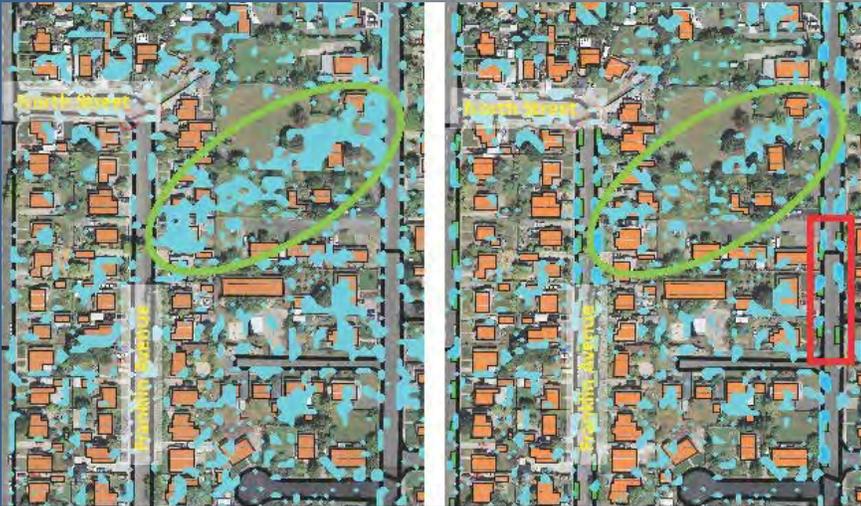
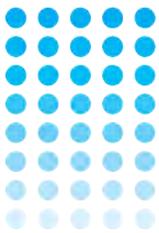


Stormwater Infrastructure Assessment Bay Point, California



Prepared for:
The Watershed Project



the
watershed
project

Prepared by:



October 31, 2017

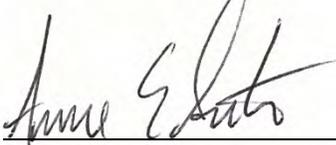
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EXECUTIVE SUMMARY

Work efforts in support of this study focused on addressing the lack of detailed assessments of stormwater infrastructure and flood hazards in disadvantaged communities (DACs), where adequate stormwater conveyance was not constructed when the community was built, or not fully improved in subsequent years. These activities were conducted in support of the Bay Area Integrated Regional Water Management Plan (IRWMP) Coordinating Committee objectives to advance local and regional water resource management goals through synergistic collaboration of agencies, communities, and other project partners. IRWMP objectives included assessment of DAC water quality and flood protection needs, such that resultant information would be of benefit within the San Francisco Bay Area region.

The DAC of unincorporated Bay Point, California, as delineated using the U.S. Census “census designated place” boundary, was the geographic location of the study. Initial stormwater infrastructure and flood hazards field reconnaissance, and review of available data, revealed nuisance flood issues related to localized erosion and ponding of water, as well as trash conveyance issues, as more problematic than larger-scale flooding issues. In consultation with The Watershed Project, the emphasis in project goals was shifted from strictly flood hazard assessment to one that included assessment of the potential benefits of low impact development (LID) features. This shift in project focus allowed for modeling efforts that investigated specific options for retrofitting existing communities with LID features such as rain gardens, bio-retention swales, permeable pavement, and trash capture installations.

A series of field site visits, hydrologic data collection and assessments, and stormwater modeling efforts were used to understand how existing stormwater infrastructure operates during storm events and to characterize local flood hazards in two representative study areas. Modeling efforts furthermore examined how inclusion of LIDs could address existing drainage issues. Public outreach efforts included plans to engage local community members and students in data collection and monitoring efforts so that community members could become more familiar with and more invested in their local watersheds.

The Bay Point community is situated in north-central Contra Costa County, along the southern coastal lowlands of the Sacramento-San Joaquin-San Francisco Bay Delta (Delta). The tributaries of Willow Creek watershed originate in the steep Diablo Range foothills and flow northerly across the low-slope coastal lowlands to the tidal wetlands of

the Delta. Average yearly rainfall in the watershed ranges from 12-18 inches depending on elevation, typical for Mediterranean-climate coastal California environments. Almost all rainfall occurs between October and May each year. Depending on storm intensity, antecedent conditions, and stormwater infrastructure, watershed responses to flows in the Willow Creek watershed can range from minor creek flows to flood conditions.

One Willow Creek channel, in the sub-watershed area identified as Willow Creek East, runs through the oldest known Bay Point neighborhood. It is approximately bounded by Highway 4 to the south, Willow Pass Road to the north and along Winter Way to Babbling Brook Way, Madison Avenue to the west, and Loftus Road to the east. Nuisance flows associated with rainfall runoff from impervious areas were the predominate neighborhood concern. These types of flows manifested as fast-moving waters along unimproved street edges with high sediment loads that caused erosion along home owner property lines. These conditions are the result of little to no stormwater infrastructure, such as curbs and gutters, to route neighborhood runoff into a stormwater drain system. This area was chosen for investigation of the addition of LID features such as bio-swales, rain gardens, and trash racks that would serve to break up long runoff pathways and reduce street and yard erosion and trash conveyance.

In the sub-watershed area of Willow Creek Central, another Bay Point neighborhood was selected for study. It is approximately bounded by the Mokelumne Aqueduct, Marys Avenue and Willow Pass Road to the south; Anchor Drive to the west; and undeveloped open space to the north and east. Intermittent flooding in the creek channel east of Anchor Drive and south of Skipper Road was the predominate neighborhood concern. This area contains a more modern stormwater drainage system; however, housing throughout this neighborhood was built prior to current regulatory requirements, so there are no significant peak flow controls or water-quality infrastructure best management practices (BMPs) in place. This neighborhood was used to investigate the addition of LID features such as pervious pavement to increase runoff infiltration and trash racks to prevent blockages.

Hydrologic monitoring efforts, consisting of instrumentation of streamflow monitoring sites and field site visits during and directly after storms, were conducted within the two study areas over portions of water years 2014 and 2015. In conjunction with monitoring information, field measurements of a modest number of stormdrain pipes were added to the modeling effort for a more accurate rendition of existing conditions.

Hydrologic data collection observations showed that stream runoff responded quickly and directly to rainfall. Late wet season rainfall produced similar volumetric runoff with less rainfall than early in the season. This result showed that with wet antecedent conditions, the watershed responds to less rainfall with similar flow magnitudes as early season, larger storms. Water quality results from two street-side samples in the Willow Creek Est neighborhood with little stormwater infrastructure indicated that road edge erosion, turbidity, and sediment transport were much more active than would be typical for neighborhoods with curb, gutter, and storm drain infrastructure.

Modeling efforts included use of 1-dimensional and 2-dimensional models to explore LID infrastructure improvements. As these investigations were at a planning scale rather than enumerating specific solutions, results are general in nature and would require refinement prior to use. Results found that in the study area of Willow Creek East, rain gardens or similar green infrastructure LID features have the potential to reduce nuisance flows, and invasive vegetation maintenance in the open channel between Hanlon Way and Willow Pass Road would reduce peak flows. In the study area of Willow Creek Central, the replacement of impermeable driveway with permeable materials but no subsurface stormwater storage capacity did not improve storm drainage conditions in this area.

Benefits derived from this project include:

1. Development of streamflow monitoring sites, resulting in a hydrologic monitoring framework that can be re-occupied in the Bay Point community for additional data collection and citizen-science involvement.
2. Field observations of wet season conditions during three water years: 2013, 2014, and 2015. Summaries of these visits are contained in this report, and can be integrated with field observations recorded in subsequent years.
3. Data collection of stream flow runoff and water quality in the Willow Creek watershed in two water years: 2014 and 2015. This information can form the basis for data collection efforts and comparisons in subsequent years.
4. Development of stormwater models that can be leveraged as platforms for investigate of additional areas in Bay Point or other DAC communities.
5. Stormwater model results that provide insights into existing conditions under a set of moderate flood conditions (i.e., 2-year and 10-year flows). Stormwater model results that identify that green infrastructure LID features could be useful, and how such installations would perform given the same set of flood conditions.

6. Stormwater model results that specifically identify areas where green infrastructure LID features could be installed, and how such installations would perform given the same set of moderate flood conditions.
7. Development of an ArcGIS database, with information that can be integrated into local and regional databases. The projected coordinate system for map package files is NAD_1983_StatePlane_California_III_FIPS_0403_Feet in Lambert_Conformal_Conic.
8. A comprehensive project report that provides a template for addressing similar hydrologic and stormwater management objectives in other communities.

1 INTRODUCTION

The California State *Safe Drinking Water, Water Quality and Supply, Flood Control, River and Coastal Protection Bond Act* (Proposition 84) was approved by California voters in 2006. To support the allocation of funds through the California Department of Water Resources to projects in the nine-county San Francisco Bay Area, the Bay Area Integrated Regional Water Management Plan (IRWMP) was instituted to provide an ongoing planning framework. From this platform, a wide range of multi-objective approaches continue to be identified, with an overarching mission of directing water resource management agencies and local communities to collaborate on projects that benefit regional citizens and the uniquely situated Bay Area ecosystem.

One specific objective of IRWMP was to identify critical water quality and flood protection needs within disadvantaged communities (DACs). To this end, IRWMP worked in collaboration with the San Francisco Estuary Partnership, Association of Bay Area Governments the Bay Area Flood Protection Agencies Association, the Bay Area Watershed Network, the Environmental Justice Coalition for Water, and the Watershed and Habitat Protection and Restoration functional area of the Bay Area IRWMP Coordinating Committee, to select DAC projects with goals of creating cooperative synergies in advancement of local and regional water resource management goals.

Within the IRWMP framework, various critical needs within DAC communities were identified. One such need included the lack of detailed assessments of stormwater infrastructure and flood hazards, particularly in areas where adequate stormwater conveyance was not originally constructed as part of a developing community. The unincorporated Bay Point area of Contra Costa County, California, was identified as a DAC community where stormwater infrastructure was not up to current standards in some locations within the community, and where no plans were under consideration to alleviate most of the inadequate conditions. In the Bay Point community, a lack of stormwater infrastructure was thought to potentially contribute to flood hazard conditions, especially in neighborhoods where no drainage improvements or best management practices (BMPs) have been implemented in the years since older housing developments were originally built.

A proposal to assess current conditions in Bay Point, California as well as to investigate potential stormwater improvements and flood reduction strategies was selected as one of the IRWMP projects in the initial Proposition 84 implementation cycle. Funding for the Bay Point project was awarded to The Watershed Project (TWP) by the San Francisco

Estuary Partnership. Located in Richmond, California, TWP is a nonprofit environmental organization dedicated to inspiring Bay Area communities to understand, appreciate, and protect local watersheds. TWP sought the services of Balance Hydrologics, Inc. (Balance) to support this work through field data collection, detailed hydrologic investigation, and stormwater modeling of representative study areas. Balance is an environmental consulting firm based in Berkeley, California, with extensive experience related to water resource assessments, stormwater control designs, and creek restoration projects. Balance professionals have extensive understanding of how water and related physical processes have shaped natural habitats and developed environments in watersheds throughout the Bay Area. This experience provides the basis for identification of effective solutions to hydrologic issues that are unique at the local level but which may be similarly applied at a regional level.

For this study, Balance staff conducted a series of field site visits, hydrologic assessments, and stormwater modeling efforts to understand how existing stormwater infrastructure operates during storm events and to characterize local flood hazards in two representative study areas. Modeling efforts examined existing conditions as well as how inclusion of low-impact development features (LIDs) could work to address known drainage issues. Public outreach efforts by TWP included plans to engage local community members and students in data collection and monitoring efforts so that community members could become more familiar with and more invested in their local watershed.

In addition to the efforts undertaken by TWP and Balance, various staff at the Contra Costa County Flood Control & Water Conservation District (“Public Works”) were important project partners, highlighting the need and desire for communities to work in unison with appropriate governmental agencies toward quality of life improvements at the public level. Public Works staff shared their time and knowledge with TWP and Balance during the investigation of stormwater infrastructure and flood hazards within the Bay Point community. Information provided by Public Works included a field site visit of problem areas of localized flooding and nuisance areas to discuss and document existing conditions, a partial storm drain inventory, and public complaint records of flooding. The Contra County information technology department provided existing Geographic Information System (GIS) layers via their publicly available website. In addition, Public Works and Balance staff.

1.1 Project Objectives

The initial goals of this study were to document and assess stormwater infrastructure and flood hazard conditions within DAC areas of unincorporated Bay Point, California. Initial field reconnaissance and a review of available data revealed that nuisance flood issues related to localized erosion and ponding of water, as well as trash conveyance issues, were more prevalent than larger-scale flooding of houses or businesses. After consultation with The Watershed Project, the emphasis in project goals was shifted from a study focused strictly on flood hazard assessment to one that included assessment of the potential benefits of LID implementation, to bridge interactions between the built and natural environment, improve stormwater management, and reduce nuisance flooding. This shift in focus allowed for modeling efforts that investigated a range of representative design storm events containing specific options for retrofitting existing communities with LID features such as green infrastructure¹ enhancements, including rain gardens, bio-retention swales, permeable pavement, and trash capture installations.

1.1.1 OVERARCHING OBJECTIVES

Overarching objectives were thus directed toward:

- Collection of hydrologic data in the form of stream flow monitoring and water quality sampling.
- Conducting stormwater infrastructure analyses via 1- and 2-dimensional modeling applications to inform understanding of:
 - Flood hazards, with a focus on infrastructure deficiencies.
- Investigation of the potential use of LID features, including:
 - Rain gardens and bio-retention swales to improve stormwater management, including reduction of stormwater nuisance flows,
 - Permeable pavements that could enhance localized infiltration capabilities, and
 - Trash collection infrastructure to improve water quality and aesthetics.

¹ “Green infrastructure” in this context represents “rain gardens” or “bio-retention swales” which are low impact development (LID) features used in areas where stormwater infrastructure is lacking, or where additional features are desired that provide an increase in rainwater infiltration capacity in relation to existing conditions.

- Documentation of methodologies that could be applied to future studies of a similar nature.

1.1.2 PROJECT TASKS

Consequently, specific project tasks included:

1. Collaboration with community groups and Contra Costa County government staff to collect information related to existing stormwater infrastructure, localized and erosive flooding issues, and trash accumulations.
2. Field monitoring of hydrologic conditions during portions of two wet seasons to assess watershed and local channel runoff responses to rainfall.
3. Development of a digital database using standards that allow for integration of new and generated data into the existing Contra Costa County GIS database.
4. Use of one- and two-dimensional model platforms to assess potential benefits of green infrastructure implementation in
 - a. an older subdivision without comprehensive, planned stormwater infrastructure, and
 - b. a newer subdivision with stormwater infrastructure but no stormwater BMPs.
5. Recommendations for implementation of green infrastructure LID features that could improve quality of life within Bay Point communities.

2 HYDROLOGIC SETTING

Key to assessing opportunities and constraints related to project objectives is development of a baseline understanding of study area geographic and hydrologic setting, including regional and local topographic setting and a review of climate conditions, manifested by rainfall and stream discharge variations, all of which influence the physical character of the watershed. This character is also translated from the underlying geology via surface soils, while at the same time surface soils transmit precipitation into the underlying geology at rates associated with soil characteristics. Existing land use within a watershed exerts strong pressures on runoff and flood conditions. Generally, more urbanization (buildings, roads, other impermeable surfaces) in a watershed, results in flashier² runoff conditions, which can be mitigated by the installation of appropriate stormwater infrastructure. Thus, localized to widespread flood hazard conditions common to communities are related to underlying watershed conditions, the degree of urbanization, and the extent and condition of existing stormwater infrastructure.

2.1 Geographic Description of the Willow Creek Watershed

2.1.1 REGIONAL SETTING

Contra Costa County is located within the San Francisco Bay Area in California (Figure 2-1)³. The County contains 32 identified watersheds according to the Contra Costa Watershed Atlas (CCCWA, 2003). Study areas associated with this project are located within the Willow Creek watershed in north-central Contra Costa County, along the south edge of the Sacramento-San Joaquin-San Francisco Bay Delta (Delta).

² "Flashier" generally means that the maximum runoff discharge from a given rain event is larger, sooner, and of shorter duration than it would be under more natural conditions.

³ The projected coordinate system for ArcGIS maps used for this report is NAD_1983_StatePlane_California_III_FIPS_0403_Feet, Lambert_Conformal_Conic projection.

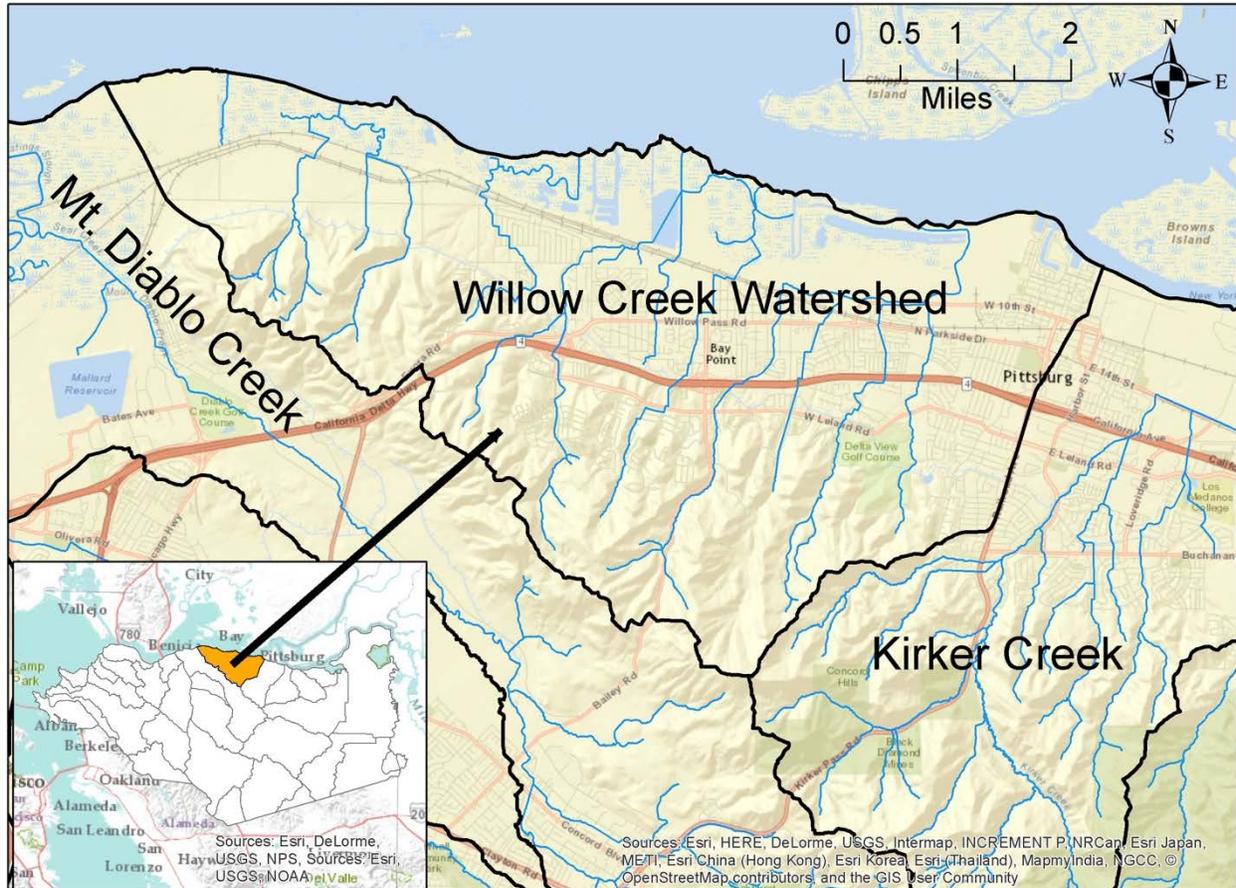


Figure 2-1 Geographic location of Willow Creek watershed within Contra Costa County. Source of watershed boundaries: Contra Costa County GIS (CCCGIS) data download, 2016.

The unincorporated community of Bay Point is situated in the north-central portion of the watershed (Figure 2-2). For the purposes of this study, Bay Point is defined as all area within the United States Census “census designated place” (CDP) of Bay Point, California (Figure 2-2, United States Census, 2016). The City of Pittsburg is located to the east and south of Bay Point.

contour intervals. The Bay Point and Pittsburg communities originated on the lowlands in the mid- to late- 1800's, with the City of Pittsburg expanding into the foothills in recent years, as evidenced by current city boundaries (Figure 2-2).

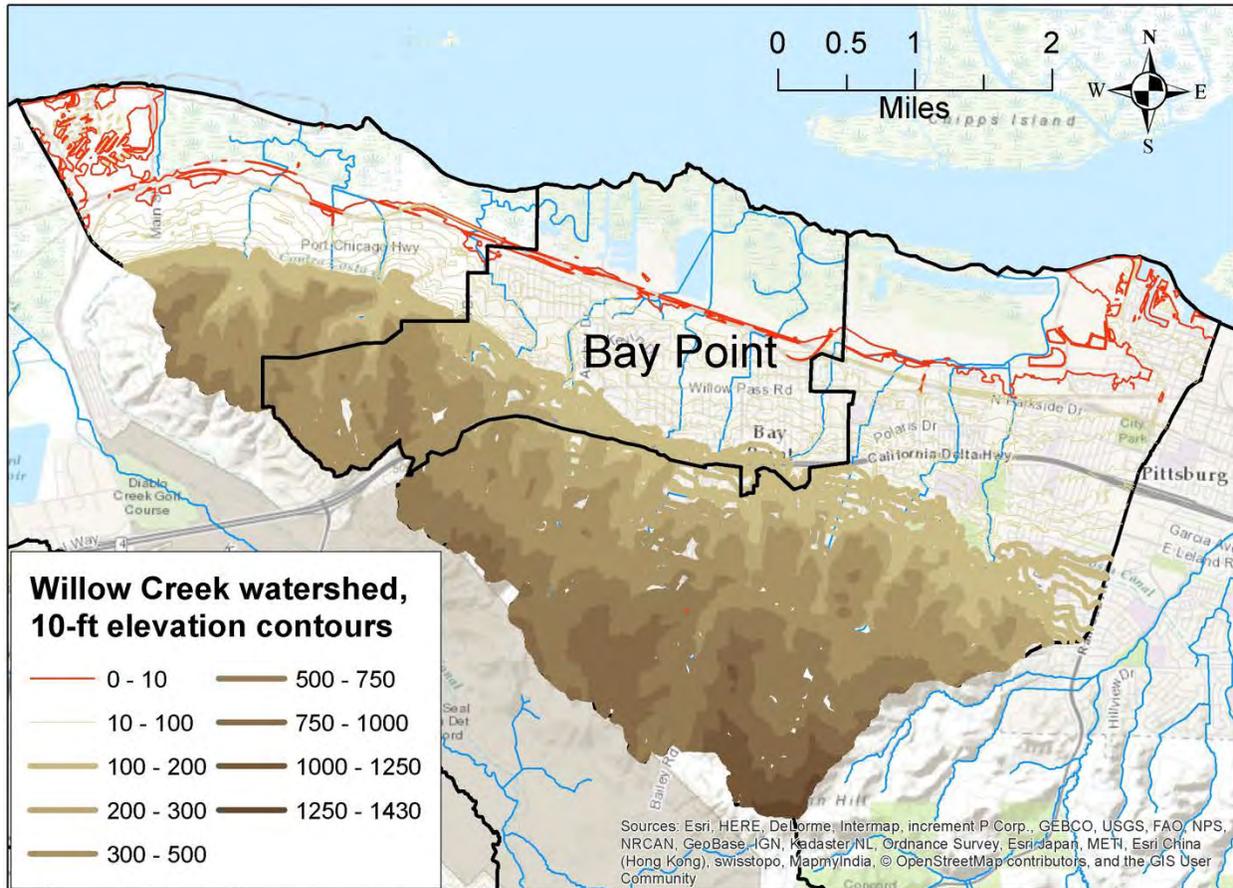


Figure 2-3 Topography of the Willow Creek watershed. Source of contour intervals: CCCGIS, 2016.

The coastal foothills of the Diablo Range ascend to the watershed's uppermost peak, Mulligan Hill, located in the southern-most corner of the watershed. An elevational increase from 100 feet to 1,430 feet over ~13,000 feet of upslope distance creates a sharp gradient of about 0.1-foot rise per foot of distance.

2.1.3 CLIMATE CHARACTERISTICS

Geographically located in a semi-arid, Mediterranean climate region, mean annual rainfall in the watershed ranges from about 12 inches at the Delta to 18 inches in the upper elevations of the foothills (Figure 2-4). The relatively low mean annual rainfall

reflects its location within the rain shadow⁴ of the coastal range. As with the rest of the Bay Area, yearly climate conditions in Bay Point include cool, wet winters and warm, dry summers. The volume of rainfall in individual wet season storm events, as well as peak rainfall intensities, can vary considerably from storm to storm and from year to year, with almost all rainfall occurring in the months October through May. Dry conditions with little or no rainfall predominate from about June through September each year.

Sea level rise associated with climate change may affect the Willow Creek watershed, particularly within the elevational band of sea level to 10 feet (Figure 2-3). The wetlands and any development within this elevational band are vulnerable to conditions in the Delta related to flooding that originates from the Sierra Nevada, or from tidal variations related to storm conditions.

⁴ A rain shadow effect can be defined as measurably less rainfall on the side of mountains opposite that of prevailing wind conditions. Bay Area winds prevail from the west, originating from the Pacific Ocean. As air masses traverse an increase in elevation, more rainfall will generally fall on the side of the rising hillslope and less will fall on the opposite side. The foothills to the west and south (Figure 2-3) create a rain shadow effect for the Bay Point community.

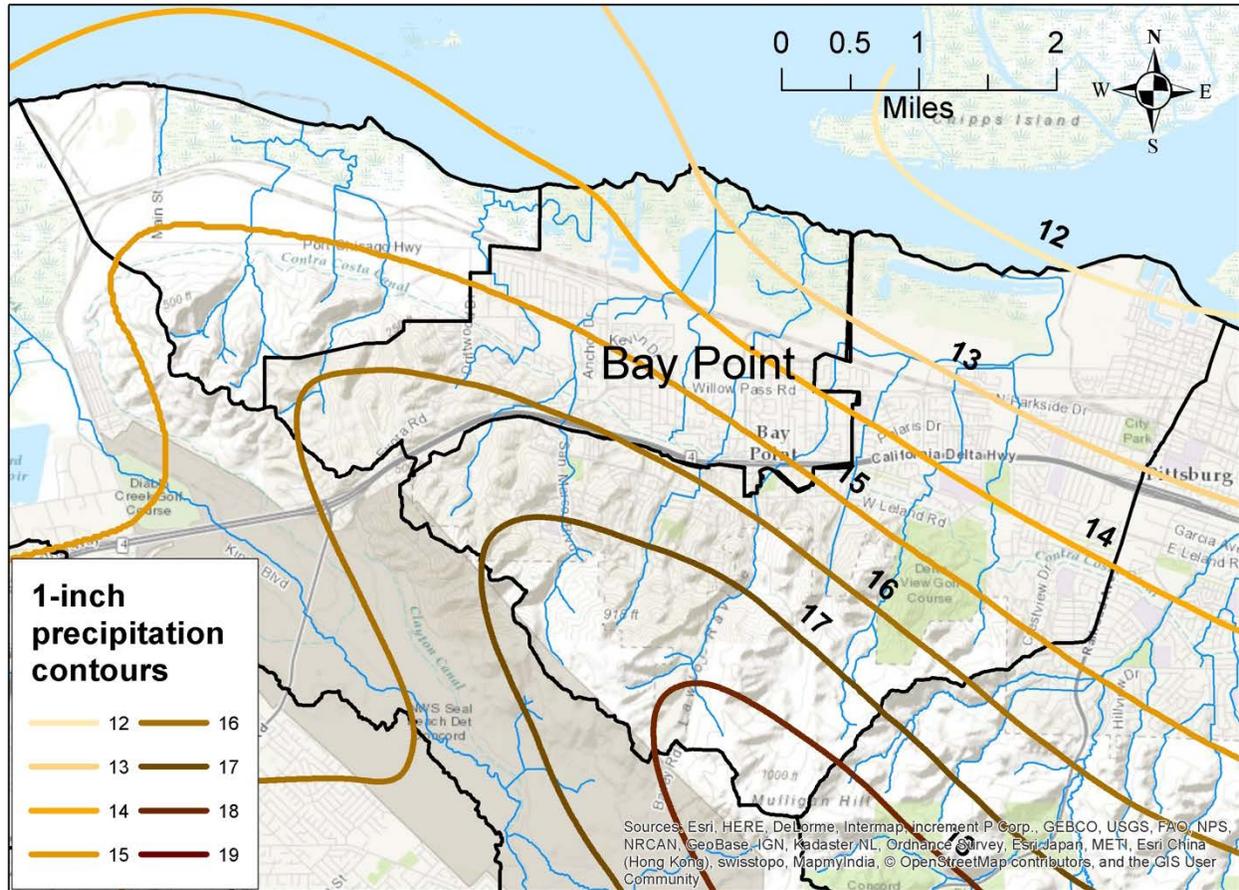


Figure 2-4 Mean annual rainfall within the Willow Creek watershed. Source of precipitation intervals: CCCGIS, 2016.

2.2 Willow Creek Sub-Watersheds

The typical definition of a watershed, where all tributaries eventually join an identifiable mainstem channel, does not apply to the Willow Creek watershed. Instead, three distinct sub-watersheds flow in a north-northeasterly direction from the foothills, across the lowland coastal plain, and into the tidal wetlands along the Delta fringe.

The Willow Creek “mainstem” channel is identified in CCCGIS shapefiles (2016) as the western-most tributary of what is identified in this study as Willow Creek East. This mainstem is the channel depicted as passing through “Wi” of Willow Creek East in Figure 2-5. The CCCGIS shapefile identifies the headwaters of this channel as Lawlor Ravine. Runoff originates from the upper watershed in Lawlor Ravine and then flows downstream in a north-northeasterly direction to the Delta. The channel length of this stream line from the headwaters to the Delta is about 6.2 miles long. This channel passes through several

culvert crossings prior to Highway 4 (e.g., Bailey Road, W. Leland Road) and then flows under Highway 4 through another series of culverts. From Highway 4 to the wetlands the channel is named Willow Creek in the GIS shapefile; however, in the current Federal Emergency Management Agency (FEMA) Flood Insurance Study (FEMA, 2017) the same channel is referred to as Lawlor Creek. There are few other named channels in the watershed, and clear differences in naming conventions depending on source (see Section 2.6 for additional discussion). In this study, the sub-watersheds are identified as Willow Creek East, Willow Creek Central, and Willow Creek West, in keeping with CCCWA naming of the watershed (2003; Figure 2-5), and because the focus is on the contribution of stream flows to localized flood issues rather than on the stream channels themselves.

Specific areas within the Willow Creek East and Willow Creek Central sub-basins were investigated to achieve the objectives of this study. The entire watershed is 23.6 square miles in area, whereas the Bay Point CDP encompasses about 25% of the watershed at 6.1 square miles (Figure 2-2).

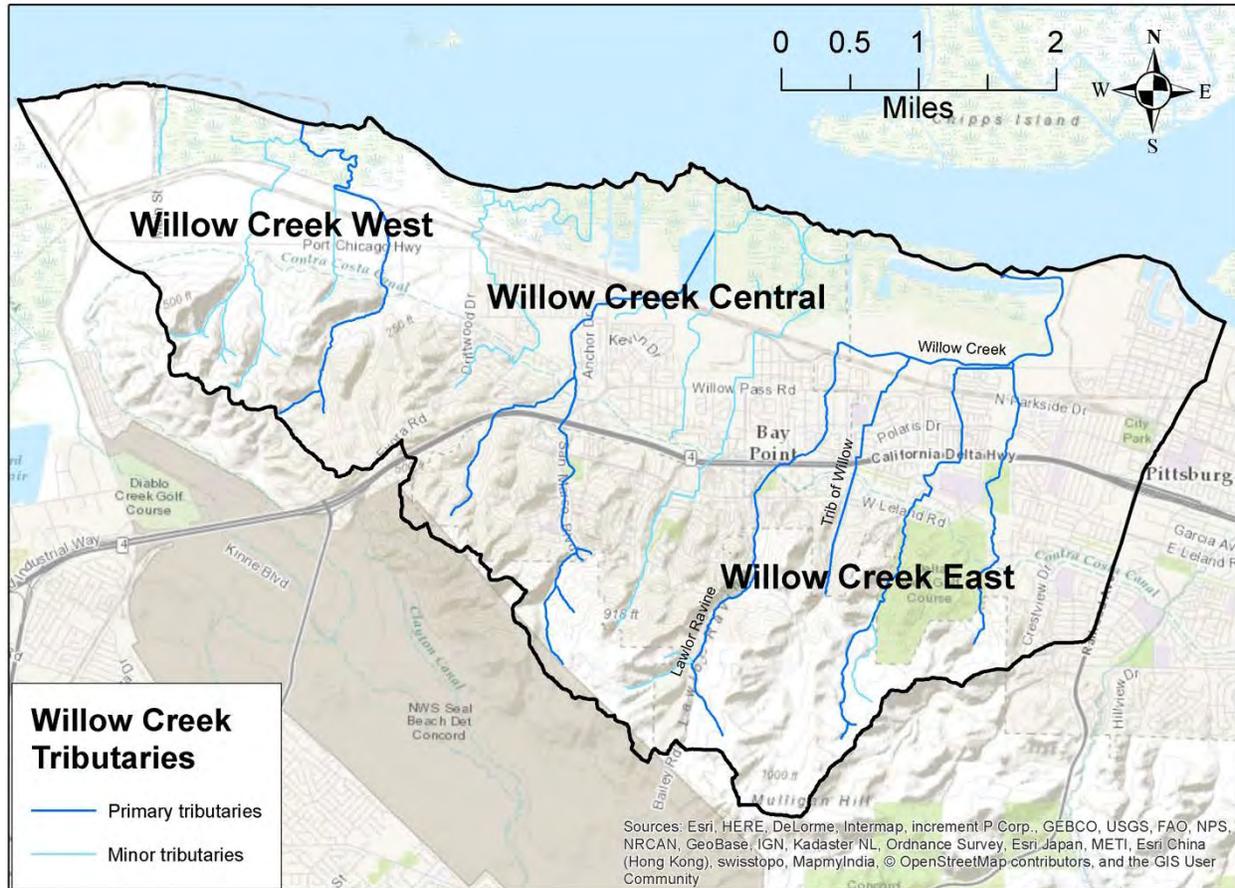


Figure 2-5 Willow Creek watershed channels and naming convention for this study. Source of stream channel shapefiles: CCCGIS, 2016.

2.3 Soil Characteristics

Soils have a natural infiltration capacity, approximated as a measure of the rate at which water can infiltrate into wetted soils, that are reported in units of soil depth over time (e.g. inches/hour). Infiltration rates are a function of physical properties, including soil particle size and how easily water can move within a given soil column; rain characteristics such as rainfall intensity, duration, and cumulative totals; and variations in ground cover.

In the Willow Creek watershed, soils in the upper elevations of the Diablo Range foothills are identified as Hydrologic Soil Group (HSG) B soils (NRCS, 2016, Figure 2-6). HSG A and B soils have higher rates of infiltration capacity and lower rates of runoff than those identified as HSG C and D soils. Soils identified as HSG D soils, including just about all lowland elevations in the Willow Creek watershed and almost all the Bay Point CDP, have

the lowest rates of infiltration capacity and the highest rates of runoff. A small portion of watershed soils located in the City of Pittsburg are classified as HSG C soils.

All HSG D soils in the urban areas of the Bay Point community are identified as clay loams characterized by very low infiltration capacities (NRCS, 2016). Overall, infiltration capacities of HSG C and D soils are generally much less than 1 inch/hour in the uppermost soil horizon. This relative inability of stormwater to infiltrate efficiently into HSG D soils, when not entirely impervious because of housing, roads, or other hardened surfaces, indicates that there is high potential for high volumes and rates of runoff during storm events in the Bay Point community.

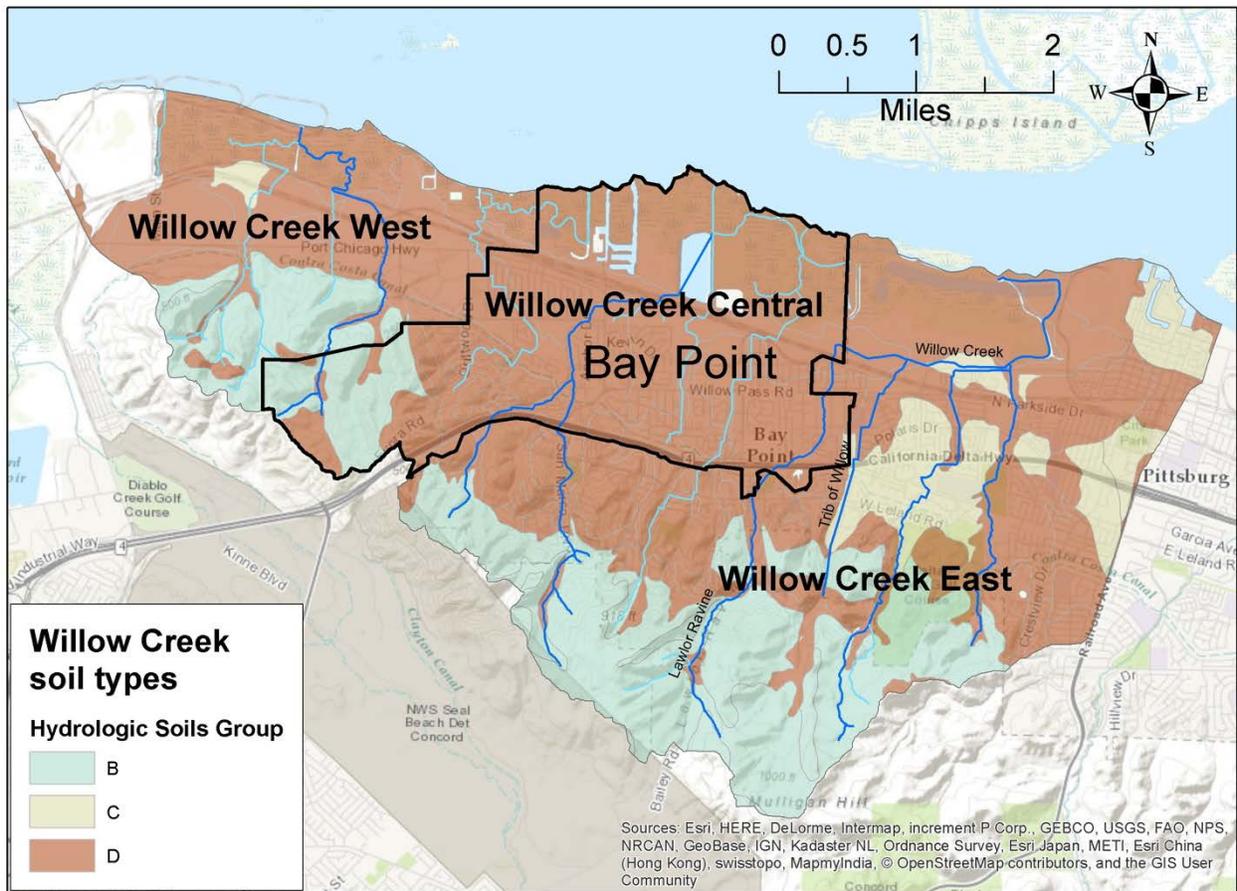
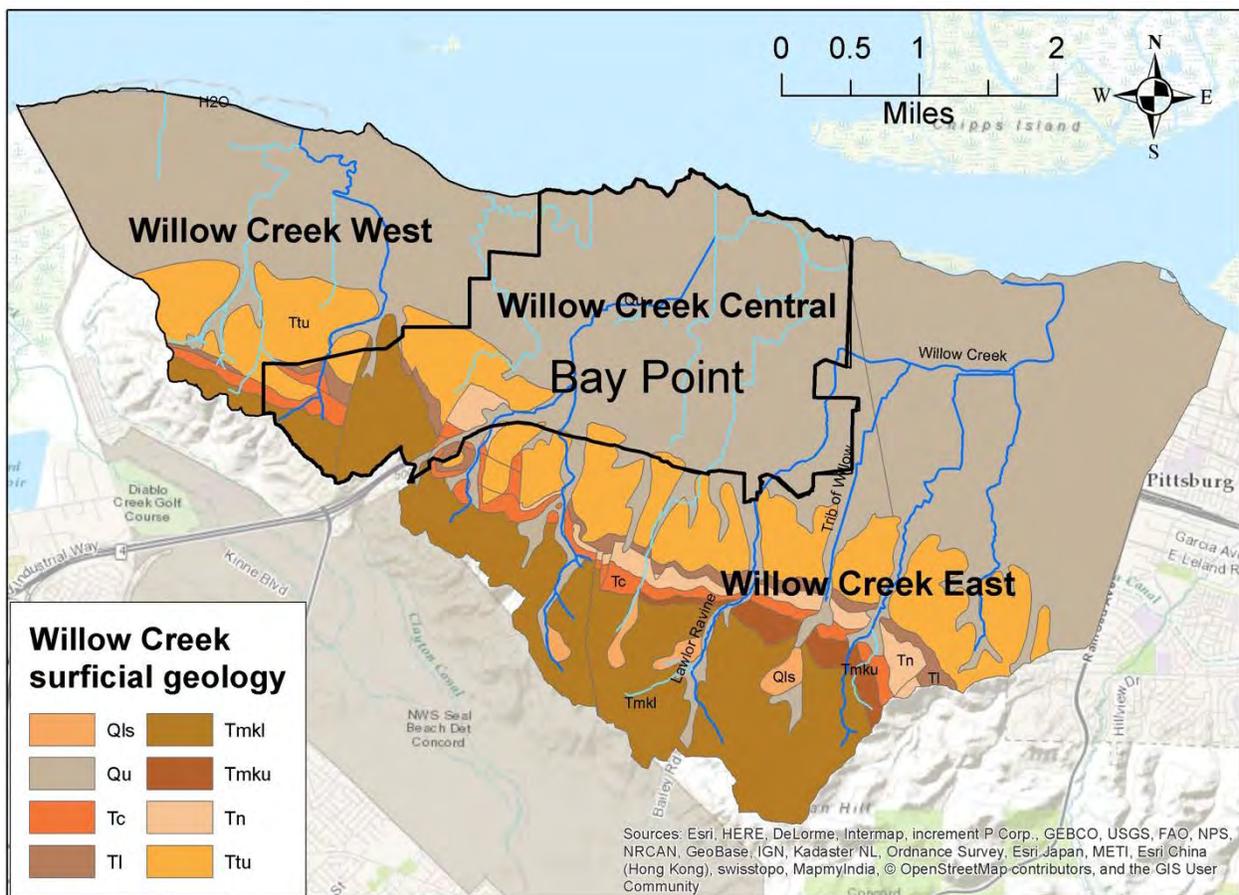


Figure 2-6 Hydrologic soils groups in the Willow Creek watershed. Source of HSG shapefile: NRCS, 2016.

2.4 Geologic Characteristics

Figure 2-7 shows Willow Creek watershed within the existing geologic framework of the local area. Geologic origins of upper watershed bedrock are from sedimentary and volcanic processes, while lowlands are filled with the alluvial⁵ depositional remnants of those upland rocks (Graymer et al., 1994). Mud deposits constitute most of the wetland surficial geology near the Delta, with alluvium making up the remainder (Qu, undifferentiated surficial deposits). In the steeper uplands, volcanic rocks (Tl) are emergent in some upper elevations. Occasional landslide deposits are located near stream headwaters (Qls).



⁵ Alluvial and alluvium are terms that indicate the process by which surficial sediments generated via erosive processes were/are carried from upstream to downstream via streamflows. Typically, these characteristics are the result of overbank deposition of transported sediments from stream channels have been deposited onto local floodplains over extended periods of time.

Figure 2-7 Geologic map of the Willow Creek watershed. Source: USGS, 2017, shapefile of geologic mapping by Graymer et al., 1994.

2.5 Existing Land Use

Bay Point CDP is located within the East County portion of Contra Costa County (CCCGP, 2005). Land uses include residential, commercial, industrial, and open spaces. Bay Point homes, commercial, and industrial locations comprise ~3.3 square miles of suburban-density development and associated impervious rooftops, roads, and other hardened surfaces (Figure 2-8). Wetlands adjacent to the Delta comprise ~1.8 square miles and ~0.9 square miles are primarily open space in the foothills. Development is not concentrated in these latter two areas, but both contain a small amount of industrial or commercial uses.

Development of the Bay Point community started in the mid-1800's, in the area west of Pittsburgh, mostly in the Willow Creek East and the Willow Creek Central sub-watersheds but also in the northwestern corner of the watershed. The disastrous Concord Naval Weapons Station munitions explosion in 1944, in the historical location of the town of Port Chicago, resulted in sequestration of that area and no development in the Willow Creek West tributary in ensuing decades.

Railroad tracks were built long ago along the margin between the lowlands and tidal wetlands, areas that provided the most open and level route for the dominate form of early long-distance transportation and commerce in the region. Tracks were elevated onto embankments to keep them from sinking into the marsh and from potential flooding. The soil materials used to build the levees were generally obtained locally, perhaps even from alongside the tracks, from borrow pits. The embankments immediately became barriers to stream flows and sediment transport (to be discussed further in Section 2.7.1). Changes to the natural environment as a result of land development tends to exacerbate flooding and drainage issues.

At a broad level across all watershed types, one focus of land development for home and community building has been to move streamflows through and out of developed areas as quickly as possible to prevent flooding of homes built on floodplains and other water nuisances. This approach may include straightening and concreting channels, installation of underground stormwater systems that collect and move water (such as pipes and culverts), and infrastructure that helps to moderate a wide range of streamflow conditions. In recent decades, a recognition of environmental degradation associated with older development methods, and advances in scientific understanding of

watershed scale ecosystem functions, prompted initiation of regulatory frameworks such as the California State Water Quality Control Board⁶, which in its current form requires stormwater infrastructure plans that avoid to the extent practicable changes to stream flow patterns prior to issuance of permits for developments. In Bay Point, land developments have adopted whatever the current standards were at that time, but existing deficiencies in older communities have not been addressed through installation of more modern stormwater management systems.

In the oldest parts of the Bay Point community, stormwater infrastructure remains deficient, primarily because of little to no storm drain pipe system and a lack of curbs and gutters. In somewhat newer parts of the community, stormwater infrastructure is more modern but there are few to no BMPs in place to address water quality issues. The newest developments of the last decade or so are in compliance with more recent regulatory requirements.

⁶ The State Water Quality Control Board and nine Regional Water Quality Control Boards (see waterboards.ca.gov), including San Francisco Bay RWQCB and Central Valley RWQCB, were formally recognized in 1967. The Boards are mandated to balance, to the extent possible, all uses of California's water resources.

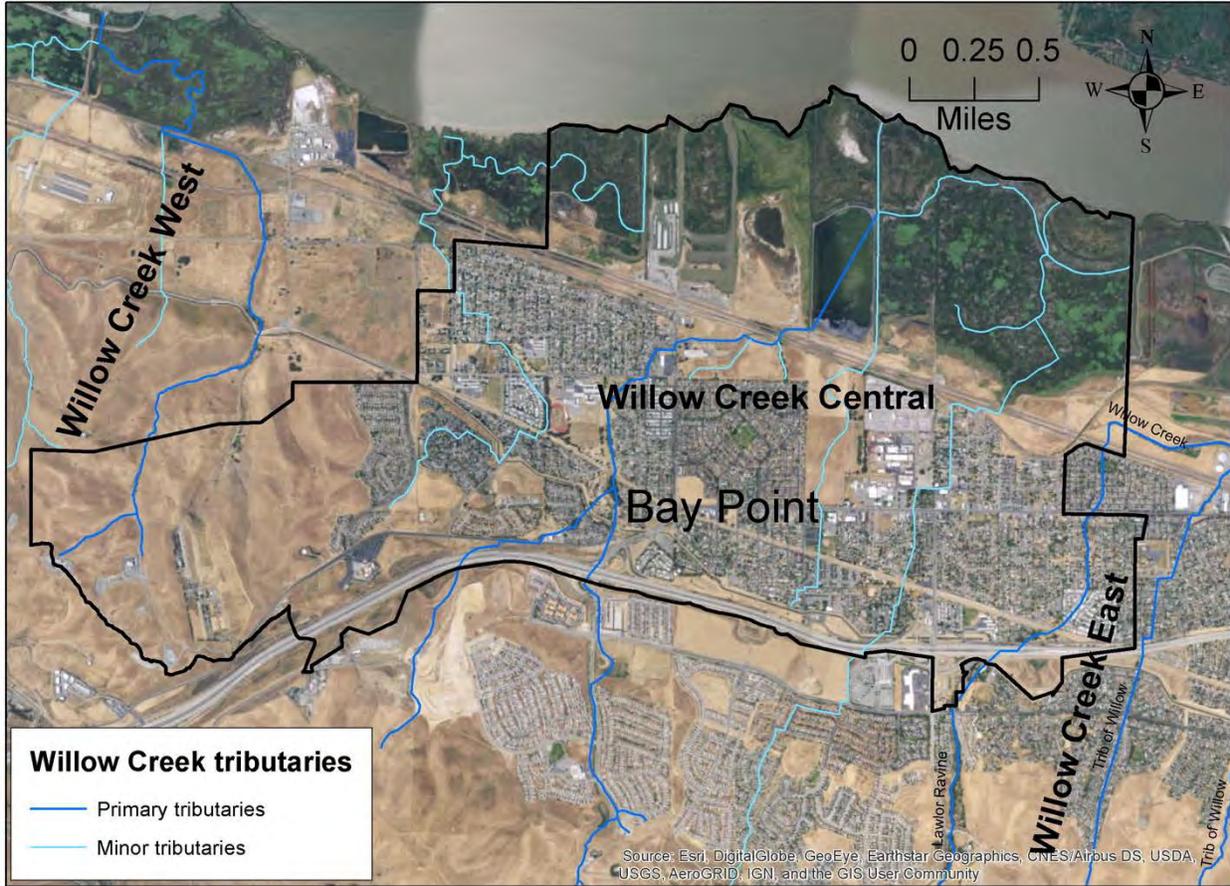


Figure 2-8 Bay Point land uses include residential, commercial, industrial, and open space.

2.6 Existing Floodplain Mapping

Several flood hazards have been mapped in the Bay Point area by the Federal Emergency Management Agency (FEMA). The mapping information is available in printed and digital versions of Flood Insurance Rate Maps (“FIRM” panels) and the Flood Insurance Study (FIS) for Contra Costa County. Predicted flood conditions in Bay Point are available on FEMA FIRM panels 06013C0111G, 06013C0112G, 06013C0113G, 06013C0114G, 06013C0116G, 06013C0118G (FEMA, 2017).

Figure 2-9 provides FIRM mapping of flood-prone areas within Bay Point. Flood Zones A are defined as Special Flood Hazard Areas (SFHA) that are predicted, using well-established approximation techniques, to be inundated by a 1% annual chance flood (i.e., a 100-year flood). Zone A water surface elevations have not been calculated, generally the result of a lack of discharge information when a watershed is unengaged. Flood Zones AE are defined as SFHA where water surface elevations have been

Anchor Drive, and Skipper Road. Upstream of Pacifica Avenue, creek-side open spaces should accommodate flooding (Zone A).

In the Willow Creek East sub-watershed (“Lawlor Creek” in the FEMA FIRM), there is potential for flooding (Zone AE, Zone A) along properties adjacent to the creek, upstream of Willow Pass Road, along properties between Bay View and Mountain View Avenues, at and upstream of the Emerald Cove Mobile Home Park, and upstream of Highway 4. Open spaces upstream of the Emerald Cove Mobile Home Park and Highway 4 act as detention basins, with culvert openings and detention basins (above Highway 4) moderating maximum downstream flows. Flows pass through pipes under the mobile home park, which then emerges into an open channel that passes through the oldest Bay Point neighborhood, prior to entering another culvert-pipe system at Willow Pass Road.

2.7 Existing Drainage Issues

The Bay Point community is situated next to Delta wetlands where there is little elevational differentiation between sea level and near-shore lowlands, followed by a much steeper slope once in the foothills (Figure 2-3). This setting presents a number of drainage challenges that includes low slopes in channels and pipes that may inhibit gravity drainage, and the potential for high tide levels at the downstream ends of drainage systems. Furthermore, the sporadic growth of the area, much of which occurred before implementation of modern engineering and development standards, has resulted in areas with little or no drainage infrastructure, and with key components necessary for such infrastructure often not publicly owned or controlled.

These circumstances have resulted in localized drainage and flooding issues at a number of locations within the community. Reports of such issues are regularly cataloged and responded to by Public Works maintenance staff as part of ongoing efforts to upgrade and maintain public facilities. Public Works staff provided applicable information to the study team and also participated in a field visit to problem locations in November of 2012 (in the beginning months of WY2013⁷). That visit was augmented by installation of hydrologic monitoring equipment and follow-up visits to the community during or

⁷ Water years are defined as October 1st (the start of the wet season) of the beginning year through September 30th (the end of the dry season) of the designation year. October 1, 2012 through September 30, 2013 is thus identified as WY2013.

immediately after storm events to assess conditions first-hand. Information from the most pertinent of these field site visits is summarized below.

2.7.1 FIELD RECONNAISSANCE, NOVEMBER 15, 2012

On November 15, 2012, Public Works personnel and Balance staff members conducted a collaborative field reconnaissance effort with the goal of visiting urbanized locations that were known to experience localized flooding issues during storm conditions. Appendix A provides details of the field site visit and photos that show conditions at that time, including standing water in drainage ditches and impaired drainage at other locations.

One image exemplifies drainage issues at the intersection between the tidal wetland to the north of the railroad tracks and the populated lowland to the south of the railroad tracks and two embankments which act as levees (Figure 2-10). These modifications to the natural environment in the form of embankments, built decades ago to support railway infrastructure⁸, act as a significant barrier to the movement of runoff from the lowlands into the wetlands and out to the Delta. At this location, east of Inlet Drive on Port Chicago Highway, two impaired culverts are the only infrastructure allowing drainage of runoff from this sub-watershed of Willow Creek Central into the wetlands. Visual evidence shows that flow tends to back-up extensively in the low-lying ditch parallel to Port Chicago Highway along the south side of the railroad embankment (Figure 2-10).

⁸ Image found via Google Earth review of historical images (conducted June 1, 2016) of the area shows that the railroad tracks pre-date the oldest image dated December 1938.



Figure 2-10 Railway embankments act as drainage barriers between developed lowlands in Bay Point and tidal wetlands.

Railway embankments have obstructed the natural flow of Willow Creek tributaries for decades. Embankment fill placement was deliberate, and presumably necessary, at the time of laying the tracks so that the rail system would not be inundated from tides, floods, or from land subsidence at the Delta margins. Inadequate conveyance capacity and lack of sufficient maintenance was observed. Figure 2-10 illustrates several issues in this regard, including:

- ***Insufficient conveyance capacity.*** Given potential flow volumes and low slopes on the lowlands, the existing dual corrugated metal pipe culverts under the foreground embankment are likely undersized per current design practices. The railroad track in the background features a much larger bridge-type stream flow crossing than the badly damaged corrugated pipes in the foreground embankment. This provides an indication that, in recent years, awareness of

drainage issues coupled with regulatory requirements have resulted in upgrades to some but not all railway infrastructure.

- Maintenance issues. The inlets to both culverts are badly damaged and crushed, greatly impairing flow efficiency. Additionally, each of the inlets are perched above the base flowline of the ditch adjacent to Port Chicago Highway, rendering them particularly ineffective during low-flow conditions.
- Backwater flooding. The deficiencies noted above result in backwater flooding of much of the ditch area south of the foreground embankment. Though runoff flows quickly into the ditch (as evidenced by flattened grasses in the lower right) there is a distinct high-water mark indicative of the extent that flow can be backed-up.
- Prolonged ponding. The site visit occurred about 6 weeks after the rainy season was underway, with about 1.7 inches of rainfall recorded at the CIMIS No. 170 rain gage in Concord, about 4 miles to the west. Standing water was clearly present over broad sections of the ditch, indicating lack of drainage capacity from the area through the damaged culverts. Ponding of this type is a public health concern as it may provide excellent breeding habitat for mosquitos.
- Trash and coarse debris. Visual illustration of the quantity of trash carried in runoff from the contributing drainage area. Trash transported from the upstream drainage system accumulates in this area, impairing water quality and aesthetics, and is reflective of urbanization and lack of trash management infrastructure. The damaged and deficient culverts have likely caused much of the trash load to be deposited before reaching the wetlands and Delta to the north, which may be more positive than conveyance of trash into the wetlands, however the condition is far from optimal compared to effective source control and/or trash capture in defined and easily maintained locations.

Field reconnaissance of existing stormwater infrastructure and potential localized flood conditions, as summarized above (see Appendix A for additional details), directly informed hydrologic monitoring goals, as described in Chapter 4.

2.7.2 FIELD RECONNAISSANCE, FEBRUARY 8, 2014

Field reconnaissance was carried out during a rain event that occurred on February 8, 2014. This site visit was timed so that rainfall-runoff conditions could be directly documented. Relatively steady precipitation over the period February 5 to 9, 2014 resulted in cumulative rainfall of approximately 2 inches. Rainfall was intermittent during

the site visit, which provided the opportunity to observe and document runoff as well as standing water issues.

One neighborhood selected for further study lies along the western-most Willow Creek East channel (Figure 2-5). Typical of many of the older neighborhoods in Bay Point, this area has little or no developed storm drain infrastructure and therefore experiences many of the drainage issues that are common in the community. Several photos from the visit are particularly illustrative of the issues commonly encountered.

Figure 2-11 shows how the community at large, as well as individual residential properties, can be affected by runoff and lack of stormwater infrastructure. Key observations include:

- **Lack of curb and gutter.** Illustration of a common condition of the streets within the older portions of the Bay Point community, namely the lack of curb and gutter. This condition results in uncontained flows at the interface between the roadway surface and private yards, and is particularly problematic in areas with no sidewalks.
- **Long flow paths and high flow rates.** The street shown, Bella Vista Avenue near Willow Pass Road, does not have an engineered storm drainage system, and the first stormwater catch basins to manage runoff from this street is located on the south side of Willow Pass Road. The flow path from the upstream end of Bella Vista Avenue to Willow Pass Road is approximately 2,300 feet long with no other stormwater catch basins. This flow path length is much longer than a typical subdivision flow path standard, which is generally of no more than 500 feet. This leads to all stormwater flows conveying along the roadway edge with associated high water levels and relatively high velocities.
- **Low lot and first floor elevations.** Typical lot configurations found in the community indicate that the yard surface is only marginally higher than the street, if at all. Many of the homes are built at grade or on low foundations, resulting in the potential for impacts from local flooding.
- **Erosion and trash.** Uncontained flow at the road edge is causing erosion, as seen by the unraveling of the street pavement edge and by entrainment of sediments, which may range from clay to gravel sizes depending on runoff conditions. Turbidity is markedly higher than would be expected in an area with more modern stormwater conveyance system of curb and gutter to convey

flow. Trash can be seen along the flow path, which can be conveyed to downstream depositional areas (such as in Figure 2-10) and eventually to the Delta if not diverted by a trash rack.



Figure 2-11 Urban runoff conditions at the north end of Bella Vista Avenue near Willow Pass Road.

Figure 2-12 shows a similar streetscape, but highlights conditions after rainfall has ceased, with relatively large amounts of post-storm ponding along roadside edges. The east side of the street (left in the figure) shows intermittent curb and gutter that is typical in the community, with newer in-fill homes built to more modern standards. As in Figure 2-11, the street width (including unpaved parking with no sidewalks) is on the order of 43 feet, generally in line with that of older communities within the Bay Area, but markedly wider than those found in new developments, which are generally on the order of 32 feet wide (including paved parking). The abundant street width could support installation of LID infrastructure without major impacts to the travel way or undue restrictions on neighborhood parking availability. The foothills seen in the background are previously described as steep, upper watershed area (Figure 2-3) where streamflow in creek channels passing through the neighborhood originates. Runoff conveyed in streets is

generated from rainfall onto locally impervious surfaces within the community rather than overflow from the channel.



Figure 2-12 Post-storm runoff and ponding along the west side of Bella Vista Avenue.

Figure 2-13 shows similarly discontinuous curbing and intermittent sidewalks along the north side of Hanlon Way, east of Bella Vista Avenue. Standing water highlights the flat, low-slope drainage conditions, and lack of positive drainage in the street profile. As elsewhere, standing water creates potential conditions for mosquito breeding, as well as interfering with parking by creating muddy, flooded conditions for homeowners.



Figure 2-13 Runoff ponding along Hanlon Way, west of Bay View Avenue.

The drainage challenges in the prevailing terrain of older developments are further highlighted in Figure 2-14, which shows that residual standing water is encountered even where full curb and sidewalk have been constructed. Curbs prevent water from entering residential yards, though water is still accumulating in smaller quantities curbside, indicating ongoing drainage issues and lack of gutters to convey flows into a stormwater drainage system. No BMPs or LID features are present, though street widths appear to be large enough to be compatible with a “green street” type of retrofit.



Figure 2-14 Intersection of Hanlon Way and Bella Vista Avenue looking east.

2.7.3 CONCEPTUAL LID SOLUTIONS

Observations recorded during reconnaissance and storm response visits helped to shape project understanding of the prevalence and magnitude of drainage issues and where those tended to occur in the Bay Point community. This understanding resulted in identification of green infrastructure approaches that could be considered, including measures such as rain gardens, bio-retention swales, pervious pavement applications, and trash capture infrastructure. Aspects of these measures are explored in more detail in subsequent chapters.

3 SITE SELECTION AND DATA COLLECTION

To thoroughly understand issues related to lack of infrastructure and consequent storm runoff issues, it was necessary to select specific study locations to investigate how well existing stormwater infrastructure could cope with storm runoff, as well as how potential improvements might affect storm runoff conditions.

The initial field reconnaissance effort (Section 2.7.1) was conducted in early winter of WY2013 to assess general community conditions. Public Works personnel provided pertinent data about the Bay Point community that included information for existing storm drain networks, public complaint records of flooding conditions and hazards as reported by members of the community (an attachment of Appendix A), a LIDAR dataset, and access to Contra Costa County GIS shapefiles and layer⁹ including elevation contours, rainfall isohyets, creek drainages, land use elements, and stormwater facilities. Together, these elements were used in selection of the study areas.

3.1 Selection of Specific Study Areas

Two study areas were chosen for detailed analyses (Figure 3-1) in subsequent WYs based on available data, potential for beneficial LID features in relation to stormwater issues, and identification by Public Works personnel as lacking stormwater infrastructure or having known problems. One area was located in the Willow Creek East sub-watershed and the other was located in the Willow Creek Central sub-watershed. These study areas lie within or adjacent to Contra Costa County formed drainage areas (DA) 48B, 48C, 48D, and 99 (Appendix B, Appendix C).

⁹ The materials obtained from the Contra Costa County mapping information center were “as current and accurate as possible” per disclaimers for each data set (<http://www.contracosta.ca.gov/1818/GIS>).

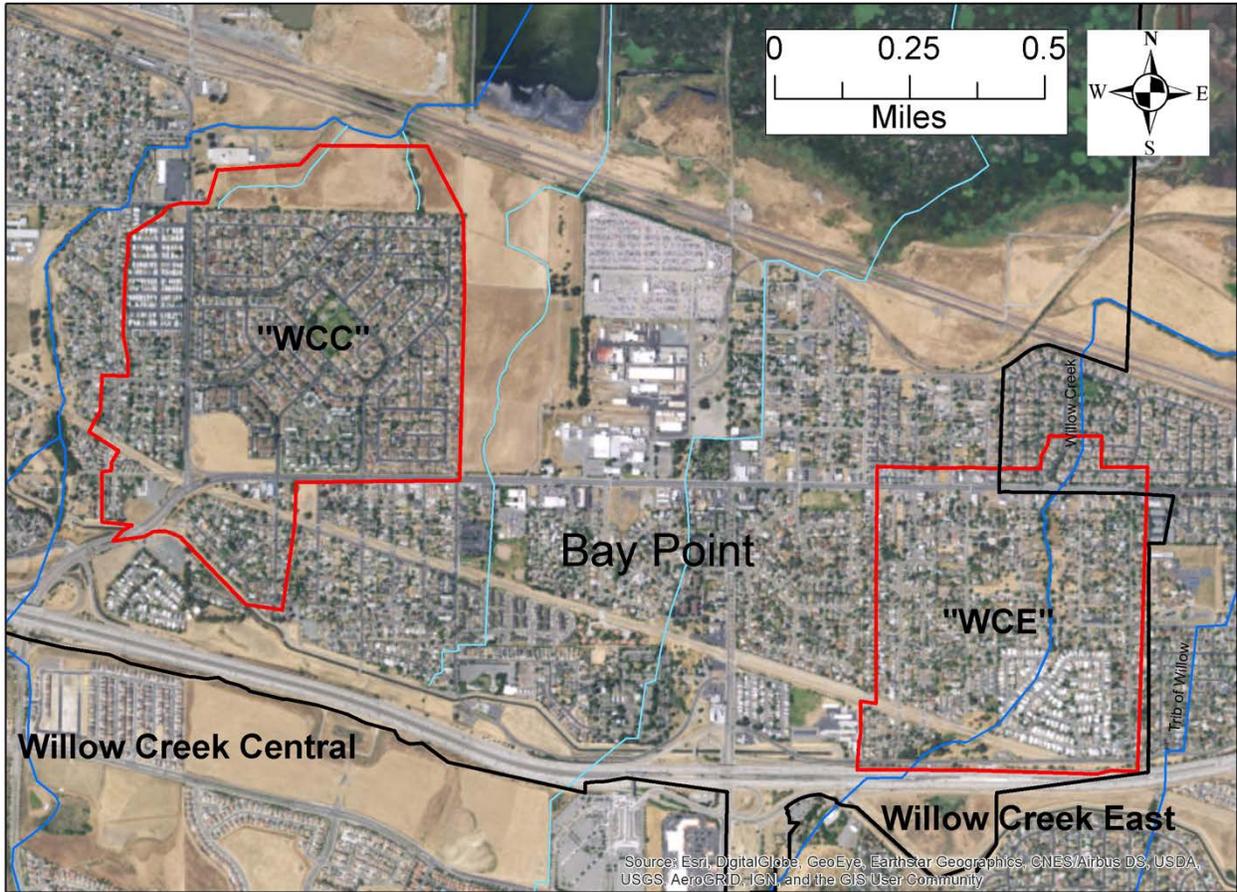


Figure 3-1 Willow Creek watershed study areas.

3.1.1 WILLOW CREEK EAST STUDY AREA

The Willow Creek East study area (Figure 3-1, hereafter referred to as “WCE”) was chosen because it contains one of the oldest neighborhoods in the Bay Point community. The creek channel is open and has been relatively unaltered where it runs through the back yards of properties from Hanlon Way to Willow Pass Road. Upstream of Hanlon Way, the creek is piped as it passed underground of the Emerald Cove Mobile Home Park. The study area is approximately bounded to the north by Willow Pass Road, to the south by Highway 4, to the east by Loftus Road, to the west by Madison Avenue, and also contains a portion of the creek corridor that is undergrounded in a pipe system north of Willow Pass Road along Winter Way to Babbling Brook Way. The study area comprises a total of 0.3 square miles of the 6.1 square miles in the Bay Point CDP. The area has little or no stormwater infrastructure, with few curbs, sidewalks, or storm drains to move runoff through the neighborhood during storm events.

Some of the first housing in Bay Point was built along both sides of Willow Creek on large lots, with houses facing away from the creek, as shown by a Google Earth image from 1938 (Figure 3-2). The portion of the WCE study area adjacent to Willow Creek East includes large lots from Hanlon Way to Willow Pass Road, and east to west from Mountain View Avenue to Bayview Avenue. The same image indicates that additional housing was in process of being developed, likely as a consequence of industrial activity along the southern edge of the Delta and the growth associated with neighboring City of Pittsburgh, as indicated by an industrial site located along the railroad line labeled “early industry”.

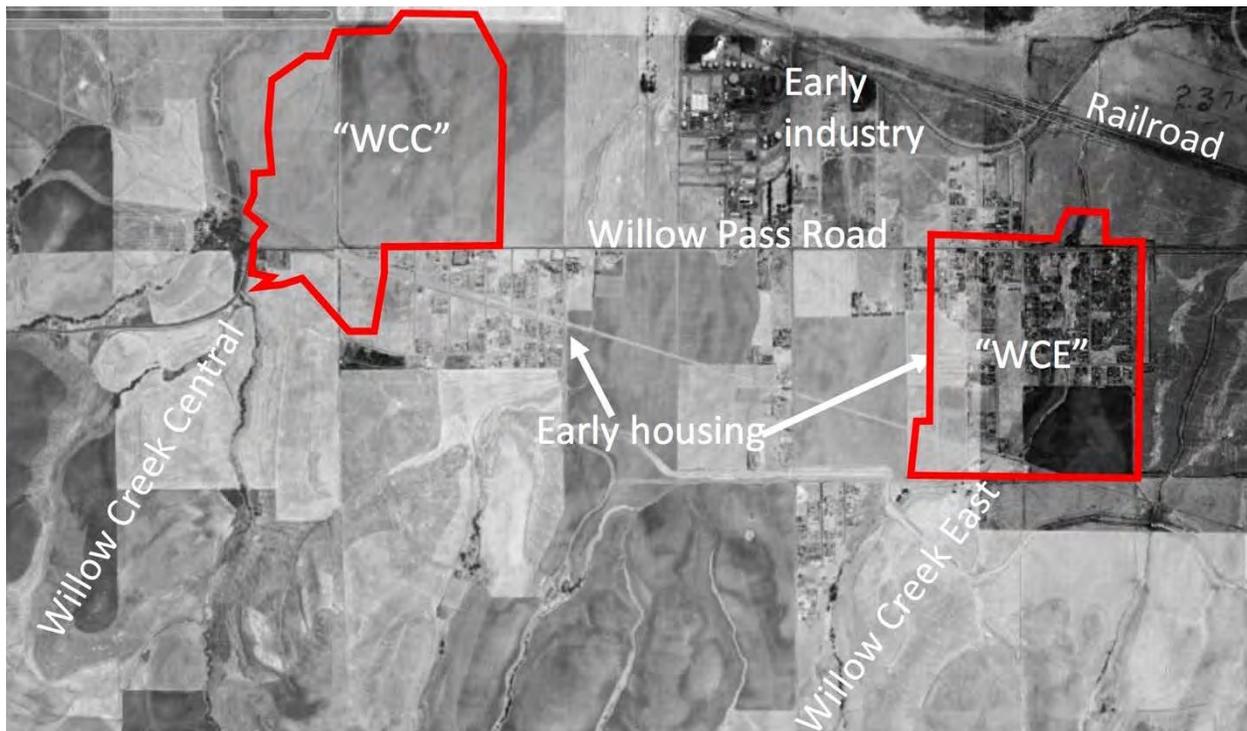


Figure 3-2 Google Earth image dated December 31, 1938 shows creek channels and early housing and industry in the Bay Point community. Source: Google Earth, accessed August 8, 2016.

Figure 3-3 provides a comparison of the 1938 image and a contemporary 2017 image focused on the WCE study area, clearly showing where in-fill development has occurred around the original neighborhood over the intervening decades. Essentially all new development is residential, with commercial development mostly concentrated along Willow Pass Road. Interestingly, the creek channel has remained open and relatively unchanged over a period of nine decades, with a few additional houses but no discernable major changes to the channel pathway. However, development practices

did change, as indicated by the creek channel culverted into underground pipes under Emerald Cove Mobile Home Park (at the bottom of the 2017 image) and in newer development downstream and to the north of Willow Pass Road.

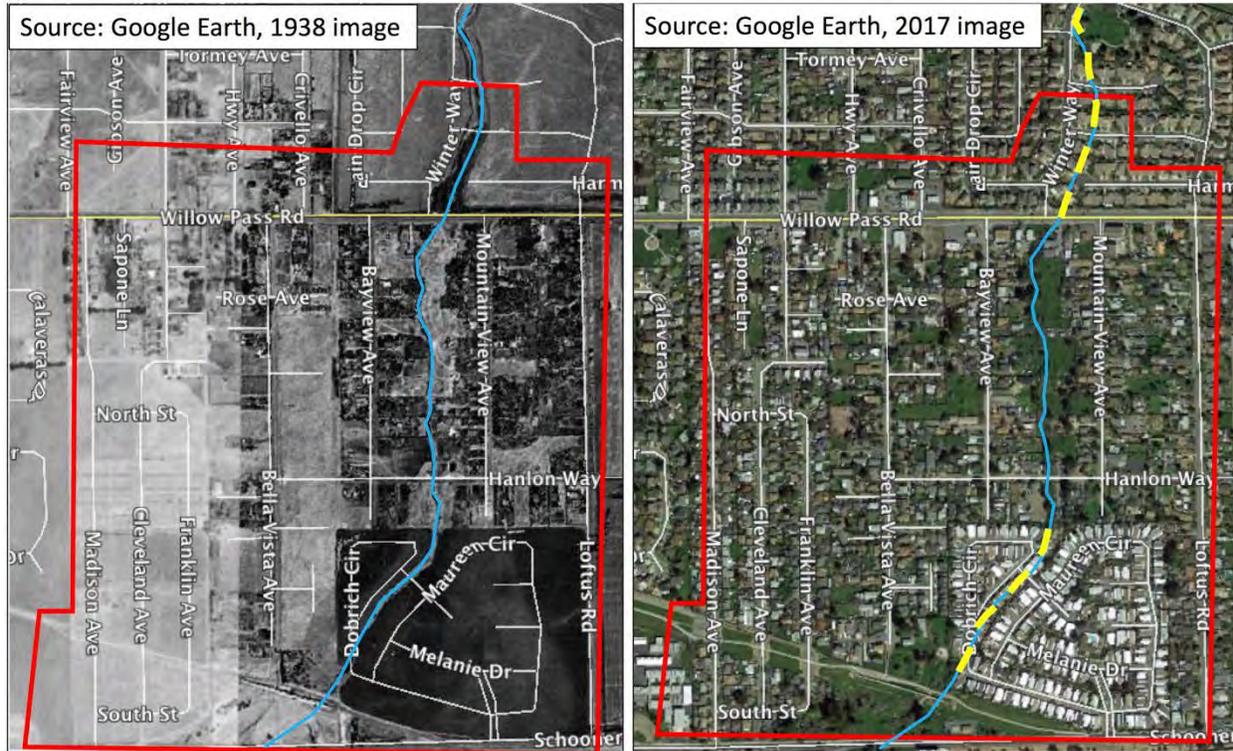


Figure 3-3 WCE study area comparison images from Google Earth, 1938 (left) and 2017 (right). 2017 street overlay on 1938 image for comparison. Dashed yellow lines on the right image indicate places where creek has been piped underground. Source: Google Earth, accessed June 26, 2017.

Remaining open space in the WCE area consists of the open reaches of Willow Creek, the East Bay Municipal Utility District Mokelumne Aqueduct right-of-way that bisects Highway 4 at about a 45-degree angle (e.g., Figure 3-1), and several undeveloped lots. The WCE study area is about 3,200 feet in downstream length. Elevation at the south edge of the WCE study area is about 90 feet north of Highway 4 and about 40 feet at Babbling Brook Way, resulting in a relatively uniform slope of about 0.02-feet per foot of distance as expected in coastal plain lowlands (Figure 2-3).

3.1.2 WILLOW CREEK CENTRAL STUDY AREA

Housing was not yet built within the footprint of the Willow Creek Central study area (hereafter referred to as "WCC") in 1938 (Figure 3-2); however, aerial photographs

confirm that essentially all existing housing and commercial space within the WCC was in place by 1993, with only modest additional impervious cover added after that time (Figure 3-4). WCC is approximately bounded by the Mokelumne Aqueduct, Marys Avenue and Willow Pass Road to the south; Anchor Drive to the west; and undeveloped open space to the north and east. Train tracks lie directly north. Land use consists of single family homes and some commercial spaces, with Lynwood Park sub-division dominating the study area. This sub-division features a sidewalk system built directly along paved streets with no grassy median between the sidewalk and the road. Relatively small front and back yard areas provide the majority of permeable area outside of park spaces. The WCC study area comprises 0.4 square miles. The stream length from Pacifica Avenue to the railroad embankment is about 2,900 feet over an elevation change of about 50 feet for a relatively uniform slope of 0.01-feet per foot of distance, resulting in the low slope expected in this coastal plain lowland.

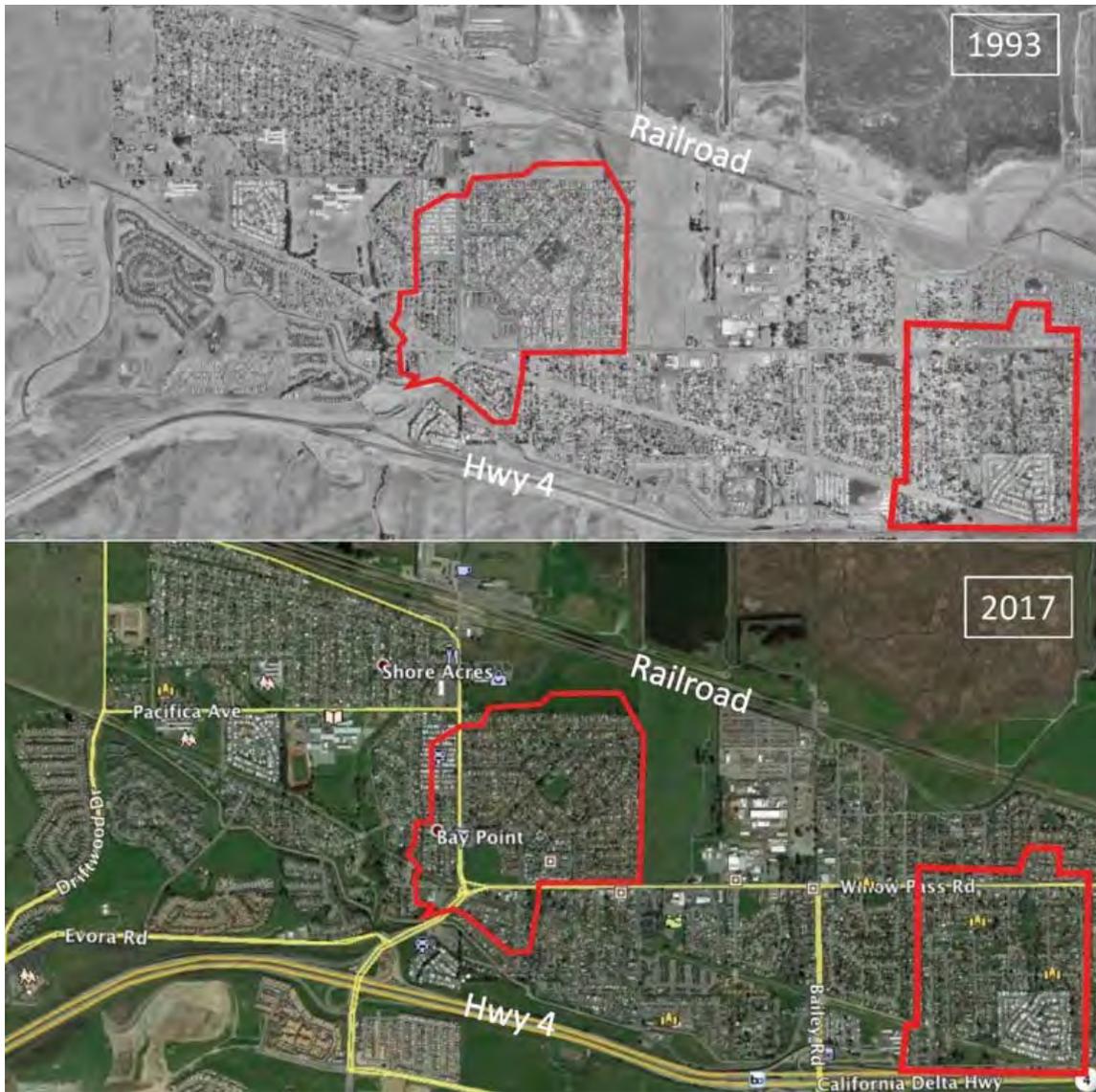


Figure 3-4 The WCC and WCE study areas were built out prior to Google Earth image dated 1993 and remain essentially unchanged in Google Earth image dated 2017. Source: Google Earth, accessed June 26, 2017.

The timing of development within the WCC study area was an important factor in its selection as a contrasting area to WCE. By the time the WCC area was built-out, generally consistent drainage engineering practices were in place and essentially the entire area was constructed with storm drain infrastructure including curbs and gutters, catch basins (with maximum allowed spacing), an extensive pipe network, and engineered outfalls that discharge into two short open channel segments to the north. This is in sharp contrast to the very low level of infrastructure in the WCE area. However, the neighborhood, including Lynwood Park, was developed before stormwater BMPs were required. There

are no significant peak flow controls or water-quality infrastructure in place, so this area provided the opportunity to examine stormwater functions with more infrastructure than the WCE area but with less than current required stormwater standards.

3.2 Streamflow Monitoring Site Selection

An important component of the overall work plan was the identification and instrumentation of streamflow monitoring sites within the community. The goals of this effort included collection of baseline hydrologic data pertinent to Bay Point watersheds and establishing a foundation for future community-driven monitoring activities. Potential monitoring locations were evaluated using a number of factors including ease of access, contributing watershed area, likely importance and utility of data, and long-term channel stability (an important consideration for multi-year efforts). A total of three sites were identified and each was instrumented and monitored for rainfall-runoff response for selected periods through the installation of water elevation data loggers that were calibrated and maintained through site visits both during and after storm events.

The selected monitoring sites are described below. With enough community interest, these sites could be re-instrumented and maintained to provide citizen scientists, or Public Works personnel, with the ability to monitor streamflow in the longer term, a potentially important endeavor since there are currently no active stream gages in the Willow Creek watershed or in the neighboring Kirker Creek watershed to the east.

3.2.1 WILLOW CREEK CENTRAL AT PACIFICA AVENUE

One gaging site was established just west of the WCC study area in the main sub-watershed channel. The gage installation was completed approximately 100 feet downstream (north) of Pacifica Avenue and east of Anchor Drive (Figure 3-5). The site was equipped with a staff plate and a continuously recording water level data logger and barometric pressure logger, with data collection beginning in November 2013. The contributing watershed area at the site is not published in the FEMA FIS (2017), but 100-year flood flow rates are reported as ~575 cubic feet per second at the culvert outlet to the east of Port Chicago Highway at Skipper Road.

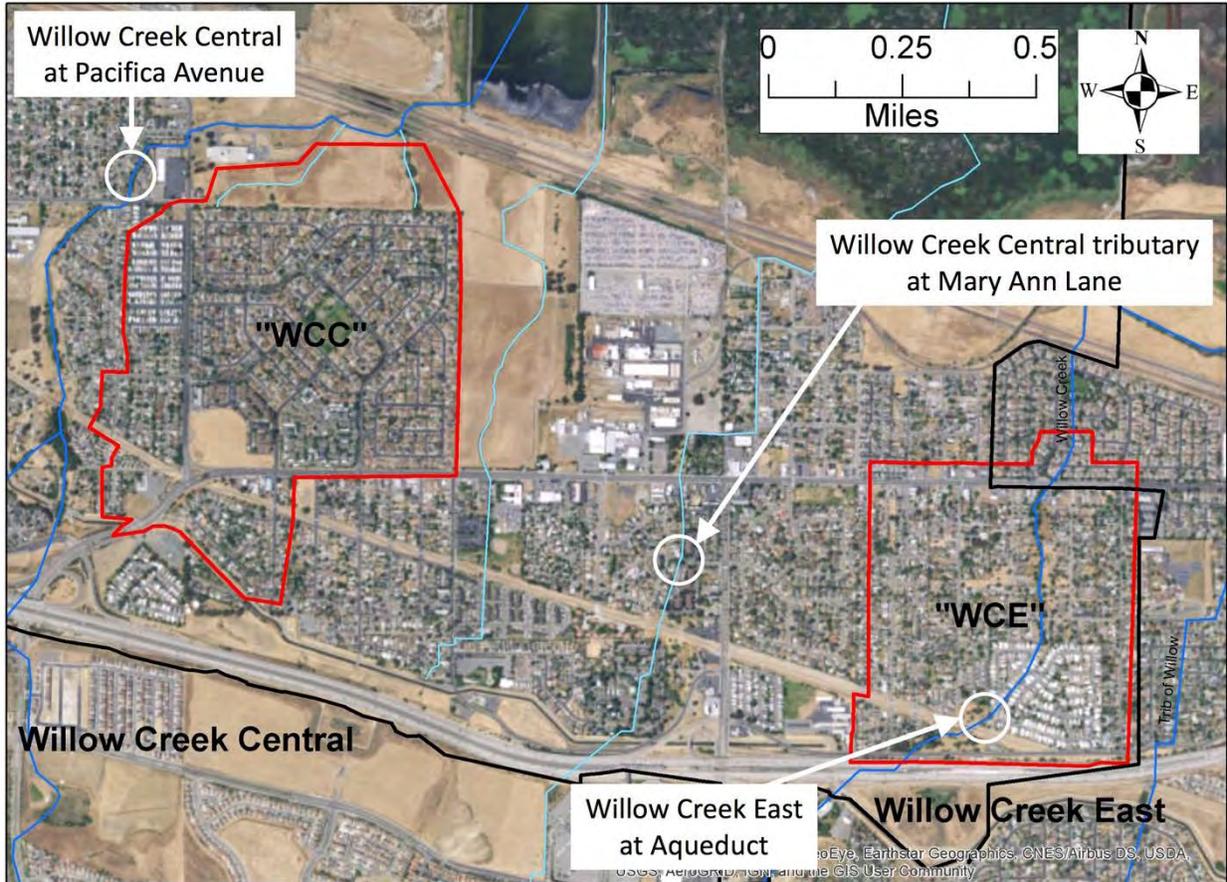


Figure 3-5 Streamflow monitoring sites in the Bay Point community.

This site was visited with Public Works personnel as part of the November 2012 field reconnaissance, and was selected because of regular reports of localized flooding potentially related to a 60-inch diameter culvert that pipes flows under Skipper Avenue. As referenced in Section 2.7, information and images related to the reconnaissance visits are included in Appendix A. Figure 6 in Appendix A includes three images that provide a composite view of the channel in the vicinity of the gage installation. In addition to potential “backwatering” due to conveyance limitations at the Skipper Avenue culvert, it was also noted that existing vegetation likely plays a role in restricting flows at this location.

Two added considerations related to selection of this site are that it lies within one of the mapped FEMA floodplains in the community (Figure 2-9), and data on runoff magnitude

and timing was directly used in setting tailwater¹⁰ conditions for the detailed hydrologic and stormwater modeling of the WCC study area (see Section 6).

3.2.2 WILLOW CREEK CENTRAL TRIBUTARY AT MARY ANN LANE

A second monitoring site was established on a tributary channel of Willow Creek Central located roughly halfway between the WCC and WCE study areas on the south side of Mary Ann Lane between Bailey Road and Clearland Circle (Figure 3-5). The installation included a staff plate and continuously recording water level data logger and barometric pressure logger, with data collection beginning in November 2013.

This site was also visited with Public Works staff during field reconnaissance in November 2012. Attention was directed here because of repeated concerns with trash blocking the existing trash rack at the pipe inlet at Mary Ann Lane. Figure 2 in Appendix A includes four images that provide a summary view of the channel and vicinity. The channel is an engineered trapezoidal concrete structure; therefore, vegetation growth is not a conveyance limiting factor.

3.2.3 WILLOW CREEK EAST AT MOKELUMNE AQUEDUCT

The third monitoring installation was established on the mainstem of Willow Creek East just downstream of Highway 4 and the Mokelumne Aqueduct and east of Bella Vista Avenue. This site contains the inlet to the 84-inch diameter culvert that carries creek flows under the Emerald Cove Mobile Home Park; the creek emerges from the pipe into its natural channel north of the mobile home park. The site was equipped with a continuously recording water level data logger and barometric pressure logger that was referenced to the inlet elevation of the culvert, with data collection over a two-week period in December 2014. The total contributing watershed area at the gage location is approximately 1.1 square miles per the FEMA FIRM (2017).

The location was selected to provide input information for the detailed hydrologic and stormwater modelling carried out for the WCE study area. In particular, the monitoring provided direct readings on time of concentration of peak flows in the creek important for setting the tailwater conditions for drainage within the study area.

¹⁰ Tailwater refers to the water surface elevation at the downstream limit of a creek reach that serves as a model control for upstream water surface elevations in typical flow conditions.

4 HYDROLOGIC MONITORING DATA AND FINDINGS

This chapter provides a summary of the data and findings associated with hydrologic monitoring that was completed as part of the project. The information is presented by site, and a compendium of the data collected is provided with the electronic file submittals accompanying this report.

One of the objectives of data collection efforts was to better understand runoff responses to rainfall events, particularly with respect to the magnitude and timing of peak flows and their role in setting tailwater conditions for local drainage systems. Urbanized areas with channelized and culverted creek channels can be expected to have a different response than natural or open space areas in this regard. The impervious surfaces associated with urbanization, including buildings and roadways, restrict the potential for infiltration of rainfall and can be expected to result in higher peak flow rates and total runoff volumes, with the peaks reacting quickly to rainfall intensity (i.e., “flashy” conditions). Willow Creek upper watershed reaches are largely undeveloped areas, so direct measurement is necessary to accurately assess runoff responses during storms.

4.1 Summary of Local Rainfall during Monitoring Periods

The Contra Costa Flood Control and Water Conservation District maintains an extensive network of recording rain gauges that provide information about the magnitude, distribution, and timing of precipitation in the County. The Bay Point community lies between a number of rain gauge locations that can be expected to be representative of storm events impacting the Willow Creek watershed. Of these, the rain gauge record at station code LSM, located at Los Medanos Community College in the City of Pittsburg, was selected for use. This station is approximately 5 miles east of Bay Point along the same foothill range¹¹. A second rain gauge data set was selected from the CIMIS rain gauge network, station code 170 in Concord, approximately 4 miles west of Bay Point and just to the west of the lowest foothill elevations¹². Bay Point is located approximately midway between these two rainfall data sets, Station LSM captures similar rain shadow effects and CIMIS 170 is similar in location along the coastal lowlands.

¹¹ Data from this site can be downloaded from the California Data Exchange Center (CDEC) maintained by the California Department of Water Resources (<http://cdec.water.ca.gov>) by referencing station code LSM (station established in 2005).

¹² Data from this site can be downloaded from the California Irrigation Management System (CIMIS) maintained by the California Department of Water Resources (<http://www.cimis.water.ca.gov>) by referencing Station 170 (station established in 2001).

Examination of paired daily rainfall data from the two rainfall stations during the WY2014 monitoring period (see Figure 4-2) generated the following observations:

- At both rainfall stations, there were relatively few days of measurable rainfall over the wet season October 1, 2013 through May 30, 2014. Measurable rain was recorded at CIMIS 170 on 18% of potential wet season days and at LSM on 13% of potential wet season days.
- In WY2014 at the CIMIS 170 station, rainfall was recorded on 44 of 243 wet season days. Of those days, at least 0.25 inches of rainfall was recorded on 13 days, at least 0.5 inches on 8 days, and there were zero days where rainfall accumulation was at least 1.0 inch.
- In WY2014 at the LSM station, rainfall was recorded on 31 of 242 wet season days. Of those 31 days, at least 0.25 inches of rainfall was recorded on 15 days, rainfall totaled at least 0.5 inches on 4 days, and there were zero days where rainfall was at least 1.0 inch.
- Of all days in which rain was recorded at either station, on 10 of 44 days (23%), rainfall totals at LSM exceeded those at CIMIS by 0.05 inches or more, and on 5 of those days, rainfall totals at LSM exceeded those at CIMIS by 0.10 inches or more.
- Variability in rainfall was expected between rainfall stations. CIMIS 170 recorded more rainfall and more days with greater amounts of rainfall. LSM recorded less overall rainfall but more rainfall on a limited number of individual days. This general pattern was expected given rain shadow effects of the Diablo Range foothills at the LSM station more so than the CIMIS station.

4.2 Data Collection Efforts, WY2014

4.2.1 STREAMFLOW ON WILLOW CREEK CENTRAL AT PACIFICA AVENUE

The Pacifica Avenue site was monitored over the WY2014 wet season from November 22, 2013 to May 29, 2014. A staff plate, a water level data logger that records changes in water elevation, and a barometric pressure data logger that records changes in air pressure were installed at this location (Figure 4-1). The loggers were installed inside a PVC pipe stilling well with drilled holes to equilibrate water levels inside the pipe to those outside the pipe. The stilling well protects the loggers from outside elements while allowing the instruments to record water elevations and barometric pressure. The loggers were set to record information at 5-minute intervals.

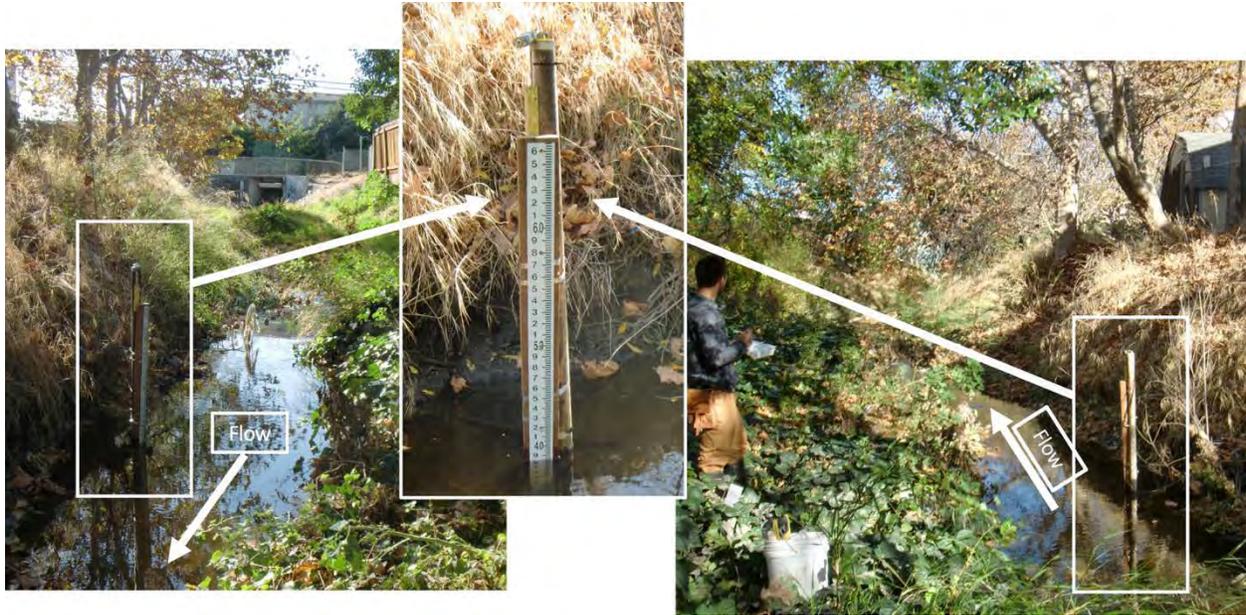


Figure 4-1 Streamflow equipment installed at Pacifica Avenue monitoring site in the Willow Creek Central sub-watershed.

A total of four site visits were conducted over the monitoring period. During each visit, the water level on the staff plate was recorded, photos were taken to document existing conditions, data from the loggers was downloaded to a field computer for processing at the office, and stream discharge was estimated by float method or visual inspection. Observations were recorded in field note books and then appropriately transferred to the observer log (Appendix D).

During each site visit, creek sections were walked to:

- Identify any changes to the channel since the previous visit.
- Identify flow obstructions, and if so describe whether or how the obstruction might be affecting stream flows. Obstructions may be removed or moved if interfering with stream gage measurements.
- Identify any high-water marks from recent storm runoff events.
- Identify any areas of notable erosion or sediment deposition.

Streamflow stage¹³ (i.e., “relative stage”) measurements from the water level data logger were plotted along with mean daily stage, maximum daily stage, and field-observed stage measurements recorded from the staff plate during site visits (Appendix D, Appendix E, Figure 4-2).

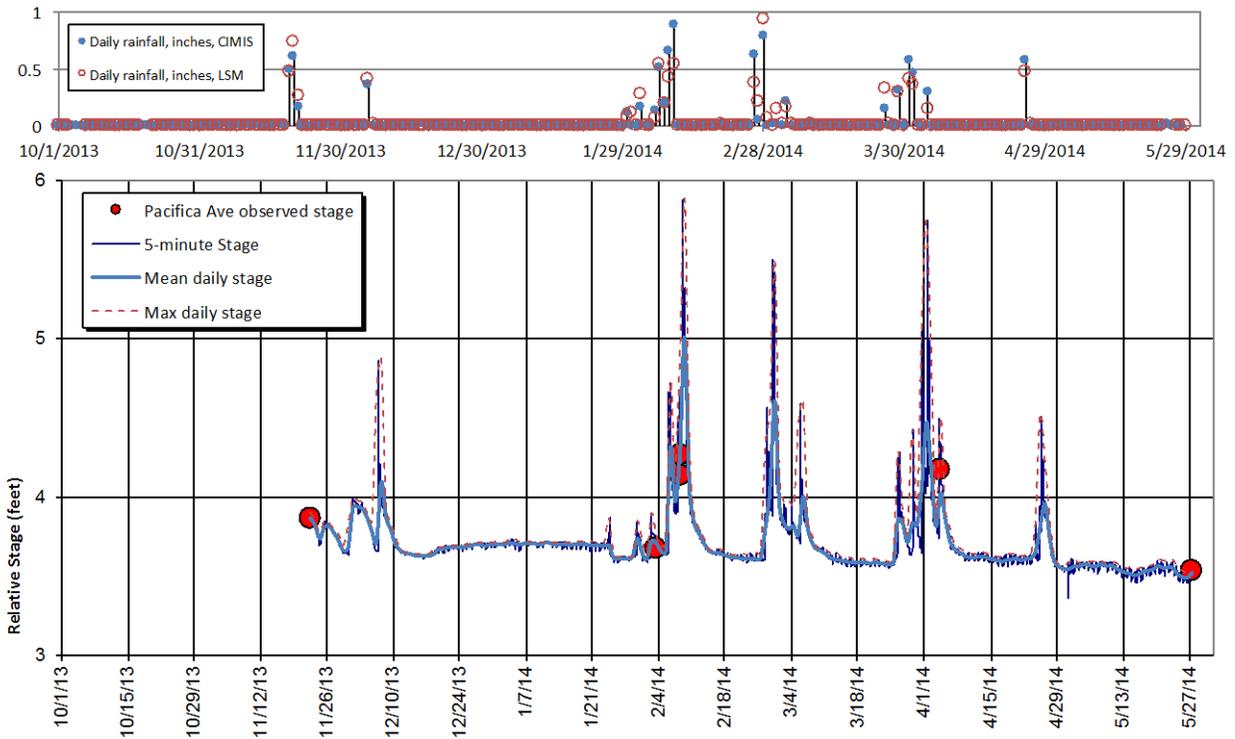


Figure 4-2 Pacifica Avenue relative stage record, field stage measurements, and two local rainfall records, partial WY2014.

Streamflow discharge observed during Pacifica Avenue site visits varied, as detailed in the observer log (Appendix D), mostly in the range of 1 cfs or less as estimated visually. The site visit on February 8, 2014 directly measured discharge on the rising limb of the hydrograph, and then again on the rising limb during a return visit a few hours later. These two measurements resulted in estimated flow discharges of 3.5 cfs (cubic feet per second) at a relative stage staff plate reading of 4.1 feet, and 5.6 cfs at a relative stage staff plate reading of 4.27 feet, respectively, which provides an indication of peak flow, perhaps as high as 200 cfs, given that increases in discharge under flooding conditions are generally exponential relationships. A field site visit on April 4, 2014 estimated flow of

¹³ A measure of water surface elevation fluctuations directly related to stream discharge. Water surface elevation data were sufficient to establish range in flow conditions and modeling assumptions.

1 cfs; however, based on the staff plate reading of 4.17 feet, flows were more likely in the 5 cfs range at that time, as long as the staff plate had not shifted from channel bed movement (unlikely given the mud substrate). Review of the water surface elevation data logger record coupled with rainfall records (Figure 4-2) shows that:

- Water surface elevations increased in response to every rainfall event.
- Maximum stage was related to position within the wet season more than total rainfall or maximum rainfall during the event.
- Similar responses in stage readings required more rainfall earlier in the wet season and to less rainfall later in the wet season.

Similarities and differences in these response rates are illustrated by very similar stage responses to different weather fronts. The stronger weather front in late January/early February produced about 2.2 inches of rain compared to a weaker weather front that produced about 1.6 inches of rain in late March, whereas staff plate stages were almost identical (Figure 4-2, Appendix D). The similar streamflow response rates are a direct result of increases in watershed moisture stored in the soil subsurface environment (both shallow and deep) over the course of the wet season. A typical watershed response to higher overall moisture content is higher runoff rates in response to a rainfall event of similar size:

- The maximum stage response in February, recorded as 5.88 feet relative to the staff plate (not to NAVD datum), is essentially equivalent to the maximum stage response in March, at 5.75 feet, even with less total rainfall in March.
- The stage response in March was more sensitive to daily rainfall totals, indicated by multiple moderate increases in stage before and after the maximum peak stage for that rainfall event, resulting in more total discharge compared to the late January/early February storm, even with less total rainfall in March.
- Antecedent rainfall from November through early March resulted in a more saturated watershed later in the wet season, which prompted multiple flow peaks and a longer elevated hydrograph during the late March storm.

These data and resultant observations were used to set model conditions, as discussed in Section 6. The data loggers were removed from the site at the end of the field campaign. The staff plate and stilling well were left in place; if gaging infrastructure remains in place, loggers could be reinstalled for additional monitoring.

4.2.2 STREAMFLOW ON WILLOW CREEK CENTRAL TRIBUTARY AT MARY ANN LANE

To provide additional assessment of streamflow during WY2014, a staff plate was installed at Mary Ann Lane in a concreted tributary of the Willow Creek Central sub-watershed (Figure 3-5). Unlike the data collected at Pacifica Avenue, there were no observed streamflows at this site during four site visits (Appendix D). Field notes indicated that ponded water was present in the channel but that water surface elevations did not reach the staff plate at any time, as evidenced by lack of high water marks¹⁴. These field observations suggest that the tributary transported low volumes of water during rainfall runoff conditions in WY2014. The streamflow response at this site in other WYs with more intense or more cumulative rainfall remains unknown. The staff plate installed at this location was removed, so any additional monitoring would require new equipment.

4.2.3 WATER QUALITY AT BELLA VISTA AND S BELLA MONTE AVENUES AT WILLOW PASS ROAD

Suspended sediment concentration (SSC) grab samples along the edge of the WCE study area were an additional streamflow discharge constituent collected during the field campaign in WY2014. SSC samples are a means to assess non-point-source water quality, as a wide range of contaminants (metals, organics, inorganics) may be associated with measurable suspended sediment. Samples were collected from uncontained street runoff of two adjacent blocks minutes apart during rainfall conditions. Analyses of the SSC grab samples provided details about particles large enough to transport within the water column at a specific streamflow discharge. Typically, the higher the runoff the larger the particles in suspension. Discharge at both locations was less than 1 cfs, so suspended particle sizes would be small. The SSC samples were collected during a site visit on February 8, 2014 (Figure 2-11).

Analysis results of the SSC grab samples (Table 4-1; Appendix D) indicated that about 80-85% of the suspended sediments in each sample were the size of silty or clay materials (<63 μm , or about 0.002 inches in diameter), whereas the remaining 15-20% were the size of very fine sand with perhaps a few larger sandy materials. Turbidity, a measure of water cloudiness and another indicator of the degree of suspended sediment particles in the water column, was well above the drinking water standard of < 1 NTU, with values of 350 and 150 NTU. The highest turbidity value was associated with the Bella Vista Avenue sample. The image in Figure 2-11 was taken at the time of SSC sample collection from

¹⁴ A high water mark is a physical indication of how high water levels reached during any recent rainfall runoff flow events. Staff plates can be discolored at the highest water level reached by flood waters. Strand lines of organic materials along natural channel edges and floodplains are good indicators of high water marks.

Bella Vista Avenue, and shows the muddiness associated with impervious surface runoff over a long, uncontained flowline where no curb and gutter system is in place to manage stormwater runoff.

Table 4-1 Suspended Sediment Sample Results

Sample Location	SSC - Total Particulate Solids	SSC - Total Coarse Fraction (>63um)	SSC - Total Fine Fraction (<63um)	SSC - Total Vol. of Sample Analyzed	Turbidity	Total Suspended Solids
	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(ntu)	(mg/l)
February 2, 2014						
Belle Vista	565	88.9	476	468	350	564.9
Belle Monte	233	40.3	193	462	150	233.3

Reported SSC values, discussed herein in reference to particle size and turbidity, and the field observations represented in Figure 2-11 provide evidence that supports two general conclusions: (1) suspended sediment concentrations were relatively high and (2) erosive processes were active during a relatively typical rainfall-runoff event (Figure 4-2). These observations provide important information about runoff conditions and how the lack of stormwater infrastructure leads to lower water quality in the community.

4.3 Data Collection Efforts, WY2015

4.3.1 STREAMFLOW ON WILLOW CREEK EAST AT THE MOKELUMNE AQUEDUCT PATHWAY

The Mokelumne Aqueduct pathway site was monitored for a two-week period during the winter wet season, December 10, 2014 to December 23, 2014 (Figure 4-3). This monitoring effort occurred in WY2015, which provided additional information about the overall Willow Creek watershed and complemented the field monitoring efforts in WY2014. A staff plate, a water level data logger that records changes in water elevation, and a barometric pressure data logger that records changes in air pressure were installed at this location in the same manner as described for the Pacifica Avenue location. The loggers were set to record information at 5-minute intervals. However, given the two-week monitoring duration, site visits were limited to those associated with installation and demobilization of the equipment. The gaging equipment installed at this location was removed, so any additional monitoring would require new equipment.

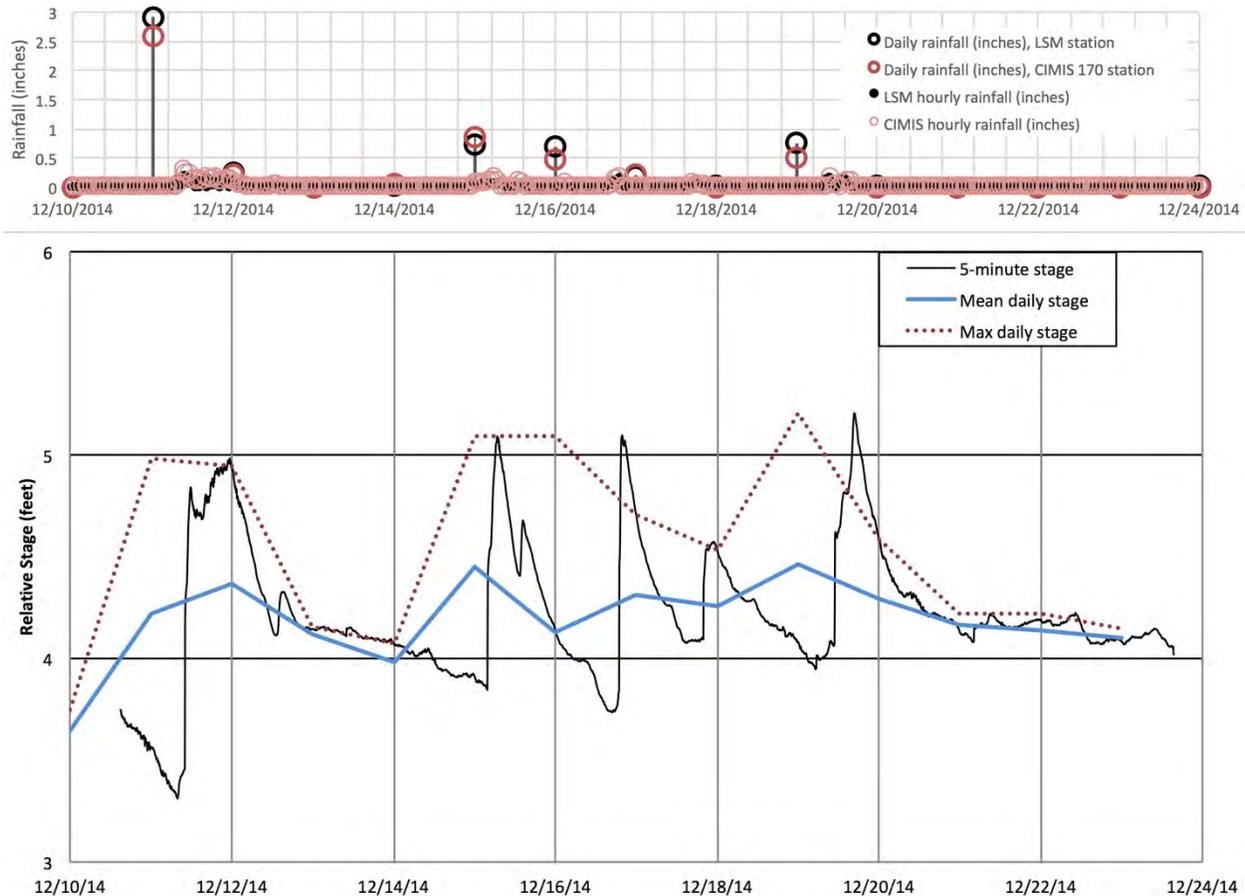


Figure 4-3 Mokelumne Aqueduct pathway relative stage record and two local rainfall records, partial WY2015.

Streamflows at the Mokelumne Aqueduct pathway site were not field-observed, but review of the water surface elevation data logger record and rainfall records (Figure 4-3) indicate the following:

- Water surface elevations increased in response to every rainfall event.
 - Perceived lag times between rainfall measurements and runoff responses are associated with positioning of daily rainfall totals at the start of each day, whereas hourly rainfall values provide detailed information over the period of each day.
- Relative stage water surface elevation data was recorded at 5-minute intervals and plotted as “5-minute stage”. This data set reveals more detailed information, whereas maximum and mean water surface elevations are representative of daily values and thus are less detailed.

- Peak water surface elevations remained relatively constant around the 5-foot relative stage, (slightly increasing across four main peaks) through the two-week period, whereas daily rainfall totals decreased sharply after the December 11-12, 2014 rainfall event.
 - This observation provides another line of evidence (different site, different WY) that as Willow Creek watershed soil infiltration capacities begin to reach saturation conditions, runoff increases.
- Rainfall recorded on December 12, 2014 yielded a cumulative one-day rainfall total of almost 3 inches at both rainfall stations, whereas hourly rates show that it rained steadily all day and into the early morning hours of December 12, 2014.
 - The LSM station recorded more rainfall, 2.92 inches, over the one-day period than the CIMIS station, 2.59 inches.
- The LSM station recorded more rainfall, 5.61 inches, over the two-week monitoring period than the CIMIS station, 4.94 inches.
 - A rain shadow effect does not constrain geographic locations on the downwind side of mountains from receiving more rainfall on a given day or during a given storm; localized variance in rainfall conditions is common.
 - Storm direction has some dependence on the approach direction of the air masses. In the Delta, it is possible for precipitation to approach from the north, which could explain why rainfall totals vary from storm to storm between these two rainfall stations.
- Total rainfall in WY2015 was much greater than in WY2014.
 - The LSM station recorded 5.61 inches of rain in the two-week monitoring period of WY2015, about 70% of the total of 8.09 inches recorded for the entire WY2014 at the same station.
 - Total WY2015 rainfall recorded at the CIMIS station was 13.48 inches, with the highest monthly total of 7.43 inches recorded in December 2014.
 - Total WY2014 rainfall recorded at the CIMIS station was 9.28 inches, with the highest monthly total of 4.04 inches recorded in February 2014.

These data were used to set model conditions, as discussed in Section 6. The gaging equipment at this site was removed at the end of the field campaign, so all components would need to be reinstalled for any additional monitoring.

5 DATABASE COMPONENTS

The modeling components of this study depended on stream flow monitoring and culvert configuration information that was collected in the field, as well as publicly available data files maintained by Contra Costa County (CCCGIS, 2016) and other publicly available data files maintained by government sources such as the U.S. Census, FEMA, NRCS, and USGS.

5.1 Available Data Sets from Contra Costa County

Contra Costa County maintains a publicly available GIS database with files that can be used by citizens for a variety of purposes. Data files downloaded from the County website for use in this project included those related to environmental and built conditions in unincorporated Bay Point, California:

- Digital elevation model
- Orthorectified aerial imagery
- LIDAR ground and structural elevation data files
- Topographic contours
- Rainfall contours
- Watershed boundaries
- Creek drainage channels
- City limits (City of Pittsburg, California)
- Public Works infrastructure
 - Catch basin inlets
 - Headwalls
 - Manholes
 - Stormwater Pipes

These data files were utilized for modeling purposes as well as for establishing baseline hydrologic knowledge of the watershed, selection of monitoring and study sites, and data collection efforts for this study. Most of the figures compiled within this report used

Contra Costa County GIS files as components, in large part to develop an understanding of the Willow Creek watershed and its relationship to the Bay Point community.

5.2 New Data Development

In pursuit of study objectives related to modeling, digital files were created for use within the model environment. These files constitute a portion of the deliverable files for this project, and are briefly described below.

5.2.1 GIS DATA

Investigation of the available visual and tabular information related to the two study areas in the Bay Point community led to the realization that (a) available data as provided through County GIS data files would be very useful in the modeling portion of the project and (b) that some of the existing stormwater infrastructure components observed in the field were missing from the existing County GIS data files.

Identification of this data gap led to collaboration with Public Works staff, which resulted in the location of a set of original analog (paper) maps that depicted additional public works infrastructure that had not been transferred to a digital platform. Analog information in the WCE and WCC study areas was identified, converted to a common datum with existing GIS files, and assimilated into a stormwater infrastructure GIS database file conforming to County standards.

The resulting GIS files augmented County files with 11 additional nodes and multiple links in the WCC study area, and with 18 additional nodes and multiple links in the WCE study area. All nodes are associated with GPS coordinates, and each link is associated with two nodes. Furthermore, information gathered in the field and using additional assumptions in other cases was used to amend pipe diameters for a number of culvert locations. These data were added to the appropriate shapefile attribute tables.

Numerous model output data files were generated during model investigations of existing conditions under design storm conditions ranging from the 2- to 200-year events.

5.2.2 LIDAR DATA

Contra Costa County LIDAR terrain data were processed into two digital elevation models. Development of this data set involved extraction of house and street elevations

in the WCC and WCE study areas. The resulting DEMs provided highly detailed elevation information that was used to model storm runoff in the two study areas.

5.2.3 WCE SUB-WATERSHED BOUNDARY

For the purposes of this study, three sub-watersheds were visually identified in the Willow Creek watershed using CCCGIS (2016) stream channel files. These watersheds were not explicitly delineated, but generally shown in Figure 2-5. The upstream sub-watershed in the WCE study area was digitized and used as the boundary condition file for modeling.

5.2.4 WCE AND WCC STUDY BOUNDARIES

Study boundary shapefiles were used as boundary conditions for modeling.

5.2.5 STREAMFLOW DATA

Raw data logger files were collected during each field campaign at 5-minute concurrent intervals for streamflow water surface elevations and barometric pressure. The WY2014 data set contains about 6 months of streamflow information from the Pacifica Avenue gage installation in the WCC study area. The WY2015 data set contains about 2 weeks of streamflow information from the Mokelumne Aqueduct gage installation in the WCE study area.

5.3 Digital Data Delivery

The digital files described above were packaged into two comprehensive ArcGIS map packages (mcp) or onto a CD for electronic delivery to TWP as well as to the Contra Costa County information technologies department.

6 MODELING OF LOW-IMPACT DEVELOPMENT AND FLOOD HAZARD REDUCTION

As noted previously, large portions of Bay Point lack fully-engineered storm drain systems designed to current County standards. Moreover, even where engineered drainage systems have been constructed, they are almost universally from a time period where modern Best Management Practices for stormwater control and avoidance of hydromodification impacts were not required. Taken together, these factors mean that the community is generally underserved with respect to infrastructure for managing both the quantity and quality of stormwater runoff, with associated implications for the health of stream systems and wetlands in Bay Point itself and in the wetland and marsh environments downstream along the Delta interface.

This realization was the underpinning for the addition of a hydrologic and stormwater modeling element to the overall study. The lack of extensive stormwater infrastructure presents the opportunity to use state-of-the-art modeling tools to assess how the implementation of green infrastructure LID measures and facilities could provide benefits. Such measures are generally agreed to provide enhanced water-quality wherever they are appropriately implemented and maintained. Thus, the focus of the modeling carried out for this study was on flood hazard reduction, and particularly the potential for LID practices to reduce the frequent, localized flooding that is both a regular nuisance and a very visible and tangible manifestation of the lack of investment in community infrastructure.

To this end, two contrasting study areas (Figure 3-1), Willow Creek East (WCE) and Willow Creek Central (WCC) were selected as representing cases where (a) there was a very low level of existing drainage infrastructure (WCE) versus one where the in-place storm drain systems approach current standards (WCC), and (b) one through which a mapped creek flood source flows (WCE) versus one that drains to a mapped flood source but does not include a creek per se (WCC).

6.1 Coupled 2-D Modeling Approach and Platform

The detailed modeling of the potential benefits of LID practices in each study area utilized a coupled hydrologic and stormwater modeling platform that combined 1-dimensional analysis of hard infrastructure (e.g. storm drain pipes, culverts, manholes, etc.) with 2-dimensional overland flow simulation. The selected model platform for the coupled approach was the xpstorm software package from Innovyze (<http://innovyze.com/products/xpstorm/>).

A model package with 2-D overland flow capabilities was specifically called for given the lack of extensive storm drain infrastructure in many areas of Bay Point. Such models, parameterized at a suitably fine resolution, provide a ready way to simulate the complex flow characteristics of such areas. This becomes particularly important in areas with relatively flat terrain (Figure 2-3), where flow pathways and obstructions may be driven by relatively small and indistinct topographic features that can lead to concentrated flow in some locations, often overflowing street rights-of-way where curbs and gutters are absent and leading to potential flood hazards ranging from nuisance-level to property damage.

High-resolution 2-D modeling was prohibitively complex and expensive until relatively recently. Multi-dimensional models require robust computing power that has become available at a practical level in only the last decade. Perhaps more daunting in the past was the difficulty and cost of acquiring topographic information at the resolution needed. The advent of LiDAR systems for wide-spread data collection leading to extensive topographic databases, often made freely available as in the case of Contra Costa County (CCCGIS, 2016), has allowed this significant limitation to be overcome. The convergence of both hardware and software capabilities has made coupled 2-D modeling a practical choice for drainage studies and evaluations of the small-scale infrastructure elements that are typical of distributed green infrastructure LID practices.

The coupled models in this study were thus built on digital terrain models compiled from LiDAR information provided by Contra Costa County (CCCGIS, 2016). The post-processed LiDAR data was converted into a triangulated irregular network from which a grid of nodes and cells was generated within the xpstorm software package. GIS tools were then used to pre-process data on existing stormwater infrastructure features, as well as to create shapefiles representing streets and buildings, which were then imported into the model. GIS pre-processing was also used to generate parameter files for constant infiltration losses (taken from digital soil survey data, NRCS, 2016) and stormwater roughness coefficients.

A key feature of the methodology was the use of distributed rainfall input (“gridded rainfall”) in the hydrologic component of the modeling. Rainfall distributions for 3-hour duration design storm events were compiled per information provided by Public Works, and the resulting rainfall (in inches) was applied to each model uniformly over the respective study area. This approach results in runoff generation as the difference between the rainfall intensity at any given time step and the constant infiltration loss pertaining to the land cover in each grid cell. The resulting distributed rainfall eliminates

the need to define sub-watersheds within the model domain as well as calculations of time lag. The overland flow component of the model is then responsible for such runoff characteristics as flow direction, flow depth, times of concentration over the terrain, and the potential for subsequent infiltration of runoff from impervious areas that flow to previous ones.

6.2 Stormwater Modeling of the Upper Lawlor Creek Watershed

The WCE area includes one of the larger creek channels in Bay Point, namely the branch of the Willow Creek system often identified as Lawlor Creek. This stream has a sub-watershed area of approximately 720 acres (1.1 square miles) where it crosses Highway 4. Immediately downstream, a significant tributary totaling 190 acres (0.3 square miles) also crosses Highway 4, and the combined stream then crosses under the Mokelumne Aqueduct before proceeding generally northerly through the study area. Hydrologic modeling of this relatively large upper watershed area was completed using a distinct software platform than that utilized for the remainder of the detailed modeling work, namely the U.S. Army Corps of Engineers HEC-HMS program parameterized per standards and guidance published by Flood Control.

HEC-HMS modeling requires watershed delineations as an input parameter, so sub-watershed boundaries for the two channels south of Highway 4 were delineated using County LiDAR information. Hydrologic parameters for these sub-watersheds were assigned per site visit observations, review of aerial photography, and associated information sources such as soil survey information. Consistent with the detailed 2-D modeling for the study areas, the design storm events included return periods of 2-, 10-, 100-, and 200-years, all with durations of 3 hours. The main Lawlor Creek watershed was assigned a mean annual precipitation of 17.2 inches per the County’s isohyetal mapping, while the smaller easterly tributary was assigned a value of 15.5 inches. Watershed parameters are summarized in Table 6-1 below.

Table 6-1 Watershed Parameters

Watershed	Total Area		Open Space		Infiltration	Flowpath (miles)		Slope	Lag
	<i>(acres)</i>	<i>(sq miles)</i>	<i>(acres)</i>	<i>(%)</i>		<i>Longest</i>	<i>Centroid</i>			(ft/mile)	(hours)
Main Stem	722.7	1.129	665.3	92	0.16	2.560	1.662	242	1.04
Tributary	188.3	0.294	89.6	48	0.12	1.202	0.475	276	0.33

As seen in Table 6-1, the larger mainstem sub-watershed has substantially more open space than the tributary. This is reflected in the modeled peak discharge values that are tabulated in Table 6-2, whereby even though the mainstem sub-watershed is nearly four times larger, peak discharge values for that part of the overall watershed are generally on the order of twice as large as those of the tributary, at least for 10-year and above storm events. The amount of pervious versus impervious surfaces and a higher infiltration rate for the mainstem are largely responsible for these peak flow differences.

Table 6-2 Modeled Peak Discharge Values

Design Storm	Peak Flow (cfs)		
	<i>Main Stem</i>	<i>Tributary</i>	<i>Overall</i>
2-year	61	50	79
10-year	284	141	350
100-year	479	220	592
200-year	596	245	722

Another important point to note is that there is a distinct difference in timing of the peak flow due to the much longer lag time in the larger mainstem sub-watershed, which again can be attributed to size, open space, and infiltration differences. This means the tributary peak flow occurs markedly earlier during any storm and is “out of phase” with the peak coming down the mainstem. The “Overall” column in Table 6-2 shows this disparity, with an overall discharge not equal to the sum of peak flows.

The output hydrographs from the HEC-HMS model runs were used as inflow boundary conditions for the detailed 2-D modeling.

6.3 2-D Model of the WCE Study Area

The WCE study area was selected due to a number of characteristics that included lack of existing storm drain infrastructure, presence of a mapped FEMA floodplain along Lawlor Creek, and frequent nuisance flooding as reported by local residents. These characteristics indicated that the area would be a good candidate to assess the degree to which localized flooding could be reduced through the installation of distributed

bioretention facilities (also known as “rain gardens”) without the associated capital improvement costs of providing a comprehensive engineered storm drain system.

2-D stormwater model builds were therefore created for a range of conditions to evaluate the potential benefit of installing distributed bioretention facilities representing four percent of the existing impervious cover within the study area, a sizing metric that is consistent with criteria presented in the Stormwater Technical Guidance published by the Contra Costa Clean Water Program¹⁵. The facilities in this case were assumed to consist of a standard surface storage zone over an 18-inch thick layer of select bioretention soil mix over a 3-foot thick gravel underlayer. For the WCE area, the facilities were assumed to not be equipped with underdrain lines or other direct pipe connections to a more comprehensive drainage network. In this sense, the features can be thought of as hybrids between bioretention facilities (due to the select fill materials) and distributed infiltration basins (due to the reliance on percolation). In all cases, ultimate percolation rates were assumed to be limited to those of the underlying soil type (NRCS, 2016).

Model builds were created for existing conditions and for the case with distributed bioretention facilities. Model runs were completed for 3-hour duration design storms ranging from the 2-year up to the 200-year event. The 2-year event was selected as being representative of the size storm that would be responsible for “frequent” localized flooding in areas not equipped with engineered stormwater collection and conveyance systems. The 10-year event was selected to measure the potential benefit in localized flooding reduction for storms that would be generally of the magnitude for which engineered drainage systems are designed. The 100-year event was included to assess whether any benefits would be maintained for truly large storm events and to compare model output for Lawlor Creek with that mapped by FEMA. The 200-year design storm was included as it has been identified by the State of California as a more conservative design event for flood control facilities through the FloodSafe program and Lawlor Creek has apparently not been modeled for such an event. Additional model runs were also completed to evaluate whether localized flooding might be impacted by mid-range

¹⁵ Limitations posed by existing driveway and street layouts, which were accounted for in identifying potential LID sites, mean that the LID features were not distributed and sized strictly per the contributing impervious area. For example, LID features were not modeled within the high-density Emerald Cover Mobile Home Park, while some streets (such as Franklin Avenue and Bella Vista Avenue) had total LID areas greater than four percent of the respective impervious cover.

changes in sea level given the relatively low elevations associated with the northern limit of the study area.

Parallel to the modeling of distributed green infrastructure LID features, a separate set of 2-D model runs were completed to assess the potential benefit of enhanced stream corridor maintenance on the open channel reaches of Lawlor Creek from Hanlon Way north to Willow Pass Road. This reach of the creek has been identified as overgrown in many places by non-native vegetation. Lack of public access easements limit opportunities for regular maintenance, but the reach has been identified by The Watershed Project as a good candidate for voluntary land-owner and/or community-oriented maintenance activities to remove invasive species, improve the overall corridor, and promote community appreciation of local creek systems.

The models created for the WCE study area shared the following characteristics:

- The spatial domain included a total of 73,000 active cells in a uniform 10-foot by 10-foot grid. This gives an active model domain of just under 168 acres in total.
- Boundary conditions were set for free outfall (e.g. runoff was not confined within the study area). Inflow hydrographs for the two Lawlor Creek segments at the south model boundary were taken from the HEC-HMS modeling described previously¹⁶.
- The Lawlor Creek hydrographs were loaded into storage nodes with outflow links representing the existing culverts under Highway 4. The storage nodes were parameterized with elevation-area data extracted from the LiDAR database to simulate the detention storage available south of the highway. In the case of the main channel of Lawlor Creek, field reconnaissance showed that runoff from extremely large storm events would potentially spill into the Contra Costa Canal, effectively limiting the maximum discharge that could flow under Highway 4. Meanwhile, the tributary flows under the highway from a detention basin constructed within the residential development in that sub-watershed.

¹⁶ Both WCE and WCC study area hydrologic models were run with current sea level derived tailwater elevations and with tailwater set 36 inches higher to assess the potential impact of future sea level rise. In both cases, the results showed that sea level rise of this magnitude would not adversely affect conveyance capacity and water surface elevations within the respective study areas.

- Gridded rainfall data was entered using the Flood Control temporal distribution for 3-hour design storms. Design storm totals were based on a mean annual precipitation of 14.3 inches, giving rainfall totals ranging from 0.68 inches for the 2-year event up to 1.71 inches for the 100-year storm. Rainfall for the 200-year event was set at 1.88 inches per guidance provided by the County Hydrologist. The temporal distribution for the 10-year design storm with 1.17 inches of total rainfall is illustrated in Figure 6-1.

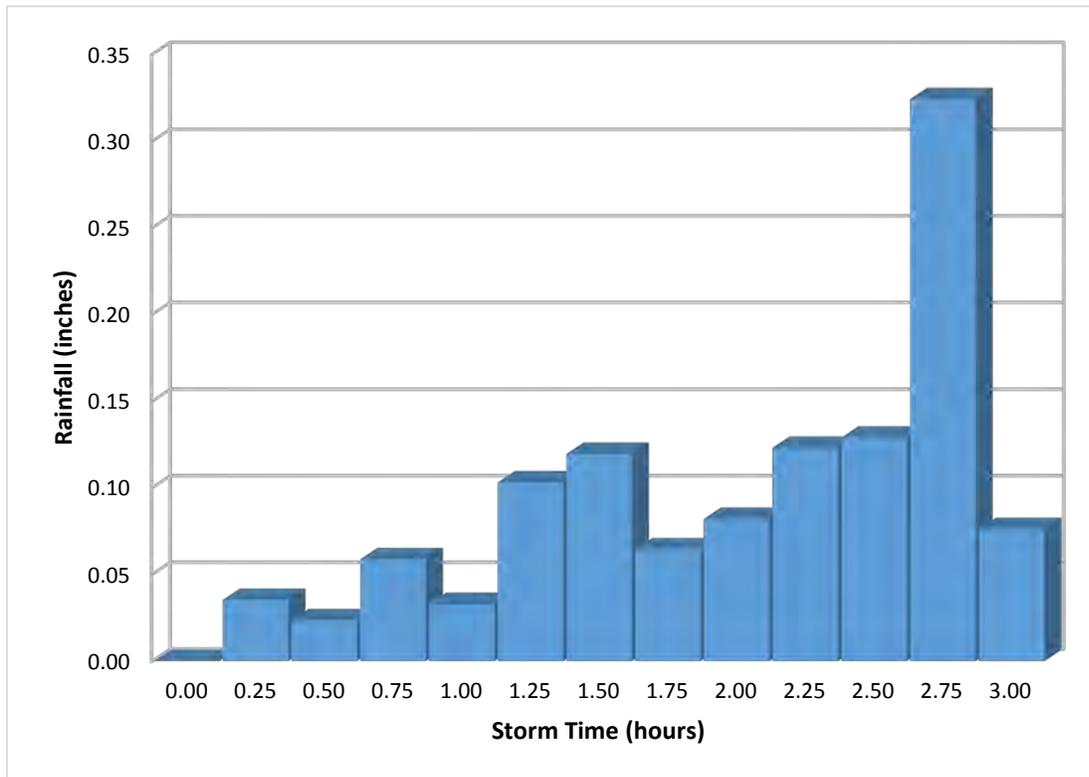


Figure 6-1 Rainfall distribution for the 10-year, 3-hour design storm.

- Impervious surfaces were digitized in GIS from high resolution aerial photography associated with the LiDAR database. Impervious cover was categorized into three groups (roads, driveways, and buildings) with separate shape files created for each cover type. An additional shapefile was created for the Lawlor Creek channel area to parameterize that separately from other areas. All area not included in these shapefiles was considered to be pervious landscaping with uniform hydrologic properties.¹⁷

¹⁷ All xpstorm model files and associated GIS shape files are included in the digital data submittal.

- Infiltration parameters were assigned based on the land cover type with impervious surfaces set to no infiltration and pervious areas set to 0.39 inches/hour. The latter value is roughly twice the value suggested by Flood Control for open space areas, but represents the average saturated stormwater conductivity for Altamont loam soils as taken from published soil survey information (NRCS, 2016). Initial loss values were not used within the 2-D model spatial domain. Infiltration rates for the mainstem and tributary watersheds modeled in HEC-HMS followed County guidelines.
- Roughness coefficients were generally set at 0.015 for existing pipe segments (1-D component of the model) with overland roughness coefficients assigned by land cover type. Streets and driveways were assigned a roughness value of 0.015 and open space areas were assigned a value of 0.15. Buildings were a special case. Building elevations were set to only slightly higher than adjacent ground elevations to avoid abrupt elevation breaks at building edges, but still allow gridded rainfall on the structures. To account for the fact that such structures represent greater obstructions to overland flow than their elevation in the surface model, roughness values were set to 2.0 for all buildings.

6.4 Modeling Results for the WCE Study Area

Multi-dimensional modeling as carried out for this study provides a very large amount of data output that can be analyzed within the xpstorm software or readily exported to other software packages for post-processing. Perhaps the most easily understood of these is flow depth, which can be tabulated at defined time steps or summarized in terms of maximum depth over the model run. Since the data represents flow depth in each grid cell, this allows for statistical analysis on the basis of overall area.

The discussion below summarizes important model output for the study area. A “representative area” was selected for the purposes of assessing the impacts of LID measures on localized flood depths comprising a rectangular area bounded by the intersection of Sapone Lane and Willow Pass Road on the northwest and a point south of the intersection of Bayview Avenue and Hanlon Way on the southeast (just north of Emerald Cove). This area was chosen to exclude the Lawlor Creek channel and adjacent areas where flood depths are almost completely driven by the upstream drainage areas described in detail earlier. The representative area totals approximately 52.2 acres, and allows for a detailed focus on how LID measures may contribute to reduction in a range of flows from nuisance to major flood conditions.

6.4.1 EXISTING CONDITIONS MODELING

The results for the existing condition modeling area are summarized in Table 6-3 for the full range of design storms. As expected, the total area predicted to experience localized flooding increases substantially with the larger design storms. Nonetheless, the general lack of stormwater infrastructure in the WCE area is underscored by the extensive localized flooding predicted for the relatively small 2-year storm, wherein fully 16 percent of the representative area is predicted to have maximum water depths greater than 0.1 feet (1.2 inches). Flood depths of greater concern (here defined as greater than 3 inches) become more evident at the scale of the 100-year event, with seven percent of the representative area impacted.

Table 6-3 Predicted Extent of Localized Flooding in the WCE Study Area under Existing Conditions

Design Storm	Max Depth > 0.1 feet		Max Depth > 0.25 feet	
	<i>(acres)</i>	<i>(% of total)</i>	<i>(acres)</i>	<i>(% of total)</i>
2-year	8.4	16	1.1	2
10-year	12.4	24	1.8	3
100-year	17.1	33	3.4	7
200-year	18.6	36	4.0	8

Localized flooding at the lower threshold value of a 2-year storm with >0.1 feet of water depths would normally not be considered problematic if it were contained within street rights-of-way with a curb and gutter system. The 2-D model platform provides a ready means of assessing whether that is the case, and the results corroborate the observations of residents with respect to the tendency for localized flooding outside of the streets as illustrated in Figure 6-2. The figure shows model output for the central portion of the WCE Study Area, including the main north-south corridor of Lawlor Creek flows and overland flows along neighborhood streets and properties. At a 10-foot by 10-foot cell size, the model does a good job of characterizing surface flow patterns with runoff generally captured and conveyed along the unimproved edges of the main streets. However, the modeling also shows distinct areas where runoff tends to gather to greater depths,

including numerous areas where roadside flow paths are deep enough to spread into adjacent yards and, in some cases, flow through private property.¹⁸

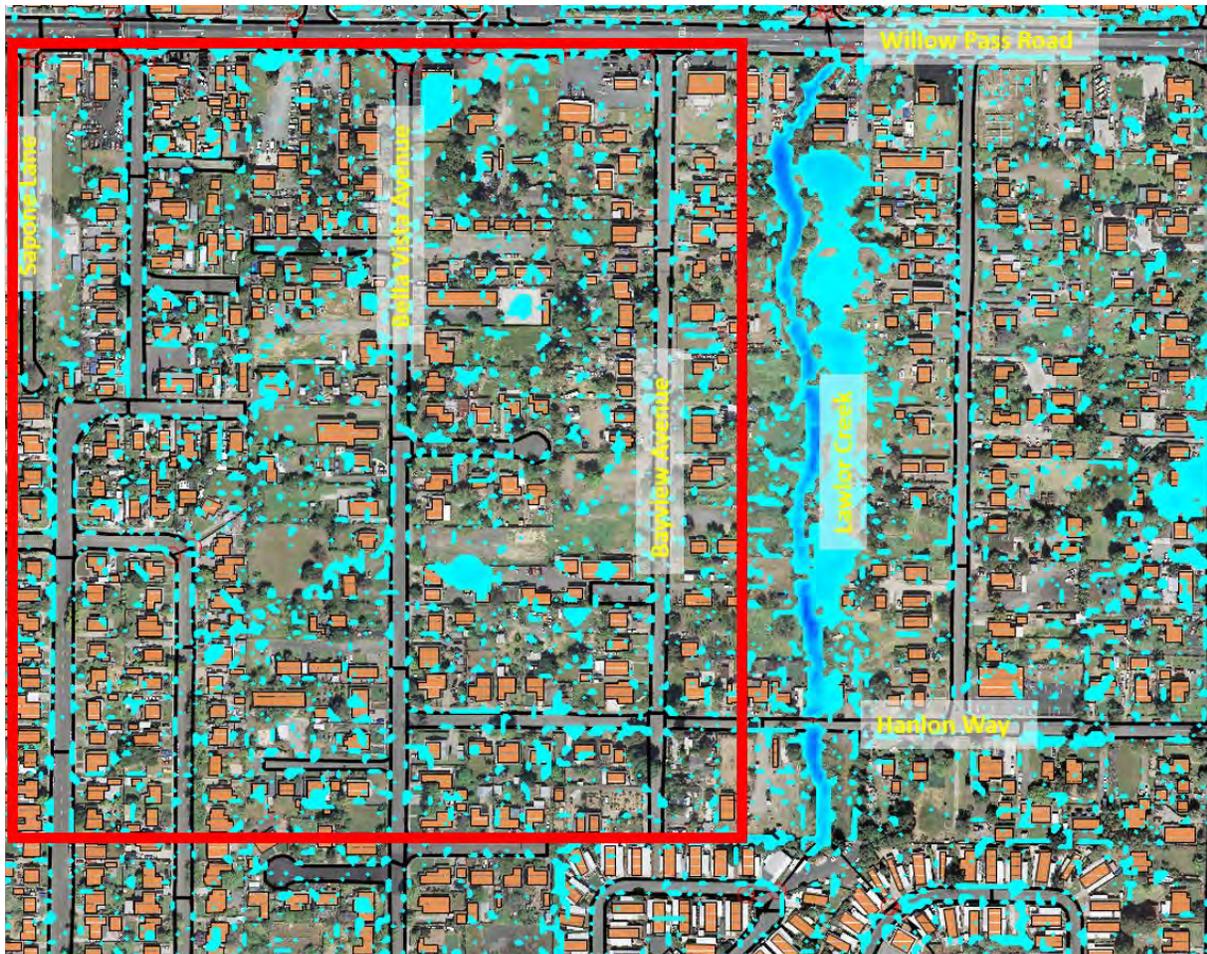


Figure 6-2 Existing conditions flood depths greater than 0.1 feet for the 2-year design storm in WCE. Red inset rectangle bounds the representative 52.2-acre area used for results and discussion related to LID facilities.

Overland flow paths crossing through private property are particularly evident for the 100-year design storm as illustrated in Figure 6-3. The figure clearly shows that in neighborhoods of this type, without curb and gutter infrastructure and raised building pads, very significant amounts of overland flow can be expected during very large storm

¹⁸ The precise extent and depth of off-street flooding may be impacted by drainage features (swales, area drains, etc.) that are not captured in the LiDAR topographic base used for the 2-D modeling. However, Figure 6-2 shows how easily the results can be visually interpreted, allowing for focused follow-up reconnaissance that could lead to pertinent supplemental information included in future model updates.

events. The northeast-trending swathes of blue on either side of Bella Vista Avenue represent locations where runoff will tend to leave the streets and flow downslope across private lots. Modern sub-division standards would typically require a safe release confined to public rights-of-way for runoff from storms up to the 100-year event, and this is clearly not what is predicted for the WCE Study Area. In fact, simple visual examination of the 2-D results readily shows where LID features could contribute most to alleviating localized flooding.

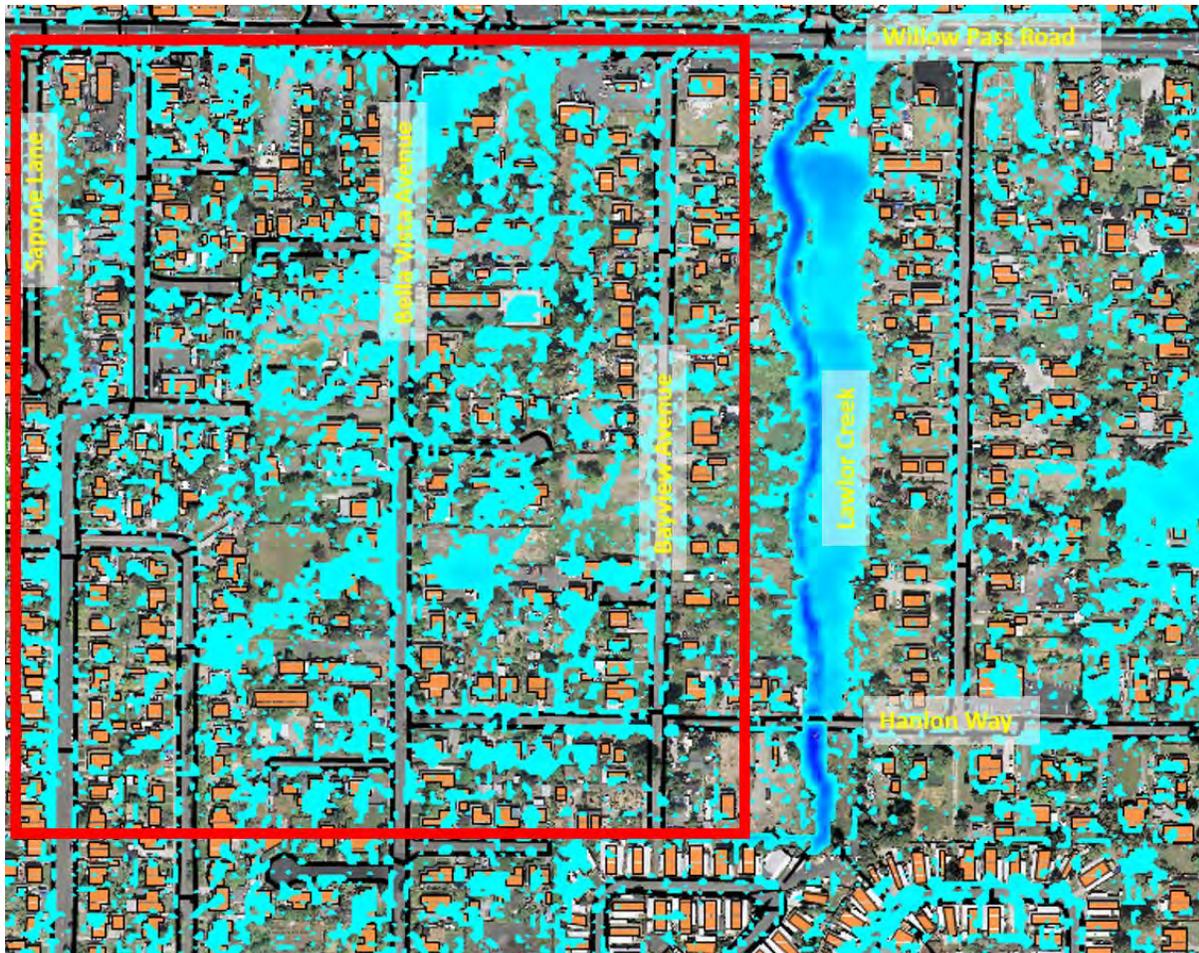


Figure 6-3 Existing conditions flood depths greater than 0.1 feet for the 100-year design storm in WCE. Note particularly the northeast trending overland flow paths east and west of Bella Vista Avenue.

6.4.2 MODELING OF CONDITIONS WITH LID FACILITIES

As discussed previously, the demonstration modeling considered a scenario where LID features (“rain gardens”) could be installed along street rights-of-way wherever space

considerations allowed.¹⁹ This exercise considered all streets in the WCE area with the exception of those in the Emerald Court Mobile Home Park. The representative sub-area has a relatively low total impervious cover of 20.4 acres (e.g. 39 percent impervious). Total LID surfaces drawn into the model geometry for demonstration in the same representative area was 1.1 acres, equivalent to 5.4 percent of the impervious area. The predicted distribution of maximum flooding depths for the representative area after installation of LID features are illustrated in Figure 6-4 for the 2-year design storm and representative performance parameters are summarized in Table 6-4.

¹⁹ Though referred to as rain gardens in this study, green infrastructure LID features could take a number of forms, including equivalently-sized tree planters or similar features. The key criteria would be an active storage volume equivalent to two feet of depth and omission of impermeable liners so that stored runoff could percolate and recharge local groundwater basins.

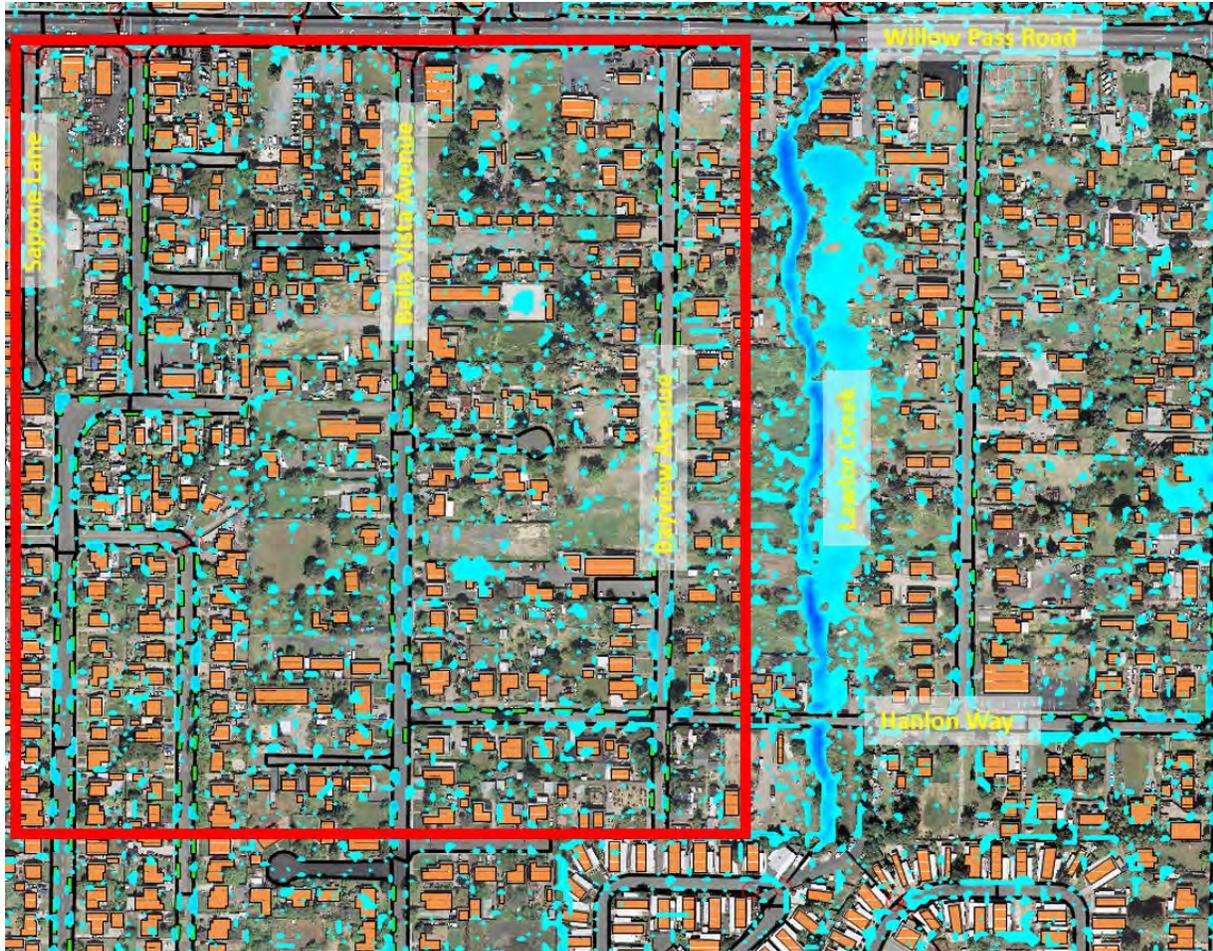


Figure 6-4 Flood depths greater than 0.1 feet for the 2-year design storm in the WCE Study Area with “rain garden” LID facilities. Total inundated acreage within the red-bounded representative area is 5.9 acres, down substantially from 8.4 acres under existing conditions.

The results in Table 6-4 focus on reductions in localized flooding greater than 3 inches in depth as a possible important threshold defining the transition from nuisance to damaging. Even though the LID features were rather uniformly placed for the demonstration modeling and not connected to additional storm drain infrastructure (catch basins, pipes, etc.), the results show that the extent of deeper flooding can be reduced by almost half across a wide range of design storm sizes.

Table 6-4 Predicted Extent of Localized Flooding Greater than 3 Inches Deep with Installation of LID Features

Design Storm	Existing <i>(acres)</i>	w/ LID <i>(acres)</i>	Change <i>(acres)</i>
2-year	1.1	0.6	-0.5
10-year	1.8	1.0	-0.8
100-year	3.4	1.9	-1.5
200-year	4.0	2.3	-1.7

Targeting green infrastructure LID installations for local areas that are prone to drainage problems could be particularly effective. The LID features are difficult to see as most of them are inundated by stormwater – an indication of reasonable feature placement but more difficult to identify placements. As an example, the red rectangle in the right-hand panel of Figure 6-5 shows six rain gardens (green boxes with black borders), but just one (lower right) is not inundated to some extent. One rain garden (middle right) is totally inundated. The other four are inundated to some extent.

A good example of relatively uniform inundation of the modeled rain gardens can be identified along Franklin Avenue, a north-south street in the southwest portion of the representative area. Review of the existing conditions model output showed that runoff along the east side of the street has a tendency to break-out and flow overland across private property toward Bella Vista Avenue (Figure 6-3). The LID modeling, therefore, included a relatively high density of rain garden installations along Franklin to investigate whether rain gardens could be used to address this issue. Results are illustrated in Figure 6-5 for the case of the 10-year design storm. The contrasting views of existing conditions (left) and that with LID features (right) show the overall reduction in localized flooding and specifically underscores the potential for reducing flow break-outs into adjacent yards.

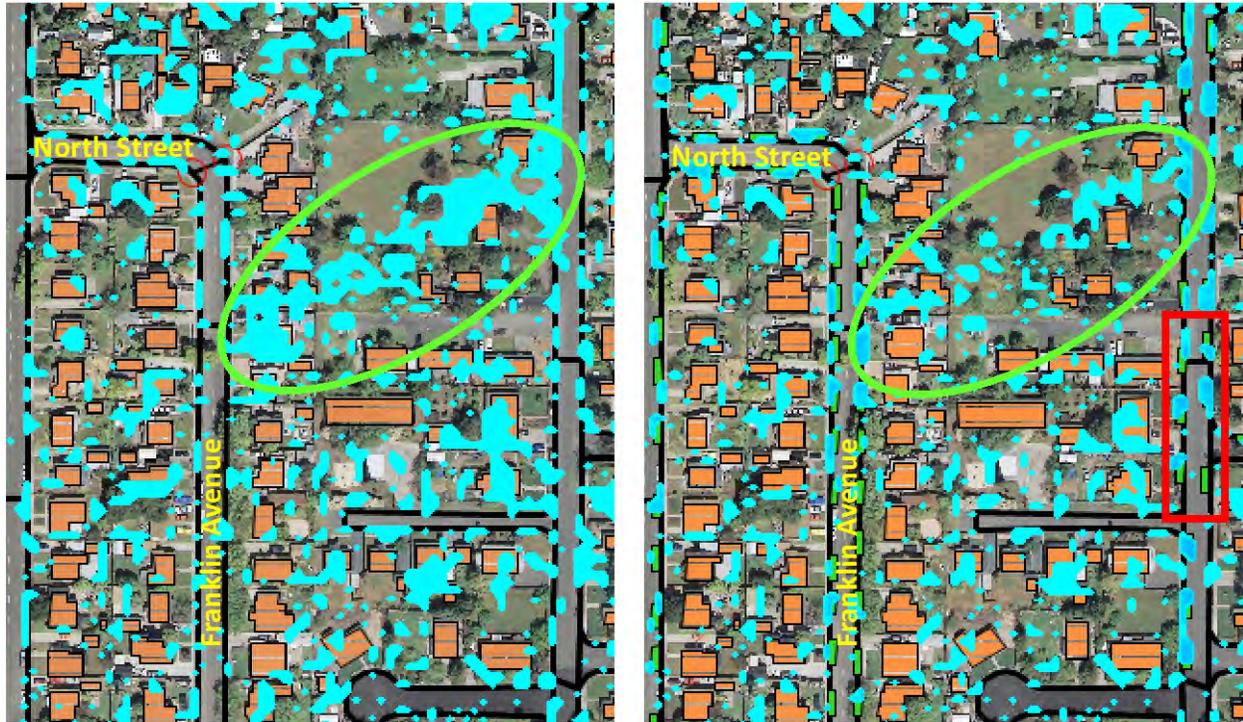


Figure 6-5 Flood depths greater than 0.1 feet for the 10-year design storm in the vicinity of Franklin Avenue under existing conditions (left) and with LID facilities (right). The area highlighted with the oval shows the potential marked reduction in overland flow across private property from the break-out east from Franklin roughly 200 feet south of North Street. LID rain gardens are difficult to identify; six units are located in the rectangle in the right panel with five of six partially or fully inundated.

6.4.3 MODELING OF LAWLOR CREEK ENHANCEMENTS

An additional demonstration application of the hydrologic modeling requested by our project partners was related to the ability of the 2-D analysis platform to generate information related to potential enhancement projects along existing creek corridors. The roughly 1,300-foot reach of Lawlor Creek between Hanlon Way and Willow Pass Road provided an excellent location for this, in large part due to the relatively low tree cover along the channel and adjacent floodplain, which allows relatively good resolution of the creek geometry using the LiDAR database provided by the County. Additionally, this reach of the creek has been significantly overgrown by invasive plants (primarily *arundo donax*) that have been noted to impede channel flow and potentially contribute to increased flood risk in the vicinity.

Therefore, additional model runs were carried out to assess the impact to flooding that might result from a coordinated program of invasive vegetation removal and re-establishment of a native creek corridor plant community. Field reconnaissance revealed that vegetation overgrowth has increased channel roughness, and that it would be quite conceivable that a corridor enhancement program could reduce roughness values by half, down to values more typical of mature riparian canopies along creeks in the region. The 2-D model platform allows for stormwater roughness values to be assigned on an individual grid cell basis, such that the impacts from vegetation management can be resolved at a very fine scale, in this case at the level of the 10-foot by 10-foot model grid.

The model results in this case are presented graphically in Figure 6-6 and Figure 6-7 for the case of the 10-year design storm, which is the level where creek flooding becomes a particular concern for this neighborhood.

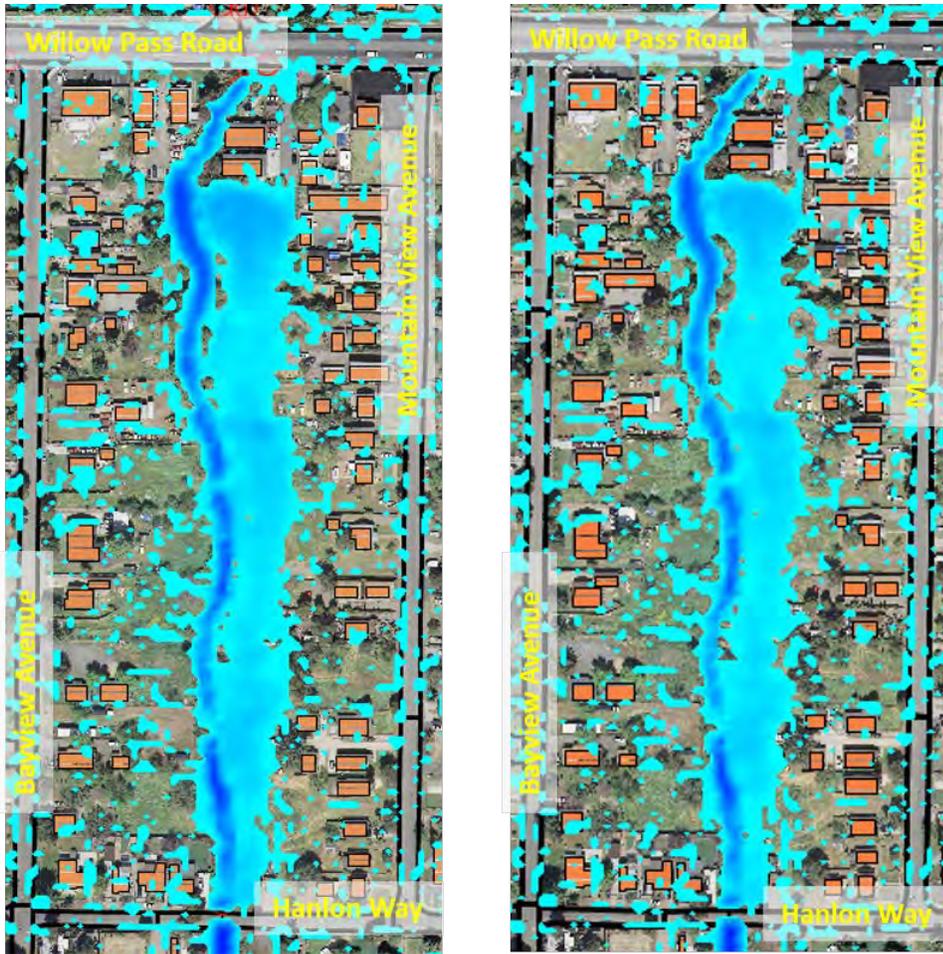


Figure 6-6 Flood depths greater than 0.1 feet for the 10-year design storm along Lawlor Creek under existing conditions (left) and with a coordinated vegetation management program.

The predicted extents of creek flooding as shown in Figure 6-6 are not dramatically different, though close inspection does reveal less encroachment to existing structures, particularly on the east (right bank) of the creek (right side of the creek in each figure). However, the gridded output data from the 2-D model platform allows for detailed statistical analysis of the results in terms of flood elevations, flood depths, and other related parameters. Figure 6-7 shows an example with respect to flood depth reduction for this case, noting that flood depth is an important factor in the amount of potential flood damage and in setting structure elevations to avoid flood risk.

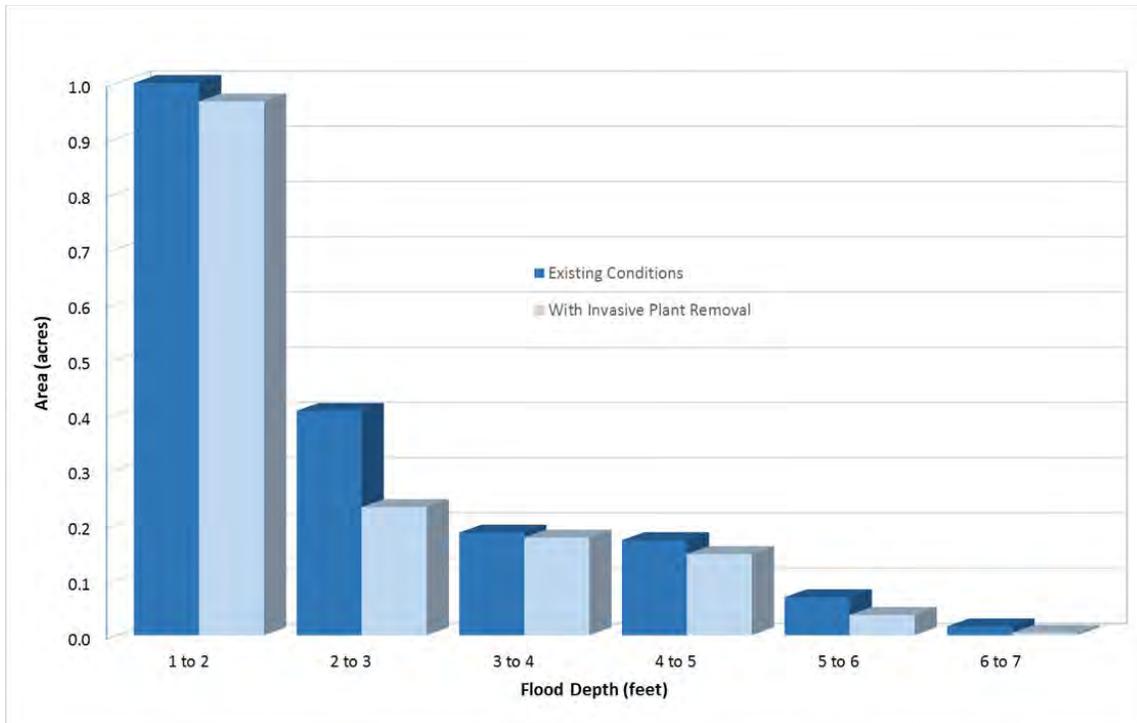


Figure 6-7 Flood depth distribution along Lawlor Creek between Hanlon Way and Willow Pass Road under existing conditions and with invasive plant removal. Note the general reduction in flood depths and the significant drop in area flooded between 2 and 3 feet deep.

The modeling results show that removal of invasive species in a coordinated manner could substantially reduce flood depths along the creek. Flood depth reductions of 6 inches or more would be expected for 0.7 acres of the floodplain, and the total area flooded to 1-foot depth or more would be reduced from 2 acres to 1.6 acres, so at least some of the structures that currently are at risk from flooding during high flows would likely benefit from a maintenance program that included vegetation control between Hanlon Way and Willow Pass Road. Any efforts at further reduction in flood potential in this neighborhood might have to consider more substantial interventions than those offered by vegetation control.

6.5 Modeling Results for the WCC Study Area

The WCC Study Area differs distinctly from the WCE area in a number of important ways. Chief among these is that essentially the entire area was constructed after the adoption of stormwater conveyance standards. Therefore, there is extensive stormwater infrastructure designed per a traditional “collect and convey” approach that utilizes streets with curbs and gutters, catch basin inlets, and pipes. That said, there is little in the

way of stormwater quality and flow control facilities, as was typical of drainage systems at the time of development of this part of Bay Point.

The study area includes 256 acres with an overall impervious cover of 47 percent, fully 12 percentage points above that in the WCE Study Area. As with the WCE area, a full 2-D hydrologic model was created using the xpstorm platform and a representative area was identified for detailed statistical analysis of results. In this case, the representative area includes all of Lynbrook Subdivision north of Chandler Circle and totals just under 119 acres and, at 55 percent impervious cover, is more densely developed than the study area as a whole (see Figure 6-8). Reconnaissance of the area with our project partners revealed a number of limitations with respect to installation of LID features such as those investigated in the WCE Study Area. Perhaps most restrictive are the very large driveway frontages associated with many property lots, often two or more car widths in total, and sidewalks running from the curb line with no landscape median. This type of lot configuration substantially limits the available space for LID features that require surface area such as rain gardens.

Therefore, it was decided to use this study area as a demonstration of the modeling platform's ability to evaluate reduced impervious cover through the use of permeable paving measures. Such measures could range from permeable concrete to various types of pavers and could potentially be deployed wherever practical to replace conventional impermeable pavements. Since driveways had already been classified and included in the geodatabase, they were a convenient basis for the evaluation. Modeling was completed for both existing conditions and for what would be an optimistic distribution of permeable pavements equivalent in area to the delineated driveways in a proposed conditions model run. The driveways totaled 10.2 acres or just under 9 percent of the 119 acres in the representative analysis area. The proposed permeability for these areas was set to match that of the underlying soils (0.39 inches/hour), and no allowance was made for subsurface storage.²⁰ This exercise allowed for consideration of impermeable driveway removal with a likely lower cost basis per permeable surface area of replacement.

²⁰ Most permeable pavement applications are laid over a permeable base (such as sand or gravel) that provides runoff storage volume in its void spaces. The decision to not include such a factor in this modeling was deliberate and intended to contrast with the LID features in the WCE Study Area that included a full 2 feet of storage.

The results of the existing conditions modeling for the WCC Study Area are presented in Table 6-5 and Figure 6-8.

Table 6-5 Predicted Extent of Localized Flooding in the WCC Study Area under Existing Conditions

Design Storm	Max Depth > 0.1 feet		Max Depth > 0.25 feet	
	<i>(acres)</i>	<i>(% of total)</i>	<i>(acres)</i>	<i>(% of total)</i>
2-year	21.8	22	6.3	6
10-year	25.5	26	7.3	7
100-year	29.7	30	8.8	9
200-year	30.7	31	9.4	10

The tabular data confirm that the higher density and impermeable surfaces associated with the representative area leads to relatively large amounts of total area, from 22 to 31 percent, subject to localized flooding. However, Figure 6-8 shows that the model captures the fact that almost all of this flooding would be limited to the public right-of-way, as can be expected of a sub-division with raised lot elevations and continuous curblines (typically 6 inches high). These observations coupled with the existing extensive storm drain pipe system allows stormwater runoff to be largely confined to the streets for even the largest of the design storms, as evidenced by the relatively small increase in the percent of the total area predicted to flood to depths greater than 3 inches between the 2-year event (six percent) and the 200-year event (ten percent). This contrasts with the WCE Study Area where the same predicted depths ranged from two to eight percent (Table 6-3), noting that much more of that flooding was off-street.



Figure 6-8 Flood depths greater than 0.1 feet for the 2-year design storm in the WCC Study Area under existing conditions. The red inset rectangle bounds the representative 119-acre area used for results and discussion.

6.5.1 MODELING OF CONDITIONS WITH PERMEABLE PAVEMENT

Results from demonstration modeling of the permeable pavement scenario are summarized in Table 6-6 for the 2- and 10-year design storms only. These results show that the modeling predicts only very limited improvements even though the permeable pavement coverage was set to relatively high level. Results were not tabulated for the larger design storms, since changes in localized flooding were less than -0.1 acres.

Table 6-6 Predicted Extent of Localized Flooding Greater than 3 Inches Deep with Installation of Permeable Pavement

Design Storm	Existing <i>(acres)</i>	w/ LID <i>(acres)</i>	Change <i>(acres)</i>
2-year	6.3	6.0	-0.3
10-year	7.3	7.2	-0.1

The very limited efficacy found for permeable pavements for this scenario reflects several factors, including:

- The low permeability of soils within the study area. Similar installations where underlying soils are sandier would likely show much more reduction in runoff and localized flooding depths.
- The lack of a runoff storage component. The results confirm that storage is an important element in LID design where soil permeabilities are limited. The rain garden type features modeled in the WCE Study Area would be located in similar soils to the WCC area, but include up to 2 feet of aggregate storage volume in each installation, which highlights the need to include additional storage capacities for any LID features.
- Location of the permeable pavement. The modeling also confirms that use of permeable pavements for driveways will be of limited effect unless roof runoff and lot drainage are intentionally directed to the driveways themselves. Absent that, a more effective location for such pavements would be along the street margins where they could intercept and infiltrate some or all of the gutter flow.
- Finally, it is important to note that xstorm and HEC-HMS were selected to demonstrate that there are multiple model platforms which could be used for investigations of this nature. The difference in results is strictly a function of the green infrastructure LID features selected for inquiry.

6.6 Consideration of Sea Level Rise

Both WCE and WCC study area hydrologic models were run with current sea level derived tailwater elevation and with tailwater elevation set 36 inches higher to assess the potential impact of future sea level rise. In both cases, the results showed that sea level rise of this magnitude would not adversely affect conveyance capacity or water surface

elevations within the respective study areas. It should be noted that predicted sea level rise could increase as those models are refined, so it would be important for sea level rise effects be revisited if additional investigations are undertaken in the Bay Point community.

7 OPPORTUNITIES, CONSTRAINTS, AND LESSONS LEARNED

This project employed a multi-faceted approach to build understanding of stormwater runoff opportunities and constraints in unincorporated Bay Point, California. A discussion of lessons learned, benefits generated, and recommendations for future applications of similar hydrologic investigations related to fulfillment of each objective are discussed below.

The primary study objectives included:

1. Collaboration with community groups and Contra Costa County water resource management entities,
2. Field monitoring of hydrologic conditions,
3. Development of a digital database,
4. Use of one- and two-dimensional modeling to assess existing conditions, and more specifically to assess the potential benefits of green infrastructure implementation.

7.1 Collaborative Efforts

Collaborative opportunities were found within the Bay Point community, although not utilized to the extent envisioned at the beginning of the project. First, we worked with Contra Costa County Public Works staff, who kindly participated in early field site visits. Paper maps were found, scanned, and used to update culvert sizes and locations stored in electronic data files, while field efforts were used to collect culvert and pipe sizes that were also added to electronic data files to augment Public Works existing data files.

Staff from our TWP partners were trained in field data collection methods and stream flow gaging protocols; however, local residents were not involved in the process. A staff plate training exercise was developed that could be used for citizen science monitoring efforts.

One lesson learned from the collaborative efforts portion of this study was that it takes committed engagement and outreach to involve members of the community. The physical nature and timing of field site visits can be inconvenient, as storms follow their own trajectories that do not fall neatly into most daily schedules. However, if a small number of people were willing to be trained and to stay actively engaged, then citizen science efforts could operate and maintain stream flow gage installations and efforts.

The SF Bay Regional Water Quality Control Board²¹ has a citizen science volunteer monitoring program, where lessons in how to maintain commitment and collect quality data could be learned.

7.2 Stream Flow Field Monitoring

It was hoped that citizen scientists would become involved in maintaining the monitoring gages, however, this opportunity has not yet been fulfilled. There are no streamflow monitoring stations in north-central Contra Costa County, so the maintenance and monitoring functions of a hydrologic gaging location in Bay Point would be beneficial for Contra Costa County and the Bay Area region as a whole.

Rainfall monitoring stations that are maintained by County and State agencies are reasonably representative of rainfall in Bay Point, however supplementing rainfall gage information with a station in Bay Point would also be beneficial in filling a geographic data gap.

It is not uncommon for data gaps to exist in rainfall and flow data records. The largest constraints related to hydrologic monitoring are that the collection and management of the data requires specialized training and, for best results, continuous efforts. The field efforts described within this report could be used as a template for additional efforts in the future, but those will require personal commitment as well as some funding for equipment at the least, and potentially professional data workup and reporting.

7.3 Digital Database

Various data files maintained by Contra Costa County personnel were instrumental in development of major elements of this report. The maintenance and utility of these files for the average citizen to the project professional reflects expertise and a commitment to public service on the part of County staff. Moreover, the willingness of Public Works personnel to share knowledge and dig for new information was readily given, and much appreciated. These levels of County support provide opportunities available to anyone who may be interested in pursuing these types of investigations.

The seamlessness of data transfers in the present day resulted in a robust ArcGIS data package that is associated with this report. The resultant ArcGIS map contains all shapefiles downloaded from the County, as well as many files acquired and generated

²¹ See http://www.waterboards.ca.gov/water_issues/programs/swamp/cwt_volunteer.shtml

for the report, including model results. The model results were analyzed and interpreted in Section 6 of this report. The ArcGIS map provides a template and the opportunity for others to create similar report figures and results for the Bay Point community or other areas, particularly those within Contra Costa County.

7.4 Potential Benefits of Green Infrastructure LID Implementation

Hydrologic modeling platforms such as xstorm and HEC-HMS, as well as others, provide detailed predictive capabilities by which to investigate existing conditions and test various infrastructure improvement scenarios. These capabilities are used for many purposes, including as planning tools for projects such as one that could demonstrably improve quality of life within the Bay Point community as well as other DAC communities.

In this study, xstorm results suggest that green infrastructure LID features, modeled as rain gardens but which could take other forms too, would be beneficial in reducing nuisance flows if implemented in the WCE study area. Specifically, these LID features could compensate relatively well for the lack of stormwater infrastructure. Moreover, model refinement would be needed to find optimal locations, densities, and sizes of these features. Invasive vegetation maintenance in the open channel reach between Hanlon Way and Willow Pass Road would provide marginal benefits for some landowners with properties directly adjacent to the creek.

Model results using HEC-HMS in WCC showed a lack of efficacy, contrary to the WCE results. This portion of the study showed that subsurface stormflow storage capacities would be needed in conjunction with permeable driveways to perform better than the demonstration investigation results. Refinements in this model could focus on street gutters, where storm flow are already directly and where permeable surfaces with subsurface stormflow storage capacities would likely provide the best return on a cost basis.

7.5 Closing

In summary, the lessons learned, benefits generated, and recommendations for future applications that can be derived from this project include:

Development of streamflow monitoring sites, resulting in a hydrologic monitoring framework that can be re-occupied in the Bay Point community for additional data collection and citizen-science involvement.

Field observations of wet season conditions during three water years: 2013, 2014, and 2015. Summaries of these visits are contained in this report, and can be integrated with field observations recorded in subsequent years.

Data collection of stream flow runoff and water quality in the Willow Creek watershed in two water years: 2014 and 2015. This information can form the basis for data collection efforts and comparisons in subsequent years.

Development of stormwater models that can be leveraged as platforms for investigate of additional areas in Bay Point or other DAC communities.

Stormwater model results that provide insights into existing conditions under a set of moderate flood conditions (i.e., 2-year and 10-year flows) and high flood conditions (i.e. 100-year and 200-year flows). Stormwater model results that identify that green infrastructure LID features could be useful, and how such installations would perform given the same set of flood conditions.

Development of an ArcGIS dataset, with information that can be integrated into local and regional databases. The projected coordinate system for the map package is NAD_1983_StatePlane_California_III_FIPS_0403_Feet, Lambert_Conformal_Conic.

A comprehensive project report that provides a template for addressing similar hydrologic and stormwater management objectives in other communities.

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APPENDICES

APPENDIX A

**Memorandum of Bay Point field site visit with District
Maintenance staff, November 15, 2012**

Memo

To: The Watershed Project
From: Balance Hydrologics, Inc.
Date: 11/19/2012
Subject: Documentation of Bay Point Field Visit with District Maintenance Staff
Attachments: Figures 1-7, Appendix A

On November 15, 2012, Balance Hydrologics representatives Erik Moreno and Jonathan Owens met with Dave Harper and Brian Louis of Contra Costa County's Flood Control & Water Conservation District (CCFCWCD) for a tour of urban locations in the unincorporated Bay Point community that were known to commonly flood. The purpose of this field reconnaissance was to become familiar with some of the problem areas associated with a list of flood control complaints as reported to the Contra Costa County Maintenance Operations department between 2004 and 2012 (**Appendix A**). The site visits did not include measurements, detailed investigations, or formulation of design solutions. This memo briefly describes observations made during the site visits, and includes photographs and descriptions of problematic locations. **Figure 1** provides a site map and **Figures 2-7** provide additional details on individual locations.

The first site that was visited was located on Mary Ann Lane east of Clearland Circle (**Figure 2**). The creek consisted of a concrete channel that conveys flows into a storm drain through a trash rack. The channel appeared to receive a high amount of trash and debris that commonly blocks the trash rack, causing storm water to overflow onto Mary Ann Lane. Trash was located on the downstream property, which suggests that during some storm events, water will overtop Mary Ann Lane (despite catch-basin inlets from the street surface) and spill onto the downstream property where it likely flows into other neighboring properties downstream.

The next location, on Shore Road west of Wharf Drive (**Figure 3**), consisted of an earthen channel that conveys flows into a culvert to pass under Shore Road and then outfalls downstream north of Shore Road into a smaller earthen channel. Standing water was observed upstream and downstream of the culvert. Standing water suggests limited conveyance capacity of the channel and culvert, which are likely because of flat channel bed slope conditions, as well as flow obstructions, including stands of vegetation growing in the channels, and trash, including concrete debris. The portion of adjacent land to the west of the channel and at a similar low elevation is not developed and likely serves as an overflow detention zone during high flows.

The above channel at Shore Road flows downstream toward the Delta, and makes a ninety-degree bend west at Port Chicago Highway before passing under the Highway in another culvert. Standing water was observed at the inlet and outlet of the culvert, suggesting the same type of reduced conveyance capacity and low slope of the channel and culvert as for the upstream site on Shore Road (**Figure 4**). Cattails had grown in at the downstream end of the culvert, but Dave Harper noted that the maintenance team removes them in a regular basis. Tidal wetlands are downstream of Port Chicago Highway; it was unclear how or whether water crosses the railroad embankments.

The next site visited was to the east on Port Chicago Highway, to a culvert under the highway located east of Inlet Drive (**Figure 5**). Cattails blocked the culvert inlet. Sediment and standing water further limited the conveyance capacity of the channel and culvert. Sediment deposition here and throughout the Willow Creek channel network is most likely related to position on the coastal plain with limited channel bed slopes. The culvert upstream of (south) the highway was relatively clean with some trash but no major hindrance. North of the Port Chicago Highway, twin corrugated metal culverts pass flow from this area under the first train track embankment. However, these pipes were bent and damaged and appeared to be undersized, all conditions that contribute to our observations of water backing up and filling the roadside area between the highway and the embankment. The storage area appeared adequate to hold water until it eventually drained under the train tracks, but that is not the intended purpose of this area north of the highway and south of railway embankments. There appeared to be some evidence that flows may move parallel along the embankment to the west. Standing water in this location may indicate a mosquito problem area, as the area is not intended as a biofiltration basin or any other best management practices area.

Another problematic location was at the downstream end of an earthen channel located between Pacifica Avenue and Skipper Road to the east of Anchor Drive (**Figure 6**). A 60-inch culvert conveys flows under Pacifica Avenue, where there were no reports of flooding as a problem, into an earthen channel that passes through another 60-inch pipe at Skipper Road. The downstream culvert is reportedly undersized and the cause of local upstream flooding. This 60-inch pipe conveys flow east under Skipper Road to an outfall east of Port Chicago Highway. The outfall is heavily vegetated with cattails that likely contribute to limited conveyance capacity through the culvert as a result of sediment deposition and low slope. Private property fencing did not allow for close inspection of the outlet, so it is unknown whether standing water was in the outfall area. Brian Louis with CCFCWCD indicated that retrofitting the single 60-inch culvert with twin 48-inch pipes had been planned, but the project was not implemented for an unknown reason.

The final problem area visited on this day was at the corner of North Street and Franklin Avenue (**Figure 7**). An inlet on the south side of the intersection captures flows and joins water from a grate inlet on the north side of the intersection. These flows move into a small earthen ditch dug by local residents that was approximately 18-inches wide and 12-inches deep. This ditch conveys flows northeast along a property line and into a larger, privately maintained ditch behind a church. Stormwater from Jefferson Street flows east to join this ditch, continuing north and then east adjacent to the church. As with the previous location, Brian Louis indicated that plans had been developed to retrofit this area back in the late 1970's but were never implemented.

In summary, field reconnaissance of problem locations was informative and useful in establishing an understanding of a range of issues that are experienced by citizens of the Bay Point community. Specifically, we found that trash and in-channel vegetation disrupted flows, that undersized pipes continued to create problems long after recognition that the locations should be retrofitted, and low channel gradients do little to assist gravity movement of flows downstream. It seems reasonable to expect that there are additional problem areas that County staff may not be aware of.

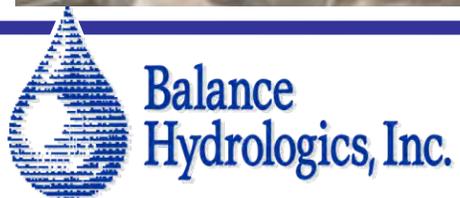
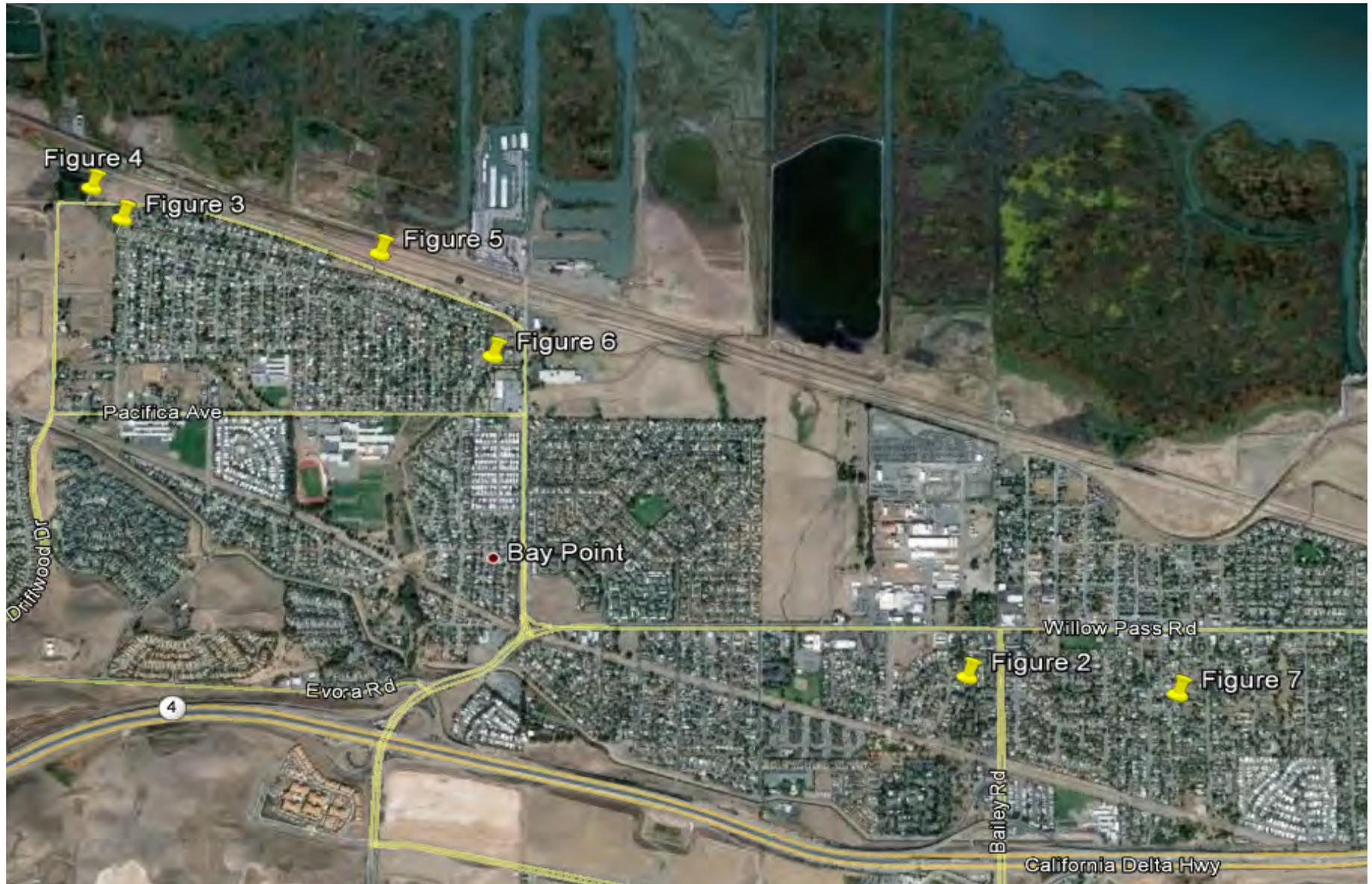


Figure 1. Location map of problematic creek areas visited by Balance Hydrologic and CCFCWCD representatives, Bay Point, Contra Costa County, California.



Figure 2. Mary Ann Lane east of Clearland Circle, Bay Point, California. Photos looking upstream at trapezoidal concrete channel, at trash rack, downstream toward road that commonly floods, and trash on downstream property that receives high flows.



Figure 3. Shore Road west of Wharf Drive, Bay Point, California. Photos looking upstream at grate inlet and vegetated earthen channel, at upstream culvert inlet with standing water, and at downstream end of culvert toward train tracks.





**Balance
Hydrologics, Inc.**

Figure 5. Port Chicago Highway east of Inlet Drive, Bay Point, California. Photos looking at cattails blocking upstream channel from upstream inlet, the upstream inlet, the downstream channel and outlet, and the twin culverts conveying flow under the railroad embankment.





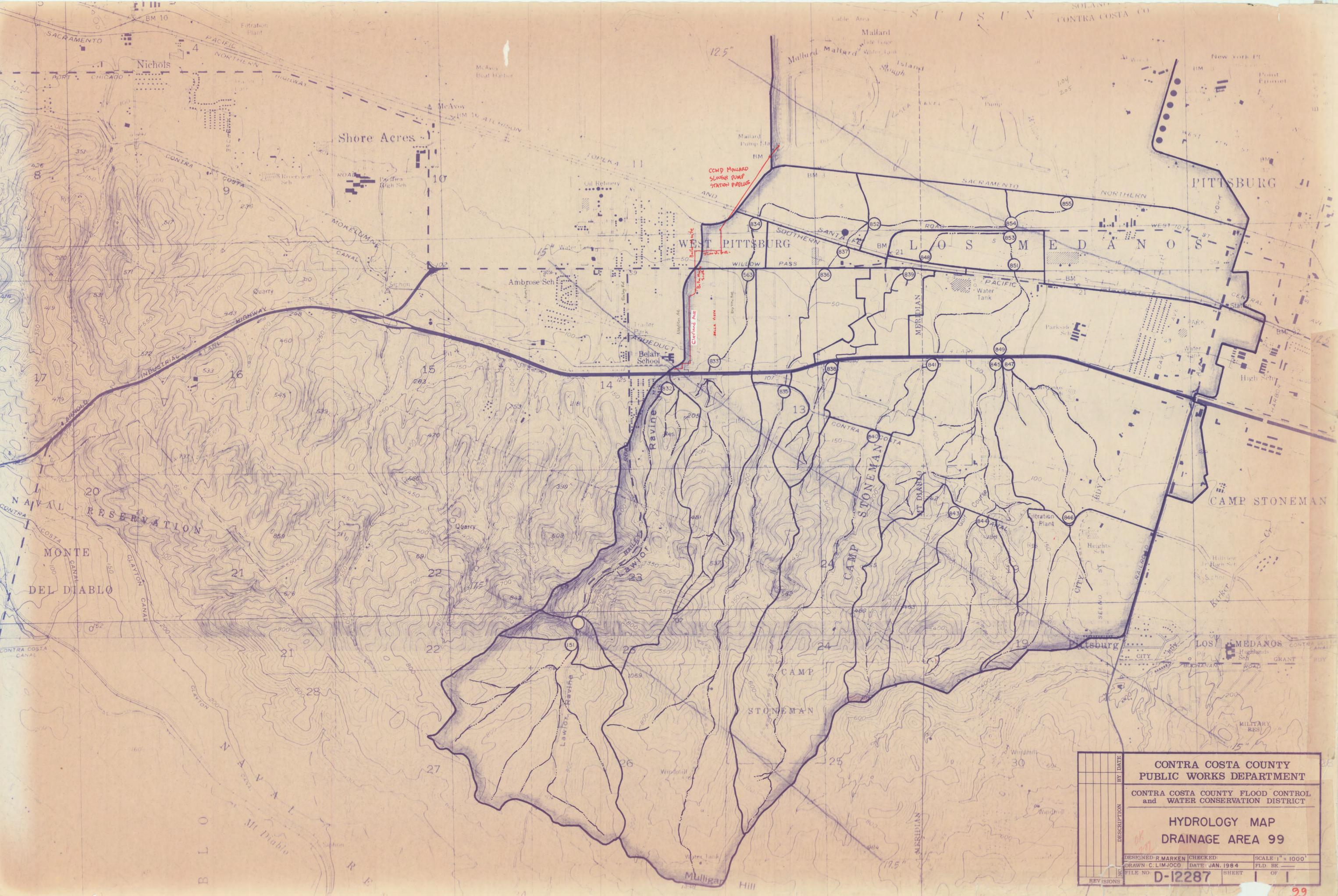
Appendix A.

Contra Costa County Maintenance Operations flood control complaints received from Bay Point, California residents from 2004-2012

Street Address	Cross Street	Date of Complaint	Complaint	Solution/Observations
Mar Vista Road	Delta	10/19/04	Flooding	Trash in catch basin box, boxes were cleaned out.
Anchor Dr	Pacifica	9/27/05	Clogged ditch	Drainage ditch was cleaned out.
Bella Vista		9/27/05	Flooding	Property owner is responsible for maintaining drainage ditch in backyard. Easement was never accepted.
Virginia Dr	Gerald Court	11/10/05	Flooding	Ditch is maintained by home owner, not the County; standing water was 18" deep.
Mar Vista Road	Delta	12/19/05	Flooding	Drain cleaned out; water was backed up into house
Alberts Ave	Water Street	12/20/05	Flooding	Crew cleaned out catch basin and culvert
Shore Rd	Canal Dr	12/28/05	Clogged	VAC-ON clean and flush all drains on Canal Rd and Shore Rd on 1/3/06
North St	Franklin	1/24/06	Flooding	Removed debris blocking drainage culvert, Type A inlet was installed.
Alberts Ave	Marin	2/28/06	Flooding	VAC-ON clean and flush and clean ditch line so water can run. Lots of trash in vacant lot
Wharf Dr	Pacifica	6/13/06		Field check indicated a lot of water running in the ditch for June. Possible spring or broken water line. Ditch cleaned, trees removed, possible lined with asphalt/concrete. Ditch not being maintained, water flowing from up hill to the ditch year round.
Sandy Cove Ln	Pomo St	6/30/06		Trash has built-up in the ravine near Sandy Cove Ln and Pomo St in Bay Point for 20 years (?) and is clogging the drainage line.
North St		5/16/07		Problem with the drainage ditch in front of home. Field inspected the drainage ditch that runs along neighbors fence from the drainage inlet in the street in front of his house. New inlet box was recently installed.
Bella Vista	Pensacola	8/20/07		Storm drainage problems at church. "...storm water has been draining from Jefferson Street, which dead ends behind and uphill of the church property. Storm water drains from west to east into Bella Vista. The water is flowing into the church's foundations. It is not clear if the drainage problem is due to blockage of a catch basin in Jefferson St.
Clearland Circle	Mary Ann Lane	9/4/07		Ditch needs to be cleaned of debris.
Rhea Court	Chandler Circle	9/6/07		Storm drain is blocked w/ debris & vegetation. Needed VACON
Clearland Circle	Flood Control Area	10/15/07		A lot of debris causing flooding when it rains - drains cleared.
Virginia Dr	Alves Ln	10/23/07		Storm drain needs to be clear of weeds and garbage.
Virginia Dr	Alves Ln	12/16/08		Storm drain needs to be cleaned
Hanlon Way	Bay View Dr	3/19/09		Area flooded after previous storm, cross culvert is clogged.
Bella Monte Ave	Willow Pass Rd	10/5/09		The storm drain needs to be cleaned out
Bella Monte Ave	Willow Pass Rd	10/15/09		The storm drain needs to be cleaned out
Wharf Dr	Pacifica	12/17/09		Culvert is plugged
Shore Rd		3/15/10		The drainage inlet gates are plugged with shopping carts. Sinkhole or pothole next to inlet was repaired with rock and cutback, needs to be removed and repaired properly.
North St	Franklin	1/18/12	Flooding	Multiple pieces of furniture dumped into drainage ditch. Worried that property will flood once rain begins.
North St	Franklin	10/24/12		Drainage inlet needs to be cleaned. Called 6 weeks ago and no work has been performed.
Virginia Dr	Alves Ln	10/26/12		Stormdrain clogged and has vegetation growing; drain was cleared out.

APPENDIX B

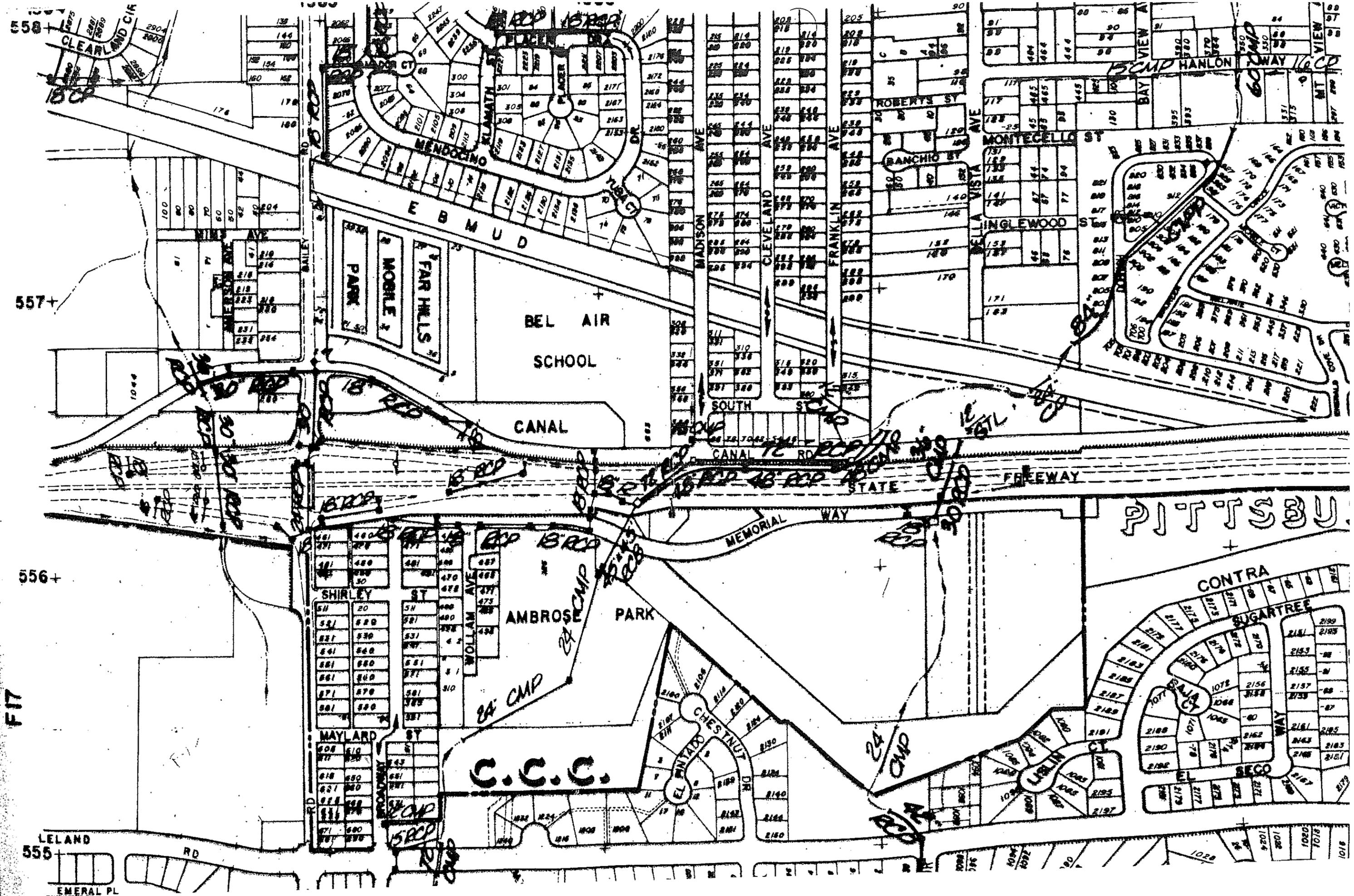
Hydrology map, Contra Costa District 99



BY DATE		CONTRA COSTA COUNTY PUBLIC WORKS DEPARTMENT	
DESCRIPTION		CONTRA COSTA COUNTY FLOOD CONTROL and WATER CONSERVATION DISTRICT	
FILE NO.		HYDROLOGY MAP DRAINAGE AREA 99	
DESIGNED: R. MARKEN	CHECKED:	SCALE: 1" = 1000'	
DRAWN: C. LIMJOCCO	DATE: JAN. 1984	FLD. BK.	
FILE NO. D-12287	SHEET 1	OF 1	
REVISIONS			

APPENDIX C

Stormwater drainage map of partial WCE study area



557+

556+

FT

555

EMERAL PL

APPENDIX D

**Station observer log for streamflow monitoring sites in Bay
Point, California, partial water year 2014**

Appendix B. Station observer log for monitoring locations in Bay Point, California, partial WY2014

Site Conditions				Streamflow				Water Quality Observations					Remarks
Date/Time (mm/dd/yr)	Observer(s)	Stage (feet)	Hydrograph (r/f/s/b)	Measured Discharge (cfs)	Estimated Discharge (cfs)	Instrument Used (AA/PY)	Estimated Accuracy (e/g/f/p)	SSC Total Particulate Solids (mg/l)	SSC Total Coarse Fraction (>63um) (mg/l)	SSC Total Fine Fraction (<63um) (mg/l)	SSC Total Volume of Sample Analyzed (mg/l)	Turbidity (ntu)	
Pacifica Avenue													
11/22/13 10:04	df, ar	3.86	b	...	0.5	visual	p, +/- 25%	...	...	...	...	...	Staff plate installed on right bank approx. 100 feet downstream of Pacifica Avenue, 1 levellogger and 1 barologger installed in stilling well, loggers started at 10 am on 11/22. A distance of 50 ft marked off on the upper right bank for float tests.
2/3/14 14:40	df	3.68	b	...	0.2	visual	p, +/- 25%	...	...	...	...	...	Levelloggers downloaded, no recent visible high water marks; water clear until disturbed.
2/8/14 9:43	ar, eb	4.02	r	...	...	...	...	...	...	...	...	...	HWM at 5.2 feet
2/8/14 9:55	ar, eb	4.10	r	...	...	...	...	...	...	...	...	...	Water rising during flow measurement
2/8/14 10:01	ar, eb	4.14	r	...	...	...	...	...	...	...	...	...	Water rising during flow measurement
2/8/14 10:09	ar, eb	4.14	r	3.5	...	float	g, +/- 5%	...	...	...	...	...	Water rising during flow measurement
2/8/14 12:11	ar, eb	4.27	r	5.6	...	float	f, +/- 9%	...	...	...	...	...	Return trip, water still rising
4/4/14 10:40	df	4.17	f	...	1.0	visual	p, +/- 25%	...	...	...	...	...	Levellogger downloaded, no clear HWM's
5/27/14 9:35	df	3.53	b	...	0.1	...	...	...	...	...	...	...	Removed gaging equipment, levellogger downloaded, end of data collection
Upstream of Emerald Cove Mobile Home Park													
2/8/14 11:14	ar, eb	wet	...	...	...	...	...	...	...	...	...	...	no ponding at bioretention basin
Franklin Ave ditch													
2/8/14 11:30	ar, eb	wet	unk	...	0.3	visual	p, +/- 25%	...	...	...	...	...	flow down Cleveland Ave and splits at North Street toward ditch
Mary Ann Lane													
11/22/13 11:00	df, ar	dry	...	...	...	...	...	...	...	...	...	...	Staff plate installed in cement ditch on left bank, visible from apartment parking lot; left bank angle approx~40 degrees from horizontal; 50 foot float test section marked off on right bank with stakes.
2/3/14 15:01	df	dry	...	...	...	...	...	...	...	...	...	...	No flow in channel but there is some small ponding at lowermost end of ditch.
4/4/14 11:00	df	dry	...	...	...	...	...	...	...	...	...	...	Some water in culvert, but not reaching the staff plate.
5/27/14 10:50	df	dry	...	...	...	...	...	...	...	...	...	...	Removed equipment, end of data collection
Bella Vista Avenue at Willow Pass Road													
2/8/14 11:57	ar	...	r	...	...	...	...	565	88.9	476	468	350	Water quality grab sample from street curb during rainfall conditions
S Bella Monte Avenue at Willow Pass Road													
2/8/14 12:01	ar	...	r	...	...	...	...	233	40.3	193	462	150	Water quality grab sample from street curb during rainfall conditions

Appendix B. Station observer log for monitoring locations in Bay Point, California, partial WY2014

Site Conditions				Streamflow				Water Quality Observations				Remarks	
Date/Time (mm/dd/yr)	Observer(s)	Stage (feet)	Hydrograph (r/f/s/b)	Measured Discharge (cfs)	Estimated Discharge (cfs)	Instrument Used (AA/PY)	Estimated Accuracy (e/g/f/p)	SSC Total Particulate Solids (mg/l)	SSC Total Coarse Fraction (>63um) (mg/l)	SSC Total Fine Fraction (<63um) (mg/l)	SSC Total Volume of Sample Analyzed (mg/l)	Turbidity (ntu)	

Observer Key: df = Dan Freitas, ar = Adam Rianda
 Stage: Water level observed at outside staff plate
 Hydrograph: Describes stream stage as rising (R), falling (F), steady (S), baseflow (B), or uncertain (U).
 Streamflow: If measured, typically made using a standard (AA); pygmy (PY) bucket-wheel ("Price-type") current meter; or portable flume (flume).
 Streamflow: if estimated, from rating curve (R), visual (V), or float test (F).
 Estimated measurement accuracy: Excellent (E) = +/- 2%; Good (G) = +/- 5%; Fair (F) = +/- 9%; Poor (P) estimated percent accuracy given
 High-water mark (HWM): Measured or estimated at location of the staff plate
 Specific conductance: Measured in microSiemens (micromhos/cm) in field, adjusted to 25°C using internal meter conversion
 Additional Sampling: Qbed = bedload; SSC = suspended sediment concentration; DO = dissolved oxygen; Nutr = nutrients

APPENDIX E

Staff plate training guide for citizen scientists

Staff Plate Quiz

Fill in the boxes with the staff plate reading of the corresponding water level

3



2



1



1.0



9



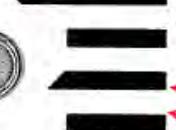
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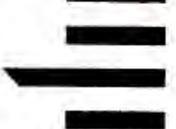
7



6



5



Staff plate -- units are in feet (tenths and hundredths)

Read the flat surface of the water level, as opposed to where surface tension might draw water up the staff plate by about 0.01 feet

3



1.25

2



1.19 feet

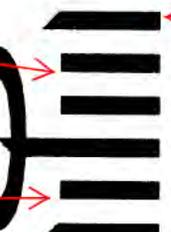
1



1.08 feet

1.03

1.0



1.06 feet

0.97

9



0.85 feet

0.92

8



0.84 feet

7



0.71 feet

6



0.60 feet

5

