City of Oakland

CITY OF OAKLAND DRAINAGE STUDY

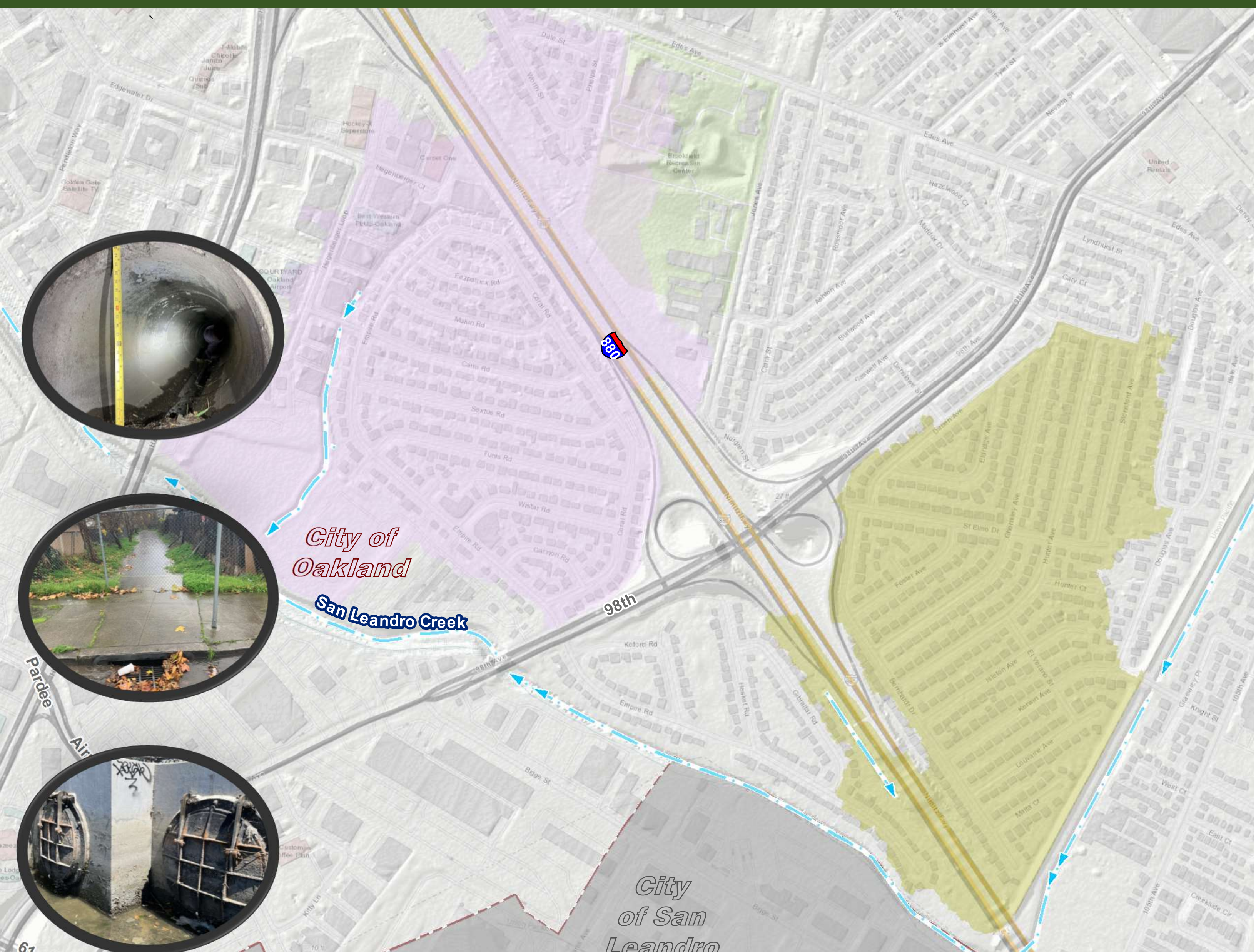
EMPIRE ROAD AND BERNHARDT DRIVE DRAINAGE AREAS

Prepared for the City of Oakland

June 2022

Report by:

WOOD RODGERS
BUILDING RELATIONSHIPS ONE PROJECT AT A TIME



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ACKNOWLEDGEMENTS

City of Oakland

Storm Drainage Master Plan, Task 11 Drainage Study

June 2022

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City of Oakland

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EXECUTIVE SUMMARY

The City of Oakland was incorporated in 1854. The City constructed and maintains more than 300 miles of storm drainage facilities for flood control. Some of the storm drains are isolated and only serve local drainage while other storm drains serve larger areas and discharge to local creeks. Lake Merritt (which existed naturally before development) has been used as a detention basin to service a large watershed in the downtown area. The City's facilities are also intermingled with those owned by Caltrans, private property owners, and the Alameda County Flood Control and Water Conservation District (District).

The City's storm drain system was mostly constructed in the early 1900s, and much of it has reached the end of its service life and must be replaced. These older structures were neither designed nor built to handle the increased demands of climate change such as sea level rise and higher intensity storm events. Their original designs do not meet increasingly stringent stormwater treatment regulatory requirements such as the incorporation of trash capture and green stormwater infrastructure systems. These challenges are further exacerbated by limited resources for maintenance and rehabilitation.

To identify drainage deficiencies and the corresponding improvements, the City secured funding through the Transformational Climate Communities (TCC) grant from the State of California Strategic Growth Council to investigate one of the localized flooding within the City in the areas of Empire Road and Bernhardt Drive in the Columbia Gardens and Brookfield Village neighborhoods, respectively (see **Figure 1**). The City solicited Wood Rodgers to perform a drainage study for the flooding area for the purpose of:

1. Inventory storm drainage facilities within the watersheds in a geodatabase;
2. Identify storm drainage capacity and condition deficiencies of facilities; and
3. Develop and prioritize capital improvement projects of drainage facilities to mitigate local flooding conditions.

This drainage study is one the subtasks of the citywide Drainage Master Plan currently being developed.

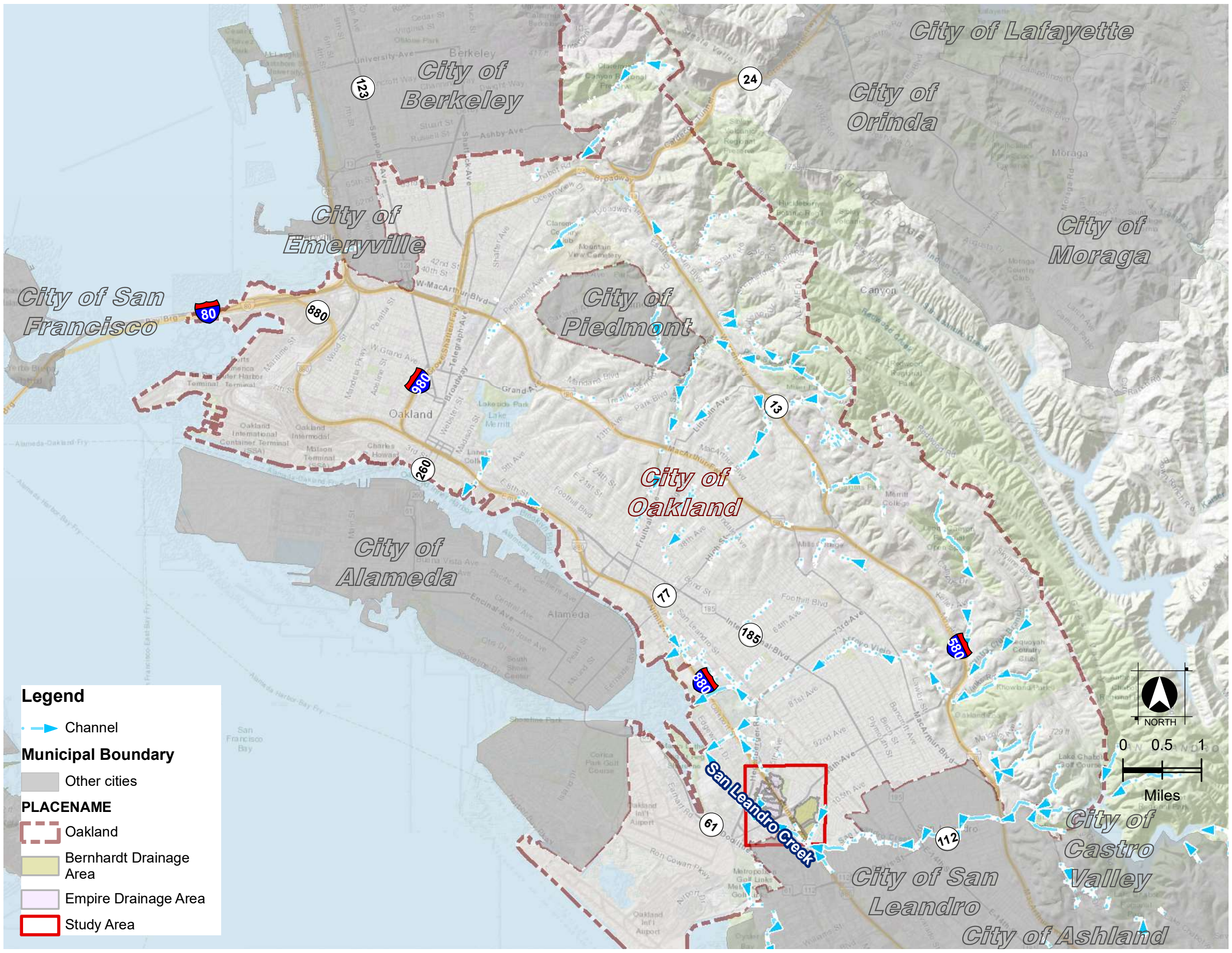


Figure 1 – Location Map

Asset Inventory

An asset inventory, including data collection and inspections, was performed to assess the drainage facilities that the City owns and maintains. There are 3,253 feet of storm drain pipes, 525 feet of earthen open channels, and other supporting facilities that the City owns within this study area. The facilities are worth approximately $3M, using replacement cost values (**Section 4.2**). Of those City's facilities, approximately 36% of them are within the City's right-of-way, and the remaining 64% of them are on acquired easements. There are another 1,690 feet of drainage facilities (pipes and channels) identified on private properties without easements.

Condition Assessment

Seven locations were inspected for structural and maintenance condition deficiencies. No structural condition deficiencies were found in the two drainage systems, and the inspected RCPs were in good condition (**Section 5.1**). One location at the 48" culvert downstream end of the Empire Road drainage system has an immediate maintenance condition deficiency due to debris. The open channel west of I-880 at the Bernhardt Drive drainage system has an immediate maintenance condition deficiency due to overgrown vegetation. Other non-immediate maintenance condition deficiencies due to sediment and overgrown vegetation for both drainage systems need continued monitoring and maintenance (**5.2**). Maintenance work is recommended based on the assessed maintenance condition deficiencies and the potential consequences (**Section 5.3**). Jet flushing maintenance activities are recommended every five years to remove sediment and debris in the pipes based on the assessed maintenance condition. Yearly vegetation clearing activities are recommended to avoid woody vegetation growth and to maintain optimal channel conveyance capacity.

Capacity Assessment

While the recommended maintenance activities will temporarily relieve flooding conditions, the capacity deficiencies were determined to be another major source of flooding. To identify and quantify the capacity deficiencies, hydrologic and hydraulic modeling, and analyses were performed.

The hydraulic model results in **Section 6.3** were used to determine the drainage facilities' conveyance capacity deficiencies shown in **Figure 33**.

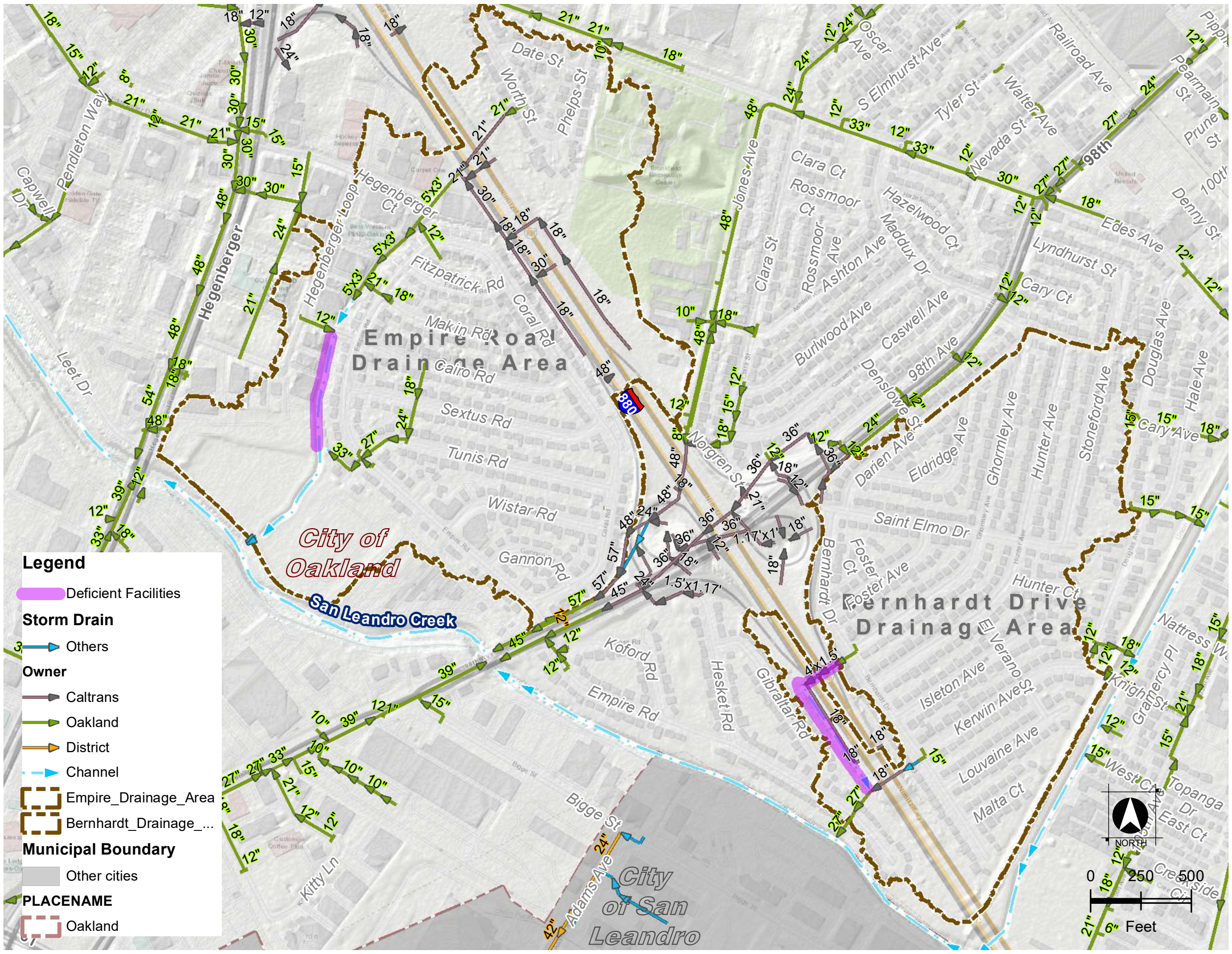


Figure 33 – Drainage Facilities Deficiency Map

The open channel (**Figure 33**) between Cairo Road and Tunis Road in the Empire Road drainage system was determined to have less than a 2-year capacity while the other facilities have capacities between 2- and 25-year based on the floodplain maps in **Section 6.3.2.**

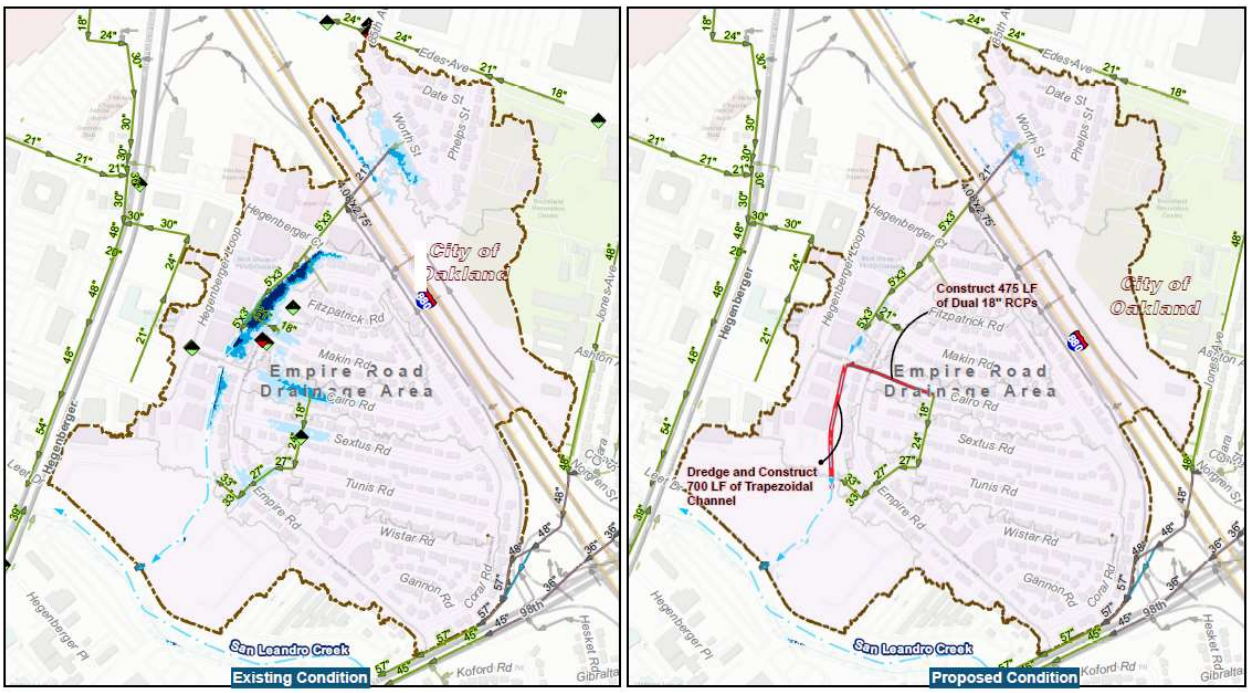
In the Bernhardt Drive drainage system, the open channel (**Figure 33**) west of I-880 was determined to have less than a 2-year capacity, and the other facilities have between 2- and 25-year capacities based on the floodplain maps in **Section 6.3.2.**

Flood Risk

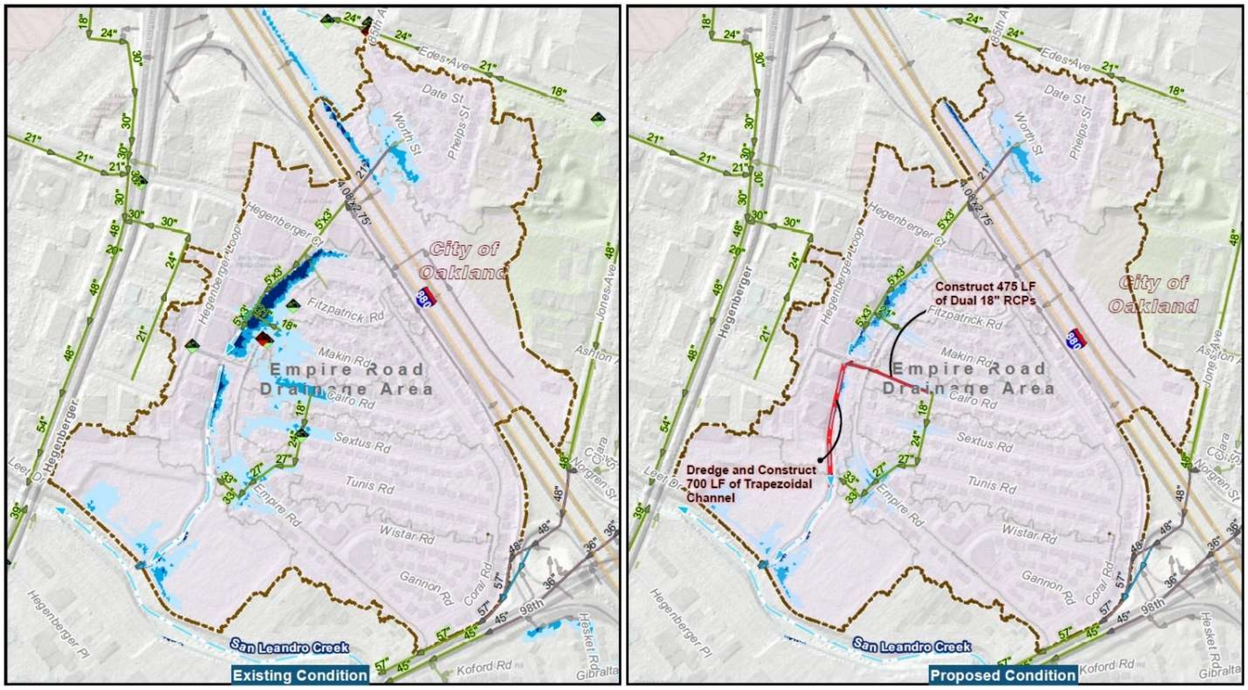
The flood risks associated with the floodplains in **Section 6.3.2** were calculated using the FEMA *Hazus* program to quantify the direct physical damage to buildings and contents, the exposure of essential facilities to flooding, the consequential direct economic losses, and the number of people displaced by evacuation and inundation. The annualized risks were used in conjunction with the capital improvement costs in **Section 8** to identify the cost effectiveness and prioritization for each project.

Capital Improvement Plan

The conveyance capacity deficiencies determined with the hydraulic model results in **Section 6.3** were used to develop the improvement alternative analysis in **Section 8.1**. The recommended alternatives are then summarized in **Exhibits C1 and C2** for Empire Road - Alternative 1 and **Exhibits C3 and C4** for Bernhardt Drive - Alternative 1 to show the simulated existing and proposed (post improvements) floodplains, the accuracy of the simulated existing floodplain compared to the citizens' service requests, the effectiveness of the proposed improvements in reducing the existing floodplains, and the extents of the improvements.



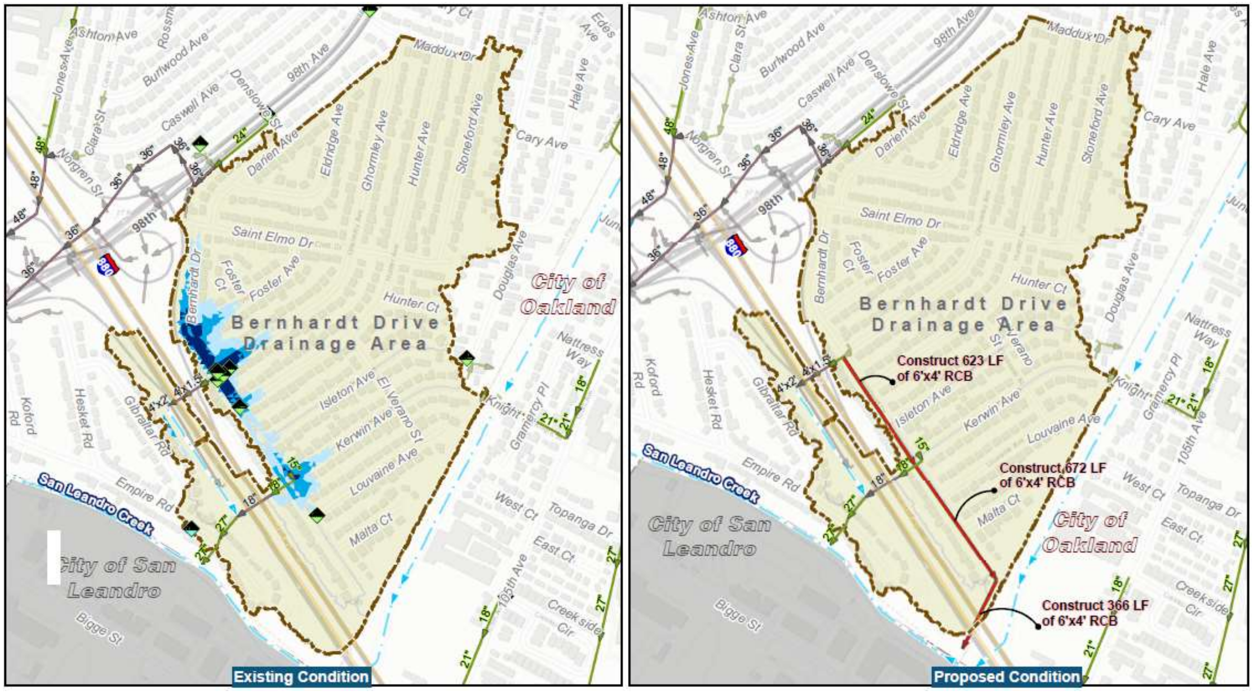
See **Exhibit C1 – Empire Road 25-year Alternative 1 Improvement Map** for the complete exhibit.



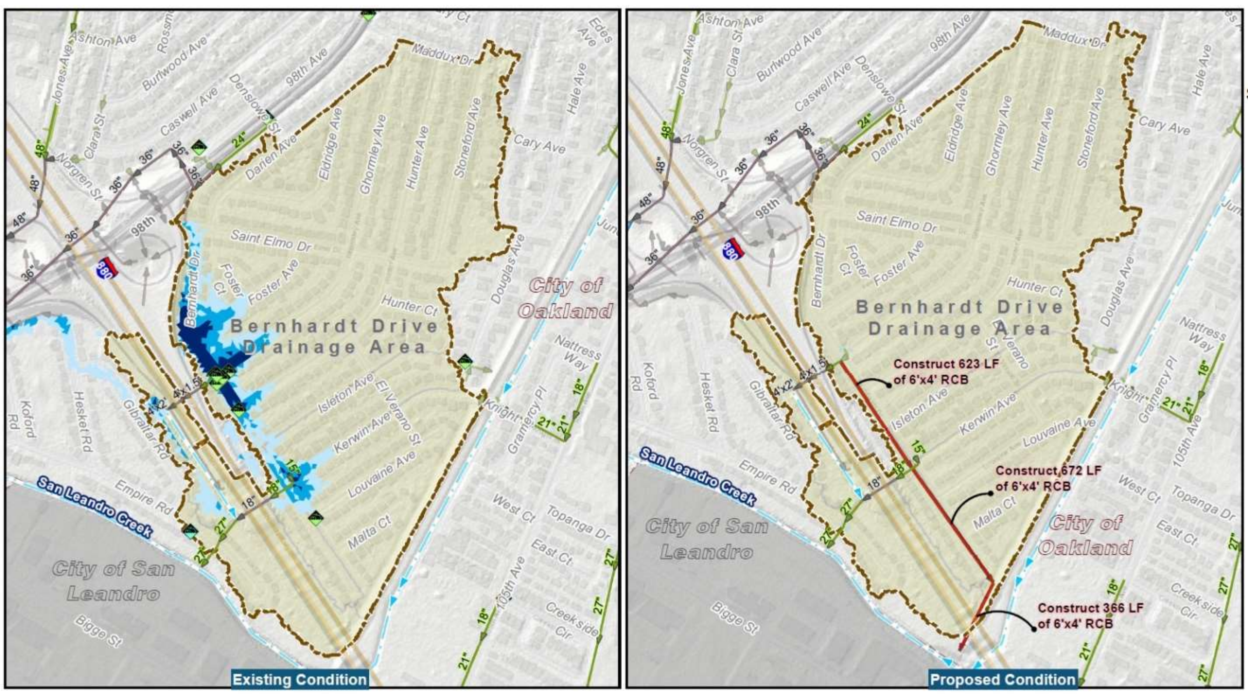
See **Exhibit C2 – Empire Road 100-year Alternative 1 Improvement Map** for the complete exhibit.

The proposed improvements at the Empire Road drainage system mitigated and removed most of the 25-year floodplain west of I-880 and effectively reduced approximately half of the 25-year floodplain east of I-880. In the 100-year simulation, the improvements mitigated the flooding to less than one foot of depth and be mostly contained within street ROW. The open channel improvements, once they are in place, will need regular maintenance to maintain their optimal conveyance capacity and performance.

The proposed improvements were developed to mitigate riverine floodplains and would not remove the FEMA regulatory floodplain, which was caused by 100-year coastal flooding. As shown in **Figure 7**, the FEMA SFHA in the Empire Road drainage area was mapped based on 100-year coastal flooding, which does not coincide with the 25- and 100-year riverine flooding developed for this study. The District typically proposes improvements to mitigate coastal flooding.



See **Exhibit C3 – Bernhardt Drive 25-year Alternative 1 Improvement Map** for the complete exhibit.



See **Exhibit C4 – Bernhardt Drive 100-year Alternative 1 Improvement Map** for the complete exhibit

The proposed improvements at the Bernhardt Drive drainage system mitigate all flooding in the 25- and 100-year storms. The excess capacity of the improvements could be used to accommodate the reduced channel conveyance capacity when the existing privately owned open channel is no longer serviceable or in service.

Life-cycle costs were then calculated for the recommended improvement alternatives, as shown in **Table 27**, to determine the project capital and maintenance costs over their expected service life spans.

Table 27 – Improvement Project Life-Cycle Cost

Improvements	Project Capital Cost ($)	Maintenance Costs ($)		Useful Life (year)	Project Life Cycle Cost ($)	Annualized Project Life Cycle Cost ($)
		Pipe Jet Flushing (every 5 years)	Vegetation Clearing (yearly)			
Empire Road - Alt 1	1,409,000	10,000	12,000	50	2,109,000	90,000
Bernhardt Drive - Alt 1	4,702,000	17,000	n/a	50	4,872,000	208,000

Based on the calculated annualized life-cycle costs in **Table 27**, the total cost to construct and maintain the Bernhardt Drive - Alt 1 improvements over 50 years of service life is greater than two times the cost of Empire Road - Alt 1. The ratios of annualized risk (**Section 7**) over annualized project life-cycle costs (**Section 8.2**) were then developed to rank improvement projects.

Table 28 – Improvement Project Prioritization

Improvements	Annualized Flood Risk ($)	Annualized Project Life Cycle Cost ($)	Annualized Risk/ Annualized Project Life Cycle Cost	Prioritization Ranking
Empire Road - Alt 1	179,600	90,000	2.0	1
Bernhardt Drive - Alt 1	197,000	208,000	1.0	2

Based on the ratios of annualized risk over annualized project life-cycle costs in **Table 28**, Empire Road - Alt 1 was ranked the highest and recommended for implementation over Bernhardt Drive - Alt 1. Both projects show relatively similar annualized flood risk, but there is a much lower annualized project life-cycle cost for Empire Road - Alt 1. This translates to a higher ratio at the Empire Road drainage system and a more cost-effective improvement project for flood risk reduction.

City of Oakland

WOOD RODGERS

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1 INTRODUCTION

The City of Oakland (City) is located in Alameda County in Northern California. Oakland is approximately 60 mi^2, and the City is bounded by the cities of Emeryville and Berkeley to the north, the Oakland and Berkeley hills to the east, San Francisco Bay to the west, and the City of San Leandro to the south. See the location map in **Figure 1**. The City has an estimated 2020 population of 440,646 residents. Lake Merritt, a 155-acre tidal lagoon, is in the heart of the City. The City also is home to the Port of Oakland, which is the fifth busiest port in the country.

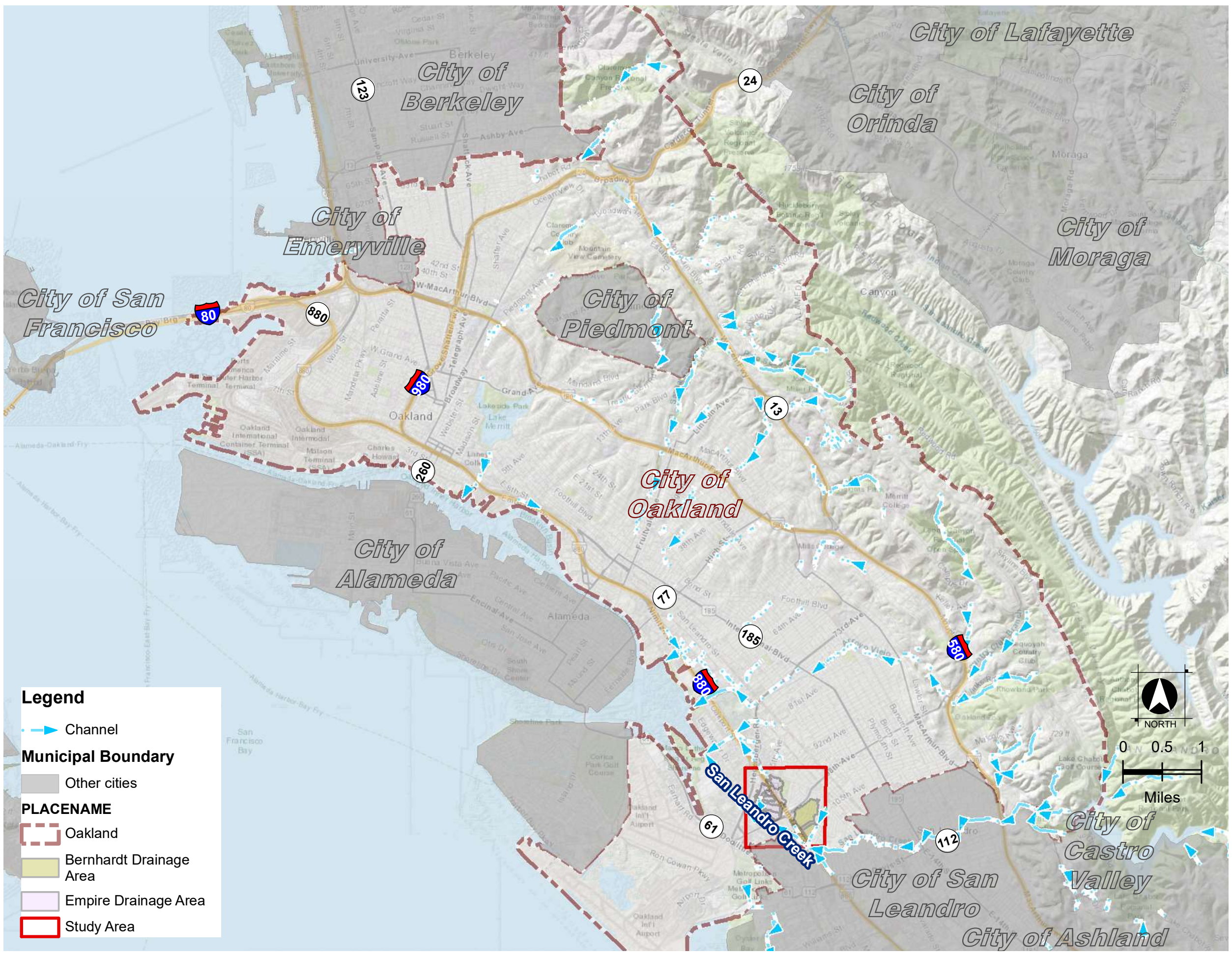

Figure 1 – Location Map

The City was incorporated in 1854. The City constructed and maintains more than 300 miles of storm drainage facilities for flood control. Some of the storm drains are isolated and only serve local drainage while other storm drains serve larger areas and discharge to local creeks. Lake Merritt (which existed naturally before development) has been used as a detention basin to service a large watershed in the downtown area. The City's facilities are also intermingled with those owned by Caltrans, private property owners, and the Alameda County Flood Control and Water Conservation District (District). All the storm drainage facilities collectively collect, convey, and discharge stormwater runoff from the open space east of Interstate 580 (I-580) and State Route 13 (SR 13), residential areas along the corridor of I-580 and Interstate 880 (I-880), and the industrial and commercial areas along I-880 to the San Francisco Bay.

The District was created by the state legislature in 1949 at the request of county residents. The District designed and constructed larger flood control infrastructure assuming full build-out of the county and has since built and maintained large storm drains, pump stations, open channels, culverts and bridges. The District's storm drains are mostly 36 inches and larger, and connect to the natural creeks and open channels engineered by the District. The construction of the 7th Street pump station by the District in 1968 transformed the Lake into a more crucial flood protection facility. The City of Oakland is within the District Flood Control Zone 12.

The City's storm drain system was mostly constructed in the early 1900s, and much of it has reached the end of its service life and must be replaced. These older structures were neither designed nor built to handle the increased demands of climate change such as sea level rise and higher intensity storm events. Their original designs do not meet increasingly stringent stormwater treatment regulatory requirements such as the incorporation of trash capture and green stormwater infrastructure systems. These challenges are further exacerbated by limited resources for maintenance and rehabilitation.

This drainage study focuses on the Columbia Gardens and Brookfield Village neighborhoods[1] at the southern edge of the City, which are served by two drainage systems in the Empire Road and Bernhardt Drive drainage areas (see the study area in **Figure 1)**. Deficient drainage facilities have caused recurring flooding in these areas.

This drainage study assesses the condition and capacity of the City's storm drainage facilities for the study area and includes a drainage facilities inventory, condition assessment, capacity assessment, flood risk identification, improvement project prioritization, and capital improvement plan (CIP) development. The CIP provides a proactive approach for drainage facilities maintenance, replacement, and upgrade.

[1] https://www.city-data.com/nbmaps/neigh-Oakland-California.html?msclkid=48588263c26511eca6a4c5394e47708e

1.1 Purpose

The City requested Wood Rodgers, Inc. to perform a comprehensive drainage study for the Empire Road and Bernhardt Drive drainage systems, which includes the following:

1. An inventory of storm drainage facilities within the drainage areas;
2. Identification of storm drainage capacity and condition deficiencies of facilities; and
3. Development and prioritization of capital improvement projects of facilities.

2 STORM DRAINAGE SYSTEM

The City's drainage facilities mostly drain to those owned by the Alameda County Flood Control and Water Conservation District (District) before discharging to San Leandro Bay. The City's facilities are also intermingled with those of Caltrans and private property owners.

The City owns and maintains a majority of the storm drain pipes, small pump stations, detention basins/lakes, and minor open channels while the District owns and maintains major open channels, large pump stations, and major storm drain systems along the arterials of the drainage systems. Caltrans owns and maintains its storm drain systems along state and interstate highway rights-of-way while private property owners own and maintain storm drain systems on their properties. The understanding of facility ownership and maintenance responsibility is crucial for the City to determine the resources for flood control.

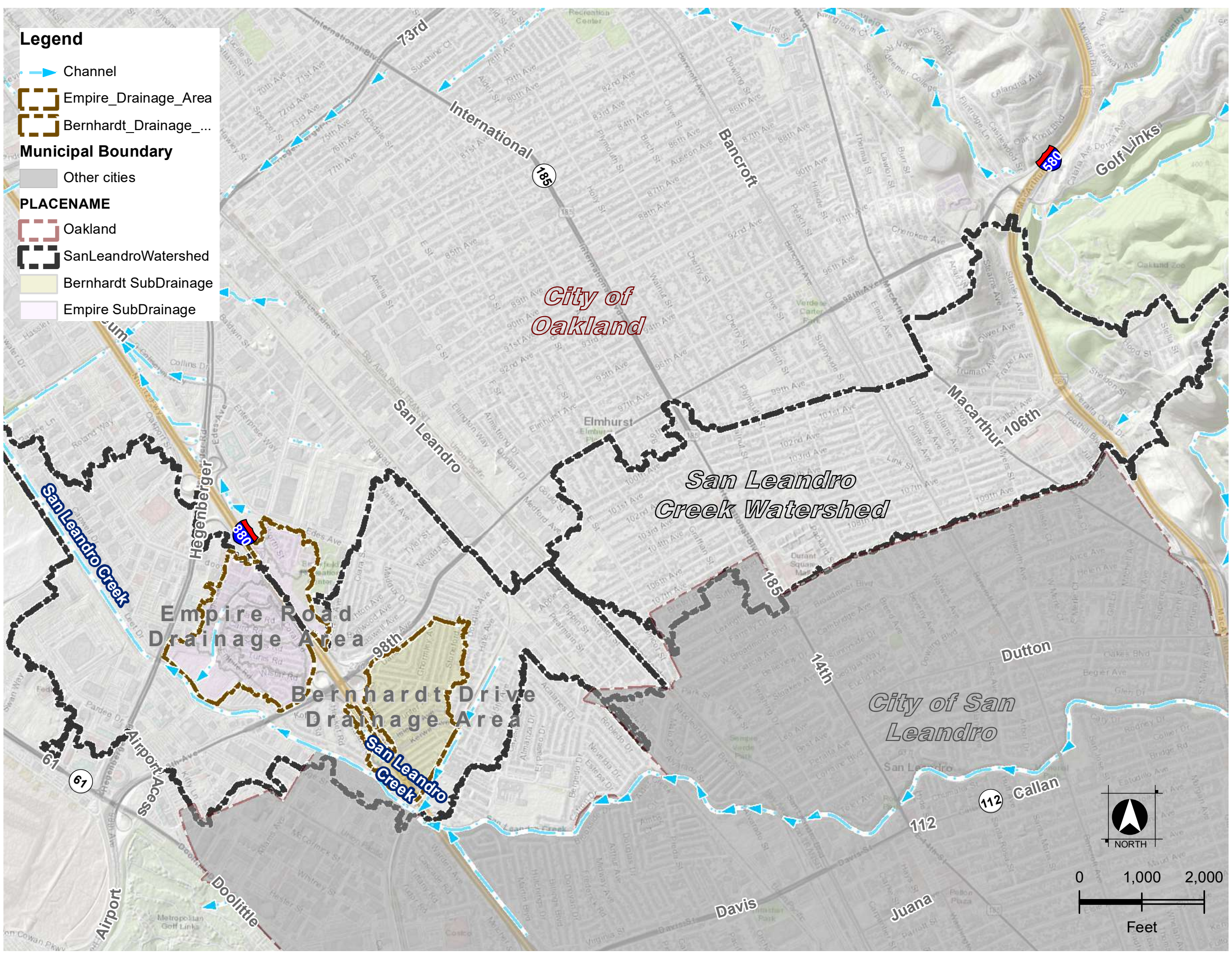

Figure 2 – San Leandro Creek Watershed (within Alameda County Flood Control Zone 12)

The storm drainage facilities in the Empire Road and Bernhardt Drive drainage areas consist of storm drain pipes and open channels that discharge stormwater into San Leandro Creek. The two drainage areas are within the larger San Leandro Creek watershed within the District Flood Control Zone 12 as shown in **Figure 2**. San Leandro Creek is subject to tidal influence up to the outfall of the Bernhardt Drive drainage system.

2.1 Empire Road Drainage System

The Empire Road drainage area is located in the Columbia Gardens neighborhood (Figure 3). The drainage area is bound by Edes Avenue to the north, 98th Avenue to the east, Hegenberger Road to the west, and San Leandro Creek to the south. The drainage system within the drainage area consists of approximately 5,600 feet of storm drain pipes varying from 12 to 48 inches in diameter and a few box culverts, and 1,300 feet of engineered earthen channels. The pipes and channels collect stormwater runoff from 105 acres of low-lying residential neighborhoods, a school, I-880 rights-of-way, and open space areas before discharging the runoff to San Leandro Creek through twin 48-inch culverts with flap gates. The flap gates prevent high water levels in San Leandro Creek from flowing backward and upstream along the drainage system. The high water levels in San Leandro Creek oftentimes prevent stormwater in the drainage system from discharging effectively.

2.2 Bernhardt Drive Drainage System

The Bernhardt Drive drainage system is located in the Brookfield Village neighborhood. The drainage area is bound by Edes Avenue to the north, Stonehurst Creek to the east, 98th Avenue to the west, and San Leandro Creek to the south. The drainage system within the drainage area consists of approximately 1,600 feet of storm drain pipes varying from 12 to 33 inches in diameter and a few box culverts, and 600 feet of heavily vegetated ditch. The pipes and ditch collect stormwater runoff from 74 acres of residential neighborhoods and I-880 rights-of-way before discharging the runoff to San Leandro Creek.

Both the Empire Road and Bernhardt Drive drainage areas and their respective drainage systems are shown in **Figure 3**.

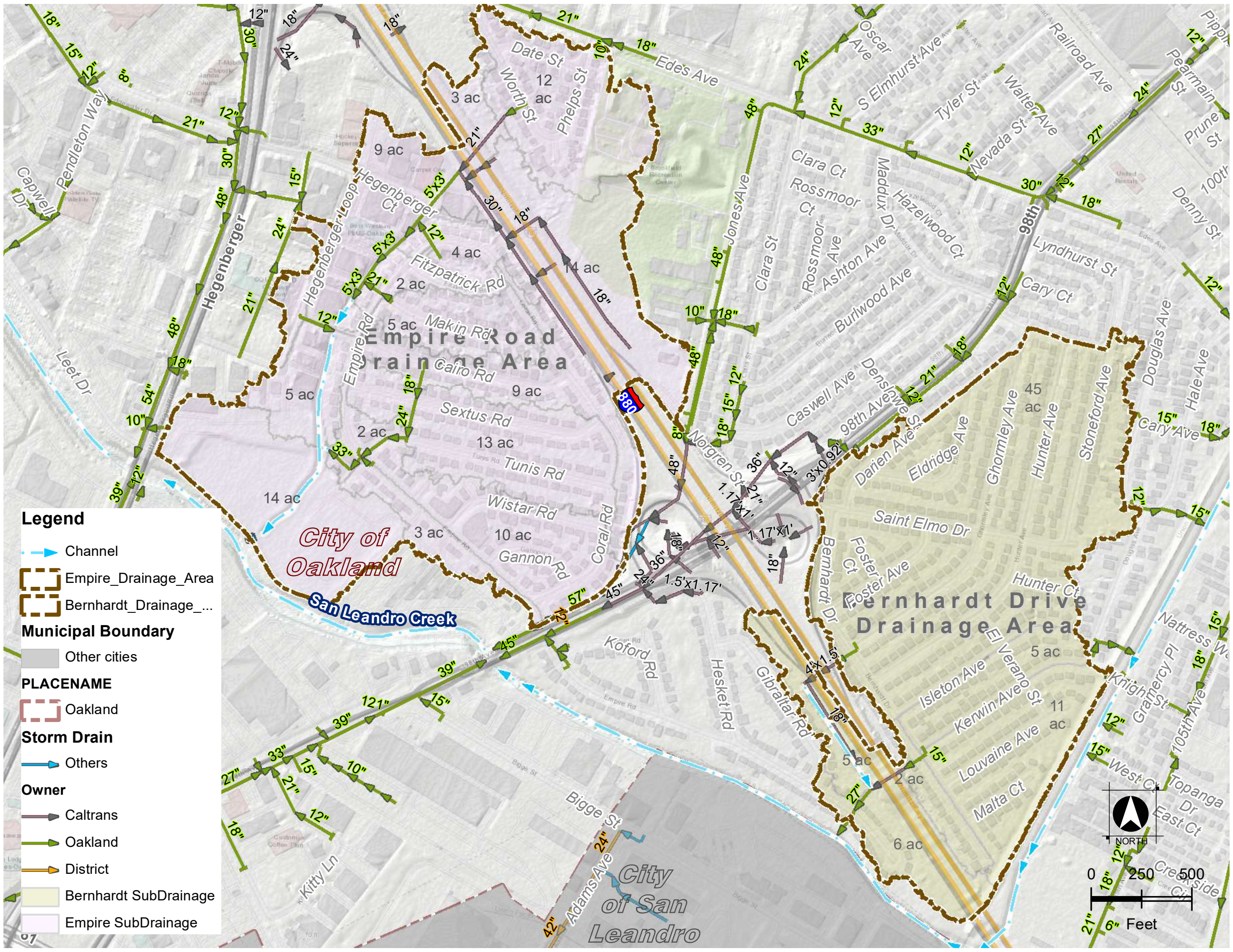

Figure 3 – Empire Road and Bernhardt Drive Drainage Systems (within the San Leandro Creek Watershed)

2.3 Existing Flooding

Recurring flooding events indicate potential maintenance and capacity deficiencies in the existing storm drainage system. Information collected from these events was used in conjunction with the modeling results to determine the location and extent of potential flooding, to validate the model, and to prioritize improvements.

Historical incidents of flooding events for a wide range of drainage problems have been reported and documented by City staff and residents. Documentation includes photos, videos, letters, and emails that detail the extent, duration, and interpreted causes of flooding. Since 2012, these reports have been recorded in *Cityworks* as service requests. *Cityworks* is a public asset management and permitting platform to support the permits, construction, maintenance, and replacement of the City's facilities. *Cityworks* data from 2012-2021 was exported and analyzed for this study.

Flooding can be caused by water levels exceeding the storm drainage system capacity and/or being backed up due to maintenance needs within the storm drain system. Capacity related flooding incidents are typically due to undersized pipes and creeks or high tailwater conditions. Maintenance related flooding incidents are typically due to clogged facilities or those blocked by excess sediment.

Overflowing manholes and creeks were likely caused by capacity issues, and other ponding could be due to combinations of capacity and maintenance issues. Locations with a single other ponding service request were likely due to maintenance issues, whereas the locations with multiple other ponding incidents were likely due to capacity issues. This judgment is based on the rationale that any maintenance issues should have been resolved when multiple incidents were reported.

Recurring flooding incidents were reported through service requests to the City on the earthen channel and surrounding storm drain systems near Cairo Road and Makin Road in the Empire Road drainage system as shown in **Figure 4**. The shallow channel running along property backyards has been reported to experience flooding from overbank spills during storm events while the surrounding storm drain catch basins overflowed.

At the Bernhardt Drive drainage system, most of the reported recurring flooding incidents are along Bernhardt Drive east of I-880, especially at the intersection with Ghormley Avenue. The storm drain catch basins have overflowed and resulted in property damage.

Recurring flooded locations referred to as service requests are notated in **Figure 4** and shown in the subsequent photos to indicate their locations and extents.

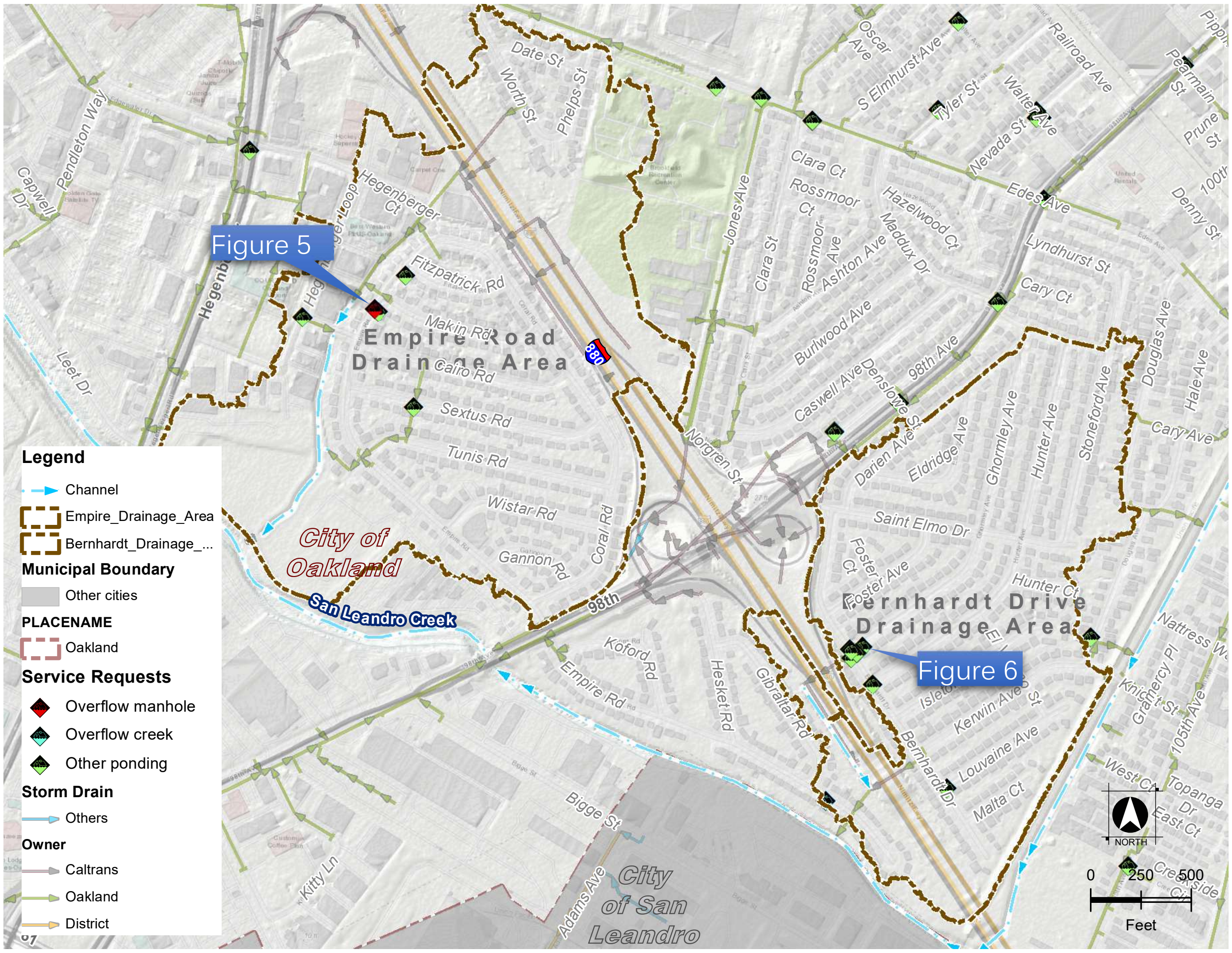

Figure 4 – Flooding Service Request Locations

Figure 5 shows the overflowing channel at the Cairo Road crossing on the channel along the Empire Road drainage system during the January 16, 2020 storm event. The storm had 0.23 inches of rainfall within the peak 15 minutes based on data from the Alameda County gauge at the Oakland fire station on 66th Avenue, which was categorized as a 2-year storm. The flooding caused by this storm event indicates severe capacity deficiencies of this system.

Figure 5 – Observed Flooding at Cairo Road Crossing on January 16th, 2020

Figure 6 shows the overflowing Empire Road storm drain system along Bernhardt Drive during the January 16, 2020 storm event. The catch basins were reported as overflowing, and the streets and properties were flooded. The flooding caused by this storm event indicates severe capacity deficiencies of this system.

Figure 6 – Observed Flooding at Bernhardt Drive on January 16, 2020

2.4 Regulatory Flooding

As part of the National Flood Insurance Program (NFIP), the Federal Emergency Management Agency (FEMA) has mapped the southern edge of the Empire Road drainage area in Special Flood Hazard Areas (SFHA) (**Figure 7**). The flood risk of the mapped SFHA area is mostly from the coastal flooding in San Francisco Bay. SFHAs are the areas defined with 1' or greater flooding depth during a 100-year design storm. The areas in SFHAs have a 1% annual chance (100-year) of flooding and are subject to the NFIP's floodplain management regulations, which require mandatory purchase of flood insurance for the affected properties. The Empire Road drainage area contains SFHA Zones X and AE (Elevation = 10') while the Bernhardt Drive drainage area contains undetermined flood hazards.

The flood risk within FEMA SFHAs is greater from drainage facilities with catchment areas greater than 1 square mile, and it requires regional and multi-agency improvements to mitigate, which is outside the focus of this study. This study was developed to assess and mitigate the smaller scale, local storm drain system flooding risk. However, the impacts of local storm drainage improvements to future regional improvements and vice versa were assessed.

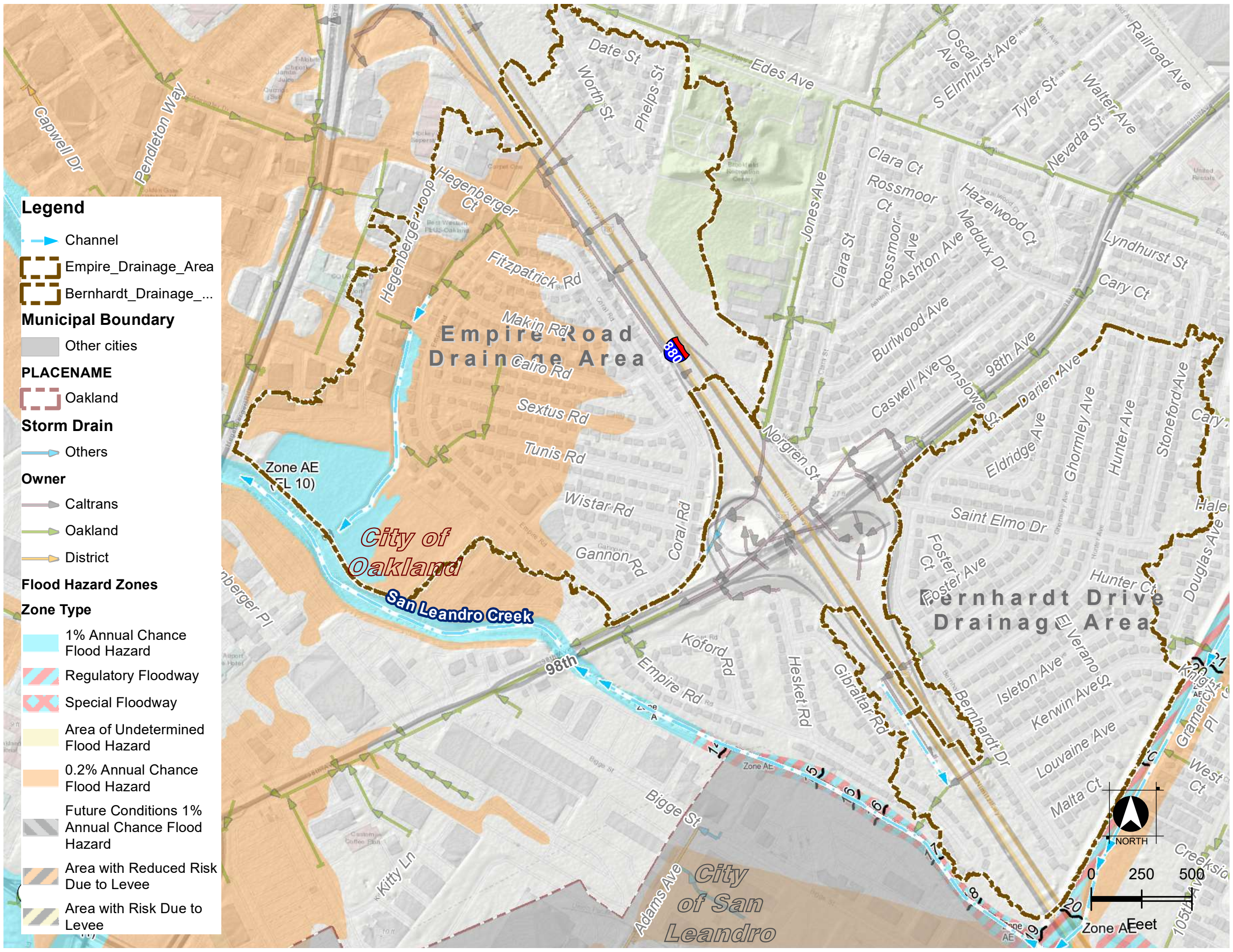

Figure 7 – FEMA Flood Hazard Zones

2.5 Facility Maintenance and Condition

Citywide, due to limited resources, the City has not been able to inspect, maintain, and repair all storm drain pipes, outfalls, and open channels on a regular basis. The impacts from this decades-long deferred maintenance are observed in response to service requests submitted by the public.

The local drainage facilities were inspected for this study to understand their conditions and to plan for appropriate maintenance, rehabilitation, and improvement projects as discussed in the later sections. Condition deficiencies are typically categorized as maintenance or structural issues. The drainage facilities within this study area were generally found to be maintenance deficient. No major structural condition deficiencies were found, as discussed in greater detail in **Section 5.1**.

Standing water was observed during a dry, sunny day inspection in the catch basin on Bernhardt Drive, as shown in **Figure 8**. Excessive sedimentation built up in the absence of sufficient maintenance, which has led to standing water and recurring and excessive flooding in the storm events as discussed in **Section 2.3**.

Figure 8 – Catch Basin on Bernhardt Drive (top); Standing Water in Catch Basin (lower left); Sedimented Culvert (lower right)

Sediment in the storm drain system reduced the conveyance capacity and contributed to recurring flooding in the storm events discussed in **Section 2.3**.

The other maintenance deficiency within the study area is caused by excessive vegetation growth. Vegetation clearing has not been performed maintain the capacity of the open drainage channels as shown in **Figure 9**. The deficiency of the channel west of I-880 at the Bernhardt Drive sub-drainage area is further complicated by access to the channel because the City does not own the property or an easement.

Figure 9 – Overgrown Pipe Inlet (left); Overgrown Channel (right)

Vegetation overgrowth significantly decreased stormwater velocity and prevented drainage facilities from conveying and adequately discharging the water. The condition resulted in excessive ponding at the channels or upstream storm drain systems.

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3 APPROACH

3.1 Policies, Regulations, and Ordinances

The ordinances, policies, standards, and regulations used for the development of this study are summarized below.

3.1.1 City of Oakland Municipal Code[2]

The criteria (**Section 3.23)** were conformed to the municipal code identified in the Chapter 13.14 – *Oakland Storm Drainage Design Standards*. The improvement plan (**Section 8)** was conformed to the municipal code identified in Chapter 13.16 - Creek Protection, Storm Water Management and Discharge Control.

3.1.2 City of Oakland Storm Drainage Design Standards[3]

The *Oakland Storm Drainage Design Standards*, updated in 2014, provide design criteria, standards, policies, and procedures for storm drainage improvements within the City of Oakland. The criteria (**Section 3.23)** and the improvement plan (**Section 8)** were documented consistent with this section.

3.1.3 Floodplain Management Ordinance[4]

The City of Oakland participates in the Federal Emergency Management Agency (FEMA) National Flood Insurance Program (NFIP). This Alameda County floodplain management ordinance (Chapter 15.40) invokes the requirements of the NFIP regarding development within special flood hazard areas. The improvement plan (**Section 8)** was conformed to the municipal code identified in this section.

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[2] https://library.municode.com/ca/oakland/codes/code_of_ordinances?nodeId=TIT13PUSE_CH13.14STDRST

[3] http://www2.oaklandnet.com/oakca1/groups/pwa/documents/webcontent/oak036229.pdf?msclkid=3c5c500ac42d11ec91e243e7670b1e00

[4] https://library.municode.com/ca/alameda_county/codes/code_of_ordinances?nodeId=TIT15BUCO_CH15.40FLMA

3.1.4 District Act 205[5]

The Alameda County Flood Control and Water Conversation District was created in 1949 when the state legislature passed Act 205 of the California Uncodified Water Code. The Act defines the District's role in providing for the control and conservation of flood and stormwater.

3.1.5 Alameda County Hydrology & Hydraulics Manual

This manual defines current Alameda County Flood Control and Water Conservation District (District) practice in the hydrologic and hydraulic design of flood control facilities in Alameda County. It is a guide for District engineers, as well as engineers who perform work for District review. The criteria (**Section 3.23)** were documented consistent with this design manual.

3.1.6 Alameda County, California Municipal Code

Chapter 6.36 - Flood Control and Water Conservation District Use Regulations establishes the requirement for obtaining a flood encroachment permit as a prerequisite of accessing and encroaching on the District's properties. The improvement plan (**Section 8)** was conformed to the municipal code identified in this section.

The improvement plan (**Section 8)** was conformed to Chapter 13.12 - Watercourse Protection.

Chapter 13.08 - Stormwater Management and Discharge Control provides the regulations for reducing or eliminating the pollution of receiving waters, including creeks and the San Francisco Bay, and to protect and enhance the water quality in county water bodies, including watercourses, wetlands, creeks, and flood control facilities, in a manner pursuant to and consistent with the Federal Clean Water Act, the State Porter/Cologne Act, and the County NPDES permit (below). The improvement plan (**Section 8)** was conformed to the municipal code identified in this section.

3.1.7 Municipal Regional Stormwater NPDES Permit

Section 402(p) of the federal Clean Water Act (CWA), as amended by the Water Quality Act of 1987, requires NPDES permits for stormwater discharges from municipal separate storm sewer systems (MS4s), stormwater discharges associated with industrial activity (including construction activities), and designated stormwater discharges, which are considered significant contributors of pollutants to waters of the United States.

The cities of Alameda, Albany, Berkeley, Dublin, Emeryville, Fremont, Hayward, Livermore, Newark, Oakland, Piedmont, Pleasanton, San Leandro, and Union City, Alameda County, the Alameda County Flood Control and Water Conservation District, and Zone 7 of the Alameda County Flood Control and

[5] https://acfloodcontrol.org/the-work-we-do/resources/

Water Conservation District, have joined together to form the Alameda Countywide Clean Water Program (Alameda County Permittees).

A final Municipal Regional Stormwater NPDES Permit (MRP) was adopted by the Water Board on November 19, 2015 (Order No. R2-2015-0049). The MRP covers stormwater discharges from municipalities and local agencies in Alameda, Contra Costa, San Mateo, and Santa Clara counties, and the cities of Fairfield, Suisun City, and Vallejo.

The permit provides the regulatory framework for stormwater discharge for municipal, new development, industrial and commercial land uses, for detection of illicit discharge, for construction site controls, for public information, monitoring, pollutant control, and reporting requirements.

3.2 Facility Type

The City considers three categories of natural and improved drainage facilities, consistent with the District:

1. Major Facilities: Major Facilities are waterways with tributary catchment areas equal to or larger than 25 square miles such as San Leandro Creek and other major waterways that are primarily owned and maintained by the District.

2. Primary Facilities: Primary Facilities are waterways and drainage facilities with tributary areas more than 50 acres and less than 25 square miles. These facilities mostly consist of creeks and larger improved waterways or drainage facilities. Most of these facilities are owned and maintained by the District; however, many are also owned by the City.

3. Secondary Facilities: Secondary Facilities include waterways or drainage facilities with tributary areas equal or less than 50 acres. Most of the City's drainage facilities fall under this category, including pipes, culverts, and drainage structures that are almost exclusively owned and maintained by the City.

3.3 Level of Service and Design Criteria

The level of service (LOS) provided by a stormwater system is a measure of its function, ability, and/or capacity with respect to some set of performance criteria. LOS standards are intended to protect public safety by ensuring emergency access and evacuation route ingress and egress, limiting damage to public and private property, and minimizing other hazards due to stormwater flooding. The LOS for storm drainage systems is defined by the "recurrence interval" or "annual exceedance probability" capacity that the facilities are designed for.

The LOS shall be 25-year for Primary Facilities and 10-year for Secondary Facilities. Primary facilities that flow into or may be located within FEMA study areas (also called National Flood Insurance Program or NFIP areas) should be designed to a 100-year LOS. Design criteria are recommended in the City's Drainage Standards for drainage facilities improvements. Hydraulic grade lines (HGLs) are compared against the design criteria for improvement sizing. HGLs are calculated or simulated with a computer model using the design storms and the corresponding tailwater conditions. For both Primary and Secondary storm drain pipes and open channels, the HGL must be at least 1.25 feet below the top of curb, and 1.0 foot below the top of bank of an open channel (both leveed and non-leveed). For street crossings, the HGL must be at least 2.0 feet below the top of curb.

While the City's Drainage Standards does not specify any other level of service, public agencies generally adopt a 100-year LOS to contain and convey stormwater flow up to 1.0 foot above street gutter flow lines and 1.0 foot below building finish floors via a network of storm drain pipes and streets to protect buildings from excessive flooding.

Table 1 – Level of Service and Design Criteria

Facility Type	Drainage Area	Design Storm (LOS)	Freeboard (Design Criteria)	Tailwater
PRIMARY				
Pipe	50 acres to 10 square miles	25-year	>1.25 ft min below top of curb	25-year
Street Crossing		25-year	>2.0 ft min below top of curb	25-year
Channel		25-year	>1.0 ft min below top of bank	25-year / MHHW
All Facilities in NFIPs		100-year	1.0 ft max above gutter flow line / 1.0 ft min below building finish floor / 1.0 ft min below top of channel bank	100-year / MHHW
SECONDARY				
Pipe	< 50 acres	10-year	>1.25 ft min below top of curb	10-year
Street Crossing			>2.0 ft min below top of curb	10-year
Channel		10-year	>1.0 ft below top of bank	10-year/ MHHW

Facility Type	Drainage Area	Design Storm (LOS)	Freeboard (Design Criteria)	Tailwater
PRIMARY /SECONDARY				
Pipe + Street	0 acres to 10 square miles	100-year	1.0 ft max above gutter flow line / 1.0 ft min below building finish floor	100-year / MHHW

Because each system will have nuances that may require additional considerations, the LOS presented in **Table 1** above are used as guidance and not considered absolute requirements in this drainage study. Deviations from established LOS are documented in the study.

Figure 10 illustrates the design criteria documented in **Table 1** for storm drain pipes and open channels graphically in cross-section views.

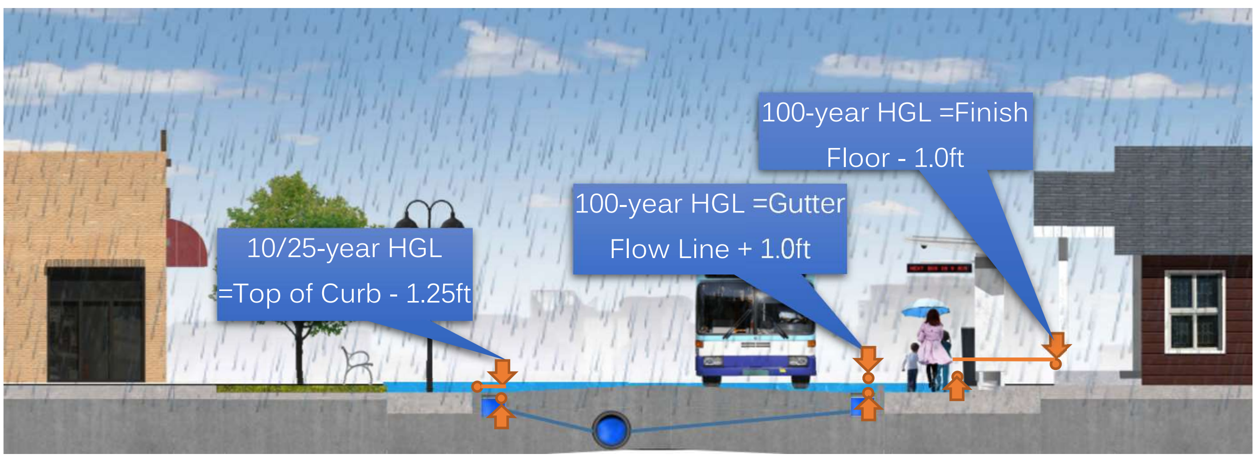


Figure 10 – Storm Drain Design Level of Service

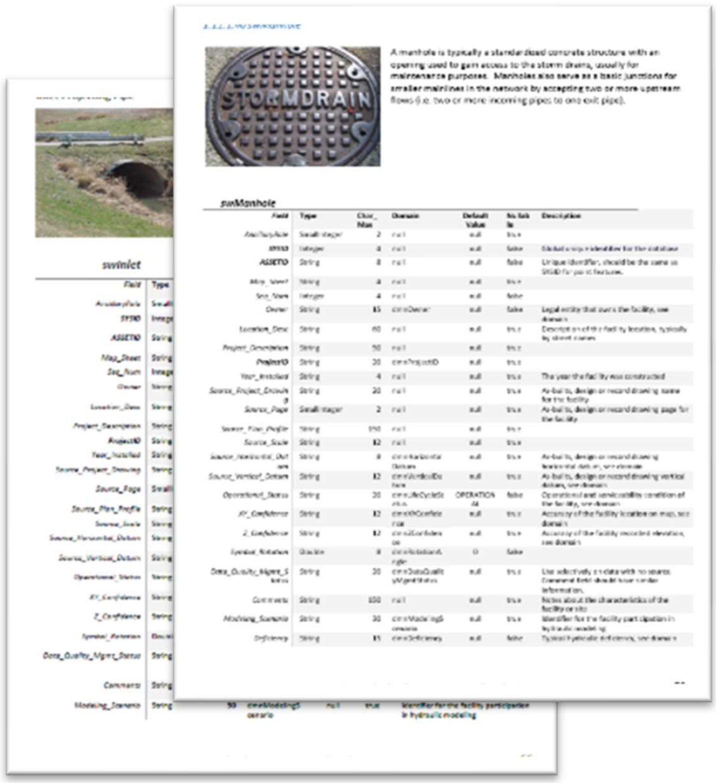
Figure 11 **– Open Channel Design Level of Service**

4 ASSET INVENTORY

A Geographic Information System (GIS) geodatabase was used to inventory storm drainage facilities, to refine the facilities attributes, and to facilitate hydrologic and hydraulic modeling for the City.

4.1 GIS Geodatabase and Collector Application

A Geographic Information System (GIS) geodatabase was used to inventory storm drainage facilities, to refine their attributes, and to facilitate hydrologic and hydraulic modeling for the City.



A manhole is typically a standardized concrete structure with an opening used to gain access to the storm drains, usually for maintenance purposes. Manholes also serve as a basic junctions for smaller mainlines in the network by accepting two or more upstream flows (i.e. two or more incoming pipes to one exit pipe).

swManhole

swInlet

A geodatabase is a digital central repository information filing system for storing spatial and attribute data and the relationships that exist among them. The data and information can be structured to work together as an integrated system using rules, relationships, and topological associations.

The geodatabase developed for the City is based on the foundation of the Local Government Information Model (LGIM) and consistent with the District's geodatabase. LGIM is a GIS information model that integrates processes across government departments in the United States.

Wood Rodgers refined and enhanced the City's geodatabase to include comprehensive storm drainage facilities, georeferenced as-builts, inspection pictures and data, condition assessment results, and hydrologic and hydraulic model input parameters and results (see **Figure 12**). Wood Rodgers refined and enhanced the City's geodatabase to include comprehensive storm drainage facility data, georeferenced as-builts, inspection pictures and data, condition assessment results, and hydrologic and hydraulic model input parameters and results (see **Figure 12**). The geodatabase was used for the sub tasks in **Task 4** to store and manage drainage facility information; to identify missing information; to prioritize data collection (as-builts, survey and inspection) and inventory; to identify facility ownerships and maintenance responsibilities; and to reconcile all the collected data.

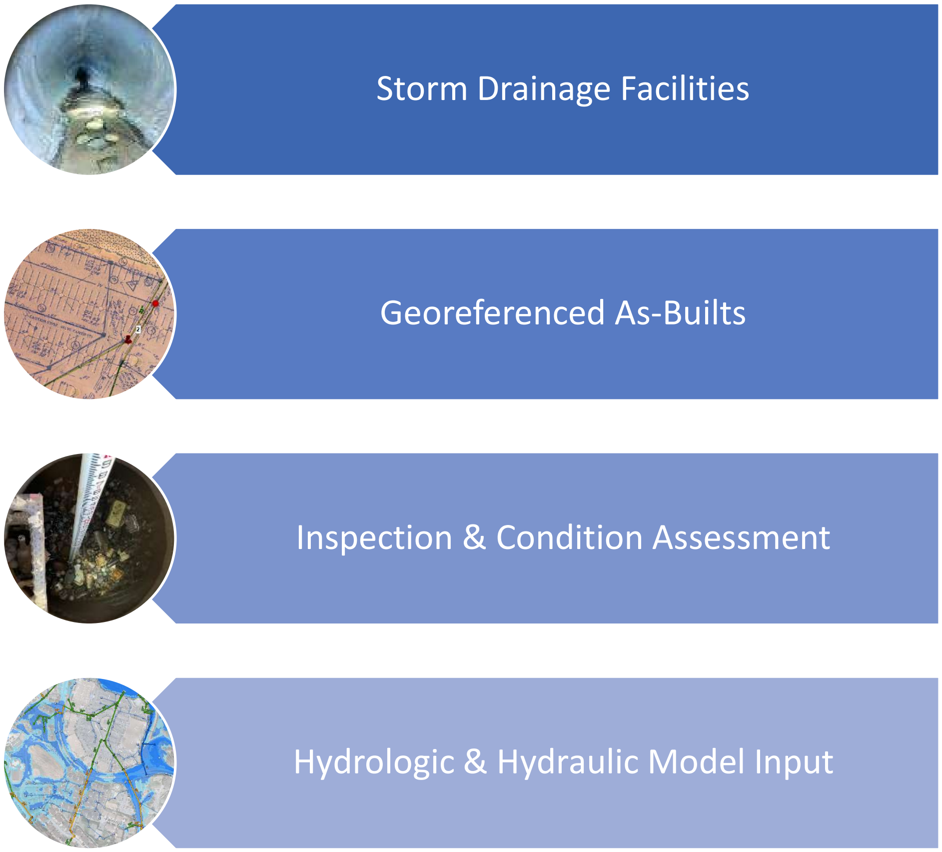


Figure 12 – GIS Geodatabase Contents

The refined geodatabase was integrated with Wood Rodgers' *ArcGIS Survey123* application to aid inspection and survey activities, and to integrate the collected data into the geodatabase. The *ArcGIS Survey123* application is a Web and mobile phone application customized by Wood Rodgers to record field survey and inspection pictures and data (see **Figure 13**).

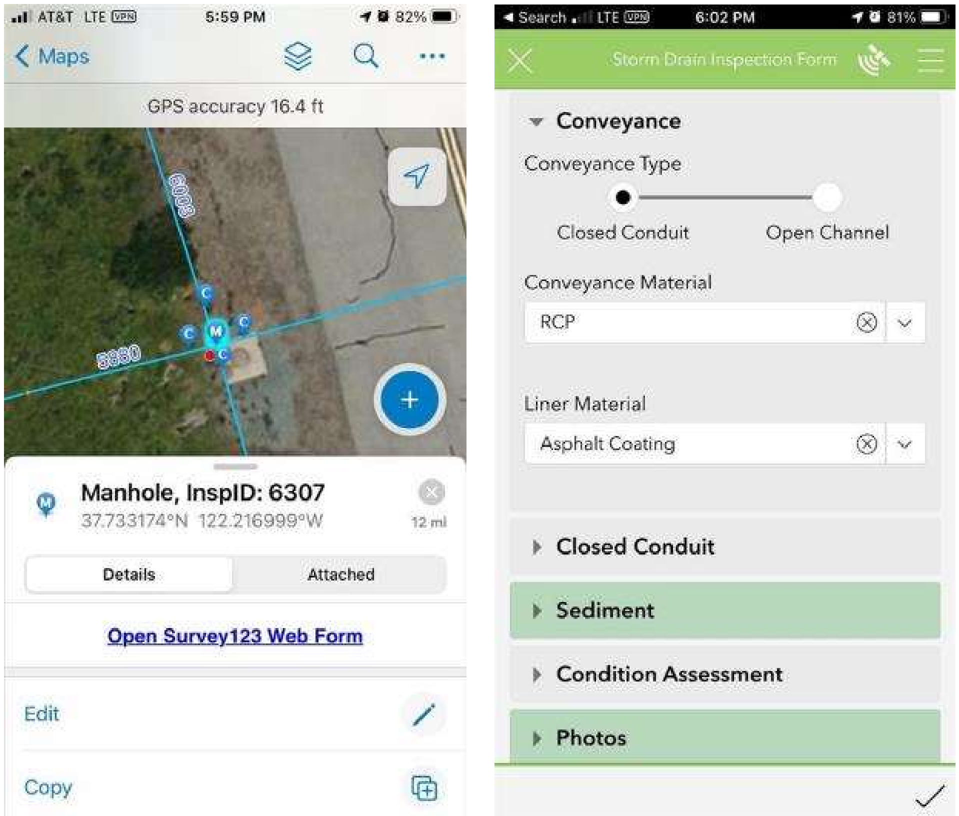


Figure 13 – Wood Rodgers' ArcGIS Survey123 Application

This *ArcGIS Survey123* application was used to collect photos, pipe location and sizes, junction locations, outfall locations, and conditions. Initial condition assessments were developed during inspections with the application and were reviewed by senior engineers and geomorphologists, as shown in a later section of this report.

4.2 Desktop Inventory

A desktop inventory is the process of georeferencing digitally scanned record drawings/as-builts to the geodatabase to add spatial properties. The georeferenced as-builts are then used to trace underground storm drain pipe alignments and to extract and convert information on the as-builts to storm drainage facilities attributes, spatial locations of manholes and catch basins, and alignments of pipes in the geodatabase (see **Figure 14**).

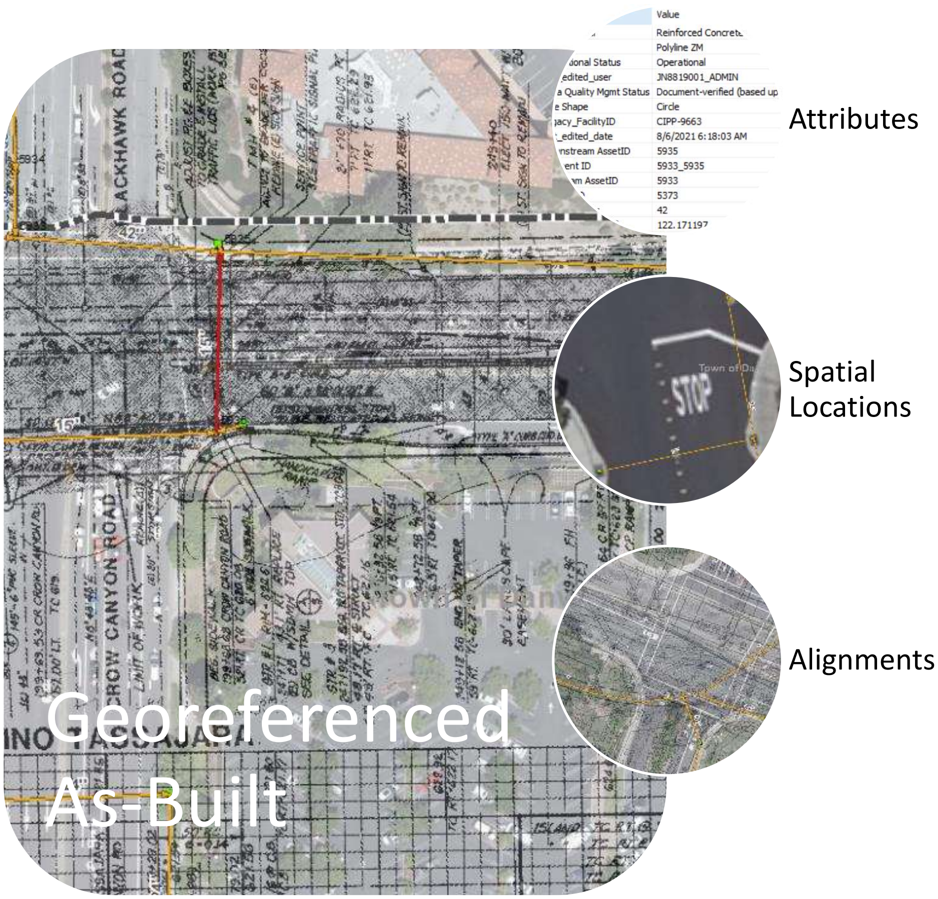


Figure 14 – Desktop Inventory with Georeferenced As-Builts

Wood Rodgers georeferenced record drawings and as-builts to complete the geodatabase inventory of the City's storm drainage systems. The latest ortho imagery with 3 inches or better resolution and *Google Street View* were used to geolocate facilities and to create or refine existing geometry. This approach provides horizontal accuracy between 1 to 3 feet, which is sufficient to determine manhole, catch basin, and outfall structure locations, as well as estimate storm drain pipe lengths. LiDAR data was used to determine the facility rim or ground elevations. The LiDAR data was collected in 2016 and 2019 and has a 20-point-per-square-meter resolution and non-vegetated vertical accuracy of

0.036 meters (1.4 inches). The LiDAR-derived facility rim or ground elevations were then used in conjunction with inspection data to verify the as-built data.

The drainage structures geolocated with ortho imagery were used in conjunction with the georeferenced as-builts to realign storm drain alignments and to identify other paved-over facilities such as junction boxes and transition structures. The georeferenced as-builts were also used to record storm drain materials, diameter/dimensions, lengths, and upstream and downstream inverts. The complete geodatabase includes an inventory of storm drains, grade breaks, manholes, outfalls, junction boxes, and transition structures.

The storm drain facilities that are missing spatial properties or attributes were identified as data gaps and planned for surveys and inspections to fill the data gaps in the geodatabase inventory.

The City's and District's GIS geodatabases and georeferenced as-builts were used for inventories of the hydraulic structures, open channels, and storm drain pipe in the study area, as presented in **Table 2** through **Table 4**.

.

Table 2 – Hydraulic Structure Inventory

Type	Empire Road Drainage Area, Count	Bernhardt Drive Drainage Area, Count	Total, Count
Catch Basin/Inlet	24	14	38
Manhole	4	0	4
Junction Box	0	0	0
Outlet	3 1 (private)	1 1 (Caltrans)	6
Flap Gate	2 (private)	0	2

Table 3 – Open Channel Inventory

Type	Empire Road Drainage Area, Length (Feet)	Bernhardt Drive Drainage Area, Length (Feet)	Total, Length (Feet)
Earthen open channel	775 (Private) 525 (City)	605 (Private)	1,905

Table 4 – Storm Drain Pipe Inventory

Diameter (inches)	Empire Road Drainage Area, Length (Feet)			Bernhardt Drive Drainage Area, Length (Feet)			Total City, Length (Feet)	Total All, Length (Feet)
	City	Caltrans	Private	City	Caltrans	Private		
<=12	521	-	-	85	-	-	606	606
15	51	-	-	131	-	-	182	183
18	269	1,796	-	-	802		269	2,867
21	286	548	-	-	-	-	286	834
24	177	-	-	-	-	-	89	176
27	260	-	-	284	-	-	544	544
30	-	368	-	-	-	-	0	368
33	226	-	-	-	-	-	226	226
48	-	57	116	-	-	-	0	173
RCB	880	51	-	83	185	-	963	1,199
Total	**2,670**	**2,820**	**116**	**583**	**892**	**95**	**3,253**	**7,175**

The storm drain pipe inventory in **Table 4** shows both the City-owned and Caltrans-owned pipes for different sizes. All pipes were found to be reinforced concrete pipe (RCP).

The City's storm drainage facilities within this study area are worth approximately $3.0M using replacement cost values of the facilities shown in Table 5. The unit costs were extracted from multiple recent contractors' bids for the respective facility types and then averaged for each facility type. The unit costs represent just furnish and install costs for the facilities and they exclude other construction services such as mobilization, traffic control, utility conflict relocation, site restoration, and other supporting facilities.

Table 5 – Storm Drainage Facilities Asset Values

Facility (City Owned)	Replacement Unit Cost	Quantity	Asset Value ($)
Catch Basin/Inlet	$5,000 each	38	190,000
Manhole	$15,000 each	4	60,000
Outlet	$50,000 each	4	200,000
Earthen open channel (20' wide x 4' deep)	$120/cuyd	525	187,000
<=12" RCPs	$260/foot	606	72,720
15" RCPs	$330/foot	182	47,320
18" RCPs	$390/foot	269	88,770
21" RCPs	$460/foot	286	111,540
24" RCPs	$520/foot	89	40,940
27" RCPs	$590/foot	544	282,880
30" RCPs	$660/foot	0	-
33" RCPs	$720/foot	226	162,720
48" RCPs	$1,050/foot	0	-
RCB (Average 5'x3')	$1,600/foot	963	1,540,800
Total			**2,984,690**

4.3 Facility Ownership and Maintenance

The City determines its storm drainage facilities' ownership and maintenance responsibility based on data found on as-builts; right-of-way (ROW) boundaries, drainage easements, title reports, and other similar information. Drainage easements are typically acquired by public agencies on private properties to install and maintain storm drainage facilities.

Facilities outside the ROW or easements were identified in this section using the georeferenced as-builts as shown in **Figure 15**.

Figure 15 – Ownership Categorization

Figure 15 shows the georeferenced as-built, aerial image, and storm drain pipes (orange lines) that were constructed within the public ROW along streets. These pipes were categorized as City-owned. The right-side image in **Figure 15** shows the georeferenced as-built, aerial image, and storm drain pipes (orange lines) that were crossing private properties where easements were dedicated to the City. These pipes were categorized as City-owned on dedicated easements.

Storm drainage facilities on private property, without easements, and not serving any public areas are typically the responsibility of private property owners. However, if these facilities are collecting and conveying stormwater runoff from public areas, it is recommended that an easement be acquired by the City to perform proper maintenance for flood control.

Figure 16 – Empire Road Drainage System Ownership Based on ROW and Easements

Based on the City Sewer Maps, the City owns the storm drain pipes within the Empire Road Sub Drainage Area on public ROW or dedicated easements. There is an approximately 30-foot-wide easement provided along the earthen open channel from Makin Road to Tunis Road that then turns west and connects to a 48-inch RCP that eventually discharges into San Leandro Creek. In 2008 (based on *Google Earth* historical images and recent LiDAR), the property owner abandoned the drainage facilities connecting the open channel to the 48-inch RCP to the west at Hegenberger Road and constructed a 100-foot-wide open channel (see the pink alignment in **Figure 16**) that drains south to San Leandro Creek. Two 48-inch culverts with flap gates were also constructed at the downstream end of the constructed open channel. As shown in **Figure 16,** a 900-foot-long and 120-foot-wide easement (including an access road) is proposed for acquisition along the open channel and dedicated to the City for proper maintenance and flood control for the upstream storm drain systems.

There exists a 24" RCP pipe on a private property between Sextus Road and Tunis Road without an easement as shown in the City Sewer Maps. A 90-foot-long by 10-foot-wide easement is proposed for acquisition and dedication to the City for proper maintenance and flood control for the upstream storm drain systems.

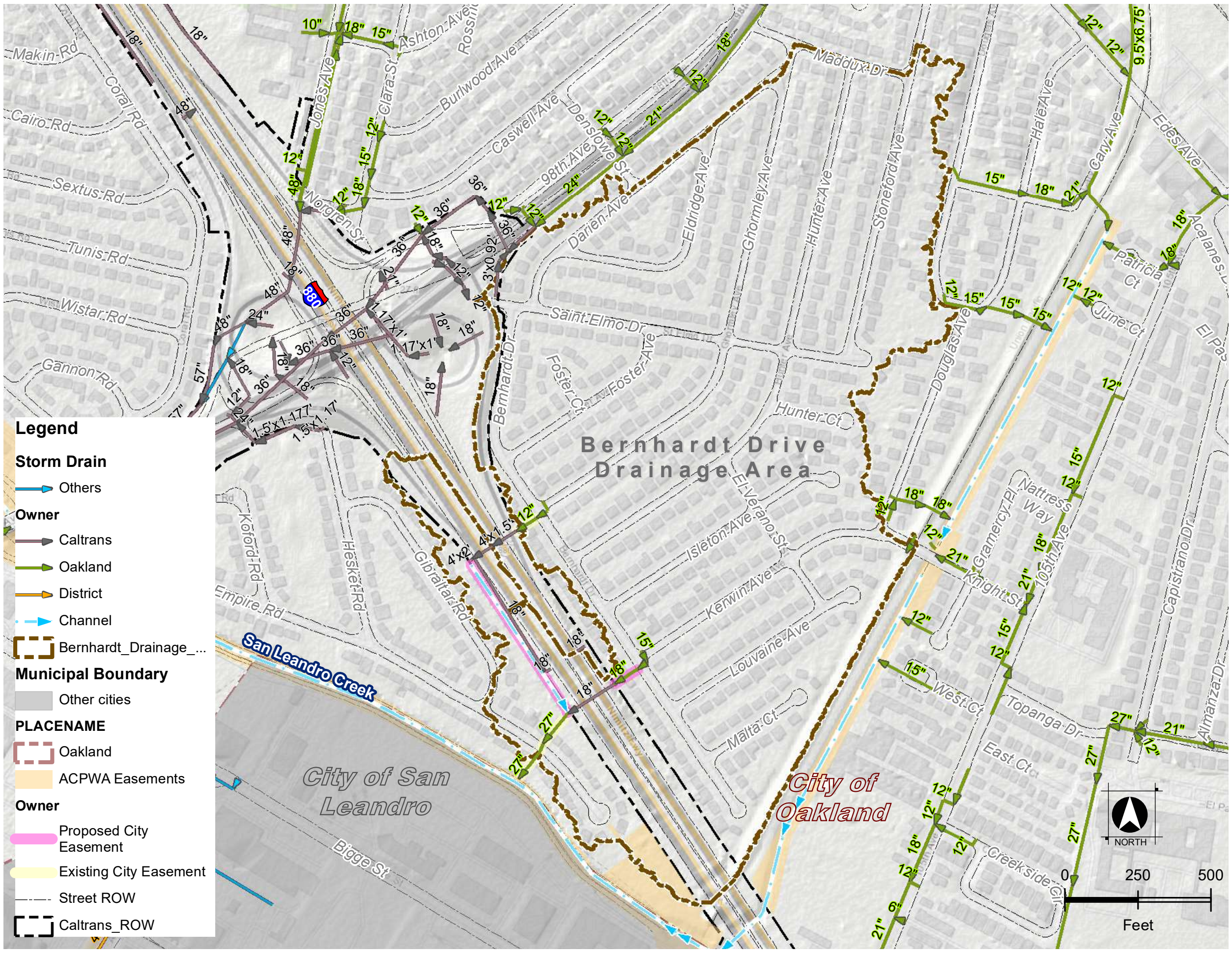


Figure 17 – Bernhardt Drive Drainage System ROW and Easements

Two storm drain pipe systems under and across I-880 in the Caltrans' ROW were extended when Caltrans widened the freeway in the mid-1990s, based on As-Built 04-233284. The two pipe systems were connected by an open channel on private properties west and parallel to the freeway. Caltrans deed documents showed only a temporary construction easement for the open channel. Title reports and deed documents for the private properties do not show any permanent easements for the open channel. The City Sewer Map developed in the 1970s shows an easement for the open channel; however, it could not be verified with any documents mentioned previously. Thus, it was assumed that the City does not have any easement on the open channel.

Based on the City Sewer Map, the City owns its storm drain pipes within the Bernhardt Drive Sub Drainage Area on public ROWs or dedicated easements. The City has easements for the 4'x1.5' RCB storm pipes under private property (before crossing I-880) near the intersection of Bernhardt Drive and Ghormley Avenue, and easements for the 27" RCP storm pipe under private property on both sides of Empire Road to the outfall at San Leandro Creek. However, the City does not have an easement for the 15" RCP connecting to the 18" RCP crossing I-880.

There are two facilities in the Bernhardt Drive drainage system without easement information where the City should consider acquiring easements (see the pink alignment in **Figure 17**). These facilities are the 15" RCP storm pipe under the private property near the intersection of Bernhardt Drive and Kerwin Avenue, and the open channel behind private property parallel to I-880.

Table 6 shows the ownership of the City's storm drainage facilities, which include pipes and channels based on the identified ROW and easements. The total lengths of the City's facilities or the facilities the City should acquire and without easements, are also listed in the table ([A]). The new easement acquisition costs are also calculated for the City's reference.

Table 6 – Empire Road and Bernhardt Drive Facility Ownerships

Drainage System	Facility Types	ROW (feet)	Easement (feet)	Unknown (feet)	[A] Private Property (feet)	New Easement Cost
Empire Road	Storm Drain Pipes	940	1,730	-	90 (10 wide)	$9,000
	Open Channels	-	525	-	900 (120 wide)	$1.08M
Bernhardt Drive	Storm Drain Pipes	243	340	-	95 (10 wide)	$10,000
	Open Channels	-	-	-	605 (20 wide)	$121,000

Based on a $10 per square foot permanent easement acquisition unit cost, the City would have to spend approximately $1.1M to acquire permanent easements along the Empire Road drainage system and $131,000 to acquire permanent easements along the Bernhardt Drive drainage system. While the unit cost could be substantially higher because of site conditions, loss of business revenues, property types and other factors, there are certain private property owners who would be relieved for the City to take over the facility's maintenance and are willing to offer their easements at a nominal cost.

4.4 Facility Survey and Inspection

Wood Rodgers performed Global Positioning System (GPS) surveys and spot inspections with a two-person crew consisting of an experienced engineer and a licensed surveyor. The process recorded spatial locations, elevations, storm drainage facility types and conditions for condition and capacity assessments as discussed in **Sections 5** and **6** respectively.

The field inspector or engineer utilized several standard inspection tools to document pipe/structure information (diameter, shape, material, depth, etc.), assess the pipe/structure conditions, and record any observed performance issues (plugging, erosions, overtopping, etc.). The inspection tools include electronic devices (digital tablets, GPS enabled cameras, and manhole inspection cameras), measurement devices (sediment probes and steel or vinyl tape measures), and standard access tools (manhole picks, sledgehammers, ratchet and sockets, and bolt hole alignment tools). The digital tablet is loaded with the ArcGIS *Survey123* application to aid the inspection as discussed in **Task 4.1**. The typical inspection setups for the storm drain system and outfall structure inspections are illustrated in **Figure 18** below.

Figure 18 – Typical Pipe (above) and Outfall (below) Inspection and Survey

The field surveys and spot inspections collected and stored notes and inspection pictures for the interior of pipes and structures. The inspection pictures can provide visibility up to 50 feet inside the pipes from the point of the inspection. The inspection tool and technique also provide accurate invert, pipe size, and sediment depth, if any, data even when the system is submerged under water.

The specifications of Wood Rodgers' spot inspection tool and technique are compared against a typical closed-circuit television (CCTV) inspection in **Table 7**. The advantages and limitations of the spot inspection when planned and used strategically have been proven to be a cost-effective approach.

Table 7 – Spot Inspection vs. CCTV Specifications

Method	Visibility	Data Collection in Dry Condition	Data Collection in Submerged Condition	Limitations
Spot Inspection	30-50 feet from point of inspection	Pipe diameter; invert; sediment depth; picture	Pipe diameter; invert; sediment depth	No visibility of cracks, minor joint issues beyond 30-50 feet and around bends
CCTV	Continuous	Pipe diameter; picture; video; alignment	No Data	Costly; requires jet flushing in sedimented pipes

Wood Rodgers has been using the spot inspection tool and technique in conjunction with a systematic site prioritization approach to optimize storm drainage facilities surveys and inspections. The approach prioritizes inspections based on the following factors in sequential order:

1. flooding or deficient pipe incidents reported by the City;
2. aged CMPs;
3. potential sedimented pipes based on flat pipe slopes and backwater conditions; and
4. key locations along a storm drain system at the upstream inlets, major confluences and outfall structures.

4.4.1 Empire Road Drainage System

The Empire Road drainage system inspection and survey focused on the open channel near the Cairo Road crossing where most of the flooding incidents were reported (see **Figure 4)** and downstream to the outfall near San Leandro Creek. The photo locations are annotated in **Figure 19**.

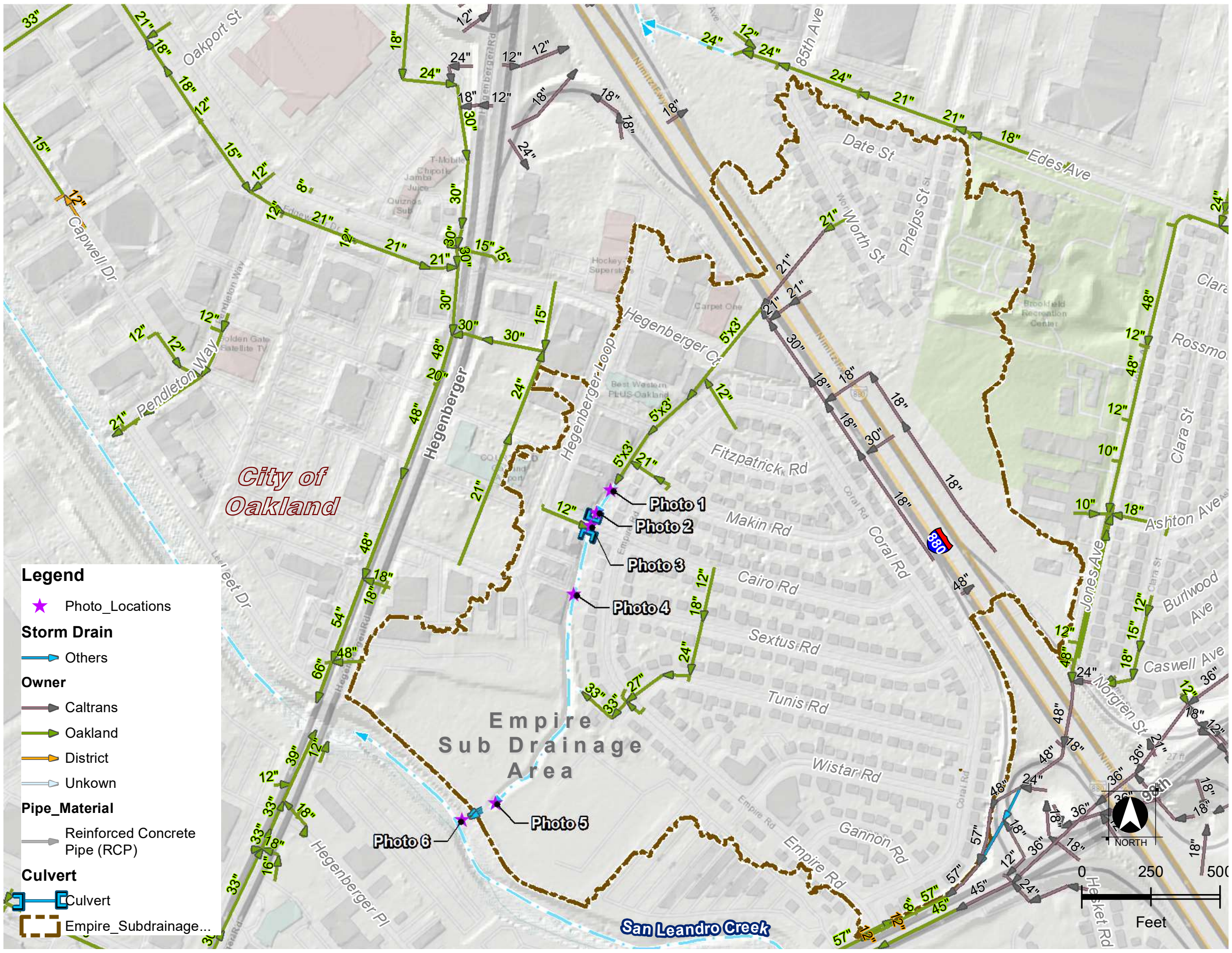


Figure 19 – Empire Road Photo Locations

Based on the inspection and survey as shown in Photos 1, 2, and 4, the earthen open channel between Makin Road and Tunis Road was relatively shallow (approximately 2-4 feet deep) and narrow (approximately 20 feet wide), filled with trash, and overgrown with vegetation. The Cairo Road 6'x3' reinforced concrete box (RCB) was found 6 inches below the bounding channels, filled with standing water and 6 inches of sediment. The channel starts to widen and deepen downstream of the 33" RCP outfall where the private property owner constructed the channel in 2008 as discussed previously in **Section 4.3**. The wider channel discharges into San Leandro Creek through a twin, 48", RCP outlet structure. The inside of the north culvert was found with two 2"x10" wooden planks as shown in Photo 5.

Photo 1: Channel downstream of 5'x3' RCB outfall

Photo 2: Channel upstream of Cairo Road

Photo 3: Cairo Road 6'x3' RCB Culvert

Photo 4: Channel downstream of Cairo Road

Photo 5: North 48" culvert of the outlet

Photo 6: Flap gates on 48" culvert outlet

4.4.2 Bernhardt Drive Drainage System

The Bernhardt Drive drainage system inspection and survey focused on the storm drain pipes crossing I-880 where most of the flooding incidents were reported (see **Figure 4**), the open channel parallel to I-880, and the outfall pipe to San Leandro Creek. The photo locations are annotated in **Figure 20**.

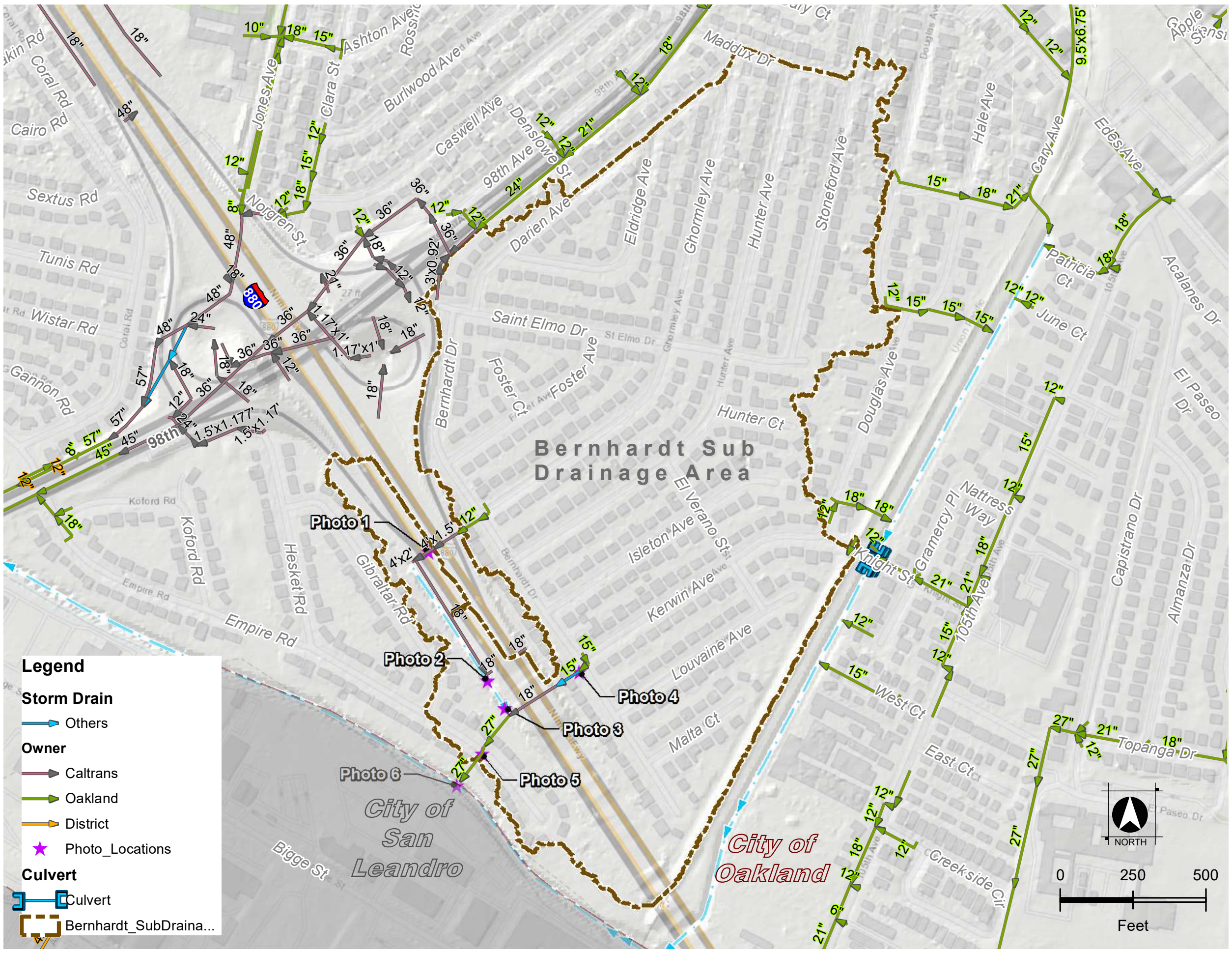


Figure 20 – Bernhardt Drive Photo Locations

Based on the inspection and survey, the Caltrans' RCB under I-880 off Ghormley Avenue was found to have 1 inch of standing water during dry weather and 4 inches of sediment and trash (as shown in Photo 1) while the Caltrans' RCPs under I-880 off Kerwin Avenue were found to be relatively dry and clean (as shown in Photo 4). At the Photo 4 location, there are dual 15" RCPs upstream that transition to a single 18" RCP downstream, which is routed under I-880. The open channel downstream of the Caltrans' pipes is shown in Photos 2 and 3. The open channel was constructed when the freeway was widened and now resides on private properties. The open channel is difficult to access and does not receive routine maintenance resulting in severe overgrowth of vegetation, which reduces the conveyance ability of the system. The open channel terminates at a 27” RCP shown in Photo 5. The 27” RCP is in a good condition but was found to have 1 inch of sediment near Empire Road. The 27” RCP outfalls to San Leandro Creek as shown in Photo 6 and does not have a flap gate.

Photo 1: 4’x’2 RCB under I-880

Photo 2: Channel parallel to I-880

Photo 3: Channel outlet to 27” RCP pipe system

Photo 4: Dual 15” transition to single 18” under I-880

Photo 5: 27" RCP pipe to outfall

Photo 6: Outfall to San Leandro Creek

5 CONDITION ASSESSMENT

A condition assessment is a technical assessment of the inspected data (**Task 4.4**) by a team of experienced civil, structural, and geotechnical engineers. The assessment provides standard ratings of the structural and maintenance conditions of the inspected facilities and the corresponding rehabilitation and replacement recommendations.

Wood Rodgers has been using the Environmental Protection Agency (EPA) *"Asset Management Handbook*" and the *National Association of Sewer Service Companies* (NASSCO) *Pipeline Assessment Certification Program* (PACP) condition grading systems guidelines to provide a standard condition rating system for inspected facilities. The information was used to calculate maintenance, rehabilitation, and replacement works for the desired service life (life-cycle cost).

5.1 Structural Condition Deficiencies

Table 8 presents the criteria used for rating the severity of structural condition deficiencies observed in the interior of the inspected facility. The ratings are categorized into Good, Fair, Poor, and Critical based on the risk of structural failure and the impacts to the hydraulic performance.

Table 8 – Structural Condition Rating Criteria

Rating	Rating Description	Example Picture
Good	Good, no repair necessary	
Fair	Minor repairs to improve functionality	
Poor	Overhaul or substantial repair required	
Critical	Not functional or requires complete replacement	

Table 9 lists the deficiency types, numbers of structural deficiencies and the corresponding ratings. The deficiencies are further categorized into different materials to demonstrate the likelihood of occurrence of the deficiencies in certain conditions. For aged CMPs, typical deficiencies found are surface corrosion and corroded holes along the bottom of pipes. For concrete pipes, typical deficiencies found are cracks, spalling, and joint separations. The facilities assessed with fair, poor, and critical ratings show the deficiencies with different levels of severity.

Table 9 – Structural Condition Assessment Results

Materials	Deficiency Types	Ratings			
		Good	Fair	Poor	Critical
Aged CMPs	Corrosion/hole	n/a			
Concrete Pipes	Crack/Spalling/ Joint separation	7			

No corrugated metal pipe (CMP) was found within the Empire Road and Bernhardt Drive drainage systems; thus, no rating was provided. Based on the GIS inventory, all the storm drain pipes in the two drainage systems are RCPs. The pipes inspected at seven locations in **Section 4.4** in the two drainage systems were also confirmed to be RCPs and in good condition.

5.2 Maintenance Condition Deficiencies

Table 10 presents the criteria used for rating the severity of maintenance condition deficiencies observed in the interior of the inspected facility. The ratings are categorized into immediate, non-immediate, and good based on the impacts of debris, vegetation, sediment, and joint infiltration to the hydraulic performance.

Table 10 – Maintenance Condition Rating Criteria

Rating	Rating Description	Sample Picture
Good	No action necessary	
Non-immediate	Requires monitoring and planned actions to restore conveyance capacity or to maintain existing performance	
Immediate	Requires immediate actions to restore conveyance capacity or to maintain existing performance	

Table 11 lists the deficiency types, numbers of sites with maintenance condition deficiencies, corresponding ratings, and potential consequences.

Table 11 – Maintenance Condition Assessment Results

Deficiency Types	Ratings			Consequence
	Immediate	Non-Immediate	Good	
Debris/Trash	1			Malfunctioning flap gate
Sediment		4		Reduced conveyance capacity
Vegetation	1	1		Clogging/reduced conveyance capacity

There is one location at the 48” culvert downstream end of the Empire Road drainage system that has an **immediate** maintenance condition deficiency due to debris. If the condition is left unattended, there is a possibility of malfunctioning flap gate that would allow high tides to flow through the tide gate and flood the upstream drainage system.

The open channel west of I-880 at the Bernhardt Drive drainage system has an **immediate** maintenance condition deficiency due to overgrown vegetation. If the condition left unattended, the channel would have reduced conveyance capacity due to slow moving flow and also the possibility of vegetation or debris clogging the outlet pipe.

There are other **non-immediate** maintenance condition deficiencies due to sediment and overgrown vegetation for both drainage systems that need continued monitoring and maintenance. Addressing these deficiencies will alleviate but not substantially reduce the flooding issues because there are inherent capacity deficiencies within these drainage facilities; the analysis of these deficiencies is presented in the following section.

5.3 Maintenance, Rehabilitation and Replacement Recommendations

Maintenance, rehabilitation, and replacement work is recommended based on the assessed structural and maintenance condition deficiencies and the potential consequences described previously. Maintenance work such as sediment removal and vegetation clearing are recommended to address maintenance condition deficiencies on City's drainage facilities or other facilities that will impact the performance of the City's facilities. Rehabilitation work such as pipe lining, invert paving, and joint grouting are recommended to address structural condition deficiencies while replacement works such as bore and jack, and open trench pipe replacements are recommended over rehabilitation works when the facility is at the end of its remaining useful life.

Figure 21 below shows the **critical** and **poor** structural condition deficiencies (if any) and the **immediate** and **non-immediate** maintenance condition deficiencies at the Empire Road drainage system.

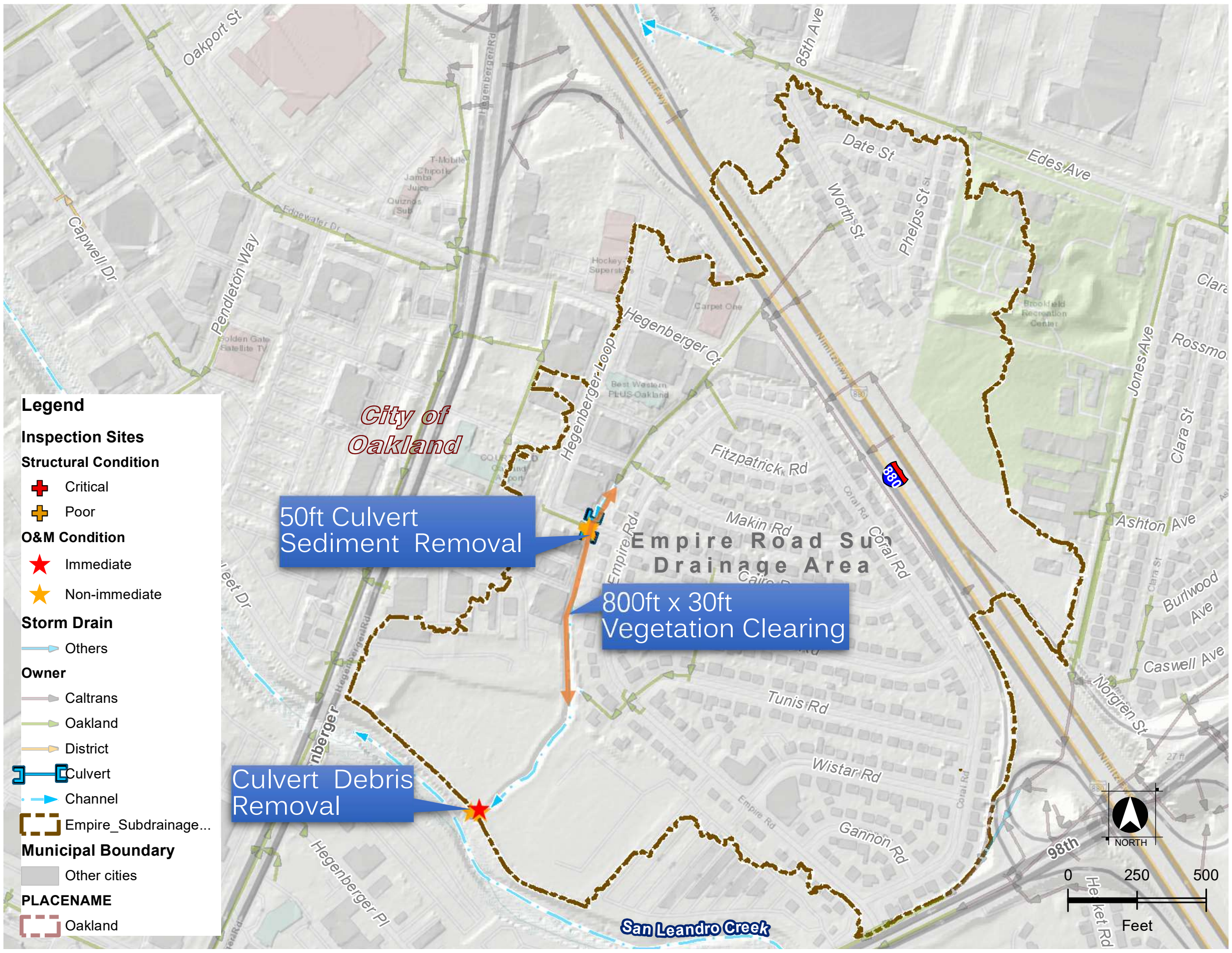


Figure 21 – Empire Road Drainage System Condition Deficiencies and Recommended Actions

The locations that have immediate and non-immediate maintenance condition deficiencies are recommended for maintenance activities and annotated on **Figure 21** with their respective extent. No **critical** or **poor** structural condition deficiencies were found in the Empire Road drainage system.

The locations with immediate and non-immediate maintenance condition deficiencies in the Bernhardt Drive drainage system are recommended for maintenance activities and annotated on **Figure 22** below with their respective extent. No **critical** or **poor** structural condition deficiencies are found in the Bernhardt Drive drainage system. Vegetation clearing maintenance works are recommended along the open channel on private properties because it creates high tailwater conditions for the City's storm drain pipes upstream of I-880.

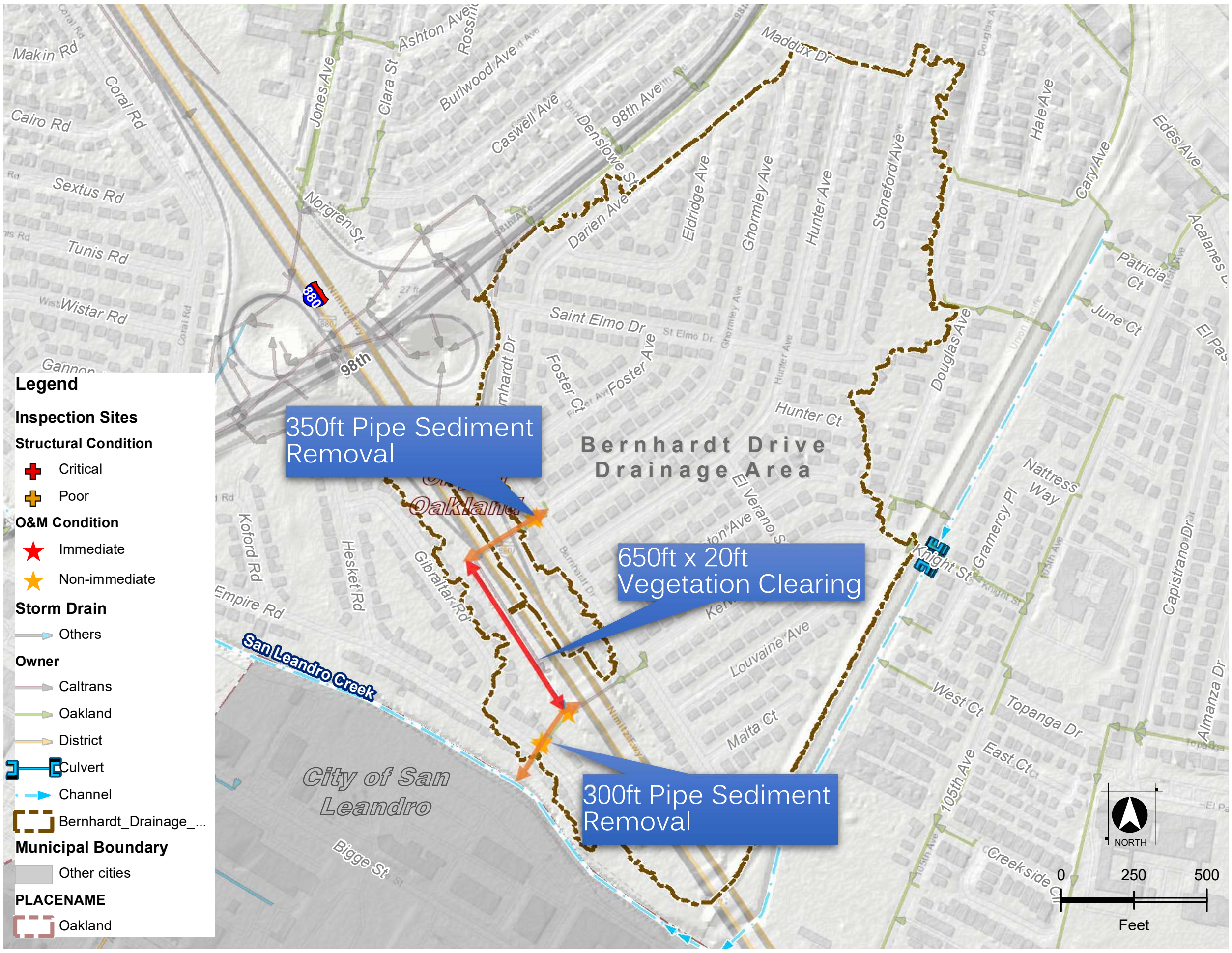


Figure 22 – Bernhardt Drive Drainage System Condition Deficiencies and Recommended Actions

Maintenance costs) were developed for the extents of the storm drainage facilities identified in **Figure 21** and **Figure 22** to maintain their conditions and performance. For storm drain pipes, jet flushing maintenance activities are recommended every five years to remove sediment and debris in the pipes based on the maintenance condition assessed in **Section 5.2**. Yearly vegetation clearing activities are recommended to avoid woody vegetation growth and to maintain optimal conveyance capacity. A jet flushing unit cost of $10 per foot was used for the pipes, and a channel vegetation clearing unit cost of $0.6 per square foot (or $5 per square yard) was used for the earthen channel. Hand removal of pickleweed/vegetation was assumed for the vegetation clearing as a conservative measure where machinery operations in the channel are prohibited.

Table 12 - Maintenance, Rehabilitation and Replacement Costs

Drainage System	Maintenance Costs ($)		Rehabilitation Costs ($)	Replacement Costs ($)	Total Yearly Cost ($)
	Pipe Jet Flushing (every 5 years)	Vegetation Clearing (yearly)			
Empire Road	500	14,000	n/a	n/a	14,100
Bernhardt Drive	6,500	7,800	n/a	n/a	9,100

The maintenace works recommended for the Empire Road and Bernhardt Drive drainage systems cost approximately $14,000 per year and $9,100 per year, respectively.

6 CAPACITY ASSESSMENT

A capacity assessment is the process of determining the capacity of storm drainage facilities by simulating statistically derived design storms with hydrologic and hydraulic computer models. Infoworks ICM one- and two-dimensional software was used to develop the hydrologic and hydraulic computer models for this study. The processes to develop hydrologic and hydraulic models and the associated analyses are illustrated in the following sub sections.

6.1 Hydrologic Analysis

Hydrologic modeling is a technical analysis to transform rainfall data to catchment runoff using a computer model. The transformation method simulates historical or statistically derived design storms in a hydrologic model developed with catchment boundaries based on topological data, imperviousness based on land use and aerial imagery, and soil infiltration rates. See **Figure 23** for the process, followed by a detailed description.

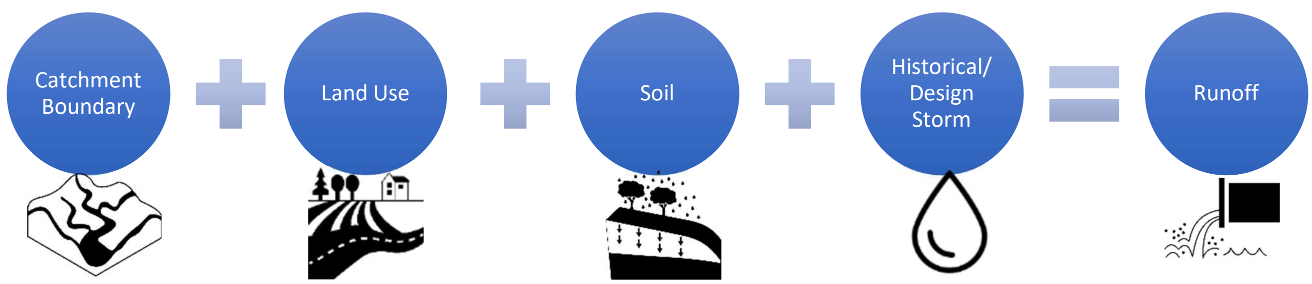
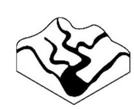


Figure 23 – Rainfall Runoff Transformation Process

Catchment Boundary and Lag Time



Catchment boundaries were developed to define the cumulative surface area draining to a drainage facility. The boundaries were developed using the highest resolution digital elevation model (DEM) available to represent the runoff flow path and accurate boundary. The boundary also incorporates storm drain facilities that can sometimes flow against the ground surface slope.

Figure 24 displays the drainage areas and the smaller catchments for Empire Road and Bernhardt Drive drainage systems that were developed and simulated for this study. The figure also includes open channels and storm drain systems that were used to develop the catchments.

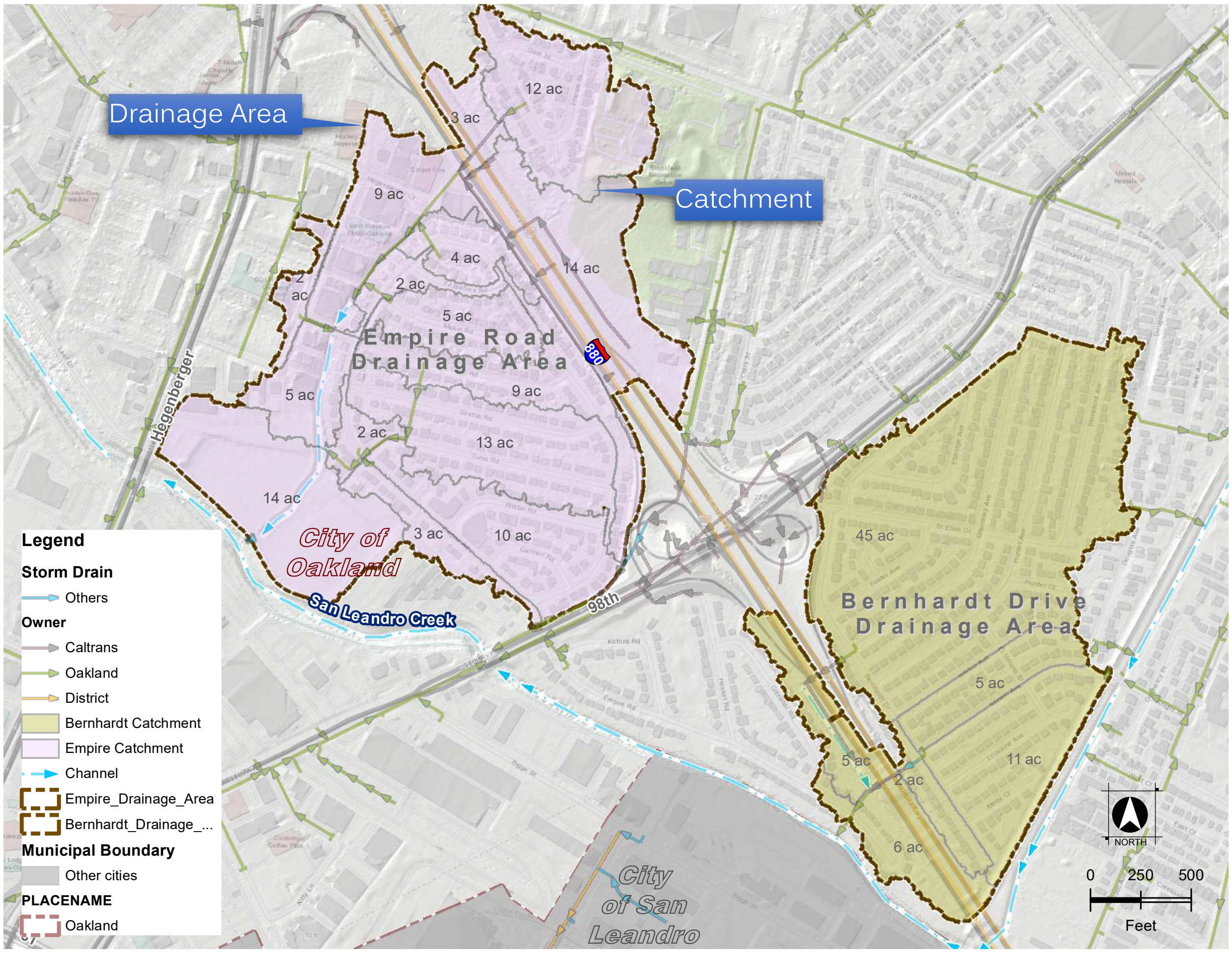


Figure 24 – Catchment Delineation

Besides the catchment boundary, the hydrologic lag time is another parameter that was used to simulate peak runoff of a catchment. Hydrologic lag time is the time between the peak flow and the centroid of rainfall/storm. Lag time can be used as a flood warning for large undeveloped and simple catchments. The factors that affect lag time are the shape, flow path, channel roughness, and slope of a catchment. The Snyder Unit Hydrograph method was used to calculate lag time for this study.

The catchment areas were summed up for each of the drainage systems to calculate the total drainage areas respectively. The calculated drainage areas and lag time for the two drainage systems are shown in **Table 13**.

Table 13 – Drainage Area Summary

Drainage Area	Area (ac)	Lag Time (min)	Runoff Characteristics
Empire Road	105	<30	Flashy
Bernhardt Drive	74	<30	Flashy

LAND USE

Land uses define the imperviousness of catchments and the corresponding catchment runoff. Impervious land is typically covered with concrete, asphalt, or structures. It has no water infiltration capability and results in excess surface runoff. Directly connected imperviousness (DCI) is the effective imperviousness that drains directly to curbs, gutters, and storm drainage facilities without flowing over pervious landscape areas. DCI is typically used in a hydrologic model to simulate impervious runoff. Pervious areas are simulated based on soil types as described in the next section.

Imperviousness is typically measured from aerial or infrared imagery and then validated with model calibration using hydrologic and hydraulic models and recorded gage data. Due to the significant resources required to develop and validate the imperviousness for different land uses, smaller public agencies have been using the parameters already developed by well-established flood control agencies. The Alameda County Flood Control and Water Conservation District, City of San Jose, and (Santa Clara) Valley Water collaborated to calibrate directly connected percent imperviousness for different land uses using recorded data from approximately 70 flow gages within the City of San Jose. The efforts resulted in the values shown in **Table 14** that are currently used for the agencies' design manuals and flood studies. Those values are also consistent with the *Sutherland 2000 Equation*[6] adopted by the *U.S. Environmental Protection Agency* (EPA)[7] for Small MS4 Permit applications.

Based on **Table 14**, the high DCI values of commercial and industrial land uses within a catchment will contribute more runoff than the residential land uses of low DCI values.

[6] Sutherland. 2000. Methods for Estimating Effective Impervious Cover. Article 32 in The Practice of Watershed Protection, Center for Watershed Protection, Ellicott City, MD

[7] https://www3.epa.gov/region1/npdes/stormwater/ma/MADCIA.pdf

Table 14 – Land Use and Percent (%) Imperviousness[8]

Land Use Type	Directly Connected % Imperviousness
Rural Undeveloped Land	0
Urban Undeveloped Land (parks, open space, golf courses)	0
Rural Residential (larger than 1 ac lot)	4
Residential 10,000 – 1 ac lot	15
Residential ¼ ac (8,000 – 10,000 sf lot)	22
Residential 1/8 ac (5,000 – 8,000 sf lot)	24
Residential (3,600 – 5,000 sf lot)	26
Residential (2,700 – 3,600 sf lot)	28
Zero Lot Line Residential & Less than 2,700 sf	35
City house and Multi-Family Dwellings	50
Condominium	60
Industrial	70
Apartment	80
Commercial	85
Freeway	70 – 90
Mobile Home Park	35 – 50
School (large open space)	15 – 20
School (small open space)	40 – 50

The City latest land use map was used and reconciled with the latest aerial imagery to represent the existing condition. See **Figure 25**. The updated land use map was then used in conjunction with the

[8] Alameda County Flood Control and Water Conservation Valley Water Hydrology and Hydraulics Manual, 201 8.

parameters in **Table 14** to intercept catchment boundaries for hydrologic runoff modeling. The land use categories in the figure have been grouped and simplified for presentation purposes.

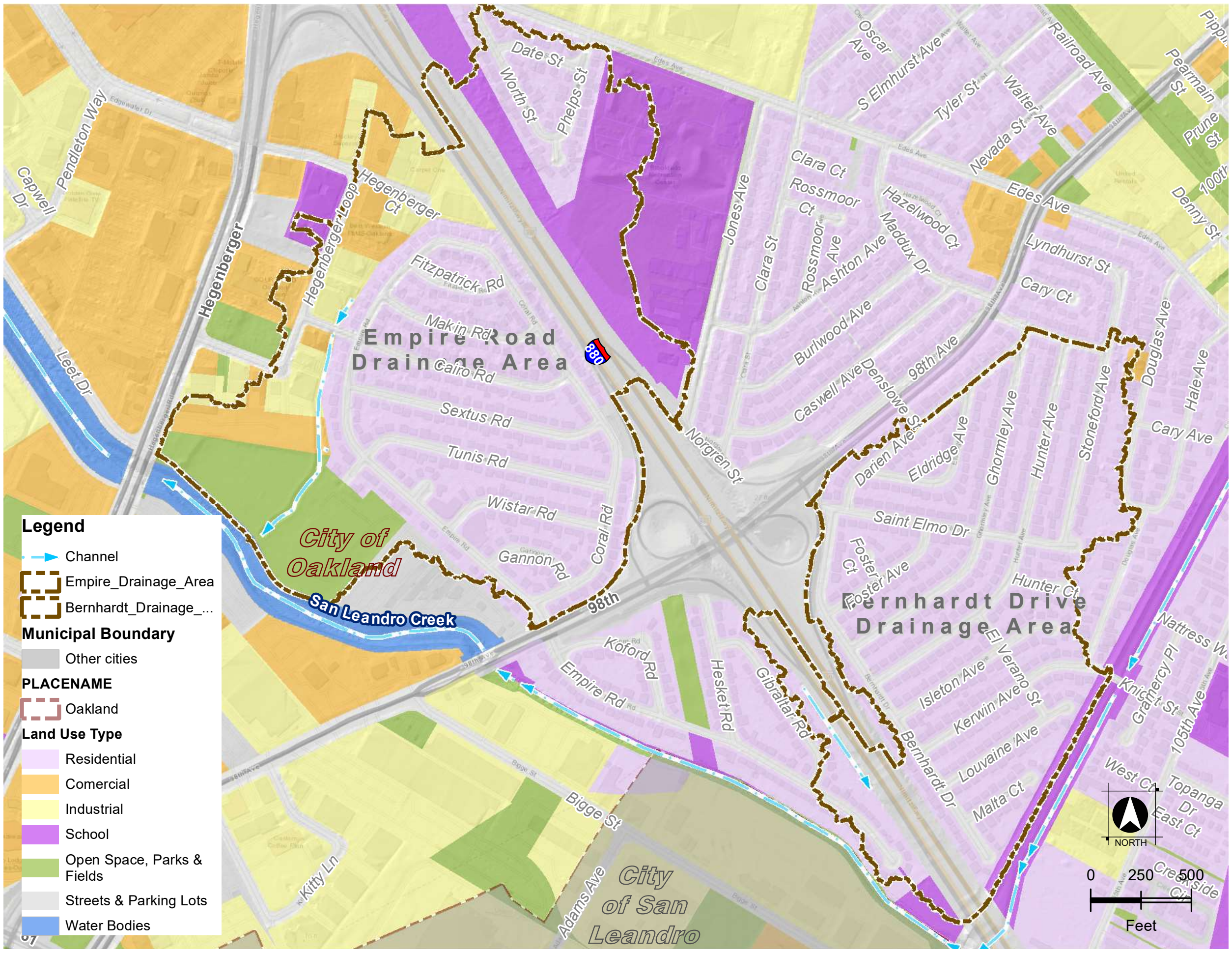


Figure 25 – 2020 Land Use Map

The catchments within the Empire Road drainage area comprise a mixture of residential, industrial, commercial, school, and open space land uses, while the catchments within the Bernhardt Drive drainage area comprise mostly residential land use. Based on the land uses, the Empire Road drainage area has higher corresponding imperviousness than the Bernhardt Drive drainage area and would likely generate more runoff.

SOIL

The hydrologic properties of soils were used to represent the infiltration rates and the corresponding excess surface runoff when storm intensities are greater than the infiltration rates. Different hydrologic properties within a catchment boundary represent different infiltration rates for pervious areas.

The Natural Resources Conservation Service (NRCS) has categorized hydrologic soil properties. There are four categories of Hydrologic Soil Groups – A, B, C, and D – which are based on potential soil infiltration rates when the soil is thoroughly wet. Soil Group A is mostly sand, has the highest infiltration rate, and results in the least amount of surface runoff. Soil Group B is mostly loamy sand, has a relatively high infiltration rate, and results in low runoff. Soil Group C is mostly silty loam, has a relatively low infiltration rate, and thus results in relatively high runoff. Soil Group D is mostly clay and has the lowest infiltration rate and results in the highest surface runoff. The corresponding infiltration rates are listed in **Table 15**.

Table 15 – Initial and Constant Loss Equation Parameters[9]

Hydrologic Soil Group	Soil Type	Initial Infiltration Rate (in/hr)	Constant Infiltration Rate (in/hr)	Sample Picture
A	Sand/ Gravel	1	0.45	
B	Loamy sand	1	0.40	
C	Silty loam	1	0.25	
D	Clay	1	0.09	

[9] *Alameda County Hydrology & Hydraulics Manual*, 2018, Alameda County Flood Control and Water Conservation District (2018 ACPWA H&H)

The Hydrologic Soil Groups for the drainage areas are displayed in **Figure 26** below.

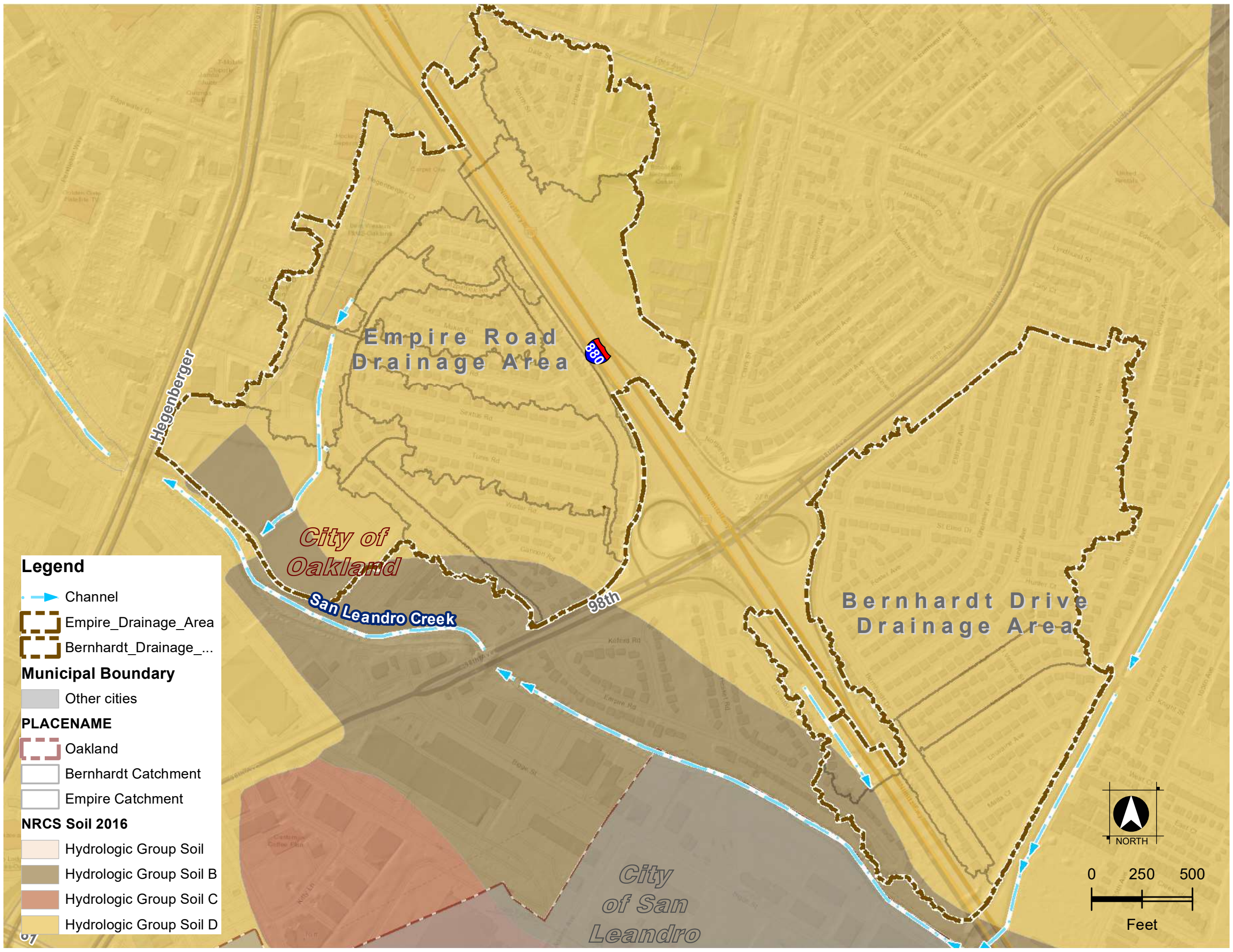


Figure 26 – NRCS Soil Map

The catchments within the Empire Road and Bernhardt Drive drainage areas contain mostly Soil Group D, which generates the highest surface runoff among all the soil groups. The initial and constant infiltration method[10] was used in this study to model the soil infiltration rates for the corresponding hydrologic soil groups and to simulate catchment runoff.

[10] 2018 ACPWA H&H

DESIGN STORM

Design storms are hypothetical storms used to approximate a given probability rainfall event and to simulate catchment runoff with a hydrologic model. A design storm represents a distinct event probability, and when it is accurately designed and transformed into rainfall runoff, the transformation will result in a reasonably accurate estimate of the corresponding probability flow. A design storm has the characteristics of return frequency (e.g., 25-year, 100-year storm), total depth, temporal distribution of the depth, total duration, and a time increment.

The design storm in the *Alameda County Hydrology & Hydraulics Manual*, 2018, Alameda County Flood Control and Water Conservation District (2018 ACPWA H&H) was used for the hydrologic modeling of this study. See **Figure 27** for the 2018 ACPWA H&H design storms in a 15-minute interval and 24-hour duration.

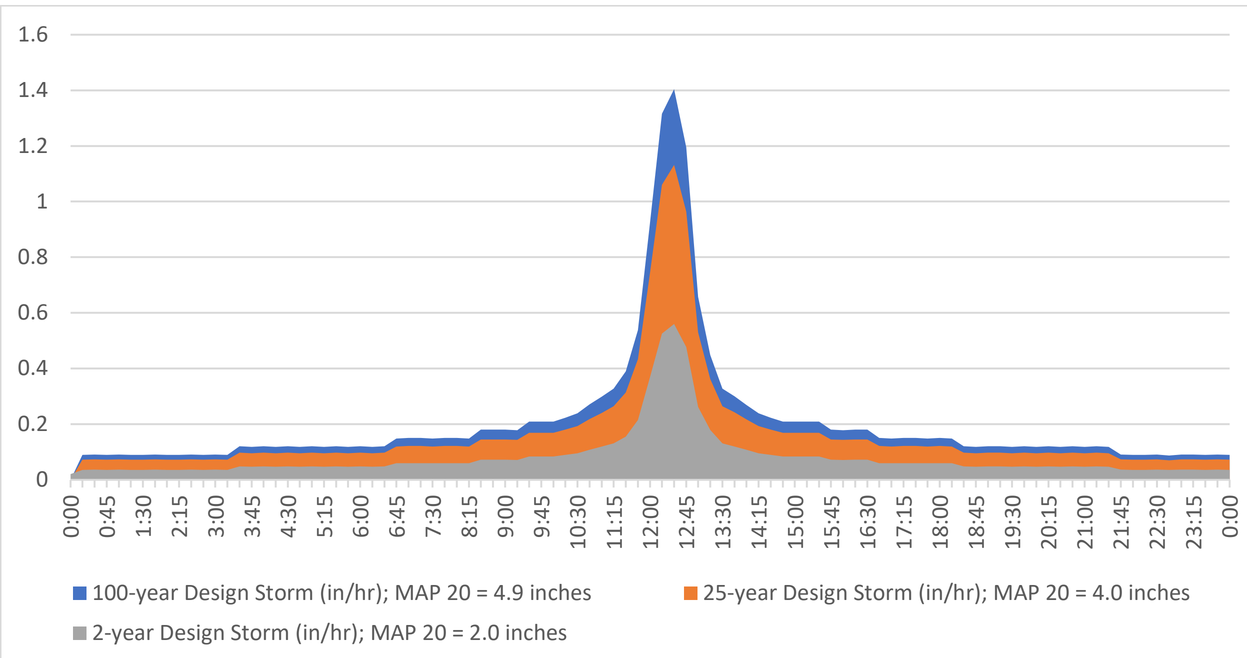


Figure 27 – 2018 ACPWA H&H Design Storms

Rainfall depths vary based on the distance of a catchment area from the ocean, altitude, terrain slopes, and direction of the slopes in relation to the moisture-bearing winds per the United States Geological Survey (USGS). The area with lower altitude typically has lower rainfall depths, whereas the area with higher altitude typically has higher rainfall depths. The rainfall depth is cumulated annually and displayed with lines of equal annual depths which are oftentimes referred to as mean annual precipitation (MAP). See **Figure 28** for the MAP distribution[11] (aka, isoline precipitation maps)

[11] 2018 ACPWA H&H

for the study area. The MAP map was used to identify design storm rainfall depths for different frequencies and durations for catchment areas.

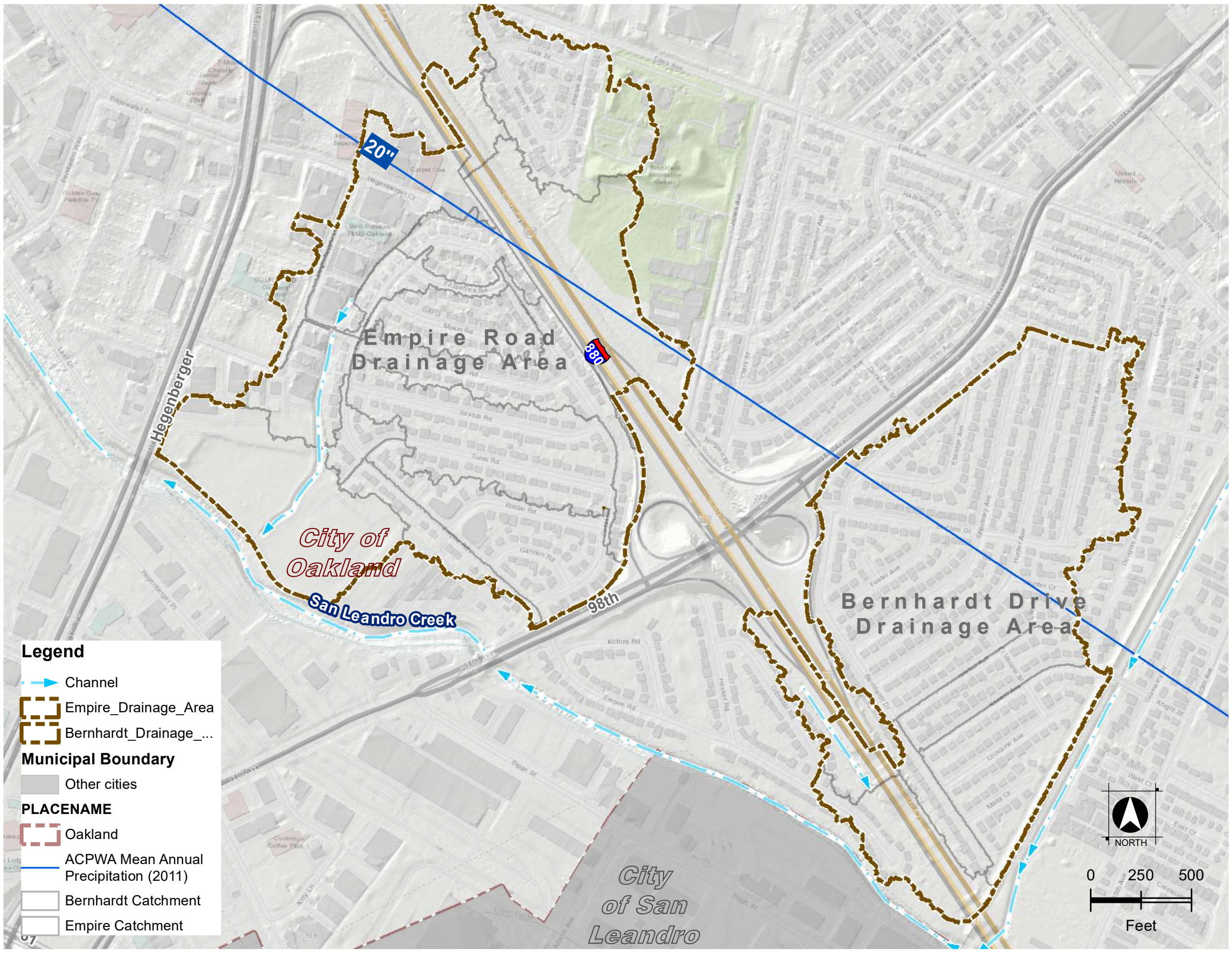


Figure 28 – Mean Annual Precipitation Map

Table 16 – Design Storm Depth

Drainage Area	MAP (inch)	100-year, 24-hour (inch)	25-year, 24-hour (inch)	2-year, 24-hour (inch)
Empire Road	20	4.9	4.0	2.0
Bernhardt Drive	20	4.9	4.0	2.0

Based on **Figure 28,** the MAP for the Empire Road and Bernhardt Drive drainage areas averaged 20 inches per year. The MAP value was then used to extract the corresponding design rainfall depths from the 2018 ACPWA H&H, which are listed in **Table 16**. The 25- and 100-year design storms were selected based on the LOS specified in **Section 3.3**, while the 2-year design storm was selected to assess more frequent flooding issues. Both the Empire Road and Bernhardt Drive drainage systems have greater than 50 acres of drainage areas and include both primary and secondary facility types. To simplify the analysis for this study and to be conservative for improvement development, a 25-year design storm was used for storm drainage facilities sizing.

6.2 Hydraulic Analysis

Storm Drain Systems

Storm drain pipes and street networks work as an integrated system to convey and discharge catchment runoff to the downstream waterbodies such as open channels, detention basins or bays. Storm drain pipes are typically designed to convey flow for design storms between 5- and 25-year frequencies.

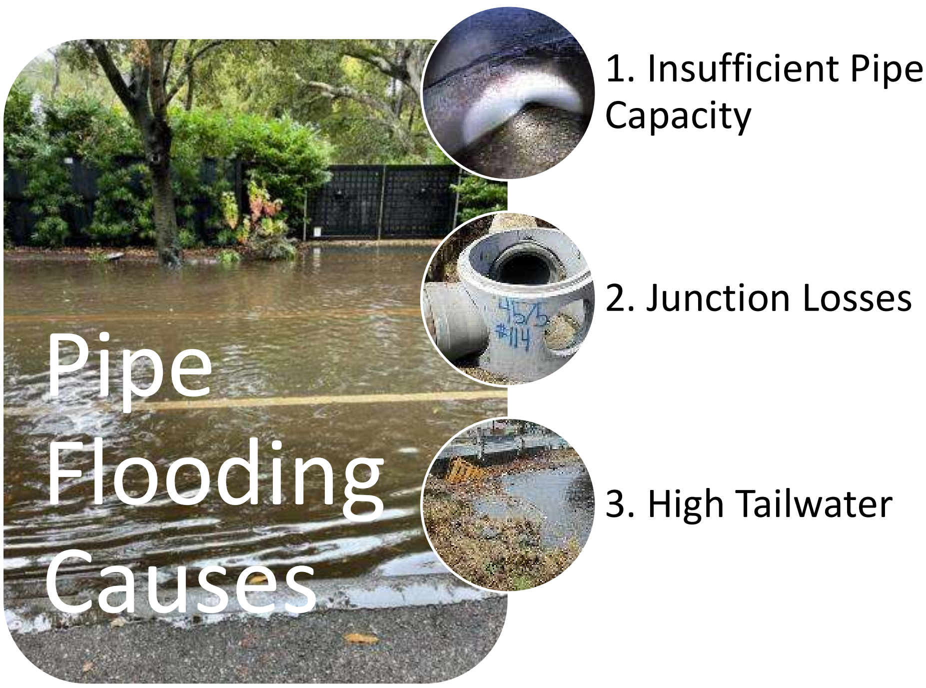


Figure 29 – Storm Drain System Flooding Causes

In drainage pipe systems such as those in Oakland, there are generally three different causes of flooding as shown in **Figure 29**. Deficient storm drain pipes with **insufficient pipe capacity** do not have the ability to convey the adopted design flow. These deficient pipes could cause the hydraulic grade lines (HGL) to surcharge above street systems and flood roadways and properties.

Storm drain systems typically meander along the street alignments and bend at intersections to change directions. Manholes are built to transition the bends; however, they introduce **junction losses** and subsequently increase the HGLs upstream of the manholes. To assess the performance of the storm drain systems, storm drain pipes with junction losses and appropriate pipe roughness (represented in Manning's n values) are modeled and connected to a two-dimensional floodplain model as described in the next section.

Junction losses are calculated as the product of the velocity head ($v^2/2g$) and the junction loss coefficient (K). As shown in **Table 17,** junction losses could contribute to significant changes (Δ) in HGLs as the velocity of the pipe system increases. The manhole with 90° connecting pipes and high velocity can lead to a system that is prone to street flooding as the flow increases or if the system experiences clogging.

Table 17 – K Coefficient for Junction Bend Losses and Sensitivity Analysis

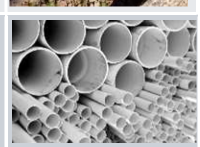
Structure Configuration	K	Sample Picture	HGLΔ Vel.=5 fps	HGLΔ Vel.=10 fps
Manhole straight run, θ = 0°	0.05		0.02	0.08
Manhole θ = 30°	0.15		0.06	0.23
Manhole θ = 45°	0.29		0.11	0.45
Manhole θ = 60°	0.48		0.29	0.75
Manhole θ = 90°	1.02		0.40	1.58

Entrance and exit losses are other factors that contribute to high HGLs. Entrance loss coefficients vary from 0.1 to 0.7[12] based on the inlet pipe entrance shape and geometry. They represent the inefficiency of conveyance at the entrance and create flow turbulence; hence, higher HGLs. The exit loss coefficient is generally 1.0, and it represents the inefficiency of conveyance when the pipe flow transitions to a stagnant body of water or to a water course with flow perpendicular to the pipe flow. There are other minor losses such as drop, expansion and contraction losses. However, those losses are generally not significant; hence, they were not modeled in the hydraulic model for this study.

[12] 2018 ACPWA H&H

Pipe friction loss is another head loss that contributes to a HGL increase due to the energy of water exerting on the pipe wall. The loss is calculated based on the pipe roughness in Manning's n values. The rougher the pipe wall material, the higher the Manning's n value and the resultant HGLs. The Manning's n values for different pipe materials are summarized in **Table 18**.

Table 18 – Pipe Roughness (Manning's n)

Storm Drain Pipe Description	Manning's n	Sample Picture
Reinforced Concrete Pipe		
> 36" Diameter	0.012	
< 36" Diameter	0.014	
Corrugated Metal Pipe		
Annular	0.021	
Helical	0.018	
Reinforced Concrete Box		
Pre-Cast/Cast-In-Place	0.015	
Other Pipe Materials		
Asbestos Cement	0.011	
Polyvinyl Chloride (PVC)	0.009	

The other common flooding cause is **high tailwater conditions** at storm drain system outfalls where high water levels of the downstream channels or basins travel into the storm sewer systems and flood the low ground. This phenomenon is typically modeled and assessed with hydraulically connected storm drain pipes and open channels/basins where timing of the pipe and channel flows are integrated.

Catch basins and lateral connecting pipes are generally not modeled except at the locations where there are observed or recorded flooding issues. This is because those facilities are generally oversized based on local minimum design standards. This approach simplifies the modeling efforts and focus on the problematic locations.

STREETS

In larger storms, stormwater flow starts to exceed storm drain pipe capacity and overflow into the street networks. The overflow contained in the street within the well-defined curb and gutter systems could convey significant flow based on the longitudinal slope and width of the street. For example, a 36-foot-wide street can convey between 42 cfs, at a longitudinal slope of 2%, and 118 cfs, at a longitudinal slope of 15%[13], before overtopping the top of curb. An integrated pipe and street system can typically convey up to 100-year design flow without flooding adjacent properties on the street.

OPEN CHANNELS

Open channels collect stormwater discharges from storm drain pipe systems and convey the flow to a large water body such as the ocean, bays, and lakes. When the stormwater flow exceeds the channel capacity, the flow will overtop the channel overbanks and flood the surrounding areas. The capacity of a channel is defined by its geometry, material, and vegetation coverage and types. Channel materials and vegetation coverage and types are calculated based on Manning's n values in **Table 19.** The higher the Manning's n value, the higher the resultant HGL in the channel.

[13] https://eng2.lacity.org/techdocs/stormdr/mafs.pdf

Table 19 – Channel Roughness (Manning's n[14])

Channel Description	Manning's n	Sample Picture
Large Trees, Large Woody Bushes	0.120	
Small Trees, Small Woody Bushes	0.085	
Small Woody Bushes, Dense Vegetation	0.065	
Between Dense Vegetation and Clean Earth	0.045	
Between Dense Vegetation and Clean Earth	0.035	
Uniform, Clean, Little Vegetation	0.025	
Concrete	0.015	

6.3 Simulation Results

6.3.1 Runoff

The hydrologic model developed in **Section 6.1** generated catchment runoff that was routed through the drainage facilities modeled in the hydraulic model in **Section 6.2**. The catchment peak runoff totals within the Empire Road and Bernhardt Drive drainage areas were divided by the corresponding total catchment areas to develop flow-per-acre ratios for the simulated design storms

[14] Combination of Wood Rodger's calibration experience in the Bay Area, and Open-channel Hydraulics, Ven Te Chow, 1959

as shown in **Table 20**. The ratio can be used to estimate design flow for drainage facility improvement design once the cumulative area is determined.

Table 20 – Catchment Runoff Summary

Drainage Area	Average MAP (in)	% Impervious	Predominant Soil Group	2-Year Flow (cfs)/ catchment (ac)	25-Year Flow (cfs)/ catchment (ac)	100-Year Flow (cfs)/ catchment (ac)
Empire Road	20	39	D	0.4	1.0	1.3
Bernhardt Drive	20	47	D	0.4	1.0	1.3

With the same average MAP value, soil group, and a marginally different percent of imperviousness, both the Empire Road and Bernhardt Drive drainage areas have the same flow-per-acre ratios for the 2-, 25-, and 100-year design storms, respectively.

6.3.2 Floodplain

Floodplains were generated in the hydraulic model in **Section 6.2** once the drainage facility conveyance capacity was exceeded. When the drainage facility capacity was exceeded, stormwater flow surcharged to street levels along storm drain pipes and overtopped channel banks along open channels. The resultant floodplain typically indicates deficient drainage facilities.

The resultant floodplains were used to determine the flood risk in **Section 7** and the improvement projects in **Section 8.1**. Two-year floodplains were simulated to assess the drainage facilities that were deficient during frequent storm events.

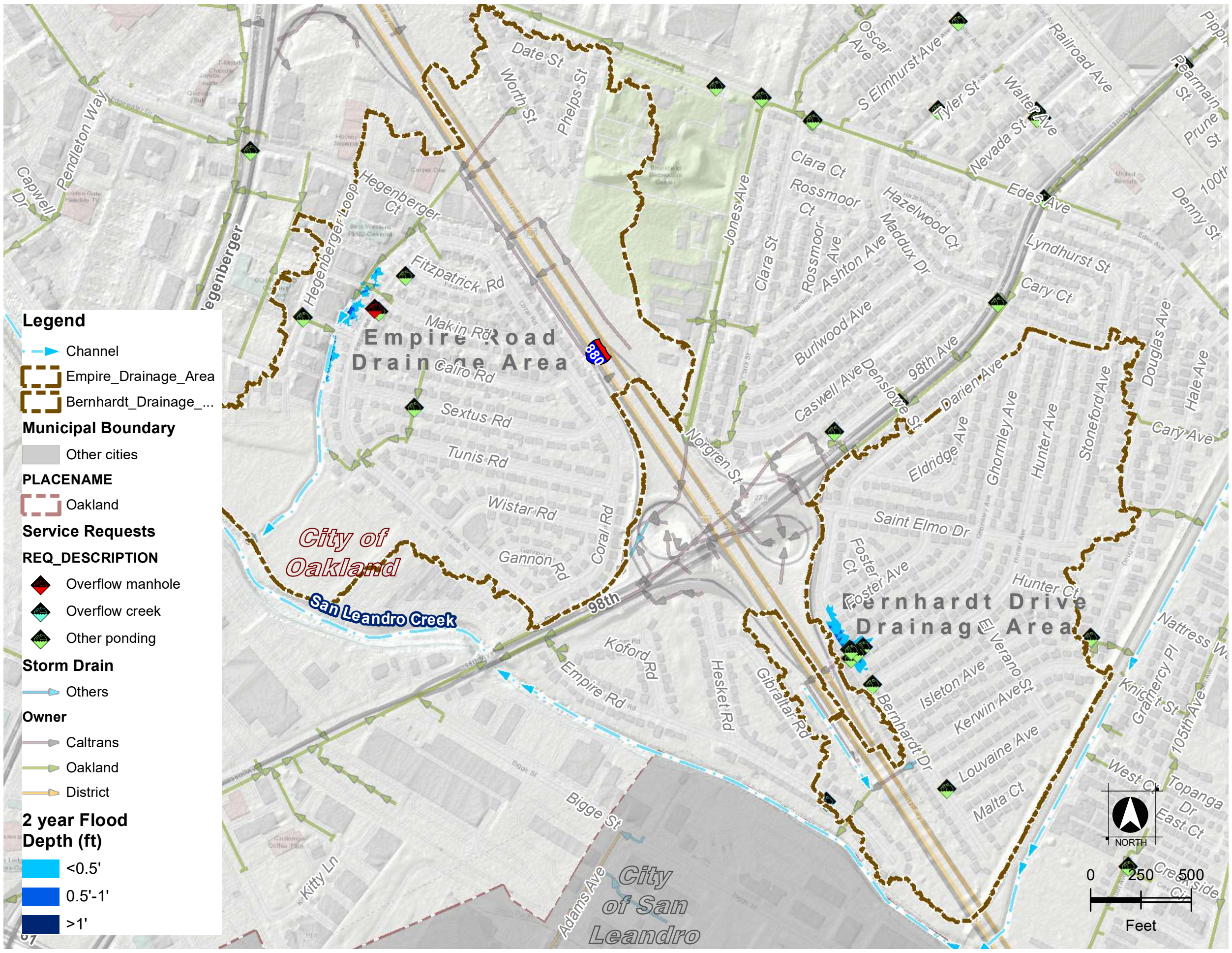


Figure 30 – Simulated 2-year Floodplain

Based on the floodplain results in **Figure 30**, the Empire Road open channel shows shallow overbank flooding (less than 0.5 feet) near Cairo Road and Makin Road. In the Bernhardt Drive drainage area, flooding up to one foot in depth was found mostly within the street ROW at the intersection of Bernhardt Drive and Ghormley Avenue. The simulated flooding locations are located around the flooding incidents recorded in the citizens' service requests discussed in **Section 2.3**. The floodplain results reflect an accurate estimation of the storm drainage facility capacity and deficiency.

Twenty-five-year floodplains were simulated to assess the drainage facilities' deficiency and to develop improvements consistent with the City's LOS as described in **Section 3.3**.

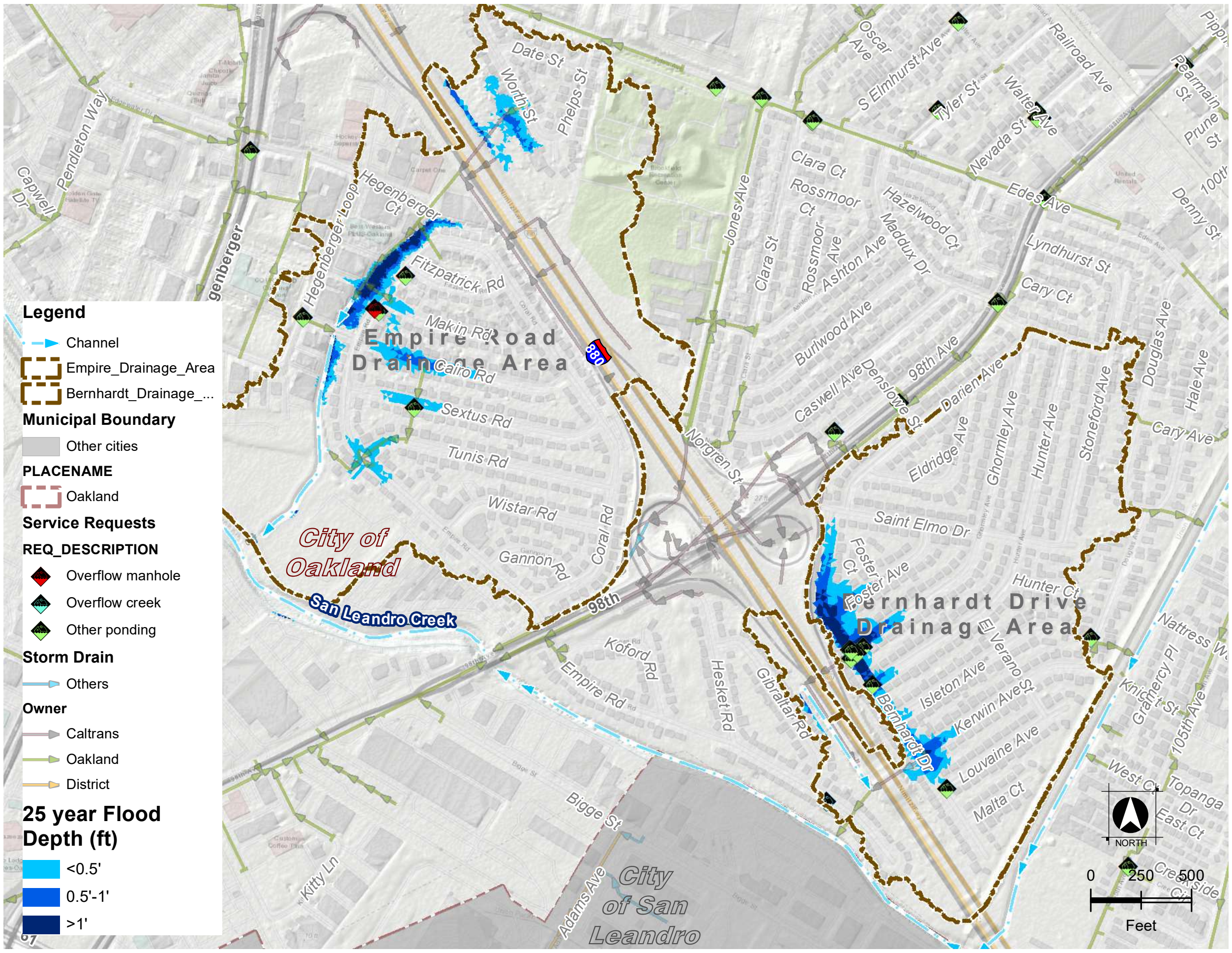


Figure 31 – Simulated 25-year Floodplain

In the 25-year storm simulation, the locations flooded in the 2-year storm event experienced wider and deeper floodplains. Other adjacent storm drain pipe systems also experienced flooding consistent with the flooding incidents recorded by the citizens' service requests. The flooding along the storm drain pipe system between Cairo Road and Empire Road coincided with the service requests in the Empire Road drainage area, while the flooding at the intersection of Kerwin Avenue and Bernhardt Drive coincided with the service requests in the Bernhardt Drive drainage area.

The flooded area to the east of I-880 and at the upstream end of the Empire Road drainage system is an open space. Flooding incidents at an unoccupied open space likely would not trigger any service request.

One-hundred-year floodplains were simulated to assess the drainage facilities' deficiencies and to develop improvements consistent with the City's LOS as described in **Section 3.3**.

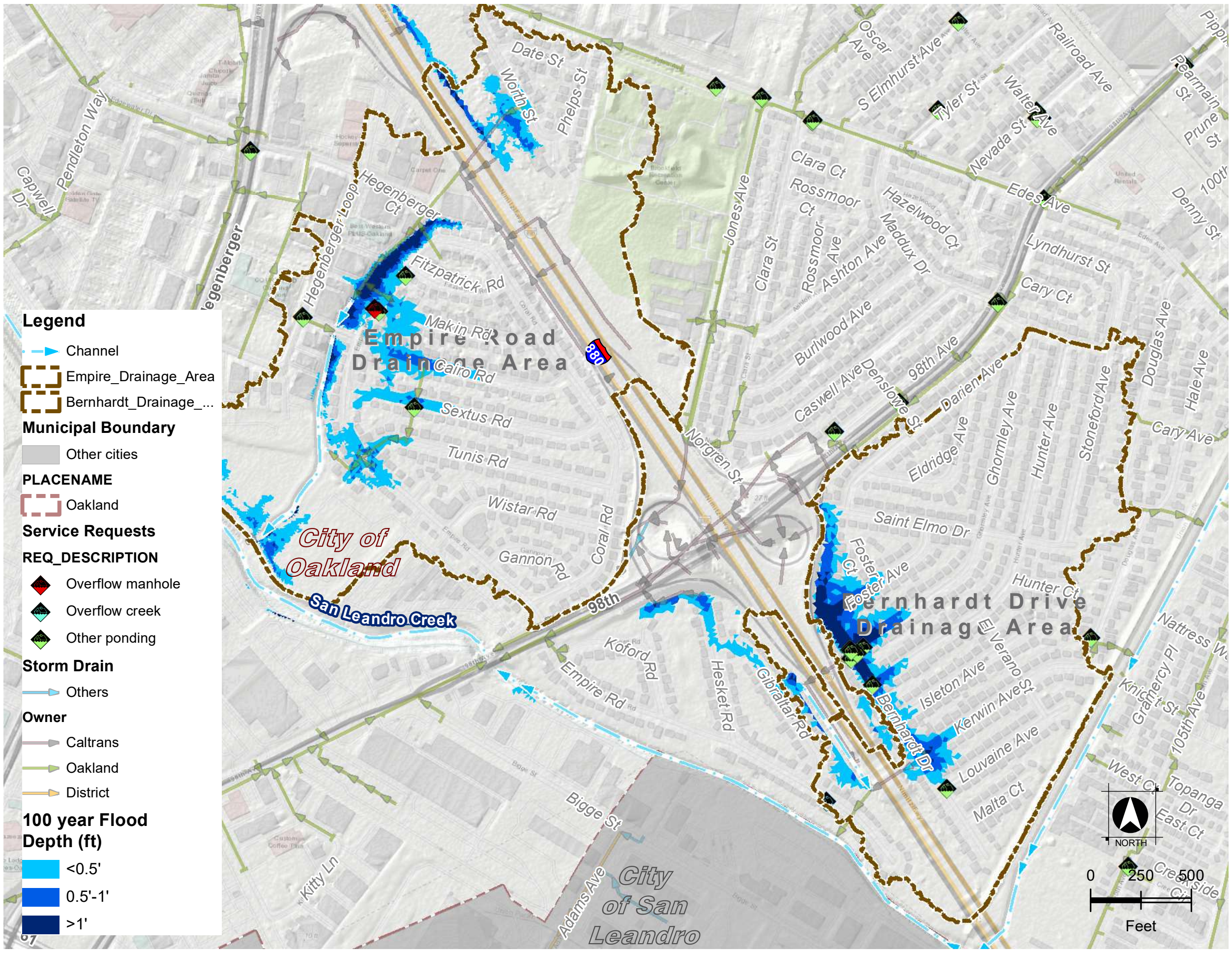


Figure 32 – Simulated 100-year 2D Floodplain

In the 100-year storm simulation, the locations that flooded in the 25-year storm event experienced wider and deeper floodplains. The open space at the confluence of the Empire Road open channel and San Leandro Creek started to flood because of the high tailwater condition in San Leandro Creek. The Bernhardt Drive storm drain pipes to the west of I-880 also experienced high tailwater conditions in San Leandro Creek and started to flood in the 100-year storm.

Table 21 summarizes the total catchment runoff calculated from the product of the flow-per-acre ratio (**Section 6.3.1**) and drainage areas, existing peak flow at the outfall of each drainage system, and the resultant floodplain areas.

Table 21 – Deficient Storm Drain System Summary

Drainage Area	Design Storm (year)	Total Catchment Runoff (cfs)	Outfall Peak Flow (cfs)	Floodplain (ac)
Empire Road	2	42	36	0.4
	25	105	63	5.1
	100	137	70	10.2
Bernhardt Drive	2	30	22	0.5
	25	74	35	4.4
	100	96	38	7.8

The total catchment runoff indicates all the runoff collected within the drainage areas before draining into storm drainage facilities. The runoff provides a good estimate of the size of drainage facility improvements and the flow the improvements need to convey to mitigate flooding.

The outfall peak flow reflects the capacity of the existing storm drainage facilities and the resultant floodplains. When the outfall peak flow is significantly less than the total catchment runoff, the runoff will exceed the storm drainage facility capacity, surcharge above streets, and result in excessive floodplains.

6.4 Capacity Deficiencies

The conveyance capacity deficiencies determined with the hydraulic model results in **Section 6.3** were used to develop the improvement alternative analysis in **Section 8.1** of this report. The deficiencies for storm drain pipes, streets, and open channels were identified as described in detail in the following paragraphs.

Deficient storm drain pipes are typically identified using the floodplains and hydraulic grade lines (HGL) relative to the ground elevation. Storm drain pipes with steeper HGL slopes than the slopes of the pipes and with extensive and deep floodplains were identified as deficient in this study. The pipes that contributed to the most floodplain areas are the most deficient and given a higher priority for improvements.

Deficient storm drain outfalls often have high backwater in the downstream channel and low ground elevations upstream of the outfalls. When an existing outfall is not equipped with a flap gate, the high water level in the channel would push water into the storm drain system and flood the low ground. In systems with flap gates, often the flap gate will stay closed for too long because of the high-water levels in the channel. The floodwater in the storm drain system therefore has no way to discharge and subsequently surcharges above the low ground.

Deficient street networks are defined based on the capacity to convey excess storm drain flow that surcharges above streets. A street is considered deficient when the floodwater inundates beyond the street right-of-way.

Deficient channels are identified when the floodwater overtops the channel overbanks and floods surrounding properties.

The deficient drainage facilities are shown in **Figure 33** below.

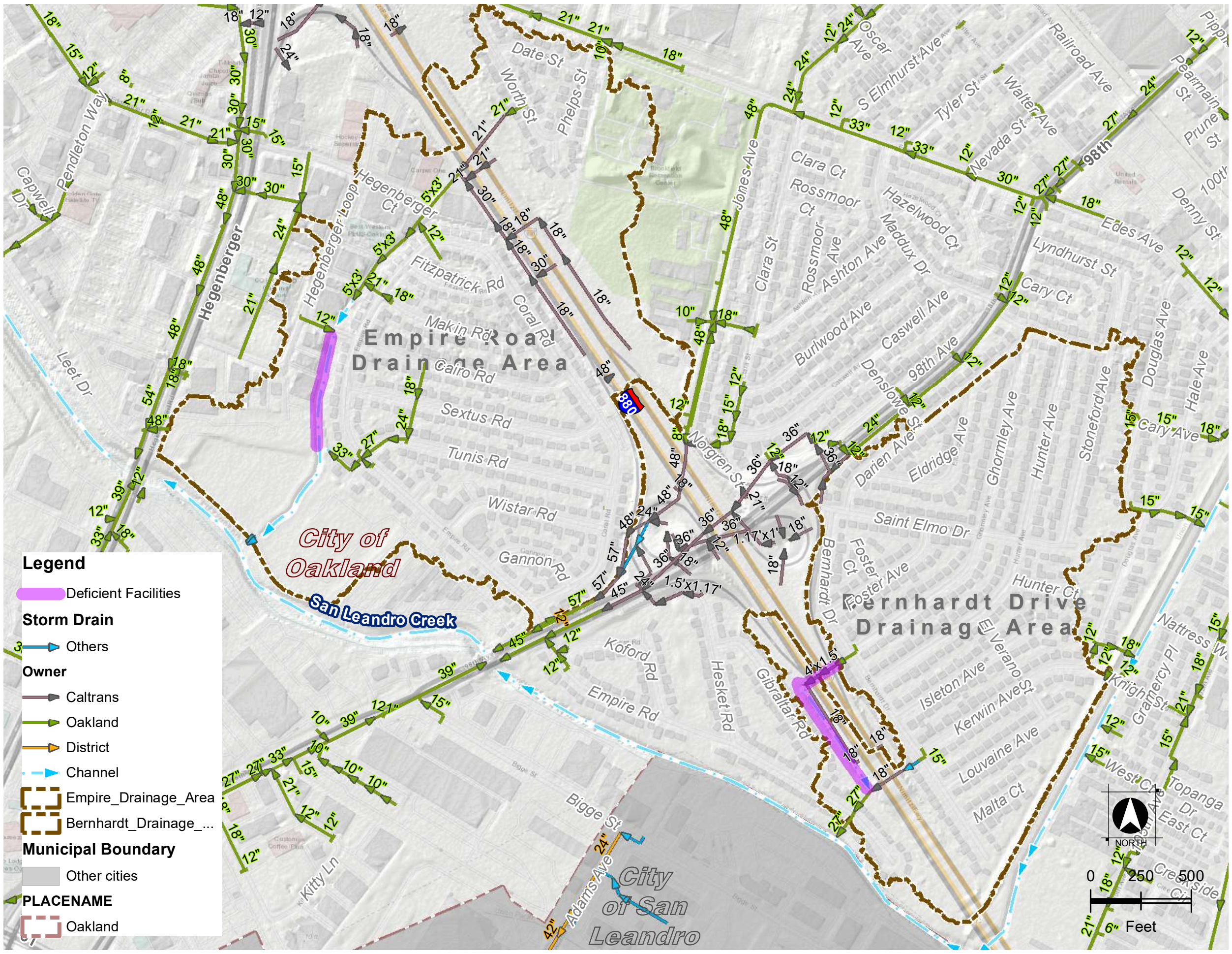


Figure 33 – Drainage Facilities Deficiency Map

The open channel (purple line in **Figure 33**) between Cairo Road and Tunis Road in the Empire Road drainage system is narrow, shallow, and overgrown with vegetation, as discussed in **Section 4.4.1**. The condition resulted in high water levels and, consequently, flooding along the channel and the storm drain pipe systems discharging into the channel. The deficient facilities highlighted in the Empire Road drainage system have less than a 2-year capacity and the other facilities have capacities between 2- and 25-year based on the floodplain maps in **Section 6.3.2.**

In the Bernhardt Drive drainage system, the open channel (purple line in **Figure 33**) west of I-880 is narrow, shallow, and overgrown with vegetation as discussed in **Section 4.4.2**, and the upstream pipe crossing I-880 is undersized as observed in the resultant floodplains in **Section 6.3.2**. The deficiencies in the open channel resulted in high water levels, and the deficiencies in the pipe restricted the stormwater from discharging across I-880. The combined deficiencies in both facilities resulted in extensive flooding east of I-880 along Bernhardt Drive. The deficient facilities highlighted in the Bernhardt Drive drainage system have less than a 2-year capacity and the other facilities have capacities between 2- and 25-year based on the floodplain maps in **Section 6.3.2.**

7 FLOOD RISK

Flood risks are quantified in this drainage study for storm drain system deficiency prioritization. Deficient storm drain systems with the highest calculated flood risk will be given the highest priority in the City's capital improvement program (CIP). This formal risk approach provides the following benefits for the City's decision-making:

1. To communicate the quantitative risk of not improving a deficient system to community stakeholders;
2. To develop the most cost-efficient capital improvement projects by allocating resources to the system with the highest flood risk.

This flood risk approach quantifies the likelihood and consequence of failure as shown in the formula in **Figure 34** below. The flood risks are quantified as annualized building damages and business interruption using FEMA's *Hazus* program. This approach differs from other flood studies, which typically use flooding extent only to prioritize CIPs.

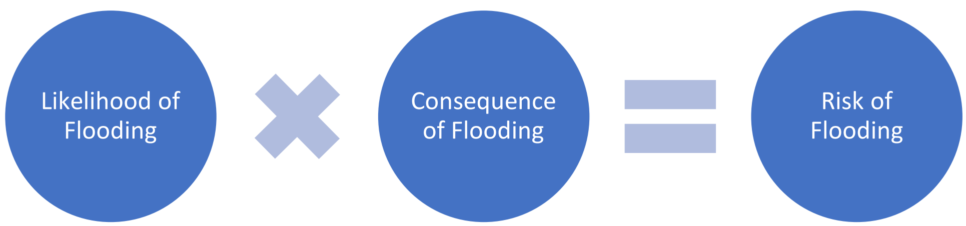


Figure 34 – Flood Risk Formula

The following sub sections describe the process of calculating the flood risk for the capacity-deficient storm drain systems identified in **Section 6.4.** The condition deficiencies identified in **Section 5** are typically built into the City's maintenance and rehabilitation activities and not included in this flood risk approach or the City's capital improvement plan. This is because the costs of maintenance and rehabilitation are relatively small compared to capital improvement projects, and they are typically included in the existing City's financial planning.

Likelihood of Flooding

The likelihood of flooding is determined based on storm drain facility capacity exceedance - when the design flow in storm drain facilities exceeds the capacity and floods above ground level. The storm drain facility capacity exceedance is defined in terms of percent annual probability. Facilities that cause flooding in a 10-year design storm simulation will have a 10% annual likelihood of capacity exceedance, while the facilities that cause flooding in a 100-year design storm simulation will have a 1% annual likelihood of capacity exceedance.

Consequence of Flooding

Wood Rodgers has estimated the consequences of failure based on the two-dimensional hydraulic model floodplain results developed in **Section 6.3** and the damages developed using the FEMA *Hazus* program in this section. The *Hazus* program is a nationally applicable standardized methodology that contains models to estimate the direct physical damages to buildings and contents, the exposure of essential facilities to flooding, the consequential direct economic losses, and the number of people displaced by evacuation and inundation. The damages to the building and its contents are estimated with the repair or replacement costs based on flood insurance data and 2010 Census Bureau data. The business interruption losses are the losses associated with inability to operate a business and temporary relocation costs during the flood. The losses include income, wages, relocation costs and rental income developed based on 2010 Census Bureau data. Because of the use of regional data and relatively old Census Bureau data to estimate the consequences of flooding, the calculated value or consequence is considered conservative or lower than the actual consequence.

The program was used to quantify the consequence of flooding for each major deficient system in this study. The consequences are tabulated for 2-, 25-, and 100-year design storms in **Table 22**.

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Flood Risk

The likelihood of flooding was multiplied by the consequence of flooding to develop a flood risk for each deficient system and design storm. The flood risks from all the design storms were then averaged to an annualized risk based on the equation in the FEMA reference (see footnote) for deficiency prioritization as shown in **Table 22**. The equation assigned a higher risk to the flooding with a more frequent design storm and a lower risk to the flooding with a less frequent design storm. The annualized risk represents the average risk quantified in annualized damages.

Table 22 – Likelihood (%), Consequence ($), and Risk ($/year) of Flooding

Deficient System	Likelihood (%)	*Design Storm (year)*	Consequence ($)	Annualized Flood Risk[15] ($/year)
Empire Road	50	2	50,000	179,600
	4	25	1,070,000	
	1	100	2,210,000	
Bernhardt Drive	50	2	90,000	197,000
	4	25	1,030,000	
	1	100	1,650,000	

Based on the comparison in **Table 22**, the Bernhardt Drive drainage system has a higher annualized flood risk than the Empire Road drainage system. The difference is mainly due to more frequent flooding and a higher consequence value in the 2-year design storm at the Bernhardt Drive drainage system. The flood risks for the 25- and 100-year design storms for both drainage systems are similar. The annualized risks were used in conjunction with the capital improvement costs in **Section 8** to identify the cost effectiveness and prioritization for each project.

[15] Eq. 14-15, https://www.fema.gov/sites/default/files/2020-09/fema_hazus_flood-model_technical-manual_2.1.pdf

8 CAPITAL IMPROVEMENT PLAN

A capital improvement plan (CIP) for a storm drainage study is defined as major and non-recurring public expenditures to maintain and improve the level of service of drainage facilities. The plan is a community planning and financial management tool used to coordinate the location, schedule, and financing of capital improvements over a long-term planned schedule. A CIP requires project justification quantified in benefits or the risk of not mitigating the risk, detailed capital costs developed based on the latest construction climate, a prioritized project list developed with a defensible and quantifiable approach, a financial plan developed based on the agency's financial conditions, and a realistic implementation schedule.

For this study, the project justification to improve existing deficient drainage systems is quantified in **Section 7** using a formal risk model. The deficit systems were then analyzed in this sub section to identify and develop improvement alternatives. A detailed life cycle cost analysis was developed to identify the cost to construct and maintain the selected improvement alternatives within the useful life of the improvements. The flood risk of the deficient system and the life cycle cost for the improvements were then used to further prioritize projects based on cost effectiveness. A financial plan will be developed (in the City Drainage Master Plan) based on the engineering information developed prior and an implementation schedule.

8.1 Capacity Improvements and Costs

Improvement alternatives and the associated capital costs were developed to mitigate the drainage facilities capacity deficiencies identified in **Section 6.4** and to lower the flood risk calculated in **Section 7**. The improvements were developed based on the City's level of service documented in **Section 3.3**. The improvement types used for this analysis included different combinations of pipe upsizing, diversion, detention basin storage, and flap gates.

The capital costs (see **Appendix B**) developed for this drainage study were based on contractor bids for similar projects to capture major elements for improvements and to minimize contingencies. The contingencies built into the capital cost were to account for incidental construction activities and other design details not captured in high-level improvement alternatives.

The improvement alternatives developed in this section are to provide high-level conceptual improvements and project costs for CIP implementation. A detailed engineering feasibility analysis would not be performed until during project construction document development. Utility conflicts, value engineering (e.g. parallel pipe or demolish and replace), construction methods, maintenance requirements, environmental permitting, geotechnical requirements, access, and other investigations will be addressed once a project is selected for CIP implementation which is outside the intended scope of this drainage study.

8.1.1 Empire Road Drainage System Improvement Alternatives

To mitigate the capacity deficiency identified in **Section 6.4**, four improvement alternatives were developed, as shown in **Figure 35**.

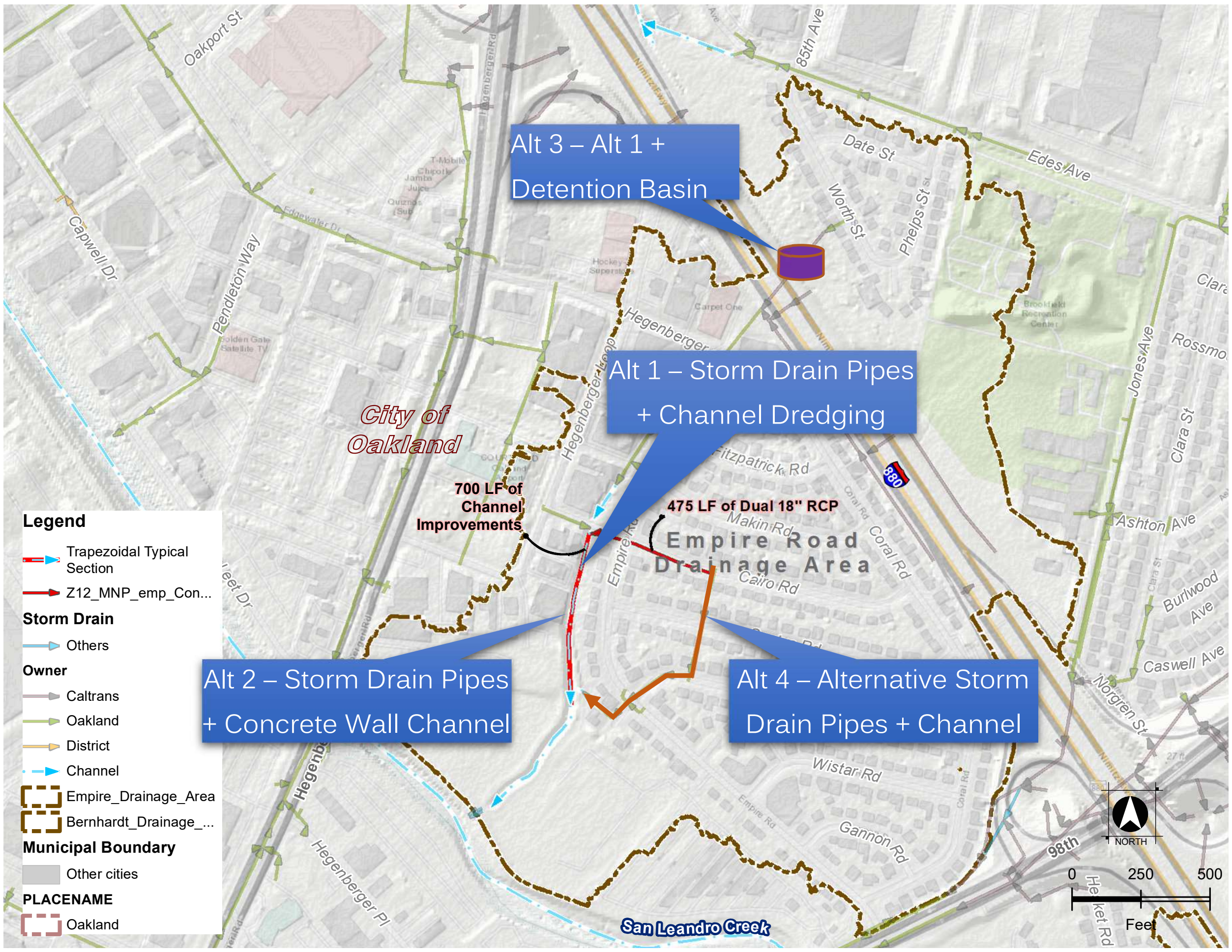


Figure 35 – Empire Road Improvement Alternatives

Alternative 1 (Alt 1) includes a bypass dual 18" storm drain pipe system along Cairo Road that works with the existing storm drain system to collect and divert flows westward into the channel. The alternative also includes dredging 700 feet of the channel south of Cairo Road to form a deeper trapezoidal channel. This alternative, however, requires routine vegetation clearing to maintain the channel capacity. Alt 1 was determined to be the most cost-effective and engineering feasible.

Alternative 2 (Alt 2) is similar to Alt 1, except that it replaces the trapezoidal channel with a rectangular channel with sheet pile side walls and an earthen channel bottom. This alternative assumes an unmaintained channel bottom overgrown with vegetation and yet maintains the required capacity for flood control. It reduces the need for channel maintenance. This alternative was not recommended because of the higher capital cost compared with Alt 1 as shown in **Table 23**.

Alternative 3 (Alt 3) includes all the improvements in Alt 1 and a detention basin at the upstream end of the system, west of I-880 and on a PG&E parcel. The basin required an acre of area to detain and reduce the flows from upstream catchments. This alternative was not selected because the basin was not effective in reducing the peak flow downstream, and because of the difficulty and cost in acquiring the PG&E easement for the construction of the basin.

Alternative 4 (Alt 4) upsizes the existing storm drain system from Cairo Road to Empire Road and improves the channel included in Alt 1. This alternative was not recommended because it was not effective in mitigating the 25-year flooding.

The resultant flows and floodplains in the existing and proposed (post improvements) conditions are shown in **Table 23** to illustrate the effectiveness of the two most effective alternatives (Alt 1 and Alt 2).

Table 23 – Empire Road Existing and Proposed 25-year Hydraulic Results

Improvements	Existing Floodplain (ac)	Existing Peak Outflow (cfs)	Proposed Floodplain (ac)	Proposed Peak Outflow (cfs)
Empire Road - Alt 1	5.09	60	1.05	82
Empire Road - Alt 2	5.09	60	1.64	82

Alt 1 is more effective than Alt 2 in mitigating the existing floodplain. Alt 1 reduced the existing floodplain area from 5.09 to 1.05 areas. The remaining floodplain areas in the proposed condition (post-improvement) are mainly shallow flooding contained within street ROW. The proposed improvements reduce the floodplain area by increasing the drainage facility capacity from 60 cfs to 82 cfs.

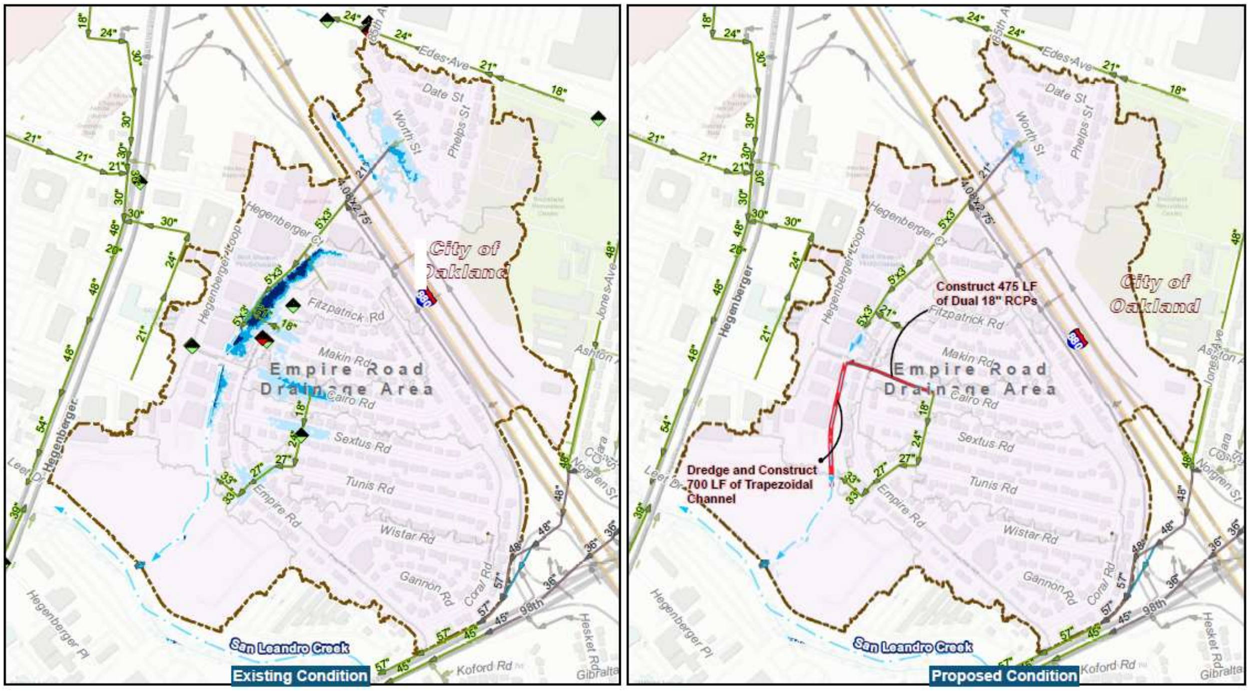
The improvement capital costs for the two alternatives were then calculated and summarized in **Table 24.** The Alt 2 capital cost was significantly higher than that of Alt 1, mainly due to the cost for sheet pile wall installation along the channel. The recommendations for the improvement alternatives discussed previously were also listed in the table.

Table 24 – Empire Road Capital Improvements

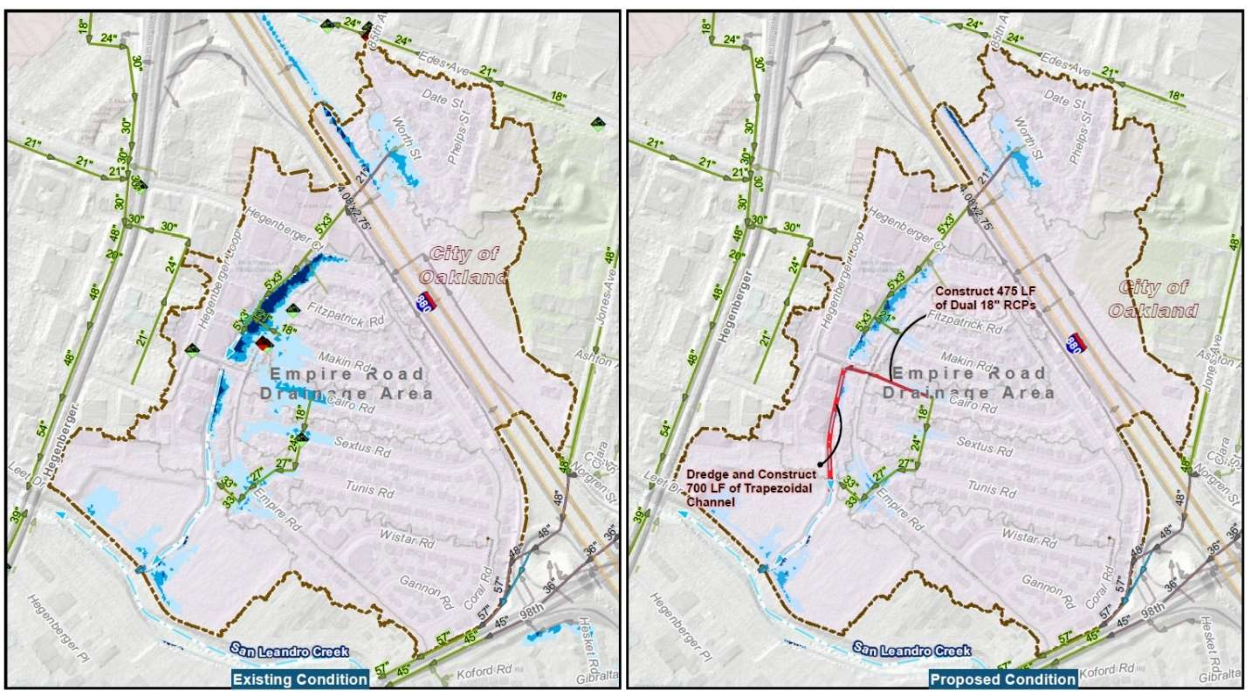
Improvements	Proposed Improvements	Capital Costs ($)	Total Project Capital Cost ($)	Recommendation
Empire Road - Alt 1	475 LF of Dual 18" RCPs	$ 691,000	$ 1,409,000	Recommended.
	700 LF of Trapezoidal Channel Dredging	$ 718,000		
Empire Road - Alt 2	475 LF of Dual 18" RCPs	$ 691,000	$ 4,199,000	Not recommended due to high cost.
	700 LF of Rectangular Channel Dredging+ Sheet Pile Walls	$ 3,508,000		

The detailed capital costs developed and summarized in **Table 24** are presented in **Appendix B. Exhibits C1 and C2** show the 25- and 100-year floodplains respectively for the Empire Road Alternative 1 improvements. The exhibits include:

- simulated existing and proposed (post improvements) floodplains,
- the accuracy of the simulated existing floodplain compared to the citizens' service requests,
- the effectiveness of the proposed improvements in reducing the existing floodplains,
- the existing flood risk, and
- the capital costs and extents of the improvements.



See **Exhibit C1 – Empire Road 25-year Alternative 1 Improvement Map** for the complete exhibit.



See **Exhibit C2 – Empire Road 100-year Alternative 1 Improvement Map** for the complete exhibit.

The proposed improvements at the Empire Road drainage system mitigated and removed most of the 25-year floodplain west of I-880 and effectively reduced approximately half of the 25-year floodplain east of I-880. In the 100-year simulation, the improvements mitigated the flooding to less than one foot of depth and be mostly contained within street ROW. The open channel improvements, once they are in place, will need regular maintenance to maintain their optimal conveyance capacity and performance.

The proposed improvements were developed to mitigate riverine floodplains and would not remove the FEMA regulatory floodplain, which was caused by 100-year coastal flooding. As shown in **Figure 7**, the FEMA SFHA in the Empire Road drainage area was mapped based on 100-year coastal flooding, which does not coincide with the 25- and 100-year riverine flooding developed for this study. The District typically proposes improvements to mitigate coastal flooding.

8.1.2 Bernhardt Drive Drainage System Improvement Alternatives

To mitigate the capacity deficiency identified in **Section 7**, three improvement alternatives were developed as shown in **Figure 36**.

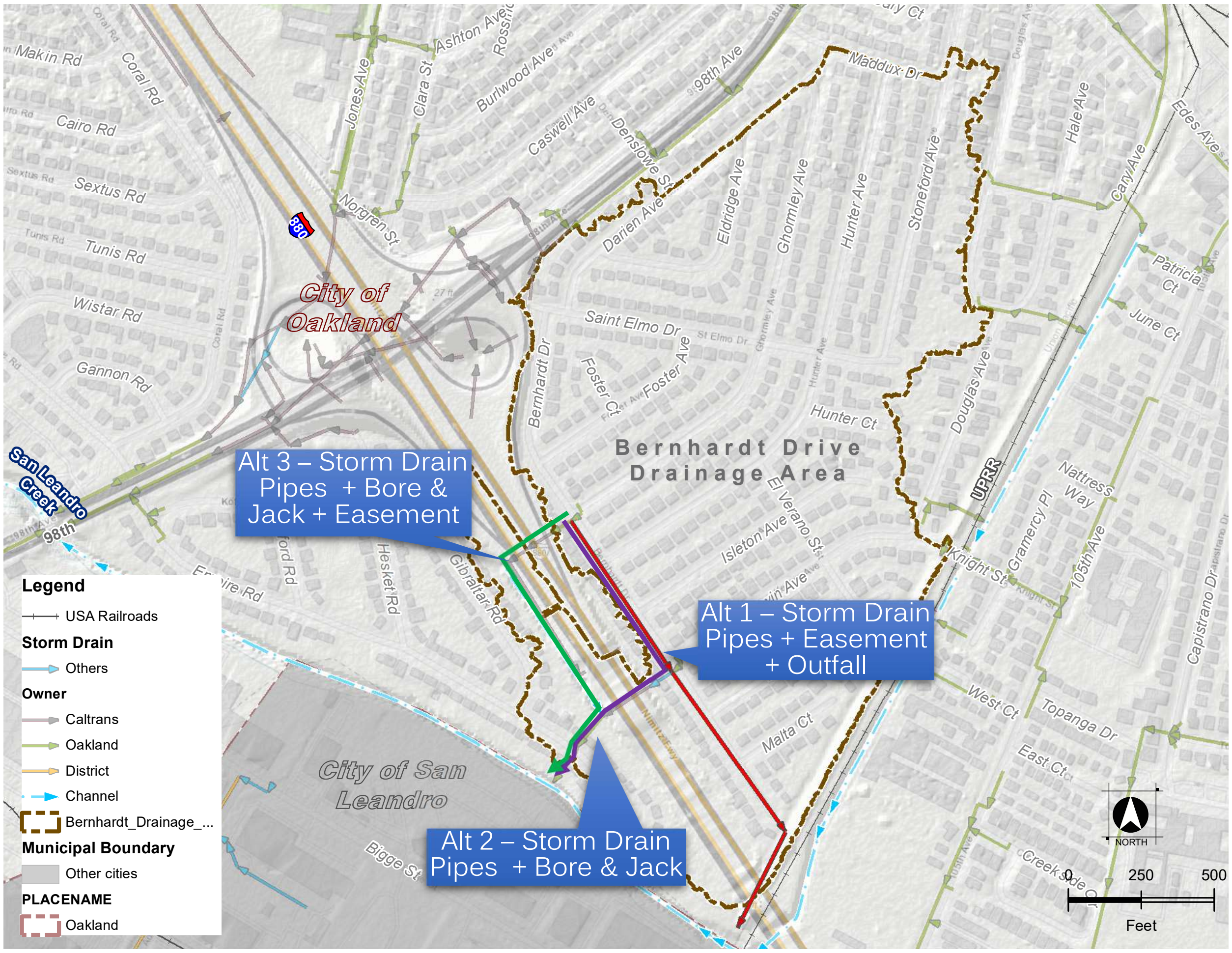


Figure 36 - Bernhardt Drive Improvement Alternatives

Alternative 1 (Alt 1) includes a bypass pipe system (1,660 feet of 6'x4' RCBs) from Ghormley Avenue to the Union Pacific Railroad (UPRR) along Bernhardt Drive and then along the UPRR easement southerly, which eventually discharges into San Leandro Creek through a new outfall structure. This alternative travels under the I-880 overpass (no bore and jack) along the UPRR easement. The City would need to acquire a 370-foot-long by 25-foot-wide easement from the UPRR for this alternative, which would cost approximately $92,000 based on the unit cost developed in **Section 4.3**. This alternative would also need environmental permitting and the District's approval for the new outfall structure. This alternative was recommended because it is the most cost-effective and engineering feasible since it can use a relatively conventional construction method that does not require boring and jacking under I-880.

Alternative 2 (Alt 2) includes a 623 foot (5'x3' RCB) diversion system collecting runoff from Ghormley Avenue to Kerwin Avenue along Bernhardt Drive, boring and jacking 295 feet of 48" RCPs under I-880 at Kerwin Avenue, and constructing another 910 feet of 5'x3' RCBs to replace the existing 27" RCPs between I-880 and San Leandro Creek. The bore and jack activity would likely require removing and reconstructing a section of the Caltrans sound wall to the west of I-880. The construction along the existing 27" RCP system through narrow easements surrounded by residential buildings would increase the construction costs and technical difficulty. This alternative was not recommended because of the construction requirements and complexities.

Alternative 3 (Alt 3) includes boring and jacking 262 feet of 48" RCPs under I-880 at Ghormley Avenue, replacing the open channel west of I-880 with 645 feet of 48" RCPs, and replacing the existing 27" RCPs between I-880 and San Leandro Creek with 284 feet of 48" RCPs. This alternative would require removing and reconstructing a section of the Caltrans sound wall to the west of I-880 for access and construction, and acquiring a 605-foot-long by 20-foot-wide easement from the private property owners (**Section 4.3**) for future maintenance. This alternative also has the challenges identified in Alt 2 for the construction along the existing 27" RCP system through narrow easements. This alternative is not as effective as Alt 2 because there would still be unmitigated flooding at the intersection of Kerwin Avenue and Bernhardt Drive. This alternative was not recommended because of the construction requirements and complexities and the low effectiveness on flood mitigation.

The resultant flows and floodplains in the existing and proposed (post improvements) conditions are shown in **Table 25** to illustrate the effectiveness of the two most effective alternatives (Alt 1 and Alt 2).

Table 25 – Bernhardt Drive Existing and Proposed 25-year Hydraulic Results

Improvements	Existing Floodplain (ac)	Existing Peak Outflow (cfs)	Proposed Floodplain (ac)	Proposed Peak Outflow (cfs)
Empire Drive - Alt 1	4.36	37	0	70
Empire Drive - Alt 2	4.36	37	0	74

Alt 1 is equally effective as Alt 2 based on the floodplain area reduction between the existing and proposed conditions. The proposed improvements reduced the floodplain area by increasing the drainage facility capacity from 37 cfs to 70/74 cfs.

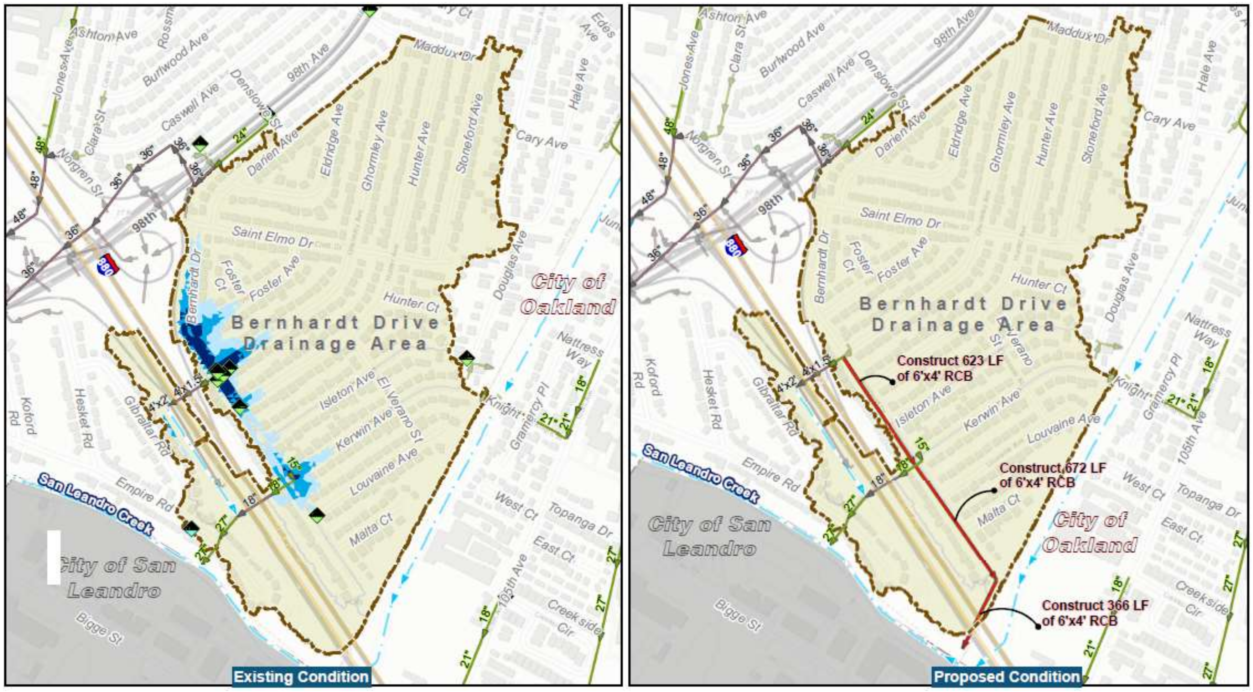
The improvement capital costs for the two alternatives were then calculated and summarized in **Table 26.** The Alt 2 capital cost was marginally higher than that of Alt 1. However, there would be a higher degree of capital cost uncertainty in Alt 2 due to its construction requirements and complexities. The recommendations for the improvement alternatives discussed previously were also listed in the table.

Table 26 – Bernhardt Drive Capital Improvements

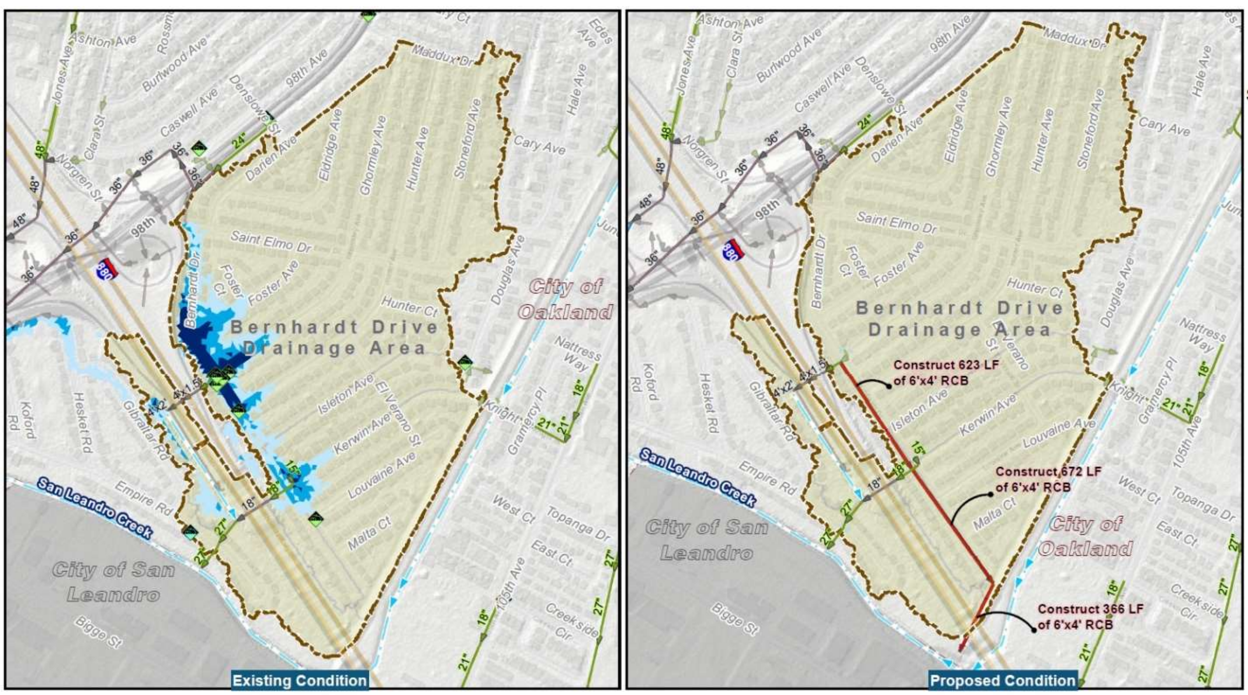
Improvements	Proposed Improvements	Capital Costs ($)	Project Capital Cost ($)	Recommendation
Bernhardt Drive - Alt 1	1,660 LF of 6'x4' RCB	4,510,000	4,702,000	Recommended.
	370 LF x 25 LF UPRR easement	92,000		
	Outfall structure	100,000		
Bernhardt Drive - Alt 2	910 LF of 5'x3' RCB	2,763,000	5,225,000	Not recommended due to construction requirements and complexities.
	285 LF of 48" Bore and Jack	2,462,000		

The detailed capital costs developed and summarized in **Table 26** are presented in **Appendix B**. **Exhibits C3 and C4** show the 25- and 100-year floodplains respectively for the Bernhardt Drive Alternative 1 improvements. The exhibits include:

- simulated existing and proposed (post improvements) floodplains,
- the accuracy of the simulated existing floodplain compared to the citizens' service requests,
- the effectiveness of the proposed improvements in reducing the existing floodplains,
- the existing flood risk, and
- the capital costs and extents of the improvements.



See **Exhibit C3 – Bernhardt Drive 25-year Alternative 1 Improvement Map** for the complete exhibit.



See **Exhibit C4 – Bernhardt Drive 100-year Alternative 1 Improvement Map** for the complete exhibit

The proposed improvements at the Bernhardt Drive drainage system operated in conjunction with the existing drainage system west of the I-880 to mitigate and remove all the flooding in the 25- and 100-year storms. The excess capacity of the improvements could be used to accommodate the reduced channel conveyance capacity when the existing privately owned open channel is no longer serviceable or in service.

8.2 Life-Cycle Cost Analysis

A life-cycle cost analysis was developed for this drainage study to calculate the total cost of drainage facilities improvements over their expected service life spans. It typically includes the costs of planning, constructing, operating, and maintaining the facilities. For improvement project prioritization purposes, the life-cycle cost analysis was simplified to exclude the planning cost. Planning costs typically include engineering design, permitting, construction support, and management costs (approximately 30% to 40% of the capital cost).

Maintenance costs were then developed for the proposed improvements to maintain the condition and performance of the drainage facilities over their expected service life spans. For storm drain pipes, jet flushing maintenance activities were recommended every five years to remove sediment and debris in the pipes based on the maintenance condition assessed in **Section 5.2**. A jet flushing unit cost of $10 per foot was used for the proposed pipes, and a channel vegetation clearing unit cost of $45 per square foot (or $5 per square yard) was used for the proposed earthen channel. Hand removal of pickleweed/vegetation was assumed for the vegetation clearing.

An industry standard expected service life of 50 years was used for reinforced concrete pipes and open channels. The total life cycle-cost for each improvement alternative was then calculated by adding up the total project capital cost and maintenance costs over 50 years. The total life-cycle costs were annualized at a 3.5% inflation rate for improvement project prioritization, as discussed in the next section.

Table 27 – Improvement Project Life-Cycle Cost

Recommended Improvements	Project Capital Cost ($)	Maintenance Costs ($)		Useful Life (year)	Project Life Cycle Cost ($)	Annualized Project Life Cycle Cost ($)
		Pipe Jet Flushing (every 5 years)	Vegetation Clearing (yearly)			
Empire Road - Alt 1	1,409,000	10,000	12,000	50	2,109,000	90,000
Bernhardt Drive - Alt 1	4,702,000	17,000	n/a	50	4,872,000	208,000

Based on the calculated annualized life-cycle costs in **Table 27**, the total cost to construct and maintain the Bernhardt Drive - Alt 1 improvements over 50 years of service life is greater than two times the cost of Empire Road - Alt 1. The costs were then used in conjunction with the flood risk reduction benefits (**Section 7**) for the respective improvement alternatives to determine the cost effectiveness and prioritization in the next section.

8.3 Prioritization

Improvement project prioritization is a process to maximize flood control benefits within limited public agency resources by ranking improvement projects based the criticality of a deficient system and the cost of improvements. The criticality of deficient systems was quantified in **Section 7** in flood risks, whereas the cost of improvements was defined in project life-cycle costs in **Section 8.2.**

Where numerous projects are required to address deficiencies, the ratios of annualized risk over annualized project life-cycle costs are used to rank improvement projects. The improvement project with the highest ratio will be ranked number 1 and prioritized for implementation over other projects.

Table 28 – Improvement Project Prioritization

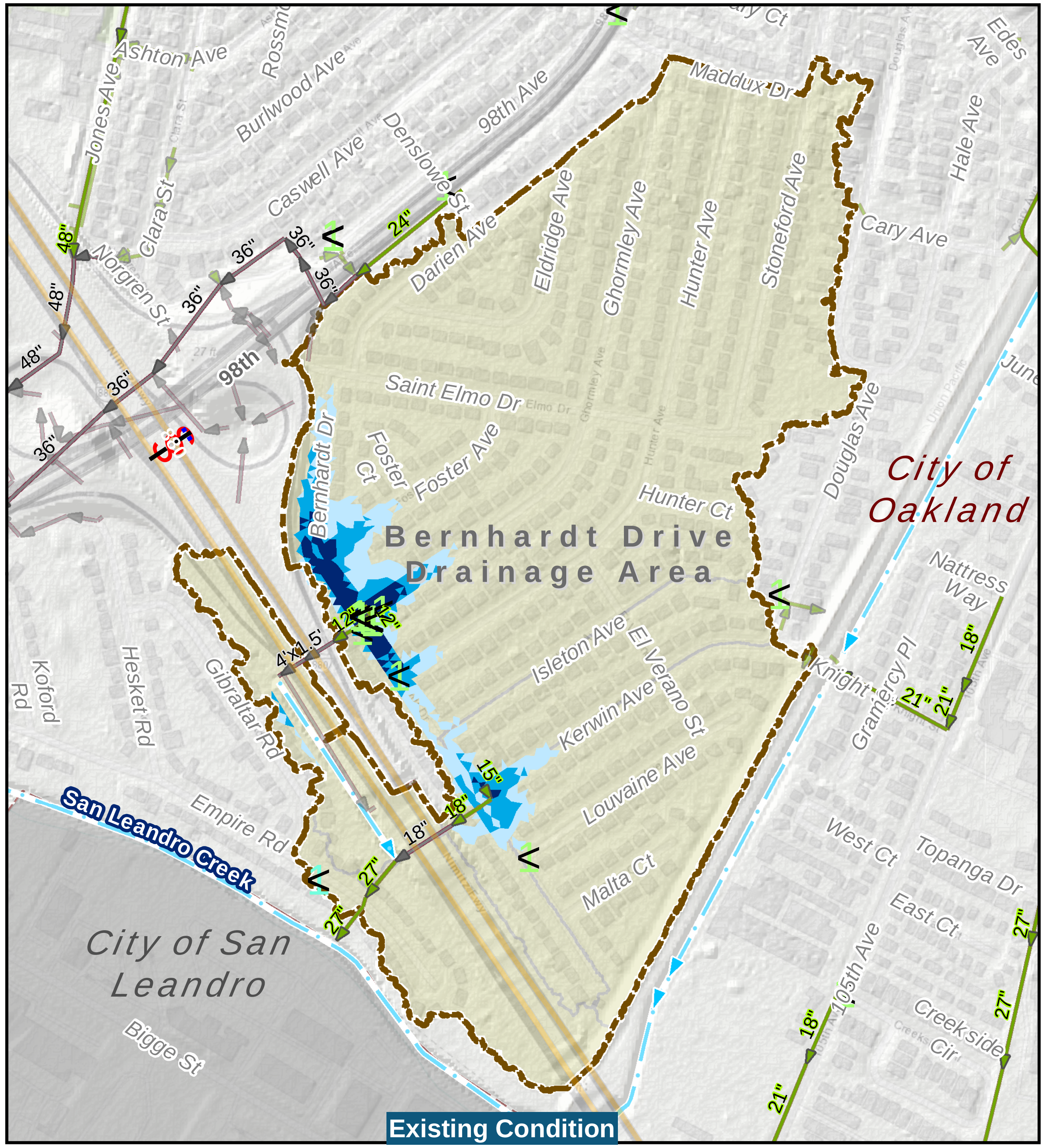
Improvements	Annualized Flood Risk ($)	Annualized Project Life Cycle Cost ($)	Annualized Risk/ Annualized Project Life Cycle Cost	Prioritization Ranking
Empire Road - Alt 1	179,600	90,000	2.0	1
Bernhardt Drive - Alt 1	197,000	208,000	1.0	2

Based on the ratios of annualized risk over annualized project life-cycle costs in **Table 28**, Empire Road - Alt 1 was ranked number 1 and recommended for implementation over Bernhardt Drive - Alt 1. Both projects show relatively similar annualized flood risk, but there is a much lower annualized project life-cycle cost for Empire Road - Alt 1. This translates to a higher ratio at the Empire Road drainage system and a cost-effective improvement project for flood risk reduction.

9 REFERENCES

The references below were used in the development of the hydrologic and hydraulic parameters and modeling methodologies for this study.

1. *Oakland Storm Drainage Design Standards*, updated 2014, City of Oakland
2. *Alameda County Hydrology & Hydraulics Manual*, 2018, Alameda County Flood Control and Water Conservation District (2018 H&H)



City of Oakland
Drainage Master Plan

Bernhart Drive Drainage System 25-year Floodplain and Improvement Map

Alameda County, California
June 2022

Legend

25 year Flood Depth (ft)

DEPTH2D

- <0.5'
- 0.5'-1'
- >1'

Service Requests

- Overflow manhole
- Overflow creek
- Other ponding

Modeled Storm Drain

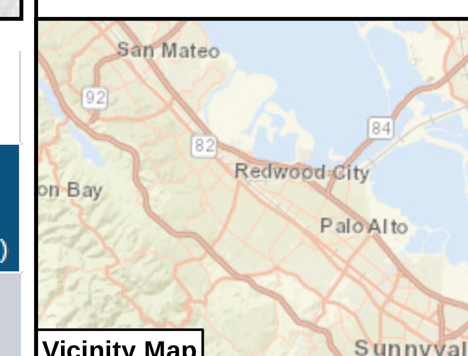
- Others

Owner

- Caltrans
- Oakland
- District
- Channel

NORTH

0 250 500
Feet



Drainage System	Rainfall (in/year)	Drainage Area (ac)	Design Storm (year)	Total Catchment Runoff (cfs)	Outfall Peak Flow (cfs)	Floodplain (ac)	Annualized Flood Risk ($/year)
Bernhardt Drive	20	74	2	30	22	0.5	197,000
			25	74	35	4.4	
			100	96	38	7.8	

Deficient System	Proposed Improvements	Capital Costs ($)	Total Project Capital Cost ($)	Project Life Cycle Costs ($)	Annualized Project Life Cycle Cost ($)
Bernhardt Drive - Alternative 1	1,660 LF of 6'x4' RCB	4,510,000	4,702,000	4,872,000	208,000
	370 LF x 25 LF UPRR easement	92,000			
	Outfall structure	100,000			

PRELIMINARY

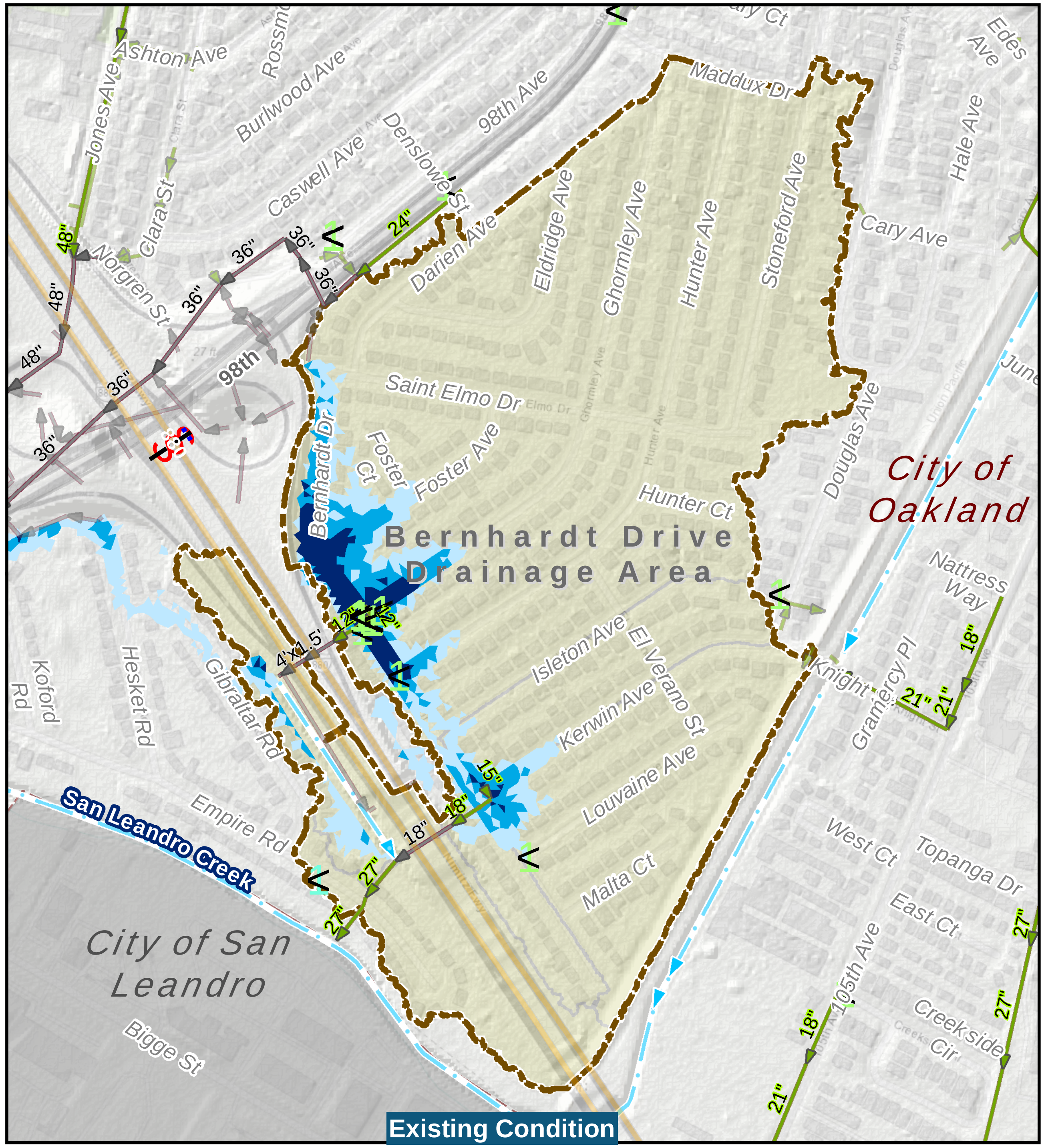
EXHIBIT C1

WOOD RODGERS

City of Oakland
Drainage Master Plan

Bernhart Drive Drainage System 100-year Floodplain and Improvement Map

Alameda County, California
June 2022



Legend

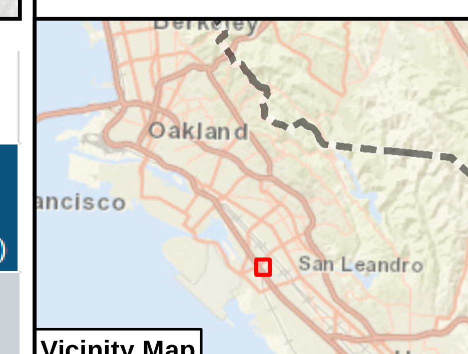
100 year Flood Depth (ft)
- <0.5'
- 0.5'-1'
- >1'

Service Requests
- Overflow manhole
- Overflow creek
- Other ponding

Modeled Storm Drain
- Others

Owner
- Caltrans
- Oakland
- District
- Channel

NORTH
0 250 500
Feet



Vicinity Map

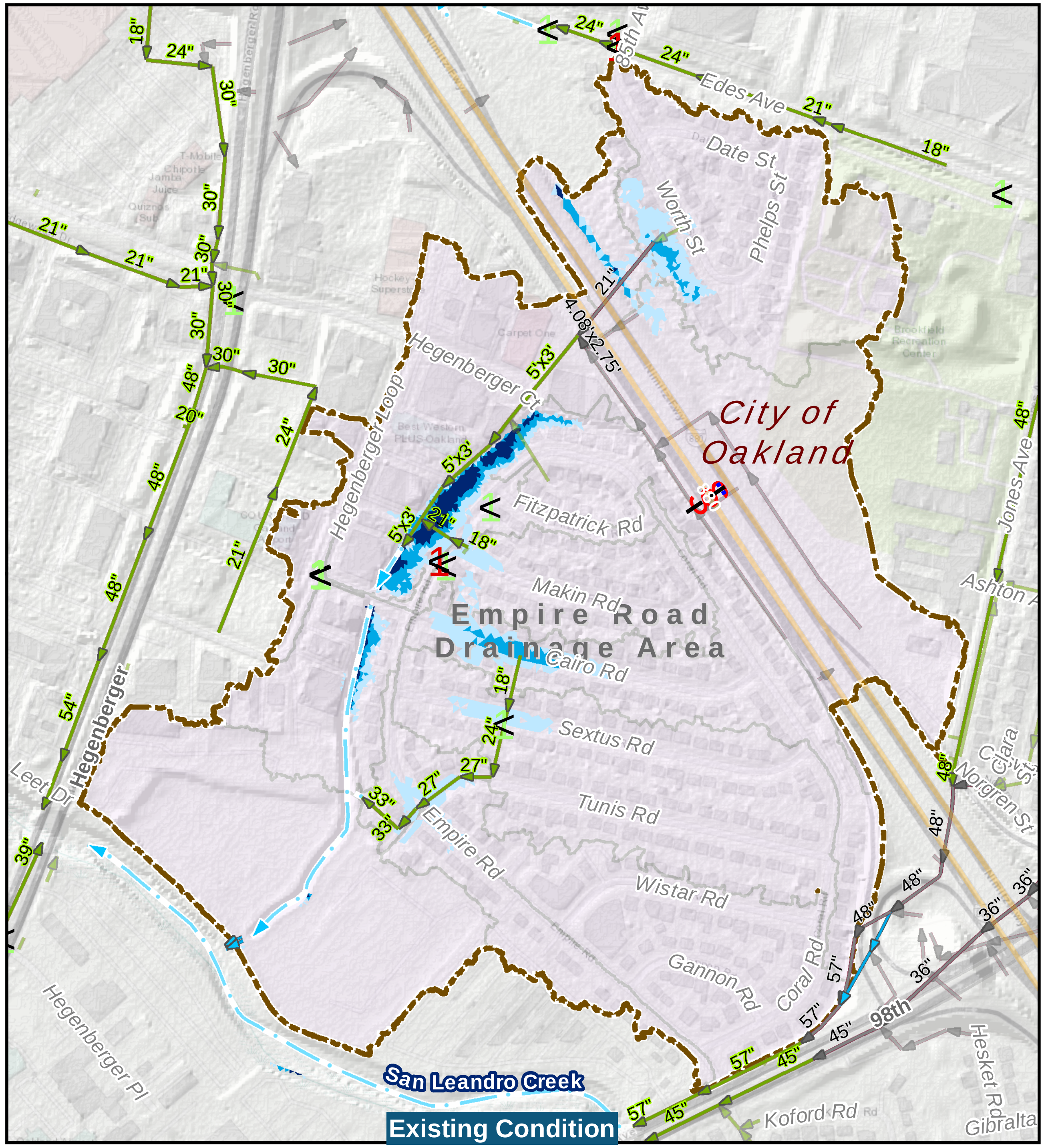
Drainage System	Rainfall (in/year)	Drainage Area (ac)	Design Storm (year)	Total Catchment Runoff (cfs)	Outfall Peak Flow (cfs)	Floodplain (ac)	Annualized Flood Risk ($/year)
Bernhardt Drive	20	74	2	30	22	0.5	197,000
			25	74	35	4.4	
			100	96	38	7.8	

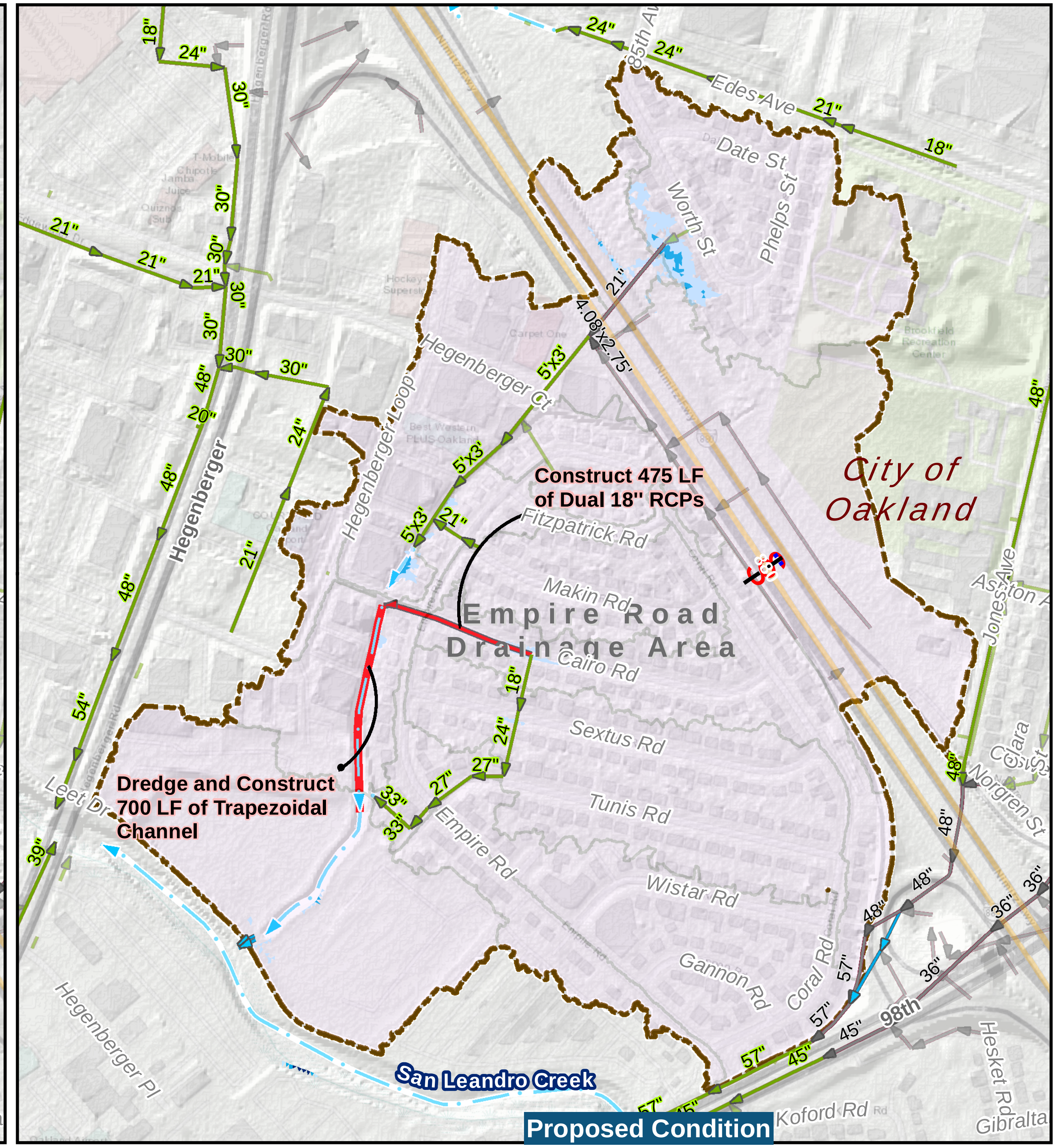
Deficient System	Proposed Improvements	Capital Costs ($)	Total Project Capital Cost ($)	Project Life Cycle Costs ($)	Annualized Project Life Cycle Cost ($)
Bernhardt Drive - Alternative 1	1,660 LF of 6'x4' RCB	4,510,000	4,702,000	4,872,000	208,000
	370 LF x 25 LF UPRR easement	92,000			
	Outfall structure	100,000			

PRELIMINARY

EXHIBIT C2

WOOD RODGERS





City of Oakland
Flood Study

Empire Road Drainage System 25-year Floodplain and Improvement Map

Alameda County, California
June 2022

Legend

25 year Flood Depth (ft)
- <0.5'
- 0.5'-1'
- >1'

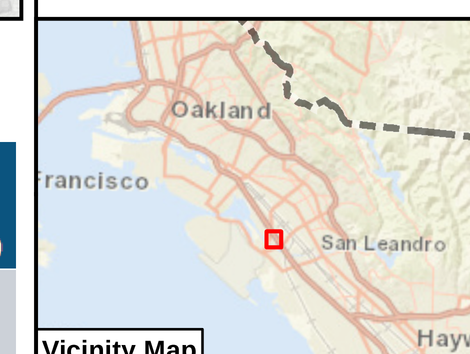
Service Requests
- Overflow manhole
- Overflow creek
- Other ponding

Modeled Storm Drain
- Others

Owner
- Caltrans
- Oakland
- District
- Channel

NORTH

0 250 500
Feet



Vicinity Map

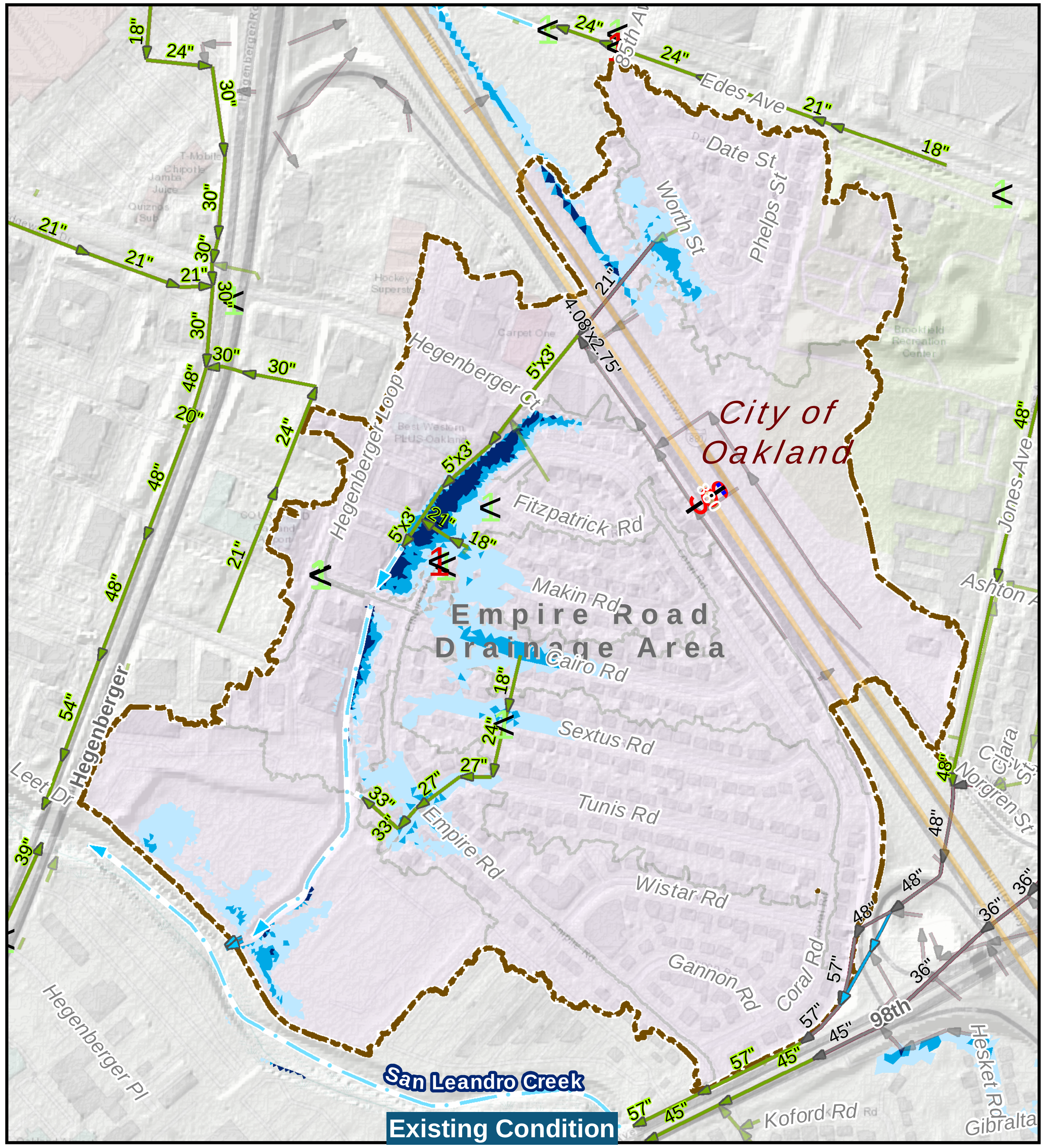
PRELIMINARY

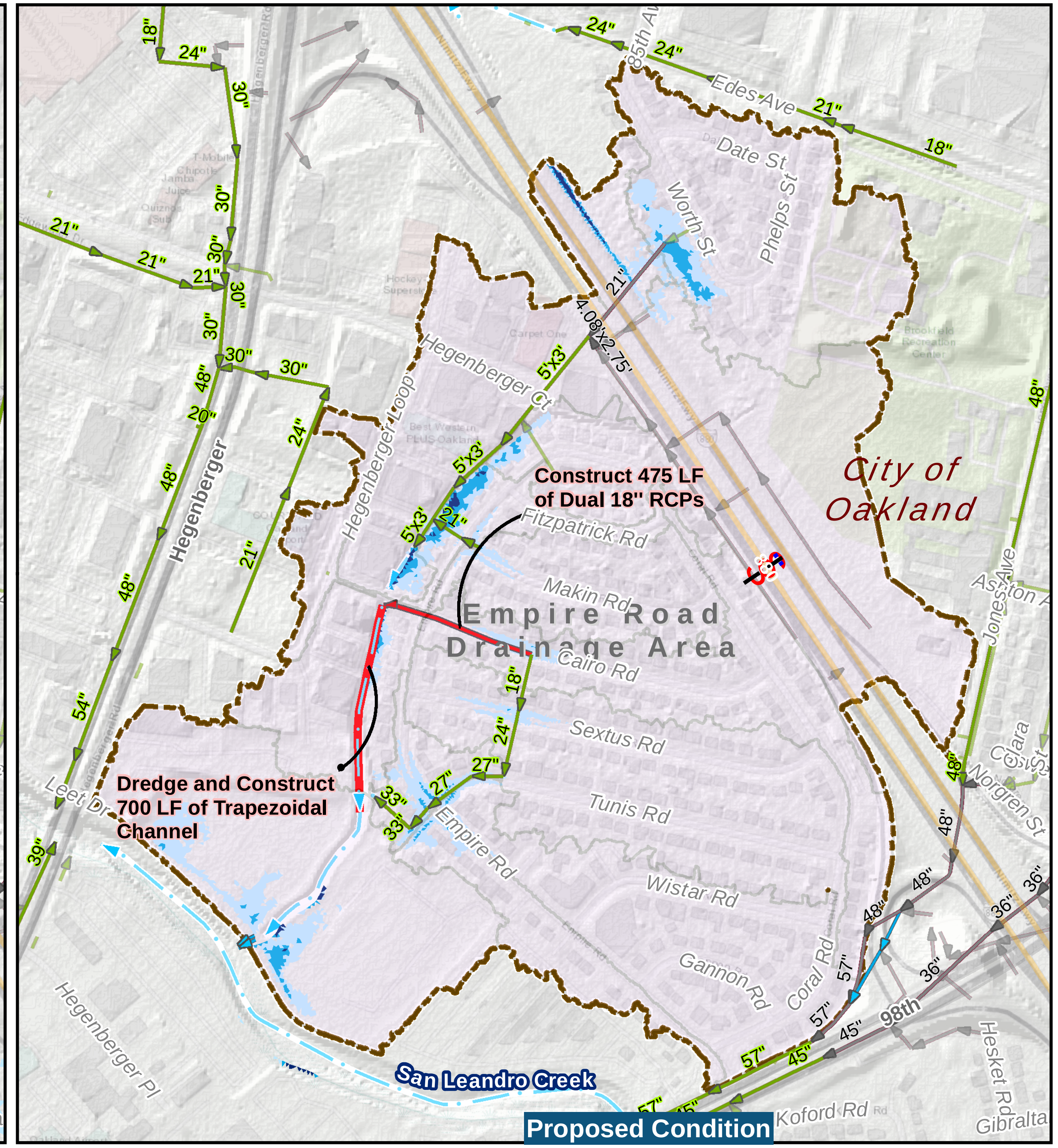
EXHIBIT C3

WOOD RODGERS

Drainage System	Rainfall (in/year)	Drainage Area (ac)	Design Storm (year)	Total Catchment Runoff (cfs)	Outfall Peak Flow (cfs)	Floodplain (ac)	Annualized Flood Risk ($/year)
Empire Road	20	105	2	42	36	0.4	179,600
			25	105	63	5.1	
			100	137	70	10.2	

Deficient System	Proposed Improvements	Capital Costs ($)	Total Project Capital Cost ($)	Project Life Cycle Costs ($)	Annualized Project Life Cycle Cost ($)
Empire Road - Alternative 1	475 LF of Dual 18" RCPs	691,000	1,409,000	2,109,000	90,000
	700 LF of Trapezoidal Channel Dredging	718,000			





City of Oakland Flood Study

Empire Road Drainage System 100-year Floodplain and Improvement Map

Alameda County, California
June 2022

Legend

100 year Flood Depth (ft)

- <0.5'
- 0.5'-1'
- \>1'

Service Requests

- Overflow manhole
- Overflow creek
- Other ponding

Modeled Storm Drain

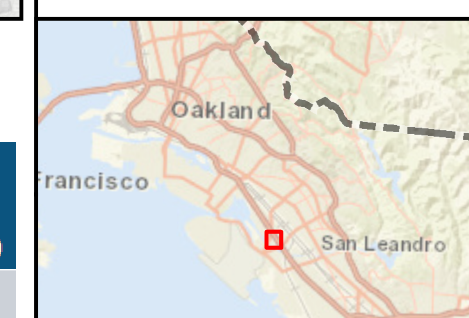
- Others

Owner

- Caltrans
- Oakland
- District
- Channel

NORTH

0 250 500
Feet



Vicinity Map

Drainage System	Rainfall (in/year)	Drainage Area (ac)	Design Storm (year)	Total Catchment Runoff (cfs)	Outfall Peak Flow (cfs)	Floodplain (ac)	Annualized Flood Risk ($/year)
Empire Road	20	105	2	42	36	0.4	179,600
			25	105	63	5.1	
			100	137	70	10.2	

Deficient System	Proposed Improvements	Capital Costs ($)	Total Project Capital Cost ($)	Project Life Cycle Costs ($)	Annualized Project Life Cycle Cost ($)
Empire Road - Alternative 1	475 LF of Dual 18" RCPs	691,000	1,409,000	2,109,000	90,000
	700 LF of Trapezoidal Channel Dredging	718,000			

PRELIMINARY

EXHIBIT C4

WOOD RODGERS

Appendix A

RECORDING REQUESTED BY:

Alameda County Transportation Commission

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WHEN RECORDED MAIL TO:

Manager of Programming
ALAMEDA COUNTY TRANSPORTATION COMMISSION
1333 Broadway, Suite 220
Oakland, CA 94612

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GRANT OF TEMPORARY CONSTRUCTION EASEMENT

RUBEN HERNANDEZ

PORTION OF APN 045-5319-036

10070 EMPIRE ROAD, OAKLAND

I-880 SOUTHBOUND HOV LANE PROJECT – NORTH SEGMENT

TITLE OF DOCUMENT

THIS PAGE HERE TO PROVIDE ADEQUATE SPACE FOR RECORDING INFORMATION
(Government Code 27361.6)

Recorded at the request of:
ALAMEDA COUNTY TRANSPORTATION COMMISSION

Return to:
Manager of Programming
Alameda County Transportation Commission
1333 Broadway, Suite 220
Oakland, CA 94612
APN: Portion of 045-5319-036
First American Title Co. Order No.: 0192-3498807

GRANT OF TEMPORARY CONSTRUCTION EASEMENT

For good and valuable consideration pursuant to that certain Right of Way Contract executed by the parties hereto on or about the date hereof (ROW CONTRACT), the undersigned, RUBEN HERNANDEZ, A MARRIED MAN AS HIS SOLE AND SEPARATE PROPERTY (GRANTOR), hereby grants to the ALAMEDA COUNTY TRANSPORTATION COMMISSION (Alameda CTC), and its successors and assigns a Temporary Construction Easement, over, across, under and through the real property situated in the City of Oakland , County of Alameda, State of California, described in Exhibit A, attached hereto (EASEMENT AREA) for public road construction and conformance purposes related to the **I-880 Southbound HOV Lane Project – North Segment** (PROJECT).

Alameda CTC's rights under the easement granted hereby shall include, without limitation, the right of Alameda CTC, its officers, agents, contractors, and employees, and other governmental agencies responsible for review or construction of any portion of the PROJECT and such agencies' officers, agents, contractors, and employees, to enter upon the EASEMENT AREA with personnel, vehicles and equipment for construction of the PROJECT, and all other activities related thereto, to remove all improvements, trees and vegetation thereon that interfere with the purpose for which this easement is granted, to conform the EASEMENT AREA to the PROJECT, and do any and all other actions necessary and appropriate to the construction of the PROJECT.

If improvements in the EASEMENT AREA are removed pursuant to this Temporary Construction Easement, such improvements will be reconstructed at Alameda CTC's sole expense upon the termination of the Temporary Construction Easement and will be restored to their original condition or as close thereto as is feasible. If reconstruction is not feasible, Alameda CTC will pay GRANTOR the value of such improvements, which payment shall be in addition to the compensation set forth in the ROW CONTRACT.

This Temporary Construction Easement is for a period of twenty four (24) months, to commence upon fourteen (14) days written notice from Alameda CTC to GRANTOR, and shall terminate twenty four (24) months after such commencement. In the event Alameda CTC occupies the Temporary Construction Easement area beyond the twenty four (24) months, Alameda CTC shall pay GRANTOR, on a month-to-month basis, additional compensation pursuant to the provisions of the ROW CONTRACT. In no event shall this Temporary Construction Easement extend beyond the completion of construction, or September 30, 2015. At no additional cost to Alameda CTC, Alameda CTC shall have the right to enter upon GRANTOR's retained property, where necessary, to reconstruct or perform any warranty or conformance works during or after the expiration of the Temporary Construction Easement and any extension thereto and/or the completion of the PROJECT. Said works include conforming driveways, walkways, lawn, landscaped and hardscaped areas, irrigation systems, sidewalks or any area where reconstruction or warranty work on GRANTOR's retained property is necessary.

All work performed by Alameda CTC in the EASEMENT AREA shall conform to applicable building, fire, and sanitary laws, ordinances and regulations relating to such work and shall be done in a good and workmanlike manner.

The rights and obligations contained in this Grant of Temporary Construction Easement will (a) run with the Property and burden, inure to and be for the benefit of and are binding on the Property, Grantor and its successors and assigns, and be an equitable servitude of Grantor and its successors and assigns, and (b) constitute an easement in gross for the benefit of Alameda CTC and its successors and assigns, and will be binding on Alameda CTC and its successors and assigns.

IN WITNESS WHEREOF, this Grant of Temporary Construction Easement is signed and executed on January 29, 2012

GRANTOR:

Ruben Hernandez

Ruben Hernandez

____

State of California
County of Alameda

On January 29, 2012 before me, Vernon R. Cummings, Notary Public, personally appeared Ruben Hernandez, who proved to me on the basis of satisfactory evidence to be the person(s) whose name(s) is/~~are~~ subscribed to the within instrument, and acknowledged to me that he/~~she~~/~~they~~ executed the same in his/~~her~~/~~their~~ authorized capacity(ies), and that by his/~~her~~/~~their~~ signature(s) on the instrument the person(s), or the entity upon behalf of which the person(s) acted, executed the instrument.

I certify under PENALTY OF PERJURY under the laws of the State of California that the foregoing paragraph is true and correct.

WITNESS my hand and official seal.

VERNON R. CUMMINGS
Commission # 1831376
Notary Public - California
Contra Costa County
My Comm. Expires Feb 8, 2013

Signature of Notary

July 19, 2010
HMH 3682.01.270

EXHIBIT "A"
TEMPORARY CONSTRUCTION EASEMENT
APN: 045-5319-036
62274

REAL PROPERTY in the City of Oakland, County of Alameda, State of California, being a portion of Lot 42 as shown upon that map of Tract 669 filed for record October 25, 1943, in Book 8 of Maps, page 64, in the Official Records of Alameda County, described as follows:

BEGINNING at the most easterly corner of said Lot 42, being a point in the westerly right of way line of Interstate 880;

Thence along the southeasterly line of said Lot 42, South 52°28'04" West, 10.02 feet;

Thence North 33°50'21" West, 83.42 feet, to the northerly line of said Lot 42;

Thence along said northerly line, South 85°56'11" East, 12.67 feet, to the northeasterly line of said Lot 42;

Thence along said northeasterly line, South 33°50'21" East, 74.99 feet, to the POINT OF BEGINNING.

Containing 792 square feet or 0.018 acres, more or less.

NOTE: Bearings and distances described herein are based on the California Coordinate System of 1983, Zone 3, Epoch 1991.35. Multiply herein described distances by 1.00007062 to obtain ground level distances.

LICENSED LAND SURVEYOR
STEVE W. DANNER
No 5106
Exp 6-30-11
STATE OF CALIFORNIA

LINE	BEARING	DISTANCE
L1	S52°28'04"W	10.02'
L2	N33°50'21"W	83.42'
L3	S85°56'11"E	12.67'
L4	S33°50'21"E	74.99'

LEGEND

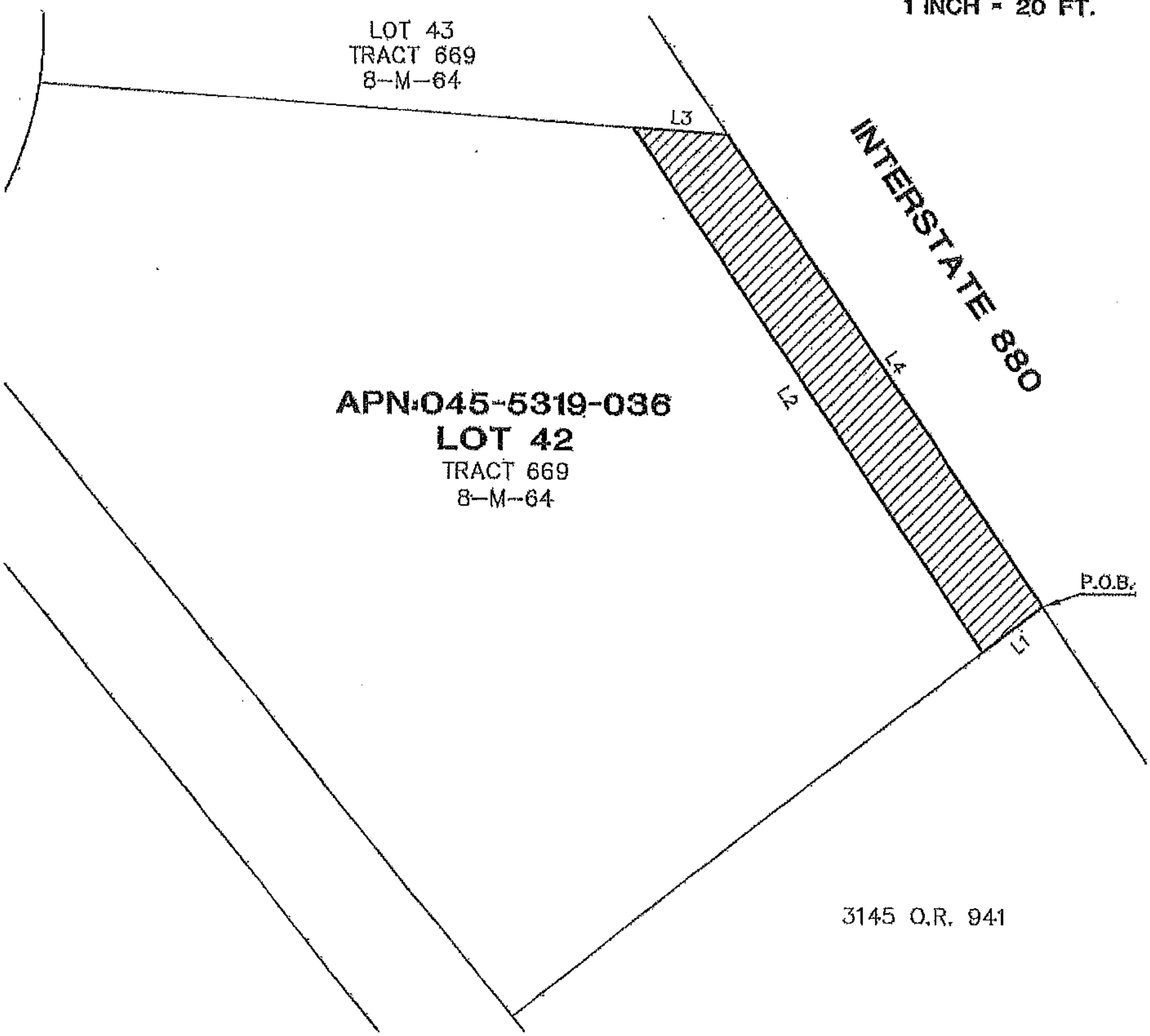
TEMPORARY CONSTRUCTION EASEMENT — 62274

P.O.B. POINT OF BEGINNING

HORIZONTAL DATUM: CCS83, ZONE 3, EPOCH 1991.35 IN U.S. SURVEY FEET. TO CONVERT GRID DISTANCES SHOWN TO GROUND DISTANCES, MULTIPLY BY 1.00007062.

0 10 20

GRAPHIC SCALE
1 INCH = 20 FT.



SHEET 1 OF 1

Date:	07-19-10
Scale:	1"= 20'
Designed:	—
Drawn:	TG
Checked:	SD
Prof. Engr.:	—
368203PL24	

1570 Oakland Road
San Jose, CA 95131
(408) 487-2200
HMHca.com

Plat to accompany description:
TEMPORARY CONSTRUCTION EASEMENT
APN: 045-5319-036
LANDS OF HERNANDEZ

OAKLAND
ALAMEDA COUNTY, CALIFORNIA

<u>Certificate of Acceptance – Alameda CTC</u>
(pursuant to Government Code §27281)

This is to certify that the interest in real property conveyed by the Grant of Temporary Construction Easement dated January 29, 2012 from **RUBEN HERNANDEZ, a Married Man as his Sole and Separate Property**, to the **ALAMEDA COUNTY TRANSPORTATION COMMISSION**, a joint powers agency ("Alameda CTC"), is hereby accepted by the undersigned officer on behalf of Alameda CTC pursuant to authority conferred by the Alameda CTC Administrative Code, as adopted by the Board of the Alameda CTC on July 22, 2010, and Alameda CTC consents to recordation thereof by its duly authorized officer.

Dated 02/08/2012

By [signature]
Arthur L. Dao
Executive Director, Alameda CTC

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Appendix B

DATE	PROJECT	DRAINAGE AREA	IMPROVEMENT PROJECT
5/1/2022	City of Oakland Drainage Master Plan	Empire Road	Alt 1- Trapezoidal Channel

#	Item Name	Unit Quantity	Unit of Measure	Unit Cost	Cost Estimate Total	Assumption
1	MOBILIZATION	1	LS	$ 60,000	$ 60,000	10% of total
2	WATER POLLUTION CONTROL WORK	1	LS	$ 6,000	$ 6,000	1% of total
3	TRAFFIC CONTROL	1	LS	$ 12,000	$ 12,000	2% of total
4	DEWATERING	1	LS	$ 178,000	$ 178,000	10% of total
5	REMOVE AND DISPOSE OF CHAIN LINK FENCE	1,400	LF	$ 40	$ 56,000	
6	SOIL EXCAVATION	750	CY	$ 120	$ 90,000	
7	HYDROSEEDING	1	AC	$ 10,000	$ 7,231	
8	INSTALL NEW CHAIN LINK FENCE	1,400	LF	$ 65	$ 91,000	
9	SITE RESTORATION	1	LS	$ 17,000	$ 17,000	3% of total
10	SETTLEMENT MONITORING	1	LS	$ 35,000	$ 35,000	
				30% Contingency:	**$ 165,669**	
				Total Project Cost Estimate:	**$ 717,901**	

Note: Contingency developed to account for incidental items based on contractor bids for similar projects

DATE	PROJECT	DRAINAGE AREA	IMPROVEMENT PROJECT
5/1/2022	City of Oakland Drainage Master Plan	Empire Road	Alt 2- Rectangular Channel

#	Item Name	Unit Quantity	Unit of Measure	Unit Cost	Cost Estimate Total	Assumption
1	MOBILIZATION	1	LS	$ 268,000	$ 268,000	10% of total
2	WATER POLLUTION CONTROL WORK	1	LS	$ 27,000	$ 27,000	1% of total
3	TRAFFIC CONTROL	1	LS	$ 54,000	$ 54,000	2% of total
4	DEWATERING	1	LS	$ 268,000	$ 268,000	10% of total
5	SHEET PILE FLOODWALL (4 FT DEEP CHANNEL)	22,400	SQFT	$ 35	$ 784,000	Sheet pile vertical length = channel depth*4
6	FLOODWALL CONCRETE COVER (4 FT DEEP CHANNEL)	207	CY	$ 3,000	$ 622,222	
7	SHEET PIPE CONCRETE CAP (2.5 FT X 1 FT)	1,400	LF	$ 200	$ 280,000	
8	REMOVE AND DISPOSE OF CHAIN LINK FENCE	1,400	LF	$ 40	$ 56,000	
9	SOIL EXCAVATION	1,100	CY	$ 120	$ 132,000	
10	INSTALL NEW CHAIN LINK FENCE	1,400	LF	$ 65	$ 91,000	
11	SITE RESTORATION	1	LS	$ 81,000	$ 81,000	3% of total
12	SETTLEMENT MONITORING	1	LS	$ 35,000	$ 35,000	
	30% Contingency:				**$ 809,467**	
	Total Project Cost Estimate:				**$ 3,507,689**	
Note: Contingency developed to account for incidental items based on contractor bids for similar projects						

DATE	PROJECT	DRAINAGE AREA	IMPROVEMENT PROJECT
5/1/2022	City of Oakland Drainage Master Plan	Empire Road	Alt 1 or Alt 2 RCP

#	Item Name	Unit Quantity	Unit of Measure	Unit Cost	Cost Estimate Total	Assumption
1	MOBILIZATION	1	LS	$ 60,000	$ 60,000	10% of total
2	WATER POLLUTION CONTROL WORK	1	LS	$ 6,000	$ 6,000	1% of total
3	TRAFFIC CONTROL	1	LS	$ 12,000	$ 12,000	2% of total
4	TRENCH AND EXCAVATION PROTECTION	1	LS	$ 6,000	$ 6,000	1% of total
5	DEWATERING	1	LS	$ 12,000	$ 12,000	2% of total
6	18" RCP	950	LF	$ 390	$ 370,500	
7	JUNCTION STRUCTURE	3	LS	$ 15,000	$ 45,000	Every 400ft
8	STORM DRAIN CATCH BASIN	4	EA	$ 5,000	$ 20,000	
				30% Contingency:	**$ 159,450**	
				Total Project Cost Estimate:	**$ 690,950**	

Note: Contingency developed to account for incidental items based on contractor bids for similar projects

DATE	PROJECT	DRAINAGE AREA	IMPROVEMENT PROJECT
5/1/2022	City of Oakland Drainage Master Plan	Bernhardt Drive	Alt 1- RCB

#	Item Name	Unit Quantity	Unit of Measure	Unit Cost	Cost Estimate Total	Assumption
1	MOBILIZATION	1	LS	$ 390,000	$ 390,000	10% of total
2	WATER POLLUTION CONTROL WORK	1	LS	$ 30,000	$ 30,000	1% of total
3	TRAFFIC CONTROL	1	LS	$ 60,000	$ 60,000	2% of total
4	TRENCH AND EXCAVATION PROTECTION	1	LS	$ 30,000	$ 30,000	1% of total
5	DEWATERING	1	LS	$ 58,000	$ 58,000	2% of total
6	6' X 4' RCB	1,660	LF	$ 1,600	$ 2,656,000	
7	JUNCTION STRUCTURE	5	LS	$ 39,000	$ 195,000	Every 400ft
8	STORM DRAIN CATCH BASIN	10	EA	$ 5,000	$ 50,000	
	30% Contingency:				**$ 1,040,700**	
	Total Project Cost Estimate:				**$ 4,509,700**	
Note: Contingency developed to account for incidental items based on contractor bids for similar projects						

DATE	PROJECT	DRAINAGE AREA	IMPROVEMENT PROJECT
5/1/2022	City of Oakland Drainage Master Plan	Bernhardt Drive	Alt 2- RCB

#	Item Name	Unit Quantity	Unit of Measure	Unit Cost	Cost Estimate Total	Assumption
1	MOBILIZATION	1	LS	$ 229,000	$ 229,000	10% of total
2	WATER POLLUTION CONTROL WORK	1	LS	$ 19,000	$ 19,000	1% of total
3	TRAFFIC CONTROL	1	LS	$ 37,000	$ 37,000	2% of total
4	TRENCH AND EXCAVATION PROTECTION	1	LS	$ 18,000	$ 18,000	1% of total
5	DEWATERING	1	LS	$ 36,000	$ 36,000	2% of total
6	REMOVE & DISPOSE EXISTING 24" RCP	910	LF	$ 160	$ 145,600	10% of install cost
7	5' X 3' RCB	910	LF	$ 1,600	$ 1,456,000	
8	JUNCTION STRUCTURE	5	LS	$ 33,000	$ 165,000	Every 400ft
9	STORM DRAIN CATCH BASIN	4	EA	$ 5,000	$ 20,000	
	30% Contingency:				**$ 637,680**	
	Total Project Cost Estimate:				**$ 2,763,280**	
Note: Contingency developed to account for incidental items based on contractor bids for similar projects						

DATE	PROJECT	DRAINAGE AREA	IMPROVEMENT PROJECT
5/1/2022	City of Oakland Drainage Master Plan	Bernhardt Drive	Alt 2- Bore and Jack

#	Item Name	Unit Quantity	Unit of Measure	Unit Cost	Cost Estimate Total	Assumption
1	MOBILIZATION	1	LS	$ 205,000	$ 205,000	10% of total
2	Utility Relocation	1	EA	$ 80,000	$ 80,000	
3	Traffic Control	1	EA	$ 37,000	$ 37,000	2% of total
4	Freeway Settlement Monitoring	1	EA	$ 50,000	$ 50,000	
5	Furnish Temp Sheet Piling (Launching Shaft Excavation Shoring)	2,800	SQFT	$ 15	$ 42,000	20'x40'x24' sheet pile
6	Furnish Temp Sheet Piling (Receiving Shaft Excavation Shor	1,700	SQFT	$ 15	$ 25,500	20'x15'x24' sheet pile
7	Drive Temp Steel Sheet Pile (Launching Shaft Excavation S	2,800	SQFT	$ 20	$ 56,000	20'x40'x24' sheet pile
8	Drive Temp Steel Sheet Pile (Receiving Shaft Excavation Sh	1,700	SQFT	$ 20	$ 34,000	20'x15'x24' sheet pile
9	Dewatering	1	EA	$ 150,000	$ 150,000	
10	Baker Tanks	4	EA	$ 10,000	$ 40,000	
11	Ground Improvement (Jet Grouting at Shafts)	100	CY	$ 940	$ 94,000	
12	Structure Excavation (Launching Shaft)	240	CY	$ 170	$ 40,800	20'x40'x8' shaft
13	Structure Excavation (Receiving Shaft)	90	CY	$ 170	$ 15,300	20'x15'x8' shaft
14	Soil Disposal, non-contaminated (Launching Shaft)	240	CY	$ 100	$ 24,000	20'x40'x8' shaft
15	Soil Disposal, non-contaminated (Receiving Shaft)	90	CY	$ 100	$ 9,000	20'x15'x8' shaft
16	Soil Disposal, non-contaminated (Tunnel)	200	CY	$ 100	$ 20,000	Steel Casing Volume
17	60" Permalok Steel Casing, installed	285	LF	$ 2,700	$ 769,500	
18	48" Reinforced Concrete Pipe (Tunnel)	285	LF	$ 1,100	$ 313,500	
19	Cellular Concrete (Launching Shaft)	240	CY	$ 140	$ 33,600	20'x40'x8' shaft
20	Cellular Concrete (Receiving Shaft)	90	CY	$ 268	$ 24,120	20'x15'x8' shaft
21	Construction Monitoring	1	EA	$ 130,000	$ 130,000	
				20% Contingency:	**$ 438,664**	
				Total Project Cost Estimate:	**$ 2,631,984**	

Note: Contingency developed to account for incidental items based on contractor bids for similar projects

DATE	PROJECT	DRAINAGE AREA
5/1/2022	City of Oakland Drainage Master Plan	

#	RCP Size (inch)	Unit Cost	Unit of Measure
1	12	$ 262	LF
2	15	$ 327	LF
3	18	$ 393	LF
4	21	$ 458	LF
5	24	$ 524	LF
6	27	$ 589	LF
7	30	$ 655	LF
8	33	$ 720	LF
9	36	$ 786	LF
10	42	$ 916	LF
11	45	$ 982	LF
12	48	$ 1,047	LF
13	54	$ 1,178	LF
14	60	$ 1,309	LF
15	66	$ 1,440	LF
16	72	$ 1,571	LF
17	78	$ 1,702	LF
18	84	$ 1,833	LF
19	90	$ 1,964	LF
20	96	$ 2,095	LF
	RCB Size (inside dimension, ft)		
Width	6	$ 2,000	LF
Height	4		
	Junction Box Size (inside dimension, ft)		
Width	8	$ 39,000	LF
Length	6		
Height	6		
Structure Concrete Unit Price		**$ 3,000**	**cy**
Assumption:	**RCP unit price based on 9" wall and structure concrete unit price.** **RCB unit price based on 12" wall and structure concrete unit price.** **Junction Box unit price based on 12" wall and structure concrete unit price.**		