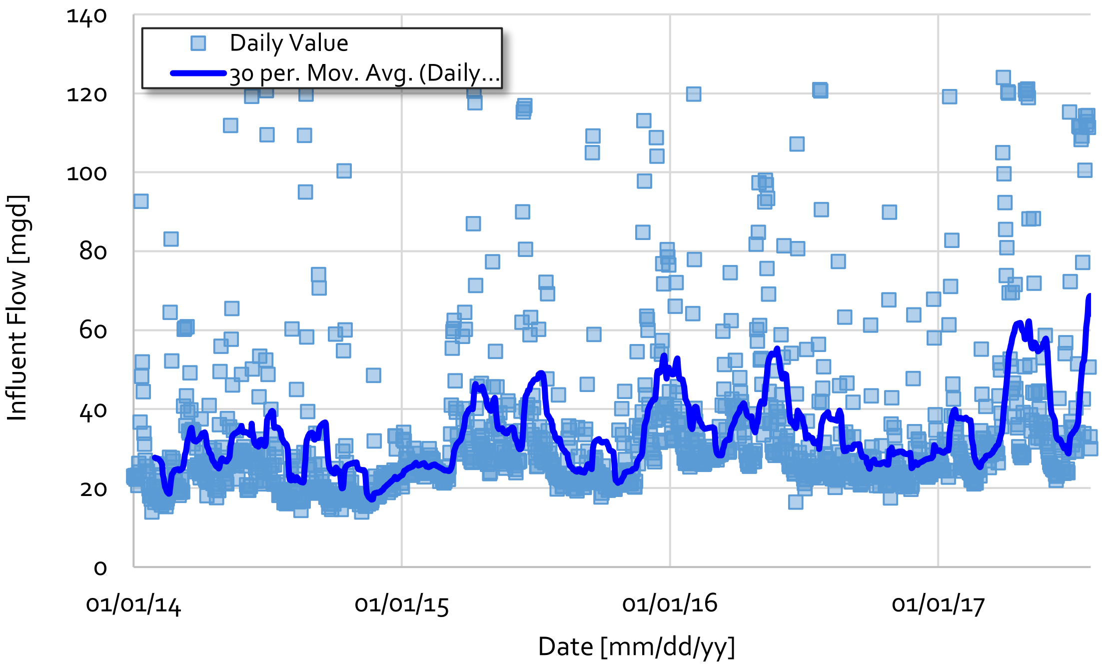


Figure B.1 Kirie WRP Historical Influent Flow

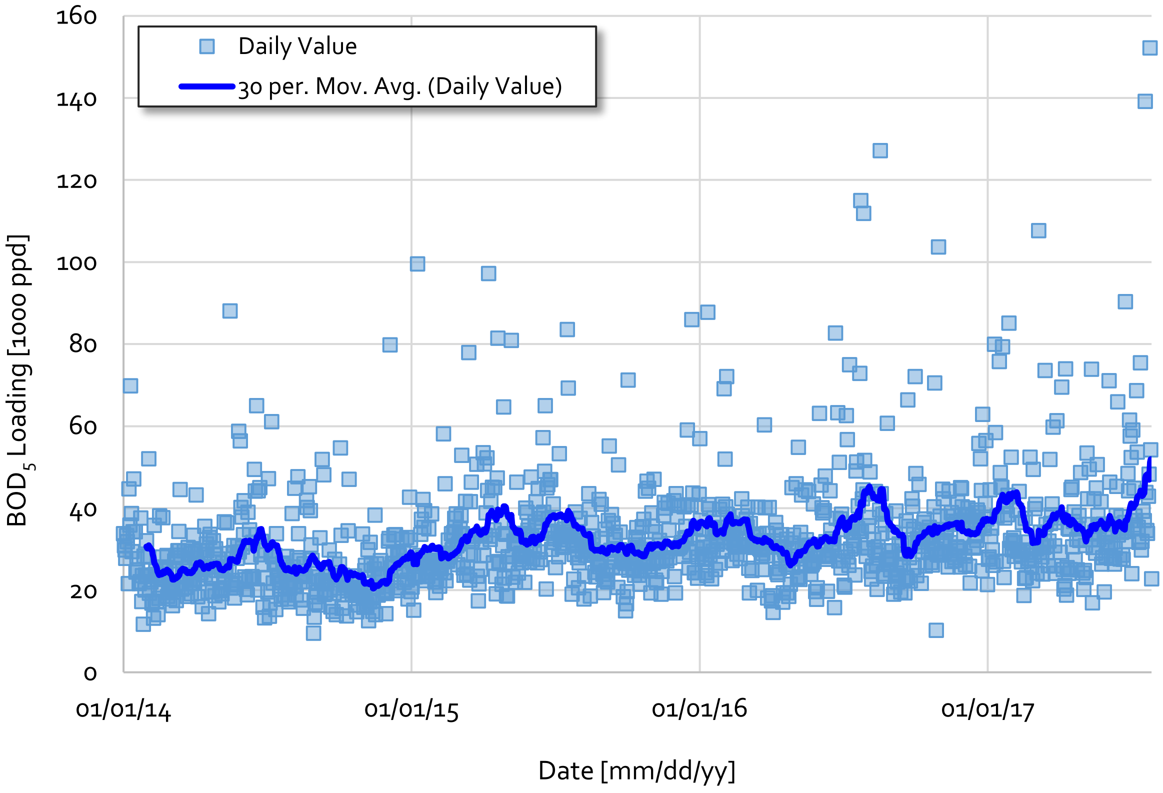


Figure B.2 Kirie WRP Historical Influent BOD5 Loading

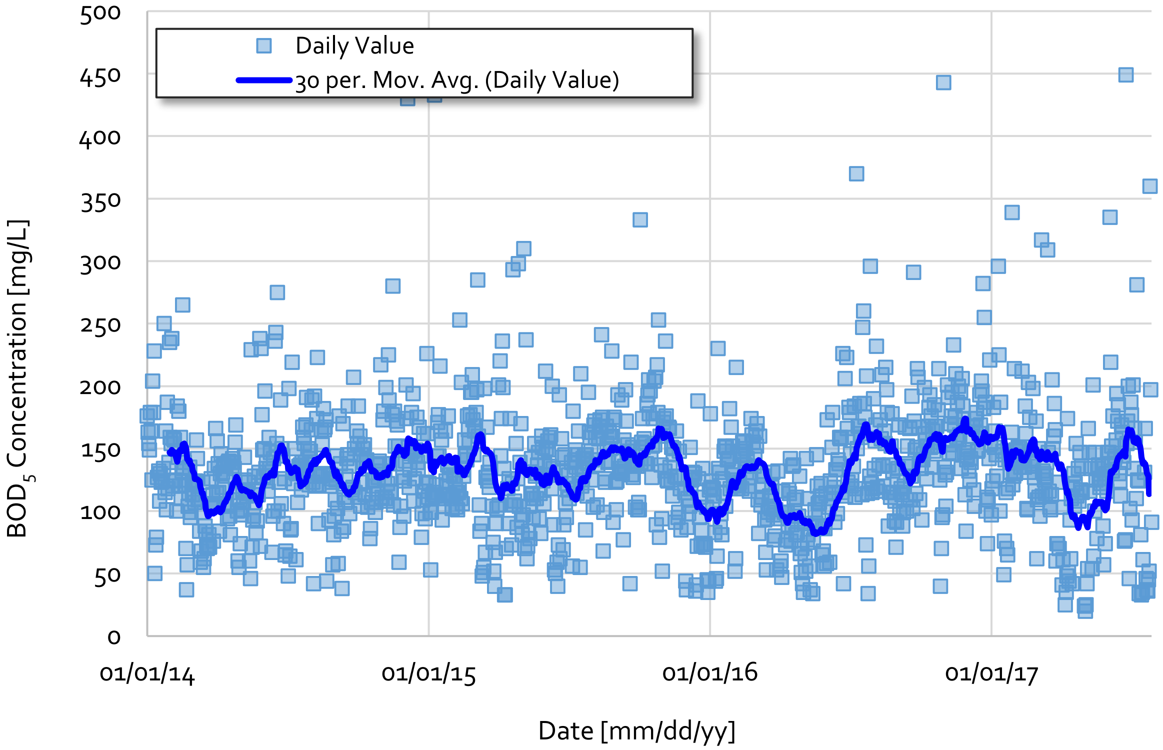


Figure B.3 Kirie WRP Historical Influent BOD₅ Concentrations

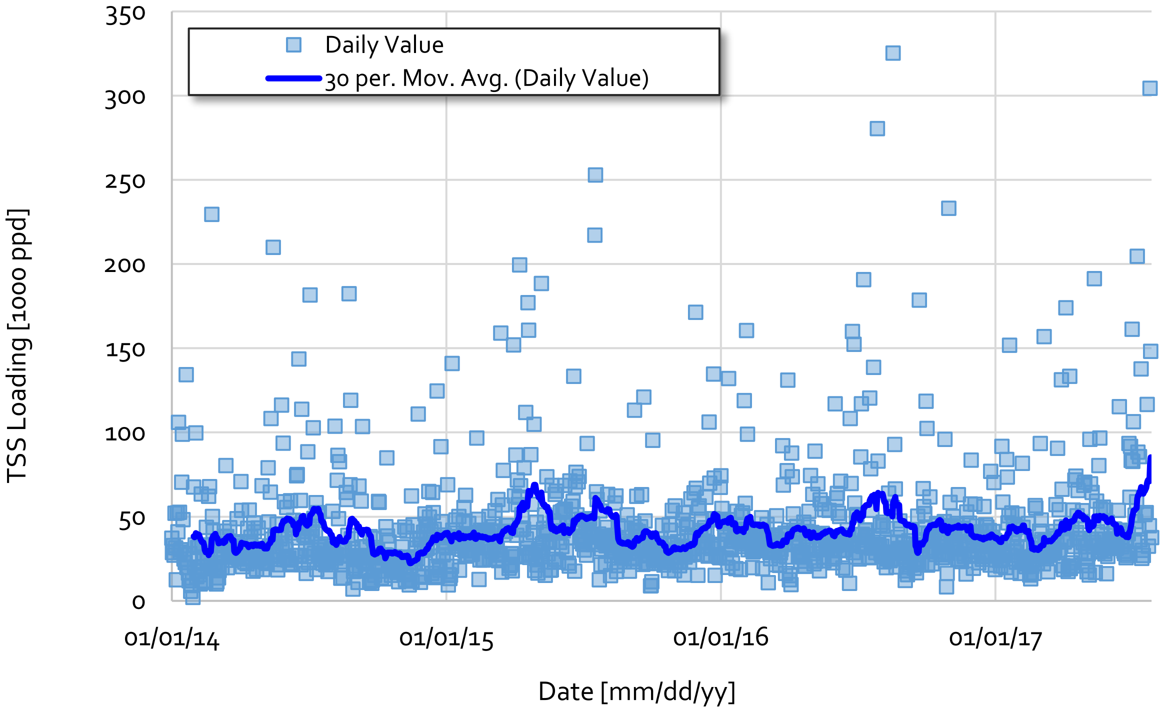


Figure B.4 Kirie WRP Historical Influent TSS Loading

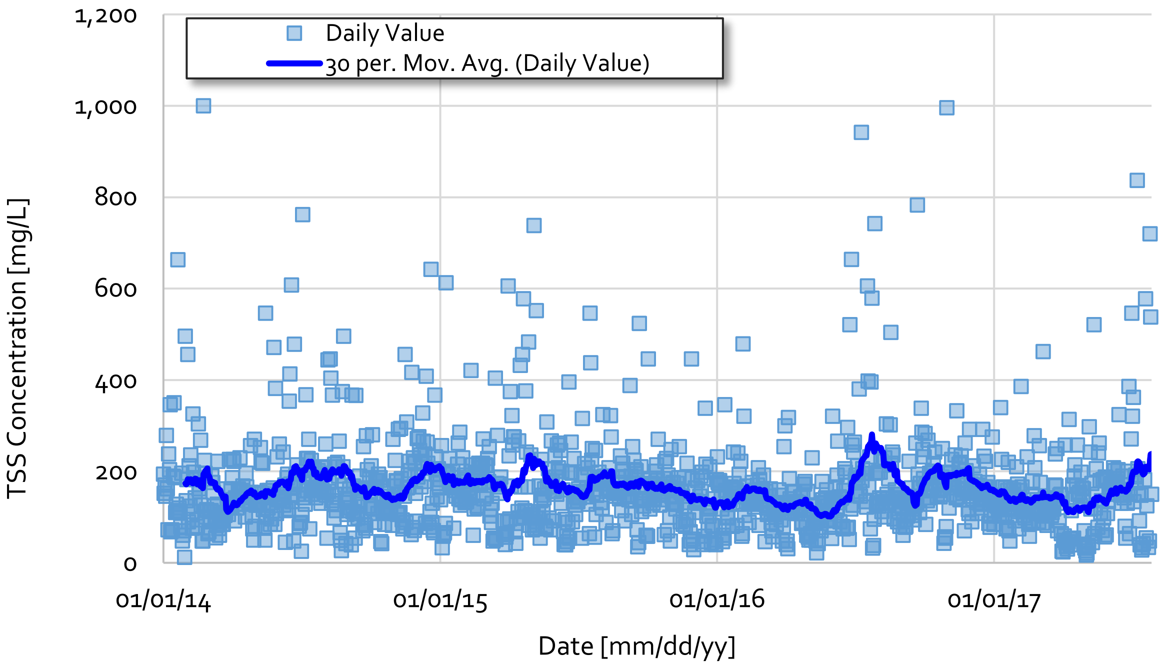


Figure B.5 Kirie WRP Historical Influent TSS Concentrations

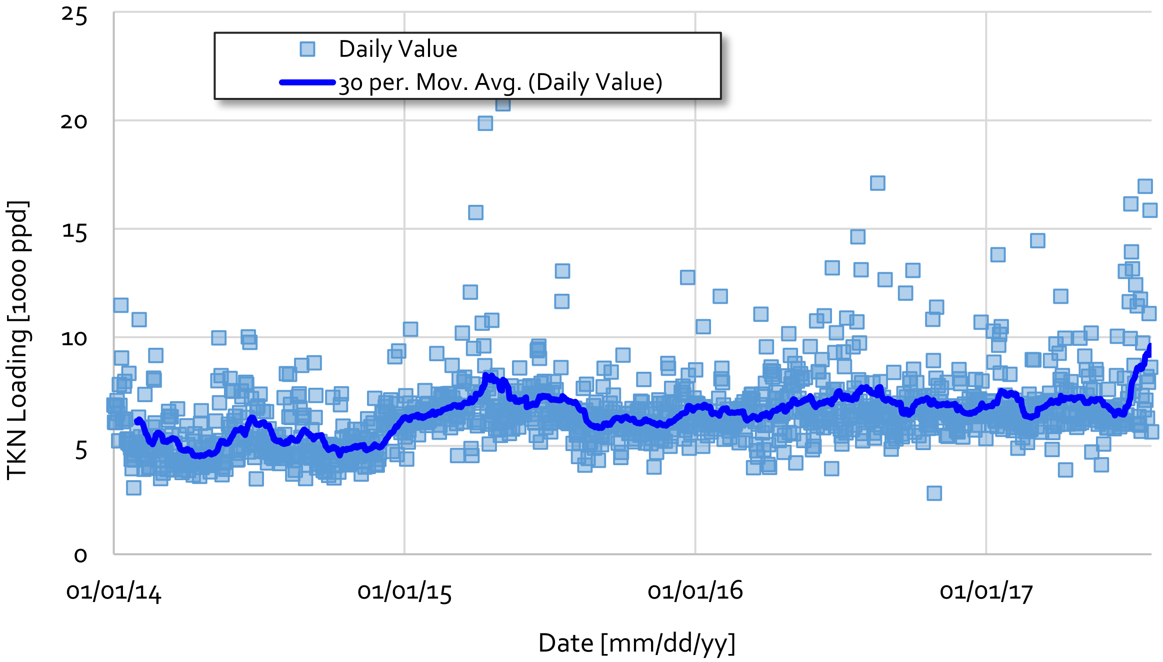


Figure B.6 Kirie WRP Historical Influent TKN Loadings

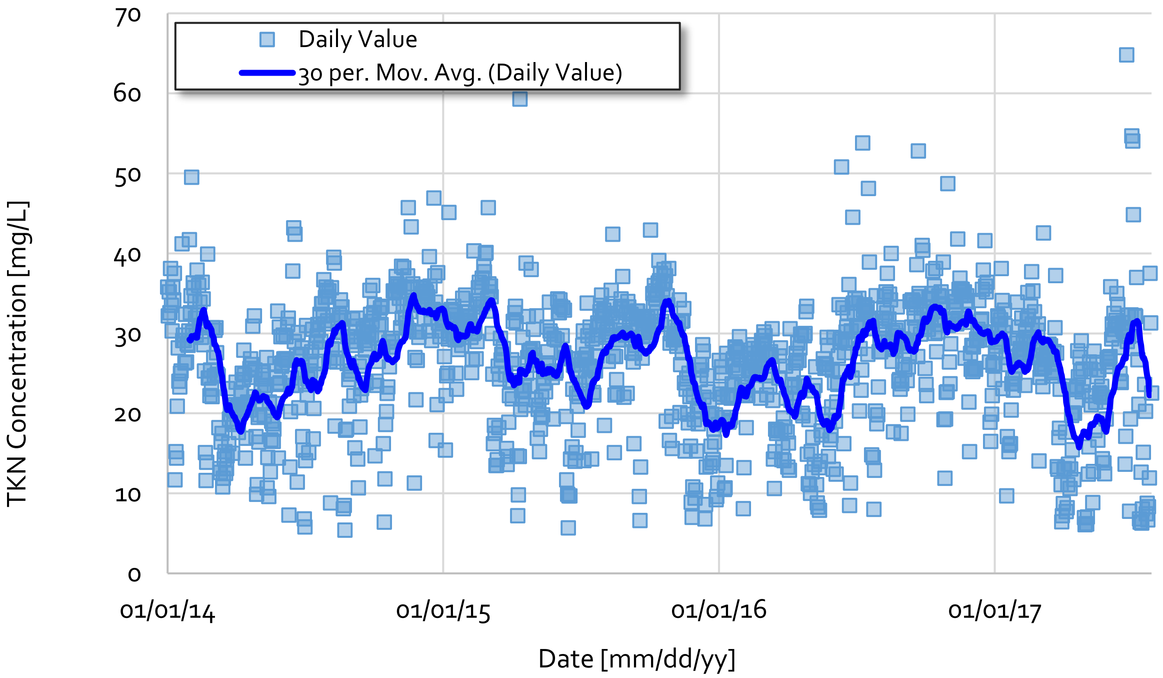


Figure B.7 Kirie WRP Historical Influent TKN Concentrations

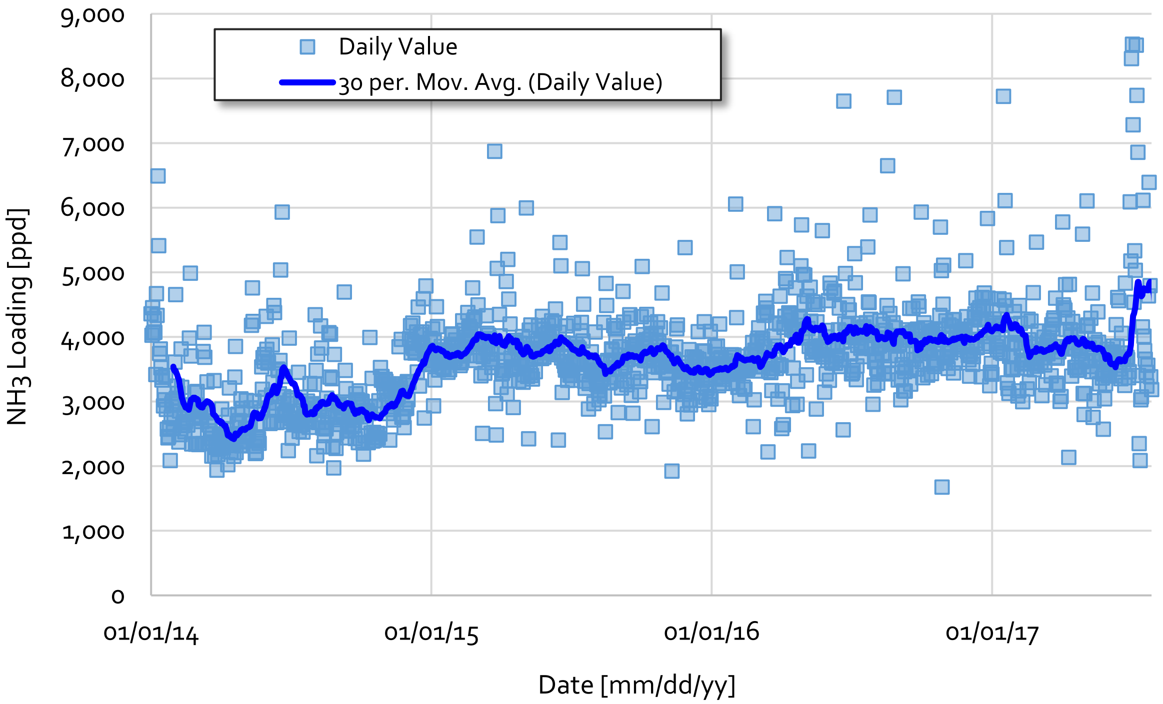


Figure B.8 Kirie WRP Historical Influent Ammonia Loading

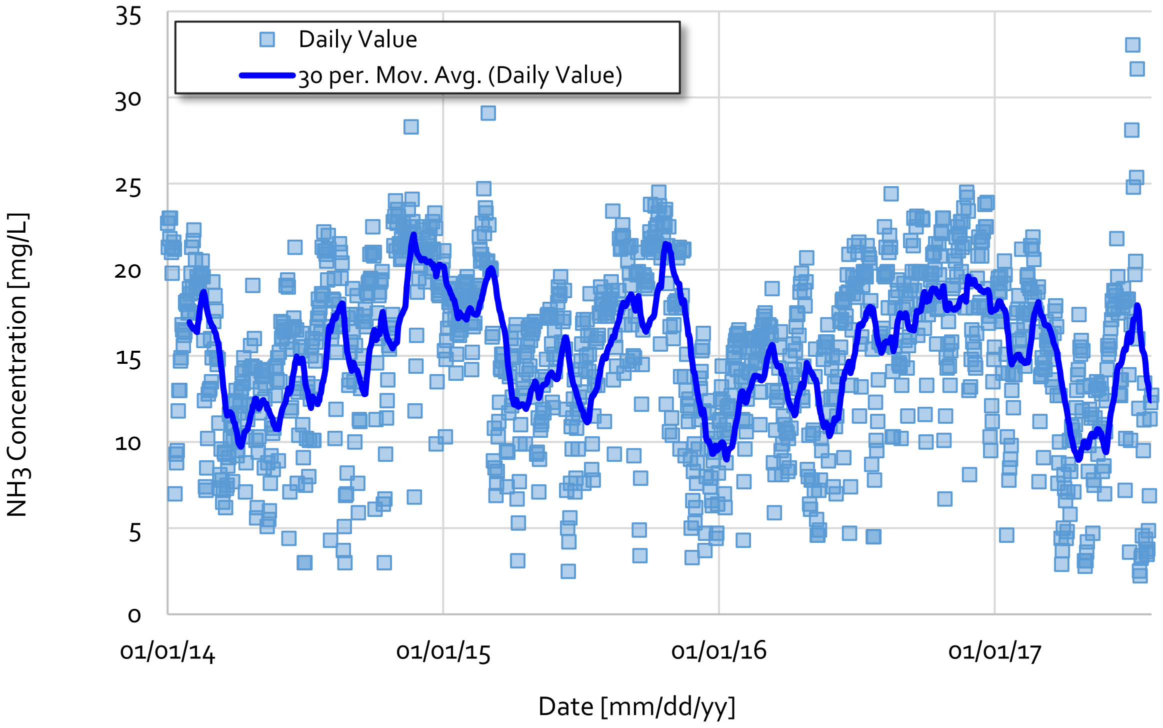


Figure B.9 Kirie WRP Historical Influent Ammonia Concentrations

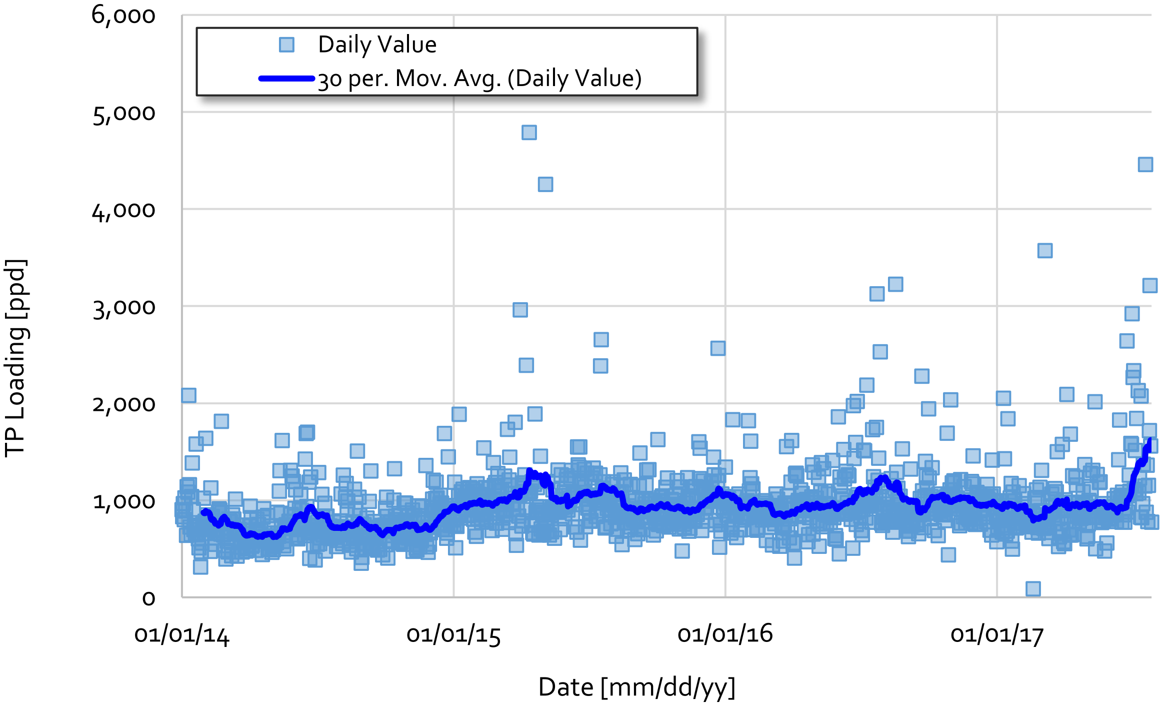


Figure B.10 Kirie WRP Historical Influent TP Loading

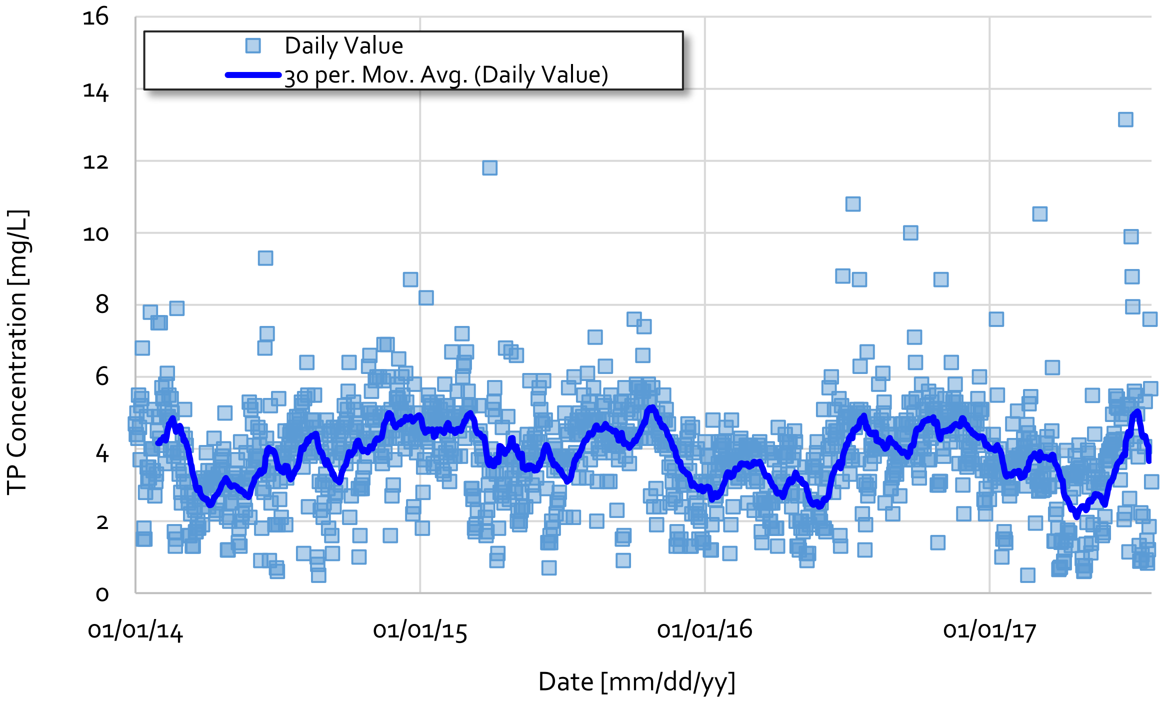


Figure B.11 Kirie WRP Historical Influent TP Concentrations

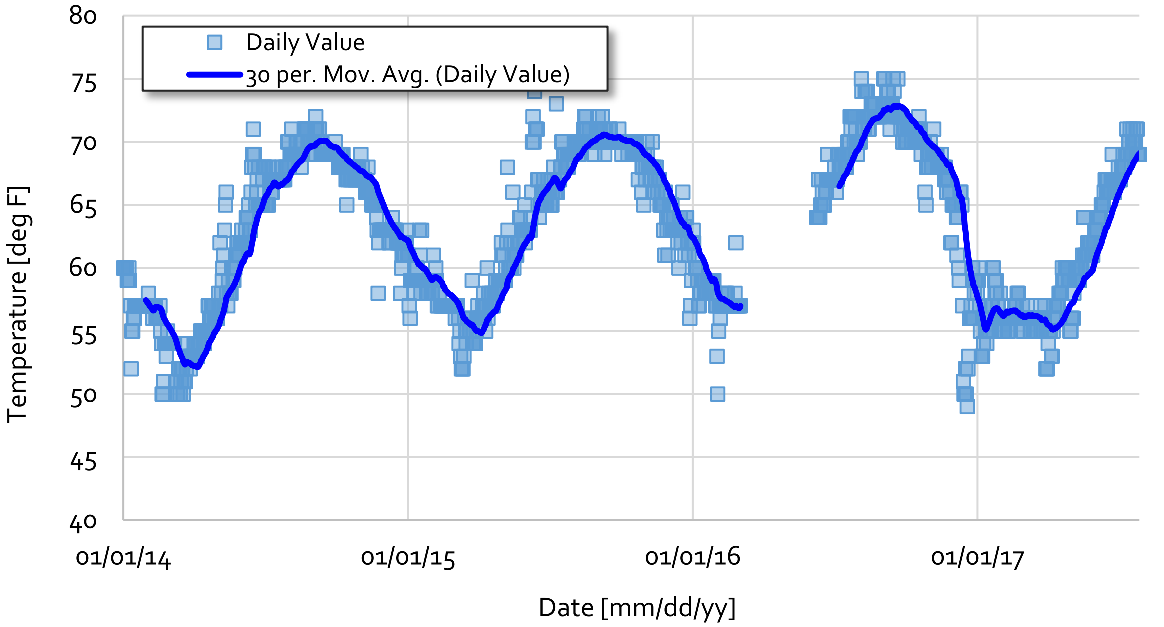


Figure B.12 Kirie WRP Historical Raw Influent Temperatures

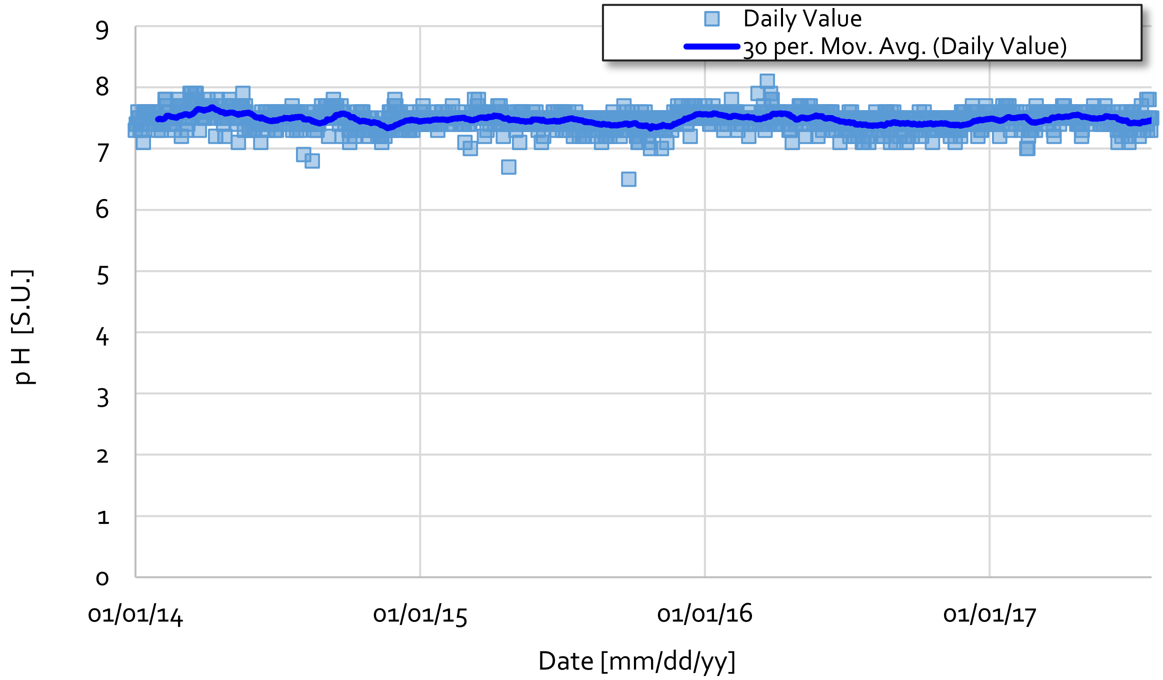


Figure B.13 Kirie WRP Historical Raw Influent pH

Historical aeration basin operating parameters, effluent characteristics, solids production were collected and analyzed. The data generally indicated reasonable values for operating parameters and was therefore used in the evaluations.

B.4. Plant Model Setup

Process flow diagrams and facility design information was provided by MWRDGC. The process model setup for the Kirie WRP included the 1st and 2nd Stage aeration tanks, the 1st and 2nd Stage secondary clarifiers, and the tertiary filters. The model configuration is shown in TM A.1 - Figure 1.6. Each aeration tank battery was divided into six parallel treatment trains. Each train was configured as a three-pass aeration tank.

Each three-pass aeration tank was modeled as nine reactors in series to simulate plug flow. Raw influent and RAS were both introduced at the head of the first pass in each tank. The target DO concentrations for the aerobic portions of the aeration tanks was set at 2.6 mg/L based on the range of 2.5 to 2.7 mg/L provided by MWRDGC. The reactors were modeled in GPS-X as diffused aeration bioreactors with default aeration characteristics. Verification of aeration air volumes for nitrification was not included in Carollo's effort.

For model calibration, Battery A Tank Nos. 1-4 were configured with 1/3 of the first pass unaerated and Battery A Tank Nos. 5-6 were configured with 2/3 of the first pass unaerated per the Bio P testing configuration. Battery B was not activated for calibration. Physical and operational parameters used for calibration and subsequent simulations are shown in Table B.1.

Table B.1 Summary of Aeration Basin Size

Process Unit	Number of Treatment Trains	Pass Dimensions	Volume, mgal
Battery A Tank Nos. 1-4	4	250 ft L x 25.5 ft W x 16 ft D	9.16
Battery A Tank Nos. 5-6	2	250 ft L x 25.5 ft W x 16 ft D	4.58
Battery A Tank Nos. 1-6	6	250 ft L x 25.5 ft W x 16 ft D	13.73

Battery A effluent was directed to the 2nd Stage (Battery B) secondary clarifiers. A summary of Battery A secondary clarifiers is shown in Table B.2.

Table B.2 Summary of Intermediate Secondary Clarifier Size

Process Unit	Number of Treatment Trains	Clarifier Dimensions	Surface Area, ft^2
Battery A SC Nos. 1-4	4	153 ft Diameter, 15 ft SWD	73,542
Battery A SC Nos. 5-6	2	153 ft Diameter, 15 ft SWD	36,771
Battery A SC Nos. 1-6	6	153 ft Diameter, 15 ft SWD	110,312

At present, the 2nd stage aeration tanks (Battery B) at the Kirie WRP are not operated as aeration basins and used to convey the secondary effluent from Battery A to the 2nd stage settling tanks for additional polishing. Historically, the polished secondary effluent has met the effluent total suspended solids (TSS) criteria. Therefore, the tertiary filters at the Kirie WRP are no longer in service, and the flow is bypassed directly to the disinfection/post-aeration facility.

The model was set up using two clarifiers in series configuration for calibration. Clarifier settling models, however, are not suitable to predict TSS removal with low influent TSS concentrations (< 50 mg/L). Therefore, the removal efficiency used in the model for final clarifiers was adjusted from the default value to 75 percent removal to match the average historical effluent TSS concentrations from the 2nd Stage of series clarification. Solids settled in Battery B are returned upstream of the aeration tanks for additional treatment.

Waste sludge is conveyed via a sludge transfer pipeline from the Kirie WRP to the Egan WRP for treatment.

B.5. Calibration and Validation

B.5.1. Influent Characterization

Influent wastewater characteristics are typically scrutinized for model calibration, as influent characterization directly affects Bio P performance, air demand, solids production, and effluent quality. Data presented in Section B.3 was used to establish facility influent loading, combined with additional influent constituent characterization including COD concentration and fractionation, nutrient fractions, and mineral content. Dedicated sampling of influent volatile fatty acids (VFAs), COD, soluble COD (sCOD), filtered-flocculated COD (ffCOD) was conducted from August 2013 through August 2014 and provided to Carollo. This data was used for preliminary influent characterization and then checked using the model predictions compared to historical effluent quality and solids production. For model calibration, certain wastewater influent and process characteristics are adjusted to better match plant performance data during the same period. Table B.3 shows the average influent constituent ratios developed from dedicated sampling, the modeling assumptions used, and typical values from literature.

Table B.3 Kirie WRP Influent Characterization Ratios

Influent Constituent Ratio	Kirie WRP		Typical Value (3)
	Historical Data	Modeling Assumption	
VSS/TSS (1)	N/A	0.84	0.74
BOD_5 / COD (2,4)	0.33	0.33	0.485
sCOD / COD (2)	0.25	0.44	0.343
ffCOD / COD (2)	0.19	0.19	N/A
NH_3-N / TKN (1)	0.58	0.58	0.684
OP / TP (1)	0.45	0.45	0.603

Notes:

(1) Based on historical data from July 2015 through July 2017

(2) Based on dedicated sampling from August 2013 through August 2014

(3) Source: Guidelines for Using Activated Sludge Models (Rieger, 2013)

(4) Influent BOD_5 was not available for August 2013 through December 2013. Influent BOD_5 was averaged from January 2013 through August 2014 and divided by the average COD from the same period. COD values above the 90th percentile were removed from consideration.

Influent constituent ratios were similar to typical values reported in literature.

Table B.4 shows the Kirie WRP modeling parameter values used for GPS-X modeling.

Table B.4 GPS-X Modeling Parameters

Modeling Parameter		Units	Kirie WRP	GPS-X Default
Influent Composition				
bod	total carbonaceous BOD5	gO2/m3	134.3	250
tkn	total TKN	gN/m3	26.1	40
tp	total phosphorus	gP/m3	3.8	10
Soluble Organic Compounds				
scol	colloidal substrate	gCOD/m3	23.6	40
sac	acetate	gCOD/m3	16	0
spro	propionate	gCOD/m3	3	0
smet	methanol	gCOD/m3	0	0
Particulate Organic Compounds				
xu	unbiodegradable cell products	gCOD/m3	0	0
xbt	poly-hydroxy alkanoates in PAO	gCOD/m3	0	0
Nitrogen Compounds				
snh	ammonia nitrogen	gN/m3	15.1	25
snoi	nitrite	gN/m3	0	0
snoa	nitrate	gN/m3	0.6	0
Phosphorus Compounds				
sp	ortho-phosphate	gP/m3	1.7	8
xpp	stored poly-phosphate in PAO	gP/m3	0	0

Table B.4 GPS-X Modeling Parameters (continued)

Modeling Parameter		Units	Kirie WRP	GPS-X Default
Influent Fractions				
ivsstotss	VSS/TSS ratio	gVSS/gTSS	0.84	0.75
Organic Fractions				
isbodtobod	soluble BOD5 to total BOD5 ratio	gsBOD5/gtBOD5	0.41	0.36
isbodtoscod	soluble BOD5 to soluble COD ratio	gsBOD5/gsCOD	0.31	0.61
ibodtocod	total BOD5 to total COD ratio	gtBOD5/gtCOD	0.33	0.58
Nitrogen Fractions				
frsnh	ammonium fraction of soluble TKN	-	0.9	0.9
insi	N content of soluble inert material	gN/gCOD	0.016	0.05
inxi	N content of inert particulate material	gN/gCOD	0.05	0.05
Phosphorus Fractions				
ipsi	P content of soluble inert material	gP/gCOD	0.0002	0.01
ipxi	P content of inert particulate material	gP/gCOD	0.01	0.01
Inorganic Compounds				
stic	total soluble inorganic carbon	gC/m3	100	84
sca	total calcium	gCa/m3	77.3	140
smg	total magnesium	gMg/m3	31.3	50
spot	total potassium	gK/m3	28	28
scat	other cation	eq/m3	3	3
sana	other anion	eq/m3	12	12
Soluble Gases				
so	dissolved oxygen	gO2/m3	2	0

Other influent characteristics include activated bacterial biomass and inorganic precipitates. Since the Kirie WRP does not receive recycle streams from other wastewater treatment facilities, significant activated bacterial biomass and inorganic precipitates are not anticipated in the influent.

The influent constituent ratios and the modeling parameters listed in Tables B.3 and B.4 were used for characterizing Kirie WRP influent. Some exceptions and notable deviations from default values are discussed below:

- Influent VSS data was not available at the time of the Phosphorus Removal Feasibility Study. The influent VSS/TSS ratio was adjusted to match the VS/TS ratio in the aeration tanks at typical SRTs. The historical average VS% at the Kirie WRP is 75 percent.

- Influent mass balances with the historical influent COD fractionation presented in Table B.3 required a higher influent TSS concentration than historically measured in order to close. Because influent TSS data has been collected more frequently than dedicated COD fractionation sampling, the sCOD:COD ratio was adjusted to match the influent TSS to the historical average value. Simulations using this mass balance approach show waste sludge production slightly (- 5 percent) lower than historical data solids production. As an additional measure to close the mass balance, the aerobic heterotroph yield was increased from 0.666 gCOD/gCOD to 0.72 gCOD/gCOD to augment solids production while maintaining influent loading and concentrations. Adjusting the heterotroph yield will have a marginal effect on treatment while allowing the solids balance to close. The VS% in the aeration basins was maintained at 75 percent.
    - A side-effect of increasing the sCOD:COD ratio in the model is an increase in simulated effluent ffCOD to 100 mg/L, where dedicated sampling shows that effluent ffCOD is approximately 35 mg/L. Because effluent sCOD is essentially inert, simulated treatment performance will not be impacted.
- Influent calcium and magnesium concentrations were developed from effluent calcium and magnesium concentrations provided as part of the Phosphorus Removal Feasibility Study.
- The P content of soluble inert material (ipsi) is the parameter in GPS-X that sets the soluble non-reactive phosphorus (sNRP) in the influent and effluent. sNRP is defined as the difference between total soluble phosphorus and orthophosphate ("reactive" phosphorus). Literature shows that an average sNRP value for municipal raw wastewater is approximately 0.01 mg/L P, although some recent case studies for ultra-low phosphorus removal have suggested that consistent values of above 0.2 mg/L P are possible. MWRDGC does not explicitly measure sNRP because orthophosphate samples do not accompany the routine effluent total soluble phosphorus assays. Therefore, historical sNRP cannot be derived from historical data. Using the default GPS-X fraction of 0.01 for ipsi leads to an sNRP well above the typical value. This leads to a model prediction of an abnormally low effluent orthophosphate to TP ratio. Discussions with Hydromantis Environmental Software Solutions, Inc. revealed that this is a known calculation anomaly with the GPS-X model and will be addressed in future versions of the software. For this planning-level study, a sNRP value of 0.01 mP/L was assumed. Knowing the exact value of the sNRP only becomes critical for ultra-low effluent phosphorus limits (i.e. 0.1 mg/L TP). The District is considering the merits of an additional sampling program to better define sNRP characteristics.
- N content of soluble inert material (insi) was lowered to close the mass balance on influent nitrogen.

B.5.2. Calibration Results

The Kirie WRP was calibrated using historical plant performance and operational data from July 2015 to July 2017. The calibration period coincided with the Bio P testing at Kirie WRP. This allowed calibration during a period of consistent plant configuration using Bio P. The model was calibrated at average day conditions (AADF, AADL) to ensure adequate prediction of key operating parameters and effluent quality. Figures B.14 and B.15 present the model predicted simulation of operating parameters compared to the historical data for the same parameters in Battery A Aeration Tank Nos. 1-4 and Tank Nos. 5-6, respectively. Figure B.16 shows the model predicted simulation of the final effluent quality compared to the historical data for the same parameters.

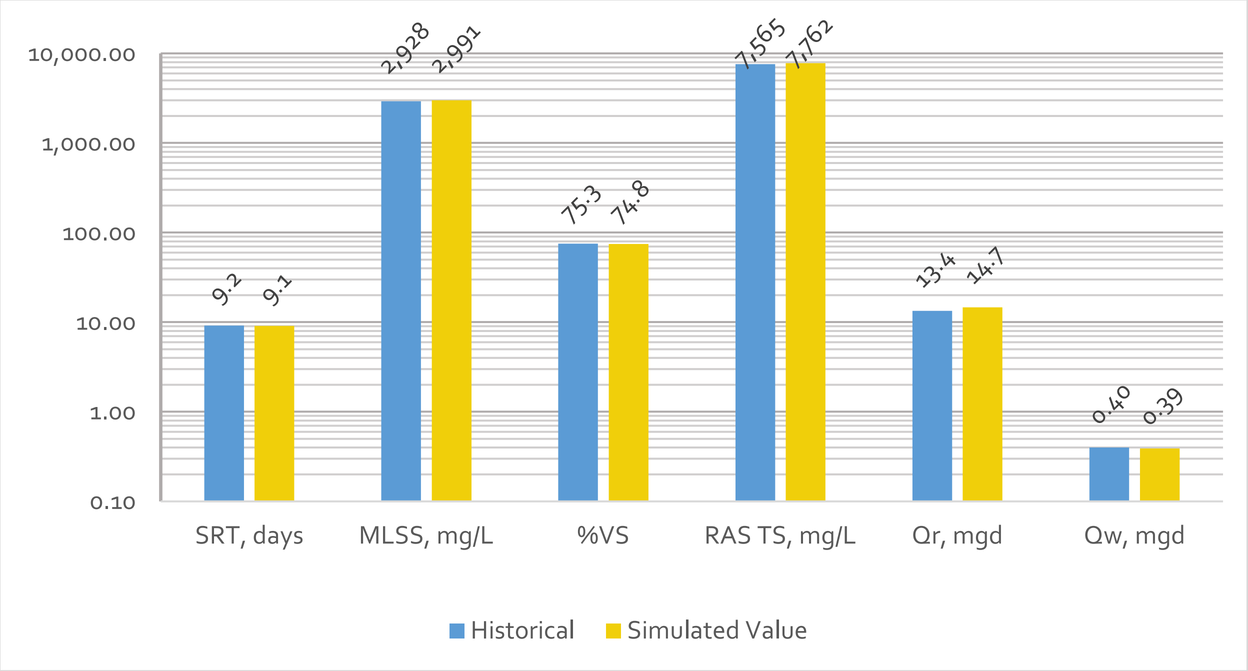


Figure B.14 Aeration Tank Nos 1-4 - Simulated Operating Parameters Compared to Historical Data

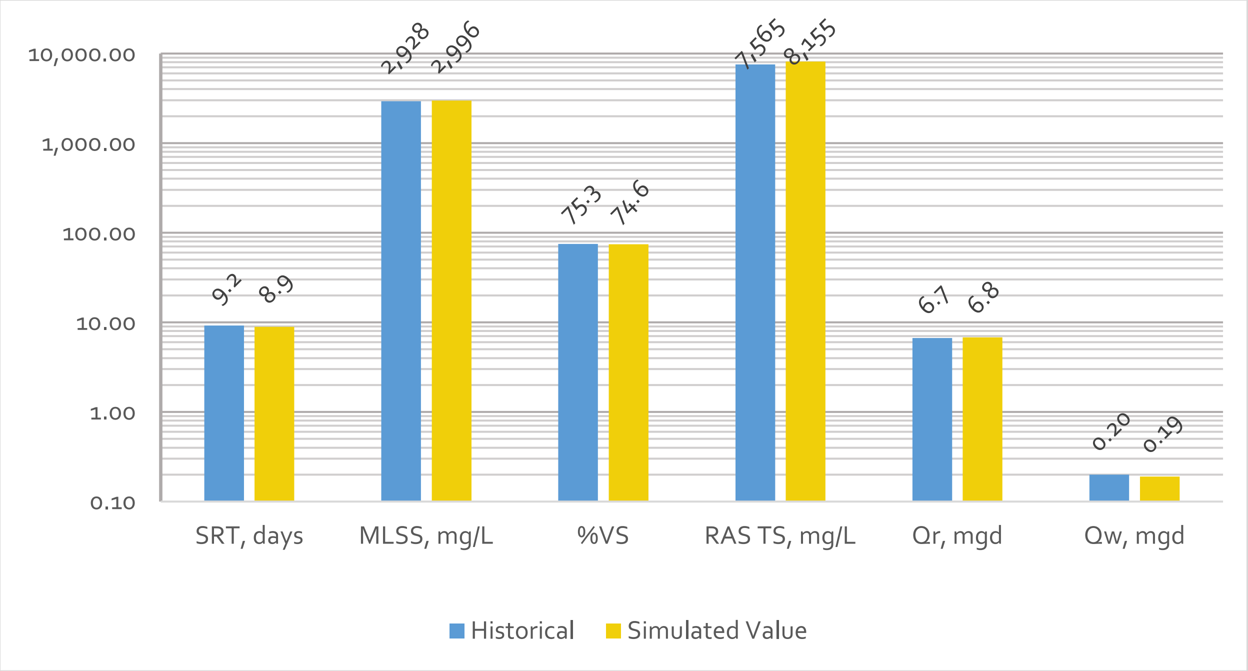


Figure B.15 Aeration Tank Nos 5-6 - Simulated Operating Parameters Compared to Historical Data

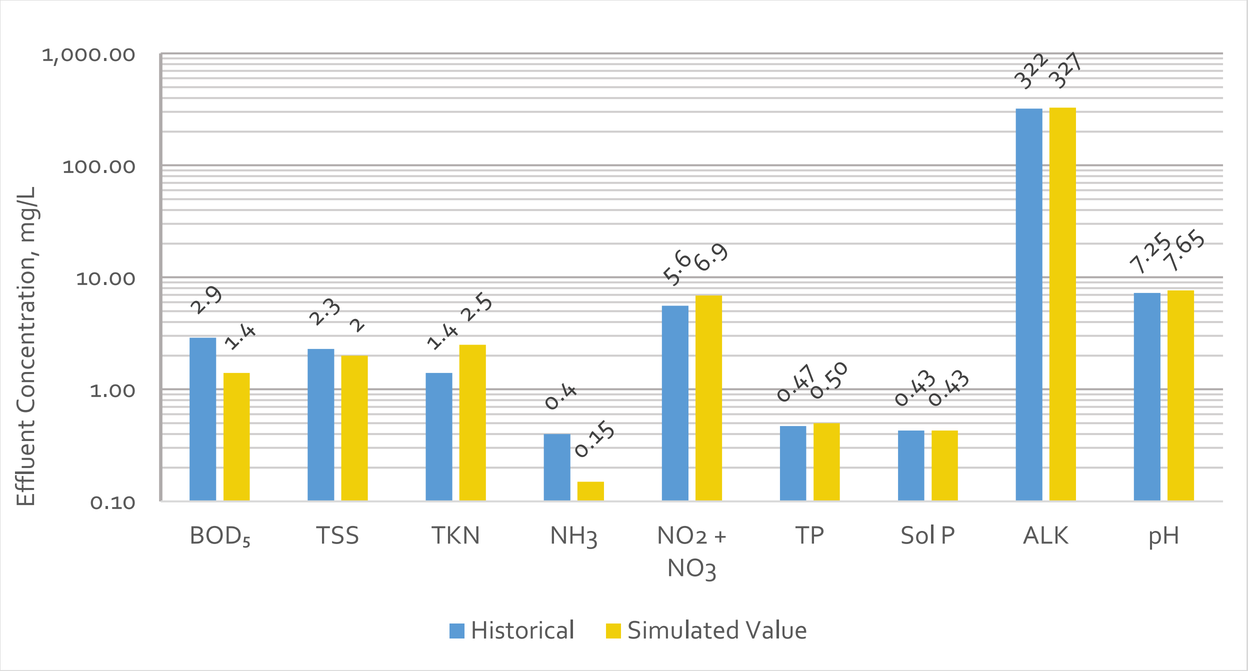


Figure B.16 Simulated Final Effluent Compared to Historical Data

After calibration, all simulated operating parameter values agreed well with historical data. The resulting simulated average effluent values also compared reasonably well with measured average values with some effluent parameters predicted to be slightly higher than measured and some effluent parameters predicted to be slightly lower than measured. For purposes of this planning level model, the correlation between predicted and measured ammonia and phosphorus are the most important. The average effluent ammonia value was predicted to be less than measured average effluent ammonia. We believe that this is due to periodic ammonia excursions that are not captured in the steady-state simulations. Both predicted and actual effluent ammonia values are well below the effluent discharge criteria. The average effluent TP and Sol P was predicted within 10% of the measured average effluent values.

In order to achieve the calibration indicated in Figures B.14, B.15, and B.16, only a few default parameters required adjustment. This calibration is considered adequate for planning level purposes with all key operating parameters (e.g. SRT, MLSS, VS%) agreement within 10 percent. Predicted effluent values were also within acceptable variation tolerances.

A winter validation was performed to ensure adequate model calibration during winter months when nitrification requires higher SRT and MLSS concentrations. All operating parameters were found to be within 10 percent of historical winter values and the effluent pollutant concentrations predicted within acceptable margins.

B.5.3. Modeling Limitations

Limitations to steady-state process simulation modeling performed at the Kirie WRP that may result in variations between predicted and actual performance include:

- Imperfect flow split between aeration tanks and clarifiers.
- Multiple aeration tanks in series approach to simulate plug flow.
- 75 percent TSS removal assumption to simulate final clarifiers in series.
- Use of a dimensional clarifier model.
- Use of constant wastewater temperatures, influent constituent ratios and modeling parameters.

B.5.3.1. Imperfect Flow Split between Aeration Tanks and Clarifiers

By modeling parallel trains as one system, the implicit assumption of perfect flow split between multiple parallel tanks is made. This is rarely the case in practice, but without field measurement or computational flow dynamics (CFD) analysis of flow splitting structures, there is no basis for alternative flow split assumptions.

B.5.3.2. Tanks-In-Series Approach

GPS-X and other similar commercial process modeling software commonly simulate plug flow in long (multiple pass) aeration tanks by using a tanks-in-series modeling approach. The actual flow-through characteristics of activated sludge aeration tanks however can vary widely. The Kirie WRP aeration tanks were modeled as nine tanks in series to coincide with three zones in each of the three passes. Carollo has performed dye studies of serpentine flow pattern multi pass aeration tanks and found that the kinetic efficiency is correlated well when using 4 to 5 tanks in series or greater. As a result, the nine tanks-in-series is an adequate representation of the hydraulic conditions for the Kirie WRP system.

B.5.3.3. Dimensional Clarifier Model

Another potential limitation in predicting accurate performance is the one-dimensional clarifier model used in GPS-X and the state point analysis (SPA). Actual conditions in three-dimensional clarifiers can vary widely from simplistic models, and vary with tank geometry and response to dynamic loading conditions. In addition, sedimentation is highly dependent on the settling characteristics of the activated sludge. For the Kirie WRP settling velocities for analysis were taken from the 2014-2017 record for 1st Stage clarifier SVI. Without long-term field data on sludge settling velocity, sludge settling characteristics can only be roughly estimated from SVI. For Kirie, Pitman’s model (Pitman 1984) correlating SVI with sludge settling characteristics was used.

The 92nd percentile SVI presented in TM A.1 - Section 1.4 indicates exceptionally good MLSS settleability. Changes in SVI, sludge settleability caused by filaments or to the factors may reduce the plant performance and capacities indicated by the models.

B.5.3.4. Constant Wastewater Temperatures, Influent Constituent Ratios, and Modeling Parameters

Steady state process simulation models assume that wastewater temperatures and parameter fractions remain the same throughout the year and during wet weather and dry weather flow. Steady state conditions rarely exist in a WRP. Appropriate safety factors were included in the analysis to account for limitations of steady state models.

Appendix A.1-C

OPTIMIZATION COST BREAKDOWN

Project: P Removal Optimization Opportunities for the Kirie WRP
Location: Kirie WRP
Element: Baffle Walls

Job Number: 10789A.00

Prepared by: Artur Pacyga (EDI)
Date: 3/30/2018

Checked by: Shantanu Agrawal
Date: 4/19/2018

Baffle Walls Capital Improvements

Description	Units	Quantity	Unit Cost	Cost
CONSTRUCTION COSTS				
Baffle Walls				
Quantity 12				
Length, ft 25.5				
Width, ft 1				
Height, ft 15.5				
Concrete - Baffle Walls	cu yd	176	$3,000	$527,000
Subtotal for Baffle Walls				$527,000
Subtotal 1				**$527,000**
Yard Piping	0%			$0
Paving/Grading	0%			$0
Coatings	0%			$0
Electrical	0%			$0
Instrumentation	0%			$0
Total Direct Cost				**$527,000**
Estimating Contingency (30%)				$158,000
General Conditions (10%)				$53,000
GC OH (10%)				$53,000
GC P (10%)				$53,000
Total Estimated Bid Day Cost				**$844,000**
Construction Contingency (5%)				$42,000
Total Estimated Construction Cost				**$886,000**
Eng, Leg & Admin (30%)				$265,800
Total Project Cost				**$1,152,000**

Project:	P Removal Optimization Opportunities for the Kirie WRP	Prepared by:	Artur Pacyga (EDI)
Location:	Kirie WRP	Date:	3/30/2018
Element:	Large Bubble Mixers		
		Checked by:	Shantanu Agrawal
Job Number:	10789A.00	Date:	4/19/2018

Large Bubble Mixers Capital Improvements

Description		Units	Quantity	Unit Cost	Cost
CONSTRUCTION COSTS					
Large Bubble Mixers					
Quantity	10				
	Mixers	LS	1	$355,350	$355,350
	Labor (Installation)	LS	1	$71,070	$71,070
Subtotal for Large Bubble Mixers					$427,000
Subtotal 1					**$427,000**
Yard Piping		0%			$0
Paving/Grading		0%			$0
Coatings		3%			$13,000
Electrical		8%			$34,000
Instrumentation		7%			$30,000
Total Direct Cost					**$504,000**
Estimating Contingency (30%)					$151,000
General Conditions (10%)					$50,000
GC OH (10%)					$50,000
GC P (10%)					$50,000
Total Estimated Bid Day Cost					**$805,000**
Construction Contingency (5%)					$40,000
Total Estimated Construction Cost					**$845,000**
Eng, Leg & Admin (30%)					$253,500
Total Project Cost					**$1,099,000**

Project: P Removal Optimization Opportunities for the Kirie WRP
Location: Kirie WRP
Element: Globe Valves

Job Number: 10789A.00

Prepared by: Artur Pacyga (EDI)
Date: 3/30/2018

Checked by: Shantanu Agrawal
Date: 4/19/2018

Globe Valves Capital Improvements

Description	Units	Quantity	Unit Cost	Cost
CONSTRUCTION COSTS				
Globe Valves				
Quantity 24				
Globe Valves	EA	24	$6,000	$144,000
Subtotal for Globe Valves				$144,000
Subtotal 1				**$144,000**
Yard Piping	0%			$0
Paving/Grading	0%			$0
Coatings	0%			$0
Electrical	8%			$12,000
Instrumentation	7%			$10,000
Total Direct Cost				**$166,000**
Estimating Contingency (30%)				$50,000
General Conditions (10%)				$17,000
GC OH (10%)				$17,000
GC P (10%)				$17,000
Total Estimated Bid Day Cost				**$267,000**
Construction Contingency (5%)				$13,000
Total Estimated Construction Cost				**$280,000**
Eng, Leg & Admin (30%)				$84,000
Total Project Cost				**$364,000**

ENVIROMIX

April 17, 2018

Shantanu Agrawal
Carollo Engineers, Inc.
8600 W. Bryn Mawr Ave., Suite 900N
Chicago, IL 60631

RE: Budgetary Proposal— BioMix System – BNR Selector Zones
MWRD – Kirie WRP
Proposal # OM-18-124467

Shan,

Please find attached our proposal for a BioMix Compressed Gas Mixing System for the BNR Selector Zones at the MWRD – Kirie WRP facility.

BioMix^{TM} Compressed Gas Mixing provides effective mixing of sludge at a fraction of the energy cost of mechanical mixers and requires **zero in-tank maintenance.**

The primary advantages of BioMix^{TM} compressed gas mixing, versus other mixing technologies are:

- ***No moving parts in the basin.***
- ***Replace 20+ mixers with a single compressor.***
- ***Adaptable to any basin geometry with power input specific to the application.***
- ***No expensive bridges or platforms required.***
- ***No demolition of existing in-basin aeration required.***
- ***The BioMix Compressed Gas Mixing system can be seamlessly integrated with the existing diffused aeration system in the Anoxic Swing Zones and the system can be operated both concurrently or intermittently with the diffused aeration system.***
- ***EnviroMix will guarantee homogeneous mixing through a Field Performance Test demonstrating Coefficient of Variation of <10%***.

Facilities today are making decisions reflective of long-term cost of ownership as well as environmental stewardship. This BioMix system provides both: The 20-year ownership costs are significantly lower and address not only the initial capital and installation costs, but also equipment replacement, maintenance and energy consumption. BioMix offers significant advantage for this application and we look forward to the opportunity of discussing further with you.

We hope that you will find this proposal responsive to your needs. Please contact me with any questions.

Best Regards,

Tyler Kunz, P.E.
Vice President of Sales

BUDGETARY PROPOSAL

PROJECT DEFINITION

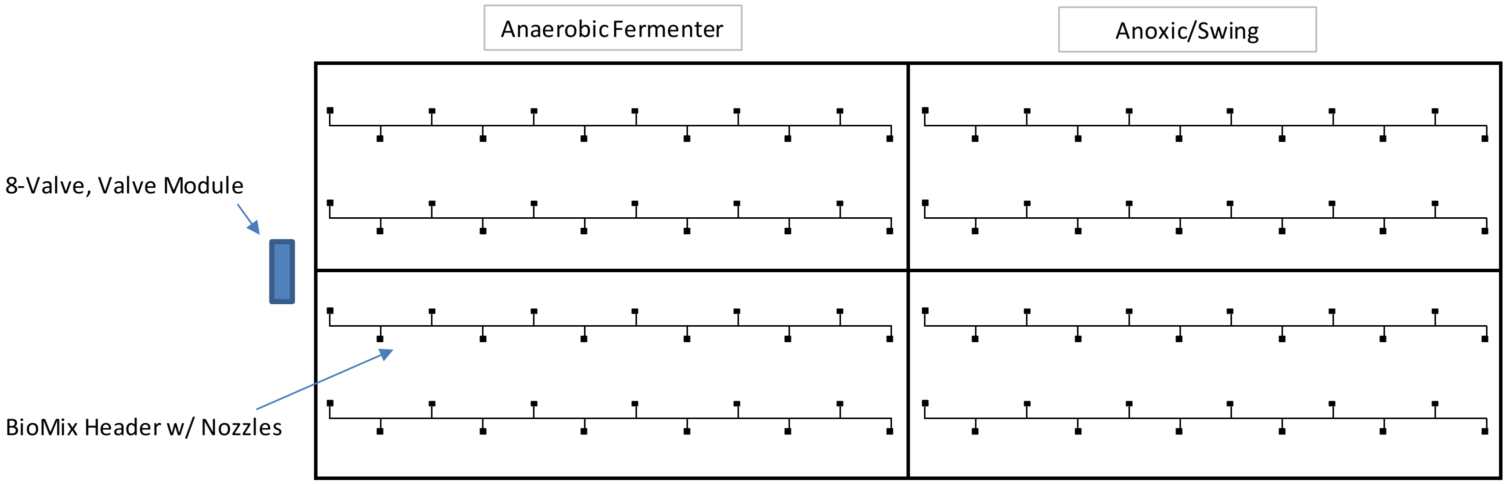
Current Process – None

Future Process – A BioMix Compressed Gas Mixing System is proposed to provide complete mix conditions of the BNR Selector Zones in six (6) Aeration Tanks. BioMix is currently installed in the Anaerobic Fermentation Zones of Tanks 5 and 6. Materials will be included from EnviroMix to modify the existing system to be consistent with the new system.

Anaerobic:	88'-5" L x 25'-6" W x 16'-3" SWD
Anoxic:	88'-5" L x 25'-6" W x 16'-3" SWD

Preliminary BioMix configuration is on the next page.

PRELIMINARY BIOMIX CONFIGURATION



Two basins shown. Typical of six basins.
Nozzles and piping in the Anaerobic Fermenter Zone of Basins 5 and 6 is Existing and will be modified to match basins 1 - 4.

BioMix^{TM} Configuration

Tank	Anaerobic Fermenter	Anoxic/Swing
Size of Pipe (Ø)	2.0-Inch	
Nozzles / Header	12	12
Headers / Basin	2	2
Total Number of Nozzles/Tank	24	24

DESCRIPTION OF SYSTEM PROPOSED

BioMix systems provide mixing in liquids by firing short bursts of compressed air through engineered nozzles affixed to the floor of a tank. This compressed air is intermittently fired in fractional second durations to mix the tank. The relatively small surface area of the large gas volumes and their rapid upward velocity enable BioMix to transfer an insignificant amount of oxygen to the wastewater, providing efficient anaerobic/anoxic mixing. Valve Panels (VP) with BioMix enclosure, mounted at the tank wall, will control the firing of the compressed air through Sch 5 BioMix press-technology tank piping and the BioMix nozzles. An operator interface in the VP allows user input to optimally control the firing pressure, sequence, frequency and duration for each tank. Electrical power requirements are limited to the power to operate the compressed air source and the 120V VP.

All BioMix installations share the following benefits:

- Significantly reduced power consumption compared to mechanical mixing
- Reduced numbers of operating equipment to be maintained
- No mechanical or electrical components in the wastewater
- Non-clogging, self-cleaning in-tank components
- Minimal scheduled maintenance of other components (compressor, air control valves) in controlled environments

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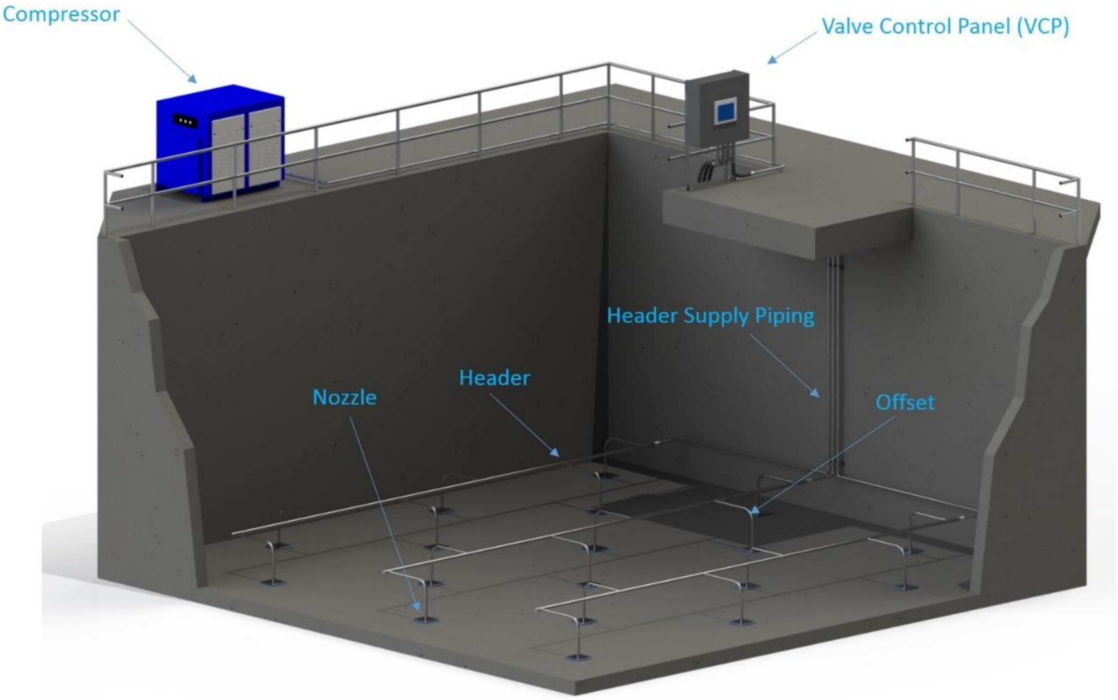
SCOPE OF SUPPLY SUMMARY

EnviroMix proposes the following BioMix System:

- (1) Master Control Panel (MCP) with EnviroMix Controller and HMI
- (3) – BioMix Valve Modules with electrically-actuated valves.
- (240)— BioMix 90-degree nozzles affixed to straight headers
- BioMix Sch5 press-technology in-tank air piping from Valve Modules to tank headers and nozzles, respective fittings and BioMix wall/pipe supports and anchors
- (3) – days of on-site time, in two (2) trips, for a qualified representative are included for equipment installation, testing, startup, and operations and maintenance training
- Submittals and Operations & Maintenance manuals
- Assumptions:
  - Electrical connection to compressor (460/3/60) and VP/receiver drain valves (120/1/60) by others
  - Interconnecting compressed air piping to Valve Modules from compressor receiver by others
  - Master Control Panel (MCP) to be installed in a building
  - Excludes installation
  - ***Compressors are NOT included. With all zones running concurrently, the estimated air requirement is 225 – 250 CFM at a minimum pressure of 40 – 100 psi.***

PICTURE FROM SIMILAR INSTALLATION

The following illustrations show a typical BioMix^{TM} layout and picture from a similar installation:



BioMix^{TM} Header and Nozzles

Valve Control Panel (VCP)

PROPOSED PRICING

It is our intent that this budgetary proposal for the BNR Selector Zones mixing system serves as the basis for a more detailed proposal. **Pricing for the above Scope of Supply is $355,350.**

Tyler Kunz, P.E.
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