Slimming Down for Whole Plant Odor Control

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ABSTRACT

Englewood, Florida is a tourist community of about 15,000 people located on the Gulf of Mexico, south of Sarasota and north of Fort Myers. The Englewood Water District (EWD) operates the Water Reclamation Facility (WRF) located in Placida, FL. The plant receives about 1.8 Million Gallons Per Day (MGD) of wastewater flow during the winter and about 1.1 MGD during the summer months. Hydrogen Sulfide (H_2S) concentrations were very high in raw sewage tanks, ranging from 300 to 800 ppm.

The District had received odor complaints from the surrounding community and unfortunately one of their odor control units was mostly ineffective in controlling odors from the facility as some raw sewage tanks were not covered.

Odor control solutions were developed that utilized some of the unique aspects of this treatment plant which significantly reduced the overall costs. These innovative solutions included:

1. By-passing four (4) raw sewage receiving tanks that were not needed to minimize the number of tanks to be covered and the amount of air to be collected and treated.
2. Taking some return activated sludge (RAS) to the screened plant influent to tie up sulfides in the raw sewage and reduce H_2S emissions in the flow equalization (surge) tanks at each of the four individual package plants.
3. Replacing an existing single stage horizontal bioscrubber that had failed with a 1st stage vertical bioscrubber followed by a 2nd stage biofilter to polish H_2S and odors.
4. Converting one of the existing concrete tanks that were taken out of service into a 2nd stage of treatment biofilter.

The primary objectives of this project were to control odor emissions to the point where odors could no longer be detected by neighbors surrounding the site and to meet the requirements of a Consent Order agreed to with the Florida Department of Environmental Protection. This was achieved by identifying, quantifying and ranking all odor sources at the facility, developing an Odor Control Master Plan and designing/constructing the most reliable, efficient and cost effective odor control facilities possible. This was accomplished by optimizing the use of existing facilities and providing creative odor control solutions.

The project began in January 2012 and construction was completed in September, 2013. Performance testing was conducted in October, 2013, and the results are presented in this paper.

KEYWORDS

Innovative Odor Control, Bioscrubber, Biofilter, Return Activated Sludge for Odor Control, Consent Order, Englewood, Florida

INTRODUCTION

Background

The EWD operates the 3 mgd Water Reclamation Facility located at 140 Telman Road in Placida, FL and was receiving on-going odor complaints from neighbors. EWD made several attempts to control the odors but experienced problems with the systems they purchased and there were still a couple of uncontrolled sources. The complaints eventually led to a Consent Order from the Florida Department of Environmental Protection (DEP).

EWD retained the services of Webster Environmental Associates, Inc. (WEA) and Giffels-Webster Engineers (GWE) to perform a plant-wide odor and hydrogen sulfide (H_2S) survey and to develop a systematic long term, reliable and cost effective odor control program for the facility to address odor complaints and DEP concerns. **Figure 1,** below, is an aerial photograph of the treatment plant.

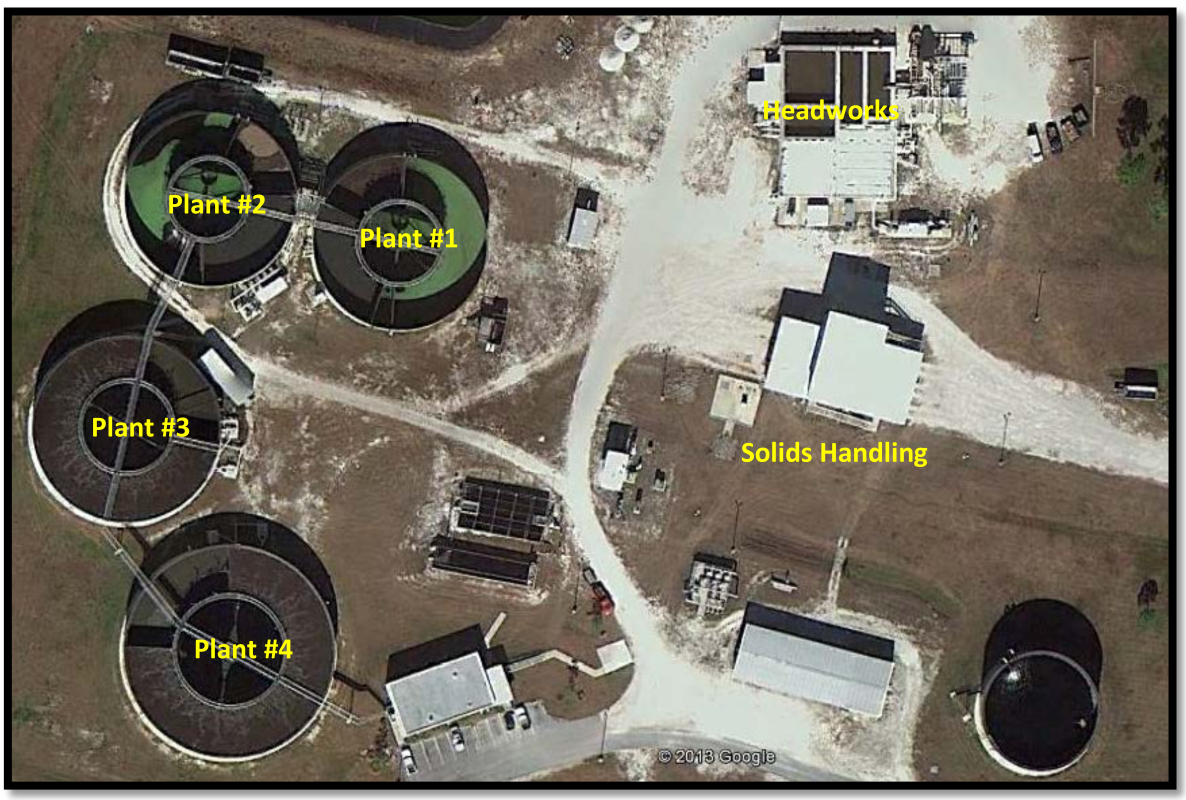

Figure 1 – Aerial View of Englewood WRF (photo from Google Earth)

Existing Plant Description

The 3 MGD facility receives wastewater from an extensive collection system through a 16 in. influent force main. Wastewater enters a series of three (3) covered tanks and is then pumped to three (3) covered influent screens. In the past, grease and sludge accumulated on the surface of these influent tanks because there was no capability to collect and separate the grease or to keep it in suspension. The raw wastewater was pumped to elevated screens and then discharged to a series of four (4) uncovered tanks with the last tank serving as the wet well for the pumps that lifted sewage to the circular package plants. The headworks structure was an existing plant that the EWD converted to its headworks treatment facility and had a unique layout. Refer to **Figure 2** for a plan view of the headworks facility.

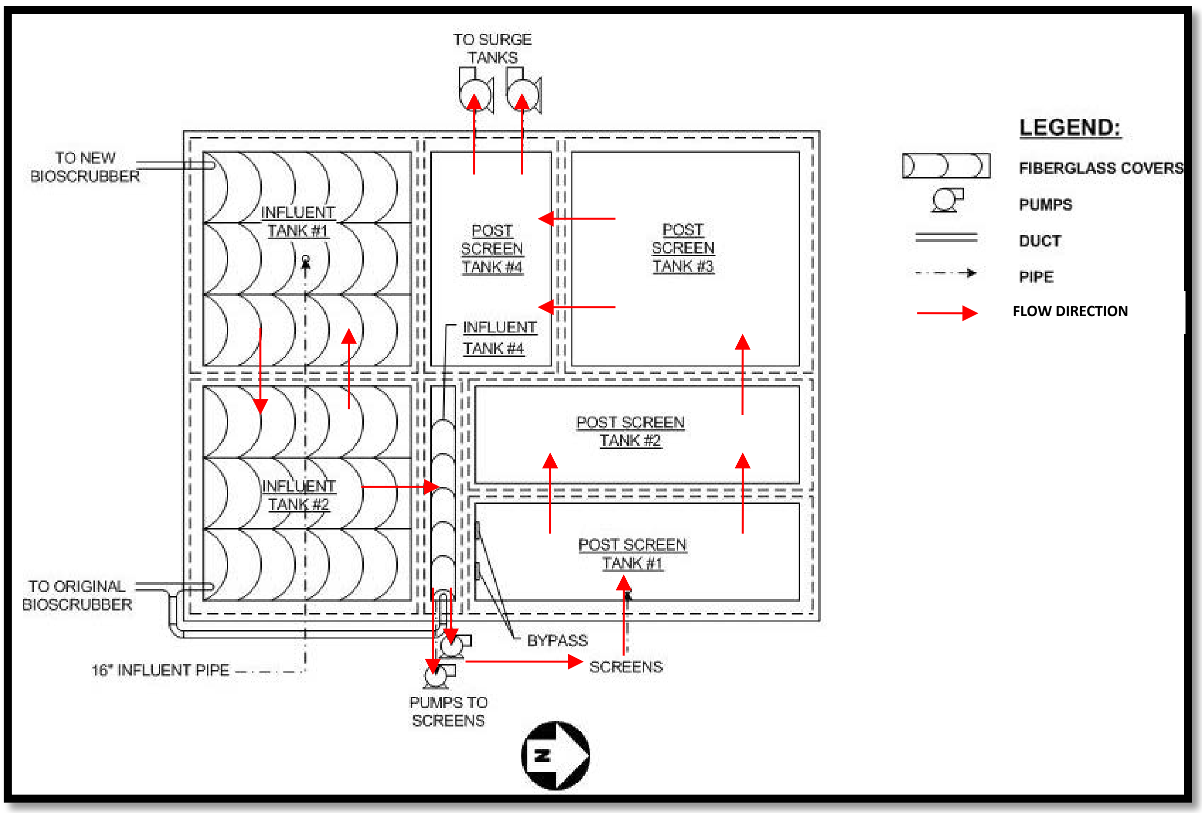

Figure 2 – Plan View of Headworks Facility

The four (4) package plants were constructed at different times over the years as demand increased. Each plant is comprised of surge tanks, aeration activated sludge, secondary clarifiers and aerated sludge holding compartments. Plants #3 and #4 are newer and are used for the aeration tanks but not sludge holding. There are four (4) 2,200 cubic feet per minute (cfm) blowers available for aeration. Effluent from the package plants is filtered and chlorinated prior to discharge as reuse water at golf courses and in the community.

2,000 cfm Horizontal Bioscrubber

Sludge from the aerated holding tanks is pumped to the centrifuge and dewatered. Sludge cake is discharged to trucks and hauled off-site to a landfill.

The existing facility had two odor control systems. One was a horizontal bioscrubber designed to treat 2,000 cfm of air drawn from the influent tanks #1 and #3, as well as the enclosed screens. The second odor control system was a vertical bioscrubber designed to treat 500 cfm of air drawn from influent tank #2. Neither of these systems were performing well at the time of testing.

500 cfm Vertical Bioscrubber

A schematic diagram of the existing plant is shown on **Figure 3**.

Project Objectives

The primary objectives of this project were to control odor emissions to the point where odors would no longer be a cause of complaints by neighbors surrounding the site and to meet the requirements of a Consent Order issued by the Florida DEP To meet these objectives it was necessary to clearly identify, quantify and rank all odor sources at the facility, develop an Odor Control Master Plan and design/construct the most reliable, efficient and cost effective odor control facilities possible. This was accomplished by optimizing the use of existing facilities and providing creative odor control solutions.

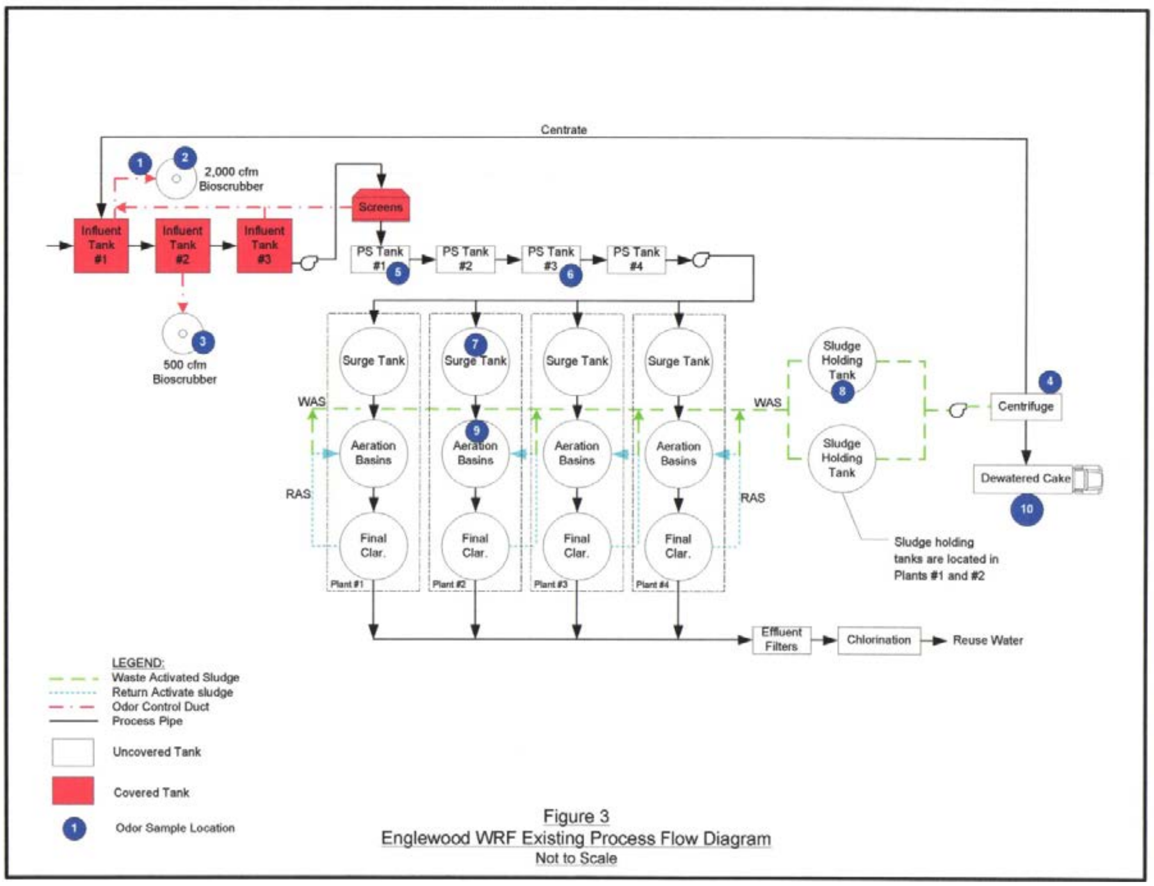

Figure 3 – Air Sample Locations

Project Status

The initial testing phase of the project began in January 2012, the odor control design was completed in November 2012, construction was completed in September 2013 and follow-up testing was performed in October 2013.

METHODOLOGY

Odor Control Master Plan

An air and liquid sampling plan was developed to identify, quantify and rank the various odor sources at the facility. The plan was reviewed by the EWD and comments were incorporated. The plan was then followed as air and liquid samples were collected and tested to identify specific compounds and to determine odor emission rates from each potentially significant odor source. Air samples were collected from the locations shown on **Figure 3** and tested for reduced sulfur compounds (RSC) and odor detection threshold. The RSC samples were analyzed by direct injection Gas Chromatography / Flame Photometric Detection GC/FPD. The odor evaluations were conducted in accordance with ASTM Standard Practice E679-91 (Determination of Odor and Taste Thresholds by a Forced-Choice Ascending Concentration Series of Limits) and E544-99 (Referencing Suprathreshold Odor Intensity). Extensive hydrogen sulfide (H_2S) monitoring was conducted over several months using Odalog H_2S monitors.

Liquid samples were collected and tested for pH, ORP and temperature using an YSI Pro Plus Multimeter and for total sulfides using a LaMotte Model P-70 sulfide test kit.

The odor panel test results were entered into odor dispersion modeling software which was used to predict off-site odor impacts using baseline conditions and with simulated odor control scenarios. The software used to complete the modeling was Breeze AERMOD v7.3.1.1 developed by Trinity Consultants Inc.

Pilot testing was also conducted to determine the effectiveness of pumping RAS to the screened plant influent in order to reduce odor, H_2S and reduced sulfur compound emissions from the surge tanks. If odor emissions could be reduced enough using RAS then the surge tanks would not have to be covered and treated. A flux chamber was placed on the surface of a surge tank and H_2S was measured with an Odalog and a sample was taken for laboratory analysis of reduced sulfur compounds (RSCs). RAS was added to the tank for a period of almost two hours and an Odalog was set up to record continuously. After about two (2) hours another air sample was taken for lab analysis of RSCs with RAS mixed in the tank.

All of the test results, modeling results, pilot testing results, alternatives analyses, conclusions and recommendations were summarized in the Odor Control Master Plan report which was used as the basis for the odor control design.

RESULTS

Odor Study Air Testing Results

The EWD was feeding calcium nitrate upstream of the EWRF in an effort to reduce odor/H_2S at the plant down to a level that the bioscrubbers could handle. The cost of feeding the calcium nitrate was high and the plant was still experiencing H_2S concentrations that averaged more than 100 ppm and spikes as high as 400 ppm. After some initial H_2S monitoring, WEA/GWE recommended feeding a magnesium hydroxide solution due to the length of the force main, long detention time and other dynamics of the upstream collection system and force main. After switching to magnesium hydroxide, the average H_2S concentrations remained about the same (low enough for the bioscrubbers to handle) but the spikes were lower and the cost per day was reduced from nearly \$450/day to about \$250/day.

The H_2S, RSC and odor panel test results for the plant are summarized on **Table 1**. The upstream odor control chemicals had been intentionally turned off while the air sampling and testing was being conducted at the plant to simulate worst-case conditions.

H_2S concentrations at the headworks were quite high as shown on **Figure 4**. This figure is an Odalog chart showing H_2S concentrations within the enclosed screens on January 12, 2012, the day most of air sampling and testing was being performed at the plant. The average H_2S concentration within the screens on that day was 231 ppm and the peak was 977 ppm, with no upstream chemical addition. The H_2S within the screens was perhaps a little higher than the H_2S within the other headworks structures due to the turbulence within the screens, but it is indicative of the levels experienced at the headworks facility.

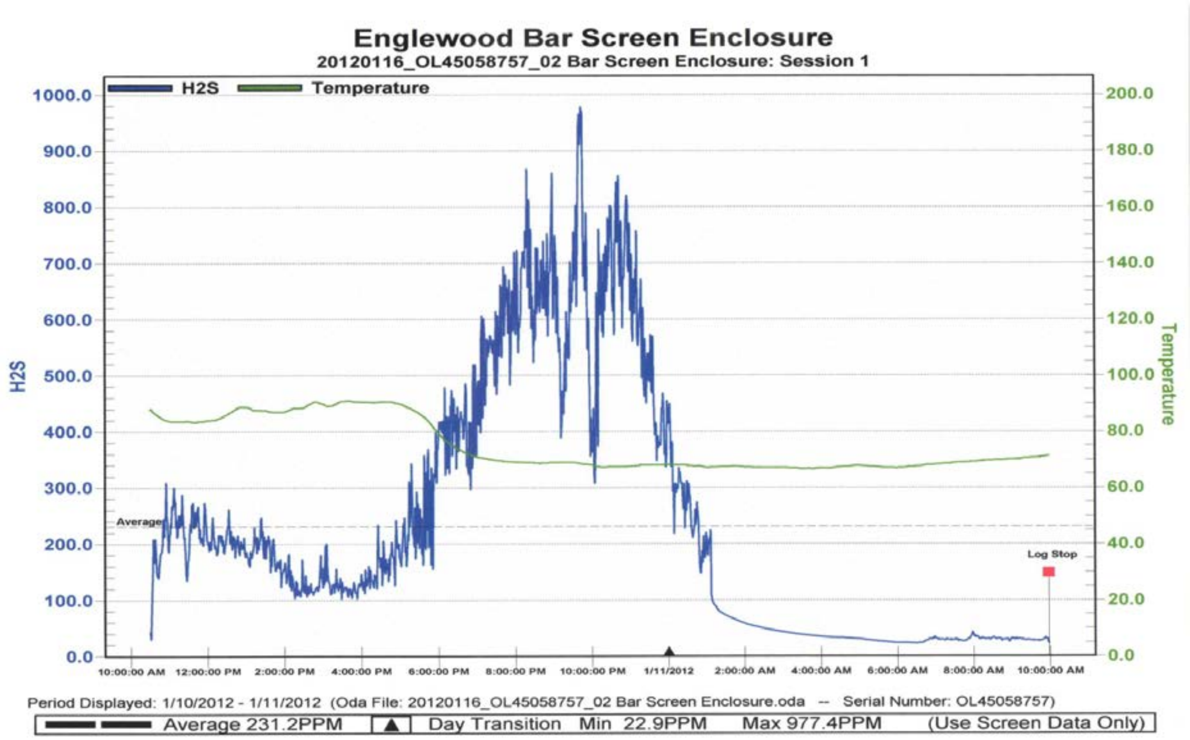

Figure 4 – Bar Screen Odalog Chart

Table 1 - Air Testing Results Summary

Location	H_2S Concentration Range (ppm)	Odor Panel Testing		RSC Testing [2]						
		Detection Threshold (DT)	Recognition Threshold (RT)	H_2S (ppm)	COS (ppb)	MM (ppb)	DMS (ppb)	CDS (ppb)	DMDS (ppb)	DMTS (ppb)
Vertical Bioscrubber Inlet	150 - 517	>60,000	>60,000	517	8.6	1,200	7.9	39	5.1	7.0
Vertical Bioscrubber Outlet	4 - 75	27,000	13,000	74	5.9	300	10	19	7.1	21
Horizontal Bioscrubber Outlet	30 - 84	24,000	13,000	84	4.7	300	4.4	11	6.5	32
Centrifuge Vent	0	330	160							
Post Screen Tank #1 Surface	300 - 3,000	>60,000	>60,000	3,022	31	3,000	28	53	15	148
Post Screen Tank #2 Surface	120 - 540	NE	NE	547	6.6	2,400	6.6	15	ND	ND
Surge Tank #2 Surface	120 - 540	28,000	17,000							
Aerated Sludge Holding Tank	0.202	360	170							
Aerated Activated Sludge Tank	0	290	140							
Sludge Truck	0.11 - 0.13	420	200							

Notes:

(1) Laboratory Reduced Sulfur Compound (RSC) results are reported in parts-per-million (ppm) for H_2S and parts-per-billion (ppb) for all others. Values left blank indicate no sampling and the ND indicates measurements were below the detection limits of the laboratory instrumentation.

(2) RSC Abbr. (odor threshold, ppb): H_2S = hydrogen sulfide (0.5), COS = carbonyl sulfide (100), MM = methyl mercaptan (0.5), DMS = dimethyl sulfide (0.1), CDS = carbon disulfide (25), DMDS = dimethyl disulfide (3) DMTS = dimethyl trisulfide (0.5)

(3) NE = Not enough sample - bag leaked

The test results showed that the existing bioscrubbers were not performing very well under these high H_2S conditions. The vertical bioscrubber (25 seconds EBRT with 60% Tri-pack plastic media and 40% Polyurethane Foam Cubes) was removing about 85% (range of 74 – 97%) of the inlet H_2S and less than 50% of the odors. However, the inlet H_2S was greater than 500 ppm when these tests were conducted.

The horizontal bioscrubber (20 second EBRT, mixture of 2 types of coated inorganic media) removed about 75% (69 – 82%) of the inlet H_2S and 60% of the odor. This bioscrubber was probably experiencing short circuiting due to its design.

The vertical and horizontal bioscrubbers had outlet DT's of 27,000 and 24,000, respectively. Post Screen Tank #1 had DT's greater than 60,000 and was higher than the odor laboratory could measure. H_2S levels in Post Screen Tank #1 during the time of testing ranged from 265 to 3,022 ppm without up-stream chemical addition. These very high levels were due to the fact that the screens create extreme turbulence, mixing air and water in the discharge pipe. The screened wastewater was then discharged into Post Screen Tank #1 where much of the odor and H_2S was released to atmosphere. Post Screen Tanks #2, #3 and #4 also released a significant amount of odor and H_2S.

The surge tanks (raw wastewater storage) are compartments within each of the four (4) circular package plants. These tanks have a large surface area and were releasing odor and H_2S. Odor levels from the tank were 28,000 DT and H_2S concentrations were 121 ppm from flux chamber samples.

The aeration tanks (activated sludge basins) and the aerated sludge holding tanks were low level sources of odors and H_2S emissions. The DT's were 290 and 360 for the activated sludge and sludge holding tanks, respectively. There were no detectable H_2S emissions from the aeration tank flux chamber sample and only 0.23 ppm of H_2S from the sludge holding tanks.

Odor Emission Rates

The potential for off-site odors from the WRF is partly impacted by "Odor Emission Rates" (OER), which is the product of the odor detection threshold multiplied by the exhaust air flow rate for each source. The OER data is used in the dispersion modeling to predict off-site odors from individual sources as well as combined source groups.

Table 2 presents the results of the odor emission rate calculations for all odor sources evaluated during the odor testing at the plant with the Bioxide off. The data includes the air flow rate, DT, and resulting OER for each of the processes evaluated during the testing visit. The OER inventory may be used as a preliminary method for considering the potential for off-site odors from the individual processes, prior to odor dispersion modeling.

Table 2 - Odor Emission Rates (Without Upstream Odor Control Chemical Addition)				
Source	Air Flow Emission Rate (cfm)	Detection Threshold (DT)	Odor Emission Rate (D/T*cfm)	Percent of Total (%)
Horizontal Bioscrubber	1,832	24,000	43,968,000	38.9%
Surge Tanks for all Four Plants	1,124	28,000	31,468,800	27.9%
Vertical Bioscrubber	540	27,000	14,580,000	12.9%
Post Screen Tanks Nos. 2-4	361	40,000	14,440,000	12.8%
Post Screen Tank No. 1	107	60,000	6,411,429	5.7%
Activated Sludge Tanks	4,400	290	1,276,000	1.1%
Aerated Sludge Holding Tanks	2,200	360	792,000	0.7%
Centrifuge Sludge Hauling Tanks	40	420	16,896	0.0%
Centrifuge Vent	50	330	16,500	0.0%
			112,969,625	100%

The source with the highest odor emission rate at the facility was the horizontal bioscrubber which contributed 39% of the total facility emissions as shown on **Figure 5**. The 2nd highest sources were the surge tanks (all four tanks combined) at 28% of the plant total. The post-screen tanks at the headworks structure contributed 18.5% of the plant odors and the vertical bioscrubber contributed 12.9%. All other sources combined contributed less than 2% of the odors at the facility.

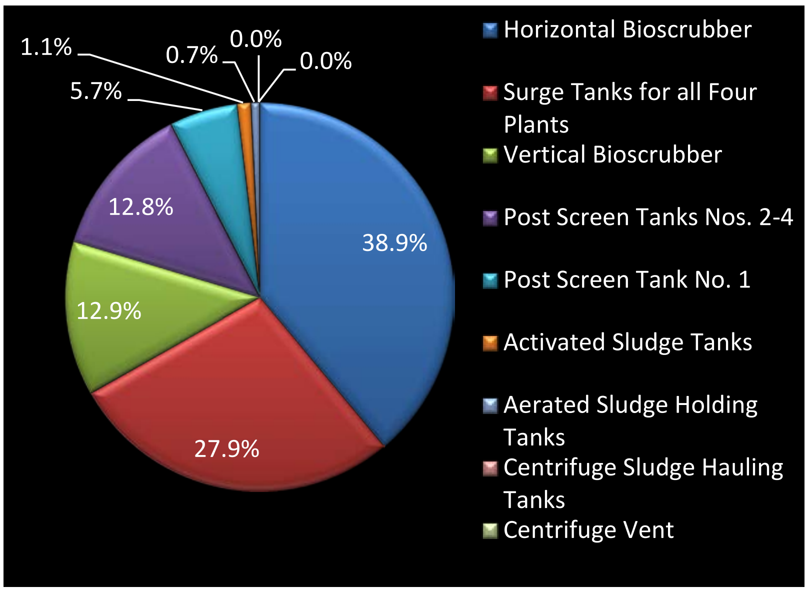

Figure 5 – Odor Emission Rate Distribution

The H_2S testing showed that 46% of the total H_2S emissions from the facility were coming from the surge tanks, 39% from the post screen tanks and 11% from the horizontal bioscrubber as shown on **Table 3**.

Table 3 - H_2S Emissions				
Source	Air Flow Emission Rate (cfm)	Hydrogen Sulfide Conc. (ppm)	Mass Emissions (lbs/day)	% of Total H_2S (%)
Surge Tanks for all Four Plants	1124	547	83.84	46.2%
Post Screen Tank No. 1	107	3022	44.04	24.3%
Post Screen Tanks Nos. 2-4	361	547	26.93	14.9%
Horizontal Bioscrubber	1,832	84	20.99	11.6%
Vertical Bioscrubber	540	74	5.45	3.0%
Aerated Sludge Holding Tanks	2,200	0.23	0.07	0.0%
Centrifuge Sludge Hauling Tanks	40	0.13	0.00	0.0%
Activated Sludge Tanks	4,400	0	0.00	0.0%
Centrifuge Vent	50	0	0.00	0.0%
		TOTALS	181.31	100%

RAS Pilot Testing Results

Pilot testing was conducted to determine the effectiveness of returning activated sludge to the screened plant influent in order to reduce odor, H_2S and RSC emissions from the surge tanks prior to designing a full scale system. RAS has been shown to be an effective method of adsorbing and oxidizing sulfides in raw sewage. A flux chamber was placed on the surface of a surge tank and H_2S was measured with an OdaLog and a sample was taken for laboratory analysis of RSCs. RAS was added to the tank for a period of almost two hours and an OdaLog was set up to record continuously. After about two (2) hours another air sample was taken for lab analysis of RSCs with RAS mixed in the tank. The results shown on **Table 4** were that H_2S emissions from the Surge tanks were reduced by nearly 93% and mercaptans were reduced by about 96% when the activated sludge was returned to the screened plant influent tank in this pilot test. Therefore, a full scale system was designed for the facility.

Table 4 – RAS Pilot Testing Results			
Compound	**Surge Tank Raw Sewage (Start) (ppb)**	**Surge Tank RAS + Raw Sewage (End) (ppb)**	**Percent Reduction (%)**
Hydrogen Sulfide	42,698	3,178	92.5
Methyl Mercaptan	123	4.6	96.2
Dimethyl Sulfide	1.6	1.4	12.5
Dimethyl Disulfide	2.0	3.1	-

Odor Dispersion Modeling

The test results were entered into the AERMOD odor dispersion modeling software. **Figure 6** shows the Peak DT contours for the existing conditions and **Figure 7** shows the frequency contours for the existing conditions. These contours showed Peak DT levels at the nearest off-site residence of greater than 400 and that detectable odors could be present at the nearest residence over 800 times per year (7 DT or greater).

Additional modeling results will be presented later in this paper showing the Peak DT and Frequency contours after the odor control improvements were implemented.

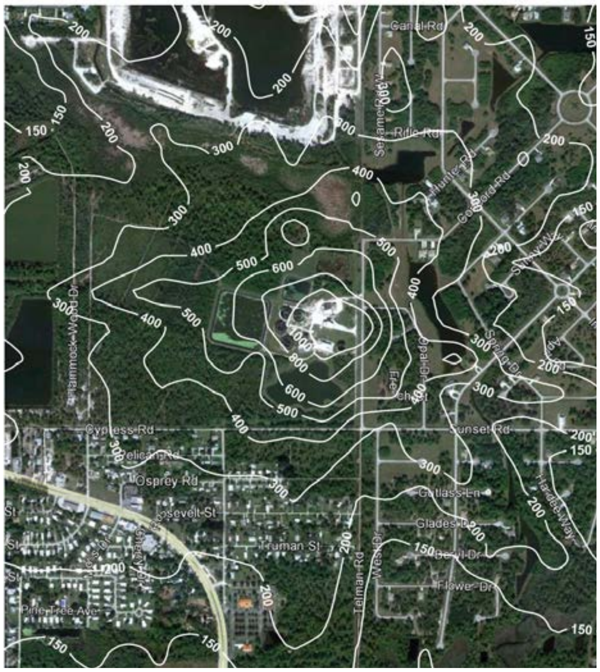

Figure 6 – Peak DT Contours

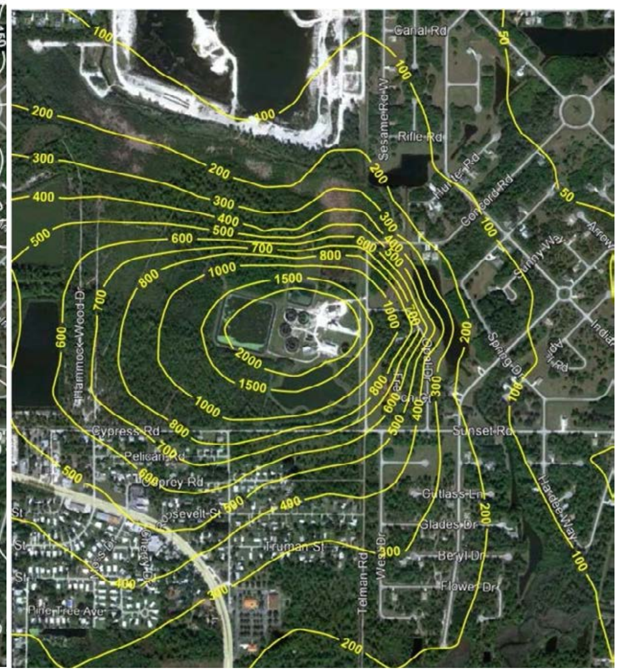

Figure 7 – Frequency Contours

DISCUSSION

Evaluation of Odor Control Alternatives

This project was unique because the WRF tanks had been modified so many times over the years and because the inlet H_2S concentrations were so high. Innovative solutions had to be developed that would provide the required level of odor control at the lowest possible cost. Making a few simple operating process modifications, re-purposing some tanks, and utilizing facilities that were already in place drastically reduced the cost of controlling odors from this facility. After careful consideration and evaluation of many alternatives, the following process modifications and odor control improvements were recommended and eventually accepted by the Owner.

1. Taking several unnecessary tanks out of the headworks treatment process to significantly reduce the area to be covered and the size of the odor control system
2. Replacing the existing poorly performing horizontal bioscrubber with a new 2,000 cfm vertical bioscrubber that would provide 1^{st} stage treatment and remove the majority of the inlet H_2S. This bioscrubber would treat air collected from the plant influent tanks and enclosed screens.

3. Maintaining the existing 500 cfm vertical bioscrubber but treating air drawn from a different tank. This bioscrubber would provide 1st stage treatment and primarily remove H_2S.
4. Re-purposing one of the tanks that was removed from service by converting it to a biofilter, thus saving the cost of constructing a new biofilter structure. The 2,500 cfm biofilter would provide 2nd stage treatment of the air exhausted from both of the bioscrubbers.
5. Returning a portion of the activated sludge to the screened plant influent to reduce H_2S and mercaptan emissions from the surge tanks by more than 90%.
6. Installing a spray system with magnesium hydroxide for the plant influent tank to keep fats, oil and grease (FOG) entrained in the wastewater and eliminate thick layers of FOG from building up on the surface of the tank that created odor and insect problems.

The proposed improvements are shown schematically on **Figure 8**. The improvements to the headworks area are also shown in plan view on **Figure 9**.

Odor Control Improvements Design/Construction

EWD accepted the odor control recommendations in the Master Plan report and WEA/GWE began the odor control design almost immediately. The design effort progressed smoothly and the project was bid on January 29, 2013.

The construction project was awarded to TLC Construction in the amount of $679,394. Construction began in March 2013 and progressed smoothly through completion in September. The two bioscrubbers and the biofilter were placed into service and the media in each system was allowed to acclimate for about 4 weeks before the system was performance tested.

Follow-up Testing

After the odor control improvements were completed and the new systems had acclimated, follow-up testing was performed to document the performance of each individual odor control system and to determine the overall odor reduction for the plant. The follow-up testing was performed on October 23, 2013. On the day of testing the new 2,000 cfm bioscrubber had an average inlet H_2S concentration of 192.4 ppm and an average outlet H_2S concentration of 0.29 ppm for a removal efficiency of 99.85%.

The existing 500 cfm bioscrubber had an average inlet H_2S concentration of 314 ppm and an outlet of 45.5 ppm for an average removal efficiency of 86%. After this testing was completed the EWD decided to replace the media in this bioscrubber.

The outlet air from both of the bioscrubbers is treated in the 2nd stage biofilter. On the day of testing the average inlet H_2S concentration to the biofilter was 9.2 ppm and the outlet averaged 0.056 ppm for a removal efficiency of 99.35%. The overall H_2S removal efficiency for both stages of treatment was 99.97%. The plant controls suspended solids concentration in the surge

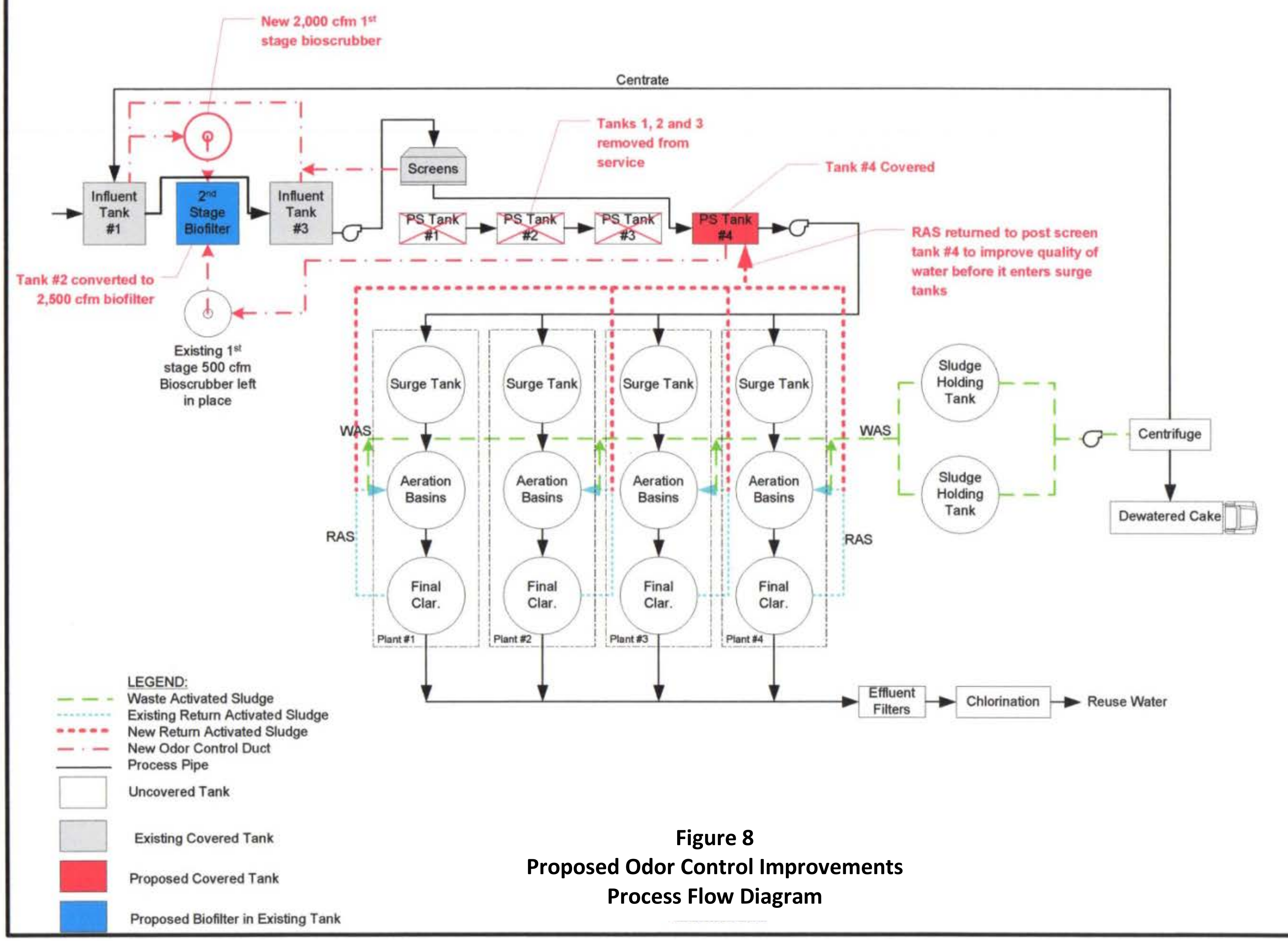

Figure 8
Proposed Odor Control Improvements
Process Flow Diagram

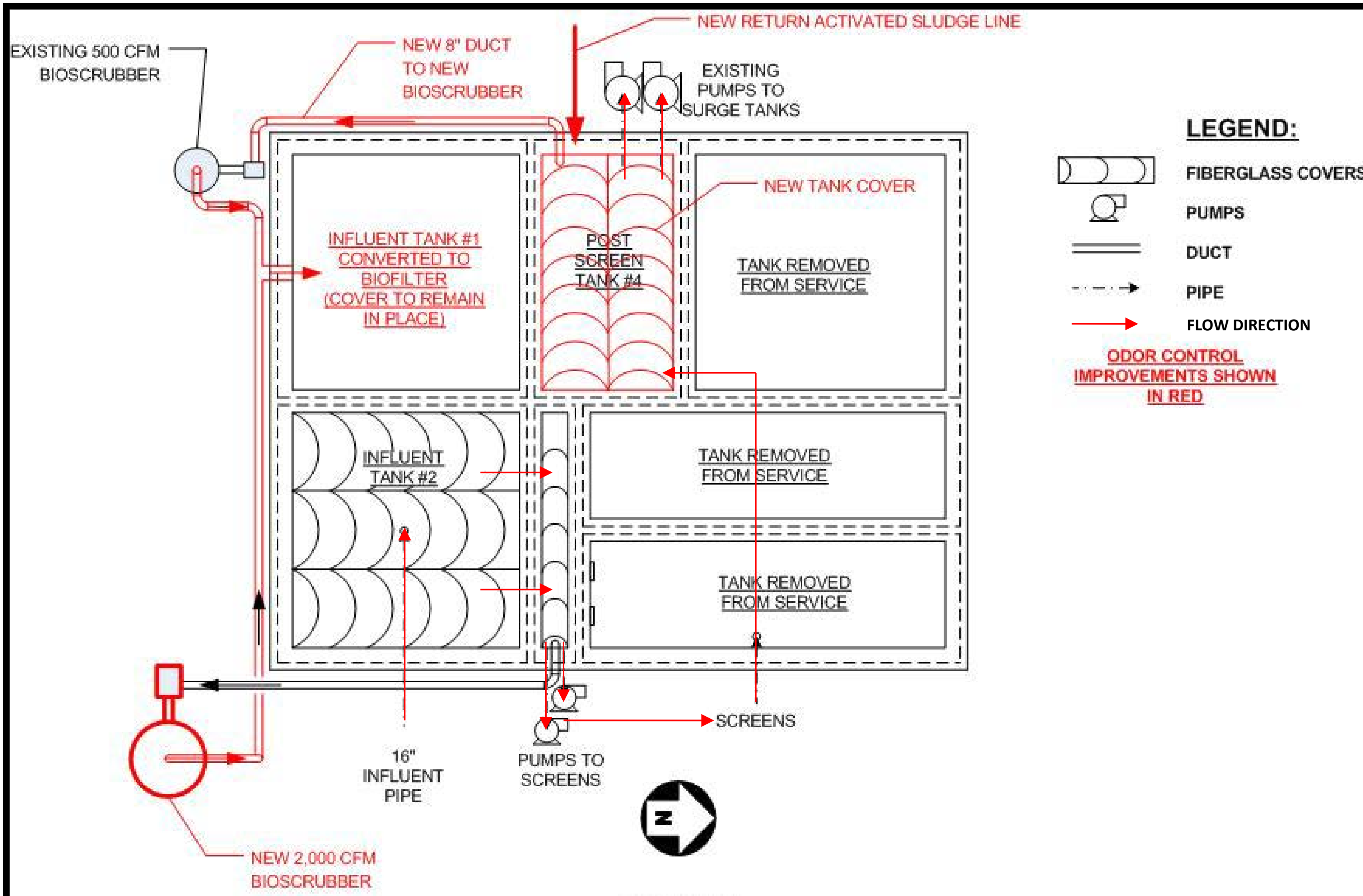

Figure 9 – Plan View of Odor Control Improvements at Headworks

tanks to around 1,000 – 1,200 mg/L by splitting RAS return to these tanks and to the aeration basins. This has reduced odor emissions from these tanks by 90% (**see Figure 10**).

Air samples were also collected for odor panel analysis. The odor panel test results were used to calculate odor emission rates (OER) for the facility. **Table 5** compares the odor emission rates for the WRF before and after the odor control improvements. This table shows that the OER for all sources at the plant were reduced from almost 113,000,000 units to less than 10,000,000 units for a total odor reduction of more than 91%.

Table 5 -Odor Emission Rates Comparison

Source	Odor Emission Rate Prior to Improvements (DT*cfm)	Odor Emission Rates After Improvements (DT*cfm)
500 cfm bioscrubber	14,580,000	0
2,000 cfm bioscrubber	43,968,000	0
2,500 cfm biofilter	0	4,500,000
Post-screen tanks No. 1	6,411,429	0
Post -screen tanks Nos. 2 -4	14,440,000	0
Surge tanks for all four plants	31,468,800	3,371,657
Activated sludge basins	1,276,000	1,276,000
Aerated sludge holding tanks	792,000	792,000
Sludge hauling tanks from centrifuge	16,896	16,896
Centrifuge vent	16,500	16,500
Total Odor Emissions (All Sources)	112,969,625	9,973,053
Odor Removal Efficiency	91.2%	

Hydrogen Sulfide (H_2S) emissions were greatly reduced as well. As a result of the new covers, taking tanks out of service, installing a new bioscrubber and new biofilter in one of the existing tanks, H_2S emissions were reduced by 99.98%. For the surge basins, using RAS returned to the tanks, resulted in a 99.94% reduction in H_2S emissions for the WRF. There are no other sources of H_2S emissions at the plant site.

The new bioscrubber from BioAir, shown in **Figure 11**, performs very well as shown in the typical Odalog Chart in **Figure 12**.

The post-construction odor panel results were entered into the odor dispersion modeling program and new Peak DT and Frequency contours were created. **Figure 13** shows the new Peak DT contours overlaid on the original Peak DT contours to show the amount of improvement. Prior to the odor control improvements, the peak DT at the nearest residence was over 400 and after the improvements the Peak DT at the nearest residence was about 75. Prior to the improvements the frequency of odor events at the nearest residence was about 800 odor events (7 DT or greater) per year and after the improvements the frequency is predicted to be less than 200 events per year, as shown on **Figure 14**.

Figure 10

Return Activated Sludge with three way valve and magnetic flow meter to split flow

Figure 11

New BioAir Bioscrubber

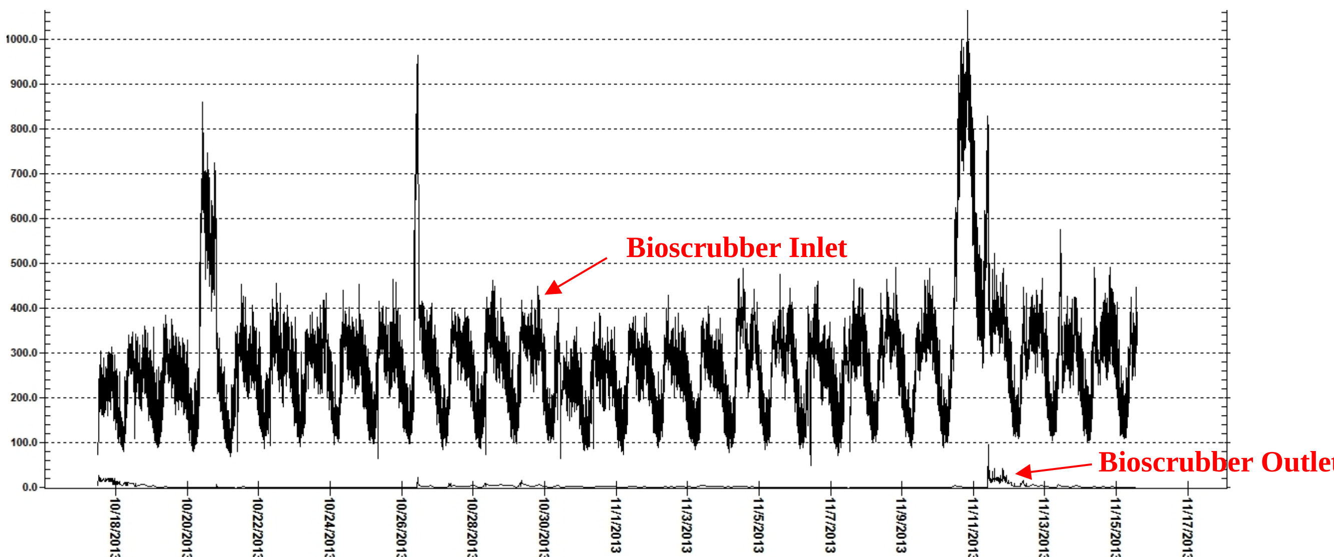

Figure 12

Odalog Readings – Inlet/Outlet H_2S for BioAir Unit (typical) Months After Start-up

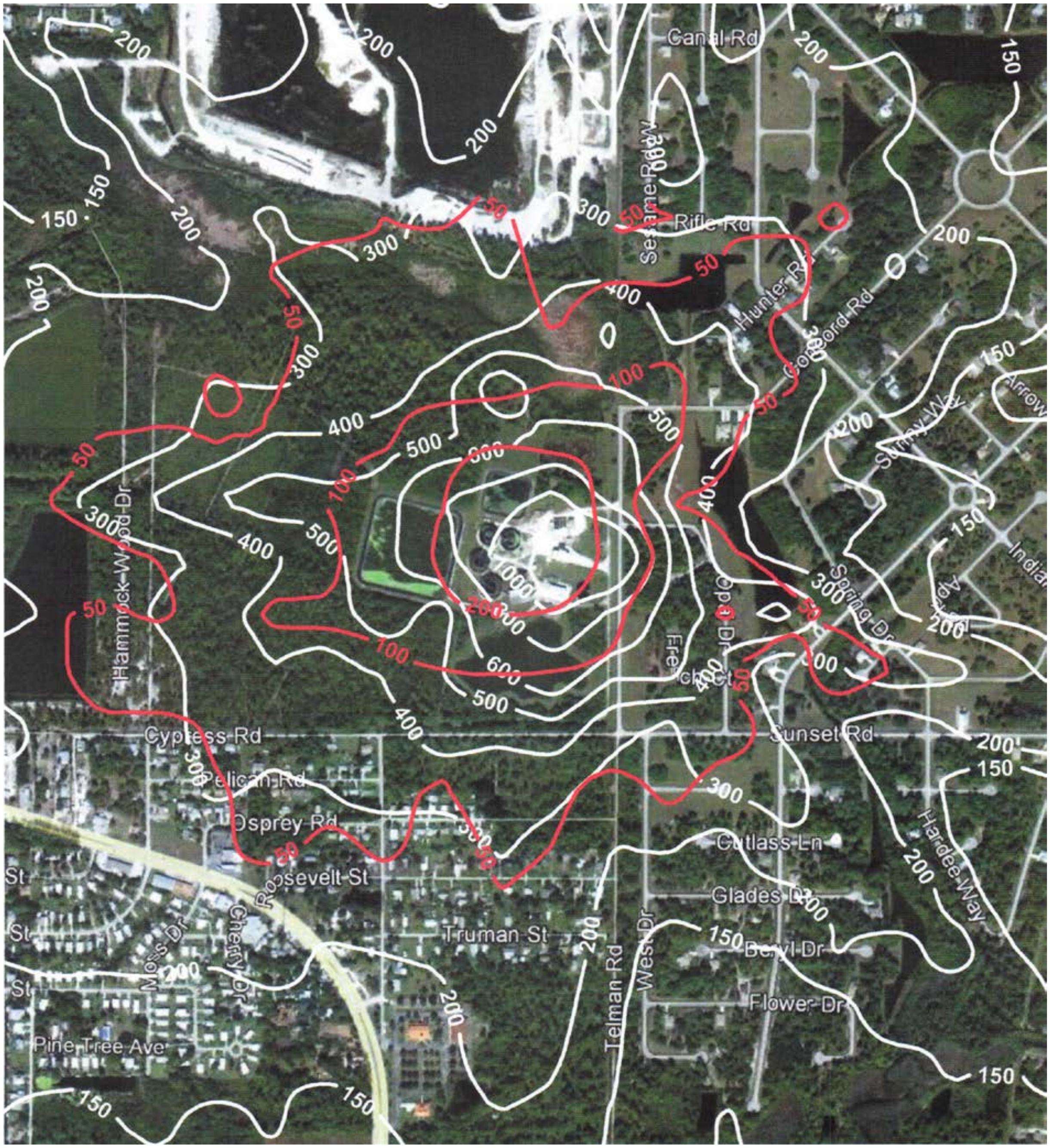

Figure 13 – Original Peak DT Contours Overlaid with Peak DT Contours after Improvements (White – Original Contours, Red – Contours with Improvements)

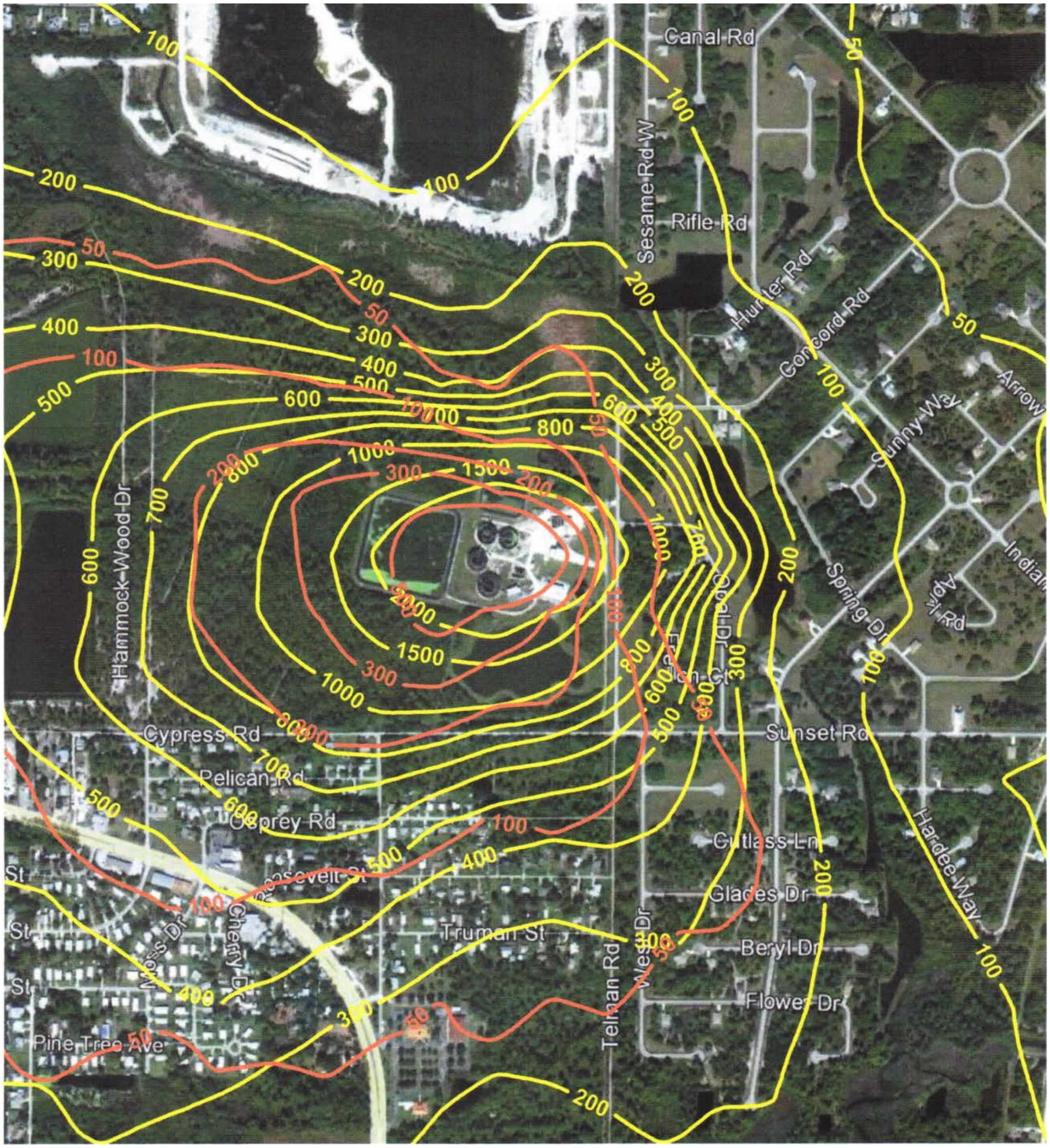

Figure 14 – Original Frequency Contours Overlaid with Frequency Contours after Improvements (Yellow – Original Contours, Orange – Contours with Improvements)(Odor Events greater than 7 DT