Selection 2020: Village of Wellington Votes for an Anaerobic Selector to Achieve Sludge Volume Index and Phosphorous Control

Shannon LaRocque, Bryan Gayoso, Alonso Griborio, Paul Pitt, and Eric Stanley

The Village of Wellington (village) Water Reclamation Facility (WRF) is an oxidation ditch aeration-type activated sludge wastewater treatment plant. The WRF is permitted to operate with a capacity of 6.5 mil gal per day (mgd) on a three-month average daily flow (TMADF) basis. Two important goals were identified in the recently completed WRF master plan and reuse master plan:

- Improvement of sludge settleability
- Reduction of effluent total phosphorous (TP)

As part of the WRF master plan, it was determined that improvement of the sludge volume index (SVI), a measure of the settleability of solids in secondary clarifiers, is a critical goal to support operation of the WRF within allowable permit constraints as it approaches a rated flow of 6.5-mgd TMADF. Simultaneously, as part of the ongoing reuse master plan, in-plant reduction of phosphorous from the WRF effluent was recommended to be reduced.

Installation of an anaerobic selector tank was identified as the preferred method to improve SVI, and as Phase 1 of a two-phased approach to reduce effluent TP. The return activated sludge (RAS) chlorination was also recommended to provide operators an additional low-cost tool to control occasional sludge-bulking episodes. It was determined that modifying the aerobic digestion process to operate at lower dissolved oxygen (DO) levels and maintain higher pH is anticipated to reduce effluent phosphorous levels. Under future Phase 2, variable frequency drives (VFDs) will be installed on the digester blowers and operational control will be modified to reduce DO or allow for cyclical aeration.

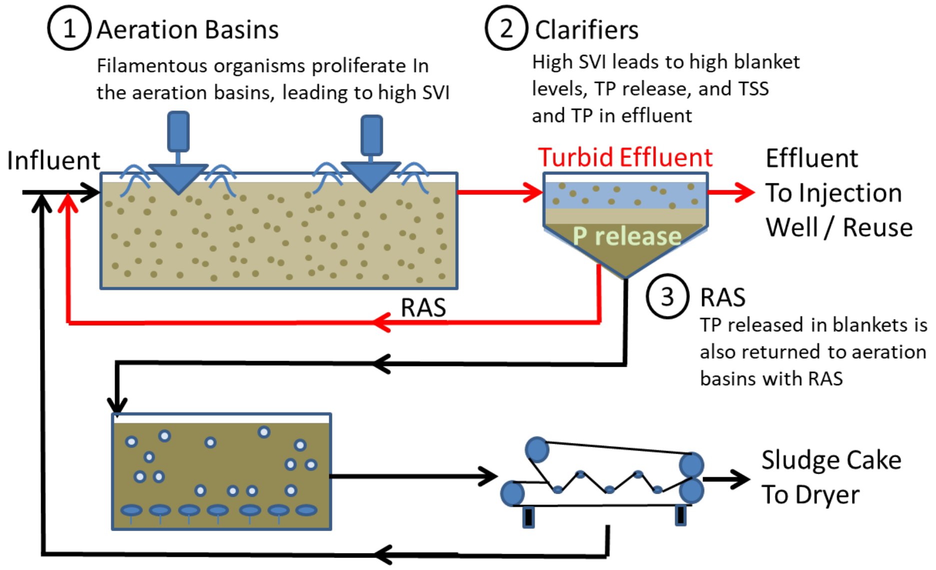


Figure 1. Slow Sludge Settleability Effects on Treatment Performance

Shannon LaRocque is utilities director and Bryan Gayoso is water reclamation facilities superintendent with Village of Wellington (Fla.) Utilities Department. Paul Pitt is wastewater process design director, Alonso Griborio is senior associate, and Eric Stanley is an associate with Hazen and Sawyer in Boca Raton.

Phases of Operation

Phase 1: Anaerobic Selector to Reduce Sludge Volume Index

Slow-settling sludge is a chronic issue at the WRF, with an average SVI of 260 milliliters per gram (ml/g), and fifth-percentile SVI of 230 ml/g always in exceedance of the typical maximum recommended value of 200 ml/g. The slow settleability is related to a long solids retention time (SRT), combined with limited oxygen, and utilization of carbon by undesirable filamentous organisms. The primary concern of high SVI is that it increases the risk of permit carbonaceous five-day biochemical oxygen demand ($cBOD_5$) and total suspended solids (TSS) permit exceedances, and the inability to produce reuse water during process upsets or wet weather events.

A secondary, but important, concern related to slow sludge settleability is that phosphorus release occurs in the clarifier sludge blankets due to the resulting high anaerobic detention time of sludge. Although the immediate concern for high SVI levels and slow settleability may be lessened due to the fact that 100 percent of effluent is filtered, the slow settleability will become more of a concern over time as flow rates to the wastewater plant are expected to increase.

Continued on page 6

Continued from page 4

A schematic illustrating the sequence of how the slow sludge settleability affects treatment performance is presented in Figure 1.

Phase 2: Reduction of Effluent Total Phosphorus

The downstream C-51 Canal has a total maximum daily flow (TMDL) requirement for TP of 50 parts per bil (ppb). Although the WRF currently does not have effluent TP or total nitrogen (TN) limits, the village continually endeavors to improve surface water quality discharged to the regional surface water system (C-51 Canal) by implementing stormwater management programs to meet the target; therefore, stakeholders may be sensitive to increased TP loading that may migrate from reuse water applied to the receiving basin and the canal system, which is why the concurrent reuse master plan investigated reuse water impacts to surface water phosphorous loadings.

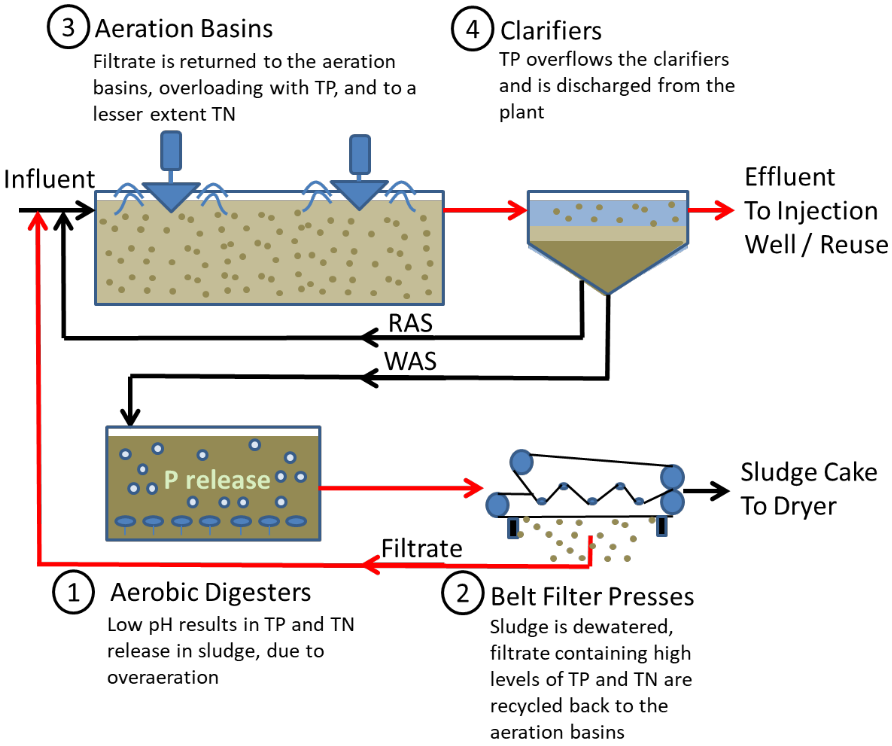


Figure 2. Effects of Digester Overaeration and Low pH Inhibition on Treatment Performance

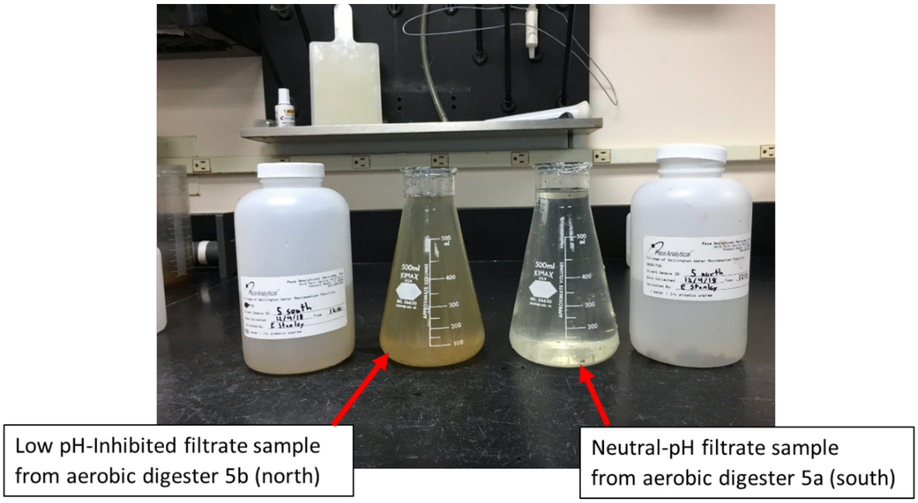


Figure 3. Comparison of Filtrate From Overaerated Digester to Neutral-pH Digester

During sampling, it was discovered that current elevated effluent phosphorous levels at the WRF appear to be mostly attributed to the low pH inhibition of the aerobic digesters. As air is provided to the aerobic digesters, nitrification occurs (conversion of ammonia [NH_3-N] to nitrate nitrogen [NO_3-N]), which consumes alkalinity; as alkalinity is consumed, the pH in the process drops. If oxygen continues to be provided after the nitrification process has occurred, acid production continues, resulting in lower pH and destruction of alkalinity to neutralize the acid. This low-pH condition can deactivate or kill biomass, since microorganisms are sensitive to low pH. Because the inactive biomass is not respiring, dissolved oxygen levels further increase. As a result, the filtrate from the belt filter presses following the digesters contains significant levels of TP, which are then returned to the main process and stress the plants ability to uptake phosphorous biologically.

Modifying the aerobic digestion process to operate at lower DO levels or cyclic aeration, and the maintenance of neutral pH, would likely reduce nutrients and oxygen demand recycled back to the aeration basins, and also improve solids capture at the belt filter presses. The biological removal of phosphorous by the anaerobic selector implemented under Phase 1 could then be leveraged for TP removal, as well as SVI reduction.

Figure 2 illustrates the sequence of how overaeration and the low pH inhibition condition affects the treatment performance of the WRF. Figure 3 presents a side-by-side comparison of filtrate from sludge taken from an overaerated low-pH digester to a neutral-pH digester.

Clarifier Capacity Analysis

Prior to recommending measures to improve the SVI, the capacity of the WRF was checked at current SVIs. The WRF clarifiers were checked against typical solids loading rate (SLR) and surface overflow rate (SOR) values, and compliance with U.S. Environmental Protection Agency (EPA) Class I reliability. Table 1 demonstrates that, for the conditions shown, the number of clarifiers online is within typical values, with

Continued on page 8

Continued from page 6

one clarifier offline; however, even though the clarifiers meet typical values, the criteria shown in Table 1 do not account for SVI values above 200 ml/g.

Clarifier blanket levels and SVI measurements were collected during the sampling week to evaluate the settleability performance of the mixed liquor suspended solids (MLSS). Eight clarifier blanket readings were taken at each clarifier over the course of five days. The blankets and transition zone were consistently high throughout the sampling event, demonstrating slow-settling solids, as shown in Figure 4. The SVI readings were also performed on the MLSS of Aeration Basin No. 2 and Aeration Basin No. 3 over the course of three days. The SVI values measured were indicative of slow-settling sludge. A picture of one of the SVI tests performed is shown in Figure 5. The slow sludge settling conditions observed during the sampling week were also consistent with available historical data.

State point analysis (SPA) is a method for evaluating secondary clarifier capacity based on the solids flux theory, which does account for SVI. This method uses site-specific SVI data to roughly predict the thickening behavior of secondary clarifiers, and also accounts for RAS underflow rates. Historical SVI values are summarized in Table 2.

The 2015-2017 5th percentile, 95th percentile, and average SVI data (reflecting the best-performing 5 percent of SVI data and the worst 5 percent of clarifier sludge settleability days, respectively) were evaluated to determine clarifier capacity to settle solids and produce satisfactory clarifier effluent. The results of the SPA analysis at the current average daily flow (ADF) flow rate of 3.6 mgd, 75 percent RAS rate, and 3,000 mg/L MLSS are shown in Figure 6.

A clarifier operating within its hydraulic and solids loading capacity should show the intersection of the diagonal lines beneath the flux curve line, and should also show the segments of the diagonal lines that are below the point of intersection, beneath the flux curve line; therefore, Figure 6 demonstrates that, even at the current 3.6-mgd ADF flow rate and average SVI of 260, the plant is already critically loaded, and at 95th percentile SVI of 290, the plant is beyond critically loaded. This is consistent with the findings during the November 2019 sampling event of high clarifier blankets, and with the recent plant upset condition in January 2020.

The results of the SPA analysis indicate that the WRF can likely not function much beyond its current capacity and continue to meet permit limits and produce reuse water at currently observed levels of SVI. As plant flow rates increase towards the plants rated capacity of 6.5-mgd TMADF, assuming current high ranges SVI persist, the WRF clarifier performance would be further reduced. More-frequent plant upset conditions and inability to produce reuse water would result; therefore, it's critical to implement improvements to reduce SVI at the plant.

Microscopic Analysis of Mixed Liquor Suspended Solids

A MLSS sample was collected and

Continued on page 10

Table 1. Clarifier Capacity Analysis Versus Typical Values

Clarifier Design Criteria			
Parameter	10 State Standards	WEF MOP 8	Village of Wellington (Design Flow Rate with 3 clarifiers online)
Surface Overflow Rate @ PHF	1,000-1,200	1,200	840
Solids Loading Rate @ MDF	35-50	40-50	27.3
EPA Class I Reliability	Treat 75% of flow with the largest unit offline		
Clarifier Details with Largest Unit Offline			
Number (each)	(1) 90 ft dia, (1) 70 ft dia, (1) 65' dia		
Surface Area Total (sf)	13,530		

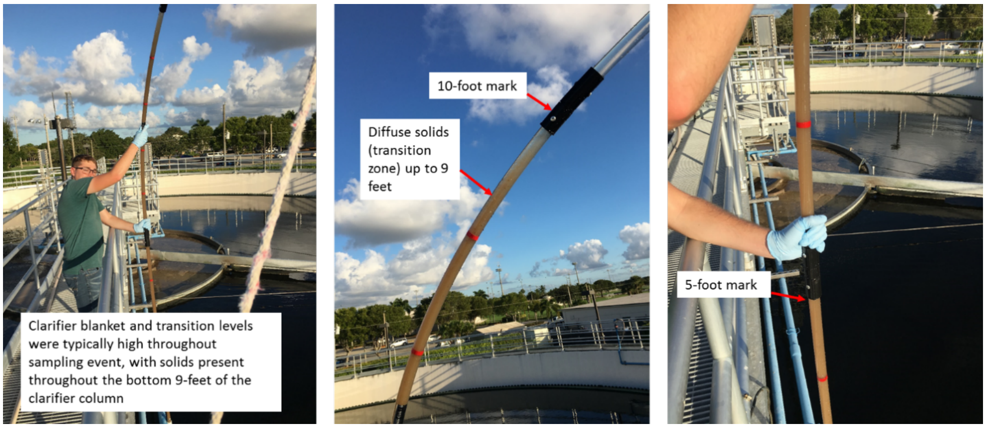

Clarifier blanket and transition levels were typically high throughout sampling event, with solids present throughout the bottom 9-feet of the clarifier column

Figure 4. Typical Photos of Clarifier Blanket Levels

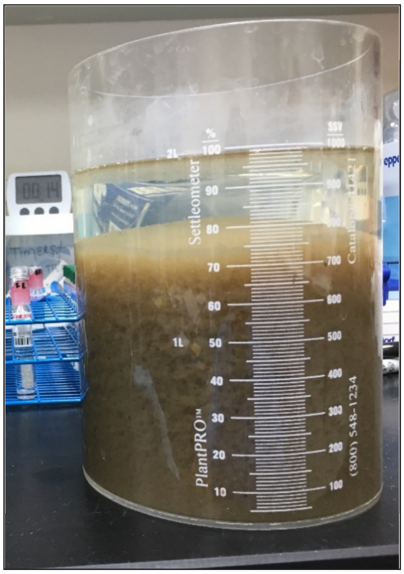
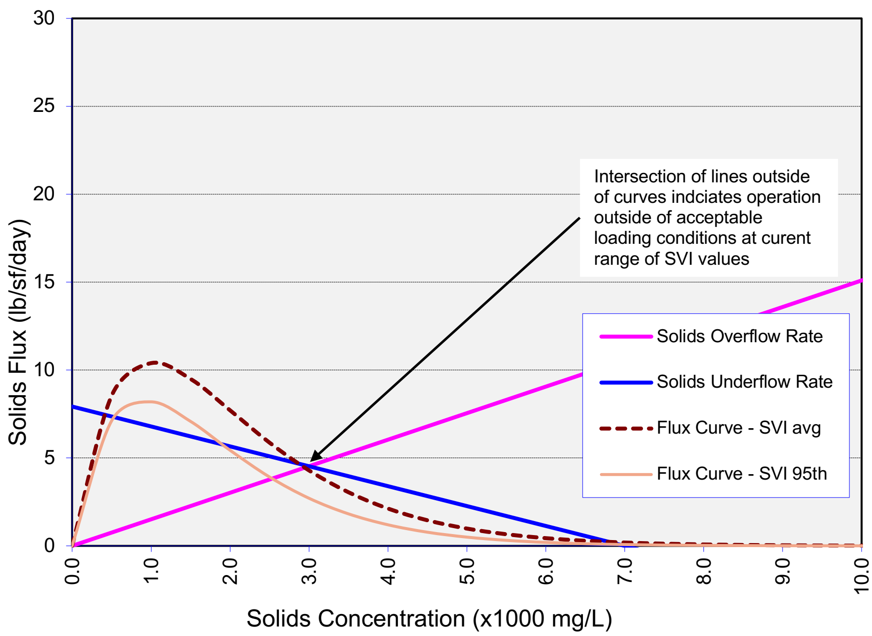


Figure 5. Photograph of Sludge Volume Index Test Results after 30 Minutes of Settling Time

Table 2. 2015-2017 Sludge Volume Index Data

Parameter	SVI (ml/g)
Average	260
5^{TH} Percentile	230
95^{TH} Percentile	290



Intersection of lines outside of curves indciates operation outside of acceptable loading conditions at curent range of SVI values

Figure 6. Clarifier State Point Analysis at 3.6-mgd Average Daily Flow

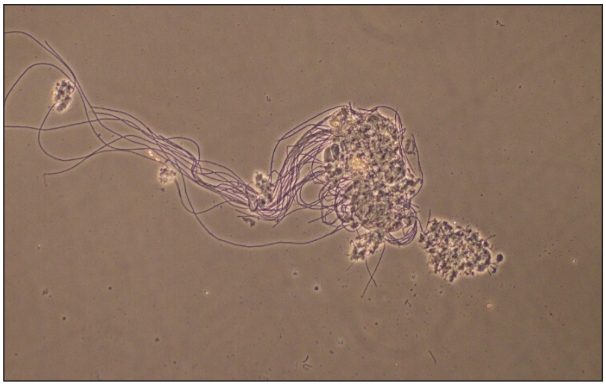
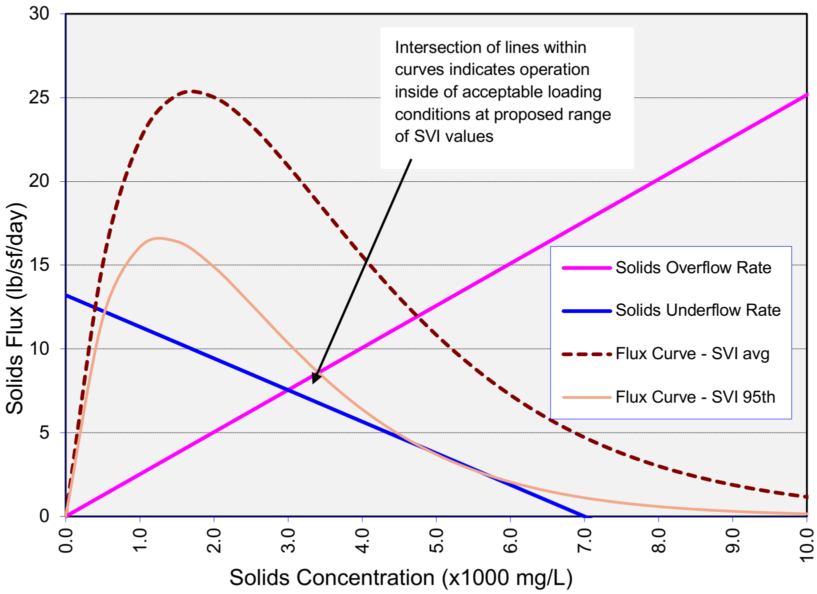


Figure 7. Microscopic Photograph of Large Flocs With Significant Amount of Filaments



Intersection of lines within curves indicates operation inside of acceptable loading conditions at proposed range of SVI values

Figure 8. Clarifier State Point Analysis at 6-mgd Average Daily Flow With Improved Sludge Volume Index

Continued from page 8

analyzed with a microscope. Significant levels of filamentous microorganisms were noted, with significant interfloc bridging and filaments protruding from the flocs. The overall filamentous organism level was "very common-abundant." At these levels, significant interference with the activated sludge settling properties would be expected. The high SVI values are caused by filamentous organisms associated with simple readily biodegradable material (rbCOD), such as Nostocoida Limicola, and long SRT (type 0041). A picture of the floc, observed with abundant levels of filament, is shown in Figure 7.

Anaerobic Selector Overview

A selector can improve secondary solids settleability by precluding the growth of filamentous bacteria and selecting for bacteria that form tight, dense flocs with good settling properties. Filamentous bacteria can form bridges between flocs, keeping them in suspension and decreasing secondary clarifier performance. Many filamentous bacteria use rbCOD very efficiently, but cannot store or utilize these substances under anoxic or anaerobic conditions.

Anaerobic selectors allow for the rapid uptake of rbCOD under conditions where filamentous organism growth is restricted, limiting their proliferation in the downstream aerobic zone of the secondary treatment process. Implementation of a selector zone can reduce the operation and maintenance costs associated with nuisance organisms, such as those identified in the microscopic samples, as well as increase secondary clarifier performance by improving settleability.

The anaerobic selector allows for the removal of rbCOD by polyphosphate-accumulating organisms (PAOs) under anaerobic conditions, which facilitates biological phosphorous removal and reduction of effluent phosphorous. Filamentous organism growth is restricted in anaerobic conditions, limiting potential proliferation in the secondary treatment process. Anaerobic selector efficacy is dependent on operation at a suitable minimum hydraulic retention time (HRT) of 30 minutes at design flowrates.

Evaluation and Sizing of Anaerobic Selector

As stated previously, an anaerobic selector HRT of 30 minutes at design flow rate is a typical criterion for anaerobic selector sizing. Additionally, a calibrated BioWin™ model was used to predict an uptake of rbCOD in the anaerobic zone (thereby preventing rbCOD availability for filamentous bacteria in the downstream aeration basin). A typical target rbCOD uptake in a selector zone is 90 percent of rbCOD.

An anaerobic selector zone was inserted into the process model at design maximum month average day flow (MMADF), as shown as Figure 9. The model predicted that a 200,000-gal tank is adequate to remove rbCOD, promote PAO growth for biological phosphorous removal, and "select" for well-settling PAO bacteria at design conditions.

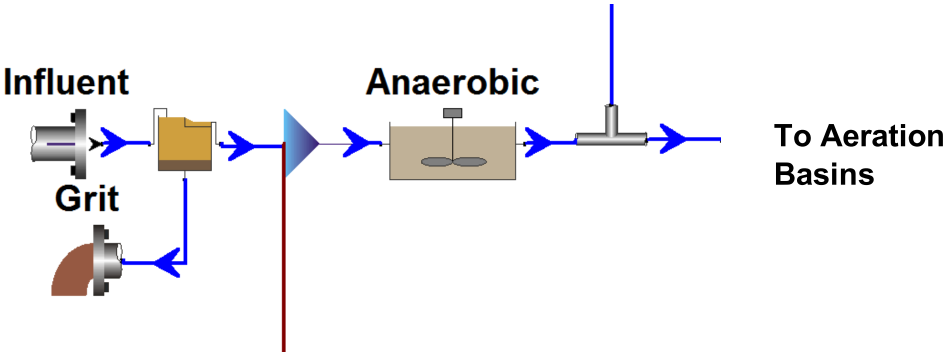


Figure 9. View of Anaerobic Selector Inserted Into BioWin Model

Description of Proposed Anaerobic Selector

An anaerobic selector is proposed as a common tank to receive all plant flow, upstream of the aeration basins. It's recommended that the anaerobic selector be baffled into at least two separate zones to allow for efficient uptake of rbCOD. High-efficiency vertical mixers are proposed for each zone. Although the anaerobic selector is not anticipated to be a significant source of odors, the zone would be contained with aluminum covers and connected to the odor control system, given the odor sensitivity of surrounding residents. Piping and valves would also allow for bypass of the anaerobic zone. The proposed location and conceptual layout for the anaerobic selector at the WRF is shown in Figure 10.

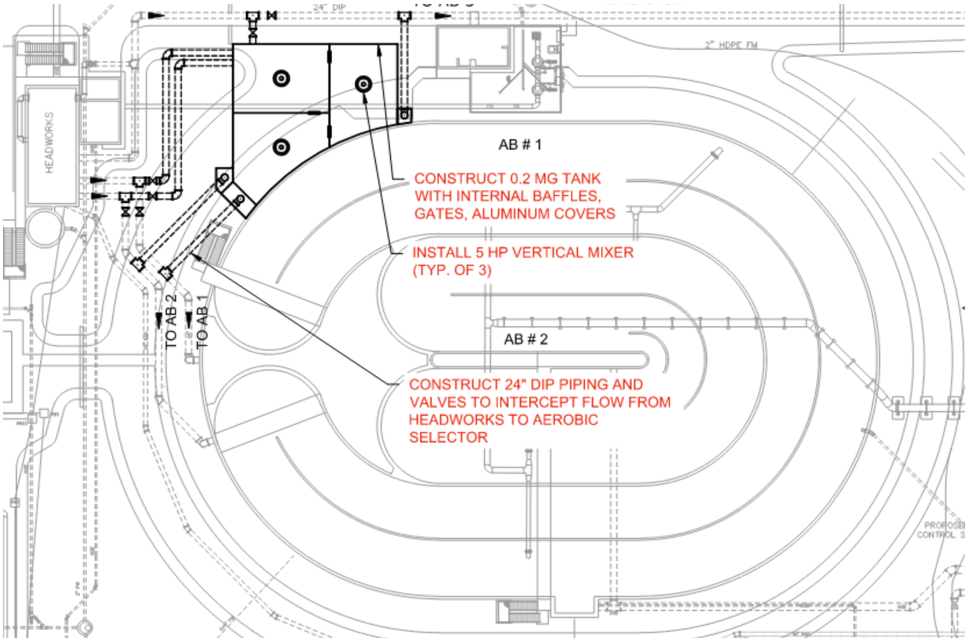


Figure 10. Plan View of Proposed Anaerobic Selector

Conclusion

Reducing SVI at the WRF is a critical goal. Reduction of SVI by implementing an anaerobic selector was identified as the preferred alternative. The detailed design of Phase 1 is currently underway at the time of this writing. The RAS chlorination was also recommended to provide operators an additional low-cost tool to control occasional sludge-bulking episodes. Figure 11 illustrates the recommended strategy to reduce SVI.

The concurrent reuse master plan recently concluded that reduction of effluent TP to <1.5 mg/L is sufficient to prevent increased TP loading into surface waterways by reuse water. Figure 12 illustrates the recommended strategy to achieve effluent TP < 1.5 mg/L. ◊

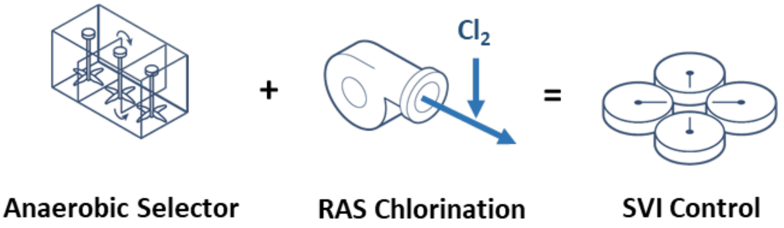


Figure 11. Phase 1 Strategy to Reduce Sludge Volume Index

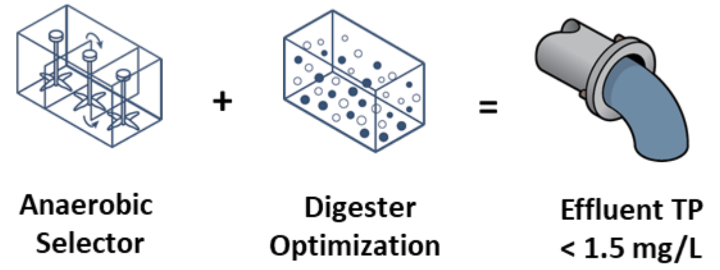


Figure 12. Phase 2 Strategy to Achieve Total Phosphorus Removal < 1.5 mg/L

www.fwrj.com