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CITY OF SANTA CLARA TRIMBLE ROAD TRUNK SANITARY SEWER CONDITION ASSESSMENT

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ABSTRACT: The Trimble Road Trunk Sanitary Sewer system is a critical component of the City of Santa Clara (City) wastewater collection and conveyance system. In 2007 the City operations and maintenance (O&M) staff observed significant corrosion and deterioration of a manhole in its Trimble Road Trunk Sewer. After the manhole was replaced, the City retained Carollo Engineers to collect condition assessment data and develop rehabilitation and replacement strategies for the trunk sewer.

The Trimble Road Trunk Sanitary Sewer consists of more than 13,000 linear feet (lf) of gravity pipeline ranging from 33 to 48-inches in diameter, 49 manholes, and 5 siphons ranging from 15 to 24-inch in diameters. Pipe materials include both lined and unlined reinforced concrete pipe (RCP), ductile iron pipe (DIP), and techite pipe. Originally constructed in 1948, the sewer has had major sections replaced in 1972, 1979, and 2001. The siphons have never been taken out of operation, nor their condition assessed, since being placed in service.

Starting at the intersection of Central Expressway and De La Cruz Blvd, the Trunk Sanitary Sewer flows north along the perimeter of San Jose's International Airport, crossing onto its property in two locations. The sanitary sewer continues north, crossing under Highway 101 (2 parallel 33-inch pipes), under the Guadalupe River (2 siphons), northwest along the base of the river's levy road, and then along the shoulder of Trimble Road where it discharges into the City of San Jose's interceptor system.

The trunk sewer system experiences of high levels of hydrogen sulfide, high flows, high water levels, and areas with insufficient slopes. This paper will describe the approaches taken during inspection, condition assessment results, and recommendations provided to reestablish the reliability of the Trimble Road Trunk Sewer system.

1. INTRODUCTION

As the current infrastructure in this country continues to age, the importance of maintenance and replacement of these facilities increases. With pipe rehabilitation and replacement costs on the rise, it can be a challenge for utility owners to acquire the necessary funds to not only assess where this work is most needed but also what type of work is required. Through the use of a benchtop study, a strategy can be developed for prioritizing the available funds for the condition assessment of a pipeline in such a way that the funds are spent efficiently in the areas most needing repair. With this in mind, a condition assessment was performed for the City of Santa Clara (City) using this technique.

The City is located in the middle of the Silicon Valley of the San Francisco Bay Area in Northern California. The City owns and operates approximately 334 miles of water distribution and 277 miles of sanitary sewer collection pipelines. Wastewater from the City is treated at the 167 million gallon per day (mgd) Regional San Jose & Santa Clara Water Pollution Control Plant (WPCP).

The Trimble Road Trunk Sanitary Sewer system is a critical component of the City's wastewater collection system. The trunk sewer consists of more than 13,000 linear feet (lf) of gravity pipeline ranging from 33 to 48-inches in diameter with 49 manholes, and 5 siphons ranging from 15 to 24-inch in diameter. Pipe materials include both lined and unlined reinforced concrete pipe (RCP), ductile iron pipe (DIP), and Techite pipe. The original trunk sewer was constructed in 1948, with major portions replaced in 1972 (Techite), 1979 (unlined RCP), and 2001 (lined RCP). The trunk sewer flows north along the perimeter of the San Jose International Airport before crossing under Highway 101 (utilizing 2 parallel 33-inch diameter pipes) and under the Guadalupe River (utilizing 2 double-barrel siphons). The trunk sewer then continues northwest along the base of the river's levy road with a single 48-inch diameter pipeline, and then northeast along the shoulder of Trimble Road before ultimately discharging into the City of San Jose's interceptor system. Shortly before the interceptors, the trunk sewer splits into two 33-inch diameter pipelines with the lower pipe discharging into an 84-inch diameter interceptor and the upper pipe used for overflow discharges into a 60-inch diameter interceptor. Figure 1 displays the layout of the Trimble Road Trunk Sewer (Sewer).

In recent years, the City has observed signs of corrosion along the Sewer between the airport and the connection to the interceptors. Based on the age of the Sewer (up to 60 years old), corrosion-related failures are not surprising. In 2007 the City uncovered significant corrosion and deterioration of a manhole (MH 79-3) - the cone section of the manhole was missing due to hydrogen sulfide attack. The manhole was replaced and the City retained Carollo Engineers to perform a condition assessment of the entire alignment and develop rehabilitation and replacement strategies for the Sewer.

The Sewer evaluation was performed in three primary phases:

1. Background data review and analysis (Benchtop Study) – including record drawings, previous studies and flow monitoring data.
2. Inspection data collection and analysis– including physical and video inspection as well as Hydrogen Sulfide (H₂S) sampling.
3. Condition Assessment - using the VANDA™© Reinforced Concrete Condition Index Rating System and the rating indices from the Pipeline Assessment and Certification Program (PACP).

Based on the condition assessment, Carollo was able to determine the high-risk areas within the Sewer and recommend solutions to address the corrosion problems.

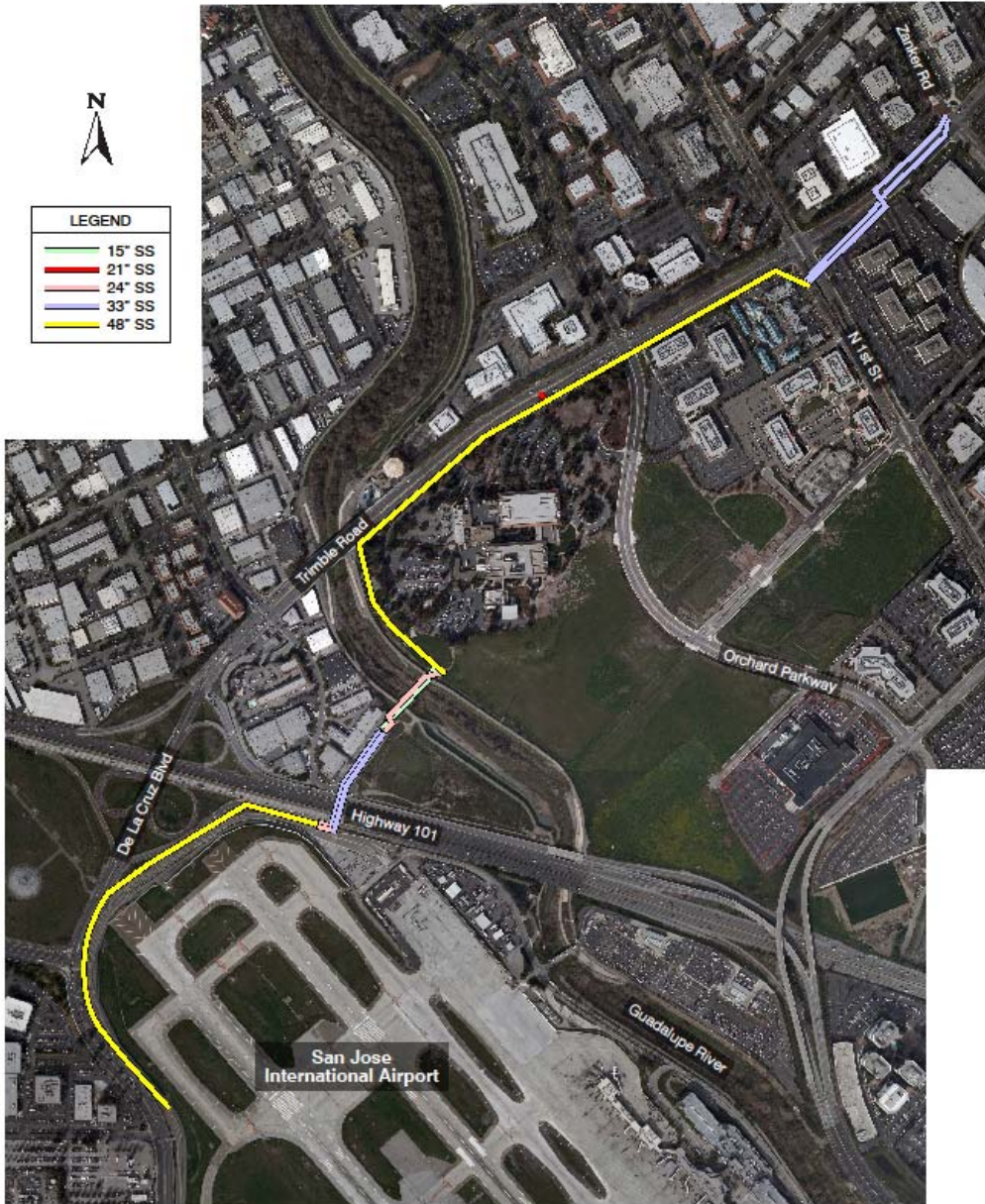


Figure 1. Trimble Road Trunk Sanitary Sewer Layout

2. BACKGROUND DATA REVIEW – BENCHTOP EVALUATION

The first step in the condition assessment was to review existing data including as-built drawings, construction records, previous studies, and flow-monitoring data. The City provided Carollo with "record" information for the Sewer dating back to 1948 and flow data from permanent flow monitors that were installed in 2008 along the alignment. A benchtop evaluation was compiled examining the following key elements of the trunk sewer:

- Areas of corrosion-related failure.
- Repairs made due to observed corrosion damage.

- Repairs scheduled to correct corrosion damage.
- Sewer reaches with substandard slopes.
- Major confluences.
- Segments with long upstream detention times.
- Drop manholes.
- Siphons.
- Bends of 90 degrees or greater through manholes.
- Bends of 45 degrees or greater through manholes.
- High Velocities.

Using City maps and as-built information, a database of pipeline length, material, diameter, year of installation, and slope was compiled. Historic flow records were used to determine the following key flow characteristics:

- Average Daily Flow (ADF): The average daily flow during the monitored period.
- Peak Instantaneous Flow (PIF): The highest flow measured during the monitored period.
- Minimum Instantaneous Flow (MIF): The lowest flow measured during the monitored period.
- Peak Hour Average Flow (PHAF): Traditionally flow in a sanitary sewer is higher during the day than it is at night. From the data collected, the Sewer sees its highest flows from 12:00 to 1:00 pm. The peak hour average flow is the average of all flows recorded during this time period.
- Minimum Hour Average Flow (MHAF): From the data collected, the Sewer sees its lowest flows from 6:00 to 7:00 am. The minimum hour average flow is the average of all flows recorded during this time.

City flow characteristics are summarized in Table 1.

Table 1. Flow Values From Guadalupe Chart Station (data collected from September 2008 to April 2009).

ADF	PIF	MIF	PHAF	MHAF
5.48 mgd	10.34 mgd	2.14 mgd	7.10 mgd	3.14 mgd

For each flow condition, the percent full and corresponding velocity in each pipe segment was calculated. The calculated velocity shows the anticipated conditions inside the pipe and can be used to determine where pipes are not sufficient for self-cleaning and where special inspection methods may need to be considered. All of the data collected was catalogued and analyzed in a spreadsheet. Based on the analysis, the elements of the Sewer were categorized into 3 levels of corrosion potential. The areas receiving high-risk ratings were inspected first and continued down through the rating list.

The benchtop evaluation provided valuable insight into the most likely areas of corrosion in the system. This information was used to help tailor the inspections to focus on the areas with the greatest potential for corrosion. With the initial construction of the Sewer being in 1948, a large percentage of the pipe has been relocated due to airport expansion and land development. Each time the pipe was moved, pipe length was added while the invert at San Jose's Interceptor connection remained the same. This caused the pipe's slopes and velocities to decrease. In some areas of the sewer, the pipe appears to have slopes as little as 0.01% and 0.05%. These flat slopes can have a detrimental effect on the operations of the trunk sewer system.

3 INSPECTION AND SAMPLING

The City decided to move forward with our recommendation to perform hydrogen sulfide (H₂S) monitoring, manhole inspections, and an internal pipeline inspection throughout the Sewer.

3.1 Manhole Inspection

After the benchtop evaluation was completed, the next step in the condition assessment was to perform the manhole inspections throughout the Sewer. The manhole inspection was performed prior to the internal pipeline inspection to not only acquire the manhole condition but to also acquire a preliminary pipe condition prior to selecting pipe inspection methods to implement.

Confined space entries were completed on the 49 manholes (MHs) and junction structures associated with the Sewer. At each manhole, penetration tests were performed to assess the condition of the concrete, samples of concrete within the manholes were taken, wastewater samples were taken for testing of sulfides, sediment levels were measured at the influent and effluent portions of the pipe, and photographs were taken to document the manhole and its influent and effluent pipe connections. Samples of the surface concrete from the penetration tests were collected and tested for pH. Two samples were taken in each manhole. The 'A' sample is of the corroded concrete, while the 'B' sample was obtained from solid concrete underneath after all the loose corroded concrete was removed from the sample area.

The condition assessment in MH 79-3 had to be aborted because levels of H₂S became unsafe for the inspector even with the presence of a powerful fan forcing fresh air into the structure.

3.2 Closed Circuit Television Pipeline Inspection

The Sewer contains approximately 11,000 lf of 33-inch and 48-inch pipe with intermediate access points spaced no more than 525 feet apart. During low flow, based on the manhole inspections and the benchtop evaluation, it was estimated that inspectors may see water depth at 25 to 30 percent of pipe diameter. Traditional Closed Circuit Television (CCTV) inspection technology is limited to approximately 2,000 lf and is capable of recording defects of pipe above the flow line. With this in mind, the project team determined that during low flow events, CCTV would be the most effective way to accomplish a thorough inspection. Therefore, inspections were conducted during low flows between the hours of 12:00 AM and 8:00 AM, allowing for the maximum viewable pipe.

3.2 Hydrogen Sulfide Monitoring

Eight manholes were selected for hydrogen sulfide (H₂S) monitoring based on the findings from the previously completed manhole inspections. H₂S monitoring was conducted over a 7-day period from June 8, 2009 to June 15, 2009. Three types of sampling techniques were used during the monitoring period. Suspended atmospheric hydrogen sulfide gas monitors were set up at all eight locations and left in place throughout the entire 7-day period. Grab samples were taken by a technician, and grab samples were taken by an automated Teledyne ISCO 24-Hour Sampler.

4 CONDITION ASSESSMENT ANALYSIS

The additional data collected during the inspections and H₂S monitoring efforts was used to form the condition assessment. Industry standards were used to evaluate the condition of the sewer from the data collected.

4.1 Manhole Inspection

The VANDA™ Reinforced Concrete Condition Index Rating System developed by V&A was used by V&A to consistently identify the condition of concrete inside the manholes. The extent of the concrete damage can vary from Level 1 to Level 4 to indicate the level of damage, with Level 1 indicating little to

no damage and Level 4 indicating severe damage. Table 2 summarizes the findings of the manhole inspection field-testing.

Table 2. Field Testing Results

Category	Measurement	Degree of Corrosivity ⁽²⁾	Manholes Tested	
			Sample A	Sample B
Concrete pH	> 7.5	Negligible	0 of 46 (0%)	8 of 44 (18%)
	6.5 – 7.5	Neutral	0 of 46 (0%)	5 of 44 (11%)
	5.5 – 6.5	Moderate	3 of 46 (7%)	12 of 44 (27%)
	< 5.5	Severe	43 of 46 (93%)	19 of 44 (43%)
VANDA™ Concrete Index	1	Negligible	1 of 49 (2%)	
	2	Minor	36 of 49 (73%)	
	3	Moderate	6 of 49 (12%)	
	4	Severe	6 of 49 (12%)	

Many of the manholes along the Trimble Road alignment have suffered minor to severe corrosion. Six of the seven manholes at the northeast end of the pipeline (just prior to discharging into the San Jose interceptor at Zanker Road) are graded VANDA™ Level 4. Based on this rating, rehabilitation of these structures is no longer feasible or recommended. Replacement is the only option. Of the 90 pH samples taken, 77 had a pH below 6.5, indicating the concrete in the majority of these manholes is experiencing moderate to severe corrosion. During the manhole inspection sediment deposits were noted. The deposits were found, primarily in the manhole channels, but minor deposits were also found in the influent or effluent pipe. Most of this debris appears to be from concrete mortar and aggregate that has fallen from the manhole chimney and barrel surfaces into the channel. Figures 2 and 3 show some of the recurring issues that were witnessed during the inspection.



Figure 2. Corroded Frame of JB 68-9



Figure 3. Exposed corroded reinforcing steel MH 79-13

4.2 Closed Circuit Television Pipeline Inspection

The CCTV evaluation was performed on the Sewer using two different types of CCTV vehicles. A wheel propelled camera was used for the majority of the inspections while a pontoon mounted camera was used for areas with low velocities and high water levels. The CCTV inspections revealed several pipe

segments with lining failures, exposed aggregate, and insufficient slopes. The insufficient slopes were identified by areas where high water marks were visible for an entire pipe segment. Condition ratings were developed for each pipe segment using the Structural Pipe Rating Index (SPRI), Maintenance Pipe Rating Index (MPRI), and the Overall Pipe Rating Index (OPRI) from the Pipeline Assessment and Certification Program (PACP). SPRI scores were derived on a scale ranging from 1 to 5 during the inspection. Table 3 presents the descriptions and categories used in the standard PACP Pipe Rating Index System for structural defects.

Table 3. PACP Pipe Rating Index

SPRI	Pipe Grade Importance ⁽¹⁾	Likelihood of Failure Estimate ⁽¹⁾
5 - Very Poor	Defects requiring immediate attention	Pipe has failed or will likely fail within the next 5 years
4 - Poor	Severe defects that will become Grade 5 defects within the foreseeable future	Pipe will probably fail in 5 to 10 years
3 - Fair	Moderate defects that will continue to deteriorate	Pipe may fail in 10 to 20 years
2 - Good	Defects that have not begun to deteriorate	Pipe unlikely to fail for at least 20 years
1 - Excellent	Minor defects	Failure is unlikely in the foreseeable future

Note:
 (1) The PACP Condition Grading System only considers internal pipe conditions obtained from CCTV inspection. While other factors such as pipe material, depth, soils, and surface conditions also affect pipe survivability and the likelihood of failure, those factors have not been incorporated into the PACP Condition Grading System

SPRI, MPRI, and OPRI are indicators of the distribution of defect severity in each pipe segment. Defect severity is graded based on defect observations during CCTV inspection as defined by the PACP Condition Grading System Code Matrix.

SPRI is calculated by dividing the Structural Pipe Rating (SPR) by the number of structural defects and is expressed as:

$$SPRI = \frac{SPR}{No. of Structural Defects} \quad [1]$$

SPR is a PACP Segment Grade Score which is calculated by multiplying the number of occurrences of each defect grade within a pipe segment by the defect grade. The five structural Segment Grade scores are then added together to obtain the SPR; SPR is expressed as:

$$SPR = (No. of Grade 5 Structural Defects \times 5) + (No. of Grade 4 Structural Defects \times 4) + (No. of Grade 3 Structural Defects \times 3) + (No. of Grade 2 Structural Defects \times 2) + (No. of Grade 1 Structural Defects \times 1) \quad [2]$$

The number of structural defects is trivial to calculate unless the defects are rated as continuous. In this case, the number of structural defects is calculated by dividing the length of the continuous defect by the joint length, and is expressed as:

$$\text{Equivalent No. of Defects} = \frac{\text{Length of Continuous Defect}}{\text{Joint Length}}$$

[3]

MPRI and OPRI are calculated in the same manner as the SPRI value except Operation and Maintenance (O&M) Pipe Rating (MPR) is used for the MPRI instead of SPR divided by the number of O&M type defects. For OPRI both the MPR and SPR are combined and divided by the total amount of defects. Table 4 shows condition rankings which were calculated for the Sewer. The coloring of Table 4 is based on the SPRI rating and corresponds to the colors on the Rating Index on Table 3.

Table 4. PACP Defined Defect Severity

Starting Node	Ending Node	Diameter (in)	As-built Length (LF)	Condition Score (SPRI)	Condition Score (MPRI)	Condition Score (OPRI)
68-20	67-26	48	228	3.0	2.0	3.0
67-26	67-27	48	325	3.0	3.0	3.0
67-27	67-28	48	398	3.0	3.0	3.0
67-28	67-21	48	146	3.0	3.0	3.0
67-29	67-30	48	178	3.0	3.0	3.0
67-30	67-31	48	187	3.0	3.0	3.0
67-31	67-32	48	320	3.0	3.0	3.0
67-32	68-19	48	330	3.0	3.0	3.0
68-19	68-18	48	400	3.0	3.0	3.0
68-18	68-17	48	249	3.0	3.0	3.0
68-17	68-15	48	298	3.0	3.0	3.0
68-12	68-13	33	260	3.5	2.5	3.4
68-13	68-11A	33	540	4.0	3.0	4.0
68-11A	68-09	33	140	4.0	3.5	4.0
68-16	68-14	33	265	3.0	4.0	3.1
68-14	68-11A	33	521	0.0	4.5	4.5
68-11A	68-10	33	105	1.0	5.0	3.0
68-08	68-04	48	13	3.0	3.0	3.0
68-04	68-03	48	483	4.0	3.0	4.0
68-03	78-25	48	515	4.0	3.0	4.0
78-25	78-22	48	454	4.8	3.0	4.8
78-22	78-21	48	47	4.0	3.0	4.0
78-21	79-10	48	467	4.0	3.0	4.0
79-10	79-08	48	448	4.0	3.0	4.0
79-08	79-10	48	448	4.0	3.0	4.0
79-08	79-07	48	455	4.0	3.0	4.0
79-07	79-06	48	460	4.0	3.0	4.0
79-06	79-01	48	431	4.0	3.0	4.0
79-01	79-04	48	210	4.0	3.0	3.1
79-02	79-04	33	118	3.2	2.0	2.6
79-02	79-18	33	668	4.0	2.1	3.0
79-18	79-02	33	668	4.0	2.2	3.0
79-19	79-18	33	501	3.9	2.0	2.9
79-19	79-12	33	106	3.3	2.0	2.7
	Totals		Average =	3.37	2.96	3.43

The internal pipeline inspection revealed that the Sewer is structurally in fair to very poor condition. Portions of the sanitary sewer pipeline appear to have already reached the end of service life and represent significant risk of failure. The field inspection also revealed numerous pipe segments with exposed aggregate, corroded structural reinforcement, and high flow lines. During manhole inspection it was discovered that the last 1,000 feet of the Sewer was surcharged, so CCTV inspection could not be completed for this section of pipe just upstream of the San Jose Interceptor

4.2 Hydrogen Sulfide Monitoring

Grab samples taken at the 8 locations chosen for H₂S monitoring revealed that the dissolved sulfides in the wastewater ranged from 0.3 to 2.1 parts per million (ppm). Average manhole temperatures during the sampling ranged from 76 degrees F to 82 degrees F. A graphical representation of the H₂S concentrations by the deployed OdaLog Gas Loggers is shown in Figure 4. The data shows a significant increase in H₂S concentration at the two manholes measured closest to the interceptor. It was also found that during normal daily operation, MH 79-3 saw levels of H₂S that were higher than the OdaLog data collector could record. During times of low flow, the concentration of H₂S at MH 79-3 would reduce to normal levels, while the level in the manhole between 79-3 and the interceptor (MH 79-13) would spike.

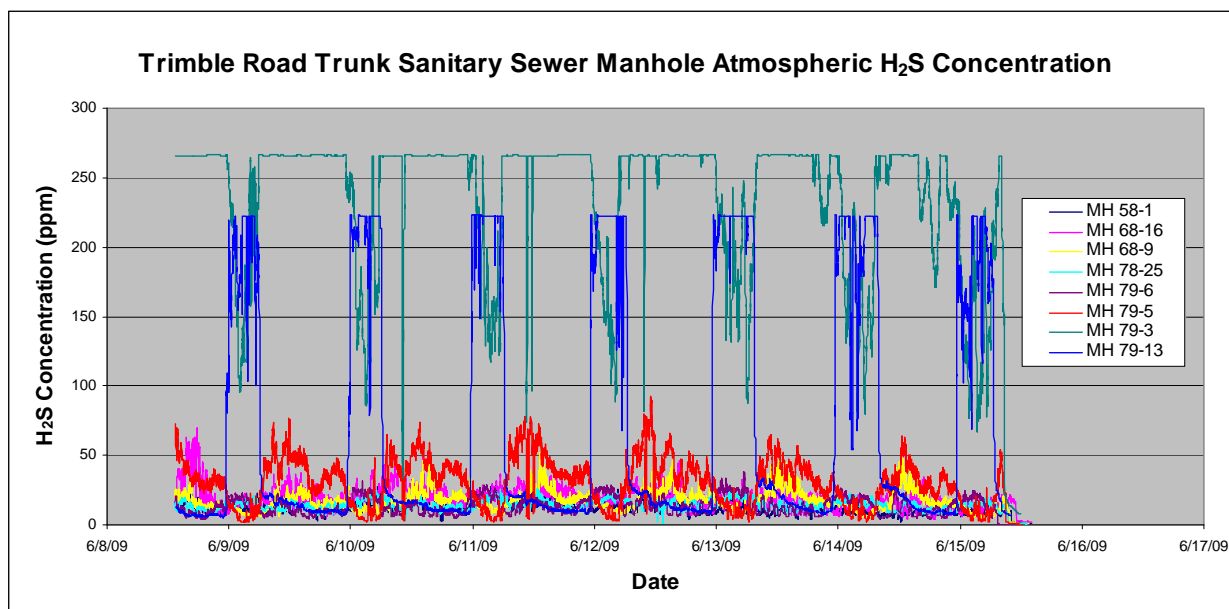


Figure 4. H₂S Concentrations In Select Manholes

5 CONCLUSIONS

Utilizing the data collected during the field inspections and the data provided by the City, a clear picture of how the system operates under normal daily operation became more clear. It was derived that the cause of the high concentration of corrosion witnessed by the City O&M staff was due to the pipe running full approximately 80% of the time on a daily basis. With the pipe full and the downstream manhole surcharged, it's apparent that there is no air gap for the H₂S gas to flow downstream. As a result, all the gas accumulates in MH 79-3, causing a lethal concentration of H₂S. At night, when the flows reduce, the level of the water in the pipe was able to subside enough to allow for the H₂S to escape downstream. The escaping H₂S gas explains why the downstream manhole MH 79-13 experiences such high concentrations when MH 79-3's surcharging is alleviated.

Initially, it was unclear as to the cause of the sewer surcharge. The current as-built information for this pipe segment had recorded inverts giving the pipe a slight reverse slope. This would account for the surcharging effect, as it would require some amount of head to push the wastewater through this section

of pipe. Lower flows would require less head and during the daily low flow events, it is possible to convey the flow through and not cause the pipe to flow full, as the increase in invert elevation is minimal and the pipe length is only 120 lf.

However, after the initial inspections, additional as-builts were uncovered showing that the invert of the City's 33-inch pipe was most likely constructed to match the invert of San Jose's 84-inch Interceptor. Over the years additional pipe length was added to the Sewer to reroute around new city development. Therefore the overall slope was decreased; to compensate, the Sewer was lowered at the interceptor. With the interceptor running at 60% full during the day, the crown of the Sewer is submerged by 1.5 feet causing a buildup of H₂S gas upstream of the connection.

6 REHABILITATION AND/OR REPLACEMENT RECOMMENDATIONS

It was recommended that a Preliminary Design Report (PDR) be developed for the entire Sewer. With high levels of corrosion and H₂S being connected to the slopes of the pipe, a change in pipe alignment will be necessary to fix the underlining problem. The City was encouraged to look into the following possibilities:

- Divert flow away from San Jose's 84-inch interceptor and into San Jose's 60-inch interceptor by diverting flow through the existing overflow 33-inch sewer.
- Raise the existing alignment and modify all slopes from the airport to the San Jose Interceptor to maintain a minimum average velocity of 2 feet per second (fps).
- Redesign and replace all siphons to maintain a minimum average velocity of 3 to 4 fps and add an air jump system to all siphons.

7. DISCUSSION

Using a benchtop evaluation for preliminary data collection and analysis is a useful tool for determining areas with the greatest potential of corrosion in a collection system. A strategy can be developed to use the available funds for a condition assessment in such a way that they are spent efficiently in the areas most needing repair. Taking this project as an example, the benchtop evaluation allowed us to estimate with a great deal of accuracy where the pipe had the greatest potential for corrosion. Since the condition of the pipe allowed for CCTV to be a useful condition assessment technique, the majority of the pipe was able to be visually inspected. Had the water level or the amount of debris made conditions such that CCTV was not a viable method of inspection a more sophisticated instrument would have been required.

With the increase in cost of new technology capable of inspecting pipe, where CCTV cannot be used (sonar/laser/combo device), inspection of the entire pipe would not have been financially feasible. With the use of the benchtop evaluation and its ratings of corrosion potential, an inspection method or methods can be selected and used to locate and investigate areas of greatest corrosion potential. By doing this, a Utility can gain confidence in the fact that the money being spent during inspection is doing so in the best possible areas.

8. REFERENCES

NASSCO. (2001). Pipeline Assessment and Certification Program, Version 3.0.2.

NASSCO. (2001). Pipeline Assessment and Certification Program, Version 4.2.

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