Storm Drain Master Plan Update

June 2015

Public Works Department/Engineering Services Division

FINAL

CITY OF PALO ALTO
CALIFORNIA

Prepared by

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Executive Summary

ES.1 Study Objectives

A significant planning effort has been undertaken to help guide the City of Palo Alto to establish a prioritized Capital Improvement Program to mitigate the impacts of stormwater runoff in Palo Alto. This document identifies capital improvement projects needed to provide a 10-year level of service throughout Palo Alto.

The main objective of this master plan document is to provide an analysis of capacity restrictions within the storm drain networks of Palo Alto, and list the recommended projects necessary to provide a 10 year level of service.

The following list presents a summary of steps taken:

1. The City's existing storm drain model was updated. Updated features include: manhole invert and rim elevations, pipe diameter, pump stations, and watershed runoff characteristics.
2. Storm drainage analysis methodologies and criterion were established with City staff.
3. The City's regulatory requirements were reviewed and proposed actions have been outlined.
4. A hydrologic and hydraulic analysis of the existing storm drain facilities throughout Palo Alto was performed for a 10-year storm event. System deficiencies are categorized in terms of the risk to private property and public safety.
5. Pump stations that impact the City's storm drain system are analyzed. Localized pump station located within the City but that do not impact the City's system, such as pump stations that serve underpasses, were not analyzed.
6. Projects that will improve storm drain performance have been identified.
7. A condition assessment was completed on previously unmapped CMP culverts located south of Highway 280. Condition related improvements are identified.
8. A prioritized Capital Improvement Program (CIP) is outlined.
9. Projected capital improvement costs have been summarized.

ES.2 Sources of Flooding

Runoff generated within the study boundary is conveyed through storm drain systems that outfall to creeks and ultimately San Francisco Bay. Capacity deficiencies within the storm drainage network can contribute to flooding within Palo Alto. For the purposes of this report, flooding is defined as the surcharge of water above ground surface at a drainage inlet or manhole. The primary objective of the Storm Drain Master Plan is to determine the cause of flooding and identify mitigation measures. Because Palo Alto is located near the Bay, the capacity of these drainage systems may be linked to the tides and influence of the surrounding waters. Flooding caused by creek spills, tidal action, or other such events have not been addressed in this report.

ES.3 Work Products

This master plan is intended to function at several levels. City planners and engineers responsible for capital improvements should find that this document contains sufficient background information and data to serve as a basis for future improvement implementation and/or modification. For those City staff and other parties interested in a more in-depth examination of storm drain facilities within Palo Alto, the companion GIS-based PCSWMM hydraulic model is available. PCSWMM uses the US EPA SWMM5 engine to model hydrology and hydraulics of urban drainage and sewer systems. As discussed in supporting reports and documents, the following information is available via the GIS:

1. **Inventory of Drainage Facilities.** Drainage pipes 12-inches in diameter and larger in the study area have been imported into the storm drain model. Information pertaining to each system component may be accessed graphically or through database spreadsheets which have been provided electronically.
2. **Tributary Drainage Areas.** Land areas used to generate local runoff are also available graphically in the storm drain model, which catalogs tributary area, factors related to land use and soil conditions and other basin morphology.
3. **Storm Drain Capacities Evaluation.** Storm drain capacities are documented in the model. For each drainage system component, peak discharge and maximum hydraulic grade line are computed. Based on hydraulic grade calculations, the degree of surcharge and depth (based on theoretical HGL) of water above ground are also determined. This determination is then used to assign priorities for system remediation.
4. **Drainage System Profiles.** Those interested in viewing drainage system profiles may do so graphically using software features specifically designed for this purpose. Real-time animations of water surface profiles and corresponding surface ponding depths for design storm events are also available.

ES.4 Capital Improvement Projects

Palo Alto was divided into three drainage areas: Part 1 which drains west to San Francisquito Creek; Part 2 is mainly the Matadero Creek watershed with sections draining north and west to San Francisquito Creek and east to Barron Creek; and Part 3 includes the Adobe Creek watershed, the majority of the Barron Creek watershed, and the area that drains to the Airport Pump Station; (Figure ES-1). Results of the drainage analyses and recommended improvements for each of these drainage areas are presented in Chapter 4.

A condition assessment of the previously unmapped CMP culverts located south of Highway 280 was performed. The culverts are rated and condition related improvements are recommended.

A Capital Improvement Program has been developed using the recommended capacity and condition related improvements. This program is presented in Chapter 6, and detailed costs are available in Appendix C. A summary of CIP costs are presented in Table ES-1. A breakdown of these costs by drainage region is presented in Table ES-2.

Table ES-1: Summary of CIP Costs Based on Priority Level

Priority Level	Cost
Highest Priority Capital Improvements	$14,102,000
High Priority Capital Improvements	$23,139,000
Moderate Priority Capital Improvements	$22,233,000
Low Priority Capital Improvements	$53,800,000
Total Capital Improvement Program	**$113,054,000**

Table ES-2: Summary of Prioritized 10-Year CIP Project Costs

Priority		Part 1	Part 2	Part 3	Condition Imps.	Total
Highest	Length (ft)	0	0	702	470	1,172
	Cost	0	$11,530,000	$2,420,000	$152,000	$14,102,000
High	Length (ft)	0	17,073	3,117	581	20,356
	Cost	0	$20,330,000	$2,640,000	$169,000	$23,139,000
Moderate	Length (ft)	0	16,592	3,829	580	21,001
	Cost	0	$16,470,000	$5,650,000	$113,000	$22,233,000
Low	Length (ft)	0	31,821	26,425	0	58,246
	Cost	0	$26,080,000	$27,720,000	0	$53,800,000

ES.5 Conclusion

Reducing existing drainage limitations by improving those portions of the drainage system that are the City's responsibility is a worthy goal. This Master Plan provides a tool for Palo Alto citizens and officials to use in their efforts to reduce both nuisance flooding, and the likelihood of more serious flood related hazards to private and/or public property, and to maintain the drainage network in good working condition.

This study and proposed CIP is merely the starting point. It is anticipated that City staff and/or their consultants will perform a more detailed study or alternatives analysis to find more affordable or effective improvements with information gathered as part of the design process (detailed topography, utility conflicts, easements, etc).

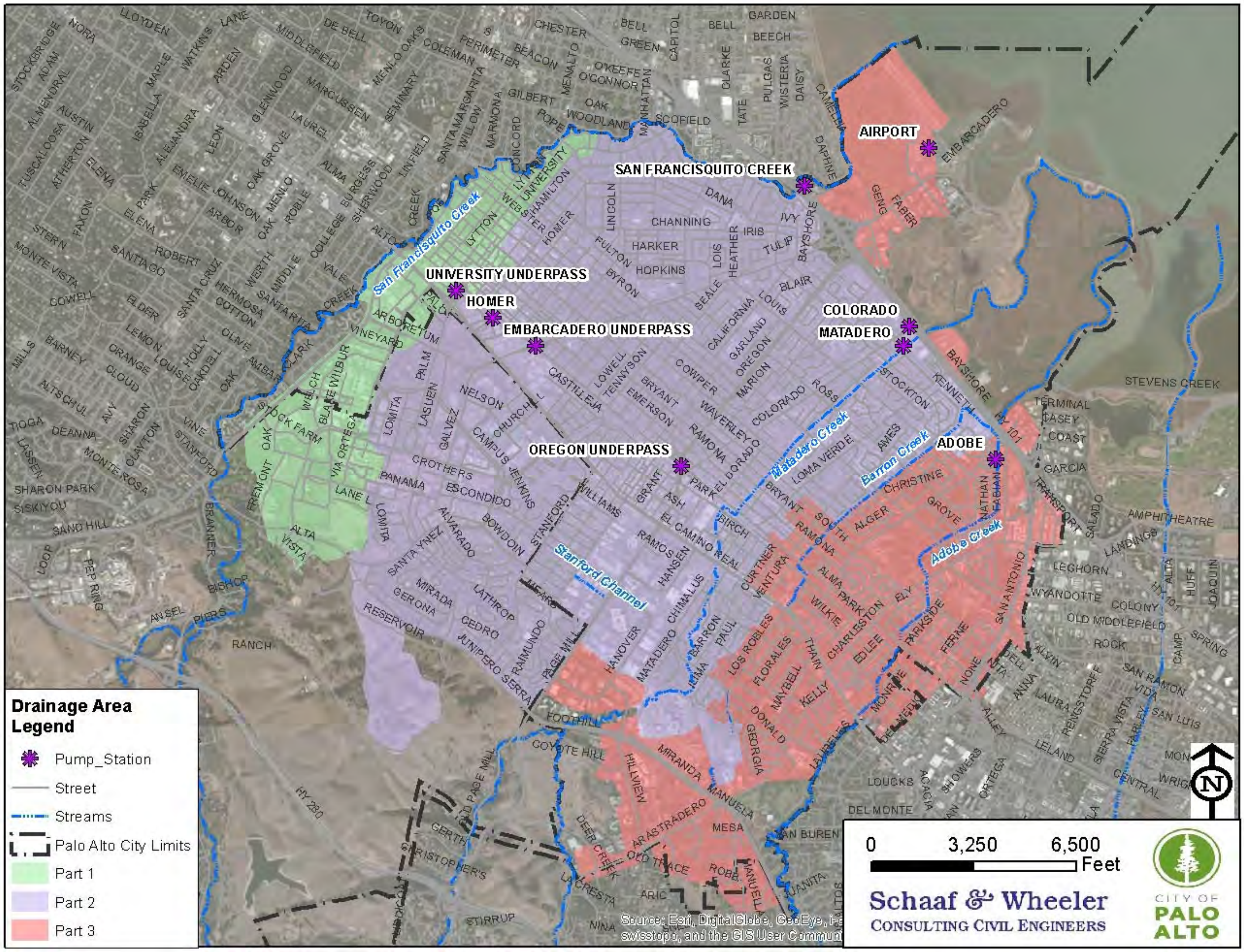


Figure ES-1: Palo Alto Drainage Areas

Chapter 1. Introduction

1.1 Overview

This City of Palo Alto Storm Drain Master Plan provides a capacity analysis, a condition assessment of CMP culverts located south of Highway 280, recommended improvement projects with estimated costs, a discussion of drainage design standards, and systematic condition assessment program recommendations. This chapter provides a general discussion of the Palo Alto area setting, storm drain network, and history of flooding. This chapter also gives a brief description of the master plan process.

1.2 Setting

The Palo Alto capacity analysis study area covers the urban core of the city. The study area is bounded by San Francisquito Creek on the north, San Francisco Bay or Bayshore Fwy (US-101) on the east, San Antonio Rd and Adobe Creek for the south limit, and by Junipero Sierra Blvd to the west as shown in Figure 1- 1. The majority of the Palo Alto study area is relatively flat with some mountainous terrain west of Junipero Sierro Blvd. Elevations range from -5 feet North Geodetic Vertical Datum (NGVD), to about 510 feet NGVD.

Figure 1- 1: Location of Palo Alto Master Plan Capacity Analysis Study Area

1.3 Soils

The Natural Resources Conservation Service (NRCS) has classified soils into four hydrologic soil groups (A, B, C, and D) according to their infiltration rates. Group A soils have low runoff potential when thoroughly wet and typically consist of sand or gravel type soils. Group B soils are moderately well draining when thoroughly wet and consist of loamy sand or sandy loam textures. Group C soils have moderately high runoff potential when thoroughly wet and consist of loam, silt loam, sandy clay loam, clay loam, and silty clay loam textures. Group D soils have high runoff potential when thoroughly wet and consist of clayey textures. All soils with a water table within 24-inches of the surface are in Group D. The Palo Alto study area consists of 3% Group B soils, 17% Group C soils, and 80% Group D soils.

1.4 Climate

Palo Alto's climate is marine-influenced with an average annual high temperature of 70.3°F and average annual low temperature of 46.8°F. Average summertime temperatures range from 80°F to 54°F. Average winter temperatures range from 57°F to 38°F. Mean annual precipitation is 16 inches, with the majority of that precipitation falling from November through March. Precipitation occurs entirely as rainfall. Snowmelt is not a hydrologic process that significantly affects runoff in the City.

1.5 Flood Protection Facilities

Precipitation that falls within Palo Alto generates stormwater runoff. This runoff is conveyed through the storm drain networks and discharged to the creeks or San Francisco Bay through a combination of pump stations and gravity outfalls. These networks can interact with one another through weirs or other connections, and potential improvements to one system may impact the performance of other systems. The total study area is roughly 14.0 square miles (8,951 acres). It has been divided up into 3 drainage areas which are shown in Figure 1-2 and detailed in Table 1-1. Most of the streets in Palo Alto have traditional curb and gutter lined streets which limits attenuation before runoff reaches a catch basin. In addition to storm drains, flood protection is provided to Palo Alto by San Francisquito Creek, Matadero Creek, Barron Creek, Adobe Creek, and the Palo Alto Flood Basin.

Table 1-1: Watershed Areas and Length of Modeled Storm Drain Pipe

Drainage Area	Area (square miles)	Pipe (miles)
San Francisquito	1.4	11.3
Matadero	8.4	55.3
Adobe/Barron	4.1	28.4
TOTAL	**13.9**	**95.0**

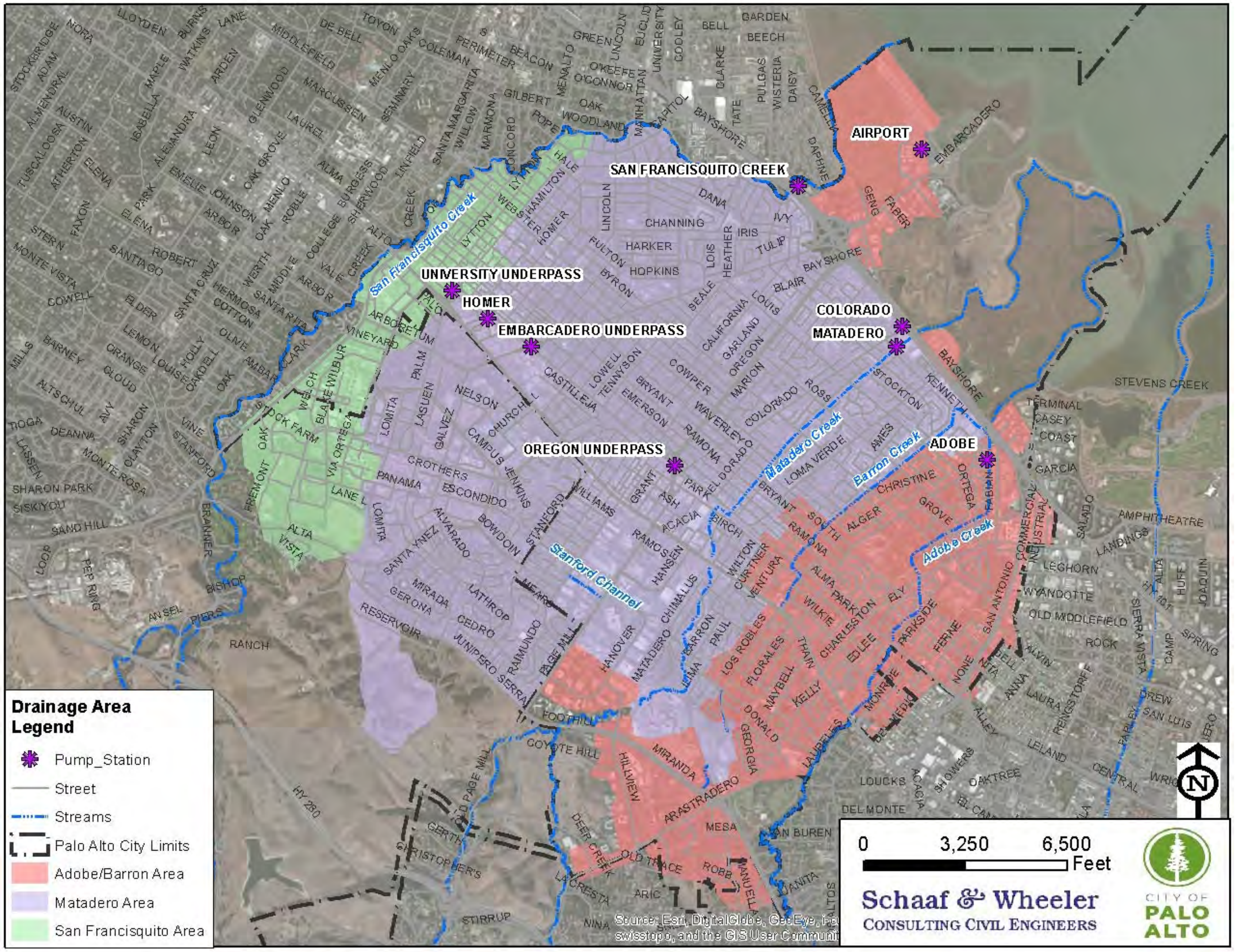


Figure 1-2: Palo Alto Drainage Areas

1.6 References

Various documents were referenced during the preparation of this master plan:

- CH2M Hill 1993 Palo Alto Storm Drain Master Plan. (1993).
- General Construction Permit. State Water Resources Control Board: Division of Water Quality. (Order 2009-0009-DWQ as amended by 2010-0014-DWQ). (2010).
- Municipal Regional Stormwater NPDES Permit No. CAS612008. California Regional Water Quality Control Board: San Francisco Bay Region. (Order R2-2009-0074). (2009).
- Santa Clara County Drainage Manual. Santa Clara County Department of Planning and Development Services. Prepared by: Schaaf & Wheeler Consulting Civil Engineers. (2007).
- Municipal Code (Supp. No. 27). City of Palo Alto, California (Ordinance No. 5250). (2014).
- Palo Alto Comprehensive Plan. City of Palo Alto Land Use and Development. (2007).
- Santa Clara County Flood Insurance Study. Federal Emergency Management Agency (2009).
- Various Technical Documents. Santa Clara Valley Urban Runoff Pollution Prevention Program. Web June 2011. < http://www.scvurppp-w2k.com >
- Various Technical Documents. Santa Clara Valley Water District. Web June 2011. < http://www.valleywater.org >
- Various Technical Documents. San Francisco Bay Conservation and Development Commission. Web 2013 < http://www.bcdc.ca.gov >

Chapter 2. Data

2.1 Overview

Schaaf & Wheeler reviewed and utilized readily available land use, topographic, geographical, and storm drain system data within the Palo Alto Storm Drain Master Plan Area (study area). Some data was missing or incorrect, and efforts were made to add to the collective data. Where necessary, assumptions and engineering judgment were used to complete remaining data gaps. This chapter summarizes the findings and data acquired as part of the Palo Alto Storm Drain Master Plan (SDMP). Data limitations, assumptions, and impacts are also summarized.

2.2 Data Sources

Topography and Aerial Imagery

All project data and results are in vertical datum NGVD29 (feet) and State Plane (California Zone III) coordinate system. Santa Clara County's 2006 1-foot contour LiDAR topography data (NAVD) with half foot accuracy (plus or minus 0.5 foot) is utilized for ground surface information. This data was converted to NGVD. The data provided by the City is not on a consistent vertical datum; steps taken to convert data to a common datum are detailed in the Data Quality and Data Assumptions sections of this chapter. The high resolution digital aerial imagery provided by ESRI was also used.

GIS Data

The City provided GIS files and the computer models created during the 1993 master planning process to the Schaaf & Wheeler team for use on this project. The City GIS attribute information includes: storm drain pipes and laterals, storm drain manholes and inlets, outfalls, pump stations, 2010 Comprehensive Plan land use, City limits, and parcel data. The City's GIS data quality and accuracy varies and some information critical to accurately model the storm drain system is absent.

The City's manhole shapefile has only limited (~3%) information on invert and rim elevations. The models created during the 1993 master planning process contain rim and invert data only for modeled pipes and nodes, based on topographic survey data collected by CH2M Hill. The topographic survey was based on a custom City of Palo Alto reference vertical datum, which is a slightly modified version of the NGVD29 vertical datum.

The steps taken to complete the data set to a master planning level of accuracy are detailed in the Data Quality and Data Assumptions sections of this chapter.

Pump Stations

There are a total of nine pump stations located in Palo Alto, as summarized in **Error! Reference source not found.**. Six pump stations are analyzed as part of this master plan: Adobe, Airport, Colorado, Matadero, Oregon Underpass, and San Francisquito. The three pump stations not included in this study, Embarcadero Road Underpass, University Avenue Underpass, and Homer Avenue Underpass, serve roadway underpasses and do not significantly impact the City's storm drain system.

Table 2-1: Pump stations located in Palo Alto

Pump station	Owner	Modeled?
Adobe	City of Palo Alto	Yes
Airport	City of Palo Alto	Yes
Colorado	City of Palo Alto	Yes
Matadero	City of Palo Alto	Yes
Oregon Underpass	County of Santa Clara	Yes
San Francisquito	City of Palo Alto	Yes
Embarcadero Rd Underpass	City of Palo Alto	No
University Ave Underpass	City of Palo Alto	No
Homer Ave Underpass	City of Palo Alto	No

All modeled pump stations, except the Oregon Underpass pump station, were visited by Schaaf & Wheeler staff to visually inspect the condition of the stations and document the equipment and settings. Each pump station's on and off levels were provided by City maintenance staff. Pump curves for the Matadero and Adobe pump stations were also provided by the City. Pump station information provided by the City is listed below.

- Adobe Pump Station: As-Builts dated 05/1967 with revisions dated 4/1998
- Airport Pump Station: As-Builts dated 4/1998
- Colorado Pump Station: As-Builts dated with revisions 04/1998
- Matadero Pump Station: As-Builts date 05/1967 with revisions dated 04/1998
- San Francisquito Pump Station: Record Drawings dated 11/2010

Historical Data and As-Builts

As-Built improvement plans were reviewed for relevant storm system data, to verify the City provided GIS data, and to fill in data gaps. As-Built plans were assumed to be accurate and up-to-date.

Field Measurements

Schaaf & Wheeler conducted selective field research to verify pipe sizes, layouts, and to measure invert depths. Unlike sanitary sewer modeling, storm water systems are designed to surcharge (pressure flow). Invert elevations become less critical than pipe diameter because the system's hydraulic grade lines (HGLs) are not governed by open channel flow dynamics. Interpolation was used to determine missing information not available from GIS, survey or As-Built drawings.

FEMA and SCVWD Data

The Santa Clara Valley Water District's (SCVWD) GIS data, which includes creek centerlines, watershed delineations and 1-foot contour topography, was referenced for this study. FEMA reports were referenced for creek water surface levels which were assigned to fixed outfalls. FEMA GIS data was referenced to obtain flood zone information.

Regulatory

Key documents referenced for the regulatory review are the California Regional Water Quality Control Board San Francisco Region Municipal Regional Stormwater NPDES Permit; Order R2-2009-0074; and NPDES Permit No. CAS612008, October 14, 2009.

Land Use Data and Runoff Characteristics

Two land use scenarios were analyzed for the SDMP: existing and 2010 Build-Out Comprehensive Plan. The existing land use is based on the City's existing zoning originally established in 1998 and modified up until 2014. The existing land use in Palo Alto is primarily single family residential, interspersed with educational facilities, office parks, commercial, light industry, and open space. The various land use descriptions found in the GIS database are summarized in

Table 2-1.

The existing land use that flows to the City storm drain system in Palo Alto, shown in Figure 2-1, is approximately 42% single family residential, 11% MIUL (major institution/university lands)/campus educational facility, 10% research/office park, 6% multi-family residential, 5% MIUL/ academic reserve and open space, and with the remaining 26% is a mix of industrial, commercial, public park, school district land, etc land use.

The majority of the land use in Palo Alto is single family residential as shown in Figure 2-1. Parcel size of the single family homes varies widely in Palo Alto, from less than ¼ of an acre to greater than ¾ acre. Due to the range of areas within this category, assigning one impervious value would not be representative. Therefore, the single family residential category was broken up into three tiers based on parcel size with each tier being assigned a unique percent impervious value, as summarized in Table 2-2.

Table 2-1: Land Use Descriptions and Percentages in Study Area

Description	Existing		2010 Build-Out	
	Area (acres)	Percent of area	Area (acres)	Percent of area
Single Family Res (<1/4 acre)	2811.15	31.70%	2811.15	31.47%
MIUL/Campus Educational Facility	1014.75	11.44%	1014.74	11.36%
Research/Office Park	886.44	10.00%	885.83	9.92%
Single Family Res (1/4-3/4 acre)	623.09	7.03%	623.09	6.98%
Multi-Family Res	499.80	5.64%	566.12	6.34%
MIUL/Academic Reserve and Open Space	463.48	5.23%	463.46	5.19%
MIUL/Campus Single Family	408.36	4.60%	408.36	4.57%
Major Institution/Special Facility	373.16	4.21%	372.98	4.18%
Public Park	356.91	4.02%	380.68	4.26%
Single Family Res (>3/4 acre)	307.47	3.47%	307.47	3.44%
School District Land	302.04	3.41%	301.28	3.37%
Regional/Community Commercial	219.24	2.47%	219.25	2.45%
Service Commercial	123.07	1.39%	122.98	1.38%
Light Industrial	103.29	1.16%	103.29	1.16%
Freeway	98.56	1.11%	98.60	1.10%
Neighborhood Commercial	89.21	1.01%	88.74	0.99%
MIUL/Campus Multiple Family	45.21	0.51%	45.21	0.51%
SOFA I CAP	40.20	0.45%	33.56	0.38%
Multi-Family Res (w/Hotel Overlay)	37.39	0.42%	18.70	0.21%
SOFA II CAP	25.96	0.29%	25.94	0.29%
Mixed Use	14.76	0.17%	14.80	0.17%
Streamside Open Space	7.29	0.08%	7.30	0.08%
Hotel Commercial	6.87	0.08%	6.87	0.08%
Public Conservation Land	5.31	0.06%	5.31	0.06%
Open Space/Controlled Development	5.03	0.06%	4.22	0.05%

1. MIUL = Major Institution/University Lands
2. SOFA = South of Forest Avenue
3. CAP = Coordinated Area Plan

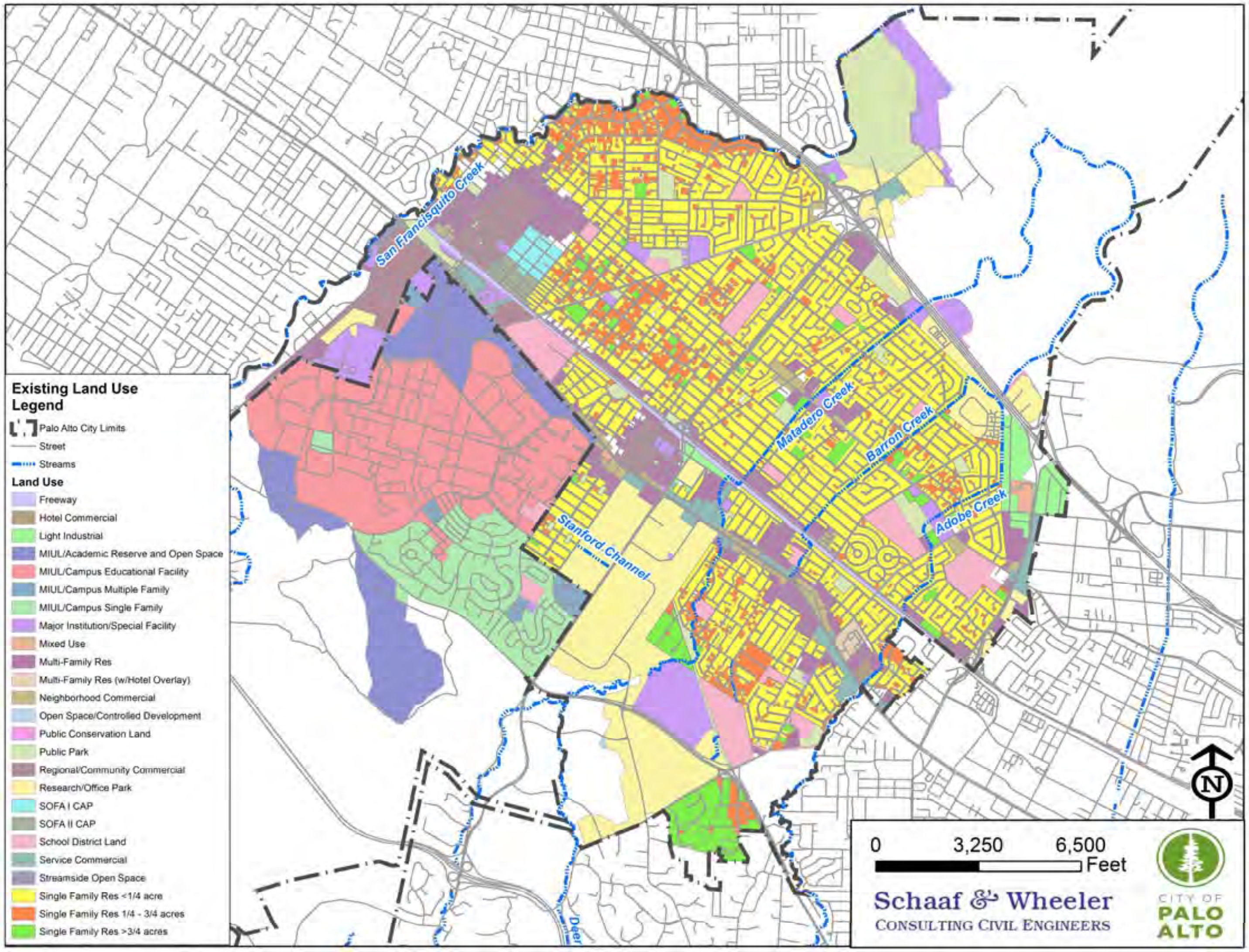


Figure 2-1: Existing Land Use of Palo Alto

Table 2-2: Single Family Residential Percent Impervious

Land Use Single Family Residential	Existing		Build-out 2010	
	% of Single Family Res	% Impervious	% of Single Family Res	% Impervious
<1/4 acre	75.13	55.4	75.30	55.4
1/4-3/4 acre	16.65	39	16.58	50.3
>3/4 acre	8.22	31.5	8.12	49.6
TOTAL	**100%**	**-**	**100%**	**-**

In addition to the existing land use conditions, Schaaf & Wheeler analyzed the land use based on full build-out of the 2010 Comprehensive Plan (2007). As discussed in Chapter 3 - Methodology, the improvements based on the 2010 build-out land use condition are used to create the CIP presented in Chapter 6. The build-out 2010 Comprehensive Plan land uses in Palo Alto, shown in Figure 2-3 and summarized in

Table 2-1, does not substantially change as compared to the existing land use. The future land use is approximately 42% single family residential, 11% MIUL/campus educational facility, 10% research/office park, 6% multi-family residential, 5% MIUL/ academic reserve and open space, and with the remaining 26% is a mix of industrial, commercial, public park, school district land, etc. land use. However, the development trend for single family residential is to build as large of homes as possible, therefore increasing the impervious value of the parcel by as much as 18%. The impervious values used to for the future land use condition are summarized in Table 2-2. These numbers were calculated using City setback requirements and average lot dimensions to determine lot coverage.

Rainfall runoff is determined by soil classification, land use, and percentage of impervious surface. Soils classification is based on Hydraulic Soil Group (A, B, C, or D); this data is produced by the National Resource Conservation Service (NRCS), and its use in the master plan analysis is described in detail in Chapter 3 - Methodology. The soil groups in Palo Alto are shown in Figure 2-4. The Curve Number methodology, also described in Chapter 3, is used for surface runoff calculations. NRCS runoff Curve Numbers (CN) were assigned to the City land use designations based on hydraulic soil group using values published in Santa Clara County Drainage Manual. The percent impervious for each land use type is based on values published in the County Drainage Manual and validated using the high-resolution aerial photography. These values are presented in Table 2-3.

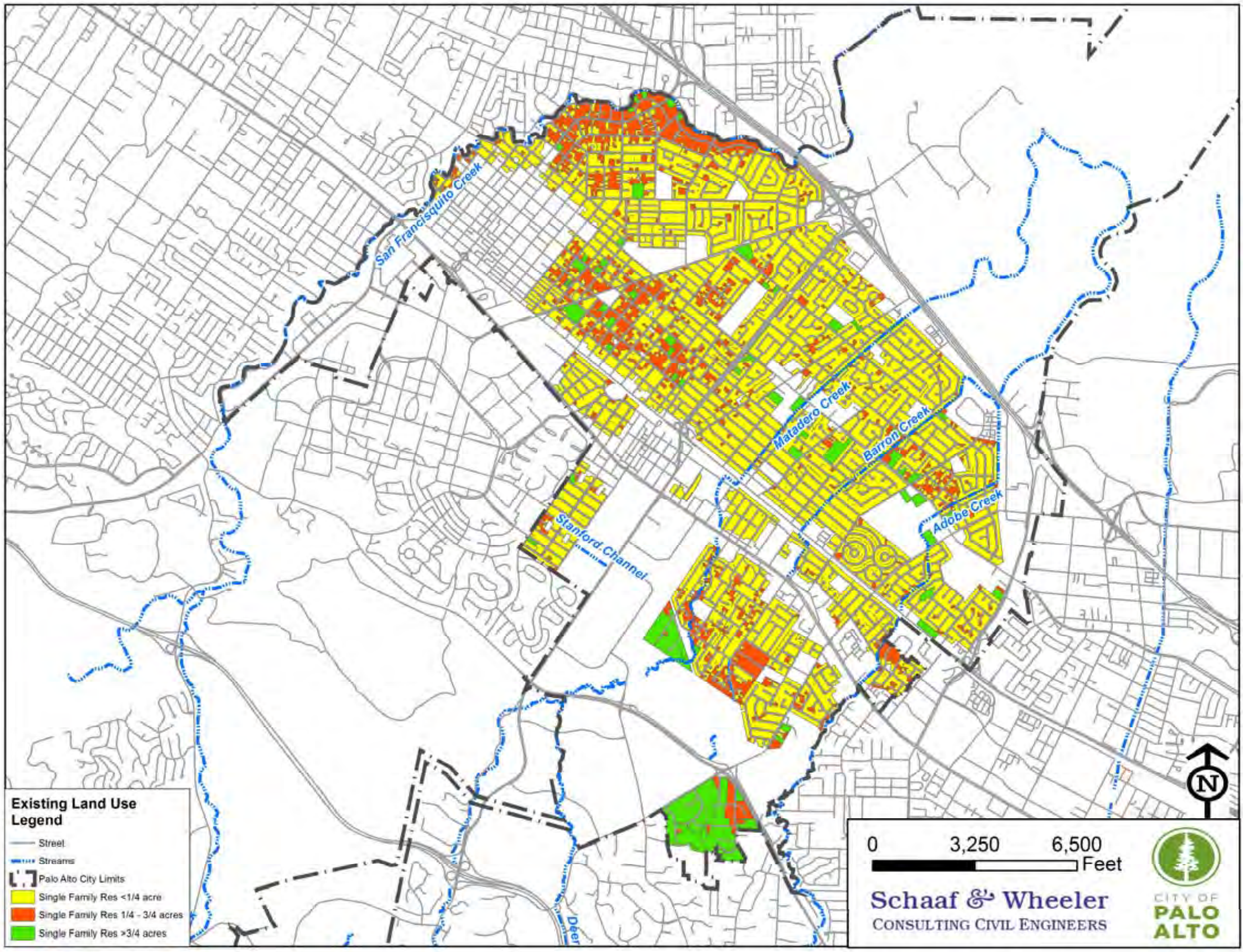


Figure 2-2: Single Family Residential Land Use of Palo Alto

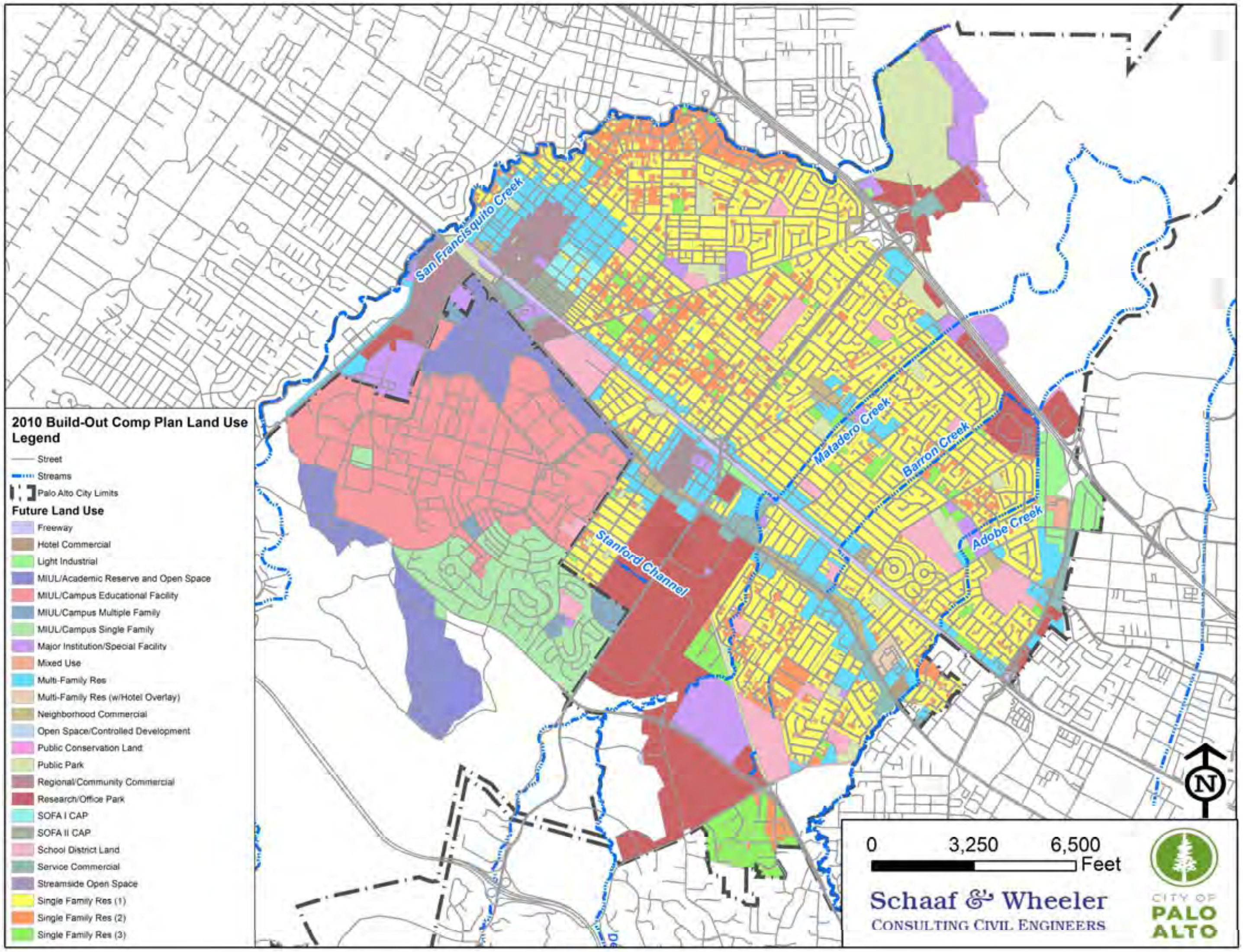


Figure 2-3: 2010 Build-out Comprehensive Plan Land Use of Palo Alto

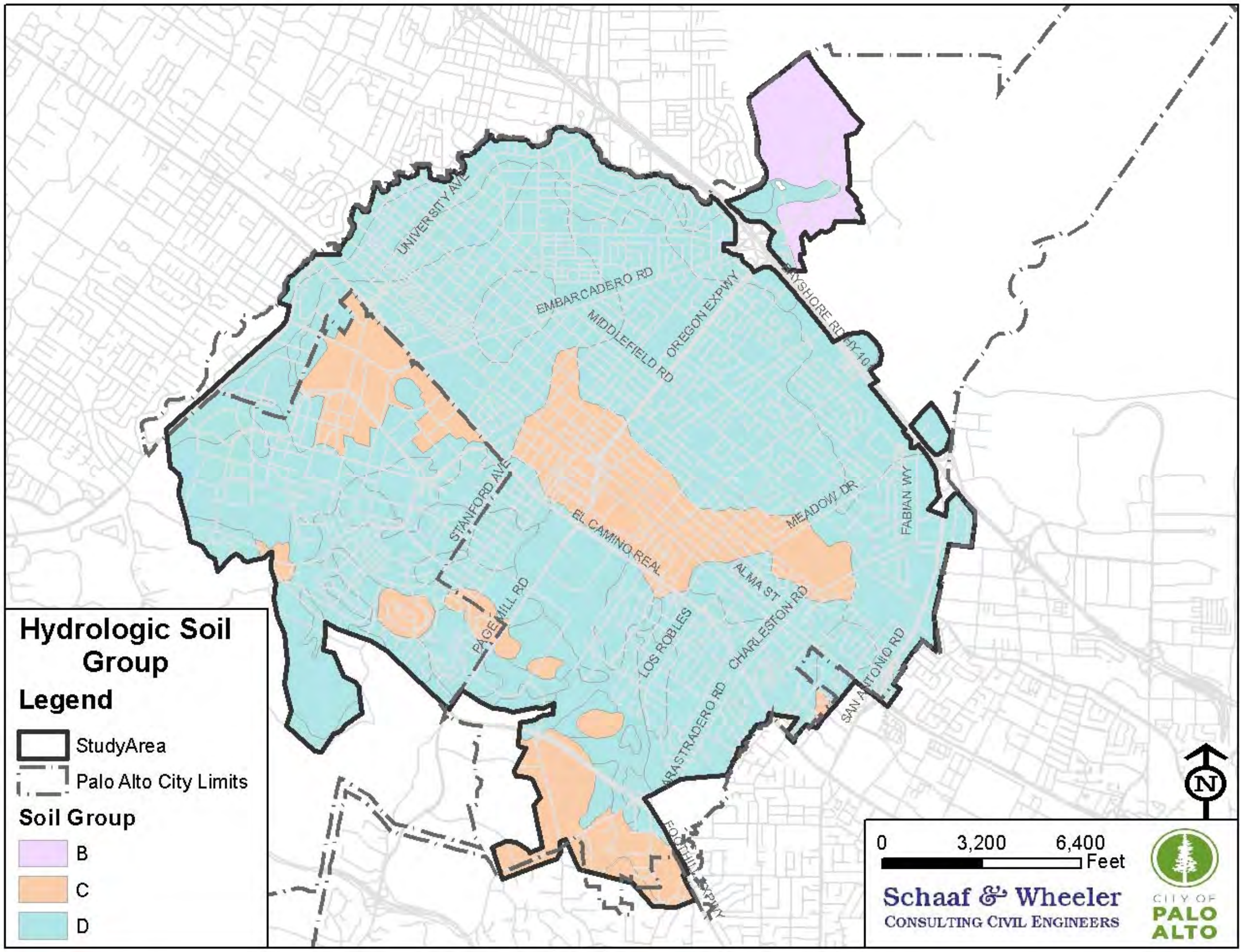


Figure 2-4: Hydrologic Soil Groups in Palo Alto

Table 2-3: Soil Groups and Imperviousness

Description	Percent Impervious	Curve Number (AMC II 1/2)			
		Group A Soil	Group B Soil	Group C Soil	Group D Soil
Freeway	75%	73	76	84	85
Hotel Commercial	88%	73	76	84	85
Light Industrial	71%	73	76	84	85
Major Institution/Special Facility	55%	73	76	84	85
MIUL/Academic Reserve and Open Space	6%	73	76	84	85
MIUL/Campus Educational Facility	59%	73	76	84	85
MIUL/Campus Multiple Family	48%	73	76	84	85
MIUL/Campus Single Family	29%	73	76	84	85
Mixed Use	89%	73	76	84	85
Multi-Family Res	84%	73	76	84	85
Multi-Family Res (w/Hotel Overlay)	81%	73	76	84	85
Neighborhood Commercial	91%	73	76	84	85
Open Space/Controlled Development	5%	63	76	86	90
Public Conservation Land	2%	67	78	86	89
Public Park	11%	73	76	84	85
Regional/Community Commercial	98%	73	76	84	85
Research/Office Park	88%	73	76	84	85
School District Land	66%	73	76	84	85
Service Commercial	76%	73	76	84	85
Single Family Res (<1/4 acre)	55%	73	76	84	85
Single Family Res (1/4 - 3/4 acre)	39%	73	76	84	85
Single Family Res (>3/4 acre)	32%	73	76	84	85
SOFA I CAP	75%	73	76	84	85
SOFA II CAP	93%	73	76	84	85
Streamside Open Space	5%	67	78	86	89

** - Site specific.

2.3 Data Quality

There is variation and inconsistency in the quality and accuracy of the data collected and available for the Palo Alto SDMP. The City's GIS is spatially accurate but some attributed data is missing and/or un-sourced.

There are a total of 126.1 linear miles of pipe, and 5,684 nodes (manholes, inlets, and outfalls) in the study area. Pipes with a diameter equal to or greater than 12-inches in the study area are included in the hydraulic models. The Palo Alto models include a total of 95.0 linear miles of pipe and 2,641 nodes. The City's pipe shapefile has more than 99% of pipe diameters and box culvert dimensions identified, but is missing 4% of the conduit system measurements. The City's manhole shapefile is missing 97% of the invert elevations and all manholes do not have rim elevations defined. The models created during the 1993 master planning process contain rim and invert data for modeled pipes and nodes, but it is Schaaf & Wheeler's understanding that these attributes were assumed and are not based on survey or as-built data. Field data, as-built data, and numerous assumptions were applied to assign missing data as described in the following section.

2.4 Modeled Data Assumptions

For this study Schaaf & Wheeler compared the original GIS data with record drawings and improvement plans provided by the City. Data corrections or additions were manually entered into GIS with data source noted. The next step included field research to collect and verify pipe sizes and material, system layouts, and to measure invert depths. Field information was collected by Schaaf & Wheeler. When field measurements were not feasible (due to either pipe location or depth), record drawings provided by the City were referenced. Any remaining unknown pipe diameters were assigned based on the diameter of surrounding pipes.

As described previously, one of the significant shortcomings of the existing GIS database was that the majority of rim and invert data was missing or an unknown datum. To create a uniform ground surface for hydraulic modeling, rim elevations were globally assigned based on the LiDAR from the ARRA (American Recovery and Reinvestment Act) 2010 San Francisco Coast flyover. For nodes containing both invert and rim elevations, the depth to invert was calculated and subtracted from the newly assigned rim elevation. The remaining inverts were assigned based on either applying the field measured depth, or interpolating between up and downstream nodes. The method of assigning elevation data is preserved in the "Description" field of the final GIS database utilized by the model.

Chapter 3. Methodologies

3.1 Overview

The criteria used to evaluate storm drain system performance must be technically sound yet simple to understand and apply. Ideally, the same methodology used to analyze system performance for this report will also continue to be used for future infrastructure design. Schaaf & Wheeler is applying the County of Santa Clara's urban hydrology methods, as described in the Santa Clara County Drainage Manual (Schaaf & Wheeler, 2007), to estimate storm runoff from current and future land uses for the Palo Alto Storm Drain Master Plan. The County's method is being used along with PCSWMM by CHI storm drain modeling software to determine system performance and necessary improvements. Physical parameters used in the model are based on the City's GIS data and other information detailed in Chapter 2 - Data. Storm drain evaluation criteria described in the following section have been discussed with and agreed upon by the City of Palo Alto.

3.2 Evaluation Criteria

The methodology described in the Santa Clara County Drainage Manual (County Drainage Manual) was used to estimate storm runoff in Palo Alto. The County Drainage Manual was developed in 2007 to provide consistent design and evaluation criteria for storm drainage throughout Santa Clara County. The unit hydrograph method (as describe in Chapter 4 of County Drainage Manual) was used because it allows for the development of a flood hydrograph using a design storm, an appropriate infiltration technique, varying antecedent moisture conditions, storage within the watershed, and a synthetic unit hydrograph.

The standard storm duration used in County Drainage Manual for rainfall simulation is 24-hours. The storm pattern is based upon the three-day December 1955 rainfall event, considered to be the storm of record for northern California. The precipitation pattern has been adjusted to preserve the local rainfall statistics in Santa Clara County, and can be found in Appendix D of the County Drainage Manual.

This master plan effort includes modeling the hydrology for the 10-year storm event, which is used as the design event for the stormwater drainage system. The 10-year level-of-service standard is consistent with the County Drainage Manual and neighboring municipalities. For the purposes of this report, improvements are recommended that reduce the hydraulic grade to no higher than 0.5 feet above the gutter elevation at any node such that the maximum hydraulic grade is the top of curb elevation. This will minimize the risk to private property and public safety.

3.3 GIS Based Modeling

The PCSWMM by CHI software with the US EPA SWMM5 engine was selected to model the Palo Alto storm drain system and pump stations because it is tested and reliable software with a GIS interface. PCSWMM is a fully featured urban drainage system modeling package designed by the Computational Hydraulics International (CHI) for the analysis, design and management of urban drainage systems. The PCSWMM model works with GIS data and can simulate runoff, open channel flow, pipe flow, and water quality. This program is ideal for the project because of its capabilities with overland flow, weirs, pumps, and storage areas and the overall stability of the model.

The Palo Alto storm drain system is modeled as three independent sub-areas based on outlet points and major drainage channels for each area. These sub-areas are: San Francisquito, Matadero, and Adobe/Barron as described in Table 3-1. Each drainage system model is composed of a conveyance network (pipes, nodes, pump stations, etc.) and the urban catchments contributing runoff to the pipe network.

Table 3-1: Palo Alto model drainage areas based on existing conditions

Model	Description	Percent of area	Miles of pipe	Modeled Pump Stations
Part 1: San Francisquito	This model is bounded by the San Francisquito Creek to the North, Sand Hill Rd to the West, and University Avenue to the South. Flow drains north into the San Francisquito Creek.	10.32%	11.32	0
Part 2: Matadero	This model is generally bounded by University Avenue to the North, Bayshore Fwy to the East, and Barron Creek to the South. Flow drains primarily into Matadero Creek with some flow draining into San Francisquito Creek. Includes the Matadero, San Francisquito, Colorado, and Embarcadero Underpass pump stations.	60.25%	55.35	4
Part 3: Adobe/Barron	This model is generally bounded Barron to the North and San Antonio Rd and Adobe Creek to the South. This model area contains the subcatchments nearest the SF Bay which includes the Palo Alto airport. Flow drains primarily into Adobe Creek and Barron Creek, with the Airport Pump Station flowing into the San Francisco Bay. Includes the adobe and Airport pump stations.	29.43%	28.37	2

Operation

Two separate calculations are performed by PCSWMM for the Palo Alto models: a runoff calculation estimating the amount of water entering the storm drain system during a design rainfall event; and the network flow calculation which replicates how the storm drain system will convey flows to outlet locations. Flows resulting from the runoff calculation are used as inflows for the subsequent network flow calculation. PCSWMM uses non-linear reservoir routing to model runoff, and gives the option of three infiltration models: Horton, Green Ampt, and NRCS curve number. The Palo Alto storm drain models use the NRCS Curve Number loss method to calculate surface runoff. This method is in keeping with the County Drainage Manual prescribed methodology. A simulation can be started at any point during the chosen design storm to assess surface runoff for any period of the design storm, with computations made based on a user-specified time step.

The PCSWMM network flow model offers a choice of three flow description approximations: Steady Flow, Dynamic Wave, and Kinematic Wave; distinguished by the set of forces each takes into account. The Palo Alto storm drain models use the most comprehensive flow description, Dynamic Wave, which incorporates the effects of gravitational, friction, pressure gradient and inertial forces. Because it accounts for all major forces affecting flow conditions, this equation allows the model to accurately simulate fast transients and backwater profiles. The simulation of flooding at a node is accommodated by the insertion of artificial “ponding” above the node which will store water when the water level rises above the ground level. The surface area of the “ponding” is user defined; a surface area can vary depending on the ground slope, node proximity, and other physical barriers. The rising water levels at the node replicate the effects of flooding in the model. Water that has ponded begins to reenter the system when the outflow from the node becomes greater than the inflow. The pipe flow simulation can be executed using either a constant or variable time step, and can be run for any portion of the time interval specified by the input rainfall time series and corresponding calculated runoff hydrograph.

Input and Output

PCSWMM surface runoff calculations require the following input data: boundary data and urban catchment data. Boundary data consists of an input rainfall time series representing the design storm event for the model. Urban catchment data includes the boundaries of each drainage catchment, along with relevant physical and hydrologic parameters including surface area, basin width, flow length, slope, and percent impervious. Drainage catchments for the three sub-areas are shown in Figure 3-1, Figure 3-2, and Figure 3-3.

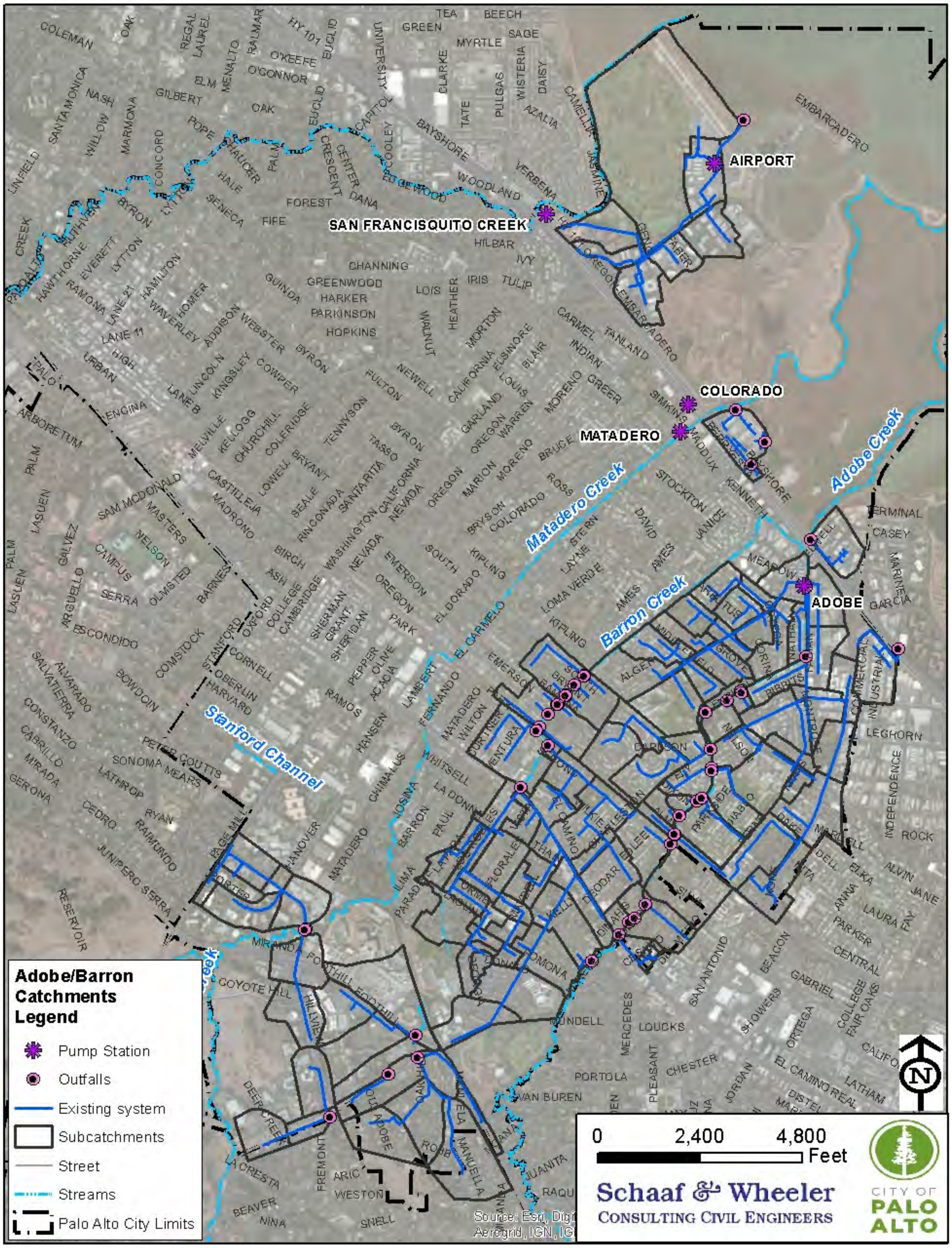


Figure 3-1: Adobe/Barron Drainage Area Catchments

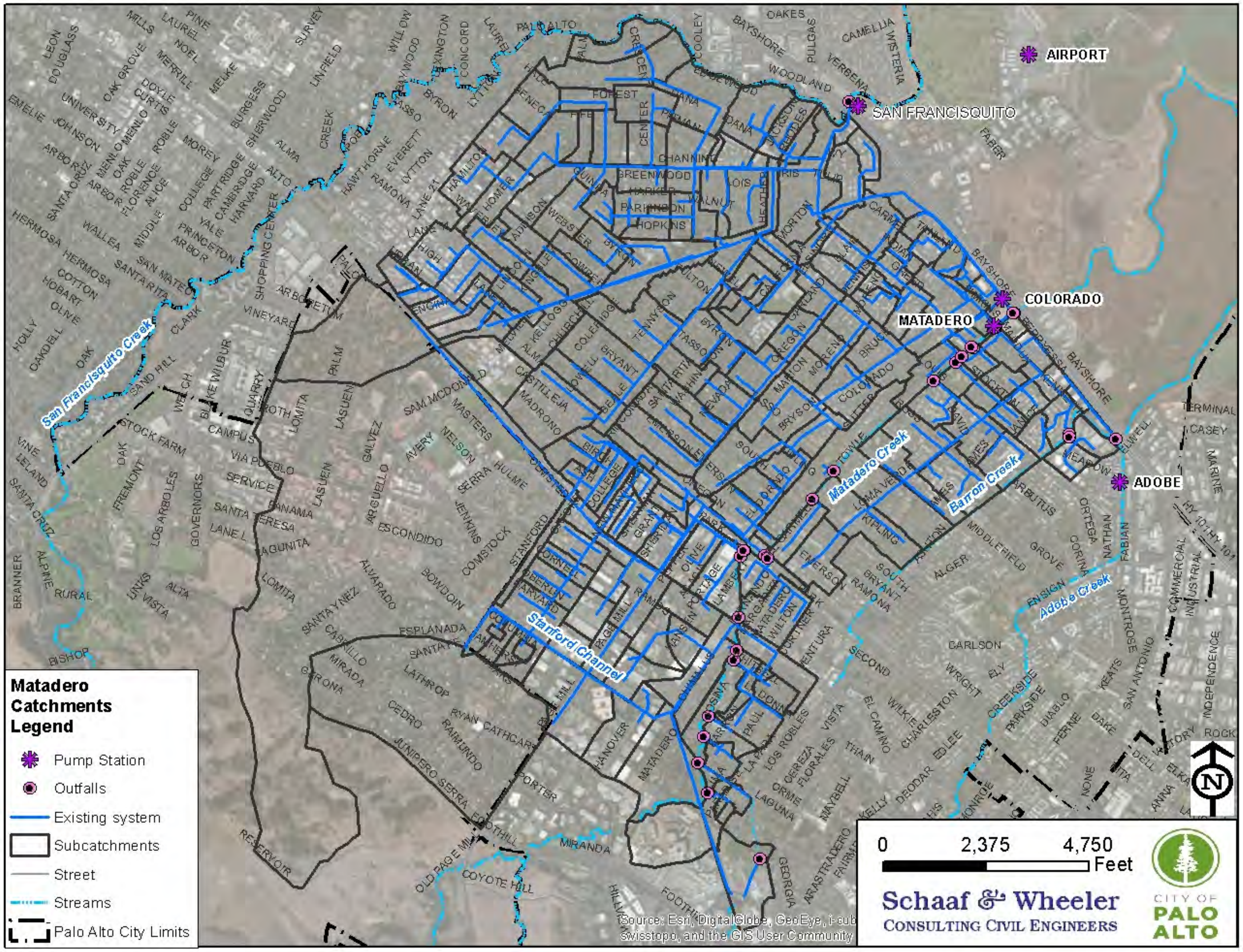


Figure 3-2: Matadero Drainage Area Catchments

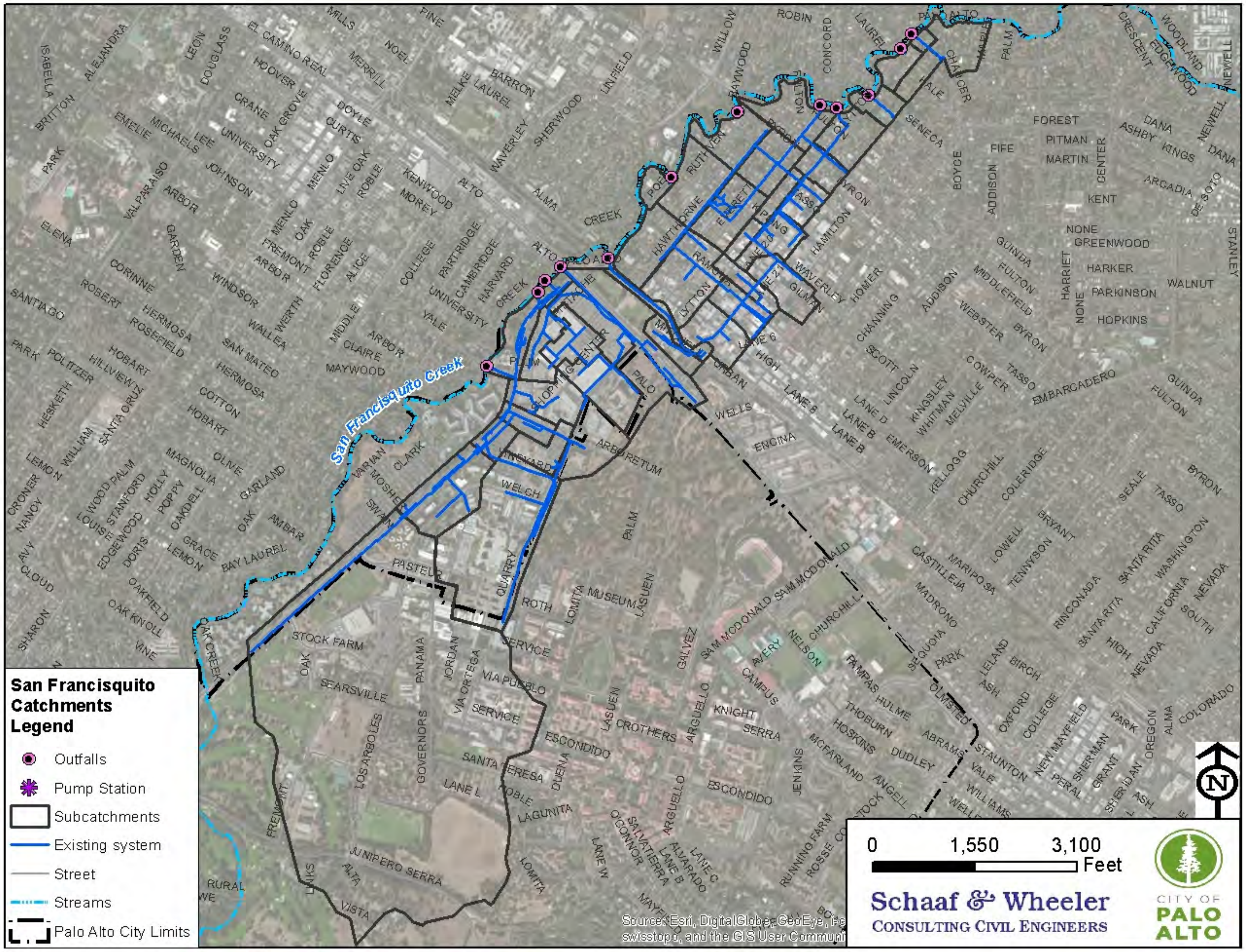


Figure 3-3: San Francisquito Drainage Area Catchments

PCSWMM pipe flow calculations require the following input data: network data, structural system elements, operational data, and boundary data. Network data consists of the pipe network elements including nodes (manholes, outlets, and storage nodes) and links (pipes, culverts, and open channels). Parameters required to describe nodes include x and y coordinates of the node, a unique name, node type (junction, outlet or basin), depth and invert levels, and water levels at outlets. Information required to describe links include the name of upstream and downstream nodes, shape and dimensions, material or roughness, and upstream and downstream inverts. Structural system elements including gates, weirs, and pumps are all modeled as functional relationships connecting two nodes in the system, or associated with one node in the case of free flow out of the system. Operational data consists of details which describe how these elements function in the network. Boundary data for the pipe flow computation can include any external loading, inflow discharges, water levels at interaction points with receiving waters, pump performance curves, as well as the results of a runoff calculation.

Output from the pipe flow computation includes the calculated water level at each node, pump discharges, weir discharges, water level in network branches, discharge in network branches, water velocity in network branches, water volume in the system, and time step data. Output is viewed using through PCSWMM or in GIS. Results may be displayed in plan view or as a profile for a selected network section, and may be viewed as a temporal animation or paused at a specific time step. Additional outputs which can be derived from PCSWMM pipe flow results using GIS include: water depth, flooding level, pressure in closed conduits, percentage pipe filling, and the flow calculated for each link.

3.4 Surface Runoff Calculations

As described above, the first step of the PCSWMM model is to complete a stormwater runoff calculation that determines the amount of water entering the storm drain system from a specific rainfall event. Rain gage and subcatchment data must be input to the model to complete this calculation.

Boundary Data

Methods used in this master plan to estimate peak storm water flow rates and volumes require the input of precipitation data. Since it is impossible to anticipate the impact of every conceivable storm, precipitation frequency analyses are often used to design facilities that control storm runoff. A common practice is to construct a design storm, which is a rainfall pattern used in hydrologic models to estimate surface runoff. A design storm is used in lieu of a single historic storm event to ensure that local rainfall statistics (i.e. depth, duration and frequency) are preserved. When combined with regional specific data for land use and loss rates, the model should produce runoff estimates that are consistent with frequency analyses of gauged stream-flow in the Santa Clara County area. In other words, the ten-year design storm pattern used for PCSWMM modeling creates results consistent with a ten-year storm runoff event.

Precipitation frequency analyses are based on concepts of probability and statistics. Engineers generally assume that frequency (probability) of a rainfall event is coincident with frequency of direct storm water runoff, although runoff is determined by a number of factors (particularly land use conditions in the basin) in addition to the precipitation event. Because the County's 24-hour storm pattern has been adjusted to preserve local statistics, there is increased confidence in this correspondence between the frequency of the rainfall and the frequency of the runoff.

Rainfall

The rainfall distribution pattern for the Palo Alto Storm Drain Master Plan was obtained from the County Drainage Manual. The County's rainfall pattern is distributed in 5-minute time increments with a fraction of the total rainfall apportioned to each 5-minute increment as shown in Table 3-2. The resulting 24-hour rainfall pattern with 5-minute time steps is then prorated based on the Mean Annual Precipitation (MAP).

Table 3-2. Fractions of Total Rainfall for 24-Hour, 5-Minute Pattern for Map 16"

Time Starting	Fraction of Total ainfall (%)	5-min pattern
0:00	0.143	1.711
1:00	0.131	1.568
2:00	0.311	3.730
3:00	0.572	6.864
4:00	0.510	6.117
5:00	0.527	6.325
6:00	4.620	9.240
6:10	1.498	5.993
6:30	1.071	6.428
7:00	0.519	6.225
8:00	0.278	3.339
9:00	0.232	2.782
10:00	0.325	3.895
11:00	0.383	4.591
12:00	0.290	3.478
13:00	0.301	3.617
14:00	0.214	2.567
15:00	0.238	2.852
16:00	0.214	2.567
17:00	0.119	1.426
18:00	0.155	1.854
19:00	0.166	1.996
20:00	0.143	1.711
21:00	0.345	4.135
22:00	0.273	3.279
23:00	0.143	1.711

The County Drainage Manual provides the total rainfall depth for each MAP and storm frequency using the following equation:

$$x_{T,D} = A_{T,D} + (B_{T,D}\ MAP)$$

Where: $x_{T,D}$ = precipitation depth for a specific return period and storm duration (inches), T = return period (years), D = storm duration (hours), $A_{T,D}$, $B_{T,D}$ = dimensionless coefficients from Tables B-1 and B-2, MAP = Mean Annual Precipitation (inches).

The precipitation intensity, $i_{T,D}$ is given by:

$$i_{T,D} = \frac{x_{TD}}{D}$$

The Mean Annual Precipitation (MAP) within Palo Alto is 16-inches based on the MAP figure in the County Drainage Manual. The rainfall total for a 24-hour 10-year event is 3.17 inches. The 10-year storm intensity graph for a MAP of 16-inches is shown in Figure 3-4. The distribution of rainfall is based on balancing the storm to shorter rainfall statistics (10-minute, 1-hour, etc). Additional information on the creation of the design storm can be found in Appendix F.

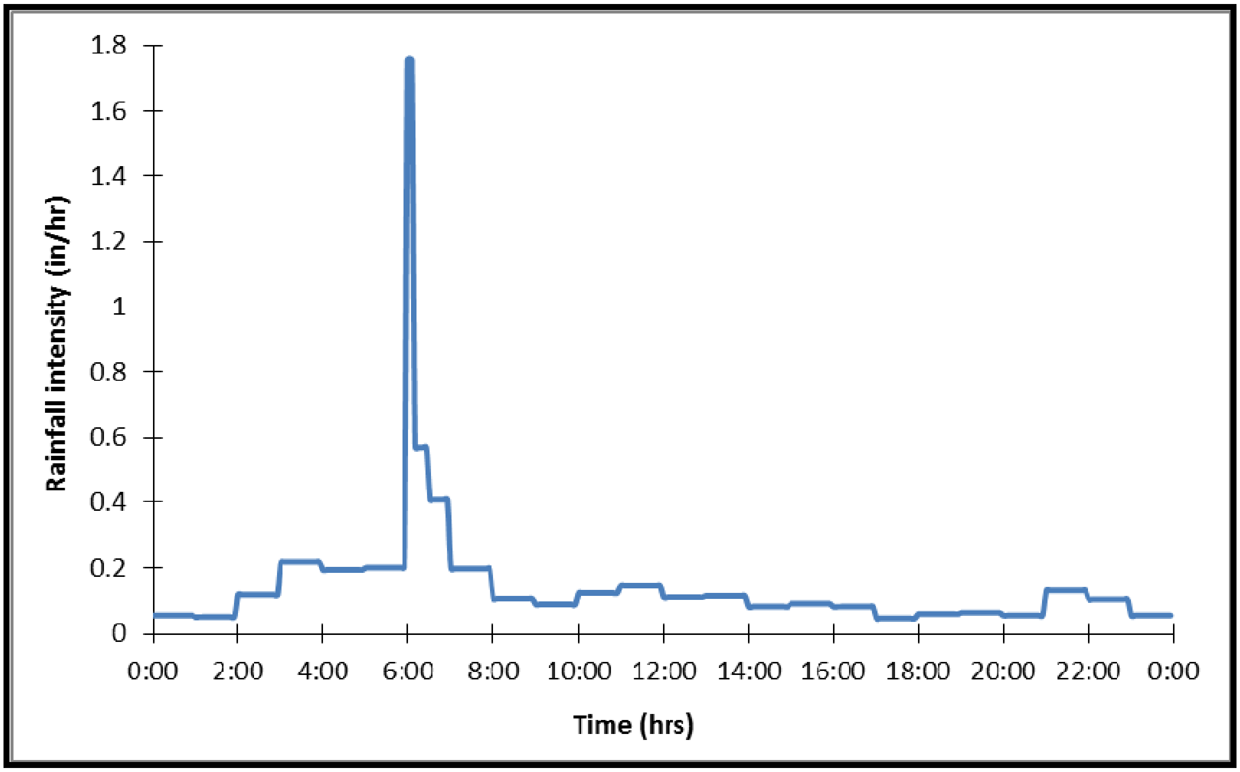


Figure 3-4: Santa Clara County 10-Year Storm Intensity Graph (MAP 16")

Catchment Data

Urban catchment data includes the boundaries of each drainage catchment, along with relevant physical and hydrologic parameters including surface area, land use characteristics, basin width, and slope. Palo Alto is divided into drainage areas, called subcatchments. The delineations completed by Schaaf & Wheeler rely heavily on engineering judgment and on experience in using contours, lot lines, storm drainage system layout, and aerial imagery.

A unit hydrograph is a numerical representation of the time response of catchment runoff caused by one inch of excess rainfall applied uniformly over a unit of time. Many different techniques are available to estimate unit hydrographs. The NRCS-dimensionless unit hydrograph is used in the Palo Alto storm drain models to be consistent with the County Drainage Manual. Direct runoff is calculated by subtracting losses, such as soil infiltration, from the rate of rainfall. The Curve Number (CN) method reflects these potential losses for a given soil type and land use.

The area that drains to the Palo Alto system is mainly single family residential, campus education facility, and research/office parks. There are some undeveloped areas that are open space, parks or conservation land. The majority of the developed parcels have high concentrations of impervious surfaces that include buildings, roads, parking lots and sidewalks. Schaaf & Wheeler used imperviousness tables from the County Drainage Manual and validated them with aerial imagery. There is a degree of uncertainty in applying standard values to all similar land uses; however, this is adequate at a master planning level. The impervious percentages for each land use category are discussed in detail in Chapter 2, Data.

Model Calibration, Basin Lag

PCSWMM includes limited hydrologic loss parameters. Basin lag, or lag time, is defined as the time elapsed between rain fall occurring within a basin and runoff occurring at an outlet point. SWMM uses basin slope (S), Manning's roughness coefficient (N), and basin width (W) to determine lag time. Slope is expressed in percent, roughness values for pervious (N-pervious) and impervious (N-impervious) are dimensionless and width is expressed in feet. SWMM does not provide detailed documentation of how width is calculated. The SWMM manual defines it as:

Characteristic width of the overland flow path for sheet flow runoff (feet or meters)... Adjustments should be made to the width parameter to produce good fits to measured runoff hydrographs.

The basin width is generally assumed to be the total catchment area divided by the longest flowpath. While SWMM gives the option of the using the Curve Number Method to compute runoff losses, literature suggests that this method produces inaccurate results when applied with nonlinear reservoir routing, which is what PCSWMM uses to simulate rainfall-runoff. During the calibration method it was found that the flow hydrographs produced by PCSWMM do not compare well to the hydrographs produced using the Unit Hydrograph Method (UHM). UHM hydrographs were developed using MIKE-URBAN (MU) which produces results identical to HEC-HMS, the accepted standard for NRCS hydrology. In order to apply the methodology outlined in the Drainage Manual, SWMM parameters must be calibrated to produce results that match the Unit Hydrograph Method. SWMM parameters width and curve number were calibrated so that the hydrographs produced by PCSWMM would match up well to the hydrographs produced by MU. Calibration parameters are shown in Table 3-. This process is described in Appendix B.

Table 3-3: Calibration parameters and scale factors

Parameter	Calibration scale factor[1]	Source
Width (area/flow length)	4.5	Physical property
Curve number	0.9	Drainage Manual

1. *Calibrated parameter = scale factor * calculated parameter*

3.5 Pipe Flow Calculations

Detailed analyses of peak stormwater discharge are performed by the PCSWMM program, which also determines the flow condition in each drainage system element. The SWMM technical manual should be referenced for a more detailed description.

Closed Conduits

Pipes are modeled as one-dimensional closed conduit links which connect two nodes in the models. The conduit link is described by a constant cross-section along its length, constant bottom slope, and straight alignment. Unsteady flow in closed conduits is calculated using conservation of continuity and momentum equations, distinguishing between pipes flowing partially full (free surface flow), and those flowing full (pressurized flow). Most pipes within the Palo Alto model are modeled as reinforced concrete pipe (RCP) with a Manning's '*n'* of 0.013.

Junction Losses

Hydraulic losses at junctions (manholes, inlets, intersections) can be significant in pressurized drainage systems. Losses can vary due to construction methods, condition, and shape. An entry and exit loss coefficient of 0.1 was used at most junctions for this master plan study.

Pump Stations

The drainage systems in Palo Alto are dependent on pump stations. There are six (6) modeled pump stations within the study area and modeling their performance correctly is an important task. Pump stations that significantly impact the City's storm drain system were analyzed, which include San Francisquito Creek, Airport, Colorado, Oregon Underpass, Matadero, and Adobe pump stations. Localized pump stations located within the City that do not significantly impact the City's system were not analyzed. These pump stations include University Avenue Underpass, Homer Avenue Underpass, and Embarcadero Road Underpass pumps stations which only serve low-lying underpass locations.

Pumps are modeled in PCSWMM as a functional relation between the water level of the inlet and outlet nodes. Pumps are characterized by starting and stopping water levels and a capacity curve of differential head vs. flow data for the pump.

Pump head vs. discharge curves, as provided by manufacturers, represent the flow through the pump itself only. It is difficult to accurately include the pump station piping and appurtenances within the model, so it's necessary to modify, or de-rate, the pump curve to account for the losses that occur between the inlet node (pump station wetwell) and the outlet node (beginning of forcemain or pump discharge manifold). This includes minor losses due to fittings, valves, expansions, contractions, and pipe spools.

The discharge velocity is calculated for each head value based on the manufacturer's pump curve flow rate (cfs) and the discharge outlet cross-sectional area (sf).

Velocity Equation

$V = Q/A$

Where: A = area of the discharge pipe (ft^2) = $\pi(D/2)^2$
Q = pump discharge from the manufacturer's curve (cfs)
D = diameter of the discharge pipe (ft)
V = velocity of discharge (ft/s)

The calculated velocity at each head level is used to calculate a corresponding friction head loss through the discharge piping using the Hazen-Williams friction loss equation. Friction loss is calculated for all elements not included in the model, which consists of piping between the pump outlet and the beginning of the force main or the pump discharge manifold, depending on the station layout. The Hazen-Williams friction loss equation is as follows:

Friction Loss Equation

$$H_f = L\,(V^2/0.115*C*D^{0.63})^{1.5}$$

Where: C = Hazen-Williams Discharge Coefficient =110 for concrete pipe
D = pump discharge pipe diameter (in)
L = length of pump discharge pipe (ft)
V = velocity of discharge (ft/s)
H_f = minor losses in head due to friction

The length of pipe and number of bends, tees, valves, reducers, etc. is determined using pump station as-built drawings. The calculated discharge velocity at each head level is used to calculate the minor losses through each fixture based on the minor loss equation from the County Drainage Manual. The resulting friction and minor losses are summed and subtracted from the original head value to create the de-rated pump curve. The de-rated curves are included in Appendix A.

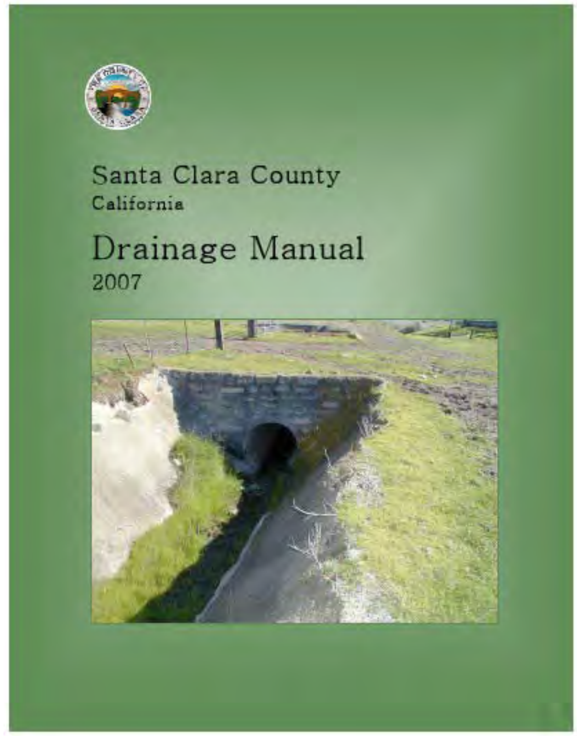
Outlet Boundary Conditions

Pipe network outlets can be modeled with either a free outfall or a water surface elevation (fixed or variable with time) which captures backwater effects due to receiving water levels. In areas that outlet to a channel and are not tidally influenced, the water surface elevation is set at the 10-year FEMA FIS level. Because there is a high uncertainty of coincident peak timing, the channel level is set as a constant throughout the model simulation.

Due to the close proximity of Palo Alto to the San Francisco Bay and Palo Alto Flood Basin, several outfalls are tidally influenced as identified in the FEMA FIS. For these outfalls, either a HEC-RAS model was used to compute the boundary condition tidal timeseries, or the coincident 10-yr tide for San Francisco Bay was used.

3.6 Comparison to Previous Reports

The methodology used in this master plan analysis differs from the methodology used in previous storm drainage report, CH2M HILL Storm Drain Master Plan, prepared in 1993 (1993 Study). The main similarity in methodologies between the 1993 Study and that used in this analysis is the use of the 10-year design standard in developing a CIP. The major differences stem from the use of the Santa Clara County Drainage Manual methodology and the inclusion of pipes 12-inches in diameter and larger for this analysis. The unit hydrograph method was used in the 1993 Study, but a different rainfall pattern was used, and the resulting runoff was not calibrated. The 1993 Study CIP is comparable to the CIP presented in this report, which increases the confidence in the results of this master plan analyses.



Chapter 4. Storm Drain Collection Systems

4.1 Overview

The performance analysis of Palo Alto's storm drain collection system forms the essential core of this master plan. This chapter describes major storm drain facilities, pump stations, and the known drainage issues. Areas requiring system improvements are identified and prioritized. For the purposes of conciseness and readability, this Chapter presents the 10-year predicted flooding depths for the existing and 2010 build-out comprehensive plan land use conditions, and those projects that are required to alleviate or minimize flooding based on the 10-year standard. The 2010 build-out land use condition is used as the project scenario for the Capital Improvement Program (CIP) discussed in Chapter 6.

4.2 Evaluation of the Storm Drain Capacity Criteria

Each collection system has been analyzed for the existing land use condition to determine its performance during the design 10-year storm. Areas of significant flooding are recognized herein and recommended improvements to establish system performance in accordance with criteria outlined in Chapter 3 - Methodologies, are summarized. The improved collection systems were then analyzed with the 2010 build-out land use condition to determine whether further improvements are required to maintain the 10-year flood standard once future development occurs.

Additional flow capacity requirements are determined by upsizing existing pipes in the PCSWMM models until the hydraulic grade is reduced to no higher than 0.5 feet above the gutter elevation at any node. It is impractical to entirely remove predicted flooding throughout the project area, either due to local topography (for example, at minor, localized 'bathtub' areas) or infeasibility of improvements, but the majority of model-predicted flooding can be mitigated with the capital improvements proposed herein.

To determine the depth of flooding at any particular node in the PCSWMM model, the maximum hydraulic grade line (HGL) and ground elevation were utilized, as shown in the following equation:

Depth of flooding = Max HGL – Ground Elevation

For example, if the ground elevation is 7.5 ft at a node and PCSWMM computes a max hydraulic grade of 8.3 ft, the depth at flooding at this node would be 0.8 ft. Water is allowed to pond at the node, until there is there capacity in pipe system to accommodate the flow.

Prioritizing Deficiencies and Needed Improvements

Palo Alto's storm drain system is broken into three drainage sub-areas: San Francisquito, Matadero, and Adobe/Barron (Figure ES-1). The basins are organized around natural topographic boundaries and drainage facility boundaries or watersheds. It should be noted that neither private drainage systems nor site-specific drainage characteristics (i.e. individual parcels) have been analyzed as that level of detail is not necessary to determine improvements at the master planning level. These models can be refined in the future to more precisely account for these site-specific drainage characteristics during the development of detailed drainage studies.

Recommended master plan improvements are described in the following sub-area discussions and in detail in Appendix D. In some locations, the hydraulic grade line (HGL) predicted by the one-dimensional (1D) model at individual nodes in the system may be greater than actual water surface elevation during a storm event. This is due to limitations and assumptions inherent in the 1D modeling software. In order to 'ground truth' predictive model results, Schaaf & Wheeler discussed model results with City staff. Locations for recommended system improvements are based on the results of this complete process, not solely on model results. As such, some locations predicted to have flooding surcharge based on model results alone are not recommended for improvements. For example, the top of drainage system where water from a catchment is added to the model, but in reality water enters that point through pipes smaller than 12-inches. The recommended improvements were then prioritized based on the results of the above process, combined with the severity of flooding at each location and the benefit/cost relationship of proposed improvements. The following color code, as shown in Table 4-1, is used to highlight project prioritization within each drainage sub-area:

Table 4-1: Improvement Priority Descriptions

Pipe Color	Improvement Priority	Priority Description
Dark Red	Highest Priority	The projects under this category play a crucial role in the operation of the existing storm drain system. Completion of these projects is either required prior to completing high priority improvements, or are required to reducing flooding at an especially flood prone area.
Red	High Priority	Projects under this category have a large area of flooding where the 10-year maximum flood depth is greater than 12-inches. These projects improve locations with the deepest and longest flooding situations. They may also be located at the downstream end of many projects, as they would logically be constructed first. Areas of significant historical flooding fall into this category.
Yellow	Moderate Priority	This category has conditions similar to high priority, but has a smaller area affected by flooding. The length and depth of flooding is less than that of a high priority improvement.
Green	Low Priority	Low priority improvements are generally smaller projects that generally address nuisance flooding. The area of flooding is much smaller and/or briefer in duration than that of moderate and high priority projects.

This section outlines the ultimate improvements needed to achieve a 10-year level of service by alleviating or minimizing predicted flooding within each of the three sub-areas. Each improvement was grouped with nearby improvements that could be undertaken simultaneously and named using a major street, generally the most downstream, within the group of improvements. The naming convention is used to identify the improvements in maps and tables. A complete CIP with tables detailing storm drain network improvement projects including existing pipe size, recommended pipe size, and costs for each improvement is available in Appendix C.

Improvement Alternatives

Improvement alternatives have been identified for the 2010 build-out land use condition in the Matadero area and the Adobe/Barron area. A preferred alternative is identified for each area. Only the preferred alternative is analyzed to identify improvements for the 2010 build-out land use condition and develop the CIP.

4.3 Condition Assessment of Storm Drain

A condition assessment of the previously unmapped CMP culverts located south of Highway 280 was performed by V&A. These condition related projects are south of I-280 along Page Mill Road, Arastradero Road, and Los Trancos Road as shown in Figure 4-1. The culverts were rated and condition related improvements were recommended as outlined in Appendix C. The condition related repair projects are summarized in Chapter 6. There are forty five condition improvement projects in this area. Of these projects, highest priority improvements are recommended at eleven locations, high priority improvements are recommended at seventeen locations, and moderate priority improvements are recommended at seventeen locations.

Flow capacities of these CMP were not verified to determine if they provide 10-year level of service. Hydrologic and hydraulic analyses are recommended as part of CMP improvements. Such an analysis can be done using the Rational Method to compute flows and the Federal's Highway Administration culvert hydraulics' software HY-8 or to analyze culvert capacity.

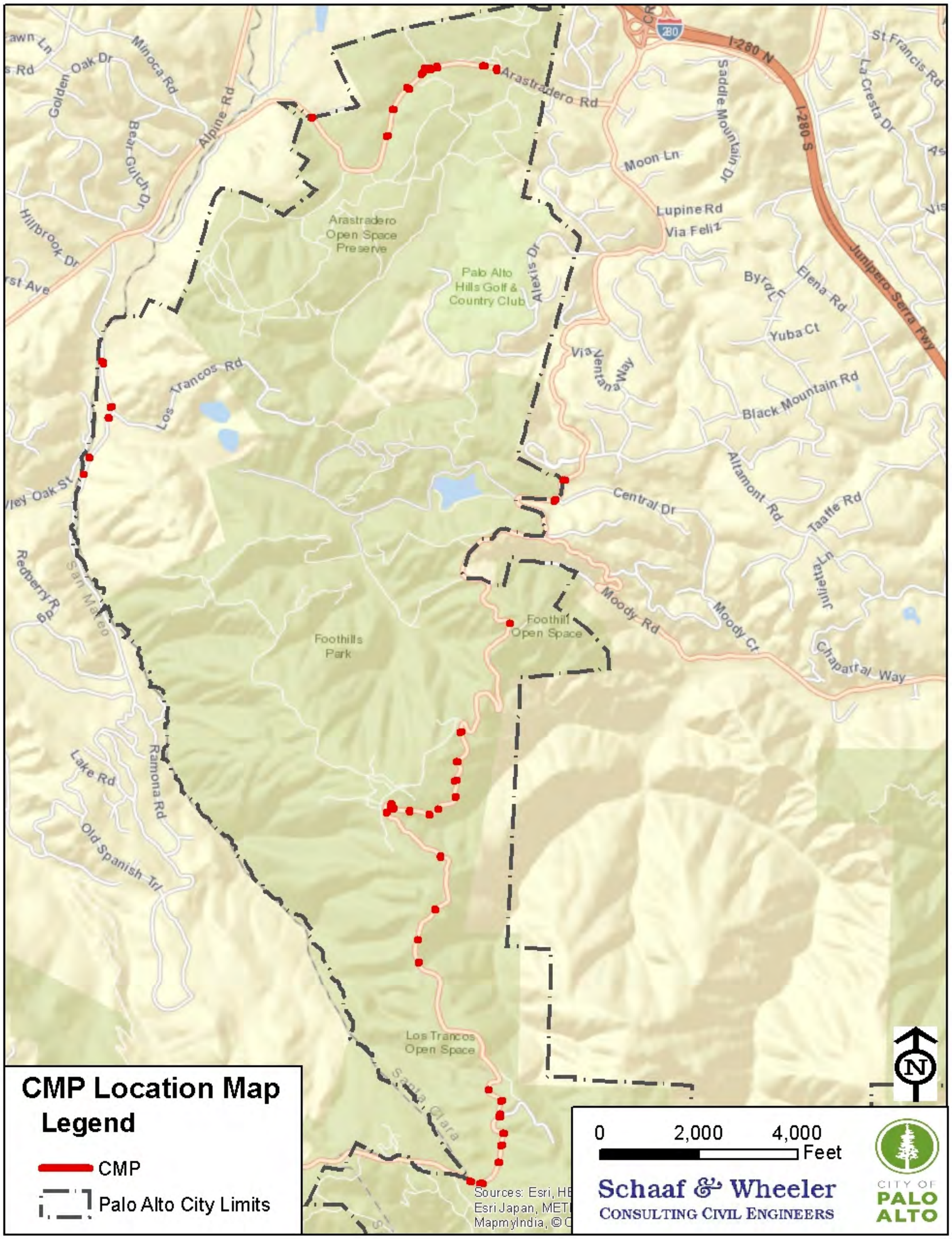


Figure 4-1: Location of CMP CIP projects

4.4 Palo Alto Systems

San Francisquito

Overview

The San Francisquito drainage area is approximately 1.44 square miles. The modeled collection system consists of 426 nodes (manholes and inlets) and twelve gravity outfalls. The San Francisquito area has a total of 59,770 linear feet (11.3 miles) of modeled storm drain pipe equal to or greater than 12-inches in diameter. The San Francisquito area drains generally north to gravity outfalls at San Francisquito Creek.

Identified Deficiencies

PCSWMM analysis of the San Francisquito systems for the 10-year storm event existing land use condition shows no flooding (HGL above the rim elevation of the node) occurring at any of the 426 nodes. A map of the 10-year flooding depths predicted by the PCSWMM analyses of the existing storm sewer system is presented in Figure 4-2.

Prioritized Improvements

There are no recommended prioritized improvements in the San Francisquito area that are required to alleviate or minimize flooding during a 10-year storm event.

2010 Build-Out Comprehensive Plan

Flooding does not occur in the San Francisquito area with the 2010 build-out land use condition. There are no recommended San Francisquito area improvements that are required to alleviate or minimize flooding during a 10-year storm event with the 2010 build-out land use.

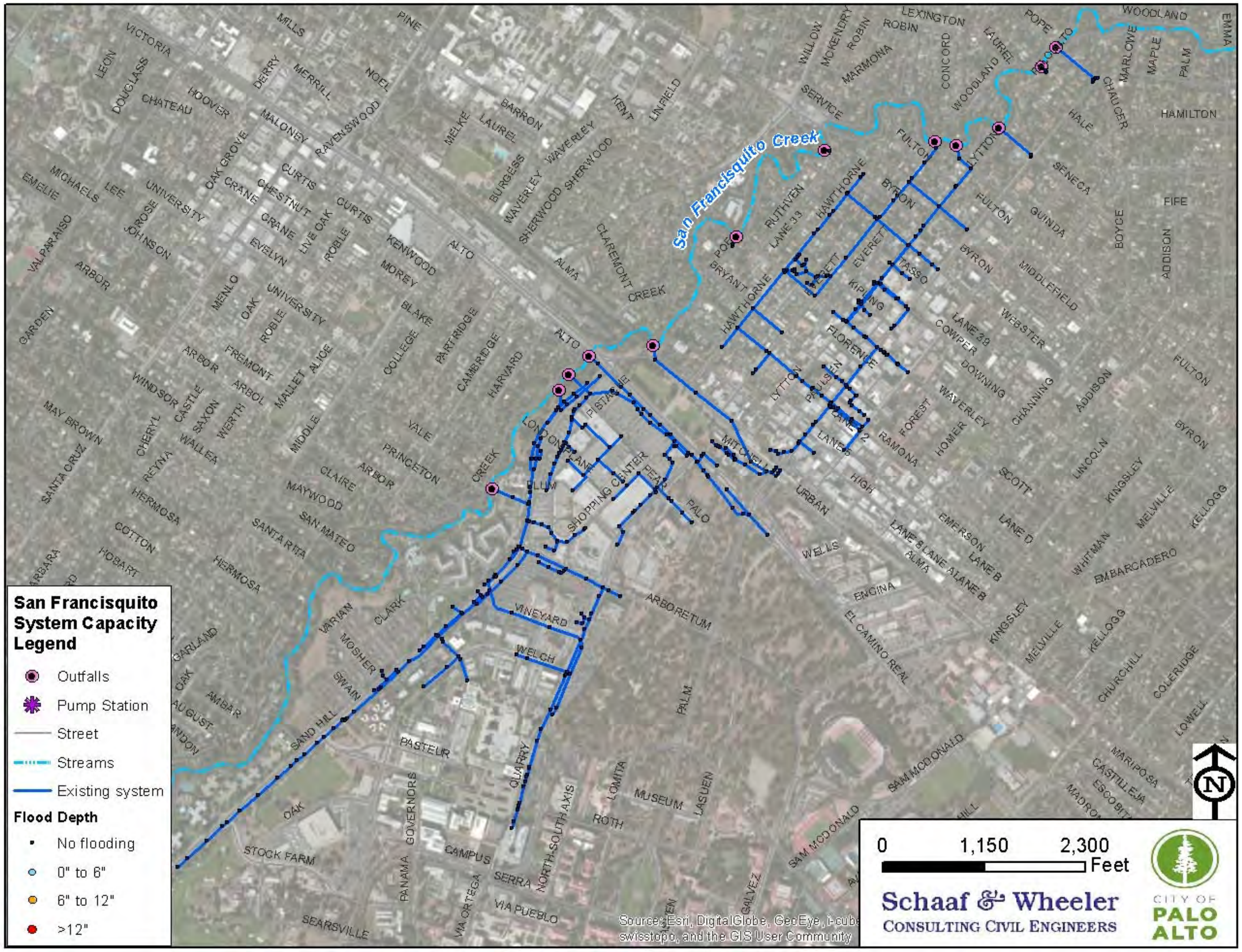


Figure 4-2: San Francisquito Area 10-Year System Capacity

Matadero

Overview

The Matadero drainage area is approximately 8.43 square miles. The modeled collection system consists of 1,373 nodes (manholes and inlets), 33 gravity outfalls, and the Matadero, Oregon Underpass, San Francisquito, and Colorado pump stations. The Matadero area has a total of 292,250 linear feet (55.4 miles) of connecting storm drain pipes equal or greater than 12-inches in diameter. In general, the Matadero area drains east to Matadero Creek or north to San Francisquito Creek.

Stanford area is the largest subcatchment in the Matadero area PCSWMM model. The Stanford storm drain system was not included in the model as it is not part of the City's system. The runoff from the Stanford subcatchment was applied to the El Camino Real pipe system. As shown in Figure 4-3, this section of pipe is shown to have flooding greater than 12 inches, but the flooding abates downstream of the Stanford area. There are no historical reports of flooding in this area, so it is assumed that the flooding in this area shown in the model is a modeling artifact and does not reflect actual conditions. The Stanford watershed contains an extensive system of piping and drainage ditches, storm water detention, and treatment facilities. It is not feasible to accurately portray these characteristics using the catchment parameters in the PCSWMM model. As the system in El Camino is not subject to flooding immediately downstream of the Stanford area, adding further detail to the model in that area was not deemed necessary for the purposes of this master plan.

Identified Deficiencies

PCSWMM analysis of the Matadero systems for the 10-year storm event existing land use condition shows flooding (HGL above the rim elevation of the node) occurring at 694 of the 1373 nodes. PCSWMM predicts a flooding depth of less than 6-inches at 353 nodes, depths between 6- and 12-inches above the street occur at 129 nodes, and a flooding depth greater than 12-inches occurs at 212 nodes. A map of the 10-year flooding depths predicted by the PCSWMM analyses of the existing storm drain system is presented in Figure 4-3.

Prioritized Improvements

There are forty recommended improvement projects in the Matadero area, shown in Figure 4-3. Twenty five are low priority projects. These projects would most likely eliminate nuisance flooding and may only get built if there are significant changes to land use, roadway, or redevelopment projects in the area.

Moderate priority improvements are recommended to provide a 10-year level of service at seven locations. These projects involve upsizing sections of pipe throughout the Matadero area system. The City may need to re-prioritize these projects based on funding, other utility improvements, and land use changes.

There are eight high priority projects and one highest priority project which include pump station capacity and pipe size deficiencies. These projects are indicated and labeled in Figure 4-5. A description of the highest and high priority improvement project is given in Table 4-2.

2010 Build-Out Comprehensive Plan

The 2010 build-out land use condition in the Matadero area does not substantially affect flooding during a 10-year storm event. No additional improvements are necessary for the 2010 build-out land use condition in this area. Thus the Matadero area improvements that are required to alleviate or minimize flooding during a 10-year storm event are unchanged for 2010 build-out land use as shown in Figure 4-4.

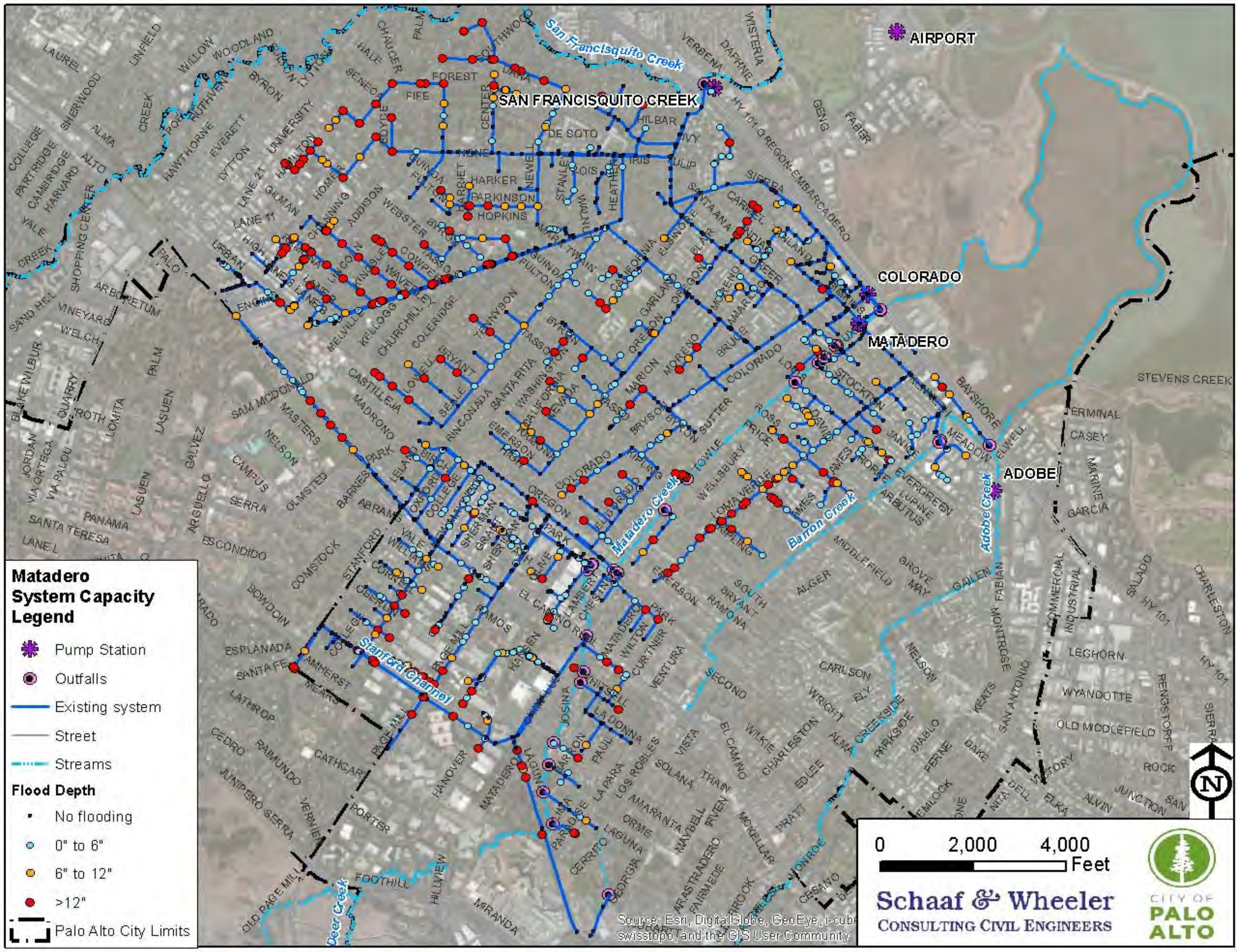


Figure 4-3: Matadero Area 10-Year System Capacity

Table 4-2: Highest and high priority improvement projects in the Matadero area

Improvement Priority	Project	Project ID	Project Description
Highest	Matadero Pump Station	2	This includes replacing the 285 cfs Matadero Pump Station with a new 371 cfs pump station.
High	Bayshore and Fabian Pump Station	4	Historically there has been flooding at the intersection of Bayshore and Fabian. Because of the influence of the tides and the low elevation of the terrain, just upsizing the pipes will not mitigate flooding during a storm event. A new 15 cfs pump station is recommended.
High	Bayshore and Fabian	3	Along with the new pump station on Bayshore and Fabain, it is recommended to upsize the pipes leading to the new pump station to 36-inches.
High	Lincoln and Channing	10	New pipe recommended on Lincoln, connecting Channing to Alma, with the goal of mitigating flooding on Embarcadero.
High	Hamilton and Rhodes	9	The new pipe recommended on Lincoln, connecting Channing to Alma, allows more flow to enter the pipe system on Channing. To avoid upsizing the pipes on Channing, Hamilton was connected to Forest, Center, and Rhodes respectively. Connecting Hamilton to Rhodes with a 48-inch pipe allows more water to flow to the San Francisquito Pump Station and away from Channing.
High	Louis	12	The entire segment of box culvert on Louis Road from Embarcadero to Matadero Creek is recommended to be upsized. This helps mitigate flooding on the smaller branches flowing into Louis Road pipeline.
High	Louis to Matadero Creek	13	New 72-inch pipe from Sycamore Drive to Matadero Creek, along with the inclusion of a new gravity outfall at the end of Louis Road improvement, is recommended. This alleviates some flooding on the upstream pipes, and allows for the Louis improvement project to be limited in size.
High	Loma Verde and Maddux	11	To mitigate flooding on Loma Verde, it is recommended to upsize the pipe to 51-inches at the most downstream end of the Loma Verde pipeline. It allows for more flow to reach to the Matadero Pump Station and helps mitigate flooding upstream of the improvement project.

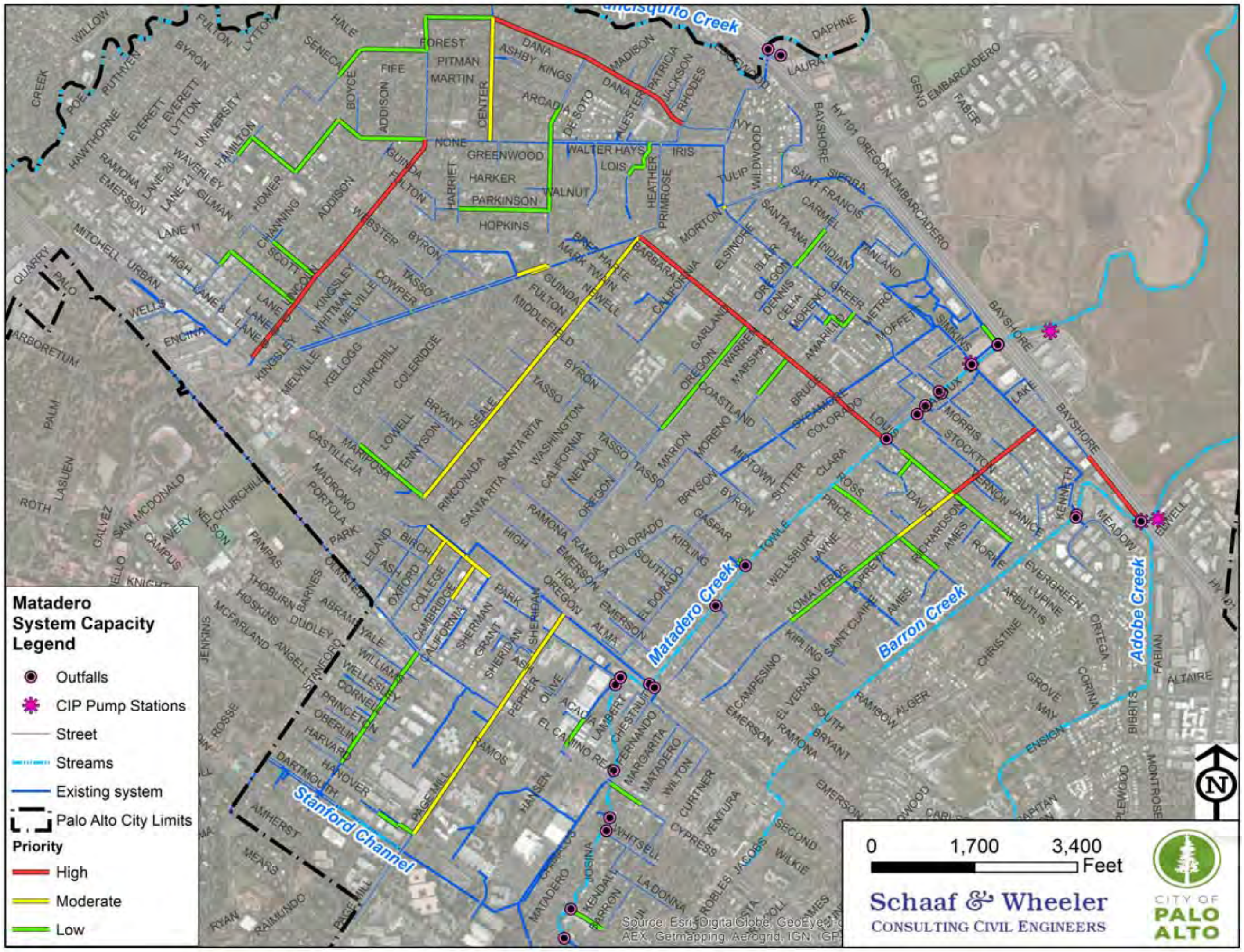


Figure 4-4: Matadero Area System Improvements

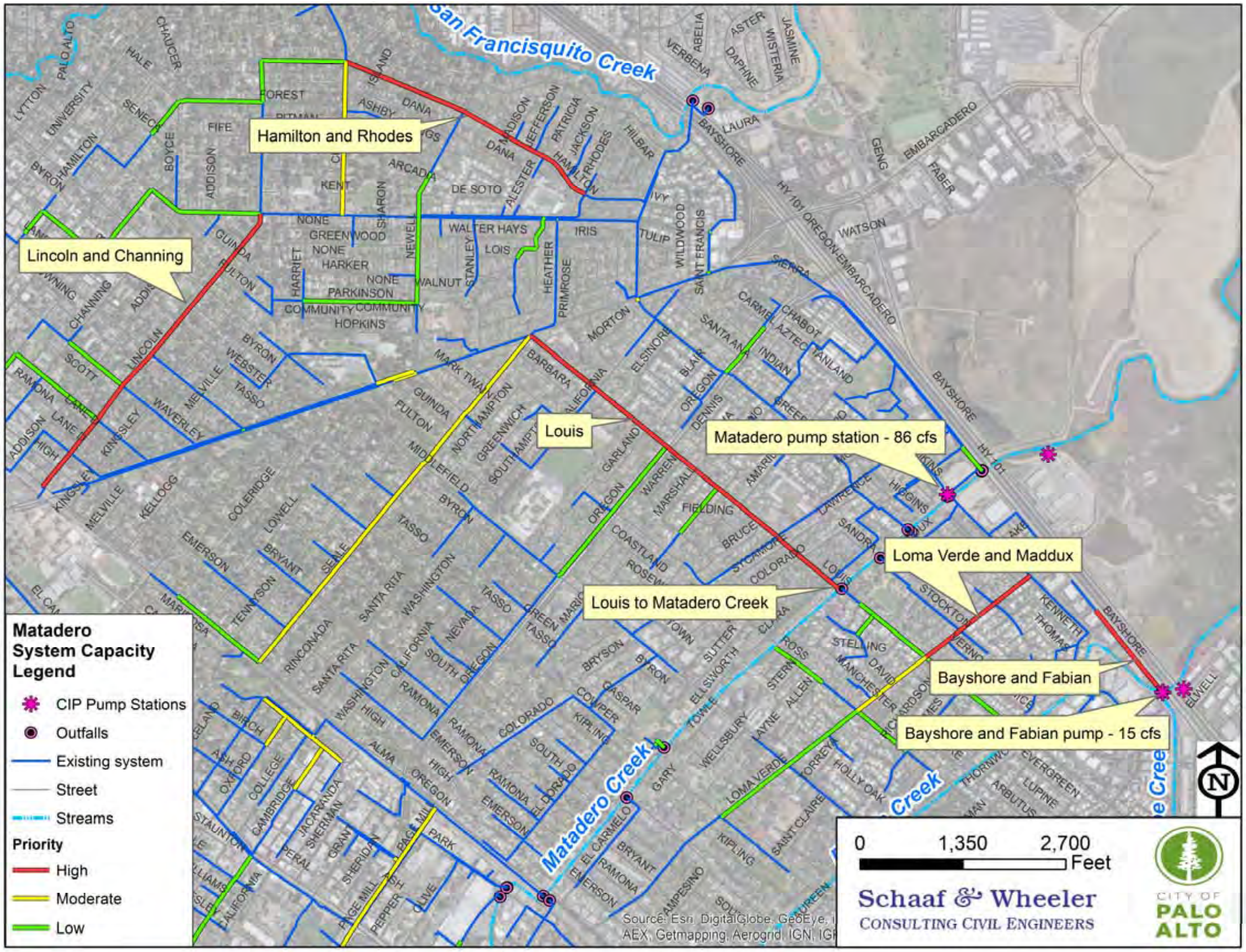


Figure 4-5: Matadero Area System Improvements – High priority improvements labeled

Adobe / Barron

Overview

The Adobe/Barron drainage area is approximately 4.11 square miles. The modeled collection system consists of 749 nodes (manholes and inlets), 48 gravity outfalls, the Adobe Pump Station, and the Airport Pump Station. The Adobe/Barron area has a total of 149,820 linear feet (28.4 miles) of connecting storm drain pipes equal to or greater than 12-inches in diameter. The majority of the Adobe/Barron area drains east to Adobe Creek or Barron Creek, with several locations draining to the San Francisco Bay.

Identified Deficiencies

PCSWMM analysis of the Adobe/Barron system for the 10-year storm event with the existing land use condition shows flooding (HGL above the rim elevation of the node) occurring at 336 of the 749 nodes. PCSWMM predicts a flooding depth of less than 6-inches at 160 nodes. Depths of between 6- and 12-inches above the street occur at 54 nodes, with the remaining 122 nodes experiencing flooding depths greater than 12-inches. A map of the 10-year flooding depths predicted by PCSWMM of the existing storm drainage system is presented in Figure 4-6.

Prioritized Improvements

The Adobe/Barron area prioritized improvements that are required to alleviate or minimize flooding during a 10-year storm event are shown in Figure 4-7.

Low priority improvements are recommended at twenty locations. Of these twenty improvements, five of them are low priority pump stations. These projects would eliminate nuisance flooding and may only get built if there are significant changes to land use, roadway, or redevelopment projects in the area.

Moderate priority improvements are recommended to provide a 10-year level of service at three locations. These projects range from upsizing small sections of pipe to large projects requiring significant pipe improvements. The City may need to re-prioritize these projects based on funding, other utility improvements, and land use changes.

High priority improvements are recommended at five locations and one highest priority improvement is recommended. These projects are indicated and labeled in Figure 4-8. These improvements include a new pump station and increasing pipe capacity on the east side of the Adobe/Barron area pipe system. Descriptions of the high priority and highest priority improvements to provide a 10-yr level of service are given in Table 4-3.

2010 Build-Out Comprehensive Plan

The 2010 build-out land use condition in the Adobe/Barron area does not substantially affect flooding during a 10-year storm event. No additional improvements are necessary for the 2010 build-out land use condition in this area. Thus the Adobe/Barron area improvements that are required to alleviate or minimize flooding during a 10-year storm event are unchanged for 2010 build-out land use as shown in Figure 4-7.

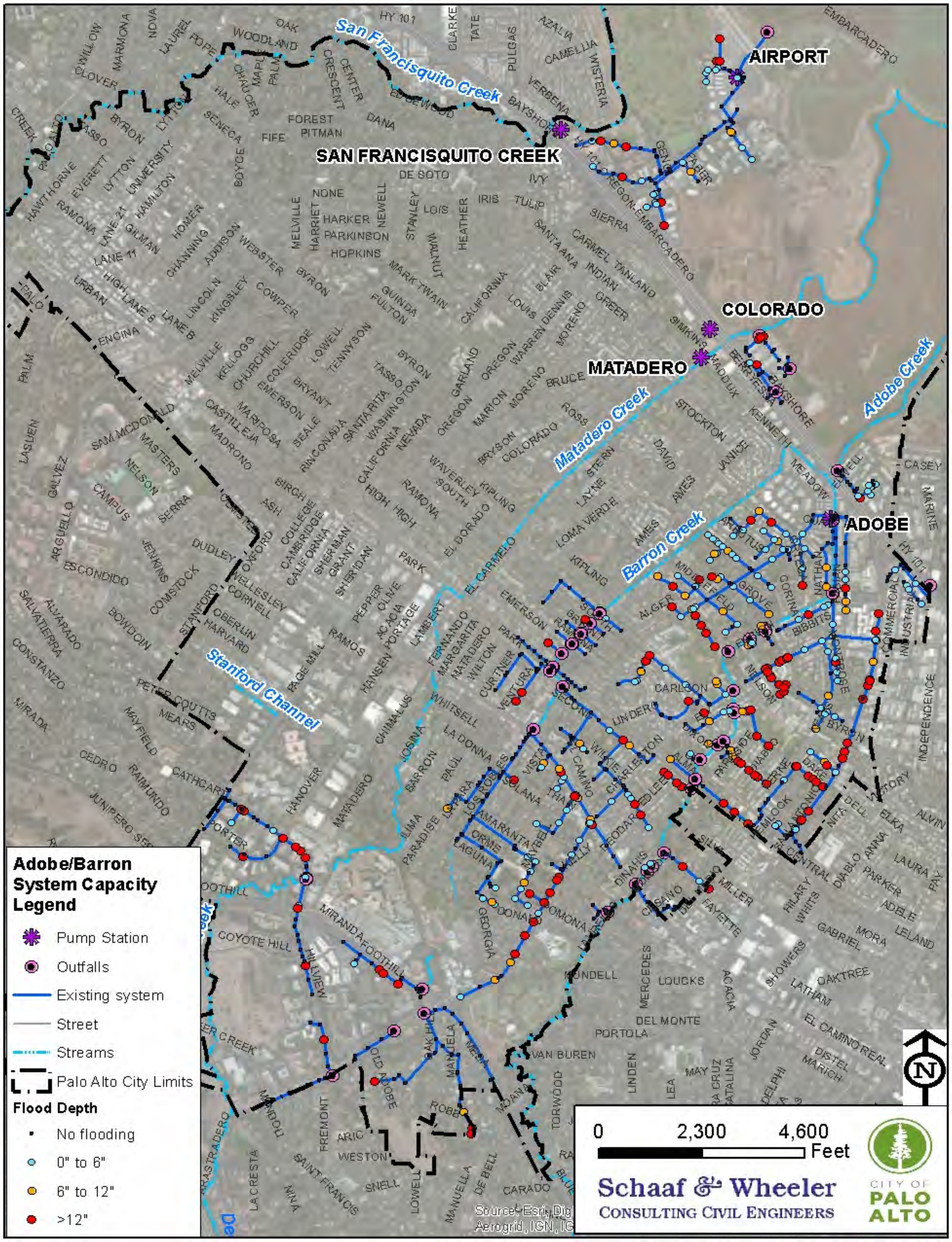


Figure 4-6: Adobe/Barron Area 10-Year System Capacity

Table 4-3: Highest and high priority improvement projects in the Adobe/Barron area

Improvement Priority	Project	Project ID	Project Description
Highest	Corporation and East Bayshore	1	Historically there has been substantial flooding in the office park bounded by the East Bayshore Road and Adobe Creek. Because of the low elevation of the area and the influence of tides, a new 25 cfs pump station and upsizing of pipe to 30-inches is recommended to mitigate flooding.
High	East Meadow Circle	6	Another location with historical flooding is on East Meadow Circle. Connecting the East Meadow Circle with new pipe to the system draining to the Adobe Pump Station is recommended. This project cannot be constructed until the East Meadow Drive project has been completed.
High	East Meadow Drive	7	To help alleviate flooding upstream of the Adobe Pump Station, the section of pipe on East Meadow Drive is recommended to be upsized to 48-inches.
High	Charleston and Adobe Creek	5	This section of pipe leading to an Adobe Creek outfall is recommended to be upsized to 72-inches. This helps mitigate flooding on the upstream reaches by routing water toward the gravity outfall and Adobe Pump station. This pipe will also provide storage during the storm peak.
High	Fabian	8	Another location with historical flooding is on Fabian Drive. A pipe section is recommended to be upsized to 21-inches to help alleviate flooding upstream of the Adobe Pump Station on Fabian Drive.

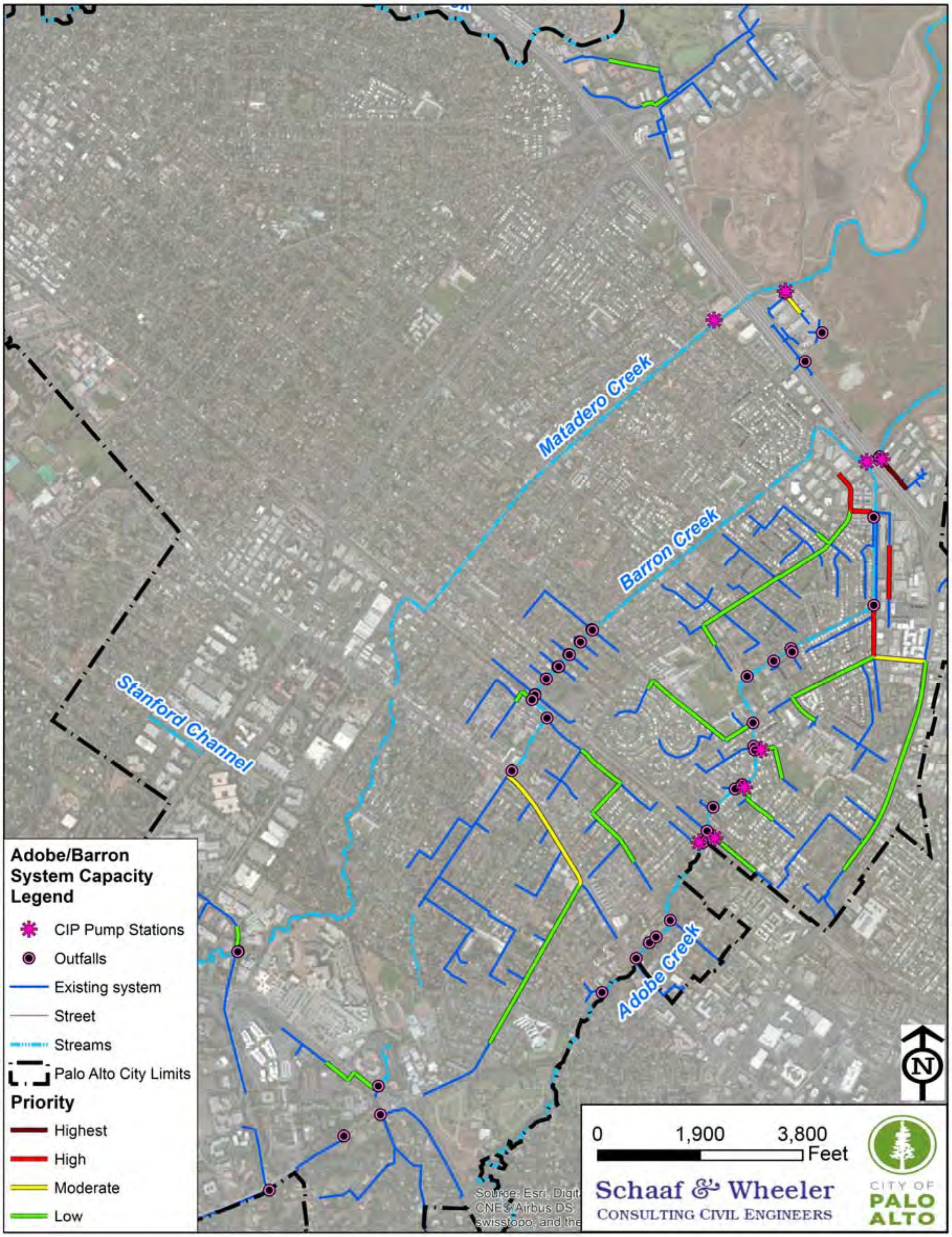


Figure 4-7: Adobe/Barron System Improvements

Figure 4-8: Adobe/Barron Improvements – Highest and high priority improvements labeled

4.5 Pump Stations

The City of Palo Alto currently operates five major stormwater pumping facilities in Palo Alto: San Francisquito, Adobe, Airport, Matadero, and Colorado. The locations of these pump stations are shown in Figure 4-9. This section evaluates pump station adequacy in the context of the storm drain master plan and recommends capacity and facility upgrades as necessary.

General Pump Station Criteria

These five pump stations have been evaluated for adequate capacity within the PCSWMM models. Pump stations are generally considered adequate if there is sufficient pump capacity to discharge design runoff into the receiving waters or if excess flows can be stored without causing property damage. The pump stations have been analyzed using the 10-year storm event with all available pumps running. Pump station design capacities are presented in Table 4-4.

Pump Station Evaluation

Palo Alto's stormwater pumping facilities comprise of new stations, updated stations, and older systems which have been partially updated or are in their original configurations. Required pump station capacities are calculated assuming that proposed 10-year CIP improvements are complete Table 4-4 provides a summary of current and required pump station capacities throughout Palo Alto, as well as whether or not the pump station requires the addition of backup power. FEMA requires backup power at pump stations that protect areas from the 100-year flood event.

Table 4-4. Pump Station Summary with 10-year Storm Drain Improvements

Station Name	Capacity of Existing Station (GPM)	Capacity of Existing Station (CFS)	Additional Req'd 10-yr Station Discharge (CFS)	Addition of Backup Power Req'd for FEMA
Adobe	84,750	189	0	No
Airport	48,000	107	0	No
Colorado	11,551	26	Recommended to remove	NA
Matadero	128,060	285	380	No
San Francisquito	160,011	357	0	No

Adobe Pump Station

The Adobe Pump Station consists of three Cascade pumps with 75 HP (horsepower) electric motors. The design point of two of the pumps is 24,000 gpm at 9' TDH (total dynamic head). The design point of the third pump is pump is 19,000 gpm at 6' TDH. Based on model results two pumps run during peak station operation. The manufacturer's pump curve is available and was used directly for model input. De-rating of the curve is not necessary because the pumps outfall directly to the creek. The station is equipped with a standby diesel engine generator. Flap gates protect the pump station and inlet storm drain system from backflow. No master plan improvements are recommended for the Adobe Pump Station.

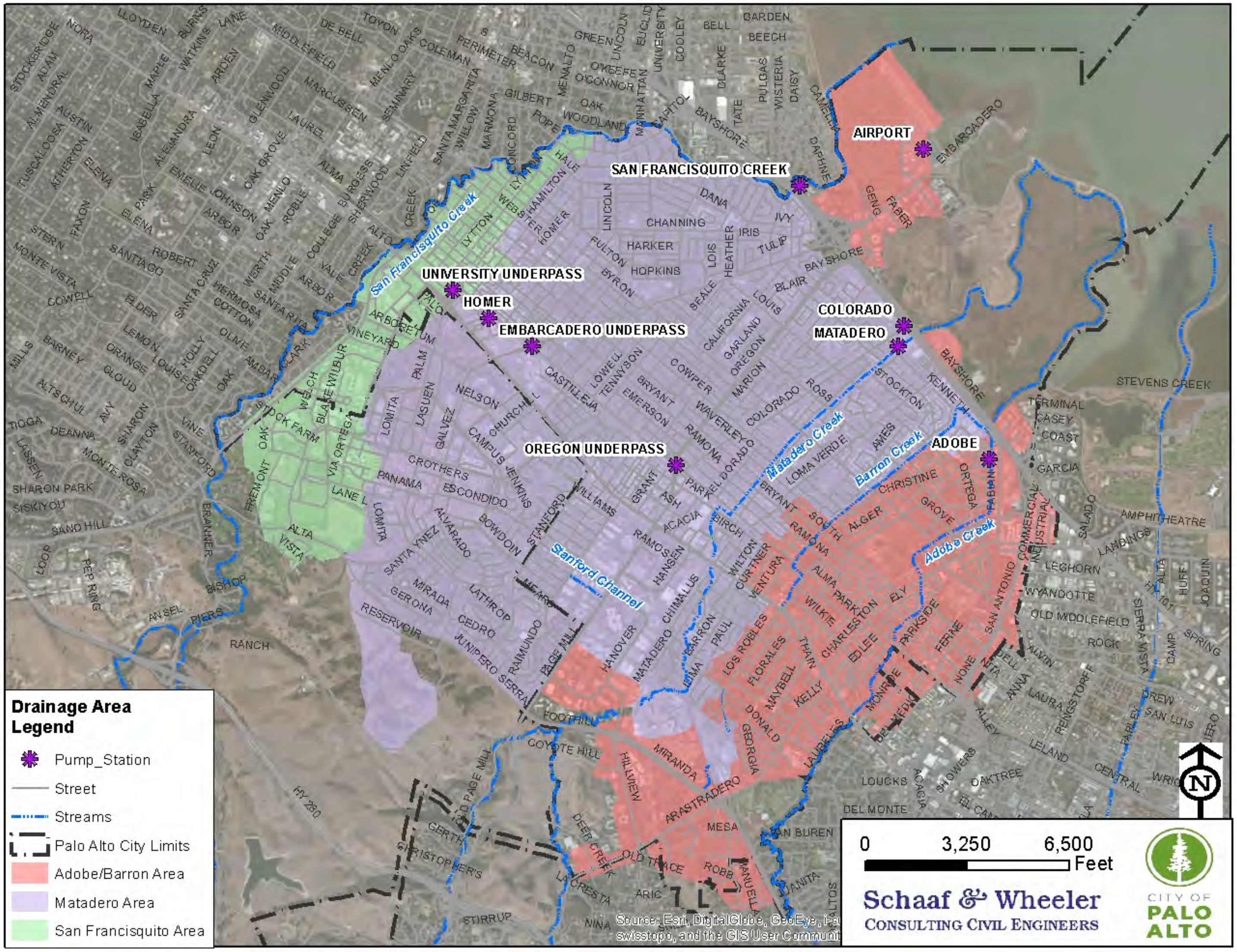


Figure 4-9: Existing Palo Alto Pump Station Locations

Airport Pump Station

The Airport Pump Station consists of three pumps driven by 125 HP electrical motors. The design point of all three pumps is 13,500 gpm at 26' TDH. The manufacturer's pump could not be located prior to model build. SCADA output for the pump station for various storm events was provided by the City. Pressure and flow data was used to calculate a system curve which was used for model input. Based on model results all three pumps run during peak operation. The station is equipped with a standby diesel engine generator. No master plan improvements are recommended for the Airport Pump Station.

Colorado Pump Station

The Colorado Pump Station consists of one Cascade pump driven by a 50 HP electrical motor. The design point of the pump is 9,000 gpm at 14.8' TDH. The manufacturer's pump curve is not available, so a readily available pump curve with similar characteristics was used for model input. The pump curve was de-rated as described in Chapter 3, Methodologies.

It is recommended to take the Colorado Pump Station offline as it is difficult to maintain, is a safety hazard due to the open wetwell, and will become obsolete when the Matadero Pump Station is replaced.

Matadero Pump Station

The Matadero Pump Station consists of five Cascade pumps. Two are low flow pumps driven by 25 HP electric motors. Three are larger pumps driven by 125 HP electric motors. All pumps run during peak station operation. The design point of the 25 HP pumps is 6,000 gpm at 10.5 TDH. The design point of the 125 HP pumps is approximately 34,000 gpm at 12' TDH. The manufacturer's pump curve is available for the 25 HP pumps. De-rating of the pump curve is not necessary because the pumps outfall directly to the creek. The 125 HP pumps were originally design to operate at variable frequency drive (VFD) pumps, so a curve to operation at 125 HP is not readily available. A curve was estimated using the VFD pump curves supplied by the City and the operating pump horsepower. The station is equipped with a standby diesel engine generator. Flap gates protect the pump station and inlet storm drain system from backflow. Additional capacity is recommended as a highest priority improvement.

San Francisquito Pump Station

The San Francisquito Pump Station consists of four Flygt PL 7101s driven by 240 HP electric motors. The design point these 240 HP pumps are 34,800 gpm at 15 TDH. There is one low flow pump driven by a 25 HP electric motor. The design point of the low flow pump is 3,000 gpm at 25 TDH. Based on model results two pumps and one low flow pump run during peak station operation. De-rating of the pump curve is not necessary because the pumps outfall directly to the creek. The station is equipped with a standby diesel engine generator. Flap gates protect the pump station and inlet storm drain system from backflow. No master plan improvements are recommended for the San Francisquito Pump Station.

Airport Pump Station

Colorado Pump Station

Matadero Pump Station

San Francisquito Pump Station

Adobe Pump Station

Chapter 5. Regulatory Guidelines and Requirements

5.1 Overview

National, regional, and local regulatory guidelines and requirements did not affect how improvements were developed, but will need to be taken into consideration when implementing the master plan improvements recommended in Chapter 4. Consideration should be taken in the following areas:

- Floodplain management
- Stormwater management
- Surface water protection
- Groundwater protection
- Riparian and wetland protection

The most significant regulatory requirements for stormwater management in Palo Alto are found in the State of California's Construction General Permit (CGP) and the San Francisco Bay Municipal Regional Stormwater Permit (MRP) under the National Pollutant Discharge Elimination System (NPDES). This chapter provides a general outline of the various guidelines and legal and regulatory requirements applicable for floodplain management, stormwater management, surface water and groundwater protection, and riparian and wetland protection.

City and private projects within the riparian corridor or near a wetland may also be required to have environmental and water quality permits from Santa Clara Valley Water District (SCVWD), San Francisco Bay Area Regional Water Quality Control Board (RWQCB), California Department of Fish and Wildlife, and the United States Army Corps of Engineers (USACE).

5.2 FEMA Regulations

Typical insurance policies do not cover the potentially devastating consequences of flooding. Even after a catastrophic event wherein houses and businesses are completely destroyed, property owners remain liable for their mortgage balances without the equity to cover them. The National Flood Insurance Program was created in 1968 for the expressed purpose of providing flood coverage even in the absence of a Presidential declaration of disaster. The intent of flood insurance is to proactively prepare for future flood damages on an equitable basis nation-wide.

National Flood Insurance Program

The National Flood Insurance Program (NFIP) as administered by the Federal Emergency Management Agency (FEMA) allows property owners within participating communities to purchase insurance that protects against losses from flooding. Most banks require mortgage holders to purchase flood insurance if the property is located in a FEMA floodplain. Damages to structures and contents are covered by the flood insurance, which may be purchased through residential and commercial insurance agents. For Palo Alto to participate in the NFIP, the City must adopt and enforce a floodplain management ordinance to reduce future flood risks to new construction and substantial improvements to existing structures in Special Flood Hazard Areas. In return, the Federal Government will make flood insurance available in the City.

Palo Alto's Participation in the NFIP

The National Flood Insurance Act of 1968 allows FEMA to make flood insurance available only where the community has adopted adequate floodplain management regulations. Palo Alto joined the NFIP in the late 1970s, and FEMA/FIA issued the first Flood Insurance Rate Map (FIRM) for the City of Palo Alto in 1980.

The City's flood hazard regulations are contained in Palo Alto Municipal Code Chapter 16.52. The regulations require that all new construction and substantial improvements to properties within the Special Flood Hazard Area are elevated above FEMA's established Base Flood Elevation and comply with special building requirements intended to protect against flood damage. Areas of the city are subject to flooding from San Francisquito Creek (2,080 properties) and San Francisco Bay high tides (2,690 properties) in a 1% (100-year) storm event.

5.3 City of Palo Alto Policy

The City of Palo Alto is responsible for ensuring compliance with Federal and State laws that regulate stormwater. The City operates under the MRP (discussed in Section 5.5), through programs and policies which include Comprehensive Plan Program N-27, Program N-29, Program N-75, Policy N-21, and Policy N-22.

All master plan improvement projects are subject to City policy. The following sites provide useful information on City policies:

Stormwater Management
http://www.cityofpaloalto.org/gov/depts/pwd/stormwater/

Planning Department
http://www.cityofpaloalto.org/gov/depts/pln/

Department of Public Works
http://www.cityofpaloalto.org/gov/depts/pwd/

Hydromodification Management Plan (see Appendix E)
http://eoainc.com/hmp_final_draft/

5.4 Construction General Permit (CGP)

The State of California requires that dischargers obtain permit coverage for projects with construction activities that disturb one or more acres in accordance with Construction General Permit Order 2009-0009-DWQ. Construction activity subject to this permit includes clearing, grading, and land disturbances such as stockpiling or excavation. The permit excludes certain regular maintenance activities from obtaining coverage.

The CGP requires the development and implementation of a Storm Water Pollution Prevention Plan (SWPPP). The SWPPP includes a Water Pollution Prevention Drawing that identifies and locates Best Management Practices (BMPs) within the limits of work, and stormwater discharge monitoring and sampling requirements. All master plan improvement projects are subject to the requirements of the CGP.

5.5 Municipal Regional Permit (MRP)

The City of Palo Alto, along with fourteen other jurisdictions within Santa Clara County, is a member of the Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP or Program) which assists in managing a shared common Municipal Regional Stormwater NPDES Permit to discharge stormwater to the San Francisco Bay which can be found here: http://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/stormwater/mrp.shtml. The City is required to meet all stormwater management requirements set forth by the MRP. The current MRP was adopted October 14, 2009 (Order no. R2-2009-0074), and became effective as of December 1, 2009.

The MRP outlines the State's requirements for municipal agencies in the San Francisco Bay Area to address the water quality and flow-related impacts of stormwater runoff. The MRP is a comprehensive permit that requires activities related to construction sites, industrial sites, illegal discharges and illicit connections, new development, and municipal operations. The permit also requires a public education program, implementing targeted pollutant reduction strategies, and a monitoring program to help characterize local water quality conditions and to begin evaluating the overall effectiveness of the permit's implementation.

A 2013-2014 Work Plan developed by SCVURPPP (February, 2013) provides detailed information regarding which required actions of the permit will be implemented at the Program level, co-permittee (i.e. City) level, and/or coordinated at the regional level. Co-permittee assistance with a Program- or regional-level activity consists of participation in ad hoc task groups or committees, review and approval of products, and/or sponsoring projects of regional benefit. The Program participates in many co-permittee activities by assisting with or developing guidance for implementation.

Trash capture is an important element of the MRP, which has a stated goal of achieving 100% trash reduction by 2022. There are many ways for the City to reach this goal, such as increased street sweeping or by installing trash capture devices. Trash capture devices can be installed at individual inlets, major junctions in the storm drain system, or at pump station inlets.

The requirements of the MRP will need to be incorporated during construction of all master plan improvements. The City should be aware that the MRP is due to be reissued later this year.

5.6 SCVWD

The Santa Clara Valley Water District (SCVWD) manages potable water, groundwater, flood protection, and stream stewardship on behalf of Santa Clara County. The City of Palo Alto has adopted the “Guidelines and Standards for Land Use Near Streams: A Manual of Tools, Standards, and Procedures to Protect Streams and Streamside Resource in Santa Clara County” (Resolution No. 8545, July 18, 2005) which clarifies and streamlines local permitting for streamside activities. It also provides design standards and various guidelines for property owners and developers. The City’s requirements for stream corridor protection are codified in Palo Alto Municipal Code Section 18.40.140.

Coordination with SCVWD will be required for the construction of master plan improvements located on stream banks. This includes the alteration of existing outfalls, or the construction of new outfalls. The City should also coordinate with SCVWD during the design of improvements that alter the floodplain in Palo Alto.

5.7 USACE

Under Section 404 of the Clean Water Act (CWA), the United States Army Corps of Engineers (USACE) regulates certain activities that “discharge dredged or fill material into waters of the United States”. Waters of the U.S. are defined to generally include such resources as tidal waters, most rivers, lakes, and streams, and certain types of wetlands. Channel stabilization and stream maintenance activities that propose to place fill, e.g. culverts, gabions, rock rip rap, logs, etc., in the channel must obtain a permit from USACE.

USACE issues two types of permits under Section 404: general permits and standard (individual) permits. General permits are issued by USACE to streamline the permit process, while individual permits are more rigorously reviewed and are reserved for projects that impact more than 1/3 acre of tidal waters or non-tidal waters greater than 1/2 acre. Specifically, the USACE Nationwide Permit (NWP) program authorizes 43 different categories of activities, each of which is governed by specific conditions for the particular NWP, as well as 27 general conditions that apply to all NWPs.

A permit will need to be obtained from USACE for the construction of improvements that will impact waters of the US. This includes the alteration of existing outfalls, the construction of new outfalls, and any construction in a marsh, wetland, or tidal waters.

5.8 BCDC

On a regional level, the San Francisco Bay Conservation and Development Commission (BCDC) regulates projects proposing to fill, extract materials, or change the use of water, land, or structures in or around San Francisco Bay. Fill is very broadly defined to include (1) solid fill, such as dirt, concrete, wood, and structures, (2) pile-supported fill, such as fixed boat piers and docks, (3) floating fill, such as floating docks, houseboats, and vessels moored for extended periods of time, and even (4) structures cantilevered over the Commission's jurisdiction. The Commission's permit jurisdiction includes San Francisco Bay which is defined as any area within the greater San Francisco Bay up to mean high tide (except in areas of tidal marsh where the Commission's jurisdiction extends to 5 feet above mean sea level) and a "shoreline band" that extends 100 feet inland from areas subject to tidal action.

A study will need to be completed to determine which projects in Palo Alto fall under BCDC jurisdiction. Only the alteration of existing outfalls and the installation of new outfalls are expected to require permits.

5.9 Low Impact Development

As of December 1, 2011, the MRP requires Low Impact Development (LID) measures for treatment of storm water runoff from all new and significant redevelopment projects. The term LID refers to practices that reduce water quality impacts by preserving and re-creating natural landscape features, minimizing imperviousness, and using stormwater as a resource, rather than a waste product. These requirements, generally referred to as the "C3 Requirements", are typically designed to treat runoff from storms small than the 10-year 24-hour storm event. While the main focus of LID measures is to improve the quality of water discharged to receiving waters, it is possible that they may decrease peak runoff but this will need to be determined on a case-by-case basis.

LID measures include rainwater harvesting/reuse, infiltration, and evapotranspiration. If these measures are deemed infeasible, then biotreatment can be used. It is likely in the future more and more emphasis will be placed on using the following technologies on construction sites recommended by the Water Board:

1. Bioretention & Rain Gardens
2. Rooftop Gardens
3. Sidewalk Storage
4. Vegetated Swales, Buffers & Strips; Tree Preservation
5. Roof Leader Disconnection
6. Rain Barrels and Cisterns
7. Permeable Pavers
8. Soil Amendments
9. Impervious Surface Reduction & Disconnection
10. Pollution Prevention & Good Housekeeping

Because of the emphasis that the MRP puts towards using LID, there are numerous regional groups tracking the most up to date technologies on LID and the corresponding NPDES regulations. The following sites contain useful information for municipal staff, developers, general public, and elected officials to keep abreast with trends and policies in the often changing arena.

City of Palo Alto
http://www.cityofpaloalto.org/gov/depts/pwd/stormwater/

CASQA
http://www.casqa.org/LID/tabid/240/Default.aspx

California State Water Resources Control Board
http://www.waterboards.ca.gov/water_issues/programs/low_impact_development/

SCVURPPP
http://www.scvurppp-w2k.com/nd_wp.shtml#lid

U.C. Davis
http://extension.ucdavis.edu/unit/center_for_water_and_land_use/low_impact.asp

BASMAA Development Committee
http://basmaa.org/BoardandCommittees/Development.aspx

Urban Design Tool
http://lid-stormwater.net/index.html

Sustainable Streets – City of San Mateo
http://sustainablestreetssanmateo.com/wp-content/uploads/2015/04/SANMATEOSSP-DESIGNGUIDELINESFINAL.pdf

Stormwater Guidelines for Green, Dense Redevelopment – City of Emeryville
http://www.ci.emeryville.ca.us/DocumentCenter/Home/View/144

City of Portland Sustainable Stormwater Management
https://www.portlandoregon.gov/bes/34598

Chapter 6. Capital Improvements

6.1 Overview

Chapter 4, Collection Systems, discusses Palo Alto's storm drain collection system and recommends prioritized capital improvements to address deficiencies. This chapter provides a Capital Improvement Program (CIP) that recognizes these priorities. The CIP provides an overall guideline for the City to use in preparing annual budgets. Exigent circumstances and future in-field experiences may necessitate deviations from the recommended Master Plan Storm Drain CIP. A master plan is intended to be just that; a tool for planning. Capital improvement priorities are not intended to be hard and fast.

The Capital Improvement Program (CIP) is based on improvements required for 2010 build-out land use condition. The Capital Improvement Program includes flow capacity projects which include installing new pipe or upsizing existing pipe and new pump stations, along with repairing or replacing existing corrugated metal pipes (CMP).

In general, a 10-year level of service can be achieved by redirecting flows from the San Francisquito Pump Station, which is limited in capacity by the 96-inch pipe under Hwy 101. This is achieved through the removal of the three weirs in the system which are located at the intersection of Heather Ln. and Channing Ave., the intersection of Embarcadero Rd. and Louis Rd., and at Greer Rd. and Embarcadero Rd. Pipes that direct flow to gravity outfalls that are not subject to backwater and to pump stations are upsized. Pump stations are added to gravity outfalls that are subject to backwater due to creek water surface elevation.

This study and proposed CIP is merely the starting point. It is anticipated that City staff and/or their consultants will perform a more detailed study or alternatives analysis to find more affordable or effective improvements with information gathered as part of the design process (detailed topography, utility conflicts, easements, etc).

6.2 Capital Improvement Priorities

The proposed CIP for storm drainage in Palo Alto is broken into four priority levels for funding and implementation. The total cost summary for all CIP projects, including pipe, pump station improvements, and CMP repair/replacement, is shown for each priority level in Table 6-1. Table 6-1 costs include a 30% construction contingency cost and a 20% increase for engineering, administrative, and inspection costs.

Table 6-1: Summary of CIP Costs Based on Priority Level

Priority Level	Cost
Highest Priority Capital Improvements	$14,102,000
High Priority Capital Improvements	$23,139,000
Moderate Priority Capital Improvements	$22,233,000
Low Priority Capital Improvements	$53,800,000
Total Capital Improvement Program	$113,374,000

6.3 Alternative Construction Method

Two essential types of projects are traditionally utilized to increase storm drain system capacity: install a new relief storm drain parallel to the system lacking capacity, or replace the overloaded pipe with larger diameter pipe in the same alignment. The CIP has been developed assuming pipe replacement with a larger diameter pipe. The two alternatives can be made equivalent to one another using the following formula, assuming that pipe material and length are equal:

$$D_R = (D_e^{2.63} + D_p^{2.63})^{0.38}$$

where D_R = diameter of replacement pipe;

D_e = diameter of overloaded pipe; and

D_p = diameter of parallel relief drain.

Assuming the existing pipe is adequate in terms of condition, the installation of a new parallel pipe is typically more cost effective than pipe replacement since the required pipe size is smaller and the existing pipe does not need to be removed. This does not take into account the long term maintenance associated with a parallel system. The selection of a capacity improvement strategy will vary from project to project, and will be governed by field constraints such as conflicting utilities, rights-of-way, environmental concerns, permit requirements and traffic control.

Traditional cut and cover methods of construction will be employed for most storm drain construction. However, the utilization of trenchless methods such as bore and jack, directional drilling, cured-in-place pipe (CIPP), slip-lining, and others, may increasingly find application in special circumstances where existing development encroaches upon the pipe alignment, or disruption of other services and land uses is too costly.

Cost of Improvements

Costs have been estimated using information from other projects, cost estimating guides (*2014 Current Construction Costs,* Saylor Publications, Inc.), and engineering judgment and are in 2014 dollars. Cost estimates can be updated for work to be performed in the future by adjusting the costs given here by the change in the Engineering News Record (ENR) construction cost index. The costs correspond to an ENR Index of 9971. Future costs can be calculated by multiplying the costs given here by ratio “Future ENR Index / 9971). The cost per linear foot of improvement used for the pipe cost estimates are given in Table 6-2 and are based on RCP installed using open trench in the roadway of up to 10-feet in depth. Connection (manhole or inlet) replacement cost estimates ranged from $11,850 to $14,250 depending on connecting pipe diameters or box culvert dimensions. New outfalls costs were estimated to be $40,000 per outfall (not including contingencies and permitting). It should be noted that wide variations in actual outfall costs are expected due to location of outfall, whether energy dissipation is required, if it crosses through a levee, etc.

Table 6-3 and Table 6-4 list the unit costs for CMP repair and/or replacement. Grade inlet refers to re-grading the ground in the vicinity of the inlet to allow flow to more efficiently enter the culvert. Replace and repair inlet refers to making improvements to the culvert inlet structure. Costs do not include permitting or any environmental documentation. Remove cable refers to removing a cable of unknown origin from the culvert and either disposing of it or burying it in the roadway adjacent to the culvert.

Most of these improvement projects are expected to qualify for negative declarations from permitting agencies.

Table 6-2: Storm Drain Unit Costs Based on RCP

Diameter (inches)	2014 Dollar per Linear foot of Pipe	2014 Dollar per Connection
15	$250	$11,850
18	$270	$11,930
21	$300	$12,010
24	$325	$12,080
27	$350	$12,155
30	$375	$12,230
33	$400	$12,305
36	$425	$12,380
42	$475	$12,530
45	$500	$12,605
48	$525	$12,680
51	$550	$12,755
54	$575	$12,830
60	$625	$12,970
66	$675	$13,120
72	$725	$13,270
78	$780	$13,360
84	$830	$13,570
90	$870	$13,720
96	$950	$14,000
3’x4’	$724	$13,820
4’x5’	$934	$14,150
4’x5.5’	$991	$14,250

Table 6-3: Storm Drain Unit Costs for CMP Repair or Replacement

Diameter (inches)	Pipe Replacement ($/LF)	Spot Repair (EA)	Pipe Lining ($/LF)
8	$200	$1,600	$80
12	$225	$1,800	$90
15	$250	$2,000	$100
18	$270	$2,160	$110
21	$290	$2,320	$120
24	$325	$2,600	$130

Table 6-4: CMP Unit Cost for Repair Projects

Project type	Unit Cost
Cleaning	$275/LF
Replace Inlet	$3,000/EA
Repair Inlet	$1,000/EA
Remove Cable	$500/EA
Grade Inlet	$1,000/EA

6.4 Capital Improvement Program

The proposed Storm Drain Capital Improvement Program pipeline and pump station improvement costs and pipe lengths based on priority level are summarized in Table 6-5 for capacity related CIP. The prioritized CMP projects are summarized in Table 6-7 for condition related CIP. Table 6-7 (Adobe/Barron) and Table 6-8 (Matadero) outline the capacity related CIP cost allowances by project name and sub-area. These projects will decrease flooding in the streets of Palo Alto. The condition related repair projects are summarized in Table 6-9, which outline the which CMP need to be repaired or replaced. Table 6-10 summarized the CIP cost allowances for new pump stations. Maps of the improvement priorities with pipe diameters and box culvert dimensions are shown in Appendix C. The CIP is for ultimate 2010 build-out land use condition.

Table 6-5: Summary of Prioritized 10-Year CIP Project Costs

Priority		Adobe/Barron	Matadero	San Francisquito	Total
Highest	Length (ft)	702	0	0	**702**
	Cost	$2,420,000	$11,530,000	0	**$13,950,000**
High	Length (ft)	3,117	17,073	0	**20,190**
	Cost	$2,640,000	$20,330,000	0	**$22,970,000**
Moderate	Length (ft)	3,829	16,592	0	**20,421**
	Cost	$5,650,000	$16,470,000	0	**$22,120,000**
Low	Length (ft)	26,425	31,821	0	**58,246**
	Cost	$27,720,000	$26,080,000	0	**$53,800,000**

Table 6-6: Summary of Prioritized CMP Project Costs

Priority		CMP
Highest	Length	470.5 ft
	Cost	$152,000
High	Length	580.7 ft
	Cost	$169,000
Moderate	Length	580.1 ft
	Cost	$113,000

Table 6-7: Adobe/Barron Drainage Area 10-Year Storm Protection CIP

Project	Project ID	Pipe Length (ft)	Connections	Outfalls	Priority	Estimated CIP
Corporation and E Bayshore	1	702	8	1	Highest	$2,420,000
Charleston and Abode Creek	5	946	5	1	High	$1,300,000
E Meadow Cir	6	770	2	0	High	$360,000
E Meadow Dr	7	401	2	0	High	$400,000
Fabian	8	1,000	5	0	High	$580,000
Charleston and Fabian	16	964	2	0	Moderate	$1,030,000
El Camino Real and Los Robles	17	2,450	11	0	Moderate	$2,530,000
Municipal Service Yard	20	415	2	1	Moderate	$2,090,000
Alma and Greenmeadow	26	1,137	4	1	Low	$840,000
Arastradero	28	3,362	15	0	Low	$2,390,000
E Bayshore Rd and Embarcadero	33	525	4	0	Low	$350,000
E Charleston and Middlefield Rd	34	2,288	14	0	Low	$1,700,000
E Meadow Dr and Middlefield Rd	35	4,249	19	0	Low	$3,580,000
Foothill and Miranda	38	1,194	8	1	Low	$1,210,000
Hillview	42	477	5	1	Low	$550,000
Laura Ln and Geng Rd	44	940	4	0	Low	$550,000
Nelson	49	961	5	1	Low	$670,000
Park and Whitclem	53	220	3	1	Low	$280,000
San Antonio	59	4,252	21	0	Low	$3,280,000
Scripps	60	955	10	1	Low	$860,000
South Ct to Adobe Creek	62	2,502	10	1	Low	$1,980,000
Ventura and Park	63	482	6	1	Low	$500,000
Wilkie and Park	66	2,906	19	0	Low	$2,220,000

Table 6-8: Matadero Drainage Area 10-Year Storm Protection CIP

Project	Project ID	Pipe Length (ft)	Connections	Outfalls	Priority	Estimated CIP
Bayshore and Fabian	3	1,392	6	1	High	$1,390,000
Hamilton and Rhodes	9	3,650	15	0	High	$3,440,000
Lincoln and Channing	10	4,629	14	0	High	$3,790,000
Loma Verde and Maddux	11	1,747	16	0	High	$2,200,000
Louis	12	4,186	27	0	High	$6,910,000
Louis and Clara	13	1,053	3	1	High	$1,560,000
Cambridge and Park	14	2,515	14	0	Moderate	$1,860,000
Center	15	2,033	10	0	Moderate	$1,620,000
Embarcadero	18	837	6	0	Moderate	$2,020,000
Loma Verde and Ross	19	1,145	6	0	Moderate	$1,340,000
Page Mill and Alma	22	1,957	14	0	Moderate	$1,800,000
Page Mill and El Camino Real	23	2,521	10	0	Moderate	$2,530,000
Seale	24	5,585	23	0	Moderate	$4,980,000
Alma	25	1,380	4	0	Low	$920,000
Bryant	29	1,665	8	0	Low	$1,130,000
Cambridge	30	2,224	12	1	Low	$1,860,000
Colonial and Amarillo	31	730	5	0	Low	$480,000
Colorado PS removal	32	425	6	0	Low	$430,000
El Camino Real	36	612	3	0	Low	$400,000
El Centro	37	639	4	1	Low	$480,000
Forest and Hamilton	39	3,332	12	0	Low	$2,290,000
Hamilton and Channing	40	3,960	14	0	Low	$2,840,000
Hanover	41	732	7	0	Low	$660,000
Hoover Park	43	217	5	1	Low	$310,000
Loma Verde and Cowper	45	2,264	12	0	Low	$2,390,000
Louis and Loma Verde	46	1,249	10	0	Low	$1,340,000
Louis and Piers	47	1,468	7	0	Low	$790,000
Moreno	48	773	3	0	Low	$460,000
Oregon	51	792	6	0	Low	$610,000
Oregon and Louis	52	2,234	13	0	Low	$3,310,000
Parkinson and Newell	55	3,258	11	0	Low	$2,340,000
Portage	56	562	5	0	Low	$420,000
Ross and Ames	57	843	3	0	Low	$660,000
Ross Road to Matadero Creek	58	784	5	1	Low	$680,000
Walter Hays	64	773	7	0	Low	$820,000
Waverley	65	907	4	0	Low	$460,000

Table 6-9: CMP Repair Project Summary

Project	Pipe Length (ft)	Action Summary	Priority	Estimated CIP
A-1	28	Replace	Highest	$11,800
A-7	31	Replace	Highest	$4,000
A-23	34	Replace	Highest	$12,000
A-25	25	Replace inlet, clear sediment, line	Highest	$10,800
A-26	34	Replace	Highest	$10,600
A-31	34	Repair	Highest	$2,800
A-34 d/s	81	Replace	Highest	$28,600
A-34 u/s	88	Replace	Highest	$30,800
A-35	55	Replace	Highest	$19,600
A-39	37	Replace	Highest	$14,400
A-42	23	Inlet structure, clear sediment	Highest	$6,400
A-2	46	Line	High	$6,400
A-6	46	Line	High	$7,100
A-12	56	Replace,remove cable	High	$18,200
A-14	30	Replace	High	$10,600
A-15	21	3 spot repair, line	High	$11,400
A-16	22	spot repair, line	High	$5,800
A-20	34	Replace	High	$12,000
A-21	27	Grade inlet, spot repair, line	High	$8,200
A-24	32	Replace inlet, line	High	$9,200
A-33 d/s	21	Replace	High	$10,800
A-33 u/s	40	Line	High	$8,200
A-36	27	Replace	High	$9,500
A-37	38	Replace inlet, clear sediment, line	High	$11,800
A-38	41	Clear sediment, line	High	$7,400
A-40	42	Replace	High	$16,200
A-41	36	Spot repair, line	High	$11,300
A-43	23	Clear sediment, line	High	$5,000
A-3	22	Line	Moderate	$3,000
A-4	39	Spot repair, line	Moderate	$8,300
A-8	28	Line	Moderate	$10,900
A-5	41	Line	Moderate	$6,400
A-9	26	Line	Moderate	$3,200
A-10	28	Line	Moderate	$4,000
A-11	28	Line	Moderate	$3,500
A-13	31	Line	Moderate	$4,300
A-17	18	Inlet repair, line	Moderate	$4,100
A-19	25	Line	Moderate	$4,200
A-22	34	Spot repair, line	Moderate	$7,700
A-27	20	Line	Moderate	$2,800

Project	Pipe Length (ft)	Action Summary	Priority	Estimated CIP
A-28	51	Line	Moderate	$7,200
A-29	43	Line	Moderate	$7,900
A-30	52	Spot repair, line	Moderate	$10,000
A-32 24-in.	48	Spot repair, line	Moderate	$11,500
A-32 18-in.	48	Spot repair, line	Moderate	$13,700

In addition to these capacity and condition improvements, there are recommended new pump stations. This includes increasing pumping capacity at the Matadero Pump Station and new pump stations on W Bayshore and E Bayshore near Adobe Creek, at the Municipal Service Yard near Matadero Creek, and several low priority new pump stations in the Adobe/Barron system.

Table 6-10: Pump Station Improvement CIP

Project	Project ID	Priority	Estimated CIP
Corporation and E Bayshore	1	Highest	$2,420,000
Matadero Pump Station	2	Highest	$11,530,000
Bayshore and Fabian Pump Station	4	High	$1,040,000
Municipal Service Yard	20	Moderate	$2,090,000
Oregon Expy Pump Station	21	Moderate	$320,000
Alma and Greenmeadow Pump Station	27	Low	$2,560,000
Colorado PS removal	32	Low	$430,000
Nelson Ct Pump Station	50	Low	$1,190,000
Park and Whitclem Pump Station	54	Low	$1,310,000
Scripps Pump Station	61	Low	$1,700,000
Total		-	**$24,590,000**

6.5 Sea Level Rise

The impact of sea level rise was not considered as part of the master plan analysis. Adobe and Barron Creeks are generally protected from sea level rise by the Palo Alto Flood Basin, although the City should coordinate with the Santa Clara Valley Water District, who controls the basin, when doing improvements to outfalls along the tidally influenced reaches of those creeks. Sea level rise is not anticipated to impact the San Francisquito Pump Station due to the high elevation of the pump outfall. Sea level rise should be considered during the design of the Matadero Pump Station, and any other pump station that outfalls to a tidally influenced reach of a creek.

6.6 LID Incorporation

The City should consider incorporating LID elements into street and utility improvement projects. Elements such as sidewalk storage, bioswales in park strips, and tree preservation can slow rainwater discharge to the storm drain system, and may reduce nuisance ponding through additional storage, although are not intended to reduce discharge to the system during larger events such as the 10-year storm.

Appendix A

Modeled Pump Curves

The following pump curves were used in the PCSWMM models for the Adobe, Airport, Colorado, Matadero, and San Francisquito pump stations. See Chapter 4 of the report for curve generation information.

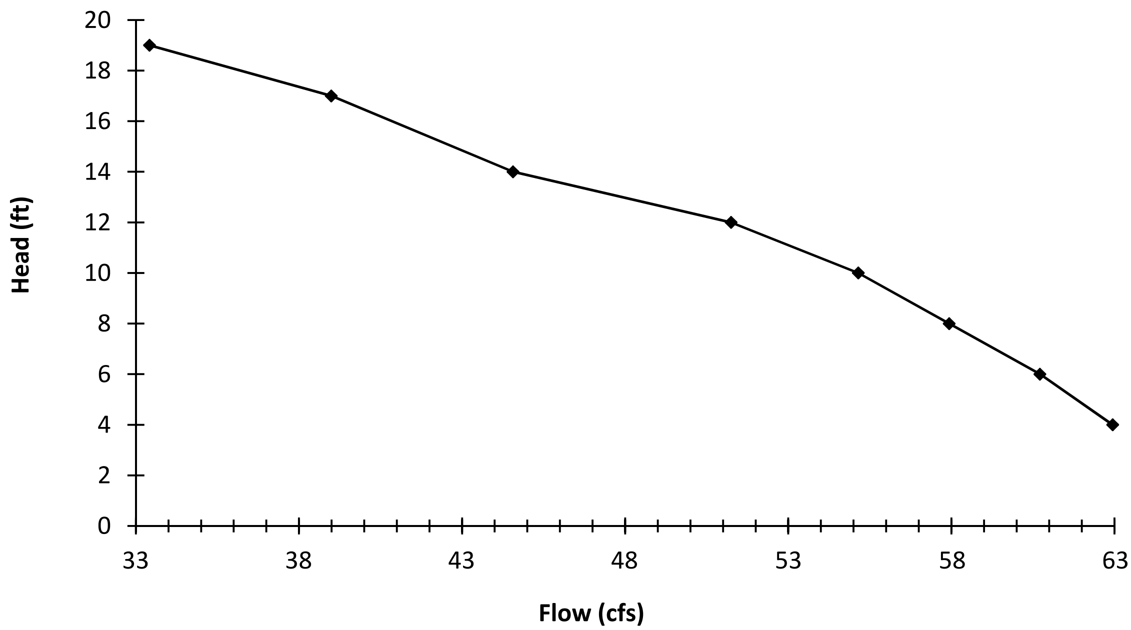


Figure A-1. Adobe Pump Curve

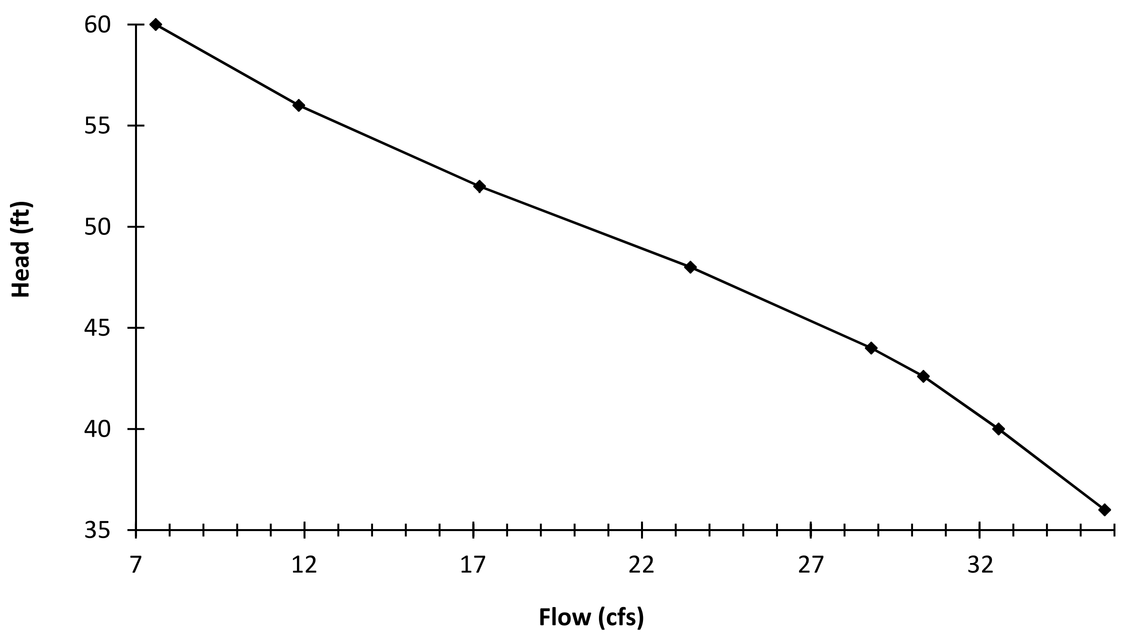


Figure A-2. Airport Pump Curve

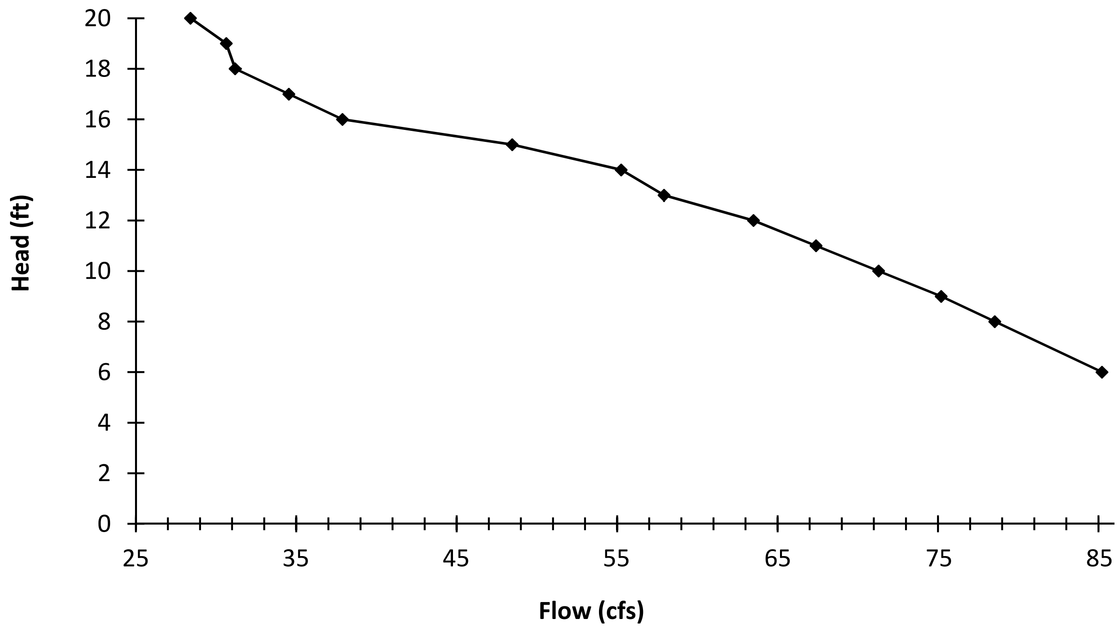


Figure A-3. Matadero 125 HP Pump Curve

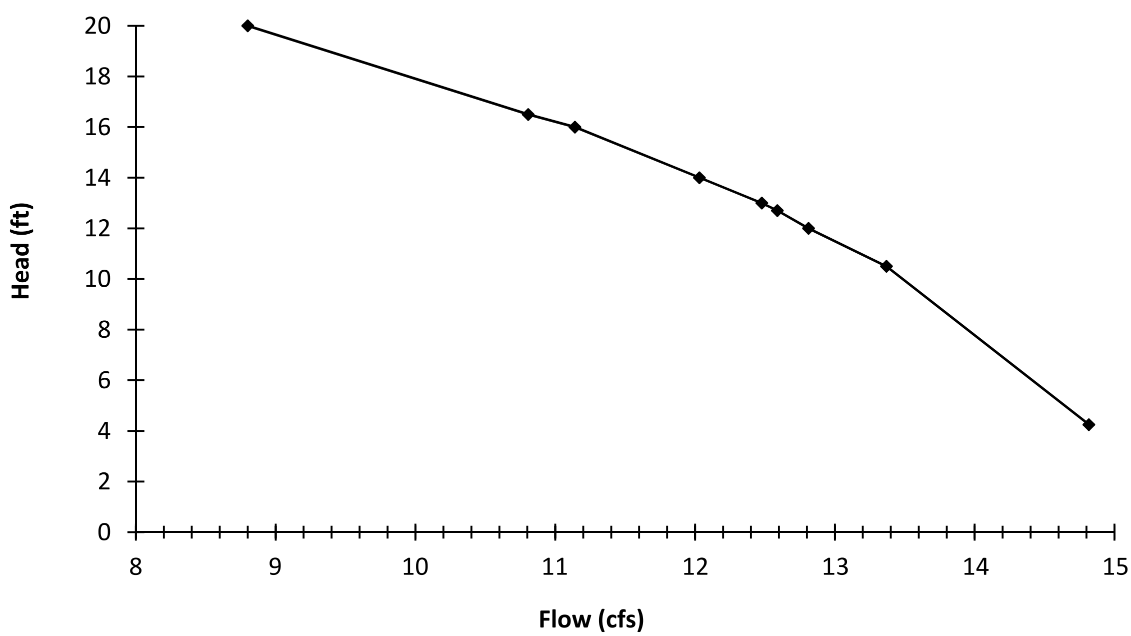


Figure A-4. Matadero 25 HP Pump Curve

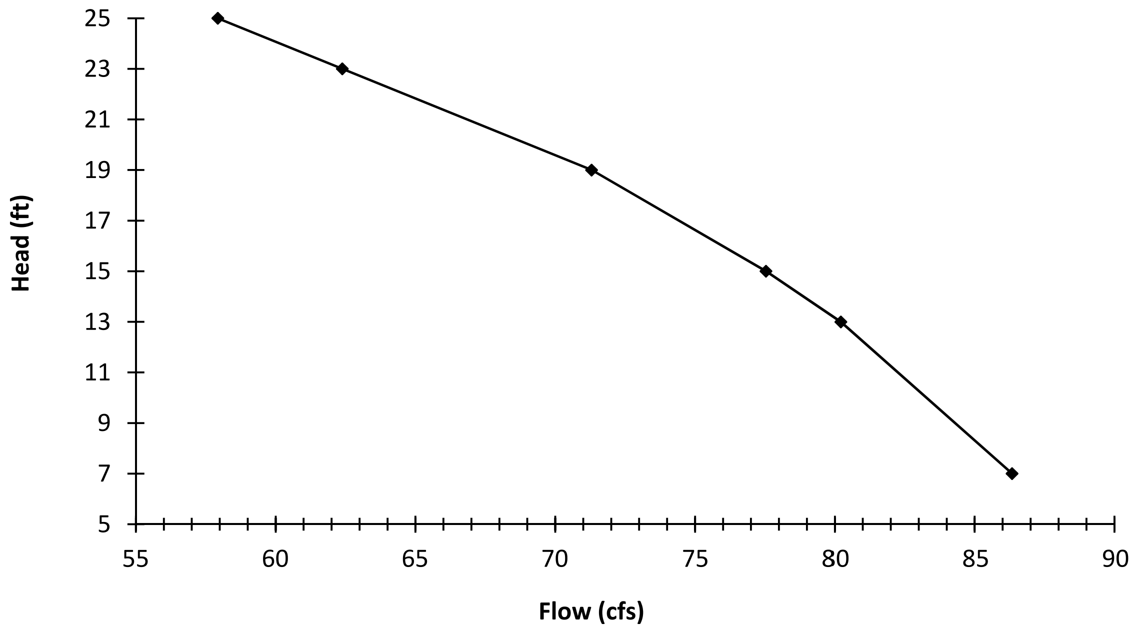


Figure A-5. San Francisquito pump curve

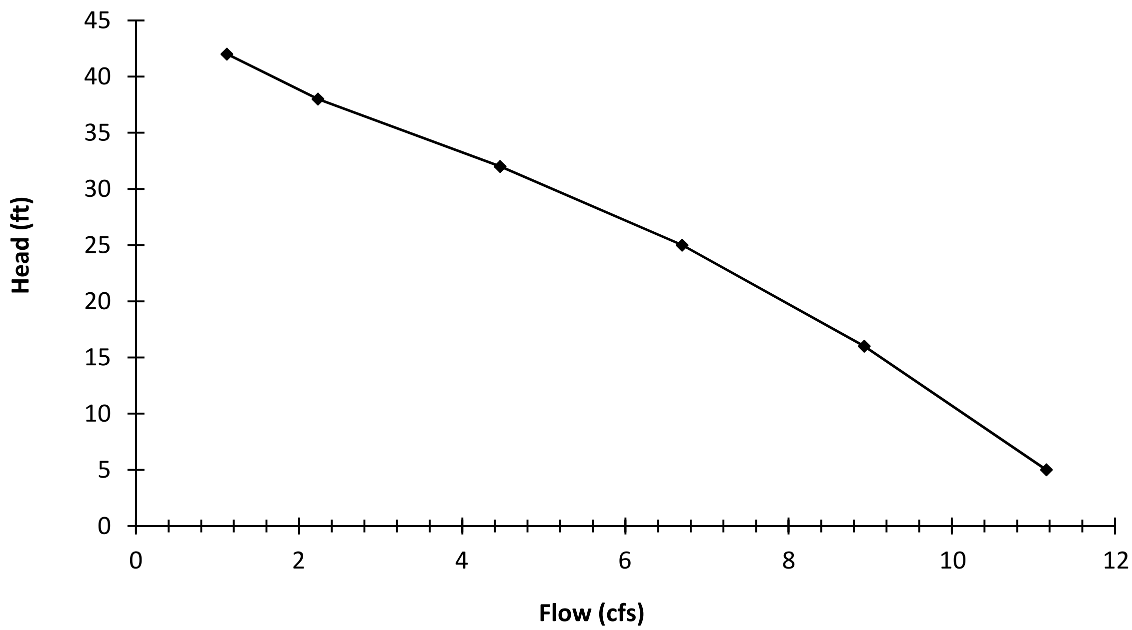


Figure A-6. San Francisquito low flow pump curve

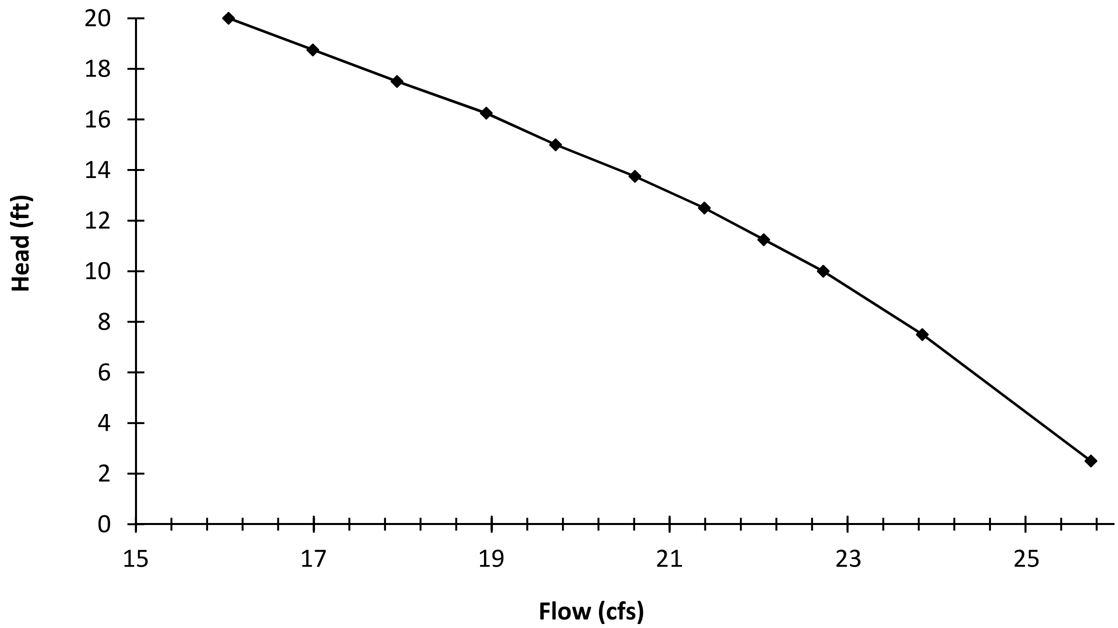


Figure A-7. Colorado de-rated pump curve

Appendix B

Model Calibration Technical Memorandum

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TECHNICAL MEMORANDUM

TO:	Rajeev Hada, P.E.	DATE:	June 23, 2015
FROM:	Emily Straley, P.E., Dan Schaaf, P.E.	JOB #:	PALO.6.14
SUBJECT:	Calibration of SWMM Parameters for use with NRCS Unit Hydrograph Method		

Introduction

The City of Palo Alto has tasked Schaaf & Wheeler with the update of their storm drain master plan. The previous storm drain master plan was completed by CH2M Hill in December 1993. The storm drain system was modeled using PCSWMM, hydrologic and hydraulic modeling software developed by CHI that operates with a GIS interface and EPA SWMM engine. EPA SWMM is a dynamic hydrology-hydraulic-water quality simulation model developed by the US Army Corps of Engineers and is free to the public. In order to update the storm drain master plan, Schaaf & Wheeler converted the previous master plan models to the new version of PCSWMM and applied updated hydrologic methodology per the Santa Clara County Drainage Manual (Schaaf & Wheeler, 2007), henceforth referred to Drainage Manual.

Literature suggests that the Curve Number Method option in the SWMM program produces inaccurate results due to the application of nonlinear reservoir routing. The City wanted to preserve the use of the SWMM model, but also wished to apply the Santa Clara County hydrology procedure which produces calibrated results using Curve Number and Unit Hydrograph Methodology. It is necessary to adjust the SWMM basin parameters to produce a basin runoff hydrograph that matches the hydrograph created using Unit Hydrograph Methodology.

This technical memorandum describes the process Schaaf & Wheeler engineers developed to determine which basin parameters should be adjusted, and the methodology used to calibrate the basin parameters. The memorandum is organized as follows: a discussion of the 1993 Storm Drain Master Plan; verification of the need for basin parameter calibration; Phase I of the calibration method in which the sensitivity of the basin parameters is determined, and initial calibration parameters are selected; and Phase II in which calibration results are compared to Rational Method results, and calibration parameters are finalized.

1993 CH2M Hill Storm Drain Master Plan

The 10-year 6-hour storm event with an IDF Simulated Storm Distribution was used as the design storm in the analysis completed for the 1993 Master Plan. This storm was selected based on comparison to neighboring cities' standards and information from the National Weather Service which indicates that, in general, storms move through the area quickly. The depth of rainfall was based on the County's intensity/duration/frequency (IDF) curve, and the IDF simulated storm distribution with a 3-hour peak (see Figure 1). The Horton infiltration equation was used to calculate runoff.

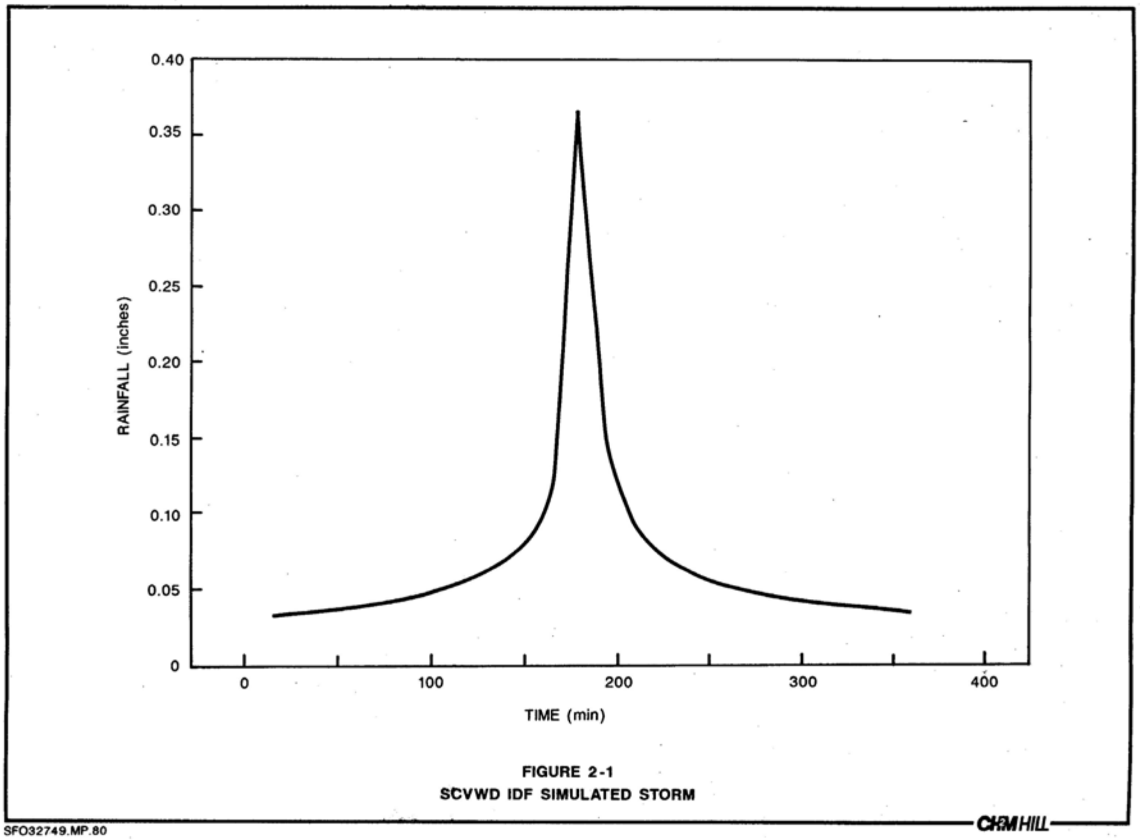

Figure 1 - Rainfall Distribution used in 1993 Storm Drain Master Plan by CH2M Hill

Need for SWMM Calibration

Rainfall-runoff is simulated in SWMM with nonlinear reservoir routing. While SWMM gives the option of the using the Curve Number Method to compute runoff losses, literature suggests that this method produces inaccurate results when applied with nonlinear reservoir routing. In order to test this theory, Schaaf & Wheeler chose 6 basins of various size, slope, and land use, and compared SWMM results with results produced using the Unit Hydrograph Method. Curve numbers are assigned based on the County Drainage Manual. Basin Width is calculated by dividing the basin area by the flow length, as suggested in the SWMM User's Manual. Table 1outlines the basin parameters for a 24-hour 10-year storm event. Comparison of SWMM and Unit Hydrograph Method results is show in Figure 2.

Table 1 - Basin Parameters

Basin	Area (ac)	Width (ft)	Flow length (ft)	Slope (%)	Imperv (%)	N Imperv	N Perv	Dstore Imperv (in)	Dstore Perv (in)	Zero Imperv (%)	Subarea Routing	Percent Routed (%)	Curve number
9	60	851	3095	1.9	78	0.025	0.025	0	0	25	PERVIOUS	100	79
38	15	408	1635	0.87	66	0.025	0.025	0	0	25	PERVIOUS	100	79
69	52	937	2398	1.06	40	0.025	0.025	0	0	25	PERVIOUS	100	79
118	71	1228	2504	0.62	65	0.025	0.025	0	0	25	PERVIOUS	100	78
172	226	1866	5274	1.29	69	0.025	0.025	0	0	25	PERVIOUS	100	72
186	0.4	60	314	1.99	89	0.025	0.025	0	0	25	PERVIOUS	100	79

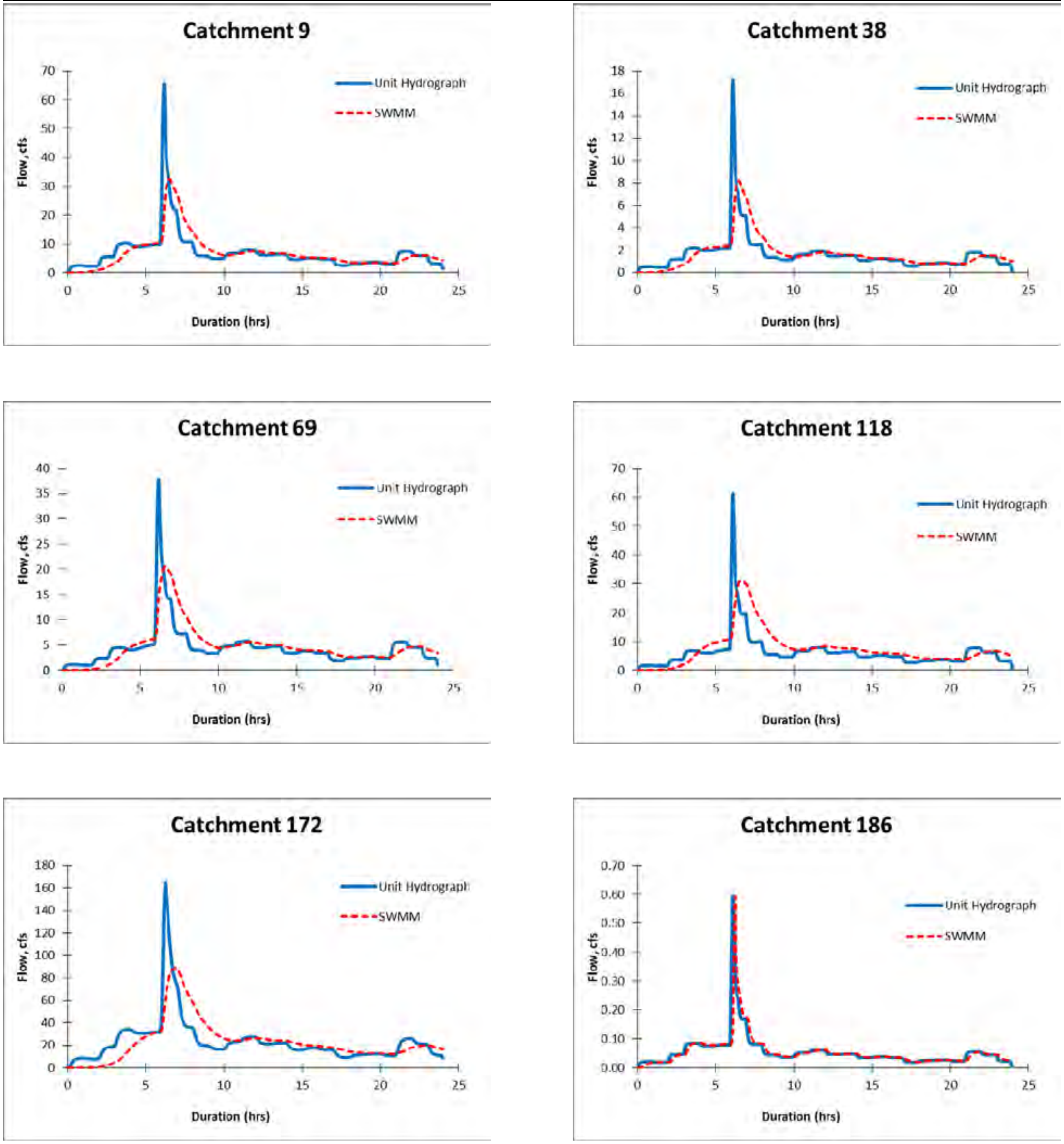

Figure 2 - Comparison of SWMM and Unit Hydrograph Results

Except for Catchment 186, the hydrographs produced by SWMM do not compare well to the hydrographs produced using the Unit Hydrograph Method. In order to apply the methodology outlined in the Drainage Manual, SWMM parameters must be calibrated to produce results that match the Unit Hydrograph Method. The calibration technique used is as follows:

- Perform a sensitivity analysis on all calibration parameters
- Use a wide variety of watersheds in Palo Alto
  - Flat/steep
  - Urban/rural
  - Large/small

- Minimize the number of parameters to "tweak"
- Compare results to results produced using the Unit Hydrograph Method

SWMM parameters for basins, their basis, and whether it is appropriate to use them to calibrate the model is presented in Table 2.

Table 2 - Calibration Parameters

Parameter	Basis	Calibration?
Slope	Physical	No
Area	Physical	No
% Impervious	Physical	No
Curve Number	Empirical	Yes
Depression Storage	Physical	Yes
Width	Physical	Yes
Direct Connection	Physical	Yes

Calibration Methdology – Phase I

A sensitivity analysis was performed on all calibration parameters to determine which parameters the model is most sensitive to. This was done by varying each parameter independently and comparing the results to the initial SWMM model run, or "SWMM baseline" run, using the following equation:

$$Percent\ difference = \frac{sensitivity\ run\ - SWMM\ baseline}{SWMM\ baseline}$$

SWMM model sensitivity to the Curve Number (CN) was determined by running the model with 80%, 90%, 110%, and 120% of the baseline CN and calculating the percent difference in peak flow and total volume from the SWMM baseline run. The percent difference in peak flow results are presented in Figure 3. The percent difference in total volume results are presented in Figure 4. Both peak flow and total volume are sensitive to changes in CN.

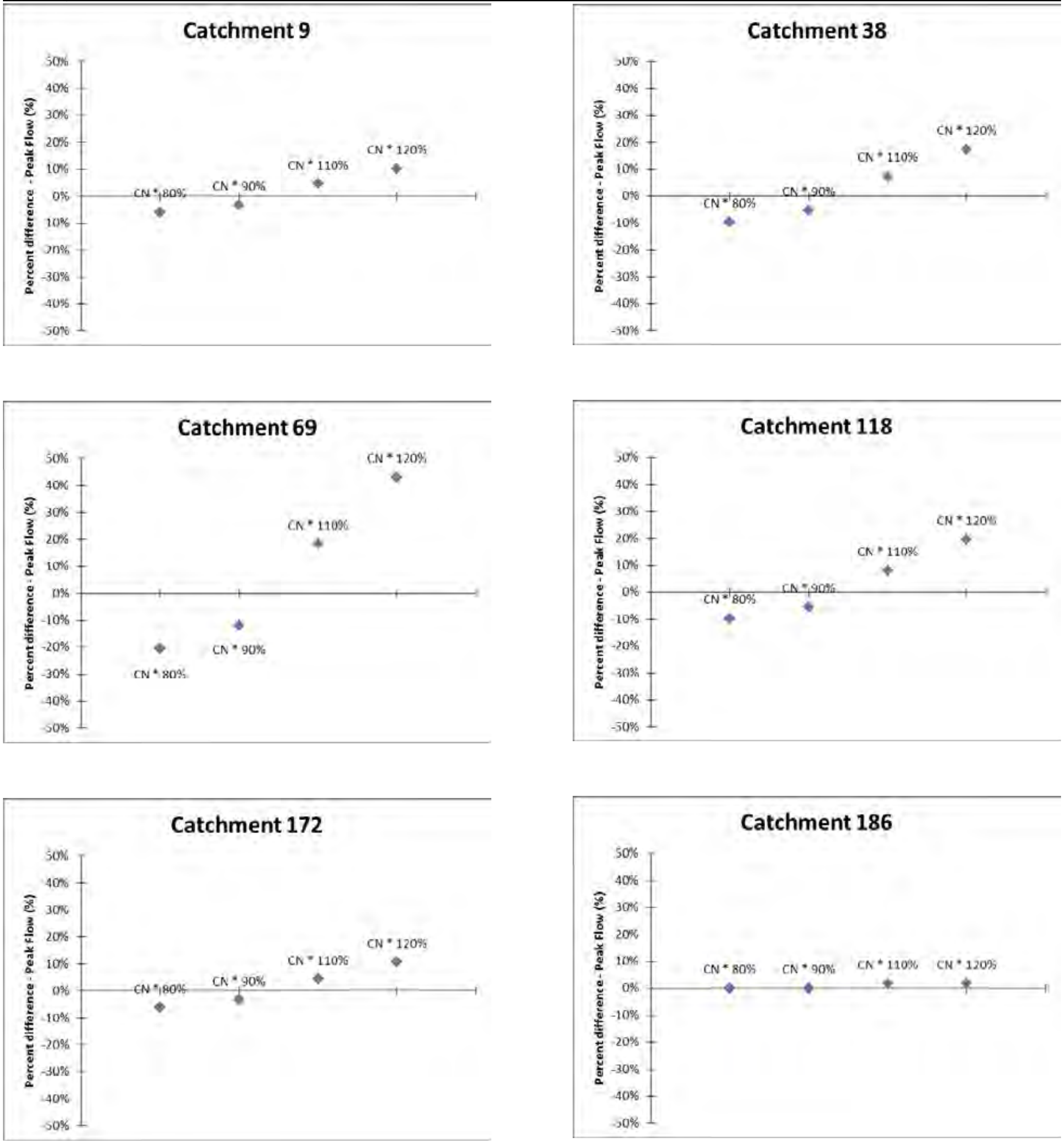

Figure 3 - SWMM Sensitivity to Changes in Curve Number - Peak Flow

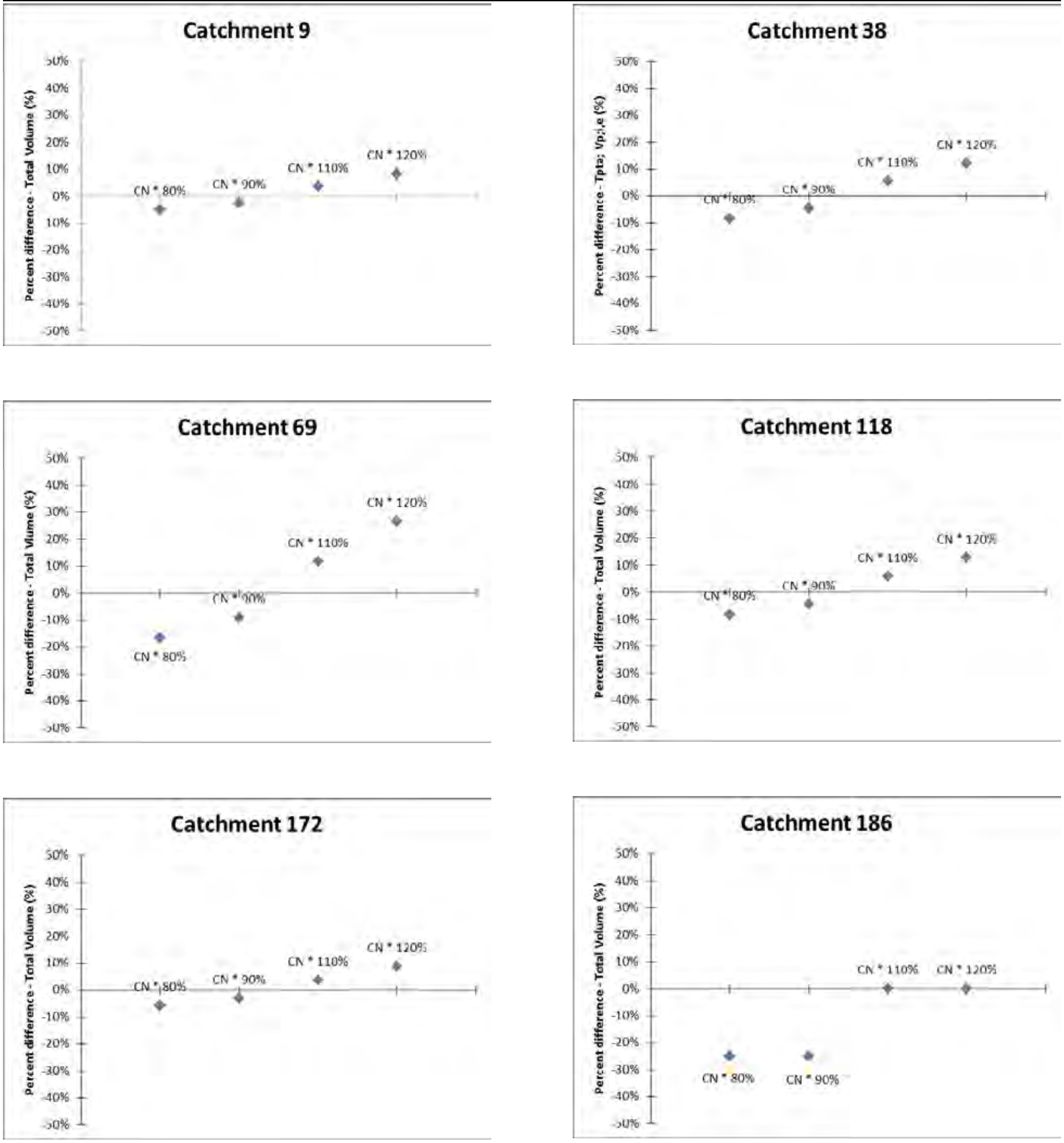

Figure 4 - SWMM Sensitivity to Changes in Curve Number - Total Volume

SWMM model sensitivity to the Width was determined by running the model with 50%, 150%, 200%, and 300% of the baseline Width and calculating the percent difference in peak flow and total volume from the SWMM baseline run. The percent difference in peak flow results are presented in Figure 5. The percent difference in total volume results are presented in Figure 6. Peak flow is highly sensitive to changes in Width, but total is volume is not.

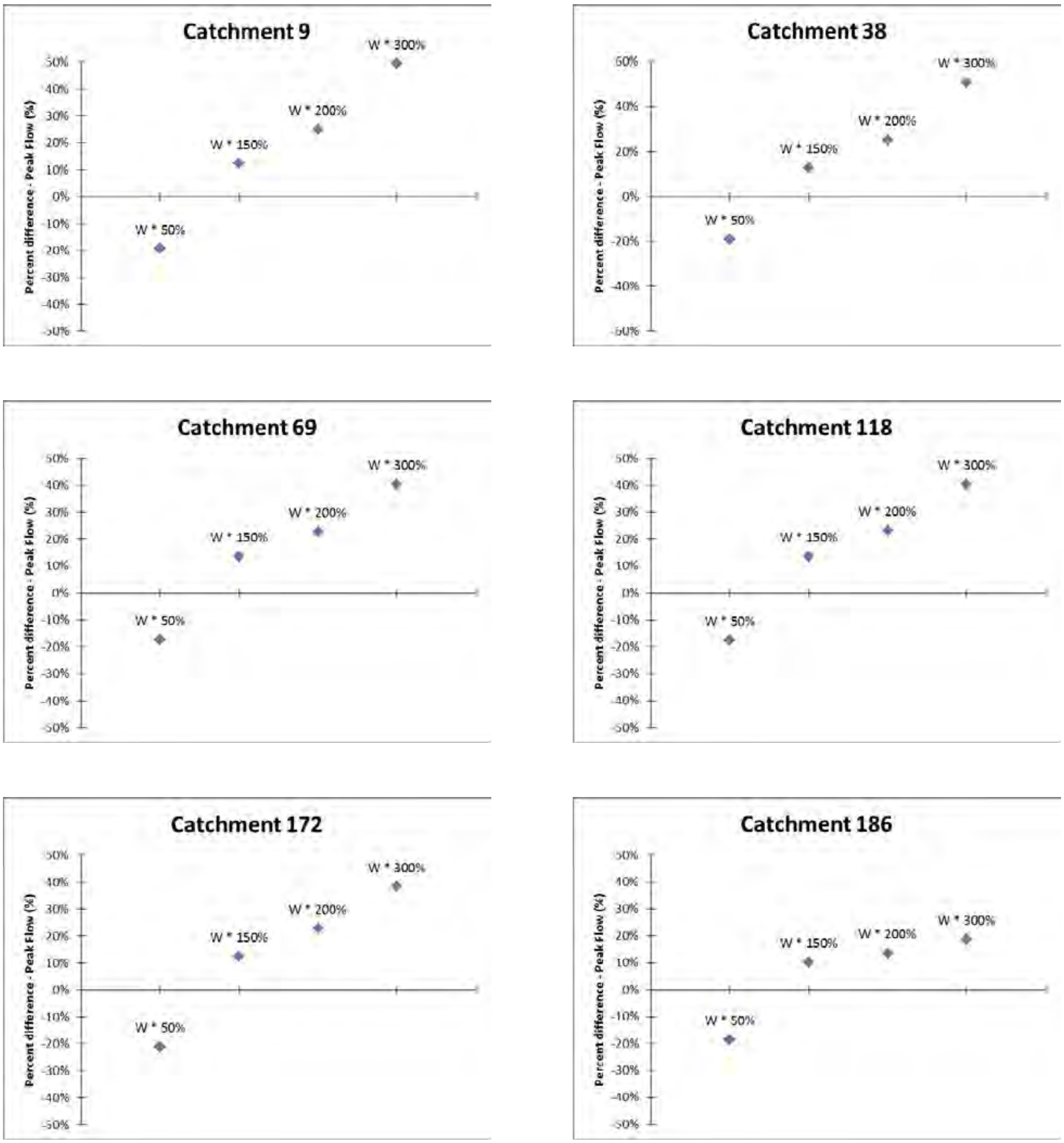

Figure 5 - SWMM Sensitivity to Changes in Width - Peak Flow

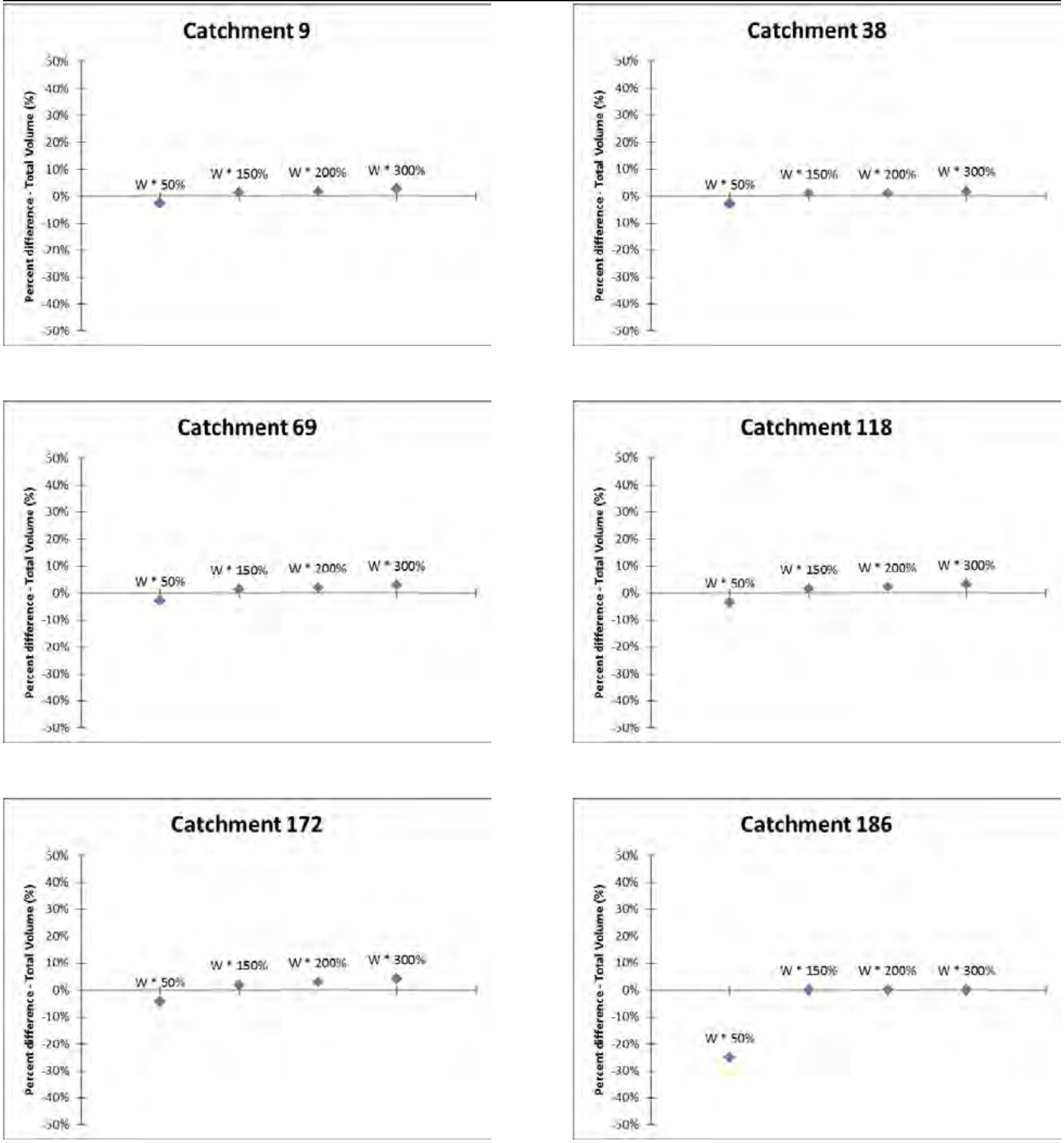

Figure 6 - SWMM Sensitivity to Changes in Width - Total Volume

SWMM model sensitivity to the depression storage in pervious and impervious areas was determined by running the model with coefficients of 0.10, 0.25, 0.50, and 1.00 then calculating the percent difference in peak flow and total volume from the SWMM baseline run. The percent difference in peak flow results are presented in Figure 7 and Figure 9. The percent difference in total volume results are presented in Figure 8 and Figure 10. Neither peak flow nor total volume are sensitive to change in depression storage in pervious and impervious areas.

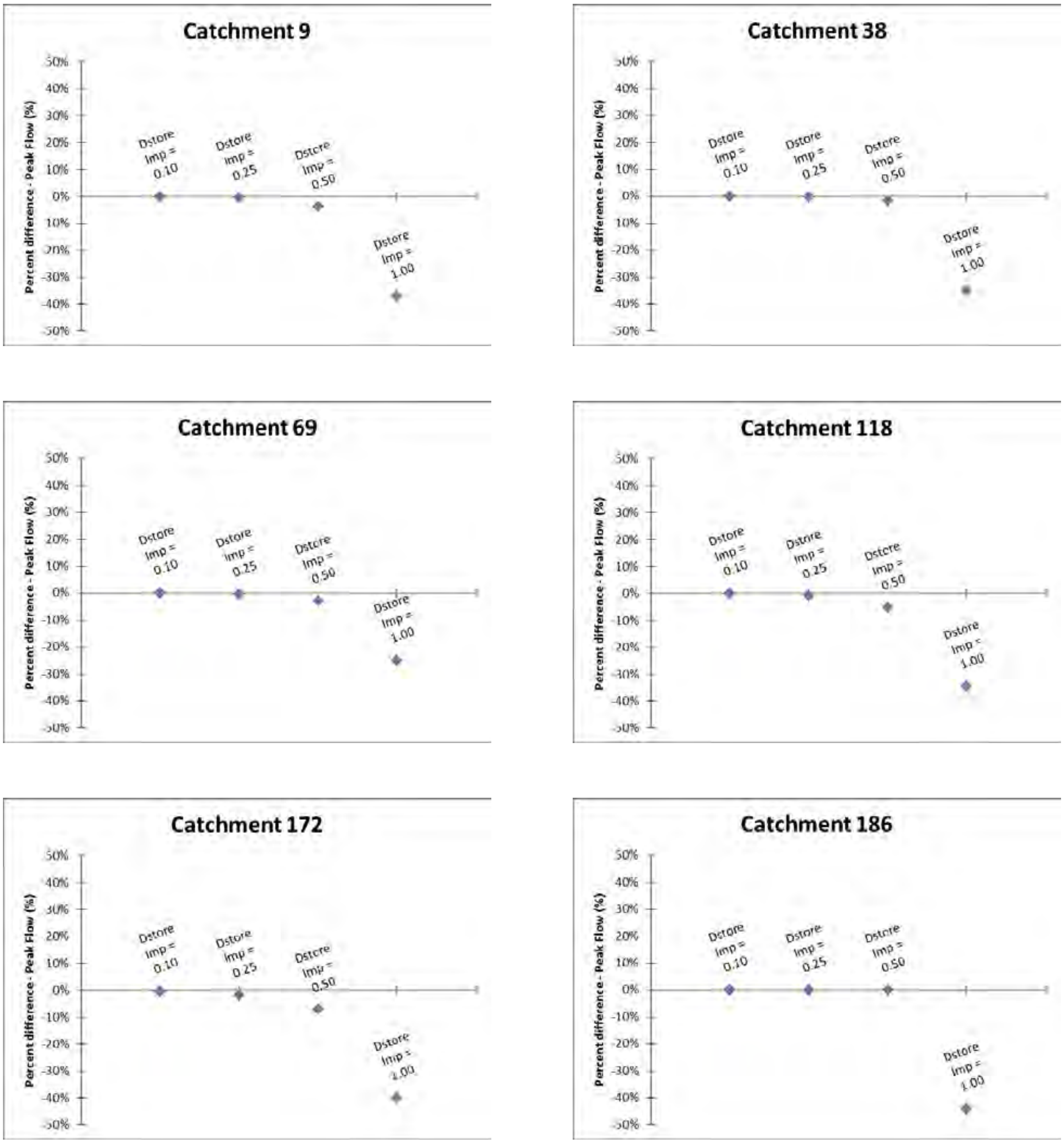

Figure 7 - SWMM Sensitivity to Changes in Depression Storage in Impervious Areas - Peak Flow

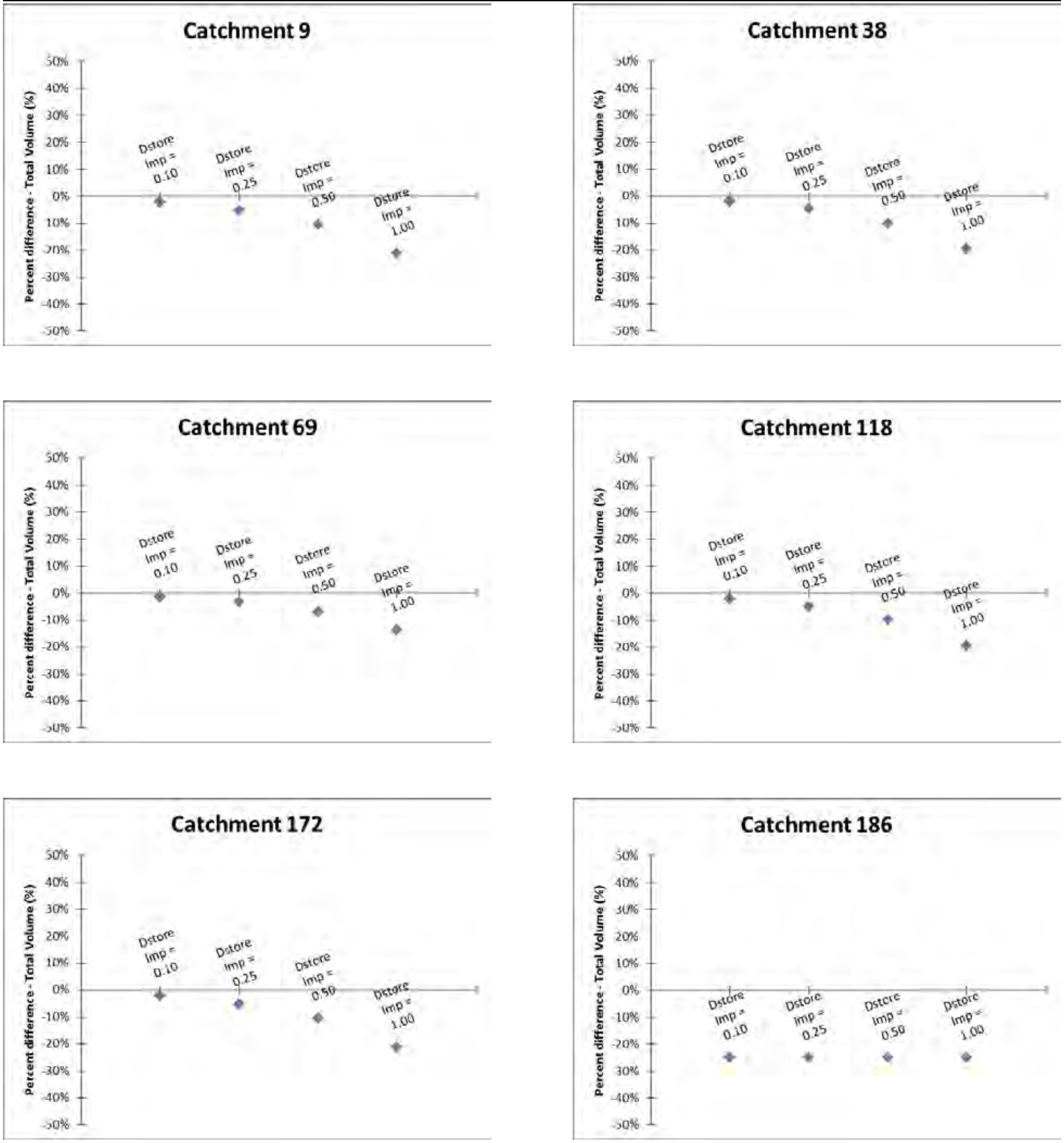

Figure 8 - SWMM Sensitivity to Changes in Depression Storage in Impervious Areas - Total Volume

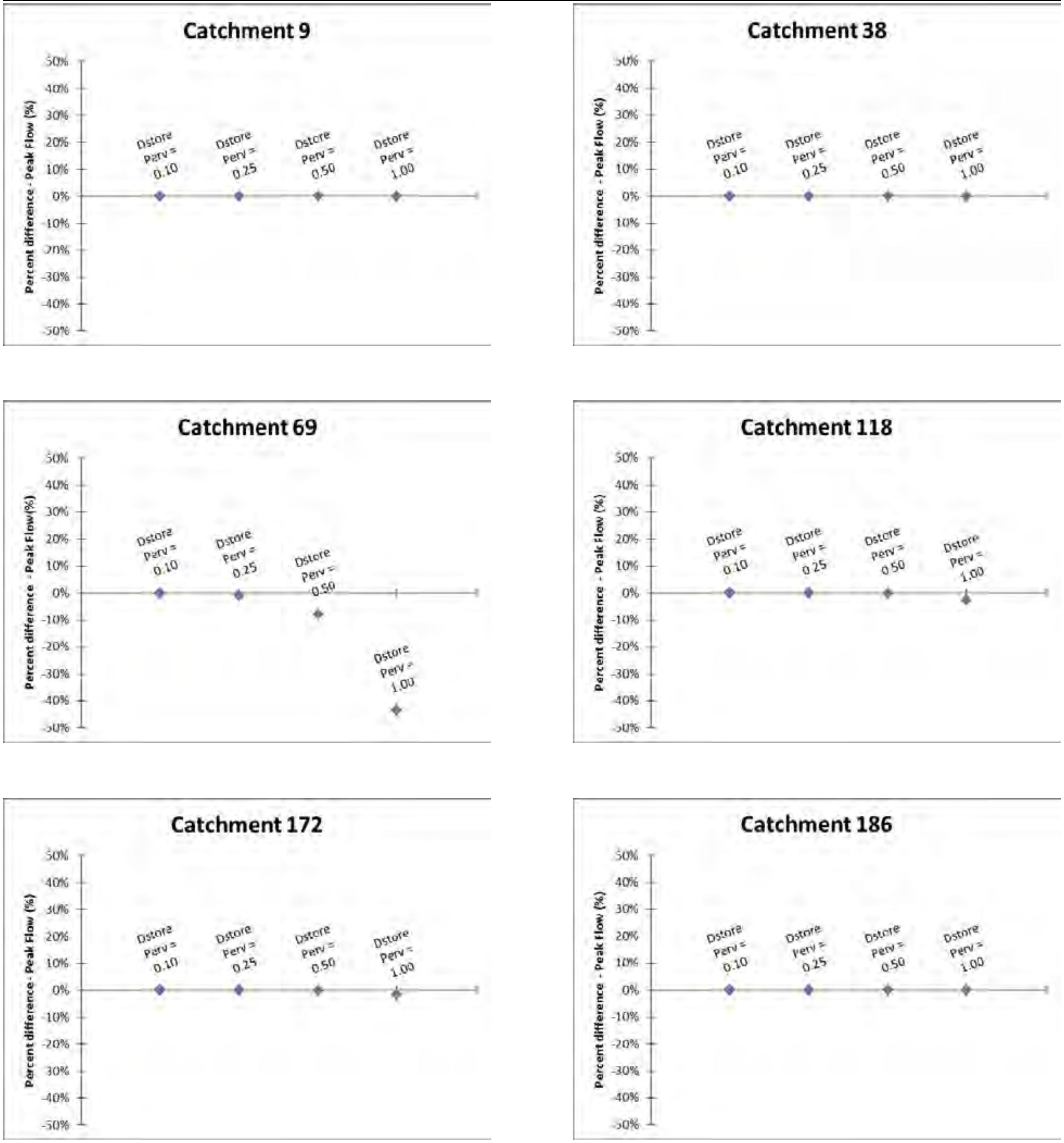

Figure 9 - SWMM Sensitivity to Depression Storage and Pervious Areas - Peak Flow

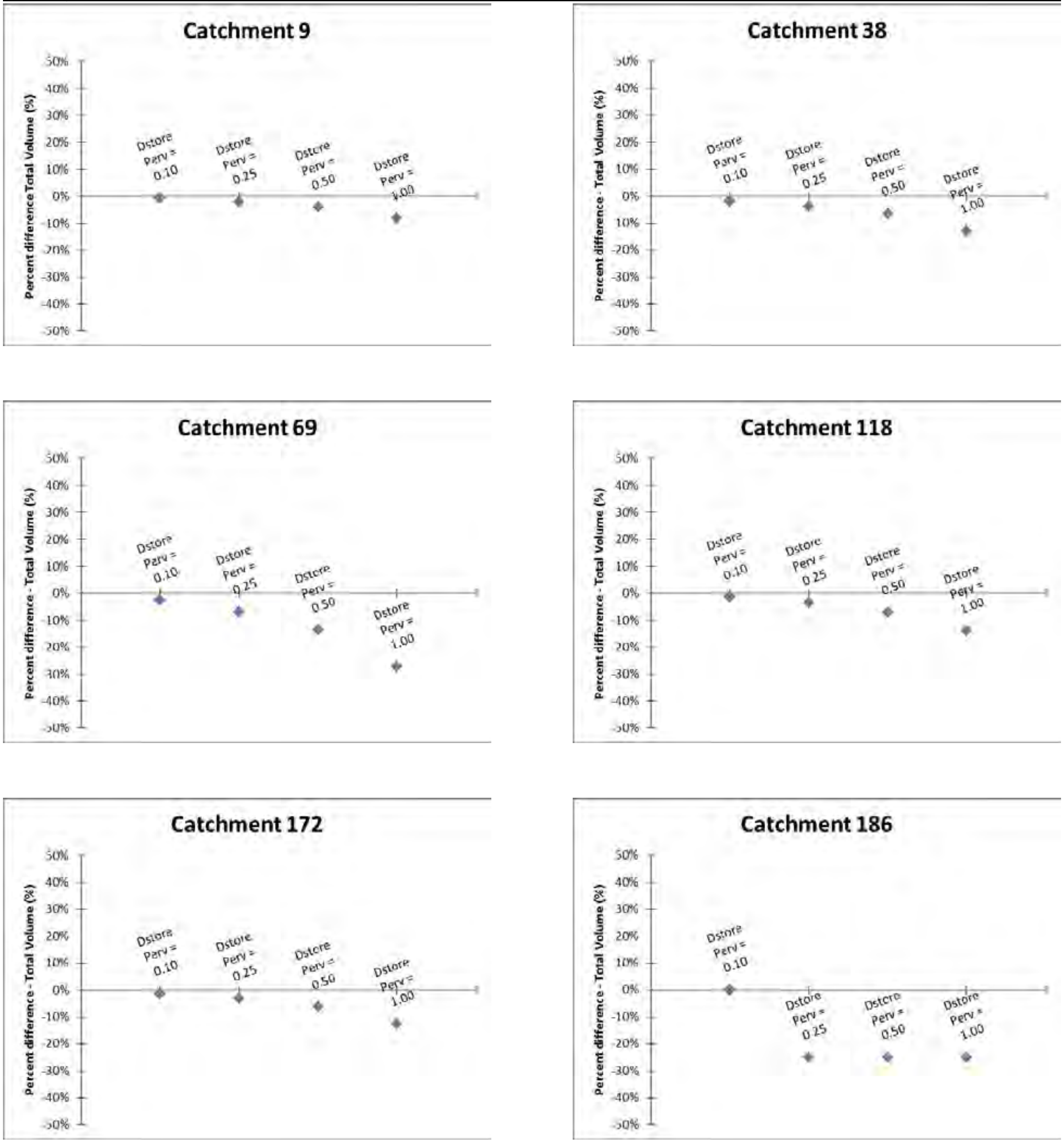

Figure 10 - SWMM Sensitivity to Changes in Depression Storage in Pervious Areas - Total Volume

SWMM model sensitivity to subarea routing was determined by running the model with coefficients of 25%, 50%, and 75% then calculating the percent difference in peak flow and total volume from the SWMM baseline run. The percent difference in peak flow results are presented in Figure 11. The percent difference in total volume results are presented in Figure 12. Neither peak flow nor total volume is sensitive to changes in subarea routing.

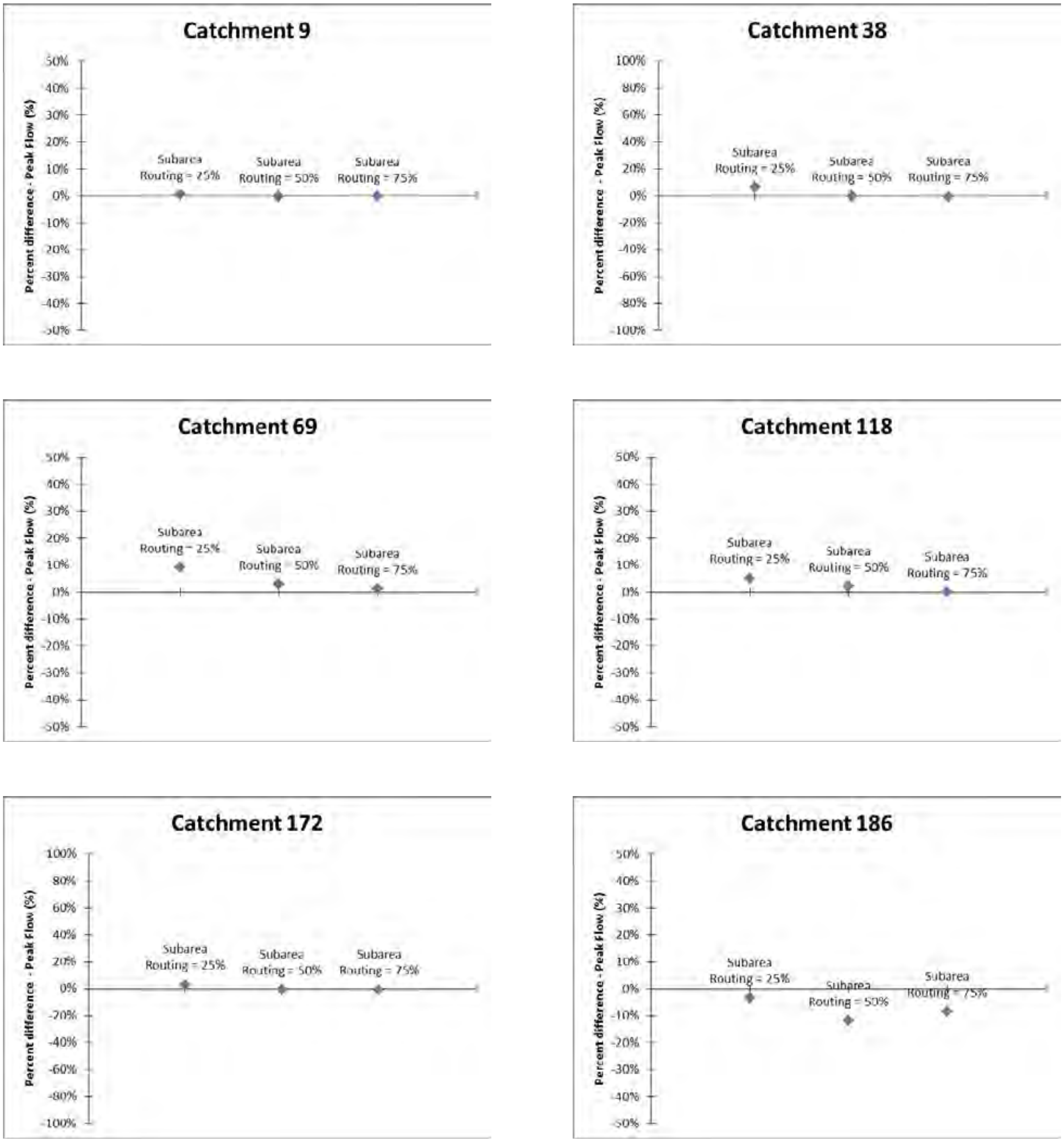

Figure 11 - SWMM Sensitivity to Changes in Subarea Routing - Peak Flow

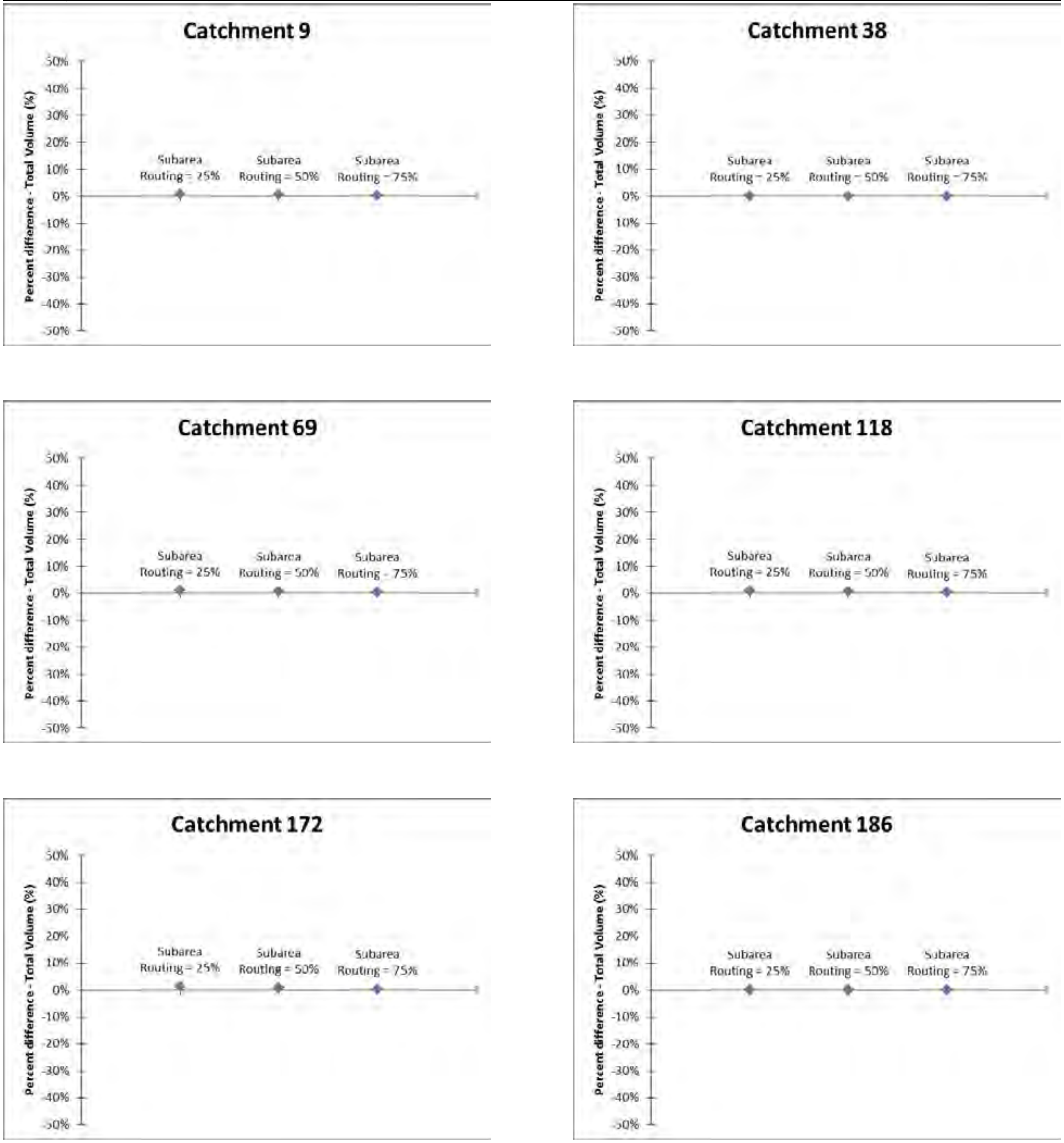

Figure 12 - SWMM Sensitivity to Changes in Subarea Routing - Total Volume

Based on this analysis, it is apparent that SWMM is most sensitive to changes in Curve Number and Width. The next step in calibrating these parameters is finding values that best match the Unit Hydrograph Method results. Two values for each parameter were input to SWMM independently and compared to Unit Hydrograph Method results by computing the percent difference. The peak flow results are shown in Figure 13, and the total volume results are shown in Figure 14

.

$$Percent\ difference = \frac{calibration\ run\ -\ Unit\ Hydrograph}{Unit\ Hydrograph}$$

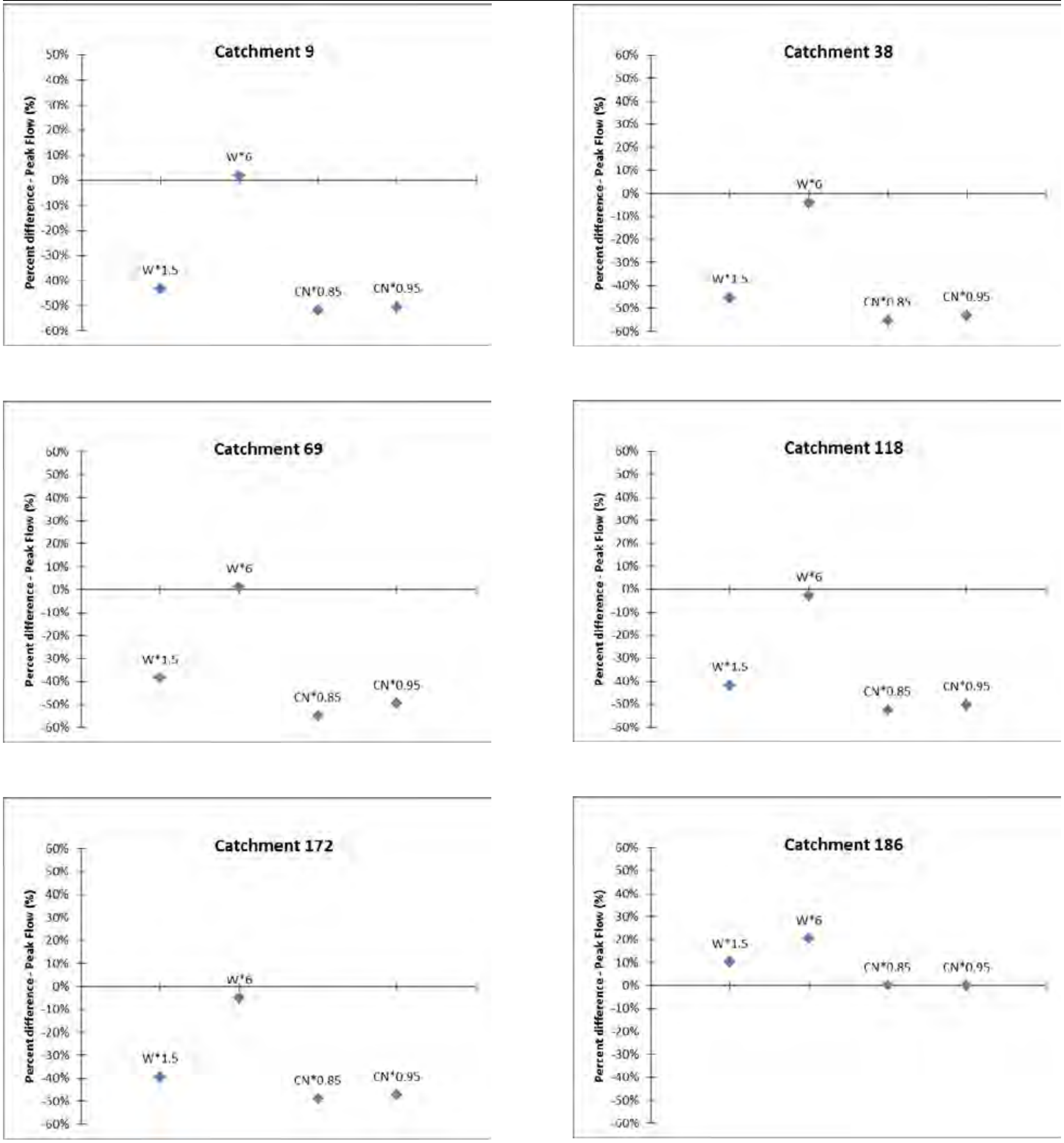

Figure 13 - Independent Variation of Curve Number and Width Values for Comparison with Unit Hydrograph Method Results – Peak Flow

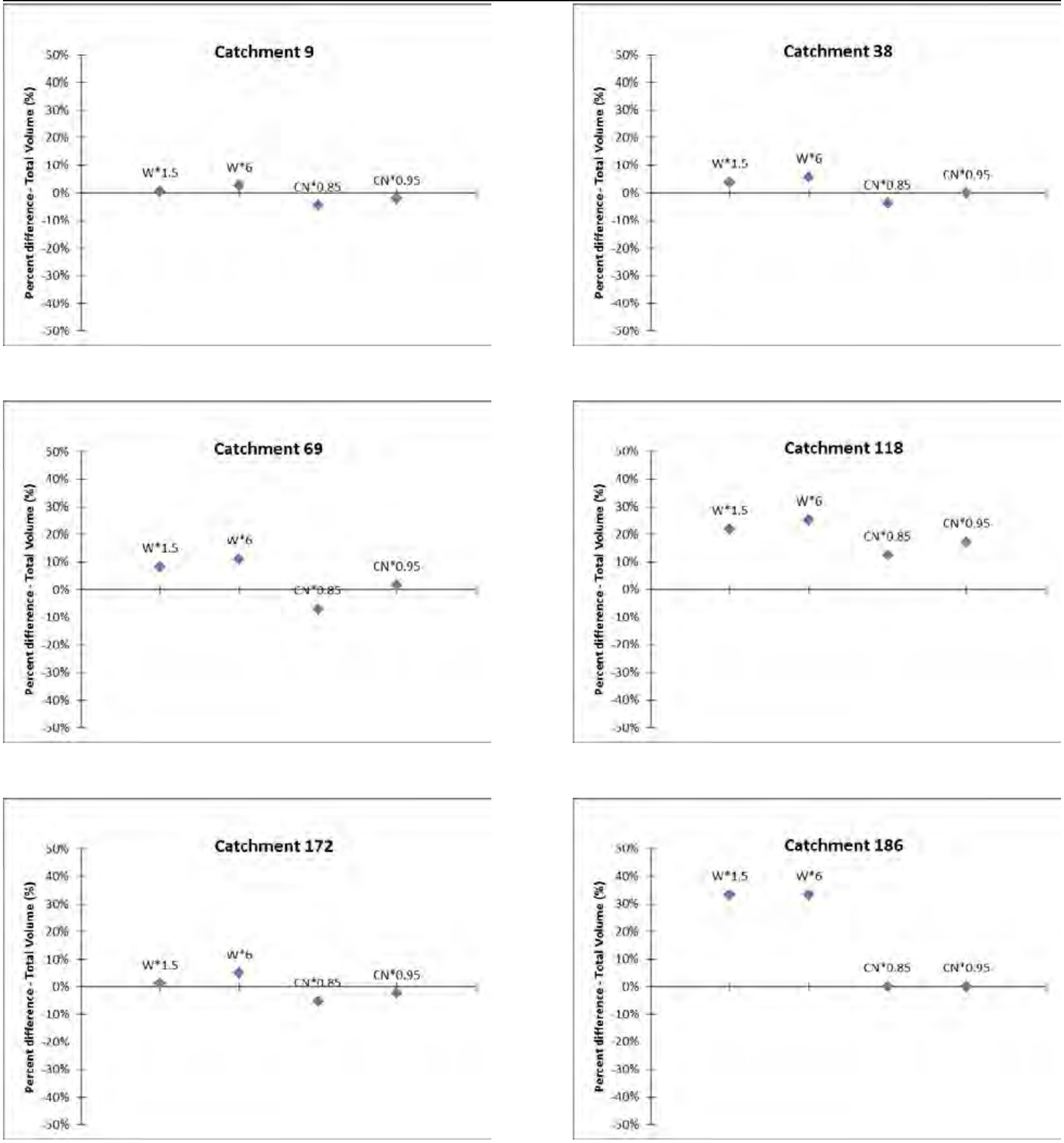

Figure 14 - Independent Variation of Curve Number and Width Values for Comparison with Unit Hydrograph Method Results – Total Volume

An understanding of how these parameters affect the hydrograph is needed in order to determine how to vary both parameters. Increasing the width increases the peak flow and volume by limiting the hydrograph attenuation. It is synonymous with decreasing the lag time in the Unit Hydrograph Method. Decreasing the CN decreases the peak flow and volume by decreasing the runoff potential. Peak flow is more sensitive to changes in width, and total volume is more sensitive to changes in CN.

The Curve Number and Width parameters were varied together to determine which combination would produce results that most closely matched Unit Hydrograph Method results. Ten combinations were tested (Table 3), and compared to Unit Hydrograph Method results by computing the percent difference. The peak flow results are shown in Figure 15, and the total volume results are shown in Figure 16.

Table 3 - Parameter Values for SWMM Calibration Model Runs

Calibration Run	Width Multiplication Factor	Curve Number Multiplication Factor
1	1.00	1.00
2	5.83	0.94
3	6.00	0.90
4	6.50	1.00
5	7.00	0.90
6	7.50	0.85
7	1.50	1.00
8	6.00	1.00
9	1.00	0.85
10	1.00	0.95

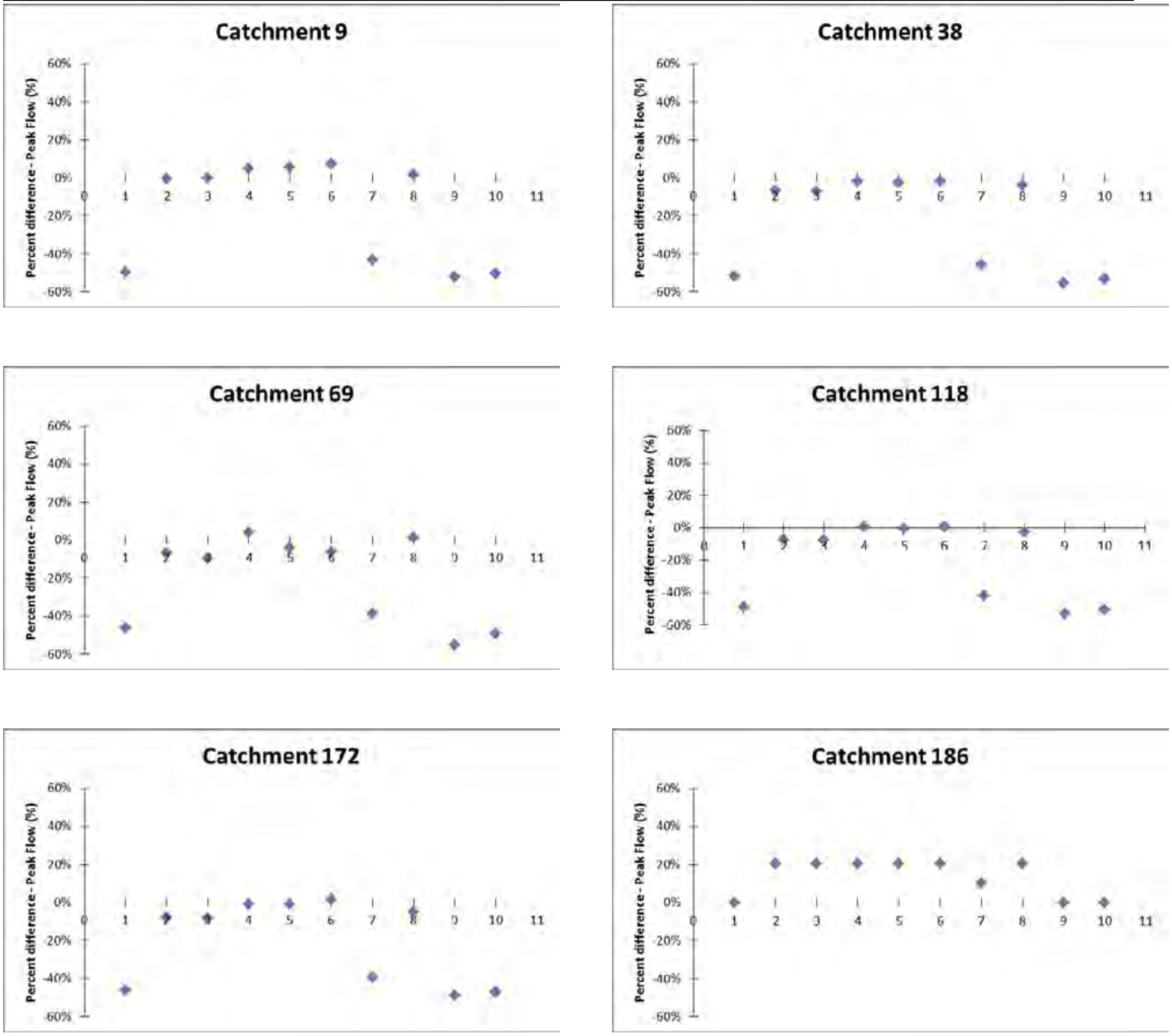

Figure 15 - Calibration Parameters - Peak Flow

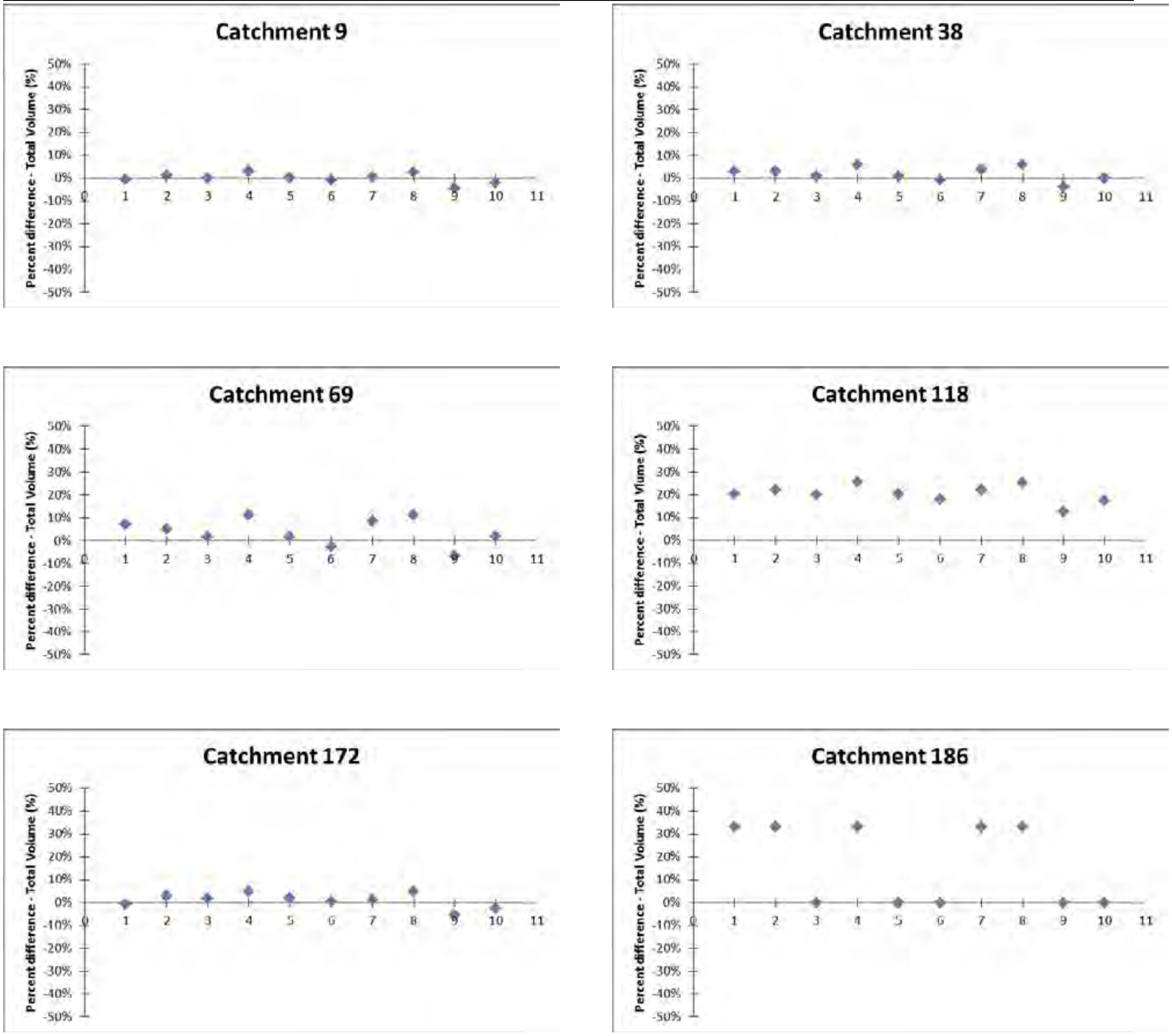

Figure 16 - Calibration Parameters - Total Volume

The calibration runs 2, 3, 4, 5, 6, and 8 matched best to the Unit Hydrograph Method results for peak flow. Calibration runs 3, 5, and 6 matched best for total volume. This indicates that a Width of approximately 6 or 7 times the original Width and a CN of approximately 0.9 times the original CN provides the best results. Varying only the Width or only the CN does not provide a match to the Unit Hydrograph Method result; both parameters need to be adjusted to calibrate the model.

Width and CN are varied together using Widths of 5.83, 6, 7, and 7.5 times the original, and CNs of 0.94, 0.9, and 0.85 times the original. Increased Width is paired with decreased CN in order to increase the peak flow while limiting the increase in volume. The peak flow results are shown in Figure 17, and the total volume results are shown in Figure 18.

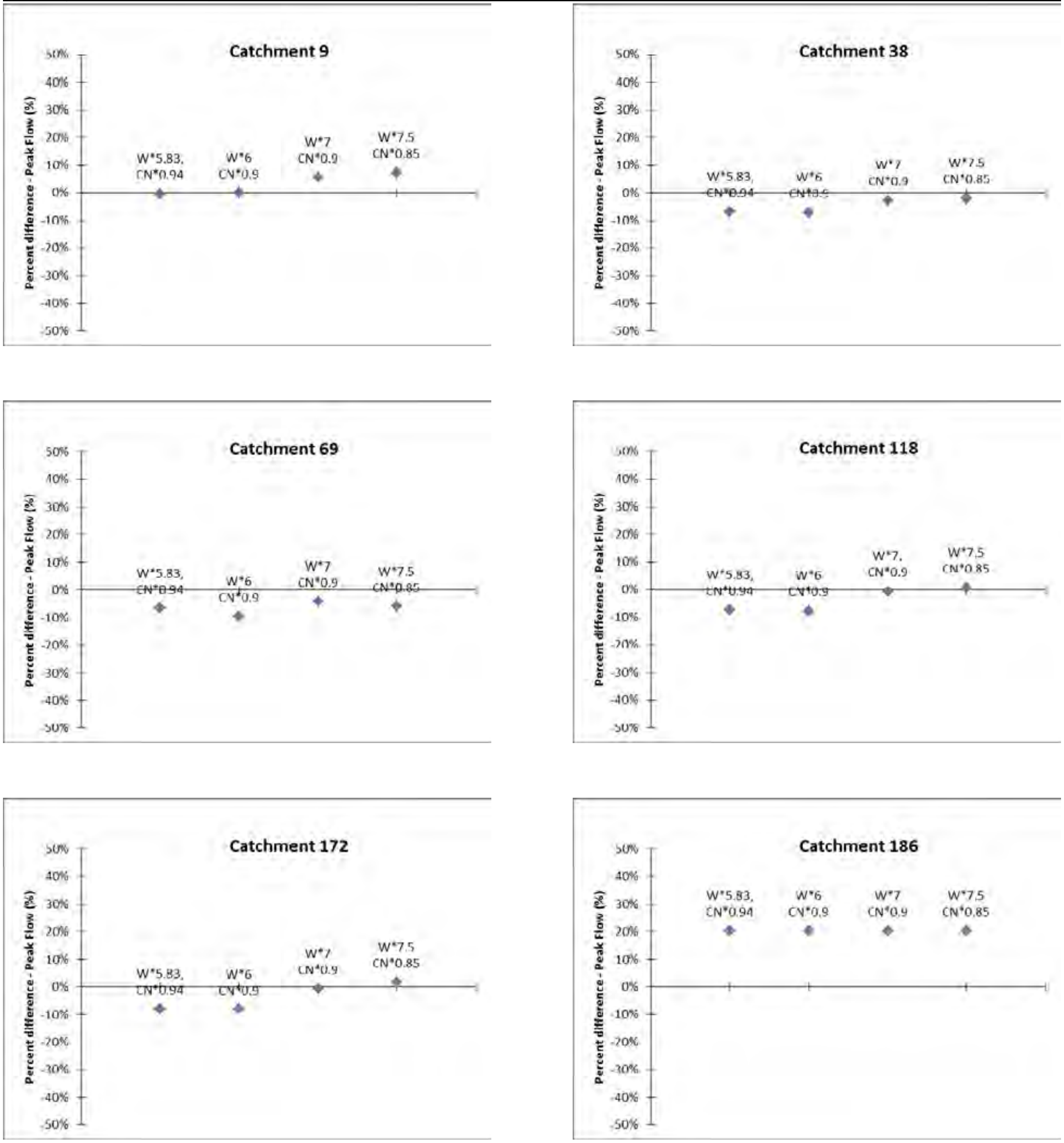

Figure 17 - Width and CN Varied Together Results - Peak Flow

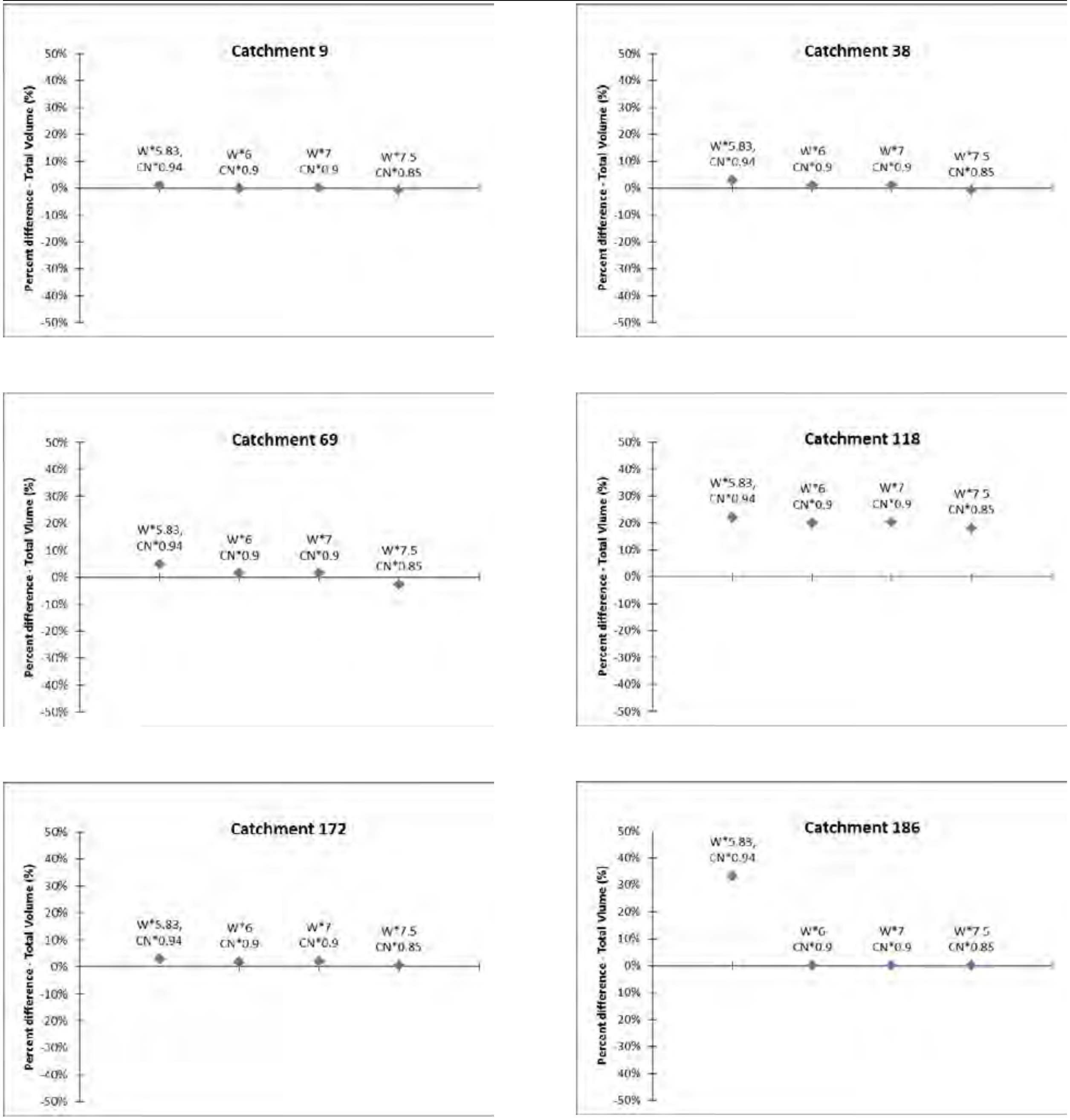

Figure 18 - Width and CN Varied Together Results - Total Volume

The calibration parameters that best fit the Unit Hydrograph Method results are Width*7.5 and CN*0.85. This is clear from Tables 2 and 3 in which the mean error and root mean square error (RMS) are compared for peak flow and total volume, respectively, from each calibration run.

Table 4 - Calibration Results – Peak Flow

Catchment #	W*5.83, CN*0.94	W*6, CN*0.9	W*7, CN*0.9	W*7.5, CN*0.85
9	0%	0%	6%	7%
38	-7%	-7%	-3%	-2%
69	-7%	-10%	-4%	-6%
118	-7%	-8%	-1%	1%
172	-8%	-8%	-1%	2%
186	20%	20%	20%	20%
RMS	10.2%	10.7%	8.9%	9.2%
Mean Error	-1.5%	-2.0%	3.0%	3.7%

Table 5 - Calibration Results - Total Volume

Catchment #	W*5.83, CN*0.94	W*6, CN*0.9	W*7, CN*0.9	W*7.5, CN*0.85
9	1%	0%	0%	-1%
38	3%	1%	1%	-1%
69	5%	1%	1%	-3%
118	22%	20%	20%	18%
172	3%	2%	2%	1%
186	33%	0%	0%	0%
RMS	16.5%	8.2%	8.3%	7.5%
Mean Error	11.1%	4.0%	4.1%	2.3%

Calibration Methodology – Phase II

These calibration parameters were then tested for catchments that are modeled as part of the Palo Alto Storm Drain Master Plan. Five catchments with a range of area, width, slope, and percent impervious were selected. The original basin parameters are given in Table 6.

Table 6 - Phase II Basin Parameters

Basin	Area (ac)	Width (ft)	Flow Length (ft)	Slope (%)	Imperv (%)	N Imperv	N Perv	Dstore Imperv (in)	Dstore Perv (in)	Zero Imperv (%)	Subarea Routing	Percent Routed (%)	Curve Number
C7	82	1380	2601	1.3	63.1	0.025	0.025	0	0	25	Pervious	100	85
G2	29	585	2186	0.6	63.1	0.025	0.025	0	0	25	Pervious	100	84
P2	32	899	1540	8.6	84.7	0.025	0.025	0	0	25	Pervious	100	84
H2-A	6	545	458	0.7	48.1	0.025	0.025	0	0	25	Pervious	100	85
N1-B	32	630	2233	0.6	62.2	0.025	0.025	0	0	25	Pervious	100	84

The SWMM results calculated using the original basin parameters were compared to Unit Hydrograph results. The Unit Hydrograph results were also compared to peak flow results calculated using the Rational Method as described in Chapter 3 of the Santa Clara County Drainage Manual. The Unit Hydrograph peak flow results are consistently higher than the Ration Method results. It was determined that adding 5 minutes to the lag time used in the Unit Hydrograph calculation provided results that best matched the Rational Method results. This is a common adjustment that is made to the lag time in order to account for roof-to-gutter flow time. The SWMM parameters were then calibrated to match the Rational Method and Unit Hydrograph + 5-min results. The results are show in Figure 19.

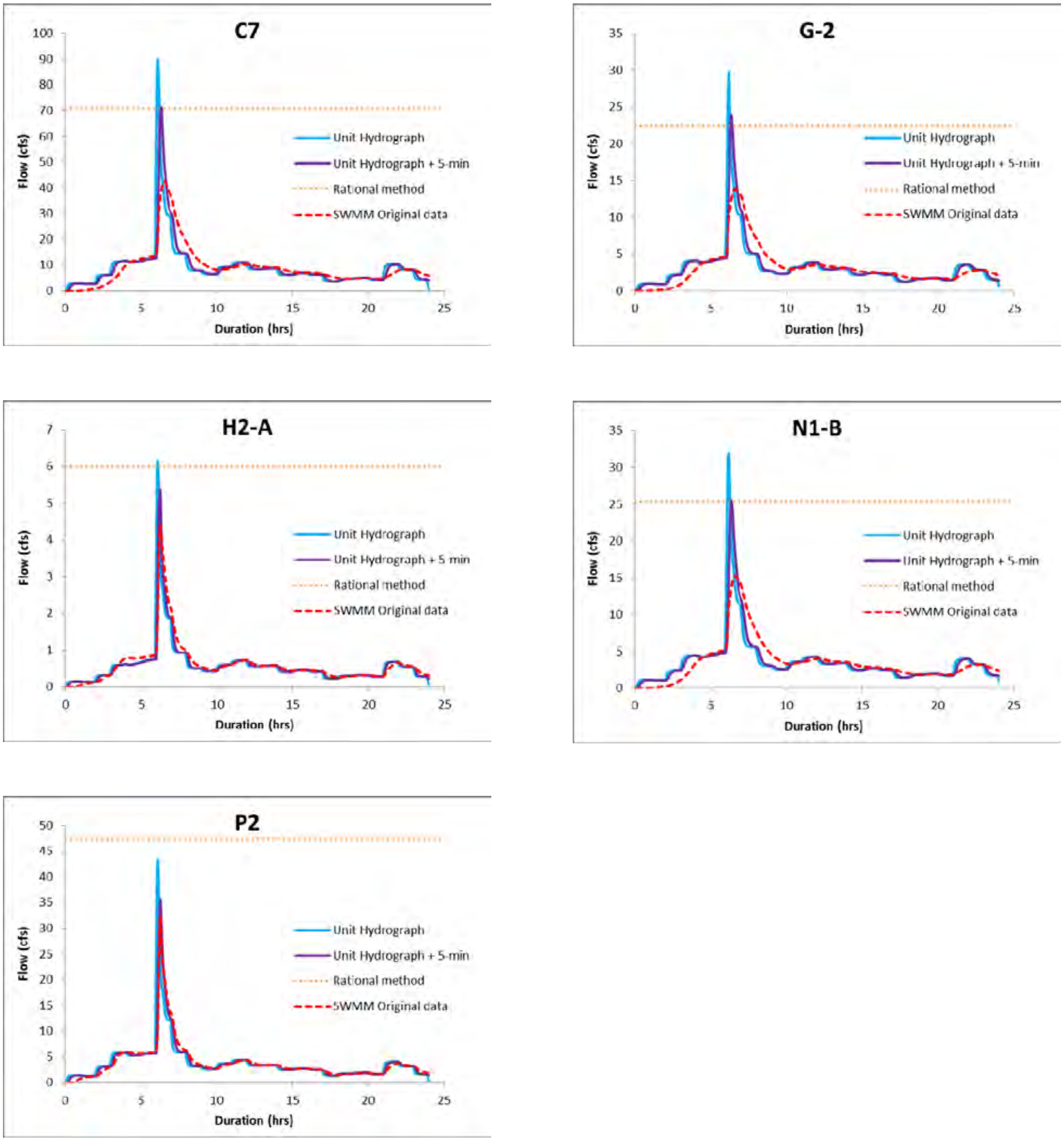

Figure 19 – Original SWMM Parameter Results Comparison with Rational Method and Unit Hydrograph Results

The calibration parameters calculated during Phase I of the calibration process were used to calculate SWMM results which were then compared to the Rational Method and Unit Hydrograph + 5-min results. The results are shown in Figure 20.

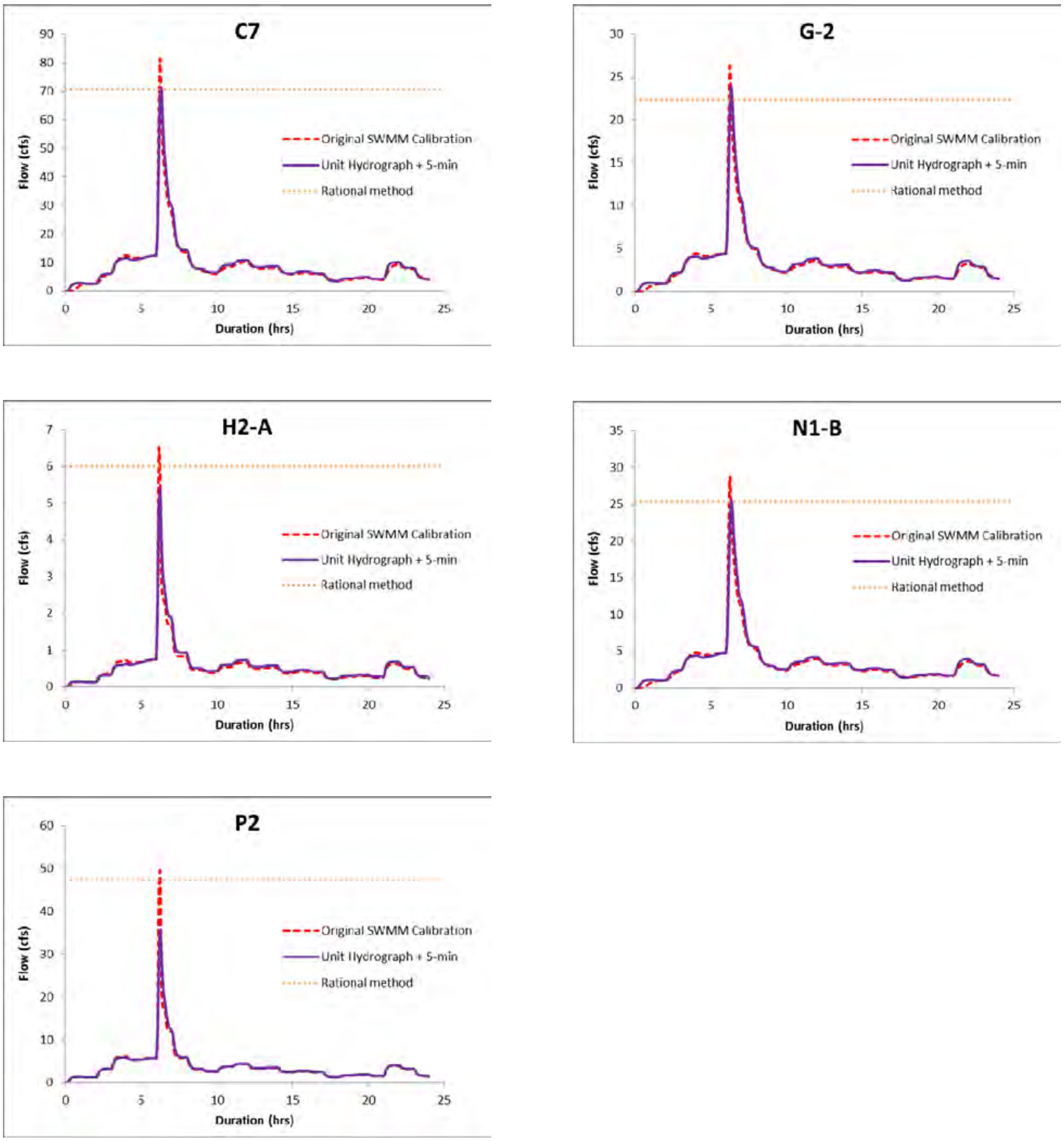

Figure 20 - Phase I SWMM Calibration Results Compared to Unit Hydrograph + 5-min and Rational Method Results

The peak flow produced using the original SWMM calibration parameters is generally greater than the peak flow produced by the Rational Method and Unit Hydrograph + 5-min methods. This is to be expected since the original SWMM parameters were not calibrated to the Rational Method or the Unit Hydrograph method with an additional 5-minute added to the lag time. The Width and Curve Numbers were then adjusted to match the peak flow produced by those methods, using the same calibration methodology as in Phase I. It was determined that Width * 4.5 and CN * 0.9 is the best fit, as shown in Figure 21.

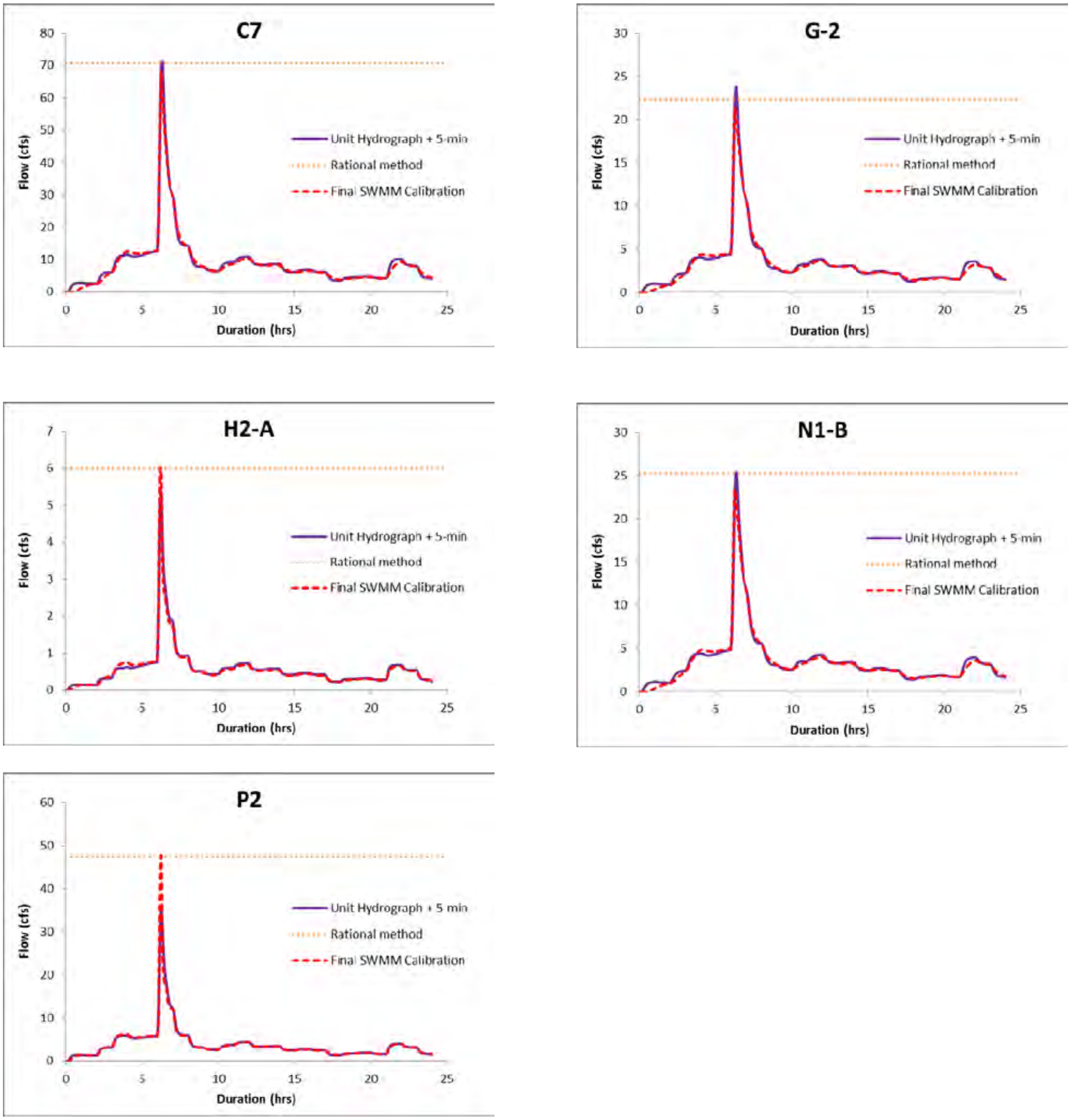

Figure 21 - Final SWMM Calibration Results Compared to Unit Hydrograph + 5-min and Rational Method Results

Conclusion

The SWMM program does not produce results that compare with Unit Hydrograph Method results. SWMM basin parameters appropriate for calibration are Curve Number, Width, Depression Storage, and % Direct Connected. It was determined that Curve Number and Width are the parameters that SWMM is most sensitive to; peak flow is most sensitive to Width, and total volume is most sensitive to Curve Number. Adjusting only Width or only Curve Number will not produce results comparable to Unit Hydrograph Method results, Width and Curve Number must be adjusted together. Multiplying the Width by 4.5 and the Curve Number taken from the Santa Clara County Drainage Manual by 0.9 will produce results that are very comparable to the Santa Clara County hydrograph procedure and the Santa Clara County Rational procedure.

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Schaaf & Wheeler
CONSULTING CIVIL ENGINEERS

MEMORANDUM

TO:	Rajeev Hada	DATE:	June 23, 2015
FROM:	Dan Schaaf	JOB#:	PALO.06.14
SUBJECT:	SCVWD SWMM Methodology Peer Review Response		

Schaaf & Wheeler has reviewed the peer review email, dated April 17, 2015, by Liang Xu of the Santa Clara Valley Water District (SCVWD) regarding the hydrologic mythology used in the City's Storm Drain Master Plan (SDMP). The proposed method used in the SDMP is slightly unorthodox; therefore, a peer is a very important step in the process. Dr. Xu felt it was a sound memo to calibrate the Unit Hydrograph method for urban catchments using SWMM and offered comments and questions. The comments and questions from Dr. Xu are addressed in this response memorandum.

Comment 1. It is not clear to us how the results using UH method were produced and how parameters were selected.

The UH method is directly from the Santa Clara County Drainage Manual (Schaaf & Wheeler, 2006). This method is calibrated to gage statistics for the San Francisquito Creek, Upper Penitencia Creek, and Bodfish Creek basins. Model parameters were selected from a variety of sources. The Curve Numbers (CN) where taken from Table E-1 of the County Manual and adjusted for AMC with Table 4-1. The land use data is from the City of Palo Alto. Percent impervious has been validated with aerial imagery. Soil data is from the NRCS. Topography is from the Districts 1-foot contours.

Comment 2. How confident are we that the UH methods are accurate compared with the SWMM method? Was there any storm event data or observations that support this? Understandably, the UH method is official and outlined in the county drainage manual, but we are curious to see how the model results are compared to real observed data.

The County method is based on a design storm and gage statistics. The accuracy of this method is well documented.

There is no storm drain network gage data in Palo Alto; there are stream gages on San Francisquito and Matadero Creeks. The North San Jose SDMP used the County UH method and was compared to a small gaged storm event (<2-year). Gage data was only useful in determining the accuracy of the lag equation. Based on the comparison the "-d/2" portion of the equation was removed which adds 5 minutes to the lag. We believe removing this term is appropriate in urban areas with small subcatchments as it adds 5 minutes to account for roof runoff.

Comment 3a. In Table 1, the sub-area routing method is pervious (runoff from impervious flows to pervious area) and at 100%. Is it possible that the reason UH flows are higher is because the impervious flows are routed directly to the outlet instead of to the pervious area?

The basin roughness (N) accounts for directly and indirectly connected impervious areas. There is a possibility the directly connected flows produce higher peaks than proportioning the impervious surfaces base on connectivity. However, the County method is calibrated using this technique. To change this we would need to re-calibrate the losses for an gaged urbanized watershed (such as Castro Valley or Carbonera).

A comparison of Soquel Creek and Carbonera Creek in Santa Cruz County using this method provides confidence in using this approach for urban watersheds. Soquel Creek is 40.6 square miles and 2 percent urbanized. Carbonera Creek is 3.7 square miles and 62 percent urbanized. Both have an AMC I¼ .

Comment 3b. In Figures 11 and 12, it shows that the % of impervious area routed to pervious area is not sensitive. In our experience, impervious area ends up making a large difference. Why is it not sensitive?

The models are sensitive to percent impervious. However, SWMM does not appear to be sensitive to the percent of the impervious surface routed to the pervious surface. Many of the routing and runoff routines in SWMM are vague and mysterious to us. The software documentation is general and typically unhelpful.

PALO ALTO - Storm Drain Master Plan CIP Summary

Matadero Area - Pipe Improvements	ID	Priority	Pipe Length	Connections	Outfalls	Cost	Total Const. Cost	Estimated CIP
Bayshore and Fabian	3	High	1,392	6	1	$890,000	$1,160,000	$1,390,000
Hamilton and Rhodes	9	High	3,650	15	0	$2,210,000	$2,870,000	$3,440,000
Lincoln and Channing	10	High	4,629	14	0	$2,430,000	$3,160,000	$3,790,000
Loma Verde and Maddux	11	High	1,747	16	0	$1,410,000	$1,830,000	$2,200,000
Louis	12	High	4,186	27	0	$4,430,000	$5,760,000	$6,910,000
Louis to Matadero Creek	13	High	1,468	7	1	$1,000,000	$1,300,000	$1,560,000
Cambridge and Park	14	Moderate	2,515	14	0	$1,190,000	$1,550,000	$1,860,000
Center	15	Moderate	2,033	10	0	$1,040,000	$1,350,000	$1,620,000
Embarcadero	18	Moderate	837	6	0	$1,290,000	$1,680,000	$2,020,000
Loma Verde and Ross	19	Moderate	1,145	6	0	$860,000	$1,120,000	$1,340,000
Page Mill and Alma	22	Moderate	1,957	14	0	$1,150,000	$1,500,000	$1,800,000
Page Mill and El Camino Real	23	Moderate	2,521	10	0	$1,620,000	$2,110,000	$2,530,000
Seale	24	Moderate	5,585	23	0	$3,190,000	$4,150,000	$4,980,000
Alma	25	Low	1,380	4	0	$590,000	$770,000	$920,000
Bryant	29	Low	1,665	8	0	$720,000	$940,000	$1,130,000
Cambridge	30	Low	2,224	12	1	$1,190,000	$1,550,000	$1,860,000
Colonial and Amarillo	31	Low	730	5	0	$310,000	$400,000	$480,000
El Camino Real	36	Low	612	3	0	$250,000	$330,000	$400,000
El Centro	37	Low	639	4	1	$310,000	$400,000	$480,000
Forest and Hamilton	39	Low	3,332	12	0	$1,470,000	$1,910,000	$2,290,000
Hamilton and Channing	40	Low	3,960	14	0	$1,820,000	$2,370,000	$2,840,000
Hanover	41	Low	732	7	0	$420,000	$550,000	$660,000
Hoover Park	43	Low	217	5	1	$200,000	$260,000	$310,000
Loma Verde and Cowper	45	Low	2,264	12	0	$1,530,000	$1,990,000	$2,390,000
Louis and Loma Verde	46	Low	1,249	10	0	$860,000	$1,120,000	$1,340,000
Louis and Piers	47	Low	1,468	7	0	$510,000	$660,000	$790,000
Moreno	48	Low	773	3	0	$290,000	$380,000	$460,000
Oregon	51	Low	792	6	0	$390,000	$510,000	$610,000
Oregon and Louis	52	Low	2,234	13	0	$2,120,000	$2,760,000	$3,310,000
Parkinson and Newell	55	Low	3,258	11	0	$1,500,000	$1,950,000	$2,340,000
Portage	56	Low	562	5	0	$270,000	$350,000	$420,000
Ross and Ames	57	Low	843	3	0	$420,000	$550,000	$660,000
Ross Road to Matadero Creek	58	Low	784	5	1	$440,000	$570,000	$680,000
Walter Hays	64	Low	773	7	0	$520,000	$680,000	$820,000
Waverley	65	Low	907	4	0	$290,000	$380,000	$460,000

Priority	Length	Cost
High	17,073	$19,290,000
Moderate	16,592	$16,150,000
Low	31,396	$25,650,000
	65,061	**$61,090,000**

Adobe/Barron Area - Pipe Improvements	ID	Priority	Pipe Length	Connections	Outfalls	Cost	Total Const. Cost	Estimated CIP
Charleston and Abode Creek	5	High	946	5	1	$830,000	$1,080,000	$1,300,000
E Meadow Cir	6	High	770	2	0	$230,000	$300,000	$360,000
E Meadow Dr	7	High	401	2	0	$250,000	$330,000	$400,000
Fabian	8	High	1,000	5	0	$370,000	$480,000	$580,000
Charleston and Fabian	16	Moderate	964	2	0	$660,000	$860,000	$1,030,000
El Camino Real and Los Robles	17	Moderate	2,450	11	0	$1,620,000	$2,110,000	$2,530,000
Alma and Greenmeadow	26	Low	1,137	4	1	$540,000	$700,000	$840,000
Arastradero	28	Low	3,362	15	0	$1,530,000	$1,990,000	$2,390,000
E Bayshore Rd and Embarcadero	33	Low	525	4	0	$220,000	$290,000	$350,000
E Charleston and Middlefield Rd	34	Low	2,288	14	0	$1,090,000	$1,420,000	$1,700,000
E Meadow Dr and Middlefield Rd	35	Low	4,249	19	0	$2,290,000	$2,980,000	$3,580,000
Foothill and Miranda	38	Low	1,194	8	1	$780,000	$1,010,000	$1,210,000
Hillview	42	Low	477	5	1	$350,000	$460,000	$550,000
Laura Ln and Geng Rd	44	Low	940	4	0	$350,000	$460,000	$550,000
Nelson	49	Low	961	5	1	$430,000	$560,000	$670,000
Park and Whitclem	53	Low	220	3	1	$180,000	$230,000	$280,000
San Antonio	59	Low	4,252	21	0	$2,100,000	$2,730,000	$3,280,000
Scripps	60	Low	955	10	1	$550,000	$720,000	$860,000
South Ct to Adobe Creek	62	Low	2,502	10	1	$1,270,000	$1,650,000	$1,980,000
Ventura and Park	63	Low	482	6	1	$320,000	$420,000	$500,000
Wilkie and Park	66	Low	2,906	19	0	$1,420,000	$1,850,000	$2,220,000

Priority	Length	Cost
High	3,117	$2,640,000
Moderate	3,414	$3,560,000
Low	26,448	$20,960,000
	32,979	**$27,160,000**

Pump Station Improvements	ID	Priority	Pipe Length	Connections	Outfalls	Cost	Total Const. Cost	Estimated CIP
Corporation and E Bayshore	1	Highest	702	8	1	$1,550,000	$2,020,000	$2,420,000
Matadero Pump Station	2	Highest	0	0	1	$7,390,000	$9,610,000	$11,530,000
Bayshore and Fabian Pump Station	4	High	0	0	1	$670,000	$870,000	$1,040,000
Municipal Service Yard	20	Moderate	415	2	1	$1,340,000	$1,740,000	$2,090,000
Oregon Expy Pump Station	21	Moderate	0	0	0	$210,000	$270,000	$320,000
Alma and Greenmeadow Pump Station	27	Low	0	0	1	$1,640,000	$2,130,000	$2,560,000
Colorado PS removal	32	Low	425	6	0	$280,000	$360,000	$430,000
Nelson Ct Pump Station	50	Low	0	0	1	$760,000	$990,000	$1,190,000
Park and Whitclem Pump Station	54	Low	0	0	1	$840,000	$1,090,000	$1,310,000
Scripps Pump Station	61	Low	0	0	1	$1,090,000	$1,420,000	$1,700,000

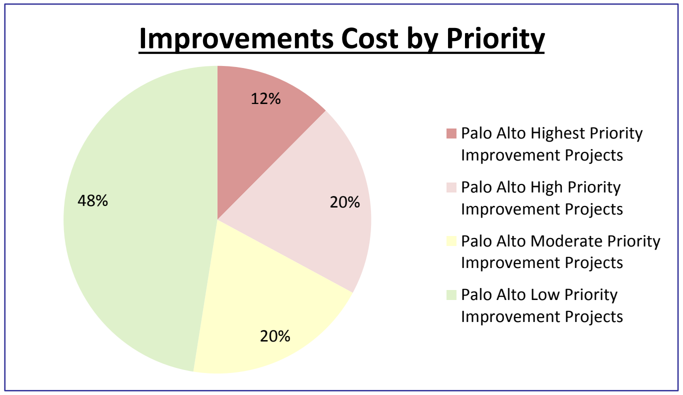
Priority	Length	Cost
Highest	702	$13,950,000
High	0	$1,040,000
Moderate	415	$2,410,000
Low	425	$7,190,000
	1,542	**$24,590,000**

Condition Improvements	Priority	Length	Cost	Total Const. Cost	Estimated CIP
A-1	Highest	28	$7,500	$9,800	$11,800
A-7	Highest	31	$2,500	$3,300	$4,000
A-23	Highest	34	$7,700	$10,000	$12,000
A-25	Highest	25	$6,900	$9,000	$10,800
A-26	Highest	34	$6,800	$8,800	$10,600
A-31	Highest	34	$1,800	$2,300	$2,800
A-34 d/s	Highest	81	$18,300	$23,800	$28,600
A-34 u/s	Highest	88	$19,800	$25,700	$30,800
A-35	Highest	55	$12,500	$16,300	$19,600
A-39	Highest	37	$9,200	$12,000	$14,400
A-42	Highest	23	$4,100	$5,300	$6,400
A-2	High	46	$4,100	$5,300	$6,400
A-6	High	46	$4,500	$5,900	$7,100
A-12	High	56	$11,700	$15,200	$18,200
A-14	High	30	$6,800	$8,800	$10,600
A-15	High	21	$7,300	$9,500	$11,400
A-16	High	22	$3,700	$4,800	$5,800
A-20	High	34	$7,700	$10,000	$12,000
A-21	High	27	$5,200	$6,800	$8,200
A-24	High	32	$5,900	$7,700	$9,200
A-33 d/s	High	21	$6,900	$9,000	$10,800
A-33 u/s	High	40	$5,200	$6,800	$8,200
A-36	High	27	$6,100	$7,900	$9,500
A-37	High	38	$7,500	$9,800	$11,800
A-38	High	41	$4,800	$6,200	$7,400
A-40	High	42	$10,400	$13,500	$16,200
A-41	High	36	$7,200	$9,400	$11,300
A-43	High	23	$3,200	$4,200	$5,000
A-3	Moderate	22	$1,900	$2,500	$3,000
A-4	Moderate	39	$5,300	$6,900	$8,300
A-5	Moderate	41	$7,000	$9,100	$10,900
A-8	Moderate	28	$4,100	$5,300	$6,400
A-9	Moderate	26	$2,100	$2,700	$3,200
A-10	Moderate	28	$2,500	$3,300	$4,000
A-11	Moderate	28	$2,200	$2,900	$3,500
A-13	Moderate	31	$2,800	$3,600	$4,300
A-17	Moderate	18	$2,600	$3,400	$4,100
A-19	Moderate	25	$2,700	$3,500	$4,200
A-22	Moderate	34	$4,900	$6,400	$7,700
A-27	Moderate	20	$1,800	$2,300	$2,800
A-28	Moderate	51	$4,600	$6,000	$7,200
A-29	Moderate	43	$5,100	$6,600	$7,900
A-30	Moderate	52	$6,400	$8,300	$10,000
A-32 24-in.	Moderate	48	$7,400	$9,600	$11,500
A-32 18-in.	Moderate	48	$8,800	$11,400	$13,700

Priority	Length	Cost
Highest	470	$152,000
High	581	$169,000
Moderate	580	$113,000
	1,631	**$434,000**

Priority Improvements	Length	Cost
Palo Alto Highest Priority Improvement Projects	1,173	$14,102,000
Palo Alto High Priority Improvement Projects	20,771	$23,139,000
Palo Alto Moderate Priority Improvement Projects	21,001	$22,233,000
Palo Alto Low Priority Improvement Projects	58,269	$53,800,000
Palo Alto Improvement Projects Total	**101,213**	**$113,274,000**

Total Construction Cost: 30% construction contingency
Estimated CIP: 20% increase for engineering, administrative, and inspection costs



ADOBE/BARRON DRAINAGE AREA
DETAILED CONSTRUCTION ESTIMATE

Project	Name	Length (ft)	Ex Diam (in)	Imp Diam (in)	Pipe Unit Cost	Pipe Cost	MHs	MH Cost	Total	Outfalls	Priority	Project Cost
Alma and Greenmeadow	IMP44715	318	12	42	$ 475	$ 151,034	1	$ 12,530	$ 163,564		Low	
Alma and Greenmeadow	IMP44717	603	18	42	$ 475	$ 286,279	2	$ 25,060	$ 311,339		Low	
Alma and Greenmeadow	IMP44757	216	18	42	$ 475	$ 102,790	1	$ 12,530	$ 115,320	1	Low	
		1137					**4**		**$ 474,903**	**$40,000**		**$ 540,000**
Alma and Greenmeadow Pump Station	Pump Station								$ 1,520,000	1	Low	
									$ 1,520,000	**$40,000**		**$ 1,640,000**
Arastradero	IMP44415	361	18	24	$ 325	$ 117,467	2	$ 24,160	$ 141,627		Low	
Arastradero	IMP44416	215	18	24	$ 325	$ 69,714	1	$ 12,080	$ 81,794		Low	
Arastradero	IMP44417	294	24	30	$ 375	$ 110,170	1	$ 12,230	$ 122,400		Low	
Arastradero	IMP44426	170	24	30	$ 375	$ 63,602	1	$ 12,230	$ 75,832		Low	
Arastradero	IMP44427	78	24	30	$ 375	$ 29,105	1	$ 12,230	$ 41,335		Low	
Arastradero	IMP44428	330	24	30	$ 375	$ 123,690	1	$ 12,230	$ 135,920		Low	
Arastradero	IMP44429	237	24	30	$ 375	$ 89,006	1	$ 12,230	$ 101,236		Low	
Arastradero	IMP44432	108	24	36	$ 425	$ 45,923	1	$ 12,380	$ 58,303		Low	
Arastradero	IMP44433	258	30	36	$ 425	$ 109,592	1	$ 12,380	$ 121,972		Low	
Arastradero	IMP44434	39	30	36	$ 425	$ 16,781	1	$ 12,380	$ 29,161		Low	
Arastradero	IMP44435	163	30	36	$ 425	$ 69,266	1	$ 12,380	$ 81,646		Low	
Arastradero	IMP44443	441	30	36	$ 425	$ 187,334	1	$ 12,380	$ 199,714		Low	
Arastradero	IMP44450	203	30	36	$ 425	$ 86,163	1	$ 12,380	$ 98,543		Low	
Arastradero	IMP44522	466	18	24	$ 325	$ 151,440	1	$ 12,080	$ 163,520		Low	
		3362					**15**		**$ 1,453,000**	**0**		**$ 1,530,000**
Charleston and Abode Creek	IMP_44203	257	36	72	$ 725	$ 186,521	2	$ 26,540	$ 213,061		High	
Charleston and Abode Creek	IMP_44206	497	36	72	$ 725	$ 360,434	1	$ 13,270	$ 373,704		High	
Charleston and Abode Creek	IMP_44207	179	36	72	$ 725	$ 129,622	1	$ 13,270	$ 142,892		High	
Charleston and Abode Creek	IMP_44663	13	36	72	$ 725	$ 9,386	1	$ 13,270	$ 22,656	1	High	
		946					**5**		**$ 752,313**	**40000**		**$ 830,000**
Charleston and Fabian	IMP_44202	964	30	60	$ 625	$ 602,673	2	$ 25,940	$ 628,613		Moderate	
		964					**2**		**$ 628,613**	**0**		**$ 660,000**
Corporation and E Bayshore	IMP44731	88	21	30	$ 375	$ 33,038	2	$ 24,460	$ 57,498		Highest	
Corporation and E Bayshore	IMP44732	170	21	30	$ 375	$ 63,678	1	$ 12,230	$ 75,908		Highest	
Corporation and E Bayshore	IMP44734	114	21	30	$ 375	$ 42,593	1	$ 12,230	$ 54,823		Highest	
Corporation and E Bayshore	IMP44736	60	22	30	$ 375	$ 22,447	1	$ 12,230	$ 34,677		Highest	
Corporation and E Bayshore	IMP44739	159	21	30	$ 375	$ 59,624	1	$ 12,230	$ 71,854		Highest	
Corporation and E Bayshore	IMP44747	86	21	30	$ 375	$ 32,127	1	$ 12,230	$ 44,357		Highest	
Corporation and E Bayshore	IMP44836	26	21	30	$ 375	$ 9,877	1	$ 12,230	$ 22,107		Highest	
Corporation and E Bayshore	Pump Station								$ 1,000,000	1	Highest	
Corporation and E Bayshore	Utilities relocation	702			$ 100	$ 70,236			$ 70,236		Highest	
		702					**8**		**$ 1,431,460**	**40000**		**$ 1,550,000**
E Bayshore Rd and Embarcadero	IMP44368	202	12	18	$ 270	$ 54,562	2	$ 23,860	$ 78,422		Low	
E Bayshore Rd and Embarcadero	IMP44383	62	12	24	$ 325	$ 20,179	1	$ 12,080	$ 32,259		Low	
E Bayshore Rd and Embarcadero	IMP44384	261	12	24	$ 325	$ 84,761	1	$ 12,080	$ 96,841		Low	
		525					**4**		**$ 207,522**	**0**		**$ 220,000**
E Charleston and Middlefield Rd	IMP44040	62	15	24	$ 325	$ 20,204	2	$ 24,160	$ 44,364		Low	
E Charleston and Middlefield Rd	IMP44041	55	15	24	$ 325	$ 17,958	1	$ 12,080	$ 30,038		Low	
E Charleston and Middlefield Rd	IMP44102	288	15	24	$ 325	$ 93,469	1	$ 12,080	$ 105,549		Low	
E Charleston and Middlefield Rd	IMP44103	88	15	24	$ 325	$ 28,485	1	$ 12,080	$ 40,565		Low	
E Charleston and Middlefield Rd	IMP44104	71	15	24	$ 325	$ 23,092	1	$ 12,080	$ 35,172		Low	
E Charleston and Middlefield Rd	IMP44106	113	15	24	$ 325	$ 36,680	1	$ 12,080	$ 48,760		Low	
E Charleston and Middlefield Rd	IMP44107	208	15	24	$ 325	$ 67,595	1	$ 12,080	$ 79,675		Low	
E Charleston and Middlefield Rd	IMP44108	143	15	24	$ 325	$ 46,420	1	$ 12,080	$ 58,500		Low	
E Charleston and Middlefield Rd	IMP44119	428	15	36	$ 425	$ 182,074	1	$ 12,380	$ 194,454		Low	
E Charleston and Middlefield Rd	IMP44120	26	15	36	$ 425	$ 10,999	1	$ 12,380	$ 23,379		Low	
E Charleston and Middlefield Rd	IMP44121	121	15	36	$ 425	$ 51,505	1	$ 12,380	$ 63,885		Low	
E Charleston and Middlefield Rd	IMP44204	270	27	36	$ 425	$ 114,709	1	$ 12,380	$ 127,089		Low	
E Charleston and Middlefield Rd	IMP44677	415	15	36	$ 425	$ 176,304	1	$ 12,380	$ 188,684		Low	
		2288					**14**		**$ 1,040,114**	**0**		**$ 1,090,000**
E Meadow Cir	IMP_E_Meadow	770	-	15	$ 250	$ 192,463.98	2	$ 23,700	$ 216,164		High	
		770					**2**		**$ 216,164**	**0**		**$ 230,000**
E Meadow Dr	IMP44201	401	36	48	$ 525	$ 210,655	2	$ 25,360	$ 236,015		High	
		401					**2**		**$ 236,015**	**0**		**$ 250,000**

ADOBE/BARRON DRAINAGE AREA
DETAILED CONSTRUCTION ESTIMATE

Project	Name	Length (ft)	Ex Diam (in)	Imp Diam (in)	Pipe Unit Cost	Pipe Cost	MHs	MH Cost	Total	Outfalls	Priority	Project Cost
E Meadow Dr and Middlefield Rd	IMP44145	631	21	36	$ 425	$ 268,074	2	$ 24,760	$ 292,834		Low	
E Meadow Dr and Middlefield Rd	IMP44160	555	24	36	$ 425	$ 235,842	2	$ 24,760	$ 260,602		Low	
E Meadow Dr and Middlefield Rd	IMP44166	520	36	48	$ 525	$ 273,033	2	$ 25,360	$ 298,393		Low	
E Meadow Dr and Middlefield Rd	IMP44172	334	36	48	$ 525	$ 175,377	1	$ 12,680	$ 188,057		Low	
E Meadow Dr and Middlefield Rd	IMP44182	248	36	48	$ 525	$ 130,335	1	$ 12,680	$ 143,015		Low	
E Meadow Dr and Middlefield Rd	IMP44183	300	12	30	$ 375	$ 112,667	1	$ 12,230	$ 124,897		Low	
E Meadow Dr and Middlefield Rd	IMP44186	45	36	48	$ 525	$ 23,363	1	$ 12,680	$ 36,043		Low	
E Meadow Dr and Middlefield Rd	IMP44187	50	36	48	$ 525	$ 26,137	1	$ 12,680	$ 38,817		Low	
E Meadow Dr and Middlefield Rd	IMP44194	216	36	48	$ 525	$ 113,381	1	$ 12,680	$ 126,061		Low	
E Meadow Dr and Middlefield Rd	IMP44199	367	36	48	$ 525	$ 192,737	1	$ 12,680	$ 205,417		Low	
E Meadow Dr and Middlefield Rd	IMP44200	138	36	48	$ 525	$ 72,576	1	$ 12,680	$ 85,256		Low	
E Meadow Dr and Middlefield Rd	IMP44610	267	12	30	$ 375	$ 100,223	1	$ 12,230	$ 112,453		Low	
E Meadow Dr and Middlefield Rd	IMP44612	43	18	30	$ 375	$ 16,266	1	$ 12,230	$ 28,496		Low	
E Meadow Dr and Middlefield Rd	IMP44615	319	18	30	$ 375	$ 119,711	1	$ 12,230	$ 131,941		Low	
E Meadow Dr and Middlefield Rd	IMP44616	61	18	30	$ 375	$ 22,983	1	$ 12,230	$ 35,213		Low	
E Meadow Dr and Middlefield Rd	IMP44617	154	12	30	$ 375	$ 57,717	1	$ 12,230	$ 69,947		Low	
		4249					**19**		**$ 2,177,442**	**0**		**$ 2,290,000**
El Camino Real and Los Robles	IMP44263	117	30	42	$ 475	$ 55,530	1	$ 12,530	$ 68,060		Moderate	
El Camino Real and Los Robles	IMP44264	94	30	42	$ 475	$ 44,877	1	$ 12,530	$ 57,407		Moderate	
El Camino Real and Los Robles	IMP44273	369	30	42	$ 475	$ 175,069	1	$ 12,530	$ 187,599		Moderate	
El Camino Real and Los Robles	IMP44444	34	30	42	$ 475	$ 15,934	1	$ 12,530	$ 28,464		Moderate	
El Camino Real and Los Robles	IMP44447	535	30	42	$ 475	$ 254,279	2	$ 25,060	$ 279,339		Moderate	
El Camino Real and Los Robles	IMP44448	481	30	42	$ 475	$ 228,581	1	$ 12,530	$ 241,111		Moderate	
El Camino Real and Los Robles	IMP44449	101	30	42	$ 475	$ 47,978	1	$ 12,530	$ 60,508		Moderate	
El Camino Real and Los Robles	IMP44452	64	30	42	$ 475	$ 30,507	1	$ 12,530	$ 43,037		Moderate	
El Camino Real and Los Robles	IMP44637	308	30	42	$ 475	$ 146,347	1	$ 12,530	$ 158,877		Moderate	
El Camino Real and Los Robles	IMP44681	346	30	42	$ 475	$ 164,489	1	$ 12,530	$ 177,019		Moderate	
El Camino Real and Los Robles	Utilities relocation	2450			$ 100	$ 244,966			$ 244,966		High	
		2450					**11**		**$ 1,546,387**	**0**		**$ 1,620,000**
Fabian	IMP44214	191	15	21	$ 290	$ 55,246	1	$ 12,010	$ 67,256		High	
Fabian	IMP44215	124	15	21	$ 290	$ 35,848	1	$ 12,010	$ 47,858		High	
Fabian	IMP44216	500	18	21	$ 290	$ 145,099	2	$ 24,020	$ 169,119		High	
Fabian	IMP44666	185	15	21	$ 290	$ 53,669	1	$ 12,010	$ 65,679		High	
		1000					**5**		**$ 349,912**	**0**		**$ 370,000**
Foothill and Miranda	IMP44556	127	30	42	$ 475	$ 60,374	2	$ 25,060	$ 85,434		Low	
Foothill and Miranda	IMP44557	402	36	42	$ 475	$ 190,977	1	$ 12,530	$ 203,507		Low	
Foothill and Miranda	IMP44560	398	42	48	$ 525	$ 209,042	1	$ 12,680	$ 221,722		Low	
Foothill and Miranda	IMP44562	44	42	48	$ 525	$ 23,005	1	$ 12,680	$ 35,685		Low	
Foothill and Miranda	IMP44563	17	12	48	$ 525	$ 8,793	1	$ 12,680	$ 21,473		Low	
Foothill and Miranda	IMP44564	111	42	48	$ 525	$ 58,418	1	$ 12,680	$ 71,098		Low	
Foothill and Miranda	IMP44689	94	42	48	$ 525	$ 49,542	1	$ 12,680	$ 62,222	1	Low	
		1194					**8**		**$ 701,141**	**40000**		**$ 780,000**
Hillview	IMP44469	49	27	42	$ 475	$ 23,307	2	$ 25,060	$ 48,367		Low	
Hillview	IMP44470	208	27	42	$ 475	$ 98,639	1	$ 12,530	$ 111,169		Low	
Hillview	IMP44474	183	27	42	$ 475	$ 86,990	1	$ 12,530	$ 99,520	1	Low	
Hillview	IMP44480	37	27	42	$ 475	$ 17,737	1	$ 12,530	$ 30,267		Low	
		477					**5**		**$ 289,323**	**40000**		**$ 350,000**
Laura Ln and Geng Rd	IMP44398	319	15	24	$ 325	$ 103,833	2	$ 24,160	$ 127,993		Low	
Laura Ln and Geng Rd	IMP44401	302	12	18	$ 270	$ 81,441	1	$ 11,930	$ 93,371		Low	
Laura Ln and Geng Rd	IMP44402	319	12	24	$ 325	$ 103,671	1	$ 12,080	$ 115,751		Low	
		940					**4**		**$ 337,115**	0		**$ 350,000**
Municipal Service Yard	IMP44798	62	30	30	$ 375	$ 23,213	1	$ 12,230	$ 35,443	1	Moderate	
Municipal Service Yard	IMP44804	251	24	30	$ 375	$ 94,018	2	$ 24,460	$ 118,478		Moderate	
Municipal Service Yard	IMP44807	164	24	30	$ 375	$ 61,564	1	$ 12,230	$ 73,794		Moderate	
Municipal Service Yard	Pump Station					Pump Station			$ 1,040,000		Moderate	
		415					**2**		**$ 1,232,272**	**40000**		**$ 1,340,000**
Nelson	IMP44058	593	18	24	$ 325	$ 192,582	2	$ 24,160	$ 216,742		Low	
Nelson	IMP44059	129	18	24	$ 325	$ 41,909	1	$ 12,080	$ 53,989		Low	
Nelson	IMP44060	67	18	24	$ 325	$ 21,676	1	$ 12,080	$ 33,756		Low	
Nelson	IMP44061	172	18	24	$ 325	$ 55,998	1	$ 12,080	$ 68,078	1	Low	

ADOBE/BARRON DRAINAGE AREA
DETAILED CONSTRUCTION ESTIMATE

Project	Name	Length (ft)	Ex Diam (in)	Imp Diam (in)	Pipe Unit Cost	Pipe Cost	MHs	MH Cost	Total	Outfalls	Priority	Project Cost
		961					**5**		**$ 372,564**	**40000**		**$ 430,000**
Nelson Ct Pump Station	Pump Station								$ 680,000	1	Low	
									$ 680,000	**40000**		**$ 760,000**
Park and Whitclem	IMP44768	132	18	36	$ 425	$ 56,058	2	$ 24,760	$ 80,818		Low	
Park and Whitclem	IMP44769	88	18	36	$ 425	$ 37,257	1	$ 12,380	$ 49,637	1	Low	
		220					**3**		**$ 130,455**	**40000**		**$ 180,000**
Park and Whitclem Pump Station	Pump Station								$ 760,000	1	Low	
									$ 760,000	**40000**		**$ 840,000**
San Antonio	IMP44043	63	12	18	$ 270	$ 16,972	1	$ 11,930	$ 28,902		Low	
San Antonio	IMP44044	338	18	24	$ 325	$ 109,940	1	$ 12,080	$ 122,020		Low	
San Antonio	IMP44049	210	18	24	$ 325	$ 68,138	1	$ 12,080	$ 80,218		Low	
San Antonio	IMP44050	137	18	24	$ 325	$ 44,663	1	$ 12,080	$ 56,743		Low	
San Antonio	IMP44051	77	18	24	$ 325	$ 24,968	1	$ 12,080	$ 37,048		Low	
San Antonio	IMP44052	194	18	24	$ 325	$ 62,998	1	$ 12,080	$ 75,078		Low	
San Antonio	IMP44053	138	18	24	$ 325	$ 45,000	1	$ 12,080	$ 57,080		Low	
San Antonio	IMP44054	27	18	24	$ 325	$ 8,913	1	$ 12,080	$ 20,993		Low	
San Antonio	IMP44094	627	12	24	$ 325	$ 203,646	2	$ 24,160	$ 227,806		Low	
San Antonio	IMP44098	30	18	24	$ 325	$ 9,715	1	$ 12,080	$ 21,795		Low	
San Antonio	IMP44130	289	18	42	$ 475	$ 137,413	1	$ 12,530	$ 149,943		Low	
San Antonio	IMP44131	741	27	42	$ 475	$ 352,160	2	$ 25,060	$ 377,220		Low	
San Antonio	IMP44132	19	27	42	$ 475	$ 9,172	1	$ 12,530	$ 21,702		Low	
San Antonio	IMP44133	321	27	42	$ 475	$ 152,621	1	$ 12,530	$ 165,151		Low	
San Antonio	IMP44134	112	27	42	$ 475	$ 53,247	1	$ 12,530	$ 65,777		Low	
San Antonio	IMP44135	20	27	42	$ 475	$ 9,595	1	$ 12,530	$ 22,125		Low	
San Antonio	IMP44136	407	27	42	$ 475	$ 193,319	1	$ 12,530	$ 205,849		Low	
San Antonio	IMP44137	462	27	42	$ 475	$ 219,459	1	$ 12,530	$ 231,989		Low	
San Antonio	IMP44209	38	27	42	$ 475	$ 18,130	1	$ 12,530	$ 30,660		Low	
		4252					**21**		**$ 1,998,099**	**0**		**$ 2,100,000**
Scripps	IMP44035	108	18	24	$ 325	$ 35,156	2	$ 24,160	$ 59,316		Low	
Scripps	IMP44056	37	18	36	$ 425	$ 15,518	1	$ 12,380	$ 27,898		Low	
Scripps	IMP44064	120	18	36	$ 425	$ 51,085	1	$ 12,380	$ 63,465	1	Low	
Scripps	IMP44069	55	18	36	$ 425	$ 23,436	1	$ 12,380	$ 35,816		Low	
Scripps	IMP44070	71	18	36	$ 425	$ 30,372	1	$ 12,380	$ 42,752		Low	
Scripps	IMP44071	104	18	36	$ 425	$ 44,209	1	$ 12,380	$ 56,589		Low	
Scripps	IMP44072	133	18	36	$ 425	$ 56,347	1	$ 12,380	$ 68,727		Low	
Scripps	IMP44073	251	15	24	$ 325	$ 81,666	1	$ 12,080	$ 93,746		Low	
Scripps	IMP44074	75	18	24	$ 325	$ 24,425	1	$ 12,080	$ 36,505		Low	
		955					**10**		**$ 484,813**	**40000**		**$ 550,000**
Scripps Pump Station	Pump Station								$ 1,000,000	1	Low	
									$ 1,000,000	**40000**		**$ 1,090,000**
South Ct to Adobe Creek	IMP44036	421	30	42	$ 475	$ 200,133	2	$ 25,060	$ 225,193		Low	
South Ct to Adobe Creek	IMP44037	186	30	42	$ 475	$ 88,463	1	$ 12,530	$ 100,993	1	Low	
South Ct to Adobe Creek	IMP44312	255	30	42	$ 475	$ 121,020	1	$ 12,530	$ 133,550		Low	
South Ct to Adobe Creek	IMP44313	424	27	36	$ 425	$ 180,178	1	$ 12,380	$ 192,558		Low	
South Ct to Adobe Creek	IMP44314	455	21	30	$ 375	$ 170,607	1	$ 12,230	$ 182,837		Low	
South Ct to Adobe Creek	IMP44315	584	24	30	$ 375	$ 218,978	2	$ 24,460	$ 243,438		Low	
South Ct to Adobe Creek	IMP44316	133	21	30	$ 375	$ 49,772	1	$ 12,230	$ 62,002		Low	
South Ct to Adobe Creek	IMP44317	44	21	30	$ 375	$ 16,422	1	$ 12,230	$ 28,652		Low	
		2502					**10**		**$ 1,169,224**	**40000**		**$ 1,270,000**
Ventura and Park	IMP44716	31	18	24	$ 325	$ 10,134	2	$ 24,160	$ 34,294		Low	
Ventura and Park	IMP44762	148	21	36	$ 425	$ 63,058	1	$ 12,380	$ 75,438		Low	
Ventura and Park	IMP44763	237	21	36	$ 425	$ 100,561	1	$ 12,380	$ 112,941		Low	
Ventura and Park	IMP44764	57	15	24	$ 325	$ 18,489	1	$ 12,080	$ 30,569	1	Low	
Ventura and Park	IMPC2	9	12	36	$ 425	$ 3,769	1	$ 12,380	$ 16,149		Low	
		482					**6**		**$ 269,391**	**40000**		**$ 320,000**
Wilkie and Park	IMP44276	269	27	36	$ 425	$ 114,338	2	$ 24,760	$ 139,098		Low	
Wilkie and Park	IMP44284	548	21	36	$ 425	$ 233,060	2	$ 24,760	$ 257,820		Low	
Wilkie and Park	IMP44286	38	21	36	$ 425	$ 16,320	1	$ 12,380	$ 28,700		Low	
Wilkie and Park	IMP44287	163	21	36	$ 425	$ 69,373	1	$ 12,380	$ 81,753		Low	
Wilkie and Park	IMP44289	135	21	24	$ 325	$ 43,848	1	$ 12,080	$ 55,928		Low	

ADOBE/BARRON DRAINAGE AREA
DETAILED CONSTRUCTION ESTIMATE

Project	Name	Length (ft)	Ex Diam (in)	Imp Diam (in)	Pipe Unit Cost	Pipe Cost	MHs	MH Cost	Total	Outfalls	Priority	Project Cost
Wilkie and Park	IMP44290	57	18	24	$ 325	$ 18,562	1	$ 12,080	$ 30,642		Low	
Wilkie and Park	IMP44291	293	18	24	$ 325	$ 95,313	1	$ 12,080	$ 107,393		Low	
Wilkie and Park	IMP44292	218	18	24	$ 325	$ 70,971	1	$ 12,080	$ 83,051		Low	
Wilkie and Park	IMP44294	314	27	36	$ 425	$ 133,642	1	$ 12,380	$ 146,022		Low	
Wilkie and Park	IMP44302	13	21	36	$ 425	$ 5,640	1	$ 12,380	$ 18,020		Low	
Wilkie and Park	IMP44303	369	27	36	$ 425	$ 156,754	1	$ 12,380	$ 169,134		Low	
Wilkie and Park	IMP44456	44	18	24	$ 325	$ 14,306	1	$ 12,080	$ 26,386		Low	
Wilkie and Park	IMP44459	80	12	24	$ 325	$ 25,904	1	$ 12,080	$ 37,984		Low	
Wilkie and Park	IMP44460	6	12	24	$ 325	$ 1,976	1	$ 12,080	$ 14,056		Low	
Wilkie and Park	IMP44461	102	12	24	$ 325	$ 33,251	1	$ 12,080	$ 45,331		Low	
Wilkie and Park	IMP44462	95	12	24	$ 325	$ 30,722	1	$ 12,080	$ 42,802		Low	
Wilkie and Park	IMP44463	160	12	24	$ 325	$ 52,072	1	$ 12,080	$ 64,152		Low	
		2906					**19**		**$ 1,348,272**	**0**		**$ 1,420,000**
TOTAL ADOBE/BARRON DRAINAGE AREA CONSTRUCTION ESTIMATE												**$ 24,600,000**

MATADERO DRAINAGE AREA
DETAILED CONSTRUCTION ESTIMATE

Project	Name	Length (ft)	Ex Diam (in)	Imp Diam (in)	Pipe Unit Cost	Pipe Cost	MHs	MH Cost	Total	Outfalls	Priority	Project Cost (w/ 5% mob/demob)
Alma	IMP22331	460	15	30	$ 375	$ 172,555	1	$ 12,230	$ 184,785		Low	
Alma	IMP22336	667	15	30	$ 375	$ 249,993	2	$ 24,460	$ 274,453		Low	
Alma	IMP22339	253	21	30	$ 375	$ 94,917	1	$ 12,230	$ 107,147		Low	
		1380					4		$566,385	$0		$590,000
Bayshore and Fabian	IMP23384	504	15	36	$ 425	$ 214,295	2	$ 24,760	$ 239,055		High	
Bayshore and Fabian	IMP23412	102	15	36	$ 425	$ 43,447	1	$ 12,380	$ 55,827		High	
Bayshore and Fabian	IMP23413	93	15	36	$ 425	$ 39,524	1	$ 12,380	$ 51,905	1	High	
Bayshore and Fabian	IMP23414	369	15	36	$ 425	$ 156,807	1	$ 12,380	$ 169,187		High	
Bayshore and Fabian	IMP23415	324	15	36	$ 425	$ 137,740	1	$ 12,380	$ 150,120		High	
Bayshore and Fabian utilites	Utilities relocation	1392			$ 100	$ 139,250			$ 139,250		High	
		1392					6		$805,343	$40,000		$890,000
Bayshore and Fabian Pump Station	Pump Station								$600,000	1	High	
									$600,000	$40,000		$670,000
Bryant	IMP22618	319	15	24	$ 325	$ 103,836	2	$ 24,160	$ 127,996		Low	
Bryant	IMP22619	259	12	24	$ 325	$ 84,250	1	$ 12,080	$ 96,330		Low	
Bryant	IMP22631	23	15	30	$ 375	$ 8,687	1	$ 12,230	$ 20,917		Low	
Bryant	IMP22634	458	15	30	$ 375	$ 171,709	1	$ 12,230	$ 183,939		Low	
Bryant	IMP22636	438	15	30	$ 375	$ 164,302	1	$ 12,230	$ 176,532		Low	
Bryant	IMP22638	140	15	24	$ 325	$ 45,589	1	$ 12,080	$ 57,669		Low	
Bryant	IMP23164	26	12	24	$ 325	$ 8,581	1	$ 12,080	$ 20,661		Low	
		1665					8		$684,044	$0		$720,000
Cambridge	IMP22996	309	15	36	$ 425	$ 131,150	2	$ 24,760	$ 155,910		Low	
Cambridge	IMP22997	313	18	36	$ 425	$ 133,124	1	$ 12,380	$ 145,504		Low	
Cambridge	IMP22998	291	18	36	$ 425	$ 123,463	1	$ 12,380	$ 135,843		Low	
Cambridge	IMP23000	156	21	36	$ 425	$ 66,247	1	$ 12,380	$ 78,627		Low	
Cambridge	IMP23001	136	21	36	$ 425	$ 57,727	1	$ 12,380	$ 70,107		Low	
Cambridge	IMP23004	316	21	36	$ 425	$ 134,182	1	$ 12,380	$ 146,562		Low	
Cambridge	IMP23006	302	21	36	$ 425	$ 128,535	1	$ 12,380	$ 140,916	1	Low	
Cambridge	IMP23012	319	18	36	$ 425	$ 135,693	1	$ 12,380	$ 148,073		Low	
Cambridge	IMP23262	25	21	36	$ 425	$ 10,478	1	$ 12,380	$ 22,858		Low	
Cambridge	IMP23302	56	21	36	$ 425	$ 23,836	1	$ 12,380	$ 36,216		Low	
Cambridge	IMP23303	1	21	36	$ 425	$ 570	1	$ 12,380	$ 12,950		Low	
		2224					12		$1,093,568	$40,000		$1,190,000
Cambridge and Park	IMP22351	182	18	36	$ 425	$ 77,354	2	$ 24,760	$ 102,114		Moderate	
Cambridge and Park	IMP22352	470	12	18	$ 270	$ 126,832	1	$ 11,930	$ 138,762		Moderate	
Cambridge and Park	IMP22353	81	12	36	$ 425	$ 34,530	1	$ 12,380	$ 46,910		Moderate	
Cambridge and Park	IMP22357	45	24	36	$ 425	$ 18,935	1	$ 12,380	$ 31,315		Moderate	
Cambridge and Park	IMP22358	184	24	36	$ 425	$ 78,259	1	$ 12,380	$ 90,639		Moderate	
Cambridge and Park	IMP22359	116	24	36	$ 425	$ 49,127	1	$ 12,380	$ 61,507		Moderate	
Cambridge and Park	IMP22361	188	18	36	$ 425	$ 80,044	1	$ 12,380	$ 92,424		Moderate	
Cambridge and Park	IMP22889	83	24	36	$ 425	$ 35,108	1	$ 12,380	$ 47,488		Moderate	
Cambridge and Park	IMP22892	138	24	36	$ 425	$ 58,787	1	$ 12,380	$ 71,167		Moderate	
Cambridge and Park	IMP22902	317	12	24	$ 325	$ 103,075	1	$ 12,080	$ 115,155		Moderate	
Cambridge and Park	IMP23228	371	15	36	$ 425	$ 157,784	1	$ 12,380	$ 170,164		Moderate	
Cambridge and Park	IMP23264	134	24	36	$ 425	$ 56,945	1	$ 12,380	$ 69,325		Moderate	
Cambridge and Park	IMP23266	206	24	36	$ 425	$ 87,640	1	$ 12,380	$ 100,020		Moderate	
		2515					14		$1,136,991	$0		$1,190,000
Center	IMP_New1	328	-	36	$ 425	$ 139,510	2	$ 24,760	$ 164,270		Moderate	
Center	IMP22174	233	12	36	$ 425	$ 98,874	1	$ 12,380	$ 111,254		Moderate	
Center	IMP22210	93	15	36	$ 425	$ 39,631	1	$ 12,380	$ 52,011		Moderate	
Center	IMP22211	153	15	36	$ 425	$ 65,058	1	$ 12,380	$ 77,438		Moderate	
Center	IMP22212	180	15	36	$ 425	$ 76,570	1	$ 12,380	$ 88,950		Moderate	
Center	IMP22213	283	15	36	$ 425	$ 120,111	1	$ 12,380	$ 132,491		Moderate	
Center	IMP22214	292	15	36	$ 425	$ 124,111	1	$ 12,380	$ 136,491		Moderate	
Center	IMP22215	195	15	36	$ 425	$ 83,055	1	$ 12,380	$ 95,435		Moderate	
Center	IMP22218	275	15	36	$ 425	$ 117,004	1	$ 12,380	$ 129,384		Moderate	
		2033					10		$987,725	$0		$1,040,000
Colonial and Amarillo	IMP22450	181	12	24	$ 325	$ 58,823	2	$ 24,160	$ 82,983		Low	
Colonial and Amarillo	IMP22451	27	12	24	$ 325	$ 8,673	1	$ 12,080	$ 20,753		Low	
Colonial and Amarillo	IMP22452	238	12	24	$ 325	$ 77,443	1	$ 12,080	$ 89,523		Low	

MATADERO DRAINAGE AREA
DETAILED CONSTRUCTION ESTIMATE

Project	Name	Length (ft)	Ex Diam (in)	Imp Diam (in)	Pipe Unit Cost	Pipe Cost	MHs	MH Cost	Total	Outfalls	Priority	Project Cost (w/ 5% mob/demob)
Colonial and Amarillo	IMP22836	284	12	24	$ 325	$ 92,353	1	$ 12,080	$ 104,433		Low	
		730					**5**		**$297,691**	**$0**		**$310,000**
Colorado PS removal	IMP_C_1	344	27	27	$ 350	$ 120,298	2	$ 24,310	$ 144,608		Low	
Colorado PS removal	IMP_C_2	51	27	27	$ 350	$ 17,778	1	$ 12,155	$ 29,933		Low	
Colorado PS removal	IMP4_1	9	42	48	$ 525	$ 4,982	1	$ 12,680	$ 17,662		Low	
Colorado PS removal	IMP4_2	7	42	48	$ 525	$ 3,687	1	$ 12,680	$ 16,367		Low	
Colorado PS removal	IMPPump_Col	14	-	27	$ 350	$ 4,737	1	$ 12,155	$ 16,892		Low	
Colorado PS removal utilites	Utilities relocation	425			$ 100	$ 42,455			$ 42,455		Low	
		425					**6**		**$267,917**	**$0**		**$280,000**
El Camino Real	IMP23119	175	15	24	$ 325	$ 56,822	2	$ 24,160	$ 80,982		Low	
El Camino Real	IMP23344	437	15	24	$ 325	$ 141,959	1	$ 12,080	$ 154,039		Low	
		612					**3**		**$235,021**	**$0**		**$250,000**
El Centro	IMP23390	376	12	24	$ 325	$ 122,328	2	$ 24,160	$ 146,488		Low	
El Centro	IMP23391	226	12	24	$ 325	$ 73,289	1	$ 12,080	$ 85,369		Low	
El Centro	IMP23392	37	12	24	$ 325	$ 11,902	1	$ 12,080	$ 23,983	1	Low	
		639					**4**		**$255,839**	**$40,000**		**$310,000**
Embarcadero	IMP22675	21	24	36	$ 425	$ 8,792	2	$ 24,760	$ 33,552		Moderate	
Embarcadero	IMP22676	302	12	24	$ 325	$ 98,009	1	$ 12,080	$ 110,089		Moderate	
Embarcadero	IMP22677	159	24	36	$ 425	$ 67,380	1	$ 12,380	$ 79,760		Moderate	
Embarcadero	IMP22681	16	12	24	$ 325	$ 5,199	1	$ 12,080	$ 17,279		Moderate	
Embarcadero	IMP23169	340	24	36	$ 425	$ 144,400	1	$ 12,380	$ 156,780		Moderate	
Embarcadero utilities	Utilities relocation	837			$ 991	$ 829,026			$ 829,026		Moderate	
		837					**6**		**$1,226,486**	**$0**		**$1,290,000**
Forest and Hamilton	IMP22171	638	12	36	$ 425	$ 270,991	2	$ 24,760	$ 295,751		Low	
Forest and Hamilton	IMP22172	435	15	36	$ 425	$ 184,883	1	$ 12,380	$ 197,263		Low	
Forest and Hamilton	IMP22189	601	15	24	$ 325	$ 195,307	2	$ 24,160	$ 219,467		Low	
Forest and Hamilton	IMP22190	566	14	24	$ 325	$ 183,922	2	$ 24,160	$ 208,082		Low	
Forest and Hamilton	IMP22196	104	15	24	$ 325	$ 33,836	1	$ 12,080	$ 45,916		Low	
Forest and Hamilton	IMP23155	39	15	36	$ 425	$ 16,495	1	$ 12,380	$ 28,875		Low	
Forest and Hamilton	IMP23156	401	15	24	$ 325	$ 130,414	1	$ 12,080	$ 142,494		Low	
Forest and Hamilton	IMPC2	548	-	36	$ 425	$ 232,953	2	$ 24,760	$ 257,713		Low	
		3332					**12**		**$1,395,561**	**$0**		**$1,470,000**
Hamilton and Channing	IMP	462	21	36	$ 425	$ 196,424	1	$ 12,380	$ 208,804		Low	
Hamilton and Channing	IMP_22195	525	21	36	$ 425	$ 222,933	2	$ 24,760	$ 247,693		Low	
Hamilton and Channing	IMP_22197	548	21	36	$ 425	$ 232,688	2	$ 24,760	$ 257,448		Low	
Hamilton and Channing	IMP22179	147	12	30	$ 375	$ 55,238	1	$ 12,230	$ 67,468		Low	
Hamilton and Channing	IMP22183	232	12	30	$ 375	$ 87,073	1	$ 12,230	$ 99,303		Low	
Hamilton and Channing	IMP22184	326	12	30	$ 375	$ 122,173	1	$ 12,230	$ 134,403		Low	
Hamilton and Channing	IMP22187	459	15	30	$ 375	$ 172,276	1	$ 12,230	$ 184,506		Low	
Hamilton and Channing	IMP22188	135	12	30	$ 375	$ 50,668	1	$ 12,230	$ 62,898		Low	
Hamilton and Channing	IMP22194	566	21	30	$ 375	$ 212,105	2	$ 24,460	$ 236,565		Low	
Hamilton and Channing	IMP22627	560	18	30	$ 375	$ 209,952	2	$ 24,460	$ 234,412		Low	
		3960					**14**		**$1,733,501**	**$0**		**$1,820,000**
Hamilton and Rhodes	IMP_Hamilton	772	-	48	$ 525	$ 405,258	2	$ 25,360	$ 430,618		High	
Hamilton and Rhodes	IMP22173	506	18	48	$ 525	$ 265,870	2	$ 25,360	$ 291,230		High	
Hamilton and Rhodes	IMP22175	133	18	48	$ 525	$ 70,000	1	$ 12,680	$ 82,680		High	
Hamilton and Rhodes	IMP22176	542	18	48	$ 525	$ 284,401	2	$ 25,360	$ 309,761		High	
Hamilton and Rhodes	IMP22177	503	21	48	$ 525	$ 264,075	2	$ 25,360	$ 289,435		High	
Hamilton and Rhodes	IMP22585	300	15	48	$ 525	$ 157,689	1	$ 12,680	$ 170,369		High	
Hamilton and Rhodes	IMP22586	138	15	48	$ 525	$ 72,267	1	$ 12,680	$ 84,947		High	
Hamilton and Rhodes	IMP22587	116	15	48	$ 525	$ 60,962	1	$ 12,680	$ 73,642		High	
Hamilton and Rhodes	IMP22588	290	18	48	$ 525	$ 152,296	1	$ 12,680	$ 164,976		High	
Hamilton and Rhodes	IMP22599	338	21	48	$ 525	$ 177,468	1	$ 12,680	$ 190,148		High	
Hamilton and Rhodes	IMP22601	12	12	36	$ 425	$ 4,981	1	$ 12,380	$ 17,361		High	
		3650					**15**		**$2,105,168**	**$0**		**$2,210,000**
Hanover	IMP22548	404	15	36	$ 425	$ 171,893	2	$ 24,760	$ 196,653		Low	
Hanover	IMP22549	41	18	36	$ 425	$ 17,495	1	$ 12,380	$ 29,875		Low	
Hanover	IMP22550	173	18	36	$ 425	$ 73,448	1	$ 12,380	$ 85,828		Low	
Hanover	IMP23085	6	18	36	$ 425	$ 2,673	1	$ 12,380	$ 15,053		Low	
Hanover	IMP23086	63	18	36	$ 425	$ 26,741	1	$ 12,380	$ 39,121		Low	

MATADERO DRAINAGE AREA
DETAILED CONSTRUCTION ESTIMATE

Project	Name	Length (ft)	Ex Diam (in)	Imp Diam (in)	Pipe Unit Cost	Pipe Cost	MHs	MH Cost	Total	Outfalls	Priority	Project Cost (w/ 5% mob/demob)
Hanover	IMP23324	45	18	36	$ 425	$ 19,046	1	$ 12,380	$ 31,426		Low	
		732					**7**		**$397,957**	**$0**		**$420,000**
Hoover Park	IMP_22113	70	12	36	$ 425	$ 29,697	2	$ 24,760	$ 54,457		Low	
Hoover Park	IMP_22114	42	12	36	$ 425	$ 17,836	1	$ 12,380	$ 30,216		Low	
Hoover Park	IMP_22116	45	12	36	$ 425	$ 19,302	1	$ 12,380	$ 31,683	1	Low	
Hoover Park	IMP_23285	60	12	36	$ 425	$ 25,557	1	$ 12,380	$ 37,937		Low	
		217					**5**		**$154,292**	**$40,000**		**$200,000**
Lincoln and Channing	IMP_22428	299	12	30	$ 375	$ 112,311	1	$ 12,230	$ 124,541		High	
Lincoln and Channing	IMP_22644	708	12	42	$ 475	$ 336,103	2	$ 25,060	$ 361,163		High	
Lincoln and Channing	IMP_22645	273	12	42	$ 475	$ 129,793	1	$ 12,530	$ 142,323		High	
Lincoln and Channing	IMP_22646	252	12	42	$ 475	$ 119,509	1	$ 12,530	$ 132,039		High	
Lincoln and Channing	IMP_22766	279	24	30	$ 375	$ 104,697	1	$ 12,230	$ 116,927		High	
Lincoln and Channing	IMP_Lincoln1	562	-	42	$ 475	$ 267,103	2	$ 25,060	$ 292,163		High	
Lincoln and Channing	IMP_Lincoln2	560	-	42	$ 475	$ 265,818	2	$ 25,060	$ 290,878		High	
Lincoln and Channing	IMP_Lincoln3	560	-	42	$ 475	$ 266,172	2	$ 25,060	$ 291,232		High	
Lincoln and Channing	IMP_Lincoln4	1136	-	42	$ 475	$ 539,371	2	$ 25,060	$ 564,431		High	
		4629					**14**		**$2,315,697**	**$0**		**$2,430,000**
Loma Verde and Cowper	IMP22961	176	27	48	$ 525	$ 92,625	2	$ 25,360	$ 117,985		Low	
Loma Verde and Cowper	IMP22962	441	24	36	$ 425	$ 187,337	1	$ 12,380	$ 199,717		Low	
Loma Verde and Cowper	IMP22963	84	24	36	$ 425	$ 35,856	1	$ 12,380	$ 48,236		Low	
Loma Verde and Cowper	IMP22964	322	24	36	$ 425	$ 136,709	1	$ 12,380	$ 149,089		Low	
Loma Verde and Cowper	IMP22966	259	24	36	$ 425	$ 110,134	1	$ 12,380	$ 122,514		Low	
Loma Verde and Cowper	IMP22968	195	27	48	$ 525	$ 102,515	1	$ 12,680	$ 115,195		Low	
Loma Verde and Cowper	IMP22969	54	27	48	$ 525	$ 28,253	1	$ 12,680	$ 40,933		Low	
Loma Verde and Cowper	IMP22970	70	27	48	$ 525	$ 36,875	1	$ 12,680	$ 49,555		Low	
Loma Verde and Cowper	IMP22971	169	27	48	$ 525	$ 88,606	1	$ 12,680	$ 101,286		Low	
Loma Verde and Cowper	IMP22973	177	27	48	$ 525	$ 92,844	1	$ 12,680	$ 105,524		Low	
Loma Verde and Cowper	IMP23286	317	27	48	$ 525	$ 166,375	1	$ 12,680	$ 179,055		Low	
Loma Verde and Cowper utilities	Utilities relocation	2264			$ 100	$ 226,424			$ 226,424		Low	
		2264					**12**		**$1,455,512**	**$0**		**$1,530,000**
Loma Verde and Maddux	IMP22250	306	36	51	$ 550	$ 168,383	2	$ 25,510	$ 193,893		High	
Loma Verde and Maddux	IMP22254	50	36	51	$ 550	$ 27,481	1	$ 12,755	$ 40,236		High	
Loma Verde and Maddux	IMP22257	231	36	51	$ 550	$ 127,233	1	$ 12,755	$ 139,988		High	
Loma Verde and Maddux	IMP23240	63	36	51	$ 550	$ 34,808	1	$ 12,755	$ 47,563		High	
Loma Verde and Maddux	IMP23241	26	36	51	$ 550	$ 14,193	1	$ 12,755	$ 26,948		High	
Loma Verde and Maddux	IMP23242	271	36	51	$ 550	$ 149,050	1	$ 12,755	$ 161,805		High	
Loma Verde and Maddux	IMP23243	21	36	51	$ 550	$ 11,603	1	$ 12,755	$ 24,358		High	
Loma Verde and Maddux	IMP23244	15	36	51	$ 550	$ 8,201	1	$ 12,755	$ 20,956		High	
Loma Verde and Maddux	IMP23245	30	36	51	$ 550	$ 16,644	1	$ 12,755	$ 29,399		High	
Loma Verde and Maddux	IMP23246	307	36	51	$ 550	$ 169,036	1	$ 12,755	$ 181,791		High	
Loma Verde and Maddux	IMP23247	42	36	51	$ 550	$ 23,171	1	$ 12,755	$ 35,926		High	
Loma Verde and Maddux	IMP23249	77	36	51	$ 550	$ 42,511	1	$ 12,755	$ 55,266		High	
Loma Verde and Maddux	IMP23250	138	36	51	$ 550	$ 76,076	1	$ 12,755	$ 88,831		High	
Loma Verde and Maddux	IMP23251	41	36	51	$ 550	$ 22,373	1	$ 12,755	$ 35,128		High	
Loma Verde and Maddux	MIP22256	127	36	51	$ 550	$ 70,089	1	$ 12,755	$ 82,844		High	
Loma Verde and Maddux utilities	Utilities relocation	1747			$ 100	$ 174,701			$ 174,701		High	
		1747					**16**		**$1,339,634**	**$0**		**$1,410,000**
Loma Verde and Ross	IMP22248	151	30	51	$ 550	$ 83,277	2	$ 25,510	$ 108,787		Moderate	
Loma Verde and Ross	IMP22249	256	30	51	$ 550	$ 140,819	1	$ 12,755	$ 153,574		Moderate	
Loma Verde and Ross	IMP22972	246	30	48	$ 525	$ 129,327	1	$ 12,680	$ 142,007		Moderate	
Loma Verde and Ross	IMP22978	285	30	51	$ 550	$ 156,783	1	$ 12,755	$ 169,538		Moderate	
Loma Verde and Ross	IMP23239	206	30	51	$ 550	$ 113,353	1	$ 12,755	$ 126,108		Moderate	
Loma Verde and Ross utilites	Utilities relocation	1145			$ 100	$ 114,494			$ 114,494		Moderate	
		1145					**6**		**$814,509**	**$0**		**$860,000**
Louis	IMP22379	493	3x4 culvert	4 X 5 Culvert	$ 724	$ 357,078	1	$ 13,820	$ 370,898		High	
Louis	IMP22385	551	3x4 culvert	4 X 5 Culvert	$ 724	$ 398,653	2	$ 27,640	$ 426,293		High	
Louis	IMP22386	43	3x4 culvert	4 X 5 Culvert	$ 724	$ 31,244	1	$ 13,820	$ 45,064		High	
Louis	IMP22438	286	3x4.5 culvert	4 X 5 Culvert	$ 724	$ 206,722	1	$ 13,820	$ 220,542		High	
Louis	IMP22440	242	3x4.5 culvert	4 X 5 Culvert	$ 724	$ 175,421	1	$ 13,820	$ 189,241		High	
Louis	IMP22441	33	3x4.5 culvert	4 X 5 Culvert	$ 724	$ 23,576	1	$ 13,820	$ 37,396		High	

MATADERO DRAINAGE AREA
DETAILED CONSTRUCTION ESTIMATE

Project	Name	Length (ft)	Ex Diam (in)	Imp Diam (in)	Pipe Unit Cost	Pipe Cost	MHs	MH Cost	Total	Outfalls	Priority	Project Cost (w/ 5% mob/demob)
Louis	IMP22442	89	3x5 culvert	4 X 5.5 Culvert	$ 934	$ 83,051	1	$ 14,150	$ 97,201		High	
Louis	IMP22443	53	3x5 culvert	4 X 5 Culvert	$ 724	$ 38,468	1	$ 13,820	$ 52,288		High	
Louis	IMP22444	39	3x4.5 culvert	4 X 5.5 Culvert	$ 934	$ 36,574	1	$ 14,150	$ 50,724		High	
Louis	IMP22445	29	3x5 culvert	4 X 5.5 Culvert	$ 934	$ 27,431	1	$ 14,150	$ 41,581		High	
Louis	IMP22453	46	3x5 culvert	4 X 5.5 Culvert	$ 934	$ 43,150	1	$ 14,150	$ 57,300		High	
Louis	IMP22454	39	3x5.5 culvert	4 X 5.5 Culvert	$ 934	$ 36,629	1	$ 14,150	$ 50,779		High	
Louis	IMP22455	35	3x5.5 culvert	4 X 5.5 Culvert	$ 934	$ 32,938	1	$ 14,150	$ 47,088		High	
Louis	IMP22456	247	3x5.5 culvert	4 X 5.5 Culvert	$ 934	$ 230,576	1	$ 14,150	$ 244,726		High	
Louis	IMP22686	24	WeirH=1xL=4	4 X 5 Culvert	$ 724	$ 17,686	1	$ 13,820	$ 31,506		High	
Louis	IMP23176	15	2.5x3.25 culvert	3 x 4 Culvert	$ 724	$ 11,070	1	$ 13,820	$ 24,890		High	
Louis	IMP23177	584	3x4.5 culvert	4 X 5 Culvert	$ 724	$ 423,087	2	$ 27,640	$ 450,727		High	
Louis	IMP23206	286	3x5 culvert	4 X 5.5 Culvert	$ 934	$ 266,803	1	$ 14,150	$ 280,953		High	
Louis	IMP23207	14	3x5 culvert	4 X 5.5 Culvert	$ 934	$ 12,835	1	$ 14,150	$ 26,985		High	
Louis	IMP23208	139	3x5 culvert	4 X 5.5 Culvert	$ 934	$ 129,652	1	$ 14,150	$ 143,802		High	
Louis	IMP23210	210	3x5 culvert	4 X 5.5 Culvert	$ 934	$ 195,982	1	$ 14,150	$ 210,132		High	
Louis	IMP23212	258	3x5.5 culvert	4 X 5.5 Culvert	$ 934	$ 240,601	1	$ 14,150	$ 254,751		High	
Louis	IMP23213	45	3x5.5 culvert	4 X 5.5 Culvert	$ 934	$ 42,177	1	$ 14,150	$ 56,327		High	
Louis	IMP23214	348	3x5.5 culvert	4 X 5.5 Culvert	$ 934	$ 324,958	1	$ 14,150	$ 339,108		High	
Louis	IMP23216	38	3x5.5 culvert	4 X 5.5 Culvert	$ 934	$ 35,525	1	$ 14,150	$ 49,675		High	
Louis utilites	Utilities relocation	4186			$ 100	$ 418,635			$ 418,635		High	
		4186					**27**		**$4,218,612**	**$0**		**$4,430,000**
Louis to Matadero Creek	IMPC5	146	-	72	$ 725	$ 105,627	1	$ 13,270	$ 118,898	1	High	
Louis to Matadero Creek	IMPC6	907	-	72	$ 725	$ 657,631	2	$ 26,540	$ 684,171		High	
Louis to Matadero Creek Utilities	Utilities relocation	1053			$ 100	$ 105,277			$ 105,277		High	
		1053					**3**		**$908,346**	**$40,000**		**$1,000,000**
Louis and Loma Verde	IMP22069	296	18	51	$ 550	$ 163,009	2	$ 25,510	$ 188,519		Low	
Louis and Loma Verde	IMP22076	252	18	51	$ 550	$ 138,841	1	$ 12,755	$ 151,596		Low	
Louis and Loma Verde	IMP22078	56	18	51	$ 550	$ 30,777	1	$ 12,755	$ 43,532		Low	
Louis and Loma Verde	IMP22079	188	18	51	$ 550	$ 103,351	1	$ 12,755	$ 116,106		Low	
Louis and Loma Verde	IMP22142	236	18	51	$ 550	$ 129,595	1	$ 12,755	$ 142,350		Low	
Louis and Loma Verde	IMP22143	33	18	51	$ 550	$ 18,159	1	$ 12,755	$ 30,914		Low	
Louis and Loma Verde	IMP22144	116	18	51	$ 550	$ 63,887	1	$ 12,755	$ 76,642		Low	
Louis and Loma Verde	IMP22258	3	18	51	$ 550	$ 1,878	1	$ 12,755	$ 14,633		Low	
Louis and Loma Verde	IMP23248	68	18	51	$ 550	$ 37,293	1	$ 12,755	$ 50,048		Low	
		1249					**10**		**$814,339**	**$0**		**$860,000**
Louis and Piers	IMP22066	144	15	24	$ 325	$ 46,924	2	$ 24,160	$ 71,084		Low	
Louis and Piers	IMP22067	360	12	15	$ 250	$ 89,975	1	$ 11,850	$ 101,825		Low	
Louis and Piers	IMP22068	316	12	24	$ 325	$ 102,642	1	$ 12,080	$ 114,722		Low	
Louis and Piers	IMP22071	62	15	24	$ 325	$ 20,302	1	$ 12,080	$ 32,382		Low	
Louis and Piers	IMP22247	242	12	15	$ 250	$ 60,462	1	$ 11,850	$ 72,312		Low	
Louis and Piers	IMP22517	344	12	15	$ 250	$ 85,882	1	$ 11,850	$ 97,732		Low	
		1468					**7**		**$490,057**	**$0**		**$510,000**
Moreno	IMP22833	140	15	24	$ 325	$ 45,527	1	$ 12,080	$ 57,607		Low	
Moreno	IMP22834	633	15	24	$ 325	$ 205,583	2	$ 24,160	$ 229,743		Low	
		773					**3**		**$287,350**	**$0**		**$300,000**
Matadero Pump Station	Pump Station								$ 7,000,000	1	Highest	
									$7,000,000	**$40,000**		**$7,390,000**
Oregon	IMP_22395	81	12	30	$ 375	$ 30,501	2	$ 24,460	$ 54,961		Low	
Oregon	IMP_22702	257	12	30	$ 375	$ 96,251	1	$ 12,230	$ 108,481		Low	
Oregon	IMP_22703	100	12	30	$ 375	$ 37,332	1	$ 12,230	$ 49,562		Low	
Oregon	IMP_22704	181	12	30	$ 375	$ 68,053	1	$ 12,230	$ 80,283		Low	
Oregon	IMP_22705	173	12	30	$ 375	$ 64,785	1	$ 12,230	$ 77,015		Low	
		792					**6**		**$370,301**	**$0**		**$390,000**
Oregon and Louis	22827	197	2.8x2.9 culvert	3 x 4 Culvert	$ 724	$ 142,474	1	$ 13,820	$ 156,294		Low	
Oregon and Louis	IMP22439	18	2.8x2.9 culvert	3 x 4 Culvert	$ 724	$ 12,907	1	$ 13,820	$ 26,727		Low	
Oregon and Louis	IMP22828	82	2.8x2.9 culvert	3 x 4 Culvert	$ 724	$ 59,486	1	$ 13,820	$ 73,306		Low	
Oregon and Louis	IMP22829	519	2.8x2.9 culvert	3 x 4 Culvert	$ 724	$ 375,590	2	$ 27,640	$ 403,230		Low	
Oregon and Louis	IMP22874	36	2.8x2.9 culvert	3 x 4 Culvert	$ 724	$ 25,869	1	$ 13,820	$ 39,689		Low	
Oregon and Louis	IMP22875	5	2.8x2.9 culvert	3 x 4 Culvert	$ 724	$ 3,476	1	$ 13,820	$ 17,296		Low	
Oregon and Louis	IMP23202	316	2.8x2.9 culvert	3 x 4 Culvert	$ 724	$ 228,697	1	$ 13,820	$ 242,517		Low	

MATADERO DRAINAGE AREA
DETAILED CONSTRUCTION ESTIMATE

Project	Name	Length (ft)	Ex Diam (in)	Imp Diam (in)	Pipe Unit Cost	Pipe Cost	MHs	MH Cost	Total	Outfalls	Priority	Project Cost (w/ 5% mob/demob)
Oregon and Louis	IMP23204	49	2.8x2.9 culvert	3 x 4 Culvert	$ 724	$ 35,441	1	$ 13,820	$ 49,261		Low	
Oregon and Louis	IMP23205	296	2.8x2.9 culvert	3 x 4 Culvert	$ 724	$ 214,592	1	$ 13,820	$ 228,412		Low	
Oregon and Louis	IMP23209	179	2.8x2.9 culvert	3 x 4 Culvert	$ 724	$ 129,598	1	$ 13,820	$ 143,418		Low	
Oregon and Louis	IMP23232	538	2.8x2.9 culvert	3 x 4 Culvert	$ 724	$ 389,169	2	$ 27,640	$ 416,809		Low	
Oregon and Louis utilites	Utilities relocation	2234			$ 100	$ 223,384			$ 223,384		Low	
		2234					**13**		**$2,020,345**	**$0**		**$2,120,000**
Oregon Expy Pump Station	Pump Station					$ -			$ 200,000		Low	
		0					**0**		**$200,000**	**$0**		**$210,000**
Page Mill and Alma	IMP22930	114	24	42	$ 475	$ 54,225	1	$ 12,530	$ 66,755		Moderate	
Page Mill and Alma	IMP22931	41	30	42	$ 475	$ 19,527	1	$ 12,530	$ 32,057		Moderate	
Page Mill and Alma	IMP22935	94	24	42	$ 475	$ 44,806	1	$ 12,530	$ 57,336		Moderate	
Page Mill and Alma	IMP23025	74	12	21	$ 290	$ 21,547	1	$ 12,010	$ 33,557		Moderate	
Page Mill and Alma	IMP23027	27	30	42	$ 475	$ 13,035	1	$ 12,530	$ 25,565		Moderate	
Page Mill and Alma	IMP23028	358	30	42	$ 475	$ 169,855	1	$ 12,530	$ 182,385		Moderate	
Page Mill and Alma	IMP23029	337	30	42	$ 475	$ 160,159	1	$ 12,530	$ 172,689		Moderate	
Page Mill and Alma	IMP23031	561	30	42	$ 475	$ 266,410	2	$ 25,060	$ 291,470		Moderate	
Page Mill and Alma	IMP23034	96	36	48	$ 525	$ 50,158	1	$ 12,680	$ 62,838		Moderate	
Page Mill and Alma	IMP23277	16	30	42	$ 475	$ 7,631	1	$ 12,530	$ 20,161		Moderate	
Page Mill and Alma	IMP23281	34	30	42	$ 475	$ 16,136	1	$ 12,530	$ 28,666		Moderate	
Page Mill and Alma	IMP23282	171	24	42	$ 475	$ 81,449	1	$ 12,530	$ 93,979		Moderate	
Page Mill and Alma	IMP23310	33	30	42	$ 475	$ 15,611	1	$ 12,530	$ 28,141		Moderate	
		1957					**14**		**$1,095,597**	**$0**		**$1,150,000**
Page Mill and El Camino Real	IMP23021	379	27	42	$ 475	$ 179,939	2	$ 25,060	$ 204,999		Moderate	
Page Mill and El Camino Real	IMP23022	329	33	42	$ 475	$ 156,464	1	$ 12,530	$ 168,994		Moderate	
Page Mill and El Camino Real	IMP23023	282	33	42	$ 475	$ 133,804	1	$ 12,530	$ 146,334		Moderate	
Page Mill and El Camino Real	IMP23036	13	36	42	$ 475	$ 6,225	1	$ 12,530	$ 18,755		Moderate	
Page Mill and El Camino Real	IMP23040	285	36	42	$ 475	$ 135,460	1	$ 12,530	$ 147,990		Moderate	
Page Mill and El Camino Real	IMP23089	361	24	36	$ 425	$ 153,624	1	$ 12,380	$ 166,004		Moderate	
Page Mill and El Camino Real	IMP23097	422	27	42	$ 475	$ 200,398	1	$ 12,530	$ 212,928		Moderate	
Page Mill and El Camino Real	IMP23098	330	24	36	$ 425	$ 140,410	1	$ 12,380	$ 152,790		Moderate	
Page Mill and El Camino Real	IMP23099	119	27	42	$ 475	$ 56,393	1	$ 12,530	$ 68,923		Moderate	
Page Mill and El Camino Real	Utilities relocation	2521			$ 100	$ 252,065			$ 252,065		Moderate	
		2521					**10**		**$1,539,781**	**$0**		**$1,620,000**
Parkinson and Newell	IMP22578	344	24	36	$ 425	$ 146,196	2	$ 24,760	$ 170,956		Low	
Parkinson and Newell	IMP22579	285	24	36	$ 425	$ 121,025	1	$ 12,380	$ 133,405		Low	
Parkinson and Newell	IMP22655	24	12	24	$ 325	$ 7,674	1	$ 12,080	$ 19,754		Low	
Parkinson and Newell	IMP22657	398	12	24	$ 325	$ 129,432	1	$ 12,080	$ 141,512		Low	
Parkinson and Newell	IMP22667	364	15	24	$ 325	$ 118,380	1	$ 12,080	$ 130,460		Low	
Parkinson and Newell	IMP22668	360	18	24	$ 325	$ 117,026	1	$ 12,080	$ 129,106		Low	
Parkinson and Newell	IMP22670	349	18	24	$ 325	$ 113,297	1	$ 12,080	$ 125,377		Low	
Parkinson and Newell	IMP22678	764	18	42	$ 475	$ 362,793	2	$ 25,060	$ 387,853		Low	
Parkinson and Newell	IMP22679	370	18	42	$ 475	$ 175,970	1	$ 12,530	$ 188,500		Low	
		3258					**11**		**$1,426,924**	**$0**		**$1,500,000**
Portage	IMP23052	89	15	27	$ 350	$ 31,232	2	$ 24,310	$ 55,542		Low	
Portage	IMP23056	316	15	27	$ 350	$ 110,577	1	$ 12,155	$ 122,732		Low	
Portage	IMP23057	151	15	27	$ 350	$ 52,826	1	$ 12,155	$ 64,981		Low	
Portage	IMP23058	6	12	27	$ 350	$ 2,023	1	$ 12,155	$ 14,178		Low	
		562					**5**		**$257,434**	**$0**		**$270,000**
Ross and Ames	IMP22133	523	18	36	$ 425	$ 222,093	2	$ 24,760	$ 246,853		Low	
Ross and Ames	IMP22977	321	15	36	$ 425	$ 136,277	1	$ 12,380	$ 148,657		Low	
		843					**3**		**$395,510**	**$0**		**$420,000**
Ross Road to Matadero Creek	IMP22243	43	12	18	$ 270	$ 11,673	2	$ 23,860	$ 35,533		Low	
Ross Road to Matadero Creek	IMP22516	266	12	18	$ 270	$ 71,788	1	$ 11,930	$ 83,718		Low	
Ross Road to Matadero Creek	IMP22900	44	12	18	$ 270	$ 11,792	1	$ 11,930	$ 23,722		Low	
Ross Road to Matadero Creek	IMPNew4	431	-	48	$ 525	$ 226,431	1	$ 12,680	$ 239,112	1	Low	
		784					**5**		**$382,085**	**$40,000**		**$440,000**
Seale	IMP22344	561	24	36	$ 425	$ 238,417	2	$ 24,760	$ 263,177		Moderate	
Seale	IMP22345	559	21	36	$ 425	$ 237,643	2	$ 24,760	$ 262,403		Moderate	
Seale	IMP22380	481	2x3 culvert	3 x 4 Culvert	$ 724	$ 348,267	1	$ 13,820	$ 362,087		Moderate	
Seale	IMP22381	300	2x3 culvert	3 x 4 Culvert	$ 724	$ 217,227	1	$ 13,820	$ 231,047		Moderate	

MATADERO DRAINAGE AREA
DETAILED CONSTRUCTION ESTIMATE

Project	Name	Length (ft)	Ex Diam (in)	Imp Diam (in)	Pipe Unit Cost	Pipe Cost	MHs	MH Cost	Total	Outfalls	Priority	Project Cost (w/ 5% mob/demob)
Seale	IMP22430	195	2x3 culvert	3 x 4 Culvert	$ 724	$ 141,252	1	$ 13,820	$ 155,072		Moderate	
Seale	IMP22685	18	2x3 culvert	3 x 4 Culvert	$ 724	$ 13,045	1	$ 13,820	$ 26,865		Moderate	
Seale	IMP22801	528	27	36	$ 425	$ 224,468	2	$ 24,760	$ 249,228		Moderate	
Seale	IMP22802	563	27	36	$ 425	$ 239,357	2	$ 24,760	$ 264,117		Moderate	
Seale	IMP22803	81	30	36	$ 425	$ 34,340	1	$ 12,380	$ 46,720		Moderate	
Seale	IMP22804	283	30	36	$ 425	$ 120,392	1	$ 12,380	$ 132,772		Moderate	
Seale	IMP22805	294	30	36	$ 425	$ 124,912	1	$ 12,380	$ 137,292		Moderate	
Seale	IMP22806	258	30	36	$ 425	$ 109,556	1	$ 12,380	$ 121,936		Moderate	
Seale	IMP22807	20	27	36	$ 425	$ 8,378	1	$ 12,380	$ 20,758		Moderate	
Seale	IMP22852	569	21	36	$ 425	$ 241,911	2	$ 24,760	$ 266,671		Moderate	
Seale	IMP22855	281	24	36	$ 425	$ 119,629	1	$ 12,380	$ 132,009		Moderate	
Seale	IMP22856	279	24	36	$ 425	$ 118,427	1	$ 12,380	$ 130,807		Moderate	
Seale	IMP23199	267	2x3 culvert	3 x 4 Culvert	$ 724	$ 193,580	1	$ 13,820	$ 207,400		Moderate	
Seale	IMP23200	47	2.25 culvert	36	$ 425	$ 19,952	1	$ 12,380	$ 32,332		Moderate	
		5585					**23**		**$3,042,692**	**$0**		**$3,190,000**
Walter Hays	IMP22032	256	18	48	$ 525	$ 134,362	2	$ 25,360	$ 159,722		Low	
Walter Hays	IMP22033	90	18	48	$ 525	$ 47,162	1	$ 12,680	$ 59,842		Low	
Walter Hays	IMP22371	63	18	48	$ 525	$ 32,818	1	$ 12,680	$ 45,498		Low	
Walter Hays	IMP22372	154	15	48	$ 525	$ 80,965	1	$ 12,680	$ 93,645		Low	
Walter Hays	IMP22592	42	21	48	$ 525	$ 21,794	1	$ 12,680	$ 34,474		Low	
Walter Hays	IMP22684	169	15	48	$ 525	$ 88,842	1	$ 12,680	$ 101,522		Low	
		773					**7**		**$494,703**	**$0**		**$520,000**
Waverley	IMP22632	13	12	15	$ 250	$ 3,192	2	$ 23,700	$ 26,892		Low	
Waverley	IMP22633	461	12	15	$ 250	$ 115,251	1	$ 11,850	$ 127,101		Low	
Waverley	IMP22637	434	12	15	$ 250	$ 108,411	1	$ 11,850	$ 120,261		Low	
		907					**4**		**$274,255**	**$0**		**$290,000**
TOTAL MATADERO DRAINAGE AREA CONSTRUCTION ESTIMATE												**$ 47,690,000**

CONDITION ASSESSMENT
DETAILED CONSTRUCTION ESTIMATE

Project	Rank	Priority	Length	Action Summary	Project Cost (w/ 5% Mob/Demob)
A-1	5	Highest	28	Replace	$7,500
A-2	4	High	46	Line	$4,100
A-3	3	Moderate	22	Line	$1,900
A-4	3	Moderate	39	Spot repair, line	$5,300
A-6	4	High	46	Line	$4,500
A-8	3	Moderate	28	Line	$4,100
A-5	3	Moderate	41	Line	$7,000
A-7	5	Highest	31	Replace	$2,500
A-9	3	Moderate	26	Line	$2,100
A-10	3	Moderate	28	Line	$2,500
A-11	3	Moderate	28	Line	$2,200
A-12	4	High	56	Replace,remove cable	$11,700
A-13	3	Moderate	31	Line	$2,800
A-14	4	High	30	Replace	$6,800
A-15	4	High	21	3 spot repair, line	$7,300
A-16	4	High	22	spot repair, line	$3,700
A-17	3	Moderate	18	Inlet repair, line	$2,600
A-19	3	Moderate	25	Line	$2,700
A-20	4	High	34	Replace	$7,700
A-21	4	High	27	Grade inlet, spot repair, line	$5,200
A-22	3	Moderate	34	Spot repair, line	$4,900
A-23	5	Highest	34	Replace	$7,700
A-24	4	High	32	Replace inlet, line	$5,900
A-25	5	Highest	25	Replace inlet, clear sediment, line	$6,900
A-26	5	Highest	34	Replace	$6,800
A-27	3	Moderate	20	Line	$1,800
A-28	3	Moderate	51	Line	$4,600
A-29	3	Moderate	43	Line	$5,100
A-30	3	Moderate	52	Spot repair, line	$6,400
A-31	5	Highest	34	Repair	$1,800
A-32 24-in.	3	Moderate	48	Spot repair, line	$7,400
A-32 18-in.	3	Moderate	48	Spot repair, line	$8,800
A-33 d/s	4	High	21	Replace	$6,900
A-33 u/s	4	High	40	Line	$5,200
A-34 d/s	5	Highest	81	Replace	$18,300
A-34 u/s	5	Highest	88	Replace	$19,800
A-35	5	Highest	55	Replace	$12,500
A-36	4	High	27	Replace	$6,100
A-37	4	High	38	Replace inlet, clear sediment, line	$7,500
A-38	4	High	41	Clear sediment, line	$4,800
A-39	5	Highest	37	Replace	$9,200
A-40	4	High	42	Replace	$10,400
A-41	4	High	36	Spot repair, line	$7,200
A-42	5	Highest	23	Inlet structure, clear sediment	$4,100
A-43	4	High	23	Clear sediment, line	$3,200
TOTAL CONSTRUCTION ESTIMATE					**$277,500**

A. Project ID: 1	B. Project Name: Corporation & E. Bayshore

C. Project Location: **E. Bayshore Rd. between Corporation Way and Adobe Creek**

D. Priority: Highest

E. Type: Capacity

F. Project Description: The existing pipes on E. Bayshore Rd. west of Corporation Way lack the capacity required to convey 10-year storm runoff and water cannot gravity flow when the water level in Adobe Creek is high. Existing pipes should be upsized and a pump station should be installed to achieve a 10 year level of service.

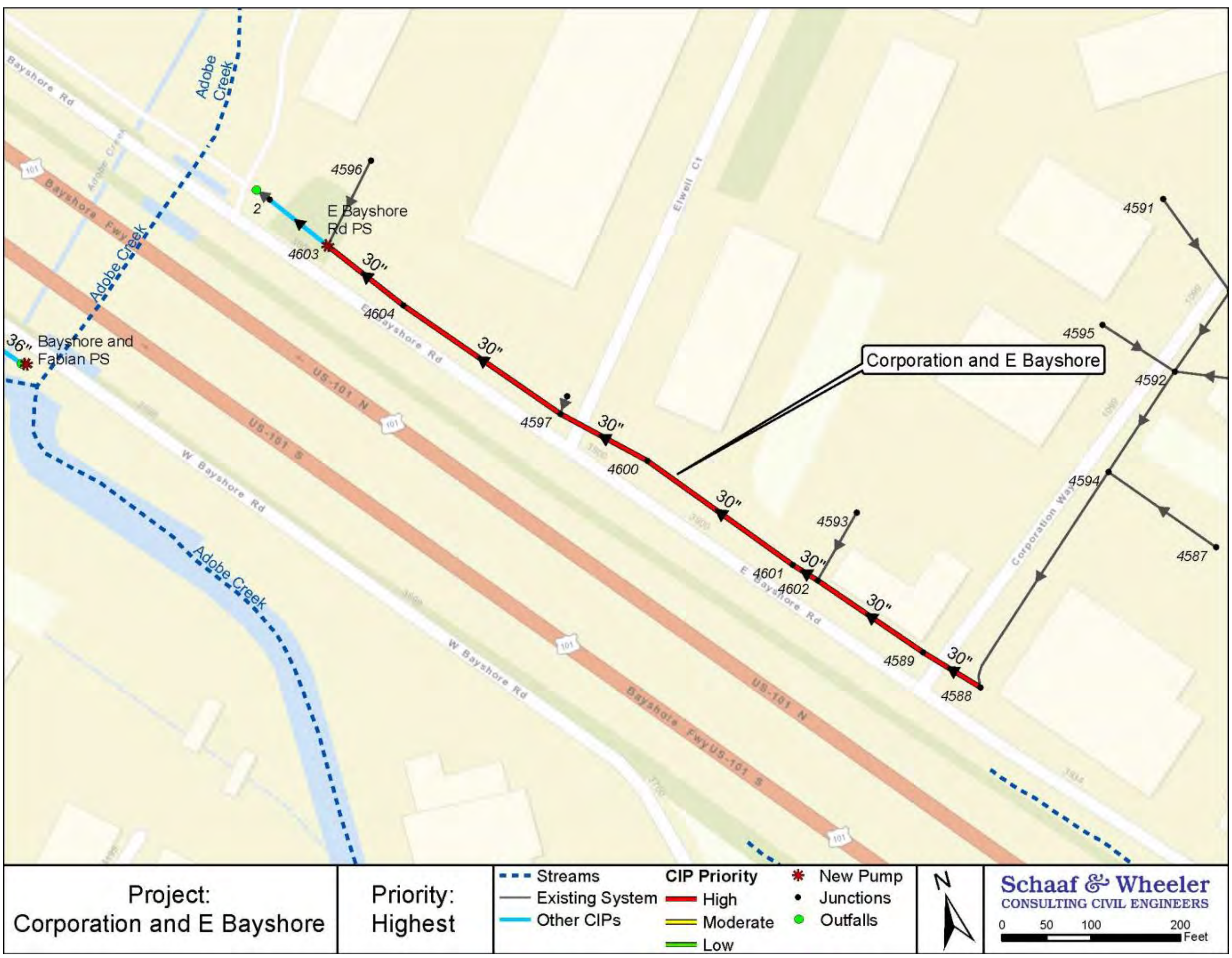
Ex. Pump Capacity (cfs)	Imp. Pump Capacity (cfs)
N/A	25

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
21	30	642
22	30	60

G. Construction Subtotal **$1,550,000**

H. Total Construction Cost **$2,020,000**

I. Estimated CIP **$2,420,000**



A. Project ID: 2	**B. Project Name: Matadero Pump Station**

C. Project Location: Existing Matadero Pump Station at Matadero Creek

D. Priority: Highest

E. Type: Capacity

F. Project Description: The existing Matadero pump station lacks the capacity required to convey 10-year storm runoff. Upsizing the Matadero Pump Station is necessary before other improvements in the Matadero system are constructed. Demolishing the existing pump station and building a new pump station in its place is recommended.

Ex. Pump Capacity (cfs)	Imp. Pump Capacity (cfs)
285	380

G. Construction Subtotal **$7,390,000**

H. Total Construction Cost **$9,610,000**

I. Estimated CIP **$11,530,000**

Project: Matadero Pump Station	Priority: Highest	Streams; Existing System; Other CIPs; CIP Priority: High, Moderate, Low; New Pump; Junctions; Outfalls	N	Schaaf & Wheeler CONSULTING CIVIL ENGINEERS 0 25 50 100 Feet

A. Project ID: 3	**B. Project Name: Bayshore & Fabian**

C. Project Location: West Bayshore Rd. near Hwy 101 to Adobe Creek outfall

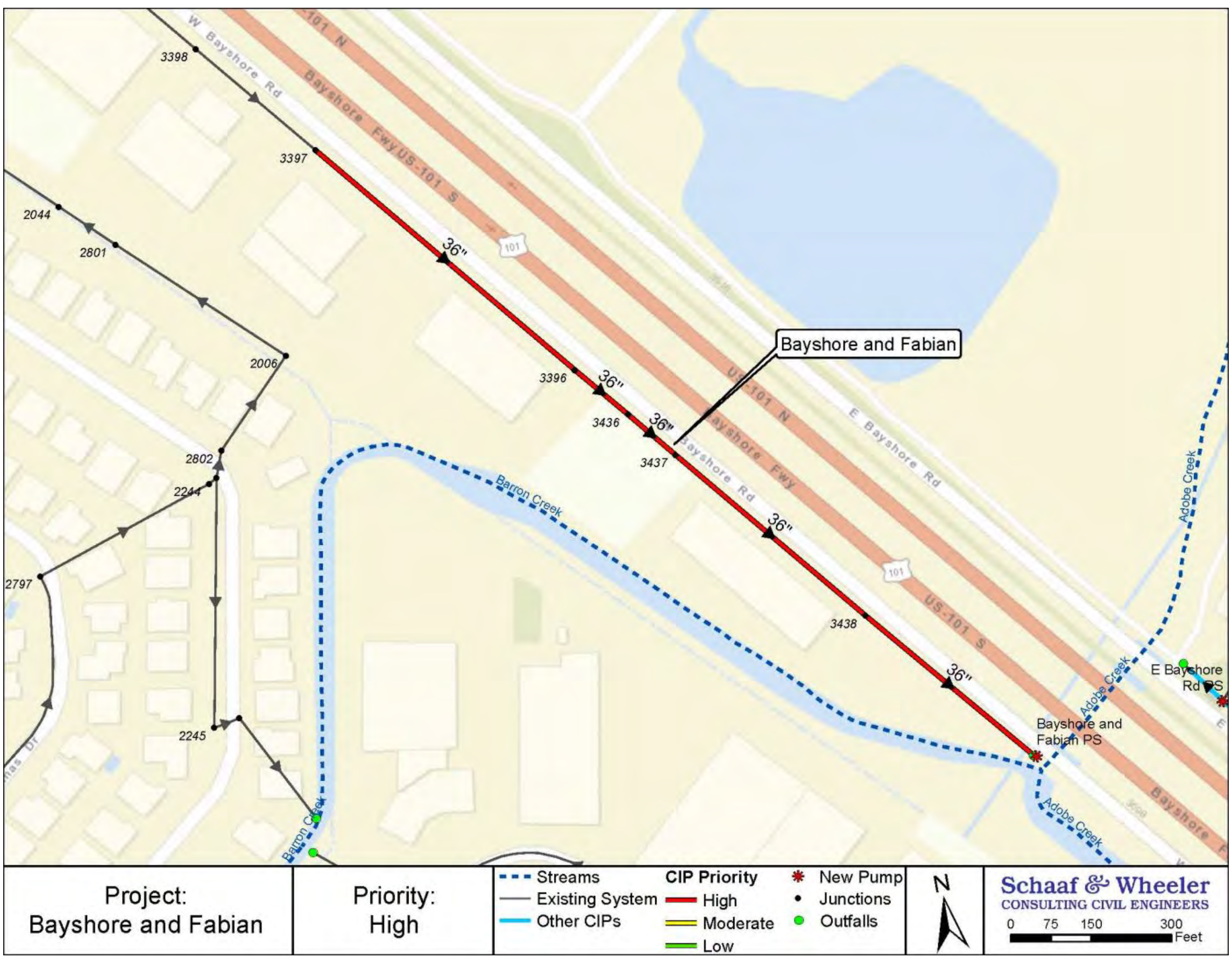
D. Priority: High

E. Type: Capacity

F. Project Description: The existing pipes on West Bayshore Rd. near Fabian Way lack the capacity required to convey 10-year storm runoff to the outlet. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
15	36	1,392

G. Construction Subtotal **$890,000**
H. Total Construction Cost **$1,160,000**
I. Estimated CIP **$1,390,000**



A. Project ID: 4 | **B. Project Name: Bayshore & Fabian Pump Station**

C. Project Location: West Bayshore Rd. near Hwy 101 to Adobe Creek outfall

D. Priority: High

E. Type: Capacity

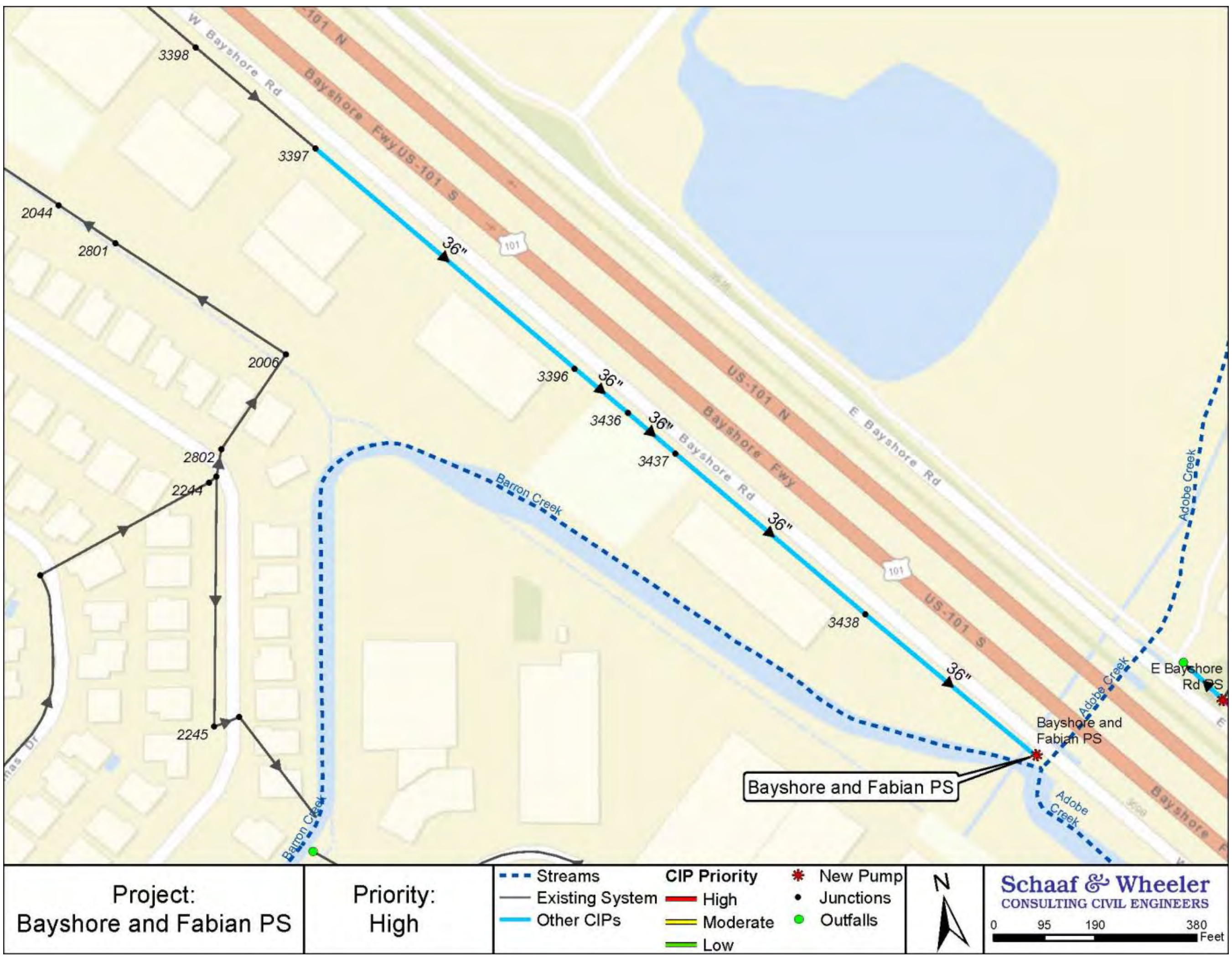
F. Project Description: The pipes on W. Bayshore Rd. near Fabian Way cannot flow by gravity to Adobe Creek when the water level in the creek is high. Installing a pump station to achieve a 10 year level of service is recommended. This project should be constructed after Project ID 3 is in place.

Ex. Pump Capacity (cfs)	Imp. Pump Capacity (cfs)
N/A	15

G. Construction Subtotal **$670,000**

H. Total Construction Cost **$870,000**

I. Estimated CIP **$1,040,000**



A. Project ID: 5 | **B. Project Name: Charleston & Adobe Cr**

C. Project Location: North of E. Charleston Rd. to Adobe Creek Outfall

D. Priority: High

E. Type: Capacity

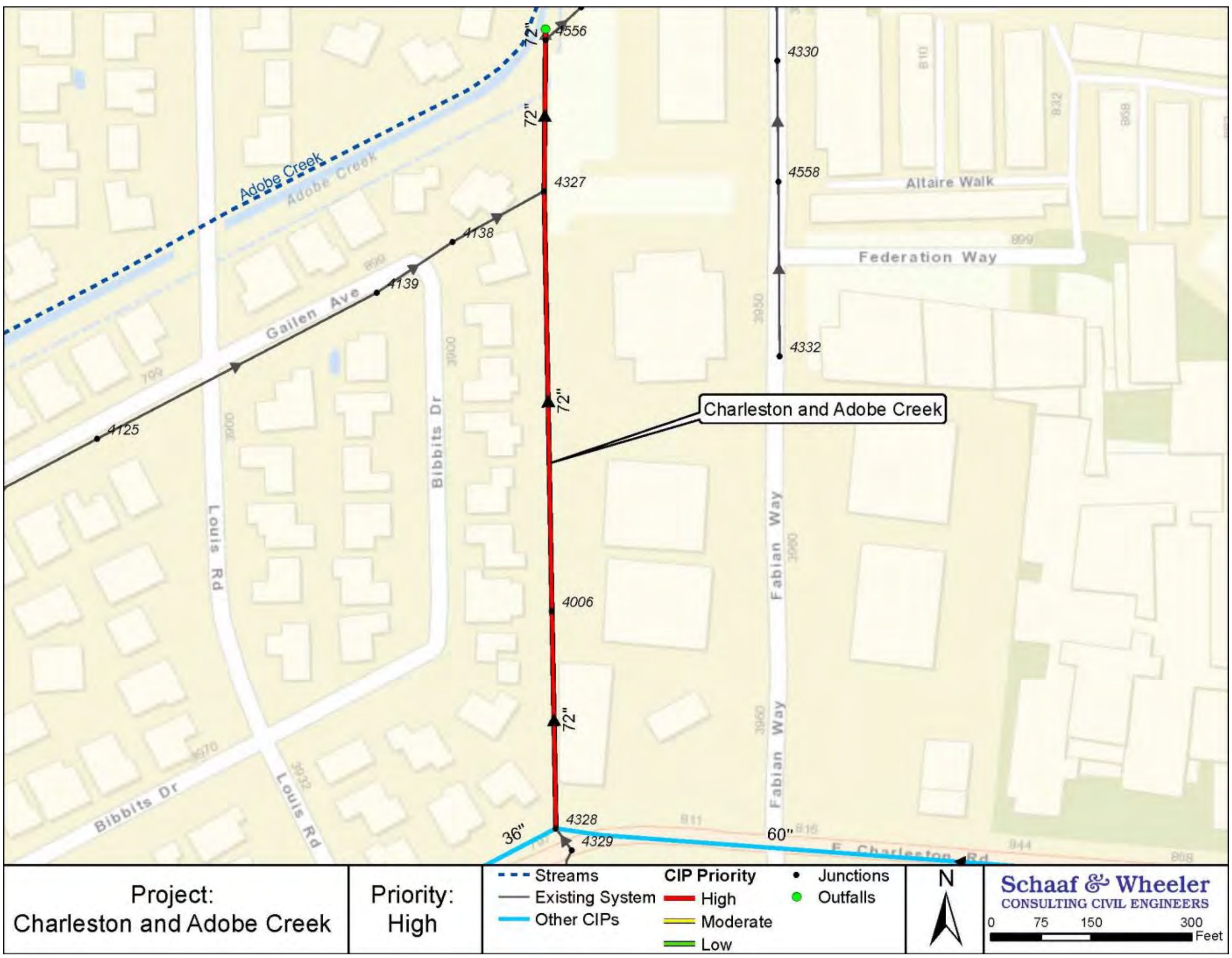
F. Project Description: The existing pipes between E. Charleston Rd. and the Adobe Creek gravity outfall near Gailen Ave. lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended. The large pipe will route water toward the gravity outfall and toward the Adobe Pump Station. The larger pipe will also provide storage during the storm peak.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
36	72	946

G. Construction Subtotal **$830,000**

H. Total Construction Cost **$1,080,000**

I. Estimated CIP **$1,300,000**



A. **Project ID**: **6**	B. **Project Name**: **E Meadow Cir**
C. **Project Location**: **E. Meadow Circle north of E. Meadow Dr.**	
D. **Priority**: **High**	

E. **Type: Capacity**

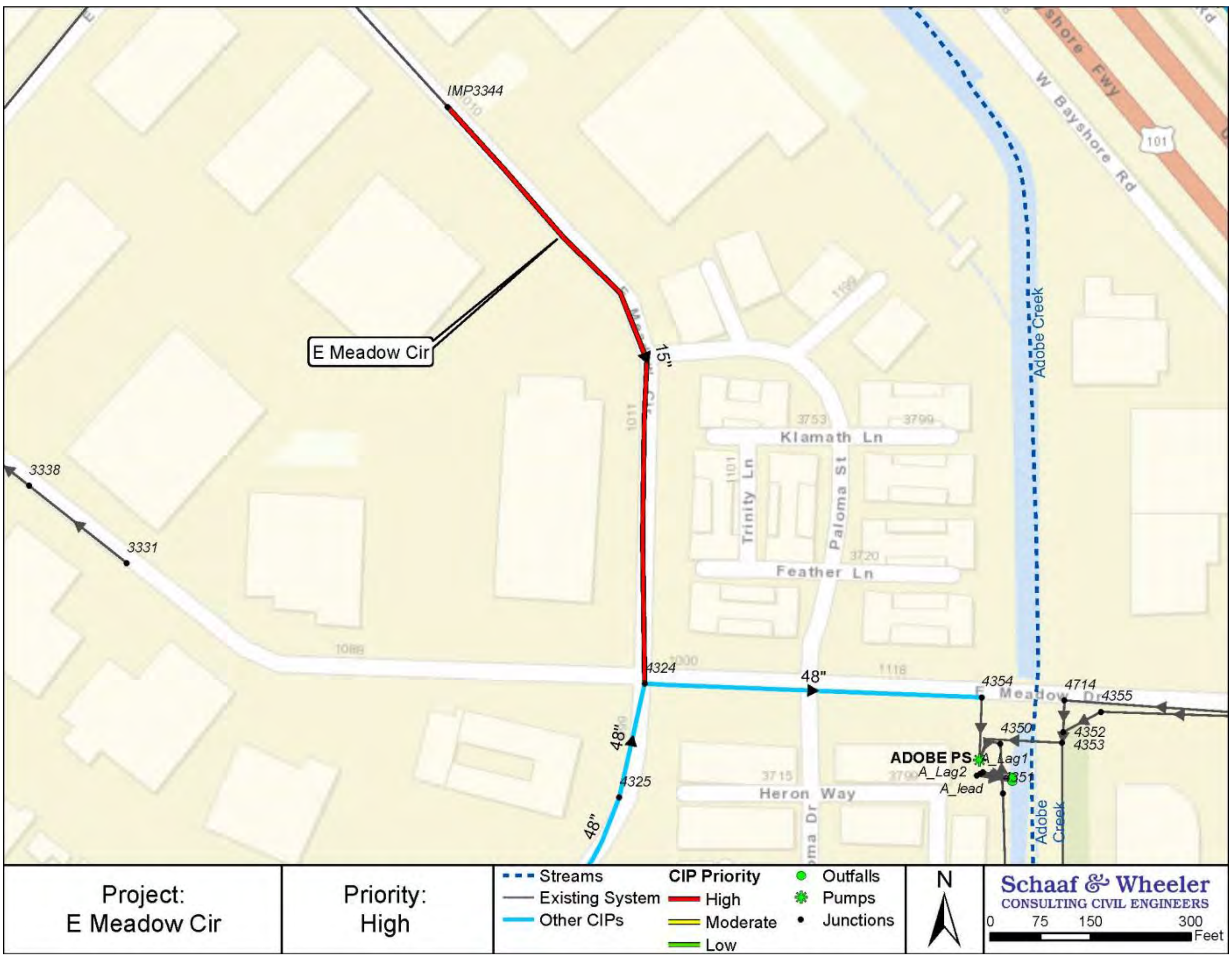
F. **Project Description:** The existing storm drain pipeline north of node IMP3344, which gravity outfalls to Barron Creek, lacks the capacity required to convey 10-year storm runoff, especially when creek levels are high. A new pipe connecting node IMP3344 to the E. Meadow Dr. system via a new pipe in E Meadow Cir will allow the system that flows to Barron Creek to overflow to the Adobe Pump Station during high flows and high creek levels.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
N/A	15	770

G. **Construction Subtotal** **$230,000**

H. **Total Construction Cost** **$300,000**

I. **Estimated CIP** **$360,000**



A. Project ID: 7	B. Project Name: E. Meadow Dr

C. Project Location: E. Meadow Dr. east of E. Meadow Cir. to Adobe PS

D. Priority: High

E. Type: Capacity

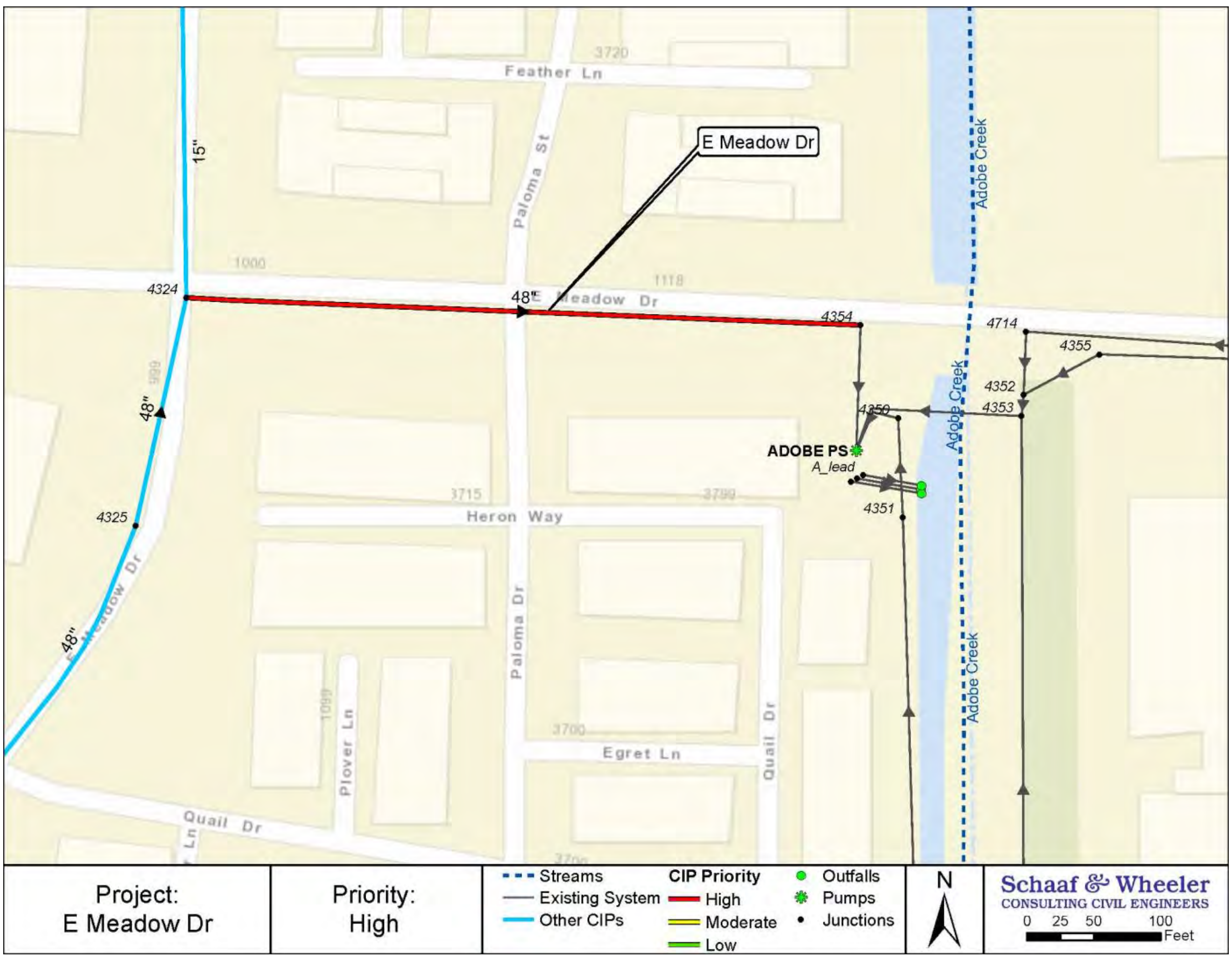
F. Project Description: The existing pipe on E. Meadow Dr. near the Adobe Pump Station lacks the capacity required to convey 10-year storm runoff to the pump station. Upsizing this pipe to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
36	48	401

G. Construction Subtotal **$250,000**

H. Total Construction Cost **$330,000**

I. Estimated CIP **$400,000**



A. Project ID: 8 | **B. Project Name: Fabian**

C. Project Location: Fabian Way between 3898 and 3850 Fabian Way

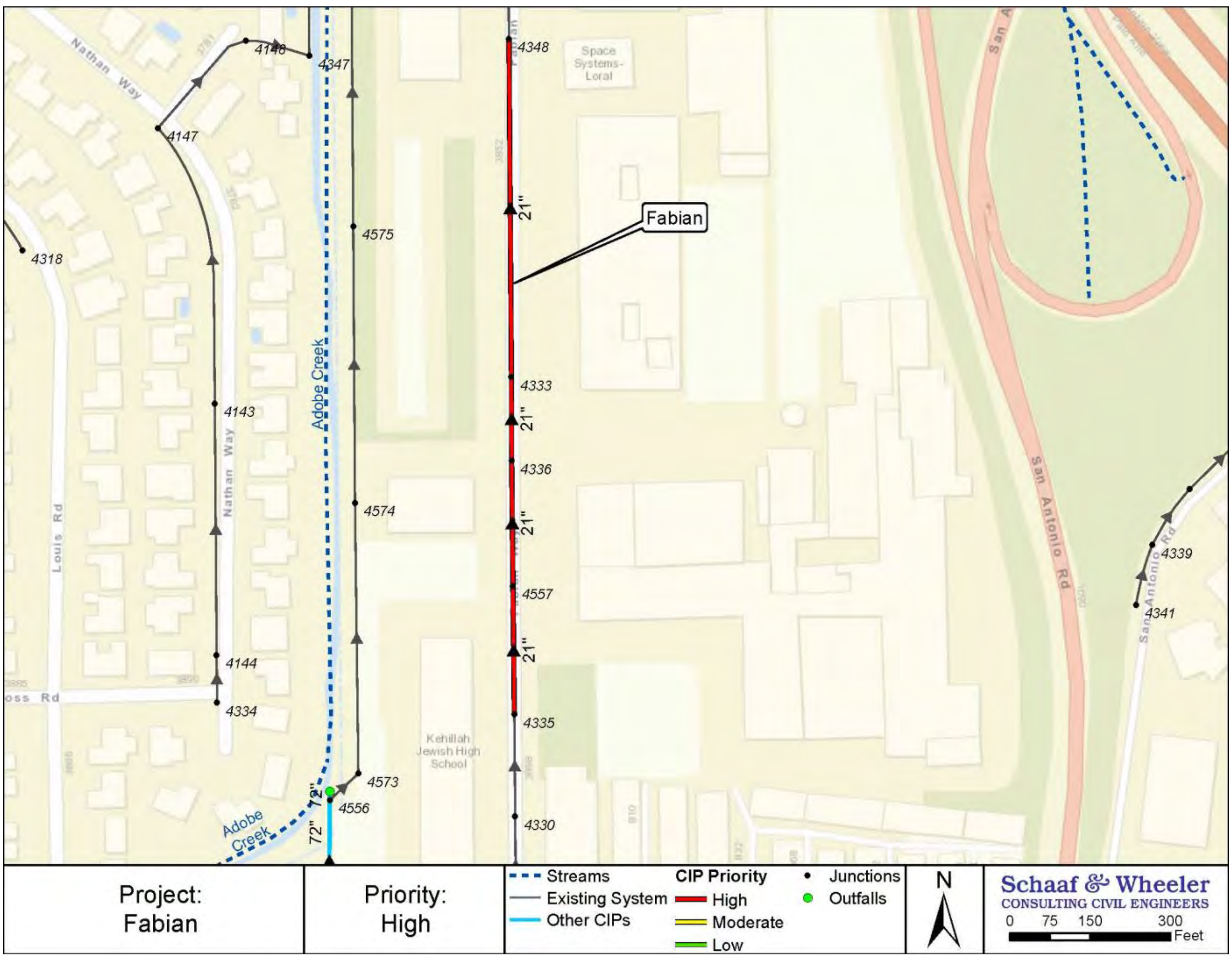
D. Priority: High

E. Type: Capacity

F. Project Description: The existing pipes on Fabian Way lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
15	21	500
18	21	500

G. Construction Subtotal $370,000
H. Total Construction Cost.. $480,000
I. Estimated CIP $580,000



A. Project ID: 9	**B. Project Name: Hamilton & Rhodes**

C. Project Location: Hamilton Ave. from Center Dr. to Rhodes Dr.

D. Priority: High

E. Type: Capacity

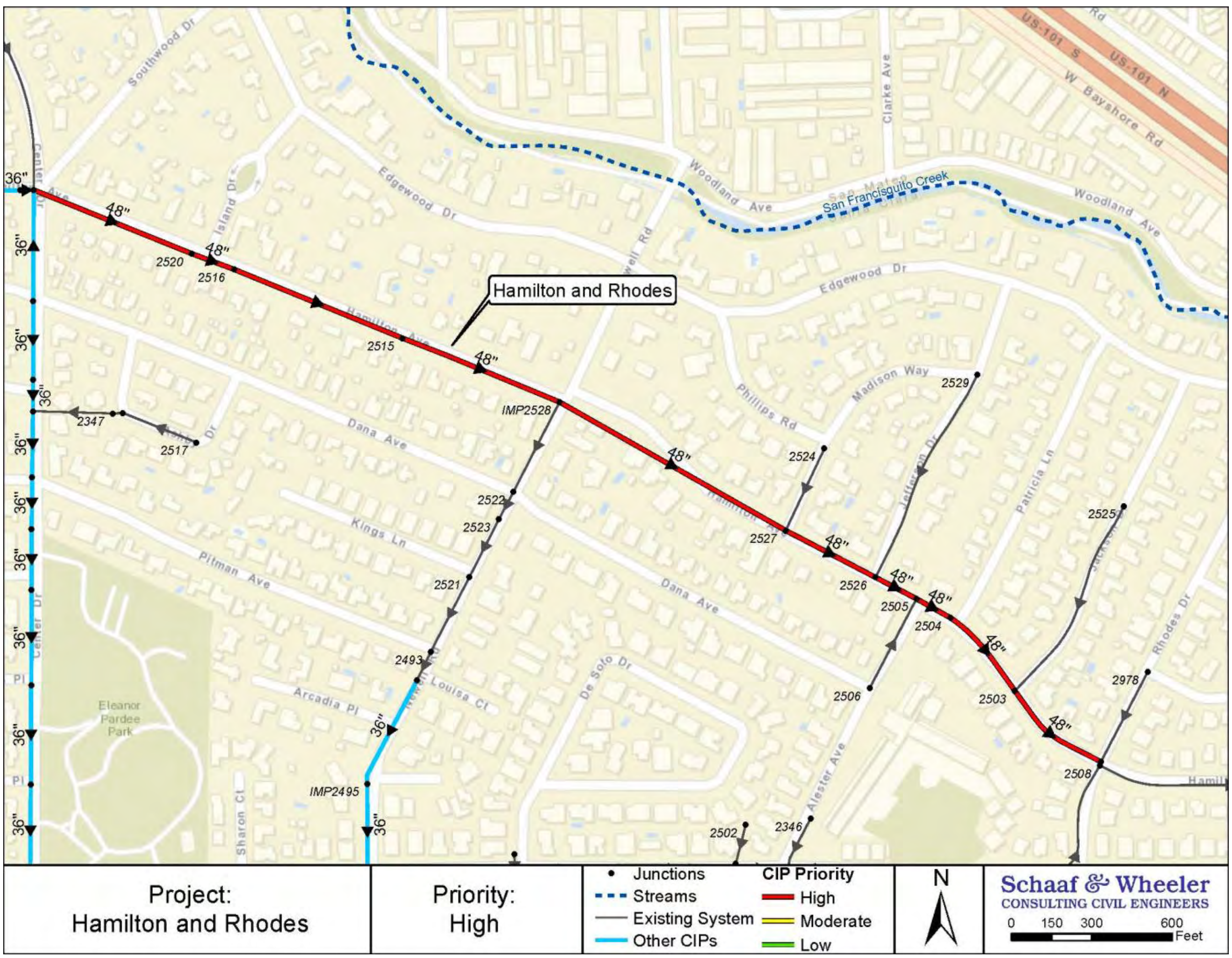
F. Project Description: The existing pipes on Hamilton Ave. and Rhodes Dr. lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
12	36	12
15	48	554
18	48	1,471
21	48	841
--	48	772

G. Construction Subtotal **$2,210,000**

H. Total Construction Cost **$2,870,000**

I. Estimated CIP **$3,440,000**



A. Project ID: 10 | **B. Project Name: Lincoln & Channing**

C. Project Location: Lincoln Ave. from Alma St. to Channing Ave.

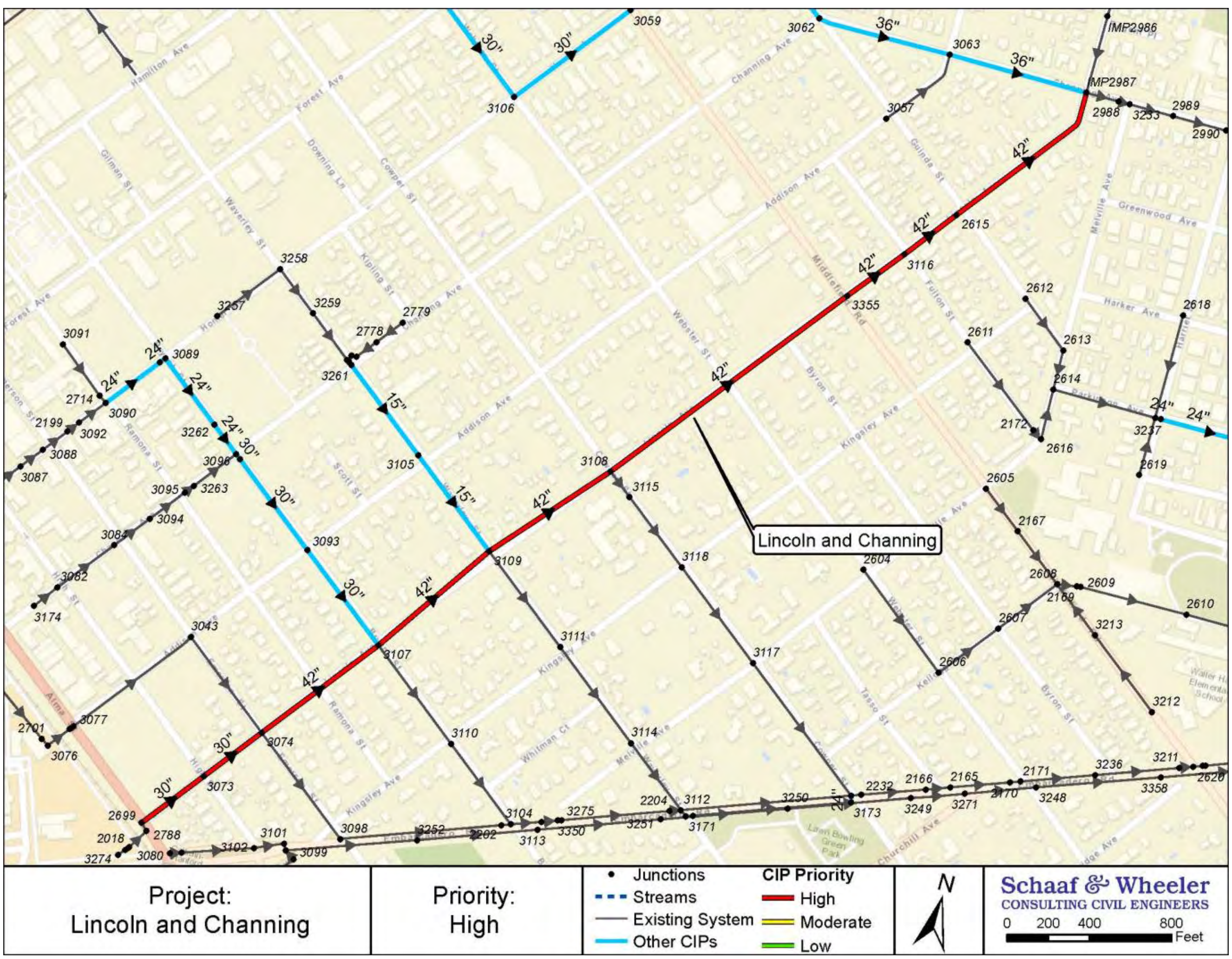
D. Priority: High

E. Type: Capacity

F. Project Description: Flooding that occurs along Embarcadero Road will be mitigated by diverting flows coming from the north by upsizing existing pipe and installing new pipe in Lincoln Ave from Alma St. to the newly upsized pipe in Channing Ave.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
12	30	299
12	42	1,232
24	30	279
--	42	2,818

G. Construction Subtotal **$2,430,000**
H. Total Construction Cost **$3,160,000**
I. Estimated CIP **$3,790,000**



A. Project ID: 11	**B. Project Name: Loma Verde & Maddux**

C. Project Location: Loma Verde Ave. between Louis Rd. and former Sterling Canal Easement just past Maddux Drive

D. Priority: High

E. Type: Capacity

F. Project Description: The existing pipes on Loma Verde Ave. between Louis Rd. and the former Sterling Canal easement just past Maddux Dr. lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
36	51	1,747

G. Construction Subtotal **$1,410,000**
H. Total Construction Cost **$1,830,000**
I. Estimated CIP **$2,200,000**

A. Project ID: 12 | **B. Project Name: Louis**

C. Project Location: Louis Rd. between Embarcadero Rd. and former Seale-Wooster Canal Easement just before Sycamore Drive

D. Priority: High

E. Type: Capacity

F. Project Description: The existing pipes on Louis Rd. between Embarcadero Rd. and the former Seale-Wooster Canal easement just before Sycamore Dr. lack the capacity required to convey 10-year storm runoff. This improvement will route the additional flow from upstream improvements to the Matadero Pump Station. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Size	Imp. Size	Length (ft)
3'x4'	4'x5'	1,087
3'x4.5'	4'x5'	1,145
3'x4.5'	4'x5.5'	39
3'x5'	4'x5'	53
3'x5'	4'x5.5'	813
3'x5.5'	4'x5.5'	1,010

G. Construction Subtotal **$4,430,000**
H. Total Construction Cost **$5,760,000**
I. Estimated CIP **$6,910,000**

A. Project ID: 13	**B. Project Name: Louis to Matadero Creek**

C. Project Location: Louis Rd. from the former Seale-Wooster Canal easement near west of Sycamore Dr. to Matadero Creek

D. Priority: High

E. Type: Capacity

F. Project Description: A new overflow pipe on Louis Rd. from near Sycamore Dr. to a new outfall at Matadero Creek is recommended to alleviate flooding in the pipes northwest of Sycamore Drive and achieve a 10 year level of service. The new pipe will provide storage during the storm peak and allow flow to leave the system when the creek water surface elevation is low.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
--	72	1,053

G. Construction Subtotal **$1,000,000**

H. Total Construction Cost **$1,300,000**

I. Estimated CIP **$1,560,000**

A. Project ID: 14

B. Project Name: Cambridge & Park

C. Project Location: Park Blvd. between Stanford Ave. and California Ave., Cambridge Ave. and Oxford Ave. between Birch St. and Park Blvd.

D. Priority: Moderate

E. Type: Capacity

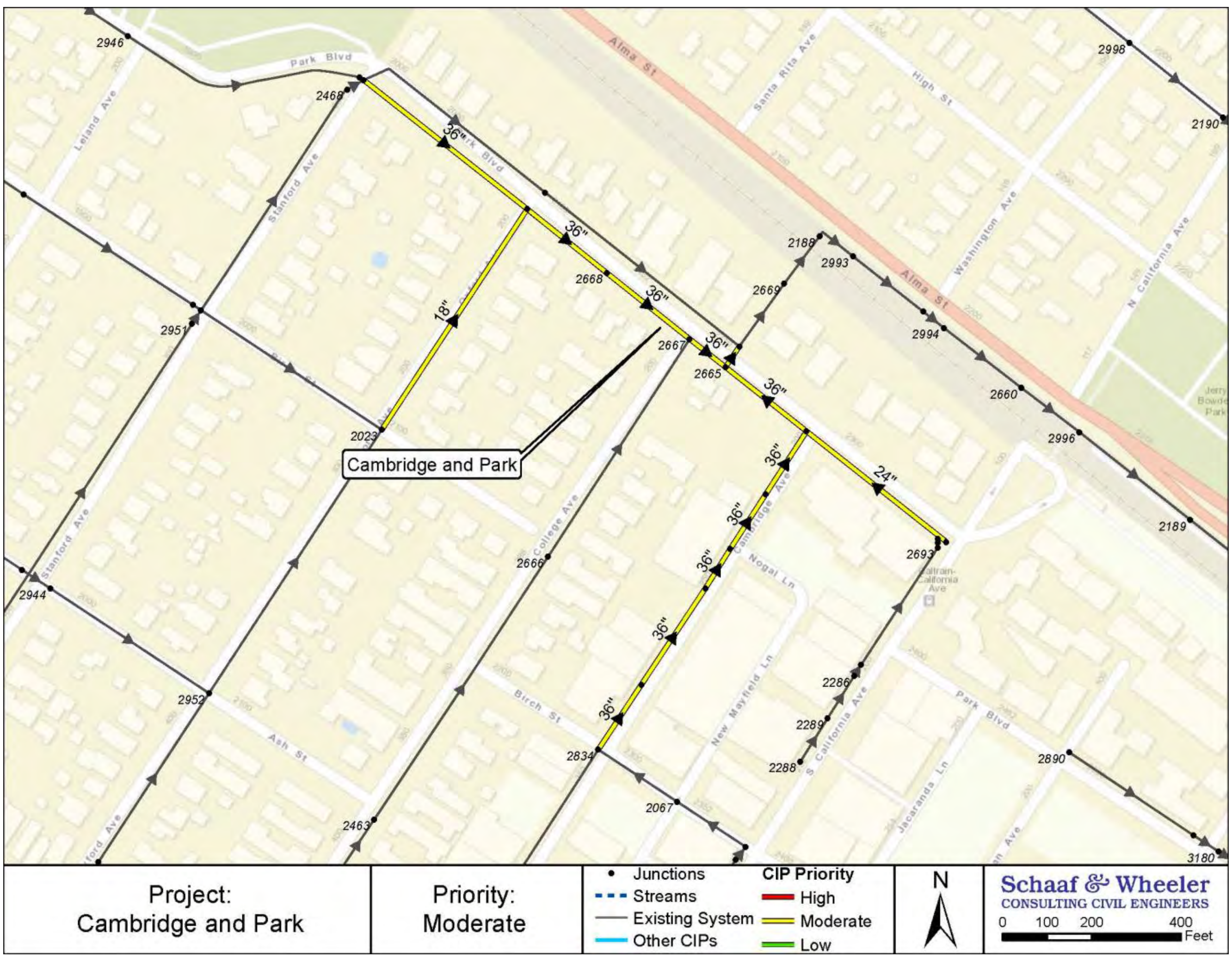
F. Project Description: The existing pipes on Cambridge Ave., Park Blvd., and Oxford Ave. lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
12	18	470
12	24	317
12	36	81
15	36	371
18	36	370
24	36	905

G. Construction Subtotal **$1,190,000**

H. Total Construction Cost **$1,550,000**

I. Estimated CIP **$1,860,000**



A. Project ID: 15	**B. Project Name: Center**

C. Project Location: Center Dr. from Channing Ave to Hamilton Ave.

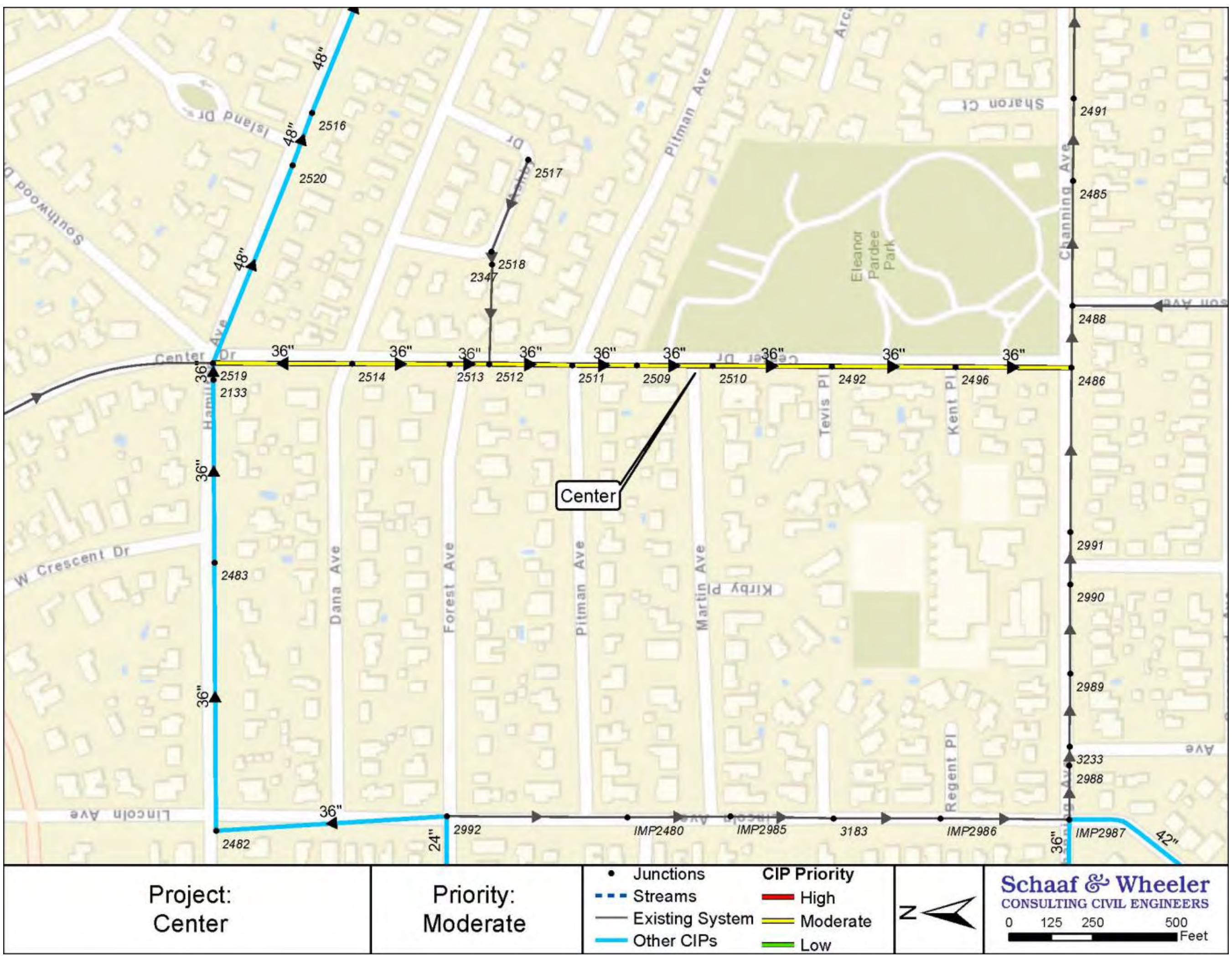
D. Priority: Moderate

E. Type: Capacity

F. Project Description: The existing pipes on Center Dr. lack the capacity required to convey 10-year storm runoff. Upsizing these pipes and adding a new pipe to connect to the Hamilton Ave. pipe network is recommended to achieve a 10 year level of service. Pipes will generally continue draining to Channing, with overflow to Hamilton during high flows.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
12	36	233
15	36	1,472
--	36	328

G. Construction Subtotal **$1,040,000**
H. Total Construction Cost **$1,350,000**
I. Estimated CIP **$1,620,000**



A. **Project ID: 16**	B. **Project Name: Charleston & Fabian**

C. Project Location: E. Charleston Rd. between San Antonio Rd. and Fabian Way

D. Priority: Moderate

E. Type: Capacity

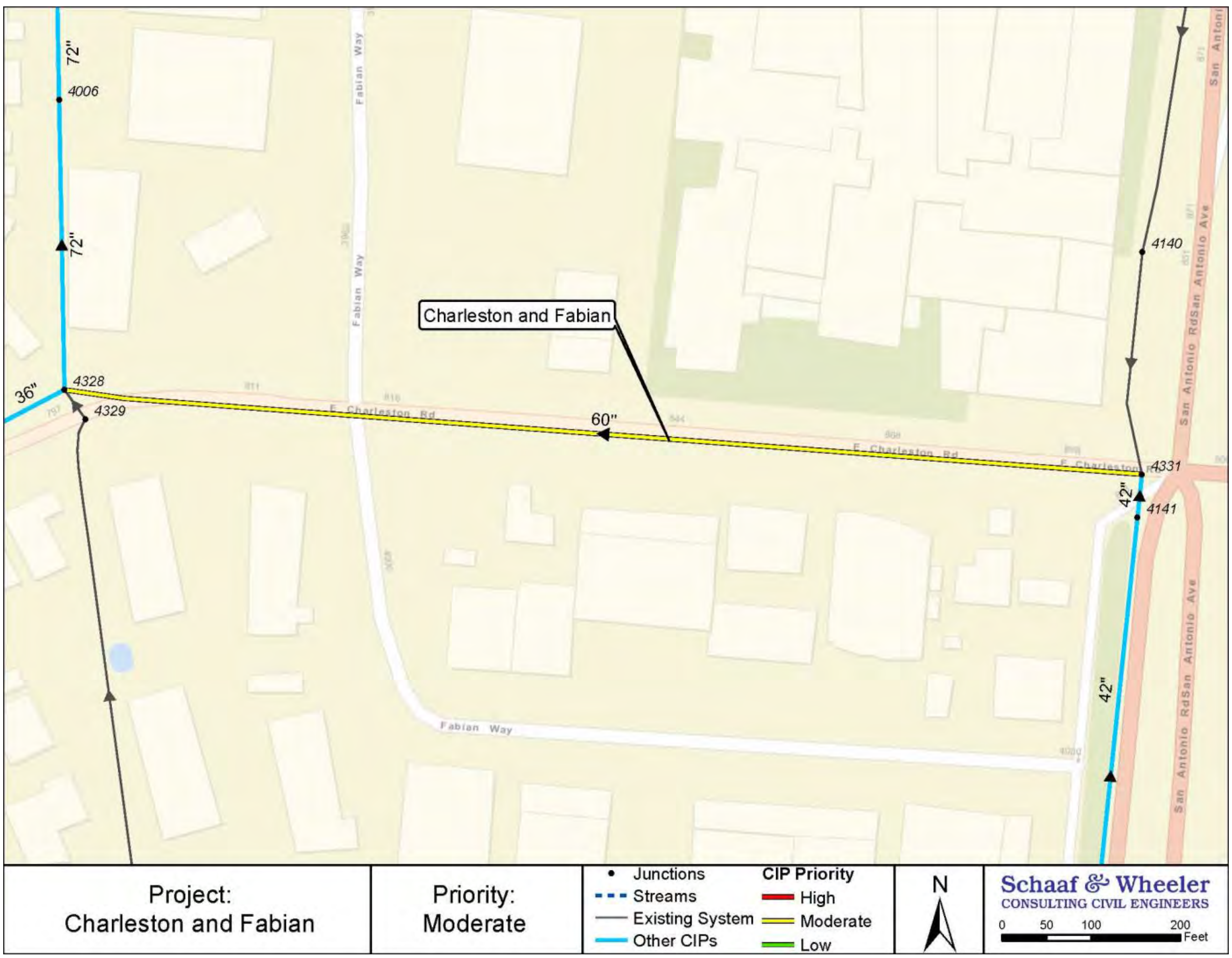
F. Project Description: The existing pipes on Charleston Rd. west of San Antonio Rd., near Fabian Way lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
30	60	964

G. Construction Subtotal **$660,000**

H. Total Construction Cost **$860,000**

I. Estimated CIP **$1,030,000**



A. **Project ID: 17**	B. **Project Name: El Camino Real & Los Robles**

C. Project Location: El Camino Real between Arastradero Rd. and Los Robles Ave.

D. Priority: Moderate

E. Type: Capacity

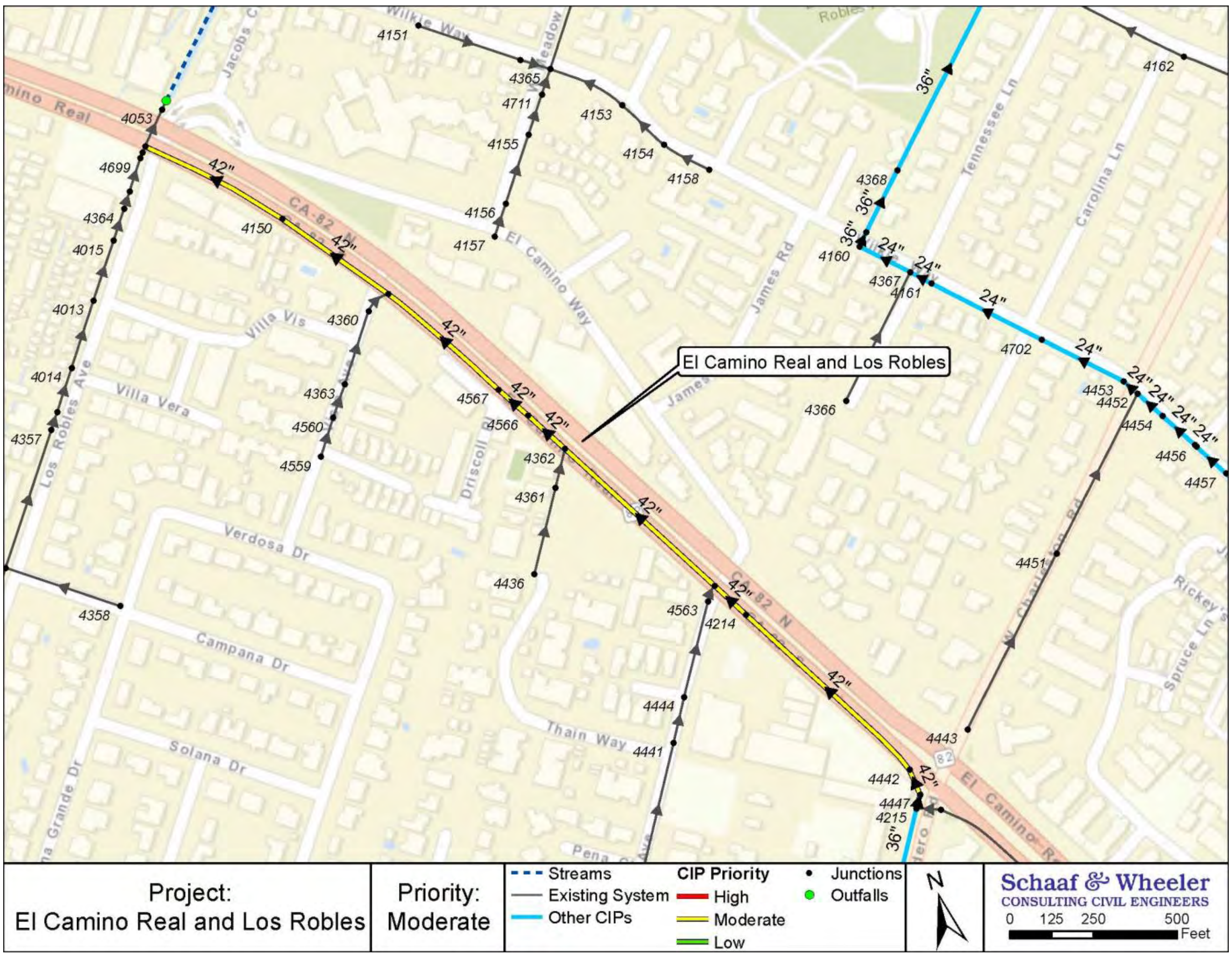
F. Project Description: The existing pipes on El Camino Real between Arastradero Rd. and the Barron Creek outfall near Los Robles Ave lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended. This project will require coordination with Caltrans.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
30	42	2,450

G. Construction Subtotal **$1,620,000**

H. Total Construction Cost..**$2,110,000**

I. Estimated CIP **$2,530,000**



A. Project ID: 18	**B. Project Name: Embarcadero**

C. Project Location: Embarcadero near Fulton St. to Newell Rd.

D. Priority: Moderate

E. Type: Capacity

F. Project Description: The existing pipes on Embarcadero Rd. near Rinconada Park lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
24	36	519
12	24	302

G. Construction Subtotal **$1,290,000**
H. Total Construction Cost **$1,680,000**
I. Estimated CIP **$2,020,000**

Project: Embarcadero	Priority: Moderate	Junctions Streams Existing System Other CIPs	CIP Priority High Moderate Low	N	Schaaf & Wheeler CONSULTING CIVIL ENGINEERS 0 75 150 300 Feet

A. Project ID: 19	B. Project Name: Loma Verde & Ross

C. Project Location: Loma Verde Ave. between Ross Rd. and Louis Rd.

D. Priority: Moderate

E. Type: Capacity

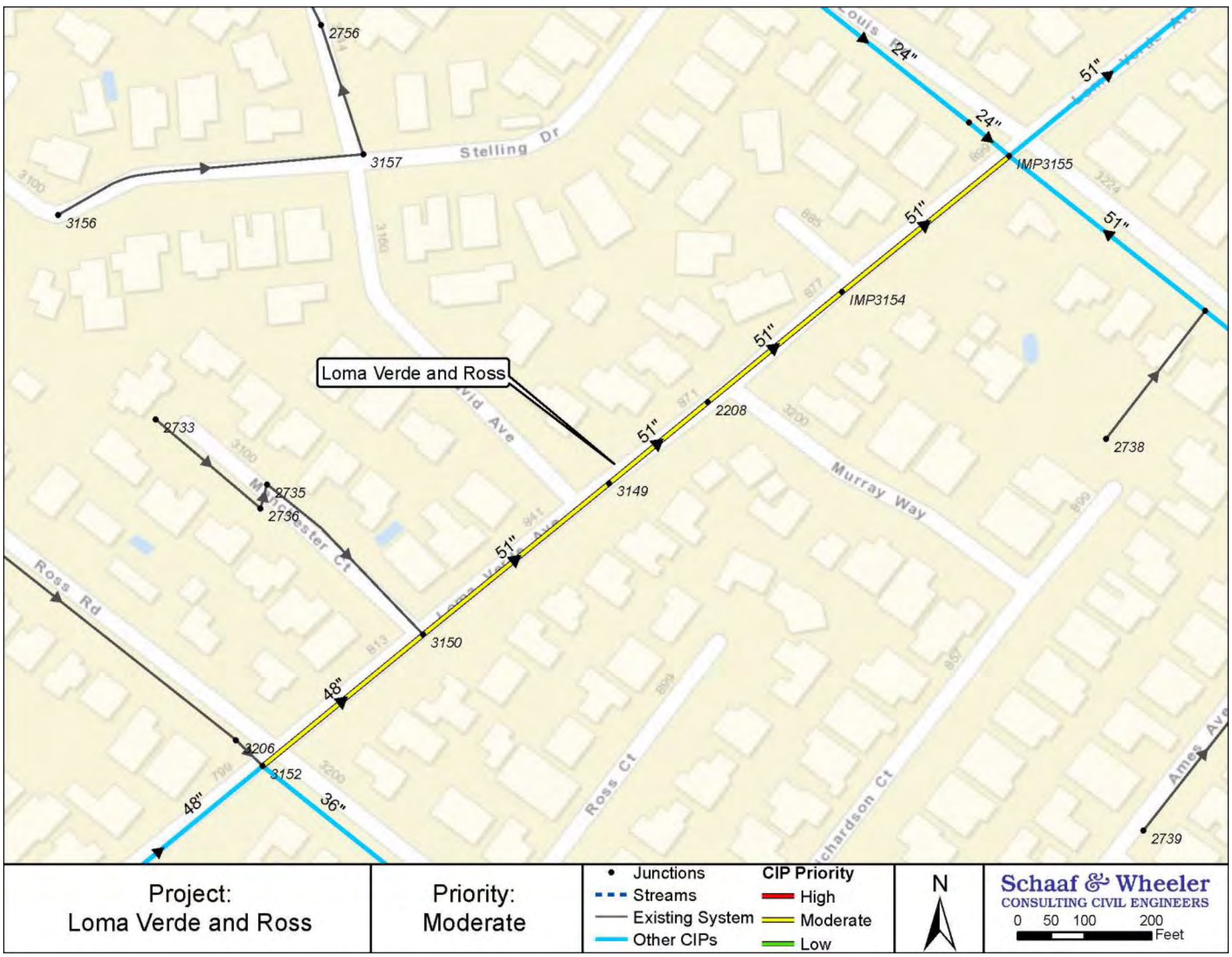
F. Project Description: The existing pipes on Loma Verde Ave. lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
30	48	246
30	51	899

G. Construction Subtotal **$860,000**

H. Total Construction Cost **$1,120,000**

I. Estimated CIP **$1,340,000**



A. **Project ID**: 20	B. **Project Name**: Municipal Service Center

C. **Project Location**: **Municipal Service Center (MSC) on East Bayshore Rd.**

D. **Priority**: **Moderate**

E. **Type**: **Capacity**

F. **Project Description:** The existing system near the MSC lacks the capacity required to convey the 10-year storm runoff. Upsizing existing pipe and constructing a new pump station with an outfall to Matadero Creek is recommended at this location.

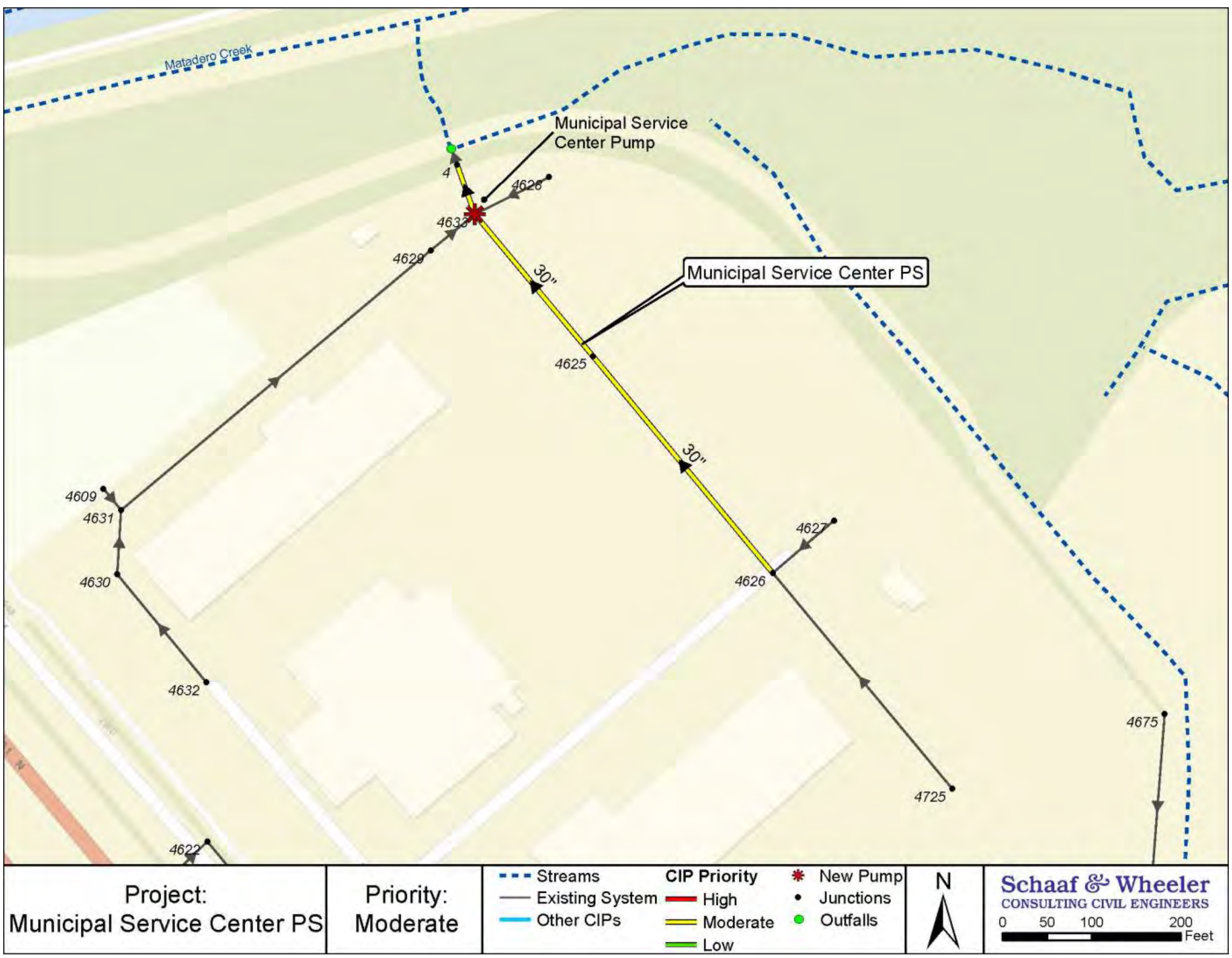
Ex. Capacity (cfs)	Imp. Capacity (cfs)
N/A	26

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
24	30	415

G. **Construction Subtotal** **$1,340,000**

H. **Total Construction Cost** **$1,740,000**

I. **Estimated CIP** **$2,090,000**



A. Project ID: 21 | **B. Project Name: Oregon Expwy Pump**

C. Project Location: Alma Street underpass on Oregon Expressway

D. Priority: Moderate

E. Type: Capacity

F. Project Description: The existing pump station at the Alma Street underpass has experienced maintenance issues and nuisance flooding. Improvement to maintenance and/or capacity of this pump station to achieve a 10-year level of service is recommended.

Ex. Capacity (cfs)	Imp. Capacity (cfs)
Unknown	5

G. Construction Subtotal **$210,000**

H. Total Construction Cost **$270,000**

I. Estimated CIP **$320,000**

A. Project ID: 22	**B. Project Name: Page Mill & Alma**

C. Project Location: Page Mill Rd. between El Camino Real and Alma St.

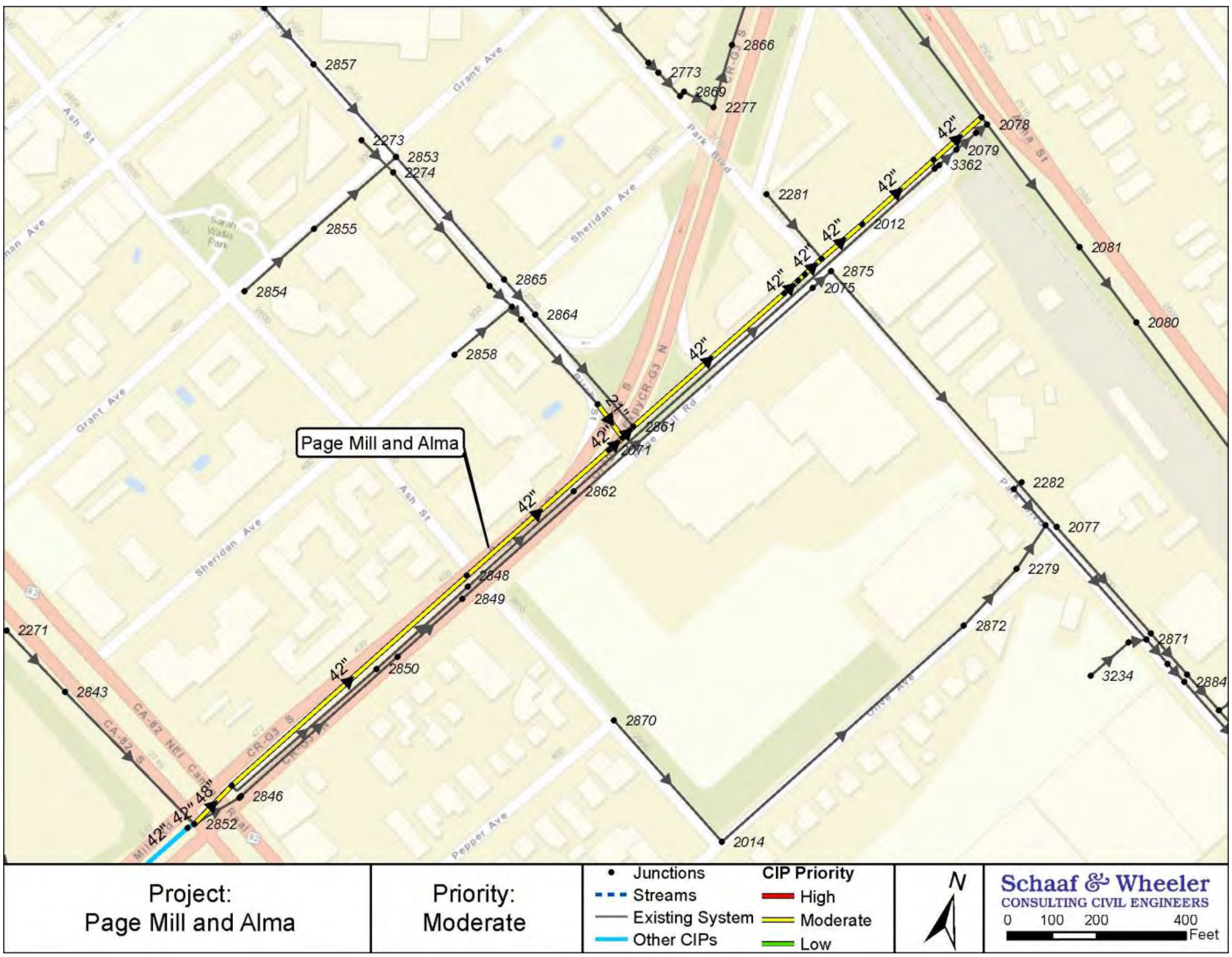
D. Priority: Moderate

E. Type: Capacity

F. Project Description: The existing pipes on Page Mill Rd. between El Camino and Alma St. lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
12	21	74
24	42	380
30	42	1,407
36	48	96

G. Construction Subtotal **$1,150,000**
H. Total Construction Cost **$1,500,000**
I. Estimated CIP **$1,800,000**



A. Project ID: 23	**B. Project Name: Page Mill & El Camino**

C. Project Location: Page Mill Rd. between Hanover St. and El Camino Real

D. Priority: Moderate

E. Type: Capacity

F. Project Description: The existing pipes on Page Mill Rd. southwest of El Camino Real lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
24	36	692
27	42	919
33	42	611
36	42	285

G. Construction Subtotal **$1,620,000**
H. Total Construction Cost **$2,110,000**
I. Estimated CIP **$2,530,000**

Project: Page Mill and El Camino Real	Priority: Moderate	Junctions; Streams; Existing System; Other CIPs; CIP Priority: High, Moderate, Low	N	Schaaf & Wheeler CONSULTING CIVIL ENGINEERS 0 125 250 500 Feet

A. Project ID: 24 | **B. Project Name: Seale**

C. Project Location: Seale Ave. between Alma St. and Louis Rd.

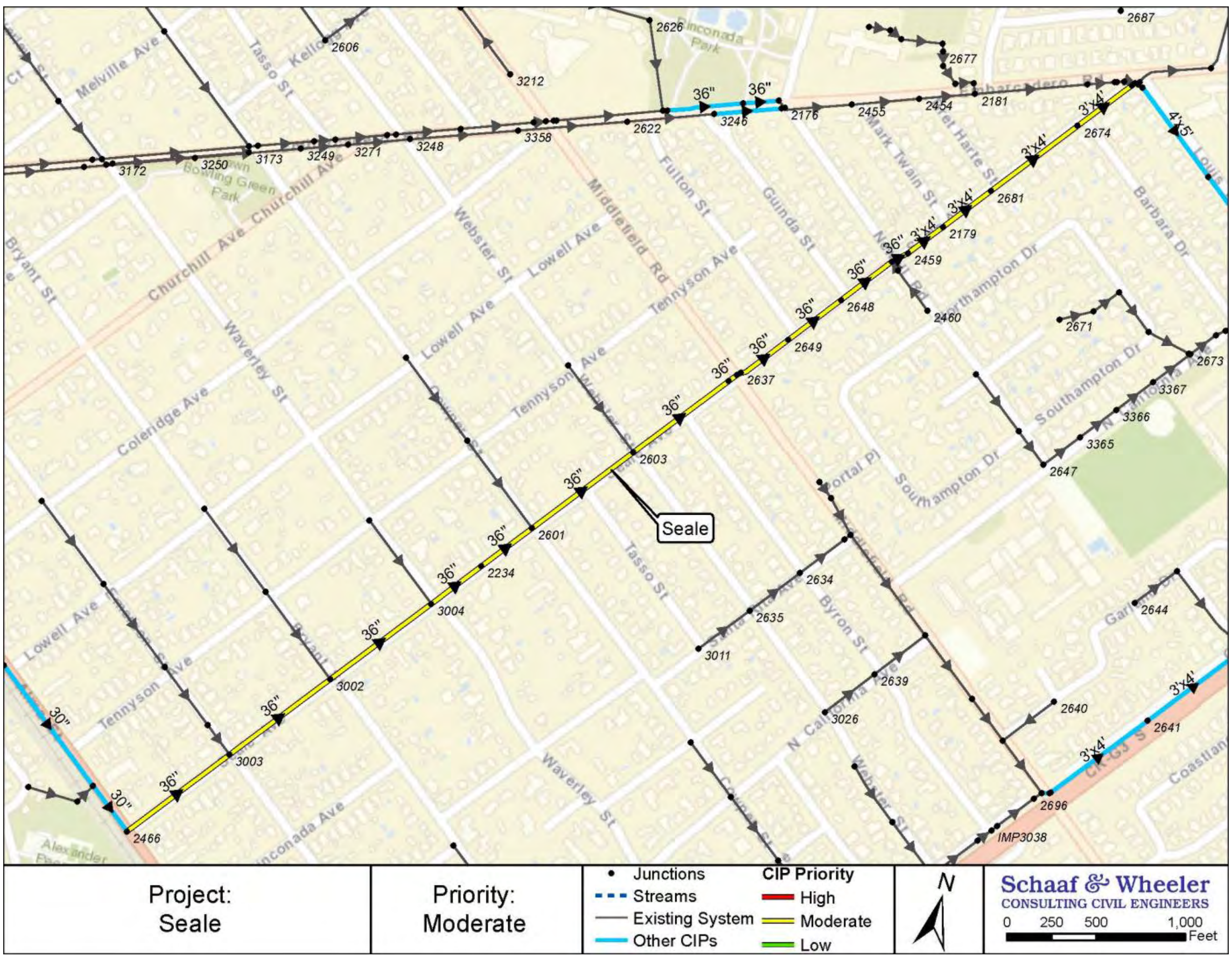
D. Priority: Moderate

E. Type: Capacity

F. Project Description: The existing pipes on Seale Ave. lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Size	Imp. Size	Length (ft)
21	36	1,128
24	36	1,121
27	36	1,111
30	36	916
2'x3'	3'x4'	1,262
2.25'x2.25'	36	47

G. Construction Subtotal **$3,190,000**
H. Total Construction Cost **$4,150,000**
I. Estimated CIP **$4,980,000**



A. Project ID: 25 | **B. Project Name: Alma**

C. Project Location: Alma St. between Coleridge Ave. and Seale Ave.

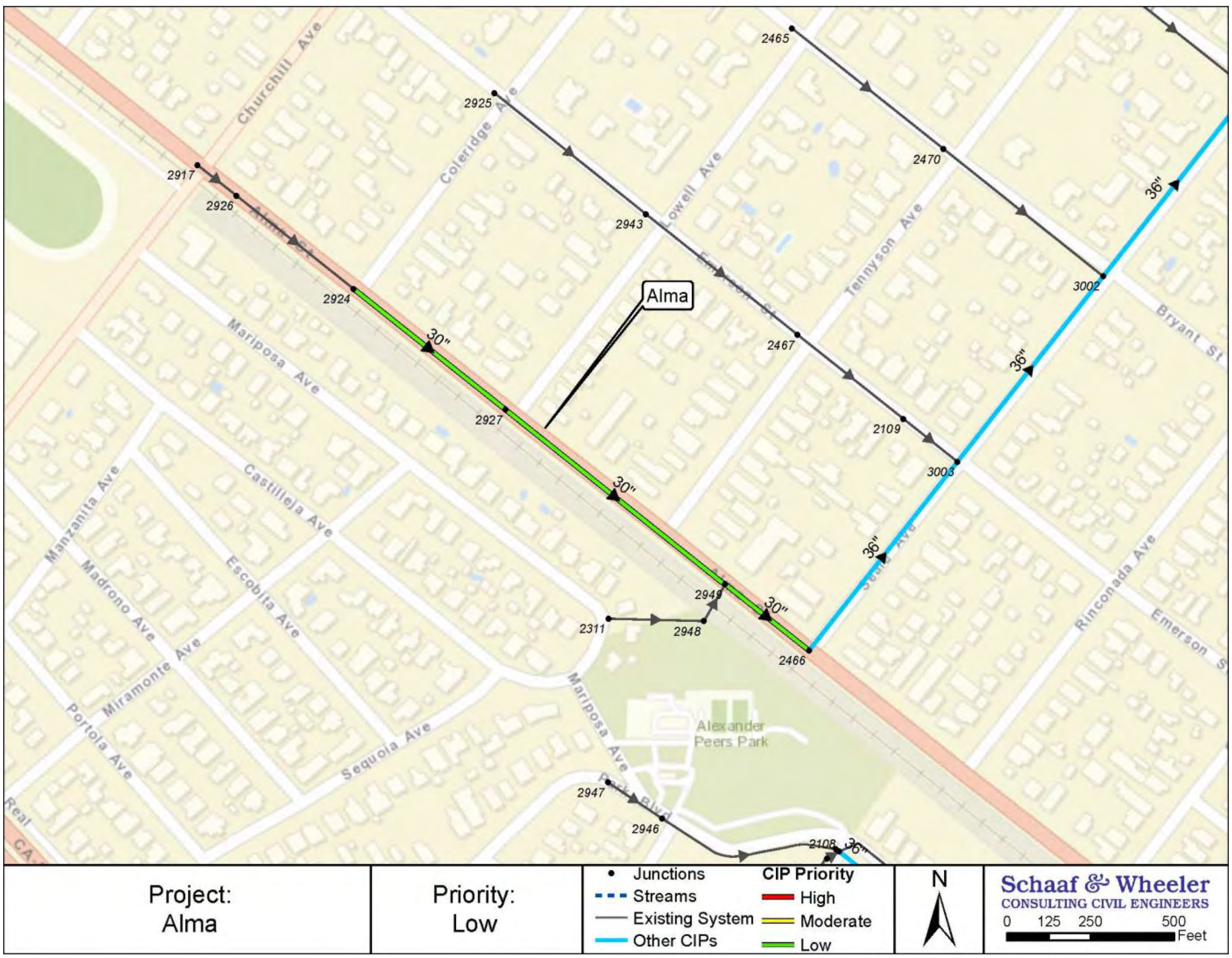
D. Priority: Low

E. Type: Capacity

F. Project Description: The existing pipes on Alma St. between Coleridge Ave. and Seale Ave. lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
15	30	1,127
21	30	253

G. Construction Subtotal **$590,000**
H. Total Construction Cost **$770,000**
I. Estimated CIP **$920,000**



A. Project ID: 26 | **B. Project Name: Alma & Greenmeadow**

C. Project Location: Alma Street east of Greenmeadow Way

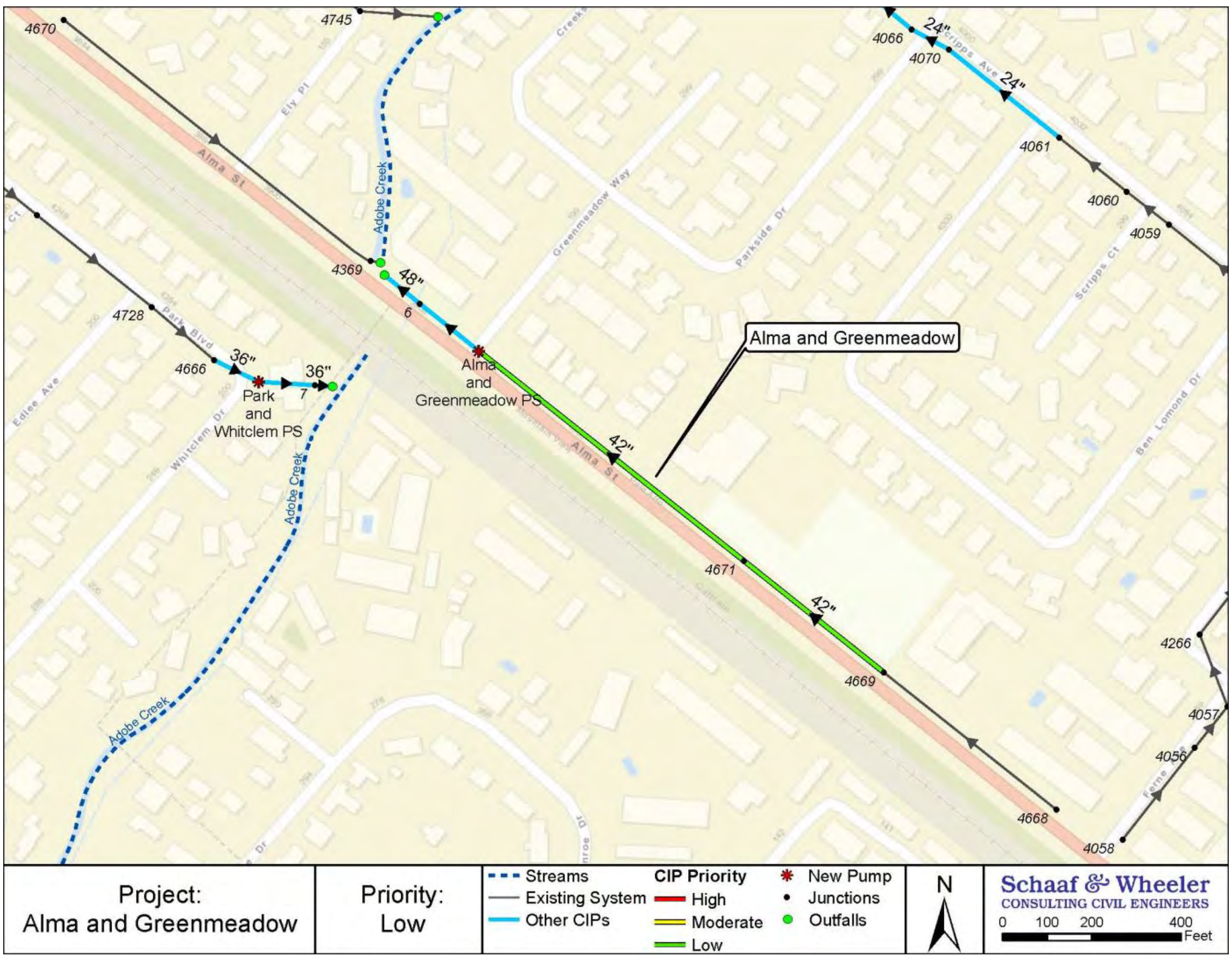
D. Priority: Low

E. Type: Capacity

F. Project Description: The existing pipes on Alma St. east of Greenmeadow Way lack the capacity to convey the 10-year storm runoff. Upsizing these pipes to provide a 10-year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
12	42	318
18	42	603

G. Construction Subtotal **$540,000**
H. Total Construction Cost **$700,000**
I. Estimated CIP **$840,000**



A. Project ID: 27	B. Project Name: Alma & Greenmeadow PS

C. Project Location: Alma Street west of Greenmeadow Way

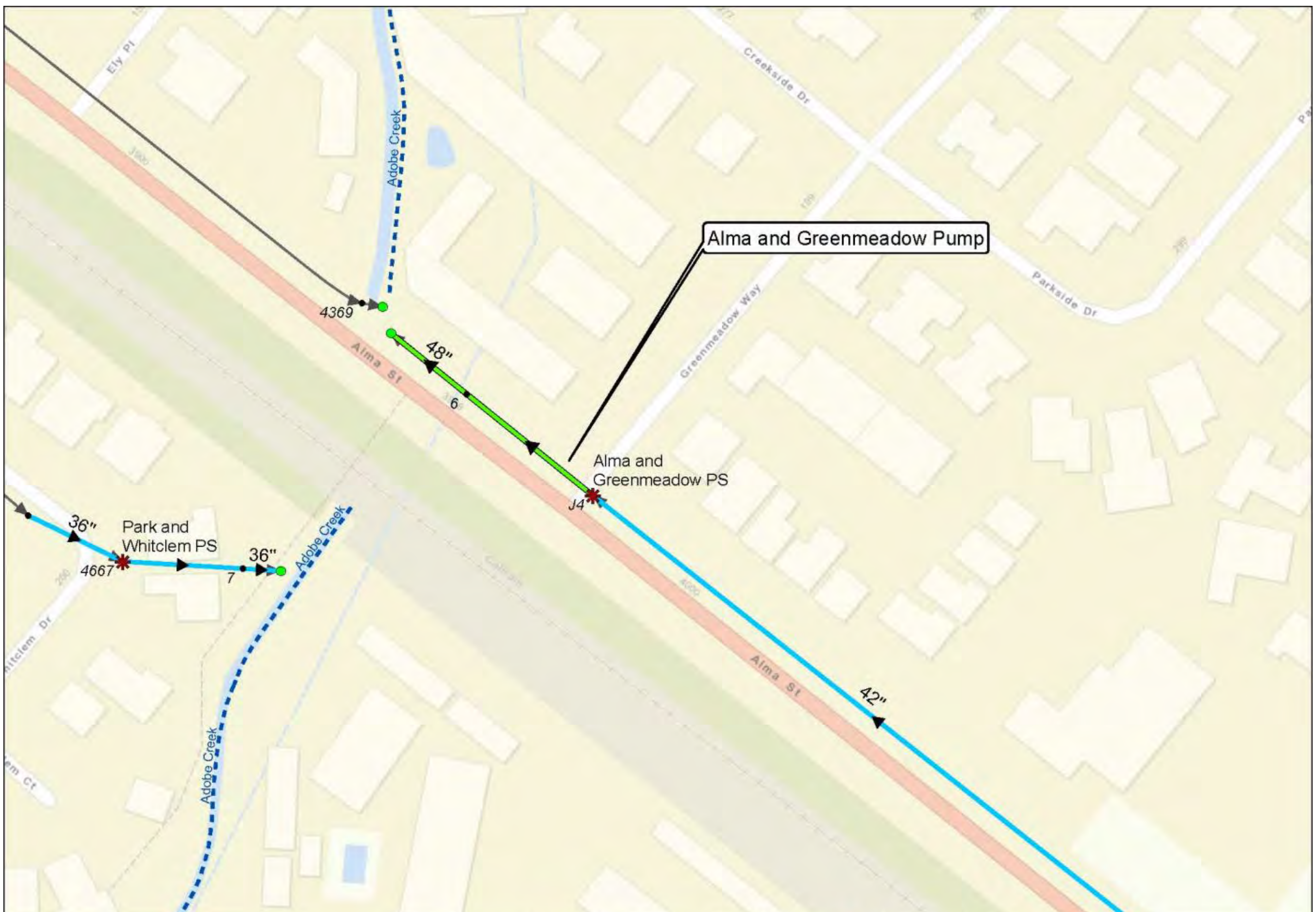
D. Priority: Low

E. Type: Capacity

F. Project Description: A new pump station near Alma St. and Greenmeadow Way is recommended to provide a 10 year level of service when the water level in Adobe Creek is high.

Ex. Capacity (cfs)	Imp. Capacity (cfs)
N/A	38

G. Construction Subtotal $1,640,000
H. Total Construction Cost $2,130,000
I. Estimated CIP $2,560,000



Project: Alma and Greenmeadow Pump	Priority: Low	Streams Existing System Other CIPs	CIP Priority High Moderate Low	New Pump Junctions Outfalls	N	Schaaf & Wheeler CONSULTING CIVIL ENGINEERS 0 50 100 200 Feet

A. Project ID: 28	B. Project Name: Arastradero
C. Project Location: Arastradero Road between Hubbartt Drive and El Camino Real	
D. Priority: Low	

E. Type: Capacity

F. Project Description: The existing pipes on Arastradero southwest of El Camino Real lack the capacity required to convey 10-year storm runoff. Upsizing pipes at this location to achieve a 10-year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
18	24	1,042
24	30	1,108
24	36	108
30	36	1,104

G. Construction Subtotal $1,530,000

H. Total Construction Cost $1,990,000

I. Estimated CIP $2,390,000

A. Project ID: 29 | **B. Project Name: Bryant**

C. Project Location: Homer Ave from Ramona St to Bryant, along Bryant St to Lincoln Ave

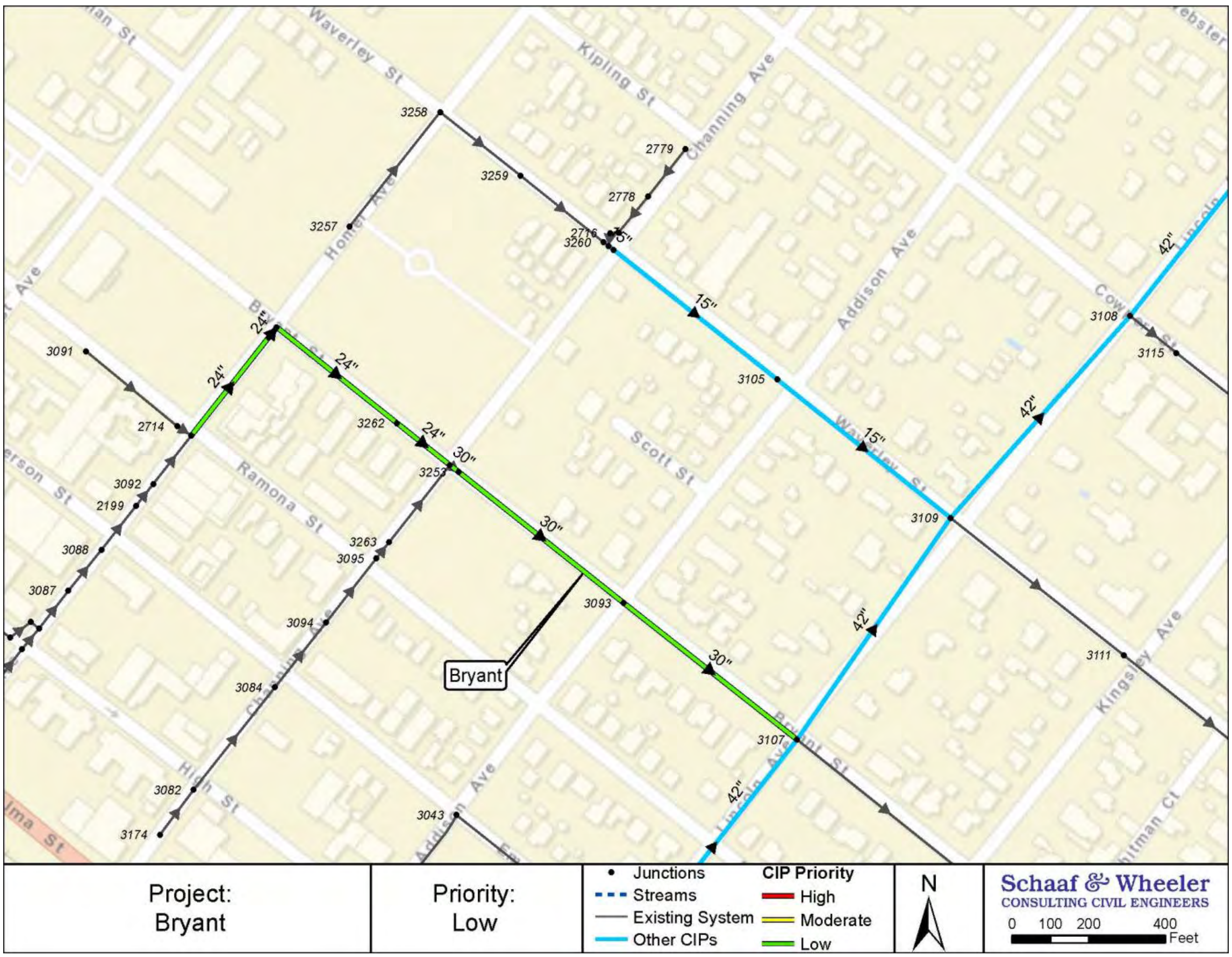
D. Priority: Low

E. Type: Capacity

F. Project Description: The existing pipes on Bryant Street west of Lincoln Ave lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
12	24	286
15	24	460
15	30	919

G. Construction Subtotal **$720,000**
H. Total Construction Cost **$940,000**
I. Estimated CIP **$1,130,000**



A. Project ID: 30	**B. Project Name: Cambridge**

C. Project Location: Aligned with Cambridge Ave. between Harvard St. and El Camino Real

D. Priority: Low

E. Type: Capacity

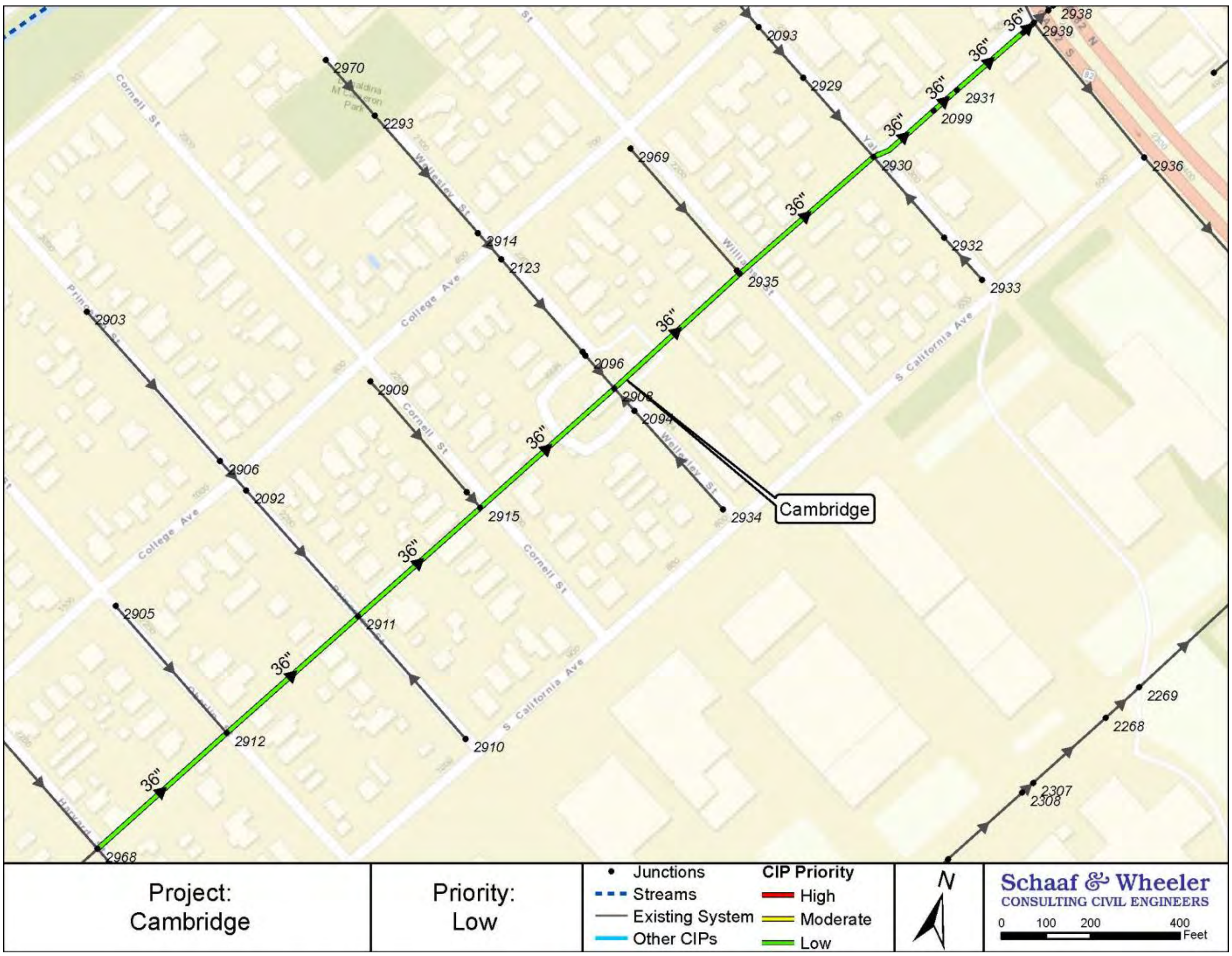
F. Project Description: The existing pipes in an easement between California Ave. and College Ave south of El Camino Real lack the capacity the required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
15	36	309
18	36	923
21	36	992

G. Construction Subtotal **$1,190,000**

H. Total Construction Cost **$1,550,000**

I. Estimated CIP **$1,860,000**



A. Project ID: 31	**B. Project Name: Colonial & Amarillo**

C. Project Location: Colonial Ln to Amarillo Ave & Greer Rd

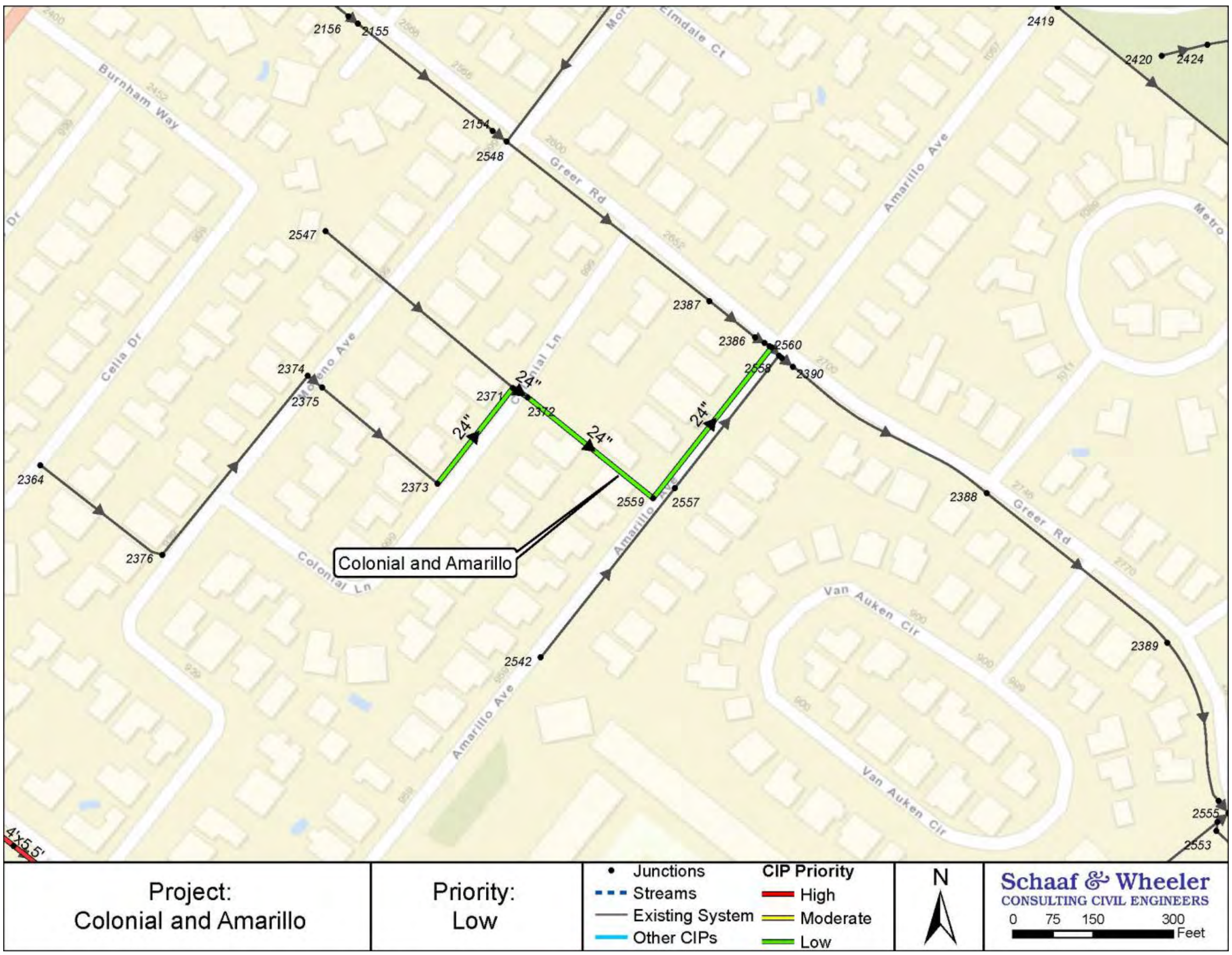
D. Priority: Low

E. Type: Capacity

F. Project Description: The existing pipes on Colonial Lane, Amarillo Ave, and between the two streets lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
12	24	730

G. Construction Subtotal **$310,000**
H. Total Construction Cost **$400,000**
I. Estimated CIP **$480,000**



A. Project ID: 32	B. Project Name: Colorado PS Removal

C. Project Location: Near Bayshore Rd and Colorado Ave to Matadero Creek

D. Priority: Low

E. Type: Maintenance

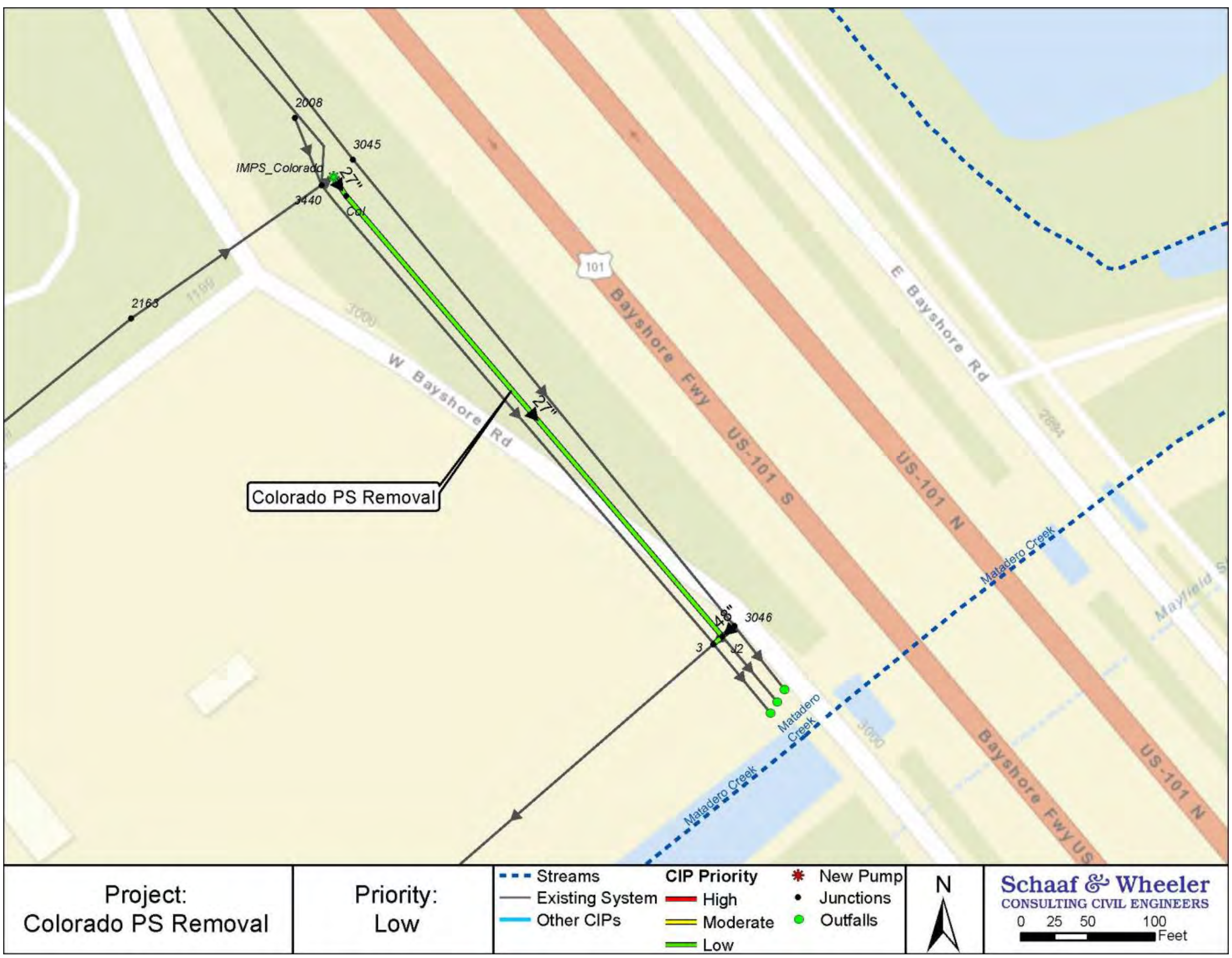
F. Project Description: The pump station at Colorado Ave is not required to convey the 10-year storm runoff once the Matadero Pump Station is upsized. Removal of this pump station is recommended due to maintenance and safety concerns. Removal requires pipe improvements downstream of the pump station in order to route flow to the Matadero Pump Station.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
27	27	395
42	48	16
--	27	14

G. Construction Subtotal **$280,000**

H. Total Construction Cost **$360,000**

I. Estimated CIP **$430,000**



A. Project ID: 33 | **B. Project Name: E. Bayshore Rd. and Embarcadero**

C. Project Location: E. Bayshore Rd. to Geng Rd. and Embarcadero

D. Priority: Low

E. Type: Capacity

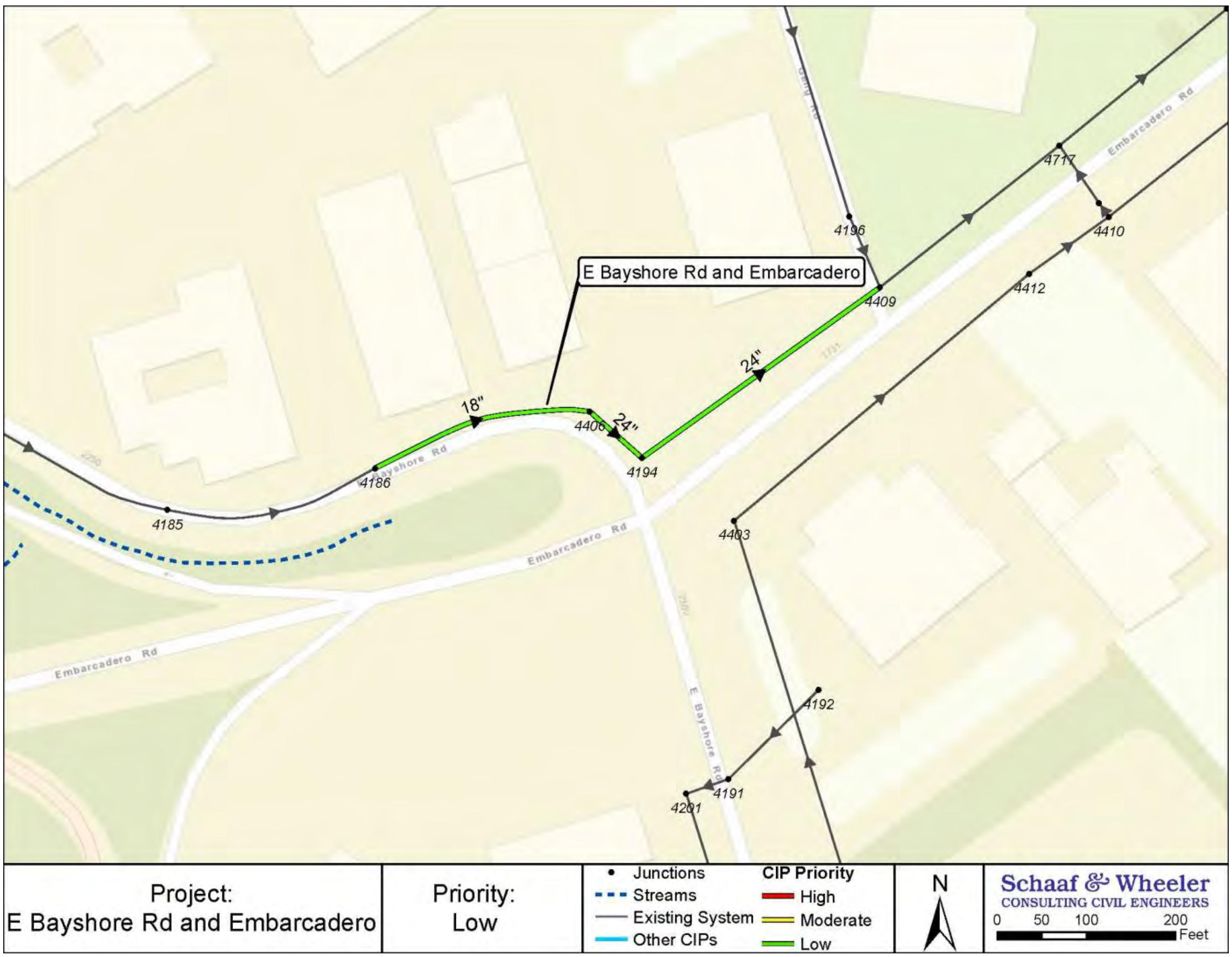
F. Project Description: The existing pipes on E. Bayshore Rd. and Embarcadero near Geng Rd. lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
12	18	202
12	24	323

G. Construction Subtotal..$220,000

H. Total Construction Cost..$290,000

I. Estimated CIP..$350,000



A. Project ID: 34	**B. Project Name: E Charleston & Middlefield Rd**

C. Project Location: Middlefield Rd. SW of Charleston, Charleston Rd. between Middlefield Rd. and near Fabian Way

D. Priority: Low

E. Type: Capacity

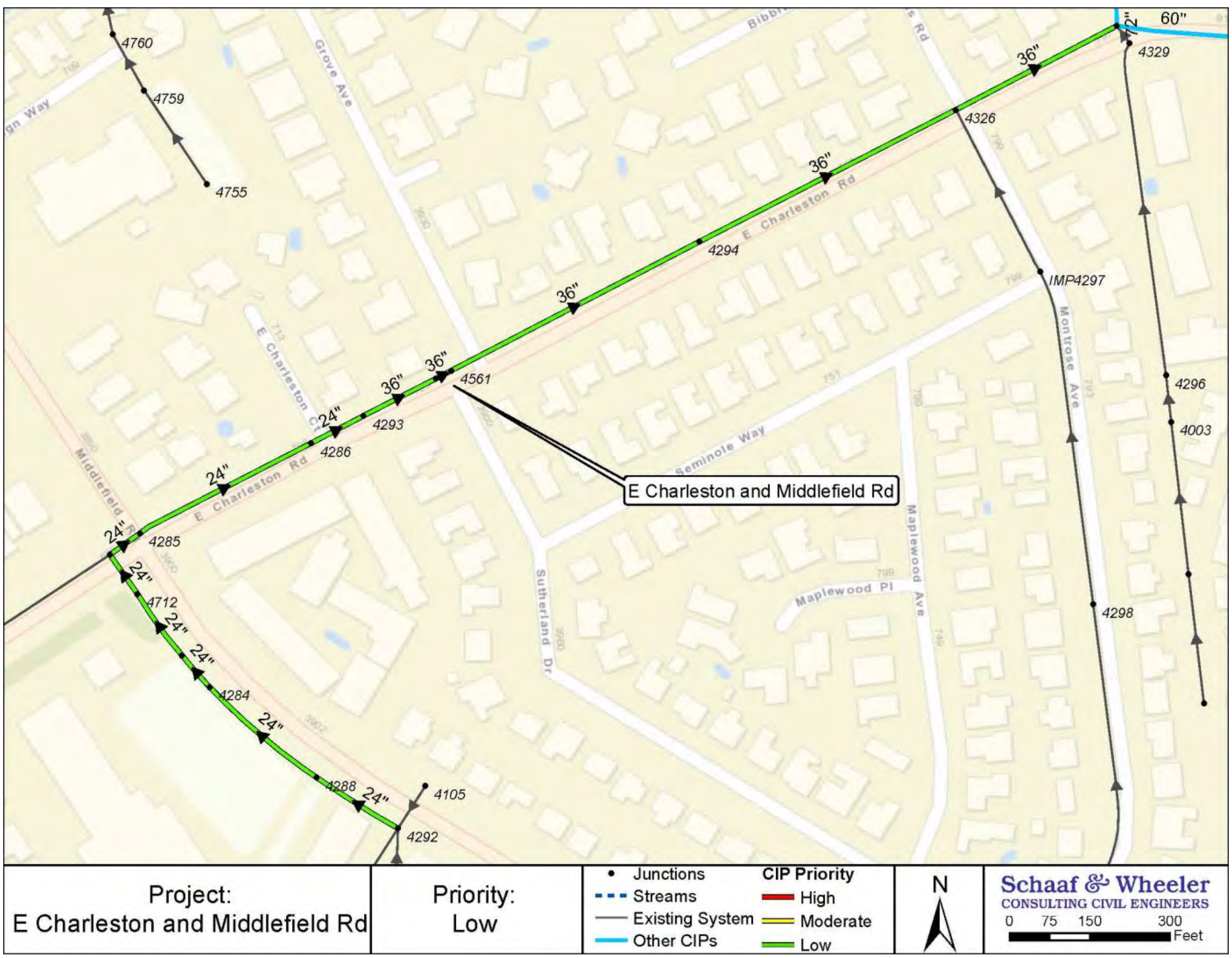
F. Project Description: The existing pipes on Middlefield Rd. and Charleston Rd. lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
15	24	1,027
15	36	990
27	36	270

G. Construction Subtotal **$1,090,000**

H. Total Construction Cost **$1,420,000**

I. Estimated CIP **$1,700,000**



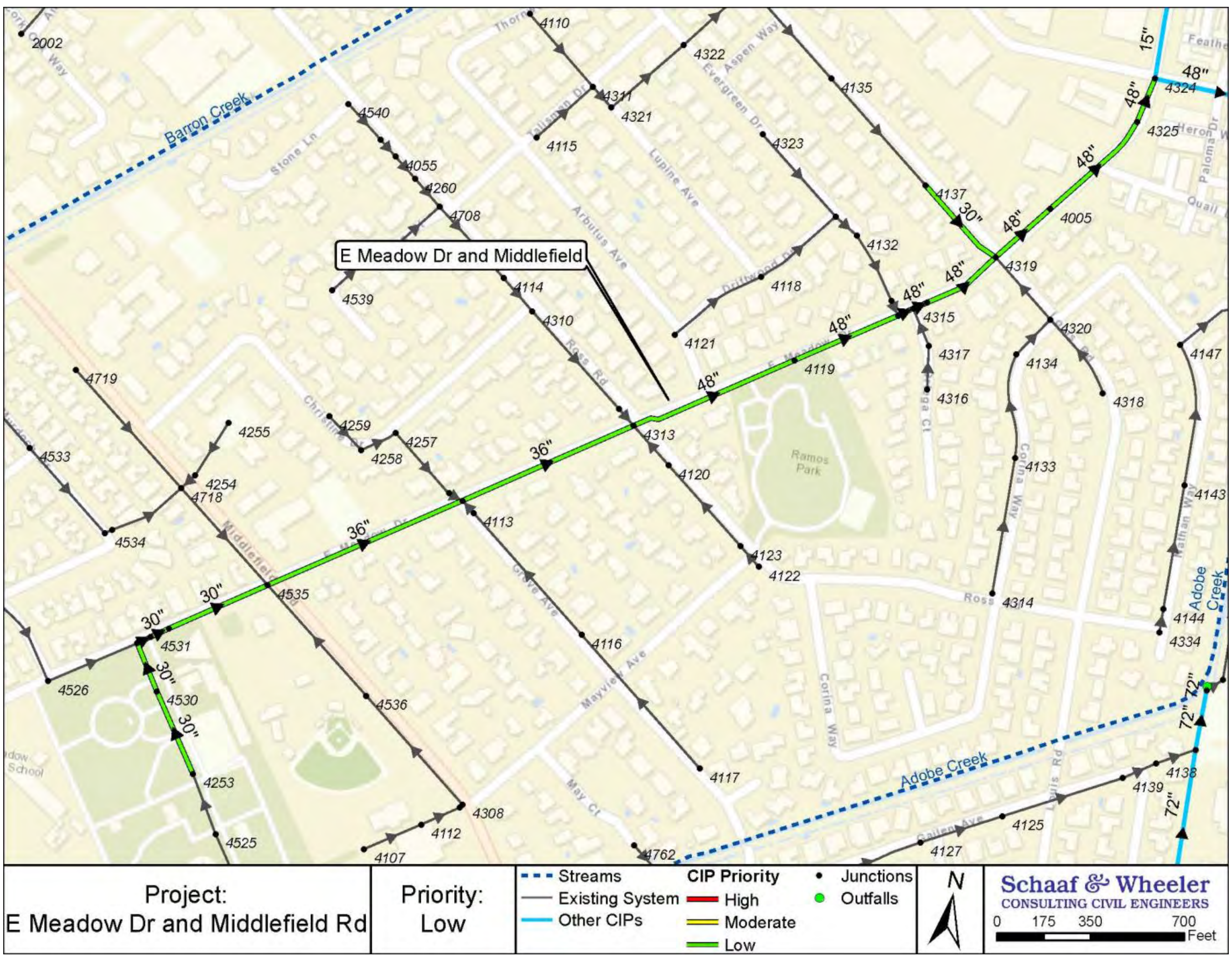
A. Project ID: 35	**B. Project Name: E. Meadow Dr. & Middlefield Rd.**
C. Project Location: E. Meadow Dr. from Fairmeadow Elementary School to E. Meadow Cir.	
D. Priority: Low	

E. Type: **Capacity**

F. Project Description: The existing pipes on E. Meadow Dr. from Fairmeadow Elementary, to E. Meadow Cir. lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
12	30	721
18	30	424
21	36	631
24	36	555
36	48	1,918

G. Construction Subtotal $2,290,000
H. Total Construction Cost $2,980,000
I. Estimated CIP $3,580,000



A. Project ID: 36	**B. Project Name: El Camino Real**
C. Project Location: El Camino Real between Matadero Creek and Matadero Ave.	
D. Priority: Low	

E. Type: Capacity

F. Project Description: The existing pipes on El Camino Real between Matadero Ave. and Matadero Creek lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended. This project will require coordination with Caltrans

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
15	24	612

G. Construction Subtotal **$250,000**
H. Total Construction Cost **$330,000**
I. Estimated CIP **$400,000**

A. Project ID: 37	B. Project Name: El Centro

C. **Project Location**: **From El Centro St. and Barron Ave. to Matadero Creek Outfall**

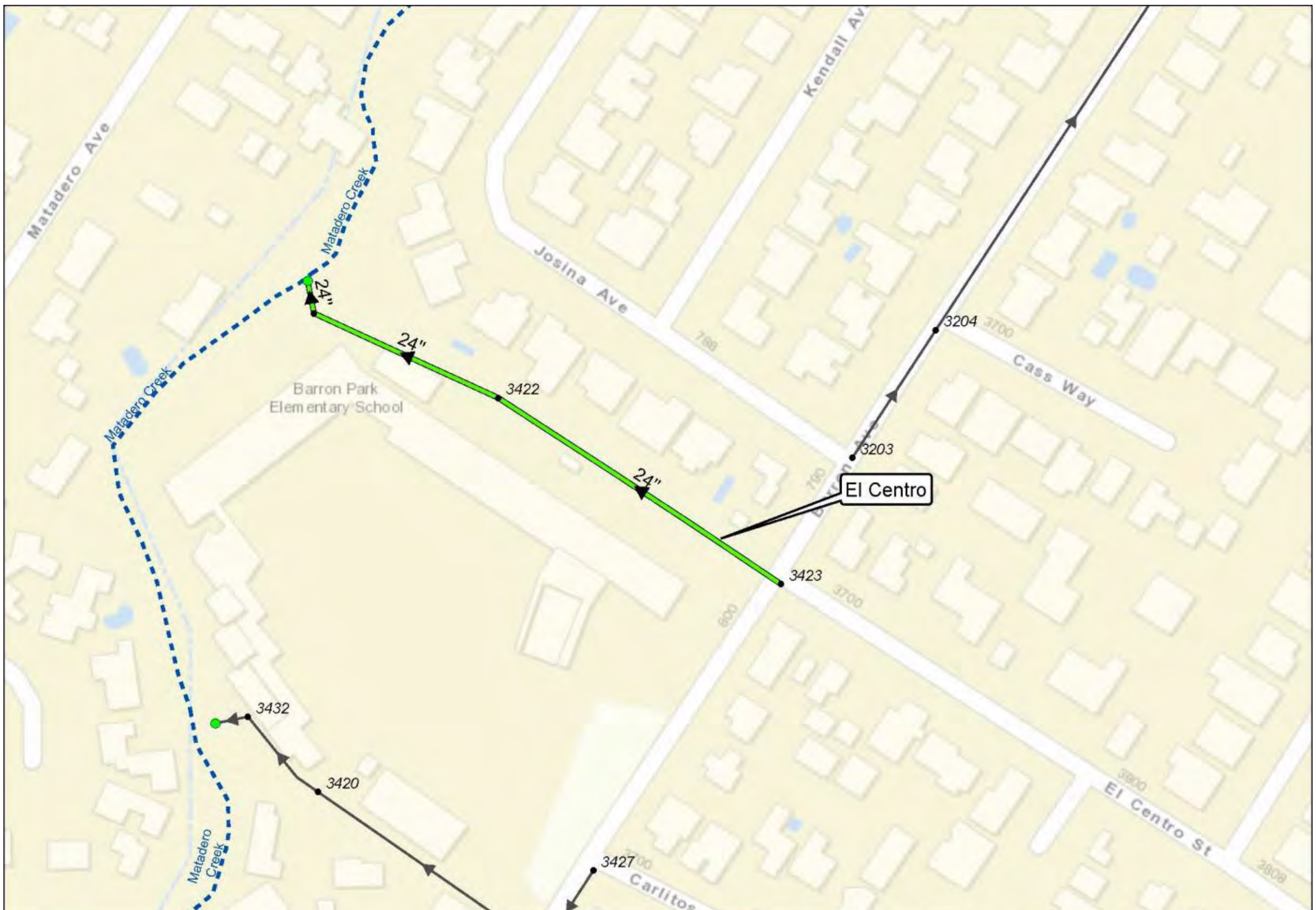
D. **Priority**: **Low**

E. **Type: Capacity**

F. **Project Description:** The existing pipes running from El Centro St. to Matadero Creek lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
12	24	639

G. **Construction Subtotal** **$310,000**
H. **Total Construction Cost** **$400,000**
I. **Estimated CIP** **$480,000**



Project: El Centro	Priority: Low	Streams, Existing System, Other CIPs; CIP Priority: High, Moderate, Low; New Pump, Junctions, Outfalls	N	Schaaf & Wheeler CONSULTING CIVIL ENGINEERS 0 50 100 200 Feet

A. Project ID: 38 | **B. Project Name: Foothill and Miranda**

C. Project Location: Foothill Expwy near VA Palo Alto to Barron Creek Outfall

D. Priority: Low

E. Type: Capacity

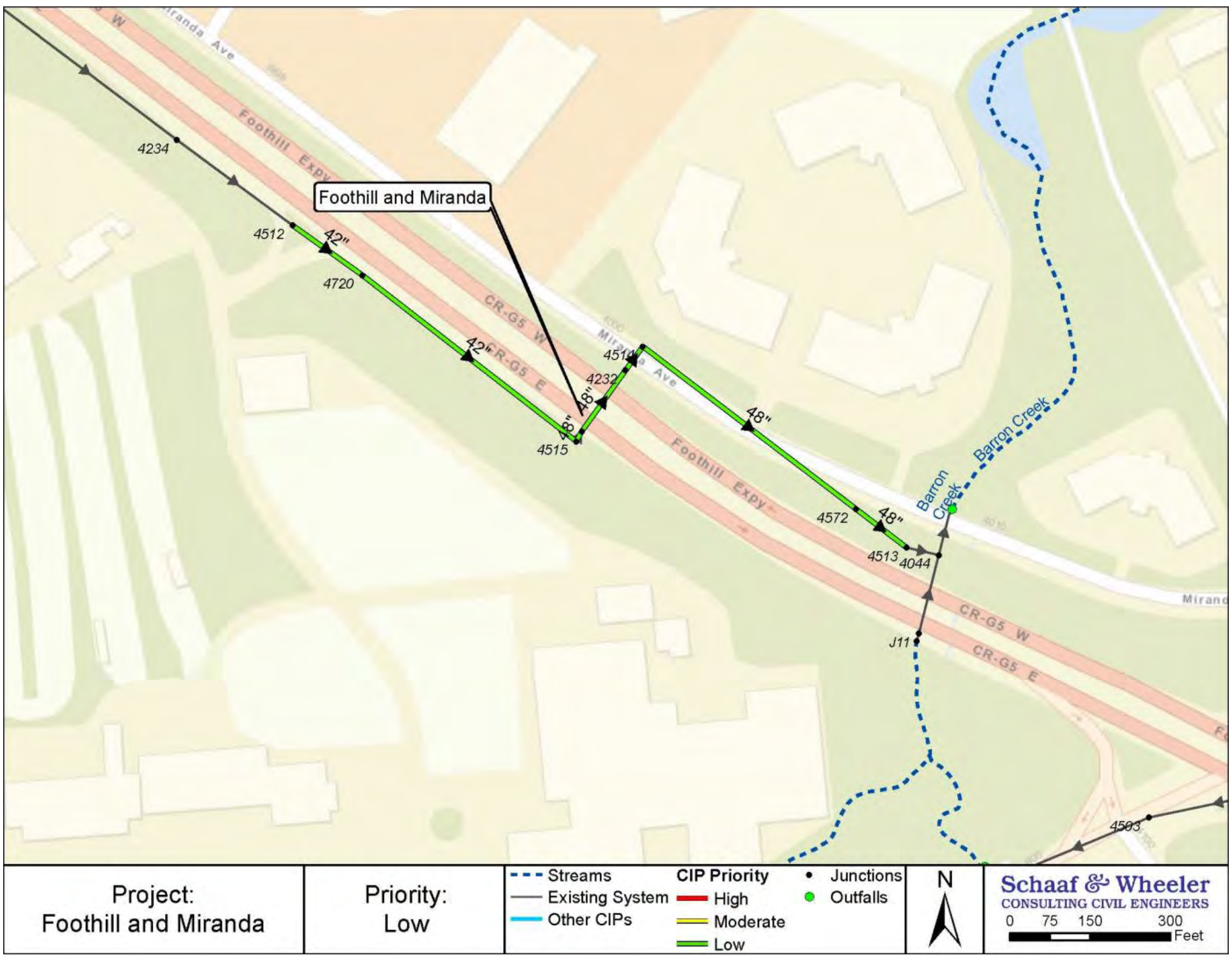
F. Project Description: The existing pipes on Foothill Expwy and Miranda Ave. near the VA Palo Alto Medical Center lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended. This project will require coordination with the Santa Clara County Roads Department.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
30	42	127
36	42	402
42	48	664

G. Construction Subtotal **$780,000**

H. Total Construction Cost..**$1,010,000**

I. Estimated CIP **$1,210,000**



A. Project ID: 39 | **B. Project Name: Forest & Hamilton**

C. Project Location: Forest Ave at Seneca St. to Hamilton Ave. at Center Dr.

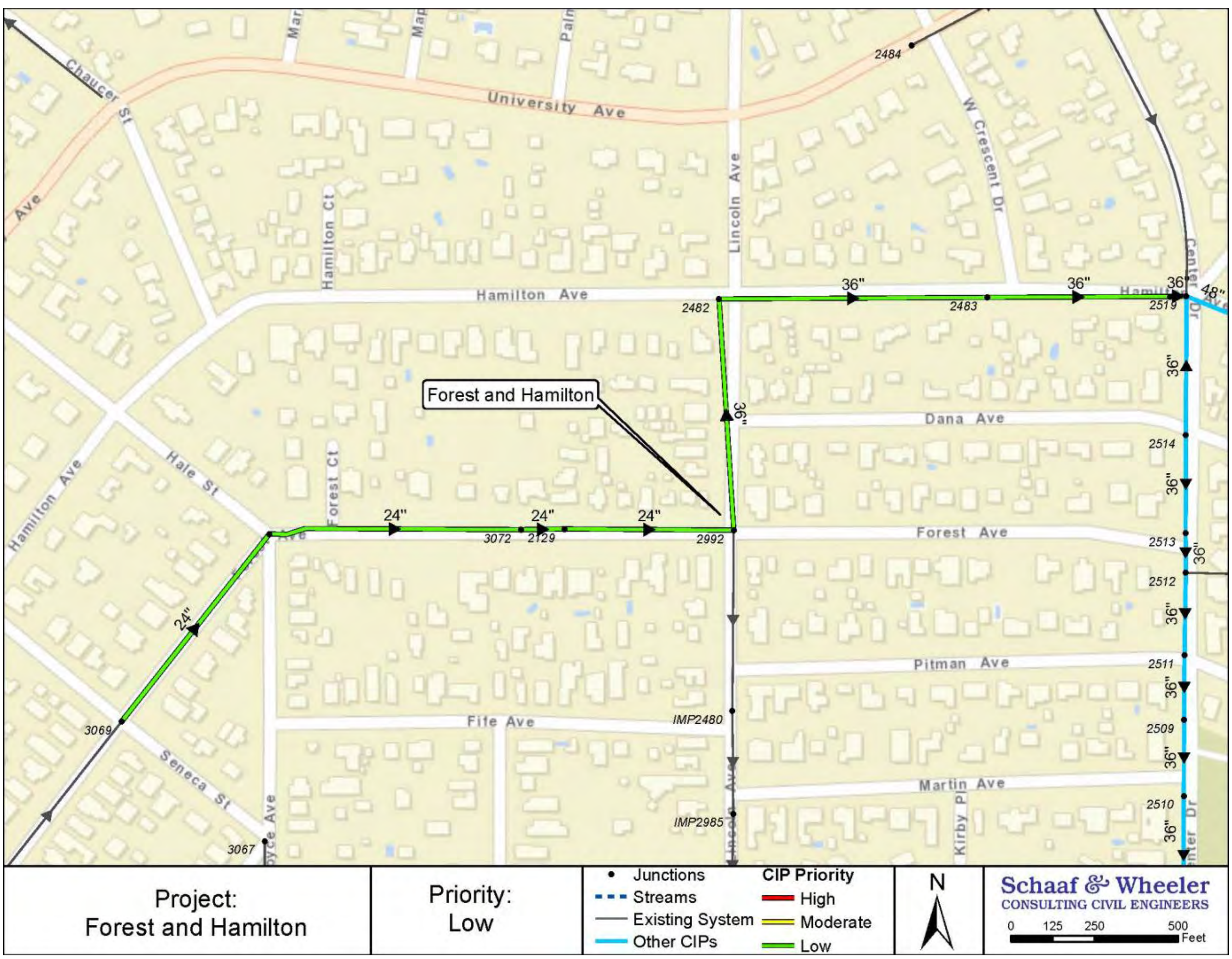
D. Priority: Low

E. Type: Capacity

F. Project Description: The existing pipes on Forest Ave. and Hamilton Ave. lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
14	24	566
15	24	1,106
12	36	1,186
15	36	435

G. Construction Subtotal **$1,470,000**
H. Total Construction Cost **$1,910,000**
I. Estimated CIP **$2,290,000**



A. Project ID: 40	**B. Project Name: Hamilton & Channing**

C. Project Location: Hamilton Ave. near Cowper St. to Channing Ave. & Lincoln Ave.

D. Priority: Low

E. Type: Capacity

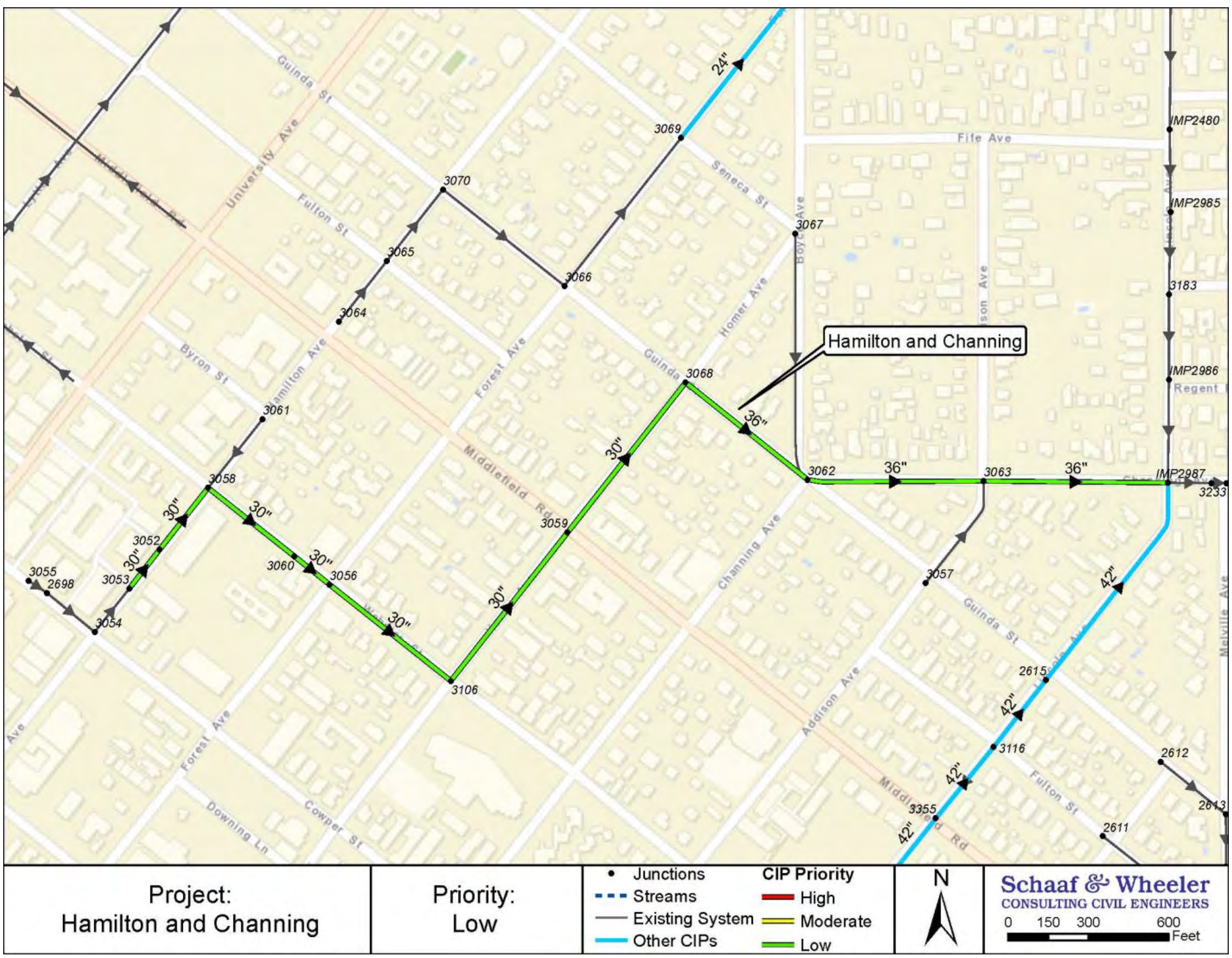
F. Project Description: The existing pipes from Hamilton Ave near Cowper St., along Webster St., along Homer Ave., and along Guinda St. to Channing Ave lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
12	30	840
15	30	459
18	30	560
21	30	566
21	36	1,534

G. Construction Subtotal **$1,820,000**

H. Total Construction Cost **$2,370,000**

I. Estimated CIP **$2,840,000**



A. Project ID: 41	**B. Project Name: Hanover**

C. Project Location: Hanover St. between 2527/2631 Hanover and Page Mill Rd.

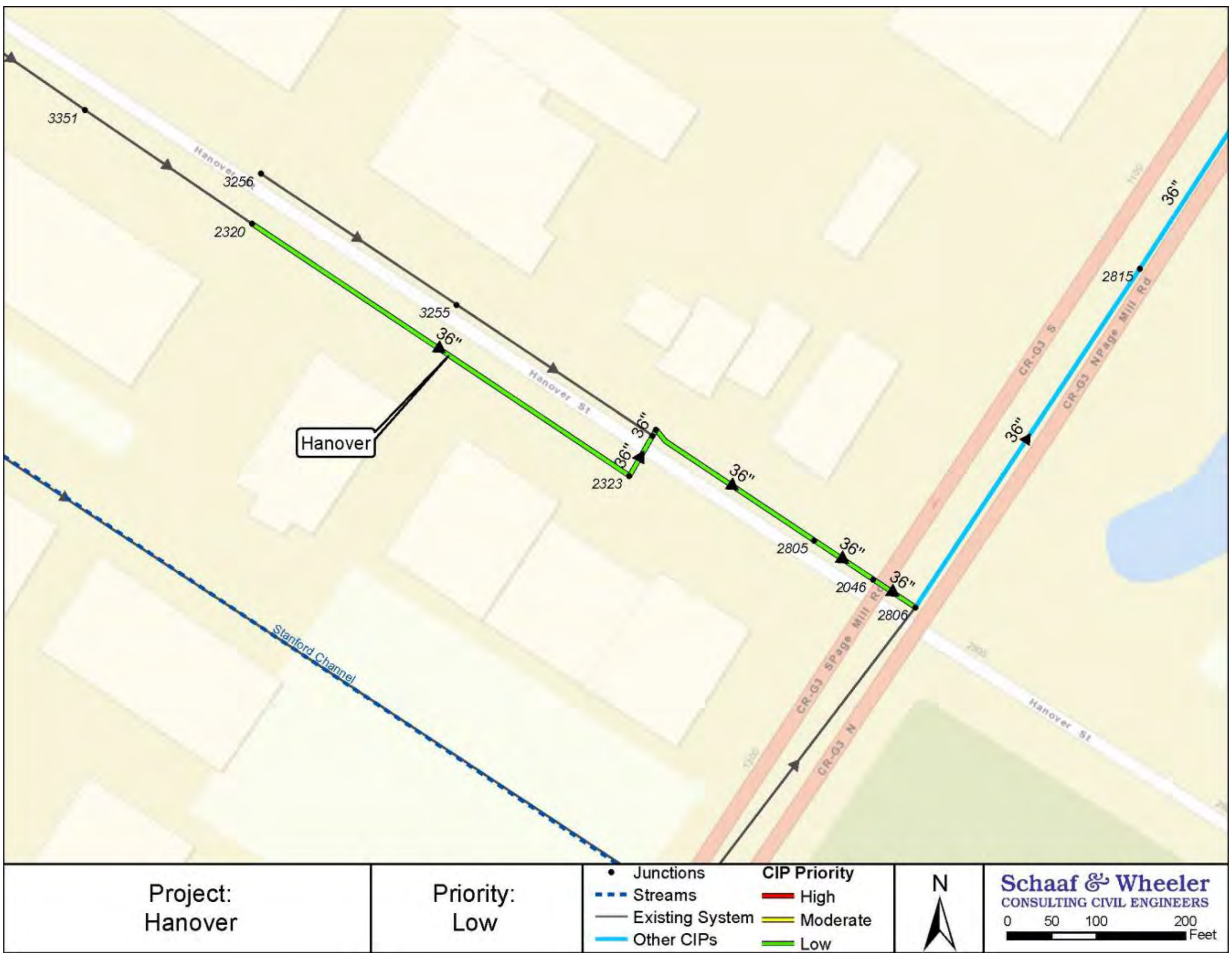
D. Priority: Low

E. Type: Capacity

F. Project Description: The existing pipes on Hanover St. northwest of Page Mill Rd. lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
15	36	404
18	36	328

G. Planning/Design/Admin/Permitting **$420,000**
H. Total Construction Cost **$550,000**
I. Estimated CIP **$660,000**



A. Project ID: 42	**B. Project Name: Hillview**

C. Project Location: Hillview Ave. near Matadero Creek

D. Priority: Low

E. Type: Capacity

F. Project Description: The existing pipes on Hillview Ave. north of the Matadero Creek outfall lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
27	42	477

G. Construction Subtotal **$350,000**
H. Total Construction Cost..**$460,000**
I. Estimated CIP **$550,000**

A. Project ID: 43	B. Project Name: Hoover Park

C. Project Location: Hoover Park near Cowper St. Entrance

D. Priority: Low

E. Type: Capacity

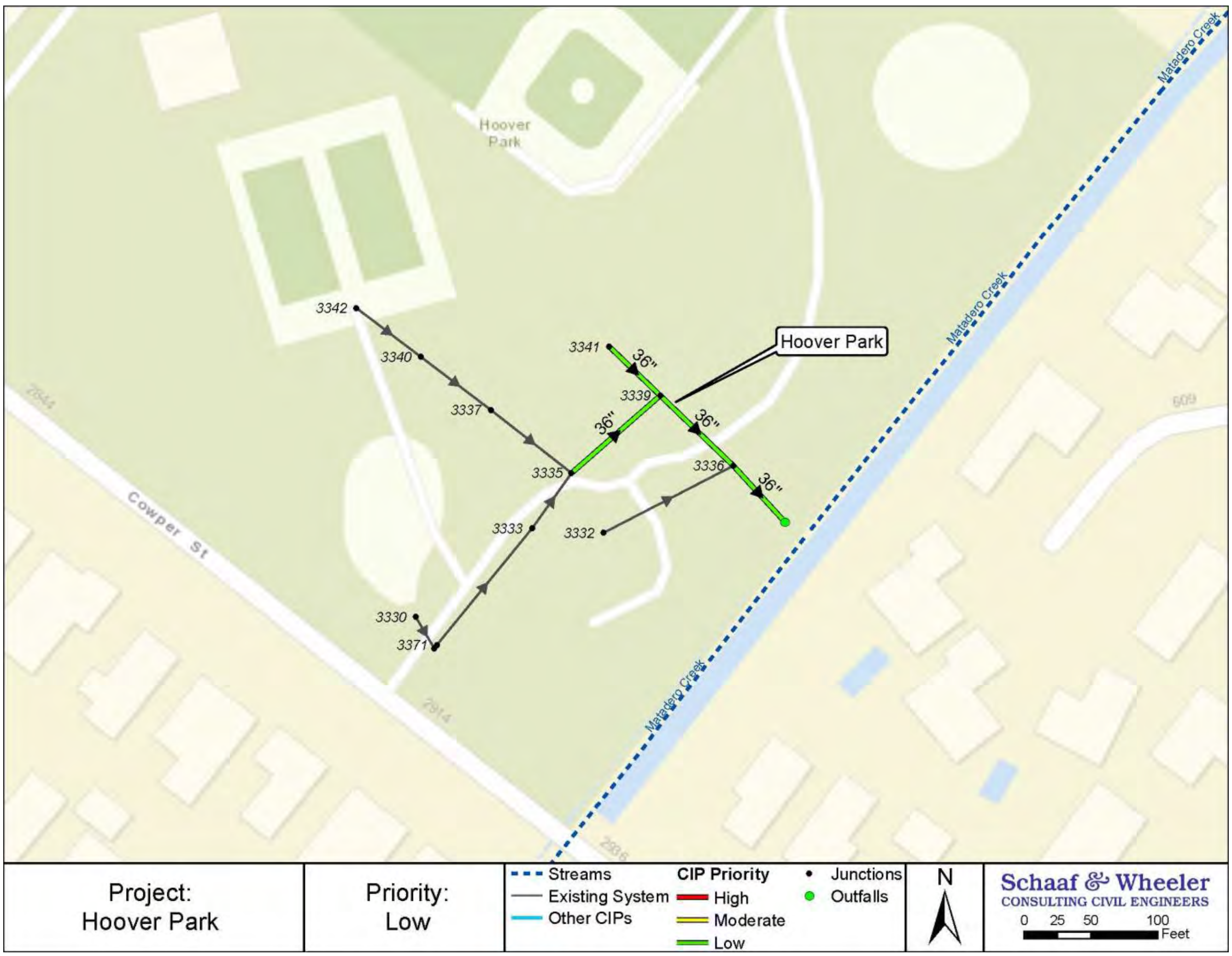
F. Project Description: The existing pipes in Hoover Park at the Matadero Creek outfall lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
12	36	217

G. Construction Subtotal $200,000

H. Total Construction Cost $260,000

I. Estimated CIP $310,000



A. Project ID: 44 | **B. Project Name: Laura Ln & Geng Rd**

C. Project Location: Laura Ln. west of Geng Rd.

D. Priority: Low

E. Type: Capacity

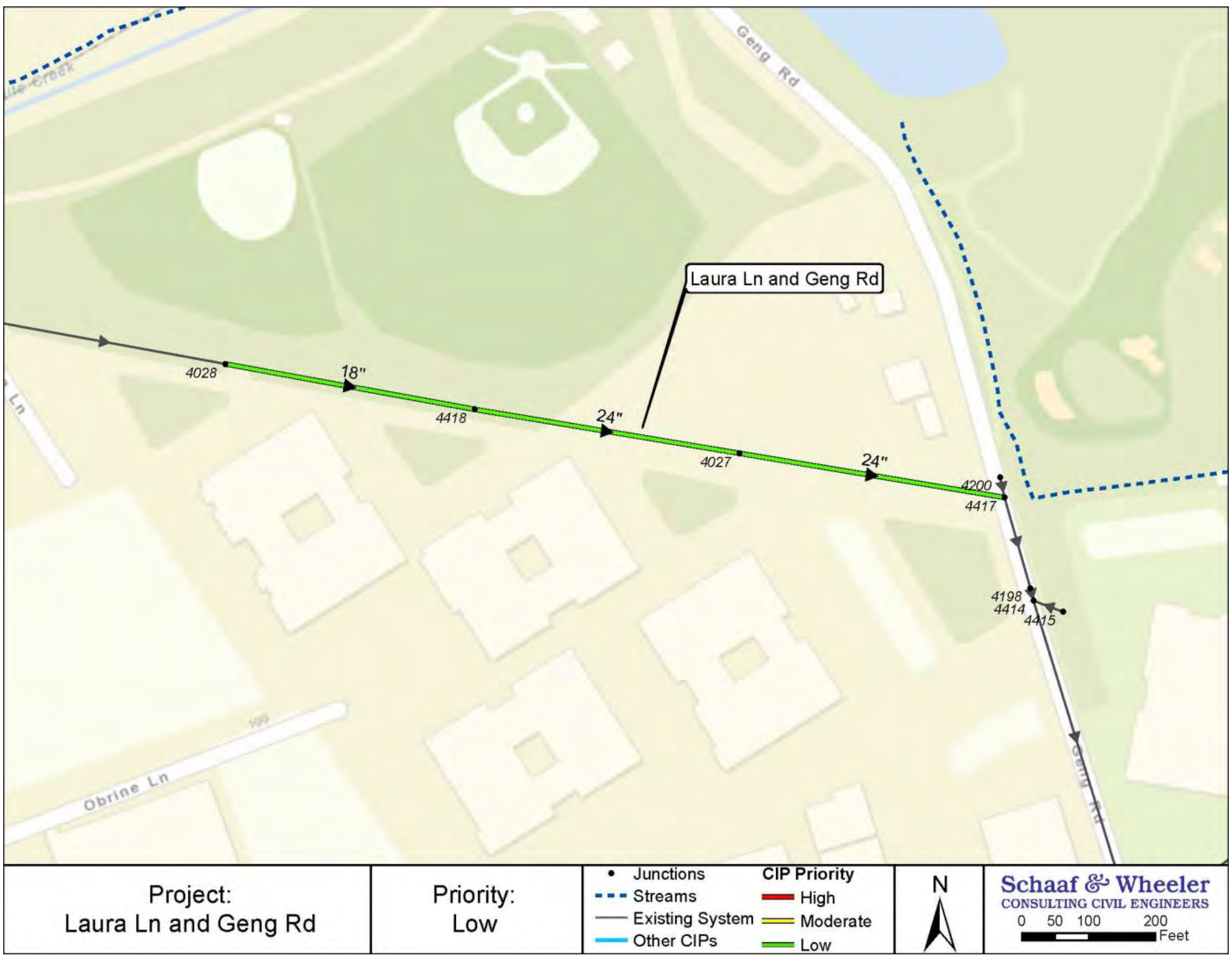
F. Project Description: The existing pipes west of Geng Rd. lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
12	18	302
12	24	319
15	24	319

G. Construction Subtotal **$350,000**

H. Total Construction Cost **$460,000**

I. Estimated CIP **$550,000**



A. **Project ID: 45**	B. **Project Name: Loma Verde & Cowper**

C. Project Location: Loma Verde Ave. between Cowper St. and Ross Rd.

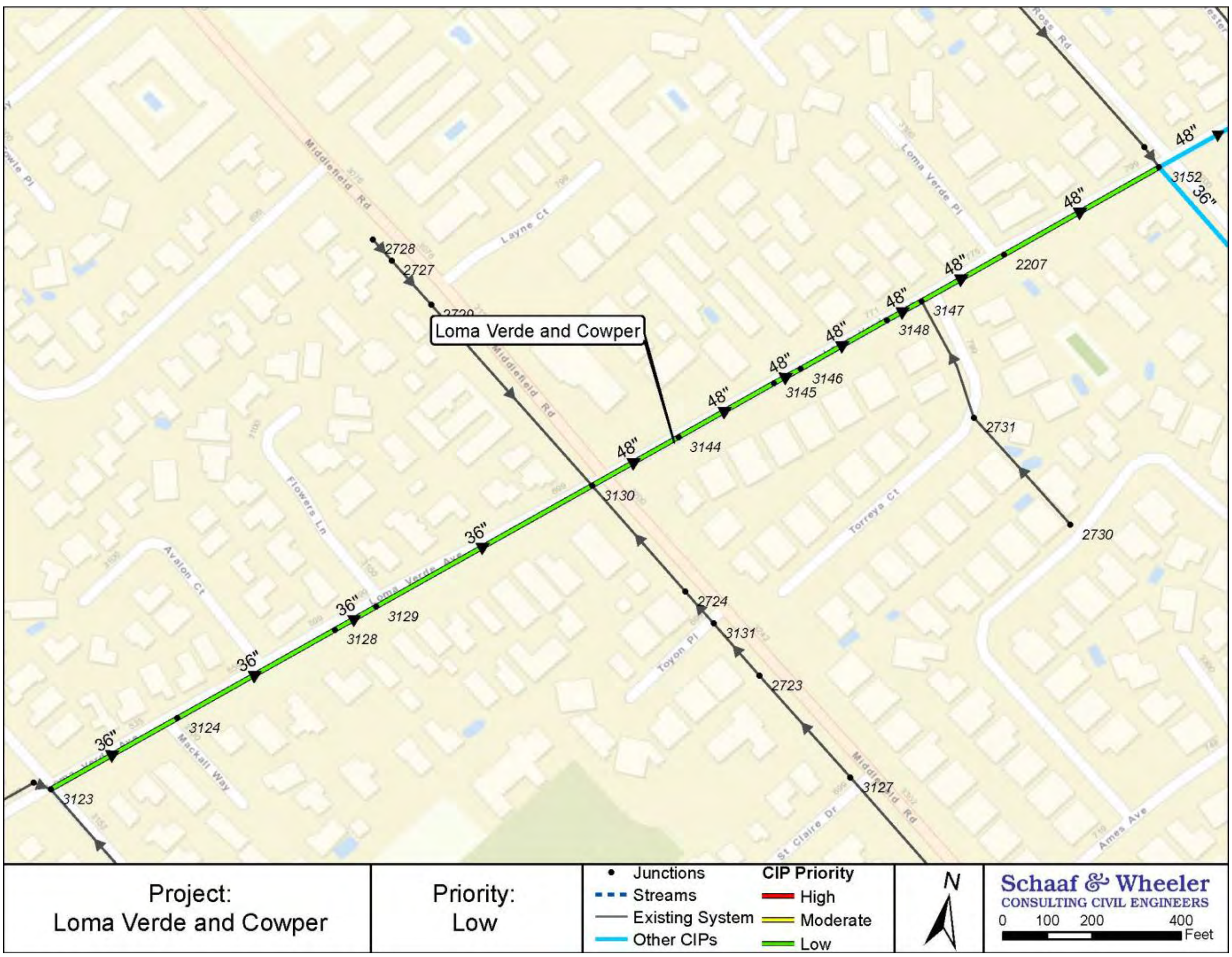
D. Priority: Low

E. Type: Capacity

F. Project Description: The existing pipes on Loma Verde Ave. lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
24	36	1,106
27	48	1,158

G. Planning/Design/Admin/Permitting **$1,530,000**
H. Total Construction Cost **$1,990,000**
I. Estimated CIP **$2,390,000**



A. Project ID: 46

B. Project Name: Louis and Loma Verde

C. Project Location: Louis Rd. between Loma Verde Ave. and 90 Degree bend near Palo Verde Elementary School

D. Priority: Low

E. Type: Capacity

F. Project Description: The existing pipes on Louis Road near Ames Ave lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
18	51	1,249

G. Construction Subtotal **$860,000**

H. Total Construction Cost **$1,120,000**

I. Estimated CIP **$1,340,000**

A. Project ID: 47	**B. Project Name: Louis and Piers**

C. Project Location: Louis Rd. between Elbridge Way and Loma Verde Ave.

D. Priority: Low

E. Type: Capacity

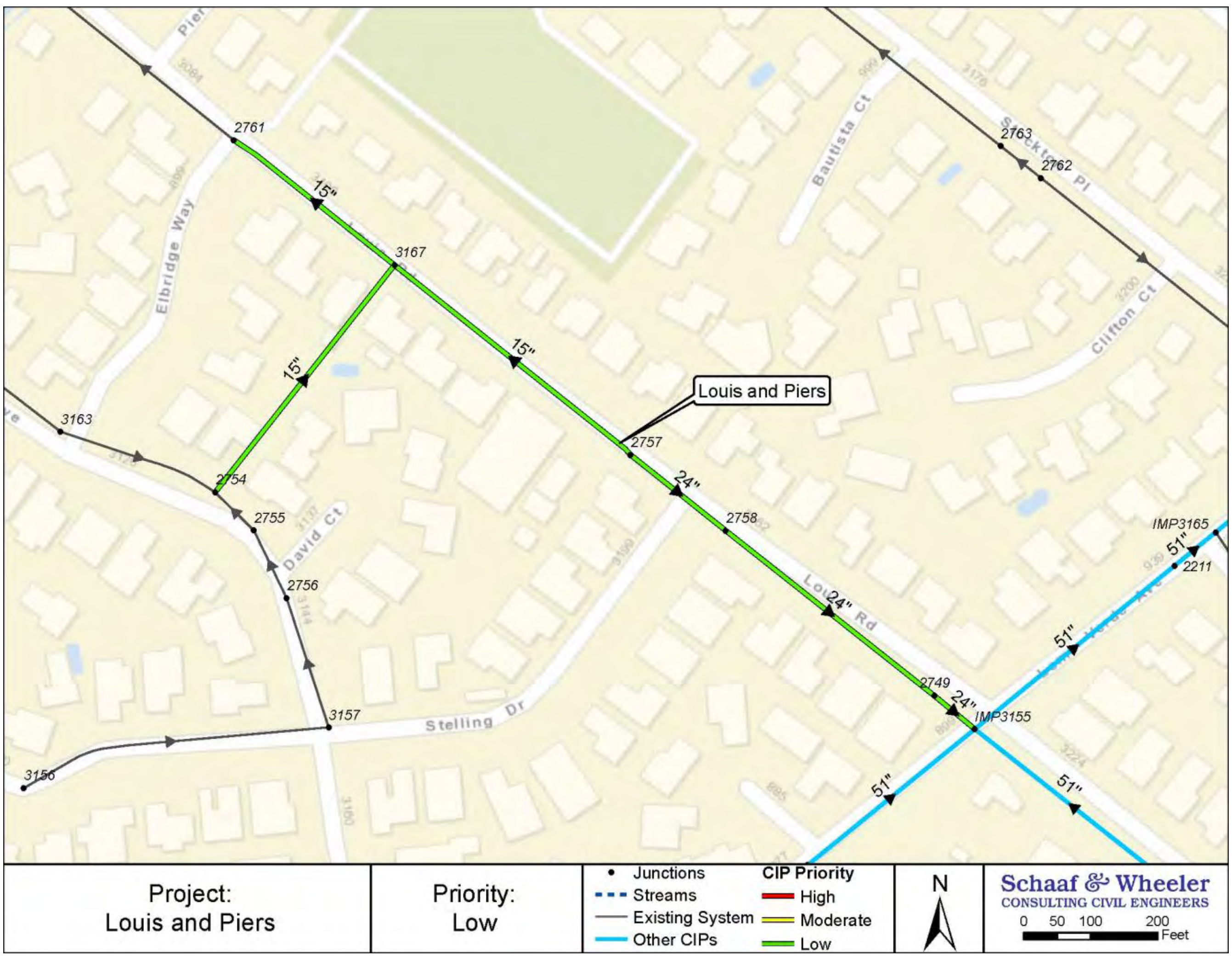
F. Project Description: The existing pipes on Louis Rd. and the connection to David Ave. lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
12	15	945
12	24	316
15	24	206

G. Construction Subtotal **$510,000**

H. Total Construction Cost **$660,000**

I. Estimated CIP **$790,000**



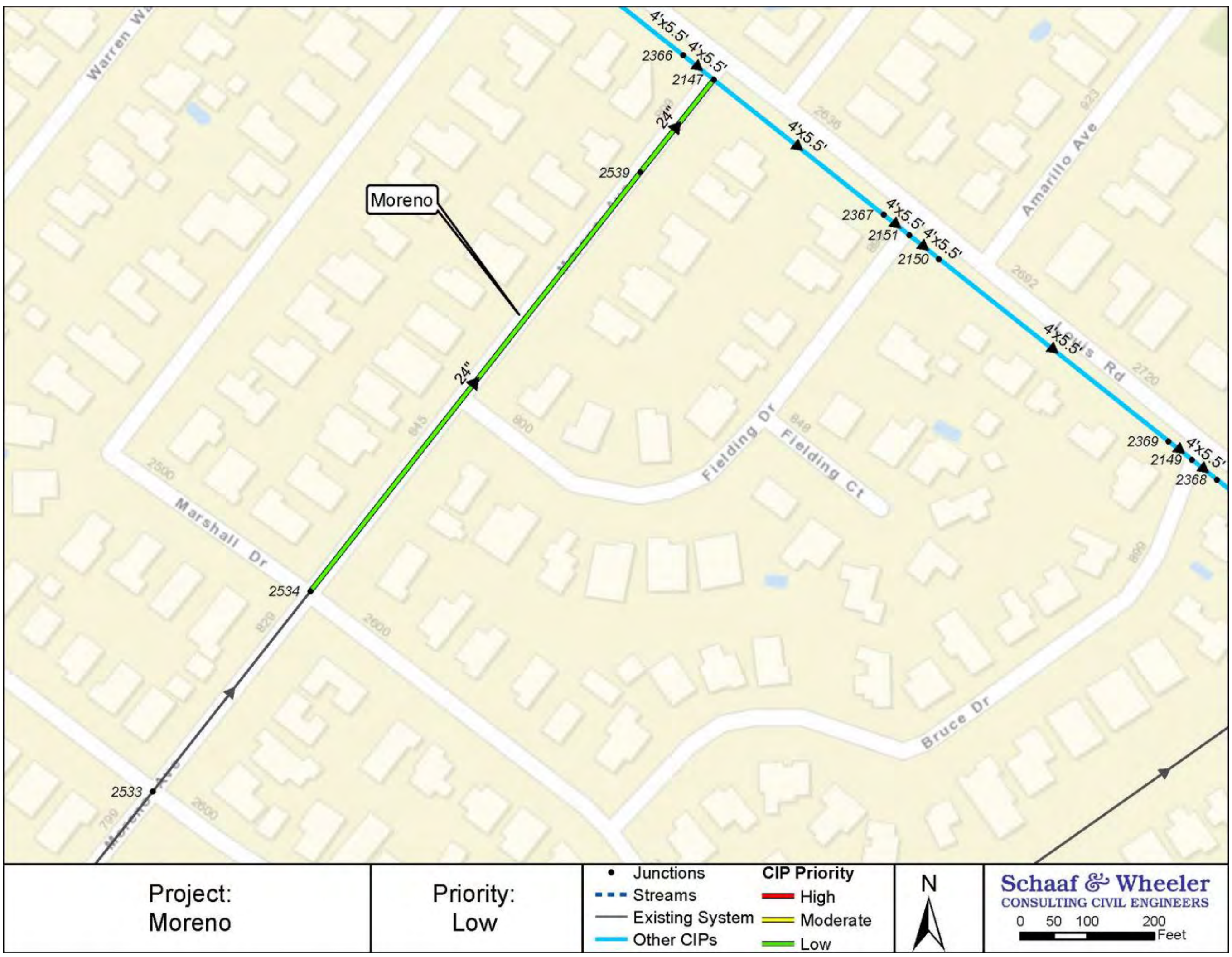
A. Project ID: 48	**B. Project Name: Moreno**
C. Project Location: Moreno Rd. between Marshall Dr. and Louis Rd.	
D. Priority: Low	

E. Type: Capacity

F. Project Description: The existing pipes on Moreno Ave. near Louis Rd. lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
15	24	773

G. Construction Subtotal **$290,000**
H. Total Construction Cost **$380,000**
I. Estimated CIP **$460,000**



A. **Project ID**: **49**	B. **Project Name**: **Nelson**

C. Project Location: Nelson Dr. near Creekside Dr. to Adobe Creek

D. Priority: Low

E. Type: Capacity

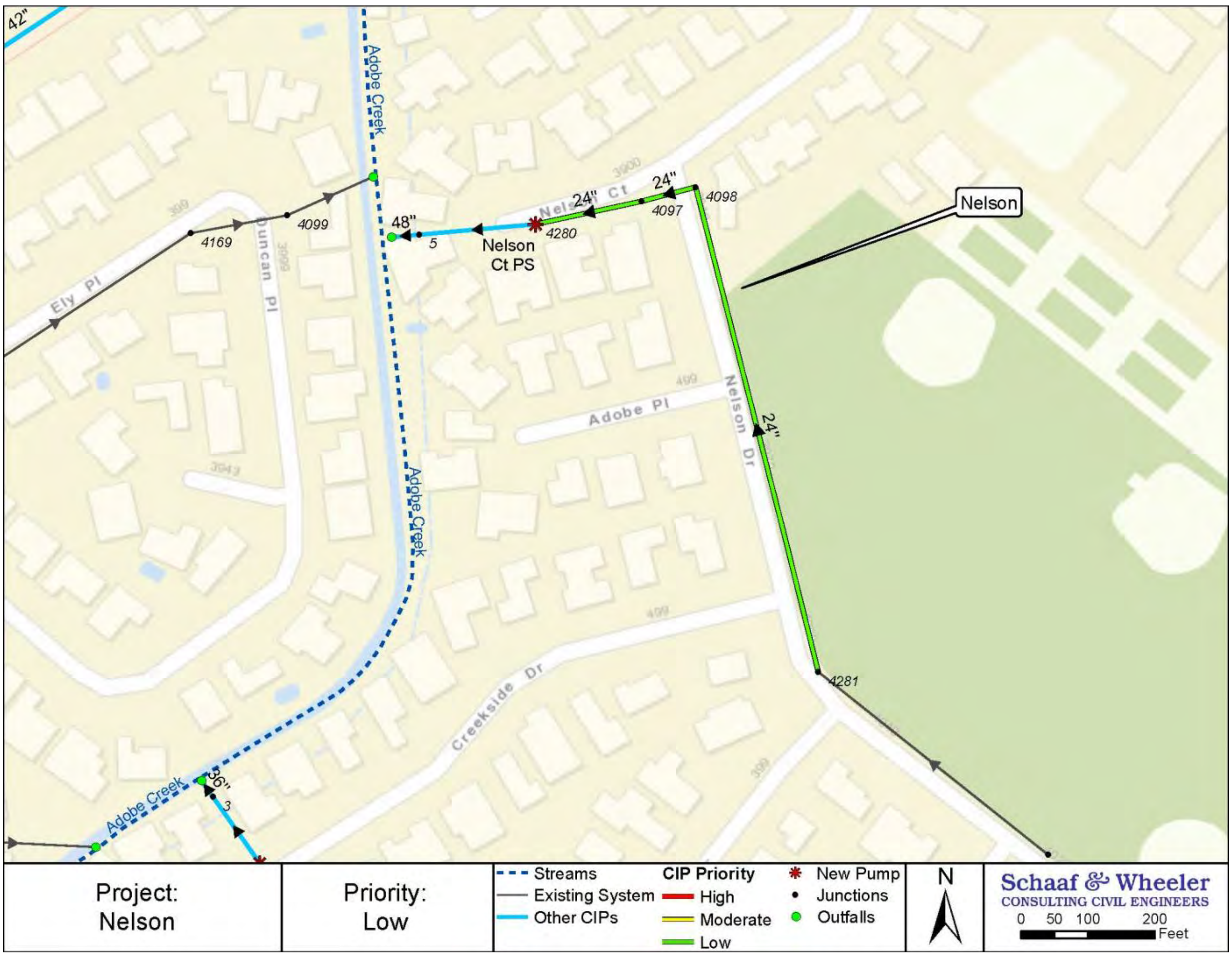
F. Project Description: The existing pipes to the Adobe Creek outfall on Nelson Dr. and Nelson Ct. lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
18	24	788

G. Construction Subtotal **$430,000**

H. Total Construction Cost **$560,000**

I. Estimated CIP **$670,000**



A. Project ID: 50

B. Project Name: Nelson Ct. Pump

C. Project Location: Nelson Ct. at Adobe Creek

D. Priority: Low

E. Type: Capacity

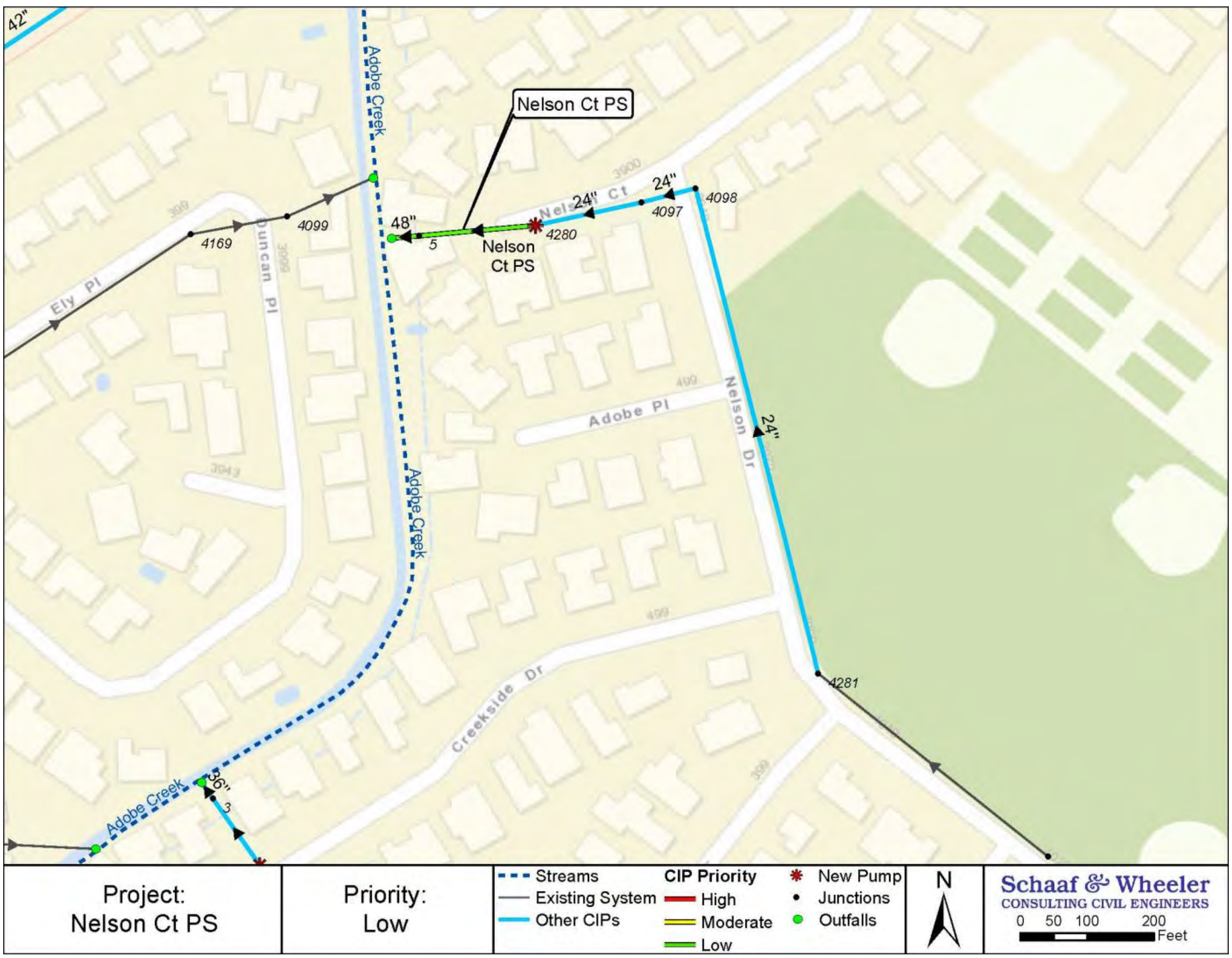
F. Project Description: A new pump station near Nelson Ct. at the Adobe Creek outfall is recommended to provide a 10 year level of service when the water level in Adobe Creek is high.

Ex. Capacity (cfs)	Imp. Capacity (cfs)
N/A	17

G. Construction Subtotal **$760,000**

H. Total Construction Cost **$990,000**

I. Estimated CIP **$1,190,000**



A. Project ID: 51	**B. Project Name: Oregon**

C. Project Location: Oregon Ave. between Greer Rd. and W. Bayshore Rd.

D. Priority: Low

E. Type: Capacity

F. Project Description: The existing pipes on Oregon Ave. near Greer Rd. lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
12	30	792

G. Construction Subtotal **$390,000**
H. Total Construction Cost **$510,000**
I. Estimated CIP **$610,000**

A. Project ID: 52	B. Project Name: Oregon and Louis

C. Project Location: **Oregon Ave. between Middlefield Rd. and Louis Rd.**

D. Priority: Low

E. Type: Capacity

F. Project Description: The existing pipes on Oregon Ave. southwest of Louis Rd. lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Size	Imp. Size	Length (ft)
2.8' x 2.9'	3'x4'	2,180

G. Construction Subtotal **$2,120,000**

H. Total Construction Cost **$2,760,000**

I. Estimated CIP **$3,310,000**

A. Project ID: 53

B. Project Name: Park & Whitclem

C. Project Location: Park Blvd. & Whitclem Dr. to Adobe Creek

D. Priority: Low

E. Type: Capacity

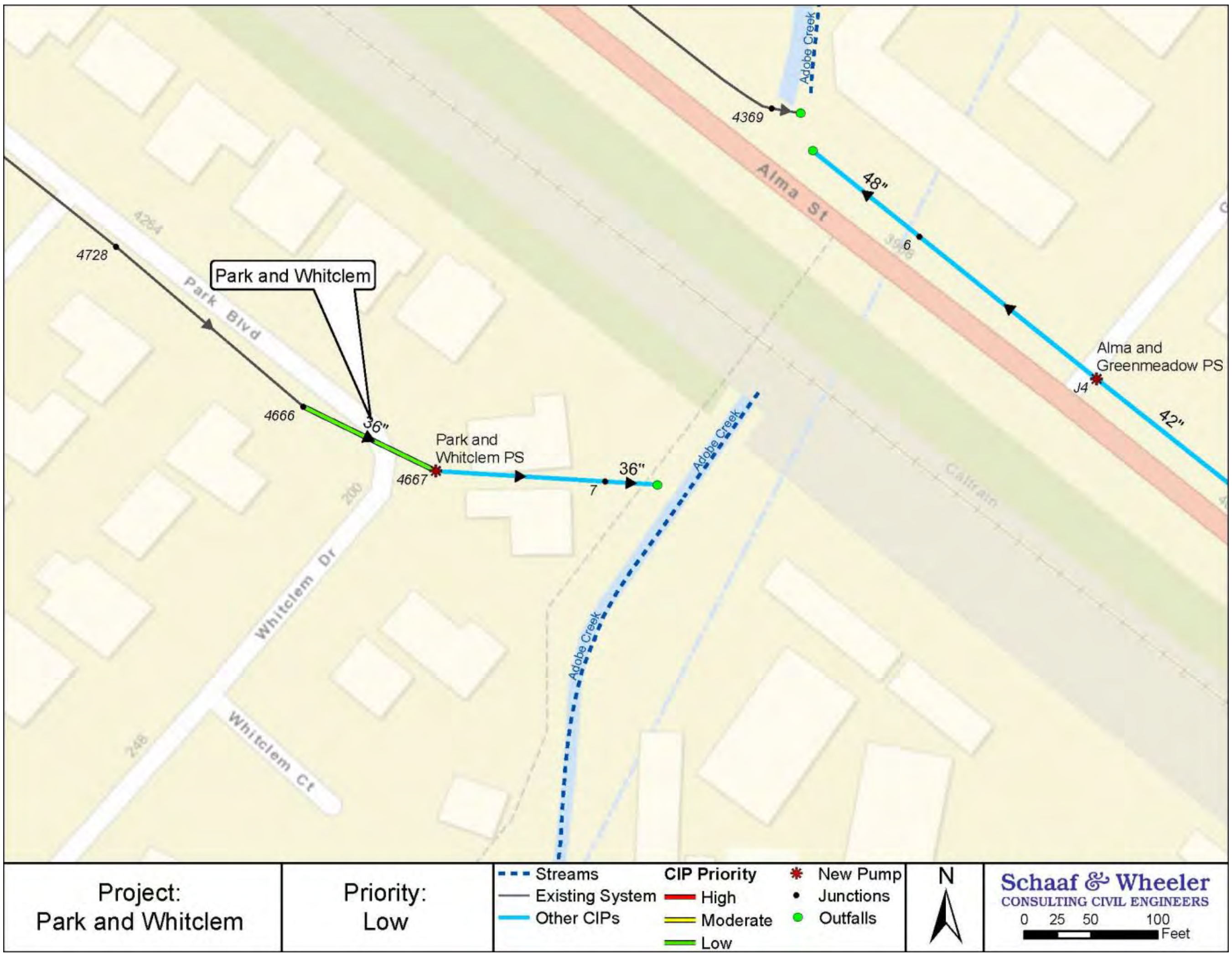
F. Project Description: The existing pipes from the intersection of Park Blvd. & Whitclem Dr. to the Adobe Creek outfall lack the capacity required to convey 10-year storm runoff. Upsizing these pipes and installing a pump station to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
18	36	88

G. Construction Subtotal $180,000

H. Total Construction Cost $230,000

I. Estimated CIP $280,000



A. Project ID: 54	**B. Project Name: Park & Whitclem PS**

C. Project Location: Park Blvd & Whitclem Drive

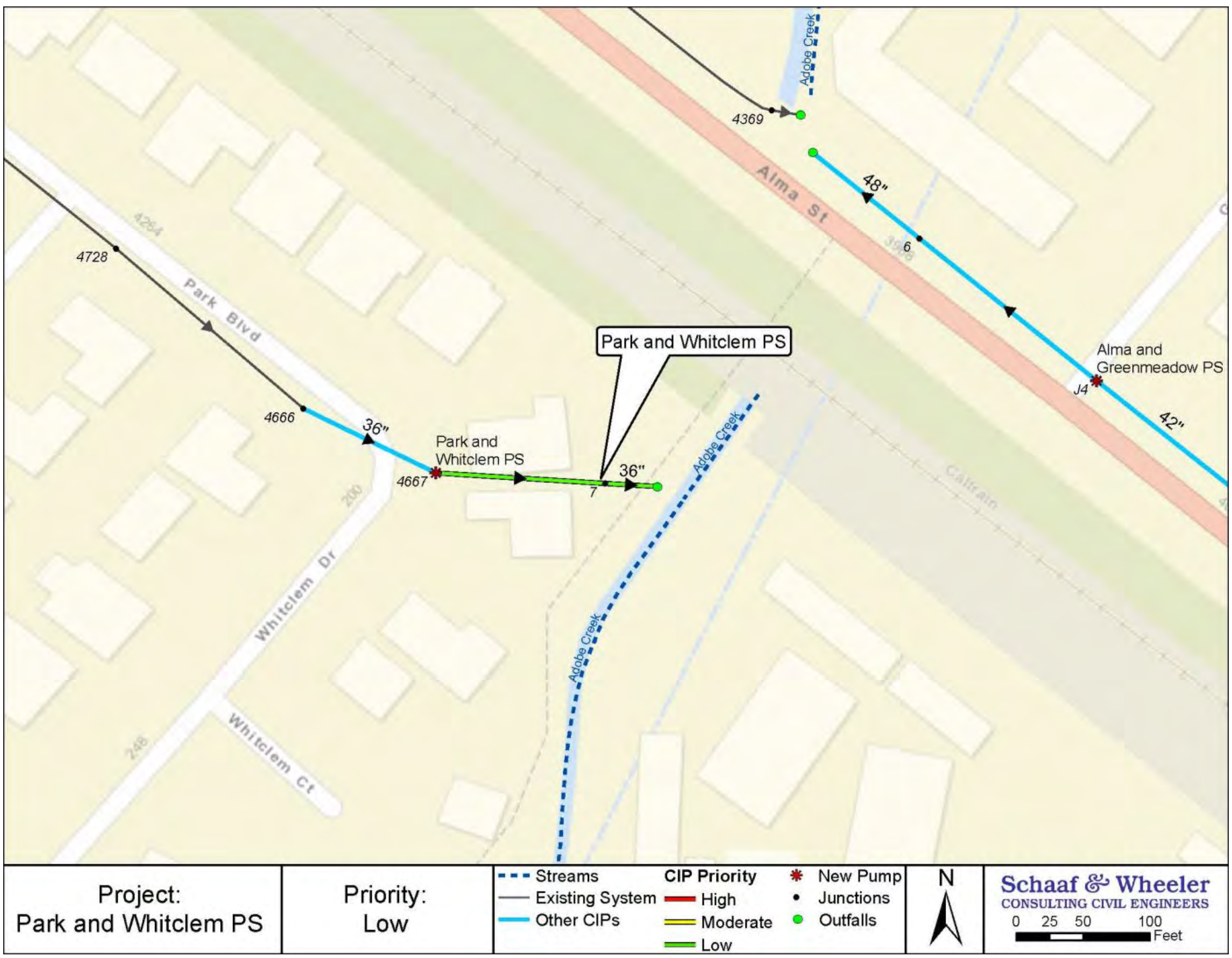
D. Priority: Low

E. Type: Capacity

F. Project Description: A new pump station near the intersection of Park Blvd. and Whitclem Dr. is recommended to provide a 10 year level of service when the water level in Adobe Creek is high.

Ex. Capacity (cfs)	Imp. Capacity (cfs)
N/A	19

G. Construction Subtotal **$840,000**
H. Total Construction Cost **$1,090,000**
I. Estimated CIP **$1,310,000**



A. Project ID: 55 | **B. Project Name: Parkinson & Newell**

C. Project Location: Parkinson Ave. at Harriet St. to Newell Rd. at Louisa Ct.

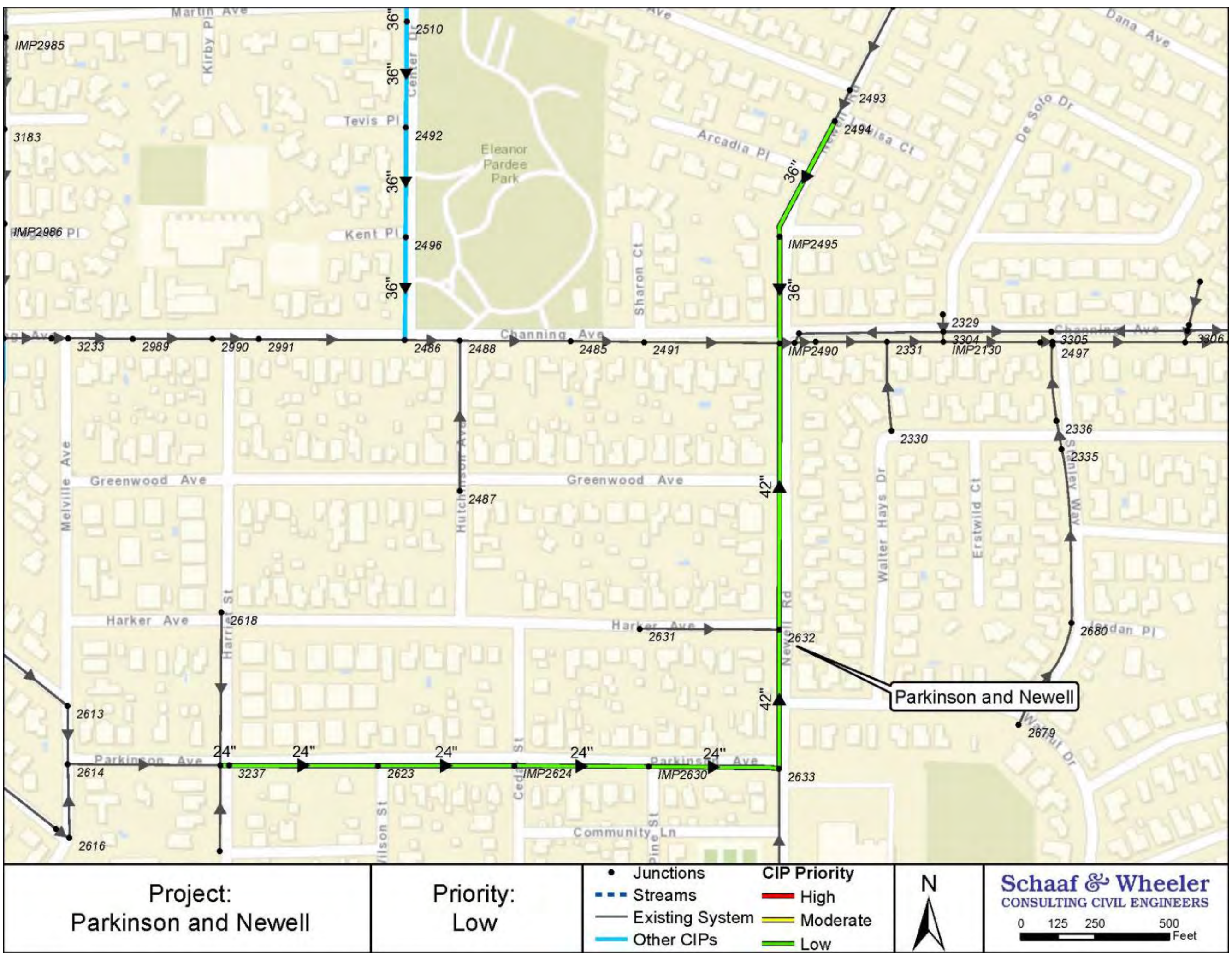
D. Priority: Low

E. Type: Capacity

F. Project Description: The existing pipes on Parkinson Ave. and Newell Rd. lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
12	24	422
15	24	364
18	24	709
24	36	629
18	42	1,134

G. Construction Subtotal **$1,500,000**
H. Total Construction Cost **$1,950,000**
I. Estimated CIP **$2,340,000**



A. Project ID: 56	B. Project Name: Portage

C. Project Location: Portage Ave. between El Camino Real and Ash St.

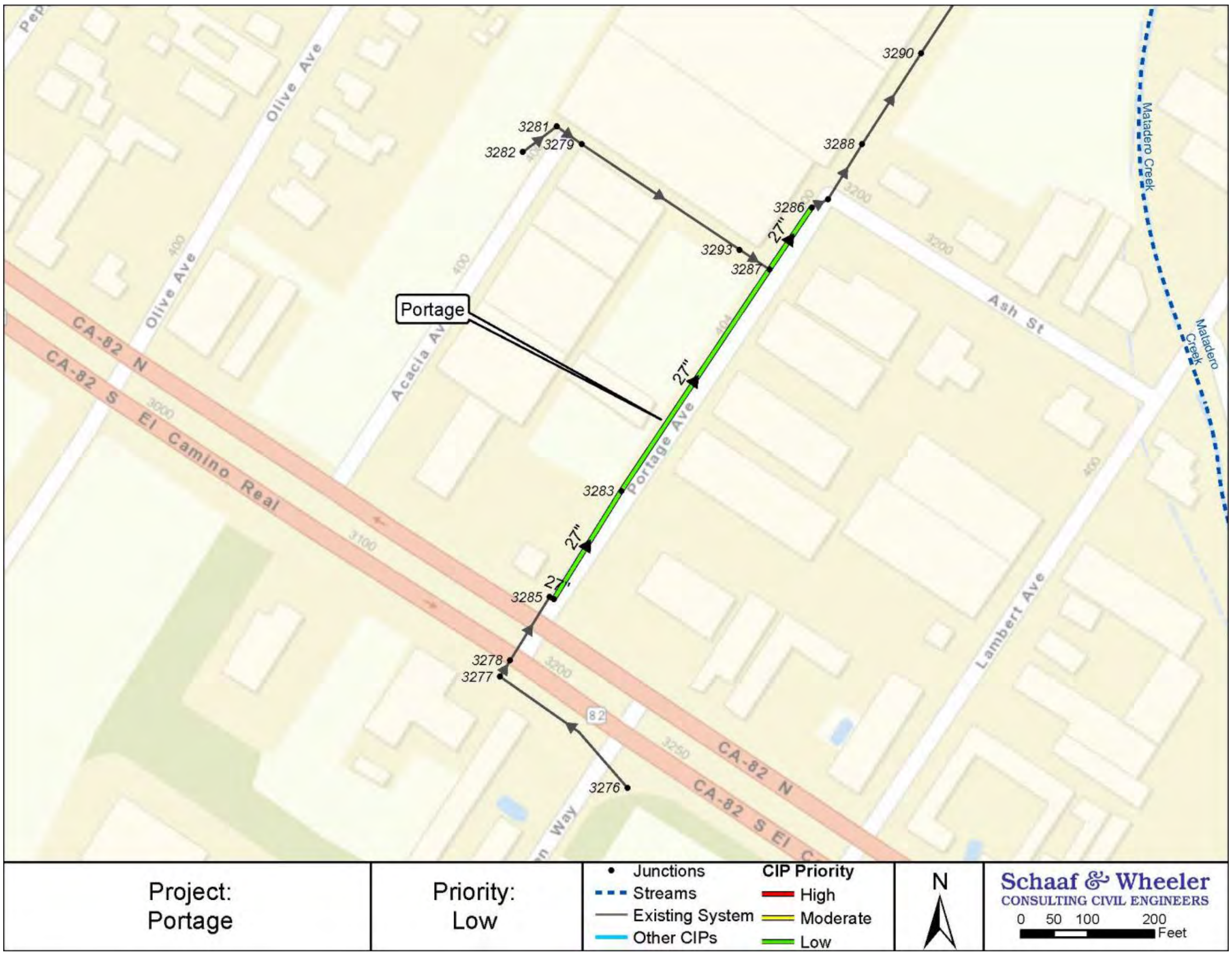
D. Priority: Low

E. Type: Capacity

F. Project Description: The existing pipes on Portage Ave. lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
12	27	6
15	27	556

G. Planning/Design/Admin/Permitting **$270,000**
H. Total Construction Cost **$350,000**
I. Estimated CIP **$420,000**



A. Project ID: 57	**B. Project Name: Ross & Ames**

C. Project Location: Ross Rd. between Ames Ave. and Loma Verde Ave.

D. Priority: Low

E. Type: Capacity

F. Project Description: The existing pipes on Ross Rd. west of Ames Ave. lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
15	36	321
18	36	553

G. Construction Subtotal **$420,000**
H. Total Construction Cost **$550,000**
I. Estimated CIP **$660,000**

A. Project ID: 58 | **B. Project Name: Ross Road to Matadero Creek**

C. Project Location: Ross Rd. between Allen Ct. and Matadero Creek

D. Priority: Low

E. Type: Capacity

F. Project Description: The existing pipes on Ross Rd. west of Allen Ct. lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended. The new outfall to Matadero Creek allows overflow to the creek during peak flow.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
12	18	353
--	48	431

G. Construction Subtotal **$440,000**

H. Total Construction Cost **$570,000**

I. Estimated CIP **$680,000**

A. Project ID: 59	**B. Project Name: San Antonio**

C. Project Location: San Antonio Rd. near Mackay Dr. to Charleston Rd.

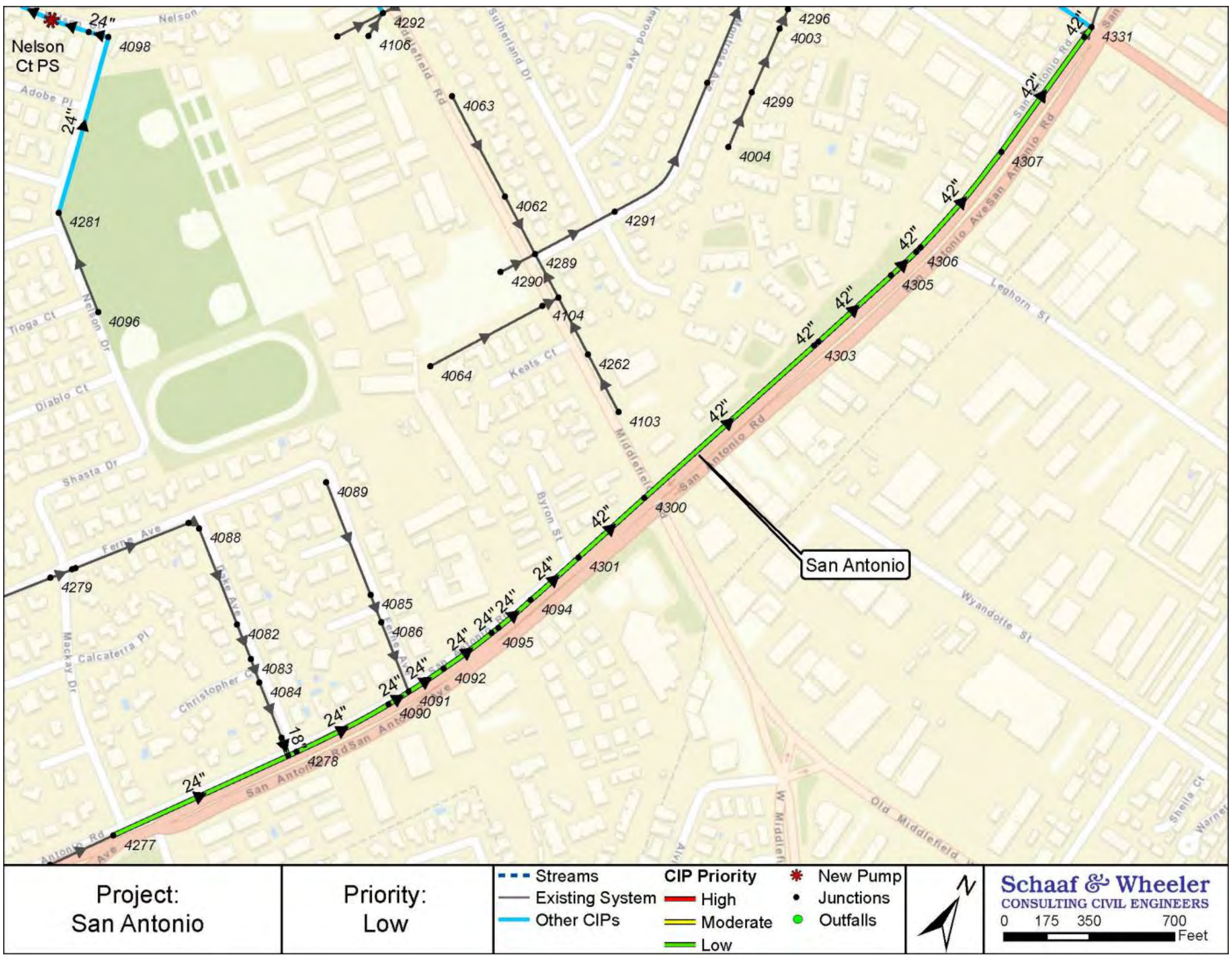
D. Priority: Low

E. Type: Capacity

F. Project Description: The existing pipes on San Antonio Rd. lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
12	18	63
12	24	627
18	24	1,152
18	42	289
27	42	2,121

G. Construction Subtotal $2,100,000
H. Total Construction Cost........ $2,730,000
I. Estimated CIP $3,280,000



A. Project ID: 60	**B. Project Name: Scripps**

C. Project Location: Scripps Ave. to Adobe Creek outfall

D. Priority: Low

E. Type: Capacity

F. Project Description: The existing pipes from Scripps Ave. to the Adobe Creek outfall near Creekside Dr. lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
15	24	251
18	24	183
18	36	400

G. Construction Subtotal **$550,000**
H. Total Construction Cost..**$720,000**
I. Estimated CIP **$860,000**

A. Project ID: 61	B. Project Name: Scripps Pump Station

C. **Project Location:** Creekside Dr. at Adobe Creek Outfall

D. **Priority:** Low

E. **Type:** Capacity

F. **Project Description:** A new pump station near Creekside Dr. is recommended to provide a 10 year level of service when the water level in Adobe Creek is high.

Ex. Capacity (cfs)	Imp. Capacity (cfs)
N/A	25

G. **Construction Subtotal** $1,090,000

H. **Total Construction Cost** $1,420,000

I. **Estimated CIP** $1,700,000

A. Project ID: 62 | **B. Project Name: South Ct. to Adobe Creek**

C. Project Location: From South Ct., to Jane Lathrop Stanford Middle School, following school driveway and E. Charleston Rd. to the outfall at Adobe Creek

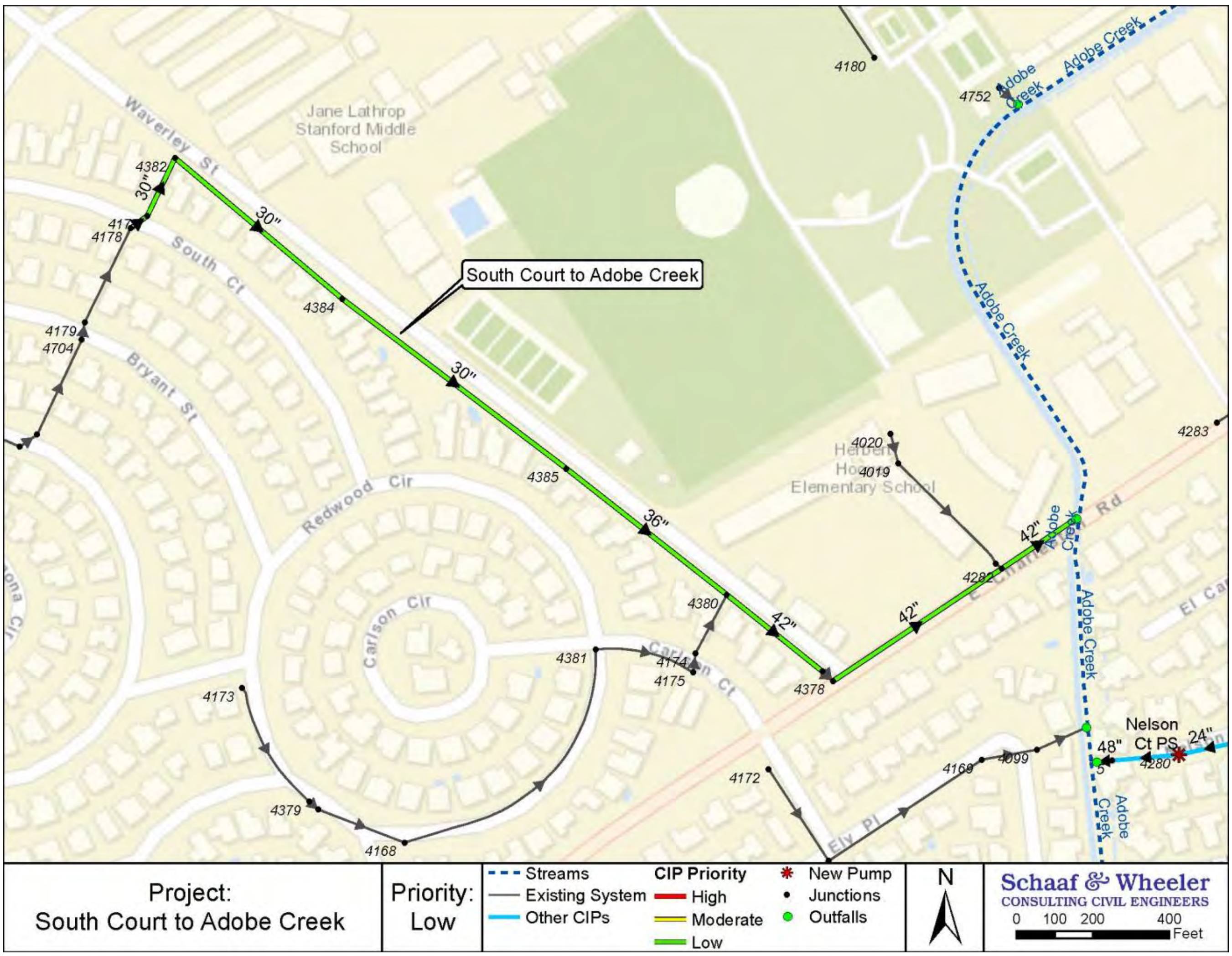
D. Priority: Low

E. Type: Capacity

F. Project Description: The existing pipes running through the easement alongside the Jane Lathrop Stanford Middle School driveway and E. Charleston Rd. to the E. Charleston outfall at Adobe Creek lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
21	30	1,215
27	36	424
30	42	862

G. Construction Subtotal **$1,270,000**
H. Total Construction Cost **$1,650,000**
I. Estimated CIP **$1,980,000**



A. Project ID: 63 | **B. Project Name: Ventura and Park**

C. Project Location: Ventura Ave. and Park Blvd., to Barron Creek outfall

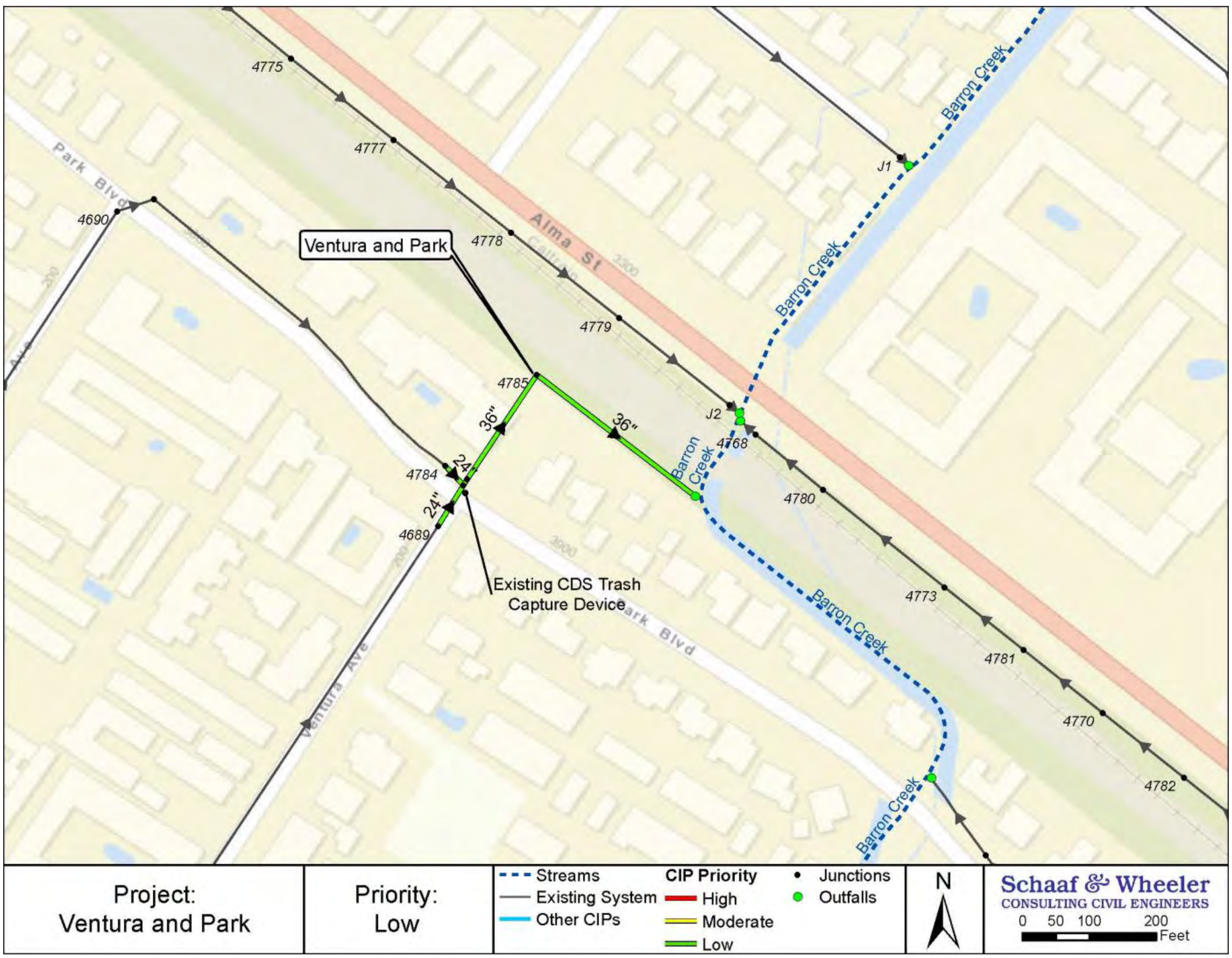
D. Priority: Low

E. Type: Capacity

F. Project Description: The existing pipes from Ventra Ave. and Park Blvd. to the outfall at Barron Creek lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended. There is an existing CDS Trash Capture Device located at Park Blvd. and Ventura Ave.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
15	24	57
18	24	31
12	36	9
21	36	385

G. Construction Subtotal **$330,000**
H. Total Construction Cost.. **$420,000**
I. Estimated CIP **$500,000**



A. Project ID: 64 | **B. Project Name: Walter Hays**

C. Project Location: Lois Ln. to Channing Ave.

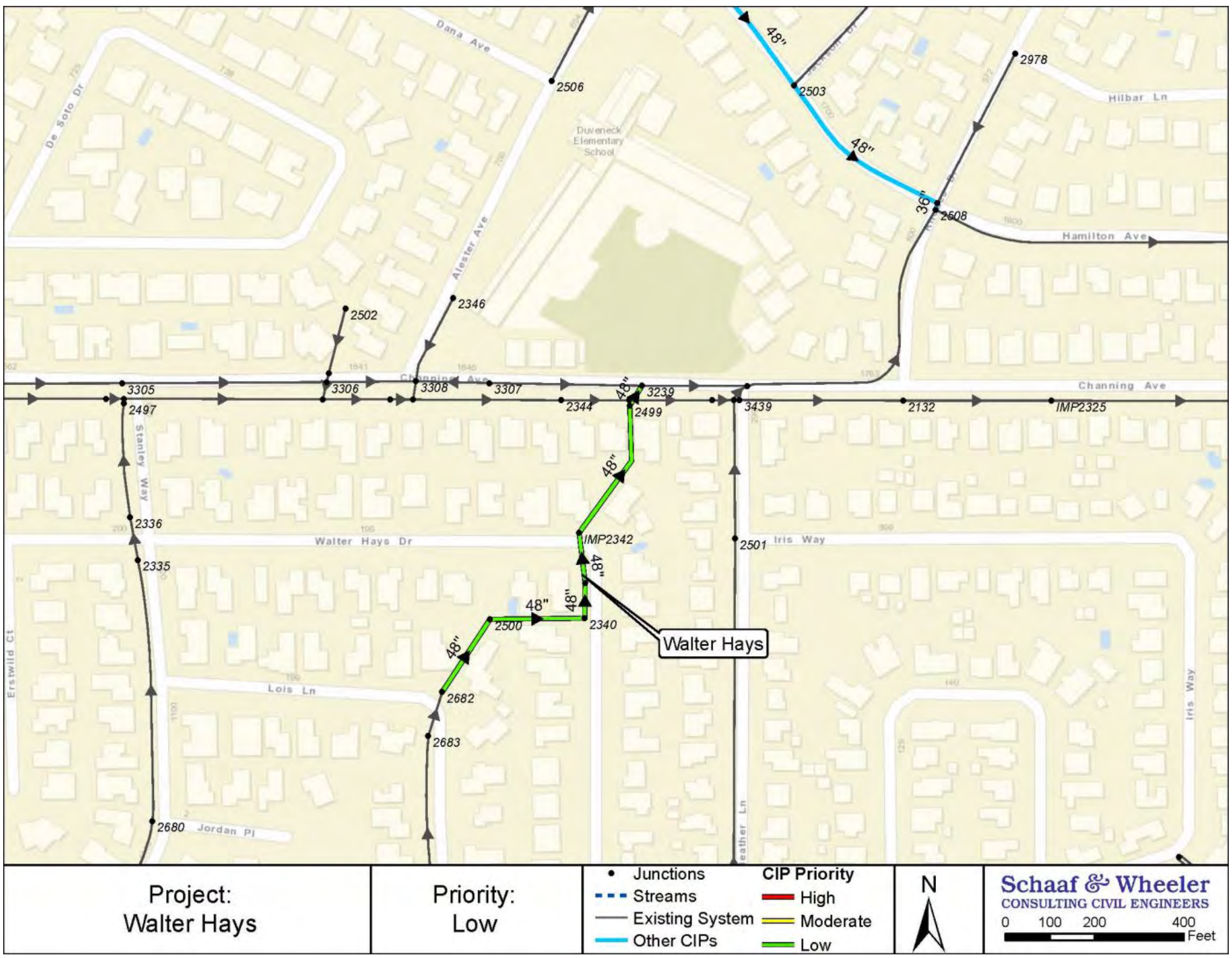
D. Priority: Low

E. Type: Capacity

F. Project Description: The existing pipes from Lois Ln., to Walter Hays Dr., and to Channing lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
15	48	323
18	48	408
21	48	42

G. Construction Subtotal **$520,000**
H. Total Construction Cost **$680,000**
I. Estimated CIP **$820,000**



A. Project ID: 65 | **B. Project Name: Waverley**

C. Project Location: Along Waverley St. from Channing Ave. to Lincoln Ave.

D. Priority: Low

E. Type: Capacity

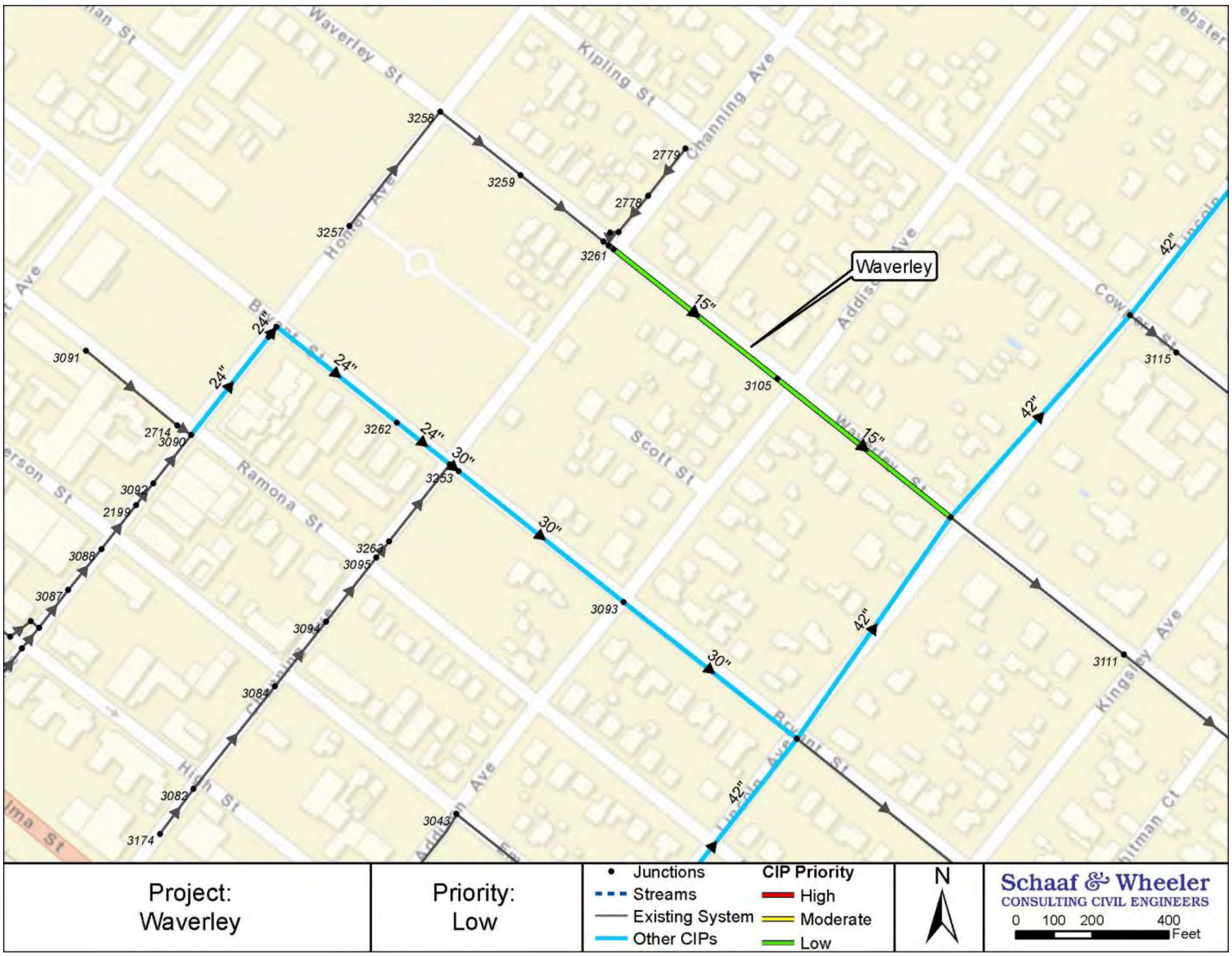
F. Project Description: The existing pipes on Waverley St. between Channing Ave. and Lincoln Ave. lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
12	15	895

G. Construction Subtotal **$290,000**

H. Total Construction Cost **$380,000**

I. Estimated CIP **$460,000**



A. Project ID: 66 | **B. Project Name: Wilkie and Park**

C. Project Location: Park Blvd. and Wilkie Way from Meadow Dr. to Duluth Cir.

D. Priority: Low

E. Type: Capacity

F. Project Description: The existing pipes on Park Blvd. and Wilkie Way lack the capacity required to convey 10-year storm runoff. Upsizing these pipes to achieve a 10 year level of service is recommended.

Ex. Diameter (in)	Imp. Diameter (in)	Length (ft)
12	24	443
18	24	613
21	24	135
21	36	763
27	36	952

G. Construction Subtotal $1,420,000
H. Total Construction Cost $1,850,000
I. Estimated CIP $2,220,000

Schaaf & Wheeler
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MEMORANDUM

TO:	Rajeev Hada, City of Palo Alto	DATE:	June 27, 2015
FROM:	Schaaf & Wheeler	JOB #:	PALO.06.14
SUBJECT:	**Palo Alto Drainage Design Standards**		

All drainage facilities shall be designed in accordance with accepted engineering principles and standard practices, and shall conform to these Design Standards. Drainage calculations are required for new subdivisions, development, redevelopment, or site improvements as deemed necessary by the City Engineer. Submittal of drainage calculations shall include the following items:

1. Hydrology and hydraulic calculations together with assumptions, charts, formulas, runoff coefficient, site specific areas, tables, references and methods used, etc.
2. A plan that clearly shows the existing and proposed drainage system, drainage patterns, tributary drainage sub-areas, and peak flow in all pipes.
3. A profile plan showing the hydraulic grade line (HGL) and the proposed storm drain pipe size, slope, length and material.

Design Flow

Per the 2007 Santa Clara County Drainage Manual, the Rational Method shall be used to calculate peak flows and the Unit Hydrograph Method shall be used to calculate flow hydrographs. Each method is described below and summarized in Table 1.

- The Rational Method is useful for estimating flood peaks and stormwater conveyance system design in highly urbanized areas with small watersheds and largely impervious areas, such as Palo Alto. The Rational Method can provide estimates for relating peak discharge to rainfall intensity by multiplying the design rainfall intensity by the watershed area and by a runoff coefficient.
- The Unit Hydrograph Method allows for the development of a flood hydrograph using a design storm, an appropriate infiltration method, and a synthetic unit hydrograph. This method allows for the analysis of complex drainage facilities by taking into account hydrologic losses including evaporation, transpiration, infiltration, surface routing, storage within the watershed, and varying antecedent moisture conditions. The parameters required to develop the flood hydrograph are summarized in Table 1.

Table 1: Method summary

Method	Result	Parameters required	Source
Rational Method	Peak flow	Runoff coefficient	Drainage Manual
		Rainfall intensity	Drainage Manual
		Drainage area	Physical
Unit Hydrograph Method	Flow hydrograph	Basin area	Physical
		Precipitation	Drainage Manual
		Initial abstraction	Equation
		SCS curve number	Drainage Manual
		Percent imperviousness	Physical
		Basin lag	Equation

Design Standards for Inlets, Pipes and Manholes

Applicant shall first determine the pre-development downstream conditions to establish the existing HGL. The design and evaluation of new systems, particularly extensions of existing systems, must be done on a case-by-case basis and these exceptions to the listed criteria for new systems are suggested where new collection systems discharge to existing systems:

With 10-year Design Discharge	Pipes shall be sized to carry the 10-year discharge with HGLs 0.5-foot below inlet grate elevations. When downstream surcharge effects are included, upstream hydraulic grades shall be no higher than the top of curb elevation at any manhole or inlet.
With 100-year Design Discharge	Hydraulic grade shall not exceed the street right-of-way elevation at any location.

New drainage conduits shall be sized based on the design criteria listed in Table 2. The following design criteria are standard practices and City requirements.

1. Projects shall include conceptual storm drain design and C.3 treatment measures as part of the Planning Phase.
2. Manholes shall be no farther than 400 feet apart.
3. Designer shall verify adequate clearances between existing utilities and proposed storm drain pipelines (or required utility relocations) in the public right-of-way prior to the start of construction work.
4. Catch basins shall be spaced so that the maximum width of gutter flow, when flooded, does not exceed eight feet from the face of curb during a 10-year design storm and the travel lane remains dry
5. The City requires that all new catch basins within the public right-of-way be hooded inlets.
6. Drainage flows shall not be pumped into the public system, instead flows shall drain by gravity into the City's system.
7. The City does not typically allow a private storm drain lines to be directly connected to the City's mains. Private lines shall daylight within private property and runoff shall bubble-up to an onsite

detention basin or connected to a junction box at the property boundary before connecting to the City system.

8. When a detention basin is required, then the City may allow a direct connection from the basin into the City's system.
9. If a private line is permitted to connect into the City's main lines, applicant shall verify that the pipe has adequate cover and does extend into the pavement section.
10. The following pipe materials are allowed within the public right-of-way, HDPE, RCP and C900 PVC.
11. Inlets in the public right-of-way shall be marked with a creek-specific "No Dumping" medallions provided by the City. Private inlets shall be marked with a creek-specific "No Dumping" message using painted stencils (stencil provided by the City), thermoplastic material, or medallions (owner's discretion as to method of labeling).

Table 2: Summary of Design Standards based on standard practice

Condition	Design Criteria
New Systems	10-year HGL 0.5' below cover or inlet grate
New Systems	100-year shall not exceed street right of way elevation
Closed Conduits	Max. Velocity = or < 15 ft/sec
Closed Conduits	Min. Velocity = or > 2 ft/sec
New Closed Conduits	Min. Slope > 0.002
Earth Channels	Max. Velocity < 5 ft/sec
Lined Channels	Min. Velocity < 10 ft/sec
Earth Channels	Min. Slope > 0.002
Closed Conduit	Min. Pipe Size 12-inches
Improvements to existing	Min. Pipe Size 12-inches or as directed by the City.

Design Standards for Single Family Residences

Palo Alto requires that all development projects avoid discharging directly into the City's storm drain system. Since the residential projects make-up a large portion of development, property owners and applicants are encouraged to implement the following drainage design standards to minimize the negative impact into the City's storm drain system and downstream properties.

1. Conceptual stormwater drainage design and C.3 treatment measures shall be considered and planned for during the project planning phase.
2. Roofs shall be designed to manage rain runoff so that it lands within the private property.
3. Install downspouts with splash blocks to direct discharge away from the building foundation.
4. Downspouts may be allowed to be hard-piped into a system with a bubbler or dissipation device that discharges within private property
5. Roof gutters, pipes, or downspouts shall not be made of copper material.
6. Bubblers or dissipation devices shall not be installed closer than 10-feet from the back of walk or 3-feet from the side or rear side yards.
7. Minimize impervious surfaces to encourage additional onsite infiltration. Where feasible install permeable pavement such as crushed aggregate, turf block, unit pavers, pervious concrete, or permeable asphalt instead of traditional concrete or asphalt.
8. The drainage system for light wells and stairwells that are associated with basements shall be independent from the site drainage system that collects downspouts and area drains. Both drain systems shall discharge within private property.

9. Basement perimeter drains are not permitted west of Foothill Expressway.
10. Drainage across property lines shall not exceed that which existed prior to grading. Plans shall include grades along the property line and within swales to verify runoff is not crossing property lines.
11. Storm drain pipelines under structures are prohibited.
12. New structures that are located on a hillside will also be subject to excessive runoff or potential flooding. Therefore, runoff shall be managed to drain around the proposed structures to avoid drainage into the foundation or flooding the living area.
13. Additional City policies and guidelines are also available on Public Works' webpage.

Outfalls
Where storm drain collection systems discharge to receiving waters, analyses shall assume that the peak of local runoff coincides with the 10-year peak stage at the collection system outfall.

Storage Facilities
There are two basic categories of stormwater storage: detention and retention. Detention generally refers to the temporary storage of incoming runoff that exceeds the permissible release. After the storm event, the facility empties and returns to its natural function; such as a parking lot, rooftop, or park. Retention facilities, on the other hand, hold on to the excess runoff for an indefinite period. Natural ponds and lakes exemplify retention facilities where water levels change only through evaporation, infiltration and additional storm runoff.

Determination of the impact of a detention basin on downstream areas shall be made on a case-by-case basis. Routing a flow hydrograph through a storage basin generally delays the peak and reduces the maximum discharge. The delayed peak may have a detrimental impact on downstream areas if the timing is such that the combined discharges downstream are greater than the combined discharge that would have resulted if the detention basin did not exist. Detention basins also tend to increase the duration of flow at downstream locations.

Design Criteria for Detention Facilities
Properly designed, constructed, and maintained stormwater storage facilities can reduce peak flows, thereby better utilizing the capacity of downstream conveyance facilities. Such facilities can also potentially mitigate the need for system upgrades. The efficacy of any detention facility, as well as ancillary improvements in the quality of storm runoff to receiving waters, shall be evaluated on a case-by-case basis. However, some general design criteria should be applied to every basin:

1. A 24-hour 10-year storm shall be used to size detention basins (basins with an outlet to the City system). If no disposal other than evaporation or percolation is provided (retention), a 24-hour 100-year storm shall be used.
2. Basins shall meet the requirements of the Santa Clara County Drainage Manual.
3. Private basins shall be maintained by the property owner; assurances for the continued maintenance of its capacity shall be provided to the City through a maintenance agreement.
4. Basins shall be sized so that their output flow does not exceed the design capacity of downstream facilities. 10 year post development runoff shall not exceed the 10 year pre development runoff. Excess post development runoff shall be mitigated in the detention basin.
5. Infiltration capacity shall not be considered when designing detention basins.
6. The design procedure outlines in Section 6.3.3 of the County Manual shall be followed for detention basin design.
7. Underground detention facilities (pipes or structures) shall be sized according to the criteria herein.

8. Retention basis shall be equipped with an emergency overflow section capable of safely discharging the 100-year peak inflow (should the outlet become blocked, or a storm event larger than the design event occurs), without causing property damage.
9. At least one foot of freeboard over the maximum 100-year water surface elevation shall be provided for excavated retention basins. Three feet of freeboard (minimum) shall be provided where retention basins are created by berms or levees.
10. Retention facilities shall only be used in areas where groundwater tables and percolation rates warrant their construction. Separate approval from the Santa Clara Valley Water District is required, and pond designed shall also be reviewed for conformance with the standards and policies of the Department of Environmental Health.
11. Retention basins shall fully drain within 48 hours of the cessation of a precipitation from a design 100-year 24-hour rainfall event.
12. Maximum side slope for turfed or landscaped basins shall be 4:1.
13. Fencing shall be provided around all basins greater than 3-feet in depth.

Debris Loading

Detention and retention basins will eventually fill up with sediment and other debris, reducing their storage capacity to the point where they will not operate as designed. Therefore, some consideration of debris loading should be made for each basin. Based on work by Schaaf & Wheeler for the Santa Clara Valley Water District, the following empirical relationships are provided as a guideline (debris load per unit drainage area) for use to evaluate debris loading:

Highly urban areas	0.1 acre-foot/mi^2/year
Hillside open space	0.4 acre-foot/mi^2/year

Depending upon the desired frequency of maintenance, some allowance for dead storage should be made to handle sediment and debris using the loading rates given above. Basin sizing should meet City of Palo Alto design guidelines for stormwater quality detention and retention basins.

General Pump Station Criteria

Pump stations are generally considered adequate if there is sufficient pump capacity to discharge design runoff into the receiving waters or if excess flows can be stored without causing property damage.

Capacity

Ideally at least two identical pumps should be installed in every stormwater pump station for some redundancy and ease of maintenance. It is not industry practice to include standby pumps in a stormwater station because providing excess capacity is expensive and generally not justified by the relatively small risk of having a major storm event coincide with a single pump failure. All things considered, installing a larger number of smaller pumps is generally better than a lesser number of large pumps for the same capacity. When individual pumps comprise a smaller percentage of overall pump station capacity, having one pump fail is less detrimental. In terms of redundancy and ease of maintenance, the pumping units within one particular station should be identical.

Pumps and Drivers

A general trend in current pump station design is to use electric motors for primary power rather than direct-drive engines due to noise, ventilation, and air quality considerations. Submersible pumps are also widely used for stormwater applications to reduce the complexity of lift station components. New pumps should be submersible, unless matching an existing pump or other site constraints dictate a more conventional pump.

Operation

Lead and lag pumps should be automatically alternated on every start to minimize pump cycling, equalize the number of operating hours among pumps as practicable, and extend the operating life of the equipment. Sufficient wet well storage must also be available in order to prevent excessive pump cycling for proposed operating levels.

The maximum number of pump starts per hour should be held below the maximum criterion established by pump, motor, and/or engine manufacturers. In the absence of specific data, pump starts should be limited to six per hour. This criterion is based on general limits set by large electric motor manufacturers; diesel engine suppliers also recommend that engines should run at least five to ten minutes at full operating temperatures each time they are started.

Pumping equipment must be specified so that motor or engine nameplate ratings are not exceeded at any point on the pump characteristic curve as far as practicable. Pump performance under different hydraulic conditions should be analyzed to ensure that pumps operate within manufacturers' recommended limits.

Excessive pump wear, vibration, noise, or cavitation could be indicative of more serious hydraulic problems associated with the pump and intake geometries. If any of these issues are noted, the City should contact the pump manufacturer or an engineer.

Standby Power

Generators should be present on-site and connected to the power supply with an automatic transfer switch to be considered as available in an emergency under FEMA flood hazard mapping requirements. The use of portable generators, or even permanently parked generators with manual transfer switches, is only feasible where crews may respond to high water alarms during power outages, physically reach the pump station with a generator, and manually restore power before property damage has occurred. Small lift or pump stations that generally handle nuisance flows (flows for which significant property damage would not occur should the pump station fail) do not necessarily require a standby power source.

Stormwater Management

The objective of this section is to prevent future development from increasing flood hazards to existing development and to maintain and improve water quality. Implementing the activities in the section below when managing new developments in Palo Alto may result in obtaining credits from the National Flood Insurance Program (NFIP) through the Community Rating System. The objective of the Community Rating System (CRS) is to reward communities that are doing more than meeting the minimum NFIP requirements to help their citizens prevent or reduce flood losses.

All new developments in the Palo Alto watershed are subject to the following three regulations based on the stormwater management, watershed master planning, erosion and sediment control, and water quality, as summarized in Table 3.

Table 3. Stormwater Regulation summary

Credit	Regulation summary	Size
Stormwater management	Peak runoff from new development shall not be greater than the runoff from the site in its pre-development condition.	All Development Projects except Single Family Residential Buildings
Erosion and sedimentation control	Erosion and sediment control measures shall be taken on land that is disturbed during development	All Development Projects (see PAMC 16.28)
Water quality	New developments must include in the design of their stormwater management facilities appropriate "best management practices" that will improve the quality of water surface.	All development projects (see PAMC 16.11)

Stormwater Management Regulations (SMR)

All new developments in Palo Alto are required to prevent the increase in runoff that results from urbanization. Stormwater management regulations for the City of Palo Alto are made up of the following subcategories:

Size of development

The City requires all new development to ensure that the post-development stormwater discharge will not exceed the amount of runoff under pre-development conditions.

Design storm

At a minimum, the peak runoff from a 10-year storm from new developments shall not be greater than the runoff from the site in its pre-development condition. All discharges from the 10-year storm must be released at rates not exceeding the pre-development peak discharge. Although not required for projects that don't increase runoff through development, controlling the volume of runoff from the 10-year storm using retention is encouraged.

Before development, the developer must submit hydrologic and hydraulic studies showing the nature and extent of runoff under present conditions and with the proposed development for the 10-year storm event.

Low-impact development (LID)

Implementation of low-impact development (LID) practices is required by the MRP for all new developments and redevelopments to control the impacts of development on runoff. Some examples of LID include bioretention facilities, rain gardens, vegetated rooftops, rain barrels, and permeable pavements. For a guide to LID practices applicable in Santa Clara County see *C.3 Stormwater Handbook* produced by the Santa Clara Valley Urban Runoff Pollution Prevention Program. A Tentative Order of the proposed MRP which may be reissued later this year (Fall 2015) is available for review. LID practices in the Tentative Order shall be followed when applicable.

As part of the City's sustainable program, City has a storm water rebate program for installing rain barrels, cisterns, permeable pavers and green roofs. The purpose of this program is to help reduce storm runoffs to our creeks and bay, recharge ground water and keep our creeks and bay clean. Developers are encouraged to take advantage of the City's rebate program. For the City's storm water rebate program, see http://www.cityofpaloalto.org/gov/depts/pwd/stormwater/rebates/

Non-LID development

LID practices may not be feasible for certain projects due to soils conditions, location, project size, etc. If non-LID measures are necessary, the applicant shall submit the request to the City and obtain a formal approval during the initial planning stages of the project.

Erosion and sedimentation control regulations (ESC)

The City requires that erosion and sediment control measures be taken on land that is disturbed during development and at all construction sites within the City. Interim and final erosion and sediment control and storm water pollution prevention plans are required as part of the grading permit application process. Requirements for the erosion and sediment control and storm water pollution prevention plans can be found in the City of Palo Alto Municipal Code Chapter 16.28 Grading and Erosion and Sediment Control.

Water Quality Regulations (WQ)

New developments must include in the design of their stormwater management facilities appropriate measures that will improve the quality of surface water. Site design requirements are detailed in the *C.3 Stormwater Handbook* produced by the Santa Clara Valley Urban Runoff Pollution Prevention Program. Site design measures include reducing the size of impervious areas, rainwater harvesting and use, and tree preservation and planting.

Appendix F

Rainfall Data

Rainfall computed for the 10-yr, 25-yr, 50-yr, and 100-yr 24-hr storms using the 5 minute pattern for MAP=16" from the Santa Clara Hydrology Drainage Manual.

Table 1. Fractions of Total Rainfall for 24-Hour, 5-Minute Pattern for MAP=16"

Time	5-min fraction	Percent of Rainfall	Time	5-min fraction	Percent of Rainfall	Time	5-min fraction	Percent of Rainfall
0:00	1.711	0.143	8:00	3.339	0.278	16:00	2.567	0.214
0:05	1.711	0.143	8:05	3.339	0.278	16:05	2.567	0.214
0:10	1.711	0.143	8:10	3.339	0.278	16:10	2.567	0.214
0:15	1.711	0.143	8:15	3.339	0.278	16:15	2.567	0.214
0:20	1.711	0.143	8:20	3.339	0.278	16:20	2.567	0.214
0:25	1.711	0.143	8:25	3.339	0.278	16:25	2.567	0.214
0:30	1.711	0.143	8:30	3.339	0.278	16:30	2.567	0.214
0:35	1.711	0.143	8:35	3.339	0.278	16:35	2.567	0.214
0:40	1.711	0.143	8:40	3.339	0.278	16:40	2.567	0.214
0:45	1.711	0.143	8:45	3.339	0.278	16:45	2.567	0.214
0:50	1.711	0.143	8:50	3.339	0.278	16:50	2.567	0.214
0:55	1.711	0.143	8:55	3.339	0.278	16:55	2.567	0.214
1:00	1.568	0.131	9:00	2.782	0.232	17:00	1.426	0.119
1:05	1.568	0.131	9:05	2.782	0.232	17:05	1.426	0.119
1:10	1.568	0.131	9:10	2.782	0.232	17:10	1.426	0.119
1:15	1.568	0.131	9:15	2.782	0.232	17:15	1.426	0.119
1:20	1.568	0.131	9:20	2.782	0.232	17:20	1.426	0.119
1:25	1.568	0.131	9:25	2.782	0.232	17:25	1.426	0.119
1:30	1.568	0.131	9:30	2.782	0.232	17:30	1.426	0.119
1:35	1.568	0.131	9:35	2.782	0.232	17:35	1.426	0.119
1:40	1.568	0.131	9:40	2.782	0.232	17:40	1.426	0.119
1:45	1.568	0.131	9:45	2.782	0.232	17:45	1.426	0.119
1:50	1.568	0.131	9:50	2.782	0.232	17:50	1.426	0.119
1:55	1.568	0.131	9:55	2.782	0.232	17:55	1.426	0.119
2:00	3.730	0.311	10:00	3.895	0.325	18:00	1.854	0.155
2:05	3.730	0.311	10:05	3.895	0.325	18:05	1.854	0.155
2:10	3.730	0.311	10:10	3.895	0.325	18:10	1.854	0.155
2:15	3.730	0.311	10:15	3.895	0.325	18:15	1.854	0.155
2:20	3.730	0.311	10:20	3.895	0.325	18:20	1.854	0.155
2:25	3.730	0.311	10:25	3.895	0.325	18:25	1.854	0.155
2:30	3.730	0.311	10:30	3.895	0.325	18:30	1.854	0.155
2:35	3.730	0.311	10:35	3.895	0.325	18:35	1.854	0.155
2:40	3.730	0.311	10:40	3.895	0.325	18:40	1.854	0.155
2:45	3.730	0.311	10:45	3.895	0.325	18:45	1.854	0.155
2:50	3.730	0.311	10:50	3.895	0.325	18:50	1.854	0.155
2:55	3.730	0.311	10:55	3.895	0.325	18:55	1.854	0.155
3:00	6.864	0.572	11:00	4.591	0.383	19:00	1.996	0.166
3:05	6.864	0.572	11:05	4.591	0.383	19:05	1.996	0.166
3:10	6.864	0.572	11:10	4.591	0.383	19:10	1.996	0.166
3:15	6.864	0.572	11:15	4.591	0.383	19:15	1.996	0.166
3:20	6.864	0.572	11:20	4.591	0.383	19:20	1.996	0.166
3:25	6.864	0.572	11:25	4.591	0.383	19:25	1.996	0.166
3:30	6.864	0.572	11:30	4.591	0.383	19:30	1.996	0.166
3:35	6.864	0.572	11:35	4.591	0.383	19:35	1.996	0.166
3:40	6.864	0.572	11:40	4.591	0.383	19:40	1.996	0.166
3:45	6.864	0.572	11:45	4.591	0.383	19:45	1.996	0.166

Time	5-min fraction	Percent of Rainfall	Time	5-min fraction	Percent of Rainfall	Time	5-min fraction	Percent of Rainfall
3:50	6.864	0.572	11:50	4.591	0.383	19:50	1.996	0.166
3:55	6.864	0.572	11:55	4.591	0.383	19:55	1.996	0.166
4:00	6.117	0.510	12:00	3.478	0.290	20:00	1.711	0.143
4:05	6.117	0.510	12:05	3.478	0.290	20:05	1.711	0.143
4:10	6.117	0.510	12:10	3.478	0.290	20:10	1.711	0.143
4:15	6.117	0.510	12:15	3.478	0.290	20:15	1.711	0.143
4:20	6.117	0.510	12:20	3.478	0.290	20:20	1.711	0.143
4:25	6.117	0.510	12:25	3.478	0.290	20:25	1.711	0.143
4:30	6.117	0.510	12:30	3.478	0.290	20:30	1.711	0.143
4:35	6.117	0.510	12:35	3.478	0.290	20:35	1.711	0.143
4:40	6.117	0.510	12:40	3.478	0.290	20:40	1.711	0.143
4:45	6.117	0.510	12:45	3.478	0.290	20:45	1.711	0.143
4:50	6.117	0.510	12:50	3.478	0.290	20:50	1.711	0.143
4:55	6.117	0.510	12:55	3.478	0.290	20:55	1.711	0.143
5:00	6.325	0.527	13:00	3.617	0.301	21:00	4.135	0.345
5:05	6.325	0.527	13:05	3.617	0.301	21:05	4.135	0.345
5:10	6.325	0.527	13:10	3.617	0.301	21:10	4.135	0.345
5:15	6.325	0.527	13:15	3.617	0.301	21:15	4.135	0.345
5:20	6.325	0.527	13:20	3.617	0.301	21:20	4.135	0.345
5:25	6.325	0.527	13:25	3.617	0.301	21:25	4.135	0.345
5:30	6.325	0.527	13:30	3.617	0.301	21:30	4.135	0.345
5:35	6.325	0.527	13:35	3.617	0.301	21:35	4.135	0.345
5:40	6.325	0.527	13:40	3.617	0.301	21:40	4.135	0.345
5:45	6.325	0.527	13:45	3.617	0.301	21:45	4.135	0.345
5:50	6.325	0.527	13:50	3.617	0.301	21:50	4.135	0.345
5:55	6.325	0.527	13:55	3.617	0.301	21:55	4.135	0.345
6:00	9.240	4.620	14:00	2.567	0.214	22:00	3.279	0.273
6:05	9.240	4.620	14:05	2.567	0.214	22:05	3.279	0.273
6:10	5.993	1.498	14:10	2.567	0.214	22:10	3.279	0.273
6:15	5.993	1.498	14:15	2.567	0.214	22:15	3.279	0.273
6:20	5.993	1.498	14:20	2.567	0.214	22:20	3.279	0.273
6:25	5.993	1.498	14:25	2.567	0.214	22:25	3.279	0.273
6:30	6.428	1.071	14:30	2.567	0.214	22:30	3.279	0.273
6:35	6.428	1.071	14:35	2.567	0.214	22:35	3.279	0.273
6:40	6.428	1.071	14:40	2.567	0.214	22:40	3.279	0.273
6:45	6.428	1.071	14:45	2.567	0.214	22:45	3.279	0.273
6:50	6.428	1.071	14:50	2.567	0.214	22:50	3.279	0.273
6:55	6.428	1.071	14:55	2.567	0.214	22:55	3.279	0.273
7:00	6.225	0.519	15:00	2.852	0.238	23:00	1.711	0.143
7:05	6.225	0.519	15:05	2.852	0.238	23:05	1.711	0.143
7:10	6.225	0.519	15:10	2.852	0.238	23:10	1.711	0.143
7:15	6.225	0.519	15:15	2.852	0.238	23:15	1.711	0.143
7:20	6.225	0.519	15:20	2.852	0.238	23:20	1.711	0.143
7:25	6.225	0.519	15:25	2.852	0.238	23:25	1.711	0.143
7:30	6.225	0.519	15:30	2.852	0.238	23:30	1.711	0.143
7:35	6.225	0.519	15:35	2.852	0.238	23:35	1.711	0.143
7:40	6.225	0.519	15:40	2.852	0.238	23:40	1.711	0.143
7:45	6.225	0.519	15:45	2.852	0.238	23:45	1.711	0.143
7:50	6.225	0.519	15:50	2.852	0.238	23:50	1.711	0.143
7:55	6.225	0.519	15:55	2.852	0.238	23:55	1.711	0.143

Table 2. Rainfall for a 10-yr 24 hour storm based on MAP 16"

Time	Intensity (in/hr)	Time	Intensity (in/hr)	Time	Intensity (in/hr)	Time	Intensity (in/hr)	Time	Intensity (in/hr)	Time	Intensity (in/hr)	Time	Intensity (in/hr)	Time	Intensity (in/hr)
0:00	0.054	3:00	0.217	6:00	1.756	9:00	0.088	12:00	0.110	15:00	0.090	18:00	0.059	21:00	0.131
0:05	0.054	3:05	0.217	6:05	1.756	9:05	0.088	12:05	0.110	15:05	0.090	18:05	0.059	21:05	0.131
0:10	0.054	3:10	0.217	6:10	0.570	9:10	0.088	12:10	0.110	15:10	0.090	18:10	0.059	21:10	0.131
0:15	0.054	3:15	0.217	6:15	0.570	9:15	0.088	12:15	0.110	15:15	0.090	18:15	0.059	21:15	0.131
0:20	0.054	3:20	0.217	6:20	0.570	9:20	0.088	12:20	0.110	15:20	0.090	18:20	0.059	21:20	0.131
0:25	0.054	3:25	0.217	6:25	0.570	9:25	0.088	12:25	0.110	15:25	0.090	18:25	0.059	21:25	0.131
0:30	0.054	3:30	0.217	6:30	0.407	9:30	0.088	12:30	0.110	15:30	0.090	18:30	0.059	21:30	0.131
0:35	0.054	3:35	0.217	6:35	0.407	9:35	0.088	12:35	0.110	15:35	0.090	18:35	0.059	21:35	0.131
0:40	0.054	3:40	0.217	6:40	0.407	9:40	0.088	12:40	0.110	15:40	0.090	18:40	0.059	21:40	0.131
0:45	0.054	3:45	0.217	6:45	0.407	9:45	0.088	12:45	0.110	15:45	0.090	18:45	0.059	21:45	0.131
0:50	0.054	3:50	0.217	6:50	0.407	9:50	0.088	12:50	0.110	15:50	0.090	18:50	0.059	21:50	0.131
0:55	0.054	3:55	0.217	6:55	0.407	9:55	0.088	12:55	0.110	15:55	0.090	18:55	0.059	21:55	0.131
1:00	0.050	4:00	0.194	7:00	0.197	10:00	0.123	13:00	0.115	16:00	0.081	19:00	0.063	22:00	0.104
1:05	0.050	4:05	0.194	7:05	0.197	10:05	0.123	13:05	0.115	16:05	0.081	19:05	0.063	22:05	0.104
1:10	0.050	4:10	0.194	7:10	0.197	10:10	0.123	13:10	0.115	16:10	0.081	19:10	0.063	22:10	0.104
1:15	0.050	4:15	0.194	7:15	0.197	10:15	0.123	13:15	0.115	16:15	0.081	19:15	0.063	22:15	0.104
1:20	0.050	4:20	0.194	7:20	0.197	10:20	0.123	13:20	0.115	16:20	0.081	19:20	0.063	22:20	0.104
1:25	0.050	4:25	0.194	7:25	0.197	10:25	0.123	13:25	0.115	16:25	0.081	19:25	0.063	22:25	0.104
1:30	0.050	4:30	0.194	7:30	0.197	10:30	0.123	13:30	0.115	16:30	0.081	19:30	0.063	22:30	0.104
1:35	0.050	4:35	0.194	7:35	0.197	10:35	0.123	13:35	0.115	16:35	0.081	19:35	0.063	22:35	0.104
1:40	0.050	4:40	0.194	7:40	0.197	10:40	0.123	13:40	0.115	16:40	0.081	19:40	0.063	22:40	0.104
1:45	0.050	4:45	0.194	7:45	0.197	10:45	0.123	13:45	0.115	16:45	0.081	19:45	0.063	22:45	0.104
1:50	0.050	4:50	0.194	7:50	0.197	10:50	0.123	13:50	0.115	16:50	0.081	19:50	0.063	22:50	0.104
1:55	0.050	4:55	0.194	7:55	0.197	10:55	0.123	13:55	0.115	16:55	0.081	19:55	0.063	22:55	0.104
2:00	0.118	5:00	0.200	8:00	0.106	11:00	0.145	14:00	0.081	17:00	0.045	20:00	0.054	23:00	0.054
2:05	0.118	5:05	0.200	8:05	0.106	11:05	0.145	14:05	0.081	17:05	0.045	20:05	0.054	23:05	0.054
2:10	0.118	5:10	0.200	8:10	0.106	11:10	0.145	14:10	0.081	17:10	0.045	20:10	0.054	23:10	0.054
2:15	0.118	5:15	0.200	8:15	0.106	11:15	0.145	14:15	0.081	17:15	0.045	20:15	0.054	23:15	0.054
2:20	0.118	5:20	0.200	8:20	0.106	11:20	0.145	14:20	0.081	17:20	0.045	20:20	0.054	23:20	0.054
2:25	0.118	5:25	0.200	8:25	0.106	11:25	0.145	14:25	0.081	17:25	0.045	20:25	0.054	23:25	0.054
2:30	0.118	5:30	0.200	8:30	0.106	11:30	0.145	14:30	0.081	17:30	0.045	20:30	0.054	23:30	0.054
2:35	0.118	5:35	0.200	8:35	0.106	11:35	0.145	14:35	0.081	17:35	0.045	20:35	0.054	23:35	0.054
2:40	0.118	5:40	0.200	8:40	0.106	11:40	0.145	14:40	0.081	17:40	0.045	20:40	0.054	23:40	0.054
2:45	0.118	5:45	0.200	8:45	0.106	11:45	0.145	14:45	0.081	17:45	0.045	20:45	0.054	23:45	0.054
2:50	0.118	5:50	0.200	8:50	0.106	11:50	0.145	14:50	0.081	17:50	0.045	20:50	0.054	23:50	0.054
2:55	0.118	5:55	0.200	8:55	0.106	11:55	0.145	14:55	0.081	17:55	0.045	20:55	0.054	23:55	0.054

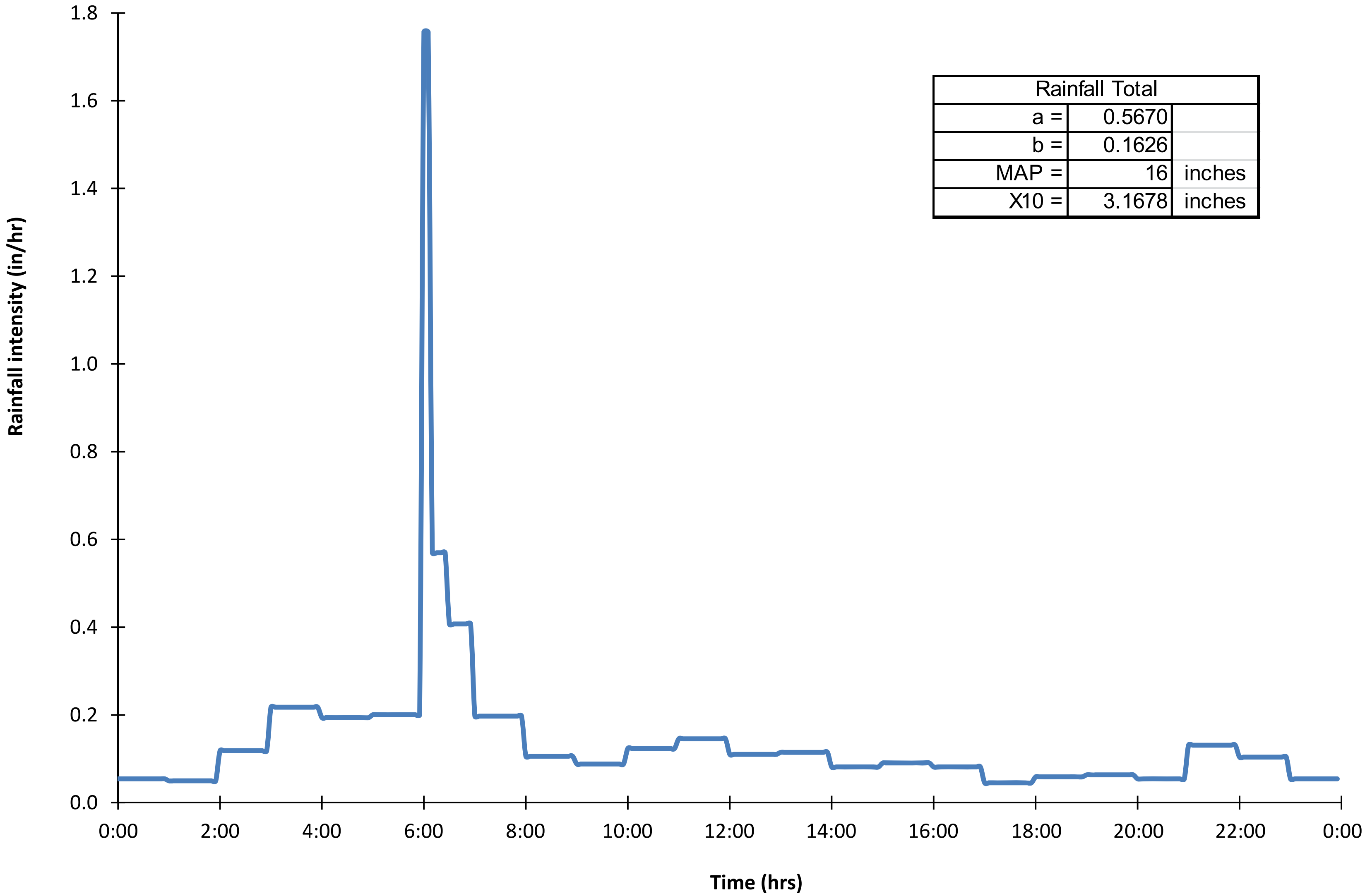

Figure 1. Rainfall for a 10-yr 24-hr storm based on MAP 16"

Table 3. Rainfall for a 25-yr 24-hr storm based on MAP 16"

Time	Intensity (in/hr)	Time	Intensity (in/hr)	Time	Intensity (in/hr)	Time	Intensity (in/hr)	Time	Intensity (in/hr)	Time	Intensity (in/hr)	Time	Intensity (in/hr)	Time	Intensity (in/hr)
0:00	0.065	3:00	0.261	6:00	2.108	9:00	0.106	12:00	0.132	15:00	0.108	18:00	0.071	21:00	0.157
0:05	0.065	3:05	0.261	6:05	2.108	9:05	0.106	12:05	0.132	15:05	0.108	18:05	0.071	21:05	0.157
0:10	0.065	3:10	0.261	6:10	0.684	9:10	0.106	12:10	0.132	15:10	0.108	18:10	0.071	21:10	0.157
0:15	0.065	3:15	0.261	6:15	0.684	9:15	0.106	12:15	0.132	15:15	0.108	18:15	0.071	21:15	0.157
0:20	0.065	3:20	0.261	6:20	0.684	9:20	0.106	12:20	0.132	15:20	0.108	18:20	0.071	21:20	0.157
0:25	0.065	3:25	0.261	6:25	0.684	9:25	0.106	12:25	0.132	15:25	0.108	18:25	0.071	21:25	0.157
0:30	0.065	3:30	0.261	6:30	0.489	9:30	0.106	12:30	0.132	15:30	0.108	18:30	0.071	21:30	0.157
0:35	0.065	3:35	0.261	6:35	0.489	9:35	0.106	12:35	0.132	15:35	0.108	18:35	0.071	21:35	0.157
0:40	0.065	3:40	0.261	6:40	0.489	9:40	0.106	12:40	0.132	15:40	0.108	18:40	0.071	21:40	0.157
0:45	0.065	3:45	0.261	6:45	0.489	9:45	0.106	12:45	0.132	15:45	0.108	18:45	0.071	21:45	0.157
0:50	0.065	3:50	0.261	6:50	0.489	9:50	0.106	12:50	0.132	15:50	0.108	18:50	0.071	21:50	0.157
0:55	0.065	3:55	0.261	6:55	0.489	9:55	0.106	12:55	0.132	15:55	0.108	18:55	0.071	21:55	0.157
1:00	0.060	4:00	0.233	7:00	0.237	10:00	0.148	13:00	0.138	16:00	0.098	19:00	0.076	22:00	0.125
1:05	0.060	4:05	0.233	7:05	0.237	10:05	0.148	13:05	0.138	16:05	0.098	19:05	0.076	22:05	0.125
1:10	0.060	4:10	0.233	7:10	0.237	10:10	0.148	13:10	0.138	16:10	0.098	19:10	0.076	22:10	0.125
1:15	0.060	4:15	0.233	7:15	0.237	10:15	0.148	13:15	0.138	16:15	0.098	19:15	0.076	22:15	0.125
1:20	0.060	4:20	0.233	7:20	0.237	10:20	0.148	13:20	0.138	16:20	0.098	19:20	0.076	22:20	0.125
1:25	0.060	4:25	0.233	7:25	0.237	10:25	0.148	13:25	0.138	16:25	0.098	19:25	0.076	22:25	0.125
1:30	0.060	4:30	0.233	7:30	0.237	10:30	0.148	13:30	0.138	16:30	0.098	19:30	0.076	22:30	0.125
1:35	0.060	4:35	0.233	7:35	0.237	10:35	0.148	13:35	0.138	16:35	0.098	19:35	0.076	22:35	0.125
1:40	0.060	4:40	0.233	7:40	0.237	10:40	0.148	13:40	0.138	16:40	0.098	19:40	0.076	22:40	0.125
1:45	0.060	4:45	0.233	7:45	0.237	10:45	0.148	13:45	0.138	16:45	0.098	19:45	0.076	22:45	0.125
1:50	0.060	4:50	0.233	7:50	0.237	10:50	0.148	13:50	0.138	16:50	0.098	19:50	0.076	22:50	0.125
1:55	0.060	4:55	0.233	7:55	0.237	10:55	0.148	13:55	0.138	16:55	0.098	19:55	0.076	22:55	0.125
2:00	0.142	5:00	0.241	8:00	0.127	11:00	0.175	14:00	0.098	17:00	0.054	20:00	0.065	23:00	0.065
2:05	0.142	5:05	0.241	8:05	0.127	11:05	0.175	14:05	0.098	17:05	0.054	20:05	0.065	23:05	0.065
2:10	0.142	5:10	0.241	8:10	0.127	11:10	0.175	14:10	0.098	17:10	0.054	20:10	0.065	23:10	0.065
2:15	0.142	5:15	0.241	8:15	0.127	11:15	0.175	14:15	0.098	17:15	0.054	20:15	0.065	23:15	0.065
2:20	0.142	5:20	0.241	8:20	0.127	11:20	0.175	14:20	0.098	17:20	0.054	20:20	0.065	23:20	0.065
2:25	0.142	5:25	0.241	8:25	0.127	11:25	0.175	14:25	0.098	17:25	0.054	20:25	0.065	23:25	0.065
2:30	0.142	5:30	0.241	8:30	0.127	11:30	0.175	14:30	0.098	17:30	0.054	20:30	0.065	23:30	0.065
2:35	0.142	5:35	0.241	8:35	0.127	11:35	0.175	14:35	0.098	17:35	0.054	20:35	0.065	23:35	0.065
2:40	0.142	5:40	0.241	8:40	0.127	11:40	0.175	14:40	0.098	17:40	0.054	20:40	0.065	23:40	0.065
2:45	0.142	5:45	0.241	8:45	0.127	11:45	0.175	14:45	0.098	17:45	0.054	20:45	0.065	23:45	0.065
2:50	0.142	5:50	0.241	8:50	0.127	11:50	0.175	14:50	0.098	17:50	0.054	20:50	0.065	23:50	0.065
2:55	0.142	5:55	0.241	8:55	0.127	11:55	0.175	14:55	0.098	17:55	0.054	20:55	0.065	23:55	0.065

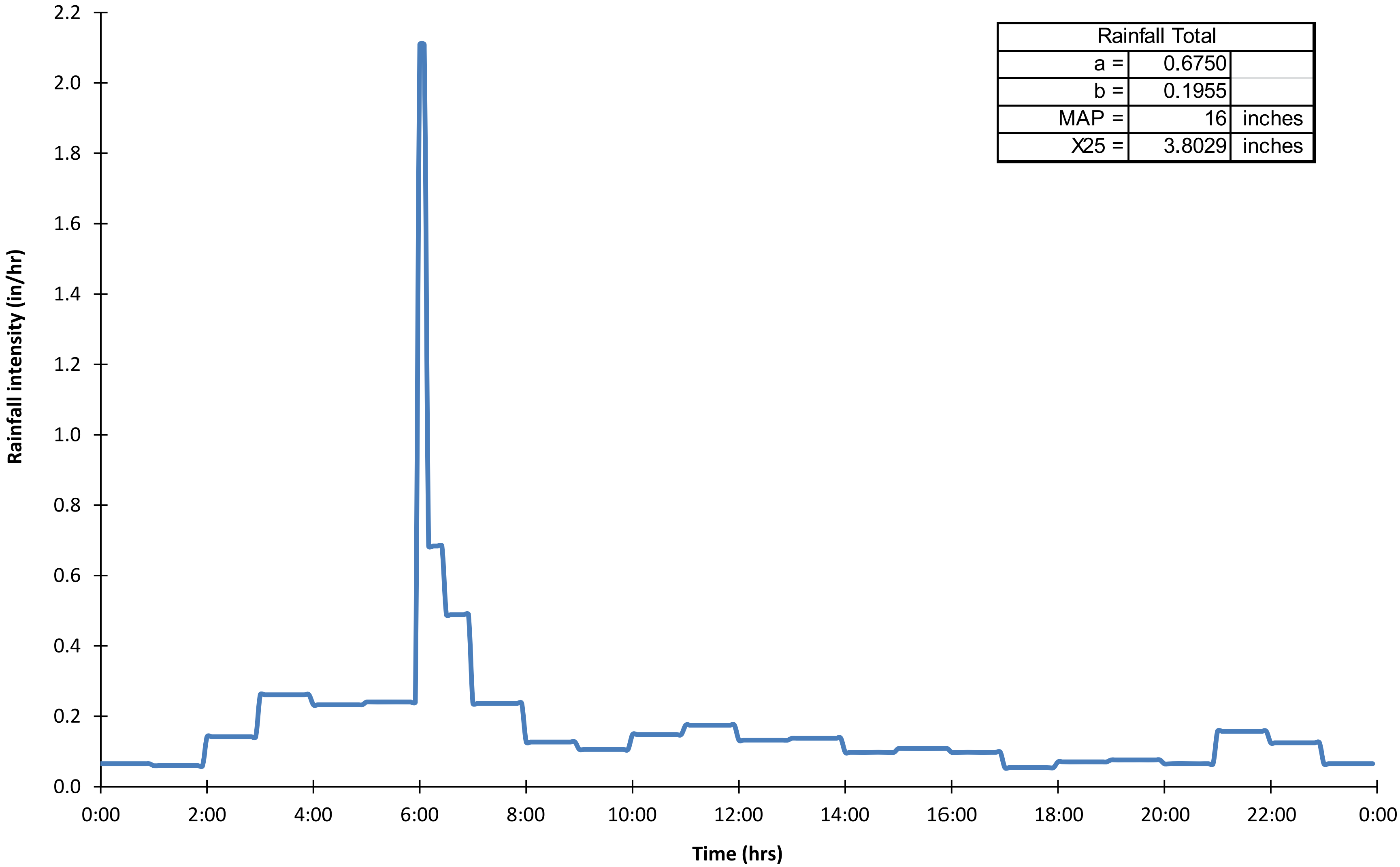

Figure 2. Rainfall for a 25-yr 10-hr storm based on MAP 16"

Table 4. Rainfall for a 50-yr 24-hr storm based on MAP 16"

Time	Intensity (in/hr)	Time	Intensity (in/hr)	Time	Intensity (in/hr)	Time	Intensity (in/hr)	Time	Intensity (in/hr)	Time	Intensity (in/hr)	Time	Intensity (in/hr)	Time	Intensity (in/hr)
0:00	0.073	3:00	0.293	6:00	2.363	9:00	0.119	12:00	0.148	15:00	0.122	18:00	0.079	21:00	0.176
0:05	0.073	3:05	0.293	6:05	2.363	9:05	0.119	12:05	0.148	15:05	0.122	18:05	0.079	21:05	0.176
0:10	0.073	3:10	0.293	6:10	0.766	9:10	0.119	12:10	0.148	15:10	0.122	18:10	0.079	21:10	0.176
0:15	0.073	3:15	0.293	6:15	0.766	9:15	0.119	12:15	0.148	15:15	0.122	18:15	0.079	21:15	0.176
0:20	0.073	3:20	0.293	6:20	0.766	9:20	0.119	12:20	0.148	15:20	0.122	18:20	0.079	21:20	0.176
0:25	0.073	3:25	0.293	6:25	0.766	9:25	0.119	12:25	0.148	15:25	0.122	18:25	0.079	21:25	0.176
0:30	0.073	3:30	0.293	6:30	0.548	9:30	0.119	12:30	0.148	15:30	0.122	18:30	0.079	21:30	0.176
0:35	0.073	3:35	0.293	6:35	0.548	9:35	0.119	12:35	0.148	15:35	0.122	18:35	0.079	21:35	0.176
0:40	0.073	3:40	0.293	6:40	0.548	9:40	0.119	12:40	0.148	15:40	0.122	18:40	0.079	21:40	0.176
0:45	0.073	3:45	0.293	6:45	0.548	9:45	0.119	12:45	0.148	15:45	0.122	18:45	0.079	21:45	0.176
0:50	0.073	3:50	0.293	6:50	0.548	9:50	0.119	12:50	0.148	15:50	0.122	18:50	0.079	21:50	0.176
0:55	0.073	3:55	0.293	6:55	0.548	9:55	0.119	12:55	0.148	15:55	0.122	18:55	0.079	21:55	0.176
1:00	0.067	4:00	0.261	7:00	0.265	10:00	0.166	13:00	0.154	16:00	0.109	19:00	0.085	22:00	0.140
1:05	0.067	4:05	0.261	7:05	0.265	10:05	0.166	13:05	0.154	16:05	0.109	19:05	0.085	22:05	0.140
1:10	0.067	4:10	0.261	7:10	0.265	10:10	0.166	13:10	0.154	16:10	0.109	19:10	0.085	22:10	0.140
1:15	0.067	4:15	0.261	7:15	0.265	10:15	0.166	13:15	0.154	16:15	0.109	19:15	0.085	22:15	0.140
1:20	0.067	4:20	0.261	7:20	0.265	10:20	0.166	13:20	0.154	16:20	0.109	19:20	0.085	22:20	0.140
1:25	0.067	4:25	0.261	7:25	0.265	10:25	0.166	13:25	0.154	16:25	0.109	19:25	0.085	22:25	0.140
1:30	0.067	4:30	0.261	7:30	0.265	10:30	0.166	13:30	0.154	16:30	0.109	19:30	0.085	22:30	0.140
1:35	0.067	4:35	0.261	7:35	0.265	10:35	0.166	13:35	0.154	16:35	0.109	19:35	0.085	22:35	0.140
1:40	0.067	4:40	0.261	7:40	0.265	10:40	0.166	13:40	0.154	16:40	0.109	19:40	0.085	22:40	0.140
1:45	0.067	4:45	0.261	7:45	0.265	10:45	0.166	13:45	0.154	16:45	0.109	19:45	0.085	22:45	0.140
1:50	0.067	4:50	0.261	7:50	0.265	10:50	0.166	13:50	0.154	16:50	0.109	19:50	0.085	22:50	0.140
1:55	0.067	4:55	0.261	7:55	0.265	10:55	0.166	13:55	0.154	16:55	0.109	19:55	0.085	22:55	0.140
2:00	0.159	5:00	0.270	8:00	0.142	11:00	0.196	14:00	0.109	17:00	0.061	20:00	0.073	23:00	0.073
2:05	0.159	5:05	0.270	8:05	0.142	11:05	0.196	14:05	0.109	17:05	0.061	20:05	0.073	23:05	0.073
2:10	0.159	5:10	0.270	8:10	0.142	11:10	0.196	14:10	0.109	17:10	0.061	20:10	0.073	23:10	0.073
2:15	0.159	5:15	0.270	8:15	0.142	11:15	0.196	14:15	0.109	17:15	0.061	20:15	0.073	23:15	0.073
2:20	0.159	5:20	0.270	8:20	0.142	11:20	0.196	14:20	0.109	17:20	0.061	20:20	0.073	23:20	0.073
2:25	0.159	5:25	0.270	8:25	0.142	11:25	0.196	14:25	0.109	17:25	0.061	20:25	0.073	23:25	0.073
2:30	0.159	5:30	0.270	8:30	0.142	11:30	0.196	14:30	0.109	17:30	0.061	20:30	0.073	23:30	0.073
2:35	0.159	5:35	0.270	8:35	0.142	11:35	0.196	14:35	0.109	17:35	0.061	20:35	0.073	23:35	0.073
2:40	0.159	5:40	0.270	8:40	0.142	11:40	0.196	14:40	0.109	17:40	0.061	20:40	0.073	23:40	0.073
2:45	0.159	5:45	0.270	8:45	0.142	11:45	0.196	14:45	0.109	17:45	0.061	20:45	0.073	23:45	0.073
2:50	0.159	5:50	0.270	8:50	0.142	11:50	0.196	14:50	0.109	17:50	0.061	20:50	0.073	23:50	0.073
2:55	0.159	5:55	0.270	8:55	0.142	11:55	0.196	14:55	0.109	17:55	0.061	20:55	0.073	23:55	0.073

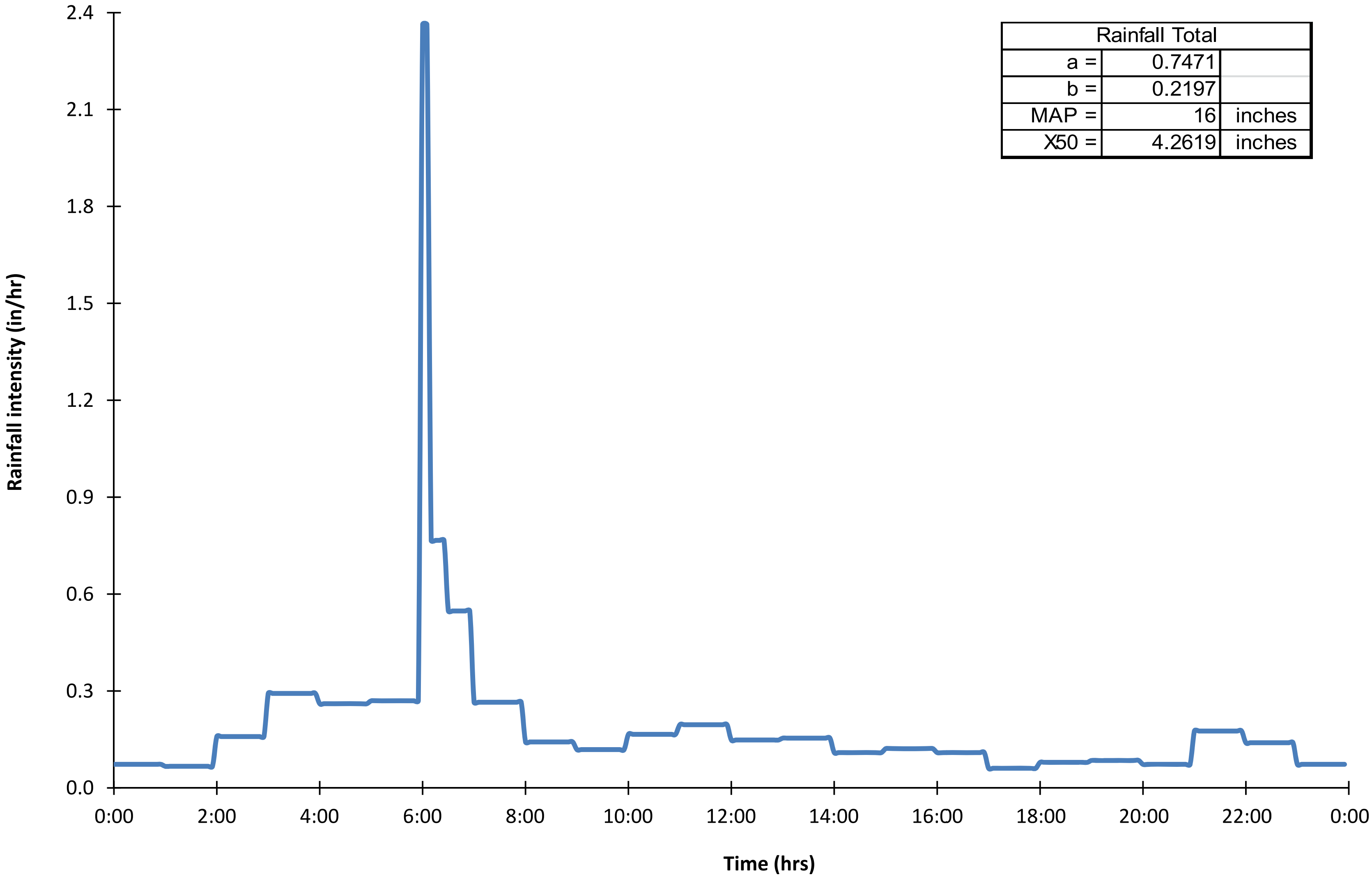

Figure 3. Rainfall for a 50-yr 24-hr storm based on MAP 16"

Table 5. Rainfall for a 100-yr 24-hr storm based on MAP 16"

Time	Intensity (in/hr)	Time	Intensity (in/hr)	Time	Intensity (in/hr)	Time	Intensity (in/hr)	Time	Intensity (in/hr)	Time	Intensity (in/hr)	Time	Intensity (in/hr)	Time	Intensity (in/hr)
0:00	0.081	3:00	0.323	6:00	2.610	9:00	0.131	12:00	0.164	15:00	0.134	18:00	0.087	21:00	0.195
0:05	0.081	3:05	0.323	6:05	2.610	9:05	0.131	12:05	0.164	15:05	0.134	18:05	0.087	21:05	0.195
0:10	0.081	3:10	0.323	6:10	0.846	9:10	0.131	12:10	0.164	15:10	0.134	18:10	0.087	21:10	0.195
0:15	0.081	3:15	0.323	6:15	0.846	9:15	0.131	12:15	0.164	15:15	0.134	18:15	0.087	21:15	0.195
0:20	0.081	3:20	0.323	6:20	0.846	9:20	0.131	12:20	0.164	15:20	0.134	18:20	0.087	21:20	0.195
0:25	0.081	3:25	0.323	6:25	0.846	9:25	0.131	12:25	0.164	15:25	0.134	18:25	0.087	21:25	0.195
0:30	0.081	3:30	0.323	6:30	0.605	9:30	0.131	12:30	0.164	15:30	0.134	18:30	0.087	21:30	0.195
0:35	0.081	3:35	0.323	6:35	0.605	9:35	0.131	12:35	0.164	15:35	0.134	18:35	0.087	21:35	0.195
0:40	0.081	3:40	0.323	6:40	0.605	9:40	0.131	12:40	0.164	15:40	0.134	18:40	0.087	21:40	0.195
0:45	0.081	3:45	0.323	6:45	0.605	9:45	0.131	12:45	0.164	15:45	0.134	18:45	0.087	21:45	0.195
0:50	0.081	3:50	0.323	6:50	0.605	9:50	0.131	12:50	0.164	15:50	0.134	18:50	0.087	21:50	0.195
0:55	0.081	3:55	0.323	6:55	0.605	9:55	0.131	12:55	0.164	15:55	0.134	18:55	0.087	21:55	0.195
1:00	0.074	4:00	0.288	7:00	0.293	10:00	0.183	13:00	0.170	16:00	0.121	19:00	0.094	22:00	0.154
1:05	0.074	4:05	0.288	7:05	0.293	10:05	0.183	13:05	0.170	16:05	0.121	19:05	0.094	22:05	0.154
1:10	0.074	4:10	0.288	7:10	0.293	10:10	0.183	13:10	0.170	16:10	0.121	19:10	0.094	22:10	0.154
1:15	0.074	4:15	0.288	7:15	0.293	10:15	0.183	13:15	0.170	16:15	0.121	19:15	0.094	22:15	0.154
1:20	0.074	4:20	0.288	7:20	0.293	10:20	0.183	13:20	0.170	16:20	0.121	19:20	0.094	22:20	0.154
1:25	0.074	4:25	0.288	7:25	0.293	10:25	0.183	13:25	0.170	16:25	0.121	19:25	0.094	22:25	0.154
1:30	0.074	4:30	0.288	7:30	0.293	10:30	0.183	13:30	0.170	16:30	0.121	19:30	0.094	22:30	0.154
1:35	0.074	4:35	0.288	7:35	0.293	10:35	0.183	13:35	0.170	16:35	0.121	19:35	0.094	22:35	0.154
1:40	0.074	4:40	0.288	7:40	0.293	10:40	0.183	13:40	0.170	16:40	0.121	19:40	0.094	22:40	0.154
1:45	0.074	4:45	0.288	7:45	0.293	10:45	0.183	13:45	0.170	16:45	0.121	19:45	0.094	22:45	0.154
1:50	0.074	4:50	0.288	7:50	0.293	10:50	0.183	13:50	0.170	16:50	0.121	19:50	0.094	22:50	0.154
1:55	0.074	4:55	0.288	7:55	0.293	10:55	0.183	13:55	0.170	16:55	0.121	19:55	0.094	22:55	0.154
2:00	0.176	5:00	0.298	8:00	0.157	11:00	0.216	14:00	0.121	17:00	0.067	20:00	0.081	23:00	0.081
2:05	0.176	5:05	0.298	8:05	0.157	11:05	0.216	14:05	0.121	17:05	0.067	20:05	0.081	23:05	0.081
2:10	0.176	5:10	0.298	8:10	0.157	11:10	0.216	14:10	0.121	17:10	0.067	20:10	0.081	23:10	0.081
2:15	0.176	5:15	0.298	8:15	0.157	11:15	0.216	14:15	0.121	17:15	0.067	20:15	0.081	23:15	0.081
2:20	0.176	5:20	0.298	8:20	0.157	11:20	0.216	14:20	0.121	17:20	0.067	20:20	0.081	23:20	0.081
2:25	0.176	5:25	0.298	8:25	0.157	11:25	0.216	14:25	0.121	17:25	0.067	20:25	0.081	23:25	0.081
2:30	0.176	5:30	0.298	8:30	0.157	11:30	0.216	14:30	0.121	17:30	0.067	20:30	0.081	23:30	0.081
2:35	0.176	5:35	0.298	8:35	0.157	11:35	0.216	14:35	0.121	17:35	0.067	20:35	0.081	23:35	0.081
2:40	0.176	5:40	0.298	8:40	0.157	11:40	0.216	14:40	0.121	17:40	0.067	20:40	0.081	23:40	0.081
2:45	0.176	5:45	0.298	8:45	0.157	11:45	0.216	14:45	0.121	17:45	0.067	20:45	0.081	23:45	0.081
2:50	0.176	5:50	0.298	8:50	0.157	11:50	0.216	14:50	0.121	17:50	0.067	20:50	0.081	23:50	0.081
2:55	0.176	5:55	0.298	8:55	0.157	11:55	0.216	14:55	0.121	17:55	0.067	20:55	0.081	23:55	0.081

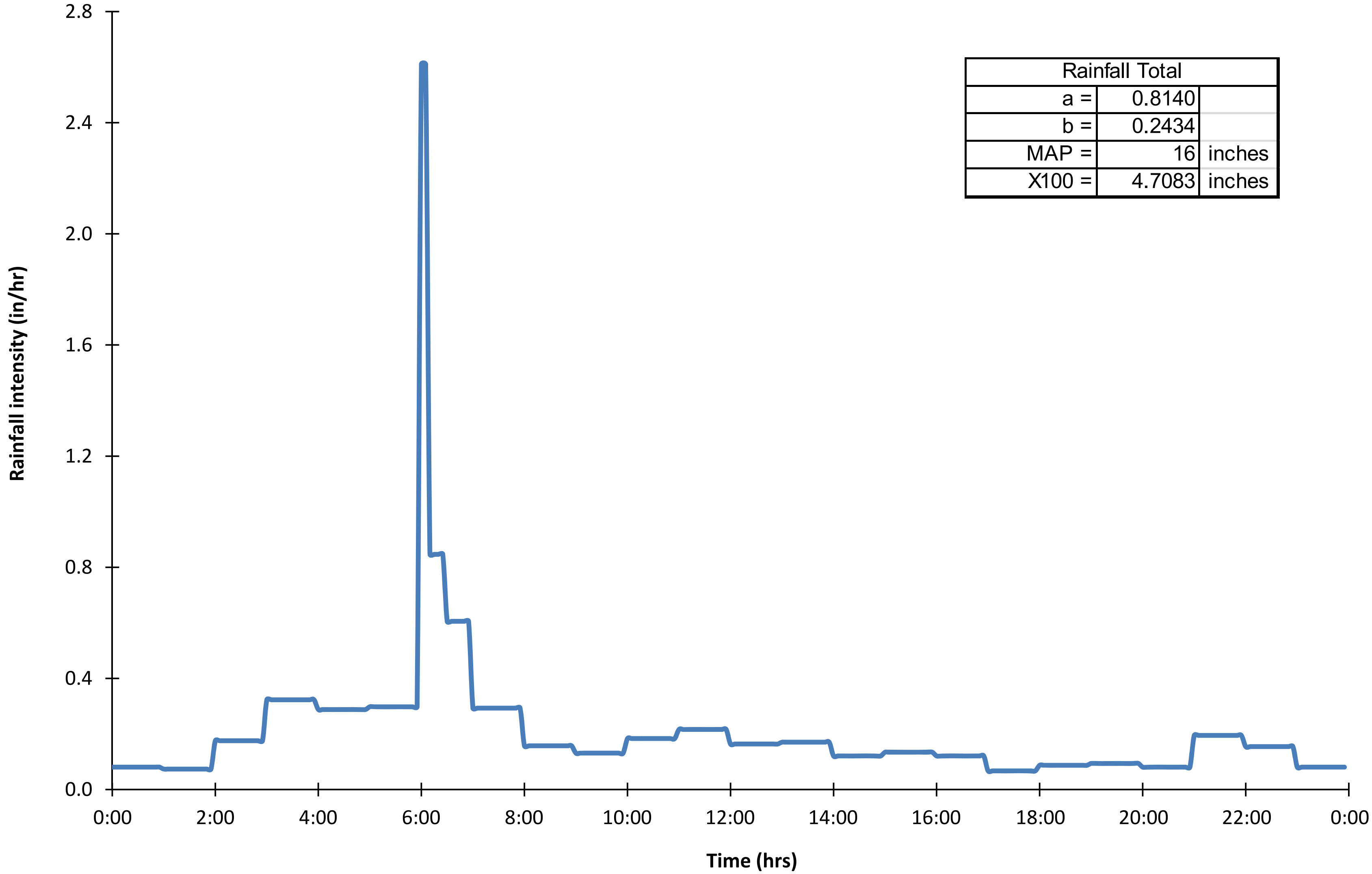

Figure 4. Rainfall for a 100-yr 24-hr storm based on MAP 16"

Appendix G

Creek and Tidal Hydrographs

Creek Boundary Hydrographs

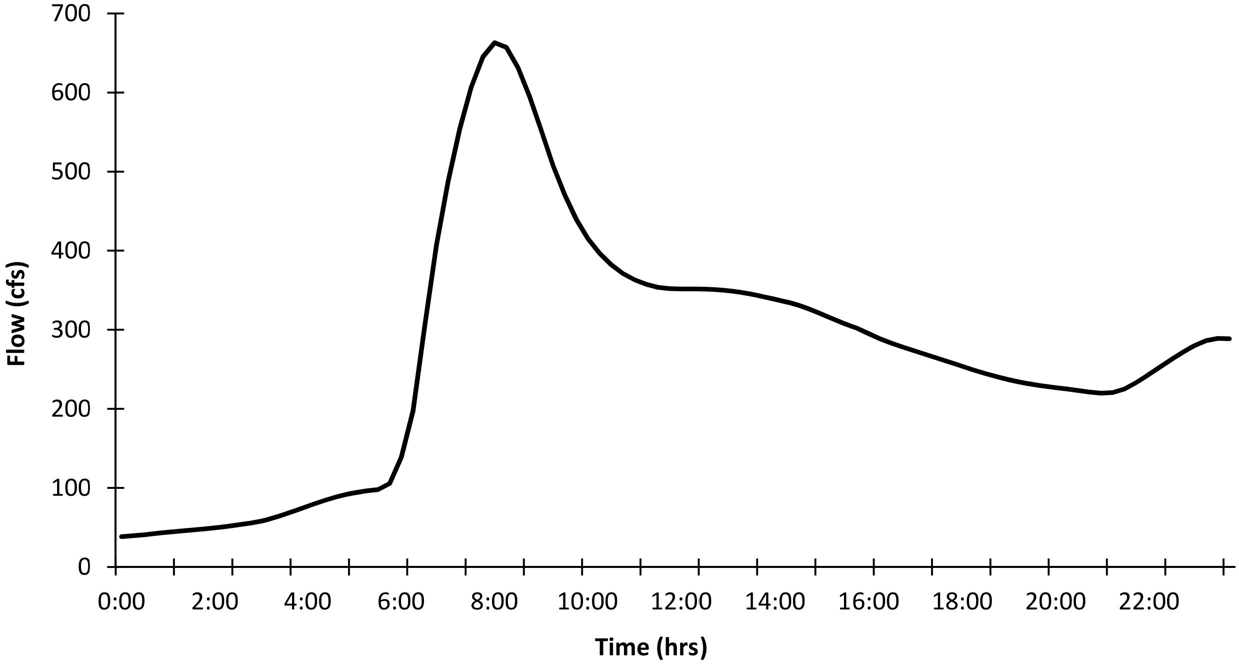

Figure 1. Creek boundary hydrograph applied at node 3361 from Matadero Bypass (near Matadero Creek)

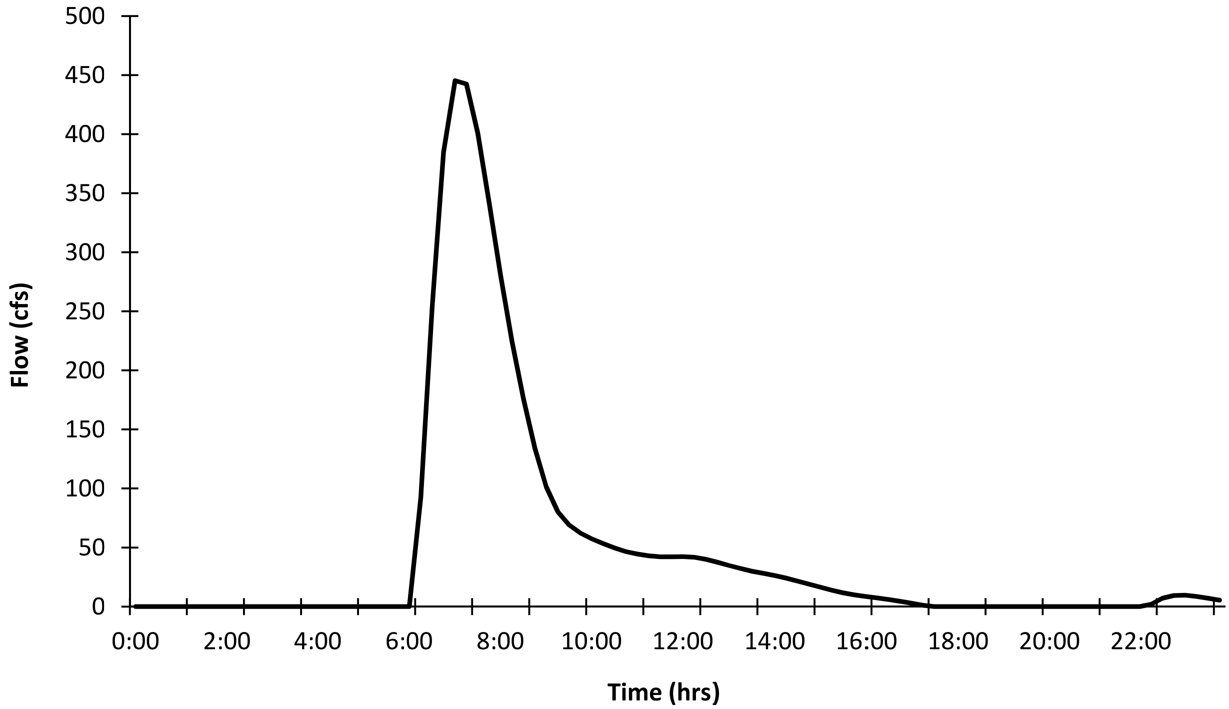

Figure 2. Creek boundary hydrograph applied at node 3364 from Matadero Bypass (north of Barron Creek)

Tidal stage hydrographs

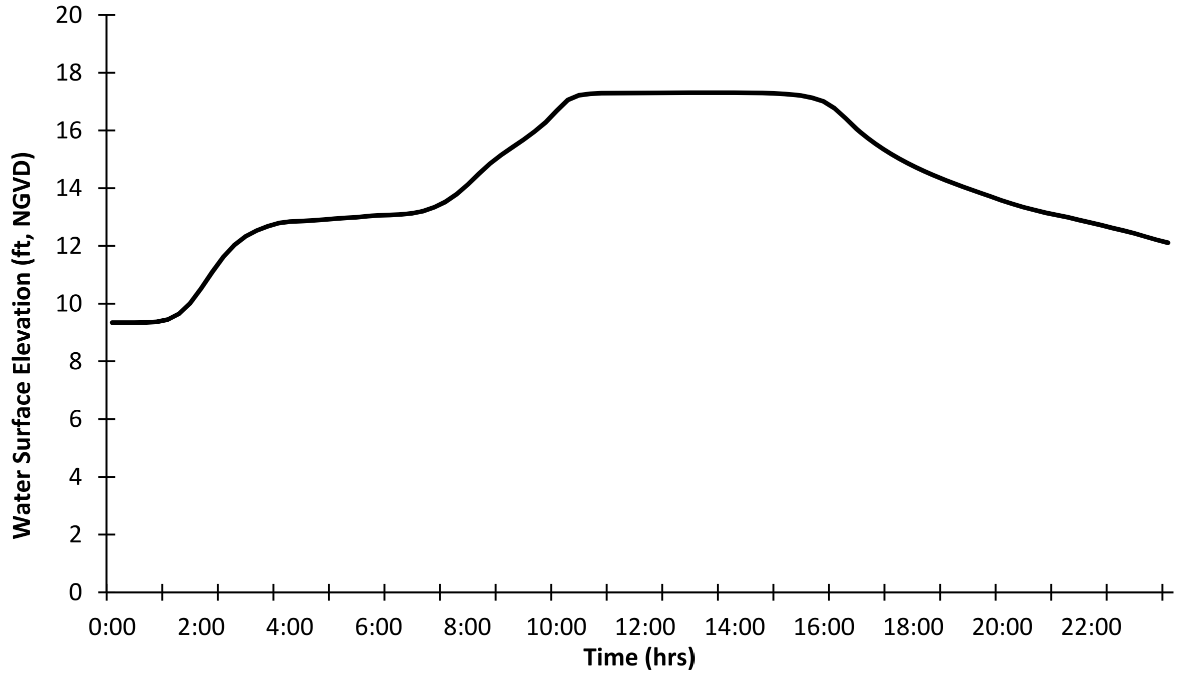

Figure 3. Downstream boundary: Stage hydrograph applied at outlets that discharge into San Francisquito Creek that are tidally influenced by the San Francisco Bay

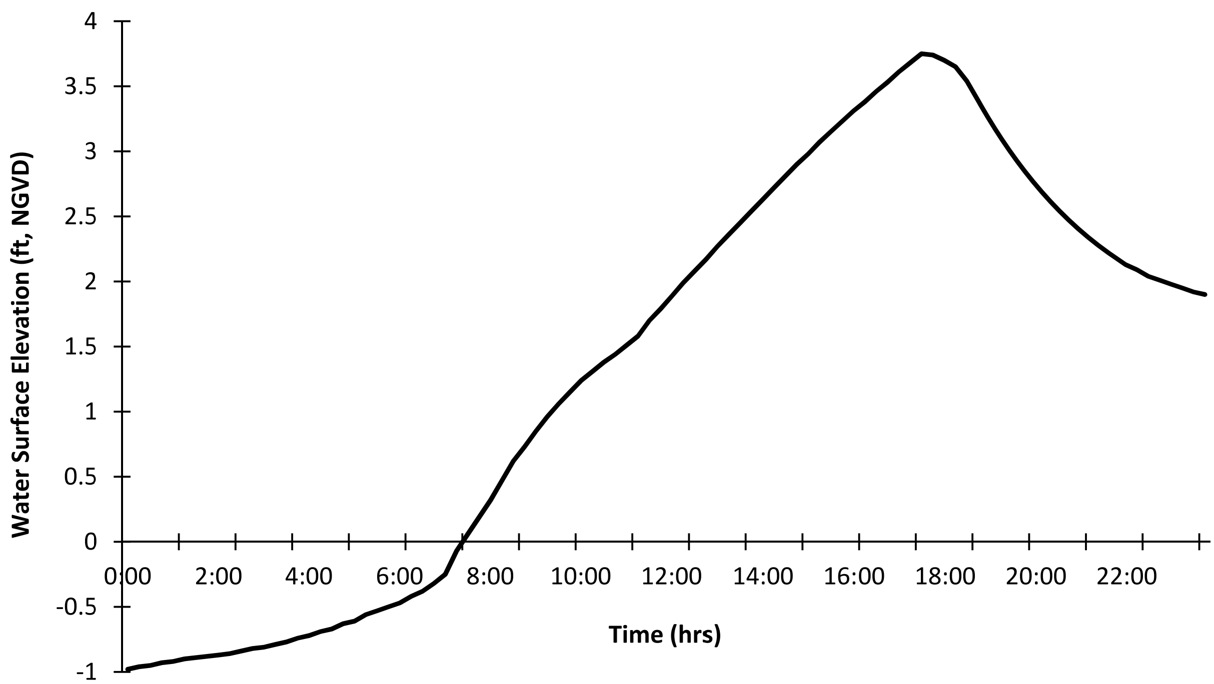

Figure 4. Downstream boundary: Stage hydrograph applied at outlets that discharge into Matadero or Adobe Creek that are tidally influenced by the San Francisco Bay

Appendix H

Condition Assessment Program Recommendations

Technical Memorandum

City of Palo Alto Storm Drain Master Plan

Condition Assessment Program Recommendations

Prepared for: Emily D. Straley, P.E., Schaaf & Wheeler

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Glenn Willson, P.E., V&A Consulting Engineers

V&A

Date: January 2015

V&A Project No. 14-0153

1.0 INTRODUCTION

V&A Consulting Engineers, Inc. (V&A), has developed recommendations for a condition assessment program for the City of Palo Alto's (City's) storm drainage system as part of Schaaf & Wheeler's (S&W's) storm drain master plan (SDMP) project. This technical memorandum provides an outline of a condition assessment program that the City can undertake in order to systematically evaluate the condition of its storm drain system. Discussions with City staff have assisted in developing these recommendations.

1.1 Background

The City of Palo Alto comprises a land area of approximately 24 square miles and can be subdivided into two distinct sections on either side of Interstate 280. The area north of I-280, which is about 14 square miles, is mostly urban and suburban, containing the downtown core and most of the known storm drain system. The area south of I-280, which is about 10 square miles, is mostly rural or open space and contains few documented storm drain facilities. These facilities were located and assessed separately by V&A, as documented in V&A's January 2015 report entitled "City of Palo Alto – Storm Drainage Condition Assessment." These recommendations focus on condition assessment in the northern portion of the City.

1.1.1 Sources of Information

The current base of information regarding the storm drain system in the northern portion of the City consists of the following items:

- **"Storm Drain Condition Assessment Final Report," June 1993, by CH2M HILL.** This report documents a comprehensive condition assessment effort that was performed from 1991 through 1993 by CH2M HILL and subconsultants. The majority of the City's storm drainage assets (pipes and structures such as inlets, catch basins, manholes, and outfalls) in the northern area were evaluated at that time. Although the data and findings in this report are now about 22 years old, it was a comprehensive effort that still is likely to be a good foundation for ongoing work.
- **City GIS information.** The City currently has storm drain record information in GIS format. There is also a map book based on this information. S&W provided this information to V&A for review.

The CH2M HILL condition assessment was based on records and the City's "STORMS" database that existed at that time. The field findings resulted in a need for updates to this documentation. The report states that the maps were updated manually and that the STORMS database would be updated later. The report also recommended follow-up repairs, rehabilitation, and condition assessment. It is assumed that the GIS information is based on these records, but it is not known to what extent they were updated based on the previous condition assessment results and capital improvements.

- **City staff knowledge.** City staff, including operations and maintenance (O&M) staff, have knowledge of certain aspects of the storm drainage system that is recorded in various formats. For example, the maintenance staff have a list of corrugated metal pipes (CMPs) that is maintained in addition to the GIS and maps. The maintenance staff also have information on sedimentation issues within the system and minor repairs that have been conducted. The City crews perform regular maintenance, including clearing sediment, based on this system.

1.1.2 Previous Condition Assessment Results

The 1993 CH2M HILL condition assessment report (see above) provided most of the known condition information regarding the storm drain system. A brief summary of the relevant findings and recommendations is as follows:

- Most observed defects were of an O&M nature, such as root intrusion and sediment or debris.
- Most of the observed condition defects were minor corrosion or cracking.
- Some defects were more severe, and specific recommendations were provided to address them within an appropriate timeframe.
- An expected useful life of 75 years was established for storm drain facilities.
- Follow-up closed-circuit television (CCTV) evaluation was recommended for pipe segments with minor or moderate defects. For pipes rated "C" on a scale from A through F, this was to be done at half of the remaining service life (time remaining until 75 years of age). For pipes rated "A" or "B," a sampling of 25% of the pipes was to be evaluated over the following 16 years.

1.2 System Inventory (Northern Area)

V&A reviewed the GIS data for the storm drain system that was provided by S&W. Most of the storm drain features shown are located in the northern area of the City. The following figures are approximate but illustrate the general character of the storm drain system in the northern area of the City:

1.2.1 Pipes

- 6,200 pipe segments in GIS, ranging in pipe diameter generally from 6 inches to 144 inches.
- 85% of the system (by number of segments) consists of concrete pipe or reinforced concrete pipe (RCP).
- At least 2% of the system (by number of segments) consists of corrugated metal pipe (CMP). The proportion may be higher than 2% because some segments listed as “unknown” may be CMP.
- Pipe materials in the remainder of the system are unknown or one of several other materials. These other materials include ABS (plastic) pipe, asbestos-cement pipe (ACP), cast iron pipe (CIP), ductile iron pipe (DIP), HDPE (plastic) pipe, steel pipe, PVC (plastic) pipe, and vitrified clay pipe (VCP).

1.2.2 Structures

- Structures consist of “point” features such as catch basins, manholes, inlets, outfalls, etc.
- 6,800 total structures in GIS, with 4,500 owned by the City and the rest owned by others such as Stanford University, Santa Clara County, or Caltrans.
- Of the total (including those owned by others), the following materials are in predominant use:
    - 50% of the structures are shown as precast or cast-in-place concrete.
    - 20% of the structures are constructed of brick.
    - The remaining structures are constructed of other or unknown materials.

2.0 Condition Assessment Methods

2.1 Basic Condition Assessment for Storm Drain Facilities

Every storm drain system is unique and will be subject to different deterioration mechanisms based on materials of construction, location, age, etc. Conditions will also vary within a single storm drainage system. V&A has not conducted field evaluations of storm drain facilities in the City of Palo Alto. However, based on V&A's extensive experience evaluating concrete and metallic structures and pipelines in the water, wastewater, and stormwater industries, the following factors are expected to be relevant to the City's storm drain system.

2.1.1 Typical Causes of Deterioration

- **Third-party damage.** This includes damage from adjacent construction activities, vandalism, etc.
- **Poor construction.** This is not a deterioration mechanism, but in other storm drain systems that V&A has evaluated, defects sometimes appeared to be the result of poor initial construction.
- **Corrosion,** for certain materials of construction:
  - Plastics and the various forms of concrete typically show good performance in storm drain systems.
  - Ferrous materials such as CIP, DIP, and CMP are subject to corrosion in storm drain systems. CMP is particularly vulnerable because the original pipe wall is considerably thinner than other types of pipe.
  - ACP may be subject to loss of strength from leaching of the cement binder, depending on the ionic constituents of the soil and water.
- **Settlement and soil loading.** Differential settlement can cause cracking in rigid pipes and joint separation in all types of pipe. Infiltration or exfiltration of water can exacerbate the problem if it undermines the soil support for the pipe. V&A has observed the following typical conditions in other storm drain systems:
  - Flexible pipe materials, particularly CMP and plastic pipes, are sometimes deflected (oval-shaped), apparently due to soil loading.

- Concrete pipes and structures typically show good performance with some instances of leakage.
- Brick structures are sometimes shifted or broken.

2.1.2 Base Evaluation Frequency

Based on the typical observations noted above, V&A recommends the evaluation frequencies shown in Table 2-1 as a general starting point. The specific defects listed in the table are likely to exist; other or more severe defects should be evaluated on a case-by-case basis. As the condition assessment program continues, a database of trend information will be built up and the reassessment intervals should be refined to reflect actual performance of the storm drain system.

Table 2-1. Base Evaluation Frequencies

Material	Condition	Base Evaluation Interval
Pipes		
Corrugated metal pipe (CMP)	**Unknown**	Within 5 years
	Intact galvanizing or protective lining around full inner circumference	Every 10 years
	Loss of galvanizing or protective lining	Every 5 years
	Perforations (holes of any size)	Rehabilitate immediately
Concrete pipe, including reinforced concrete pipe (RCP)	**Unknown**	Within 15 years
	Good condition	Every 15 years
	Minor defects, such as hairline cracks (dry)	Every 10 years
Plastic pipes (including ABS, HDPE, PVC, etc.)	**Unknown**	Within 10 years
	Good condition	Every 15 years
	Ovality more than 10%	Every 5 years
Other pipe materials	**Unknown**	Within 5 years
	Good condition	Every 10 years
Structures		
Concrete manholes and catch basins, cast in place or precast	**Unknown**	Within 15 years
	Good condition	Every 15 years
	Minor defects, such as hairline cracks (dry)	Every 10 years
Brick structures	**Unknown**	Within 5 years
	Good condition	Every 10 years
Inlet and outfall structures (other than curb inlets)	**Unknown**	Within 5 years
	Good condition	Every 5 years
Structures with devices such as weirs, sluice gates, trash racks, etc.	**Unknown**	Within 5 years
	Good condition	Every 5 years

2.2 Condition Assessment Techniques

V&A recommends a combination of the following core methods for evaluating the storm drain system:

- **Visual and photographic evaluation.** The most basic condition assessment technique is conducted at the access points, consisting of a visual evaluation from outside the structures and pipes. Photographic documentation of observations and measurement of relevant dimensions, as needed, are a standard part of this process. This technique is typically sufficient for most catch basins and inlets, as well as some other structures, within a storm drain system. Condition information for the pipes will be limited to what is visible from outside the structures.
- **Zoom camera evaluation.** A pole-mounted zoom camera can be used at the access points to see farther inside the pipe segments. Lighting and zoom capabilities can allow the operator to see features inside the pipe hundreds of feet away. This technique does not provide as much detail as conventional CCTV evaluation (see below), but it can be used to quickly evaluate the storm drain system for significant defects.
- **CCTV evaluation.** Conventional CCTV evaluation consists of inserting a mobile camera, typically on a motorized crawler, inside the storm drain pipes. This allows for an up-close view of individual pipe defects and measurement of their distance along the pipe segment.
- **Confined-space-entry evaluation.** The above condition assessment techniques can be extended by performing confined space entries into storm drain structures such as manholes. Trained staff can perform detailed evaluation and further qualitative and quantitative testing. One standard test method for entry evaluations is to perform soundings and penetration testing on concrete surfaces. This evaluates the specific, localized hardness and integrity of the material. Confined space entry can allow visual and photographic evaluation of deeper or more complicated structures, as well as “calibration” of zoom-camera or CCTV observations to the physical conditions.

Additional, optional techniques can be employed in specific circumstances in order to increase the overall understanding of the storm drain system. The following optional techniques can be performed on their own or in conjunction with the core methods listed above:

- **Measurement and verification** of the size and presence of the storm drain facilities. The principal measurements are the structure rim-to-invert depths and the pipe diameters. If the City chooses a risk-based approach (see below), this may be adequate for some parts of the storm drain system.
- **GPS locating or surveying.** These techniques can be used to increase the accuracy of maps and elevations of the storm drain system.

- **Smoke testing.** This method can be used to verify connections within the storm drain system or to identify improper connections between the storm drain system and the sanitary sewer system.

- **PACP/MACP coding.** Coding of defect observations in accordance with the National Association of Sewer Service Companies' (NASSCO's) Pipeline Assessment and Certification Program (PACP) is standard for most CCTV contractors today and should be required for CCTV evaluations. PACP provides a standardized, detailed approach for coding and rating observed defects, and this level of detail is warranted if CCTV evaluation is used. PACP can also be applied to zoom camera evaluations, but a less detailed approach may suffice for these, depending on the goals of the evaluation.

  NASSCO's Manhole Assessment and Certification Program (MACP) is a similar coding and rating system for manholes. MACP results in a very detailed evaluation of each structure. MACP evaluations may or may not be necessary depending on the level of detail required. If the City chooses a risk-based approach (see below), it should consider MACP for the more critical assets and determine if a more limited evaluation would suffice for other assets. It should also be noted that MACP is primarily based on visual observations from within the manhole. For a complete condition assessment, physical entry and testing, and additional documentation based on the City's specific needs, should also be conducted.

- **Wet-weather evaluation.** The storm drain system can be monitored during wet weather to see its actual performance. This can be a simple visual evaluation to check for flooding, surcharge, etc., or it can be a quantitative study using flow meters and rain gauges.

- **Testing of gates and other devices.** Devices such as sluice gates, flap gates, etc., should be tested or observed for proper operation. This can be part of the regular O&M program or integrated with the condition assessment program.

- **Cleaning** of the storm drain system is already part of the City's maintenance program. In some cases, pre-cleaning may make condition assessment activities easier or more productive. For instance, cleaning the pipes prior to CCTV can make it easier for the camera to travel and make more of the pipe surface visible. Combining cleaning and condition assessment may also make staff or contractors' time more productive.

3.0 ASSET MANAGEMENT AND RISK ASSESSMENT

Due to the size of the storm drain system, the City should consider implementing an asset management program for it in order to derive the most value from its O&M activities and capital improvements. Asset management is providing a desired level of service from an agency's infrastructure at the lowest life-cycle cost. It is a proactive process to evaluate and estimate the maintenance and rehabilitation needs of the assets. The full asset management process includes the following:

- Developing/maintaining an asset inventory.
- Assessing the condition of assets.
- Determining the desired level of service.
- Conducting an assessment of the probability and consequences of asset failure (risk assessment).
- Estimating the renewal and replacement schedule.
- Preparing a life-cycle analysis of maintenance, capital project, and financial needs.

Condition assessment is a key component of an asset management program because it provides real data for decision-making. At the same time, should the City not choose to implement a full asset management program, several asset management concepts are recommended to help prioritize the condition assessment program and enhance its value. In particular, V&A recommends that the City determine the desired level of service and conduct a risk assessment for the storm drain system as the ongoing condition assessment program is developed.

The level of service can be defined by failure rate over time, ability to convey flows for certain design storms without flooding, etc. Increasing the level of service will require increasing the scope or frequency of condition assessment, which will increase the cost of the program. By using a risk-based model, the City will derive more value from the program because it can maintain high levels of service in areas where it is more important to do so.

Risk assessment can be conducted by evaluating the likelihood and consequences of failure of a given asset. Risk for a given asset can be considered as the likelihood of failure multiplied by the consequences of failure. The likelihood and consequences of failure can each be broken down and scored according to objective criteria. The likelihood of failure of a given storm drain asset can be rated according to factors such as the following:

- Existing condition.
- Material and age.
- Depth of burial and proximity to other utilities.
- Capacity for anticipated flows.

The consequences of failure can be taken as the likely impact of the asset's failure based on factors such as the following:

- Volume or area of flooding.
- Traffic disruption.
- Sinkholes or washouts.
- Impacts to public perception.
- Value of property impacted.
- Disruption to commerce.
- Population density in impacted area.

Each of these factors can be rated against specific, objective criteria in order to arrive at a risk rating for the asset. Figure 1 shows the risk assessment concept and the basic strategies warranted for each category of asset. Four example assets are shown, Assets A through D, each with different ratings for likelihood and consequences of failure. As shown, assets with high likelihood and high consequences of failure receive the highest risk ratings and warrant immediate attention. Assets with low likelihood and low consequences of failure do not warrant the same level of attention and may be adequately managed by periodic monitoring of a representative sample. In between, assets with moderate risk ratings should be monitored more closely.

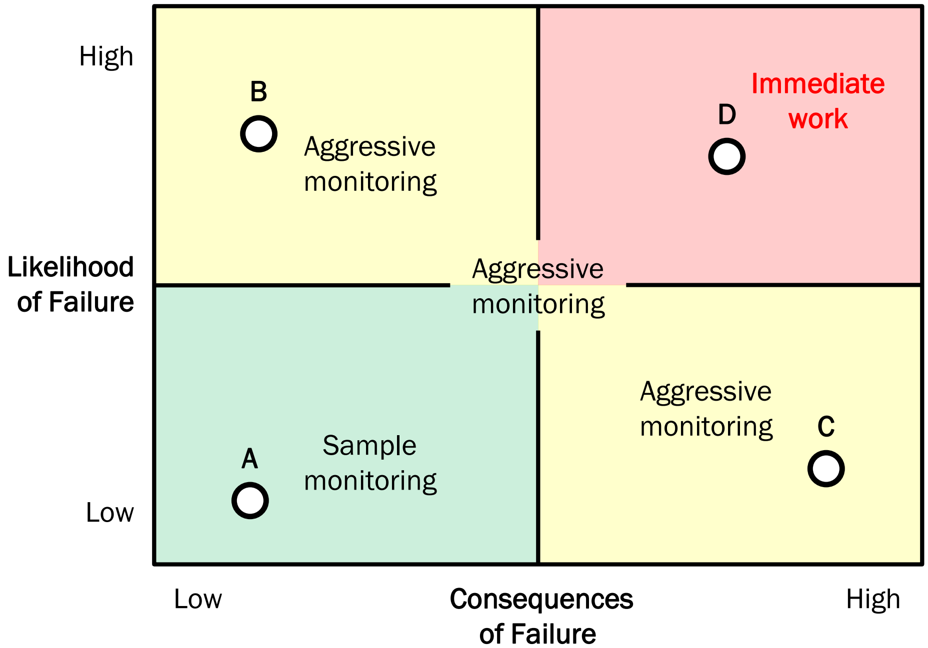

Figure 1. Risk Assessment Overview

With a risk assessment as the basis of the condition assessment program, the City can choose between a comprehensive condition assessment, including all assets, or a sampling approach:

- **Comprehensive approach.** If this approach is selected, all storm drain assets would be slated for assessment on some interval. However, the lower-risk assets may not warrant the same level of condition assessment effort, and they can be prioritized later or less frequently in the program.
- **Sampling approach.** If this approach is selected, all storm drain assets above a certain threshold risk score should be evaluated. A representative sample of the lower-risk assets would be evaluated. The risk ratings will influence the sample size and possibly the evaluation techniques.

In the City of Palo Alto's storm drain system, it is likely that a majority of the assets would receive low risk ratings. In particular, 85% of the pipe segments are made of concrete and RCP, which are typically more resistant to deterioration and have a low likelihood of failure. The consequences of failure for these lines would vary primarily based on size and location. The smaller lines in many areas of the City would probably receive low or moderate ratings for consequences of failure. On the other hand, materials such as CMP would receive higher risk ratings and be prioritized for earlier and more detailed evaluation.

4.0 Recommended Condition Assessment Program

V&A recommends the following phased approach for condition assessment of the City's storm drain system.

4.1 Phase 1: Review and Compile Documentation

The first phase of the program should be to establish a central location for all storm drain system information and bring the data up to date based on existing records. Having all of the information in one place in a consistent format is key to keeping the data current as ongoing work is performed. The City's existing GIS system already has some of the records, but it should be extended to capture all of the relevant information. At a minimum, the following sources of data should be reviewed and compiled:

- **Existing GIS information.**
- **Previous condition assessment data,** including the 1993 report by CH2M HILL.
- **Staff knowledge and records.** In particular, staff knowledge regarding the location of CMPs, sedimentation issues, flooding, and previous repair work should be captured. If some of the information is uncertain, it can be flagged for field verification.
- **Record drawings,** if available, for rehabilitations and repairs. The City should consider if it is feasible to search through existing records for this information or whether it would be more effective to capture this information in the field.

For simplicity and consistency, the GIS information can contain basic information such as location, size, material, and condition ratings, with detailed records attached. Care should be taken in designing the GIS data format to ensure that rehabilitation information is entered appropriately. A notation of the type of repair, along with an updated overall condition rating, is recommended. For example, replacing the cover may be listed as a repair, but care should be taken so this is not interpreted as the whole structure having been rehabilitated. Linking or attaching the original records is one way of resolving discrepancies that may arise.

The storm drain GIS system should be designed so it can be kept up to date. A procedure should be established to ensure uniform data input from all sources, including the following:

- **Field crews.** Some cities have direct access to their GIS systems for field crews using tablet computers, allowing for access to current information and real-time updates. Alternatively, written records of O&M activities, perhaps with additional staff training if needed, could be used to keep the data current. Consider linking in the original records for future reference.
- **Condition assessment activities.** Not all of the condition assessment details will necessarily be applicable for entry, but a uniform data format with a listing of required information should be established. The detailed condition assessment reports should be linked in for future reference. Require condition assessment crews or consultants to provide data in a specified format.
- **New record drawings.** As new construction and capital improvements are conducted, ensure that the information from the record drawings is captured in the storm drain information system. The City may elect to require contractors to provide GIS data directly. The record drawings should be linked in for future reference.
- **Risk assessment.** If the City conducts a risk assessment to drive the condition assessment program, the ratings should be stored along with the storm drain system data. Some or all of the risk ratings can be generated by a GIS system by integrating other relevant data sets.

4.2 Phase 2: Conduct Risk Analysis and Prioritize Assessments

The City should consider conducting a formal risk analysis as the basis of the ongoing condition assessment program. See Section 3.0 above. If the City chooses not to conduct a formal risk analysis, it should still consider weighting and prioritizing the program towards storm drain assets that are perceived to be of higher risk. A very simple approach could consider pipe sizes and materials, the evaluation intervals shown in Section 2.1, and pipe location. The results of this process should be used in conjunction with the desired level of service to determine the exact assets and condition assessment techniques to be included in the program.

The risk assessment should be continuously updated with the results of ongoing condition assessment, O&M activities, and capital projects. It may be possible to automate this using the GIS system. Future condition assessment intervals and capital improvements should be adjusted based on the field findings.

4.3 Phase 3: Conduct Priority Evaluations

The prioritization process conducted in Phase 2 will produce a list of assets that should be evaluated within the near term. Regardless of the risk assessment approach selected, the initial phase of condition assessment should include the following items (in order of decreasing importance):

- Assets with known issues. Unless it can be verified that they have been rehabilitated, assets shown to be in poor condition in the CH2M HILL report should be included in this category.
- Corrugated metal pipes (CMPs), given their unique susceptibility to corrosion.
- Assets not evaluated by CH2M HILL during the previous condition assessment project.
- Other types of assets of special concern (i.e., brick structures).
- Assets not known to have been evaluated within the timeframes shown in Table 2-1. This will probably mean that most storm drain assets are overdue for reevaluation, so judgment should be employed here. The intent is to update the baseline condition data across the spectrum of construction materials and locations. A limited sampling approach is probably sufficient for Phase 3.

All CMPs and a sampling of other types of pipes should be assessed. This portion of the initial evaluation should be designed to provide an overall understanding of the storm drainage system in this part of the City. It may be effective to perform this portion of the work as a separate project.

4.4 Phase 4: Conduct Ongoing Evaluations

Phase 4 continues over the length of the condition assessment program. Based on the risk assessment and prioritization approach, this may be a comprehensive evaluation (all storm drain assets are evaluated on some interval) or focus on a representative sample. The assessment intervals shown in Table 2-1 should be used as a guideline and adjusted based on field findings.

The risk assessment and the entire condition assessment program should be kept up to date and reevaluated periodically as the knowledge of the storm drain system develops.

4.5 Cost Estimates

Planning-level cost estimates for the condition assessment field work in Phases 3 and 4 above were developed based on V&A's experience (see Table 4-1). The following assumptions were made in developing the cost estimates:

- Phase 3 (priority evaluations) are conducted over an initial 5-year period.

- In Phase 3, assess about 30% of the concrete or RCP pipe segments and 100% of pipe segments constructed of other materials, including CMP.
- In Phase 3, assess about 30% of the concrete structures and 100% of the structures constructed of other or unknown materials, including brick.
- In Phase 4, assess about 30% of the concrete or RCP pipe segments and 50% of pipe segments constructed of other materials every 5 years.
- In Phase 4, assess about 30% of the concrete structures, 50% of the brick structures, and 30% of the structures constructed of other or unknown materials every 5 years.
- About 10% of the assets would be assessed by confined space entry. The remainder would be assessed by non-entry methods.
- Unit costs for condition assessment were taken as $1,600 to $2,400 per entry assessment and $640 to $960 per non-entry assessment in the quantities assumed. This includes the field work and report generation under Phases 3 and 4 (initial and ongoing field assessment), but not the costs for Phases 1 and 2 (document review and optional risk assessment).

Table 4-1. Planning-Level Cost Estimates for Condition Assessment Program

Item	Quantity	Unit cost	Cost
Phase 3 (priority assessments – initial 5 years)			
Confined space entry assessments	540 assets	$1,600 – $2,400 per asset	$864,000 – $1,296,000
Non-entry assessments	4,860 assets	$640 – $960 per asset	$3,110,400 – $4,665,600
Condition assessment – total	**5,400 assets**		**$3,974,400 – $5,961,600**
Phase 4 (routine assessments, per each 5 years following Phase 3)			
Confined space entry assessments	200 assets	$1,600 – $2,400 per asset	$320,000 – $480,000
Non-entry assessments	1,800 assets	$640 – $960 per asset	$1,152,000 – $1,728,000
Condition assessment – total	**2,000 assets**		**$1,472,000 – $2,208,000**

Appendix I

Storm Drainage Condition Assessment

TECHNICAL MEMORANDUM

CITY OF PALO ALTO
STORM DRAINAGE CONDITION ASSESSMENT

Prepared for: Emily Straley, P.E., Schaaf & Wheeler

Prepared by: Michael Johannessen, P.E., V&A Consulting Engineers

Reviewed by: Clinton McAdams, V&A Consulting Engineers
Glenn Willson, P.E., V&A Consulting Engineers

Date: January 2015

V&A Project No. 14-0153

1.0 INTRODUCTION

V&A Consulting Engineers, Inc. (V&A) was retained by Schaaf & Wheeler (S&W) to conduct a condition assessment of storm drain facilities in support of the Storm Drain Master Plan (SDMP) update that S&W is conducting for the City of Palo Alto, California (City). Most of the City's storm drainage features are located in the portion of the City north of Interstate 280 and have previously been mapped and documented. In the portion of the City south of I-280, however, it was known that the City owned several culverts but did not have a map or other systematic documentation for them. The purpose of this investigation was to locate, map, and evaluate the culverts in this portion of the City.

City staff identified three areas where there were known culverts that were not mapped or previously assessed: Page Mill Road, Arastradero Road, and Los Trancos Road. The culverts were numbered A-1 through A-43 in the field with marker posts. Most of the culverts were believed to consist of corrugated metal pipe (CMP). The condition assessment field work was conducted over the course of four days during November 2014.

The primary focus of the project was to map the locations of the culverts and assess their condition through photo documentation. The assessment included collection of information to support the development of the City's GIS files. The collected information includes pipe materials, dimensions, condition ratings, pictures, and other assessment information of the evaluated features.

2.0 METHODS AND PROCEDURES

Evaluation methods consisted of visual examinations, documentation with photographs, measurements of relevant dimensions, and mapping with a high-accuracy GPS unit. Qualitative condition assessment observations were based on V&A's extensive experience evaluating potable water, wastewater, and storm water structures and pipelines. Assessment methods included the following:

- Visual examinations and documentation with photographs. A pole-mounted zoom camera was used to evaluate the interior of the culverts as visible from the access points.
- Feature locations were recorded using a handheld high-accuracy GPS unit or through written documentation if necessary.
- Relevant dimensions and grade/rim to invert depth were measured or estimated, depending on access and the surrounding environment.
- Sediment/debris was briefly described and its depth was measured or estimated. Water depth within the feature was also measured or estimated.
- Deflections, cracking, corrosion, perforations, displacement, and other defects and concerns were documented.
- VANDA Condition Index ratings were used as appropriate (Table 2-1 and Table 2-2).
- Observations of infiltration were rated according to the National Association of Sewer Service Companies (NASSCO) Pipeline Assessment and Certification Program (PACP) codes (Table 2-3).
- V&A used a prioritization rating scale from 1 to 5 to classify the storm water facilities needing attention. The rating is in the order of increasing priority from 1 to 5, with facilities rated 5 needing immediate attention. Table 2-4 summarizes the methods used to prioritize the facilities and some example defects associated with each priority level.

The condition assessment data gathered for this project was limited to what was visible from the available access points. Defects may exist in portions of the pipe segments not visible to the evaluator. In some situations, a view into the pipe was not possible due to access limitations or sediment. Also, sediment often obscured the view of the invert of CMP culverts, which is where the greatest deterioration is typically found. Condition and priority ratings were assigned based on the visible portions of the pipe surface and V&A's experience.

2.1 VANDA™ Reinforced Concrete Condition Index

The VANDA™ Reinforced Concrete Condition Index was created by V&A to provide consistent reporting of corrosion damage based on qualitative, objective criteria. Condition of corrosion can vary from Level 1 to Level 4 based upon visual observations and field measurements, with Level 1 indicating the best condition and Level 4 indicating severe damage. Table 2-1 describes the concrete condition index system.

Table 2-1. VANDA™ Reinforced Concrete Condition Index Rating System

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

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2.2 VANDA™ Metal Condition Index

The VANDA™ Metal Condition Index was created by V&A to provide consistent reporting of metal corrosion damage based on qualitative, objective criteria. Condition of metal can vary from Level 1 to Level 4 based upon visual observations and field measurements, with Level 1 indicating the best case and Level 4 indicating severe damage. Table 2-2 displays the metal condition index system.

Table 2-2. VANDA™ Metal Condition Index Rating System

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

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2.3 Infiltration Ratings

Observations of groundwater infiltration (groundwater leaking into the storm drain system) were rated according to the NASSCO PACP codes and broken down into the categories shown in Table 2-3.

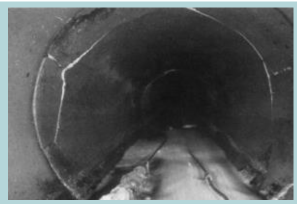
Table 2-3. Infiltration Ratings

Category	NASSCO PACP Code	Code Meaning	Type of Infiltration
None	–	–	No observed infiltration
Evidence	IS	Infiltration, stains	Stains or dry encrustations
	IW	Infiltration, weeper	Wet marks or stains (water weeping in)
Active	ID	Infiltration, dripper	Dripping water
	IR	Infiltration, runner	Small stream of flowing water
	IG	Infiltration, gusher	Larger stream of flowing water under apparent external pressure

2.4 Storm Drainage Facility Prioritization Scale

Storm drain features received overall evaluations according to the prioritization ratings shown in Table 2-4. Note that this scale is used for reporting the overall priority ratings of the storm water drainage facilities, while the material conditions, with respect to corrosion, are reported using the VANDA ratings. The prioritization ratings take into account the overall condition of the structure or pipeline, isolated defects that were noted, and factors such as the possible effects on the surrounding area. Some features may need immediate attention for certain problems even if they are in good condition otherwise. The table also provides a recommended timeline for repair or reassessment of the facilities.

Table 2-4. Storm Drainage Facility Prioritization Scale

Color Code	Rating	Reassessment or Repair Priority	Structural Rating Example	
	1 Excellent	Failure unlikely in the foreseeable future. Reassess on a 15-year interval.		Minor or no defects
	2 Good	Reassess on a 10-year interval.	 Longitudinal Cracking	Defects that have not begun to deteriorate
	3 Fair	Reassess on a 5-year interval and consider conducting repairs.	 Multiple Fractures	Moderate defects that will continue to deteriorate
	4 Poor	Prioritize for rehabilitation within 5 years.	 Broken Pipe	Severe defects
	5 Immediate Attention	Repair or replace immediately.	 Collapsed Pipe	Defect requires immediate action

In the findings and detailed results that are shown in Appendix A, a shorthand rationale was provided for each prioritization rating based on the categories described in Table 2-5. Note that more than one category may influence the provided prioritization rating for each feature.

Table 2-5. Prioritization Rating Rationale

Rationale	Description
Condition	The condition of the structure warrants the specified rating level due to likelihood or consequences of asset failure.
Location	The location of the asset warrants the specified rating level due to effects on the surrounding area (i.e., the asset is located under a roadway and would have a higher consequence upon failing).
Sediment/Debris	The level of sediment/debris within the asset warrants the specified rating level due to likelihood of hindering asset performance. High levels of sediment/debris can block a pipe and subsequently flood the surrounding area.
Safety	There is a safety concern which warrants the specified prioritization rating, (i.e., public access is permitted to an asset that has potential trip and fall or other hazards).
Other	There are other aspects that need to be taken into account and warrant the specified prioritization rating.

3.0 FINDINGS AND CONCLUSIONS

A total of 42 culverts were evaluated. The culverts were numbered A-1 through A-43. Culvert A-18 could not be found along Page Mill Rd. and is abandoned per City staff. Figure 3-1 through Figure 3-3 display the culverts that were assessed and their associated prioritization ratings.

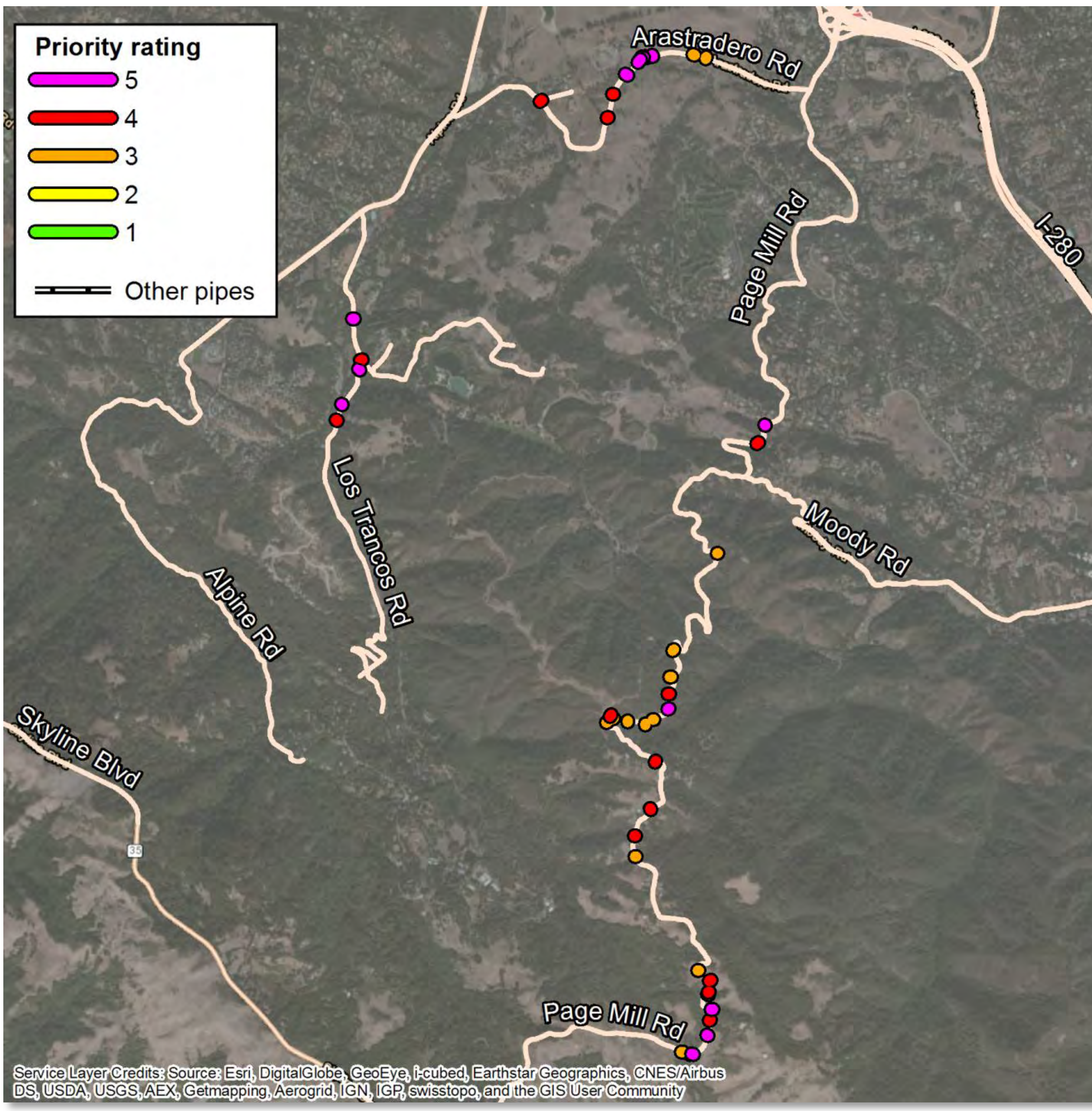


Figure 3-1. Overall Map – Prioritization Ratings

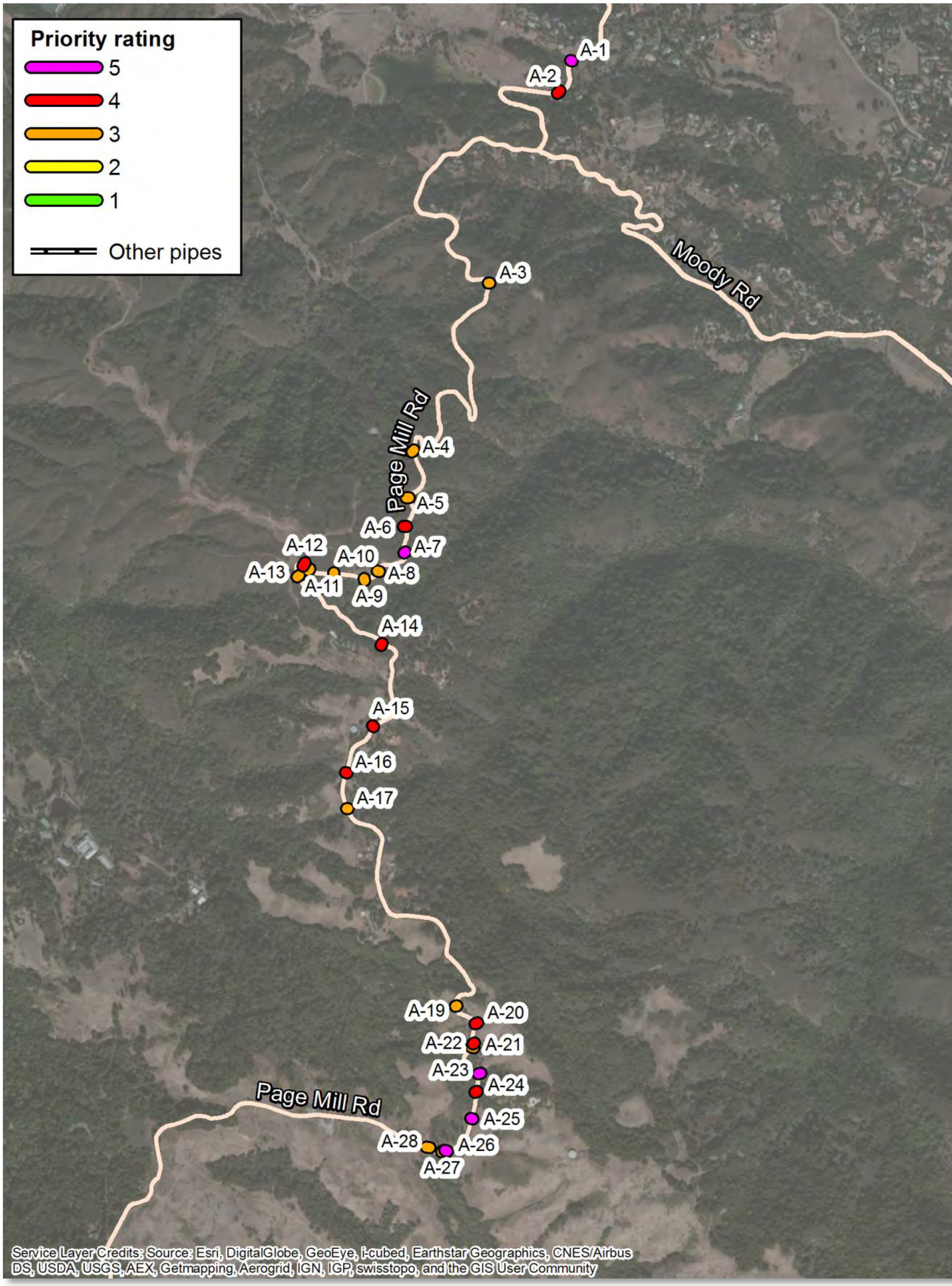


Figure 3-2. Prioritization Ratings – Page Mill Rd.

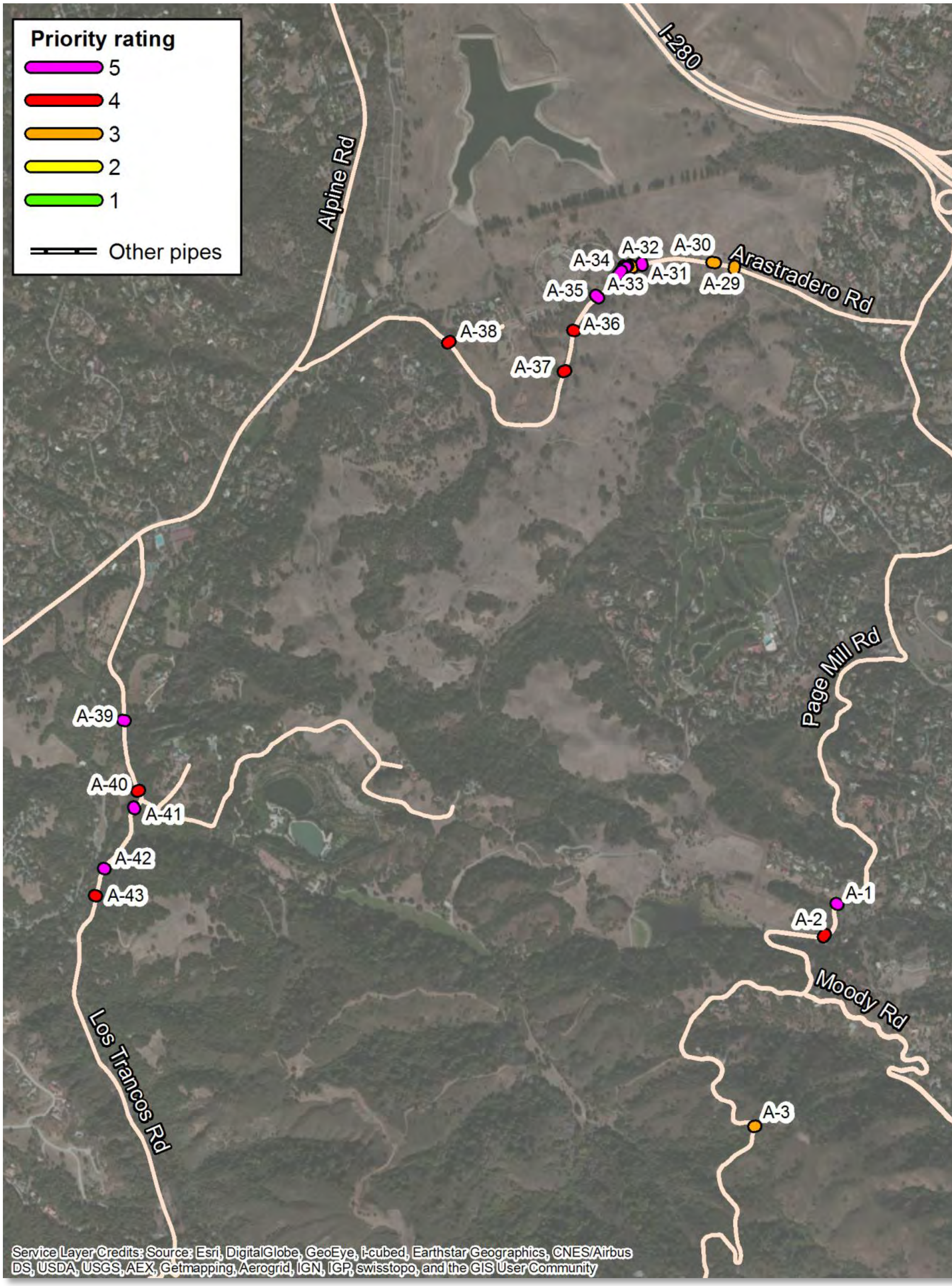


Figure 3-3. Prioritization Ratings – Arastradero Rd. and Los Trancos Rd.

In general, the culverts were in fair to poor condition. A few of the culverts were in good condition with VANDA ratings of 1 or 2, but all culverts received prioritization ratings of 3 or above due to a variety of reasons. It should be noted that almost all of the culverts run under roadways, so the consequences of failure are higher, resulting in a need for more frequent monitoring and a higher rating per Table 2-4. Most of the culverts also exhibited minor or moderate issues that were not necessarily the result of corrosion, resulting in higher prioritization ratings than might otherwise be expected based on the VANDA condition ratings.

Typical observed defects included the following:

- Perforations, particularly at the invert of CMPs.
- Surface corrosion.
- Loss of galvanizing.
- Offset or separated joints.
- Deflection of the ends of the pipe.
- Sediment, debris and/or obstructions.

Table 3-1 through Table 3-3 summarize the condition assessment findings and ratings. Maps, photos, and more detailed condition information are found in Appendix A.

Table 3-1. Condition Assessment Results – Page Mill Rd.

Culvert ID	Size (in.)	Material	Length (ft.)	VANDA Rating	Prioritization Rating	Prioritization Rationale
A-1	20	CMP	30	4	5	Condition, location
A-2	12	CMP	45*	1	4	Could not locate downstream end
A-3	12	CMP	20	2	3	Ends deflected
A-4	12	CMP	40	2	3	Condition, location
A-5	18	CMP	40+	2	3	Condition, location
A-6	12	CMP	45+	2	4	Sediment
A-7	12	CMP	30+	3	5	Sediment
A-8	12	CMP	30+	2	3	Condition, location
A-9	10	Steel/CMP	25+	2	3	Condition, location, sediment
A-10	12	CMP	30+	2	3	Condition, location
A-11	8	CIP	30	2	3	Condition, location
A-12	10	CMP	55	3	4	Location, sediment, cable penetration
A-13	12	CMP	30	2	3	Condition, location
A-14	12	CMP/plastic	30	3	4	Condition, location
A-15	12	CMP	20	2	4	Condition, location
A-16	12	CMP	20	3	4	Condition, location

Table 3-1 continued

Culvert ID	Size (in.)	Material	Length (ft.)	VANDA Rating	Prioritization Rating	Prioritization Rationale
A-17	12	CMP	20	2	3	Ends deflected, sediment
A-18	Abandoned					
A-19	17	CMP	25	2	3	Condition, location, ends deflected
A-20	8 - 12	CMP	35	4	4	Condition, location, joints
A-21	12	CMP	25+	2	4	Condition, location
A-22	12	CMP	35+	2	3	Condition, location
A-23	12	CMP	35+	4	5	Condition, location
A-24	12	CMP	30	3	4	Condition, location
A-25	18	CMP	25	3	5	Condition, location, sediment, pavement undermining
A-26	8	CMP	35	2	5	Sediment
A-27	12	CMP	20	3	3	Condition
A-28	12	CMP	50	2	3	Ends deflected

* End points not found. Length estimated.
+ End points not accessible. Length based on GPS location of accessible points; culvert may be longer.

Table 3-2. Condition Assessment Results – Arastradero Rd.

Culvert ID	Size (in.)	Material	Length (ft.)	VANDA Rating	Prioritization Rating	Prioritization Rationale
A-29	21	CMP	45	2	3	Condition, location
A-30	12	CMP	50	2	3	Condition
A-31	12	CMP	35	4	5	Condition, location
A-32	24, 18	CMP	50	2	3	Condition, location
A-33	24	CMP	60*	3	4	Condition, location, sediment
A-34	12	CMP	170*	4	5	Condition, location, burial
A-35	12	CMP	55	2	5	Condition, location, sediment
A-36	12	CMP	25	3	4	Condition, location, sediment
A-37	12	CMP	40	3	4	Condition, location, burial
A-38	12	CMP	40	2	4	Sediment

* End points not found. Length estimated. For Culvert A-33, the length of the City's portion is not known.

Table 3-3. Condition Assessment Results – Los Trancos Rd.

Culvert ID	Size (in.)	Material	Length (ft.)	VANDA Rating	Prioritization Rating	Prioritization Rationale
A-39	15	CMP	35+	2	5	Condition, location, blockage
A-40	15	CMP	40+	3	4	Condition, location
A-41	24	CMP	35	3	5	Condition, location, capacity
A-42	12	RCP	25	1	5	Sediment
A-43	12	CMP/RCP	25	4	4	Condition, location, construction features

+ End points not accessible. Length based on GPS location of accessible points; culvert may be longer.

APPENDIX A. FACILITY INVENTORY

Page Mill Rd.

Culvert A-1

Location Map

Page Mill Rd.

Culvert A-1

Evaluation date/time:	11/10/2014 9:20 AM
Address/location:	Page Mill Rd.
Weather:	Dry

General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	No
Access:	Good	**Susceptible to ponding/flooding:**	No
Traffic:	Light	Sediment/debris depth (%):	15
Ground surface type:	Asphalt, grass/dirt	Type of sediment/debris:	Silt, vegetation
Dia./Ht. (in.):	20	Infiltration:	None
Width (in.):		Obstruction/deflection:	0
Material:	CMP	VANDA condition rating:	Level 4 - Severe/Significant Damage
U/S grade/rim-inv. (ft.):	3.5	Prioritization rating:	Level 5 - Immediate Attention
D/S grade/rim-inv. (ft.):	3.5	Prioritization rationale:	Condition, location
Water level (%):	0	Illegal dumping evidence:	No

Notes

Pipe runs under the road. Lower half of CMP is severely corroded and perforated. Outlet is deflected.

Photos

Area near inlet.


Area above inlet.

Page Mill Rd.

Culvert A-1

Inlet.

Inlet.

Inlet with perforations in CMP.

Perforations in CMP at inlet.

View inside inlet.

View inside inlet.

Page Mill Rd.

Culvert A-1

Area near outlet.

Outlet.

Outlet. CMP is deflected at outlet. Void in soil at left.

View inside outlet. Note perforations at spring lines.

Perforated CMP at outlet.

Perforated CMP at outlet.

Page Mill Rd.

Culvert A-1

Culvert on private property just downstream of A-1.

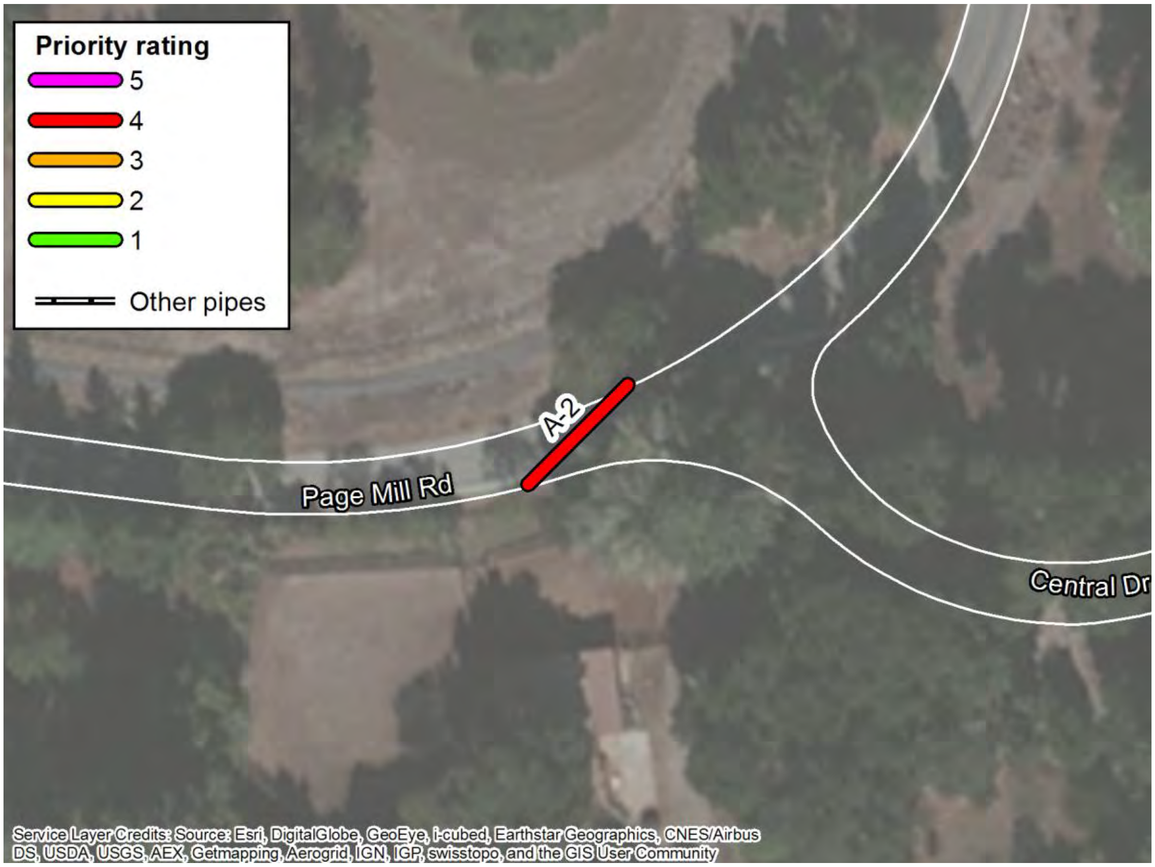
Culvert on private property just downstream of A-1.

Culvert on private property just downstream of A-1.

Page Mill Rd.

Culvert A-2

Location Map



Page Mill Rd.

Culvert A-2

Evaluation date/time:	11/10/2014 10:41 AM
Address/location:	Page Mill Rd.
Weather:	Dry

General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	Yes
Access:	Fair	**Susceptible to ponding/flooding:**	No
Traffic:	Light	Sediment/debris depth (%):	20
Ground surface type:	Asphalt	Type of sediment/debris:	Silt, vegetation
Dia./Ht. (in.):	12	Infiltration:	None
Width (in.):		Obstruction/deflection:	0
Material:	CMP	VANDA condition rating:	Level 1 - No Damage
U/S grade/rim-inv. (ft.):	2	Prioritization rating:	Level 4 - Poor
D/S grade/rim-inv. (ft.):		Prioritization rationale:	Could not locate downstream end
Water level (%):	0	Illegal dumping evidence:	No

Notes

Downstream end of culvert could not be located.

Photos

Area view.

Area near inlet.

Page Mill Rd.

Culvert A-2

Area near inlet.

Inlet.

View inside inlet.

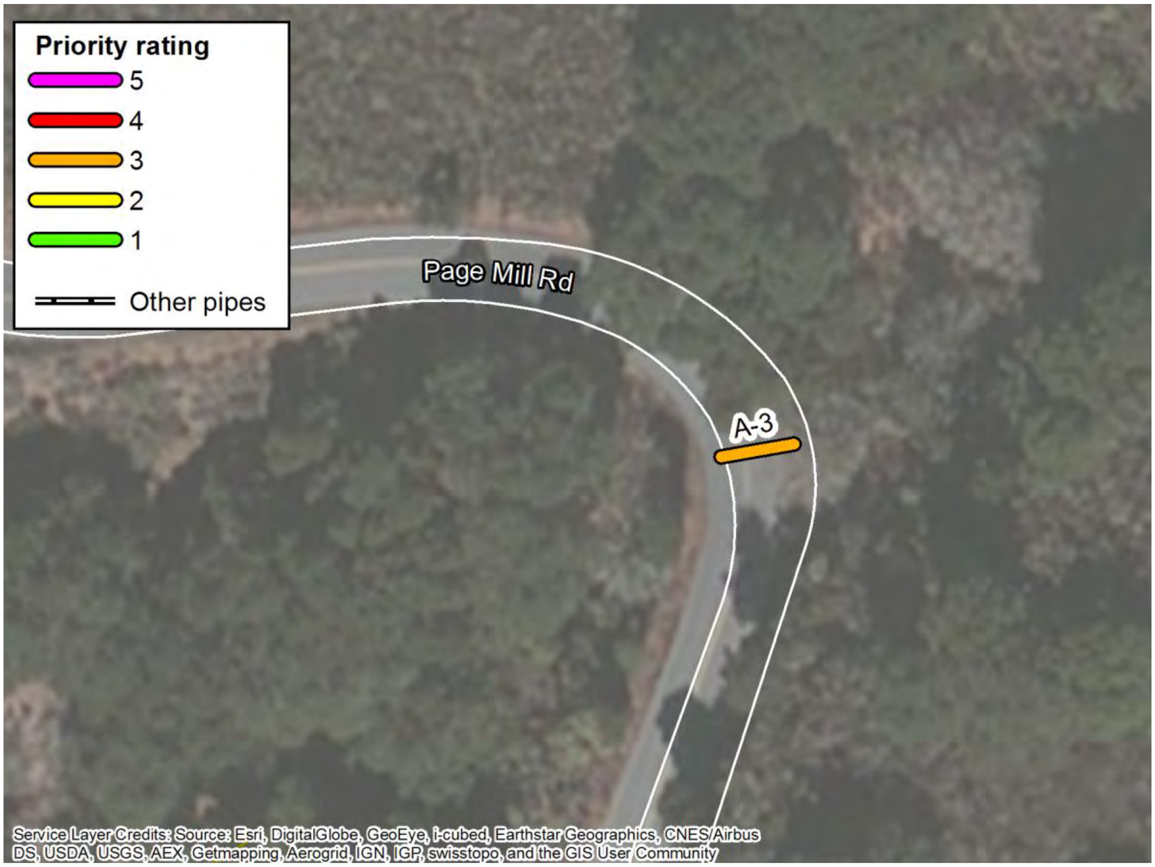
View inside inlet.

Address marker near inlet.

Page Mill Rd.

Culvert A-3

Location Map



Page Mill Rd.

Culvert A-3

Evaluation date/time:	11/10/2014 10:13 AM
Address/location:	Page Mill Rd.
Weather:	Dry

General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	Yes
Access:	Good	**Susceptible to ponding/flooding:**	No
Traffic:	Light	Sediment/debris depth (%):	10
Ground surface type:	Asphalt	Type of sediment/debris:	Silt, vegetation
Dia./Ht. (in.):	12	Infiltration:	None
Width (in.):		Obstruction/deflection:	0
Material:	CMP	VANDA condition rating:	Level 2 - Minor Damage
U/S grade/rim-inv. (ft.):	1.5	Prioritization rating:	Level 3 - Fair
D/S grade/rim-inv. (ft.):	5	Prioritization rationale:	Ends deflected
Water level (%):	0	Illegal dumping evidence:	No

Notes

Pipe runs under the road. CMP deflected at ends. Coating failure and minor corrosion at invert.

Photos

Area view.

Area view.

Page Mill Rd.

Culvert A-3


Area near inlet.


Area near outlet.


Inlet.


View inside inlet.

View inside inlet.

View inside inlet.

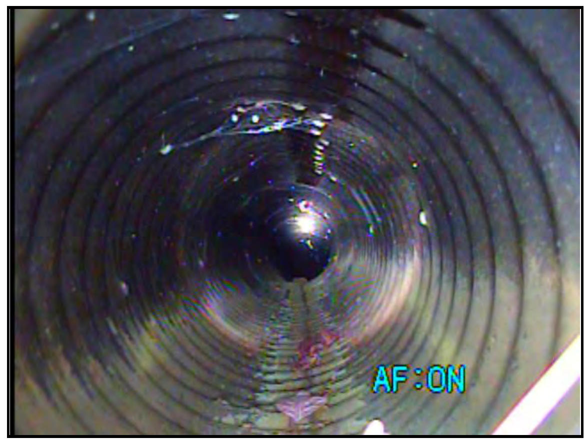
Page Mill Rd.

Culvert A-3

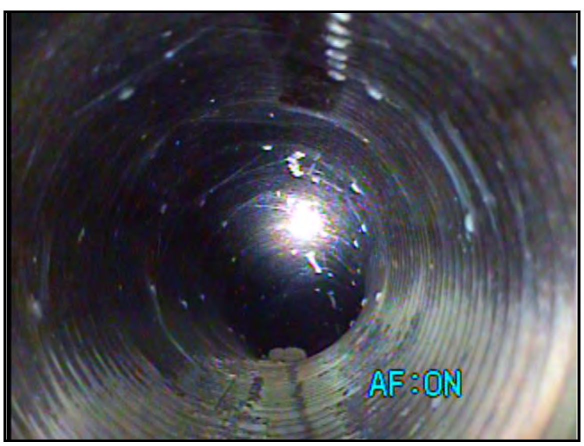
Outlet.

Outlet.

View inside outlet.



View inside outlet.



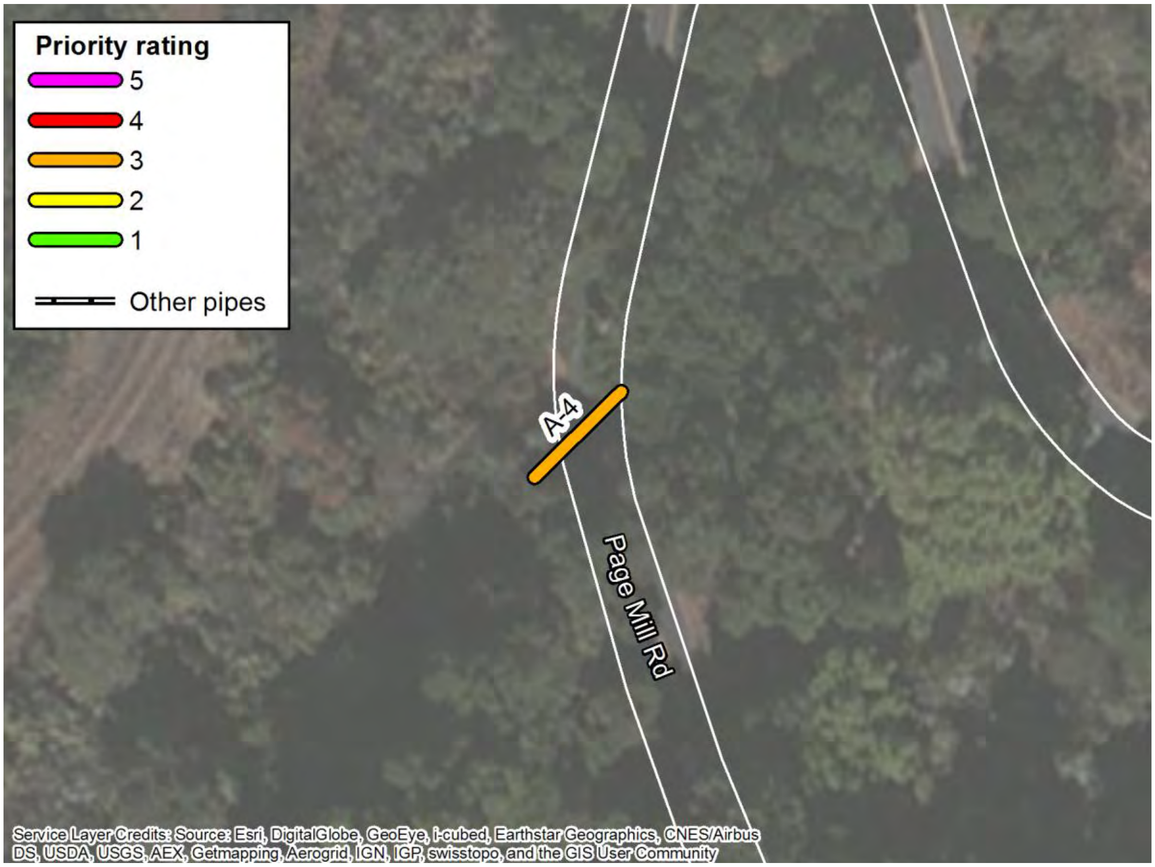
View inside outlet.

View inside outlet.

Page Mill Rd.

Culvert A-4

<u>Location Map</u>



Page Mill Rd.

Culvert A-4

Evaluation date/time:	11/10/2014 11:15 AM
Address/location:	Page Mill Rd.
Weather:	Dry

General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	No
Access:	Good	**Susceptible to ponding/flooding:**	No
Traffic:	Light	Sediment/debris depth (%):	15
Ground surface type:	Asphalt, grass/dirt	Type of sediment/debris:	Asphalt, vegetation
Dia./Ht. (in.):	12	Infiltration:	None
Width (in.):		Obstruction/deflection:	0
Material:	CMP	VANDA condition rating:	Level 2 - Minor Damage
U/S grade/rim-inv. (ft.):	2	Prioritization rating:	Level 3 - Fair
D/S grade/rim-inv. (ft.):	2	Prioritization rationale:	Condition, location
Water level (%):	0	Illegal dumping evidence:	No

Notes

Pipe runs under the road. Apparent offset joint inside pipe. Asphalt and other debris at invert. Pipe has loss of galvanizing at invert and minor corrosion.

Photos

Area view.

Area view.

Page Mill Rd.

Culvert A-4

Area near inlet.

Area near outlet. Outlet at lower left.

Channel downstream of outlet.

Inlet.

Inlet.

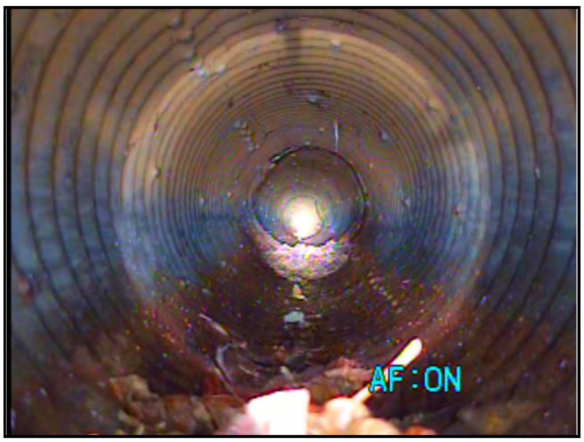
Inlet.

Page Mill Rd.

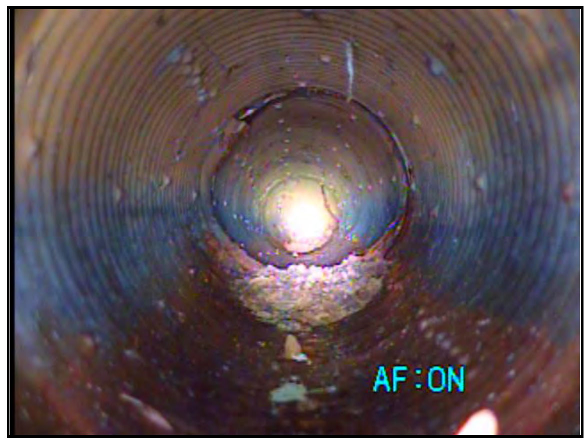
Culvert A-4

View inside inlet.

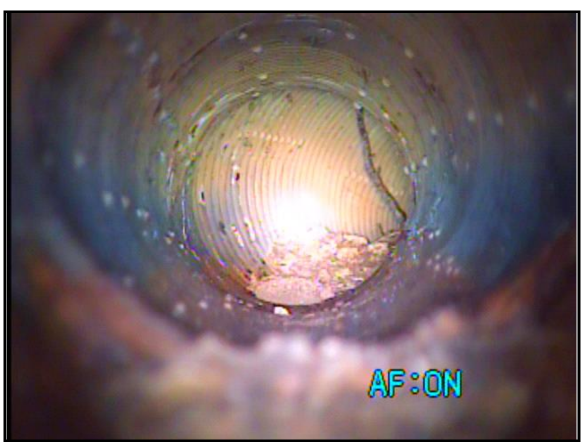
View inside inlet.



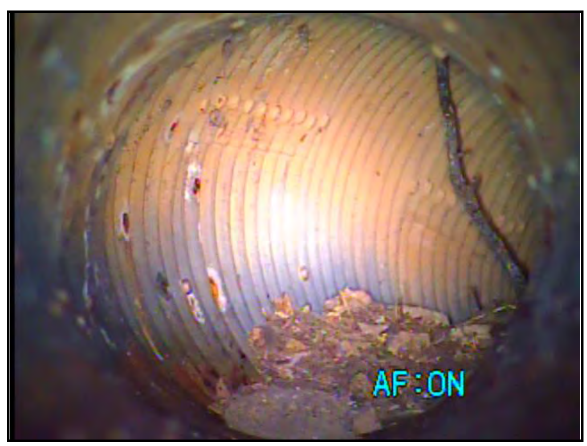
View inside inlet.



View inside inlet.



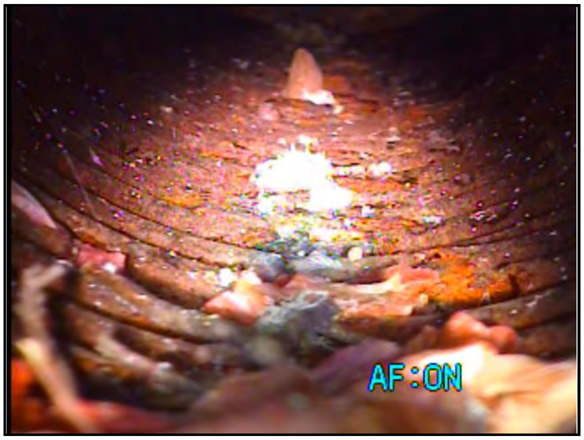
View inside inlet.



View inside inlet.

Page Mill Rd.

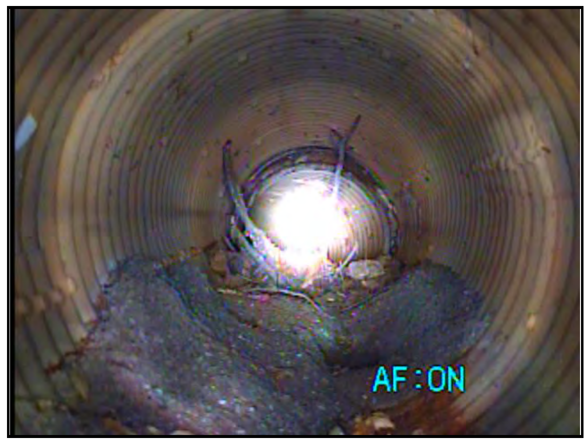
Culvert A-4



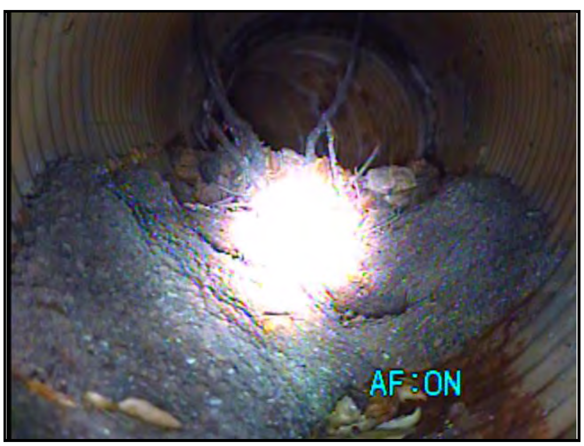
View inside inlet.

Outlet.

View inside outlet.



Debris and asphalt inside culvert (viewed from outlet).

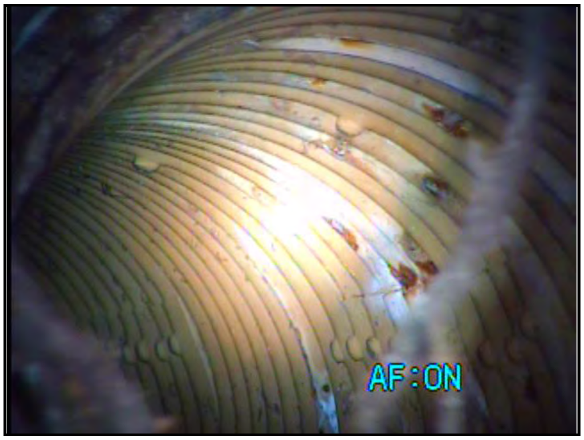


Asphalt inside culvert (viewed from outlet).

Debris inside culvert and apparent offset joint (viewed from outlet).

Page Mill Rd.

Culvert A-4

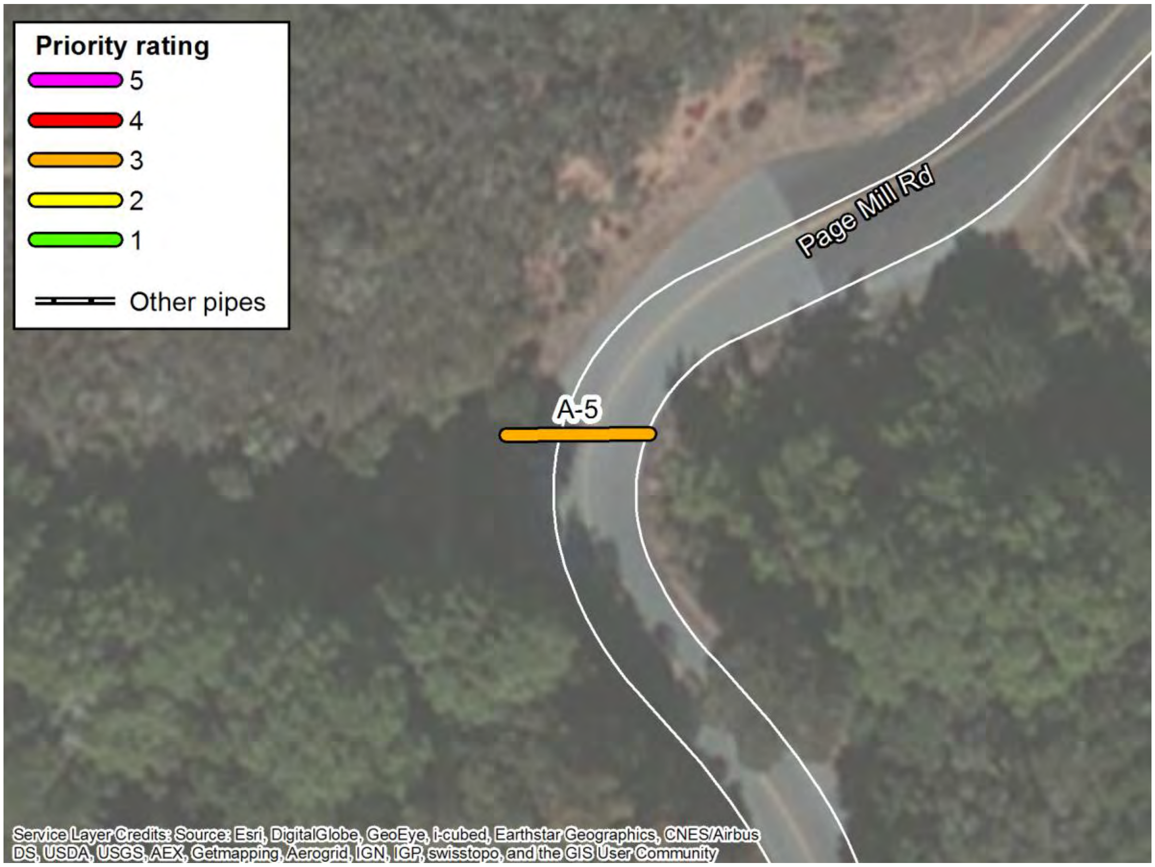


View inside outlet.

Page Mill Rd.

Culvert A-5

Location Map



Page Mill Rd.

Culvert A-5

Evaluation date/time: 11/10/2014 2:31 PM

Address/location: Page Mill Rd.

Weather: Dry

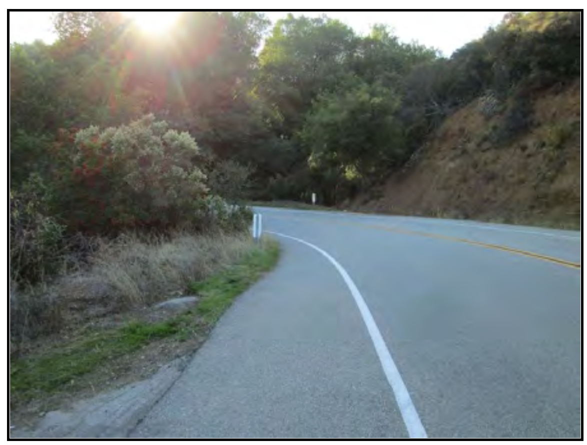
General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	Yes
Access:	Fair	**Susceptible to ponding/flooding:**	No
Traffic:	Light	Sediment/debris depth (%):	0
Ground surface type:	Asphalt, grass/dirt	Type of sediment/debris:	Vegetation
Dia./Ht. (in.):	18	Infiltration:	None
Width (in.):		Obstruction/deflection:	5
Material:	CMP	VANDA condition rating:	Level 2 - Minor Damage
U/S grade/rim-inv. (ft.):	2	Prioritization rating:	Level 3 - Fair
D/S grade/rim-inv. (ft.):		Prioritization rationale:	Condition, location
Water level (%):	0	Illegal dumping evidence:	No

Notes

Could not locate downstream end of pipe due to slope and vegetation. Marker post is not labeled with A-5 identifier. Coating failure and minor corrosion at invert. Possible deterioration at joints.

Photos

Area view from vicinity of inlet.



Area view from vicinity of outlet.

Page Mill Rd.

Culvert A-5

Area view from vicinity of outlet.

Area near inlet.

Area near inlet.

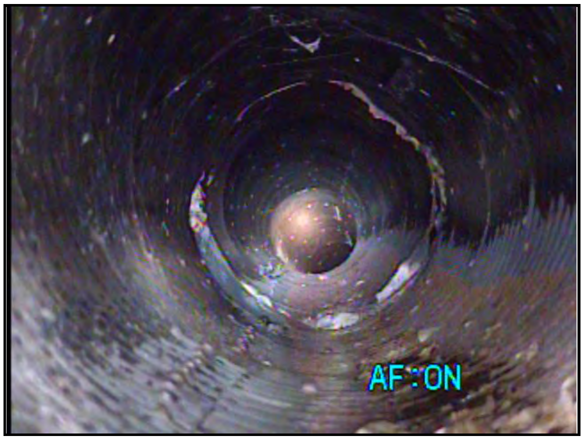
Area near outlet.

Inlet.

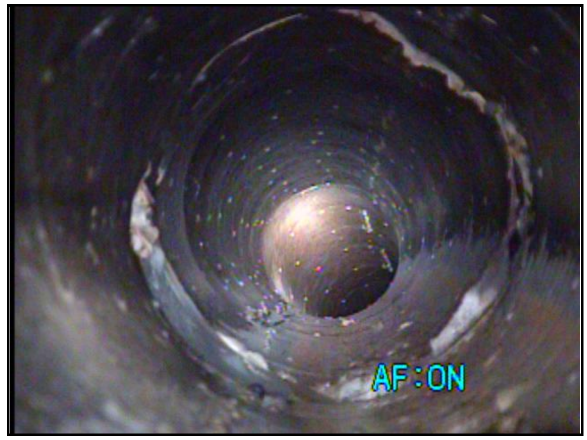
View inside inlet.

Page Mill Rd.

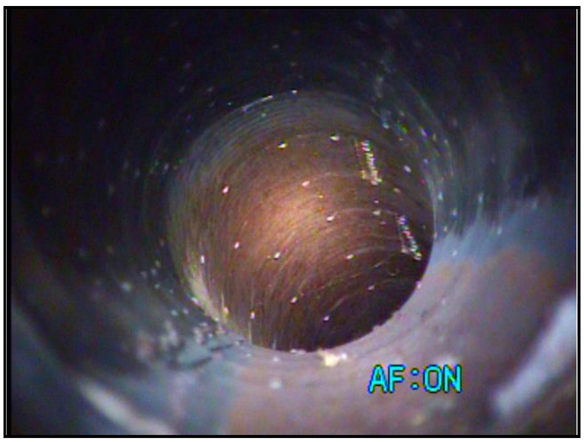
Culvert A-5



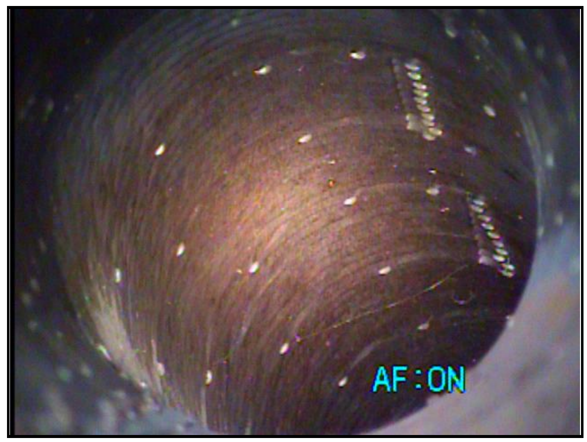
View inside inlet.



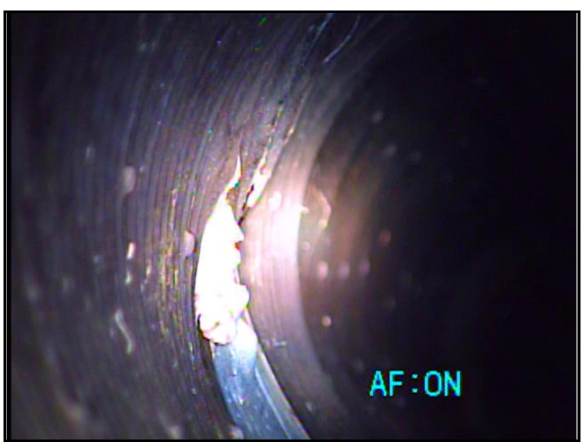
View inside inlet.



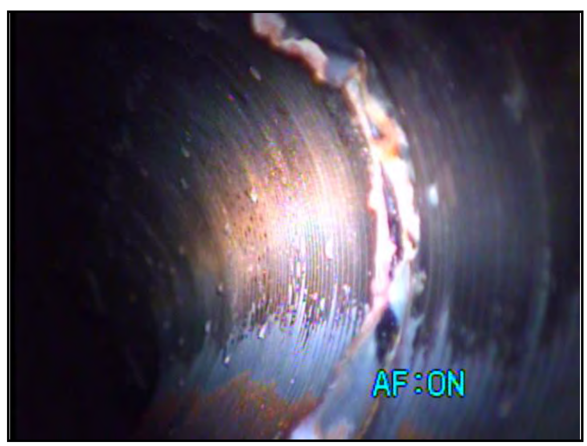
View inside inlet.



View inside inlet.



Possible deterioration at joint (viewed from inlet).

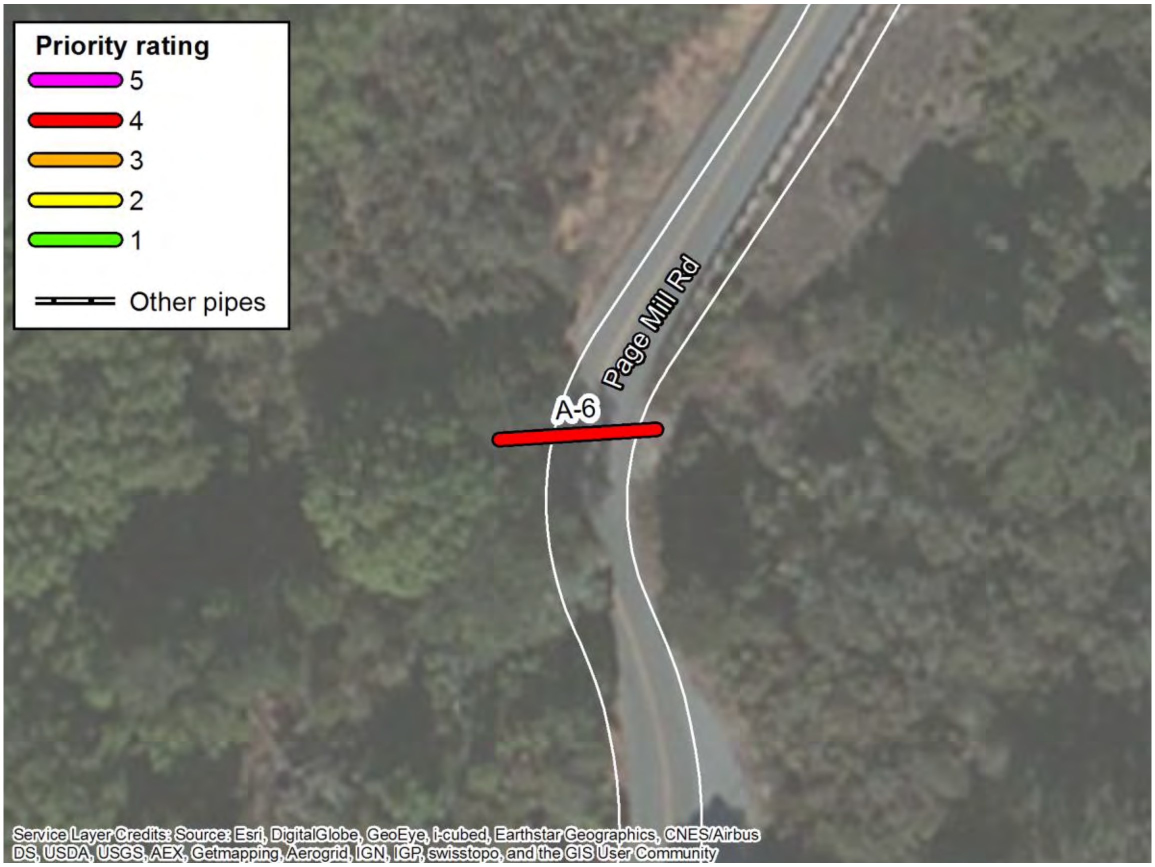


Possible deterioration at joint (viewed from inlet).

Page Mill Rd.

Culvert A-6

Location Map



Page Mill Rd.

Culvert A-6

Evaluation date/time:	11/10/2014 12:49 PM
Address/location:	Page Mill Rd.
Weather:	Dry

General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	Yes
Access:	Fair	**Susceptible to ponding/flooding:**	No
Traffic:	Light	Sediment/debris depth (%):	0
Ground surface type:	Asphalt, grass/dirt	Type of sediment/debris:	None
Dia./Ht. (in.):	12	Infiltration:	None
Width (in.):		Obstruction/deflection:	5
Material:	CMP	VANDA condition rating:	Level 2 - Minor Damage
U/S grade/rim-inv. (ft.):	1	Prioritization rating:	Level 4 - Poor
D/S grade/rim-inv. (ft.):	6	Prioritization rationale:	Sediment
Water level (%):	0	Illegal dumping evidence:	No

Notes

Pipe runs under the road. Downstream end not accessible. Pipe has loss of galvanizing and minor corrosion at invert. Possible separated or offset joint inside pipe.

Photos

Area view.

Area view.

Page Mill Rd.

Culvert A-6

Area view near inlet.

Area view near inlet.

Area near outlet.

Inlet.

Inlet.

Inlet mostly obstructed by debris.

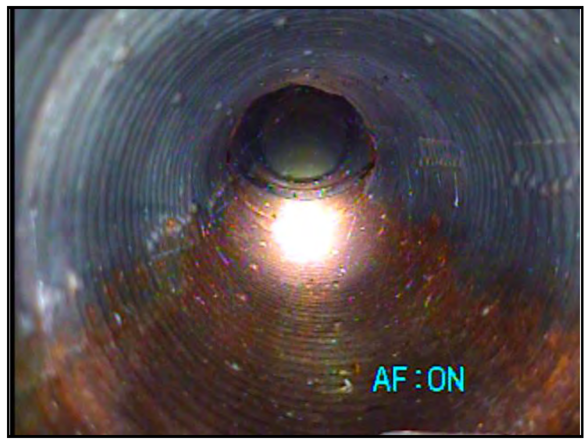
Page Mill Rd.

Culvert A-6

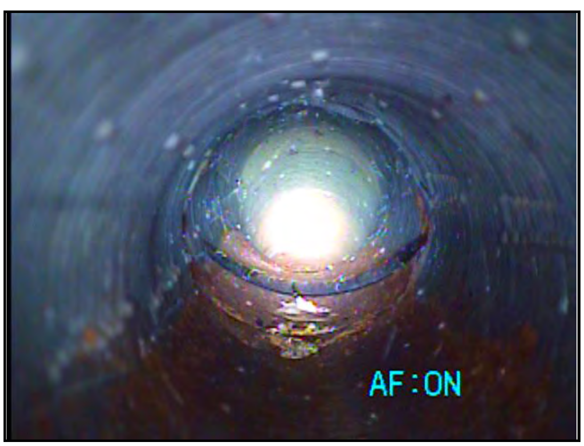
Inlet mostly obstructed by debris.

View inside inlet.

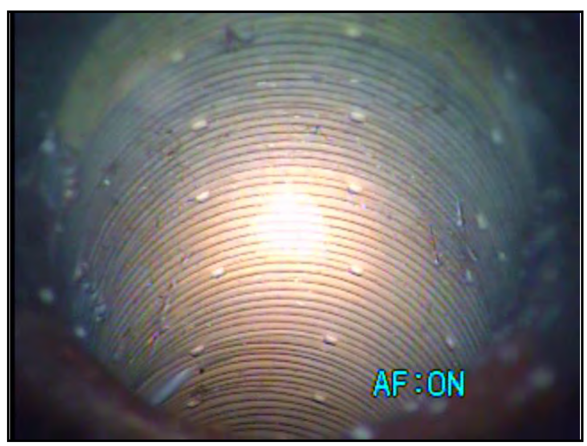
View inside inlet.



View inside inlet.



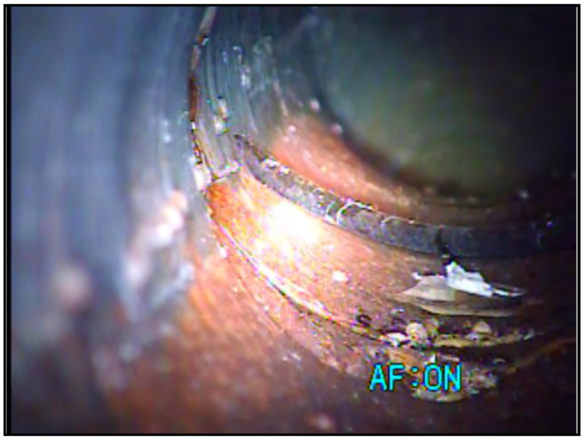
View inside inlet. Apparent offset joints within pipe.



View inside inlet.

Page Mill Rd.

Culvert A-6



Possible offset joint within pipe.

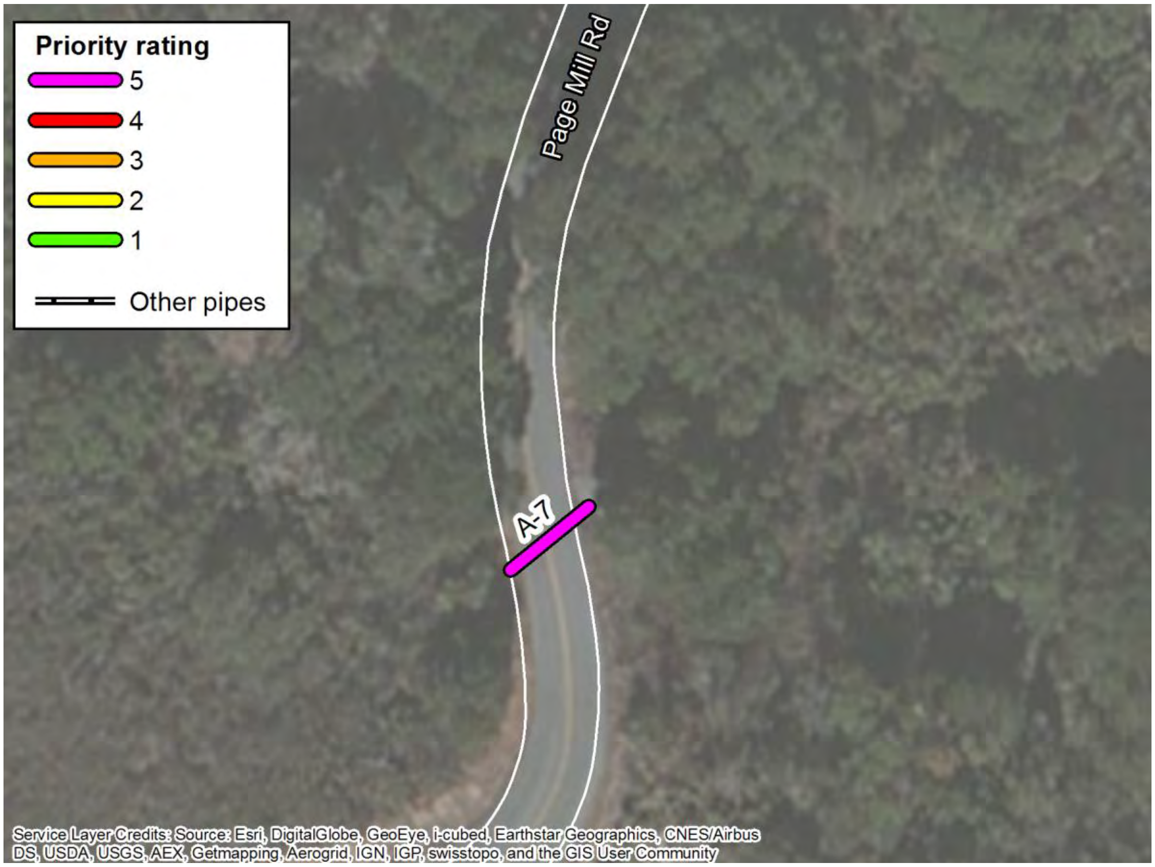
Outlet.

Outlet.

Page Mill Rd.

Culvert A-7

Location Map



Page Mill Rd.

Culvert A-7

Evaluation date/time:	11/10/2014 1:06 PM
Address/location:	Page Mill Rd.
Weather:	Dry

General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	Yes
Access:	Fair	**Susceptible to ponding/flooding:**	No
Traffic:	Light	Sediment/debris depth (%):	100
Ground surface type:	Asphalt	Type of sediment/debris:	Sand, gravel
Dia./Ht. (in.):	12	Infiltration:	None
Width (in.):		Obstruction/deflection:	50
Material:	CMP	VANDA condition rating:	Level 3 - Moderate Damage
U/S grade/rim-inv. (ft.):	1	Prioritization rating:	Level 5 - Immediate Attention
D/S grade/rim-inv. (ft.):		Prioritization rationale:	Sediment
Water level (%):	0	Illegal dumping evidence:	No

Notes

Inlet is buried and filled with sediment and debris. Large hole in exposed portion of CMP at inlet. Outlet could not be located.

Photos

Area view.

Area view.

Page Mill Rd.

Culvert A-7

Area near inlet.

Inlet.

Inlet.

Inlet. Large section of pipe wall missing.

View inside inlet.

Area near outlet. Outlet could not be located.

Page Mill Rd.

Culvert A-7

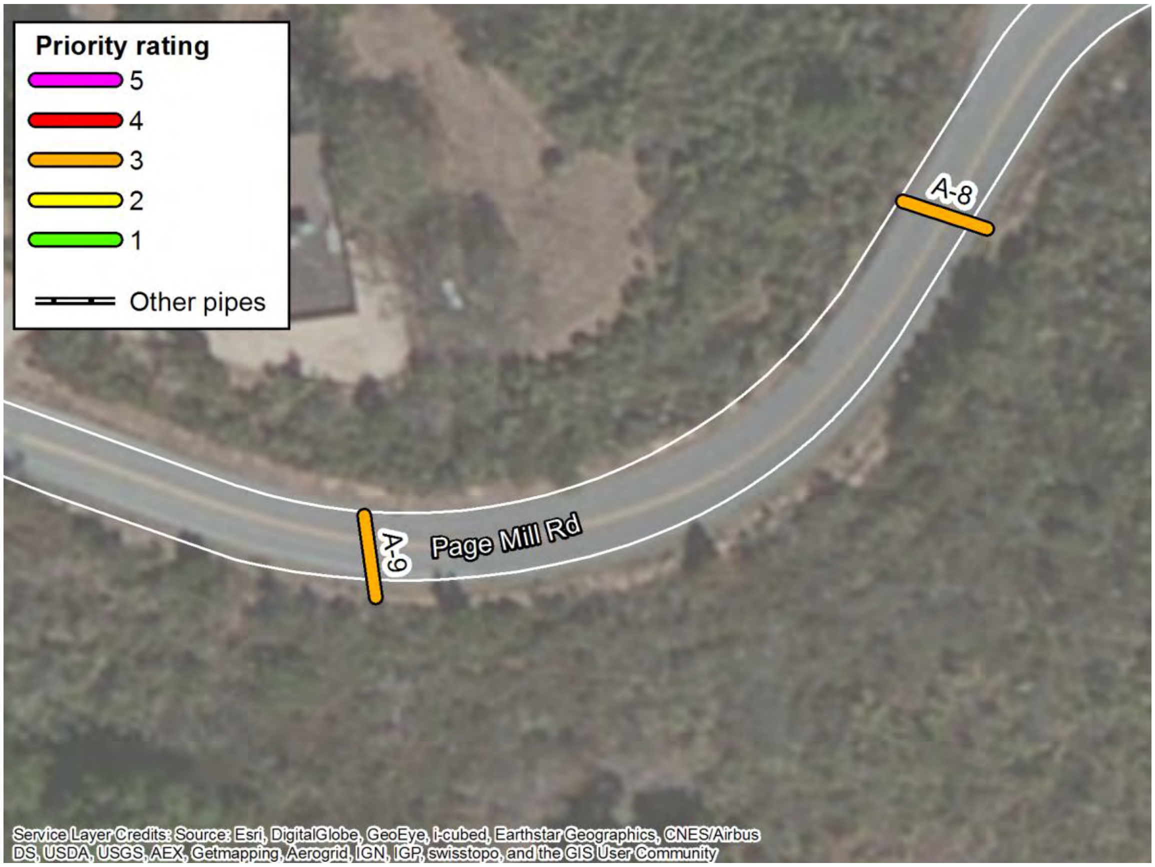
Area near outlet. Outlet could not be located.

Area near outlet. Outlet could not be located.

Page Mill Rd.

Culvert A-8

Location Map



Page Mill Rd.

Culvert A-8

Evaluation date/time:	11/10/2014 2:06 PM
Address/location:	Page Mill Rd.
Weather:	Dry

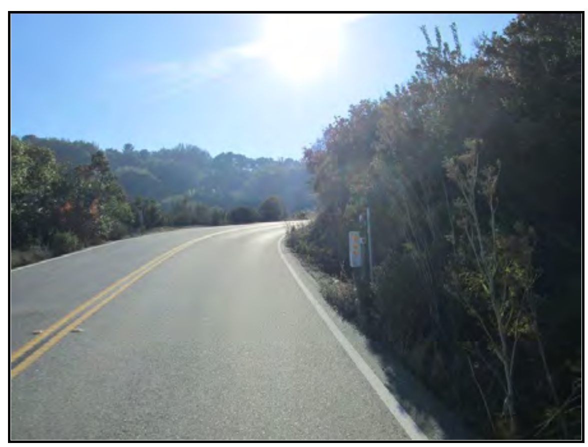
General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	Yes
Access:	Fair	**Susceptible to ponding/flooding:**	No
Traffic:	Light	Sediment/debris depth (%):	0
Ground surface type:	Asphalt	Type of sediment/debris:	None
Dia./Ht. (in.):	12	Infiltration:	None
Width (in.):		Obstruction/deflection:	0
Material:	CMP	VANDA condition rating:	Level 2 - Minor Damage
U/S grade/rim-inv. (ft.):	2	Prioritization rating:	Level 3 - Fair
D/S grade/rim-inv. (ft.):		Prioritization rationale:	Condition, location
Water level (%):	0	Illegal dumping evidence:	No

Notes

Could not locate downstream end of pipe. Coating failure and minor to moderate corrosion at invert. Potential offset or separated joints within pipe.

Photos


Area view.


Area view.

Page Mill Rd.

Culvert A-8

Area near outlet.

Area near outlet.

Inlet.

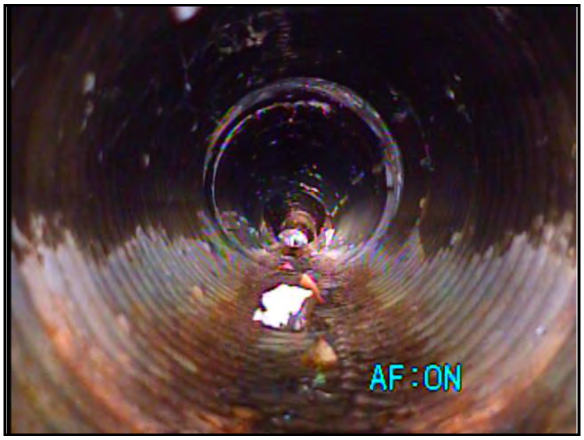
Inlet.

View inside inlet.

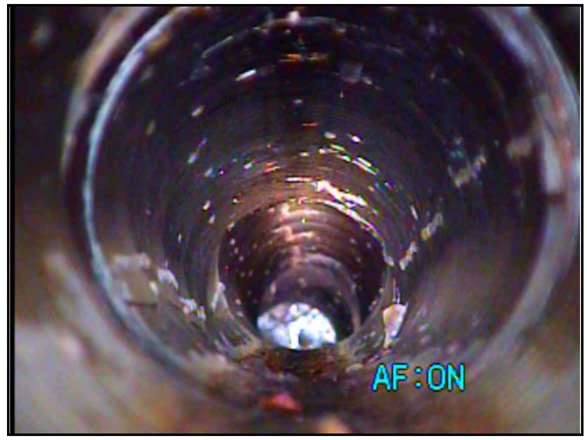
View inside inlet.

Page Mill Rd.

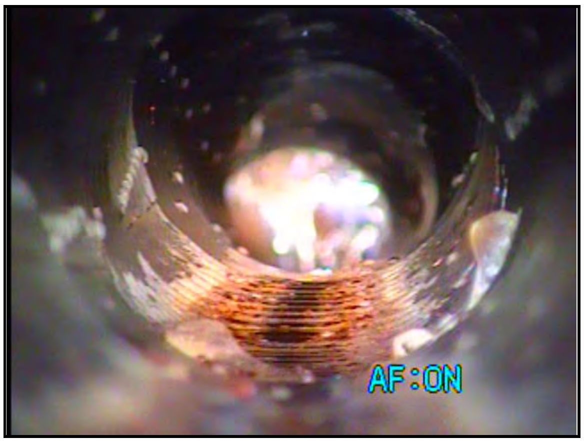
Culvert A-8



View inside inlet.



View inside inlet.

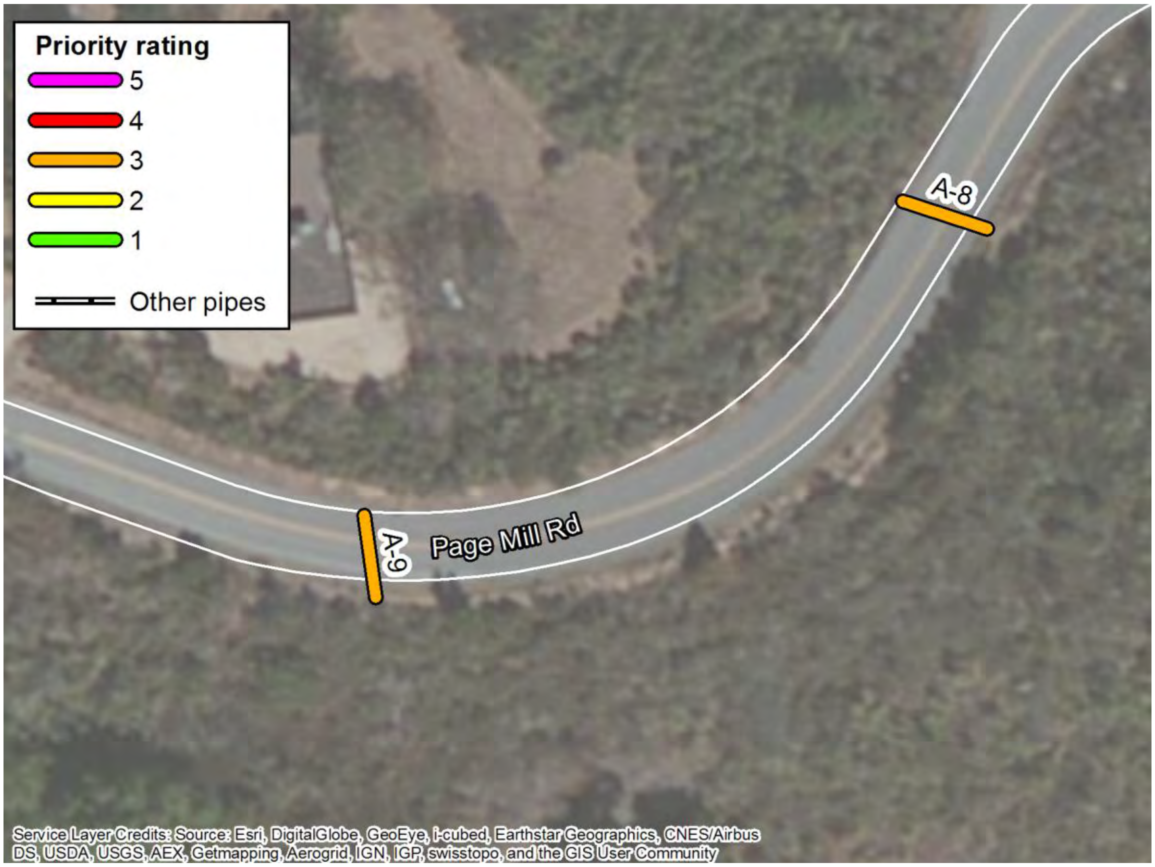


View inside inlet.

Page Mill Rd.

Culvert A-9

Location Map



Page Mill Rd.

Culvert A-9

Evaluation date/time:	11/10/2014 2:13 PM
Address/location:	Page Mill Rd.
Weather:	Dry

General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	Yes
Access:	Fair	**Susceptible to ponding/flooding:**	No
Traffic:	Light	Sediment/debris depth (%):	5
Ground surface type:	Asphalt	Type of sediment/debris:	Silt
Dia./Ht. (in.):	10	Infiltration:	None
Width (in.):		Obstruction/deflection:	15
Material:	Steel/CMP	VANDA condition rating:	Level 2 - Minor Damage
U/S grade/rim-inv. (ft.):	2	Prioritization rating:	Level 3 - Fair
D/S grade/rim-inv. (ft.):		Prioritization rationale:	Condition, location, sediment
Water level (%):	0	Illegal dumping evidence:	No

Notes

Could not locate downstream end of pipe. Pipe appears to be cement-mortar-lined steel pipe for a few feet near the inlet and transitions to CMP downstream. Pipe deflects at transition point, so it is possible that the joint is open. Pipe deflected at inlet. CMP portion of culvert has loss of galvanizing and minor to moderate corrosion at invert.

Photos


Area view.


Area view.

Page Mill Rd.

Culvert A-9

Area near inlet.

Area near outlet.

Area near outlet.

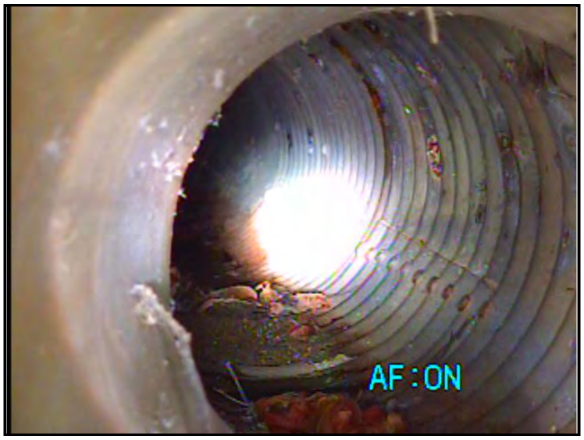
Inlet.

Inlet.

View inside inlet.

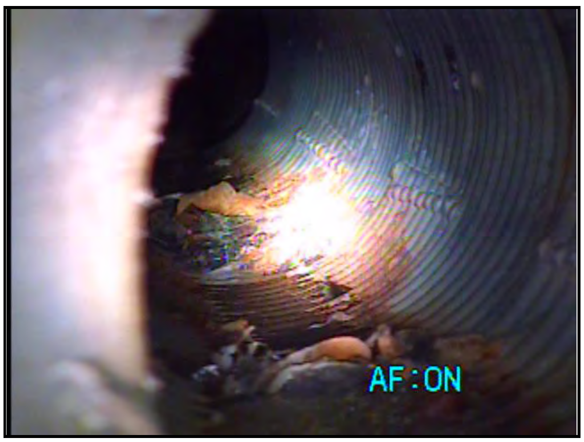
Page Mill Rd.

Culvert A-9



View inside inlet.

View inside inlet.

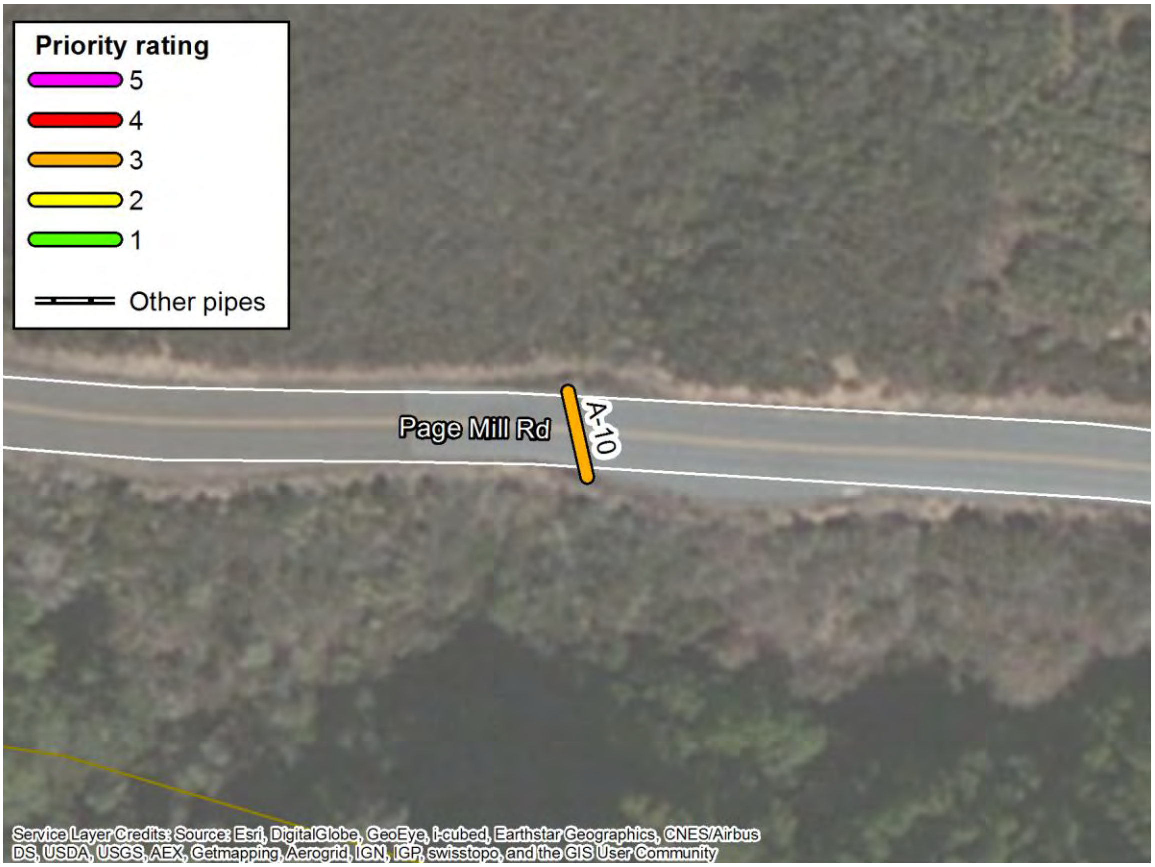


View inside inlet.

Page Mill Rd.

Culvert A-10

Location Map



Page Mill Rd.

Culvert A-10

Evaluation date/time:	11/10/2014 1:50 PM
Address/location:	Page Mill Rd.
Weather:	Dry

General Information

Property type:	Public
Access:	Fair
Traffic:	Light
Ground surface type:	Asphalt
Dia./Ht. (in.):	12
Width (in.):	
Material:	CMP
U/S grade/rim-inv. (ft.):	2
D/S grade/rim-inv. (ft.):	
Water level (%):	0

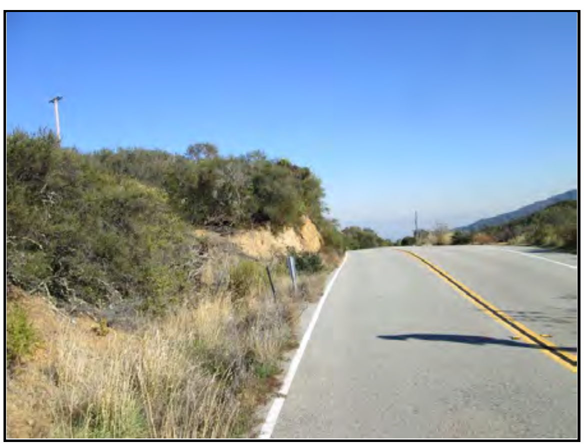
Condition Information and Ratings

Susceptible to burial/overgrowth:	Yes
Susceptible to ponding/flooding:	No
Sediment/debris depth (%):	0
Type of sediment/debris:	None
Infiltration:	None
Obstruction/deflection:	0
VANDA condition rating:	Level 2 - Minor Damage
Prioritization rating:	Level 3 - Fair
Prioritization rationale:	Condition, location
Illegal dumping evidence:	No

Notes

Could not locate downstream end of pipe. Pipe has coating failure and loss of galvanizing at invert with minor corrosion. Pipe appears to have been supplied with a paved invert, which was installed at about the 10:00 position rather than at the invert.

Photos



Area view.

Area near inlet.

Page Mill Rd.

Culvert A-10


Area near inlet.


Area near inlet.


Area near outlet.


Area near outlet.

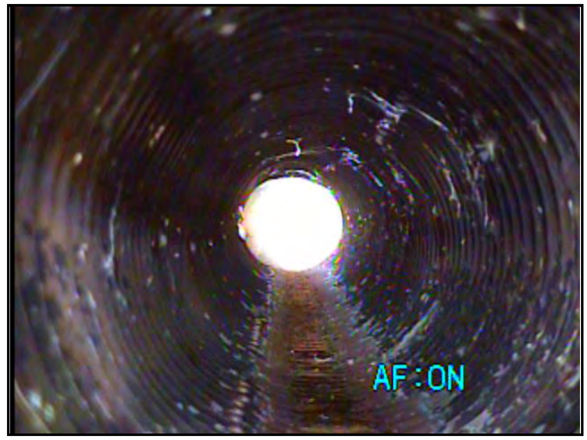

Inlet.


Inlet.

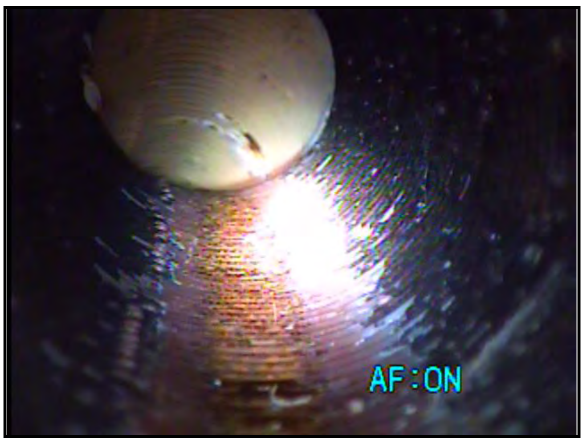
Page Mill Rd.

Culvert A-10

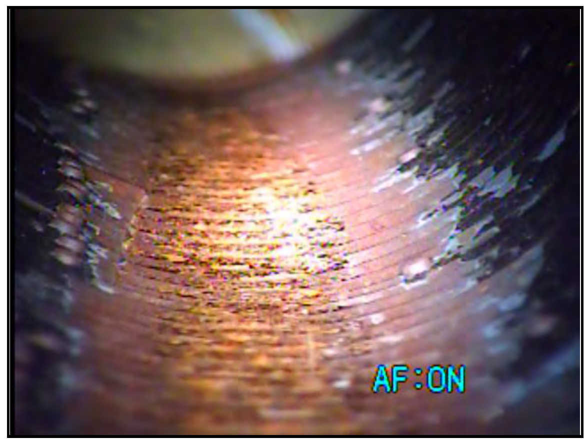
View inside inlet.



View inside inlet.



View inside inlet.



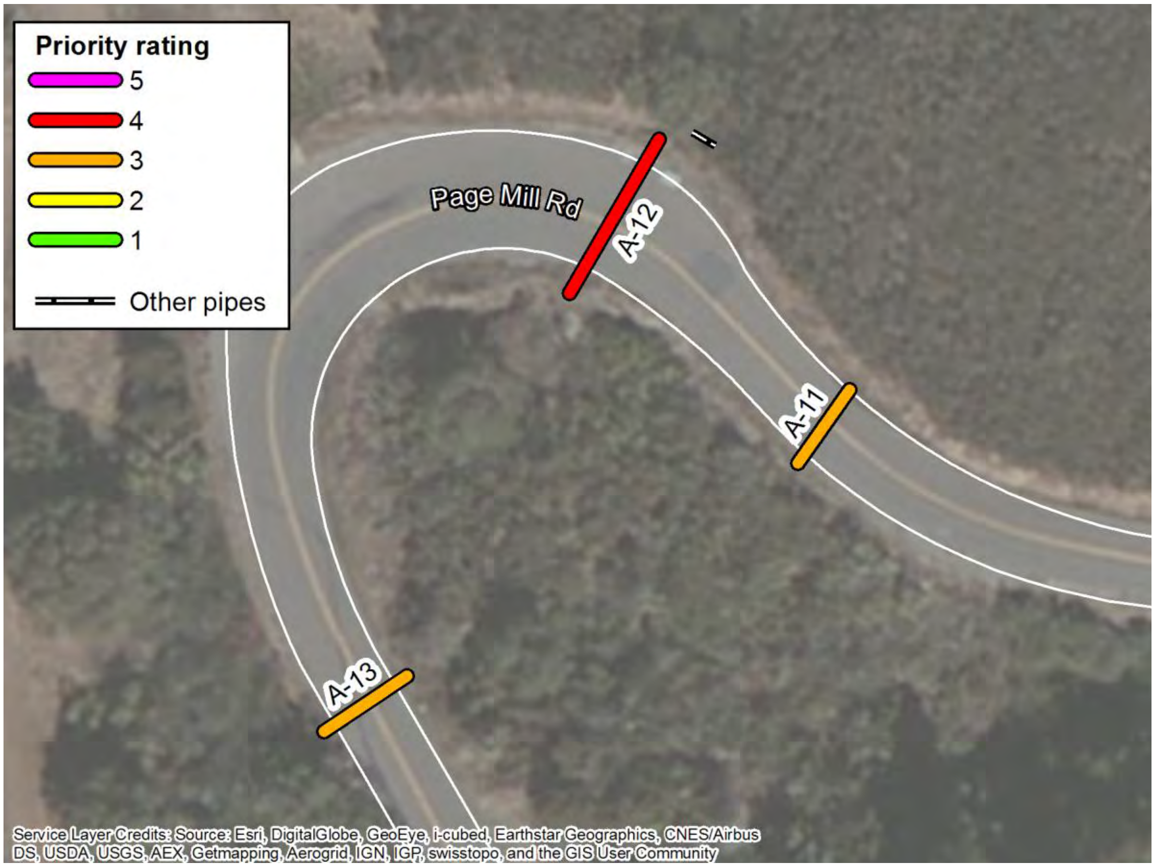
View inside inlet.

View inside inlet.

Page Mill Rd.

Culvert A-11

Location Map



Page Mill Rd.

Culvert A-11

Evaluation date/time:	11/10/2014 1:43 PM
Address/location:	Page Mill Rd.
Weather:	Dry

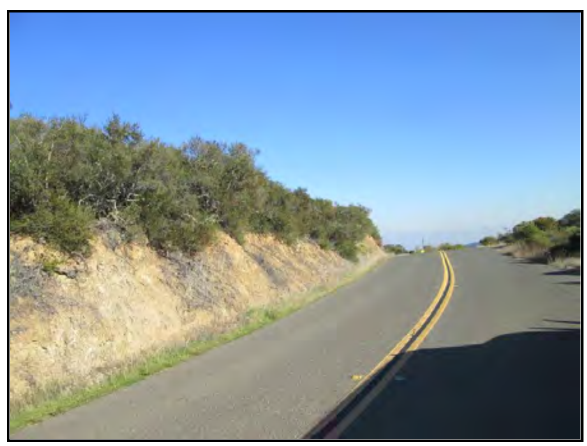
General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	Yes
Access:	Good	**Susceptible to ponding/flooding:**	No
Traffic:	Light	Sediment/debris depth (%):	0
Ground surface type:	Asphalt, grass/dirt	Type of sediment/debris:	None
Dia./Ht. (in.):	8	Infiltration:	None
Width (in.):		Obstruction/deflection:	0
Material:	CIP	VANDA condition rating:	Level 2 - Minor Damage
U/S grade/rim-inv. (ft.):	1.2	Prioritization rating:	Level 3 - Fair
D/S grade/rim-inv. (ft.):	2	Prioritization rationale:	Condition, location
Water level (%):	0	Illegal dumping evidence:	No

Notes

Pipe runs under the road. Coating failure and minor corrosion on interior surfaces of pipe. Possible section of different pipe material in middle section of culvert.

Photos


Area view.


Area view.

Page Mill Rd.

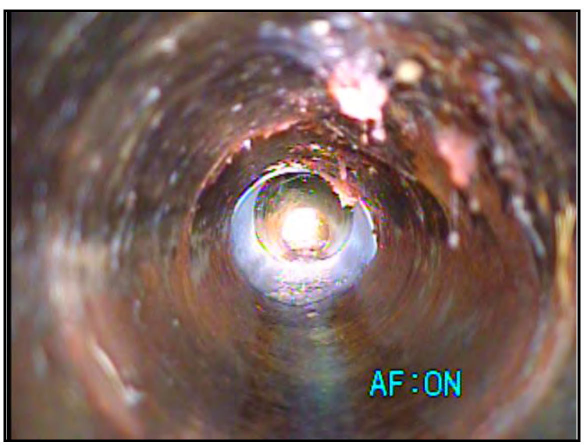
Culvert A-11

Area near inlet.

Area near outlet.

Inlet.

View inside inlet.

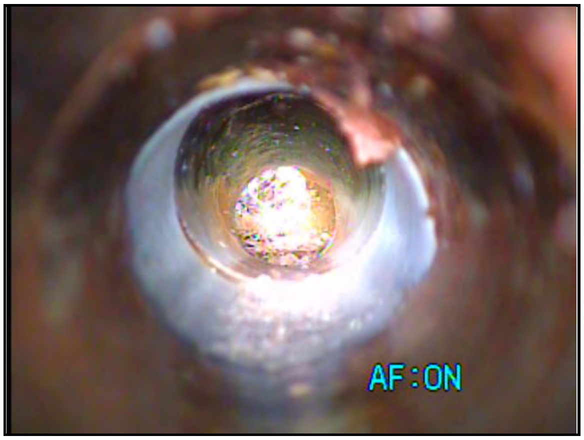


View inside inlet.

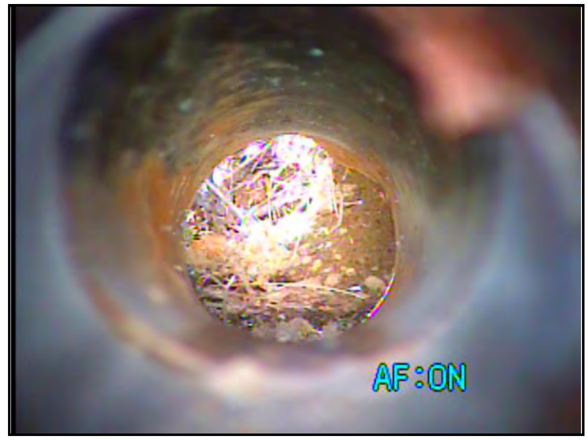
View inside inlet.

Page Mill Rd.

Culvert A-11



View inside inlet.

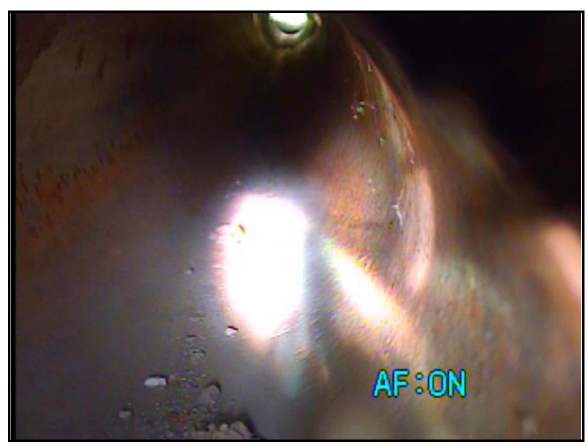


View inside inlet.

Outlet.

View inside outlet.

View inside outlet.

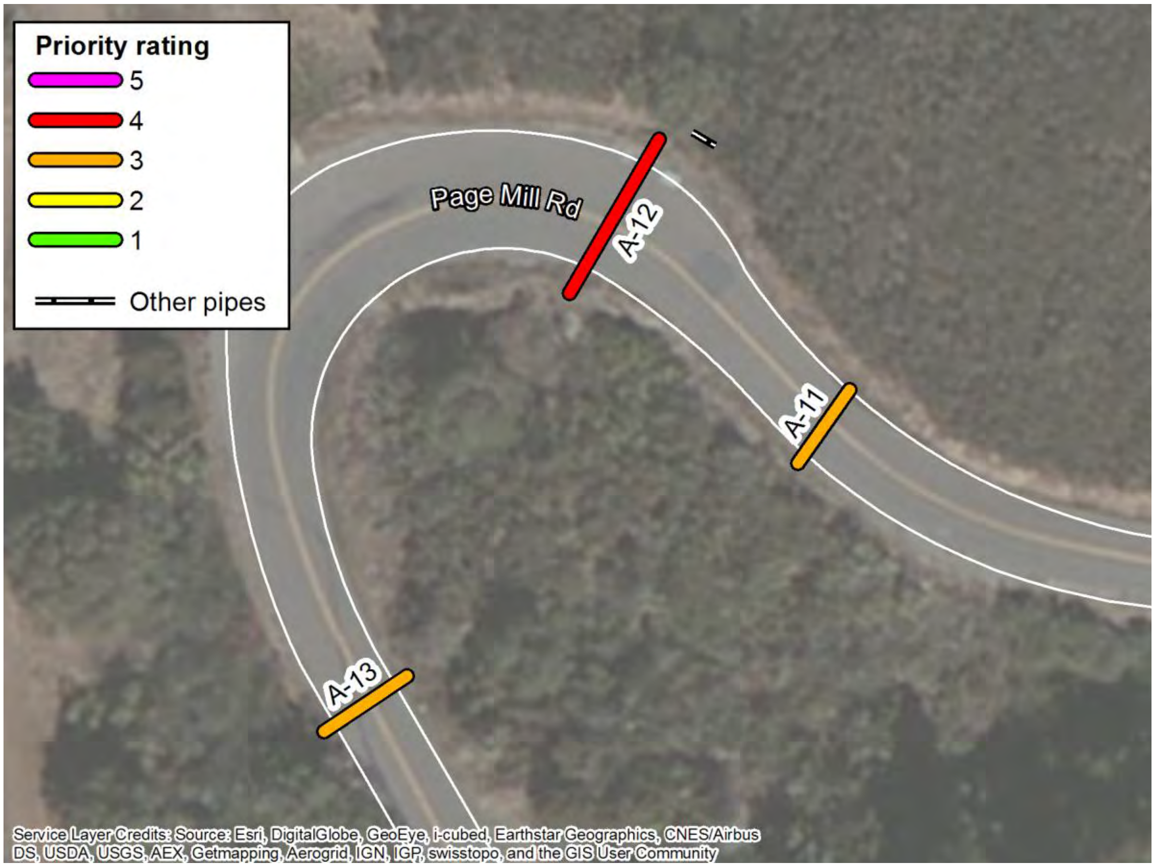


View inside outlet.

Page Mill Rd.

Culvert A-12

Location Map



Page Mill Rd.

Culvert A-12

Evaluation date/time:	11/10/2014 1:23 PM
Address/location:	Page Mill Rd.
Weather:	Dry

General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	No
Access:	Fair	**Susceptible to ponding/flooding:**	No
Traffic:	Light	Sediment/debris depth (%):	5
Ground surface type:	Asphalt	Type of sediment/debris:	Soil, gravel, vegetation
Dia./Ht. (in.):	10	Infiltration:	None
Width (in.):		Obstruction/deflection:	15
Material:	CMP	VANDA condition rating:	Level 3 - Moderate Damage
U/S grade/rim-inv. (ft.):	2	Prioritization rating:	Level 4 - Poor
D/S grade/rim-inv. (ft.):	5	Prioritization rationale:	Location, sediment, cable penetration
Water level (%):	0	Illegal dumping evidence:	No

Notes

Cable of unknown origin penetrates and runs through culvert. Voids above pipe at outlet. Apparent open joint and deflection (localized) at one of the joints within the pipe. Loss of galvanizing and moderate corrosion (exfoliation) at invert. Short additional culvert adjacent to inlet is in similar condition.

Photos

Area view.

Area view.

Page Mill Rd.

Culvert A-12

Area near inlet.

Area near inlet.

Area near outlet.

Area near outlet.

Inlet. Short additional culvert in background.

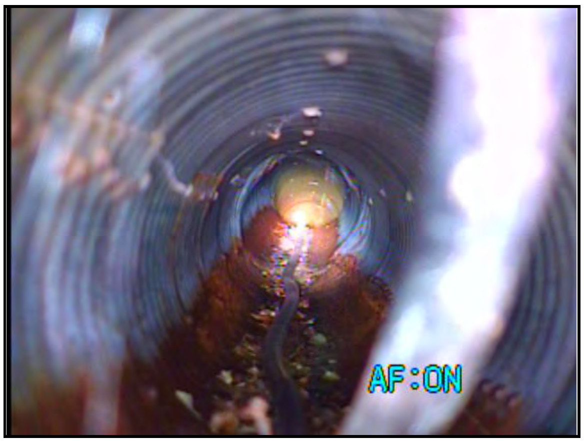
Inlet.

Page Mill Rd.

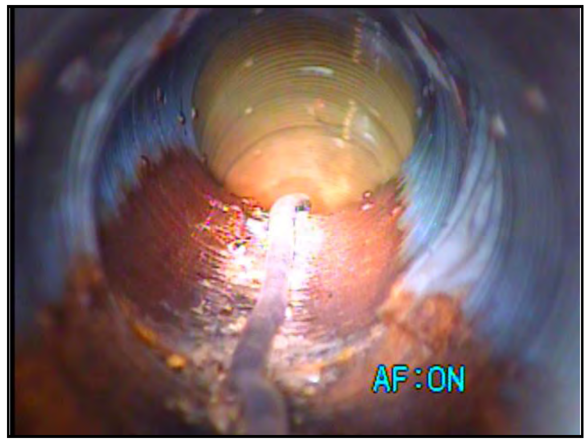
Culvert A-12

Inlet.

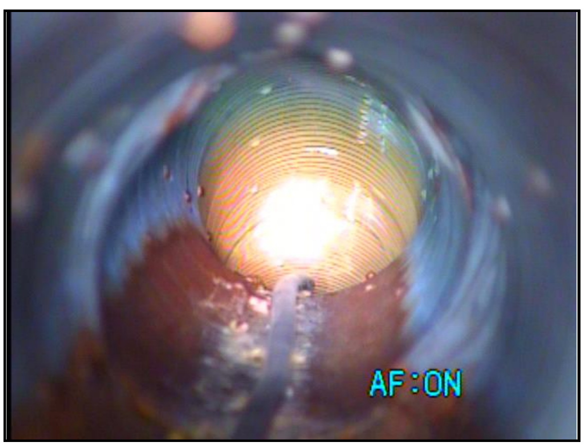
View inside inlet.



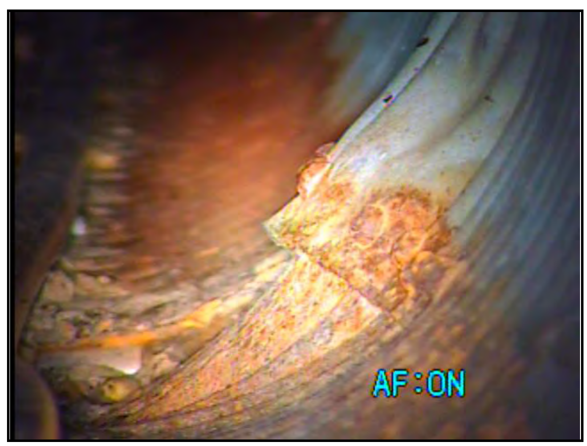
View inside inlet.



View inside inlet.



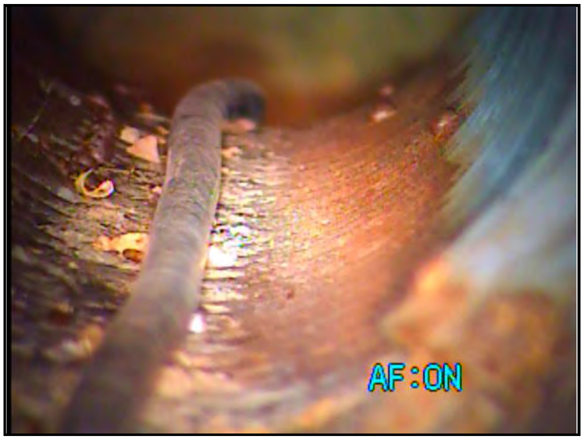
View inside inlet.



View inside inlet. Apparent open joint and deflection within pipe.

Page Mill Rd.

Culvert A-12



View inside inlet.


Outlet.


Outlet.


Outlet. Note voids above pipe.


View inside outlet.


View inside outlet.

Page Mill Rd.

Culvert A-12

Short additional culvert near inlet of A-12.

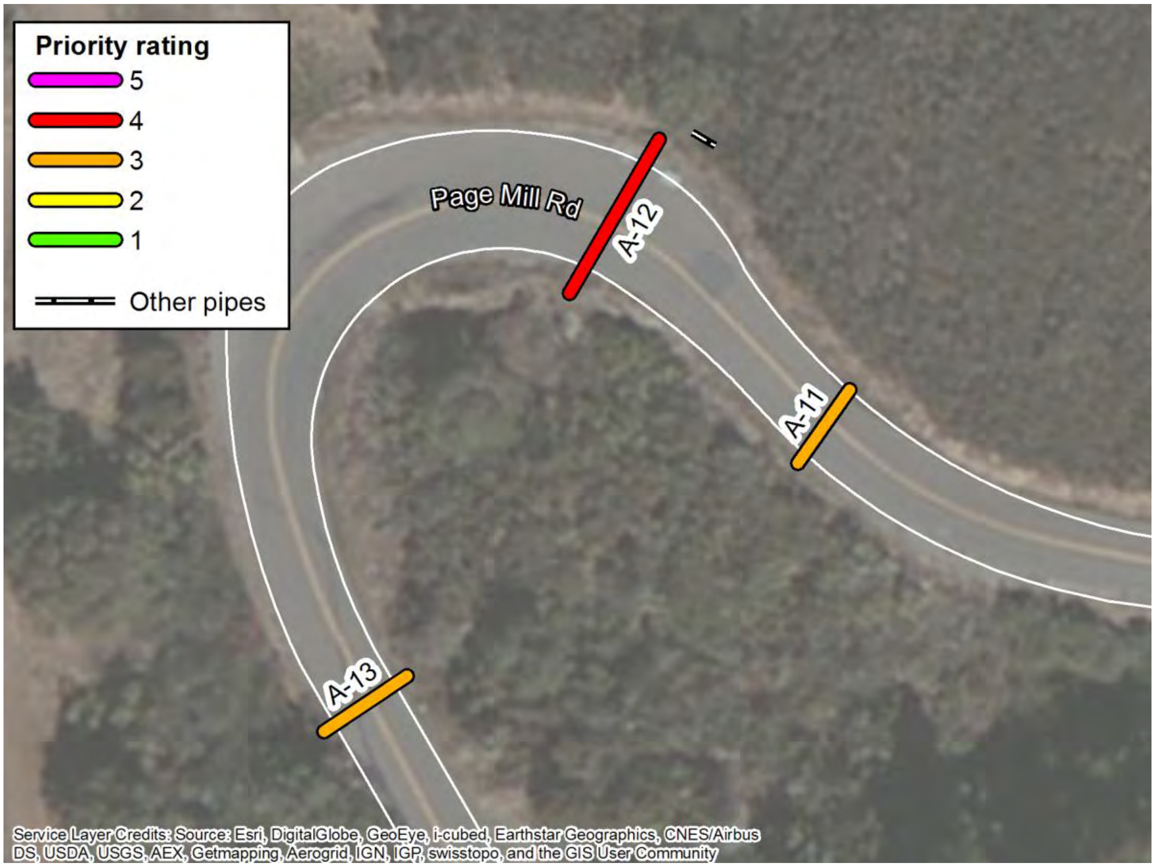
Short additional culvert near inlet of A-12.

Short additional culvert near inlet of A-12.

Page Mill Rd.

Culvert A-13

Location Map



Page Mill Rd.

Culvert A-13

Evaluation date/time:	11/14/2014 10:22 AM
Address/location:	Page Mill Rd.
Weather:	Dry

General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	No
Access:	Good	**Susceptible to ponding/flooding:**	No
Traffic:	Light	Sediment/debris depth (%):	5
Ground surface type:	Grass/dirt	Type of sediment/debris:	Silt, gravel
Dia./Ht. (in.):	12	Infiltration:	None
Width (in.):		Obstruction/deflection:	0
Material:	CMP	VANDA condition rating:	Level 2 - Minor Damage
U/S grade/rim-inv. (ft.):	1.5	Prioritization rating:	Level 3 - Fair
D/S grade/rim-inv. (ft.):	3.5	Prioritization rationale:	Condition, location
Water level (%):	0	Illegal dumping evidence:	No

Notes

Pipe runs under the road. Loss of galvanizing and minor corrosion at invert.

Photos

Area view.

Area near inlet.

Page Mill Rd.

Culvert A-13

Area near inlet.

Area near outlet.

Area near outlet.

Inlet.

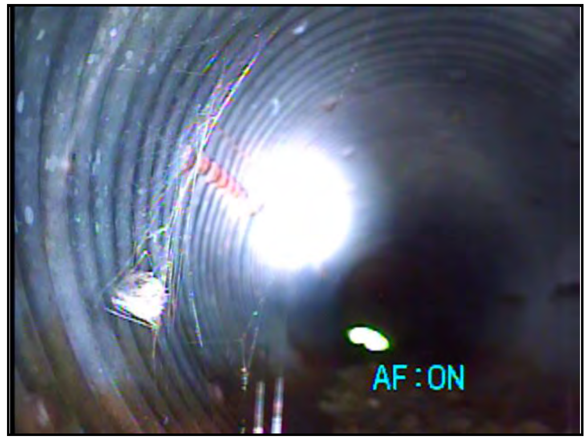
View inside inlet.

View inside inlet.

Page Mill Rd.

Culvert A-13

View inside inlet.



View inside inlet.

View inside inlet.


Outlet.


View inside outlet.

Page Mill Rd.

Culvert A-14

Location Map

Page Mill Rd.

Culvert A-14

Evaluation date/time:	11/14/2014 10:42 AM
Address/location:	Page Mill Rd.
Weather:	Dry

General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	No
Access:	Good	**Susceptible to ponding/flooding:**	No
Traffic:	Light	Sediment/debris depth (%):	15
Ground surface type:	Asphalt, grass/dirt	Type of sediment/debris:	Silt, vegetation, gravel
Dia./Ht. (in.):	12	Infiltration:	None
Width (in.):		Obstruction/deflection:	10
Material:	CMP/plastic	VANDA condition rating:	Level 3 - Moderate Damage
U/S grade/rim-inv. (ft.):	2	Prioritization rating:	Level 4 - Poor
D/S grade/rim-inv. (ft.):	2.5	Prioritization rationale:	Condition, location
Water level (%):	0	Illegal dumping evidence:	No

Notes

Pipe runs under the road. Downstream end of culvert is plastic pipe. Transition from CMP to plastic pipe appears to be offset. CMP portion has coating failure and minor corrosion at invert. CMP appears to be moderately to severely corroded near transition to plastic pipe.

Photos

Area view.

Area view.

Page Mill Rd.

Culvert A-14

Area near inlet.

Area near outlet.

Inlet.

Inlet.

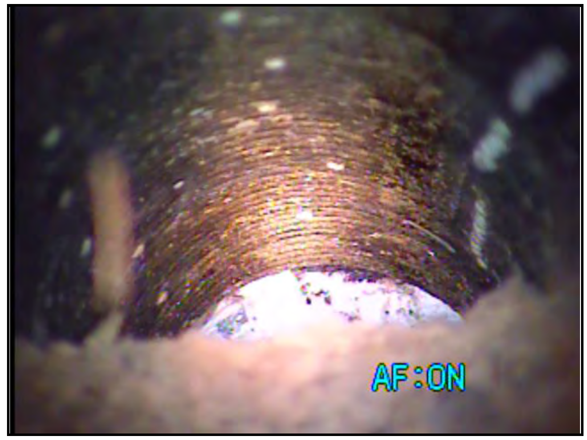
View inside inlet.

View inside inlet.

Page Mill Rd.

Culvert A-14

View inside inlet.



View inside inlet.

View inside inlet.

Outlet.

Outlet.

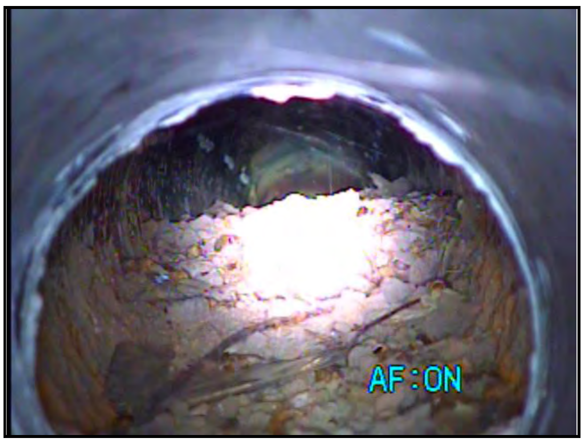
View inside outlet.

Page Mill Rd.

Culvert A-14

View inside outlet.

View inside outlet.

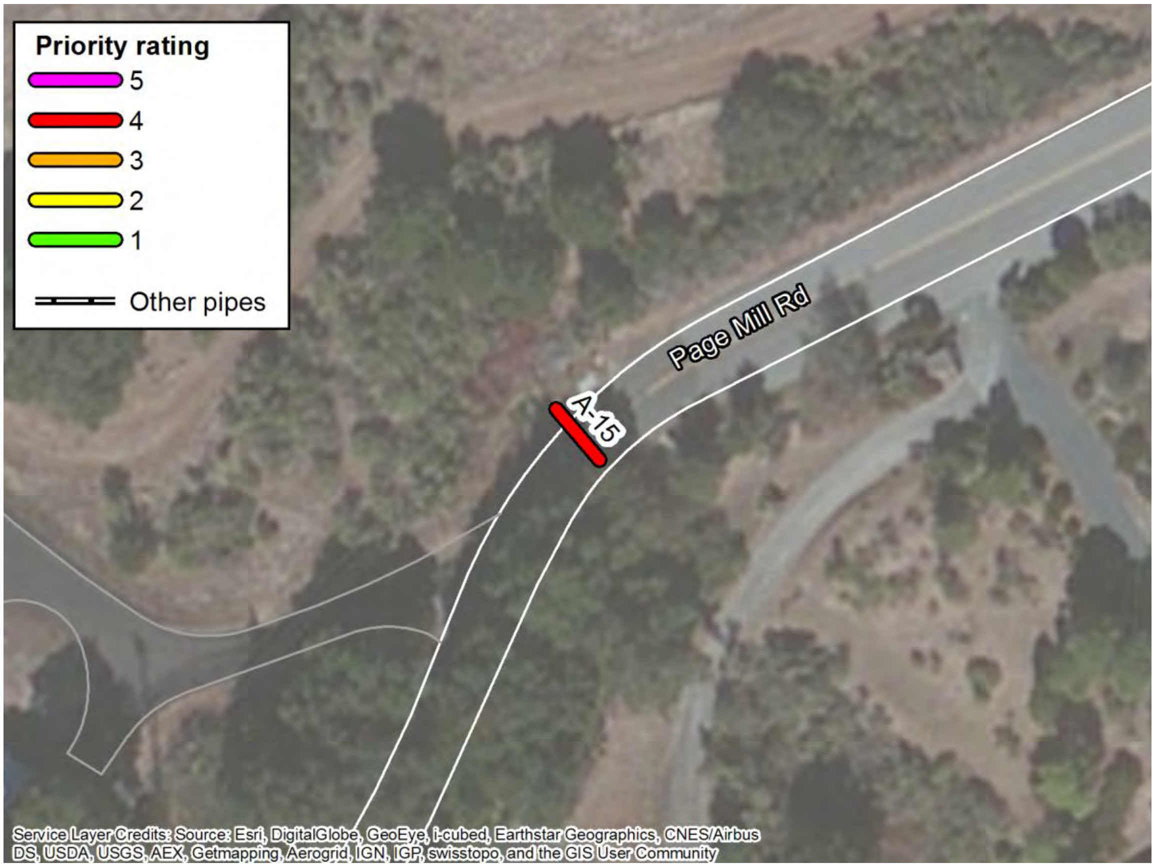


View inside outlet. CMP portion appears to be corroded at right.

Page Mill Rd.

Culvert A-15

Location Map



Page Mill Rd.

Culvert A-15

Evaluation date/time:	11/14/2014 11:04 AM
Address/location:	Page Mill Rd.
Weather:	Dry

General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	No
Access:	Good	**Susceptible to ponding/flooding:**	No
Traffic:	Light	Sediment/debris depth (%):	20
Ground surface type:	Asphalt	Type of sediment/debris:	Silt, gravel
Dia./Ht. (in.):	12	Infiltration:	None
Width (in.):		Obstruction/deflection:	0
Material:	CMP	VANDA condition rating:	Level 2 - Minor Damage
U/S grade/rim-inv. (ft.):	2	Prioritization rating:	Level 4 - Poor
D/S grade/rim-inv. (ft.):	3.5	Prioritization rationale:	Condition, location
Water level (%):	0	Illegal dumping evidence:	No

Notes

Pipe runs under the road. Marker post at inlet may penetrate the pipe. Possible additional third-party damage downstream from intlet. Coating failure and minor corrosion at invert. Void in soil next to outlet.

Photos

Area view.

Area view.

Page Mill Rd.

Culvert A-15

Area near inlet.


Area near outlet.


Area near outlet.


Area near outlet.


Area near outlet. Concrete headwall structure does not appear to be related to storm drainage.


Inlet.

Page Mill Rd.

Culvert A-15

Inlet.

Inlet.

Exposed CMP at inlet.

Exposed CMP at inlet.

Exposed CMP at inlet with minor surface corrosion above soil.

Separated joint near inlet.

Page Mill Rd.

Culvert A-15


Separated joint near inlet.


Separated joint near inlet.


View inside inlet.


Puncture (possibly from marker post) at crown of pipe near inlet.

View inside inlet.

View inside inlet.

Page Mill Rd.

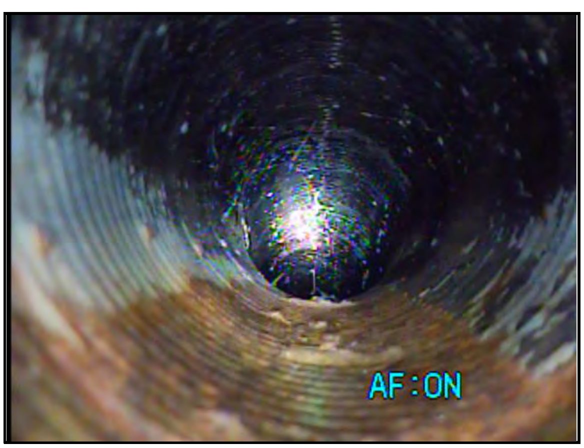
Culvert A-15

View inside inlet. Pipe may have third-party damage (puncture and debris inside) downstream from inlet.

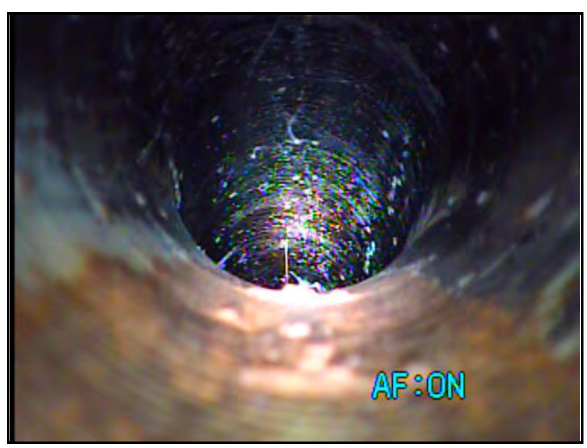
Outlet.

Void adjacent to outlet.

View inside outlet.



View inside outlet.



View inside outlet.

Page Mill Rd.

Culvert A-15

Outfall structure adjacent to culvert outlet.

Outfall structure adjacent to culvert outlet.

Outfall structure adjacent to culvert outlet.

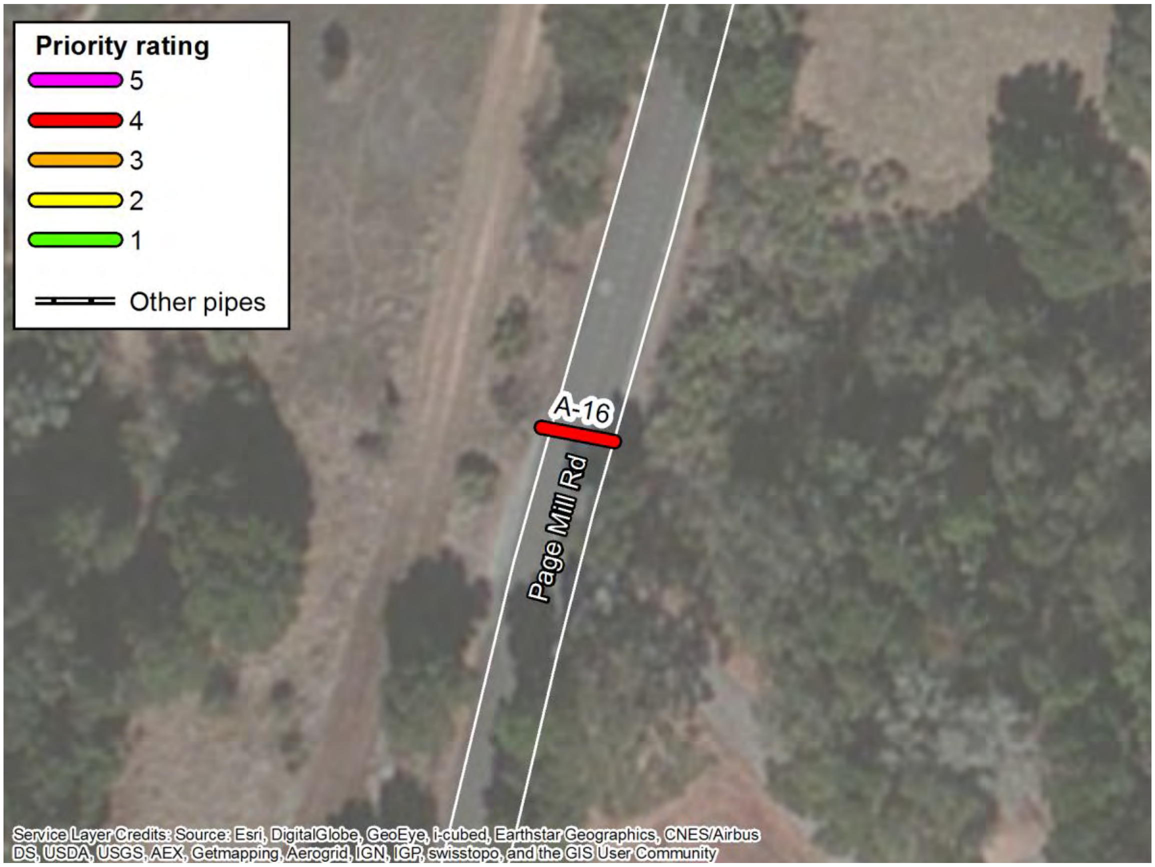
Outfall structure adjacent to culvert outlet.

Outfall structure adjacent to culvert outlet.

Page Mill Rd.

Culvert A-16

Location Map



Page Mill Rd.

Culvert A-16

Evaluation date/time:	11/14/2014 11:32 AM
Address/location:	Page Mill Rd.
Weather:	Dry

General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	No
Access:	Good	**Susceptible to ponding/flooding:**	No
Traffic:	Light	Sediment/debris depth (%):	30
Ground surface type:	Asphalt	Type of sediment/debris:	Gravel, silt, asphalt
Dia./Ht. (in.):	12	Infiltration:	None
Width (in.):		Obstruction/deflection:	0
Material:	CMP	VANDA condition rating:	Level 3 - Moderate Damage
U/S grade/rim-inv. (ft.):	1.7	Prioritization rating:	Level 4 - Poor
D/S grade/rim-inv. (ft.):	3	Prioritization rationale:	Condition, location
Water level (%):	0	Illegal dumping evidence:	No

Notes

Pipe runs under the road. Coating failure and moderate corrosion near invert of pipe.

Photos


Area view.


Area view.

Page Mill Rd.

Culvert A-16


Area near inlet.


Area near outlet.


Area near outlet.


Inlet.


Inlet.

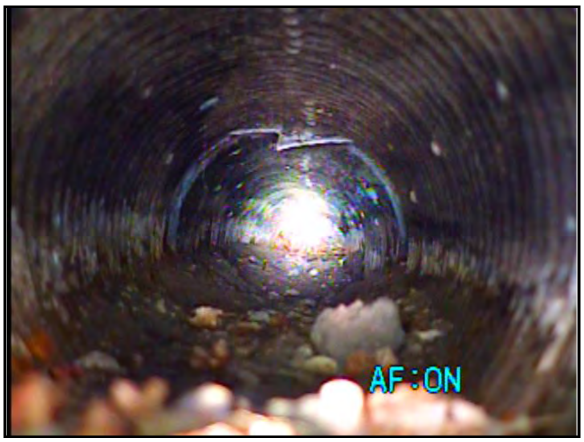

View inside inlet.

Page Mill Rd.

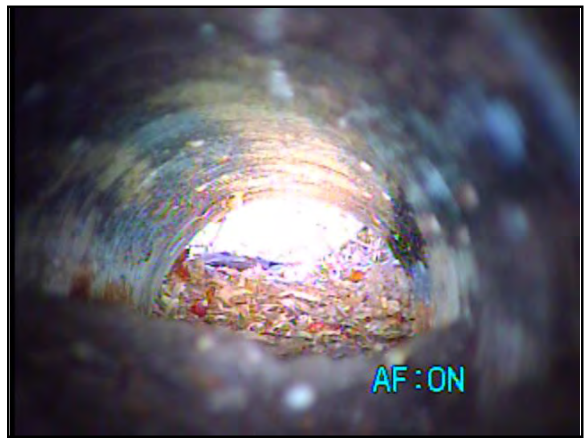
Culvert A-16

View inside inlet. Note hole in pipe at crown, apparently covered by concrete-filled bags.

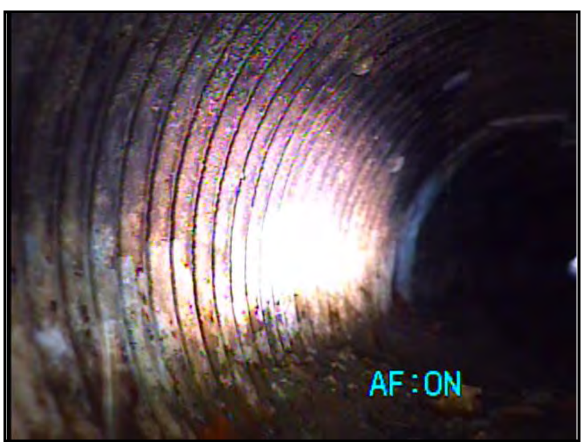
View inside inlet. Apparent deflection at crown at joint downstream.



View inside inlet. Apparent deflection at crown at joint downstream.



View inside inlet.



View inside inlet.

Outlet.

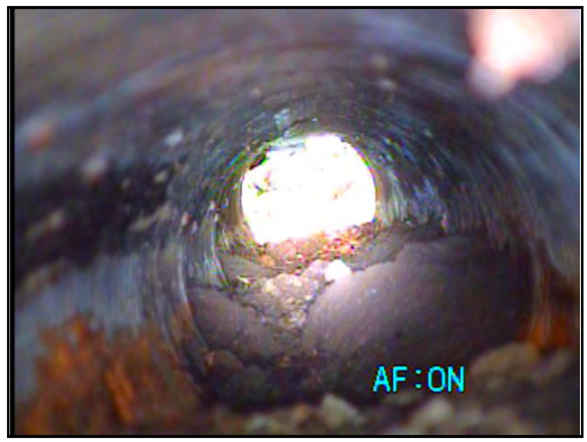
Page Mill Rd.

Culvert A-16

View inside outlet.

View inside outlet.

View inside outlet.



View inside outlet.

View inside outlet. Note moderate corrosion.

View inside outlet. Note moderate corrosion.

Page Mill Rd.

Culvert A-17

<u>Location Map</u>

Page Mill Rd.

Culvert A-17

Evaluation date/time:	11/14/2014 11:46 AM
Address/location:	Page Mill Rd.
Weather:	Dry

General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	No
Access:	Good	**Susceptible to ponding/flooding:**	No
Traffic:	Light	Sediment/debris depth (%):	10
Ground surface type:	Asphalt	Type of sediment/debris:	Silt, gravel, vegetation
Dia./Ht. (in.):	12	Infiltration:	None
Width (in.):		Obstruction/deflection:	25
Material:	CMP	VANDA condition rating:	Level 2 - Minor Damage
U/S grade/rim-inv. (ft.):	1.5	Prioritization rating:	Level 3 - Fair
D/S grade/rim-inv. (ft.):	3	Prioritization rationale:	Ends deflected, sediment
Water level (%):	0	Illegal dumping evidence:	No

Notes

Pipe runs under the road. Pipe deflected and torn at inlet. Coating failure and minor corrosion at invert.

Photos

Area view.

Area view.

Page Mill Rd.

Culvert A-17

Area near outlet.

Area near outlet.

Inlet.

Inlet.

Inlet.

Coating failure on exterior of CMP at inlet.

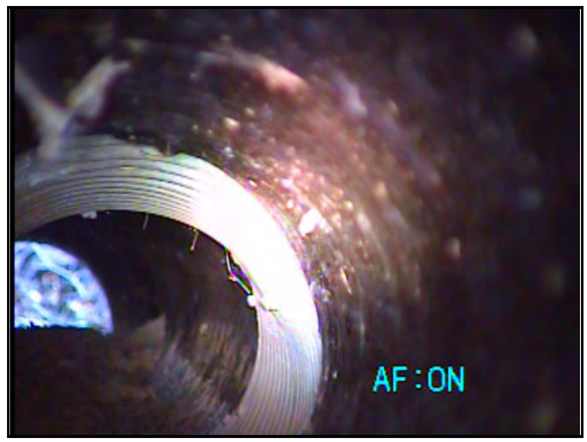
Page Mill Rd.

Culvert A-17

View inside inlet.

View inside inlet.

View inside inlet.



View inside inlet.

View inside inlet.

View inside inlet.

Page Mill Rd.

Culvert A-17

Outlet.

View inside outlet.

View inside outlet.

Page Mill Rd.

Culvert A-19

<u>Location Map</u>

Page Mill Rd.

Culvert A-19

Evaluation date/time:	11/14/2014 11:55 AM
Address/location:	Page Mill Rd.
Weather:	Dry

General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	No
Access:	Good	**Susceptible to ponding/flooding:**	No
Traffic:	Light	Sediment/debris depth (%):	0
Ground surface type:	Asphalt	Type of sediment/debris:	None
Dia./Ht. (in.):	17	Infiltration:	None
Width (in.):		Obstruction/deflection:	0
Material:	CMP	VANDA condition rating:	Level 2 - Minor Damage
U/S grade/rim-inv. (ft.):	1.5	Prioritization rating:	Level 3 - Fair
D/S grade/rim-inv. (ft.):	4	Prioritization rationale:	Condition, location, ends deflected
Water level (%):	0	Illegal dumping evidence:	No

Notes

Outlet projects out of the bank for approximately 1.5 feet. Coating failure and minor corrosion at invert.

Photos

Area view.

Area view.

Page Mill Rd.

Culvert A-19

Area near inlet.

Area near outlet.

Crack in pavement extends across road above culvert.

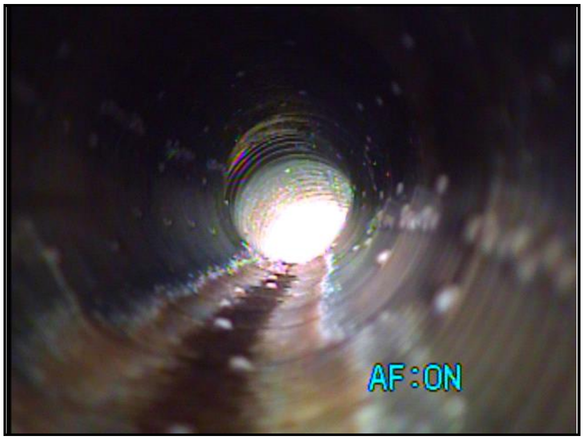
Inlet.

View inside inlet.

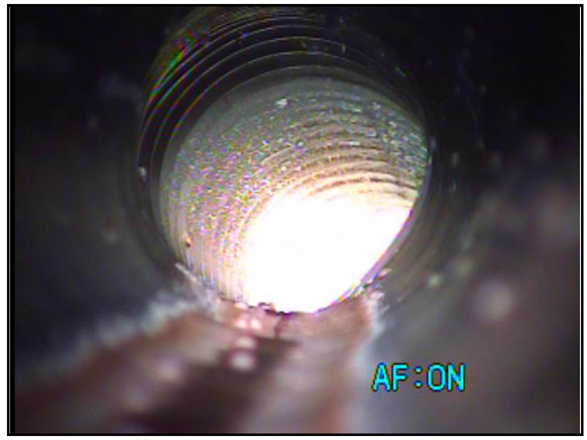
View inside inlet.

Page Mill Rd.

Culvert A-19



View inside inlet.



View inside inlet.

Outlet.

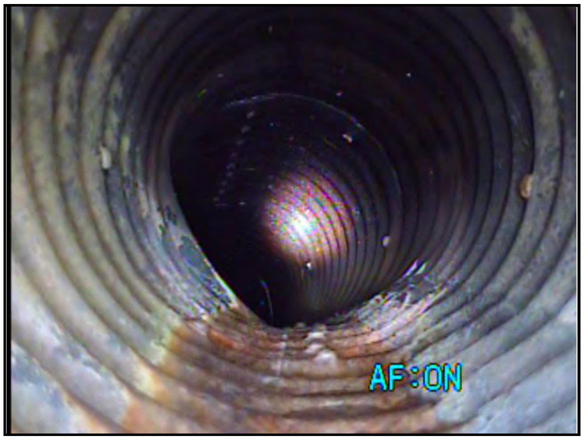
Outlet.

View inside outlet.

View inside outlet.

Page Mill Rd.

Culvert A-19

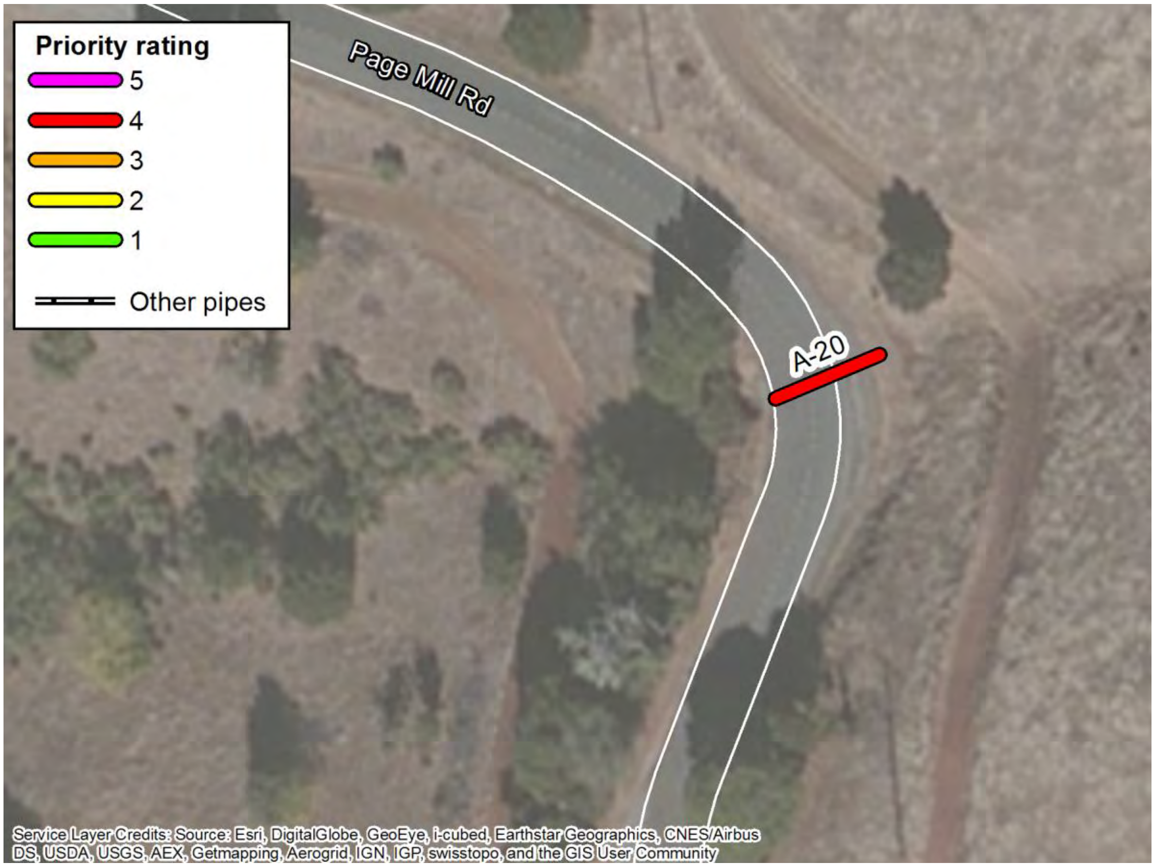


View inside outlet.

Page Mill Rd.

Culvert A-20

Location Map



Page Mill Rd.

Culvert A-20

Evaluation date/time:	11/14/2014 12:13 PM
Address/location:	Page Mill Rd.
Weather:	Dry

General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	No
Access:	Good	**Susceptible to ponding/flooding:**	No
Traffic:	Light	Sediment/debris depth (%):	0
Ground surface type:	Asphalt	Type of sediment/debris:	None
Dia./Ht. (in.):	8 - 12	Infiltration:	None
Width (in.):		Obstruction/deflection:	10
Material:	CMP	VANDA condition rating:	Level 4 - Severe/Significant Damage
U/S grade/rim-inv. (ft.):	2	Prioritization rating:	Level 4 - Poor
D/S grade/rim-inv. (ft.):	7	Prioritization rationale:	Condition, location, joints
Water level (%):	0	Illegal dumping evidence:	No

Notes

Pipe runs under the road. Upstream segment is 8-inch-diameter and downstream segment is 12-inch. Invert at the inlet is missing due to corrosion; unable to determine how far this condition extends due to vegetation within the pipe. Loss of galvanizing and minor corrosion at invert throughout pipe. Possible deflected or separated joints within pipe.

Photos

Area view.

Area view.

Page Mill Rd.

Culvert A-20

Area view.

Area near inlet.

Area near inlet.

Area near outlet.

Inlet.

Inlet. Invert has corroded away.

Page Mill Rd.

Culvert A-20

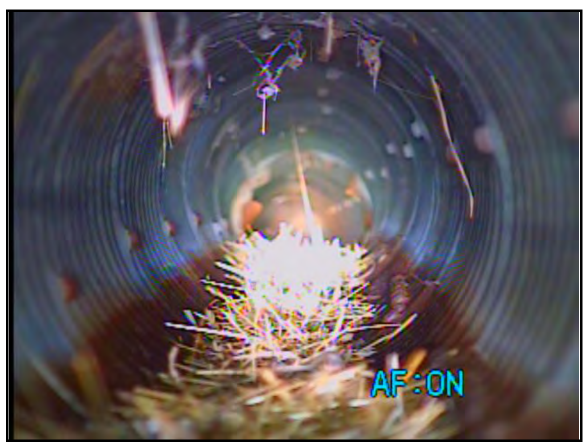
Missing invert at inlet.

Missing invert at inlet.

Missing invert at inlet.

View inside inlet.

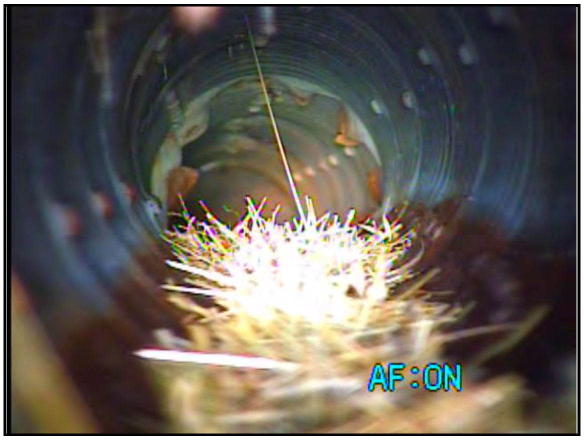
View inside inlet.



View inside inlet.

Page Mill Rd.

Culvert A-20



View inside inlet.

View inside inlet. Joint within pipe appears to be deflected.

Outlet.

Outlet.

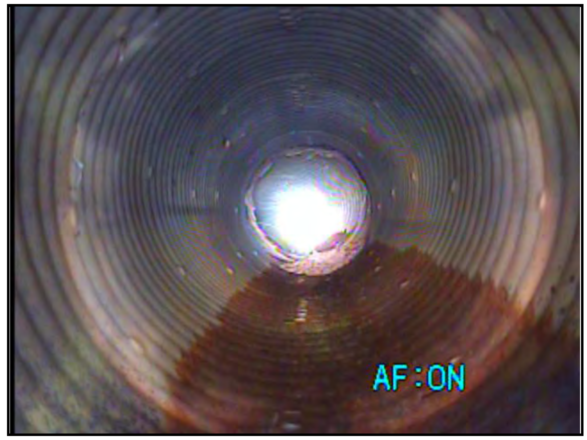
Outlet.

Outlet.

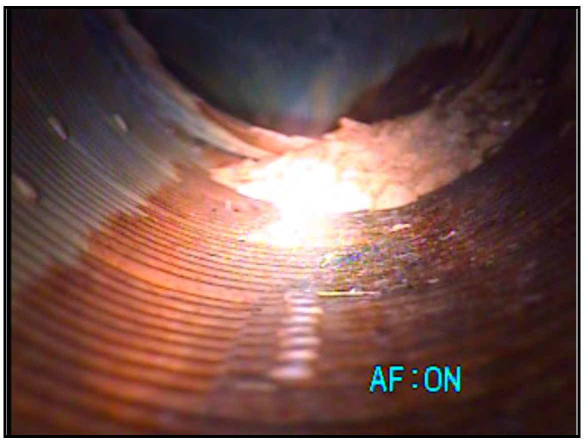
Page Mill Rd.

Culvert A-20

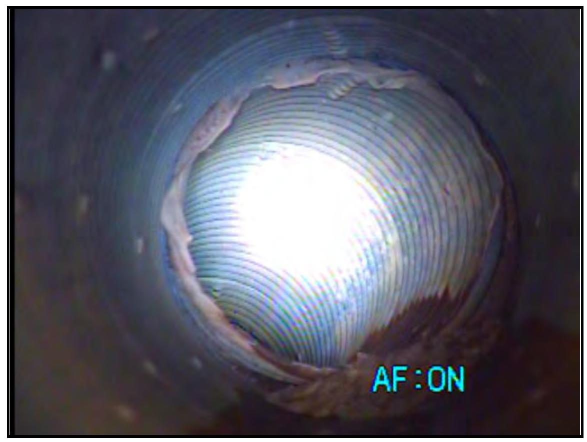
View inside outlet.



View inside outlet.



View inside outlet.

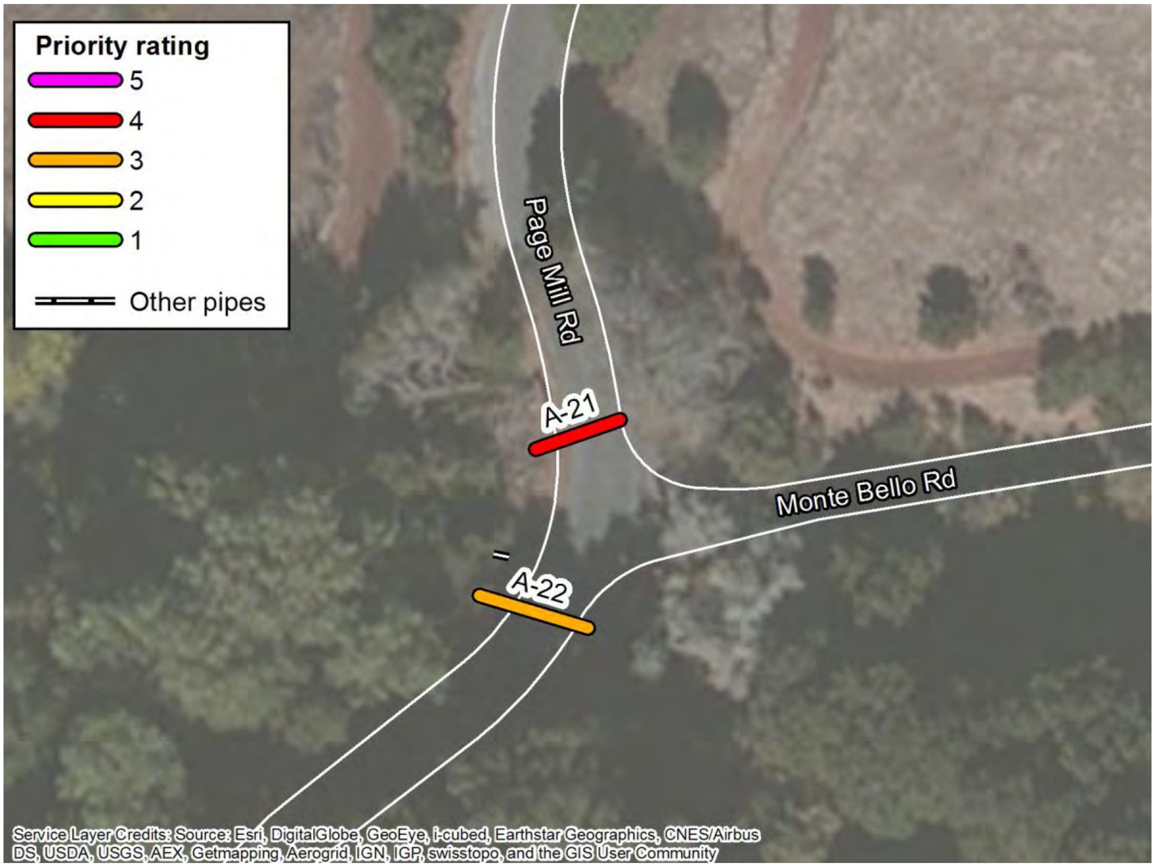


View inside outlet. Possible deflection at joint within pipe.

Page Mill Rd.

Culvert A-21

Location Map



Page Mill Rd.

Culvert A-21

Evaluation date/time:	11/14/2014 12:38 PM
Address/location:	Page Mill Rd.
Weather:	Dry

General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	No
Access:	Fair	**Susceptible to ponding/flooding:**	No
Traffic:	Light	Sediment/debris depth (%):	0
Ground surface type:	Asphalt	Type of sediment/debris:	None
Dia./Ht. (in.):	12	Infiltration:	None
Width (in.):	13.5	Obstruction/deflection:	0
Material:	CMP	VANDA condition rating:	Level 2 - Minor Damage
U/S grade/rim-inv. (ft.):	2	Prioritization rating:	Level 4 - Poor
D/S grade/rim-inv. (ft.):	4	Prioritization rationale:	Condition, location
Water level (%):	0	Illegal dumping evidence:	No

Notes

Pipe runs under the road. Outlet not accessible. Loss of galvanizing and moderate corrosion at invert. Separated or offset joint within pipe with soil visible.

Photos

Area view.

Area view near inlet.

Page Mill Rd.

Culvert A-21

Area near outlet.

Area near outlet.

Area near outlet.

Area near outlet.

Inlet.

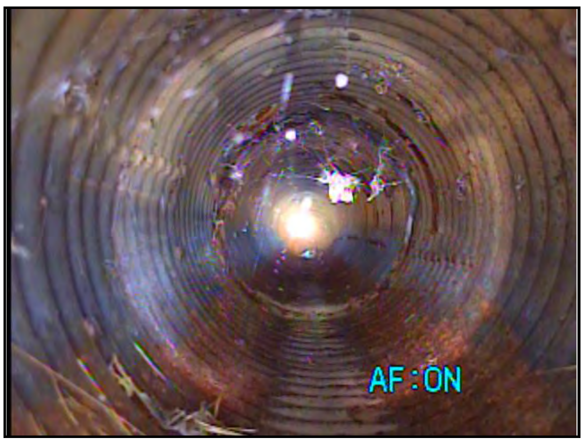
Inlet.

Page Mill Rd.

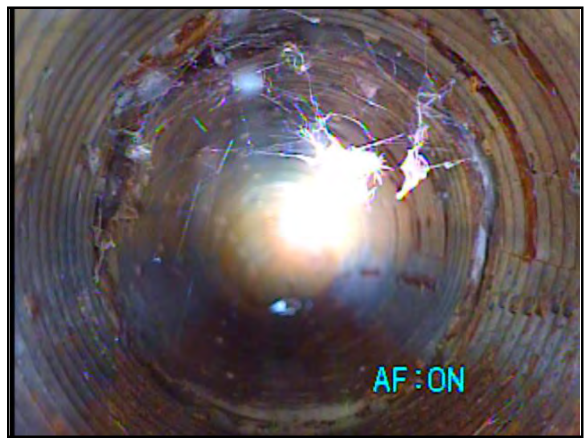
Culvert A-21

View inside inlet.

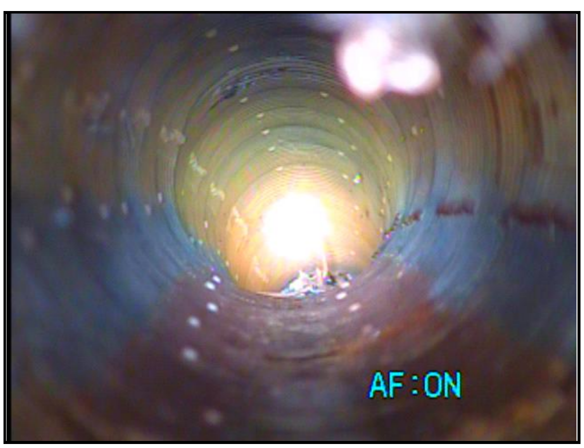
View inside inlet. Separated or offset joint within pipe with soil visible.



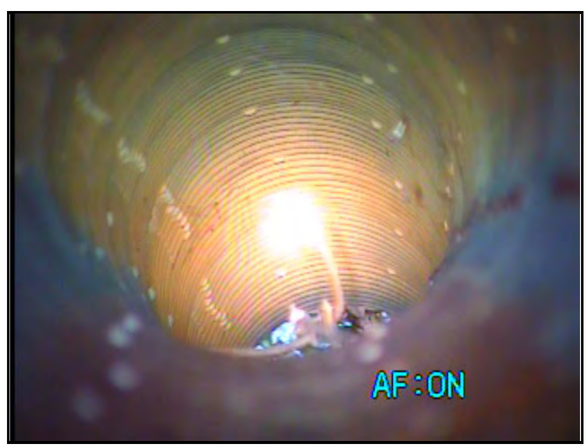
View inside inlet.



View inside inlet.



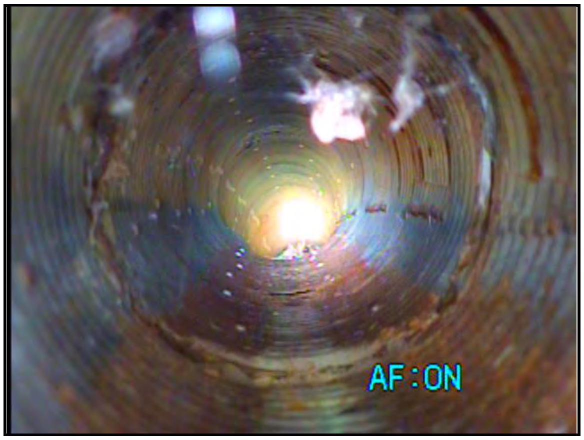
View inside inlet.



View inside inlet.

Page Mill Rd.

Culvert A-21



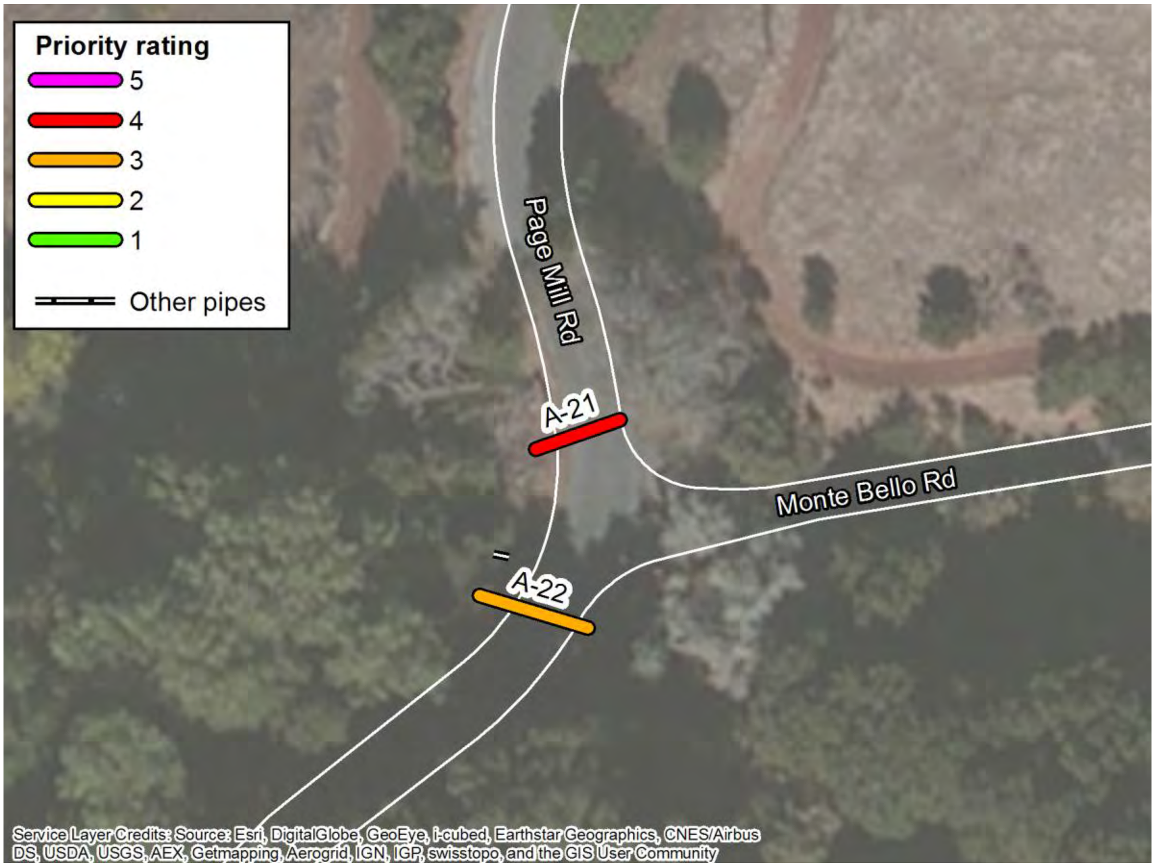
View inside inlet. Separated or offset joint within pipe with soil visible.

Nearby culvert apparently on private property.

Page Mill Rd.

Culvert A-22

<u>Location Map</u>



Page Mill Rd.

Culvert A-22

Evaluation date/time:	11/14/2014 12:45 PM
Address/location:	Page Mill Rd.
Weather:	Dry

General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	No
Access:	Fair	**Susceptible to ponding/flooding:**	No
Traffic:	Light	Sediment/debris depth (%):	10
Ground surface type:	Asphalt	Type of sediment/debris:	Silt, vegetation
Dia./Ht. (in.):	12	Infiltration:	None
Width (in.):	13	Obstruction/deflection:	0
Material:	CMP	VANDA condition rating:	Level 2 - Minor Damage
U/S grade/rim-inv. (ft.):	1.5	Prioritization rating:	Level 3 - Fair
D/S grade/rim-inv. (ft.):	4	Prioritization rationale:	Condition, location
Water level (%):	0	Illegal dumping evidence:	No

Notes

Pipe runs under the road. Outlet not accessible. Coating failure and minor corrosion at invert of CMP. Apparent separated joint within pipe near inlet. Ends of CMP deflected. Nearby short RCP culvert is in good condition.

Photos

Area view.

Area view.

Page Mill Rd.

Culvert A-22

Area near inlet.


Area near outlet.


Area near outlet.


Inlet.

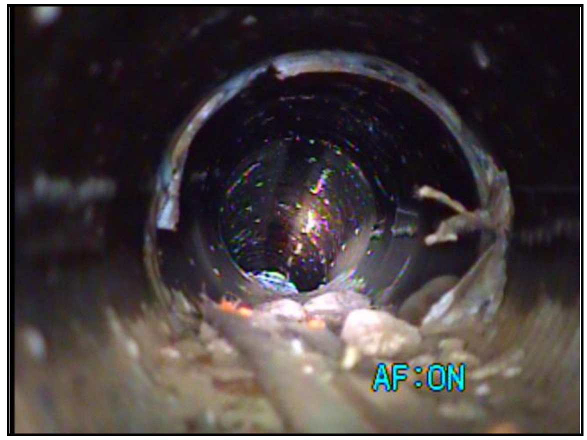

Inlet.


View inside inlet.

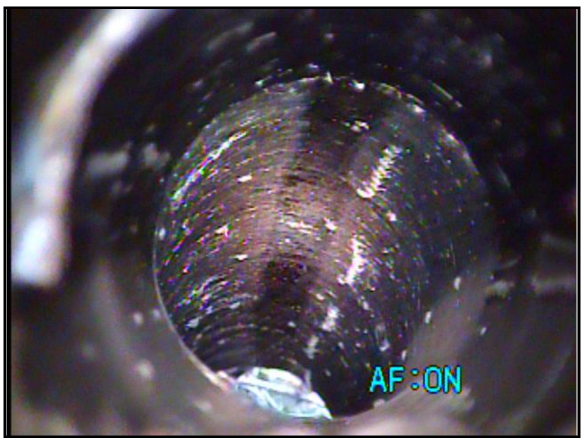
Page Mill Rd.

Culvert A-22

View inside inlet.



View inside inlet. Apparent separated joint within pipe.



View inside inlet.

View inside inlet.

Nearby short RCP culvert.

Nearby short RCP culvert.

Page Mill Rd.

Culvert A-22

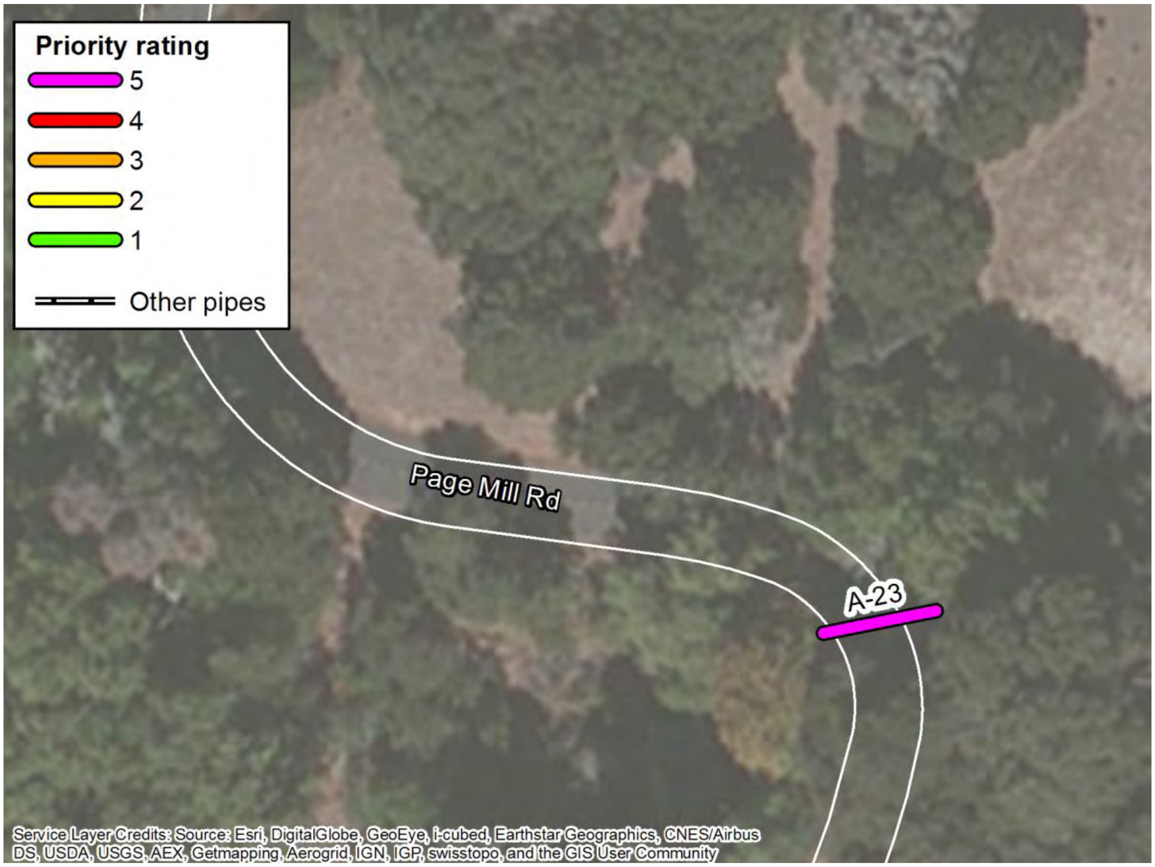
Nearby short RCP culvert.

Nearby short RCP culvert.

Page Mill Rd.

Culvert A-23

Location Map



Page Mill Rd.

Culvert A-23

Evaluation date/time:	11/24/2014 1:14 PM
Address/location:	Page Mill Rd.
Weather:	Dry

General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	No
Access:	Fair	**Susceptible to ponding/flooding:**	No
Traffic:	Light	Sediment/debris depth (%):	0
Ground surface type:	Asphalt, grass/dirt	Type of sediment/debris:	None
Dia./Ht. (in.):	12	Infiltration:	None
Width (in.):		Obstruction/deflection:	0
Material:	CMP	VANDA condition rating:	Level 4 - Severe/Significant Damage
U/S grade/rim-inv. (ft.):	2.5	Prioritization rating:	Level 5 - Immediate Attention
D/S grade/rim-inv. (ft.):		Prioritization rationale:	Condition, location
Water level (%):	0	Illegal dumping evidence:	No

Notes

Invert missing along section of pipe downstream from inlet. Outlet not accessible.

Photos

Area view.

Area near inlet.

Page Mill Rd.

Culvert A-23

Area near inlet.

Channel upstream from inlet.

Area near outlet.

Inlet.

Inlet.

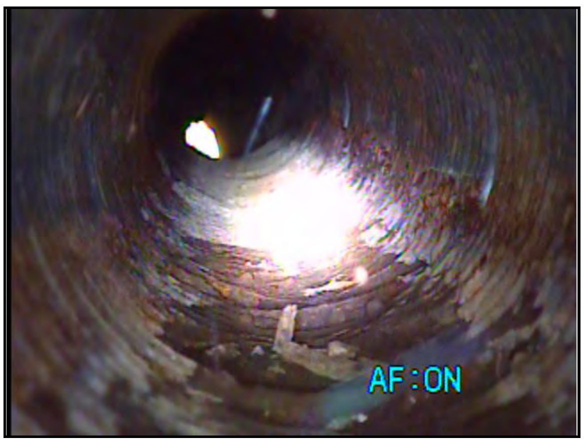
View inside inlet.

Page Mill Rd.

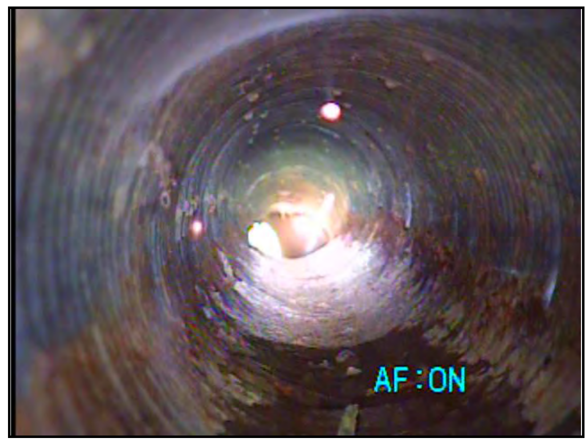
Culvert A-23

View inside inlet.

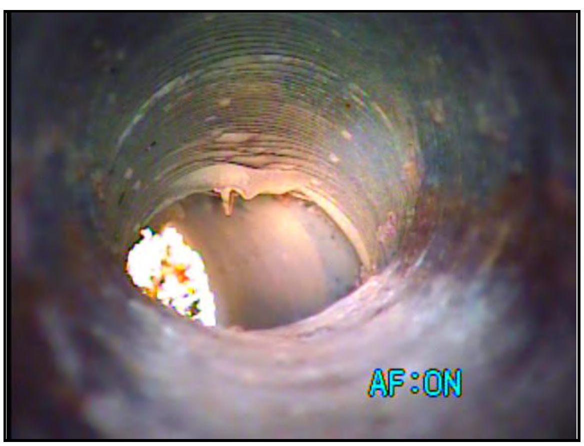
View inside inlet. Invert missing over significant distance due to corrosion.



View inside inlet.



View inside inlet.

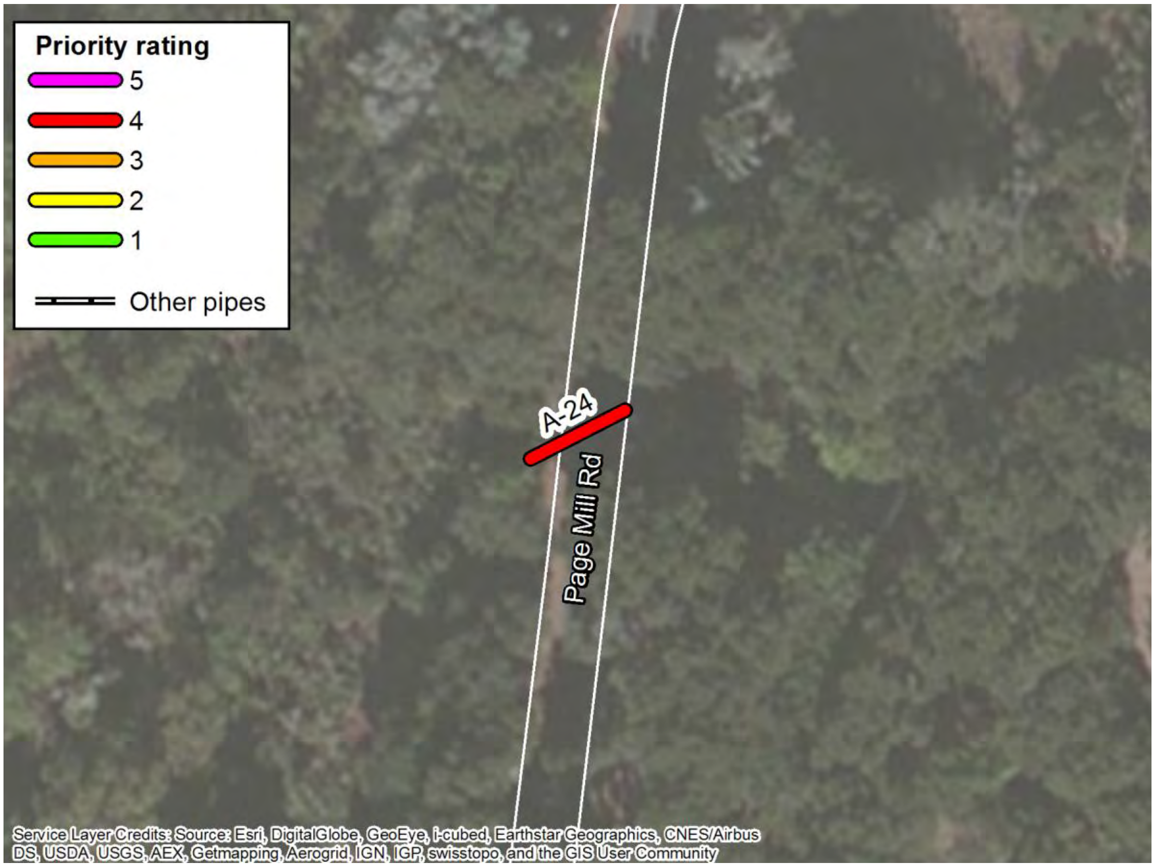


View inside inlet.

Page Mill Rd.

Culvert A-24

Location Map



Page Mill Rd.

Culvert A-24

Evaluation date/time:	11/24/2014 12:54 PM
Address/location:	Page Mill Rd.
Weather:	Dry

General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	No
Access:	Fair	**Susceptible to ponding/flooding:**	No
Traffic:	Light	Sediment/debris depth (%):	30
Ground surface type:	Asphalt	Type of sediment/debris:	Silt, vegetation
Dia./Ht. (in.):	12	Infiltration:	None
Width (in.):		Obstruction/deflection:	0
Material:	CMP	VANDA condition rating:	Level 3 - Moderate Damage
U/S grade/rim-inv. (ft.):	2	Prioritization rating:	Level 4 - Poor
D/S grade/rim-inv. (ft.):	4	Prioritization rationale:	Condition, location
Water level (%):	0	Illegal dumping evidence:	No

Notes

Pipe runs under the road. Moderate corrosion. Invert missing at inlet but not visible through majority of culvert due to debris. Concrete structure just upstream of inlet (purpose of structure is unknown) may obstruct flow into culvert; hole at bottom of structure does not allow flow to pass through.

Photos

Area view.

Area near inlet.

Page Mill Rd.

Culvert A-24

Area near outlet.

Inlet. Purpose of concrete structure at right is unknown. Hole at bottom of concrete structure does not appear to allow flow to pass through. Invert of CMP at inlet is missing due to corrosion.

Concrete structure near inlet.

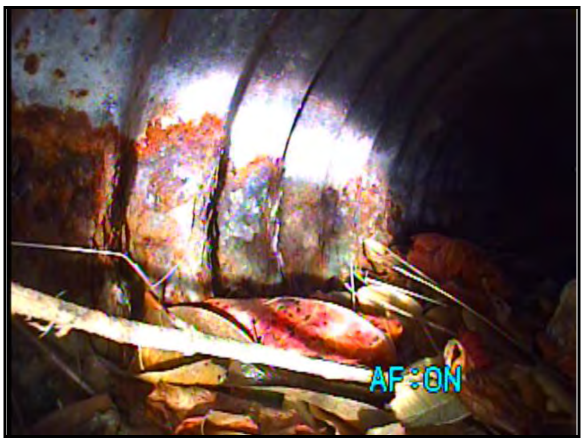
View inside hole at bottom of concrete structure near inlet. Hole is full of debris and may not pass all the way through the structure.

Page Mill Rd.

Culvert A-24

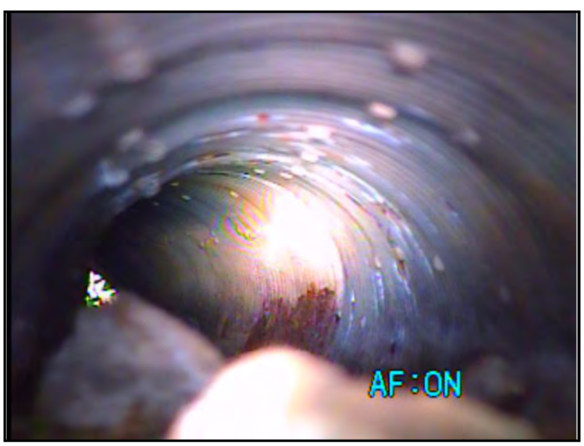
Inlet.

View inside inlet.



View inside inlet.

View inside inlet.

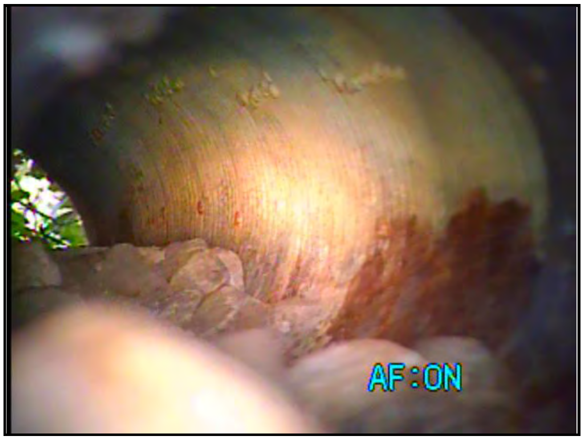


View inside inlet.

View inside inlet.

Page Mill Rd.

Culvert A-24



View inside inlet.

View inside inlet.

Outlet.

Outlet.

Outlet.

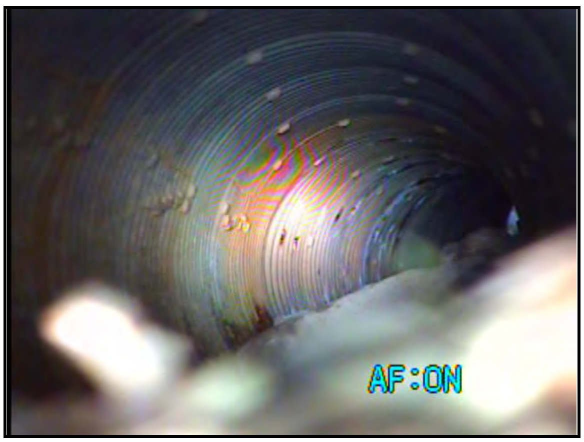
Outlet.

Page Mill Rd.

Culvert A-24


View inside outlet.

View inside outlet.



View inside outlet.

Page Mill Rd.

Culvert A-25

Location Map

Page Mill Rd.

Culvert A-25

Evaluation date/time:	11/24/2014 12:35 PM
Address/location:	Page Mill Rd.
Weather:	Dry

General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	No
Access:	Fair	**Susceptible to ponding/flooding:**	No
Traffic:	Light	Sediment/debris depth (%):	75
Ground surface type:	Asphalt	Type of sediment/debris:	Silt, sand
Dia./Ht. (in.):	18	Infiltration:	None
Width (in.):		Obstruction/deflection:	0
Material:	CMP	VANDA condition rating:	Level 3 - Moderate Damage
U/S grade/rim-inv. (ft.):	2.5	Prioritization rating:	Level 5 - Immediate Attention
D/S grade/rim-inv. (ft.):		Prioritization rationale:	Condition, location, sediment, pavement undermining
Water level (%):	0	Illegal dumping evidence:	No

Notes

About 75 percent sediment in the downstream end. Loss of galvanizing and moderate corrosion at invert. Edge of pavement at inlet is becoming undermined.

Photos

Area view.


Area near inlet.

Page Mill Rd.

Culvert A-25

Area near outlet.

Inlet. Edge of pavement is becoming undermined.

Inlet. Edge of pavement is becoming undermined.

Void under pavement above inlet.

Inlet.

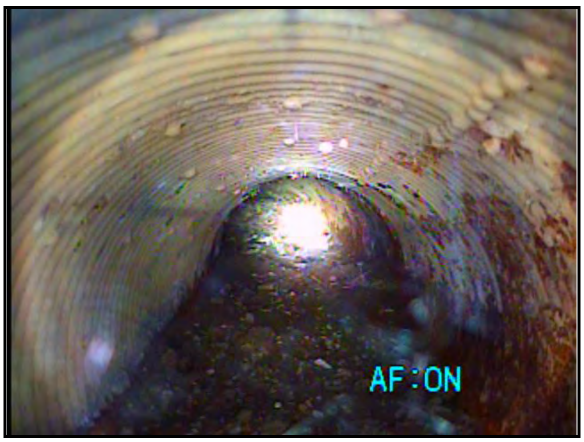
View inside inlet.

Page Mill Rd.

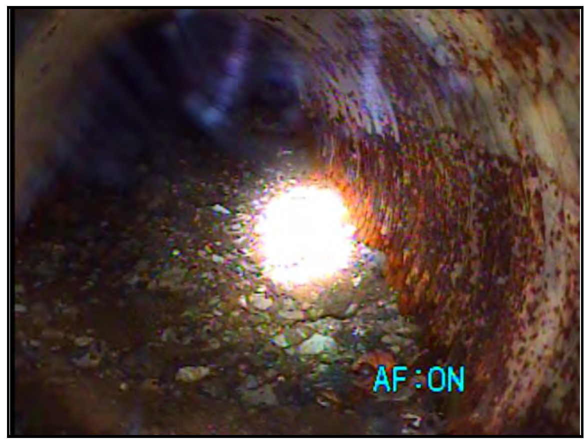
Culvert A-25

View inside inlet.

View inside inlet.



View inside inlet.



View inside inlet.

View inside inlet.

View inside inlet.

Page Mill Rd.

Culvert A-25

View inside inlet.

Outlet about 3/4 obstructed.

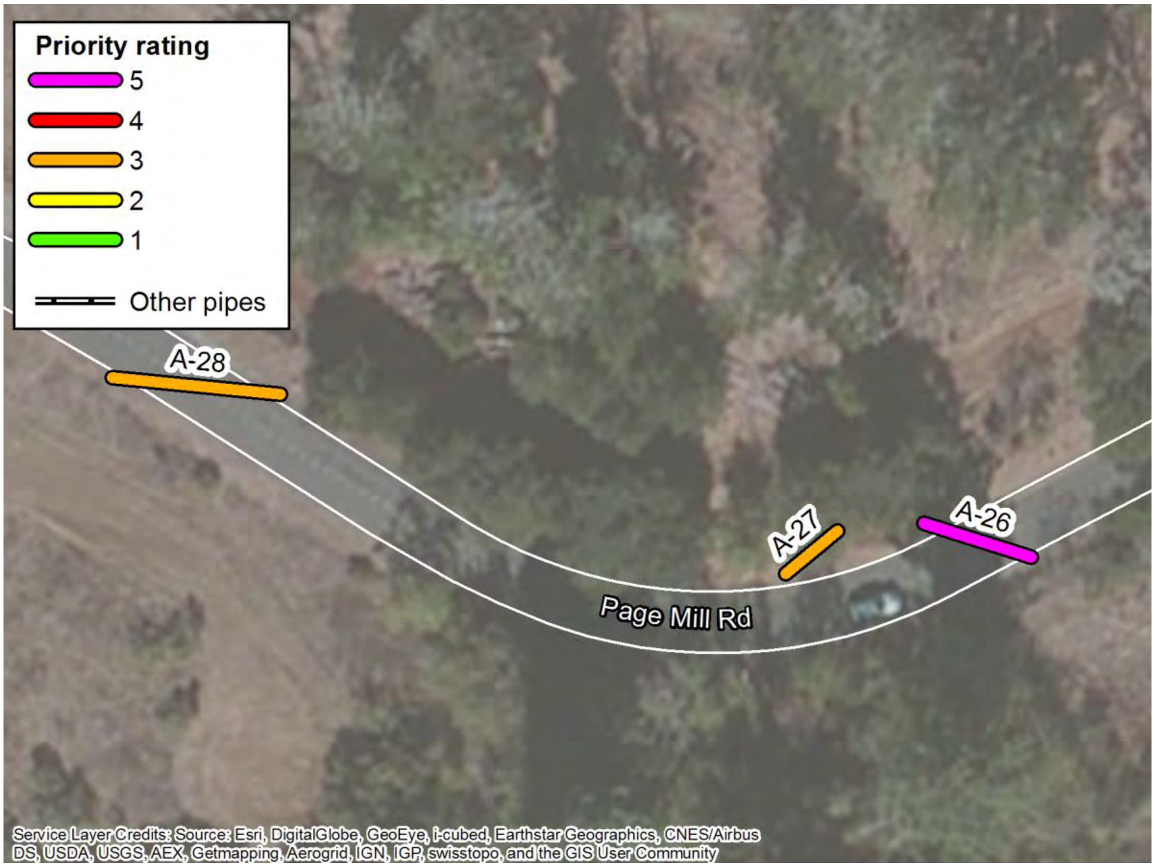
Outlet about 3/4 obstructed.

Outlet about 3/4 obstructed.

Page Mill Rd.

Culvert A-26

Location Map



Page Mill Rd.

Culvert A-26

Evaluation date/time:	11/24/2014 12:19 PM
Address/location:	Page Mill Rd.
Weather:	Dry

General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	Yes
Access:	Good	**Susceptible to ponding/flooding:**	No
Traffic:	Light	Sediment/debris depth (%):	100
Ground surface type:	Asphalt	Type of sediment/debris:	Silt, sand
Dia./Ht. (in.):	8	Infiltration:	None
Width (in.):		Obstruction/deflection:	0
Material:	CMP	VANDA condition rating:	Level 2 - Minor Damage
U/S grade/rim-inv. (ft.):	1.5	Prioritization rating:	Level 5 - Immediate Attention
D/S grade/rim-inv. (ft.):	1.75	Prioritization rationale:	Sediment
Water level (%):	0	Illegal dumping evidence:	No

Notes

Culvert may be completely obstructed with soil, gravel, etc. Minor to moderate corrosion visible.

Photos

Area view.

Area near inlet.

Page Mill Rd.

Culvert A-26

Area near inlet.


Area near outlet.


Area near outlet.


Inlet.

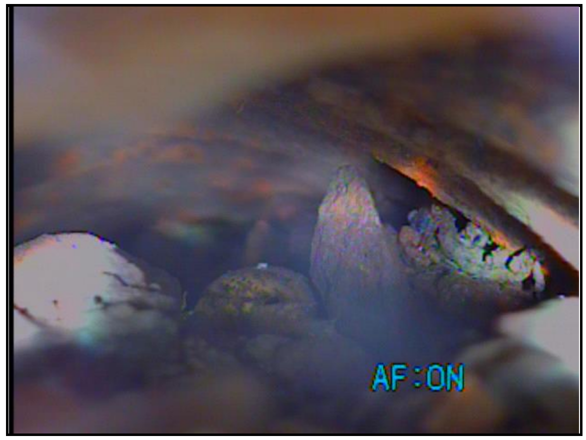

Outlet.


View inside outlet.

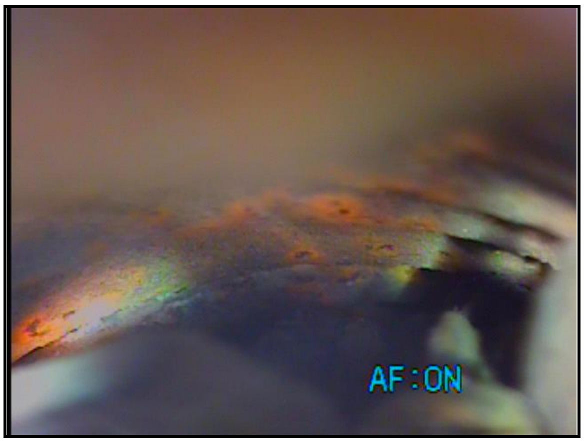
Page Mill Rd.

Culvert A-26

View inside outlet.



View inside outlet.

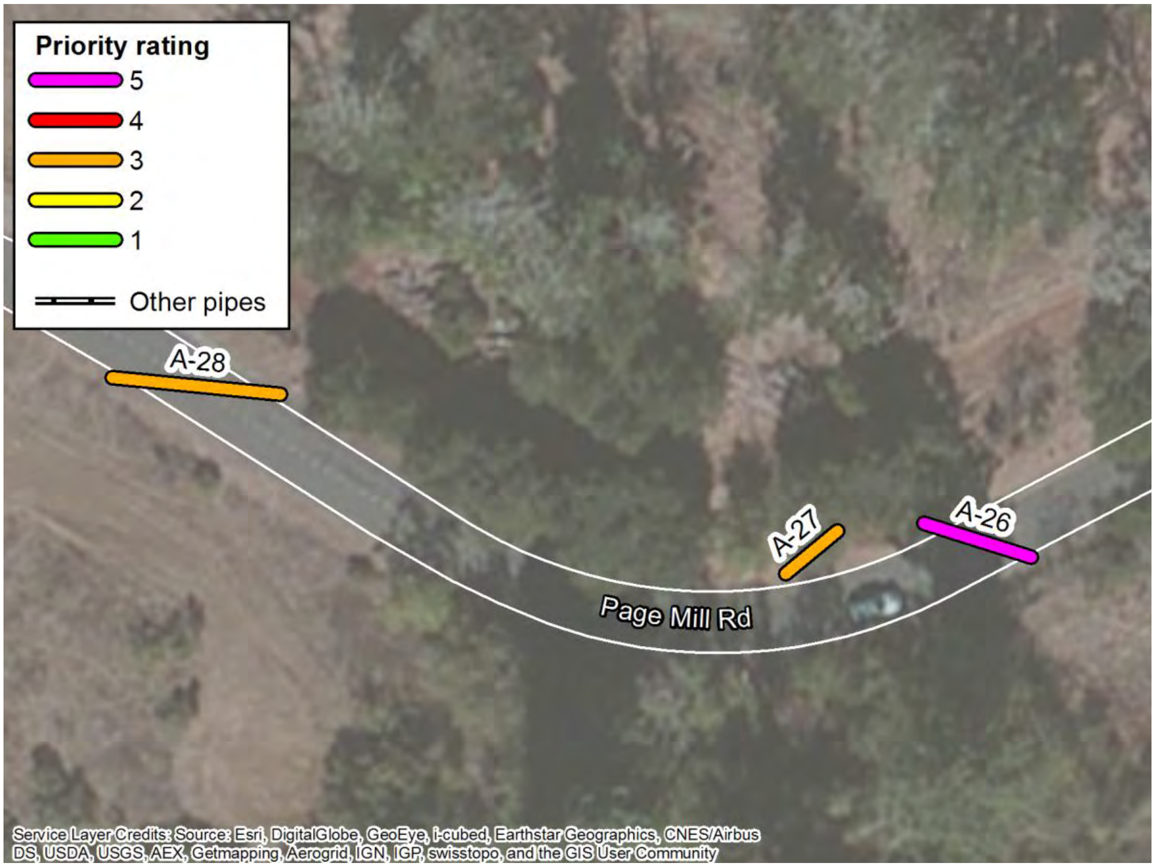


View inside outlet.

Page Mill Rd.

Culvert A-27

Location Map



Page Mill Rd.

Culvert A-27

Evaluation date/time:	11/24/2014 12:22 PM
Address/location:	Page Mill Rd.
Weather:	Dry

General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	No
Access:	Good	**Susceptible to ponding/flooding:**	No
Traffic:	Light	Sediment/debris depth (%):	10
Ground surface type:	Grass/dirt	Type of sediment/debris:	Vegetation
Dia./Ht. (in.):	12	Infiltration:	None
Width (in.):		Obstruction/deflection:	0
Material:	CMP	VANDA condition rating:	Level 3 - Moderate Damage
U/S grade/rim-inv. (ft.):	0	Prioritization rating:	Level 3 - Fair
D/S grade/rim-inv. (ft.):	0	Prioritization rationale:	Condition
Water level (%):	0	Illegal dumping evidence:	No

Notes

Loss of galvanizing and moderate corrosion on interior pipe surfaces. Pipe deflected at inlet.

Photos

Area near inlet.


Area near inlet.

Page Mill Rd.

Culvert A-27


Area near outlet.


Inlet.


Inlet.

Inlet.


View inside inlet.

View inside inlet.

Page Mill Rd.

Culvert A-27

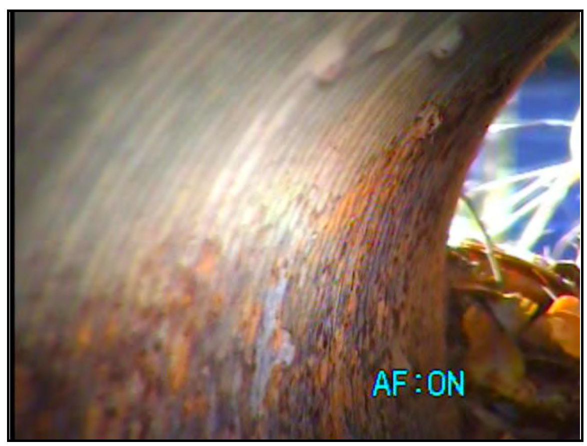
View inside inlet.

View inside inlet.

View inside inlet.

View inside inlet.

View inside inlet.



View inside inlet.

Page Mill Rd.

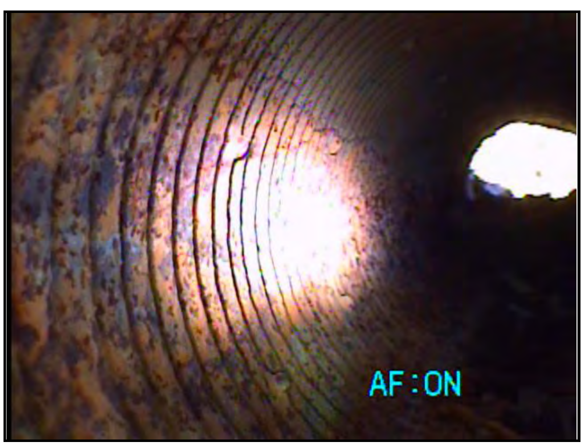
Culvert A-27

View inside inlet.


Outlet.

View inside outlet.

View inside outlet.



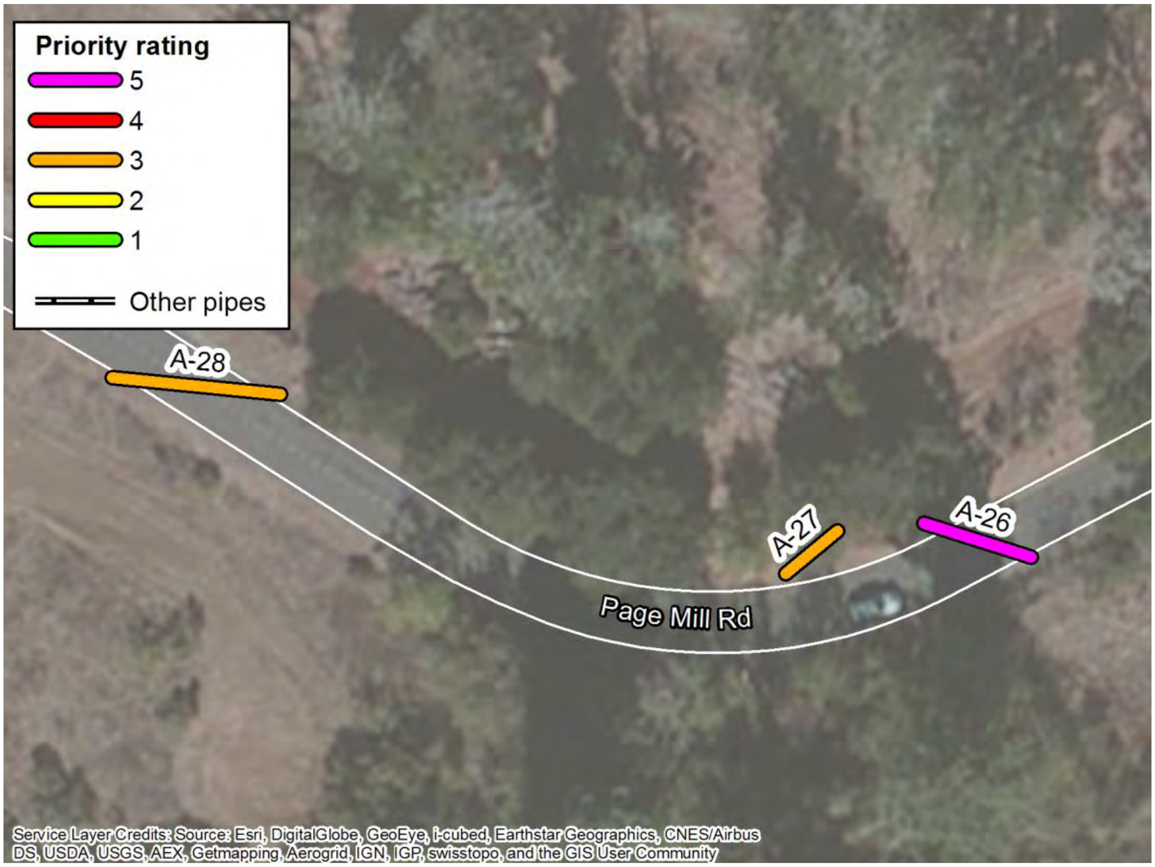
View inside outlet.

View inside outlet.

Page Mill Rd.

Culvert A-28

Location Map



Page Mill Rd.

Culvert A-28

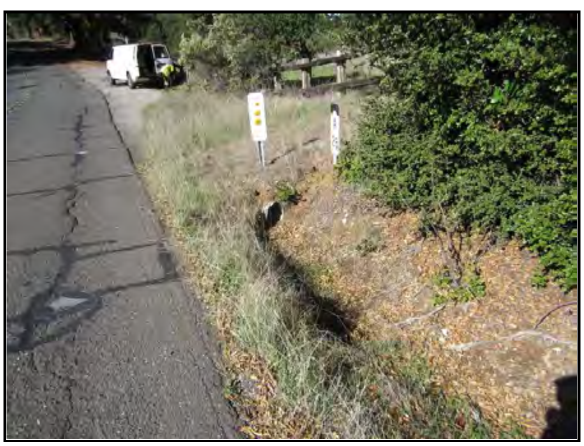
Evaluation date/time:	11/24/2014 11:59 AM
Address/location:	Page Mill Rd.
Weather:	Dry

General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	No
Access:	Good	**Susceptible to ponding/flooding:**	No
Traffic:	Light	Sediment/debris depth (%):	15
Ground surface type:	Asphalt	Type of sediment/debris:	Silt, vegetation
Dia./Ht. (in.):	12	Infiltration:	None
Width (in.):		Obstruction/deflection:	0
Material:	CMP	VANDA condition rating:	Level 2 - Minor Damage
U/S grade/rim-inv. (ft.):	1.75	Prioritization rating:	Level 3 - Fair
D/S grade/rim-inv. (ft.):	2	Prioritization rationale:	Ends deflected
Water level (%):	0	Illegal dumping evidence:	No

Notes

Pipe runs under the road. Coating failure and minor corrosion at invert.

Photos



Area near inlet.

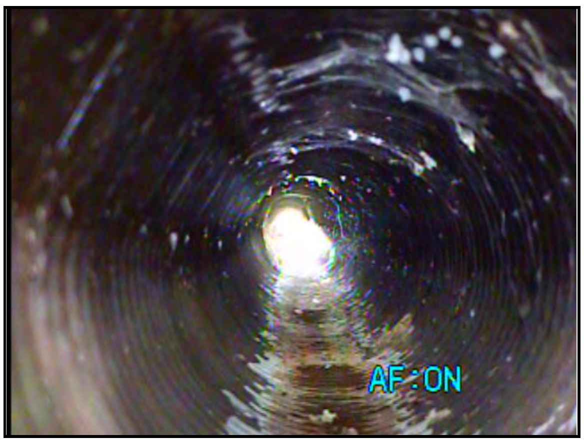
Area near inlet.

Page Mill Rd.

Culvert A-28

Area near outlet.

Inlet.



View inside inlet.

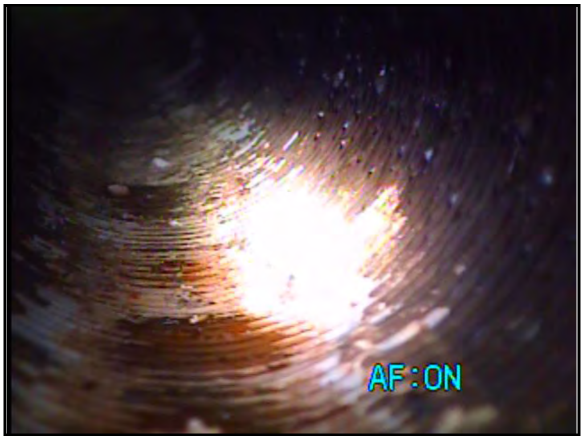
View inside inlet.

View inside inlet.

View inside inlet.

Page Mill Rd.

Culvert A-28



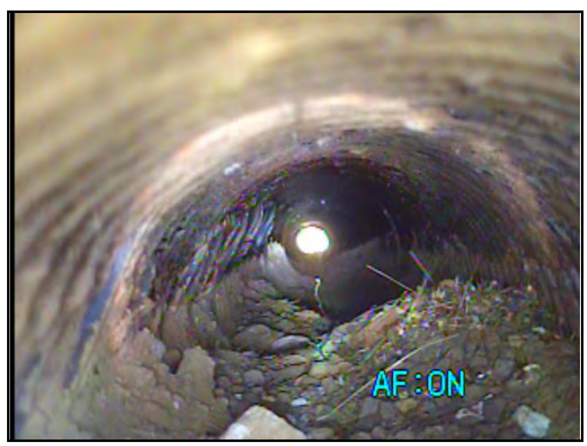
View inside inlet.

View inside inlet.


Outlet.


View inside outlet.

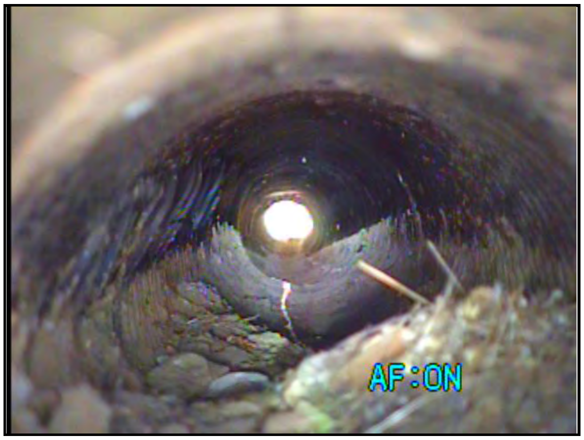
View inside outlet.



View inside outlet.

Page Mill Rd.

Culvert A-28

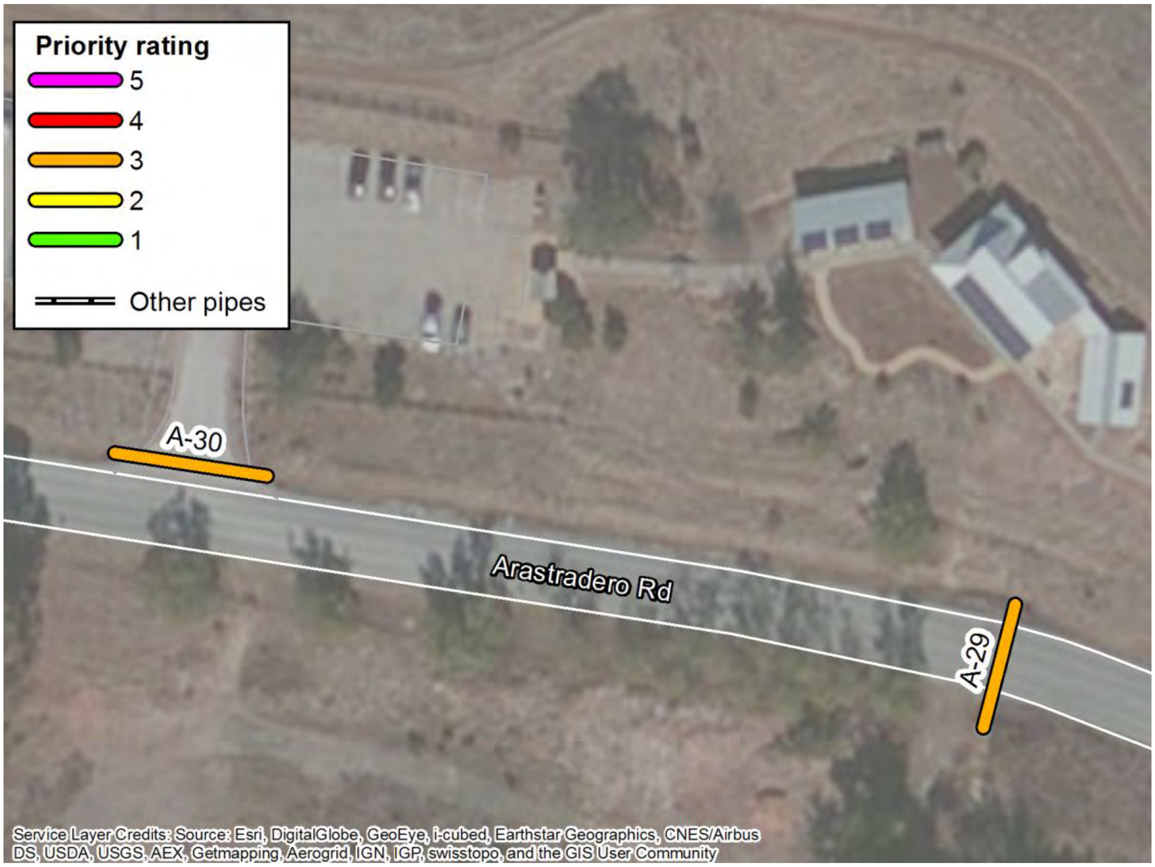


View inside outlet.

Arastradero Rd.

Culvert A-29

Location Map



Arastradero Rd.

Culvert A-29

Evaluation date/time:	11/19/2014 8:56 AM
Address/location:	Arastradero Rd.
Weather:	Dry

General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	No
Access:	Good	**Susceptible to ponding/flooding:**	No
Traffic:	Light	Sediment/debris depth (%):	5
Ground surface type:	Asphalt	Type of sediment/debris:	Silt, vegetation
Dia./Ht. (in.):	21	Infiltration:	None
Width (in.):		Obstruction/deflection:	0
Material:	CMP	VANDA condition rating:	Level 2 - Minor Damage
U/S grade/rim-inv. (ft.):	2	Prioritization rating:	Level 3 - Fair
D/S grade/rim-inv. (ft.):	2.5	Prioritization rationale:	Condition, location
Water level (%):	0	Illegal dumping evidence:	No

Notes

Pipe runs under the road. Possible small perforation and puncture near invert near inlet. Loss of galvanizing and minor corrosion at invert throughout culvert.

Photos

Area view.

Area near inlet.

Arastradero Rd.

Culvert A-29

Area near outlet.

Inlet.

Inlet.

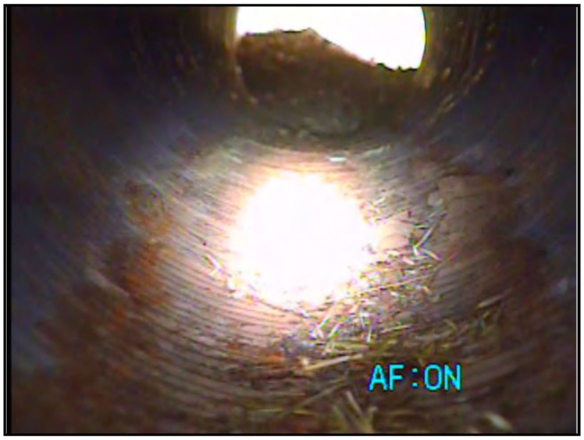
View inside inlet.

View inside inlet.

View inside inlet. Deflection and possible puncture at lower right.

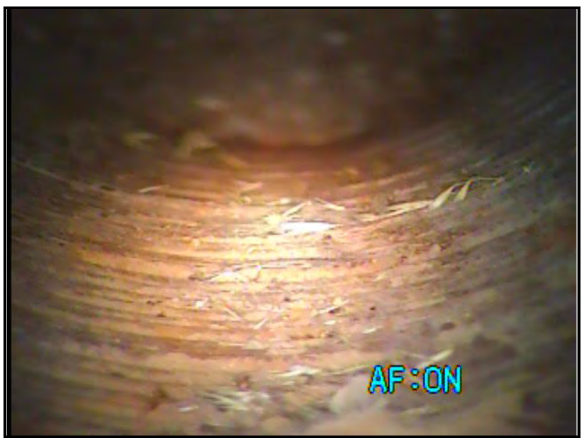
Arastradero Rd.

Culvert A-29

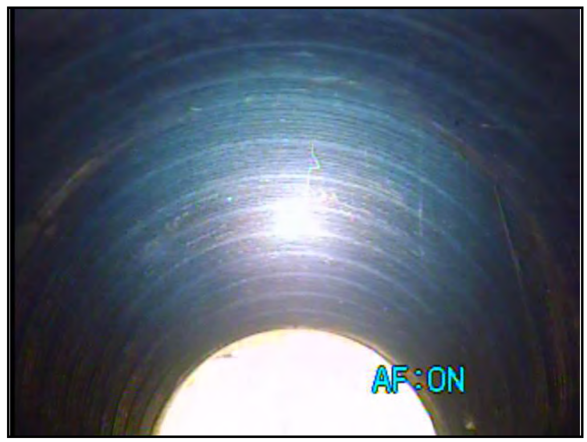


View inside inlet.

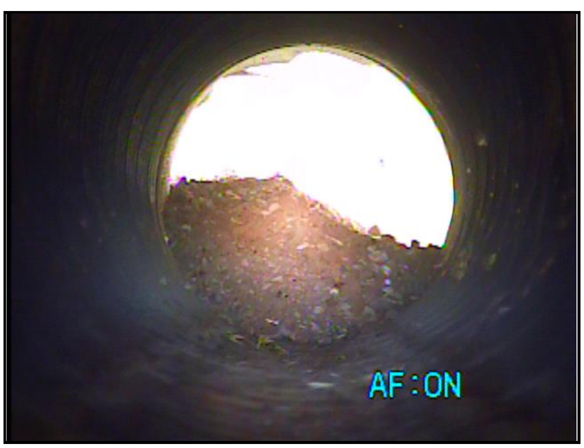
View inside inlet. Possible corrosion through pipe wall.



View inside inlet.



View inside inlet.



View inside inlet.

Outlet.

Arastradero Rd.

Culvert A-29

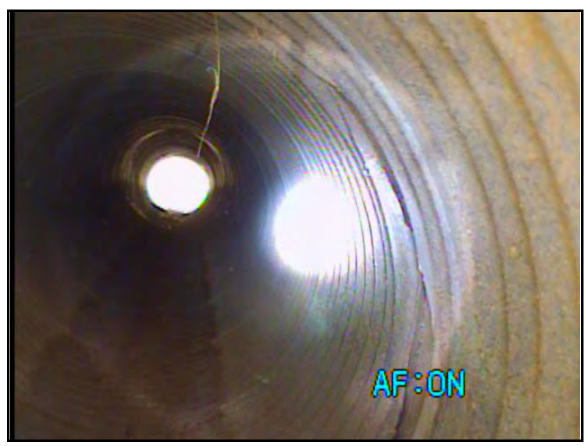

Exposed CMP at outlet.


Puncture in exposed CMP at outlet.


Void in soil above pipe at outlet.


View inside outlet.

View inside outlet.



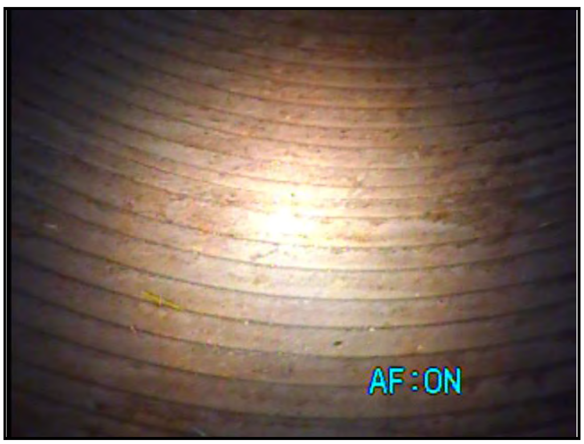
View inside outlet.

Arastradero Rd.

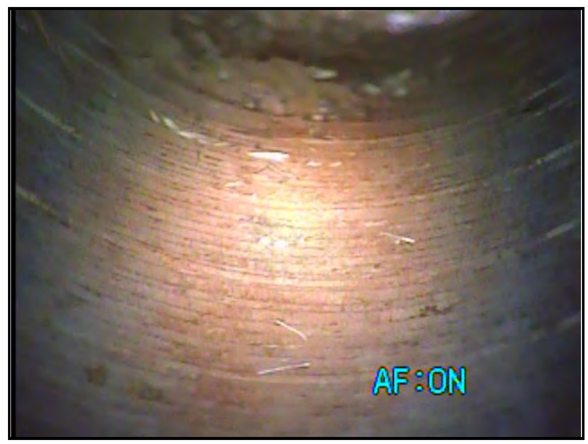
Culvert A-29

View inside outlet.

View inside outlet.



View inside outlet.



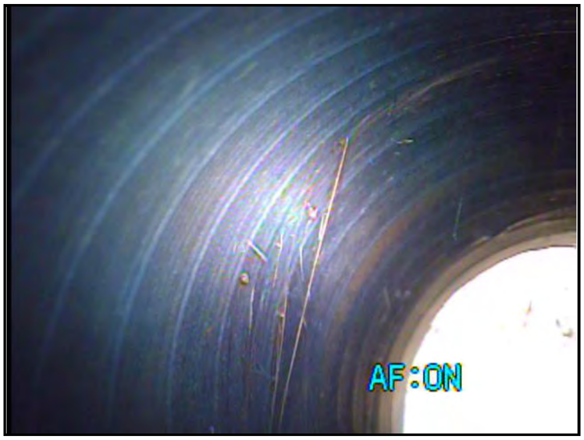
View inside outlet.

View inside outlet.

View inside outlet.

Arastradero Rd.

Culvert A-29



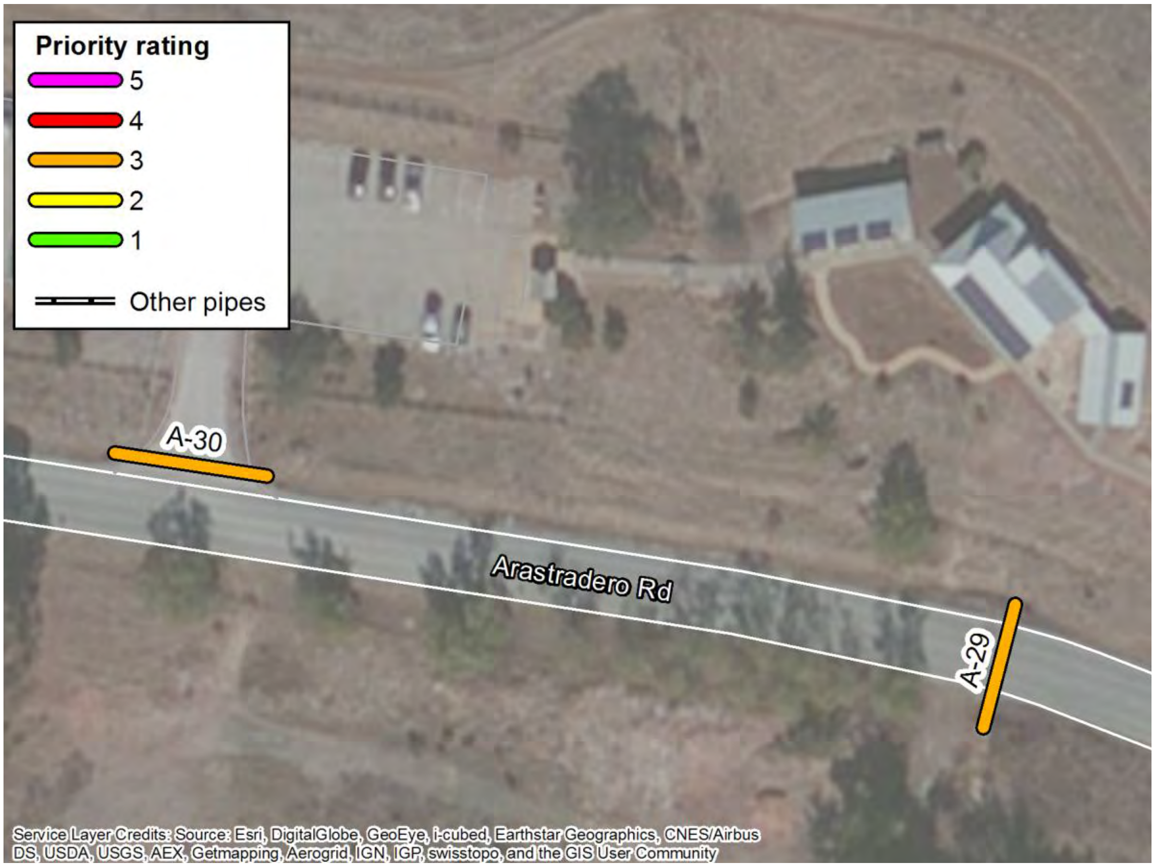
View inside outlet.

View inside outlet.

Arastradero Rd.

Culvert A-30

Location Map



Arastradero Rd.

Culvert A-30

Evaluation date/time:	11/19/2014 2:09 PM
Address/location:	Arastradero Rd.
Weather:	Dry

General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	No
Access:	Good	**Susceptible to ponding/flooding:**	No
Traffic:	Light	Sediment/debris depth (%):	0
Ground surface type:	Asphalt	Type of sediment/debris:	None
Dia./Ht. (in.):	12	Infiltration:	None
Width (in.):		Obstruction/deflection:	0
Material:	CMP	VANDA condition rating:	Level 2 - Minor Damage
U/S grade/rim-inv. (ft.):	1.25	Prioritization rating:	Level 3 - Fair
D/S grade/rim-inv. (ft.):	1.25	Prioritization rationale:	Condition
Water level (%):	0	Illegal dumping evidence:	No

Notes

Minor corrosion. Apparent offset or separated joint near outlet.

Photos

Area view.

Area near inlet.

Arastradero Rd.

Culvert A-30

Area near outlet.

Inlet.

View inside inlet.

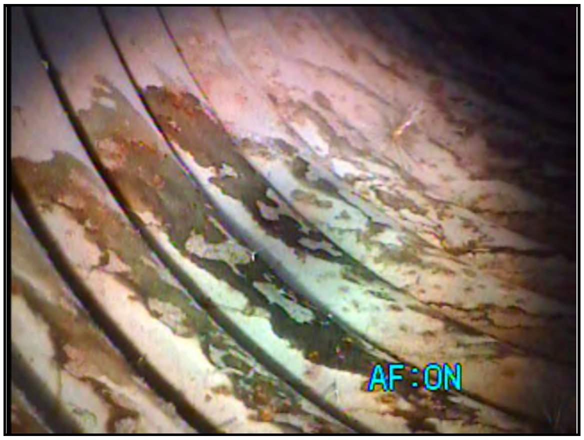
View inside inlet.

View inside inlet.

View inside inlet.

Arastradero Rd.

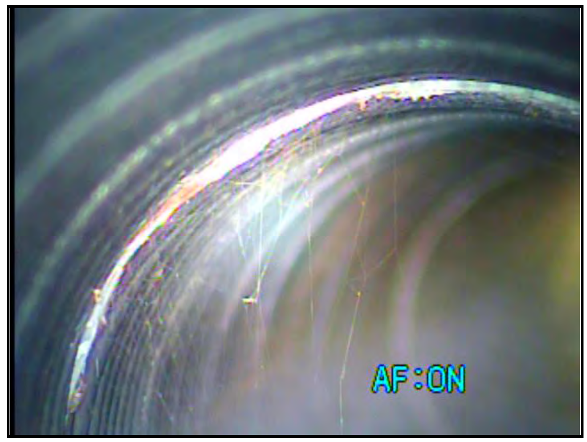
Culvert A-30



View inside inlet.

View inside inlet.

View inside inlet.



View inside inlet.

View inside inlet.


Outlet.

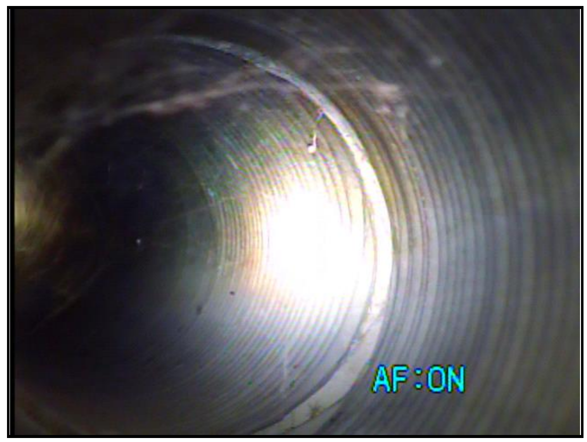
Arastradero Rd.

Culvert A-30

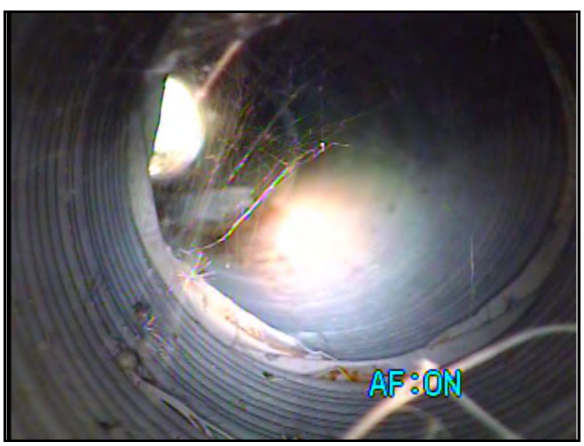
View inside outlet.

View inside outlet.

View inside outlet.



View inside outlet.



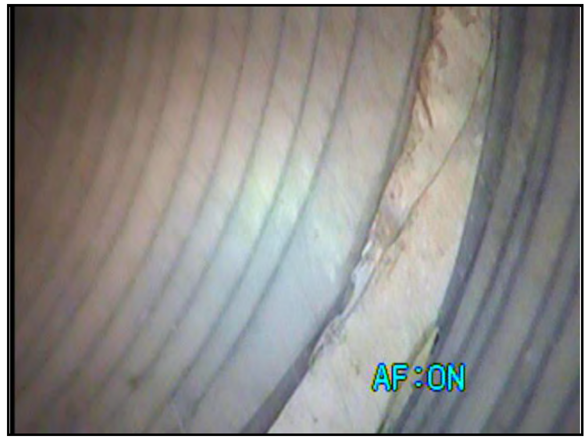
View inside outlet.

View inside outlet.

Arastradero Rd.

Culvert A-30

View inside outlet. Possible deflected joint.



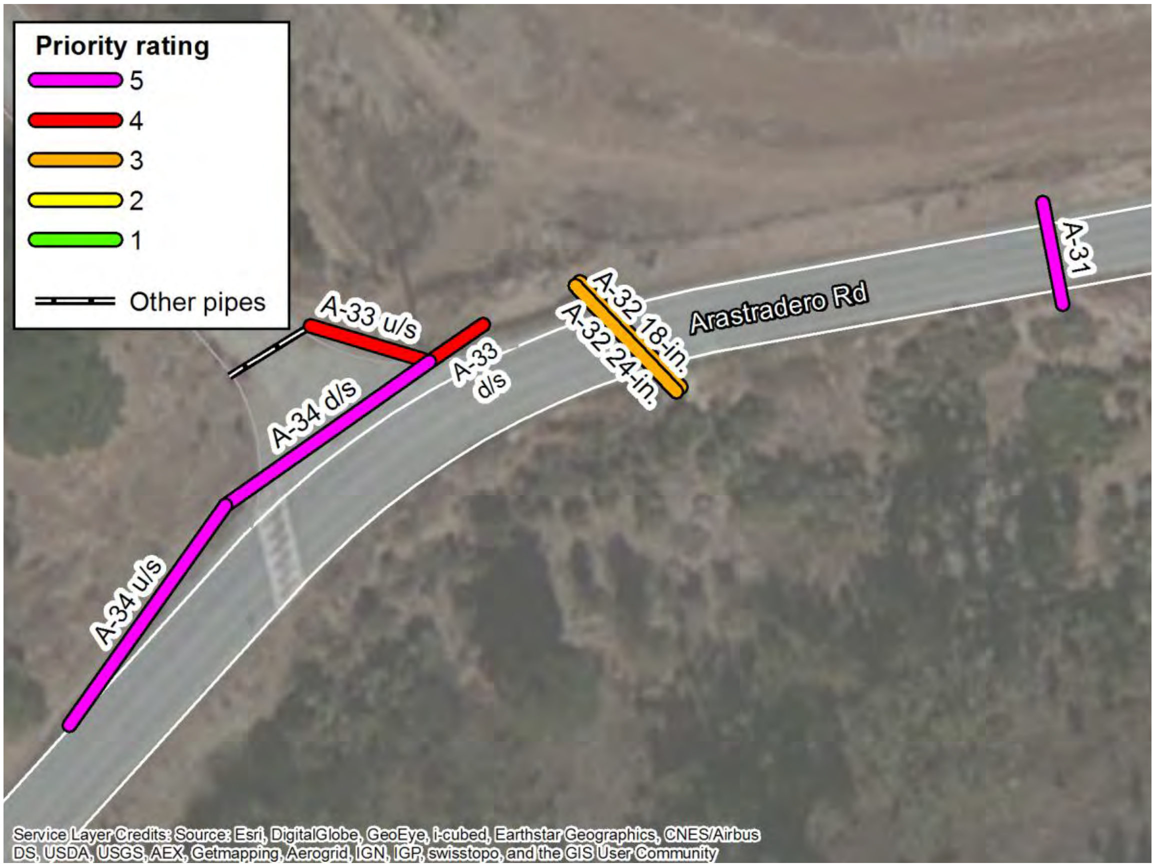
View inside outlet. Possible deflected or separated joint.

View inside outlet. Possible deflected or separated joint.

Arastradero Rd.

Culvert A-31

<u>Location Map</u>



Arastradero Rd.

Culvert A-31

Evaluation date/time:	11/19/2014 10:37 AM
Address/location:	Arastradero Rd.
Weather:	Dry

General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	No
Access:	Good	**Susceptible to ponding/flooding:**	No
Traffic:	Light	Sediment/debris depth (%):	10
Ground surface type:	Asphalt	Type of sediment/debris:	Soil
Dia./Ht. (in.):	12	Infiltration:	None
Width (in.):		Obstruction/deflection:	0
Material:	CMP	VANDA condition rating:	Level 4 - Severe/Significant Damage
U/S grade/rim-inv. (ft.):	1.5	Prioritization rating:	Level 5 - Immediate Attention
D/S grade/rim-inv. (ft.):	4	Prioritization rationale:	Condition, location
Water level (%):	0	Illegal dumping evidence:	No

Notes

Pipe runs under the road. Invert appears to be perforated or missing near inlet due to corrosion.

Photos

Area view.

Inlet.

Arastradero Rd.

Culvert A-31

Inlet.

View inside inlet.

View inside inlet.

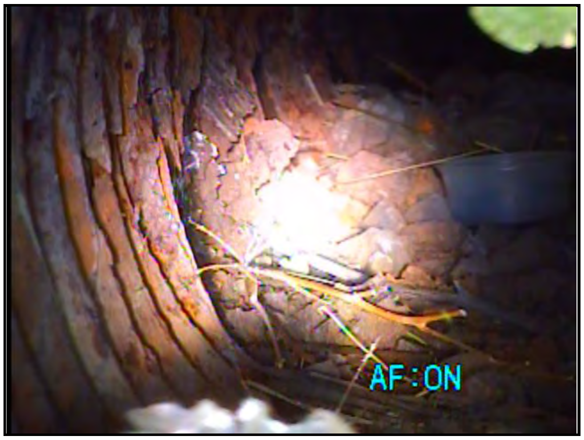
View inside inlet.

View inside inlet. Pipe appears to be perforated.

View inside inlet. Pipe appears to be perforated.

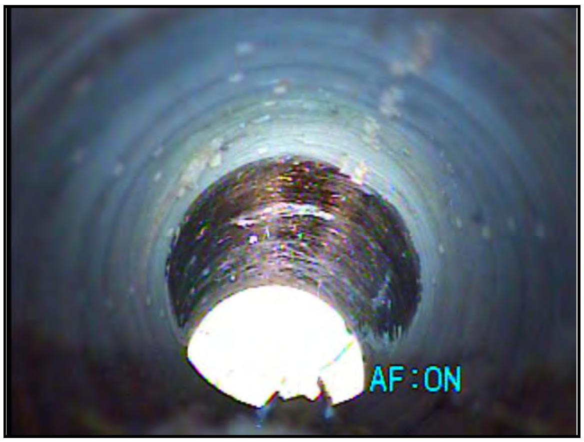
Arastradero Rd.

Culvert A-31



View inside inlet. Pipe appears to be perforated.

View inside inlet. Pipe appears to be perforated.



View inside inlet.


Outlet.

Outlet.


View inside outlet.

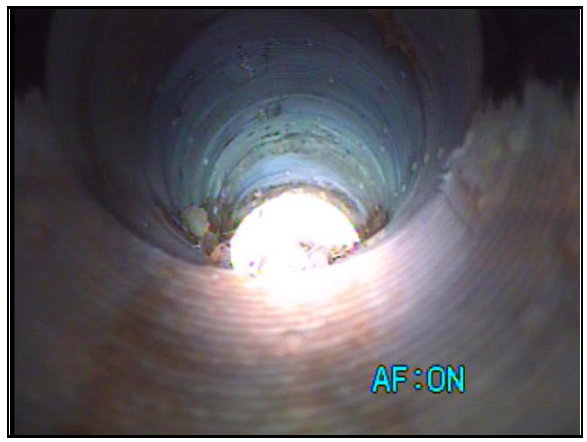
Arastradero Rd.

Culvert A-31

View inside outlet.

View inside outlet.

View inside outlet.



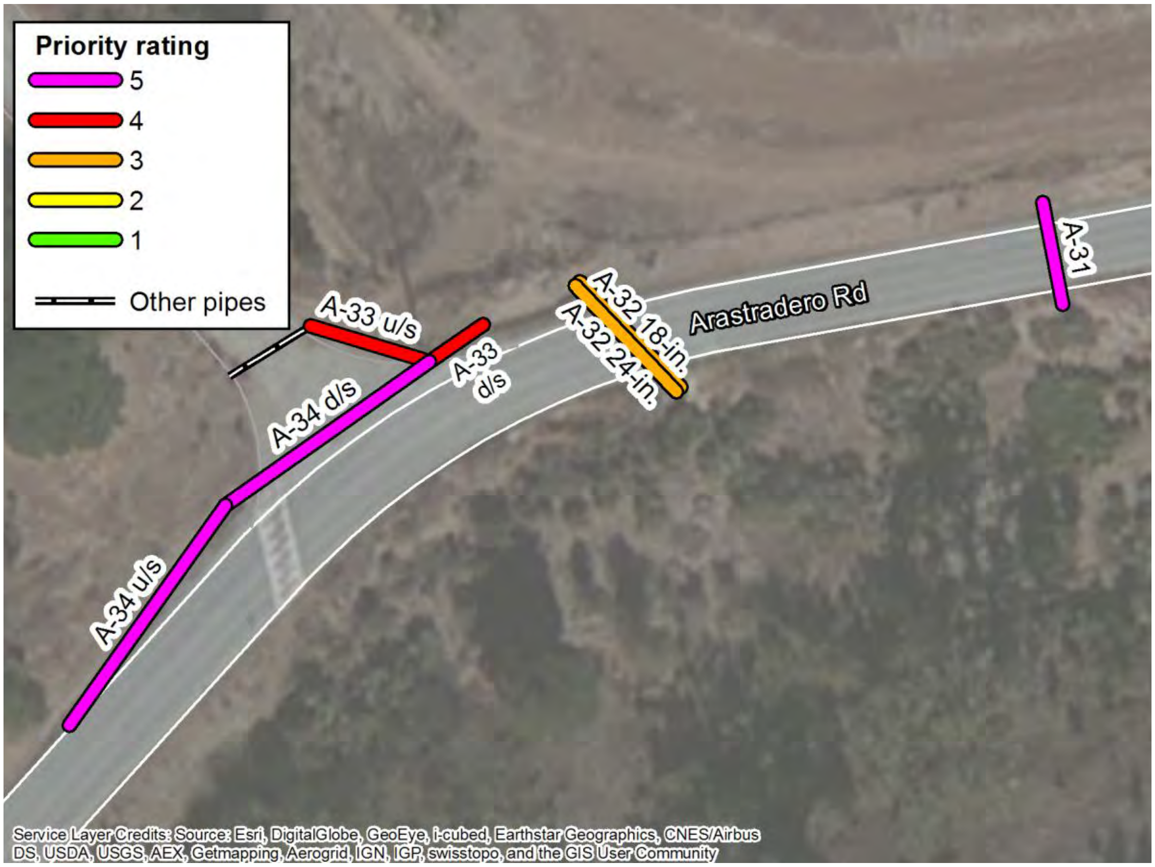
View inside outlet.

View inside outlet.

Arastradero Rd.

Culvert A-32

Location Map



Arastradero Rd.

Culvert A-32

Evaluation date/time:	11/19/2014 10:19 AM
Address/location:	Arastradero Rd.
Weather:	Dry

General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	No
Access:	Good	**Susceptible to ponding/flooding:**	No
Traffic:	Light	Sediment/debris depth (%):	0
Ground surface type:	Asphalt	Type of sediment/debris:	None
Dia./Ht. (in.):	24, 18	Infiltration:	None
Width (in.):		Obstruction/deflection:	0
Material:	CMP	VANDA condition rating:	Level 2 - Minor Damage
U/S grade/rim-inv. (ft.):	3.25	Prioritization rating:	Level 3 - Fair
D/S grade/rim-inv. (ft.):	3.5	Prioritization rationale:	Condition, location
Water level (%):	0	Illegal dumping evidence:	No

Notes

Two parallel culvert pipes under the road. Possible separated joint or hole within 18-in. line. Coating failure and moderate corrosion at invert of pipes. Portions of 24-in. culvert have cement mortar overlay at invert.

Photos

Area view.

Area view.

Arastradero Rd.

Culvert A-32

Area near outlet.

Area near outlet.

Area near outlet.

Inlet.

Inlet.

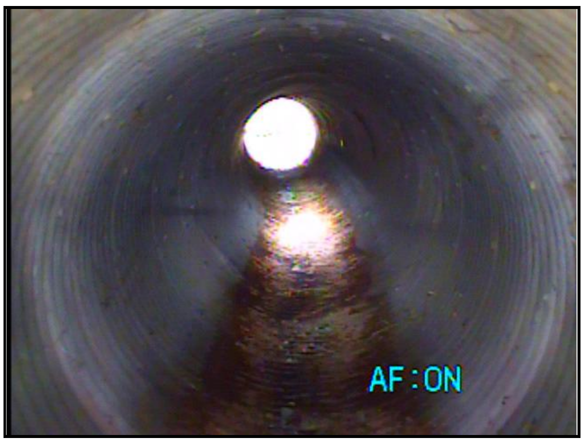
Inlet to 24-inch culvert.

Arastradero Rd.

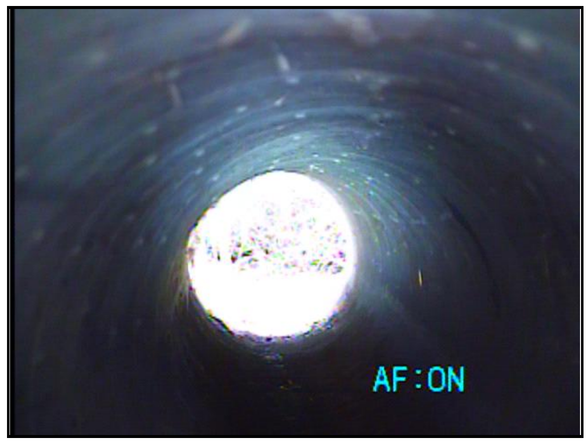
Culvert A-32

View inside 24-inch inlet.

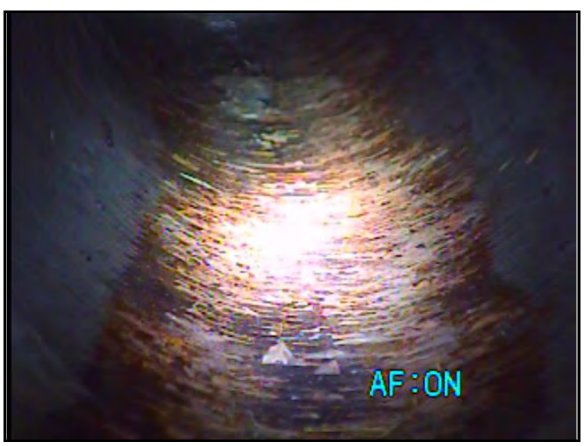
View inside 24-inch inlet.



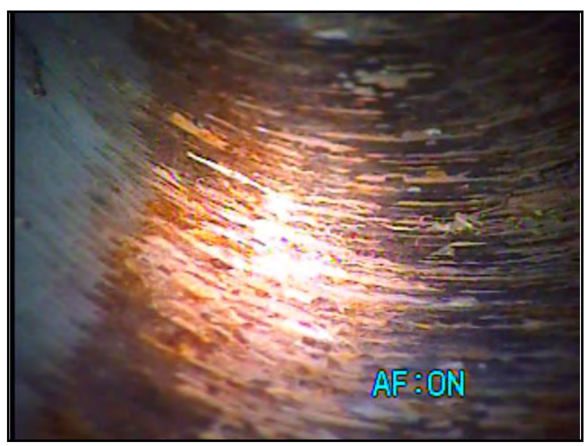
View inside 24-inch inlet.



View inside 24-inch inlet.



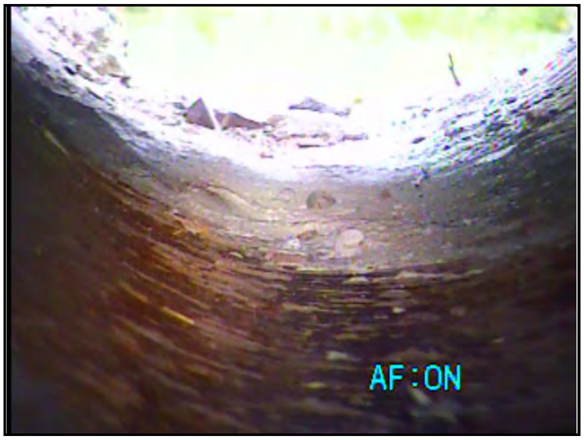
View inside 24-inch inlet.



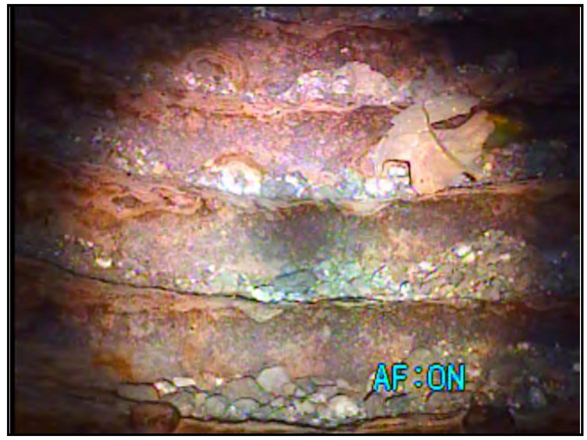
View inside 24-inch inlet.

Arastradero Rd.

Culvert A-32



View inside 24-inch inlet.

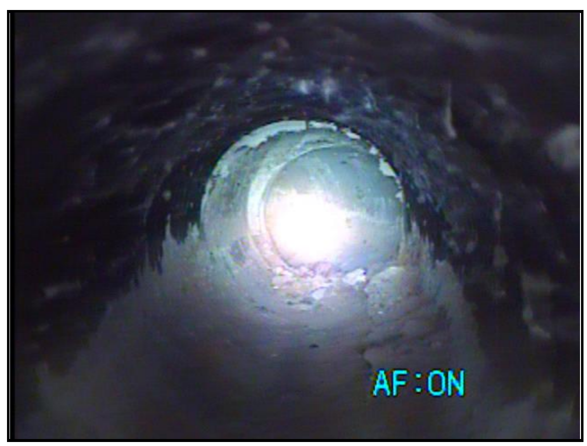


View inside 24-inch inlet.

Inlet to 18-inch culvert. Note crack in headwall above pipe.

View inside 18-inch inlet.

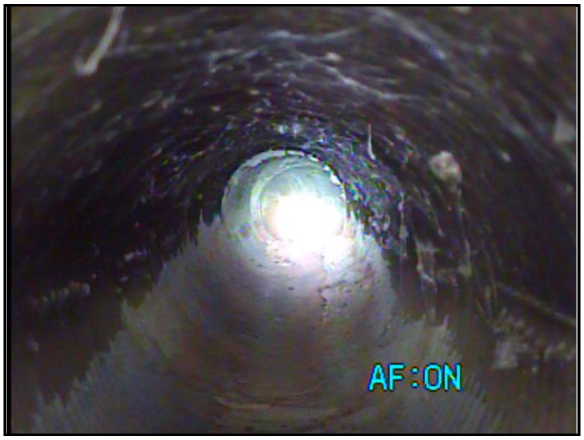
View inside 18-inch inlet.



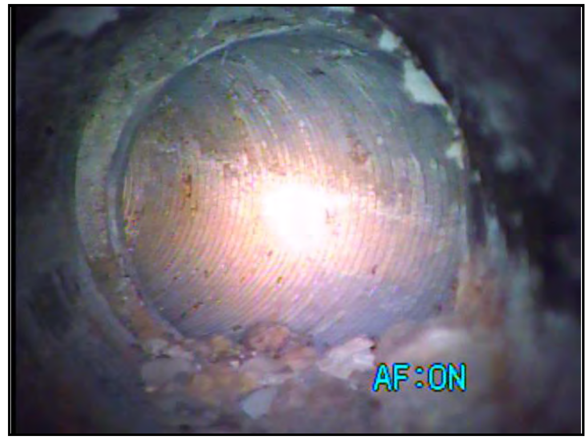
View inside 18-inch inlet.

Arastradero Rd.

Culvert A-32

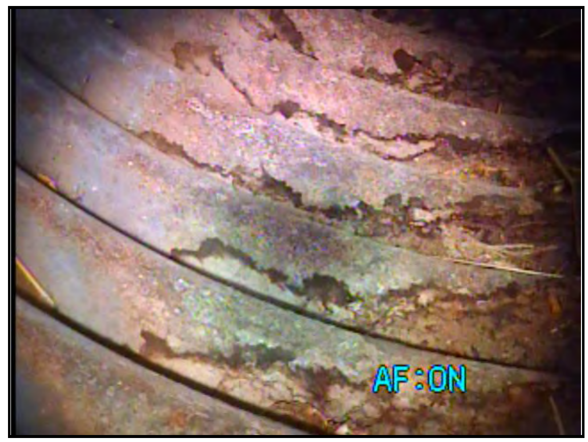


View inside 18-inch inlet.



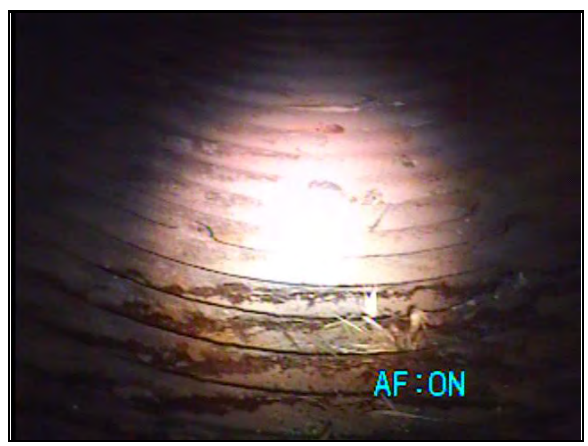
View inside 18-inch inlet.

View inside 18-inch inlet.



View inside 18-inch inlet.

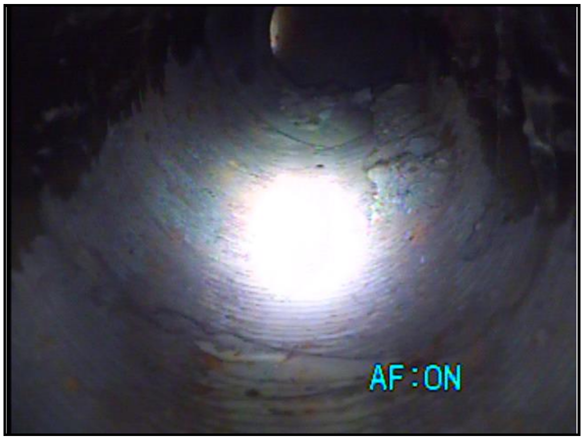
View inside 18-inch inlet.



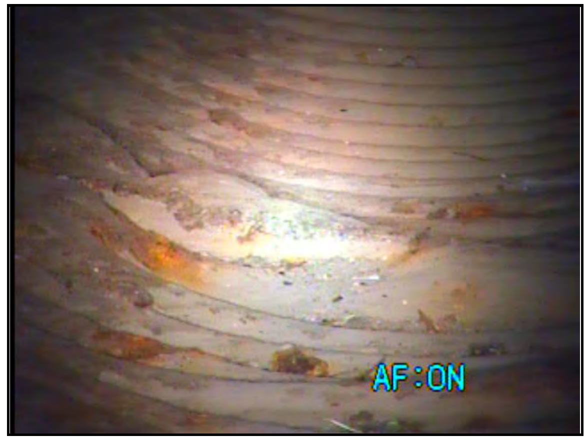
View inside 18-inch inlet.

Arastradero Rd.

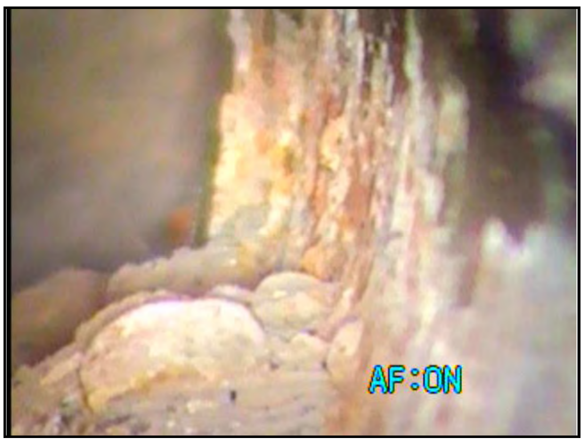
Culvert A-32



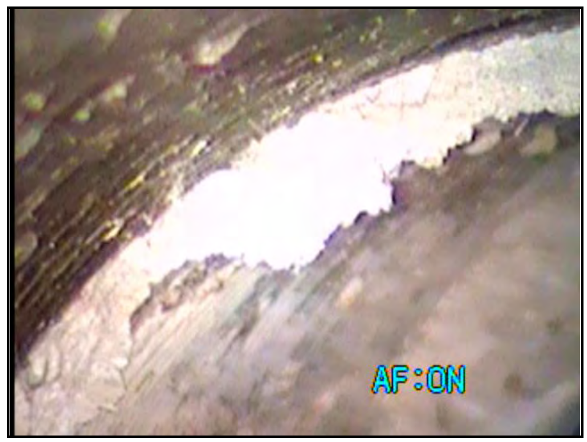
View inside 18-inch inlet.



View inside 18-inch inlet. Deflection at invert within pipe.

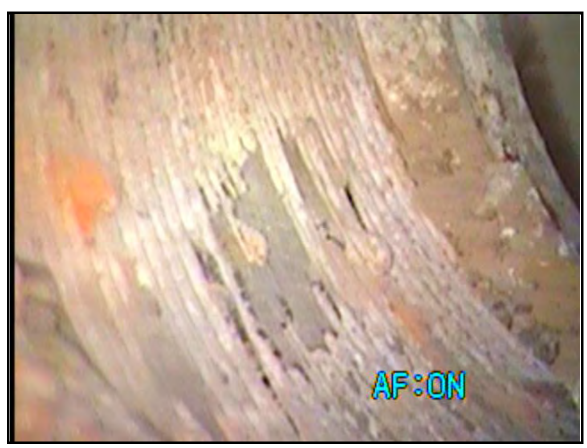


View inside 18-inch inlet.



View inside 18-inch inlet. Apparent offset joint within pipe.

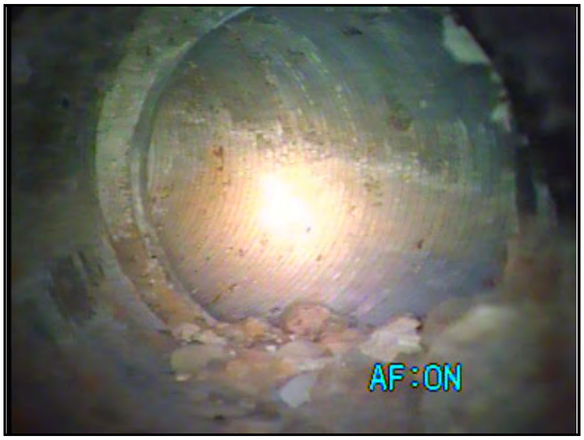
View inside 18-inch inlet. Apparent offset joint within pipe.



View inside 18-inch inlet. Apparent offset joint within pipe.

Arastradero Rd.

Culvert A-32



View inside 18-inch inlet. Apparent offset joint within pipe.

Outlet. End of concrete apron is slightly undermined.

Outlet.

Outlet.

Concrete apron at outlet is cracked.

Outlet of 24-inch culvert.

Arastradero Rd.

Culvert A-32

Outlet of 24-inch culvert.

View inside 24-inch outlet.

View inside 24-inch outlet.

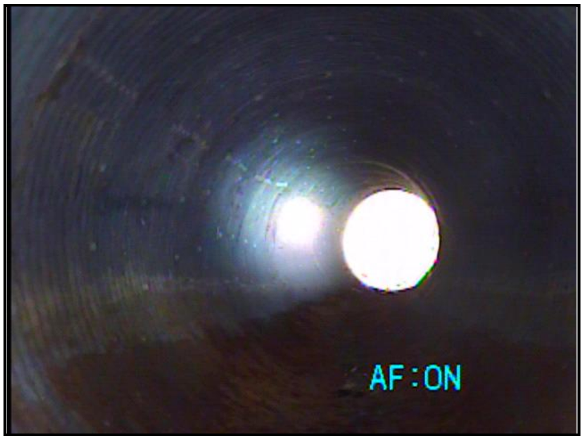
View inside 24-inch outlet.

View inside 24-inch outlet. Invert paved with concrete.

View inside 24-inch outlet.

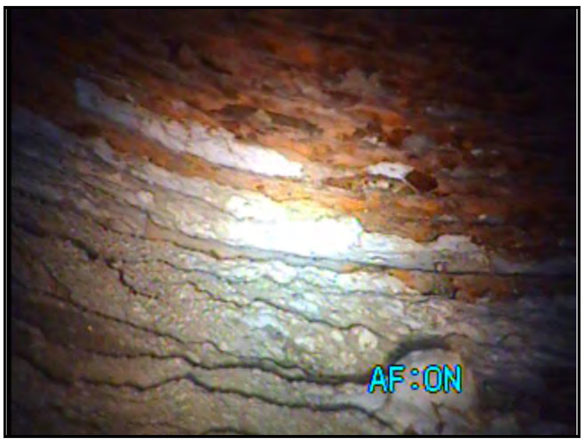
Arastradero Rd.

Culvert A-32

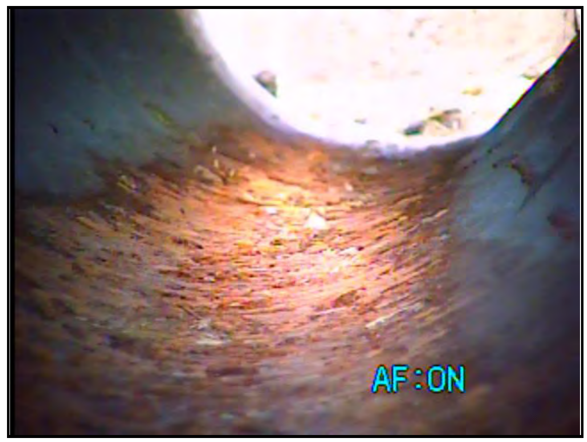


View inside 24-inch outlet.

View inside 24-inch outlet.



View inside 24-inch outlet.



View inside 24-inch outlet.

Outlet of 18-inch culvert.

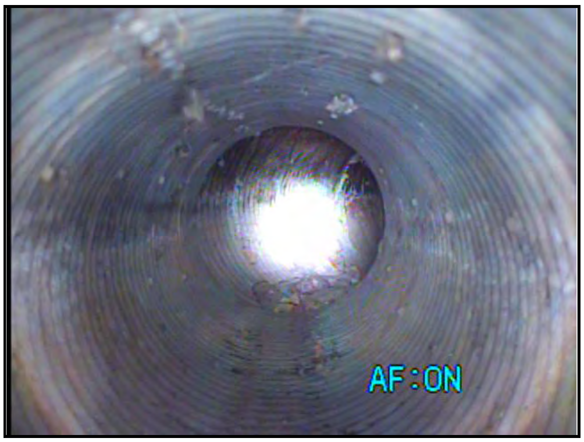
Outlet of 18-inch culvert.

Arastradero Rd.

Culvert A-32

View inside 18-inch outlet.

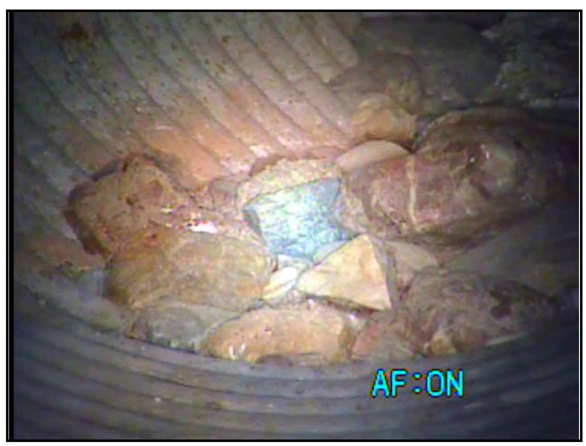
View inside 18-inch outlet.



View inside 18-inch outlet.

View inside 18-inch outlet.

View inside 18-inch outlet.

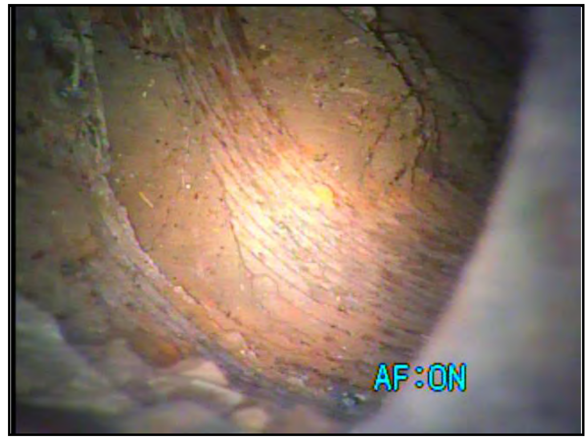


View inside 18-inch outlet. Debris inside pipe.

Arastradero Rd.

Culvert A-32

View inside 18-inch outlet. Possible separated joint or hole within pipe.

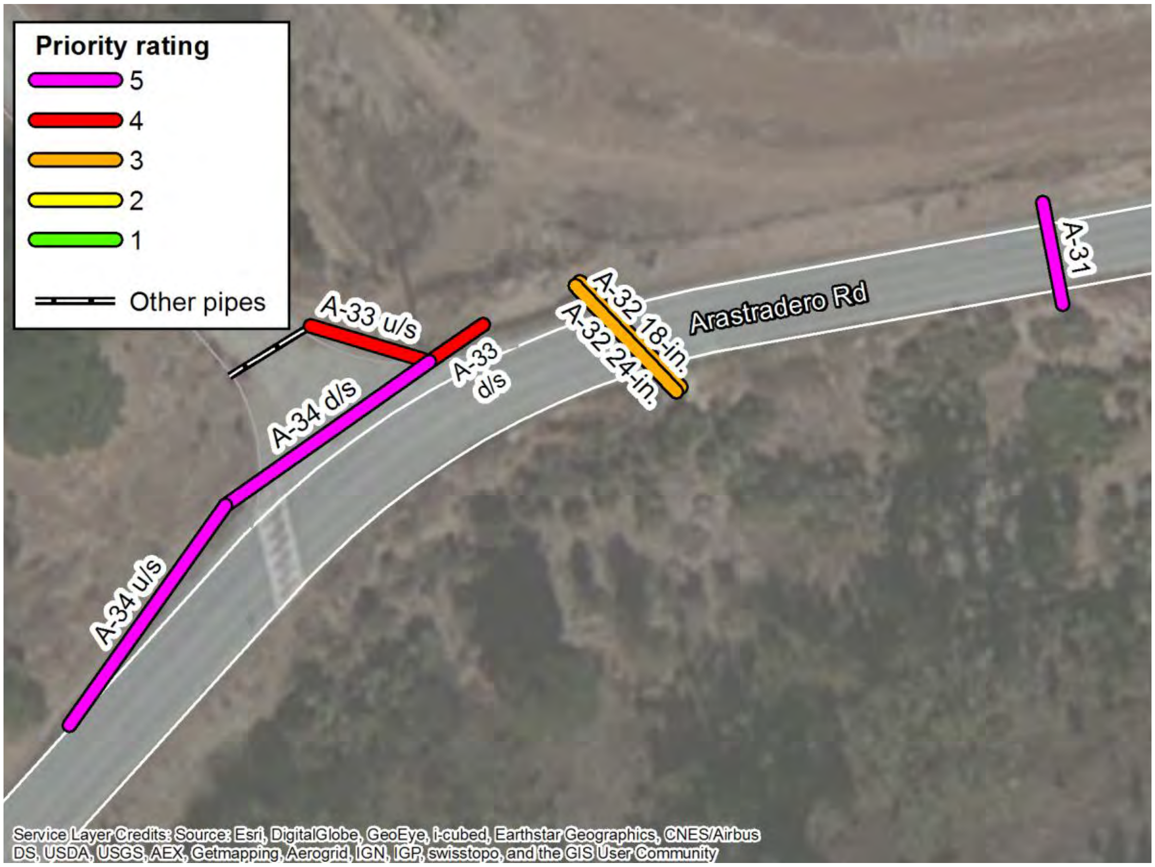


View inside 18-inch outlet. Possible separated joint or hole within pipe.

Arastradero Rd.

Culvert A-33

Location Map



Arastradero Rd.

Culvert A-33

Evaluation date/time:	11/19/2014 9:53 AM
Address/location:	Arastradero Rd.
Weather:	Dry

General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	No
Access:	Good	**Susceptible to ponding/flooding:**	No
Traffic:	Light	Sediment/debris depth (%):	50
Ground surface type:	Asphalt, grass/dirt	Type of sediment/debris:	Soil
Dia./Ht. (in.):	24	Infiltration:	None
Width (in.):		Obstruction/deflection:	0
Material:	CMP	VANDA condition rating:	Level 3 - Moderate Damage
U/S grade/rim-inv. (ft.):		Prioritization rating:	Level 4 - Poor
D/S grade/rim-inv. (ft.):	2	Prioritization rationale:	Condition, location, sediment
Water level (%):	0	Illegal dumping evidence:	No

Notes

Upstream pipe has moderate corrosion. Downstream pipe has significant corrosion and possible perforations. Downstream pipe is about half full of sediment.

Photos


Area view.

Inlet.

Arastradero Rd.

Culvert A-33

Pipes entering A-33 inlet structure. Pipe on left is the downstream pipe for A-34 and is almost completely obstructed with sediment. Pipe on right is the upstream pipe for A-33.

View inside upstream pipe from A-33.

View inside upstream pipe from A-33.

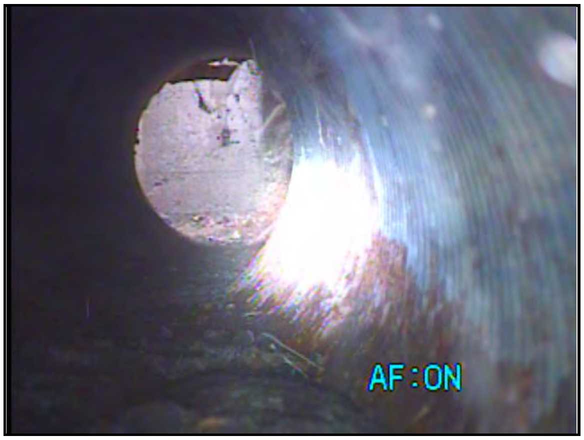
View inside upstream pipe from A-33.

View inside upstream pipe from A-33.

View inside upstream pipe from A-33.

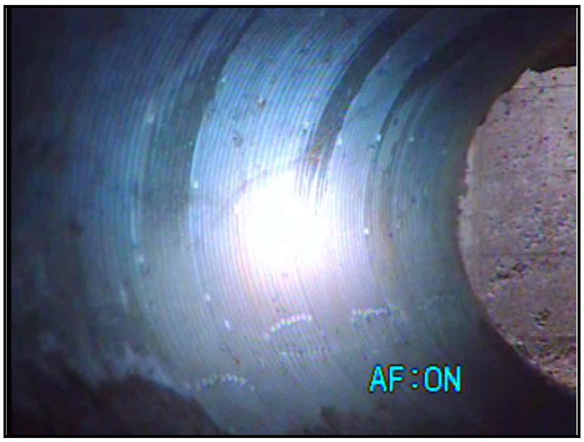
Arastradero Rd.

Culvert A-33

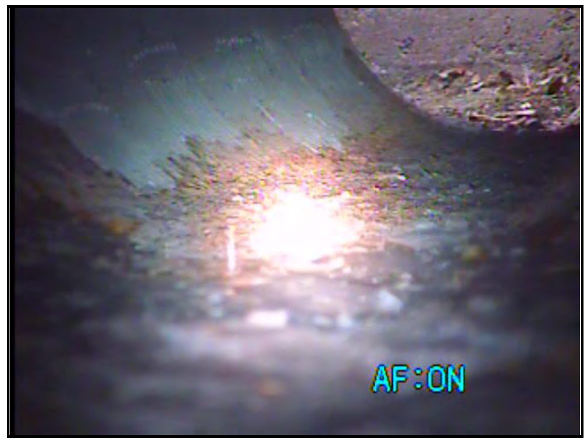


View inside upstream pipe from A-33.

View inside upstream pipe from A-33.



View inside upstream pipe from A-33.



View inside upstream pipe from A-33.


View inside upstream pipe from upstream inlet.


Area near outlet of downstream pipe.

Arastradero Rd.

Culvert A-33

Outlet of downstream pipe.

View inside outlet of downstream pipe.

View inside outlet of downstream pipe.

View inside outlet of downstream pipe.

View inside outlet of downstream pipe.

View inside outlet of downstream pipe.

Arastradero Rd.

Culvert A-33

View inside outlet of downstream pipe.

View inside outlet of downstream pipe.

View inside outlet of downstream pipe.

View inside outlet of downstream pipe.

View inside downstream pipe from A-33.

View inside downstream pipe from A-33.

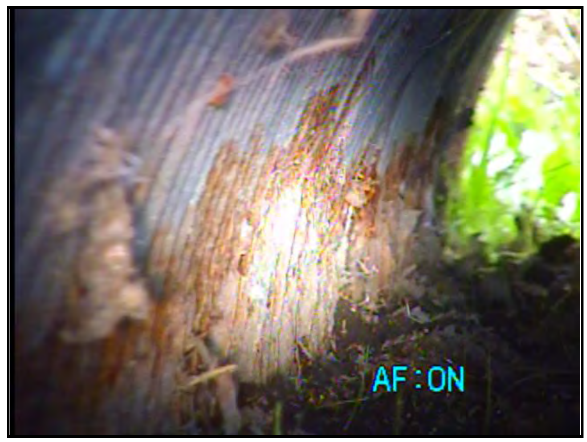
Arastradero Rd.

Culvert A-33

View inside downstream pipe from A-33.

View inside downstream pipe from A-33.

View inside downstream pipe from A-33.



View inside downstream pipe from A-33.

View inside downstream pipe from A-33.

View inside downstream pipe from A-33.

Arastradero Rd.

Culvert A-33

View inside downstream pipe from A-33.

Inlet upstream of A-33.

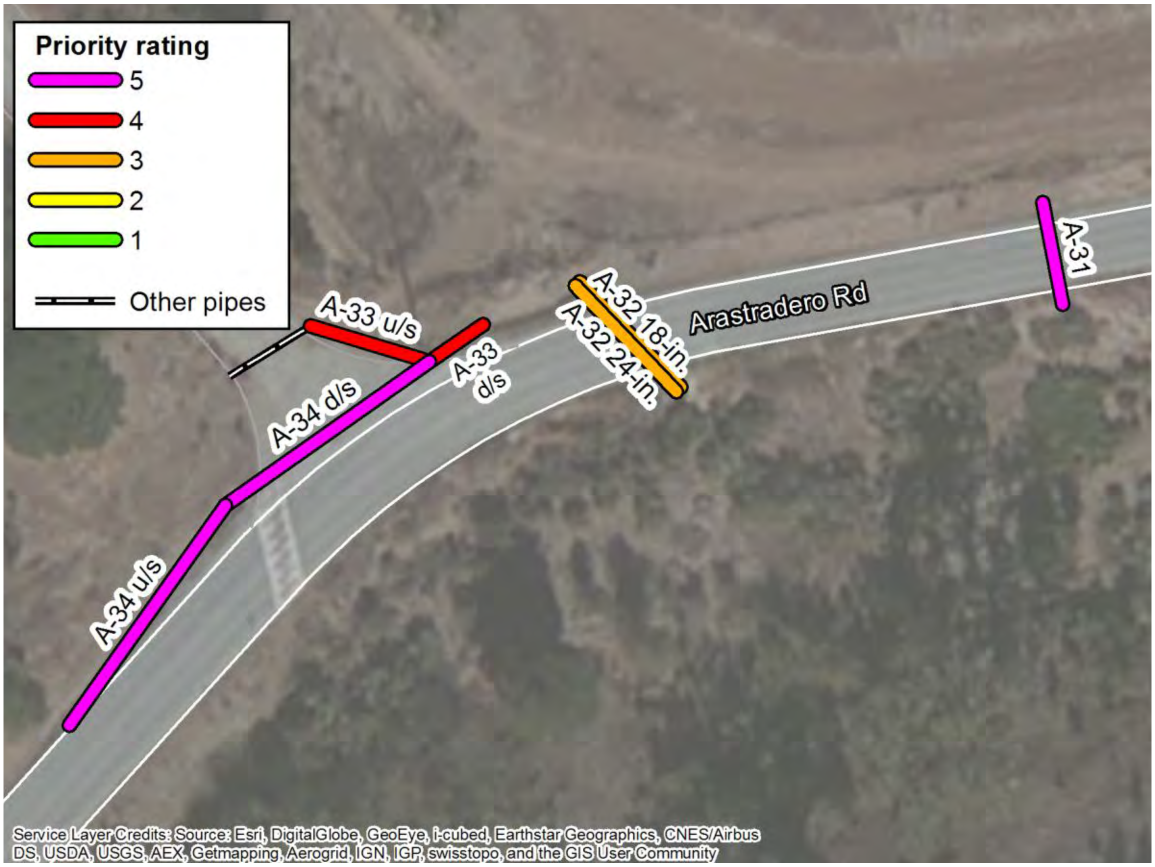
Inlet upstream of A-33.

Second inlet upstream of A-33 (near A-34).

Arastradero Rd.

Culvert A-34

Location Map



Arastradero Rd.

Culvert A-34

Evaluation date/time:	11/19/2014 10:32 AM
Address/location:	Arastradero Rd.
Weather:	Dry

General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	Yes
Access:	Fair	**Susceptible to ponding/flooding:**	No
Traffic:	Light	Sediment/debris depth (%):	80
Ground surface type:	Grass/dirt, sand	Type of sediment/debris:	Silt, sand
Dia./Ht. (in.):	12	Infiltration:	None
Width (in.):		Obstruction/deflection:	0
Material:	CMP	VANDA condition rating:	Level 4 - Severe/Significant Damage
U/S grade/rim-inv. (ft.):		Prioritization rating:	Level 5 - Immediate Attention
D/S grade/rim-inv. (ft.):	2	Prioritization rationale:	Condition, location, burial
Water level (%):	0	Illegal dumping evidence:	No

Notes

Concrete spalling on wall of inlet structure. Upstream end of upstream pipe could not be located. Pipe appears to have a pool of green liquid inside it. Upstream and downstream pipes appear to have experienced severe corrosion. Downstream pipe is almost completely obstructed with sediment where it enters the A-33 inlet structure.

Photos

Area near inlet.

Arastradero Rd.

Culvert A-34

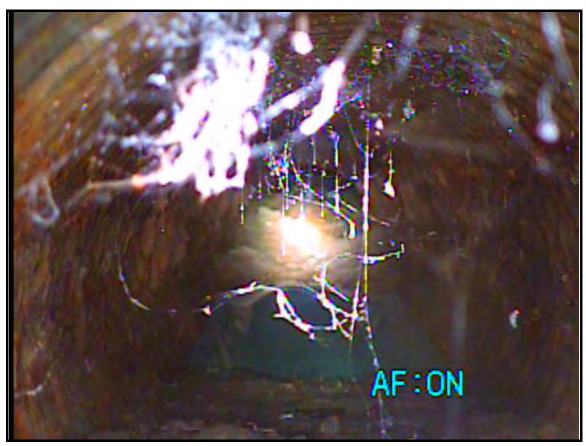
Interior of inlet structure. Concrete spalling on wall surface.

Concrete spalling on wall above outlet of structure.

View inside upstream pipe.

View inside upstream pipe. Pipe corroded near invert.

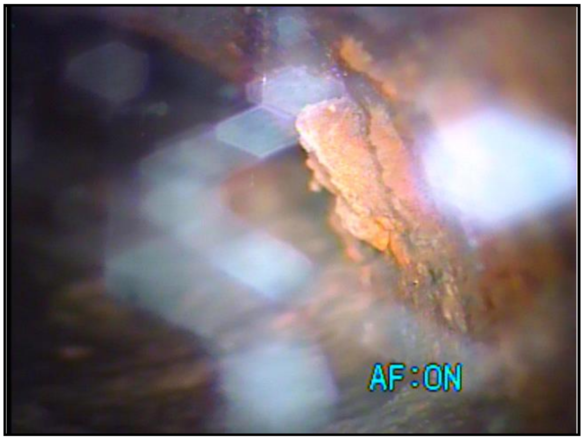
View inside upstream pipe. Pipe corroded near invert.



View inside upstream pipe.

Arastradero Rd.

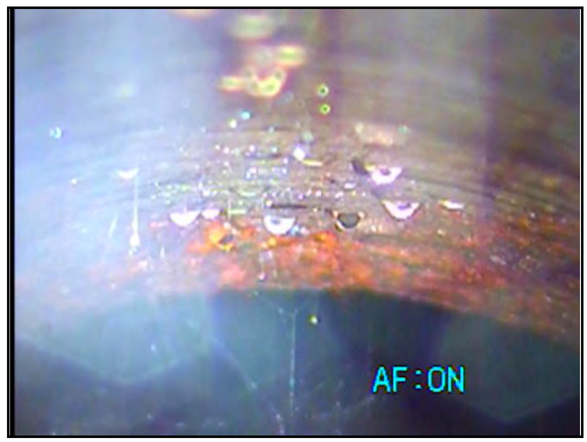
Culvert A-34



View inside upstream pipe. Pipe surfaces appear to be severely corroded.

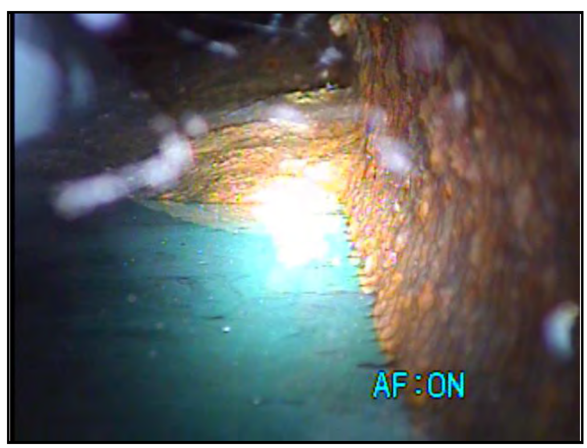
View inside upstream pipe. Pipe surfaces appear to be severely corroded.

Debris inside upstream pipe.



Crown of upstream pipe.

Green liquid inside upstream pipe.



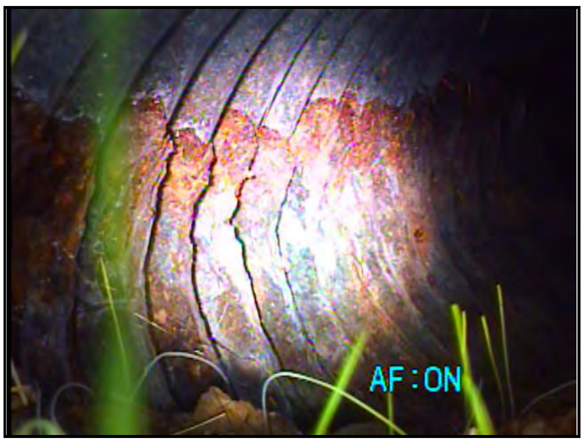
Green liquid inside upstream pipe.

Arastradero Rd.

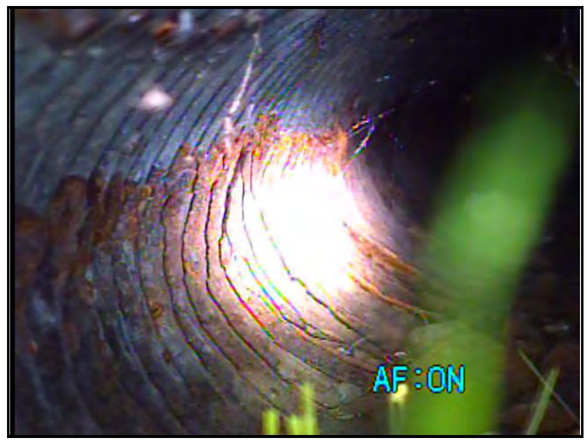
Culvert A-34

Outlet of structure.

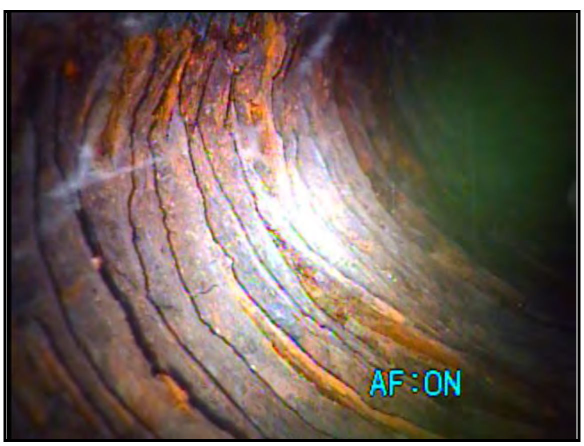
View inside downstream pipe.



View inside downstream pipe. Significant corrosion.



View inside downstream pipe. Significant corrosion and apparent deflection.

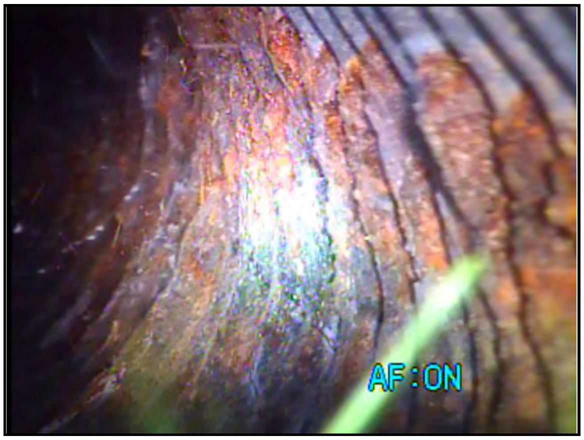


View inside downstream pipe. Significant corrosion.

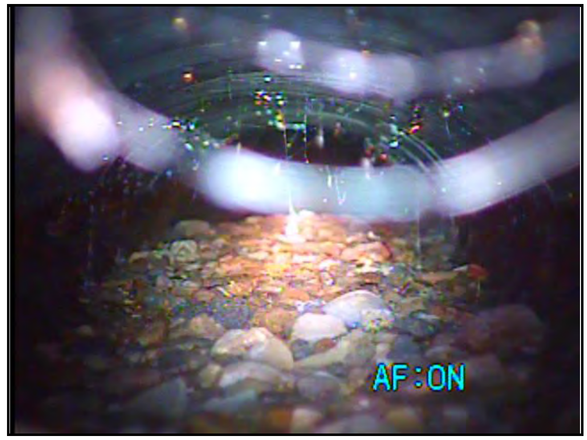
View inside downstream pipe.

Arastradero Rd.

Culvert A-34



View inside downstream pipe. Significant corrosion.



View inside downstream pipe.

View inside downstream pipe. Significant corrosion.

View inside downstream pipe. Significant corrosion.

Arastradero Rd.

Culvert A-35

Location Map

Arastradero Rd.

Culvert A-35

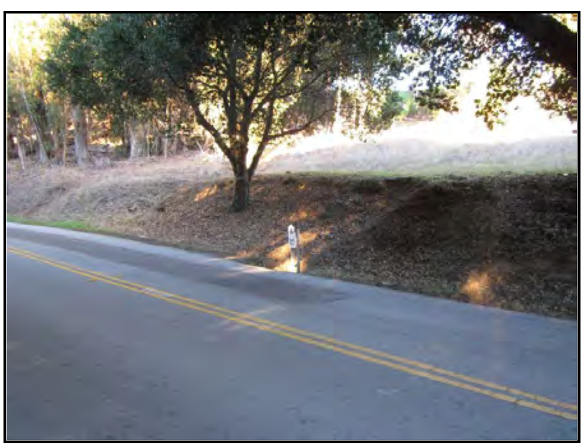
Evaluation date/time:	11/24/2014 8:30 AM
Address/location:	Arastradero Rd.
Weather:	Dry

General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	Yes
Access:	Good	**Susceptible to ponding/flooding:**	No
Traffic:	Heavy	Sediment/debris depth (%):	75 - 100
Ground surface type:	Asphalt, grass/dirt	Type of sediment/debris:	Silt, vegetation, possible construction debris
Dia./Ht. (in.):	12	Infiltration:	None
Width (in.):		Obstruction/deflection:	0
Material:	CMP	VANDA condition rating:	Level 2 - Minor Damage
U/S grade/rim-inv. (ft.):	2	Prioritization rating:	Level 5 - Immediate Attention
D/S grade/rim-inv. (ft.):	5	Prioritization rationale:	Condition, location, sediment
Water level (%):	0	Illegal dumping evidence:	No

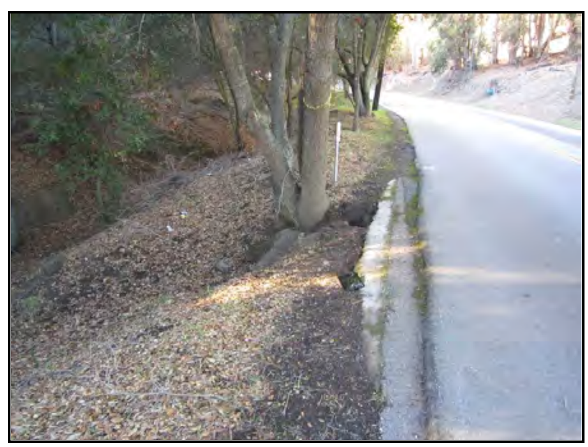
Notes

Pipe runs under roadway. Minor surface corrosion. Pipe appears to be obstructed near inlet, possibly due to construction (trenching) in street. Pipe is possibly damaged or collapsed at this location.

Photos



Area near inlet. Note patch in pavement over apparent trench; construction may have damaged culvert.



Area near outlet.

Arastradero Rd.

Culvert A-35

Area near outlet.

Inlet.

Inlet.

View inside inlet.

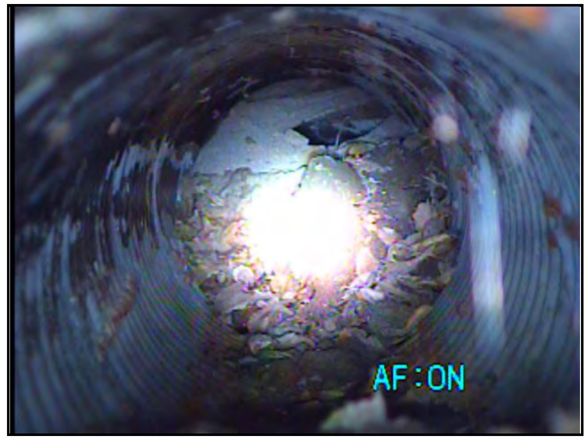
Outlet.

View inside outlet.

Arastradero Rd.

Culvert A-35

View inside outlet.



View inside outlet.

View inside outlet.

Arastradero Rd.

Culvert A-36

Location Map

Arastradero Rd.

Culvert A-36

Evaluation date/time:	11/24/2014 8:51 AM
Address/location:	Arastradero Rd.
Weather:	Dry

General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	No
Access:	Good	**Susceptible to ponding/flooding:**	No
Traffic:	Heavy	Sediment/debris depth (%):	50
Ground surface type:	Asphalt	Type of sediment/debris:	Silt, gravel, vegetation
Dia./Ht. (in.):	12	Infiltration:	None
Width (in.):		Obstruction/deflection:	0
Material:	CMP	VANDA condition rating:	Level 3 - Moderate Damage
U/S grade/rim-inv. (ft.):	1.5	Prioritization rating:	Level 4 - Poor
D/S grade/rim-inv. (ft.):	1.75	Prioritization rationale:	Condition, location, sediment
Water level (%):	0	Illegal dumping evidence:	No

Notes

Pipe runs under the road. Pipe about half full of debris. Possible significant corrosion.

Photos

Area view.

Area near inlet.

Arastradero Rd.

Culvert A-36

Area near inlet.

Area near outlet.

Area near outlet.

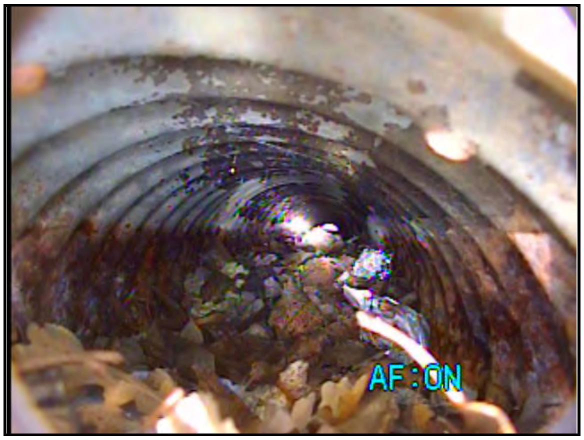
Inlet.

Inlet.

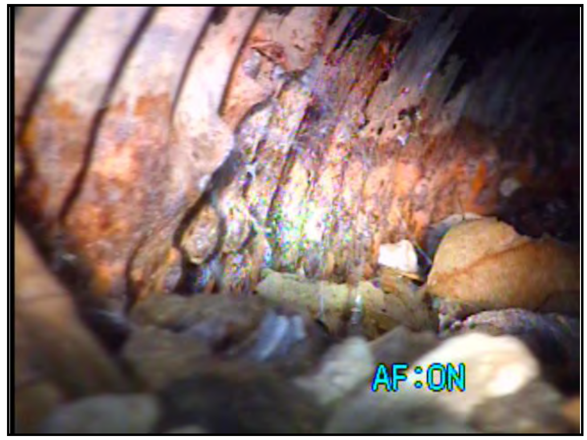
View inside inlet.

Arastradero Rd.

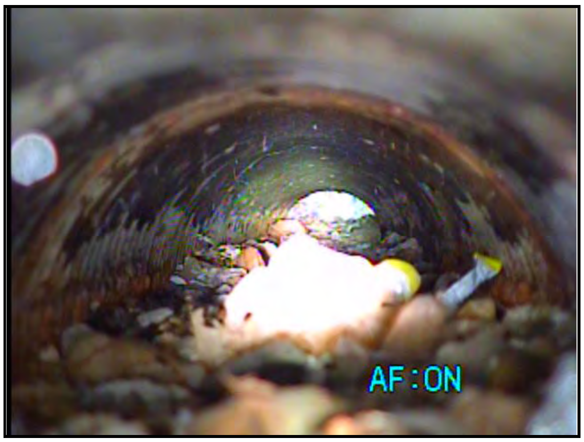
Culvert A-36



View inside inlet.



View inside inlet.



View inside inlet.

Outlet.

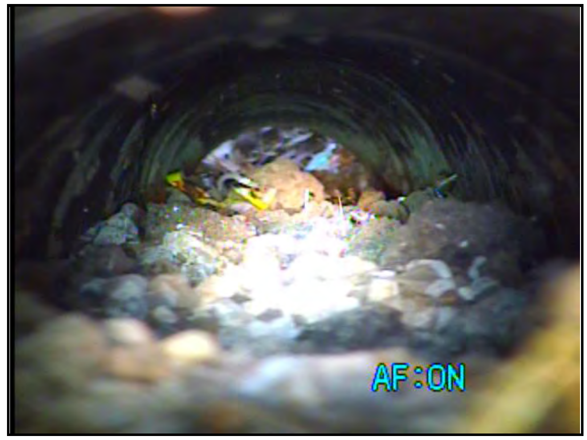
Outlet.

View inside outlet.

Arastradero Rd.

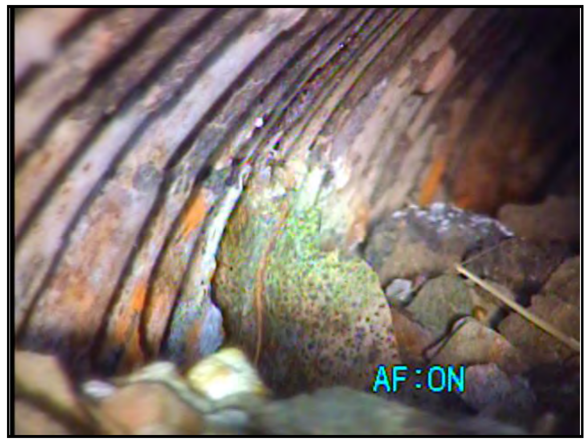
Culvert A-36

View inside outlet.



View inside outlet.

View inside outlet.

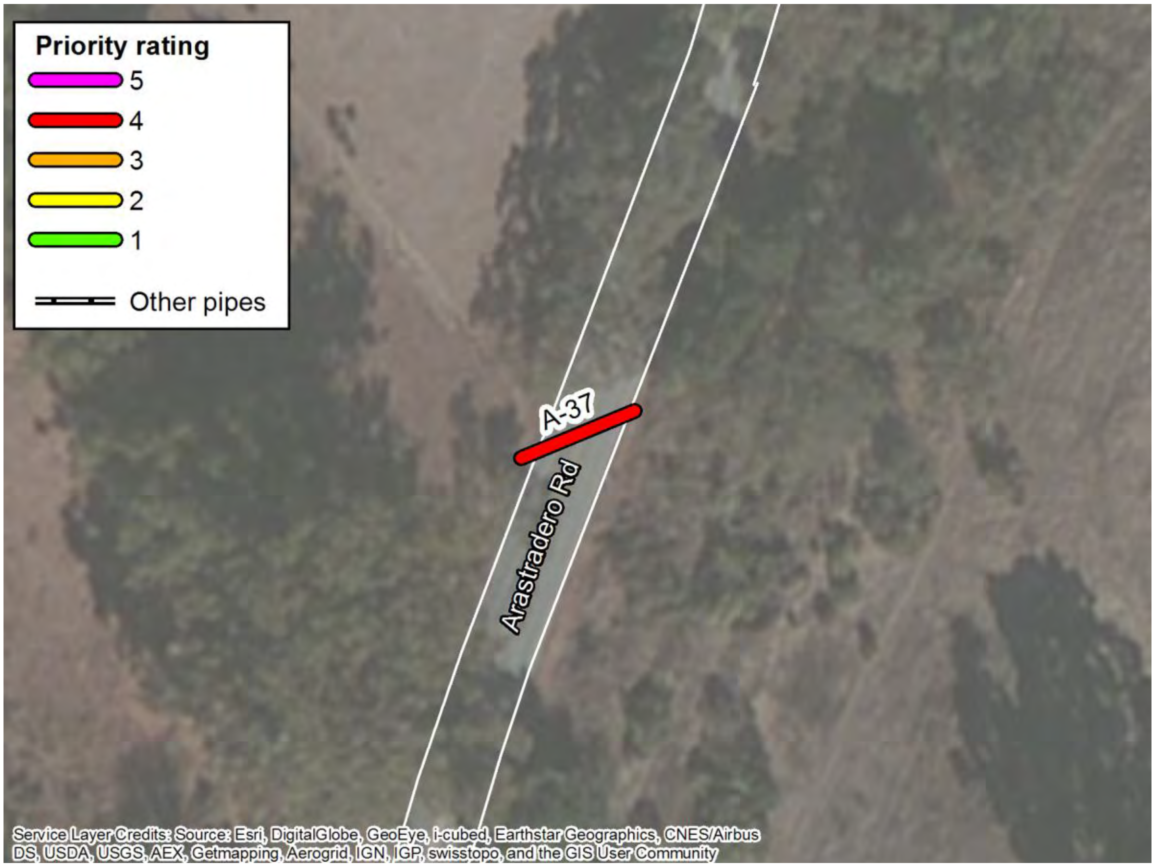


View inside outlet.

Arastradero Rd.

Culvert A-37

Location Map



Arastradero Rd.

Culvert A-37

Evaluation date/time:	11/24/2014 9:06 AM
Address/location:	Arastradero Rd.
Weather:	Dry

General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	Yes
Access:	Fair	**Susceptible to ponding/flooding:**	No
Traffic:	Heavy	Sediment/debris depth (%):	30
Ground surface type:	Asphalt, grass/dirt	Type of sediment/debris:	Silt, gravel, vegetation
Dia./Ht. (in.):	12	Infiltration:	None
Width (in.):		Obstruction/deflection:	0
Material:	CMP	VANDA condition rating:	Level 3 - Moderate Damage
U/S grade/rim-inv. (ft.):		Prioritization rating:	Level 4 - Poor
D/S grade/rim-inv. (ft.):	4	Prioritization rationale:	Condition, location, burial
Water level (%):	0	Illegal dumping evidence:	No

Notes

Pipe runs under roadway. Inlet not accessible; apparently buried under vegetation. Moderate corrosion on interior surfaces.

Photos

Area near inlet.

Inlet (apparently buried).

Arastradero Rd.

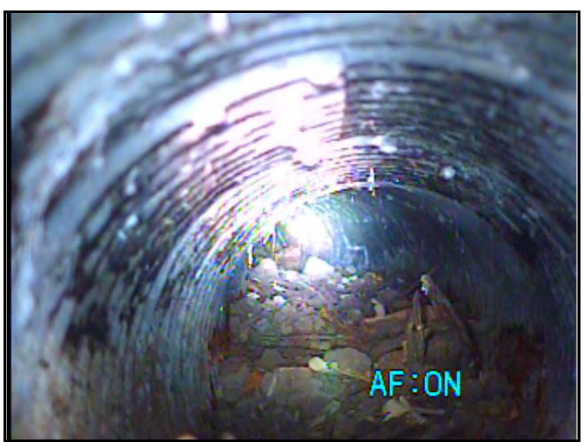
Culvert A-37


Outlet (nearly obstructed).


Outlet (nearly obstructed).


View inside outlet.

View inside outlet.

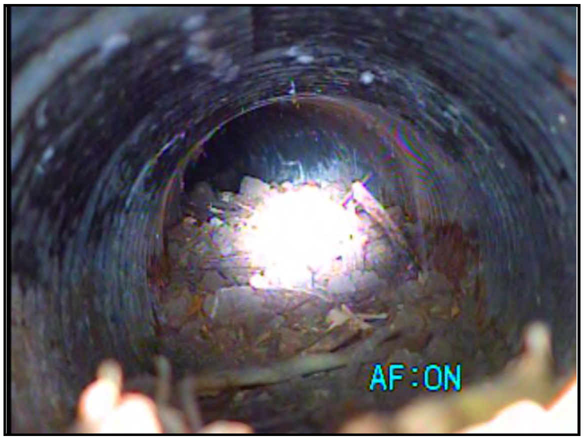


View inside outlet.

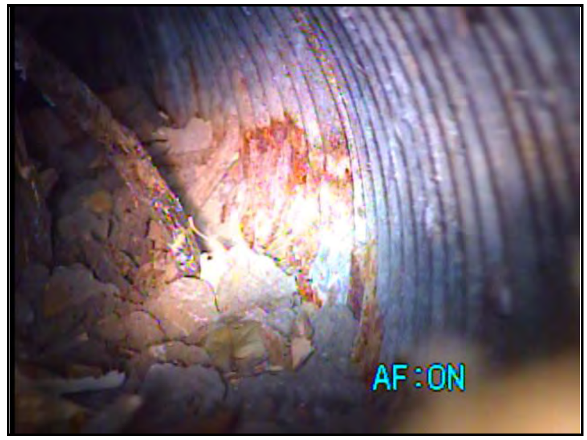
View inside outlet.

Arastradero Rd.

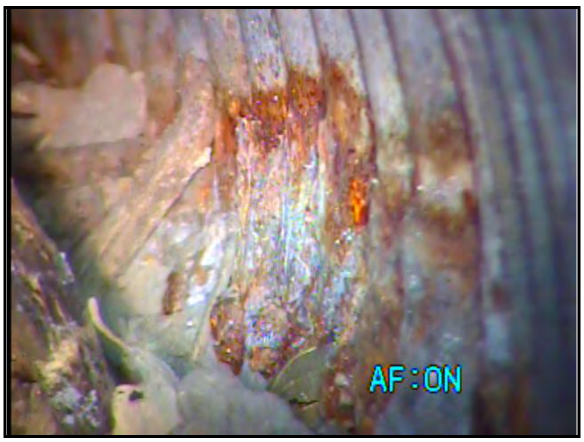
Culvert A-37



View inside outlet.



View inside outlet.

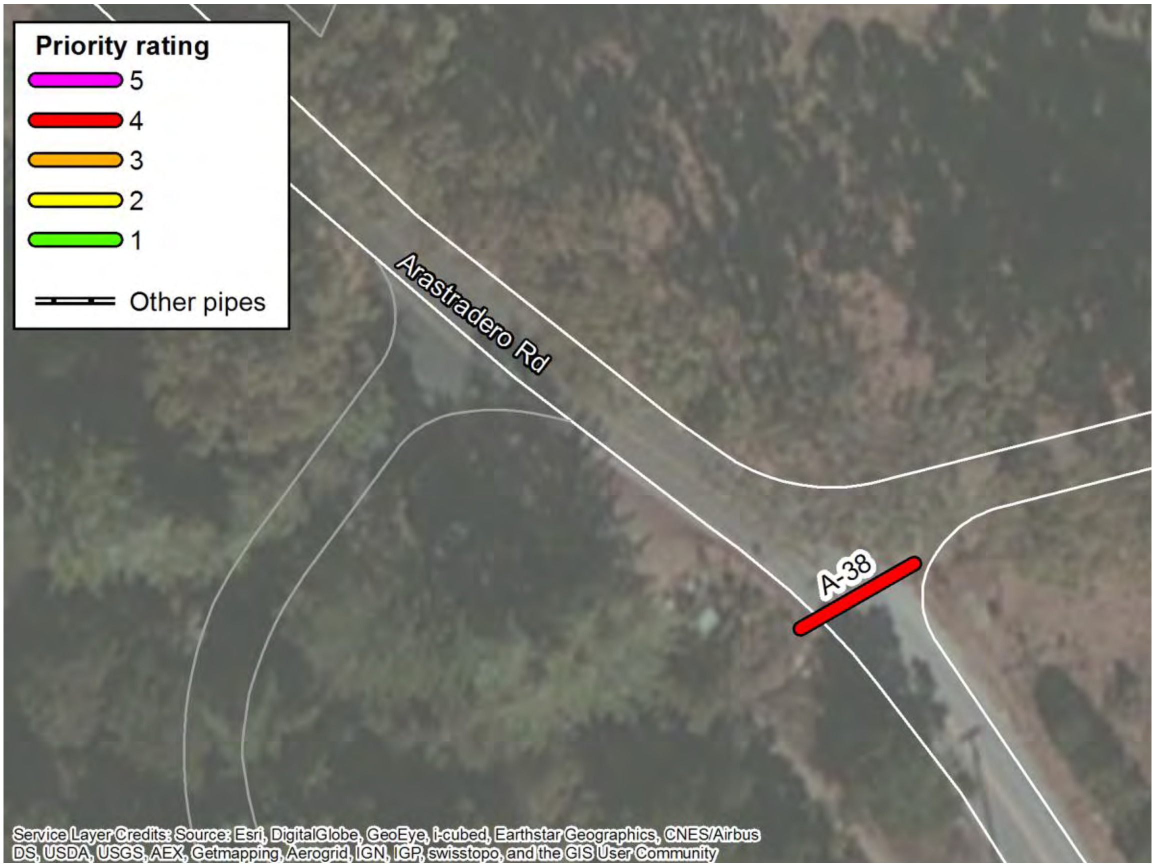


View inside outlet.

Arastradero Rd.

Culvert A-38

Location Map



Arastradero Rd.

Culvert A-38

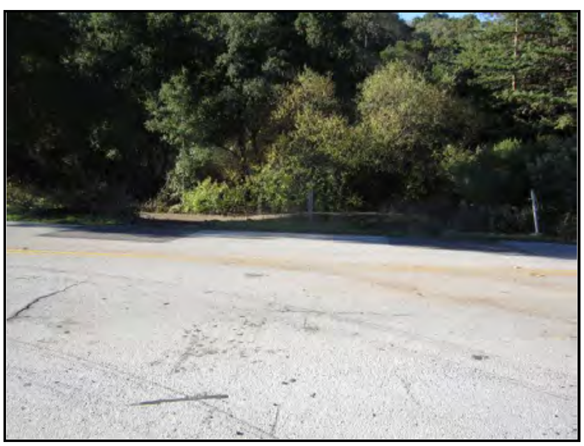
Evaluation date/time:	11/24/2014 9:22 AM
Address/location:	Arastradero Rd.
Weather:	Dry

General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	No
Access:	Good	**Susceptible to ponding/flooding:**	No
Traffic:	Heavy	Sediment/debris depth (%):	50
Ground surface type:	Asphalt	Type of sediment/debris:	Silt, vegetation
Dia./Ht. (in.):	12	Infiltration:	None
Width (in.):		Obstruction/deflection:	0
Material:	CMP	VANDA condition rating:	Level 2 - Minor Damage
U/S grade/rim-inv. (ft.):	2	Prioritization rating:	Level 4 - Poor
D/S grade/rim-inv. (ft.):	2.5	Prioritization rationale:	Sediment
Water level (%):	0	Illegal dumping evidence:	No

Notes

Pipe runs under the road. Coating failure and minor corrosion at invert. About half full of dirt at inlet. Inlet has short section of plastic pipe and then transitions to CMP.

Photos



Area view.

Area near inlet.

Arastradero Rd.

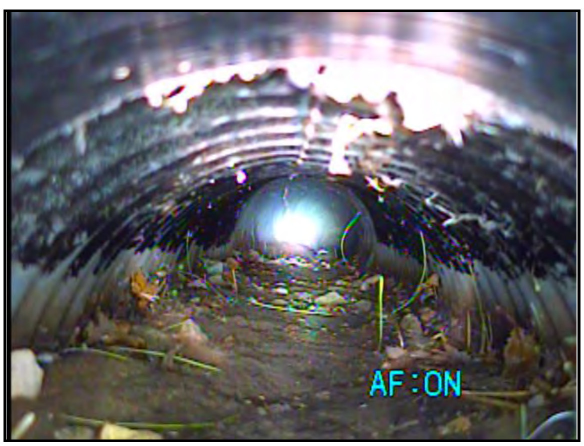
Culvert A-38

Area near outlet.

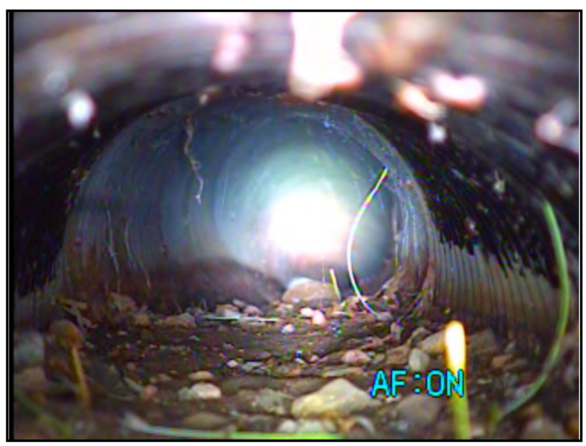
Inlet.

Inlet.

View inside inlet.



View inside inlet.



View inside inlet.

Arastradero Rd.

Culvert A-38

View inside inlet.

View inside inlet.

Outlet.

Outlet.

Outlet.

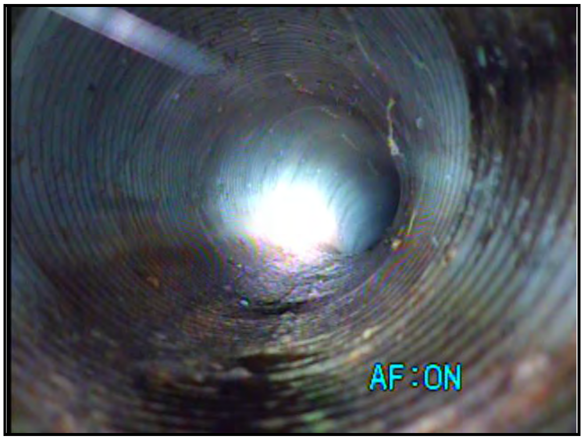
View inside outlet.

Arastradero Rd.

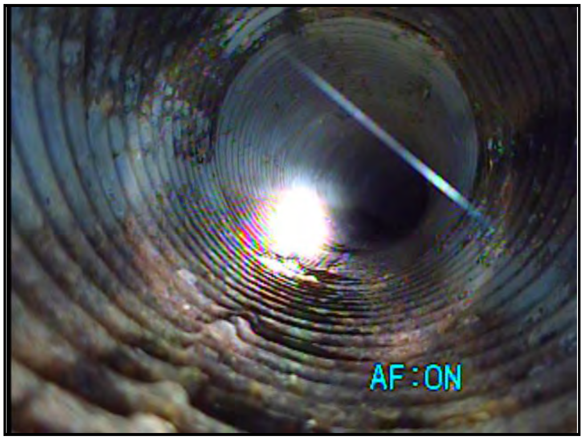
Culvert A-38

View inside outlet.

View inside outlet.



View inside outlet.



View inside outlet.

Los Trancos Rd.

Culvert A-39

Location Map

Los Trancos Rd.

Culvert A-39

Evaluation date/time:	11/19/2014 1:44 PM
Address/location:	Los Trancos Rd.
Weather:	Dry

General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	Yes
Access:	Fair	**Susceptible to ponding/flooding:**	No
Traffic:	Light	Sediment/debris depth (%):	50
Ground surface type:	Asphalt	Type of sediment/debris:	Unknown
Dia./Ht. (in.):	15	Infiltration:	None
Width (in.):		Obstruction/deflection:	0
Material:	CMP	VANDA condition rating:	Level 2 - Minor Damage
U/S grade/rim-inv. (ft.):	2	Prioritization rating:	Level 5 - Immediate Attention
D/S grade/rim-inv. (ft.):		Prioritization rationale:	Condition, location, blockage
Water level (%):	0	Illegal dumping evidence:	No

Notes

Pipe appears to be blocked. Outlet not accessible. Inlet deflected. Minor corrosion on interior pipe surfaces. There is another culvert near the inlet under a nearby driveway.

Photos

Area view.

Area near inlet.

Los Trancos Rd.

Culvert A-39

Area near inlet. Inlet to A-39 at upper left. Outlet of culvert under driveway at lower right.

Area near outlet.

Area near outlet.

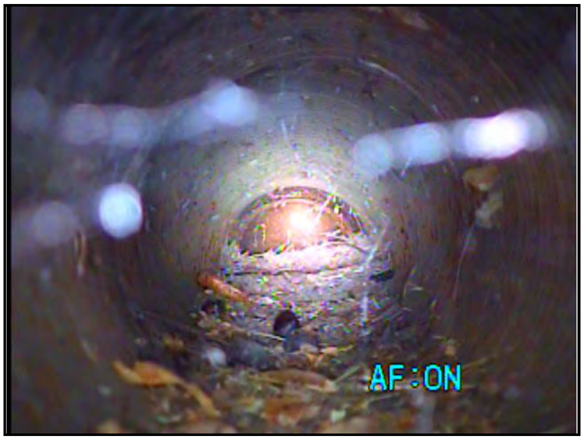
Inlet.

View inside inlet.

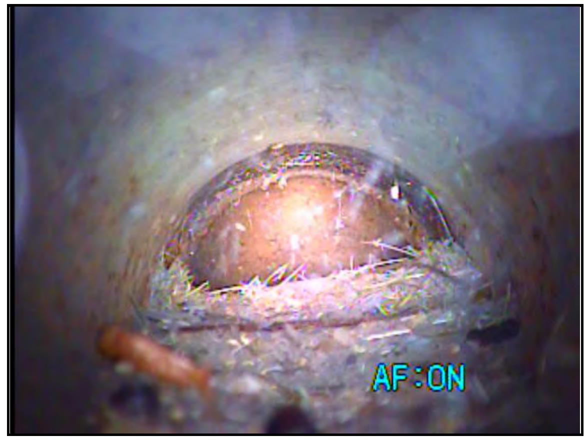
View inside inlet.

Los Trancos Rd.

Culvert A-39

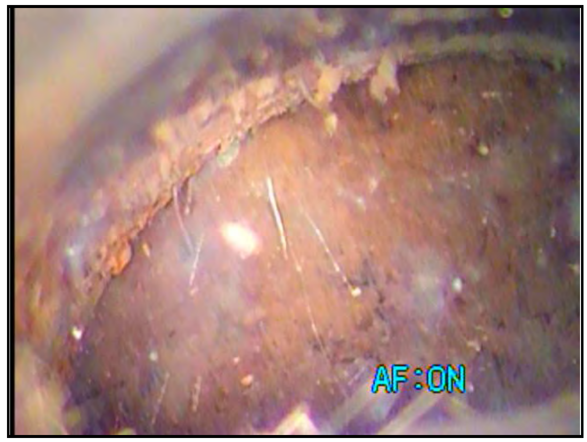


View inside inlet.

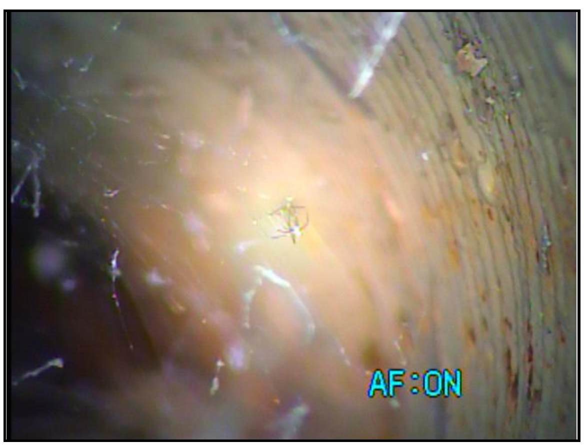


View inside inlet. Culvert appears to be blocked.

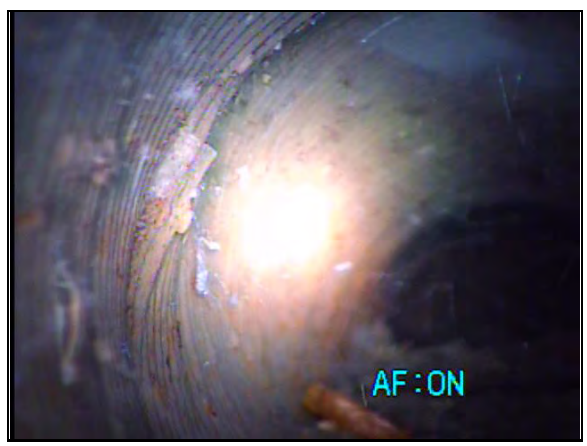
View inside inlet. Culvert appears to be blocked.



View inside inlet. Culvert appears to be blocked.



View inside inlet.



View inside inlet.

Los Trancos Rd.

Culvert A-39

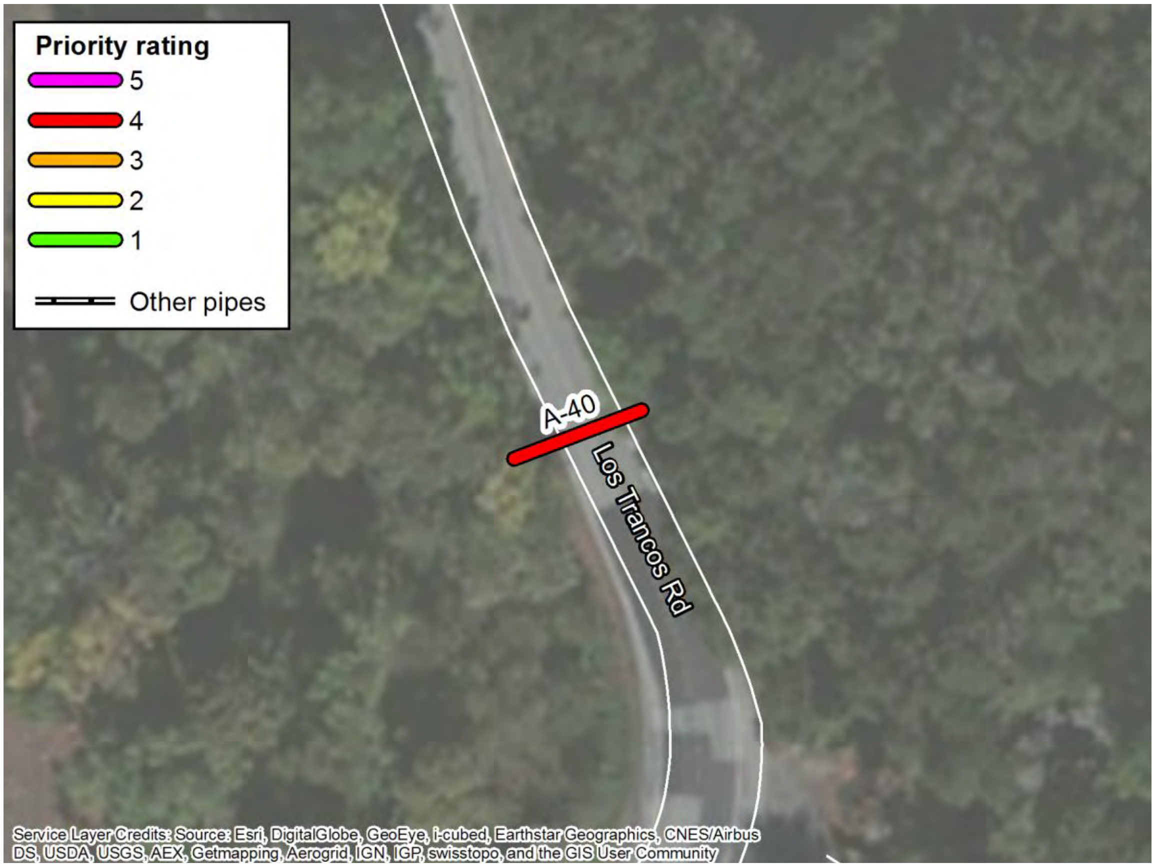
View inside inlet.

Outlet of culvert under driveway.

Los Trancos Rd.

Culvert A-40

Location Map



Los Trancos Rd.

Culvert A-40

Evaluation date/time:	11/19/2014 1:21 PM
Address/location:	Los Trancos Rd.
Weather:	Dry

General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	Yes
Access:	Fair	**Susceptible to ponding/flooding:**	No
Traffic:	Light	Sediment/debris depth (%):	50
Ground surface type:	Asphalt	Type of sediment/debris:	Silt, vegetation
Dia./Ht. (in.):	15	Infiltration:	None
Width (in.):		Obstruction/deflection:	0
Material:	CMP	VANDA condition rating:	Level 3 - Moderate Damage
U/S grade/rim-inv. (ft.):	2	Prioritization rating:	Level 4 - Poor
D/S grade/rim-inv. (ft.):		Prioritization rationale:	Condition, location
Water level (%):	50	Illegal dumping evidence:	No

Notes

Pipe runs under the road. Could not locate outlet. Pipe appears to have experienced significant corrosion and may be perforated. Pipe is about half full with sediment or standing water.

Photos

Area near inlet.


Area near outlet.

Los Trancos Rd.

Culvert A-40


Inlet.


Inlet.


View inside inlet.

View inside inlet.

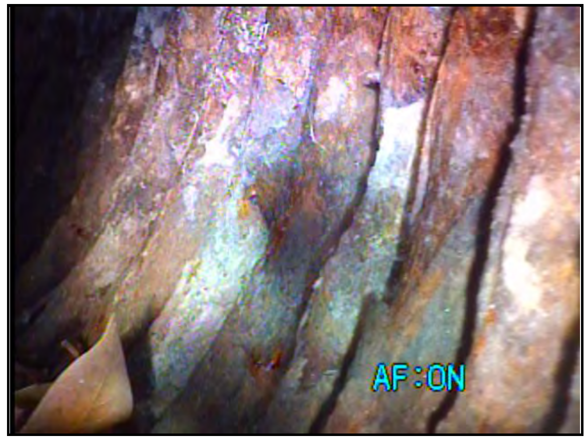
View inside inlet.

View inside inlet.

Los Trancos Rd.

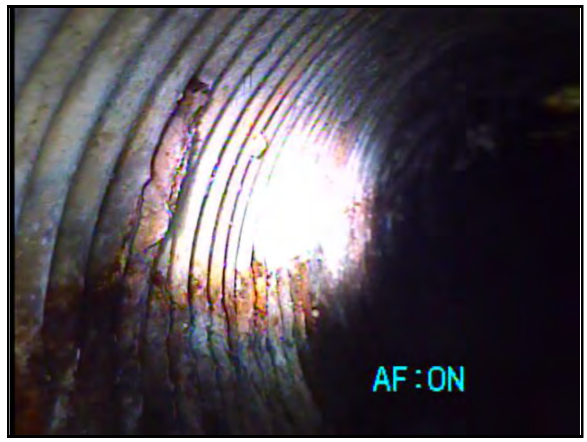
Culvert A-40

View inside inlet.



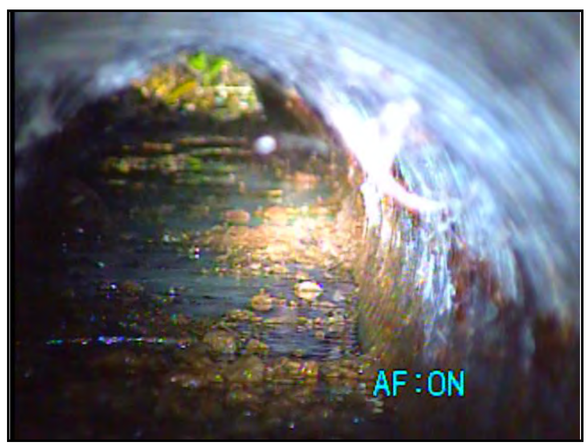
View inside inlet.

View inside inlet.



View inside inlet.

View inside inlet.



View inside inlet.

Los Trancos Rd.

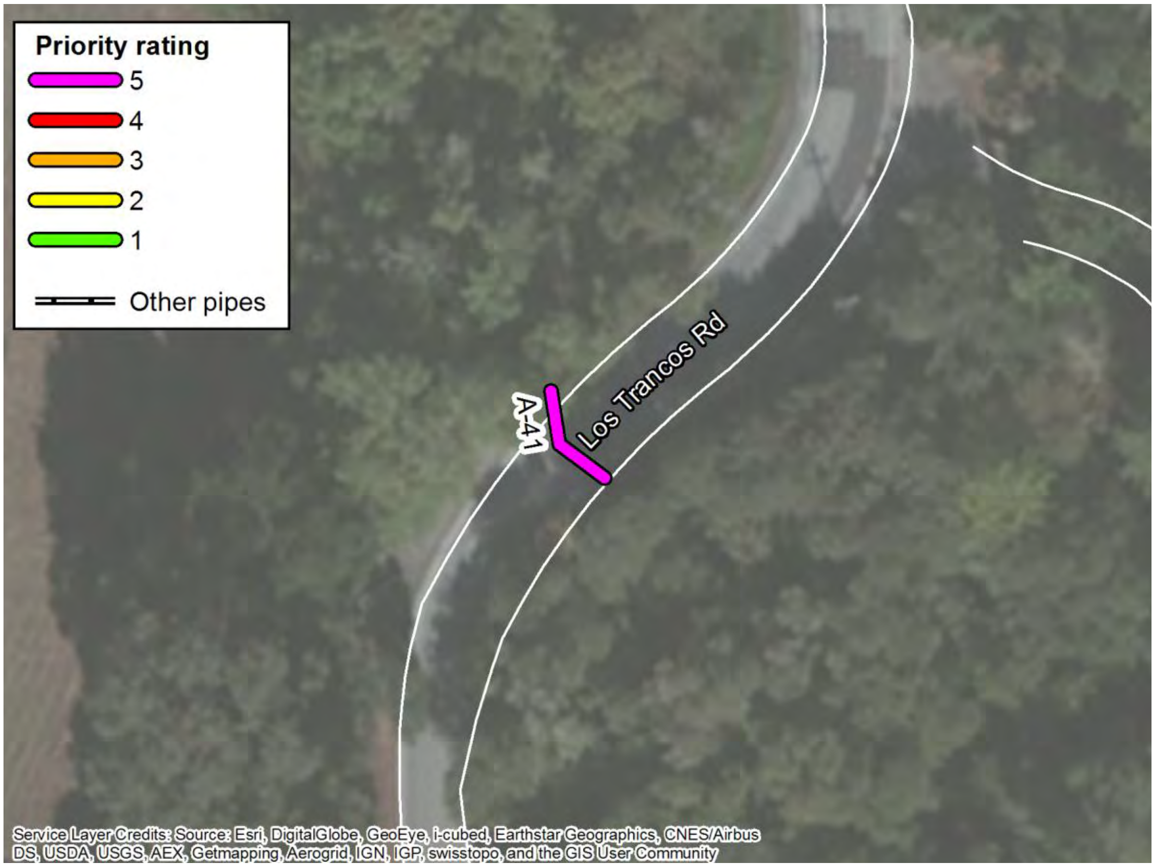
Culvert A-40

View inside inlet.

Los Trancos Rd.

Culvert A-41

Location Map



Los Trancos Rd.

Culvert A-41

Evaluation date/time:	11/19/2014 1:13 PM
Address/location:	Los Trancos Rd.
Weather:	Dry

General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	No
Access:	Good	**Susceptible to ponding/flooding:**	Yes
Traffic:	Light	Sediment/debris depth (%):	0
Ground surface type:	Asphalt	Type of sediment/debris:	None
Dia./Ht. (in.):	24	Infiltration:	None
Width (in.):		Obstruction/deflection:	0
Material:	CMP	VANDA condition rating:	Level 3 - Moderate Damage
U/S grade/rim-inv. (ft.):	5	Prioritization rating:	Level 5 - Immediate Attention
D/S grade/rim-inv. (ft.):	5.25	Prioritization rationale:	Condition, location, capacity
Water level (%):	25	Illegal dumping evidence:	No

Notes

Standing water at outlet. Significant corrosion above water level. Could not see invert due to flowing water. Possible void at bend near outlet. City staff indicated that this culvert overtops on approximately a yearly basis during wet weather.

Photos

Area view.

Area near inlet.

Los Trancos Rd.

Culvert A-41

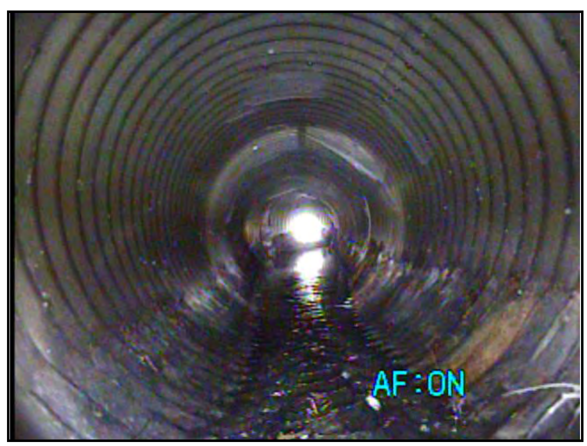
Area near outlet.

Area near outlet.

Inlet.

Inlet.

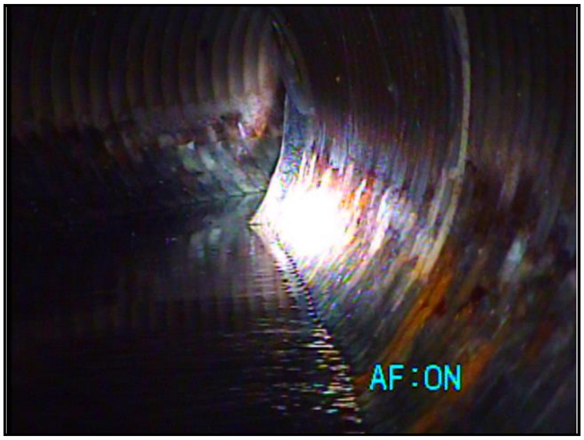
View inside inlet.



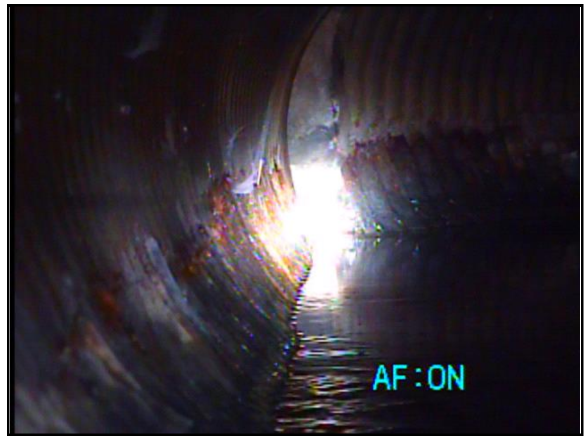
View inside inlet.

Los Trancos Rd.

Culvert A-41

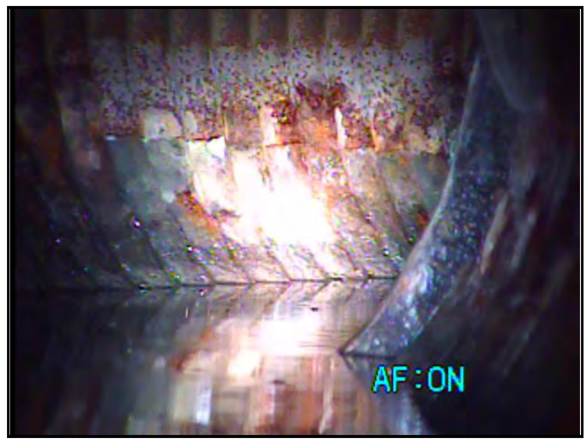


View inside inlet.

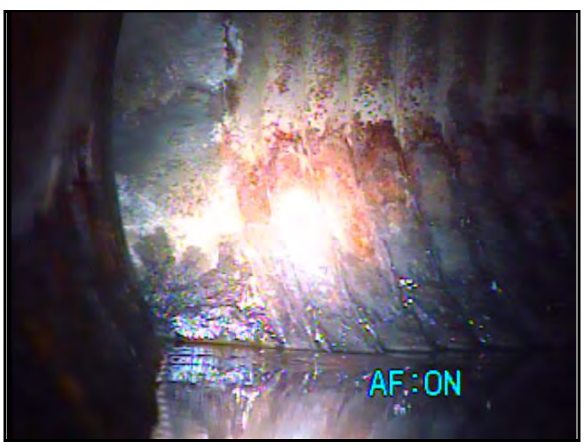


View inside inlet.

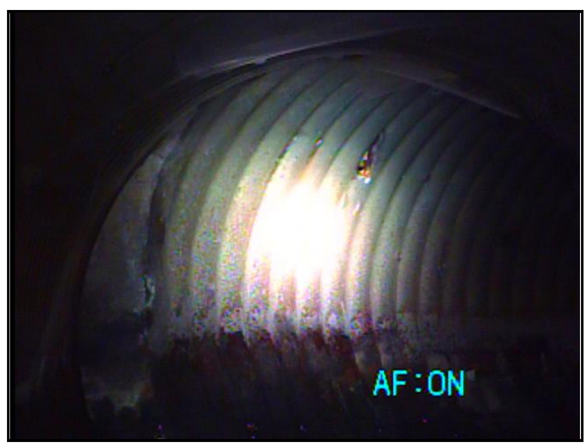
View inside inlet.



View inside inlet. Possible void at bend downstream.



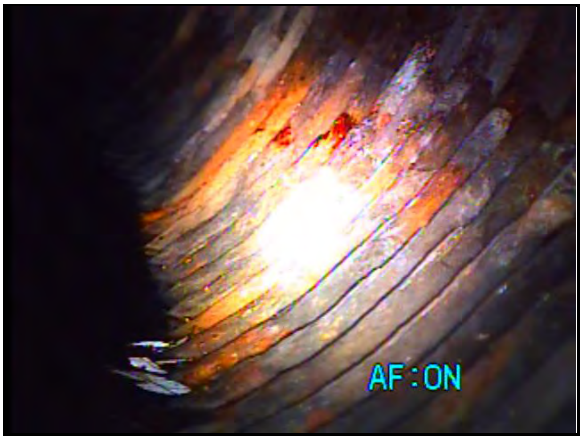
View inside inlet. Possible void at bend downstream.



View inside inlet. Possible void at bend downstream.

Los Trancos Rd.

Culvert A-41



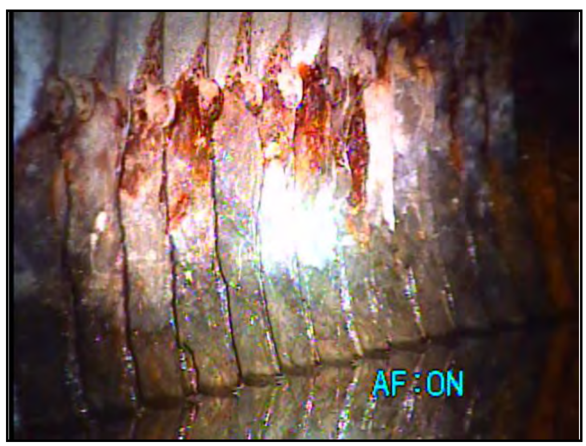
View inside inlet.

View inside inlet.

View inside inlet.

Outlet.

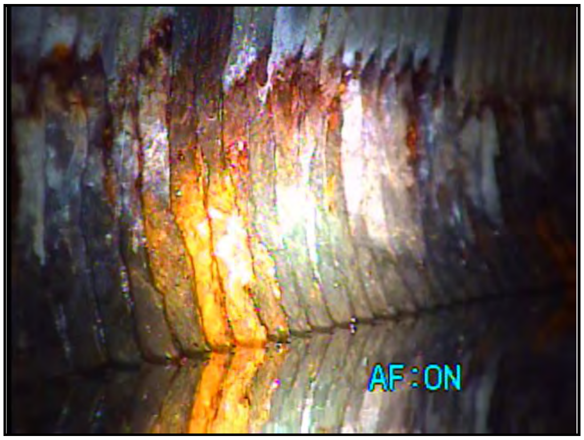
View inside outlet.



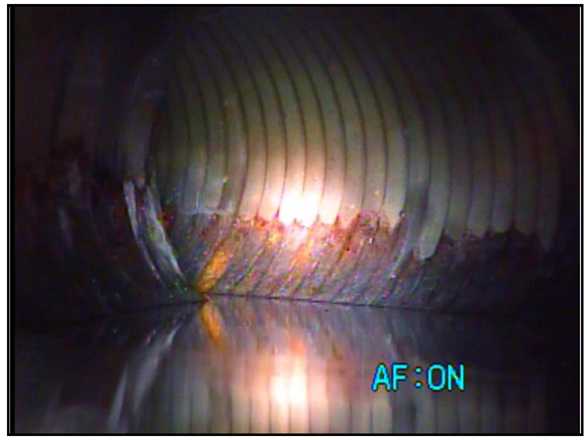
View inside outlet.

Los Trancos Rd.

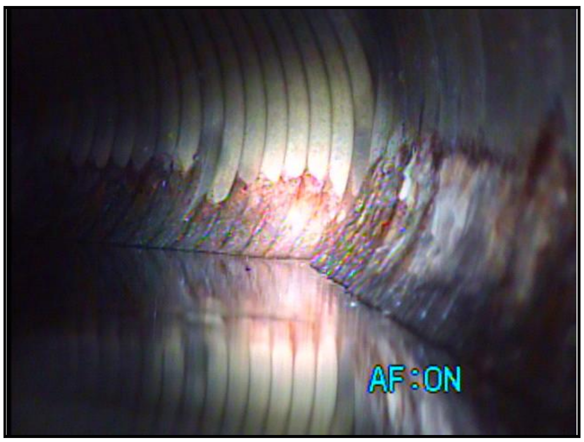
Culvert A-41



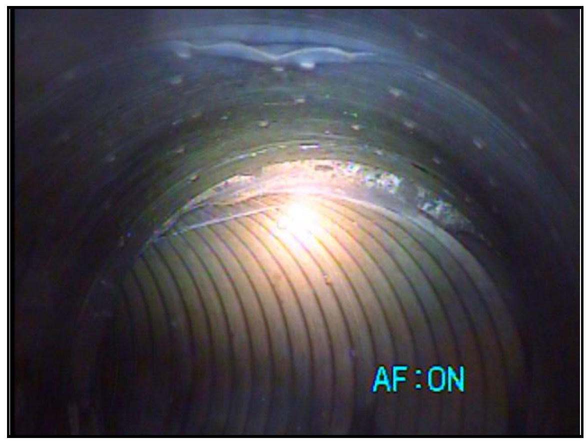
View inside outlet.



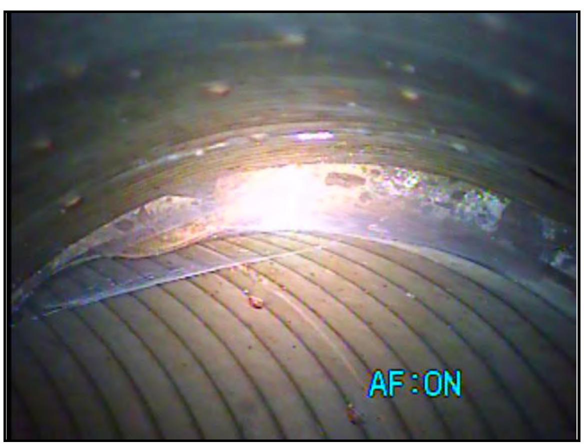
View inside outlet.



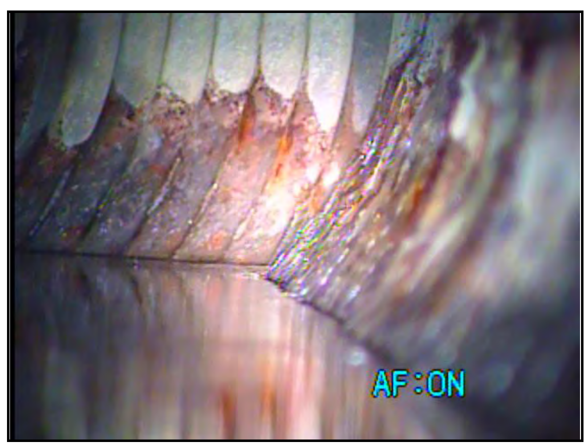
View inside outlet.



View inside outlet. Possible void at bend.



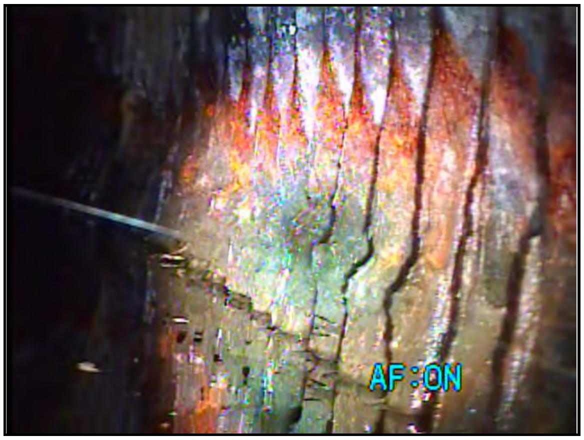
View inside outlet. Possible void at bend.



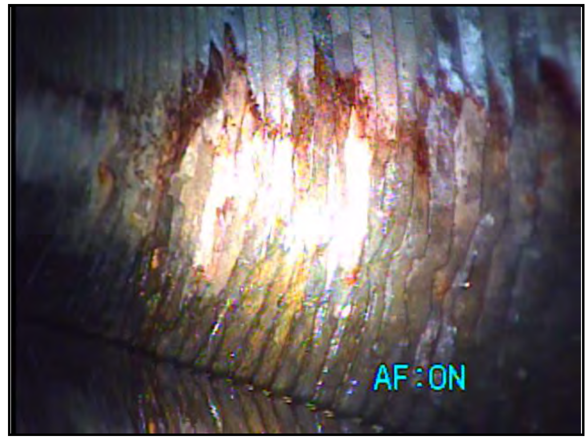
View inside outlet.

Los Trancos Rd.

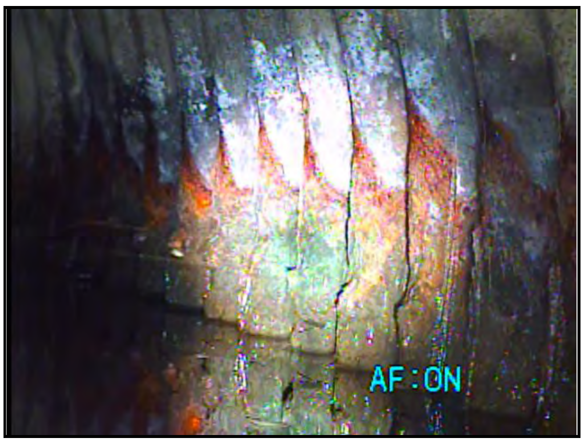
Culvert A-41



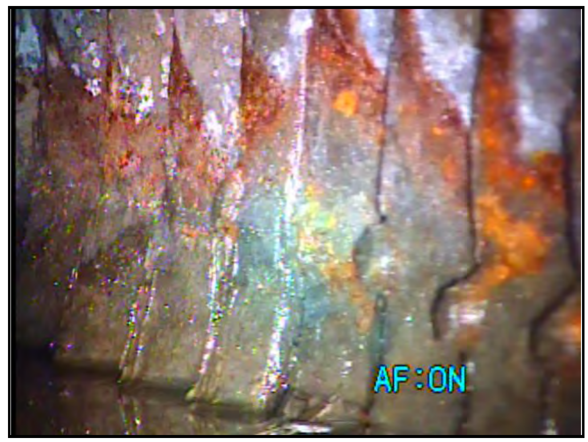
View inside outlet. Significant corrosion.



View inside outlet. Significant corrosion.



View inside outlet. Significant corrosion.



View inside outlet.

Los Trancos Rd.

Culvert A-42

Location Map

Los Trancos Rd.

Culvert A-42

Evaluation date/time:	11/19/2014 12:50 PM
Address/location:	Los Trancos Rd.
Weather:	Dry

General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	Yes
Access:	Good	**Susceptible to ponding/flooding:**	No
Traffic:	Light	Sediment/debris depth (%):	80 - 100
Ground surface type:	Asphalt	Type of sediment/debris:	Soil
Dia./Ht. (in.):	12	Infiltration:	None
Width (in.):		Obstruction/deflection:	0
Material:	RCP	VANDA condition rating:	Level 1 - No Damage
U/S grade/rim-inv. (ft.):	1.5	Prioritization rating:	Level 5 - Immediate Attention
D/S grade/rim-inv. (ft.):	1.5	Prioritization rationale:	Sediment
Water level (%):	0	Illegal dumping evidence:	No

Notes

Pipe nearly completely full of sediment. Concrete pipe is in good condition.

Photos


Area view.


Inlet after digging out debris.

Los Trancos Rd.

Culvert A-42

View inside inlet.

View inside inlet.

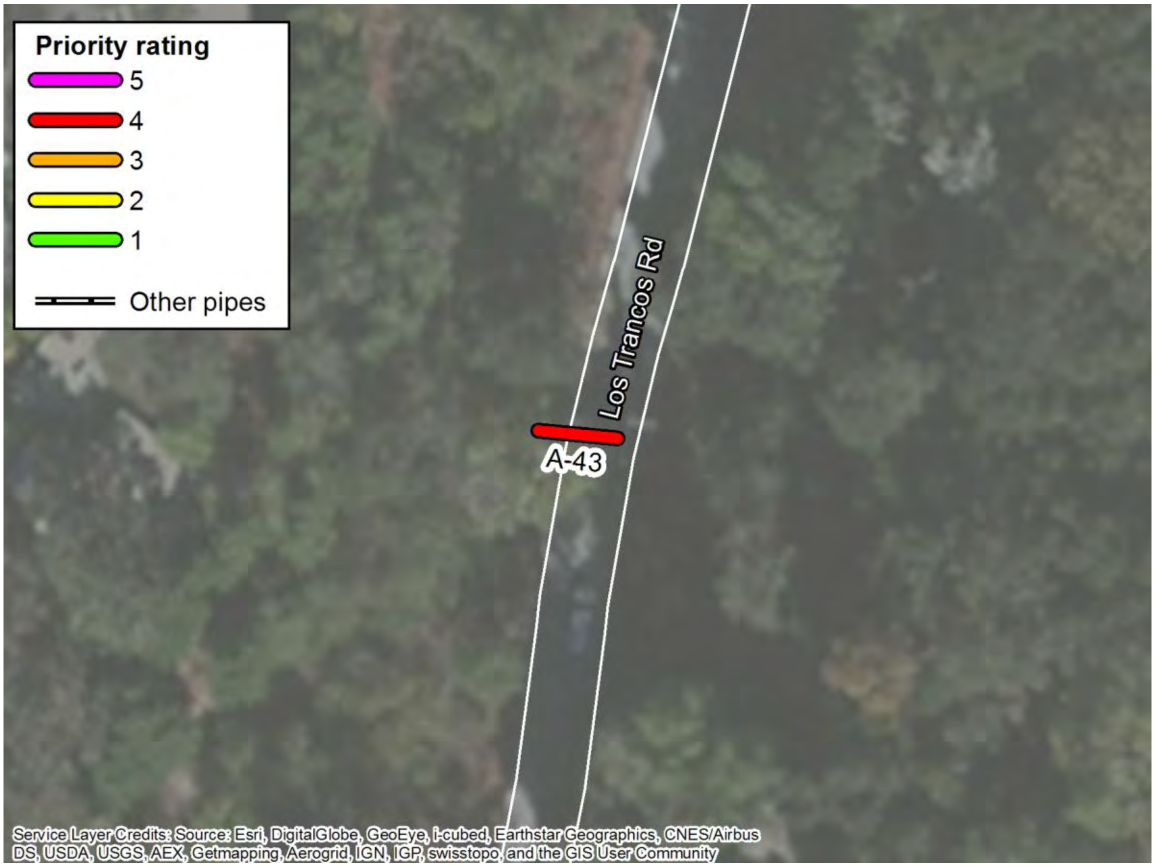
View inside outlet.

View inside outlet.

Los Trancos Rd.

Culvert A-43

Location Map



Los Trancos Rd.

Culvert A-43

Evaluation date/time:	11/19/2014 12:21 PM
Address/location:	Los Trancos Rd.
Weather:	Dry

General Information		Condition Information and Ratings	
Property type:	Public	**Susceptible to burial/overgrowth:**	No
Access:	Good	**Susceptible to ponding/flooding:**	No
Traffic:	Light	Sediment/debris depth (%):	20
Ground surface type:	Asphalt	Type of sediment/debris:	Soil
Dia./Ht. (in.):	12	Infiltration:	None
Width (in.):		Obstruction/deflection:	15
Material:	CMP/RCP	VANDA condition rating:	Level 4 - Severe/Significant Damage
U/S grade/rim-inv. (ft.):	1.5	Prioritization rating:	Level 4 - Poor
D/S grade/rim-inv. (ft.):	4	Prioritization rationale:	Condition, location, construction features
Water level (%):	0	Illegal dumping evidence:	No

Notes

Ends of culvert appear to be RCP. Middle section under roadway is CMP, which is in poor condition. Joints are offset at transitions to CMP. Invert of CMP may be perforated.

Photos

Area view.

Area near inlet.

Los Trancos Rd.

Culvert A-43

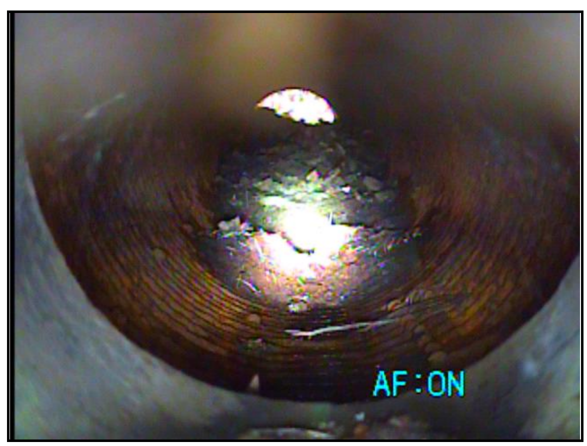
Area near outlet.

Inlet.

View inside inlet.

View inside inlet.

View inside inlet. Offset joint at transition to CMP. CMP appears to be significantly corroded.



View inside inlet. Offset joint at transition to CMP. CMP appears to be significantly corroded.

Los Trancos Rd.

Culvert A-43

View inside inlet. Offset joint at transition to CMP. CMP appears to be significantly corroded.

View inside inlet. Offset joint at transition to CMP. CMP appears to be significantly corroded.

Outlet.

Outlet.

Outlet.

View inside outlet.

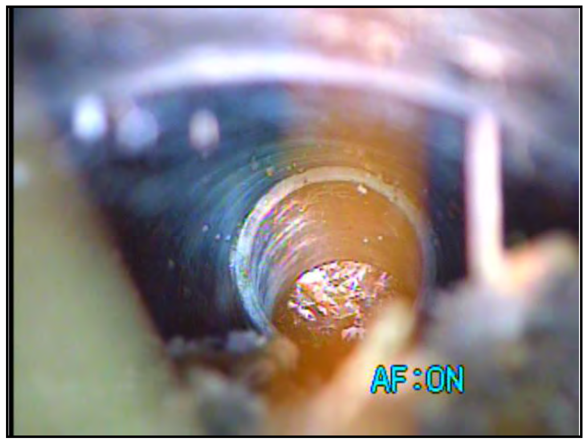
Los Trancos Rd.

Culvert A-43

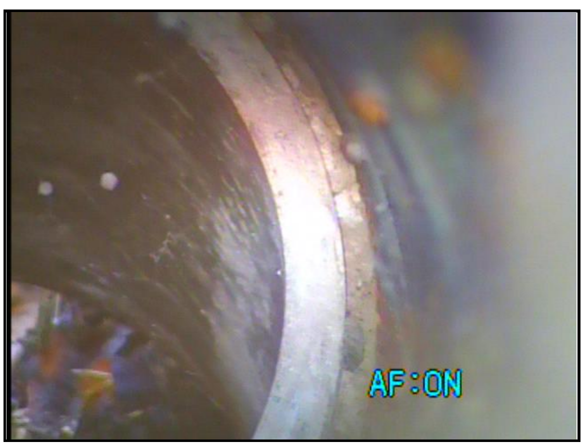
View inside outlet.

View inside outlet. Offset joint at transition to CMP.

View inside outlet. Offset joint at transition to CMP.



View inside outlet. Offset joint at transition to CMP.

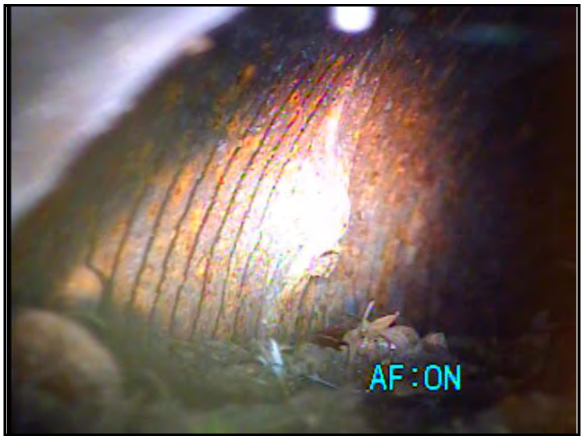


View inside outlet. Offset joint at transition to CMP.

View inside outlet. Apparent damage to CMP.

Los Trancos Rd.

Culvert A-43



View inside outlet. Offset joint at transition to CMP.

Los Trancos Rd.

Bridge Bridge_near_A-43

Location Map

Los Trancos Rd.

Bridge Bridge_near_A-43

Evaluation date/time:	11/19/2014 12:00 PM
Address/location:	Los Trancos Rd.
Weather:	Dry

Notes

Bridge near A-43 includes a storm drain inlet over the creek channel. Bridge was not assessed.

Photos


Area view.

Storm drain inlet on bridge.


Storm drain inlet on bridge.