Odor Control Technology Evaluation

Annapolis Water Reclamation Facility

Odor Control Evaluations

December 10, 2024

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1 INTRODUCTION

The Annapolis Water Reclamation Facility (WRF) is a wastewater treatment plant, jointly owned by the City of Annapolis and Anne Arundel County. The County is responsible for the operation and maintenance of the facility. The facility employs an advanced activated sludge process with nitrification/de-nitrification for Enhanced Nutrient Removal (ENR) level treatment. The treated effluent is discharged into the Chesapeake Bay. The aerial view of the WRF and its surrounding neighborhoods is shown in Figure 1-1.

Figure 1-1 Aerial view of the Annapolis Water Reclamation Facility

Recent projects at the WRF have upgraded various portions of the treatment plant. However, the odor control facilities have not been evaluated. The County desired to complete a comprehensive odor control evaluation at the plant to identify sources of odor and potential capital improvements.

The overall goal of the project is to conduct a comprehensive odor evaluation including monitoring, data collection, data analysis, and air dispersion modeling to identify sources of odors and potential capital improvements needed to address them.

The purpose of this Technical Memo (TM) is to summarize the results of technology evaluations and identify recommended odor control improvements for the Annapolis WRF.

2 ODOROUS AIR LOAD DESIGN CRITERIA

2.1 Background

The Annapolis WRF has multiple existing odor control systems. Odor monitoring and air dispersion modeling (documented in separate TMs) have identified multiple areas that require odor control improvements.

- The septic hauler discharge area is subject to fugitive emissions during septic unloading. Training and operational adjustment should be considered to employ odor capture best practices, namely keeping covers in place and immediately replacing after unloading operations.
- The influent pump station has a Biorem biofilter system that was installed in the early 2000's. This system has some structural deficiencies. In addition, summer odor monitoring provided evidence that the biofilter is not fully removing odors and it should be considered for replacement.
- The screen and grit building (headworks) has a packed tower scrubber system. This system is currently not functional. The County is in the process of rehabilitating the scrubber system. However, given the age and condition of the existing system, it should be considered for replacement.
- The primary clarifiers are covered at the effluent launders, which is the most odorous area of a primary (where the wastewater falls over a weir and odors can be stripped out). The odors from the primary clarifiers are currently sent to the existing aeration blowers for diffusion and oxidation through the aeration tanks. While this is an effective odor control technique, the existing aeration blowers are slated for replacement with more efficient technology that is not compatible with the hydrogen sulfide coming from the odorous sources, so a replacement odor control system is required.
- The aeration tanks, secondary clarifiers, and denitrification filters do not have any existing odor control systems. Odors were monitored near the aeration tanks and secondary clarifiers during the winter/spring. Based on these results, the aeration tanks and secondary clarifiers are not suspected to be contributors to offsite odors. While the denitrification filters are also expected to have low odors, the backwash tank associated with the denitrification filters has shown to be a likely contributor to offsite odors. This is likely due to solids accumulation and biological activity within the tank. The County is currently working on an active flushing program to minimize odor generation. Additionally, the County is initiating odor control improvements for this area under a separate project.
- The gravity sludge thickeners (GSTs) are covered for odor containment. Like the primary clarifiers, the odors from the GSTs are sent to the existing aeration blowers. With the aeration blowers slated for replacement, a replacement odor control system is required for the GSTs.
- The solids handling facilities were recently upgraded, including new odor control systems, the odor control systems include a packed tower scrubber for ammonia removal and a carbon vessel for odor polishing. The odor monitoring results indicate that these systems are performing well, and no replacement or upgrades are recommended. Training and

operational adjustment should be considered to employ odor capture best practices, namely keeping doors closed and covering trucks when onsite.

The focus of this TM is on evaluation and recommendations for odor control at the influent pump station, screen and grit building, primary clarifier launders, and GSTs.

2.2 Basis of Design

The odorous air loads for each process area are detailed in Table 2-1. The air flow rates were based on air turnover and the hydrogen sulfide levels were based on the results of the odor monitoring.

Table 2-1: Odorous Air Load Basis of Design

Process Areas	Air Load (CFM)	Air Load Basis	H_2S Levels (PPM)	
			Average	Peak
Influent Pump Station	1,300	12 air changes/hr (ACH) empty	10	30
Screen and Grit Building	24,200	12 ACH	10	30
Primary Clarifier Launders	400	12 ACH	10	30
Gravity Thickeners	1,800	12 ACH full	10	30

Due to the small air load from the primary clarifier launders, it is recommended that the air flow be combined with the odors from the screen and grit building.

3 GAS-PHASE TREATMENT TECHNOLOGIES

Gas-phase treatment options were evaluated to treat the odorous air generated. The treatment options considered include the following:

- Biofilter System
- Biotower System
- Packed-Tower Chemical Scrubbers
- Activated Carbon System

Given the expected odor loads, the activated carbon filter is only considered as a polishing step for the biotower system.

3.1 Biofilter System

Biofilter systems consist of solid media where bacteria and other organisms form and biologically consume the odor-causing compounds. Figure 3-1 provides a schematic and photo of a biofilter system.

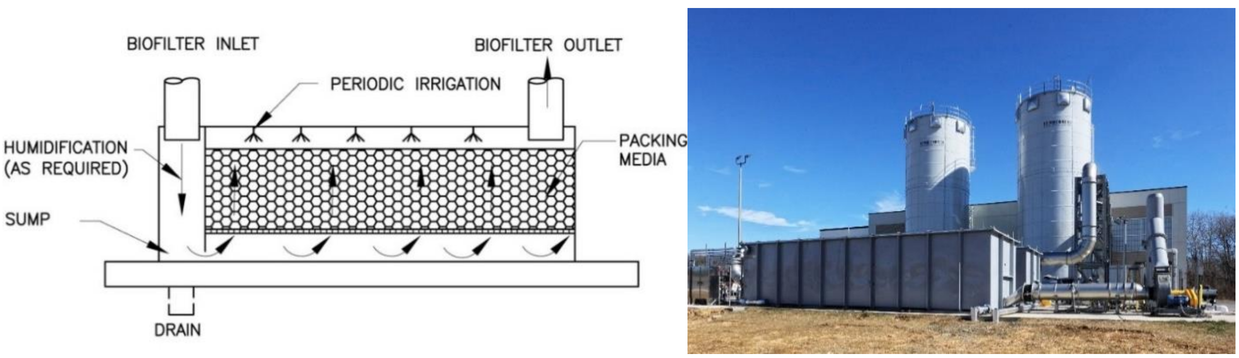

Figure 3-1. Biofilter schematic and photo

Biotower systems rely primarily on heterotrophic organisms targeting H_2S removal, operating at a near neutral pH. Biofilter system technology—particularly the media used—has evolved over time. The older biofilter systems were made with bark mulch style media that would gradually decay and compact, which required regular media replacements. The older biofilter systems also required larger footprints because of longer empty-bed contact time (EBCT) requirements of at least 60 seconds. More recently, long-life media biofilter systems have been developed that do not decay and compact and come with 10-year warranties. Some of these long-life biofilter systems have been in proven service for more than 10 years. These long-life biofilter systems also require less EBCT because the manufactured media achieves a better performance. Although the EBCT is lower on the newer systems, further decreasing the overall sizing requirements of the biofilter footprint, it is still a large footprint compared to other treatment options.

Some of the advantages and disadvantages of biofilter system are listed in Table 3-1.

Table 3-1: Advantages and Disadvantages of Biofilter System

Advantages	Disadvantages
• Able to treat wide range of compounds • No chemical costs or safety concerns • Relatively low maintenance requirements	• Larger footprint • Upper limit of 50 PPM of H_2S loading for treatment • Biological system must be kept running and requires winterization to keep above 40 degrees F

3.2 Biotower Systems

Biotower systems, also referred to as bio-trickling filters, are odor control treatment technologies that consist of solid media for bacteria to grow. Figure 3-2 provides a schematic and photo of a biotower system.

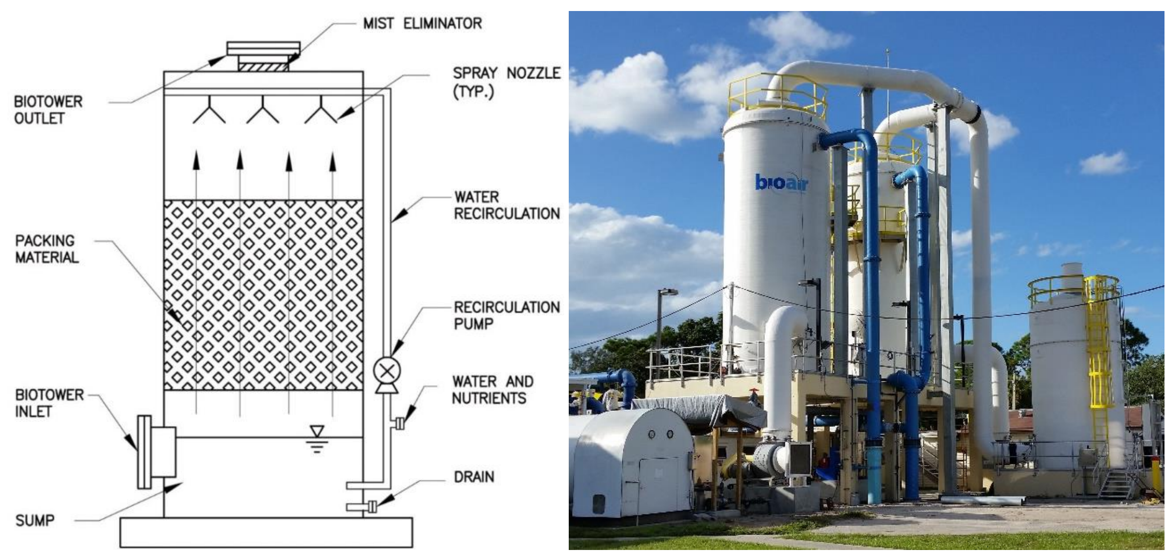

Figure 3-2. Biotower schematic and photo

Biotower systems rely primarily on autotrophic organisms targeting H_2S removal, operating at lower pH. Biotower systems consists of a media that is completely inert and resistant to decay and compaction. As a results, nutrient addition (such as trace organics, nitrogen, phosphorus, and potassium) is required for the biology and is added to biotowers with spray water. Typically, the spray water consists of plant effluent water.

Some of the advantages and disadvantages of biotower system are listed in Table 3-2.

Table 3-2: Advantages and Disadvantages of Biotower System

Advantages	Disadvantages
• High removal efficiency of H_2S (99%+). • No chemical costs or safety concerns. • Smaller footprint than biofilters due to shorter EBCTs (less than 10 seconds) and the ability to stack media much higher.	• Low removal efficiency for non-H_2S odorous compounds (25-75%). • Works best at high H_2S loading rates (20 ppm and above). • Biotowers produce acidic blowdown or leachate (sulfuric acid), a waste product requiring management.

3.3 Packed-Tower Chemical Scrubbers

Packed-tower chemical scrubbers have been used extensively to control odors and are classified as wet scrubbers because they use a scrubbing solution to remove odor-causing compounds from odorous air streams. Figure 3-3 provides a schematic and photo of packed-tower chemical scrubbers.

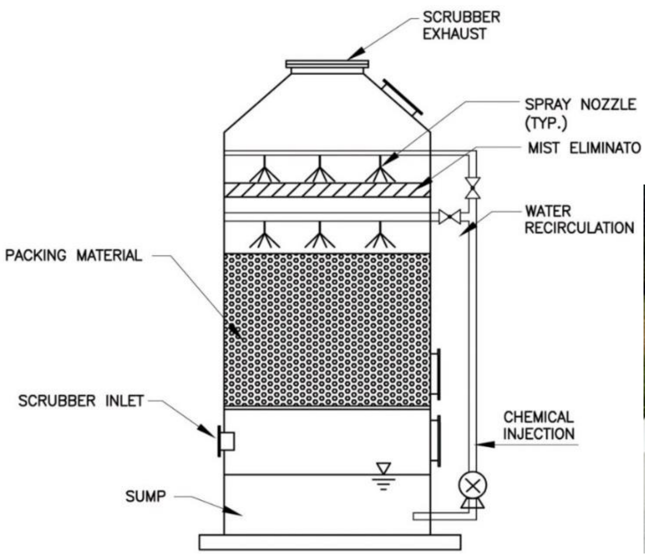

Figure 3-3. Packed-Tower Chemical Scrubbers Schematic and Photo

System configurations for packed-tower scrubbers range from single-stage systems that may or may not use oxidants to two-stage systems that typically use both absorption and oxidation to remove odorous air contaminants. Properly sized and operated single-stage caustic/sodium hypochlorite scrubbers should achieve 99 percent removal, whereas two-stage systems can reach 99.5 to 99.9 percent removal of H_2S and other odor species. The packed-tower chemical scrubber system chemistries are selected and designed specifically for the types of odorous compounds being treated.

Some of the advantages and disadvantages of packed-tower chemical scrubber are listed in Table 3-3.

Table 3-3: Advantages and Disadvantages of Packed-Tower Chemical Scrubber

Advantages	Disadvantages
• A proven technology with a long track record. • Can treat wide array of odorous compounds at high removal efficiency. • Can react quickly to changes in odorant loading. • Low required contact time allows for smaller tank volumes.	• High capital costs associated with chemical pumping, piping, and containment. • Periodic cleaning of the scrubber media requires acid washing, introducing strong acids like sulfuric acid to the wastewater facility. • High chemical costs with high odorant loads. • Chemical safety concerns. • Scrubber systems generate a continuous flow of contaminant solution called blowdown, necessitating management.

3.4 Activated Carbon System

Carbon adsorption is a technology used for various forms of contaminant removal including odorous compounds. Figure 3-4 provides a photo of a carbon adsorption system.

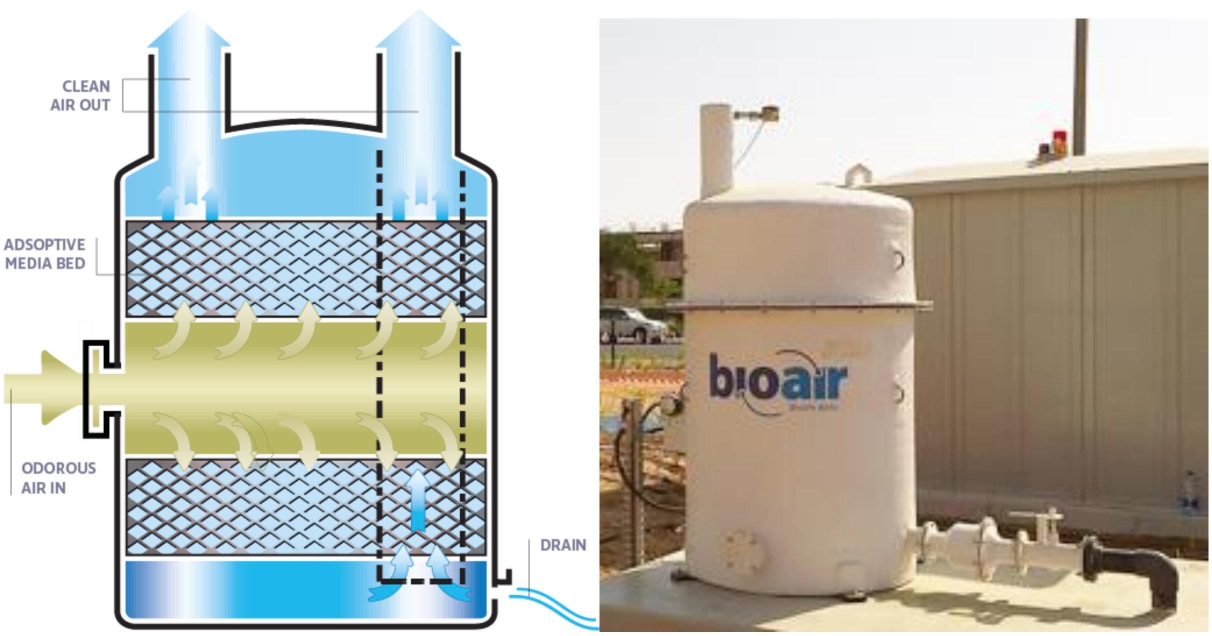

Figure 3-4. Carbon adsorption system

For odor control, odorous air is passed through a bed of media composed of carbon-based adsorbents that adhere to or chemically react with odorous gases. As the gas-phase odor contaminants pass through the media, they contact and collide with the internal surfaces and are removed via adsorption from the airstream exiting the system. As the gas-phase odor contaminants accumulate on the internal surface area of the carbon (adsorbent), the carbon becomes exhausted, and the media must be regenerated or replaced. This can be a downside to this technology because replacing the carbon can be expensive and labor-intensive.

When H_2S concentrations are low (below 5 parts per million [ppm]), and ammonia is not present at high concentrations, carbon-adsorption systems typically have lower capital costs compared to other gas-phase treatment systems (such as chemical scrubbers and biological systems) because odors can be removed with a much shorter contact time. The height of activated carbon systems is limited, so airflows above 10,000 cfm typically require multiple vessels. When concentrations of H_2S or ammonia are higher, or when other odor species are present besides H_2S, carbon systems become uncompetitive because of the costs of replacing the media (high H_2S) and/or need for additional media types to treat the ammonia. There have also been case studies where odor sources with varying odor species (organic sulfides, etc.) have been treated with carbon systems and resulted in more organic sulfide compounds in the effluent air.

Placing a carbon unit after a biotower can help remove any residual odors as well as provide protection in case there is a biological upset. Under these conditions, the carbon should last several years.

Some of the advantages and disadvantages activated carbon system are listed in Table 3-4.

Table 3-4: Advantages and Disadvantages of Activated Carbon System

Advantages	Disadvantages
• Low capital cost when used for low concentration influent • No chemical costs or safety concerns • Smaller footprint	• Replace carbon media is costly and labor-intensive • Works best for low H_2S loads and is typically used as a polishing step or when odor load is low

4 FACILITY ODOR CONTROL SYSTEMS

4.1 Influent Pump Station

Each of the technologies identified above were evaluated for the influent pump station:

- Biofilter System
- Biotower System
- Biotower with Activated Carbon
- Packed Tower Scrubber

Figure 4-1 shows the footprints of each alternative overlaid at the proposed location for the odor control system. It is assumed that the new odor control system will be located in a similar location to the existing biofilter.

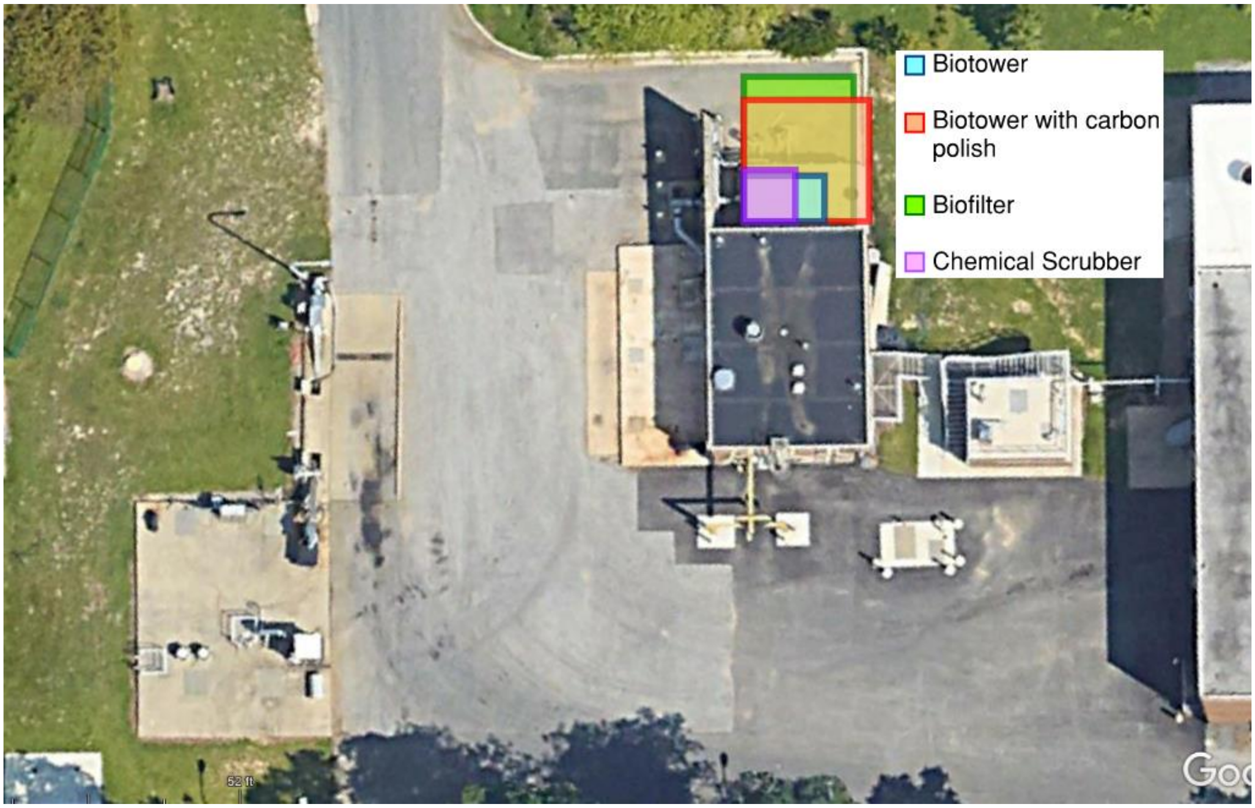

Figure 4-1: Proposed site layouts for alternatives at Influent Pump Station

4.1.1 Biofilter System

The preliminary proposal and the budgetary quote for the biofilter system at the influent pump station were obtained from BIOREM. To treat 1,300 CFM of odorous air generated from the influent pump station, one biofilter vessel that is 16 ft long, 10 ft wide, and 10 ft tall, two recirculation pumps (1 duty + 1 standby) for the humidifier rated for 25 GPM at 100 ft head, and two exhaust fans (1 duty + 1 standby) rated for 1,300 CFM. In addition, the proposal system includes biofilter media, spray nozzles, control panel, water box, winterization system, instrumentation, and fluid control valves.

Based on the preliminary sizing provided by the vendor, an approximate pad dimension of 26 ft x 20 ft is required to implement this treatment system. Figure 4-2 shows the assumed preliminary arrangement of the biofilter vessel to estimate the site footprint requirements.

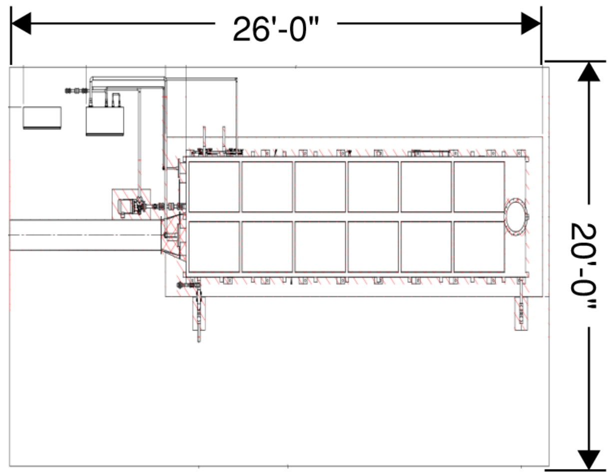

Figure 4-2: Preliminary Arrangement and Footprint Requirements for the Biofilter System at the Influent Pump Station

4.1.2 Biotower System

The preliminary proposal and the budgetary quote for the biotower system at the influent pump station were obtained from Bioair. To treat 1,300 CFM of odorous air generated from the influent pump station, one biotower vessel that is approximately 14 ft tall and 5 ft diameter, two blowers (1 duty + 1 standby). In addition, the proposal also includes an electrical control panel and a water control panel with a nutrient dosing system. Based on the preliminary sizing provided by the vendor, an approximate pad dimension of 15 ft x 9 ft is required to implement this treatment system. Figure 4-3 shows the assumed preliminary arrangement of the reactors to estimate the site footprint requirements.

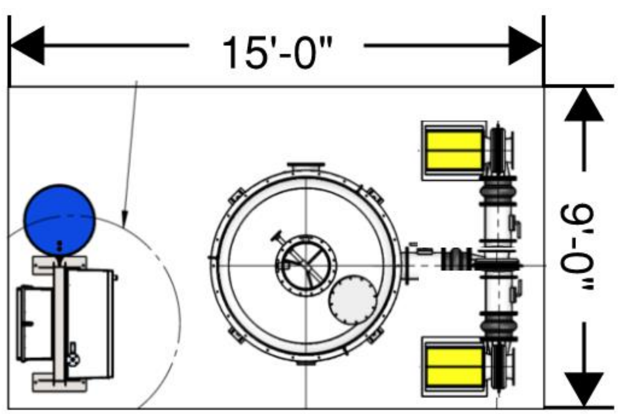

Figure 4-3: Preliminary Arrangement and Footprint Requirements for the Biotower System at the Influent Pump Station

4.1.3 Biotower with Activated Carbon

The preliminary proposal and the budgetary quote for the biotower with carbon polishing at the influent pump station were also obtained from Bioair. The biotower is the same as previous. However, there is an additional carbon vessel that is 7.5 ft tall and 6.0 ft diameter. Based on the preliminary sizing provided by the vendor, an approximate pad dimension of 23 ft x 22 ft is required to implement this treatment system. Figure 4-4 shows the assumed preliminary arrangement of the reactors to estimate the site footprint requirements.

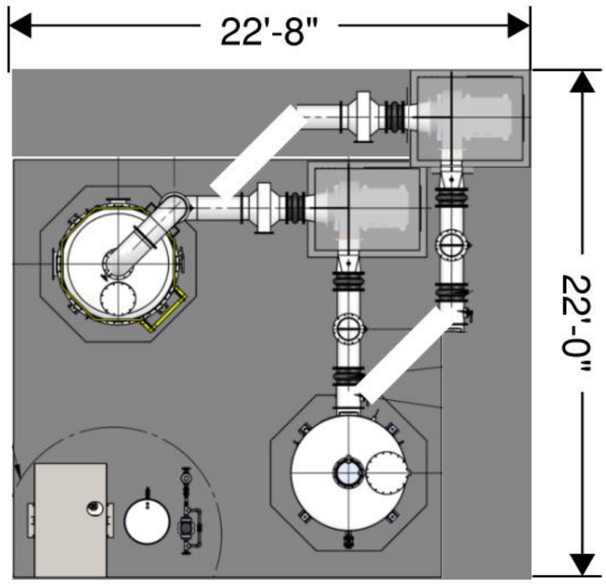

Figure 4-4: Preliminary Arrangement and Footprint Requirements for the Biotower System with Carbon Polishing at the Influent Pump Station

4.1.4 Packed-Tower Chemical Scrubbers

The preliminary proposal and the budgetary quote for packed-tower chemical scrubbers at grit chambers were obtained from Daniel Mechanical. To treat 1,300 CFM of odorous air generated by the grit chambers, one 2-ft diameter 1-stage chemical scrubbers rated for 1,300 cfm (each) with packing media bed depth of 10-ft are proposed. The proposed system also includes two fans, two recirculation pumps, and one electrical control panel. However, chemical storage and feed system are not included in the proposal. The WRF can either utilize their existing chemical systems or considered a new chemical system dedicated to this odor control treatment system. Based on the preliminary sizing provided by the vendor, an approximate pad dimension of 10 ft x 10 ft is required to implement this treatment system. Figure 4-5 shows the assumed preliminary arrangement of the reactors to estimate the required spacing shows the assumed preliminary arrangement of the scrubbers to estimate the site footprint requirements.

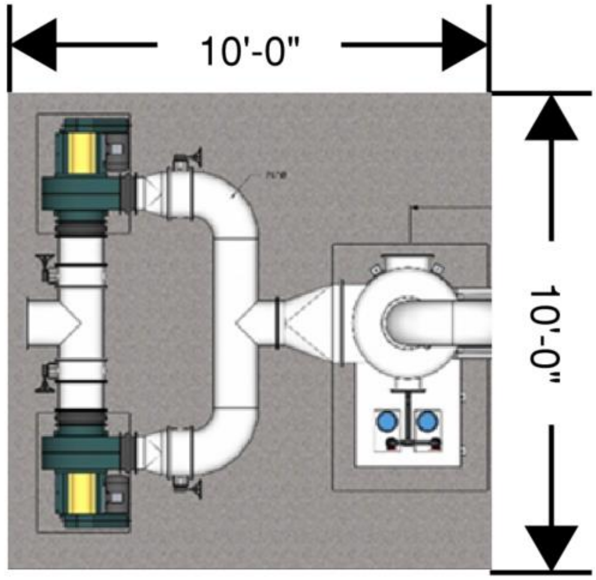

Figure 4-5: Preliminary Arrangement and Footprint Requirements for the Packed-Tower Chemical Scrubbers at the IPS

4.2 Screen and Grit Building and Primary Clarifiers

Given the larger air flows at the screen and grit building, standalone biofilters would require a very large footprint. Therefore, biofilters were not considered for this facility. The following technologies were evaluated for the combined odors from the screen and grit building and primary clarifiers.

- Biotower
- Biotower with Activated Carbon
- Packed Tower Scrubber

Figure 4-6 shows the footprints of each alternative laid over each other at the proposed location for the odor control system. It is assumed that the new odor control system will be located outside, to the north of the existing facility. The ductwork connecting the primary clarifiers to the existing screen and grit building is recommended to be above grade. A bridge will connect the two systems, and the location of the bridge and ductwork will need to be coordinated with operations during final design considering truck traffic impacts.

Figure 4-6: Proposed site layouts for alternatives at Screen and Grit Building

4.2.1 Biotower

The preliminary proposal and the budgetary quote for the biotower system at the influent pump station were obtained from Bioair. To treat 24,600 CFM of odorous air generated from the facilities, one 31 ft tall and 14 ft diameter biotower is required, with two blowers (1 duty + 1 standby). In addition, the proposal also includes an electrical control panel and a water control panel with a nutrient dosing system. Based on the preliminary sizing provided by the vendor, an approximate pad dimension of 34 ft x 26 ft is required to implement this treatment system. Figure 4-7 shows the assumed preliminary arrangement of the reactors to estimate the site footprint requirements.

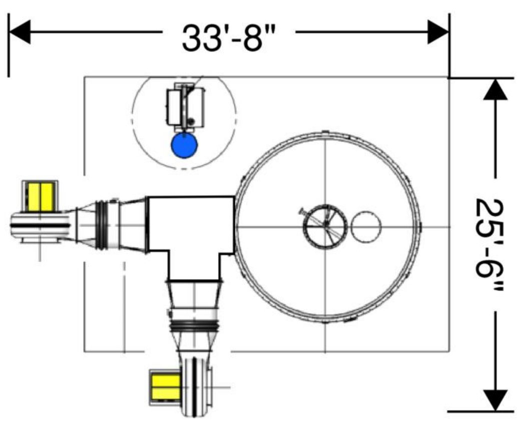

Figure 4-7: Preliminary Arrangement and Footprint Requirements for the Biotower at the Screen and Grit Building

4.2.2 Biotower with Activated Carbon

The preliminary proposal and the budgetary quote for the biotower with carbon polishing at the screen and grit building were also obtained from Bioair. The biotower is the same as previous, with the addition of two carbon vessels that are 12 ft tall and 11 ft diameter. Based on the preliminary sizing provided by the vendor, an approximate pad dimension of 58 ft x 36 ft is required to implement this treatment system. Figure 4-8 shows the assumed preliminary arrangement of the reactors to estimate the site footprint requirements.

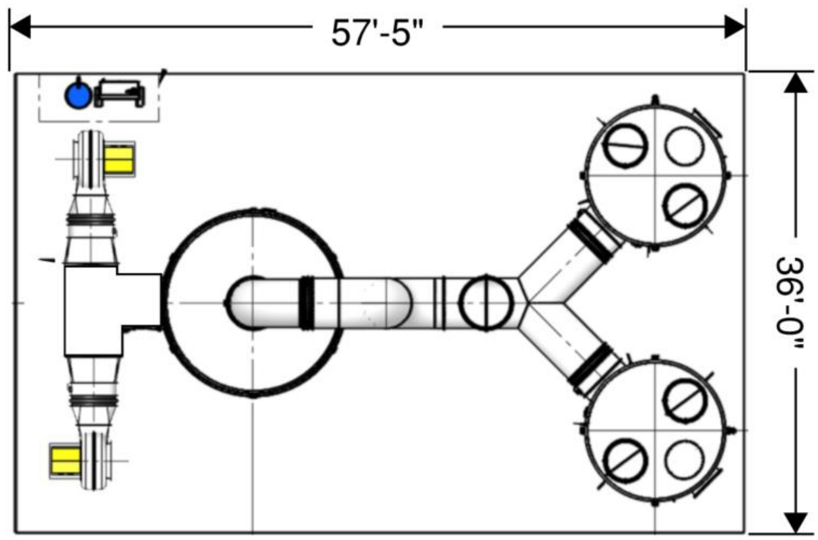

Figure 4-8: Preliminary Arrangement and Footprint Requirements for the Biotower System with Carbon Polishing at the Screen and Grit Building

4.2.3 Packed-Tower Chemical Scrubbers

The preliminary proposal and the budgetary quote for packed-tower chemical scrubbers at grit chambers were obtained from Daniel Mechanical. To treat 24,600 CFM of odorous air generated by the facilities, one 8-ft diameter 1-stage chemical scrubbers rated for 24,600 cfm (each) with packing media bed depth of 10-ft are proposed. The proposed system also includes two fans, two recirculation pumps, and one electrical control panel. However, chemical storage and feed system are not included in the proposal. The WRF can either utilize their existing chemical systems or considered a new chemical system dedicated to this odor control treatment system. Based on the preliminary sizing provided by the vendor, an approximate pad dimension of 33 ft x 31 ft is required to implement this treatment system. Figure 4-9 shows the assumed preliminary arrangement of the reactors to estimate the required spacing shows the assumed preliminary arrangement of the scrubbers to estimate the site footprint requirements.

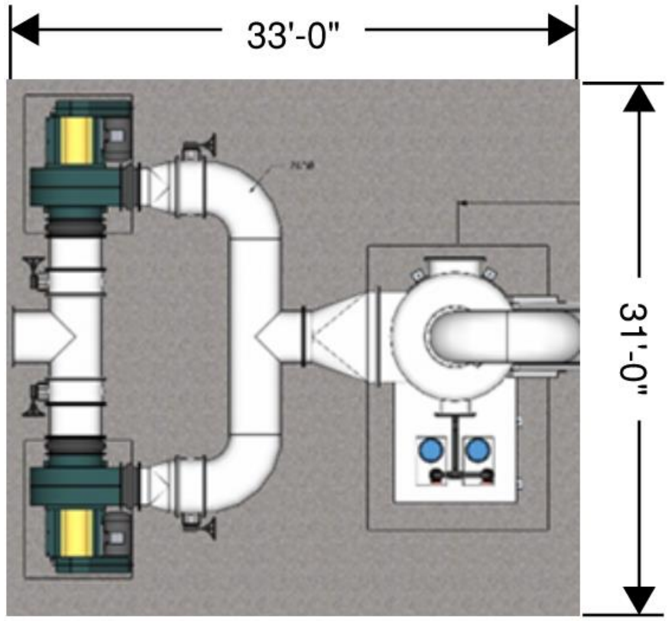

Figure 4-9: Preliminary Arrangement and Footprint Requirements for the Packed-Tower Chemical Scrubbers at the Screen and Grit Building

4.3 Gravity Sludge Thickeners

Each of the technologies identified above were evaluated for the GSTs:

- Biofilter
- Biotower
- Biotower with Activated Carbon
- Packed Tower Scrubber

Figure 4-10 shows the footprints of each alternative laid over each other at the proposed location for the odor control system. The new odor control system was assumed to be located to the northeast of the GSTs.

A combined system with the primary clarifiers (as is done now) is not recommended because of the extensive underground ducts. Odorous air from covered tanks is typically saturated with water, and this water can condense and accumulate in underground ducts. Operations has reported this has happened at the past at Annapolis. Best practice include overhead ductwork sloped to the takeoff points or odor control system to avoid moisture accumulation.

Figure 4-10: Proposed site layouts for alternatives at Screen and Grit Building

4.3.1 Biofilter System

The preliminary proposal and the budgetary quote for the biofilter system at the influent pump station were obtained from BIOREM. To treat 1,800 CFM of odorous air generated from the GSTs, one biofilter vessel that is 20 ft long, 10 ft wide, and 10 ft tall, two recirculation pumps (1 duty + 1 standby) for the humidifier rated for 30 GPM at 100 ft head, and two exhaust fans (1 duty + 1 standby) rated for 1,800 CFM. In addition, the proposal system includes biofilter media, spray nozzles, control panel, water box, winterization system, instrumentation, and fluid control valves. Based on the preliminary sizing provided by the vendor, an approximate pad dimension of 30 ft x 20 ft is required to implement this treatment system. Figure 4-11 shows the assumed preliminary arrangement of the biofilter vessel to estimate the site footprint requirements.

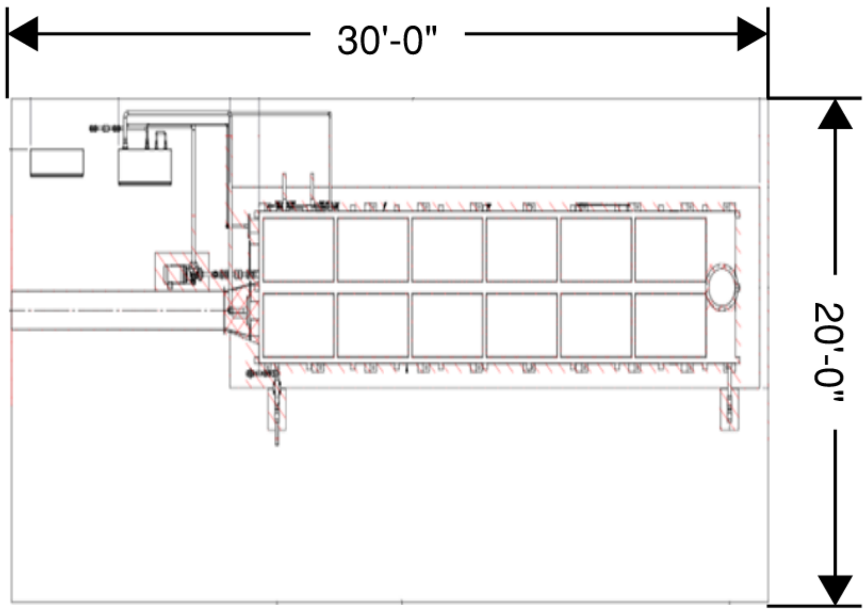

Figure 4-11: Preliminary Arrangement and Footprint Requirements for the Biofilter System at the GSTs

4.3.2 Biotower System

The preliminary proposal and the budgetary quote for the biotower system at the influent pump station were obtained from Bioair. To treat 1,800 CFM of odorous air generated from the GSTs, one 15 ft tall and 6 ft diameter biotower is required, with two blowers. In addition, the proposal also includes an electrical control panel and a water control panel with a nutrient dosing system. Based on the preliminary sizing provided by the vendor, an approximate pad dimension of 14 ft x 14 ft is required to implement this treatment system. Figure 4-12 shows the assumed preliminary arrangement of the reactors to estimate the site footprint requirements.

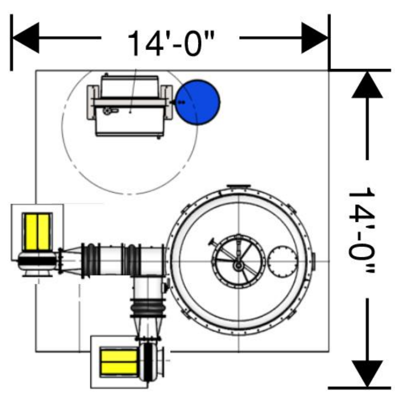

Figure 4-12: Preliminary Arrangement and Footprint Requirements for the Biotower at the GSTs

4.3.3 Biotower with Activated Carbon

The preliminary proposal and the budgetary quote for the biotower with carbon polishing at the GSTs were also obtained from Bioair. The biotower is the same as previous, with the addition of two carbon units that are 7.5 ft tall and 6.0 ft diameter. Based on the preliminary sizing provided by the vendor, an approximate pad dimension of 25 ft x 12 ft is required to implement this treatment system. Figure 4-13 shows the assumed preliminary arrangement of the reactors to estimate the site footprint requirements.

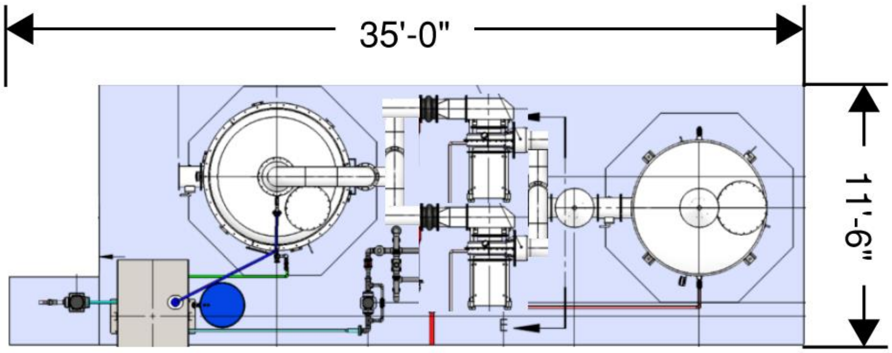

Figure 4-13: Preliminary Arrangement and Footprint Requirements for the Biotower System with Carbon Polishing at the Screen and Grit Building

4.3.4 Packed-Tower Chemical Scrubbers

The preliminary proposal and the budgetary quote for packed-tower chemical scrubbers at grit chambers were obtained from Daniel Mechanical. To treat 1.800 CFM of odorous air generated by the grit chambers, one 2.5-ft diameter 1-stage chemical scrubbers rated for 1,800 cfm (each) with packing media bed depth of 10-ft are proposed. The proposed system also includes two fans, two recirculation pumps, and one electrical control panel. However, chemical storage and feed system are not included in the proposal. The WWTP can either utilize their existing chemical systems or considered a new chemical system dedicated to this odor control treatment system. Based on the preliminary sizing provided by the vendor, an approximate pad dimension of 10 ft x 10 ft is required to implement this treatment system. Figure 4-14 shows the assumed preliminary arrangement of the reactors to estimate the required spacing shows the assumed preliminary arrangement of the scrubbers to estimate the site footprint requirements.

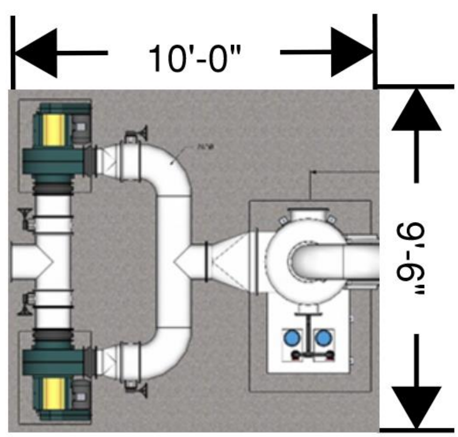

Figure 4-14: Preliminary Arrangement and Footprint Requirements for the Packed-Tower Chemical Scrubbers at the Gravity Thickeners

5 EVALUATIONS

5.1 Cost Estimate Development

Comparative cost estimates were developed for each of the short-listed alternatives. Cost estimates included both an estimate of capital cost and annual O&M costs to develop a 20-year present-worth economic understanding. Capital costs included line-item equipment costs for readily identifiable items, as well as percentage markups for unknown costs for general conditions, mechanical systems, electrical, and instrumentation. The following additional markups were included in the capital cost estimates:

- 27.5% electrical and I&C
- 30% general contingency
- 8% for contractor overhead
- 8% Contractor Profit
- 6% mobilization and bonds

Annual O&M costs include the following:

- Chemicals for the packed tower chemical scrubber system option(s)
- Water for the packed tower chemical scrubber and biotower system option(s)
- Cost for maintenance as a percentage of a plant staff's anticipated time dedicated to operating and maintaining the treatment alternative (assumed hourly rate of $60)
- Cost for power to run fans and pump systems

For the packed tower scrubber options, a chemical storage and feed system was estimated and the cost split between all three odor sources.

The primary purpose of these cost estimates was to allow a comparison of each option and thereby allow selection of the recommended odor control alternative that considered cost to build, operate, and maintain the system.

Table 5-1 provides a summary of the alternative cost estimates for the influent pump station including estimated capital, annual O&M, and 20-year present worth.

Table 5-1: Comparative Cost Estimate Summary for IPS

Parameter	Proposed Treatment Options for Influent Pump Station			
	Biofilter System	Biotower	Biotower (w/ carbon polishing)	Packed Tower Scrubber
Capital Cost	$1,000,000	$700,000	$1,000,000	$1,200,000
Annual O&M	$30,000	$20,000	$20,000	$40,000

Parameter	Proposed Treatment Options for Influent Pump Station			
	Biofilter System	Biotower	Biotower (w/ carbon polishing)	Packed Tower Scrubber
Project Present Worth (O&M only)	$400,000	$300,000	$400,000	$500,000
Total Project Present Worth (Capital + O&M)	**$1,400,000**	**$1,000,000**	**$1,400,000**	**$1,700,000**

Table 5-2 provides a summary of the alternative cost estimates for screen and grit building + primary clarifiers including estimated capital, annual O&M, and 20-year present worth.

Table 5-2: Comparative Cost Estimate Summary for Screen and Grit Building + Primary Clarifiers

Parameter	Proposed Treatment Options for Screen and Grit Building + Primary Clarifiers		
	Biotower	Biotower (w/ carbon polishing)	Packed Tower Scrubber
Capital Cost	$3,400,000	$5,000,000	$4,400,000
Annual O&M	$80,000	$130,000	$150,000
Project Present Worth (O&M only)	$1,100,000	$1,800,000	$2,000,000
Total Project Present Worth (Capital + O&M)	**$4,500,000**	**$6,800,000**	**$6,400,000**

Table 5-3 provides a summary of the alternative cost estimates for the gravity thickeners including estimated capital, annual O&M, and 20-year present worth.

Table 5-3: Comparative Cost Estimate Summary for Gravity Thickeners

Parameter	Proposed Treatment Options for Gravity Thickeners

	Biofilter System	Biotower	Biotower (w/ carbon polishing)	Packed Tower Scrubber
Capital Cost	$2,200,000	$1,700,000	$2,000,000	$1,600,000
Annual O&M	$40,000	$30,000	$40,000	$40,000
Project Present Worth (O&M only)	$500,000	$400,000	$500,000	$500,000
Total Project Present Worth (Capital + O&M)	**$2,700,000**	**$2,100,000**	**$2,500,000**	**$2,100,000**

5.2 Economic Comparison

Table 5-4 provides a summary of the alternative total project present worth for all locations and technology alternatives.

Table 5-4: Comparative Present Worth Cost Estimate Summary for All Alternatives

	Biofilter System	Biotower	Biotower (w/ carbon polishing)	Packed Tower Scrubber
Influent Pump Station	$1,400,000	$1,000,000	$1,400,000	$1,700,000
Screen and Grit Building + Primary Clarifiers	N/A	$4,500,000	$6,800,000	$6,400,000
Gravity Thickeners	$2,700,000	$2,100,000	$2,500,000	$2,100,000
Total	**$8,600,000***	**$7,600,000**	**$10,700,000**	**$10,200,000**

* Assume biotower for screen and grit building

For all three locations, the biotower was the lowest cost or tied for lowest cost. The biotower with carbon polishing had higher capital costs and O&M costs due to the additional equipment used. The biofilter system had a higher capital and O&M costs compared to the biotower in the locations evaluated. The packed-tower scrubber also had higher capital and O&M for two of the locations, and the requirement to construct and chemical storage and feed system makes this alternative more complex. This indicates that the biotower is the most economical option for all three locations and provides consistency across all three locations.

5.3 Non-Economic Factors

The biotower system offers the following advantages over other technologies:

- No chemicals other than small nutrient systems
- Small footprint
- Simple operation

The expected hydrogen sulfide load from all three systems is also consistent with those that can be effectively treated in a biotower system. Biotower systems typically operate very consistently, with over 99% H_2S removal.

The biggest disadvantage of a biotower system is the loss of H_2S removal should there be a biological upset. A biological upset would require reacclimation of the biology, which result in several weeks of below optimal odor removal. If consistent air, water, nutrients, and odor loads are provided, the potential for a biological upset is low. A carbon system after the biotower system can provide additional protection from loss of biology, while also providing odor polishing during normal operation. The carbon system can also provide removal of some organic sulfur compounds, should those be present and not removed in the biotower system. Given the expected excellent treatment in a biotower system, the carbon should last several years.

It is recommended that biotower systems be installed and designed for the new odor control facilities. A second stage carbon unit adds about $3 million in present worth to the base biotower systems and should be considered by the County for inclusion during design. Additionally, the County could consider combining the influent pump station and headworks odor control systems to minimize the number of new systems. The small odor volume of 1300 cfm would not add significantly to the base cost of the headworks system.

6 SCREEN AND GRIT BUILDING VENTILATION RECOMMENDATIONS

6.1 Existing Ventilation

As discussed in the summer odor monitoring TM, the H_2S concentrations within the screen and grit building are high. Ventilation improvements should be considered. One option for reducing both odorous air volumes and H_2S concentrations within the building would be to cover the open channels and grit tanks, while providing point-source odor collection. However, the County expressed a desire to keep the tanks open for operational purposes.

The existing space is currently fully ventilated through the odor control system. An NFPA evaluation is outside the scope of this study. However, it was verified that the design ventilation rates for the space exceed 12 air changes/hour. Current ventilation is based on passive supply air through three louvers with forced exhaust through the odor control system, as shown in Figure 6-1 below.

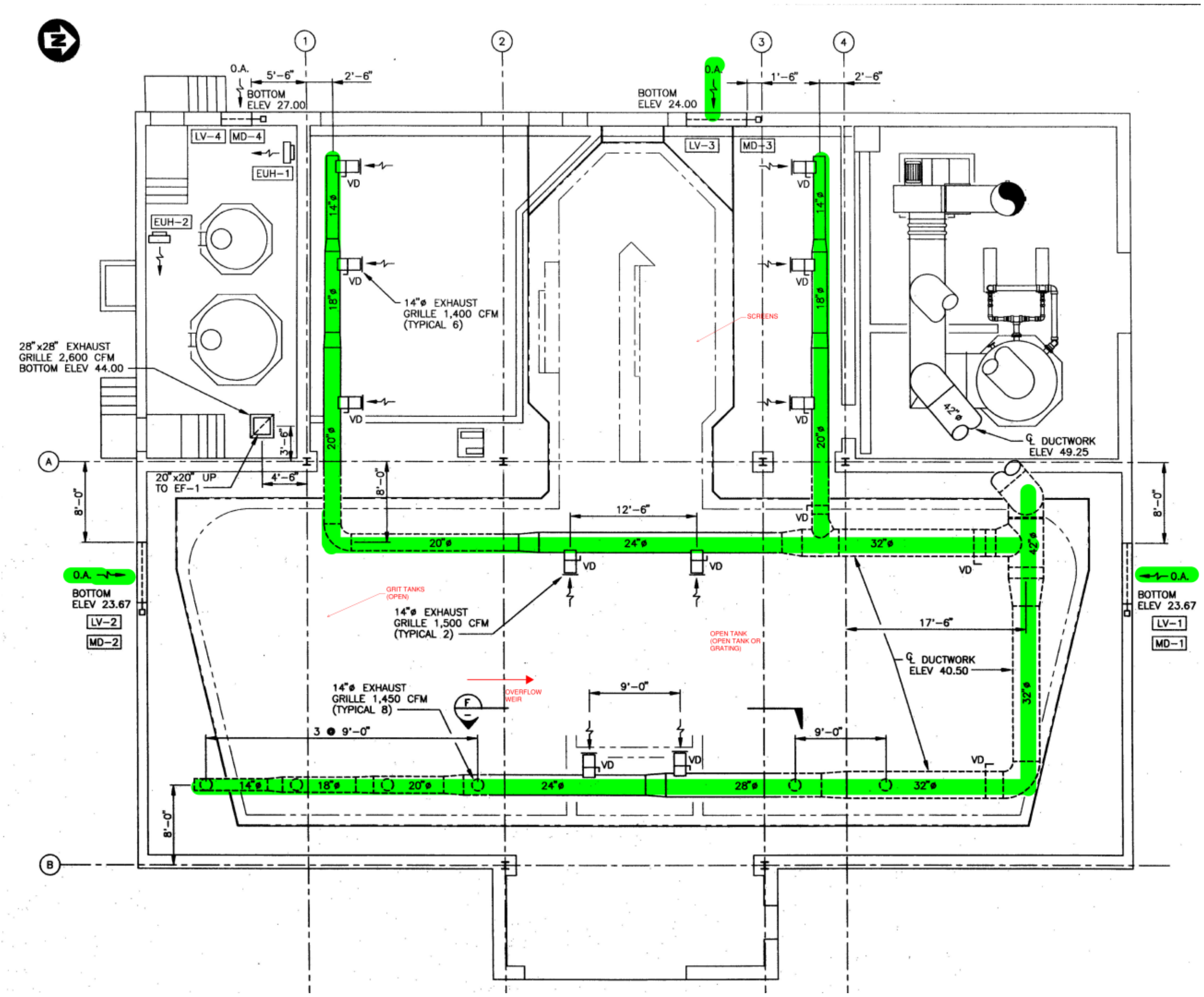

Figure 6-1: Existing Screen and Grit Building Ventilation

All of the intakes are located near the same height and not necessarily near where odors are emitted. In addition, the lack of forced ventilation limites the crossflow and mixing of fresh air to aid in collection of odors. To improve the odor collection with the room, it is recommended that the space be retrofitted for forced supply air and with modifications to the exhaust duct.

Three supply air alternatives were considered, as discussed below.

6.2 Supply Ventilation Concept 1

In this concept, shown in Figure 6-2 below, three new make-up air units (MAUs) would be provided near the existing intake louvers. An inline fan would also be provided near the grit dumpster to improve air movement in that area.

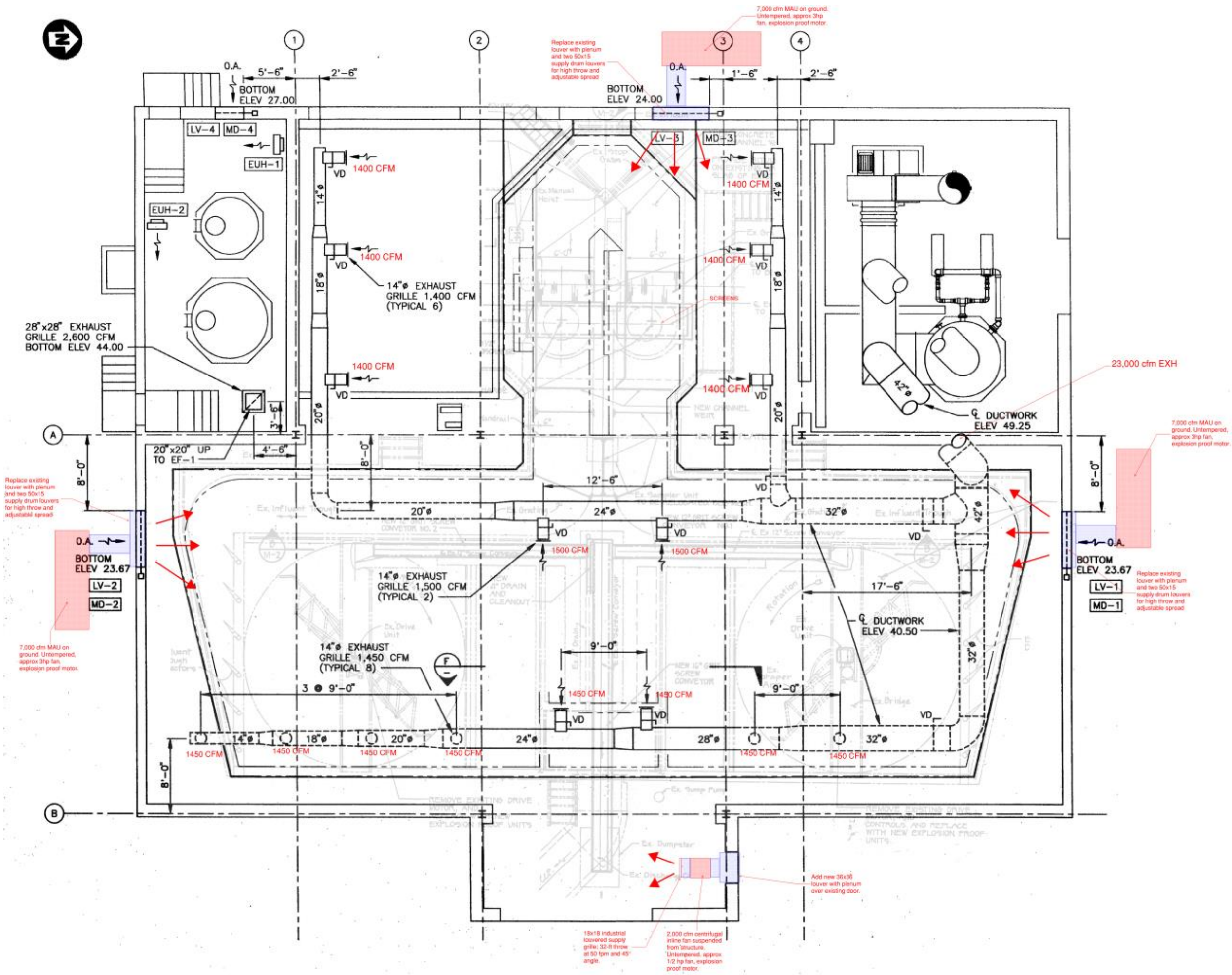

Figure 6-2: Supply Ventilation Concept 1

The main advantages of this concept are the simplicity of construction, with no new major supply ductwork and no modifications to the existing roof. The main disadvantages are MAUs located at grade, which may obstruct waling and traffic flow, as well as no significant changes to the air flow (promoting sweep air across the odor emitting areas).

6.3 Supply Ventilation Concept 2

In this concept, shown in Figure 6-3 below, one new MAU would be provided at the existing intake louver near the screens. Two roof-mounted MAUs would be provided on the roof with supply air directed overtop of the grit tanks An inline fan would also be provided near the grit dumpster to improve air movement in that area as in concept 1.

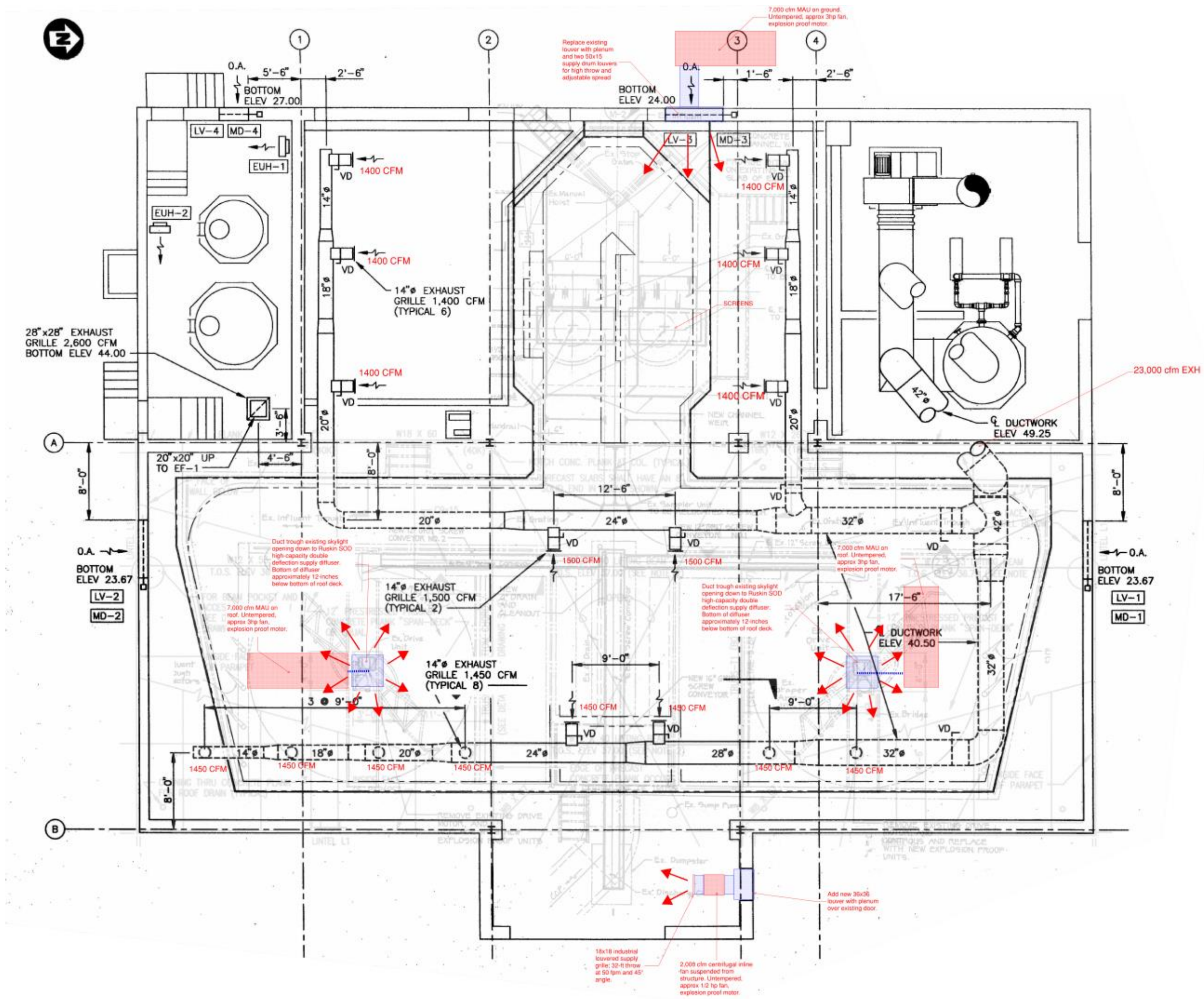

Figure 6-3: Supply Ventilation Concept 2

The main advantages of this concept are the improved air movement over the grit space, including overhead supply grilles to provide flexibility with directing make-up air to problem spots in the space. The main disadvantages are one MAU located at grade, which may obstruct waling and traffic flow, as well as modifications required to the roof. Structural support on the roof may also be required.

6.4 Supply Ventilation Concept 3

This concept, shown in Figure 6-4 below, is similar to concept 2 except that a single MAU would be provided on the roof with additional supply ductwork to the two new diffusers.

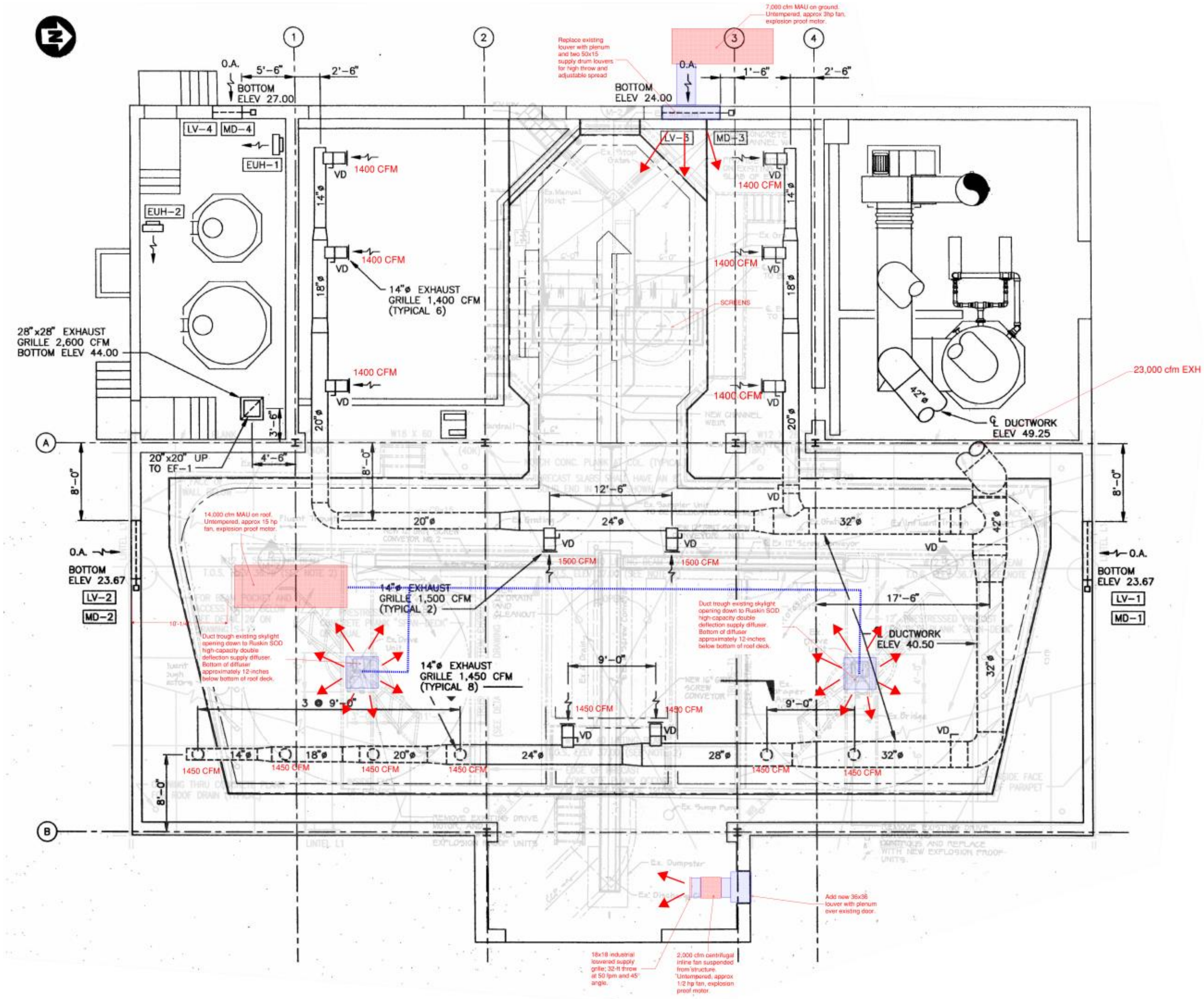

Figure 6-4: Supply Ventilation Concept 3

The main advantages of this concept over concept 2 are fewer electrical and controls additions. However, this comes with the increased likelihood of structural modifications for a large MAU, as well as a loss of all supply ventilation if the unit is offline.

6.5 Exhaust Ventilation Concept

It is recommended that several exhaust inlets be lowered to reduce H2S concentrations at personnel levels and improve overall air movement in the space. These modifications are shown in Figure 6-5 below.

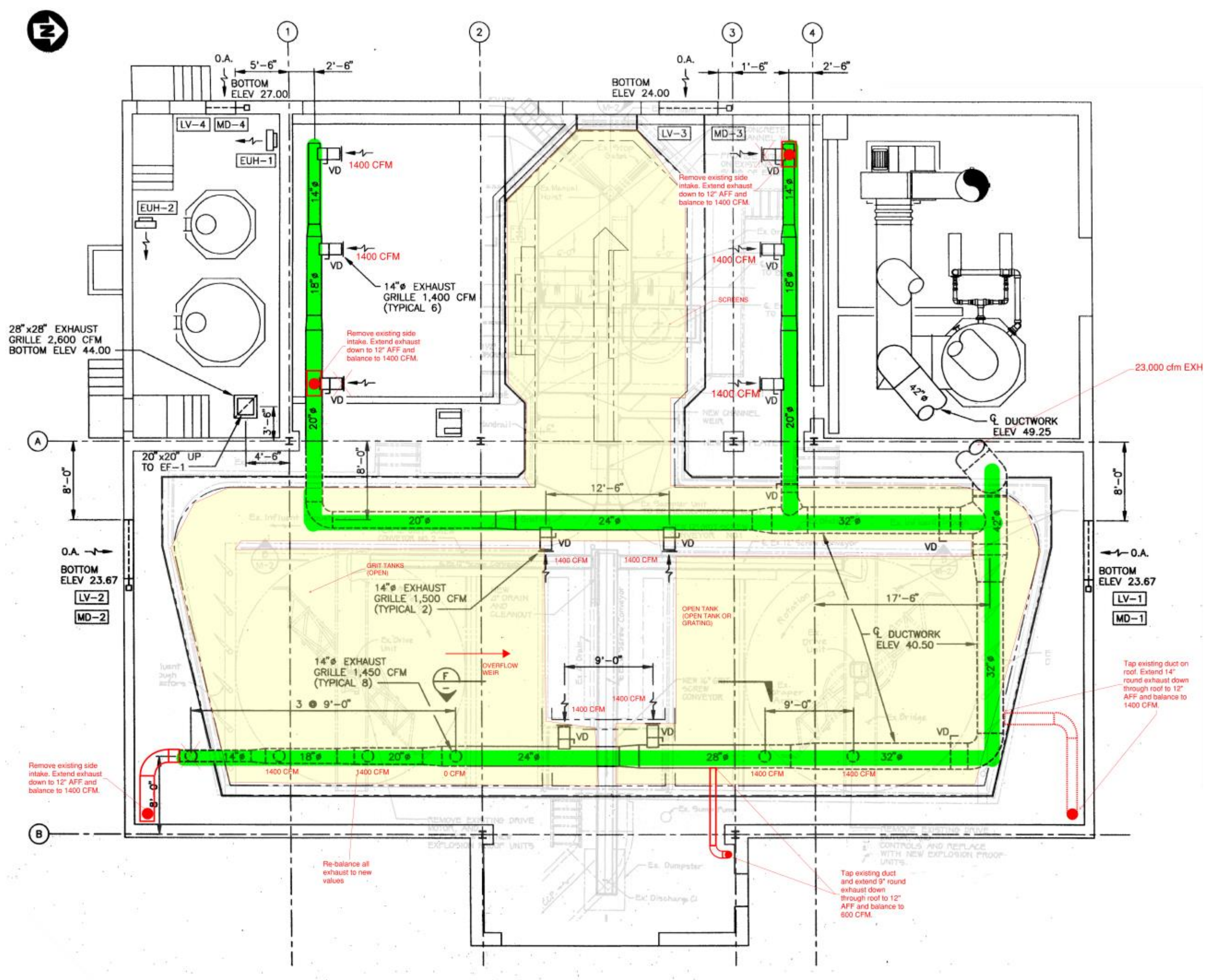

Figure 6-5: Exhaust Ventilation Concept

6.6 Ventilation Evaluation

Given the limited amount of ductwork in all of the concepts and the similar equipment requirements, the cost for all three concepts is very similar at approximately $500,000.

7 RECOMMENDATIONS

It is recommended that biotower systems be installed and designed for the new odor control facilities and ventilation improvements at the screen and grit building be implemented consistent with supply ventilation concept 2 (two new roof mounted MAUs).

The following additional evaluations and considerations should be considered during design:

- Confirmation of technology selection.
  - A second stage carbon unit on the biotower systems adds about $3 million in present worth to the base systems and should be considered by the County for inclusion during design.

  - The County may consider combining the influent pump station and headworks odor control systems to minimize the number of new systems and capital cost. Based on correspondence with the manufacturer, the budgetary estimate for a combined system would be very close in cost to the system for the screen and grit building/primary clarifiers. There would be additional costs associated with the ductwork from the influent pump station. It is estimated that combining these systems could save approximately $800,000 in the total project cost.
- Final location of odor control units.
- Maintenance of plant operations.
- Structural evaluation of the screen and grit building roof for addition of MAUs.
- NFPA considerations for screen and grit building and all of the odor control systems.