



City of Richmond Storm Drain Master Plan Update

Final Report
03/19/2021

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City of Richmond

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Storm Drain Master Plan Update Report for:

City of Richmond Stormwater Support Services
Richmond, California

Prepared for:

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1.0 INTRODUCTION

1.1 PROJECT BACKGROUND AND PURPOSE

The City of Richmond (City) needed an analysis of its storm drain network, identification of drainage and flooding issues, and a prioritized list of Capital Improvement Program (CIP) projects to address flooding and drainage issues. Due to the City's large size and the complex nature of the City's drainage infrastructure only high priority areas were analyzed in this Storm Drain Master Plan (SDMP) Update. The critical factor in identifying high priority areas was a known history of flooding issues.

The purpose of this study is the following:

- Model the storm drain system in high priority areas for 2-, 10- and 100-year frequency interval design storm events
- Identify deficiencies in the systems in the prioritized areas
- Utilize model results to recommend CIP projects

1.2 OVERVIEW AND SETTING

The City is in Contra Costa County, California just north of Berkeley along the San Francisco Bay. The City encompasses 52.5 square miles and has a population of approximately 110,000. The City has a complex and vast drainage network consisting mostly of underground storm drain with some open channels and ditches. Most of the storm drain network discharges directly to channels or inlets of the San Francisco Bay (Bay) or the San Pablo Bay. A vicinity map is included as **Figure 1.1**.

1.3 EXISTING INFORMATION AND STUDIES

1.3.1 Storm Drain Master Plan

Boyle Engineering developed a storm drain master plan (SDMP) for the City in 2006 (Boyle, 2006). The master plan analyzed the main storm drain trunk lines within the City, identified capacity issues, and identified projects to address the capacity issues. Lateral storm drain pipes and inlet capacities were not analyzed. The Boyle Master Plan study was used as a data point for this Master Plan Update in identifying high priority areas.

1.3.2 City of Richmond Green Infrastructure Plan

The City of Richmond published its Stormwater Green Infrastructure Plan (GI Plan) in September 2019 (City of Richmond, 2019). The Plan includes water quality improvement targets, public project identification and prioritization, design guidelines and specifications, and funding options for green infrastructure projects and practices that will reduce stormwater runoff volumes and promote infiltration. Strategies for water quality improvement included in the green infrastructure planning include infiltration basins, bioretention facilities, pervious pavement, raingardens and rainwater harvesting. Current and future projects proposing green infrastructure are mapped in the GI Plan according to their projected time horizon.

1.3.3 Storm Drain System

In 2011, NCE completed an extensive field and mapping effort to create a comprehensive and accurate storm drain network for the City. The basis of the network is a geodatabase that includes spatial (horizontal and vertical location) and attribute (type, size, length, condition, material, etc.) information on storm drain assets (**Figure 1.2**). The City has

continued to update the geodatabase as new information becomes available. The most current version was used as the basis for this storm drain analysis.

Flood complaints taken and compiled by the City were mapped for use in the storm drain analysis and generation of CIP projects. A map of the flooding complaints (hot spots) is included as **Figure 1.3**.

1.3.4 Surface Elevation Data

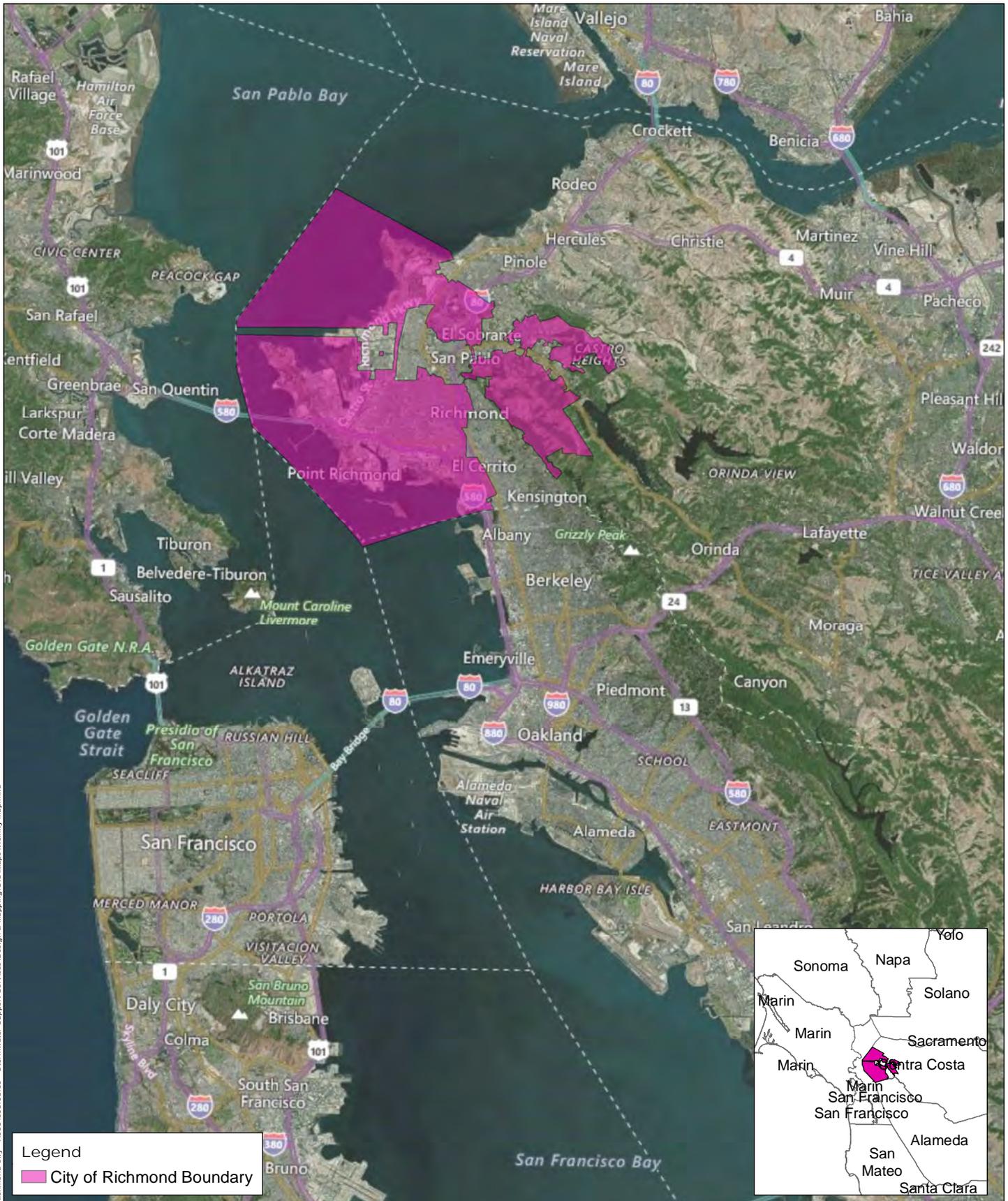
Contra Costa County has 2-foot contour interval LiDAR elevation data available for the entire extent of the City of Richmond (Contra Costa County, 2008). This data was used as the surface for the overland flood modeling.

1.4 PRIORITY AREAS

After review of the Boyle SDMP and the drainage complaint hot spots, the City's storm drain system was divided into draft priority areas ranked as low, medium or high. After discussion with the City's Engineering, Stormwater, and Operations and Maintenance (O&M) staff regarding known flooding and drainage problems, the ranking was finalized. For this study, only analysis of the high priority areas was carried forward. The high priority areas are shown in **Figure 1.4** and presented in **Table 1**. The 7th Street priority area was added in the later stages of this study as it drains directly to a project currently being implemented by the City, the Yellow Brick Road Complete Streets Project. To support integration between this SDMP Update and the City's GI Plan, green infrastructure projects are shown in the **Figure 1.4** to demonstrate their vicinity to the storm drain high priority areas.

Table 1.1: High Priority Areas

High Priority Area	Description
Central Avenue	Small storm drain system with one major hotspot.
South 32nd Street	Includes one hotspot and two Boyle project areas. Large storm drain system with high priority land use (commercial and high density residential).
South 8th Street	Includes one Boyle Project Area. Large storm drain system with high priority land use (commercial and high density residential).
McLaughlin Park	Large storm drain system with three hotspots.
7 th Street	Storm drain services Yellow Brick Road Complete Streets Project area with one hot spot



Legend
 City of Richmond Boundary



City of Richmond Storm Drain Master Plan Update
 Vicinity Map

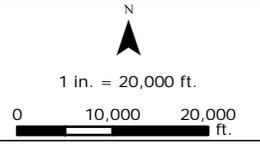


FIGURE
1.1

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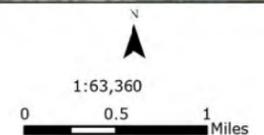
City of Richmond Storm Drain Master Plan Update
Storm Drainage Database

SOURCE Map data ©

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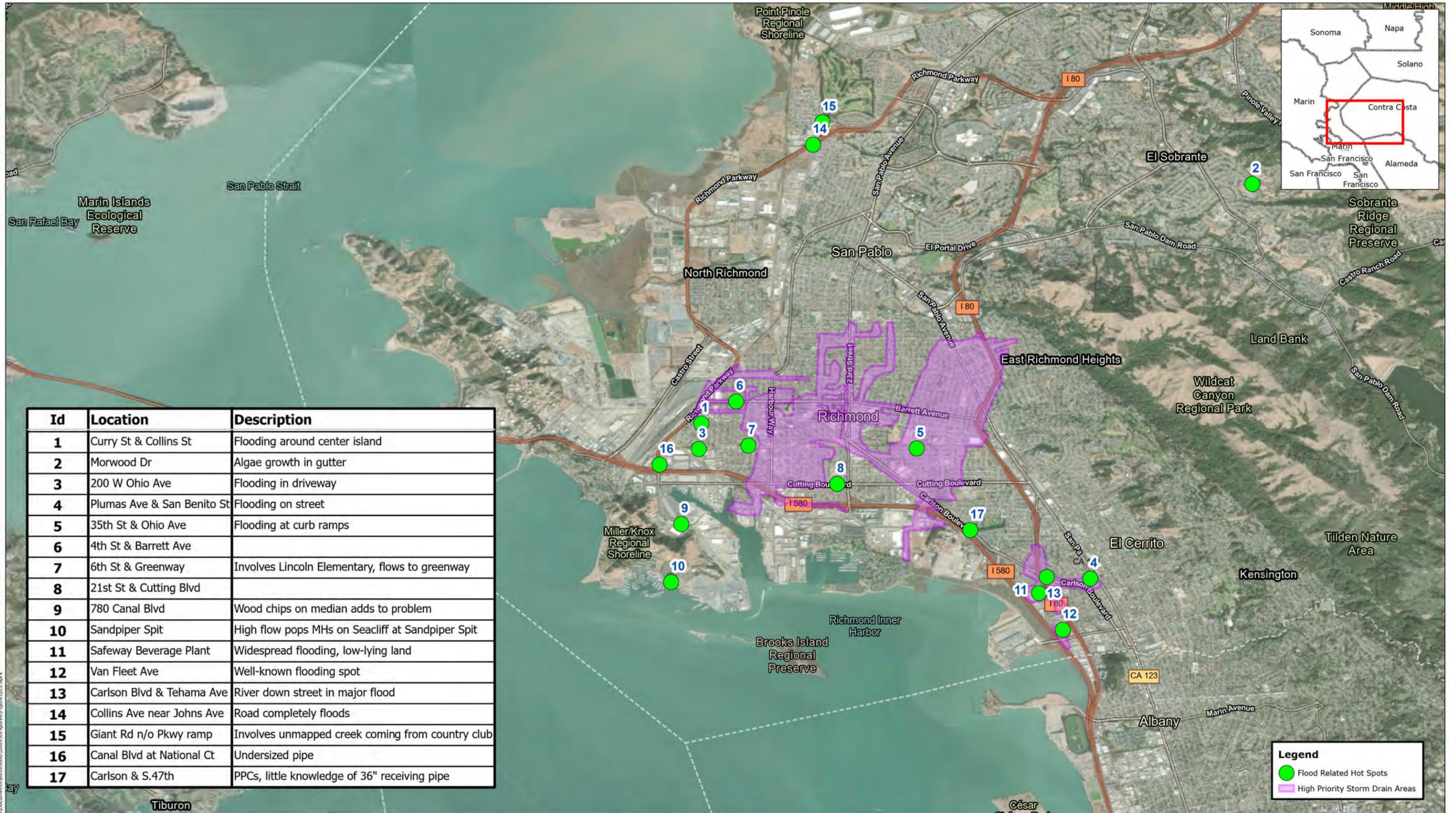
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FIGURE
1.2

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Id	Location	Description
1	Curry St & Collins St	Flooding around center island
2	Morwood Dr	Algae growth in gutter
3	200 W Ohio Ave	Flooding in driveway
4	Plumas Ave & San Benito St	Flooding on street
5	35th St & Ohio Ave	Flooding at curb ramps
6	4th St & Barrett Ave	
7	6th St & Greenway	Involves Lincoln Elementary, flows to greenway
8	21st St & Cutting Blvd	
9	780 Canal Blvd	Wood chips on median adds to problem
10	Sandpiper Spit	High flow pops MHs on Seacliff at Sandpiper Spit
11	Safeway Beverage Plant	Widespread flooding, low-lying land
12	Van Fleet Ave	Well-known flooding spot
13	Carlson Blvd & Tehama Ave	River down street in major flood
14	Collins Ave near Johns Ave	Road completely floods
15	Giant Rd n/o Pkwy ramp	Involves unmapped creek coming from country club
16	Canal Blvd at National Ct	Undersized pipe
17	Carlson & S.47th	PPCs, little knowledge of 36" receiving pipe

Legend

- Flood Related Hot Spots
- High Priority Storm Drain Areas

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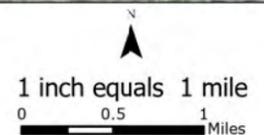
City of Richmond Storm Drain Master Plan Update
Storm Drain Hot Spots

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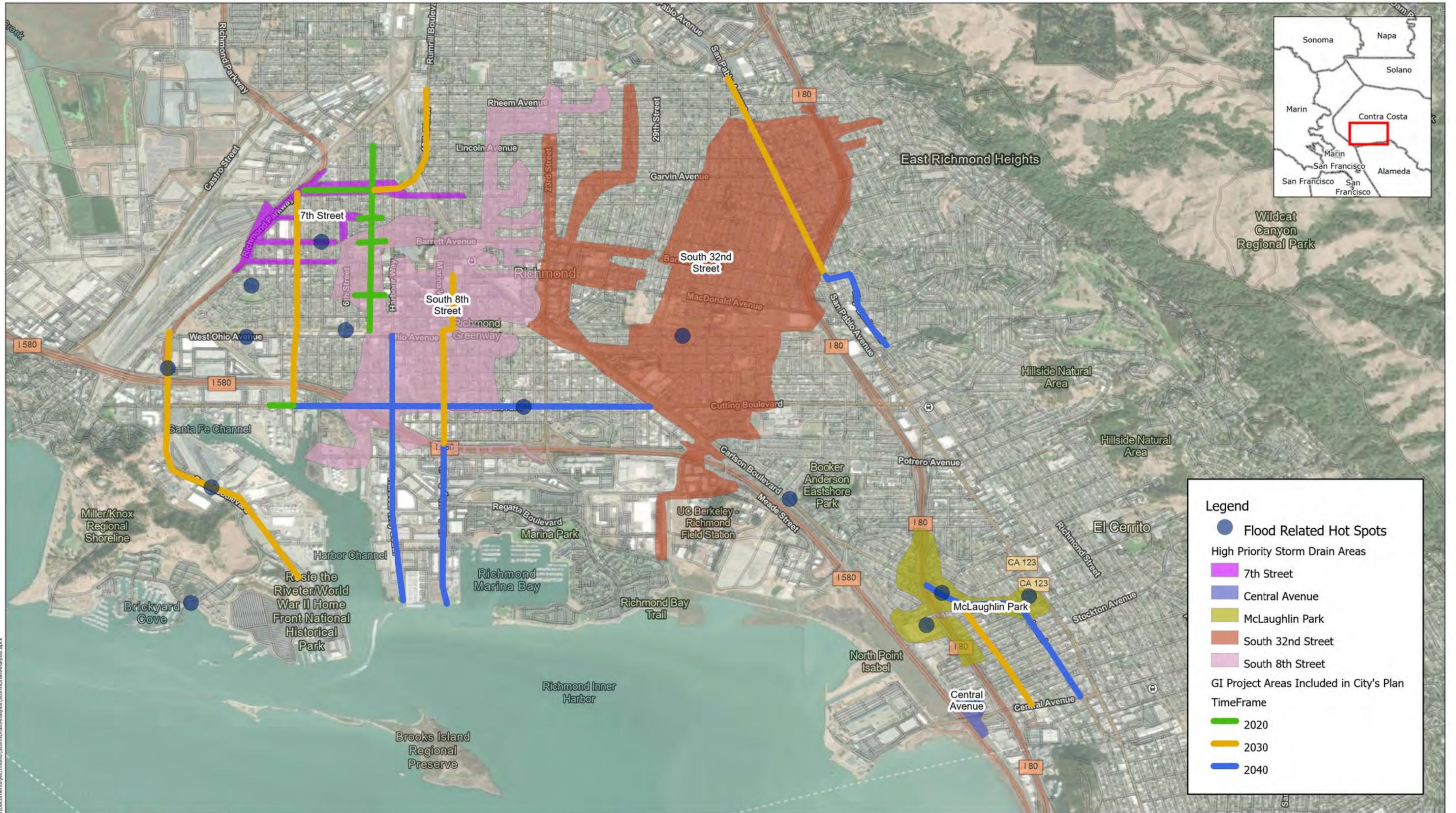
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FIGURE
1.3

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Legend

- Flood Related Hot Spots
- High Priority Storm Drain Areas
 - 7th Street
 - Central Avenue
 - McLaughlin Park
 - South 32nd Street
 - South 8th Street
- GI Project Areas Included in City's Plan TimeFrame
 - 2020
 - 2030
 - 2040

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City of Richmond Storm Drain Master Plan Update
High Priority Areas

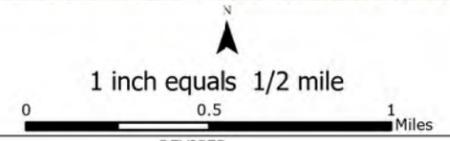


FIGURE
1.4

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2.0 STORM DRAIN ANALYSIS

2.1 APPROACH

The storm drain in the five high priority areas were analyzed using XPStorm, a proprietary hydraulic/hydrologic linked software package developed by Innovyze. The model simulates pressurized and gravity flow in pipe networks. XPStorm also has both rainfall/runoff/loss and two-dimensional (2D) hydraulic modeling components, both of which were used in this analysis. The 2D hydraulic model engine within XPStorm is TuFLOW (<https://www.tuflow.com/>). The hydrologic, storm drain modeling, and 2D overland flow modeling is done simultaneously in XPStorm. The XPStorm model for the Richmond Master Plan Update simulates three distinct processes for each priority area: rainfall runoff within catchments concentrating at storm drain inlets, one-dimensional (1D) hydraulics of the intercepted flow within the storm drain, and 2D overland flow hydraulics of the excess runoff that is not collected by the storm drain system.

Due to model-size limitations within the software, the larger storm drain systems of both the 8th Street and 32nd Street high priority areas had to be divided into three XPStorm models each.

2.2 HYDROLOGIC INPUT DEVELOPMENT

The hydrologic rainfall/loss/translation modeling was done within XPStorm. Catchments were delineated to each storm drain inlet within City's Right of Way (ROW) in the four high priority modeled systems. Please see **Figure 2.1-2.5** for catchment delineations. For areas that drain into the City storm drain system from multiple inlets on private property, such as within office parks and apartment complexes, catchments were delineated to the storm drain at the outlet of the private property. Some catchments within State of California highways draining to City systems were also combined.

For most of the catchments (ranging in size from less than an acre to slightly over 10 acres), the preferred method for runoff computation according to Contra Costa County standards is the Rational Method. However, to generate hydrographs needed for the 2D analysis, the Rational Method cannot be utilized. Instead, a runoff method that produces peak flows similar to the Rational Method and matches or exceeds the Contra Costa County Flood Control District hydrograph methodology was utilized with the following assumptions/clarifications:

- Hydrologic methods within XPStorm were chosen to mimic Contra Costa County loss and hydrograph methods as closely as possible
- Catchments were delineated to inlets within the studied systems
- Hydrologic analysis was done per catchment
- Impervious area was assumed to be 80% for all catchments assuming highly urbanized area
- Precipitation depths were taken from NOAA Atlas 14 for the 2-, 10-, and 100-year return intervals. The storm duration was set to 3-hours
- The loss method used in XPStorm was Uniform Loss with an initial loss set to 0.15 inch and continuing loss set to 0.05 inch/hour
- The translation/routing method was set to Snyder Unit Hydrograph Alameda with following parameters
 - Longest watercourse (L) and slope were measured from Contra Costa County LiDAR
 - Length from centroid was assumed to be $0.5 \times L$ for all catchments
 - Roughness for the time of concentration calculations was assumed to be 0.025 for all catchments (assuming most flow routes through aging roads)



Legend

- Storm Drain
- Central Avenue Catchments

City of Richmond Storm Drain Master Plan Update
Central Avenue Priority Area

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FIGURE 2.1

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Legend

- Interstate
- Storm Drain
- South 32nd Street Catchments



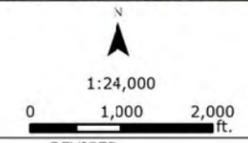
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City of Richmond Storm Drain Master Plan Update
South 32nd Street Priority Area

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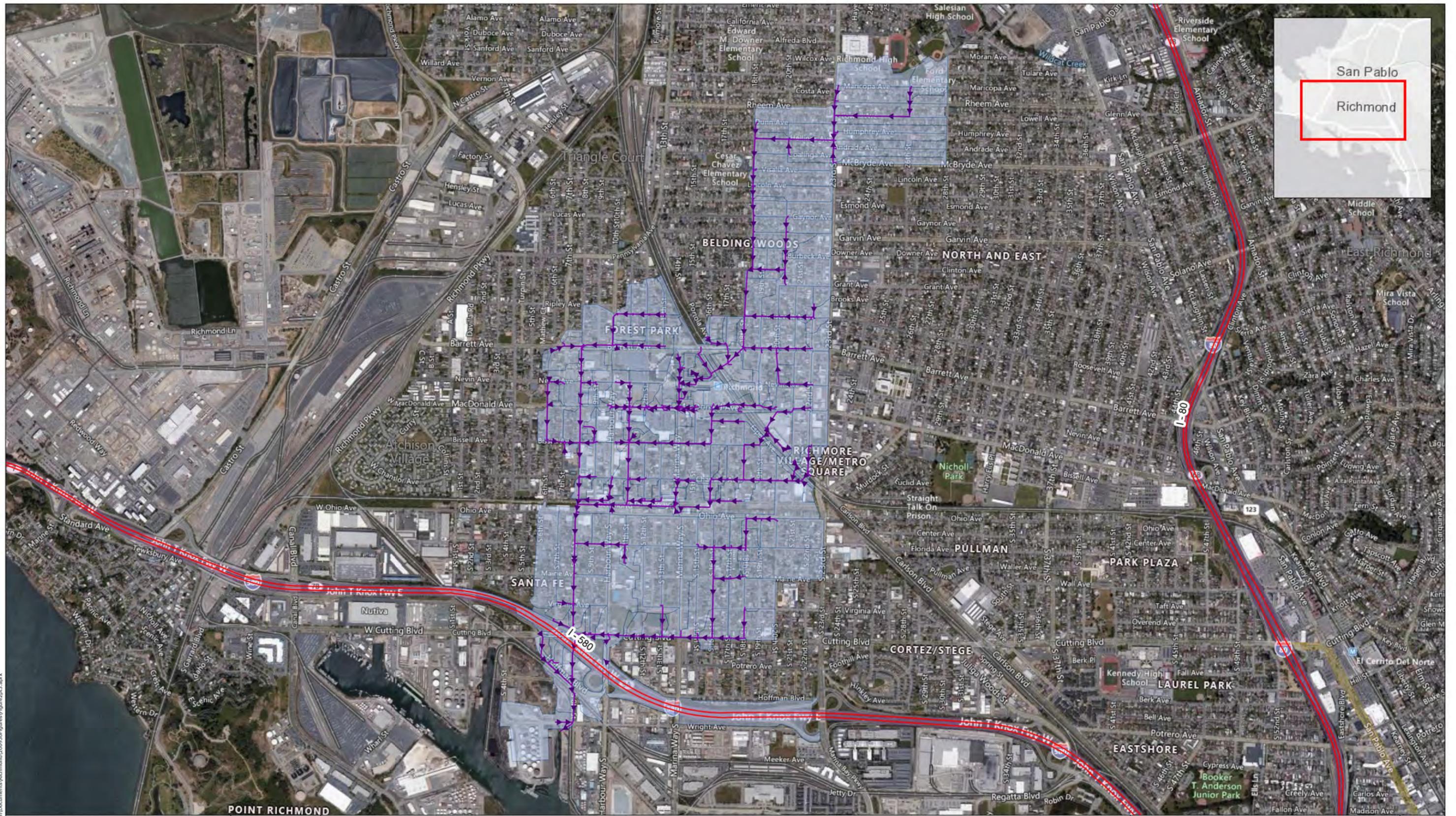
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FIGURE
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- Interstate
- Storm Drain
- South 8th Street Catchments



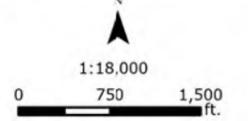
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City of Richmond Storm Drain Master Plan Update
South 8th Street Priority Area

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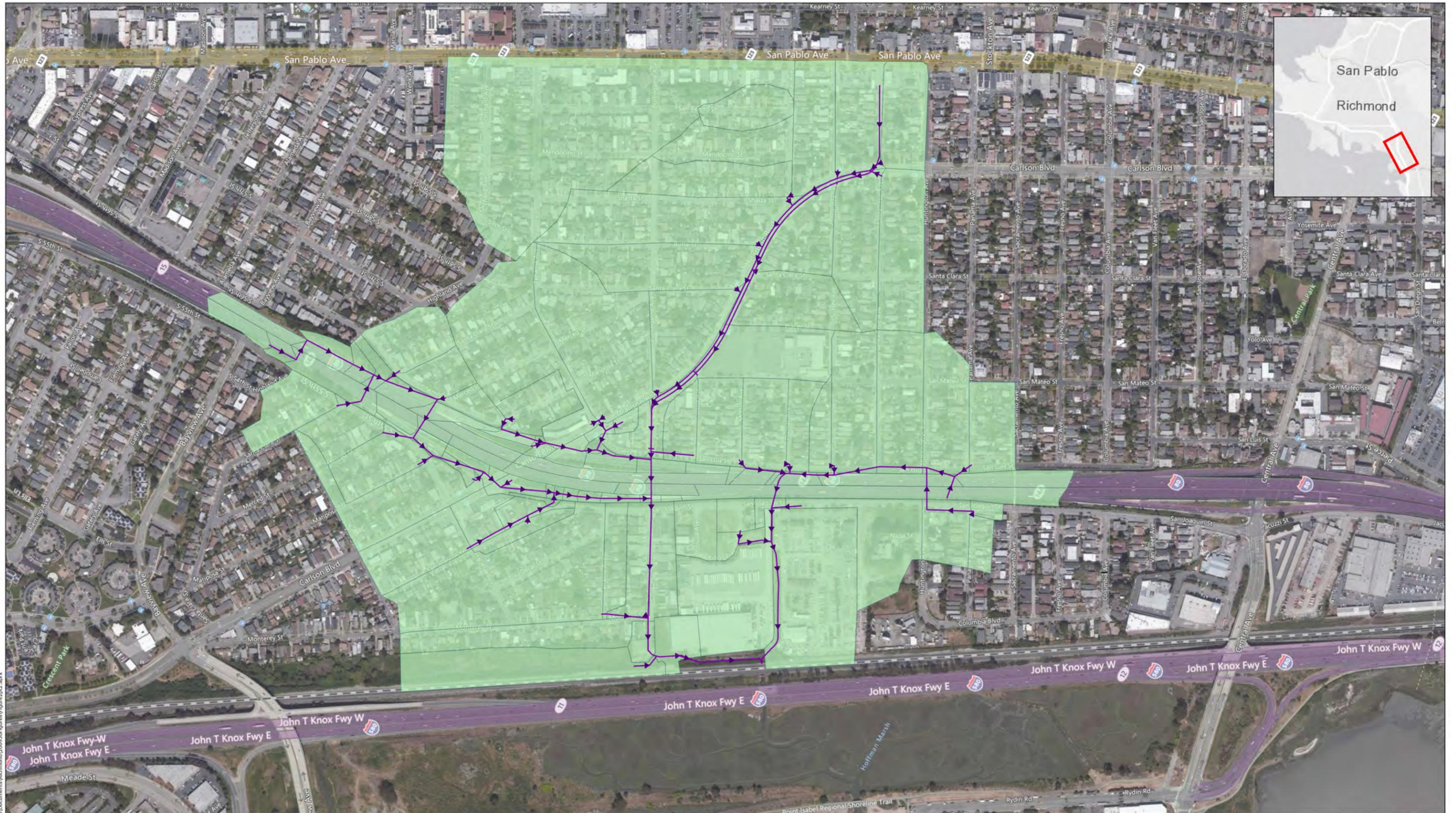


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City of Richmond Storm Drain Master Plan Update
 McLaughlin Park Priority Area

- Legend**
- Storm Drain
 - McLaughlin Park Catchments

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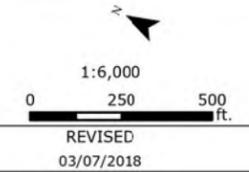
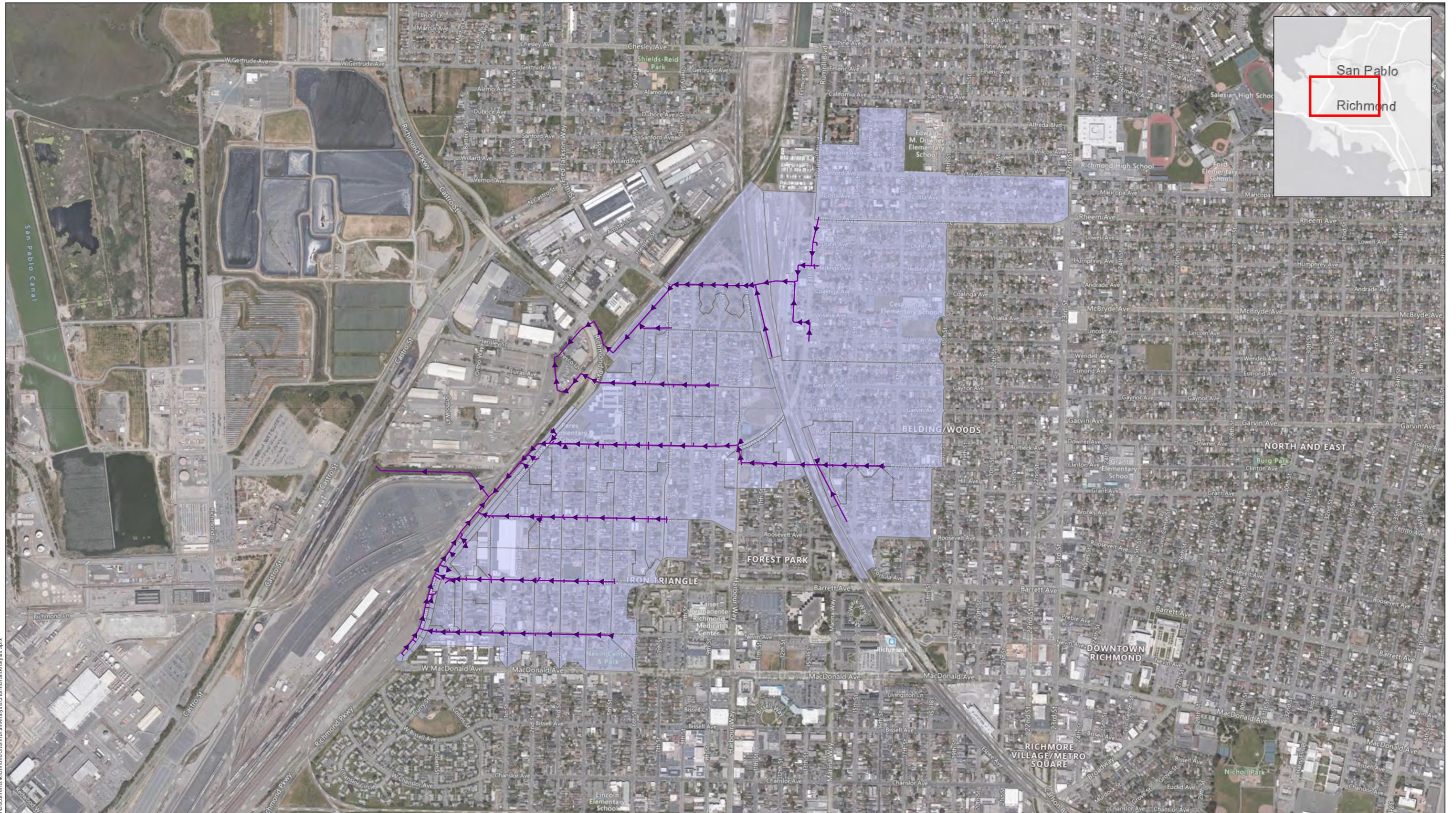


FIGURE
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Legend
 - Storm Drain
 - 7th Street Catchments



SOURCE
 ESRI World Imagery Basemap: City of Richmond

City of Richmond Storm Drain Master Plan Update
 7th Street Priority Area

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FIGURE
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2.3 HYDRAULIC ANALYSIS

The 1D portion of the XPStorm model, for the five high priority areas, was built from the City's geodatabase. County LiDAR data were used to build the surface for the 2D of model overlaying the four storm drain models.

2.3.1 Storm Drain Parameters

The storm drain system is represented within XPStorm as a network of nodes (manholes, inlets, and outfalls) and links (storm drain pipes, culverts, and open channels) which accept the rainfall runoff from the delineated catchments. Elevation, size and specifications for the storm drain pipes, inlets, manholes, and outfalls are based on the geodatabase. For inlets within the City ROW accepting flow from one upstream catchment, the inlet capacity functionality was used within XPStorm which calculates how much flow can be intercepted by a given inlet. For inlets accepting flow from an upstream system on private property where catchments were consolidated, the inlet capacity functionality was not used.

The storm drain systems analyzed discharge to a channel or inlet that is connected to the Bay and are tidally controlled. Three types of tailwater were modeled for each design storm for each system:

- Normal Depth: assuming low tide in normal present-day conditions
- Storm Surge: with high tide occurring during storm surging present-day conditions
- Sea Level Rise (SLR): assuming mean tide during end-of-century condition with 6-feet of sea level rise which is the 1% probability for the high emission scenario for San Francisco according to State of California Sea-Level Rise Guidance (State of California, 2018).

The tailwater conditions representing storm surge include high tide. Estimations of high tide were taken from NOAA data for the Richmond, CA NOAA weather station (NOAA, 2018b). Storm surge depths were adjusted according to the return interval of the design storm taken from San Francisco, California weather station (NOAA, 2018c).

2.3.2 2D Modeling Parameters

The Digital Elevation Model (DEM) used for the 2D analysis was developed using the County LiDAR datasets compiled in 2007. The DEM has enough resolution to represent topographic highs and lows of the curbs and gutters in the City, which allows preferential flow through the streets. Modeled grid cell size of 15 feet was chosen to optimize for model run time, while still resolving curb topography, to allow for preferential flow in the streets.

The models are set up so that the inlets and manhole nodes are linked to the 2D model. When inlet capacities are overwhelmed in the model or when the computed hydraulic grade line goes above the surface elevation at an inlet or manhole, the excess flow enters the 2D overland flow model.

2.3.3 Modeling Assumptions

The geodatabase does not have complete information on all assets. A portion of the facilities lack invert/surface elevations, size, inlet dimension/type, and/or pipe size/type. Assumptions based on upstream and downstream facilities and the LiDAR surface information were used to fill in any missing elevation data. Missing diameters were based on upstream and downstream facility information. When inlet type and size were missing, the inlet was assumed to be a 2-foot x 2-foot grate.

In addition to the missing data assumptions, the following assumptions were made to simplify the model input:

- Storm drain pipe roughness was set to a default value of 0.014 assuming most are aging concrete.

- To calculate the capacity of each inlet, XPStorm requires a roadway cross section, including curb and gutter, and longitudinal roadway slope at each location. A typical section, having a 2% road cross slope, 8% gutter cross slope, 6-inch vertical curb, and 1% longitudinal slope was applied.
- Inlets were assumed to be either curb openings, grates, or combination. No investigation was done to confirm sizing or specifications.
- For 2D routing, all roughness was assumed to be 0.05 (assuming most flow routes through roads while considering building and vegetative obstructions).
- The 8th Street and 32nd Street model domains had to be divided into 3 models each and run in series. Each individual model shared a node with its upstream model and downstream model. For each design event and tailwater combination, the upstream model was run first, and the hydrograph at the most downstream node in the first model was transferred to the next downstream model, which was run, and the most downstream flow was transferred to the most downstream model. A sensitivity analysis was done to see if the tailwater from the downstream model would affect the results of the upstream model. Although it did impact the flows in the model during the beginning of the run, it did not change the peak water surface elevations or inundation results.
- There are several pump stations throughout the City that collect flow from low-lying areas and convey it to outlet pipes. Some low-lying areas are outside the City's ROW or do not drain to the City's storm drain system (e.g. depressed State Highway areas). These areas were not delineated and were left as-is in the 2D overland flow model. This is represented as pooled flow in the 2D hydraulics model. Low-lying neighborhoods connected to the City's storm drain system were included in the catchment delineation and connected to the storm drain system at the outlet of the pump station; not simulating the pump station hydraulics but including the flow in the storm drain hydraulics. In one location in the McLaughlin modeling domain, a pump station was added to the XPStorm model in the Annex region.
- Model runs were done with both the inlet capacity functionality turned on, where the model computes the capacity of each inlet, and with the inlet capacity functionality turned off. The runs with the inlet capacity turned off assume that all flow generated in the model can be conveyed to the pipe network and were done to test the capacity of the storm drain pipes.
- The main storm drain going through the McLaughlin Park area, within Carlson Boulevard, comes from the City of El Cerrito. The City obtained the storm drain database from El Cerrito and this storm drain has a large contributing drainage area. To account for flow within the storm drain, it is assumed to be conveying full pipe discharge in all design events.
- One of the hot spots in the McLaughlin Park high priority area is along Plumas Avenue upstream and east of Carlson Boulevard. The City has received numerous drainage complaints of street flooding. There is no storm drain along this stretch; flow runs down Plumas Avenue to concentrate at the inlets to the storm drain along the east side of Carlson Boulevard. Catchments in the area were initially delineated to concentrate at these inlets, which potentially under-emphasized flooding that could be occurring upstream within Plumas Avenue. After discussion with the City about potential CIP projects, this area was flagged for more detailed study. The catchments were reconfigured to concentrate along Plumas Avenue and the street was input as a conveyance facility. If the street is overwhelmed in the revised model runs, flow will be transferred to the 2D model within XPStorm.

3.0 RESULTS

3.1 STORM DRAIN SIMULATION RESULTS

The inundation results of the XPStorm models are included in **Appendix A**. Inundation indicates where the rainfall runoff of the delineated catchment overwhelms the storm drain, either through limited inlet capacity, or where the HGL of the storm drain goes above ground and flows to the surface through an inlet or manhole. Where the inlet capacity functionality within the model was turned off to assess the capacity of the pipes in comparison to the design storm flows, the inundation is only a result of the HGL of the pipe going above ground at a manhole or inlet. In comparing the model results with the inlet capacities turned on and off, inundation that goes away with the inlet capacity turned off indicates that the storm drain pipe has capacity but there are insufficient inlets to capture the flow.

When looking at the inundation results the following modeling limitations/assumptions should be considered:

- The five priority areas were modeled separately. The boundaries of the 2D modeling domains are beyond the limits of the associated 1D storm drain model boundaries. Inundation outside of the 1D model boundary on the figures is not relevant and should be ignored. This inundation simply indicates flow moving outside of the 1D model boundary into another storm drain system that was not modeled as a part of this effort.
- Pump systems – As mentioned above, pump systems associated with low lying areas of the City were not included in this modeling effort except in the Annex region in the McLaughlin Park priority area. As a result, the results may identify inundation that does not exist in reality due to the pump systems.

3.1.1 Central Avenue

The results show no surface flooding in the 2-year event in the normal depth and storm surge model runs, overflow of the storm drain and surface flooding in the 10- and 100-year event in the normal depth and storm surge model runs, and overland flooding in all events in the SLR model runs. The main limitation of the storm drain in the 10-year event is the capacity of the inlets and the lateral connections.

A portion of the project area sits at a lower elevation than the estimated elevation of the Bay at SLR. This means that low-lying land will be inundated in high tides with the estimated SLR without a precipitation event.

3.1.2 32nd Street

There is some overland flooding in the 2-year event in the Macdonald Avenue and 38th Street region, along Center Avenue near S. 33rd Street, and along 24th Street north of Macdonald Avenue. This is more pronounced in the model with the inlet capacity turned on, indicating that the storm drain has capacity but there are insufficient inlets to capture flow. Flooding in the 2-year event is not made worse by storm surge or with SLR.

In the 10-year event, the flooding in the above locations is more pronounced and there is additional overland flooding north of Barrett Avenue between 23rd Street and 28th Street. Again, the flooding is improved when the inlet capacity is turned off but not completely removed, demonstrating that there are insufficient inlets but also that not all the pipes have capacity for the peak 10-year event. In the storm surge and SLR boundary condition models, low-lying land south of I-580 near the outlet of the storm drain system is flooded.

In the 100-year event, there is overland flooding throughout the modeled area. Turning off the inlet capacity only slightly lessens the flooded limits.

3.1.3 8th Street

In the 2-year event, there is overland flooding within streets near 23rd and Rheem Streets, 19th Street between Pennsylvania and Roosevelt Avenues, and between South 8th and South 19th Streets from Ohio Avenue to Cutting Boulevard. The flooding between South 8th and 19th Streets is improved in the model with the inlet capacity turned off, indicating that the storm drain has capacity but there are insufficient inlets to capture flow. There is inundation between I-580 and the train tracks near the outlet of the storm drain system in the storm surge and SLR boundary condition models.

In the 10-year event, the flooding in the above locations is more pronounced and there is additional overland flooding between Marina Way and 17th Street just north of the Richmond Greenway Trail. Like the 2-year event, much of the overland flooding between South 8th and 19th Streets is alleviated when the inlet capacity is turned off in the model.

In the 100-year event, there is overland flooding throughout the modeled area. Turning off the inlet capacity only slightly lessens the inundation limits.

3.1.4 McLaughlin

In the 2-year event model, there is slight flooding along Carlson Boulevard east of I-80 that gets more extensive toward Tehama Avenue, along San Luis Street east of I-80, and on Mercer Street and Mariposa Street west of South 55th Street. Most of this flooding is alleviated when the inlet capacity is turned off in the model, indicating that the pipes have sufficient capacity, but the inlets do not have interception capacity for the flow. In models with the storm surge and particularly the SLR boundary conditions, there is flooding on Monterey Street near Tehama Avenue. This low-lying area has a pump station, but the modeling results show that it is ineffective with high tailwater from the Bay.

In the 10-year event, the flooding in the above locations is more pronounced, with flow shown going onto private lots. Excess flow from the Carlson Boulevard storm drain is flowing west on the streets to the west such as Sutter Avenue and Colusa Avenue. Plumas Avenue east of Carlson Boulevard is also flooded. Much of the overland flooding is alleviated in the model with the inlets capacity turned off, demonstrating that the main pipe capacities are adequate for the 10-year peak flows. Even with the inlet capacities turned off, there is still flooding along Carlson Boulevard and in its intersection with Tehama Avenue. Several streets west of I-80 are flooded in models with storm surge and SLR boundary conditions.

The 100-year event model shows all of Carlson Boulevard and San Luis Street east of I-80 flooded with significant private property impacts west of I-80, particularly in the models with the storm surge and SLR boundary conditions. The overland flooding east of I-80 is slightly improved with the inlet capacity turned off.

3.1.5 7th Street

The 7th Street analysis demonstrates that there is some ponding and bypass in the 2- and 10-year events caused by ineffective inlet capacity. All ponding issues in the 2-year event are removed in the model run with the inlets turned off, demonstrating the pipes have adequate capacity. The 10-year model run with the inlets turned off show some ponding on 13th Street and east of the Bart tracks in the 10-year event as well as on the east-west streets east of Richmond Parkway including Barrett, Ripley and Pennsylvania Avenues. In the 100-year event, all the storm drain pipes are overwhelmed with significant overflow into the east-west Avenues and the north-south Streets. Additionally, there is significant ponding at Richmond Parkway and B Street north of Barret Avenue in both the 10- and 100-year event.

For the Yellow Brick Road Project, drainage improvements are proposed for intersections that drain to the 7th Street storm drain including Lincoln Avenue and 8th Street, Lucas Avenue and 8th Street, Pennsylvania Avenue from 4th Street to 9th Street, and 7th Street and Ripley Avenue. The improvements will intercept runoff from catchments already draining to the storm drain and include new inlets and lateral storm drain that connect to the existing facilities. The analysis shows that at the four intersections, the existing inlet facilities do not adequately capture the peak flows generated in the 2- and 10- year events. The addition of inlets will mitigate the issue in the 2-year event. The 10-year event does cause surcharge in the pipes in existing conditions. However, as the catchments draining to the new inlets already drain to the storm drain, the new inlets will not negatively impact the capacity conditions of the storm drain.

The model runs that simulate the SLR and storm surge on the hydraulic conditions of the 7th Street storm drains do not show a significant negative impact to the hydraulic capacity or flood issues in the area.

4.0 CAPITAL IMPROVEMENT PROGRAM

After completion of the storm drain analysis, CIP projects were identified to address known flooding issues and those highlighted and confirmed by the XPStorm analysis. Suggested improvement areas and recommended infrastructure upgrades were presented to and reviewed by the City. Following approval, the infrastructure upgrades were analyzed with the XPStorm models. In most projects, inlets and pipes are proposed to be enlarged. For a proposed improvement within the McLaughlin priority area, a new length of storm drain is proposed to be connected to an existing main storm drain line.

Cost estimates were developed for the proposed improvements based on recently bid or completed projects. A 30% contingency and 20% inflation were added to the final costs to account for the steep rise in construction materials and labor of the current market.

The proposed CIP projects are shown in **Table 4.1** and in **Figures 4.1** through **4.13**. Inundation results with the CIP projects in place are shown in **Appendix B**. As with the existing conditions, not all figures for each simulated event with each backwater conditions were created due to the sheer quantity of studied events.

4.1 CENTRAL AVENUE

The Central Avenue priority area has repeated flooding issues. The proposed CIP project includes upsizing catch basin sizes and lateral storm drain connections. The project (Project 1) was modeled using XPStorm simulating the proposed improved facilities. The results of the modeling are included in Appendix B. The modeling results show that upsizing the inlet and lateral capacities would adequately address the 10-year inundation issues and improve the flooding in the 100-year event. However, the area will continue to be inundated during SLR conditions in all events. Due to the elevation of the area, the site will be inundated during dry weather in high-tide with SLR conditions; only a sea-wall or levee would prevent inundation under this condition.

Before design of these improvements could take place, a complete survey of the existing storm drain will be required as the database represents facilities draining public ROW going through a private parking lot. If this is accurate, the project may need to include re-routing of storm drain through public ROW.

4.2 32ND STREET

Apart from some street flooding, the storm drain analysis did not identify major drainage issues in this area and no CIP projects are proposed.

4.3 8TH STREET

The storm drain analysis shows that the inlets in the South 8th and 9th Street area north of Cutting Boulevard are under-capacity while the downstream storm drain has adequate capacity for the 10-year peak flows. The proposed CIP project would add 16 double-sized inlets to capture additional flow throughout the area. No proposed modeling was done to analyze this. Instead, the results of the XPStorm model runs with the inlet capacity turned off show the potential improvements of the project. A project to improve capacity of the inlets could incorporate green infrastructure infiltration and bioretention facilities. The suggested storm drain project area coincides with 2030 and 2040 timeline projected green infrastructure project areas included in the City's GI Plan.

Table 4.1: Proposed CIP Projects

Location	Problem	Project #	Project	Cost
Central Avenue				
West end of Van Fleet Avenue	frequent flooding spot- hydraulic model shows significant ponding at the site- the major issue is the lateral storm drain pipes and inlet capacity	1	Replace/upsized pipes upstream in storm drain system through area and increase inlet capacity.	\$676,000
8th Street				
8th-9th Street and Harbor Way	Storm drain modeling shows surface flooding due to lack of inlet capacity	2	Replace/upsized inlets to storm drain throughout area to alleviate flooding	\$332,000
McLaughlin				
Plumas Ave and San Benito St.	Surface flooding - no inlets from San Pablo Avenue to Shasta Street	3	Add new storm drain along Plumas Ave. and upsized an additional existing storm drain near Plumas and San Benito St. and connect to Carlson Blvd. system. Add inlets along Plumas Ave.	\$950,000
Carlson Blvd & Tehama Ave	Carlson Boulevard, particularly near Tehama is flooded in even minor events- confirmed by hydraulic model.	4A	Upsize inlets in Tehama and Carlson intersection.	\$105,000
		4B	Upsize inlets and laterals in Tehama and Carlson intersection.	\$226,000
		4C	Upsize inlets and laterals along Carlson Boulevard from Santa Cruz Avenue to Tehama Avenue.	\$560,000
Green infrastructure along Carlson Boulevard/ Plumas Avenue.	Streets experience frequent flooding.	5A	Construct infiltration within the public ROW along Carlson Boulevard from Santa Cruz Avenue to Tehama Avenue.	\$2,215,000
		5B	Construct infiltration within the public ROW along Plumas Avenue from San Pablo Avenue to Carlson Boulevard.	\$701,000

4.4 McLAUGHLIN PARK

The McLaughlin Park area has significant flooding issues per repeated drainage complaints and as confirmed by the storm drain analysis. To help address the issues, 3 CIP Projects are proposed for the area concentrating in the Carlson Boulevard/Tehama Avenue and Plumas Avenue areas. They include upsizing inlets and lateral storm drain, adding a storm drain within Plumas Avenue and adding infiltration facilities to the Carlson Boulevard and Plumas Avenue.

Projects 5, improvements within Carlson Boulevard, has three options (4A, 4B, And 4C) with increasing levels of improvements and costs that provide increasing levels of flood improvement.

The green infrastructure improvements included in Projects 5A and 5B coincide with a 2040 project outlined in the City's GI Plan.

To look at the impacts of the potential improvements included in the proposed McLaughlin Park projects, a series of proposed conditions XPStorm models were constructed. A model that represents each project was run with the three design events. One additional model was constructed to represent the cumulative impact of all the projects together and run with the three design events. All the with-project models were run with normal depth outlet conditions as the storm surge and SLR outlet conditions do not impact flood conditions east of I-80 where all the improvements are proposed. Green infrastructure was simulated by increasing the infiltration capacity in the relevant catchments to meet the guidance in the Contra Costa County C.3 Guidebook (Contra Costa Clean Water Program, 2017). The flood inundation results of the analysis are included in Appendix B.

The modeling result demonstrate the following:

- The results of the simulation of Project 3 show that the flooding along Plumas Avenue and to the south on Sutter Avenue are improved in both the 10-year and 100-year events (there is no flooding in this location in the existing conditions 2-year event)
- Neither Project 4A or 4B with localized improvements at the Tehama Avenue and Carlson Boulevard intersection have noticeable impact on the flooding in the three simulated events. This is because the flooding from the upstream portion of Carlson Boulevard continues to inundate Carlson Boulevard upstream and downstream of the intersection.
- The improvements included in Project 4C virtually eliminate flooding along Carlson Boulevard in the 2- and 10- year events and decrease flood inundation in the 100-year event
- Projects 5A and 5B with proposed infiltration sized to treat the first flush of volume in frequent precipitation events only slightly improve the flood inundation results in the 2- and 10-year events
- The cumulative improvement modeling results show the combined benefit of Project 3 and 4C, the two projects with the most noticeable impact on flood inundation.

CITY OF RICHMOND STORM DRAIN MASTER PLAN UPDATE

Stormwater Capital Improvement Program

Date: December 2018, Updated October 2020

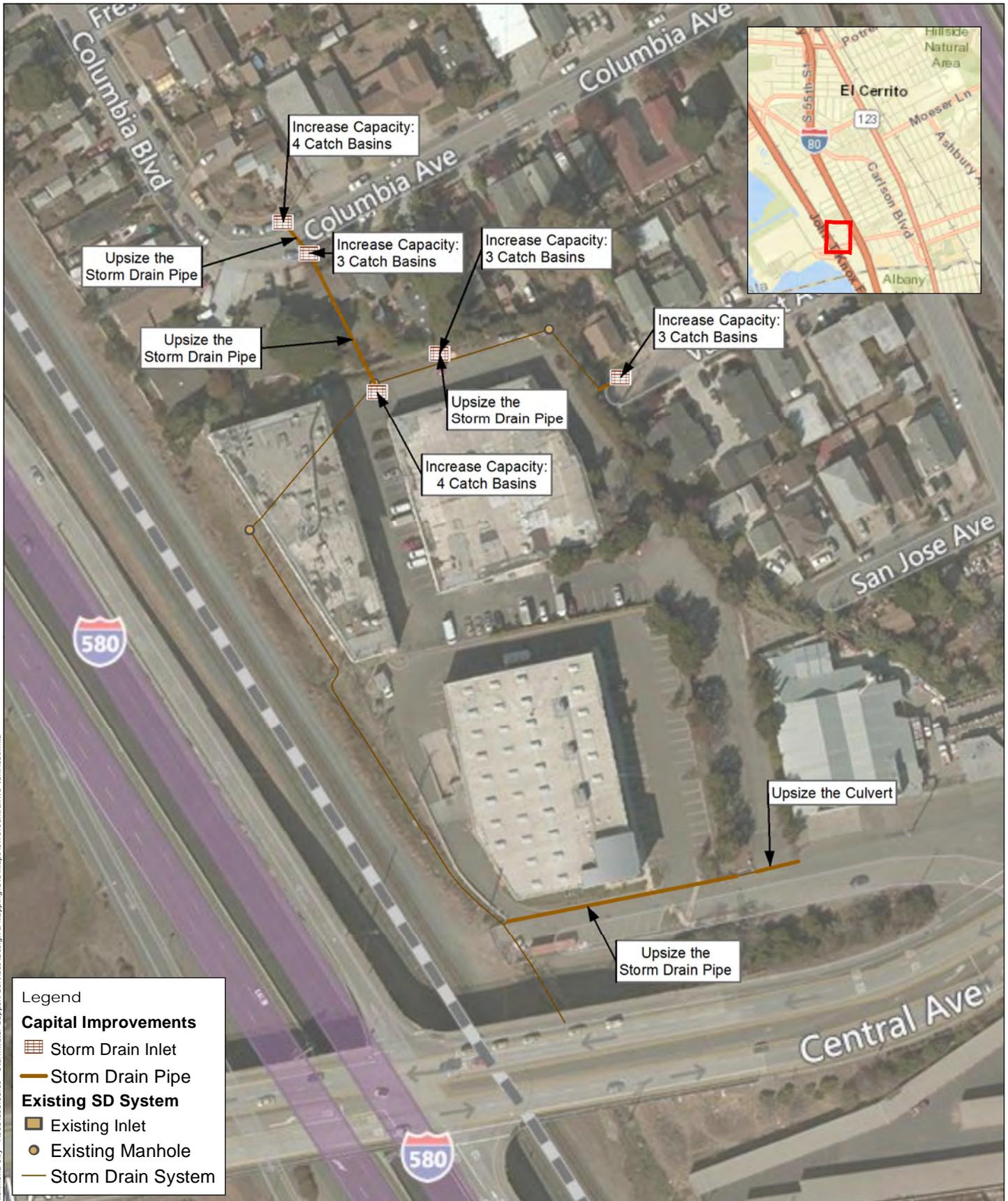
Prepared By: NCE

Project Title: Central Avenue Storm Drain Improvements		Project # 1 Figure 4.1
Location: Central Avenue Storm Drain to Van Fleet Avenue	Est. Days Required for Construction: 120	
	Expected Service Life: 25-50 years	
Program: Storm Drain Projects	Est. Project Cost: \$676,000	Est. Annual Maintenance Cost: \$ 1,800

Project Description: The Project would include replacement and upsizing of approximately 500 feet of storm drain pipe. Upsize a section of culvert pipe and increase the number of inlet grates. Pipe alignments would need to be verified.	Justification: Significant flooding in area during event high frequency rainfall caused by lack of inlets and lateral storm drain capacity.	Public Benefit: Reduction in flooding in neighborhood and on City maintained streets.
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Item	CONSTRUCTION COST ESTIMATE				MAINTENANCE COST ESTIMATE		
	Unit	Quantity	Unit Cost	Total	Unit Maint. Cost LF	Annual Freq.	Annual Maint.
12" RCP Storm Drain Pipe	LF	47	\$ 230.00	\$ 10,810	\$ 4.00	1	\$ 188
18" RCP Storm Drain Pipe	LF	372	\$ 260.00	\$ 96,720	\$ 4.00	1	\$ 1,488
24" RCP Storm Drain Pipe	LF	22	\$ 290.00	\$ 6,380	\$ 4.00	1	\$ 88
Storm Drain Manhole	EA	5	\$ 12,000.00	\$ 60,000			See Note ◇
Storm Drain Combination Inlet	EA	7	\$ 7,000.00	\$ 49,000			See Note ◇
Drop Inlet	EA	10	\$ 5,000.00	\$ 50,000			See Note ◇
Aggregate Base	TON	111	\$ 80.00	\$ 8,880			See Note ◇
AC Paving	TON	58	\$ 120.00	\$ 6,960			See Note ◇
Sidewalk and Curb & Gutter	SF	168	\$ 25.00				See Note ◇
General Conditions			15%	\$ 44,000			
Construction Contingency			30%	\$ 100,000			
Inflation			20%	\$ 87,000			
Construction Subtotal				\$ 520,000			
Planning, Design, Permitting & CM			30%	\$ 156,000			
Project Total				\$ 676,000	Total Annual Maintenance		\$ 1,800

Notes:
 ◇ Assuming proper design and construction, maintenance cost should be negligible for these items.
 See Figure 4.2 for details related to pipe sizing and length.



City of Richmond Storm Drain Master Plan Update
 CIP Project 1: Central Avenue Storm Drain to Van Fleet Avenue

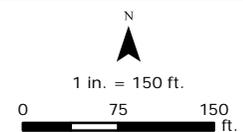


FIGURE
 4.2

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CITY OF RICHMOND STORM DRAIN MASTER PLAN UPDATE

Stormwater Capital Improvement Program

Date: December 2018, Updated October 2020

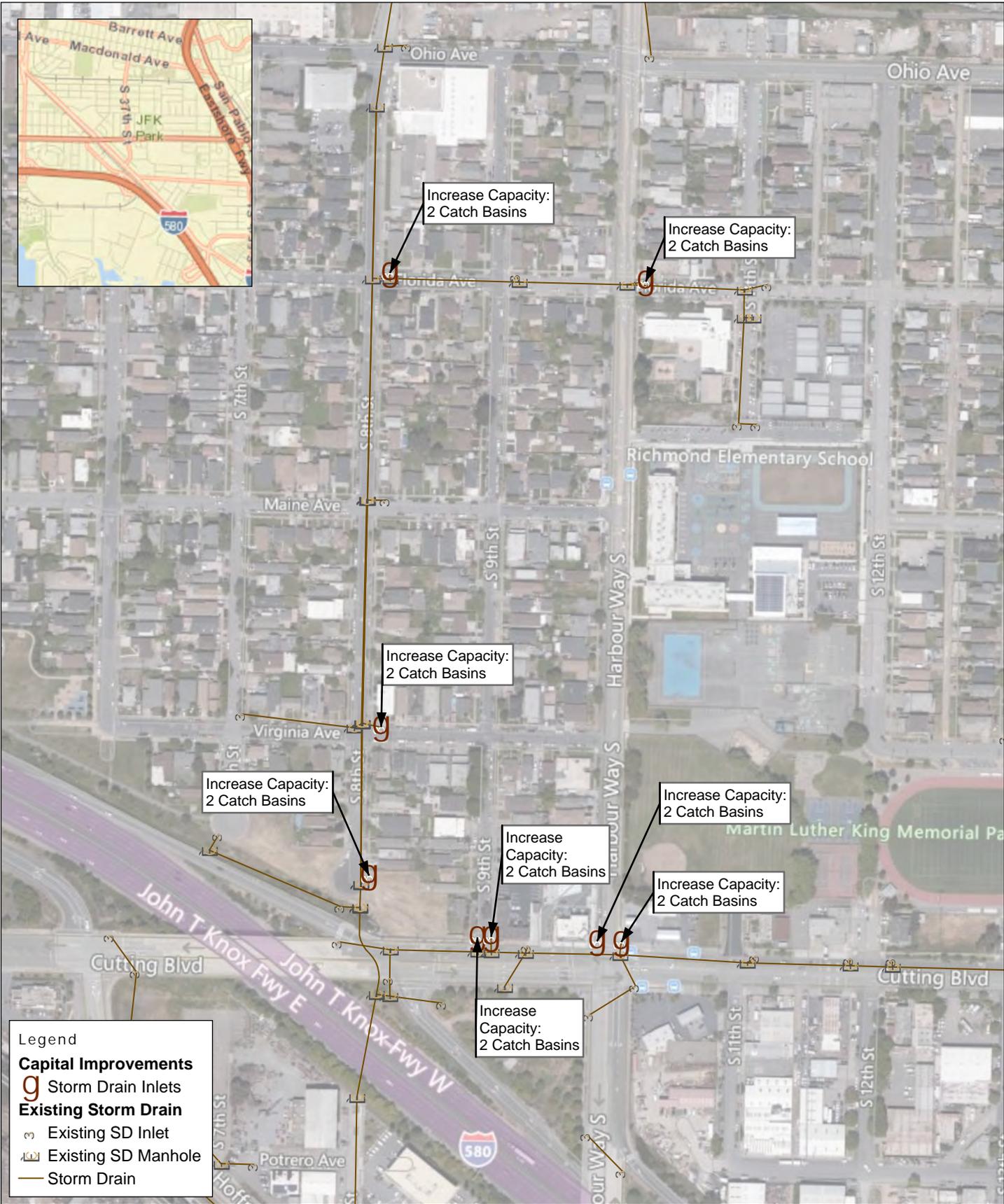
Prepared By: NCE

Project Title: South 8th Street Inlet Capacity			Project # 2 Figure 4.3
Location: 8th Street, 9th Street, and Harbor Way		Est. Days Required for Construction: 60	
		Expected Service Life: 25-50 years	
Program: Storm Drain Projects	Est. Project Cost: \$331,500	Est. Annual Maintenance Cost: \$ 100	

Project Description:	Justification:	Public Benefit:
Increase storm water capture through installation of additional catch basins.	The storm drain hydraulic modeling shows inundation in the streets in the area during even frequent rain events. Upsizing inlets would address the problem as the storm drain pipe has sufficient capacity.	Additoinal inlet capacity would lessen flooding on City maintained streets.

Item	CONSTRUCTION COST ESTIMATE				MAINTENANCE COST ESTIMATE		
	Unit	Quantity	Unit Cost	Total	Unit Maint. Cost LF	Annual Freq.	Annual Maint.
Storm Drain Combination Inlet	EA	16	\$ 7,000.00	\$ 112,000			See Note ◊
Sidewalk and Curb & Gutter	SF	384	\$ 25.00	\$ 9,600			See Note ◊
Storm Drain Manhole	EA	1	\$ 12,000.00	\$ 12,000			See Note ◊
12" RCP Storm Drain Pipe	LF	30	\$ 230.00	\$ 6,900	\$ 4.00	1	\$ 120
				\$ -			
				\$ -			
				\$ -			
				\$ -			
				\$ -			
				\$ -			
General Conditions			15%	\$ 22,000			
Construction Contingency			30%	\$ 49,000			
Inflation			20%	\$ 43,000			
Construction Subtotal				\$ 255,000			
Planning, Design, Permitting & CM			30%	\$ 76,500			
Project Total				\$ 331,500	Total Annual Maintenance		\$ 100

Notes:
 ◊ Assuming proper design and construction, maintenance cost should be negligible for these items.
 See Figure 4.6 for details related to pipe sizing and length.



Legend

Capital Improvements

- Storm Drain Inlets
- Existing Storm Drain**
- Existing SD Inlet
- Existing SD Manhole
- Storm Drain



South 8th Street Inlet Capacity
CIP Project # 2: South 8th Street Inlet Capacity

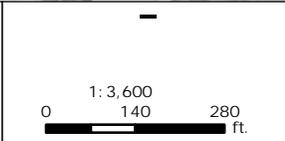


FIGURE
4.4

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CITY OF RICHMOND STORM DRAIN MASTER PLAN UPDATE

Stormwater Capital Improvement Program

Date: December 2018, Updated October 2020

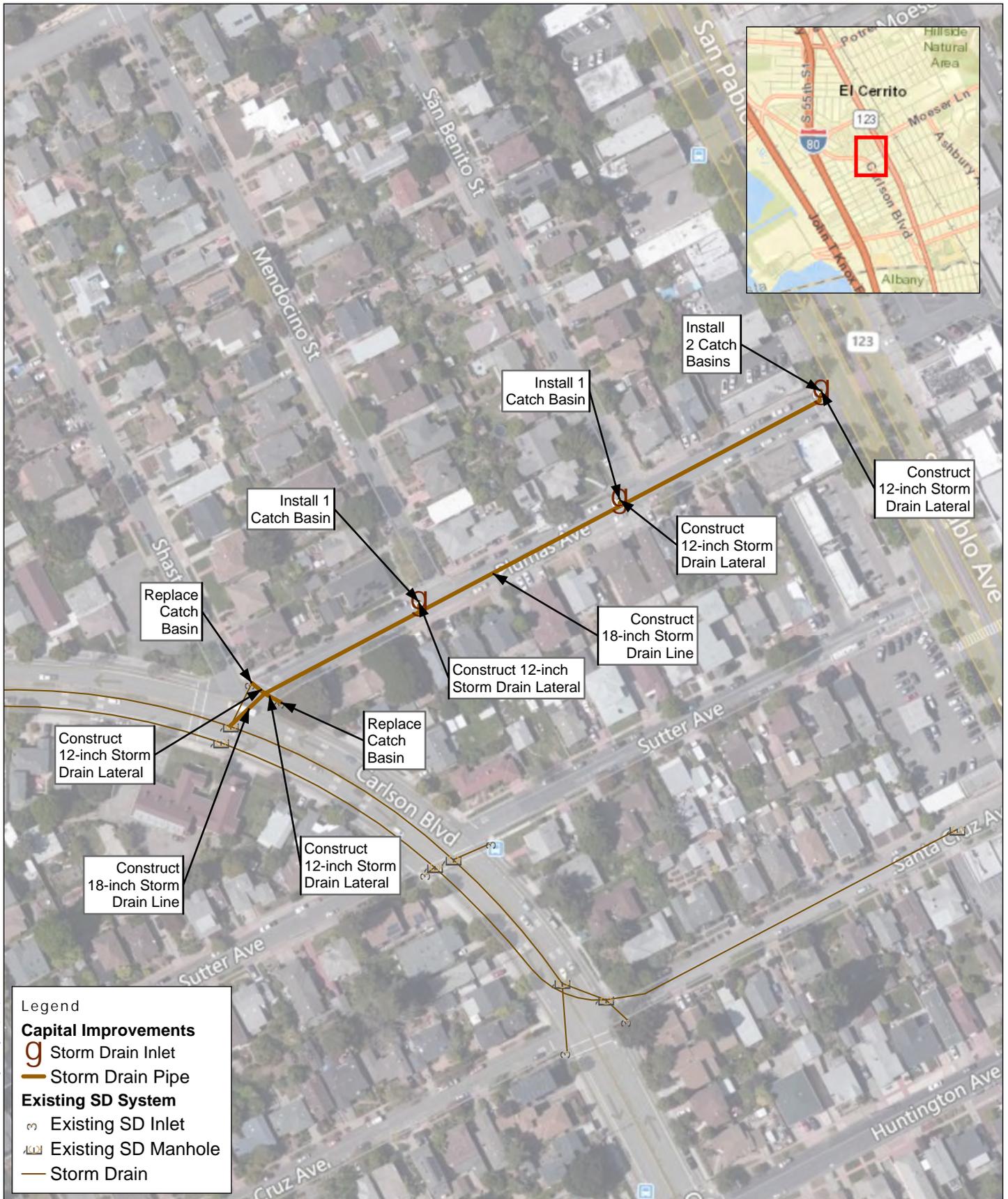
Prepared By: NCE

Project Title: New Storm Drain Infrastructure on Plumas Avenue				Project # 3 Figure 4.5
Plumas Avenue from San Pablo Avenue to Carlson Boulevard.		Est. Days Required for Construction:	60	
		Expected Service Life:	25-50 years	
Program: Storm Drain Projects	Est. Project Cost:	\$942,500	Est. Annual Maintenance Cost:	\$ 3,500

Project Description:	Justification:	Public Benefit:
Install a new storm drain pipe on Plumas Avenue between San Pablo Avenue and Carlson Boulevard, including new catch basins, replacement of existing catch basins, and new manholes.	Plumas Avenue is frequently flooded during even minor storm events.	Installing storm drain would alleviate flooding on City maintained street and lower risk to private property along street.

Item	CONSTRUCTION COST ESTIMATE				MAINTENANCE COST ESTIMATE		
	Unit	Quantity	Unit Cost	Total	Unit Maint. Cost LF	Annual Freq.	Annual Maint.
Storm Drain Combination Inlet	EA	6	\$ 7,000.00	\$ 42,000	\$ 180.00	1	\$ 180
Storm Drain Manhole	EA	4	\$ 12,000.00	\$ 48,000			See Note ◊
12-inch RCP	LF	59	\$ 230.00	\$ 13,570	\$ 4.00	1	\$ 236
24-inch RCP	LF	771	\$ 290.00	\$ 223,590	\$ 4.00	1	\$ 3,084
Sidewalk and Curb & Gutter	SF	72	\$ 25.00	\$ 1,800			See Note ◊
Aggregate Base	TON	426	\$ 80.00	\$ 34,080			See Note ◊
AC Paving	TON	331	\$ 120.00	\$ 39,720			See Note ◊
General Conditions			15%	\$ 61,000			
Construction Contingency			30%	\$ 140,000			
Inflation			20%	\$ 121,000			
Construction Subtotal				\$ 725,000			
Planning, Design, Permitting & CM			30%	\$ 217,500			
Project Total				\$ 942,500	Total Annual Maintenance		\$ 3,500

Notes:
 ◊ Assuming proper design and construction, maintenance cost should be negligible for these items.
 See Figure 4.8 for details related to pipe sizing and length.



Legend

Capital Improvements

- Storm Drain Inlet
- Storm Drain Pipe

Existing SD System

- Existing SD Inlet
- Existing SD Manhole
- Storm Drain

City of Richmond Storm Drain Master Plan Update
 CIP Project 3: Plumas Avenue

FIGURE 4.6

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CITY OF RICHMOND
Stormwater Capital Improvement Program

Date: December 2018, Updated October 2020

Prepared By: NCE

Project Title: Tehama Avenue & Carlson Boulevard						Project # 4A-4C Figure 4.7
Location: Tahema and Carlson Boulevard				Est. Days Required for Construction: 60		
				Expected Service Life: 25-50 years		
Program: Storm Drain Projects	Est. Project Cost:	5A	\$105,300	Est. Annual Maintenance Cost:	5A	NA
		5B	\$226,200		5B	\$648
		5C	\$559,000		5C	\$1,516

Project Description: Increase catch basin inlet capacity, upsize storm drain laterals, and upsize storm drain pipe.	Justification: Carlson Boulevard and Tehama Avenue experience frequent flooding even in minor storm events.	Public Benefit: Increasing storm drain conveyance would alleviate flooding on City maintained street and lower risk to private property along street.
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INLETS AT TEHAMA (Project 5A)		CONSTRUCTION COST ESTIMATE			MAINTENANCE COST ESTIMATE		
Item	Unit	Quantity	Unit Cost	Total	Unit Maint. Cost LF	Annual Freq.	Annual Maint.
Storm Drain Combination Inlet	EA	6	\$ 7,000.00	\$ 42,000			See Note ◊
Sidewalk and Curb & Gutter	SF	72	\$ 25.00	\$ 1,800			See Note ◊
General Conditions			15%	\$ 7,000			
Construction Contingency			30%	\$ 16,000			
Inflation			20%	\$ 14,000			
Construction Subtotal				\$ 81,000			
Planning, Design, Permitting & CM			30%	\$ 24,300			
Total Cost				\$ 105,300	Total Annual Maintenance		\$ -

INLETS AND LATERALS AT TEHAMA (Project 5B)		CONSTRUCTION COST ESTIMATE			MAINTENANCE COST ESTIMATE		
Item	Unit	Quantity	Unit Cost	Total	Unit Maint. Cost LF	Annual Freq.	Annual Maint.
Storm Drain Combination Inlet	EA	6	\$ 7,000.00	\$ 42,000			See Note ◊
24-inch RCP	LF	162	\$ 290.00	\$ 46,980	\$ 4.00	1	\$ 648
Sidewalk and Curb & Gutter	SF	72	\$ 25.00	\$ 1,800			See Note ◊
Aggregate Base	TON	28	\$ 80.00	\$ 2,240			See Note ◊
AC Paving	TON	23	\$ 120.00	\$ 2,760			See Note ◊
General Conditions			15%	\$ 15,000			
Construction Contingency			30%	\$ 34,000			
Inflation			20%	\$ 29,000			
Construction Subtotal				\$ 174,000			
Planning, Design, Permitting & CM			30%	\$ 52,200			
Total Cost				\$ 226,200	Total Annual Maintenance		\$ 600

INLETS AND LATERALS ALONG CARLSON BLVD		CONSTRUCTION COST ESTIMATE			MAINTENANCE COST ESTIMATE		
Item	Unit	Quantity	Unit Cost	Total	Unit Maint. Cost LF	Annual Freq.	Annual Maint.
Storm Drain Combination Inlet	EA	16	\$ 7,000.00	\$ 112,000			See Note ◊
24-inch RCP	LF	379	\$ 290.00	\$ 109,910	\$ 4.00	1	\$ 1,516
Sidewalk and Curb & Gutter	SF	192	\$ 25.00	\$ 4,800			See Note ◊
Aggregate Base	TON	66	\$ 80.00	\$ 5,280			See Note ◊
AC Paving	TON	55	\$ 120.00	\$ 6,600			See Note ◊
General Conditions			15%	\$ 36,000			
Construction Contingency			30%	\$ 83,000			
Inflation			20%	\$ 72,000			
Construction Subtotal				\$ 430,000			
Planning, Design, Permitting & CM			30%	\$ 129,000			
Total Cost				\$ 559,000	Total Annual Maintenance		\$ 1,500

Notes:
 ◊ Assuming proper design and construction, additional maintenance cost should be negligible for these items.
 See Figures 4.10, 4.11, and 4.12 for details related to pipe sizing and length.



Legend

Capital Improvements
 Storm Drain Inlet

Existing SD System
 Existing SD Inlet
 Existing SD Manhole
 Storm Drain



City of Richmond Storm Drain Master Plan Update
 CIP Project 4A: Tehama Avenue and Carlson Boulevard

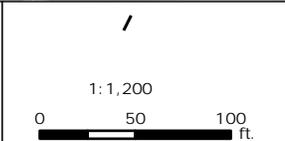


FIGURE
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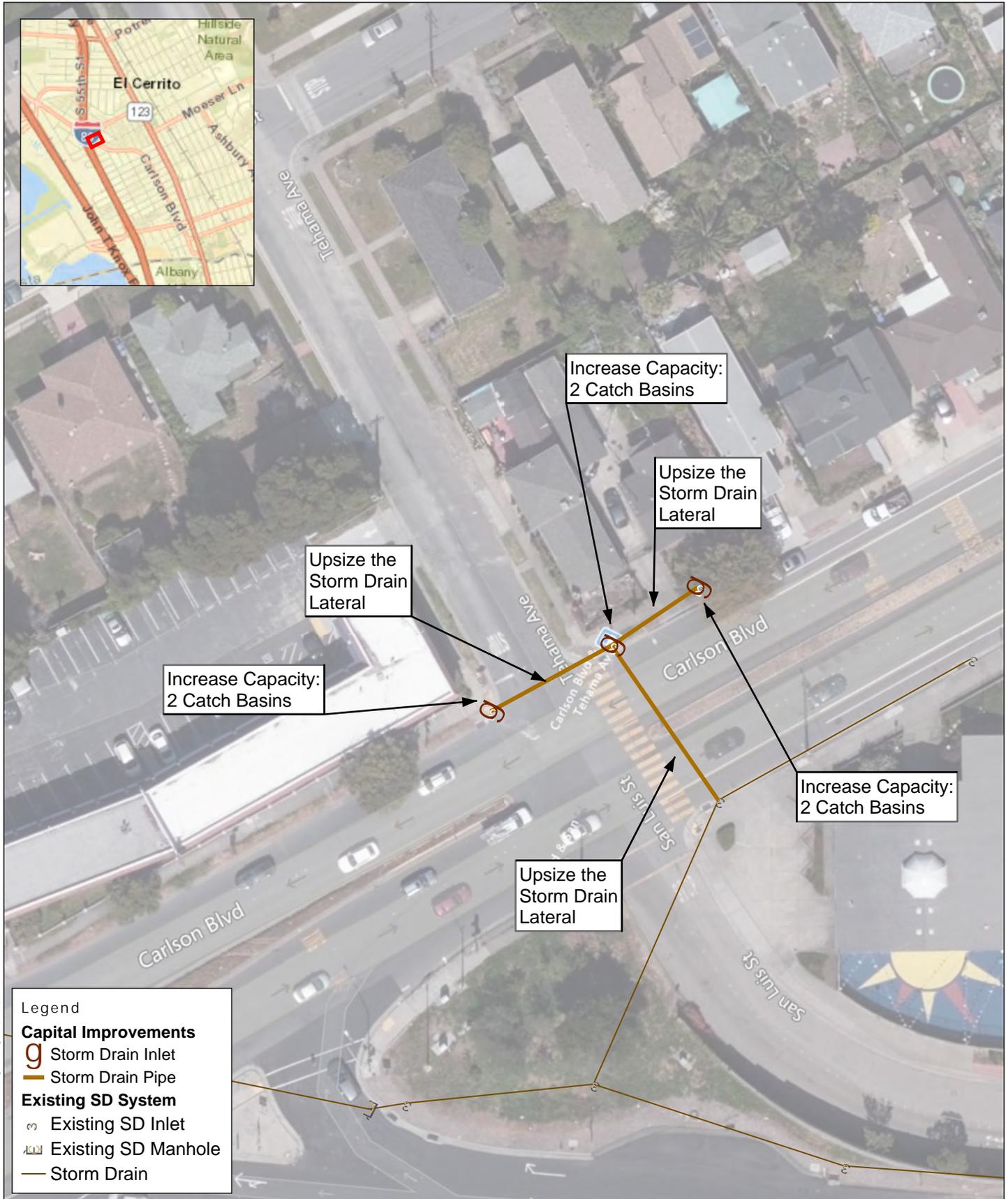
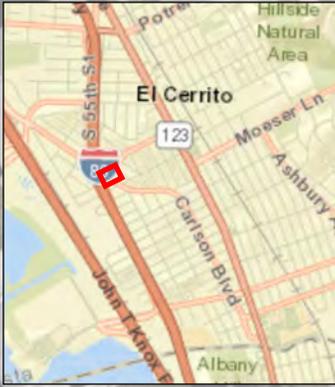
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Tehama Avenue & Carlson Boulevard
 CIP Project 4B: Tehama Avenue and Carlson Boulevard

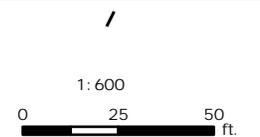


FIGURE
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City of Richmond Storm Drain Master Plan Update
 Project 4C: Carlson Boulevard

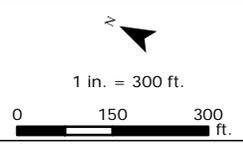


FIGURE
4.10

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CITY OF RICHMOND STORM DRAIN MASTER PLAN UPDATE

Stormwater Capital Improvement Program

Date: December 2018

Prepared By: NCE

Project Title: GI Improvements along Carlson Boulevard and Plumas Avenue				Project #	
Location: Carlson Boulevard from Santa Cruz Avenue to Tehama Avenue			Est. Days Required for Construction:	60	5A-5B Figure
			Expected Service Life:	25-50 years	
Program: Storm Drain Projects	Est. Project Cost:	\$700,700 - \$2,215,200	Est. Annual Maintenance Cost:	900 - 1900	4.11
Project Description: Construct infiltration facilities such as bioswales in the public ROW within Carlson Boulevard and Plumas Avenue.		Justification: Streets experience frequent flooding in even minor storm events.		Public Benefit: Infiltration facilities would improve water quality and lower flooding issues in small, frequent rain events.	

GI IMPROVEMENTS ALONG CARLSON BLVD	CONSTRUCTION COST ESTIMATE				MAINTENANCE COST ESTIMATE		
Item	Unit	Quantity	Unit Cost	Total	Unit Maint. Cost LF	Annual Freq.	Annual Maint.
Bioswale Soils, Aggregate, Plantings	SF	9,620	\$ 25.00	\$ 240,500	\$ 920.00	2	\$ 1,840
Earthwork Excavation for Bioswale	CY	1,425	\$ 75.00	\$ 106,889			See Note ◊
Bioswale Wall with Curb and Gutter	LF	2,405	\$ 250.00	\$ 601,250			See Note ◊
General Conditions			15%	\$ 143,000			
Construction Contingency			30%	\$ 328,000			
Inflation			20%	\$ 284,000			
Construction Subtotal				\$ 1,704,000			
Planning, Design, Permitting & CM			30%	\$ 511,200			
Total Cost				\$ 2,215,200	Total Annual Maintenance		\$ 1,900

GI IMPROVEMENTS ALONG PLUMAS AVE	CONSTRUCTION COST ESTIMATE				MAINTENANCE COST ESTIMATE		
Item	Unit	Quantity	Unit Cost	Total	Unit Maint. Cost LF	Annual Freq.	Annual Maint.
Bioswale Soils, Aggregate, Plantings	SF	3,040	\$ 25.00	\$ 76,000	\$ 440.00	2	\$ 880
Earthwork Excavation for Bioswale	CY	450	\$ 75.00	\$ 33,778			See Note ◊
Bioswale Wall with Curb and Gutter	LF	760	\$ 250.00	\$ 190,000			See Note ◊
General Conditions			15%	\$ 45,000			
Construction Contingency			30%	\$ 104,000			
Inflation			20%	\$ 90,000			
Construction Subtotal				\$ 539,000			
Planning, Design, Permitting & CM			30%	\$ 161,700			
Total Cost				\$ 700,700	Total Annual Maintenance		\$ 900

Notes:
 ◊ Assuming proper design and construction, maintenance cost should be negligible for these items
 See Figures 4.14 and 4.15 for details related to pipe sizing and length.



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Legend

- Green Infrastructure
- Existing SD System**
- Existing SD Inlet
- Existing SD Manhole
- Storm Drain

	<p>City of Richmond Storm Drain Master Plan Update</p> <p>CIP Project 5A: GI Improvements along Carlson Boulevard</p>	 <p>1 in. = 350 ft.</p> 	<p>FIGURE</p> <p>4.12</p>
SOURCE BING basemap	JOB NUMBER 568.38.55	DRAWN skobs	DATE 10/24/2018
		REVISED 03/19/2021	APPROVED mhorvath

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Distribution and Quality Control

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City of Richmond Stormwater Support Services
Richmond, California

March 19, 2021

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Quality Control Reviewer:

Jason Drew
Principal

Appendix A

EXISTING CONDITIONS INUNDATION MAPS

Appendix B

WITH CIP PROJECT INUNDATION MAPS