Fort Smith Massard WRF
Corrective Action Plan

Permit Number AR0021750

CAO LIS # 24-023

Utilities Department

City of Fort Smith, Arkansas

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Engineer's Certification

I hereby certify that this Ammonia Treatment Alternatives Technical Memorandum for the Fort Smith Massard Water Reclamation Facility (WRF) Assessment was prepared by Garver under my direct supervision for the City of Fort Smith, Arkansas.

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List of Acronyms

Acronym	Definition
AADF	Annual Average Daily Flow
AD	Average Day
aSRT	Aerobic Solids Retention Time
BFU	Ballasted Flocculation Unit
BNR	Biological Nutrient Removal
MGD	Million Gallons per Day
MM	Maximum Month
MOB	Mobile Organic Biofilm
OPCC	Opinion of Probable Construction Cost
PAA	Peracetic Acid
PFD	Process Flow Diagram
PHF	Peak Hour Flow
SRT	Solids Retention Time
TF	Trickling Filters
TM	technical memorandum
TM	Technical Memorandum
WRFW**RF**	Water Reclamation Facility

Executive Summary

The Massard Water Reclamation Facility (WRF) operates under an ammonia-nitrogen (ammonia-N) permit limit from May to October annually. In 2023, the plant faced nitrification challenges, leading to instances where the ammonia-N levels in the effluent exceeded the permit limits. This technical memorandum (TM) summarizes the measures taken to address these issues, outlines future action items, and reviews both historical data and treatment alternatives for the Massard WRF in accordance with the Consent Administrative Order (CAO) LIS 24-023 approved in February of 2024.

To immediately address the permit violations, city staff have taken immediate actions to address the nitrification issue including the following measures:

1. July to August 2023 – Conducted a thorough review of plant operations and testing to pinpoint concerns. Initiated the addition of microorganism supplements to enhance the mixed liquor biome and maintain nitrifying bacteria in the suspended-growth portion of the secondary treatment train. Secondary clarifier number 3 was cleaned by the City. Pretreatment Program surveyed the existing industries discharging to the Massard WRF for excess ammonia-N and found none.
2. November 2023 – Drained aeration basins to remove buildup in the bottom of the existing tankage and repaired leaks in the stainless-steel air piping between the blower facility and the diffused aeration system. Several diffusers were found to be damaged, and a large air leak was repaired. The removal of sediment buildup freed up volume in the existing aeration basins and is anticipated to aid in nitrification rates.
3. December 2023 – Cleaned the remaining secondary clarifiers.
4. February 2024 – During review of existing facilities and alternatives, city staff identified an immediate project that would allow for an increase in aeration volume and operating mixed liquor. This includes utilizing an older solids aeration tank for extended aeration volume and converting unused gravity thickener to a secondary clarifier. This project required some modification to existing site piping and structures but is not a modification to the plant requiring a permit modification. Below is a summary of the project:
    a. Flow from the aeration tank will continue to the clarifier splitter box.
    b. A portion of the flow in the splitter box is being routed via an existing gate (to be removed) to the additional aeration tank adjacent to the splitter box. This side stream will allow for additional aeration time, giving nitrifying bacteria more time to remove ammonia.
    c. The flow will then be routed back into the splitter box and can be distributed to Clarifier 3 and the converted gravity thickener which is now a new secondary clarifier.
    d. Although this is a short-term solution, it is viable that this extended aeration volume and operating mixed liquor concentration will provide additional capacity to aid in reducing ammonia in the effluent.
5. March 2024 - Replaced all membranes of fine bubble diffusers in the existing aeration basins.
6. April 2024 – City staff will begin feeding plant pro bio health supplement suitable for cold temperature growth to start populating nitrifying bacteria before the ammonia-N permit cycle

starts. This will help to boost the biological health of the microorganisms. Additionally, the plant staff will maintain an inventory of the pro bio supplement for the warmer months and continue enhancement of biomass by addition of pro bio heath supplement as needed.

City staff are also working to evaluate the ability to apply for a pilot program for nutrient trading between their two existing NPDES permitted facilities. Although nutrient trading is not currently an approved rule, the City of Fort Smith is ideally situated to pilot and document the viability of this program. By balancing the load between both of their facilities, they will not add additional nutrients to the stream, but will have flexibility in the operations until long-term solutions can be implemented.

Several ammonia-N treatment alternatives are screened in this TM and four alternatives are selected for detailed evaluation. All investigated alternatives focus on increasing the operational aerobic solids retention time (aSRT) to create a better environment for growth of nitrifying bacteria and consequently, provide more reliable nitrification. The alternatives evaluated in this TM include:

- Additional Aeration Basin
- Mobile Organic Biofilm (MOB)
- Ballasted Flocculation Unit (BFU)
- Gravity Thickener Retrofit

Table ES-1 shows a summary of the alternative's evaluation conducted in this TM. Advantages and disadvantages of each alternative together with their schedule to implement and long-term viability of the project. Viability is based on the cost of the project, the return on investment, and the ability to provide a long-term solution for the facility to maximize capital investments.

For a sustainable, long-term solution, we recommend the construction of two new aeration basins. This alternative allows the operations staff to decommission trickling filters that have surpassed their useful life. Furthermore, this aligns with the 2021 master plan recommendations. While this alternative has the highest OPCC, it poses the lowest risk for meeting the ammonia-N permit limits during average and peak loading conditions. In addition, the design and construction investments will be used to address the plants most pressing needs instead of a band-aid approach.

The plant staff is in the process of converting the existing abandoned gravity thickener into a fourth secondary clarifier. While this conversion may offer interim relief, it may pose operational challenges due to the shallow depth of this unit. Flow from the unit can be diverted to the head of the plant should a process upset occur. Hence, the additional aeration basin alternative is the recommended long term and most viable long-term solution.

Table ES-1: Summary of Treatment Alternatives Evaluation

Alternative	Advantages	Disadvantages	Schedule	Viability
Construction of Two New Aeration Basins and Associated Blower Facility	• Aligns with the master plan recommendations • No chemical addition is needed • Minimal disruption of existing processes • Complete nitrification under max month loading conditions	• Highest capital costs • Longer design duration • Longer construction period • Cannot be in operational by next ammonia-N permit cycle	36 months	Yes
Implementation of Mobile Organic Biofilm (MOB)	• Shorter design and implementation duration • Not building additional basins	• High Capital Costs • Media should be added to the system routinely since it will degrade over time • Proprietary system with a few installations in the US • Only a short-term solution	16 months	No
Ballasted Flocculation Unit (BFU)	• Only operated during peak flows • Fits within long term plans for plant • Small footprint • Staff already familiar with technology • Minimal disruption of existing processes	• Requires addition of coagulants, polymer, and microsand • Partial biological treatment during peak flows • Does not meet effluent ammonia-N concentration target during peak flows, meeting weekly average ammonia-N limit may be challenging during high flow periods	20 months	No
Gravity Thickener Retrofitted to Aeration Basin	• Repurposes an existing abandoned structure • Minimal construction • May be operational by next permit cycle • Lowest capital costs	• May not provide sufficient SRT for ammonia removal during max month/increased loading conditions • Higher risk since the condition of existing piping that is to be repurposed is unknown • Only a short-term solution, construction of additional aeration basins still needed	9 months	Yes (Short Term solution only)

1.0 Introduction

The Massard WRF, owned, operated, and maintained by the City of Fort Smith Utilities Department, is located at 1609 9th St, Barling Arkansas. The plant has been facing consistent nitrification challenges and exceeded its ammonia-nitrogen permit limits on several occasions between May to October of 2023 when ammonia-N limits are active. The purpose of this technical memorandum (TM) is to evaluate historical data and several alternatives to improve the treatment capabilities at the Massard WRF prior to the implementation of the more comprehensive upgrades recommended in the most recent (2021) phasing study for the facility. The Massard WRF currently has a rated capacity of 10 million gallons per day (MGD) and a peak hour flow (PHF) capacity of 20 MGD. An aerial view of the Massard WRF can be found in Figure 1-1 below.

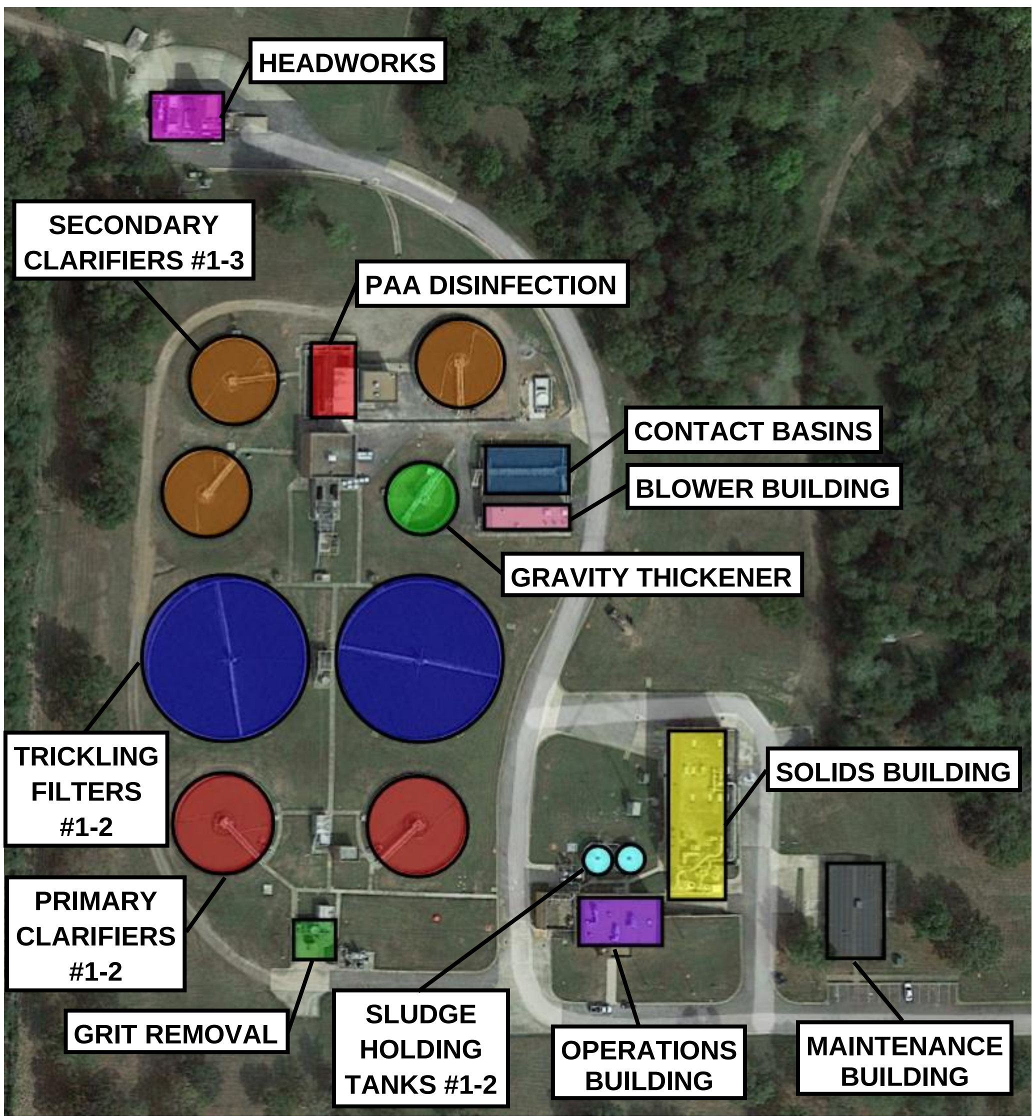

Figure 1-1: Aerial View of the Massard WRF

Figure 1-2 shows a schematic process flow diagram (PFD) of the existing plant. The Massard plant currently operates with the following facilities:

- Influent bar screens
- Influent pump station
- Grit removal system
- Primary clarifiers
- Trickling filters
- Aeration basins (configurable as conventional or contact stabilization)
- Secondary clarifiers
- Peracetic Acid (PAA) disinfection
- Sludge holding tanks
- Dewatering

The gravity thickener is not in operation but is illustrated on the PFD below.

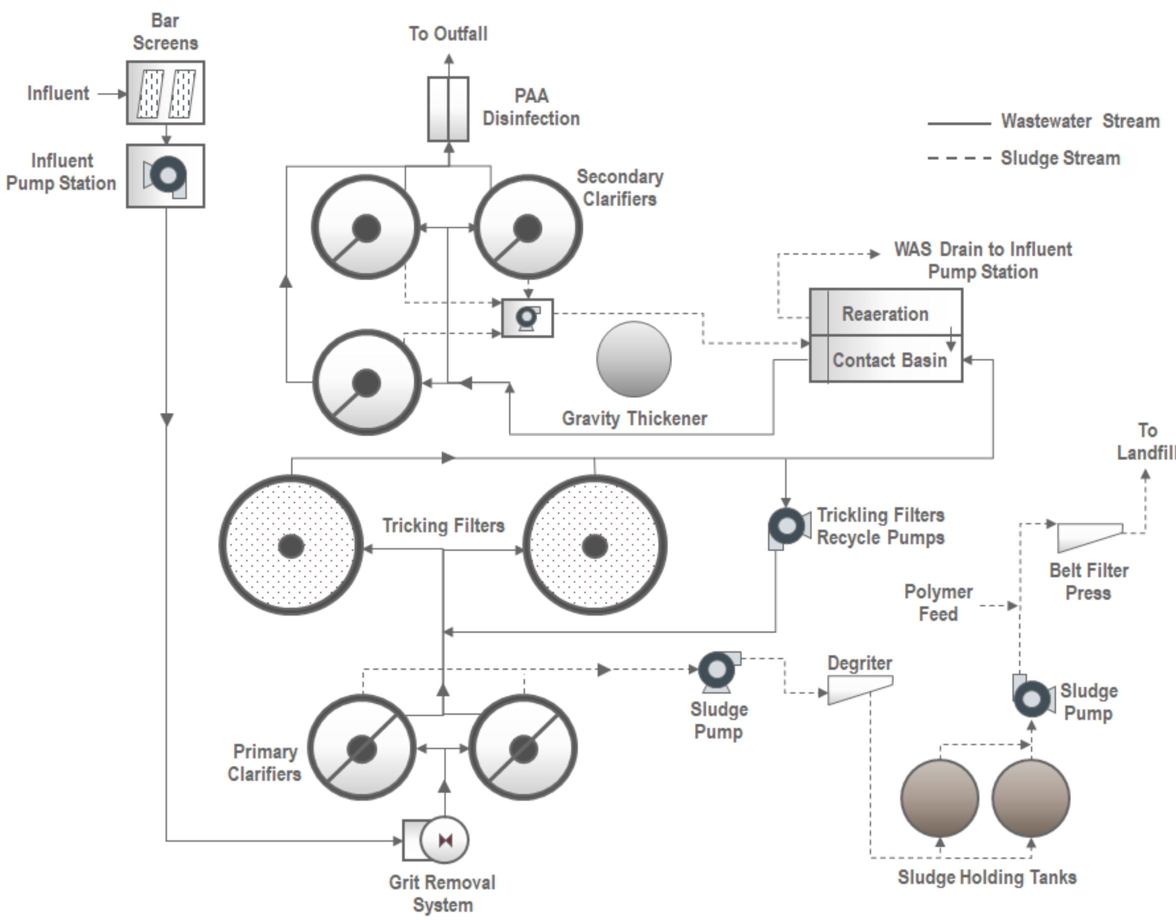

Figure 1-2: Massard WRF Existing Process Flow Diagram

2.0 Historical Data Review

The Fort Smith Massard WRF currently operates with primary clarifiers, trickling filters, aeration (contact) basins and Secondary Clarifiers. This section provides an overview of the historical data recorded at the facility.

2.1 Historical Influent Flow

The recorded influent wastewater flows entering the Massard WRF from 2013 to 2023 are illustrated in Figure 2-1 below. Daily data measurements, monthly running averages, and annual running averages are shown on the graph. The Massard WRF currently has a peak flow capacity of 20 MGD, matching the firm pumping capacity of the influent pump station. Daily influent flow rates are capped at 20 MGD during the observation period. The recent monthly average influent flow ranges from 5.5 to 15.5 MGD. The annual average influent flow ranges from 7 to 11 MGD. The maximum daily influent flow on record during this period is 19.92 MGD. There has been a slight decrease in influent flow in 2023 but the general flow pattern has remained the same.

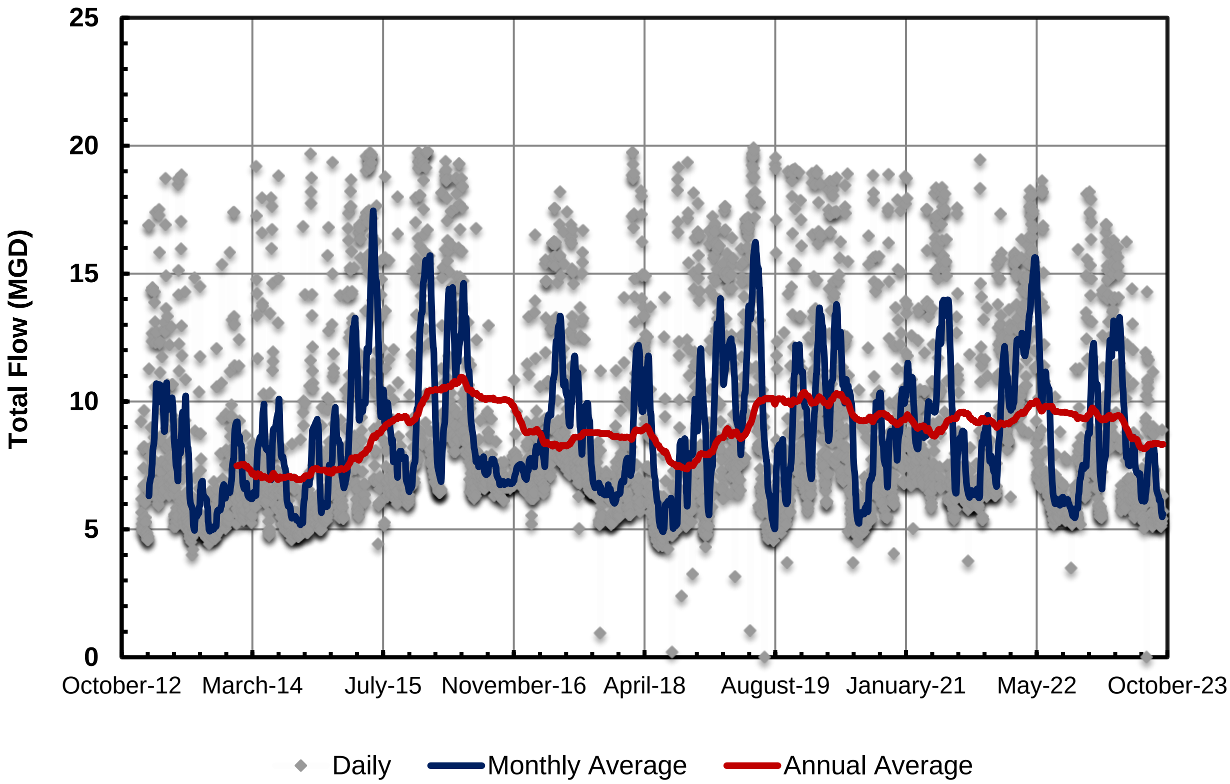

Figure 2-1: Historical Influent Flow at Massard WRF

2.2 Historical Influent Quality

The wastewater influent quality was also monitored by plant staff and analyzed in this TM during the 2013-2023 period. The parameters recorded and discussed here are BOD, TSS, Ammonia-N, and pH.

2.2.1 Historical BOD Loading

Historical influent BOD loadings entering the Massard WRF are shown in Figure 2-2. Daily loadings were observed to be as high as 60,000 lb/day in March 2016 and 55,000 in January 2022. The monthly average BOD loading ranges from 4,500 to 21,000 lb/day during the study period and 5,000 to 15,000 lb/day in recent years. The monthly average seems to be fairly stable throughout 2013-2023 except for some frequently higher values in 2016.

The annual average BOD loading has little change throughout this time period ranging from 5,700 to 14,000 lb/day. As shown below, there is a slight increase in the annual average and monthly average BOD loadings in recent months.

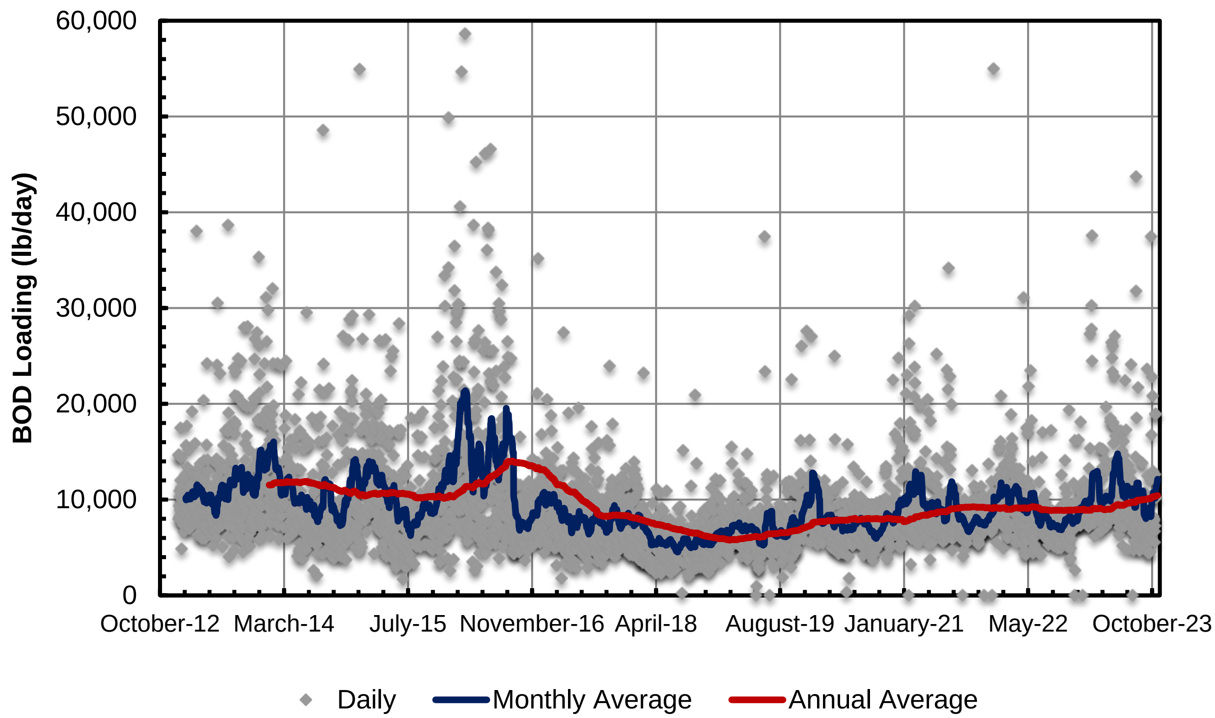

Figure 2-2: Massard WRF Influent BOD 2013-2023

2.2.2 Historical TSS Loading

Figure 2-3 presents the historical influent TSS loading entering the Massard WRF. Daily values, monthly rolling averages, and annual rolling averages are shown in the figure. Daily TSS data points are observed to be up to 71,500 lb/day. Monthly average TSS loadings range from 4,800 to 39,500 lb/day with peaks occurring in May – June 2020 and October 2023. Annual average TSS ranges from approximately 6,600 to 22,500 lb/day and has little change throughout 2020-2023. The graph shows a that the monthly and annual average TSS loadings have been fairly consistent in recent months.

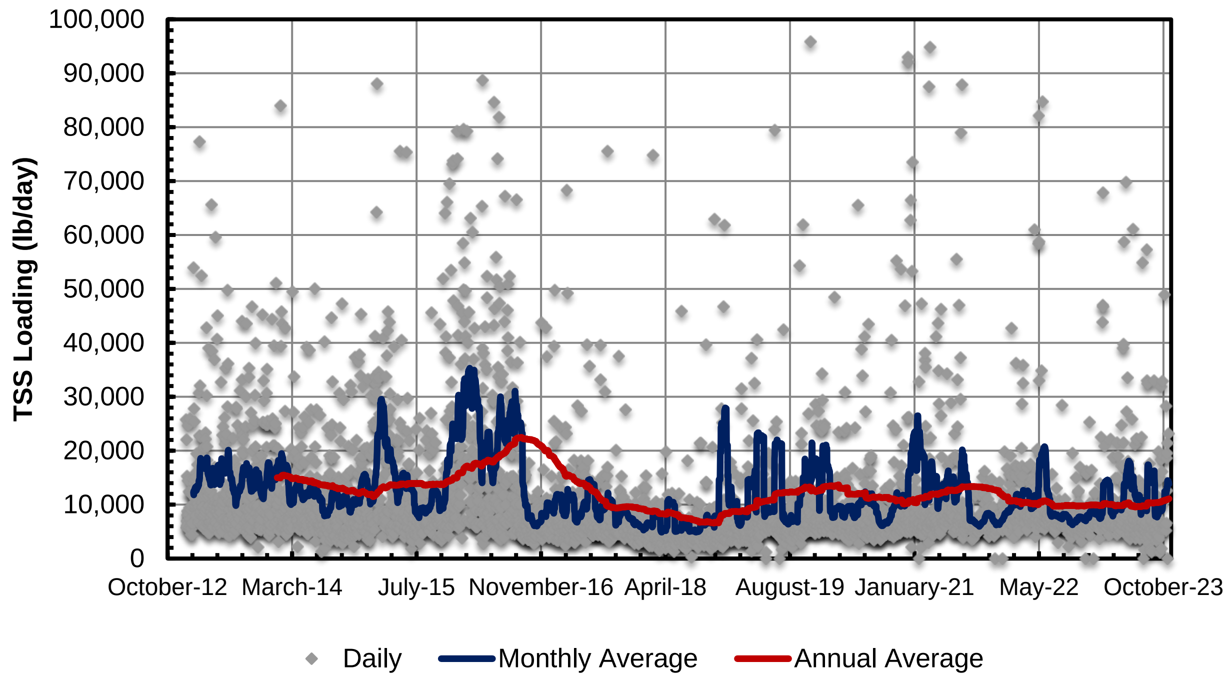

Figure 2-3: Massard WRF Influent TSS 2013-2023

2.2.3 Historical Ammonia-N Loading

Historical Ammonia loading is shown in the figures below. Figure 2-4 illustrates the loading from 2013-2018 that was studied in the master plan. The daily ammonia loading during this period ranges from approximately 600 to 2,600 lb/day. The annual average has gradually increased from 2013 to 2018. Figure 2-5 presents the most recent Ammonia data collected from May to September 2023. The daily loadings range from approximately 725 to 2,325 lb/day with a daily average of 1,350 lb/day. The ammonia loading has slightly increased from 2013 to 2023.

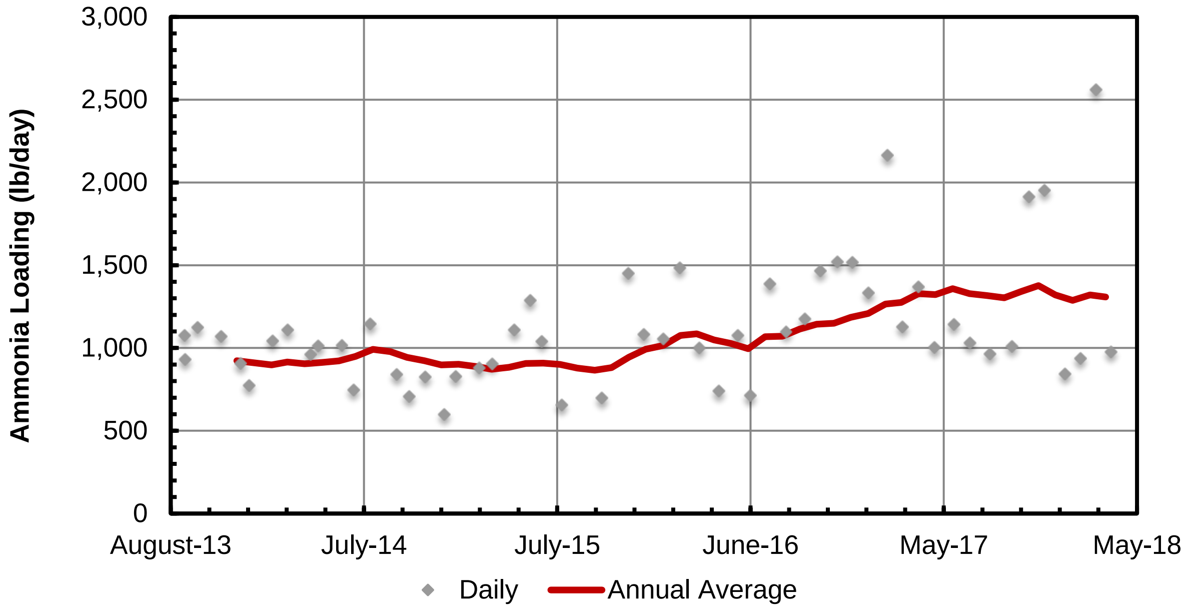

Figure 2-4: Massard WRF Influent Ammonia 2013-2018

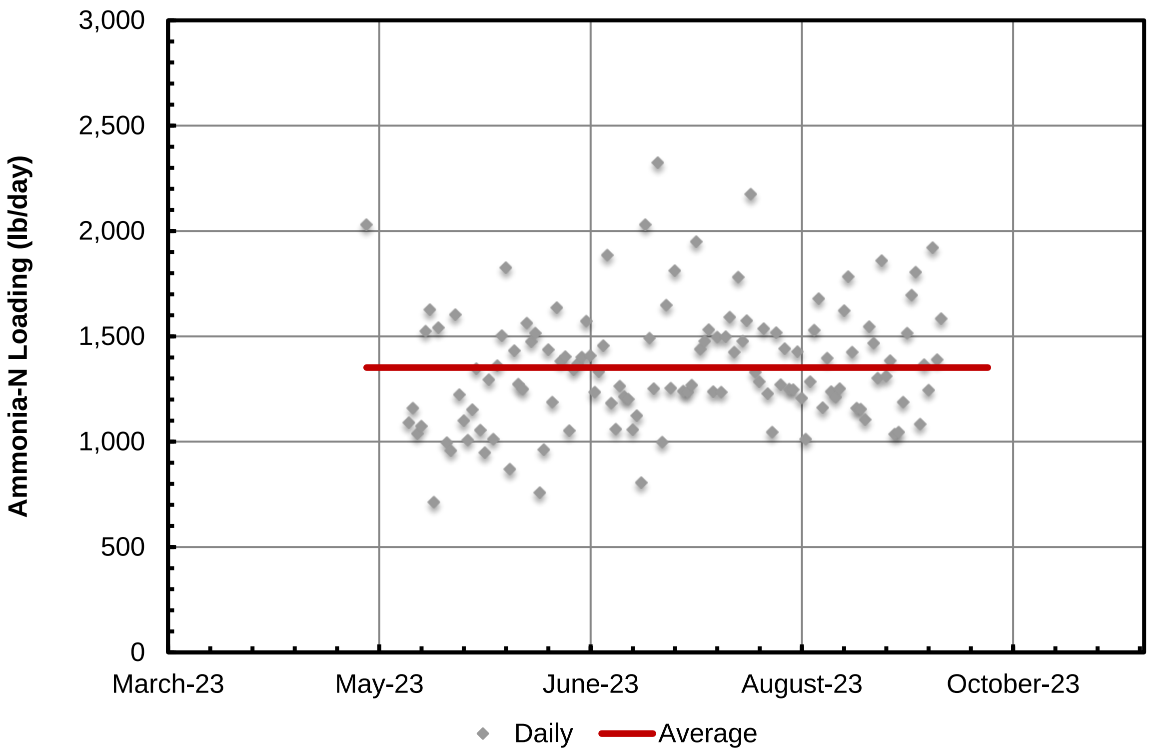

Figure 2-5: Massard WRF Historical Influent Ammonia 2023

2.2.4 Historical Influent pH

Figure 2-6 below presents the historical daily influent pH entering the Massard WRF. The pH ranges from approximately 5.8 to 8.9 with an average of 7.0. There seems to be a slight increase in influent pH in recent months but the general influent pH pattern remains the same.

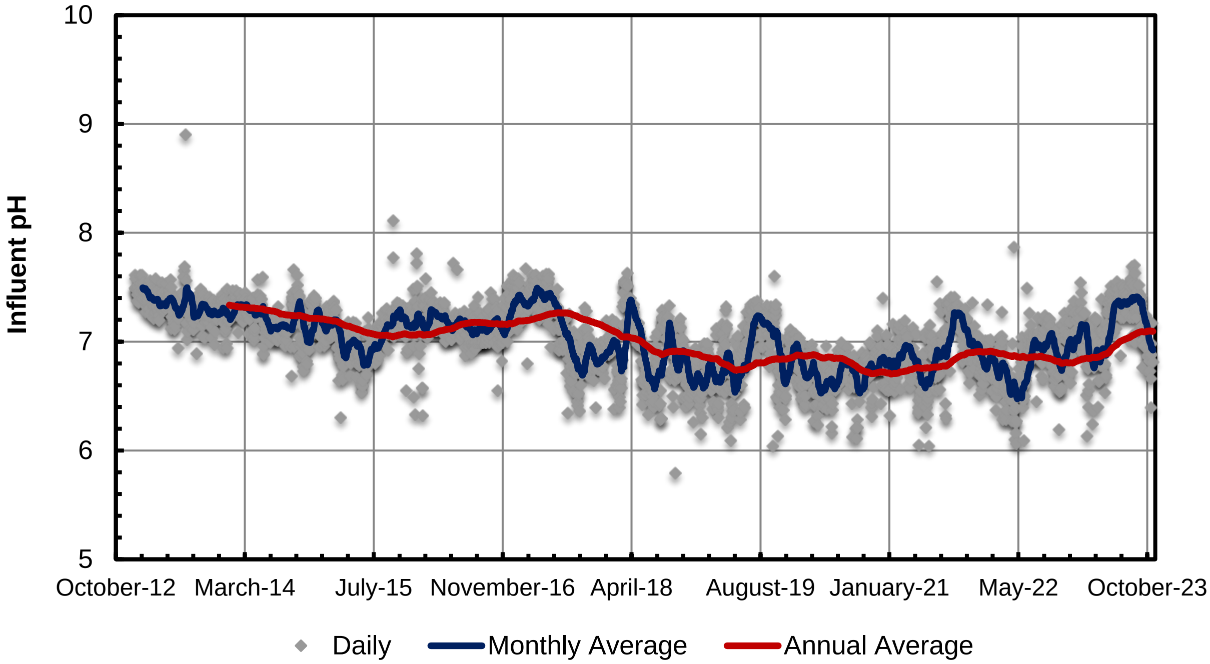

Figure 2-6: Historical Influent pH

2.2.5 Historical Influent Data Review Summary

The recorded data shows that the influent flow, TSS loadings, and pH typically follow the same general pattern from 2013 to 2023. Recent months show a slight decrease in flow. A slight increase in pH, annual BOD loadings, and monthly average BOD loadings have been observed in recent months. Influent ammonia has increased from 2013 to 2023 and has slightly increased in recent months.

2.3 Historical Effluent Quality

The Massard WRF operates under National Pollutant Discharge Elimination System (NPDES) permit number AR0021750 issued by Arkansas Department of Energy and Environment (ADEE) on December 31, 2014. Table 2-1 lists the permit limits for the Massard WRF.

Table 2-1: Massard WRF Effluent Permit Limits

Parameter[1]	Mass (lb/day)[2]	Concentration (mg/L Monthly Average	Concentration (mg/L) 7-day Average	Frequency	Sample Type
Flow	N/A	Report	Report	Once/day	Totalizing Meter
BOD (November-April)	2502	30	45	Once/Weekday	Composite
cBOD (May-October)	2085	25	37.5	Once/Weekday	Composite
TSS	2502	30	45	Once/Weekday	Composite
Ammonia-N (May-October)	417	5	7.5	Once/Weekday	Composite
Dissolved Oxygen (DO), Minimum	N/A	2	2	Once/Weekday	Grab
Fecal Coliform Bacteria (April-September)[3]	N/A	200	400	Once/Weekday	Grab
Fecal Coliform Bacteria (October-March)[3]	N/A	1,000	2,000	Once/Weekday	Grab
Peracetic Acid Residual (PAA)	N/A	2.0 (Inst. Max)		Once/Weekday	Grab
TP	Report	Report	Report	Once/Month	Composite
Nitrate+Nitrate as N	Report	Report	Report	Once/Month	Composite
pH	N/A	Min. 6.0	Max. 9.0	Once/Weekday	Grab
Cyanide, Total Recoverable	5.9	0.071	0.142	Once/Quarter	Grab

Table Notes:

1. Massard WRF has overflow reporting requirements.
2. Mass loadings are determined based on the average flow of 10 MGD.
3. Cfu/100mL.

2.3.1 Historical Effluent BOD and cBOD

Figure 2-7 illustrates the historical effluent BOD and cBOD concentrations. In order to meet permit limits, BOD concentrations are measured November to April and cBOD concentrations are measured May to October. The daily and weekly average permit limits for BOD and cBOD are shown as the stepped dashed lines in the figure. It is observed that the daily and weekly average BOD concentrations from November 2021 – May 2022 and November 2022-June 2023 are higher than concentrations recorded in 2013-2018. The weekly average effluent BOD and cBOD concentrations have approximately doubled in 2022 and 2023 compared to the previous data.

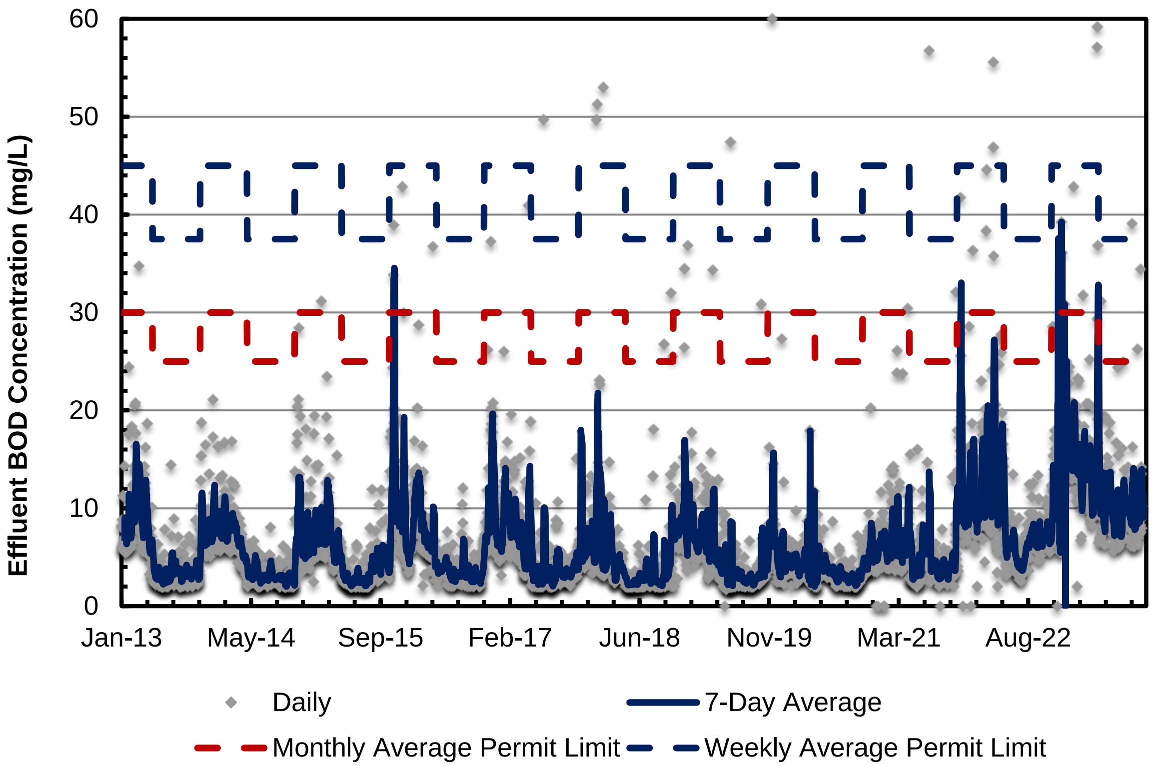

Figure 2-7: Massard WRF Effluent BOD and cBOD 2013-2023

Figure 2-8 shows the BOD and cBOD profile through the existing treatment stages at the Massard WRF. The date presented in these graphs is collected from August to October of 2023 on site. As seen, BOD and cBOD are removed significantly in each treatment stage. Average BOD concentration of approximately 42 mg/L has been measured for the trickling filter effluent stream.

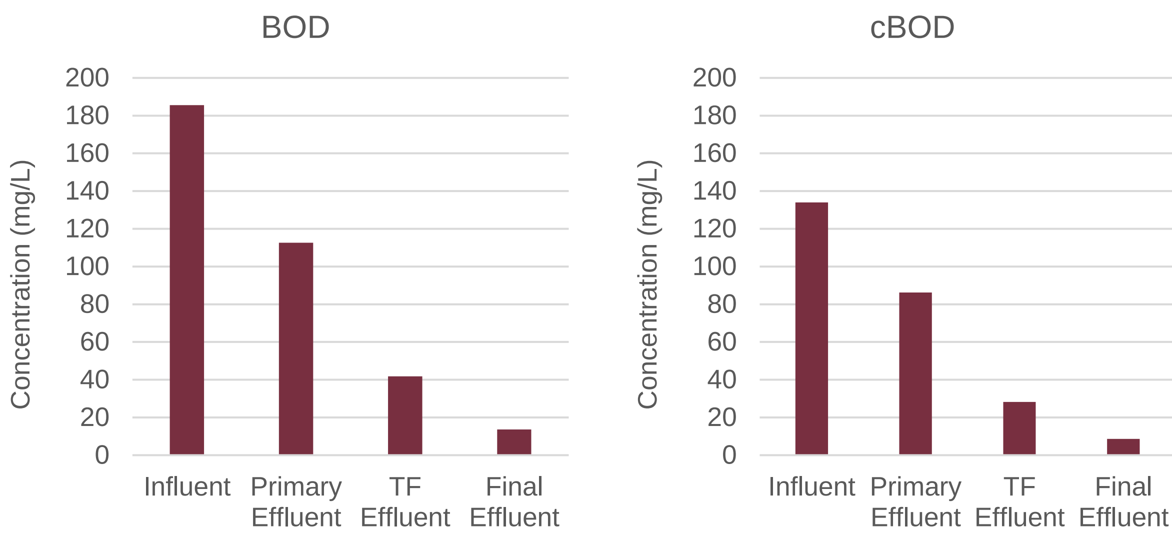

Figure 2-8: BOD and cBOD Profile

2.3.2 Historical Effluent TSS

The daily and weekly average effluent TSS concentrations are shown in Figure 2-9 below. Weekly average TSS concentrations range from 5 to 60 mg/L. The weekly average effluent TSS concentrations have increased in recent years. Weekly average permit exceedances occur in March 2022, December 2022, and May 2023.

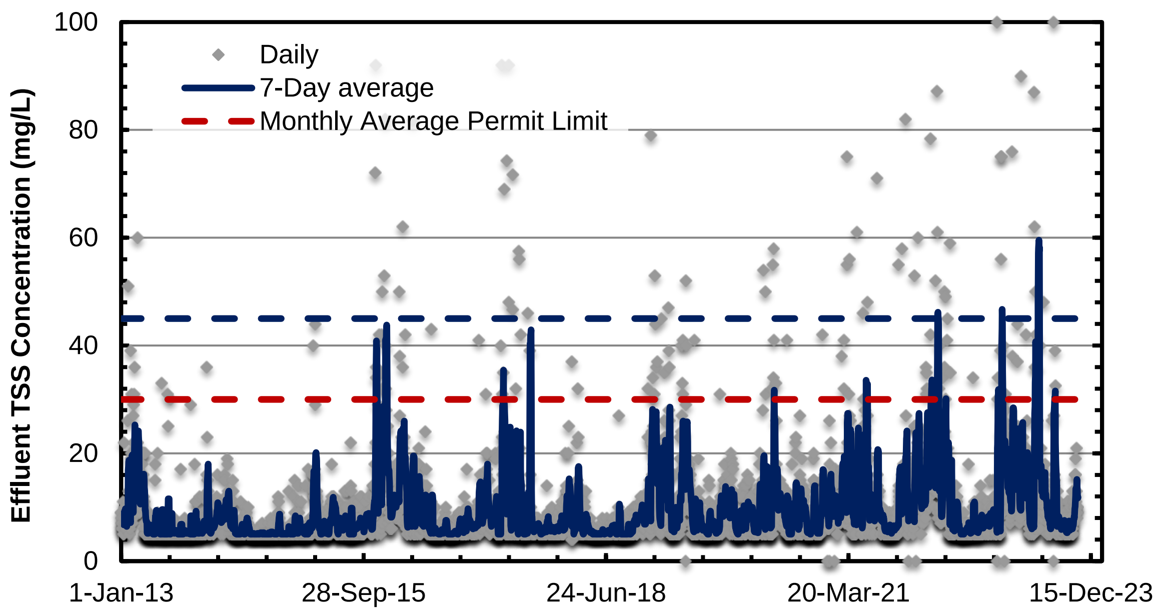

Figure 2-9: Massard WRF Effluent TSS 2013-2023

2.3.3 Historical Effluent Ammonia-N

Figure 2-10 presents the historical daily and 7-day average effluent ammonia-N concentration at the Massard WRF. Daily exceedances occur multiple times in every observation period. The chart shows no exceedances 2015-2019 but several since then in 2020, 2021, and 2023. This is due to the system's inability to effectively remove ammonia through the existing liquid treatment train.

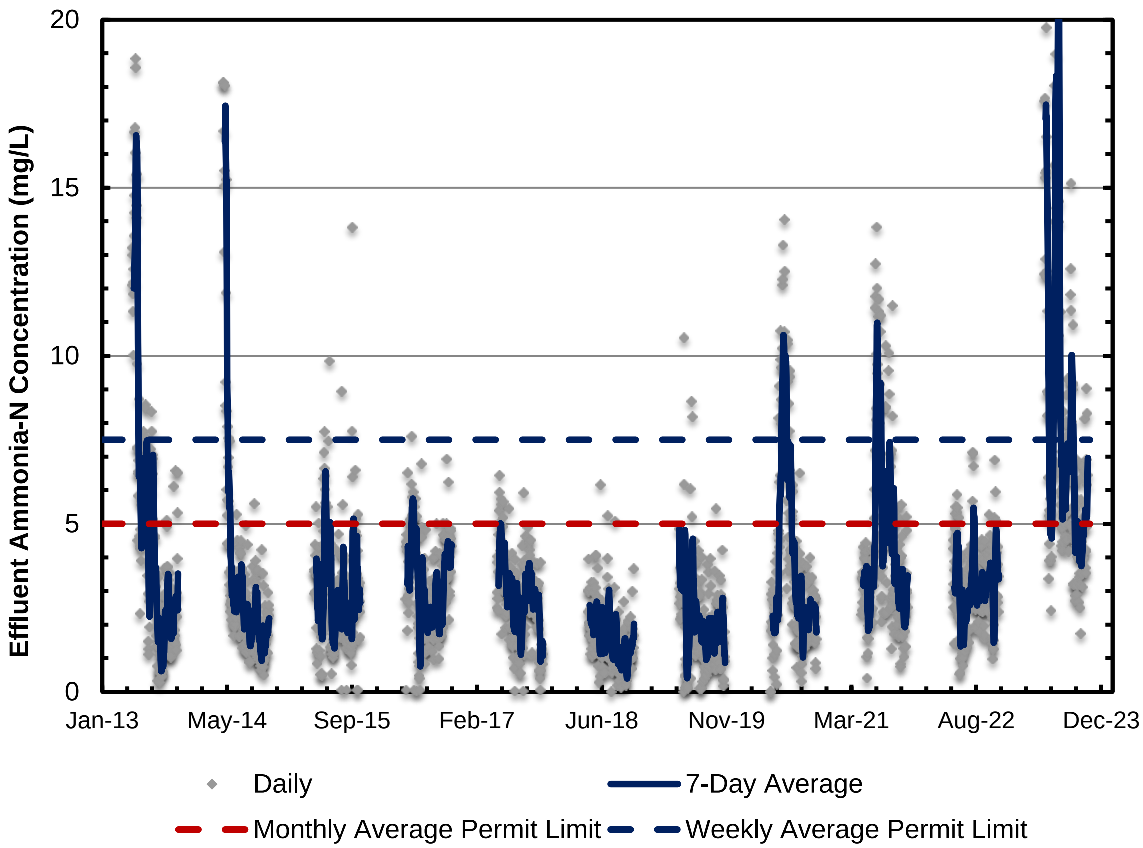

Figure 2-10: Massard WRF Effluent Ammonia-N 2013-2023

Ammonia is not effectively removed through the existing liquid treatment train. Figure 2-11 illustrates the ammonia removal profile through the plant during the period August - October 2023. Ammonia concentrations through the process are highly variable as shown in the large differences in the whiskers of each plot, as well as the outliers for each stage of treatment.

The primary clarifiers remove a small amount of ammonia due to the co-settling of primary sludge and WAS. The biofilm growth on the trickling filter media primarily consumes nitrogen through the biofilm media growth resulting in a small amount of ammonia removal. The vast majority of the ammonia removal occurs via nitrification in the aeration basins as shown in the difference between the trickling filter effluent average at approximately 25 mg/L to the final effluent average at approximately 5 mg/L. Because nitrification is essentially an "all or none" type process, any effluent ammonia-N concentration greater than about 2 mg/L indicates an unstable and therefore unreliable process. This kind of nitrification process instability is evident over most of the data period shown in Figure 2-10 and has become even more clear in 2023.

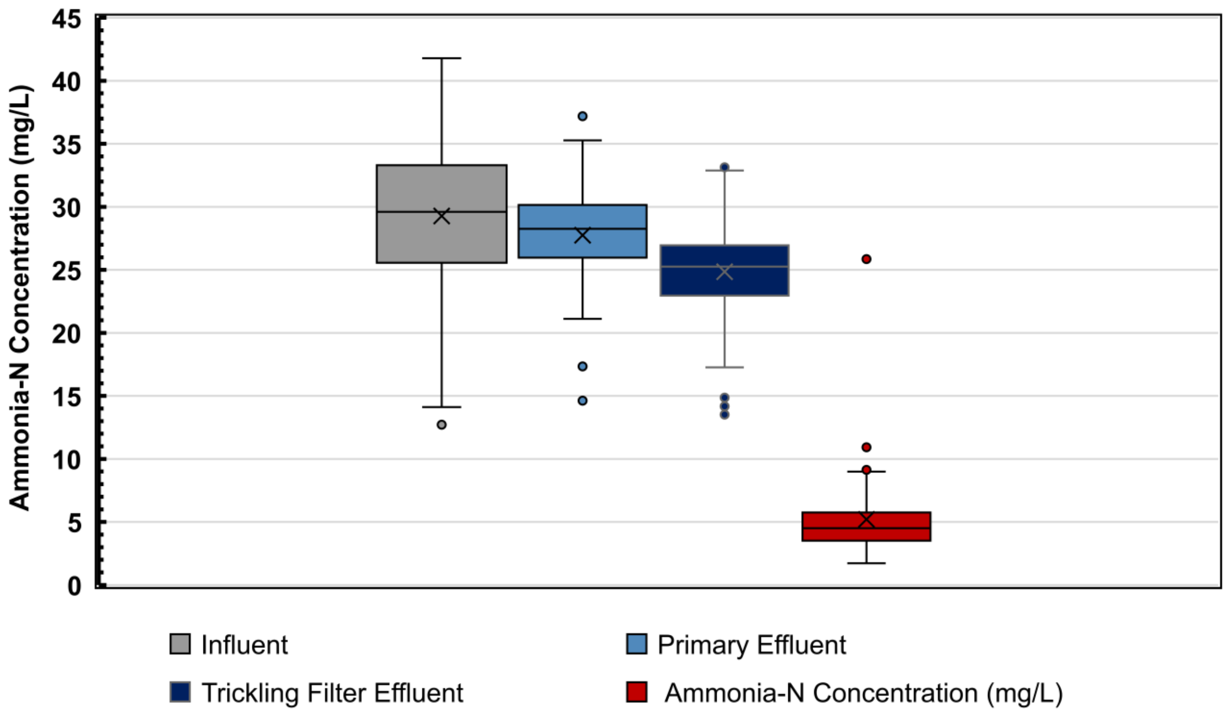

Figure 2-11: Ammonia Concentration Profile Throughout Plant

2.3.4 Historical Effluent Temperature

Historical effluent temperature data is shown in Figure 2-12 below. Daily data points and 7-day average values are presented. Notably, during July-August each year, maximum effluent temperatures reach approximately 29.4°C (85°F), while minimum temperatures dip to about 7°C (45°F) in January-March. Of particular significance is the observation that in April, a crucial period for nitrifiers growth in preparation for meeting ammonia seasonal limits, the minimum 7-day average temperature is 14.8°C. These temperatures are downstream of the trickling filter process, where heat loss (or gain) is more pronounced than in other processes.

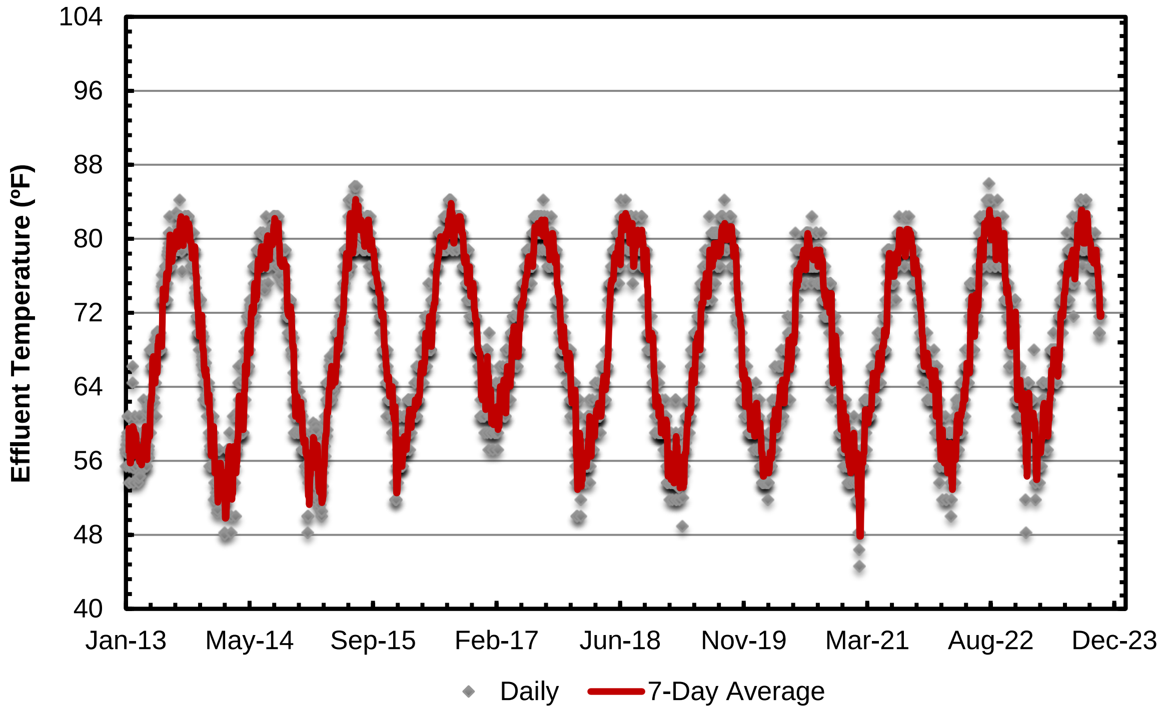

Figure 2-12: Historical Effluent Temperature

2.4 Historical Effluent Data Review Summary

The effluent data shows that BOD/cBOD and TSS have both increased over the 2022-2023 period. It is common for an increase in effluent BOD /cBOD to accompany an increase in effluent TSS because of the organic content of the TSS solids. The effluent ammonia has increased over the period 2020-2023 and is independent of the high effluent BOD or TSS. The high effluent ammonia indicates unstable nitrification, while the high effluent TSS (and the high BOD/cBOD that comes with it) indicates poor solids settleability. Both problems are frequently indicators of insufficient solids retention time (SRT) in the aeration basins.

3.0 Solids Retention Time Findings

The nitrification challenges at the Massard WRF stem from a combination of factors influencing the growth rate of nitrifying bacteria. Nitrification is a biological process that depends on the presence and activity of nitrifying bacteria, which tend to grow at a slower pace than the heterotrophic bacteria that are responsible for cBOD removal. The slower growth of nitrifiers means that a longer SRT is necessary to retain them in the process. They grow slowest when the water temperature is cold so the lowest temperature under which nitrification is needed defines the required minimum SRT.

Because the permit includes ammonia limits that take effect beginning each May, the nitrifying bacteria population must be established no later than April. The coldest water temperature in the historical period from April 1 to October 31 is 14.8 C. Figure 3-1 shows the relationship between ammonia concentration and SRT at 14.8 C and indicates that an SRT of 3.6 days is needed to achieve the 5 mg/L effluent ammonia-N required by the permit. However, it also shows that even a minor variance below the target SRT will result in a spike in ammonia concentration.

For example, at this temperature, a minor drift from an SRT of 3.6 days to an SRT of 3.3 days would result in an increase in effluent ammonia concentration from the 5 mg/L target to nearly almost 10 mg/L. Because aeration basin SRT is proportional to the aeration basin biomass quantity divided by the BOD loading to the aeration basins (and therefore the quantity of excess biomass produced there) small shifts in BOD removal at the trickling filters can easily impact the SRT to this degree.

Conversely, if targeting an SRT of 5 days or more, the SRT could drift down by 1.5 days before the effluent ammonia would exceed the limit. To maintain a longer SRT requires operating with more biomass. There are several alternatives that facilitate this by allowing operation at a higher mixed liquor concentration or by providing more aeration basin volume. Other alternatives seek to decrease the BOD loading to the aeration basins which will also increase the SRT. Note that in addition to stabilizing nitrification, operating at a higher SRT will also improve settleability which is frequently poor at low SRT.

To address these issues, the plant staff resort to adding PlantPro Bio-Health Supplement to help maintain nitrifiers in the MLSS. This routine supplementation has helped the process in past and confirms the lack of sufficient SRT for consistent nitrification.

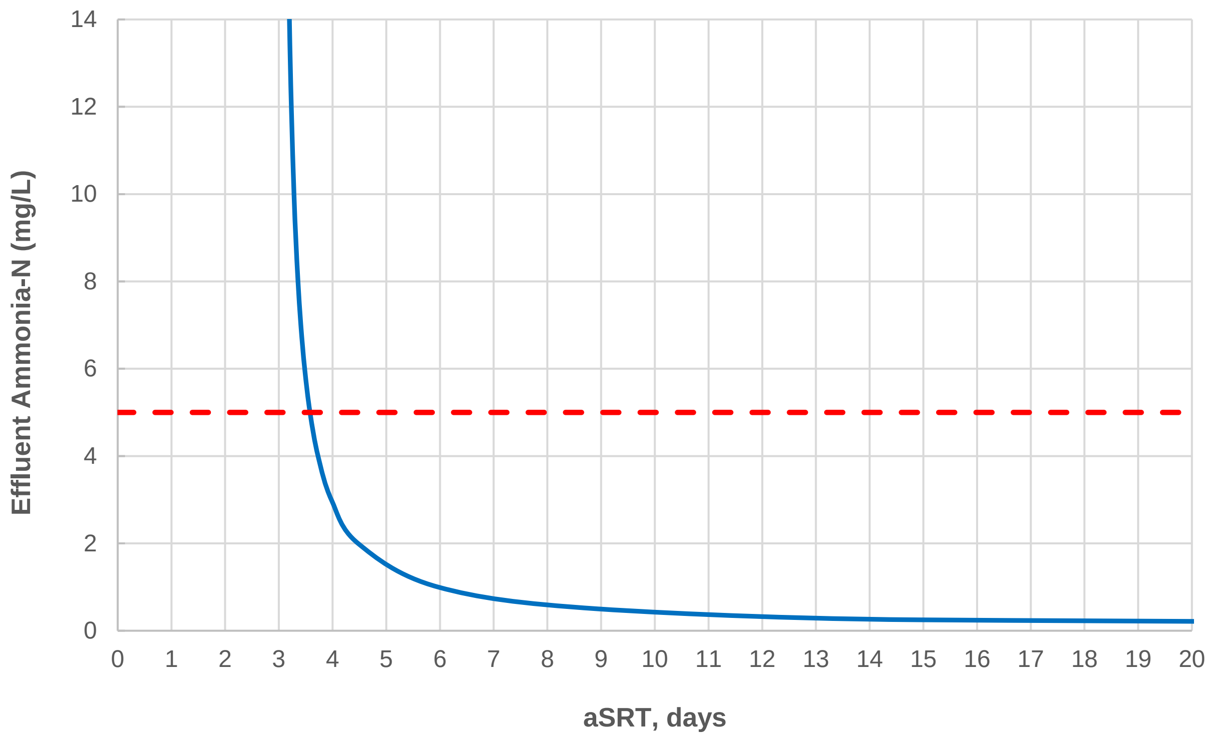

Figure 3-1: Aerobic SRT and Effluent Ammonia at 14.8 deg. C

4.0 Alternatives Screening

The proposed solutions outlined in this TM center around increasing the operating SRT, with options such as enhancing the operational MLSS concentration or augmenting aeration basin volume, aiming to create a more conducive environment for nitrifying bacteria growth and sustained nitrification performance. Several alternatives were screened for this study in a workshop between the project team and the City of Fort Smith staff:

- New aeration basin
  - This alternative consists of a construction of new aeration basins adjacent to the existing processes, fine bubble aeration, blowers, and new electrical equipment to provide power to the blowers and other ancillary equipment.
- Chemically enhanced primary treatment
  - The chemically enhanced primary treatment alternative includes constructing a chemical room, chemical feed system, and chemical storage tanks.
- Intermediate filtration
  - Trickling filter solids can be separated through the use of pile cloth media filtration. This alternative consists of pumps and piping for flow routing to filters as well as tank-mounted cloth media filter units.
- Integrated fixed film activated sludge
  - The existing contact basin can be converted into an integrated fixed film activated sludge (IFAS) system by adding plastic porous media to act as biofilm carriers to hold nitrifying bacteria in the basin. Screens must be installed at the discharge side of the contact basin to ensure media remains in the basin.
- Mobile organic biofilm (MOB)
  - This alternative requires the addition of MOB media to the aeration basins. The media creates heavier flocs and improves settleability in the secondary clarifiers. This enables the aeration basins to run at a higher MLSS concentration, thus increasing the operating SRT. The media is screened from the waste activated sludge (WAS) and returned to the activated sludge process.
- Ballasted flocculation unit
  - In the ballasted flocculation unit (BFU), there is coagulation, flocculation, and sedimentation. The process operates with microsand which enhances floc formation and acts as a ballast to aid in rapid settlement of coagulated material. During peak flows, some of the flow from the primary clarifiers will be diverted away from the trickling filters to the BFU for wet weather treatment. This enables the aeration basins to operate at higher MLSS concentration without increased risk of MLSS washout.
- Gravity thickener retrofit
  - This alternative includes demolition of the existing mechanism and retrofitting the structure into an additional aeration basin equipped with surface aerators. Pumps will be used to pump the mixed liquor from this retrofitted basin to the existing aeration basins.

A brief description of each alternative along with the advantages and disadvantages of each are shown in Table 4-1. Four alternatives are selected for further evaluation in this TM.

Table 4-1: Ammonia Treatment Alternatives Advantages and Disadvantages

Alternative	Advantages	Disadvantages	Further Evaluation
Additional Aeration Basin	✓ Fits within master plan recommendation ✓ Long-term solution ✓ No chemical addition is needed ✓ Minimal disruption of existing processes	× Higher capital costs × Longer design and construction duration × Cannot be in operation by next ammonia permit cycle (2025)	**Selected**
Mobile Organic Biofilm	✓ Large media surface area compared to IFAS ✓ Utilizes organic material ✓ Increased biological treatment capacity within the same volume	× Must screen MOB material out of WAS prior to wasting × Newer technology with low number of installs	**Selected**
Ballasted Flocculation Unit (BFU)	✓ Only operated during peak flows ✓ Fits within long term plans for plant ✓ Small footprint ✓ Familiar technology for staff	× Requires addition of coagulants, polymer, and microsand × Cannot be in operation by next ammonia permit cycle × Cannot guarantee effluent ammonia-N concentrations meet permit limits during peak flows	**Selected**
Gravity Thickener Retrofit	✓ Utilizes existing structure to provide additional aeration volume ✓ Minimal construction ✓ May be in operation by next permit cycle (2025)	× Short-term solution, does not fit within master plan recommendations × Will not provide sufficient SRT for ammonia removal at high loadings	**Selected**
Chemically Enhanced Primary Treatment	✓ Lower capital cost ✓ Can be in operation by next permit cycle for ammonia-N (2025)	× Potential primary sludge pumping issues due to long run between primary clarifiers and primary sludge pumps × Higher risk of failure due to less reference data on performance of CEPT for removal of BOD and TSS in co-settling primary clarifiers	Not Selected
Intermediate Filtration	✓ May be in operation by next ammonia permit cycle (2025)	× Higher operational costs if rented × Equipment does not fit in long term plans for the facility × Higher risk of success since the data shows low TSS concentration in trickling filter effluent flow	Not Selected
IFAS	✓ Better nitrification control without construction of additional basins	× Rags and other items passed through upstream processes can get tangled on discharge screen × Plastic media can degrade existing fine bubble diffusers	Not Selected

5.0 Basis of Evaluation

Conceptual designs, layouts, and opinion of probable construction cost (OPCC) developments are based on the criteria shown in this section of the TM. Design criteria provided by 10 State Standards (10SS) and industry-accepted design guidelines for municipal wastewater treatment facilities are used to complete the evaluations.

5.1 Design Criteria

Table 5-1 shows the flow and loading criteria used as the basis for evaluation in this TM. The average values flow and concentrations represent the recent historical data. The maximum month loadings will serve as the basis of capacity evaluation of the biological treatment processes. The peak hour flow (PHF) rate is used to determine flow diversion for the BFU unit for that alternative.

Table 5-1: Existing Flow and Loadings to the Massard WRF

	Flow (MGD)	BOD (mg/L)	BOD (lb/d)	TSS (mg/L)	TSS (lb/d)	NH_3-N (mg/L)	NH_3-N (mg/L)
Average Day	8.9	147	10,860	196	14,480	25	1,840
Max Month[1]	12.4	-	14,120	205	20,280	-	2,390
Peak Hour Flow	20	-					
Note: [1]Constituent max month loadings are based on peaking factors identified in the historical data review of the 2021 master plan project.							

5.2 Cost Estimating Criteria

Table 5-2 provides the contingencies, contractor overhead and profit, and mobilization costs assumed in the development of the estimated OPCCs. The following items are used as a baseline for preparation of OPCCs:

- Actual cost estimates provided by equipment manufacturers and vendors
- Previous cost estimates prepared by Garver
- Contractor bid tabulations from recent project deliveries

Table 5-2: Preliminary Cost Estimate Contingencies and Contractor Margins

Consideration	Assumption
Contingency	30%
Contractor Overhead & Profit	25%
Mobilization	5%

6.0 Ammonia Treatment Alternatives

After screening several alternatives in a workshop with the City of Fort Smith staff, it was determined that the study should focus on the following alternatives:

- Additional aeration basins (similar to master plan recommendation),
- Mobile organic biofilm (MOB),
- Ballasted flocculation unit (BFU),
- Gravity thickener retrofit.

6.1 Additional Aeration Basins

This alternative includes the construction of a new splitter box, blower building, electrical building and aeration basins with selector zones adjacent to the existing processes. Some ancillary equipment necessary with this option include a fine bubble aeration system, blowers, and new electrical equipment providing power to the blower.

The current contact basin and reaeration basin have a combined volume of 0.32 million gallons (MG). According to mass balance calculations, the theoretical volume of the new aeration basins should be 1.4 MG, meaning that the aeration basins should be greater than or equal to this volume to enable sufficient nitrification via adequate SRT. The additional aeration basin in this alternative is sized to replace the trickling filters and existing aeration basins. The additional volume is to increase the aerobic SRT to enable complete nitrification in the system.

Diffused air calculations were performed and the total oxygen requirement was calculated to be approximately 22,000 lb O_2 /day for average day flows and 30,750 lb O_2 /day for MM conditions. The required airflow for the additional aeration basins is roughly 5,750 standard cubic ft per minute (scfm) and 8,050 scfm for average day and max month conditions, respectively.

Including a safety factor of 1.35, the aeration system capacity will be rated for approximately 10,800 scfm. The system includes 3 blowers total: 2 duty and 1 standby. To provide sufficient aeration for MM conditions, the blowers are sized to be 300 hp each and provide up to 5,400 scfm each with the ability to turn down with variable frequency drives (VFDs). The main air piping header from the blower building to the aeration basins was estimated to be 24 inch diameter. The two basins will have three or four diffuser grids per basin with the air piping feeding drop legs for each grid.

Selector zones are considered prior to the aeration basins to help with maintaining good settling MLSS, enhance denitrification, and ease construction of future processes if total phosphorus or total nitrogen limits are imposed for the discharged effluent in the future. Some alkalinity will be recovered in the selector zones that will help to stabilize the pH in the final effluent. In the future, the Massard WRF will convert to a biological nutrient removal (BNR) process and the selector zones will already be in place when this switch occurs.

6.1.1 Process Flow Diagram

Figure 6-1 shows a schematic PFD of the plant with two additional aeration basins. The existing secondary treatment train can be decommissioned after implementation of these improvements.

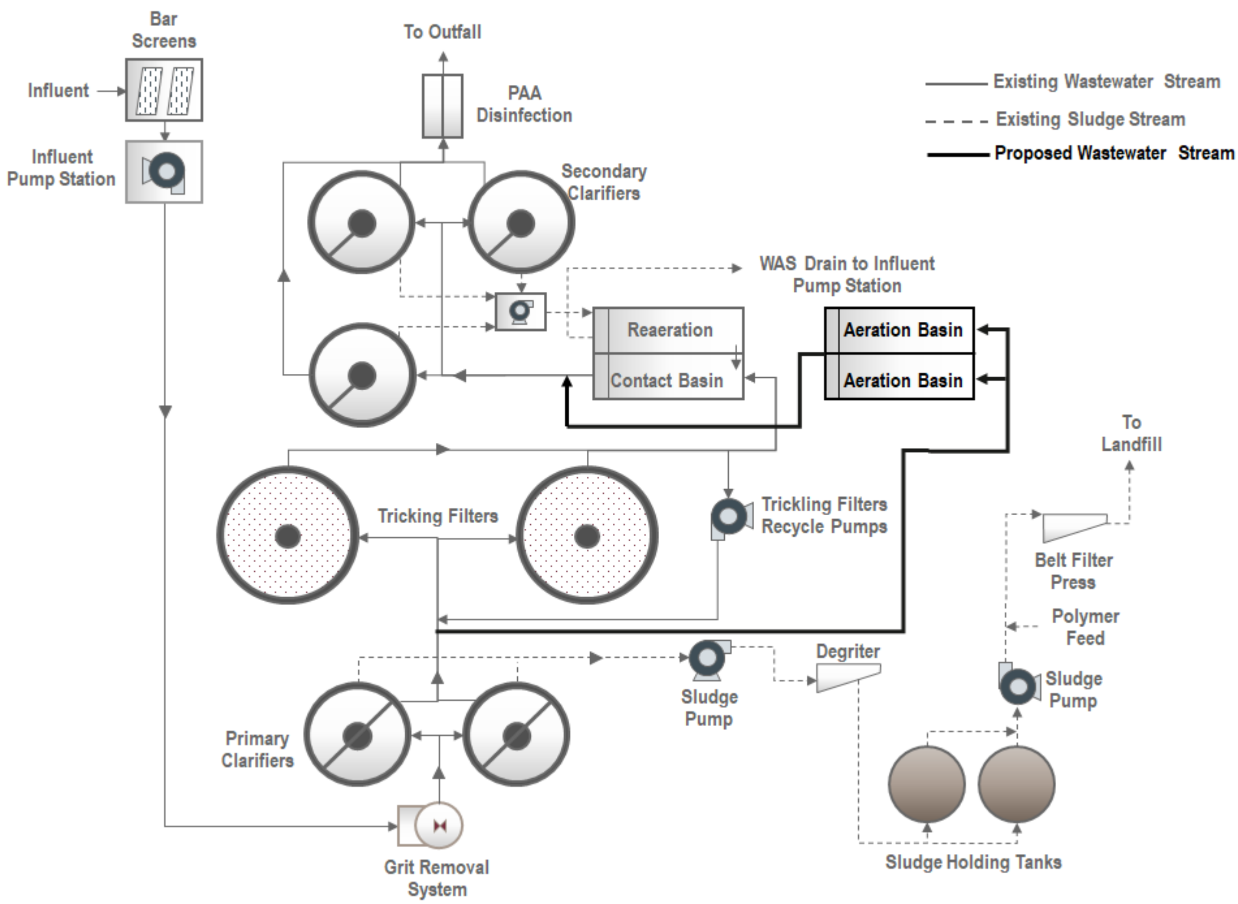

Figure 6-1: Additional Aeration Basin Process Flow Diagram

6.1.2 Site Layout

A preliminary site plan with the additional aeration basins and blower building is shown in Figure 6-2 below. As seen, a new electrical building is considered to house the electrical gear including the blowers VFDs.

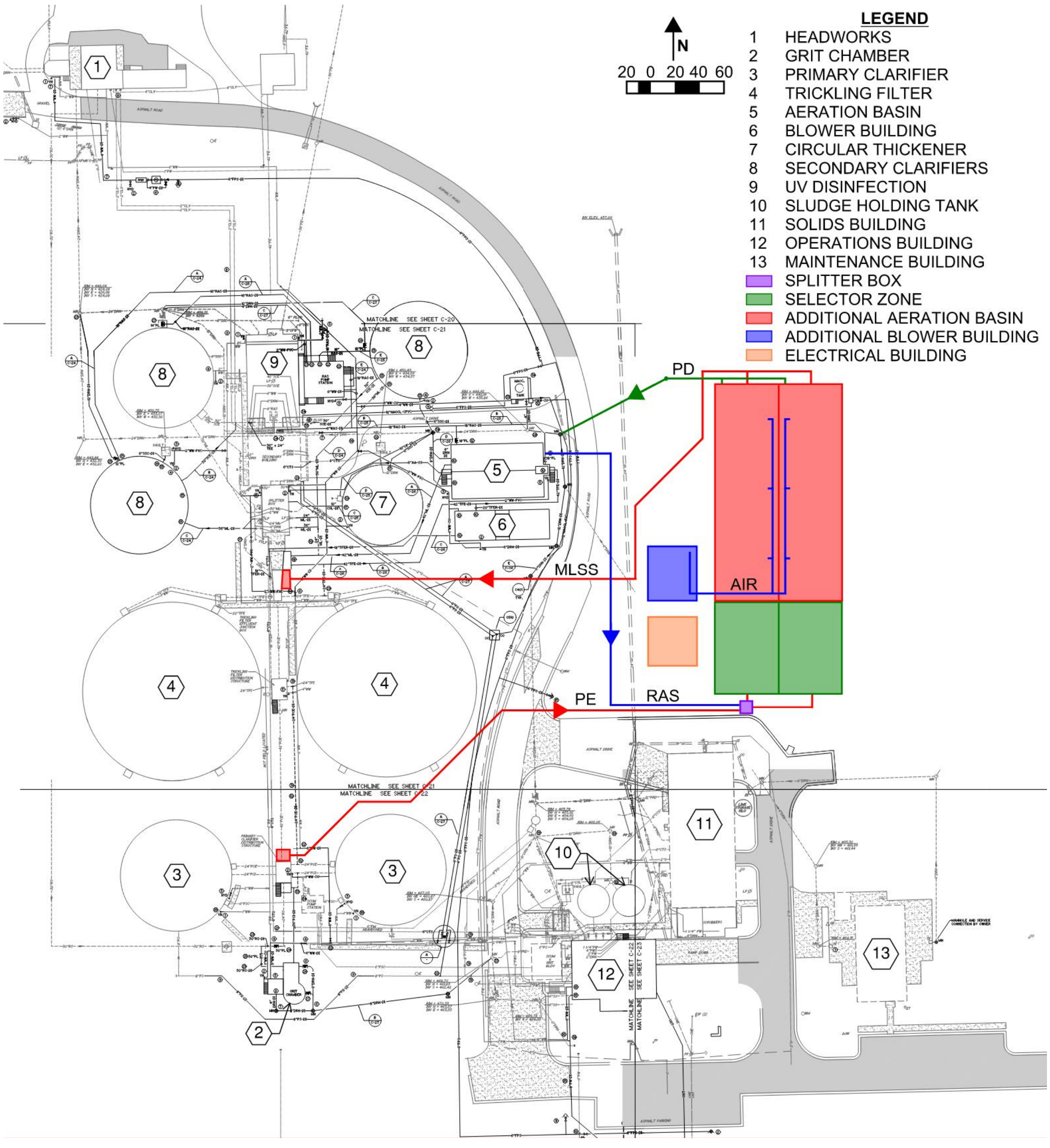

Figure 6-2: Additional Aeration Basin Site Layout

6.1.3 Cost Analysis

Table 6-1 shows a summary of the estimated OPCC for the additional aeration basins alternative. This table also shows a list of the facilities and elements considered in the OPCC.

Table 6-1: Additional Aeration Basin OPCC

Facility	Quantity	Element
Aeration Basins and Selector Zones	LS	Concrete, Stairs, Handrails
	LS	Air Piping
	LS	Excavation, Backfill, Stabilization, Grading
	LS	Fine Bubble Diffuser Grids
	4	Submersible Mixers
Blower Building	LS	Concrete slab and pads, Stairs
	LS	Air Piping
	LS	Excavation, Backfill, Stabilization, Grading
	4	Multi-stage Centrifugal Blowers
	LS	Canopy, Roll-up Door
Electrical Building	LS	Building
	LS	Electrical Gear and VFDs
	LS	Excavation, Backfill, Stabilization, Grading
Splitter Box	LS	Concrete, Stairs, Handrails
	2	Slide Gates
	LS	Excavation, Backfill, Stabilization, Grading
Electrical	LS	Site Electrical
Site Civil	LS	Yard Piping and Site Civil Elements
TOTAL OPCC		**$23,400,000**

6.2 Mobile Organic Biofilm (MOB)

This alternative includes the addition of MOB media to the aeration basins and installation of two rotary drum screen to screen the MOB media from WAS. The ballasted organic cellulosic plant material encourages growth of biofilm, including nitrifying bacteria, on the media. The media flows freely throughout the existing aeration basins and secondary clarifier. The MOB media settles at the secondary clarifier and is returned to the existing aeration basins via the existing RAS Pumps.

The proposed approach for this alternative incorporates a biomedia fill rate of 1.25% in the bioreactors, providing 250 m² of media surface area per cubic meter of bioreactor volume. This biomedia serves as a substratum for stratified biofilm growth, with mobile carriers retained by a rotary drum screen and redirected back to the aeration basins. The MOB System operates as a closed-loop process and requires an annual replenishment rate of approximately 5% of the initial fill fraction. Implementation can be carried out over several sludge ages, avoiding the interventions associated with other process solutions.

Figure 6-3 provides an illustration of how the MOB System can be implemented at the Massard WRF.

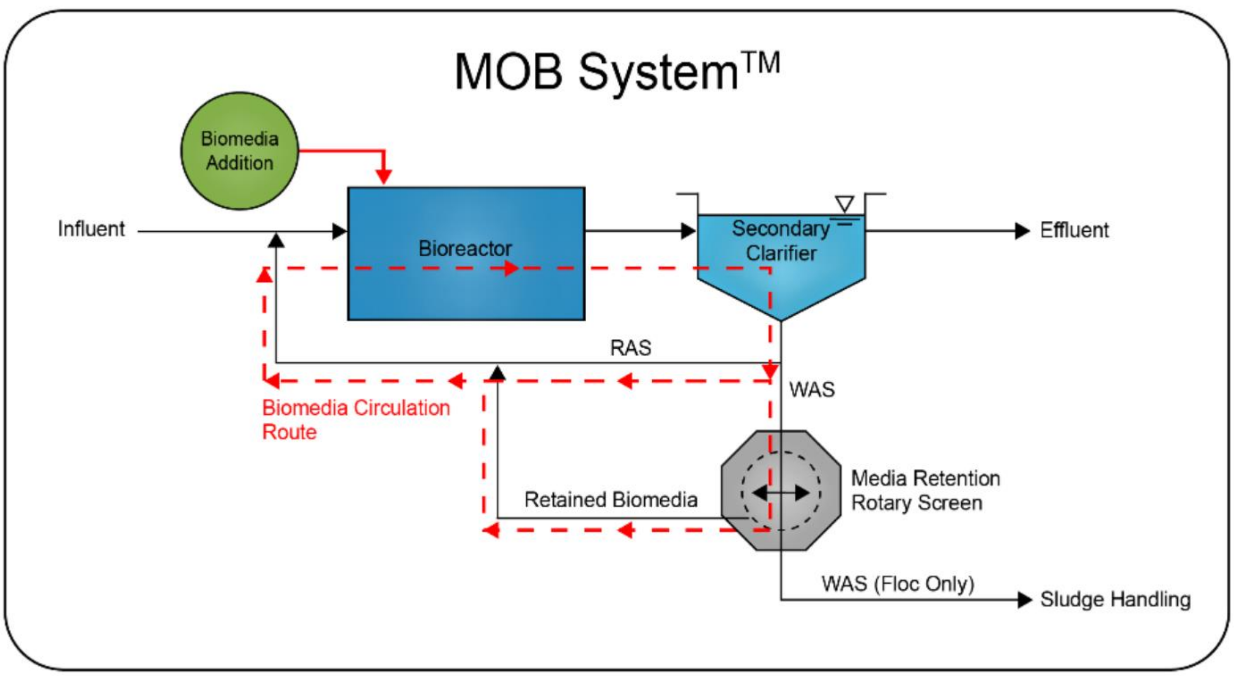

Figure 6-3: MOB System Conceptual Flow Diagram (NUVODA)

6.2.1 Process Flow Diagram

A schematic process flow diagram of the modified system with the MOB process is illustrated in Figure 6-4.

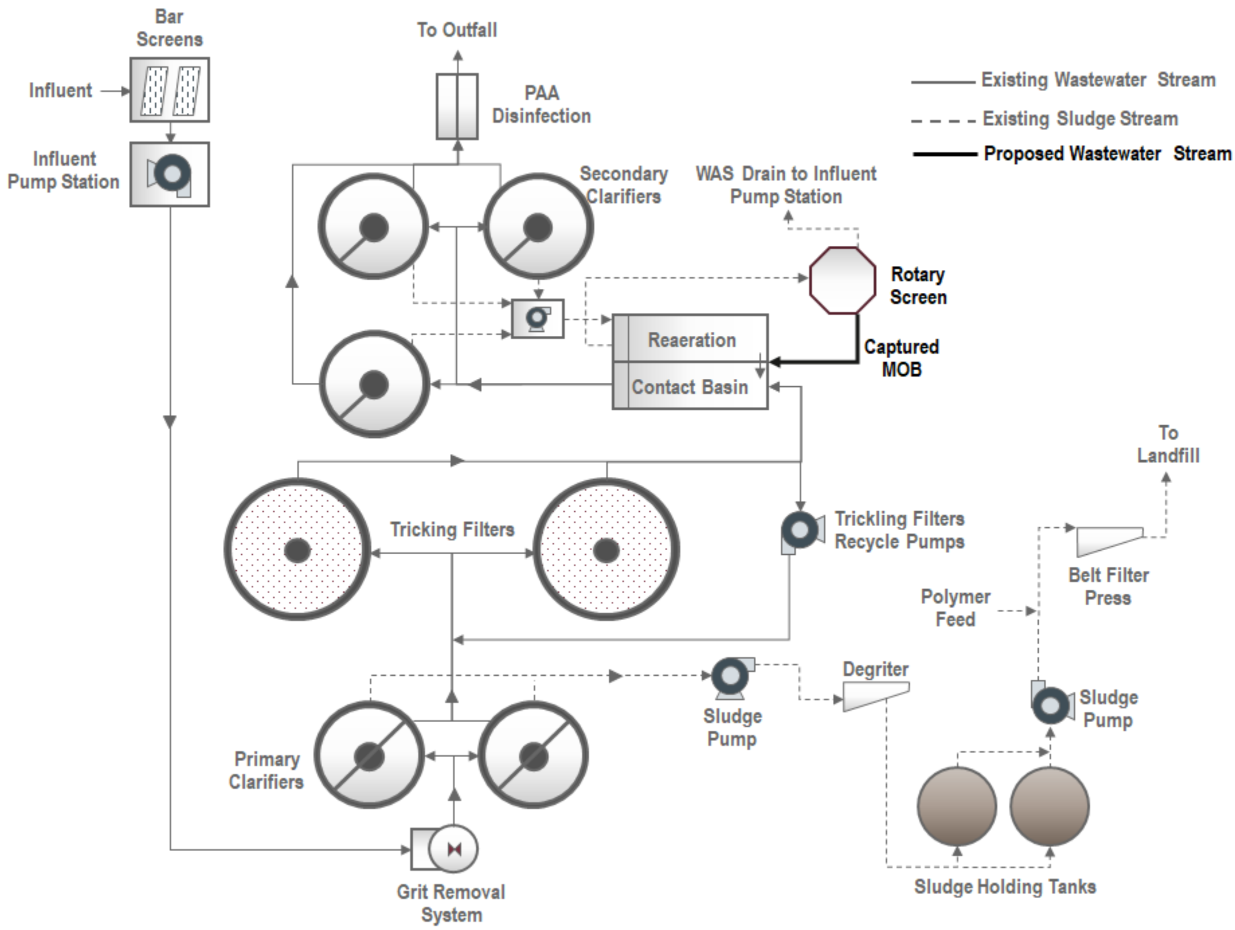

Figure 6-4: Mobile Organic Biofilm (MOB) Process Flow Diagram

6.2.2 Site Layout

Figure 6-5 shows the preliminary site plan of the plant with the MOB improvements. As seen, new pipes are needed to route the WAS stream to the new drum screens to capture the media. In some designs the drum screens are located on top of aeration basins. However, since this could impact the structural integrity of the existing contact basins, the drum screens are considered to be located on slab. New positive displacement pumps are considered for returning the captured media to the contact basins.

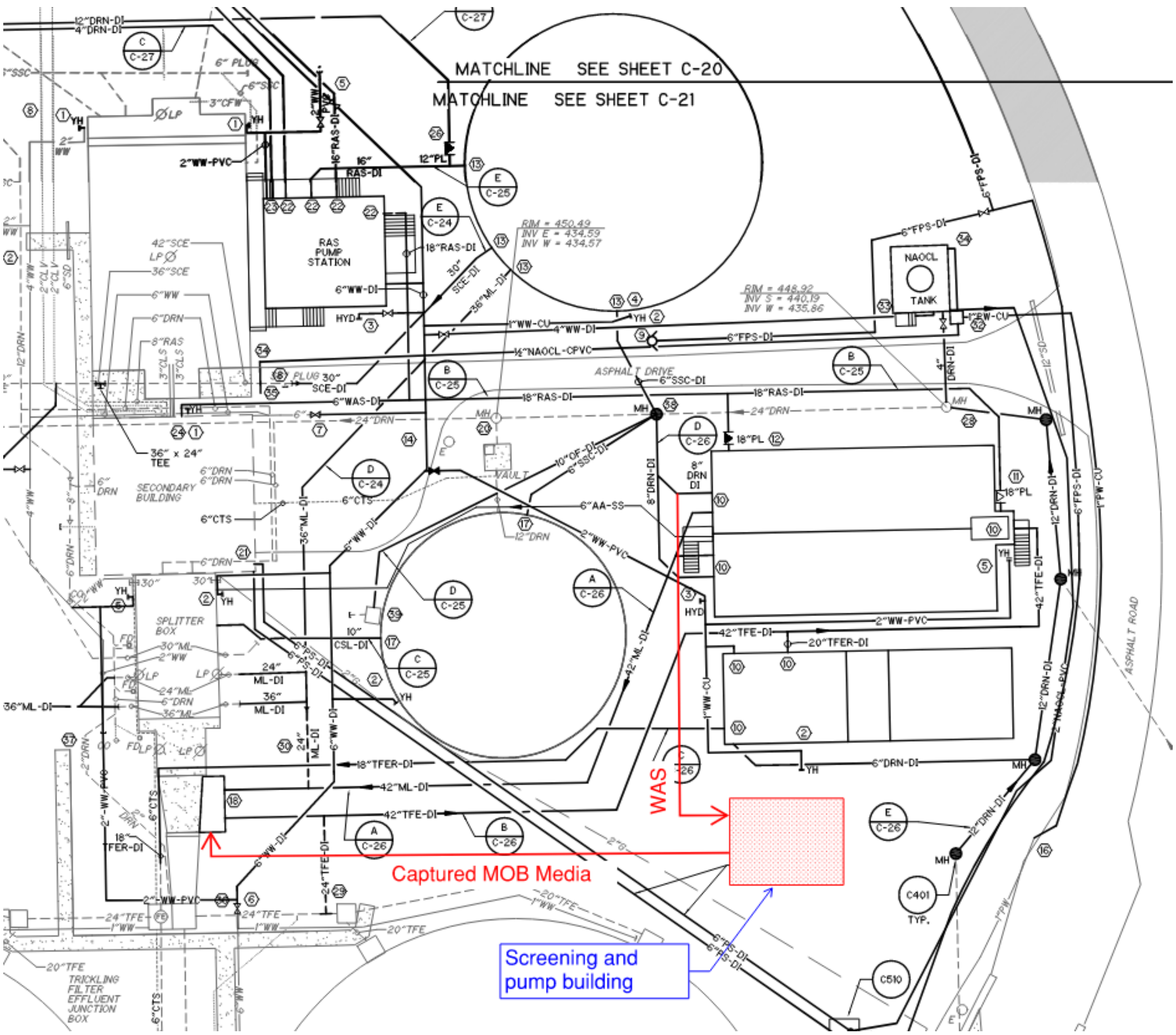

Figure 6-5: Mobile Organic Biofilm Site Layout

6.2.3 Cost Analysis

Table 6-2 The table below illustrates the OPCC estimate for the MOB alternative. A significant portion of the cost in this alternative is allocated to the proprietary MOB media. The estimate also encompasses rotary drum screens, essential for capturing the media before biomass wasting. Furthermore, the installation of new WAS pumps is required in this alternative to convey flow to the rotary drum thickeners. Electrical, yard piping, and site civil improvement costs are also factored into this estimate.

Table 6-2: Mobile Organic Biofilm OPCC

Facility	Quantity	Element
Mobile Organic Biofilm	LS	Mobile Organic Biofilm
	2 Duty + 1 Standby	Rotary Screen
Building to house the equipment	1	Metal building
Pumping	2	WAS Pumps
	2	Captured Media Pumps
Electrical	LS	Site Electrical
Site Civil	LS	Yard Piping and Site Civil Elements
TOTAL OPCC	**$7,400,000**	

6.3 Ballasted Flocculation Unit (BFU)

As highlighted in this TM, the key strategy to overcome nitrification challenges at the Massard WRF involves a primary focus on enhancing operational SRT. Presently, the system operates within a MLSS range of 3,500 to 4,000 mg/L. Elevating the MLSS concentration stands as a viable approach to extend the SRT. However, operational challenges have surfaced, notably poor settling and washout occurrences during peak flow conditions, hindering the ability of the operations staff to increase the MLSS within the current system.

With this alternative, the existing aeration basins will be operated at a higher MLSS concentration of approximately 6,000 mg/L. To prevent solids washout, a BFU will be installed on the existing site. During peak flows, the existing contact basin will be operated at a maximum of 10 MGD and the excess flows up to 10 MGD will be diverted to the new BFU. The secondary effluent will be blended with the BFU effluent prior to disinfection.

The BFU process is not equipped to remove ammonia. The combined effluent ammonia concentration from the BFU and the biological treatment train must be below the NPDES permit limit as stated in Table 2-1. Mass balance calculations were performed to determine the flow split ratio between the biological treatment train and the BFU train. The ratio in Table 6-3 is based on a peak hour flow capacity of 20 MGD.

Under peak conditions and sending 10 MGD to BFU, the combined final effluent ammonia-N concentration may be up to approximately 15 mg/L. Because the peak hour flow conditions do not last long, the plant may be able to catch up on ammonia-N removal and offset the high effluent concentrations. It is possible for the effluent to still meet 7-day average and monthly limits but it is not guaranteed. This is a risk to diverting excess flow to the BFU during high flow conditions.

Table 6-3: BFU and Biological Treatment Train Flow Split Ratio

Parameter	Unit	NH3-N
10 MGD Biological Treatment Train		
Influent Concentration	mg/L	25
Effluent Concentration	mg/L	4
10 MGD BFU		
Influent Concentration	mg/L	25
Effluent Concentration	mg/L	25
20 MGD Combined Effluent		
Combined Effluent Concentration	mg/L	14.5

6.3.1 Process Flow Diagram

Figure 6-6 shows a schematic PFD of the plant with the BFU unit implemented. During peak flow conditions, a portion of the primary effluent will be diverted to the BFU system. The effluent from the BFU system will be combined with the secondary effluent from the secondary clarifiers prior to disinfection. The generated solids in the BFU system will be sent to plant drain and returned to the influent pump station. The captured solids will then settle in the primary clarifiers and be taken out of the system in primary sludge.

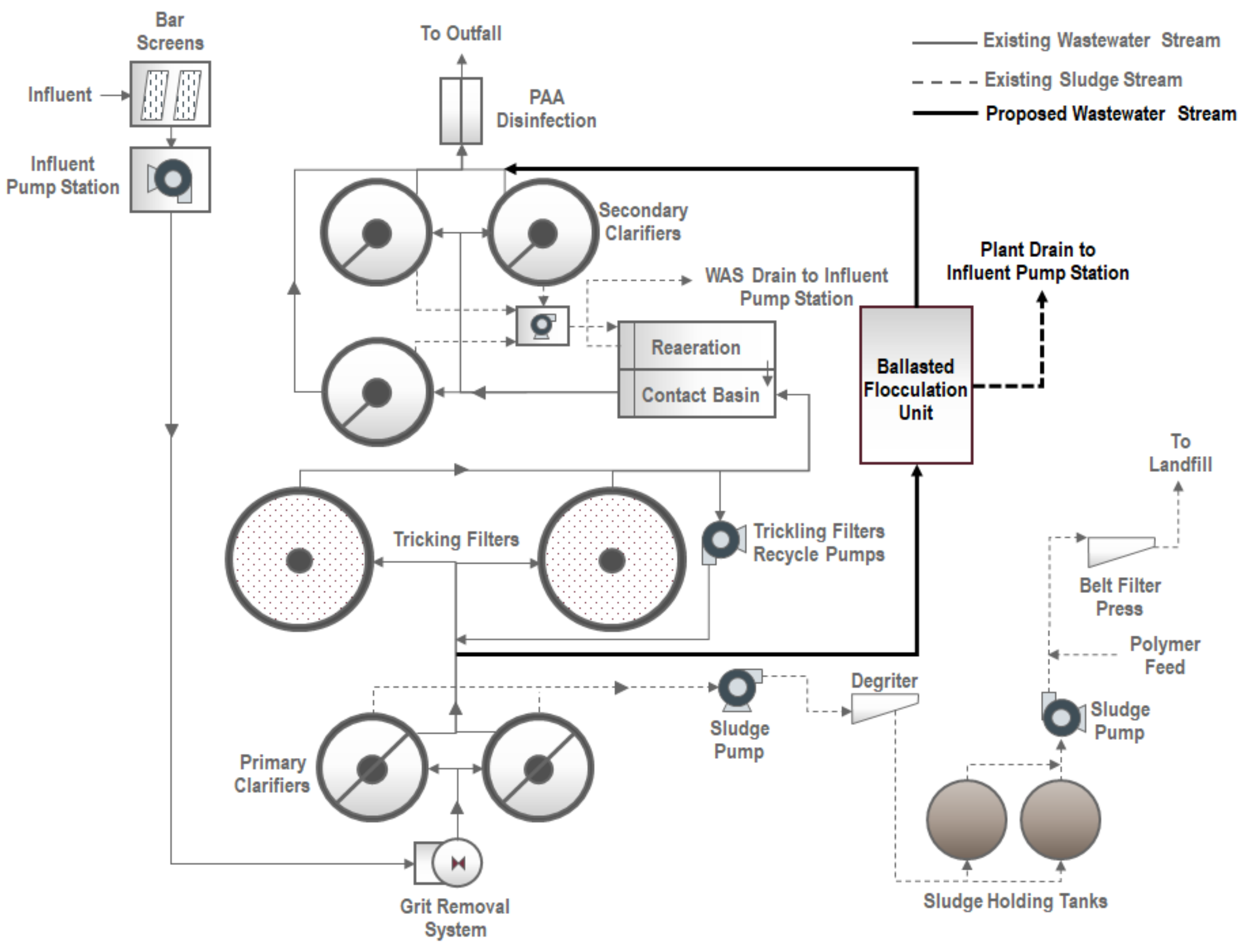

Figure 6-6: Ballasted Flocculation Unit Process Flow Diagram

6.3.2 Site Layout

A preliminary site plan with the BFU is shown in Figure 6-7 below. The largest tank mounted BFU that can be shipped to the site and installed on a slab is a 6 MGD unit. Thus, two 6 MGD BFUs will be needed for this alternative. Alternatively, a larger single BFU system in a concrete tank can be installed. However, building the concrete structure will take more time than installing tank mounted unit and the system won't be in service by next permit cycle for ammonia-nitrogen.

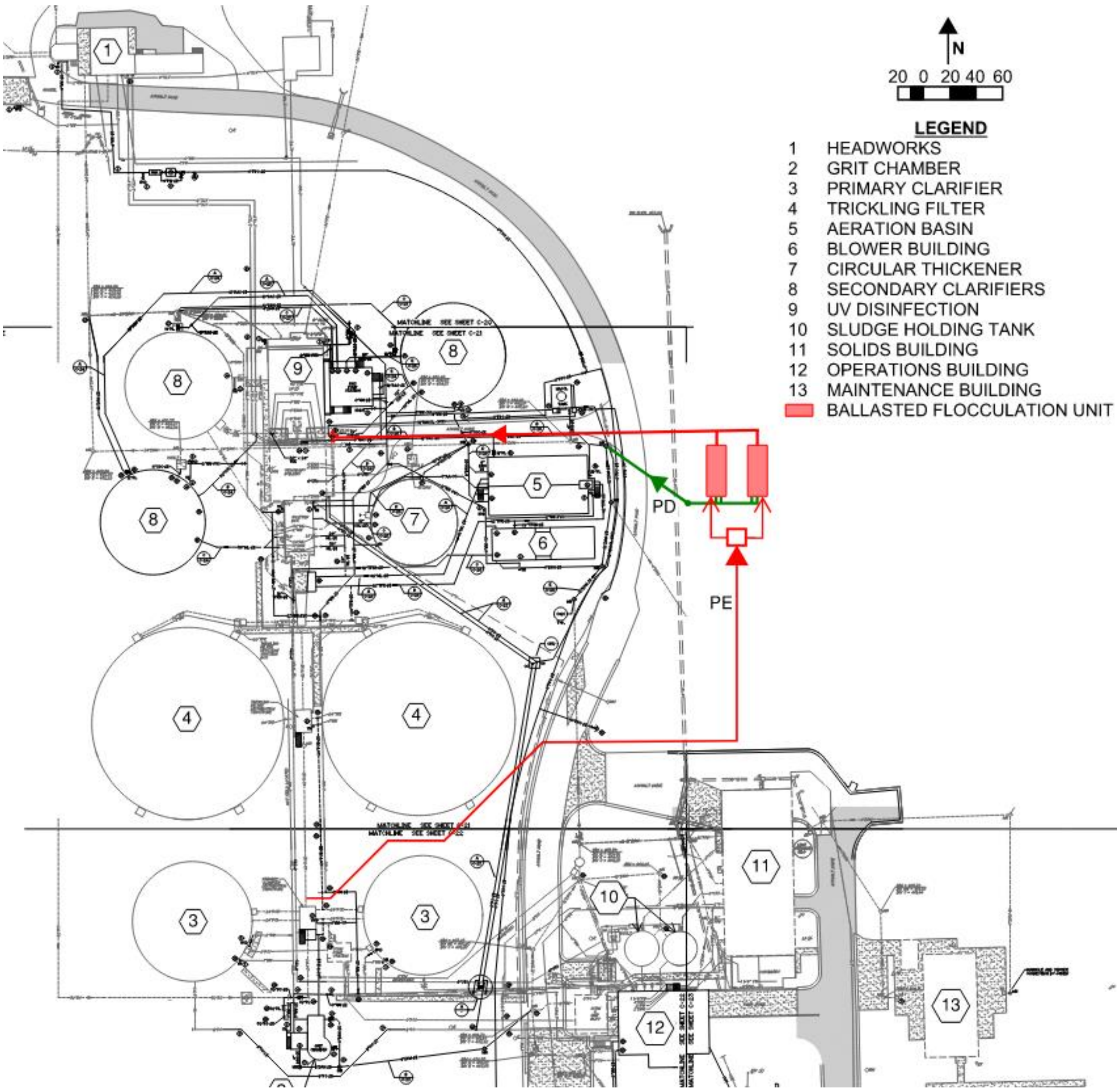

Figure 6-7: Ballasted Flocculation Unit Site Layout

6.3.3 Cost Analysis

Table 6-4 shows the OPCC for the BFU alternative, including the elements used to

Table 6-4: Ballasted Flocculation Unit OPCC

Facility	Quantity	Element
Ballasted Flocculation Unit	2	BFU Tank and Equipment
	LS	Chemical Feed System
	LS	Control Panels and Electrical Equipment
	LS	Concrete Slab
Electrical	LS	Site Electrical
Site Civil	LS	New Process Piping
TOTAL OPCC	**$11,900,000**	

6.4 Gravity Thickener Retrofit

This alternative includes retrofitting the existing gravity thickener to be an additional aeration basin. The existing gravity thickener equipment will be removed. Surface aerators will be installed at the facility to properly aerate the basin. A new pump installation is necessary to transport the mixed liquor in the retrofitted basin to the existing aeration basin.

The existing aeration basin provides 0.32 MG of volume. The gravity thickener is currently 0.18 MG. If the gravity thickener were converted to an aeration basin, a total of 0.5 MG would be provided for treatment. According to mass balance calculations, the necessary volume of the aeration basins must be 0.32 and 0.65 MG for AD and MM conditions, respectively, to achieve a SRT of 3 days during summer months after passing through the trickling filters. Retrofitting the gravity thickener to an aeration basin provides additional volume to achieve a 3-day SRT to under normal flow conditions. However, the system still needs more volume for sustainable growth of nitrifier bacteria and proper nitrification during max month conditions.

Aeration must be provided for treatment within the retrofitted gravity thickener. Surface aerators can be installed to provide the required air for biological treatment as well as mixing. Three 60-hp blower-assisted angled surface aerators are considered for this alternative.

6.4.1 Process Flow Diagram

A schematic of the plant with the gravity thickener retrofit is illustrated in Figure 6-8 below. The mixed liquor will be directed to the gravity thickener via the existing feed line at the existing sludge mixing basin (not in operation). This approach allows for both influent and RAS to be fed to the retrofitted tank. Modifications to this structure will be needed to enable the system to send flow to the gravity thickener. The aerated mixed liquor from the gravity thickener will be returned to the secondary clarifiers splitter box for settling.

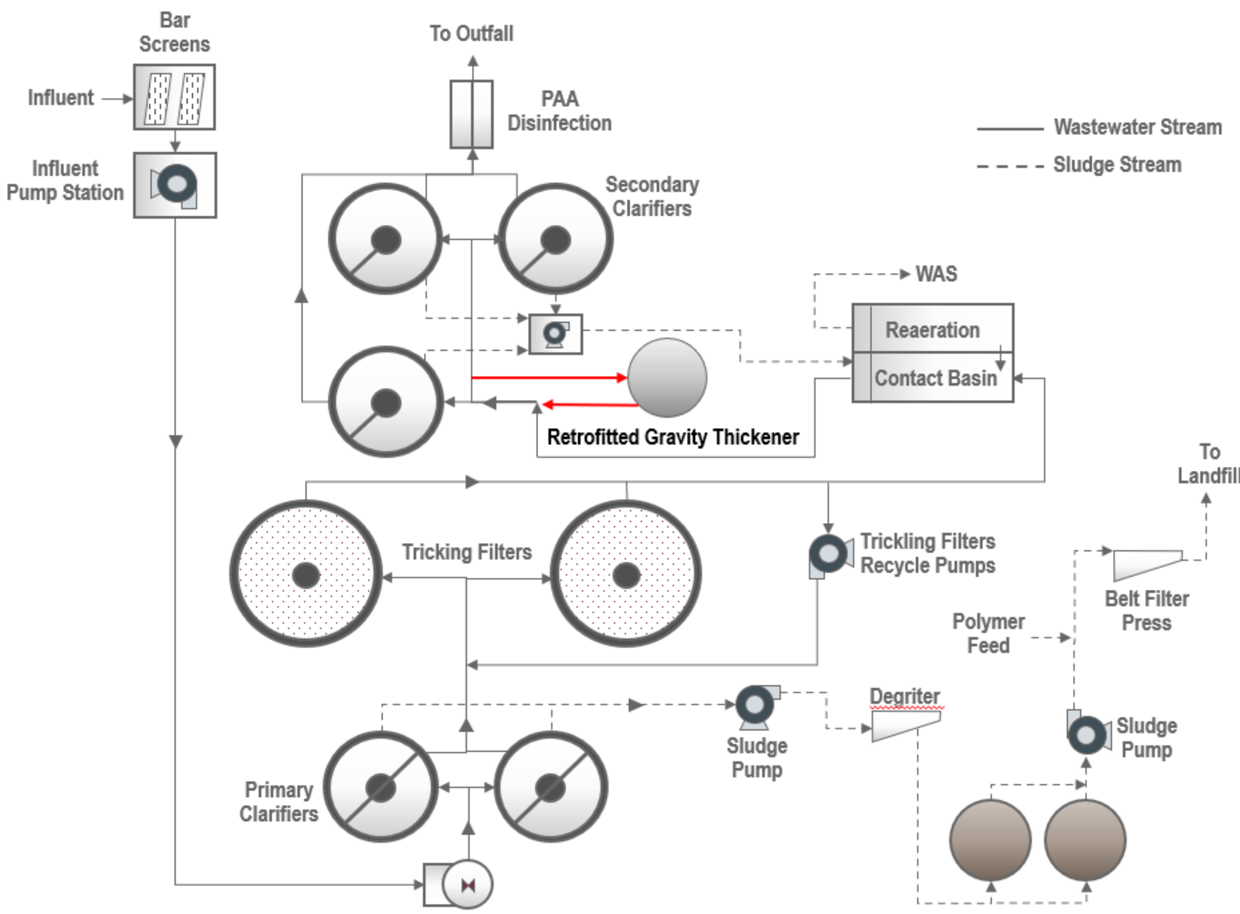

Figure 6-8: Gravity Thickener Retrofit Process Flow Diagram

6.4.2 Site Layout

Figure 6-9 shows the preliminary site plan of the plant with the gravity thickener retrofitted.

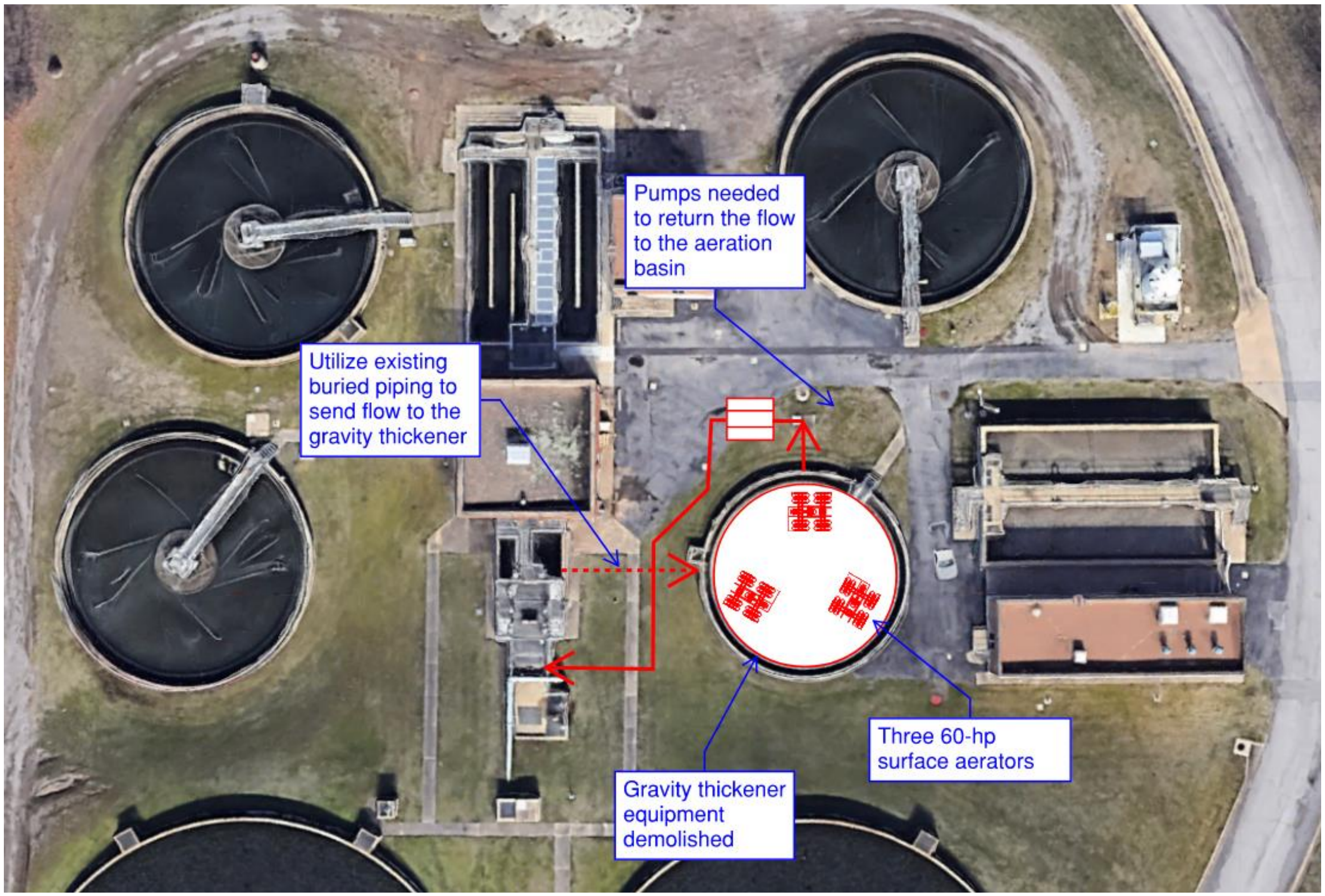

Figure 6-9: Gravity Thickener Retrofit Site Layout

6.4.3 Cost Analysis

Table 6-5 shows the estimated OPCC for the gravity thickener retrofit alternative.

Table 6-5: Gravity Thickener Retrofit OPCC

Facility	Quantity	Element
Gravity Thickener	LS	Demolition of Existing Equipment
	LS	Installation of New Equipment
	3	Surface Aerators
	2	Submersible Pumps
Electrical Building	LS	Concrete
	LS	Excavation, Backfill, Stabilization, Grading
Electrical	LS	Site Electrical Modifications
Site Civil	LS	New Process Piping
TOTAL OPCC	**$2,300,000**	

6.5 Implementation Duration

Table 6-6 shows the implementation schedule for the evaluated alternatives. The design period for the Alternative 1 (Additional Aeration Basins) assumes a Construction Manager at Risk (CMAR) approach for accelerated design and procurement.

Table 6-6: Implementation Schedule for the Evaluated Alternatives (months)

	Aeration Basin	MOB	BFU	Gravity Thickener Retrofit
Design Period	6 (CMAR)	4	4	3
Permitting Period	4	2	4	N/A
Construction Period	26	10	12	6
Total (months)	**36**	**16**	**20**	**9**

7.0 Conclusions

In this TM, four alternatives were evaluated to address the Massard WRF’s recent nitrification challenges. Table 7-1 shows a summary of the findings for the ammonia treatment alternatives evaluation. A summary of the advantages and disadvantages, as well as the OPCC results are included in the table below.

Table 7-1: Summary of Treatment Alternatives Evaluation

Alternative	Advantages	Disadvantages	OPCC
Additional Aeration Basin	• Aligns with the master plan recommendations • No chemical addition is needed • Minimal disruption of existing processes • Complete nitrification under max month loading conditions	• Highest capital costs • Longer design duration • Longer construction period • Cannot be in operational by next ammonia-N permit cycle	$23,400,000
MOB	• Shorter design and implementation duration	• High Capital Costs • Media should be added to the system routinely since it will degrade over time • Proprietary system with a few installations in the US • Only a short-term solution	$7,400,000
BFU	• Only operated during peak flows • Fits within long term plans for plant • Small footprint • Staff already familiar with technology • Minimal disruption of existing processes	• Requires addition of coagulants, polymer, and microsand • Partial biological treatment during peak flows • Does not meet effluent ammonia-N concentration target during peak flows, meeting weekly average ammonia-N limit may be challenging during high flow periods	$11,900,000
Gravity Thickener Retrofit	• Repurposes an existing abandoned structure • Minimal construction • May be operational by next permit cycle • Lowest capital costs	• May not provide sufficient SRT for ammonia removal during max month/increased loading conditions • Higher risk since the condition of existing piping that is to be repurposed is unknown • Only a short-term solution, construction of additional aeration basins still needed	$2,300,000