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City of Torrance
North Torrance Well Field Project
C.I.P. No. I-108

Tank Failure Inundation Study Report

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1. PROJECT DESCRIPTION

1.1 Introduction

The North Torrance Well Field (NTWF) Project is being implemented by the City of Torrance (City) to provide sufficient pumping, treatment, and storage capacity for utilization of the City's full groundwater allotment. As part of this project, a 3 million gallon (MG) or 9.25 acre-feet (ac-ft) prestressed concrete water storage reservoir (tank) will be used to store pumped groundwater and provide water supply to the distribution system. The purpose of this study was to characterize the inundation and associated impacts that would result from a hypothetical failure of the tank. Four scenarios were analyzed to compare how design variations (impact mitigation measures) would help reduce potential impacts in the event of a tank failure. The four model scenarios are as follows:

Scenario 1 - Base design conditions (Section 1.2).

Scenario 2 - Base design with partial burial of the tank (base of tank three feet below grade), and installation of a solid 8-foot high wall around the site with two open 30-foot wide access gates (Section 1.3).

Scenario 3 - Same as Scenario 2, except the northwest access gate would be solid and capable of retaining water (Section 1.3).

Scenario 4 – Base design with the site grade lowered an average of 1-foot, partial burial of the tank (base of the tank twenty feet below new grade), and installation of three-foot high passive flood gates at both access gates (above original grade) (Section 1.3).

Key components of this study included: 1) development of tank failure outflow hydrographs for each design scenario based on input from the tank manufacturer; 2) routing of the tank failure hydrographs using a two-dimensional overland flow model (FLO-2D) under the first three design scenarios; 3) documenting impacts to surrounding properties and structures; 4) mapping of the tank failure inundation extents, depths, and velocities within the model domain using ArcGIS mapping and spatial analysis software; 5) calculating the required on-site storage capacity necessary to retain all water and mitigate all off-site impacts for the fourth scenario; 6) comparing the impacts and inundation for the two mitigation scenarios to the base design scenario; and 7) developing a conceptual-level design feature or installation method (tank failure mitigation measure) to help reduce the risk of a potential tank failure.

1.2 Site and Storage Tank Description

The proposed NTWF site (Site) location comprises approximately 1.5 acres and is bordered by Interstate 405 (I-405) to the south and west, a right-of-way owned by Southern California Edison (SCE) to the north, and Yukon Elementary School to the east (Figure 1). The SCE right-of-way is approximately 150 feet wide (north to south) and is bordered by a residential area to the north which includes McMaster Park and extends to the northern edge of the study area at Artesia Boulevard. Several residences to the north of the SCE right-of-way have block walls along their southern property boundary which, if left intact, create a flow barrier. Yukon Avenue, located directly east of Yukon Elementary School, runs north-south crossing under the I-405 via an underpass. The Yukon Avenue / I-405 underpass is the lowest part of the study area, and, pending selected impact mitigation measures, would potentially collect and store much of the water released from a hypothetical tank failure. Stormwater is evacuated from the underpass via a 7.5 horsepower pump which discharges to the existing storm sewer system[1]. Adjacent to the Yukon Ave. / I-405 underpass in the southeast corner of the Yukon Elementary parking lot, a 4-foot by 2-foot box culvert (I-405 box culvert) receives drainage from the northwest (including the project site) and routes flow under I-405 toward 180th Place. For the purposes of this study, it was assumed that all of the flow routed through the I-405 box culvert would be contained within the existing storm water system[2]. A substation owned by SCE is located across Yukon Avenue to the east of the Site. A 10-foot-high noise-reduction wall runs adjacent to I-405 to the southeast of the Site, creating hydraulic separation of the Interstate from the NTWF Site.

The proposed 3 MG tank would be situated adjacent to a proposed on-site pump house (to the east), and will be approximately 118 feet in diameter, 50 feet above existing grade in the base design scenario (tank height includes 40-foot high vertical walls and a 10-foot high domed roof), and constructed of prestressed concrete. An overflow drain will be positioned in the tank to provide 3 feet of freeboard, so the maximum water depth in the tank will be 37 feet. A storm drain is included in the Site design and is discussed in detail in Section 2.8. The proposed mitigation measures for the three mitigation scenarios are discussed in Section 1.3.

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[1] Lang, Eric, *Email communication between Eric Lang (AECOM) and Casey Dick (AECOM) documenting information obtained from City of Torrance*. April 15, 2013.

[2] City of Torrance. *Telephone communications between Eric Lang (AECOM) and the City of Torrance discussing alternative design conditions*. November 2013.

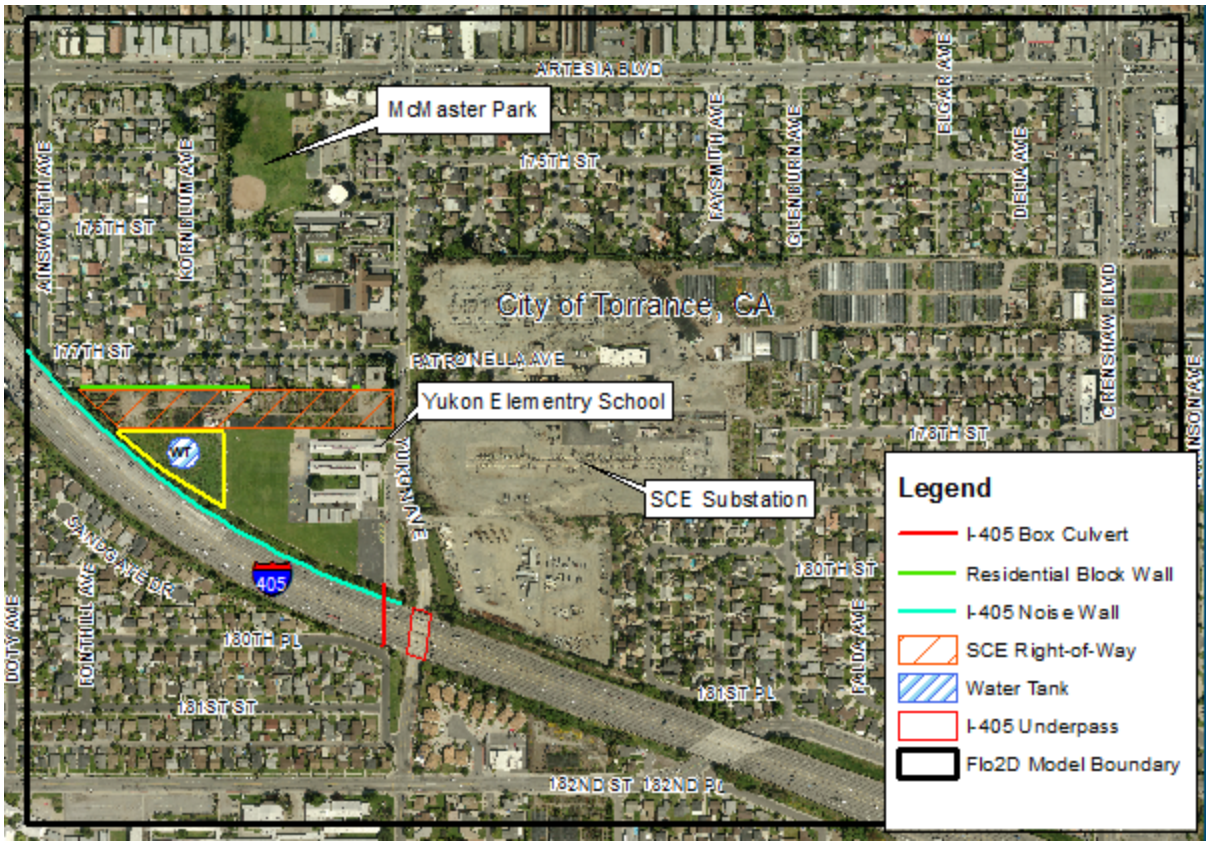


Figure 1. Site vicinity map (Source: USGS 2012[3]).

1.3 Impact Mitigation Measures

To help reduce the potential impacts associated with a hypothetical tank failure, the following two design measures were implemented into the second model scenario:

- Installation of an 8 foot solid block wall around the perimeter of the proposed NTWF Site boundary with two 30 foot wide gates located at the northwest and southeast corners of the boundary
- Partial burial of the tank 3 feet below existing site grade to reduce the effective head within the tank and the volume of water released during a tank failure event

The third model scenario included both of the mitigation measures described for Scenario 2,

[3] *USGS High Resolution State Orthoimagery for Los Angeles County, CA.* [Geospatial data] 1-foot pixel resolution. Sioux Falls, SD: U.S. Geological Survey, 2012. The National Map, http://viewer.nationalmap.gov/viewer/. Accessed March 13, 2013.

except the northwest access gate would be constructed and installed to provide water retention, causing water from a potential tank failure to leave the site through the southeast access gate.

The fourth scenario was developed to eliminate all off-site impacts due to a hypothetical tank failure by retaining all of the water on-site. The mitigation measures include:

- Lowering the average site grade by 1 foot to increase on-site storage capacity
- Installation of an 8-foot solid block wall around the perimeter of the proposed NTWF Site boundary with two 30-foot wide gates located at the northwest and southeast corners of the boundary
- Installation of 3-foot high flood gates across the northwest and southeast access gates
- Partial burial of the tank 20 feet below existing site grade leaving 30 feet of the tank exposed above grade (20 feet of vertical tank walls and the 10-foot domed roof) to reduce the effective head within the tank and the volume of water released in the event of a tank failure.

All of the above described mitigation measures were developed under direction of the City[2], and this study did not analyze the constructability or structural feasibility of any of the impact mitigation measures. If adopted as part of the final design, these impact mitigation measures will require further study. The mitigation measures for Scenarios 2 and 3 were represented in the FLO-2D model according to the methodology discussed in Sections 2.1 and 2.6 of this report. Volume calculations indicate that the Scenario 4 mitigation measures provide adequate storage capacity to retain all water from a hypothetical tank failure on-site and it was therefore not necessary to model this scenario in FLO-2D (calculations contained in Appendix C). In addition to impact mitigation measures, tank failure mitigation measures were considered and are discussed in the following section.

1.4 Tank Failure Mitigation Measures

Based on input from DN Tanks, a reputable prestressed concrete tank manufacturer[4], there are several options for increasing the conservatism of water storage tank designs to reduce the risk of failure. DN tanks are constructed of prestressed concrete which were found to sustain less damage than tanks constructed of steel during the 6.7 magnitude 1994 Northridge

[4] DN Tanks, *Email communication between Eli Gruber (AECOM) and Kevin Peacock (DN Tanks)*. December 30, 2013.

Earthquake[5]. According to DN tanks, at the time of the Northridge Earthquake, 22 DN prestressed concrete water storage tanks were in service within 30 miles of the epicenter, none of which sustained significant damage and all 22 are still in service[4]. It was also observed that pre-stressed concrete tanks installed partially or completely below grade performed better than those installed fully above grade[5]. Therefore, installation of the proposed NTWF water storage tank partially below grade as an impact mitigation measure will also likely decrease the risk of a potential tank failure. According to Mr. Peacock, the backfill must be uniform around the tank, thereby reducing the anticipated seismic load imposed on the tank.

[5]Earthquake Spectra, Northridge Earthquake Reconnaissance Report, Vol. 1, Supplement C (April 1995), pp. 162-168.

2. METHODOLOGY

FLO-2D was used to simulate the hydraulic conditions and associated inundation that would result from the rapid release of water due to a hypothetical tank failure for Scenarios 1, 2 and 3. FLO-2D is a two-dimensional hydraulic model used for dynamic flood routing of overland and channelized flow. It is well-suited to modeling this water tank failure due to the two-dimensional flow patterns created by the rapid release of water and the flat floodplain-like topography. The model solves the full dynamic wave momentum equation using a central finite difference scheme to route the flood across square computational grid cells.

Inputs to the FLO-2D model include topographic data, ground surface and soil attributes (surface roughness and abstraction), infiltration parameters, inflow/outflow conditions, and significant hydraulic structures as described in the following sections. Components of the existing storm sewer network in the immediate vicinity of the Site were considered in this study, and implemented into the model (i.e., the I-405 box culvert and the Yukon Ave. / I-405 Underpass pump). Although other components of the existing storm sewer network may provide some flood attenuation following a tank failure, it is anticipated that they would not drain a significant portion of the initial tank failure wave due to the relative capacity of the storm sewer network compared to the magnitude of the initial flood surge. Therefore, to provide conservative estimates of inundation, additional components of the existing storm sewer network were not considered as part of this study.

2.1 Topography

The ground surface was represented in the FLO-2D model as a grid consisting of 10-foot by 10-foot square grid cells with elevation values interpolated from a digital terrain model (DTM). The size of the grid cells used in FLO-2D was established by balancing acceptable accuracy of results with computational time. For this study, it was determined that a 10-foot grid cell size would provide the optimal combination of accuracy of results and model stability. Therefore, the ground surface representation used in this study was generated by down-sampling (reducing the resolution of) a 5-foot horizontal resolution DTM[6] to a 10-foot horizontal resolution dataset.

[6] *Los Angeles Region Imagery Acquisition Consortium Digital Elevation Model (LARIAC.DEM).* [Geospatial data] 5-foot horizontal resolution. Sterling, VA: Infotech Enterprises America, Inc. 2006. Acquired via FTP: http://egis3.lacounty.gov/public with access granted by Mark Greninger (County of Los Angeles Chief Information Office) on March 13, 2013.

In addition to the existing topography, there are several block walls of varying heights in the vicinity of the Site that are not represented in the DTM. These include walls associated with the residences north of the 150-foot SCE right-of-way, the noise barrier wall running alongside I-405, and the impact mitigation block wall proposed as part of the NTWF Project described in Section 1.3 (Scenarios 2 and 3). The block walls in the vicinity of the Site were represented in the FLO-2D model by manually increasing the elevation of the associated grid cells by the nominal height of each wall section[7]. The approximate locations and heights of the block walls included in the model are shown in Figure 2.

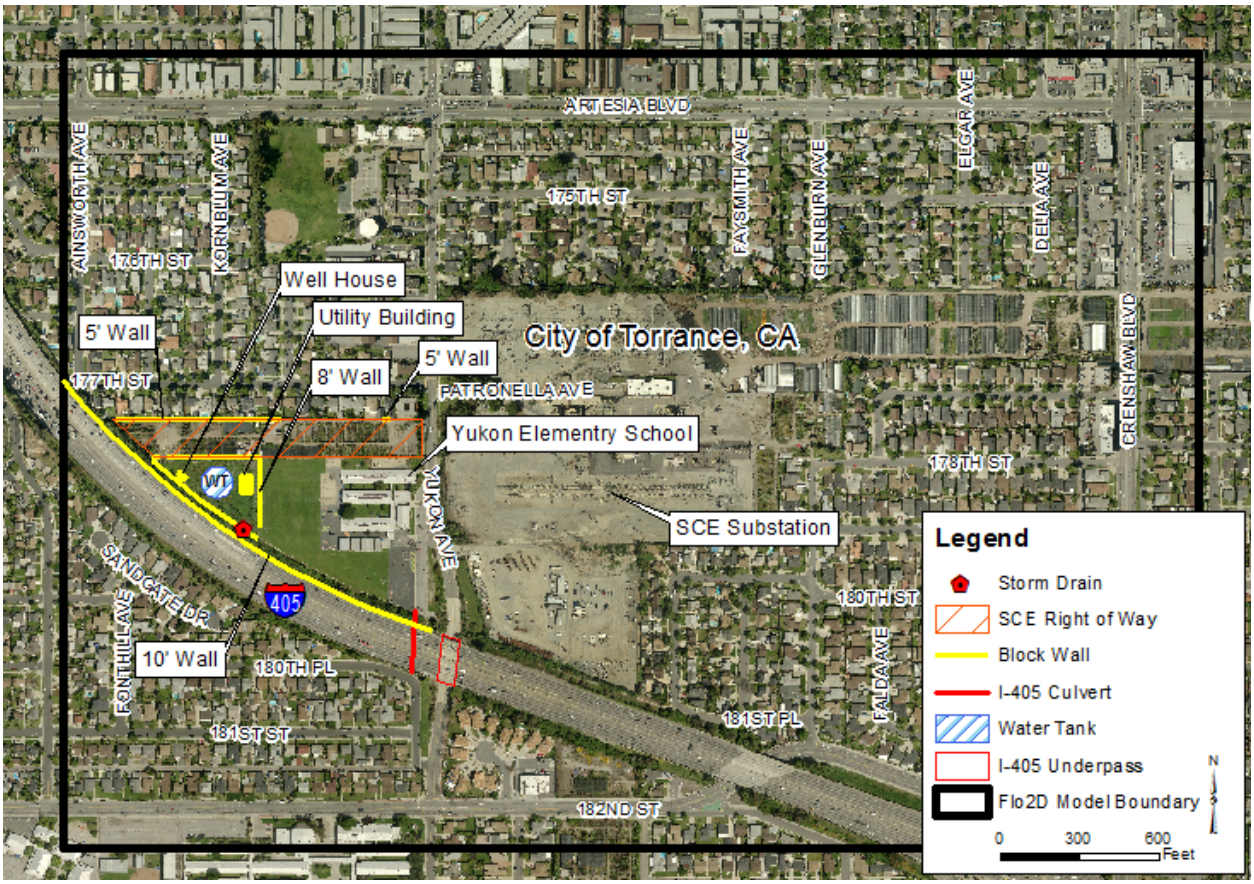


Figure 2. Locations of block walls and proposed structures.

[7] Approximate block wall locations and heights were provided via email by Martin Emmanuel (Associate Engineer, City of Torrance) on March 25, 2013.

Two additional structures proposed as part of the NTWF project include a well house and a utility building (locations shown on Figure 2). These two proposed structures were similarly represented in the topographic dataset by manually raising the elevations of the associated grid cells because the structures do not exist in the DTM.

2.2 Surface Roughness

FLO-2D uses the Manning's n coefficient to account for the effects of surface roughness on overland flow. The Manning's n roughness values used in FLO-2D are specific to overland flow computations[8], and are significantly higher than the Manning's n value specific to open channel flow computations[9]. Manning's n values were spatially distributed within the computational domain of the model using aerial imagery to delineate the different types of land cover within the study area. Similar land types (e.g., residential, pavement, grass) were identified and grouped together. Manning's n values were assigned to each land-cover type based on typical values for overland flow[8]. Figure 3 shows the spatial distribution of Manning's n values used in the FLO-2D model.

[8] FLO-2D Software Inc., FLO-2D Reference Manual (Version 2009), 2009.

[9] Army Corps of Engineers, HEC-1 Manual (1990) and Technical Engineering Design Guide, No. 19 (1997).

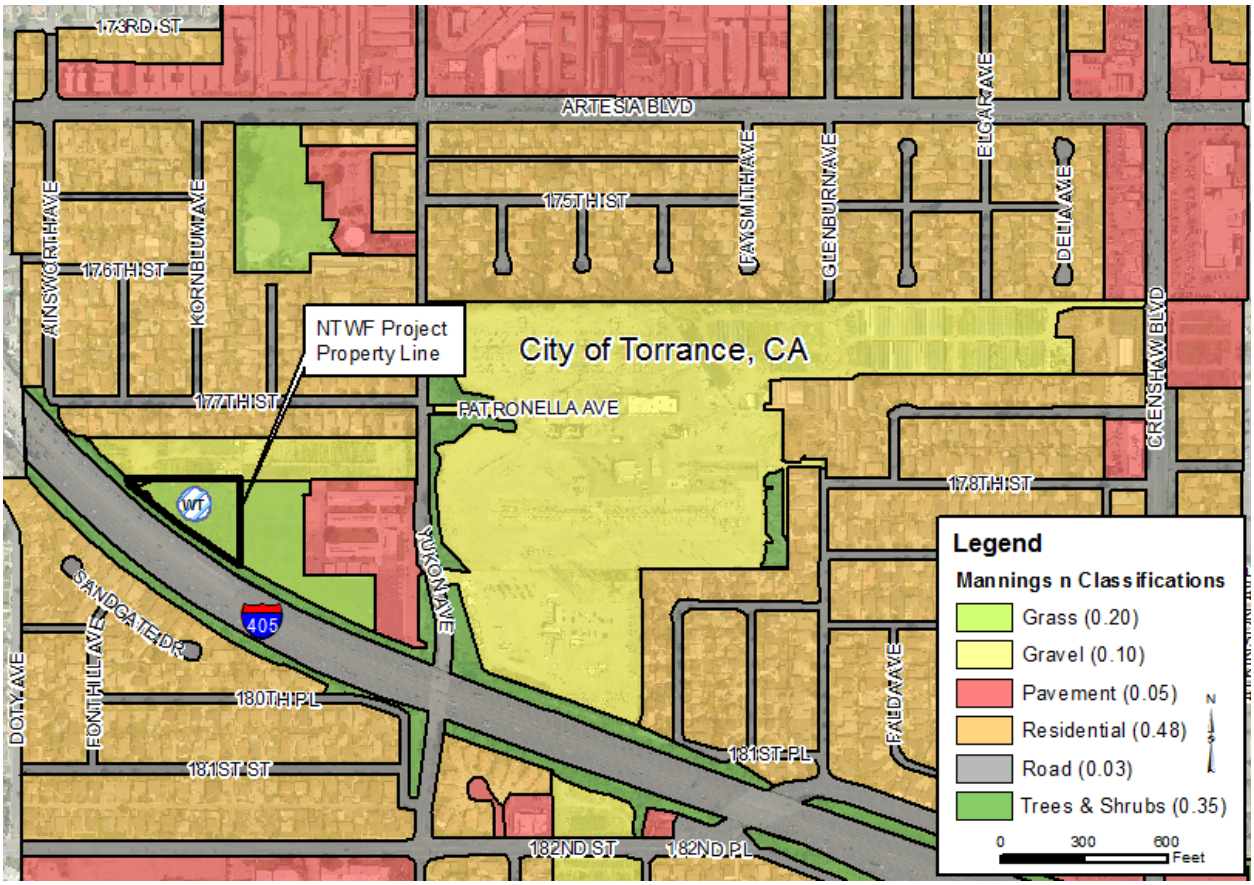


Figure 3. Spatial distribution of Manning's n values within the study area.

2.3 Surface Abstraction

Surface abstraction refers to the amount of water lost to depression storage, evaporation, and interception during a hydrologic event. FLO-2D accounts for surface abstraction with the user defined variable TOLER (a required input file in FLO-2D). Flood routing is not to be performed for any flow depth within a grid cell below the TOLER value. A TOLER value of 0.025 feet, representing urban areas[10], was specified for all model scenarios.

2.4 Infiltration Parameters

FLO-2D uses the Green-Ampt method to estimate infiltration, which is a physical infiltration model and depends on the following soil properties: hydraulic conductivity, soil suction, volumetric moisture deficiency, and percent impervious area[3]. The entire area of interest for

[10] FLO-2D Software Inc., FLO-2D Data Input Manual (Version 2009), 2009.

this study is comprised of Montezuma Clay Adobe as determined from a soil map obtained from the Los Angeles County GIS data portal[11]. This soil type is clay loam based on the gradation provided in United States Department of Agriculture (USDA) Soil Survey[12] and the USDA soil textural triangle[13]. The infiltration parameters were determined from reference tables provided in the FLO-2D reference manual[10].

2.5 Flow Analysis Cross-Sections

Fourteen (14) flow analysis cross-sections (XS-1 through XS-14) were established within the FLO-2D model. The flow analysis cross-sections are used to quantify the magnitude and timing of peak flow rate and total outflow volume at various locations within the study area. Locations of the flow analysis cross-sections were selected to capture the major flow paths throughout the study area based on preliminary model iterations. The cross-section locations are shown in Figure 4 (light blue lines).

[11] Los Angeles County. Data obtained from website on November 27, 2013. http://egis3.lacounty.gov/dataportal/2011/01/27/soil-types/.

[12] USDA, E.C. Eckmann, *et al.*. *Soil Survey of the Anaheim Area, California*. Washington, DC (1916), pp 43-44.

[13] USDA Soil Textural Triangle. Downloaded from USDA web page on November 27, 2013. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/edu/?cid=nrcs142p2_054311.

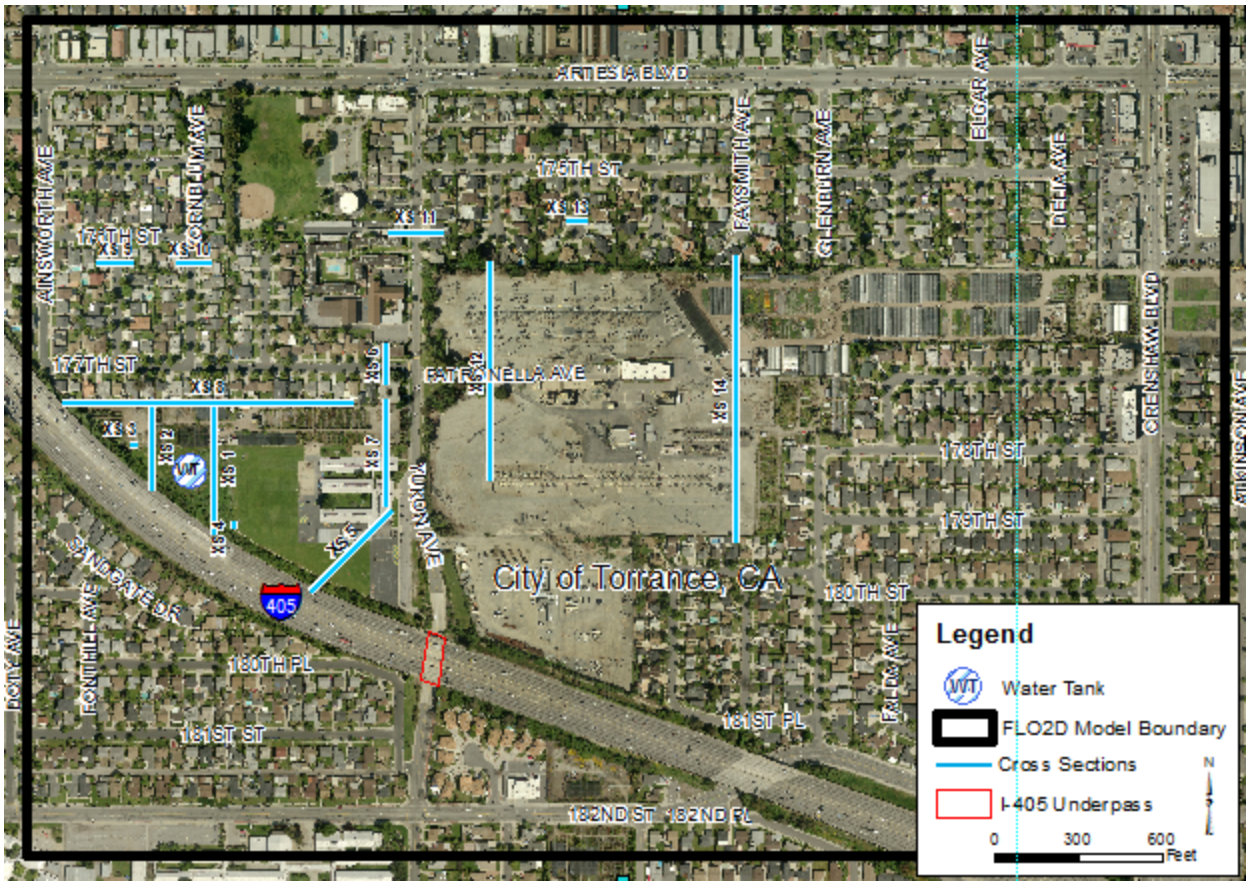


Figure 4. Flow analysis cross-section locations.

2.6 Tank Failure Hydrograph Development

A tank failure hydrograph was developed based on input from Eric Magee of DN Tanks[14]. As discussed in Section 1.4, prestressed concrete tanks have performed well in previous earthquakes, and additional conservatism can be implemented into the design to further reduce the potential of a tank failure. According to Mr. Magee, the most likely seismic-induced failure mechanism would be a separation of approximately 2 to 3 inches between the base and sidewalls of the tank. For the purposes of this study, the tank failure was simulated as a 2-inch opening between the sidewall and base around the circumference of the tank. Two tank failure rating curves were developed to simulate the base condition and the partially buried tank mitigation measure for Scenarios 2 and 3. The tank failure rating curves were developed for

[14] DN Tanks, *Telephone communication between Erin Gleason (AECOM) and Eric Magee, PE (DN Tanks)*. March 18, 2013.

varying head using the orifice equation[15] (Eq. 1):

$$Q = CA\sqrt{2\mathrm{gH}} \qquad \text{Eq. 1}$$

where

Q = Tank outflow in cubic feet per second (cfs)

C = Orifice coefficient

A = Cross-sectional area of outflow from the tank

H = Head of water in the tank (feet)

g = Acceleration due to gravity (32.2 feet per second)

The orifice coefficient was selected to be 0.55 based on the *Handbook of Hydraulics for the Solution of Hydraulic Engineering*[15]. The cross-sectional area of outflow used for the tank was determined by multiplying the tank circumference by the assumed 2-inch separation of the tank from the base due to failure. The initial above-grade head of water in the tank was 37 feet for Scenario 1 (3.00 MG) and 34 feet for Scenarios 2 and 3 (2.77 MG).

The tank failure hydrographs were generated using the rating curve and the tank geometry as input into HEC-1[16] to calculate the outflow hydrographs for use in the FLO-2D model. Figure 5 shows the outflow hydrographs used to simulate the outflow from the tank (with time) that would result from a hypothetical tank failure under the two design conditions.

[15] Brater, E.F., and King, H.W. (1918). Handbook of Hydraulics for the Solution of Hydraulic Engineering. McGraw-Hill Book Company, Inc., New York, NY.

[16] USACE (1998). *HEC-1: Flood Hydrograph Package, User's Manual*. Hydrologic Engineering Center, U.S. Army Corps of Engineers, Davis, CA.

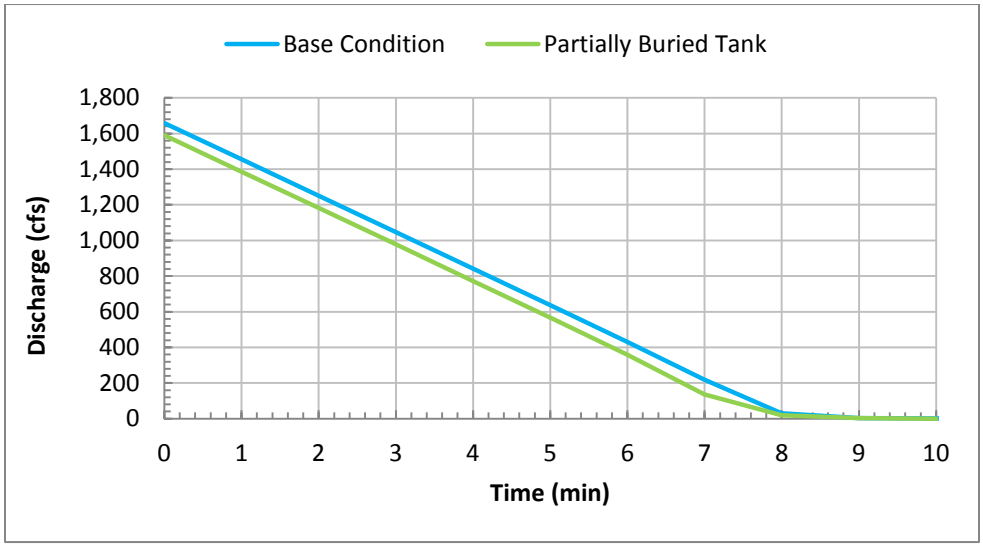


Figure 5. Tank failure outflow hydrographs.

2.7 Yukon Avenue / I-405 Underpass Evacuation Pumping

The Yukon Avenue / I-405 underpass is a low area to the southeast of the Site that collects local surface water runoff. A 7.5-horsepower pump[1] is used to evacuate stormwater from the underpass. Due to limited information on the configuration of the evacuation pump system, the pumping capacity of the underpass evacuation pump was estimated using the basic hydraulic power equation (Eq. 2):

$$Q_p = \frac{\eta_p W_h}{\gamma(H_p - H_s)} \qquad \text{Eq. 2}$$

where

Q_p = Pump discharge (cfs)

η_p = Pump efficiency

W_h = Pump power (ft-lb/s)

γ = Specific weight of fluid being pumped (lb/ft^3)

H_p = Pumping head (ft)

H_s = Submersion depth (taken as depth of water (ft) above lowest point in underpass)

The pump was assumed to be pumping water (γ = 62.4 pounds per cubic foot [lb/ft^3]) at 30 feet of total head (with no underpass submersion), at 50% efficiency. A relationship was developed between submersion depth in the underpass and pumping rate of the evacuation pump by increasing H_s values in Equation 2 by 1 foot increments between 0 feet and 15 feet. Figure 6 shows the resulting relationship.

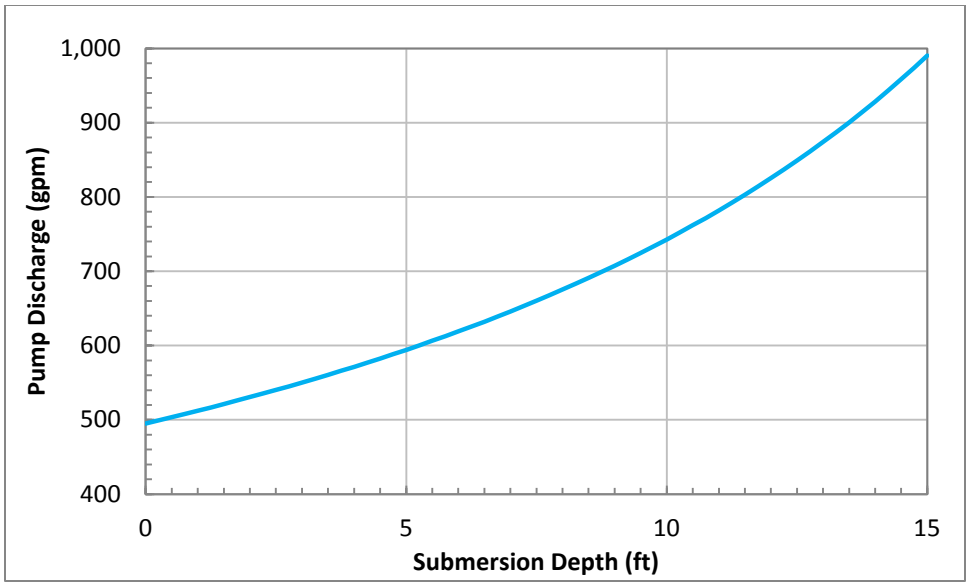


Figure 6. Rating curve for underpass evacuation pump.

2.8 On-Site Storm Drain

Based on preliminary design drawings[17], it was assumed that a 30-inch-diameter storm sewer pipe will be installed to convey stormwater and tank drainage from the Site to the existing storm sewer network. The on-site storm drain was simulated in the FLO-2D model to account for water that would be drained from the Site in the event of a tank failure. It was assumed that the inlet to this pipe would have a higher flow capacity than the pipe itself, and therefore the pipe capacity was the limiting factor[1]. A stage-discharge relationship was developed using the US Environmental Protection Agency's Storm Water Management Model Version 5 (SWMM 5). The model was developed to replicate design drawings for the pipe network that connected the Site drainage to the main storm sewer network. The model assumed a concrete pipe, with an invert elevation equal to ground surface.

Figure 7 shows the head-discharge relationship for the storm drain, where head is measured from the invert of the pipe.

[17] AECOM, 2013, *Construction of North Torrance Well Field Project, C.I.P. No. I-108 (30% Design Plans)*, Plotted November 22, 2011.

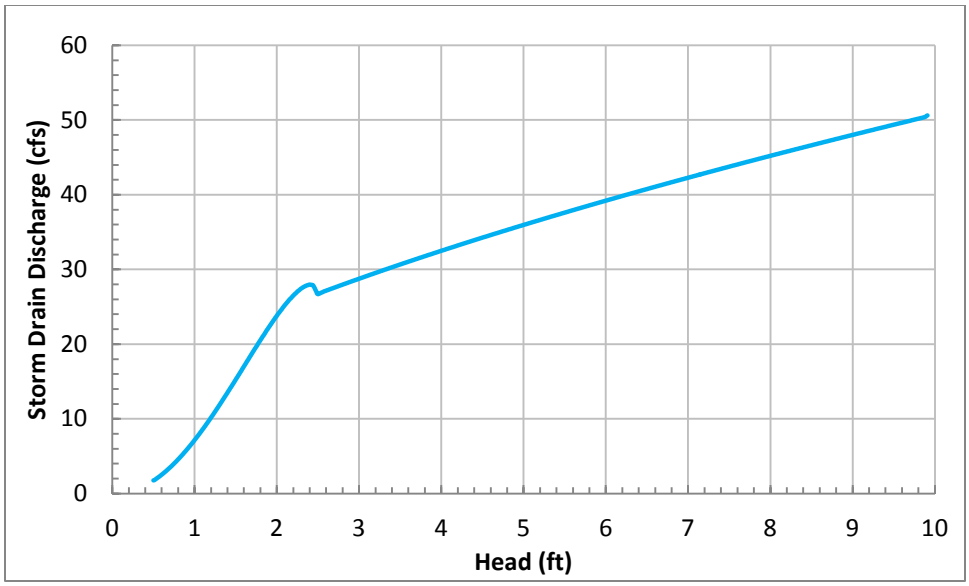


Figure 7. Rating curve for on-site storm drain.

2.9 I-405 Box Culvert

Based on storm drain plans provided by the City[1], an existing 4-foot by 2-foot box culvert that conveys surface water flows from north to south under I-405 was identified and included in the FLO-2D model. The inlet to the I-405 box culvert is located near the southeast corner of the Yukon Elementary parking lot. The I-405 box culvert is designed to intercept drainage from the northwest, including portions of the project site, before it enters the Yukon Ave. / I-405 underpass. An earthen channel collects and routes drainage along the northeastern noise-barrier wall for I-405 toward the culvert inlet. Under current conditions, the culvert passes drainage under I-405 and discharges directly onto the street surface of 180th Place. Per conversations with the City, in order to eliminate impacts south of I-405, flows will either be passed directly into the storm sewer network or through a detention pond (to be constructed) to attenuate the flood waters passed through the culvert. Therefore, all of the water passed through the culvert is assumed to exit the model domain. A stage-discharge relationship was developed for the I-405 box culvert using Bentley CulvertMaster. Inputs for the rating curve calculations were taken directly from the storm drain plans provided by the City, and are listed below:

- Slope = 0.11%
- Size = 4 ft. X 2 ft.
- Pipe length ~ 210 ft. (scaled from drawing)
- Mannings n = 0.013 (assumed based on a concrete pipe)
- No tailwater (assumed condition)

Figure 8 shows the head-discharge relationship for the storm drain, where head is measured from the invert of the culvert inlet.

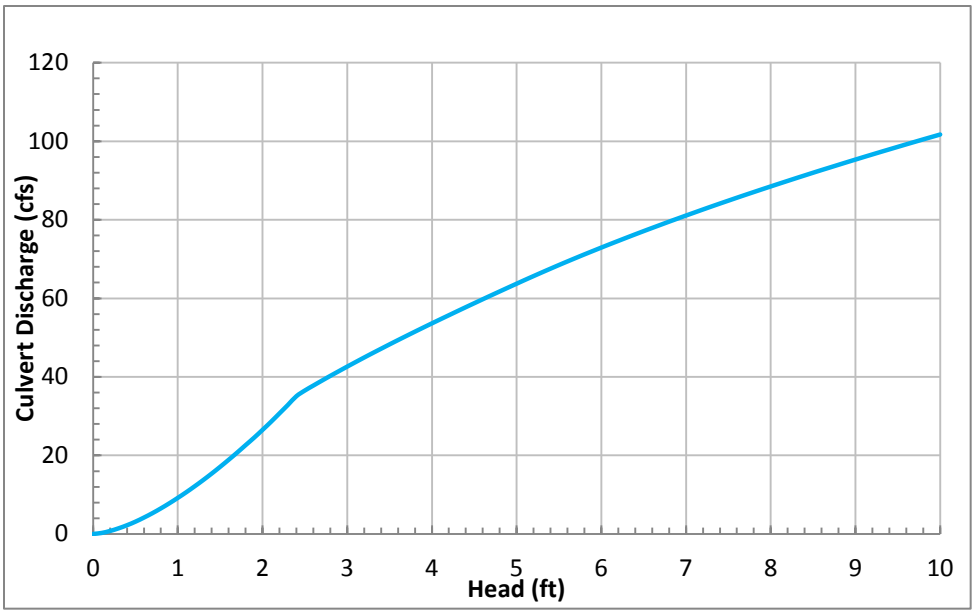


Figure 8. Rating curve for I-405 box culvert.

3. RESULTS

Scenarios 1, 2, and 3 were each run for a simulation time of 4 hours, which was a sufficient amount of time to establish the maximum inundated area and allow flows to subside to a level at which it is anticipated the storm sewer network would capture the remaining inundation. Inundation maps were created for the three scenarios to display the limits of flooding and the critical infrastructure impacted due to a hypothetical tank failure. The inundation maps including maximum flow depth, final flow depth, maximum velocity, and final velocity for all three scenarios are presented in Appendix A as shown in Table 1.

Table 1. Map key.

Map ID	Map Description
1A	Maximum Flow Depth (Scenario 1)
1B	Maximum Flow Depth (Scenario 2)
1C	Maximum Flow Depth (Scenario 3)
2A	Final Flow Depth (Scenario 1)
2B	Final Flow Depth (Scenario 2)
2C	Final Flow Depth (Scenario 3)
3A	Maximum Velocity (Scenario 1)
3B	Maximum Velocity (Scenario 2)
3C	Maximum Velocity (Scenario 3)
4A	Final Velocity (Scenario 1)
4B	Final Velocity (Scenario 2)
4C	Final Velocity (Scenario 3)

Scenario 4 was not modeled, but the volume calculations are presented and discussed in the following section.

3.1 Inundation Mapping and Impact Analysis

Scenario 1: Base Condition – No Mitigation Measures

Maps 1A and 2A show the maximum flow depths (inundation limits) and final flow depths (after 4 hours), respectively, for Scenario 1. The total inundated area during this simulation was 28.3 acres. After 4 hours of simulation time, most of the water remaining in the study area had accumulated in low areas and streets, with a final inundated area of 15.3 acres. The largest flow depths were along the I-405 wall directly south of the Site (5.3 feet) and in the Yukon Ave. / I-405 underpass (5.3 feet).

Maps 3A and 4A show the maximum and final velocities, respectively, for Scenario 1. The largest velocities were approximately 9 feet per second (fps) which occurred in the entrance to the Yukon Ave. / I-405 underpass and were attributable to a steep slope and flow constriction resulting in acceleration of flows into the underpass. Maximum velocities immediately adjacent to the tank were approximately 2 to 3 fps. Maximum velocities in the roads ranged from 0.5 fps to 3 fps. The final velocities did not exceed 0.5 fps anywhere in the study area, except for isolated areas in the underpass where velocities were 2 to 3 fps.

Under Scenario 1, water flowed away from the Site in three primary directions: north, through the SCE right-of-way and around the residential property walls; east, along the SCE right-of-way north of Yukon Elementary toward the SCE substation; and southeast, along the noise-barrier wall bordering I-405 to the south of Yukon Elementary and toward the Yukon Ave. / I-405 underpass. Flows traveling to the north became channelized within the streets (i.e., 177th St., Fonthill Ave., Kornblum Ave., Artesia Blvd.) after passing through (and impacting) several residential properties where there are breaks in the residential property wall. The flows in the streets were generally less than 1 to 2 feet deep. Flows traveling east divided and either, continued to the east impacting several buildings and the SCE substation parking area, traveled to the north channelizing along Yukon Ave., or flowed to the northeast across residential properties north of the SCE substation and eventually channelized in streets (i.e., Cerise Ave., 175th St., Faysmith Ave., Artesia Blvd.) toward the model boundary along Artesia Boulevard. The flows to the northeast reached maximum depths of approximately 1 to 2 feet. The flows toward the southeast generally remained south of Yukon elementary, but appeared to impact several of the southern buildings at Yukon Elementary and eventually flowed through the I-405 culvert or accumulated in the Yukon Avenue / I-405 underpass. Flows near the Yukon elementary School buildings ranged from 0.5 feet to 1.5 feet. The on-site storm drain, the I-405 culvert, and the Yukon Ave. /I-405 underpass conveyed approximately 1.2 ac-ft (ac-ft), 0.7 ac-ft, and 0.4 ac-ft of water, respectively (not including volume remaining stored at the end of the 4-hour simulation – see Section 3.2). At the end of the 4 hour simulation, approximately 1.9 ac-ft (20% of the total tank volume) of water had infiltrated into the soil.

Scenario 2: Site Walls with Open Gates and Partially Buried Tank

Maps 1B and 2B show the maximum flow depths and final flow depths (after 4 hours), respectively, for Scenario 2. The total inundated area during this simulation was 21 acres, slightly less than the total for Scenario 1. The final inundated area at 4 hours for Scenario 2 was 11.6 acres. The largest flow depth was approximately 7.2 feet, which occurred in the Yukon Ave. / I-405 underpass. Immediately adjacent to the tank (within the site walls) the maximum

flow depth was approximately 6.6 feet.

Maps 3B and 4B show the maximum and final velocities, respectively, for Scenario 2. The largest velocities were approximately 12 feet per second (fps) which occurred in the entrance to the Yukon Ave. / I-405 underpass and were attributable to a steep slope and flow constriction resulting in acceleration of flows into the underpass. Maximum velocities immediately adjacent to the tank and at the north and south site wall gates were approximately 4 to 6 fps. These higher velocities occurred in isolated areas and are not easily distinguishable on Map 3B. Slightly lower maximum velocities (between 2 and 4 fps) were more prevalent within the site walls. The final velocities did not exceed 0.5 fps anywhere in the study area, except for isolated areas in the underpass where velocities were higher (4 to 6 fps).

Under Scenario 2, water exited the site through the north and south access gates in the site walls (the site walls are not overtopped) and had the same general flow patterns that were observed in the Scenario 1 model results. Water flowed away from the site to the north around the residential property wall, to the east along the SCE right-of-way north of Yukon Elementary, and to the southeast toward the Yukon Ave. / I-405 underpass. Flow depth and inundation around Yukon Elementary School increased slightly compared to the base conditions scenario. The on-site storm drain, the I-405 culvert, and the Yukon Ave. /I-405 underpass conveyed approximately 1.4 ac-ft, 1.0 ac-ft, and 0.4 ac-ft of water, respectively (not including volume remaining stored at the end of the 4-hour simulation – see Section 3.2). At the end of the 4 hour simulation, approximately 1.4 ac-ft (16% of the total tank volume) of water had infiltrated into the soil.

Scenario 3: Site Walls with Closed North Gate, Open South Gate, and Partially Buried Tank

Maps 1C and 2C show the maximum flow depths and final flow depths (after 4 hours), respectively, for Scenario 3. The total inundated area during this simulation was 6.9 acres, significantly less than the totals for Scenario 1 and Scenario 2. The final inundated area at 4 hours for Scenario 2 was 2.5 acres, with virtually all of the water accumulating in the Yukon Ave. / I-405 underpass. The largest flow depth was approximately 10.4 feet, which occurred in the Yukon Ave. / I-405 underpass. Immediately adjacent to the tank (within the site walls) the maximum flow depth was approximately 7.2 feet.

Maps 3C and 4C show the maximum and final velocities, respectively, for Scenario 3. The largest velocities were approximately 18 feet per second (fps) which occurred in the entrance to the Yukon Ave. / I-405 underpass and were attributable to a steep slope and flow constriction resulting in acceleration of flows into the underpass. Maximum velocities

immediately adjacent to the tank and at the south gate of the site wall were approximately 4 to 6 fps. These higher velocities occurred in isolated areas and are not easily distinguishable on Map 3C. Slightly lower maximum velocities between 2 and 4 fps were more prevalent within the site walls. Maximum velocities in the roads ranged from 0.5 fps to 3 fps. The final velocities did not exceed 0.5 fps anywhere in the study area, except for isolated areas in the underpass where velocities were slightly higher (4 to 6 fps).

Under Scenario 3, all of the water was forced to leave the site through the south access gate (site walls are not overtopped) toward the Yukon Ave. / I-405 underpass. The southern Yukon Elementary buildings were impacted with flow depths up to approximately 2 feet. Eventually all of the water that did not infiltrate was conveyed to the existing storm sewer network (or a proposed stormwater detention pond) via the on-site drain, I-405 culvert, or the underpass pump. The on-site storm drain, the I-405 culvert, and the Yukon Ave. /I-405 underpass conveyed approximately 1.8 ac-ft, 1.3 ac-ft, and 0.5 ac-ft of water, respectively (not including volume remaining stored at the end of the 4-hour simulation – see Section 3.2). At the end of the 4 hour simulation, approximately 0.4 ac-ft (7% of the total tank volume) of water had infiltrated into the soil.

Scenario 4: Site Walls with Flood Gates, Lowered Site Grade, and Partially Buried Tank

The impact mitigation measures proposed under this scenario are intended to eliminate all offsite impacts. The optimal combination of flood gate height, site grade elevation, and tank burial depth was selected based on cost and system functionality. Approximately 1.66 MG of the total 3 MG tank volume is accounted for by burial of the tank 20 feet below the lowered site grade. The remaining 1.34 MG can be retained on site assuming an effective site area of approximately 1 acre (total area less on-site structures) and 4 feet of depth (lowered grade of 1-foot in addition to 3-foot high flood gates). Controlled drainage from the site to the storm sewer system would occur via the on-site drainage structures. Based on these volumes, it will require approximately 147 minutes to drain water from the site through the site drain, as described in Appendix C. Design of these structures was beyond the scope of this study.

3.2 Yukon Avenue / I-405 Underpass Evacuation Pumping

The underpass pump evacuated water continuously during the simulations based on the rating curve described in Section 2.8. At the end of each of the 4-hour simulations, a significant amount of water remained pooled in the underpass. The remaining volume of water pooled in the underpass at the end of each simulation was determined to be approximately 0.8 ac-ft for Scenario 1, 1.7 ac-ft for Scenario 2, and 3.6 ac-ft for Scenario 3. The time required for the pump

to evacuate the volume of water remaining in the underpass following the 4-hr simulation was calculated using a stage-storage curve developed using the topography for the underpass area and the pump rating curve. Figure 9 shows the inundation depth in the underpass versus time starting at the end of the FLO-2D simulations for the three scenarios.

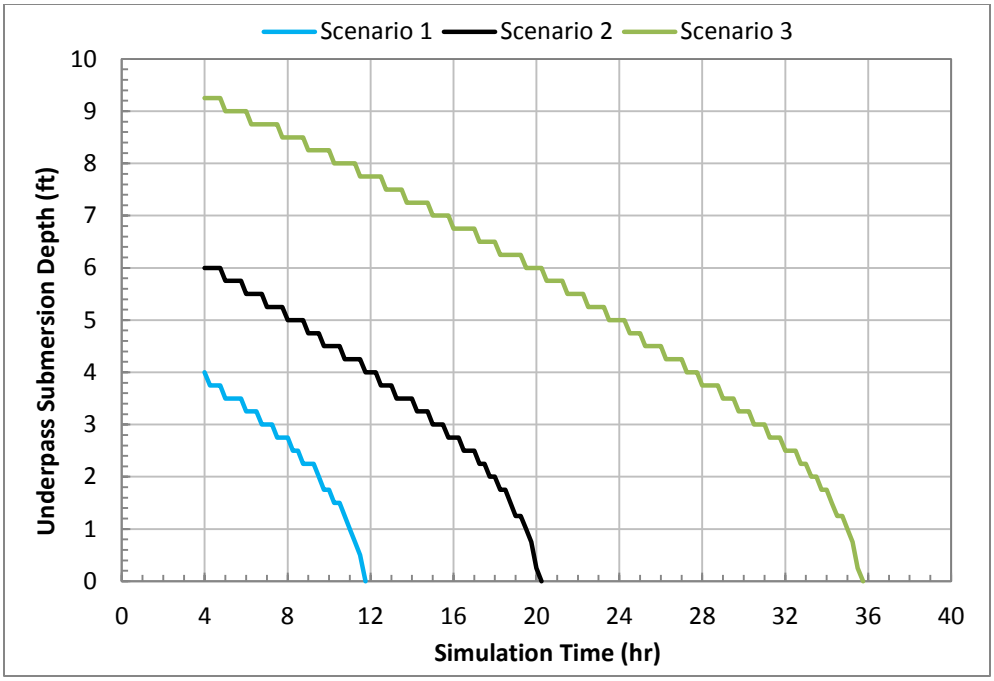


Figure 9. Depth of water in I-405 underpass vs. time following 4-hr FLO-2D simulation.

The time required for the evacuation pump to remove the water from the underpass was approximately 12 hours for Scenario 1, 20 hours for Scenario 2, and 36 hours for Scenario 3. The difference in the underpass evacuation times is a function of the site walls diverting water toward the underpass out of the south access gate, particularly in Scenario 3 where all of the water from the tank failure leaves the site through the south gate.

3.3 Flow Analysis Cross-Sections

Hydrographs for each of the flow analysis cross-sections are included in Appendix B. Table 2 provides a summary of the peak flow rates recorded at each of the cross-sections (locations shown in Figure 4) for scenarios 1, 2, and 3.

Table 2. Peak flow rates at flow analysis cross-sections.

Location	Peak Flow Rate (cfs)		
	Scenario 1	Scenario 2	Scenario 3
XS-1	577.8	448.7	507.2
XS-2	38.1	38.3	36.6
XS-3	14.1	260.6	0.0
XS-4	44.9	289.6	382.1
XS-5	52.6	74.9	127.6
XS-6	22.9	13.6	0.0
XS-7	30.9	1.9	0.0
XS-8	92.3	36.8	0.0
XS-9	2.3	2.4	0.0
XS-10	11.3	5.2	0.0
XS-11	3.5	0.6	0.0
XS-12	28.7	8.0	0.0
XS-13	12.2	4.0	0.0
XS-14	0.7	0.0	0.0

The magnitude of peak flow rates is helpful in comparing the movement of water throughout the study area for the three scenarios. The peak flows through cross-sections 1 and 2 are similar for the three scenarios as they represent the water discharging directly adjacent to the tank. It is important to note that the flow rates moving to the east away from the site are an order of magnitude greater than those moving to the west. Cross-sections 3 and 4 represent flow passing through the northwest and southeast access gates, respectively. High peak flows are observed through both gates for Scenario 2 and through the southeast gate for Scenario 3, as is expected. Cross-section 5 flows provide a good indication of the flows that eventually enter the Yukon Ave. / I-405 underpass, and the highest flow rates are observed in Scenario 3. Cross-sections 6 and 7 represent the water that flows to the east toward the SCE substation. Cross-sections 8, 9, and 10 give an indication of the amount of water that passes through the residential area to the north and into the residential streets.

4. CONCLUSIONS

A potential failure of the 3 MG water tank associated with the NTWF Project would cause a rapid release of water to the surrounding areas. A FLO-2D model was built to investigate the impacts from a hypothetical tank failure under three different design conditions, including the base conditions scenario and two scenarios with mitigation measures in place. Under the base conditions scenario (Scenario 1), approximately 28.3 acres would be inundated and impacted infrastructure would include: Yukon Elementary School, the SCE right-of-way, the SCE substation, proximal residential neighborhoods, and several residential roadways including the Yukon Ave. / I-405 underpass. The first mitigation scenario (Scenario 2) assumed partial burial of the tank (3 feet below grade) and construction of 8-foot block walls around the site (with two 30-foot wide access gates). Under these conditions, the inundated area would be reduced by approximately 25% to 21 acres, but the same infrastructure would be impacted as the base conditions scenario. The second mitigation scenario (Scenario 3) assumed the same mitigation measures as the first, except that the north gate would be constructed to contain water and force all of the water to drain from the site through the southeast gate. This mitigation scenario would reduce inundation by over 75% from the base condition to approximately 7 acres, and would limit the impacted infrastructure to Yukon Elementary and the Yukon Ave. / I-405 underpass. Additionally, a third mitigation scenario (Scenario 4) was developed to eliminate all impacts to surrounding areas by retaining all water on-site. This scenario would eliminate all inundation except for the Site area, which would be inundated by approximately 4 feet of water above the new site grade, or 3 feet above the original grade.

Most of the inundation under the first three design scenarios would occur as shallow overland flow with typical maximum flow depths of less than 3 feet and peak velocities of less than 3 fps. A combination of clayey soils and relatively small pervious areas in the vicinity of the site limit the amount of infiltration that would occur. Under Scenarios 2 and 3, the majority of the flow that did not pool in the underpass would either channelize in residential streets north and northeast of the Site, eventually flowing to Artesia Boulevard, or flow directly east past the SCE substation. The flows conveyed through the I-405 box culvert, the on-site storm drain, and/or the underpass pump were assumed to discharge to the existing storm sewer network, or a detention pond to provide controlled releases and attenuate the flood wave. Under Scenario 3, this would account for approximately 85% of the total tank volume. The block walls around the Site for Scenarios 2 and 3 would cause an increase of localized flow depths as water would be initially contained on-site. Scenario 3 would increase the flow depths around the southern buildings at Yukon Elementary, potentially increasing the impacts in this area. The deepest

inundation would occur in the Yukon Avenue / I-405 underpass area, with maximum depths of 5.3 feet, 6.6 feet, and 10.4 feet for Scenarios 1, 2, and 3, respectively. Based on the existing pump in the Yukon Avenue / I-405 underpass, it is estimated that it would take approximately 12 hours, 20 hours, and 36 hours to evacuate the pooled water from the underpass for Scenarios 1, 2, and 3, respectively. A traffic detour and control plan would need to be designed and implemented under these scenarios.

While this study did not consider the actual capacity of the existing storm sewer network outside the Site, it is anticipated that the inundation remaining at the end of the 4-hour simulation would be primarily contained within the streets and could be captured by the existing storm sewer network, or would be contained within the Yukon Ave. / I-405 underpass.

5. RECOMMENDATIONS

Of the design scenarios, the model results from this study indicate that the design conditions associated with Scenario 4 provide the most effective impact mitigation for a potential tank failure. Scenario 4 mitigates all off-site impacts including disruption to adjacent school and local traffic circulation, therefore flood inundation risks will be reduced to less than significant. It should also be noted that the installation of the tank 20 feet below grade will significantly decrease the risk of a tank failure. Additional analysis is needed with regard to the design strength of the mitigation measures to ensure that in the event of a tank failure, the elements of that measure function as assumed in this study and comply with all applicable building codes.

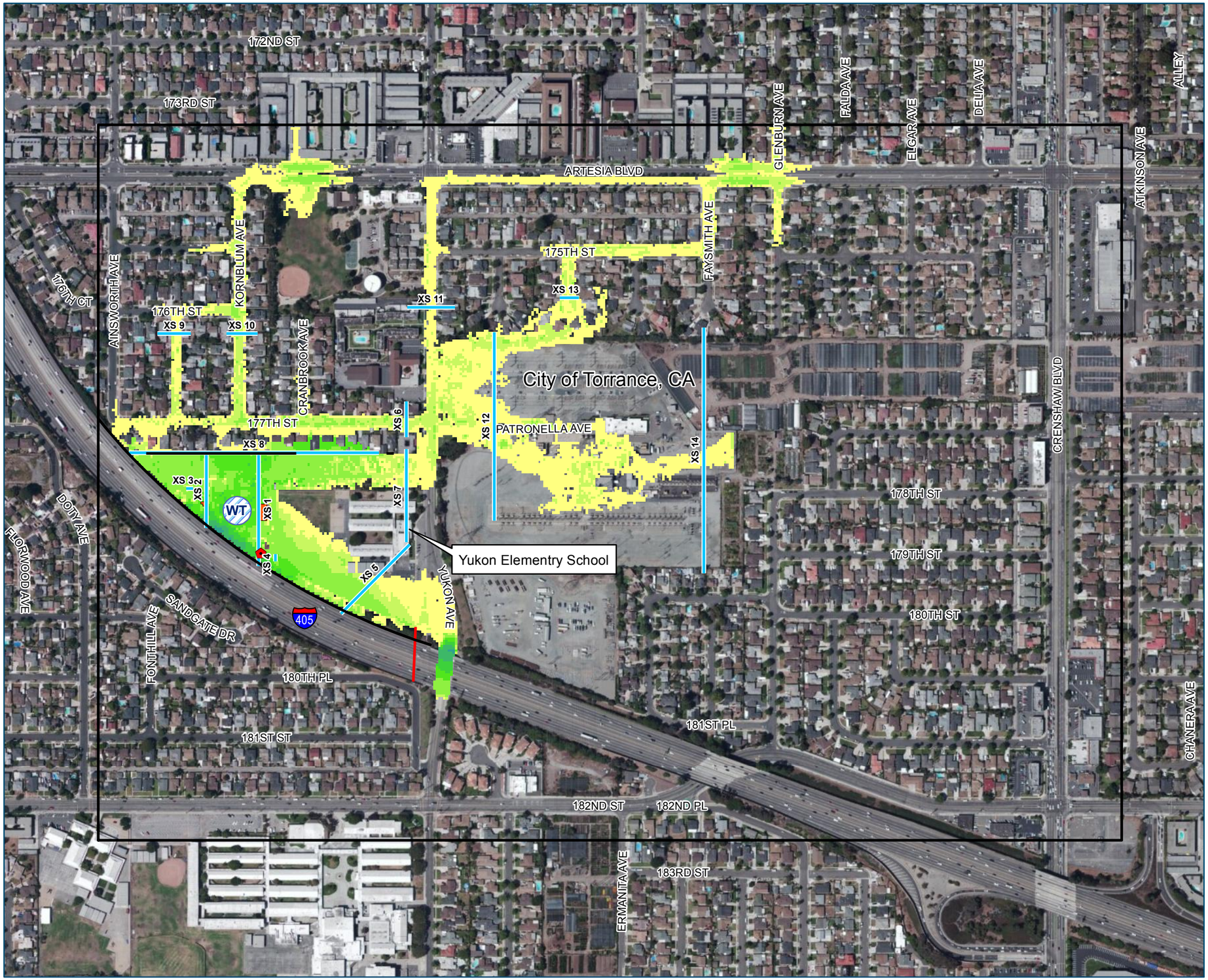
APPENDIX A

Inundation Maps

Water Tank Failure Analysis

City of Torrance, CA 1/29/2014

MAP 1A - MAXIMUM FLOW DEPTH
SCENARIO 1 - BASE CONDITION
NO MITIGATION MEASURES



LEGEND

- Water Tank
- Storm Drain
- On-Site Buildings
- Flo2D Model Boundary
- Block Wall
- I-405 Box Culvert

Maximum Depth (Feet)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 7.0
- 7.0 - 8.0
- 8.0 - 9.0
- 9.0 - 10.0
- > 10

0 200 400 Feet

N

PROJECT LOCATOR MAP

File Name: FIG_1A_BaseCondition_MaxDepth
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PDF File Path: Torrance\60287821\GIS\Maps
Date Modified: December 30, 2013
Projection: NAD 1983 State Plane, California V, Feet
Data Sources: ESRI, USGS, US Census, LAR-IAC

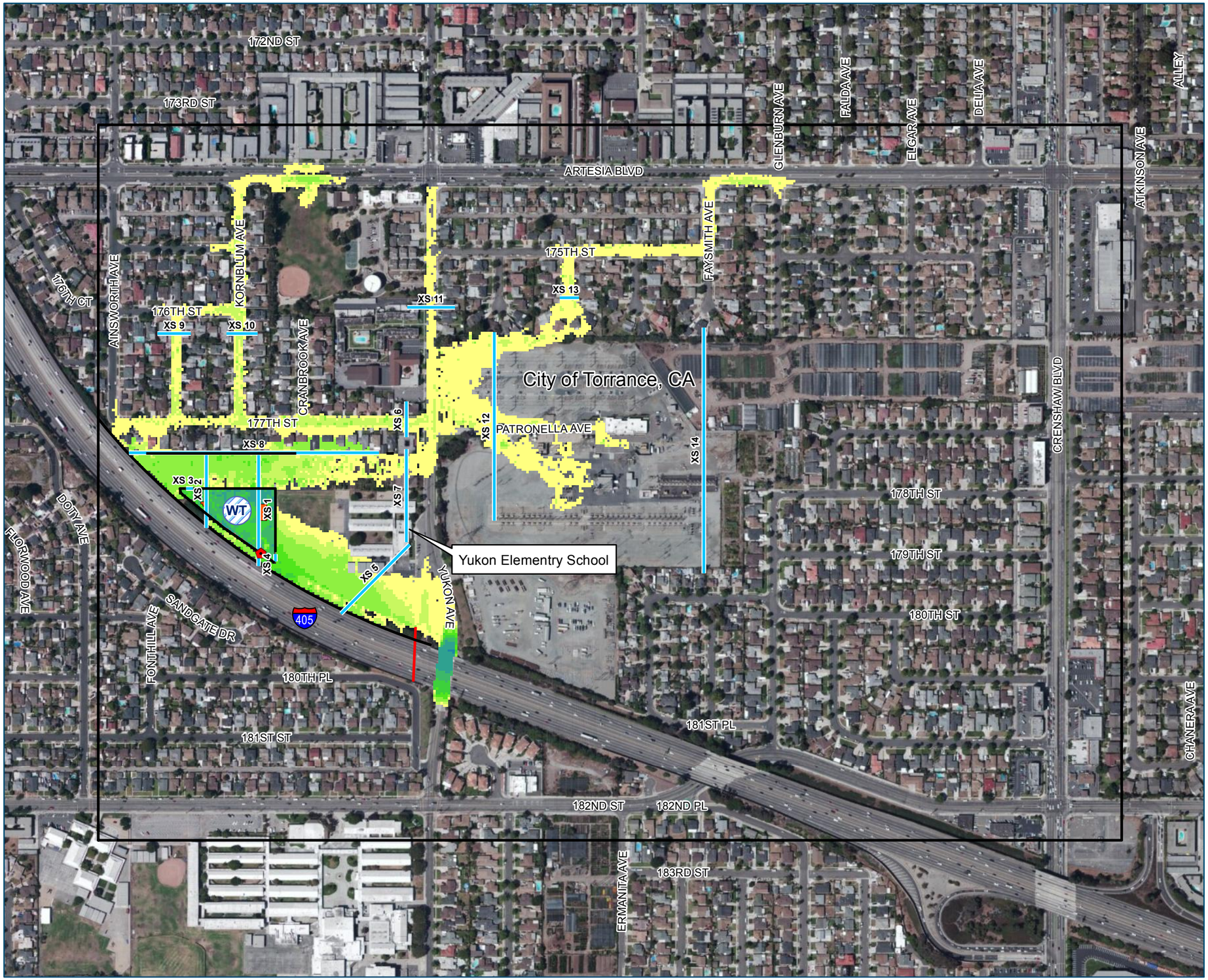
AECOM

Water Tank Failure Analysis

City of Torrance, CA 1/29/2014

MAP 1B - MAXIMUM FLOW DEPTH

SCENARIO 2 - SITE WALLS WITH OPEN GATES AND PARTIALLY BURIED TANK



LEGEND

- Water Tank
- Storm Drain
- On-Site Buildings
- Flo2D Model Boundary
- Block Wall
- I-405 Box Culvert

Maximum Depth (Feet)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 7.0
- 7.0 - 8.0
- 8.0 - 9.0
- 9.0 - 10.0
- > 10

0 200 400 Feet

N

PROJECT LOCATOR MAP

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Projection: NAD 1983 State Plane, California V, Feet
Data Sources: ESRI, USGS, US Census, LAR-IAC

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Water Tank Failure Analysis

City of Torrance, CA 1/29/2014

MAP 1C - MAXIMUM FLOW DEPTH

SCENARIO 3 - SITE WALLS WITH CLOSED NORTH GATE, OPEN SOUTH GATE AND PARTIALLY BURIED TANK

LEGEND

- Water Tank
- Storm Drain
- On-Site Buildings
- Flo2D Model Boundary
- Block Wall
- I-405 Box Culvert
- Closed North Gate

Maximum Depth (Feet)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 7.0
- 7.0 - 8.0
- 8.0 - 9.0
- 9.0 - 10.0
- > 10

0 200 400 Feet

N

PROJECT LOCATOR MAP

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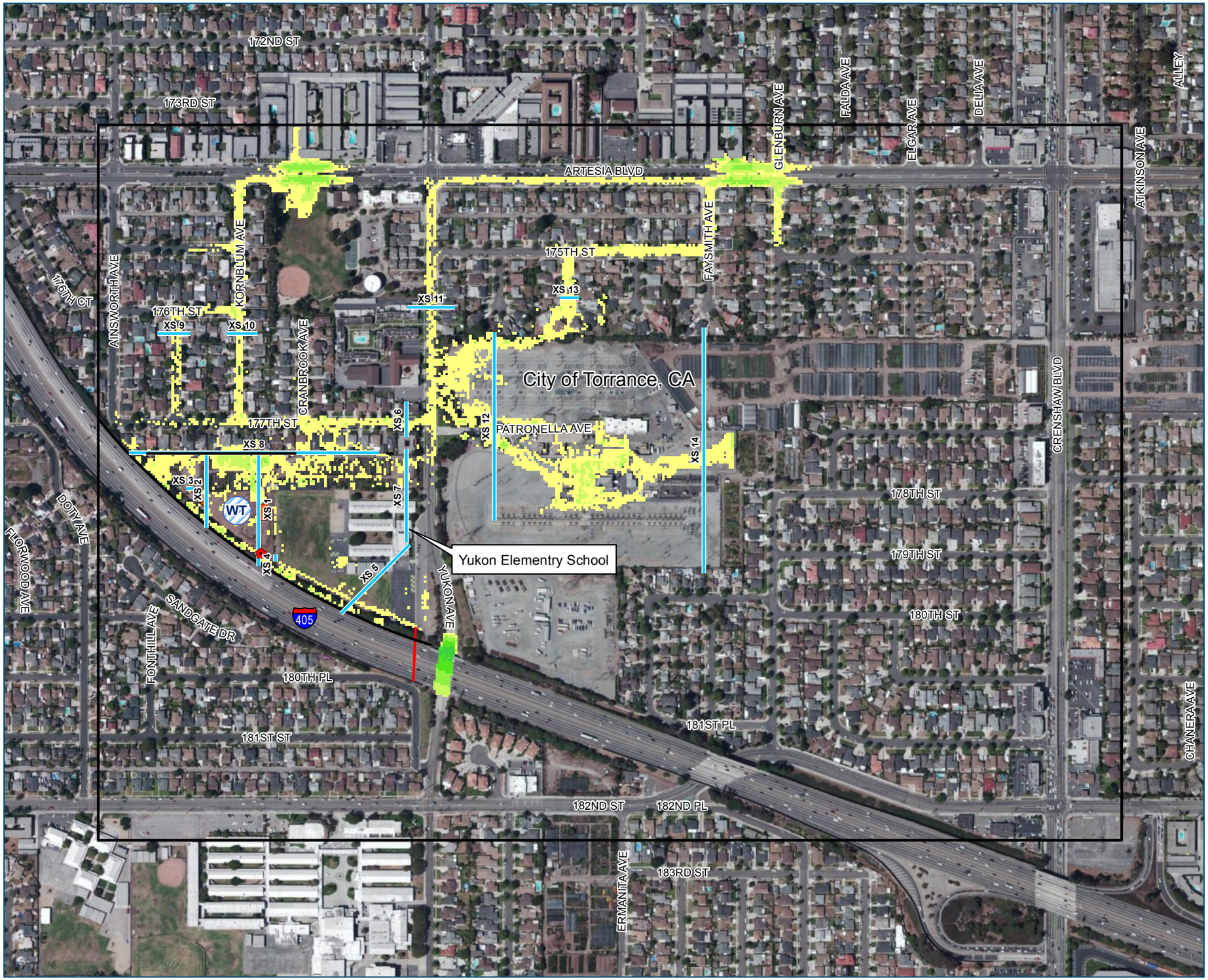
Projection: NAD 1983 State Plane, California V, Feet
Data Sources: ESRI, USGS, US Census, LAR-IAC

AECOM

Water Tank Failure Analysis

City of Torrance, CA 1/29/2014

MAP 2A - FINAL FLOW DEPTH
SCENARIO 1 - BASE CONDITION
NO MITIGATION MEASURES



LEGEND

- Water Tank
- Storm Drain
- On-Site Buildings
- Flo2D Model Boundary
- Block Wall
- I-405 Box Culvert

Final Depth (Feet)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 7.0
- 7.0 - 8.0
- 8.0 - 9.0
- 9.0 - 10.0
- > 10

0 200 400 Feet

N

PROJECT LOCATOR MAP

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Projection: NAD 1983 State Plane, California V, Feet
Data Sources: ESRI, USGS, US Census, LAR-IAC

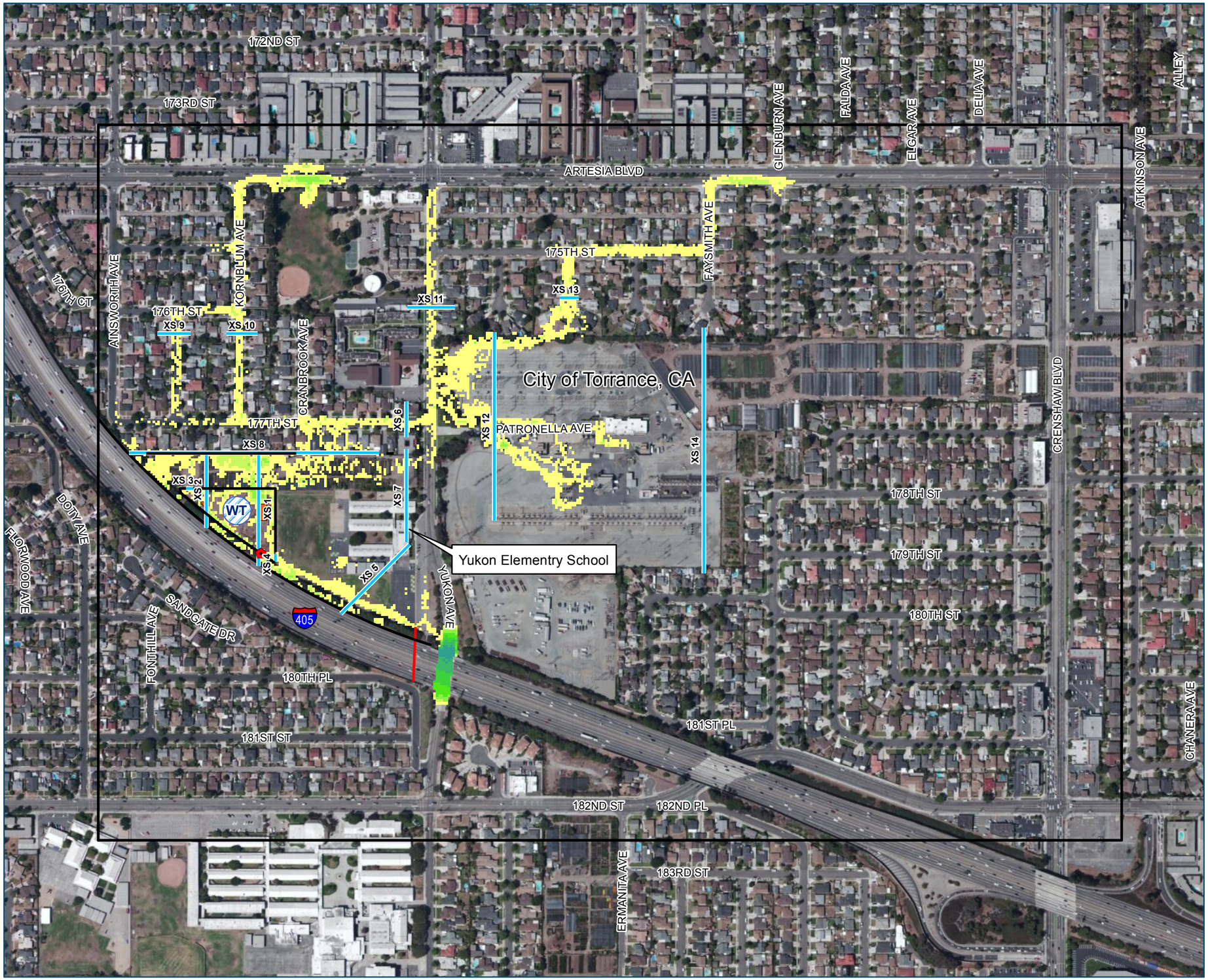
AECOM

Water Tank Failure Analysis

City of Torrance, CA 1/29/2014

MAP 2B - FINAL FLOW DEPTH

SCENARIO 2 - SITE WALLS WITH OPEN GATES AND PARTIALLY BURIED TANK



LEGEND

- Water Tank
- Storm Drain
- On-Site Buildings
- Flo2D Model Boundary
- Block Wall
- I-405 Box Culvert

Final Depth (Feet)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 7.0
- 7.0 - 8.0
- 8.0 - 9.0
- 9.0 - 10.0
- > 10

0 200 400 Feet

N

PROJECT LOCATOR MAP

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Projection: NAD 1983 State Plane, California V, Feet
Data Sources: ESRI, USGS, US Census, LAR-IAC

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Water Tank Failure Analysis

City of Torrance, CA 1/29/2014

MAP 2C - FINAL FLOW DEPTH

SCENARIO 3 - SITE WALLS WITH CLOSED NORTH GATE, OPEN SOUTH GATE AND PARTIALLY BURIED TANK

LEGEND

- Water Tank
- Storm Drain
- On-Site Buildings
- Flo2D Model Boundary
- Block Wall
- I-405 Box Culvert
- Closed North Gate

Final Depth (Feet)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 7.0
- 7.0 - 8.0
- 8.0 - 9.0
- 9.0 - 10.0
- > 10

0 200 400 Feet

N

PROJECT LOCATOR MAP

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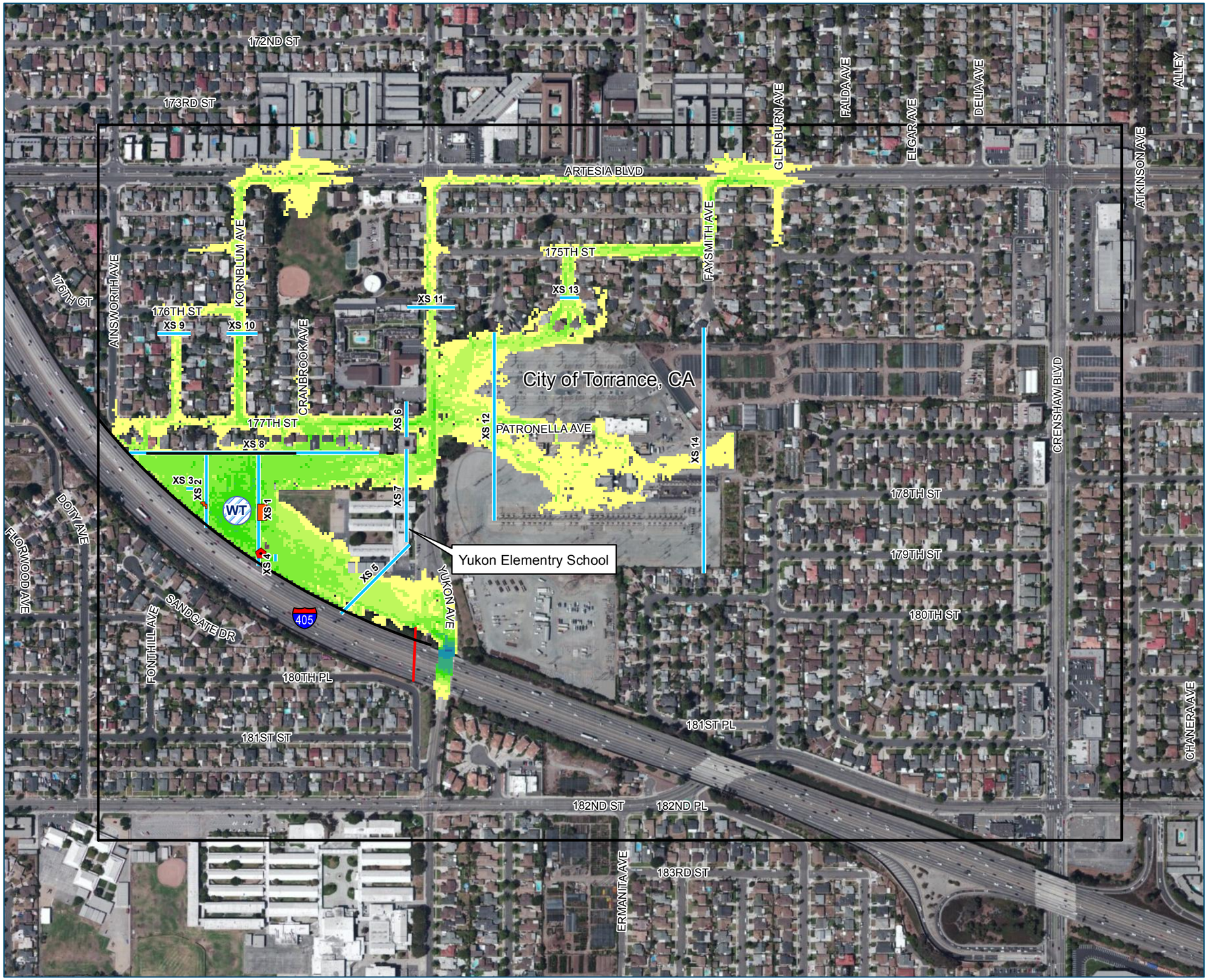
Projection: NAD 1983 State Plane, California V, Feet
Data Sources: ESRI, USGS, US Census, LAR-IAC

AECOM

Water Tank Failure Analysis

City of Torrance, CA 1/29/2014

MAP 3A - MAXIMUM VELOCITY
SCENARIO 1 - BASE CONDITION
NO MITIGATION MEASURES



LEGEND

- Water Tank
- Storm Drain
- On-Site Buildings
- Flo2D Model Boundary
- Block Wall
- I-405 Box Culvert

Maximum Velocity (Feet/Second)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 6.0
- 6.0 - 8.0
- 8.0 - 10.0
- 10.0 - 12.0
- > 12.0

0 200 400 Feet

N

PROJECT LOCATOR MAP

File Name: FIG_3A_BaseCondition_MaxVelocity
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Date Modified: December 30, 2013
Projection: NAD 1983 State Plane, California V, Feet
Data Sources: ESRI, USGS, US Census, LAR-IAC

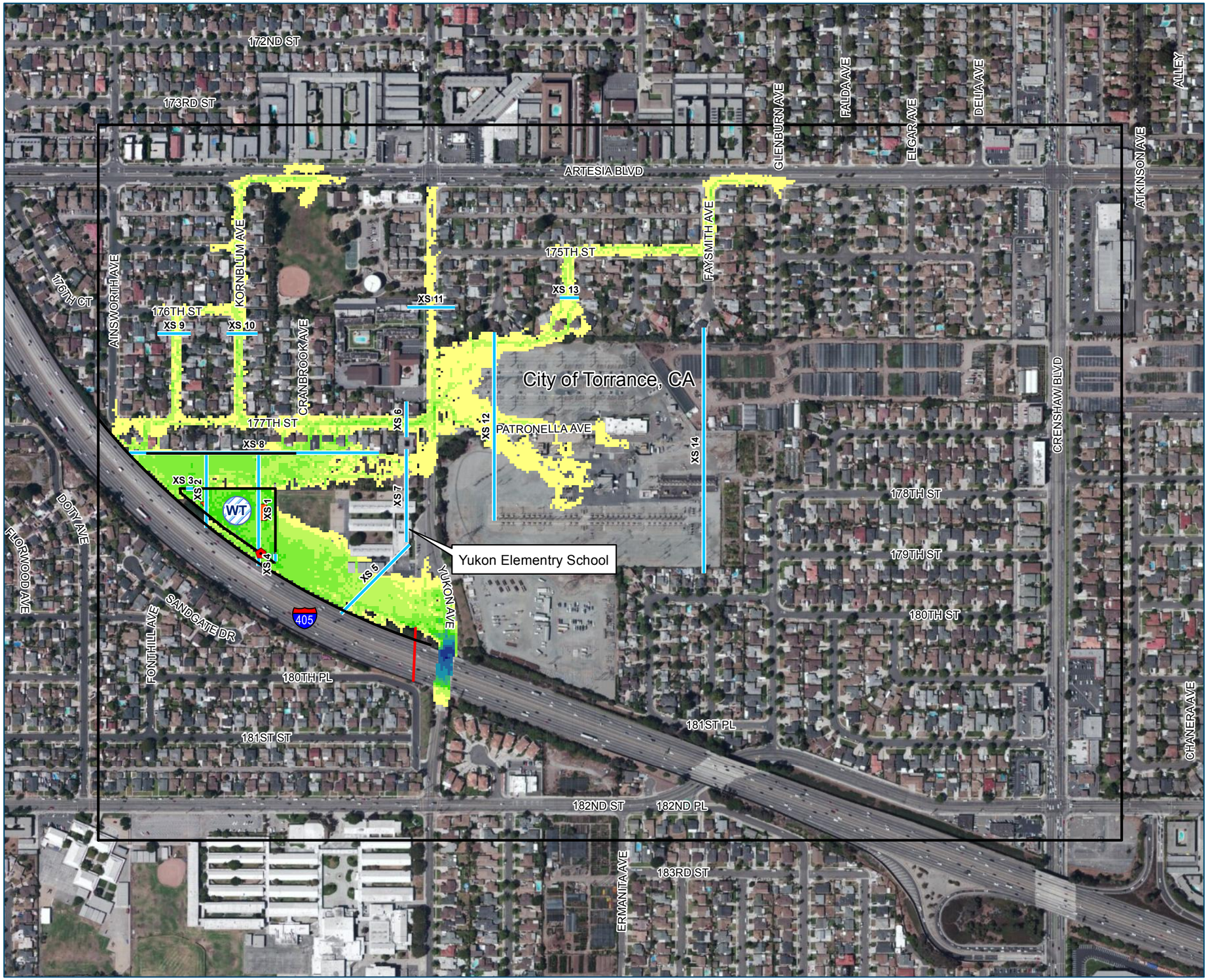
AECOM

Water Tank Failure Analysis

City of Torrance, CA 1/29/2014

MAP 3B - MAXIMUM VELOCITY

SCENARIO 2 - SITE WALLS WITH OPEN GATES AND PARTIALLY BURIED TANK



LEGEND

- Water Tank
- Storm Drain
- On-Site Buildings
- Flo2D Model Boundary
- Block Wall
- I-405 Box Culvert

Maximum Velocity (Feet/Second)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 6.0
- 6.0 - 8.0
- 8.0 - 10.0
- 10.0 - 12.0
- > 12.0

0 200 400 Feet

N

PROJECT LOCATOR MAP

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Data Sources: ESRI, USGS, US Census, LAR-IAC

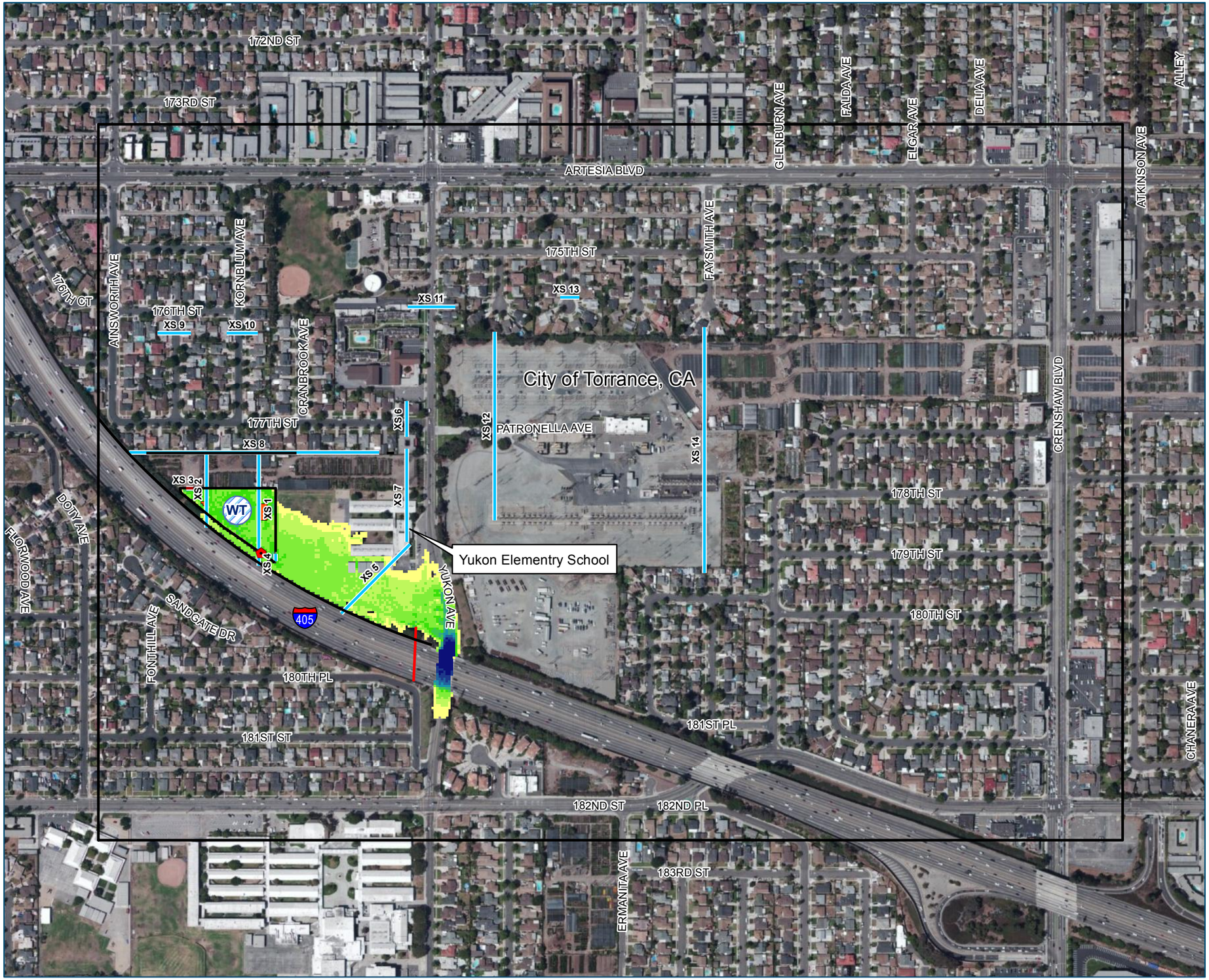
AECOM

Water Tank Failure Analysis

City of Torrance, CA 1/29/2014

MAP 3C - MAXIMUM VELOCITY

SCENARIO 3 - SITE WALLS WITH CLOSED NORTH GATE, OPEN SOUTH GATE AND PARTIALLY BURIED TANK



LEGEND

- Water Tank
- Storm Drain
- On-Site Buildings
- Flo2D Model Boundary
- Block Wall
- I-405 Box Culvert
- Closed North Gate

Maximum Velocity (Feet/Second)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 6.0
- 6.0 - 8.0
- 8.0 - 10.0
- 10.0 - 12.0
- > 12.0

0 200 400 Feet

N

PROJECT LOCATOR MAP

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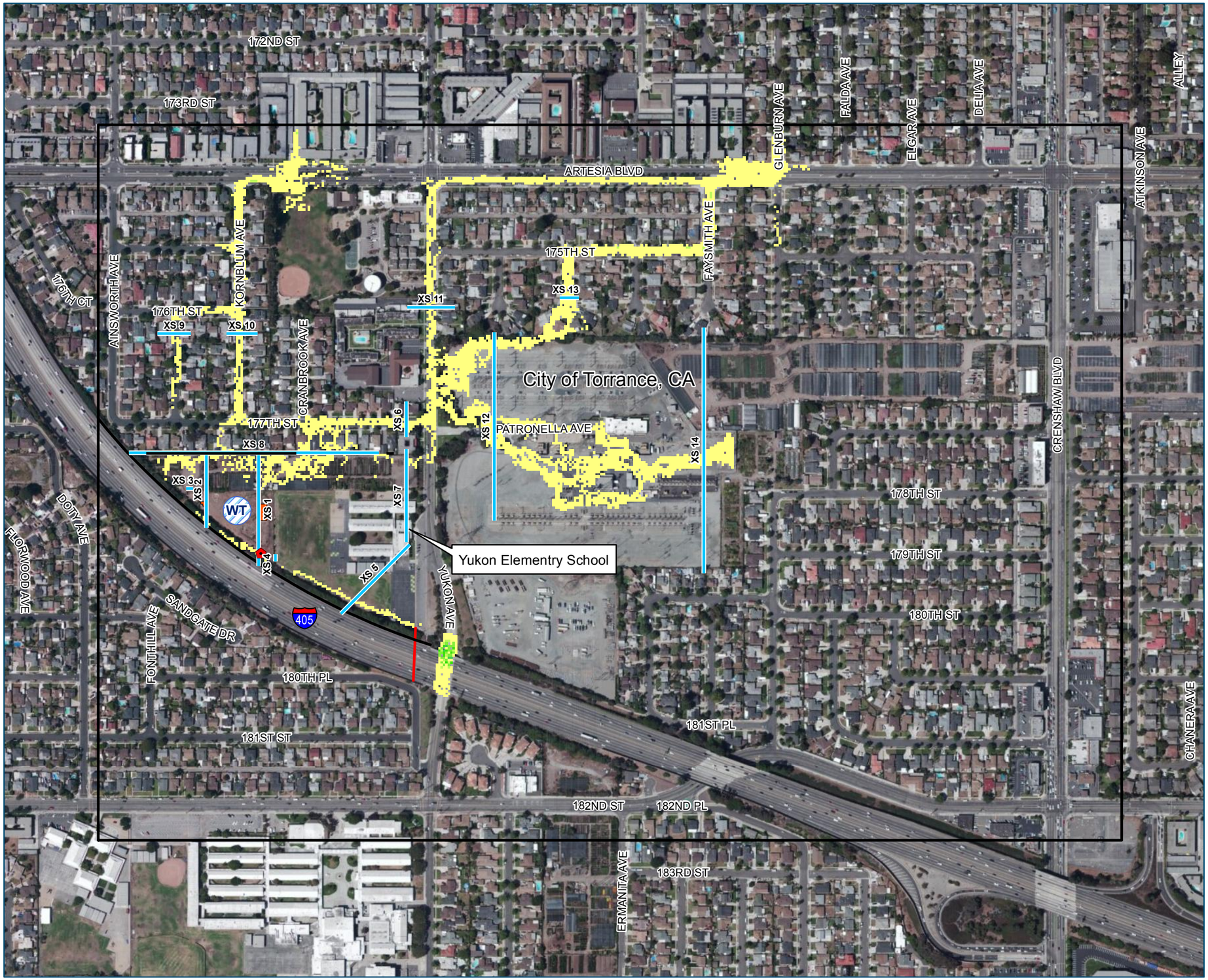
Data Sources: ESRI, USGS, US Census, LAR-IAC

AECOM

Water Tank Failure Analysis

City of Torrance, CA 1/29/2014

MAP 4A - FINAL VELOCITY
SCENARIO 1 - BASE CONDITION
NO MITIGATION MEASURES



LEGEND

- Water Tank
- Storm Drain
- On-Site Buildings
- Flo2D Model Boundary
- Block Wall
- I-405 Box Culvert

Final Velocity (Feet/Second)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 6.0
- 6.0 - 8.0
- 8.0 - 10.0
- 10.0 - 12.0
- > 12.0

0 200 400 Feet

N

PROJECT LOCATOR MAP

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Date Modified: December 30, 2013
Projection: NAD 1983 State Plane, California V, Feet
Data Sources: ESRI, USGS, US Census, LAR-IAC

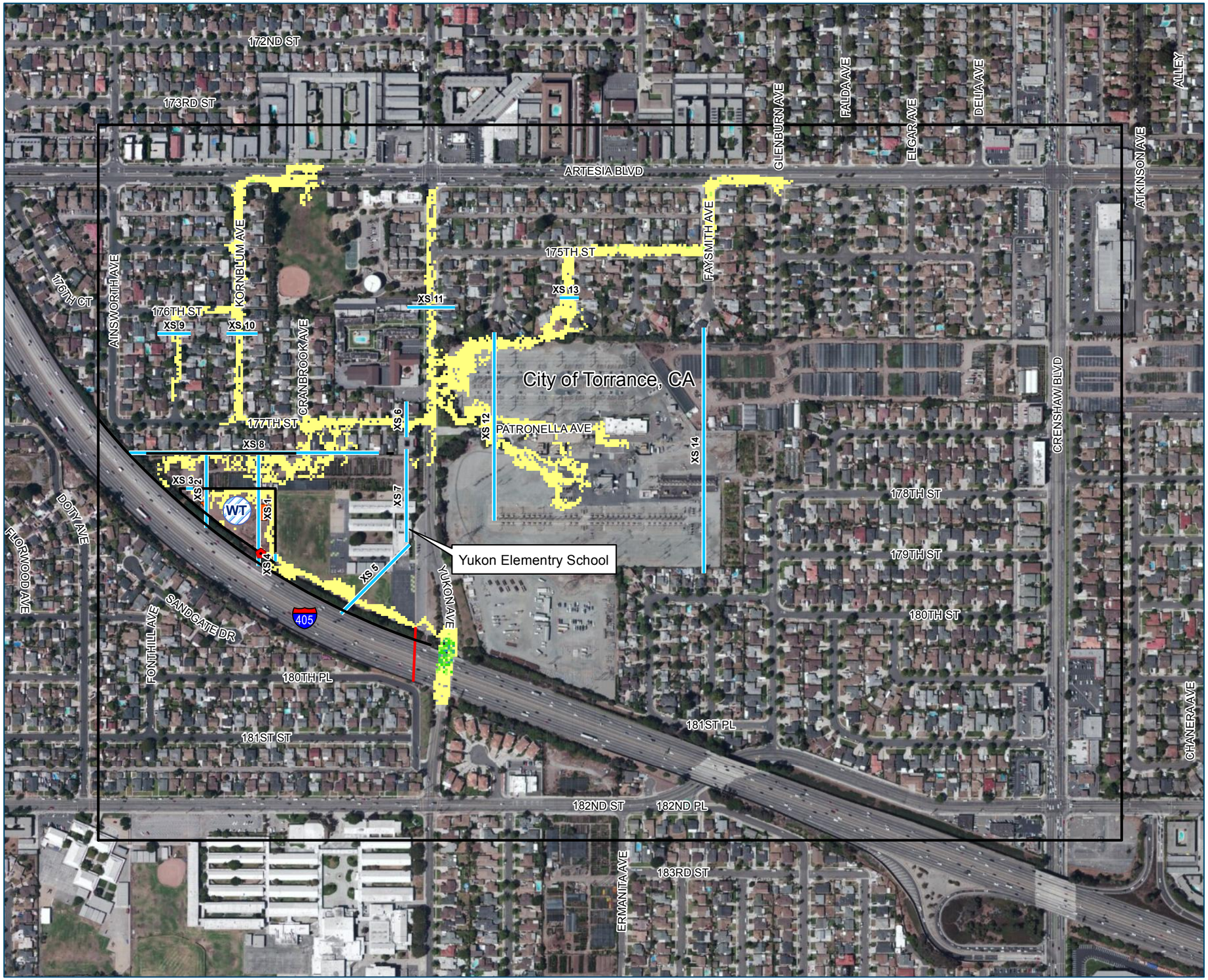
AECOM

Water Tank Failure Analysis

City of Torrance, CA 1/29/2014

MAP 4B - FINAL VELOCITY

SCENARIO 2 - SITE WALLS WITH OPEN GATES AND PARTIALLY BURIED TANK



LEGEND

- Water Tank
- Storm Drain
- On-Site Buildings
- Flo2D Model Boundary
- Block Wall
- I-405 Box Culvert

Final Velocity (Feet/Second)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 6.0
- 6.0 - 8.0
- 8.0 - 10.0
- 10.0 - 12.0
- > 12.0

0 200 400 Feet

N

PROJECT LOCATOR MAP

File Name: FIG_4B_Alt1_FinalVelocity
MXD File Path: Torrance\60287821\GIS\Layouts
PDF File Path: Torrance\60287821\GIS\Maps
Date Modified: December 30, 2013
Projection: NAD 1983 State Plane, California V, Feet
Data Sources: ESRI, USGS, US Census, LAR-IAC

AECOM

Water Tank Failure Analysis

City of Torrance, CA 1/29/2014

MAP 4C - FINAL VELOCITY

SCENARIO 3 - SITE WALLS WITH CLOSED NORTH GATE, OPEN SOUTH GATE AND PARTIALLY BURIED TANK

LEGEND

- Water Tank
- Storm Drain
- On-Site Buildings
- Flo2D Model Boundary
- Block Wall
- I-405 Box Culvert
- Closed North Gate

Final Velocity (Feet/Second)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 6.0
- 6.0 - 8.0
- 8.0 - 10.0
- 10.0 - 12.0
- > 12.0

0 200 400 Feet

N

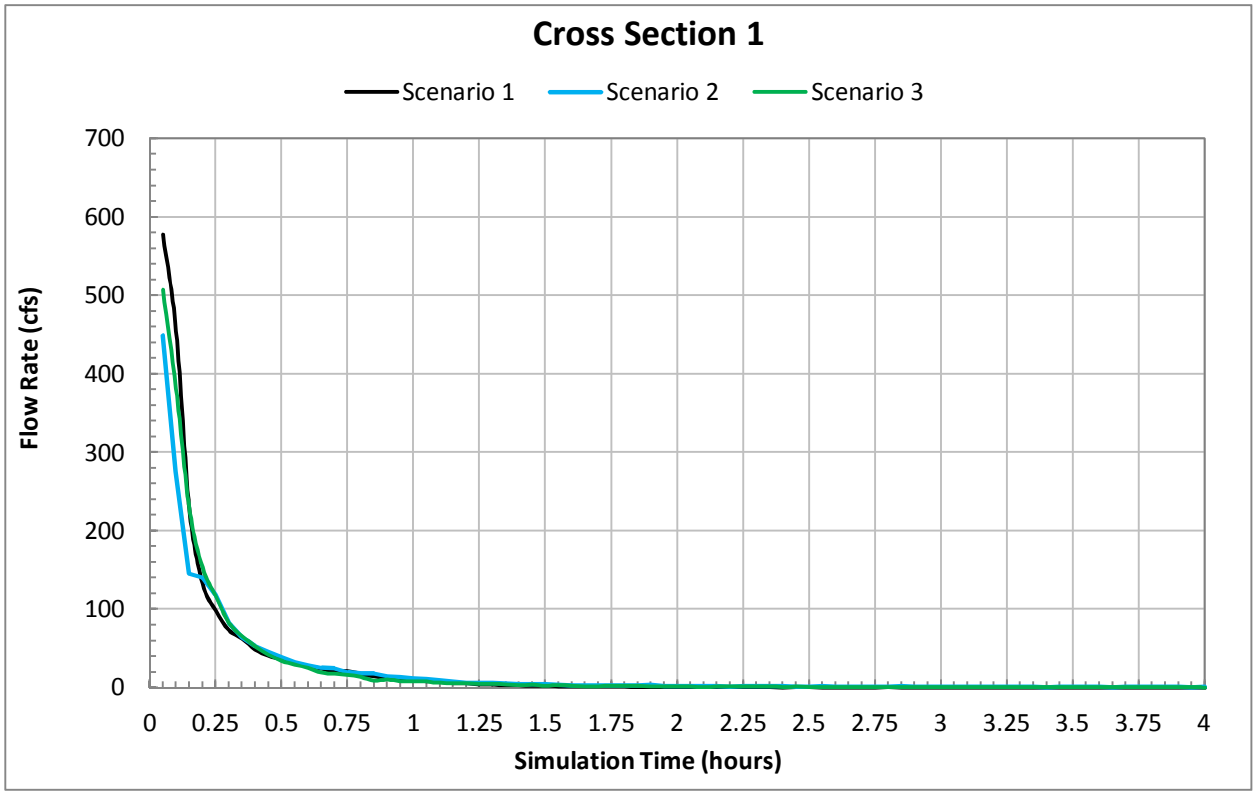
PROJECT LOCATOR MAP

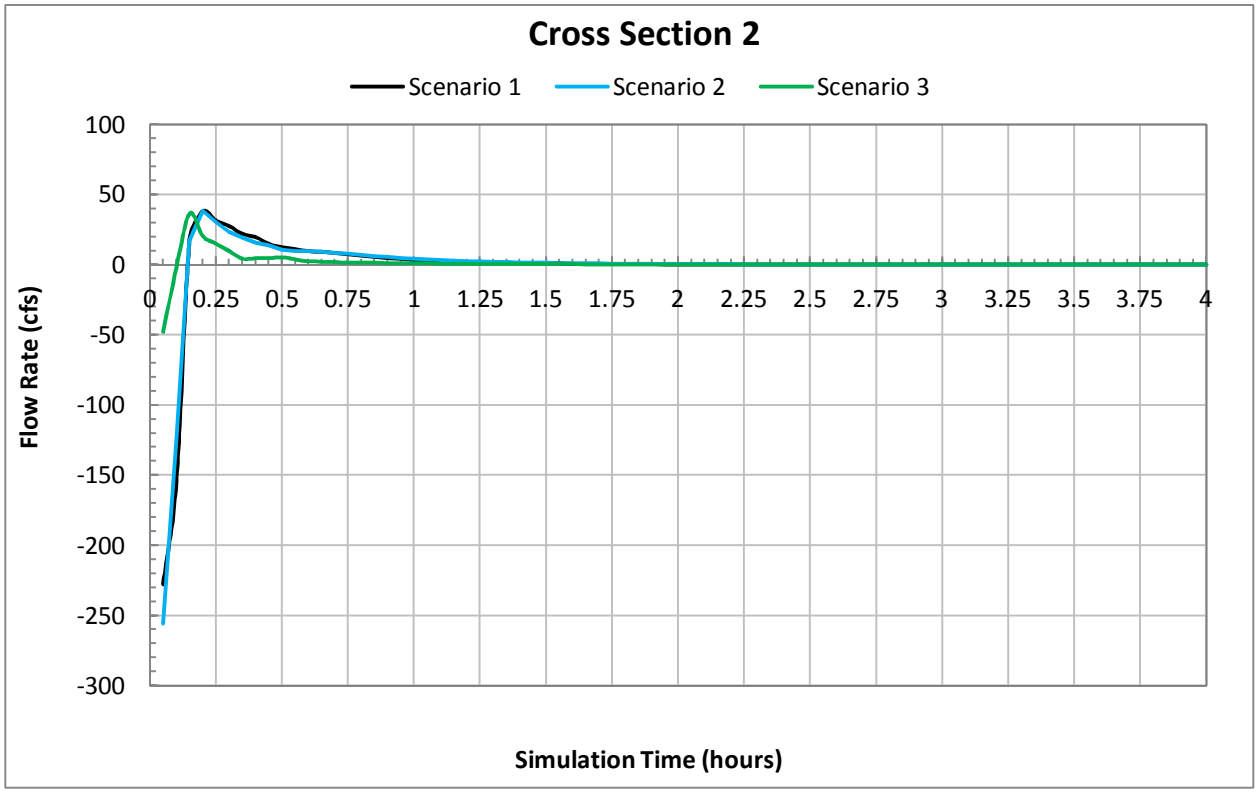
File Name: FIG_4C_Alt3_FinalVelocity
MXD File Path: Torrance\60287821\GIS\Layouts
PDF File Path: Torrance\60287821\GIS\Maps
Date Modified: December 30, 2013
Projection: NAD 1983 State Plane, California V, Feet
Data Sources: ESRI, USGS, US Census, LAR-IAC

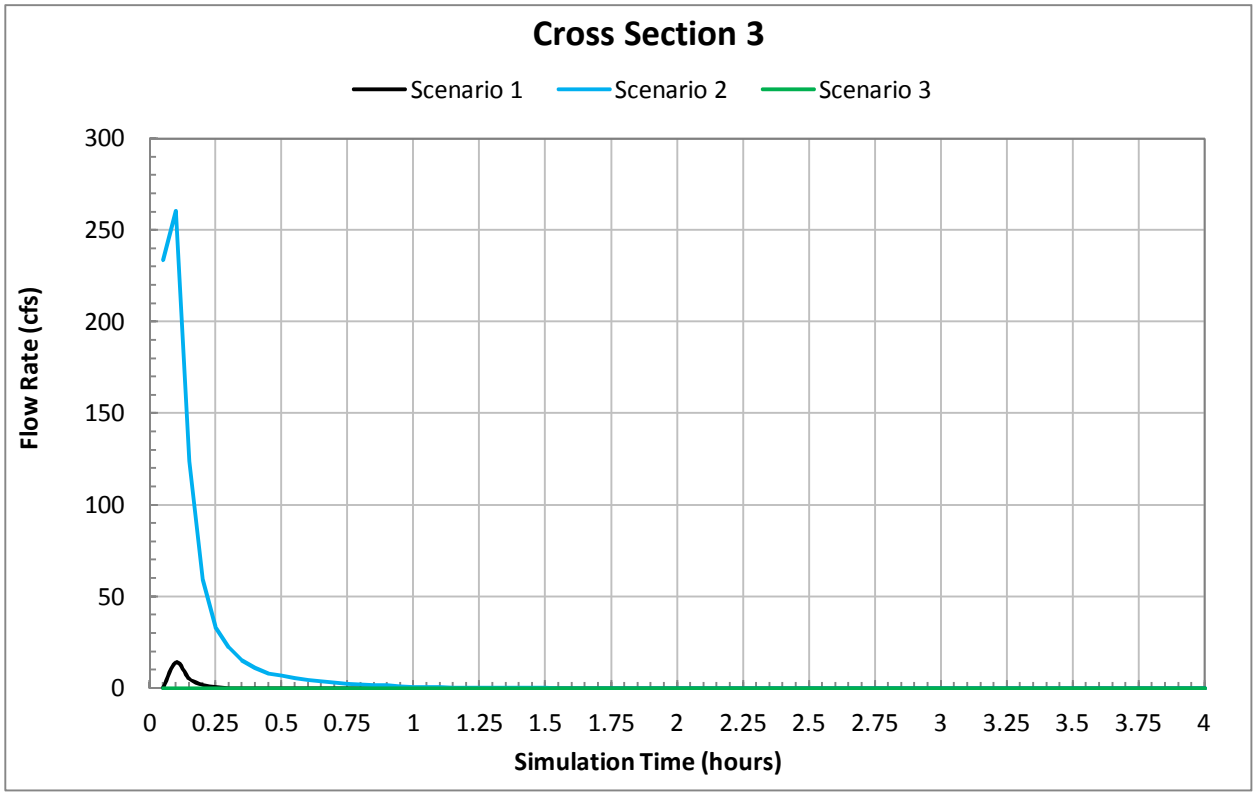
AECOM

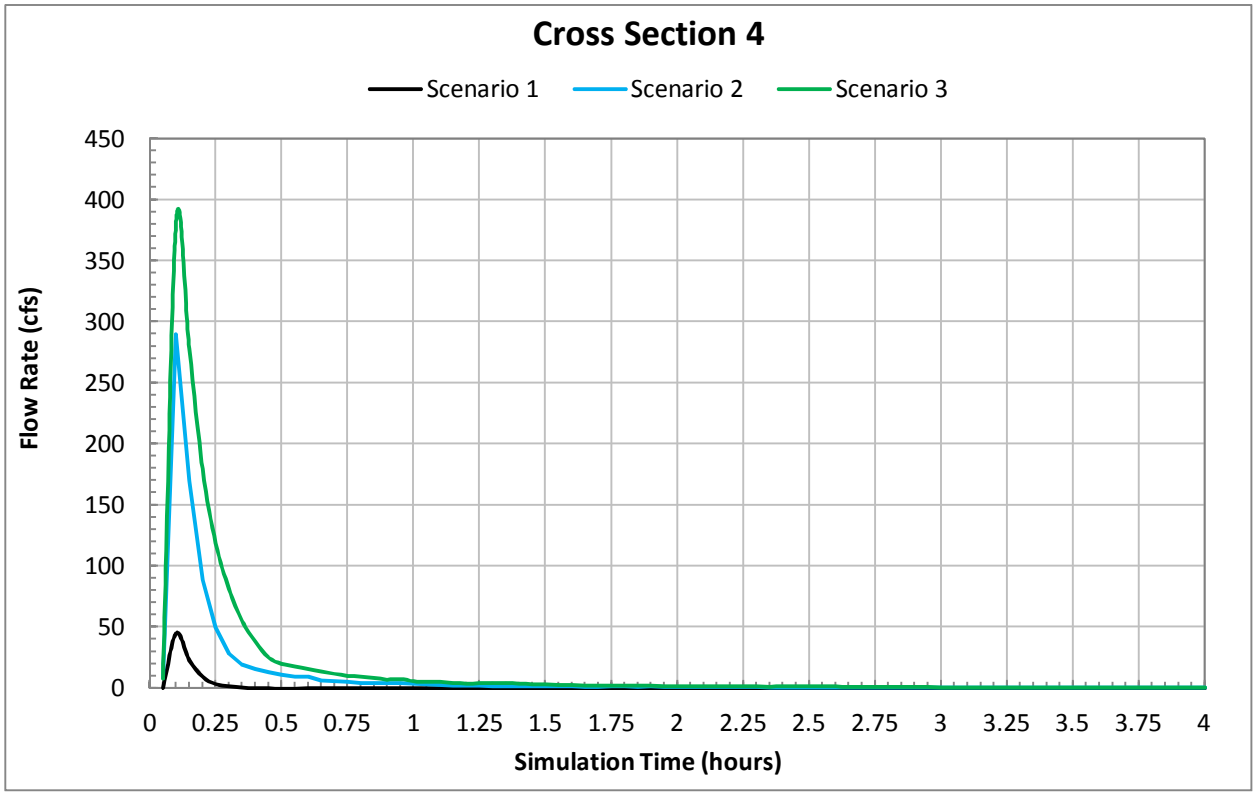
APPENDIX B

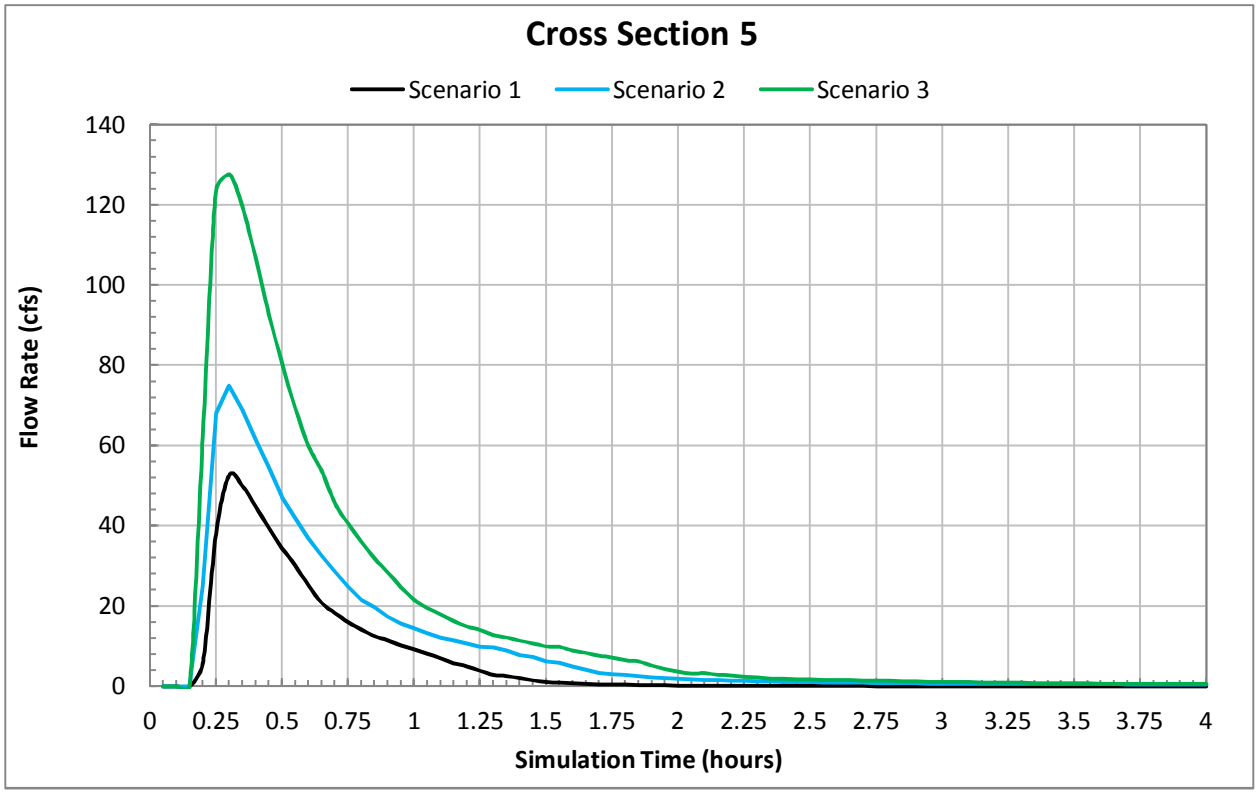
Hydrographs for Flow Measurement Cross-Sections

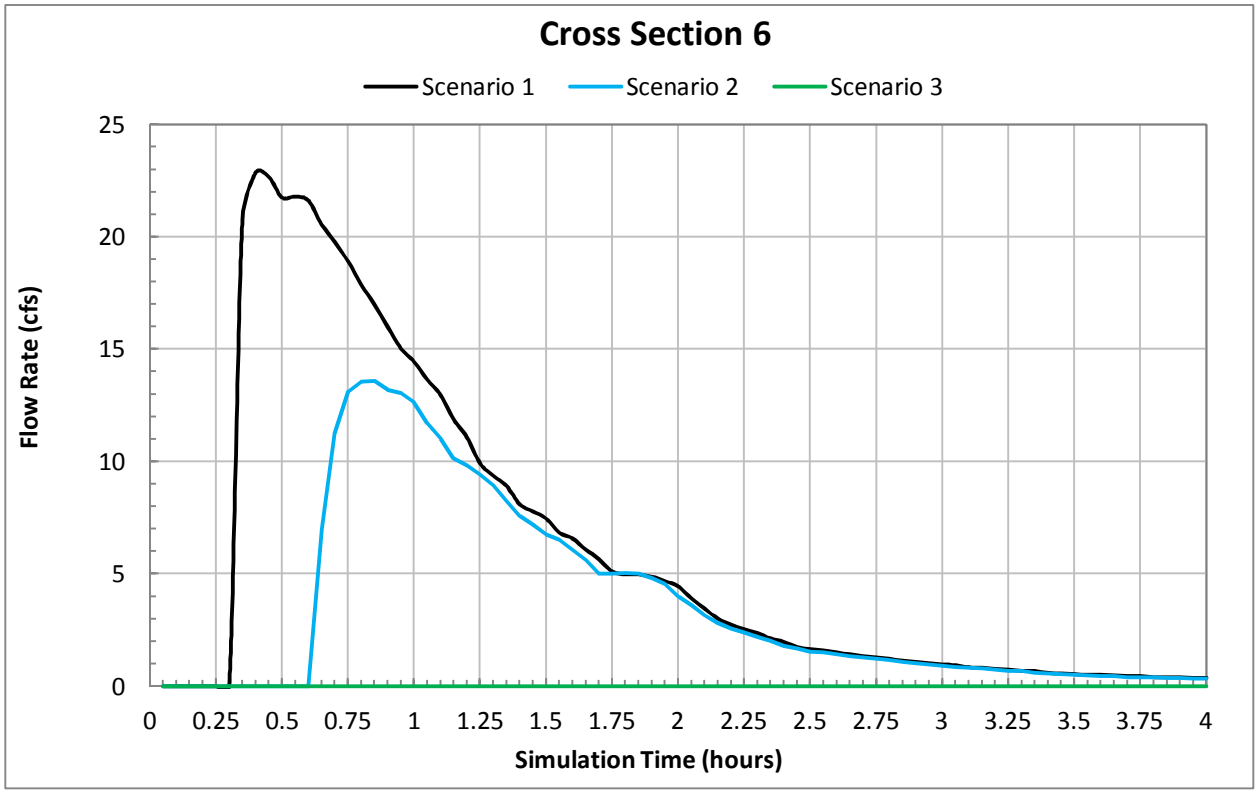

Cross Section 1
Scenario 1
Scenario 2
Scenario 3
Flow Rate (cfs)
700
600
500
400
300
200
100
0
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
2.75
3
3.25
3.5
3.75
4
Simulation Time (hours)

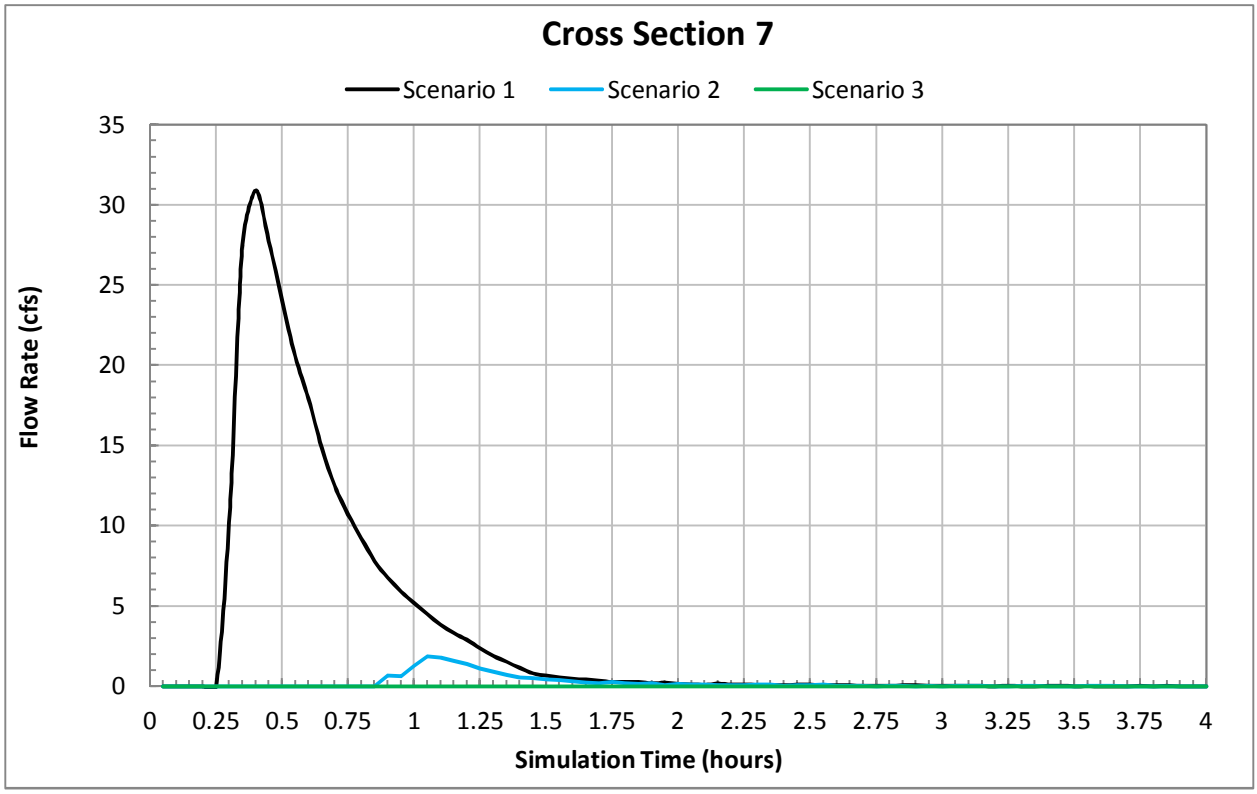

Cross Section 2
Scenario 1
Scenario 2
Scenario 3
Flow Rate (cfs)
100
50
0
-50
-100
-150
-200
-250
-300
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
2.75
3
3.25
3.5
3.75
4
Simulation Time (hours)

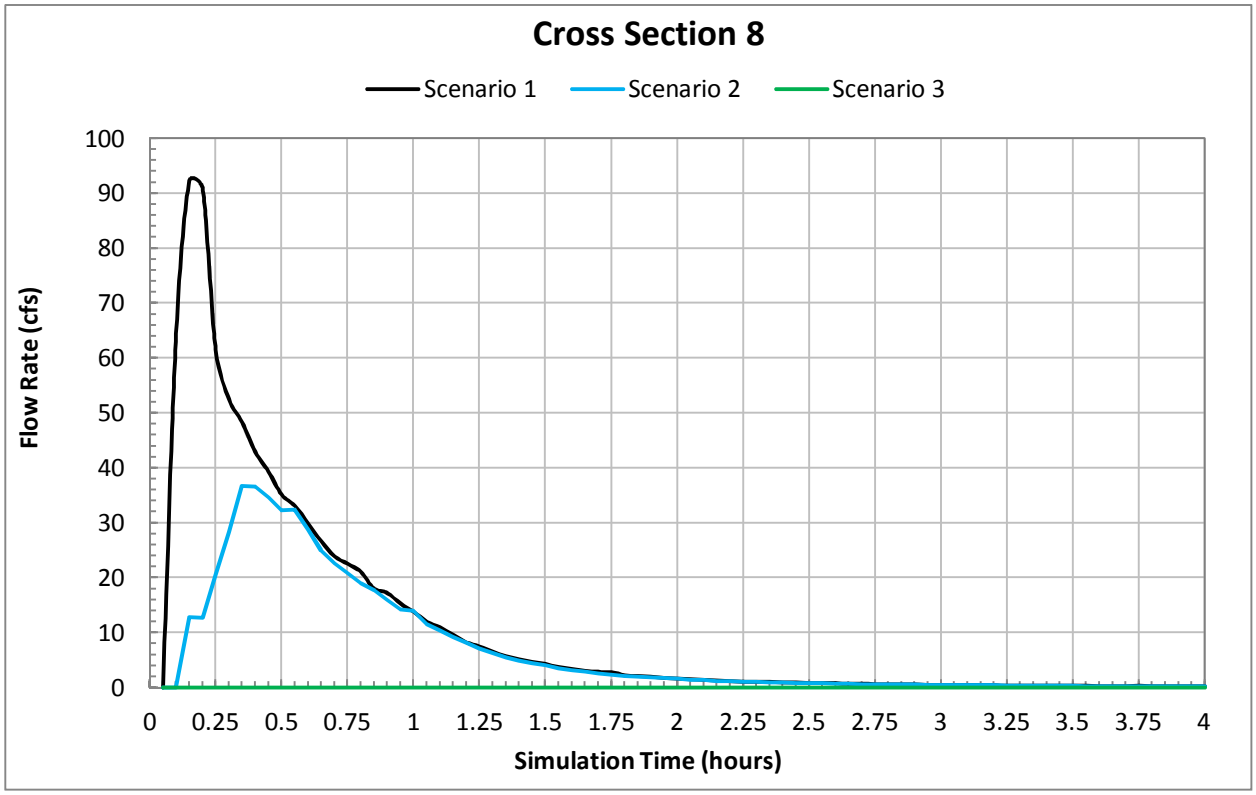

Cross Section 3
Scenario 1
Scenario 2
Scenario 3
Flow Rate (cfs)
300
250
200
150
100
50
0
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
2.75
3
3.25
3.5
3.75
4
Simulation Time (hours)

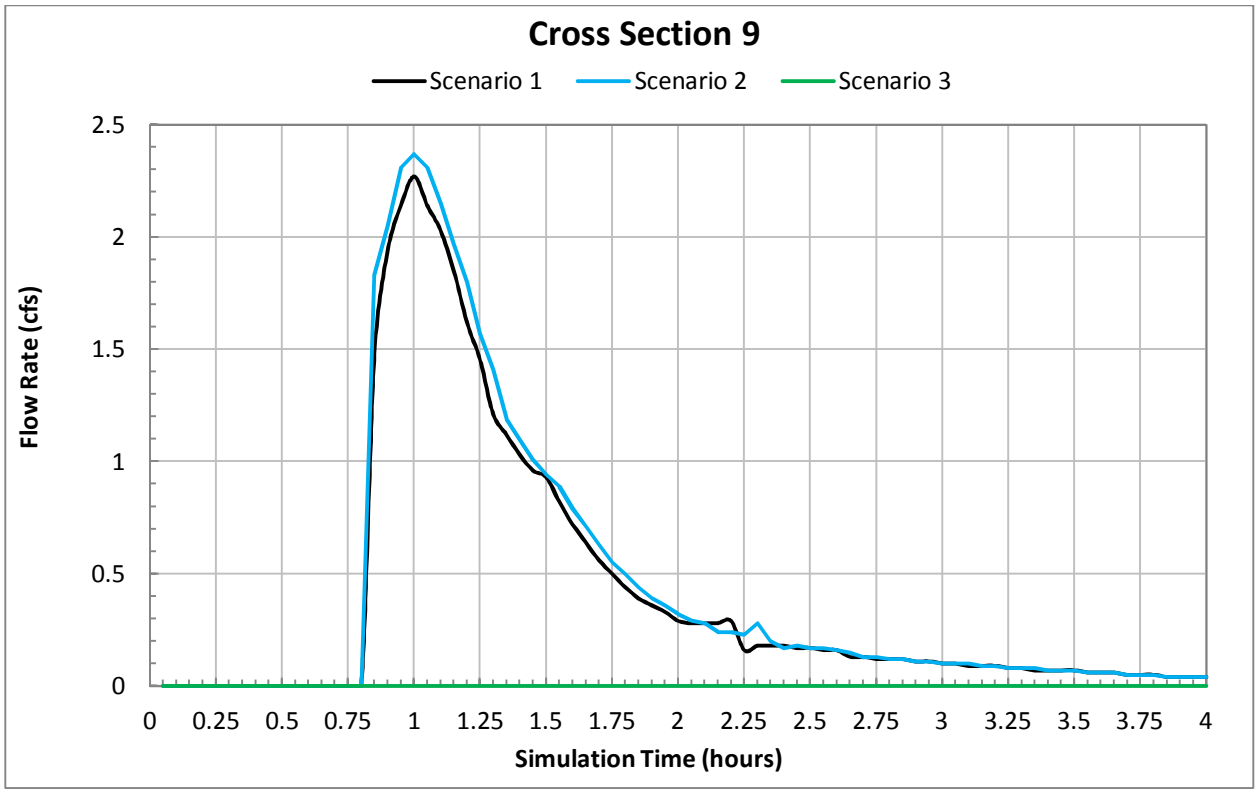

Cross Section 4
Scenario 1
Scenario 2
Scenario 3
Flow Rate (cfs)
450
400
350
300
250
200
150
100
50
0
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
2.75
3
3.25
3.5
3.75
4
Simulation Time (hours)

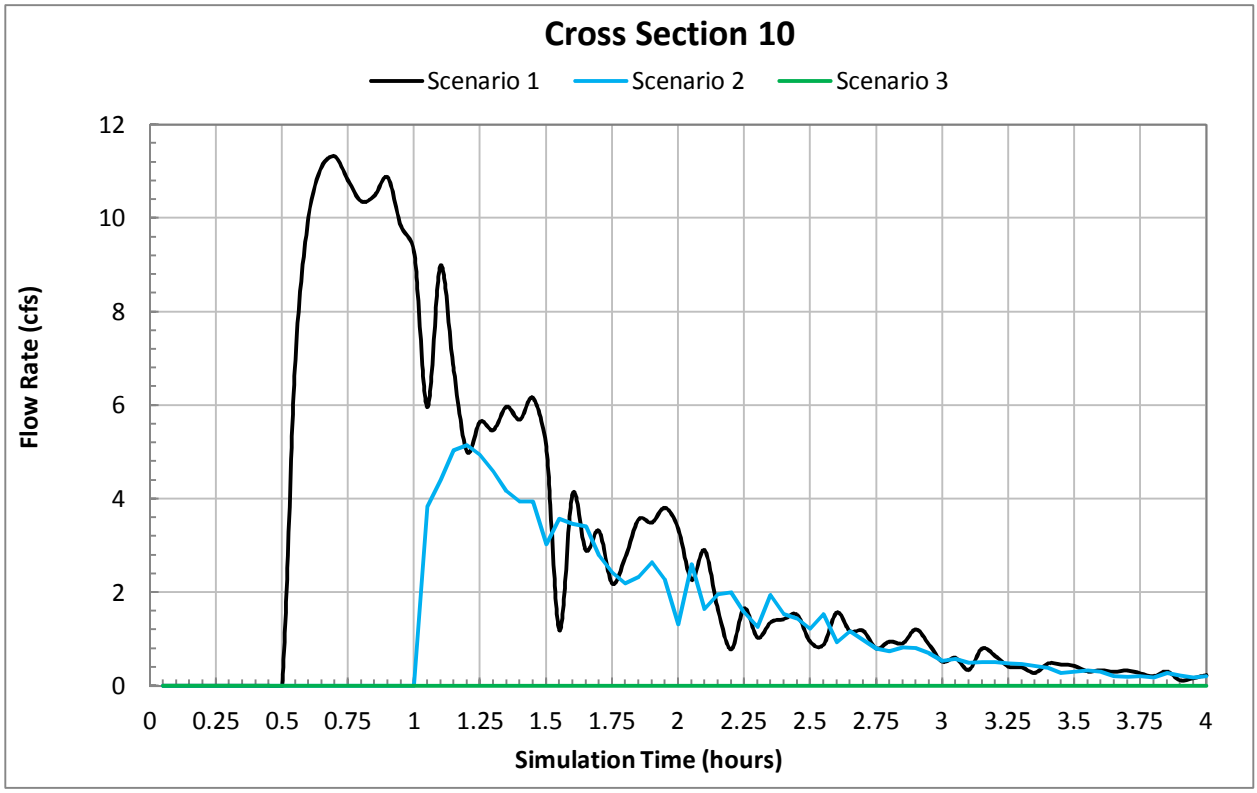

Cross Section 5
Scenario 1
Scenario 2
Scenario 3
Flow Rate (cfs)
140
120
100
80
60
40
20
0
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
2.75
3
3.25
3.5
3.75
4
Simulation Time (hours)

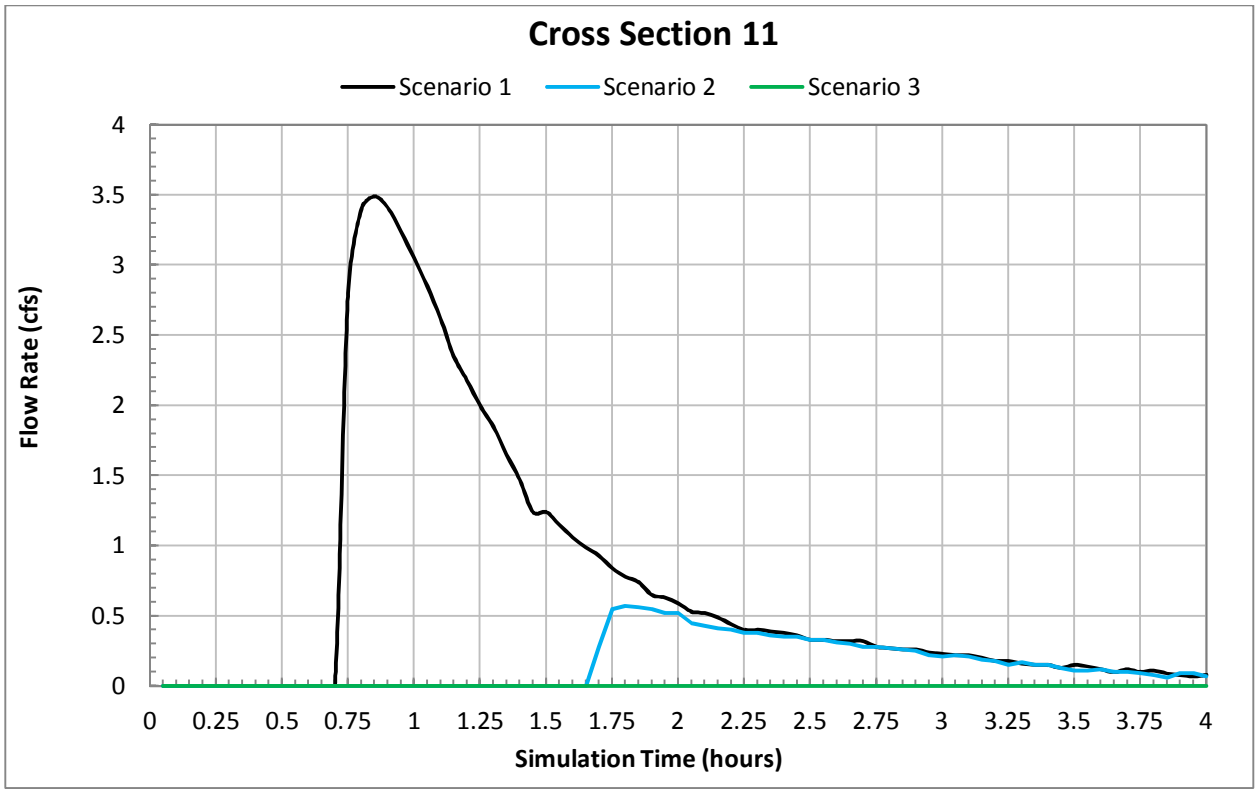

Cross Section 6
Scenario 1
Scenario 2
Scenario 3
Flow Rate (cfs)
25
20
15
10
5
0
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
2.75
3
3.25
3.5
3.75
4
Simulation Time (hours)

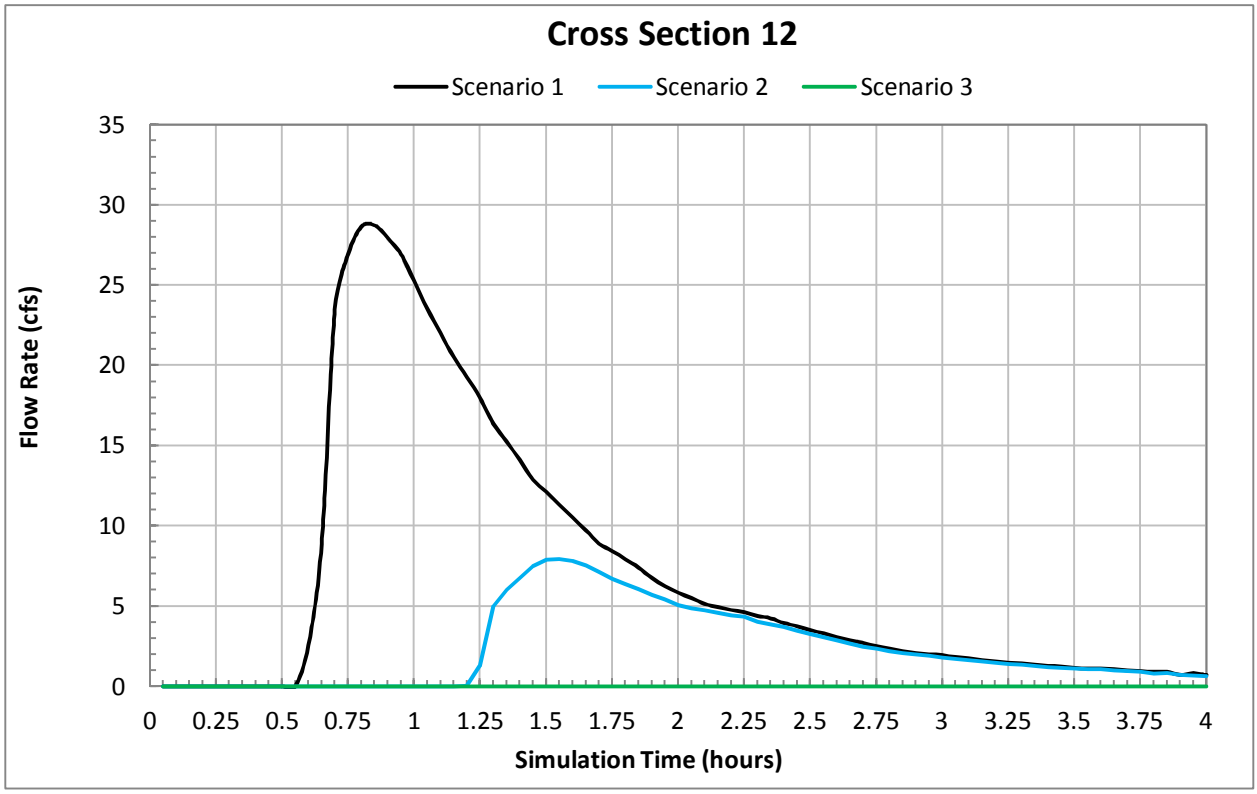

Cross Section 7
Scenario 1
Scenario 2
Scenario 3
Flow Rate (cfs)
35
30
25
20
15
10
5
0
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
2.75
3
3.25
3.5
3.75
4
Simulation Time (hours)

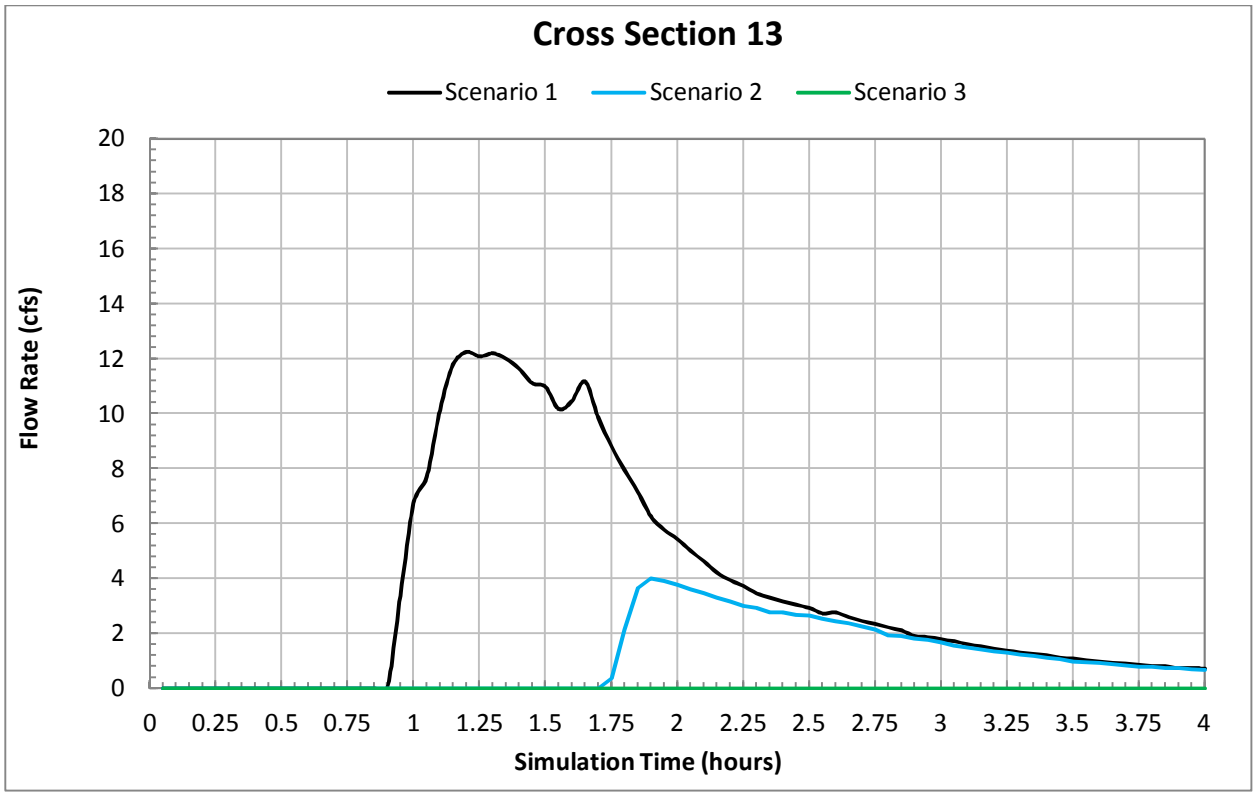

Cross Section 8
Scenario 1
Scenario 2
Scenario 3
Flow Rate (cfs)
100
90
80
70
60
50
40
30
20
10
0
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
2.75
3
3.25
3.5
3.75
4
Simulation Time (hours)

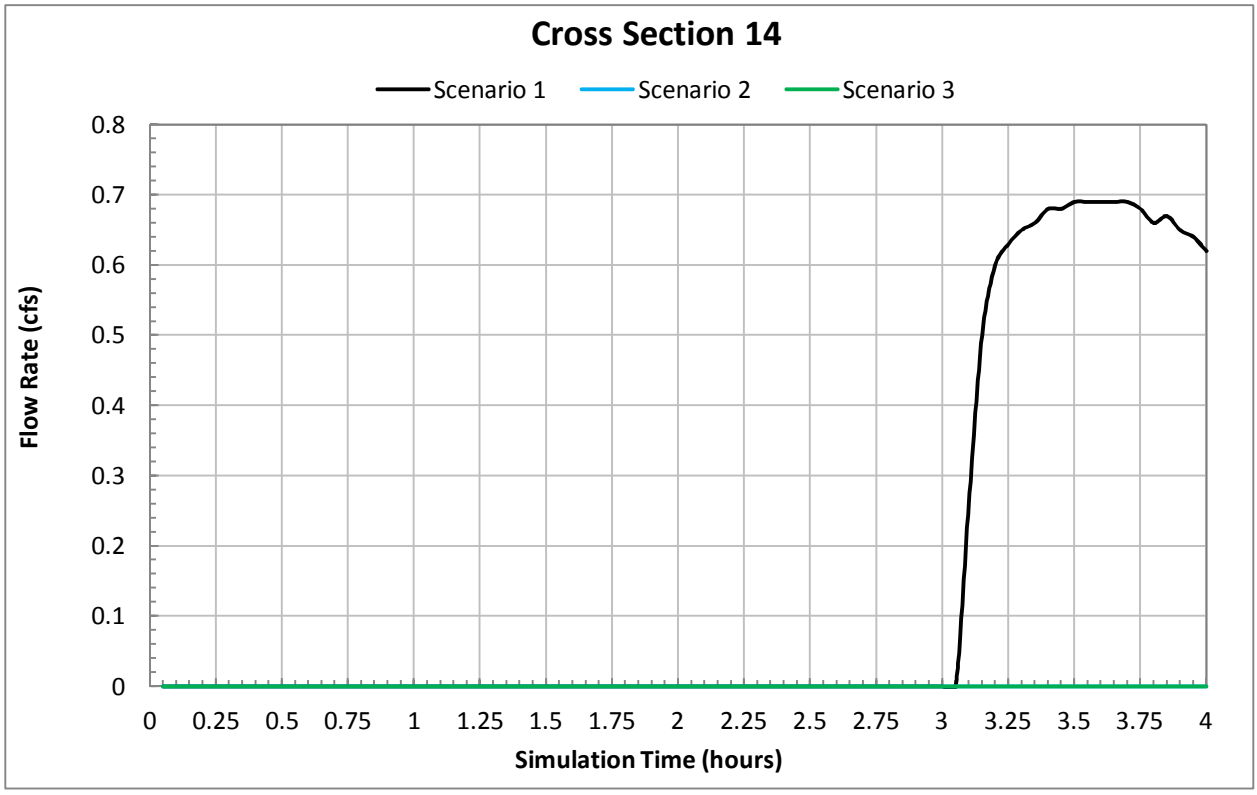

Cross Section 9
Scenario 1
Scenario 2
Scenario 3
Flow Rate (cfs)
2.5
2
1.5
1
0.5
0
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
2.75
3
3.25
3.5
3.75
4
Simulation Time (hours)


Cross Section 10
Scenario 1
Scenario 2
Scenario 3
Flow Rate (cfs)
12
10
8
6
4
2
0
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
2.75
3
3.25
3.5
3.75
4
Simulation Time (hours)


Cross Section 11
Scenario 1
Scenario 2
Scenario 3
Flow Rate (cfs)
4
3.5
3
2.5
2
1.5
1
0.5
0
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
2.75
3
3.25
3.5
3.75
4
Simulation Time (hours)

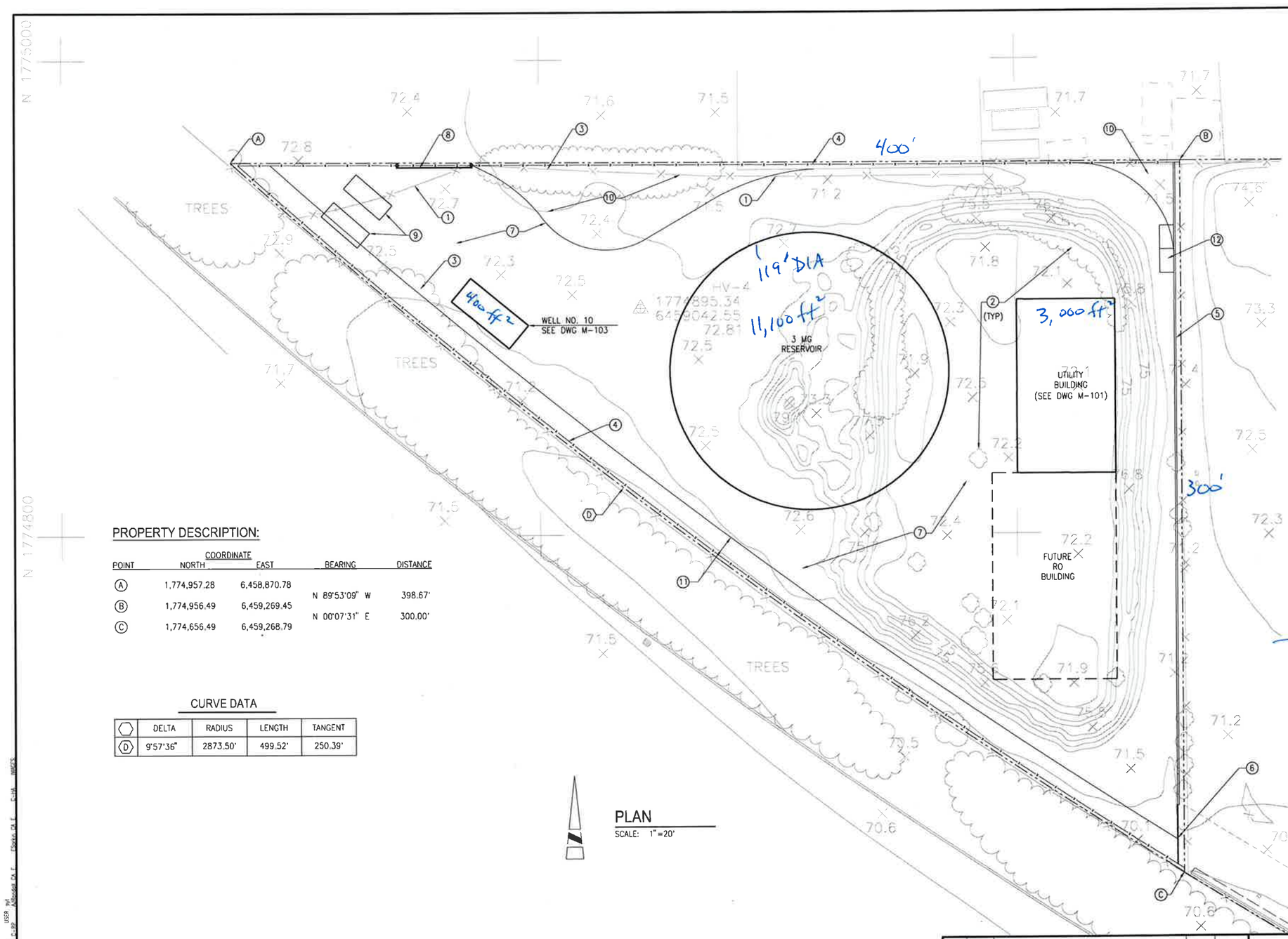

Cross Section 12
Scenario 1
Scenario 2
Scenario 3
Flow Rate (cfs)
35
30
25
20
15
10
5
0
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
2.75
3
3.25
3.5
3.75
4
Simulation Time (hours)


Cross Section 13
Scenario 1
Scenario 2
Scenario 3
Flow Rate (cfs)
20
18
16
14
12
10
8
6
4
2
0
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
2.75
3
3.25
3.5
3.75
4
Simulation Time (hours)


Cross Section 14
Scenario 1
Scenario 2
Scenario 3
Flow Rate (cfs)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
2.75
3
3.25
3.5
3.75
4
Simulation Time (hours)

APPENDIX C

Calculations



CONSTRUCTION NOTES:

1. REMOVE EXIST CHAIN LINK FENCING, INCLUDING POSTS AND CONCRETE.
2. REMOVE EXIST TREES/BUSHES WITHIN PROJECT SITE.
3. TRIM EXIST BRANCHES TO PROPERTY LINE.
4. 8' CHAIN LINK FENCE, 1' INSIDE PROPERTY LINE WITH FIBERGLASS FILLER STRIPS
5. 8' CMU BLOCK WALL. SIMILAR TO BLDGS. SPLIT FACE ON EXTERNAL SURFACE ONLY. INSIDE FACE TO BE 2' INSIDE PROPERTY LINE.
6. 25' ROLLING GATE, 8' HIGH WITH ELECTRIC OPERATOR. MATERIALS SAME AS NOTE 4.
7. CLEAR AND GRUB, GRADE AND PAVE SITE WITH 4" AC/6"AB EDGE OF PAVEMENT TO BE BLOCK WALL, POROUS PAVEMENT, OR HEADER BOARD ONE FOOT FROM CHAIN LINK FENCE.
8. 30' ROLLING GATE, MANUALLY OPERATED WITH HASP AND LOCK.
9. STORAGE SPACE FOR TWO PORTABLE GENERATORS. GENERATORS ARE NIC
10. GRAVEL SURFACE (6" AB)
11. POROUS PAVEMENT, 10' WIDE ALONG SOUTH PROPERTY LINE
12. TWO PARKING SPACES

$A_{SITE} = 60{,}000\ ft^2$

$A_{TANK} = -11{,}100\ ft^2$

$A_{UTIL\ BLDG} = -3{,}000\ ft^2$

$A_{WELL\ BLDG} = -400\ ft^2$

$A_{NET} = 45{,}500\ ft^2$

PROPERTY DESCRIPTION:

POINT	COORDINATE NORTH	COORDINATE EAST	BEARING	DISTANCE
A	1,774,957.28	6,458,870.78		
			N 89°53'09" W	398.67'
B	1,774,956.49	6,459,269.45		
			N 00°07'31" E	300.00'
C	1,774,656.49	6,459,268.79		

CURVE DATA

	DELTA	RADIUS	LENGTH	TANGENT
D	9°57'36"	2873.50'	499.52'	250.39'

PLAN

SCALE: 1"=20'

NORTH TORRANCE WELL FIELD PROJECT

SITE PLAN

C-101

DIG ALERT

1-800-227-2600
AT LEAST TWO DAYS BEFORE YOU DIG

THE CONFIGURATIONS, DIMENSIONS AND SIZES ON THESE PLANS FOR THE PROPOSED IMPROVEMENTS ARE INTENDED TO REPRESENT THE INTENT OF THE PROJECT. DIMENSIONS, CONFIGURATIONS AND SIZES SHOWN ARE BASED ON CONCEPT-LEVEL ENGINEERING. THE DB TEAM IS TO VERIFY AND SUBSEQUENTLY DESIGN THE PROJECT COMPONENTS FOR THE DESIGN DEVELOPMENT AND CONSTRUCTION PHASES. THE CONTRACTOR WILL BE RESPONSIBLE FOR THE ULTIMATE PERFORMANCE OF THE PROJECT AS SPECIFIED IN THE CONTRACT DOCUMENTS.

REV.	DATE	DESCRIPTION	BY	CHECKED

CITY OF TORRANCE
PUBLIC WORKS DEPARTMENT

DRAWN:
DESIGNED:
PROJECT ENGINEER:
DIVISION ENGINEER:
APPROVED:
SCALE: AS SHOWN SHEET XX OF XX
PLAN NO. WP-

CALCULATIONS

Volume Calculation for Containment of Water

Scenario 4:

- Lower ground surface an average of 1 foot
- Provide 3-foot flood gates
- Construct the tank base 20 feet below the surface

Volume that can be contained within site walls: 45,500 square feet x (3+1) feet x 7.48 gallons/cubic foot =	1,360,000 gallons
+ volume in tank below grade = (3.14 x 119^2/4) x 20 cubic feet x 7.48 gallons per cubic foot =	1,660,000 gallons
Total volume contained on-site:	**3,020,000 gallons**

Time Required to Drain Water from the site in the Event of Release from the Tank

Scenario 4:

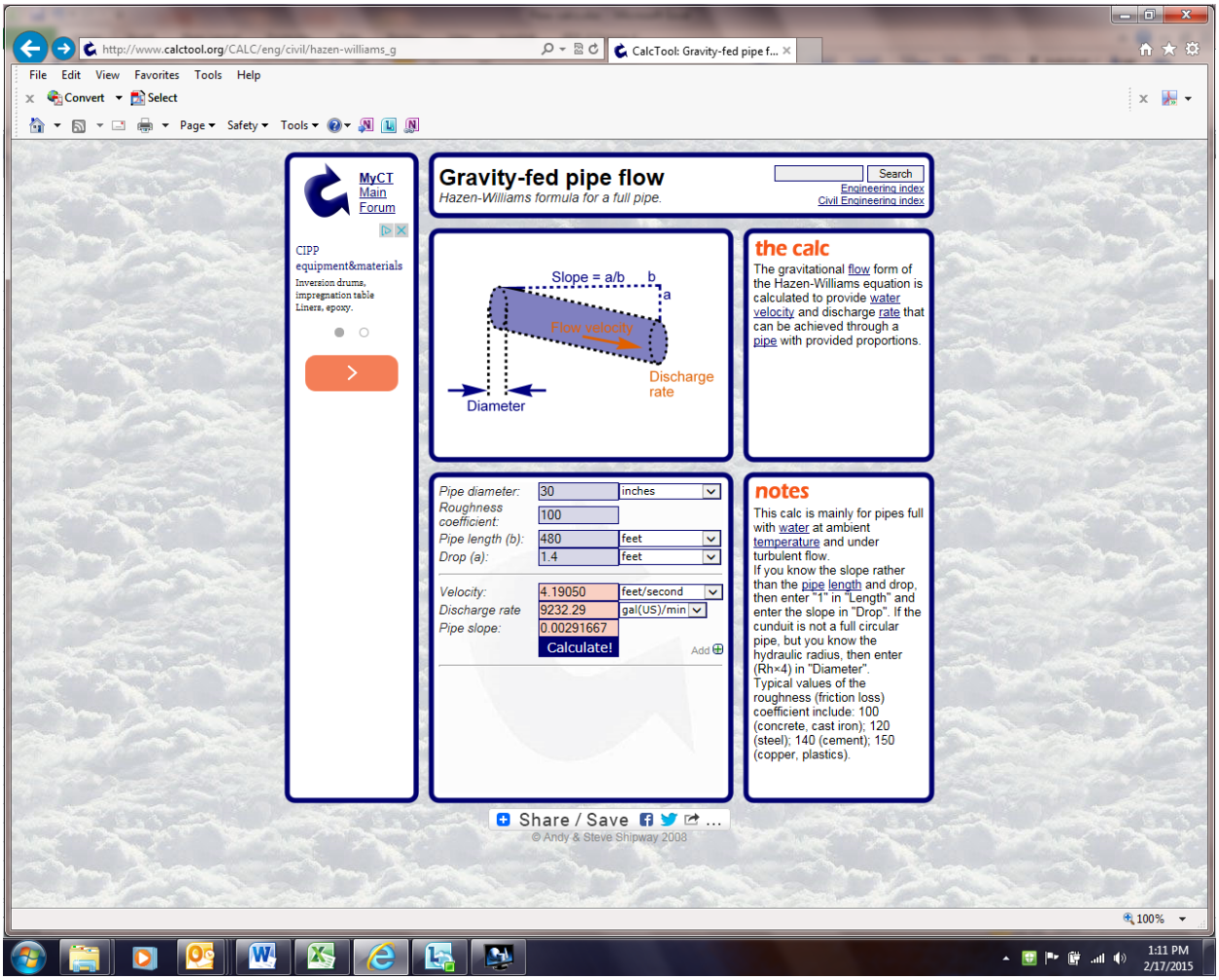
Assume all water inside the site drains through the site drain to the storm drain with no on-site percolation.

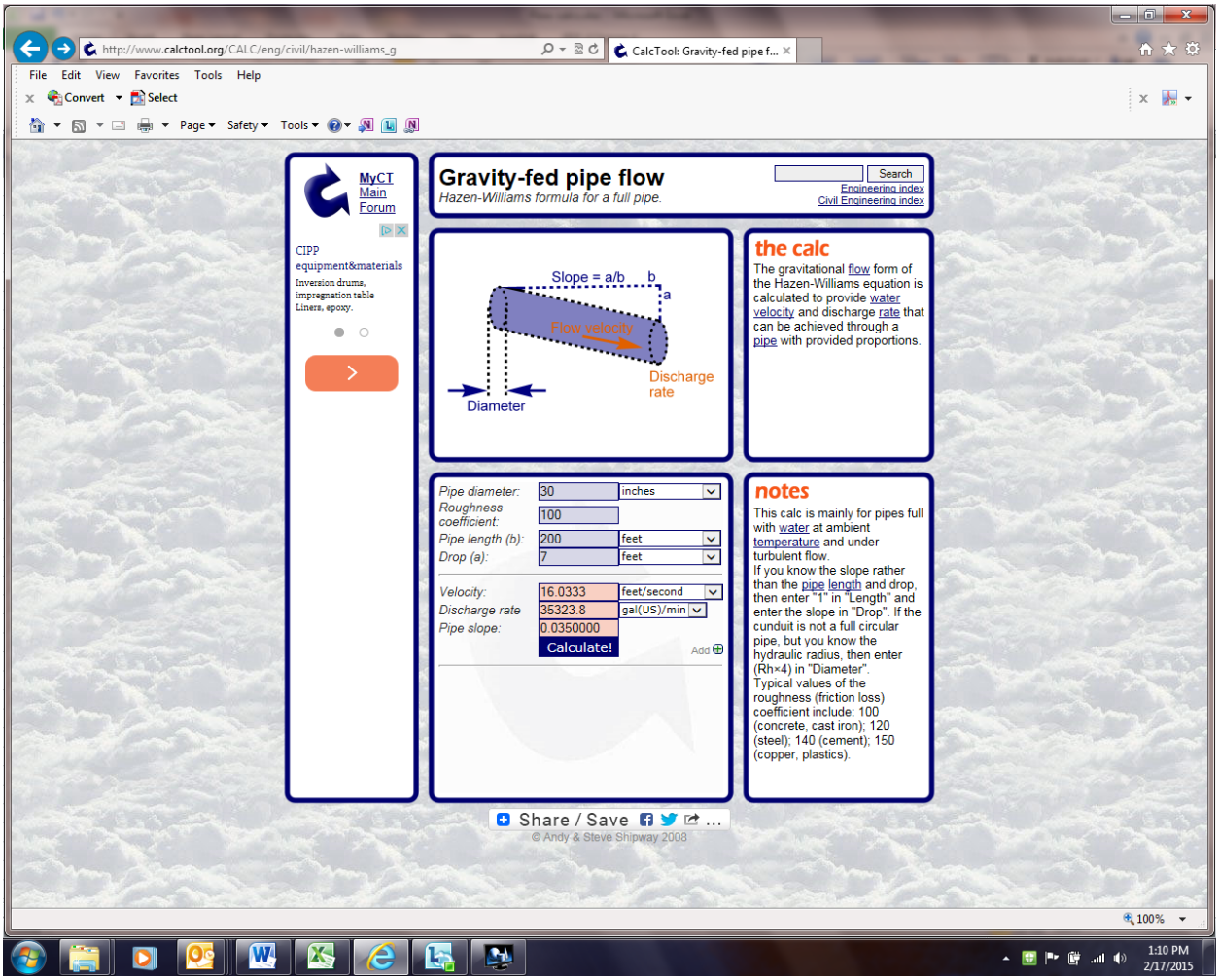
Drain line data and flow rate (based on Hazen-Williams equation):

Section	Diameter (in)	Length (ft)	Slope (%)	Drop	Flow Rate (gpm)
Site drain to manhole #1	30	480	0.293	1.4	9232
Manhole #1 to manhole #2	30	200	3.521	7.0	35324
Manhole #2 to manhole #3	30	290	0.63	1.8	13881
Manhole #3 to manhole #4	30	285	0.63	1.8	14012
Manole #4 to manhole #5	30	40	0.63	0.3	15375
Manhole #5 to storm drain tie-in	24	90	2.8	2.5	18432

The first section of piping limits the flow draining from the site (9,232 gpm). To drain 1,360,000 gallons of water from the site will require:

1,360,000 gallons / 9,232 gallon/min = **147 minutes**


http://www.calctool.org/CALC/eng/civil/hazen-williams_g
CalcTool: Gravity-fed pipe f...
File Edit View Favorites Tools Help
Convert Select
Page Safety Tools
MyCT
Main
Forum
CIPP equipment&materials
Inversion drums, impregnation table Liners, epoxy.
Gravity-fed pipe flow
Hazen-Williams formula for a full pipe.
Search
Engineering index
Civil Engineering index
Slope = a/b
b
a
Flow velocity
Discharge rate
Diameter
the calc
The gravitational flow form of the Hazen-Williams equation is calculated to provide water velocity and discharge rate that can be achieved through a pipe with provided proportions.
Pipe diameter: 30 inches
Roughness coefficient: 100
Pipe length (b): 480 feet
Drop (a): 1.4 feet
Velocity: 4.19050 feet/second
Discharge rate 9232.29 gal(US)/min
Pipe slope: 0.00291667
Calculate!
Add
notes
This calc is mainly for pipes full with water at ambient temperature and under turbulent flow.
If you know the slope rather than the pipe length and drop, then enter "1" in "Length" and enter the slope in "Drop". If the cunduit is not a full circular pipe, but you know the hydraulic radius, then enter (Rh×4) in "Diameter".
Typical values of the roughness (friction loss) coefficient include: 100 (concrete, cast iron); 120 (steel); 140 (cement); 150 (copper, plastics).
Share / Save
© Andy & Steve Shipway 2008
100%
1:11 PM
2/17/2015


http://www.calctool.org/CALC/eng/civil/hazen-williams_g
CalcTool: Gravity-fed pipe f...
File Edit View Favorites Tools Help
Convert Select
Page Safety Tools
MyCT
Main
Forum
CIPP equipment&materials
Inversion drums, impregnation table Liners, epoxy.
Gravity-fed pipe flow
Hazen-Williams formula for a full pipe.
Search
Engineering index
Civil Engineering index
Slope = a/b
b
a
Flow velocity
Discharge rate
Diameter
the calc
The gravitational flow form of the Hazen-Williams equation is calculated to provide water velocity and discharge rate that can be achieved through a pipe with provided proportions.
Pipe diameter: 30 inches
Roughness coefficient: 100
Pipe length (b): 200 feet
Drop (a): 7 feet
Velocity: 16.0333 feet/second
Discharge rate 35323.8 gal(US)/min
Pipe slope: 0.0350000
Calculate!
Add
notes
This calc is mainly for pipes full with water at ambient temperature and under turbulent flow.
If you know the slope rather than the pipe length and drop, then enter "1" in "Length" and enter the slope in "Drop". If the cunduit is not a full circular pipe, but you know the hydraulic radius, then enter (Rh×4) in "Diameter".
Typical values of the roughness (friction loss) coefficient include: 100 (concrete, cast iron); 120 (steel); 140 (cement); 150 (copper, plastics).
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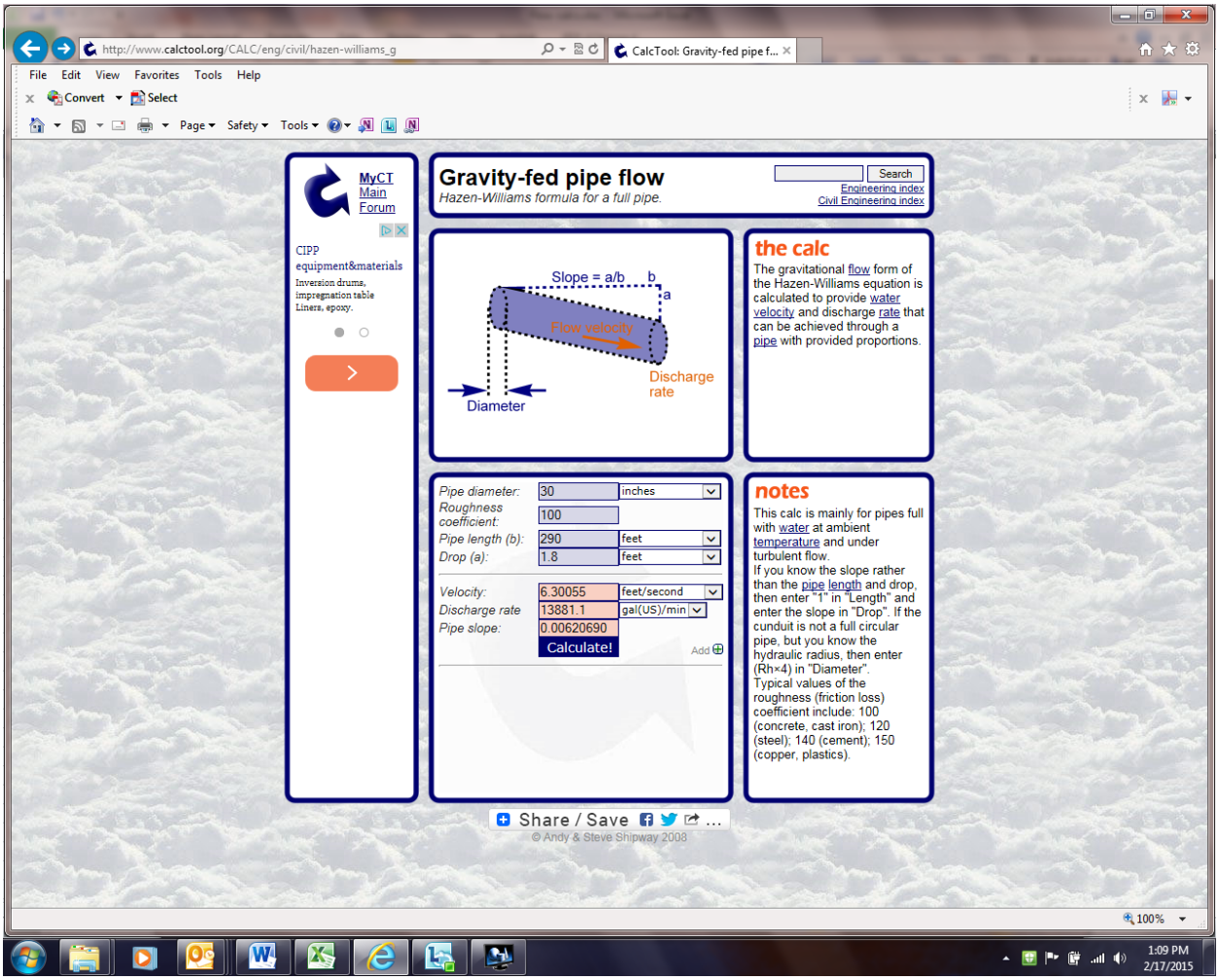
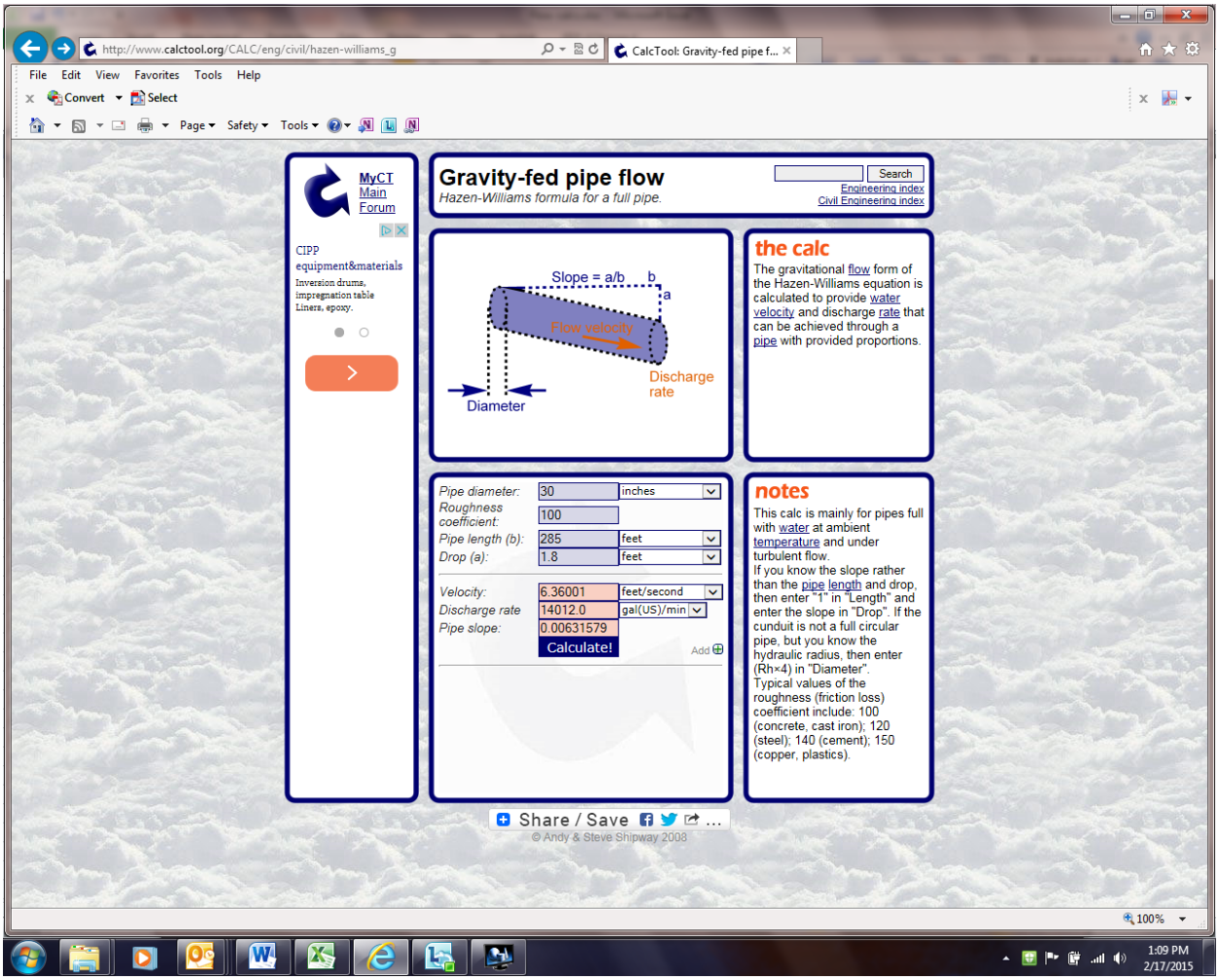
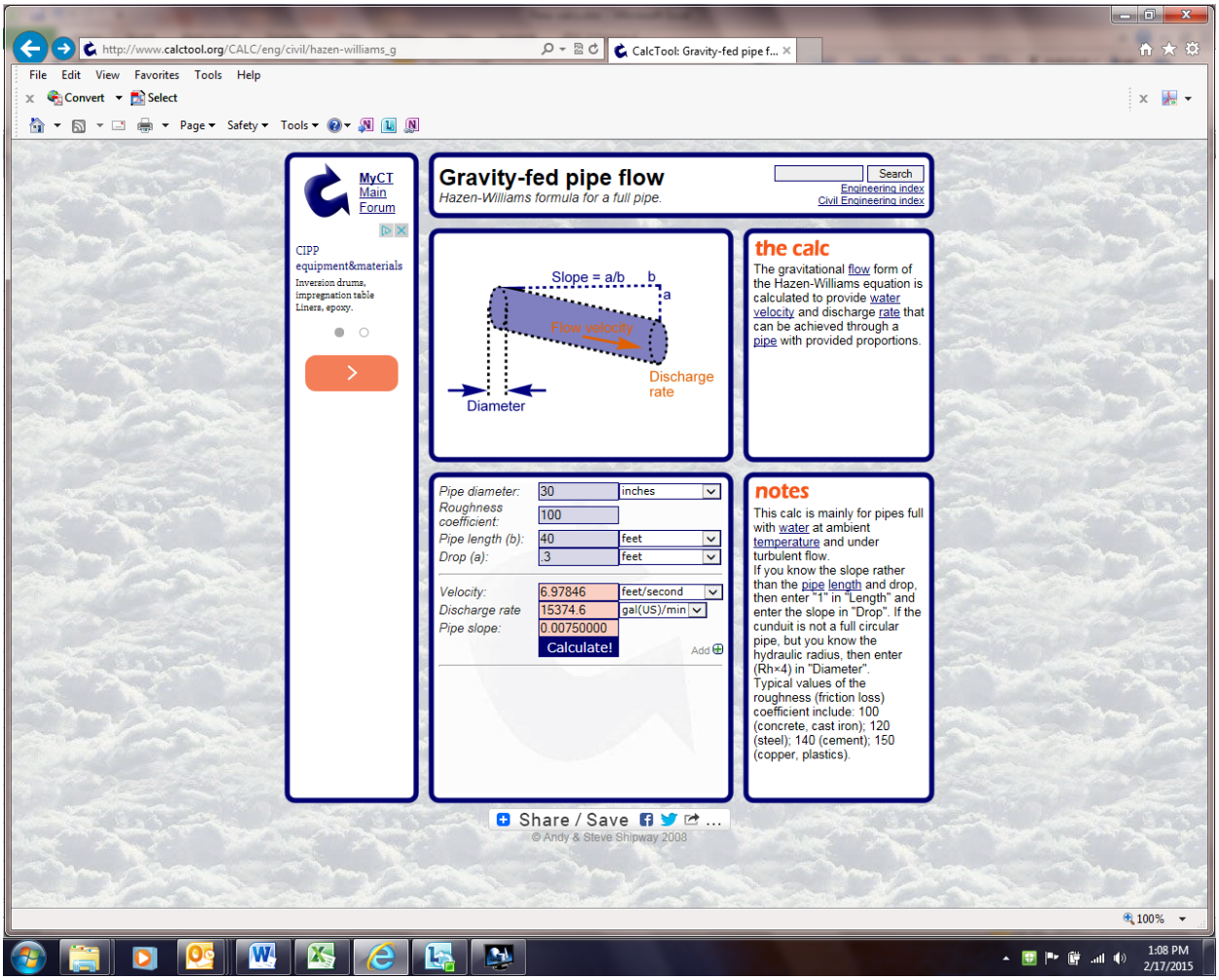
100%
1:10 PM
2/17/2015


http://www.calctool.org/CALC/eng/civil/hazen-williams_g
CalcTool: Gravity-fed pipe f...
File Edit View Favorites Tools Help
Convert Select
Page Safety Tools
MyCT Main Forum
CIPP equipment&materials
Inversion drums, impregnation table Liners, epoxy.
Gravity-fed pipe flow
Hazen-Williams formula for a full pipe.
Search
Engineering index
Civil Engineering index
Slope = a/b
b
a
Flow velocity
Discharge rate
Diameter
the calc
The gravitational flow form of the Hazen-Williams equation is calculated to provide water velocity and discharge rate that can be achieved through a pipe with provided proportions.
Pipe diameter: 30 inches
Roughness coefficient: 100
Pipe length (b): 290 feet
Drop (a): 1.8 feet
Velocity: 6.30055 feet/second
Discharge rate 13881.1 gal(US)/min
Pipe slope: 0.00620690
Calculate!
Add
notes
This calc is mainly for pipes full with water at ambient temperature and under turbulent flow.
If you know the slope rather than the pipe length and drop, then enter "1" in "Length" and enter the slope in "Drop". If the cunduit is not a full circular pipe, but you know the hydraulic radius, then enter (Rh×4) in "Diameter".
Typical values of the roughness (friction loss) coefficient include: 100 (concrete, cast iron); 120 (steel); 140 (cement); 150 (copper, plastics).
Share / Save
© Andy & Steve Shipway 2008
100%
1:09 PM
2/17/2015


http://www.calctool.org/CALC/eng/civil/hazen-williams_g
CalcTool: Gravity-fed pipe f...
File Edit View Favorites Tools Help
Convert Select
Page Safety Tools
MyCT
Main
Forum
CIPP equipment&materials
Inversion drums, impregnation table Liners, epoxy.
Gravity-fed pipe flow
Hazen-Williams formula for a full pipe.
Search
Engineering index
Civil Engineering index
Slope = a/b
b
a
Flow velocity
Discharge rate
Diameter
the calc
The gravitational flow form of the Hazen-Williams equation is calculated to provide water velocity and discharge rate that can be achieved through a pipe with provided proportions.
Pipe diameter: 30 inches
Roughness coefficient: 100
Pipe length (b): 285 feet
Drop (a): 1.8 feet
Velocity: 6.36001 feet/second
Discharge rate 14012.0 gal(US)/min
Pipe slope: 0.00631579
Calculate!
Add
notes
This calc is mainly for pipes full with water at ambient temperature and under turbulent flow.
If you know the slope rather than the pipe length and drop, then enter "1" in "Length" and enter the slope in "Drop". If the cunduit is not a full circular pipe, but you know the hydraulic radius, then enter (Rh×4) in "Diameter".
Typical values of the roughness (friction loss) coefficient include: 100 (concrete, cast iron); 120 (steel); 140 (cement); 150 (copper, plastics).
Share / Save
© Andy & Steve Shipway 2008
100%
1:09 PM
2/17/2015


http://www.calctool.org/CALC/eng/civil/hazen-williams_g
CalcTool: Gravity-fed pipe f...
File Edit View Favorites Tools Help
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MyCT
Main
Forum
CIPP
equipment&materials
Inversion drums,
impregnation table
Liners, epoxy.
Gravity-fed pipe flow
Hazen-Williams formula for a full pipe.
Search
Engineering index
Civil Engineering index
Slope = a/b
b
a
Flow velocity
Discharge
rate
Diameter
the calc
The gravitational flow form of the Hazen-Williams equation is calculated to provide water velocity and discharge rate that can be achieved through a pipe with provided proportions.
Pipe diameter: 30 inches
Roughness coefficient: 100
Pipe length (b): 40 feet
Drop (a): 3 feet
Velocity: 6.97846 feet/second
Discharge rate 15374.6 gal(US)/min
Pipe slope: 0.00750000
Calculate!
Add
notes
This calc is mainly for pipes full with water at ambient temperature and under turbulent flow.
If you know the slope rather than the pipe length and drop, then enter "1" in "Length" and enter the slope in "Drop". If the cunduit is not a full circular pipe, but you know the hydraulic radius, then enter (Rh×4) in "Diameter".
Typical values of the roughness (friction loss) coefficient include: 100 (concrete, cast iron); 120 (steel); 140 (cement); 150 (copper, plastics).
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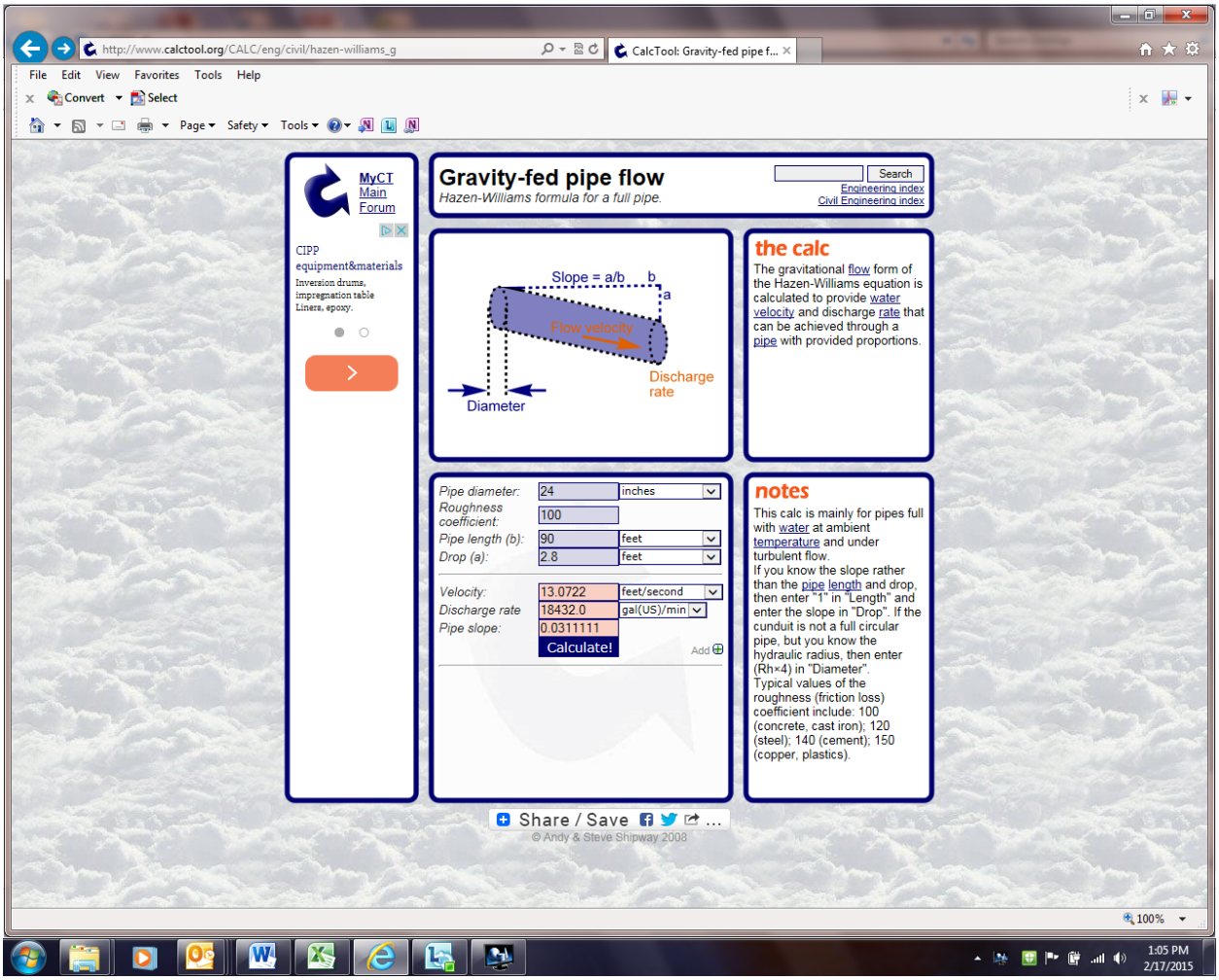
http://www.calctool.org/CALC/eng/civil/hazen-williams_g
CalcTool: Gravity-fed pipe f...
File Edit View Favorites Tools Help
Convert Select
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equipment&materials
Inversion drums,
impregnation table
Liners, epoxy.
Gravity-fed pipe flow
Hazen-Williams formula for a full pipe.
Search
Engineering index
Civil Engineering index
Slope = a/b
b
a
Flow velocity
Discharge
rate
Diameter
the calc
The gravitational flow form of the Hazen-Williams equation is calculated to provide water velocity and discharge rate that can be achieved through a pipe with provided proportions.
Pipe diameter: 24 inches
Roughness coefficient: 100
Pipe length (b): 90 feet
Drop (a): 2.8 feet
Velocity: 13.0722 feet/second
Discharge rate 18432.0 gal(US)/min
Pipe slope: 0.0311111
Calculate!
Add
notes
This calc is mainly for pipes full with water at ambient temperature and under turbulent flow.
If you know the slope rather than the pipe length and drop, then enter "1" in "Length" and enter the slope in "Drop". If the cunduit is not a full circular pipe, but you know the hydraulic radius, then enter (Rh×4) in "Diameter".
Typical values of the roughness (friction loss) coefficient include: 100 (concrete, cast iron); 120 (steel); 140 (cement); 150 (copper, plastics).
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100%
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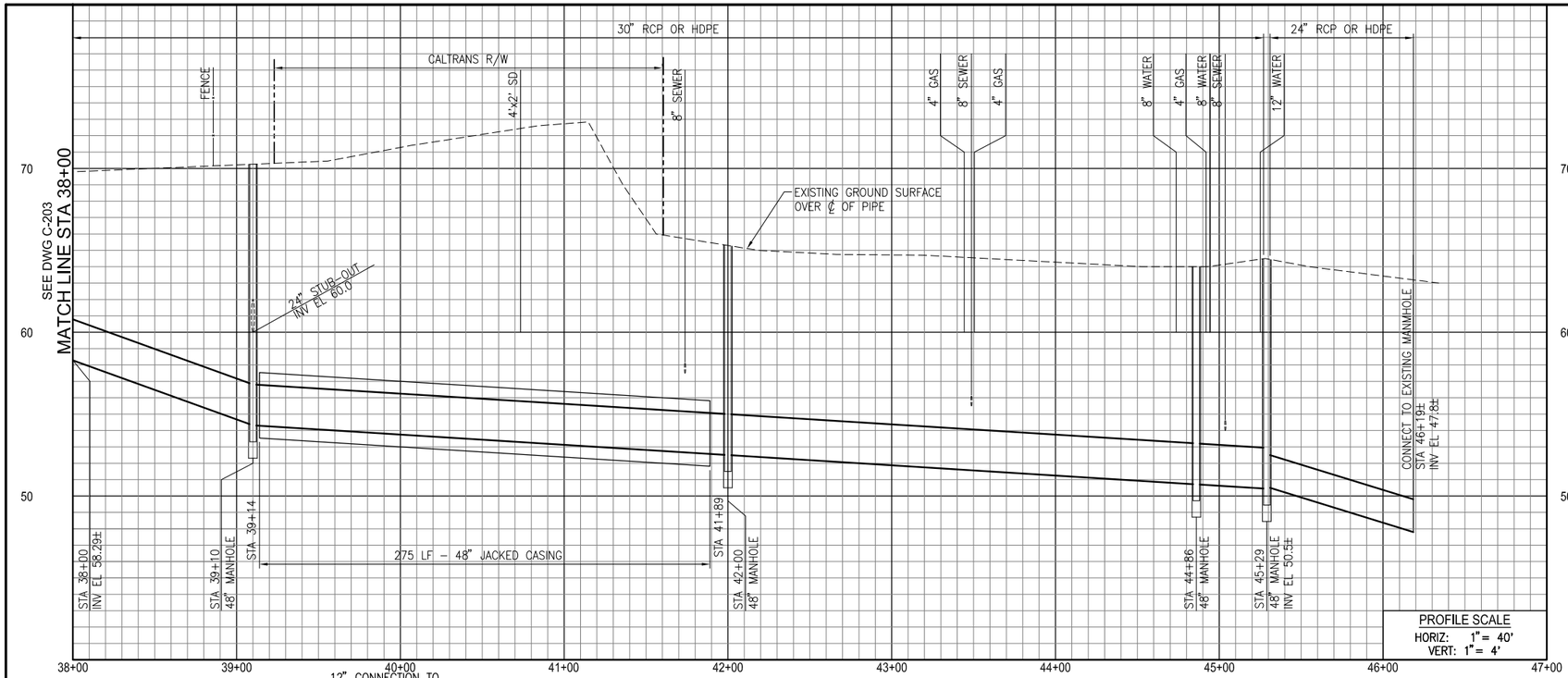
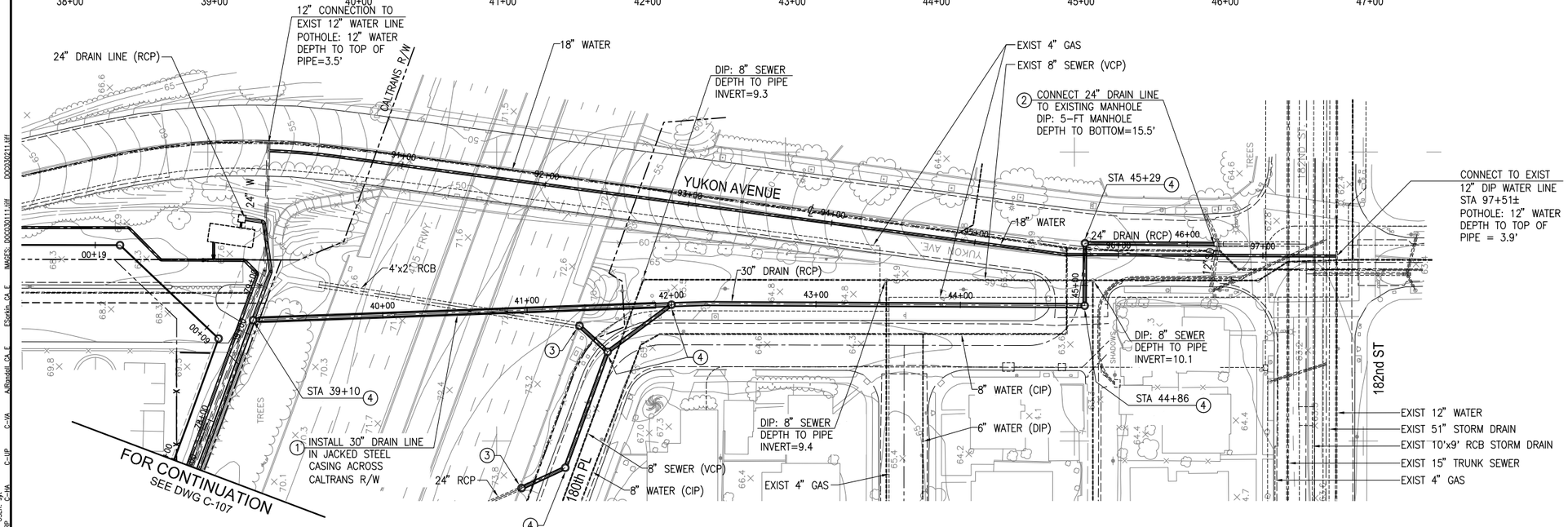
2/17/2015



CONSTRUCTION NOTES:

1. JACKED STEEL CASING. MINIMUM DIAMETER = 48", MIN T=3/4" COORDINATE WITH CALTRANS.
2. COORDINATE STORM DRAIN CONNECTION WITH COUNTY OF LOS ANGELES, DEPARTMENT OF PUBLIC WORKS.
3. REMOVE EXISTING OUTLET STRUCTURE. CONSTRUCT JUNCTION STRUCTURE AND 24" RCP TO OVERFLOW DRAIN LINE. COORDINATE WITH CALTRANS.
4. 48" MANHOLE



PLAN
SCALE: 1"=40'

DIG ALERT
1-800-227-2600
AT LEAST TWO DAYS BEFORE YOU DIG

THE CONFIGURATIONS, DIMENSIONS AND SIZES ON THESE PLANS FOR THE PROPOSED IMPROVEMENTS ARE INTENDED TO REPRESENT THE INTENT OF THE PROJECT. DIMENSIONS, CONFIGURATIONS AND SIZES SHOWN ARE BASED ON CONCEPT-LEVEL ENGINEERING. THE DB TEAM IS TO VERIFY AND SUBSEQUENTLY DESIGN THE PROJECT COMPONENTS FOR THE DESIGN DEVELOPMENT AND CONSTRUCTION PHASES. THE CONTRACTOR WILL BE RESPONSIBLE FOR THE ULTIMATE PERFORMANCE OF THE PROJECT AS SPECIFIED IN THE CONTRACT DOCUMENTS.

REV.	DATE	DESCRIPTION	BY	CHECKED

NORTH TORRANCE WELL FIELD PROJECT

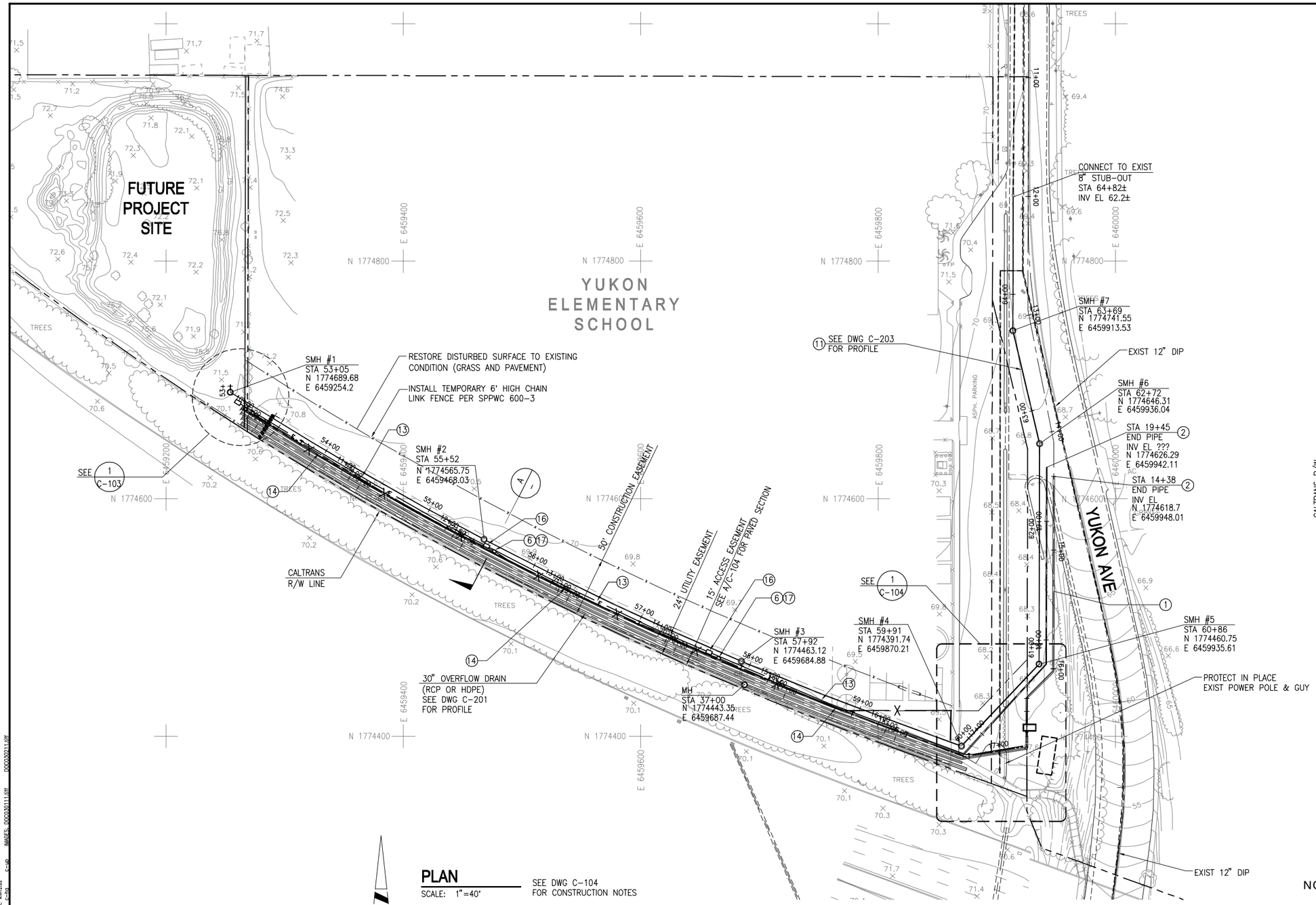
PIPING PLAN AND RES OVERFLOW PROFILE

C-204

CITY OF TORRANCE
PUBLIC WORKS DEPARTMENT

DRAWN:
DESIGNED:
PROJECT ENGINEER:
DIVISION ENGINEER:
APPROVED:
SCALE: AS SHOWN SHEET XX OF XX
PLAN NO. WP-

DWG: Y:\TorranceCityof\60186875-NTWF\CAD\Planset\C-204.dwg USER: sy1
DATE: Jun 18, 2012 - 3:52pm XREFS: C-SB1 (BB) C-HA C-HP C-HR C-VA AJRandall, QA, E EStolzin, QA, E IMAGES: D0030111.tif D0030111.tif



PLAN

SCALE: 1"=40'

SEE DWG C-104 FOR CONSTRUCTION NOTES

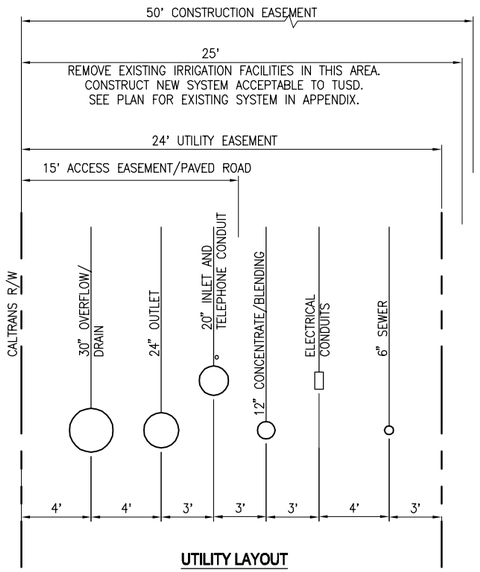
CONDUIT NOTES:

CONCRETE ENCASE ALL CONDUITS

PULL BOXES TO COMPLY WITH SCE REQUIREMENTS.

CONDUIT SHALL BE PVC SCHEDULE 40, 90% RISE RATING, CONFORMING TO NEMA TC-2 TYPE EC-40 AND UL 651. COUPLINGS TO BE FACTORY-MADE IN ACCORDANCE WITH NEMA TC-2 AND TC-3. USE JOINT CEMENT AS RECOMMENDED BY MANUFACTURER, MANUFACTURERS: CARLON, CONDUX OR EQUAL.

PROVIDE MINIMUM 24" COVER.



UTILITY LAYOUT

SECTION A C-101

SCALE: 1"=4'-0"

NORTH TORRANCE WELL FIELD PROJECT PHASE I

OFFSITE PIPING PLAN

C-102

REGISTERED PROFESSIONAL ENGINEER C. RUSSELL HULSE No. C17139 Exp. 6/30/13 CIVIL STATE OF CALIFORNIA

AECOM

AECOM
999 Town & Country Road
Orange, California 92868
T 714-567-2400
www.aecom.com

REV.	DATE	DESCRIPTION	BY	CHECKED

CITY OF TORRANCE
PUBLIC WORKS DEPARTMENT

DRAWN: S. KIVRIZIS

DESIGNED: C. R. HULSE

APPROVED:

PROJECT ENGINEER: EMMANUEL MARTIN

TOUFIC J. SEMAAN, PE DATE:
ACTING CITY ENGINEER
RCE #59226
EXP. 6/30/13

ENGINEERING MANAGER: JOHN C. DETTLE, P.E.

SCALE: AS SHOWN SHEET 4 OF 10

PLAN NO. WP-297

DWG: Y:\TorranceCityof\NTWF Phase 1\CAD\Planset\C-102.dwg USER: kivrizis
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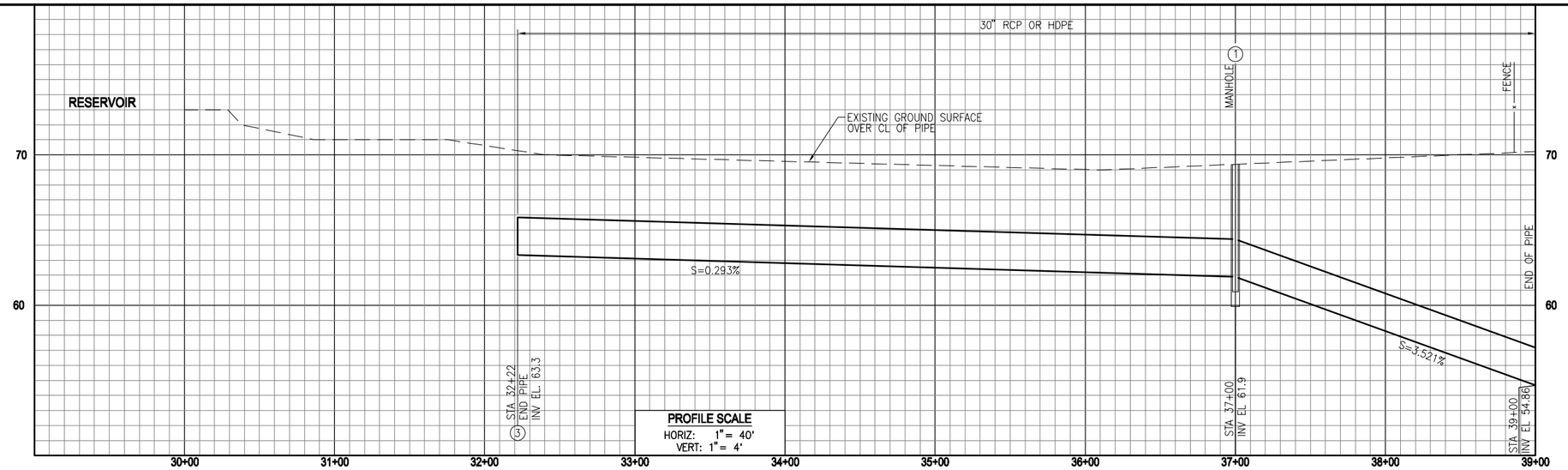

CONSTRUCTION NOTES:

1. MANHOLE PER SPPWC 321-2.

SEE DWG C-102, C-103 AND C-104 FOR PLAN

NORTH TORRANCE WELL FIELD PROJECT PHASE I

RESERVOIR OVERFLOW PROFILE

C-201

REGISTERED PROFESSIONAL ENGINEER
C. RUSSELL HULSE
No. C17139
Exp. 6/30/13
CIVIL
STATE OF CALIFORNIA

AECOM

AECOM
999 Town & Country Road
Orange, California 92868
T 714-567-2400
www.aecom.com

REV.	DATE	DESCRIPTION	BY	CHECKED

CITY OF TORRANCE
PUBLIC WORKS DEPARTMENT

DRAWN: T. R. SY

DESIGNED: C. R. HULSE

APPROVED:

PROJECT ENGINEER: EMMANUEL MARTIN

TOUFIC J. SEMAAN, PE DATE:
ACTING CITY ENGINEER
RCE #59226
EXP. 6/30/13

ENGINEERING MANAGER: JOHN C. DETTLE, P.E.

SCALE: AS SHOWN SHEET 8 OF 10

PLAN NO. WP-297

DWG: Y:\TorranceCityof\NTWF Phase 1\CAD\Planset\C-201.dwg USER: kivinlss
DATE: Apr 18, 2013 2:17pm XREFS: c-bd grid c-rp c-hp c-up c-vg IMAGES: DOC030111.tiff DOC030211.tiff