Odor & Corrosion Juggling Act: Challenges of Upgrading a Major Municipal Collection System Odor Control Program to Include Corrosion Control Objectives

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ABSTRACT

Since the 1990's Manatee County Utilities (MCU) utilized a combination of liquid phase and vapor phase hydrogen sulfide (H_2S) treatment strategies to effectively address public odor complaints associated with emissions from high sulfide loading gravity sewers and pump stations. Recognizing the need to explore reducing the corrosive conditions in many of these portions of the collection system, rather than simply planning to rehabilitate or replace severely corroded elements of collection system infrastructure, MCU began an odor and corrosion evaluation focus on upgrading their existing odor control program to further reduce H_2S in the sewers and pump stations to concentrations that would significantly reduce corrosion rates.

Hydraulic model information for MCU's three regional treatment facility collection systems was used to calculate dissolved sulfide generation rates within numerous master lift station (MLS) basins. These results were used to evaluate the overall sulfide loading within each basin and compare various corrosion control alternatives. The evaluation identified wastewater pH elevation as an additional liquid phase treatment approach to complement the existing odor control focused sulfide control program. Optimization of wastewater pH elevation, dissolved sulfide reduction, and wastewater turbulence reduction within the constraints of a given MLS basin were identified as the key components to achieve significant H_2S reduction.

Ultimately, H_2S was reduced from hundreds of parts per million (ppm) to under 50 ppm at dozens of pump stations, gravity interceptors, MLSs, and headworks locations via a multi-year, collaborative and iterative effort by MCU, vendor, and consulting firm personnel. The parties worked together to evaluate the impact of pH elevation in concert with various other sulfide control tools within a given MLS basin. The goal of significantly reducing H_2S induced corrosive conditions, while maintaining high quality odor control, was frequently achieved without increasing overall liquid phase and vapor phase treatment operating costs for a given MLS basin.

KEYWORDS

Hydrogen sulfide, odor control, corrosion, collection system, liquid phase treatment, vapor phase treatmen.

INTRODUCTION

Manatee County, Florida is located along Florida's Gulf Coast and is part of the Greater Tampa Bay Region. It includes barrier island communities with beautiful white sand beaches, extensive mainland waterfront development along an intracoastal waterway, along the shores of Tampa

Bay, and the banks of the Manatee River, the cities of Bradenton and Palmetto, a major planned community known as Lakewood Ranch, and extensive agricultural acreage in eastern and northern sections of the County. The year round warm and sunny weather draws tourists, retirees, and businesses from across the U.S. and beyond.

Manatee County Utilities (MCU) provides water and wastewater services to approximately 100,000 customers across 900 square miles of unincorporated portions of Manatee County, Florida. MCU's three regional wastewater treatment facilities currently treat an annual average daily flow of 22 mgd. With a forecasted population growth of 50% over the next 25 years, the County is planning ongoing major infrastructure investment, including wastewater collection and treatment systems, to accommodate the ever-growing population.

As the flat terrain and high-water table of coastal Florida is not suitable for construction of traditional gravity sewer interceptors, large portions of MCU's collection systems are comprised of lift stations and force mains to convey wastewater to the regional treatment facilities. Therefore, MCU has a large and growing collection system involving an extensive network of lift stations (over 700) involving many long retention time single and manifolded force mains. The long retention time of significant portions of MCU's wastewater collection system along with the warm year-round temperatures associated with a humid subtropical climate leads to extensive hydrogen sulfide (H_2S) generation across all three collection systems. These collection system basins are referred to as North Service Area (NSA), Southwest Service Area (SWSA), and Southeast Service Area (SESA). Figure 1 shows the hundreds of outlying, repump, and master lift stations (MLSs) that comprise complex manifolded force main networks interspersed with gravity interceptor sections in each of the three Service Areas. The extensive H_2S generation within the force mains upstream and downstream of all these lift stations has required MCU to expend significant personnel time, operating budget funds, and capital investment over the past thirty years to address an ever-evolving variety set of challenges associated with preventing public odor impacts and corrosion of collection system infrastructure.

Odor nuisances caused by anerobic wastewater can be difficult to manage effectively, particularly in the collection system. In order to be a good neighbor and meet the expectations of their stakeholders, municipalities like MCU are increasingly taking proactive steps to mitigate release of hydrogen sulfide (H_2S) and other odorous compounds before they lead to odor complaints. Often, a treatment strategy developed to prevent complaints at an odor hotspot may still result in corrosion of the collection system and treatment facility infrastructure.

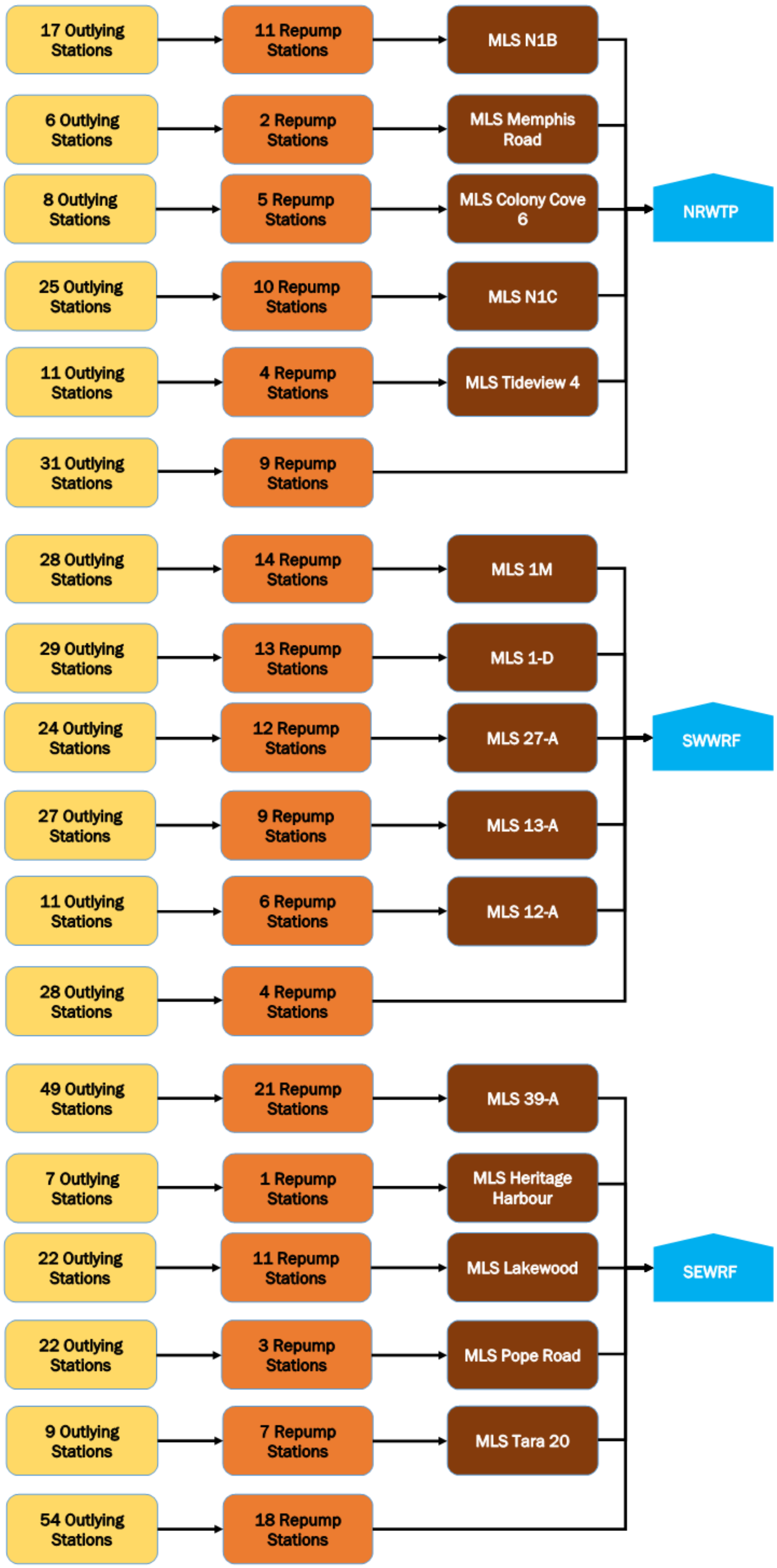

Figure 1. MCU Pump Station and MLS Schematic

Since the 1990's MCU has utilized a combination of liquid and vapor phase treatment strategies to effectively address public odor complaints associated with venting from high sulfide loaded gravity sewers, force mains and pump stations. The historic strategy for liquid phase treatment was to utilize upstream chemical addition to reduce the dissolved sulfide levels in a targeted downstream section of the collection system and in turn lower atmospheric hydrogen sulfide (H_2S) levels in targeted sewer and pump station head spaces. Dissolved sulfide treatment levels were set so a vapor phase treatment system could cost effectively prevent fugitive odorous emissions and discharge a treated exhaust stream with little to no odor/odor complaints.

Over time the increasing use of biological vapor phase units led to the ability to cost effectively treat higher levels of hydrogen sulfide in the air streams from pump stations, gravity lines, and treatment plant headworks. This in turn enabled dissolved sulfide levels in targeted downstream locations, primarily repump stations, to be higher without causing odor complaints. Rising inlet H_2S levels to the vapor phase units resulted in more corrosion of concrete and metallic components within gravity sewer segments downstream of sulfide laden force main discharges, master lift stations (MLS) that repumped wastewater from numerous upstream pump stations and the headworks of the three regional treatment facilities serving the NSA, SWSA, and SESA.

As MCU began observing more widespread corrosion of its wastewater infrastructure, a strategic decision was made to adjust the strategy that had been primarily focused on meeting odor control objectives to one that also minimizes corrosive conditions and prolongs the remaining useful life of their infrastructure.

Recognizing the need to manage corrosive conditions in many portions of the collection system rather than simply planning to rehabilitate or replace severely corroded elements of their collection system infrastructure. In 2017, MCU embarked on developing an updated odor and corrosion control program with two primary objectives for sulfide control. The first, continuing to be a good neighbor to the public and maintain a high level of odor control. The other, significantly reducing the corrosive conditions associated with hydrogen sulfide at key locations throughout the collection system.

METHODOLOGY

Initially Carollo Engineers (Carollo) and V&A Consulting Engineers, Inc. (V&A) were retained by MCU to perform a desk top study, utilizing hydraulic model information for each of the County's three regional treatment facility collection systems to model dissolved sulfide generation for the master lift stations, force mains, and gravity sewers. Wastewater samples were collected to determine characteristics such as sulfate, biochemical oxygen demand (BOD), and pH. Estimated dissolved sulfide concentrations at master lift station (MLS) locations were then compared to historical dissolved sulfide and atmospheric H_2S field testing data at odor program control points and adjusted to factor in upstream chemical treatment dosing.

Additional liquid and vapor phase treatment strategies, along with infrastructure improvements (i.e. coatings, inert materials, etc.), were then considered to mitigate future corrosion within the collection system. Due to the complex nature of the collection system and extremely high hydrogen sulfide concentrations observed within portions of the MCU's collection system

(>1000 ppm), expanding the existing vapor phase treatment program was not a viable strategy for providing effective corrosion control on its own. The capital cost associated with providing protective barriers and/or replacing infrastructure with inert materials was prohibitive to mitigating corrosion within MCU's available funding mechanisms.

Various liquid phase chemical treatment alternatives evaluated included pure oxygen, nitrate salts, iron salts, and pH elevation. Due to the high dissolved sulfide concentration generated in many long detention time force main segments, a key recommendation of the study involved elevating the wastewater pH as an additional means to limit hydrogen sulfide gas release and reduce corrosive conditions at key release points (master lift stations, forcemain discharges/transition manholes, etc.). As part of the recommendation, the existing liquid phase dose sites and vapor phase treatment locations would also be evaluated and reduced, eliminated, or relocated to complement the wastewater pH elevation strategy. MCU agreed to evaluate elevating wastewater pH to complement their existing sulfide control program.

Use of magnesium hydroxide was selected to elevate the wastewater pH to 8.0-8.5. At this pH level dissolved sulfide volatility is reduced as the percentage of such in the H_2S form is significantly lower, as seen in Figure 2. As a result, atmospheric H_2S levels in equilibrium with a given wastewater dissolved sulfide concentration range can be reduced.

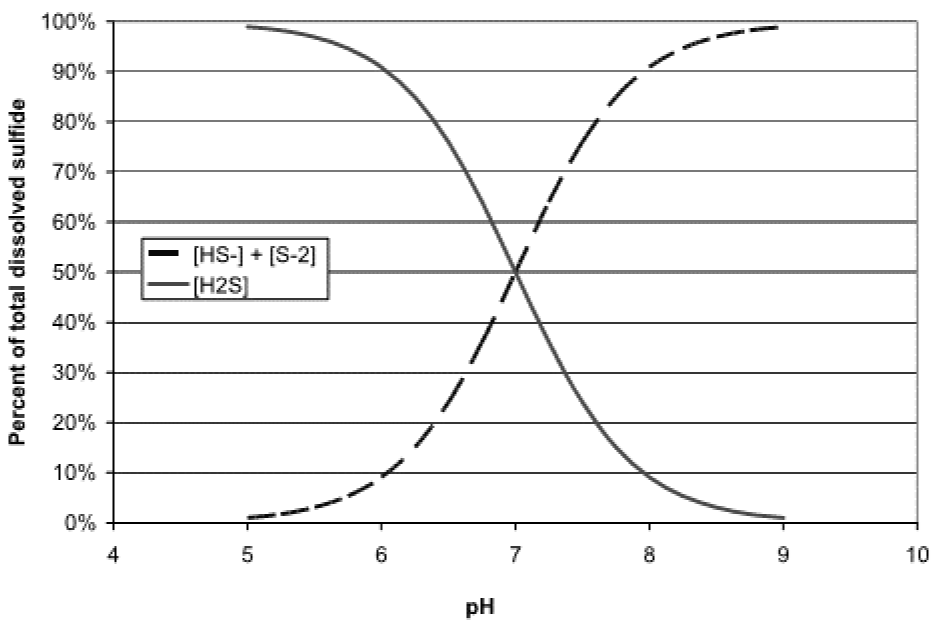

Figure 2. Sulfide Volatility vs pH (WERF 2007)

The goal was to significantly reduce H_2S levels at most MLS locations by using a combination of upstream liquid phase treatments that would now utilize both dissolved sulfide reduction and pH elevation of the wastewater arriving at a given MLS. MLS target H_2S goals were 20 ppm average, 50 ppm peak.

In 2018, MCU established a vendor contract with Premier Magnesia, LLC (Premier) for supply of magnesium hydroxide slurry (under Thioguard® brand name), dosing equipment, and associated technical services. An ongoing odor control services contract with Evoqua Water Technologies LLC (Evoqua) was extended which provided for a variety of liquid phase and vapor phase treatment options. The primary products being employed from Evoqua were nitrate based chemicals to reduce wastewater dissolved sulfide levels and high rate bio-scrubbers to treat foul air from pump station wet wells and upstream gravity lines.

Due to the extensive geographic magnitude of MCU's wastewater collection system, along with the massive and ever growing number of outlying pump stations, repump stations and MLSs and their associated downstream manifolded force main networks/interspersed gravity sewer sectors; a phased approach was recommended to implement and fine tune the new odor and corrosion (O&C) strategy. The implementation plan was broken down by MLS basin within each service area. Initial focus was on MLS basins in the NSA, then the SWSA, and finally the SESA.

Implementation activity within a given MLS basin was typically conducted over a two to three month period. Such activity included baseline testing (dissolved sulfide, pH, atmospheric H_2S), implementation of the proposed liquid phase dosing approach involving pH elevation, and optimization of dosing based on actual performance of magnesium hydroxide and other chemical treatment technologies (primarily nitrate based) at the recommended or trialed chemical feed locations. The effectiveness of the various liquid phase treatment sites was evaluated by measuring and tracking changes in key downstream factors, such as wastewater pH, dissolved sulfide, and H_2S, over time with changes in upstream chemical feed rates. Figure 3 provides an example of the data reporting approach typically utilized. In this case, varying Lift Station 5 (LS 5) dose levels of magnesium hydroxide and nitrate product on MLS 1M pH, H_2S, and dissolved sulfide.

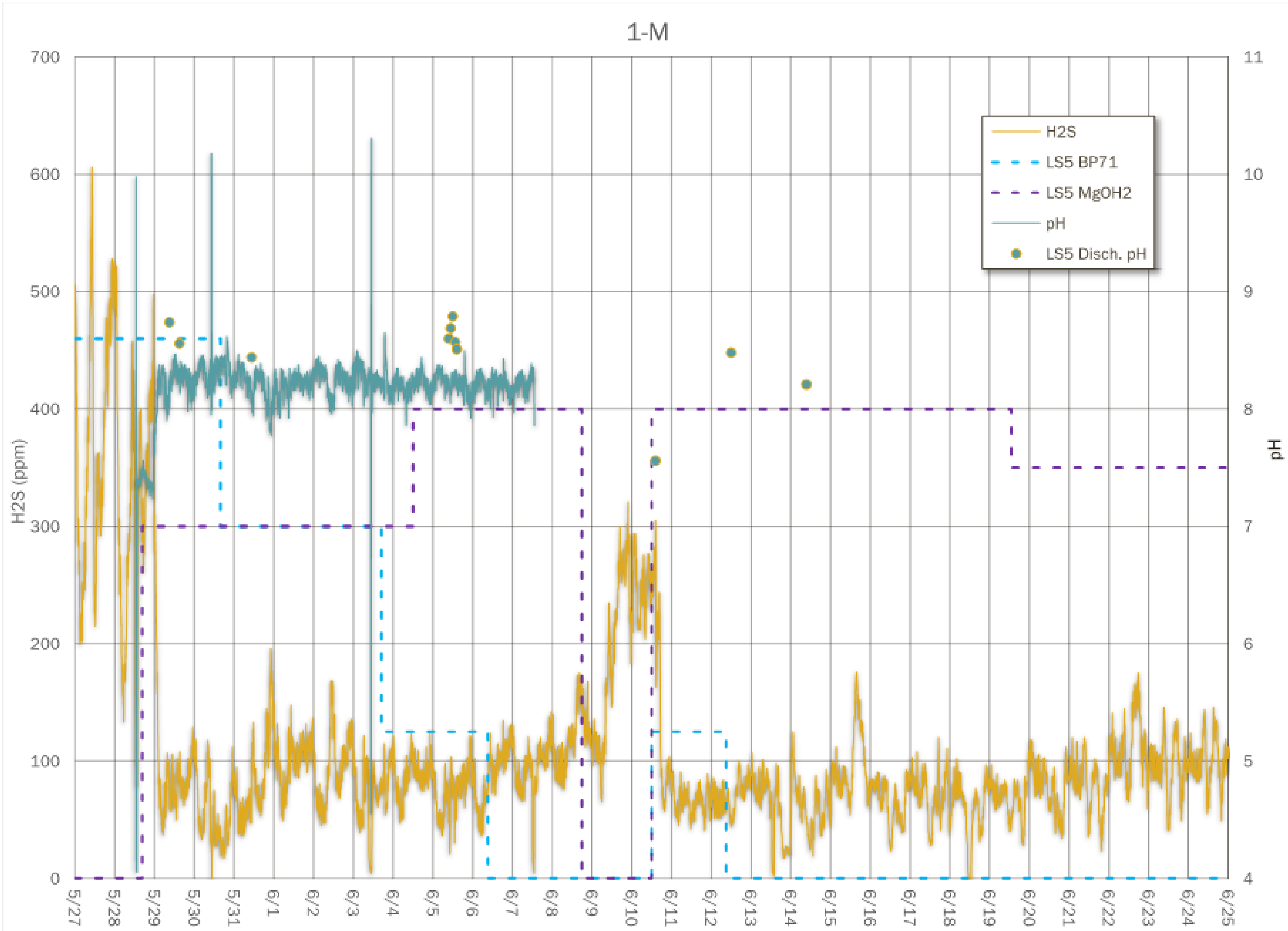

Figure 3. Typical MLS Performance Monitoring Data

Based on initial findings, the need for additional or different upstream dose sites was frequently identified in order to get closer to the target MLS H_2S goals. This field data based iterative process required extensive data collection by the two vendors, evaluation of such by all parties, and determination of next steps with regard to upstream chemical dose changes. The process to accomplish such required an extensive weekly team effort over a multi-year period involving MCU collections system managers, superintendents, and operators along with two vendors and the engineering consultants.

After the implementation and optimization phases for a MLS basin, the O&C program for a basin moved into a maintenance mode with final optimized liquid phase treatment dosing curves to achieve significantly lower hydrogen sulfide loading on the vapor phase treatment systems. Monthly monitoring of key performance parameters, primarily atmospheric H_2S and secondarily wastewater pH and dissolved sulfide, at the MLS and key upstream pump stations and force main discharge locations was conducted to determine the need for further dosing adjustments to meet or maintain the MLS specific “corrosion control” H_2S concentration objectives.

RESULTS

Optimizing the three key wastewater factors of pH elevation, dissolved sulfide reduction, and wastewater turbulence reduction within a given MLS basin reduced H_2S levels from hundreds of ppm to under 50 ppm at dozens of pump stations, gravity lines, MLSs, and headworks locations throughout the County's North Service Area (NSA), Southwest Service Area (SWSA), and Southeast Service Area (SESA). The ability to cost effectively adjust each factor was unique for each MLS basin. Adjusting a single factor did have a significant impact in some cases, but typically H_2S goals were not achieved without leveraging two of the three factors. Without turbulence reduction, MLS H_2S target goals (20 ppm average, 50 ppm peak) were often unable to be achieved cost effectively.

In order to understand the impacts of a chemical dose site and pump station operational changes it was generally advantageous to start-up new dose sites individually and make dose changes to one dose site at a time. After an adequate period of time, the impact of a given change on atmospheric H2S, dissolved sulfide, and pH was assessed at the downstream control point(s).

MCU's goal of significantly reducing corrosive conditions while maintaining high quality odor control has been achieved to a large degree without increasing overall liquid phase and vapor phase treatment operating costs. An 80% or greater reduction of average H_2S was achieved at most MLSs as well as upstream pump stations and gravity lines. A 65% or greater reduction of average H_2S levels was achieved at the headworks of the NSA, SWSA, and SESA wastewater treatment facilities. This was a result of a collaborative and iterative effort by all parties to evaluate the impact of various tools against the unique combination of operational factors for a given MLS basin.

pH Elevation

Historically MLS 1M in the SWSA experienced some of the highest H_2S levels due to collecting approximately 2.5 mgd of wastewater from an upstream network of over 40 pump stations, many of which are on barrier islands and along the mainland coastline. The most remote being over twelve miles upstream at the northern tip of Anna Maria Island, as shown in Figure 4.

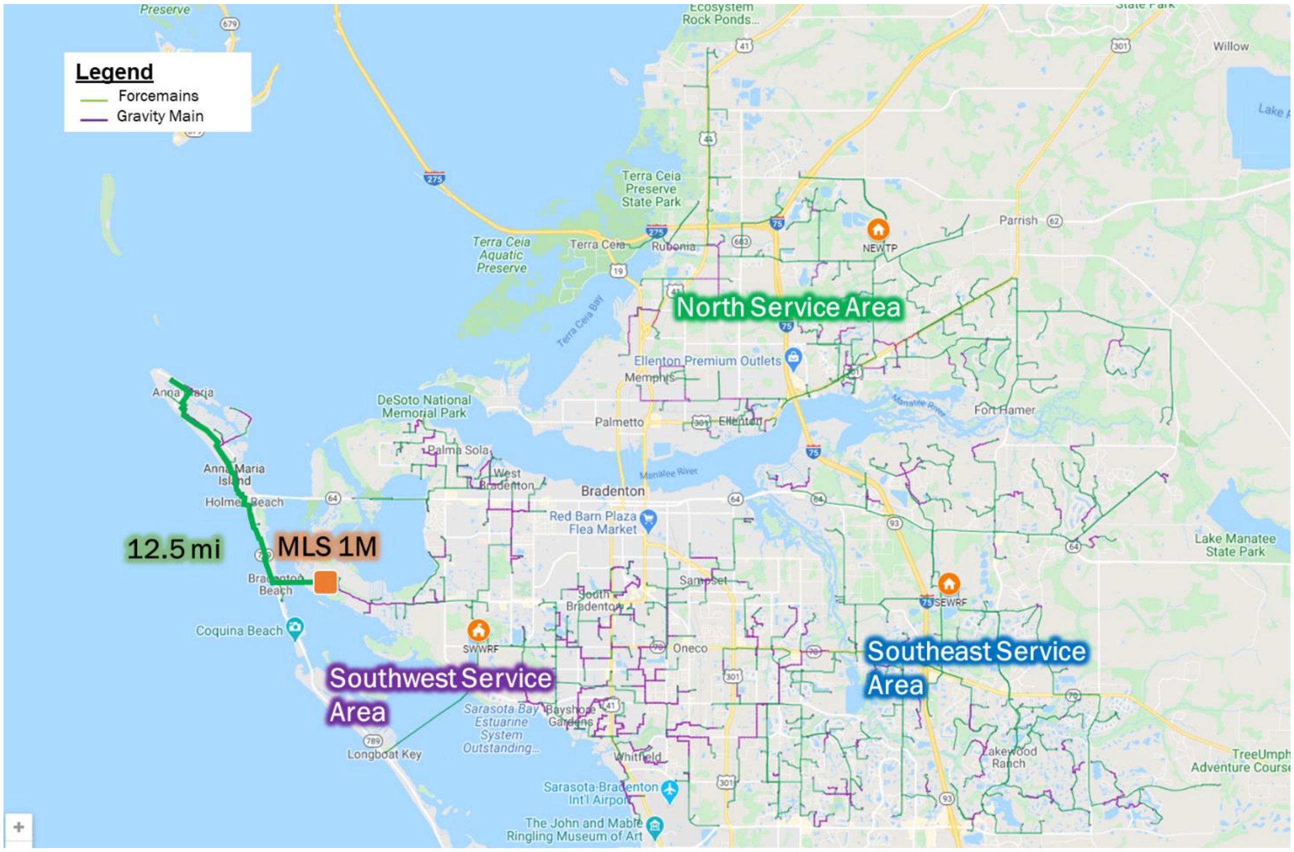

Figure 4. MLS 1M Basin Barrier Island FM Route & MCU Collection System Overview

Wastewater from that portion of the 1M MLS collection basin is repumped three or four times before reaching MLS 1M. A combination of long retention time flow from the barrier islands, elevated sulfate content due to salt water intrusion, warm (18 C) to hot (32 C) wastewater temperatures year round, and varying weekly and seasonal flow conditions associated with beach and tourist activity created very challenging conditions to sufficiently lower dissolved sulfide concentrations to prevent major H_2S at MLS 1M and within the influent gravity interceptor from the west.

Historically, use of iron or nitrate based liquid phase treatment at pump stations on the barrier islands, helped to lower H_2S levels at downstream island repump stations such that chemical, biological or carbon-based vapor phase odor control systems could prevent odorous emissions. However, the 20+ mg/L dissolved sulfide load associated with the barrier island wastewater and the budget realities of removing over 90% of the dissolved sulfide in order to prevent MLS 1M odor complaints led to a heavy reliance on vapor phase treatment systems at MLS 1M (see Figure 5) that regularly experienced inlet air H_2S concentrations in the 200-500 ppm range.

Figure 5. MLS 1M and Bioscrubber

After years of successful MLS 1M odor control using a strategy of sufficient upstream chemical treatment to keep the MLS 1M vapor phase treatment system H_2S loading capacity from being exceeded; this basin was a key target for significantly reducing H_2S levels using a combination of elevating the barrier island wastewater pH and reducing dissolved sulfide content.

Based on sulfide modeling information and assessing existing chemical dosing sites on Anna Maria Island, a magnesium hydroxide dosing system was installed at LS5 (shown in Figure 6).

Figure 6. LS 5 and Magnesium Hydroxide Dose System

LS5 was located next to a public beach access parking lot and was the final “island” repump station. It’s force main delivered the majority of Anna Maria Island wastewater to the mainland, including through a subaqueous crossing of the intra-coastal waterway from Bradenton Beach to a coastal point on the mainland. From the LS5 force main discharge manhole (discharge manhole) the wastewater continued by gravity along Cortez Road to MLS 1M. Baseline testing done at the discharge manhole and MLS 1M to establish the dissolved sulfide, pH, and H_2S under existing nitrate/chlorite based chemical treatment on Anna Maria Island is shown in Table 1 and Figure 7. The majority of this upstream chemical treatment was being dosed at LS5 at an average daily rate of 480 gallons per day (gpd).

Table 1. MLS 1M Baseline Data

Location	Date/Time	Nitrate (mg/L)	Dissolved Sulfide (mg/L)	pH	H_2S (ppm)
#5 FM Discharge	5/7/19 0:00	-	0.2	7.55	50
#5 FM Discharge	5/7/19 16:40	0	0.3	7.75	11
#5 FM Discharge	5/9/19 10:00	0	1	7.69	12
#5 FM Discharge	5/9/19 14:57	10+	0	7.69	10
#5 FM Discharge	5/11/19 11:45	0	1.3	7.43	90
#5 FM Discharge	5/11/19 15:50	0	5	7.49	25
LS 1-M MH	5/7/19 0:00	N/A	3	7.43	154
LS 1-M MH	5/7/19 17:10	0	3	7.16	0
LS 1-M MH	5/8/19 23:59	-	-	7.46	-
LS 1-M MH	5/9/19 9:30	2	1	7.43	3
LS 1-M MH	5/9/19 14:40	0	7	7.25	75
LS 1-M MH	5/11/19 11:45	0	3	7.00	32
LS 1-M MH	5/11/19 16:05	0	6	7.14	91

Grab sampling data over a few days showed nitrate based chemical dosing (BP-71) at LS5 (along with dose sites upstream of LS5) was generally maintaining dissolved sulfide under 2 mg/L at the discharge manhole and under 5 mg/L at MLS 1M. A varying dose curve was employed at the LS5 BP-71 dose site in an effort to match variation in sulfide load treatment demand. MLS 1M H_2S data collected during the same time period varied each day from lows of 20-50 ppm to highs of 150-300 ppm. pH was generally in the 7.2-7.5 range and wastewater temperature was 28-29 °C.

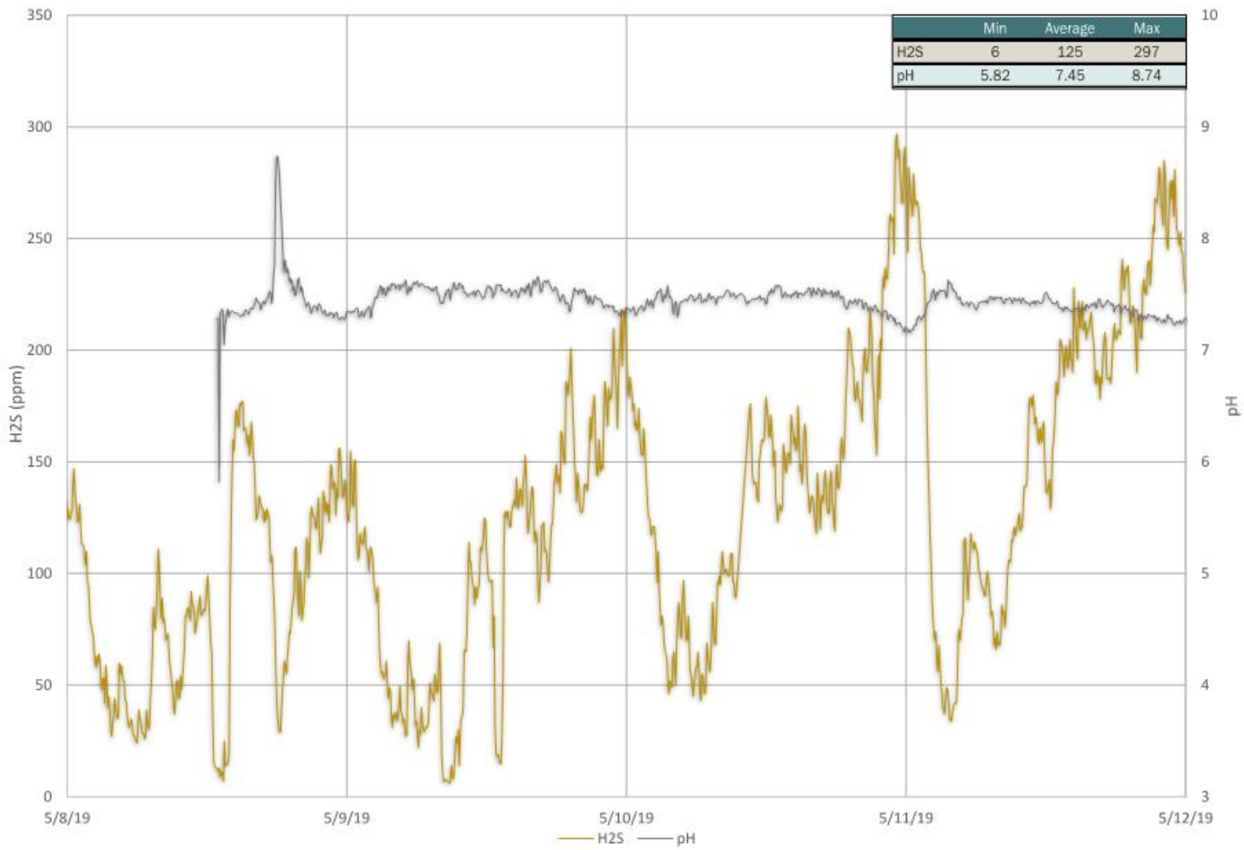

Figure 7. Baseline Continuous H_2S and pH Data at MLS 1M

The MLS 1M basin pH elevation start-up period occurred in late May/June 2019, which is historically a transition period to higher sulfide generation rates associated with rising wastewater temperatures and lower wastewater flow (leading to longer retention times). In order to understand the impact of elevated wastewater pH on MLS 1M at the dissolved sulfide concentrations observed during baseline testing, magnesium hydroxide dosing was started at LS5 while the existing BP-71 dose rate was maintained. Magnesium Hydroxide dosing was to follow the LS5 diurnal flow pattern as the goal was to consistently elevate the wastewater pH at MLS 1M into the 8.2-8.5 range. The initial start-up rate was equivalent to 300 gpd.

As Figures 3 and 8 show, within a day of beginning magnesium hydroxide dose the wastewater pH at MLS 1M was elevated into the 8.0-8.4 range. The corresponding MLS 1M H_2S dropped dramatically, from a range of 200-500 ppm over the preceding few days to a range of 40-120 ppm. Over the next month, a variety of magnesium hydroxide and nitrate based chemical dosage combinations at LS5 were evaluated. Ultimately 400 gpd of magnesium hydroxide alone was found to be effective in maintaining MLS 1M H_2S in the 30-100 ppm range. The dissolved sulfide at the discharge manhole at this time increased to 3-9 mg/L, from the 0-2 mg/L baseline levels. The change from 480 gpd of BP-71 to 400 gpd of magnesium hydroxide at LS5 resulted in a daily cost savings of approximately $600/day and a much less corrosive environment in the MLS 1M wet well and upstream gravity line.

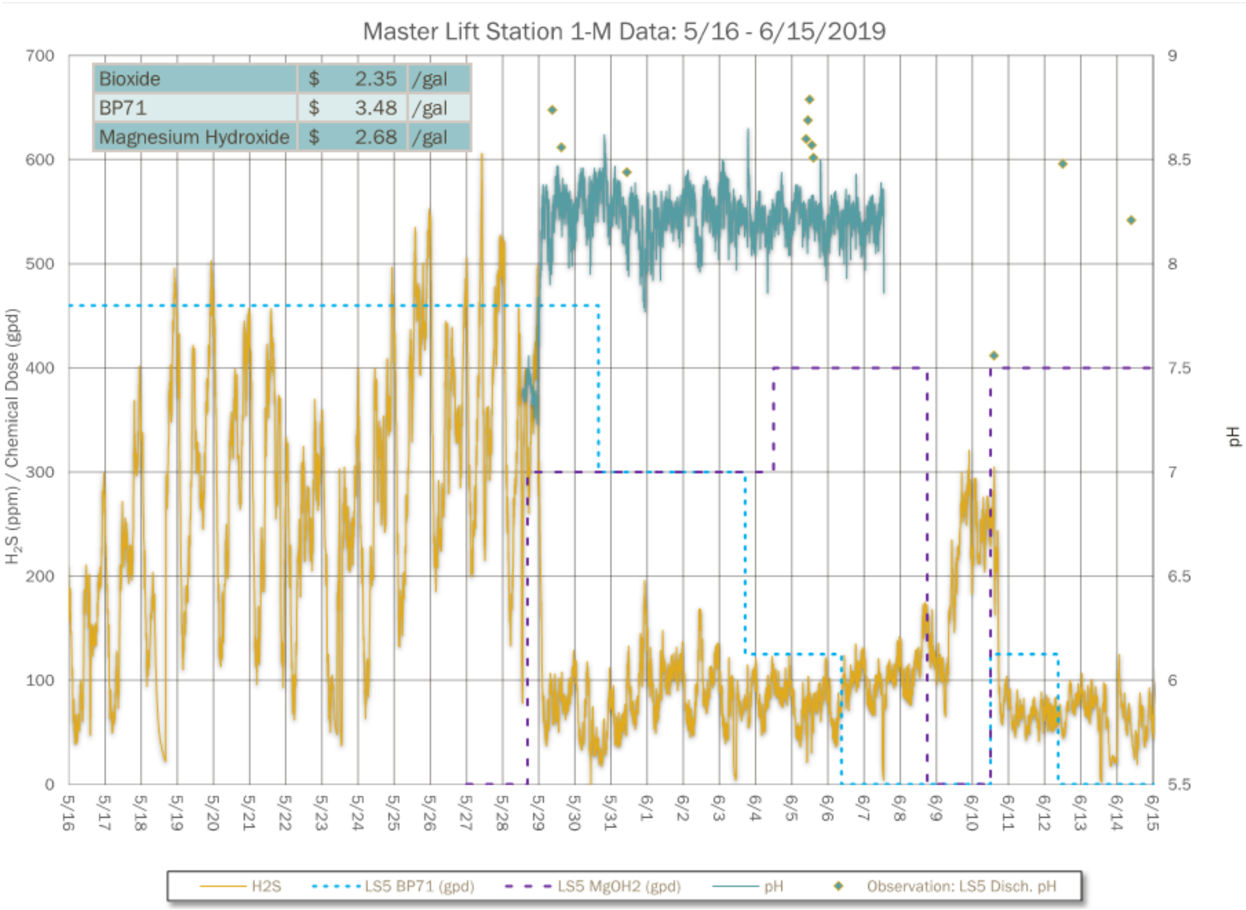

Figure 8. Impact of Magnesium Hydroxide Dosing at LS5 on MLS 1M

Comparison of grab sample pH values at the discharge manhole to continuous pH data measured in MLS 1M wet well showed the LS5 FM wastewater had a pH of 8.5-8.8, at both a 300 gpd and 400 gpd magnesium hydroxide dose, while total wastewater flow passing through MLS 1M was 0.5 pH units lower. This indicated there was sufficient alkalinity increase at 300 gpd for the approximately 1.5 mgd of average daily flow exiting the LS 5 force main on the mainland. However, insufficient downstream mixing time with wastewater along the gravity interceptor to MLS 1M and wastewater contributed from the eastern portion of the MLS 1M basin prevented the entire 2.5 mgd of average daily flow entering MLS 1M from consistently exceeding 8.3 at both doses.

This observation led to installing a second magnesium hydroxide dose system at Lift Station 19D (located in the collection system to the east of MLS 1M) to raise the pH of that wastewater stream before it entered MLS 1M. This enabled MLS 1M H_2S to average 40-50 ppm at the same overall 400 gpd dose rate, with 350 gpd applied at LS5 and 50 gpd applied at LS19D.

MLS 1M is a wet pit/dry pit design with limited ability to raise the well operating level to reduce incoming flow turbulence. Being unable to reduce turbulence at this location along with understanding achieving the 20 ppm H_2S average goal would require significantly more liquid phase treatment expense (in order to lower dissolved sulfide levels), the 40-50 ppm average H_2S level was deemed adequate for this location.

Impacts of Turbulence Reduction

MLS N1C in the NSA receives approximately 0.5 mgd of average daily flow from approximately 40 upstream pump stations. Wastewater from some of the most remote stations have retention times in excess of one day. As a result, the dissolved sulfide levels in the wastewater arriving at MLS N1C are frequently in excess of 20 mg/L. Figure 9 shows the variation in MLS N1C H_2S moving from a single upstream magnesium hydroxide dose location at the River Wilderness (RW) lift station near the upper end of one sector of the N1C basin to additional dose sites, first at Twin Rivers (TR) lift station and then the LS River Plantation (RP) lift station, near the upper end of the other sector of the N1C basin.

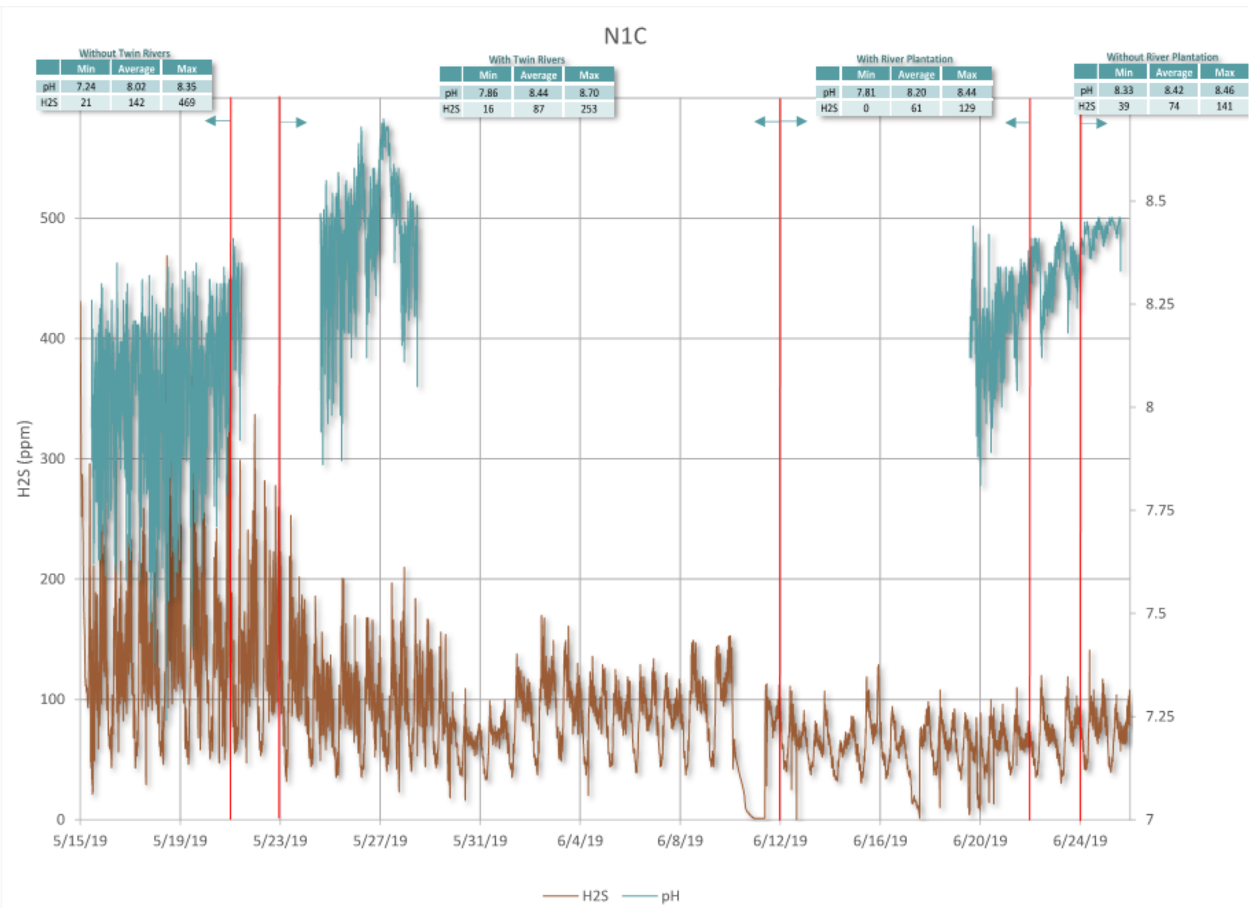

Figure 9. Impact of Increased Magnesium Hydroxide Dose on MLS N1C H_2S and pH

RW magnesium hydroxide dose was approximately 100 gpd, while the TR and RP doses were each approximately 40 gpd. The feed pumps were set to operate when the lift station pumps operated, resulting in a variation of the daily magnesium hydroxide dose rates. These doses were near the maximum amount deemed safe based on the flow characteristics of each lift station. In all cases the flows from these sites joined with that from dozens of other stations prior to arriving at MLS N1C.

With only RW dosing, N1C pH was frequently 7.7-8.0 and the H_2S generally ranged from 50-300ppm. With the addition of the TR dose site, a 40% increase in magnesium hydroxide dosing increased the N1C pH to over 8.2 most of the time and H_2S peaks dropped by 50% (150 ppm vs 300 ppm). With addition of RP dose site, a 28% increase in daily dose had no observable impact on pH. However, H_2S peaks dropped by 33% (100 ppm vs 150 ppm).

This trend of diminishing pH and H_2S change at higher magnesium hydroxide dose rates was observed in numerous MLS basins. Based on the smaller incremental impact of the third magnesium hydroxide dose site, the impact of raising the MLS N1C operating level was evaluated. The goal was to reduce the height between the influent pipe invert and the water surface within the wet well, thereby reducing turbulence associated with the incoming wastewater. Without RP dosing, raising the low point operating level 5 feet and the high point operating level 3 feet reduced the average H_2S from 70 ppm to 38 ppm (46% reduction).

Two other significant examples of the impact of turbulence reduction on H_2S gas concentrations occurred at MLS CC6 in the NSA and MLS Tara 20 in the SESA.

In the case of MLS CC6, the incoming wastewater gravity line was near the top of the submersible station well and a drop pipe had been installed to ensure the wastewater discharged below the wastewater surface. However, as Figure 10 shows the top of the drop pipe was open allowing for H_2S gas to escape from the turbulence caused by the falling wastewater. MCU temporarily covered the opening to assess the impact on well H_2S. Within minutes H_2S concentration within the wet well dropped from the 20-100 ppm range it had been running for the previous 36 hours (typical conditions) to under 10 ppm (see Figure 11).

Figure 10. MLS CC6 Influent Drop Pipe

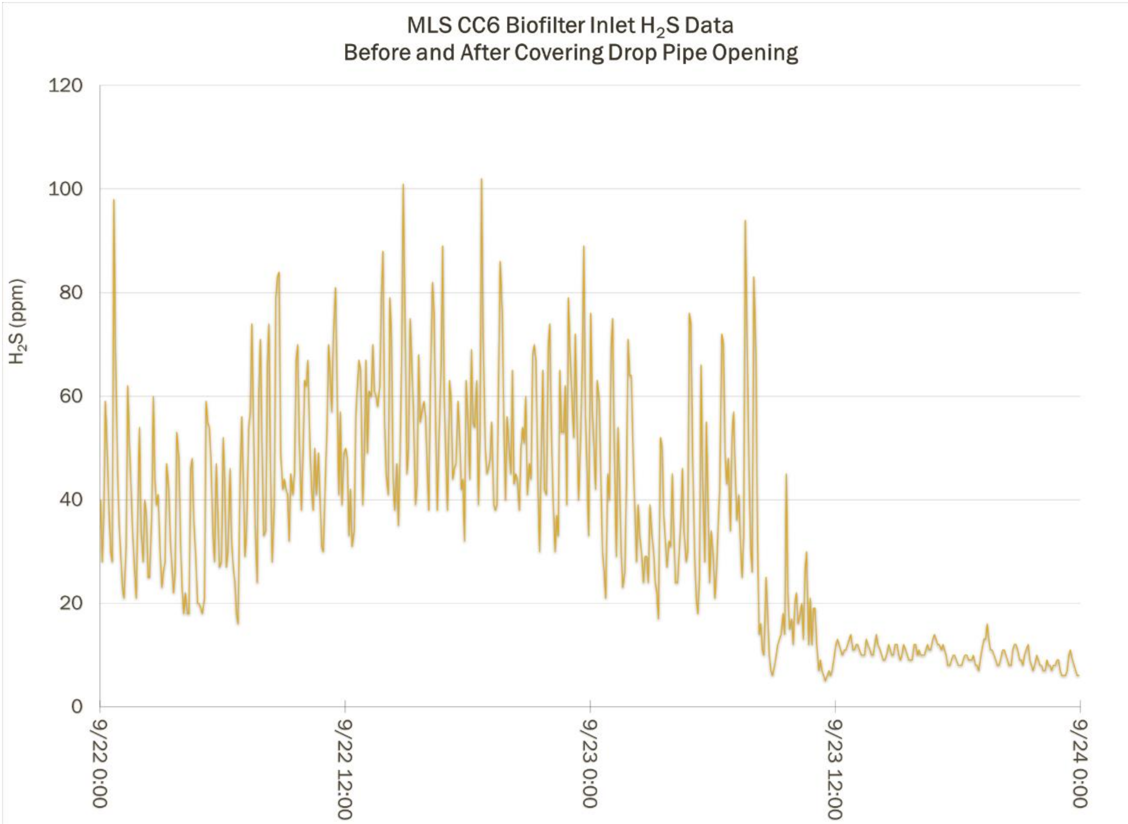

Figure 11. MLS CC6 H_2S Data – Before and After Covering Drop Pipe Opening

At MLS Tara 20, the biofilter that treated air from the wet well regularly experienced inlet H_2S concentrations of 100-300 ppm. This was with the addition of calcium hydroxide into the upstream manhole. While calcium hydroxide reacts more quickly to raise wastewater pH compared to magnesium hydroxide, the severely turbulent force main discharge of highly septic wastewater into the manhole released significant H_2S before the wastewater pH was elevated as it flowed to the wet well. Without calcium hydroxide addition the wet well H_2S concentration would exceed 500 ppm.

The operating level of the wet well below the incoming gravity line resulted in turbulence as wastewater entered the well. This operating level also allowed for unimpeded migration of air between the gravity line and the wet well. By raising the well operating level to nearly submerge the incoming pipe (see Figure 12), H_2S concentrations in the well dropped dramatically within hours as shown in Figure 13. Wet well H_2S was maintained at an average of 5 ppm under that operating condition with better utilization of the onsite pH elevation liquid phase treatment. This operational change did not increase H_2S concentrations in the upstream manhole or generate odor complaints from the area served by the local gravity system that flowed to MLS Tara 20.

Figure 12. MLS Tara 20 – Raised Operating Level Photos

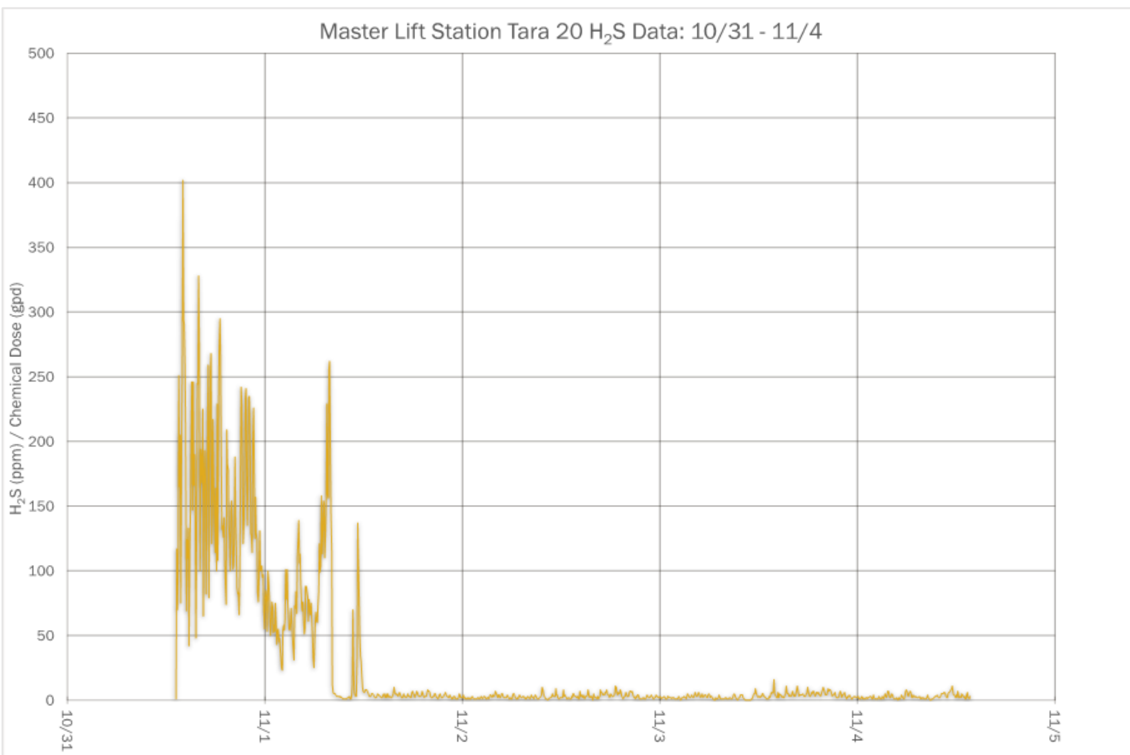

Figure 13. Impact of Raising Wet Well Operating Level on MLS Tara 20 H_2S

Sulfide Reduction

MLS 1D in the SWSA is typical of all MCU MLS locations. It receives wastewater from a network of upstream lift stations see Figure 14), some of which are repump stations themselves, and local gravity pipelines. It had a biological vapor phase odor control facility (VPOCF) capable of cost effectively treating a high H_2S (200-500 ppm) air stream, with sufficient air flow capacity to prevent fugitive emissions from the MLS (and in some cases influent gravity lines).

Upstream liquid phase sulfide control measures were intended primarily for repump station odor control, but also lowered MLS dissolved sulfide loading so the VPOCF's exhaust had < 1 ppm H_2S.

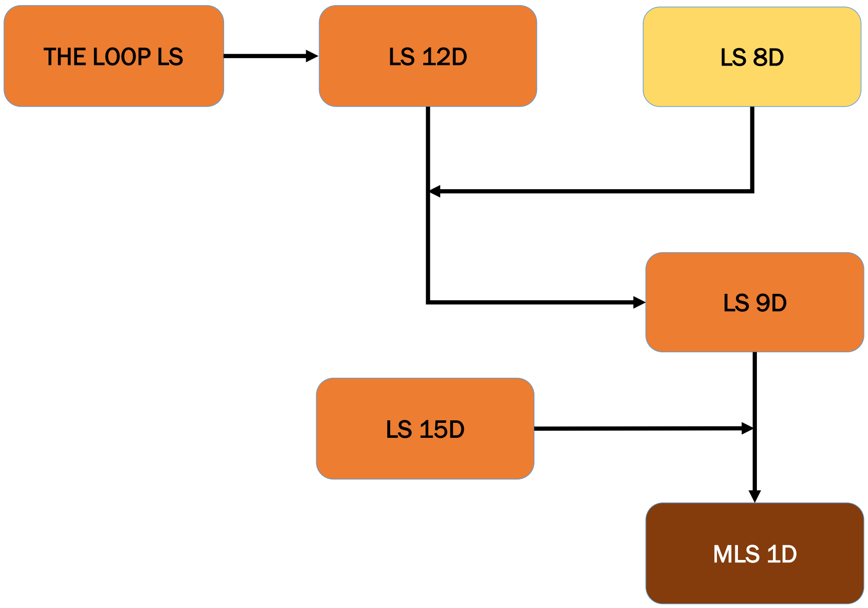

Figure 14. Simplified MLS 1B Basin Schematic

Prior to implementing pH elevation in the MLS 1D basin, nitrate based liquid phase treatment was occurring on a small scale at three small pump stations at the outer edges of the basin (total dose for all three was approximately 30 gpd) and 34 gpd was being dosed at one significant outlying pump station, LS 8D. LS 8D is one of a number of lift stations that conveys flow to LS 9D, which is located adjacent to residential homes and is the largest repump station influent to MLS 1D. Iron based liquid phase treatment was occurring at another repump station, LS 15D, to reduce the odor emissions at that site. Nitrate dosing at LS 8D (34 gpd) and The Loop LS (17 gpd), one of the small outer edge dose sites, was intended to reduce dissolved sulfide loading to LS 9D so that a small biofilter there could effectively mitigate odor complaints. This combination of LPOC dose sites and feed rates was intended primarily to control odors at LS 9D and LS 15D. This level of upstream focused liquid phase treatment resulted in summertime H_2S levels at MLS 1D of 200-600 ppm; which contributed to significant corrosion at MLS 1D. As MCU had recently made a significant capital investment on a major rehabilitation of this station, it was appropriate to protect that investment with additional liquid phase treatment using magnesium hydroxide to assist in achieving the 50 ppm peak, 20 ppm average H_2S goals at MLS 1D.

As Figure 15 shows, the addition of 50 gpd of magnesium hydroxide at LS 12D (a repump station located between The Loop LS and LS 9D) reduced MLS 1D H_2S over 50% (from 300-600 ppm to 70-300 ppm). Replacing the iron-based treatment at LS 15D with 50 gpd of magnesium hydroxide further reduced MLS 1D H_2S concentrations to the 30-120 ppm range at a wastewater pH of 7.5-7.8. Nitrate based dosing at 8D was then shut off. The MLS 1D H_2S range increase 30-40 ppm as a result of higher dissolved sulfide concentrations. At this combination of upstream liquid phase treatment the daily chemical expense was approximately $130/day greater, but the MLS 1D H_2S was dramatically lower (~100 ppm vs ~450 ppm average).

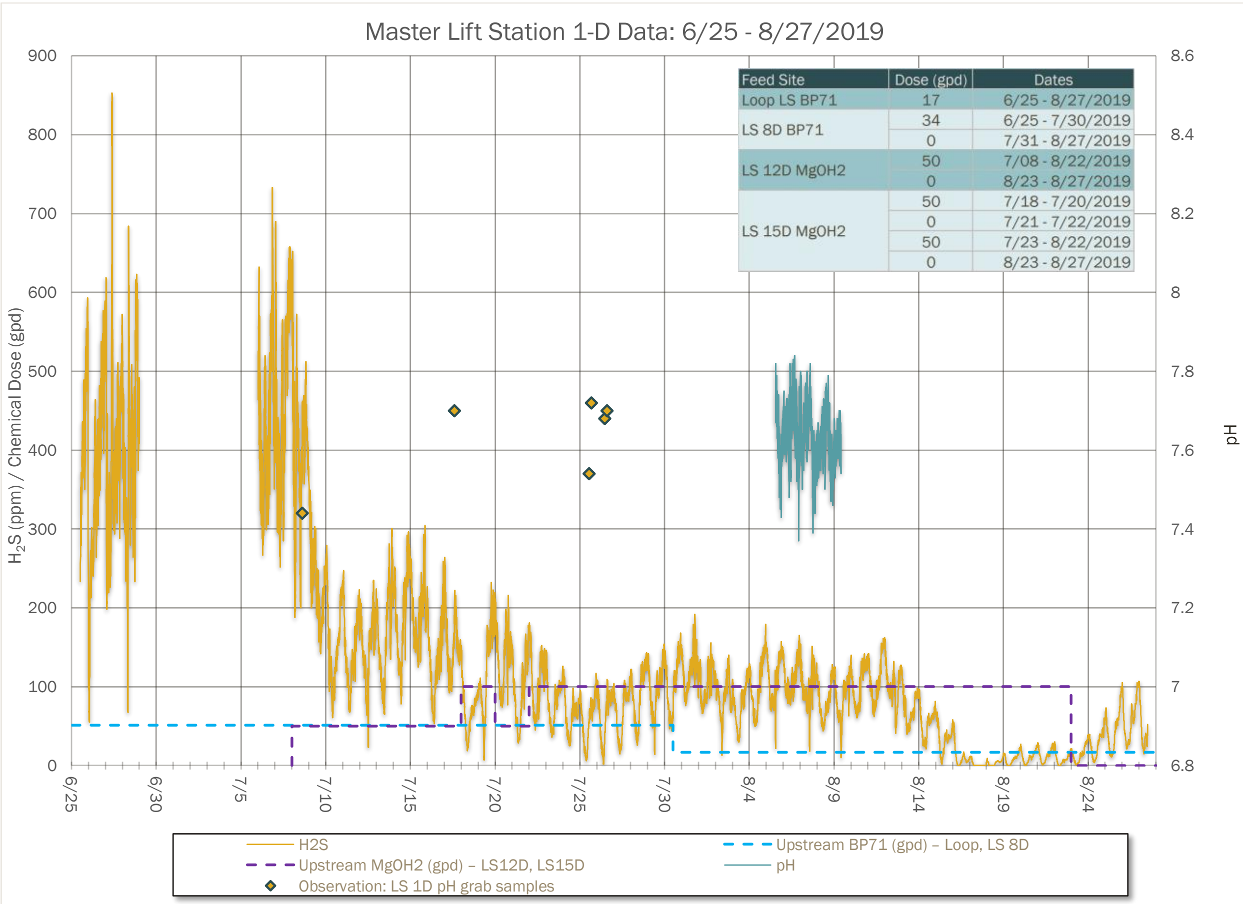

Figure 15. Impact of Upstream Magnesium Hydroxide on MLS 1D H_2S & pH

While a 100 ppm average H_2S was a major accomplishment, it was still well above the corrosion control goal of 20 ppm; so further optimization efforts were expended toward that goal. The initial pH elevation implementation occurred during the start of the rainy season. Major rain events periodically flushed the system with higher than normal flows. While these events dropped H_2S levels to the goal for temporary periods (as Figure 15 shows starting on 8/14), a third magnesium hydroxide dose site was added at LS 8D to further increase the MLS 1D wastewater pH and achieve the target H_2S goals under dry weather conditions. An additional 50 gpd was added at LS 8D toward the end of the rainy season. During dry weather conditions, the additional magnesium hydroxide dose only resulted in an average MLS 1D H_2S concentration of 100 ppm average range and had no observable impact on MLS 1D wastewater pH.

In order to achieve lower MLS 1D H_2S concentrations, a nitrate based chemical dose trial was initiated at LS 9D. As Figure 16 shows, with an optimized dose curve equivalent to 65 gpd, MLS 1D H_2S was lowered to under 30 ppm.

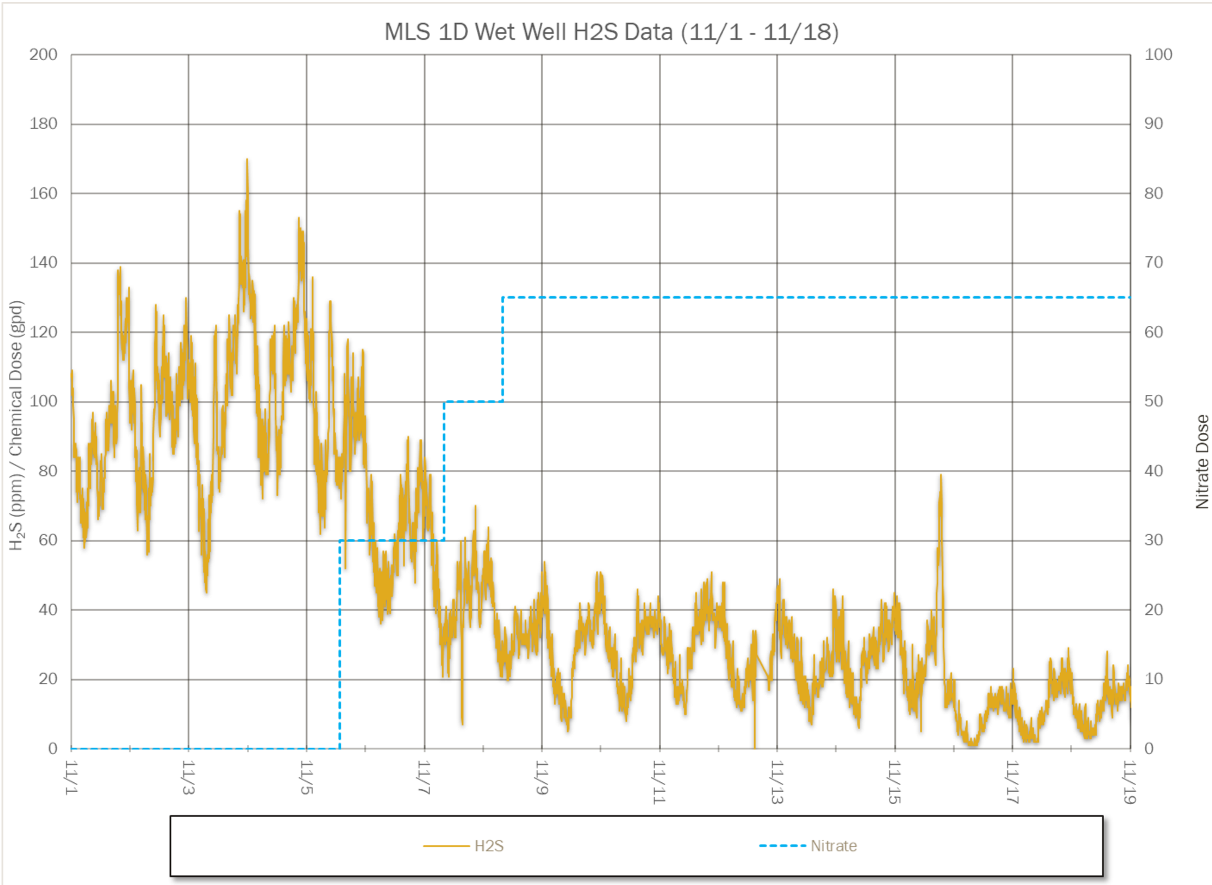

Figure 16. MLS 1D H_2S Change with Nitrate Dosing at LS 9D

Figure 17 shows a typical two-week period under this scenario two months later, with MLS 1D average H_2S of 12 ppm and peaks of 30-33 ppm. The total additional daily chemical cost under this upstream liquid phase treatment combination of pH elevation and dissolve sulfide reduction is approximately $410/day greater (than the LPOC program only focused on odor control), but the average H_2S is 95% lower.

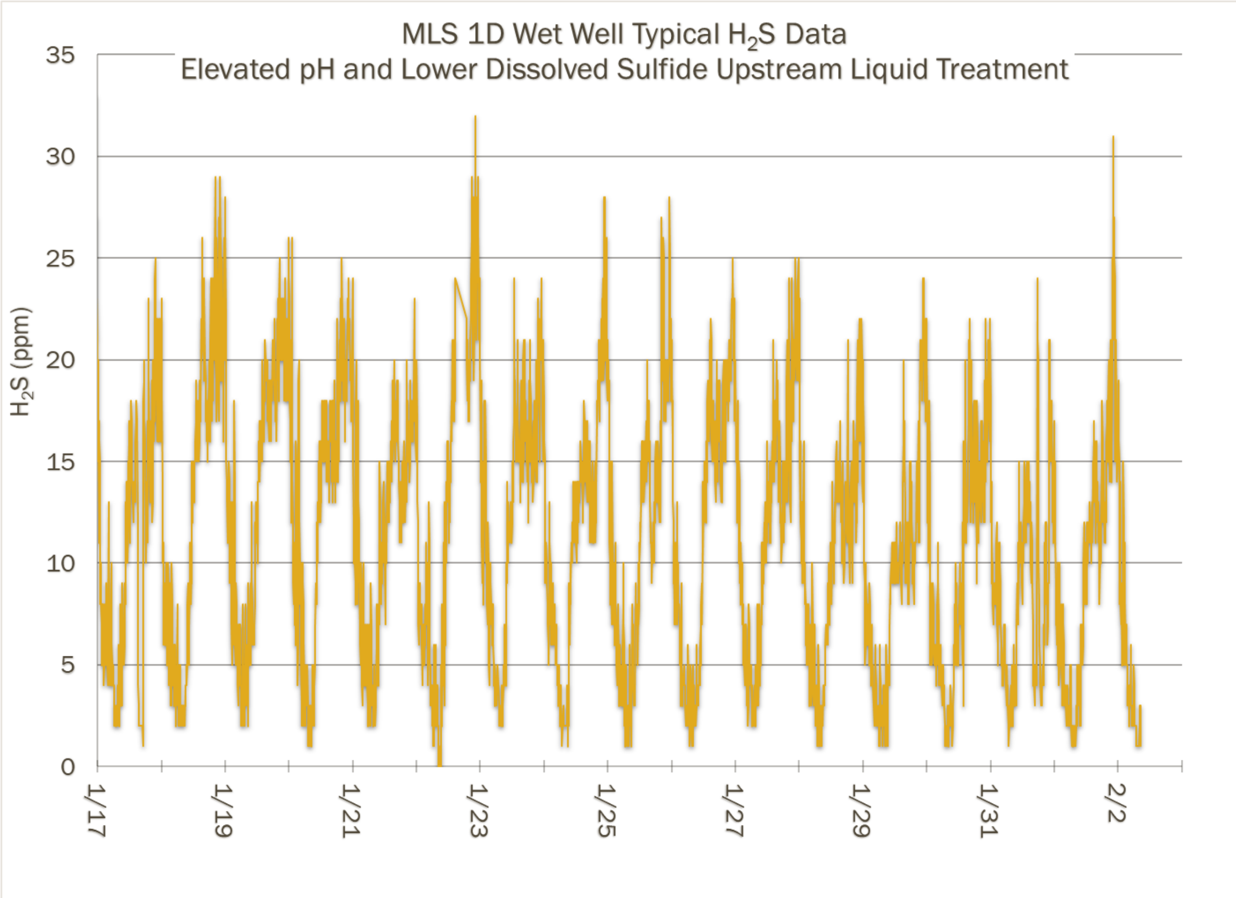

Figure 17. Typical MLS 1D H_2S with Combination of Elevated pH and Lower Dissolved Sulfide

As MLS 1D is a wet pit/dry pit design (similar to MLS 1M) operational changes to reduce turbulence were not possible. The MLS 1D optimization approach was typical of how MCU, their engineering consultants, and vendors had to evolve a combination of pH elevation and dissolved sulfide reduction approaches using an iterative data-based, decision making process when the degree turbulence could not be controlled.

Odor & Corrosion Control Program Performance

Implementation of the strategy to optimize a combination of elevating wastewater pH and reducing dissolved sulfide content via liquid phase chemical treatment in conjunction with operational changes to reduce wastewater turbulence has resulted in reducing typical H_2S levels at most MLS locations from 150-600 ppm to 5-60 ppm. This has dramatically reduced the corrosive and hazardous conditions within the MLS wet wells, in upstream pump stations and gravity interceptors, and downstream at the Wastewater Treatment Plant (WWTP) headworks. Notably, as shown in Figure 18, this was accomplished with minimal additional LPOC chemical spending (an approximately 6% increase). LPOC spend on magnesium hydroxide shifted from 0% in fiscal years 2017 and 2018 to approaching 60% of all monthly chemical expense by the beginning of fiscal year 2020.

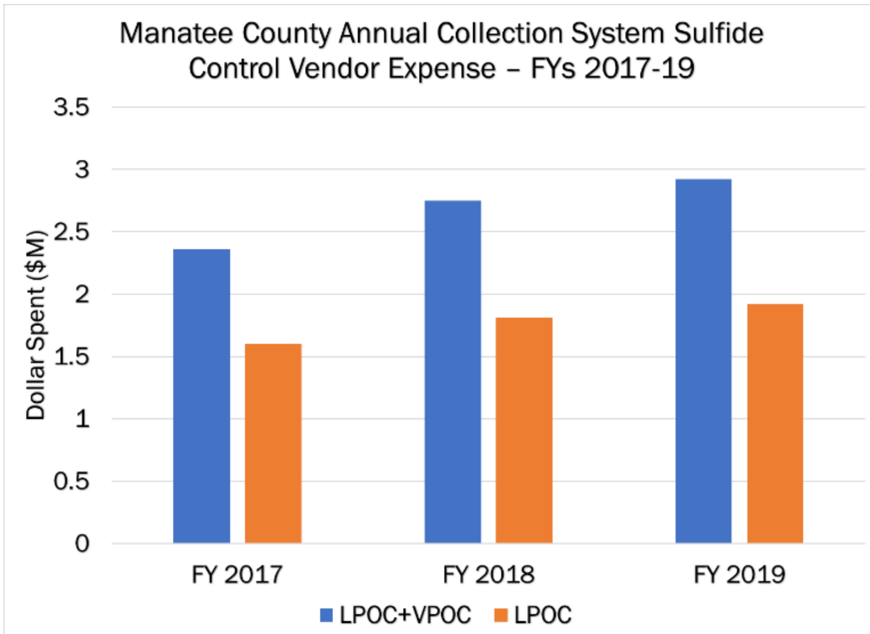

Figure 18. LPOC & VPOC Spending – Fiscal Years 2017-2019

DISCUSSION

The following section discusses a number of key challenges experienced and lessons learned by MCU staff, the vendors, and the consulting engineers during implementation of the improved odor and corrosion control strategy.

Hydraulic Conditions

Collection system characteristics upstream in each MLS basin and design characteristics of a given MLS were frequently limiting factors to achieving an optimum balance of pH elevation, dissolved sulfide reduction, and wastewater turbulence reduction. Such characteristics included: numbers & flow breakdown of upstream stations, retention time for mixing of treated and untreated flows, degree of long retention time force mains, access to ideal dose locations, incoming gravity line elevation to a pump station vs upstream gravity elevation, ability to vary wet well water levels, and operational factors that contributed to turbulent conditions within or near pump stations.

Wastewater pH Elevation Limitations

The ability to adequately raise the pH of the entire wastewater flow to a given MLS with magnesium hydroxide was limited by several factors. Magnesium hydroxide was originally selected as the means to raise the wastewater pH due to its ability to limit the pH rise to approximately 8.5, safety and handling considerations, and for the alkalinity benefit it offers in many wastewater treatment processes. This meant the wastewater pH entering the treatment facility should never be problematic to the biological or physical removal steps.

The extensive upstream network of manifolded force mains in most MLS basins, coupled with the lack of one or two dominant pump stations representing a high percentage of a MLS average daily flow in some basins, prevented a pH over 8 from being maintaining at some of the MLSs. When magnesium hydroxide elevated pH wastewater mixed with significant flows of normal pH wastewater near a MLS (or other upstream control point), total wastewater flow pH could drop below 8 at the MLS. This phenomenon was primarily due to insufficient detention time for “residual” magnesium hydroxide in a treated wastewater stream to become available to elevate the pH of the untreated flow. Once the SESA system treatment upgrades began, use of a calcium hydroxide-based product was utilized in cases where higher pH of treated lines or faster pH elevation was needed to maintain a MLS pH of 8.5-9.0.

Achieving the low H_2S goals within a pH range of 7.5-8.5 was found to be highly dependent on the dissolved sulfide concentrations and degree of turbulence for a given MLS. This resulted in needing to depend to a greater degree on reducing dissolved sulfides and/or turbulence in order to achieve corrosion control H_2S goals than was anticipated. Ultimately, a variety of factors including availability of high flow dose locations, to proximity with the MLS (or intermediate control points), connection points of untreated wastewater streams, to dissolved sulfide levels and degree of turbulence, impacted the degree to which pH elevation was cost effective in a given MLS basin.

Turbulence Reduction Limitations

The ability to reduce wastewater turbulence at a given MLS via simple operational changes was often limited**.** In some cases, MLS or intermediate pump station design and upstream gravity system configuration allowed for raising the wastewater operating levels to a degree. This in turn could reduce the wastewater agitation associated with entry into the wet well. In as many cases, MLS or pump station design and/or upstream gravity system conditions didn’t allow for such.

In some cases, other operational needs demanded maintaining low wet well operating levels due to floatable material, fats/oils/grease (FOG) content, and potential for debris build-up in upstream gravity lines due to lower velocity. MSU also utilized a biological FOG treatment system in numerous upstream pump stations that required bubbling air into the wastewater in the wet well, so reducing turbulence wasn’t possible for all hours of the day in such cases. With time, MCU collection staff became more comfortable and proficient in taking measures to reduce H_2S stripping due to turbulence within pump station and MLS wet wells. Major H_2S reductions were achieved at numerous MLS and intermediate upstream pump stations at minimal cost by reducing turbulent conditions and in turn the driving force for stripping dissolved sulfide into the wet well atmosphere.

Managing Multiple Vendors

Introduction of pH elevation with magnesium hydroxide led to a second vendor being part of MCU’s collection system odor and corrosion control program. While very experienced in application of this technology in municipal wastewater collection systems, the approach for this program of incorporating pH elevation as one tool in concert with others (supplied by an incumbent vendor) to achieve consistently low downstream H_2S goals was a different approach for all parties.

The NSA system was the first one into which pH elevation was introduced as it was anticipated that due to a number of extremely long retention time force mains in the N1C and N1B MLS basins, magnesium hydroxide should be less expensive than the nitrate-based chemicals which were being employed. MSU staff in conjunction with engineering consultant coordinated the NSA dosing equipment installation conversions, start-ups, implementation, and optimization over a 9-month period with both vendors.

Typically, a monthly meeting was held with each vendor at which point a vendor supplied report covering implementation/optimization progress of the past month was reviewed and need for relocation of or installation of additional dose locations discussed. As each MLS, and many upstream pump stations, had existing leased vapor phase odor control facilities (VPOCF) and MLS units were equipped with online H_2S monitors the performance relative to MLS H_2S goals could be readily tracked. Significant H_2S reduction was often achieved with initial pH elevation dose sites, but MLS H_2S remained above target goals due to inconsistent pH elevation. With time, turbulence reduction was pursued, and additional magnesium hydroxide sites were added to approach the target H_2S goals. The NSA treatment facility needed more alkalinity and CBOD, so conversion of the NSA system liquid phase treatment from nitrate-based chemicals to primarily magnesium hydroxide based was considered a positive change by NSA WWTP staff. Use of multiple liquid phase products within each NSA MLS basin was limited, allowing for relatively clear lines of vendor responsibility for H_2S performance at a given MLS.

The characteristics of the SWSA resulted in more instances of multiple liquid phase products within a given MLS basin. This led to less clarity on which vendor was responsible for H_2S performance in some SWSA MLS basins. More weekly management and tracking of installation, start-up, implementation, and optimization activity was required with both vendors by MSU and engineering consultant staff. While the initial plan was to address one SWSA MLS basin at a time, as NSA optimization activity was still happening, ultimately implementation/optimization activity was still occurring in the initial SWSA MLS basins while installation and start-up activity kicked off in the later scheduled basins. This numerous basin activity involving both vendors required a concerted team effort and increased communication among all parties on a weekly basis facilitated by increased consultant involvement.

The SESA was the third system to be implemented as it involved the most extensive network of manifolded force mains, an ever-growing number of pump stations (as it covers the area of fastest development activity) and pending rerouting of two major force mains. The lessons learned in upgrading the NSA and SWSA systems proved invaluable to effectively upgrading the SESA system as multiple liquid phase products were required to an even greater degree across the majority of MLS basins.

Lessons Learned

Key lessons learned for upgrading a large collection system odor control program to incorporate widespread corrosion control objectives included:

1. Ongoing coordination between utility staff, consultants, and vendors is vital to implementing a comprehensive odor and corrosion control program involving multiple liquid phase technologies as well as VPOCF. The fine-tuning process requires all parties to be flexible based on performance data with respect to adjusting dose rate, altering liquid and vapor phase treatment strategies, and adjusting lift station and other collection system operations.

2. Cost-effective achievement of a corrosion control based H_2S goal (in MCU's case: 20 ppm average, 50 ppm peak) at most control points generally requires a balancing act of three wastewater factors: pH, dissolved sulfide, and turbulence. Utility support for collection system operational changes to reduce turbulence is frequently instrumental in minimizing chemical dose and VPOCF expense to achieve the H_2S goals.

3. Effective communication, from progress tracking to data management and reporting, is increasingly critical from a project management standpoint as the degree of collection system areas in implementation and optimization phases expands. Data communication means utilized to track progress may have to evolve throughout the project life as field activity progresses across single or multiple regional collection systems.

CONCLUSIONS

All three MCU regional collection systems and treatment facilities benefited from incorporating an additional liquid phase treatment approach that reduced the volatility of dissolved sulfide by elevating the wastewater pH. More importantly, collective utilization of elevating wastewater pH, reducing wastewater dissolved sulfide concentrations, and minimizing wastewater turbulence resulted in dramatically lower H_2S concentrations (in some cases 95% less) within MCU's collection system, MLS wet wells, and treatment facility headworks.

Maintaining H_2S concentrations under 50 ppm at most MLS locations, and in many cases less than 30 ppm on average, compared to previous averages in the hundreds, has significantly reduced the potential for corrosion of concrete, metal, and electrical systems. VPOCF costs have also been reduced in the process.

Development of a municipal wastewater collection system wide sulfide control program that considers both odor control and corrosion control needs require all stakeholders to clearly understand the program goals and indicators of success at the outset of the project. Performance versus these goals and success indicators must be closely monitored to confirm goals are realistic given actual system conditions/limitations, operating budgets, and varying seasonal factors.

The iterative process required to develop a cost-effective odor and corrosion program for a municipal collection system requires a significant commitment of time and energy on the part of utility management and operation staff intimately familiar with the collection system history, current operating criteria, and impending changes.

REFERENCES

Water Environment Research Foundation (WERF) (2007). *Minimization Of Odors And Corrosion In Collection Systems* (p. 7-27, Figure 7-9). Water Environment Research Foundation, Alexandria, VA.