Nutrient Study for the South Wastewater Treatment Plant

City of Iowa City
Iowa City, Iowa

Issued for Agency Review
May 2016

Stanley Consultants INC.

In association with

Brown AND Caldwell

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I hereby certify that this engineering document was prepared by me or under my direct personal supervision and that I am a duly Licensed Professional Engineer under the laws of the State of Iowa.

Jay M. Brady, P.E. 5/3/2016

My license renewal date is December 31, 2017.

Pages or sheets covered by this seal: Entire Report

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Stanley Consultants INC.

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Section 1

Existing Treatment Facility

General

The City of Iowa City (City) South wastewater treatment plant (SWWTP) received a new National Discharge Pollutant Elimination System (NDPES) permit on May 1, 2014 from the Iowa Department of Natural Resources (IDNR). The NPDES permit contains provisions consistent with the Iowa Nutrient Reduction Strategy (INRS) that requires the City to prepare and submit a report evaluating feasibility and reasonableness of reducing the amounts of nitrogen and phosphorus discharged to the Iowa River. The overall goal of the INRS is to significantly reduce nutrient discharges through implementation of feasible operational and practical technological approaches. The City retained Stanley Consultants, Inc. and Brown and Caldwell to prepare the nutrient study. The study will include, per IDNR guidelines and NPDES permit provisions:

- A description of the existing treatment facility and its capabilities for removing nitrogen and phosphorus.
- A description and evaluation of operational changes to the existing facility that could be implemented to reduce the amounts of total nitrogen (TN) and total phosphorus (TP) discharged in the final effluent and the feasibility and reasonableness of each.
- A description and evaluation of new or additional treatment technologies that would achieve significant reductions in the amounts of TN and TP discharged in the final effluent, with a goal of achieving annual average mass limits based on average wet weather (AWW) design flow equivalent to concentrations of 10 mg/L TN and 1 mg/L TP for plants treating typical domestic strength sewage (TN of 25-35 mg/L and TP of 4-8 mg/L), or at least 66 percent reduction in TN and 75 percent reduction in TP.
- A selection of the preferred method(s) for reducing TN and TP in the final effluent, the rationale for the elected method(s) and an estimate of the effluent quality achievable.

- A schedule for making operational changes and/or installing treatment technologies to achieve the projected effluent quality attainable.

Existing Wastewater System

The SWWTP is located approximately three miles southeast of the downtown in a predominately rural area, adjacent to the City's soccer complex. The original plant, constructed in 1990, was a complete mix activated sludge process with a design capacity of 5 million gallons per day (mgd). The plant was upgraded to achieve nitrification and partial denitrification, and expanded to a design capacity of 10 mgd in 2001.

In 2014, the plant was upgraded a second time to accommodate additional flows and loads from the decommissioning of the City's North WWTP (NWWTP) with a design AWW capacity of 24.2 mgd. The rated maximum month design process capacity is 32,658 pounds per day of five-day carbonaceous biochemical oxygen demand ($cBOD_5$) and 6,311 pounds per day of Total Kjeldahl Nitrogen (TKN).

Liquid treatment units include a 17.6 million gallon influent equalization basin, influent lift station, screening, two vortex grit units for grit removal, five primary clarifiers, four, ten-cell activated sludge trains, two bio-augmentation re-aeration reactors (BAR), 25 mgd mixed liquor pumping station, six secondary clarifiers, and ultraviolet (UV) disinfection. The treated wastewater is discharged to the Iowa River approximately four miles downstream of Iowa City.

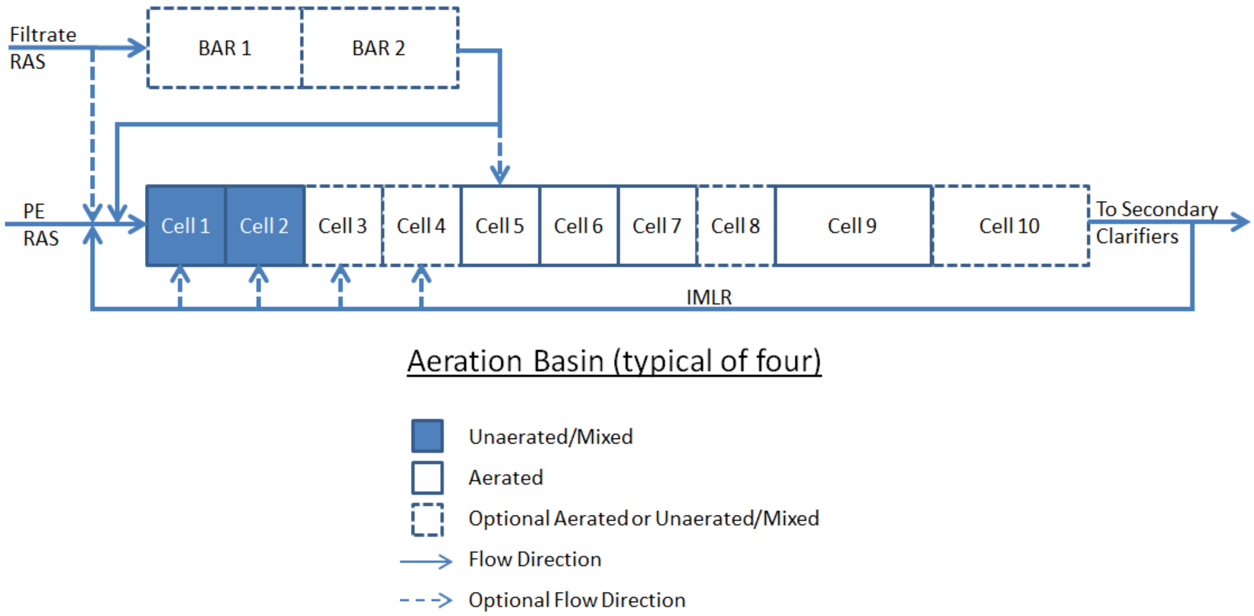
Solids processing includes thickening of waste activated sludge (WAS) prior to blending with primary sludge for stabilization by temperature phased anaerobic digestion. Ferric chloride is added to the sludge equalization tank to minimize hydrogen sulfide formation. The digested solids are dewatered with belt filter presses prior to storage in a cake storage facility and ultimate land application. High strength dewatering filtrate is routed to a high strength waste (HSW) equalization tank prior to returning to the liquid stream at the aeration basins. The processed solids meet the Class A/I criteria.

Performance Evaluation

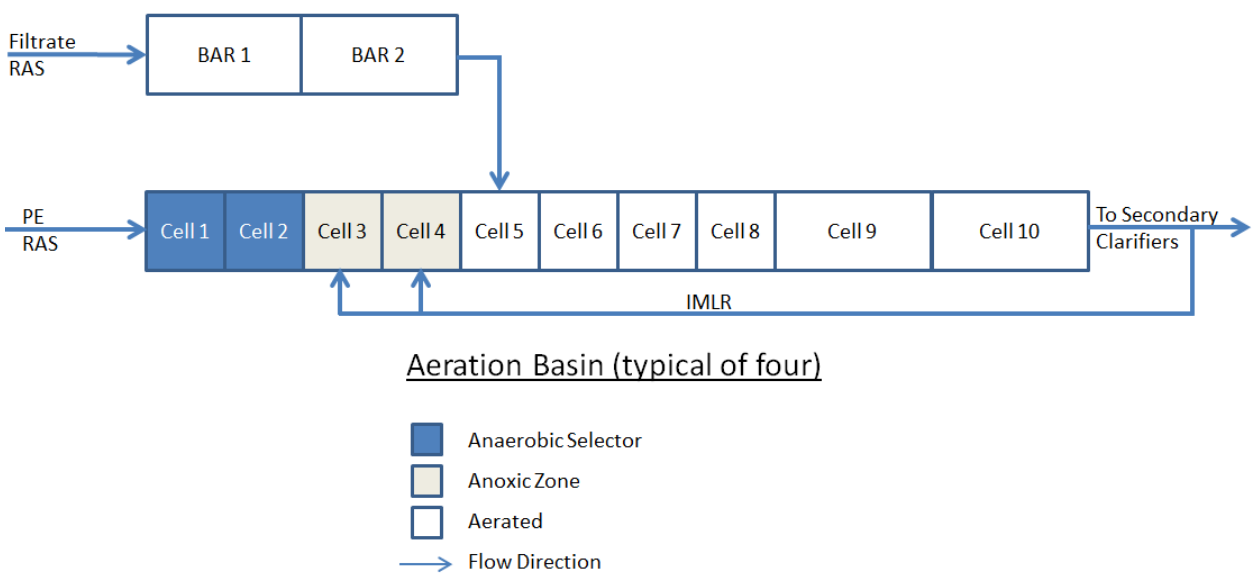
In the 2014 expansion, the activated sludge system trains were lengthened by adding two additional cells for a total of ten cells. The two additional cells per train are double the length of the original cells. New aeration blowers and air diffusers were added to accommodate additional air demand and improve dissolved oxygen control to each cell. Additional mechanical mixers were added as well as side stream bioaugmentation treatment, aka BAR. The original internal mixed liquor recycle was replaced.

The BAR process utilizes a portion of the return activated sludge (RAS) to treat high strength waste such as belt filter press filtrate generated by dewatering anaerobically digested sludge. The reactors primary purpose is to fully nitrify the filtrate and grow nitrifying bacteria that are discharged into the aeration basin increasing overall nitrifier population and improving/stabilizing nitrification during cold weather periods. The design flow scheme includes an anoxic selector zone to improve sludge quality. Each basin was intended to operate with the first two cells without aeration to facilitate anoxic conditions and the remainder of the basin to be aerated. Internal mixed liquor recycle (IMLR) is pumped via a pump station which routes recycle mixed liquor flow to Cell 1.

The design also included capabilities to operate in an anaerobic/anoxic/aerobic (A2O) mode to facilitate biological TN and TP removal. Under A2O operations, IMLR is routed to Cell 3 creating an anaerobic selector (Cells 1 and 2) and anoxic zone (Cells 3 and 4). Under the MLE mode, the BAR effluent is routed to Cell 1 to provide additional nitrates to the anoxic zone and when in A2O mode the high nitrate recycle is routed to Cell 5. Figure 1-1 shows the MLE flow scheme designed with flexibility indicated. Figure 1-2 presents the A2O mode flow schematic.



MLE Flow Schematic
Figure 1-1



A2O Flow Schematic
Figure 1-2

The 2014 expansion also included expanding the capacity of the influent equalization basin and the HSW equalization tank. The earthen influent equalization basin size increased from 5 million gallons to 17.6 million gallons capacity. When the plant flows reach 30 mgd, flows above 30 mgd are diverted to the equalization basin. The diverted flow is gradually bled back to the influent pump station once influent flows have subsided. The HSW tank is an elevated steel tank that stores the HSW before it is conveyed to the BAR or aeration basins for treatment. The tank allows the HSW to be discharged into the BAR or the primary effluent at a constant, controlled rate. Both the EQ basin and the HSW tank minimize spikes in flows and loads that may negatively affect the biology within the secondary treatment process.

Section 2

Historical Flow and Load Data

Influent Flow and Loadings

In February of 2011, Stanley Consultants and Brown and Caldwell published the **Facility Plan for Expansion of South Wastewater Treatment Plant** (Facility Plan) which provided the basis for expanding the South WWTP (SWWTP) capacity and abandoning the NWWTP. The Facility Plan defined the SWWTP influent design flows and loadings based upon the combined flows and loadings from the SWWTP and NWWTP from January 1, 2006 through July 2010 along with future growth projections. Similarly, this analysis defines the "current" SWWTP influent flow and loading data as the combined SWWTP and NWWTP flows and loadings (up to the NWWTP decommissioning date of February 7, 2014) from July 1, 2010 through March 2016. Table 2-1 compares the Facility Plan Year 2011 and 2025 design flows and loadings with current values. Note that Total Kjeldahl Nitrogen (TKN) is calculated using the reported influent ammonia nitrogen (NH3-N) loadings and applying the historical NH3-N: TKN ratio of 0.57.

Table 2-1 SWWTP Historical Influent Flows and Loadings

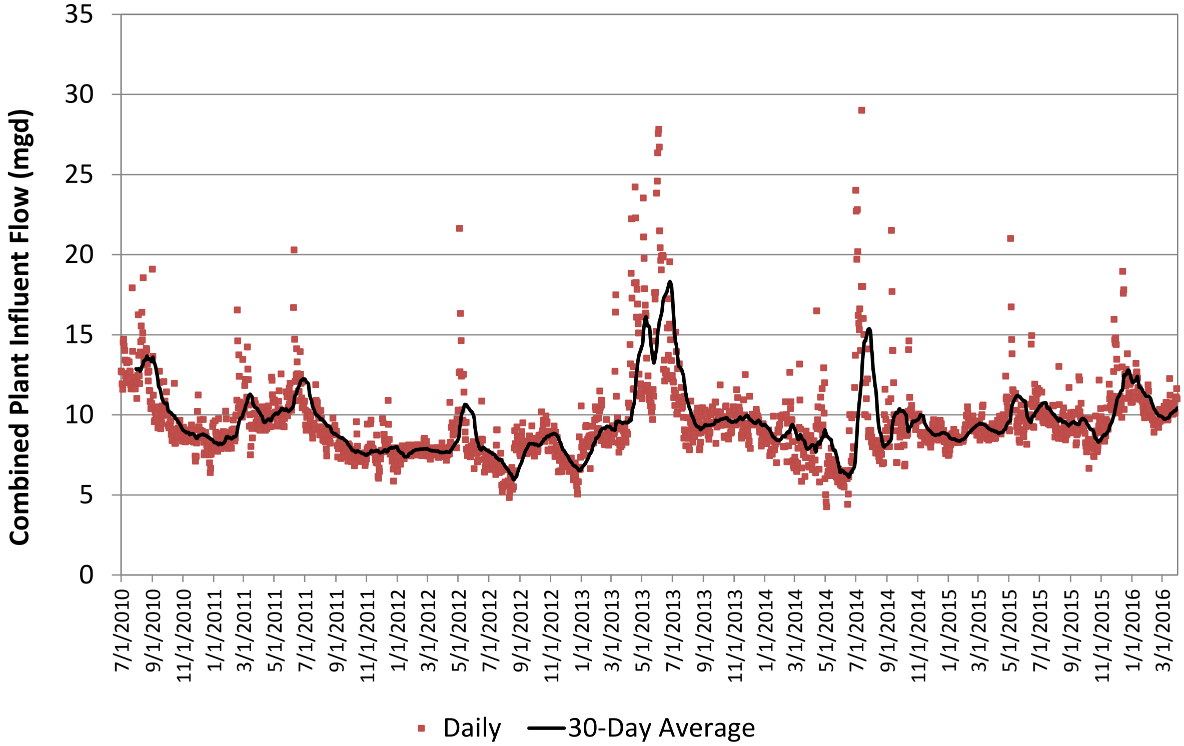
Item	Source	Average Dry Weather	Average Daily Flow[6]	Average Wet Weather	Maximum Wet Weather
Flow (mgd)	Facility Plan-Year 2011[1]	8.0	11.3	18.6	33.1
	Facility Plan–Year 2025	10.5	14.5	24.2	43.3/30[8]
	Current[2]	6.0	10	18.3	29.0
	Current: Facility Plan-Year 2011	75%	88%	98%	88%
	Current: Facility Plan-Year 2025	57%	68%	76%	97%

Table 2-1 SWWTP Historical Influent Flows and Loadings (continued)

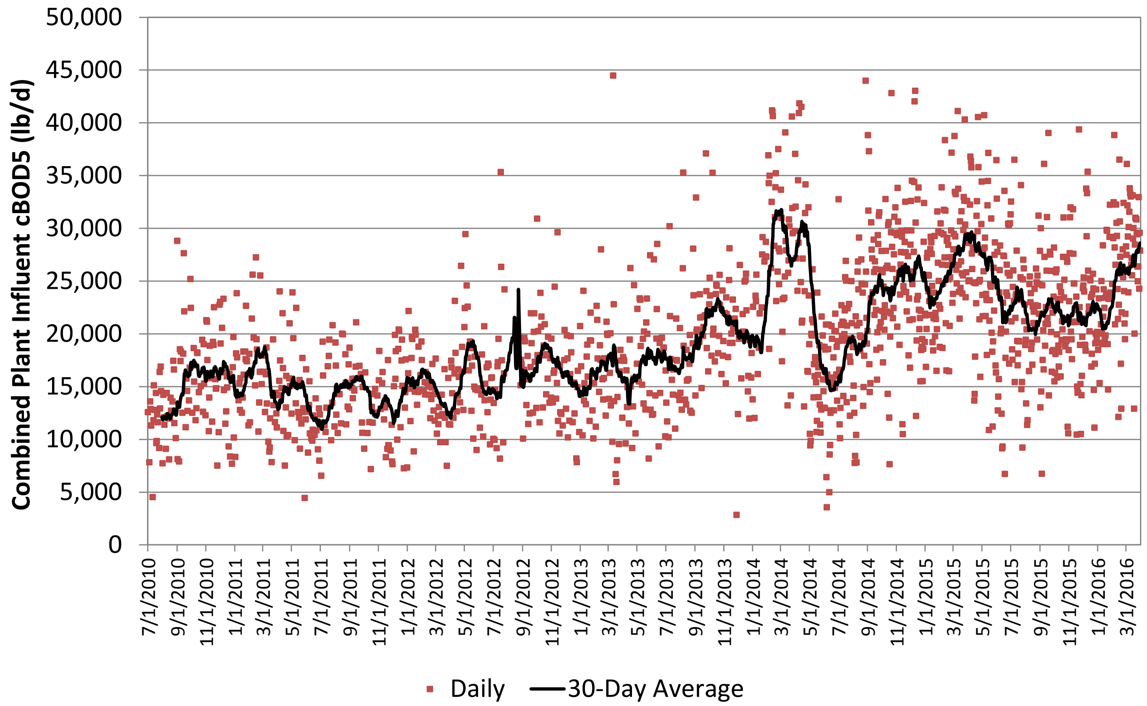
		Annual Average[6]	Maximum Month	Maximum Week	Maximum Day
Carbonaceous Biochemical Oxygen Demand (lb/d)[4]	Facility Plan-Year 2011[1]	15,425	21,643	25,193	31,381
	Facility Plan–Year 2025	25,100	32,658	--	47,745
	Current[2]	23,600	31,800	36,700	44,500
	Current: Facility Plan-Year 2011	153%	147%	146%	142%
	Current: Facility Plan-Year 2025	94%	97%	--	93%
Total Suspended Solids (lb/d)	Facility Plan-Year 2011[1]	17,110	22,075	28,541	33,796
	Facility Plan–Year 2025	--	34,386	--	55,653
	Current[2]	23,800	29,900	34,900	60.900
	Current: Facility Plan-Year 2011	139%	135%	122%	180%
	Current: Facility Plan-Year 2025	--	87%	--	109%
Total Kjeldahl Nitrogen (lb/d)[5]	Facility Plan-Year 2011[1]	3,316	4,665	5,232	6,754
	Facility Plan–Year 2025	4,800	6,311	7,200	9,490
	Current[2,]	3,200	4,100	4,500	5,800
	Current: Facility Plan-Year 2011	97%	88%	86%	86%
	Current: Facility Plan-Year 2025	67%	65%	63%	61%
Total Phosphorus (lb/d)	Design–Year 2025[7]	655	860	980	1,285
	Current[3]	460	570	670	700
	Current: Design-Year 2025	70%	66%	68%	55%

1. *Facility Plan –Year 2011 represents combined NWWTP and SWWTP flows and loadings from 1/1/06 through 6/1/2010*
2. *Current based upon combined NWWTP and SWWTP flows and loadings from 7/1/10 through 3/31/2016. Flows based on reported SWWTP influent flow data which are subject to equalization operations.*
3. *Current represents SWWTP loadings from 5/7/14 through 3/31/2016.*
4. *Carbonaceous biochemical oxygen demand as measured on a five day basis.*
5. *Calculated using influent NH3-N loading and influent NH3-N:TKN = 0.57.*
6. *Current average daily flow or annual average loads based on April 1, 2015 through March 31, 2016.*
7. *TP loads were not specifically stated in the Facility Plan, values represented were applied in the BioWin modeling for design.*
8. *Unequalized influent flow = 43.3 mgd, Equalized flow = 30 mgd*

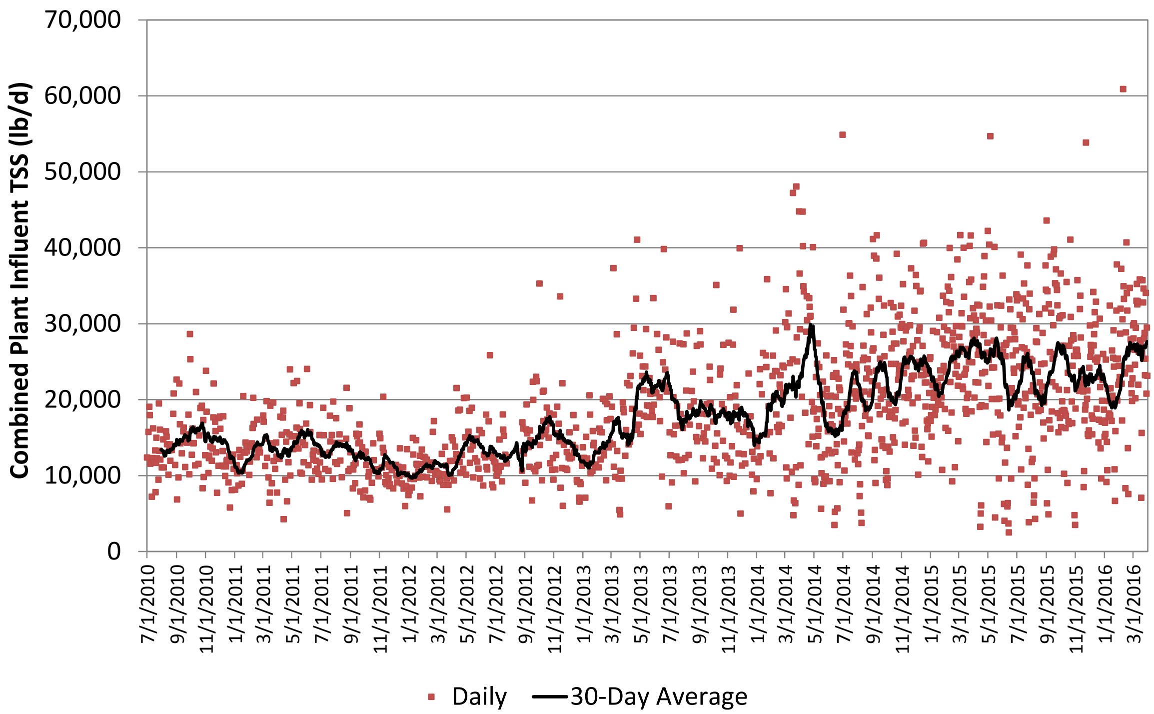
The current average daily and dry weather flows are 12% and 25% respectively lower than the Facility Plan Year 2011 values while current wet weather flows have remained similar to the Year 2011 data. Figure 2-1 presents the daily flows from July 1, 2010 through March 31, 2016.



Figures 2-2 and 2-3 show influent $cBOD_5$ and total suspended solids (TSS) loadings have increased steadily since 2013. The increase in $cBOD_5$ and TSS loadings does not correspond to influent flow trends, hence it is believed the increase is attributed to either higher industrial loadings, change in SWWTP sampling location, or more representative sampling with the NWWTP off-line. The increase in influent loading variability suggests changes in industrial loadings, however plant staff report the industrial loadings have not changed significantly from 2010. The influent sampling location was changed on October 12, 2015 for better reliability and does not correlate to the increased influent loadings beginning in 2013. Influent $cBOD_5$ loadings have increased by 53% on an annual average basis compared to the Facility Plan Year 2011 values while influent TSS loadings increased 39% on the same basis. On a maximum month and maximum week basis, $cBOD_5$ and TSS have increased roughly 20-50% compared to the Facility Plan Year 2011 values and are approaching Year 2025 loadings. The current maximum day $cBOD_5$ and TSS loadings are dramatically greater than the Facility Plan Year 2011 values and are approaching, or even greater than Year 2025 design loadings.



Combined Historical Influent cBOD5 Load
Figure 2-2

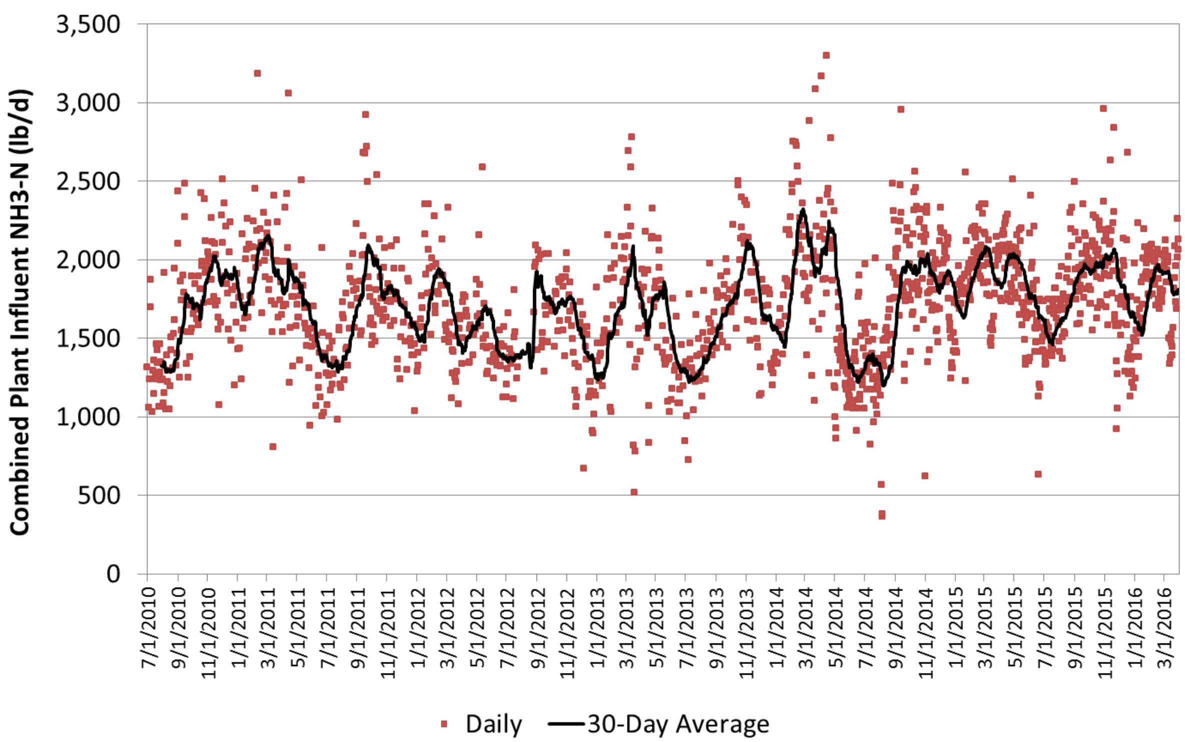


Combined Historical Influent TSS Load
Figure 2-3

Influent NH3-N loadings have remained fairly constant since July 1, 2010 as shown in Figure 2-4. On a maximum month basis, current influent TKN loadings have slightly decreased (12%) compared to the Facility Plan Year 2011 values. Similarly, the maximum week and day TKN values have decreased by 14% compared to the Facility Plan Year 2011 values. Current TKN loadings are roughly 60% to 65% of the Year 2025 design loadings.

The Facility Plan did not directly address the TP loads calculated for Year 2025 design. The process modeling conducted by Brown and Caldwell used the loadings summarized in Table 2-1. The current annual average, maximum month, and maximum week TP loadings are 70% of the Year 2025 design loadings while current maximum day load is 55% of the Year 2025 loading.

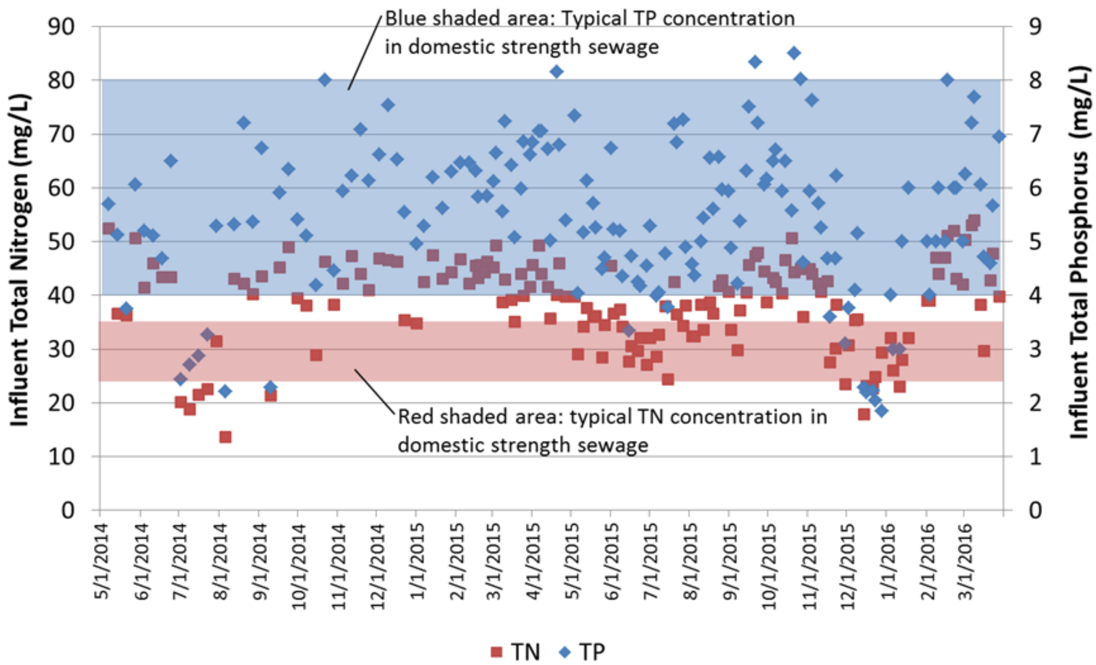
Plant staff continues to investigate why the influent cBOD5 and TSS loadings have increased so dramatically while TKN (NH3-N) and TP loadings have remained relatively constant.



Combined Historical Influent NH3-N Load
Figure 2-4

Nutrient Reduction Treatment Goals

The City began measuring the plant influent TN and TP concentrations once per week in May 2014 and later increased the analysis frequency to twice a week starting in February 2015. Figure 2-5 shows the SWWTP influent TN and TP measurements during this time period. Through March 2016, the median influent TN concentration was 40 mgN/L and 70% of the influent TN samples (103 of the 146) had concentrations greater than 35 mgN/L. The median influent TP concentration during this same period was 5.5 mgP/L and only 3 of the 144 influent TP samples were greater than 8 mg/L. Since the influent TN concentrations are consistently higher than the range specified as "typical domestic sewage", the SWWTP treatment performance goals are 66% reduction of TN and 75% reduction of TP.



SWWTP Influent TN and TP Concentrations
Figure 2-5

Section 3

Nutrient Removal Optimization

General

The NWWTP was shut down on February 7, 2014 with all flow then going to the SWWTP. The SWWTP was operated in MLE mode from February 2014 to December 23, 2014. The plant operated in the A2O mode from December 23, 2014 through March 31, 2016.

The City began influent TN and TP sampling in May 2014. After making process adjustments in June 2014, the City began trials to optimize the SWWTP biological nutrient removal (BNR) system for TN and TP removal in July of 2014. During the nutrient removal optimization trial period, additional sampling within the treatment facility was completed. Furthermore, various operating parameters were changed during the optimization period to improve system performance. This section summarizes the optimization trial operations and plant performance related to nutrient removal including the following.

- Operational Trial Sampling and Data Collection
- Operational Trial Influent Characteristics
- Operational Trial Operations
- Operational Trial Nutrient Removal Performance

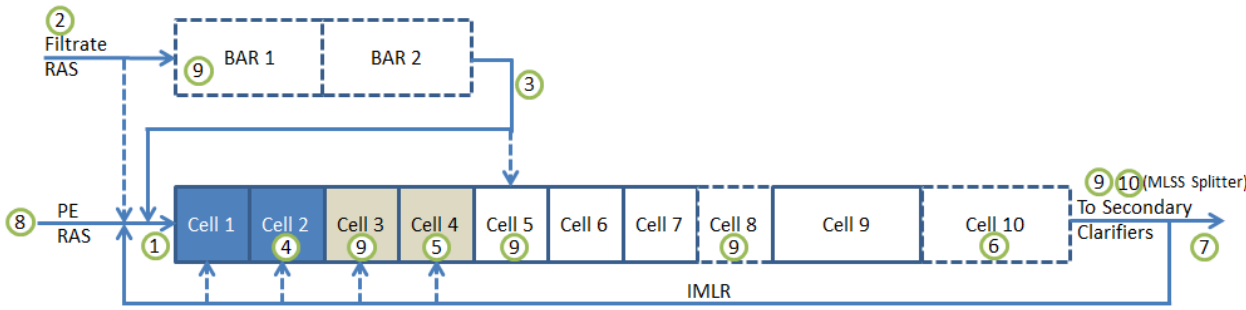
Operational Trial Sampling and Data Collection

The existing BNR system consists of four aeration basins, two BAR reactors, and six secondary clarifiers. All RAS is pumped to a common channel. A portion of the RAS is diverted to the BAR reactors when in service and the remaining RAS flow is evenly distributed to Cell 1 of the on-line basins. The existing RAS configuration along with equal primary effluent flow distribution to on-line basins creates a homogenously mixed single sludge activated sludge system. Since all four aeration basins act as a single system, aeration basin samples were collected from Train 4.

Sampling during the optimization trial included additional analytes and sampling locations along with influent TN and TP samples discussed in Section 2. The analytes collected and analyzed include the following:

1. **Alkalinity** – consumed during nitrification and produced during denitrification, both are typical for biological nutrient removal processes.
2. **Total Nitrogen –** measure of all organic and inorganic, including particulate and soluble forms of nitrogen.
3. **TKN** – measure of organically bound nitrogen and NH3-N, includes both particulate and soluble fractions.
4. **Soluble TKN (sTKN)** – TKN measured after filtering out particulate fraction using a 0.45 um filter, used to determine organically bound soluble nitrogen by subtracting NH3-N.
5. **NH3-N** – converted during nitrification to NO3-N, required under current NPDES permit.
6. **NO3-N** – generated by oxidation of NH3-N and reduced during denitrification to nitrogen gas, included in TN measurement.
7. **Total phosphorus –** measure of all organic and inorganic phosphorus, including particulate and soluble forms.
8. **Phosphate (PO4-P)** – soluble form of phosphorus as measured by a 0.45 um filter that can be released and removed during enhanced biological phosphorus removal (EBPR).
9. **Dissolved Oxygen (DO) –** oxygen gas dissolved into solution that serves as the electron acceptor in metabolic reactions.
10. **Temperature –** influences rate at which biological reactions occur.
11. **cBOD5 –** generalized measure of biodegradable organic carbon in the wastewater.
12. **TSS –** measure of the solids suspended in wastewater.
13. **Sludge Volume Index –** measure of BNR system sludge quality.
14. **pH** – measure of hydrogen ion concentration for defining whether liquid is acid or base

Influent and effluent samples, except pH, were collected using the City's existing composite samplers. The remaining samples were grab samples collected once per day and typically five days per week to measure the performance of the process. Figure 3-1 shows the general sample locations and samples collected. In addition to these samples the plant routinely measures the following flows which were used in the evaluation: influent, effluent, RAS total, RAS to BAR, internal mixed liquor recycle (IMLR), high strength waste, and filtrate.



(1) Aeration Basin Influent Channel – alkalinity, NH3-N, NO3-N, PO4-P

(2) Filtrate - alkalinity, NH3-N, NO3-N, TKN, sTKN, PO4-P, TP (prior to RAS introduction)

(3) BAR Effluent - alkalinity, NH3-N, NO3-N, TKN, PO4-P, TP, pH

(4) Anaerobic Selector - NH3-N, NO3-N, PO4-P

(5) Anoxic Selector - alkalinity, NH3-N, NO3-N, TKN, PO4-P

(6) Cell 10 - alkalinity, NH3-N, NO3-N, PO4-P, TP

(7) Final Effluent (after clarification and disinfection)– TN, NH3-N, NO3-N, TP, PO4-P, pH, TSS, cBOD5, DO, and alkalinity

(8) Influent (prior to primary clarifiers and grit removal)– TN, NH3-N, NO3-N, TP, PO4-P, pH, TSS, cBOD5, DO, and alkalinity

(9) DO (Train 4)

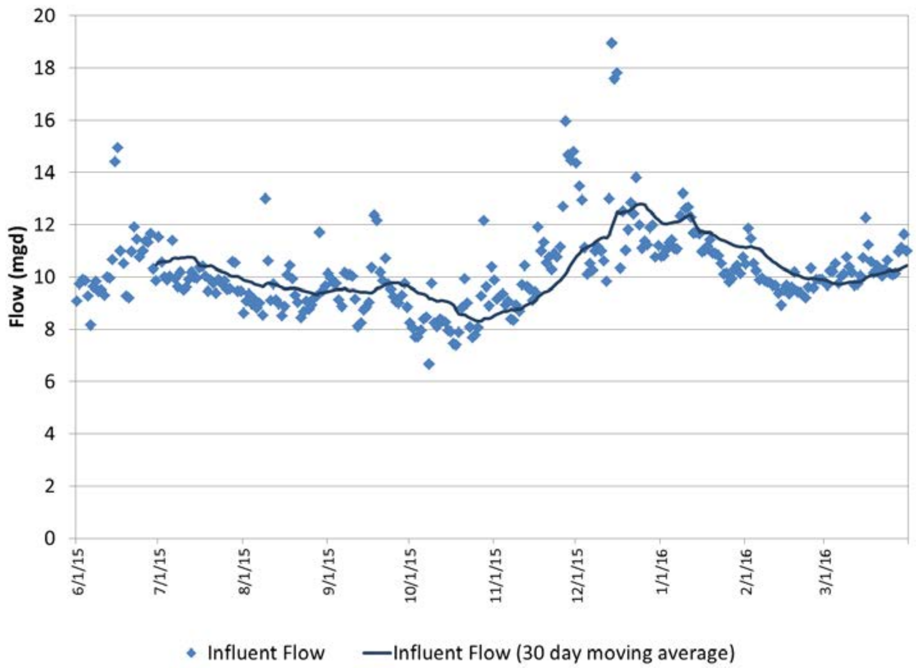
(10) SVI

Nutrient Removal Optimization Trial Sample Locations
Figure 3-1

Optimization Trial Influent Characteristics

Figures 3-2 through 3-7 show the reported SWWTP influent wastewater characteristics applicable to the A2O nutrient removal optimization trial from June 1, 2015 through March 31, 2016.

The median flow during the optimization trial was 10 mgd which matches the historical annual average yearly flows. The maximum month flow of 13 mgd and maximum day flow of 19 mgd (December 14, 2015) are significantly lower than the historical average wet weather and maximum day flows creating flow conditions favorable to BNR.



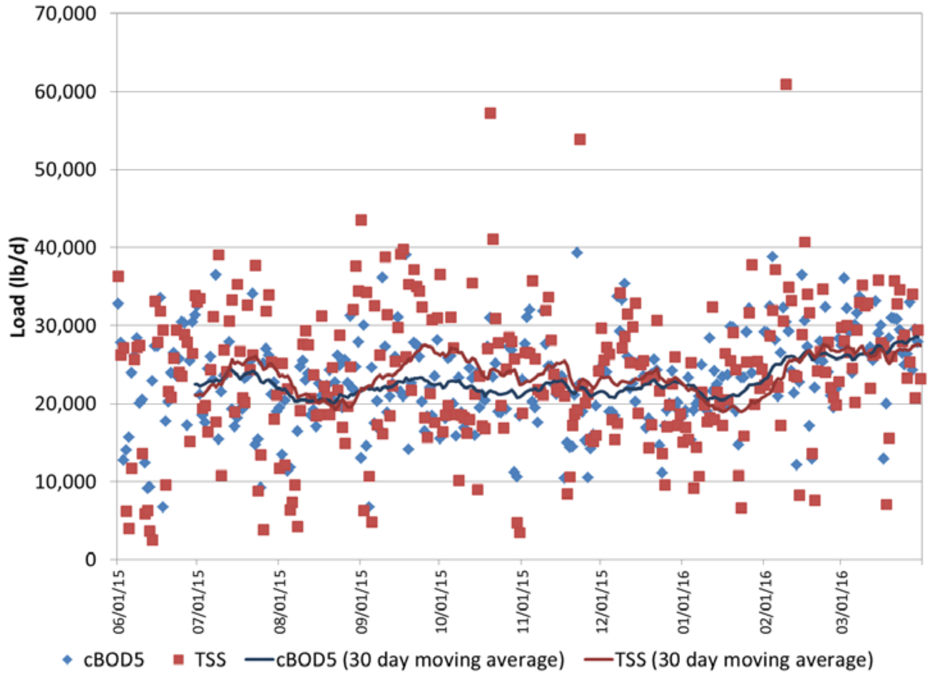
Influent Flow during Optimization Trial
Figure 3-2

The median and maximum month $cBOD_5$ loadings were 23,300 lb/d and 28,600 lb/d respectively. These loadings are within 10% of the current $cBOD_5$ loadings listed in Table 2-1 and are roughly 51% and 32% higher than the Facility Plan Year 2011 average and maximum month loads.

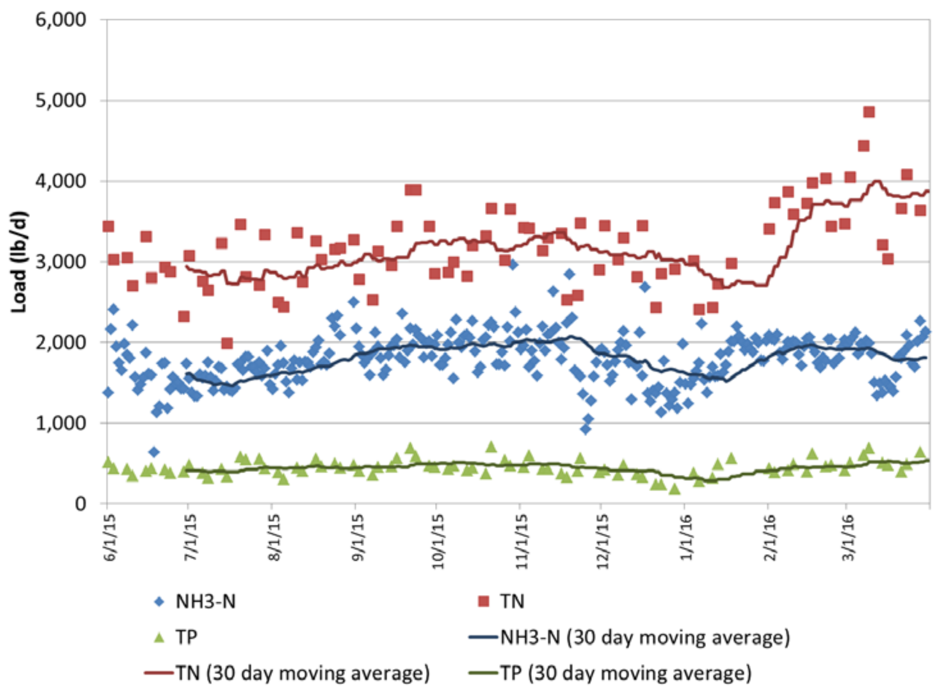
The influent TSS median load was 24,000 lb/d and the maximum month was 27,600 lb/d. These loadings are also within 10% of the current TSS loadings listed in Table 2-1 and 40% and 30% higher than the Facility Plan Year 2011 respective loads.

Reported median influent nitrogen loadings during the optimization trial period (NH3-N = 1,800 lb/d, TN = 3,200 lb/d, TKN = 3,200 lb/d) were nearly identical to current average TKN loadings in Table 2-1 and average TKN loadings measured from May 2014 through March 2016. Furthermore, Figure 3-5 shows the influent TN and TKN loads were basically identical which indicates there is negligible NO3-N or nitrite (NO2-N) in the influent as expected.

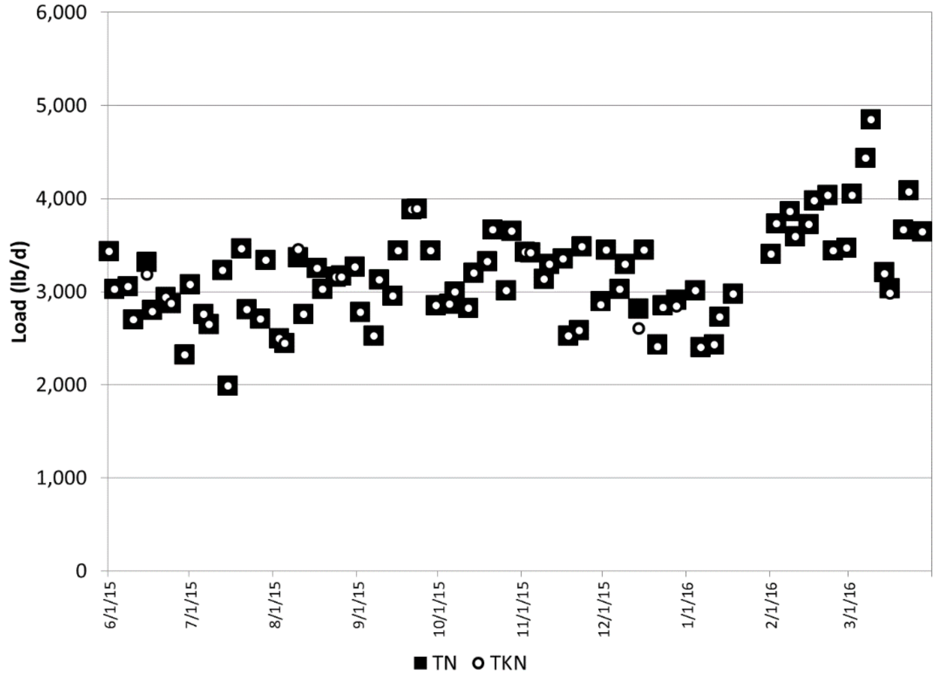
The median influent TP loading was 440 lb/d during the optimization trial period which again was nearly identical to current average TP loadings in Table 2-1 and average TP loadings measured from May 2014 through March 2016.



Influent $cBOD_5$ and TSS Loading during Optimization Trial
Figure 3-3

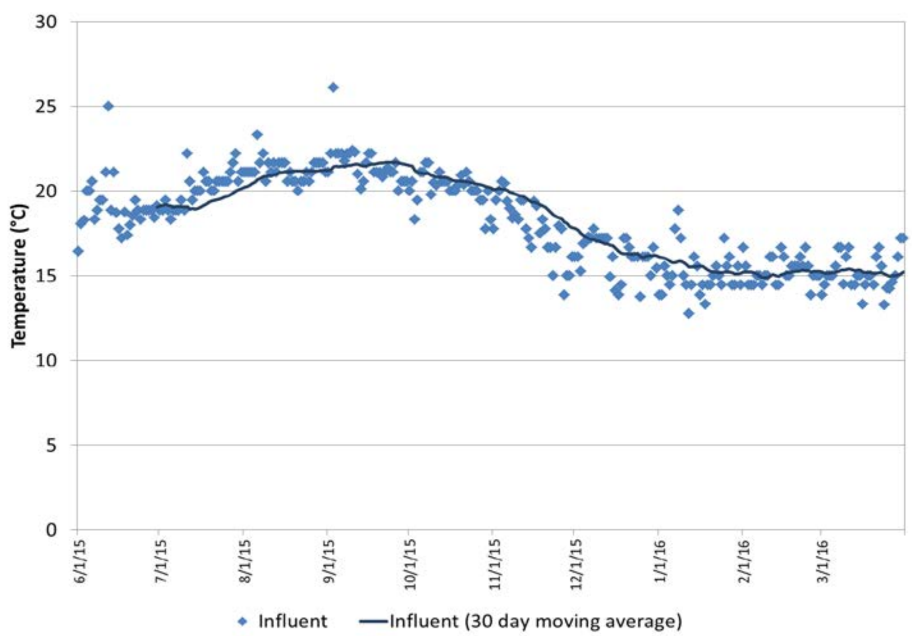


Influent NH3-N, TN, and TP Loading during Optimization Trial
Figure 3-4



Influent TN and TKN Loadings during Optimization Trial
Figure 3-5

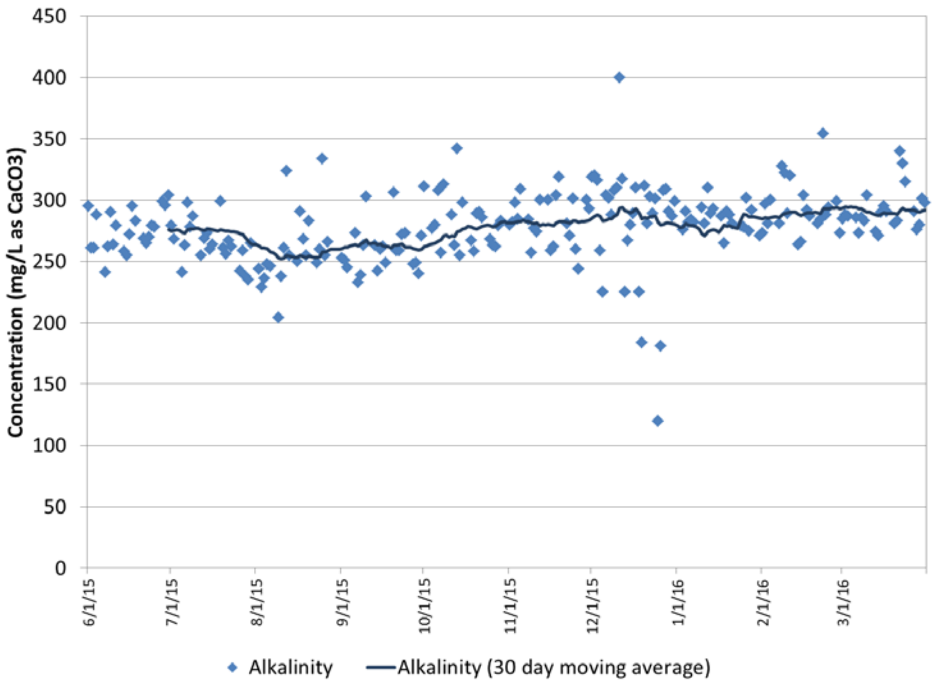
Influent temperature ranged from 13 to 26 degrees Celsius (°C) during the optimization period. The lowest 30 day running average was about 15 °C which is well above the 12 °C monthly average used in the design basis for the SWWTP upgrades (Technical Memorandum Number 3 – Secondary Treatment Alternative Assessment, Brown and Caldwell, April 6, 2011).



Influent Temperature during Optimization Trial
Figure 3-6

Influent alkalinity (median 280 mg/L as CaCO3) and alkalinity generated via denitrification was more than adequate to nitrify the influent NH3-N (7.14 parts of alkalinity required per part of NH3-N nitrified).

Overall, the influent characteristics during the operational trial are more favorable for BNR than historical and design conditions given the lower wet weather flows, higher influent temperatures, and high cBOD5 loadings.



Influent Alkalinity during Optimization Trial
Figure 3-7

Carbon to Nutrient Ratios

For optimal BNR an adequate supply of readily biodegradable carbon is required to drive the biological removal of nitrogen and phosphorus. Carbon can be measured indirectly using cBOD5 while the nutrients are measured as TKN and TP. Table 3-1 shows the cBOD5 to nutrient ratios observed during the operational trial period were much higher than the Facility Plan Year 2025 design basis. The higher cBOD5:TKN and cBOD5:TP ratios provide more favorable conditions for TN and TP reduction than used in the design upgrades. To better understand the ramifications of the increased carbon in the SWWTP influent an additional sampling/analysis campaign is needed to determine if the readily biodegradable fraction of the total influent carbon has changed.

Table 3-1 SWWTP Influent Carbon and Nutrient Ratios

Parameter	Facility Plan Design (Annual Average)*	Operational Period
cBOD5:TKN	5.2	7.7
cBOD5:TP	38	56

NH3-N to TKN Ratio

The NH3-N to TKN ratio, or F_{NA}, is also an important indicator of whether the influent wastewater characteristics are different from the Facility Plan basis of design. For example, a drop in the F_{NA} may indicate a higher fraction of unbiodegradable nitrogen is present which could result in higher final effluent TN. The wastewater characterization conducted in 2010 observed an F_{NA} of 0.57. During the operational trial period, the average F_{NA} was 0.59. The relative similarity of the F_{NA} values suggests the influent nitrogen characteristics are unchanged.

Recycle Loads

The recycled nutrient loads in the filtrate stream from dewatering anaerobically digested sludge can account for a significant portion of the treatment burden in the secondary system. At the SWWTP, nutrients were measured in the recycle stream prior to treatment in either the BAR or mainstream processes from June 2015 through March 2016. Table 3-2 compares the filtrate recycle loading to the SWWTP influent load over the same period. On average the filtrate recycle TN loading is 20% of the SWWTP influent TN load while the filtrate recycle NH3-N loading is 33% of the influent NH3-N load. The filtrate recycle TP load was also 20% of the SWWTP influent TP load on average during the same period. The filtrate PO4-P recycle load averaged 80 lb/d during the sampling period. PO4-P was not measured in the SWWTP influent, but applying the influent PO4-P:TP ratio (F_{PO4} = 0.33) observed during the wastewater characterization in 2010 (Technical Memorandum Number 2 – South Plant Wastewater Characterization and Biowin Calibration, Brown and Caldwell, April 6, 2011) yields an influent PO4-P load of 150 lb/d. This suggests the filtrate recycle PO4-P load is over 50% of the SWWTP influent load.

Table 3-2 SWWTP Average Filtrate Recycle Loads (June 2015 – March 2016)

Parameter	Filtrate Recycle (lb/d)	SWWTP Influent (lb/d)	Recycle: SWWTP Influent
TN	650*	3,060	20%
NH3-N	590	1,710	33%
TP	90	430	20%
PO4-P	80	140**	53%

**TN load based on sum of reported TKN and NO3-N in high strength filtrate stream.*

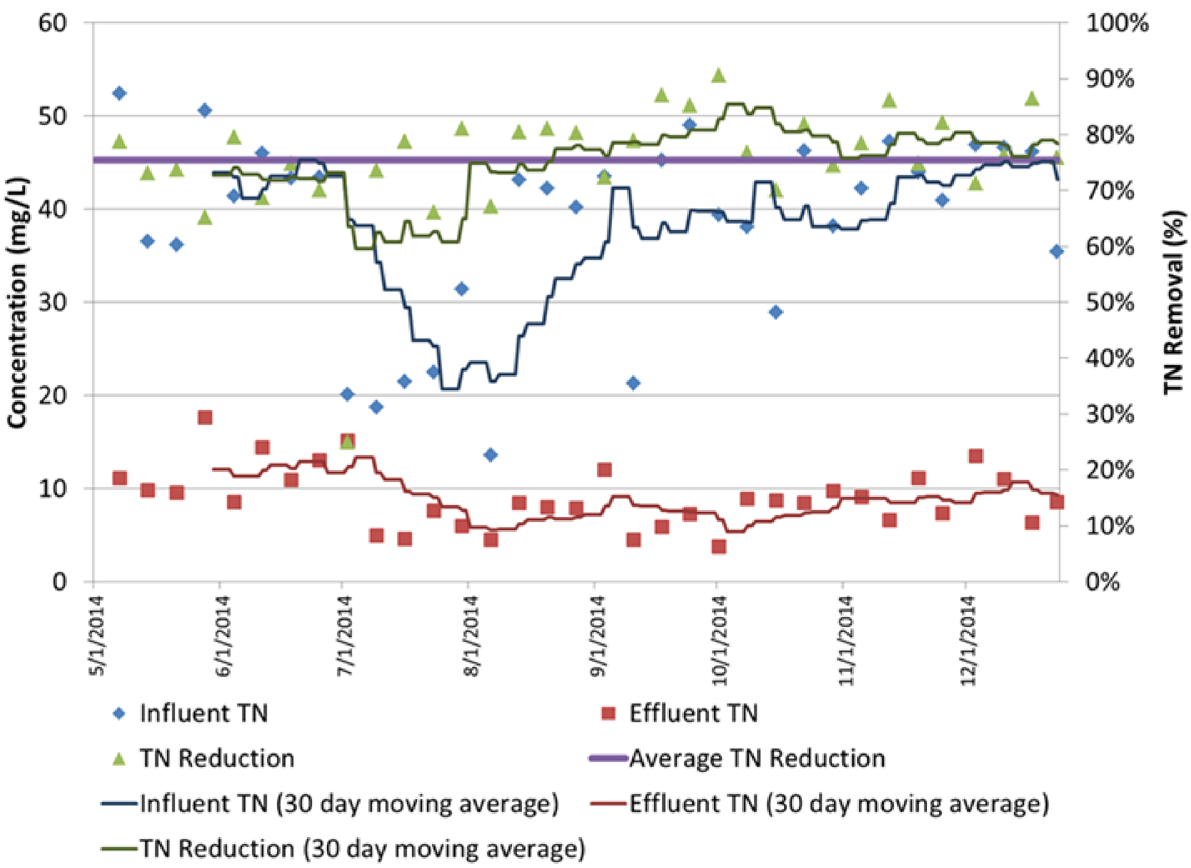
*** Influent PO4-P estimated using the observed PO4-P:TP ratio (0.33) during the wastewater characterization (Technical Memorandum Number 2 – South Plant Wastewater Characterization and Biowin Calibration, Brown and Caldwell, April 6, 2011).*

MLE Trial

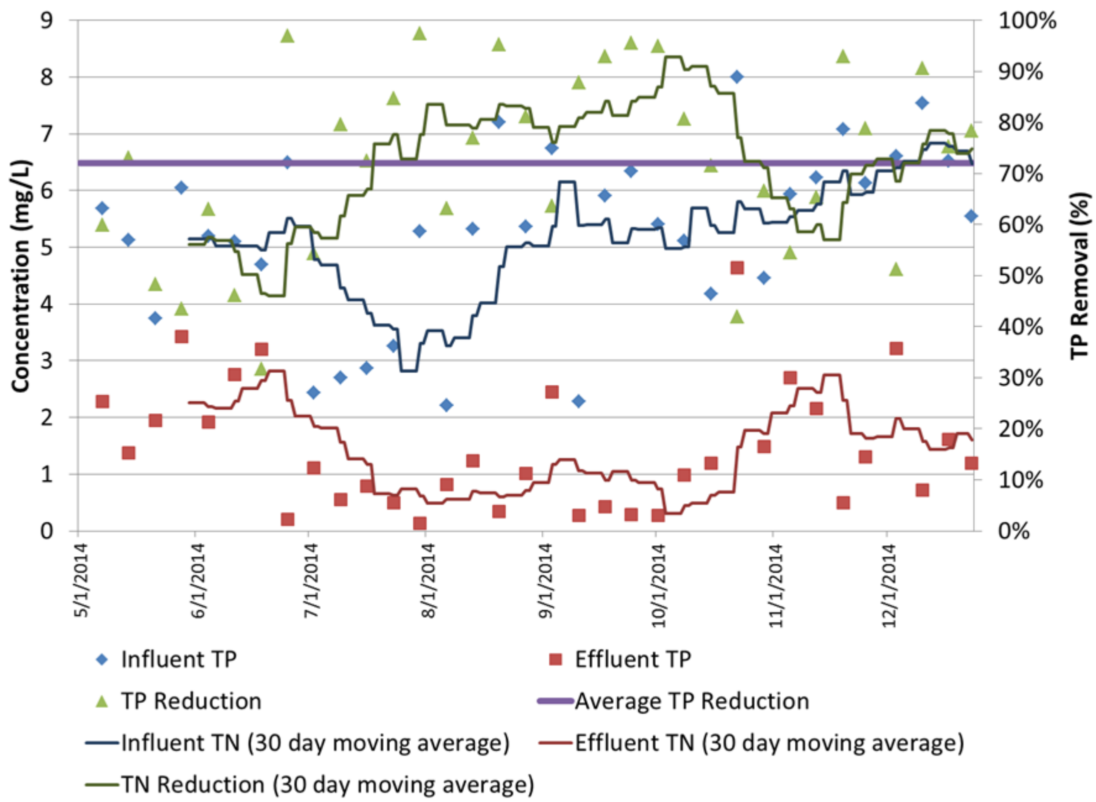
While MLE operation began in February 2014, the first few months of operation involved plant staff becoming familiar with the new facilities and systems. By June 2014, plant staff had familiarized themselves with the system. There the MLE trial is considered to have started on June 1, 2014 and lasted 206 days until December 23, 2014.

Three trains were in operation in June 2014. Four trains were placed online on June 29, 2014 and were kept in operation for the remainder of the MLE trail. BAR was in operation for the duration of the MLE trial with BAR effluent going to the aeration basin influent channel. The IMLR was discharged to the anoxic zone (1st two cells of the treatment trains).

Influent TN was variable ranging from 12 to just over 50 mg/L. The effluent TN varies from 5 to 15 mg/L with the moving 30 day average generally 10 mg/L or lower. Influent TP ranged from just over 2 mg/L to 8 mg/L. Effluent TP ranged from 0.1 to 3.5 mg/L. Figures 3-8 and 3-9 summarize the TN and TP data.



TN Concentrations during MLE Trial
Figure 3-8



TP Concentrations during MLE Trial
Figure 3-9

A2O Optimization Trial Operations

The A2O optimization trial formally began on July 1, 2015 and lasted 275 days until March 31, 2016. Table 3-3 summarizes the operational changes that were instituted during the optimization trial to investigate treatment performance and respond to treatment performance. All figures referenced in this section are located at the end of the section.

Periodic conferences were held between City staff, Stanley Consultants, and Brown and Caldwell. The project kickoff conference was held on June 30, 2016. Conference calls were conducted on August 21, 2015, December 14, 2015, and February 24, 2016. These conferences served to aid the City in operating strategies based on operating data.

Table 3-3 SWWTP Optimization Trial Secondary Treatment Configuration

Period	Date	Aeration Basins in Service)	BAR Tanks in Service	BAR Effluent/Filtrate Discharge	IMLR Rate, % Influent Flow[1]	RAS Flow, % Influent Flow	Average Aerobic SRT, days	Fully Aerated Cells[3]
1	7/1/15-7/16/15	3	1	Cell 5	150	0.67	8.3	5, 6, and 7
2	7/17/15-9/20/15	3	0	Cell 1	90	0.70	7.2	5, 6, and 7
3	9/21/15-9/23/15	2	0	Cell 1	--	--	6.6	5, 6, and 7
4	9/24/15-12/14/15	2	1	Cell 1	80	0.58	4.5	5, 6, and 7
5	12/15/15-1/14/16	2	1	Cell 5	80	0.59	4.3	5, 6, and 7
6	1/15/16-2/1/16	2	1	Cell 5	80	0.61	5.2	5, 6, 7, and 8
7	2/2/16-2/10/16	2	1	Cell 5	80	0.65	4.7	5, 6, 7, 8, and 9
8	2/11/16-3/13/16	3	2	Cell 5	90	0.65	6.3	5, 6, 7, 8, and 9
9	3/14/16-3/31/16	3	2	Cell 5	90	0.61	6.1	5, 6, 7, and 8

= *operational configuration change*

1. IMLR returned to Cells 3 and 4 during optimization trial.

2. Cells 1 and 2 operated in anaerobic mode and Cells 3 and 4 in anoxic mode during optimization trial.

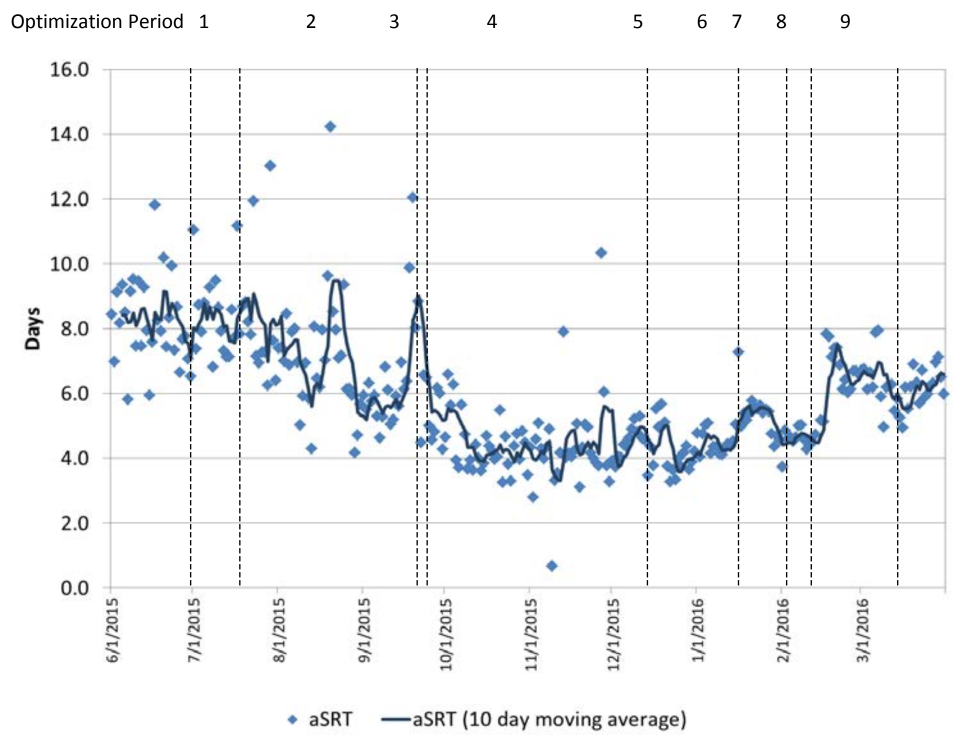
3. Cells 8, 9, and 10 not identified were mixed to reduce cell operating DO levels below 1 to 2 mg/L.

There are nine distinct periods during the A2O optimization trial resulting from operational changes. The following summarizes each period from an operational standpoint and the process implications of the changes made.

Period 1: July 1 – July 16, 2015 (16 days)

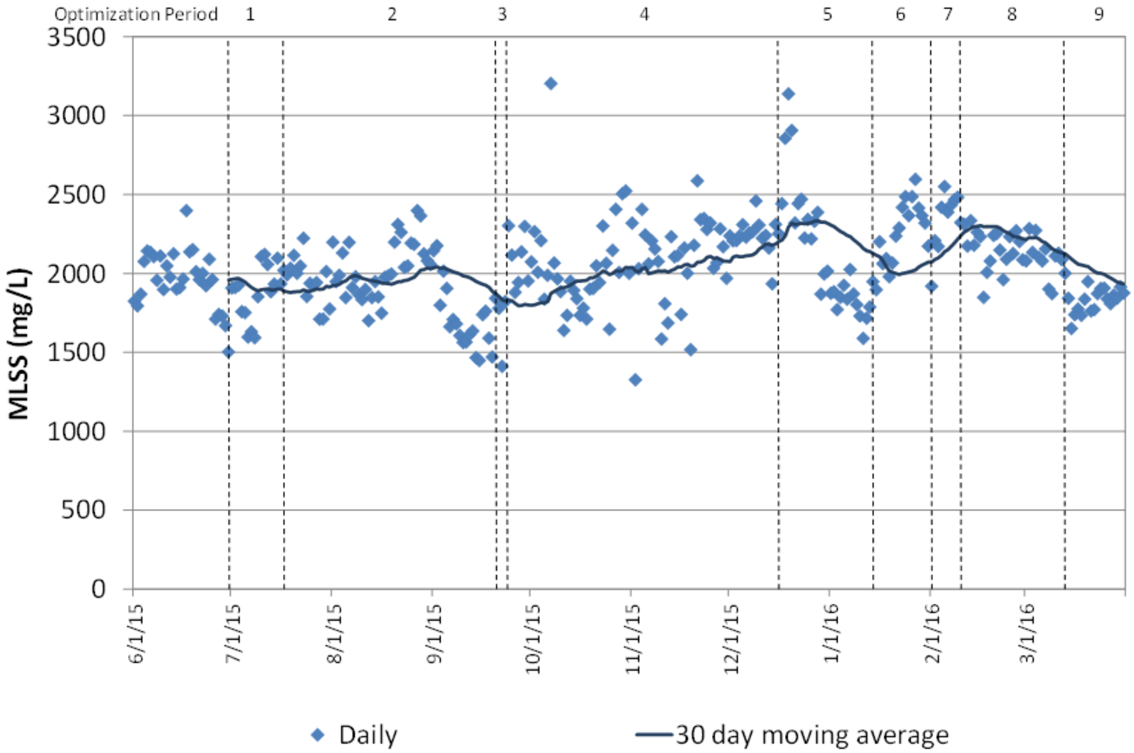
The start of the optimization trial included three aeration basins in A2O mode and one BAR tank in service. The aeration basins were arranged with Cells 1 and 2 operated anaerobically and Cells 3 and 4 operated as an anoxic zone. IMLR was routed to Cells 3 and 4 to limit the NO3-N in the anaerobic cells which would have a negative impact on the EBPR performance. The anaerobic/anoxic cells and IMLR discharge location did not change during the optimization trial. Nitrified effluent from the BAR tank was discharged to Cell 5 to avoid introducing NO3-N to the anaerobic cells. Cells 5, 6, and 7 were aerated for nitrification purposes while Cells 8, 9, and 10 were mixed or had minimal aeration to reduce DO levels which minimized oxygen recycles back to the anaerobic selector in the RAS and anoxic zone in the IMLR.

Key to the performance of the BNR systems is the solids retention time (SRT), and specifically the aerobic SRT (aSRT) which controls nitrification. The required aSRT for maintaining full nitrification is dependent on the wastewater temperature. During this first period of the optimization trial the aSRT averaged 8.3 days (calculated as the pounds of solids under aeration in the main stream aeration basins (Cells 5 through 10) divided by the pounds of solids wasted daily) and the temperature was 19.5 °C. Figure 3-6 displays the wastewater temperature and Figure 3-10 the aSRT during the optimization trial.

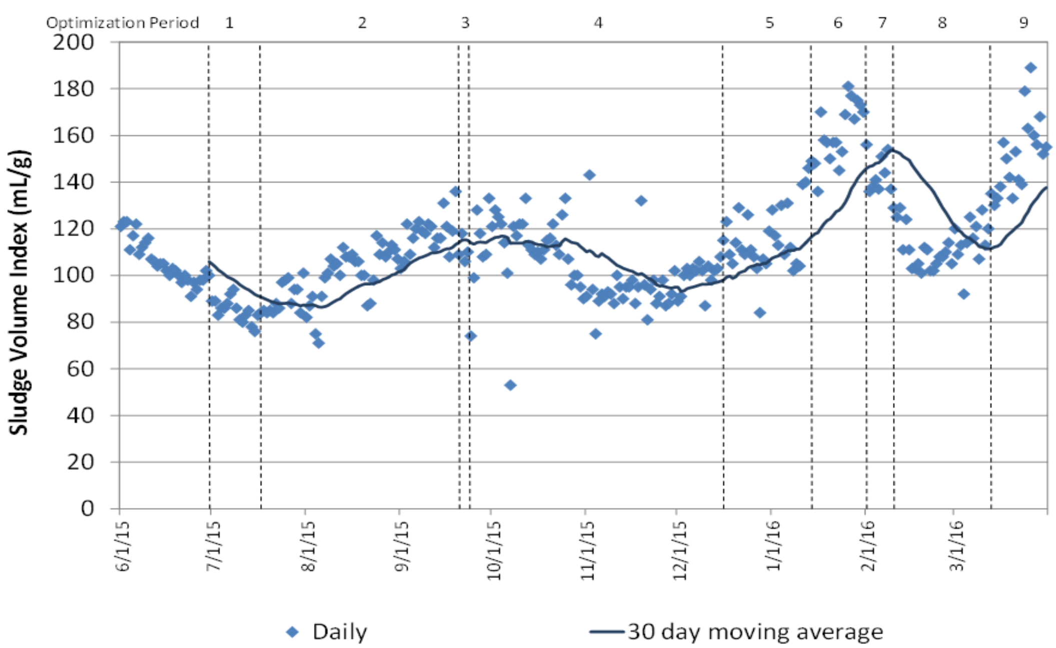


Aerobic SRT (aSRT) during Optimization Trial
Figure 3-10

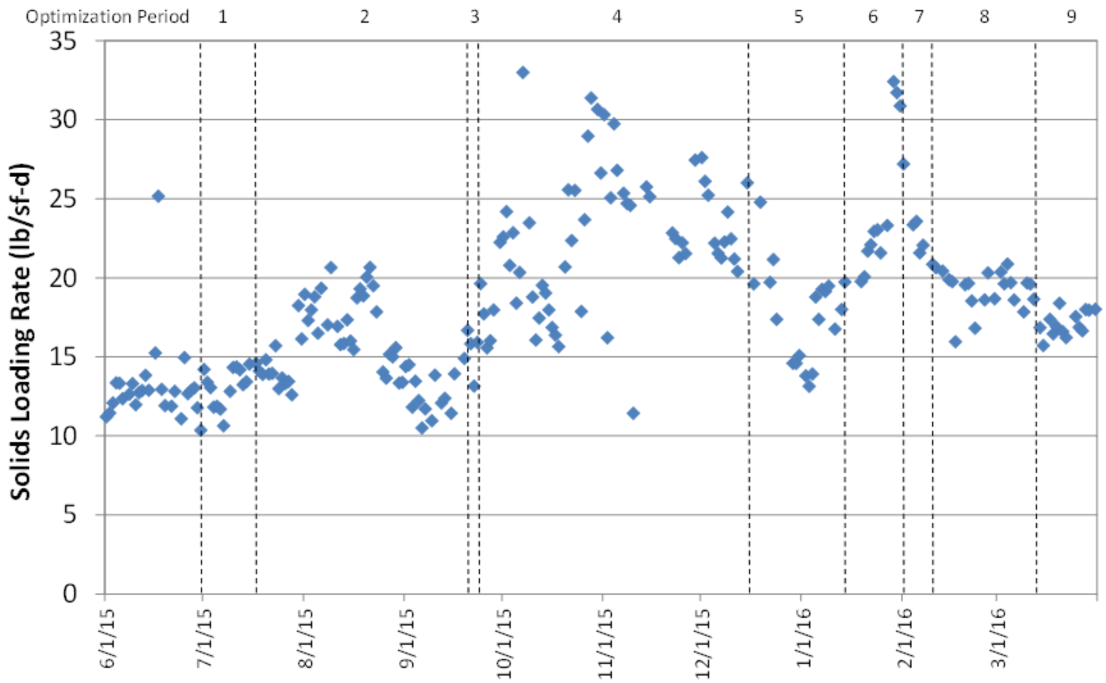
Another important factor in the design of BNR systems is sludge quality and the secondary clarifier solids loading rate (SLR). A common indicator for sludge quality is the sludge volume index (SVI). The higher the SVI, the poorer the sludge quality. The SWWTP secondary system was designed based on a 90th percentile SVI of 150 mL/g. The design SVI was based on facilities with anaerobic, anoxic, and/or classifying selectors. From June 2015 through March 2016 the 90th percentile SVI was 148 mL/g. Using a design SVI of 150 mL/g, secondary clarifier CFD modeling showed the maximum allowable SLR of 43 lb/sf-d (Technical Memorandum Number 1 – Secondary Clarifier Capacity Modeling, Brown and Caldwell, April 6, 2011). At SVI values greater than 150 mL/g, the clarifier SLR capacity decreases. Figures 3-11, 3-12, and 3-13 show the aeration basin MLSS, SVI, and SLR, respectively. During the first period of the optimization trial the average MLSS, SVI, and SLR were 1,880 mg/L, 85 mL/g, and 13.1 lb/sf-d, respectively which are well within the design capacity of the system.



Aeration Basin MLSS during Optimization Trial
Figure 3-11



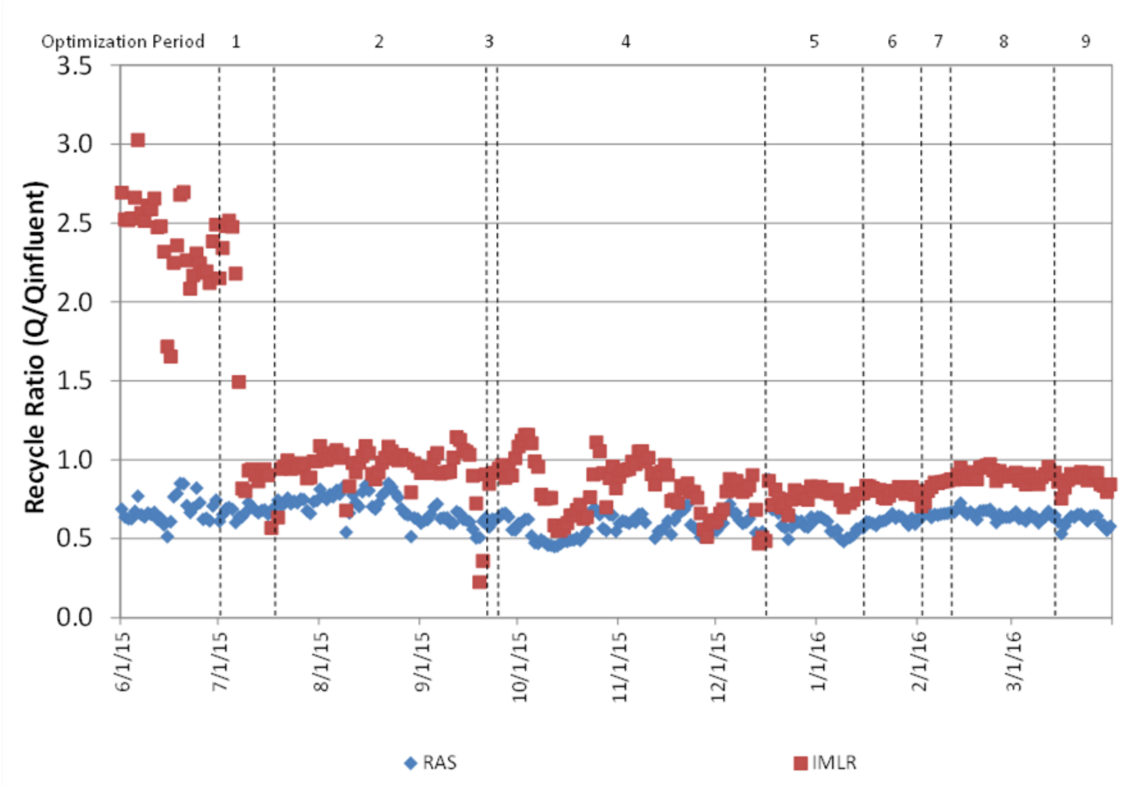
SVI during Optimization Trial
Figure 3-12



Secondary Clarifier Solids Loading Rate during Optimization Trial
Figure 3-13

RAS is critical in activated sludge since it returns the biomass to the aeration basin which maintains treatment performance. Brown and Caldwell typically recommends setting the RAS flow to the minimum flow that maintains a negligible sludge blanket in the secondary clarifiers. In BNR facilities with anaerobic selectors another consideration is how much DO and NO3-N is being returned with the RAS. Both DO and NO3-N impede EBPR performance by supplying oxygen to non-phosphate accumulating organisms allowing them to consume readily biodegradable carbon in the anaerobic zone leaving less carbon for the phosphate accumulating organisms (PAOs). For BNR systems with anaerobic selectors, the RAS flow is typically 35% to 65% of the influent flow rate. Figure 3-14 shows the RAS flow rate during the optimization trial, and the average rate for the first period was 0.67.

The IMLR return flow is critical in nitrogen removal plants because it recycles NO3-N produced by the oxidation of NH3-N back to the anoxic zone for denitrification. Typical recycle rates for the A2O configuration can range from 1 up to 4 times the plant influent flow and depending on the desired nitrogen removal and available carbon. Figure 3-14 shows that IMLR for the optimization trial and for the first period the IMLR ratio averaged 1.5, though the IMLR flow was dropping over the period.



RAS and IMLR Recycle Ratios (Q/Qinfluent) during Optimization Trial
Figure 3-14

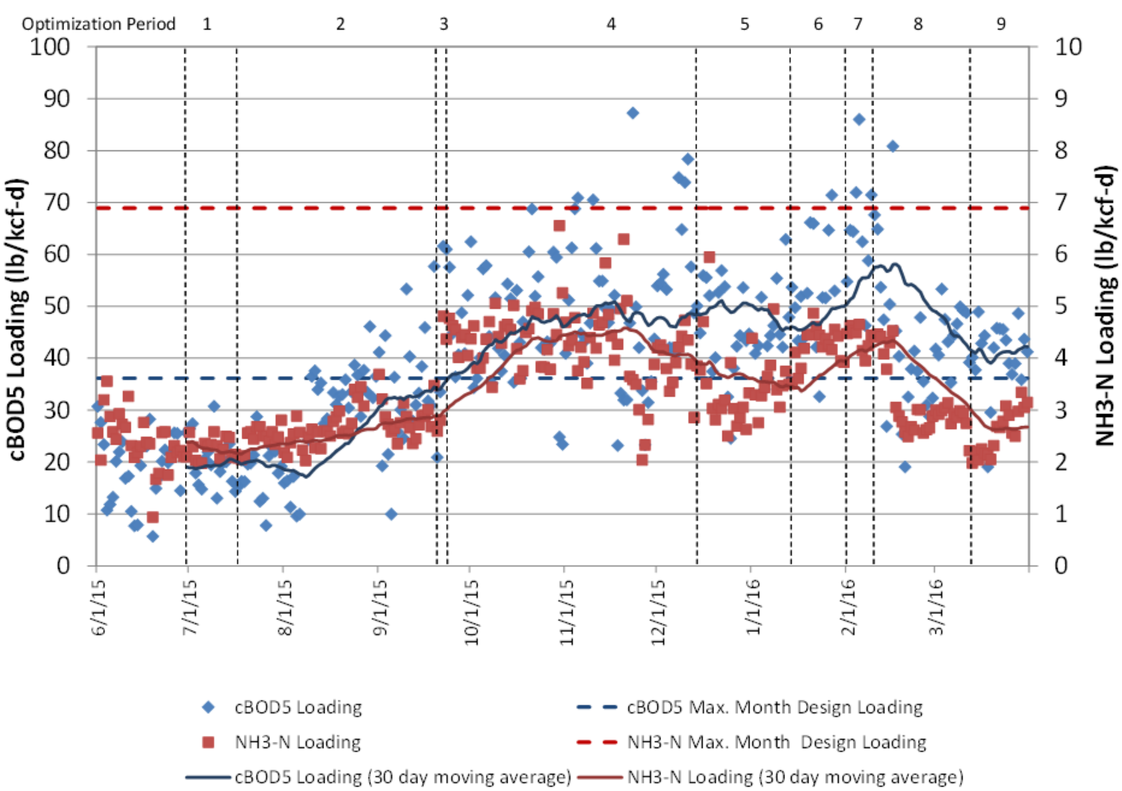
Another way to look at the treatment capacity is the influent loadings to the SWWTP on a total volume basis. Under maximum month loading conditions the aeration basins were designed to handle 23 lb cBOD5 and 5 lb NH3-N per thousand cubic feet (kcf) of aerated volume at 12 °C (Technical Memorandum Number 3 – Secondary Treatment Alternative Assessment, Brown and Caldwell, April 6, 2011). Figure 3-15 illustrates the cBOD5 and NH3-N loading rates on the aeration basins in service. For the first period the average loading rates were 20 and 2.3 lb/kcf-d for cBOD5 and NH3-N, respectively. Compared to the design loadings the cBOD5 loading is high, though the wastewater temperature averaged 19.5 °C, see Figure 3-6.

One method to evaluate the stability of an EBPR system is to measure the relative amount of PO4-P released in the anaerobic selector and the phosphorus content of the biomass. During the EBPR process, the PAOs release PO4-P into solution in the anaerobic selector, only to uptake more PO4-P in the aerobic zones (than released in the anaerobic selector) resulting in luxury uptake of PO4-P. In stable EBPR systems, the amount of PO4-P released (as measured by the selector PO4-P concentration) is typically two times greater the aeration basin influent PO4-P concentration. Figure 3-16 displays the ratio of the aeration basin influent PO4-P:anaerobic selector effluent PO4-P. During the first period of the optimization trial the PO4-P release ratio was consistently less than 2 suggesting non-stable EBPR operations. Another indicator of EBPR activity is the MLSS TP to mixed liquor volatile solids (MLVSS) ratio. At ratios greater 0.035 EBPR is considered active. During the first period of the optimization trial the MLSS TP:MLVSS ratio was 0.035 on a median basis (assuming a MLVSS:MLSS factor of 0.79 based on the median value observed documented in Technical Memorandum Number 2 – South Plant

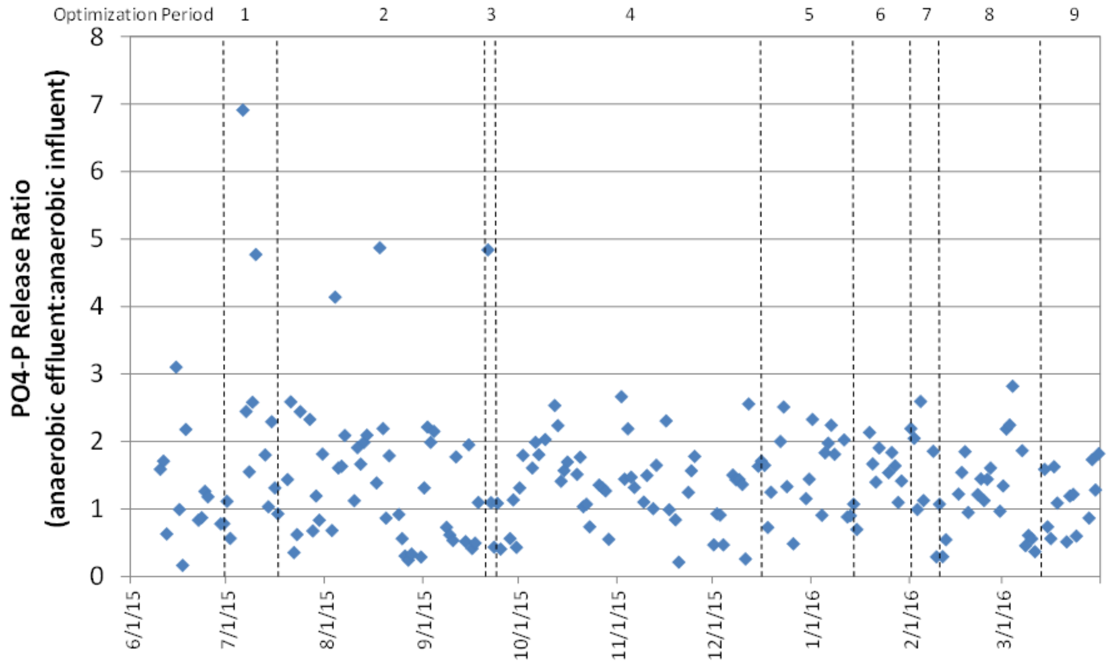
Wastewater Characterization and Biowin Calibration, Brown and Caldwell, April 6, 2011). As with the PO4-P release, the MLSS TP:MLVSS was at the lower threshold for indicating EBPR activity further suggesting that EBPR was not stable.

Nitrogen removal will predominantly occur via the denitrification of RAS in the anaerobic selector and denitrification of IMLR flow in the anoxic zone. The anoxic zone is generally operating efficiently when the anoxic zone effluent contains 0.5 to 1.5 mg/L NO3-N. Anoxic zone effluent NO3-N less than 0.5 mg/L suggests the IMLR return could be increased to improve TN removal, while NO3-N values greater than 1.5 mg/L suggest insufficient carbon or excessive IMLR which could be impeding denitrification as a result of returning excess DO to the anoxic zone. Figure 3-17 shows the anoxic effluent NO3-N during the optimization period. During this first period of the optimization trial the anoxic effluent NO3-N averaged 1.1 mg/L.

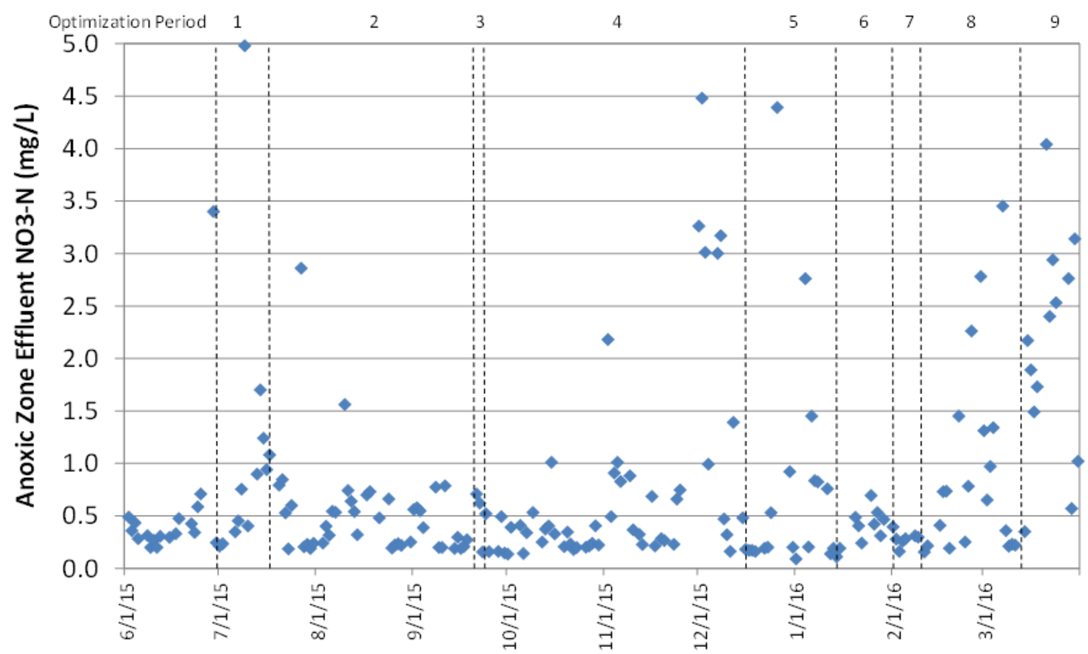
The BAR system was operating during this period of the optimization trial with one tank in service. The BAR system is a dedicated system for nitrifying the NH3-N in the recycle stream using a fraction of the RAS flow and subsequently returning the nitrified flow to the mainstream process to bio-augment the nitrifying bacteria and provide process stability at reduced SRTs. Nitrogen and alkalinity mass balances around the BAR tank suggest roughly 100 lbN/d was denitrifed in the BAR reactors when in service. This equate to denitrifying roughly1 mgN/L in the mainstream flow at 10 mgd.



Aeration Basin Loading during Optimization Trial
Figure 3-15



Anaerobic Selector P-Release Ratio during Optimization Trial
Figure 3-16



Anoxic Zone Effluent NO3-N Concentration during Optimization Trial
Figure 3-17

Period 2: July 17 – September 20, 2015 (66 days)

The second period of the optimization trial from July 17 through September 20, 2015 is distinguishable because the BAR system was taken out of service and the high strength filtrate was re-routed to the aeration basin influent (Cell 1). In addition, the IMLR was reduced to roughly 90% of the influent flow and the aSRT decreased by roughly 1 day. The BAR system was taken out of service and the filtrate was re-routed to the aeration basin influent in (1) an effort to direct any readily biodegradable carbon in the filtrate to the anaerobic selector to improve EBPR performance and (2) warm influent wastewater temperatures to greater than 20 °C allowing complete nitrification at lower SRTs without BAR.

These changes in operation did improve EBPR (and TN) removal performance as discussed further below. Interestingly, the anaerobic selector PO4-P release ratio did not improve and averaged 1.5 during this period as shown in Figure 3-16. Over this period the SVI increased from approximately 90 to 120 mL/g and the average MLSS increased slightly from 1,880 mg/L to 1,920 mg/L which is counterintuitive as the reduction in aSRT should theoretically result in a reduced MLSS. The steady/ increased MLSS is likely due to the increased aeration basin $cBOD_5$ loading (average 28 lb/kcf-d per Figure 3-15 compared to 20 lb/kcf-d on average in previous period). The NH3-N loading nominally increased to 2.7 lb/kcf-d on average.

The RAS and IMLR recycle ratios were quite stable as shown in Figure 3-12, with reported average recycle ratios of 0.70 and 0.94 respectively. The SLR was also fairly stable at 15 lb/sf-d on average per Figure 3-13.

The anoxic zone appeared to perform better as indicated by the drop in outlet NO3-N to 0.52 mg/L during this period. This is likely due to the higher $cBOD_5$ loadings and decrease in IMLR flow from the previous period.

Period 3: September 21 – September 23, 2015 (3 days)

One of the three aeration basins (trains) was taken out of service by plant staff to increase the loading to the secondary system on an aeration basin volume basis. Given this period lasted only three days before the next configuration change no data interpretation is provided.

Period 4: September 24 – December 14, 2015 (82 days)

Due to concerns with high effluent NH3-N after 3 days of operation (Period 3), one BAR tank was brought into service to increase the nitrification capacity with the nitrified BAR effluent routed to Cell 1.

Figure 3-10 shows the aSRT was decreased to approximately 4.5 days during this period to reduce the secondary clarifier SLR. In relation the MLSS increased to 2,100 mg/L on average as shown in Figure 3-11. The removal of an aeration basin from service in Period 3 did have the expected impact of increasing the loading on the system with an average $cBOD_5$ and NH3-N load of 48 lb/kcf-d and 4.3 lb/kcf-d, respectively as shown in Figure 3-15. The aeration basin loadings were up 71% and 59%, respectively for $cBOD_5$ and NH3-N from the Period 2. Along the same lines the SLR increased as well on average to 22 lb/sf-d per Figure 3-13, but was still well within the design limits. The SVI declined in the initial two months, down to roughly 95 mL/g, before starting to rise again by the end and reaching almost 105 mL/g (Figure 3-12). Overall the SVI averaged 103 mL/g for this period.

Period 5: December 14, 2015 – January 14, 2016 (31 days)

BAR effluent was re- routed to Cell 5 to avoid NO3-N returns to the anaerobic selector during this period. SVI continued to rise reaching 150 mL/g (Figure 3-12). The SLR did drop slightly, averaging 18 lb/sf-d per Figure 3-13. MLSS and aSRT were nearly the same as the previous period while aeration basin loadings dropped slightly per Figure 3-15 to 46 lb/kcf-d for $cBOD_5$ and 3.5 lb/kcf-d for NH3-N.

Period 6: January 15 – February 1, 2016 (18 days)

The configuration changes this period were addition of Cell 8 into a fully aerated zone and a small increase in aSRT in efforts to improve nitrification. While most operational parameters again remained relatively constant the SVI continued to increase, peaking at 180 mL/g as shown in Figure 3-12.

Period 7: February 2 – 10, 2016 (9 days)

This period was defined by fully aerating Cell 9 in the aeration basins to improve nitrification. This may have played a role in stabilizing the SVI to an average 141 mL/g (Figure 3-12).

Period 8: February 11 – March 13, 2016 (32 days)

A third aeration basin and the second BAR tank were placed into service during this period along with increasing the aSRT to approximately 6.3 days which reduced effluent NH3-N to target levels. The MLSS decreased slightly to about 2,000 mg/L by the end of the period as shown in Figure 3-11, in part due to the additional aeration basin, but the decline was tempered by the increasing aSRT. Similarly, the aeration basin loadings displayed in Figure 3-15 dropped immediately with addition of the third aeration basin train. SVI appeared to directly respond (decrease) with addition of the third aeration basin per Figure 3-12, declining to 100 mL/g by February 16, but then increased to about 130 mL/g by the end of the period.

Period 9: March 14 – 31, 2016 (18 days)

In this final period of the optimization trial nitrification had returned to an acceptable level allowing the City to return Cell 9 to a mixing mode of operation, providing just enough air to keep the solids in suspension. Figure 3-11 shows MLSS continued declining, reaching approximately 1,800 mg/L by the end of the trial. Conversely, SVIs continued to increase reaching 160 mL/g by the end of the trial. The elevated SVI was slightly greater than design SVI although the SLR was 17 lb/sf-d indicating the secondary clarifiers are well within design capacity. The anaerobic selector continued to show a PO4-P release ratio averaging 1.1 for this period per Figure 3-16. Meanwhile the aeration basin $cBOD_5$ and NH3-N loading appear to be increasing, reaching approximately 41 lb/kcf-d and 2.6 lb/kcf-d, respectively, per Figure 3-15.

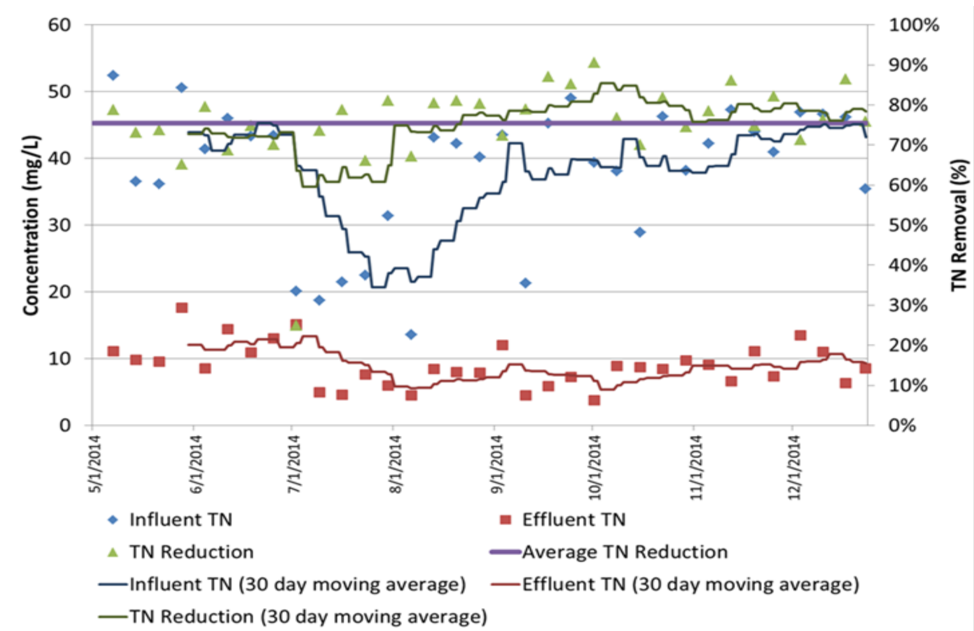
Section 4

Nutrient Removal Performance

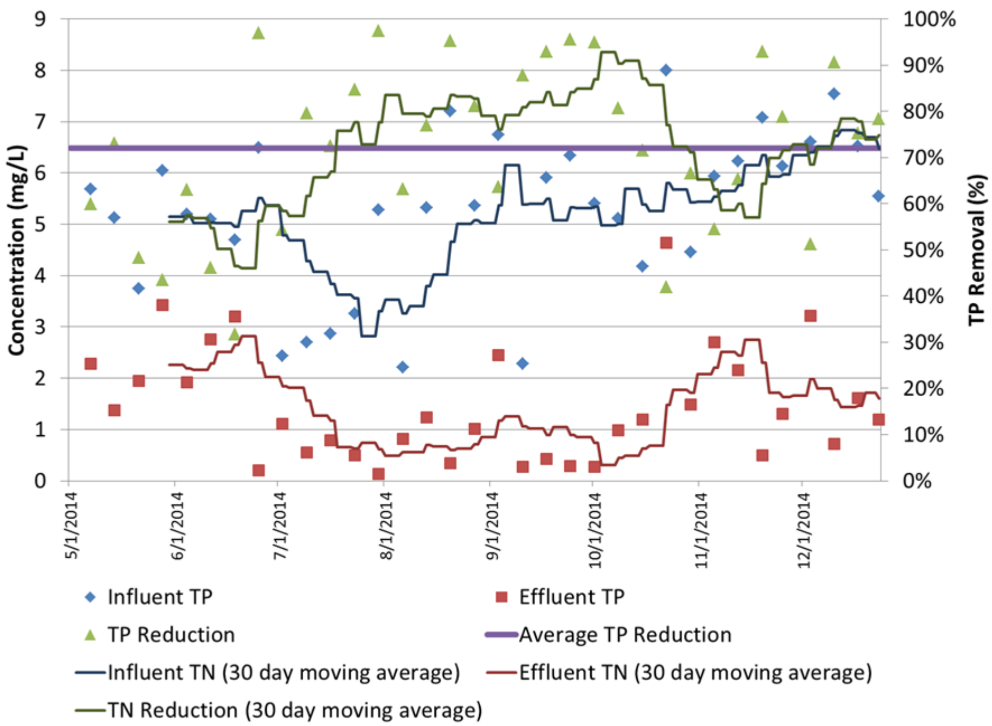
This section summarizes the TN and TP treatment performance during MLE Operations prior to the optimization trial along with the A2O optimization trial.

MLE Operation Performance (Prior to A2O Optimization Trial)

The MLE process achieved an average TN removal of 75% and an average TP removal of 72% slightly below the desired 75% TP reduction. Figures 4-1 and 4-2 summarize the TN and TP data and performance.



TN Performance during MLE Trial
Figure 4-1



TP Performance during MLE Trial
Figure 4-2

A2O Optimization Trial Nutrient Removal Performance

During the A2O optimization trial the SWWTP effluent was sampled for TN, TP, TKN, NH3-N, NO3-N, and PO4-P. As reviewed in Section 3, the SWWTP influent TN and TP concentrations are greater than typical domestic strength and set the City nutrient reduction goals to 66% reduction of TN and 75% for TP.

Table 4-1 summarizes the SWWTP effluent TN and TP values for the nine periods comprising the A2O optimization trial. When considering the entire trial the average TN removal was 74% and the TP removal was 82%, both exceeding the Strategy goals. Figures 4-3 and 4-4 show the influent and effluent TN, TP, and related reductions over the optimization trial. TN and TP removal surpassed the Strategy goals during each operating trial period. Period 7 was the poorest performing period for TN removal reporting 64% TN removal. During this relatively short operating period, the elevated effluent NH3-N concentrations seen in Figure 4-5 limited TN reduction. The reduced nitrification performance was corrected by increasing the aerobic SRT, and placing an adding additional aeration and a BAR tank into service.

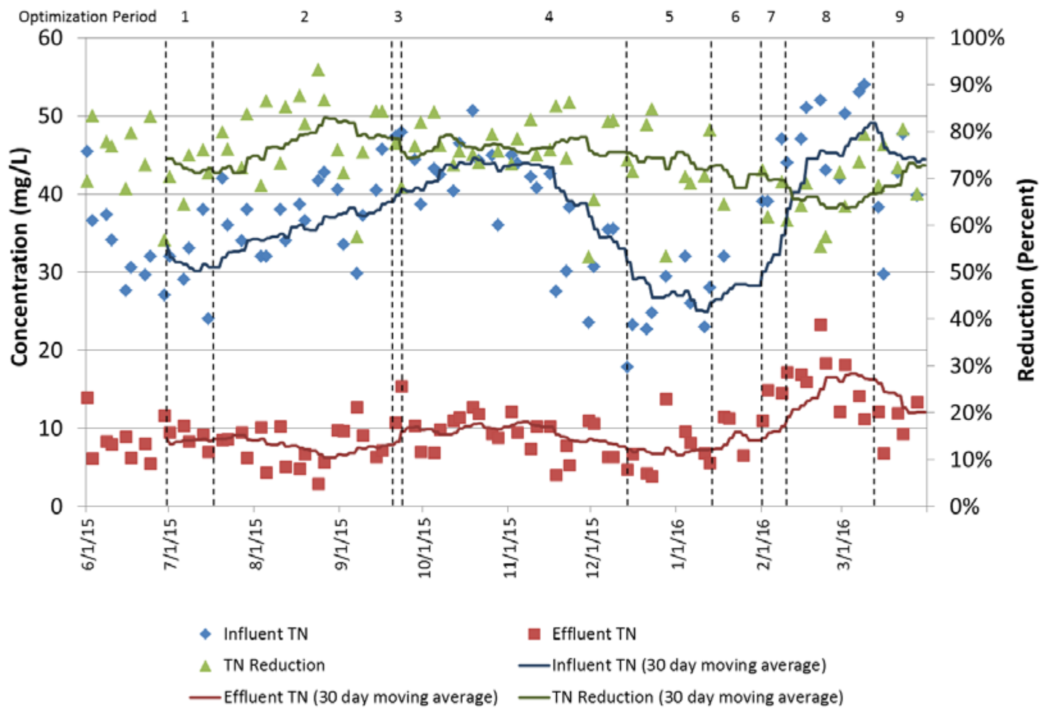
The effluent TP reduction was greater than the 75% reduction goal for all periods except for Periods 4 and 9. The effluent TSS is not elevated as seen in Figure 4-6. As such, the majority of the effluent TP must be comprised of the soluble PO4-P. When compared to the other sampling periods, the sampling location exhibiting extraordinarily high PO4-P loadings was the filtrate, 37% and 26% higher than the overall optimization trial average for Periods 4 and 8, respectively. Figure 4-7 compares the effluent TP concentration with the filtrate PO4-P load indicating that as the filtrate peaked in Periods 4 and 9 so did the effluent TP. The spikes in filtrate PO4-P could be from either

(1) increased solids destruction in the digester or (2) a reduction in ferric chloride addition to the sludge equalization tank for hydrogen sulfide control prior to feeding to digesters.

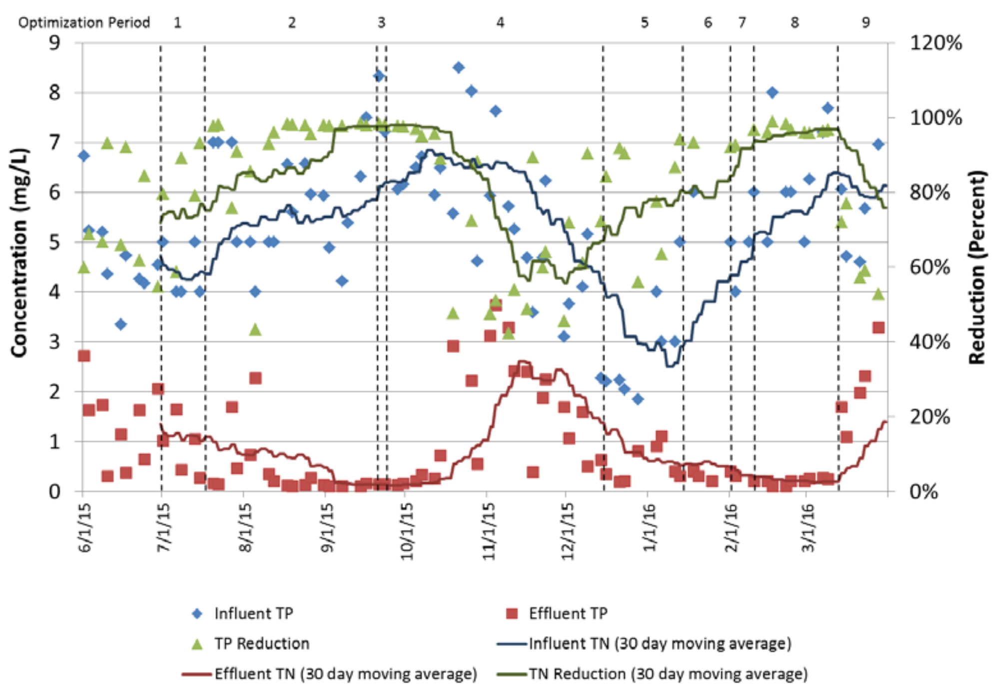
Overall the plant performed quite well despite being stressed by high $cBOD_5$ loadings to the aeration basins. The low influent flow, high influent $cBOD_5$ loadings, and warmer water temperatures, facilitated good BNR treatment performance. The current NPDES permit limits for effluent $cBOD_5$, TSS, and NH3-N were not exceeded.

Table 4-1 SWWTP A2O Optimization Trial Nutrient Removal Performance (July 2015 – March 2016)

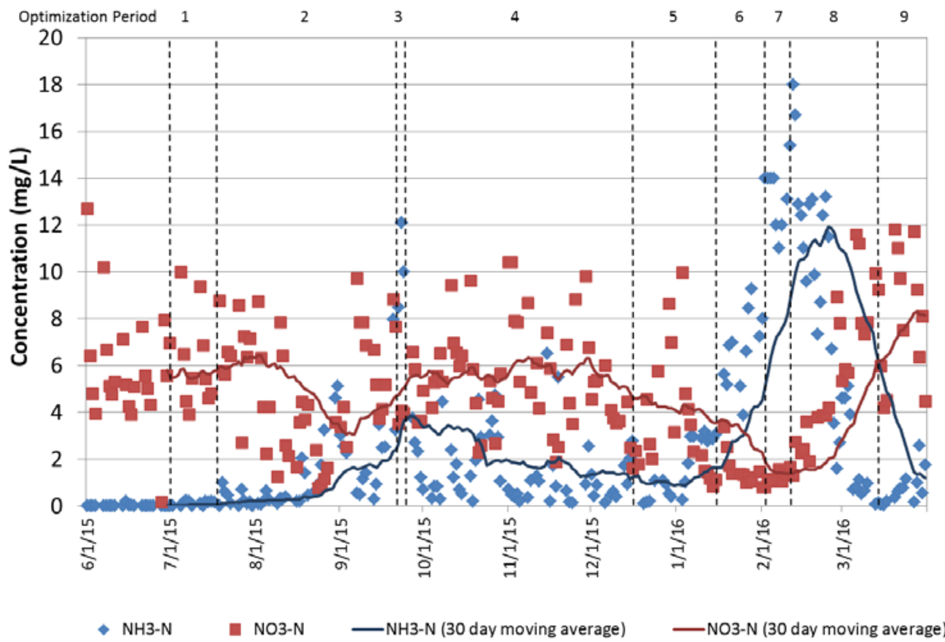
		Effluent TN			Effluent TP		
Period	Date	Average, mgN/L	Range, mgN/L	Average Removal, Percent	Average, mgP/L	Range, mgP/L	Average Removal, Percent
1	7/1/15-7/16/15	8.8	6.9 - 10.3	71%	0.9	0.3 - 1.7	80%
2	7/17/15-9/20/15	7.6	2.9 - 12.7	79%	0.4	0.1 - 2.3	92%
3	9/21/15-9/23/15	--	-- - --	--	--	-- - --	--
4	9/24/15-12/14/15	8.9	4.0 - 12.6	76%	1.5	0.1 - 3.7	72%
5	12/15/15-1/14/16	7.3	3.8 - 13.7	73%	0.5	0.2 - 1.1	80%
6	1/15/16-2/1/16	10.1	6.5 - 11.4	68%	0.3	0.2 - 0.4	93%
7	2/2/16-2/10/16	15.5	14.5 - 17.2	64%	0.3	0.2 - 0.3	95%
8	2/11/16-3/13/16	16.2	11.2 - 23.2	67%	0.2	0.1 - 0.3	97%
9	3/14/16-3/31/16	10.7	6.8 - 13.3	73%	2.1	1.1 - 3.3	64%
	Overall Optimization Trial	9.7	2.9 - 23.2	74%	0.9	1.0 - 3.7	82%



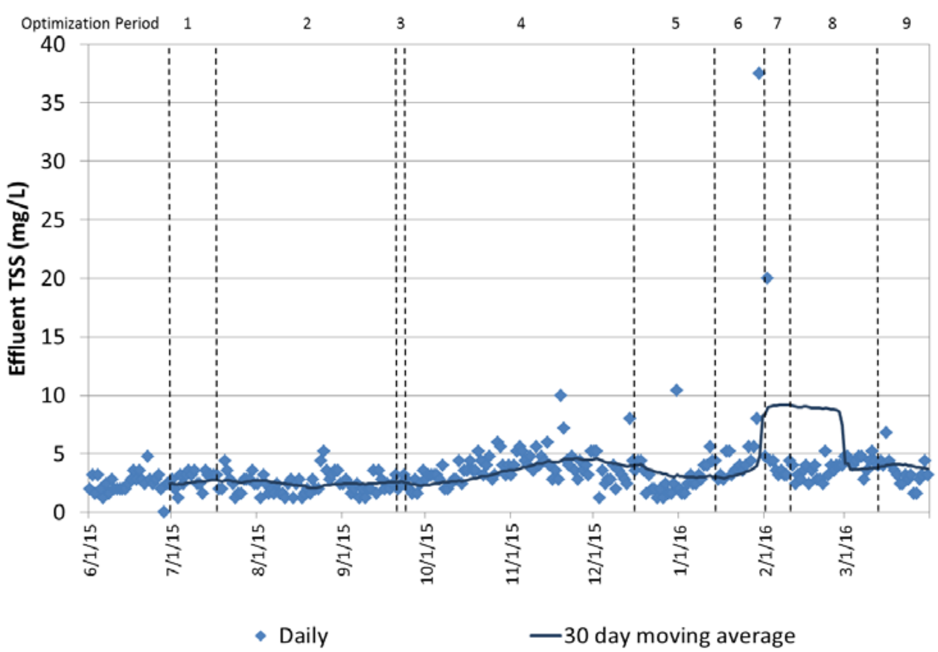
Influent, Effluent, and TN Reduction during A2O Optimization Trial
Figure 4-3



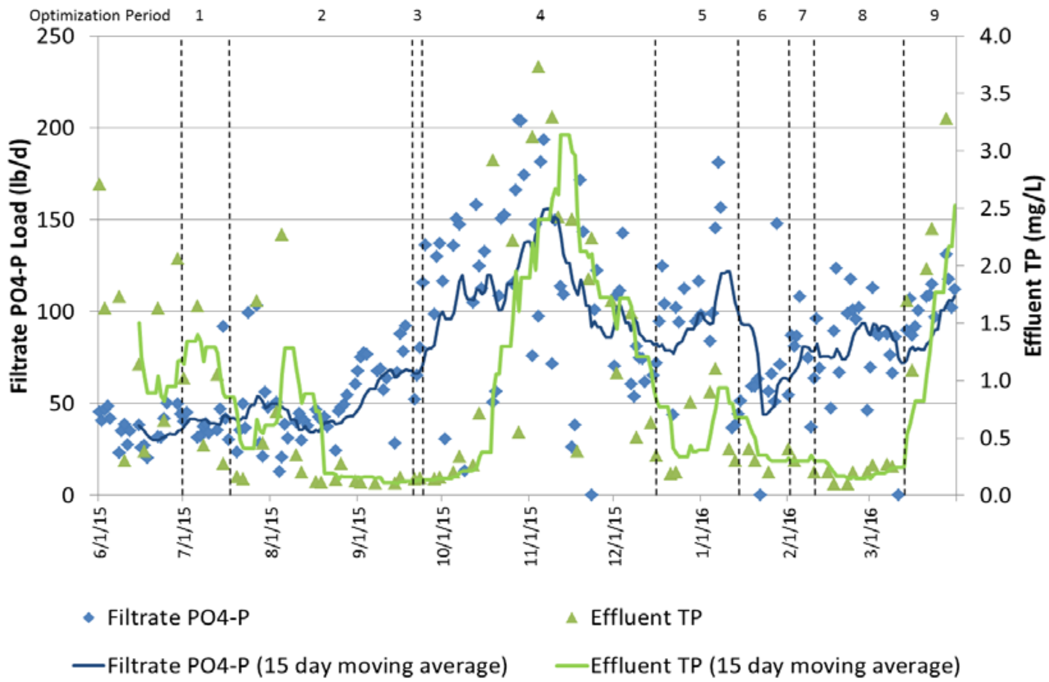
Influent, Effluent, and TP Reduction during A2O Optimization Trial
Figure 4-4



Effluent NH3-N and NO3-N during A2O Optimization Trial
Figure 4-5



Effluent TSS during A2O Optimization Trial
Figure 4-6



Effluent TSS during A2O Optimization Trial
Figure 4-7

Statistical Performance Evaluation of A2O Operations

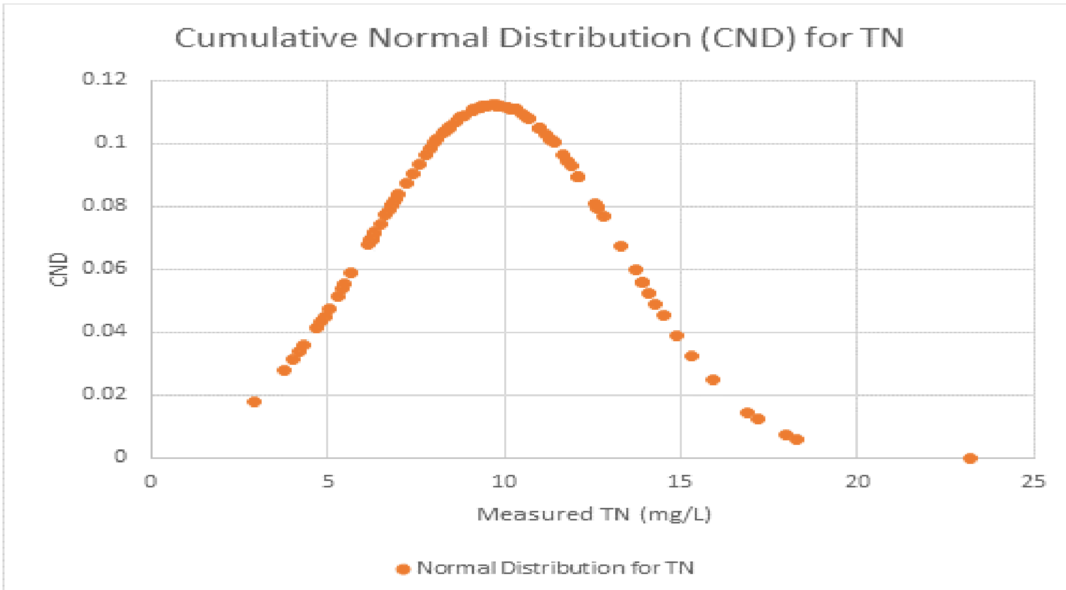
A year of sample data from April 2015 through March 2016 when the plant was operating in A2O mode was analyzed to verify logarithmic distribution of the data and estimate the annual mass limits for TN and TP. The analysis procedures are patterned after the approach developed by the EPA and being adopted by the IDNR. The data distribution was examined and the distribution favors a normal distribution over a lognormal distribution. The sample data was plotted as a cumulative normal distribution graph (Figures 4-8 and 4-9). Estimated TN and TP limits used the same natural log formulas as IDNR. The data set contains 101 data points. Table 4-2 presents the count, average, maximum, minimum, and standard deviation of the sample data set.

Table 4-2 Calculations of Annual Average Effluent Limitations

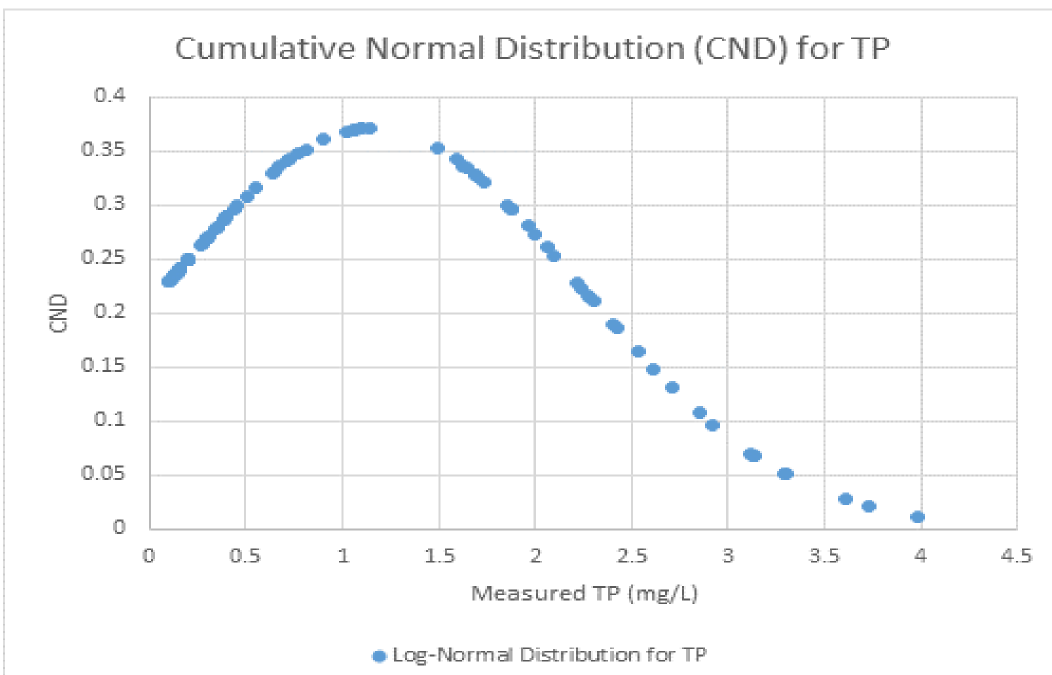
	Effluent TP [mg/L]	Effluent TN [mg/L]	ln (TP) [mg/L]	ln (TN) [mg/L]
Count	100	101	96	101
Average	1.11	9.71	-0.41	2.21
Maximum	3.98	23.20	1.38	3.14
Minimum	0.10	2.90	-2.30	1.06
Standard Deviation	1.08	3.55	1.15	0.38

Source: Stanley Consultants and Brown and Caldwell

Based on the IDNR's analytical procedures, the 99th percentile value for effluent TN and TP are 10.6 mg/L and 1.5 mg/L. The plant's design average wet weather flow is 24.2 mgd. The plant's annual mass limits for TN and TP based on A2O operation are estimated to be 2,148 lb/day and 319 lbs/day. The sample data set and associated calculations can be found in Appendix A.



Cumulative Log-Normal Distribution Plot of TN
Figure 4-8



Cumulative Log-Normal Distribution Plot of TP
Figure 4-9

Section 5

Supplemental Treatment Technologies

Treatment Technologies

The SWWTP uses a biological nutrient removal (BNR) activated sludge process (MLE) to nitrify ammonia to nitrate and partially denitrify nitrate to nitrogen gas. The plant also has the ability to run their BNR system in A2O for biological TP and TN removal. This recently updated treatment system meets current IDNR guidelines without any necessary modifications. Additional technologies may need to be implemented in the future if wastewater characteristics change from those observed during the operational trial period altering treatment performance, or if TN and TP limits become more stringent.

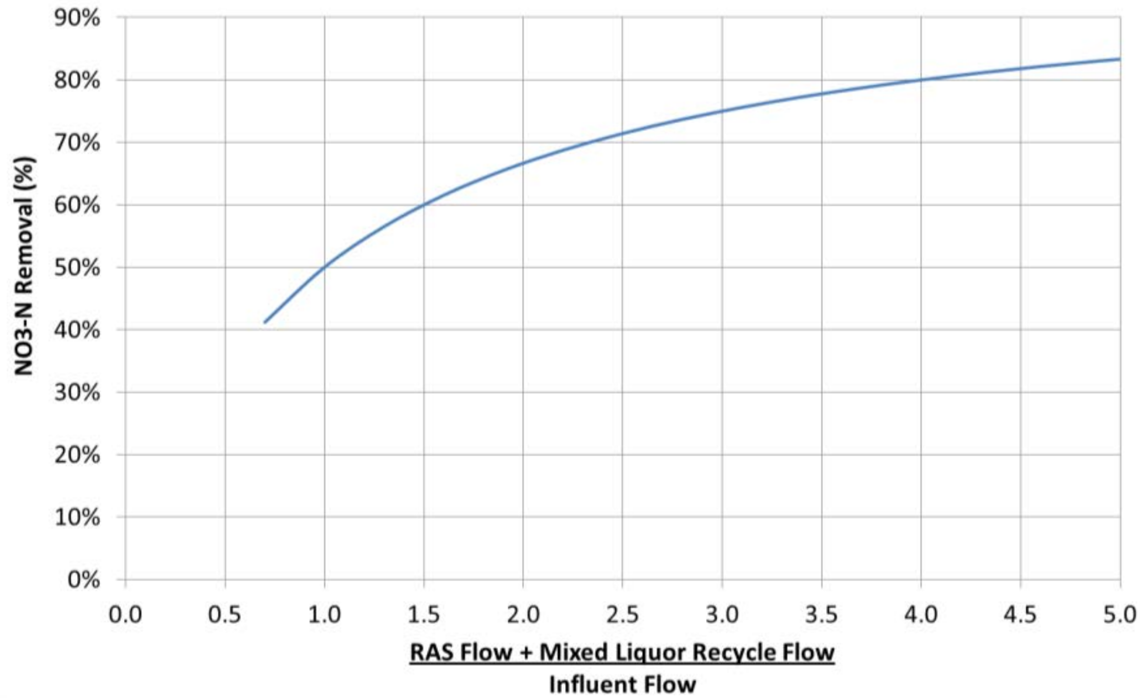
The statistical evaluation conducted in Section 4 shows the average TP and TN discharges of 1.1 mgP/L and 9.7 mgN/L are roughly 70 % and 90% of the 99% percentile value which may be used in calculating the effluent TP and TN discharges when plant is operating in A2O mode. MLE performance was slightly less for TP. This section provides several possible treatment improvements to further reduce TN and/or TP discharges.

Potential supplemental treatment technologies include:

- Increased Internal Mixed Liquor Recycle (IMLR)
- Primary Sludge Fermenter
- Ferric Chloride Addition

IMLR Pumping Expansion

During the A2O optimization trial, the total recycle flow to the anoxic zone (RAS plus IMLR) was generally 150% of the plant influent. At this total recycle flow, Figure 5-1 shows 60% of the NO3-N generated from nitrogen oxidation is theoretically reduced to nitrogen gas provided sufficient carbon and anoxic zone volume are available.



Theoretical NO3-N Reduction vs Total Recycle Flow
Figure 5-1

If the plant increased the IMLR to its rated capacity of 25 mgd and maintained the average RAS flow at 6 mgd, the total recycle flow ratio with an influent flow of 10 mgd increases to 3.1. At this total flow recycle ratio, the theoretical NO3-N removal improves to 75% which equates to an additional TN reduction of roughly 2.0 mgN/L to 2.5 mgN/L or roughly 70% of the 99th percentile value. Further increasing the total recycle flow ratio to 4.0 increases the theoretical NO3-N removal improves to 80% which would reduce effluent TN by 3 mgN/L compared to the optimization trial period estimate.

To achieve a total recycle flow ratio of approximately 4x the Year 2023 annual average design flow of 14.5 mgd (58 mgd) , the IMLR capacity would need to be increased to 50 mgd. Increasing the RAS flow rate beyond 50 to 60% of the influent flow is not recommended as the higher RAS recycle rates will return DO and NO3-N to the anaerobic selector negatively impacting EBPR performance.

The IMLR system provided in the 2012 expansion economically increased IMLR flow by taking advantage of unused internal piping originally envisioned as ability to feed RAS into cells 1, 2, 3, or 4. This original RAS feed piping is smaller diameter and limits the overall ability to increase the IMLR flow capacity. Increasing the IMLR capacity to 3 or 4 times Year 2025 or 2040 influent flows would require replacement of the existing IMLR system. The concept developed during the facility planning was to provide submersible pumps with VFDs for each train with individual return headers with valved discharges for flexibility in discharge to cells 1, 2, 3, or 4. Increasing IMLR capacity may be required if the plant approaches its rated flow and design TKN capacity or if wastewater characteristics change resulting in difficulty in meeting TN reduction requirements.

Primary Sludge Fermenter

If the amount of readily biodegradable chemical oxygen demand (COD) or volatile fatty acids (VFAs) are limiting BNR performance, one method to add readily biodegradable substrate to either the anaerobic or anoxic zone is to ferment primary sludge creating VFAs and then route the elutriated VFAs back to the main liquid stream. Running in A2O mode during the operational trial demonstrates the plant's ability to meet current IDNR TN and TP reduction guidelines and no additional technology is necessary. However, the operational trial period TN discharge concentration is 90% of the "probable" TN concentration limit and if the wastewater characteristics change resulting in poor TP or TN removal, if influent flows increase to a significant percentage of the plant's hydraulic capacity, or if nutrient limits tighten, a fermenter can be implemented to provide additional carbon/VFAs if needed. If treatment performance suggests a fermenter is needed to increase the readily biodegradable carbon to the BNR system, site sampling and testing would be required to estimate actual fermenter performance and the effects on the performance of the A2O process.

An acetic acid feed system is another alternative to add VFAs if needed for EBPR. Acetic acid is most effective when consistently fed. For this reason, acetic acid is not suggested for intermittent feeding in response to short term wastewater changes. Other readily biodegradable carbon such as methanol, ethanol, or MIrco-C could be used for TN reduction if needed.

The fermenter would be constructed north of the blower building to minimize site piping between the clarifiers and the fermenter. An alternate location north of the primary clarifiers has underground utilities that would need to be relocated to facilitate installation. Figure 5-1 presents the proposed location of the fermenter. The site north of the blower building is the closest location to the primary clarifiers without encroaching on underground site utilities. The fermenter would have a minimum diameter of 55 feet with a side water depth of 14 feet.

The primary sludge would be drawn off the main primary sludge line and redirected to the fermenter. The fermenter would provide mixing and a solids retention time of 3-6 days. VFAs would be released within the fermenter by recycling thickened primary sludge back to the thickener influent. The VFAs elutriated through the sludge recycling are then routed to the primary clarifier splitter box or to the aeration basin anoxic zone if needed for denitrification either through a supernatant stream or the fermented sludge return line. A pump vault would be constructed adjacent to the fermenter that would allow fermented sludge to either be pumped back to the primary clarifier splitter box or be fed back into the main primary sludge line to the digesters.

Ferric Chloride Addition

A Ferric Chloride ($FeCl_3$) chemical feed system would be installed at the end of the aeration basin to reduce effluent TP discharge. The plant meets current IDNR guidelines for TP removal under the both MLE and A20 processes under current loading conditions. However, if the wastewater characteristics change resulting in higher influent phosphorus, lower VFAs, or if phosphorus limits tighten, a ferric chloride chemical feed system can be implemented. The ferric feed system would consist of two 5,000 gallon bulk liquid storage tanks with containment and metering pumps located outside near the aeration basin. The metering pump system would utilize two adjustable speed positive displacement metering pumps to feed the 37 percent ferric chloride solution to the aeration basin discharge allowing flow paced chemical dosing. With an assumed iron to phosphorus mass ratio of 4:1 and with a reduction of 1 mg/L phosphorus, approximately 350 gallons per day of ferric chloride would be used at average day flow conditions. If treatment performance suggests a ferric chloride system is needed, site sampling and testing would be required to estimate actual chemical dosage required.

The chemical storage tanks and feed pumps would be constructed on the southeast side of the aeration basins. Figure 5-2 presents the proposed location of the ferric chloride feed system. Storage tanks would be approximately 8.5 feet in diameter and 12 feet high. Chemical pumps would be installed in a weatherproof enclosure. Exposed piping would be heat traced and insulated or tank heaters provided for cold weather operation.

Cost Analysis

A present worth cost analysis has been developed for both treatment technology alternatives. Construction cost estimates and annual operation and maintenance costs were developed for each alternative. The present worth values for annual operating and maintenance costs were developed using an interest rate of three percent over a period of 20 years. Table 5-1 summarize the treatment technology alternatives and the costs.

Table 5-1 Treatment Technology Present Worth Costs

Alternative	Description	20-Year Present Worth Cost
1	IMLR Capacity Increase	$2,500,000
2	Primary Sludge Fermenter	$5,000,000
3	Ferric Chloride Feed System	$3,000,000

Source: Stanley Consultants, Inc.

Present worth cost for IMLR capacity increase is estimated to be $2,500,000 with 20 year present worth of the pump power cost being a significant contributor to the overall cost.

Present worth cost to construct a fermenter with cover and odor control, pumps and piping, plus maintenance, would be approximately $5,000,000. The fermenter would be anticipated to be equipped with a cover and odor control system.

Present worth cost for the ferric chloride feed system is approximately $3,000,000. A majority of the cost is due to the purchase of ferric chloride.

Alternative Evaluation

Table 5-2 summarizes whether each supplemental treatment alternative is practical, feasible to construct, and reasonable to implement.

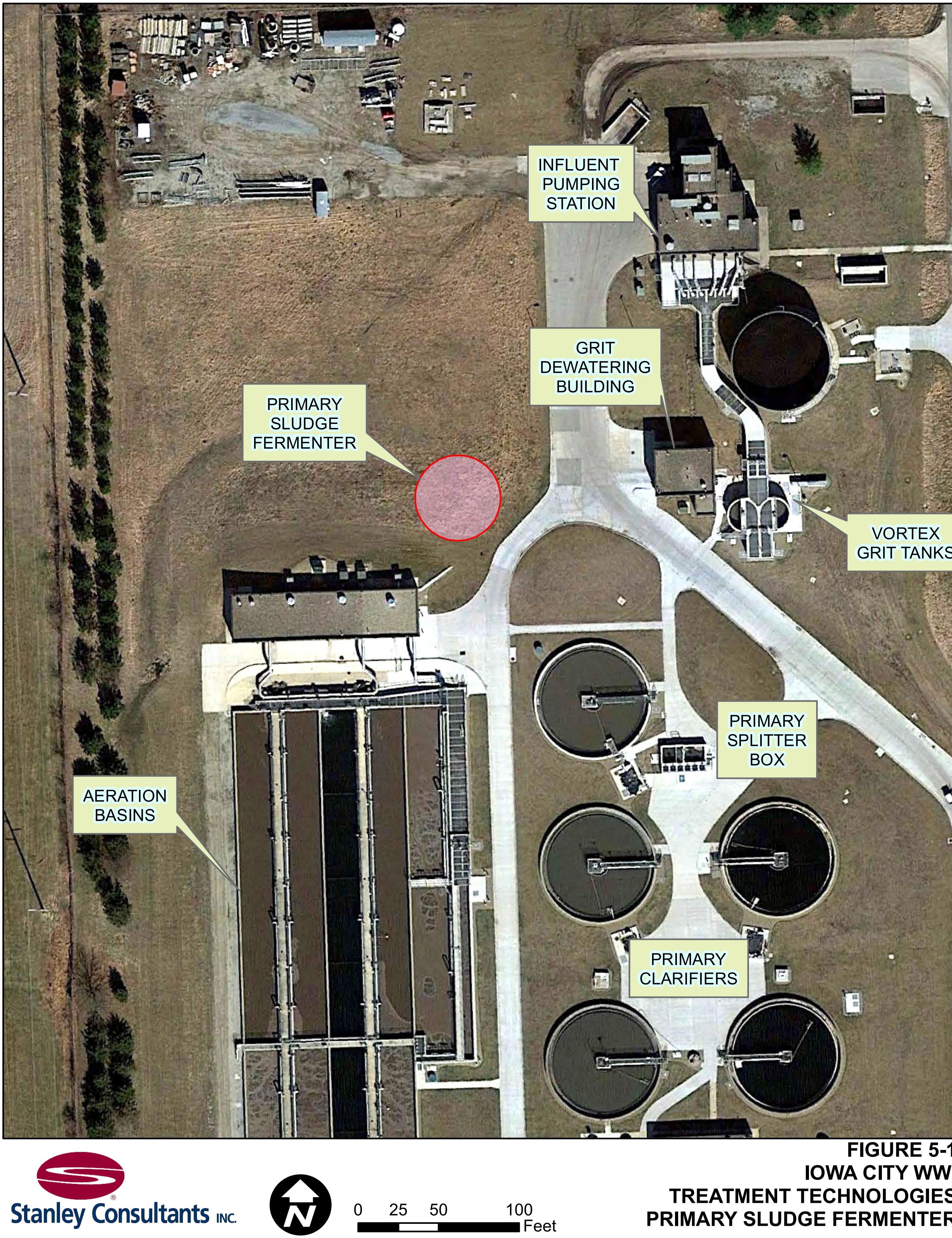
Table 5-2 Treatment Technology Evaluation

Alternative	Practical	Feasible	Reasonable
1	Yes	Yes	No
2	Yes	Yes	No
3	Yes	Yes	No

Source: Stanley Consultants, Inc.

The supplemental treatment alternatives are practical and reliable technologies that are commonly used at wastewater treatment facilities. The SWWTP can implement the technologies onsite without much modification to their treatment operations. However, the SWWTP can meet IDNR guidelines for TP and TN reduction at current loadings and wastewater characteristics and alternative treatment technologies are not currently needed.

Some the technologies will likely need to be implemented if the design loads especially TKN are realized or if wastewater characteristics significantly change. If these conditions develop and the current process configuration cannot meet the final nutrient limits added to the City's NPDES permit via permit amendment, then implementation of one or several of these supplemental technologies would be reasonable to implement.



Stanley Consultants INC.

FIGURE 5-1
IOWA CITY WW
TREATMENT TECHNOLOGIES
PRIMARY SLUDGE FERMENTER

Stanley Consultants INC.

FIGURE 5-2
IOWA CITY WW
TREATMENT TECHNOLOGIES
FERRIC CHORIDE CHEMICAL
FEED SYSTEM

Section 6

Discussion and Recommendation

Since EBPR in the A2O configuration has not performed optimally during the operational trial and a previous full-scale testing period in June and July 2010, a second operating trial operating in the MLE mode to optimize TN reduction and evaluate TP removal with and/or without increasing ferric chloride addition to the sludge storage tank upstream of the belt filter presses is recommended. This mode of operational offers much simpler plant operations and ability to meet target TN and TP reduction criteria. Data collected during the operational trial suggests treating the dewatering feed/recycle could reduce the effluent TP discharges by up to 1.0 mgP/L if all phosphate is bound in particulate form. Increasing the IMLR flow to extent existing system allows is recommended during the trial to maximize TN reduction.

A2O Optimization Trial Influent Characteristics

Influent loadings during the optimization trial period were representative of “current” loadings. Overall, the influent characteristics were more favorable for BNR than long-term historical/Facility Plan design conditions. Due primarily to higher influent $cBOD_5$ loadings, the influent $cBOD_5$:TKN and $cBOD_5$:TP ratios were greater than the Facility Plan design basis providing more organic carbon for nutrient removal. Influent maximum month and maximum day flows of 13 mgd and 19 mgd (December 14, 2015) respectively are significantly lower than the historical average wet weather flow (18 mgd) and maximum day flow (29 mgd) which also promotes better BNR treatment performance. Similarly, the minimum month influent temperature of 15 °C is three degrees warmer than the basis of design. The warmer wastewater temperature will also favor better nitrification and BNR treatment performance. Future changes can easily alter the performance of the nutrient removal systems at the SWWTP and should be considered for future permit requirements.

A2O Optimization Trial Treatment Performance

Operating in the A2O mode, the plant reduced TN and TP discharges by 74% and 82%, respectively on an average basis meeting the target nutrient removal treatment goals. Operating data suggest the EBPR system was operating in an unstable condition as the anaerobic selector PO4-P release, which is one indicator of EBPR process stability, was lower than expected. Based on a typical phosphorus content in a non-EBPR activated sludge of 2% (TP:MLVSS), the solids wasted from a conventional secondary treatment system account for a 33% reduction in TP. Assuming that TP is reduced by 25% across the primary clarifiers as observed in the SWWTP wastewater characterization in 2010 (Technical Memorandum Number 2 – South Plant Wastewater Characterization and BioWin Calibration, Brown and Caldwell, April 6, 2011), a total TP reduction of 58% is achieved under non-EBPR activated sludge operations. To achieve 82% TP reduction, the wasted solids phosphorus concentration needs to be increased to just shy of 3.5% which suggests some EBPR activity, but not a significant amount.

MLE Operations Prior to A2O Operational Trial Treatment Performance

Operating in the MLE mode from June 2014 to December 2014, the plant reduced TN and TP discharges by 75% and 72%, respectively on an average basis meeting the target nutrient removal treatment goal for TN but slightly below the target nutrient removal goal of 75% for TP.

Conclusions

The following conclusions can be derived from the operational trial data:

- Influent wastewater characteristics during the A2O trial were better than historical and the design conditions, namely the wastewater temperature is slightly warmer and the wastewater contains more carbon improving TN and TP reduction.
- A2O operating mode appear to be capable of meeting the anticipated TN and TP reductions/limits under current load and wastewater characteristics.
- MLE operating mode was very close to meeting both TN and TP removal goals falling slightly below the TP goal. Additional trialing should be performed to optimize the performance of MLE to determine whether this process can meet both nutrient reduction targets.
- EBPR in the A2O process is not performing to the levels that would normally be expected. This sub-optimal performance is consistent with facility planning full scale testing and model predictions.
- Investment in additional nutrient reduction technologies such as increasing IMLR capacity, increasing VFAs via fermenter or acetic acid feed, or addition of ferric chloride is not warranted at this time.
- Investment in additional nutrient reduction technologies will likely become necessary if wastewater characteristics change and performance declines, or as the plant approaches its rated flow and nutrient load capacity.

Recommendations

Since EBPR in the A2O configuration has not performed optimally during the operational trial and a previous full-scale testing period in June and July 2010, and data suggests the MLE mode has the potential to achieve the required reductions under current load conditions, a second operating trial while operating in the MLE mode to optimize TN and TP removal is recommended.

Increasing the IMLR flow to extent existing system allows is recommended during the trial to maximize TN reduction.

Implementation Schedule

While the plant was able to meet the nutrient performance requirements using A2O mode, MLE operation would be preferred given the unstable EBPR performance in the Operational Trial and previous 2010 full-scale testing. Thus, the City proposes to trial the MLE mode and submit a report addendum to the IDNR prior to development of nutrient standards for inclusion in a NPDES permit amendment. The SWWTP staff will change their operations to the MLE mode and perform data collection for a 12 month trial period to capture warm and cold temperature periods. Filtrate phosphorus returned to the aeration basin will be measured to assist in determining possible P sequestering or recovery from the filtrate. The data in MLE mode will be analyzed and compared to the A2O mode results giving staff a more even comparison of performance. A supplemental report containing the results of the 12 month trial can be submitted within 3 months of trial completion.

Closing

Respectfully submitted,

Stanley Consultants, Inc.

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Appendix A

Calculated Annual Average Mass Limits

	Effluent		Log Transferred		TN		TP	
Composite Date	Total Phos as P	Total Nitrogen as N	Ln(P)	Ln(N)	Cumulative Log-Normal Dist Function	Normal Probability Density Function	Cumulative Log-Normal Dist Function	Normal Probability Density Function
	mg/L	mg/L	mg/L	mg/L				
1-Apr-15	1.88	12.8	0.631271777	2.549445171	0.021924147	0.001150341	0.32816633	0.178529244
6-Apr-15	3.61	13.9	1.283707772	2.63188884	0.02316679	0.001109711	0.563971087	0.10132703
8-Apr-15	2.61	10.2	0.959350221	2.32238772	0.01878923	0.00126657	0.444235036	0.140589578
13-Apr-15	3.13	14.3	1.141033005	2.660259537	0.023607901	0.001095927	0.511375915	0.118343224
15-Apr-15	0.765	11.3	-0.267879445	2.424802726	0.020152583	0.001213371	0.100241715	0.213467281
20-Apr-15	3.98	12.6	1.381281819	2.533696814	0.021693296	0.001158199	0.599355264	0.090204189
22-Apr-15	2.85	9.3	1.047318994	2.2300144	0.017627662	0.001315614	0.476663654	0.129800277
27-Apr-15	1.49	10.5	0.39877612	2.351375257	0.01916691	0.001251386	0.254325379	0.199902901
4-May-15	3.14	10.1	1.1442228	2.312535424	0.018662315	0.001271753	0.51255741	0.117955849
6-May-15	0.674	7.57	-0.394525168	2.024193067	0.015258145	0.001428354	0.081084658	0.206978254
11-May-15	1.88	9.37	0.631271777	2.237513096	0.017719614	0.001311596	0.32816633	0.178529244
13-May-15	1.86	9.3	0.620576488	2.2300144	0.017627662	0.001315614	0.324584599	0.179644102
18-May-15	2.53	9.9	0.928219303	2.292534757	0.018406913	0.001282311	0.432836612	0.144387754
20-May-15	1.96	4.9	0.672944473	1.589235205	0.011135791	0.001680757	0.342270761	0.174086992
25-May-15	2.28	8.43	0.824175443	2.131796772	0.016460386	0.00136883	0.395196628	0.156887422
27-May-15	2.1	10.3	0.741937345	2.332143895	0.018915631	0.001261448	0.366104569	0.166425035
1-Jun-15	2.71	13.9	0.996948635	2.63188884	0.02316679	0.001109711	0.458062379	0.135983607
3-Jun-15	1.63	6.14	0.488580015	1.814824742	0.013133821	0.001547621	0.281792753	0.19242024
8-Jun-15	1.73	8.32	0.548121409	2.118662255	0.01630942	0.001376029	0.30075931	0.186895862
10-Jun-15	0.304	7.91	-1.190727578	2.068127782	0.015739592	0.0014039	0.016283543	0.124158556
15-Jun-15	1.14	8.88	0.131028262	2.183801557	0.017069923	0.001340518	0.181505504	0.214922098
17-Jun-15	0.382	6.24	-0.96233467	1.830980182	0.013288114	0.001538264	0.0271001	0.152033688
22-Jun-15	1.63	8.04	0.488580015	2.084429083	0.015921511	0.001394879	0.281792753	0.19242024
24-Jun-15	0.649	5.41	-0.432322562	1.688249093	0.011977652	0.001621771	0.075940133	0.204530942
29-Jun-15	2.06	11.66	0.722705983	2.456164181	0.020586491	0.001197332	0.359404207	0.168595799
1-Jul-15	1.02	9.49	0.019802627	2.250238613	0.017876596	0.001304792	0.155540438	0.217497108
6-Jul-15	1.65	10.3	0.500775288	2.332143895	0.018915631	0.001261448	0.285630196	0.191323245
8-Jul-15	0.436	8.28	-0.830113036	2.113842968	0.016254326	0.001378675	0.035739943	0.167467446
13-Jul-15	1.05	9.14	0.048790164	2.212660385	0.01741642	0.001324937	0.162058946	0.21704615
15-Jul-15	0.277	6.93	-1.283737773	1.935859813	0.014328346	0.001478135	0.013081814	0.112863631
20-Jul-15	0.16	8.47	-1.832581464	2.136530509	0.016515088	0.001366241	0.003132514	0.055223343
22-Jul-15	0.14	8.61	-1.966112856	2.152924318	0.016705733	0.001357292	0.002134215	0.044619493
27-Jul-15	1.69	9.44	0.524728529	2.24495598	0.017811286	0.001307614	0.293239035	0.189116108
29-Jul-15	0.455	6.22	-0.78745786	1.827769907	0.01325733	0.001540121	0.038967489	0.172218245
3-Aug-15	0.727	10.1	-0.318828801	2.312535424	0.018662315	0.001271753	0.092171549	0.211183718
5-Aug-15	2.27	4.33	0.819779831	1.465567542	0.010156942	0.001755537	0.393625161	0.157406325
10-Aug-15	0.35	10.2	-1.049822124	2.32238772	0.01878923	0.00126657	0.022401599	0.141434232
12-Aug-15	0.2	5.04	-1.609437912	1.617406082	0.01136991	0.001663891	0.005763435	0.076199364
17-Aug-15	0.118	4.82	-2.137070655	1.572773928	0.011000936	0.001690642	0.001278942	0.03320629
19-Aug-15	0.111	6.73	-2.198225078	1.906575144	0.014031061	0.001494815	0.001058837	0.029693703
24-Aug-15	0.138	2.9	-1.980501594	1.064710737	0.007481263	0.002004816	0.00204603	0.043566024
26-Aug-15	0.276	5.68	-1.287354413	1.736951233	0.01241162	0.001593068	0.012969168	0.112428872
31-Aug-15	0.126	9.76	-2.071473372	2.2782924	0.018226862	0.001289858	0.001560929	0.037303206
2-Sep-15	0.111	9.68	-2.198225078	2.270061901	0.018123499	0.00129423	0.001058837	0.029693703
7-Sep-15	0.102	12.66	-2.282782466	2.538447417	0.021762716	0.001155826	0.00081146	0.025305695
9-Sep-15	0	9.11		2.209372711	0.017376646	0.001326707		
14-Sep-15	0.102	6.35	-2.282782466	1.848454813	0.013456766	0.00152817	0.00081146	0.025305695
16-Sep-15	0.156	7.21	-1.857899272	1.975468951	0.014739061	0.001455713	0.002915871	0.05309813
21-Sep-15	0.144	10.7	-1.937941979	2.370243741	0.0194162	0.001241555	0.002316916	0.046732172
23-Sep-15	0.151	15.3	-1.890475442	2.727852828	0.024687383	0.0010635	0.00265702	0.050442455
28-Sep-15	0.139	10.3	-1.973281346	2.332143895	0.018915631	0.001261448	0.00208986	0.044092491
30-Sep-15	0.157	7.01	-1.851509474	1.947337701	0.014446336	0.001471621	0.002969234	0.053629454
5-Oct-15	0.202	6.86	-1.599487582	1.925707442	0.014224675	0.001483908	0.005916859	0.077223946
7-Oct-15	0.338	9.8	-1.084709383	2.282382386	0.018278413	0.001287688	0.020729847	0.137163699

12-Oct-15	0.263	11	-1.335601247	2.397895273	0.019786505	0.001227226	0.011544804	0.10667155
14-Oct-15	0.714	11.34	-0.336872317	2.428336298	0.020201082	0.001211558	0.089432036	0.210267922
19-Oct-15	2.92	12.64	1.071583616	2.536866389	0.021739592	0.001156615	0.485645047	0.126823643
21-Oct-15		11.8		2.468099531	0.020753692	0.00119126		
26-Oct-15	2.22	9.29	0.797507196	2.228938553	0.017614503	0.001316191	0.385689614	0.160021106
28-Oct-15	0.547	8.77	-0.603306477	2.171336806	0.016922095	0.001347276	0.055721219	0.190854653
2-Nov-15	3.12	12.1	1.137833002	2.493205453	0.021109152	0.001178544	0.51019054	0.118732069
4-Nov-15	3.73	9.46	1.316408234	2.247072383	0.017837427	0.001306483	0.575901567	0.097543632
9-Nov-15	3.29	7.39	1.190887565	2.000127735	0.014999834	0.001441836	0.529823976	0.112318841
11-Nov-15	2.42	10.2	0.88376754	2.32238772	0.01878923	0.00126657	0.416659502	0.149772473
16-Nov-15	2.4	10.2	0.875468737	2.32238772	0.01878923	0.00126657	0.413654075	0.150771306
18-Nov-15	0.386	4.04	-0.95191791	1.396244692	0.009641766	0.001797949	0.027710733	0.153280064
22-Nov-15	1.88	7.75	0.631271777	2.047692843	0.015514064	0.001415248	0.32816633	0.178529244
23-Nov-15	2.24	5.28	0.806475866	1.663926098	0.01176589	0.001636184	0.388879528	0.158971194
30-Nov-15	1.69	11	0.524728529	2.397895273	0.019786505	0.001227226	0.293239035	0.189116108
2-Dec-15	1.06	10.62	0.058268908	2.362739016	0.01931672	0.00124546	0.164228513	0.216864778
7-Dec-15	1.59	6.34	0.463734016	1.846878768	0.013441479	0.00152908	0.274052318	0.194597424
9-Dec-15	0.503	6.26	-0.687165109	1.834180185	0.01331886	0.001536413	0.047495626	0.182792276
14-Dec-15	0.634	4.68	-0.455706325	1.54329811	0.010763011	0.001708397	0.072884203	0.202906129
16-Dec-15	0.348	6.65	-1.055552799	1.894616855	0.013911203	0.00150165	0.02211943	0.140733868
21-Dec-15	0	4.21		1.437462648	0.009945254	0.001772691		
23-Dec-15	0	3.8		1.335001067	0.00920578	0.001835689		
28-Dec-15	0.808	13.7	-0.21319322	2.617395833	0.022944142	0.001116791	0.10946484	0.215408325
4-Jan-16	0.9	9.5	-0.105360516	2.251291799	0.017889641	0.001304229	0.129403206	0.217636021
6-Jan-16	1.1	8.1	0.09531018	2.091864062	0.01600508	0.001390774	0.17288648	0.215996836
11-Jan-16	0.4	6.8	-0.916290732	1.916922612	0.014135491	0.001488911	0.029886497	0.157509134
13-Jan-16	0.3	5.5	-1.203972804	1.704748092	0.012123172	0.001612024	0.015790141	0.122539401
18-Jan-16	0.4	11.4	-0.916290732	2.433613355	0.020273694	0.001208853	0.029886497	0.157509134
20-Jan-16	0.3	11.3	-1.203972804	2.424802726	0.020152583	0.001213371	0.015790141	0.122539401
25-Jan-16	0.2	6.5	-1.609437912	1.871802177	0.013684979	0.001514731	0.005763435	0.076199364
1-Feb-16	0.4	11	-0.916290732	2.397895273	0.019786505	0.001227226	0.029886497	0.157509134
3-Feb-16	0.3	14.9	-1.203972804	2.701361213	0.02425947	0.001076139	0.015790141	0.122539401
8-Feb-16	0	14.5		2.674148649	0.023826414	0.001089216		
10-Feb-16	0.2	17.2	-1.609437912	2.844909384	0.026654709	0.001008733	0.005763435	0.076199364
15-Feb-16	0.2	16.9	-1.609437912	2.827313622	0.026350876	0.001016852	0.005763435	0.076199364
17-Feb-16	0.1	15.9	-2.302585093	2.766319109	0.025319981	0.001045307	0.000761802	0.024353837
22-Feb-16	0.1	23.2	-2.302585093	3.144152279	0.032285939	0.000876873	0.000761802	0.024353837
24-Feb-16	0.2	18.3	-1.609437912	2.90690106	0.027748553	0.00098045	0.005763435	0.076199364
29-Feb-16	0.2	12.1	-1.609437912	2.493205453	0.021109152	0.001178544	0.005763435	0.076199364
2-Mar-16	0.3	18	-1.203972804	2.890371758	0.027453298	0.000987942	0.015790141	0.122539401
7-Mar-16	0.3	14.1	-1.203972804	2.646174797	0.023388035	0.001102757	0.015790141	0.122539401
9-Mar-16	0.2	11.2	-1.609437912	2.415913778	0.020031018	0.001217938	0.005763435	0.076199364
14-Mar-16	1.7	12.1	0.530628251	2.493205453	0.021109152	0.001178544	0.295127427	0.188562078
16-Mar-16	1.1	6.8	0.09531018	1.916922612	0.014135491	0.001488911	0.17288648	0.215996836
21-Mar-16	2	11.9	0.693147181	2.4765384	0.020872603	0.001186977	0.349190074	0.171880649
23-Mar-16	2.3	9.3	0.832909123	2.2300144	0.017627662	0.001315614	0.398324031	0.15585377
28-Mar-16	3.3	13.3	1.193922468	2.587764035	0.022494532	0.00113135	0.530945342	0.111954417

	Effluent TP [mg/L]	Effluent TN [mg/L]	Ln (TP) [mg/L]	LN (TN) [mg/L]
Count	100	101	96	101
Average	1.11	9.71	-0.41	2.21
Maximum	3.98	23.20	1.38	3.14
Minimum	0.00	2.90	-2.30	1.06
Standard Deviation	1.08	3.55	1.15	0.38
CV	0.969602	0.36591794	-2.799062962	0.172334206

Total Nitrogen

n>10 samples

Assuming the original data are normal distribution

n=	101	Sampling frequency		
μy=	2.20539313			
σy^2=	0.14444916			
E(X)=	9.75341727			
V(X)=	14.7833502			
E(Xn)=	9.75341727			
V(Xn)=	0.1463698			
AML=	X.95			
MDL=	X.99			
Z.95=	1.645			
Z.99=	2.326			
X.99=	10.6433055	mg/l	17.97992	mg/L (value if normally dist)
Design AWW =	24.2	mgd		

Annual mass loading **2148** **lb/day**

Equation	Description
	Average Ln(TN) within Dataset
	Std Dev Ln(TN) within Dataset
E(X) = exp(μy + 0.5σy^2)	
V(X) = exp(2*μy + σy^2)*[exp(σy^2)-1]	
E(Xn) = E(X)	
V(Xn) = V(x)/n	
	AML/X.95 is the 95th percentile concentration of daily values
	MDL/X.99 is the 99th percentile concentration of daily values
	conversion factor for AML/X.95 equation
	conversion factor for MDL/X.99 equation
X.99 = E(Xn) + 2.326*$[V(Xn)]^{1/2}$	

Total Phosphorus

n>10 samples

Assuming the original data are normal distribution

n=	101	Sampling frequency		
μy=	-0.41083042			
σy^2=	1.14994021			
E(X)=	1.17837891			
V(X)=	2.9965545			
E(Xn)=	1.17837891			
V(Xn)=	0.02966886			
AML=	X.95			
MDL=	X.99			
Z.95=	1.645			
Z.99=	2.326			
X.99=	1.57902426	mg/l	3.614452	mg/L (value if normally dist)
Design AWW =	24.2	mgd		

Annual mass loading **319** **lb/day**