CITY OF RICHMOND, CA.
FORCE MAIN SYSTEM CONDITION ASSESSMENT REPORT

Prepared for: Veolia Water North America
601 Canal Blvd
Richmond, CA 94804

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Prepared by: V&A

V&A Project No. 14-0338

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ES EXECUTIVE SUMMARY

V&A assessed the condition of five force main (FM) systems in the City of Richmond by entering manholes and wet well, testing exposed surfaces, and taking soil and wastewater samples. The five force main systems were in various conditions and had different notable characteristics, as expected from the various ages, materials and alignments of the force mains. Table ES-1 and the following bullet points summarize the findings and recommendations:

1) Force Main System No. 1 – Marina Bay Parkway:
   - Good condition, but continuous sag prohibited full evaluation.
     - ⇒ Seal open joints and spall cavity in the manhole chimney with a repair mortar
     - ⇒ Remove and reapply concrete top coat that is spalling in the discharge manhole
     - ⇒ Monitor location for problems arising from turbulent flow
2) Force Main System No. 2 – Ferry Point & Keller Beach:
   - Ferry Point FM condition is unknown due to lack of access, but may have issues considering moderate sulfide levels and discharge manhole's poor condition.
   - Keller Beach FM was in good condition with no apparent wall thickness loss and the soil was mildly corrosive.
     - ⇒ Consider excavation of Ferry Point FM to gain more condition information.
     - ⇒ Consider providing more protection and slope stabilization for the Keller Beach FM section on the hillside
     - ⇒ Rehabilitate the Ferry Point/ Keller Beach FM discharge manhole
     - ⇒ Consider installing an odor control system at the Keller Beach pump station
3) Force Main System No. 3 – Canyon Estates:
   - Good condition, no issues found except that the discharge manhole concrete was in poor condition.
     - ⇒ Consider rehabilitation of the discharge manhole
4) Force Main System No. 4 – Brickyard Cove & Brickyard Booster:
   - Brickyard Cove FM was in good condition, but the section surveyed may only be the relatively new part.

- Brickyard Booster FM's external surface was in a moderate condition at the pressure manhole and the FM's interior surface was in a very poor condition at the discharge manhole.
- The Brickyard Booster FM pressure and discharge manhole concrete were similarly in a moderate and poor condition respectively.
  - ⇒ Repair the T-Lock joints in the Brickyard Booster PS wet well liner
  - ⇒ Regular/more frequent cleaning of the Brickyard Booster FM.
  - ⇒ Consider rehabilitation of the Brickyard Booster FM/Port FM discharge manhole.

5) Force Main System No. 5 – Port:
- Poor condition. A severely corroded metallic pipe at the pressure manhole and a reinforced concrete pipe with grease and partial cave-in at the discharge manhole.
- The pressure manhole concrete was in a good to moderate condition. The discharge manhole was in poor condition.
  - ⇒ Replace the severely corroded metallic section.
  - ⇒ Regular/ more frequent cleaning of the Port FM

6) Other:
- There is approximately 10,000 linear feet of additional force mains in the City not assessed in this study.
  - ⇒ More condition assessments and a risk assessment

A prioritization of the recommendations is listed below. The prioritization is based on the condition found and ease of recommended actions listed from most to least urgent. The prioritization also maintains the focus on the force mains and recalls that the overall program was to systematically reduce odor complaints and sanitary sewer overflows.

1) Replace the severely corroded metallic section of the Port FM.
2) Perform regular/ more frequent cleaning of the Port FM.
3) Excavation of Ferry Point FM to gain more condition information.
4) Rehabilitate the Ferry Point/ Keller Beach FM discharge manhole.
5) Regular/more frequent cleaning of the Brickyard Booster FM.
6) Rehabilitate the Brickyard Booster FM/Port FM discharge manhole.
7) More condition assessments and a risk assessment for the City force mains not yet assessed.
8) Repair the T-Lock joints in the Brickyard Booster PS wet well liner.
9) Monitor Marina Bay Parkway discharge manhole location due to turbulent flow.
10) Remove and reapply concrete top coat in the Marina Bay Parkway FM discharge manhole.

11) Provide more protection and slope stabilization for the Keller Beach FM hillside section.
12) Rehabilitate the Canyon Estates FM discharge manhole.
13) Install an odor control system at the Keller Beach pump station.
14) Seal open joints and spall cavity with a repair mortar in the Marina Bay Parkway FM discharge manhole chimney.

Table ES-1. Summary of Force Main Information

FM	FM Section	Year Installed	Size (in.)		Material		Length (linear ft.)		FM condition	MH Concrete Condition	Sulfide Level	Notes
			Drawing	Field	Drawing	Field	Drawing	CCTV				
1	Marina Bay	1987	10	10	HDPE	Plastic (HDPE)	~2,000	340	Good, but mostly under water	Good, top coat spalling	Non-detectable	Bends and high flow easy for surcharge
2a	Ferry Pt	No drawings	6, 8	8 [1]	CIP	Plastic (PVC)[1]	~1,600	No access	—	Poor, very soft, pipe channel good	Moderate	At wet well thick top FOG layer
2b	Keller Beach	Exist before 1996	8	8	CIP w/ concrete encasement	CIP	~1,300	No access	Good	See 2a for discharge MH	Low	No apparent wall thickness loss
3	Canyon Estates PS 1	Exist before 2005	6	6	DIP at PS 1 (may transition to PVC)	PVC	2,640[2]	50	Good	Poor, soft and chalky; pipe channel good	Non-detectable	–
4a	Brickyard Cove	2002 connect to 1984	6	8	HDPE, SDR 32.5	Plastic (PVC)	2,305[3]	39 (bend)	Good, but only surveyed new	Good, surprisingly corrosive pH	Non-detectable	Discharge at MH before wet well
4b	Brickyard Booster	2002	8	8	HDPE	Plastic (HDPE)	~3,000	8 (bend)	Moderate to Poor	Moderate pressure MH, poor discharge MH	Non-detectable	–
5	Port	2005. original 1984	6, 4	8, 4[4]	PVC at PS, CIP elsewhere	Possibly RCP; Metallic[4]	~1,200	24 (partial cave-in)	Poor	Good to moderate pressure MH, see 4b for discharge MH	Low to negligible	Severely corroded at pressure MH, strong odor

[1] At discharge manhole, after combining with Keller Beach Force Main.
[2] 1,320 on Wildcat Drive and 1,320 on Rifle Range Dr.
[3] 460 from 2002, 1,845 from 1984.
[4] At discharge manhole and pressure manhole respectively.

1.0 INTRODUCTION

V&A Consulting Engineers, Inc. (V&A) was retained by Veolia Water North America (Veolia) to assess the condition of five sanitary sewer force mains in the City of Richmond (City). The force main condition assessment is to support the Richmond Municipal Sewer District's Pipeline Rehabilitation and Replacement (R&R) Program for the City's sewer collection system. This program is part of the Settlement Agreement between Veolia Water, the City, other parties, and San Francisco Baykeeper to systematically reduce odor complaints and sanitary sewer overflows (SSO).

The five force main systems of interest are located in the Point Richmond area, Marina Bay area, and Canyon Estates area in the City. Figure 1-1 shows the locations of the force main systems that will be discussed in this report. Table 1-1summarizes pertinent information about each of the force mains from Phase 1 and drawings. The force main systems, as indicated in Figure 1-1, are identified below:

- Force Main System No. 1 – Marina Bay Parkway
- Force Main System No. 2 – Ferry Point / Keller Beach
- Force Main System No. 3 – Canyon Estates
- Force Main System No. 4 – Brickyard Cove / Brickyard Booster
- Force Main System No. 5 – Port

Figure 1-1. Aerial Map Showing Locations of the Force Mains Assessed

Table 1-1. Summary of Force Main Information from Phase 1 and Drawings

FM	FM Section	Year Installed	Size (in.)	Material	Length (linear ft.)[5]
1	Marina Bay	1987	10	HDPE	~2,000
2a	Ferry Pt	No drawings	6, 8	CIP	~1,600
2b	Keller Beach	Exist before 1996	8	CIP w/ concrete encasement	~1,300
3	Canyon Estates Pump Station 1	Exist before 2005	6	DIP at Pump Station 1 (may transition to PVC downstream[6])	~2,640 (~1,320 on Wildcat Drive and ~1,320 on Rifle Range Dr.)
4a	Brickyard Cove	2002 then connect to existing since 1984	6	HDPE, SDR 32.5	2,305 (460 ft. from 2002 and 1,845 ft. from 1984)
4b	Brickyard Booster	2002	8	HDPE	~3,000
5	Port	2005. original 1984	6, 4	PVC at PS, CIP elsewhere	~1,200

The force mains and manholes were assessed using the evaluation techniques listed below. The techniques selected for a given force main or manhole was a function of its materials and construction. Not all techniques are appropriate for every force main or manhole. See Table A-1 for a summary of the work schedule.

Internal Evaluation Techniques:

1) Visual assessment with digital photo documentation
2) Concrete sounding and penetration testing
3) In situ concrete pH testing
4) Wastewater grab sample test for dissolved and total sulfide
5) CCTV (by Veolia)

External Evaluation Techniques:

1) Ultrasonic Testing (UT) of metallic pipe surfaces
2) Pit depth measurement of metallic pipe surfaces
3) Broadband Electromagnetic (BEM) testing of metallic pipe surfaces
4) In situ soil resistivity testing
5) Soil sample analysis
6) Pipe-to-soil potential testing

[5] The actual length to be investigated depends on accessibility.
[6] Not confirmed during reconnaissance site visit due to inaccessibility; lack of adjacent manholes.

2.0 METHODS AND PROCEDURES

The methods discussed in this section were used to evaluate the five force mains and associated concrete structures and metallic appurtenances in the City of Richmond. The methods follow standard procedures that are used to assess and test concrete and metal structures in the water and wastewater industries.

2.1 Access

The assessment was limited to accessible locations, which were typically at the manholes and wet wells. Extrapolating the condition at manholes or wet wells to the remaining length of pipe in the five force main systems is based on engineering judgement, risk analysis, and CCTV results.

Manholes and wet wells are considered permit-required confined spaces. The confined space entry evaluations were made using precautions including permit procedures, ventilation and monitoring equipment, and appropriate personal protective equipment. A self-retracting lifeline (SRL) was used to provide fall protection and emergency retrieval capabilities. The pumps were not locked-out-tagged out, but when needed, there was a Veolia pump technician attending the upstream pump with radio communication with the Veolia field lead at the confined space entry site. Veolia provided traffic control for the day sites; V&A provided traffic control for the night sites.

2.1.1 Discharge and Pressure Manhole Access

A total of 7 manholes along the five force main systems were used for access. Of these, 2 were pressure manholes, 5 were discharge manholes; two of which have two force mains discharging to the same manhole. Pressure manholes for 3 sections of the five force main systems could not be found during Phase 1 or by Veolia. Access was by a davit arm and tripod system. The blower was used at the Port pressure and discharge manhole and the Ferry Point/Keller Beach discharge manhole due to high odor or sulfide issues.

2.1.2 Wet Well Access

Only the Brickyard Booster Wet Well was entered for condition assessment; all other wet wells were visually observed and wastewater samples obtained from above. It was initially assumed from drawings that the Brickyard Cove Force Main discharged into the wet well. Figure A-2 shows the Brickyard Booster Pump Station site plan and the markups from field observations. The at-grade entry hatch was located in the median of a sloped two-way wide street (see Photo 2-1).

Photo 2-1. Brickyard Booster Pump Station

Access was by a davit arm and frame system, with the frame legs properly leveled on the sloped street. The blower was used as a provision for the higher potential of gases in wet wells. A plug was also used to block the 8-inch gravity line coming from Northeast (uphill), and Veolia personnel attended the upstream manhole for signs of overflow.

2.1.3 External Pipe Access

The recommended excavations in Phase 1 have been deemed too costly. The only external pipe assessment that was still possible was at one location found during Phase 1 at Keller Beach. The force main was already exposed approximately 3 feet along its length, at the 10:00-2:00 o'clock position, due to soil erosion. This location is on the hillside between a railway track and Dorman Drive, see Photo 2-2. Prior to V&A's arrival, Veolia carefully excavated the force main to expose approximately 7 feet of pipe all-around, and shoveled a "shelf" for testing equipment and personnel. This site is not considered a confined space and no additional access equipment was required. The native soil and plants are assumed not to be hazardous or contaminated. However, this location is on a steep slope, and equipment and personnel still kept slipping downslope.

Photo 2-2. Exposed Force Main near Keller Beach: prepared site prior to assessment

2.2 Visual Assessment

Observations made during the condition assessment of the force main systems were documented with digital photographs. The visual assessment focused on the condition of the force mains, which were cast iron pipe (CIP), polyvinyl chloride (PVC), high density polyethylene (HDPE), and an unidentified metallic pipe. Observations such as corrosion, root intrusion, oil and grease, cave-ins, and bends or sags along the alignment were recorded. Visual condition assessment data is subjective and is based upon V&A's extensive experience evaluating force mains in the wastewater industry.

2.2.1 VANDA™ Reinforced Concrete Condition Index

The VANDA™ Reinforced Concrete Condition Index was created by V&A to provide consistent reporting of corrosion damage based on qualitative, objective criteria. As shown in Table 2-1, the condition of concrete corrosion can vary from Level 1 to Level 4 based upon visual observations and field measurements. Level 1 indicates the best condition and Level 4 indicates severe damage. In general, Level 1 and 2 conditions do not require remedial action. However, sometimes recommendations are presented for Level 2 observations to prolong the useful life of a structure. Level 3 warrants remedial action, such as minor repairs or coating to prolong useful life. Level 4 warrants repair and/or replacement.

Table 2-1. VANDA™ Reinforced Concrete Condition Index

Condition Rating	Description	Representative Photograph
Level 1	**None/Minimal Damage to Concrete** Hardness: No Loss Surface Profile: No Loss Cracking: Shrinkage Cracks Spalling: None Reinforcing Steel (Rebar): Not Exposed or Damaged	
Level 2	**Damage to Concrete Mortar** Hardness: Damage to Concrete Mortar Surface Profile: Some Loss Cracking: Thumbnail Sized Cracks of Minimal Frequency Spalling: Shallow Spalling of Minimal Frequency, Related Rebar Damage Reinforcing Steel (Rebar): May Be Exposed, but Not Damaged	
Level 3	**Loss of Concrete Mortar/Damage to Rebar** Hardness: Complete Loss Surface Profile: Large Diameter Exposed Aggregate Cracking: ¼-inch to ½-inch Cracks of Moderate Frequency Spalling: Deep Spalling of Moderate Frequency, Related Rebar Damage Reinforcing Steel (Rebar): Exposed and Damaged, Can Be Rehabilitated	
Level 4	**Rebar Severely Corroded/Significant Damage to Structure** Hardness: Complete Loss Surface Profile: Large Diameter Exposed Aggregate Cracking: ½-inch Cracks or Greater of High Frequency Spalling: Deep Spalling of High Frequency, Related Rebar Damage Reinforcing Steel (Rebar): Damaged or Consumed, Loss of Structural Integrity	

2.2.2 VANDA™ Metal Condition Index

The VANDA™ Metal Condition Index was created by V&A to provide consistent reporting of metal corrosion damage based on qualitative, objective criteria. Condition of metal can vary from Level 1 to Level 4 based upon visual observations and field measurements. Level 1 indicates the best condition and Level 4 indicates severe damage. In general, Level 1 and 2 conditions do not require remedial action. However, sometimes recommendations are presented for Level 2 observations to prolong the useful life of a structure. Level 3 warrants remedial action, such as minor repairs or coating. Level 4 warrants repair and/or replacement. Table 2-2 shows the VANDA Metal Condition Index System.

Table 2-2. VANDA™ Metal Condition Index

Condition Rating	Description	Representative Photograph
Level 1	**Little or No Corrosion** Loss of Wall Thickness: None Pitting Depth (as % of Wall Thickness): None to Minimal Extent (Area) of Corrosion: None	
Level 2	**Minor Surface Corrosion** Loss of Wall Thickness: < 25% Pitting Depth (as % of Wall Thickness): < 25% Extent (Area) of Corrosion: Localized	
Level 3	**Moderate to Significant Corrosion** Loss of Wall Thickness: 25%-75% Pitting Depth (as % of Wall Thickness): 25%-75% Extent (Area) of Corrosion: 25%-75%	
Level 4	**Severe Corrosion; Immediate Repair/Replacement Needed** Loss of Wall Thickness: > 75% Pitting Depth (as % of Wall Thickness): 75% or More Extent (Area) of Corrosion: Affects Most or All of Surface	

2.3 Concrete Tests

2.3.1 Concrete Surface pH

V&A conducted in-situ pH measurements within each structure to determine the pH of the concrete exposed to the wastewater environment. Concrete is generally made from a combination of aggregate, sand, and Portland cement. The Portland cement in mortar has a pH of approximately 13.5 after curing. This elevated pH level provides corrosion protection for the reinforcing steel. Steel will transform from a state of active corrosion to a state of passivity when exposed to a pH greater than 10. Passivity is characterized by a thin layer of iron oxide that protects the steel from corrosion. At a concrete pH of less than 10, corrosion can occur. V&A has developed a table correlating pH and the corrosion rate of reinforcing steel in concrete. The data in Table 2-3 is derived from past experience and literature, such as American Concrete Institute (ACI) 201.2R-01, "Guide to Durable Concrete."

Table 2-3. pH and Corrosivity Correlation for Reinforcing Steel in Concrete

pH	Degree of Corrosivity
< 7	Severe
7 to 9	Moderate
9 to 11	Mild
> 11	Negligible

2.3.2 Concrete Sounding

Sounding a surface refers to tapping the concrete structure surfaces with a chipping hammer and listening for discontinuities within the surface. The sound returned from good, hard concrete without subsurface voids is a solid "ping" noise. A "hollow" sound generally means that a void or discontinuity exists beneath the test location. A soft "thud" typically results from concrete with a deteriorated and soft cement paste.

2.3.3 Concrete Penetration

Penetration measurements involve applying a consistent level of force from a chipping hammer to the concrete surface until sound, hard material is exposed, and then measuring the depth of the resulting cavity. The cavity depth provides quantitative data on the integrity and condition of the concrete surfaces. Typically, as concrete deteriorates, the cement paste begins to lose integrity and becomes soft. Carbonation and exposure to high levels of hydrogen sulfide are typical causes of degraded concrete surface hardness. A measure of the loss of concrete surface hardness based on depth of penetration measurements is displayed in Table 2-4.

Table 2-4. Evaluation of Concrete Surface Hardness

Penetration Depth (inches)	Loss of Surface Hardness
> 1/4	Significant
1/8 – 1/4	Moderate
1/16 – 1/8	Minor
< 1/16	Negligible

2.4 Sulfide Tests

Sulfides can indicate odor and corrosion problems. The rankings used when correlating the sulfide concentration with corrosivity or odor vary among engineers; however, Table 2-5 is a generally accepted guide. These are the same threshold concentrations that were provided in Table B- 1 of the "2013 Richmond Odor Evaluation Report."

Table 2-5. Corrosivity and Odor as a Function of Sulfide Concentration

Corrosivity & Odor Ranking	Total Sulfide in Wastewater (mg/L)	Atmospheric H_2S (ppm)
Very high	>15	>40
High	8-15	8-40
Moderate	5-8	5-8
Low	1-5	1-5
Negligible	<1	<1

2.4.1 Sulfides in Wastewater

Grab samples of wastewater were collected from the discharge manholes, pressure manholes, and wet wells using a bucket and tested on-site for total and dissolved sulfide using a LaMotte Drop Count Sulfide Test Kit. These kits use the Pomeroy methylene blue method for analysis. This titration method uses colorimetric standards to determine sulfide concentrations. Total sulfide, dissolved sulfide, and hydrogen sulfide can be separated in the titration test. The sulfide concentration is determined using a color dye, which is added to an unreacted sample until its color matches a reacted sample.

2.4.2 Atmospheric Hydrogen Sulfide

V&A measured the hydrogen sulfide (H_2S) concentration in the wet wells and manholes prior to or during activities conducted at the wet wells and manholes. Atmospheric levels of H_2S were measured using four-gas meters, which produce instantaneous measurements. V&A also recorded the time the reading was taken.

2.5 CCTV

Closed-circuit television (CCTV) was used to visually examine the interior pipe surfaces of the force mains. Specific defects in the force main were located and identified. A remote crawler camera was deployed by Veolia into the force mains from the discharge manholes and wet well. Video and images of the pipe's interior surface were recorded. CCTV evaluation reports prepared by Veolia included the video recording, still images, pipe condition information, and observations recorded in NASSCO PACP format.

2.6 UT Testing

Ultrasonic Thickness (UT) testing is a non-destructive evaluation technique that measures metal wall thickness. High frequency sound waves are transmitted through one side of a metal wall from a transducer. When sound waves reach the other side of the metal wall, a fraction of the waves will echo back to the transducer. The metal thickness is determined by recording the time it takes for the sound wave to travel through the metal and return.

Cast iron is a non-homogeneous material, and it is difficult to measure wall thickness of cast iron due to the scatter of the echo signal back to the transducer. V&A used the Olympus Epoch XT ultrasonic flaw detector. Figure 2-1 shows a picture of the instrument and a typical waveform. This device allows more adjustment of the return echo signal waveform than other UT gauges, which gives greater confidence in the measurements. Prior to taking measurements, the gauge was calibrated to the velocity of sound in cast iron. When properly calibrated, the gauge has a measurement accuracy of one thousandth of an inch (0.001 inches).

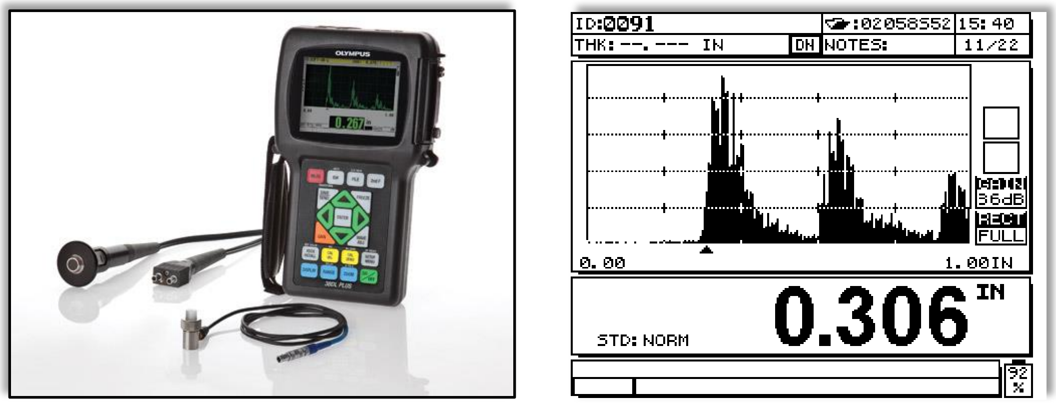


Figure 2-1. Olympus 38DL Plus UT Gauge and Example Waveform

2.7 Pit Depth Measurements

Where reliable UT tests cannot be made, and the pipe shows surface pitting, V&A will measure the pit depths using a handheld pit depth gauge, shown in Figure 2-2. The gauge is held in a vertical position above the pit to be measured with the lower edge flush against the metal surface. The pointer is inserted into the pit and the depth is read off the calibrated scale on the right.

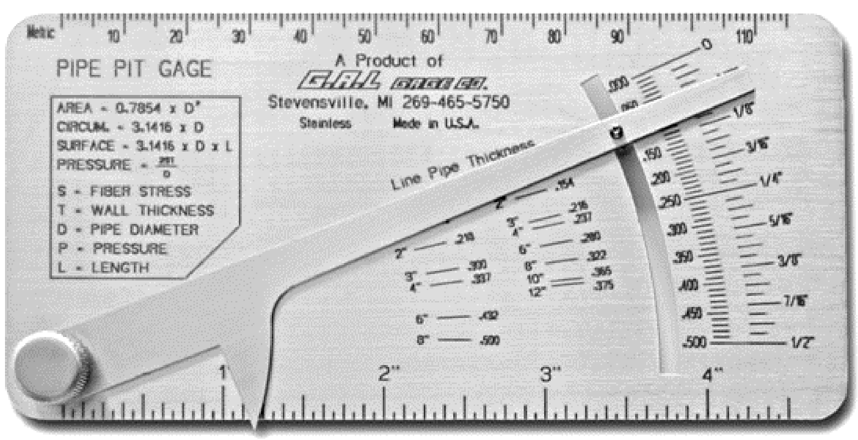


Figure 2-2. Standard Pit Depth Gauge

2.8 BEM

Broadband electromagnetic scanning (BEM) is a nondestructive test method that uses an electromagnetic or eddy current transducer to generate a profile of the wall thickness of metallic pipes.

V&A used the HSK 300 system, produced by Rock Solid Group, with a 2-inch sensor antenna to perform BEM scanning (Photo 2-3). BEM allows thickness scanning to be performed without the removal of coatings, mortar, or insulation from pipe surfaces. BEM technology allows metallic pipe to be evaluated with 100% surface coverage.

This technology allows for the assessment of metal thickness loss and evaluation of metallurgical changes in the pipe composition formed by corrosion processes such as graphitization. The electromagnetic signal of the pipe is altered by changes in wall thickness. This change in the signal is used to provide a contour map of apparent wall thicknesses, which can indicate internal and external corrosion.

Photo 2-3. Broadband Electromagnetic Thickness Scanning

2.9 In Situ Soil Resistivity

2.9.1 Wenner 4-Electrode Method: General Information

The Wenner 4-Electrode Method determines electric current's ability to flow through an electrolyte, which directly relates to the degree of corrosivity of the electrolyte. Each location is set up by driving four metallic pins into the ground in a straight line at equidistant spacing. Each pin is driven into the ground to a depth that allows for adequate contact between the soil and the pin. An insulated harness containing multiple wires is laid out along the pins, and clips are used to create a metallic connection between each pin and the corresponding wire inside the harness. Each of the wires is referred to as one of the following: C1, P1, P2, or C2. Pins C1 and C2 are used to flow current and are positioned as the outer two pins of the array, while pins P1 and P2 are used to measure potential and are positioned as the inner two pins of the array. Figure 2-3 is presented to visually represent this concept. The wires are connected to a soil resistance meter, and the resistance of the soil mass below the pins is determined as follows.

The soil resistance meter discharges alternating current into the electrolyte between pins C1 and C2 in a hemi-spherical manner. Due to the resistance of the soil, the current creates a voltage gradient that is proportional to the average resistance of the soil mass to a depth equal to the spacing between each pin. While the alternating current is flowing through the electrolyte, the soil resistance meter measures the voltage drop, or potential, between pins P1 and P2. The average resistance of the soil mass is calculated by the meter by rearranging Ohm's Law (V=IR) to solve for resistance. Once the resistance value from the display of the meter is recorded, the spacing between each pin is adjusted, and the measurement is performed again.

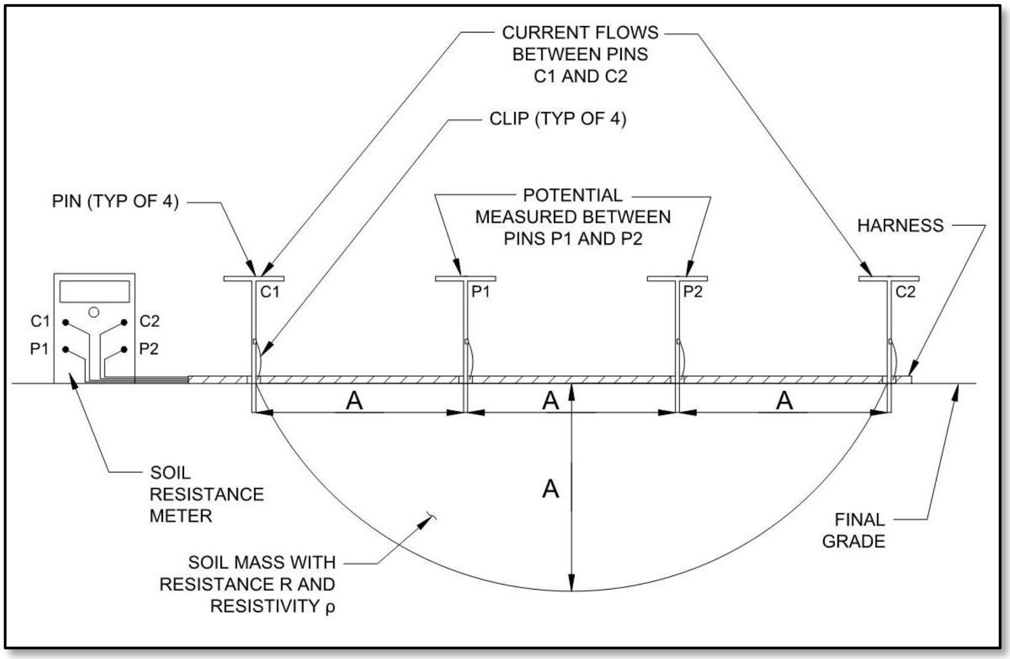


Figure 2-3. Wenner 4-Electrode Method Schematic

At each location, soil resistance measurements were recorded at pin spacing of 5 feet and 10 feet. The meter measures and displays soil resistances. The soil resistance values were used to calculate resistivity to depth and layer resistivity.

2.9.2 Resistivity to Depth

Average resistivity (ρ) of the soil mass below the pins to a depth equal to the spacing between each pin is calculated with the following equation.

$$\rho = 2 \cdot \pi \cdot A \cdot R$$

Where:

Where:	ρ	=	Average soil resistivity to a depth of *A* (ohm-cm)
	A	=	Distance between electrodes (cm)
	R	=	Soil resistance to a depth of *A*, soil resistance meter reading (ohm)
	π	=	3.14 (approximately)

Once the spacing between each pin was converted from feet to centimeters and the resistance value obtained from the meter display was substituted into the equation, a resistivity value was obtained to represent the average resistivity of the soil below the pins to a depth equal to the pin spacing. The resistivity values were then compared to generally accepted ranges of resistivity and their corresponding level of corrosivity to buried metal structures.

2.9.3 Resistivity of Soil Layer (Barnes Layer Resistivity)

The recorded soil resistance values were also used to calculate the resistivity of multiple layers of soil as opposed to the average resistivity of the soil from grade to a desired depth. For example, after the resistance of the soil mass to the depths of five and ten feet are measured, the average resistivity of the soil layer between five feet and ten feet below grade may be calculated. This method of calculating the resistivity of a layer of soil is referred to as the Barnes Layer Soil Resistivity Calculation; Figure 2-4 is presented to visually represent this concept.

When determining the resistivity and corresponding corrosivity of the electrolyte, the Barnes Layer Soil Resistivity calculations are used in lieu of the average resistivity to depth calculations. This is due to the Barnes Layer Resistivity calculation's ability to isolate the layer of soil that the proposed structure will be in contact with while neglecting the soil in layers that will not be in contact with the structure. The soil in the layers that are not in contact with the structure will have little to no effect on the corrosion rate of the structure. By isolating the layer of soil that will be in contact with the proposed structure, a more accurate representation of the proposed structure's environment may be obtained. Soil corrosivity as a function of soil resistivity is provided in Table 2-6 in Section 2.10.

Average soil layer **resistivity** ($\rho_{A\text{-}B}$) is calculated using the following equation.

$$\rho_{A\text{-}B} = 2 \cdot \pi \cdot (B - A) \cdot R_{A\text{-}B}$$

Where:	$\rho_{A\text{-}B}$	=	Average soil layer resistivity between depth "A" to depth "B" (ohm-cm)
	A	=	Depth below grade to the top of the soil layer (cm)
	B	=	Depth below grade to the bottom of the soil layer (cm)
	π	=	3.14 (approximately)
	$R_{A\text{-}B}$	=	Soil layer resistance from depth *A* to depth *B* (ohm); see next equation

Soil layer **resistance** ($R_{A\text{-}B}$) is calculated using the following equation.

$$R_{A\text{-}B} = (R_A \cdot R_B)/(R_A - R_B)$$

Where:	$R_{A\text{-}B}$	=	Soil layer resistance between depth *A* to depth *B* (ohm)
	R_A	=	Soil resistance to a depth of *A*, soil resistance meter reading (ohm)
	R_B	=	Soil resistance to a depth of *B*, soil resistance meter reading (ohm)

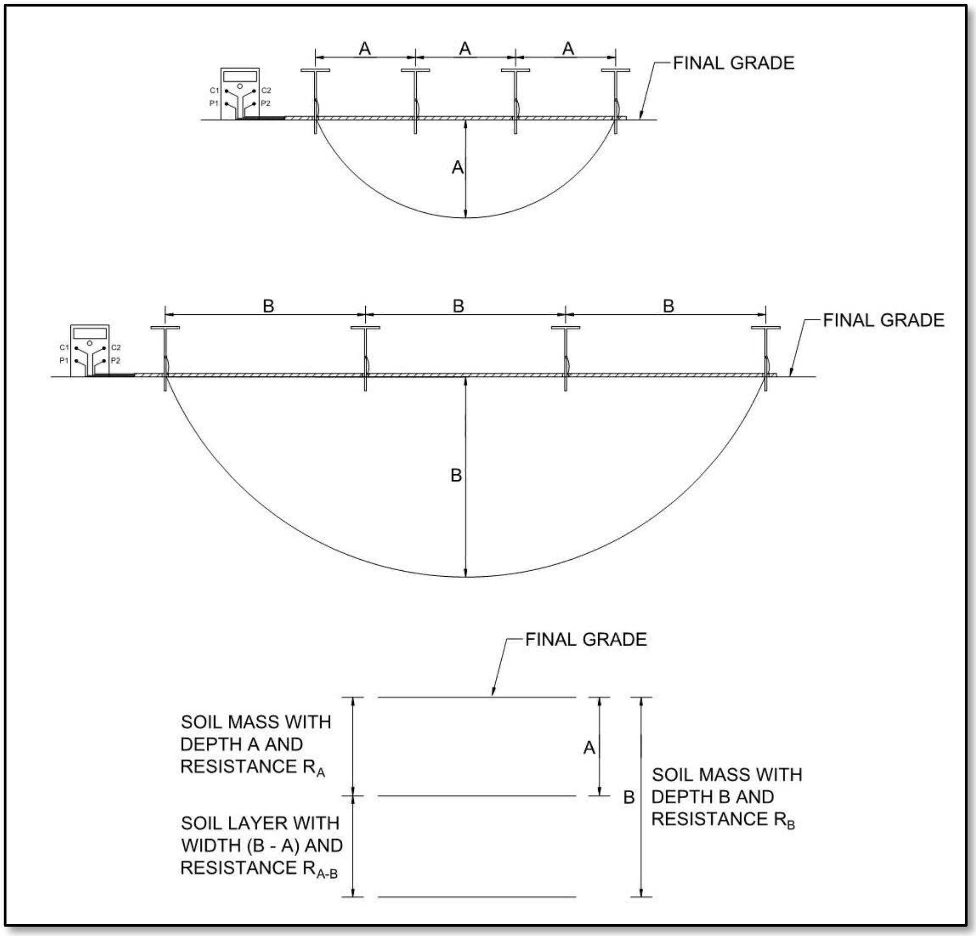


Figure 2-4. Barnes Method for Determining the Resistance of a Soil Layer

2.10 Soil Corrosivity: Laboratory Analysis

Corrosion is an electrochemical process that involves electron flow as part of the reaction. A more conductive (low resistivity) soil would favor corrosion of buried metal. Corrosion is affected by the following parameters.

- Soil Resistivity: The soil resistivity is a measure of a soil's ability to conduct an electric current. The more easily a soil conducts electricity, the more rapidly corrosion activity can occur on a buried metal structure exposed to the soil. Soil resistivity was measured both in situ (Section 2.9) and in the laboratory (Section 2.10.1). The corrosivity rankings as a function of soil resistivity that are used in this report are listed in Table 2-6. This table is based upon corrosivity rankings presented in "Corrosion Basics – An Introduction," pg. 191 (1984), published by the National Association of Corrosion Engineers (NACE).

- pH: Low pH will cause increased concentration of reducible hydrogen ion which eventually consumes the metal. A low pH breaks down the passive oxide film on the metal surface that protects it from corrosion. Table 2-7 lists the pH, chloride, and sulfate rankings used by V&A

as guidelines to assess soil corrosivity. These ranges are generally accepted by the corrosion engineering community.

- Chlorides: Chlorides affect the soil corrosivity by lowering its resistivity, which promotes metal corrosion. Also, chlorides are aggressive to buried steel by destroying surface passive oxide films that protect it from corrosion.
- Sulfates: Sulfates affect the soil corrosivity by lowering its resistivity, which promotes metal corrosion. Sulfate ions do not alter steel nor do they affect protective oxide films on the metal surfaces. Sulfate ions are a concern for concrete, however, because they react with the Portland cement binder, which causes expansion and concrete cracking. In buried metal applications, the sulfate ions lower the soil resistivity and accelerate other corrosion processes.
- Bicarbonates: Bicarbonates affect the soil corrosivity by lowering its resistivity, which promotes metal corrosion. No ranking system for bicarbonate ion concentration has been provided in the technical literature, but the effects of bicarbonate ion concentration on soil resistivity have been observed in laboratory test samples.

Table 2-6. Effect of Soil Resistivity on Soil Corrosivity

Soil Resistivity (ohm-cm)	Degree of Corrosivity
< 500	Very High
500 – 1,000	High
1,000 – 2,000	Moderate
2,000 – 10,000	Mild
> 10,000	Negligible

Table 2-7. Effects of pH and of Chloride and Sulfate Concentration on Soil Corrosivity

Soil Corrosivity Ranking	pH	Soluble Chloride (mg/kg)	Soluble Sulfate (mg/kg)
Very High	-	> 5,000	> 2,000
High	< 5.5	1,500 – 5,000	-
Moderate	5.5 – 6.5	500 – 1,500	1,000 – 2,000
Mild	6.5 – 7.5	100 - 500	-
Negligible	> 7.5	< 100	< 1,000

mg/kg = milligrams per kilogram

2.10.1 Laboratory Soil Resistivity

A soil sample was obtained by V&A at the Keller Beach Force Main exposed metal pipe for analysis of saturated soil resistivity using a soil box (see Figure 2-5). The resistivity testing was performed in accordance with NACE International analytical procedures.

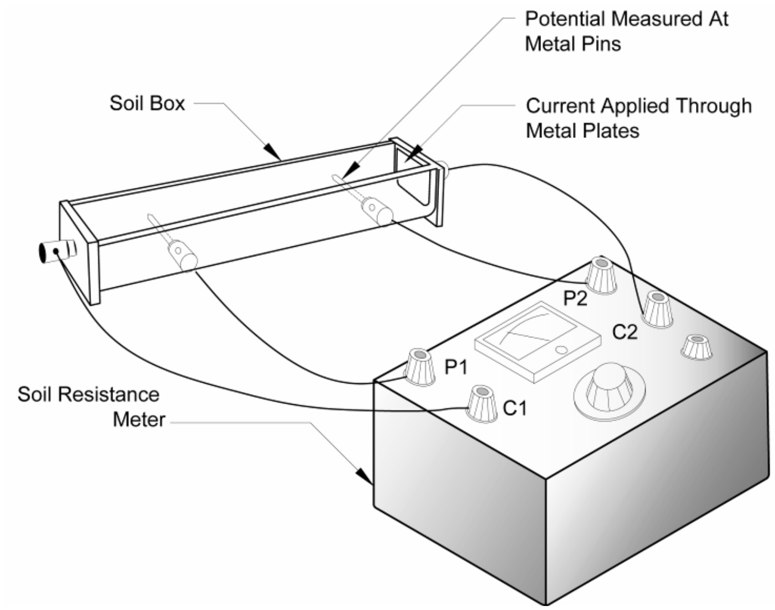


Figure 2-5. Soil Resistivity Measurement Using the Soil Box Method

The test apparatus consists of a small plastic box with metal end plates for passing current through the soil sample packed tightly into the box. Current flows through the sample, causing a voltage drop across the sample, which is measured between the two pins. The current is supplied by a soil resistance meter, which also measures the voltage drop between pins P1 and P2. The meter calculates the soil resistance using Ohm's Law, stated as "resistance equals the voltage divided by the current," or R = V/I. The geometry of the soil box is designed so that the measured soil resistance is also the sample resistivity in ohm-cm.

A soil sample was placed in the soil box, and the soil resistivity was measured in the "as-received" state. Distilled water was added to the soil sample, and the resistivity was measured after each addition. As the soil sample became more saturated, the soil resistivity decreased until the minimum soil resistivity was reached. The saturated (minimum) resistivity represents the most corrosive conditions in the soil to iron pipe, which occurs when all the soluble salts are taken into solution. The salts provide less resistance to electric current flow in the soil, which promotes corrosion of buried iron pipe.

2.10.2 Soil Chemical Analysis Test Methods

A soil sample taken from the exposed Keller Beach Force Main metal pipe site was tested for pH as well as concentrations of water soluble chloride, water soluble sulfate, and bicarbonate ions. The samples were sent to an accredited analytical laboratory for analysis. Standard analytical methods were used to determine these chemical constituents:

- pH by EPA 9045C
- Inorganic anions (chloride and sulfate) by SW 9056
- Bicarbonate Alkalinity (as $CaCO_3$) by SM 2320B

2.11 Pipe-to-Soil Potential

Pipe-to-soil potential testing is a method for determining whether metallic pipes are susceptible to corrosion. The pipe-to-soil potential was measured on the Keller Beach Force Main metal pipe using a digital voltmeter. The potential was measured between an exposed portion of pipe and a copper/copper-sulfate reference electrode placed in contact with soil 1/2 inch and 6 inches from the exposed pipe. The pipeline test lead is connected to the positive terminal of the voltmeter and the reference electrode is connected to the negative terminal of the voltmeter. A high impedance voltmeter was used to reduce the effects of contact resistance between the electrode and the soil and to prevent the electrode from polarizing. Tap water was poured on the ground and the electrode was set in the wet soil to reduce contact resistance between the reference electrode and the soil.

The pipeline potential with respect to a reference electrode can be used to roughly characterize the extent of corrosion on the exterior of the pipeline. Typically, newer and less corroded pipelines will have more negative potential values, while old corroded pipelines are more positive. According to one NACE criterion, the pipeline is protected from corrosion when the potential is -850 mV or less (more negative).

3.0 FINDINGS

The condition assessment findings for the five force main systems are summarized in this section. These findings are based on data gathered using the tests and methods described in the previous section: Visual assessment, sulfide tests, concrete tests, CCTV, UT measurements, BEM measurements, pit depth measurements, soil resistivity, and soil chemical analysis.

3.1 Force Main System No. 1 – Marina Bay Parkway

The Marina Bay Parkway force main system was accessed at the Marina Bay Parkway discharge manhole on October 5th, 2015 at 9:20 am. The discharge manhole is considered a confined space, and appropriate safety procedures were followed to enter the confined space. The location of the manhole is shown in Figure 3-1.

Figure 3-1. Marina Bay Parkway Discharge Manhole Location

3.1.1 Visual Assessment

The discharge manhole in the Marina Bay Parkway force main system was generally in good condition and was sealed well to the pipe connections. The pipe connections included the force main and a gravity outlet. The force main was black plastic (possibly HDPE) and was approximately 9.375 inches in diameter in the vertical direction and 9.5 inches in diameter in the horizontal direction. The gravity outlet was white plastic (also possibly HDPE) measuring approximately 14.25 inches in diameter, and oriented 90 degrees to the influent pipe. During the pump cycle, the discharged water became quite turbulent (Photo 3-1). The pipes are clear of debris and buildups except for minor thin apparent grease coatings on the wall surfaces (Photo 3-2 and Photo 3-3). A thin mortar layer on the manhole concrete surface is chipping off in places (Photo 3-4).

Photo 3-1. Plan View of Marina Bay Discharge Manhole During Discharge

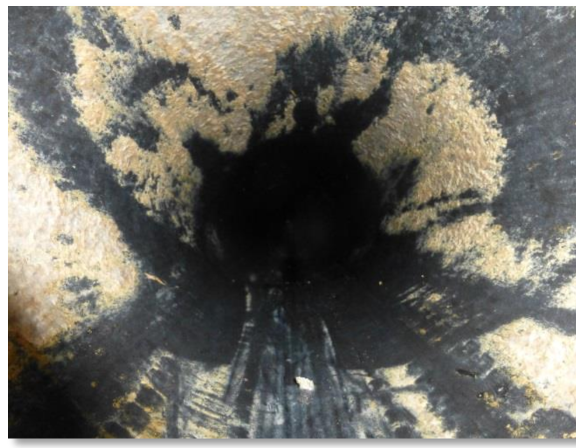


Photo 3-2. 9.5-inch Diameter Black HDPE Influent Force Main

Photo 3-3. 14.25-inch Diameter White HDPE Effluent Force Main

Photo 3-4. Thin Surface Mortar Detachment on Discharge Manhole Wall

The concrete under the thin mortar layer is fresh and solid as evidenced by an in situ pH reading of 12 (Photo 3-5), and concrete sounding/penetration test results. Both the cone and barrel/bench sections of the manhole are in good condition. The chimney is constructed of three stacked rings 3 inches (two rings) and 5 inches thick. The joints are not sealed (Photo 3-6). An open 3/4 to 1-inch wide gap separates the bottom ring from the cone section (Photo 3-7). A 4-inch wide by 3-inch high triangular piece of concrete is missing from the middle ring (Photo 3-8). The manhole chimney is structurally sound but the open joints and the triangular spall cavity should be sealed with a repair mortar. The right angle turn between the influent and effluent pipes generates turbulent flow during discharge cycles that will release corrosive hydrogen sulfide gas into the manhole headspace. The new manhole concrete condition is rated a VANDA Level 1 according to Table 2-1 guidelines.

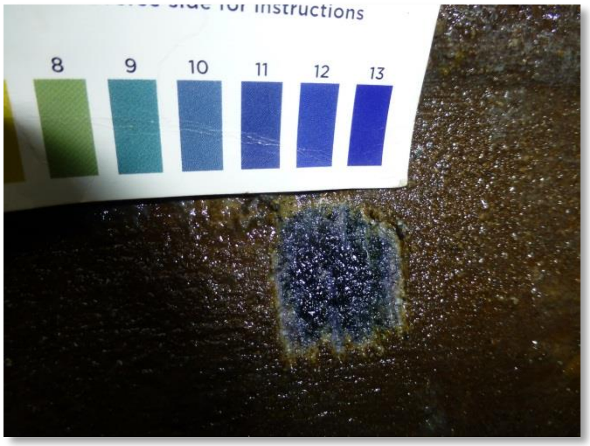


Photo 3-5. Concrete Under Thin Mortar Coating is pH 12

Photo 3-6. Open Joints Between Manhole Rings and the Manhole Cone; A Concrete Fragment is Missing from the Middle Ring

Photo 3-7. A 3/4-inch Wide Gap Separates the Lower Ring and the Cone Section

Photo 3-8. A Triangular Spall Fragment is Missing From the Middle Ring

3.1.2 Sulfide Test Results

A grab sample of wastewater was collected from the Marina Bay Parkway discharge manhole using a bucket and tested on-site for total and dissolved sulfide using a LaMotte Drop Count Sulfide Test Kit. There was no detectable concentration of total sulfide or dissolved sulfide.

The 4-gas meters were monitoring the H_2S concentrations in the Marina Bay Parkway discharge manhole. The H_2S concentration was not detectable (< 1 ppm).

3.1.3 Concrete Test Results

V&A conducted concrete sounding tests, penetration tests, and surface pH measurements in the Marina Bay Parkway discharge manhole. The sounding test indicated good, hard concrete without subsurface voids. No concrete was removed when doing the penetration test because the surface was sound, hard material. The surface pH was 12. These results indicate the concrete is in good condition.

3.1.4 CCTV

There were multiple trial entries and cleanings required to CCTV the Marina Bay Parkway force main. The camera was under water from 5.5 feet upstream of the discharge manhole up to 340 feet upstream. Note that only 180 feet were recorded. This signifies a continuous sag in the force main and not much more can be evaluated from the CCTV to add to the confined space entry at the discharge manhole. Photo 3-9 shows the condition at the discharge manhole.

Photo 3-9. CCTV of Marina Bay Parkway FM at the Discharge Manhole

The new gravity line was also CCTVed and cleaned by Veolia on September 24th, 2015 from the same manhole and one manhole 267.6 feet downstream. There were no issues.

3.2 Force Main System No. 2 – Ferry Point & Keller Beach

The Ferry Point and Keller Beach force main system was accessed at a discharge manhole on October 13th, 2015 at 11:00 pm. The manhole is considered a confined space, and appropriate safety procedures were followed to enter it. Veolia had attempted to CCTV the force main from the discharge manhole before but the force main has two 90-degree bends and a vertical section immediately upstream of the manhole and cannot be CCTVed. The Ferry Point wet well and the Keller Beach wet well were observed without entry on October 12th, 2015 at 3:15 pm and October 5th, 2015 at 1:00 pm, respectively.

The exterior of the force main was assessed at an exposed portion located at Keller Beach on October 5th, 2015 at 1:00 pm. This was the only exterior assessment for all five of the force main systems in this project. No confined space entry was required to assess the exterior of the pipe. The locations of the manhole wet wells at the pump stations are shown in Figure 3-2. The location of the exposed pipe is shown in Figure A-1.

Figure 3-2. Ferry Point and Keller Beach Discharge Manhole and Pump Stations Locations

3.2.1 Visual Assessment

3.2.1.1 Exterior of Force Main

The 8-inch diameter ductile iron pipe (DIP) discharge force main at the Keller Beach Pump Station was exposed on a steep hillside above the railroad tracks between the pump station and Dorman Drive (Photo 2-2). The pipe exterior is corroded, but only at the immediate surface. No significant pitting or pipe wall thinning was visually observed. A second partially buried DIP was noted west of the exhumed pipe. The tested pipe was confirmed as the force main by an Lmic sonic test conducted while the wet well pump was running.

3.2.1.2 Discharge Manhole

The Ferry Point & Keller Beach discharge manhole is located in the eastbound lane of Dorman Drive at Garrard Boulevard, which is at the east entrance to the Ferry Point Tunnel. The manhole is completely coated on the inside surfaces (Photo 3-10), and the coating has completely failed in the manhole (Photo 3-11). Near the top of the manhole the liner has pulled away from the wall below the ring, and the underlying concrete is soft and crumbly (Photo 3-12). Similar liner detachment from the concrete substrate is observed at the bottom of the manhole riser (Photo 3-13). The liner is brittle and easily punctured. An in situ pH reading could not be made because the concrete was too soft. From past experience, it is likely the concrete pH is 4 or lower. The concrete, where exposed, is rated a VANDA Level 3. No exposed reinforcing steel was seen.

The influent and effluent pipes are 8 inches in diameter. Their compositions are difficult to determine, but the influent pipe is thought to be an RCP or VCP (clay) pipe, and the effluent pipe is thought to be PVC. The force main discharge is turbulent and accompanied by considerable splashing (Photo 3-14). The force main flowed for approximately 10 minutes during the assessment.

Photo 3-10. Plan View into the Ferry Point & Keller Beach Discharge Manhole

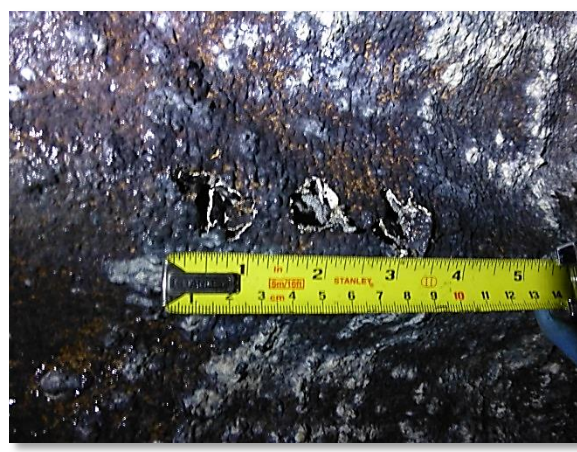


Photo 3-11. Three Holes in the Detached Manhole Liner

Photo 3-12. Liner Pulled Away From the Concrete Near the Manhole Ring

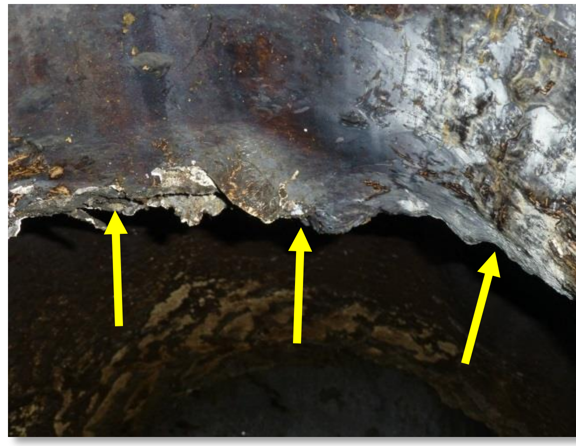


Photo 3-13. Liner Detached from Concrete at the Bottom of Manhole Riser

Photo 3-14. Wastewater Spraying from the Force Main into the Discharge Manhole

3.2.2 Sulfide Test Results

Grab samples of wastewater were collected from the Keller Beach wet well and Ferry Point wet well using a bucket and tested on-site for total and dissolved sulfide using a LaMotte Drop Count Sulfide Test Kit. There were moderate concentrations of total sulfide or dissolved sulfide measured at the Ferry Point wet well and low concentrations measured at the Keller Beach wet well, as shown in Table 3-1.

Table 3-1. Sulfide Concentrations in Keller Beach and Ferry Point Wet Wells

Location	Total Sulfide (ppm)	Dissolved Sulfide (ppm)
Keller Beach wet well	1.6	1.2
Ferry Point wet well	7.1	6.4

A 4-gas meter was monitoring the H_2S concentrations in the Keller Beach & Ferry Point discharge manhole. The H_2S concentration was a high 12 ppm before entry. A blower was used to reduce the concentration to allow for safe entry. The resulting concentration was below the detectable limit.

The Keller Beach and Ferry Point wet wells have the highest concentration of sulfide amongst the wet wells in this study. The associated force mains and appurtenances are likely to have experienced and continue to experience increased corrosion rates due to biological acid formation on the surfaces. In particular, these force mains have a history of high sulfide levels and odor issues. Before 2013, approximately 90% of all odor complaints received have come from this discharge manhole area and the total sulfide concentrations in the Ferry Point wet well ranged from 8 to 12 mg/L, averaging 9 mg/L and the discharge manhole ranged from 5 to greater than 20 mg/L, averaging over 16 mg/L. (See Table B- 1 and Figure B- 1 for relevant parts of the 2013 Odor Evaluation Report). Veolia and the City had since installed a hydrogen peroxide chemical feed system at the Ferry Point pump station. The effect can be seen in the lower sulfide levels.

3.2.3 Concrete Test Results

V&A attempted to conduct the concrete sounding tests, penetration tests, and surface pH measurements in the Ferry Point & Keller Beach discharge manhole. The sounding test indicated soft, putty-like cement. The penetration test revealed that the soft concrete continued for at least 1.5 inches, at which point the test was stopped to prevent further damage to the manhole. The concrete was too soft to take surface pH measurements. These results indicate the concrete is in poor condition.

The pipe channel below the manhole was concrete. It looked like it was generally in good condition, except for some exposed aggregate at the influent entrance. The channel surface was too wet for testing.

3.2.4 UT & BEM Test Results

UT and BEM testing were performed on the exposed portion of the Keller Beach force main. Table 3-2 and Figure 3-3 show the BEM and UT results; the latter BEM contour plot is courtesy of RockSolid Group. Both tests show low variation in thickness of 0.04 inches. The minimum thickness mostly occurred near the 9:00 clock position, looking towards the flow direction, or the north side of the force main. Since the force main was partially exposed prior to testing, the minimum thickness location may simply be where the slope had eroded the most.

Table 3-2. Keller Beach Force Main - BEM and UT Results

Test	Wall Thickness (in.)				
	Min	Max	Average	Range	Coefficient of Variation
BEM	0.370	0.404	0.390	0.034	1.9%
UT	0.369	0.410	0.390	0.041	5.2%

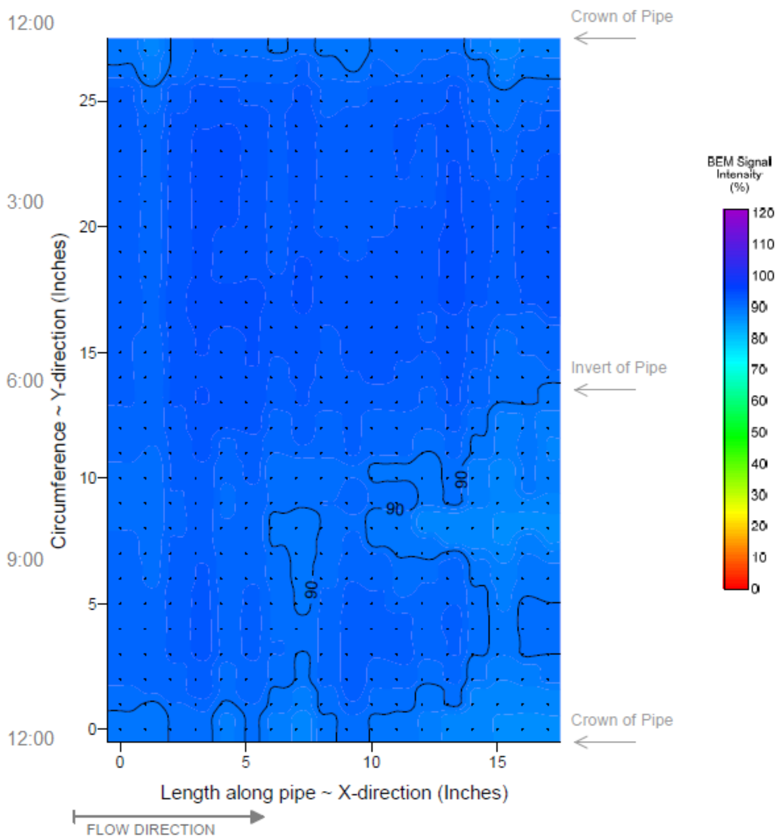


Figure 3-3. Keller Beach Force Main - BEM Contour Plot

To assess the thickness loss, the current thickness needs to be compared with the nominal thickness. The nominal thickness of the Keller Beach force main is unknown, but an estimate is 0.41 inches. Available drawings indicate that the pipe existed before 1996 and is an 8–inch diameter CIP. It was field verified as an 8-inch CIP, with mild surface rust, no real pitting and the maximum wall thickness measured was 0.41 inches. Based on the age, markings and external appearance, the pipe appears to have been centrifugally cast. Centrifugally cast CIP was covered by two American Standards Association (ASA) standards introduced in 1952:

- ASA A21.6-1952, "Cast Iron Pipe Centrifugally Cast in Metal Molds, for Water or Other Liquids."
- ASA A21.8-1952, "Cast Iron Pipe Centrifugally Cast in Sand-lined Molds, for Water or Other Liquids."

Out of these standard thickness classes, the pipe is most likely thickness Class 22 of nominal thickness 0.41 inches.

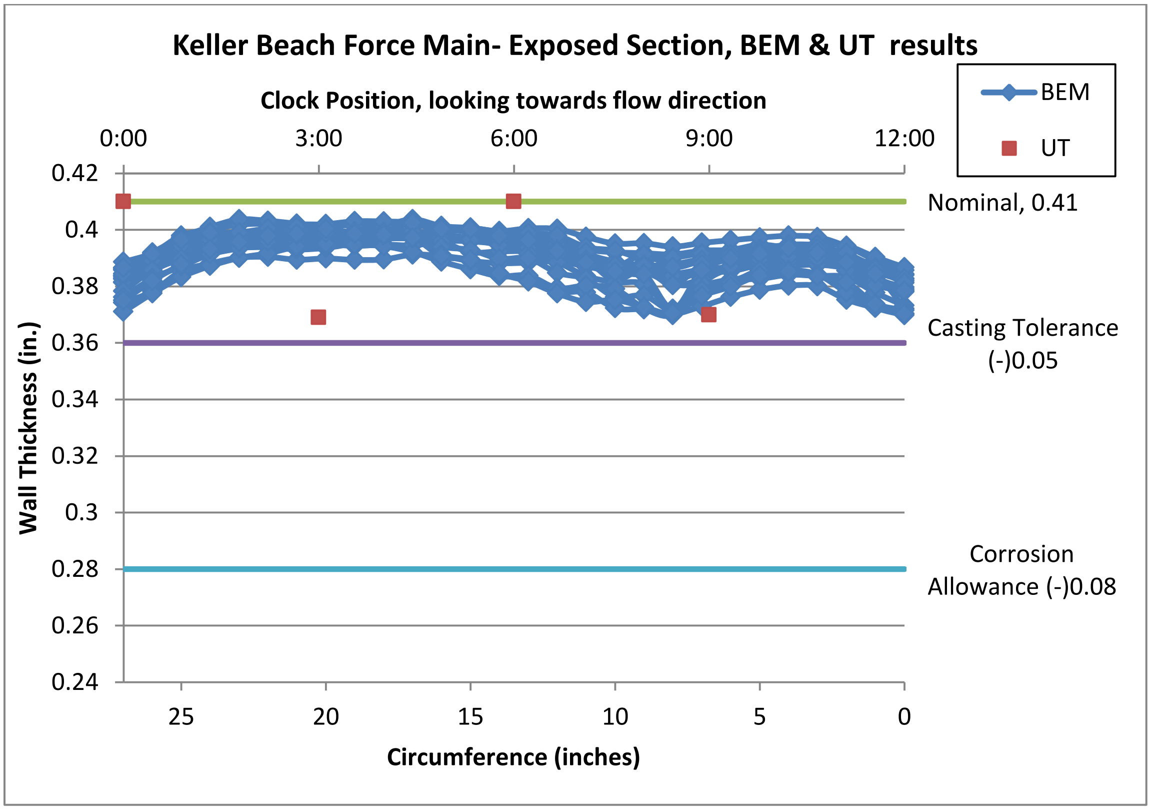


Figure 3-4. Keller Beach Force Main - BEM & UT results plotted with Nominal Thickness

Nominal thicknesses for standard pipe classes, casting tolerance, and corrosion allowance from ASA A21.1 and ASA A21.8. Each line represents one circumferential ring of BEM measurements.

The standards also specify a casting tolerance for each size of pipe and a corrosion allowance for buried pipe. The wall thicknesses measured on the Keller Beach Force Main are within the manufacturing tolerance for the pipe based on the assumed nominal thickness. There has been no significant wall thickness loss at the location tested.

3.2.5 Soil Test Results

Pipe-to-soil potential measurements were taken at the Keller Beach force main and are summarized in Table 3-3. The soil was loose and very dry when the measurements were taken. The potentials indicate that the exterior of the bare DIP pipeline is subject to corrosion.

Table 3-3. Keller Beach Force Main: Pipe-to-Soil Potential

Test Number	Potential (mV)	Reference Cell Location
1	-272	6 inches from pipeline
2	-245	1/2 inch from pipeline

The in situ soil resistivity is presented in Table 3-4 with supporting statistics in Table 3-5. The "resistivity to depth" at a given test site is the resistivity of the soil mass between grade and down to the designated depth. Per Table 2-6, resistivities of 2,000 to 10,000 ohm-cm are considered *mildly corrosive*. At the Keller Beach force main, the minimum soil resistivity to depth is 4,290 ohm-cm and the maximum is 9,269 ohm-cm, both of which are considered *mildly corrosive*.

The Keller Beach force main pipe crown is approximately 0 to 6 inches below grade near the test location, and probably less than 12 inches below grade on the hillside. The resistivity of the soil layer between 0 to 5 feet below grade is 7,182 to 9,269 ohm-cm, which is considered *mildly corrosive*.

Table 3-4. Keller Beach Force Main: In Situ Soil Resistivity

Site Number	Depth (feet)	Resistance at Depth, Meter Reading (ohm)	Resistivity to Depth (ohm-cm)	Layer (feet)	Resistance of Soil Layer (ohm)	Resistivity of Soil Layer (ohm-cm)	Degree of Corrosivity for Layer
1	5	9.68	9,269	0 - 5	9.7	9,269	Mild
	10	4.71	9,020	5 - 10	9.2	8,784	Mild
2	5	7.50	7,182	0 - 5	7.5	7,182	Mild
	10	2.24	4,290	5 - 10	3.2	3,058	Mild

Table 3-5. Keller Beach Force Main: Summary of In Situ Soil Resistivity Statistics

Depth (feet)	Resistivity at Depth (ohm-cm)			Layer (feet)	Resistivity of Layer (ohm-cm)		
	Average	Minimum	Maximum		Average	Minimum	Maximum
5	8,225	7,182	9,269	0 - 5	8,225	7,182	9,269
10	6,655	4,290	9,020	5 - 10	5,921	3,058	8,784
All Depths	7,440	4,290	9,269	All Layers	7,073	3,058	9,269

Table 3-6 presents the laboratory analysis of a soil sample collected near the Keller Beach force main. These results are compared with the guidelines in Table 2-7 to determine the soil corrosivity. The soil sample has a minimum resistivity of 6,170 ohm-cm, which is *mildly corrosive*. The soil sample pH was 7.25, which is also *mildly corrosive*. The soluble chloride concentration was 23.8 mg/kg, which is *negligibly corrosive*. The sulfate concentration was below the detection limit, which is will have a *negligible impact* on soil corrosivity and concrete degradation. The bicarbonate concentration is 79.5 mg/kg, which will have a *negligible impact* on soil corrosivity.

Table 3-6. Keller Beach Force Main: Laboratory Soil Analysis

Soil Sample	Saturated Resistivity (ohm-cm)	pH	Chloride (mg/kg)	Sulfate (mg/kg)	Bicarbonate (mg/kg)
14-0338	6,170	7.25	23.8	BRL	79.5

At the Keller Beach force main, the soil resistivity and pH have the greatest effect on metal corrosion. Based on these parameters, the soil in this area is *mildly corrosive* to buried iron.

3.3 Force Main System No. 3 – Canyon Estates

The Canyon Estates force main system was accessed at a discharge manhole on October 8th, 2015 at 1:30 pm. The discharge manhole is considered a confined space, and appropriate safety procedures were followed to enter the confined space. The location of the manhole is shown in Figure 3-5. The Canyon Estates Pump Station No. 3 (PS3) wet well was visited, but there was no entry into the wet well. The sulfide test grab sample was taken from the PS3 wet well, and some visual observations were made from the top of the wet well without entrance.

Figure 3-5. Canyon Estates Discharge Manhole and Pump Station (PS) Locations

3.3.1 Visual Assessment

3.3.1.1 Canyon Estates Discharge Manhole

The Discharge Manhole is located in the center of Rifle Range Road. Two inlets are on the north side of the manhole (Photo 3-15). One is a 6-inch diameter PVC pipe, which is the force main (Photo 3-16). The other influent pipe is a 6-inch diameter apparent iron pipe that is a lateral collecting from nearby residences (Photo 3-18). Photo 3-17 and Photo 3-19 are upstream views into the PVC and the iron lateral, respectively. Photo 3-20 shows active flow from the PVC force main. Photo 3-16 and Photo 3-18 show soft, chalky concrete in the bench area with protruding coarse aggregate. The concrete is rated a VANDA Level 2 to Level 3 based on criteria presented in Table 2-1. Concrete in the bench channel, the cone, and the barrel sections underneath a thin veneer of mortar is hard, has no exposed aggregate, and is rated VANDA Level 1 Condition.

Photo 3-15. Plan View of the Canyon Estates Discharge Manhole Bench and Channel. North is at the Top of the Photo.

Photo 3-16. 6-inch Diameter PVC Force Main Influent Line

Photo 3-17. Upstream View into PVC Force Main

Photo 3-18. 6-inch Diameter Iron Pipe Lateral Inlet

Photo 3-19. Upstream View into Iron Lateral

Photo 3-20. Plan View into Discharge Manhole During Active Pump Cycle

3.3.2 Sulfide Test Results

Grab samples of wastewater were collected from the PS3 wet well using a bucket and tested on-site for total and dissolved sulfide using a LaMotte Drop Count Sulfide Test Kit. There was no detectable concentration of total sulfide or dissolved sulfide. However, an operator commented that there have been odor issues and that they use a rubber cover under the manhole cover.

The 4-gas meters were monitoring the H_2S concentrations in the Canyon Estates discharge manhole. The H_2S concentration was not detectable (< 1 ppm).

3.3.3 Concrete Test Results

V&A conducted concrete sounding tests, penetration tests, and surface pH measurements in the Canyon Estates discharge manhole. The sounding test indicated the concrete was deteriorated and soft. Also, there was medium to course aggregate exposed. The penetration test revealed that the soft and chalky concrete continued for 0.5 inches, which indicates significant loss of concrete surface hardness. The concrete surface pH was 2 to 3, which is severely corrosive to any reinforcing steel in the concrete. These results indicate the concrete is in poor condition.

The force main channel beneath the manhole was hard concrete with no exposed aggregate. It was in good condition.

3.3.4 CCTV

Veolia reported that approximately 50 feet of pipe beginning at the Canyon Estates discharge manhole was analyzed via CCTV. The CCTV video was clear, and the pipe was visible; however, only the first 4 feet were recorded. The pipe was identified as Green SDR 26. The pipe was in good condition, though a little dirty. No issues were found in the examined pipe.

3.4 Force Main System No. 4 – Brickyard Cove & Brickyard Booster

The Brickyard Cove & Brickyard Booster force main system was accessed at the Brickyard Cove discharge manhole on October 13th, 2015 at 9:50 pm, Brickyard Booster PS wet well on October 8th, 2015 at 9:00 am, Brickyard Booster pressure manhole on October 13th, 2015 at 9:15 pm and Brickyard Booster discharge manhole on October 12th, 2015 at 11:55 am. The Brickyard Booster discharge manhole is shared with Port force main system covered in Section 3.5. The manholes and wet well are considered confined spaces, and appropriate safety procedures were followed to enter the confined spaces. The locations of the manholes and wet well are shown in Figure 3-6 and Figure 3-7.

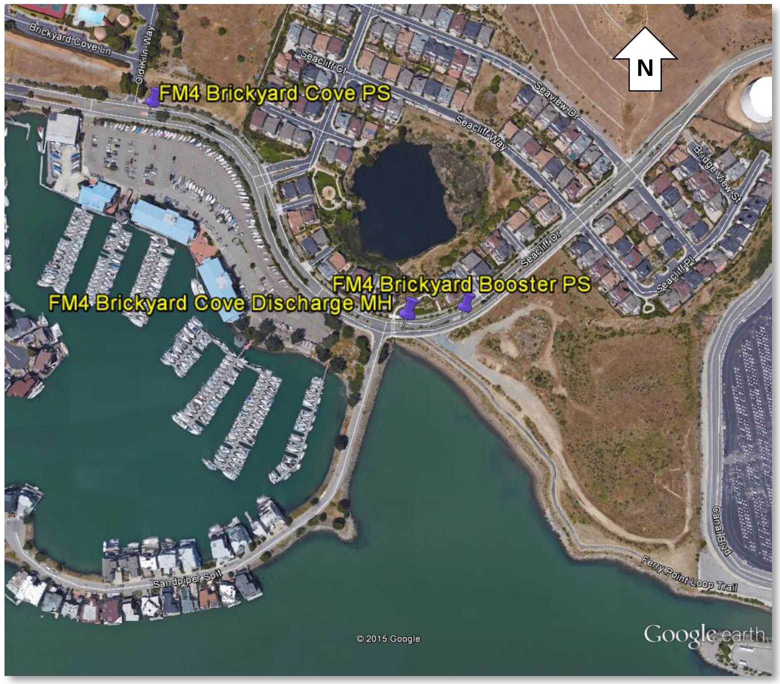


Figure 3-6. Brickyard Booster PS and Brickyard Cove Discharge Manhole and PS Locations

Figure 3-7. Brickyard Booster Pressure and Discharge Manhole Locations

3.4.1 Visual Assessment

3.4.1.1 Brickyard Booster Pump Station Wet Well

The Brickyard Booster Pump Station Wet Well was assessed as a substitute for a discharge manhole since it was thought that the Brickyard Cove Force Main discharged directly into the Booster Pump Station Wet Well. The wet well is cylindrical in shape and is completely lined with T-Lock (Photo 3-21). The weld strips at the horizontal joints between sheets are failing, and in places, are exposing the underlying concrete (Photo 3-22 and Photo 3-23). Two vertical discharge pipes from the submerged pumps show moderate surface corrosion exfoliation (Photo 3-24). Stainless steel flange bolts and other stainless steel hardware in the wet well are in good condition (Photo 3-25). The concrete exposed where the T-Lock liner strips have failed is hard beneath a thin soft, chalky surface layer. The concrete is rated VANDA Level 2 Condition per Table 2-1. The wet well liner is pliable and intact, but is being undermined in places by moisture penetration behind it.

Photo 3-21. Plan View Looking into the Brickyard Booster Pump Station

Photo 3-22. Failed T-Lock Weld Strips at Horizontal Joints

Photo 3-23. Exposed Concrete at Failed Horizontal Joint in T-Lock Liner

Photo 3-24. Moderate Corrosion Exfoliation on Discharge Pipe Surface

Photo 3-25. Stainless Steel Hardware is in Good Condition

A precast pipe vault is located downstream of the wet well. The two discharge pipes join into a single force main in this structure (Photo 3-26). The concrete and metallic piping and valves are in good condition. Metal corrosion is minor (Photo 3-27). No leakage at joints and sealed wall-to-floor seams was observed (Photo 3-28).

Photo 3-26. Topside View into Valve Vault Discharge Force Main from Wet Well

Photo 3-27. Minor Localized Corrosion on Valve Components

Photo 3-28. Minor Concrete Staining on Valve Vault Walls and Well Sealed Joint Seams

3.4.1.2 Brickyard Cove Discharge Manhole

During reconnaissance investigation of the Brickyard Booster PS, it was noticed that the force main influent stream to the wet well was gravity feed when the Brickyard Cove PS was discharging. Further investigation revealed the Brickyard Cove PS force main discharged one manhole upstream of the Brickyard Booster PS, at a manhole at the median near the intersection of Seacliff Drive and Sandpiper Spit.

The Discharge Manhole has a 6-inch diameter PVC drop inlet force main from the Brickyard Cove PS entering the manhole from the northeast (Photo 3-29). An 8-inch diameter black HDPE influent pipe and an 8-inch diameter white PVC effluent pipe are connected by a channel in the bench. Views into these pipes are shown in Photo 3-30 through Photo 3-32. The manhole barrel displays exposed medium size aggregate, but not significant aggregate protrusion (Photo 3-33). The concrete is hard from the bench and barrel upward through the cone and riser sections.

Photo 3-29. Topside View into Brickyard Cove Discharge Manhole (Top is to the Northeast Direction)

Photo 3-30. Upstream View into the 6-inch Diameter PVC Force Main from the Brickyard Cove PS

Photo 3-31. Upstream View into 8-inch Diameter Black HDPE Influent Pipe from Local Collection Systems

Photo 3-32. View Downstream in the 8-inch Diameter White PVC Effluent Pipe to the Brickyard Booster PS

Photo 3-33. Bench and Lower Barrel Concrete in Good Condition. VANDA Level 1 to 2 Condition.

3.4.1.3 Brickyard Booster Pressure Manhole

The Brickyard Booster Pressure Manhole No. 2 was assessed on the night of October 12th at 9:15 pm. The pipe is an 8-inch diameter black HDPE plastic composition with a spool section joined to the pipe penetrations at the manhole wall by two flange coupling adapters (Photo 3-34). The pipe surface has a thin coating of mud and mortar debris. The metal flanges have a thicker coating of debris. Underneath the surface debris the flange rings are moderately corroded and the stainless steel nuts and bolts are not corroded (Photo 3-35). The pipe is lying on, or near to, the gravelly bottom of the manhole. The lower portion of the flange couplings are buried in the gravelly fill. The fill is moist although there is no standing water in the manhole.

Photo 3-34. 8-inch Diameter Black HDPE Brickyard Booster Force Main.

Photo 3-35. Flange Coupling on HDPE Force Main Showing Exposed Stainless Steel Nut.

The concrete in the manhole is in good condition. It is hard and mortar-coated with no exposed or protruding aggregate (Photo 3-36). Concrete condition throughout the pressure manhole is rated a VANDA Level 1 per Table 2-1. . A small slit-shaped hole approximately 1-1/2 inches deep was seen in the wall near the bottom of the manhole, apparently an original construction defect (Photo 3-37). It is merely a curiosity and has had no effect on the functionality of the manhole, outside of possible source of infiltration. There was no evidence of active infiltration but the drought conditions may have contributed.

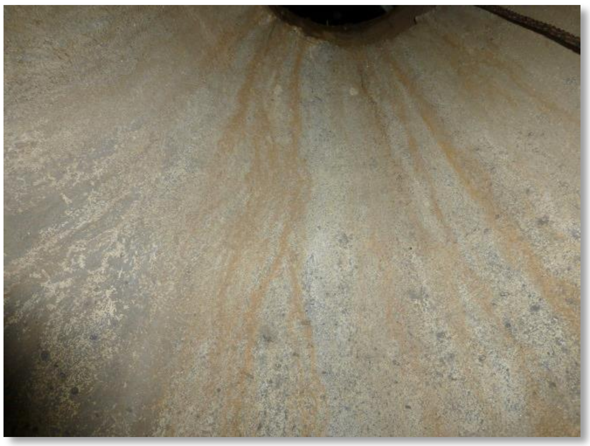


Photo 3-36. 8-inch Diameter Black HDPE Brickyard Booster Force Main.

Photo 3-37. Small Slit-Shaped Hole in Manhole Wall 1-1/2-inches Deep.

3.4.1.4 Brickyard Booster Discharge Manhole

The Brickyard Booster discharge manhole is shared by the Brickyard Cove & Brickyard Booster force main system and the Port force main system. This manhole is also called the “Port discharge manhole” in Section 3.5.1.1.

The Port Force Main Discharge Manhole is located in the Point Potrero Marine Terminal Automotive Distribution Center parking lot at the Port of Richmond. An 8-inch diameter force main from the Brickyard Booster PS discharges from the northwest, two 8-inch diameter lines enter from the southwest Port PS direction, a 6-inch diameter gravity line feeds into the manhole from the southeast, and a 12-inch diameter RCP gravity effluent line discharges to the northeast.

In order to identify which pipe was associated with the Port force main system, the pumps were selectively turned on and off. Both of the southwest inlets were active when the Port pump turned on, but there was more flow increase on the west-most southwest inlet. Additionally the west-most southwest inlet had lower flow when the Port PS and Brickyard Booster PS pumps were off, so it was speculated that was the Port force main. Although the east-most southwest inlet had the most flow, it was always flowing, so it was apparently not the force main, but perhaps a line from a car wash station in the automobile warehouses. The 8-inch inlet from the northwest discharged when the Brickyard Booster pumps were activated, so it was speculated that was the Brickyard Booster FM.

The east-most southwest inlet is a black HDPE composition. The Port and Brickyard Booster FM compositions were not positively confirmed, but appeared to be concrete pipes. The 6-inch diameter gravity pipe from the southeast is an apparent concrete composition. The 12-inch diameter effluent line on the northeast quadrant is a reinforced concrete pipe (RCP).

The manhole is approximately 5 feet deep and unlined concrete. Coarse concrete aggregate is exposed and protruding in the manhole bench around the influent force mains and gravity inlets (Photo 3-38 to Photo 3-40). Grease buildup was observed in the black HDPE inlet pipe, and in the concrete inlets and effluent pipe (Photo 3-41 and Photo 3-42). Thin crown peel wear is occurring in the concrete inlets and effluent pipe. Mortar coating is peeling off the manhole riser surface and the corroded manhole ring surface is exfoliating (Photo 3-43). The deep aggregate embayment and mortar peeling in the upper manhole are a VANDA Level 2 Concrete Condition per Table 2-1 rating criteria. The exfoliation on the manhole ring is a VANDA Level 2 Condition per Table 2-2 guidelines.

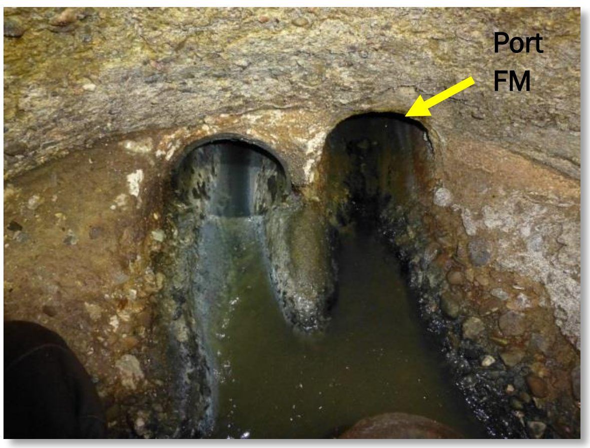


Photo 3-38. 8-inch Diameter Inlets on Southwest Side of Discharge Manhole.

Photo 3-39. 8-inch Diameter Concrete Pipe from the Brickyard Booster PS.

Photo 3-40. 6-inch Diameter Concrete Gravity Inlet on Southeast Side of Manhole

Photo 3-41. Grease Buildup in Invert of the 8-inch Black HDPE Inlet Pipe

Photo 3-42. Grease Deposit in Springline Area of Concrete Pipe. Crown is Peeling

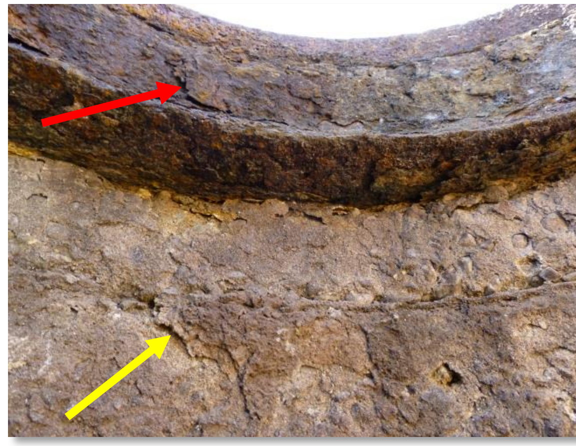


Photo 3-43. Mortar Peeling Off Manhole Riser Surface (yellow arrow), and Metal Exfoliating on Manhole Ring (red arrow)

3.4.2 Sulfide Test Results

Grab samples of wastewater were collected from the Brickyard Booster wet well using a bucket and tested on-site for total and dissolved sulfide using a LaMotte Drop Count Sulfide Test Kit. There was no detectable concentration of total sulfide or dissolved sulfide.

The 4-gas meters were monitoring the H_2S concentrations in the Brickyard Cove discharge manhole, Brickyard Booster wet well, Brickyard Booster pressure manhole, and Brickyard Booster discharge manhole. The H_2S concentration was 1 ppm in the Brickyard Booster discharge manhole and undetectable in the other manholes and wet well.

Additionally the Brickyard Cove pump station is one of eight H_2S monitoring stations that the City implemented in the Point Richmond area. The monitoring system can be accessed by the public online at https://www.mysmartcover.com/h2s/map.php. The H_2S monitors are set to alert when concentrations of 30 parts-per-billion (ppb) are detected by a monitor. At the Brickyard Cove PS, no alerts were documented in 2013-2015 and a maximum of 16ppb was recorded in 2015 (See Figure B- 2).

3.4.3 Concrete Test Results

V&A conducted concrete sounding tests, penetration tests, and surface pH measurements in the Brickyard Booster discharge manhole. The bench had exposed aggregate and produced hollow sounds in the sounding test. The lower cone had some exposed aggregate and was soft and chalky. The upper cone had no exposed aggregate, but was still soft. The penetration test revealed that the soft and chalky concrete continued for 1 inch, which indicates significant loss of concrete surface hardness. The concrete surface pH was 3, which is severely corrosive to any reinforcing steel in the concrete. These results indicate the concrete is in poor condition.

V&A also conducted concrete sounding tests, penetration tests, and surface pH measurements in the Brickyard Booster pressure manhole. The sounding test indicated good, hard concrete without subsurface voids. Negligible concrete was removed when doing the penetration test because the surface was sound, hard material. There was a 1.5-inch deep hole in the concrete observed where mortar would have been used to repair a pipe penetration. The surface pH was 8, which is moderately corrosive to reinforcing steel in concrete. Overall, these results indicate the concrete is currently in good condition, though it is progressing towards moderate condition.

V&A conducted concrete sounding tests, penetration tests, and surface pH measurements in the Brickyard Cove discharge manhole. The concrete was sounded hard. There was very fine aggregate used, which is unusual for poured concrete. About 1/16 inches of concrete was removed in the penetration test on both the cone and barrel, which indicates minor loss of surface hardness. The surface pH was 5 to 6 in the lower cone and 4 in the barrel, all of which are severely corrosive to reinforcing steel in concrete. These results indicate that the concrete surface is exposed to severe corrosive conditions.

3.4.4 CCTV

The CCTV that began at the Brickyard Cove discharge manhole was successful. The Brickyard Cove force main was identified as plastic; probably PVC given the blue-green color. The force main looked relatively new and was in good condition. A joint was approximately 27 feet from the manhole and was in good condition (Photo 3-44). At approximately 39 feet, there was a 45 degree bend that prohibited further advancement. This alignment was previously not documented nor understood well, and the Brickyard Cove discharge manhole location was previously unknown.

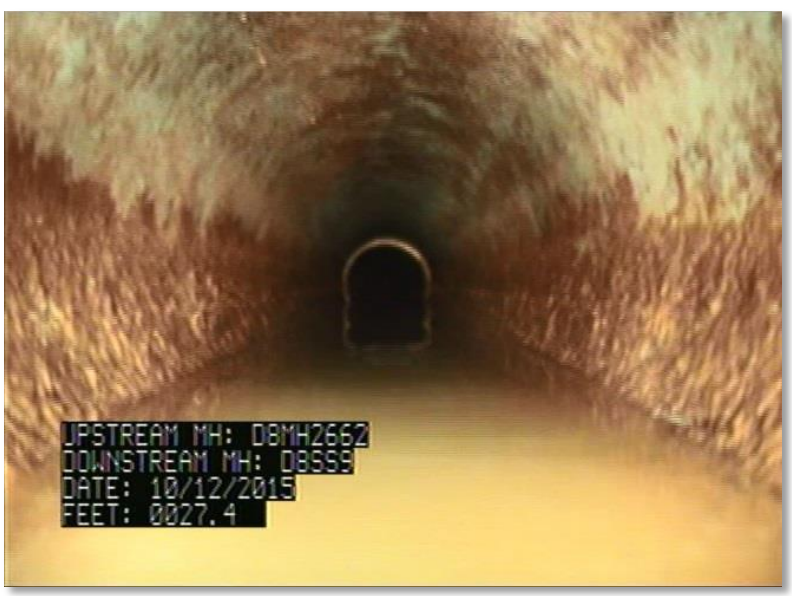


Photo 3-44. CCTV of Brickyard Cove Force Main Showing Joint at ~27 feet from Discharge Manhole

The CCTV that began at the Brickyard Booster wet well actually examined a gravity line. Through this CCTV work, it was discovered that the Brickyard Booster force main does not discharge directly into the wet well, but instead into this gravity line. The gravity line began as PVC that was in good condition. After approximately 171 feet, the pipe transitioned from PVC to clay. At approximately 301 feet, there was a manhole with daylight, which is indicative of a gravity line, not a force main. There was a clay joint at approximately 340 feet, a crack at 358 feet, a sealed crack and joint at 396 feet, and another manhole with daylight was at 420 feet. At 427 feet, there were cobwebs, which indicate there is low flow through that pipe section. The pump was turned on while the CCTV sat at 430 feet, and no increase in flow was noted, indicating that the CCTV was sitting upstream of the force main discharge point. See Figure A-2 of the alignment found in the field.

The CCTV that began at the Brickyard Booster discharge manhole had some challenges. Roots, worms and debris were encountered about 7 feet into the pipe as shown in Photo 3-45 and Photo 3-46, which indicates the force main would benefit from more regular cleaning. The pipe was cleaned to allow further progression of the CCTV and better viewing of the pipe surface. Photo 3-47 shows a possible fracture at the pipe-crown. This was a similar location to where roots were observed prior to cleaning. There was a bend about 8 feet upstream of the discharge manhole that inhibited further progress.

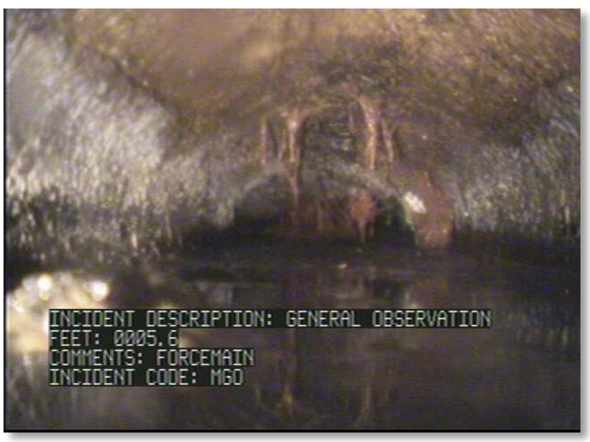


Photo 3-45. CCTV of Brickyard Booster Force Main showing Roots before Cleaning

Photo 3-46. CCTV of Brickyard Booster Force Main showing Slime and Dirt before Cleaning

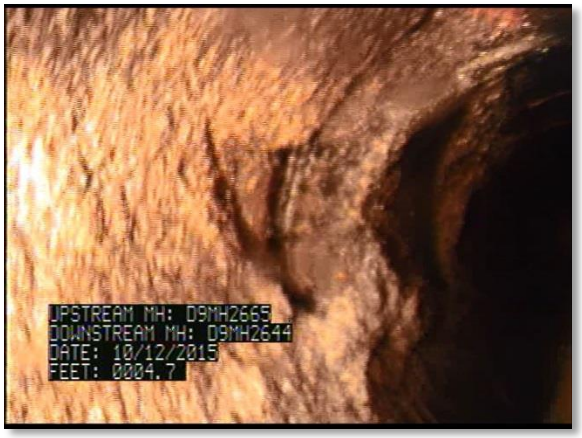


Photo 3-47. CCTV of Brickyard Booster FM after Cleaning

3.5 Force Main System No. 5 – Port

The Port force main system was accessed at a pressure manhole on October 12th, 2015 at 9:30 am, discharge manhole on October 12th, 2015 at 11:00 am, and wet well on October 12th, 2015 at 9:45 am. The discharge manhole is shared with the Brickyard Booster force main covered in Section 3.4. The manholes and wet well are considered confined spaces, and appropriate safety procedures were followed. The location of the manholes and wet well are shown in Figure 3-8.

Figure 3-8. Port Manhole and Pump Station Locations

3.5.1 Visual Assessment

3.5.1.1 Port Discharge Manhole

The Port discharge manhole is shared by the Brickyard Cove & Brickyard Booster force main system and the Port force main system. This is the same manhole as the "Brickyard Booster discharge manhole" in Section 0. Refer to that section for the visual assessment results.

3.5.1.2 Port Pressure Manhole

The Port Force Main pressure manhole that was assessed on October 8th is located one manhole upstream of the discharge manhole. The pipes are metallic, most likely cast iron, and are 4-inches in diameter. One pipe is cut off and the other is offset by two 45-degree elbows (Photo 3-48). The metal pipe surfaces are strongly corroded (Photo 3-49) and rated a VANDA Level 2 to Level 3 per guidelines discussed in Table 2-2. The manhole is partially full of water (approximately 2 feet deep) and the bottom is covered with 2 to 10 inches of sediment. The mean water level in the manhole is approximately two-thirds up from the bottom. Concrete below the mean water level is hard when impacted with a chipping hammer. Above the water line the concrete surface is softer, but is still solid. The concrete is rated a VANDA Level 1 to Level 2 Condition based on Table 2-1 physical criteria (Photo 3-50).

Photo 3-48. Plan View into Port Pressure MH with One Pipe Severed and Abandoned

Photo 3-49. Corroded Surfaces of 4-inch Diameter Metal Force Main Pipes

Photo 3-50. Port Force Main Pressure Manhole Concrete Surface.

3.5.2 Sulfide Test Results

Grab samples of wastewater were collected from the Port wet well using a bucket and tested on-site for total and dissolved sulfide using a LaMotte Drop Count Sulfide Test Kit. There was 1.1 ppm of total sulfide and 0.5 ppm of dissolved sulfide measured. These are considered low to negligible concentrations that could result in low odor issues.

The 4-gas meters were monitoring the H_2S concentrations in the Port pressure manhole and Port discharge manhole. The H_2S concentration was undetectable at the Port pressure manhole and 1 ppm at the Port discharge manhole.

3.5.3 Concrete Test Results

V&A conducted concrete sounding tests, penetration tests, and surface pH measurements in the Port pressure manhole. The mean water line was approximately two thirds of the way up the manhole. The sounding and penetration tests revealed hard concrete below the water line and soft concrete above the water line. There was approximately 1/8 inches of penetration above the water line, which indicates minor to moderate loss in concrete surface hardness. The surface pH was 8, which is moderately corrosive to reinforcing steel in concrete. These results indicate the concrete is in good condition below the water line and moderate condition above the water line.

The Port discharge manhole is the same manhole as the “Brickyard Booster discharge manhole” in Section 3.4.3. Refer to Section 3.4.3 for the concrete testing results.

3.5.4 CCTV

The CCTV that began at the Port discharge manhole was challenging. The Port force main appears to be in poor condition. The CCTV from the Port discharge manhole showed lots of grease in the Port force main (Photo 3-51). About 16 feet down the line, the pipe was halfway full of water. After approximately 24 feet, there was a partial cave-in, as shown in Photo 3-52.

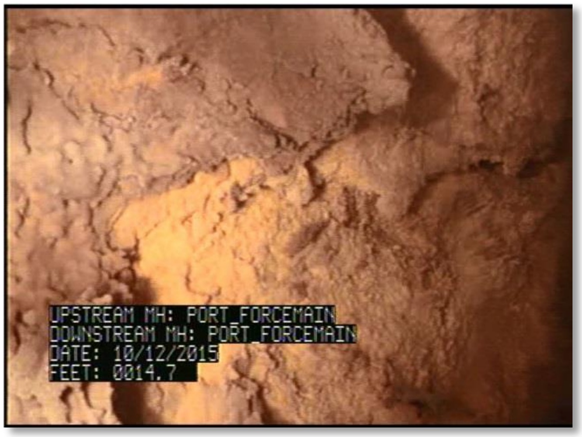


Photo 3-51. Port Force Main- typical thick layer of FOG at pipe crown

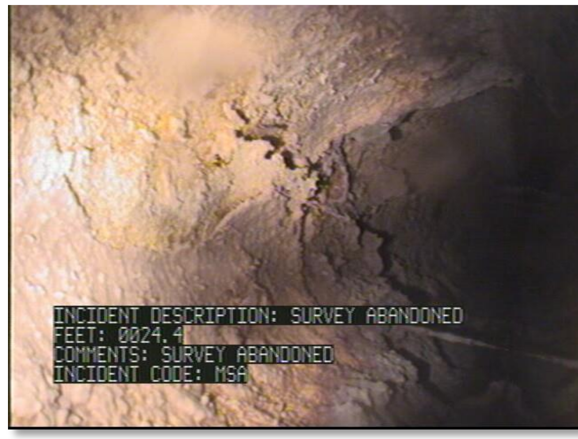


Photo 3-52. Port Force Main- partial cave-in at ~24 feet from discharge MH

4.0 CONCLUSIONS

The following section and Table 4-1 summarizes the findings from the field condition assessment of the five force main systems:

4.1 Marina Bay Parkway FM

The Marina Bay Parkway force main was generally in good condition. This could be attributed to the pipe material being black plastic (possibly HDPE) and no detectible sulfide being present. However, there was continuous sag along the line and the force main could not be fully evaluated.

Notably, the line regularly operates under high flow conditions and there is a 90-degree bend at the discharge manhole and further downstream. The combination of these factors can easily create blockage, sanitary sewer overflows (SSO), and fast concrete deterioration in the manholes.

Since the discharge manhole is new as of this year, it is still generally in good condition with a negligibly corrosive surface pH of 12, good sounding, no penetration and good seals to the pipe connections. However due to the very turbulent conditions, some of the concrete top coat at the bend was already spalling.

4.2 Ferry Point / Keller Beach FM

The Ferry Point force main condition is generally still unknown due to a lack of access points. The Ferry Point force main may have issues considering the currently moderate but previously high sulfide levels, and discharge manhole condition.

The Ferry Point/Keller Beach discharge manhole is in poor condition with very soft concrete (too soft for sounding, penetration, or pH tests), highly corroded manhole cover and failed manhole liner. Only the pipe channel was generally in a good condition. The force main condition was difficult to assess from the discharge manhole as the flow was splashing all over and the force main has multiple vertical 90 degree bends immediately upstream.

The Keller Beach force main is in a relatively good condition, considering the low sulfide level and exposure to the coastal air and moisture. The soil in the exposed force main area was mildly corrosive to buried iron. There was a low variation of wall thickness and no wall thickness loss with the assumed nominal thickness of 0.41 inches.

4.3 Canyon Estates FM

The Canyon Estates force main system was generally in a good condition. No issues were found in the CCTV survey or at the discharge manhole. This could be attributed to the pipe material being plastic (PVC) and no detectible sulfide being present.

The discharge manhole concrete was in poor condition. The concrete was deteriorated and soft, with medium to coarse aggregate exposed, 0.5 inch penetration and a severely corrosive surface pH of 2 to 3. Only the pipe channel was in good condition; a hard concrete with no exposed aggregate.

4.4 Brickyard Cove / Brickyard Booster FM

The sulfide levels for this force main system were mostly undetectable, except for 1ppm of H_2S at the Brickyard Booster discharge manhole.

The Brickyard Cove force main is generally in a good condition for the section surveyed. This could be attributed to the pipe material being plastic (probably PVC) and the section surveyed was probably only the more recent 2002 installation. The discharge manhole also seemed relatively new and in good condition with hard concrete and 1/16-inch penetration. Surprisingly the surface pH was a severely corrosive 4 to 6.

The Brickyard Booster force main's external surface was in moderate condition at the pressure manhole and the force main's interior surface was in a very poor condition at the discharge manhole. The force main was plastic at the pressure manhole with two moderately corroded couplers. The pressure manhole concrete was hard with negligible penetration and a moderately corrosive pH of 8. At the discharge manhole, the force main had a lot of roots, debris, uneven surface that can develop into a blockage or broken pipe. The concrete was in poor condition; the discharge manhole bench and lower cone were soft and chalky with exposed aggregate, penetration of 1 inch and a severely corrosive surface pH of 3.

4.5 Port FM

The Port force main system has a variety of material and notable characteristics but was generally in a poor condition. The force main was a metallic material at the pressure manhole and was severely corroded. At the discharge manhole, the force main had transitioned to probably a reinforced concrete pipe and was in a slightly better condition but still had lots of grease and a partial cave-in.

The discharge manhole is the same as the Brickyard Booster force main discharge manhole described above and was in a poor condition. The pressure manhole concrete was in a good condition below the water line and moderate condition above the water line. The sulfide levels were at low to negligible concentrations for both manholes and the wet well.

Table 4-1. Summary of Force Main Condition Assessment Information

FM	FM Section	Size (in.)	Material	CCTV results	MH Concrete Condition	Sulfide (ppm)	Notes
1	Marina Bay	9.375 vert., 9.5 horiz.	Plastic (probably HDPE)	Mostly under water	Good, pH 12, top coat spalling	Non-detectable, total 0; dissolved 0	Bends and high flow, easy for surcharge
2a	Ferry Pt	8 [7]	Plastic (probably PVC) [7]	---	Poor, too soft for pH test. Pipe channel good	Moderate, total 7.1; dissolved 6.4	At wet well thick top FOG layer
2b	Keller Beach	8	CIP	---	See 2a for discharge MH	Low, Total 1.6; dissolved 1.2	BEM and UT 0.37-0.41" no wall thickness loss, no pitting
3	Canyon Estates PS 1	6	PVC	Good condition	Poor, pH 2, bench soft and chalky, ½" penetration. Pipe channel good	Non-detectable, Total 0; dissolved 0	--
4a	Brickyard Cove	8	Plastic (probably PVC)	Good condition, incl. for joint	Good, hard concrete, 1/16" penetration. Surprisingly lower cone pH 5-6; barrel pH 4.	Non-detectable, Total 0; dissolved 0	Discharge at MH before wet well
4b	Brickyard Booster	8	Plastic (probably HDPE)	Roots	pH 6-7; chalky surface, hard underneath, no penetration[8]	Non-detectable, Total 0; dissolved 0	--
5	Port	8, 4[9]	Possibly RCP; Metallic[9]	Grease, partial cave-in	pH 3; bench exposed aggregate, hollow soundings[10]	Low to negligible, Total 1.1; dissolved 0.5	Severely corroded at pressure MH, strong odor

[7] At discharge manhole, after combining with Keller Beach Force Main.
[8] At Brickyard Booster PS wet well. For pressure manhole: pH 8, solid concrete, no penetration. For discharge manhole, see Port.
[9] At discharge manhole and pressure manhole respectively.
[10] At discharge manhole. For pressure manhole: pH 8, hard concrete below mean water line (M.W.L.) of 2/3 up MH, softer concrete above M.W.L, with 1/8" penetration.

5.0 RECOMMENDATIONS

Based on the condition assessment findings, V&A presents the City with the following recommendations to repair defects and protect the force main or associated structure and appurtenances from further corrosion damage:

A prioritization of the recommendations is listed below. The prioritization considers the condition found and ease of recommended actions. The prioritization also maintains the focus on the force mains and recalls that the overall program was to systematically reduce odor complaints and sanitary sewer overflows. To that effect, the manhole and appurtenances recommendations have been highlighted in blue and were only prioritized if the condition were poor; possibly affecting the system performance or if rehabilitation will greatly enhance its useful life. Veolia and the City are recommended to group activities together as practical.

1) Replace the severely corroded metallic section of the Port FM.
2) Perform regular/ more frequent cleaning of the Port FM; the FM was a reinforced concrete pipe with grease and partial cave-in at the discharge manhole.
3) Excavation of Ferry Point FM to gain more condition information considering lack of access, moderate sulfide levels and discharge manhole's poor condition.
4) Rehabilitate the Ferry Point / Keller Beach FM discharge manhole
5) Regular/more frequent cleaning of the Brickyard Booster FM. The Brickyard Booster FM's external surface was in a moderate condition at the pressure manhole and the FM's interior surface was in a very poor condition at the discharge manhole.
6) Consider rehabilitation of the Brickyard Booster FM/Port FM discharge manhole.
7) More condition assessments and a risk assessment for the approximately 10,000 linear feet of additional force mains in the City not assessed in this study.
8) Repair the T-Lock joints in the Brickyard Booster PS wet well liner.
9) Monitor Marina Bay Parkway discharge manhole location for problems arising from turbulent flow.
10) Remove and reapply concrete top coat that is spalling in the Marina Bay Parkway FM discharge manhole.
11) Consider providing more protection and slope stabilization for the Keller Beach FM section on the hillside. The FM was in good condition with no apparent wall thickness loss and the soil was mildly corrosive.

12) Consider rehabilitation of the Canyon Estates FM discharge manhole. The FM itself was in good condition, no issues found except that the discharge manhole concrete was in poor condition.

13) Consider installing an odor control system at the Keller Beach pump station. The Keller Beach FM had low sulfide levels, but the Keller Beach/ Ferry Point FM discharge manhole was in poor condition within a short time since rehabilitation.

14) Seal open joints and spall cavity with a repair mortar in the Marina Bay Parkway FM discharge manhole chimney.

The following gives further details on the recommendations under each force main system.

5.1 Marina Bay Parkway FM:

1) The open joints and the triangular spall cavity in the manhole chimney should be sealed with a repair mortar.
    - The existing concrete should be prepared by high pressure water jetting at 20,000 psi and abrasive blasting to remove deteriorated concrete.
    - Then the concrete substrate should be resurfaced up to the approximate original surface by spray-applying or hand-applying a repair mortar such as Raven Lining Systems' Raven 755, Tnemec Series 217 Mortarcrete or approved equal. Note that if the repair mortar is spray-applied, the repair surface should be hand-finished to a surface suitable for coating.
2) At the discharge manhole, the concrete top coat is spalling at the bend. V&A recommends reapplying the top coat.
    - Coating Option 1: For lining manholes in live flow, calcium aluminates are corrosion resistant repair mortars that can withstand corrosion caused by the acid attack found in wastewater environments. Calcium aluminate application requires low pressure wet spray equipment. However, hand troweling is required after the material is applied to the substrate to achieve a smooth finish. Advantages include a shorter turnaround time to return the structure to service, and the application does not require as stringent of a coating inspection as compared to polymer-modified spray applied coatings. Products such as Kerneos Sewpercoat PG (see Appendix C for the product datasheet) or Raven 705CA are commonly used. Additional epoxy topcoats are not needed but are allowed for Raven 705CA, and not allowed for Sewpercoat PG. The number of experienced calcium aluminate applicators is limited as compared to the other rehabilitation options. A unit cost of $30 per square foot is estimated for the surface preparation and application of this coating.
    - Coating Option 2: Epoxy novolac coatings such as Raven Lining Systems' Raven 405, Sauereisen Sewergard 210S, or an approved equal offer excellent resistance to abrasion, chemicals and sulfuric acid. However these coatings require dry conditions; a

temporary bypass of the flow for the Marina Bay Parkway FM discharge manhole conditions. A unit cost of $40 per square foot is estimated for the surface preparation and application of this coating.

- The long term problem of turbulent flow is harder to solve. The 90 degree bends are new; perhaps the approval process can be reviewed to prevent such alignment in the future.

3) While negligible sulfide levels were measured, there is still a potential for odor emissions and spikes of hydrogen sulfide due to turbulence and the resulting stripping of H_2S from the wastewater. V&A recommends monitoring this location to avoid odor complaints and SSOs.

5.2 Ferry Point/ Keller Beach FM:

1) No access is apparent for the Ferry Point force main and the condition is still unknown. Additionally there was a lack of drawings and high sulfide levels were found at the wet well and discharge manhole. Although excavation was avoided due to high costs, excavation should be reconsidered for this one force main.
2) The Ferry Point and Keller Beach force mains manifold together just north of the Keller Beach Pump station. This was confirmed when wastewater samples for the 2013 study were taken at the discharge manhole while running only one pump station at a time. However the exact details of this union are unknown and the joint is potentially a highly vulnerable location. If the excavation for the Ferry Point force main mentioned above was strategically placed, the joint can also be assessed.
3) In addition to covering up the Keller Beach force main exposed section, consider also adding a layer of dirt to the entire length of pipe on the steep slope and slope stabilization methods such as re-planting native vegetation, adding erosion control geo-textile mats and reshaping drainage channels away from the force main.
4) Rehabilitation is needed for the discharge manhole with an emphasis on long-term solutions.
5) V&A recommends installing an odor control system at the Keller Beach pump station considering the success of the chemical feed system at Ferry Point pump station, the discharge manhole condition and average hydrogen sulfide concentrations above 5 ppm still present conditions that may lead to biogenic corrosion at a rate capable of impacting the useful life of unprotected infrastructure.

5.3 Canyon Estates FM:

1) The force main appears to be in good condition, no recommendation apart from continual maintenance and observation.
2) The discharge manhole concrete is in poor condition; consider rehabilitation by coating as detailed in Section 5.1. Since the pipe channel itself was in good condition and the flow

stayed in the pipe channel (unlike the Marina Bay Parkways discharge manhole), either coating systems can be used without bypass.

5.4 Brickyard Cove/Brickyard Booster FM:

1) Brickyard Cove FM appears to be in good condition, no recommendation apart from continual maintenance and observation.
2) At the Brickyard Booster PS wet well, the T-Lock horizontal joints are failing and the wet well liner is getting undermined by moisture. V&A recommends repairing the T-Lock joints with new weld strips and repair patches.
3) Brickyard Booster FM can benefit from regular and more frequent cleaning. The cleaning done during this assessment for CCTV was quite effective at removing the roots and dirt.
4) The discharge manhole concrete is in poor condition; consider rehabilitation by coating as detailed in Section 5.1. Since the pipe channel itself was in good condition and the flow stayed in the pipe channel (unlike the Marina Bay Parkways discharge manhole), either coating systems can be used without bypass.

5.5 Port FM:

1) Replace the severely corroded metallic section. The extent of the metallic section and where it transitions to RCP or other materials is unknown. The total length of the Port FM is up to 1,200 feet.
2) Port FM can benefit from regular and more frequent cleaning. The FOG build up can potentially cause blockage and odor issues. The car wash line and lateral near the PS seemed not to be on Veolia's or the City's records. Perhaps laterals and FOG potential can be better recorded or regulated.

5.6 Other:

1) These five force mains were chosen by Veolia and the City for condition assessment. As shown in Figure 1-1, there is approximately 10,000 linear feet of additional force mains in the City not assessed in this study. More condition assessment is needed to gather conclusions regarding the force main system. A desk-top risk assessment can then be done to extend data from the limited access points to the force main length and system.

APPENDIX A. FIELD NOTES

Table A-1. Summary of Work Schedule

Method	Force Mains						
	1	2		3	4		5
	Marina Bay	a. Ferry Point	b. Keller Beach	Canyon Estates PS1	a. Brickyard Cove[1]	b. Brickyard Booster	Port
Internal Pipe Assessment							
Discharge Manhole Assessment (1 per location)	Day 1	Night 1	Night 1	Day 2	Night 1	Day 3	Day 3
Pressure Manhole Assessment (1 per location)						Night 1	Day 3
Sulfide Test	Day 1	Day 3	Day 1	Day 2	Day 2	Day 2	Day 3
Wet Well Assessment						Day 2 [1]	
CCTV	Day 1			Day 2	Day 3	Day 3	Day 3
External Pipe Assessment							
External Pipe Assessment (Visual/hands-on, UT, BEM, Soil)			Day 1				
Lmic microphone			Day 3				

[1] Brickyard Cove Force Main discharges at a manhole instead of the Brickyard Booster Wet Well as previously assumed. CCTV and confined space entry were performed at the Brickyard Booster Wet Well and at the Brickyard Cove discharge manhole.

Monday October 5: Day 1 of field work.

- Marina Bay Parkway FM Discharge MH: CCTV, CSE condition assessment, sulfide test
- Exposed Keller Beach FM: exterior condition assessment.
- Keller Beach PS: sulfide test

Thursday October 8: Day 2 of field work.

- Brickyard Booster PS Wet well: CCTV, CSE condition assessment, sulfide test
- Canyon Estates FM PS3: sulfide test
- Canyon Estates FM Discharge MH: CCTV and CSE condition assessment

Monday October 12: Day 3 of field work.

- Port PS: sulfide test
- Port FM & Brickyard Booster FM Discharge MH: CCTV and CSE condition assessment.

- Port FM pressure MH: CSE condition assessment
- Seacliff Brickyard FM Discharge MH: Veolia and V&A investigated the Seacliff Brickyard FM again as suspect the FM did not connect to the Brickyard Booster Wet well. Found the discharge MH, CCTVed.
- Ferry Point PS: sulfide test.
- Keller Beach FM: investigated again as found another parallel pipe. Confirmed the exposed pipe of which condition assessment was performed is indeed the FM using Lmic microphone.

Tuesday October 13: Night 1 of field work.

- Brickyard Booster FM Pressure MH: CSE condition assessment
- Seacliff Brickyard FM Discharge MH: CSE condition assessment
- Keller Beach FM & Ferry Point FM Discharge MH: CSE condition assessment

Important Project Issues/ Findings:

- Marina Bay Parkway FM had a sag from the discharge MH to the PS, CCTV often under water
- The Seacliff Brickyard FM discharges to a gravity line that then connects to the Brickyard Booster PS Wet well. Found the discharge MH and added CSE condition assessment to scope.
- From the Port FM and Brickyard Booster FM discharge MH, quickly encountered non-navigable bends, couldn't CCTV very far. There was also a lot of grease and roots- Veolia performed cleaning.
- Confirmed the exposed north pipe near Keller Beach is the FM. Do not know what the other pipe is for, may be abandoned.
- Discussed with Wayne, the Keller Beach FM & Ferry Point FM immediately does a 90 degree bend up at the Discharge MH, cannot be CCTVed.
- The Keller Beach FM & Ferry Point FM Discharge MH is in poor condition. The MH cover rim is highly corroded, very difficult to open, the MH liner has completely failed and the concrete is very soft.

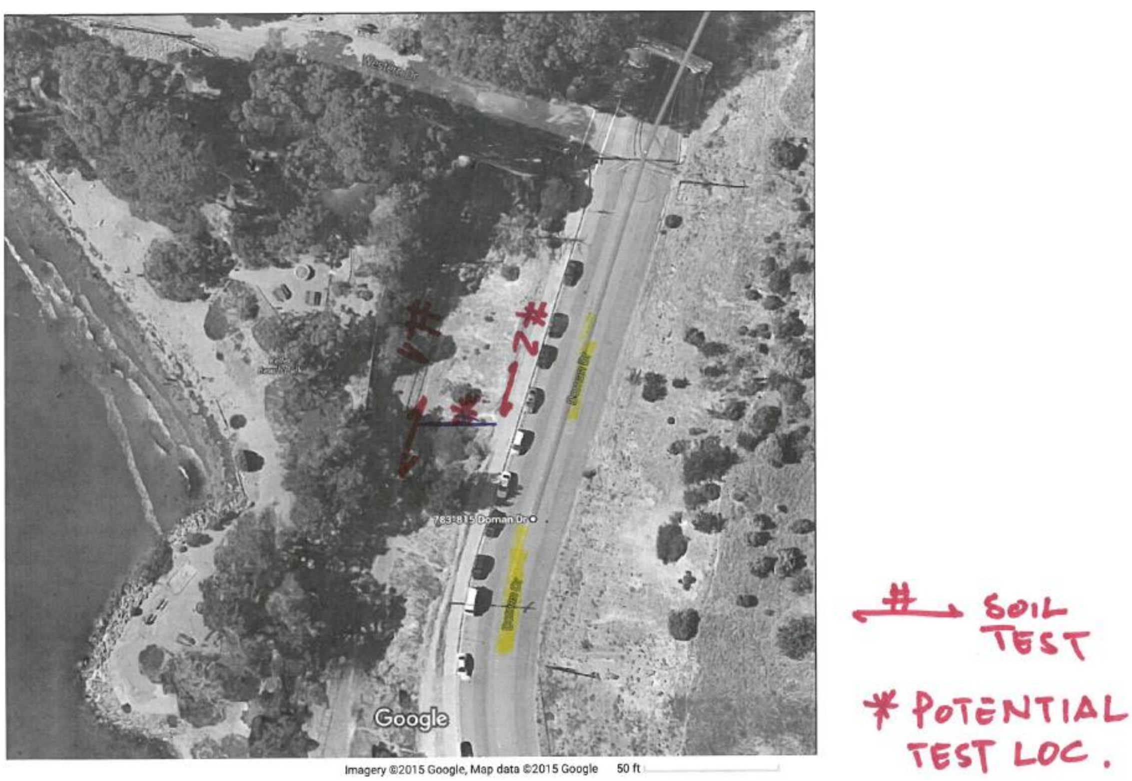


Figure A-1. Soil Test Location at Keller Beach Force Main

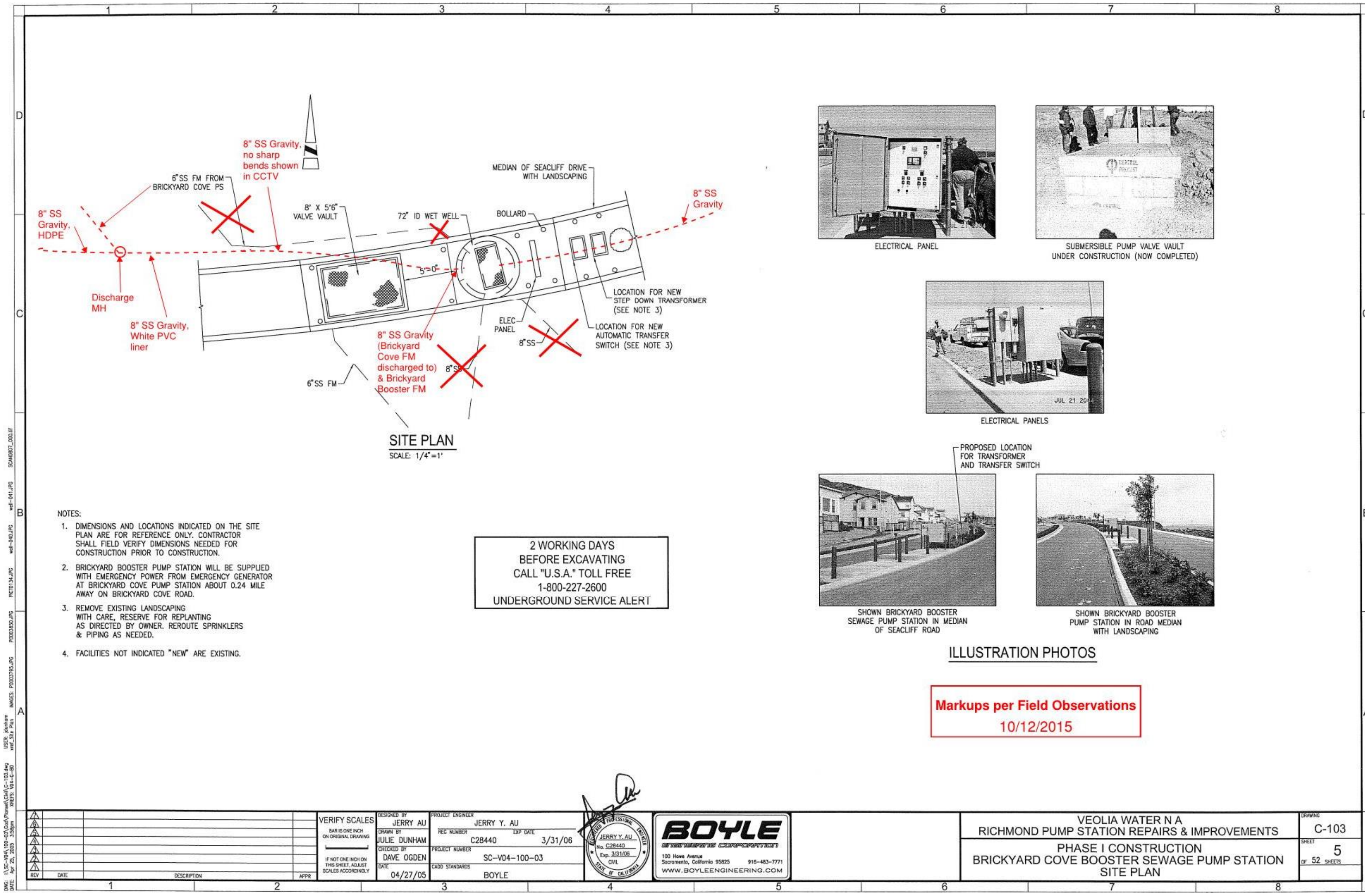


Figure A-2. Brickyard Booster Pump Station Site Plan with Field Markups

BEM Pipe Scan - NDT FIELD NOTES

JOB AND SITE DETAILS

Site Reference: Keller Beach Exposed Force Main

Site Address: 783 Dornan Dr., Richmond, CA

Inspection Date: 5 Oct 2015

Distance from landmarks : ~10ft downhill from Dornan Dr. ~20 ft uphill from railroad tracks. *(to accurately re-locate pipe section)*

GPS co-ordinates: Approximately 37.920685°, -122.385977°

Is the pipe buried: Mostly; approximately 3ft exposed before test 10:00-2:00
Approximately 7ft exposed all-around for testing

Ground Surface Use: Steep hillside with ice plant (Aizoaceae)

Ground Surface Finish: N/A

Traffic Disruption During Excavation: No

COMMENTS:

INSPECTION OF INTERNAL / EXTERNAL LINING/COATING

Is Lining/Coating Present: No

Antenna Liftoff During Scanning: None

State of Surface During Inspection: mild surface rust

Number of visible Pits Per 4 Inch^2: no real pitting

Minimum / Maximum Pit Diameter: N/A

Minimum / Maximum Pit Depth: N/A

COMMENTS:

PIPE DETAILS

Pipe Material: Cast iron   Conveyed Product: Pumped wastewater

Nominal Wall Thickness (if known): UT data: top 12:00- 0.410", 3:00 – 0.369", 6:00 – 0.410, 9:00 – 0.370

Joint Details (if any): None

Internal Diameter from Plans: 8in

Measured External Circumference: 28.5in (thus external diameter 9.0718in)

Installation Date: Unknown, before 1996

Internal Protection: None

Bedding/Surroundings: Crumbly rock

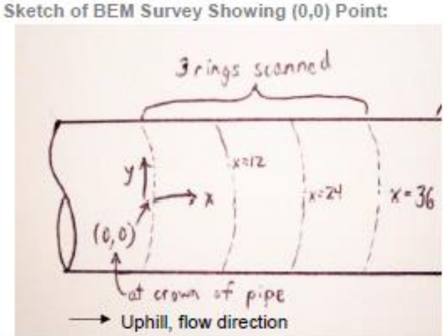
Depth of Cover (Ground Level to Crown of Pipe): At test location 0-6 inches, probably less than 12 inches along hillside

COMMENTS: Pipe supported by concrete thrust block 6ft uphill. Another 8in CIP 8ft south- details to be determined

Sketch of Site Locality:

N

Sketch of BEM Survey Showing (0,0) Point:



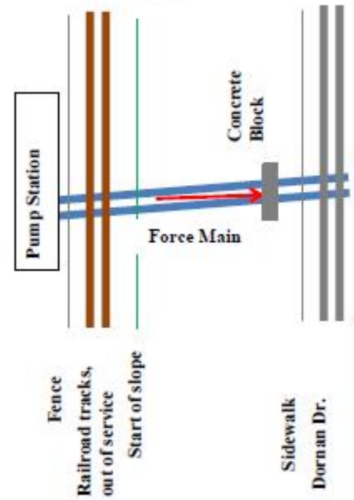
N

Site Photo:

See attached photos P1020026, P1020035, P1020038, P1020039.

Additional Photos / Notes:

- Scanning Process
- Corrosion
- Joints



TITLE: City of Richmond Force Main Condition Assessment

CLIENT: Veolia Water Technologies, North America.

PROJECT No.:	PREPARED BY:	DATE:
14-0338	NK	6 Oct 2015

BEM Pipe Scan NDT FIELD NOTES

Figure A-3. BEM Pipe Scan Field Notes

• Table A-2. Field Notes

Project No.	14-0338
Project	Richmond Force Main Condition Assessment
Client	Veolia Water, North America

Day 1

Force Main:	**Marina Bay Parkway**		
	Discharge Manhole		
Date, time of arrival:	10/5/15 9:20am		
V&A personnel:	Nicole K., Oliver P.		
Condition Assessment:			
pipe material:	force main:	Black plastic, HDPE	
	gravity outlet:	White plastic, HDPE	
pipe diameter:	FM interior, vert:	9.375	inches
	FM interior, horiz:	9.5	inches
	gravity outlet:	14.25	inches
Concrete pH		12	
Photos:		Y	
Total Sulfide:	10:40am	0	ppm
Dissolved Sulfide:	10:40am	0	ppm
Notes:	4"x3" triangular defect on MH wall above FM		
	good, well-sealed MH to pipe connections.		
	concrete top coat spalling at bend, 8-9inch diameter, recommend knock-out and reapply.		
	90 degree bend creates a lot of turbulence.		
	Also a lot of flow when pump turned on. If there is any blockage, will create an immediate surcharge.		
CCTV:	10inch setup, multiple trial entries and cleaning		
6ft	start encountering water		
22 ft	pipe joint		
75 ft	camera under water		
340ft	till end of CCTV		

Force Main:	**Keller Beach**		
	Exposed Section		
Date, time of arrival:	10/5/2015 13:00		
V&A personnel:	Nicole K., Oliver P.		
Condition Assessment:			
pipe material:	force main:	CIP	
pipe wall thickness:		see UT 0.369-0.410 & BEM	
pipe diameter:	FM exterior	9.0718	inches
measured from circumference:		28.5	inches
pipe depth below grade:	at test	0-5	inches
	on slope	probably < 12	inches
pitting:		none	
Photos:		Y	
Notes:	steep slope with crumbly rock, see soil tests		
	small concrete section below pipe, perhaps part of slope stabilization		
	concrete thrust block ~8 ft uphill of exposed section		
	Veolia helped expose 7 feet all-around		
	found another 8inch CIP 8 ft south of exposed pipe- from ferry point??		
	10/12/15 came back with Lmic and turned on pump. Verified North pipe of which testing was done is indeed the FM		
Wet Well:			
Total Sulfide:	13:30	1.6	ppm
Dissolved Sulfide:	13:30	1.2	ppm
Notes:	good condition concrete and metal appurtenances, some corrosion and staining at typical water level		
	Inlet from manhole west of wetwell, then from line in Bay, gravity fed from large houses in West & North.		

Project No.	14-0338	Day 2
Project	Richmond Force Main Condition Assessment	
Client	Veolia Water, North America	

Force Main:	Brickyard Booster Wetwell			
Date, time of arrival:	10/8/2015	9am		
V&A personnel:	Oliver P., Nicole K., Chelsea T.			
Condition Assessment:				
pipe material:	top inlet:	white PVC		
	bottom inlet	white PVC		
wetwell diameter:		72	inches	
pipe diameter:	top inlet:	8	inch	(plugged for assessment)
	bottom inlet:	8	inch	
Rim to Inverts:	top inlet:	5'-6"		
	bottom inlet:	18'-10"		
Concrete Hardness	good, chalky surface, hard underneath			
	no penetration			
Concrete pH	6-7			
Liner:	Plastic			
Liner Condition:	All the t-lock horizontal joints are failing, peeling off.			
	Wetwell liner is pliable, but getting undermined by moisture			
Photos:	Y			
Total Sulfide:	0	ppm		
Dissolved Sulfide:	0	ppm		
Notes:	Bottom inlet is actually a gravity line that FM connects to. see Seacliff			
	Seacliff Brickyard 10am-11am, 1 hr only raised 20", have 80"			
	bottom inlet transition to wetwell is good.			
CCTV:	CCTVed mostly a gravity line! later came back and figured out FM discharged into this gravity line.			
	10/8/15 10:20am start		"Forcemain_Sandpiper"	
	good condition, PVC			
	turned pump on, CCTV sat at 430', did not see increase in flow.			

Force Main:	Canyon Estates Discharge MH			
Date, time of arrival:	10/8/2015	1:30pm		
V&A personnel:	Oliver P., Nicole K., Chelsea T.			
Condition Assessment:				
pipe material:	FM:	PVC		
pipe diameter:	FM:	6	inch	
	east inlet:	6	inch	
	outlet:	7.75	inch	
Rim to Inverts:	FM:	45	inch	
	FM rim-to-char	46.5	inch	
	east inlet rim-t	42.5		
	outlet:	47.25		
Concrete Hardness	bench:	medium to coarse aggregate		
		concrete soft & chalky		
		1/2" penetration		
	cone:	soft top mortar layer, hard under		
	FM channel:	hard, no exposed aggregate, good condition		
Concrete pH	2-3, closer to 2			
Photos:	Y			
Total Sulfide:	0	ppm	at PS 3 wetwell (operator commented	
Dissolved Sulfide:	0	ppm	have odor issues, using rubber cover	
			under MH cover	
Notes:	MH is bench-cone-barrel style.			
CCTV:	CCTVed 50'			
	can see well, good condition, a little dirty			
	green SDR 26			
	typical 1gpm; pump on 150gpm.			

Project No.	14-0338	Day 3
Project	Richmond Force Main Condition Assessment	
Client	Veolia Water, North America	

Force Main:	**Port**		
	Pressure MH		
Date, time of arrival:	10/12/2015 9:30am		
V&A personnel:	Oliver P., Nicole K., Dan D.		
Condition Assessment:			
pipe material:	metallic, cast iron?		
	severely corroded, exfoliation on outside surface, peeling off in large chunks		
pipe diameter:	East:	4"	(outside circumference 15.25")
	West:	4"	cut off
Rim to Inverts:	60" to lower collar and 19" to rim		
	rim to crown is 27" –> Rim to invert = 31"		
Concrete Hardness	mean water line at 2/3 up MH		
	hard concrete below M.W.L, softer concrete above & 1/8" penetration		
Concrete pH	8		
Photos:	Y		
Notes:	two 45deg bends down then horizontal		
	2 feet of standing water, same strong smell as wetwell (used blower)		
	mean water line at 2/3 up MH		
	sediment: 2-10 inches		
Wetwell:			
Total Sulfide:	9:45am	1.1	ppm
Dissolved Sulfide:	9:45am	0.5	ppm
	good condition of hardware and plastic lining		
	2 risers, good condition.		
	Could not see inlet(s) at typical level		

Force Main:	**Port & Brickyard Booster**		
	Discharge MH		
Date, time of arrival:	10/12/2015 11:00am		
V&A personnel:	Oliver P., Nicole K., Dan D.		
Condition Assessment:			
pipe material:	SW L inlet (wash station):		Black plastic
(clockwise order)	SW R inlet (from port PS):		RCP?
	W inlet (from brickyard):		cannot tell material
	Outlet		RCP
	E inlet		cannot tell material
pipe diameter:	SW L inlet (wash station):		7.75"
	SW R inlet (from port PS):		8"
	W inlet (from brickyard):		8"
	Outlet		12"
	E inlet	6"	could be larger because of grease
Rim to Inverts:	SW L inlet (wash station):		55"
	SW R inlet (from port PS):		56.5"
	W inlet (from brickyard):		60"
	Outlet		61"
	E inlet		61"
Concrete Hardness	bench:	exposed aggregate, hollow soundings	
	lower cone:	medium exposed aggregate, soft, chalky	
	upper cone:	no exposed aggregate, but still soft	
Concrete pH	3		
Photos:	Y		
Notes:	varying amount of sediment, mostly 1-2"		
CCTV:	Both SW inlets active when Port pump turned on, but more flow on		
	"Port_FM":	a lot of grease	
	16'	half full of water	
	24'	partial cave-in	
	"Upstream MH D9MH2665, Downstream MH D9MH2644" =		
	7'	roots	
	Cleaned, still only got to 8' only as there is a bend		

Project No.	14-0338
Project	Richmond Force Main Condition Assessment
Client	Veolia Water, North America

Night 1

Force Main:	**Brickyard Booster Pressure MH**		
Date, time of arrival:	10/13/2015	9:15pm	
V&A personnel:	Oliver P., Nicole K., Sergio M.		
Condition Assessment:			
pipe material:	plastic		
pipe diameter:		8	inches
	outer diameter	8.67	inches
	(circumference:	27.25	inches)
Rim to Inverts:		115.83	
	(rim-to-crown:	124.5	inches)
Concrete Hardness	solid, hard surface mortar, negligible penetration		
	at downstream end where would have used mortar to repair pipe penetration,		
	11:00-11:30 there is a 1.5" deep hole in the concrete		
Concrete pH	East wall:	8	
	West wall:	8	
Photos:	Y		
Notes:	Bottom of manhole slightly wet		
	two couplers, moderately corroded. If there was lining, it is now gone		
	Stainless steel coupler bolts encrusted, underneath good condition		
	There is a cathodic protection system, wire running along pipe		

Force Main:	**Brickyard Cove Discharge MH**		
Date, time of arrival:	10/13/2015	9:50pm	
V&A personnel:	Oliver P., Nicole K., Sergio M.		
Condition Assessment:			
pipe material:	FM NE inlet:	blue-green pvc	
	Gravity N inlet:	blue-green pvc	
	outlet:	white pvc liner	
pipe diameter:	FM NE inlet:	8	inches
	Gravity N inlet:	6	inches
	outlet:	8	inches
Rim to Inverts:	FM NE inlet:	102.25	inches
	Gravity N inlet:	71.5	inches
	outlet:	100	inches
Concrete Hardness	hard. Lower level very fine aggregate, unusual for typical pouring		
	1/16" penetration on cone & barrel		
Concrete pH	lower cone:	5-6	surprising considering not much
	barrel:	4	concrete degradation
Photos:	Y		
Notes:	few fine roots at manhole riser, where it meets the cone.		
CCTV:	start 10/12/15 2:15pm		
	"Upstream MH D8MH2662, Downstream MH D8SS9"		
	blue PVC 6", drop inlet		
	27'	joint, good condition (note looking upstream, joint is not offset)	
	(45' then tighten to 39')	45deg bend, difficult to advance, just zoom in (note water reflection mirror top of pipe, not a cave-in)	

Project No.	14-0338			
Project	Richmond Force Main Condition Assessment			
Client	Veolia Water, North America			

Night 1 (continued)

Force Main:	**Keller Beach & Ferry Point**			
	Discharge MH (@ tunnel)			
Date, time of arrival:	10/13/2015	10:15 PM		
V&A personnel:	Oliver P., Nicole K., Sergio M.			
Condition Assessment:				
pipe material:	inlet:	may be PVC		
	outlet:	RCP or clay, hard to tell, a lot of dirt/ encrustation		
pipe diameter:	inlet:	8	inch	hard to tell as splashing all over
	outlet:	8	inch	
Rim to Inverts:	inlet:	103	inch	
	outlet:	106	inch	
Concrete Hardness	very soft, riser has a lot of exfoliation, concrete underneath liner has texture of wet cement			
	manhole channel solid concrete			
	where influent enters mahole, base of channel is not smooth, probably due to debris and pumping action.			
Concrete pH	concrete too soft for pH test			
Photos:	Y			
Notes:	MH cover rim highly corroded, very difficult to open			
	MH liner completely failed, brittle, can punch through with chipping hammer.			
	FM flowing for a while, >10min, did not wait for FM to stop flowing for entry.			
Ferry Point Wetwell:				
10/12/2015	3:15pm			
total sulfide:	7.1	ppm		
dissolved sulfide:	6.4	ppm		
	hydrogen peroxide feed into wetwell			
	thick top layer of oil & grease			

Appendix B. Reference Data

Table B- 1. 2013 Richmond Odor Evaluation: Collection System Testing Data Summary

Location	Date	Time	H_2S Concentration Measurements (ppm) Range	Avg	Inst	Total Sulfide (mg/L)	pH	ORP (mV)	Temp (°F)	Notes
F8MH1201 (505 Canal Blvd)	9/17/12 - 9/20/12		0 - 4.1	0.8						
	9/18/12	9:05 AM			1.2	6	8.0	-250	71	
	9/18/12	3:10 PM			0.0	4	7.1	-201	71	
	9/20/12	8:25 AM			0.5	6	7.2	-222	72	
	Averages		**0 - 4.1**	**0.8**	**0.6**	**5**	**7.4**	**-224**	**71.3**	
E8MH2401 (1040 Canal Blvd)	9/17/12 - 9/20/12		0 - 8	0.0						
	9/18/12	9:25 AM			1.0	2	7.3	-211	70	
	9/18/12	3:30 PM			0.0	2	7.0	13	71	
	9/20/12	8:40 AM			1.0	2	7.1	-145	71	
	Averages		**0 - 8**	**0.0**	**0.7**	**2**	**7.1**	**-114**	**70.7**	
G7MH755 (1 W Richmond Ave)	9/17/12 - 9/20/12		0 - 337	36						
	9/18/12	11:02 AM			54	12	7.7	-144	70	
	9/20/12	9:50 AM			104	4	8.0	-190	70	
	Averages		**0 - 337**	**36**	**79**	**8**	**7.9**	**-167**	**70.0**	
18MH997 (525 Castro St)	9/17/12 - 9/20/12		0 - 7	2						
	9/18/12	11:20 AM			2.0	2	7.5	-205	72	
	9/20/12	10:10 AM			2.0	2	8.1	-170	71	
	Averages		**0 - 7**	**2**	**2**	**2**	**7.8**	**-188**	**71.5**	
F7MH2881 (S Garrard Blvd, just north of tunnel)	9/17/12 - 9/20/12		5 - 595	76						
	9/18/12	10:55 AM			47	21	7.5	-183	69	TS exceeded testing limit (> 20)
	9/18/12	1:40 PM			26	21	7.0	-268	70	TS exceeded testing limit (> 20). Ferry Pt PS on, Keller Bch PS off
	9/18/12	2:23 PM				8	7.2	-217	69	Keller Pt PS on, Ferry Point PS off
	9/20/12	9:40 AM			21	21	6.9	-217	70	TS exceeded testing limit (> 20)
	9/20/12	1:39 PM				5	7.9	-285	68	Keller Bch PS on, Ferry Pt PS off
	9/20/12	2:07 PM				21	7.2	-80	70	Ferry Pt PS on, Keller Bch PS off
	Averages		**5 - 595**	**76**	**31**	**16**	**7.3**	**-208**	**69.3**	
Brickyard Cove Pump Station	9/18/12	10:00 AM			0.017	0	8.0	-81	76	
	9/20/12	8:55 AM			0.020	0	8.1	-42	71	
	Averages				**0.019**	**0**	**8.1**	**-62**	**73.5**	
Ferry Point Pump Station	9/18/12	10:15 AM			0.053	9	7.4	-258	71	
	9/18/12	1:15 PM				8	7.4	-230	70	
	9/20/12	9:10 AM			0.025	12	6.7	-120	71	
	9/20/12	1:04 PM				8	7.4	-13	71	
	Averages				**0.039**	**9**	**7.2**	**-155**	**70.8**	
Keller Beach Pump Station	9/18/12	10:40 AM			0.16	1.5	8.0	-180	68	
	9/18/12	2:40 PM			0.59	2.0	6.8	-176	68	
	9/20/12	9:25 AM			0.25	1.5	6.3	-190	68	
	9/20/12	1:20 PM				1.5	7.9	-160	66	
	Averages				**0.33**	**1.6**	**7.3**	**-177**	**67.5**	

Legend: H_2S Range = range of concentrations measured by OdaLog during the logging interval

H_2S Avg = average of concentrations measured by OdaLog during the logging interval

H_2S Inst = instantaneous concentration measured at this time

ORP = Oxidation-Reduction Potential

Moderate - High H_2S or TS

High - Very High H_2S or TS

Reference: 2013 Richmond Odor Evaluation Report by Webster Environmental Associates, Inc. p.22

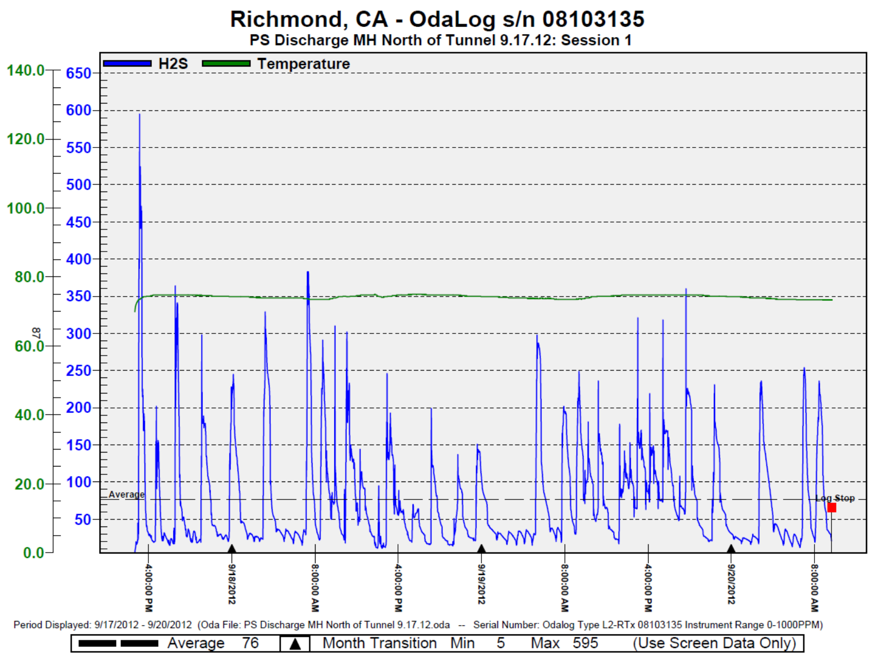


Figure B- 1. 2012 OdaLog at Ferry Point & Keller Beach Force Main Discharge Manhole

Reference: 2013 Richmond Odor Evaluation Report by Webster Environmental Associates, Inc. p.91

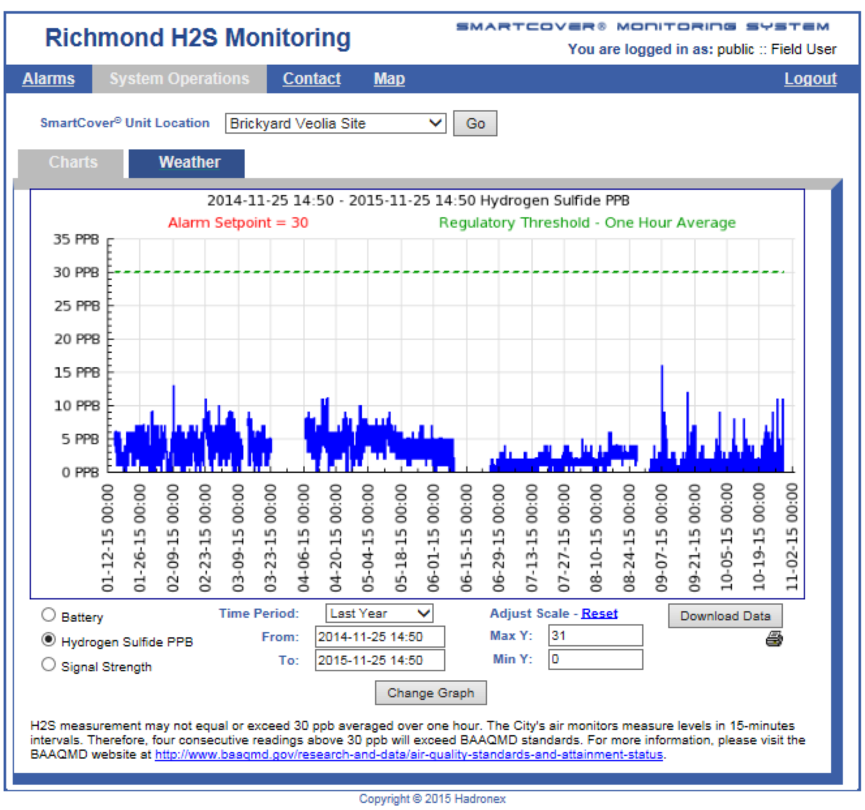


Figure B- 2. 2015 H_2S Monitoring at Brickyard Cove Pump Station

APPENDIX C. PRODUCT DATASHEETS

Product data sheet

Reference PDS-US-PG-10/06

SEWPERCOAT
PG

Updated 10/13/2006

1 General Characteristics

Composed entirely of calcium aluminates, SEWPERCOAT® PG is a pre-packaged ready to use high strength wet shotcrete material.

SEWPERCOAT® PG is a mortar that is designed to coat both new and existing municipal wastewater structures including manholes, lift stations, wet wells, etc. It is designed specifically to provide an abrasion and corrosion-resistant, protective lining that can withstand severe biogenic corrosion caused by the hydrogen sulfide (H_2S) found in wastewater environments.

The unique properties of SEWPERCOAT® result from the chemical and mineral phases formed during the hydration process. SewperCoat is unique when compared to other materials such as ordinary Portland cement (OPC) concrete, epoxies, poly-vinyl chloride (PVC) or polyethylene, because of its capacity to inhibit bacterial activity by effectively neutralizing sulfuric acid production.

SEWPERCOAT® is an adhesive mortar that possesses thin section toughness as well as high compressive and flexural strengths. Additional features include high early strength, freeze-thaw resistance as well as high temperature resistance (1,800°F/1,000°C). SEWPERCOAT® is also resistant to many other types of corrosion including sulfates, seawater, oils, gases, and dilute acids (pH range 3.5 – 11).

SEWPERCOAT® enhances the structural integrity of existing systems and reduces infiltration due to its high-density and low-porosity characteristics.

SEWPERCOAT® PG does not release calcium hydroxide as a hydration product. This imparts good chemical resistance and eliminates the major cause of efflorescence.

SEWPERCOAT® PG is a very dark gray color. SEWPERCOAT® PG does not contain crystalline silica.

TYPICAL* MATERIAL PROPERTIES (*PERFORMED BY AN INDEPENDENT TESTING LABORATORY*)

SEWPERCOAT®		24 HRS	7 DAYS	28 DAYS
ASTM C 109	Compressive Strength, psi	>5,500	>7,000	>8,000
ASTM C 293	Flexural Strength, psi	>1,300	>1,400	>1,600
ASTM C 596	Shrinkage at 90% Humidity, %	< 0.04	< 0.06	< 0.08
ASTM C 666	Freeze-Thaw After 300 Cycles	No Damage		
ASTM C 496	Splitting Tensile Strength	> 900 psi		
ASTM C 882	Bond Strength by Slant Shear	> 2,300 psi at 28 days		
ASTM C 457	Air Void Content (7 Days)	2-4%		
ASTM C 642	Specific Gravity/Absorption Test (7 Days)	3-5%		
	Static Modulus of Elasticity (24 hrs)	7.1×10^6		

*The test results above were obtained under standard laboratory conditions and are presented as typical material properties only. Those properties presented above are not warranted or guaranteed by Kerneos. Properties obtained from field cast specimens may result in values lower than those listed above. The warranted material properties are presented in section two of this Product Data Sheet.

Kerneos Inc.
1316 Priority Lane Chesapeake, VA 23324
Phone: (757) 284-3200 - FAX: (757) 284-3300

Kerneos
ALUMINATE TECHNOLOGIES

ISO 9001

Product data sheet

Reference PDS-US-PG-10/06

SEWPERCOAT

PG

Updated 10/13/2006

2 Specifications

SEWPERCOAT® PG sold and distributed by Kerneos Inc. adheres to the following specifications:

Sieve Analysis

	Min (%)	Max (%)
# 8 (2.36 mm)	0	0
# 16 (1.18 mm)	1.5	9.5
# 30 (600 µm)	22	32
# 50 (300 µm)	38	52
# 100 (150 µm)	48	62
# 200 (75 µm)	52	68
Pan	32	48

Mortar Properties (using 14.5% water)

- Vibration flow
  - 0 min. 120 - 160 %
  - 30 min. 110 - 160 %
- Penetrometer Final Set
  - 4 – 10 hours
- Compressive Strength @ 24 hours
  - 5500 - 11000 psi

For detailed test procedures, please contact a Kerneos Technical or Quality Manager.

3 Technical properties

Biogenic Corrosion Resistance: SEWPERCOAT® withstands the most severe corrosive environments containing H_2S gas, which results in strong Thiobacillus bacterial activity. Due to its high neutralization capacity, SEWPERCOAT® has the ability to locally raise the surface pH found on the surface of wastewater structures and prevent the successive colonization of the most aggressive strains of bacteria.

Abrasion Resistance: U.S. Army Corps of Engineers test CRD-C-63-80, Test Method for Abrasion-Erosion Resistance of Concrete, resulted in 0.5% weight loss after 12 hours of testing and 2.0% weight loss after 72 hours of testing. Typical 5,000-psi high-performance OPC concrete experienced a 3.6% weight loss after only 12 hours of testing. SEWPERCOAT® is approximately seven times more resistant to this type of abrasion than high-performance OPC concrete.

Aggregate Size: #14 mesh and finer (0 – 1.4mm)

Working Time at 68°F: 2 hours

Wet Density at 68°F: 148-155 lb./ft^3 (2.4 – 2.5 g/cc)

Coefficient of Thermal Expansion: 5 x 10^{-6} in/in/°F (68°F to 1832°F)

4 Chemical Composition

SEWPERCOAT® contains no calcium sulfate, calcium chloride, tricalcium aluminate, lime hydrates or aggressive agents that attack reinforcing steel. The high-performance properties of SEWPERCOAT® are achieved through a blend of mineral elements.

Chemical analysis main constituents			
Al_2O_3	CaO	FeO+Fe_2O_3	SiO_2
41% - 46%	33% - 38%	8% - 13%	4% - 9%

5 Installation

Clean, potable water should be used for mixing. The water requirement is provided on each individual bag and is critical to obtain the specified performance properties. Always stay within the recommended specifications for mixing water.

Kerneos Inc.
1316 Priority Lane Chesapeake, VA 23324
Phone: (757) 284-3200 - FAX: (757) 284-3300

Kerneos™ ALUMINATE TECHNOLOGIES

ISO 9001

SEWPERCOAT® products are not designed to be hand-applied. SEWPERCOAT® PG is designed to be applied with low-pressure, wet-spray equipment.

Preparation of the surface to be coated should be performed in accordance with applicable industry standards and specific project specification requirements. Sandblasting and/or hydro-demolition with high-pressure water may be used to remove existing deterioration and debris. The immediate bonding surface should be rough, damp and free of any existing coatings, sewer residue and running water. The structure itself should be fully saturated prior to a SEWPERCOAT® installation. Please see our suggested SEWPERCOAT® specification language for detailed surface preparation recommendations.

SEWPERCOAT® products are to be used as packaged. Under no circumstances should any substance other than water be added to SEWPERCOAT® products.

SEWPERCOAT® should not be used as a "build-out" mix or underlayment for any other product. SEWPERCOAT® should not be used in conjunction with or adjacent to any inert or organic coatings, including but not limited to epoxy, polyurethane, polyurea, and fiberglass. Curing should be implemented as soon as the surface begins to harden and dry (as early as one hour after application). Several layers of ASTM C309 liquid membrane curing compound or a 100%-humid moisture cure may be used.

Equipment used must always be clean and free of portland cement build-up to avoid accelerated set.

Generally accepted concreting practices (water ratio per bag, compaction, curing, etc.) should be employed to obtain the best quality installation with respect to mechanical strength and corrosion resistance.

6 Availability

SEWPERCOAT® is available in North America directly through Kerneos Inc. main office and warehouses.

SEWPERCOAT® is packaged in various bag sizes depending upon application and installation methods. SEWPERCOAT® PG is typically supplied palletized in 65-lb bags.

For more information about SEWPERCOAT®, including a listing of competent installers, please contact Kerneos, Inc. at 1-800-524-8463.

7 Technical Assistance

A licensed Professional Engineer is responsible for the determination of suitability, overall design, specifications and follow up for each project.

Kerneos Inc. has a Technical Assistance Department with on-site laboratory facilities available to provide customer support. Kerneos assistance in technical planning and installation of a project does not warrant the success of any application and is not a substitute for professional engineering judgment.

8 Packaging & Shelf Life

SEWPERCOAT® PG is available palletized in 65-lb bags. SEWPERCOAT® PG packaging is designed to protect it from humidity. However, as with all prepackaged concretes, it is recommended that SEWPERCOAT® PG not be placed outdoors or in direct contact with the ground. When correctly stored in dry conditions, the properties of SEWPERCOAT® PG will remain within specification limit for at least 6 months. In most cases, its properties will be retained for over a year.

SEWPERCOAT
PG

Updated 10/13/2006

KERNEOS LIMITED WARRANTY

Kerneos warrants to its Buyer that this product, at the time of shipment, conforms to the Specifications set forth in Section 2 of this Product Data Sheet. ALL OTHER WARRANTIES, INCLUDING WITHOUT LIMITATION THE WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, ARE EXCLUDED. Kerneos' sole obligation and the sole and exclusive remedy under this limited warranty shall be the replacement of any nonconforming product or, at Kerneos' option, the refund of the purchase price paid by its Buyer. No warranty is given for, or may be implied from, any technical advice or recommendations provided by Kerneos. All claims under this limited warranty are excluded unless Kerneos has been given written notice of nonconformity within 30 days of use of the product or 6 months of delivery to its Buyer, whichever comes first.

WARRANTY CLAIM PROCEDURE

Kerneos reserves the rights to inspect and determine whether any failure of a SEWPERCOAT® product is the result of a breach of a warranty set forth herein or is related to another cause (any and all of which such other causes are expressly excluded from coverage by the warranties contained herein).

Any claim under this limited warranty requiring an investigation by Kerneos may require extensive laboratory testing. It is the responsibility of any party making a claim hereunder to make accessible and available to Kerneos within a reasonable period of time after a claim arises any product or structure requiring testing. Inspection may require the removal of a portion of the SEWPERCOAT® lining in question or, if a structure requiring investigation cannot be made readily accessible, the removal of any frames, covers, or obstructions for thickness verification and the gathering of sample testing specimens. At Kerneos's option, technical investigations and testing may be performed by either Kerneos internal facilities or by an independent agency.

It is the responsibility of the customer to maintain and document product installation reports in accordance with all applicable instructions including, without limitation, the location and date, the quantities installed, the mixing methods, installation personnel, existing conditions of the structure including H_2S concentrations and initial surface pH. Kerneos will provide installation report forms upon request.