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12-0013

May 9, 2012

Dan Stevenson
Wastewater Operations Manager
City of Sunnyvale
221 Commercial Street
Sunnyvale, CA 94086

SUBJECT: City of Sunnyvale Lawrence Expressway Trunk Sewer Main Evaluation

Dear Mr. Stevenson,

V&A has completed an assessment of the City of Sunnyvale reinforced concrete wastewater trunk line along the Lawrence Expressway at manholes selected by the City between Ryder Street and Highway 237. The manned entry and assessment was completed on the night of April 18 to April 19, 2012. The Lawrence Expressway is a multi-lane major traffic thoroughfare. The majority of the manhole entry points were located in traffic lanes or at busy intersections, and had to be entered at night when traffic was minimal and low flow conditions would expose a greater surface area for assessment. The 50 mph maximum speed limit required extensive traffic control to adequately warn approaching motorists of the roadwork ahead. A total of nine manholes were entered. A tenth manhole (345-211) was surcharged and inaccessible.

The assessment involved visual examination of the reinforced concrete trunk line, digital camera documentation of the trunk line condition immediately upstream and downstream from the manhole, measuring atmospheric hydrogen sulfide concentration, measuring dissolved sulfide concentration in a wastewater sample, noting and recording the depth of any sediment in the trunk line, and taking a representative concrete sample from the pipe crown for pH measurement. The concrete sampling was done with a welder's chipping hammer, which permitted the entrant to determine the depth to hard concrete (penetration depth) and listen to hammer impact sounds to estimate the degree of concrete physical deterioration or the presence of near-surface cracks and delaminations. Dull sounds indicate concrete alteration or cracks and laminations beneath the surface. A sharp pinging sound reflects solid, relatively unaltered concrete.

The hydrogen sulfide concentration in the manhole atmosphere was monitored by a BW Technologies Gas Alert 4-gas meter. This meter continuously monitors the atmosphere for percent oxygen, flammable gas concentrations, hydrogen sulfide concentration, and carbon monoxide concentration. The hydrogen sulfide concentration recorded when the 4-gas meter sampled the manhole headspace gasses before entry provided the reported atmospheric hydrogen sulfide values. A wastewater grab sample was taken by the entrant and was immediately tested for dissolved sulfide using a Gastec No. 211LL Sulfide Ion Detector Tube. The glass detector tube ends are broken and one end is inserted into the wastewater sample. Capillary action draws the water into the tube packing. If dissolved sulfide ion is present, the white packing turns brown. The tube is marked in increments from 0.5 to 20 ppm sulfide. The wastewater sulfide concentration is read off the scale where the brown discoloration ends.

Concrete sample pH is measured by taking a small quantity of powder chipped from the pipe surface and adding 20 mL of distilled water to it. The sample is kept in a waterproof plastic bag during the

measurement. An Oakton ECO Testr pH2 meter is inserted into the water solution in the bag. The meter measures the solution pH, which represents hydrogen ion leached from the concrete powder. The pH meter is calibrated using pH 4.0, 7.0, and 10.0 standard buffer solutions manufactured by Lab Chem, Inc. The concrete samples are kept at approximately equal powder volumes. None of the samples were weighed or otherwise quantitatively processed for the pH testing. The reported pH test results are consistent with visual features observed during the assessment, and with the pH value of 11.5 measured on a cured and unaltered concrete powder sample tested with these samples.

Figure 1 shows an aerial view of the manholes that were entered for the reinforced concrete pipe wastewater trunk line condition assessment.

Figure 1. Aerial view of the Lawrence Expressway showing the manhole locations.

Table 1 lists the size and composition of influent and effluent piping in each manhole. Manhole 345-211 was not entered because the manhole was in a surcharged condition.

Table 1.
Manhole Influent and Effluent Pipe Descriptions*

Manhole I.D.	Manhole Location	Influent Pipe Dimensions	Effluent Pipe Dimensions
576-206	Elko Dr & Lawrence Station Rd	10 in. VCP from E 39 in. RCP from S 12 in. VCP from W	39 in. RCP to N
536-203	Tasman Dr & Lawrence Expwy	10 in. VCP(?) from E (submerged) 39 in. VCP from S	39 in. VCP to NW
505-205	Lakebird Dr & Lawrence Expwy	10 in. VCP from E 39 in. RCP from S 10 in. VCP from W (submerged) 6 in. VCP drop from SW	39 in. RCP to N
496-218	325 feet north of Sandia Ave & Lawrence Expwy	36 in. RCP from S	36 in. RCP to N
496-217	Sandia Ave & Lawrence Expwy	8 in. VCP from E 36 in. RCP from S 12 in. VCP from W	36 in. RCP to N
425-211	Lawrence Expwy east of Duane Ct	15 in. VCP from E 27 in. RCP from S 18 in. VCP from W 6 in. VCP drop from W	27 in. RCP to N
376-202	Arques Ave & Lawrence Expwy	26 in. RCP from S	21 in. VCP to W 24 in. RCP to N
376-203	Arques Ave & Lawrence Expwy	10 in. VCP from E was not seen 26 in. RCP from S 10 in. VCP from W	26 in. RCP to N
376-204*	Miraloma Way & Lawrence Expwy in median strip	10 in. VCP from E 27 in. RCP from S 10 in. VCP from W	27 in. RCP to N
345-211	Off Lawrence Expwy 200 feet north of Ryder St	Surcharged	Surcharged

VCP = vitrified clay pipe
RCP = reinforced concrete pipe
*Manhole 376-204 was entered instead of Manhole 345-201, which was not found.

The measurements and data collected for each manhole is presented in Table 2.

Table 2.
Reinforced Concrete Trunk Line Assessment Measurements and Observations

Manhole I.D.*	Sediment (inches)	Atmospheric H_2S (ppm)	Dissolved H_2S (ppm)	Penetration Depth (inches)	Crown Concrete pH	Comments
576-206	none	2	0.2	⅛	8.0	Thin skinning of influent and effluent RCP crown to spring line exposed surfaces. Hard, firm concrete
536-203	5½ to 7	0	<0.2	VCP	VCP	Silty sediment at 39-inch influent VCP pipe. Submerged apparent 10-inch VCP from east.
505-205	concrete debris	0	<0.2	⅛	8.7	Approximately 6 inches of solidified concrete rubble in channel. Shallow surface losses on RCP crown to spring line. Hard, firm concrete.
496-218	none	0	<0.2	⅛	8.8	Shallow surface losses and thin peeling on RCP crown to spring line.
496-217	none	0	<0.2	⅛	8.0	High flow velocity. Clear water from 12-inch VCP. Shallow surface losses and thin peeling on RCP crown to spring line similar to MH 496-218 (one manhole upstream of SFPUC siphon).
425-211	none	0	<0.2	⅛	7.1	Infiltration seepage at barrel joint just above 18-inch VCP. Clear water flowing in the 15-inch and 18-inch VCP. Thin concrete peeling at pipe crown to spring line.
376-202	none	0	<0.2	¼ to ½	3.8	Minor pipe crown deterioration. Aggregate found in concrete pH sample. Groundwater infiltration at 10 o'clock position on edge of west 21-inch VCP effluent pipe.
376-203	2 to 3	0	<0.2	⅛ to ¼	8.0	Pebbly sediment in influent RCP. Exposed aggregate on influent pipe crown.
376-204	none	0	0.3	¼ to ½	3.5	Concrete pH sample contains aggregate. Aggregate exposed in RCP crown. High flow velocity.
345-211	N/A	N/A	N/A	N/A	N/A	Manhole was surcharged and was not entered. Plan view photo only. Manhole lid and ring are corroded.

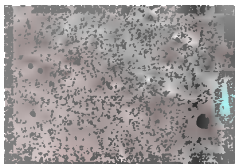
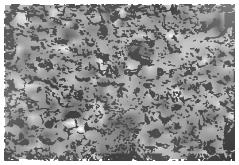
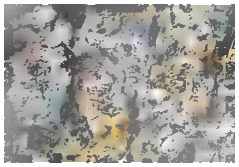
* Manhole I.D.'s are arranged in reverse numerical order from north, downstream (576-206) to south, upstream (345-211).

DISCUSSION

The City of Sunnyvale Lawrence Expressway trunk line is in overall good condition from Manhole 345-201 at Miraloma Way and Lawrence Expressway north to Manhole 576-206 at Elko Drive and Lawrence Station Road. The reinforced concrete pipe exhibited minor surface peeling and concrete scaling losses above the water line in the manholes from Manhole 425-211 immediately south of the US 101 overpass to Manhole 576-206 at Elko Drive. Chipping hammer impacts indicate the pipe crown areas are hard and mildly altered. The concrete sample pH tests gave pH values of 7.1 to 8.8 for all samples except samples taken at Manhole 376-202 at Arques Avenue (pH = 3.8) and Manhole 376-204 at Miraloma Way (pH = 3.5). Coarse aggregate is exposed in the pipe crowns at these manholes, and at Manhole 376-203 located about 6 feet south of Manhole 376-202 at Arques Avenue.

V&A has developed an empirical condition rating system for concrete. The concrete rating can vary from Level 1 to Level 4, based upon the extent of corrosion determined by visual observations, penetration depth measurements, and concrete pH test values. The VANDA™ concrete condition rating system is summarized in Table 3.

Table 3
VANDA™ Concrete Condition Index Rating System

Concrete Condition Rating	Description	Descriptive Photograph
Level 1	Overall: No/minimal damage to concrete Hardness: No loss of hardness of mortar Smoothness: No loss of smoothness Cracking: No cracks Spalling: No spalling Reinforcing Steel: Not exposed or damaged	
Level 2	Overall: Damage to concrete mortar Hardness: Some loss of hardness of mortar Smoothness: Small-diameter exposed aggregate Cracking: Thumbnail-sized cracks of minimal frequency Spalling: Shallow spalling of minimal frequency, no related reinforcing steel damage Reinforcing Steel: May be exposed but not damaged or corroded	
Level 3	Overall: Loss of concrete mortar/damage to reinforcing steel Hardness: Complete loss of hardness of mortar Smoothness: Larger-diameter exposed aggregate Cracking: ¼-inch to ½-inch cracks, moderate frequency Spalling: Deep spalling of moderate frequency, related reinforcing steel damage Reinforcing Steel: Exposed, damaged and corroded, but can be rehabilitated	
Level 4	Overall: Reinforcing steel Severely corroded/significant damage to structure Hardness: Complete loss of hardness of mortar Smoothness: Large-diameter exposed aggregate Cracking: ½-inch cracks or greater, high frequency Spalling: Deep spalling at high frequency, related reinforcing steel damage Reinforcing Steel: Corroded or consumed, loss of structural integrity	

Using the concrete rating criteria in Table 3, all seven assessed manhole sites north of, and including, Manhole 425-211 immediately south of the US 101 overpass and east of the Duane Court cul-de-sac are rated a VANDA Level 1. Manholes 376-202, 376-203 (both at Arques Avenue), and Manhole 345-201 at Miraloma Way are rated a VANDA Level 2. The latter is based on the coarse aggregate exposed above the water line, the physically weakened condition of the concrete surface layer, and the concrete sample pH readings of 3.5 and 3.8.

Manhole 345-211 just south of the Central Freeway overpass between the Central Freeway and Ryder St. was surcharged and was not assessed. Its metal lid and ring show moderate corrosion, and the odor emanating from the manhole when the lid was removed suggests some atmospheric hydrogen sulfide was present in the headspace above the swirling wastewater pool.

The Tasman Drive manhole (536-203) is one of four manholes that access either end of a siphon under the VTA train tracks at this intersection. The manhole that was entered is closest to the tracks on the downstream end of the siphon. One submerged 10-inch diameter pipe, presumably a VCP, enters from the east. The influent and effluent trunk line pipes are both 39-inch diameter VCP. The manhole and piping show no visible deterioration. Up to 7 inches of sediment has been deposited on the invert of the 39-inch diameter influent VCP. The effluent line makes a 135 degree bend northwest to the downstream manhole several feet away.

Digital camera photographs illustrating the key features of influent and effluent piping at each assessed manhole are presented in Appendix 1.

CONCLUSIONS

- The City of Sunnyvale concrete trunk line transporting wastewater northward beneath the Lawrence Expressway from the Central Expressway overcrossing to the intersection of Elko Drive and Lawrence Station Road is overall in good physical condition.
- Shallow surface (<¼-inch deep) apparent concrete alteration occurs at the assessed pipe crowns from Manhole 425-211 at Lawrence Expressway and Duane Court northward to Elko Drive, but the underlying concrete is hard and pings resolutely when struck with a chipping hammer.
- The manholes at the Arques Avenue intersection (376-202 and 376-203) and Manhole 345-201 at Miraloma Way display more prevalent crown concrete deterioration. Exposed concrete aggregate is visible. Two crown samples (376-202 and 345-201) gave pH values of 3.5 and 3.8, indicating strong cement paste deterioration, most likely by atmospheric hydrogen sulfide attack.
- Groundwater infiltration is occurring at the 10 o'clock edge of the 21-inch diameter HDPE effluent pipe in Manhole 376-202.
- The southernmost manhole that was assessed, Manhole 345-211, is surcharged. The manhole atmosphere had a hydrogen sulfide odor. The metal lid and ring on the topside concrete collar are corroded. The surcharged condition at Manhole 345-211 was noted on April 1, 2012, at 4:15 p.m., and again on the night of April 18, 2012 at 11:00 p.m. This appears to be a chronic condition. Hydrogen sulfide may also be collecting in piping and manholes upstream.
- The Tasman Drive manhole (536-203) is one of four manholes that access either end of a siphon under the VTA train tracks at this intersection. The manhole that was entered is immediately

downstream of the siphon near the north side of the railroad track. The 39-inch vitrified clay pipes show no visible signs of deterioration. Sediment in the 39-inch diameter vitrified clay influent pipe is 5½ to 7 inches deep.

- Manholes 376-202 and 376-203 at Arques Avenue, and Manhole 376-204 at Miraloma Way show the most concrete alteration. Here coarse concrete aggregate is exposed at the surface. The loss of surface concrete due to corrosion appears to be less than ½ inch deep.
- Manhole 456-206 off the eastbound US 101 on-ramp was not entered because its proximity to the traffic right of way would most likely require a separate Caltrans encroachment permit. However, based on observations at manholes upstream and downstream of that site, V&A anticipates the conditions to be similar.

RECOMMENDATIONS

- The City of Sunnyvale wastewater trunk line north of Manhole 345-211 is in overall good condition. The pipe crowns show only minor ⅛ to ¼-inch deep thin surface peeling and scaling losses. V&A recommends that the City re-evaluate the trunk line condition on 5-year intervals.
- The drawings provided by the City of Sunnyvale indicate that the trunk line connecting Manholes 336-202, 265-204, 176-205, and 065-214 south (upstream) of Manhole 345-211 to Homestead Road are VCP. VCP is inert to biogenic corrosion. Therefore, these manholes were not entered by V&A.
- The surcharged Manhole 345-211 is a concern. This condition restricts the pipe headspace air flow and may be allowing hydrogen sulfide gas to collect in the piping and in manholes immediately upstream. V&A recommends remedial action to correct line obstructions or possible sags that may be causing this manhole to surcharge.
- Due to the surcharge in Manhole 345-211, pressurized air conditions could exist in piping and manholes upstream. If atmospheric hydrogen sulfide gas is present in the manhole, a possible release of odors could occur. Should efforts to alleviate the surcharged condition be unsuccessful, it is recommended that an air pressure and sulfide monitoring study be conducted to evaluate the potential for odors.
- The point defect in the crown of the 26-inch concrete pipe between Manholes 376-202 and 376-203 should be repaired. The cause of the point defect is unknown although it is possible the condition leading to crown wear and exposed aggregate may be remedied by eliminating the surcharging at Manhole 345-211 upstream. Other point defects could be present in segments of piping out of sight from the manhole vantage point. Therefore, it is recommended that CCTV documentation of the trunk line be performed.
- The groundwater infiltration around the 21-inch diameter HDPE pipe in Manhole 376-202 requires repair. Groundwater and other sources of inflow and infiltration on the trunk line should be evaluated by conducting flow monitoring during wet weather. Results from a flow monitoring study can be used to identify inflow and infiltration as well as capacity constraints in the trunk line.
- The sediment buildup on the downstream (north) side of the Tasman Drive siphon under the light rail tracks indicates the siphon may need cleaning.
- The City of Sunnyvale trunk line north (downstream) of Manhole 425-211 does not require rehabilitation at this time. The pipe crowns show only minor ⅛ to ¼-inch deep thin surface peeling and scaling losses.

On behalf of our staff and myself I would like to thank you for the opportunity to be of service to you and the City of Sunnyvale. Please feel free to contact us if you have any questions or comments.

Sincerely,

Daniel Day
Associate Engineer

V&A

APPENDIX A
Reinforced Concrete Trunk Line Photographs

Manhole 576-206
Elko Drive & Lawrence Station Road

Photo 1. Manhole 576-206. 39-inch diameter concrete pipe effluent to the north

Photo 2. Manhole 576-206. 10-inch diameter VCP influent from the east.

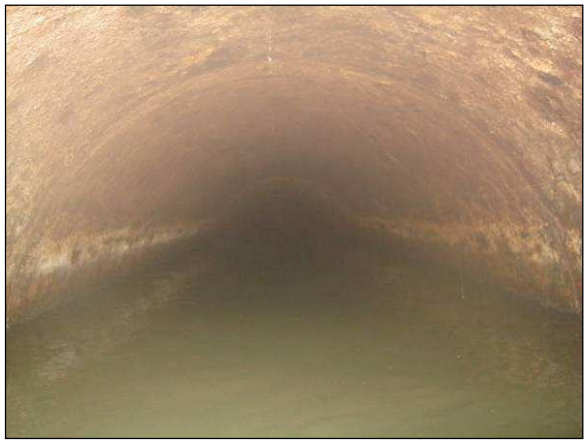


Photo 3. Manhole 576-206. 39-inch diameter concrete pipe influent from the south.

Photo 4. Manhole 576-206. 12-inch diameter VCP influent from the west.

Manhole 536-203
Tasman Drive & Lawrence Expressway

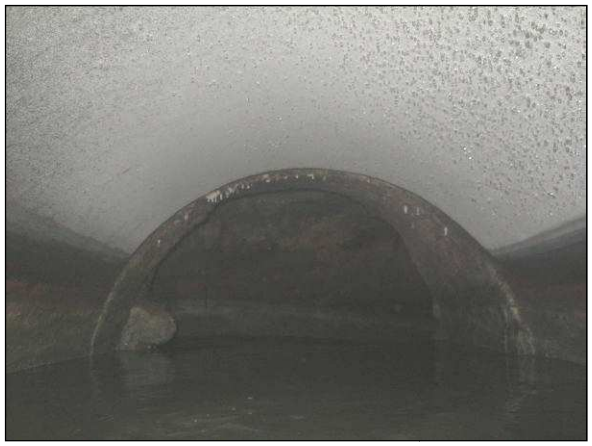


Photo 5. Manhole 536-203. 39-inch diameter VCP effluent to the northwest.

Photo 6. Manhole 536-203. 10-inch diameter apparent VCP influent from the east (submerged).

Photo 7. Manhole 536-203. 39-inch diameter VCP influent from the south.

Manhole 505-205
Lakebird Drive & Lawrence Expressway

Photo 8. Manhole 505-205. 39-inch diameter concrete pipe effluent to the north.

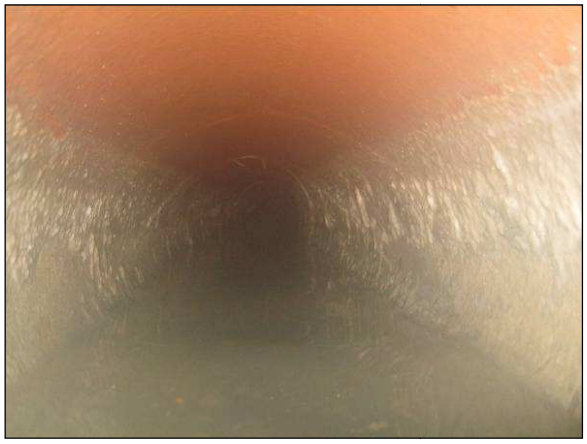


Photo 9. Manhole 505-205. 10-inch diameter VCP influent from the east.

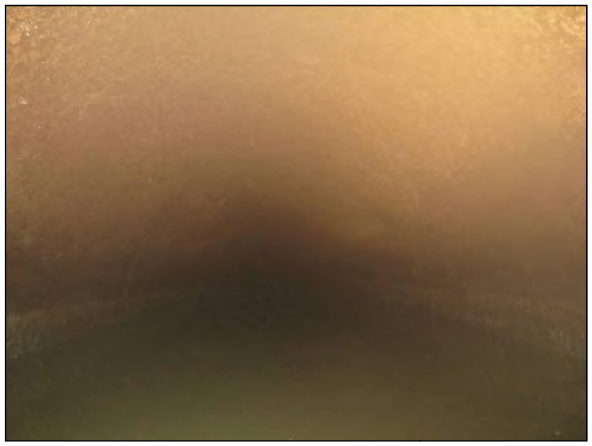


Photo 10. Manhole 505-205. 39-inch diameter concrete pipe influent from the south. Concrete condition is identical to Photo 8.

Photo 11. Manhole 505-205. 10-inch diameter apparent VCP influent from the west. Submerged.

Manhole 496-218
325 feet north of Sandia Avenue & Lawrence Expressway

Photo 12. Manhole 496-218. 36-inch diameter concrete pipe effluent to the north. Thin peeling of shallow alteration zone.

Photo 13. Manhole 496-218. 36-inch diameter concrete pipe influent from the south

Manhole 496-217
Sandia Avenue & Lawrence Expressway

Photo 14. Manhole 496-217. 36-inch diameter concrete pipe effluent to the north.

Photo 15. Manhole 496-217. 8-inch diameter VCP influent from the east.

Photo 16. Manhole 496-217. 36-inch diameter concrete pipe influent from the south

Photo 17. Manhole 496-217. 12-inch diameter VCP influent from the west.

Manhole 425-211
Northbound Lawrence Expressway east of the Duane Court cul-de-sac

Photo 18. Manhole 425-211. 27-inch diameter concrete pipe effluent to the north.

Photo 19. Manhole 425-211. 15-inch diameter VCP influent from the east.

Photo 20. Manhole 425-211. 27-inch diameter concrete pipe influent from the south.

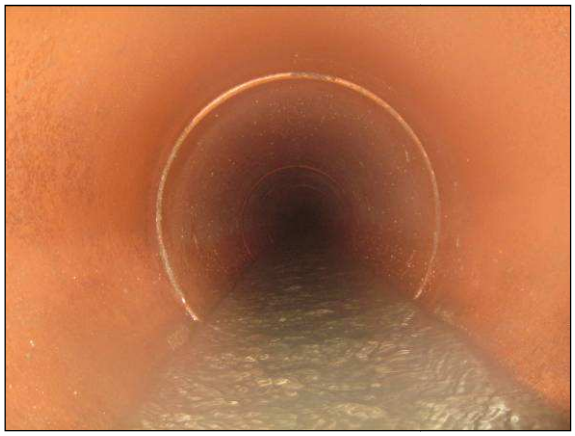


Photo 21. Manhole 425-211. 18-inch diameter VCP influent from the west.

Photo 22. Manhole 425-211. 6-inch diameter VCP drop inlet from the west. Abandoned.

Manhole 376-202
Arques Avenue & Lawrence Expressway

Photo 23. Manhole 376-202. 26-inch diameter concrete pipe effluent to the north.

Photo 24. Manhole 376-202. 26-inch diameter concrete pipe influent from the south. Note exposed aggregate on crown.

Photo 25. Manhole 376-202. 21-inch diameter HDPE pipe effluent to the west.

Photo 26. Manhole 376-202. 21-inch diameter HDPE pipe. Groundwater infiltration

Photo 27. Manhole 376-202. 24-inch diameter concrete pipe effluent to the north.

Manhole 376-203
Sandia Avenue & Lawrence Expressway

Photo 28. Manhole 376-203. 26-inch diameter concrete pipe effluent to the north. Note weir in Manhole 376-202 that channels flow into the 21-inch diameter HDPE effluent pipe.

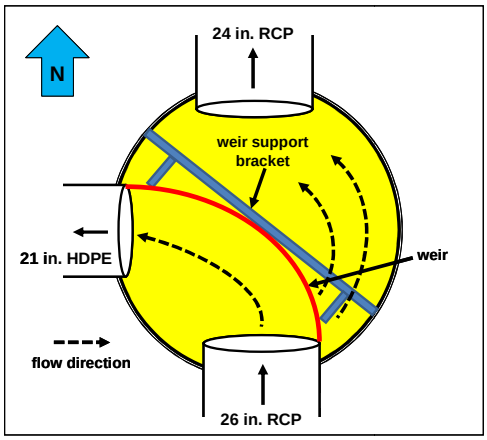


Photo 29. Manhole 376-203. Schematic plan view of diversion weir.

Photo 30. Manhole 376-203. 26-inch diameter concrete pipe influent from the south.

Photo 31. Manhole 376-203. 10-inch diameter VCP influent from the west.

Manhole 376-204
Miraloma Way & Lawrence Expressway

Photo 32. Manhole 376-204. 27-inch diameter concrete pipe effluent to the north.

Photo 33. Manhole 376-204. 10-inch diameter VCP influent from the east.

Photo 32. Manhole 376-204. 27-inch diameter concrete pipe influent from the south.

Photo 35. Manhole 376-204. 10-inch diameter VCP influent from the west.

Manhole 345-211
Off Northbound Lawrence Expressway 200 feet North of Ryder St. and 150 feet south of the Central Expressway overpass

Photo 36. Manhole 345-211. Manhole is off northbound lane of Lawrence Expressway on sidewalk. Manhole lid and ring are corroded.

Photo 37. Manhole 345-211. Plan view showing surcharged condition.