PROCESS CAPACITY ASSESSMENT AND PLANT EXPANSION

Addendum to the SSAIA Master Plan Report

B&V PROJECT NO. 194803

Hendersonville Water Sewer

PREPARED FOR

CITY OF HENDERSONVILLE

11 APRIL 2019

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1 Introduction

The purpose of this memorandum is to evaluate current plant performance to determine any process limitations at the Hendersonville WWTP. The facility has experienced issues with sludge blankets being washed out during storm events leading to potential TSS compliance issues. The plant is currently rated at 4.8 mgd design average flow and 12 mgd peak design flow. However, the City has limited peak flows to the facility to 6.5 mgd to avoid any solids washout from the clarifiers. This memorandum provides a summary of a process capacity assessment and a historical data review to mitigate any potential issues with solids washout.

This memorandum also includes discussion on plant expansion to meet future projected flows for the planning year of 2040.

2 Influent Flows and Loads

Plant influent data from January 2014 through October 2018 were reviewed and analyzed to evaluate influent water quality and compare to the original plant basis of design. Influent data were available for flow, BOD, and TSS. No influent TKN or ammonia data were available. It is recommended that TKN be added to the influent monitoring program to determine the total nitrogen load to be treated by the facility.

Figure 2-1 presents the plant daily flows to the facility. The daily flows over the evaluation period averaged 3 mgd with a peak flow of 10 mgd. A 30-day moving average is included to provide a reference for monthly average data. Figure 2-1 shows that the 30-day moving average is below the design average flow of 4.8 mgd and the daily flows are below peak design flow of 12 mgd.

Plant influent daily BOD and TSS concentrations and loads data are presented in Figure 2-2 - Figure 2-5. Maximum month loads are typically used for capacity assessment and sizing of activated sludge processes. A 30-day moving average is included in the figures to provide a reference for monthly average data. As shown in the figures, both BOD and TSS concentrations have exceeded the design average and peak concentrations but on a load basis, both BOD and TSS 30-day moving average loads are below the design average loads of 8,000 lbs/d respectively for both parameters, except for March of 2014 when the 30-day moving average BOD load exceeded 8,000 lbs/d.

The peak observed daily BOD load is below the peak design load. The observed TSS load exceeded the peak daily design load on 12/14/2016 which was due to extremely high TSS concentration of 2,200 mg/L (Figure 2-5). Further investigation is needed to confirm the source of high TSS. The TSS concentration on 12/15/2016 was also high at 578 mg/L.

Generally, the current flows and loads to the plant are within the original design envelop, except for occasional excursions.

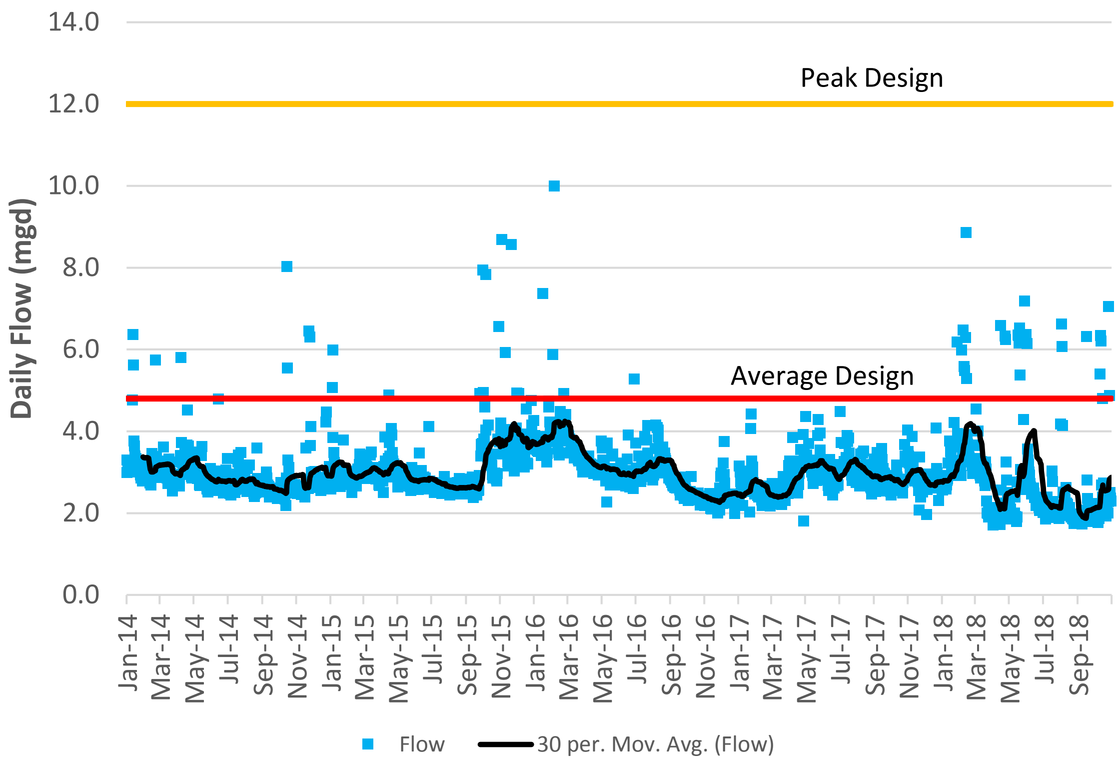


Figure 2-1: Influent Daily Flows

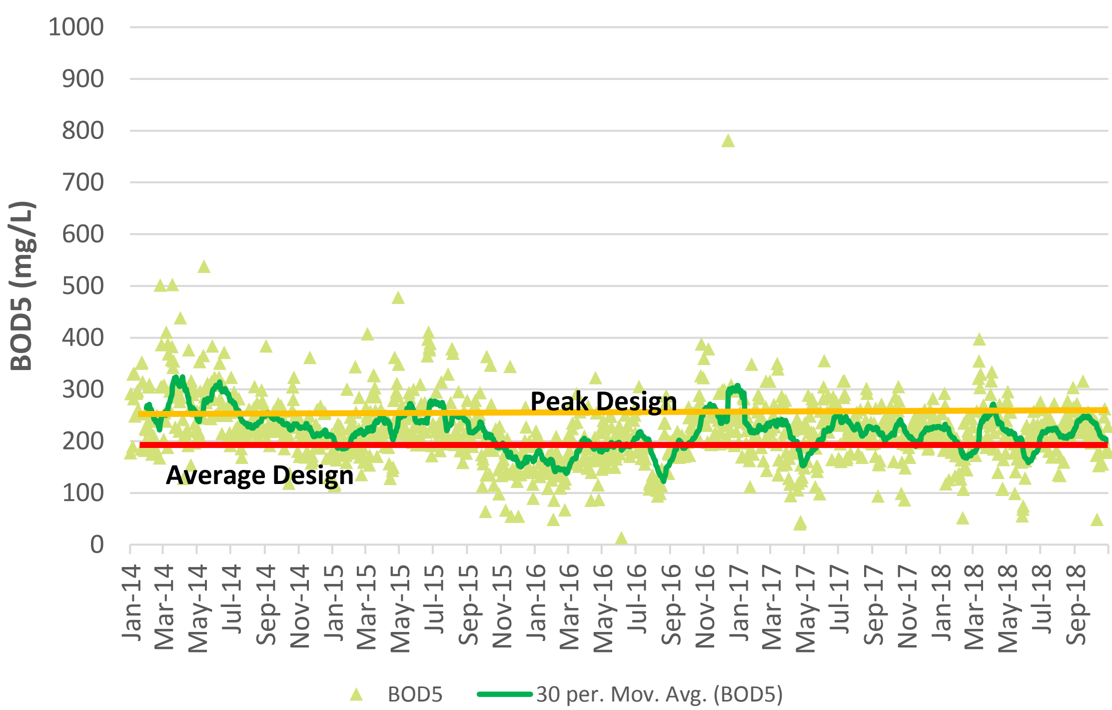


Figure 2-2: Influent Daily BOD5 Concentrations

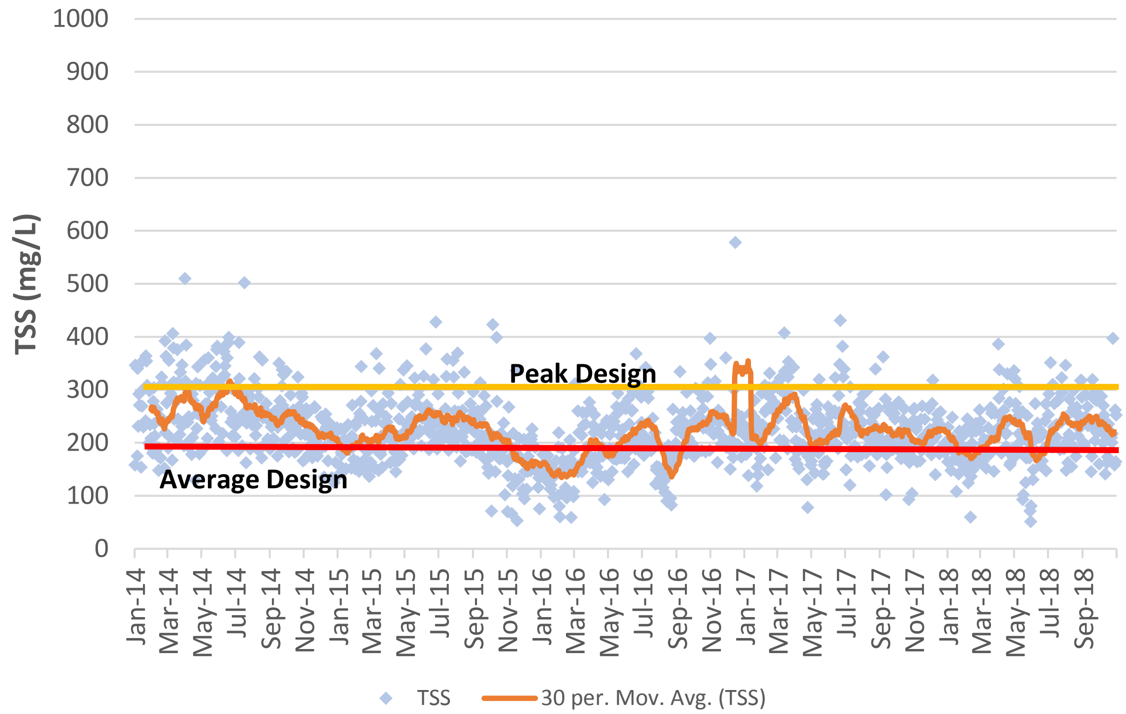


Figure 2-3: Influent Daily TSS Concentrations

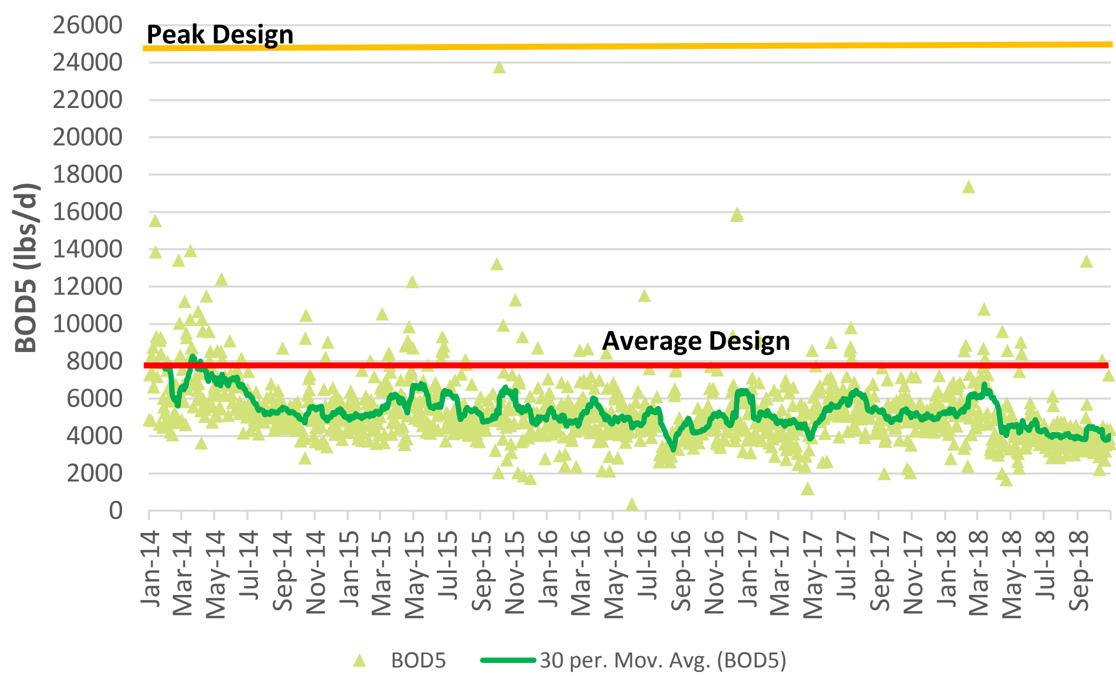


Figure 2-4: Influent Daily BOD Load

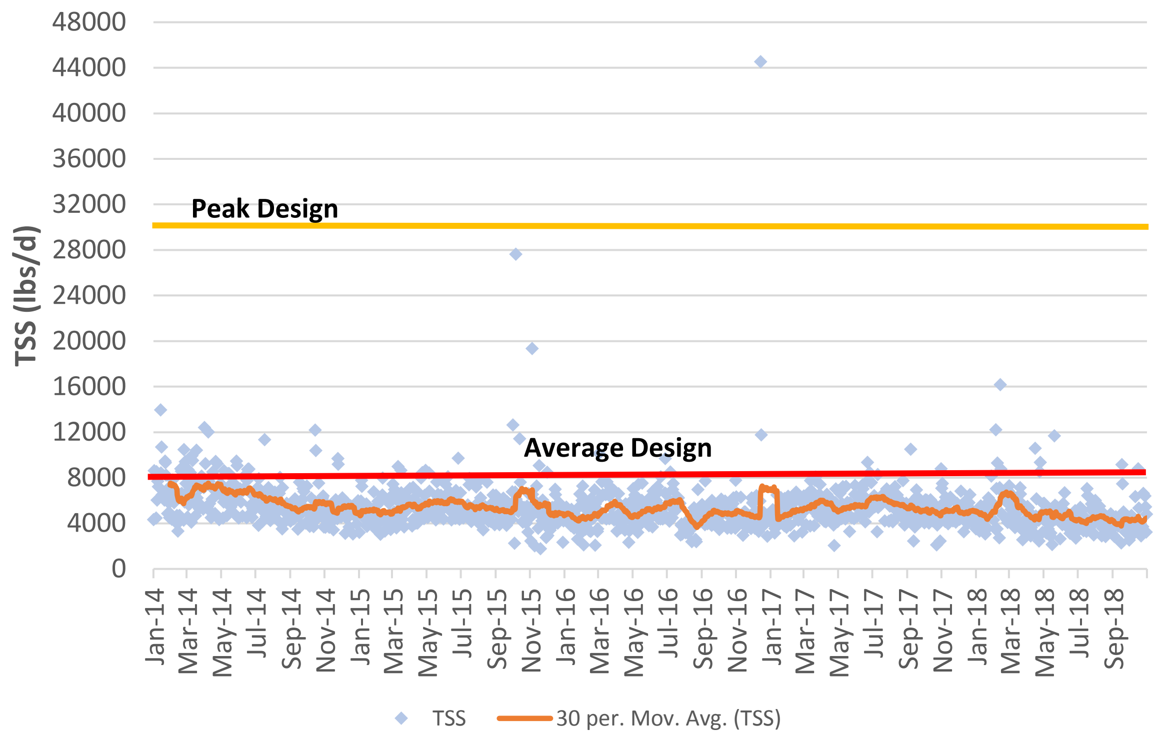


Figure 2-5: Influent Daily TSS Load

3 Plant Performance

The Hendersonville WWTP consists of a mechanical bar screen, aerated grit removal, two aeration basins, two secondary clarifiers, two automatic backwash filters, and two channels for UV disinfection. Waste-activated sludge is sent to gravity thickeners and then dewatered using a belt filter press. Current NPDES permit requirements are presented in Table 3-1. The Hendersonville WWTP effluent data for the evaluation period for BOD, TSS and ammonia are shown in Figure 3-1, Figure 3-2 and Figure 3-3 respectively. Each graph shows daily data as well as the 7-day and 30-day rolling average trend lines. These trend lines provide a visual indication of the plant's ability to meet its weekly average and monthly average permit limits.

Table 3-1: Current NPDES Permit Requirements

PARAMETER	MONTHLY AVERAGE	WEEKLY AVERAGE
BOD5, mg/L (April – October)	10	15
BOD5, mg/L (November – March)	20	30
Total Suspended Solids, mg/L	30	45
Ammonia Nitrogen, mg/L (April – October)	2	6
Ammonia Nitrogen, mg/L (November – March)	4	12
Fecal Coliform (geometric mean), MPN/100 mL	200	400
pH (S.U.)	Between 6 and 9	
Dissolved Oxygen, mg/L	Daily Average ≥ 5	

The Hendersonville WWTP effluent BOD5 averaged approximately 5 mg/L for the evaluation period. BOD5 has seasonal permit limits with less stringent limits for winter months. Both the monthly average and weekly average values were consistently below the current permit requirements.

The plant also performed very well with respect to effluent TSS, with an average of 5 mg/L for the evaluation period. The weekly and monthly averages were consistently less than 12 mg/L, which is well below the permit requirement.

Ammonia-N has seasonal permit limits with less stringent limits for winter months. The plant effluent ammonia-N averaged 0.6 mg/L during the evaluation period. Both the monthly average and weekly average values were consistently below the current permit requirements though there were several instances when the facility was not nitrifying completely. For nitrification to remain stable, dissolved oxygen concentration, solids retention time, and buffering capacity in the wastewater must be adequate. There were a couple samples in 2018 for which aeration basin alkalinity dropped below 50 mg/L as $CaCO_3$, which is below the typical recommended effluent alkalinity to provide buffering capacity.

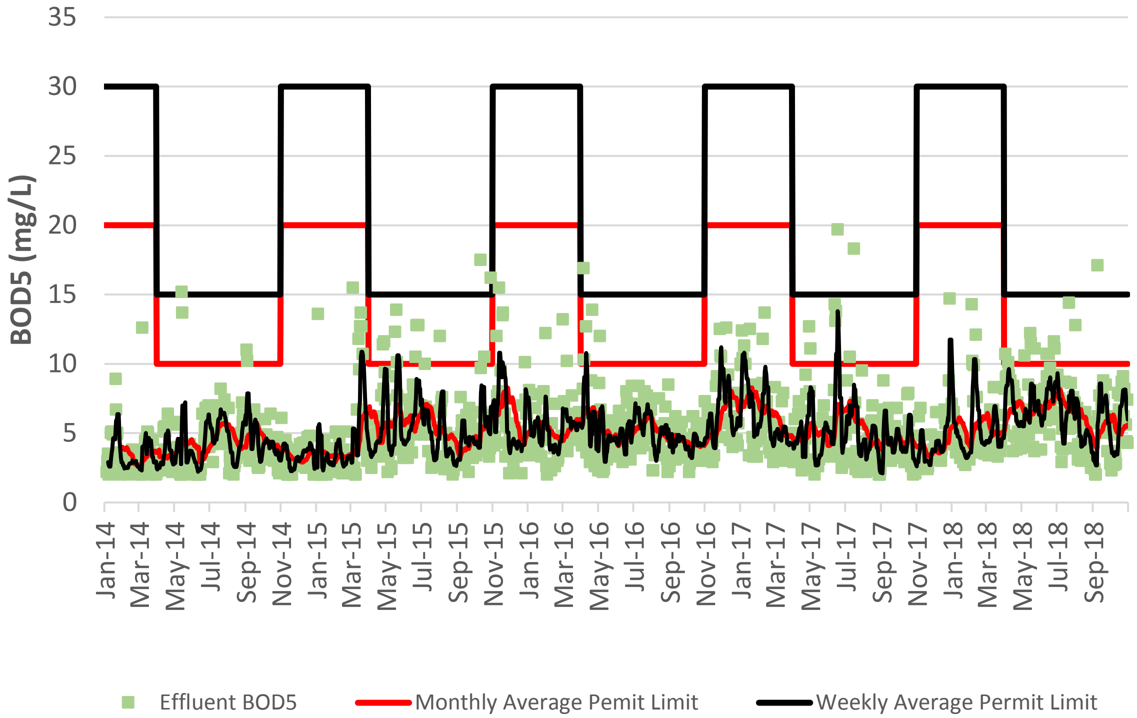


Figure 3-1: Effluent Daily BOD5 Concentrations

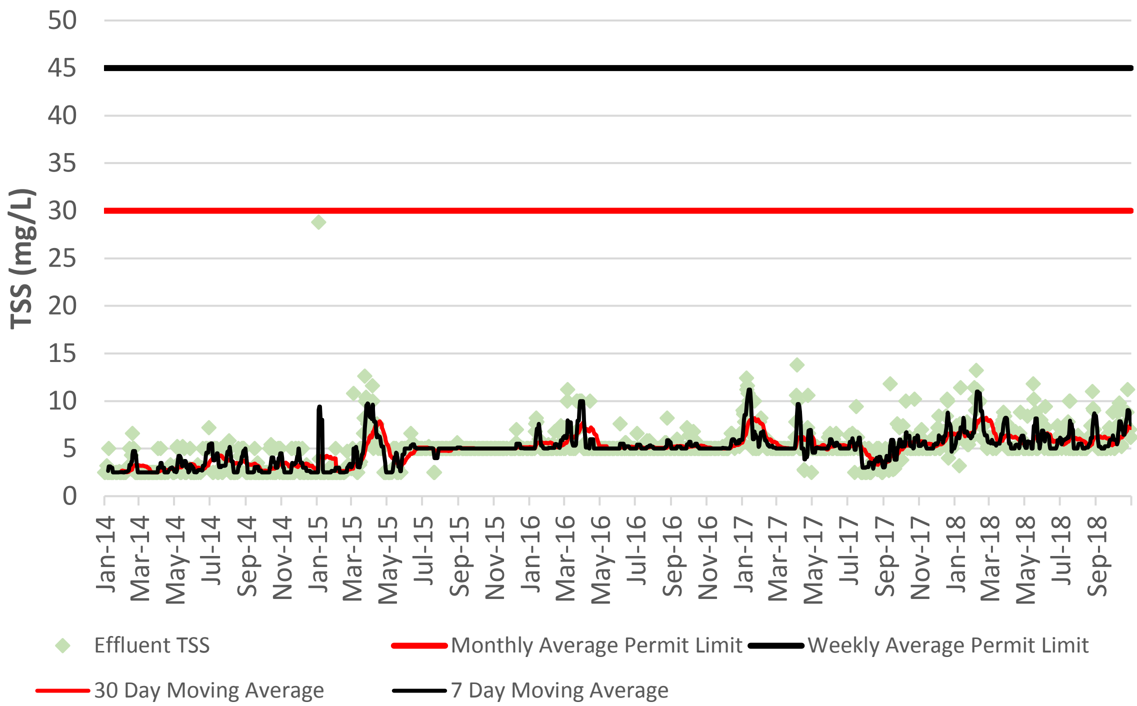


Figure 3-2: Effluent Daily TSS Concentrations

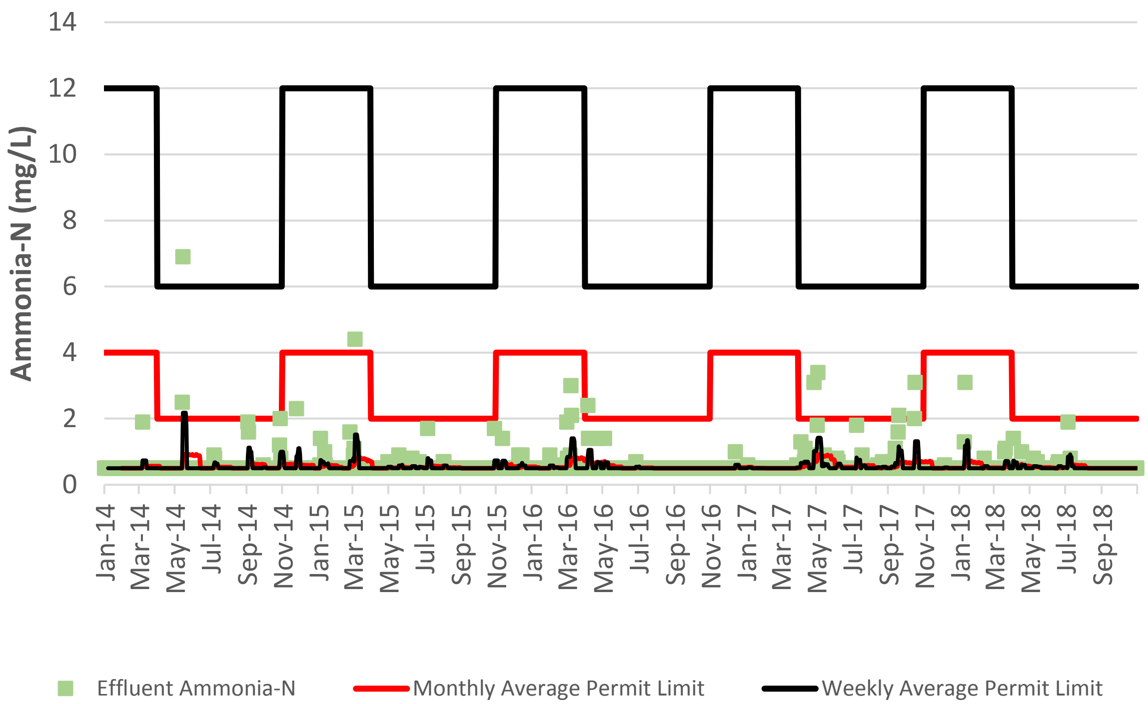


Figure 3-3: Effluent Daily Ammonia-N Concentrations

4 Secondary Process Capacity Assessment

4.1 SRT CRITERIA

The limiting condition for sizing an activated sludge plant for nitrification is the maximum month load during the coldest period of operation under winter temperatures. To maintain nitrification, activated sludge plants need to maintain sufficient solids residence time (SRT) under aerobic conditions for nitrification to occur given the temperature conditions. The SRT required increases as temperature decreases, due to a reduction in the growth rate of nitrifying bacteria at low temperatures.

Figure 4-1 shows the recommended design and minimum washout aerobic SRT versus water temperature required for complete nitrification. As shown in the Figure, a minimum monthly temperature of 11°C requires an aerobic SRT of 9.6 days for complete nitrification. Nitrification may occur below 9.6 days but cannot be guaranteed. As shown in Figure 2-4 and Figure 2-5, the maximum month loadings have occurred during winter temperatures.

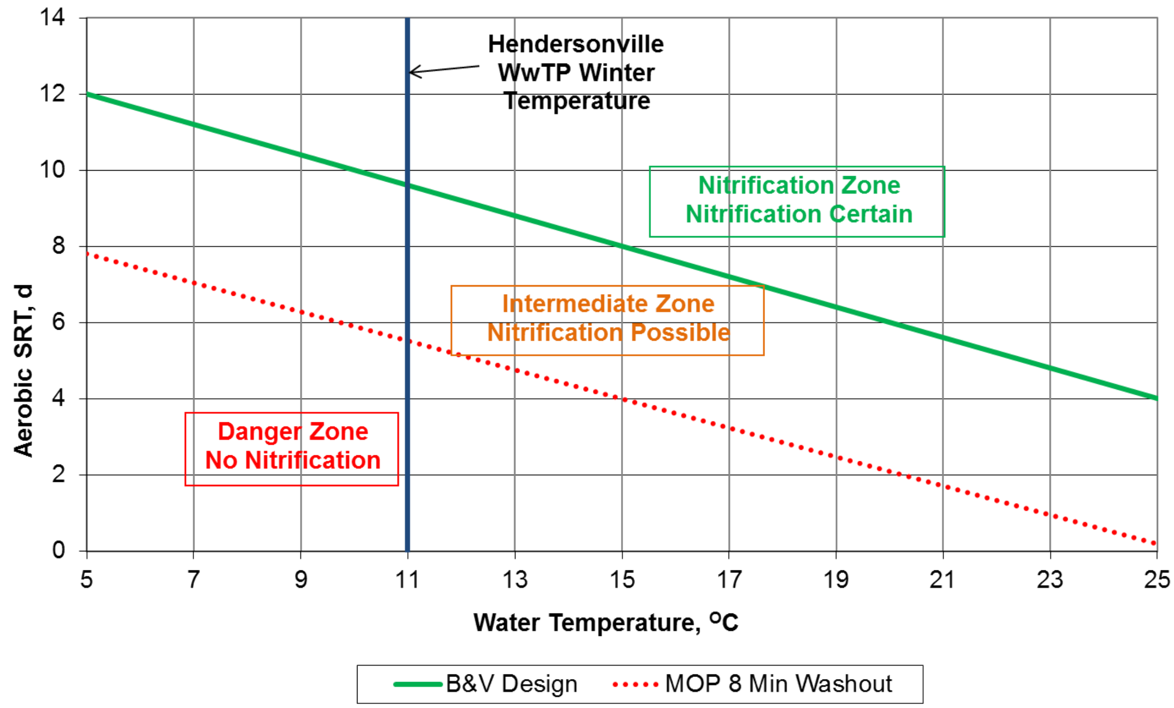


Figure 4-1: Nitrification SRT requirement based on Water Temperature

The formula below provides the calculation for aerobic SRT:

$$Aerobic\ SRT(days) = \frac{MLSS(mg/l) \times aerobic\ basin\ volume\ (MG) \times 8.34}{Mass\ of\ WAS\ solids\ wasted\ per\ day\ (lb/d)}$$

As can be seen from the above equation, the SRT is intrinsically related to the required operating MLSS in the aeration basins. A higher SRT value requires a higher MLSS in the aeration basins.

The operating MLSS concentration also determines the solids loading rate on the secondary clarifiers, according to the equation below:

$$Clarifier\ surface\ loading\ (lb/d/ft^2) = \frac{[Influent\ flow + RAS\ flow]\ (MGD) \times MLSS(mg/l) \times 8.34}{Clarifier\ surface\ area\ (ft^2)}$$

A higher MLSS in the aeration basins results in a higher solids loading rate on the clarifiers. The solids loading rate on the clarifiers is proportional to the MLSS concentration for a given flow.

4.2 SOLIDS SETTLEABILITY

Secondary clarifiers are often the capacity-limiting unit process in an activated sludge system. The capacity of an activated sludge system is dependent on how well sludge settles and as a result, how well the secondary clarifiers perform.

Sludge volume index (SVI) is a key indicator of how well the mixed liquor settles in a clarifier. Hendersonville WWTP collects SVI data periodically for both north and south trains. SVI data for the year 2018 were reviewed and analyzed to better understand sludge settleability for Hendersonville WWTP. SVI data were also plotted against temperature to determine any seasonal trends in settling characteristics.

Figure 4-2 presents SVI data and Figure 4-3 presents SVI versus temperature plot for the two trains. Typically, SVIs < 150 mg/L are an indication of good settling characteristics and SVIs > 150 mg/L are an indication of potential settling issues. All SVI values for 2018 are below 150 mg/L indicating good settling solids. The plant operates with the first 20% of the aeration basins as selector zones with no air which is possibly the reason for low SVIs. In addition, the selector zones provide aeration and alkalinity credits. As shown in the figures, there is a clear correlation between SVI and temperature with higher SVIs during winter and lower SVIs during summer for the two trains. Table 4-1 summarizes the SVI data for the two trains.

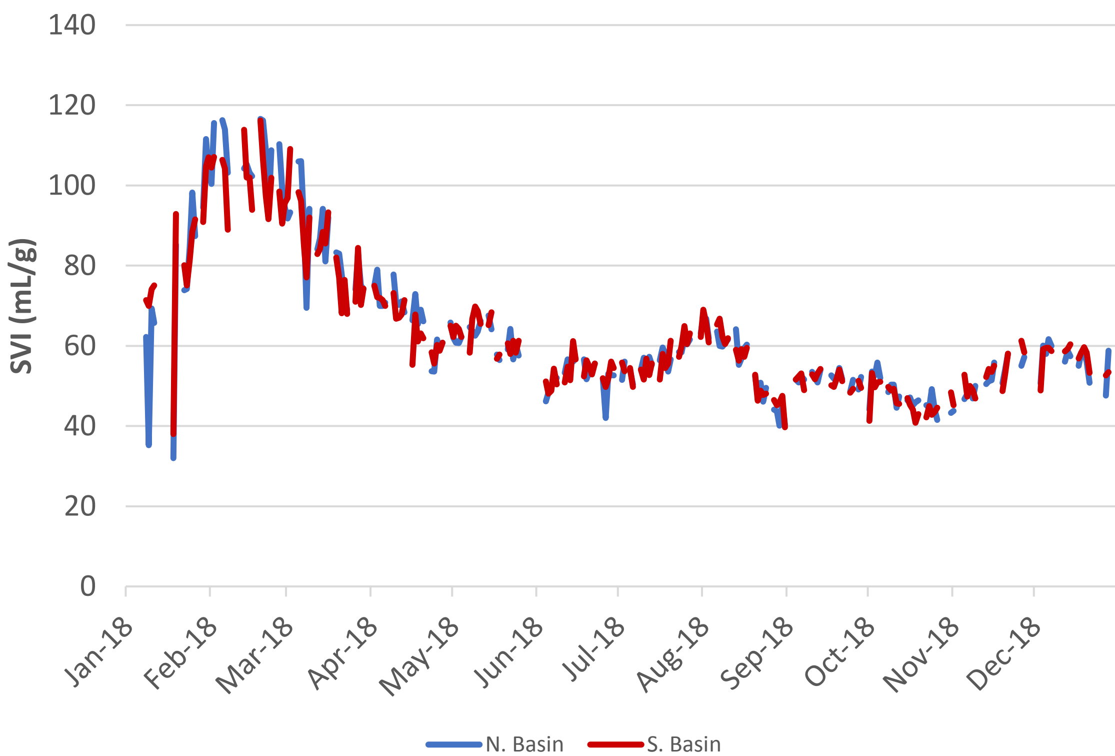


Figure 4-2: SVI data for North and South Trains

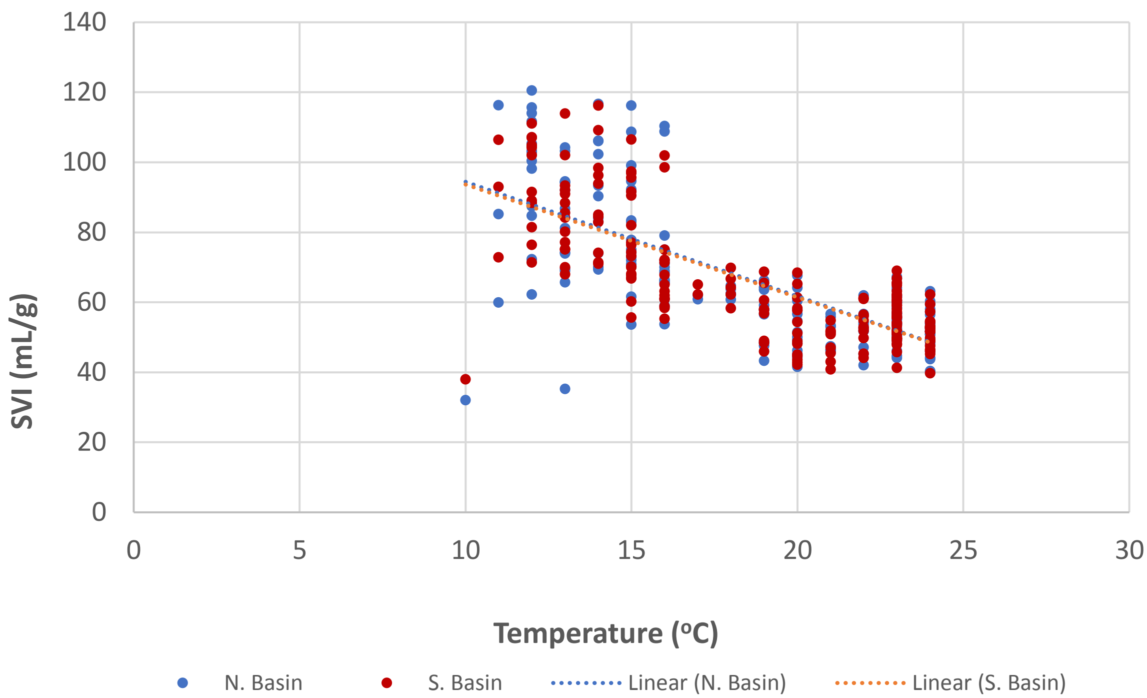


Figure 4-3: SVI data versus Water Temperature for North and South Trains

Table 4-1: SVI Data Summary (2018) for each Train

TRAIN	SVI AVERAGE (mL/g)		SVI 90TH PERCENTILE (mL/g)	
	SUMMER	WINTER	SUMMER	WINTER
North	56	76	67	109
South	56	76	67	105
Average	56	76	67	107

4.3 SLUDGE BLANKETS

Sludge blanket levels were reviewed for 2018 and are presented in Figure 4-4 for the north and south clarifiers. The blanket levels averaged approximately 2 ft for the year 2018. As shown in the figure, there were several instances when the sludge blankets were above 3 ft and even approached as high as 8 ft. It is recommended that sludge blanket levels be kept below 1 ft for average flows and below 1.5 ft for peak flows to avoid any potential solids washout during diurnal peaks or storm flows.

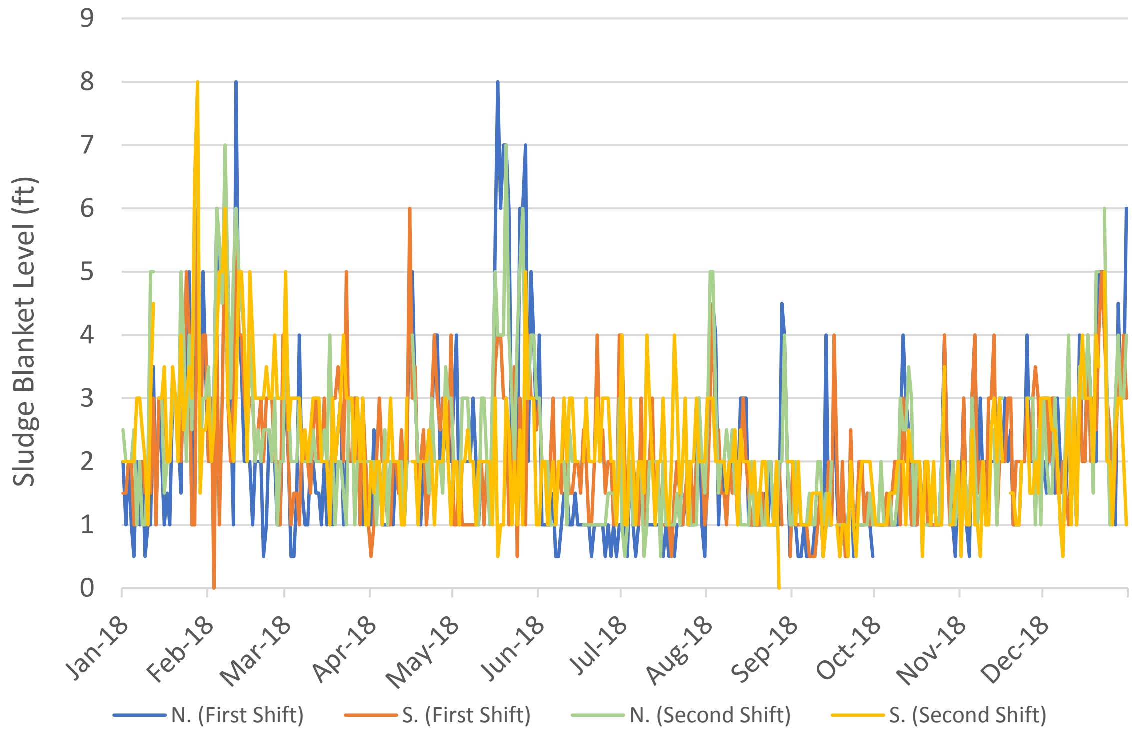


Figure 4-4: Historical Sludge Blanket Levels in Clarifiers

4.4 PROCESS MODELING

A process model for Hendersonville WWTP was configured using BioWin simulator to determine MLSS in the aeration basins at design flow and loads during winter conditions. Both aeration basins and clarifiers were used for this evaluation. Key inputs and results are presented in Table 4-2.

As can be seen in Table 4-2, the model predicts that a MLSS concentration of 1,920mg/l is sufficient to maintain nitrification under the winter loading condition.

Table 4-2: Model Simulation

PARAMETER	VALUE
Design Flow, mgd	4.8
Design BOD load, lbs/d	8,000
Design TSS load, lbs/d	8,000
Assumed TKN load, lbs/d	1,600
Water Temperature, ^{o}C	11
Aerobic SRT, d	9.6
MLSS, mg/L	1,920
WAS, lbs/d	6,400
RAS, mgd	4.8
Surface overflow rate, gal/d/ft2	380
Solids loading rate, lbs/d/ft2	12

Figure 4-5 presents the historical aeration basin MLSS for the north and south trains. MLSS in the aeration basins averaged 4,300 mg/L for the year 2018, which is more than double the required operating MLSS concentration predicted by the model for the worst case winter temperatures. Historical WAS data was not available to compare the aerobic SRT the facility is operated to the SRT required for complete nitrification. In the future, it is recommended that the operating MLSS be reduced based on the SRT that is required for complete nitrification. This can be achieved via a simple calculation sheet to assist the operators in adjusting the volume of WAS wasted each day to maintain the nitrifying SRT.

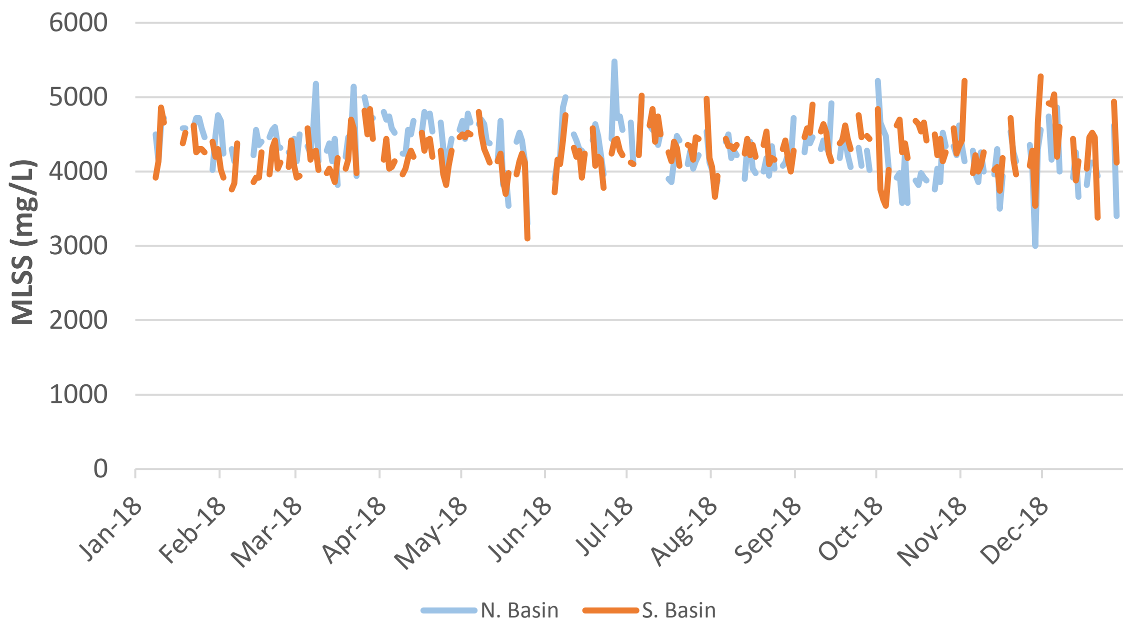


Figure 4-5: Historical Aeration Basin MLSS

4.5 STATE POINT ANALYSIS

To further evaluate the clarifier capacity, a state point analysis was conducted using reported historical SVI data.

To assess clarifier capacity, a desktop evaluation known as a state point analysis was conducted using reported historical SVI data. The state point analysis uses a model that predicts the solids handling capacity of the clarifiers based on a given value of SVI. The state point analysis was conducted using the winter 90th percentile SVI to consider the worst case operating scenario.

The state point analysis was conducted for following conditions:

- Design average flow of 4.8 mgd
- Design Peak flow of 12 mgd
- MLSS concentration
  - 1920 mg/L as determined by BioWin simulation
  - 4300 mg/L, average of 2018 plant data
- SVI 90th percentile winter 107 mL/g

State point analysis at MLSS concentration of 1920 mg/L was performed with both clarifiers in service and with one clarifier out of service. At both design average and peak conditions with two clarifiers in service, the clarifiers were under loaded at an SVI of 107 mL/g. This shows that clarifiers have adequate capacity at design flows for worst-case winter conditions. The clarifiers also have adequate capacity at design average flows during winter with one clarifier out of service.

However, it would be challenging to treat a design peak flow of 12 mgd with one clarifier in operation if it happened during the maximum month winter conditions with MLSS of 1,920 mg/L.

State point analysis at MLSS concentration of 4300 mg/L was also performed with both clarifiers in service and with one clarifier out of service. At design average flows with two clarifiers in service, the clarifiers were under loaded at an SVI of 107 mL/g. This shows that clarifiers have adequate capacity at design average flows. However, the clarifiers were overloaded at peak design flows. The clarifiers were also critically loaded at design average flows and overloaded at peak design flows with one clarifier out of service.

State point analysis plots are presented in Appendix A.

Figure 4-6 summarizes the key results of this analysis. The figure shows that at MLSS on 1920 mg/L the solids loading rate is below the critical solids loading rate determined by state point analysis but at an MLSS concentration of 4300 mg/L, the solids loading rate on the clarifiers is too high leading to failure causing solids to wash out.

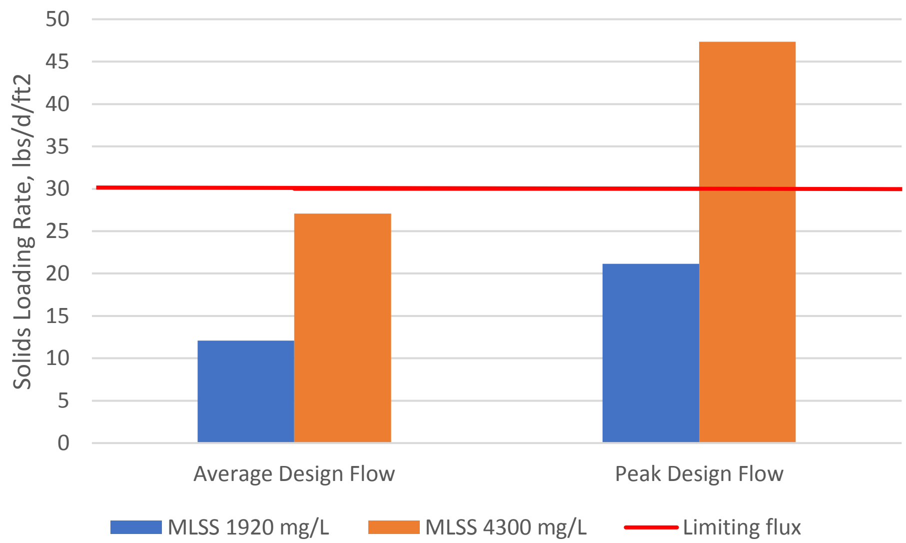


Figure 4-6: Solids loading rates on clarifiers with both clarifiers in operation

5 Recommendations

The following recommendations are made based on the above analysis.

Immediate Recommendations

- MLSS in the aeration basins averaged 4,300 mg/L for the year 2018, which is more than twice the concentration required to maintain a nitrifying SRT based on a BioWin model simulation of design conditions at worst case winter temperatures. It is recommended that MLSS be reduced based on the SRT that is required for complete nitrification, with an operating protocol put in place for WAS wasting.
- It is recommended that sludge blankets be reduced to less than 1 foot at average flows and 1.5 ft at peak flows to avoid any potential solids washout during diurnal peaks or storm flows. Lower sludge blankets can be targeted by increasing wasting or increasing return flows. Lowering the MLSS by increasing wasting in the above recommendation will help reduce the sludge blankets.

Future Investigations

- Secondary clarifier field testing/stress testing to confirm available capacity based on desk-top state point analysis.
- Dispersed suspended solids and flocculated suspended solids field testing to determine any hydrodynamic and flocculation deficiency in the clarifiers.
- Evaluate surface wasting of mixed liquor to further improve SVIs.

6 Plant Expansion

The Hendersonville WWTP has a 4.8 mgd discharge permit that allows for system upgrades to increase discharge capacity up to 6.0 mgd. Flow projections for the facility were developed for the base year (2017) and future planning year (2040). Based on the projections, the maximum month flow would surpass the plant capacity (4.8 mgd) in 2021 and the discharge permit capacity in 2028. To reduce the risk of violating the permit during a single month, an expansion of the WWTP is recommended to occur by 2021. The projected maximum month flows for the future planning year (2040) is 7.7 mgd, which is an increase of 2.9 mgd over the current design capacity of 4.8 mgd.

The current plant is rated at 12 mgd peak day flow, which is a 2.5 peaking factor based on design maximum month flow. To maintain the same peaking factor at future projected maximum month flow of 7.7 mgd would require an equalization basin volume of 6 mg. To allow a peaking factor of 3 through the expanded facility would require an equalization basin volume of 3 mg.

To expand the facility from 4.8 mgd to 7.7 mgd design capacity potential alternatives have been presented in this section. These alternatives would require evaluation during preliminary engineering to select the most viable alternative for expanding Hendersonville WWTP.

Alternative 1 – Addition of primary clarifiers

In this alternative, primary clarifiers would be added upstream of the biological basins to provide additional plant capacity. The old plant site can potentially be utilized for primary clarifier addition. The preliminary treatment including screens and grit removal are currently located adjacent to the biological basins. Utilization of the old plant site for primary clarifiers would require new preliminary treatment at the old plant site.

Alternative 2 – Addition of conventional process treatment train

There are currently two conventional process treatment trains, each consisting of a biological basin and a secondary clarifier and each rated at 2.4 mgd maximum month design capacity. A third process treatment train would be added to meet the additional capacity. The new biological basin would be built deeper to minimize footprint and achieve 2.9 mgd capacity. A deeper basin would also increase oxygen transfer efficiency but would require dedicated blowers for this basin. Further investigation is needed to ensure a third treatment train can be fit into the existing plant site. This option would likely require a new preliminary treatment system to be located at the old plant site in order to free up the location occupied by the existing system.

Alternative 3 – Process Intensification

There are several process intensification technologies available in the market today which can be utilized to retrofit the existing treatment trains to get more capacity in a smaller footprint while using less energy and less chemicals. Membrane bioreactors (MBR), Integrated Fixed-film Activated Sludge (IFAS), and BioMag™ are well established technologies with several installations in the North America. Membrane Aerated Bio-film Reactor (MABR) is an emerging technology which uses the membranes to diffuse oxygen and provide a surface for biofilm growth. Currently, there is no existing MABR facility in North America. All of these technologies would use existing basins to provide additional capacity. IFAS, BioMag™, and MABR would use final clarifiers for solids separation. MBRs would use membranes as the solids separation step, hence providing very high effluent quality fit for reuse. In the MBR alternative, final clarifiers could be utilized as equalization or storage tanks. This MBR alternative would require new tanks to house the membranes.

Alternative 4 – Addition of new treatment train with Aerobic Granular Sludge

Aerobic granular sludge (AGS) is the next evolution of activated sludge, where rapidly settling granular solids are grown in a sequencing batch reactor configuration by selectively wasting slower settling solids. The SVI in AGS systems is typically less than 40 mL/g, allowing rapid settling in a batch reactor, reducing the footprint considerably. AquaAerobic Systems is currently the only supplier of AGS systems in North America. In this alternative, a new treatment train with a capacity of 2.9 mgd would be added at the old plant site location which would be operated as an independent treatment train.

There are several alternatives which should be evaluated to select the best fit of Hendersonville WWTP. The conceptual capital cost for plant expansion to 7.7 mgd for the 2040 planning year would be in the range of $24–36 million.

7 Equalization

The collection system CIP was designed to accommodate the peak flow from a 2-year design storm event. The 2-year peak storm flow to the Hendersonville WWTP exceed the hydraulic capacity of the 12 mgd. The collection system hydraulic model predicted an instantaneous peak flow of 17.4 mgd during a 2-year design storm. In order to prevent SSOs in the collection system caused by the hydraulic capacity of the WWTP, an equalization (EQ) tank is recommended. Figure 7-1 shows the storm hydrograph for a 2-year storm event in the base year model. The volume of flow that exceeds the 12 mgd capacity was estimated to be 0.95 mgd.

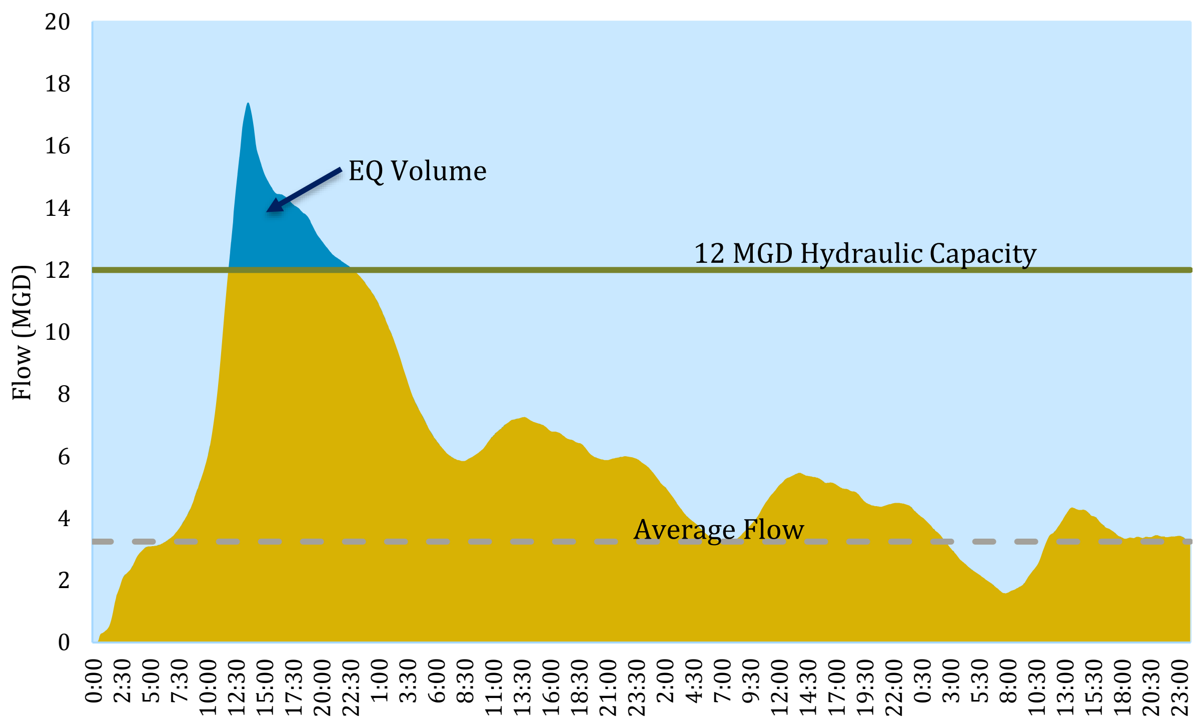


Figure 7-1: Base Year Hydrograph during a 2-year return interval storm event

The EQ calculation was repeated for a 2-year storm event using the 2025 and 2040 model years. Table 7-1 lists the EQ volume required to mitigate the 2-year peak storm flow dependent on the hydraulic capacity of the plant. The hydraulic capacity was assumed to be equal to 2.5 times the permitted treatment capacity.

Table 7-1: Equalization Basin Sizing Calculations

YEAR	2-YEAR STORM PEAK FLOW (MGD)	PERMITTED TREATMENT PLANT FLOW (MGD)	PLANT HYDRAULIC CAPACITY (MGD) (PF=2.5)	STORM EQ VOLUME (MG)
Base	17.4	4.8	12	0.95
2025[1]	22.5	6	15	1.86
2025[2]	22.5	7.8	19.5	0.25
2040	39.4	9	22.5	5.74

[1]Maximum discharge capacity into Mud Creek based on the current permit
[2]Assume the addition of one 3 mgd treatment train

To meet current needs, at least a 1.0 mg EQ Tank should be added to the existing plant to mitigate the impact of the 2-year storm event on the WWTP and the collection system. The planning level construction cost for the 1.0 mg EQ Tank project, T-01, was estimated to be $1.9M. With markups for contingency, planning and design costs, COH should plan for a total project cost of $2.78M.

In the future, the plant will be expanded to allow for system growth. During the design of the next expansion, the need for additional storm flow EQ should be assessed. As discussed in Section 6, a 6.0 mg EQ tank would be needed by 2040 to reduce the peak flow to the plant to a 2.5 peaking factor based on the modeled 2-year storm event.

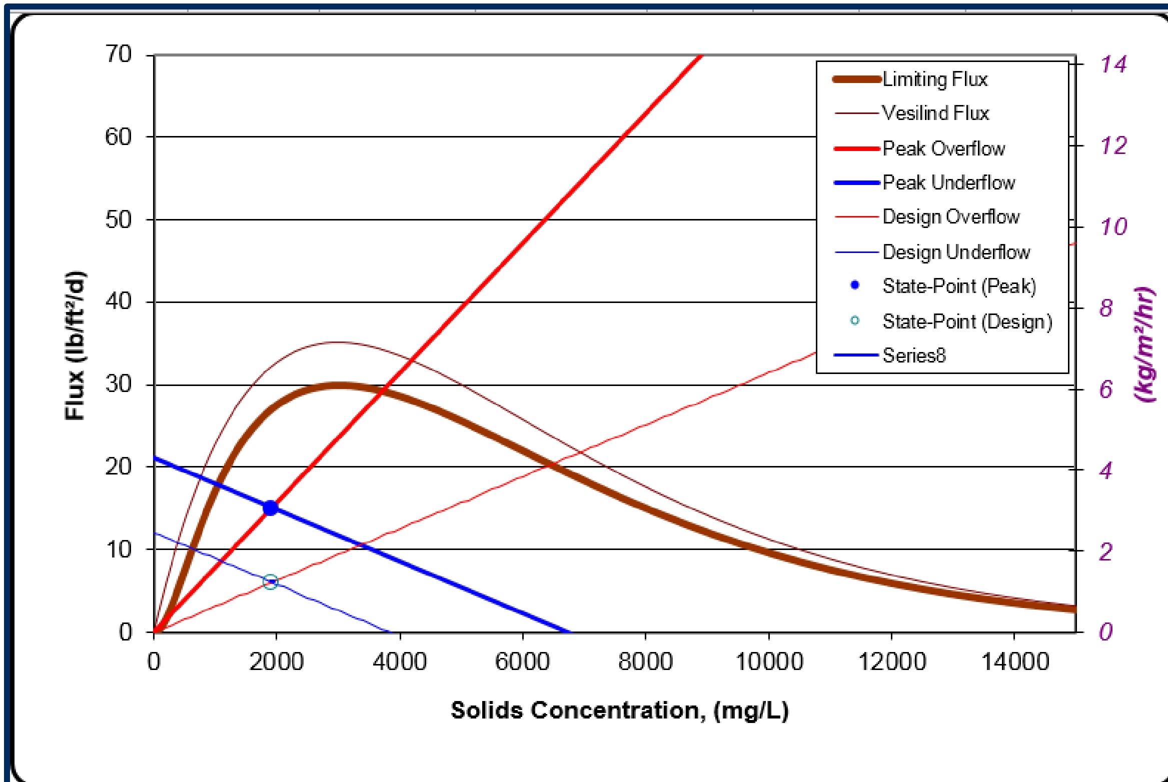
8 Treatment Plant Location

The existing Hendersonville WWTP is located on Mud Creek. The ultimate COH service area includes all the Mud Creek Basin upstream of the existing plant location. The area downstream of the existing plant location is part of the Cane Creek Sewer System service area. Since the service area drains to the existing plant site, it is the ideal location for the Hendersonville WWTP in terms of collection.

The existing plant layout does not leave much room for additional treatment on the current site. A significant portion of the parcel is within the 100-year flood plain. As COH looks to expand their facility, they should consider multiple options to best utilize their existing infrastructure. Options could include converting the existing plant to a small footprint treatment technology as presented in Section 6, relocating headworks and EQ to the old plant site across the street, or evaluating a new plant site downstream. A new site downstream should be located close to the existing site to minimize conveyance costs but should be located above the 100 year flood plain and provide room for future facility expansion.

A Treatment Master Plan is recommended to further investigate the most efficient way forward. The Treatment Master Plan should evaluate treatment technology options, plant siting, and EQ storage.

Appendix A



State-Point Analysis
Black & Veatch Corporation
Water Technology Group

Peak	Design
Peak SLR (ppd/sf) 21.15	Design SLR 12.09
Peak SOR (gpd/sf) 940	Design SOR 380
Peak RAS SS (mg/L) 6,720	Design RAS SS 3,840

Takacs Modifications

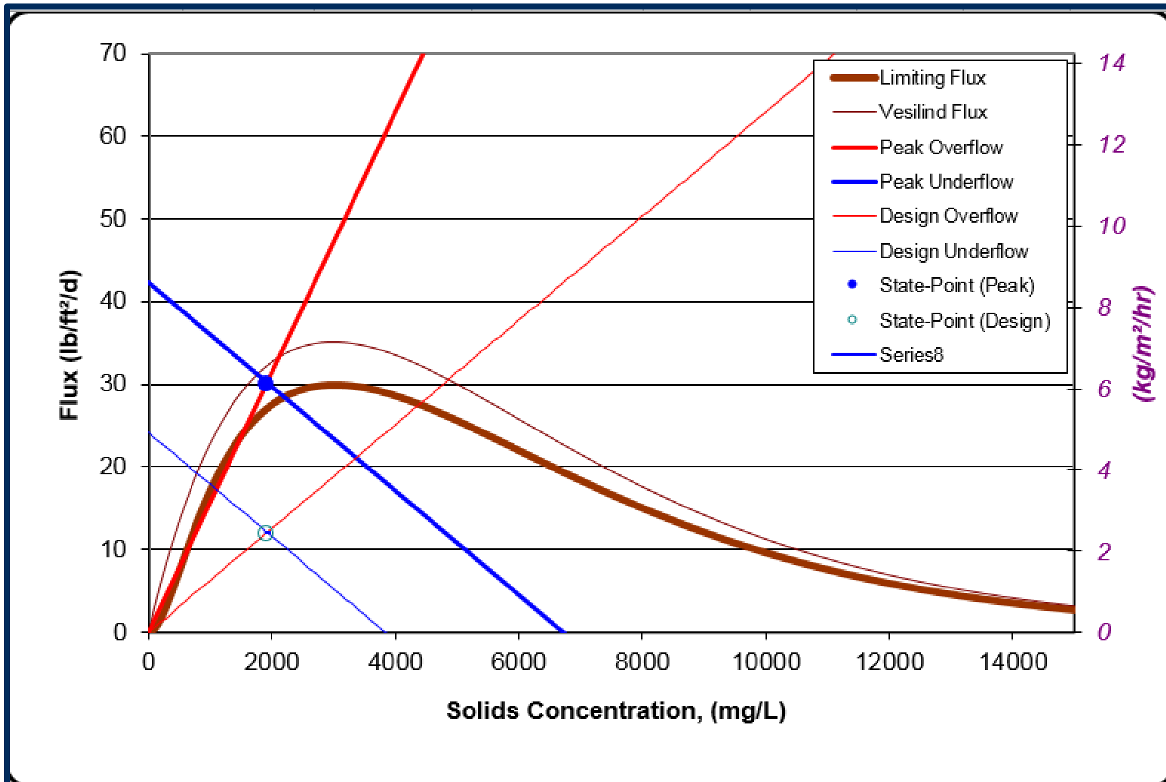
rfloc	0.0025	L/mg
Vo-factor	100	%
Xmin	20	mg/L
Vbnd	800	ft/d

Vesilind Settling Parameters **Ekama Factor** 85%

	Vo (ft/d)	k (L/mg)
Selected	511.80	0.000334
User Input		
Correlation	*511.80*	*0.000334*
based on SVI	*SVI*	***107***

Clarifiers Diameter (ft)	Number	SA (sf)	Q (MM) mgd	Peaking Factor	Q (PKDY) mgd	QRAS mgd	MLSS mg/L
90.00	2	*12720*	4.8	2.50	12.0	4.8	1920

Figure A-1: State Point Analysis – **Two Clarifiers, MLSS 1920 mg/L**, RAS 100%Q, SVI 90th percentile, Ekama safety factor 85%, Vesilind settling coefficients as developed by Diagger (1995). **Clarifier underloaded at both average and peak flows.**



State-Point Analysis
Black & Veatch Corporation
Water Technology Group

Peak SLR (ppd/sf)	Design SLR
42.30	24.17
Peak SOR (gpd/sf)	Design SOR
1890	750
Peak RAS SS (mg/L)	Design RAS SS
6,720	3,840

Takacs Modifications

rfloc	0.0025	L/mg
Vo-factor	100	%
Xmin	20	mg/L
Vbnd	800	ft/d

Vesilind Settling Parameters **Ekama Factor** 85%

	Vo ft/d	k L/mg
Selected	511.80	0.000334
User Input		
Correlation	*511.80*	*0.000334*
based on SVI	*SVI*	***107***

Clarifiers Diameter (ft)	Number	SA (sf)	Q (MM) mgd	Peaking Factor	Q (PKDY) mgd	QRAS mgd	MLSS mg/L
90.00	1	*6360*	4.8	2.50	12.0	4.8	1920

Figure A-2: State Point Analysis – **One Clarifier, MLSS 1920 mg/L**, RAS 100%Q, SVI 90th percentile, Ekama safety factor 85%, Vesilind settling coefficients as developed by Diagger (1995). **Clarifier Overloaded at peak flows.**

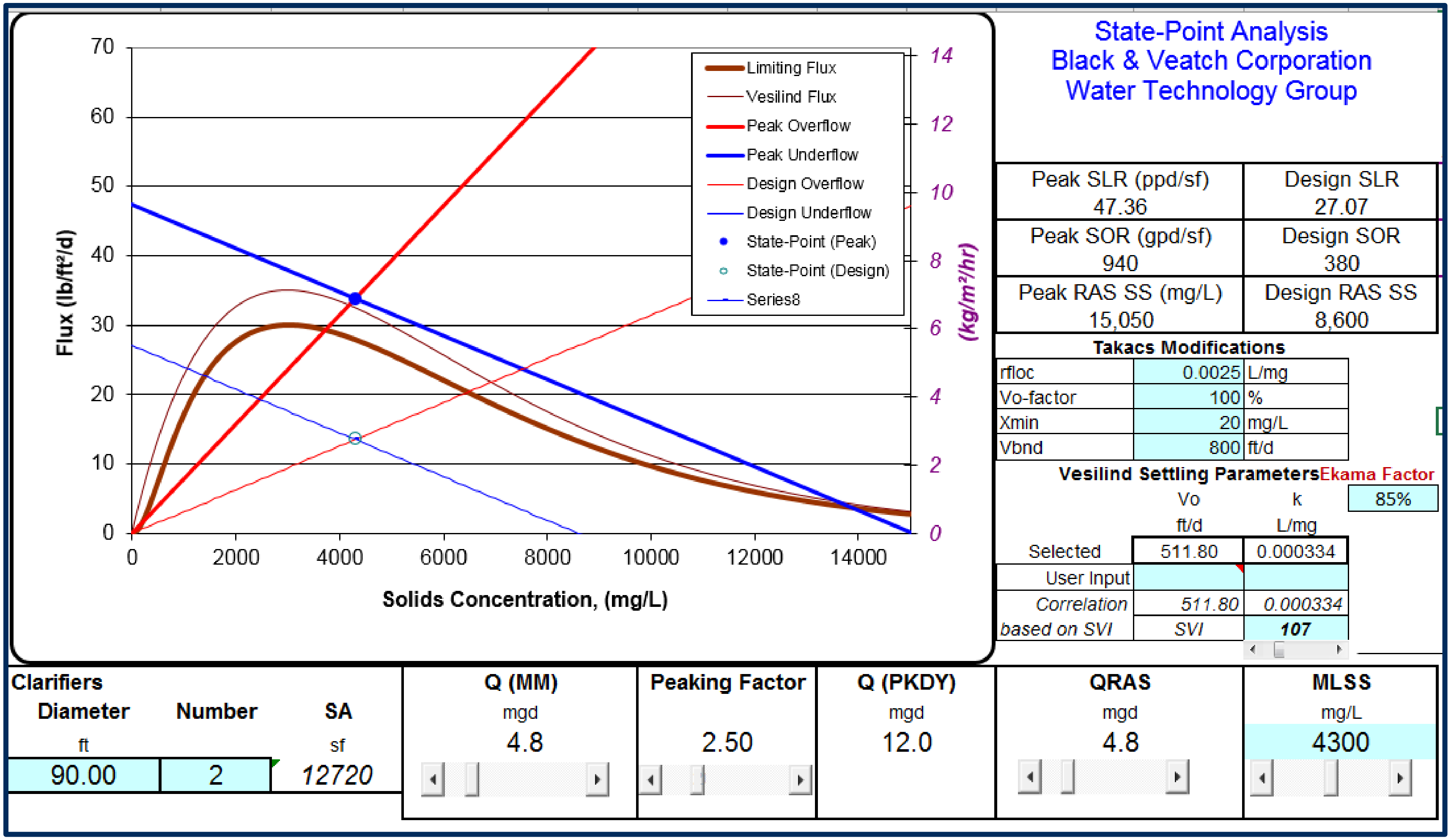


Figure A-3: State Point Analysis – **Two Clarifier, MLSS 4300 mg/L**, RAS 100%Q, SVI 90th percentile, Ekama safety factor 85%, Vesilind settling coefficients as developed by Diagger (1995). **Clarifiers Overloaded at peak flows.**

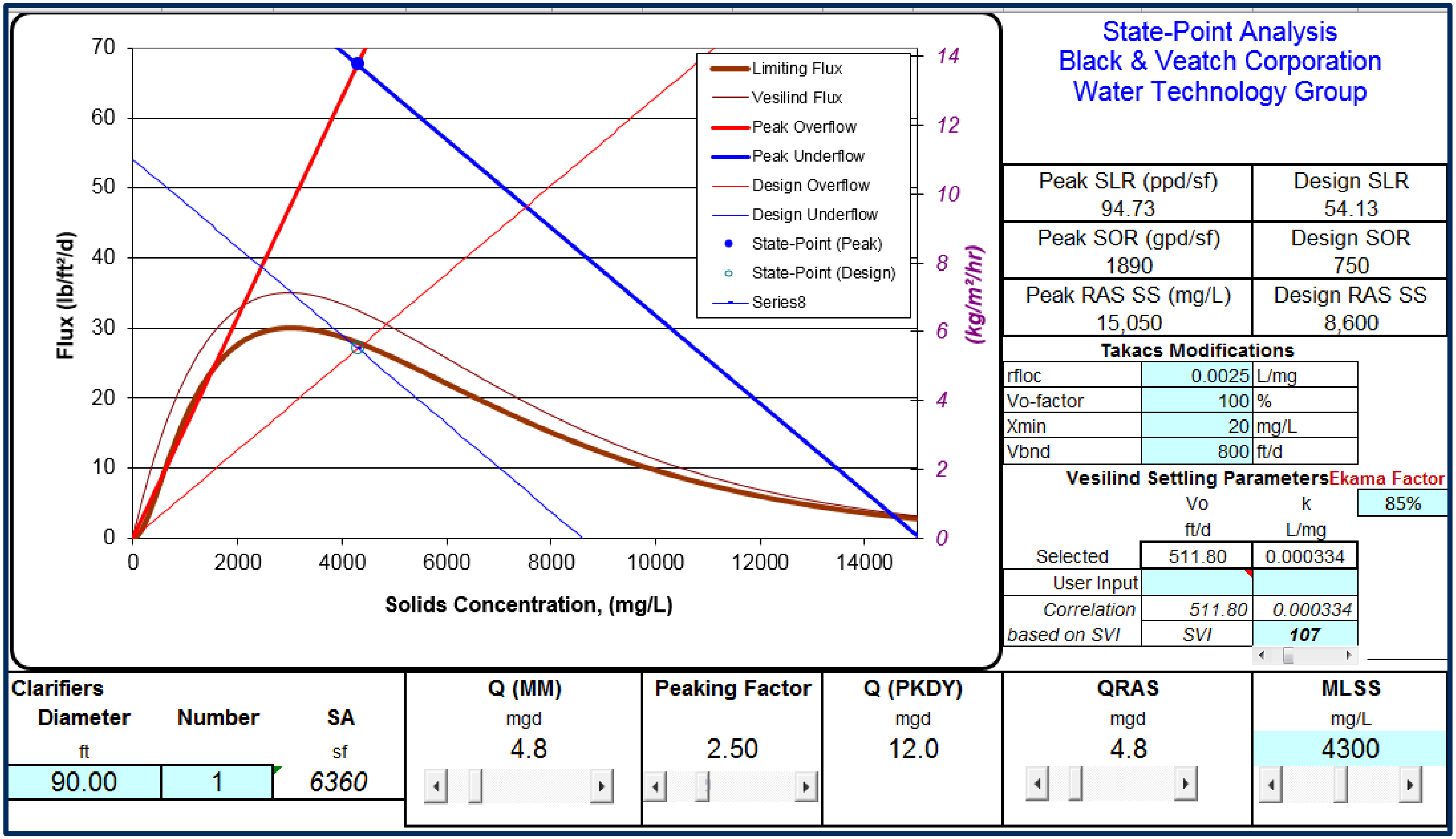


Figure A-4: State Point Analysis – **One Clarifier, MLSS 4300 mg/L**, RAS 100%Q, SVI 90th percentile, Ekama safety factor 85%, Vesilind settling coefficients as developed by Diagger (1995). **Clarifier Overloaded at peak flows.**