Mill Valley Flood Management and Storm Drain Master Plan



Report By

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CONSULTING CIVIL ENGINEERS

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List of Abbreviations

ACMdP	Arroyo Corte Madera del Presidio Creek
AMC	Antecedent Moisture Condition
CCTV	Closed Caption Television
CIP	Capital Improvement Program
CFD	Community Facilities District
CFS	cubic feet per second
CMP	Corrugated Metal Pipe
CN	Curve Number
CPP	Corrugated Plastic Pipe
DHI	Danish Hydraulic Institute
FT	feet
GIS	Geographic Information System
HDPE	High-Density Polyethylene
LiDAR	Light Detection and Ranging
MAP	Mean Annual Precipitation
MU	MIKE URBAN (software)
NAVD	North American Vertical Datum of 1988
NOAA	National Oceanic and Atmospheric Administration
NRCS	National Resource Conservation Service
RCP	Reinforced Concrete Pipe
ROW	Right of Way
S&W	Schaaf & Wheeler
SQ.MI	square mile
UHM	Unit Hydrograph Method
USGS	United States Geological Survey

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Executive Summary

This Executive Summary is meant to serve as a standalone document for the general public and elected officials to read. The Flood Management and Storm Drain Master Plan (Master Plan) chapters and appendices provide more detail for those interested in the technical modeling aspect of the master plan. The chapters and appendices of the Master Plan further detail the conceptual improvement projects so that the City can seek funding in the future.

Purpose

This Master Plan establishes a prioritized capital improvement program to reduce the risk of flooding within the City of Mill Valley (City). The study is a continuation of work that started back in 2006 to develop potential flood mitigation measures on the Creek system. In 2017 the City's urban storm drainage system was added to the project scope.

The creek and storm drainage system mitigation measures are intended to provide 10-year (10% annual exceedance) storm conveyance throughout the City. In 2019 the City formed a Task Force to work together with Schaaf & Wheeler to develop this master plan. The overall goals of the Master Plan are:

- Serve as a tool to inform policies, priorities, and to guide future City land-use policies and infrastructure projects.
- Assist in the development of comprehensive and achievable drainage improvement and flood reduction goals, objectives, financing, and implementing projects and programs.
- Educate and attain a broad consensus on goals, objectives, and implementation strategies.

Background

On December 31, 2005, the City experienced significant flooding from a large rainfall event. Approximately 230 homes reported damages. The City hired Stetson Engineers in 2006 to study the City's Creek drainage system and presented several reports containing potential mitigation measures to City Council.

In 2017, the City prioritized the development of a Flood Management and Drainage Master Plan Marin County Flood Control Zone 3 supported this effort and funded the Master Plan. The City hired Schaaf & Wheeler to further investigate some of the concepts to alleviate creek flooding and to analyze the City's urban storm drainage system that consists of pipes, inlets, and one pump station.

The purpose of the Master Plan is to identify what projects are and are not feasible, at what costs, and to what level of protection can be achieved.

Evaluation Criteria

This Master Plan focuses on what is termed a "10-year storm event." This is a storm event that has a 10% chance of occurring each year. A "100-year storm event" is a storm event that has a 1% chance of occurring each year. The Federal Emergency Management Agency (FEMA)

studies and maps the 100-year storm event. These maps are used to determine which properties require flood insurance if they have a federally back loan and are used often by state and local governments to moderate development in the floodplain. The storm that occurred on New Year's Eve of 2005 was quantified as a 50-year storm event.

Ideally, creek and storm drainage systems would convey the 100-year storm event; however, this is costly and rarely met. Instead, the majority of municipalities require storm drainage systems to be designed to convey the 10-year to 25-year storm event. In Marin County, natural creeks generally convey 10-year storm or less and then use what is termed the "floodplain" for additional conveyance.

In Mill Valley, urban development has encroached into the natural floodplain. Figure ES-1 below shows the difference between a natural creek floodplain and an urbanized floodplain.

Attempts to evaluate the creek system for larger storm events were made, but the modeling software was not capable of analyzing the existing condition due to the complex nature of the over crossings (culverts and bridges) and the limited channel capacity. This is further detailed in the report itself.

The Stetson Report identifies the number of properties impacted by storm events, which is listed in Table ES-1 below. During the 10-year storm event, the City can anticipate that approximately 14 residential and 16 non-residential buildings will be impacted. Task Force members agreed that this is not a significant amount of at-risk properties. During larger events, the number of impacted buildings increases for both residential and non-residential. Unfortunately, the solutions developed to protect the limited at-risk buildings during a 10-year storm event, do little for the larger storm events as the mitigation measures will be overwhelmed.

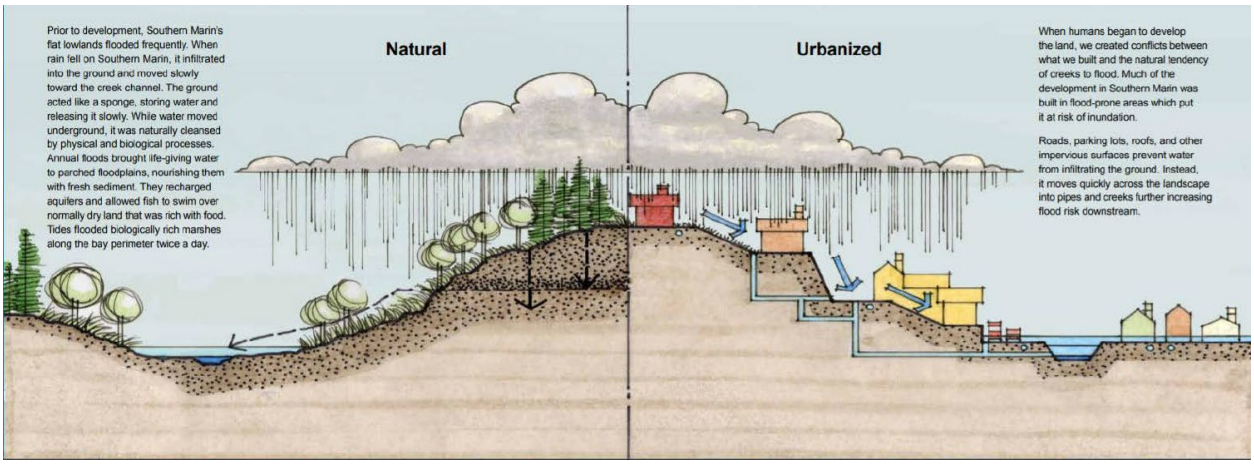


Figure ES-1. Natural vs Urbanized Floodplain *(figure from Southern Marin Watershed Guide, 2016)*

Table ES-1: Stetson Reported At-Risk Buildings for Storm Events

Storm Event	Number of At-Risk Non-Residential Buildings	Number of At-Risk Residential Buildings
5-Year	7	1
10-Year	16	14
25-Year	27	60
50-Year	40	103
100-Year	59	150

City Drainage Infrastructure

The City's urban storm drainage system consists of almost 16 miles of pipes, 1,300 junctions such as inlets and manholes, and one pump station located in Sycamore Park. The urban drainage is conveyed through the pipes into the creek channels that discharge into Richardson Bay (Bay). The City has the following Creeks draining through the City:

- Arroyo Corte Madera del Presidio (ACMdP)
- Warner Canyon Creek
- Cascade Creek
- Old Mill Creek
- Sutton Manor
- Reed Creek
- Ryan Creek

The most significant creeks are the Arroyo Corte Madera del Presidio (ACMdP) and Warner Canyon Creeks because they capture around 70% of runoff within the City boundaries.

While the majority of the City's piped storm drainage system has capacity for the 10-year event, the creek channels do not have the capacity to convey a 10-year storm event and consequently spill over the creek banks and through public and private properties and into the streets.

Flood Threats in the Mill Valley Watershed

Mill Valley resides within the Richardson Bay Watershed that is part of Marin County Flood Control's Zone 3. Figure ES-2 shows the City outline in pink overlayed on Flood Control Zone 3. With the watershed topography, large rainfall events convey significant runoff from the top of Mount Tamalpais (Mt. Tam) to the low-lying marshlands that have been occupied by homes built when the City first developed.

The flood threats in the City have been broken into three categories for this study:

1. Creeks
2. Urban drainage system (i.e., pipes and pumps)
3. Low lying (tidal) areas

Within each category, Schaaf & Wheeler performed an analysis and/or literature review to develop potential mitigation measures that were presented to the City. This report details the mitigation measures to minimize the occurrence of flooding in Mill Valley.

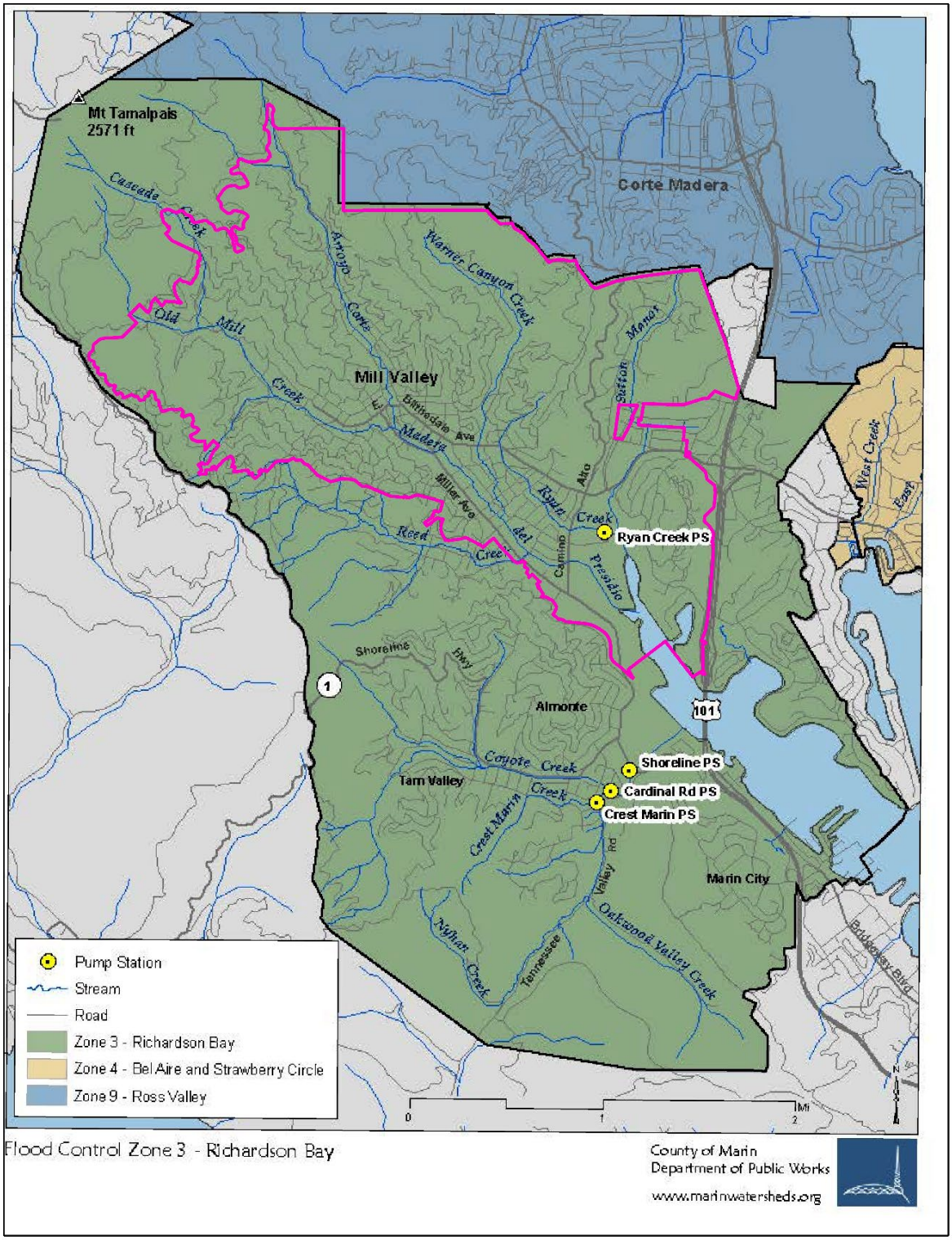


Figure ES-2. Flood Zone 3 (green) and City of Mill Valley (pink outline)

Task Force

In 2019, the City formed the Flood Management and Drainage Master Plan Task Force (Task Force) intending to assist the City in bringing choices to the community concerning drainage improvements and flood management strategies, estimated costs, and funding options in conjunction with the development of a Master Plan.

The Task Force met four times and presented their findings to the community via Zoom Meeting in September 2020. More details, members, and meeting notes can be found on the City's website here:

https://www.cityofmillvalley.org/gov/departments/publicworks/waterresources/presido/default.htm

Creek Evaluation and Mitigation Measures

This Study utilized the hydraulic model developed by Stetson Engineers and developed hydrologic flows based on Marin County design storm methodology in MIKE URBAN software that was used for the urban drainage system model. The Creek Model focus was on the lower sections of ACMdP and Warner Creeks.

A two-dimensional (2D) hydraulic model was developed in the United States Army Corps of Engineers (USACE) software HEC-RAS version 5.05. The model determined that both creek channels have less than a 10-year conveyance capacity. The majority of the spills from ACMdP break out around Willow Street and travel down Miller Avenue. The spills from Warner Creek break out around Locust Avenue and travel down Sycamore Avenue. These breakouts are shown with yellow arrows in Figure ES-3.

During a 10-year storm event, the majority of spills are shallow and contained within the streets by the curbs. This is shown in the lighter blue in Figure ES-3. There is a section of more significant ponding near the confluence of the ACMdP and Warner Creek, which is a darker blue shade. Figure ES-3 depicts the majority of flooding during a 10-year storm event.

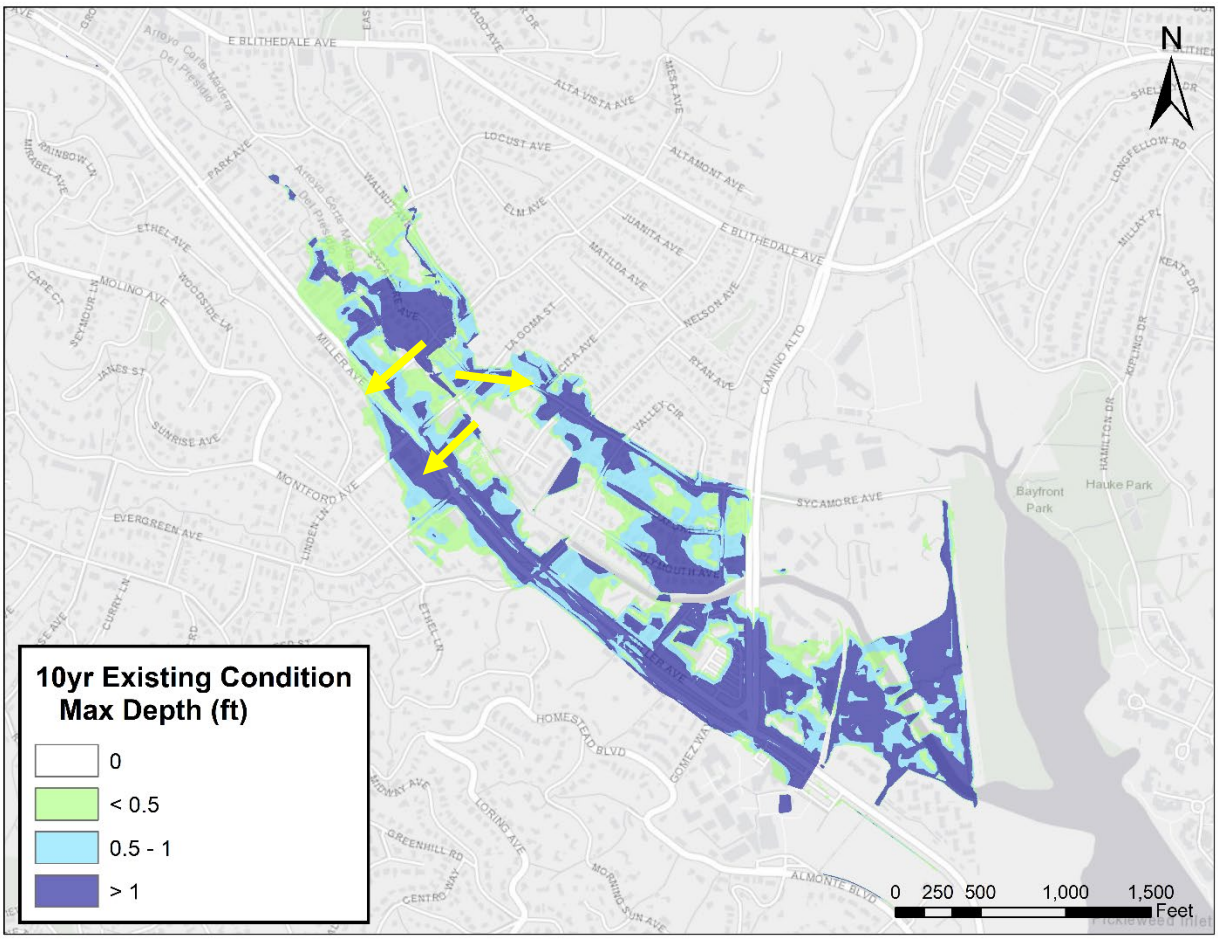


Figure ES-3. Flooding During 10-Year Storm Event (darker blue is deeper flooding)

Stetson Engineers listed the following potential mitigation measures:

- Mill Valley Golf Course detention basin
- Bridge replacements
- Raising streets
- Partial and full bypasses
- Dredging
- Raising homes
- Levees, berms and flood walls
- Channel widening

These were used as a starting point and presented to the Task Force. Some of the mitigation measures above are located on private property or would require the City to obtain easements to construct and maintain mitigation measures. This issue was discussed at the first Task Force meeting.

The Task Force decided that the focus of the Master Plan would be on mitigation measures on city-owned property. Figure ES-4 shows the parcels that the City owns along the creeks in orange.

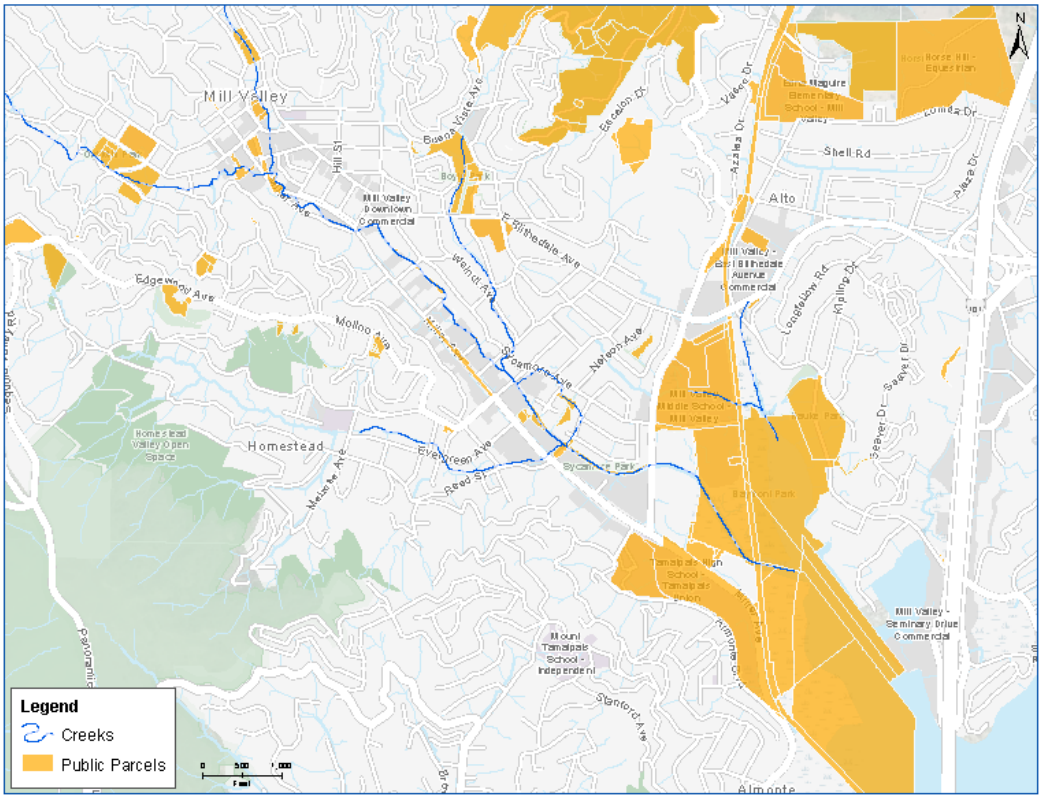


Figure ES-4 City-Owned Parcels Along ACMdP and Warner Creeks

This decision to focus on city-owned property eliminated the mitigation measures such as floodwalls, berms and channel widening as they require improvements on, or procurement of private property.

Bridge replacement and street raising was discussed, but due to the numerous bridge over the ACMdP, it was deemed infeasible. Instead, the focus of Creek mitigation measures in the Master Plan are detention based solutions, creek bypass channels, and dredging.

Detention Based Mitigation Measures

The most viable mitigation measure presented by Stetson Engineers appeared to be the construction of a 40-foot dam to detain water in the public golf course along Warner Creek. It is estimated to store about 150 to 227 acre-feet of water. This was studied in the hydraulic model by removing the flows entirely from Warner Creek to see if the flooding was alleviated on the ACMdP.

Unfortunately, the volume of runoff during a 10-year storm event that is being conveyed through the ACMdP Creek channel is so large that the detention of Warner Creek does not prevent the spills from ACMdP, which are driven by the limited capacity of the creek channel. Instead,

alternative detention locations were identified that detained runoff from ACMdP at Old Mille Park and Grove Park. Figure ES-5 shows these two potential detention locations.

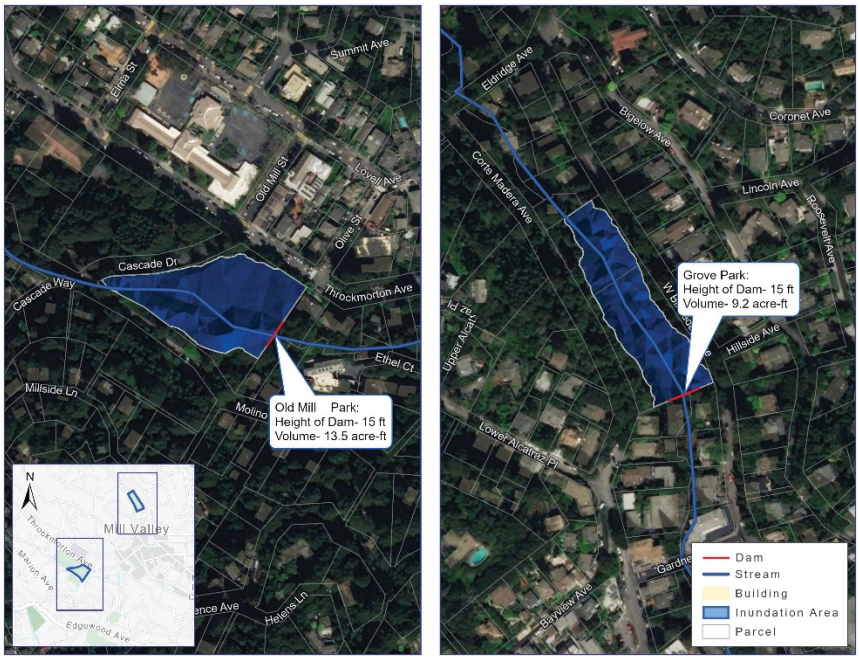


Figure ES-5 Detention Sites Located on ACMdP

These two locations required dam heights of 13 to 15 feet, which qualifies them as dams, not detention basins, and would need to follow the requirements of the Division of Safety of Dams (DSOD). The total volume detained would be around 23 acre-feet, which is less than 18% of the necessary 130 acre-feet required to alleviate flooding during a 10-year, 24-hour storm event.

The Task Force agreed that these mitigation measures did not provide meaningful improvements and would require a significant cost to permit and maintain DSOD standards.

Creek Bypasses

The Stetson Report conceptually designed a creek bypass for Warner Creek down Blithedale and ACMdP down Miller Avenue as shown in Figure ES-6. Two bypass alternatives were designed for the ACMdP, one full bypass, and one partial bypass.

The bypasses were put into the two-dimensional hydraulic model which showed that the bypass for the ACMdP needed to travel all the way to Richardson Bay without returning to the creek channel. This is because the majority of the creek channels do not have sufficient capacity so returning flows to the creek channels was not recommended.

Instead, bypasses travel down East Blithedale with a pump station into Richardson Bay and down Miller Avenue with a pump station into Richardson Bay as well. A third bypass was modeled that took flows from Warner Creek into ACMdP at Fern Street. This option showed that the bypass on Miller Avenue was still required, and the bypass would need to proceed through private property at the end of Fern Street to ACMdP.

This bypass alternative was not furthered considered as it did not provide additional benefits beyond the Blithedale bypass and was not on public property. Figure ES-6 shows the Miller and Blithedale bypass alignments and pump stations in orange squares.

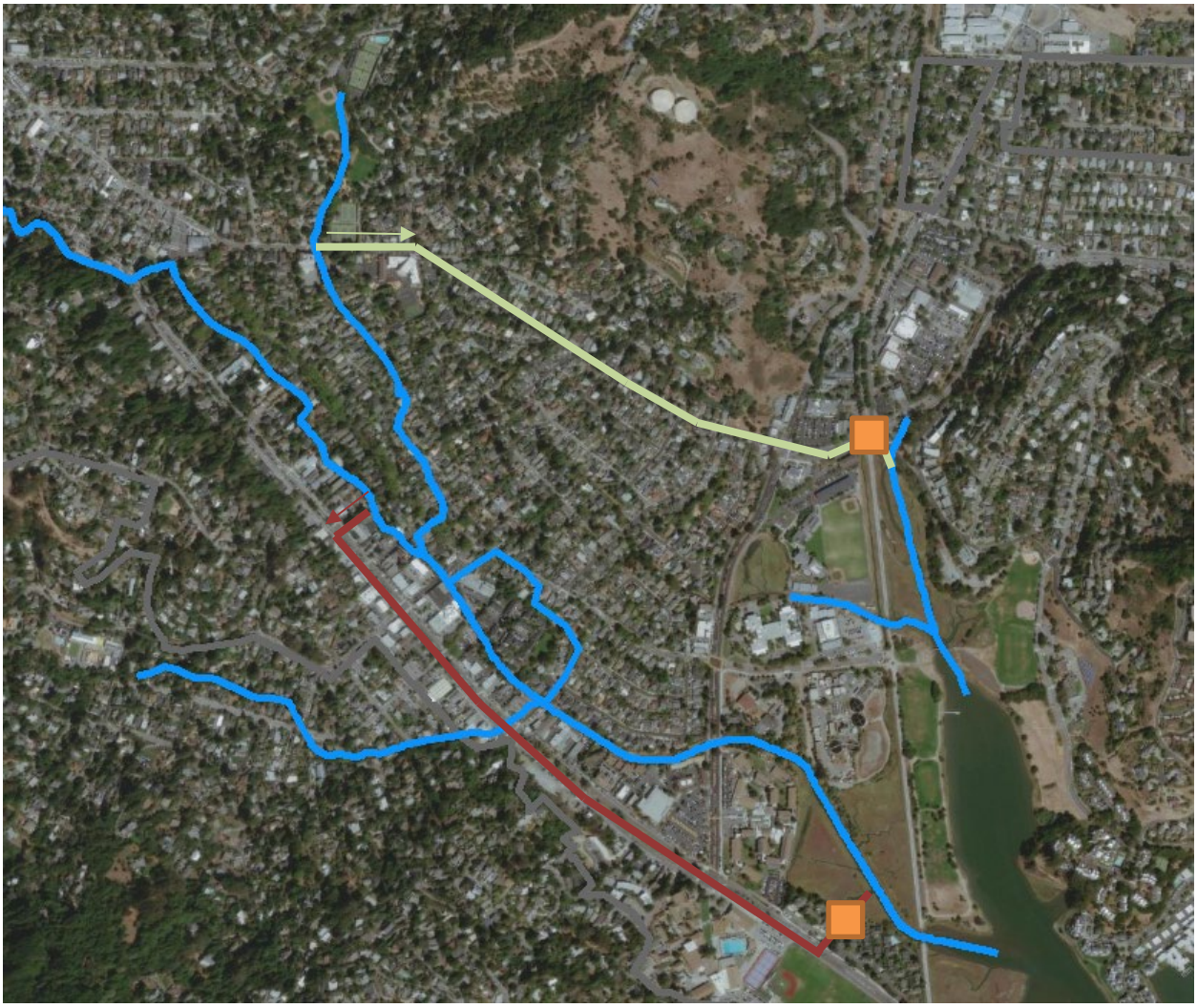


Figure ES-6. Miller Bypass (red) Blithedale Bypass (green) Pump Stations (orange)

Conceptual cost estimates were developed for the Miller and Blithedale bypasses including estimated utility conflicts, pump stations, and bypass structure themselves. The Miller bypass is estimated between $35 million (M) and $45M and the Blithedale bypass at $10M to $13M. Both bypasses are needed to alleviate flooding during the 10-year storm event. Both bypasses would total of $45M to $58M. Storm events larger in magnitude would overwhelm these bypass structures. Because the 10-year storm event impacts only 14 residential properties, the Task Force and Community did not show eagerness to support funding such large projects that only benefit a few at-risk properties.

Dredging

WRA Inc. Environmental Consultants attended a Task Force meeting to provide an overview of dredging in Marin County. WRA is located in San Rafael and has supported permitting for

several dredging projects throughout Marin. WRA presented the many factors to consider when dredging including timing, permitting, material disposal, and costs.

WRA presented the comparison of the dredging of Novato Creek which has an existing dredge permit and costs $1.5M every time it is dredged. It is anticipated that the costs for Mill Valley would be higher due to mitigation requirements for new dredge permits. Dredging projects are typically required every five to ten years as sediment will build back up. A recent study of the dredging on Novato Creek suggests that the dredging provides little benefit the hydraulic capacity (https://www.marinwatersheds.org/resources/publications-reports/novato-creek-local-levee-evaluation-2020).

The estimated additional capacity gained from dredging was compared to the bypass using the additional area provided. It was agreed by the Task Force, with consultant recommendation, that dredging was not going to provide significant reductions to flooding and have high costs in terms of both cost and impact to the environment and was not worth the small benefits are given to a handful of properties.

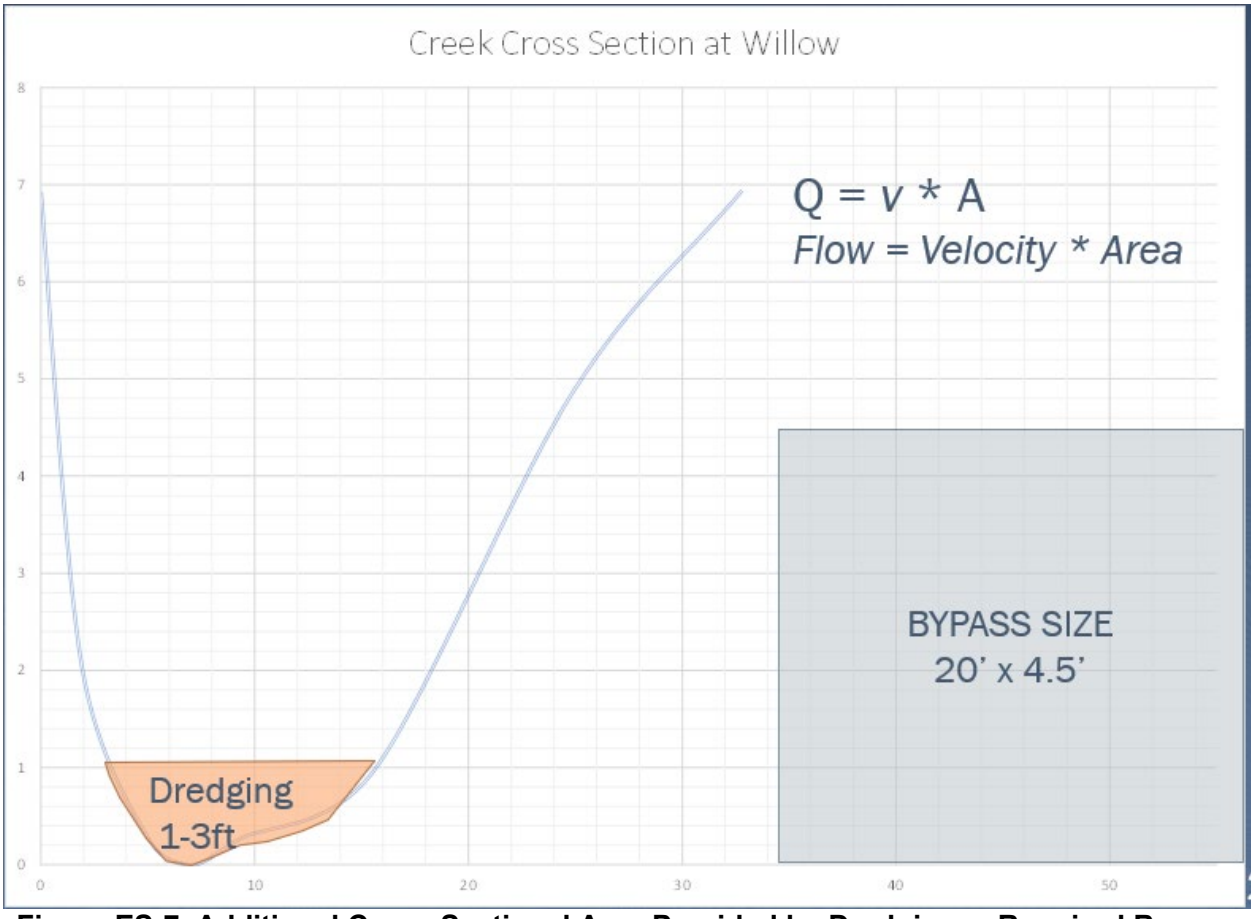


Figure ES-7. Additional Cross-Sectional Area Provided by Dredging v. Required Bypass for 10-year

Storm Drain System Mitigation Measures

A rainfall-runoff model was developed for the City which contains the portions of the overall storm drainage pipe and channel system that provide essential conveyance capacity for the

City's urban runoff. The model includes the main conveyance that is 18-inches or larger on the hillsides and 12-inches or larger in the downtown corridor as the majority of the pipes are only 12-inches in the downtown area, which is where the City experiences flooding.

Detailed review, field investigations, analysis, and modeling of the area's storm drainage system led to several conclusions. These conclusions have been utilized to recommend improvements to the system, which are preliminary in nature, to reduce flood risk within the City. Detailed project designs will ultimately require more data such as utility locations and topographical surveys.

A key finding from the evaluation is the lack of data on the storm drain system infrastructure. A majority of the data downloaded from Marin Map was outdated and missing key information such as pipe diameter and material. Limited fieldwork was performed to better understand model areas and pipe connections.

One of the Capital Improvement Projects (CIPs) recommended is for the City to hire a consultant to investigate actual conditions and digitally map the City's storm drain system.

The current physical condition of the drainage system was evaluated using CCTV camera inspections. The CCTV work focused on the City identified critical segments and segments. Most of the observed system is in good condition; however, there are reaches with debris and sediment, damaged pipes, and corrugated metal pipes (CMP) that are at or near the end of their useful life. Improvements for the condition related projects are detailed in this Master Plan.

The drainage system is overwhelmed in areas where the pipes do not provide the necessary capacity to convey the 10-year storm event. Some flooding may occur in areas where the surcharge is higher than the ground surface.

Generally, streets provide some capacity for conveying flow and it is not uncommon to observe gutter flows near or up to the top of adjacent curbs during high-intensity rainfall events. Flooding greater than a foot in-depth, however, is regarded as problematic regardless of the property damage caused by it. There is a concern because some hillside residential areas lack curb-and-gutter or have curbs that are too short to prevent water from flowing off the road and into private property.

The City's storm drain pipes discharge into numerous creek systems. When Creek levels are higher than the drain pipe outfall, the pipes cannot discharge into the creeks and some back up into streets. The evaluation of the pipe conveyance capacity looked at two different modeling scenarios: (1) Creeks Empty and (2) Creeks Full.

Pipes that showed surcharging when the Creeks were empty were put into a higher priority for capacity improvements than those that surcharge when Creek levels were high. To prevent the Creek Full surcharging issues, improvements need to be made on the creeks to lower the water surface so the pipes can drain such as the creek bypass channels.

A CIP for the storm drain system has been developed based on the model results and suggested improvements. It is roughly $8 million in capacity improvements, $8 million in condition improvements, $1 million for pump station rehabilitation, fixing flap gates, and detailed mapping of the storm drain system. This sums to a total CIP of $17 million with an annual budget of $250k to maintain, inspect, and clean the system. Recommended improvements are

intended for public rights-of-way and other City-owned property, not private facilities, or private property.

Low Lying Areas Mitigation Measures

Parts of the urbanized area of the City used to be salt marsh. Figure ES-7 depicts the historical boundaries of the salt marshes around Richardson Bay on the left and that same figure is superimposed over the current day USGS map to show the areas of urban development that historically were salt marsh on the right. With the watershed topography, large rainfall event convey significant runoff to the low lying marsh lands that have been occupied by homes built many decades ago when the City first developed.

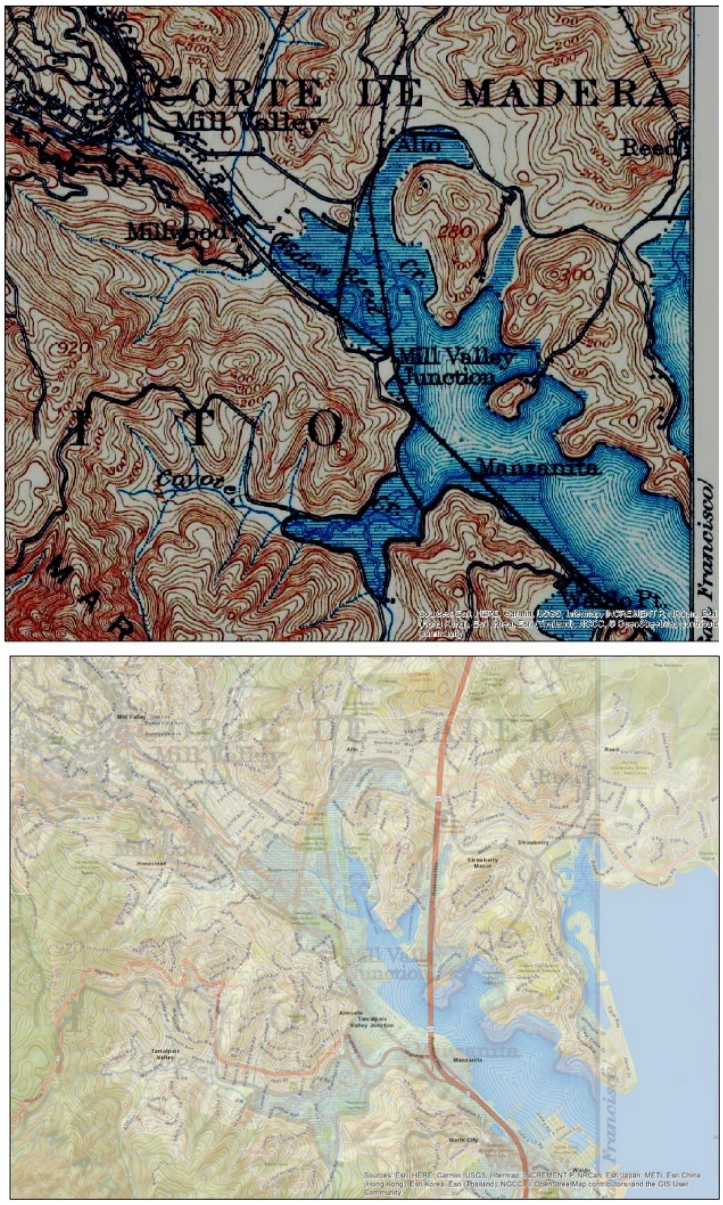


Figure ES-8. Historical Richardson Bay (top) Superimposed onto Current Day USGS Map (bottom)

These areas are currently impacted by high tides. Literature suggests that sea-level rise will significantly impact waterfront communities. It is anticipated that the flood-related issues due to high tides today will be worsened in the future. Marin County has developed a dedicated website for information including vulnerability assessments, sea-level rise scenarios, adaptation land use guidance, public outreach, and a board game.

In 2020 the initial planning memo was released for ideas on evolving shorelines in Richardson Bay. Many of the concepts for sea-level rise protection would protect areas of Mill Valley by raising the bike trail to protect against rising tides. The report can be downloaded at the link below.

https://www.marincountyparks.org/-/media/files/sites/marin-county-parks/projects-and-plans/restoration-and-fire-prevention/evolving-shorelines/bothinoppsandconstraintsmemo_final.pdf?la=en

The County has produced numerous planning documents that contain conceptual projects along Mill Valley's shoreline and regional projects such as a tide gate structure under Highway 101. These projects are conceptual in nature and funding mechanisms have not yet been identified.

https://www.marinwatersheds.org/resources/publications-reports/2015-richardson-bay-shoreline-study

This Master Plan includes these conceptual projects to help protect the City against rising tides. The link below contains information that the County has prepared on sea level rise impacts to Marin County.

https://www.marincounty.org/main/marin-sea-level-rise

Raising Residential Homes

The immediate mitigation measure that can be done while waiting for regional and citywide shoreline protection projects is for a homeowner to raise their home out of the FEMA mapped flood plain. This was one of the improvements suggested in the Stetson Report. Property owners should consider raising some extra height to protect against sea-level rise. The County recommends at least three feet above the FEMA base flood elevation (BFE) if feasible.

Raising homes was evaluated in this Master Plan to have a relative comparison of costs to the larger capital improvement projects such as dams and bypasses. The estimated cost to raise a home is between $100,000 and $150,000 and would be paid for by the private property owner. The creek bypass was around $58M and protected against a 10-year storm event. Seeing as only a handful of properties are inundated by the 10-year storm event, the cost to raise those homes is significantly less than the creek bypasses. City staff will work with the community, Planning Commission and Council to develop and implement a program that facilitates homeowner's ability to raise their homes in alignment with community's overall goals.

Owners implementing improvements on homes that reside within the FEMA mapped floodplain (100-year storm event) are required to raise their home to meet current building codes, which includes raising the finished floor elevation about the base flood elevation if the home improvements equal 50% or more of the assessed value of the home.

Several of the homes in the Sycamore and Plymouth neighborhoods have been raised to meet the building code for homes within a floodplain. Figure ES-8 shows the FEMA mapped flood zones within the City.

The County recently received a grant to raise some homes in Marin County which will serve as a good pilot testing program. The County has a Structure Elevation Program. Details can be found at the following website:

https://www.marincounty.org/depts/bs/board-actions-meetings/2020/july/july-28/structure-elevation-program

While properties within the City were eligible for this grant, the County has already selected the properties and does not have any more funding available at this time. Grant funding for home raising has to be done through a local agency and individual property owners can't apply for grants on their own.

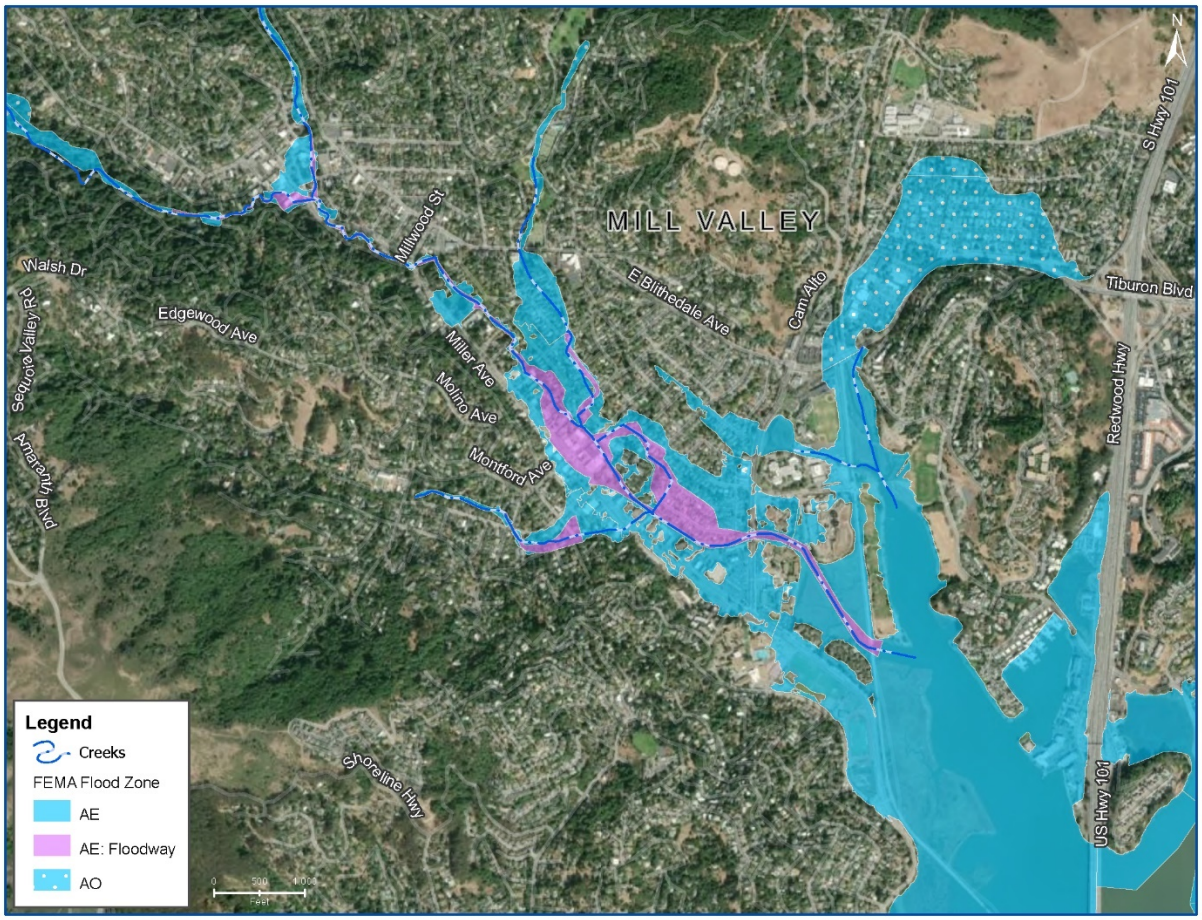


Figure ES-9. FEMA mapped Floodplain in the City

Work Products

This Master Plan is intended to function as a multipurpose flood management and storm drain system resource guide for the City's staff and residents. City engineers responsible for the storm drain capital improvements should find sufficient background information and data in this document to serve as the basis for storm drainage CIP implementation and/or modification. Improvement descriptions, maps, project costs, and other modeling data have been included in the appendices of this report.

Conclusion

The creek channels in the urbanized area of the City have less than 10-year capacity. A 10-year storm event has a 10% chance of occurring every year and presents risks to around 30 properties (see Table ES-1). Improvements along the creek channels are restricted by private property surrounding the creek channels. Dredging presents too many environmental impacts with limited additional capacity achieved.

While this Master Plan does not identify a "silver bullet" project that can alleviate the spills from the Creek, it does present the high costs associated with channel bypass and those costs can be compared to costs for raising homes. The channel bypasses are only designed for a 10-year storm event, while raising homes can provide protection to the 100-year storm event and include additional height to protect against future sea-level rise.

The Master Plan also highlights that the City lacks ownership to construct improvements along the creek channels. While this is not unique to Mill Valley, it conveys the importance that the City maintains creek setbacks to ensure that future development does not encroach upon the creek channels, limiting capacity even further.

The modeling conducted in this Master Plan provides the City with animations of where flood flows are conveyed. In the future, the City may elect to focus more on containment in the street through the use of curbs and/or sandbags to ensure that flood flows do not damage property.

The low-lying areas are susceptible to sea-level rise. The County has ongoing efforts to coordinate protection and has presented conceptual projects that are included in this Master Plan. Should homeowners seek immediate protection from flooding, they can raise their home above the 100-year flood plain and add additional height to protect from future sea-level rise. Raising homes has the least obstacles to overcome to achieving flood protection and might be the only option for 100-year storm event protection.

The City's urban storm drainage system has a backlog of projects to upgrade, maintain, and replace the system. This backlog of work is common among public agencies as storm drain systems are not clearly considered a utility in California and Prop 218 makes it challenging to get dedicated storm drain funding.

Storm drains do not receive dedicated funding like the sewer and water systems. The highest priority for the City should be a detailed mapping of the City's storm drain infrastructure to better understand and track maintenance and nuisance drainage issues. The City now has an inventory and a roadmap for City Council consideration.

This Master Plan provides a tool for citizens to better understand the quantifications of flooding and the necessary funding required to mitigate those risks. This study and proposed CIP are merely the conceptual starting point.

It is anticipated that City staff and/or their consultants will perform more detailed studies and alternatives analyses to identify the most affordable and effective improvement projects with information gathered as part of the design process, including detailed topography, utility conflicts, available easements and rights-of-way, construction impacts, long-term operation, and maintenance.

Per the California Environmental Quality Act (CEQA) Guidelines, Section 15262 (Statutory Exemptions), this Flood Management and Storm Drain Master Plan is considered a planning document. The adoption of this document is exempt from the requirements to prepare Environmental Impact Reports (EIR) or Negative Declarations (ND). However, CEQA must be satisfied for any capital improvement project described in this report that may be implemented by the City in the future through the preparation of an appropriate EIR, ND, or determined to be categorically excluded.

Flood Source	Mitigation Measure	Mitigation Level	Cost	Environmental Impacts	City Owned Property	Permitting/Design Duration	Construction Duration	Task Force Recommendation
CREEKS	Detention	10-year	$$$	3	Y	3	2	Does not resolve flooding issues
	Dredging	1-2-year	$$	3	Y	3	1	Does not resolve flooding issues
	Bypass	10-year	$$$	1	Y	2	2	Too expensive, only resolves 10-year
	Channel Widening	10-year	$$$	2	N	3	2	Do not pursue as not within public property
	Flood Walls	10-year	$$$	2	N	3	2	Do not pursue as not within public property
STORM DRAIN SYSTEM	Upsize Pipes	10-year	$$	1	Y	1	1	City to seek funding for improvements
	Repair Flap Gates	10-year	$	1	Y	2	1	City to seek funding for improvements
	Repair damaged pipes	10-year	$$	1	Y	1	1	City to seek funding for improvements
	Replace CMP	10-year	$$	1	Y	1	3	City to seek funding for improvements
	Maintain System	10-year	$$	1	Y	1	1	City to seek funding for improvements
	Map System	N/A	$	1	Y	1	1	City to seek funding for improvements
	Address nuisance drainage issues	10-year	$	1	Y	1	1	City to seek funding for improvements
LOW LYING AREAS	City shoreline improvements	2100 SLR	$$$	2	N	2	2	City to play support role to regional efforts
	Richardson Bay Tide Gate	2100 SLR	$$$	3	N	3	2	City to play support role to regional efforts
	Raising Home	100-year + SLR	$	1	N	1	1	City to work to develop and implement a program

LEGEND					
$	<$1M project costs	1	Low Environmental Impact	1	2-31 year to complete
$$	>$1M & <$3M project costs	2	Medium Environmental Impact	2	3-5 years to completed
$$$	>$3M project costs	3	High Environmental Impact	3	More than 5 years to complete

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Chapter 1: Introduction

1.1. Purpose

This Flood Management and Storm Drain Master Plan (Master Plan) provides the City with an inventory of mitigation measures and the associated costs for City Council consideration. The Master Plan further analyzes improvement projects developed by Stetson Engineers to alleviate creek flooding. The work from Stetson Engineers has been included into this report under Appendix A.

In addition, the Master Plan recommends improvement projects to reduce the risk of flooding in the City's urban storm drain system in the City right-of-way and the estimated costs. This Master Plan should be used to guide the City in planning, financing, engineering, and maintaining its infrastructure. Each chapter of this report is intended to help the City identify problems, manage resources, and provide cost information on potential improvement projects.

This chapter provides a general discussion of drainage and flood management systems and issues currently affecting the City, historic flooding, and a summary of FEMA floodplain mapping efforts within the City.

1.2. Setting

Mill Valley lies within the County Flood Control District Zone 3. This is also known as the Southern Marin Watershed which includes Flood Zones 3 and 4 that drains into northwestern Richardson Bay. The City is bound by Corte Madera in the north, unincorporated areas to the south, Mount Tam to the west, and Richardson Bay to the east. The *Southern Marin Watershed Guide* is included as Appendix B and details the watershed in Southern Marin and possible flood protection measures.

The City is predominantly urban and ranges in elevation from sea level to approximately 2,571 feet on the 1988 North American Vertical Datum (NAVD88). While the focus of the study is within the City limits, the drainage boundaries include areas outside of the City limits that drain into the City's drainage infrastructure. Figure 1-1 shows the vicinity of the City Limits and study area.

The primary drainage system through Mill Valley is the Arroyo Corte Madera del Presidio (ACMdP). Several tributaries drain to the ACMdP including Warner Canyon Creek, Cascade Creek, Old Mill Creek, and Reed Creek. Then there are two smaller tributaries to Richardson Bay from Ryan Creek and the Sutton Manor Watershed which capture runoff from the City. Urban runoff gets collected into pipes that ultimately drain to the creeks.

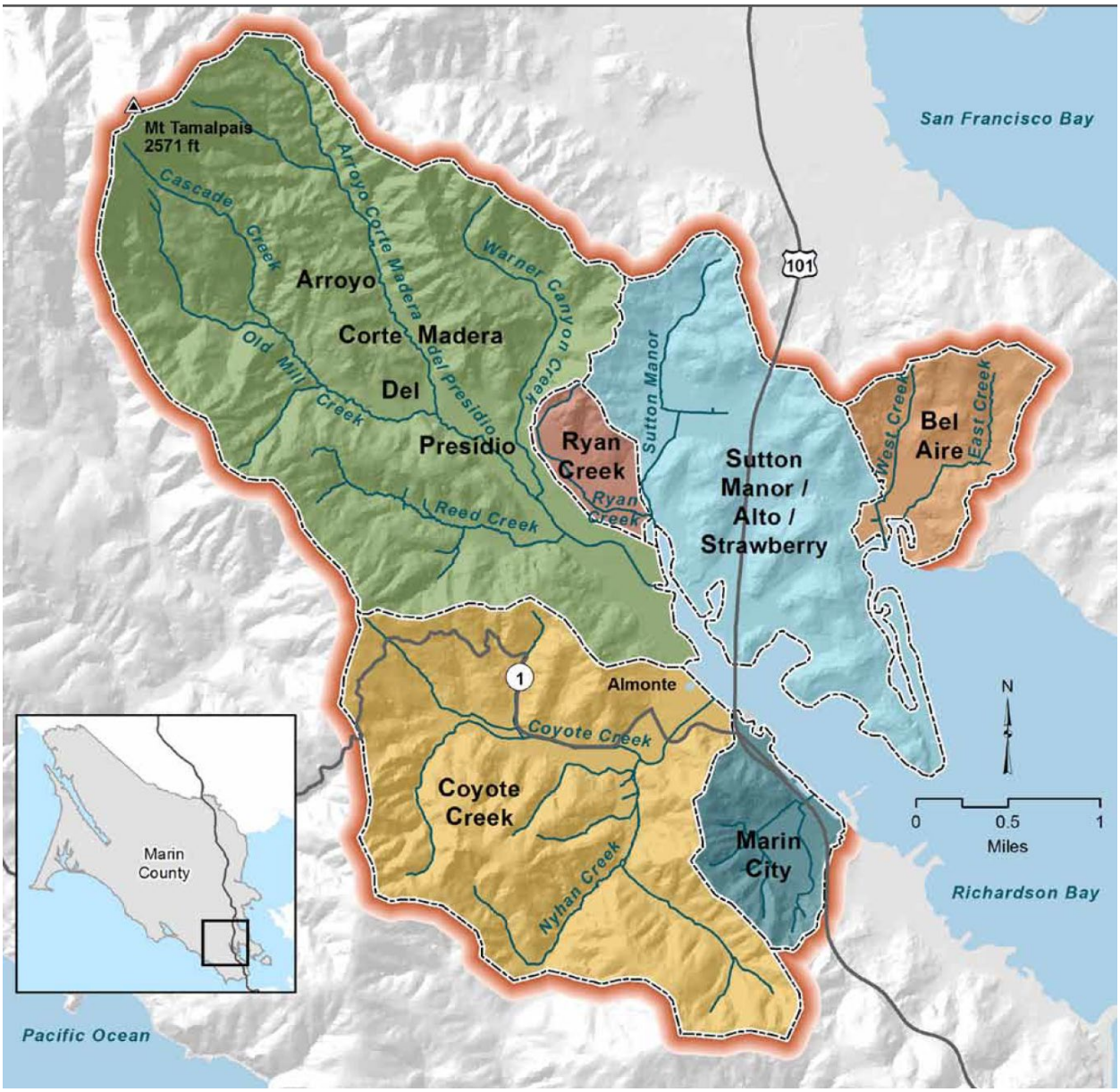


Figure 1-1: Mill Valley Watershed

1.3. Climate

From October to April, Mount Tamalpais and its ridges capture storms off the Pacific Ocean. An average of 55 inches of rain falls each year at the summit of Mount Tamalpais. Down on the flats of the City, 32 inches of rain fall each year.

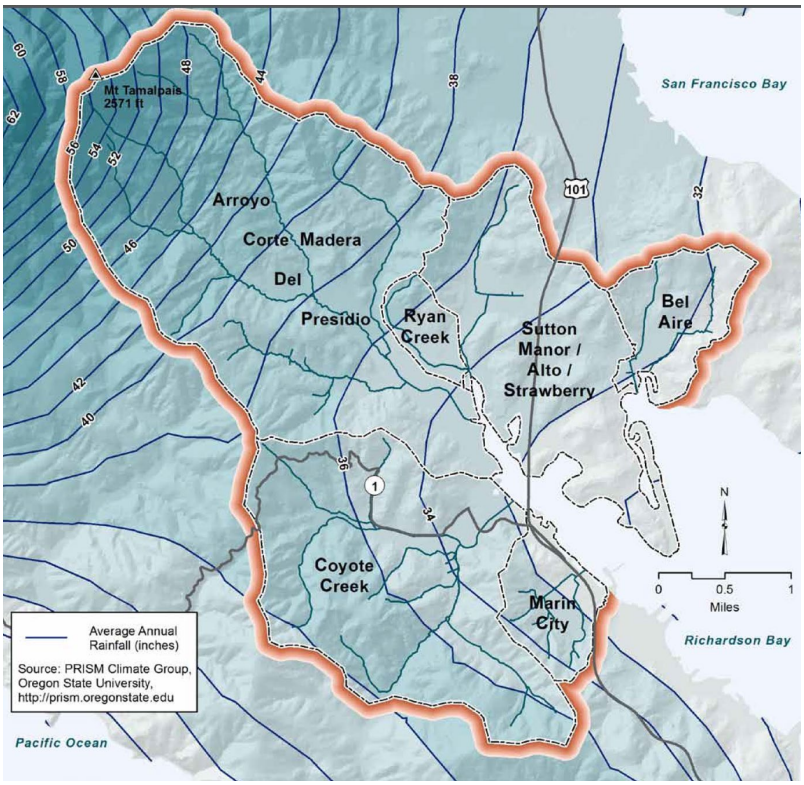


Figure 1-2: Mean Annual Precipitation

1.4. Flood Protection Facilities

Runoff generated by precipitation within the City and surrounding area is conveyed through various stormwater systems. The majority of urban runoff is captured by the storm drain system consisting of approximately 16 miles of pipes and one City operated pump station at Sycamore Park. The pipe system drains into the creeks and some discharge directly to Richardson Bay.

Runoff from the hillsides of Mount Tamalpais (Mt. Tam) is conveyed through a system of approximately 22 miles of creeks and streams that discharge into Richardson Bay. There is one pump station that is used primarily for managing tides and environmental habitat that is operated by the Marin County Flood Control & Water Conservation District. The City also maintains flap gates at the end of some of the storm drain pipes in the low-lying areas to prevent high tides backwatering into neighborhoods.

1.5. History of Flooding within Mill Valley

Historical flooding information is valuable in highlighting areas of recurring problems and prioritizing future improvements. City employees provided Schaaf & Wheeler information about areas with known flooding problems. The majority of the problem areas within the City are within the low-lying areas that are susceptible to flooding during King Tide events on a sunny day.

When a rainfall event peaks during a high tide, the impacts are worse. The low-lying neighborhood around Sycamore Avenue and Plymouth Street are hit the hardest. In addition, the area around the 2AM Club has notoriously been known for flooding. In 2016, the City installed two 48-inch diameter pipes under Miller Avenue which has alleviated the flooding around the 2 AM Club.

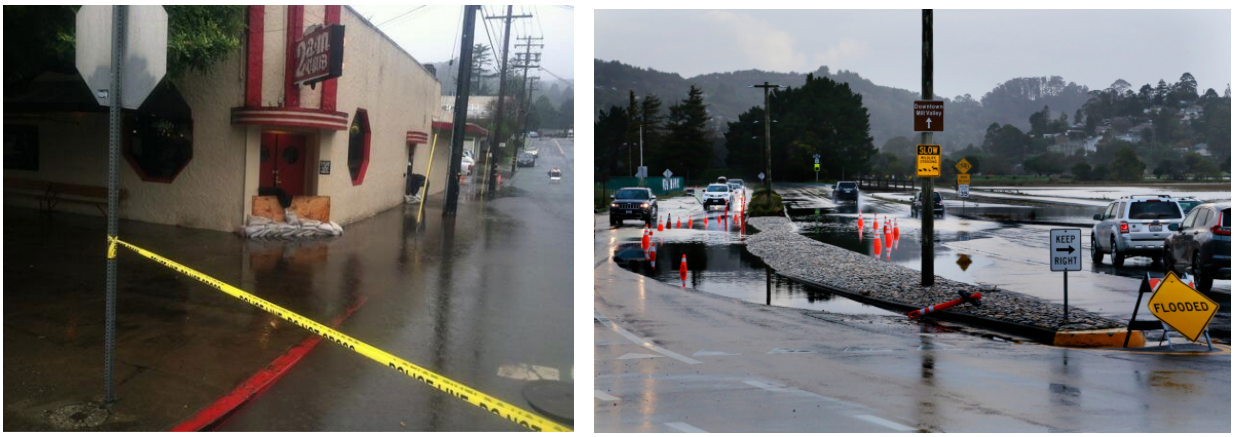


Figure 1-3: Flooding Events at 2am Club (left) and Streets around Mount Tamalpais HS (right)

The most recent storm event in the region occurred on New Year's Eve 2005 and caused a reported one billion dollars of damage across Marin County. Within the City of Mill Valley, 230 properties reported damages. This storm event was later classified as a 50-year storm event. This storm has a 2% chance of occurring each year.

1.6. Previous Studies

In 2008 the City hired Stetson Engineers to study flooding problems and describe measures to reduce flooding and flood damages from the mainstem of the Aroyo Corte Madera del Presidio (ACMdP) and its major tributaries Old Mill Creek and Warner Canyon Creek.

From 2008 to 2017, Stetson Engineers released several reports and memos focusing on potential solutions to reduce flooding upstream of Camino Alto (see Appendix A). Downstream of Camino Alto is coastal flooding which is being evaluated through the Southern Marin Watershed Program, a joint effort of the City, the County and the Marin County Flood Control and Water Conservation District (MCFCWCD).

1.7. Ongoing Studies

BayWAVE is Marin County's coordinated planning for sea-level rise along the bay shoreline. Adaptation planning is led by multiple agencies, partners, and municipalities, including the county. Marin County Department of Public Works has been awarded a grant from the SB1 funds through Caltrans to study adaptation to climate change addressing sea-level rise and current flooding at Highway 1 in Southern Marin.

The focus of the project will be increasing resilience for the area in conjunction with other complementary efforts addressing sea-level rise, tidal flooding, and habitat restoration at Bothin Marsh. More information on the County's ongoing efforts can be found here https://www.marincounty.org/main/marin-sea-level-rise.

OneTam is a partnership that mobilizes the resources of the National Park Service, California State Parks, The Marin Municipal Water District, Marin County Parks, and Golden Gate National Parks Conservancy to ensure a vibrant future for Mt. Tamalpais.

The organization is looking into climate change and sea-level rise and how those will impact the multi-use trail through Bothin Marsh. In October 2020, they released some planning concepts to raise the multi-use trail and to alleviate some of the flooding due to high tides and protect the multi-use trail, see Appendix C. More information can be found here at their website https://www.onetam.org/.

1.8. Master Plan Process

The City analyzed its major creek channels and storm drain system performance using the level-of-service criteria established herein to identify deficiencies and recommend capital improvements. Several tasks have been completed to reach this goal:

1) Reviewed existing data and field verify where necessary to complete representative models of the system.
2) Established storm drainage analysis methodologies and performance criteria with city staff.
3) Established tidal boundary conditions for creek model.
4) Created a hydraulic model using the GIS data provided by the City. Network features include:
   a) Manhole invert and rim elevations
   b) Pipe length, diameter, and material,
   c) Watershed runoff characteristics.
5) Performed hydrologic and hydraulic analyses of the existing storm drain facilities throughout the City for 10-year event based on methodology previously developed for use in Marin County. System deficiencies on city-owned facilities are categorized in terms of the risk to public safety, property, and infrastructure.
6) Ran storm drain system model under creek full and creek empty scenarios.
7) Updated Stetson Engineers Creek models into a two-dimensional model to further investigate mitigation measures from their study.
8) Inspected the condition of the drainage network using a pole-mounted camera and CCTV.
9) Identified projects that will improve storm drain system performance and reliability.
10) Outlined a prioritized Capital Improvement Program (CIP) for storm drainage infrastructure.
11) Summarized creek mitigation measures and costs.
12) Summarized regional efforts on addressing sea-level rise.
13) Further investigated raising home options for areas that are low-lying.
14) Presented mitigation measures to Task Force and collaboratively work to develop community presentation to convey the Master Plan process and recommendations to the community.
15) Presented concepts, findings, and recommendations in community and sought public feedback

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Chapter 2: Data Collection and Methodology

This chapter explains the criteria and methodology used to evaluate storm drain system performance and presents a summary of the data collected as a part of this storm drain master planning process and from previous drainage studies. Described are existing hydrologic and environmental settings of the City along with flood protection and storm drain facilities.

The criteria used to evaluate storm drain system performance must be technically sound yet simple to understand and apply. Ideally, the same methodology used to analyze system performance for this report will also continue to be used for future infrastructure design.

Schaaf & Wheeler applied NRCS hydrology methods to estimate storm runoff from current land uses for the Mill Valley Storm Drain Master Plan. This method is being used along with MIKE URBAN storm drain modeling software by DHI to evaluate system performance, identify deficiencies, and recommend necessary improvements.

Storm drain evaluation criteria described in this chapter have been discussed with and agreed upon by the City, Zone 3, and Task Force.

2.1. Data Sources

Several data sources were used and referenced to develop this study. A complete listing of all collected data and its source is included in Appendix D.

2.1.1. Topography and Aerial Imagery

All project data and results are in vertical datum NAVD88 (feet) and the State Plane (California Zone III) coordinate system. Marin County's 2010 LiDAR topography data (NAVD) with roughly half-foot accuracy (plus or minus 0.6 feet) was utilized for ground surface information throughout this study. High resolution digital aerial imagery provided by ESRI was also used.

2.1.2. GIS Data

Schaaf & Wheeler obtained GIS data from the City and MarinMap which aggregates local governments, special districts, and other public agencies infrastructure, planning and core administrative data to create a comprehensive GIS source for public use.

MarinMap data includes creek watershed delineations; city boundaries; parcels; creeks; building footprints; and storm drain pipes, manholes, catch basins, and pumps. Mill Valley zoning and land use were obtained from MarinMap.

In addition, Schaaf & Wheeler obtained National Resources Conservation Service (NRCS) soils data, National Land Cover data, FEMA floodplains, and aerial imagery. MarinMap GIS data completeness and accuracy varies and some information critical to accurately model the storm drain system was absent.

2.1.3. Field Measurements

Schaaf & Wheeler conducted selective field research to verify pipe sizes, layouts, and to measure invert depths. Because storm drain systems are designed for pressure flow and surcharge, the system's hydraulic grade lines (HGLs) are typically not governed by open

channel flow dynamics. For this reason, pipe diameters are a more critical component of the model than the invert elevations. Schaaf & Wheeler carried out multiple field visits to collect or verify data. City staff was able to field verify and answer questions about the storm drain system.

2.1.4. CCTV Inspections

Presidio Systems spent three days inspecting the drainage system using closed-caption television (CCTV) technology. It is cost-prohibitive to inspect the entire system; therefore, Presidio focused on regions with known issues and segments that were noted during the Schaaf & Wheeler fieldwork.

The CCTV data was reviewed by Schaaf & Wheeler and utilized to fill in system information gaps and develop condition improvements. Appendix E contains detailed CCTV maps.

2.1.5. Pump Stations

There are two pump stations within the City. The Sycamore Pump Station is the only City-owned and operated storm drain pump station. Pump station information is limited to pump set levels and hours run. Pump curves and flow data are not available. Stetson Engineers stated that the pump station has a capacity of approximately 7 cfs in the “Appraisal-Level Flood Study for Arroyo Corte Madera del Presidio” report prepared for the City in December 2012.

In 2020, the City took a look at the Sycamore Pump Station and believes that the pump station needs a full rehabilitation which could cost in excess of one million dollars. The City has approached Flood Zone 3 (FZ3) to collaborate future pump operations and ownership.

Zone 3 owns and operates a pump station located within the City that pumps Ryan Creek during the winter months. FZ3 staff control the maintenance and operations the pump station.

The Stetson Report indicated an improvement to the Ryan pump station to relocate the pump intake to the marsh area which would lengthen the pump operating time and help pump more water to the Bay and thus reduce floodplain inundation. The report does state that the improvements to the floodplain are minor. FZ3 staff have reviewed this project and included it in their Multi-Jurisdictional Local Hazard Mitigation Plan, but the project has not risen as a high priority project at the moment and is unlikely to receive grant funding.

2.1.6. FEMA Data

The City of Mill Valley was studied along with the rest of Marin County. The initial Flood Insurance Study of Marin County was published May 4, 2009, with the latest revision published August 15, 2017. The parts of the City that are low-lying and adjacent to creeks are located in the FEMA floodplain or floodway as shown in Figure 2-1.

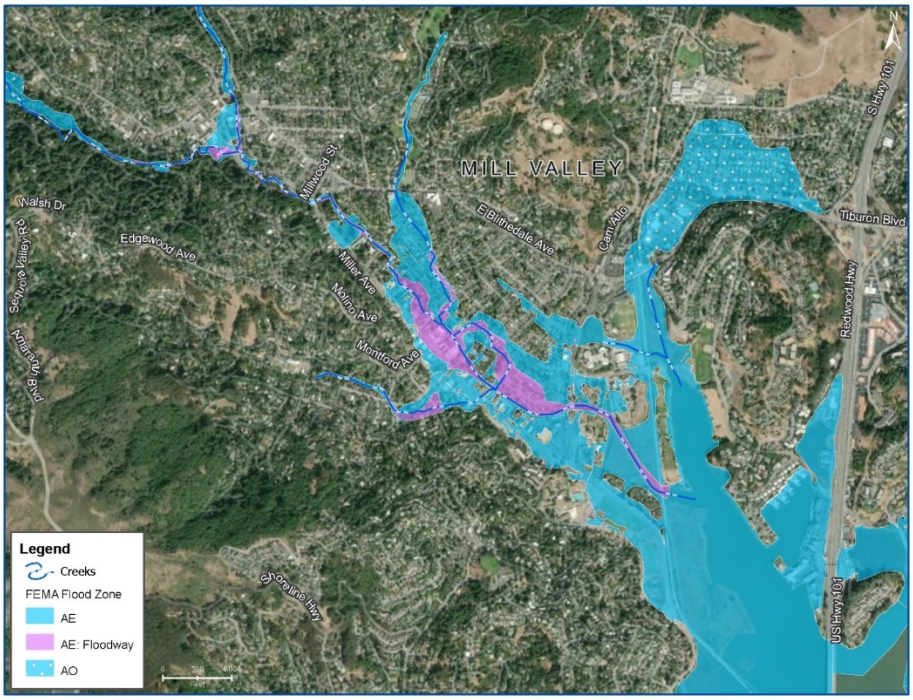


Figure 2-1. FEMA mapped Floodplain in the City

2.2. Land Use Data and Runoff Characteristics

2.2.1. Land Use

The land use conditions used in this study reflect the existing conditions within the City of Mill Valley drainage area. The land use data is based on the City of Mill Valley's current zoning, which was obtained as a GIS shapefile from MarinMap.

In general, land use is primarily single-family residential, interspersed with multi-family residential, commercial, educational facilities, and open space. The single-family parcels have a wide variety of acreage with different runoff characteristics so that land use type has been divided up. The various land use descriptions within the GIS database are summarized in Table 2-1. A map showing the land-use types within the study area are shown in Figure 2-2.

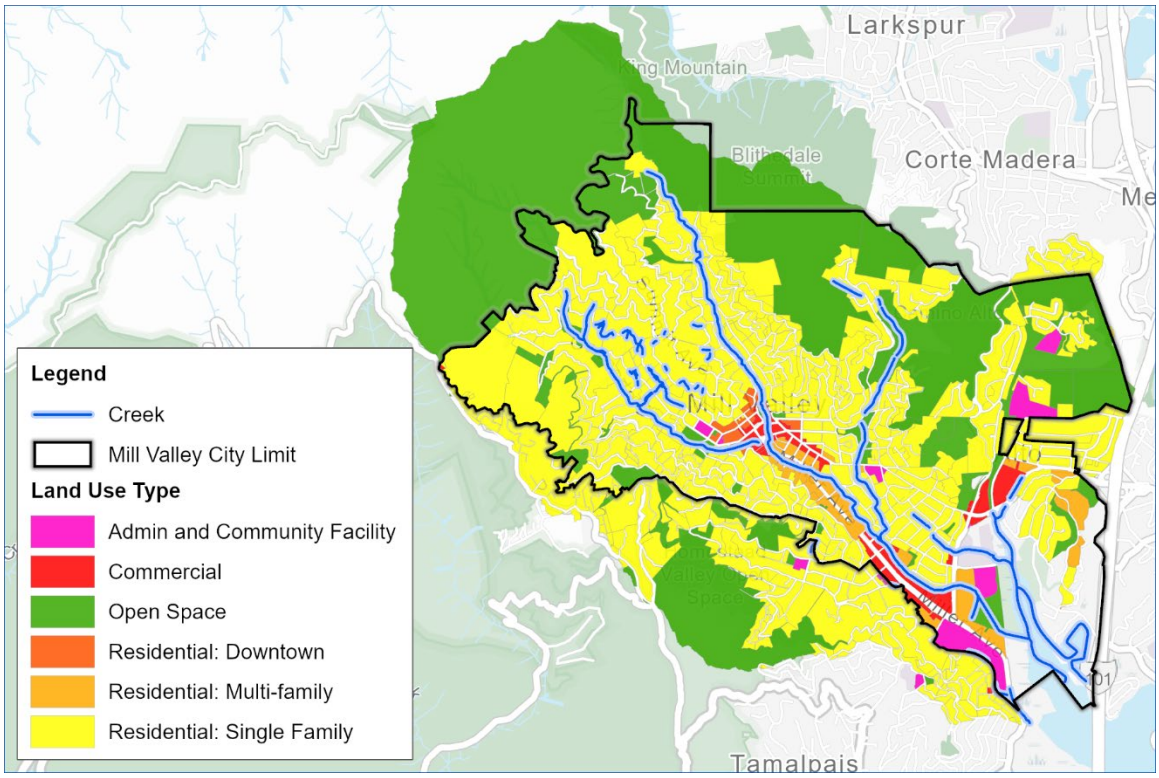


Figure 2-2: Mill Valley Land Use

2.2.2. Percent Impervious Surface

By sampling representative sub-areas in GIS for each land-use type, the percentage pervious, and impervious cover was estimated based on aerial images. Percent impervious values for each land use type are summarized in Table 2-1.

Table 2-1: Percent Impervious Surface Comparison and Assumed Model Values

Land Use Type	Percent Impervious
Admin and Professional	85
Community Facilities	NA*
Downtown Commercial	90
Downtown Residential	75
General Commercial	85
Limited Commercial	85
Neighborhood Commercial	85
Open Space	10
Residential Multi-family	80

Land Use Type	Percent Impervious
Residential Single Family	65
Single Fam Res (min 6,000 SF)	65
Single Fam Res (min 7,500 SF)	65
Single Fam Res (min 10,000 SF)	65
Single Fam Res (min 15,000 SF)	65
Single Fam Res (min 20,000 SF)	65
Single Fam Res (min 30,000 SF)	50
Single Fam Res (min 1 acre)	45
Single Fam Res (min 10 acre)	10
Streets	98

2.2.3. Soil Classification

Figure 2-3 presents a map showing the hydrologic group of the soils found in the study area. The Natural Resources Conservation Services (NRCS) has classified soils into four hydrologic soil groups ('A', 'B', 'C', and 'D') according to their infiltration rates.

Group 'A' soils have low runoff potential when thoroughly wet and typically consist of sand or gravel type soils. Group 'B' soils are moderately well-draining when thoroughly wet and consist of loamy sand or sandy loam textures. Group 'C' soils have moderately high runoff potential when thoroughly wet and consist of loam, silt loam, sandy clay loam, clay loam, and silty clay loam textures. Group 'D' soils have high runoff potential when thoroughly wet and consist of clayey textures. All soils with a water table within 24-inches of the surface are in Group 'D'.

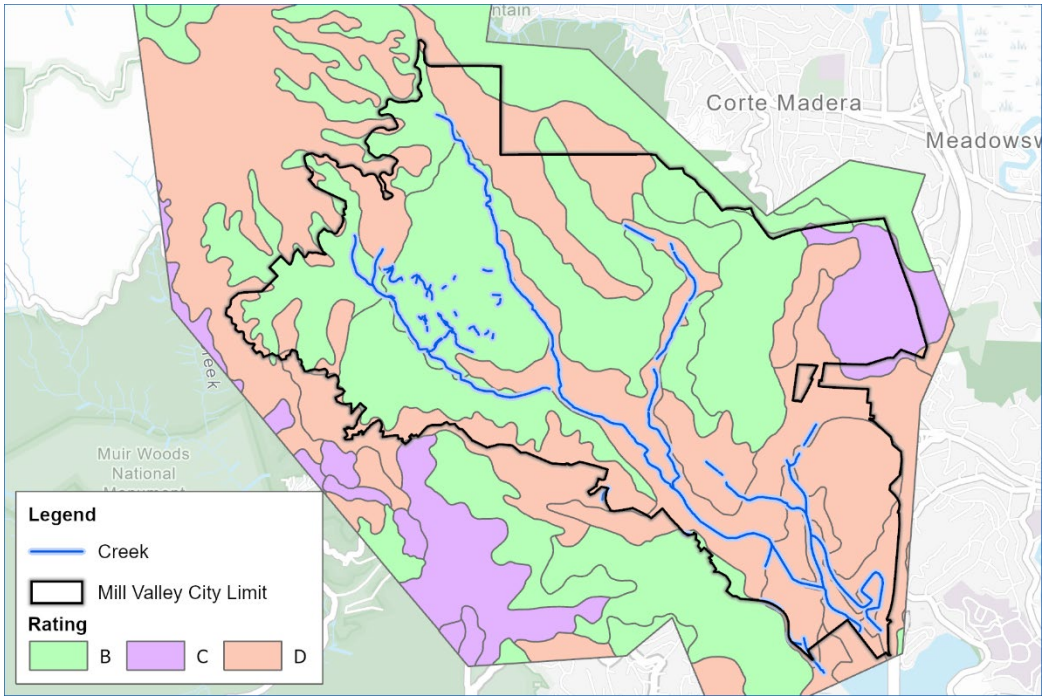


Figure 2-3: NRCS Soil Classification in Mill Valley

2.3. Data Quality

There were some variations and inconsistencies in the quality and accuracy of available data. While some information was present in County GIS files at the start of the study, the invert of many nodes (manholes, inlets, and outlets) was not included.

Record drawings used to fill in these data gaps where available while the remaining missing inverts were estimated based on the data already available in GIS, depth data collected during field visits, and terrain data. In addition, field maps were given to the maintenance crews to collect measurements in the field while conducting annual maintenance of the storm drain catch basins. This information has also been entered into the GIS data.

The City has an estimated 15.7 linear miles of pipe, 21.7 miles of open channel, and 1,300 nodes (including manholes, catch basins, detention basins, inlets, and outlets); not all of these components are analyzed in detail. The hydraulic model contains all known pipes 12-inches in diameter or larger in the downtown area and 18-inches in diameter and larger in the remaining area, primarily belonging to the City of Mill Valley.

After an initial model was built and missing data were estimated or interpolated, results revealed some locations where further verification was necessary. These areas were investigated with help from the City.

2.3.1. Modeled Data Assumptions

To create a uniform ground surface for hydraulic modeling, rim elevations at all system nodes have been extracted to the system node shapefile from the DEM terrain model. Invert elevations were assigned to each node based on inverts or depths from GIS data or field measurements where available.

Where node depths were unknown or missing, invert elevations were assumed or interpolated for modeling purposes. These inverts were estimated based on the nearby nodes with known depth data. Pipe profiles were investigated thoroughly to identify areas where assumed inverts resulted in negative slopes or other unrealistic conditions.

For these cases, invert elevations were interpolated between nodes with known depth data using the interpolation tool in the MIKE URBAN (MU). Once surcharged, storm drain pipe slopes (and therefore inverts) do not affect hydraulic analyses.

Inverts and ground elevations in the model were checked manually for irregularity (e.g., ground elevations below the top of pipes, negative pipe slopes, and incorrect pipe diameters) and corrected, as necessary. Pipe diameters missing from GIS data were assigned based on field measurements where available or have been assumed based on the connecting pipes or the pipe location.

2.4. Evaluation Criteria

Hydrologic analysis and one-dimensional (1-D) hydraulic models were created for the 10-year event. The 10-year storm event was used as the design event for the storm drain system evaluation since the 10-year level-of-service standard was agreed upon by the City and Task Force as the governing criteria for general storm drain system conveyance. This is a typical level of service for municipalities in the Bay Area.

Improvements are recommended to reduce the 10-year hydraulic grade to no higher than 0.5 foot above the rim elevation at any location. These criteria minimize the risk to private property and public safety and are common standards used throughout California by other jurisdictions.

2.5. Model Development

The Danish Hydraulic Institute (DHI) MIKE-URBAN (MU) software with MOUSE solver is selected to model the City of Mill Valley storm drain system. MU is a package of software programs designed by DHI for the analysis, design, and management of urban drainage systems, including stormwater sewers and sanitary sewers.

The MU model works within the ArcMap GIS interface and can simulate runoff, open channel flow, pipe flow, water quality, sediment transport, and two-dimensional surface flow. The City's modeling package consists of two interrelated products:

1. MIKE-1D is a group of hydrologic, hydraulic, water quality, and sediment transport modeling modules that can be used together or used independently. The modules used in the Mill Valley storm drain model include the Surface Runoff Module, which computes surface runoff using one of five computational methods; and the Hydrodynamic Pipe Flow Module, which calculates an implicit finite-difference numerical solution of the St. Venant flow equations for the modeled pipe network.

2. MIKE-URBAN (MU) is an ArcMap based program that includes tools specifically designed to develop urban drainage models. MU provides a graphical user interface for data input and editing and serves as a bridge between ArcMap GIS and the MOUSE modeling program. Capabilities of MU include import and export of model data, network editing and gap-filling, catchment delineation, and network simplification. MU can also be used to present results including plan, longitudinal, and cross-section views; animation of results; presentation of flooding including water depth and pressure; and overlay of results on background graphics such as maps or aerial photos.

The entire City's "main" conveyance pipes are included in a single model. Small lateral pipes are not included.

2.6. Hydrologic Calculations

Methods used in this master plan to estimate peak stormwater flow rates and volumes require the input of precipitation data. Since it is impossible to anticipate the impact of every conceivable storm, precipitation frequency analyses are often used to design facilities that control storm runoff.

A common practice is to construct a design storm, which is a rainfall pattern used in hydrologic models to estimate surface runoff. A design storm is used in place of a single historic storm event to ensure that local rainfall statistics (i.e., depth, duration, and frequency) are preserved.

When combined with regional-specific data for land use and loss rates, the model should produce runoff estimates that are consistent with frequency analyses of gauged stream flow around Marin County. In other words, the 10-year design storm pattern used for MU modeling creates results consistent with 10-year storm runoff events.

Precipitation frequency analyses are based on concepts of probability and statistics. Engineers generally assume that the frequency (probability) of a rainfall event is coincident with the frequency of direct stormwater runoff, although runoff is determined by several factors (particularly land use conditions in the basin) in addition to the precipitation event.

This study utilizes hydrology methodology developed by Schaaf & Wheeler for the "Cove Pump Station and Collection System Hydrology & Hydraulic Study" for Marin County in July 2016 which was calibrated for Marin County and is suitable for future hydrologic studies in County. This memo is included as Appendix F to this Master Plan.

2.6.1. Point Precipitation Values

Point precipitation value estimates for several randomly generated locations in the study area were obtained from the NOAA Atlas 14 website1. Point precipitation values generally decrease across Mill Valley from west to east due to elevation and proximity to the bay. The study area is divided into four bands of point precipitation values. The 10-year 24-hour storm depths in the study area range from 7.42 inches to 5.37 inches as shown in Figure 2-4.

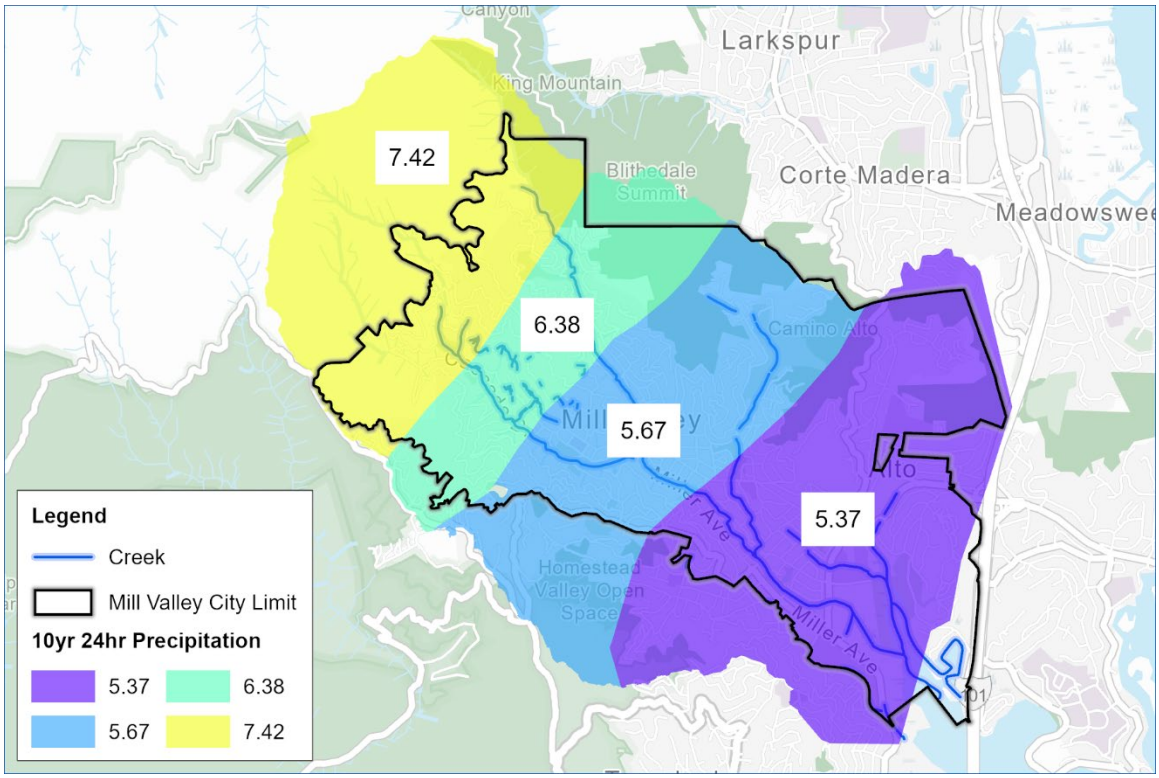


Figure 2-4: Precipitation Depth (inches) Values in Mill Valley

[1] PF Map: Contiguous US. https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=ca. Accessed on 2019.

2.6.2. Rainfall Depth and Pattern

The rainfall distribution pattern for this study is based on the 48-hour New Year's 2005 storm. However, the 48-hour storm was shortened to a 24-hour design storm and balanced with NOAA Atlas 14 statistics. The design storm is balanced to the following durations: 15-minute, 30-minute, 1-hour, 2-hour, 3-hour, 6-hour, 12-hour, and 24-hour.

The final 24-hour design storm pattern was developed using a 10-minute time-step and the precipitation frequency estimates were applied to the design storm pattern to develop the 10-year design storm event. See Figure 2-5 for the 10-year, 24-hr rainfall pattern.

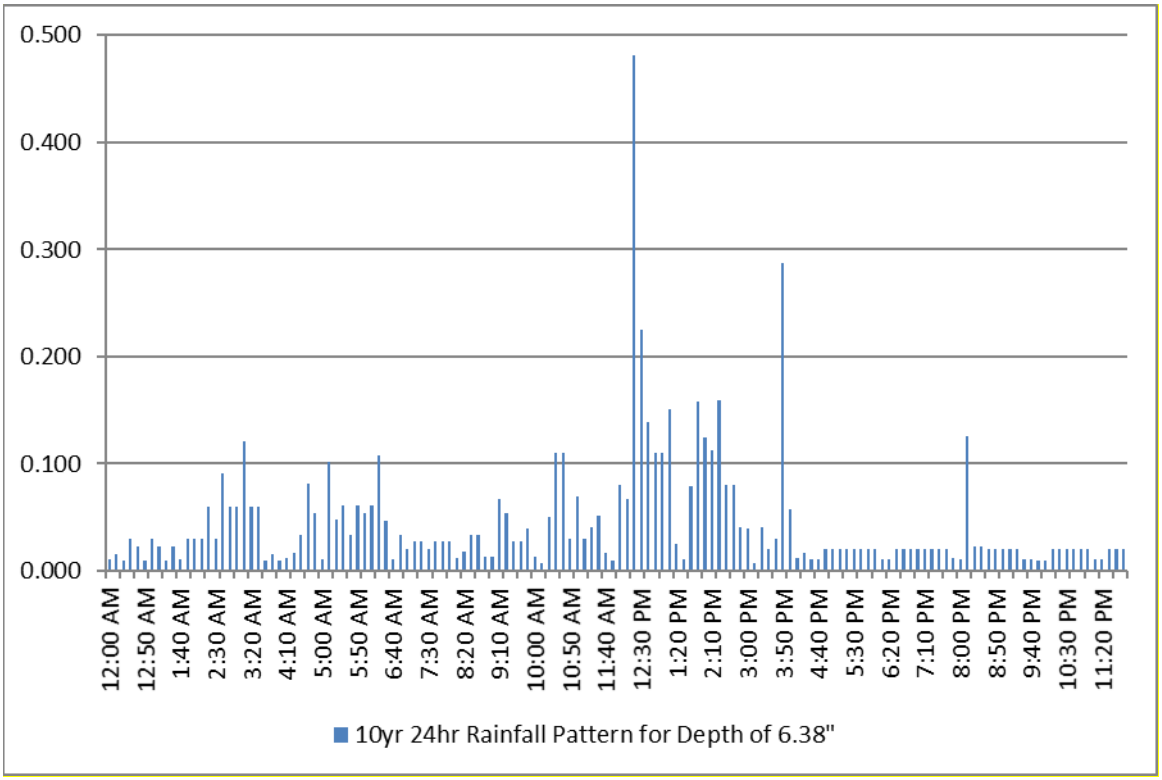


Figure 2-5: 10-year, 24-hour Design Storm Pattern

2.7. Catchment Data

The Mill Valley study area is divided into 382 drainage areas, called catchments. The catchment delineations completed by Schaaf & Wheeler rely on engineering judgment and experience using contours, lot lines, storm drainage systems, and aerial imagery.

Urban catchment data includes the boundaries of each drainage catchment, along with relevant physical and hydrologic parameters including surface area, land use characteristics, and parameters used to calculate basin lag times.

2.7.1. NRCS Curve Number

The NRCS Curve Number (CN) methodology was used to determine stormwater runoff from each catchment with design precipitation. Curve numbers are used to characterize basin infiltration and runoff potential based on a combination of land use and soil characteristics

discussed in Section 2.2.3 and a parameter known as antecedent moisture condition (AMC). AMC is defined as the moisture content of soil prior to any precipitation event. AMC is characterized by the NRCS as:

- AMC I Soils are dry
- AMC II Average conditions
- AMC III Heavy rainfall, saturated soil

A calibrated AMC value is used to properly convert the rainfall event's frequency of occurrence into the equivalent frequency of runoff event. The standard AMC assumption for a 10-year model is II, lying between heavily saturated and average conditions; AMC calibration for the design storm used in this study yields an AMC of I ½.

Curve numbers vary from 0 to 100, with a CN of 0 representing no runoff from a basin and a CN of 100 meaning that all precipitation will runoff. Pervious surface curve numbers were applied to the Mill Valley model based on land use and soil type. The area-weighted CN for the previous portion of each catchment is adjusted to AMC II 1/2 for use in the 10-year analysis. The impervious portion of the catchments was assigned a CN of 98.

2.7.2. Basin Roughness Factor (N-factor)

The basin roughness factor, also known as the basin friction factor, is used to describe the condition, vegetation level, and overall clearness of a representative watercourse throughout a catchment. This is typically determined through site visits and/or a combination of aerial photography. The N-factor value is based on the 2011 National Land Cover Dataset (NLCD). For this study, the N values are summarized in Table 2-2 below.

Table 2-2: Basin Roughness Values

Classification	Basin Roughness
Water	0.01
Developed, Open Space	0.06
Developed, Low Intensity	0.06
Developed, Medium Intensity	0.05
Developed High Intensity	0.04
Bare Rock/Sand/Clay	0.04
Deciduous Forest	0.10
Evergreen Forest	0.10
Mixed Forest	0.10
Shrub/Scrub	0.09
Grasslands/Herbaceous	0.04
Pasture/Hay	0.05
Cultivated Crops	0.05
Woody Wetlands	0.08
Emergent Herbaceous Wetlands	0.08
Water	0.01

2.7.3. Basin Lag

This study uses the Soil Conservation Service (SCS) Dimensionless Transform method to derive a Synthetic Unit Hydrograph (UH). This method was chosen because it is a commonly accepted hydrology method, and it works well with the MU model.

Two parameters are required for this methodology; the area, as discussed previously, and a timing parameter. The timing parameter, called basin lag (hour), is a function of basin geometry and basin roughness, or basin N-value shown in the following equation.

$$Lag = KN\left(\frac{L * L_C}{\sqrt{S}}\right)^{0.38}$$

where:

Lag SCS basin lag (hours)

K for L> 1.7miles K = 24, for rest K = 15.22 + 2.1464*L + 8.6981/L

N Basin roughness factor

L length the longest flow path (miles)

Lc length along flow path from a point perpendicular with the basin centroid to its outlet (miles)

S average stream slope (feet/mile)

2.8. Model Calculations

MU pipe flow calculations require network data, operational data, and boundary data as input. Network data consists of the pipe network elements including nodes (manholes, outlets, and storage nodes) and links (pipes, culverts, and open channels).

Detailed analyses of peak stormwater discharge is performed by the MU program, which also determines the flow condition in each drainage system element. The MU technical manuals may be referenced for a more detailed description.

2.8.1. Links

Parameters required to describe model links include the name of upstream and downstream nodes, pipe shape and dimensions, material or roughness, and upstream and downstream inverts. Structural system elements are modeled as functional relationships connecting two nodes in the system or associated with one node in the case of free flow out of the system.

Operational data consists of parameters that describe how these elements function in the network. Boundary data for the pipe flow computation can include any external loading, inflow discharges, water levels at interaction points with receiving waters, as well as the results of a run-off calculation.

Pipes are modeled as one-dimensional closed conduit links that connect two nodes in the models. The conduit link is described by a constant cross-section along its length, constant bottom slope, and straight alignment. Unsteady flow in closed conduits is calculated using conservation of continuity and momentum equations, distinguishing between pipes flowing partially full (free surface flow) and completely full (pressurized flow).

Most pipes within the Mill Valley model are modeled as reinforced concrete pipe (RCP) with a Manning's 'n' of 0.015 or corrugated metal pipe (CMP) with an 'n' of 0.024.

2.8.2. Nodes

Parameters required to describe nodes include x and y coordinates of the node, a unique name, node type (junction, outlet, or basin), depth and invert levels, and water levels at outlets. Hydraulic losses at junctions (manholes, inlets, or intersections) can be significant in pressurized drainage systems. Losses can vary due to construction methods, conditions, and shape. The MU Weighted Inlet Energy Method is used for this study.

2.8.3. Outlet Boundary Conditions

Pipe network outlets can be modeled with either a free outlet or a water surface elevation (fixed or variable with time) which captures backwater effects due to the receiving water levels. The modeled system contains 82 nodes modeled as outlets.

The system was modeled with two boundary conditions: "free outfall" which simulates receiving water levels below the pipe outfall elevation, and "creek full" which simulates the water surface elevation of receiving creek at top of the bank elevation.

2.8.4. Calibration and Validation

The hydrologic method used for this study is based on the study of Cove Pump Station for Marin County where the AMC was calibrated to a value of II ½ for the 10-year storm event. Hydrologic model results were compared to those from the Cove

Pump station project results using a flow per square mile comparison to ensure that hydrologic flows were within reason. The storm drain pipe mode results of the storm drain model were validated with city staff to ensure that known issue areas were showing up in the model results.

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Chapter 3: Storm Drain System Evaluation and Mitigation Measures

3.1. Overview

A performance and condition analysis of Mill Valley's storm drain system is the primary focus of the storm drain master plan. This chapter:

- Describes City's storm drainage facilities and known drainage system issues.
- 10-year flooding depths predicted by the one-dimensional model.
- Details observed in condition-related issues.
- Identifies and prioritizes improvement projects that alleviate or minimize flooding due to undersized pipes or pumps.
- Identifies and prioritizes projects to fix condition-related issues and improve system reliability.

3.2. Prioritizing Deficiencies and Needed Capital Improvements

Storm drain systems in Mill Valley convey the majority of stormwater runoff toward the creeks and Richardson Bay through storm drain systems consisting of gutters, catch basins, pipes, and channels.

Recommended improvements have been prioritized based on the results of the above process, combined with consideration of the anticipated severity of flooding at each location and the benefit/cost relationship of proposed improvements. The following color code is used to highlight project prioritization:

Priority	Description
High Priority	Projects under this category eliminate areas of 10-year flooding with significant depths, or address areas where City staff has indicated frequent and/or significant historical flooding issues. These projects improve conditions at locations with the deepest and longest-duration flooding situations.
Moderate Priority	These improvements are intended to contain most of the 10-year flooding within the street right-of-way. The duration and depth of flooding corrected by a moderate priority improvement is less than that of a high priority improvement.
Low Priority	Low priority improvements are aimed at containing the remaining 10-year flooding in the street right-of-way. The areas of flooding addressed by low priority projects are much smaller than those of moderate and high priority projects.

This chapter summarizes improvements to City-owned systems needed to achieve a level-of-service characterized by flooding no greater than the street level for a 10-year event. Improvements have been grouped to reflect projects that could feasibly be undertaken simultaneously. Project naming conventions use major street names where possible. Project names and unique numerical IDs assigned to each project identify improvements in maps and tables included in this SDMP.

3.3. Known Nuisance Drainage Problem Areas

City staff has been notified and is aware of the following drainage issues:

- Presidio Ave and Grove Street
- Miller Ave and Simon Way
- Rose Ave near Dots Lane
- Birch St and Edgewood Ave
- Throckmorton Ave and Olive St
- Throckmorton Ave and Madrona St
- Reed Creek at ACMdP Creek
- Meadow Dr at Tower Dr

This Master Plan has not evaluated responsibility or developed detailed mitigation options for nuisance drainage problems. These locations have been used as a sample set to predict annual funding levels that may be necessary to address nuisance issues that may be the responsibility of the City.

3.4. Evaluation of Storm Drain Capacity

The conveyance capacity of Mill Valley's storm drain system was analyzed with current land use conditions during the 10-year design storm.

- Areas of notable flooding based on historic occurrences and results of the MIKE URBAN (MU) models are discussed.
- Improvement projects are recommended based on required additional flow capacity.
- Projects have been developed by upsizing existing pipes in the MU model until flooding is contained within the street right-of-way for the 10-year event.

It is impossible to entirely remedy every drainage issue throughout the City, either due to local topography (for example, at minor 'bathtub' areas that can occur in parking lots where private systems are not modeled); however, the majority of model-predicted flooding due to storm drain pipe system surcharge can be mitigated with the capital improvements proposed. Appendix G contains electronic modeling files.

It should be noted that while these capital improvements improve the storm drain piped system and alleviate flooding, they do not resolve the flooding issue related to the undersized creek channels. So, in larger storm events there is a likelihood of water in the streets from the creeks.

3.4.1. Design Criteria

Storm drain system improvements are designed in this SDMP such that the 10-year storm runoff would not be higher than the top of the gutter at any location.

Similar standards are common practice to prevent flooding during more frequent storm events and utilize street conveyance capacity and storage in large, less frequent events. This standard will form the basis of the storm drain master plan effort and the development of a capital improvement plan. It is important to note the lack of curb-and-gutter on many City streets reduces the system's ability to convey runoff.

While specifying a design standard such as the conveyance of 10-year runoff is the most important element in governing the sizing of a system, minimum pipe diameter and slope may also be established to reduce maintenance requirements through the life of the system.

Where feasible, reinforced concrete pipe (RCP) with a minimum pipe size of 18-inches should be used. Setting such requirements helps to ensure that pipes remain clean and clear of blockage to the greatest extent possible. The additional construction costs are anticipated to be less than the long-term maintenance considerations when comparing and 12-inch pipe to an 18-inch pipe.

A citywide model was developed to analyze the 10-year event for existing land use conditions and recorded soil conditions. The model revealed that a portion of the City's storm drain system does not meet the 10-year criteria.

While containing the 10-year below the top of curb forms the foundation of this analysis in general, at certain project locations this standard is not economically feasible to achieve. This does not necessarily mean that a standard should not be enforced on future construction; however, a CIP may deviate from the standard for several reasons (for example, utility conflicts that make meeting a standard prohibitively expensive).

3.4.2. System Evaluation

This Master Plan focuses on the major conveyance components within the City; therefore, not all the City drainage infrastructure is in the models. However, the entire drainage areas contributing runoff within the City boundaries and including areas outside the City boundary that drain into the City are modeled for the runoff they generate. The pipe model focuses on the larger conveyances that are 18-inches and larger. In the downtown corridor, pipes 12-inches and greater are modeled. The Capital Improvement Projects (CIPs) identified from the system evaluation and summary of associated cost estimates are presented in Chapter 7.

3.4.3. Modeling Results

MU analysis of the City of Mill Valley system for the 10-year storm event existing land use condition shows flooding (HGL above the rim elevation of the node) at several nodes when modeled with free outfalls. Flooding occurs in even more nodes when the bank full boundary condition is applied at the outfalls as pipes cannot drain into the creeks. A map of the 10-year flooding depths predicted by the MU analysis of the existing system with free outfalls is presented in Figure 3-1. Flood depths predicted with the bank full boundary condition applied are shown in Figure 3-2.

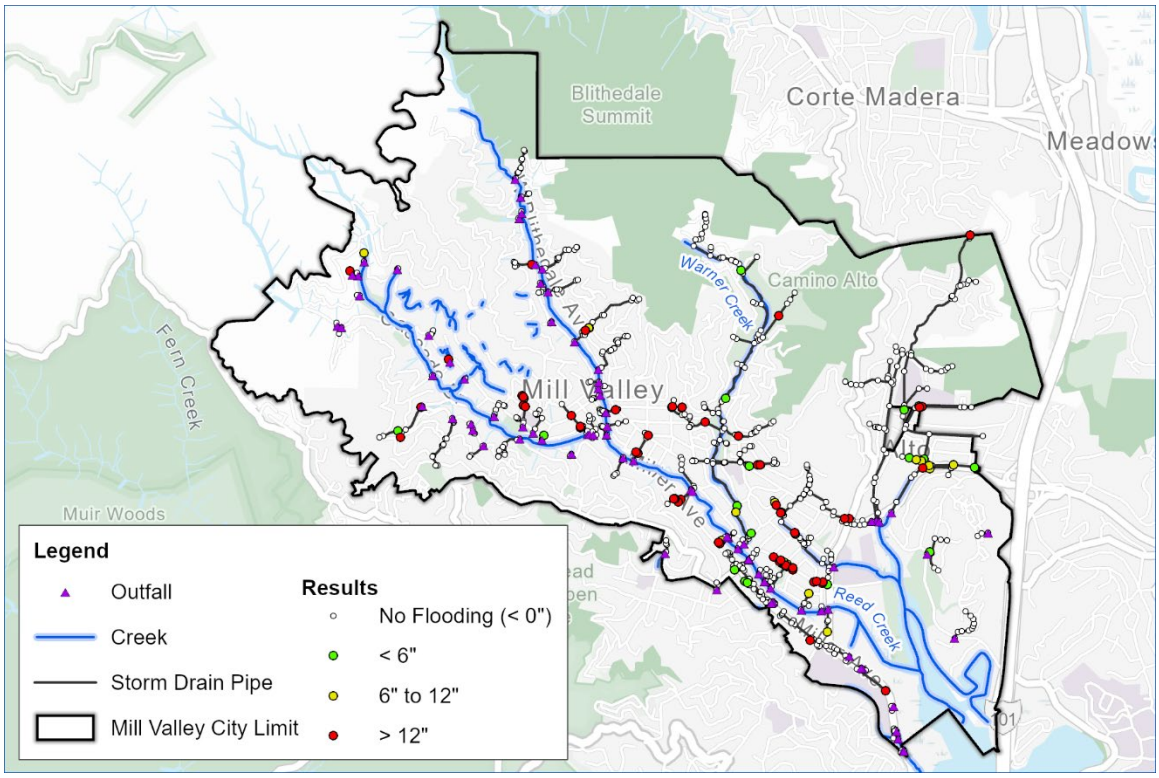


Figure 3-1. Free Outfall Flood Node Map

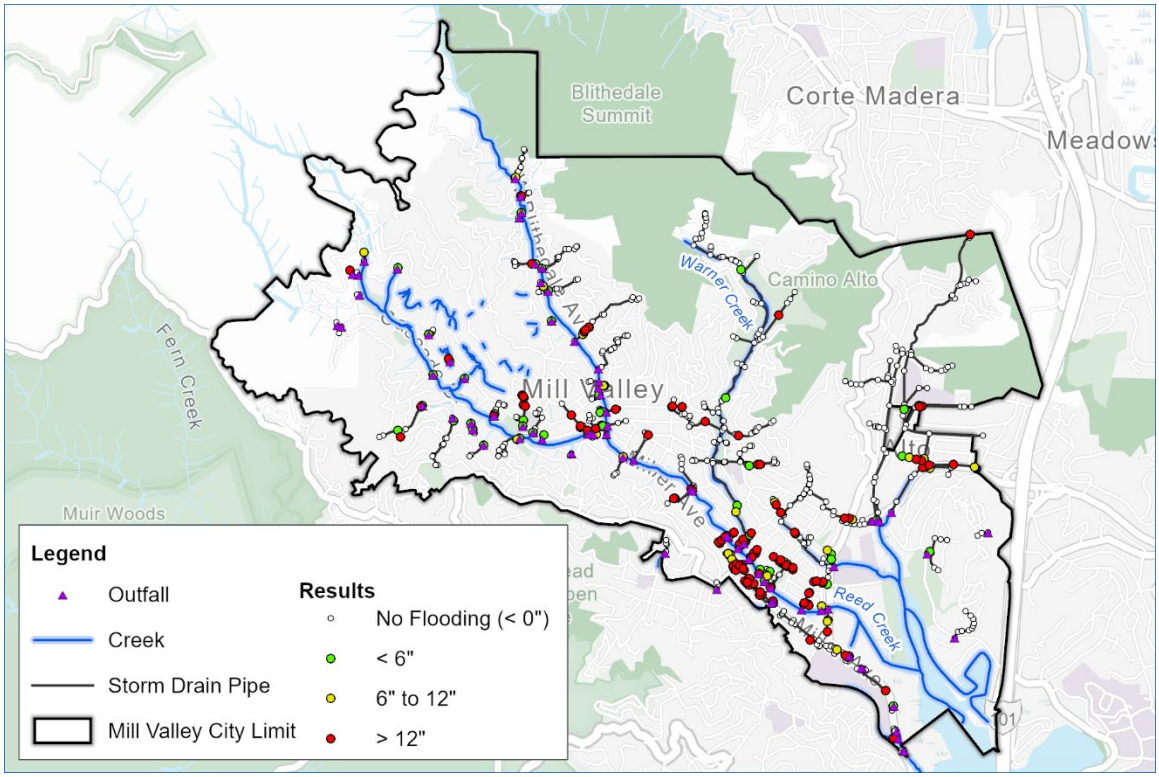


Figure 3-2. Bank Full Flood Node Map

3.5. Condition Assessment

Based on the field visits and CCTV discussed in Sections 2.1.4 and 2.1.3, most pipes were found to be reinforced concrete pipe (RCP) in good condition, although some pipes in low-lying areas contained sediment. The corrugated metal pipe (CMP) located during field inspection and CCTV is generally in poor condition and should be replaced as the expected life span for the CMP has been exhausted. Pipe lining, such as cured-in-place-pipe (CIPP), may be considered in lieu of replacement on a case-by-case basis during the design process which may reduce the improvement cost. However, due to the condition of the inverts and corrosion that has occurred in the CMP, it is unlikely to be an option for the ones that were observed. Condition issue locations are shown in Appendix E.

3.6. Prioritized Improvements

Three high priority projects (Figure 3-3) are aimed at reducing flooding in problematic locations and at carrying out short term condition improvements.

Seven moderate priority projects aim to reduce flooding at the 10-year level of service at selected locations. The City may need to progressively re-prioritize moderate priority projects based on funding, other utility improvements, and land-use changes.

Six low priority projects are recommended to alleviate minor flooding and reliability issues. These projects are not likely to be constructed before the next storm drain Master Plan update.

The following sections describe the projects. Appendix I contains summary sheets for each of the prioritized improvements. These summary sheets can be used in the future as a starting point for further investigations and designs.

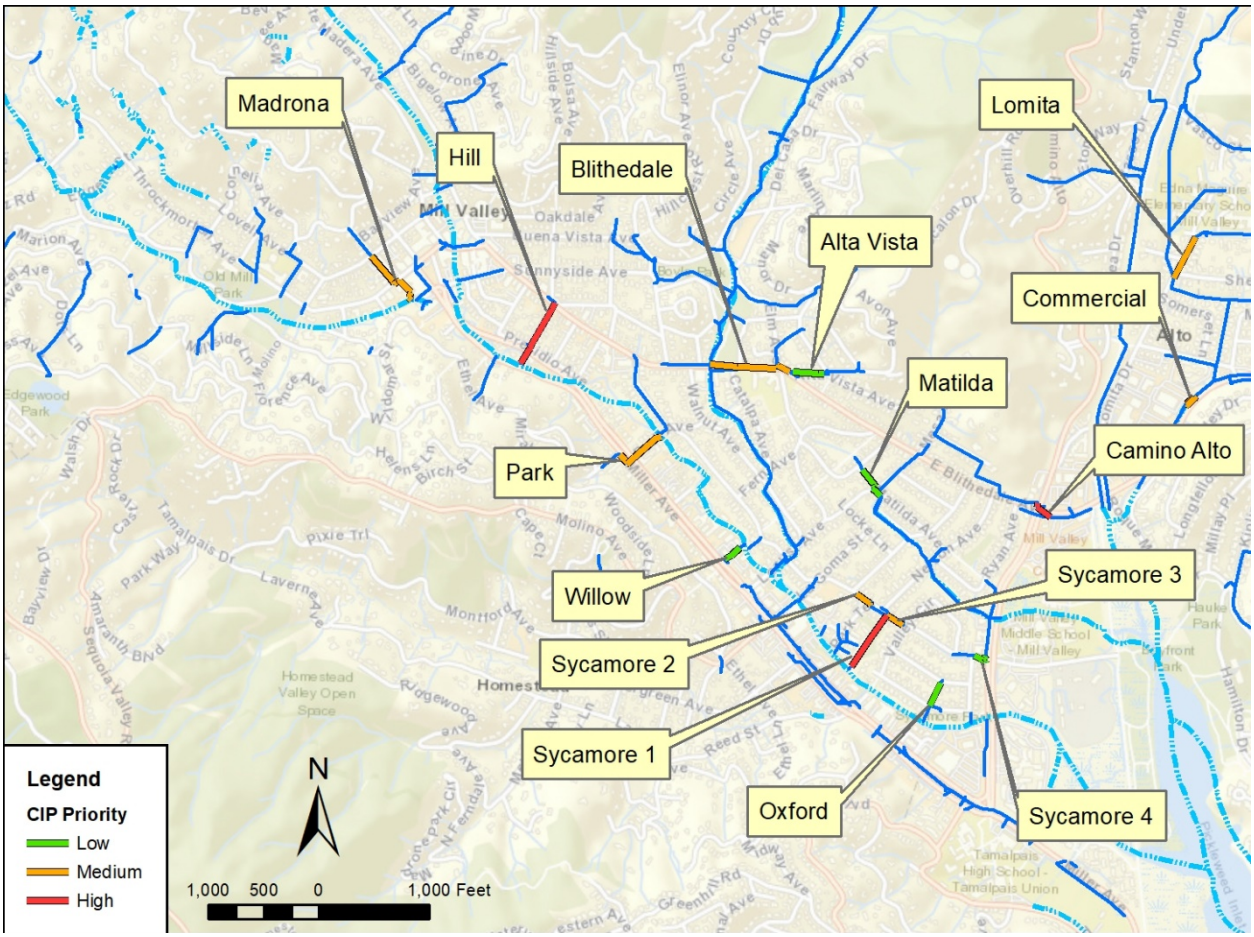


Figure 3-3. Prioritized CIP Projects

3.6.1. Annual Inspection of Pipes

CMPs typically are more susceptible to corrosion and damage compared to concrete pipes. Observations made during field inspections identified several CMPs in Mill Valley's storm drain system with visible damage and deformities. Several other pipes had varying levels of sedimentation. This project recommends performing continued CCTV video inspections. The CCTV inspections could potentially result in additional capital projects to repair the system.

3.6.2. High Priority Projects

The highest priority projects (Figure 3-4) are a combination of condition and capacity improvements.

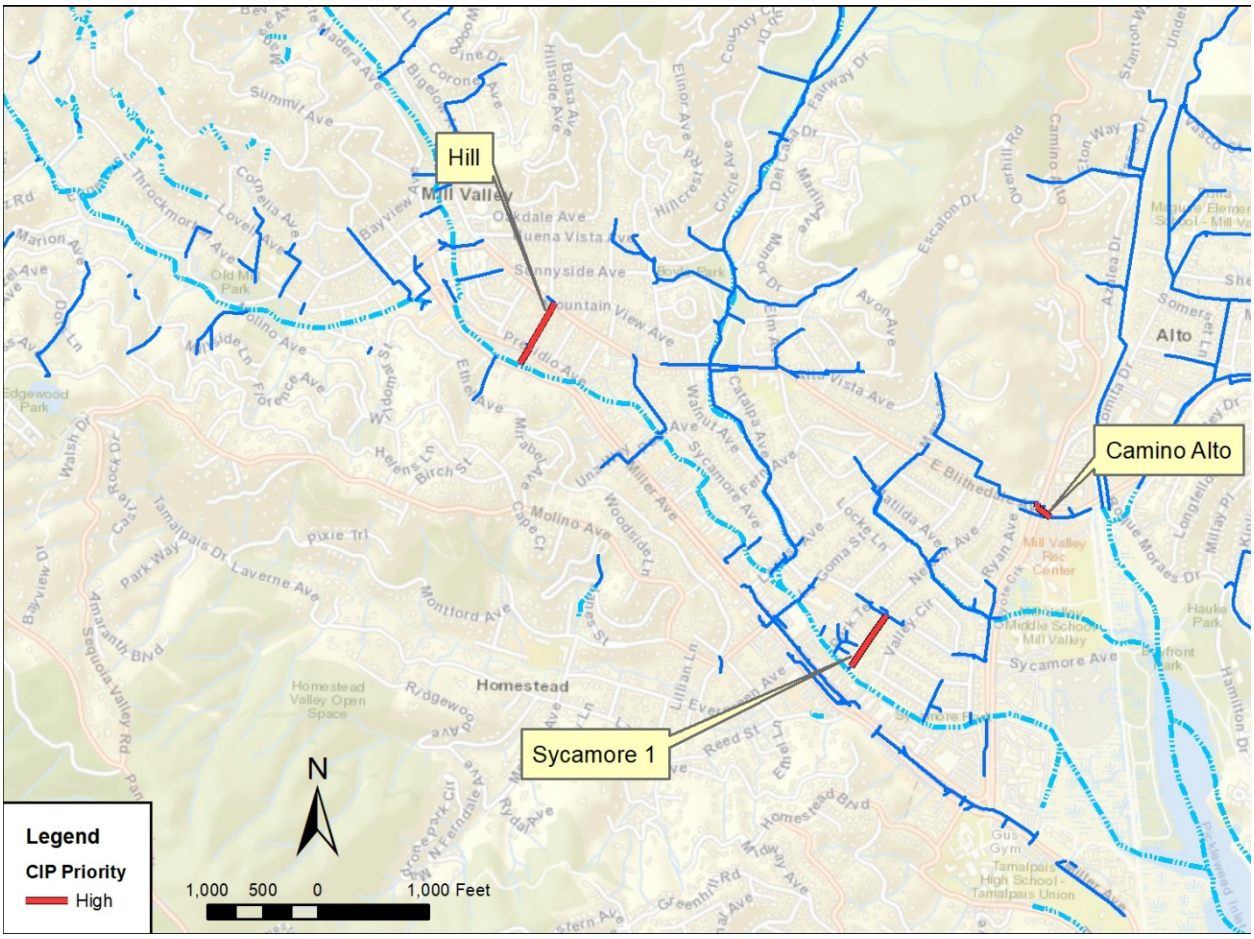


Figure 3-4. High Priority CIP Projects

Sycamore 1

Flooding occurs in the Sycamore neighborhood. Upsizing the existing pump station and the pipe that conveys water from Sycamore Ave to the pump station will mitigate this flooding. This improvement should be constructed before other Sycamore area improvements.

Camino Alto

Flooding occurs at the north-west corner of Blithedale Ave and Camino Alto. Upsizing the pipes that cross under Blithedale Ave will mitigate this flooding.

Hill

Flooding occurs along Hill St at Mountain View Ave and Presidio Ave. Upsizing the pipe in Hill St to the outfall will mitigate this flooding.

Condition Improvements

Condition related improvements consist of cleaning pipes/removing sediment, spot repairs, and replacing pipes in poor condition.

3.6.3. Moderate Priority Projects

The moderate priority projects (Figure 3-5) are a combination of nuisance and capacity CIPs.

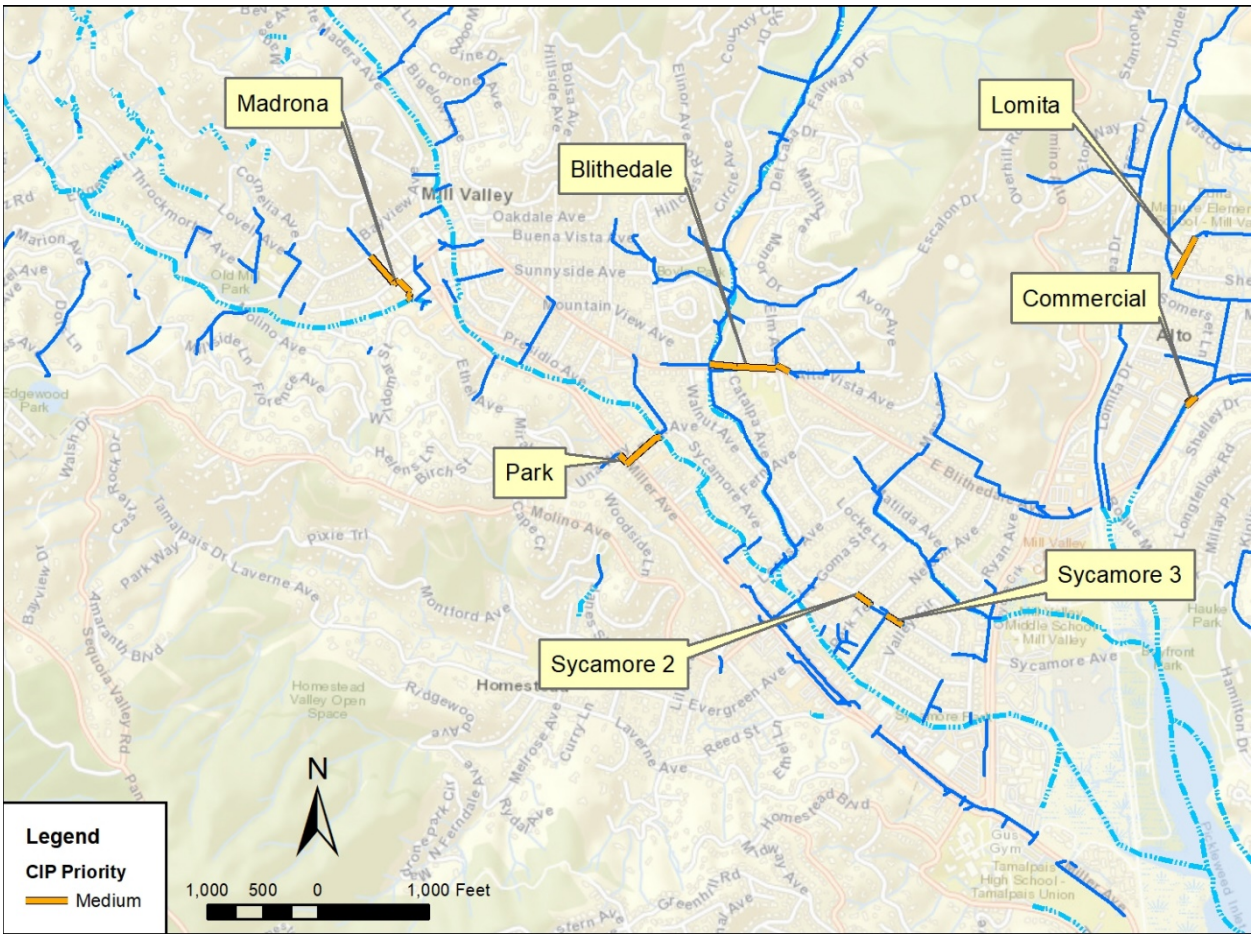


Figure 3-5. Moderate Priority CIP Projects

Blithedale

Flooding occurs along Blithedale Ave upstream of this improvement along Alta Vista Ave. due to undersized pipes. This improvement will mitigate this flooding should be constructed prior to construction of upstream improvements.

Commercial

The culverts under the driveway from Blithedale Ave to the commercial development are undersized causing upstream flooding. Upsizing the culverts will mitigate this flooding.

Lomita

Flooding occurs at the Elementary School at Lomita Dr. Upsizing the pipe in Lomita Dr to Shell Rd will mitigate this flooding. This project should be coordinated with the County and FZ3 as the drainage upstream is both City and County and Lomita Drive is within County jurisdiction.

Madrona

Flooding occurs along Madrona St at Lovell Ave and Throckmorton Ave. Upsizing the pipe in Madrona St from Lovell Ave to the outfall at Mill Creek will mitigate this flooding.

Park

Flooding occurs at Park Ave and Miller Ave. Upsizing the pipe in Park Ave from Miller Ave to the outfall at ACMdP Creek will mitigate this flooding.

3.6.4. Low Priority Projects

The low priority projects (Figure 3-6) are a combination of nuisance and capacity CIPs that can be addressed as funding allows.



Figure 3-6. Low Priority CIP Projects

Alta Vista

The undersized pipe in Alta Vista Ave causes water to travel overland toward Blithedale Ave. Upsizing the pipe in Alta Vista Ave will mitigate this overland flow.

Matilda

Flooding occurs along Matilda Ave between Elm Ave and Hilarita Ave. Upsizing the pipe in Matilda Ave from Elm Ave to the outfall at Ryan Creek will mitigate this flooding.

Oxford

Flooding occurs at Oxford Ave just west of Surrey Ave. Upsizing the pipe between Oxford Ave and Plymouth Ave will mitigate this flooding.

Sycamore 4

Flooding occurs along Sycamore Ave between Valley Circle and Camino Alto. Upsizing the pipe in Sycamore Ave between Surrey Ave and Camino Alto will mitigate this flooding.

Willow

Flooding occurs at Miller Ave and Willow St. Upsizing the pipe in Willow St will mitigate this flooding.

3.7. Climate Change Impacts to Storm Drain Projects

Climate change has the potential to modify rainfall patterns throughout the Bay Area. Though no one knows the exact impact of climate change on storm patterns, science has provided useful predictions.

The US EPA has developed SWMM-CAT to help engineers estimate the increase in precipitation in the future. These predictions have a high degree of uncertainty and should not be used to design current projects; however, they are helpful in the long-term planning of drainage infrastructure. The projects in this Master Plan are conceptually designed and precipitation changes should be further investigated during detailed design.

The City will likely be more impacted by climate change impacts to sea levels than precipitation changes. Sea level rise is further discussed in Chapter 5. The City should monitor climate change and consider precipitation changes when planning or designing long-term drainage projects.

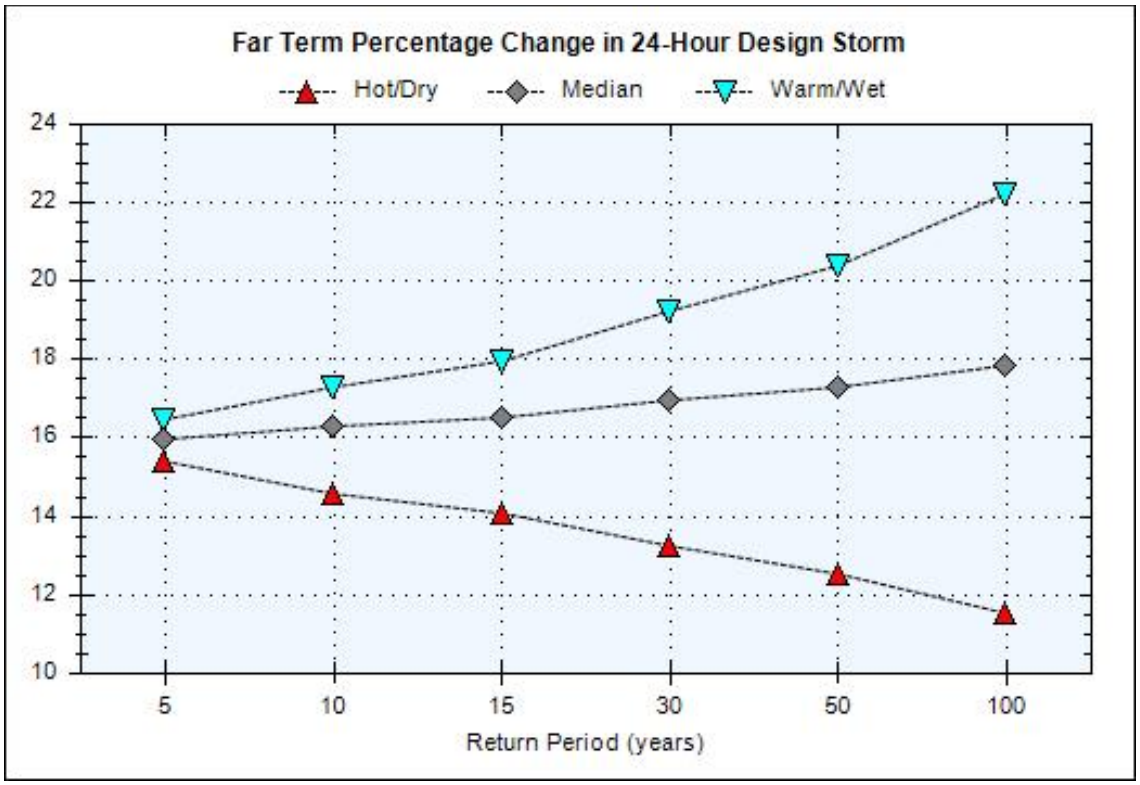


Figure 3-7: SWMM-CAT Predicted Changes in Precipitation

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Chapter 4: Creek System Evaluation and Mitigation Measures

4.1. Overview

Stetson Engineers Inc. developed a hydrologic and hydraulic model (H&H) of the lower mainstem of the Arroyo Corte Madera del Presidio (ACMdP). The study began in 2006, updated in 2010, and finalized in 2012. The focus of the study was the capacity of the creek and the surrounding floodplain. The reports created during this time can be found in Appendix A.

The primary purpose of the study was to identify creek flooding and develop conceptual measures to reduce flood damage by reducing creek overflow or other means. The study also developed conceptual plans and cost estimates. The study assessed the potential flood reduction measures including:

- Hydraulic capacity improvements – these measures increase the channels flow capacity by replacing or enlarging structural crossings or by modifying the channel through widening, dredging, or floodwalls or landscape berms around reaches that lack sufficient flow capacity
- Bypass channels – these measures divert and route floodwater around reaches that lack sufficient flow capacity
- Detention basins – these measures reduce the magnitude of flood flow by temporarily detaining flood water in large ponds, referred to as detention basins, then slowly releasing the water back to the creek after the storm subsides and flooding recedes

These measures were conceptually designed, and cost estimates prepared which were then compared to raising properties out of the floodplain.

4.2. Model Development

This Master Plan was built upon the one-dimensional model developed by Stetson Engineers Inc. and 2009 topographical data collected by Stetson Engineers to create a two-dimensional model that analyzed the flooding over time.

The hydrologic flows developed for the storm drain system model were used in the creek to analyze a 10-year, 24-hour storm event. Ideally, larger storm events would also have been run in the model, however, due to the capacity limitations of the creek channels, it was too challenging to get the model to run a storm event of a 10-year magnitude.

Bridge crossings were removed to allow the model to run more stable and then added back in where possible. It has been identified by Stetson Engineers that many of the bridge crossings are undersized. This was not the focus of this study. Instead, the focus of this study was to further analyze the flood reduction measures conceptually designed by Stetson Engineers. A topographical study was conducted by Stetson Engineers Inc. that was used as the basis of the 2D topography in the model.

4.2.1. Hydrologic Flows

The creek models used the same hydrologic methodology as the storm drain model as discussed in Section 2.6. Larger drainage catchments were delineated in the hillslopes to

capture all the runoff that is entering the creek channels. Figure 4-1 depicts the watersheds used for hydrologic flows to the creek models.

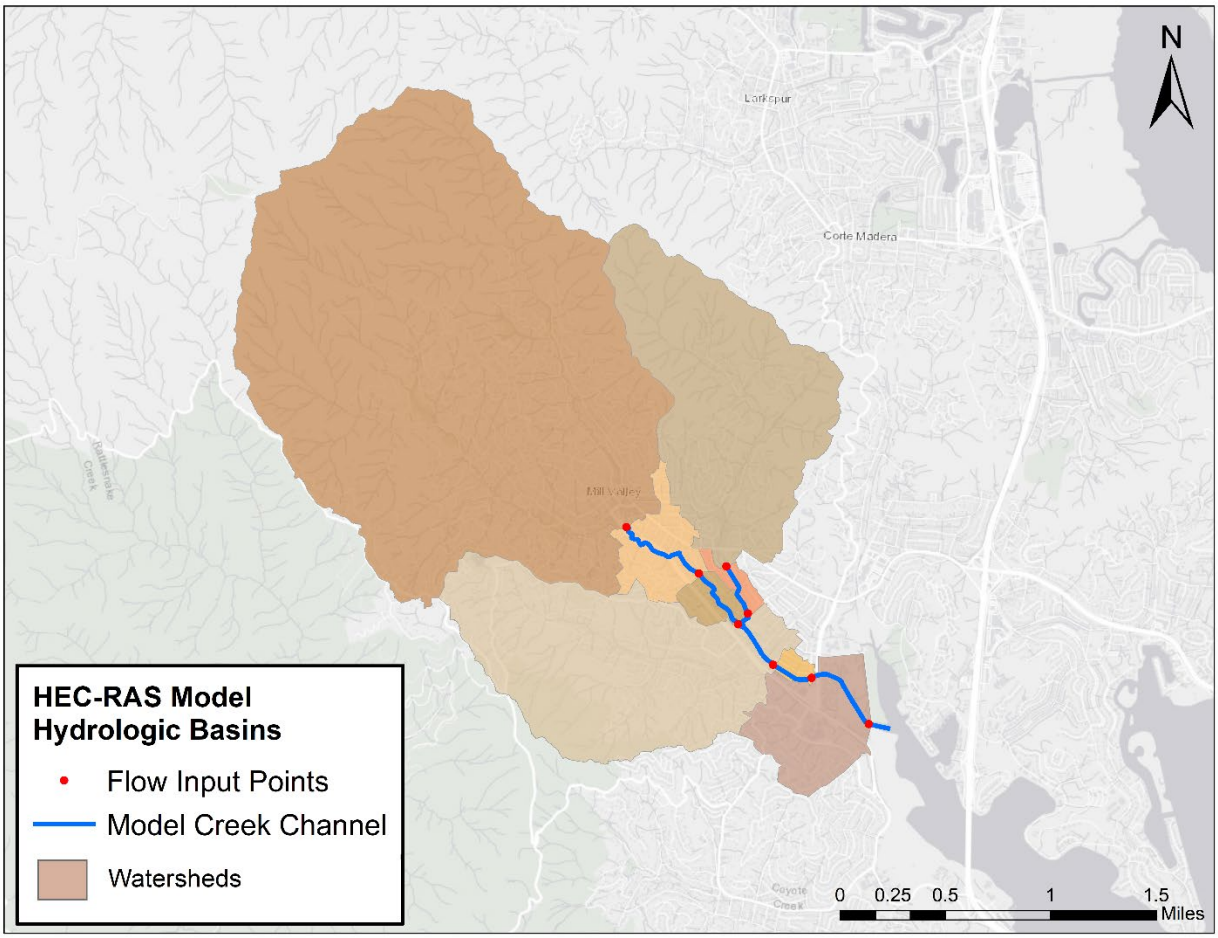


Figure 4-1. Creek Model Hydrologic Flows

4.3. Creek Channel Capacity Summary

Model analysis suggests that the creek channel capacity is less than a 10-year storm event. Around 40% of the 10-year flows can remain in the creek channel, the rest is conveyed through the urban floodplain consisting of roads, backyards, front yards, and a few properties. The primary overflow from the ACMdP occurs around Willow Street where approximately 620 cubic feet per second (cfs) leaves the channel and is conveyed down Miller Avenue.

The primary overflow from Warner Canyon Creek is near Locust Street where approximately 60 cfs leaves the channel and is conveyed back into the ACMdP or down Sycamore Avenue. The area of most significant ponding occurred between Miller Avenue and Sycamore just above Locust Street due to a depression in the natural topography.

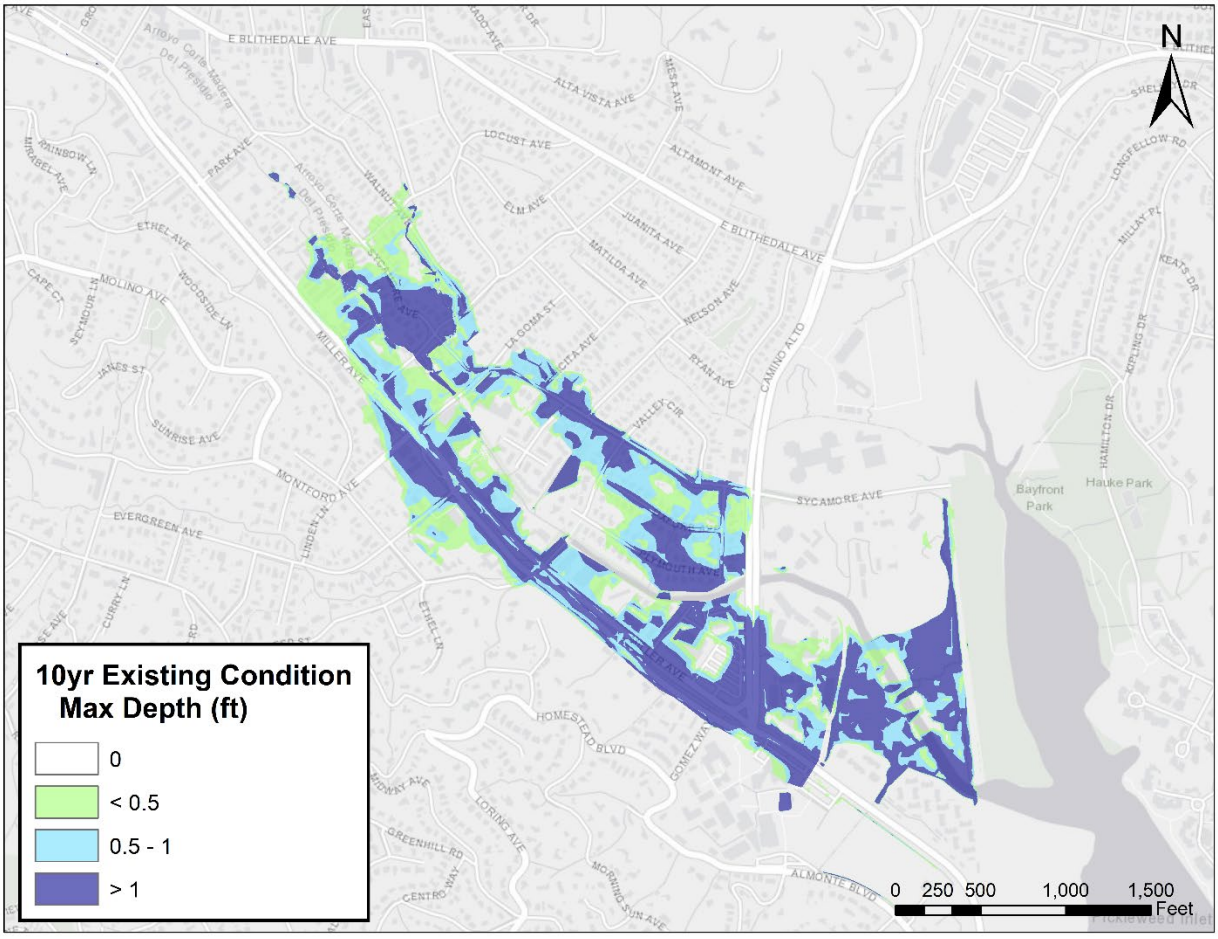


Figure 4-2. 10-Year Storm Event Creek Model

During the 10-year, 24-hour storm event, a significant amount of volume leaves each creek channel. These volumes were used to further investigate detention-based mitigation measures. Results show that at the Willow Street spill from ACMdP, approximately 130 acre-feet of water leaves the creek channel. This is the equivalent of having approximately 100 feet of standing water on a football field. There are approximately 15 acre-feet of water leaving Warner Canyon Creek near Locust Street.

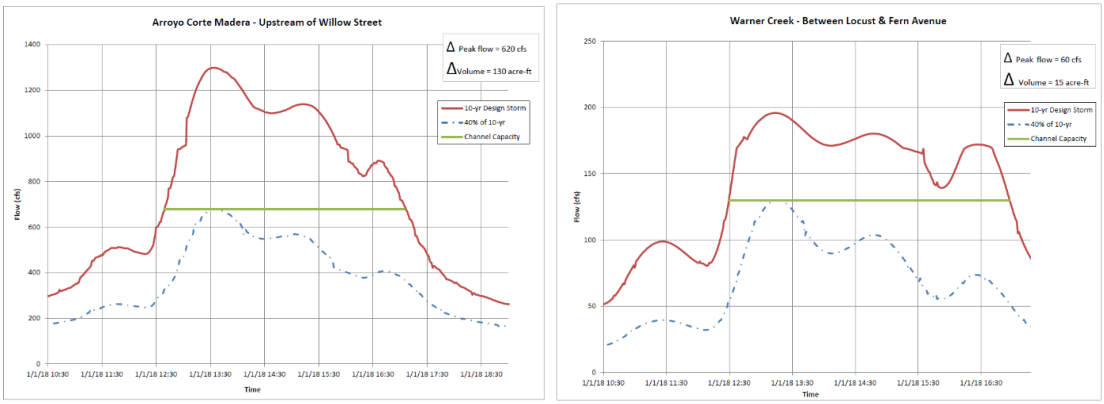


Figure 4-3. Spill Hydrographs ACMdP (left) Warner Canyon Creek (right)

4.4. Creek Channel Mitigation Measures

Mitigation measures studied by Stetson Engineers were presented to the Task Force to gage the City's interest in further pursuing certain types of mitigation measures. The Stetson study was conceptual and did not detail the costs of property acquisition for improvements constructed on private property. Further investigation was done to identify what property the City owns along the creek.

Figure 4-4 below depicts the public parcels along the creeks, which indicates that the City owns very little of the creek banks. This would mean that the City would need to obtain easements of the creek banks for any measures that are constructed along the creek banks. This was discussed at the second Task Force Meeting and the Task Force agreed that the focus of this study should be on the mitigation measures that can be constructed and maintained on public property.

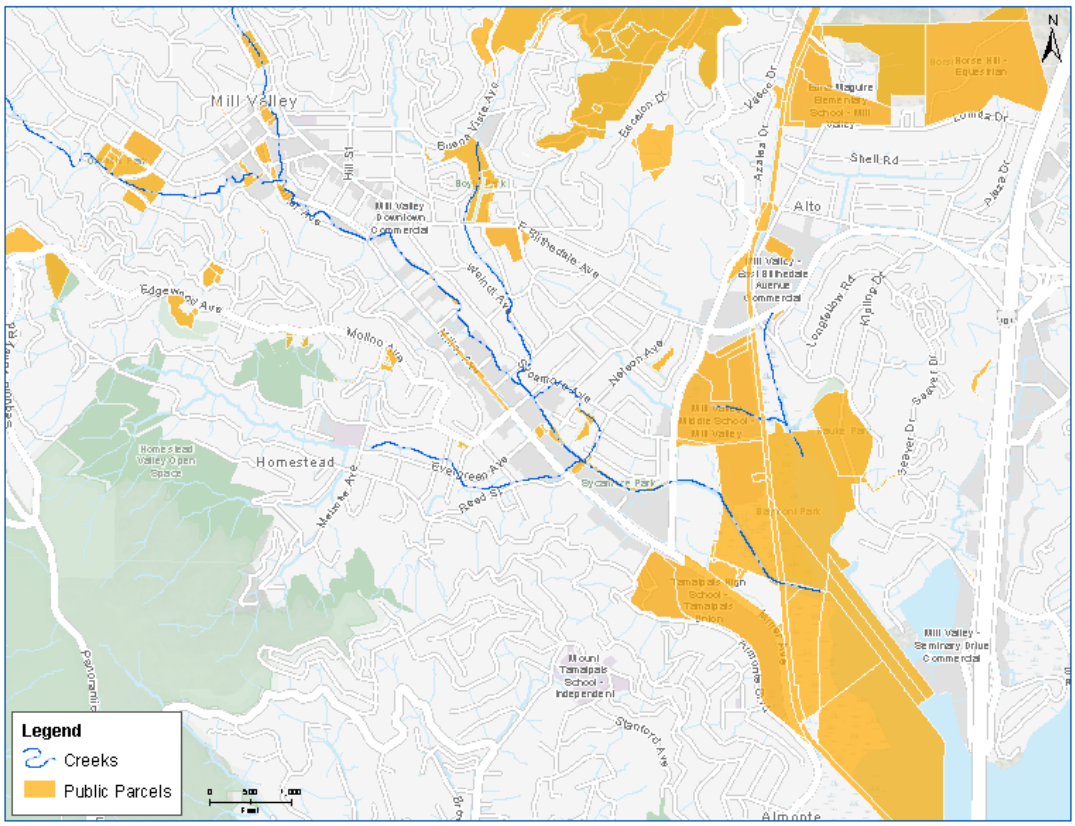


Figure 4-4. Public Parcels

4.4.1. Floodwalls, Channel Widening, and Berms

These mitigation measures would require the City to obtain easements to construct and maintain since the City does not own the majority of the property surrounding the creek channels. The Task Force agreed that these measures were unlikely to get community support and were not investigated in any more detail.

4.4.2. Detention

Flood detention reduces flooding by reducing the magnitude of the peak of the flood by storing creek flows that would otherwise spill out of the creek channel. Stetson Engineers developed a concept for a detention basin at the public golf course to detain flows from Warner Canyon Creek. The concept includes the construction of an earthen dam that would be approximately 40-ft tall to detain water into the golf course.

The detention basin would qualify as a dam and could store up to 227 acre-feet of water. This detention-based mitigation solution was analyzed in the 2D H&H model and showed that while there were some benefits made in the Sycamore area due to detaining flows from Warner Canyon Creek, the majority of the spills are coming from the ACMdP and the detention basin at the golf course is too high in elevation to capture any of the spills from the ACMdP.

Instead, additional detention sites were investigated in public property that would detain flows from the ACMdP. Two potential sites were identified, and conceptual volumes were developed. Both sites would require berms of around 15-ft high which would qualify them as dams. The dam at Old Miller Park could provide approximately 13.5 acre-feet of storage and the dam at Grove Park could provide approximately 9.2 acre-feet of storage.

Together, these dams only provide around 18% of the total detention required based on the volumes of spills described in Section 4.3. Figure 4-5 shows these two conceptual dam site locations. Due to the limited capacity achieved, these dam sites were not recommended nor studied any further.

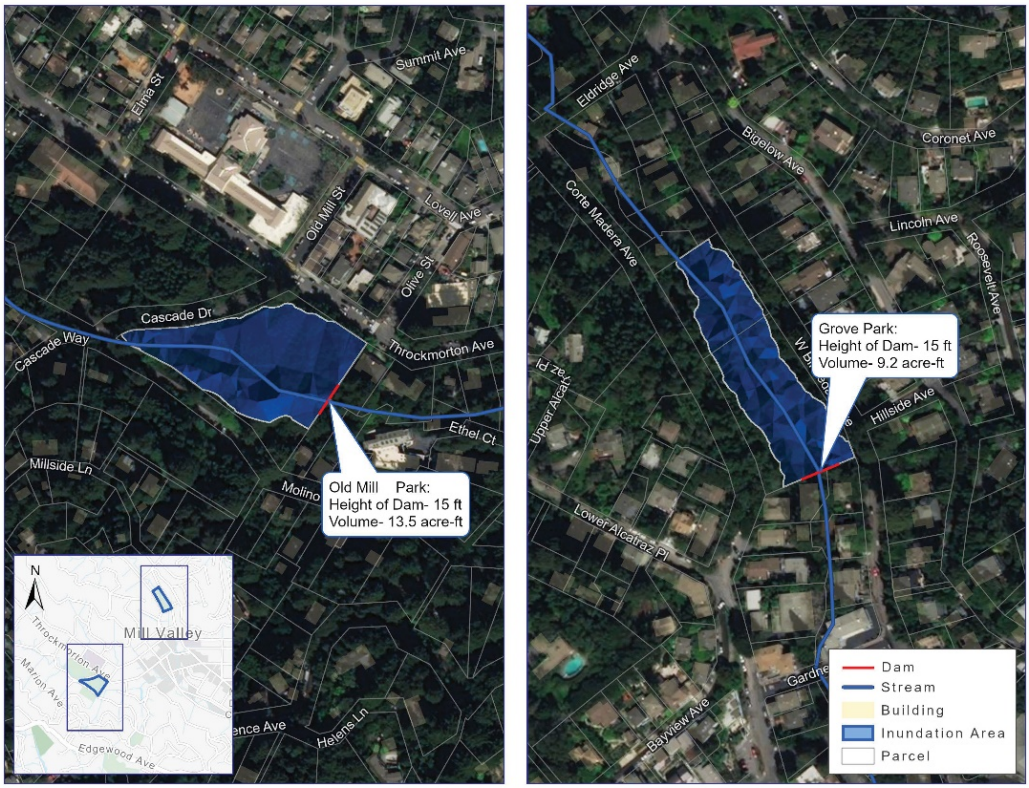


Figure 4-5. Potential Dam Sites Upstream of Willow Street

4.4.3. Creek Channel Bypass

A channel bypass reduces flooding by diverting and conveying floodwater around the severely constructed and obstructed creek channels through a culvert. Two-channel bypasses were further investigated in this Master Plan – one to convey spills from ACMdP and the other to convey spills from Warner Canyon Creek.

The channel bypass for the ACMdP is conceptually designed to take flows just upstream of Willow Street into a 20 ft wide by 4.5 ft tall culvert down Miller Avenue to Richardson Bay. At the end of the culvert, a pump station is required to pump the flows into Richardson Bay as this culvert would lack gravity flow at higher tides.

The channel bypass for Warner Canyon Creek is conceptually designed to take flows at the intersection with East Blithedale and convey flows through a 4.5 ft circular culvert down East Blithedale into Richardson Bay.

To remove the overflows from the streets of Mill Valley, both channel bypasses are required. A third channel bypass was investigated that conveyed Warner Creek flows into ACMdP near Fern Street. This channel bypass was thrown out as it still relied upon the Mill Avenue bypass to be constructed and needed to go through private property.

Figure 4-6 below shows the conceptual alignment of the ACMdP and Warner Canyon channel bypasses.

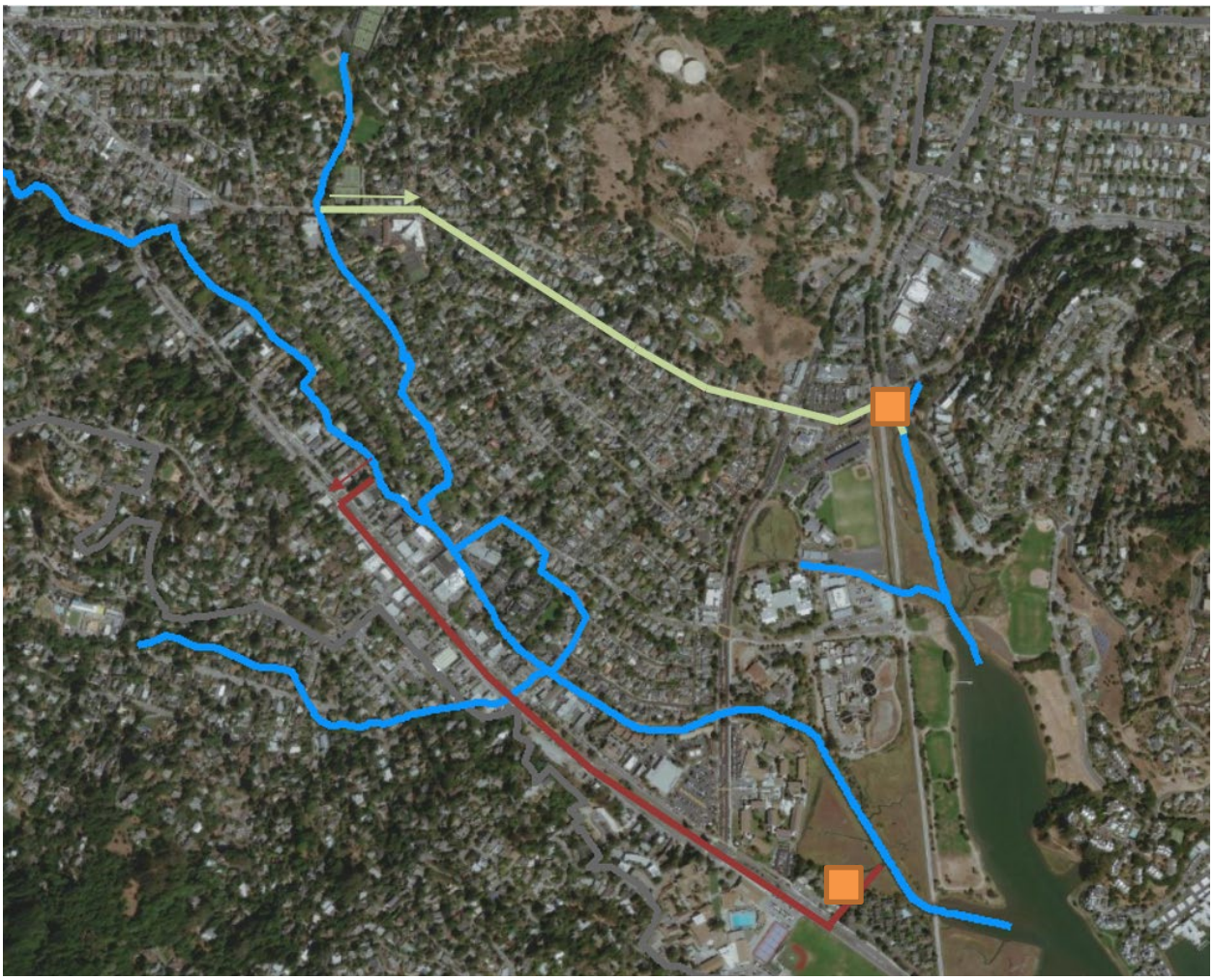


Figure 4-6. Creek Channel Bypass – ACMdP (red) Warner Canyon Creek (green)

The ACMdP bypass down Miller Avenue and the Warner Canyon bypass down East Blithedale were further investigated for conceptual cost estimates. Each bypass would have considerable utility conflicts and require pump stations at the end.

Tables 4-1 and 4-2 detail the potential costs for each bypass. Considering that both need to be constructed, it could cost the City upwards of $58M to reduce impacts from the 10-year storm event.

Figure 4-7 shows the improvements from both bypasses during the 10-year storm event. Larger storm events were not investigated as the channel and bridge restrictions are too limiting for the model to handle larger flows that a 10-year storm event without crashing.

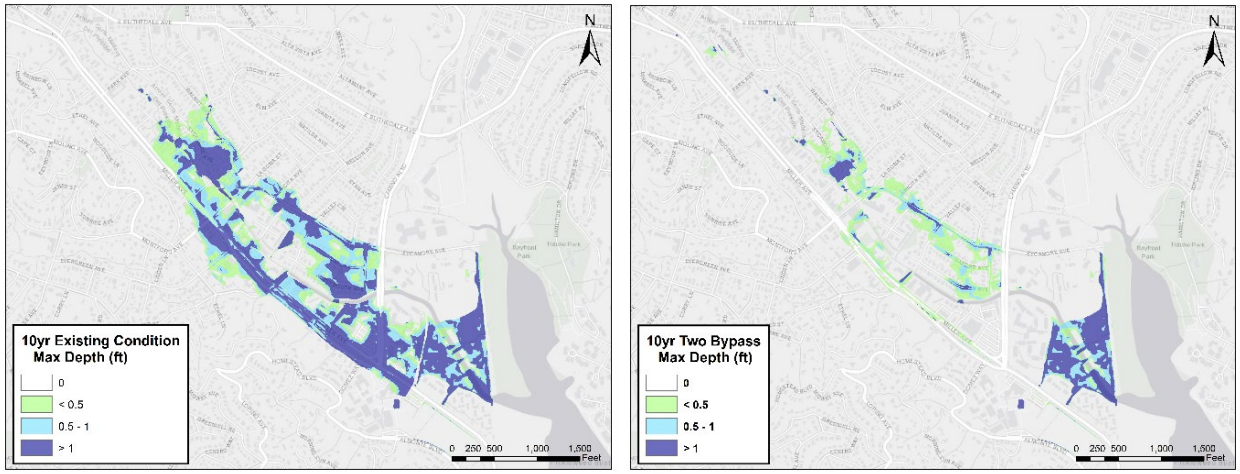


Figure 4-7. Existing Condition 10-year Storm Event (left) Proposed Two Bypass Condition (right)

Table 4-1. Preliminary Cost Estimate Miller Avenue Bypass for the ACMdP

Item No.	Item Description	Unit of Measure	Estimated Quantity	Item Unit Price	Bid Item Extension
1	Mobilization/Demobilization	LS	1	$700,000	$700,000
2	Pedestrian and Traffic Control	LS	1	$250,000	$250,000
3	4.5'HX20'W Reinforce Concrete Box Culvert	LF	4300	$1,500	$6,450,000
4	Paving and Striping	SF	102500	$7.50	$768,750
5	Utility Relocation	LS	1	$300,000	$300,000
6	Pump Station	LS	1	$14,000,000	$14,000,000
				SubTotal	**$22,469,000**
Soft Costs				***Design - 10%***	**$2,247,000**
				Permitting - 10%	**$2,247,000**
				Contingencies - 30%	**$6,741,000**
				Construction Managemment - 10%	**$2,247,000**
				Total (LOW END)	**$35,951,000**
				Total (HIGH END)	**$44,938,000**

Table 4-2. Preliminary Cost Estimate East Blithedale Bypass for the Warner Canyon Creek

Item No.	Item Description	Unit of Measure	Estimated Quantity	Item Unit Price	Bid Item Extension
1	Mobilization/Demobilization	LS	1	$700,000	$700,000
2	Pedestrian and Traffic Control	LS	1	$250,000	$250,000
3	4.5' Diameter RCP	LF	4000	$750	$3,000,000
4	Paving and Striping	SF	80000	$7.50	$600,000
5	Utility Relocation	LS	1	$300,000	$300,000
6	Pump Station	LS	1	$1,400,000	$1,400,000
				SubTotal	**$6,250,000**
Soft Costs				***Design - 10%***	**$625,000**
				Permitting - 10%	**$625,000**
				Contingencies - 30%	**$1,875,000**
				Construction Managemment - 10%	**$625,000**
				Total (LOW END)	**$10,000,000**
				Total (HIGH END)	**$12,500,000**

4.4.4. Dredging

WRA Inc. Environmental Consultants attended a Task Force meeting to provide an overview of dredging in Marin County. WRA is located in San Rafael and has supported permitting for several dredging projects throughout Marin County. WRA presented the many factors to consider when dredging including timing, permitting, material disposal, and costs. WRA presented the comparison of the dredging of Novato Creek which has an existing dredge permit and costs $1.5M every time it is dredged.

It is anticipated that the costs for Mill Valley would be higher due to mitigation requirements for new dredge permits. Dredging projects are typically required every five to ten years as sediment will build back up. The estimated additional capacity gained from dredging was compared to the bypass using the additional area provided.

It was agreed by the Task Force, with consultant recommendation, that dredging was not going to provide significant reductions to flooding and have high costs in terms of both dollars and impact to the environment and was not worth the small benefits are given to a handful of properties.

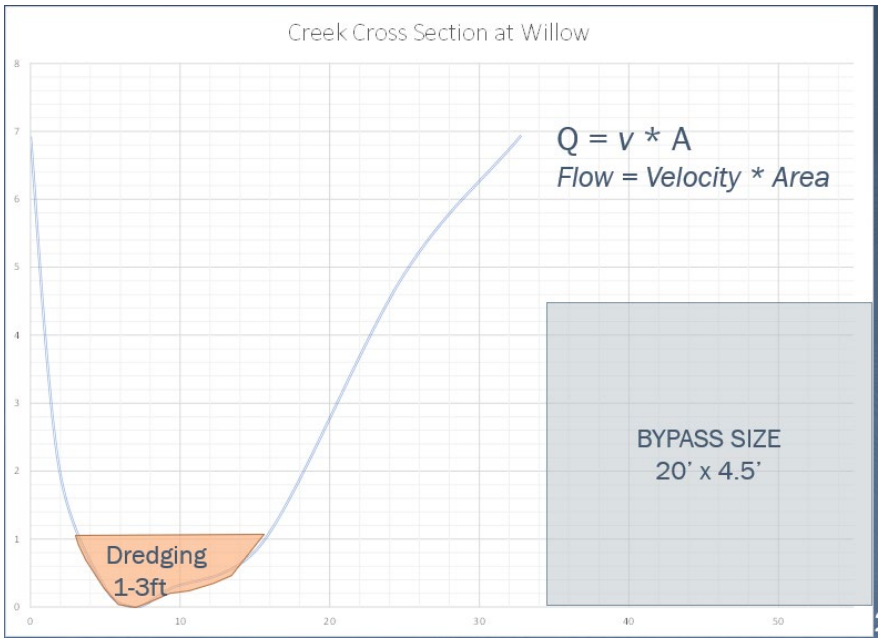


Figure 4-8. Additional Cross Sectional Area Provided by Dredging v. Required Bypass for 10-year

4.4.5. Sedimentation Basin

Dredging did not prove to increase capacity significantly, but it does have reduced maintenance implications in some areas of the City where sediments are deposited from the upper watersheds into the City's storm drain pipes and culverts.

One area has been identified by City maintenance staff that could use some mitigation to reduce the amount of sediment deposited into the City five foot by two and a half foot culverts at the intersection of Miller Avenue and Reed Street.

The City spends significant time and money to clean the culverts that have sediment deposited from Reed Creek which drains the steep hillslopes outside the City limits.



Figure 4-9. Proposed Sedimentation Basin (red)

The sediments deposited into the culvert also limit the culvert's capacity. Figure 4-9 shows the location for the proposed sedimentation basin to alleviate the sediments deposited into the City's culvert under Miller Avenue. A high-level construction estimate for this basin would be around $250,000. However, this location is private property so the cost would be even higher.

4.4.6. Water Capture and Reuse

One of the first questions raised by the Task Force was whether enough water could be detained by each property to alleviate the flooding. Primarily, the thought was that perhaps if homes on the hillsides each had a rain barrel, runoff could be detained enough to prevent spills in the low-lying areas.

A closer look into the ACMdP spill of 130 acre-feet. There are approximately 5,900 parcels within the City of Mill Valley. A typical rain barrel as depicted in Figure 4-10 is around 60 gallons.



Figure 4-10. Typical 60-gallon Rain Barrel

The one-acre foot is equal to approximately one foot of water on a football field, which is around 326,000 gallons. Due to the magnitude of the spill volume, each of the 5,900 parcels would need to have over 100 rain barrels. And each one of those would have to be empty at the onset of a storm event.

Rain barrels and other green measures such as rain gardens or bioretention areas should be more of a focus for water quality improvement and not as much on flood mitigation. The City is regulated by the Municipal Regional Stormwater Permit Order No. R2-2015-0049 (MRP) which requires that the City prevent pollution to the City's storm drain system and improve water quality through the use of green infrastructure.

4.5. Creek Channel Summary

While this Master Plan does not identify a "silver bullet" project that can alleviate the spills from the Creek, it does present the high costs associated with channel bypass and those costs can be compared to costs presented in the next chapter for raising homes. The channel bypasses are only designed for a 10-year storm event, while raising homes can provide protection to the 100-year storm event and include additional height to protect against future sea-level rise.

The Master Plan also highlights that the City lacks ownership to construct improvements along the creek channels. While this is not unique to Mill Valley, it conveys the importance that the City maintains creek setbacks to ensure that future development does not encroach upon the creek channels, limiting capacity even further.

The modeling conducted in this Master Plan provides the City with animations of where flood flows are conveyed. In the future, the City may elect to focus more on containment in the street through the use of curbs and/or sandbags to ensure that flood flows do not damage property.

Chapter 5: Mitigation Measure Considerations in Low-Lying Areas

5.1. Overview

Portions of the City of Mill Valley lie in an area that was historically salt marsh. Figure 5-1 below shows a historical map overlayed with present-day Google Maps. Due to the low-lying elevations, some of the areas of the City are inundated during high tides known as "King Tides." Climate change predictions suggest that tides could be higher in elevations in the years to come. Figure 5-2 shows a King Tide during November of 2020.



Figure 5-1. Historical Salt Marsh on Present Day Mill Valley



Figure 5-2. Multiuse Path near Wastewater Treatment Plant (left) and Plymouth Street (right)

Climate change impacts are being studied at a regional scale through county efforts which are summarized in this Master Plan. At the time of this Master Plan, the focus was more on the creek and the storm drain mitigation measures and city-specific sea-level rise projects were not developed.

5.2. Regional Climate Change Studies

Literature suggests that sea-level rise will significantly impact waterfront communities. It is anticipated that the flood-related issues due to high tides today will be worsened in the future. Marin County has developed a dedicated website for information including vulnerability assessments, sea-level rise scenarios, adaptation land use guidance, public outreach, and a board game.

https://www.marincounty.org/main/marin-sea-level-rise

In 2020 the initial planning memo was released for ideas on evolving shorelines in Richardson Bay. The memorandum presents alternative designs to protect the Bay Trail from future sea-level rise impacts. The memorandum also presents strategies to protect Bothin Marsh such as oyster reefs, ecotone slopes, coarse beaches, and other strategies that have benefits to both the environment and may protect the surrounding community. Appendix C contains the memo from June 2020.

The County has produced numerous planning documents that contain conceptual projects along Mill Valley's shoreline and regional projects such as a tide gate structure under highway 101. These projects are conceptual in nature and funding mechanisms have not yet been identified.

Figure 5-3 shows the regional tide gate structure under Highway 101 and Figure 5-4 shows more localized shoreline improvements to protect the City against rising tides.



Figure 5-3. Richardson Bay Tide Gate Concept

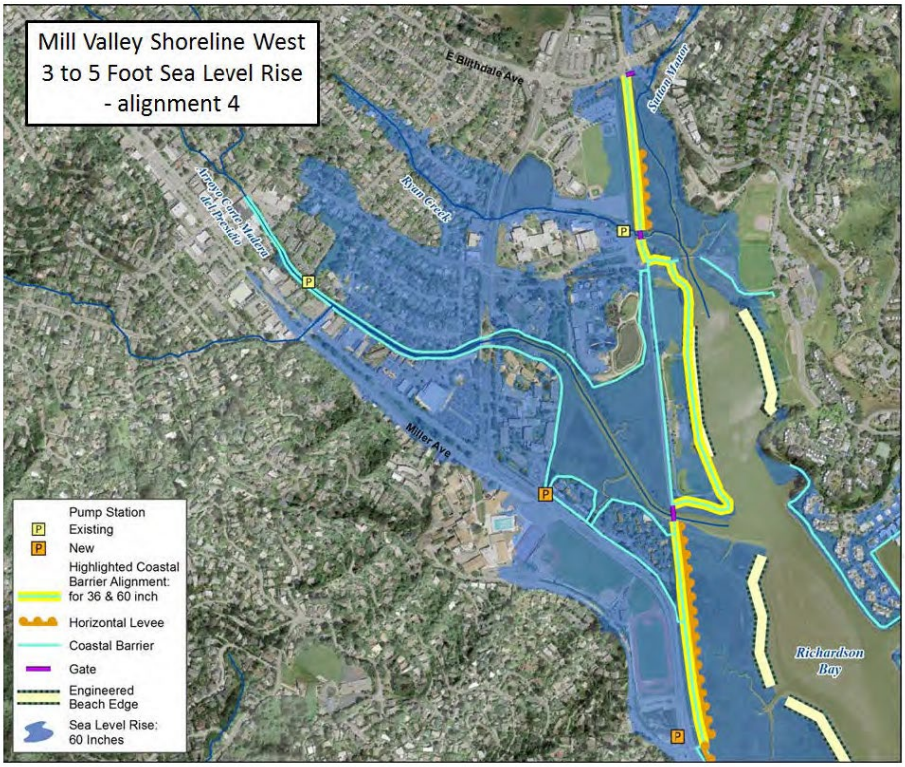


Figure 5-4. Mill Valley Shoreline Protection Concepts

5.3. Raising Homes

The immediate mitigation measure that can be done while waiting for regional and citywide shoreline protection projects is for a homeowner to raise their home out of the FEMA mapped flood plain. While raising their home, property owners should consider raising some extra height to protect against sea-level rise. This was one of the improvements suggested in the Stetson Report.

Raising homes was evaluated in this Master Plan to have a relative comparison of costs to the larger capital improvement projects such as dams and bypasses. The estimated cost to raise a home is between $100k-$150k and would be paid for by the private property owner. The creek bypass was around $58M and protected against a 10-year storm event. Seeing as only a handful of properties are inundated by the 10-year storm event, the cost to raise those homes is significantly less than the creek bypasses.

The County has recently received a grant to raise some homes in Marin County which will serve as a good pilot testing program. The County has a Structure Elevation Program. Details can be found at the following website:

https://www.marincounty.org/depts/bs/board-actions-meetings/2020/july/july-28/structure-elevation-program

Owners implementing improvements on homes that reside within the FEMA mapped floodplain (100-year storm event) are required to raise their home to meet current building codes, which includes raising the finished floor elevation about the base flood elevation if the home improvements equal 50% or more of the assessed value of the home.

Several of the homes in the Sycamore and Plymouth neighborhoods have been raised to meet the building code for homes within a floodplain. Figure 5-5 shows the FEMA mapped flood zones within the City. Figure 5-6 shows homes in Mill Valley that have already been raised to meet FEMA requirements. It is recommended that homeowners take into consideration some level of sea-level rise into their first-floor elevations to ensure that future higher tides do not impact their homes. At this time, FEMA does not include sea-level rise predictions into their mapping. The Task Force recommends City staff will work with the community, Planning Commission and Council to develop and implement a program that facilitates homeowner's ability to raise their homes in alignment with community's overall goals.

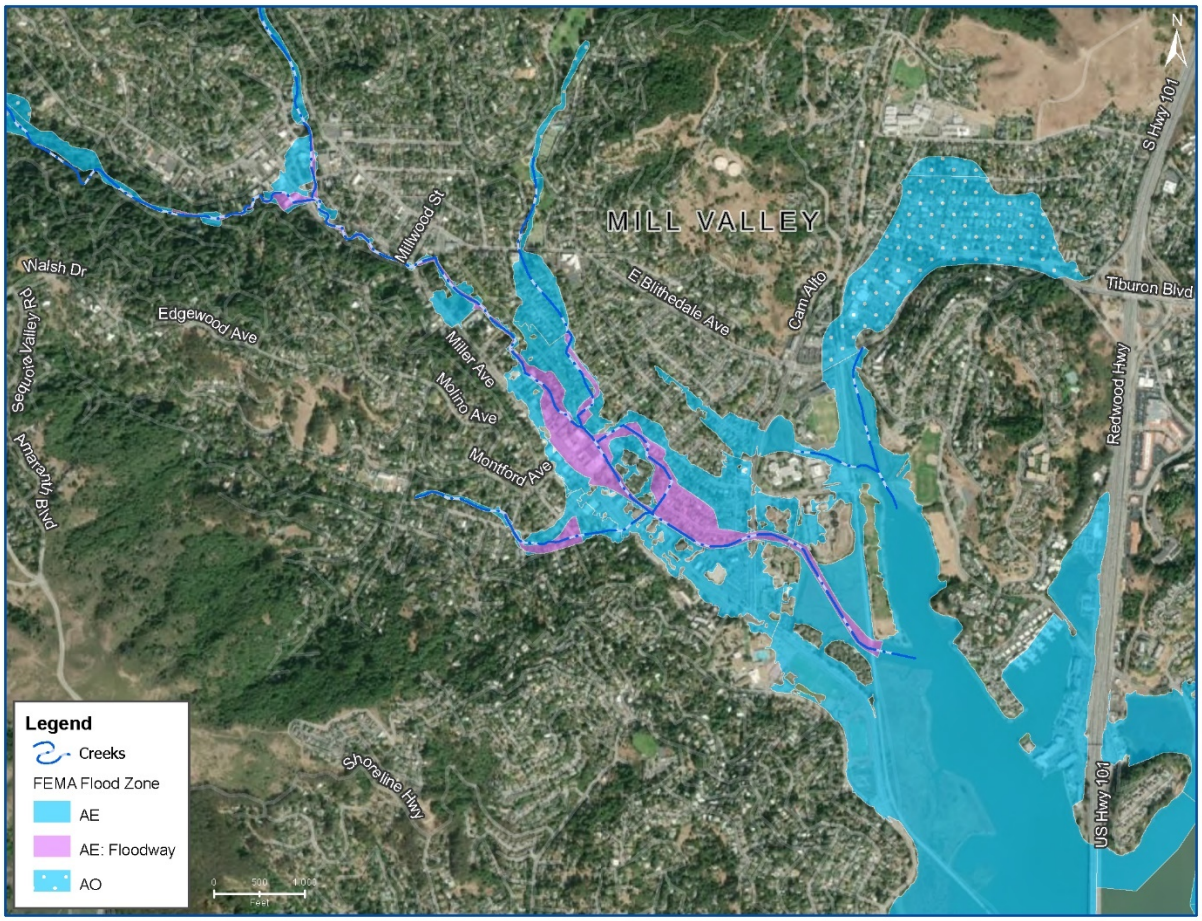


Figure 5-5. FEMA mapped Floodplain in the City



Figure 5-6. Homes Raised to meet FEMA Requirements in Mill Valley

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Chapter 6: Task Force

6.1. Overview

In 2019, the City formed the Flood Management and Drainage Master Plan Task Force to assist the City in bringing choices to the community concerning drainage improvements and flood management strategies, estimated costs and funding options in conjunction with the development of a Master Plan.

The Task Force met four times and presented their findings to the community in September 2020. More details, members, and meeting notes can be found on the City's website here:

https://www.cityofmillvalley.org/gov/departments/publicworks/waterresources/presido/default.htm

The overall goals of the Master Plan are:

- Serve as a tool to inform policies, priorities, and to guide future City land use policies and infrastructure projects.
- Assist in the development of comprehensive and achievable drainage improvement and flood reduction goals, objectives, financing, and implementing projects and programs.
- Educate and attain broad consensus on goals, objectives, and implementation strategies.

Below are meeting summaries for the four meetings and community meeting of the Task Force. Notes from these meetings can be found in Appendix H.

6.2. Meeting 1 - November 2019 Summary

During the first Task Force meeting introductions were made and an overview of the purpose of the Task Force and the Master Plan were provided. Discussions were had about what types of projects to consider.

Task Force members wanted to further investigate the problem source and identify if there are anyways to hold back the water in the hillside so that the low lying and flat areas of the City are not inundated. A preliminary discussion of the level of service and design storms was had to identify the evaluation criteria for the Creeks and the pipe storm drain system.

6.3. Meeting 2 - February 2020 Summary

In the second Task Force meeting, preliminary results of modeling efforts on the creeks and the pipes were presented to the Task Force members. In addition, regional efforts on addressing sea-level rise and conceptual projects were presented. The driving force of flooding throughout the City is driven by the undersized creek channels.

Task Force members requested further analysis into the creek bypass channels and detention solutions that were concepts included in the Stetson report. The Task Force agreed upon using the 10-year storm event for both creek and pipe evaluation.

6.4. Meeting 3 - March 2020 Summary

In the third Task Force meeting, additional detention sites were presented to the Task Force as it was shown that detention at the golf course did not solve the flooding issues on the ACMdP because the golf course only detains flows from Warner Creek and not ACMdP. Two additional sites were analyzed – Old Mill Park and Grove Park for potential detention sites.

In addition to large dams, rain barrels were researched to determine how many rain barrels would be require on each parcel to detain the 130 acre-feet.

During Meeting 3, order of magnitude costs were presented on the channel bypasses. The Task Force requested more detailed costs for the next meeting.

The piped storm drain system backlog of projects was presented. The City maintains approximately the same linear feet of storm drain pipes as sewer pipes. The City has a dedicated sewer funding source from utility fees.

The City does not have a dedicated storm drain fund as storm drains are not considered a utility in the state of California. Instead, the City has historically set aside a small funding from the General Fund for emergencies. However, the City has not had sufficient budget to reserve funding for storm drains in recent years.

6.5. Meeting 4 - May 2020 Summary

This was the final meeting of the Task Force. The Task Force Chair, John McCauley, helped the task force to work through the details and logistics of a community meeting. A historical map of Mill Valley and the salt marsh was presented for context and to be used in the community meeting.

The conceptual costs of the bypass channels were presented. Costs ranged from $45M to $58M. These costs were compared to the cost to raise homes out of the 100-year floodplain. The creek channel bypasses only protects homes from a 10-year event. It was estimated to cost a homeowner around $100k to $150k to raise a home out of the floodplain. This would still have water flooding in the streets, but it would not enter into homes. The costs of raising homes was significantly cheaper than the channel bypass projects.

WRA Inc., an environmental firm based out of San Rafael attended the task force meeting to discuss dredging in Marin and the necessary permits, timing, and environmental impacts. In addition, dredging has to be done on a routine schedule or the sediments build back up.

Dredging also does not provide meaningful capacity to the system as it is limited to one to three feet of sediment, which is a significantly smaller surface area than the proposed channel bypasses as shown in Figure below.

6.6. September 2020 Community Meeting Summary

A 45-minute presentation was made to summarize the Master Plan analysis and results in September 2020. The purpose of the presentation was to answer questions below and to gather input and answer questions from the community.

- Can the City reduce flooding?
- If so, at what level?
- If so, at what cost?
- What is the state of the Mill Valley drainage system?

Members from the Task Force, community, City Council, and FZ3 were in attendance.

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Chapter 7: Capital Improvement Program

7.1. Summary of Findings

While there are many areas within the City of Mill Valley that provide adequate stormwater conveyance for a 10-year event, there are also areas that would benefit from improvements to enhance stormwater conveyance capacity. There are also regions of the City that lack a formal drainage system and require improvements. There are approximately 83,000 feet of pipe in the city's storm drain system that should be periodically inspected via CCTV for condition assessment.

Improvements are recommended for the Mill Valley's storm drain system's performance to ensure level-of-service during a 10-year storm. The improvements recommended in this Master Plan should be considered a comprehensive Capital Improvement Program within the study area.

7.2. Prioritizing Deficiencies in the Storm Drain System

Storm drain systems in Mill Valley convey the majority of stormwater runoff toward Richardson Bay through storm drain systems consisting of gutters, catch basins, pipes, and creek culverts.

Recommended improvements have been prioritized based on the results of the above process, combined with consideration of the anticipated severity of flooding at each location and the benefit/cost relationship of proposed improvements.

The capital improvements focus on the capacity-related issues that were identified in the Creek Empty modeled scenario. This means that these projects are independent of the creeks. The projects identified in the Creek Full model should be considered if creek improvements are conducted first to lower the water surface elevation in the creek.

The following color code is used to highlight project prioritization:

Priority	Description
High Priority	Projects under this category eliminate areas of 10-year flooding with significant depths, or address areas where City staff has indicated frequent and/or significant historical flooding issues. These projects are also independent of creek water levels. These projects improve conditions at locations with the deepest and longest-duration flooding situations.
Moderate Priority	These improvements are intended to contain most of the 10-year flooding within the street right-of-way. The duration and depth of flooding corrected by a moderate priority improvement is less than that of a high priority improvement.
Low Priority	Low priority improvements are aimed at containing the remaining 10-year flooding in the street right-of-way. The areas of flooding addressed by low priority projects are much smaller than those of moderate and high priority projects.

This chapter summarizes improvements to City-owned systems needed to achieve a level-of-service characterized by flooding no greater than the street level for a 10-year event. Improvements have been grouped to reflect projects that could feasibly be undertaken simultaneously. Project naming conventions use major street names where possible. Project names and unique numerical IDs assigned to each project identify improvements in maps and tables included in this SDMP.

Assuming that the continued CCTV video inspection of the system will be carried out over ten years, the annual cost for video inspection is estimated to be around $50,000. This is included into the annual operations and maintenance budget.

The remaining proposed CIP for storm drainage in Mill Valley is broken into three priority levels for the purpose of funding and implementation. The total cost summary for capacity related CIP projects is shown for each priority level in Table 7-1.

Table 7-1: Summary of Storm System CIP Costs Based on Priority Level (Total Project Cost) in 2020 Dollars

Priority Level	Cost
High Priority Capital Improvements	$3,220,000
Moderate Priority Capital Improvements	$2,760,000
Low Priority Capital Improvements	$1,140,000
Total Capital Improvement Program	**$7,120,000**

The above costs include a 40% contingency for design, administration, and construction contingencies. The City may elect to have a financial firm escalate these costs in the future to develop a funding mechanism for the CIP.

7.2.1. Annual Inspection of Pipes

The total cost for CCTV video inspection of approximately 8,500 feet of pipe was estimated to be $50,000 annually. Assuming that the video inspection will be carried out every year over a 10-year term. This annual fee is lumped into the annual system maintenance budget described below.

7.2.2. Annual System Maintenance

The City currently cleans all catch basins within the City annually. This Master Plan includes an annual budget of $250,000 to provide additional cleaning of the system throughout the winter and to address nuisance drainage related issues and to collect annual CCTV inspection data.

7.2.3. Condition Related CIP

Based on the initial CCTV investigations performed, there is approximately $350k worth of repairs that are needed to the system. In addition, it is recommended that the CMPs within the City are replaced over the next 20 years as the majority of CMPs investigated were deteriorating and in need of repair. The total cost to replace all the CMPs throughout the City is estimated at $8M.

7.2.4. Storm Drain Improvement CIP

The CIP costs priority levels are summarized in Table 7-2. Detailed project sheets with required replacement pipe for high and moderate priority CIPs are included in Appendix I.

Table 7-2: CIP Projects for the City of Mill Valley

Priority	Asset Name	Estimated Cost[1]
High Priority	Camino Alto	$200,000
	Hill	$540,000
	Sycamore 1	$2,480,000
High Priority Total		**$3,220,000**
Moderate Priority	Blithedale	$670,000
	Commercial	$330,000
	Lomita[2]	$330,000
	Madrona	$580,000
	Park	$520,000
	Sycamore 2	$160,000
	Sycamore 3	$160,000
Moderate Priority Total		**$2,760,000**
Low Priority	Alta Vista	$210,000
	Matilda	$340,000
	Oxford	$170,000
	Sycamore 4	$240,000
	Willow	$190,000
Low Priority Total		**$1,140,000**
Grand Total		**$7,120,000**

[1]Includes Contingencies (40%). 2020 Construction cost includes mobilization, traffic control, trench, and surface restoration. Does not include costs associated with permitting, land acquisition, or other unforeseen special circumstances.
[2]Research needs to be conducted to confirm that these are City responsibility.

7.3. Cost Basis for Storm Drain Improvements

Costs have been estimated using information from other projects, other master plans, and engineering judgment. The cost per linear foot of improvement used for the pipe cost estimates are given in Table 7-3. Most projects assume replacement pipe is installed using the open trench method. These costs do not include the cost of permitting, land acquisition, and other unforeseen special circumstances as the majority of the work is within the public right-of-way on public infrastructure.

Costs are likely to vary greatly depending on site-specific circumstances and the economic climate at the time of bidding; in some cases, it may be more practical to use trenchless methods or a parallel pipe for construction. These cost estimates are also based on larger scaled projects and thus, the replacement of shorter lengths of pipe as individual projects may incur significantly higher costs due to the nature of construction work.

Cost estimate of replacing connections (manhole or catch basin) depend on connecting pipe diameters and range from $18,700 (18-inch pipe) to $19,900 (36-inch pipe). CCTV video inspection and cleaning costs were estimated to be $5 per linear foot.

Since most of these improvement projects are expected to qualify for negative declarations from permitting agencies, these costs do not include permitting or any environmental documentation. Unit costs for pipes and connections assuming four feet of pipe cover are shown in Table 7-3.

Table 7-3: Storm Drain Replacement Unit Costs for Pipes and Connections

Diameter (inches)	2020 Rate	
	Per linear foot of Pipe[1]	Per Connection[1]
12	$230	$13,080
15	$260	$13,230
18	$280	$13,370
24	$350	$13,660
30	$450	$13,940
36	$520	$14,230
48	$690	$14,800

[1]Dollar amounts rounded to the nearest ten. Includes construction contingencies (40%).
Note: These are unit costs and do not include increases for design, administration, and unforeseen special circumstances. Unit costs are based on an average 4-feet of ground cover over the pipe. Greater cover will raise estimated costs. The construction costs presented in Table 7-2 do include contingencies and design estimates.

7.4. Creek Mitigation Considerations

This Master Plan does not recommend any immediate capital improvement projects, but rather more a focus on ensuring that creek setback requirements are maintained and educating the public in regard to the limited capacity of the creeks within the urbanized area and the high costs to increase the conveyance capacities.

The most viable means of flood mitigation was the creek channel bypasses which range anywhere from $36M to $58M. These bypass channels only solve the 10-year flooding event. The City may elect to take a further look at these solutions in the future, however, the Community nor the Task Force seemed interested in these high-cost projects at the time of this Master Plan.

Without a large investment in a capital improvement project, the City can expect to experience water in the streets during larger storm events due to the limited capacity of the creek channels that are surrounded by privately owned property. The City can help to contain this water in the streets by maintaining curb heights to the maximum height allowable in the streets to contain creek spills in the streets and protect properties from damage. There are areas within the street that have curbs that are lower than the standard six inches and there are places within the City that do not have any curbs at all.

7.5. Low Lying Areas Considerations

Climate change is anticipated to impact coastal and bayfront communities in the not-so-distant future. The City of Mill Valley is susceptible to sea-level rise in the low-lying areas. Some of these areas are already impacted by King Tides today, and those impacts will worsen with rising sea-level. Seal-level rise projections start around the year 2030 and move up to the year 2100 when the projections have a high level of uncertainty.

Because Marin has a significant amount of waterfront properties, there is a coordinated planning effort called BayWAVE. Adaptation is being looked at on a regional and local scale with several different project concepts. The most appealing concepts at this time revolve around using the environment as a protective barrier against rising tides. Appendix J contains the *Marin Shoreline Sea Level Rise Vulnerability Assessment* executive summary which is a recent planning effort that includes protection of some of the areas along Miller Avenue in Mill Valley. The City should stay up to date with County efforts and support the County where needed. Most of the work is being done by grant efforts.

Private property owners who are interested in immediate flood protection and climate change resiliency can elect to raise their home above the FEMA mapped 100-year floodplain (also referred to as the Base Flood Elevation, BFE) and include some additional height to combat sea-level rise. While the City will not pay for this type of project as it is private property, the City is looking into ways to support homeowners who wish to raise their home out of floodwater harm. It should be noted that this type of work will not alleviate the flood water in the street.

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Chapter 8: Financial Analysis and Funding Strategies

This chapter presents the funding strategies and their implications that are available to the City to fund capital improvement projects within this Master Plan. The findings presented in this chapter represent a high-level overview of the financial condition of the City's funding for creek and storm drains and potential impacts to the General Fund and/or property owners. Financial plans and levy/fee options should not be implemented without the specific analysis and justification required by statutory obligations for the revenue mechanism the City selects.

8.1. Overview

This chapter has been prepared following a "revenue requirements" analytical methodology common to financial analyses underlying most utility rates and charges imposed by traditional utilities, similar to the sanitary sewer systems.

While California law does not enable municipalities to impose "utility rates" for stormwater management services, the storm drain system shares similarities to traditional utilities and will likely require a primary, dedicated revenue source akin to rates.

The Master Plan includes long-term capital financing requirements to fund equipment, infrastructure, and problem-spot maintenance projects and will eventually have ongoing operations, maintenance, administration, and regulatory obligations to fund.

Properly managing the program may also require establishing reserves and using debt financing. Therefore, the following analyses have been prepared:

- Evaluation of financing strategies for the capital improvement program.
- Projected debt proceeds and debt service payments.
- Analysis of cash and reserve requirements.
- Determination of net annual revenue requirements for the program.

8.2. Potential Revenue Sources

In establishing a dedicated revenue stream for the Master Plan, the City may want to pursue a property-related fee or a special tax. The political feasibility of these mechanisms will likely be critical factors in determining which one the City implements.

8.2.1. Property-Related Fee

A property-related fee is a fee for service attributable to the parcel being charged. A fee for stormwater services is levied upon the county tax roll and is imposed as an incident of property ownership. As such, it would be subject to the substantive and procedural requirements of California Constitution Article XIII D (known commonly by its enacting ballot measure: Proposition 218).

The fee must be submitted and approved by a majority vote of the property owners or by a two-thirds vote of the electorate. The amount charged to each parcel must be proportional to the cost of service attributable to that parcel. Due to this proportionality requirement, the costs attributable to public parcels should be paid by City revenues (e.g., General Fund appropriation) or by individual City departments.

For a property owner election, each parcel generally receives one ballot, and each ballot has one vote regardless of the potential levy amount, although the City may also have the power to provide for weighted voting. In one-parcel-per-vote elections, a large commercial parcel with a calculated levy that is an order of magnitude greater than that of a smaller parcel would have the same, single vote as the smaller parcel.

The revenue stream from a property-related fee may be used for capital, annual operating, and maintenance costs. This revenue stream could also be pledged as credit support for a revenue bond issued to fund major capital improvements.

8.2.2. Special Tax

A Community Facilities District (CFD) can be formed pursuant to the Mello-Roos Community Facilities Act of 1982. A CFD can fund capital projects as well as ongoing maintenance. Bonds would be issued to pay for capital costs secured by a special tax levy. The same CFD can also fund ongoing maintenance costs through a special tax levy.

There is great flexibility in both the geographic area to be levied and the formula by which to levy when using a CFD. A CFD may include non-contiguous geographic areas. There is no requirement that the special tax is apportioned based on the benefit to any property. Property owned by a public entity is generally exempt from the CFD special tax, ensuring no lingering obligation of other City revenues.

Another option is to create a Subzone 3A special tax such as being done on Subzone 7A which is a ballot measure in Santa Venetia. Or a broader Zone 3 special tax which could include some of the backlog of work in this report into Flood Zone 3 responsibility.

Successful creation of a CFD requires the approval of two-thirds of the registered voters voting in an election. With a voter election, each voter has one vote, regardless of their weighted share of the proposed special tax levy. In a landowner election, the vote is one vote per acre or portion thereof.

8.3. Other Sources of Revenue

Although the revenue strategy introduced in this chapter has estimated the full cost to property owners of funding the entire Master Plan, there are at least two other additional revenue sources that, if justifiable and collectible on a substantive scale, would reduce that final levy amount needed from the community, or in other words, the total revenue requirement.

The chief benefit of examining the viability of these revenue sources is that both may be approved by consensus of the City Council alone after proper public noticing and public hearing processes.

8.3.1. Development Impact Fees

A development impact fee is a one-time fee imposed as a condition of approval on new development, infill, or redevelopment that creates new, unmitigated impermeable surface area. Development impact fees are authorized by Government Code 66000 et seq., created by the Mitigation Fee Act, and commonly referred to as “AB 1600” fees.

A development impact fee may be justifiable for the Master Plan under one of two conditions:

- The City has previously invested in drainage infrastructure which has remaining value and is available and/or sized to meet impacts caused by future development/redevelopment.
- The capital projects documented in this Stormwater Master Plan are sized to meet stormwater-related impacts caused by future development/redevelopment and not just the demands of existing development.

An impact fee may be based on (1) a "buy-in" to existing infrastructure, or (2) the "incremental" costs of new facilities necessary to serve new development that will create additional impermeable surface areas. A combination of these two impact fees may also be used to repay existing customers for historical capital investments. However, they cannot be used to fund operating or maintenance costs, which must be met through the Master Plan's annual fees.

8.3.2. Regulatory Fees

Regulatory fees are imposed to recover costs associated with the City's constitutional and statutory power to govern activities, such as development and construction. For example, within the Stormwater program, the City provides services/activities which may be eligible for recovery in a regulatory fee. These services/activities may include:

- Plan review and site inspection of development/construction that must meet Stormwater program regulations. (A common area for stormwater program activity is grading and drainage permitting/oversight.)
- Review of maintenance plans for, and periodic site inspection of onsite stormwater management/mitigation facilities.
- Inspection of properties documented under the municipal permit as high-pollution risk operations requiring onsite management and/or facilities to mitigate risk to the environment and public rights-of-way.

The statutory limit in imposing these fees is that they may not exceed the estimated reasonable cost of service. Most regulatory fees like these have historically been implemented by consensus of the City Council alone. Data used to justify fee amounts must be prepared and made available to the public in advance of the public hearing.

8.3.3. Benefit-Assessment District

A benefit-assessment district assigns project costs in direct proportion to the benefits received. Benefit assessment districts are often formed for specific projects within a specific watershed. The only properties assessed are those that directly benefit from the projects and in direct proportion to that benefit.

8.3.4. Grants

There are grant opportunities for stormwater, flood control and climate adaptation projects in California. These grants are competitive and require a good deal of effort to secure. If the City wishes to pursue grant opportunities, it is recommended they secure a grant writer or dedicate significant staff time to the application process.

8.4. Flood Zone 3

Flood Zone 3 (FZ3) was formed in 1956 to address creek and tidal flooding adjacent to Richardson Bay and is overseen by a 7-member Advisory Board. FZ3 covers over 13 square miles, including the City of Mill Valley and numerous unincorporated communities including

Marin City, Alto, Sutton Manor, Almonte, Tamalpais Valley, Homestead Valley, and portions of Strawberry Point.

There are 12,560 parcels in the Zone which generated approximately $2.5M in FY 2020-2021. This equates to roughly $200 per parcel annually. This fee is paid with property taxes annually.

8.5. SB 231

The 2017 passage of Senate Bill 231 by the California legislature has defined “sewer” to include “storm waters.” As “sewers” are already established as a utility, this would allow municipalities to bypass the Proposition 218 voting process (see section 8.2.1). While this legislation appears promising for simplifying the storm drain fee process, it has yet to be successfully utilized by any municipality.

The likelihood of this bill being challenged in court is very high and many cities and counties are awaiting a court decision before relying on SB 231 to form or modify a storm drain fee without voter approval.

8.6. Summary

This Master Plan presents the improvements that the City finds:

- The City of Mill Valley, like many California cities, faces increasing expenditures to fulfill mandated obligations and community expectations associated with its Master Plan.
- The storm drain pipes have historically been supported by the General Fund; however, the projected cost of these expenditures in a time of increasing demands on the City’s General Fund warrants the consideration of a dedicated revenue stream. In addition, the recent General Fund does not include any funding for storm drain pipes.
- Due to the recent pandemic and economic downturn, a financial study and pursuit of a dedicated storm drain fee or tax unlikely to pass by the voters. Any tax or fee should be coordinated with FZ3 so that both entities are not pursuing fees at the same time.
- The City should consider requesting funding from FZ3 to improve the drainage to the Creek systems.
- Over the next 10-years, the Master Plan program could invest approximately $7.4 million (in 2020 dollars) to improve or construct capital infrastructure These investments, while ordered in a prioritized manner, could occur in an uneven pattern from year to year.
- Over this 10-year period, the Master Plan recommends the City spend approximately $250,000 annually (in 2020 values) on operation and maintenance and addressing nuisance drainage issues in the system. This includes $50,000 annually to clean and inspect a portion of the drainage infrastructure.
- Within the next five years the City should consider rehabilitating the Sycamore Pump station at a cost of approximately $1M. After the pump station has been rehabilitated, the City should request support from FZ3 in the operations and maintenance of the pump station as the various flood zones throughout the County maintain pump stations.
- While multiple levy/fee mechanisms are available to create a dedicated revenue stream from properties in the City, some form of direct property owner or voter approval of the fee will likely be required. The City will need to determine the political feasibility of this new funding source, in addition to preparing the formal justification and documentation of the selected levy/fee mechanism.
- This Master Plan was funded by FZ3 and contingent on the City not unilaterally seeking a funding mechanism without coordinating with FZ3 so that the two agencies don’t have competing ballot measures.

- Other minor revenue streams may also be developed which would reduce the annual levy on property owners. These might include fees for specific operational or regulatory tasks and/or mitigation fees from new development or redevelopment that impact the stormwater infrastructure.
- Grants should be applied for where applicable to Master Plan projects, however, they are not a reliable source of revenue and generally do not fund operation and maintenance activities. The City should focus grant efforts on sea-level rise resiliency, shoreline protection measures that enhance the environment, and provide assistance to property owners seeking FEMA grant assistance to raise their homes.

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APPENDIX A

Stetson Reports

DRAFT APPRAISAL-LEVEL FLOOD STUDY FOR ARROYO CORTE MADERA DEL PRESIDIO, MILL VALLEY, CA

DRAFT

PREPARED FOR

CITY OF MILL VALLEY

JANUARY 2013

PREPARED BY

STETSON ENGINEERS INC.

STETSON ENGINEERS INC.

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EXECUTIVE SUMMARY

This report documents flooding problems and describes measures to reduce flooding and flood damage resulting from breaching of the banks of the mainstem Arroyo Corte Madera del Presidio (ACMdP) and its major tributaries Old Mill Creek and Warner Canyon Creek. This report focuses on the flow capacity of the creek and develops a range of potential solutions to reduce flooding upstream of Camino Alto. Downstream of Camino Alto coastal flooding is the dominant source of flooding. Coastal flooding will be evaluated through the Southern Marin Watershed Program, which is a joint effort of the City and the Marin County Flood Control and Water Conservation District (MCFCWCD).[1] Flooding from overflow of interior stormwater drainage systems, including minor creeks, ditches, and storm drains, is generally excluded from this study, with the exception of the Sycamore Avenue Pump Station, Ryan Creek Pump Station, and Camino Alto North Outfall. Following are highlights of the report.

The December 31, 2005 Flood

The damage that resulted from the New Year's Eve 2005 flood has renewed interest in flood management along the flood-prone ACMdP in Mill Valley. Of the estimated 217 parcels inundated by floodwaters, 167 parcels (77%) reported damage. Most of the reported damage was concentrated in the Sycamore neighborhood and resulted from breaching of the banks of the channel between Willow Street and Camino Alto.

The December 31, 2005 flood was a rare, enormous runoff event, with a peak discharge of about 1,810 cubic feet per second (cfs), the highest flow measured over the period of historical gage record. The probability of a flood of this magnitude occurring in any given year is estimated at approximately 2 percent. Stated another way, on average and over the long term, a flood of this magnitude would be expected to occur only about once every 50 years.

Natural stream channels have limited conveyance capacities and typically overtop their banks during floods of a much smaller magnitude than the 50-year event; or about once every 1 to 4 years. In view of this, overtopping of banks of ACMdP on December 31, 2005 was characteristic of a natural stream given the enormous magnitude of the event. Even in its quasi-natural condition (i.e., hypothetical condition with all bridges, culverts, and other structural crossings removed), the creek still would have overtopped its banks and inundated parcels in the floodplain on December 31, 2005.

[1] Information about the Southern Marin Watershed Program can be found at www.marinwatersheds.org.

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Flood Damage Reduction by Raising At-Risk Residential Buildings

The results of this study demonstrate that a reduction in flood damage could be achieved by raising the elevation of the first finished floor of vulnerable residential buildings. The number of at-risk buildings (i.e., buildings in the flood prone area with first finished floors that would be inundated during floods) is given in Table ES1. Most at-risk residential buildings could be feasibly raised, assuming the owners agree to undertake the work. The total estimated capital cost to raise all of the at-risk residential buildings ranges from about $40,000 for those located in the 5-year flood prone area to $4,300,000 for those located in the 100-year flood prone area. Most non-residential at-risk buildings, such as commercial buildings along lower Miller Avenue, are not suitable for raising because of the methods and materials used in their construction[2]. Other approaches to flood damage reduction, such as flood proofing, may be feasible for these types of structures, but detailed evaluation of these approaches was beyond the scope of this study.

Table ES1. Summary of Raising At-Risk Residential Buildings

Level of Flood Protection	Number of At-Risk Non-Residential Buildings	Number of At-Risk Residential Buildings	Total Estimated Capital Cost of Raising At-Risk Residential Buildings ($)
5-Year Flood	7	1	42,000
10-Year Flood	16	14	492,000
25-Year Flood	27	60	1,760,000
50-Year Flood	40	103	3,086,000
100-Year Flood	59	150	4,289,000

Note: The cost of raising at-risk residential buildings varies from building to building. Costs above are based on an estimated average unit cost of $22 per square foot. Refer to page 9 of Appendix H for the basis of this estimated unit cost.

Flood Damage Reduction by Improving Creek Flood Control Infrastructure and Additional Public Benefits

Flood damage reduction could also be achieved by implementing the flood control measures[3] developed through this study. These measures reduce flooding by increasing the flow capacity of the creek at key locations where capacity is limited, by bypassing floodwaters around these

[2] Commercial buildings constructed of concrete block, concrete tilt up, brick wall or stone wall typically are not suitable for raising. It is typically not feasible to raise buildings that are not constructed with light weight and strong materials such as wood and steel.

[3] "Flood control measures" is a term used herein to describe physical facilities or improvements to creek infrastructure designed to keep floodwaters, that would occur as a result of a specific magnitude flood event, in the channel and away from developed areas in the floodplain. Flooding could still occur even after work is performed to achieve a specific level of flood protection.

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reaches in a separate channel, and by reducing the magnitude of the peak flood discharge through attenuation in a large detention basin. An existing computerized HEC-HMS hydrologic model of the watershed was modified and improved and a new HEC-RAS hydraulic model of the creek was constructed to develop and test the effectiveness of possible measures. The measures were evaluated for potential feasibility and cost estimates were calculated. Combinations of measures deemed potentially feasible were bundled into groups, each group providing a targeted level of protection. Collectively, these groups provide from 5-year flood protection to 100-year flood protection (see Table ES2). Estimated capital costs range from $2,333,000 for 5-year flood protection to $42,597,000 for 100-year flood protection. Of the levels of flood protection analyzed, the 10-year and 25-year levels provide the greatest benefit-cost ratio, about 1.4 to 1[4]. The estimated capital costs of the 10-year and 25-year levels of flood protection are $8,125,000 and $15,745,000, respectively.

Table ES2. Summary of Bundled Measures for Different Levels of Flood Protection

Level of Flood Protection	Bundled Measures	Estimated Capital Cost ($)	Estimated Benefit-Cost Ratio
5-Year Protection	• Willow Street pedestrian bridge replacements (2); channel widening over about a 150 ft reach near the bridges • Removal of concrete weir at the streamflow gage; channel dredging over the 150 ft reach upstream of the gage • Low floodwalls/berms	2,333,000	0.5
10-Year Protection	• All 5-Year Flood Protection Measures • La Goma Street Bridge replacement • Raise Sycamore Avenue grade • Park Street Bridge replacement • Additional low floodwalls/berms	8,125,000	1.4
25-Year Protection	• All 10-Year Flood Protection Measures w/o La Goma Street Bridge replacement • Arroyo Corte Madera del Presidio partial bypass • Additional low floodwalls/berms	15,745,000	1.4
50-Year Protection	• All 25-Year Flood Protection Measures • Culvert enlargement beneath private building downstream of Sunnyside Avenue • Egger Plaza Bridge replacement • Mill Valley Golf Course detention basin • Additional low floodwalls/berms	38,131,000	0.8
100-Year Protection	• All 50-Year Flood Protection Measures • Additional low floodwalls/berms	42,597,000	0.8

Notes: Refer to Appendix H for details on the cost estimates and the benefit-cost analysis.

[4] Additional benefits not included in the benefit-cost ratio include benefits to business, ecosystems, infrastructure and public services, transportation systems, and others. Including these benefits would increase the benefit-cost ratios shown.

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Creek infrastructure improvements offer a broad array of public benefits beyond protecting buildings and contents from damage. Flood control measures enhance public health and safety, avoid public hardship and disruption associated with flooding, and protect public infrastructure, facilities, water quality, and ecosystems. Flood control measures also prevent economic losses to private businesses, municipalities, and the general public. These types of public benefits were not evaluated in this report and are not accounted for in the benefit cost ratios in Table ES2. Including these benefits would increase the benefit-cost ratios shown in the table.

Creek infrastructure improvements also offer the benefit of improving the habitat of the creek, particularly for native fish such steelhead trout, Coho salmon and Chinook salmon. These anadromous fish are protected under federal and state law. By incorporating fish passage features and biotechnical bank treatments using native vegetation into the final designs of the flood control measures, flood reduction and habitat improvement can be accomplished concomitantly.

Effects of Climate Change and Resulting Sea Level Rise on Flood Control Measures

Higher downstream water levels resulting from future sea level rise would not have an important effect on the performance of the flood control measures described in this report. The reason is that the projected rise in sea level will extend only as far up the creek as the Valley Circle Pedestrian Bridge, and most of the proposed flood damage reduction measures are farther upstream. Sea level rise will, however, exacerbate localized flooding resulting from surface runoff from streets and properties in areas where stormwater drainage systems are unable to discharge to the creek due to higher creek levels downstream of Valley Circle. Sea level rise is expected to have major impacts on direct coastal flooding and wind-wave erosion along the Richardson Bay shoreline, including impacts to properties and critical infrastructure.

Moving Forward

This report provides technical information to support future flood mitigation planning efforts and decision-making. It describes how flooding can be reduced by containing more of the floodwater in the channel through physical improvements to creek flood control infrastructure, and it provides estimated costs for different levels of flood protection. This report also describes how damage can be reduced by raising the first floor elevations of residential structures. Commercial structures and critical infrastructure that can not practicably be raised may be protected by flood-proofing.

One way to move forward with flood mitigation planning and decision-making would be to follow a phased approach as illustrated in the flow chart below.

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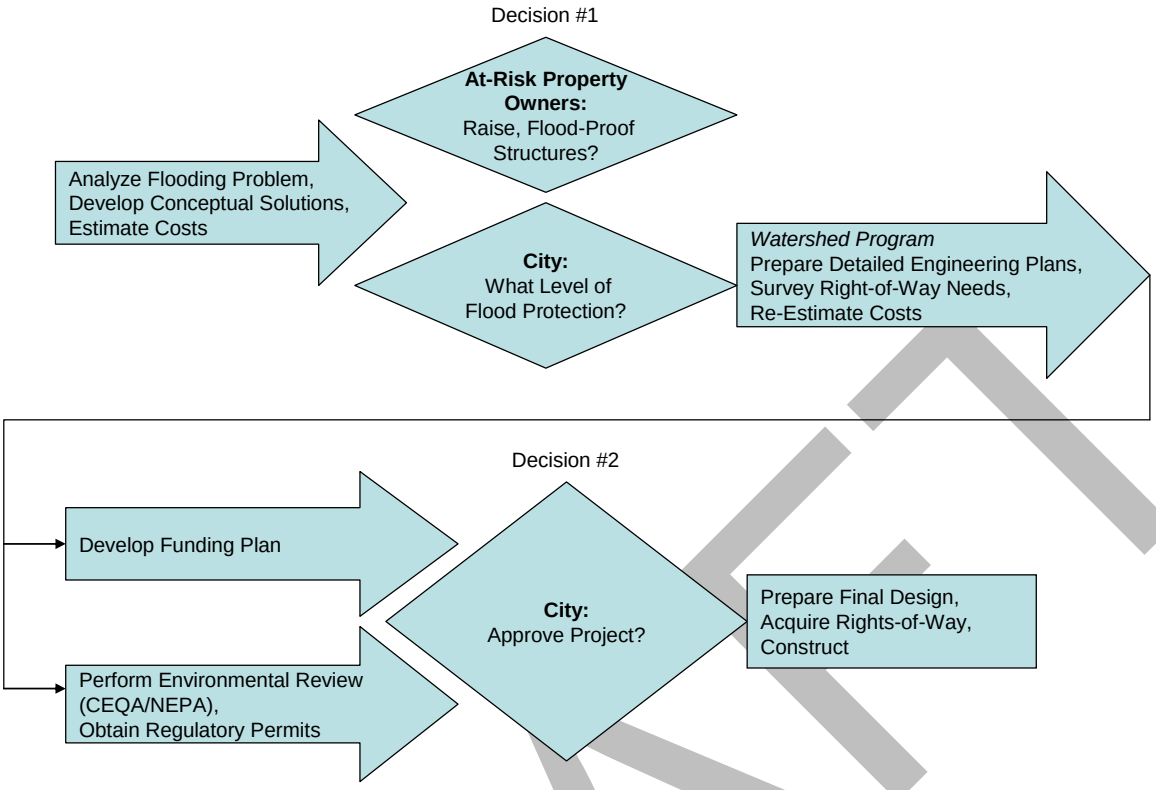


Figure ES1 Arroyo Corte Madera del Presidio Flood Control Project Implementation Plan

With this appraisal-level study, the first phase, characterizing the flood problem, developing conceptual solutions, and estimating costs for various levels of flood protection, has been completed. Individual owners of at-risk properties can use flood elevations developed through this study to help them decide on raising or flood-proofing their structures. Similarly, the City can decide to pursue a particular level of flood protection considering what it can afford in light of the benefits and costs presented in this report.

The next step is to prepare detailed engineering design plans for the measures comprising the City's selected level of flood protection, conduct land surveys to delineate encroachments on private properties and determine right-of way needs, and prepare an updated cost estimate. This effort should be carried out under the Watershed Program because it needs to consider broader issues, such as sea level rise and environmental enhancement. With detailed engineering design completed, planners can, in parallel efforts, better define the funding requirements necessary to finance the project, proceed with environmental review under CEQA and NEPA, and pursue regulatory permits. Upon approval of the project by the CEQA and NEPA lead agencies and receipt of permits, the project can move to the last phase, which includes final design, rights-of-way acquisition, and construction.

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1.0 PURPOSE, BACKGROUND, STUDY REACH, AND STUDY LIMITATIONS

This report documents an appraisal-level engineering study[5] performed by Stetson Engineers Inc., San Rafael, of flooding along the lower mainstem of Arroyo Corte Madera del Presidio, Mill Valley, California. Mr. David R. Dawdy, Consulting Hydrologist, assisted in the flood frequency analysis. Mr. Chad Corsten, structural engineer with Wood Rodgers, Sacramento, assisted in developing the preliminary feasibility assessments for replacements of structural crossings. This study was begun in 2006, updated and expanded in 2010, and finalized in 2012.

The focus of the study was the hydrology and hydraulics or flow capacity of the creek and surrounding floodplain. The storm water drainage system that drains streets and other lands and discharges to the creek, referred to as the "interior drainage system," was generally excluded from the study (with the exception of the Sycamore Avenue Pump Station, Ryan Creek Pump Station, and Camino Alto North Outfall).[6] The primary purpose of the study was to identify sources of creek flooding and develop conceptual measures to reduce flood damage by reducing creek overflow or other means, preliminarily assess the feasibility of the measures, prepare conceptual plans, and estimate costs. The study assessed the potential effects of future sea level rise on the effectiveness of the conceptual flood damage reduction measures.

The study addressed other flooding issues and specific flood reduction measures including the following:

- the flow capacity of the creek at the Willow St. Bridge and Valley Circle Pedestrian Bridge;
- using cisterns to reduce flooding;
- the effects of additional development and impervious areas on increased flood flows;
- diverting flood flows to marsh areas;
- increasing the flow capacity of the Sycamore Pump Station; and,
- dredging as a means to enlarge the creek, increase its flow capacity and reduce flooding.

The study area covered the lower reaches of Arroyo Corte Madera del Presidio, Old Mill Creek, Warner Canyon Creek, and their surrounding floodplains (Figure 1). The study was limited to

[5] The U.S. Bureau of Reclamation also uses the term, "appraisal-level" engineering study. At the appraisal-level, the problem is identified, conceptual alternative remedies are developed and their effectiveness evaluated, and recommendations are made for more detailed study of the most viable and promising alternative(s). The U.S. Army Corps of Engineers uses the term, "reconnaissance-level" to refer to this same level of engineering study.

[6] Independent of this study, MCFCWCD studied flooding on Miller Avenue between Camino Alto and Almonte Boulevard (Winzler and Kelly, 2008). The MCFCWCD study area was farther downstream and focused on tidal effects on the interior storm drain system. This report focuses on the hydraulic capacity of the mainstem of Arroyo Corte Madera del Presidio and flooding problems that originate upstream of Camino Alto.

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this area because it is most susceptible to flood damage as demonstrated by the December 31, 2005 flood event. The study considered the effect of the tide acting on creek flow where it discharges to the bay, concentrated inflows entering the study area from upper Arroyo Corte Madera del Presidio, upper Old Mill Creek, upper Warner Canyon Creek, Reed Creek, and distributed inflows entering from numerous small unnamed drainages. Flooding along Ryan Creek was analyzed separately because it drains a separate watershed.

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FIGURE 1

ACMdP UPSTREAM STUDY LIMIT AT GARDNER STREET

OLD MILL CREEK CONFLUENCE

OLD MILL CREEK UPSTREAM STUDY LIMIT

WARNER CREEK UPSTREAM STUDY LIMIT

WARNER CREEK CONFLUENCE

EGGER PLAZA

SYCAMORE STORM DRAIN SYSTEM

GAGING STATION

SYCAMORE PUMP STATION AND DISCHARGE

REED CREEK NOT INCLUDED IN STUDY AREA

N

W E

S

SCALE (FEET)

0 350 750

LEGEND

STUDY STREAM REACH

STUDY FLOODPLAIN (MODEL DOMAIN)

STETSON ENGINEERS INC.

DATE: SEPTEMBER 13, 2012 | JN: 2165

LOCATION OF STUDY AREA

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2.0 HISTORICAL FLOODING IN THE STUDY AREA

2.1 Factors Influencing Flooding

Flooding is a natural phenomenon that occurs when the runoff from a watershed generated during an intense storm exceeds the capacity of the stream channel to convey it.[7] In the study area, historical floods have been of short duration, reaching their maximum intensity rapidly, generally within 8 to 12 hours after the beginning of flood-producing storms. Flooding has usually subsided within 24 hours after the end of such storms. Under existing conditions, high tides in San Francisco Bay can back-up the channel as far as the streamflow gage below La Goma Street, reducing hydraulic capacity along this lowermost reach. This effect can exacerbate flooding along the lower estuarine end of the channel below La Goma Street (U.S. Army Corps of Engineers, 1967).

Areas adjacent to the channel that are now subject to flooding were formerly low-lying marshlands which were filled in recent decades for urban and commercial expansion. Buildings and homes have encroached along the channel banks and, in some cases, directly over the channel. Bridges and culverts have been built across the channel, further limiting the capability of the creek to convey large flood flows. Consequently, the problem of flooding has increased with time (U.S. Army Corps of Engineers, 1967). FEMA has characterized the flooding problem as follows:

> Existing drainage is inadequate and the flood problems are accentuated by encroachment of residential developments upon the channels. Channel capacities have been reduced to the extent that flooding occurs in the low areas whenever there is an intense storm over the Arroyo Corte Madera del Presidio basin. In areas where the general ground was lower than the stream channel, development was made possible by using random fill to reclaim the land. This reclamation was accomplished at different times under varying governing criteria. As a result, low pockets of land have developed along the channel. During overbank flow, ponds in these areas make flood damage a function of duration as well as peak. Near the lower portion Arroyo Corte Madera del Presidio (i.e., Sycamore neighborhood), a residential development has been built on bay fill along the north side of the stream channel, immediately upstream from Camino Alto and south of Sycamore Avenue. This fill formed a sump area where it meets the natural valley slopes. Flooding occurs in the sump area nearly every year. Beginning in the vicinity

[7] The type of flooding that is addressed in this report occurs when floodwaters break out of the channel and spill over into adjacent areas due to the lack of flow capacity of the channel. This type of flooding is differentiated from "interior flooding" which is localized flooding that occurs when storm-generated runoff from streets and other lands exceeds the capacity of the interior drainage system to convey the stormwater to the creek.

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> of Willow Street and extending downstream, flooding occurs because the channel is above the surrounding ground. Overbank flows do not return to the channel until they reach Camino Alto because of the natural topography. Adding to the problem is the inadequacy of the existing drainage system in this area (Federal Insurance Administration, 1978).

Using hydraulic modeling techniques,[8] locations where the channel lacks the flow capacity to convey floods were identified. These locations are identified in Appendix E and ranked in order how frequent flooding occurs at those locations. For the most part, the locations that are most susceptible to flooding lie between approximately Willow Street and Camino Alto. This area is susceptible to overbank flow about every five years on average. Above Willow Street, a few isolated locations are susceptible to overbank flow but the extent and severity of flood damage is probably minor based on observations from the December 31, 2005 flood event.

2.2 Historical Floods and Flood Frequency

Floods along the study reach occurred with varying degrees of severity in 1907, 1909, 1916, 1938, 1940, 1945, 1952, 1955, 1956, 1962, 1963 (U.S. Army Corps of Engineers, 1967), 1970, 1973, 1982, 1983, and 2005. Of these, the five most severe floods occurred in 1938, 1945, 1955 (U.S. Army Corps of Engineers, 1967), 1982, and 2005. The peak flood discharge of December 31, 2005, the largest of recent history, was estimated to be 1,810 cfs based on the recorded peak stage of 13.79 ft NAVD88 (North American Vertical Datum of 1988) at the Arroyo Corte Madera del Presidio streamflow gage (Figure 2). For comparison, according to the United States Geological Survey (USGS), the January 4, 1982 flood peak stage was recorded at 12.67 ft NAVD88 with an estimated peak flood discharge of 1,170 cfs. The 1982 storm may have resulted in more extensive flooding than the 2005 storm even though the 1982 peak discharge was lower. The extent of flooding is affected by multiple factors, such as rainfall duration and intensity, flood flow volume and peak discharge, tidal effect, and blockage of the channel and culverts by debris. More extensive flooding in 1982 may be explained by that storm's lower rainfall intensity but longer duration and a higher tidal level at the time of peak discharge. Some long-time local residents have reported that the channel and culverts were blocked by debris during the 1982 flood event. These factors could have contributed to more floodwater escaping from the channel and, hence, more extensive flooding.

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[8] Refer to Appendix D for details on the development of the hydraulic model and Appendix E for simulations to identify locations of insufficient channel capacity.

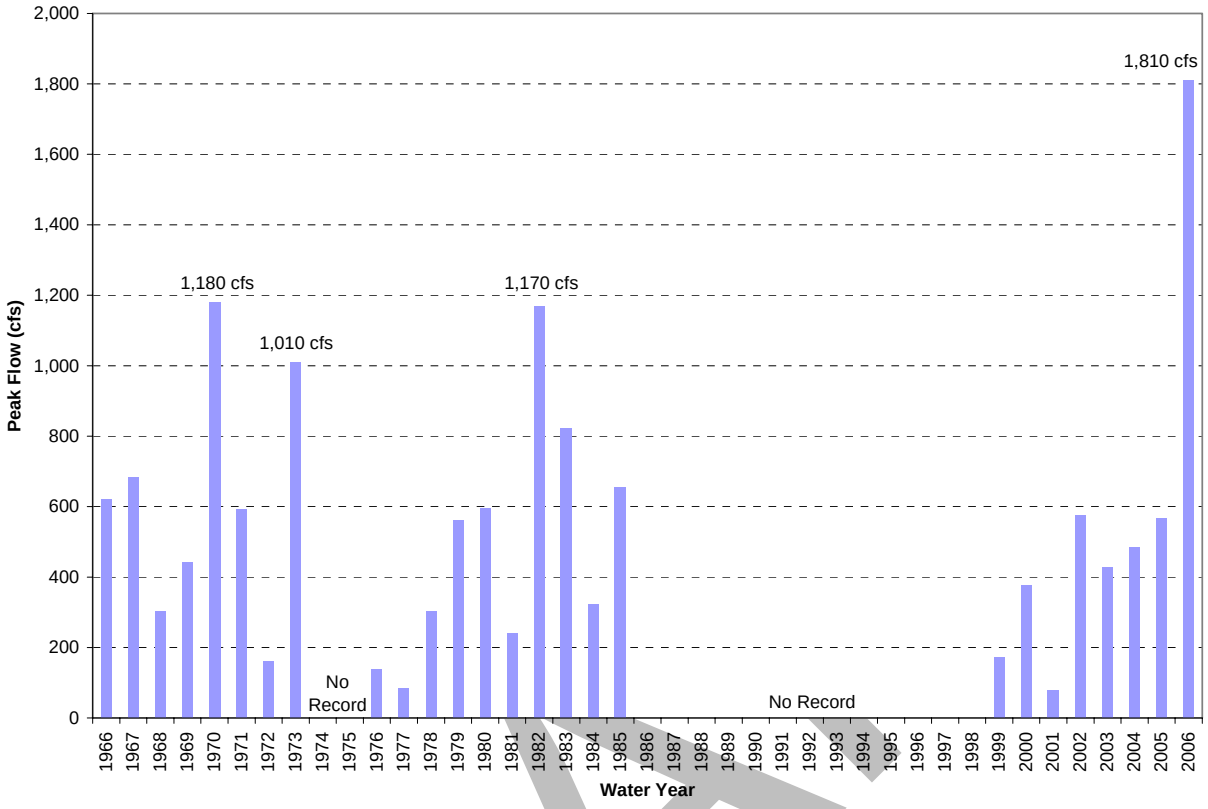


Figure 2 Historical Annual Peak Flows Observed at the ACMdP Gage

Flood frequency analysis[9] was performed using historical streamflow records for the Arroyo Corte Madera del Presidio Gage (Dawdy, 2006[10]). The purpose of the analysis was to develop a relationship between magnitude of a given flood flow and its probability of occurrence in any given year, or its average recurrence interval over the long term. This relationship would provide a means for ascertaining the magnitude of flood flow that the Arroyo Corte Madera del Presidio flood control system would need to be designed to provide a desired level of flood protection.[11]

The first step in the flood frequency analysis was to convert the historical streamflow records, measured and recorded in terms of peak stage, to peak discharges using an updated stage-

[9] Flood frequency analysis is the statistical analysis of historical streamflow records of annual instantaneous peak flow. Flood frequency analysis determines the magnitude of a flood associated with a given probability of occurrence in any given year, or recurrence interval.

[10] Refer to Appendix A for Dawdy 2006.

[11] Typically the level of protection that a flood control system provides is expressed in terms of its recurrence interval, which is the long-term average interval, in years, between floods that equal or exceed the system's capacity. The probability for failure in any given year is the reciprocal of the recurrence interval. So, for example, a flood control system that provides a 100-year level of protection would be flooded, on average over the long-term, less than once every 100 years, and the probability for flooding in any given year would be less than 1 percent.

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discharge rating curve[12]. The result of this conversion procedure is the set of historical peak discharges summarized in Table 1.

Table 1. Annual Peak Flows Used in Flood Frequency Analysis

Date	Water Year	Peak discharge (cfs)	Date	Water Year	Peak discharge (cfs)
01/05/1966	1966	620	01/04/1982	1982	1,170
01/20/1967	1967	682	03/13/1983	1983	821
01/29/1968	1968	303	11/19/1983	1984	323
12/28/1968	1969	443	02/08/1985	1985	654
01/21/1970	1970	1,180	02/07/1999	1999	172
12/04/1970	1971	593	01/24/2000	2000	377
02/05/1972	1972	160	02/24/2001	2001	79
01/12/1973	1973	1,010	12/01/2001	2002	574
10/26/1975	1976	139	12/13/2002	2003	428
01/02/1977	1977	83	02/25/2004	2004	484
01/14/1978	1978	301	12/27/2004	2005	565
01/11/1979	1979	561	12/31/2005	2006	1,810
01/11/1980	1980	595			
01/27/1981	1981	240			

1) Source: Dawdy 2006.
2) Water year is a term commonly used in hydrology to describe the 12-month period from October 1st of one year through September 30th of the next year.

The next step in the flood frequency analysis was to develop the relationship between magnitude of flood flow and probability of occurrence in any given year (and, hence, the average recurrence interval) using the peak discharge data in Table 1. The standard method used by FEMA was used to develop this relationship. The result is graphically shown in Figure 3. Table 2 draws from Figure 3 and summarizes the magnitudes of selected flood events.

Table 2. Magnitudes of Selected Flood Events and Probabilities

Recurrence Interval (yr)	Probability	Magnitude of Peak Discharge (cfs)
2	0.5	449
5	0.2	836
10	0.1	1,120
25	0.04	1,500
50	0.02	1,810
100	0.01	2,110

[12] Refer to Appendix A for Dawdy 2006 for the updated stage-discharge rating curve.

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The flood frequency analysis indicates that the December 31, 2005 flood, estimated using the updated stage-discharge rating curve to be 1,810 cfs, was approximately a 50-year event (i.e., long-term average recurrence interval, 50-years; probability of occurrence in any given year, 2 percent; also referred to as the 2-percent-annual-chance flood).

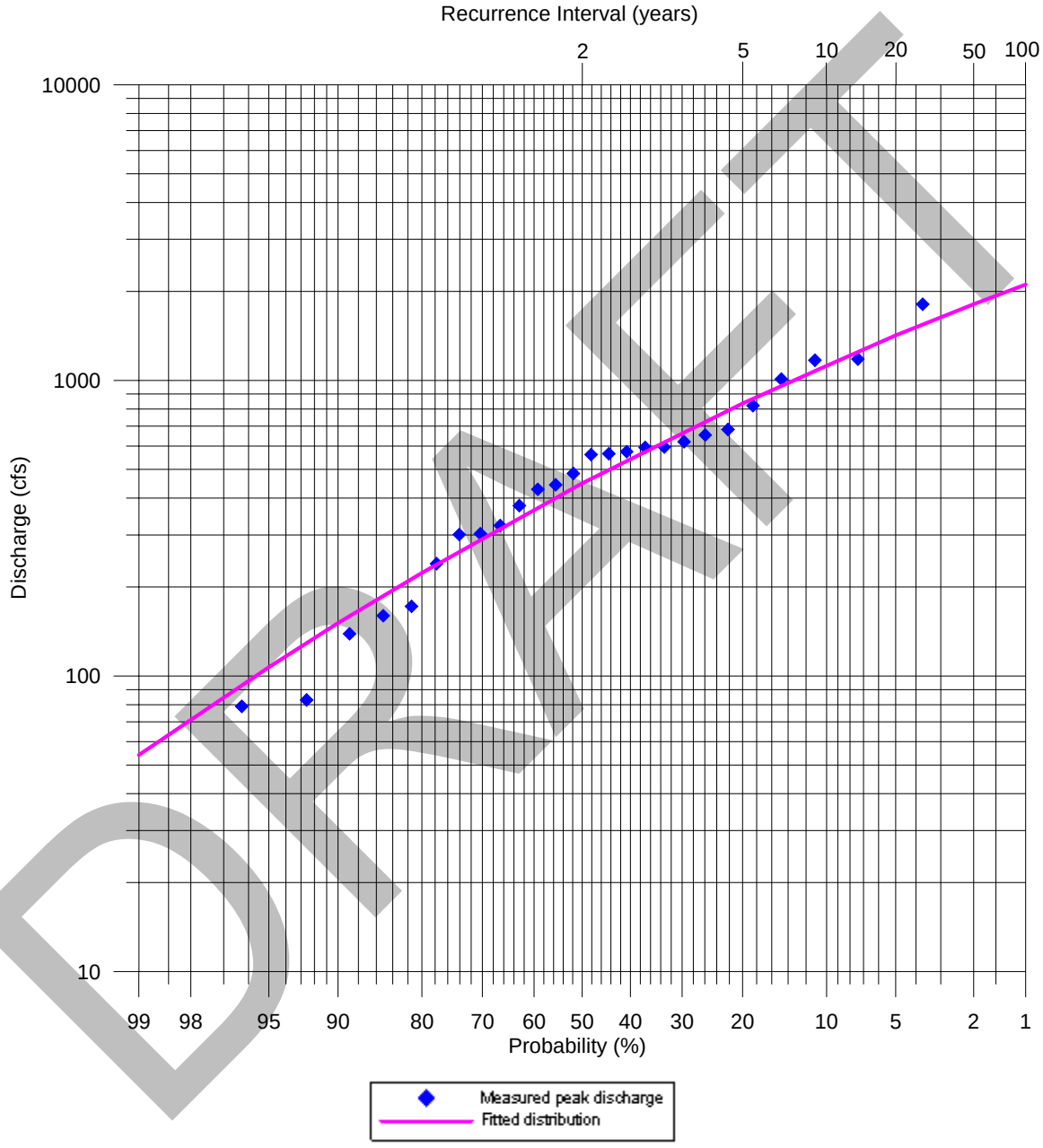


Figure 3 Flood Frequency Curve for the ACMdP Streamflow Gage
(Source: Dawdy 2006)

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2.3 Characterization of the December 31, 2005 Flood

2.3.1 Hydrologic Characteristics

This hydrologic characterization of the December 31, 2005 flood event is based on rainfall measurements recorded at the CIMIS (California Irrigation Management Information System) rainfall gage at Point San Pedro, San Rafael[13] and streamflow measurements recorded at the MCDPW Arroyo Corte Madera del Presidio streamflow gaging station. Refer to Figures 4 and 5.

Antecedent Soil Moisture Conditions

Prior to December 30, about 10.1 inches of rain had fallen over the preceding two-week period (December 17 through 30). By December 30, soils were generally saturated, and the baseflow stage at the Arroyo Corte Madera del Presidio Gage was about 8.01 ft NAVD88. Saturated soil conditions increase runoff and the potential for flooding.

Flood Event Measurements

The storm began on December 30 at about 6:00 am. Thereafter rainfall continued steadily over the following 25-hour period, stopping on December 31 at about 7:00 am. The highest intensity rainfall occurred on December 31 over a three-hour period from about 3:00 am to 6:00 am. The stage at the Arroyo Corte Madera del Presidio Gage reached 12.31 feet NAVD88 (assumed flood threshold) at about 3:00 am, peaked at 13.79 feet NAVD88 at about 6:00 am, and receded back down to flood threshold level at about 9:00 am. The channel was breached for about 6 hours, although it probably took several hours for all the water to return to the channel. Following are preliminary summary findings based on the rainfall measurements:

- From December 30 at 0600 to December 31 0600, approximately 6.0 inches of rain fell. This equated to a 15-year, 24-hour rainfall event (per the new NOAA Atlas 14).
- From December 31 at 0300 to 0600, approximately 2.1 inches of rain fell. This equated to a 15-year, 3-hour rainfall event (per the new NOAA Atlas 14)[14].

[13] MCFCWCD also operates rainfall gage at Arroyo Corte Madera del Presidio and at Kentfield, but during maintenance checks on January 19 and 20, 2006 both gages were found to be malfunctioning, so the recorded measurements for the December 31, 2005 storm were deemed unreliable. The nearest official functioning rainfall gage with reliable measurements was the CIMIS gage at Point San Pedro, San Rafael. MCFCWCD's Arroyo Corte Madera del Presidio rainfall gage and the CIMIS gage at Point San Pedro, San Rafael are within about 7 miles of each other and have similar elevations (Point San Pedro station is at elevation 17 ft NGVD29 and the Arroyo Corte Madera del Presidio station is at elevation 33 ft NGVD). The CIMIS gage was used for this data because it was deemed the best alternative source of authoritative rainfall measurements for the December 31, 2005 storm. Examination of the Army Corps-developed mean annual rainfall isohyetal map for the area indicated that the mean annual rainfall amounts at Point San Pedro and Arroyo Corte Madera del Presidio rainfall gages are similar.

[14] In small watersheds, such as Arroyo Corte Madera del Presidio, where the time of concentration is 3-hours or less, short intensities (e.g., the 3-hour intensity) are typically used as indicators of flooding potential.

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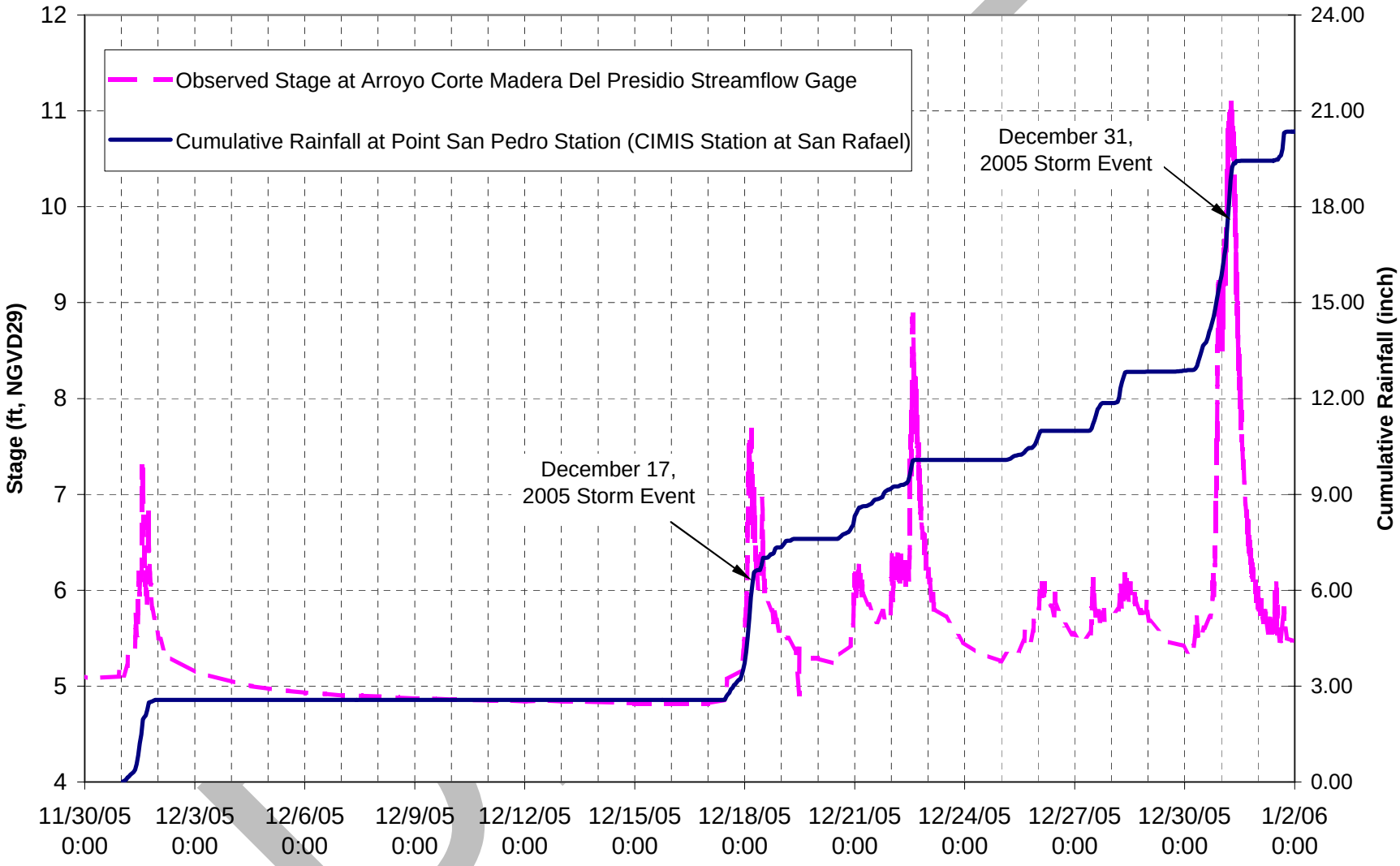


Figure 4 Hydrograph of Arroyo Corte Madera Del Presidio Streamflow Gage Stage and CIMIS Point San Pedro Station Cumulative Rainfall, December 2005

(Rainfall Source: CIMIS Website http://wwwcimis.water.ca.gov/cimis/data.jsp)

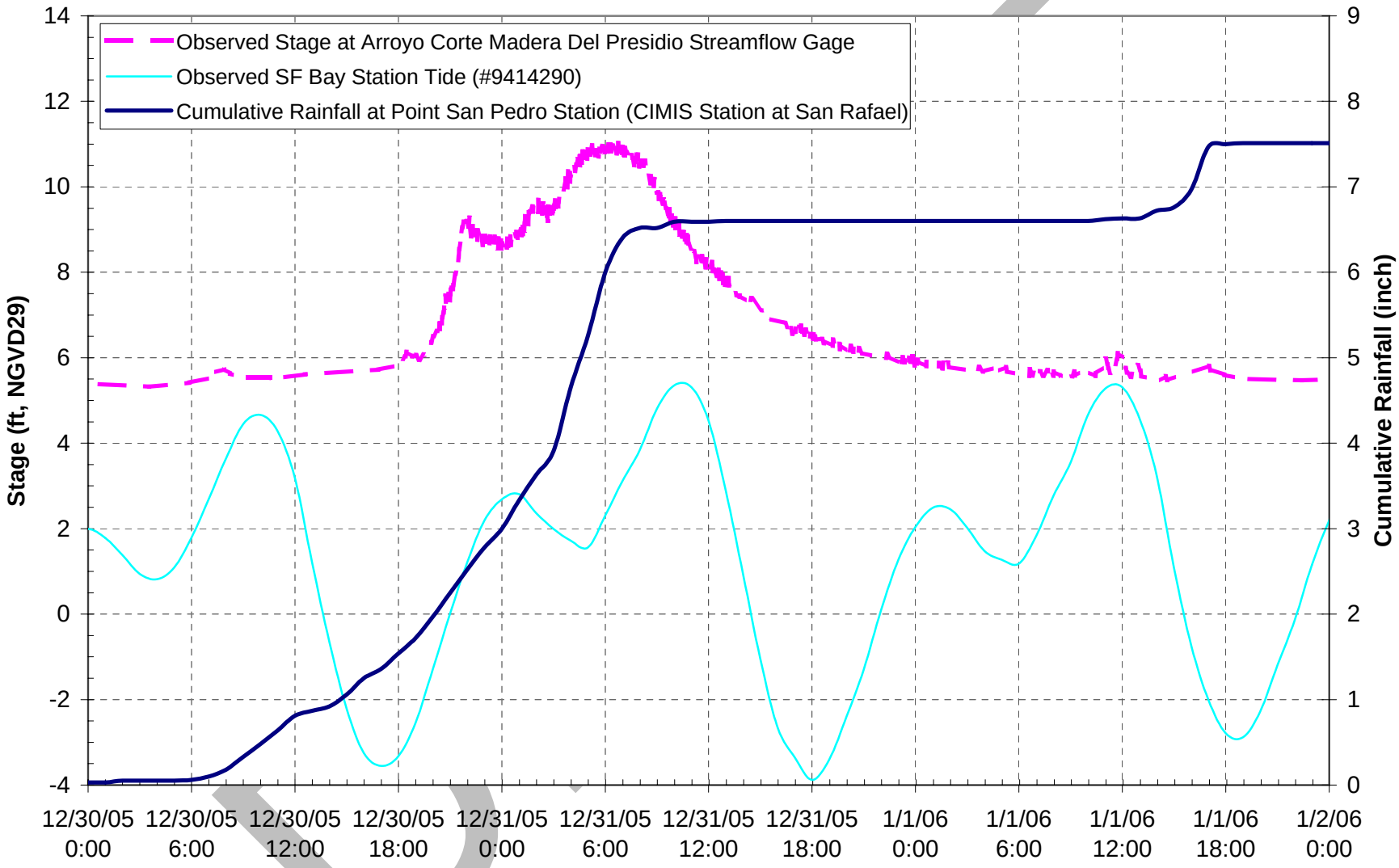


Figure 5 Hydrograph of Arroyo Corte Madera Del Presidio Streamflow Gage Stage, SF Bay Tide, CIMIS Point San Pedro Station Cumulative Rainfall, December 31, 2005 Flood

(Rainfall Source: CIMIS Website http://wwwcimis.water.ca.gov/cimis/data.jsp)

Preliminary Observations and Inferences from the Measurements

A few observations and inferences can be made from the December 31, 2005 flood event measurements that will aid in developing flood damage reduction solutions for Mill Valley. These are as follows:

- The storms on December 17 and the December 31 had similar 3-hour rainfall intensities (1.7 inches and 2.1 inches, respectively), but very different discharges: The peak discharges were 385 cfs and 1,810 cfs, respectively. Further, the December 31 storm, which was a 15-year/24-hour and 15-year/3-hour rainfall event, produced a 50-year flood event. These observations can be explained by the saturated antecedent watershed conditions that preceded the December 31 storm (i.e., saturated soils and little available storage in the system to attenuate intense rainfall as a result of the steady rainfall over the preceding two-week period, December 17 - 30). This demonstrates why it is prudent in flood studies to assume saturated antecedent watershed conditions.
- The observed peak stage at the Arroyo Corte Madera del Presidio streamflow gage occurred as the tide was rising toward the daily higher high. The nearly high tide backed-up the channel and reduced the capacity of the channel for some distance upstream. This demonstrates why it is prudent in flood studies to assume high tide as the downstream boundary condition. In fact, the FEMA's method for flood studies uses the Mean Higher High Water[15] level as the downstream tidal boundary condition.

The December 31, 2005 flood (an approximate 50-year flood event)[16] was simulated using the HEC-HMS model. The simulated hydrograph matched closely, but not exactly, with the hydrograph recorded at the gage. The simulated hydrograph showed a peak discharge of 1,720 cfs, 90 cfs less (about 5 percent less) than the 1,810 cfs peak discharge estimated using the updated stage-discharge curve. The difference between the two hydrographs was deemed acceptable. In the development of conceptual measures for flood damage reduction, the hydrologic model-simulated hydrograph for the December 31, 2005 flood event was used to generate hydrographs for other flood events by increasing it according to the ratios between the peak flows developed in the flood frequency analysis and the simulated peak flow for the December 31, 2005 flood event. For example, a peak flow ratio of 1810/1720 was used to generate hydrograph for the 50-year flood event and a peak flow ratio of 2110/1720 was used to generate hydrograph for the 100-year flood event.

[15] There are two high tides each day in the San Francisco Bay, High Water (HW) and Higher High Water (HHW). The Mean Higher High Water (MHHW) is the average of the higher high water of each tidal day observed over the National Tidal Datum Epoch (Currently NOAA uses the 19-year period of 1983-2001 as the National Tidal Datum Epoch).

[16] Refer to Appendix C for details on the hydrologic modeling and simulation of the December 31, 2005 flood.

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On December 31, 2005 at peak discharge, an estimated 1,350 cfs was flowing in-channel and 460 cfs was flowing out-of-channel across the floodplain at the streamflow gage, totaling 1,810 cfs. Most of the out-of-channel flood flow, which ultimately returned to the channel at Camino Alto, was derived from overbank flow along Arroyo Corte Madera del Presidio between Willow Street and Camino Alto[17] and along the end of Warner Canyon Creek. Estimated flows at selected locations along Arroyo Corte Madera del Presidio and major flow paths for the December 31, 2005 flood (an approximate 50-year flood event) and the hypothetical 100-year flood are shown in Figures 6 and 7. The lateral extents of inundation as determined through hydraulic modeling and floodplain mapping are also shown in the figures in Section 3.0.

2.3.2 Flood Damage

The Marin Office of Emergency Services (MCOES) developed an inventory of parcels that reported damage due to the December 31, 2005 storm event (Figure 8)[18]. In a few instances, the listed causes of damage were mudslides, erosion, or falling trees, but by far most of the listed causes were from floodwater or mud 6 to 8 inches deep. The inventory lists 167 damaged parcels. By far most of the listed damaged parcels were between Willow Street and Camino Alto and were concentrated in the Sycamore neighborhood.

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[17] A nearby homeowner reported that overbank flooding occurred at Park Street. Unreported localized overbank flow might have occurred at other locations, but most of the damage-causing overbank flood flows probably originated at Willow Street and downstream.

[18] The inventory includes only those parcels that reported flood damage. The inventory does not necessarily include all parcels that were damaged by flooding as some damage may not have been reported.

FIGURE 6

610 cfs

750 cfs

OLD MILL CREEK CONFLUENCE

OLD MILL CREEK

ARROYO CORTE MADERA DEL PRESIDIO

100 cfs (lateral inflow along reach)

700 cfs

310 cfs

110 cfs

WARNER CREEK CONFLUENCE

WARNER CREEK

1350 cfs

350 cfs

310 cfs

SYCAMORE STORM WATER INTAKE (TYP)

SYCAMORE AVE 2 BOX 8'W X 4.5'H STORM WATER BOX CULVERT

REED CREEK

N

W E

S

SCALE (FEET)

0 250 500

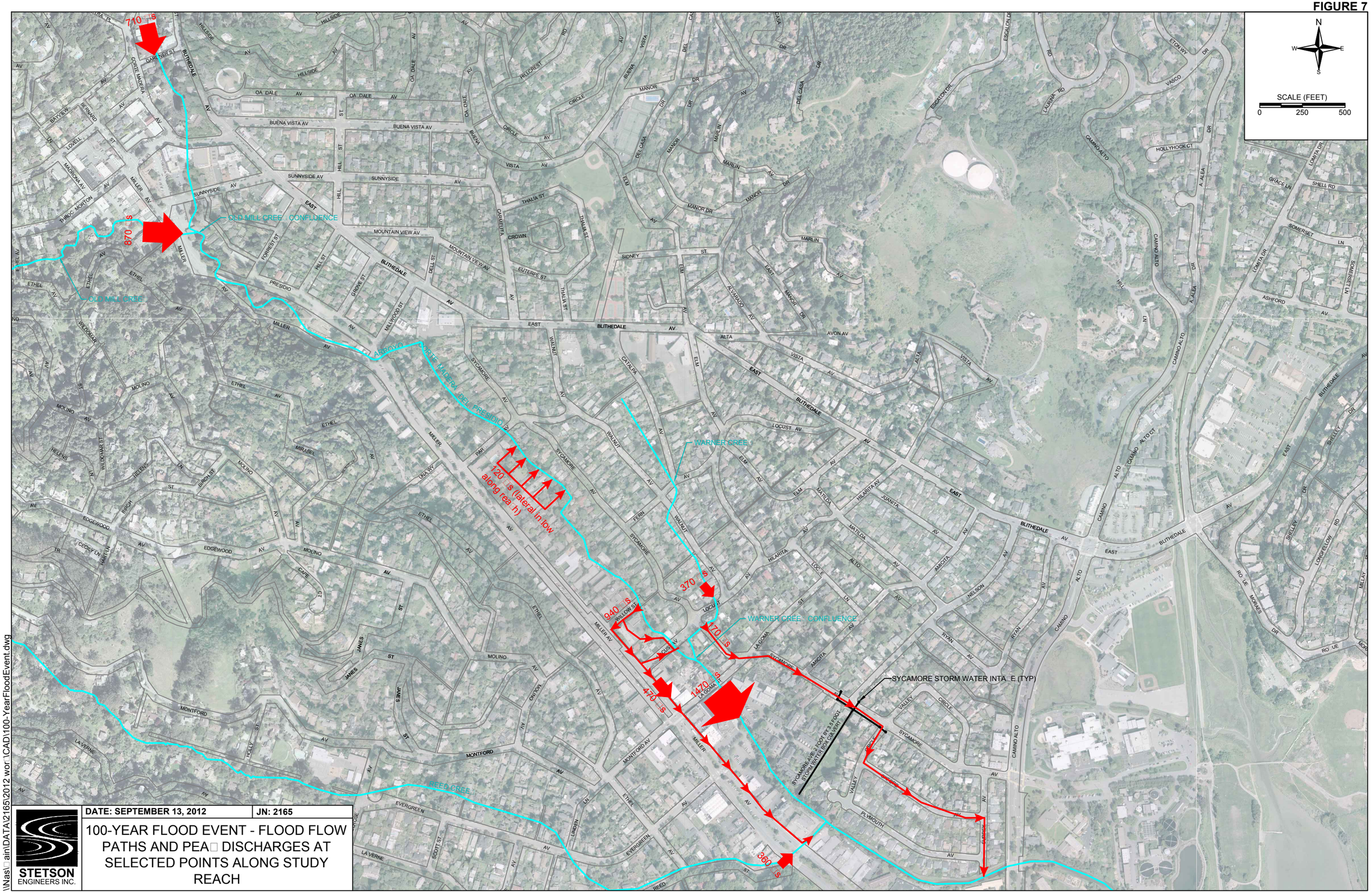
STETSON ENGINEERS INC.

DATE: SEPTEMBER 13, 2012	JN: 2165

12/31/05 FLOOD EVENT (APPROXIMATE 50-YEAR FLOOD) - FLOOD FLOW PATHS AND PEAK DISCHARGES AT SELECTED POINTS ALONG STUDY REACH

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FIGURE 7



DATE: SEPTEMBER 13, 2012	JN: 2165

100-YEAR FLOOD EVENT - FLOOD FLOW PATHS AND PEA□ DISCHARGES AT SELECTED POINTS ALONG STUDY REACH

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N

W E

S

SCALE (FEET)

0 250 500

FIGURE 8

12/31/05 FLOOD EVENT - LOCATION OF PARCELS REPORTING DAMAGE

SOURCE: MCOES 2007

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2.3.3 Analysis of the Sycamore Pump Station, Cisterns, and Impervious Areas

MCFCWCD and City of Mill Valley requested that the Sycamore Pump Station, cisterns, and impervious areas be analyzed in connection with the December 31, 2005 flood.

The Sycamore Pump Station is part of the interior drainage system that was designed to handle runoff originating locally in the Sycamore neighborhood[19]. It has the flow capacity to pump up to 3,000 gallons per minute, or about 7 cfs, through pipelines that discharge to Arroyo Corte Madera del Presidio. During the December 31, 2005 flood, in addition to the local runoff, an estimated 90 cfs from Warner Canyon Creek, plus possibly additional overflow from Arroyo Corte Madera del Presidio, spilled over into the Sycamore neighborhood. This flow overwhelmed the pump station's 7 cfs capacity. Moreover, the pump station was probably inundated both at its inlets and discharge, resulting in a pumping action that was merely recirculating floodwaters and rendering the pump station ineffective. Increasing the capacity of the pump station would be prohibitively costly and ineffective at preventing flooding originating from overbank flow, such as occurred on December 31, 2005.

The effect that installing cisterns on individual properties (parcels) would have on large-scale flooding was evaluated[20]. Using hydrologic modeling techniques on a selected sample sub-area of the watershed, it was found that cisterns would reduce the magnitude of the December 31, 2005 flood by about 4%. Because the volume of storage that cisterns would provide is very small in comparison to the volume of floodwater that is generated during a large-scale flood, cisterns would offer relatively little attenuation of runoff. It follows that cisterns would not be effective in reducing large-scale flooding. However, cisterns could offer other benefits related to water supply, enhancement of summertime instream flow and water quality. Therefore, cisterns should be considered further for these purposes.

The effect that expanding impervious surfaces through development would have on large-scale flooding was also evaluated[21]. Using hydrologic modeling techniques on two selected sub-areas of the watershed, one developed and one relatively undeveloped, it was found that the magnitude of the December 31, 2005 flood was relatively insensitive to impervious area. This can be attributed to the saturated antecedent watershed conditions that preceded the storm. During intense storms that generate large-scale floods, the saturated undeveloped watershed produces runoff at a high rate, approaching that of a developed watershed. Therefore, expanding impervious surfaces appears to have little effect on flooding of this magnitude.

[19] Refer to Appendix E for details on the analysis of the Sycamore Pump Station.

[20] Refer to Appendix F for details on the analysis of cisterns.

[21] Refer to Appendix F for details on the analysis of impervious area.

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3.0 FLOODPLAIN MAPPING

Using HEC-RAS hydraulic modeling, the extent and depth of flood inundation under existing conditions, referred to as "baseline" conditions, was estimated for a range of recurrence interval/annual-chance-probability floods. The hydraulic model was satisfactorily calibrated to the December 31, 2005 flood using high water marks that were identified in the field and then surveyed for elevation (refer to Appendix D for model calibration results). Floodplain mapping was done by intersecting the model-computed water surface with the floodplain topographic (ground) surface. Floodplain maps for the 5-year, 10-year, 25-year, 50-year, and 100-year recurrence/annual-chance floods for baseline conditions are shown in Figures 9 – 13.

First finished floor elevations of most buildings within the floodplain were surveyed by MCFCWCD.[22] First finished floor elevations were compared to the model-computed water surfaces for the 5-year, 10-year, 25-year, 50-year, and 100-year recurrence/probability floods under baseline conditions. Buildings with first finished floor elevations lower than the model-computed water surface would be inundated. Inundated buildings are highlighted and the depths of inundation above the first finished floor are also shown in the floodplain maps. Plate 1 shows all the information in Figure 13, plus it shows surveyed first finished floor elevations of all buildings surveyed overlain on the 100-year floodplain map.

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[22] In the study area, there are 1,179 buildings. Of which 1,102 buildings were surveyed for first finished floor elevations.

Limit of Study Area

5-YEAR FLOOD EVENT INUNDATION and AT-RISK BUILDINGS

- Inundation: 0 - 0.99 feet
- Inundation: 1 - 1.99 feet
- Inundation: 2 - 2.99 feet
- Inundation: 3 - 3.99 feet
- Inundation: 4 - 4.99 feet
- Inundation: 5 - 5.99 feet

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N

0 500 1,000 Feet

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FIGURE 9

Limit of Study Area

10-YEAR FLOOD EVENT INUNDATION and AT-RISK BUILDINGS

- Inundation: 0 - 0.99 feet
- Inundation: 1 - 1.99 feet
- Inundation: 2 - 2.99 feet
- Inundation: 3 - 3.99 feet
- Inundation: 4 - 4.99 feet
- Inundation: 5 - 5.99 feet

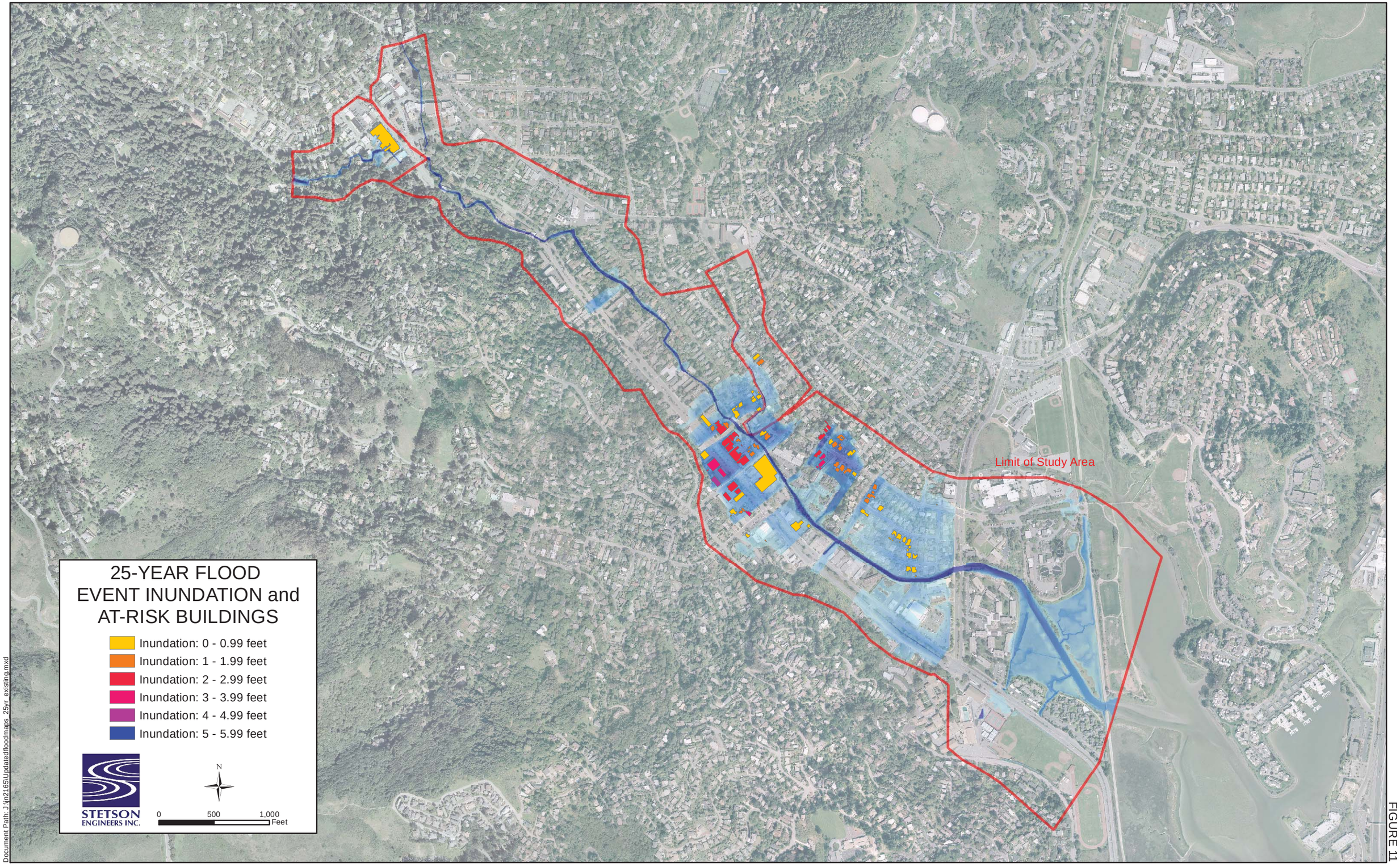
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0 500 1,000 Feet

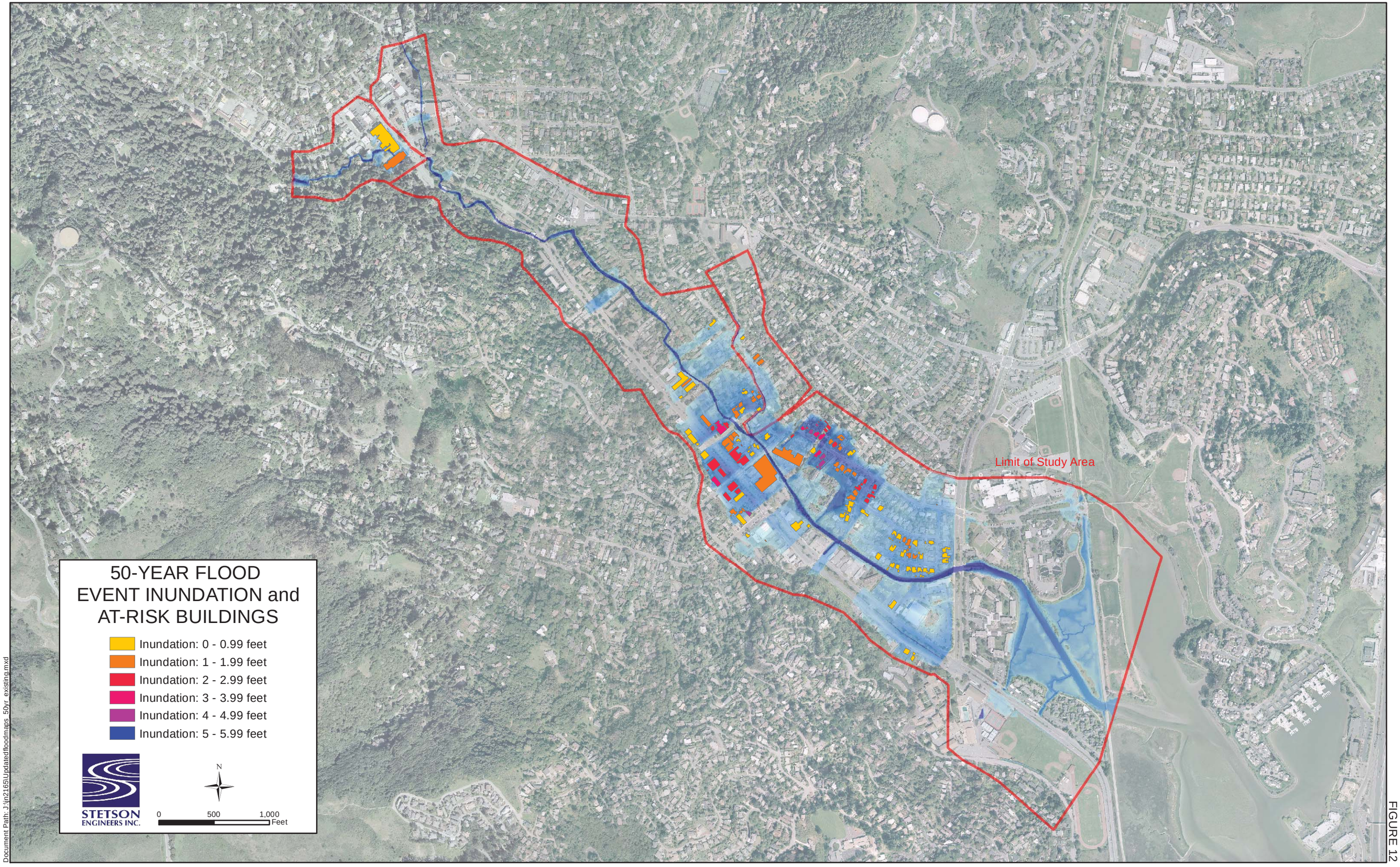
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FIGURE 10



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FIGURE 11



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FIGURE 12

Limit of Study Area

100-YEAR FLOOD EVENT INUNDATION and AT-RISK BUILDINGS

- Inundation: 0 - 0.99 feet
- Inundation: 1 - 1.99 feet
- Inundation: 2 - 2.99 feet
- Inundation: 3 - 3.99 feet
- Inundation: 4 - 4.99 feet
- Inundation: 5 - 5.99 feet

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0 500 1,000 Feet

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FIGURE 13

4.0 FLOOD DAMAGE REDUCTION BY RAISING AT-RISK RESIDENTIAL BUILDINGS

Substantial flood damage reduction could be achieved by raising at-risk residential buildings. Residential buildings with a first finished floor elevation lower than the flood water surface elevation should be raised at least two feet above the flood elevation. At-risk buildings (including residential and non-residential buildings) are highlighted in Figures 9 - 13 and summarized in Table 3. The cost of raising at-risk residential buildings was estimated using an estimated unit cost of $22 per square foot (Refer to page 9 of Appendix H for the basis of this estimated unit cost). Commercial and other types of non-residential buildings are typically not suitable for raising because of the construction methods and materials used[23]; therefore, cost estimates were not prepared for these types of structures. Flood proofing at-risk non-residential buildings and critical infrastructure in the floodplain may be feasible, but it was not evaluated in this study. The number of at-risk non-residential building is given in Table 3.

Table 3. Summary of Raising At-Risk Residential Buildings

Level of Flood Protection	Number of At-Risk Non-Residential Buildings	Number of At-Risk Residential Buildings	Estimated Capital Cost of Raising At-Risk Residential Buildings ($)
5-Year Flood	7	1	42,000
10-Year Flood	16	14	492,000
25-Year Flood	27	60	1,760,000
50-Year Flood	40	103	3,086,000
100-Year Flood	59	150	4,289,000

Note: The cost of raising at-risk residential buildings varies from building to building. Costs above were based on an estimated average unit cost of $22 per square foot (Refer to page 9 of Appendix H for the basis of this estimated unit cost).

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[23] Commercial buildings constructed of concrete block, concrete tilt up, brick wall or stone wall are not suitable for raising. It is not feasible to raise buildings that are not constructed with light weight and strong material such as wood and steel.

5.0 FLOOD DAMAGE REDUCTION BY IMPROVING CREEK FLOOD CONTROL INFRASTRUCTURE

Another approach to reduce flood damage due to overtopping of the creek is improving creek flood control infrastructure. Compared to raising or flood proofing at-risk buildings, this approach offers a broader array of public benefits, including reduction in damage to other non-building assets and enhanced public safety.

Using hydrologic and hydraulic modeling, conceptual flood control measures targeting reaches of insufficient capacity were developed. These measures fall under the following general categories:

- Hydraulic capacity improvements[24] – These measures increase the channel's flow capacity by replacing or enlarging structural crossings or by modifying the channel through widening, dredging, or floodwalls or landscape berms along the tops of banks.
- Bypass channels – These measures divert and route floodwater around reaches that lack sufficient flow capacity.
- Detention basins[25] – These measures reduce the magnitude of flood flow by temporarily detaining flood water in large ponds, referred to as detention basins, then slowly releasing the water back to the creek after the storm subsides and flooding recedes.

Individual conceptual measures were designed and evaluated preliminarily for feasibility. Refer to Appendix G for details on the conceptual designs and preliminary feasibility evaluations. Based on the evaluation, those measures deemed potentially feasible were grouped in bundles to achieve a desired level of flood protection. These bundled measures are described below in order of the increasing level of flood protection provided. A preliminary assessment of utility conflicts was performed as part of this study based on available information on utility locations. Identified utility conflicts were considered in the conceptual designs and construction cost estimates.

5.1 5-Year Flood Protection

The magnitude of the 5-year flood, or the 20-percent-annual-chance flood, is approximately 800 cfs at the gage[26]. The 5-year flood level protection measures focus on preventing overbank flow

[24] Refer to Appendix E for details on hydraulic modeling simulations to develop hydraulic capacity enhancement and bypass channel measures.

[25] Refer to Appendix F for details on hydrologic modeling simulations to develop detention basin measures.

[26] According to anecdotal reports, the 1983 flood had a peak discharge of about 821 cfs (an approximate 5-year flood) and caused some damage. This verifies the need of 5-year flood protection.

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at Willow Street, upstream from La Goma Street, and from the Egger Plaza Bridge downstream to Camino Alto. These measures are listed in Table 4 and shown in Figure 14. The numbering of measures includes two numbers; the first number represents the flood protection level and the second represents the measure number.

Table 4. Summary of 5-Year Flood Protection Measures

Measure	I.D. number in Figure 14
Willow Street Pedestrian Bridges replacements (2) and channel widening over about a 150 ft reach near the bridges	[5-04]; [5-05]; [5-06]
Removal of concrete weir at the streamflow gage; channel dredging over the 150 ft reach upstream of the gage	[5-03]
Low floodwalls/berms	[5-01]; [5-02]

At Willow Street, the two pedestrian bridges need to be raised by about 3.4 feet or removed to prevent blockage of flow.[27] In this same area, development has narrowed the channel, limiting its capacity to convey floodwaters. The channel needs to be widened by about 20 feet over about a 150-foot reach extending from about 60 feet above the public pedestrian bridge to 70 feet below the private pedestrian bridge. These measures should be implemented in concert and are considered potentially feasible, provided approvals are obtained, where required, for work on private property.

The concrete weir at the streamflow gage needs to be removed and the channel upstream of the streamflow gage needs to be dredged by a maximum of about 1.5 feet over a distance of about 150 feet to increase its hydraulic capacity. The dredged reach could refill with sediment during a moderate flood. The long-term sustainability of dredging and the need for repeat dredging requires further study. A more detailed description of this measure is provided in section 5.4.2.

Starting at about the Valley Circle Pedestrian Bridge and extending downstream to Camino Alto low floodwalls or floodberms, 2 feet high or less, are needed along the tops of both banks to prevent overbank flow. Additional low floodwalls/berms are needed along a short reach of the right bank starting about 100 feet below the Egger Plaza Bridge. These measures are considered potentially feasible provided approval is obtained, where required, for work on private property.

[27] For all bridge/structure designs except the La Goma and Egger Plaza bridges, 2 ft of freeboard was considered to account for the hydraulic effects of debris and allow for passage of aquatic wildlife. A 0.5 ft of freeboard was considered for La Goma and Egger Plaza bridges due to site-specific problems with raising these bridges any higher.

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FIGURE 14

ID NUMBER DESCRIPTION

PROTECTION LEVEL – ID NUMBER

SCALE (FEET) 0 200 400

N W E S

LEGEND

- STREAM
- FLOODWALLS □ BERMS
- RAISE AND WIDEN BRIDGES
- CHANNEL MODIFICATION

OLD MILL CREE□

WARNER CREE□

ARROYO CORTE MADERA DEL PRESIDIO

REED CREE□

EXISTING PEDESTRIAN BRIDGES REMAIN

EXISTING DRIVEWAY BRIDGE REMAINS

5-05□REPLACE WILLOW PUBLIC PEDESTRIAN BRIDGE

5-04□REPLACE PRIVATE PEDESTRIAN BRIDGE

5-06□WIDEN □ MODIFY CHANNEL

WARNER CREE□ CONFLUENCE

5-03□EXCAVATE CHANNEL BOTTOM (1.5□DEEP AVG) REPLACE GAGE STATION

GAGE STATION

EGGER PLA□A

5-02□TOP OF RIGHT BAN□ FLOODWALL

EXISTING PEDESTRIAN BRIDGE REMAINS

5-01□TOP OF LEFT BAN□ FLOODWALL

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5-YEAR FLOOD PROTECTION MEASURES

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5.2 10-Year Flood Protection

The magnitude of the 10-year flood is approximately 1,100 cfs at the gage. Protection against the 10-year flood requires all of the 5-year protection measures (Section 5.1) plus additional measures. The additional measures focus on preventing further overbank flow at and above Willow Street, at and above La Goma Street, above the Egger Plaza Bridge, and above Park Street. These measures are listed in Table 5 and shown in Figure 15.

Table 5. Summary of 10-Year Flood Protection Measures

Measure	I.D. number in Figure 15
5-Year Flood Protection Measures (from Table 4)	[5-01]; [5-02]; [5-03]; [5-04]; [5-05]; [5-06]
La Goma Street Bridge replacement	[10-03]
Additional low floodwalls/berms	[10-01]; [10-02]; [10-04]; [10-06]
Raise Sycamore Ave grade	[10-05]
Park Street Bridge replacement	[10-07]

Starting at about 300 feet above Willow Street extending to Willow Street low floodwalls/berms, 2 feet high or less, are needed along the tops of both banks to prevent overbank flow. This is considered potentially feasible provided approvals are obtained for work on private property.

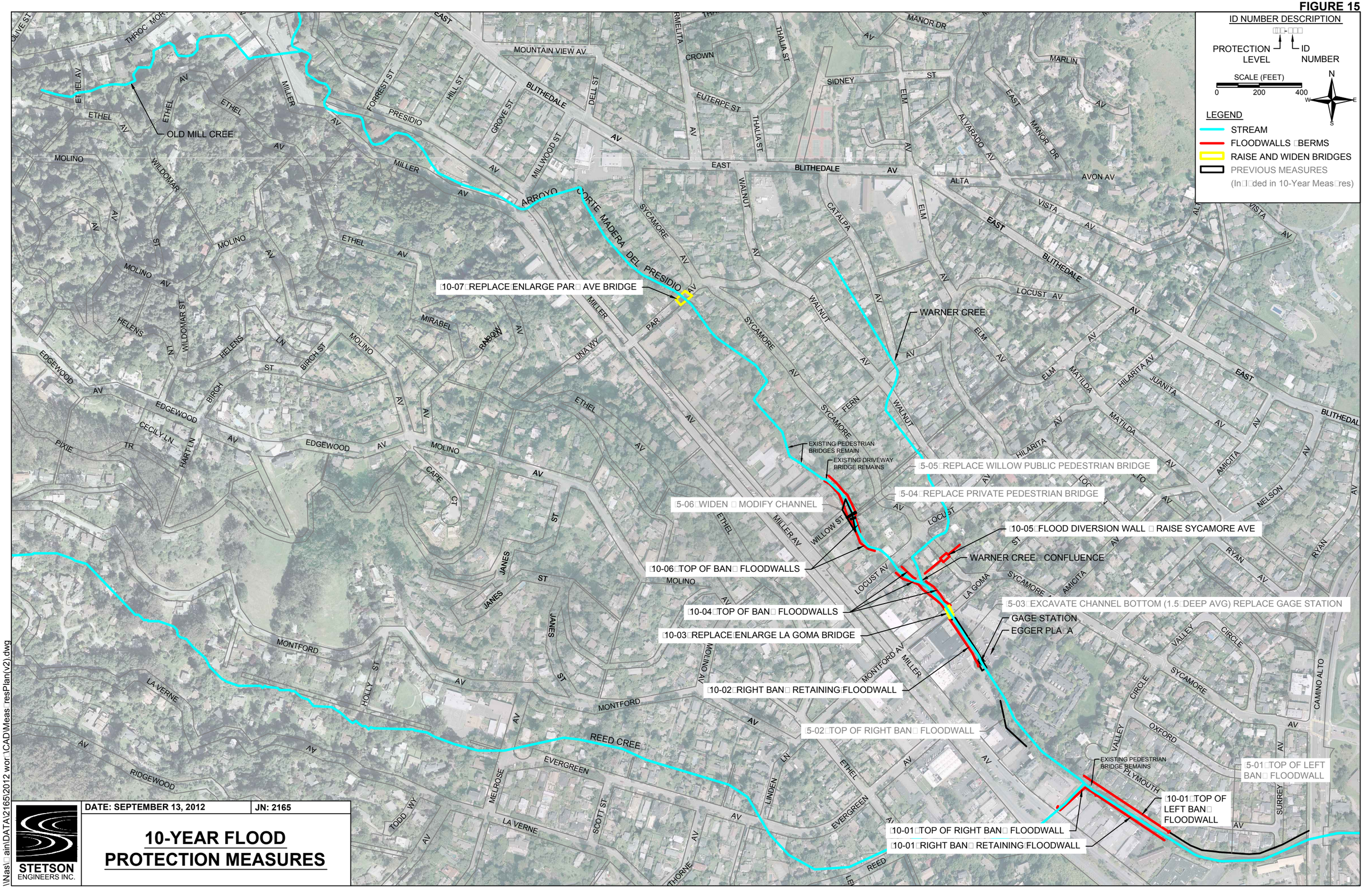
The La Goma Street Bridge needs to be raised by about 1.5 feet to prevent blockage of flow. Upstream of La Goma Street, low floodwalls or floodberms, 2 feet high or less, are needed along the tops of both banks from Locust Street extending to La Goma Street; along the top of the left bank and partially along the top of the right bank from La Goma to the Egger Plaza Bridge; and along the top of the left bank from below the Egger Plaza Bridge to the Valley Circle Pedestrian Bridge. These measures are considered potentially feasible provided approvals from private property owners for floodwalls/berms are obtained where required.

Raising a short reach of the Sycamore Avenue grade would be needed to create a containment barrier that would prevent floodwaters that overtop lower Warner Canyon Creek from escaping farther down Sycamore Avenue. The containment barrier would direct floodwaters back to the creek. The containment barrier would consist of a 2-foot high raised grade across Sycamore Avenue with floodwalls extending from both ends of the raise. These floodwalls are located on private property and are considered potentially feasible provided required approvals from property owners are obtained. The level of the floodwater surface within the containment barrier would not rise above the first finished floors of the interior residential buildings.

The Park Street culvert would need to be replaced with a bridge structure that provides higher clearance. This could be accomplished without raising the grade of the street at the bridge. This is considered potentially feasible.

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FIGURE 15



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10-YEAR FLOOD PROTECTION MEASURES

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5.3 Greater Than 10-Year Flood Protection

Flows greater than the 10-year flood, about 1,100 cfs at the gage, exceed the capacity of the channel at several locations due to capacity limitations at structural crossings. The capacity of Warner Canyon Creek, about 200 cfs along the constricted segment near the confluence with Arroyo Corte Madera del Presidio, is also exceeded at the 10-year event. Rectifying some of these capacity limitations, such as the La Goma Street Bridge and Locust Street Bridge and adjacent structures, is probably not feasible because, in addition to being prohibitively costly, it would involve raising structural crossings and street grade approaches which would block adjacent driveway inlets and make pedestrian and vehicular approaches impracticably steep. Consequently, protection against the floods greater than the 10-year event requires all of the 5-year and 10-year protection measures (Section 5.1, and Section 5.2 without raising the La Goma Street Bridge) plus additional measures involving flood detention and/or bypass.

Flood detention reduces flooding by reducing the magnitude of the peak of the flood. The flood detention measure analyzed in this report consists of a large detention basin formed by constructing an earthen dam across Warner Canyon Creek at the Mill Valley Golf Course[28]. The dam would have a low-level outlet for passing flows and sediment and enabling passage of fish and other aquatic organisms. The dam would also have a spillway to safely pass floodwaters in the event that the basin is filled during an extremely large flood, greater than the 100-year event. Depending on the target level of flood protection, the height of the dam would be up to 40 feet high and the storage capacity of up to 227 acre-feet for 50-year and 100-year flood protection. During large floods, the stored water would temporarily inundate much of the 100-acre golf course but would be drained following storms. The detention basin would not affect the use of the golf course except during and immediately following large floods. Some private lands (but not structures) along the perimeter of the detention basin may be inundated which would require that flood easements be obtained. During severe storms, rainfall forecasts and streamflow stage would need to be closely monitored. Operators would use the monitoring information to determine when to close the detention basin floodgate. Floodwaters would be temporarily detained in the detention basin and then released back to the creek after the high flows recede.

Bypass reduces flooding by diverting and conveying floodwaters around the severely constricted and obstructed reach through a culvert. The bypass measure consists of a diversion structure along Arroyo Corte Madera del Presidio at Willow Street and a bypass culvert to route the diverted flood flows (i.e., flows that exceed the channel capacity and would otherwise spill over

[28] Refer to Appendices F and G for details on the Mill Valley Golf Course detention basin as well as other detention basins considered.

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bank) around the reach from Willow Street to La Goma Street and return those flows back to the creek below Egger Plaza where the creek capacity is adequate.[29, 30]

5.3.1 25-Year Flood Protection

The magnitude of the 25-year flood is approximately 1,500 cfs at the gage, of which about 300 cfs is contributed from Warner Canyon Creek. Protection against the 25-year flood requires all of the 5-year and 10-year protection measures (Section 5.1, and Section 5.2 without raising the La Goma Street Bridge) plus additional measures. The additional measures focus on preventing overbank flow along the end of Warner Canyon Creek and further overbank flow from above Willow Street to the Egger Plaza Bridge. These measures are listed in Table 6 and shown in Figure 16.

Table 6. Summary of 25-year Flood Protection Measures

Measure	I.D. number in Figure 16
5-Year Flood Protection Measures (from Table 4)	[5-01]; [5-02]; [5-03]; [5-04]; [5-05]; [5-06]
10-Year Flood Protection Measures w/o La Goma Street Bridge replacement (from Table 5)	[10-01]; [10-02]; [10-04]; [10-05]; [10-06]; [10-07]
Additional low floodwalls/berms	[25-01]; [25-02]; [25-03]; [25-05]
Arroyo Corte Madera del Presidio partial bypass	[25-04]

Partial bypass is considered to be the most feasible and appropriate measure to prevent further overbank flow from above Willow Street to the Egger Plaza Bridge. Constructing the partial bypass has the following benefits:

- Avoids hydraulic conveyance increase measures between Willow Street and Egger Plaza that would otherwise be needed, including
    - Replacement of the existing La Goma Bridge
    - Replacement of the Locust Avenue Bridge and the private office driveway bridge just upstream
    - Replacement of the private driveway bridge upstream of Willow Street pedestrian bridge and channel widening
    - Raising of the private building upstream of Locust Avenue Bridge
- Reduces the heights of floodwalls upstream of Willow Street and between Willow Street and Egger Plaza. Without the partial bypass but with the avoided hydraulic conveyance increase measures described above, floodwall heights would need to be

[29] Because the diverted flows are returned back to the channel this measures is referred to as "partial bypass", as opposed to "total bypass" where the diverted flows are conveyed all the way to the bay.

[30] Refer to Appendix G for details on the partial bypass.

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up to 5 ft, 6 ft, and 7 ft in order to contain the 25-year, 50-year, and 100-year floods, respectively.

Partial bypass consists of a diversion structure and culvert. The diversion structure would be constructed along the creek at Willow Street, or at an alternative location just above Willow Street. The diversion structure would consist of a lateral weir, also referred to as a "side weir," placed along the right bank of the creek[31]. The length of lateral spillway would be 72 feet and 79 feet for the 50-year and 100-year design events, respectively. The lateral weir crest would be sufficiently low to "crop off" the upper portion of flow that would otherwise overtop the creek banks downstream. A concrete manifold inlet structure would collect flow over the lateral weir and direct the water to the diversion culvert. The diversion culvert would be a rectangular, reinforced concrete box culvert that would convey the diverted water down Willow Street and Miller Avenue and return the water back to the creek below Egger Plaza. The diversion culvert would be buried within the Willow Street right-of-way and within the median right-of-way along Miller Avenue. Hydraulic modeling analysis shows that the concrete culvert would need to be 18.5 wide by 4.5 feet deep and 26 feet wide by 4.5 feet deep for the 50-year and 100-year design events, respectively, assuming a ground cover thickness of 3 ft. Further detailed engineering and design work would be needed to verify that the culvert could be accommodated within the Miller Avenue median and would be compatible with overall Miller Avenue streetscape plan. Since sediment carried with large flood flows could "drop out," settle, and aggrade the channel along the diverted reach when large flows are diverted to the bypass channel, further engineering analysis would also be needed to determine whether substantial and frequent channel dredging would be required.

<u>Preliminary Feasibility Assessment of the Arroyo Corte Madera del Presidio Partial Bypass</u>
This measure would likely require removing/reinstalling or relocating utilities, particularly sewer lines, which would be encountered at several locations along the route of the approximately 1,500-foot long diversion bypass channel. The need and feasibility of removing/reinstalling or relocating these utilities would require substantial research and further engineering analysis. It is anticipated that this further analysis will be performed as part of the Miller Avenue streetscape project, as this project would also require removing/reinstalling or relocating utilities. Further, the lateral weir that would be required would likely encroach onto adjacent private property. The diversion bypass channel return to Arroyo Corte Madera del Presidio would pass over private commercial property. This measure is considered potentially feasible provided research and further engineering analysis finds that utilities can be removed/reinstalled or relocated, substantial and frequent channel dredging would not be required, and provided private property owner approval is obtained where required.

[31] A lateral weir, or side weir, is a type of diversion structures that allows water to flow over a weir placed along one side of a channel into an inlet that collects and routes the overflow to a diversion culvert.

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FIGURE 16

25-05 BAN RETAINING FLOODWALLS UPSTREAM BRIDGE WALL

OLD MILL CREE

10-07 REPLACE ENLARGE PAR AVE BRIDGE

WARNER CREE

REED CREE

5-06 WIDEN MODIFY CHANNEL

10-06 TOP OF BAN FLOODWALLS

25-04 ACMDP CREE PARTIAL BYPASS

10-04 TOP OF BAN FLOODWALLS

10-02 RIGHT BAN RETAINING FLOODWALL

10-02 TOP OF RIGHT BAN FLOODWALL

5-02 TOP OF RIGHT BAN FLOODWALL

EXISTING PEDESTRIAN BRIDGES REMAIN

EXISTING DRIVEWAY BRIDGE REMAINS

5-05 REPLACE WILLOW PUBLIC PEDESTRIAN BRIDGE

5-04 REPLACE PRIVATE PEDESTRIAN BRIDGE

10-05 FLOOD DIVERSION WALL RAISE SYCAMORE AVE

WARNER CREE CONFLUENCE

5-03 EXCAVATE CHANNEL BOTTOM (1.5 DEEP AVG) REPLACE GAGE STATION

GAGE STATION

EGGER PLA A

25-03 TOP OF LEFT BAN FLOODWALL

25-02 TOP OF LEFT BAN FLOODWALL

EXISTING PEDESTRIAN BRIDGE REMAINS

5-01 TOP OF LEFT BAN FLOODWALL

10-01 TOP OF LEFT BAN FLOODWALL

10-01 TOP OF RIGHT BAN FLOODWALL

10-01 RIGHT BAN RETAINING FLOODWALL

10-01 RIGHT BAN RETAINING FLOODWALL

25-01 TOP OF RIGHT BAN FLOODWALL

ID NUMBER DESCRIPTION

PROTECTION LEVEL — ID NUMBER

SCALE (FEET)

0 200 400

N W E S

LEGEND

- STREAM
- FLOODWALLS BERMS
- RAISE AND WIDEN BRIDGE
- CHANNEL MODIFICATION
- PREVIOUS MEASURES (In ded in 25-Year Meas res)

NOTE: LA GOMA BRIDGE REPLACEMENT ENLARGEMENT NOT NEEDED DUE TO PARTIAL BYPASS.

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25-YEAR FLOOD PROTECTION MEASURES

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5.3.2 50-year and 100-Year Flood Protection

The magnitudes of the 50-year and 100-year floods are approximately 1,800 cfs and 2,100 cfs at the gage, of which about 310 cfs and 370 cfs are contributed from Warner Canyon Creek, respectively. Protection against the 50-year and 100-year floods requires all of the 5-year and 10-year protection measures (Section 5.1, and Section 5.2 without raising the La Goma Street Bridge) and the partial bypass, plus additional measures. The additional measures, which focus on preventing overbank flow near Sunnyside Avenue, along the end of Warner Canyon Creek and further overbank flow above Willow Street to the Egger Plaza Bridge, include the Mill Valley Golf Course detention basin and enlargement of a private culvert and a private bridge. These measures are listed in Table 7 and shown in Figure 17.

Table 7. Summary of 50-Year and 100-Year Flood Protection Measures

Component	I.D. number in Figure 17
5-Year Flood Protection Measures (from Table 4)	[5-01]; [5-02]; [5-03]; [5-04]; [5-05]; [5-06]
10-Year Flood Protection Measures w/o La Goma Street Bridge replacement (from Table 5)	[10-01]; [10-02]; [10-04]; [10-05]; [10-06]; [10-07]
25-Year Flood Protection Measures (from Table 6)	[25-01]; [25-02]; [25-03]; [25-04]; [25-05]
Culvert enlargement beneath private building downstream of Sunnyside Avenue	[50-02]
Egger Plaza Bridge replacement	[50-01]
Mill Valley Golf Course detention basin	[50-04]
Additional low floodwalls/berms	[50-03]; [50-05]; [100-01]

In the area just downstream of Sunnyside Avenue, the creek passes through a circular, concrete culvert that passes beneath a private commercial building. The culvert obstructs flows exceeding approximately the 38-year flood and needs to be enlarged. This measure is potentially feasible but is entirely on private property and, therefore, would require approval by the property owner.

The Egger Plaza Bridge obstructs flows starting at about the 43-year flood. This bridge needs to be raised by about 2.6 ft to prevent blockage of flow. This measure is potentially feasible but is entirely on private property and, therefore, would require approval by the property owner.

The Mill Valley Golf Course detention basin would reduce peak flows in Warner Canyon Creek, thereby eliminating overflow that would otherwise spill over into the Sycamore neighborhood. The detention basin would also reduce flooding farther downstream along lower Arroyo Corte Madera del Presidio.

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Feasibility Assessment of the Mill Valley Golf Course Detention Basin[32]

Based on a preliminary review it appears feasible to construct a dam across Warner Canyon Creek and using Mill Valley Golf Course as a detention basin. However, several major technical issues described below would need to be addressed through further engineering study to confirm feasibility.

- Geotechnical integrity of the dam site to provide stability for the dam and abutments;
- Availability of structurally suitable fill material for the earthen dam in sufficient quantities from a nearby source;
- Design of an adequate gated, high capacity, low level outlet and conduit to pass small flood flows, enhance operation for detention, and enable passage by fish and other aquatic biota;
- Geotechnical stability of creek banks and other slopes within the inundated area and the need to implement stabilization measures;
- Potential impacts of the dam on the play of the golf course;
- Potential impacts of the dam on sensitive biological resources and other environmental considerations;
- Willingness of adjacent property owners along the perimeter of inundation to grant flood easements, where needed;
- Potential impacts of construction and operation of detention facilities on adjacent private and public properties and structures/facilities.
- Public safety procedures during detention operations;
- Potential inundation of Glen Drive during detention operations; and
- Dam failure analysis.

The dam would need to be designed and constructed in accordance with safety standards adopted by the State Department of Water Resources, Division of Safety of Dams. Environmental regulatory permits would be required and the permitting process could be lengthy and complicated, especially if sensitive species are determined to be present or potentially affected.

Factors supporting a detention basin at Mill Valley Golf Course include the following:

- The site is publicly owned.
- Most of the inundated area is golf course fairways and green, which would not be expected to be extensively damaged through inundation.
- Flooding during a 50-year event could be reduced by up to about 190 cfs, which is a 60% reduction in peak flow in Warner Canyon Creek and a 10% reduction at the ACMdP streamflow gage, based on a maximum of 227 acre-feet of storage.

[32] Refer to Appendix G for details on the Mill Valley Golf Course detention basin.

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FIGURE 17

[25-05] BANK RETAINING/FLOODWALLS & UPSTREAM BRIDGE WALL

[50-02] REPLACE/ENLARGE CULVERT

[50-04] MILL VALLEY GOLF COURSE DETENTION BASIN (NOT SHOWN)

[50-03] TOP OF RIGHT BANK FLOODWALL & UPSTREAM BRIDGE WALL

OLD MILL CREEK

[10-07] REPLACE/ENLARGE PARK AVE BRIDGE

WARNER CREEK

[50-05] TOP OF BANK FLOODWALLS

EXISTING PEDESTRIAN BRIDGES REMAIN

EXISTING DRIVEWAY BRIDGE REMAINS

[5-05] REPLACE WILLOW PUBLIC PEDESTRIAN BRIDGE

[50-05] EXTEND FLOODWALL ON TOP EXISTING RETAINING WALL

[5-04] REPLACE PRIVATE PEDESTRIAN BRIDGE

[5-06] WIDEN & MODIFY CHANNEL

[10-05] FLOOD DIVERSION WALL & RAISE SYCAMORE AVE

WARNER CREEK CONFLUENCE

[10-06] TOP OF BANK FLOODWALLS

[25-04] ACMDP CREEK PARTIAL BYPASS

[10-04] TOP OF BANK FLOODWALLS

[5-03] EXCAVATE CHANNEL BOTTOM (1.5' DEEP AVG) REPLACE GAGE STATION

GAGE STATION

EGGER PLAZA

[25-03] TOP OF LEFT BANK FLOODWALL

[50-01] REPLACE/ENLARGE EGGER PLAZA BRIDGE

[10-02] RIGHT BANK RETAINING/FLOODWALL

[10-02] TOP OF RIGHT BANK FLOODWALL

[10-02] RIGHT BANK RETAINING/FLOODWALL (100-Year)

[5-02] TOP OF RIGHT BANK FLOODWALL

[25-02] TOP OF LEFT BANK FLOODWALL

EXISTING PEDESTRIAN BRIDGE REMAINS

[5-01] TOP OF LEFT BANK FLOODWALL

[100-01] TOP OF RIGHT BANK FLOODWALL

[10-01] TOP OF LEFT BANK FLOODWALL

[10-01] TOP OF RIGHT BANK FLOODWALL

[10-01] RIGHT BANK RETAINING/FLOODWALL

[10-01] RIGHT BANK RETAINING/FLOODWALL

[25-01] TOP OF RIGHT BANK FLOODWALL

ID NUMBER DESCRIPTION

PROTECTION LEVEL — ID NUMBER

SCALE (FEET)

0 200 400

N W E S

LEGEND

- STREAM
- FLOODWALLS □ BERMS
- RAISE AND WIDEN BRIDGE
- REPLACE□ENLARGE CULVERT
- PREVIOUS MEASURES (In□□ded in 50-Year □ 100-Year Meas□res)

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50-YEAR AND 100-YEAR FLOOD PROTECTION MEASURES

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5.4 Fish Passage Measures and Other Environmental Enhancements

Arroyo Corte Madera del Presidio provides habitat for native salmonid fish, including resident trout, steelhead trout, Coho salmon and Chinook salmon. The National Marine Fisheries Services and the California Department of Fish and Game have listed steelhead trout and Chinook salmon as "threatened" under the federal Endangered Species Act (ESA) and the California Endangered Species Act, respectively. Coho salmon are listed as "endangered" on both the ESA and CESA. Freshwater aquatic and riparian habitats that support these fish species have been degraded by past human activities and the ongoing presence of development; most noteworthy are bridges and culverts that impede fish passage. Retaining walls and other permanent infrastructure flank the creek, and dense development has gradually filled in along the edges of the creek corridor eliminating portions of the riparian canopy and natural creek bank vegetation and encouraging invasion by non-native vegetation.

Opportunities are available to simultaneously reduce flooding and improve creek habitat for the native salmonids. Barriers to fish passage could be rectified in ways that also increase the hydraulic conveyance capacity of the creek. In-channel habitat features that provide fish resting, refuge, and rearing habitat could be incorporated into measures aimed at increasing channel flow capacity. Biotechnical treatments using native vegetation that provide near-shore cover and canopy, necessary for reducing fish predation and keeping water temperatures cool, could similarly be incorporated into retaining walls, floodwalls and landscape berms. These opportunities should be explored further and, where feasible, incorporated into the final designs of the flood reduction measures.

5.4.1 Fish Passage Barrier Removal

A previous fish passage study of creeks in Marin County identified ten culverts, including seven along Arroyo Corte Madera del Presidio and three along Old Mill Creek, as partial or complete barriers to fish passage. The study also described general approaches to remedy the barriers (Ross Taylor and Associates, 2003). Mill Valley Streamkeepers (MVSK) later commissioned a study to further evaluate the feasibility of rectifying five of the barriers. The study also included preliminary designs (Far West Restoration Engineering, 2004). The barriers are located in Figure 18 and the remedies described in the studies are listed in Table 8. Only one of the ten barriers is a site also targeted in this study for flood reduction: MR-069, which is a concrete culvert in Arroyo Corte Madera del Presidio passing beneath a private building downstream of Sunnyside Avenue just upstream of the confluence with Old Mill Creek. Accordingly, this fish passage remedy has been incorporated into the conceptual design and cost estimate of the flood reduction measure at this culvert. In addition, site MR-077, the culvert at Cascade Drive crossing, appears to limit the hydraulic capacity of Old Mill Creek to convey the 100-year flood

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based on examination of the FEMA Flood Insurance Rate Map (FEMA, 1979). Accordingly, in addition to rectifying the culvert for fish passage, the culvert should also be enlarged to provide sufficient capacity to convey the 100-year flood.

Table 8. Summary of Fish Barriers and Remedies for Mill Valley Creeks

Site I.D.	Creek	Road	Remedy
MR-068	ACMdP	Locust Ave.	Cut a 4 ft to 10 ft wide by 2 ft deep "notch" into 180 ft long concrete apron and culvert bottom; place rock and gravel into notch to provide a natural bottom passageway; construct downstream step pools to raise tailwater at outlet. (Far West, 2004)
MR-069	ACMdP	Building	Modify existing circular concrete culvert to form a new, larger box culvert (shoring and tie-backs will be needed) to increase hydraulic capacity; install a series of weirs and pool cross-baffles in culvert to reduce flow velocities and increase depths; construct downstream step pools to raise tailwater at outlet. (Far West, 2004)
MR-070	ACMdP	King St.	Place downstream boulder weirs to raise tailwater at outlet; install corner baffles within the culvert to reduce flow velocities and increase depths. (Taylor, 2003)
MR-071	ACMdP	Marguerite Ave.	Place downstream boulder weirs to raise tailwater at outlet; install fully-spanning, sloped concrete weirs within the culvert and an outlet beam with a low-flow notch to reduce flow velocities and increase depths. (Taylor, 2003)
MR-072	ACMdP	W. Blithedale Ave.	Install corner baffles within culvert to reduce flow velocities. (Taylor, 2003)
MR-073	ACMdP	W. Blithedale Ave.	Place downstream boulder weirs to raise tailwater at outlet. (Taylor, 2003)
MR-074	ACMdP	Blithedale Summit Fire Rd.	No remedy described in previous studies.
MR-075	Old Mill Creek	Miller Ave.	Construct downstream step pools to raise tailwater at outlet; evaluate need to install corner baffles within culvert to reduce flow velocities. (Far West, 2004)
MR-076	Old Mill Creek	Building	Construct baffles in existing culvert. (Far West, 2004)
MR-077	Old Mill Creek	Cascade Dr.	Construct a new arch bridge to increase hydraulic capacity; place rock and gravel in bottom to provide a natural bottom passageway. (Far West, 2004)

Sources: Ross Taylor and Associates, 2003; Far West Restoration Engineering, 2004.

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FISH BARRIERS ON MILL VALLEY CREEKS

- Fish Barrier
- Stream

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N

0 500 1,000 Feet

MR-073 (W. Blithedale Ave.)
MR-072 (W. Blithedale Ave.)
MR-071 (Marguerite Ave.)
MR-070 (King St.)
MR-077 (Cascade Dr.)
MR-075 (Miller Ave.)
MR-069 (Miller Ave.)
MR-068 (Locust Ave.)

Corte Madera Del Presidio Arroyo
Old Mill Creek
Ryan Creek

J:\jn2165\Inundationdepth_5yr.mxd 3/4/2010 N.Wasserman

FIGURE 18

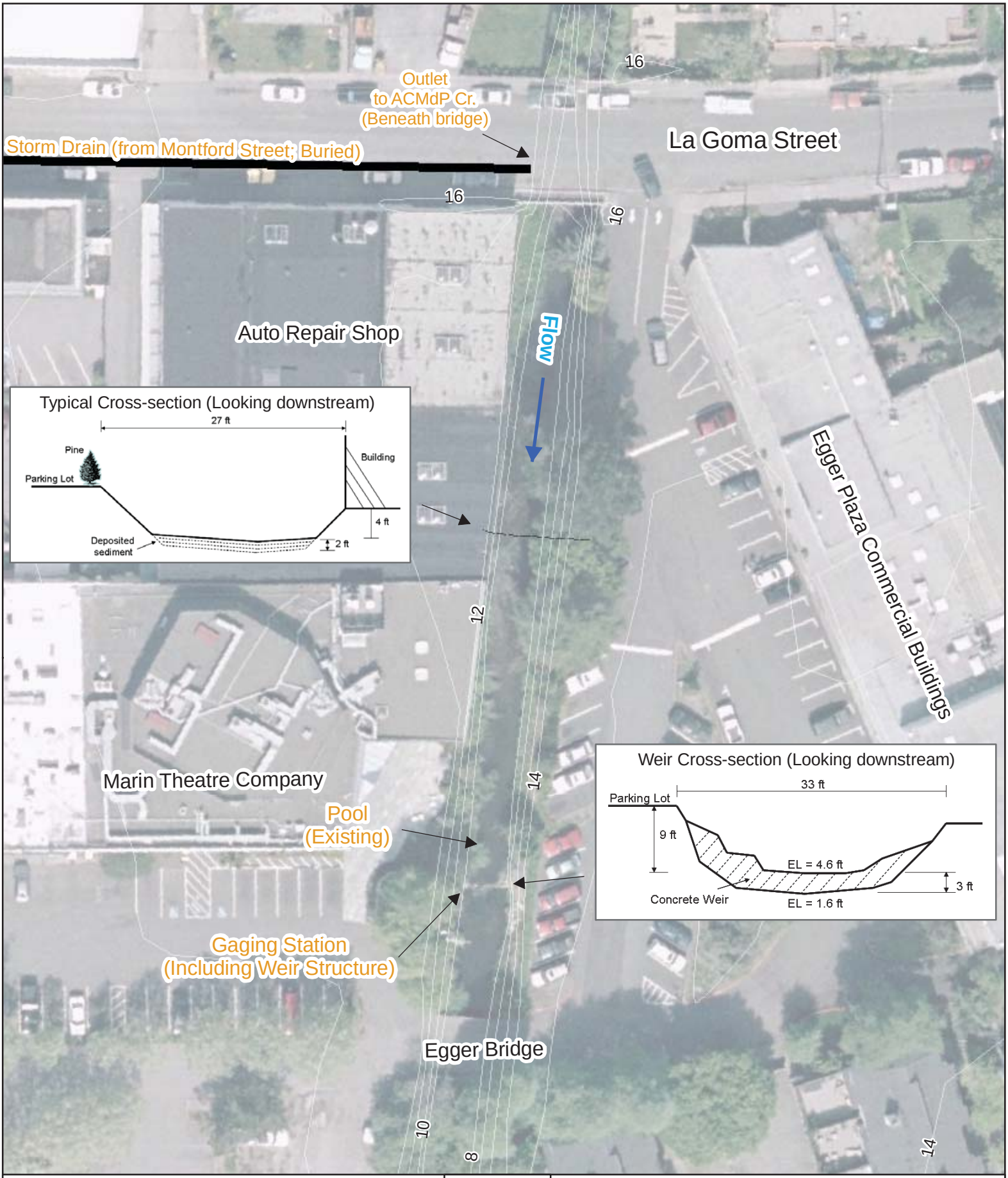
5.4.2 In-Channel Habitat Features and Biotechnical Treatments

The City of Mill Valley and MVSK collaborated to develop a conceptual plan (Stetson, 2010) for simultaneous flood reduction and habitat improvement that incorporates in-channel habitat features and biotechnical treatments along the reach of creek between La Goma Street Bridge and the Egger Plaza Bridge (Figure 19). This project demonstrates how flood damage reduction can be accomplished concomitantly with habitat improvement. Opportunities to apply this approach should be explored further and, where feasible, incorporated into the final designs of the flood protection measures described in this study.

The 300-foot reach between La Goma Street Bridge and Egger Plaza Bridge has aggraded over the years and its hydraulic conveyance capacity has been reduced (Figure 20) due to sediment accumulation behind the concrete weir at the streamflow gage. Generally, in Arroyo Corte Madera del Presidio a lack of deep resting pools for migrating fish is impairing the recovery of native salmonids. Lack of adequate riparian canopy to provide shade allows water temperatures to rise to unsuitable levels during summer. The project addresses these problems.

The project consists of removing the existing concrete weir structure at a the streamflow gage and replacing it with a stone structure set at a lower grade that allows for improved transport of bedload sediment (Figure 21). Any existing gage equipment affected by the work would need to be replaced and reinstalled. Because it would be re-set at a lower level, the stone structure would induce natural scouring and lowering of the channel bed upstream along the approximately 300-foot reach where up to 2 feet of sediment has deposited over the years. Lowering of the bed would increase the hydraulic conveyance capacity of the channel by about 140 cfs and, consequently, reduce the frequency and severity of overbank flows that break out along the project reach during severe storms. Lowering of the bed would also improve outflow from the Montford Avenue storm drain, which often becomes clogged at its outlet to the creek by sediment deposited in the bed. To guard against potential erosion and undermining of the banks resulting from lowering of the bed, stacked natural stone wall protection would be constructed along the toes of the banks. The banks would be further stabilized using biotechnical treatments, which would include plantings of native riparian shrubs and trees to provide nearshore cover and canopy for shade and refuge from terrestrial predators. To replace the loss of pools that have formed upstream and downstream of the existing concrete weir, three replacement pools would be constructed along the project reach using stone weirs. Interpretive signage would be placed on the La Goma Bridge overlooking the restored reach downstream.

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Figure 19

Stream Restoration Project along the Reach between La Goma Street Bridge and Egger Plaza Bridge

Site Plan - Existing Conditions

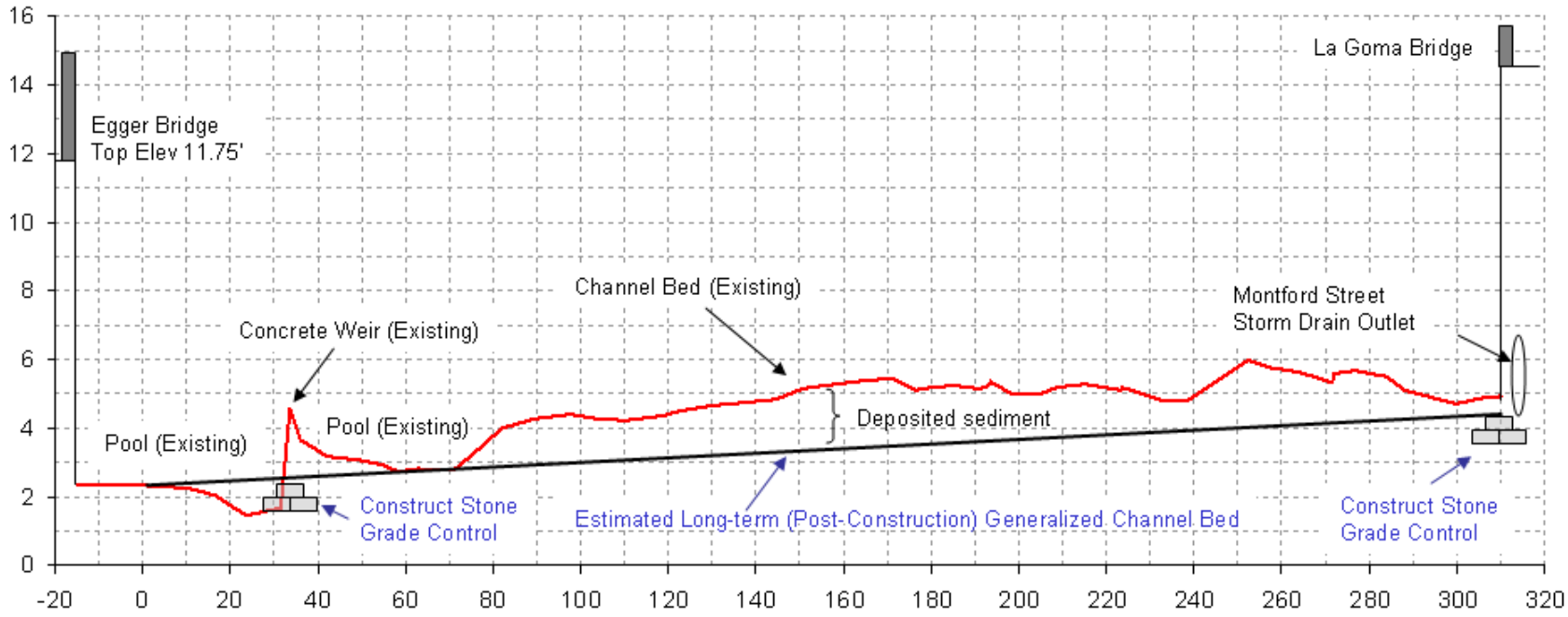
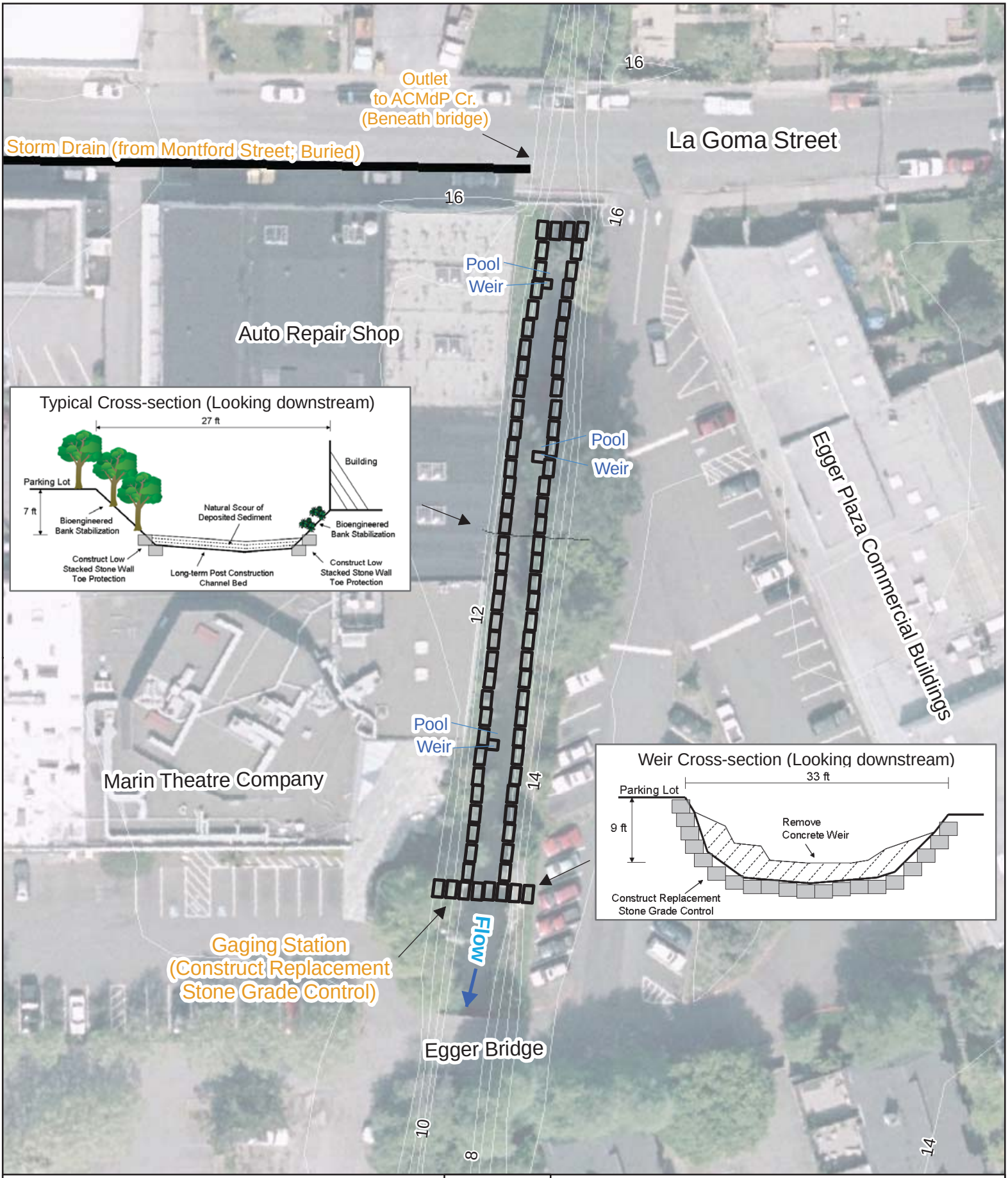


Figure 20
Arroyo Corte Madera del Presidio
Channel Bed Longitudinal Profile
La Goma Street Bridge to Egger Bridge



0 25 50 100 Feet

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Figure 21

Stream Restoration Project along the Reach between La Goma Street Bridge and Egger Plaza Bridge

Site Plan - Proposed Conditions

5.5 Estimated Costs

Capital costs were estimated for all measures, including in-channel measures to increase conveyance capacity, the ACMdP Creek partial bypass, and the Mill Valley Golf Course detention basin. These estimates cover all costs associated with initial project implementation include planning, environmental review, regulatory permitting, right-of-way acquisition, design, construction, and construction management. A contingency cost has been added. Refer to Appendix H for detailed cost estimates. Attachment 1 to Appendix H contains an estimate of the expected flood damage under existing conditions, and Attachment 2 contains the details on the estimated costs for the flood damage reduction alternatives.

Annual costs were also estimated. Annual costs are recurring costs that are incurred over the project facilities' life. Annual costs include operation, maintenance and repairs; monitoring, inspections and reporting; and administration, insurance, and management. Annual costs were estimated as a percentage of the capital costs of the various projects. For purposes of this analysis, annual costs were assumed to be 1% of the capital cost. Annual costs were brought forward to a present worth using a 5% discount rate based on an assumed 50-year project life.

Table 9 is a summary of the estimated costs for the five alternative levels of flood protection measures.

Table 9. Estimated Cost of the Alternatives

Alternative Level of Flood Protection	Capital Cost ($)	Annual Cost			Total Present Worth of Cost ($)
		Percent of Capital (%)	Annual Cost ($/yr)	Present Worth of Annual Cost ($)	
5-Year Measures	2,333,000	1%	23,000	420,000	2,753,000
10-Year Measures	8,125,000	1%	81,000	1,479,000	9,604,000
25-Year Measures	15,745,000	1%	157,000	2,867,000	18,612,000
50-Year Measures	38,131,000	1%	381,000	6,957,000	45,088,000
100-Year Measures	42,597,000	1%	426,000	7,779,000	50,376,000

* Future annual costs include operation, maintenance and repairs; monitoring, inspections and reporting; and administration, insurance, and management, and other recurring costs associated with the alternative measures.

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6.0 EFFECTS OF CLIMATE CHANGE AND RESULTING SEA LEVEL RISE

This section describes the anticipated effects of rising sea levels due to climate change on the proposed flood protection measures developed under this study. Other potential aspects of climate change, such as increased storm intensity, are not evaluated in this study but would be expected to increase peak flooding and impacts. Also, this section only evaluates the effects of sea level rise (SLR) on riverine flooding and does not evaluate direct coastal inundation which is expected to be a significant source of flooding under future SLR conditions. Finally, this section does not evaluate the full range of adaptive management measures to climate change impacts which may include a range of shoreline planning strategies. It is anticipated that this future watershed based analysis will be conducted in cooperation with the Marin County watershed program and the City of Mill Valley. Section 6.1 was prepared by Roger Leventhal of Marin County Flood Control and Water Conservation District.

6.1 Background on Sea Level Rise (*This section was prepared by Roger Leventhal, PE, Marin County Flood Control and Water Conservation District*)

Sea levels in San Francisco Bay have risen approximately 2 cm/decade (or approximately 7 inches in the past 100 years), which is approximately equal to the global measurements in sea level changes. Water levels in San Francisco Bay are anticipated by most climate scientists to at least increase at this rate and likely even accelerate due to a variety of local and global factors. Sea level rise is generally split into two broad parts – a global term that is controlled by global processes, such as the warming of the oceans and the melting of ice; and a local term that is controlled by local or regional processes, such as local winds and land movements. Local sea level rise is also referred to as relative sea level rise as it combines changes in the both the sea and land elevations.

Global (or eustatic) sea level rise is the combination of two factors:

1. Thermal expansion of the ocean. Thermal expansion is the result of higher water temperatures leading to an increase in ocean volume while the mass remains constant. The oceans are a major sink for greenhouse gases.

2. Melting of global ice. The melting of glaciers and land grounded ice caps, such as Antarctica and Greenland, will increase the mass of water in the oceans leading to sea level rise. The recent National Research Council report (NRC, 2012) has noted that current research indicates that the relative contribution from the melting of land ice to SLR is increasing.

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The local rise in sea level is a combination of global sea level rise together with three local factors:

1. Local ocean circulation. Atmospheric and ocean circulation patterns can affect regional sea levels. Wind-driven enhancement of sea level can occur on the Pacific coast to the northward wind especially in winter months and during El Nino events (Mote *et al*, 2008). Combined with Coriolis effects due to the Earth's rotation, they push ocean water toward the shore. Other phenomena associated with the El-Nino-Southern Oscillation, such as the frequency and magnitude of storms and storm surges, may also be altered by climate change. The effects have likely been responsible for the temporary flattening of the sea level rise slope for the past 20 years as measured at the NOAA Golden Gate tide gauges.

2. Vertical land movement. Relative sea level rise is the sum of global sea level rise and the change in vertical land movement. Thus, if sea level rises and the shoreline rises or subsides, the relative rise in sea level could be lesser or greater than the global sea level rise. Vertical land movement can occur due to tectonics (earthquakes, regional subsidence or uplift), sediment compaction, isostatic readjustment and groundwater depletion (USACE, 2009). It is anticipated that as rates of global sea level continue to increase with climate change, at some point in the future, the rate of vertical land movement will become less significant in determining the impact of sea level rise. However, areas that have subsided such as the Richardson Bay shoreline are particularly vulnerable to sea level rise and extreme events.

3. Local hydrodynamic variations. Differences have been found between the rates of global sea level rise and regional sea level rise in large, semi-enclosed water bodies such as estuaries and large embayments (USACE, 2009) which are likely not as much of a factor within Richardson Bay.

There have been numerous studies and reports developed over the past decade related to climate change and SLR. For this study, we have relied on the recent National Resource Council (NRC) prepublication report "*Sea Level Rise for the Coasts of California, Oregon and Washington: Past, Present and Future*" which to our knowledge is the most comprehensive, recent report synthesizing the science regarding SLR focusing on the Pacific Coast states. Note that the SLR projects in this new study (Table 10 below) do not significantly differ from the SLR projections from previous studies.

Why Assess the Impacts of Sea level Rise?

Although the exact timing and magnitude of sea level rise in San Francisco Bay is not known, it is prudent to start incorporating the potential impacts of a rising sea level into local capital

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improvement planning over the next 20 to 100 year time frame. New sources of flooding such as direct coastal inundation (not addressed in this study) may become the primary sources of flooding and shoreline erosion over the next several decades and also exacerbate riverine and stormdrain flooding. While planning for SLR does not mean necessarily spending funds now for an uncertain rise in bay water levels; it does mean assessing the impacts of sea level rise on proposed capital improvement projects and to the extent practical, allowing the space to adaptively manage these projects should future sea rise projections turn out to be correct. This study only assesses impacts to riverine flooding but future studies in the watershed will focus more on adaptive strategies and the cost-effectiveness of designing flood control projects under higher bay water levels. One such regional study is the Our Coast, Our Future project underway by the United States Geologic Survey (USGS) that will analyze the impacts of SLR on coastal flooding around San Francisco Bay.

Other reasons to evaluate SLR impacts include many other factors important to the quality of life in the Mill Valley watershed outside of flooding. These other potentially impacted uses include public usage of trails and parks, fish passage and wetlands habitat. Finally, certain permitting agencies (e.g., the BCDC) are requiring evaluation of SLR in the design process for projects subject to the impacts of a raising sea level. It is anticipated that sea level rise and climate change evaluations will become a standard part of the design, permitting and grant funding process into the future.

6.2 Work Performed Under this Study

Sea level rise resulting from future climate change was considered in the analysis of flood protection measures. The analysis was performed using the HEC-RAS steady-state hydraulic model to (1) determine the level of flood protection provided by the respective flood protection measures under sea level rise conditions and (2) determine alterations and/or additional measures that would be needed to maintain the intended level of flood protection provided by the measures. In addition, areas subject to tidal backflow flooding under future sea level rise conditions by way of storm drain systems were delineated to indicate where storm drain system improvements would be necessary to prevent localized flooding.

According to a recently published sea level rise study report prepared by the National Research Council in June 2012 (NRC, 2012), projected sea level rises in San Francisco Bay for year 2030, 2050, and 2100 (relative to year 2000) are summarized in Table 10.

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Table 10. San Francisco Bay Sea Level Rise Projections Relative to 2000 (in centimeters)

2030		2050		2100	
Projection	Range	Projection	Range	Projection	Range
14.4 ± 5.0	4.3 – 29.7	28.0 ± 9.2	12.3 – 60.8	91.9 ± 25.5	42.4 – 166.4

1) Source: NRC, 2012.
2) 1 cm = 0.39 inch; 1 inch = 2.54 cm.
3) The value under "Projection" represents the projected mean sea level rise with one standard deviation.

The current mean higher high water (MHHW) published in the NOAA website is based on the tidal epoch 1983-2001. The NRC-projected sea level rise is relative to 2000. Since the base year in the sea level rise projection is within the tidal epoch 1983-2001, the projected sea level rise values were directly added to the current MHHW to derive the future MHHW under sea level rise conditions. The existing MHHW in San Francisco Bay (NOAA Station ID: 9414290) is 5.9 ft NAVD 88.

Assuming a 50-year project life for the flood damage reduction facilities, three different downstream boundary conditions (2030 high plus 2050 low and high SLR projections) were analyzed. The 2030 low SLR projection was not analyzed because it is just 4.3 cm, or 0.1 ft, in sea level rise. The 2100 low/high SLR projections were not analyzed either because 2100 is beyond the facilities' 50-year project life. Table 11 summarizes the three future MHHW conditions that were used as the downstream boundary conditions for the HEC-RAS modeling analysis. The analysis assumed that some form of barrier is put in place along the historic railroad grade to prevent further inland encroachment of tides greater than Mean Higher High Water.

Table 11. Summary of the Downstream Boundary Conditions under Future Sea Level Rise MHHW Scenarios

Downstream Boundary Condition	Existing MHHW (ft NAVD 88)	Projected Sea Level Rise	Future MHHW (ft NAVD 88)
2030 high SLR projection	5.9	29.7 cm = 1.0 ft	6.9
2050 low SLR projection	5.9	12.3 cm = 0.4 ft	6.3
2050 high SLR projection	5.9	60.8 cm = 2.0 ft	7.9

The analysis was conducted for the 10-year and 100-year flood protection measures using the HEC-RAS steady-state hydraulic model. Figure 22 shows the simulated 10-year water surface profile (with the 10-year flood protection measures in place) for the three different sea level rise scenarios. It shows that the influence of tidal condition diminishes with distance upstream, with a maximum difference in water level of 0.4 ft at Camino Alto Bridge under the 2050 high projection scenario. The influence of the tidal condition fully peters out at Camino Alto Bridge under both the 2030 high projection and 2050 low projection scenarios. The influence of the

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tidal condition fully peters out at Valley Circle Pedestrian Bridge under the 2050 high projection scenario.

Figure 23 shows the simulated 100-year water surface profile (with the 100-year flood protection measures in place) for the three different sea level rise scenarios. It shows that the influence of the tidal condition fully peters out at Camino Alto Bridge under all three sea level rise scenarios. Compared to the 10-year water surface profile, sea level rises have less effect on the 100-year water surface profile in terms of the affected distance.

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Figure 22 ACMdP 10-Year Water Surface Profile (with 10-Year Flood Protection Measures in Place) under Different Sea Level Rise Scenarios

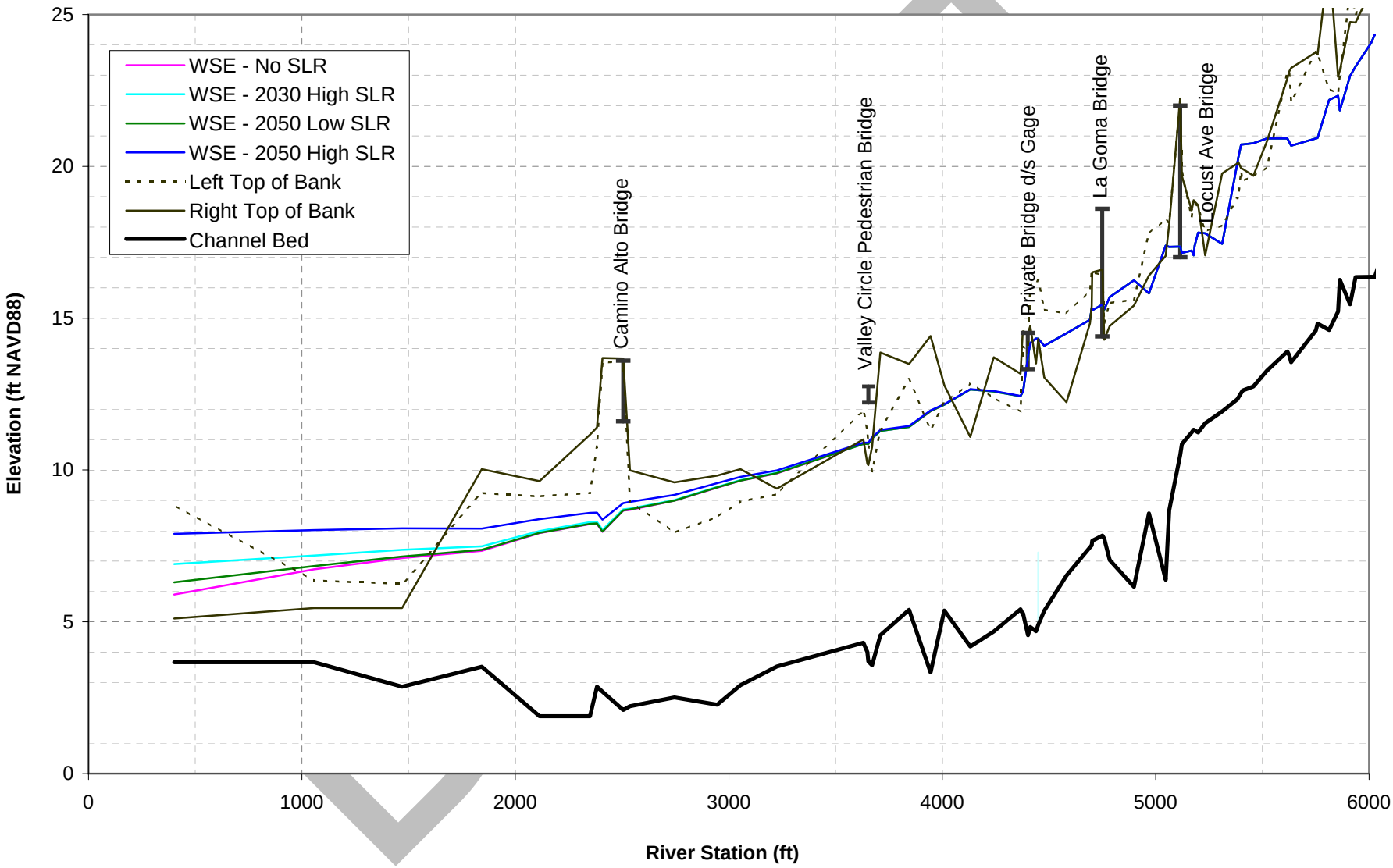
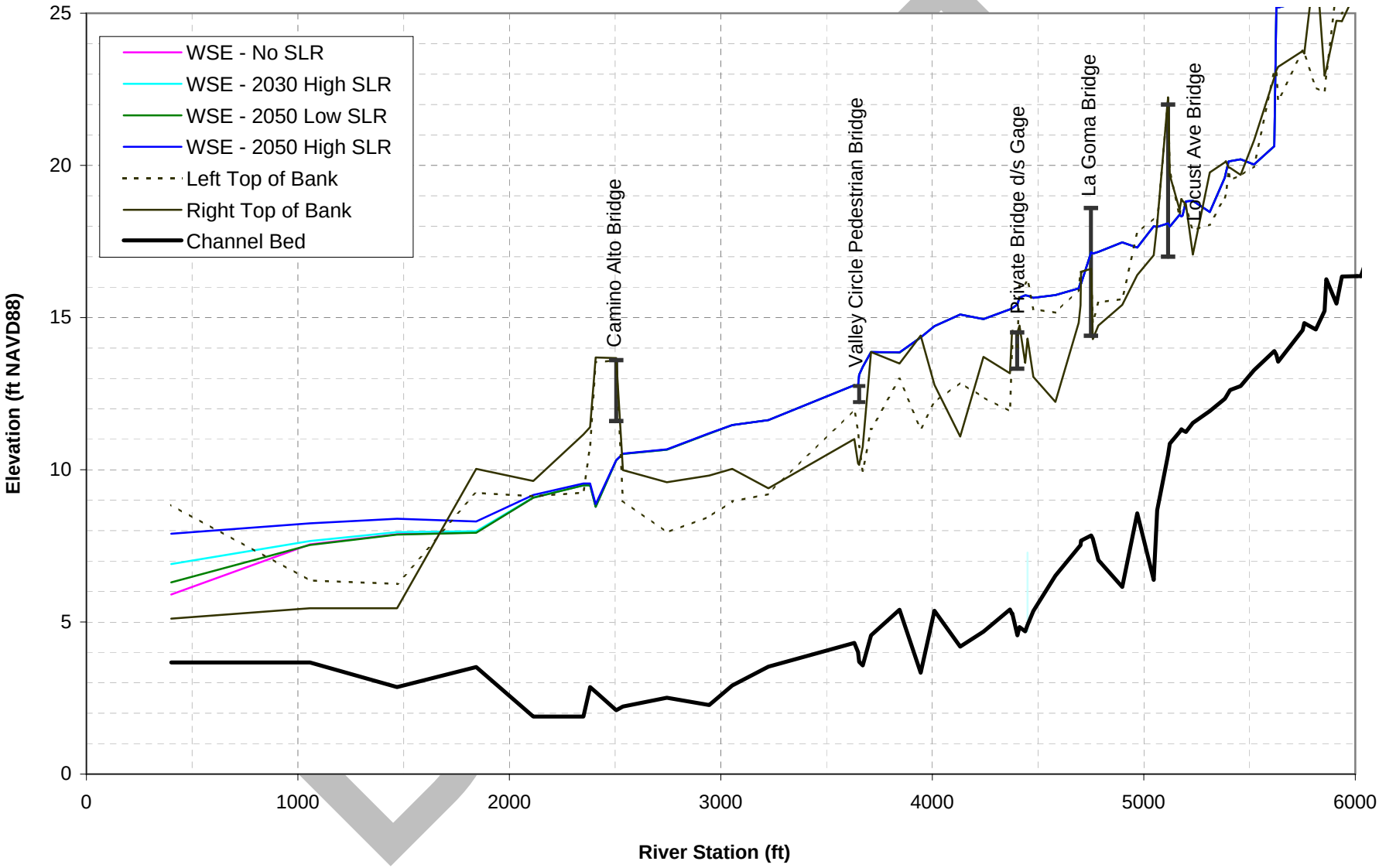


Figure 23 ACMdP 100-Year Water Surface Profile (with 100-Year Flood Protection Measures in Place) under Different Sea Level Rise Scenarios



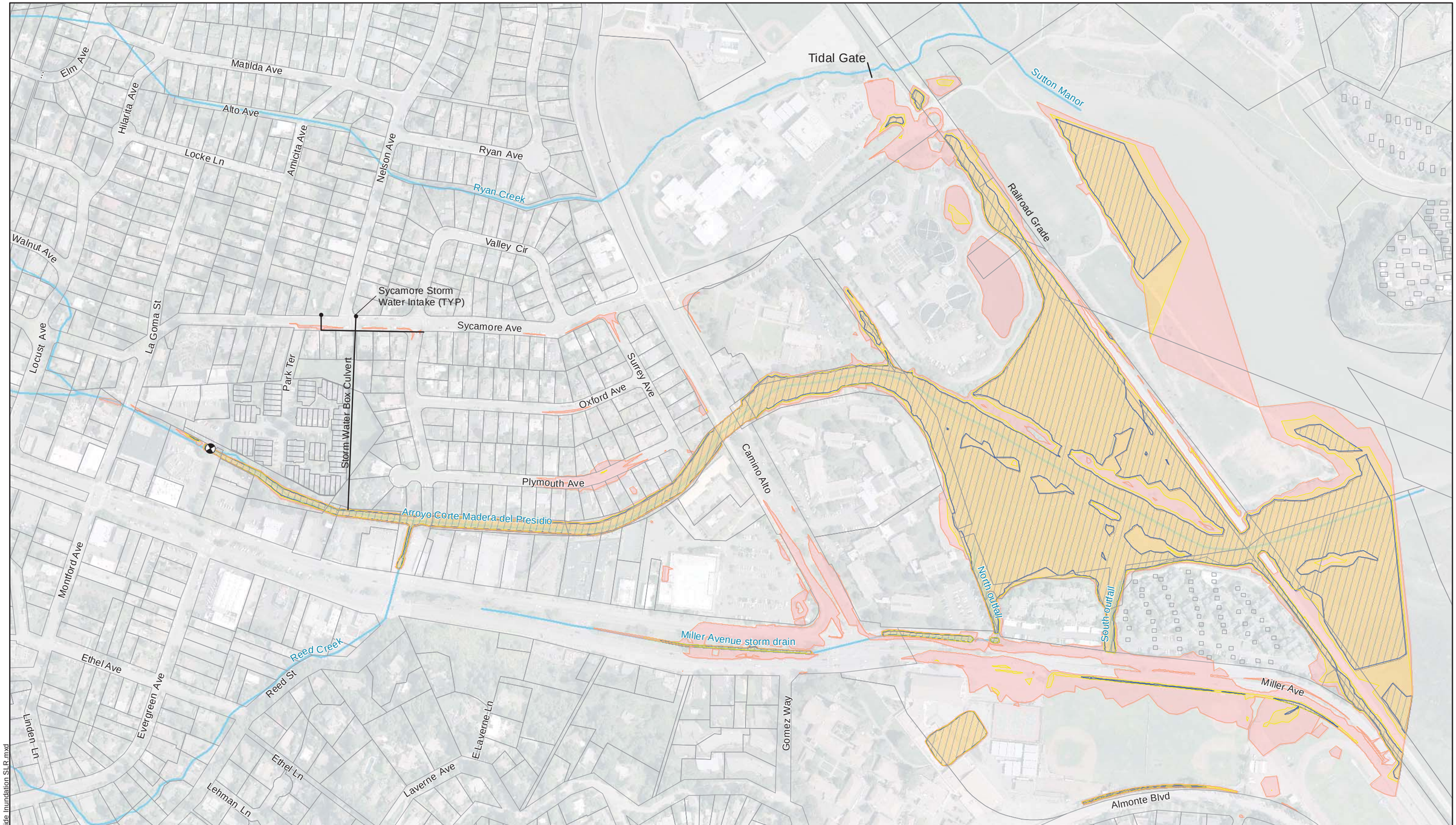
As shown in Figures 22 and 23, both the 10-year and 100-year water surface profiles above Camino Alto Bridge have relatively steep gradients and are higher than the three future MHHWs. Steep water surface gradients limit the effect that the higher downstream boundary conditions have on the water surface profiles above Camino Alto Bridge. This suggests that the three downstream boundary conditions should not have an important effect on the proposed flood protection measures because all the proposed flood protection measures are located above Camino Alto Bridge. Table 12 is a summary of the analysis results.

Figure 24 shows the areas subject to tidal backflow flooding by way of storm drain systems under the three different sea level rise scenarios. The land surface in these areas is lower than the MHHWs. During heavy storms coincident with the MHHWs, interior stormwater flooding due to inadequate storm drain hydraulic capacity would cover larger areas. Note that the floodplain of Ryan Creek would not have any areas subject to tidal backflow flooding because Ryan Creek is currently isolated from the bay by a tidal gate and pump station located at the downstream end of the creek (see Figure 24).

Table 12. Summary of Analysis Results for Future Sea Level Rise Scenarios

Sea Level Rise Scenario	Future Level of Flood Protection Provided by the Flood Protection Measures		Alterations and/or Additional Measures That Would Be Needed to Maintain Intended Level of Flood Protection under Future Sea Level Rise	
	10-Year Measures	100-Year Measures	10-Year Measures	100-Year Measures
2030 High SLR Projection	10-Year Flood	100-Year Flood	No change	No change
2050 Low SLR Projection	10-Year Flood	100-Year Flood	No change	No change
2050 High SLR Projection	8-Year Flood	100-Year Flood	Raise floodwalls between Camino Alto Bridge and Valley Circle Pedestrian Bridge by 0.4 ft	No change

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Gage Station
Stream
Storm Water Culvert
Parcel Boundary

2030 High Projection MHHW*: 6.9ft (NAVD88)
2050 Low Projection MHHW*: 6.3ft (NAVD88)
2050 High Projection MHHW*: 7.9ft (NAVD88)

* Mean Higher High Water

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AREAS SUBJECT TO TIDAL BACKFLOW FLOODING
BY WAY OF STORM DRAIN SYSTEMS
UNDER THREE DIFFERENT FUTURE SEA LEVEL RISE SCENARIOS

0 250 500 Feet

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FIGURE 24

Document Path: J:\sh2433\Tide Inundation SLR.mxd

Assumption: A barrier system along the Railroad Grade is assumed to be put in place to prevent tides greater than MHHW from propagating upstream.

7.0 IMPLEMENTING FLOOD DAMAGE REDUCTION MEASURES IN ACCORDANCE WITH FEMA FLOODPLAIN REGULATION

FEMA is in the process of revising its Flood Insurance Rate Maps (FIRMs) for Ross Valley and Mill Valley. This process involves flood studies including new hydraulic and hydrologic models to determine water surface elevations for the 100-year flood, or the 1-percent-annual-chance flood. These elevations are referred to as "base flood elevations (BFEs)" from riverine and coastal flooding sources. The FIRM for Mill Valley was revised in 1979 and most recently in 2009. The new FIRM for Mill Valley is expected to become effective in 2014.

In April 2012, FEMA offered affected communities the opportunity to review and comment on the flood studies from riverine sources and the "working maps," which are essentially draft FIRMs, before they are officially released for public review and comment in November 2012. The City of Mill Valley commissioned Stetson Engineers to review the riverine flood source working map for Mill Valley. The working map delineates the riverine Special Flood Hazard Area (SFHA); that is, the area contained within the 1-percent-annual-chance flood boundary. Unlike previous FIRMs, this working map also delineates the regulatory floodway, which is the area within the SFHA that must be reserved in order to discharge the base flood. Communities must regulate any new development in the regulatory floodway to ensure that there are *no* increases in upstream flood elevations. Figure 25 shows the delineated regulatory floodway and its spatial relation to the flood damage reduction measures described in this report. All of the flood reduction measures described in this study are also located within the regulatory floodway and, as such, would be subject to FEMA's floodplain regulations.

Flood reduction measures described in this study include floodwalls. By design, floodwalls raise the water surface elevation of the 1-percent-annual-chance flood; up to 3.5 feet in some reaches of the creek. However, it is important to point out that flooding is not exacerbated because the floodwalls keep the floodwater contained in the creek, just at a raised elevation.

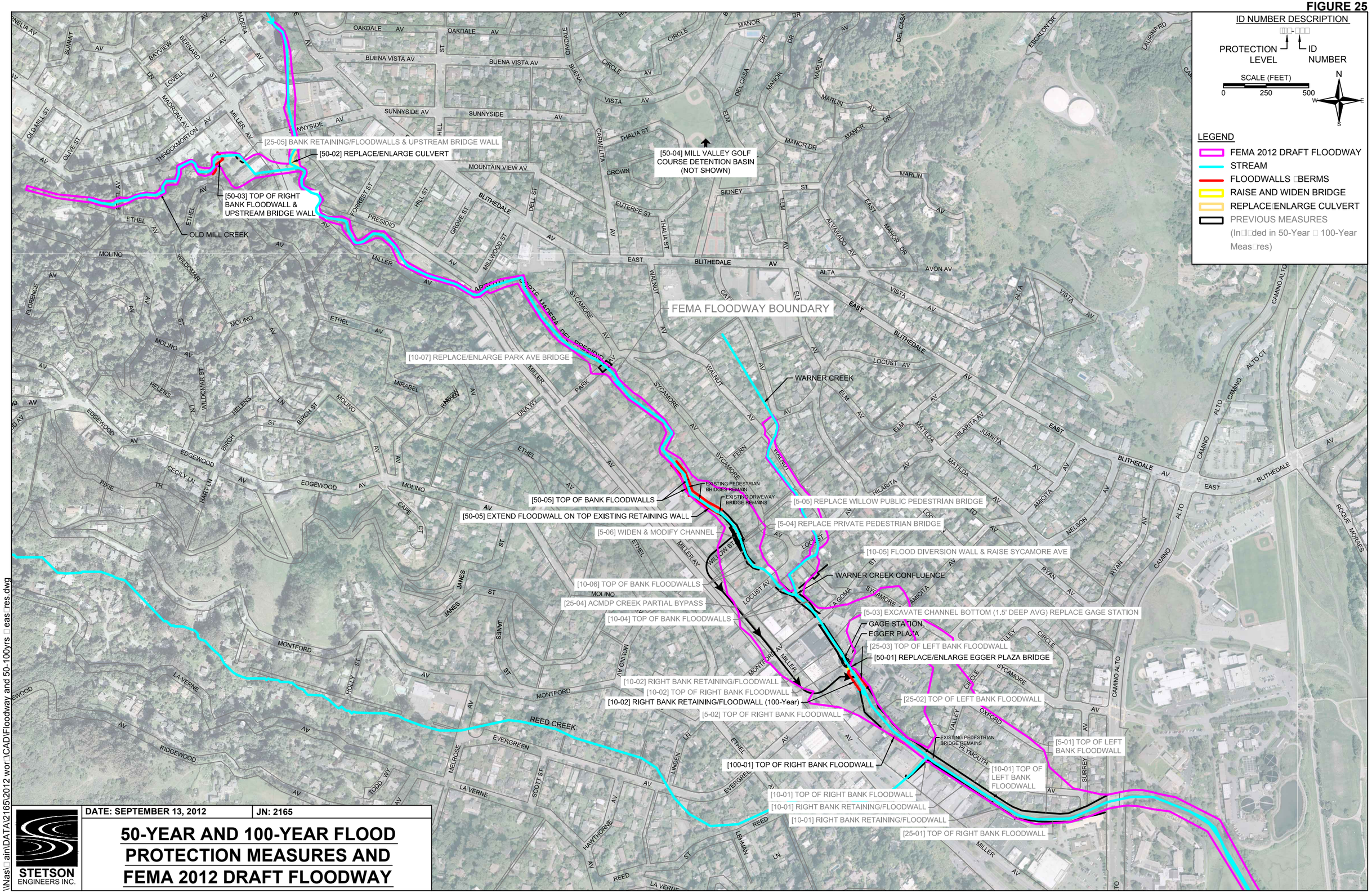
Nonetheless, the issue arises as to how the flood damage reduction measures, floodwalls in particular, can be implemented in accordance with FEMA floodplain regulations regulating new development in the regulatory floodway and prohibiting a rise in upstream flood elevations. A Letter of Map Revision (LOMR) is the vehicle that would enable these measures to be implemented. A LOMR is an official revision to a FIRM. LOMRs reflect changes to the mapped SFHAs, BFEs, floodplain widths, and regulatory floodways. LOMRs are issued after a floodplain has been remapped due to a major flood event, after better mapping data becomes available, or after structural flood control improvements have been constructed.

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Through the LOMR process, flood damage reduction measures can be implemented. Prior to constructing any measure(s) that may trigger the need for a LOMR, the City will need to submit an application to FEMA requesting FIRM revision. The application will need to include design plans and other technical information concerning the proposed flood reduction measure(s). If FEMA approves the application, it will issue a Conditional Letter of Map Revision (CLOMR). A CLOMR is similar to a LOMR, but is based on proposed conditions and does not change the FIRMs. A CLOMR is the method used by FEMA to let people know that if a project is constructed per the design submitted to and approved by FEMA then revision of the FIRM with a LOMR is likely. If FEMA issues the CLOMR, the City can be assured that a LOMR for the project will be approved upon completion of the flood reduction measure.

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FIGURE 25



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DATE: SEPTEMBER 13, 2012 | JN: 2165

50-YEAR AND 100-YEAR FLOOD PROTECTION MEASURES AND FEMA 2012 DRAFT FLOODWAY

\\Nas\□ain\DATA\2165\2012 wor□\CAD\Floodway and 50-100yrs □eas□res.dwg

8.0 RELATED STUDIES

MCFCWCD commissioned Stetson Engineers for two studies related to flooding in Mill Valley. The Evaluation of the Ryan Creek Pump Station Study is provided in Appendix I. This study analyzed the Ryan Creek pump station and local drainage issues. Ryan Creek has its own watershed separate from Arroyo Corte Madera del Presidio. The Evaluation of the Camino Alto North Outfall Study is provided in Appendix J. This study addressed drainage issues regarding the Camino Alto North Outfall. These studies have little bearing on the flood damage reduction measures covered in this report, but they are included herein to provide a more complete compendium of studies that address Mill Valley flooding issues.

8.1 Camino Alto North Outfall Evaluation

The North Outfall functions as the discharge outlet to Richardson Bay for the Camino Alto North storm drain system. During normal storm events, the Camino Alto North system drains a local area of about 38 acres covering both sides of Miller Avenue from about Valley Circle down to the North Outfall. During high tides, tidal inflows enter through the outfall and back up into the storm drain system. During very heavy storm events, overtopping of Arroyo Corte Madera del Presidio and Reed Creek farther upstream can spill over into the system, joining with the local runoff flowing along Miller Avenue to the North Outfall, as demonstrated during the approximate 50-year recurrence flood event on December 31, 2005. If coupled with a high tide, these heavy storm events can inundate the Miller Avenue-Camino Alto intersection making it impassible as well as affecting adjacent properties.

Stetson performed an engineering analysis and prepared conceptual designs for improvements at the North Outfall. These improvements aim to prevent tidal backflow, handle runoff generated within the 38-acre drainage area, and also handle additional runoff originating farther from overtopping of Arroyo Corte Madera del Presidio and Reed Creek that may reach the North Outfall. These improvements to the Camino Alto North storm drain system could be integrated with the greater Miller Avenue streetscape project.

8.2 Ryan Creek Pump Station Evaluation

MCFCWCD operates a tidal gate and pump station on lower Ryan Creek at its discharge to Richardson Bay. Ryan Creek drains an area of about 117 acres composed of a 100-acre residential area above Camino Alto and a 17-acre area below Camino Alto, which includes Mill Valley Middle School and a 3-acre marsh. The average depth of the marsh is about 3 feet and it holds about 9 acre-feet of water. Marsh storage attenuates flow in Ryan Creek during heavy

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storms and reduces the peak discharge in the outlet channel reaching the tidal gate and pump station. This attenuation effect is dependent on the antecedent water level in the marsh – the effect is diminished if the marsh is partially or completely filled prior to a heavy storm.

The tidal gate is normally kept open in the dry season to help support the marsh and keeps it closed in the wet season to prevent tidal waters from backing upstream into Ryan Creek. This mode of operation also preserves storage space in the marsh for attenuating heavy storm flows. The pump station is needed to convey water over the tidal gate to the bay. Discharge from the marsh is controlled by the hydraulics of the outlet channel and the pump discharge. The Ryan Creek pump station consists of two pumps, each with a capacity of 8,000 gallons per minute (18 cfs), for a total combined installed capacity of about 16,000 gallons per minute (36 cfs). If discharge from the marsh exceeds the capacity of the pump, the water level in the marsh would rise. This rise, if sufficiently high, could have a backwater effect extending upstream and affecting creek water levels in the residential area above Camino Alto.

The purpose of the study was to analyze the hydraulics of lower Ryan Creek and assess the adequacy of the existing pump station to convey heavy storm flows and maintain protective water levels in the marsh. The study found that the current pump station capacity does not substantially differ from the originally designed capacity. When two pumps are in operation as designed for heavy storms, their combined capacity is adequate to prevent flood damage to buildings upstream along Ryan Creek; that is; none of the first finished floor elevations of buildings upstream along Ryan Creek would be inundated, even during a 100-year flood event although there would be some inundation of the lands along the creek corridor.

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REFERENCES CITED

Dawdy, David R. "Analysis of the Flooding on Arroyo Corte Madera." March 28, 2006.

Far West Restoration Engineering. Tech Memo "Preliminary Fish Barrier Culvert Modifications and Flood Assessment, Arroyo Corte Madera/Old Mill Creek." November 15, 2004.

Federal Insurance Administration. "Flood Insurance Study, City of Mill Valley, Marin County, California." July 1978.

Federal Insurance Administration. "Flood Insurance Rate Map, City of Mill Valley, Marin County, California." Panel Number 060177 0005B. Effective January 3, 1979.

National Research Council. "Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future." June 2012.

Ross Taylor and Associates. "Marin County Stream Crossing Inventory and Fish Passage Evaluation." July 2003.

U.S. Army Corps of Engineers, 1967. Survey Report for Flood Control and Allied Purposes, Stream Flowing into Richardson Bay.

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APPRAISAL-LEVEL FLOOD STUDY
FOR
ARROYO CORTE MADERA DEL PRESIDIO,
MILL VALLEY, CA

PREPARED FOR

CITY OF MILL VALLEY

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PREPARED BY

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EXECUTIVE SUMMARY

This report documents flooding problems and describes measures to reduce flooding and flood damage resulting from breaching of the banks of the mainstem Arroyo Corte Madera del Presidio (ACMdP) and its major tributaries Old Mill Creek and Warner Canyon Creek. This report focuses on the flow capacity of the creek and develops a range of potential solutions to reduce flooding upstream of Camino Alto. Downstream of Camino Alto coastal flooding is the dominant source of flooding. Coastal flooding will be evaluated through the Southern Marin Watershed Program, which is a joint effort of the City and the Marin County Flood Control and Water Conservation District (MCFCWCD).[1] Flooding from overflow of interior stormwater drainage systems, including minor creeks, ditches, and storm drains, is generally excluded from this study, with the exception of the Sycamore Avenue Pump Station, Ryan Creek Pump Station, and Camino Alto North Outfall. Following are highlights of the report.

The December 31, 2005 Flood

The damage that resulted from the New Year's Eve 2005 flood has renewed interest in flood management along the flood-prone ACMdP in Mill Valley. Of the estimated 217 parcels inundated by floodwaters, 167 parcels (77%) reported damage. Most of the reported damage was concentrated in the Sycamore neighborhood and resulted from breaching of the banks of the channel between Willow Street and Camino Alto.

The December 31, 2005 flood was a rare, enormous runoff event, with a peak discharge of about 1,810 cubic feet per second (cfs), the highest flow measured over the period of historical gage record. The probability of a flood of this magnitude occurring in any given year is estimated at approximately 2 percent. Stated another way, on average and over the long term, a flood of this magnitude would be expected to occur only about once every 50 years.

Natural stream channels have limited conveyance capacities and typically overtop their banks during floods of a much smaller magnitude than the 50-year event; or about once every 1 to 4 years. In view of this, overtopping of banks of ACMdP on December 31, 2005 was characteristic of a natural stream given the enormous magnitude of the event. Even in its quasi-natural condition (i.e., hypothetical condition with all bridges, culverts, and other structural crossings removed), the creek still would have overtopped its banks and inundated parcels in the floodplain on December 31, 2005.

[1] Information about the Southern Marin Watershed Program can be found at www.marinwatersheds.org.

Flood Damage Reduction by Raising At-Risk Residential Buildings

The results of this study demonstrate that a reduction in flood damage could be achieved by raising the elevation of the first finished floor of vulnerable residential buildings. The number of at-risk buildings (i.e., buildings in the flood prone area with first finished floors that would be inundated during floods) is given in Table ES1. Most at-risk residential buildings could be feasibly raised, assuming the owners agree to undertake the work. The total estimated capital cost to raise all of the at-risk residential buildings ranges from about $40,000 for those located in the 5-year flood prone area to $4,300,000 for those located in the 100-year flood prone area. Most non-residential at-risk buildings, such as commercial buildings along lower Miller Avenue, are not suitable for raising because of the methods and materials used in their construction[2]. Other approaches to flood damage reduction, such as flood proofing, may be feasible for these types of structures, but detailed evaluation of these approaches was beyond the scope of this study.

Table ES1. Summary of Raising At-Risk Residential Buildings

Level of Flood Protection	Number of At-Risk Non-Residential Buildings	Number of At-Risk Residential Buildings	Total Estimated Capital Cost of Raising At-Risk Residential Buildings ($)
5-Year Flood	7	1	42,000
10-Year Flood	16	14	492,000
25-Year Flood	27	60	1,760,000
50-Year Flood	40	103	3,086,000
100-Year Flood	59	150	4,289,000

Note: The cost of raising at-risk residential buildings varies from building to building. Costs above are based on an estimated average unit cost of $22 per square foot. Refer to page 9 of Appendix H for the basis of this estimated unit cost.

Flood Damage Reduction by Improving Creek Flood Control Infrastructure and Additional Public Benefits

Flood damage reduction could also be achieved by implementing the flood control measures[3] developed through this study. These measures reduce flooding by increasing the flow capacity of the creek at key locations where capacity is limited, by bypassing floodwaters around these

[2] Commercial buildings constructed of concrete block, concrete tilt up, brick wall or stone wall typically are not suitable for raising. It is typically not feasible to raise buildings that are not constructed with light weight and strong materials such as wood and steel.

[3] "Flood control measures" is a term used herein to describe physical facilities or improvements to creek infrastructure designed to keep floodwaters, that would occur as a result of a specific magnitude flood event, in the channel and away from developed areas in the floodplain. Flooding could still occur even after work is performed to achieve a specific level of flood protection.

reaches in a separate channel, and by reducing the magnitude of the peak flood discharge through attenuation in a large detention basin. An existing computerized HEC-HMS hydrologic model of the watershed was modified and improved and a new HEC-RAS hydraulic model of the creek was constructed to develop and test the effectiveness of possible measures. The measures were evaluated for potential feasibility and cost estimates were calculated. Combinations of measures deemed potentially feasible were bundled into groups, each group providing a targeted level of protection. Collectively, these groups provide from 5-year flood protection to 100-year flood protection (see Table ES2). Estimated capital costs range from $2,333,000 for 5-year flood protection to $42,597,000 for 100-year flood protection. Of the levels of flood protection analyzed, the 10-year and 25-year levels provide the greatest benefit-cost ratio, about 1.4 to 1[4]. The estimated capital costs of the 10-year and 25-year levels of flood protection are $8,125,000 and $15,745,000, respectively.

Table ES2. Summary of Bundled Measures for Different Levels of Flood Protection

Level of Flood Protection	Bundled Measures	Estimated Capital Cost ($)	Estimated Benefit-Cost Ratio
5-Year Protection	• Willow Street pedestrian bridge replacements (2); channel widening over about a 150 ft reach near the bridges • Removal of concrete weir at the streamflow gage; channel dredging over the 150 ft reach upstream of the gage • Low floodwalls/berms	2,333,000	0.5
10-Year Protection	• All 5-Year Flood Protection Measures • La Goma Street Bridge replacement • Raise Sycamore Avenue grade • Park Street Bridge replacement • Additional low floodwalls/berms	8,125,000	1.4
25-Year Protection	• All 10-Year Flood Protection Measures w/o La Goma Street Bridge replacement • Arroyo Corte Madera del Presidio partial bypass • Additional low floodwalls/berms	15,745,000	1.4
50-Year Protection	• All 25-Year Flood Protection Measures • Culvert enlargement beneath private building downstream of Sunnyside Avenue • Egger Plaza Bridge replacement • Mill Valley Golf Course detention basin • Additional low floodwalls/berms	38,131,000	0.8
100-Year Protection	• All 50-Year Flood Protection Measures • Additional low floodwalls/berms	42,597,000	0.8

Notes: Refer to Appendix H for details on the cost estimates and the benefit-cost analysis.

[4] Additional benefits not included in the benefit-cost ratio include benefits to business, ecosystems, infrastructure and public services, transportation systems, and others. Including these benefits would increase the benefit-cost ratios shown.

Creek infrastructure improvements offer a broad array of public benefits beyond protecting buildings and contents from damage. Flood control measures enhance public health and safety, avoid public hardship and disruption associated with flooding, and protect public infrastructure, facilities, water quality, and ecosystems. Flood control measures also prevent economic losses to private businesses, municipalities, and the general public. These types of public benefits were not evaluated in this report and are not accounted for in the benefit cost ratios in Table ES2. Including these benefits would increase the benefit-cost ratios shown in the table.

Creek infrastructure improvements also offer the benefit of improving the habitat of the creek, particularly for native fish such steelhead trout, Coho salmon and Chinook salmon. These anadromous fish are protected under federal and state law. By incorporating fish passage features and biotechnical bank treatments using native vegetation into the final designs of the flood control measures, flood reduction and habitat improvement can be accomplished concomitantly.

Effects of Climate Change and Resulting Sea Level Rise on Flood Control Measures

Higher downstream water levels resulting from future sea level rise would not have an important effect on the performance of the flood control measures described in this report. The reason is that the projected rise in sea level will extend only as far up the creek as the Valley Circle Pedestrian Bridge, and most of the proposed flood damage reduction measures are farther upstream. Sea level rise will, however, exacerbate localized flooding resulting from surface runoff from streets and properties in areas where stormwater drainage systems are unable to discharge to the creek due to higher creek levels downstream of Valley Circle. Sea level rise is expected to have major impacts on direct coastal flooding and wind-wave erosion along the Richardson Bay shoreline, including impacts to properties and critical infrastructure.

Moving Forward

This report provides technical information to support future flood mitigation planning efforts and decision-making. It describes how flooding can be reduced by containing more of the floodwater in the channel through physical improvements to creek flood control infrastructure, and it provides estimated costs for different levels of flood protection. This report also describes how damage can be reduced by raising the first floor elevations of residential structures. Commercial structures and critical infrastructure that can not practicably be raised may be protected by flood-proofing.

One way to move forward with flood mitigation planning and decision-making would be to follow a phased approach as illustrated in the flow chart below.

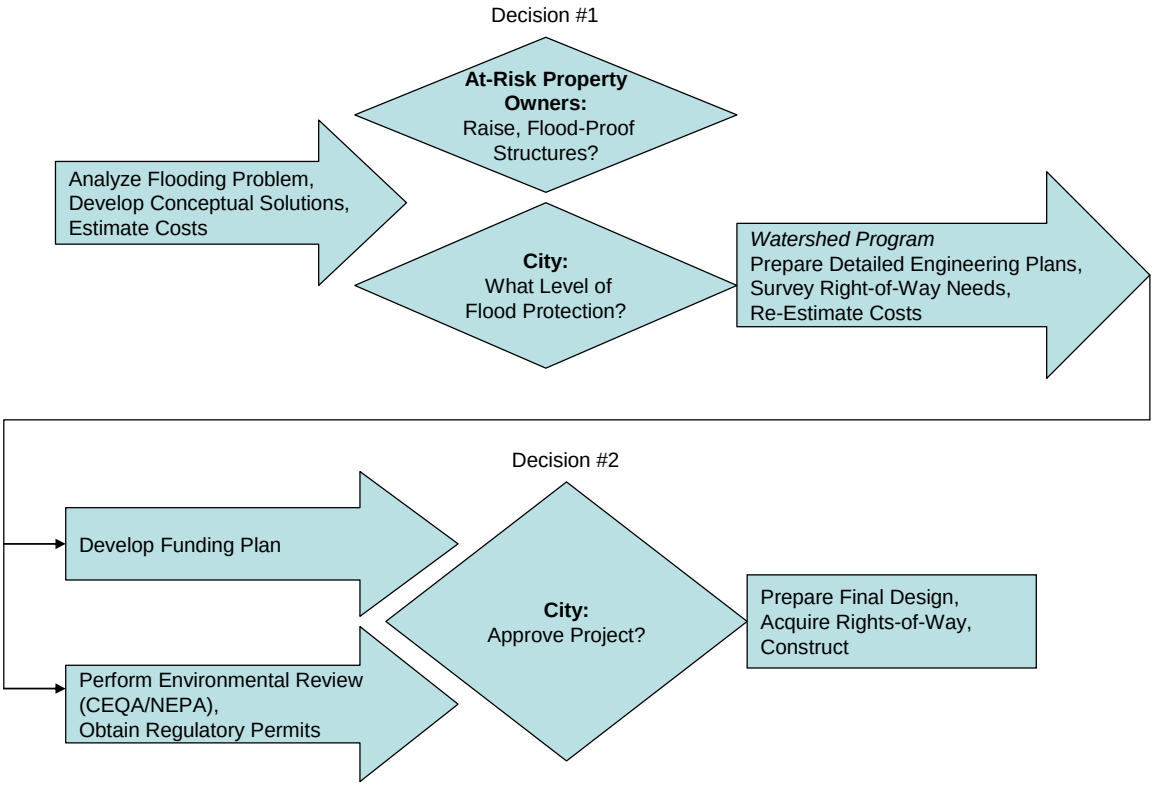


Figure ES1 Arroyo Corte Madera del Presidio Flood Control Project Implementation Plan

With this appraisal-level study, the first phase, characterizing the flood problem, developing conceptual solutions, and estimating costs for various levels of flood protection, has been completed. Individual owners of at-risk properties can use flood elevations developed through this study to help them decide on raising or flood-proofing their structures. Similarly, the City can decide to pursue a particular level of flood protection considering what it can afford in light of the benefits and costs presented in this report.

The next step is to prepare detailed engineering design plans for the measures comprising the City's selected level of flood protection, conduct land surveys to delineate encroachments on private properties and determine right-of way needs, and prepare an updated cost estimate. This effort should be carried out under the Watershed Program because it needs to consider broader issues, such as sea level rise and environmental enhancement. With detailed engineering design completed, planners can, in parallel efforts, better define the funding requirements necessary to finance the project, proceed with environmental review under CEQA and NEPA, and pursue regulatory permits. Upon approval of the project by the CEQA and NEPA lead agencies and receipt of permits, the project can move to the last phase, which includes final design, rights-of-way acquisition, and construction.

1.0 PURPOSE, BACKGROUND, STUDY REACH, AND STUDY LIMITATIONS

This report documents an appraisal-level engineering study[5] performed by Stetson Engineers Inc., San Rafael, of flooding along the lower mainstem of Arroyo Corte Madera del Presidio, Mill Valley, California. Mr. David R. Dawdy, Consulting Hydrologist, assisted in the flood frequency analysis. Mr. Chad Corsten, structural engineer with Wood Rodgers, Sacramento, assisted in developing the preliminary feasibility assessments for replacements of structural crossings. This study was begun in 2006, updated and expanded in 2010, and finalized in 2012.

The focus of the study was the hydrology and hydraulics or flow capacity of the creek and surrounding floodplain. The storm water drainage system that drains streets and other lands and discharges to the creek, referred to as the "interior drainage system," was generally excluded from the study (with the exception of the Sycamore Avenue Pump Station, Ryan Creek Pump Station, and Camino Alto North Outfall).[6] The primary purpose of the study was to identify sources of creek flooding and develop conceptual measures to reduce flood damage by reducing creek overflow or other means, preliminarily assess the feasibility of the measures, prepare conceptual plans, and estimate costs. The study assessed the potential effects of future sea level rise on the effectiveness of the conceptual flood damage reduction measures.

The study addressed other flooding issues and specific flood reduction measures including the following:

- the flow capacity of the creek at the Willow St. Bridge and Valley Circle Pedestrian Bridge;
- using cisterns to reduce flooding;
- the effects of additional development and impervious areas on increased flood flows;
- diverting flood flows to marsh areas;
- increasing the flow capacity of the Sycamore Pump Station; and,
- dredging as a means to enlarge the creek, increase its flow capacity and reduce flooding.

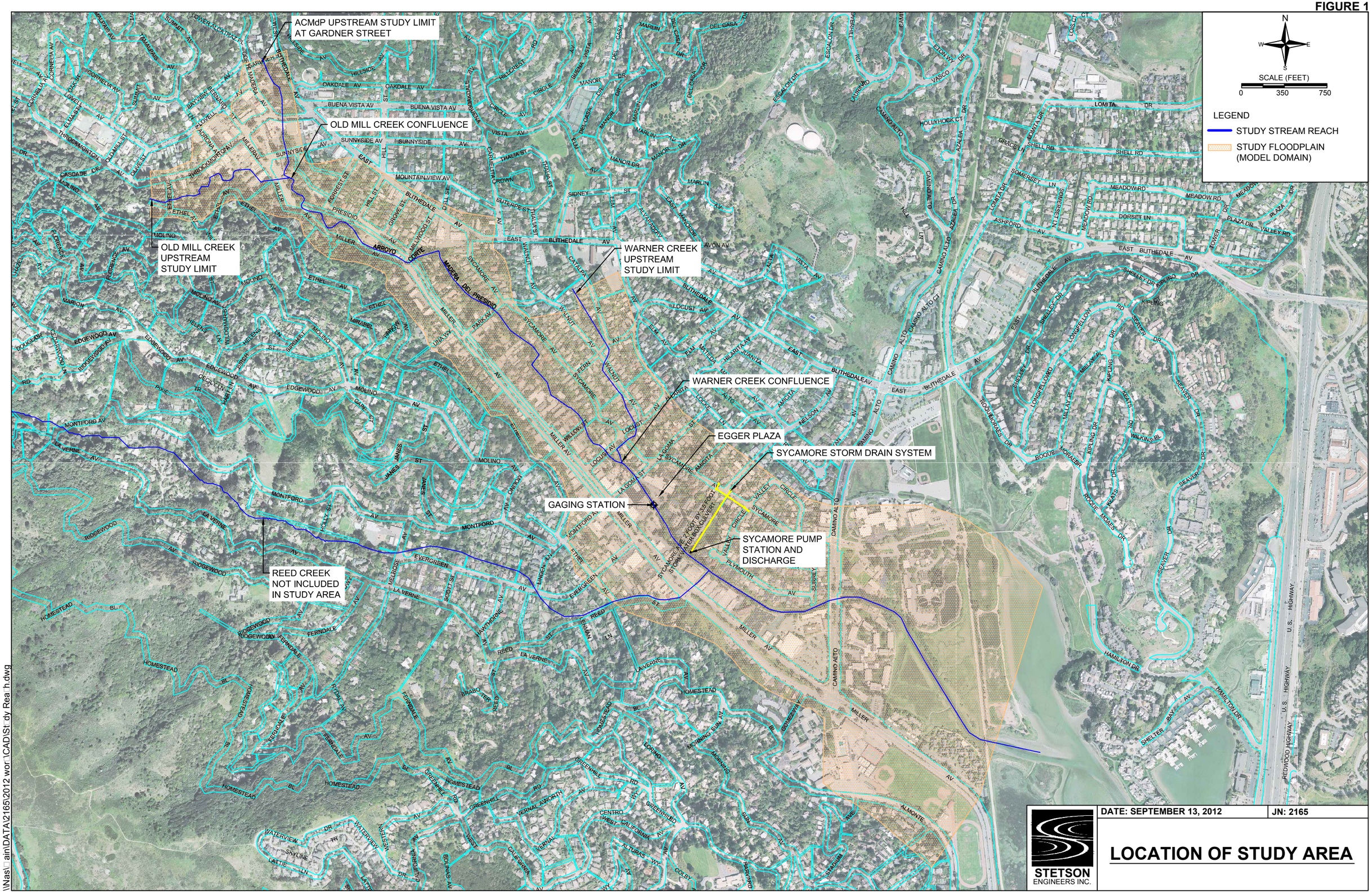
The study area covered the lower reaches of Arroyo Corte Madera del Presidio, Old Mill Creek, Warner Canyon Creek, and their surrounding floodplains (Figure 1). The study was limited to

[5] The U.S. Bureau of Reclamation also uses the term, "appraisal-level" engineering study. At the appraisal-level, the problem is identified, conceptual alternative remedies are developed and their effectiveness evaluated, and recommendations are made for more detailed study of the most viable and promising alternative(s). The U.S. Army Corps of Engineers uses the term, "reconnaissance-level" to refer to this same level of engineering study.

[6] Independent of this study, MCFCWCD studied flooding on Miller Avenue between Camino Alto and Almonte Boulevard (Winzler and Kelly, 2008). The MCFCWCD study area was farther downstream and focused on tidal effects on the interior storm drain system. This report focuses on the hydraulic capacity of the mainstem of Arroyo Corte Madera del Presidio and flooding problems that originate upstream of Camino Alto.

this area because it is most susceptible to flood damage as demonstrated by the December 31, 2005 flood event. The study considered the effect of the tide acting on creek flow where it discharges to the bay, concentrated inflows entering the study area from upper Arroyo Corte Madera del Presidio, upper Old Mill Creek, upper Warner Canyon Creek, Reed Creek, and distributed inflows entering from numerous small unnamed drainages. Flooding along Ryan Creek was analyzed separately because it drains a separate watershed.

FIGURE 1



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LOCATION OF STUDY AREA

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2.0 HISTORICAL FLOODING IN THE STUDY AREA

2.1 Factors Influencing Flooding

Flooding is a natural phenomenon that occurs when the runoff from a watershed generated during an intense storm exceeds the capacity of the stream channel to convey it.[7] In the study area, historical floods have been of short duration, reaching their maximum intensity rapidly, generally within 8 to 12 hours after the beginning of flood-producing storms. Flooding has usually subsided within 24 hours after the end of such storms. Under existing conditions, high tides in San Francisco Bay can back-up the channel as far as the streamflow gage below La Goma Street, reducing hydraulic capacity along this lowermost reach. This effect can exacerbate flooding along the lower estuarine end of the channel below La Goma Street (U.S. Army Corps of Engineers, 1967).

Areas adjacent to the channel that are now subject to flooding were formerly low-lying marshlands which were filled in recent decades for urban and commercial expansion. Buildings and homes have encroached along the channel banks and, in some cases, directly over the channel. Bridges and culverts have been built across the channel, further limiting the capability of the creek to convey large flood flows. Consequently, the problem of flooding has increased with time (U.S. Army Corps of Engineers, 1967). FEMA has characterized the flooding problem as follows:

> Existing drainage is inadequate and the flood problems are accentuated by encroachment of residential developments upon the channels. Channel capacities have been reduced to the extent that flooding occurs in the low areas whenever there is an intense storm over the Arroyo Corte Madera del Presidio basin. In areas where the general ground was lower than the stream channel, development was made possible by using random fill to reclaim the land. This reclamation was accomplished at different times under varying governing criteria. As a result, low pockets of land have developed along the channel. During overbank flow, ponds in these areas make flood damage a function of duration as well as peak. Near the lower portion Arroyo Corte Madera del Presidio (i.e., Sycamore neighborhood), a residential development has been built on bay fill along the north side of the stream channel, immediately upstream from Camino Alto and south of Sycamore Avenue. This fill formed a sump area where it meets the natural valley slopes. Flooding occurs in the sump area nearly every year. Beginning in the vicinity

[7] The type of flooding that is addressed in this report occurs when floodwaters break out of the channel and spill over into adjacent areas due to the lack of flow capacity of the channel. This type of flooding is differentiated from "interior flooding" which is localized flooding that occurs when storm-generated runoff from streets and other lands exceeds the capacity of the interior drainage system to convey the stormwater to the creek.

> of Willow Street and extending downstream, flooding occurs because the channel is above the surrounding ground. Overbank flows do not return to the channel until they reach Camino Alto because of the natural topography. Adding to the problem is the inadequacy of the existing drainage system in this area (Federal Insurance Administration, 1978).

Using hydraulic modeling techniques,[8] locations where the channel lacks the flow capacity to convey floods were identified. These locations are identified in Appendix E and ranked in order how frequent flooding occurs at those locations. For the most part, the locations that are most susceptible to flooding lie between approximately Willow Street and Camino Alto. This area is susceptible to overbank flow about every five years on average. Above Willow Street, a few isolated locations are susceptible to overbank flow but the extent and severity of flood damage is probably minor based on observations from the December 31, 2005 flood event.

2.2 Historical Floods and Flood Frequency

Floods along the study reach occurred with varying degrees of severity in 1907, 1909, 1916, 1938, 1940, 1945, 1952, 1955, 1956, 1962, 1963 (U.S. Army Corps of Engineers, 1967), 1970, 1973, 1982, 1983, and 2005. Of these, the five most severe floods occurred in 1938, 1945, 1955 (U.S. Army Corps of Engineers, 1967), 1982, and 2005. The peak flood discharge of December 31, 2005, the largest of recent history, was estimated to be 1,810 cfs based on the recorded peak stage of 13.79 ft NAVD88 (North American Vertical Datum of 1988) at the Arroyo Corte Madera del Presidio streamflow gage (Figure 2). For comparison, according to the United States Geological Survey (USGS), the January 4, 1982 flood peak stage was recorded at 12.67 ft NAVD88 with an estimated peak flood discharge of 1,170 cfs. The 1982 storm may have resulted in more extensive flooding than the 2005 storm even though the 1982 peak discharge was lower. The extent of flooding is affected by multiple factors, such as rainfall duration and intensity, flood flow volume and peak discharge, tidal effect, and blockage of the channel and culverts by debris. More extensive flooding in 1982 may be explained by that storm's lower rainfall intensity but longer duration and a higher tidal level at the time of peak discharge. Some long-time local residents have reported that the channel and culverts were blocked by debris during the 1982 flood event. These factors could have contributed to more floodwater escaping from the channel and, hence, more extensive flooding.

[8] Refer to Appendix D for details on the development of the hydraulic model and Appendix E for simulations to identify locations of insufficient channel capacity.

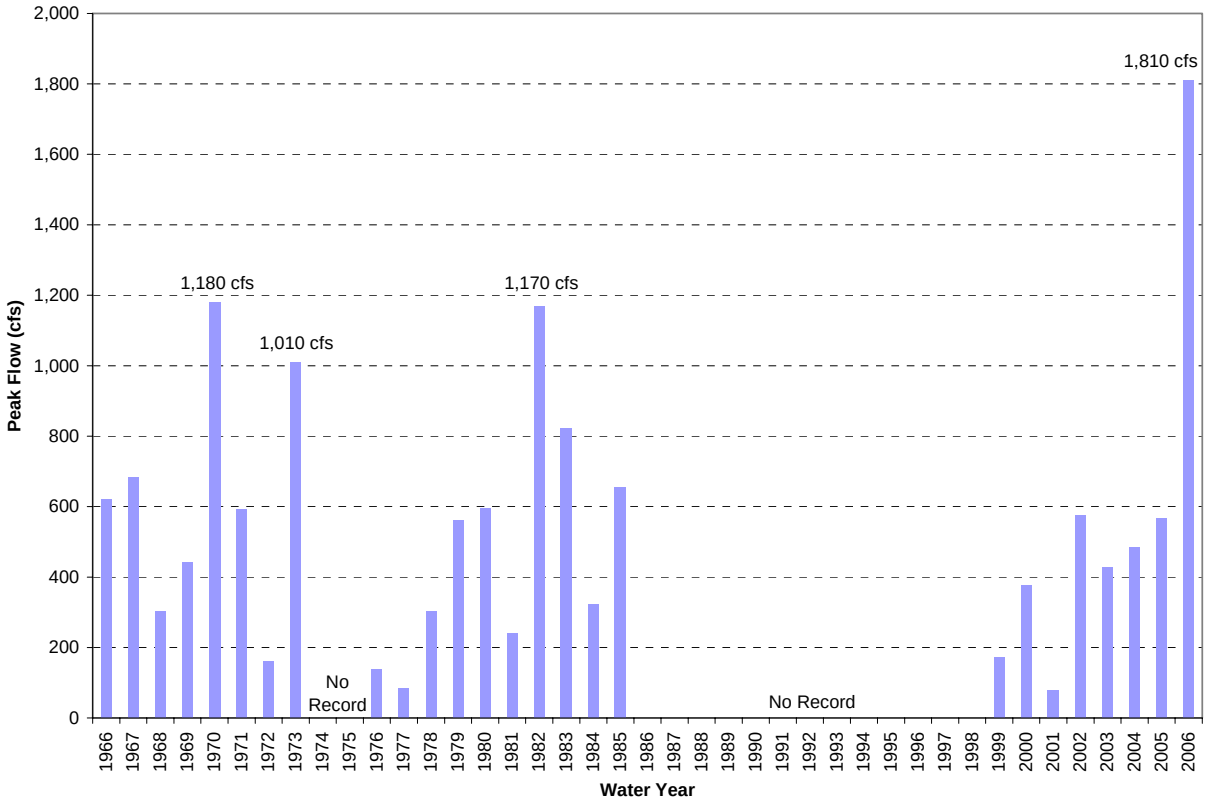


Figure 2 Historical Annual Peak Flows Observed at the ACMdP Gage

Flood frequency analysis[9] was performed using historical streamflow records for the Arroyo Corte Madera del Presidio Gage (Dawdy, 2006[10]). The purpose of the analysis was to develop a relationship between magnitude of a given flood flow and its probability of occurrence in any given year, or its average recurrence interval over the long term. This relationship would provide a means for ascertaining the magnitude of flood flow that the Arroyo Corte Madera del Presidio flood control system would need to be designed to provide a desired level of flood protection.[11]

The first step in the flood frequency analysis was to convert the historical streamflow records, measured and recorded in terms of peak stage, to peak discharges using an updated stage-

[9] Flood frequency analysis is the statistical analysis of historical streamflow records of annual instantaneous peak flow. Flood frequency analysis determines the magnitude of a flood associated with a given probability of occurrence in any given year, or recurrence interval.

[10] Refer to Appendix A for Dawdy 2006.

[11] Typically the level of protection that a flood control system provides is expressed in terms of its recurrence interval, which is the long-term average interval, in years, between floods that equal or exceed the system's capacity. The probability for failure in any given year is the reciprocal of the recurrence interval. So, for example, a flood control system that provides a 100-year level of protection would be flooded, on average over the long-term, less than once every 100 years, and the probability for flooding in any given year would be less than 1 percent.

discharge rating curve[12]. The result of this conversion procedure is the set of historical peak discharges summarized in Table 1.

Table 1. Annual Peak Flows Used in Flood Frequency Analysis

Date	Water Year	Peak discharge (cfs)	Date	Water Year	Peak discharge (cfs)
01/05/1966	1966	620	01/04/1982	1982	1,170
01/20/1967	1967	682	03/13/1983	1983	821
01/29/1968	1968	303	11/19/1983	1984	323
12/28/1968	1969	443	02/08/1985	1985	654
01/21/1970	1970	1,180	02/07/1999	1999	172
12/04/1970	1971	593	01/24/2000	2000	377
02/05/1972	1972	160	02/24/2001	2001	79
01/12/1973	1973	1,010	12/01/2001	2002	574
10/26/1975	1976	139	12/13/2002	2003	428
01/02/1977	1977	83	02/25/2004	2004	484
01/14/1978	1978	301	12/27/2004	2005	565
01/11/1979	1979	561	12/31/2005	2006	1,810
01/11/1980	1980	595			
01/27/1981	1981	240			

1) Source: Dawdy 2006.
2) Water year is a term commonly used in hydrology to describe the 12-month period from October 1st of one year through September 30th of the next year.

The next step in the flood frequency analysis was to develop the relationship between magnitude of flood flow and probability of occurrence in any given year (and, hence, the average recurrence interval) using the peak discharge data in Table 1. The standard method used by FEMA was used to develop this relationship. The result is graphically shown in Figure 3. Table 2 draws from Figure 3 and summarizes the magnitudes of selected flood events.

Table 2. Magnitudes of Selected Flood Events and Probabilities

Recurrence Interval (yr)	Probability	Magnitude of Peak Discharge (cfs)
2	0.5	449
5	0.2	836
10	0.1	1,120
25	0.04	1,500
50	0.02	1,810
100	0.01	2,110

[12] Refer to Appendix A for Dawdy 2006 for the updated stage-discharge rating curve.

The flood frequency analysis indicates that the December 31, 2005 flood, estimated using the updated stage-discharge rating curve to be 1,810 cfs, was approximately a 50-year event (i.e., long-term average recurrence interval, 50-years; probability of occurrence in any given year, 2 percent; also referred to as the 2-percent-annual-chance flood).

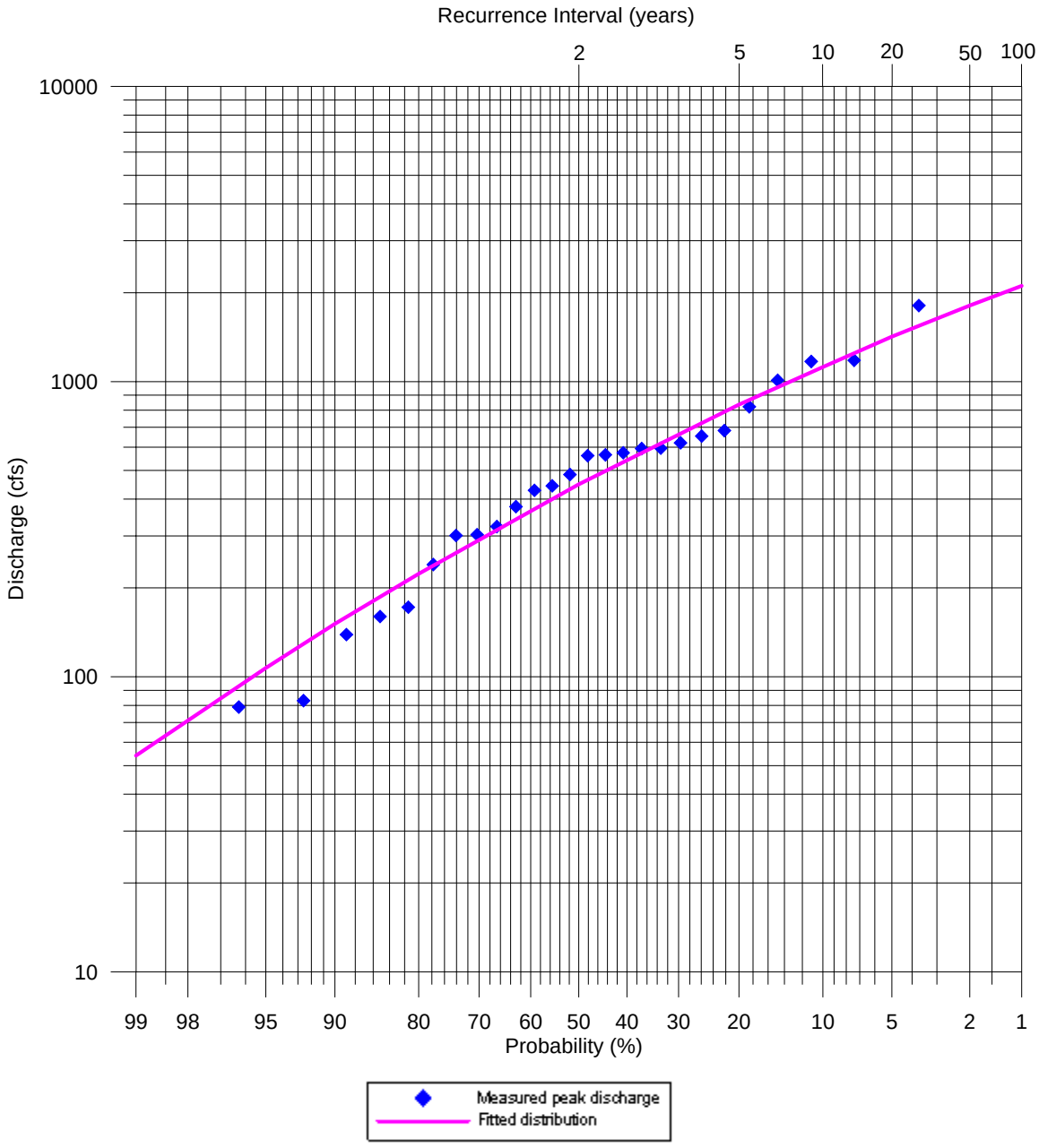


Figure 3 Flood Frequency Curve for the ACMdP Streamflow Gage
(Source: Dawdy 2006)

2.3 Characterization of the December 31, 2005 Flood

2.3.1 Hydrologic Characteristics

This hydrologic characterization of the December 31, 2005 flood event is based on rainfall measurements recorded at the CIMIS (California Irrigation Management Information System) rainfall gage at Point San Pedro, San Rafael[13] and streamflow measurements recorded at the MCDPW Arroyo Corte Madera del Presidio streamflow gaging station. Refer to Figures 4 and 5.

Antecedent Soil Moisture Conditions

Prior to December 30, about 10.1 inches of rain had fallen over the preceding two-week period (December 17 through 30). By December 30, soils were generally saturated, and the baseflow stage at the Arroyo Corte Madera del Presidio Gage was about 8.01 ft NAVD88. Saturated soil conditions increase runoff and the potential for flooding.

Flood Event Measurements

The storm began on December 30 at about 6:00 am. Thereafter rainfall continued steadily over the following 25-hour period, stopping on December 31 at about 7:00 am. The highest intensity rainfall occurred on December 31 over a three-hour period from about 3:00 am to 6:00 am. The stage at the Arroyo Corte Madera del Presidio Gage reached 12.31 feet NAVD88 (assumed flood threshold) at about 3:00 am, peaked at 13.79 feet NAVD88 at about 6:00 am, and receded back down to flood threshold level at about 9:00 am. The channel was breached for about 6 hours, although it probably took several hours for all the water to return to the channel. Following are preliminary summary findings based on the rainfall measurements:

- From December 30 at 0600 to December 31 0600, approximately 6.0 inches of rain fell. This equated to a 15-year, 24-hour rainfall event (per the new NOAA Atlas 14).
- From December 31 at 0300 to 0600, approximately 2.1 inches of rain fell. This equated to a 15-year, 3-hour rainfall event (per the new NOAA Atlas 14)[14].

[13] MCFCWCD also operates rainfall gage at Arroyo Corte Madera del Presidio and at Kentfield, but during maintenance checks on January 19 and 20, 2006 both gages were found to be malfunctioning, so the recorded measurements for the December 31, 2005 storm were deemed unreliable. The nearest official functioning rainfall gage with reliable measurements was the CIMIS gage at Point San Pedro, San Rafael. MCFCWCD's Arroyo Corte Madera del Presidio rainfall gage and the CIMIS gage at Point San Pedro, San Rafael are within about 7 miles of each other and have similar elevations (Point San Pedro station is at elevation 17 ft NGVD29 and the Arroyo Corte Madera del Presidio station is at elevation 33 ft NGVD). The CIMIS gage was used for this data because it was deemed the best alternative source of authoritative rainfall measurements for the December 31, 2005 storm. Examination of the Army Corps-developed mean annual rainfall isohyetal map for the area indicated that the mean annual rainfall amounts at Point San Pedro and Arroyo Corte Madera del Presidio rainfall gages are similar.

[14] In small watersheds, such as Arroyo Corte Madera del Presidio, where the time of concentration is 3-hours or less, short intensities (e.g., the 3-hour intensity) are typically used as indicators of flooding potential.

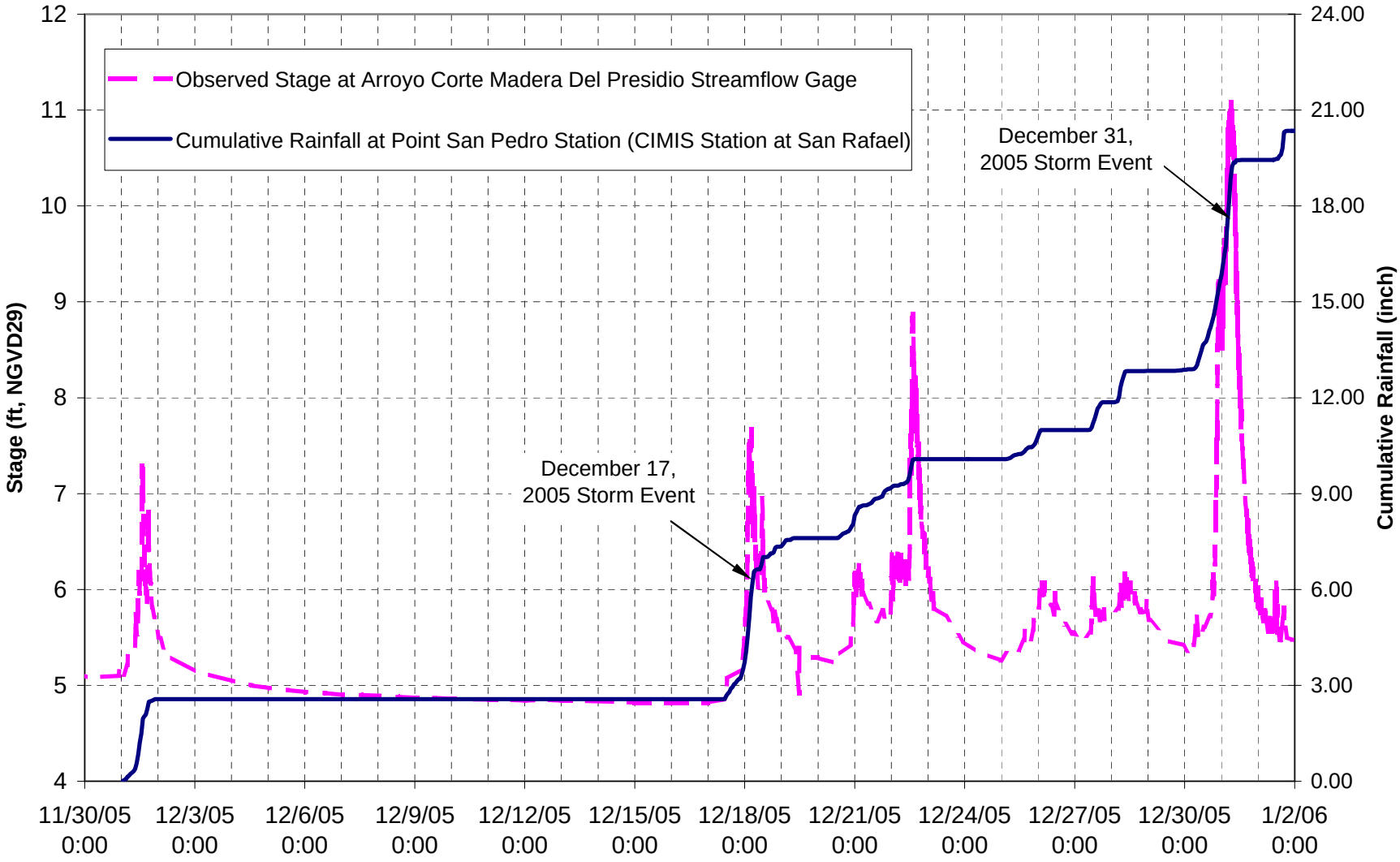


Figure 4 Hydrograph of Arroyo Corte Madera Del Presidio Streamflow Gage Stage and CIMIS Point San Pedro Station Cumulative Rainfall, December 2005

(Rainfall Source: CIMIS Website http://wwwcimis.water.ca.gov/cimis/data.jsp)

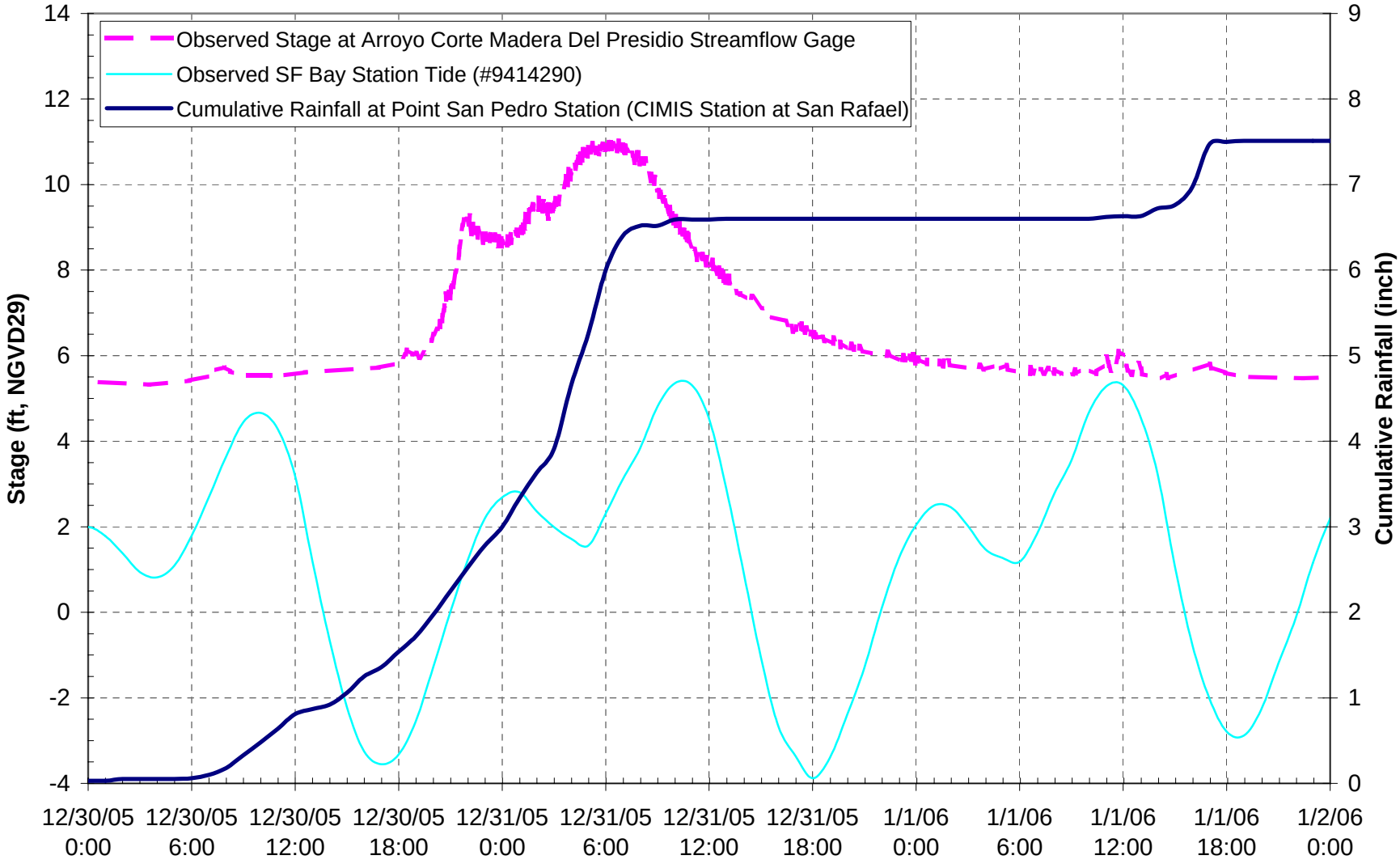


Figure 5 Hydrograph of Arroyo Corte Madera Del Presidio Streamflow Gage Stage, SF Bay Tide, CIMIS Point San Pedro Station Cumulative Rainfall, December 31, 2005 Flood

(Rainfall Source: CIMIS Website http://wwwcimis.water.ca.gov/cimis/data.jsp)

Preliminary Observations and Inferences from the Measurements

A few observations and inferences can be made from the December 31, 2005 flood event measurements that will aid in developing flood damage reduction solutions for Mill Valley. These are as follows:

- The storms on December 17 and the December 31 had similar 3-hour rainfall intensities (1.7 inches and 2.1 inches, respectively), but very different discharges: The peak discharges were 385 cfs and 1,810 cfs, respectively. Further, the December 31 storm, which was a 15-year/24-hour and 15-year/3-hour rainfall event, produced a 50-year flood event. These observations can be explained by the saturated antecedent watershed conditions that preceded the December 31 storm (i.e., saturated soils and little available storage in the system to attenuate intense rainfall as a result of the steady rainfall over the preceding two-week period, December 17 - 30). This demonstrates why it is prudent in flood studies to assume saturated antecedent watershed conditions.
- The observed peak stage at the Arroyo Corte Madera del Presidio streamflow gage occurred as the tide was rising toward the daily higher high. The nearly high tide backed-up the channel and reduced the capacity of the channel for some distance upstream. This demonstrates why it is prudent in flood studies to assume high tide as the downstream boundary condition. In fact, the FEMA's method for flood studies uses the Mean Higher High Water[15] level as the downstream tidal boundary condition.

The December 31, 2005 flood (an approximate 50-year flood event)[16] was simulated using the HEC-HMS model. The simulated hydrograph matched closely, but not exactly, with the hydrograph recorded at the gage. The simulated hydrograph showed a peak discharge of 1,720 cfs, 90 cfs less (about 5 percent less) than the 1,810 cfs peak discharge estimated using the updated stage-discharge curve. The difference between the two hydrographs was deemed acceptable. In the development of conceptual measures for flood damage reduction, the hydrologic model-simulated hydrograph for the December 31, 2005 flood event was used to generate hydrographs for other flood events by increasing it according to the ratios between the peak flows developed in the flood frequency analysis and the simulated peak flow for the December 31, 2005 flood event. For example, a peak flow ratio of 1810/1720 was used to generate hydrograph for the 50-year flood event and a peak flow ratio of 2110/1720 was used to generate hydrograph for the 100-year flood event.

[15] There are two high tides each day in the San Francisco Bay, High Water (HW) and Higher High Water (HHW). The Mean Higher High Water (MHHW) is the average of the higher high water of each tidal day observed over the National Tidal Datum Epoch (Currently NOAA uses the 19-year period of 1983-2001 as the National Tidal Datum Epoch).

[16] Refer to Appendix C for details on the hydrologic modeling and simulation of the December 31, 2005 flood.

On December 31, 2005 at peak discharge, an estimated 1,350 cfs was flowing in-channel and 460 cfs was flowing out-of-channel across the floodplain at the streamflow gage, totaling 1,810 cfs. Most of the out-of-channel flood flow, which ultimately returned to the channel at Camino Alto, was derived from overbank flow along Arroyo Corte Madera del Presidio between Willow Street and Camino Alto[17] and along the end of Warner Canyon Creek. Estimated flows at selected locations along Arroyo Corte Madera del Presidio and major flow paths for the December 31, 2005 flood (an approximate 50-year flood event) and the hypothetical 100-year flood are shown in Figures 6 and 7. The lateral extents of inundation as determined through hydraulic modeling and floodplain mapping are also shown in the figures in Section 3.0.

2.3.2 Flood Damage

The Marin Office of Emergency Services (MCOES) developed an inventory of parcels that reported damage due to the December 31, 2005 storm event (Figure 8)[18]. In a few instances, the listed causes of damage were mudslides, erosion, or falling trees, but by far most of the listed causes were from floodwater or mud 6 to 8 inches deep. The inventory lists 167 damaged parcels. By far most of the listed damaged parcels were between Willow Street and Camino Alto and were concentrated in the Sycamore neighborhood.

[17] A nearby homeowner reported that overbank flooding occurred at Park Street. Unreported localized overbank flow might have occurred at other locations, but most of the damage-causing overbank flood flows probably originated at Willow Street and downstream.

[18] The inventory includes only those parcels that reported flood damage. The inventory does not necessarily include all parcels that were damaged by flooding as some damage may not have been reported.

FIGURE 6

610 cfs

750 cfs

OLD MILL CREEK CONFLUENCE

OLD MILL CREEK

ARROYO CORTE MADERA DEL PRESIDIO

100 cfs (lateral inflow along reach)

310 cfs

700 cfs

110 cfs

WARNER CREEK CONFLUENCE

1350 cfs

350 cfs

310 cfs

SYCAMORE STORM WATER INTAKE (TYP)

SYCAMORE AVE 2 BOXY BY 4.5 FOOT STORM WATER BOX CULVERT

REED CREEK

N

W E

S

SCALE (FEET)

0 250 500

DATE: SEPTEMBER 13, 2012	JN: 2165

12/31/05 FLOOD EVENT (APPROXIMATE 50-YEAR FLOOD) - FLOOD FLOW PATHS AND PEAK DISCHARGES AT SELECTED POINTS ALONG STUDY REACH

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FIGURE 7

N

W E

S

SCALE (FEET)

0 250 500

710 cfs

870 cfs

OLD MILL CREE CONFLUENCE

OLD MILL CREE

ARROYO CORTE MADERA DEL PRESIDIO

120 cfs (lateral inflow along reach)

370 cfs

940 cfs

WARNER CREEK

WARNER CREE CONFLUENCE

170 cfs

1470 cfs

470 cfs

SYCAMORE STORM WATER INTA E (TYP)

SYCAMORE AVE 2 BOXY BY 4.5 FOOT STORM WATER BOX CULVERT

360 cfs

REED CREE

DATE: SEPTEMBER 13, 2012	JN: 2165

100-YEAR FLOOD EVENT - FLOOD FLOW PATHS AND PEA DISCHARGES AT SELECTED POINTS ALONG STUDY REACH

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N

W E

S

SCALE (FEET)

0 250 500

FIGURE 8

12/31/05 FLOOD EVENT - LOCATION OF PARCELS REPORTING DAMAGE

SOURCE: MCOES 2007

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2.3.3 Analysis of the Sycamore Pump Station, Cisterns, and Impervious Areas

MCFCWCD and City of Mill Valley requested that the Sycamore Pump Station, cisterns, and impervious areas be analyzed in connection with the December 31, 2005 flood.

The Sycamore Pump Station is part of the interior drainage system that was designed to handle runoff originating locally in the Sycamore neighborhood[19]. It has the flow capacity to pump up to 3,000 gallons per minute, or about 7 cfs, through pipelines that discharge to Arroyo Corte Madera del Presidio. During the December 31, 2005 flood, in addition to the local runoff, an estimated 90 cfs from Warner Canyon Creek, plus possibly additional overflow from Arroyo Corte Madera del Presidio, spilled over into the Sycamore neighborhood. This flow overwhelmed the pump station's 7 cfs capacity. Moreover, the pump station was probably inundated both at its inlets and discharge, resulting in a pumping action that was merely recirculating floodwaters and rendering the pump station ineffective. Increasing the capacity of the pump station would be prohibitively costly and ineffective at preventing flooding originating from overbank flow, such as occurred on December 31, 2005.

The effect that installing cisterns on individual properties (parcels) would have on large-scale flooding was evaluated[20]. Using hydrologic modeling techniques on a selected sample sub-area of the watershed, it was found that cisterns would reduce the magnitude of the December 31, 2005 flood by about 4%. Because the volume of storage that cisterns would provide is very small in comparison to the volume of floodwater that is generated during a large-scale flood, cisterns would offer relatively little attenuation of runoff. It follows that cisterns would not be effective in reducing large-scale flooding. However, cisterns could offer other benefits related to water supply, enhancement of summertime instream flow and water quality. Therefore, cisterns should be considered further for these purposes.

The effect that expanding impervious surfaces through development would have on large-scale flooding was also evaluated[21]. Using hydrologic modeling techniques on two selected sub-areas of the watershed, one developed and one relatively undeveloped, it was found that the magnitude of the December 31, 2005 flood was relatively insensitive to impervious area. This can be attributed to the saturated antecedent watershed conditions that preceded the storm. During intense storms that generate large-scale floods, the saturated undeveloped watershed produces runoff at a high rate, approaching that of a developed watershed. Therefore, expanding impervious surfaces appears to have little effect on flooding of this magnitude.

[19] Refer to Appendix E for details on the analysis of the Sycamore Pump Station.

[20] Refer to Appendix F for details on the analysis of cisterns.

[21] Refer to Appendix F for details on the analysis of impervious area.

3.0 FLOODPLAIN MAPPING

Using HEC-RAS hydraulic modeling, the extent and depth of flood inundation under existing conditions, referred to as "baseline" conditions, was estimated for a range of recurrence interval/annual-chance-probability floods. The hydraulic model was satisfactorily calibrated to the December 31, 2005 flood using high water marks that were identified in the field and then surveyed for elevation (refer to Appendix D for model calibration results). Floodplain mapping was done by intersecting the model-computed water surface with the floodplain topographic (ground) surface. Floodplain maps for the 5-year, 10-year, 25-year, 50-year, and 100-year recurrence/annual-chance floods for baseline conditions are shown in Figures 9 – 13.

First finished floor elevations of most buildings within the floodplain were surveyed by MCFCWCD.[22] First finished floor elevations were compared to the model-computed water surfaces for the 5-year, 10-year, 25-year, 50-year, and 100-year recurrence/probability floods under baseline conditions. Buildings with first finished floor elevations lower than the model-computed water surface would be inundated. Inundated buildings are highlighted and the depths of inundation above the first finished floor are also shown in the floodplain maps. Plate 1 shows all the information in Figure 13, plus it shows surveyed first finished floor elevations of all buildings surveyed overlain on the 100-year floodplain map.

[22] In the study area, there are 1,179 buildings. Of which 1,102 buildings were surveyed for first finished floor elevations.

Limit of Study Area

5-YEAR FLOOD EVENT INUNDATION and AT-RISK BUILDINGS

- Inundation: 0 - 0.99 feet
- Inundation: 1 - 1.99 feet
- Inundation: 2 - 2.99 feet
- Inundation: 3 - 3.99 feet
- Inundation: 4 - 4.99 feet
- Inundation: 5 - 5.99 feet

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0 500 1,000 Feet

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FIGURE 9

Limit of Study Area

10-YEAR FLOOD EVENT INUNDATION and AT-RISK BUILDINGS

- Inundation: 0 - 0.99 feet
- Inundation: 1 - 1.99 feet
- Inundation: 2 - 2.99 feet
- Inundation: 3 - 3.99 feet
- Inundation: 4 - 4.99 feet
- Inundation: 5 - 5.99 feet

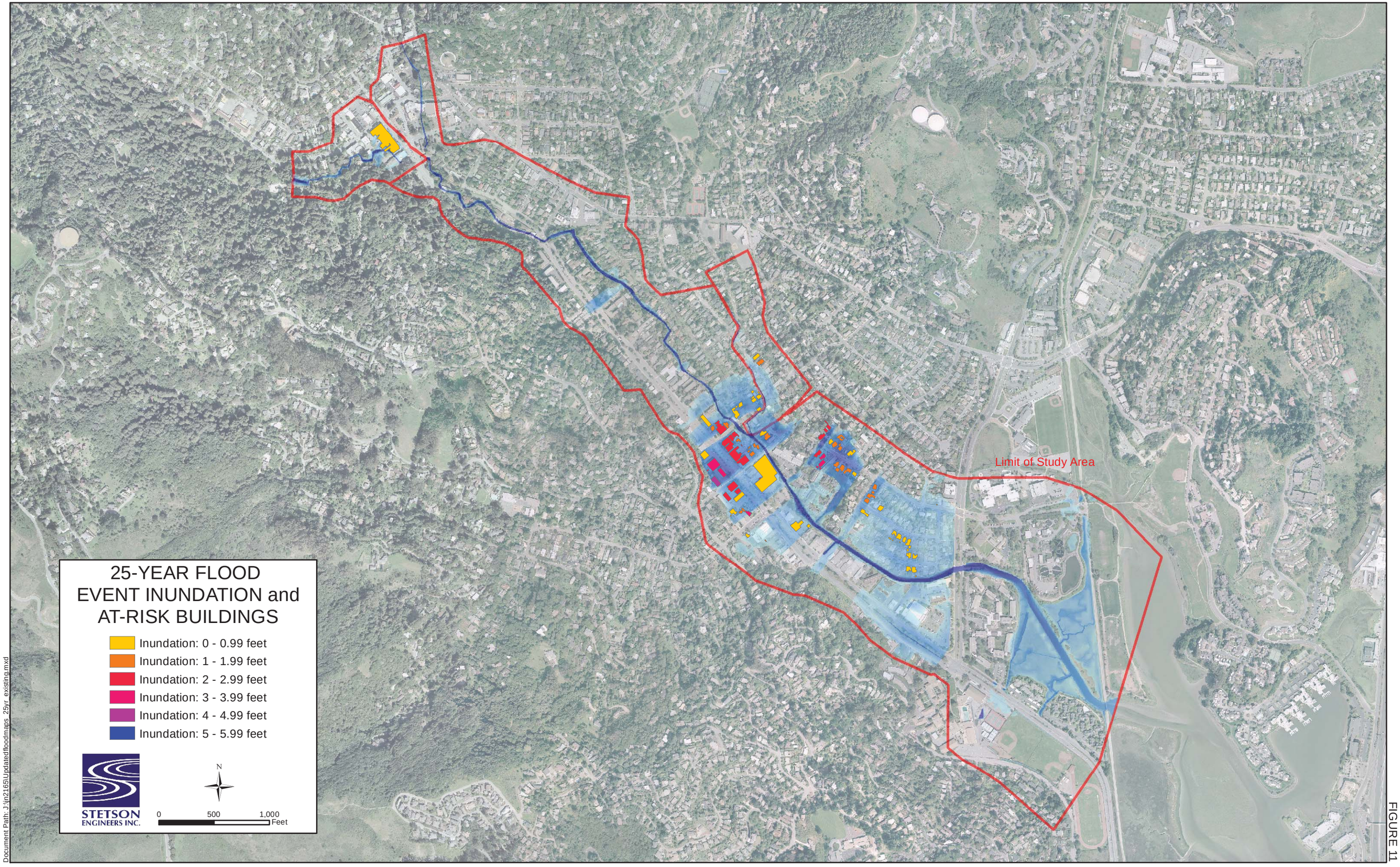
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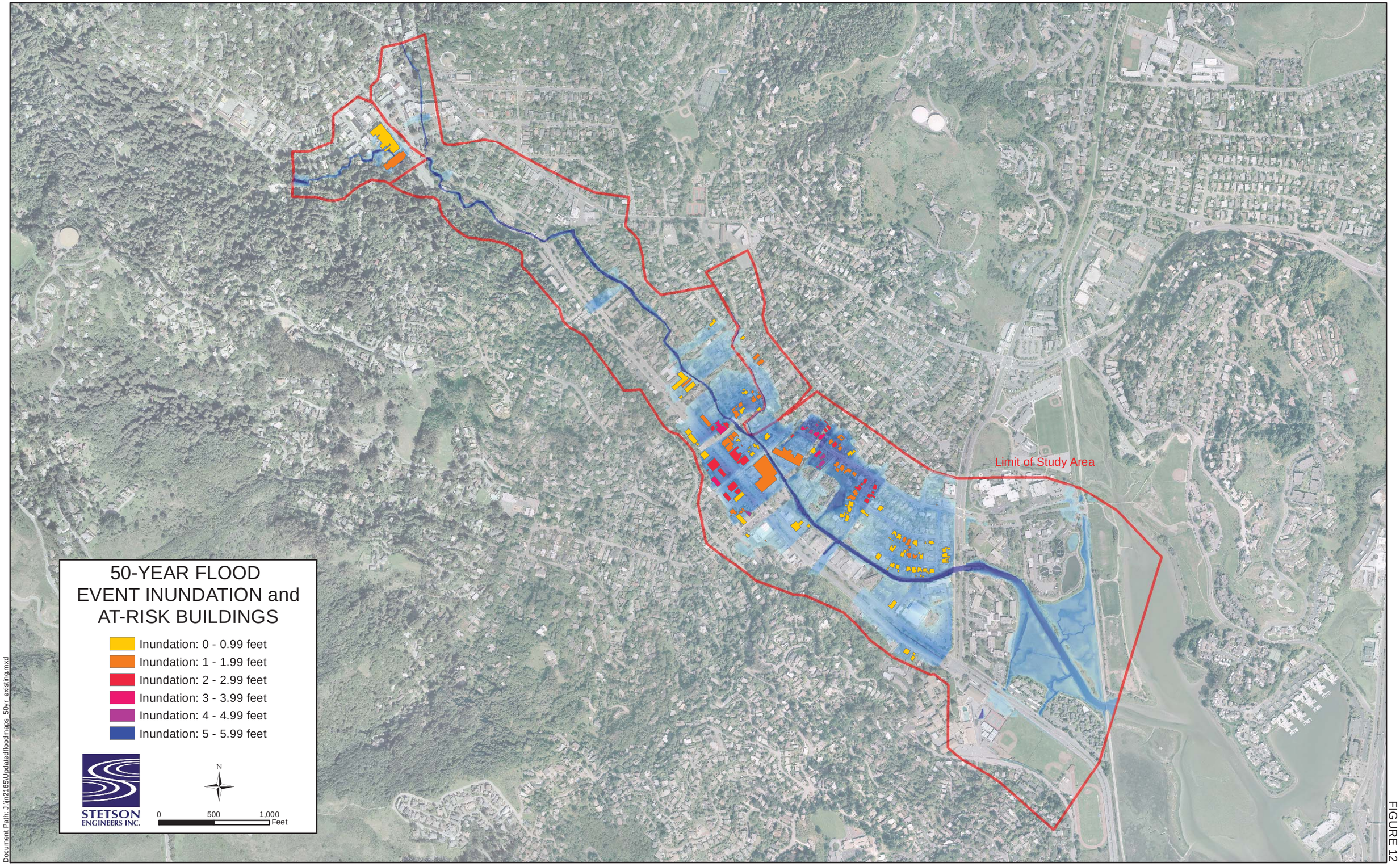
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FIGURE 10



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FIGURE 11



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FIGURE 12

Limit of Study Area

100-YEAR FLOOD EVENT INUNDATION and AT-RISK BUILDINGS

- Inundation: 0 - 0.99 feet
- Inundation: 1 - 1.99 feet
- Inundation: 2 - 2.99 feet
- Inundation: 3 - 3.99 feet
- Inundation: 4 - 4.99 feet
- Inundation: 5 - 5.99 feet

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N

0 500 1,000 Feet

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FIGURE 13

4.0 FLOOD DAMAGE REDUCTION BY RAISING AT-RISK RESIDENTIAL BUILDINGS

Substantial flood damage reduction could be achieved by raising at-risk residential buildings. Residential buildings with a first finished floor elevation lower than the flood water surface elevation should be raised at least two feet above the flood elevation. At-risk buildings (including residential and non-residential buildings) are highlighted in Figures 9 - 13 and summarized in Table 3. The cost of raising at-risk residential buildings was estimated using an estimated unit cost of $22 per square foot (Refer to page 9 of Appendix H for the basis of this estimated unit cost). Commercial and other types of non-residential buildings are typically not suitable for raising because of the construction methods and materials used[23]; therefore, cost estimates were not prepared for these types of structures. Flood proofing at-risk non-residential buildings and critical infrastructure in the floodplain may be feasible, but it was not evaluated in this study. The number of at-risk non-residential building is given in Table 3.

Table 3. Summary of Raising At-Risk Residential Buildings

Level of Flood Protection	Number of At-Risk Non-Residential Buildings	Number of At-Risk Residential Buildings	Estimated Capital Cost of Raising At-Risk Residential Buildings ($)
5-Year Flood	7	1	42,000
10-Year Flood	16	14	492,000
25-Year Flood	27	60	1,760,000
50-Year Flood	40	103	3,086,000
100-Year Flood	59	150	4,289,000

Note: The cost of raising at-risk residential buildings varies from building to building. Costs above were based on an estimated average unit cost of $22 per square foot (Refer to page 9 of Appendix H for the basis of this estimated unit cost).

[23] Commercial buildings constructed of concrete block, concrete tilt up, brick wall or stone wall are not suitable for raising. It is not feasible to raise buildings that are not constructed with light weight and strong material such as wood and steel.

5.0 FLOOD DAMAGE REDUCTION BY IMPROVING CREEK FLOOD CONTROL INFRASTRUCTURE

Another approach to reduce flood damage due to overtopping of the creek is improving creek flood control infrastructure. Compared to raising or flood proofing at-risk buildings, this approach offers a broader array of public benefits, including reduction in damage to other non-building assets and enhanced public safety.

Using hydrologic and hydraulic modeling, conceptual flood control measures targeting reaches of insufficient capacity were developed. These measures fall under the following general categories:

- Hydraulic capacity improvements[24] – These measures increase the channel's flow capacity by replacing or enlarging structural crossings or by modifying the channel through widening, dredging, or floodwalls or landscape berms along the tops of banks.
- Bypass channels – These measures divert and route floodwater around reaches that lack sufficient flow capacity.
- Detention basins[25] – These measures reduce the magnitude of flood flow by temporarily detaining flood water in large ponds, referred to as detention basins, then slowly releasing the water back to the creek after the storm subsides and flooding recedes.

Individual conceptual measures were designed and evaluated preliminarily for feasibility. Refer to Appendix G for details on the conceptual designs and preliminary feasibility evaluations. Based on the evaluation, those measures deemed potentially feasible were grouped in bundles to achieve a desired level of flood protection. These bundled measures are described below in order of the increasing level of flood protection provided. A preliminary assessment of utility conflicts was performed as part of this study based on available information on utility locations. Identified utility conflicts were considered in the conceptual designs and construction cost estimates.

5.1 5-Year Flood Protection

The magnitude of the 5-year flood, or the 20-percent-annual-chance flood, is approximately 800 cfs at the gage[26]. The 5-year flood level protection measures focus on preventing overbank flow

[24] Refer to Appendix E for details on hydraulic modeling simulations to develop hydraulic capacity enhancement and bypass channel measures.

[25] Refer to Appendix F for details on hydrologic modeling simulations to develop detention basin measures.

[26] According to anecdotal reports, the 1983 flood had a peak discharge of about 821 cfs (an approximate 5-year flood) and caused some damage. This verifies the need of 5-year flood protection.

at Willow Street, upstream from La Goma Street, and from the Egger Plaza Bridge downstream to Camino Alto. These measures are listed in Table 4 and shown in Figure 14. The numbering of measures includes two numbers; the first number represents the flood protection level and the second represents the measure number.

Table 4. Summary of 5-Year Flood Protection Measures

Measure	I.D. number in Figure 14
Willow Street Pedestrian Bridges replacements (2) and channel widening over about a 150 ft reach near the bridges	[5-04]; [5-05]; [5-06]
Removal of concrete weir at the streamflow gage; channel dredging over the 150 ft reach upstream of the gage	[5-03]
Low floodwalls/berms	[5-01]; [5-02]

At Willow Street, the two pedestrian bridges need to be raised by about 3.4 feet or removed to prevent blockage of flow.[27] In this same area, development has narrowed the channel, limiting its capacity to convey floodwaters. The channel needs to be widened by about 20 feet over about a 150-foot reach extending from about 60 feet above the public pedestrian bridge to 70 feet below the private pedestrian bridge. These measures should be implemented in concert and are considered potentially feasible, provided approvals are obtained, where required, for work on private property.

The concrete weir at the streamflow gage needs to be removed and the channel upstream of the streamflow gage needs to be dredged by a maximum of about 1.5 feet over a distance of about 150 feet to increase its hydraulic capacity. The dredged reach could refill with sediment during a moderate flood. The long-term sustainability of dredging and the need for repeat dredging requires further study. A more detailed description of this measure is provided in section 5.4.2.

Starting at about the Valley Circle Pedestrian Bridge and extending downstream to Camino Alto low floodwalls or floodberms, 2 feet high or less, are needed along the tops of both banks to prevent overbank flow. Additional low floodwalls/berms are needed along a short reach of the right bank starting about 100 feet below the Egger Plaza Bridge. These measures are considered potentially feasible provided approval is obtained, where required, for work on private property.

[27] For all bridge/structure designs except the La Goma and Egger Plaza bridges, 2 ft of freeboard was considered to account for the hydraulic effects of debris and allow for passage of aquatic wildlife. A 0.5 ft of freeboard was considered for La Goma and Egger Plaza bridges due to site-specific problems with raising these bridges any higher.

FIGURE 14



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5-YEAR FLOOD PROTECTION MEASURES

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5.2 10-Year Flood Protection

The magnitude of the 10-year flood is approximately 1,100 cfs at the gage. Protection against the 10-year flood requires all of the 5-year protection measures (Section 5.1) plus additional measures. The additional measures focus on preventing further overbank flow at and above Willow Street, at and above La Goma Street, above the Egger Plaza Bridge, and above Park Street. These measures are listed in Table 5 and shown in Figure 15.

Table 5. Summary of 10-Year Flood Protection Measures

Measure	I.D. number in Figure 15
5-Year Flood Protection Measures (from Table 4)	[5-01]; [5-02]; [5-03]; [5-04]; [5-05]; [5-06]
La Goma Street Bridge replacement	[10-03]
Additional low floodwalls/berms	[10-01]; [10-02]; [10-04]; [10-06]
Raise Sycamore Ave grade	[10-05]
Park Street Bridge replacement	[10-07]

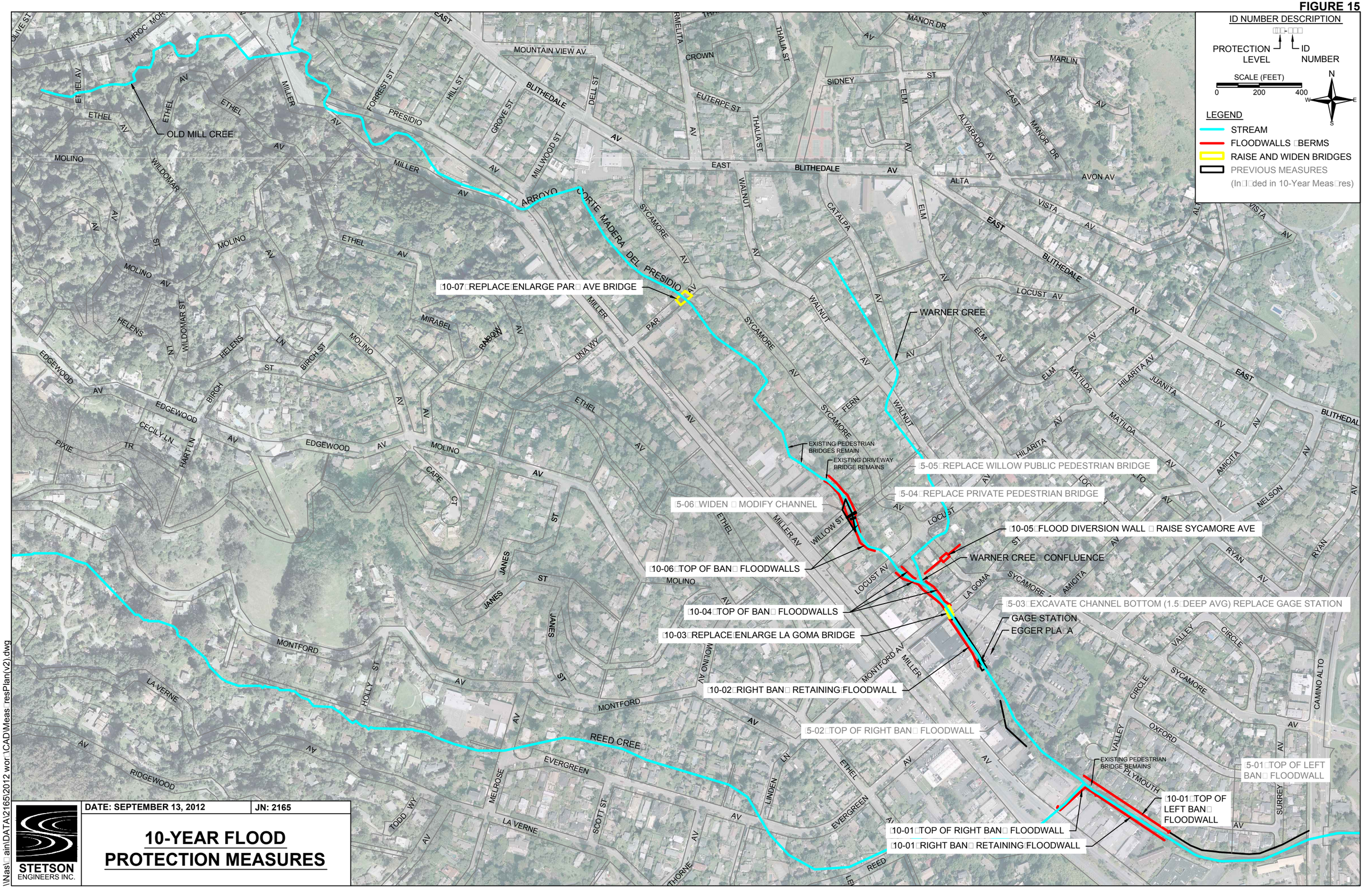
Starting at about 300 feet above Willow Street extending to Willow Street low floodwalls/berms, 2 feet high or less, are needed along the tops of both banks to prevent overbank flow. This is considered potentially feasible provided approvals are obtained for work on private property.

The La Goma Street Bridge needs to be raised by about 1.5 feet to prevent blockage of flow. Upstream of La Goma Street, low floodwalls or floodberms, 2 feet high or less, are needed along the tops of both banks from Locust Street extending to La Goma Street; along the top of the left bank and partially along the top of the right bank from La Goma to the Egger Plaza Bridge; and along the top of the left bank from below the Egger Plaza Bridge to the Valley Circle Pedestrian Bridge. These measures are considered potentially feasible provided approvals from private property owners for floodwalls/berms are obtained where required.

Raising a short reach of the Sycamore Avenue grade would be needed to create a containment barrier that would prevent floodwaters that overtop lower Warner Canyon Creek from escaping farther down Sycamore Avenue. The containment barrier would direct floodwaters back to the creek. The containment barrier would consist of a 2-foot high raised grade across Sycamore Avenue with floodwalls extending from both ends of the raise. These floodwalls are located on private property and are considered potentially feasible provided required approvals from property owners are obtained. The level of the floodwater surface within the containment barrier would not rise above the first finished floors of the interior residential buildings.

The Park Street culvert would need to be replaced with a bridge structure that provides higher clearance. This could be accomplished without raising the grade of the street at the bridge. This is considered potentially feasible.

FIGURE 15



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10-YEAR FLOOD PROTECTION MEASURES

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5.3 Greater Than 10-Year Flood Protection

Flows greater than the 10-year flood, about 1,100 cfs at the gage, exceed the capacity of the channel at several locations due to capacity limitations at structural crossings. The capacity of Warner Canyon Creek, about 200 cfs along the constricted segment near the confluence with Arroyo Corte Madera del Presidio, is also exceeded at the 10-year event. Rectifying some of these capacity limitations, such as the La Goma Street Bridge and Locust Street Bridge and adjacent structures, is probably not feasible because, in addition to being prohibitively costly, it would involve raising structural crossings and street grade approaches which would block adjacent driveway inlets and make pedestrian and vehicular approaches impracticably steep. Consequently, protection against the floods greater than the 10-year event requires all of the 5-year and 10-year protection measures (Section 5.1, and Section 5.2 without raising the La Goma Street Bridge) plus additional measures involving flood detention and/or bypass.

Flood detention reduces flooding by reducing the magnitude of the peak of the flood. The flood detention measure analyzed in this report consists of a large detention basin formed by constructing an earthen dam across Warner Canyon Creek at the Mill Valley Golf Course[28]. The dam would have a low-level outlet for passing flows and sediment and enabling passage of fish and other aquatic organisms. The dam would also have a spillway to safely pass floodwaters in the event that the basin is filled during an extremely large flood, greater than the 100-year event. Depending on the target level of flood protection, the height of the dam would be up to 40 feet high and the storage capacity of up to 227 acre-feet for 50-year and 100-year flood protection. During large floods, the stored water would temporarily inundate much of the 100-acre golf course but would be drained following storms. The detention basin would not affect the use of the golf course except during and immediately following large floods. Some private lands (but not structures) along the perimeter of the detention basin may be inundated which would require that flood easements be obtained. During severe storms, rainfall forecasts and streamflow stage would need to be closely monitored. Operators would use the monitoring information to determine when to close the detention basin floodgate. Floodwaters would be temporarily detained in the detention basin and then released back to the creek after the high flows recede.

Bypass reduces flooding by diverting and conveying floodwaters around the severely constricted and obstructed reach through a culvert. The bypass measure consists of a diversion structure along Arroyo Corte Madera del Presidio at Willow Street and a bypass culvert to route the diverted flood flows (i.e., flows that exceed the channel capacity and would otherwise spill over

[28] Refer to Appendices F and G for details on the Mill Valley Golf Course detention basin as well as other detention basins considered.

bank) around the reach from Willow Street to La Goma Street and return those flows back to the creek below Egger Plaza where the creek capacity is adequate.[29, 30]

5.3.1 25-Year Flood Protection

The magnitude of the 25-year flood is approximately 1,500 cfs at the gage, of which about 300 cfs is contributed from Warner Canyon Creek. Protection against the 25-year flood requires all of the 5-year and 10-year protection measures (Section 5.1, and Section 5.2 without raising the La Goma Street Bridge) plus additional measures. The additional measures focus on preventing overbank flow along the end of Warner Canyon Creek and further overbank flow from above Willow Street to the Egger Plaza Bridge. These measures are listed in Table 6 and shown in Figure 16.

Table 6. Summary of 25-year Flood Protection Measures

Measure	I.D. number in Figure 16
5-Year Flood Protection Measures (from Table 4)	[5-01]; [5-02]; [5-03]; [5-04]; [5-05]; [5-06]
10-Year Flood Protection Measures w/o La Goma Street Bridge replacement (from Table 5)	[10-01]; [10-02]; [10-04]; [10-05]; [10-06]; [10-07]
Additional low floodwalls/berms	[25-01]; [25-02]; [25-03]; [25-05]
Arroyo Corte Madera del Presidio partial bypass	[25-04]

Partial bypass is considered to be the most feasible and appropriate measure to prevent further overbank flow from above Willow Street to the Egger Plaza Bridge. Constructing the partial bypass has the following benefits:

- Avoids hydraulic conveyance increase measures between Willow Street and Egger Plaza that would otherwise be needed, including
  - Replacement of the existing La Goma Bridge
  - Replacement of the Locust Avenue Bridge and the private office driveway bridge just upstream
  - Replacement of the private driveway bridge upstream of Willow Street pedestrian bridge and channel widening
  - Raising of the private building upstream of Locust Avenue Bridge
- Reduces the heights of floodwalls upstream of Willow Street and between Willow Street and Egger Plaza. Without the partial bypass but with the avoided hydraulic conveyance increase measures described above, floodwall heights would need to be

[29] Because the diverted flows are returned back to the channel this measures is referred to as "partial bypass", as opposed to "total bypass" where the diverted flows are conveyed all the way to the bay.

[30] Refer to Appendix G for details on the partial bypass.

up to 5 ft, 6 ft, and 7 ft in order to contain the 25-year, 50-year, and 100-year floods, respectively.

Partial bypass consists of a diversion structure and culvert. The diversion structure would be constructed along the creek at Willow Street, or at an alternative location just above Willow Street. The diversion structure would consist of a lateral weir, also referred to as a "side weir," placed along the right bank of the creek[31]. The length of lateral spillway would be 72 feet and 79 feet for the 50-year and 100-year design events, respectively. The lateral weir crest would be sufficiently low to "crop off" the upper portion of flow that would otherwise overtop the creek banks downstream. A concrete manifold inlet structure would collect flow over the lateral weir and direct the water to the diversion culvert. The diversion culvert would be a rectangular, reinforced concrete box culvert that would convey the diverted water down Willow Street and Miller Avenue and return the water back to the creek below Egger Plaza. The diversion culvert would be buried within the Willow Street right-of-way and within the median right-of-way along Miller Avenue. Hydraulic modeling analysis shows that the concrete culvert would need to be 18.5 wide by 4.5 feet deep and 26 feet wide by 4.5 feet deep for the 50-year and 100-year design events, respectively, assuming a ground cover thickness of 3 ft. Further detailed engineering and design work would be needed to verify that the culvert could be accommodated within the Miller Avenue median and would be compatible with overall Miller Avenue streetscape plan. Since sediment carried with large flood flows could "drop out," settle, and aggrade the channel along the diverted reach when large flows are diverted to the bypass channel, further engineering analysis would also be needed to determine whether substantial and frequent channel dredging would be required.

Preliminary Feasibility Assessment of the Arroyo Corte Madera del Presidio Partial Bypass

This measure would likely require removing/reinstalling or relocating utilities, particularly sewer lines, which would be encountered at several locations along the route of the approximately 1,500-foot long diversion bypass channel. The need and feasibility of removing/reinstalling or relocating these utilities would require substantial research and further engineering analysis. It is anticipated that this further analysis will be performed as part of the Miller Avenue streetscape project, as this project would also require removing/reinstalling or relocating utilities. Further, the lateral weir that would be required would likely encroach onto adjacent private property. The diversion bypass channel return to Arroyo Corte Madera del Presidio would pass over private commercial property. This measure is considered potentially feasible provided research and further engineering analysis finds that utilities can be removed/reinstalled or relocated, substantial and frequent channel dredging would not be required, and provided private property owner approval is obtained where required.

[31] A lateral weir, or side weir, is a type of diversion structures that allows water to flow over a weir placed along one side of a channel into an inlet that collects and routes the overflow to a diversion culvert.

FIGURE 16

25-05 BAN RETAINING FLOODWALLS UPSTREAM BRIDGE WALL

10-07 REPLACE ENLARGE PARAVE BRIDGE

OLD MILL CREE

WARNER CREE

REED CREE

EXISTING PEDESTRIAN BRIDGES REMAIN

EXISTING DRIVEWAY BRIDGE REMAINS

5-06 WIDEN MODIFY CHANNEL

5-05 REPLACE WILLOW PUBLIC PEDESTRIAN BRIDGE

5-04 REPLACE PRIVATE PEDESTRIAN BRIDGE

10-06 TOP OF BAN FLOODWALLS

25-04 ACMDP CREE PARTIAL BYPASS

10-04 TOP OF BAN FLOODWALLS

10-05 FLOOD DIVERSION WALL RAISE SYCAMORE AVE

WARNER CREE CONFLUENCE

5-03 EXCAVATE CHANNEL BOTTOM (1.5 DEEP AVG) REPLACE GAGE STATION

GAGE STATION

EGGER PLA A

25-03 TOP OF LEFT BAN FLOODWALL

10-02 RIGHT BAN RETAINING FLOODWALL

10-02 TOP OF RIGHT BAN FLOODWALL

25-02 TOP OF LEFT BAN FLOODWALL

5-02 TOP OF RIGHT BAN FLOODWALL

EXISTING PEDESTRIAN BRIDGE REMAIN

5-01 TOP OF LEFT BAN FLOODWALL

10-01 TOP OF LEFT BAN FLOODWALL

10-01 TOP OF RIGHT BAN FLOODWALL

10-01 RIGHT BAN RETAINING FLOODWALL

10-01 RIGHT BAN RETAINING FLOODWALL

25-01 TOP OF RIGHT BAN FLOODWALL

ID NUMBER DESCRIPTION

PROTECTION LEVEL — ID NUMBER

SCALE (FEET)

0 200 400

N W E S

LEGEND

- STREAM
- FLOODWALLS BERMS
- RAISE AND WIDEN BRIDGE
- CHANNEL MODIFICATION
- PREVIOUS MEASURES (In ded in 25-Year Meas res)

NOTE: LA GOMA BRIDGE REPLACEMENT ENLARGEMENT NOT NEEDED DUE TO PARTIAL BYPASS.

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DATE: SEPTEMBER 13, 2012 | JN: 2165

25-YEAR FLOOD PROTECTION MEASURES

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5.3.2 50-year and 100-Year Flood Protection

The magnitudes of the 50-year and 100-year floods are approximately 1,800 cfs and 2,100 cfs at the gage, of which about 310 cfs and 370 cfs are contributed from Warner Canyon Creek, respectively. Protection against the 50-year and 100-year floods requires all of the 5-year and 10-year protection measures (Section 5.1, and Section 5.2 without raising the La Goma Street Bridge) and the partial bypass, plus additional measures. The additional measures, which focus on preventing overbank flow near Sunnyside Avenue, along the end of Warner Canyon Creek and further overbank flow above Willow Street to the Egger Plaza Bridge, include the Mill Valley Golf Course detention basin and enlargement of a private culvert and a private bridge. These measures are listed in Table 7 and shown in Figure 17.

Table 7. Summary of 50-Year and 100-Year Flood Protection Measures

Component	I.D. number in Figure 17
5-Year Flood Protection Measures (from Table 4)	[5-01]; [5-02]; [5-03]; [5-04]; [5-05]; [5-06]
10-Year Flood Protection Measures w/o La Goma Street Bridge replacement (from Table 5)	[10-01]; [10-02]; [10-04]; [10-05]; [10-06]; [10-07]
25-Year Flood Protection Measures (from Table 6)	[25-01]; [25-02]; [25-03]; [25-04]; [25-05]
Culvert enlargement beneath private building downstream of Sunnyside Avenue	[50-02]
Egger Plaza Bridge replacement	[50-01]
Mill Valley Golf Course detention basin	[50-04]
Additional low floodwalls/berms	[50-03]; [50-05]; [100-01]

In the area just downstream of Sunnyside Avenue, the creek passes through a circular, concrete culvert that passes beneath a private commercial building. The culvert obstructs flows exceeding approximately the 38-year flood and needs to be enlarged. This measure is potentially feasible but is entirely on private property and, therefore, would require approval by the property owner.

The Egger Plaza Bridge obstructs flows starting at about the 43-year flood. This bridge needs to be raised by about 2.6 ft to prevent blockage of flow. This measure is potentially feasible but is entirely on private property and, therefore, would require approval by the property owner.

The Mill Valley Golf Course detention basin would reduce peak flows in Warner Canyon Creek, thereby eliminating overflow that would otherwise spill over into the Sycamore neighborhood. The detention basin would also reduce flooding farther downstream along lower Arroyo Corte Madera del Presidio.

Feasibility Assessment of the Mill Valley Golf Course Detention Basin[32]

Based on a preliminary review it appears feasible to construct a dam across Warner Canyon Creek and using Mill Valley Golf Course as a detention basin. However, several major technical issues described below would need to be addressed through further engineering study to confirm feasibility.

- Geotechnical integrity of the dam site to provide stability for the dam and abutments;
- Availability of structurally suitable fill material for the earthen dam in sufficient quantities from a nearby source;
- Design of an adequate gated, high capacity, low level outlet and conduit to pass small flood flows, enhance operation for detention, and enable passage by fish and other aquatic biota;
- Geotechnical stability of creek banks and other slopes within the inundated area and the need to implement stabilization measures;
- Potential impacts of the dam on the play of the golf course;
- Potential impacts of the dam on sensitive biological resources and other environmental considerations;
- Willingness of adjacent property owners along the perimeter of inundation to grant flood easements, where needed;
- Potential impacts of construction and operation of detention facilities on adjacent private and public properties and structures/facilities.
- Public safety procedures during detention operations;
- Potential inundation of Glen Drive during detention operations; and
- Dam failure analysis.

The dam would need to be designed and constructed in accordance with safety standards adopted by the State Department of Water Resources, Division of Safety of Dams. Environmental regulatory permits would be required and the permitting process could be lengthy and complicated, especially if sensitive species are determined to be present or potentially affected.

Factors supporting a detention basin at Mill Valley Golf Course include the following:

- The site is publicly owned.
- Most of the inundated area is golf course fairways and green, which would not be expected to be extensively damaged through inundation.
- Flooding during a 50-year event could be reduced by up to about 190 cfs, which is a 60% reduction in peak flow in Warner Canyon Creek and a 10% reduction at the ACMdP streamflow gage, based on a maximum of 227 acre-feet of storage.

[32] Refer to Appendix G for details on the Mill Valley Golf Course detention basin.

FIGURE 17

[25-05] BANK RETAINING/FLOODWALLS & UPSTREAM BRIDGE WALL

[50-02] REPLACE/ENLARGE CULVERT

[50-04] MILL VALLEY GOLF COURSE DETENTION BASIN (NOT SHOWN)

[50-03] TOP OF RIGHT BANK FLOODWALL & UPSTREAM BRIDGE WALL

OLD MILL CREEK

[10-07] REPLACE/ENLARGE PARK AVE BRIDGE

WARNER CREEK

[50-05] TOP OF BANK FLOODWALLS

EXISTING PEDESTRIAN BRIDGES REMAIN

EXISTING DRIVEWAY BRIDGE REMAINS

[5-05] REPLACE WILLOW PUBLIC PEDESTRIAN BRIDGE

[50-05] EXTEND FLOODWALL ON TOP EXISTING RETAINING WALL

[5-04] REPLACE PRIVATE PEDESTRIAN BRIDGE

[5-06] WIDEN & MODIFY CHANNEL

[10-05] FLOOD DIVERSION WALL & RAISE SYCAMORE AVE

WARNER CREEK CONFLUENCE

[10-06] TOP OF BANK FLOODWALLS

[25-04] ACMDP CREEK PARTIAL BYPASS

[10-04] TOP OF BANK FLOODWALLS

[5-03] EXCAVATE CHANNEL BOTTOM (1.5' DEEP AVG) REPLACE GAGE STATION

GAGE STATION

EGGER PLAZA

[25-03] TOP OF LEFT BANK FLOODWALL

[50-01] REPLACE/ENLARGE EGGER PLAZA BRIDGE

[10-02] RIGHT BANK RETAINING/FLOODWALL

[10-02] TOP OF RIGHT BANK FLOODWALL

[10-02] RIGHT BANK RETAINING/FLOODWALL (100-Year)

[25-02] TOP OF LEFT BANK FLOODWALL

[5-02] TOP OF RIGHT BANK FLOODWALL

EXISTING PEDESTRIAN BRIDGE REMAINS

[5-01] TOP OF LEFT BANK FLOODWALL

[100-01] TOP OF RIGHT BANK FLOODWALL

[10-01] TOP OF LEFT BANK FLOODWALL

[10-01] TOP OF RIGHT BANK FLOODWALL

[10-01] RIGHT BANK RETAINING/FLOODWALL

[10-01] RIGHT BANK RETAINING/FLOODWALL

[25-01] TOP OF RIGHT BANK FLOODWALL

ID NUMBER DESCRIPTION

PROTECTION LEVEL — ID NUMBER

SCALE (FEET)

0 200 400

N W E S

LEGEND

- STREAM
- FLOODWALLS □ BERMS
- RAISE AND WIDEN BRIDGE
- REPLACE□ENLARGE CULVERT
- PREVIOUS MEASURES (In□□ded in 50-Year □ 100-Year Meas□res)

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50-YEAR AND 100-YEAR FLOOD PROTECTION MEASURES

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5.4 Fish Passage Measures and Other Environmental Enhancements

Arroyo Corte Madera del Presidio provides habitat for native salmonid fish, including resident trout, steelhead trout, Coho salmon and Chinook salmon. The National Marine Fisheries Services and the California Department of Fish and Game have listed steelhead trout and Chinook salmon as "threatened" under the federal Endangered Species Act (ESA) and the California Endangered Species Act, respectively. Coho salmon are listed as "endangered" on both the ESA and CESA. Freshwater aquatic and riparian habitats that support these fish species have been degraded by past human activities and the ongoing presence of development; most noteworthy are bridges and culverts that impede fish passage. Retaining walls and other permanent infrastructure flank the creek, and dense development has gradually filled in along the edges of the creek corridor eliminating portions of the riparian canopy and natural creek bank vegetation and encouraging invasion by non-native vegetation.

Opportunities are available to simultaneously reduce flooding and improve creek habitat for the native salmonids. Barriers to fish passage could be rectified in ways that also increase the hydraulic conveyance capacity of the creek. In-channel habitat features that provide fish resting, refuge, and rearing habitat could be incorporated into measures aimed at increasing channel flow capacity. Biotechnical treatments using native vegetation that provide near-shore cover and canopy, necessary for reducing fish predation and keeping water temperatures cool, could similarly be incorporated into retaining walls, floodwalls and landscape berms. These opportunities should be explored further and, where feasible, incorporated into the final designs of the flood reduction measures.

5.4.1 Fish Passage Barrier Removal

A previous fish passage study of creeks in Marin County identified ten culverts, including seven along Arroyo Corte Madera del Presidio and three along Old Mill Creek, as partial or complete barriers to fish passage. The study also described general approaches to remedy the barriers (Ross Taylor and Associates, 2003). Mill Valley Streamkeepers (MVSK) later commissioned a study to further evaluate the feasibility of rectifying five of the barriers. The study also included preliminary designs (Far West Restoration Engineering, 2004). The barriers are located in Figure 18 and the remedies described in the studies are listed in Table 8. Only one of the ten barriers is a site also targeted in this study for flood reduction: MR-069, which is a concrete culvert in Arroyo Corte Madera del Presidio passing beneath a private building downstream of Sunnyside Avenue just upstream of the confluence with Old Mill Creek. Accordingly, this fish passage remedy has been incorporated into the conceptual design and cost estimate of the flood reduction measure at this culvert. In addition, site MR-077, the culvert at Cascade Drive crossing, appears to limit the hydraulic capacity of Old Mill Creek to convey the 100-year flood

based on examination of the FEMA Flood Insurance Rate Map (FEMA, 1979). Accordingly, in addition to rectifying the culvert for fish passage, the culvert should also be enlarged to provide sufficient capacity to convey the 100-year flood.

Table 8. Summary of Fish Barriers and Remedies for Mill Valley Creeks

Site I.D.	Creek	Road	Remedy
MR-068	ACMdP	Locust Ave.	Cut a 4 ft to 10 ft wide by 2 ft deep "notch" into 180 ft long concrete apron and culvert bottom; place rock and gravel into notch to provide a natural bottom passageway; construct downstream step pools to raise tailwater at outlet. (Far West, 2004)
MR-069	ACMdP	Building	Modify existing circular concrete culvert to form a new, larger box culvert (shoring and tie-backs will be needed) to increase hydraulic capacity; install a series of weirs and pool cross-baffles in culvert to reduce flow velocities and increase depths; construct downstream step pools to raise tailwater at outlet. (Far West, 2004)
MR-070	ACMdP	King St.	Place downstream boulder weirs to raise tailwater at outlet; install corner baffles within the culvert to reduce flow velocities and increase depths. (Taylor, 2003)
MR-071	ACMdP	Marguerite Ave.	Place downstream boulder weirs to raise tailwater at outlet; install fully-spanning, sloped concrete weirs within the culvert and an outlet beam with a low-flow notch to reduce flow velocities and increase depths. (Taylor, 2003)
MR-072	ACMdP	W. Blithedale Ave.	Install corner baffles within culvert to reduce flow velocities. (Taylor, 2003)
MR-073	ACMdP	W. Blithedale Ave.	Place downstream boulder weirs to raise tailwater at outlet. (Taylor, 2003)
MR-074	ACMdP	Blithedale Summit Fire Rd.	No remedy described in previous studies.
MR-075	Old Mill Creek	Miller Ave.	Construct downstream step pools to raise tailwater at outlet; evaluate need to install corner baffles within culvert to reduce flow velocities. (Far West, 2004)
MR-076	Old Mill Creek	Building	Construct baffles in existing culvert. (Far West, 2004)
MR-077	Old Mill Creek	Cascade Dr.	Construct a new arch bridge to increase hydraulic capacity; place rock and gravel in bottom to provide a natural bottom passageway. (Far West, 2004)

Sources: Ross Taylor and Associates, 2003; Far West Restoration Engineering, 2004.

FISH BARRIERS ON MILL VALLEY CREEKS

- Fish Barrier
- Stream

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N

0 500 1,000 Feet

MR-073 (W. Blithedale Ave.)
MR-072 (W. Blithedale Ave.)
MR-071 (Marguerite Ave.)
MR-070 (King St.)
MR-077 (Cascade Dr.)
MR-075 (Miller Ave.)
MR-069 (Miller Ave.)
MR-068 (Locust Ave.)

Corte Madera Del Presidio Arroyo
Old Mill Creek
Ryan Creek

J:\jn2165\Inundationdepth_5yr.mxd 3/4/2010 N.Wasserman

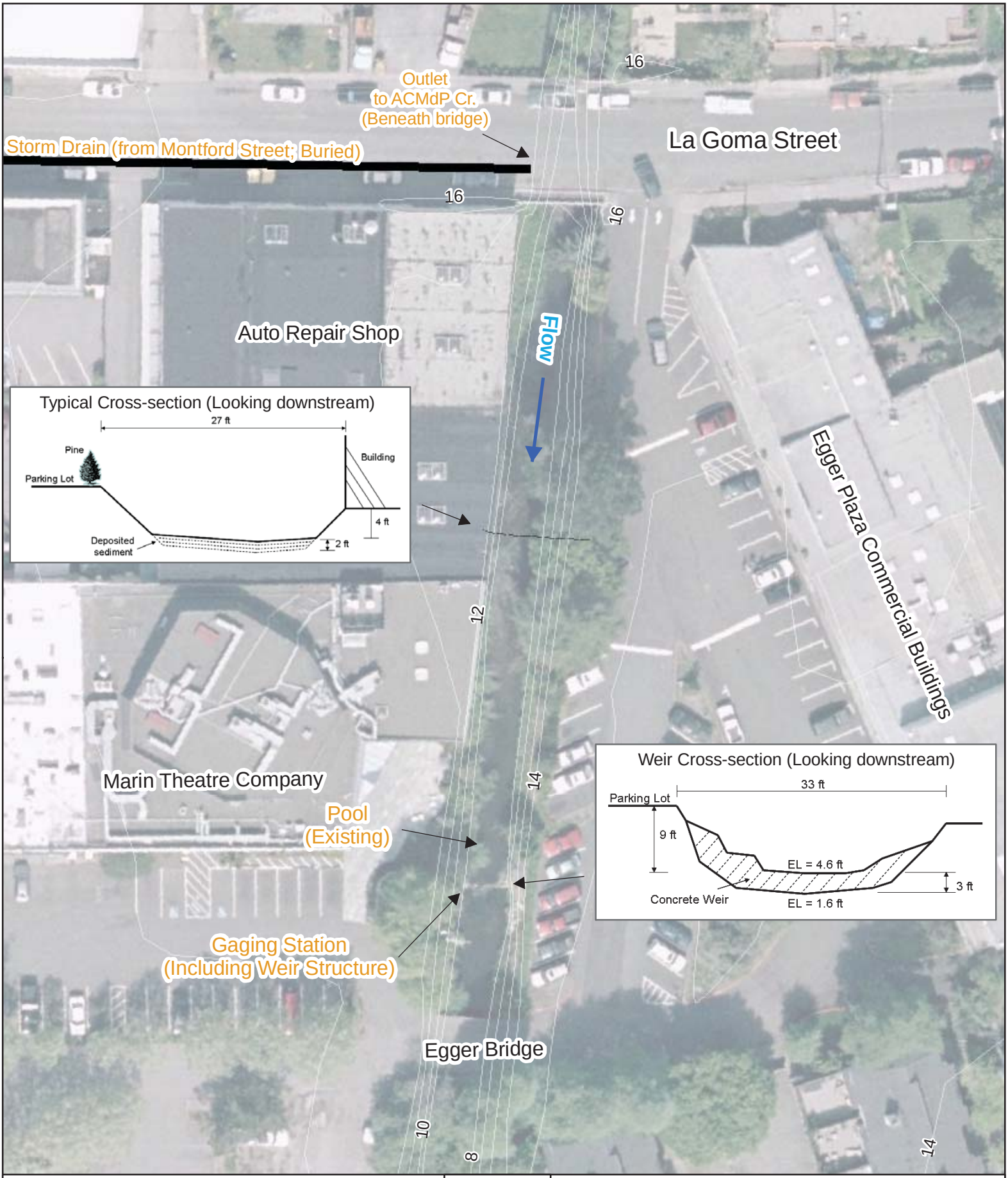
FIGURE 18

5.4.2 In-Channel Habitat Features and Biotechnical Treatments

The City of Mill Valley and MVSK collaborated to develop a conceptual plan (Stetson, 2010) for simultaneous flood reduction and habitat improvement that incorporates in-channel habitat features and biotechnical treatments along the reach of creek between La Goma Street Bridge and the Egger Plaza Bridge (Figure 19). This project demonstrates how flood damage reduction can be accomplished concomitantly with habitat improvement. Opportunities to apply this approach should be explored further and, where feasible, incorporated into the final designs of the flood protection measures described in this study.

The 300-foot reach between La Goma Street Bridge and Egger Plaza Bridge has aggraded over the years and its hydraulic conveyance capacity has been reduced (Figure 20) due to sediment accumulation behind the concrete weir at the streamflow gage. Generally, in Arroyo Corte Madera del Presidio a lack of deep resting pools for migrating fish is impairing the recovery of native salmonids. Lack of adequate riparian canopy to provide shade allows water temperatures to rise to unsuitable levels during summer. The project addresses these problems.

The project consists of removing the existing concrete weir structure at a the streamflow gage and replacing it with a stone structure set at a lower grade that allows for improved transport of bedload sediment (Figure 21). Any existing gage equipment affected by the work would need to be replaced and reinstalled. Because it would be re-set at a lower level, the stone structure would induce natural scouring and lowering of the channel bed upstream along the approximately 300-foot reach where up to 2 feet of sediment has deposited over the years. Lowering of the bed would increase the hydraulic conveyance capacity of the channel by about 140 cfs and, consequently, reduce the frequency and severity of overbank flows that break out along the project reach during severe storms. Lowering of the bed would also improve outflow from the Montford Avenue storm drain, which often becomes clogged at its outlet to the creek by sediment deposited in the bed. To guard against potential erosion and undermining of the banks resulting from lowering of the bed, stacked natural stone wall protection would be constructed along the toes of the banks. The banks would be further stabilized using biotechnical treatments, which would include plantings of native riparian shrubs and trees to provide nearshore cover and canopy for shade and refuge from terrestrial predators. To replace the loss of pools that have formed upstream and downstream of the existing concrete weir, three replacement pools would be constructed along the project reach using stone weirs. Interpretive signage would be placed on the La Goma Bridge overlooking the restored reach downstream.



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Figure 19

Stream Restoration Project along the Reach between La Goma Street Bridge and Egger Plaza Bridge

Site Plan - Existing Conditions

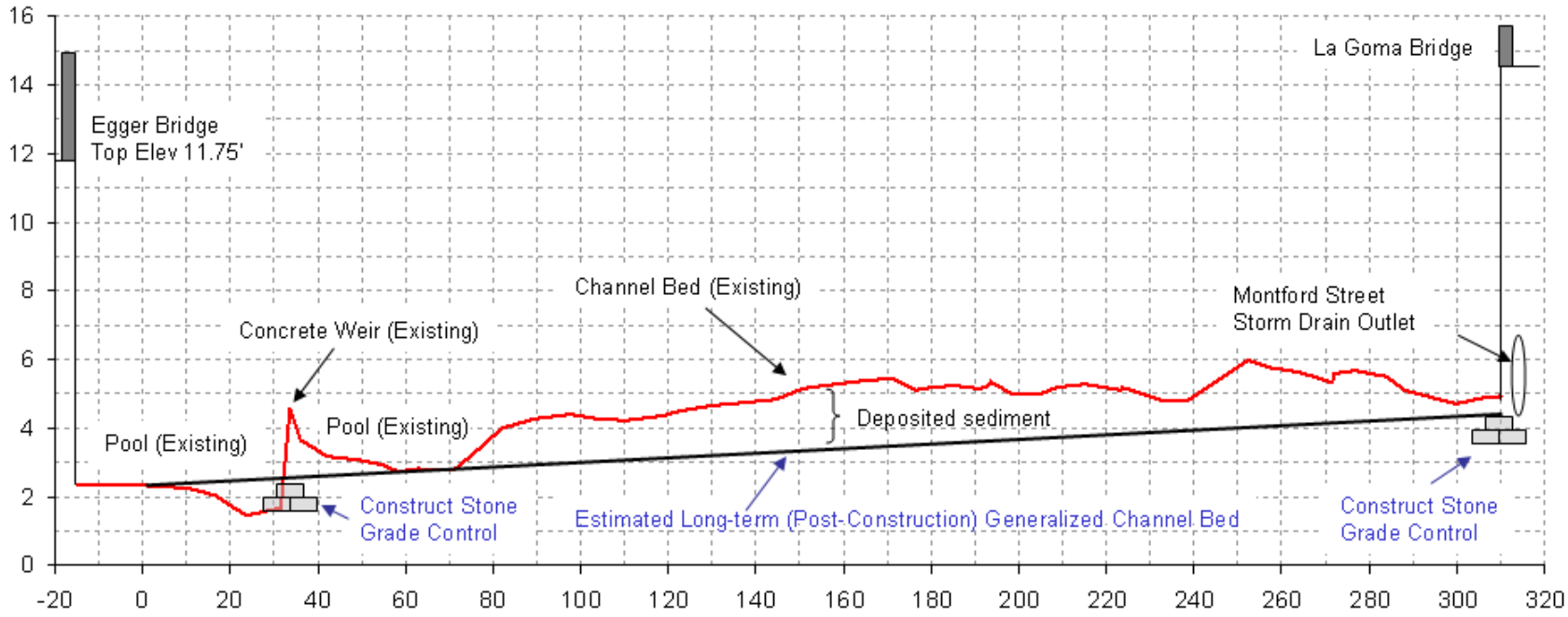
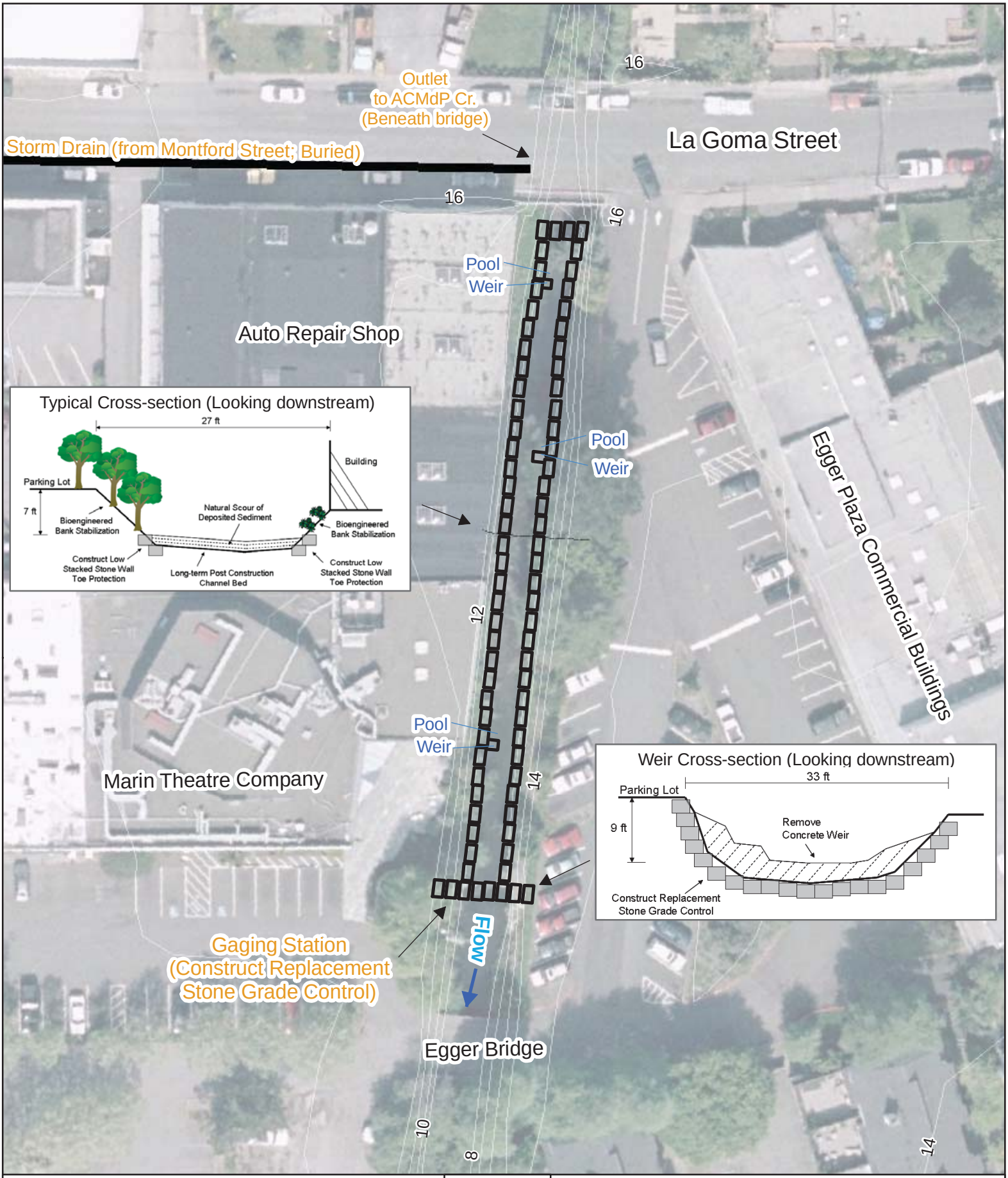


Figure 20
Arroyo Corte Madera del Presidio
Channel Bed Longitudinal Profile
La Goma Street Bridge to Egger Bridge



0 25 50 100 Feet

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Figure 21

Stream Restoration Project along the Reach between La Goma Street Bridge and Egger Plaza Bridge

Site Plan - Proposed Conditions

5.5 Estimated Costs

Capital costs were estimated for all measures, including in-channel measures to increase conveyance capacity, the ACMdP Creek partial bypass, and the Mill Valley Golf Course detention basin. These estimates cover all costs associated with initial project implementation include planning, environmental review, regulatory permitting, right-of-way acquisition, design, construction, and construction management. A contingency cost has been added. Refer to Appendix H for detailed cost estimates. Attachment 1 to Appendix H contains an estimate of the expected flood damage under existing conditions, and Attachment 2 contains the details on the estimated costs for the flood damage reduction alternatives.

Annual costs were also estimated. Annual costs are recurring costs that are incurred over the project facilities' life. Annual costs include operation, maintenance and repairs; monitoring, inspections and reporting; and administration, insurance, and management. Annual costs were estimated as a percentage of the capital costs of the various projects. For purposes of this analysis, annual costs were assumed to be 1% of the capital cost. Annual costs were brought forward to a present worth using a 5% discount rate based on an assumed 50-year project life.

Table 9 is a summary of the estimated costs for the five alternative levels of flood protection measures.

Table 9. Estimated Cost of the Alternatives

Alternative Level of Flood Protection	Capital Cost ($)	Annual Cost			Total Present Worth of Cost ($)
		Percent of Capital (%)	Annual Cost ($/yr)	Present Worth of Annual Cost ($)	
5-Year Measures	2,333,000	1%	23,000	420,000	2,753,000
10-Year Measures	8,125,000	1%	81,000	1,479,000	9,604,000
25-Year Measures	15,745,000	1%	157,000	2,867,000	18,612,000
50-Year Measures	38,131,000	1%	381,000	6,957,000	45,088,000
100-Year Measures	42,597,000	1%	426,000	7,779,000	50,376,000

* Future annual costs include operation, maintenance and repairs; monitoring, inspections and reporting; and administration, insurance, and management, and other recurring costs associated with the alternative measures.

6.0 EFFECTS OF CLIMATE CHANGE AND RESULTING SEA LEVEL RISE

This section describes the anticipated effects of rising sea levels due to climate change on the proposed flood protection measures developed under this study. Other potential aspects of climate change, such as increased storm intensity, are not evaluated in this study but would be expected to increase peak flooding and impacts. Also, this section only evaluates the effects of sea level rise (SLR) on riverine flooding and does not evaluate direct coastal inundation which is expected to be a significant source of flooding under future SLR conditions. Finally, this section does not evaluate the full range of adaptive management measures to climate change impacts which may include a range of shoreline planning strategies. It is anticipated that this future watershed based analysis will be conducted in cooperation with the Marin County watershed program and the City of Mill Valley. Section 6.1 was prepared by Roger Leventhal of Marin County Flood Control and Water Conservation District.

6.1 Background on Sea Level Rise (*This section was prepared by Roger Leventhal, PE, Marin County Flood Control and Water Conservation District*)

Sea levels in San Francisco Bay have risen approximately 2 cm/decade (or approximately 7 inches in the past 100 years), which is approximately equal to the global measurements in sea level changes. Water levels in San Francisco Bay are anticipated by most climate scientists to at least increase at this rate and likely even accelerate due to a variety of local and global factors. Sea level rise is generally split into two broad parts – a global term that is controlled by global processes, such as the warming of the oceans and the melting of ice; and a local term that is controlled by local or regional processes, such as local winds and land movements. Local sea level rise is also referred to as relative sea level rise as it combines changes in the both the sea and land elevations.

Global (or eustatic) sea level rise is the combination of two factors:

1. Thermal expansion of the ocean. Thermal expansion is the result of higher water temperatures leading to an increase in ocean volume while the mass remains constant. The oceans are a major sink for greenhouse gases.

2. Melting of global ice. The melting of glaciers and land grounded ice caps, such as Antarctica and Greenland, will increase the mass of water in the oceans leading to sea level rise. The recent National Research Council report (NRC, 2012) has noted that current research indicates that the relative contribution from the melting of land ice to SLR is increasing.

The local rise in sea level is a combination of global sea level rise together with three local factors:

1. Local ocean circulation. Atmospheric and ocean circulation patterns can affect regional sea levels. Wind-driven enhancement of sea level can occur on the Pacific coast to the northward wind especially in winter months and during El Nino events (Mote *et al*, 2008). Combined with Coriolis effects due to the Earth's rotation, they push ocean water toward the shore. Other phenomena associated with the El-Nino-Southern Oscillation, such as the frequency and magnitude of storms and storm surges, may also be altered by climate change. The effects have likely been responsible for the temporary flattening of the sea level rise slope for the past 20 years as measured at the NOAA Golden Gate tide gauges.

2. Vertical land movement. Relative sea level rise is the sum of global sea level rise and the change in vertical land movement. Thus, if sea level rises and the shoreline rises or subsides, the relative rise in sea level could be lesser or greater than the global sea level rise. Vertical land movement can occur due to tectonics (earthquakes, regional subsidence or uplift), sediment compaction, isostatic readjustment and groundwater depletion (USACE, 2009). It is anticipated that as rates of global sea level continue to increase with climate change, at some point in the future, the rate of vertical land movement will become less significant in determining the impact of sea level rise. However, areas that have subsided such as the Richardson Bay shoreline are particularly vulnerable to sea level rise and extreme events.

3. Local hydrodynamic variations. Differences have been found between the rates of global sea level rise and regional sea level rise in large, semi-enclosed water bodies such as estuaries and large embayments (USACE, 2009) which are likely not as much of a factor within Richardson Bay.

There have been numerous studies and reports developed over the past decade related to climate change and SLR. For this study, we have relied on the recent National Resource Council (NRC) prepublication report "*Sea Level Rise for the Coasts of California, Oregon and Washington: Past, Present and Future*" which to our knowledge is the most comprehensive, recent report synthesizing the science regarding SLR focusing on the Pacific Coast states. Note that the SLR projects in this new study (Table 10 below) do not significantly differ from the SLR projections from previous studies.

Why Assess the Impacts of Sea level Rise?

Although the exact timing and magnitude of sea level rise in San Francisco Bay is not known, it is prudent to start incorporating the potential impacts of a rising sea level into local capital

improvement planning over the next 20 to 100 year time frame. New sources of flooding such as direct coastal inundation (not addressed in this study) may become the primary sources of flooding and shoreline erosion over the next several decades and also exacerbate riverine and stormdrain flooding. While planning for SLR does not mean necessarily spending funds now for an uncertain rise in bay water levels; it does mean assessing the impacts of sea level rise on proposed capital improvement projects and to the extent practical, allowing the space to adaptively manage these projects should future sea rise projections turn out to be correct. This study only assesses impacts to riverine flooding but future studies in the watershed will focus more on adaptive strategies and the cost-effectiveness of designing flood control projects under higher bay water levels. One such regional study is the Our Coast, Our Future project underway by the United States Geologic Survey (USGS) that will analyze the impacts of SLR on coastal flooding around San Francisco Bay.

Other reasons to evaluate SLR impacts include many other factors important to the quality of life in the Mill Valley watershed outside of flooding. These other potentially impacted uses include public usage of trails and parks, fish passage and wetlands habitat. Finally, certain permitting agencies (e.g., the BCDC) are requiring evaluation of SLR in the design process for projects subject to the impacts of a raising sea level. It is anticipated that sea level rise and climate change evaluations will become a standard part of the design, permitting and grant funding process into the future.

6.2 Work Performed Under this Study

Sea level rise resulting from future climate change was considered in the analysis of flood protection measures. The analysis was performed using the HEC-RAS steady-state hydraulic model to (1) determine the level of flood protection provided by the respective flood protection measures under sea level rise conditions and (2) determine alterations and/or additional measures that would be needed to maintain the intended level of flood protection provided by the measures. In addition, areas subject to tidal backflow flooding under future sea level rise conditions by way of storm drain systems were delineated to indicate where storm drain system improvements would be necessary to prevent localized flooding.

According to a recently published sea level rise study report prepared by the National Research Council in June 2012 (NRC, 2012), projected sea level rises in San Francisco Bay for year 2030, 2050, and 2100 (relative to year 2000) are summarized in Table 10.

Table 10. San Francisco Bay Sea Level Rise Projections Relative to 2000 (in centimeters)

2030		2050		2100	
Projection	Range	Projection	Range	Projection	Range
14.4 ± 5.0	4.3 – 29.7	28.0 ± 9.2	12.3 – 60.8	91.9 ± 25.5	42.4 – 166.4

1) Source: NRC, 2012.
2) 1 cm = 0.39 inch; 1 inch = 2.54 cm.
3) The value under "Projection" represents the projected mean sea level rise with one standard deviation.

The current mean higher high water (MHHW) published in the NOAA website is based on the tidal epoch 1983-2001. The NRC-projected sea level rise is relative to 2000. Since the base year in the sea level rise projection is within the tidal epoch 1983-2001, the projected sea level rise values were directly added to the current MHHW to derive the future MHHW under sea level rise conditions. The existing MHHW in San Francisco Bay (NOAA Station ID: 9414290) is 5.9 ft NAVD 88.

Assuming a 50-year project life for the flood damage reduction facilities, three different downstream boundary conditions (2030 high plus 2050 low and high SLR projections) were analyzed. The 2030 low SLR projection was not analyzed because it is just 4.3 cm, or 0.1 ft, in sea level rise. The 2100 low/high SLR projections were not analyzed either because 2100 is beyond the facilities' 50-year project life. Table 11 summarizes the three future MHHW conditions that were used as the downstream boundary conditions for the HEC-RAS modeling analysis. The analysis assumed that some form of barrier is put in place along the historic railroad grade to prevent further inland encroachment of tides greater than Mean Higher High Water.

Table 11. Summary of the Downstream Boundary Conditions under Future Sea Level Rise MHHW Scenarios

Downstream Boundary Condition	Existing MHHW (ft NAVD 88)	Projected Sea Level Rise	Future MHHW (ft NAVD 88)
2030 high SLR projection	5.9	29.7 cm = 1.0 ft	6.9
2050 low SLR projection	5.9	12.3 cm = 0.4 ft	6.3
2050 high SLR projection	5.9	60.8 cm = 2.0 ft	7.9

The analysis was conducted for the 10-year and 100-year flood protection measures using the HEC-RAS steady-state hydraulic model. Figure 22 shows the simulated 10-year water surface profile (with the 10-year flood protection measures in place) for the three different sea level rise scenarios. It shows that the influence of tidal condition diminishes with distance upstream, with a maximum difference in water level of 0.4 ft at Camino Alto Bridge under the 2050 high projection scenario. The influence of the tidal condition fully peters out at Camino Alto Bridge under both the 2030 high projection and 2050 low projection scenarios. The influence of the

tidal condition fully peters out at Valley Circle Pedestrian Bridge under the 2050 high projection scenario.

Figure 23 shows the simulated 100-year water surface profile (with the 100-year flood protection measures in place) for the three different sea level rise scenarios. It shows that the influence of the tidal condition fully peters out at Camino Alto Bridge under all three sea level rise scenarios. Compared to the 10-year water surface profile, sea level rises have less effect on the 100-year water surface profile in terms of the affected distance.

Figure 22 ACMdP 10-Year Water Surface Profile (with 10-Year Flood Protection Measures in Place) under Different Sea Level Rise Scenarios

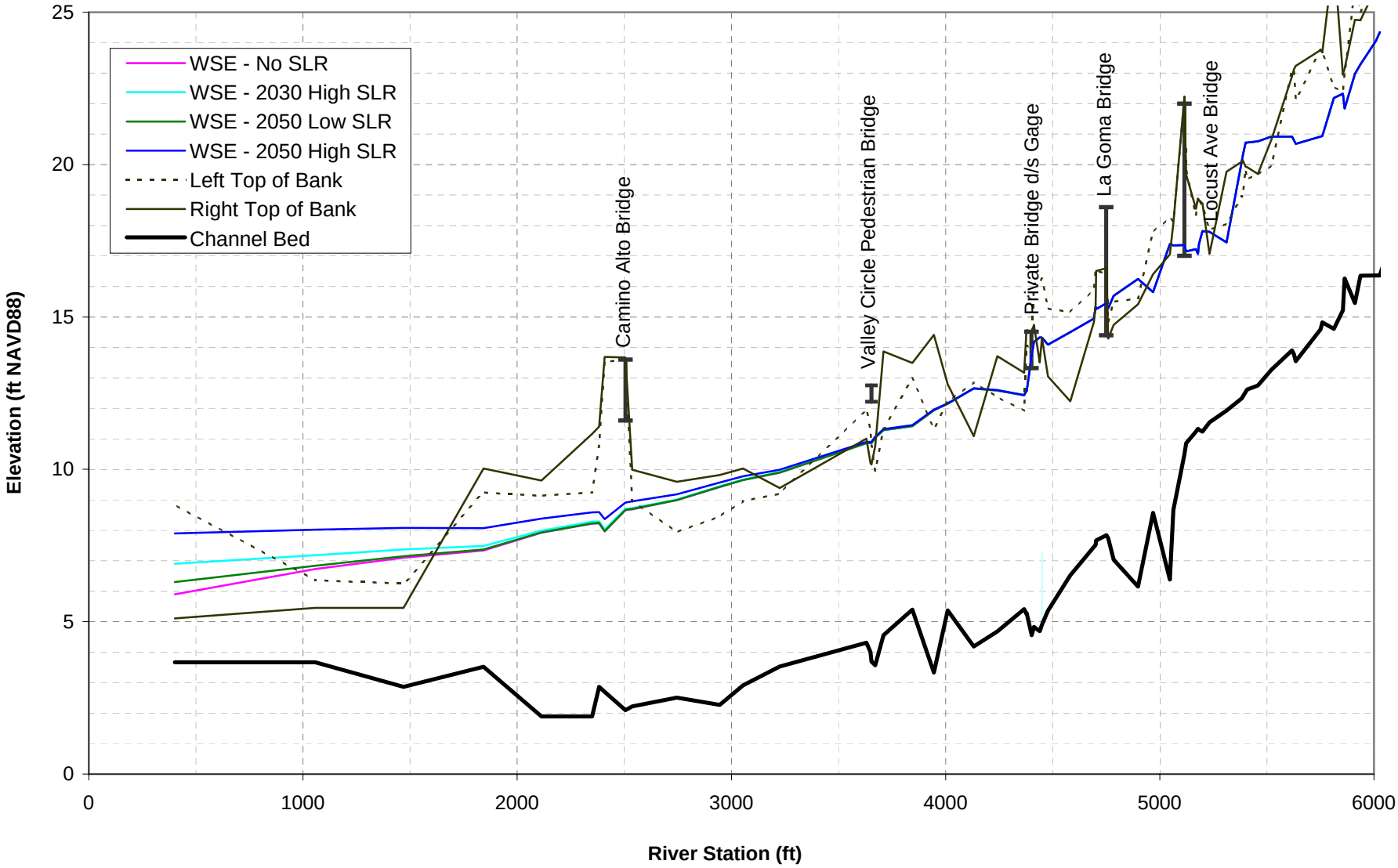
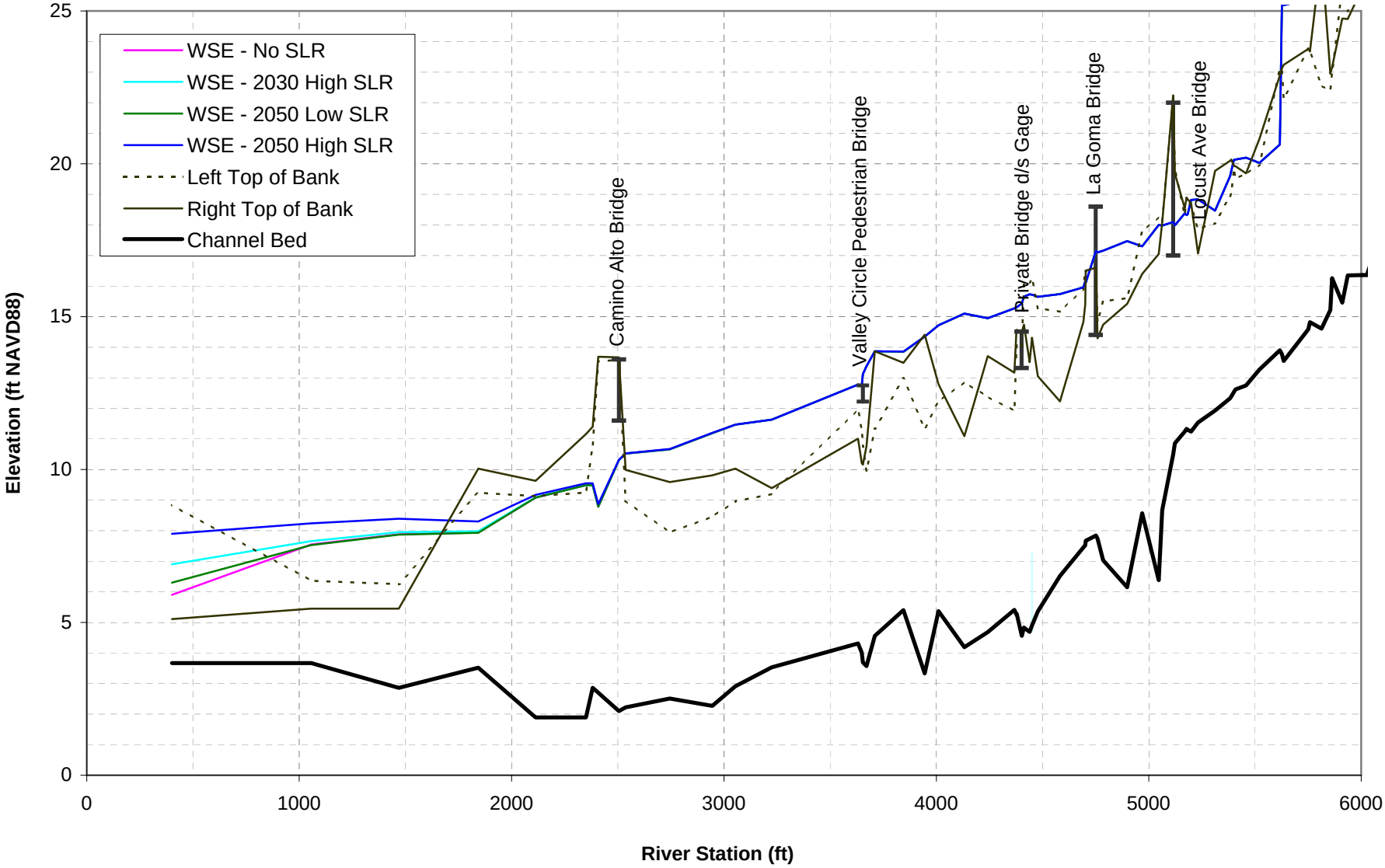


Figure 23 ACMdP 100-Year Water Surface Profile (with 100-Year Flood Protection Measures in Place) under Different Sea Level Rise Scenarios

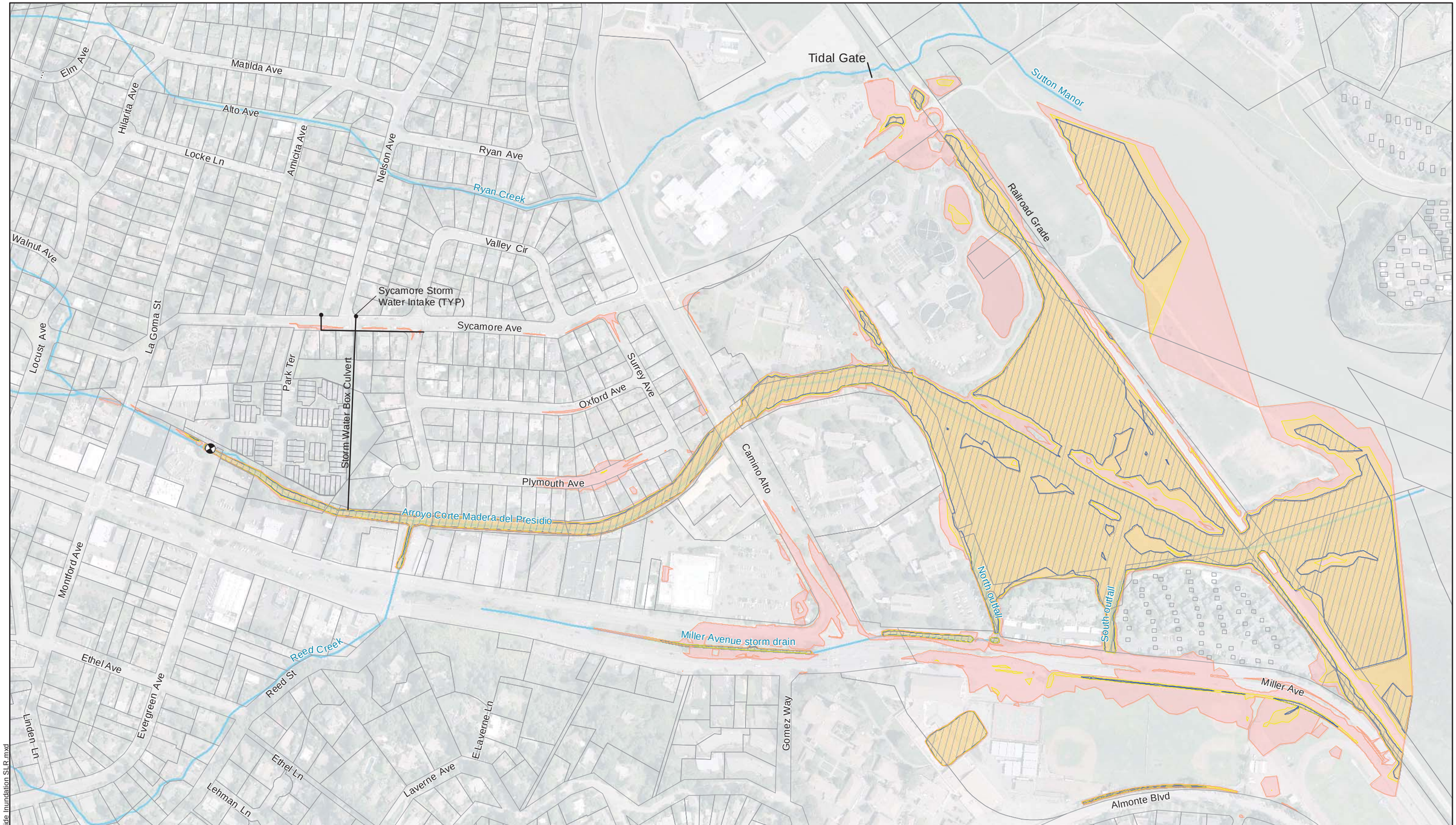


As shown in Figures 22 and 23, both the 10-year and 100-year water surface profiles above Camino Alto Bridge have relatively steep gradients and are higher than the three future MHHWs. Steep water surface gradients limit the effect that the higher downstream boundary conditions have on the water surface profiles above Camino Alto Bridge. This suggests that the three downstream boundary conditions should not have an important effect on the proposed flood protection measures because all the proposed flood protection measures are located above Camino Alto Bridge. Table 12 is a summary of the analysis results.

Figure 24 shows the areas subject to tidal backflow flooding by way of storm drain systems under the three different sea level rise scenarios. The land surface in these areas is lower than the MHHWs. During heavy storms coincident with the MHHWs, interior stormwater flooding due to inadequate storm drain hydraulic capacity would cover larger areas. Note that the floodplain of Ryan Creek would not have any areas subject to tidal backflow flooding because Ryan Creek is currently isolated from the bay by a tidal gate and pump station located at the downstream end of the creek (see Figure 24).

Table 12. Summary of Analysis Results for Future Sea Level Rise Scenarios

Sea Level Rise Scenario	Future Level of Flood Protection Provided by the Flood Protection Measures		Alterations and/or Additional Measures That Would Be Needed to Maintain Intended Level of Flood Protection under Future Sea Level Rise	
	10-Year Measures	100-Year Measures	10-Year Measures	100-Year Measures
2030 High SLR Projection	10-Year Flood	100-Year Flood	No change	No change
2050 Low SLR Projection	10-Year Flood	100-Year Flood	No change	No change
2050 High SLR Projection	8-Year Flood	100-Year Flood	Raise floodwalls between Camino Alto Bridge and Valley Circle Pedestrian Bridge by 0.4 ft	No change



Gage Station
Stream
Storm Water Culvert
Parcel Boundary

2030 High Projection MHHW*: 6.9ft (NAVD88)
2050 Low Projection MHHW*: 6.3ft (NAVD88)
2050 High Projection MHHW*: 7.9ft (NAVD88)

* Mean Higher High Water

STETSON ENGINEERS INC.

AREAS SUBJECT TO TIDAL BACKFLOW FLOODING
BY WAY OF STORM DRAIN SYSTEMS
UNDER THREE DIFFERENT FUTURE SEA LEVEL RISE SCENARIOS

0 250 500 Feet

N

FIGURE 24

Document Path: J:\sh2433\Tide Inundation SLR.mxd

Assumption: A barrier system along the Railroad Grade is assumed to be put in place to prevent tides greater than MHHW from propagating upstream.

7.0 IMPLEMENTING FLOOD DAMAGE REDUCTION MEASURES IN ACCORDANCE WITH FEMA FLOODPLAIN REGULATION

FEMA is in the process of revising its Flood Insurance Rate Maps (FIRMs) for Ross Valley and Mill Valley. This process involves flood studies including new hydraulic and hydrologic models to determine water surface elevations for the 100-year flood, or the 1-percent-annual-chance flood. These elevations are referred to as "base flood elevations (BFEs)" from riverine and coastal flooding sources. The FIRM for Mill Valley was revised in 1979 and most recently in 2009. The new FIRM for Mill Valley is expected to become effective in 2014.

In April 2012, FEMA offered affected communities the opportunity to review and comment on the flood studies from riverine sources and the "working maps," which are essentially draft FIRMs, before they are officially released for public review and comment in November 2012. The City of Mill Valley commissioned Stetson Engineers to review the riverine flood source working map for Mill Valley. The working map delineates the riverine Special Flood Hazard Area (SFHA); that is, the area contained within the 1-percent-annual-chance flood boundary. Unlike previous FIRMs, this working map also delineates the regulatory floodway, which is the area within the SFHA that must be reserved in order to discharge the base flood. Communities must regulate any new development in the regulatory floodway to ensure that there are *no* increases in upstream flood elevations. Figure 25 shows the delineated regulatory floodway and its spatial relation to the flood damage reduction measures described in this report. All of the flood reduction measures described in this study are also located within the regulatory floodway and, as such, would be subject to FEMA's floodplain regulations.

Flood reduction measures described in this study include floodwalls. By design, floodwalls raise the water surface elevation of the 1-percent-annual-chance flood; up to 3.5 feet in some reaches of the creek. However, it is important to point out that flooding is not exacerbated because the floodwalls keep the floodwater contained in the creek, just at a raised elevation.

Nonetheless, the issue arises as to how the flood damage reduction measures, floodwalls in particular, can be implemented in accordance with FEMA floodplain regulations regulating new development in the regulatory floodway and prohibiting a rise in upstream flood elevations. A Letter of Map Revision (LOMR) is the vehicle that would enable these measures to be implemented. A LOMR is an official revision to a FIRM. LOMRs reflect changes to the mapped SFHAs, BFEs, floodplain widths, and regulatory floodways. LOMRs are issued after a floodplain has been remapped due to a major flood event, after better mapping data becomes available, or after structural flood control improvements have been constructed.

Through the LOMR process, flood damage reduction measures can be implemented. Prior to constructing any measure(s) that may trigger the need for a LOMR, the City will need to submit an application to FEMA requesting FIRM revision. The application will need to include design plans and other technical information concerning the proposed flood reduction measure(s). If FEMA approves the application, it will issue a Conditional Letter of Map Revision (CLOMR). A CLOMR is similar to a LOMR, but is based on proposed conditions and does not change the FIRMs. A CLOMR is the method used by FEMA to let people know that if a project is constructed per the design submitted to and approved by FEMA then revision of the FIRM with a LOMR is likely. If FEMA issues the CLOMR, the City can be assured that a LOMR for the project will be approved upon completion of the flood reduction measure.

FIGURE 25

ID NUMBER DESCRIPTION

PROTECTION LEVEL — ID NUMBER

SCALE (FEET)

0 250 500

N W E S

LEGEND

- FEMA 2012 DRAFT FLOODWAY
- STREAM
- FLOODWALLS □BERMS
- RAISE AND WIDEN BRIDGE
- REPLACE□ENLARGE CULVERT
- PREVIOUS MEASURES (In□□ded in 50-Year □ 100-Year Meas□res)

[25-05] BANK RETAINING/FLOODWALLS & UPSTREAM BRIDGE WALL

[50-02] REPLACE/ENLARGE CULVERT

[50-03] TOP OF RIGHT BANK FLOODWALL & UPSTREAM BRIDGE WALL

OLD MILL CREEK

[50-04] MILL VALLEY GOLF COURSE DETENTION BASIN (NOT SHOWN)

FEMA FLOODWAY BOUNDARY

[10-07] REPLACE/ENLARGE PARK AVE BRIDGE

WARNER CREEK

[50-05] TOP OF BANK FLOODWALLS

[50-05] EXTEND FLOODWALL ON TOP EXISTING RETAINING WALL

EXISTING PEDESTRIAN BRIDGES REMAIN

EXISTING DRIVEWAY BRIDGE REMAINS

[5-05] REPLACE WILLOW PUBLIC PEDESTRIAN BRIDGE

[5-04] REPLACE PRIVATE PEDESTRIAN BRIDGE

[5-06] WIDEN & MODIFY CHANNEL

[10-05] FLOOD DIVERSION WALL & RAISE SYCAMORE AVE

WARNER CREEK CONFLUENCE

[10-06] TOP OF BANK FLOODWALLS

[25-04] ACMDP CREEK PARTIAL BYPASS

[10-04] TOP OF BANK FLOODWALLS

[5-03] EXCAVATE CHANNEL BOTTOM (1.5' DEEP AVG) REPLACE GAGE STATION

GAGE STATION

EGGER PLAZA

[25-03] TOP OF LEFT BANK FLOODWALL

[50-01] REPLACE/ENLARGE EGGER PLAZA BRIDGE

[10-02] RIGHT BANK RETAINING/FLOODWALL

[10-02] TOP OF RIGHT BANK FLOODWALL

[10-02] RIGHT BANK RETAINING/FLOODWALL (100-Year)

[5-02] TOP OF RIGHT BANK FLOODWALL

[25-02] TOP OF LEFT BANK FLOODWALL

[100-01] TOP OF RIGHT BANK FLOODWALL

EXISTING PEDESTRIAN BRIDGE REMAINS

[5-01] TOP OF LEFT BANK FLOODWALL

[10-01] TOP OF LEFT BANK FLOODWALL

[10-01] TOP OF RIGHT BANK FLOODWALL

[10-01] RIGHT BANK RETAINING/FLOODWALL

[10-01] RIGHT BANK RETAINING/FLOODWALL

[25-01] TOP OF RIGHT BANK FLOODWALL

STETSON ENGINEERS INC.

DATE: SEPTEMBER 13, 2012 | JN: 2165

50-YEAR AND 100-YEAR FLOOD PROTECTION MEASURES AND FEMA 2012 DRAFT FLOODWAY

\\Nas\□ain\DATA\2165\2012 wor□\CAD\Floodway and 50-100yrs □eas□res.dwg

8.0 RELATED STUDIES

MCFCWCD commissioned Stetson Engineers for two studies related to flooding in Mill Valley. The Evaluation of the Ryan Creek Pump Station Study is provided in Appendix I. This study analyzed the Ryan Creek pump station and local drainage issues. Ryan Creek has its own watershed separate from Arroyo Corte Madera del Presidio. The Evaluation of the Camino Alto North Outfall Study is provided in Appendix J. This study addressed drainage issues regarding the Camino Alto North Outfall. These studies have little bearing on the flood damage reduction measures covered in this report, but they are included herein to provide a more complete compendium of studies that address Mill Valley flooding issues.

8.1 Camino Alto North Outfall Evaluation

The North Outfall functions as the discharge outlet to Richardson Bay for the Camino Alto North storm drain system. During normal storm events, the Camino Alto North system drains a local area of about 38 acres covering both sides of Miller Avenue from about Valley Circle down to the North Outfall. During high tides, tidal inflows enter through the outfall and back up into the storm drain system. During very heavy storm events, overtopping of Arroyo Corte Madera del Presidio and Reed Creek farther upstream can spill over into the system, joining with the local runoff flowing along Miller Avenue to the North Outfall, as demonstrated during the approximate 50-year recurrence flood event on December 31, 2005. If coupled with a high tide, these heavy storm events can inundate the Miller Avenue-Camino Alto intersection making it impassible as well as affecting adjacent properties.

Stetson performed an engineering analysis and prepared conceptual designs for improvements at the North Outfall. These improvements aim to prevent tidal backflow, handle runoff generated within the 38-acre drainage area, and also handle additional runoff originating farther from overtopping of Arroyo Corte Madera del Presidio and Reed Creek that may reach the North Outfall. These improvements to the Camino Alto North storm drain system could be integrated with the greater Miller Avenue streetscape project.

8.2 Ryan Creek Pump Station Evaluation

MCFCWCD operates a tidal gate and pump station on lower Ryan Creek at its discharge to Richardson Bay. Ryan Creek drains an area of about 117 acres composed of a 100-acre residential area above Camino Alto and a 17-acre area below Camino Alto, which includes Mill Valley Middle School and a 3-acre marsh. The average depth of the marsh is about 3 feet and it holds about 9 acre-feet of water. Marsh storage attenuates flow in Ryan Creek during heavy

storms and reduces the peak discharge in the outlet channel reaching the tidal gate and pump station. This attenuation effect is dependent on the antecedent water level in the marsh – the effect is diminished if the marsh is partially or completely filled prior to a heavy storm.

The tidal gate is normally kept open in the dry season to help support the marsh and keeps it closed in the wet season to prevent tidal waters from backing upstream into Ryan Creek. This mode of operation also preserves storage space in the marsh for attenuating heavy storm flows. The pump station is needed to convey water over the tidal gate to the bay. Discharge from the marsh is controlled by the hydraulics of the outlet channel and the pump discharge. The Ryan Creek pump station consists of two pumps, each with a capacity of 8,000 gallons per minute (18 cfs), for a total combined installed capacity of about 16,000 gallons per minute (36 cfs). If discharge from the marsh exceeds the capacity of the pump, the water level in the marsh would rise. This rise, if sufficiently high, could have a backwater effect extending upstream and affecting creek water levels in the residential area above Camino Alto.

The purpose of the study was to analyze the hydraulics of lower Ryan Creek and assess the adequacy of the existing pump station to convey heavy storm flows and maintain protective water levels in the marsh. The study found that the current pump station capacity does not substantially differ from the originally designed capacity. When two pumps are in operation as designed for heavy storms, their combined capacity is adequate to prevent flood damage to buildings upstream along Ryan Creek; that is; none of the first finished floor elevations of buildings upstream along Ryan Creek would be inundated, even during a 100-year flood event although there would be some inundation of the lands along the creek corridor.

REFERENCES CITED

Dawdy, David R. "Analysis of the Flooding on Arroyo Corte Madera." March 28, 2006.

Far West Restoration Engineering. Tech Memo "Preliminary Fish Barrier Culvert Modifications and Flood Assessment, Arroyo Corte Madera/Old Mill Creek." November 15, 2004.

Federal Insurance Administration. "Flood Insurance Study, City of Mill Valley, Marin County, California." July 1978.

Federal Insurance Administration. "Flood Insurance Rate Map, City of Mill Valley, Marin County, California." Panel Number 060177 0005B. Effective January 3, 1979.

National Research Council. "Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future." June 2012.

Ross Taylor and Associates. "Marin County Stream Crossing Inventory and Fish Passage Evaluation." July 2003.

U.S. Army Corps of Engineers, 1967. Survey Report for Flood Control and Allied Purposes, Stream Flowing into Richardson Bay.

Phase 2 Re-evaluation of Conceptual Flood Reduction Measures Described in the 2012 Flood Study for Arroyo Corte Madera del Presidio

Stetson Engineers Inc.
8/16/2017

Background

Stetson completed the Phase 1 re-evaluation study in 2015 (attached). The study found through HEC-HMS hydrologic modeling that the February 9, 2014 storm event produced a peak discharge of about 1,070 cfs, an approximate 10-year flood discharge. The February 9, 2014 storm resulted in a bankfull condition but did not cause flooding of any significance, suggesting that Arroyo Corte Madera del Presidio (ACMdP) has an approximate 10-year flood discharge capacity. The findings of the Phase 1 study suggested that flood damage reduction measures that were developed in the 2012 Flood Study for protecting against the 5-year and 10-year floods may not be necessary and measures for protecting against greater floods (e.g., 25-year, 50-year, and 100-year floods) should be re-examined and revised if/as needed. The Phase 1 study also found that the stage-discharge rating curve previously developed by Dawdy for the ACMdP streamflow gage is not reliable and should be re-constructed and the succeeding flood frequency curve be revised accordingly.

The following tasks were included in the scope of work for the Phase 2 re-evaluation study and are described herein:

1) Develop a new stage-discharge rating curve for the ACMdP streamflow gage;
2) Perform HEC-HMS hydrologic modeling to compute the estimated peak discharge for the 1982 flood;
3) Estimate annual peak discharges since 1985 (post USGS operation of the ACMdP streamflow gage) using the new stage-discharge rating curve and the recorded peak stage;
4) Prepare an updated flood frequency analysis for the ACMdP streamflow gage;
5) Revise the conceptual flood reduction measures for the 25-year, 50-year, and 100-year levels of flood protection;
6) Prepare report; and
7) Perform stage-discharge measurements at the ACMdP streamflow gage.

1) Develop a new stage-discharge rating curve for the ACMdP streamflow gage

A new stage-discharge rating curve for the ACMdP streamflow gage was developed.

The in-channel portion of the discharge rating curve was developed first. The following data were used to develop the new stage-discharge rating curve for the in-channel range of stage-discharge:

- The gage-measured peak stage (8.42 ft gage height) and the corresponding HEC-HMS-simulated peak discharge (1,070 cfs) for the February 9, 2014 storm (bankfull condition);
- USGS annual peak stage-discharge records for historical annual peaks prior to 1985 (excluding the peaks of flood years 1970, 1973, 1982, and 1983)[1], which is the year when USGS stopped operating the gage and recording annual peak stage-discharges; and
- USGS records of field-measured stages and discharges during the period of 1965-1973, labeled "good quality."

Based on the data described above, MS EXCEL was used to develop a "best fit" function for the in-channel portion (or lower portion) of the discharge rating curve: $Q = 20.731 \cdot GH^2 - 33.729 \cdot GH - 81.0$, where GH is the gage height.

Next, the upper portion of the discharge rating curve for out-of-channel stage-discharge was developed. This upper portion of the discharge rating curve has two discharge components; (1) the in-channel discharge with surcharge and (2) the out-of-channel discharge that occurs upstream of the streamflow gage. The in-channel discharge with surcharge can be estimated using the in-channel portion of the discharge rating curve extended to account for surcharge. Out-of-channel discharges upstream of the gage can be estimated using a simplified weir flow stage-discharge equation[2] because the hydraulics of overbank flow (i.e., overtopping of the streambank) is similar to weir flow. The weir flow stage-discharge equation can be solved using the HEC-HMS simulated peak discharge of 1,720 cfs for the 12/31/2005 flood event and the corresponding peak stage of 9.23 ft (gage height) measured at the ACMdP streamflow gage.

Using the rating curve formula for the in-channel portion stage-discharge extended to the recorded peak stage of 9.23 ft for the 12/31/2005 flood event to account for surcharge, the in-channel discharge (with surcharge) was estimated to be about 1,374 cfs.

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[1] These flood years were excluded because these flood years likely had overbank flows upstream of the ACMdP streamflow gage, most likely due to upstream debris obstruction. The recorded peak gage heights for these flood years may have not represented the true gage heights because overbank flows upstream likely bypassed the gage.

[2] Weir flow equation: $Q = C \cdot L \cdot H^{3/2}$, where Q is the discharge rate of the overbank flow (in cfs), C is a dimensionless constant (in the range of 0.2 - 0.5 for weir flow through non-elevated overbank terrain and 0.5 - 1.0 for weir flow through natural high ground barrier (1-3 ft high). Source: HEC-RAS 2D Modeling User's Manual), H is the water head over the bank (ft), and L is the length of the bank over which overtopping occurs (in ft). Using this simplified weir flow equation to estimate the out-of-channel discharge upstream of the streamflow gage assumes that the overflow head along any overflow reach upstream of the gage is the same as that at the gage.

So it follows that the total out-of-channel discharge upstream of the streamflow gage would be estimated at about 346 cfs (1,720 – 1,374 = 346 cfs).

Based on observation that the gage-measured peak stage for the February 9, 2014 storm (8.42 ft stage) represented bankfull condition, then it also follows that the estimated out-of-channel discharge, 346 cfs, was the result of an overflow head of 0.81 ft over the bankfull stage (9.23 - 8.42 = 0.81 ft).

The weir flow stage-discharge equation ($Q = 0.5 \cdot L \cdot H^{3/2}$) [3] was solved for L based on the estimated out-of-channel discharge Q of 346 cfs and the overflow head H of 0.81 ft; L was computed to be 949 ft. Thus, the weir flow stage-discharge equation becomes $Q = 0.5 \times 949 \cdot (GH - 8.42)^{3/2}$, which is applicable for stages greater than 8.42 ft.

Figure 1 shows the new discharge rating curve covering the full range of stage-discharge, in-channel and out-of-channel. Field stage-discharge measurements during the 12/15/2016 and 2/7/2017 storm events are also shown in Figure 1[4]. The field stage-discharge measurements have verified the new rating curve. Figure 2 compares the Dawdy rating curve and the new rating curve. As shown in Figure 1, the stage-discharge function for the upper portion of the rating curve has two parts; (1) the in-channel stage-discharge and (2) the out-of-channel stage-discharge determined by the weir flow stage-discharge equation.

Figure 3 compares the HEC-HMS-simulated discharge hydrograph and the estimated hydrograph derived by applying recorded stage data to the new Stetson rating curve for the 12/31/2005 flood event. Figure 4 compares the HEC-HMS-simulated discharge hydrograph and the estimated hydrograph derived by applying recorded stage data to the Dawdy rating curve for the same event. The estimated hydrograph based on the new Stetson rating curve shows a better match with the simulated hydrograph, particularly with regard to peak discharge, suggesting that the new Stetson rating curve and the HEC-HMS model are both reasonable.

[3] According to the HEC-RAS 2D Modeling User's Manual, the weir flow coefficient is in the range of 0.2 - 0.5 for weir flow through non-elevated overbank terrain and 0.5 - 1.0 for weir flow through natural high ground barrier (1-3 ft high). For the purpose of this analysis, a weir flow coefficient of 0.5 was assumed.

[4] During the 12/15/2016 storm event between 4:20pm and 4:57pm, Stetson performed stage-discharge measurements at ACMdP at the Egger Plaza Bridge. During that period two discharge measurements were made, 440.1 cfs and 451.4 cfs, which accounted for changing stage heights during the measurements. The average of the two measurements was **445.8 cfs**. That period followed the peak of the event and the stage at the bridge was receding. At 4:20pm the stage was 11.36 ft WSE and at 4:57pm the stage was 10.76 ft WSE. The correlating ACMdP gage reading for the average discharge measurement was **6.04 ft**. During the 2/7/2017 storm event, Stetson performed similar discharge measurement. The measured average discharge was about **620.7 cfs** at the ACMdP gage height of **6.87 ft**.

2) Perform HEC-HMS hydrologic modeling to compute the estimated peak discharge for the 1982 flood

The USGS-published 1/4/1982 peak discharge of 1,170 cfs is questionable because it resulted in substantially more extensive flooding and property damage compared to the February 9, 2014 bankfull event (no flood damage reported) and the December 31, 2005 flood event, yet it is only 100 cfs greater than the estimated peak discharge for the February 9, 2014 bankfull storm event (1,070 cfs) and it is much less (550 cfs) than the estimated peak discharge for the December 31, 2005 flood event (1,720 cfs). The USGS-published 1/4/1982 peak stage of 8.11 ft (gage height) was 1.12 ft lower than both the February 9, 2014 bankfull event (8.42 ft) and the December 31, 2005 flood event (9.23 ft).

It's clear that the recorded peak stage for the 1/4/1982 flood event is too low (unreasonably) to use as a reliable indicator of peak discharge. The unreasonableness of this recorded stage may have resulted from a debris obstruction upstream of the gage, which caused flood water to escape from the channel and bypass the gage. In order to develop a more reliable flood frequency curve for the ACMdP streamflow gage, the 1/4/1982 flood peak discharge was re-computed using HEC-HMS modeling.

To generate the time-series rainfall needed for input into the HEC-HMS model, the USGS-published regional total rainfall contours for the 1/4/1982 flood in the Bay Area (Figure 5; USGS, 1989) were used with consideration of local rainfall data recorded at rain gages at Kentfield and Phoenix Lake. The regional rainfall contours indicated 15.34 inches of rainfall at Kentfield. In the same USGS report, the USGS-published local rainfall at Kentfield for the 1/4/1982 storm event was 13.48 inches. The reported local rainfall value was about 88% of the rainfall indicated by the regional rainfall contours. The regional rainfall contours indicated 16 inches of rainfall at Phoenix Lake for the 1/4/1982 event. The MMWD rain gage at Phoenix Lake recorded a local rainfall of 14 inches for the same 1/4/1982 event. The MMWD gage-recorded local rainfall was also about 88% of the rainfall indicated by the regional rainfall contours. Given the discrepancies between the regional rainfall contours and the local rainfall, the following steps were taken to derive the time-series rainfall for each sub basin in the ACMdP watershed:

a. Calculated the area weighted average rainfall for each sub-basin using the USGS regional rainfall contours.
b. Adjusted the area weighted average rainfall by multiplying 88% to compensate for the discrepancies between the regional rainfall contours and the reported local rainfall at Kentfield and Phoenix Lake.
c. Derived the 15-minute time-series rainfall using the 15-minute time-series rainfall pattern for Kentfield provided by Jan Null, Consulting Meteorologist.

With the so-derived time-series rainfall, the calibrated HEC-HMS model (calibrated to the 12/31/2005 flood event) was used to simulate the peak discharge and hydrograph for the 1982

flood without changing any model parameters. Figure 6 shows the simulated results for the 1982 flood. The simulated peak discharge for the 1982 flood was about 2,220 cfs. Using the new Stetson rating curve, the peak stage would be about 9.69 ft assuming no debris obstruction upstream. This estimated peak stage for the 1982 flood would be about 0.46 ft higher than the 12/31/2005 flood. For comparison, the peak stage difference at the Ross Gage in the neighboring Ross Valley between the two flood events was about 0.22 ft. The comparison indicates that the simulated peak discharge for the 1982 flood and the new rating curve are both reasonable.

3) Estimate annual peak discharges since 1985 (post USGS operation of the gage)

The USGS annual peak discharge records are available for the ACMdP streamflow gage for water years 1966 to 1985 with missing data for two years (1974 and 1976). The USGS discontinued operating the streamflow gage in 1985. Since 1999, the County has operated the streamflow gage. The recorded stage data at the ACMdP streamflow gage since 1999 were downloaded from the County's website and the annual peak stages were identified. The new stage-discharge rating curve was then used to estimate annual peak discharges since 1999 to arrive at a complete data set of historical annual peak discharges covering the 50-year period of 1966 to 2016 (with 16 years of no recorded data: 1974, 1976, 1986-1998, and 2009). Table 1 is a summary of the historical annual peak discharges.

Table 1 Historical Annual Peak Discharges at ACMdP Streamflow Gage

Water Year	Date	Peak Gage Height (ft)	Peak Discharge (cfs)
1966	1/5/1966	6.70	620
1967	1/20/1967	6.96	682
1968	1/29/1968	5.17	303
1969	12/28/1968	5.51	443
1970	1/21/1970	7.52	1,180
1971	12/4/1970	6.05	593
1972	5/5/1972	4.60	160
1973	1/12/1973	7.09	1,010
1974	No Record		
1975	10/26/1975	4.33	139
1976	No Record		
1977	1/2/1977	4.18	83
1978	1/14/1978	5.48	301
1979	1/11/1979	6.44	561
1980	1/11/1980	6.55	595
1981	1/27/1981	5.17	240
1982	1/4/1982	8.11 **(9.69)**	1,170 **(2,220)**
1983	3/13/1983	7.22	821
1984	11/19/1983	5.58	323
1985	2/8/1985	6.74	654
1986-1998	No Record		
1999	2/7/1999	4.80	235
2000	1/24/2000	5.80	421
2001	2/24/2001	4.10	129
2002	12/1/2001	6.50	576
2003	12/13/2002	6.00	463
2004	2/25/2004	6.20	507
2005	12/27/2004	6.47	569
2006	12/31/2005	9.23	1,720
2007	12/12/2006	6.08	480
2008	1/25/2008	6.66	614
2009	Record Not Reliable		
2010	1/19/2010	6.13	491
2011	12/28/2010	7.67	880
2012	1/20/2012	7.05	712
2013	12/23/2012	6.07	478
2014	2/9/2014	8.42	1,070
2015	12/15/2014	6.99	696
2016	12/20/2015	6.17	500

Notes: The peak gage height and discharge data for 1966 - 1985 are from the USGS database. The peak gage height data for 1999 - 2016 are from the County website. The peak discharge data for 1999-2016 are derived from the peak gage height data using the new rating curve.

4) Prepare an updated flood frequency analysis for the ACMdP streamflow gage

Using the complete data set of historical annual peak discharges covering the period 1966 to 2016, an updated flood frequency analysis was conducted to develop the relationship between magnitude of flood discharge and probability of occurrence in any given year (and, hence, the long-term average recurrence interval). The HEC-SSP statistical software package program was used to develop this relationship (with the regional skew of -0.49 incorporated into the selected weighted skew in the analysis). The result is graphically shown in Figure 7. Table 2 draws from Figure 7 and summarizes the magnitudes of selected flood events. For comparison, the results of the 2012 Flood Study are also shown in the table.

The updated flood frequency analysis indicates that the December 31, 2005 flood, estimated to be 1,720 cfs, was a 50-year event (i.e., long-term average recurrence interval, 50-years; probability of occurrence in any given year, 2 percent; also referred to as the 2-percent-annual-chance flood). The 1982 flood, estimated to be 2,220 cfs, was approximately a 200-year flood.

Table 2 List of Selected Flood Events and Probabilities

Recurrence interval (year)	Probability	Magnitude of Peak Discharge (cfs) (Updated Analysis)	Magnitude of Peak Discharge (cfs) (2012 Flood Study)
2	0.5	520	449
5	0.2	900	836
10	0.1	1,160	1,120
25	0.04	1,480	1,500
50	0.02	1,720	1,810
100	0.01	1,950	2,110
200	0.005	2,170	
500	0.002	2,460	

5) Revise the conceptual flood reduction measures for the 25-year, 50-year, and 100-year levels of flood protection

This task included the following work:

a. Used the HEC-RAS 1D steady-state model refined during the Phase 1 re-evaluation study to revise the conceptual flood reduction measures for the 25-year, 50-year, and 100-year levels of flood protection using the corresponding discharges derived from the updated flood frequency analysis and using the measures from the 2012 Flood Study as a starting point.

b. Prepared conceptual layouts and designs and cost estimates to a level of detail similar to the 2012 Flood Study.

As shown in Table 2, the 25-year, 50-year, and 100-year peak discharges derived from the updated flood frequency analysis are all less than those in the 2012 Flood Study. In addition, the HEC-RAS model, as refined during the Phase 1 re-evaluation study, had a lower Manning's n in two reaches (the lower reach of ACMdP downstream of Valley Circle and the short reach near La Goma) than the model used in the 2012 Flood Study. Given the same discharge, the water surface profile computed by the refined model would be lower than that computed by the model used in the 2012 Flood Study. Therefore, in light of this new information, the conceptual flood reduction measures for the 25-year, 50-year, and 100-year levels of flood protection in the 2012 Flood Study need to be revised.

The methodology for revising the conceptual flood reduction measures for the 25-year, 50-year, and 100-year levels of flood protection in the 2012 Flood Study employed an iterative modeling approach in which the most effective flood reduction categories were analyzed first. The types of flood reduction measures that were proposed up to the 25-year level of flood protection involved four general categories. These categories were ranked in the order of their relative effectiveness in flood reduction (1 = highest effectiveness, 4 = lowest effectiveness):

1. Construction of the Arroyo Corte Madera del Presidio partial bypass[5]
2. Bridge and culvert enlargement/replacement
3. Creek channel modifications
4. Low floodwalls/berms

The flood reduction measures for the 50- and 100-year levels of flood protection were composed of these same general categories plus a detention basin at the Mill Valley Golf Course.

[5] The partial bypass would divert excess flows (i.e., flows that exceed the channel capacity) around the hydraulically limited reach from Willow to La Goma and return those flows back to the creek below Egger Plaza where the creek capacity increases to about 1,200 cfs. In comparison, the full bypass would divert excess flows (i.e., flows that exceed the channel capacity) around the hydraulically limited reach from Willow to La Goma all the way down to the marsh across from the Tamalpais High School.

Revise the 25-Year Flood Protection Measures

The magnitude of the 25-year flood is approximately 1,480 cfs at the gage (see Table 2), of which about 300 cfs is contributed from Warner Canyon Creek. In the 2012 Flood Study, protection against the 25-year flood required all of the 5-year and 10-year protection measures (without raising the La Goma Street Bridge) plus additional measures. The additional measures focused on preventing overbank flow along the end of Warner Canyon Creek and further overbank flow from above Willow Street to the Egger Plaza Bridge. In this updated analysis, it was found that all the flood reductions measures presented in the 2012 Flood Study are still needed, except that the floodwalls would be reduced in terms of length and height. The measures are listed in Table 3 and shown in Figure 8. The same format as in the 2012 Flood Study was used for numbering the measures.

Table 3 Summary of 25-year Flood Protection Measures

Measure	I.D. number in Figure 1	Notes
Willow Street pedestrian bridge replacements (2); channel widening over about a 150 ft reach near the bridges	[5-04]; [5-05]; [5-06]	The same as the 2012 Flood Study
Removal of concrete weir at the streamflow gage; channel dredging over the 150 ft reach upstream of the gage	[5-03]	The same as the 2012 Flood Study
Raise Sycamore Avenue grade	[10-05]	The same as the 2012 Flood Study
Park Street Bridge replacement	[10-07]	The same as the 2012 Flood Study
Arroyo Corte Madera del Presidio partial bypass	[25-04]	The same as the 2012 Flood Study
Low floodwalls/berms	[5-01]; [5-02]; [10-01]; [10-02]; [10-04]; [10-06]; [25-01]; [25-02]; [25-03]; [25-05]	All floodwalls have reduced length and height, compared to the 2012 Flood Study. The total length is reduced from 4,930 ft to 2,940 ft.

Partial bypass is considered to be the most feasible and appropriate measure to prevent further overbank flow over the reach from above Willow Street to the Egger Plaza Bridge. Constructing a partial bypass has the following benefits:

- Avoids hydraulic conveyance increase measures between Willow Street and Egger Plaza that would otherwise be needed, including
    - Replacement of the existing La Goma Bridge;
    - Replacement of the Locust Avenue Bridge and the private office driveway bridge just upstream;
    - Replacement of the private driveway bridge upstream of Willow Street pedestrian bridge and channel widening; and
    - Raising of the private building upstream of Locust Avenue Bridge.
- Reduces the heights of floodwalls upstream of Willow Street and between Willow Street and Egger Plaza. Without the partial bypass but with the avoided hydraulic conveyance increase measures described above, floodwall heights would need to be up to 5 ft, 6 ft, and 7 ft in order to contain the 25-year, 50-year, and 100-year floods, respectively.

Partial bypass consists of a diversion structure and culvert (see Figures 10, 11, and 12). The diversion structure would be constructed along the creek at Willow Street, or at another suitable alternative location just above Willow Street. The diversion structure would consist of a lateral weir, also commonly referred to as a "side weir," placed along the right bank of the creek[6]. The length of the lateral weir would be 38 feet, 72 feet and 79 feet for the 25-year, 50-year and 100-year design discharge events, respectively. The height of the lateral weir crest would be sufficient low to "crop off" the upper portion of discharge that would otherwise overtop the creek bank downstream during the design discharge event. A concrete manifold inlet structure would collect discharge over the lateral weir and direct the water to the diversion culvert. The diversion culvert would be a rectangular, reinforced concrete box culvert that would convey the diverted water down Willow Street and Miller Avenue and return the water back to the creek below Egger Plaza. The diversion culvert would be buried within the Willow Street right-of-way and within the median right-of-way along Miller Avenue. Hydraulic modeling analysis shows that the concrete culvert would need to be 11 feet wide by 4.5 feet deep, 20 feet wide by 4.5 feet deep and 27 feet wide by 4.5 feet deep for the 25-year, 50-year and 100-year design discharge events, respectively. Considering the maximum width of 12 feet for a CalTrans highway culvert, one 11-foot wide culvert was selected for the 25-year design discharge event, two 10-foot wide culverts, side-by-side, were selected for the 50-year design discharge event, and three 9-foot wide culverts, side-by-side, were selected for the 100-year design discharge event. The culvert would have a design slope of about 0.5%. Due to limited depth of ground cover above the culvert (Figure 12) and traffic loading, the culvert would need to be steel-reinforced with a wall

[6] A lateral weir, or side weir, is a type of diversion structures that allows water to flow over a weir placed along one side of a channel into a manifold inlet that collects and routes the overflow to a diversion culvert.

thickness of 12 inches in accordance with CalTrans design criteria. Further detailed engineering and design work would be needed to verify that the culvert could be accommodated within the Miller Avenue median and be compatible with the overall Miller Avenue streetscape plan. Since sediment carried with large flood discharges could "drop out," settle, and aggrade the channel along the diverted reach when large discharges are diverted to the bypass channel, further adaptive management actions may be needed to control potential sediment accumulation that may be required following a design flood event.

Revise the 50-year and 100-Year Flood Protection Measures

The magnitudes of the 50-year and 100-year floods are approximately 1,720 cfs and 1,950 cfs at the gage (see Table 2), of which about 310 cfs and 370 cfs are contributed from Warner Canyon Creek, respectively. Protection against the 50-year and 100-year floods requires all of the 25-year protection measures, plus additional measures. The additional measures, which focus on preventing overbank flow near Sunnyside Avenue, along the end of Warner Canyon Creek and further overbank flow above Willow Street to the Egger Plaza Bridge, include the Mill Valley Golf Course detention basin[7] and enlargement of a private culvert and a private bridge. These measures are listed in Table 4 and shown in Figure 9.

In the area just downstream of Sunnyside Avenue, the creek passes through a circular, concrete culvert that passes beneath a private commercial building. The culvert obstructs flows exceeding approximately the 38-year flood and needs to be enlarged. This measure is potentially feasible but is entirely on private property and, therefore, would require approval by the property owner.

The Egger Plaza Bridge obstructs discharges starting at about the 43-year flood. This bridge needs to be raised by about 2.6 ft to prevent blockage of flow. This measure is potentially feasible but is entirely on private property and, therefore, would require approval by the property owner.

The Mill Valley Golf Course detention basin would reduce peak discharges in Warner Canyon Creek, thereby eliminating overflow that would otherwise spill over into the Sycamore neighborhood. The detention basin would also reduce flooding farther downstream along lower Arroyo Corte Madera del Presidio. Flooding during a 50-year event could be reduced by up to about 190 cfs, which is a 61% reduction in peak discharge in Warner Canyon Creek and an 11% reduction at the ACMdP streamflow gage, based on a conceptually designed maximum storage of 227 acre-feet. During a 100-year event, flooding could be reduced by up to about 180 cfs, which is a 49% reduction in peak discharge in Warner Canyon Creek and a 9% reduction at the ACMdP streamflow gage.

[7] Refer to Appendix G in the 2012 Flood Study report for details on the Mill Valley Golf Course detention basin.

Table 4 Summary of 50-Year and 100-Year Flood Protection Measures

Measure	I.D. number in Figure 1	Notes
Willow Street pedestrian bridge replacements (2); channel widening over about a 150 ft reach near the bridges	[5-04]; [5-05]; [5-06]	The same as the 2012 Flood Study
Removal of concrete weir at the streamflow gage; channel dredging over the 150 ft reach upstream of the gage	[5-03]	The same as the 2012 Flood Study
Raise Sycamore Avenue grade	[10-05]	The same as the 2012 Flood Study
Park Street Bridge replacement	[10-07]	The same as the 2012 Flood Study
Arroyo Corte Madera del Presidio partial bypass	[25-04]	The same as the 2012 Flood Study
Culvert enlargement beneath private building downstream of Sunnyside Avenue	[50-02]	The same as the 2012 Flood Study
Egger Plaza Bridge replacement	[50-01]	The same as the 2012 Flood Study
Mill Valley Golf Course detention basin	[50-04]	The same as the 2012 Flood Study
Low floodwalls/berms	[5-01]; [5-02]; [10-01]; [10-02]; [10-04]; [10-06]; [25-01]; [25-02]; [25-03]; [25-05]; [50-03]; [50-05]; [100-01]	All floodwalls have reduced length and height, compared to the 2012 Flood Study. For the 50-year flood protection, the total length is reduced from 5,590 ft to 2,920 ft. For the 100-year flood protection, the total length is reduced from 6,155 ft to 4,100 ft.

Cost Estimates

Table 5 is a summary of the estimated total cost for each scenario. The estimated total cost for the 25-year, 50-year, and 100-year levels of flood protection is $14.5 million, $34.8 million, and $40.2 million, respectively. A breakdown of the estimated cost for each measure is attached.

Table 5 Summary of Bundled Measures for the 25-, 50-, and 100-Year Levels of Flood Protection and Estimated Total Cost

Level of Flood Protection	Bundled Measures	Estimated Total Cost ($)
25-Year Protection	• Willow Street pedestrian bridge replacements (2); channel widening over about a 150 ft reach near the bridges • Removal of concrete weir at the streamflow gage; channel dredging over the 150 ft reach upstream of the gage • Raise Sycamore Avenue grade • Park Street Bridge replacement • Arroyo Corte Madera del Presidio partial bypass • Low floodwalls/berms	14,500,000
50-Year Protection	• All 25-Year Flood Protection Measures • Culvert enlargement beneath private building downstream of Sunnyside Avenue • Egger Plaza Bridge replacement • Mill Valley Golf Course detention basin • Additional low floodwalls/berms	34,800,000
100-Year Protection	• All 50-Year Flood Protection Measures • Additional low floodwalls/berms	40,200,000

Notes: Refer to Appendix A for details on the cost estimates.

Figure 1 Updated Rating Curve of the ACMdP Streamflow Gage

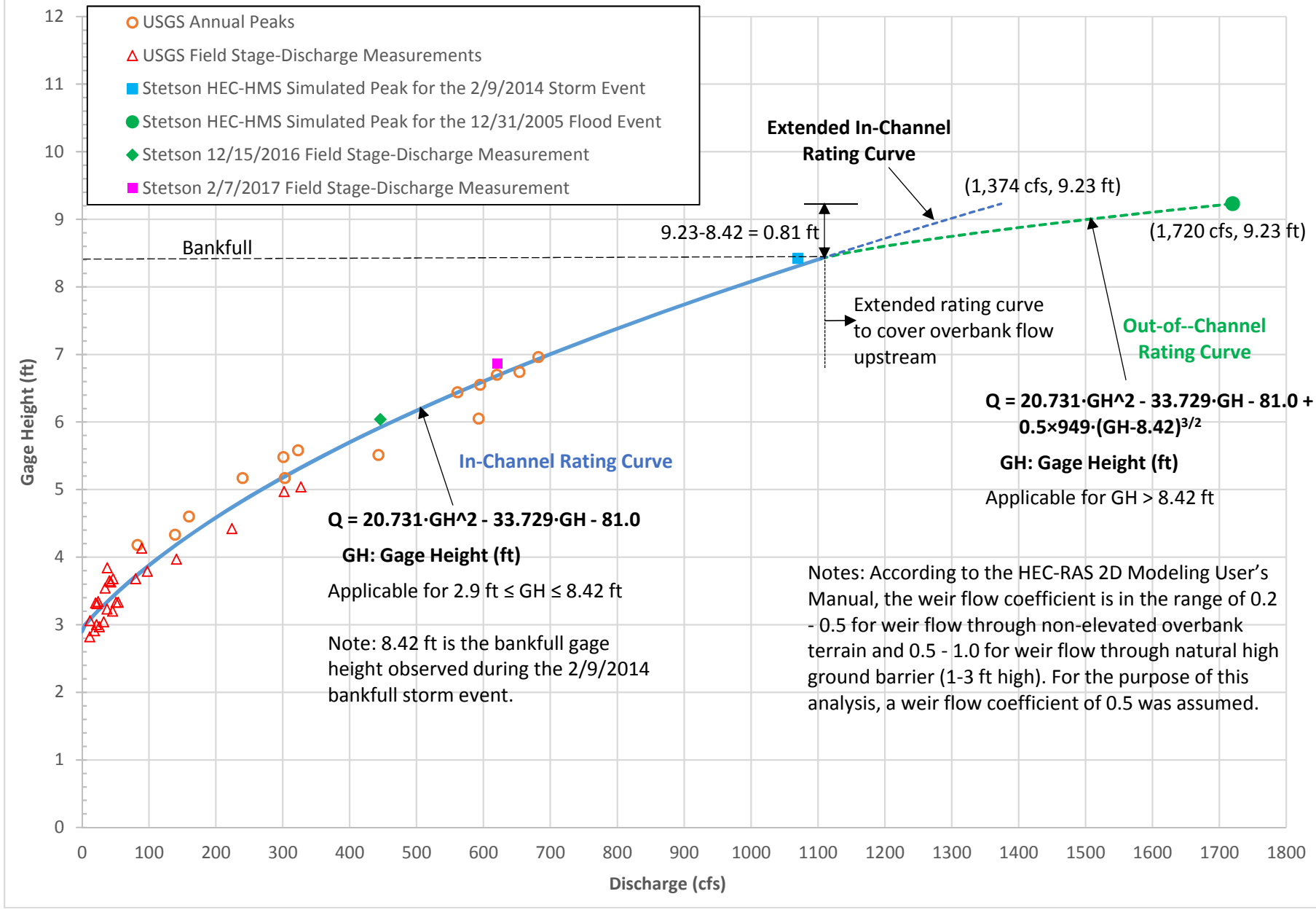


Figure 2 Comparison between Dawdy Rating Curve and Stetson Updated Rating Curve

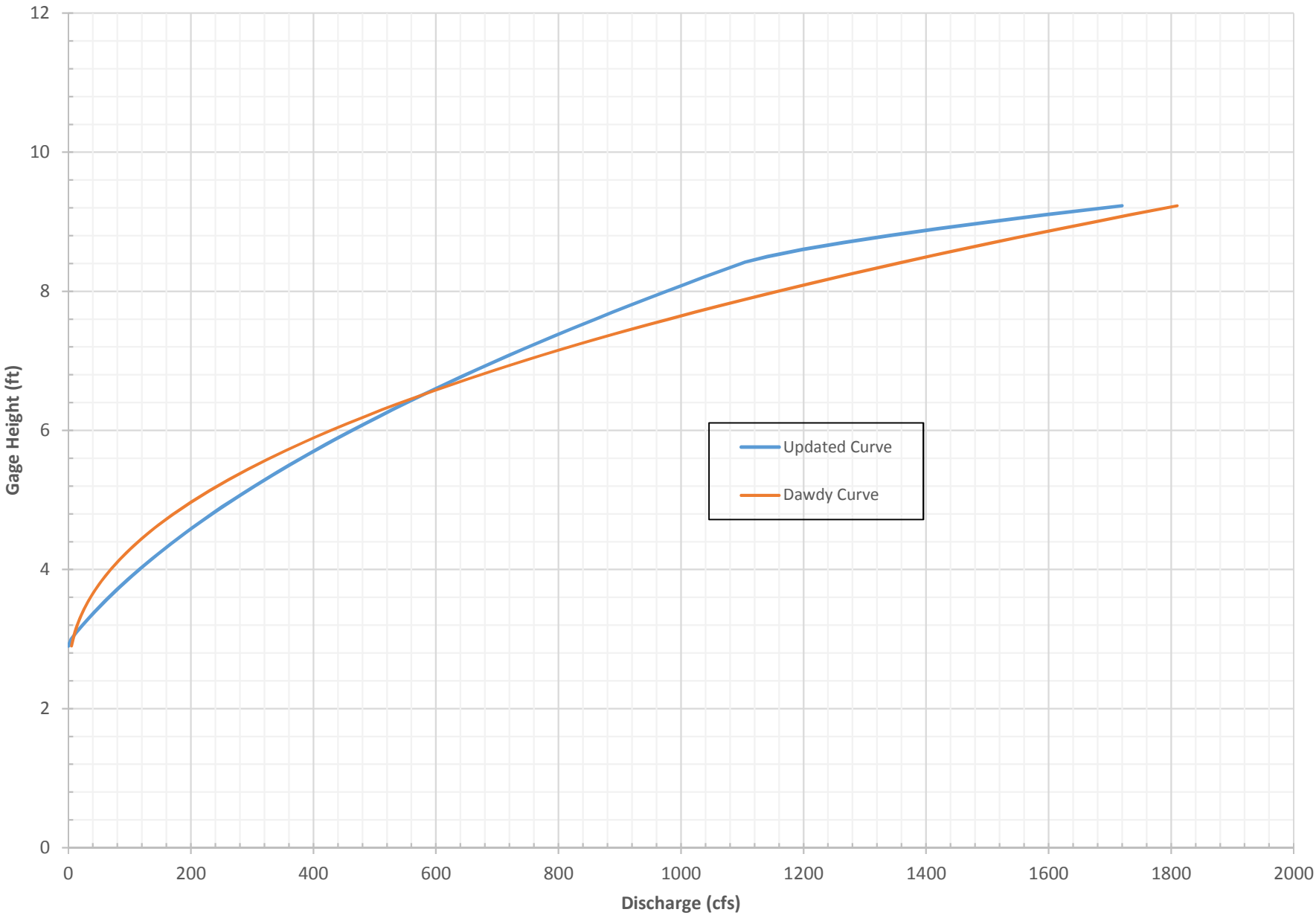


Figure 3 Comparison between Simulated Discharge by HEC-HMS Modeling and Estimated Discharge by the Stetson Updated Rating Curve

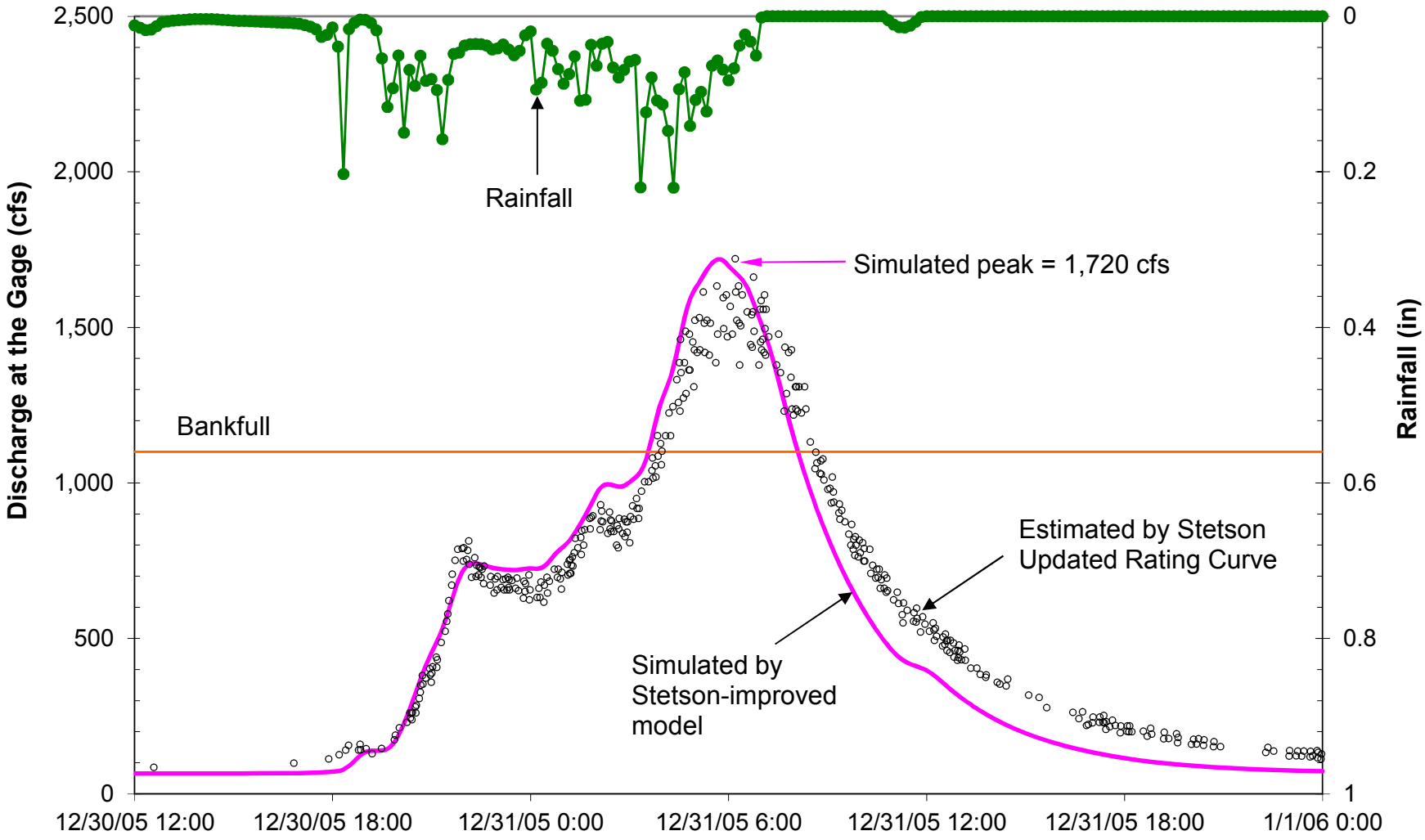


Figure 4 Comparison between Simulated Discharge by HEC-HMS Modeling and Estimated Discharge by the Dawdy Rating Curve

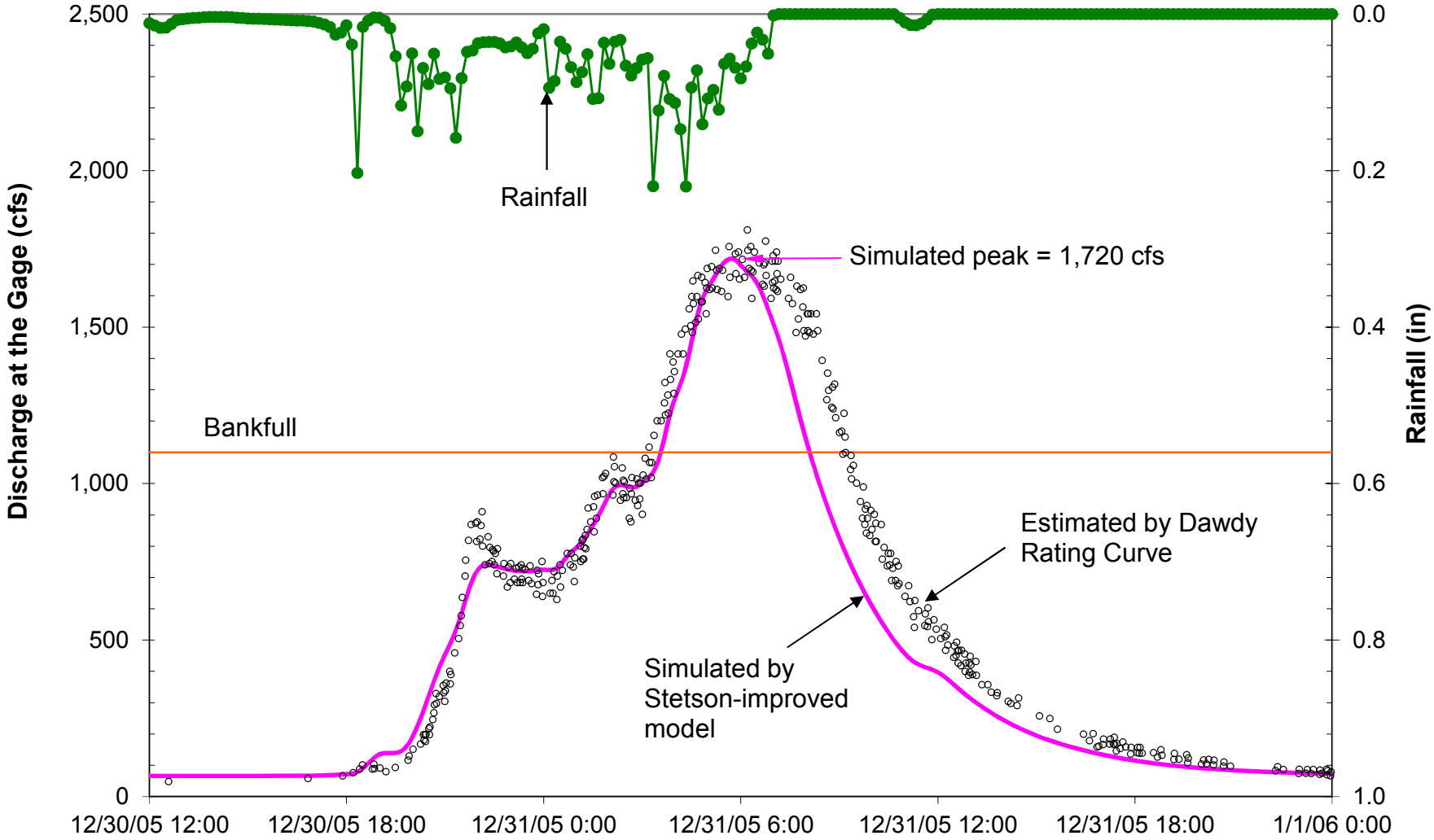
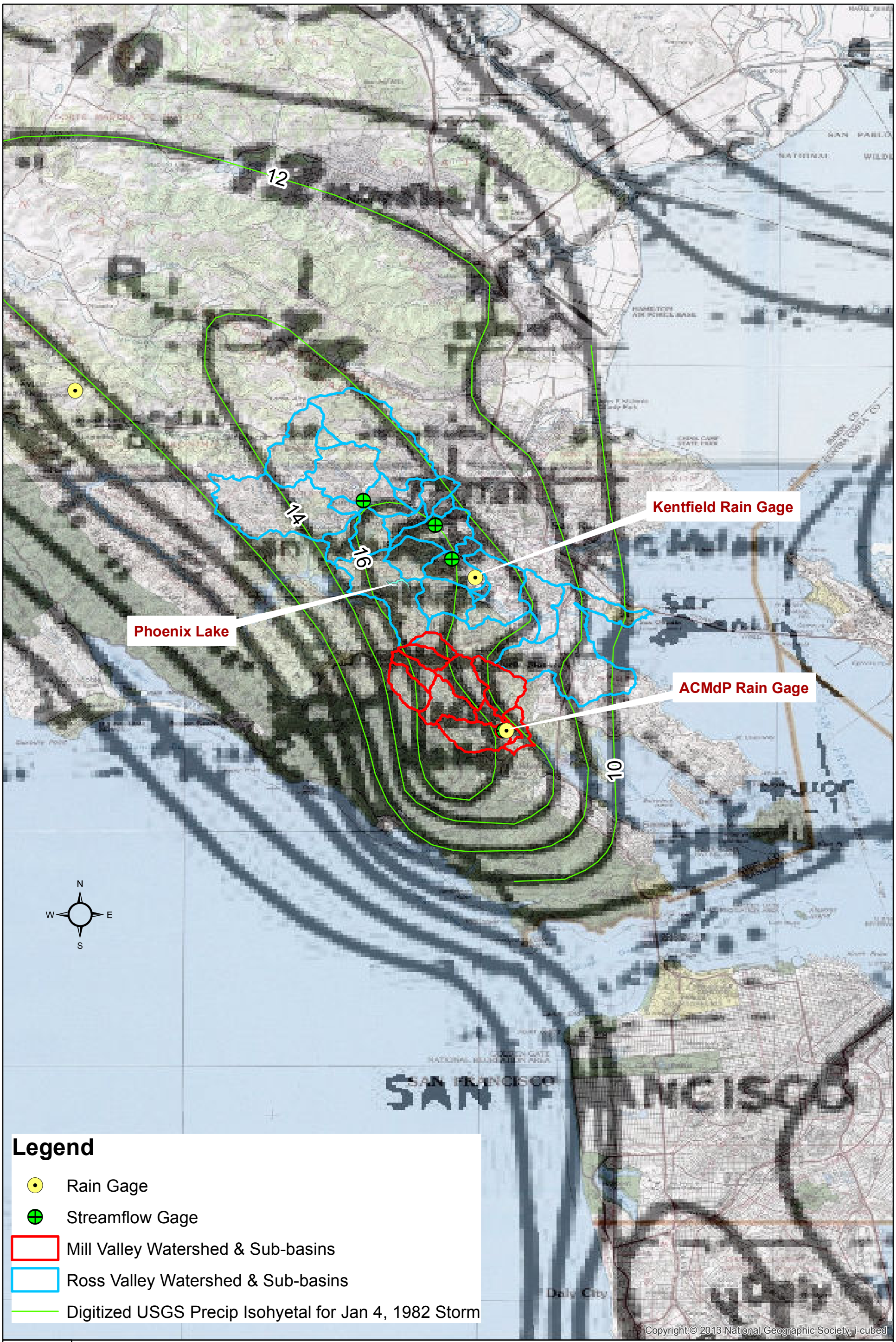


Figure 5



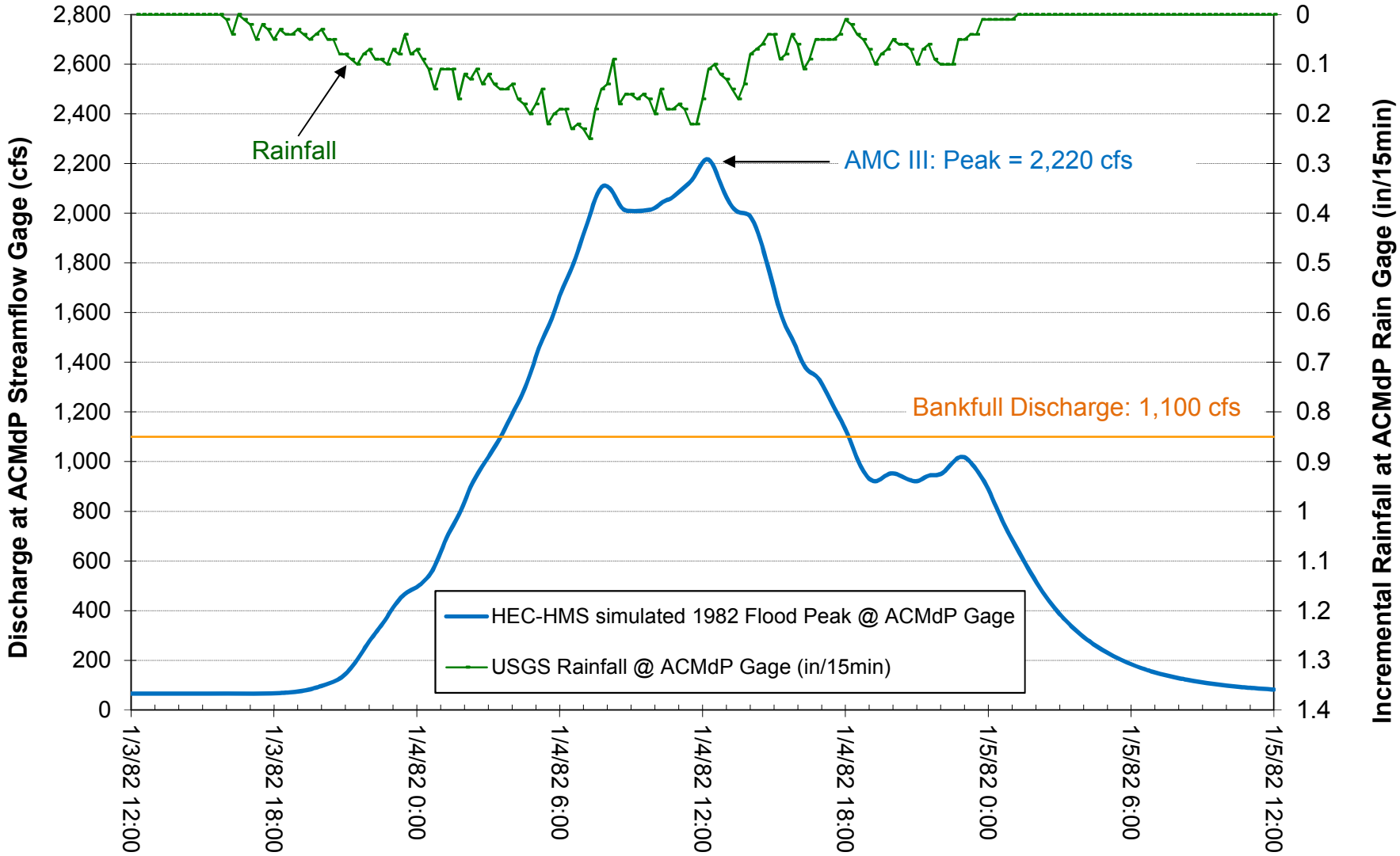
Distribution of Rainfall in the San Francisco Bay Area, January 3-5,1982

Source:
USGS Water-Resources Investigations Report 88-4236
FLOOD OF JANUARY 1982 IN THE SAN FRANCISCO BAY AREA, CALIFORNIA

STETSON ENGINEERS INC.

Document Name: USGS Rainfall GeoReferencing - Map

Figure 6 HEC-HMS Simulated Flow Hydrograph at ACMdP Streamflow Gage for 1/4/1982 Flood Event
(USGS Rainfall Spatial Distribution Adjusted with Kentfield Rainfall Total; Jan Null Temporal Distribution; AMC III)



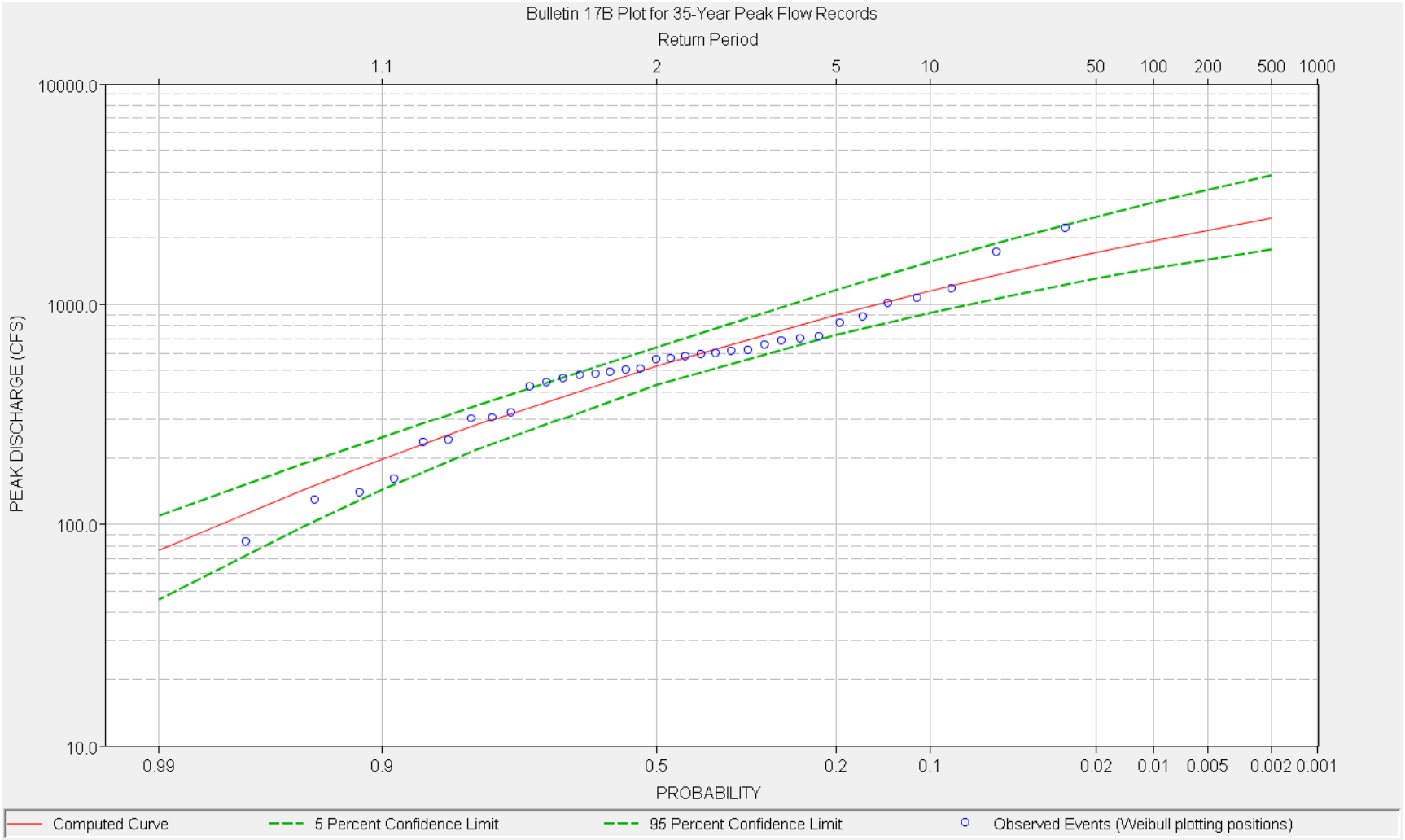
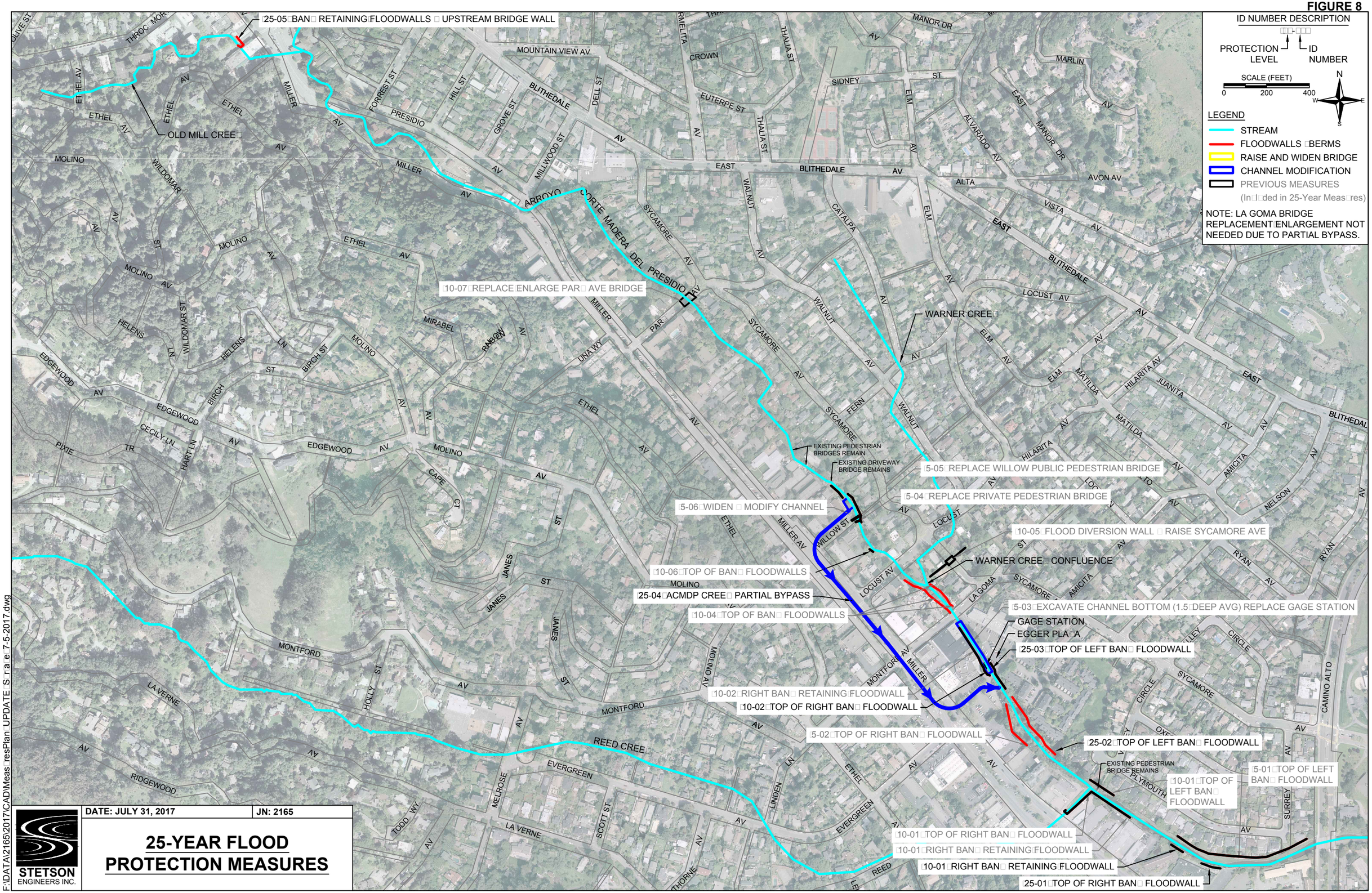


Figure 7 Updated Flood Frequency Curve for the ACMdP Streamflow Gage

FIGURE 8



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25-YEAR FLOOD PROTECTION MEASURES

F:\DATA\2165\2017\CAD\Measures\Plan UPDATE Sheet 7-5-2017.dwg

FIGURE 9

25-05 BAN RETAINING FLOODWALLS UPSTREAM BRIDGE WALL

50-02 REPLACE ENLARGE CULVERT

50-03 TOP OF RIGHT BAN FLOODWALL UPSTREAM BRIDGE WALL

OLD MILL CREE

50-04 MILL VALLEY GOLF COURSE DETENTION BASIN (NOT SHOWN)

10-07 REPLACE ENLARGE PAR AVE BRIDGE

WARNER CREE

50-05 TOP OF BAN FLOODWALLS

EXISTING PEDESTRIAN BRIDGES REMAIN

EXISTING DRIVEWAY BRIDGE REMAINS

50-05 EXTEND FLOODWALL ON TOP EXISTING RETAINING WALL

5-05 REPLACE WILLOW PUBLIC PEDESTRIAN BRIDGE

5-04 REPLACE PRIVATE PEDESTRIAN BRIDGE

5-06 WIDEN MODIFY CHANNEL

10-05 FLOOD DIVERSION WALL RAISE SYCAMORE AVE

WARNER CREE CONFLUENCE

10-06 TOP OF BAN FLOODWALLS

25-04 ACMDP CREE PARTIAL BYPASS

10-04 TOP OF BAN FLOODWALLS

5-03 EXCAVATE CHANNEL BOTTOM (1.5 DEEP AVG) REPLACE GAGE STATION

GAGE STATION

EGGER PLA A

25-03 TOP OF LEFT BAN FLOODWALL

50-01 REPLACE ENLARGE EGGER PLA A BRIDGE

10-02 RIGHT BAN RETAINING FLOODWALL

10-02 TOP OF RIGHT BAN FLOODWALL

10-02 RIGHT BAN RETAINING FLOODWALL (100-Year)

5-02 TOP OF RIGHT BAN FLOODWALL

25-02 TOP OF LEFT BAN FLOODWALL

EXISTING PEDESTRIAN BRIDGE REMAINS

5-01 TOP OF LEFT BAN FLOODWALL

10-01 TOP OF LEFT BAN FLOODWALL

100-01 TOP OF RIGHT BAN FLOODWALL

10-01 TOP OF RIGHT BAN FLOODWALL

10-01 RIGHT BAN RETAINING FLOODWALL

10-01 RIGHT BAN RETAINING FLOODWALL

25-01 TOP OF RIGHT BAN FLOODWALL

ID NUMBER DESCRIPTION

PROTECTION LEVEL – ID NUMBER

SCALE (FEET) 0 200 400

N W E S

LEGEND

- STREAM
- FLOODWALLS BERMS
- RAISE AND WIDEN BRIDGE
- REPLACE ENLARGE CULVERT
- PREVIOUS MEASURES (In ded in 50-Year 100-Year Meas res)

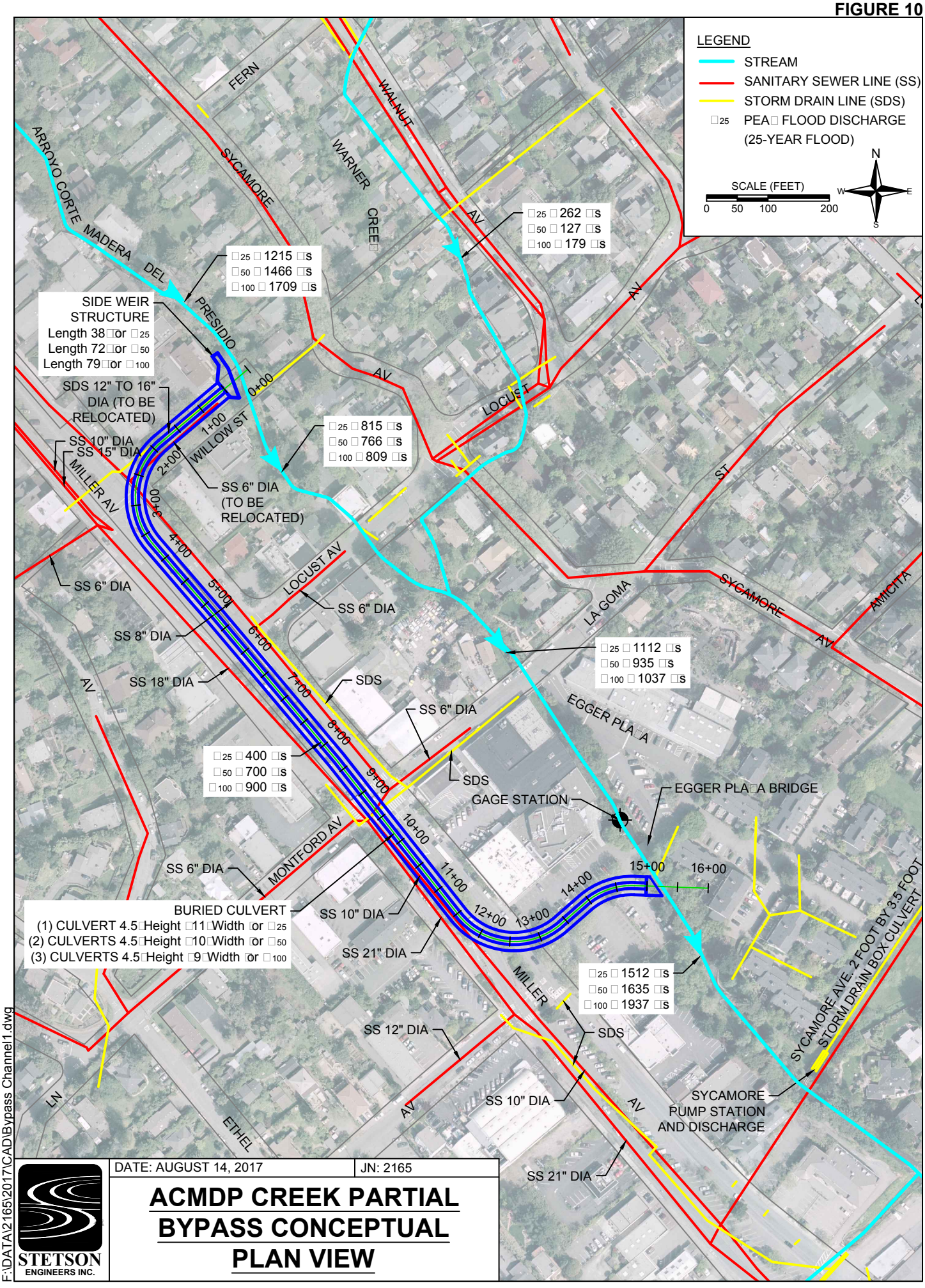
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DATE: JULY 31, 2017 | JN: 2165

50-YEAR AND 100-YEAR FLOOD PROTECTION MEASURES

FIGURE 10



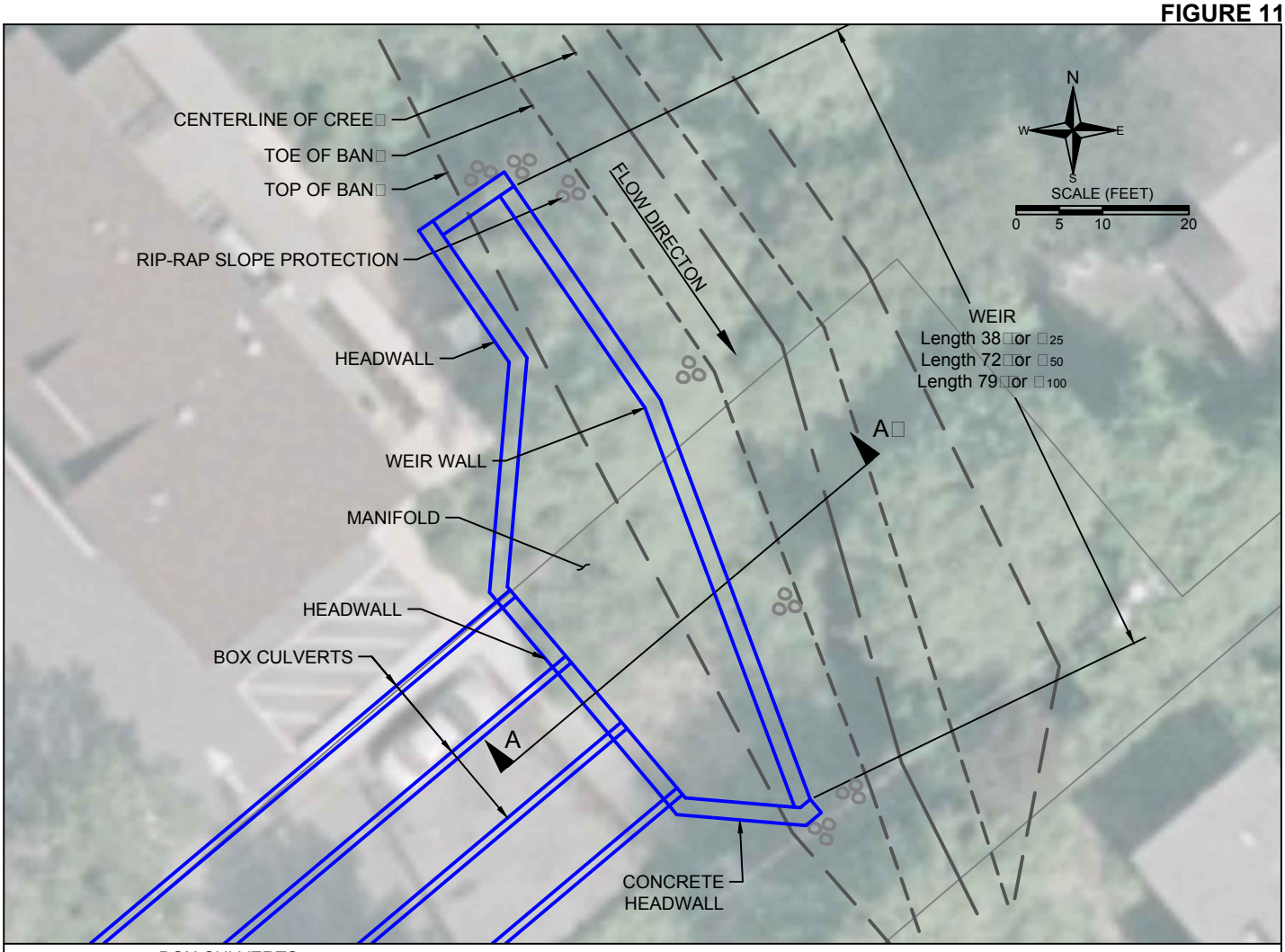
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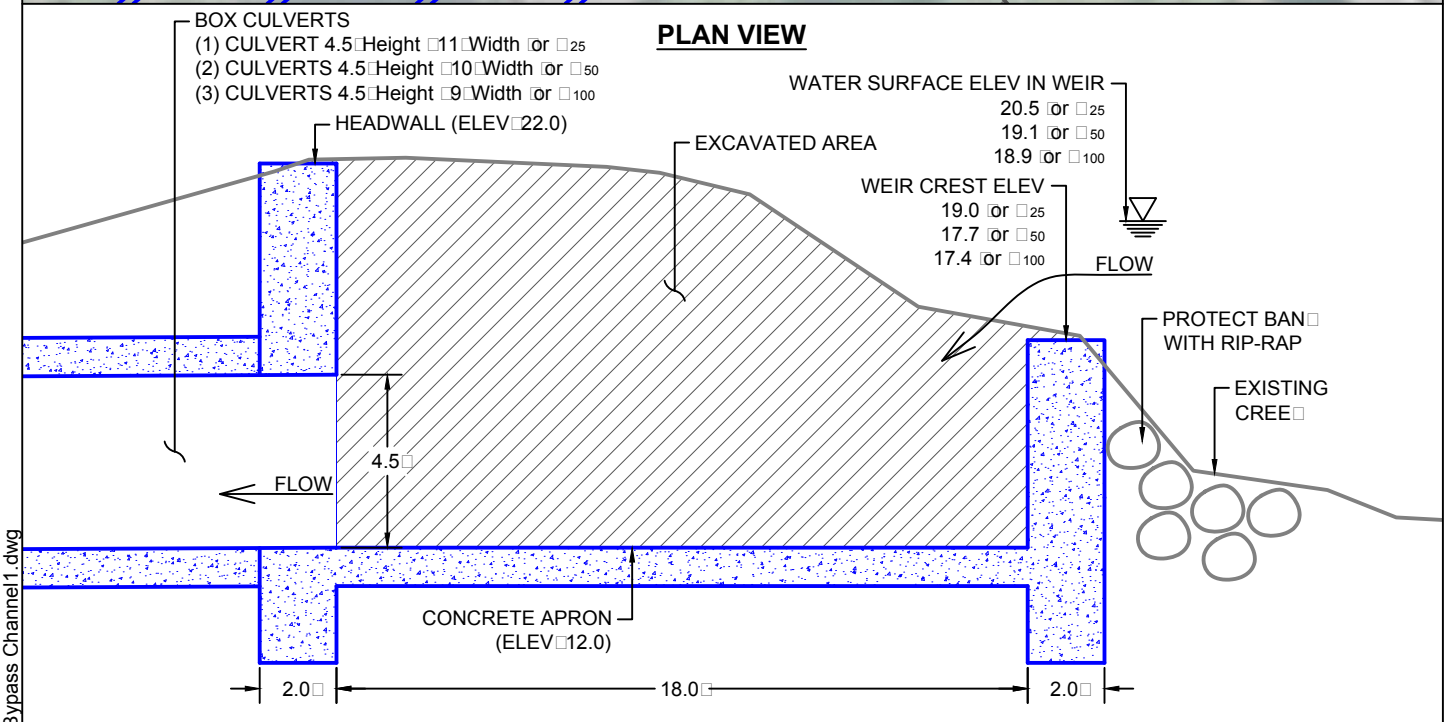
STETSON ENGINEERS INC.

DATE: AUGUST 14, 2017 | JN: 2165

ACMDP CREEK PARTIAL BYPASS CONCEPTUAL PLAN VIEW

FIGURE 11





SECTION A-A (Looking Upstream)

SCALE (FEET)
0 2.5 5

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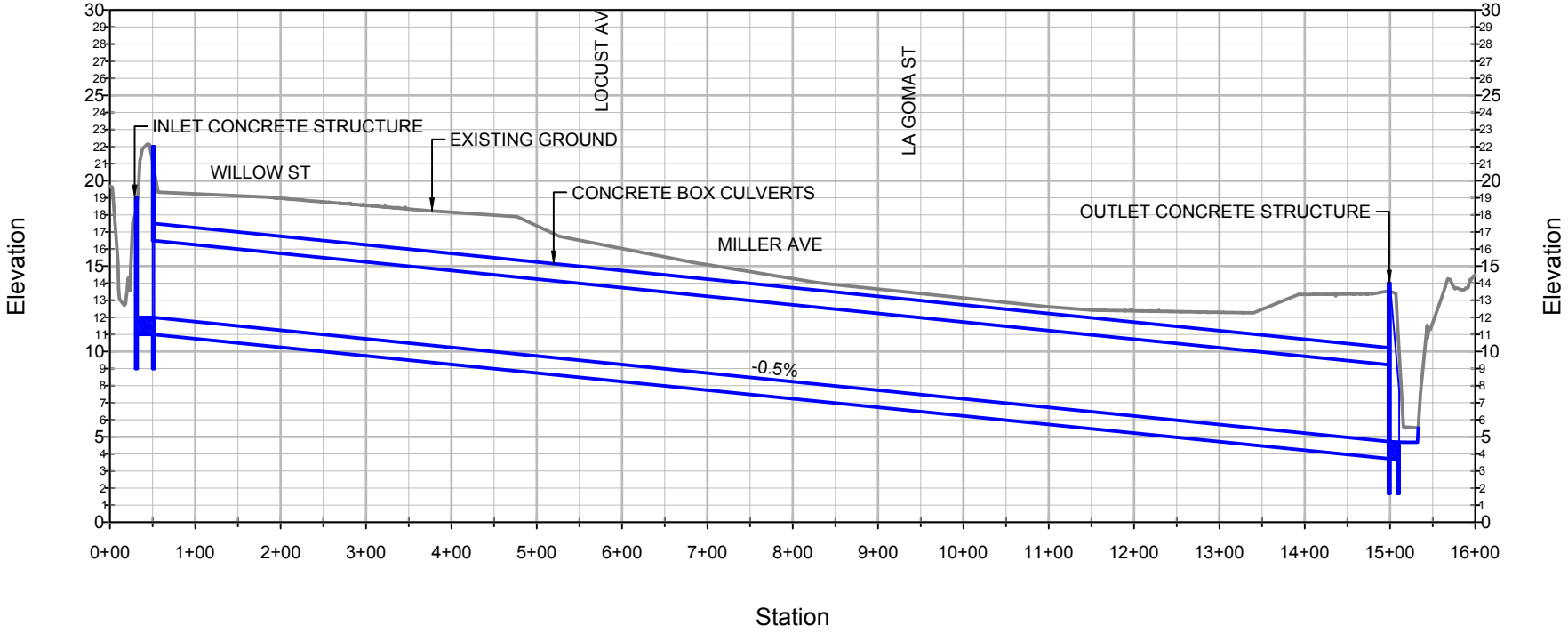
DATE: AUGUST 14, 2017 | JN: 2165

ACMDP CREEK PARTIAL BYPASS INLET CONCEPTUAL STRUCTURE DETAIL

F:\DATA\2165\2017\CAD\Bypass Channel1.dwg

F:\DATA\2165\2017\CAD\Bypass Channel.dwg

BY-PASS CHANNEL CENTERLINE PROFILE



SCALE (FEET)
0 50 100 200

SCALE (FEET)
0 5 10

STETSON ENGINEERS INC.

DATE: JULY 13, 2017 | JN: 2165

ACMDP CREEK PARTIAL BYPASS PROFILE

FIGURE 12

Appendix A

Cost Estimates of Flood Protection Alternatives

- **25-Year Flood Protection Measures**
- **50-Year Flood Protection Measures**
- **100-Year Flood Protection Measures**

- **Sources for Cost Estimates**

Table 1 Cost Summary of 25-Year Flood Damage Reduction Measures

Measure	Construction Cost	Engineering/ Permitting Cost @41% (*)	City's Staff Adminstrative Cost @5%(**)	Contingencies @25% (***)	Total Project Cost
Willow Street pedestrian bridge replacement (2); channel widening over about a 150 ft reach near the bridges [5-04], [5-05], [5-06]	$ 529,750	$ 217,000	$ 38,000	$ 197,000	$ 981,750
Removal of concrete weir at the streamflow gage; channel dredging over the 150 ft reach upstream of the gage [5-03]	$ 429,000	$ 176,000	$ 30,000	$ 159,000	$ 794,000
Raise Sycamore Avenue grade [10-05]	$ 283,000	$ 116,000	$ 20,000	$ 105,000	$ 524,000
Park Street Bridge replacement [10-07]	$ 623,000	$ 255,000	$ 44,000	$ 231,000	$ 1,153,000
ACMDP Creek Partial Bypass [25-04]	$ 3,552,000	$ 1,456,000	$ 250,000	$ 1,315,000	$ 6,573,000
Floodwall/Berms [5-01], [5-02],[10-01], [10-02], [10-04], 10-06], [25-01], [25-02], [25-03], [25-05]	$ 2,385,020	$ 977,000	$ 169,000	$ 883,000	$ 4,414,020
Total	$ 7,801,770	$ 3,197,000	$ 551,000	$ 2,890,000	$ 14,439,770
			Total (Roundup)		**$ 14,500,000**

Notes:

(*) Engineering/Permitting Cost includes:

Engineering and Design	15% of Construction Cost
Environmental Permitting	10% of Construction Cost
Engineering Construction Management	10% of Construction Cost
Environmental Monitoring During Construction	6% of Construction Cost
	41% of Construction Cost

(**) The City's Staff Administrative Cost is 5% of the total cost of Construction and Engineering/Permitting.

(***)The Contingency Cost is 25% of the total cost of Construction, Engineering/Permitting, and the City's Staff Administration.

25-YEAR FLOOD PROTECTION MEASURES
Arroyo Corte Madera Del Presidio Creek, Mill Valley, CA

Item	Description	Quantity	Unit	Unit Price	Const Cost	Engineering/ Permitting Cost @41% (*)	City's Staff Admin. Cost @5%(**)	Contingencies @25% (***)	Total Project Cost	Assumption for Estimated Quantity	Assumption for Unit Price
5-01	**Left Bank Floodwall (Upstream Camino Alto Bridge) Max. Height = 2'**	**650**	**LF**	**$ 514**	**$ 334,170**	**$ 137,000**	**$ 24,000**	**$ 124,000**	**$ 619,170**		
1	Mobilization and Demolization	1	LS	$ 15,000	$ 15,000					--	5% const cost
2	Cleaning and Grubbing	1	LS	$ 29,000	$ 29,000					--	10% const cost
3	Excavation	290	CY	$ 120	$ 34,800					650 x2x 2.0 x3'/(27CY/CF)= 289 CY	BID Averg Arroyo Culvert Replacement Project x 1.5 to account for small volume
4	Reinforced Concrete (Including footings)	130	CY	$ 800	$ 104,000					See FloodwallSummary.xls.	BID Averg Arroyo Culvert Replacement Project
5	4" Dia 6' Long Drainage Pipes	33	Each	$ 30	$ 990					650 /20= 33	2012 RSMeans $4.35/ft x 6 = 30 $/lf (rounded)
6	4" Check Valve	33	Each	$ 50	$ 1,650					650 /20= 33	Price listed in backwater-valves.com ($39) + shipping and installation
7	Rock Veneer	2,600	SF	$ 30	$ 78,000					650 x 2 x2= 2,600 SF	2012 RSMeans $29/sf
8	Geotextile	730	SY	$ 6	$ 4,380					650 x (2x 2.0 +6)/(9SY/SF)= 722 SY	2012 RSMeans $5.34/sy. Use $6/sy
9	Class 2 Aggregate Base	25	CY	$ 80	$ 2,000					650 x 2x 1.0 x0.5'/(27CY/CF)= 24 CY	Lagunitas Road Bridge Replacement Project Contract Unit Price.
10	Backfill	195	CY	$ 80	$ 15,600					650 x 2 x 2.0 x2/27= 193 CY	BID Averg Arroyo Culvert Replacement Project
11	Erosion Protection	650	LF	$ 75	$ 48,750					--	Ross Valley Flood Protection Project
5-02	**Right Bank Floodwall (Between Gage & Valley Circle Pedestrian Bridge) Max. Height = 3'**	**170**	**LF**	**$ 931**	**$ 158,295**	**$ 65,000**	**$ 11,000**	**$ 59,000**	**$ 293,295**		
1	Mobilization and Demolization	1	LS	$ 7,000	$ 7,000					--	5% const cost
2	Cleaning and Grubbing	1	LS	$ 14,000	$ 14,000					--	10% const cost
3	Excavation	110	CY	$ 120	$ 13,200					170 x2x 3.0 x3'/(27CY/CF)= 113 CY	BID Averg Arroyo Culvert Replacement Project x 1.5 to account for small volume
4	Reinforced Concrete (Including footings)	60	CY	$ 1,200	$ 72,000					See FloodwallSummary.xls.	BID Averg Arroyo Culvert Replacement Project
5	4" Dia 8' Long Drainage Pipes	9	Each	$ 35	$ 315					170 /20= 9	2012 RSMeans $4.35/ft x 8 = 35 $/lf (rounded)
6	4" Check Valve	9	Each	$ 50	$ 450					170 /20= 9	Price listed in backwater-valves.com ($39) + shipping and installation
7	Rock Veneer	1,000	SF	$ 30	$ 30,000					170 x 3 x2= 1,020 SF	2012 RSMeans $29/sf
8	Geotextile	230	SY	$ 6	$ 1,380					170 x (2x 3.0 +6)/(9SY/SF)= 227 SY	2012 RSMeans $5.34/sy. Use $6/sy
9	Class 2 Aggregate Base	10	CY	$ 80	$ 800					170 x 2x 1.0 x0.5'/(27CY/CF)= 6 CY	Lagunitas Road Bridge Replacement Project Contract Unit Price.
10	Backfill	80	CY	$ 80	$ 6,400					170 x 2 x 3.0 x2/27= 76 CY	BID Averg Arroyo Culvert Replacement Project
11	Erosion Protection	170	LF	$ 75	$ 12,750					--	Ross Valley Flood Protection Project
5-03	**Excavate Channel Bottom (Upstream of Gage) and Replace Gage (L=300')**	**300**	**LF**	**$ 1,430**	**$ 429,000**	**$ 176,000**	**$ 30,000**	**$ 159,000**	**$ 794,000**		
1	Mobilization / Demobilization	1	LS	$ 19,000	$ 19,000					--	5% Cons Cost
2	Clearing and Grubbing	1	LS	$ 40,000	$ 40,000					--	Assumed
3	Excavation (Incl Dewatering)	400	CY	$ 160	$ 64,000					300'x20'x1.5'=333CY Use400CY	200%BID Avg Arroyo (Excavation)
4	Disposal Excavated Material	400	CY	$ 40	$ 16,000					Same as Excavation	50%BID Avg Arroyo (Excavation)
5	Removal of Existing Concrete Weir Structure	20	CY	$ 500	$ 10,000					30'x2'x5'=11CY Use 20CY	Ross Valley Flood Protection Project
6	Construct Stone Weir Structure	60	TN	$ 500	$ 30,000					30'x5'x5'=28CY@2TN/CY=56TN Use60TN	200%BID Avg Arroyo (Rock-River Boulders)
7	Stream Flow Gaging Equipment	1	LS	$ 27,000	$ 27,000						USR Grant Application
8	Rock Toe Bankline	300	TN	$ 150	$ 45,000					2x300'x4'x2'=178CY@1.6TN/CY=284TN Use300TN	BID Avg Arroyo (Rock-1/4 Ton Class)
9	Bioengineered Bank Stabilization	2,400	SF	$ 45	$ 108,000					2x300'x4'=2400SF	Ross Valley Flood Protection Project
10	Stone Weirs (3 Fish Pools)	100	TN	$ 500	$ 50,000					3(20'x4'x4')=35CY@2TN/CY=71TN Use100TN	200% BID Avg Arroyo (Rock-River Boulders)
11	Revegetation & Cleaning	1,000	SY	$ 20	$ 20,000					300'x30'=1000SY	Assumed
5-04	**Replace Pedestrian Bridge (Private) 41'Span-5'Width-3'Raise-2'Freeboard (WSE=19.3')**	**205**	**SF**	**$ 521**	**$ 106,750**	**$ 44,000**	**$ 8,000**	**$ 40,000**	**$ 198,750**		
1	Mobilization / Demobilization	1	LS	$ 5,000	$ 5,000					--	5% Cons Cost
2	Clearing and Grubbing	1	LS	$ 5,000	$ 5,000					--	Assumed
3	Removal of Existing Bridge	200	SF	$ 30	$ 6,000					30'x6'=180SF.Use 200 SF	Florida Department of Transportation
4	Earthworks for Abutments	15	CY	$ 200	$ 3,000					2x7'x7'x4'=15CY.Use 20cy	200%BID Avg Arroyo (Small Volume)
5	Concrete Abutments	15	CY	$ 1,800	$ 27,000					2x5'x5'x 7.0 = 13	BID Avg Arroyo Culvert Replacement Project
6	Pre-fabricated Steel Truss and Wood Deck	220	SF	$ 150	$ 33,000					41'x5'=205SF Use 220SF	CONTECH
7	Pathway Fill	35	CY	$ 250	$ 8,750					0.5x(5'x 3.0 x 60)x2= 33	300%BID Avg Arroyo (Small Volume & Gravel)
8	Bioengineered Bank Stabilization	400	SF	$ 35	$ 14,000					2x20'x10'=400SF	Ross Valley Flood Protection Project
9	Revegetation & Cleaning	1	LS	$ 5,000	$ 5,000					--	Assumed
5-05	**Replace Pedestrian Bridge (Public) 54'Span-7'Width-3.5'Raise-2'Freeboard (WSE=19.87')**	**378**	**SF**	**$ 415**	**$ 157,000**	**$ 64,000**	**$ 11,000**	**$ 58,000**	**$ 290,000**		
1	Mobilization / Demobilization	1	LS	$ 7,000	$ 7,000					--	5% Cons Cost
2	Clearing and Grubbing	1	LS	$ 7,000	$ 7,000					--	Assumed
3	Removal of Existing Bridge	400	SF	$ 30	$ 12,000					50'x8'=400SF	Florida Department of Transportation
4	Earthworks for Abutments	20	CY	$ 200	$ 4,000					2x7'x9'x4'=19CY Use 20CY	200%BID Avg Arroyo (Small Volume)
5	Concrete Abutments	20	CY	$ 1,800	$ 36,000					2x5'x7'x 7.5 = 19	BID Avg Arroyo Culvert Replacement Project
6	Pre-fabricated Steel Truss and Wood Deck	380	SF	$ 150	$ 57,000					54'x7'=378SF Use 380SF	CONTECH
7	Pathway Fill	60	CY	$ 250	$ 15,000					0.5x(7'x 3.5 x 70)x2= 64	300%BID Avg Arroyo (Small Volume & Gravel)
8	Bioengineered Bank Stabilization	400	SF	$ 35	$ 14,000					2x20'x10'=400SF	Ross Valley Flood Protection Project
9	Revegetation & Cleaning	1	LS	$ 5,000	$ 5,000						Assumed

25-YEAR FLOOD PROTECTION MEASURES
Arroyo Corte Madera Del Presidio Creek, Mill Valley, CA

Item	Description	Quantity	Unit	Unit Price	Const Cost	Engineering/ Permitting Cost @41% (*)	City's Staff Admin. Cost @5%(**)	Contingencies @25% (***)	Total Project Cost	Assumption for Estimated Quantity	Assumption for Unit Price
5-06	**Channel Widening (L=150' w=23')**	**3,450**	**SF**	**$ 77**	**$ 266,000**	**$ 109,000**	**$ 19,000**	**$ 99,000**	**$ 493,000**		
	1 Mobilization / Demobilization	1	LS	$ 12,000	$ 12,000					--	5% Cons Cost
	2 Clearing and Grubbing	1	LS	$ 22,000	$ 22,000					--	Assumed
	3 Excavation	1,300	CY	$ 80	$ 104,000					150'x23'x10'=1278CY Use1300CY	BID Avg Arroyo Culvert Replacement Project
	4 Disposal	1,300	CY	$ 40	$ 52,000					Same as Excavation	50%BID Avg Arroyo Culvert Replacement Project
	5 Bioengineered Bank Stabilization	1,600	SF	$ 35	$ 56,000					150'x10'=1500SF. Use 1600 SF	Ross Valley Flood Protection Project
	7 Revegetation & Cleaning	1	LS	$ 20,000	$ 20,000					--	Assumed
10-01	**Right & Left Bank Floodwalls (Upstream Camino Alto Bridge) RB: Max. Height = 2', LB: Max. Height = 2.5'**	**570**	**LF**	**$ 1,260**	**$ 718,245**	**$ 294,000**	**$ 51,000**	**$ 266,000**	**$ 1,329,245**		
	a Floodwalls	**170**	**LF**	**$ 1,099**	**$ 186,845**						
	1 Mobilization and Demolization	1	LS	$ 8,000	$ 8,000					--	5% const cost
	2 Cleaning and Grubbing	1	LS	$ 16,000	$ 16,000					--	10% const cost
	3 Excavation	90	CY	$ 120	$ 10,800					170 x2x 2.5 x3'/(27CF/CY)= 94 CY	BID Averg Arroyo Culvert Replacement Project x 1.5 to account for small volume
	4 Reinforced Concrete (Including footings)	130	CY	$ 800	$ 104,000					See FloodwallSummary.xls.	BID Averg Arroyo Culvert Replacement Project
	5 4" Dia 6' Long Drainage Pipes	9	Each	$ 65	$ 585					170 /20= 9	2012 RSMeans $4.35/ft x $/lf (rounded)
	6 4" Check Valve	9	Each	$ 50	$ 450					170 /20= 9	Price listed in backwater-valves.com ($39) + shipping and installation
	7 Rock Veneer	900	SF	$ 30	$ 27,000					170 x 2.5 x2= 850 SF	2012 RSMeans $29/sf
	8 Geotextile	210	SY	$ 6	$ 1,260					170 x (2x 2.5 +6)/(9SY/SF)= 208 SY	2012 RSMeans $5.34/sy. Use $6/sy
	9 Class 2 Aggregate Base	10	CY	$ 80	$ 800					170 x 2x 1.0 x0.5'/(27CY/CF)= 6 CY	Lagunitas Road Bridge Replacement Project Contract Unit Price.
	10 Backfill	65	CY	$ 80	$ 5,200					170 x 2 x 2.5 x2/27= 63 CY	BID Averg Arroyo Culvert Replacement Project
	11 Erosion Protection	170	LF	$ 75	$ 12,750					--	Ross Valley Flood Protection Project
	b Retaining/Floodwalls	**400**	**LF**	**$ 1,329**	**$ 531,400**						
	1 Mobilization and Demolization	1	LS	$ 23,000	$ 23,000					--	5% const cost
	2 Cleaning and Grubbing	1	LS	$ 46,000	$ 46,000					--	10% const cost
	3 Excavation	330	CY	$ 120	$ 39,600					400 x 7.5 x3'/(27CF/CY)= 333 CY	BID Averg Arroyo Culvert Replacement Project x 1.5 to account for small volume
	4 Reinforced Concrete (Including footings)	440	CY	$ 800	$ 352,000					See FloodwallSummary.xls.	BID Averg Arroyo Culvert Replacement Project
	5 4" Dia 16' Long Drainage Pipes	20	Each	$ 70	$ 1,400					400 /20= 20	2012 RSMeans $4.35/ft
	6 4" Check Valve	20	Each	$ 50	$ 1,000					400 /20= 20	Price listed in backwater-valves.com ($39) + shipping and installation
	7 Rock Veneer	400	SF	$ 30	$ 12,000					400 x 7.5 x1= 3,000 SF	2012 RSMeans $29/sf
	8 Geotextile	600	SY	$ 6	$ 3,600					400 x 7.5 +6)/(9SY/SF)= 600 SY	2012 RSMeans $5.34/sy. Use $6/sy
	9 Class 2 Aggregate Base	60	CY	$ 80	$ 4,800					400 x 7.5 x0.5'/(27CY/CF)= 56 CY	Lagunitas Road Bridge Replacement Project Contract Unit Price.
	10 Backfill	225	CY	$ 80	$ 18,000					400 x 7.5 x2/27= 222 CY	BID Averg Arroyo Culvert Replacement Project
	11 Erosion Protection	400	LF	$ 75	$ 30,000					--	Ross Valley Flood Protection Project
10-02	**Right Bank Retaining/Floodwall (Near Gage) Max. Height = 7'**	**260**	**LF**	**$ 1,346**	**$ 349,940**	**$ 143,000**	**$ 25,000**	**$ 129,000**	**$ 646,940**		
	1 Mobilization and Demolization	1	LS	$ 15,000	$ 15,000					--	5% const cost
	2 Cleaning and Grubbing	1	LS	$ 30,000	$ 30,000					--	10% const cost
	3 Excavation	200	CY	$ 120	$ 24,000					260 x 7.0 x3'/(27CF/CY)= 202 CY	BID Averg Arroyo Culvert Replacement Project x 1.5 to account for small volume
	4 Reinforced Concrete (Including footings)	180	CY	$ 1,000	$ 180,000					See FloodwallSummary.xls.	BID Averg Arroyo Culvert Replacement Project
	5 4" Dia 16' Long Drainage Pipes	13	Each	$ 70	$ 910					260 /20= 13	2012 RSMeans $4.35/ft x ## = 70 $/lf (rounded)
	6 4" Check Valve	13	Each	$ 50	$ 650					260 /20= 13	Price listed in backwater-valves.com ($39) + shipping and installation
	7 Rock Veneer	1,800	SF	$ 30	$ 54,000					260 x 7 x1= 1,820 SF	2012 RSMeans $29/sf
	8 Geotextile	380	SY	$ 6	$ 2,280					260 x 7.0 +6)/(9SY/SF)= 376 SY	2012 RSMeans $5.34/sy. Use $6/sy
	9 Class 2 Aggregate Base	35	CY	$ 80	$ 2,800					260 x 7.0 x0.5'/(27CY/CF)= 34 CY	Lagunitas Road Bridge Replacement Project Contract Unit Price.
	10 Backfill	135	CY	$ 80	$ 10,800					260 x 7.0 x2/27= 135 CY	BID Averg Arroyo Culvert Replacement Project
	11 Erosion Protection	260	LF	$ 75	$ 19,500					--	Ross Valley Flood Protection Project
	12 Allowance for Tree Protection	1	LS	$ 10,000	$ 10,000					--	Assumed
10-04	**Right & Left Bank Floodwall (Between La Goma Brige & Locust Ave) RB: Max. Height = 3', LB: Max. Height = 2.5'**	**450**	**LF**	**$ 750**	**$ 337,505**	**$ 138,000**	**$ 24,000**	**$ 125,000**	**$ 624,505**		
	1 Mobilization and Demolization	1	LS	$ 15,000	$ 15,000					--	5% const cost
	2 Cleaning and Grubbing	1	LS	$ 29,000	$ 29,000					--	10% const cost
	3 Excavation	300	CY	$ 120	$ 36,000					450 x2x 3.0 x3'/(27CY/CF)= 300 CY	BID Averg Arroyo Culvert Replacement Project x 1.5 to account for small volume
	4 Reinforced Concrete (Including footings)	120	CY	$ 1,000	$ 120,000					See FloodwallSummary.xls.	BID Averg Arroyo Culvert Replacement Project
	5 4" Dia 8' Long Drainage Pipes	23	Each	$ 35	$ 805					450 /20= 23	2012 RSMeans $4.35/ft x 8 = 35 $/lf (rounded)
	6 4" Check Valve	23	Each	$ 50	$ 1,150					450 /20= 23	Price listed in backwater-valves.com ($39) + shipping and installation
	7 Rock Veneer	2,700	SF	$ 30	$ 81,000					450 x 3 x2= 2,700 SF	2012 RSMeans $29/sf
	8 Geotextile	600	SY	$ 6	$ 3,600					450 x (2x 3.0 +6)/(9SY/SF)= 600 SY	2012 RSMeans $5.34/sy. Use $6/sy
	9 Class 2 Aggregate Base	20	CY	$ 80	$ 1,600					450 x 2x 1.0 x0.5'/(27CY/CF)= 17 CY	Lagunitas Road Bridge Replacement Project Contract Unit Price.
	10 Backfill	70	CY	$ 80	$ 5,600					450 x2x2/(27CF/CY)= 67 CY	BID Averg Arroyo Culvert Replacement Project
	11 Erosion Protection	450	LF	$ 75	$ 33,750					--	Ross Valley Flood Protection Project
	12 Allowance for Tree Protection	1	LS	$ 10,000	$ 10,000					--	

25-YEAR FLOOD PROTECTION MEASURES
Arroyo Corte Madera Del Presidio Creek, Mill Valley, CA

Item	Description	Quantity	Unit	Unit Price	Const Cost	Engineering/ Permitting Cost @41% (*)	City's Staff Admin. Cost @5%(**)	Contingencies @25% (***)	Total Project Cost	Assumption for Estimated Quantity	Assumption for Unit Price
10-05	**Flood Diversion Wall (L=170') and Raise Sycamore Ave (h=2' Slope5%)**	**1**	**LS**	**$ 283,000**	**$ 283,000**	**$ 116,000**	**$ 20,000**	**$ 105,000**	**$ 524,000**		
1	Traffic Control and Signs	1	LS	$ 13,000	$ 13,000					--	5% Cons Cost
2	Clearing and Grubbing (Includes Safety Works)	1	LS	$ 10,000	$ 10,000					--	Assumed
4	Traffic Control and Signs	1	LS	$ 10,000	$ 10,000					--	Lagunitas Road Bridge Replacement Project
5	Removal of Existing Road (incl Sidewalk)	400	SY	$ 60	$ 24,000					(2x40'+20')x40'x0.5'=72CY@2TN/CY=148TN Use150TN	200%Lagunitas Road Bridge Replacement Project
6	Road Sub-grade Compacted Backfill	150	CY	$ 80	$ 12,000					(0.5x(100'+20'))x40'x2'=178CY Use180CY	BID Avg Arroyo Culvert Replacement Project
7	Class 2 Aggregate Base	100	CY	$ 80	$ 8,000					100'x20'x0.5'=37CY@2TN/CY=74TN Use80TN	Lagunitas Road Bridge Replacement Project
8	Asphalt Concrete Resurfacing	80	TN	$ 300	$ 24,000					2x100'x4'x1'=30CY	BID Avg Arroyo Culvert Replacement Project
9	Concrete Curb and Sidewalk	40	CY	$ 1,800	$ 72,000					(11'+3'/2)x(96'+72')x2'=87CY Use90CY	BID Avg Arroyo Culvert Replacement Project
10	2' Floodwalls (incl Earthworks & Others)	200	LF	$ 400	$ 80,000					--	See Floodwall Estimates
11	Driveway Modifications	1	TN	$ 10,000	$ 10,000					One each side	Assumed
12	Signs and Painting	1	LS	$ 10,000	$ 10,000					--	Assumed
13	Revegetation	1	LS	$ 10,000	$ 10,000					--	Assumed
10-06	**Right & Left Bank Floodwall (Upstream from Locust Ave) RB: Max. Height = 1.5', LB: Max. Height = 1'**	**280**	**LF**	**$ 557**	**$ 156,000**	**$ 64,000**	**$ 11,000**	**$ 58,000**	**$ 289,000**		
1	Mobilization and Demolization	1	LS	$ 7,000	$ 7,000					--	5% const cost
2	Cleaning and Grubbing	1	LS	$ 14,000	$ 14,000					--	10% const cost
3	Excavation	90	CY	$ 120	$ 10,800					280 x2x 1.5 x3'/(27CY/CF)= 93 CY	BID Averg Arroyo Culvert Replacement Project x 1.5 to account for small volume
4	Reinforced Concrete (Including footings)	30	CY	$ 1,500	$ 45,000					See FloodwallSummary.xls.	BID Averg Arroyo Culvert Replacement Project
5	4" Dia 6' Long Drainage Pipes	14	Each	$ 30	$ 420					280 /20= 14	2012 RSMeans $4.35/ft x 6 = 30 $/lf (rounded)
6	4" Check Valve	14	Each	$ 50	$ 700					280 /20= 14	Price listed in backwater-valves.com ($39) + shipping and installation
7	Rock Veneer	800	SF	$ 30	$ 24,000					280 x 1.5 x2= 840 SF	2012 RSMeans $29/sf
8	Geotextile	280	SY	$ 6	$ 1,680					280 x (2x 1.5 +6)/(9SY/SF)= 280 SY	2012 RSMeans $5.34/sy. Use $6/sy
9	Class 2 Aggregate Base	15	CY	$ 80	$ 1,200					280 x 2x 1.0 x0.5'/(27CY/CF)= 10 CY	Lagunitas Road Bridge Replacement Project Contract Unit Price.
10	Backfill	65	CY	$ 80	$ 5,200					280 x 2 x 1.5 x2/27= 62 CY	BID Averg Arroyo Culvert Replacement Project
11	Erosion Protection	280	LF	$ 75	$ 21,000					--	Ross Valley Flood Protection Project
12	Allowance for Tree Protection	1	LS	$ 25,000	$ 25,000					--	Assumed
10-07	**Replace Park Ave Bridge 27'Span-40'Width-No Raise-4.3'Freeboard (WSE=29.53')**	**1,080**	**SF**	**$ 577**	**$ 623,000**	**$ 255,000**	**$ 44,000**	**$ 231,000**	**$ 1,153,000**		
1	Mobilization / Demobilization	1	LS	$ 29,000	$ 29,000					--	5% Cons Cost
2	Clearing and Grubbing	1	LS	$ 10,000	$ 10,000					--	Assumed
3	Traffic Control and Signs	1	LS	$ 10,000	$ 10,000					--	Lagunitas Road Bridge Replacement Project
4	Removal of Existing Bridge (Incl Culvert)	1,080	SF	$ 50	$ 54,000					27'x40'=1080SF	Florida Department of Transportation
5	Excavation for Abutments	150	CY	$ 160	$ 24,000					2x7'x42'x6'=131CY Use 150CY	200%BID Avg Arroyo (Small Volume)
6	Concrete Abutments	90	CY	$ 1,000	$ 90,000					2x5'x40'x6'=89CY Use 90CY	BID Avg Arroyo Culvert Replacement Project & Lagunitas
7	Concrete Slab Deck	110	CY	$ 1,800	$ 198,000					(27'+2x5')x40'x2'=110CY	BID Avg Arroyo Culvert Replacement Project & lagunitas
8	Concrete Barrier & Railing	40	LF	$ 300	$ 12,000					27'+20'=37' Use40LF	Lagunitas Road Bridge Replacement Project
9	Concrete Wingwalls (Incl Earthworks)	30	CY	$ 1,800	$ 54,000					4(10'x20'x1')=30CY	Ross Valley Flood Protection Project
10	Concrete Curb and Sidewalk	10	CY	$ 1,800	$ 18,000					2x37'x5'x0.5'=7CY Use10CY	BID Avg Arroyo Culvert Replacement Project
11	Asphalt Concrete Resurfacing	40	TN	$ 300	$ 12,000					37'x30'x0.5'=20CY@2TN/CY=40TN	BID Avg Arroyo Culvert Replacement Project
12	Signs and Painting	1	LS	$ 10,000	$ 10,000					--	Assumed
13	Bioengineered Bank Stabilization	1,200	SF	$ 35	$ 42,000					2x60'x10'=1200SF	Ross Valley Flood Protection Project (1.5:1 Slope)
14	Revegetation	1	LS	$ 10,000	$ 10,000					--	Assumed
15	Allowance for Utilities	1	LS	$ 50,000	$ 50,000					--	Assumed
25-01	**Right Bank Floodwall (Upstream Camino Alto Bridge) Max. Height = 0.5'**	**60**	**LF**	**$ 650**	**$ 39,010**	**$ 16,000**	**$ 3,000**	**$ 15,000**	**$ 73,010**		
1	Mobilization and Demolization	1	LS	$ 2,000	$ 2,000					--	5% const cost
2	Cleaning and Grubbing	1	LS	$ 3,000	$ 3,000					--	10% const cost
3	Excavation	10	CY	$ 120	$ 1,200					60 x2x 0.5 x3'/(27CY/CF)= 7 CY	BID Averg Arroyo Culvert Replacement Project x 1.5 to account for small volume
4	Reinforced Concrete (Including footings)	30	CY	$ 800	$ 24,000					See FloodwallSummary.xls.	BID Averg Arroyo Culvert Replacement Project
5	4" Dia 4' Long Drainage Pipes	3	Each	$ 20	$ 60					60 /20= 3	2012 RSMeans $4.35/ft x 4 = 20 $/lf (rounded)
6	4" Check Valve	3	Each	$ 50	$ 150					60 /20= 3	Price listed in backwater-valves.com ($39) + shipping and installation
7	Rock Veneer	100	SF	$ 30	$ 3,000					60 x 0.5 x2= 60 SF	2012 RSMeans $29/sf
8	Geotextile	50	SY	$ 6	$ 300					60 x (2x 0.5 +6)/(9SY/SF)= 47 SY	2012 RSMeans $5.34/sy. Use $6/sy
9	Class 2 Aggregate Base	5	CY	$ 80	$ 400					60 x 2x 1.0 x0.5'/(27CY/CF)= 2 CY	Lagunitas Road Bridge Replacement Project Contract Unit Price.
10	Backfill	5	CY	$ 80	$ 400					60 x 2 x 0.5 x2/27= 4 CY	BID Averg Arroyo Culvert Replacement Project
11	Erosion Protection	60	LF	$ 75	$ 4,500					--	Ross Valley Flood Protection Project

25-YEAR FLOOD PROTECTION MEASURES
Arroyo Corte Madera Del Presidio Creek, Mill Valley, CA

Item	Description	Quantity	Unit	Unit Price	Const Cost	Engineering/ Permitting Cost @41% (*)	City's Staff Admin. Cost @5%(**)	Contingencies @25% (***)	Total Project Cost	Assumption for Estimated Quantity	Assumption for Unit Price
25-02	**Left Bank Floodwall (Between Gage & Valley Circle Pedestrian Bridge) Max. Height = 2'**	**300**	**LF**	**$ 571**	**$ 171,255**	**$ 70,000**	**$ 12,000**	**$ 63,000**	**$ 316,255**		
	1 Mobilization and Demolization	1	LS	$ 7,000	$ 7,000					--	5% const cost
	2 Cleaning and Grubbing	1	LS	$ 15,000	$ 15,000					--	10% const cost
	3 Excavation	130	CY	$ 120	$ 15,600					300 x2x 2.0 x3'/(27CY/CF)= 133 CY	BID Averg Arroyo Culvert Replacement Project x 1.5 to account for small volume
	4 Reinforced Concrete (Including footings)	70	CY	$ 800	$ 56,000					See FloodwallSummary.xls.	BID Averg Arroyo Culvert Replacement Project
	5 4" Dia 6' Long Drainage Pipes	15	Each	$ 30	$ 450					300 /20= 15	2012 RSMeans $4.35/ft x 6 = 30 $/lf (rounded)
	6 4" Check Valve	15	Each	$ 50	$ 750					300 /20= 15	Price listed in backwater-valves.com ($39) + shipping and installation
	7 Rock Veneer	1,200	SF	$ 30	$ 36,000					300 x 2 x2= 1,200 SF	2012 RSMeans $29/sf
	8 Geotextile	330	SY	$ 6	$ 1,980					300 x (2x 2.0 +6)/(9SY/SF)= 333 SY	2012 RSMeans $5.34/sy. Use $6/sy
	9 Class 2 Aggregate Base	15	CY	$ 80	$ 1,200					300 x 2x 1.0 x0.5'/(27CY/CF)= 11 CY	Lagunitas Road Bridge Replacement Project Contract Unit Price.
	10 Backfill	90	CY	$ 80	$ 7,200					300 x 2 x 2.0 x2/27= 89 CY	BID Averg Arroyo Culvert Replacement Project
	11 Erosion Protection	1	LF	$ 75	$ 75					--	Ross Valley Flood Protection Project
	12 Allowance for Tree Protection	1	LS	$ 30,000	$ 30,000						
25-03	**Left Bank Floodwall (Near Gage) Max. Height = 1'**	**130**	**LF**	**$ 255**	**$ 33,160**	**$ 14,000**	**$ 2,000**	**$ 12,000**	**$ 61,160**		
	1 Mobilization and Demolization	1	LS	$ 1,000	$ 1,000					--	5% const cost
	2 Cleaning and Grubbing	1	LS	$ 3,000	$ 3,000					--	10% const cost
	3 Excavation	30	CY	$ 120	$ 3,600					130 x2x 1.0 x3'/(27CY/CF)= 29 CY	BID Averg Arroyo Culvert Replacement Project x 1.5 to account for small volume
	4 Reinforced Concrete (Including footings)	2	CY	$ 1,800	$ 3,600					See FloodwallSummary.xls.	BID Averg Arroyo Culvert Replacement Project
	5 4" Dia 4' Long Drainage Pipes	7	Each	$ 20	$ 140					130 /20= 7	2012 RSMeans $4.35/ft x 4 = 20 $/lf (rounded)
	6 4" Check Valve	7	Each	$ 50	$ 350					130 /20= 7	Price listed in backwater-valves.com ($39) + shipping and installation
	7 Rock Veneer	300	SF	$ 30	$ 9,000					130 x 1 x2= 260 SF	2012 RSMeans $29/sf
	8 Geotextile	120	SY	$ 6	$ 720					130 x (2x 1.0 +6)/(9SY/SF)= 116 SY	2012 RSMeans $5.34/sy. Use $6/sy
	9 Class 2 Aggregate Base	5	CY	$ 80	$ 400					130 x 2x 1.0 x0.5'/(27CY/CF)= 5 CY	Lagunitas Road Bridge Replacement Project Contract Unit Price.
	10 Backfill	20	CY	$ 80	$ 1,600					130 x 2 x 1.0 x2/27= 19 CY	BID Averg Arroyo Culvert Replacement Project
	11 Erosion Protection	130	LF	$ 75	$ 9,750					--	Ross Valley Flood Protection Project
25-04	**ACMDP Creek Partial Bypass ((1)RC Culvert h=4.5' w=11' L=1600') (Weir L=38') (Q=400cfs)**	**1,600**	**LF**	**$ 2,220**	**$ 3,552,000**	**$ 1,456,000**	**$ 250,000**	**$ 1,315,000**	**$ 6,573,000**		5% Const Cost
	1 Mobilization / Demobilization	1	LS	$ 164,000	$ 164,000					--	Assumed
	2 Clearing and Grubbing	1	LS	$ 75,000	$ 75,000					--	Assumed
	3 Traffic Control and Signs	1	LS	$ 40,000	$ 40,000					--	Assumed
	4 Earthworks for Concrete Diversion Structure	500	CY	$ 80	$ 40,000					40'x20'x15'=444CY Use450CY	BID Avg Arroyo Culvert Replacement Project
	5 Concrete for Inlet and Outlet Structures	150	CY	$ 1,500	$ 225,000					40'x30'x2'=89CY Use90CY	BID Avg Arroyo Culvert Replacement Project
	6 5' x 11' Sluice Gate	1	EA	$ 50,000	$ 50,000					--	Assumed
	7 Removal of Existing Road	1	LS	$ 32,000	$ 32,000					1600'x15'=2667SY Use2700SY	Lagunitas Road Bridge Replacement Project
	8 Earthworks for Concrete Box Culvert	8,000	CY	$ 80	$ 640,000					1600'x15'x10'=8889CY Use9000CY	BID Avg Arroyo Culvert Replacement Project
	9 Prefabricated Reinforced Concrete Box (4.5'x11')	2,000	CY	$ 1,000	$ 2,000,000					--	33'x1'x1'=1.22CY/LF@$1000/CY=$1222/LF Use $1220/LF
	10 Class 2 Aggregate Base	650	TN	$ 80	$ 52,000					1600'x15'x0.75'=667CY Use700CY	Lagunitas Road Bridge Replacement Project
	11 Asphalt Concrete Resurfacing	1	LS	$ 110,000	$ 110,000					1600'x15'x0.5'=444CY@2TN/CY=889TN Use900TN	BID Avg Arroyo Culvert Replacement Project
	12 Rip-Rap Outlet Structure	140	TN	$ 100	$ 14,000					40'x20'x4'=118CY@1.6TN/CY=190TN Use200TN	BID Avg Arroyo Culvert Replacement Project
	13 Signs and Painting	1	LS	$ 20,000	$ 20,000					--	Assumed
	14 Relocate 16" Storm Drain Pipe Line @ Willow St.	300	LF	$ 200	$ 60,000						Assumed
	15 Relocate 6" Sewer Pipe Line @ Willow St.	200	LF	$ 150	$ 30,000						Assumed
	Note: Utilities in Miller Ave will be charged to Miller Avenue Project, and, therefore, were not considered										
25-05	**Bank Retaining/ Floodwall and Upstream Bridge Wall (Downstream of Parking Bridge in Old Mill Creek) RB: Max. Height = 1.5', LB: Max. Height = 4.5'**	**70**	**LF**	**$ 1,249**	**$ 87,440**	**$ 36,000**	**$ 6,000**	**$ 32,000**	**$ 161,440**		
	1 Mobilization and Demolization	1	LS	$ 4,000	$ 4,000					--	5% const cost
	2 Cleaning and Grubbing	1	LS	$ 8,000	$ 8,000					--	10% const cost
	3 Excavation	70	CY	$ 120	$ 8,400					70 x2x 4.5 x3'/(27CY/CF)= 70 CY	BID Averg Arroyo Culvert Replacement Project x 1.5 to account for small volume
	4 Reinforced Concrete (Including footings)	20	CY	$ 1,800	$ 36,000					See FloodwallSummary.xls.	BID Averg Arroyo Culvert Replacement Project
	5 4" Dia 12' Long Drainage Pipes	4	Each	$ 55	$ 220					70 /20= 4	2012 RSMeans $4.35/ft x 12 = 55 $/lf (rounded)
	6 4" Check Valve	4	Each	$ 50	$ 200					70 /20= 4	Price listed in backwater-valves.com ($39) + shipping and installation
	7 Rock Veneer	600	SF	$ 30	$ 18,000					70 x 4.5 x2= 630 SF	2012 RSMeans $29/sf
	8 Geotextile	120	SY	$ 6	$ 720					70 x (2x 4.5 +6)/(9SY/SF)= 117 SY	2012 RSMeans $5.34/sy. Use $6/sy
	9 Class 2 Aggregate Base	5	CY	$ 80	$ 400					70 x 2x 1.0 x0.5'/(27CY/CF)= 3 CY	Lagunitas Road Bridge Replacement Project Contract Unit Price.
	10 Backfill	50	CY	$ 80	$ 4,000					70 x 2 x 4.5 x2/27= 47 CY	BID Averg Arroyo Culvert Replacement Project
	11 Erosion Protection	100	LF	$ 75	$ 7,500					--	Ross Valley Flood Protection Project
				Total	**$ 7,801,770**	**$ 3,197,000**	**$ 551,000**	**$ 2,890,000**	**$ 14,439,770**		
								Total (Roundup)	**$ 14,500,000**		

Notes:
(*) Engineering/Permitting Cost includes:

Engineering and Design	15% of Construction Cost
Environmental Permitting	10% of Construction Cost
Engineering Construction Management	10% of Construction Cost
Environmental Monitoring During Construction	6% of Construction Cost
	41% of Construction Cost

(**) The City's Staff Administrative Cost is 5% of the total cost of Construction and Engineering/Permitting.
(***)The Contingency Cost is 25% of the total cost of Construction, Engineering/Permitting, and the City's Staff Administration.

Table 2 Cost Summary of 50-Year Flood Damage Reduction Measures

Measure	Construction Cost	Engineering/ Permitting Cost @41% (*)	City's Staff Adminstrative Cost @5%(**)	Contingencies @25% (***)	Total Project Cost
25-Year Flood Protection Measures (from Tabel -x)	$ 7,801,770	$ 3,197,000	$ 551,000	$ 2,890,000	$ 14,439,770
Additonal Costs for 25-Year Flood Protection Measures	$ 2,145,840	$ 881,000	$ 151,000	$ 795,000	$ 3,972,840
Floodwall/Berms [50-03], [50-05]	$ 325,160	$ 133,000	$ 23,000	$ 121,000	$ 602,160
Replace Edgar Plaza Bridge [50-01]	$ 510,000	$ 209,000	$ 36,000	$ 189,000	$ 944,000
Replace/Enlarge Culvert Under Private Building from Sunnyside Ave [50-02]	$ 569,000	$ 233,000	$ 40,000	$ 211,000	$ 1,053,000
Mill Valley Golf Course Detention Basin [50-04]	$ 7,407,000	$ 3,037,000	$ 522,000	$ 2,742,000	$ 13,708,000
Total	$ 18,758,770	$ 7,690,000	$ 1,323,000	$ 6,948,000	$ 34,719,770
			Total (Roundup)		**$ 34,800,000**

Notes:

(*) Engineering/Permitting Cost includes:

Engineering and Design	15% of Construction Cost
Environmental Permitting	10% of Construction Cost
Engineering Construction Management	10% of Construction Cost
Environmental Monitoring During Construction	6% of Construction Cost
	41% of Construction Cost

(**) The City's Staff Administrative Cost is 5% of the total cost of Construction and Engineering/Permitting.

(***)The Contingency Cost is 25% of the total cost of Construction, Engineering/Permitting, and the City's Staff Administration.

50-YEAR FLOOD PROTECTION MEASURES
Arroyo Corte Madera Del Presidio Creek, Mill Valley, CA

Item	Description	Quantity	Unit	Unit Price	Const Cost	Engineering/ Permitting Cost @41% (*)	City's Staff Admin. Cost @5%(**)	Contingencies @25% (***)	Total Project Cost	Assumption for Estimated Quantity	Assumption for Unit Price
5-01	**Left Bank Floodwall (Upstream Camino Alto Bridge) Max. Height = 2.5'**	**680**	**LF**	**$ 658**	**$ 447,730**	**$ 184,000**	**$ 32,000**	**$ 166,000**	**$ 829,730**		
	1 Mobilization and Demolization	1	LS	$ 19,000	$ 19,000					--	5% const cost
	2 Cleaning and Grubbing	1	LS	$ 39,000	$ 39,000					--	10% const cost
	3 Excavation	380	CY	$ 120	$ 45,600					680 x2x 2.5 x3'/(27CY/CF)= 378 CY	BID Averg Arroyo Culvert Replacement Project x 1.5 to account for small volume
	4 Reinforced Concrete (Including footings)	200	CY	$ 800	$ 160,000					See FloodwallSummary.xls.	BID Averg Arroyo Culvert Replacement Project
	5 4" Dia 8' Long Drainage Pipes	34	Each	$ 35	$ 1,190					680 /20= 34	2012 RSMeans $4.35/ft x 8 = 35 $/lf (rounded)
	6 4" Check Valve	34	Each	$ 50	$ 1,700					680 /20= 34	Price listed in backwater-valves.com ($39) + shipping and installation
	7 Rock Veneer	3,400	SF	$ 30	$ 102,000					680 x 3 x2= 3,400 SF	2012 RSMeans $29/sf
	8 Geotextile	840	SY	$ 6	$ 5,040					680 x (2x 2.5 +6)/(9SY/SF)= 831 SY	2012 RSMeans $5.34/sy. Use $6/sy
	9 Class 2 Aggregate Base	30	CY	$ 80	$ 2,400					680 x 2x 1.0 x0.5'/(27CY/CF)= 25 CY	Lagunitas Road Bridge Replacement Project Contract Unit Price.
	10 Backfill	260	CY	$ 80	$ 20,800					680 x 2 x 2.5 x2/27= 252 CY	BID Averg Arroyo Culvert Replacement Project
	11 Erosion Protection	680	LF	$ 75	$ 51,000					--	Ross Valley Flood Protection Project
5-02	**Right Bank Floodwall (Between Gage & Valley Circle Pedestrian Bridge) Max. Height = 3.5'**	**210**	**LF**	**$ 954**	**$ 200,395**	**$ 82,000**	**$ 14,000**	**$ 74,000**	**$ 370,395**		
	1 Mobilization and Demolization	1	LS	$ 8,000	$ 8,000					--	5% const cost
	2 Cleaning and Grubbing	1	LS	$ 16,000	$ 16,000					--	10% const cost
	3 Excavation	160	CY	$ 120	$ 19,200					210 x2x 3.5 x3'/(27CY/CF)= 163 CY	BID Averg Arroyo Culvert Replacement Project x 1.5 to account for small volume
	4 Reinforced Concrete (Including footings)	70	CY	$ 1,200	$ 84,000					See FloodwallSummary.xls.	BID Averg Arroyo Culvert Replacement Project
	5 4" Dia 10' Long Drainage Pipes	11	Each	$ 45	$ 495					210 /20= 11	2012 RSMeans $4.35/ft x 10 = 45 $/lf (rounded)
	6 4" Check Valve	11	Each	$ 50	$ 550					210 /20= 11	Price listed in backwater-valves.com ($39) + shipping and installation
	7 Rock Veneer	1,500	SF	$ 30	$ 45,000					210 x 4 x2= 1,470 SF	2012 RSMeans $29/sf
	8 Geotextile	300	SY	$ 6	$ 1,800					210 x (2x 3.5 +6)/(9SY/SF)= 303 SY	2012 RSMeans $5.34/sy. Use $6/sy
	9 Class 2 Aggregate Base	10	CY	$ 80	$ 800					210 x 2x 1.0 x0.5'/(27CY/CF)= 8 CY	Lagunitas Road Bridge Replacement Project Contract Unit Price.
	10 Backfill	110	CY	$ 80	$ 8,800					210 x 2 x 3.5 x2/27= 109 CY	BID Averg Arroyo Culvert Replacement Project
	12 Erosion Protection	210	LF	$ 75	$ 15,750					--	25% const cost
5-03	**Excavate Channel Bottom (Upstream of Gage) and Replace Gage (L=300')**	**300**	**LF**	**$ 1,430**	**$ 429,000**	**$ 176,000**	**$ 30,000**	**$ 159,000**	**$ 794,000**		
	1 Mobilization / Demobilization	1	LS	$ 19,000	$ 19,000					--	5% Cons Cost
	2 Clearing and Grubbing	1	LS	$ 40,000	$ 40,000					--	Assumed
	3 Excavation (Incl Dewatering)	400	CY	$ 160	$ 64,000					300'x20'x1.5'=333CY Use400CY	200%BID Avg Arroyo (Excavation)
	4 Disposal Excavated Material	400	CY	$ 40	$ 16,000					Same as Excavation	50%BID Avg Arroyo (Excavation)
	5 Removal of Existing Concrete Weir Structure	20	CY	$ 500	$ 10,000					30'x2'x5'=11CY Use 20CY	Ross Valley Flood Protection Project
	6 Construct Stone Weir Structure	60	TN	$ 500	$ 30,000					30'x5'x5'=28CY@2TN/CY=56TN Use60TN	200%BID Avg Arroyo (Rock-River Boulders)
	7 Stream Flow Gaging Equipment	1	LS	$ 27,000	$ 27,000					--	USR Grant Application
	8 Rock Toe Bankline	300	TN	$ 150	$ 45,000					2x300'x4'x2'=178CY@1.6TN/CY=284TN Use300TN	BID Avg Arroyo (Rock-1/4 Ton Class)
	9 Bioengineered Bank Stabilization	2,400	SF	$ 45	$ 108,000					2x300'x4'=2400SF	Ross Valley Flood Protection Project
	10 Stone Weirs (3 Fish Pools)	100	TN	$ 500	$ 50,000					3(20'x4'x4')=35CY@2TN/CY=71TN Use100TN	200% BID Avg Arroyo (Rock-River Boulders)
	11 Revegetation & Cleaning	1,000	SY	$ 20	$ 20,000					300'x30'=1000SY	Assumed
5-04	**Replace Pedestrian Bridge (Private) 41'Span-5'Width-3'Raise-2'Freeboard (WSE=19.25')**	**205**	**SF**	**$ 521**	**$ 106,750**	**$ 44,000**	**$ 8,000**	**$ 40,000**	**$ 198,750**		
	1 Mobilization / Demobilization	1	LS	$ 5,000	$ 5,000					--	5% Cons Cost
	2 Clearing and Grubbing	1	LS	$ 5,000	$ 5,000					--	Assumed
	3 Removal of Existing Bridge	200	SF	$ 30	$ 6,000					30'x6'=180SF.Use 200 SF	Florida Department of Transportation
	4 Earthworks for Abutments	15	CY	$ 200	$ 3,000					2x7'x7'x4'=15CY.Use 20cy	200%BID Avg Arroyo (Small Volume)
	5 Concrete Abutments	15	CY	$ 1,800	$ 27,000					2x5'x5'x 7.0 = 13	BID Avg Arroyo Culvert Replacement Project
	6 Pre-fabricated Steel Truss and Wood Deck	220	SF	$ 150	$ 33,000					41'x5'=205SF Use 220SF	CONTECH
	7 Pathway Fill	35	CY	$ 250	$ 8,750					0.5x(5'x 3.0 x 60)x2= 33	300%BID Avg Arroyo (Small Volume & Gravel)
	8 Bioengineered Bank Stabilization	400	SF	$ 35	$ 14,000					2x20'x10'=400SF	Ross Valley Flood Protection Project
	9 Revegetation & Cleaning	1	LS	$ 5,000	$ 5,000					--	Assumed
5-05	**Replace Pedestrian Bridge (Public) 54'Span-7'Width-3'Raise-2'Freeboard (WSE=19.77')**	**378**	**SF**	**$ 409**	**$ 154,500**	**$ 63,000**	**$ 11,000**	**$ 57,000**	**$ 285,500**		
	1 Mobilization / Demobilization	1	LS	$ 7,000	$ 7,000					--	5% Cons Cost
	2 Clearing and Grubbing	1	LS	$ 7,000	$ 7,000					--	Assumed
	3 Removal of Existing Bridge	400	SF	$ 30	$ 12,000					50'x8'=400SF	Florida Department of Transportation
	4 Earthworks for Abutments	20	CY	$ 200	$ 4,000					2x7'x9'x4'=19CY Use 20CY	200%BID Avg Arroyo (Small Volume)
	5 Concrete Abutments	20	CY	$ 1,800	$ 36,000					2x5'x7'x 7.0 = 18	BID Avg Arroyo Culvert Replacement Project
	6 Pre-fabricated Steel Truss and Wood Deck	380	SF	$ 150	$ 57,000					54'x7'=378SF Use 380SF	CONTECH
	7 Pathway Fill	50	CY	$ 250	$ 12,500					0.5x(7'x 3.0 x 60)x2= 47	300%BID Avg Arroyo (Small Volume & Gravel)
	8 Bioengineered Bank Stabilization	400	SF	$ 35	$ 14,000					2x20'x10'=400SF	Ross Valley Flood Protection Project
	9 Revegetation & Cleaning	1	LS	$ 5,000	$ 5,000					--	Assumed

50-YEAR FLOOD PROTECTION MEASURES
Arroyo Corte Madera Del Presidio Creek, Mill Valley, CA

Item	Description	Quantity	Unit	Unit Price	Const Cost	Engineering/ Permitting Cost @41% (*)	City's Staff Admin. Cost @5%(**)	Contingencies @25% (***)	Total Project Cost	Assumption for Estimated Quantity	Assumption for Unit Price
5-06	**Channel Widening (L=150' w=23')**	**3,450**	**SF**	**$ 77**	**$ 266,000**	**$ 109,000**	**$ 19,000**	**$ 99,000**	**$ 493,000**		
	1 Mobilization / Demobilization	1	LS	$ 12,000	$ 12,000					--	5% Cons Cost
	2 Clearing and Grubbing	1	LS	$ 22,000	$ 22,000					--	Assumed
	3 Excavation	1,300	CY	$ 80	$ 104,000					150'x23'x10'=1278CY Use1300CY	BID Avg Arroyo Culvert Replacement Project
	4 Disposal	1,300	CY	$ 40	$ 52,000					Same as Excavation	50%BID Avg Arroyo Culvert Replacement Project
	5 Bioengineered Bank Stabilization	1,600	SF	$ 35	$ 56,000					150'x10'=1500SF. Use 1600 SF	Ross Valley Flood Protection Project
	7 Revegetation & Cleaning	1	LS	$ 20,000	$ 20,000						Assumed
10-01	**Right & Left Bank Floodwalls (Upstream Camino Alto Bridge) RB: Max. Height = 2.5', LB: Max. Height = 3'**	**720**	**LF**	**$ 1,188**	**$ 855,050**	**$ 351,000**	**$ 60,000**	**$ 317,000**	**$ 1,583,050**		
	a Floodwalls	**520**	**LF**	**$ 689**	**$ 358,050**						
	1 Mobilization and Demolization	1	LS	$ 16,000	$ 16,000					--	5% const cost
	2 Cleaning and Grubbing	1	LS	$ 31,000	$ 31,000					--	10% const cost
	3 Excavation	290	CY	$ 120	$ 34,800					520 x2x 2.5 x3'/(27CF/CY)= 289 CY	BID Averg Arroyo Culvert Replacement Project x 1.5 to account for small volume
	4 Reinforced Concrete (Including footings)	170	CY	$ 800	$ 136,000					See FloodwallSummary.xls.	BID Averg Arroyo Culvert Replacement Project
	5 4" Dia 6' Long Drainage Pipes	26	Each	$ 35	$ 910					520 /20= 26	2012 RSMeans $4.35/ft x 8 = 35 $/lf (rounded)
	6 4" Check Valve	26	Each	$ 50	$ 1,300					520 /20= 26	Price listed in backwater-valves.com ($39) + shipping and installation
	7 Rock Veneer	2,600	SF	$ 30	$ 78,000					520 x # x2= 2,600 SF	2012 RSMeans $29/sf
	8 Geotextile	640	SY	$ 6	$ 3,840					520 x (2x 2.5 +6)/(9SY/SF)= 636 SY	2012 RSMeans $5.34/sy. Use $6/sy
	9 Class 2 Aggregate Base	20	CY	$ 80	$ 1,600					520 x 2x 1.0 x0.5'/(27CY/CF)= 19 CY	Lagunitas Road Bridge Replacement Project Contract Unit Price.
	10 Backfill	195	CY	$ 80	$ 15,600					520 x 2 x 2.5 x2/27= 193 CY	BID Averg Arroyo Culvert Replacement Project
	11 Erosion Protection	520	LF	$ 75	$ 39,000					--	Ross Valley Flood Protection Project
	b Retaining/Floodwalls	**200**	**LF**	**$ 2,485**	**$ 497,000**						
	1 Mobilization and Demolization	1	LS	$ 22,000	$ 22,000					--	5% const cost
	2 Cleaning and Grubbing	1	LS	$ 43,000	$ 43,000					--	10% const cost
	3 Excavation	170	CY	$ 120	$ 20,400					200 x 7.5 x3'/(27CF/CY)= 167 CY	BID Averg Arroyo Culvert Replacement Project x 1.5 to account for small volume
	4 Reinforced Concrete (Including footings)	470	CY	$ 800	$ 376,000					See FloodwallSummary.xls.	BID Averg Arroyo Culvert Replacement Project
	5 4" Dia 16' Long Drainage Pipes	10	Each	$ 70	$ 700					200 /20= 10	2012 RSMeans $4.35/ft
	6 4" Check Valve	10	Each	$ 50	$ 500					200 /20= 10	Price listed in backwater-valves.com ($39) + shipping and installation
	7 Rock Veneer	200	SF	$ 30	$ 6,000					200 x 8 x1= 1,500 SF	2012 RSMeans $29/sf
	8 Geotextile	300	SY	$ 6	$ 1,800					200 x 7.5 +6)/(9SY/SF)= 300 SY	2012 RSMeans $5.34/sy. Use $6/sy
	9 Class 2 Aggregate Base	30	CY	$ 80	$ 2,400					200 x 7.5 x0.5'/(27CY/CF)= 28 CY	Lagunitas Road Bridge Replacement Project Contract Unit Price.
	10 Backfill	115	CY	$ 80	$ 9,200					200 x 7.5 x2/27= 111 CY	BID Averg Arroyo Culvert Replacement Project
	11 Erosion Protection	200	LF	$ 75	$ 15,000					--	Ross Valley Flood Protection Project
10-02	**Right Bank Retaining/Floodwall (Near Gage) Max. Height = 7'**	**270**	**LF**	**$ 1,409**	**$ 380,470**	**$ 156,000**	**$ 27,000**	**$ 141,000**	**$ 704,470**		
	1 Mobilization and Demolization	1	LS	$ 17,000	$ 17,000					--	5% const cost
	2 Cleaning and Grubbing	1	LS	$ 33,000	$ 33,000					--	10% const cost
	3 Excavation	210	CY	$ 120	$ 25,200					270 x 7.0 x3'/(27CF/CY)= 210 CY	BID Averg Arroyo Culvert Replacement Project x 1.5 to account for small volume
	4 Reinforced Concrete (Including footings)	200	CY	$ 1,000	$ 200,000					See FloodwallSummary.xls.	BID Averg Arroyo Culvert Replacement Project
	5 4" Dia 16' Long Drainage Pipes	14	Each	$ 70	$ 980					270 /20= 14	2012 RSMeans $4.35/ft ## =
	6 4" Check Valve	14	Each	$ 50	$ 700					270 /20= 14	Price listed in backwater-valves.com ($39) + shipping and installation
	7 Rock Veneer	1,900	SF	$ 30	$ 57,000					270 x 7 x1= 1,890 SF	2012 RSMeans $29/sf
	8 Geotextile	390	SY	$ 6	$ 2,340					270 x 7.0 +6)/(9SY/SF)= 390 SY	2012 RSMeans $5.34/sy. Use $6/sy
	9 Class 2 Aggregate Base	35	CY	$ 80	$ 2,800					270 x 7.0 x0.5'/(27CY/CF)= 35 CY	Lagunitas Road Bridge Replacement Project Contract Unit Price.
	10 Backfill	140	CY	$ 80	$ 11,200					270 x 7.0 x2/27= 140 CY	BID Averg Arroyo Culvert Replacement Project
	11 Erosion Protection	270	LF	$ 75	$ 20,250					--	Ross Valley Flood Protection Project
	12 Allowance for Tree Protection	1	LS	$ 10,000	$ 10,000					--	Assumed
10-04	**Right & Left Bank Floodwall (Between La Goma Brige & Locust Ave) RB: Max. Height = 2', LB: Max. Height = 1.5'**	**40**	**LF**	**$ 3,985**	**$ 159,400**	**$ 65,000**	**$ 11,000**	**$ 59,000**	**$ 294,400**		
	1 Mobilization and Demolization	1	LS	$ 11,000	$ 11,000					--	5% const cost
	2 Cleaning and Grubbing	1	LS	$ 23,000	$ 23,000					--	10% const cost
	3 Excavation	20	CY	$ 120	$ 2,400					40 x2x 2.0 x3'/(27CY/CF)= 18 CY	BID Averg Arroyo Culvert Replacement Project x 1.5 to account for small volume
	4 Reinforced Concrete (Including footings)	85	CY	$ 1,200	$ 102,000					See FloodwallSummary.xls.	BID Averg Arroyo Culvert Replacement Project
	5 4" Dia 6' Long Drainage Pipes	2	Each	$ 30	$ 60					40 /20= 2	2012 RSMeans $4.35/ft 6 = 30
	6 4" Check Valve	2	Each	$ 50	$ 100					40 /20= 2	Price listed in backwater-valves.com ($39) + shipping and installation
	7 Rock Veneer	200	SF	$ 30	$ 6,000					40 x 2 x2= 160 SF	2012 RSMeans $29/sf
	8 Geotextile	40	SY	$ 6	$ 240					40 x (2x 2.0 +6)/(9SY/SF)= 44 SY	2012 RSMeans $5.34/sy. Use $6/sy
	9 Class 2 Aggregate Base	5	CY	$ 80	$ 400					40 x 2x 1.0 x0.5'/(27CY/CF)= 1 CY	Lagunitas Road Bridge Replacement Project Contract Unit Price.
	10 Backfill	15	CY	$ 80	$ 1,200					40 x 2 x 2.0 x2/27= 12 CY	BID Averg Arroyo Culvert Replacement Project
	11 Erosion Protection	40	LF	$ 75	$ 3,000					--	Ross Valley Flood Protection Project
	12 Allowance for Tree Protection	1	LS	$ 10,000	$ 10,000					--	Assumed

50-YEAR FLOOD PROTECTION MEASURES
Arroyo Corte Madera Del Presidio Creek, Mill Valley, CA

Item	Description	Quantity	Unit	Unit Price	Const Cost	Engineering/ Permitting Cost @41% (*)	City's Staff Admin. Cost @5%(**)	Contingencies @25% (***)	Total Project Cost	Assumption for Estimated Quantity	Assumption for Unit Price
10-05	**Flood Diversion Wall (L=170') and Raise Sycamore Ave (h=2' Slope5%)**	**1**	**LS**	**$ 283,000**	**$ 283,000**	**$ 116,000**	**$ 20,000**	**$ 105,000**	**$ 524,000**		
1	Traffic Control and Signs	1	LS	$ 13,000	$ 13,000					--	5% Cons Cost
2	Clearing and Grubbing (Includes Safety Works)	1	LS	$ 10,000	$ 10,000					--	Assumed
4	Traffic Control and Signs	1	LS	$ 10,000	$ 10,000					--	Lagunitas Road Bridge Replacement Project
5	Removal of Existing Road (incl Sidewalk)	400	SY	$ 60	$ 24,000					(2x40'+20')x40'x0.5'=72CY@2TN/CY=148TN Use150TN	200%Lagunitas Road Bridge Replacement Project
6	Road Sub-grade Compacted Backfill	150	CY	$ 80	$ 12,000					(0.5x(100'+20'))x40'x2'=178CY Use180CY	BID Avg Arroyo Culvert Replacement Project
7	Class 2 Aggregate Base	100	CY	$ 80	$ 8,000					100'x20'x0.5'=37CY@2TN/CY=74TN Use80TN	Lagunitas Road Bridge Replacement Project
8	Asphalt Concrete Resurfacing	80	TN	$ 300	$ 24,000					2x100'x4'x1'=30CY	BID Avg Arroyo Culvert Replacement Project
9	Concrete Curb and Sidewalk	40	CY	$ 1,800	$ 72,000					(11'+3'/2)x(96'+72')x2'=87CY Use90CY	BID Avg Arroyo Culvert Replacement Project
10	2' Floodwalls (incl Earthworks & Others)	200	LF	$ 400	$ 80,000					--	See Floodwall Estimates
11	Driveway Modifications	1	TN	$ 10,000	$ 10,000					One each side	Assumed
12	Signs and Painting	1	LS	$ 10,000	$ 10,000					--	Assumed
13	Revegetation	1	LS	$ 10,000	$ 10,000					--	Assumed
10-06	**Right & Left Bank Floodwall (Upstream from Locust Ave) RB: Max. Height = 0.5', LB: Max. Height = 0.5'**	**280**	**LF**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**		
1	Mobilization and Demolization	1	LS	$ 3,000	$ 3,000					--	5% const cost
2	Cleaning and Grubbing	1	LS	$ 6,000	$ 6,000					--	10% const cost
3	Excavation	30	CY	$ 120	$ 3,600					280 x2x 0.5 x3'/(27CY/CF)= 31 CY	BID Averg Arroyo Culvert Replacement Project x 1.5 to account for small volume
4	Reinforced Concrete (Including footings)	10	CY	$ 1,000	$ 10,000					See FloodwallSummary.xls.	BID Averg Arroyo Culvert Replacement Project
5	4" Dia 4' Long Drainage Pipes	14	Each	$ 20	$ 280					280 /20= 14	2012 RSMeans $4.35/ft x 4 = 20 $/lf (rounded)
6	4" Check Valve	14	Each	$ 50	$ 700					280 /20= 14	Price listed in backwater-valves.com ($39) + shipping and installation
7	Rock Veneer	300	SF	$ 30	$ 9,000					280 x 1 x2= 280 SF	2012 RSMeans $29/sf
8	Geotextile	220	SY	$ 6	$ 1,320					280 x (2x 0.5 +6)/(9SY/SF)= 218 SY	2012 RSMeans $5.34/sy. Use $6/sy
9	Class 2 Aggregate Base	15	CY	$ 80	$ 1,200					280 x 2x 1.0 x0.5'/(27CY/CF)= 10 CY	Lagunitas Road Bridge Replacement Project Contract Unit Price.
10	Backfill	25	CY	$ 80	$ 2,000					280 x 2 x 0.5 x2/27= 21 CY	BID Averg Arroyo Culvert Replacement Project
11	Erosion Protection	280	LF	$ 75	$ 21,000					--	Ross Valley Flood Protection Project
12	Allowance for Tree Protection	1	LS	$ 10,000	$ 10,000					--	Assumed
10-07	**Replace Park Ave Bridge 27'Span-40'Width-No Raise-3.7'Freeboard (WSE=30.25')**	**1,080**	**SF**	**$ 577**	**$ 623,000**	**$ 255,000**	**$ 44,000**	**$ 231,000**	**$ 1,153,000**		
1	Mobilization / Demobilization	1	LS	$ 29,000	$ 29,000					--	5% Cons Cost
2	Clearing and Grubbing	1	LS	$ 10,000	$ 10,000					--	Assumed
3	Traffic Control and Signs	1	LS	$ 10,000	$ 10,000					--	Lagunitas Road Bridge Replacement Project
4	Removal of Existing Bridge (Incl Culvert)	1,080	SF	$ 50	$ 54,000					27'x40'=1080SF	Florida Department of Transportation
5	Excavation for Abutments	150	CY	$ 160	$ 24,000					2x7'x42'x6'=131CY Use 150CY	200%BID Avg Arroyo (Small Volume)
6	Concrete Abutments	90	CY	$ 1,000	$ 90,000					2x5'x40'x6'=89CY Use 90CY	BID Avg Arroyo Culvert Replacement Project & Lagunitas
7	Concrete Slab Deck	110	CY	$ 1,800	$ 198,000					(27'+2x5')x40'x2'=110CY	BID Avg Arroyo Culvert Replacement Project & lagunitas
8	Concrete Barrier & Railing	40	LF	$ 300	$ 12,000					27'+20'=37' Use40LF	Lagunitas Road Bridge Replacement Project
9	Concrete Wingwalls (Incl Earthworks)	30	CY	$ 1,800	$ 54,000					4(10'x20'x1')=30CY	Ross Valley Flood Protection Project
10	Concrete Curb and Sidewalk	10	CY	$ 1,800	$ 18,000					2x37'x5'x0.5'=7CY Use10CY	BID Avg Arroyo Culvert Replacement Project
11	Asphalt Concrete Resurfacing	40	TN	$ 300	$ 12,000					37'x30'x0.5'=20CY@2TN/CY=40TN	BID Avg Arroyo Culvert Replacement Project
12	Signs and Painting	1	LS	$ 10,000	$ 10,000					--	Assumed
13	Bioengineered Bank Stabilization	1,200	SF	$ 35	$ 42,000					2x60'x10'=1200SF	Ross Valley Flood Protection Project (1.5:1 Slope)
14	Revegetation	1	LS	$ 10,000	$ 10,000					--	Assumed
15	Allowance for Utilities	1	LS	$ 50,000	$ 50,000					--	Assumed
25-01	**Right Bank Floodwall (Upstream Camino Alto Bridge) Max. Height = 1'**	**90**	**LF**	**$ 443**	**$ 39,905**	**$ 16,000**	**$ 3,000**	**$ 15,000**	**$ 73,905**		
1	Mobilization and Demolization	1	LS	$ 2,000	$ 2,000					--	5% const cost
2	Cleaning and Grubbing	1	LS	$ 3,000	$ 3,000					--	10% const cost
3	Excavation	20	CY	$ 120	$ 2,400					90 x2x 1.0 x3'/(27CY/CF)= 20 CY	BID Averg Arroyo Culvert Replacement Project x 1.5 to account for small volume
4	Reinforced Concrete (Including footings)	30	CY	$ 800	$ 24,000					See FloodwallSummary.xls.	BID Averg Arroyo Culvert Replacement Project
5	4" Dia 4' Long Drainage Pipes	5	Each	$ 20	$ 100					90 /20= 5	2012 RSMeans $4.35/ft x 4 = 20 $/lf (rounded)
6	4" Check Valve	5	Each	$ 50	$ 250					90 /20= 5	Price listed in backwater-valves.com ($39) + shipping and installation
7	Rock Veneer	200	SF	$ 30	$ 6,000					90 x 1 x2= 180 SF	2012 RSMeans $29/sf
8	Geotextile	80	SY	$ 6	$ 480					90 x (2x 1.0 +6)/(9SY/SF)= 80 SY	2012 RSMeans $5.34/sy. Use $6/sy
9	Class 2 Aggregate Base	5	CY	$ 80	$ 400					90 x 2x 1.0 x0.5'/(27CY/CF)= 3 CY	Lagunitas Road Bridge Replacement Project Contract Unit Price.
10	Backfill	15	CY	$ 80	$ 1,200					90 x 2 x 1.0 x2/27= 13 CY	BID Averg Arroyo Culvert Replacement Project
11	Erosion Protection	1	LF	$ 75	$ 75					--	Ross Valley Flood Protection Project

50-YEAR FLOOD PROTECTION MEASURES
Arroyo Corte Madera Del Presidio Creek, Mill Valley, CA

Item	Description	Quantity	Unit	Unit Price	Const Cost	Engineering/ Permitting Cost @41% (*)	City's Staff Admin. Cost @5%(**)	Contingencies @25% (***)	Total Project Cost	Assumption for Estimated Quantity	Assumption for Unit Price
	Left Bank Floodwall (Between Gage & Valley Circle										
25-02	**Pedestrian Bridge) Max. Height = 2.5'**	**350**	**LF**	**$ 779**	**$ 272,760**	**$ 112,000**	**$ 19,000**	**$ 101,000**	**$ 504,760**		
1	Mobilization and Demolization	1	LS	$ 12,000	$ 12,000					--	5% const cost
2	Cleaning and Grubbing	1	LS	$ 24,000	$ 24,000					--	10% const cost
3	Excavation	190	CY	$ 120	$ 22,800					350 x2x 2.5 x3'/(27CY/CF)= 194 CY	BID Averg Arroyo Culvert Replacement Project x 1.5 to account for small volume
4	Reinforced Concrete (Including footings)	110	CY	$ 800	$ 88,000					See FloodwallSummary.xls.	BID Averg Arroyo Culvert Replacement Project
5	4" Dia 8' Long Drainage Pipes	18	Each	$ 35	$ 630					350 /20= 18	2012 RSMeans $4.35/ft x 8 = 35 $/lf (rounded)
6	4" Check Valve	18	Each	$ 50	$ 900					350 /20= 18	Price listed in backwater-valves.com ($39) + shipping and installation
7	Rock Veneer	1,800	SF	$ 30	$ 54,000					350 x 3 x2= 1,750 SF	2012 RSMeans $29/sf
8	Geotextile	430	SY	$ 6	$ 2,580					350 x (2x 2.5 +6)/(9SY/SF)= 428 SY	2012 RSMeans $5.34/sy. Use $6/sy
9	Class 2 Aggregate Base	15	CY	$ 80	$ 1,200					350 x 2x 1.0 x0.5'/(27CY/CF)= 13 CY	Lagunitas Road Bridge Replacement Project Contract Unit Price.
10	Backfill	130	CY	$ 80	$ 10,400					350 x 2 x 2.5 x2/27= 130 CY	BID Averg Arroyo Culvert Replacement Project
11	Erosion Protection	350	LF	$ 75	$ 26,250					--	Ross Valley Flood Protection Project
12	Allowance for Tree Protection	1	LS	$ 30,000	$ 30,000					--	Assumed
25-03	**Left Bank Floodwall (Near Gage) Max. Height = 2.5'**	**130**	**LF**	**$ 978**	**$ 127,105**	**$ 52,000**	**$ 9,000**	**$ 47,000**	**$ 235,105**		
1	Mobilization and Demolization	1	LS	$ 6,000	$ 6,000					--	5% const cost
2	Cleaning and Grubbing	1	LS	$ 11,000	$ 11,000					--	10% const cost
3	Excavation	70	CY	$ 120	$ 8,400					130 x2x 2.5 x3'/(27CY/CF)= 72 CY	BID Averg Arroyo Culvert Replacement Project x 1.5 to account for small volume
4	Reinforced Concrete (Including footings)	30	CY	$ 1,500	$ 45,000					See FloodwallSummary.xls.	BID Averg Arroyo Culvert Replacement Project
5	4" Dia 8' Long Drainage Pipes	7	Each	$ 35	$ 245					130 /20= 7	2012 RSMeans $4.35/ft x 8 = 35 $/lf (rounded)
6	4" Check Valve	7	Each	$ 50	$ 350					130 /20= 7	Price listed in backwater-valves.com ($39) + shipping and installation
7	Rock Veneer	700	SF	$ 30	$ 21,000					130 x 3 x2= 650 SF	2012 RSMeans $29/sf
8	Geotextile	160	SY	$ 6	$ 960					130 x (2x 2.5 +6)/(9SY/SF)= 159 SY	2012 RSMeans $5.34/sy. Use $6/sy
9	Class 2 Aggregate Base	5	CY	$ 80	$ 400					130 x 2x 1.0 x0.5'/(27CY/CF)= 5 CY	Lagunitas Road Bridge Replacement Project Contract Unit Price.
10	Backfill	50	CY	$ 80	$ 4,000					130 x 2 x 2.5 x2/27= 48 CY	BID Averg Arroyo Culvert Replacement Project
11	Erosion Protection	130	LF	$ 75	$ 9,750					--	Ross Valley Flood Protection Project
12	Allowance for Tree Protection	1	LS	$ 20,000	$ 20,000						Assumed
	ACMDP Creek Partial Bypass ((2)RC Culverts h=4.5'										
25-04	**w=10' L=1600' Each) (Weir L=72') (Q=700cfs)**	**1,600**	**LF**	**$ 3,436**	**$ 5,497,000**	**$ 2,254,000**	**$ 388,000**	**$ 2,035,000**	**$ 10,174,000**		5% Const Cost
1	Mobilization / Demobilization	1	LS	$ 256,000	$ 256,000					--	Assumed
2	Clearing and Grubbing	1	LS	$ 75,000	$ 75,000					--	Assumed
3	Traffic Control and Signs	1	LS	$ 50,000	$ 50,000					--	Assumed
4	Earthworks for Concrete Diversion Structure	850	CY	$ 80	$ 68,000					74'x20'x15'=822CY Use800CY	BID Avg Arroyo Culvert Replacement Project
5	Concrete for Inlet and Outlet Structures	230	CY	$ 1,500	$ 345,000					74'x30'x2'=164CY Use160CY	BID Avg Arroyo Culvert Replacement Project
6	5' x 10' Sluice Gate	2	EA	$ 40,000	$ 80,000					--	Assumed
7	Removal of Existing Road	1	LS	$ 56,000	$ 56,000					1600'x27'=4800SY	Lagunitas Road Bridge Replacement Project
8	Earthworks for Concrete Box Culvert	12,000	CY	$ 80	$ 960,000					1600'x27'x10'=16000CY	BID Avg Arroyo Culvert Replacement Project
9	Prefabricated Reinforced Concrete Box (4.5'x10')	3,200	CY	$ 1,000	$ 3,200,000					--	31'x1'x1'=1.15CY/LF@$1000/CY=$1148/LF Use $1150/LF
10	Class 2 Aggregate Base	1,100	TN	$ 80	$ 88,000					1600'x27'x0.75'=1200CY	Lagunitas Road Bridge Replacement Project
11	Asphalt Concrete Resurfacing	1	LS	$ 187,000	$ 187,000					1600'x27'x0.5'=875CY@2TN/CY=1600TN	BID Avg Arroyo Culvert Replacement Project
12	Rip-Rap Outlet Structure	220	TN	$ 100	$ 22,000					40'x20'x4'=118CY@1.6TN/CY=190TN Use200TN	BID Avg Arroyo Culvert Replacement Project
13	Signs and Painting	1	LS	$ 20,000	$ 20,000					--	Assumed
14	Relocate 16" Storm Drain Pipe Line @ Willow St.	300	LF	$ 200	$ 60,000					--	Assumed
15	Relocate 6" Sewer Pipe Line @ Willow St.	200	LF	$ 150	$ 30,000					--	Assumed
	Note: Utilities in Miller Ave will be charged to Miller Avenue Project, and, therefore, were not considered										
	Bank Retaining/ Floodwall and Upstream Bridge Wall										
	(Downstream of Parking Bridge in Old Mill Creek) RB:										
25-05	**Max. Height = 1.5', LB: Max. Height = 4.5'**	**100**	**LF**	**$ 1,055**	**$ 105,545**	**$ 43,000**	**$ 7,000**	**$ 39,000**	**$ 194,545**		
1	Mobilization and Demolization	1	LS	$ 5,000	$ 5,000					--	5% const cost
2	Cleaning and Grubbing	1	LS	$ 9,000	$ 9,000					--	10% const cost
3	Excavation	100	CY	$ 120	$ 12,000					100 x2x 4.5 x3'/(27CY/CF)= 100 CY	BID Averg Arroyo Culvert Replacement Project x 1.5 to account for small volume
4	Reinforced Concrete (Including footings)	25	CY	$ 1,500	$ 37,500					See FloodwallSummary.xls.	BID Averg Arroyo Culvert Replacement Project
5	4" Dia 12' Long Drainage Pipes	5	Each	$ 55	$ 275					100 /20= 5	2012 RSMeans $4.35/ft x 12 = 55 $/lf (rounded)
6	4" Check Valve	5	Each	$ 50	$ 250					100 /20= 5	Price listed in backwater-valves.com ($39) + shipping and installation
7	Rock Veneer	900	SF	$ 30	$ 27,000					100 x 5 x2= 900 SF	2012 RSMeans $29/sf
8	Geotextile	170	SY	$ 6	$ 1,020					100 x (2x 4.5 +6)/(9SY/SF)= 167 SY	2012 RSMeans $5.34/sy. Use $6/sy
9	Class 2 Aggregate Base	5	CY	$ 80	$ 400					100 x 2x 1.0 x0.5'/(27CY/CF)= 4 CY	Lagunitas Road Bridge Replacement Project Contract Unit Price.
10	Backfill	70	CY	$ 80	$ 5,600					100 x 2 x 4.5 x2/27= 67 CY	BID Averg Arroyo Culvert Replacement Project
11	Erosion Protection	100	LF	$ 75	$ 7,500					--	Ross Valley Flood Protection Project

50-YEAR FLOOD PROTECTION MEASURES
Arroyo Corte Madera Del Presidio Creek, Mill Valley, CA

Item	Description	Quantity	Unit	Unit Price	Const Cost	Engineering/ Permitting Cost @41% (*)	City's Staff Admin. Cost @5%(**)	Contingencies @25% (***)	Total Project Cost	Assumption for Estimated Quantity	Assumption for Unit Price
50-01	**Replace Egger Plaza Bridge 31'Span-25'Width-2.5'Raise-0.5'Freeboard (WSE=14.58')**	**775**	**SF**	**$ 658**	**$ 510,000**	**$ 209,000**	**$ 36,000**	**$ 189,000**	**$ 944,000**		
1	Mobilization / Demobilization	1	LS	$ 23,000	$ 23,000					--	5% Const Cost
2	Clearing and Grubbing (Includes Safety Works)	1	LS	$ 20,000	$ 20,000					--	Lagunitas Road Bridge Replacement Estimate
3	Traffic Control and Signs	1	LS	$ 5,000	$ 5,000					--	Lagunitas Road Bridge Replacement Estimate
4	Removal of Existing Bridge (w/o Abutments)	800	SF	$ 40	$ 32,000					31'x25'=775SF Use800SF	Florida Department of Transportation($50/SFx80%w/oAbutments)
5	Removal of Existing Road	200	SY	$ 60	$ 12,000					2x40'x25'=222SY Use200SY	200%Lagunitas Road Bridge Replacement Estimate
6	Raise Concrete Abutments (Incl reinforcement of Existing)	40	CY	$ 1,000	$ 40,000					2x25'(5'x2'+2'x5')=37CY Use40CY	BID Avg Arroyo Culvert Replacement Project & Lagunitas
7	Pre-Fabricated Bridge	780	SF	$ 250	$ 195,000					31'x25'=775SF Use780SF	CONTECH
8	Concrete Wingwalls (Incl Earthworks)	30	CY	$ 1,800	$ 54,000					4(10'x20'x1')=30CY	Ross Valley Flood Protection Project
9	Road Sub-grade Compacted Backfill	75	CY	$ 80	$ 6,000					2(0.5x40'x2'x25')=74CY Use75CY	BID Avg Arroyo Culvert Replacement Project
10	Class 2 Aggregate Base	50	CY	$ 80	$ 4,000					2(40'x25'x0.75')=56CY Use50CY	Lagunitas Road Bridge Replacement Estimate
11	Asphalt Concrete Resurfacing	100	TN	$ 300	$ 30,000					(2x40'+31')x25'x0.5'=51CY@2TN/CY=102TN Use100TN	BID Avg Arroyo Culvert Replacement Project
12	Parking Modifications	2	EA	$ 10,000	$ 20,000					2 DS Parking Lot (2'Raise) + 2 US Private (2'Raise)	Assumed
13	Signs and Painting	1	LS	$ 5,000	$ 5,000					--	Lagunitas Road Bridge Replacement Estimate
14	Bioengineered Bank Stabilization	400	SF	$ 35	$ 14,000					2x20'x10'=400SF	Ross Valley Flood Protection Project
15	Allowance Utilities	1	LS	$ 50,000	$ 50,000					--	Assumed
50-02	**Replace/Enlarge Culvert Under Private Building from Sunnyside Ave (Culvert w=9' L=120)**	**120**	**LF**	**$ 4,742**	**$ 569,000**	**$ 233,000**	**$ 40,000**	**$ 211,000**	**$ 1,053,000**		
1	Mobilization / Demobilization	1	LS	$ 26,000	$ 26,000					--	5% Const Cost
2	Clearing and Grubbing (Includes Safety Works)	1	LS	$ 20,000	$ 20,000					--	Lagunitas Road Bridge Replacement Project
3	Traffic Control and Signs	1	LS	$ 10,000	$ 10,000					--	Lagunitas Road Bridge Replacement Project
4	Earthworks for Removal Existing Culvert	200	CY	$ 240	$ 48,000					120'x10'x4'=178CY Use200CY	300%BID Avg Arroyo Culvert Replacement Project
5	Removal of Existing Culvert	120	LF	$ 500	$ 60,000					81'x30'x2'=180CY	Assumed
6	Shoring	90	CY	$ 1,000	$ 90,000					2(120'x2'x5')=89CY Use90CY	BID Avg Arroyo Culvert Replacement Project
7	Tie-backs	240	LF	$ 125	$ 30,000					120'/10'=12x20'=240LF	Lansdale Project
8	Concrete Box Culvert (9'x9')	120	LF	$ 1,100	$ 132,000					--	28'x1'x1'=1.04CY/LF@$1000/CY=$1037/LF Use$1100/LF
9	Inlet and Oulet Concrete Structure (Incl Earthworks)	30	CY	$ 1,800	$ 54,000					2(20'x20'x1')=35CY	Ross Valley Flood Protection Project
10	Erosion Control	1	LS	$ 20,000	$ 20,000					--	Assumed
11	Bioengineered Bank Stabilization	400	SF	$ 35	$ 14,000					2x20'x10'=400SF	Ross Valley Flood Protection Project (1.5:1 Slope)
12	Fish Passage Baffles	5	CY	$ 3,000	$ 15,000					120'/20'=6x10'x1'x2'=4.4CY Use5CY	Lansdale Project
13	Fish Passage Step Pools	100	TN	$ 500	$ 50,000					3x25'x3'x6'=50CY@2TN/CY=100TN	200%BID Avg Arroyo (Rock-River Boulders)
50-03	**Bank Floodwall and Upstream Bridge Wall (Downstream of Old Mill Creek above Old Mill Creek Confluence) RB: Max. Height = 3', LB: Max. Height = 2'**	**20**	**LF**	**$ 4,283**	**$ 85,665**	**$ 35,000**	**$ 6,000**	**$ 32,000**	**$ 158,665**		
1	Mobilization and Demolization	1	LS	$ 4,000	$ 4,000					--	5% const cost
2	Cleaning and Grubbing	1	LS	$ 7,000	$ 7,000					--	10% const cost
3	Excavation	10	CY	$ 120	$ 1,200					20 x2x 3.0 x3'/(27CY/CF)= 13 CY	BID Averg Arroyo Culvert Replacement Project x 1.5 to account for small volume
4	Reinforced Concrete (Including footings)	45	CY	$ 1,500	$ 67,500					See FloodwallSummary.xls.	BID Averg Arroyo Culvert Replacement Project
5	4" Dia 8' Long Drainage Pipes	1	Each	$ 35	$ 35					20 /20= 1	2012 RSMeans $4.35/ft x 8 = 35 $/lf (rounded)
6	4" Check Valve	1	Each	$ 50	$ 50					20 /20= 1	Price listed in backwater-valves.com ($39) + shipping and installation
7	Rock Veneer	100	SF	$ 30	$ 3,000					20 x 3 x2= 120 SF	2012 RSMeans $29/sf
8	Geotextile	30	SY	$ 6	$ 180					20 x (2x 3.0 +6)/(9SY/SF)= 27 SY	2012 RSMeans $5.34/sy. Use $6/sy
9	Class 2 Aggregate Base	5	CY	$ 80	$ 400					20 x 2x 1.0 x0.5'/(27CY/CF)= 1 CY	Lagunitas Road Bridge Replacement Project Contract Unit Price.
10	Backfill	10	CY	$ 80	$ 800					20 x 2 x 3.0 x2/27= 9 CY	BID Averg Arroyo Culvert Replacement Project
11	Erosion Protection	20	LF	$ 75	$ 1,500					--	Ross Valley Flood Protection Project
50-04	**Mill Valley Golf Course Detention Basin**	**227**	**AF**	**$ 32,630**	**$ 7,407,000**	**$ 3,037,000**	**$ 522,000**	**$ 2,742,000**	**$ 13,708,000**		
1	Mobilization / Demobilization	1	LS	$ 351,000	$ 351,000					--	5% Const Cost
2	Clearing and Grubbing (Includes Safety Works)	1	LS	$ 20,000	$ 20,000					--	Lagunitas Road Bridge Replacement Project
3	Traffic Control and Signs	1	LS	$ 10,000	$ 10,000					--	Lagunitas Road Bridge Replacement Project
4	Floodwalls	1,100	LF	$ 1,200	$ 1,320,000					870'@8'Max + 230'@4'Max	See Floodwalls cost
5	Dam Embankment	60,000	CY	$ 30	$ 1,800,000					LDD Calculation	Including Key, Impermeable, permeable & slope protection
6	Dam Foundation / Cut off Wall	1	LS	$ 300,000	$ 300,000					--	20% of Dam Embankment
7	Fish Passage Conduit	260	LF	$ 1,600	$ 416,000					Measure	42'x1'x1'=1.56CY/LF@$1000/CY=$1556/LF Use$1600/LF
8	Gated Inlet	1	LS	$ 150,000	$ 150,000					--	Assumed
9	Rip-Rap / Outlet Works	3,000	TN	$ 150	$ 450,000					150'x150'x2'=1670CY@1.6TN/CY=2667TN Use3000TN	BID Avg Arroyo Culvert Replacement Project
10	Spillway Structure	300	CY	$ 1,800	$ 540,000					200'x20'x2'=296CY Use300CY	Ross Valley Flood Protection Project
11	Environmental Protection	1	LS	$ 50,000	$ 50,000					--	Assumed
12	Allowance for Golf Course Repair/Restoration	1	LS	$ 2,000,000	$ 2,000,000						Assumed

50-YEAR FLOOD PROTECTION MEASURES
Arroyo Corte Madera Del Presidio Creek, Mill Valley, CA

Item	Description	Quantity	Unit	Unit Price	Const Cost	Engineering/ Permitting Cost @41% (*)	City's Staff Admin. Cost @5%(**)	Contingencies @25% (***)	Total Project Cost	Assumption for Estimated Quantity	Assumption for Unit Price
50-05	**Right & Left Bank Floodwalls (Upstream Willow Pedestrian Bridge) RB: Max. Height = 3.6', LB: Max. Height = 2.6'**	**310**	**LF**	**$ 773**	**$ 239,495**	**$ 98,000**	**$ 17,000**	**$ 89,000**	**$ 443,495**		
	1 Mobilization and Demolization	1	LS	$ 10,000	$ 10,000					--	5% const cost
	2 Cleaning and Grubbing	1	LS	$ 21,000	$ 21,000					--	10% const cost
	3 Excavation	210	CY	$ 120	$ 25,200					310 x2x 3.0 x3'/(27CY/CF)= 207 CY	BID Averg Arroyo Culvert Replacement Project x 1.5 to account for small volume
	4 Reinforced Concrete (Including footings)	110	CY	$ 1,000	$ 110,000					See FloodwallSummary.xls.	BID Averg Arroyo Culvert Replacement Project
	5 4" Dia 8' Long Drainage Pipes	16	Each	$ 35	$ 560					310 /20= 16	2012 RSMeans $4.35/ft x 8 = 35 $/lf (rounded)
	6 4" Check Valve	16	Each	$ 50	$ 800					310 /20= 16	Price listed in backwater-valves.com ($39) + shipping and installation
	7 Rock Veneer	1,900	SF	$ 30	$ 57,000					310 x 3 x2= 1,860 SF	2012 RSMeans $29/sf
	8 Geotextile	410	SY	$ 6	$ 2,460					310 x (2x 3.0 +6)/(9SY/SF)= 413 SY	2012 RSMeans $5.34/sy. Use $6/sy
	9 Class 2 Aggregate Base	15	CY	$ 80	$ 1,200					310 x 2x 1.0 x0.5'/(27CY/CF)= 11 CY	Lagunitas Road Bridge Replacement Project Contract Unit Price.
	10 Backfill	140	CY	$ 80	$ 11,200					310 x 2 x 3.0 x2/27= 138 CY	BID Averg Arroyo Culvert Replacement Project
	11 Erosion Protection	1	LF	$ 75	$ 75					--	Ross Valley Flood Protection Project
				Total	**$ 18,758,770**	**$ 7,690,000**	**$ 1,323,000**	**$ 6,948,000**	**$ 34,719,770**		
								Total (Roundup)	**$ 34,800,000**		

Notes:
(*) Engineering/Permitting Cost includes:

Engineering and Design	15% of Construction Cost
Environmental Permitting	10% of Construction Cost
Engineering Construction Management	10% of Construction Cost
Environmental Monitoring During Construction	6% of Construction Cost
	41% of Construction Cost

(**) The City's Staff Administrative Cost is 5% of the total cost of Construction and Engineering/Permitting.
(***)The Contingency Cost is 25% of the total cost of Construction, Engineering/Permitting, and the City's Staff Administration.

Table 3 Cost Summary of 100-Year Flood Damage Reduction Measures

Measure	Construction Cost	Engineering/ Permitting Cost @41% (*)	City's Staff Adminstrative Cost @5%(**)	Contingencies @25% (***)	Total Project Cost
50-Year Flood Protection Measures (from Tabel -x)	$ 18,758,770	$ 7,690,000	$ 1,323,000	$ 6,948,000	$ 34,719,770
Additonal Costs for 50-Year Flood Protection Measures	$ 2,934,384	$ 1,204,000	$ 207,000	$ 1,085,000	$ 5,430,384
Floodwall/Berms [100-01]	$ 9,510	$ 4,000	$ 1,000	$ 4,000	$ 18,510
Total	$ 21,702,664	$ 8,898,000	$ 1,531,000	$ 8,037,000	$ 40,168,664
			Total (Roundup)		**$ 40,200,000**

Notes:

(*) Engineering/Permitting Cost includes:

Engineering and Design	15% of Construction Cost
Environmental Permitting	10% of Construction Cost
Engineering Construction Management	10% of Construction Cost
Environmental Monitoring During Construction	6% of Construction Cost
	41% of Construction Cost

(**) The City's Staff Administrative Cost is 5% of the total cost of Construction and Engineering/Permitting.

(***)The Contingency Cost is 25% of the total cost of Construction, Engineering/Permitting, and the City's Staff Administration.

100-YEAR FLOOD PROTECTION MEASURES
Arroyo Corte Madera Del Presidio Creek, Mill Valley, CA

Item	Description	Quantity	Unit	Unit Price	Const Cost	Engineering/ Permitting Cost @41% (*)	City's Staff Admin. Cost @5%(**)	Contingencies @25% (***)	Total Project Cost	Assumption for Estimated Quantity	Assumption for Unit Price
5-01	**Left Bank Floodwall (Upstream Camino Alto Bridge) Max. Height = 3'**	**690**	**LF**	**$ 755**	**$ 520,645**	**$ 213,000**	**$ 37,000**	**$ 193,000**	**$ 963,645**		
1	Mobilization and Demolization	1	LS	$ 23,000	$ 23,000					--	5% const cost
2	Cleaning and Grubbing	1	LS	$ 45,000	$ 45,000					--	10% const cost
3	Excavation	460	CY	$ 120	$ 55,200					690 x2x 3.0 x3'/(27CY/CF)= 460 CY	BID Averg Arroyo Culvert Replacement Project x 1.5 to account for small volume
4	Reinforced Concrete (Including footings)	230	CY	$ 800	$ 184,000					See FloodwallSummary.xls.	BID Averg Arroyo Culvert Replacement Project
5	4" Dia 8' Long Drainage Pipes	35	Each	$ 35	$ 1,225					690 /20= 35	2012 RSMeans $4.35/ft x 8 = 35 $/lf (rounded)
6	4" Check Valve	35	Each	$ 50	$ 1,750					690 /20= 35	Price listed in backwater-valves.com ($39) + shipping and installation
7	Rock Veneer	4,200	SF	$ 30	$ 126,000					690 x 3 x2= 4,140 SF	2012 RSMeans $29/sf
8	Geotextile	920	SY	$ 6	$ 5,520					690 x (2x 3.0 +6)/(9SY/SF)= 920 SY	2012 RSMeans $5.34/sy. Use $6/sy
9	Class 2 Aggregate Base	30	CY	$ 80	$ 2,400					690 x 2x 1.0 x0.5'/(27CY/CF)= 26 CY	Lagunitas Road Bridge Replacement Project Contract Unit Price.
10	Backfill	310	CY	$ 80	$ 24,800					690 x 2 x 3.0 x2/27= 307 CY	BID Averg Arroyo Culvert Replacement Project
11	Erosion Protection	690	LF	$ 75	$ 51,750					--	Ross Valley Flood Protection Project
5-02	**Right Bank Floodwall (Between Gage & Valley Circle Pedestrian Bridge) Max. Height = 4'**	**230**	**LF**	**$ 1,160**	**$ 266,750**	**$ 109,000**	**$ 19,000**	**$ 99,000**	**$ 493,750**		
1	Mobilization and Demolization	1	LS	$ 12,000	$ 12,000					--	5% const cost
2	Cleaning and Grubbing	1	LS	$ 23,000	$ 23,000					--	10% const cost
3	Excavation	210	CY	$ 120	$ 25,200					230 x2x 4.0 x3'/(27CY/CF)= 204 CY	BID Averg Arroyo Culvert Replacement Project x 1.5 to account for small volume
4	Reinforced Concrete (Including footings)	120	CY	$ 1,000	$ 120,000					See FloodwallSummary.xls.	BID Averg Arroyo Culvert Replacement Project
5	4" Dia 10' Long Drainage Pipes	12	Each	$ 45	$ 540					230 /20= 12	2012 RSMeans $4.35/ft x 10 = 45 $/lf (rounded)
6	4" Check Valve	12	Each	$ 50	$ 600					230 /20= 12	Price listed in backwater-valves.com ($39) + shipping and installation
7	Rock Veneer	1,800	SF	$ 30	$ 54,000					230 x 4 x2= 1,840 SF	2012 RSMeans $29/sf
8	Geotextile	360	SY	$ 6	$ 2,160					230 x (2x 4.0 +6)/(9SY/SF)= 358 SY	2012 RSMeans $5.34/sy. Use $6/sy
9	Class 2 Aggregate Base	10	CY	$ 80	$ 800					230 x 2x 1.0 x0.5'/(27CY/CF)= 9 CY	Lagunitas Road Bridge Replacement Project Contract Unit Price.
10	Backfill	140	CY	$ 80	$ 11,200					230 x 2 x 4.0 x2/27= 136 CY	BID Averg Arroyo Culvert Replacement Project
11	Erosion Protection	230	LF	$ 75	$ 17,250					--	Ross Valley Flood Protection Project
5-03	**Excavate Channel Bottom (Upstream of Gage) and Replace Gage (L=300')**	**300**	**LF**	**$ 1,430**	**$ 429,000**	**$ 176,000**	**$ 30,000**	**$ 159,000**	**$ 794,000**		
1	Mobilization / Demobilization	1	LS	$ 19,000	$ 19,000					--	5% Cons Cost
2	Clearing and Grubbing	1	LS	$ 40,000	$ 40,000					--	Assumed
3	Excavation (Incl Dewatering)	400	CY	$ 160	$ 64,000					300'x20'x1.5'=333CY Use400CY	200%BID Avg Arroyo (Excavation)
4	Disposal Excavated Material	400	CY	$ 40	$ 16,000					Same as Excavation	50%BID Avg Arroyo (Excavation)
5	Removal of Existing Concrete Weir Structure	20	CY	$ 500	$ 10,000					30'x2'x5'=11CY Use 20CY	Ross Valley Flood Protection Project
6	Construct Stone Weir Structure	60	TN	$ 500	$ 30,000					30'x5'x5'=28CY@2TN/CY=56TN Use60TN	200%BID Avg Arroyo (Rock-River Boulders)
7	Stream Flow Gaging Equipment	1	LS	$ 27,000	$ 27,000					--	USR Grant Application
8	Rock Toe Bankline	300	TN	$ 150	$ 45,000					2x300'x4'x2'=178CY@1.6TN/CY=284TN Use300TN	BID Avg Arroyo (Rock-1/4 Ton Class)
9	Bioengineered Bank Stabilization	2,400	SF	$ 45	$ 108,000					2x300'x4'=2400SF	Ross Valley Flood Protection Project
10	Stone Weirs (3 Fish Pools)	100	TN	$ 500	$ 50,000					3(20'x4'x4')=35CY@2TN/CY=71TN Use100TN	200% BID Avg Arroyo (Rock-River Boulders)
11	Revegetation & Cleaning	1,000	SY	$ 20	$ 20,000					300'x30'=1000SY	Assumed
5-04	**Replace Pedestrian Bridge (Private) 41'Span-5'Width-3'Raise-2'Freeboard (WSE=19.4218.84')**	**205**	**SF**	**$ 521**	**$ 106,750**	**$ 44,000**	**$ 8,000**	**$ 40,000**	**$ 198,750**		
1	Mobilization / Demobilization	1	LS	$ 5,000	$ 5,000					--	5% Cons Cost
2	Clearing and Grubbing	1	LS	$ 5,000	$ 5,000					--	Assumed
3	Removal of Existing Bridge	200	SF	$ 30	$ 6,000					30'x6'=180SF.Use 200 SF	Florida Department of Transportation
4	Earthworks for Abutments	15	CY	$ 200	$ 3,000					2x7'x7'x4'=15CY.Use 20cy	200%BID Avg Arroyo (Small Volume)
5	Concrete Abutments	15	CY	$ 1,800	$ 27,000					2x5'x5'x 7.0 = 13	BID Avg Arroyo Culvert Replacement Project
6	Pre-fabricated Steel Truss and Wood Deck	220	SF	$ 150	$ 33,000					41'x5'=205SF Use 220SF	CONTECH
7	Pathway Fill	35	CY	$ 250	$ 8,750					0.5x(5'x 3.0 x 60)x2= 33	300%BID Avg Arroyo (Small Volume & Gravel)
8	Bioengineered Bank Stabilization	400	SF	$ 35	$ 14,000					2x20'x10'=400SF	Ross Valley Flood Protection Project
9	Revegetation & Cleaning	1	LS	$ 5,000	$ 5,000					--	Assumed
5-05	**Replace Pedestrian Bridge (Public) 54'Span-7'Width-3.5'Raise-2'Freeboard (WSE=20.01')**	**378**	**SF**	**$ 419**	**$ 158,250**	**$ 65,000**	**$ 11,000**	**$ 59,000**	**$ 293,250**		
1	Mobilization / Demobilization	1	LS	$ 7,000	$ 7,000					--	5% Cons Cost
2	Clearing and Grubbing	1	LS	$ 7,000	$ 7,000					--	Assumed
3	Removal of Existing Bridge	400	SF	$ 30	$ 12,000					50'x8'=400SF	Florida Department of Transportation
4	Earthworks for Abutments	20	CY	$ 200	$ 4,000					2x7'x9'x4'=19CY Use 20CY	200%BID Avg Arroyo (Small Volume)
5	Concrete Abutments	20	CY	$ 1,800	$ 36,000					2x5'x7'x 7.5 = 19	BID Avg Arroyo Culvert Replacement Project
6	Pre-fabricated Steel Truss and Wood Deck	380	SF	$ 150	$ 57,000					54'x7'=378SF Use 380SF	CONTECH
7	Pathway Fill	65	CY	$ 250	$ 16,250					0.5x(7'x 3.5 x 70)x2= 64	300%BID Avg Arroyo (Small Volume & Gravel)
8	Bioengineered Bank Stabilization	400	SF	$ 35	$ 14,000					2x20'x10'=400SF	Ross Valley Flood Protection Project
9	Revegetation & Cleaning	1	LS	$ 5,000	$ 5,000					--	Assumed

100-YEAR FLOOD PROTECTION MEASURES
Arroyo Corte Madera Del Presidio Creek, Mill Valley, CA

Item	Description	Quantity	Unit	Unit Price	Const Cost	Engineering/ Permitting Cost @41% (*)	City's Staff Admin. Cost @5%(**)	Contingencies @25% (***)	Total Project Cost	Assumption for Estimated Quantity	Assumption for Unit Price
5-06	**Channel Widening (L=150' w=23')**	**3,450**	**SF**	**$ 77**	**$ 266,000**	**$ 109,000**	**$ 19,000**	**$ 99,000**	**$ 493,000**		
1	Mobilization / Demobilization	1	LS	$ 12,000	$ 12,000					--	5% Cons Cost
2	Clearing and Grubbing	1	LS	$ 22,000	$ 22,000					--	Assumed
3	Excavation	1,300	CY	$ 80	$ 104,000					150'x23'x10'=1278CY Use1300CY	BID Avg Arroyo Culvert Replacement Project
4	Disposal	1,300	CY	$ 40	$ 52,000					Same as Excavation	50%BID Avg Arroyo Culvert Replacement Project
5	Bioengineered Bank Stabilization	1,600	SF	$ 35	$ 56,000					150'x10'=1500SF. Use 1600 SF	Ross Valley Flood Protection Project
7	Revegetation & Cleaning	1	LS	$ 20,000	$ 20,000					--	Assumed
10-01	**Right & Left Bank Floodwalls (Upstream Camino Alto Bridge) RB: Max. Height = 3', LB: Max. Height = 3.5'**	**920**	**LF**	**$ 1,083**	**$ 996,095**	**$ 408,000**	**$ 70,000**	**$ 369,000**	**$ 1,843,095**		
a	**Floodwalls**	**620**	**LF**	**$ 711**	**$ 440,895**						
1	Mobilization and Demolization	1	LS	$ 19,000	$ 19,000					--	5% const cost
2	Cleaning and Grubbing	1	LS	$ 38,000	$ 38,000					--	10% const cost
3	Excavation	340	CY	$ 120	$ 40,800					620 x2x 2.5 x3'/(27CF/CY)= 344 CY	BID Averg Arroyo Culvert Replacement Project x 1.5 to account for small volume
4	Reinforced Concrete (Including footings)	220	CY	$ 800	$ 176,000					See FloodwallSummary.xls.	BID Averg Arroyo Culvert Replacement Project
5	4" Dia 6' Long Drainage Pipes	31	Each	$ 35	$ 1,085					620 /20= 31	2012 RSMeans $4.35/ft = 35 $/lf (rounded)
6	4" Check Valve	31	Each	$ 50	$ 1,550					620 /20= 31	Price listed in backwater-valves.com ($39) + shipping and installation
7	Rock Veneer	3,100	SF	$ 30	$ 93,000					620 x 2.5 x2= 3,100 SF	2012 RSMeans $29/sf
8	Geotextile	760	SY	$ 6	$ 4,560					620 x (2x 2.5 +6)/(9SY/SF)= 758 SY	2012 RSMeans $5.34/sy. Use $6/sy
9	Class 2 Aggregate Base	25	CY	$ 80	$ 2,000					620 x 2x 1.0 x0.5'/(27CY/CF)= 23 CY	Lagunitas Road Bridge Replacement Project Contract Unit Price.
10	Backfill	230	CY	$ 80	$ 18,400					620 x 2 x 2.5 x2/27= 230 CY	BID Averg Arroyo Culvert Replacement Project
11	Erosion Protection	620	LF	$ 75	$ 46,500					--	Ross Valley Flood Protection Project
b	**Retaining/Floodwalls**	**300**	**LF**	**$ 1,851**	**$ 555,200**						
1	Mobilization and Demolization	1	LS	$ 24,000	$ 24,000					--	5% const cost
2	Cleaning and Grubbing	1	LS	$ 48,000	$ 48,000					--	10% const cost
3	Excavation	250	CY	$ 120	$ 30,000					300 x 7.5 x3'/(27CF/CY)= 250 CY	BID Averg Arroyo Culvert Replacement Project x 1.5 to account for small volume
4	Reinforced Concrete (Including footings)	500	CY	$ 800	$ 400,000					See FloodwallSummary.xls.	BID Averg Arroyo Culvert Replacement Project
5	4" Dia 16' Long Drainage Pipes	15	Each	$ 70	$ 1,050					300 /20= 15	2012 RSMeans $4.35/ft
6	4" Check Valve	15	Each	$ 50	$ 750					300 /20= 15	Price listed in backwater-valves.com ($39) + shipping and installation
7	Rock Veneer	300	SF	$ 30	$ 9,000					300 x 8 x1= 2,250 SF	2012 RSMeans $29/sf
8	Geotextile	450	SY	$ 6	$ 2,700					300 x 7.5 +6)/(9SY/SF)= 450 SY	2012 RSMeans $5.34/sy. Use $6/sy
9	Class 2 Aggregate Base	45	CY	$ 80	$ 3,600					300 x 7.5 x0.5'/(27CY/CF)= 42 CY	Lagunitas Road Bridge Replacement Project Contract Unit Price.
10	Backfill	170	CY	$ 80	$ 13,600					300 x 7.5 x2/27= 167 CY	BID Averg Arroyo Culvert Replacement Project
11	Erosion Protection	300	LF	$ 75	$ 22,500					--	Ross Valley Flood Protection Project
10-02	**Right Bank Retaining/Floodwall (Near Gage) Max. Height=7.5'**	**450**	**LF**	**$ 1,256**	**$ 565,390**	**$ 232,000**	**$ 40,000**	**$ 209,000**	**$ 1,046,390**		
1	Mobilization and Demolization	1	LS	$ 25,000	$ 25,000					--	5% const cost
2	Cleaning and Grubbing	1	LS	$ 49,000	$ 49,000					--	10% const cost
3	Excavation	380	CY	$ 120	$ 45,600					450 x 7.5 x3'/(27CF/CY)= 375 CY	BID Averg Arroyo Culvert Replacement Project x 1.5 to account for small volume
4	Reinforced Concrete (Including footings)	310	CY	$ 800	$ 248,000					See FloodwallSummary.xls.	BID Averg Arroyo Culvert Replacement Project
5	4" Dia 16' Long Drainage Pipes	23	Each	$ 70	$ 1,610					450 /20= 23	2012 RSMeans $4.35/ft = ### $/lf (rounded)
6	4" Check Valve	23	Each	$ 50	$ 1,150					450 /20= 23	Price listed in backwater-valves.com ($39) + shipping and installation
7	Rock Veneer	3,400	SF	$ 30	$ 102,000					450 x 8 x1= 3,375 SF	2012 RSMeans $29/sf
8	Geotextile	680	SY	$ 6	$ 4,080					450 x 7.5 +6)/(9SY/SF)= 675 SY	2012 RSMeans $5.34/sy. Use $6/sy
9	Class 2 Aggregate Base	65	CY	$ 80	$ 5,200					450 x 7.5 x0.5'/(27CY/CF)= 63 CY	Lagunitas Road Bridge Replacement Project Contract Unit Price.
10	Backfill	250	CY	$ 80	$ 20,000					450 x 7.5 x2/27= 250 CY	BID Averg Arroyo Culvert Replacement Project
11	Erosion Protection	450	LF	$ 75	$ 33,750					--	Ross Valley Flood Protection Project
12	Allowance for Tree Protection	1	LS	$ 30,000	$ 30,000					--	Assumed
10-04	**Right & Left Bank Floodwall (Between La Goma Brige & Locust Ave) RB:Max. Height=3', LB:Max. Height=2.5'**	**140**	**LF**	**$ 1,509**	**$ 211,235**	**$ 87,000**	**$ 15,000**	**$ 78,000**	**$ 391,235**		
1	Mobilization and Demolization	1	LS	$ 9,000	$ 9,000					--	5% const cost
2	Cleaning and Grubbing	1	LS	$ 18,000	$ 18,000					--	10% const cost
3	Excavation	100	CY	$ 120	$ 12,000					140 x2x 3.0 x3'/(27CY/CF)= 93 CY	BID Averg Arroyo Culvert Replacement Project x 1.5 to account for small volume
4	Reinforced Concrete (Including footings)	120	CY	$ 1,000	$ 120,000					See FloodwallSummary.xls.	BID Averg Arroyo Culvert Replacement Project
5	4" Dia 16' Long Drainage Pipes	7	Each	$ 35	$ 245					140 /20= 7	2012 RSMeans $4.35/ft = 35 Each
6	4" Check Valve	7	Each	$ 50	$ 350					140 /20= 7	Price listed in backwater-valves.com ($39) + shipping and installation
7	Rock Veneer	800	SF	$ 30	$ 24,000					140 x 3 x2= 840 SF	2012 RSMeans $29/sf
8	Geotextile	190	SY	$ 6	$ 1,140					140 x (2x 3.0 +6)/(9SY/SF)= 187 SY	2012 RSMeans $5.34/sy. Use $6/sy
9	Class 2 Aggregate Base	10	CY	$ 80	$ 800					140 x 2x 1.0 x0.5'/(27CY/CF)= 5 CY	Lagunitas Road Bridge Replacement Project Contract Unit Price.
10	Backfill	65	CY	$ 80	$ 5,200					140 x 2 x 3.0 x2/27= 62 CY	BID Averg Arroyo Culvert Replacement Project
11	Erosion Protection	140	LF	$ 75	$ 10,500					--	Ross Valley Flood Protection Project
12	Allowance for Tree Protection	1	LS	$ 10,000	$ 10,000					--	Assumed

100-YEAR FLOOD PROTECTION MEASURES
Arroyo Corte Madera Del Presidio Creek, Mill Valley, CA

Item	Description	Quantity	Unit	Unit Price	Const Cost	Engineering/ Permitting Cost @41% (*)	City's Staff Admin. Cost @5%(**)	Contingencies @25% (***)	Total Project Cost	Assumption for Estimated Quantity	Assumption for Unit Price
10-05	**Flood Diversion Wall (L=170') and Raise Sycamore Ave (h=2' Slope5%)**	**1**	**LS**	**$ 283,000**	**$ 283,000**	**$ 116,000**	**$ 20,000**	**$ 105,000**	**$ 524,000**		
1	Traffic Control and Signs	1	LS	$ 13,000	$ 13,000					--	5% Cons Cost
2	Clearing and Grubbing (Includes Safety Works)	1	LS	$ 10,000	$ 10,000					--	Assumed
4	Traffic Control and Signs	1	LS	$ 10,000	$ 10,000					--	Lagunitas Road Bridge Replacement Project
5	Removal of Existing Road (incl Sidewalk)	400	SY	$ 60	$ 24,000					(2x40'+20')x40'x0.5'=72CY@2TN/CY=148TN Use150TN	200%Lagunitas Road Bridge Replacement Project
6	Road Sub-grade Compacted Backfill	150	CY	$ 80	$ 12,000					(0.5x(100'+20'))x40'x2'=178CY Use180CY	BID Avg Arroyo Culvert Replacement Project
7	Class 2 Aggregate Base	100	CY	$ 80	$ 8,000					100'x20'x0.5'=37CY@2TN/CY=74TN Use80TN	Lagunitas Road Bridge Replacement Project
8	Asphalt Concrete Resurfacing	80	TN	$ 300	$ 24,000					2x100'x4'x1'=30CY	BID Avg Arroyo Culvert Replacement Project
9	Concrete Curb and Sidewalk	40	CY	$ 1,800	$ 72,000					(11'+3'/2)x(96'+72')x2'=87CY Use90CY	BID Avg Arroyo Culvert Replacement Project
10	2' Floodwalls (incl Earthworks & Others)	200	LF	$ 400	$ 80,000					--	See Floodwall Estimates
11	Driveway Modifications	1	TN	$ 10,000	$ 10,000					One each side	Assumed
12	Signs and Painting	1	LS	$ 10,000	$ 10,000					--	Assumed
13	Revegetation	1	LS	$ 10,000	$ 10,000					--	Assumed
10-06	**Right & Left Bank Floodwall (Upstream from Locust Ave) RB: Max. Height = 1', LB: Max. Height = 1'**	**510**	**LF**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**		
1	Mobilization and Demolization	1	LS	$ 8,000	$ 8,000					--	5% const cost
2	Cleaning and Grubbing	1	LS	$ 15,000	$ 15,000					--	10% const cost
3	Excavation	120	CY	$ 120	$ 14,400					510 x2x 1.0 x3'/(27CY/CF)= 113 CY	BID Averg Arroyo Culvert Replacement Project x 1.5 to account for small volume
4	Reinforced Concrete (Including footings)	25	CY	$ 1,000	$ 25,000					See FloodwallSummary.xls.	BID Averg Arroyo Culvert Replacement Project
5	4" Dia 4' Long Drainage Pipes	26	Each	$ 20	$ 520					510 /20= 26	2012 RSMeans $4.35/ft x 4 = 20 $/lf (rounded)
6	4" Check Valve	26	Each	$ 50	$ 1,300					510 /20= 26	Price listed in backwater-valves.com ($39) + shipping and installation
7	Rock Veneer	1,000	SF	$ 30	$ 30,000					510 x 1 x2= 1,020 SF	2012 RSMeans $29/sf
8	Geotextile	450	SY	$ 6	$ 2,700					510 x (2x 1.0 +6)/(9SY/SF)= 453 SY	2012 RSMeans $5.34/sy. Use $6/sy
9	Class 2 Aggregate Base	20	CY	$ 80	$ 1,600					510 x 2x 1.0 x0.5'/(27CY/CF)= 19 CY	Lagunitas Road Bridge Replacement Project Contract Unit Price.
10	Backfill	80	CY	$ 80	$ 6,400					510 x 2 x 1.0 x2/27= 76 CY	BID Averg Arroyo Culvert Replacement Project
11	Erosion Protection	510	LF	$ 75	$ 38,250					--	Ross Valley Flood Protection Project
12	Allowance for Tree Protection	1	LS	$ 30,000	$ 30,000					--	Assumed
10-07	**Replace Park Ave Bridge 27'Span-40'Width-No Raise-3.1'Freeboard (WSE=30.9')**	**1,080**	**SF**	**$ 577**	**$ 623,000**	**$ 255,000**	**$ 44,000**	**$ 231,000**	**$ 1,153,000**		
1	Mobilization / Demobilization	1	LS	$ 29,000	$ 29,000					--	5% Cons Cost
2	Clearing and Grubbing	1	LS	$ 10,000	$ 10,000					--	Assumed
3	Traffic Control and Signs	1	LS	$ 10,000	$ 10,000					--	Lagunitas Road Bridge Replacement Project
4	Removal of Existing Bridge (Incl Culvert)	1,080	SF	$ 50	$ 54,000					27'x40'=1080SF	Florida Department of Transportation
5	Excavation for Abutments	150	CY	$ 160	$ 24,000					2x7'x42'x6'=131CY Use 150CY	200%BID Avg Arroyo (Small Volume)
6	Concrete Abutments	90	CY	$ 1,000	$ 90,000					2x5'x40'x6'=89CY Use 90CY	BID Avg Arroyo Culvert Replacement Project & Lagunitas
7	Concrete Slab Deck	110	CY	$ 1,800	$ 198,000					(27'+2x5')x40'x2'=110CY	BID Avg Arroyo Culvert Replacement Project & lagunitas
8	Concrete Barrier & Railing	40	LF	$ 300	$ 12,000					27'+20'=37' Use40LF	Lagunitas Road Bridge Replacement Project
9	Concrete Wingwalls (Incl Earthworks)	30	CY	$ 1,800	$ 54,000					4(10'x20'x1')=30CY	Ross Valley Flood Protection Project
10	Concrete Curb and Sidewalk	10	CY	$ 1,800	$ 18,000					2x37'x5'x0.5'=7CY Use10CY	BID Avg Arroyo Culvert Replacement Project
11	Asphalt Concrete Resurfacing	40	TN	$ 300	$ 12,000					37'x30'x0.5'=20CY@2TN/CY=40TN	BID Avg Arroyo Culvert Replacement Project
12	Signs and Painting	1	LS	$ 10,000	$ 10,000					--	Assumed
13	Bioengineered Bank Stabilization	1,200	SF	$ 35	$ 42,000					2x60'x10'=1200SF	Ross Valley Flood Protection Project (1.5:1 Slope)
14	Revegetation	1	LS	$ 10,000	$ 10,000					--	Assumed
15	Allowance for Utilities	1	LS	$ 50,000	$ 50,000					--	Assumed
25-01	**Right Bank Floodwall (Upstream Camino Alto Bridge) Max. Height = 1.5'**	**240**	**LF**	**$ 538**	**$ 129,200**	**$ 53,000**	**$ 9,000**	**$ 48,000**	**$ 239,200**		
1	Mobilization and Demolization	1	LS	$ 6,000	$ 6,000					--	5% const cost
2	Cleaning and Grubbing	1	LS	$ 11,000	$ 11,000					--	10% const cost
3	Excavation	80	CY	$ 120	$ 9,600					240 x2x 1.5 x3'/(27CY/CF)= 80 CY	BID Averg Arroyo Culvert Replacement Project x 1.5 to account for small volume
4	Reinforced Concrete (Including footings)	70	CY	$ 800	$ 56,000					See FloodwallSummary.xls.	BID Averg Arroyo Culvert Replacement Project
5	4" Dia 6' Long Drainage Pipes	12	Each	$ 30	$ 360					240 /20= 12	2012 RSMeans $4.35/ft x 6 = 30 $/lf (rounded)
6	4" Check Valve	12	Each	$ 50	$ 600					240 /20= 12	Price listed in backwater-valves.com ($39) + shipping and installation
7	Rock Veneer	700	SF	$ 30	$ 21,000					240 x 2 x2= 720 SF	2012 RSMeans $29/sf
8	Geotextile	240	SY	$ 6	$ 1,440					240 x (2x 1.5 +6)/(9SY/SF)= 240 SY	2012 RSMeans $5.34/sy. Use $6/sy
9	Class 2 Aggregate Base	10	CY	$ 80	$ 800					240 x 2x 1.0 x0.5'/(27CY/CF)= 9 CY	Lagunitas Road Bridge Replacement Project Contract Unit Price.
10	Backfill	55	CY	$ 80	$ 4,400					240 x 2 x 1.5 x2/27= 53 CY	BID Averg Arroyo Culvert Replacement Project
11	Erosion Protection	240	LF	$ 75	$ 18,000					--	Ross Valley Flood Protection Project

100-YEAR FLOOD PROTECTION MEASURES
Arroyo Corte Madera Del Presidio Creek, Mill Valley, CA

Item	Description	Quantity	Unit	Unit Price	Const Cost	Engineering/ Permitting Cost @41% (*)	City's Staff Admin. Cost @5%(**)	Contingencies @25% (***)	Total Project Cost	Assumption for Estimated Quantity	Assumption for Unit Price
25-02	**Left Bank Floodwall (Between Gage & Valley Circle Pedestrian Bridge) Max. Height = 3'**	**370**	**LF**	**$ 905**	**$ 334,705**	**$ 137,000**	**$ 24,000**	**$ 124,000**	**$ 619,705**		
1	Mobilization and Demolization	1	LS	$ 15,000	$ 15,000					--	5% const cost
2	Cleaning and Grubbing	1	LS	$ 29,000	$ 29,000					--	10% const cost
3	Excavation	250	CY	$ 120	$ 30,000					370 x2x 3.0 x3'/(27CY/CF)= 247 CY	BID Averg Arroyo Culvert Replacement Project x 1.5 to account for small volume
4	Reinforced Concrete (Including footings)	160	CY	$ 800	$ 128,000					See FloodwallSummary.xls.	BID Averg Arroyo Culvert Replacement Project
5	4" Dia 8' Long Drainage Pipes	19	Each	$ 35	$ 665					370 /20= 19	2012 RSMeans $4.35/ft x 8 = 35 $/lf (rounded)
6	4" Check Valve	19	Each	$ 50	$ 950					370 /20= 19	Price listed in backwater-valves.com ($39) + shipping and installation
7	Rock Veneer	2,200	SF	$ 30	$ 66,000					370 x 3 x2= 2,220 SF	2012 RSMeans $29/sf
8	Geotextile	490	SY	$ 6	$ 2,940					370 x (2x 3.0 +6)/(9SY/SF)= 493 SY	2012 RSMeans $5.34/sy. Use $6/sy
9	Class 2 Aggregate Base	15	CY	$ 80	$ 1,200					370 x 2x 1.0 x0.5'/(27CY/CF)= 14 CY	Lagunitas Road Bridge Replacement Project Contract Unit Price.
10	Backfill	165	CY	$ 80	$ 13,200					370 x 2 x 3.0 x2/27= 164 CY	BID Averg Arroyo Culvert Replacement Project
11	Erosion Protection	370	LF	$ 75	$ 27,750					--	Ross Valley Flood Protection Project
12	Allowance for Tree Protection	1	LS	$ 20,000	$ 20,000					--	Assumed
25-03	**Left Bank Floodwall (Near Gage) Max. Height = 3.5'**	**160**	**LF**	**$ 740**	**$ 118,415**	**$ 49,000**	**$ 8,000**	**$ 44,000**	**$ 219,415**		
1	Mobilization and Demolization	1	LS	$ 5,000	$ 5,000					--	5% const cost
2	Cleaning and Grubbing	1	LS	$ 10,000	$ 10,000					--	10% const cost
3	Excavation	130	CY	$ 120	$ 15,600					160 x2x 3.5 x3'/(27CY/CF)= 124 CY	BID Averg Arroyo Culvert Replacement Project x 1.5 to account for small volume
4	Reinforced Concrete (Including footings)	30	CY	$ 1,500	$ 45,000					See FloodwallSummary.xls.	BID Averg Arroyo Culvert Replacement Project
5	4" Dia 10' Long Drainage Pipes	8	Each	$ 45	$ 360					160 /20= 8	2012 RSMeans $4.35/ft x 10 = 45 $/lf (rounded)
6	4" Check Valve	8	Each	$ 50	$ 400					160 /20= 8	Price listed in backwater-valves.com ($39) + shipping and installation
7	Rock Veneer	1,100	SF	$ 30	$ 33,000					160 x 4 x2= 1,120 SF	2012 RSMeans $29/sf
8	Geotextile	230	SY	$ 6	$ 1,380					160 x (2x 3.5 +6)/(9SY/SF)= 231 SY	2012 RSMeans $5.34/sy. Use $6/sy
9	Class 2 Aggregate Base	10	CY	$ 80	$ 800					160 x 2x 1.0 x0.5'/(27CY/CF)= 6 CY	Lagunitas Road Bridge Replacement Project Contract Unit Price.
10	Backfill	85	CY	$ 80	$ 6,800					160 x 2 x 3.5 x2/27= 83 CY	BID Averg Arroyo Culvert Replacement Project
11	Erosion Protection	1	LF	$ 75	$ 75					--	Ross Valley Flood Protection Project
25-04	**ACMDP Creek Partial Bypass ((2)RC Culverts h=4.5' w=13' L=1600' Each) (Weir L=79') (Q=900cfs)**	**1,600**	**LF**	**$ 4,556**	**$ 7,290,000**	**$ 2,989,000**	**$ 514,000**	**$ 2,698,000**	**$ 13,491,000**		
1	Mobilization / Demobilization	1	LS	$ 341,000	$ 341,000					--	5% Const Cost
2	Clearing and Grubbing	1	LS	$ 75,000	$ 75,000					--	Assumed
3	Traffic Control and Signs	1	LS	$ 60,000	$ 60,000					--	Assumed
4	Earthworks for Concrete Diversion Structure	1,000	CY	$ 80	$ 80,000					81'x20'x15'=900CY	BID Avg Arroyo Culvert Replacement Project
5	Concrete for Inlet and Outlet Structures	260	CY	$ 1,500	$ 390,000					81'x30'x2'=180CY	BID Avg Arroyo Culvert Replacement Project
6	5' x 13' Sluice Gate	3	EA	$ 30,000	$ 90,000					--	Assumed
7	Removal of Existing Road	1	LS	$ 80,000	$ 80,000					1600'x33'=5866SY Use5900SY	Lagunitas Road Bridge Replacement Project
8	Earthworks for Concrete Box Culvert	17,000	CY	$ 80	$ 1,360,000					1600'x33'x10'=19556CY Use19600CY	BID Avg Arroyo Culvert Replacement Project
9	Prefabricated Reinforced Concrete Box (4.5'x13')	4,300	CY	$ 1,000	$ 4,300,000					--	37'x1'x1'=1.37CY/LF@$1000/CY=$1370/LF
10	Class 2 Aggregate Base	1,500	TN	$ 80	$ 120,000					1600'x33'x0.75'=1467CY Use1500CY	Lagunitas Road Bridge Replacement Project
11	Asphalt Concrete Resurfacing	1	LS	$ 259,000	$ 259,000					1600'x33'x0.5'=977CY@2TN/CY=1956TN Use1960TN	BID Avg Arroyo Culvert Replacement Project
12	Rip-Rap Outlet Structure	250	TN	$ 100	$ 25,000					40'x20'x4'=118CY@1.6TN/CY=190TN Use200TN	BID Avg Arroyo Culvert Replacement Project
13	Signs and Painting	1	LS	$ 20,000	$ 20,000					--	Assumed
14	Relocate 16" Storm Drain Pipe Line @ Willow St.	300	LF	$ 200	$ 60,000					--	Assumed
15	Relocate 6" Sewer Pipe Line @ Willow St.	200	LF	$ 150	$ 30,000					--	Assumed
	Note: Utilities in Miller Ave will be charged to Miller Avenue Project, and, therefore, were not considered										
25-05	**Bank Retaining/ Floodwall and Upstream Bridge Wall (Downstream of Parking Bridge in Old Mill Creek) RB:Max. Height=2.5', LB:Max. Height=5.5'**	**100**	**LF**	**$ 1,440.15**	**$ 144,015**	**$ 59,000**	**$ 10,000**	**$ 53,000**	**$ 266,015**		
1	Mobilization and Demolization	1	LS	$ 6,000	$ 6,000					--	5% const cost
2	Cleaning and Grubbing	1	LS	$ 13,000	$ 13,000					--	10% const cost
3	Excavation	130	CY	$ 120	$ 15,600					100 x2x 5.5 x3'/(27CY/CF)= 122 CY	BID Averg Arroyo Culvert Replacement Project x 1.5 to account for small volume
4	Reinforced Concrete (Including footings)	50	CY	$ 1,200	$ 60,000					See FloodwallSummary.xls.	BID Averg Arroyo Culvert Replacement Project
5	4" Dia 14' Long Drainage Pipes	5	Each	$ 65	$ 325					100 /20= 5	2012 RSMeans $4.35/ft x 14 = 65 $/lf (rounded)
6	4" Check Valve	5	Each	$ 50	$ 250					100 /20= 5	Price listed in backwater-valves.com ($39) + shipping and installation
7	Rock Veneer	1,100	SF	$ 30	$ 33,000					100 x 6 x2= 1,100 SF	2012 RSMeans $29/sf
8	Geotextile	190	SY	$ 6	$ 1,140					100 x (2x 5.5 +6)/(9SY/SF)= 189 SY	2012 RSMeans $5.34/sy. Use $6/sy
9	Class 2 Aggregate Base	5	CY	$ 80	$ 400					100 x 2x 1.0 x0.5'/(27CY/CF)= 4 CY	Lagunitas Road Bridge Replacement Project Contract Unit Price.
10	Backfill	85	CY	$ 80	$ 6,800					100 x 2 x 5.5 x2/27= 81 CY	BID Averg Arroyo Culvert Replacement Project
11	Erosion Protection	100	LF	$ 75	$ 7,500					--	Ross Valley Flood Protection Project

100-YEAR FLOOD PROTECTION MEASURES
Arroyo Corte Madera Del Presidio Creek, Mill Valley, CA

Item	Description	Quantity	Unit	Unit Price	Const Cost	Engineering/ Permitting Cost @41% (*)	City's Staff Admin. Cost @5%(**)	Contingencies @25% (***)	Total Project Cost	Assumption for Estimated Quantity	Assumption for Unit Price
50-01	**Replace Egger Plaza Bridge 31'Span-25'Width-2.5'Raise-0.5'Freeboard (WSE=15.43')**	**775**	**SF**	**$ 714**	**$ 553,000**	**$ 227,000**	**$ 39,000**	**$ 205,000**	**$ 1,024,000**		
1	Mobilization / Demobilization	1	LS	$ 25,000	$ 25,000					--	5% Const Cost
2	Clearing and Grubbing (Includes Safety Works)	1	LS	$ 20,000	$ 20,000					--	Lagunitas Road Bridge Replacement Estimate
3	Traffic Control and Signs	1	LS	$ 5,000	$ 5,000					--	Lagunitas Road Bridge Replacement Estimate
4	Removal of Existing Bridge (w/o Abutments)	800	SF	$ 40	$ 32,000					31'x25'=775SF Use800SF	Florida Department of Transportation($50/SFx80%w/oAbutments)
5	Removal of Existing Road	300	SY	$ 60	$ 18,000					2x50'x25'=278SY Use300SY	200%Lagunitas Road Bridge Replacement Estimate
6	Raise Concrete Abutments (Incl reinforcement of Existing)	50	CY	$ 1,000	$ 50,000					2x25'(5'x2.5'+2'x5.5')=44CY Use50CY	BID Avg Arroyo Culvert Replacement Project & Lagunitas
7	Pre-Fabricated Bridge	780	SF	$ 250	$ 195,000					31'x25'=775SF Use780SF	CONTECH
8	Concrete Wingwalls (Incl Earthworks)	30	CY	$ 1,800	$ 54,000					4(10'x20'x1')=30CY	Ross Valley Flood Protection Project
9	Road Sub-grade Compacted Backfill	125	CY	$ 80	$ 10,000					2(0.5x50'x2.5'x25')=116CY Use125CY	BID Avg Arroyo Culvert Replacement Project
10	Class 2 Aggregate Base	75	CY	$ 80	$ 6,000					2(50'x25'x0.75')=69CY Use75CY	Lagunitas Road Bridge Replacement Estimate
11	Asphalt Concrete Resurfacing	130	TN	$ 300	$ 39,000					(2x50'+31')x25'x0.5'=61CY@2TN/CY=122TN Use130TN	BID Avg Arroyo Culvert Replacement Project
12	Parking Modifications	2	EA	$ 15,000	$ 30,000					2 DS Parking Lot (2'Raise) + 2 US Private (2'Raise)	Assumed
13	Signs and Painting	1	LS	$ 5,000	$ 5,000					--	Lagunitas Road Bridge Replacement Estimate
14	Bioengineered Bank Stabilization	400	SF	$ 35	$ 14,000					2x20'x10'=400SF	Ross Valley Flood Protection Project
15	Allowance Utilities	1	LS	$ 50,000	$ 50,000					--	--
50-02	**Replace/Enlarge Culvert Under Private Building from Sunnyside Ave (Culvert w=9' L=120)**	**120**	**LF**	**$ 4,742**	**$ 569,000**	**$ 233,000**	**$ 40,000**	**$ 211,000**	**$ 1,053,000**		
1	Mobilization / Demobilization	1	LS	$ 26,000	$ 26,000					--	5% Const Cost
2	Clearing and Grubbing (Includes Safety Works)	1	LS	$ 20,000	$ 20,000					--	Lagunitas Road Bridge Replacement Project
3	Traffic Control and Signs	1	LS	$ 10,000	$ 10,000					--	Lagunitas Road Bridge Replacement Project
4	Earthworks for Removal Existing Culvert	200	CY	$ 240	$ 48,000					120'x10'x4'=178CY Use200CY	300%BID Avg Arroyo Culvert Replacement Project
5	Removal of Existing Culvert	120	LF	$ 500	$ 60,000					81'x30'x2'=180CY	Assumed
6	Shoring	90	CY	$ 1,000	$ 90,000					2(120'x2'x5')=89CY Use90CY	BID Avg Arroyo Culvert Replacement Project
7	Tie-backs	240	LF	$ 125	$ 30,000					120'/10'=12x20'=240LF	Lansdale Project
8	Concrete Box Culvert (9'x9')	120	LF	$ 1,100	$ 132,000					--	28'x1'x1'=1.04CY/LF@$1000/CY=$1037/LF Use$1100/LF
9	Inlet and Oulet Concrete Structure (Incl Earthworks)	30	CY	$ 1,800	$ 54,000					2(20'x20'x1')=35CY	Ross Valley Flood Protection Project
10	Erosion Control	1	LS	$ 20,000	$ 20,000					--	Assumed
11	Bioengineered Bank Stabilization	400	SF	$ 35	$ 14,000					2x20'x10'=400SF	Ross Valley Flood Protection Project (1.5:1 Slope)
12	Fish Passage Baffles	5	CY	$ 3,000	$ 15,000					120'/20'=6x10'x1'x2'=4.4CY Use5CY	Lansdale Project
13	Fish Passage Step Pools	100	TN	$ 500	$ 50,000					3x25'x3'x6'=50CY@2TN/CY=100TN	200%BID Avg Arroyo (Rock-River Boulders)
50-03	**Bank Floodwall and Upstream Bridge Wall (Downstream of Old Mill Creek above Old Mill Creek Confluence) RB:Max. Height=3', LB:Max. Height=3'**	**40**	**LF**	**$ 2,145**	**$ 85,789**	**$ 35,000**	**$ 6,000**	**$ 32,000**	**$ 158,789**		
1	Mobilization and Demolization	1	LS	$ 4,000	$ 4,000					--	5% const cost
2	Cleaning and Grubbing	1	LS	$ 7,000	$ 7,000					--	10% const cost
3	Excavation	30	CY	$ 120	$ 3,600					40 x2x 3.0 x3'/(27CY/CF)= 27 CY	BID Averg Arroyo Culvert Replacement Project x 1.5 to account for small volume
4	Reinforced Concrete (Including footings)	40	CY	$ 1,500	$ 60,000					See FloodwallSummary.xls.	BID Averg Arroyo Culvert Replacement Project
5	4" Dia 8' Long Drainage Pipes	2	Each	$ 35	$ 70					40 /20= 2	2012 RSMeans $4.35/ft x 8 = 35 $/lf (rounded)
6	4" Check Valve	2	Each	$ 50	$ 100					40 /20= 2	Price listed in backwater-valves.com ($39) + shipping and installation
7	Rock Veneer	200	SF	$ 30	$ 6,000					40 x 3 x2= 240 SF	2012 RSMeans $29/sf
8	Geotextile	50	SY	$ 6	$ 300					40 x (2x 3.0 +6)/(9SY/SF)= 53 SY	2012 RSMeans $5.34/sy. Use $6/sy
9	Class 2 Aggregate Base	1	CY	$ 80	$ 119					40 x 2x 1.0 x0.5'/(27CY/CF)= 1 CY	Lagunitas Road Bridge Replacement Project Contract Unit Price.
10	Backfill	20	CY	$ 80	$ 1,600					40 x 2 x 3.0 x2/27= 18 CY	BID Averg Arroyo Culvert Replacement Project
11	Erosion Protection	40	LF	$ 75	$ 3,000					--	Ross Valley Flood Protection Project
50-04	**Mill Valley Golf Course Detention Basin**	**227**	**AF**	**$ 32,630**	**$ 7,407,000**	**$ 3,037,000**	**$ 522,000**	**$ 2,742,000**	**$ 13,708,000**		5% Const Cost
1	Mobilization / Demobilization	1	LS	$ 351,000	$ 351,000					--	Lagunitas Road Bridge Replacement Project
2	Clearing and Grubbing (Includes Safety Works)	1	LS	$ 20,000	$ 20,000					--	Lagunitas Road Bridge Replacement Project
3	Traffic Control and Signs	1	LS	$ 10,000	$ 10,000					870'@8'Max + 230'@4'Max	See Floodwalls cost
4	Floodwalls	1,100	LF	$ 1,200	$ 1,320,000					LDD Calculation	Including Key, Impermeable, permeable & slope protection
5	Dam Embankment	60,000	CY	$ 30	$ 1,800,000					Measure	42'x1'x1'=1.56CY/LF@$1000/CY=$1556/LF Use$1600/LF
6	Dam Foundation / Cut off Wall	1	LS	$ 300,000	$ 300,000					--	20% of Dam Embankment
7	Fish Passage Conduit	260	LF	$ 1,600	$ 416,000					--	Assumed
8	Gated Inlet	1	LS	$ 150,000	$ 150,000					150'x150'x2'=1670CY@1.6TN/CY=2667TN Use3000TN	BID Avg Arroyo Culvert Replacement Project
9	Rip-Rap / Outlet Works	3,000	TN	$ 150	$ 450,000					200'x20'x2'=296CY Use300CY	Ross Valley Flood Protection Project
10	Spillway Structure	300	CY	$ 1,800	$ 540,000					--	25% const cost
11	Environmental Protection	1	LS	$ 50,000	$ 50,000					--	Assumed
12	Allowance for Golf Course Repair/Restoration	1	LS	$ 2,000,000	$ 2,000,000						Assumed

100-YEAR FLOOD PROTECTION MEASURES
Arroyo Corte Madera Del Presidio Creek, Mill Valley, CA

Item	Description	Quantity	Unit	Unit Price	Const Cost	Engineering/ Permitting Cost @41% (*)	City's Staff Admin. Cost @5%(**)	Contingencies @25% (***)	Total Project Cost	Assumption for Estimated Quantity	Assumption for Unit Price
50-05	**Right & Left Bank Floodwalls (Upstream Willow Pedestrian Bridge) RB: Max. Height = 3.6', LB: Max. Height = 3.8'**	**730**	**LF**	**$ 871**	**$ 635,915**	**$ 261,000**	**$ 45,000**	**$ 235,000**	**$ 1,176,915**		
	1 Mobilization and Demolization	1	LS	$ 28,000	$ 28,000					--	5% const cost
	2 Cleaning and Grubbing	1	LS	$ 55,000	$ 55,000					--	10% const cost
	3 Excavation	490	CY	$ 120	$ 58,800					730 x2x 3.0 x3'/(27CY/CF)= 487 CY	BID Averg Arroyo Culvert Replacement Project x 1.5 to account for small volume
	4 Reinforced Concrete (Including footings)	270	CY	$ 1,000	$ 270,000					See FloodwallSummary.xls.	BID Averg Arroyo Culvert Replacement Project
	5 4" Dia 8' Long Drainage Pipes	37	Each	$ 35	$ 1,295					730 /20= 37	2012 RSMeans $4.35/ft x 8 = 35 $/lf (rounded)
	6 4" Check Valve	37	Each	$ 50	$ 1,850					730 /20= 37	Price listed in backwater-valves.com ($39) + shipping and installation
	7 Rock Veneer	4,400	SF	$ 30	$ 132,000					730 x 3 x2= 4,380 SF	2012 RSMeans $29/sf
	8 Geotextile	970	SY	$ 6	$ 5,820					730 x (2x 3.0 +6)/(9SY/SF)= 973 SY	2012 RSMeans $5.34/sy. Use $6/sy
	9 Class 2 Aggregate Base	30	CY	$ 80	$ 2,400					730 x 2x 1.0 x0.5'/(27CY/CF)= 27 CY	Lagunitas Road Bridge Replacement Project Contract Unit Price.
	10 Backfill	325	CY	$ 80	$ 26,000					730 x 2 x 3.0 x2/27= 324 CY	BID Averg Arroyo Culvert Replacement Project
	11 Erosion Protection	730	LF	$ 75	$ 54,750					--	Ross Valley Flood Protection Project
100-01	**Right Bank Floodwall (Upstream Camino Alto Bridge) Max. Height = 0.5'**	**30**	**LF**	**$ 317**	**$ 9,510**	**$ 4,000**	**$ 1,000**	**$ 4,000**	**$ 18,510**		
	1 Mobilization and Demolization	1	LS	$ -	$ -					--	5% const cost
	2 Cleaning and Grubbing	1	LS	$ 1,000	$ 1,000					--	10% const cost
	3 Excavation	10	CY	$ 120	$ 1,200					30 x2x 0.5 x3'/(27CY/CF)= 3 CY	BID Averg Arroyo Culvert Replacement Project x 1.5 to account for small volume
	4 Reinforced Concrete (Including footings)	5	CY	$ 800	$ 4,000					See FloodwallSummary.xls.	BID Averg Arroyo Culvert Replacement Project
	5 4" Dia 4' Long Drainage Pipes	2	Each	$ 20	$ 40					30 /20= 2	2012 RSMeans $4.35/ft x 4 = 20 $/lf (rounded)
	6 4" Check Valve	2	Each	$ 50	$ 100					30 /20= 2	Price listed in backwater-valves.com ($39) + shipping and installation
	7 Rock Veneer	0	SF	$ 30	$ -					30 x 1 x2= 30 SF	2012 RSMeans $29/sf
	8 Geotextile	20	SY	$ 6	$ 120					30 x (2x 0.5 +6)/(9SY/SF)= 23 SY	2012 RSMeans $5.34/sy. Use $6/sy
	9 Class 2 Aggregate Base	5	CY	$ 80	$ 400					30 x 2x 1.0 x0.5'/(27CY/CF)= 1 CY	Lagunitas Road Bridge Replacement Project Contract Unit Price.
	10 Backfill	5	CY	$ 80	$ 400					30 x 2 x 0.5 x2/27= 2 CY	BID Averg Arroyo Culvert Replacement Project
	11 Erosion Protection	30	LF	$ 75	$ 2,250					--	Ross Valley Flood Protection Project
				Total	**$ 21,702,664**	**$ 8,898,000**	**$ 1,531,000**	**$ 8,037,000**	**$ 40,168,664**		
								Total (Roundup)	**$ 40,200,000**		

Notes:
(*) Engineering/Permitting Cost includes:

Engineering and Design	15% of Construction Cost
Environmental Permitting	10% of Construction Cost
Engineering Construction Management	10% of Construction Cost
Environmental Monitoring During Construction	6% of Construction Cost
	41% of Construction Cost

(**) The City's Staff Administrative Cost is 5% of the total cost of Construction and Engineering/Permitting.
(***)The Contingency Cost is 25% of the total cost of Construction, Engineering/Permitting, and the City's Staff Administration.

Cost Estimate By-Pass Channel

Arroyo Corte Madera del Presidion Creek - Mill Valley

Scenario: 25 Year Flow **Date: 7/13/2017**

Item No.	Description	Estimated Quantity	Unit Measures	Unit Price	Amount	Assumption for Estimated Quantity	Assumption for Unit Price
1	**Mobilization and Demobilization**	**1**	**LS**	**$ 164,000**	**$ 164,000**		
1.1	Mobilization and Demobilization	1	LS	$ 164,000	$ 164,000		5% Construction Cost (Base on Upper Green Valley BID 2450)
2	**Clearing and Grubbing**	**1**	**LS**	**$ 75,000**	**$ 75,000**		
2.1	Clear and dispose of trees	1	LS	$ 10,000	$ 10,000	5K each site	M&G Clear &Grub BID Jewell Creek 2442
2.2	Remove and storage existing features	1	LS	$ 5,000	$ 5,000		Assumed
2.3	Pre-Construction Potholing (Utilities)	1	LS	$ 30,000	$ 30,000	For sewer lines and utilities	Assumed
2.4	Dewater and care of creek	1	LS	$ 30,000	$ 30,000	2 sites @ 15k each	M&G Dewater BID Jewell Creek 2442
3	**Traffic Control**	**1**	**LS**	**$ 40,000**	**$ 40,000**		
3.1	Personal	1	LS	$ 20,000	$ 20,000	40*8*20*3=19200 Use 20k	
3.2	Equipment and features	1	LS	$ 20,000	$ 20,000	Same as personal	
4	**Earthworks for Inlet and Outlet Structures**	**500**	**CY**	**$ 80**	**$ 40,000**		
4.1	Earthworks for inlet structure	350	CY	$ 80	$ 28,000	10'*22'*40'=326CY Use 350CY	Base on Upper Green Valley BID 2450
4.2	Earthworks for outlet structure	150	CY	$ 80	$ 12,000	30'*8'*15'=133CY Use 150CY	Base on Upper Green Valley BID 2450
5	**Concrete for Inlet and Outlet Structures**	**150**	**CY**	**$ 1,500**	**$ 225,000**		
5.1	Spillway Reinforced concrete	20	CY	$ 1,500	$ 30,000	7'*2'*40'=20CY	Based on Glissman Excavating cost for Lansdale 2393
5.2	Headwalls inlet structure	100	CY	$ 1,500	$ 150,000	50sf*50'-11'*4.5"=91CY Use 100CY	Based on Glissman Excavating cost for Lansdale 2393
5.3	Wingwalss and headwalls outlet structure	30	CY	$ 1,500	$ 45,000	13'*2'*10+30'*7'*1'+13'*15'*1'=25CY Use30CY	Based on Glissman Excavating cost for Lansdale 2393
6	**Sluice Gates**	**1**	**EA**	**$ 50,000**	**$ 50,000**		
5.1	4.5'x11' Sluice gates	1	EA	$ 50,000	$ 50,000		Base on CPEN
7	**Remove and Dispose Existing Road**	**1**	**LS**	**$ 32,000**	**$ 32,000**		
7.1	Remove and dispose asphalt	400	CY	$ 50	$ 20,000	1450'*15'*.5'=403cy Use 400CY	$30/CY remove + $20/CY dispose
7.2	Remove and dispose structures	40	CY	$ 300	$ 12,000	10% of asphalt	$200/CY remove + $100/CY dispose
8	**Earthworks for Concrete Box Culverts**	**8,000**	**CY**	**$ 80**	**$ 640,000**		
8.1	Earthworks for concrete box culverts	8,000	CY	$ 80	$ 640,000	1450'*9'*15'=7250CY Use 8000CY	Base on Upper Green Valley BID 2450
9	**Prefabricated Concrete Box Culverts**	**2,000**	**CY**	**$ 1,000**	**$ 2,000,000**		
9.1	(1) 4.5'x10' Reinforced concrete culverts	2,000	CY	$ 1,000	$ 2,000,000	35sf*1450'=1880cy Use 2000CY	Based on Glissman Excavating cost for Lansdale 2393
10	**Class 2 Aggregate Base**	**650**	**TN**	**$ 80**	**$ 52,000**		
10.1	Class 2 aggregate base	650	TN	$ 80	$ 52,000	15'x1450'*.5'=403cy@1.6Tn/cy=650TN	Base on Upper Green Valley BID 2450
11	**Asphalt Concrete Resurfacing**	**1**	**LS**	**$ 110,000**	**$ 110,000**		
11.1	Asphalt	400	TN	$ 250	$ 100,000	15'x1450'*.25'=201cy@2Tn/cy=400TN	Base on Arroyo Cr BID
11.2	Structures	1	LS	$ 10,000	$ 10,000	10% of asphalt	Assumed
12	**Vegetated Rip Rap Slope Protection**	**140**	**TN**	**$ 100**	**$ 14,000**		
12.1	Vegetated rip rap	140	TN	$ 100	$ 14,000	50'x20'x1.5'+25'x20'x1.5'=83cy@1.6tn/cy=140CY	Base on Upper Green Valley BID 2450
13	**Signs and Painting**	**1**	**LS**	**$ 20,000**	**$ 20,000**		
13.1	Signs and painting	1	LS	$ 20,000	$ 20,000		Assumed
14	**Relocate 16" Storm Drain Pipe Line @ Willow St.**	**300**	**LF**	**$ 200**	**$ 60,000**		
14.1	General	300	LF	$ 200	$ 60,000		Assumed
15	**Relocate 6" Sewer Pipe Line @ Willow St.**	**200**	**LF**	**$ 150**	**$ 30,000**		
15.1	General	200	LF	$ 150	$ 30,000		Assumed
			TOTAL CONSTRUCTION		**$ 3,552,000**		
16	**Engineering/Permitting Cost (41% Construction Cost)**	**1**	**LS**	**$ 1,457,000**	**$ 1,457,000**		41% Construction Cost
17	**City's Staff Administrative (5% Above)**	**1**	**LS**	**$ 251,000**	**$ 251,000**		5% Construction Cost+E/P
18	**Contingencies (25% Above)**	**1**	**LS**	**$ 1,315,000**	**$ 1,315,000**		25% Construction Cost+E/P+City's
				TOTAL	**$ 6,575,000**		

Cost Estimate By-Pass Channel

Arroyo Corte Madera del Presidion Creek - Mill Valley

Scenario: 50 Year Flow **Date: 7/12/2017**

Item No.	Description	Estimated Quantity	Unit Measures	Unit Price	Amount	Assumption for Estimated Quantity	Assumption for Unit Price
1	**Mobilization and Demobilization**	**1**	**LS**	**$ 256,000**	**$ 256,000**		
1.1	Mobilization and Demobilization	1	LS	$ 256,000	$ 256,000		5% Construction Cost (Base on Upper Green Valley BID 2450)
2	**Clearing and Grubbing**	**1**	**LS**	**$ 75,000**	**$ 75,000**		
2.1	Clear and dispose of trees	1	LS	$ 10,000	$ 10,000	5K each site	M&G Clear &Grub BID Jewell Creek 2442
2.2	Remove and storage existing features	1	LS	$ 5,000	$ 5,000		Assumed
2.3	Pre-Construction Potholing (Utilities)	1	LS	$ 30,000	$ 30,000	For sewer lines and utilities	Assumed
2.4	Dewater and care of creek	1	LS	$ 30,000	$ 30,000	2 sites @ 15k each	M&G Dewater BID Jewell Creek 2442
3	**Traffic Control**	**1**	**LS**	**$ 50,000**	**$ 50,000**		
3.1	Personal	1	LS	$ 25,000	$ 25,000	40*8*25*3=24000 Use 25k	
3.2	Equipment and features	1	LS	$ 25,000	$ 25,000	Same as personal	
4	**Earthworks for Inlet and Outlet Structures**	**850**	**CY**	**$ 80**	**$ 68,000**		
4.1	Earthworks for inlet structure	600	CY	$ 80	$ 48,000	10'*22'*72'=587CY Use 600CY	Base on Upper Green Valley BID 2450
4.2	Earthworks for outlet structure	250	CY	$ 80	$ 20,000	30'*8'*25'=222CY Use 250CY	Base on Upper Green Valley BID 2450
5	**Concrete for Inlet and Outlet Structures**	**230**	**CY**	**$ 1,500**	**$ 345,000**		
5.1	Spillway Reinforced concrete	30	CY	$ 1,500	$ 45,000	5.7'*2'*72'=30CY	Based on Glissman Excavating cost for Lansdale 2393
5.2	Headwalls inlet structure	160	CY	$ 1,500	$ 240,000	50sf*90'-2*10'*4.5"=163CY Use 160CY	Based on Glissman Excavating cost for Lansdale 2393
5.3	Wingwalss and headwalls outlet structure	40	CY	$ 1,500	$ 60,000	23'*2'*10+30'*7'*1'+23'*15'*1'=38CY Use 40CY	Based on Glissman Excavating cost for Lansdale 2393
6	**Sluice Gates**	**2**	**EA**	**$ 40,000**	**$ 80,000**		
5.1	4.5'x10' Sluice gates	2	EA	$ 40,000	$ 80,000		Base on CPEN
7	**Remove and Dispose Existing Road**	**1**	**LS**	**$ 56,000**	**$ 56,000**		
7.1	Remove and dispose asphalt	700	CY	$ 50	$ 35,000	1450'*25'*.5'=671cy Use 700CY	$30/CY remove + $20/CY dispose
7.2	Remove and dispose structures	70	CY	$ 300	$ 21,000	10% of asphalt	$200/CY remove + $100/CY dispose
8	**Earthworks for Concrete Box Culverts**	**12,000**	**CY**	**$ 80**	**$ 960,000**		
8.1	Earthworks for concrete box culverts	12,000	CY	$ 80	$ 960,000	1450'*9'*25'=12083CY Use 12000CY	Base on Upper Green Valley BID 2450
9	**Prefabricated Concrete Box Culverts**	**3,200**	**CY**	**$ 1,000**	**$ 3,200,000**		
9.1	(2) 4.5'x10' Reinforced concrete culverts	3,200	CY	$ 1,000	$ 3,200,000	59.5sf*1450'=3195cy Use 3200CY	Based on Glissman Excavating cost for Lansdale 2393
10	**Class 2 Aggregate Base**	**1,100**	**TN**	**$ 80**	**$ 88,000**		
10.1	Class 2 aggregate base	1,100	TN	$ 80	$ 88,000	25'x1450'*.5'=671cy@1.6Tn/cy=1100TN	Base on Upper Green Valley BID 2450
11	**Asphalt Concrete Resurfacing**	**1**	**LS**	**$ 187,000**	**$ 187,000**		
11.1	Asphalt	680	TN	$ 250	$ 170,000	25'x1450'*.25'=335cy@2Tn/cy=671TN Use680TN	Base on Arroyo Cr BID
11.2	Structures	1	LS	$ 17,000	$ 17,000	10% of asphalt	Assumed
12	**Vegetated Rip Rap Slope Protection**	**220**	**TN**	**$ 100**	**$ 22,000**		
12.1	Vegetated rip rap	220	TN	$ 100	$ 22,000	90'x20'x1.5'+35'x20'x1.5'=138cy@1.6tn/cy=220CY	Base on Upper Green Valley BID 2450
13	**Signs and Painting**	**1**	**LS**	**$ 20,000**	**$ 20,000**		
13.1	Signs and painting	1	LS	$ 20,000	$ 20,000		Assumed
14	**Relocate 16" Storm Drain Pipe Line @ Willow St.**	**300**	**LF**	**$ 200**	**$ 60,000**		
14.1	General	300	LF	$ 200	$ 60,000		Assumed
15	**Relocate 6" Sewer Pipe Line @ Willow St.**	**200**	**LF**	**$ 150**	**$ 30,000**		
15.1	General	200	LF	$ 150	$ 30,000		Assumed
			TOTAL CONSTRUCTION		**$ 5,497,000**		
16	**Engineering/Permitting Cost (41% Construction Cost)**	**1**	**LS**	**$ 2,254,000**	**$ 2,254,000**		41% Construction Cost
17	**City's Staff Administrative (5% Above)**	**1**	**LS**	**$ 388,000**	**$ 388,000**		5% Construction Cost+E/P
18	**Contingencies (25% Above)**	**1**	**LS**	**$ 2,035,000**	**$ 2,035,000**		25% Construction Cost+E/P+City's
				TOTAL	**$ 10,174,000**		

Cost Estimate By-Pass Channel

Arroyo Corte Madera del Presidion Creek - Mill Valley

Scenario: 100 Year Flow **Date: 7/12/2017**

Item No.	Description	Estimated Quantity	Unit Measures	Unit Price	Amount	Assumption for Estimated Quantity	Assumption for Unit Price
1	**Mobilization and Demobilization**	**1**	**LS**	**$ 341,000**	**$ 341,000**		
1.1	Mobilization and Demobilization	1	LS	$ 341,000	$ 341,000		5% Construction Cost (Base on Upper Green Valley BID 2450)
2	**Clearing and Grubbing**	**1**	**LS**	**$ 75,000**	**$ 75,000**		
2.1	Clear and dispose of trees	1	LS	$ 10,000	$ 10,000	5K each site	M&G Clear &Grub BID Jewell Creek 2442
2.2	Remove and storage existing features	1	LS	$ 5,000	$ 5,000		Assumed
2.3	Pre-Construction Potholing (Utilities)	1	LS	$ 30,000	$ 30,000	For sewer lines and utilities	Assumed
2.4	Dewater and care of creek	1	LS	$ 30,000	$ 30,000	2 sites @ 15k each	M&G Dewater BID Jewell Creek 2442
3	**Traffic Control**	**1**	**LS**	**$ 60,000**	**$ 60,000**		
3.1	Personal	1	LS	$ 30,000	$ 30,000	40*8*30*3=28800 Use 30k	
3.2	Equipment and features	1	LS	$ 30,000	$ 30,000	Same as personal	
4	**Earthworks for Inlet and Outlet Structures**	**1,000**	**CY**	**$ 80**	**$ 80,000**		
4.1	Earthworks for inlet structure	700	CY	$ 80	$ 56,000	10'*22'*80'=651CY Use 700CY	Base on Upper Green Valley BID 2450
4.2	Earthworks for outlet structure	300	CY	$ 80	$ 24,000	30'*8'*35'=311CY Use 300CY	Base on Upper Green Valley BID 2450
5	**Concrete for Inlet and Outlet Structures**	**260**	**CY**	**$ 1,500**	**$ 390,000**		
5.1	Spillway Reinforced concrete	30	CY	$ 1,500	$ 45,000	5.4'*2'*80'=32CY Use 30CY	Based on Glissman Excavating cost for Lansdale 2393
5.2	Headwalls inlet structure	180	CY	$ 1,500	$ 270,000	50sf*100'-3*9'*4.5"=180CY	Based on Glissman Excavating cost for Lansdale 2393
5.3	Wingwalss and headwalls outlet structure	50	CY	$ 1,500	$ 75,000	31'*2'*10+30'*7'*1'+31'*15'*1'=48CY Use 50CY	Based on Glissman Excavating cost for Lansdale 2393
6	**Sluice Gates**	**3**	**EA**	**$ 30,000**	**$ 90,000**		
5.1	4.5'x9' Sluice gates	3	EA	$ 30,000	$ 90,000		Base on CPEN
7	**Remove and Dispose Existing Road**	**1**	**LS**	**$ 80,000**	**$ 80,000**		
7.1	Remove and dispose asphalt	1,000	CY	$ 50	$ 50,000	1450'*35'*.5'=940cy Use 1000CY	$30/CY remove + $20/CY dispose
7.2	Remove and dispose structures	100	CY	$ 300	$ 30,000	10% of asphalt	$200/CY remove + $100/CY dispose
8	**Earthworks for Concrete Box Culverts**	**17,000**	**CY**	**$ 80**	**$ 1,360,000**		
8.1	Earthworks for concrete box culverts	17,000	CY	$ 80	$ 1,360,000	1450'*9'*35'=16917CY Use 17000CY	Base on Upper Green Valley BID 2450
9	**Prefabricated Concrete Box Culverts**	**4,300**	**CY**	**$ 1,000**	**$ 4,300,000**		
9.1	(3) 4.5'x9' Reinforced concrete culverts	4,300	CY	$ 1,000	$ 4,300,000	80sf*1450'=4296cy Use 4300CY	Based on Glissman Excavating cost for Lansdale 2393
10	**Class 2 Aggregate Base**	**1,500**	**TN**	**$ 80**	**$ 120,000**		
10.1	Class 2 aggregate base	1,500	TN	$ 80	$ 120,000	35'x1450'*.5'=940cy@1.6Tn/cy=1500TN	Base on Upper Green Valley BID 2450
11	**Asphalt Concrete Resurfacing**	**1**	**LS**	**$ 259,000**	**$ 259,000**		
11.1	Asphalt	940	TN	$ 250	$ 235,000	35'x1450'*.25'=470cy@2Tn/cy=940TN	Base on Arroyo Cr BID
11.2	Structures	1	LS	$ 24,000	$ 24,000	10% of asphalt	Assumed
12	**Vegetated Rip Rap Slope Protection**	**250**	**TN**	**$ 100**	**$ 25,000**		
12.1	Vegetated rip rap	250	TN	$ 100	$ 25,000	100'x20'x1.5'+40'x20'x1.5'=156cy@1.6tn/cy=250CY	Base on Upper Green Valley BID 2450
13	**Signs and Painting**	**1**	**LS**	**$ 20,000**	**$ 20,000**		
13.1	Signs and painting	1	LS	$ 20,000	$ 20,000		Assumed
14	**Relocate 16" Storm Drain Pipe Line @ Willow St.**	**300**	**LF**	**$ 200**	**$ 60,000**		
14.1	General	300	LF	$ 200	$ 60,000		Assumed
15	**Relocate 6" Sewer Pipe Line @ Willow St.**	**200**	**LF**	**$ 150**	**$ 30,000**		
15.1	General	200	LF	$ 150	$ 30,000		Assumed
			TOTAL CONSTRUCTION		**$ 7,290,000**		
16	**Engineering/Permitting Cost (41% Construction Cost)**	**1**	**LS**	**$ 2,989,000**	**$ 2,989,000**		41% Construction Cost
17	**City's Staff Administrative (5% Above)**	**1**	**LS**	**$ 514,000**	**$ 514,000**		5% Construction Cost+E/P
18	**Contingencies (25% Above)**	**1**	**LS**	**$ 2,699,000**	**$ 2,699,000**		25% Construction Cost+E/P+City's
				TOTAL	**$ 13,492,000**		

COUNTY OF MARIN - DEPARTMENT OF PUBLIC WORKS SUMMARY OF PROPOSALS OPENED

For Construction of:
Fish Passage Restoration
Arroyo Creek at Castro St.

8/5/2010 (Date) 2:00 PM (Time) 304 (Room No.)

Project No.: FP-08
Plan No.: 2007-027

Bids Opened by: Joanna Charlton
Checked by: John Berg
Recorded by: Gary Schwartz

ITEM No.	DESCRIPTION	Estimated Quantity	Unit Measure	W.R. Forde Assoc. Richmond, CA xx Unit Bid	W.R. Forde Assoc. Richmond, CA xx Amount	Maggiora & Ghilotti, Inc. San Rafael, CA xx Unit Bid	Maggiora & Ghilotti, Inc. San Rafael, CA xx Amount	Engelke Construction Healdsburg, CA xx Unit Bid	Engelke Construction Healdsburg, CA xx Amount	Greener Excavations & Const. Fairfax, CA xx Unit Bid	Greener Excavations & Const. Fairfax, CA xx Amount
1.	Signs & Traffic Control	1	LS	$6,000.00	$6,000.00	$5,000.00	$5,000.00	$6,500.00	$6,500.00	$4,892.62	$4,892.62
2.	Clearing & Grubbing	1	LS	$60,000.00	$60,000.00	$27,904.00	$27,904.00	$21,000.00	$21,000.00	$58,016.00	$58,016.00
3.	Earthwork*	520	CY	$55.00	$28,600.00	$67.00	$34,840.00	$100.00	$52,000.00	$41.60	$21,632.00
4.	Install & Backfill Arched Culvert*	24	LF	$800.00	$19,200.00	$625.00	$15,000.00	$900.00	$21,600.00	$783.71	$18,809.04
5.	Structural Concrete Footing*	28	CY	$875.00	$24,500.00	$970.00	$27,160.00	$1,000.00	$28,000.00	$1,180.21	$33,045.88
6.	Structural Concrete Headwall*	25	CY	$1,050.00	$26,250.00	$1,450.00	$36,250.00	$1,300.00	$32,500.00	$1,444.76	$36,119.00
7.	MMWD Drain Line Extension	1	LS	$300.00	$300.00	$1,100.00	$1,100.00	$1,200.00	$1,200.00	$1,030.00	$1,030.00
8.	Concrete Barrier & Tubular Railing *	8	CY	$2,300.00	$18,400.00	$3,650.00	$29,200.00	$2,400.00	$19,200.00	$2,454.13	$19,633.04
9a.	Rock-1 Ton Class	120	TON	$88.00	$10,560.00	$125.00	$15,000.00	$150.00	$18,000.00	$95.44	$11,452.80
9b.	Rock-1/4 Ton Class	80	TON	$88.00	$7,040.00	$118.00	$9,440.00	$150.00	$12,000.00	$111.95	$8,956.00
9c1.	Rock-River Boulders 1.2'-2.5' Dia.	20	TON	$130.00	$2,600.00	$118.00	$2,360.00	$250.00	$5,000.00	$494.15	$9,883.00
9c2.	Rock-River Cobbles 6"-1.2' Dia.	35	TON	$88.00	$3,080.00	$118.00	$4,130.00	$170.00	$5,950.00	$242.49	$8,487.15
9c3.	Rock-River Run Gravels .08"-6" Dia.	40	TON	$86.00	$3,440.00	$162.00	$6,480.00	$200.00	$8,000.00	$231.93	$9,277.20
9c4.	Rock-River Run Filler Material	8	TON	$86.00	$688.00	$460.00	$3,680.00	$300.00	$2,400.00	$734.75	$5,878.00
10.	Class II Aggregate Base	60	TON	$35.00	$2,100.00	$95.00	$5,700.00	$85.00	$5,100.00	$51.83	$3,109.80
11.	Asphalt Concrete Resurfacing	25	TON	$220.00	$5,500.00	$200.00	$5,000.00	$400.00	$10,000.00	$243.60	$6,090.00
12.	Erosion Control & Revegetation	1	LS	$12,000.00	$12,000.00	$14,000.00	$14,000.00	$11,600.00	$11,600.00	$10,995.00	$10,995.00
13.	Split Rail Fencing	40	LF	$50.00	$2,000.00	$50.00	$2,000.00	$50.00	$2,000.00	$55.75	$2,230.00
*Final Pay Quantity	**Total Base Bid**			**$232,258.00**		**$244,244.00**		**$262,050.00**		**$269,536.53**	

ITEM No.	DESCRIPTION	Estimated Quantity	Unit Measure	Ghilotti Construction Co. Santa Rosa, CA xx Unit Bid	Ghilotti Construction Co. Santa Rosa, CA xx Amount	Massa Construction Co., Inc. San Rafael, CA xx Unit Bid	Massa Construction Co., Inc. San Rafael, CA xx Amount	Ghilotti Bros., Inc. San Rafael, CA xx Unit Bid	Ghilotti Bros., Inc. San Rafael, CA xx Amount	**Average** Unit Bid	**Average** Amount
1.	Signs & Traffic Control	1	LS	$3,580.00	$3,580.00	$14,000.00	$14,000.00	$4,000.00	$4,000.00	**$6,281.80**	**$6,281.80**
2.	Clearing & Grubbing	1	LS	$55,900.00	$55,900.00	$24,000.00	$24,000.00	$31,750.00	$31,750.00	**$39,795.71**	**$39,795.71**
3.	Earthwork*	520	CY	$93.00	$48,360.00	$85.00	$44,200.00	$120.00	$62,400.00	**$80.23**	**$41,718.86**
4.	Install & Backfill Arched Culvert*	24	LF	$750.00	$18,000.00	$995.00	$23,880.00	$417.25	$10,014.00	**$752.99**	**$18,071.86**
5.	Structural Concrete Footing*	28	CY	$760.00	$21,280.00	$895.00	$25,060.00	$900.00	$25,200.00	**$940.03**	**$26,320.84**
6.	Structural Concrete Headwall*	25	CY	$1,320.00	$33,000.00	$2,400.00	$60,000.00	$3,750.00	$93,750.00	**$1,816.39**	**$45,409.86**
7.	MMWD Drain Line Extension	1	LS	$1,420.00	$1,420.00	$500.00	$500.00	$3,000.00	$3,000.00	**$1,221.43**	**$1,221.43**
8.	Concrete Barrier & Tubular Railing *	8	CY	$4,150.00	$33,200.00	$3,400.00	$27,200.00	$2,925.00	$23,400.00	**$3,039.88**	**$24,319.01**
9a.	Rock-1 Ton Class	120	TON	$120.00	$14,400.00	$240.00	$28,800.00	$185.00	$22,200.00	**$143.35**	**$17,201.83**
9b.	Rock-1/4 Ton Class	80	TON	$150.00	$12,000.00	$195.00	$15,600.00	$182.00	$14,560.00	**$142.14**	**$11,370.86**
9c1.	Rock-River Boulders 1.2'-2.5' Dia.	20	TON	$190.00	$3,800.00	$170.00	$3,400.00	$200.00	$4,000.00	**$221.74**	**$4,434.71**
9c2.	Rock-River Cobbles 6"-1.2' Dia.	35	TON	$190.00	$6,650.00	$170.00	$5,950.00	$250.00	$8,750.00	**$175.50**	**$6,142.45**
9c3.	Rock-River Run Gravels .08"-6" Dia.	40	TON	$190.00	$7,600.00	$170.00	$6,800.00	$225.00	$9,000.00	**$180.70**	**$7,228.17**
9c4.	Rock-River Run Filler Material	8	TON	$370.00	$2,960.00	$330.00	$2,640.00	$1,250.00	$10,000.00	**$504.39**	**$4,035.14**
10.	Class II Aggregate Base	60	TON	$54.00	$3,240.00	$125.00	$7,500.00	$112.00	$6,720.00	**$79.69**	**$4,781.40**
11.	Asphalt Concrete Resurfacing	25	TON	$240.00	$6,000.00	$242.00	$6,050.00	$330.00	$8,250.00	**$267.94**	**$6,698.57**
12.	Erosion Control & Revegetation	1	LS	$10,600.00	$10,600.00	$11,300.00	$11,300.00	$24,450.00	$24,450.00	**$13,563.57**	**$13,563.57**
13.	Split Rail Fencing	40	LF	$50.00	$2,000.00	$40.00	$1,600.00	$53.65	$2,146.00	**$49.91**	**$1,996.57**
*Final Pay Quantity	**Total Base Bid**			**$283,990.00**		**$308,480.00**		**$363,590.00**		**$280,592.65**	

URS ENGINEER'S ESTIMATE
Lagunitas Road Bridge Replacement
Town of Ross
Project No. BRLS-5176(003)
January 13, 2010

Item No.	P-S-F	Item Code	Item	Unit of Measure	Estimated Quantity	Unit Price	Item Total
1		071325	Temporary Fence (Type ESA)	LF	497	$6.60	$3,280
2		074016	Construction Site Management	LS	1	$4,500.00	$4,500
3		074017	Prepare Water Pollution Control Program	LS	1	$3,500.00	$3,500
4		074028	Temporary Fiber Roll	LS	1	$4,200.00	$4,200
5		074038	Temporary Drainage Inlet Protection	LS	1	$1,000.00	$1,000
6		120090	Construction Area Signs	LS	1	$10,000.00	$10,000
7		120100	Traffic Control System	LS	1	$4,000.00	$4,000
8		128650	Portable Changeable Message Sign	LS	1	$10,000.00	$10,000
9		146004	Fish Protection	LS	1	$10,000.00	$10,000
10		146009A	Environmental Protection (California Red-Legged Frog and Foothills Yellow Legged Frog)	LS	1	$2,500.00	$2,500
11		146009B	Environmental Protection (Western Pond Turtle)	LS	1	$2,500.00	$2,500
12		146009C	Environmental Protection (Hoary Bat, Pallid Bat and Western Red Bat)	LS	1	$10,000.00	$10,000
13		150742	Remove Roadside Sign	EA	2	$155.00	$310
14		150810	Remove Reinforced Concrete Pipe	LF	4	$150.00	$600
15		150820	Remove Inlet	EA	1	$1,060.00	$1,060
16		151291A	Salvage Bridge Decorative Electrolier	LS	1	$6,000.00	$6,000
17		152320	Reset Roadside Sign	EA	3	$225.00	$675
18		152390	Relocate Roadside Sign	EA	5	$205.00	$1,025
19		152438	Adjust Frame and Cover to Grade	EA	11	$470.00	$5,170
20		153103	Cold Plane Asphalt Concrete Pavement	SQYD	220	$26.50	$5,830
21		153216	Remove Concrete Curb and Sidewalk	SQYD	470	$25.00	$11,750
22		157550	Bridge Removal	LS	1	$45,000.00	$45,000
23		160101	Clearing and Grubbing	LS	1	$2,000.00	$2,000
24		190101	Roadway Excavation	CY	230	$110.00	$25,300
25		190110	Lead Compliance Plan	LS	1	$3,500.00	$3,500
26	F	192020	Structure Excavation (Type D)	CY	280	$350.00	$98,000
27	F	193003	Structure Backfill (Bridge)	CY	190	$45.00	$8,550
28		198001	Imported Borrow	CY	270	$105.00	$28,350
29		204096	Maintain Existing Planted Areas	LS	1	$2,000.00	$2,000
30		208005	2" Galvanized Steel Pipe (Water Supply Line)	LF	83	$40.00	$3,320
31		260201	Class 2 Aggregate Base	CY	540	$78.00	$42,120
32		390132	Hot Mixed Asphalt (Type A)	TON	580	$130.50	$75,690
33		490604	30" Cast-In-Drilled-Hole Concrete Piling	LF	618	$400.00	$247,200
34	F	510051	Structural Concrete, Bridge Footing	CY	63	$275.00	$17,325
35	F	510053	Structural Concrete, Bridge	CY	258	$800.00	$206,400
36	P	512205	Furnish Precast Prestressed Concrete Girder (60' - 70')	EA	11	$9,500.00	$104,500
37		512500	Erect Precast Prestressed Concrete Girder	EA	11	$3,500.00	$38,500
38		515010A	Decorative Bridge Electrolier	EA	4	$8,500.00	$34,000
39	P-F	520102	Bar Reinforcing Steel (Bridge)	LB	96955	$1.05	$101,803
40		568023	Install Roadside Sign	EA	8	$300.00	$2,400
41		560248A	Furnish Sign	SQFT	54	$25.00	$1,350
42		650010	12" Reinforced Concrete Pipe	LF	190	$55.00	$10,450
43		700617	Drainage Inlet Marker	EA	3	$150.00	$450
44	P	703450B	6" Welded Steel Pipe Casing (Bridge)	LF	9	$40.00	$360
45		707051A	Type "C" Catch Basin	EA	3	$3,500.00	$10,500
46		707051B	Drop Inlet	EA	1	$4,000.00	$4,000
47		731502	Minor Concrete (Miscellaneous Construction)	CY	110	$550.00	$60,500
48			Future Utility Conduit	LF	190	$115.00	$21,850
49			AT&T Duct System	LF	190	$35.00	$6,650
50	P-F	833000	Metal Railing	LF	113	$325.00	$36,725
51	F	839401	Concrete Barrier	LF	190	$225.00	$42,750
52		839521	Cable Railing	LF	33	$100.00	$3,300
53		840656	Paint Traffic Stripe (2-Coat)	LF	710	$3.00	$2,130
54		840660	Paint Pavement Marking	SQFT	480	$4.00	$1,920
55		842000	Parking Bumper (Precast Concrete)	EA	7	$250.00	$1,750
56		850111	Pavement Marker (Retroreflective)	EA	8	$25.00	$200
57		860402	Lighting (City Street)	LS	1	$12,000.00	$12,000
58		999990	Mobilization	LS			$155,638
			SUBTOTAL (ENGINEERS ESTIMATE BID ITEMS)				**$1,556,381**
			SUPPLEMENTAL WORK				
			Environmental Mitigation Measures				
59			Environmental Protection (listed salmonoids)	LS	1	$38,000.00	$38,000
60		066041	Bird Protection	LS	1	$8,000.00	$8,000
61		066060	Additional Traffic Control	LS	1	$2,500.00	$2,500
62		066179	Check Existing Irrigation System	LS	1	$2,000.00	$2,000
63		066208	Repair Existing Irrigation System	LS	1	$2,000.00	$2,000
64		066578	Portable Changeable Message Signs	LS	1	$5,000.00	$5,000
65		066596	Additional Water Pollution Control	LS	1	$8,000.00	$8,000
66		066666	Compensation Adjustment For Price Index Fluctuation of Paving Asphalt	LS	1	$3,900.00	$3,900
			SUBTOTAL (SUPPLEMENTAL WORK)				**$69,400**
			TOWN-FURNISHED MATERIALS				
			SUBTOTAL (TOWN-FURNISHED MATERIALS)				**$0**
			PROJECT SUBTOTAL				**$1,625,781**
			5% CONTINGENCY				$81,290
			PROJECT TOTAL				**$1,707,071**

Attachment

Phase 1 Re-Evaluation Report

Phase 1 Re-Evaluation of Conceptual Flood Reduction Measures Described in the 2012 Flood Study for Arroyo Corte Madera del Presidio

Stetson Engineers Inc.
July 21, 2015

Background

In 2012 Stetson Engineers Inc. (Stetson) completed an "Appraisal-Level Flood Study for Arroyo Corte Madera del Presidio Creek" for the City of Mill Valley[1] (2012 Flood Study). The 2012 Flood Study found that the creek floods when discharge exceeds the 5-year flood event. The 2012 Flood Study identified the sources and locations of creek flooding and developed conceptual measures to reduce flood damage. These conceptual measures were designed to protect against a range of floods, including the 5-year, 10-year, 25-year, 50-year, and 100-year floods. To accomplish this work, Stetson developed and employed two computer models that worked hand-in-hand.

Stetson modified and improved an existing computerized HEC-HMS hydrologic model of the watershed developed in 2005 for the County. The HEC-HMS model simulates the rainfall-runoff process. The HEC-HMS model output is the time-varying discharge (i.e., discharge hydrograph) at different locations along the creek in response to a given rainfall event. The key feature of the model output hydrograph is the maximum, or "peak," discharge at selected locations in the creek. Flood protection measures are typically designed with the objective of containing the peak discharge within the banks of the creek.

Stetson also developed a new computerized HEC-RAS hydraulic model of the creek. The HEC-RAS model simulates the water level in the creek. The HEC-RAS model uses the peak discharge computed from the HEC-HMS model to compute a profile of the water level along the creek associated with the rainfall event.

Stetson calibrated the models to available measurements of creek discharge. The HEC-HMS model was calibrated to the December 31, 2005 discharge hydrograph as measured at the streamflow gage located downstream of La Goma bridge (2012 Flood Study, Appendix C). The HEC-RAS model was calibrated to water levels in the creek during discharge events on December 29, 2003, December 31, 2005, and November 26, 2006 (2012 Flood Study, Appendix D).

After completion of the 2012 Flood Study, an intense storm event occurred on February 9, 2014 which produced a completely full flow condition along ACMdP, referred to as "bankfull" discharge. Only minor overtopping of the creek bank was observed (over the north bank just

[1] Mr. David R. Dawdy, Consulting Hydrologist, prepared the flood frequency analysis and the stage-discharge rating curve for the Arroyo Corte Madera del Presidio streamflow gage.

upstream of La Goma) and there was no reported flood damage. The peak height recorded at the ACMdP streamflow gage during this storm event was 8.42 ft (equivalent to 10.27 ft NGVD29 or 12.98 ft NAVD88), the second highest ever recorded over the gage's period of record dating back to 1966. This gage reading was only about 0.81 ft lower than the peak reading of 9.23 ft recorded during the December 31, 2005 flood event, which was an approximate 50-year flood event which caused extensive flood damage. At the time of the February 9, 2014 storm peak, the tide was low at 1.6 ft NAVD88 (Figure 1a). For comparison, at the time of the December 31, 2005 peak the tide was higher at 5.5 ft NAVD88 (Figure 1b). Mean Higher High Water is 5.9 ft NAVD88.

In view of the relatively small difference in peak heights yet large difference in flooding and flood damage between the February 9, 2014 and December 31, 2005 storm events, the City engaged Stetson to investigate this apparent anomaly and any implications with respect to the conceptual flood reduction measures described in the 2012 Flood Study.

This report documents a study to re-examine the HEC-HMS and HEC-RAS model and re-evaluate the effectiveness of the flood damage reduction measures recommended in the 2012 Flood Study. The study included the following work:

- Survey of high water marks (HWMs) along ACMdP for the 2/9/2014 storm event;
- Re-examination of the HEC-HMS model and computation of the peak discharge at the ACMdP streamflow gage using the HEC-HMS model;
- Re-examination and refinement of the HEC-RAS hydraulic model using the surveyed HWMs for the 2/9/2014 storm event and the computed HEC-HMS peak discharge;
- Re-evaluation of effectiveness of the flood damage reduction measures developed in the 2012 appraisal-level flood study; and
- Evaluation of the reliability of the existing stage-discharge rating curve for the ACMdP streamflow gage and recommendations for future monitoring.

A follow up Phase 2 study is anticipated. The Phase 2 study will build on the Phase 1 work to revise, as needed, the conceptual flood reduction measures described in the 2012 Flood Study for the 25-year, 50-year, and 100-year levels of flood protection (see Recommendations).

Survey of High Water Marks along ACMdP for the 2/9/2014 Storm Event

Shortly after the February 9, 2014 storm event, Stetson identified and tagged 13 HWMs along ACMdP and 3 HWMs along Old Mill Creek (Figure 2). HWMs appeared as clear, fresh lines of debris, scour, or vegetation disturbance along the top of the creek banks. On March 6, 2014, Stetson used an engineering level to survey the elevations of all HWMs relative to local control points, which Stetson founded with PK nails or established as the tops of three fire hydrants (Figure 2). On March 2 and 3, 2015, Stetson performed a follow-up survey, using an engineer's level, to determine the elevations of all HWMs relative to NAVD88 vertical datum by tying the local control points to established bench marks in NAVD88. For QA/QC purposes, the elevation differences between HWMs with tags found to be still intact and their respective local control points were resurveyed and verified.

On March 2 and 3, 2015, Stetson used a Total Station to also survey the railroad bridge and the channel cross section at the upstream face of the bridge (Figure 2). The railroad bridge was not

represented in the existing HEC-RAS hydraulic model, and the survey was done to allow it to be represented in the refined model. The channel cross section at the upstream face of the bridge was surveyed so that the channel reach from that point upstream to the downstream face of the Camino Alto Bridge could be better represented in the refined model.

Re-examination of the HEC-HMS Model and Computation of the Peak Discharge at the ACMdP Streamflow Gage for the 2/9/2014 Storm Event

The existing HEC-HMS hydrologic model was calibrated to the 12/31/2005 storm event based on a wet antecedent moisture condition, AMC III[2]. The 2/9/2014 storm event was modeled using an average antecedent moisture condition, AMC II. According to the MMWD's rainfall record at Phoenix Lake in Ross Valley, the 30-day rainfall prior to the 12/31/2005 storm event was about 18.7 inches while the 30-day rainfall prior to the 2/9/2014 storm event was about 2.4 inches. Since the antecedent moisture condition prior to the 12/31/2005 storm event was much wetter than the condition prior to the 2/9/2014 storm event, an average antecedent moisture condition was deemed appropriate for use in modeling the 2/9/2014 storm event.

The 2/9/2014 storm event generated two runoff peaks at the gage; the second peak was measurably higher than the first (Figure 1a). The first peak reached stage 7.44 ft and the second peak reached stage 8.42 ft, about 1 foot higher. The observed real-time rainfall at the ACMdP rain gage was distributed across the 12 different subwatersheds by prorating the ACMdP rainfall based the annual isohyetal map. This approach is based on the assumption that the distribution of storm rainfall followed the same distribution of average annual rainfall reflected in the annual isohyetal map. This was the same approach used in the 2012 Flood Study[3]. But when the HEC-HMS model simulation was run, it was found that the model could not produce a measurably higher discharge for the second peak (see the blue line in Figure 3). This suggested that the actual storm rainfall distribution differed from the distribution reflected in the annual isohyetal map. In order to better represent the rainfall distribution for the 2/9/2014 storm event, real-time rainfall data for two other rainfall stations in and around the ACMdP watershed were obtained from Weather Underground and used in the HEC-HMS model. Figure 4 shows the ACMdP subwatersheds, the locations of these two other rainfall stations, the ACMdP rainfall gage, and the subwatersheds represented by each rainfall station. Examination of the rainfall data for the 2/9/2014 storm event for the three stations indicated that rainfall in the upper subwatersheds of ACMdP was much more intense than in the lower subwatersheds. Using the rainfall data for the three stations, the HEC-HMS model was able to produce a measurably higher discharge for the second peak. The HEC-HMS model-simulated peak discharge for the first peak was about 860 cfs and 1,070 cfs for the second peak, a difference of about 210 cfs (Figure 3). This 210 cfs

[2] AMC I, II, and III are commonly used to denote dry, average, and wet antecedent moisture conditions. The antecedent moisture condition affects the curve number, which is a parameter used in the HEC-HMS model. AMC III has the highest curve number and produces the greatest runoff volume for a given rainfall. AMC I has the lowest curve number and produces the least runoff volume.

[3] For example, the annual isohyetal map indicates that the annual rainfall in the Warner Canyon subwatershed is about 34 inches and about 32 inches at the ACMdP rain gage. Given the observed real-time rainfall at the ACMdP rain gage, the time-series rainfall for the Warner Canyon subwatershed was derived by multiplying the rainfall observed at the AMCdP rain gage by 1.06 (34 ÷ 32 = 1.06).

difference in discharge between the two peaks is corroborated by rough hydraulic calculation[4]. The hydrograph showing the time varying discharge using the stage-discharge rating curve developed by Dawdy is also shown in Figure 3. The HEC-HMS model-simulated peak discharge of 1,070 cfs is about 300 cfs lower than the peak discharge estimated by the Dawdy rating curve (about 1,360 cfs), which suggests that the Dawdy rating curve over-estimates discharge for a given stage (see Evaluation of Rating Curve below).

Figure 5 shows the historical annual peak gage heights and peak discharges at the streamflow gage obtained from USGS database and the HEC-HMS simulated peak discharges for the 2/9/2014 and the 12/31/2005 storm events. Also shown are data for gage height and discharge measured by Environmental Data Solutions (EDS) for the Marin County Flood District on 12/11/2014. The HEC-HMS model-simulated data points are generally consistent with the USGS and EDS data points.

Re-examination and Refinement of the HEC-RAS Hydraulic Model

The existing HEC-RAS hydraulic model (2012 HEC-RAS model) was re-examined and refined using the recent survey data to represent the railroad bridge. The model channel geometry between Camino Alto and the railroad bridge was improved by interpolating channel cross sections between the downstream face of the Camino Alto Bridge and the upstream face of the railroad bridge. The HEC-HMS model-simulated peak discharges at different locations for the 2/9/2014 storm event were then input into the refined HEC-RAS model. As shown in Figure 6a, both the original HEC-RAS model and the refined HEC-RAS model generally produced a higher water surface profile than the observed HMWs, suggesting the need to recalibrate the model. The refined HEC-RAS model was further refined through re-calibration. Re-calibration consisted of reducing Manning's n for the lower reach of the channel downstream of Valley Circle from 0.025-0.030 to 0.020 and reducing Manning's n for three cross sections near La Goma from 0.070 to 0.032. These reductions in Manning's n were justified given the sandy channel bed and sparse riparian vegetation along this reach. With these modifications, the refined (and recalibrated) HEC-RAS model satisfactorily matched the observed HMWs for the 2/9/2014 storm event (Figure 6b).

The refined (and recalibrated) HEC-RAS model was verified to the 12/31/2005 flood event. Figure 7 shows that the refined HEC-RAS model produces a similar water surface profile that is similar to that produced by the 2012 HEC-RAS model and satisfactorily matches the HMMs for the 12/31/2005 flood event.

To understand the effect that the low tide had on creek water levels farther upstream at the time of the 2/9/2014 peak, a supplemental HEC-RAS hydraulic model simulation was run using a higher tide at the downstream end of the model (in the bay) for comparison. A tide equal to Mean Higher High Water, 5.9 ft NAVD88, was used in the supplemental simulation. This is the

[4] The HEC-HMS-simulated discharge for the second peak is about 210 cfs higher than the first peak. The surveyed top width of the channel at the ACMdP gage is about 35 ft. The observed stage for the second peak is about 1 ft higher than the first peak. By applying the rough hydraulic equation Q (discharge) = V (velocity) times A (cross sectional flow area) and using a velocity of about 6 fps computed from the HEC-RAS hydraulic model, the flow difference between the two peaks should be about 210 cfs (35 ft x 1 ft x 6 ft/s = 210 cfs).

same tide level that was used to develop flood damage reduction measures in the 2012 Flood Study. Results of the supplemental model simulation indicate that tide has little effect on creek water levels upstream of Camino Alto (Figure 8). Given the relatively small channel size, streamflow hydraulics, not the height of the tide, has a greater effect on the stream water level by pushing the tidal water downstream.

Re-Evaluation of the Effectiveness of the Flood Damage Reduction Measures Developed in the 2012 Flood Study

The HEC-HMS model-estimated peak discharge of 1,070 cfs at the ACMdP streamflow gage for the 2/9/2014 storm event was approximately a 10-year discharge based on the flood frequency analysis by Dawdy. The 2/9/2014 storm event did not cause flooding, indicating the creek has 10-year discharge capacity. Accordingly, flood damage reduction measures for protection against the 5-year and 10-year floods that were developed in the 2012 Flood Study are not necessary based on the finding of this study.

To re-evaluate the effectiveness of the 25-, 50-, and 100-year flood damage reduction measures developed in the 2012 Flood Study, the following analysis was performed:

1) Input the 25-, 50-, and 100-year flood damage reduction measures into the refined HEC-RAS model to arrive at a refined 25-year project conditions model, a refined 50-year project conditions model, and a refined 100-year project conditions model. Run the refined project conditions models using the corresponding discharges (e.g., for the 25-year project conditions model use the 25-year flood discharge).
2) Re-run the refined project conditions models in an iterative fashion with progressively higher discharges until the model-computed water levels along the critical reach between La Goma and Willow Street rise to the flood threshold level. This reach is critical because it is where flood flows break out of the channel and flow onto Miller Avenue. The incremental higher discharges needed to rise to the flood threshold water level represent the additional (or excess) discharge that can be handled by the 2012 Flood Study measures based on the refined HEC-RAS model.

Table 1 shows the computed discharge capacities at the streamflow gage with the 2012 Flood Study measures in place based on the original HEC-RAS model and the refined model. Re-evaluation of the 2012 Flood Study measures using the refined HEC-RAS model indicates that with the measures in place the creek can marginally handle an additional 5% of the design discharge.

Figures 9a, 9b, and 9c compare the simulated water level profiles for the original HEC-RAS project conditions model and the refined HEC-RAS project conditions model for the corresponding discharges (Table 1 column (2)). The figures also show the simulated water level profiles for the refined HEC-RAS project conditions model for the corresponding increased discharges (Table 1 column (3)). The results show that:

- For the reach between Camino Alto and Valley Circle, the 2012 Flood Study floodwall measures provide a higher level of flood protection than required to contain the corresponding design flood discharge – i.e., floodwalls could be slightly lower than indicated in the 2012 Flood Study;

- For the reach between Valley Circle and Willow, the 2012 Flood Study measures provide a higher level of flood protection than required to contain the corresponding flood discharge – the measures could contain roughly an additional 5% of the corresponding design flood discharge;
- For the reach upstream of Willow Street, further analysis is needed to determine the adequacy of the 2012 Flood Study measures.

Table 1 Computed Discharge Capacities of ACMdP with the 2012 Flood Study Measures In Place Based on the Original HEC-RAS Model and the Refined HEC-RAS Model

(1) Flood Damage Reduction Measures in 2012 Flood Study	Capacity of ACMdP at Gage with Measures In Place		Additional (Excess) Design Capacity Based on Refined HEC-RAS Model	
	(2) Gage Based on Original HEC-RAS Model	(3) Based on Refined HEC-RAS Model	(4) CFS	(5) %
25-year Measures	1,500 cfs	1,576 cfs	76 cfs	5%
50-year Measures	1,810 cfs	1,892 cfs	82 cfs	5%
100-year Measures	2,110 cfs	2,207 cfs	97 cfs	5%

Notes: The 25-year measures include all the 5-year and 10-year measures plus the ACMdP partial bypass. The 50-year and 100-year measures include all the 25-year measures plus the Mill Valley Golf Course detention basin. The capacity of ACMdP given in (2) and (3) is the sum of the discharges in the ACMdP channel, in the ACMdP partial bypass, and the discharge that is detained in the Mill Valley Golf Course detention basin.

Evaluation of Rating Curve

The 2012 stage-discharge rating curve for the ACMdP streamflow gage is deemed unreliable for the reasons explained below:

1) The 2/9/2014 storm event generated two runoff peaks at the gage, the second peak was measurably higher than the first. The first peak reached stage 7.44 ft and the second peak reached stage 8.42 ft, about 1 foot higher. Using the 2012 rating curve, the peak discharges for the first and second peaks would be about 910 cfs and 1,360 cfs, respectively (Figure 3). For these discharges to be correct, a flow velocity of about 13 fps would be required to produce the 450 cfs difference in discharge. This required velocity is much higher than the 6 fps velocity computed by the refined HEC-RAS hydraulic model. This implies that the 2012 rating curve does not give an accurate discharge for either or both 2/9/2014 peak stages.

2) The peak discharge estimate for the 2/9/2014 storm event indicated by the 2012 stage-discharge rating curve (1,360 cfs) requires an unreasonably low Manning's n (i.e., outside of the range of literature values) in order for the HEC-RAS model to match the 2/9/2014 HWMs. This implies that the 2012 rating curve gives a discharge for the 2/9/2014 peak stage that is too high – i.e., produces a creek water level profile that is higher than observed on 2/9/2014.

Recommendations for Phase 2 Study

1. Develop a new in-channel only stage-discharge rating curve for the ACMdP gage using the HEC-HMS simulated peak discharge for 2014 (bankfull condition), field-measured discharge by EDS, and the USGS annual peak stage-discharge records for non-flood years.
2. Use the in-channel only stage-discharge rating curve developed in "1" to estimate annual peak discharges since 1985 when USGS did not record annual peak discharges to achieve a complete data set of historical annual peak discharges covering the period 1966 to 2015.
3. Using the complete set of historical annual peak discharges, prepare an updated flood frequency analysis for the ACMdP gage.
4. Use the refined HEC-RAS model to develop conceptual flood reduction measures for the 25-year, 50-year, and 100-year levels of flood protection using the discharges corresponding to those events determined from the updated flood frequency analysis. Use the corresponding protection level measures from the 2012 Flood Study as a starting point.
5. Perform stage-discharge measurements at the ACMdP gage during future high flow events and use the measurements to refine and update the rating curve developed in "1" as needed.

Figure 1a SF Bay Tide and ACMdP Streamflow Gage Height during the Feb 9, 2014 Storm Event

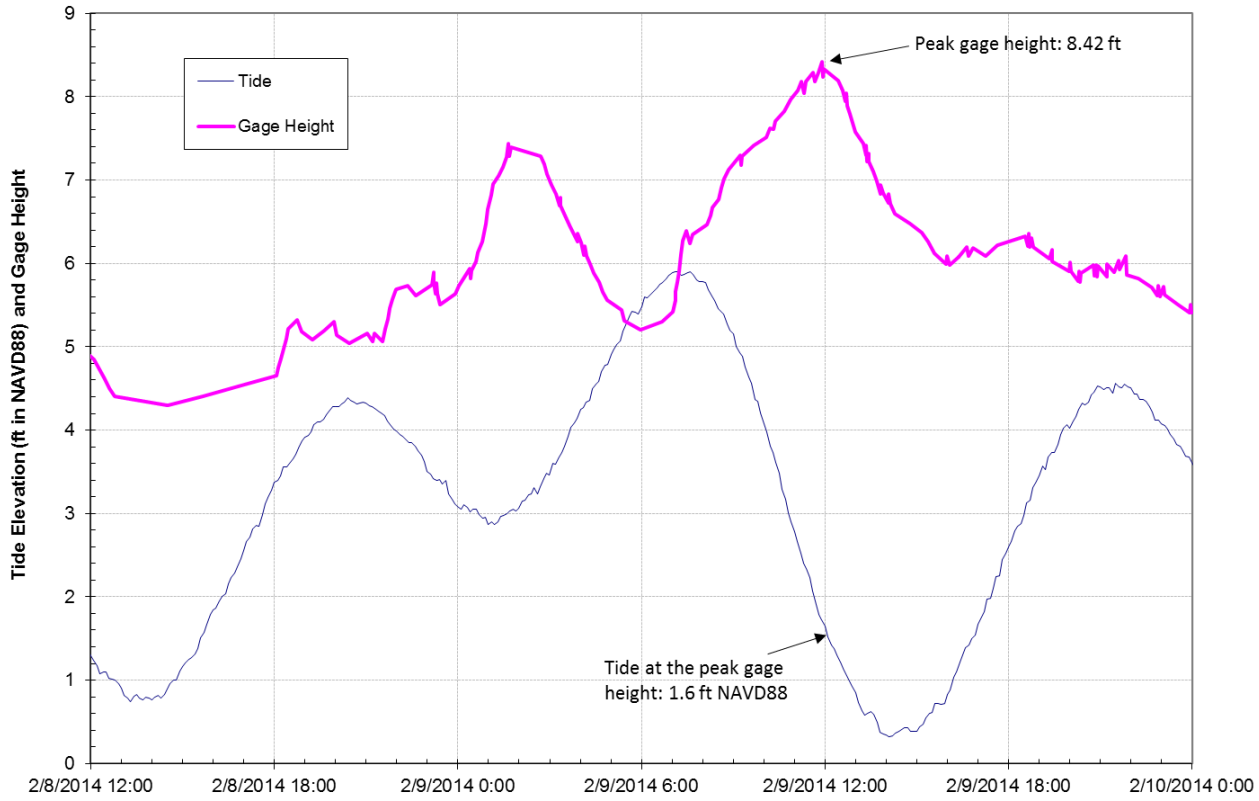


Figure 1b SF Bay Tide and ACMdP Streamflow Gage Height during the Dec 31, 2005 Flood Event

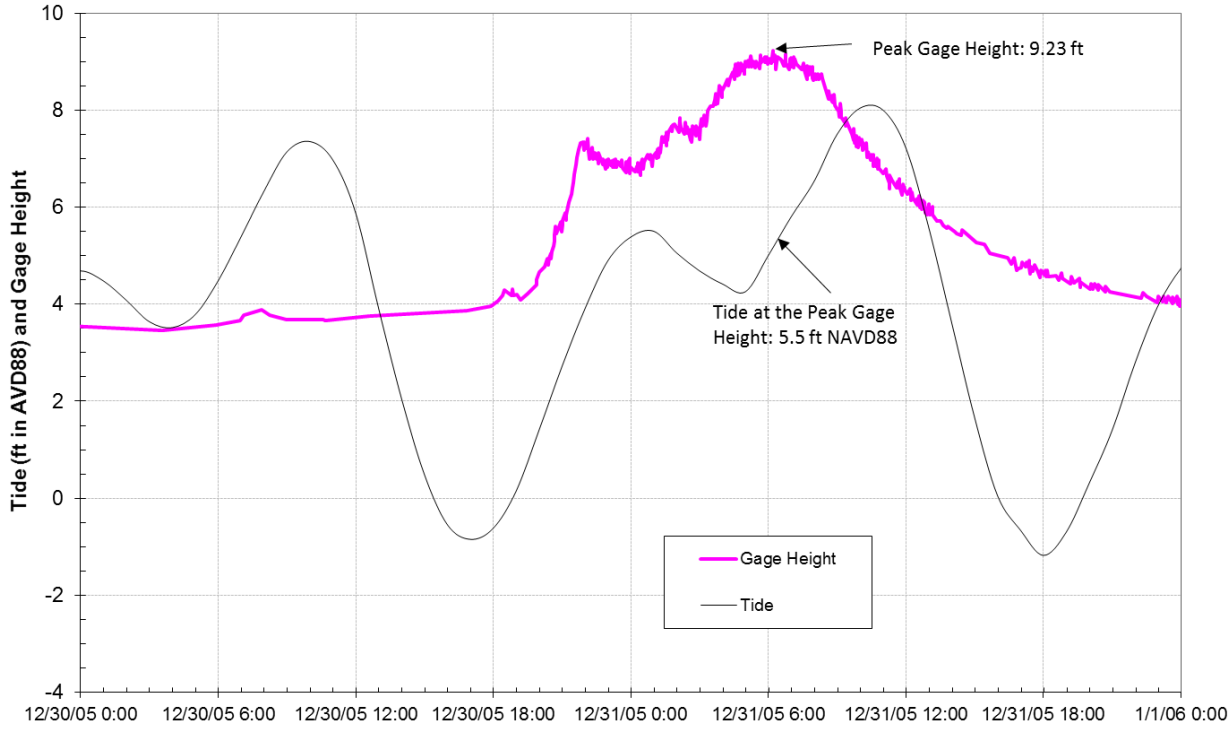


FIGURE 2

STETSON ENGINEERS INC.

DATE: MARCH 11, 2015 | JN: 2165-014

HIGH WATER MARK SURVEY
(Storm Event 2/9/2014)

LEGEND

- 2 HIGH WATER MARK LOCATION
- P NAIL SET FOR HWM SURVEY
- CONTROL POINT OR BENCHMARK
- CREEK CENTERLINE

N / W / E / S

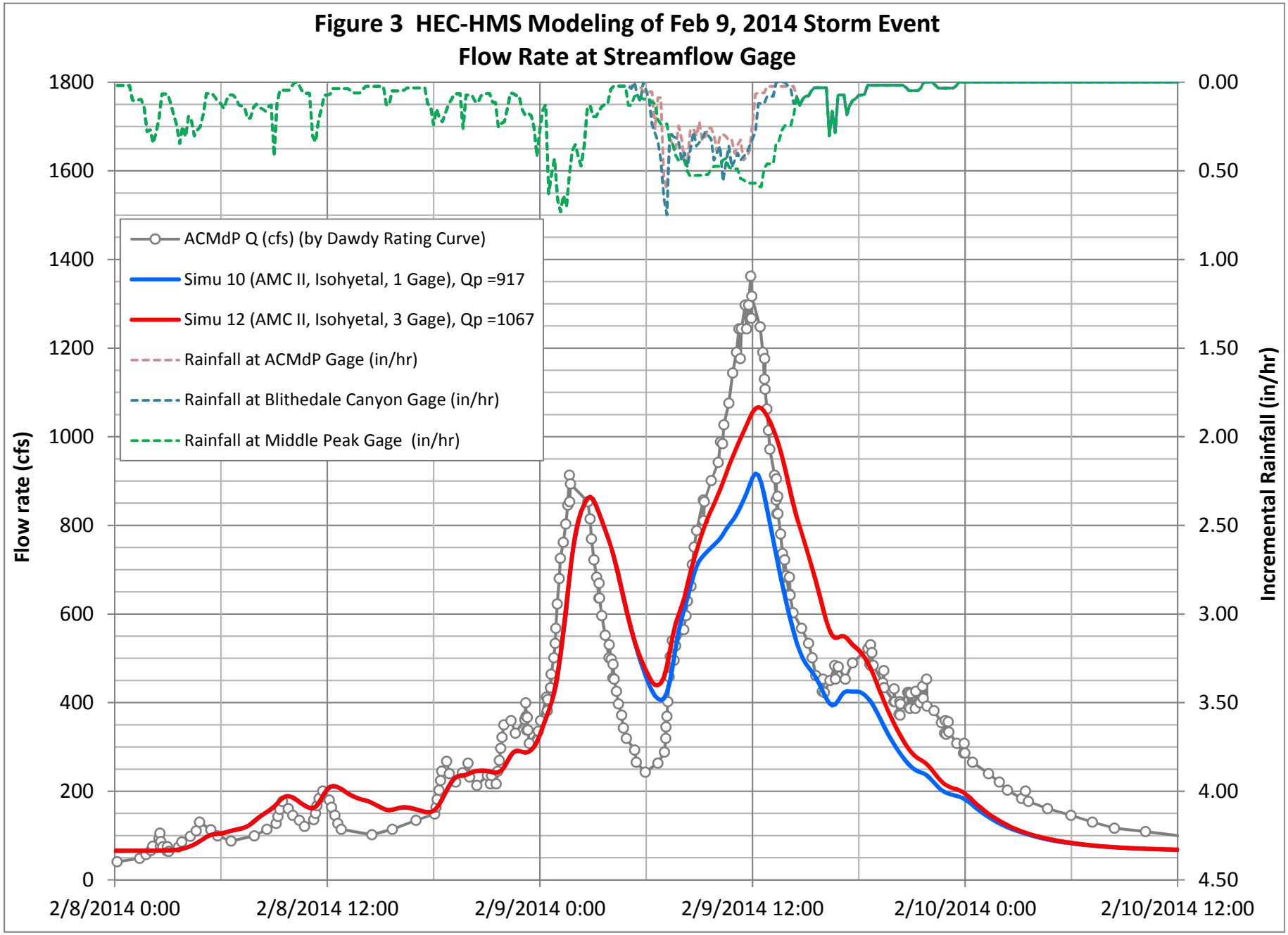
SCALE (Feet)

0 300 600 1200

CP MAG No24
CP PK8 Old Mill
CP PK3 Old Mill
CP PK No12
CP PK No11
CP PK No10
OLD MILL CREEK
OLD MILL CREEK CONFLUENCE
ARROYO CORTE MADERA DEL PRESIDIO
WARNER CREEK
WARNER CREEK CONFLUENCE
REED CREEK
Benchmark
PK nail No4
NBolt
SBolt
FH1
FH2
FH3
BM RV-223 RIVET ON CONC
BM RM 19 Chsld Sq
CROSS-SECTION

I:\DATA\2165\2014\FEB 9, 2014 STORM EVENT\Feb 9, 2014 Storm Data\HWMs Survey\DS Section.dwg

Figure 3 HEC-HMS Modeling of Feb 9, 2014 Storm Event
Flow Rate at Streamflow Gage



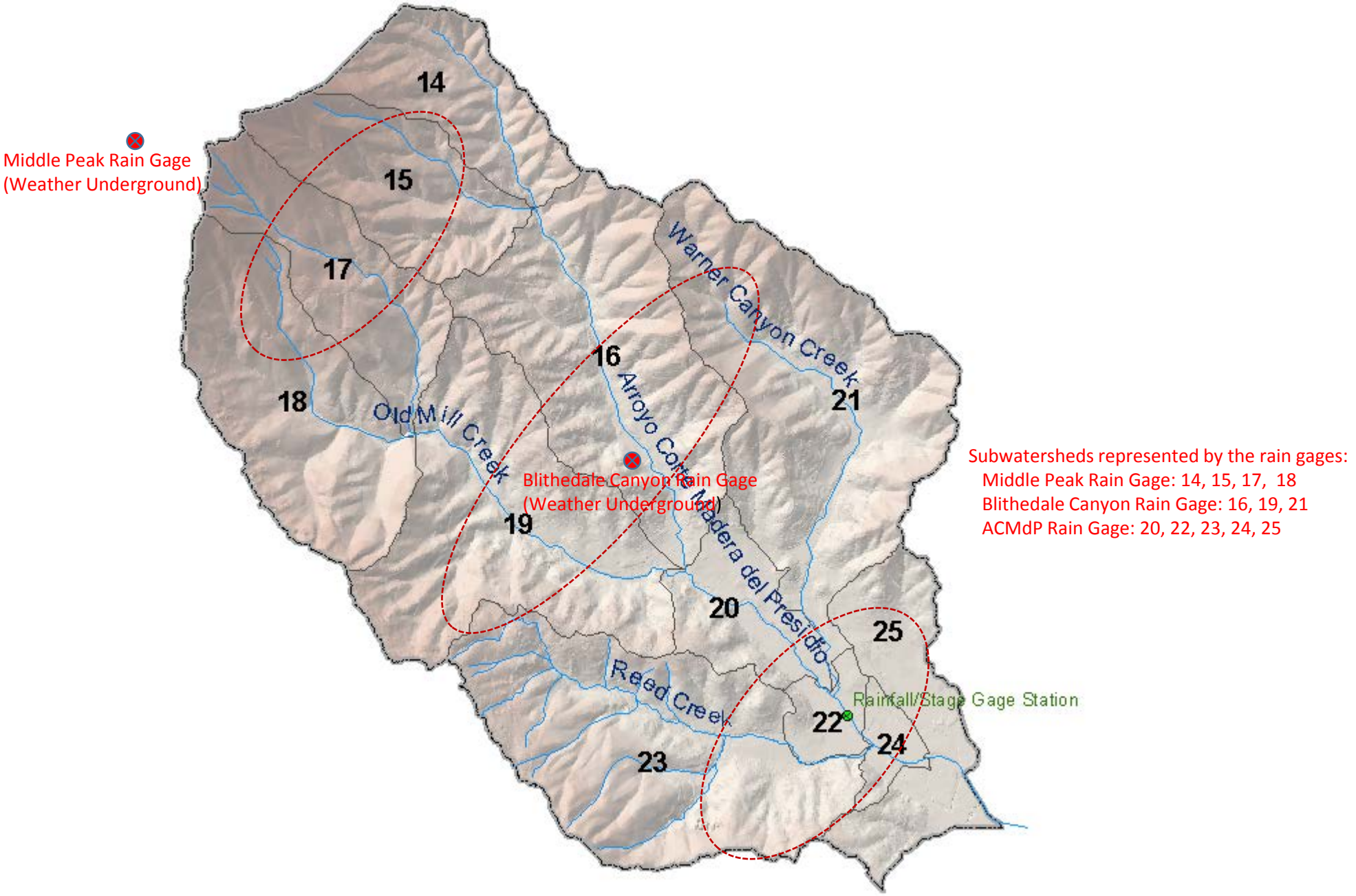


Figure 4 ACMdP subwatersheds, the locations of the two rainfall stations from Weather Underground and the ACMdP rainfall gage, and the subwatersheds represented by each rainfall station

Figure 5 Historical Annual Peak Gage Height and Peak Flow (1966-1985)

(Source: USGS Database)

Date	Peak Gage Height (ft)	Peak Flow (cfs)
1/5/1966	6.70	620
1/20/1967	6.96	682
1/29/1968	5.17	303
12/28/1968	5.51	443
1/21/1970	7.52	1,180
12/4/1970	6.05	593
5/5/1972	4.60	160
1/12/1973	7.09	1,010
10/26/1975	4.33	139
1/2/1977	4.18	83
1/14/1978	5.48	301
1/11/1979	6.44	561
1/11/1980	6.55	595
1/27/1981	5.17	240
1/4/1982	8.11	1,170
3/13/1983	7.22	821
11/19/1983	5.58	323
2/8/1985	6.74	654
12/31/2005	9.23	1,720
2/9/2014	8.42	1,070

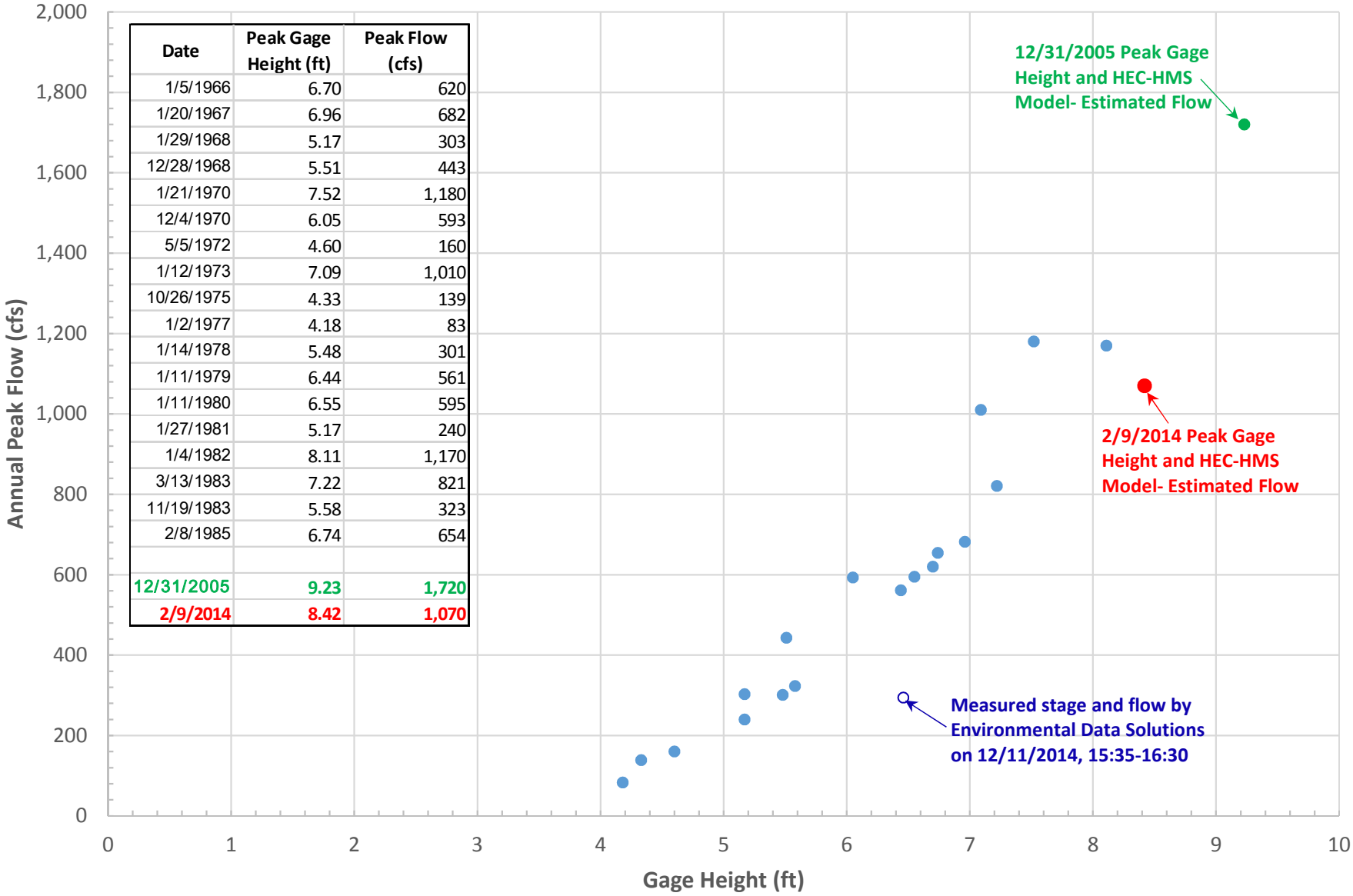


Figure 6a Effect of the Channel Bed Update on Water Surface Profile

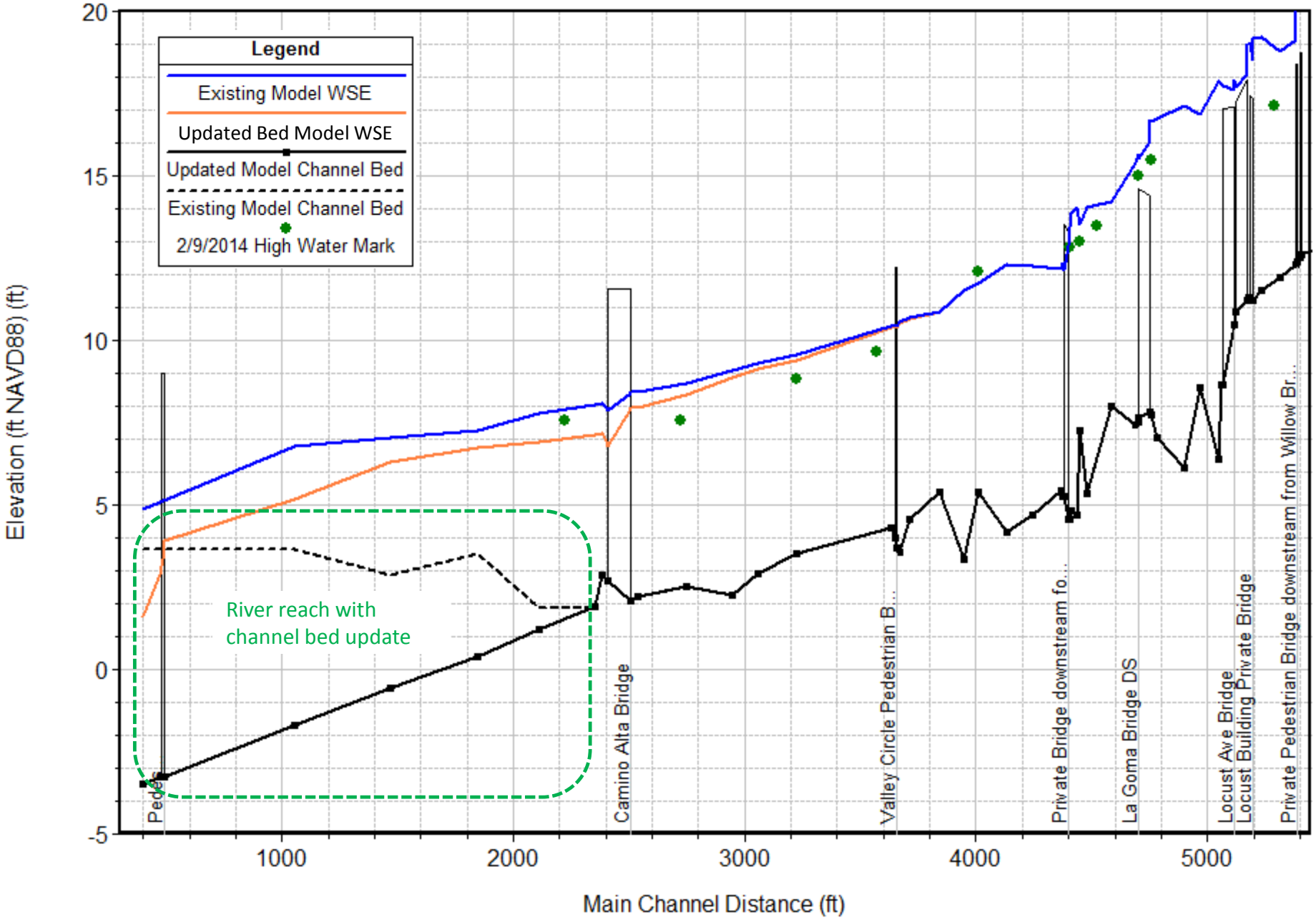


Figure 6b Recalibration Result of the HEC-RAS Hydraulic Model for the 2/9/2014 Storm Event
(Recalibrated model: updated channel bed with recalibrated Manning's n)

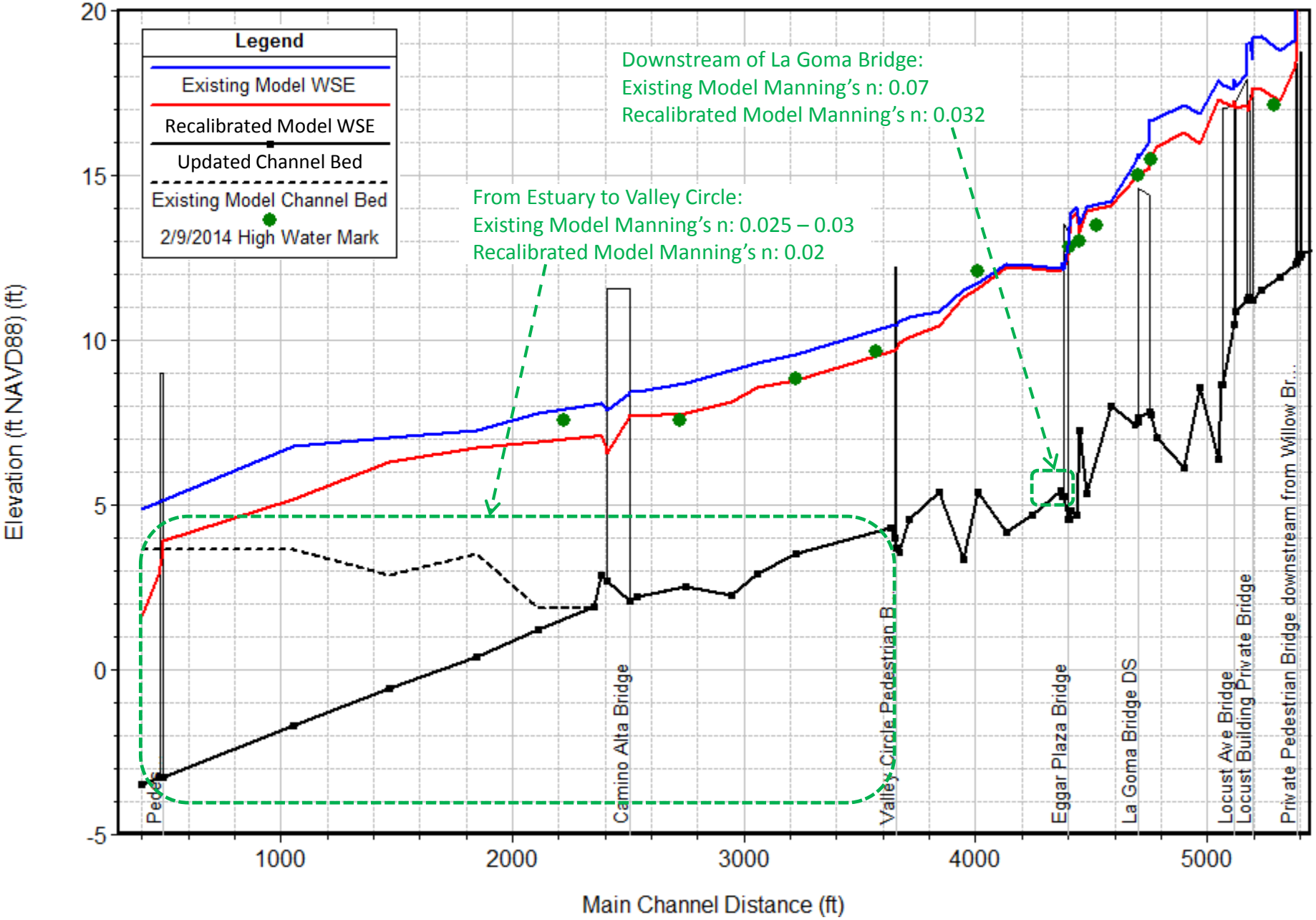


Figure 7 Verification of the Recalibrated HEC-RAS Model for the 12/31/2005 Storm Event

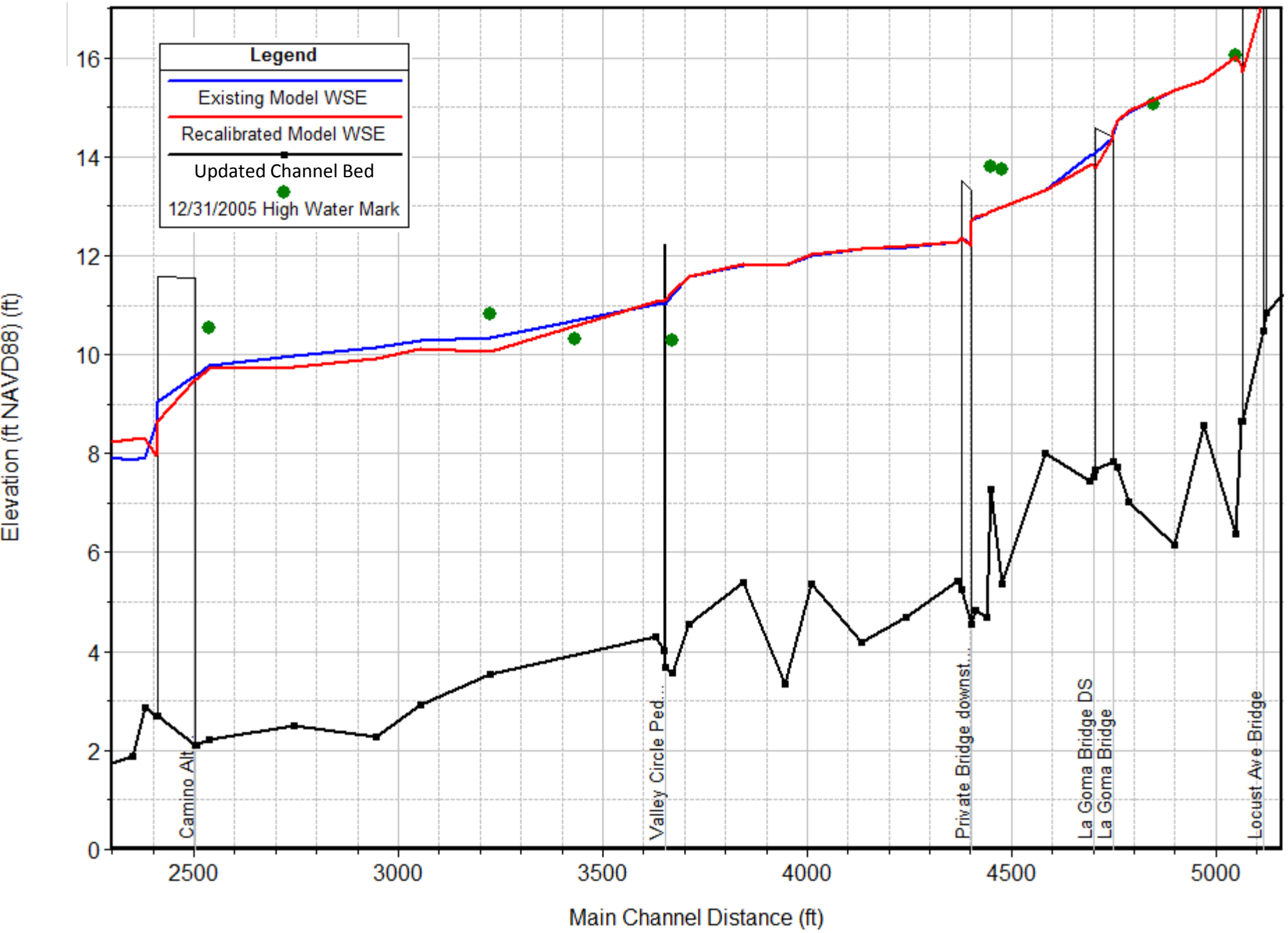


Figure 8 Sensitivity Analysis of Tidal Effect on the 2/9/2014 Water Surface Using the Recalibrated Model

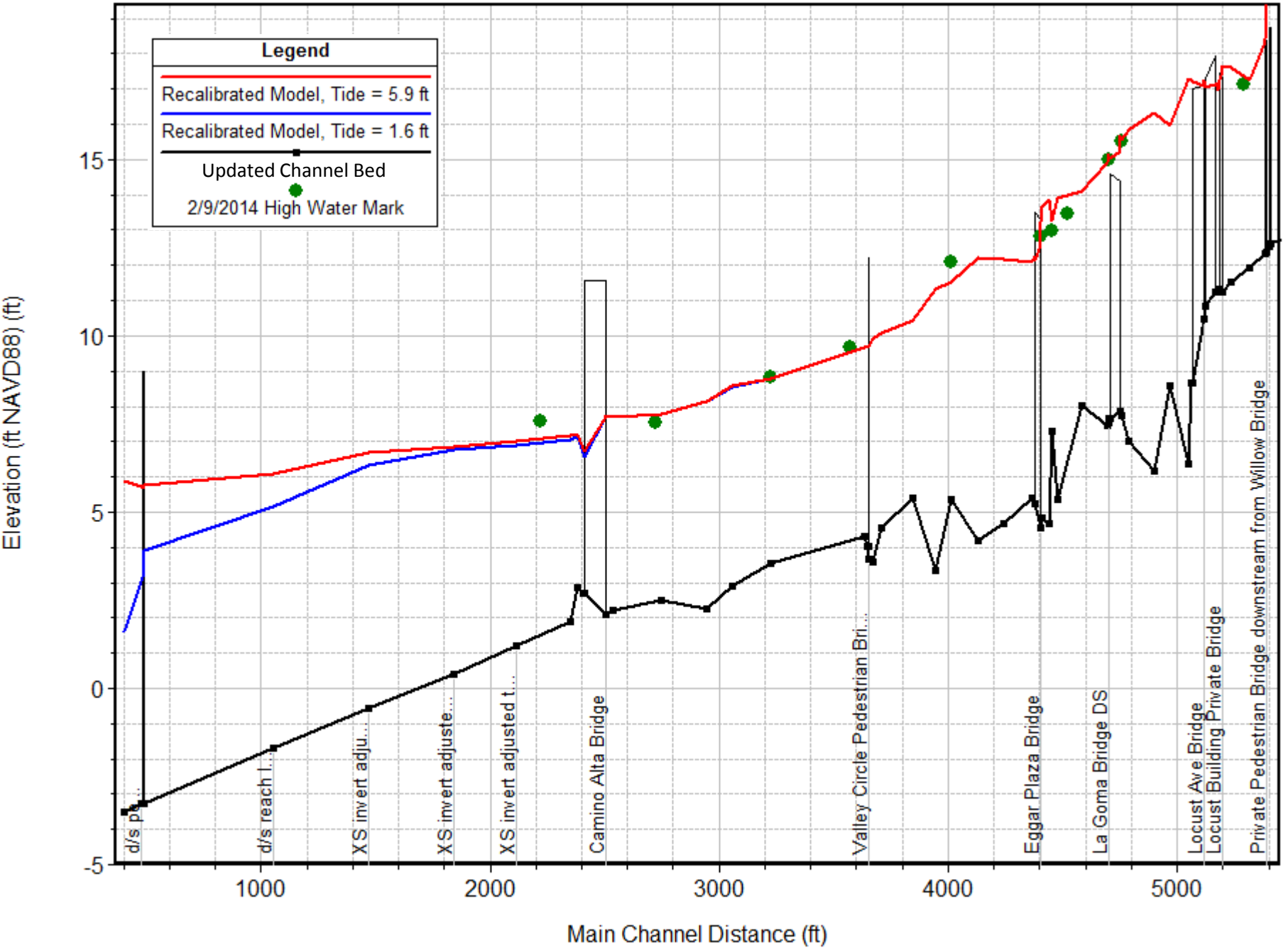


Figure 9a Comparison of Water Surface Profiles between the 2012 Project Conditions Model and the Updated Project Conditions Model for the 25-Year Flood Damage Reduction Measures

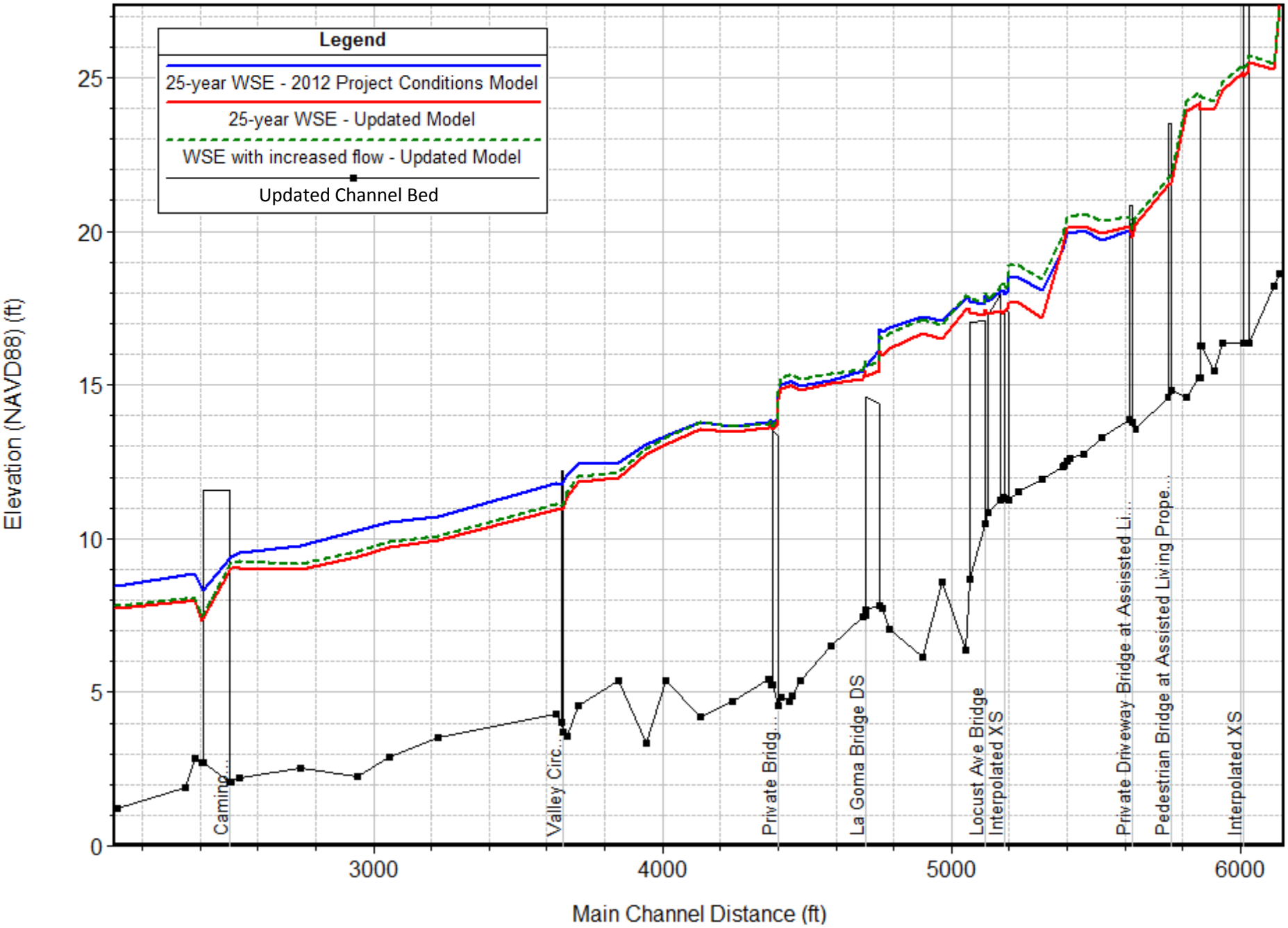


Figure 9b Comparison of Water Surface Profiles between the 2012 Project Conditions Model and the Updated Project Conditions Model for the 50-Year Flood Damage Reduction Measures

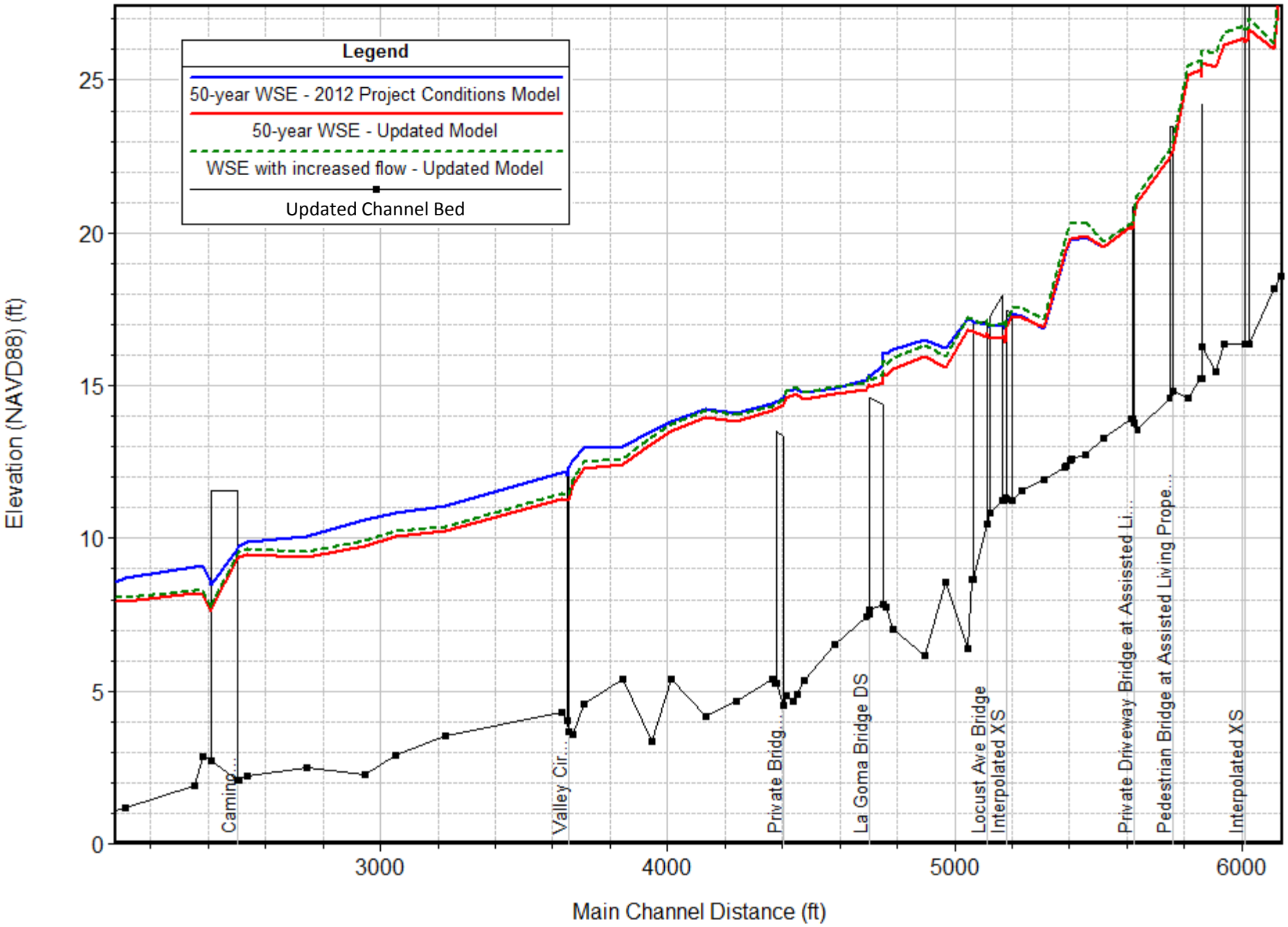
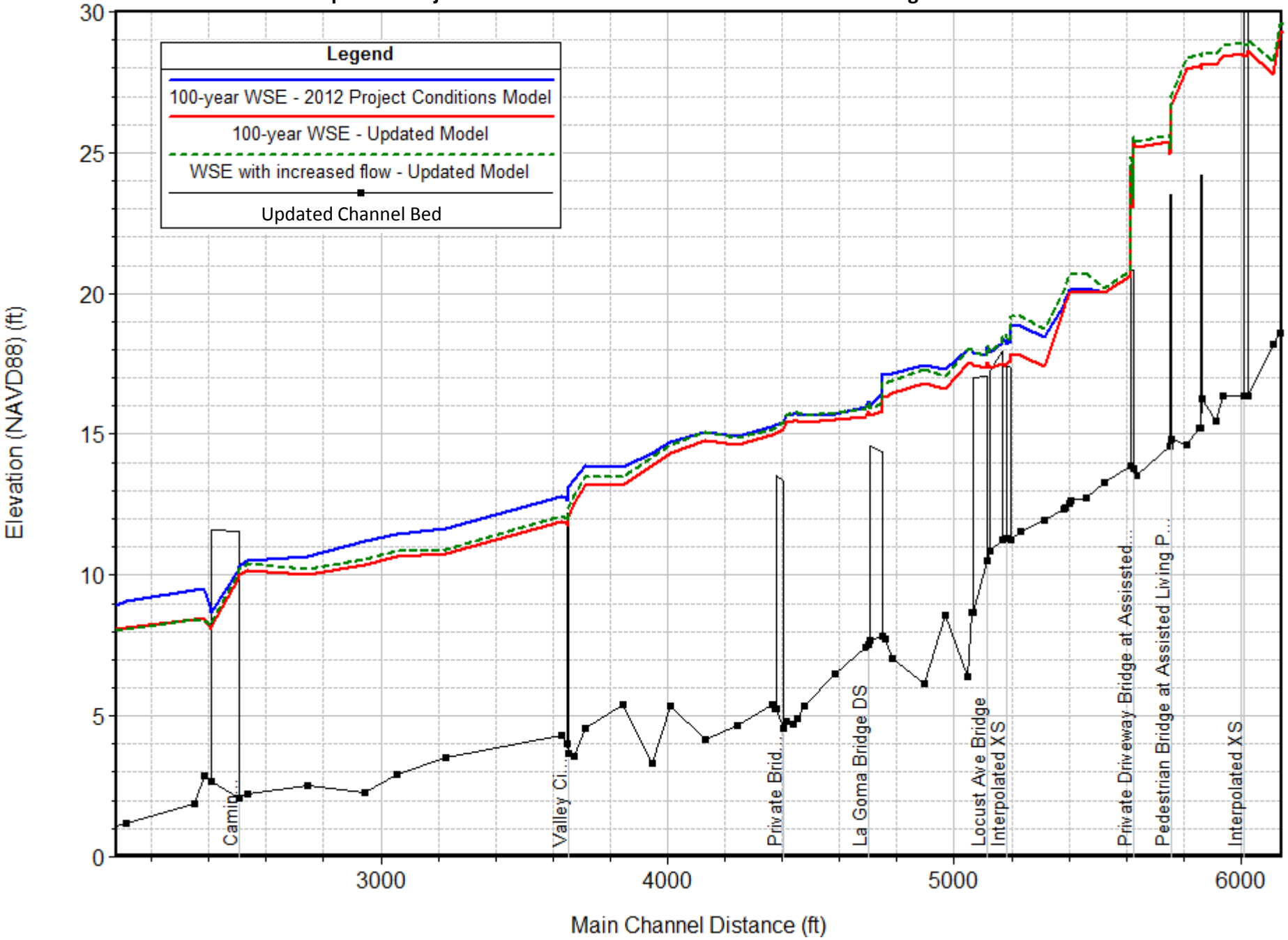


Figure 9c Comparison of Water Surface Profiles between the 2012 Project Conditions Model and the Updated Project Conditions Model for the 100-Year Flood Damage Reduction Measures



APPENDIX B

Southern Marin Watershed Guide





Southern Marin Watershed Guide

Planning for Floods







Southern Marin
Flood Protection
and Watershed Program

July 2016



PHOTO: ANDREA DUNLAP

Southern Marin Watershed Guide

Planning for Floods

Southern Marin
Flood Protection
and Watershed Program

July 2016

Miles

Acknowledgements

This publication is a product of the Southern Marin Flood Protection and Watershed Program, a collaborative effort of the County of Marin, Marin County Flood Control and Water Conservation District Zones 3 and 4, and the City of Mill Valley.

This watershed guide and the Southern Marin Watershed Program are elements of the Marin County Department of Public Works' countywide Watershed Program.

The website **www.marinwatersheds.org** provides a wealth of information to support the community's understanding of watershed issues and to introduce ideas and possible next steps for watershed improvement and flood control, including existing condition reports for each watershed, descriptions of existing facilities, and other products.

The following people provided valuable feedback on draft versions of this report:

Chris Choo, County of Marin
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This guidebook tells the story of our watershed and the flood risks we face together. Flooding affects our quality of life and livelihood: it threatens our homes and our businesses, and can impact everything we do in our normal day-to-day life, from getting our children to school to our access to emergency services.

The entire watershed landscape drains steeply, falling from Mt. Tam, flowing under buildings in downtown, widens and spreads through neighborhoods along the valley floor, past businesses on Miller Avenue, until reaching the wetlands at the bay. Sea level rise is also a concern and must be factored into any options we consider as we move forward. Solutions need to be integrative and work with our natural environment to ensure they protect the habitat and special species living in our backyards, such as the steelhead trout and Ridgway's rail. And since water disregards boundaries of any sort, we must carefully craft solutions that don't cause harm to one neighborhood while protecting another.

How we approach planning for watershed management and flooding defines our community, and the complexity of the issues highlights our need to work together. There are no easy solutions, but this guide will help us start from a common point of understanding as we work together to define solutions for the short-term as well as long-range planning. Learning to live with water will be a part of our future together.

We hope that you find this guide to be a useful resource, and that after reading it you will head outside to experience our beautiful watershed. We'll come back to ask for your help identifying the issues, developing projects, and improving the watershed for our future.



Stephanie Moulton-Peters
Mill Valley councilmember



Kathrin Sears
Marin County Supervisor, District 3

Introduction: Why we made this guide

Prevailing wisdom about California water asserts that two things are inevitable: there will be another drought and there will be another flood. Though it is hard to prepare for one while experiencing the other, this is exactly what our communities must do. The next flood will come and its consequences will be determined by our actions today.

The impacts of flooding are far-reaching. While flood waters may not reach your home or business, floods do close the roads you use, the businesses you rely on, and your local schools. They can restrict access for emergency vehicles. They can cause landslides and leave standing water in low-lying areas. They can impact our wastewater treatment and leave wildlife stranded and vulnerable. Should the current trends in climate change continue, these conditions will almost certainly become worse. These challenges require community input and support.

Use this guide as a springboard to understand and engage in planning for flood and habitat protection in Southern Marin. The guide will help articulate the balance we all seek between living among the natural beauty and addressing the flood risks of this unique location. It will assist you in understanding the existing conditions as well as the process for considering options to reduce flood risk and protect habitat.

The guide describes:

- The characteristics of a watershed and influences on flooding
- Habitat and inhabitants of the watershed
- What happens when it floods
- What causes flooding
- How land use affects flooding
- How flooding affects water quality and habitat
- How climate change and sea level rise impact flooding
- Who is responsible for flood protection in Southern Marin
- Potential tools to address flooding and sea level rise
- Flood issues and options for reducing flood risk in Southern Marin
- A process for project implementation

We hope you will enjoy this guide and engage in the planning process with us.



FLOOD PHOTO WITH CAR: COURTESY OF THE LUCRETIA LITTLE HISTORY ROOM, MILL VALLEY PUBLIC LIBRARY

As long as people have lived in Southern Marin, we have been dealing with floods and their impacts.

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Understanding Watersheds

Look to the hills above the community – from the Golden Gate National Recreation Area lands to Mount Tamalpais to Ring Mountain – and you will see the top of the Southern Marin Watershed. Rain that falls in this area drains to Richardson Bay.

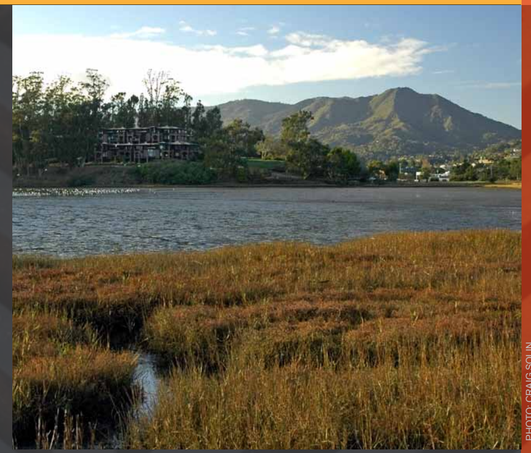
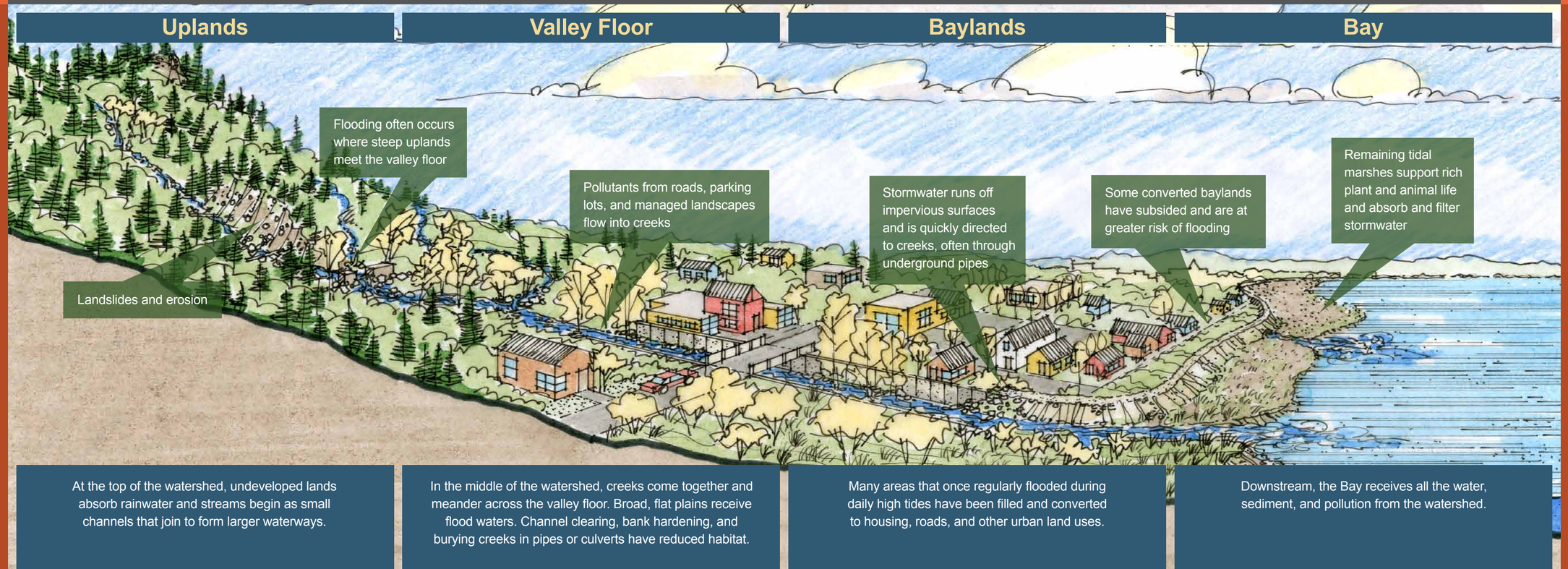


PHOTO: CRAIG SOLIN

What is a watershed?

The cities and communities of Southern Marin tend to be nestled in valleys or on adjacent, rolling hillsides. Steep ridgelines upstream and the waters of Richardson Bay downstream cradle these communities.



At the top of the watershed, undeveloped lands absorb rainwater and streams begin as small channels that join to form larger waterways.

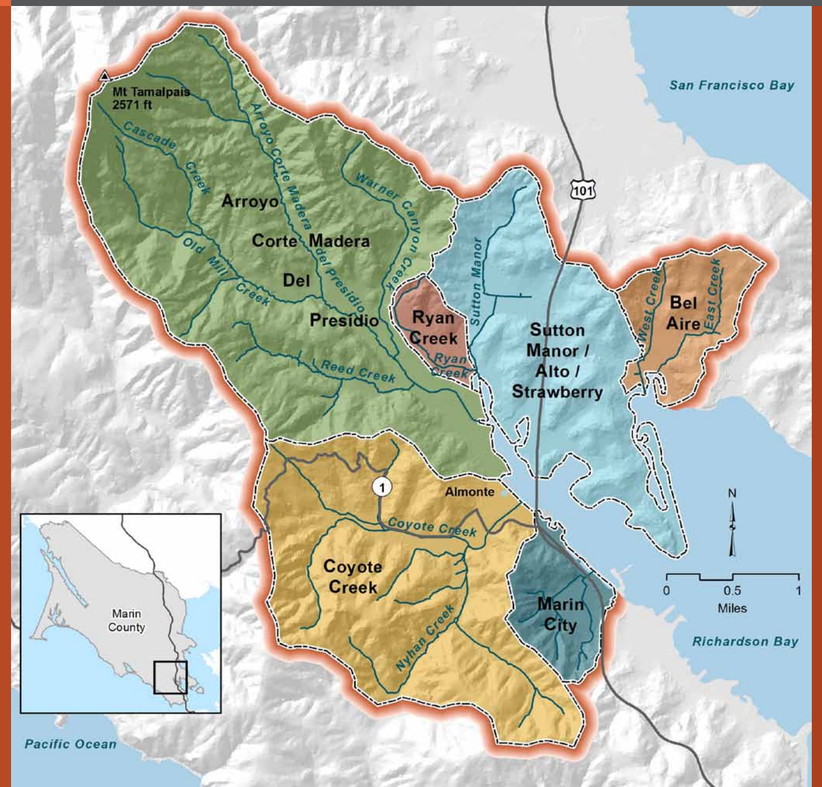
In the middle of the watershed, creeks come together and meander across the valley floor. Broad, flat plains receive flood waters. Channel clearing, bank hardening, and burying creeks in pipes or culverts have reduced habitat.

Many areas that once regularly flooded during daily high tides have been filled and converted to housing, roads, and other urban land uses.

Downstream, the Bay receives all the water, sediment, and pollution from the watershed.

What watershed do you live in?

The Southern Marin Watershed includes all the land that drains into northwestern Richardson Bay – 14 square miles in total. It is the body of land that roughly corresponds to the County of Marin's Flood Control Zones 3 and 4 – entities that were established to help address flooding in Southern Marin.



Within the Southern Marin Watershed are multiple smaller watersheds (subwatersheds) with their own outlets into the Bay. Planning at the watershed scale makes sense when dealing with water because it encompasses all the drainage area, upstream and down, with all its inhabitants and habitat.

Marin City Watershed

- 0.64 square miles
- For a century, the watershed was home to a dairy farm
- During World War II, the area was developed to house workers for the nearby shipyards

Coyote Creek Watershed

- 3.66 square miles
- Coyote and Nyhan Creeks drain steep slopes and join in former tidal marsh
- In the 1960s, lower Coyote Creek was converted to a flood control channel to protect nearby neighborhoods
- Includes Bothin Marsh, the largest remaining tidal marsh in the Southern Marin Watershed

Arroyo Corte Madera del Presidio Watershed

- 6.0 square miles
- In Spanish, the name means *the creek where wood is cut for the Presidio*
- In the late 1800s, the area developed first as a summer retreat and later as a full-fledged town

Ryan Creek Watershed

- 0.31 square miles
- Ryan Creek only flows after storms

Sutton Manor/Alto/Strawberry Watershed

- 2.5 square miles
- Includes Sutton Manor Creek and the Strawberry Peninsula
- In the late 1800s, the Eagle Dairy and the North Pacific Coast Railroad operated here

Bel Aire Watershed

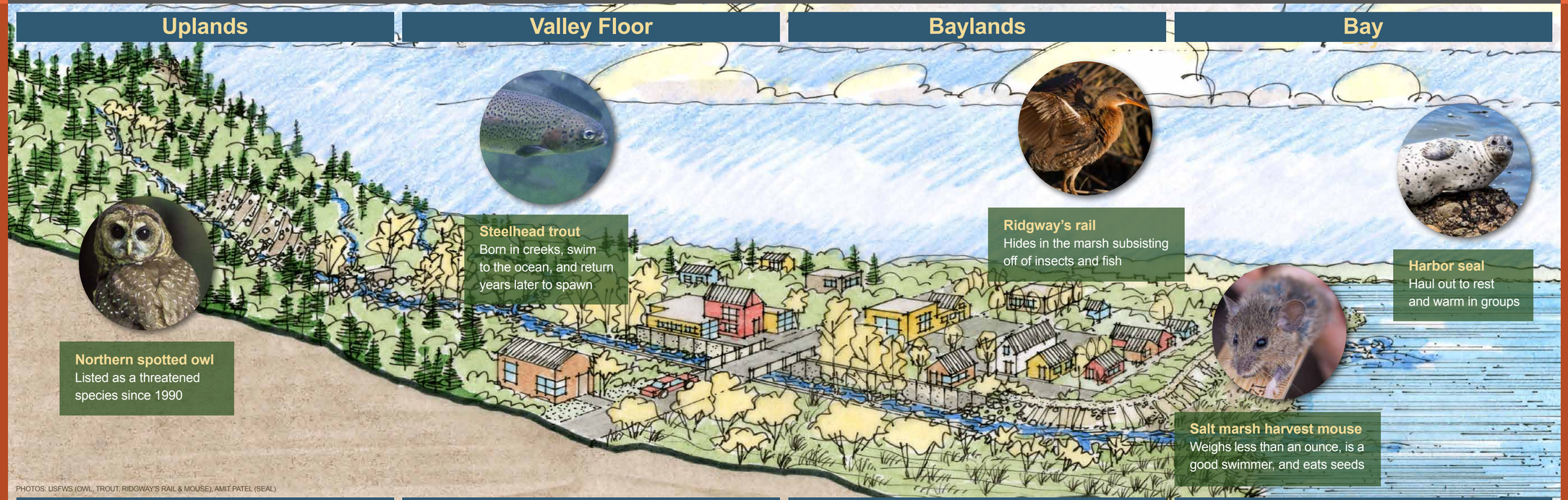
- 0.78 square miles
- Includes the Ring Mountain Open Space Preserve and neighborhoods in Tiburon

Fifty minutes from San Francisco; delightful climate; perfect drainage; trout streams; purest and best of water in great abundance; beautiful drives and perfect views of mountain, bay, forest, and city.

– Promotional material for Southern Marin from the 1890s

Creek and marsh habitat

Southern Marin's creeks and marshes are home to many threatened populations of plants and animals or species of concern. Species of concern have undergone a severe population decline and are now protected by law. Flood management decisions must give these species and their habitats – much of which are lost or fragmented – special consideration. Many would benefit from natural flooding.



PHOTOS: USFWS (OWL, TROUT, RIDGWAY'S RAIL & MOUSE), AMIT PATEL (SEAL)

Open spaces provide habitat for wildlife

Nine species of fish live in Southern Marin's creeks

Remaining tidal marshes provide valuable habitat for wildlife

Richardson Bay is home to 55 species of fish, thousands of water birds, seals, and other animals



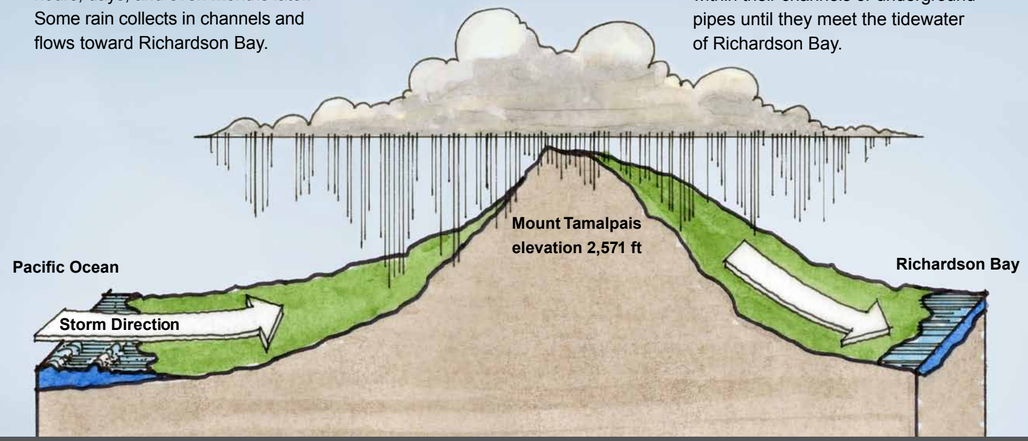
Understanding Flooding

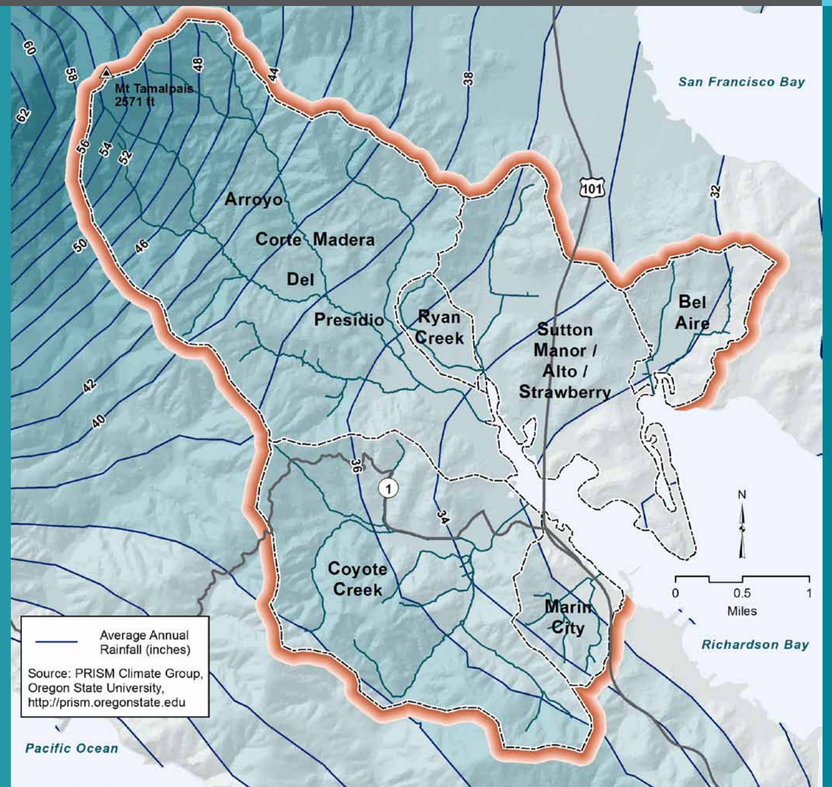
With this introduction to the Southern Marin Watershed, we can begin to understand how and why flooding occurs. Every drop of rain follows a different path downhill. Where it goes depends on how much rain falls, what people have done to modify its route through the watershed, and many other factors. If we understand the causes of flooding, we can begin to address its impacts.

What happens when it rains?

From roughly October to April, Mount Tamalpais and its ridges capture storms off the Pacific. An average of 56 inches of rain falls each year at the summit of Mount Tamalpais. Some of the rain seeps into the ground and emerges hours, days, and even months later. Some rain collects in channels and flows toward Richardson Bay.

Downstream, steep slopes give way to broad, flat valleys. On average, only 32 inches of rain fall each year at the mouth of the watershed but rain from the uplands contributes to the flows on the valley floor. During most rainfall events, waterways remain within their channels or underground pipes until they meet the tidewater of Richardson Bay.





The summit of Mount Tamalpais receives the most rainfall. The watershed is drier at lower elevations near the bay.

What happens when it floods?

Flood types



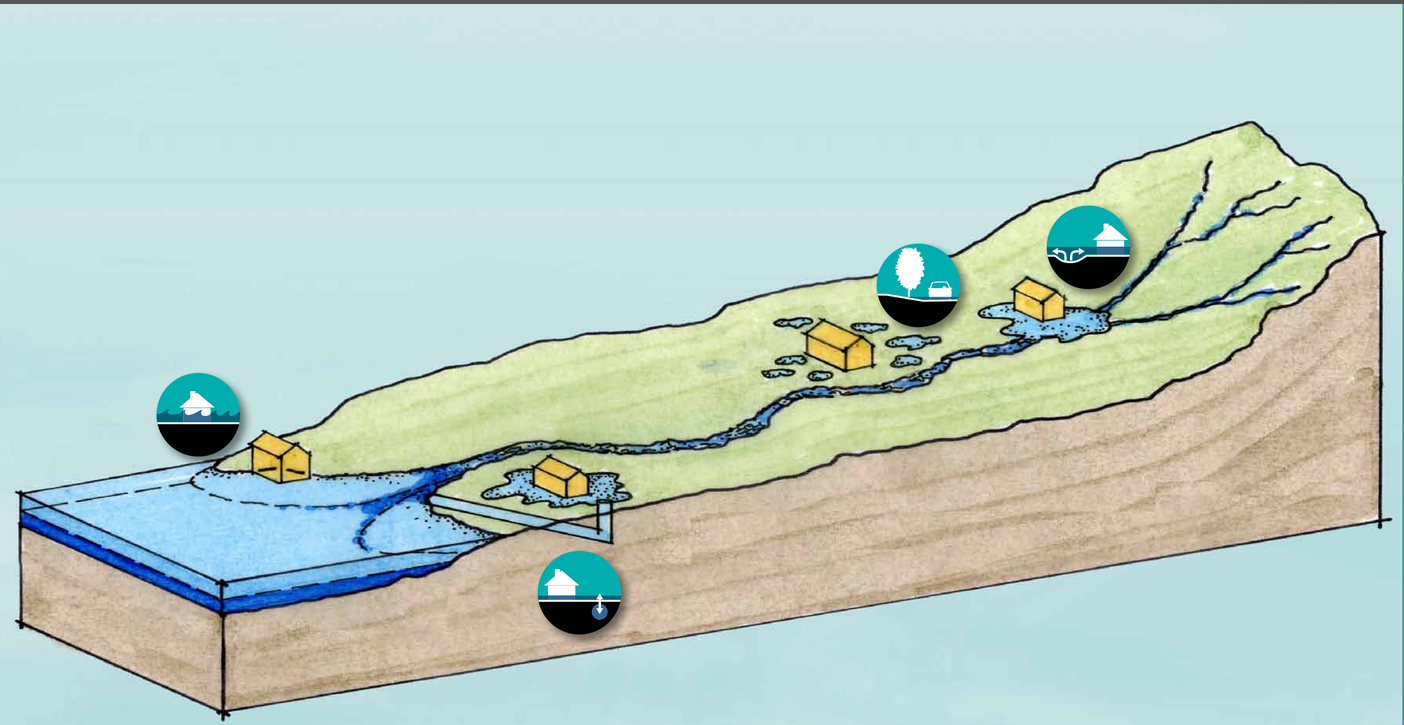
TIDAL INUNDATION
Rising tides fill creeks and flood lowlands

Extreme high tide events exacerbate creek or stormwater overflow during storms. High tides can back up stormwater pipes and prevent non-tidal areas from draining. Sea level rise will increase the extent and frequency of tidal inundation.



STORMWATER OVERFLOW
Stormdrains back up

Stormwater drainage systems quickly convey rainwater through underground pipes to creeks and the Bay. When the stormdrains are obstructed or broken or when the creeks that they lead to are already full, water backs up onto the streets.





ISOLATED PONDING
Pools form on the ground

Isolated ponding can occur in any area that doesn't drain effectively – for example, in a natural depression in the landscape.

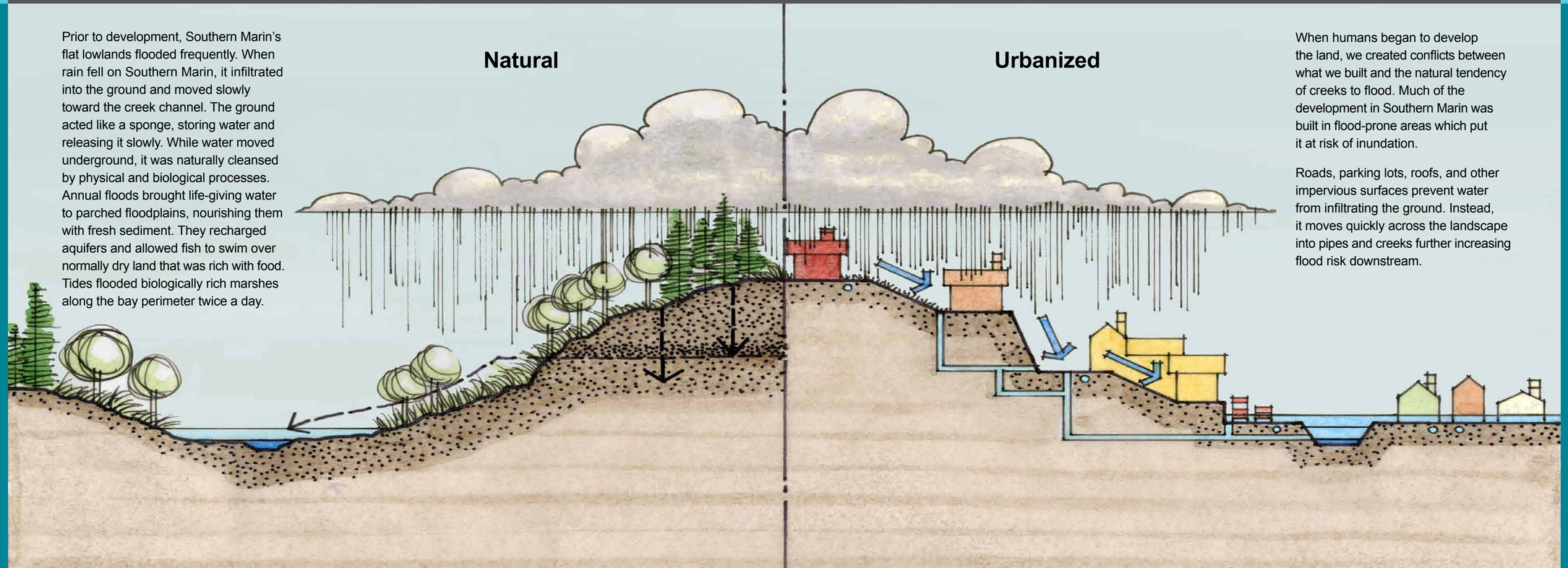


CREEK OVERFLOW
Creeks spill over their banks

Naturally, waterways regularly overflowed onto an adjacent flood plain. Buildings are now often located on these flood plains. The size and slope of a channel, blockages, proximity to the bay, and constrictions obstructing flow such as bridges, utility pipes, or adjacent buildings all influence the frequency and volume of creek overflow.

How have land use changes impacted flooding?

Prior to development, Southern Marin's flat lowlands flooded frequently. When rain fell on Southern Marin, it infiltrated into the ground and moved slowly toward the creek channel. The ground acted like a sponge, storing water and releasing it slowly. While water moved underground, it was naturally cleansed by physical and biological processes. Annual floods brought life-giving water to parched floodplains, nourishing them with fresh sediment. They recharged aquifers and allowed fish to swim over normally dry land that was rich with food. Tides flooded biologically rich marshes along the bay perimeter twice a day.



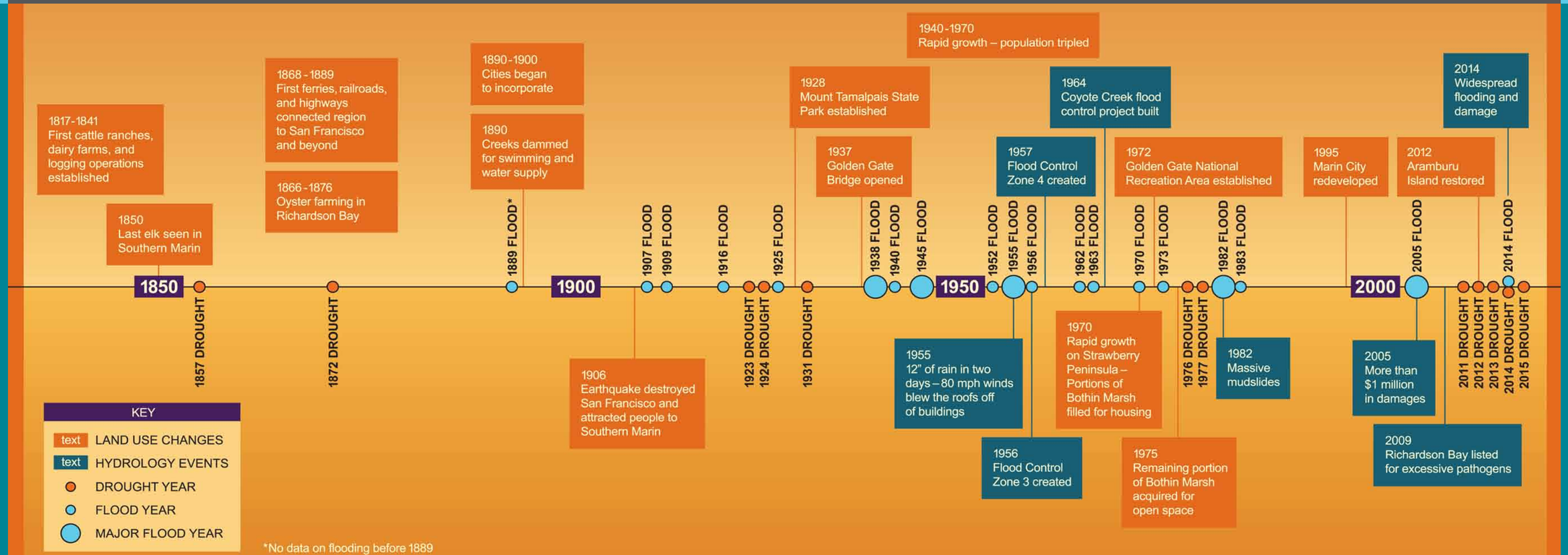
When humans began to develop the land, we created conflicts between what we built and the natural tendency of creeks to flood. Much of the development in Southern Marin was built in flood-prone areas which put it at risk of inundation.

Roads, parking lots, roofs, and other impervious surfaces prevent water from infiltrating the ground. Instead, it moves quickly across the landscape into pipes and creeks further increasing flood risk downstream.

The Southern Marin Watershed is home to 32,000 people, over 200 miles of roads and highways, 150 miles of sanitary sewers/ waterlines, seven sewage treatment districts, one sewage treatment plant, eight pump stations, and 40 miles of stormwater pipes. It is also home to our dwellings, the commercial areas where we gather, the schools we attend, and the creeks, hills, and wildlife we enjoy.

How have land use changes impacted flooding?

Prior to the arrival of the Spanish in 1775, 1,500 to 2,000 Coast Miwok made their home in Southern Marin. The land, creeks, and bay provided fresh water and food sources to sustain the local human population as well as elk and grizzly bears.



How does flooding impact water quality?

Water quality in Southern Marin is impaired by excessive nutrients, pesticides, elevated bacterial levels (such as fecal coliform), sediment from erosion, and sewage spills.

Moving water out to Richardson Bay as quickly as possible can have negative impacts on water quality. Waters that move slowly and have an opportunity to infiltrate can be cleansed by physical and biological processes that naturally occur underground.

The cities and county have stormwater programs to protect water quality. Flood protection must work to improve water quality in ways that are consistent with the mandates of the government agencies and the many water quality requirements in place.

By better managing our floods, we can improve water quality in Southern Marin and Richardson Bay.



Floods can also overwhelm sewage treatment facilities and wash untreated sewage into creeks, stormdrains, and Richardson Bay.



Stormdrains take untreated runoff from the exteriors of our homes and businesses directly to creeks and Bay.



How do climate change and sea level rise affect flooding?

Dealing with flooding from rain and upstream runoff is already complicated. Sea level rise will make it even more complicated by increasing the frequency and duration of flooding.

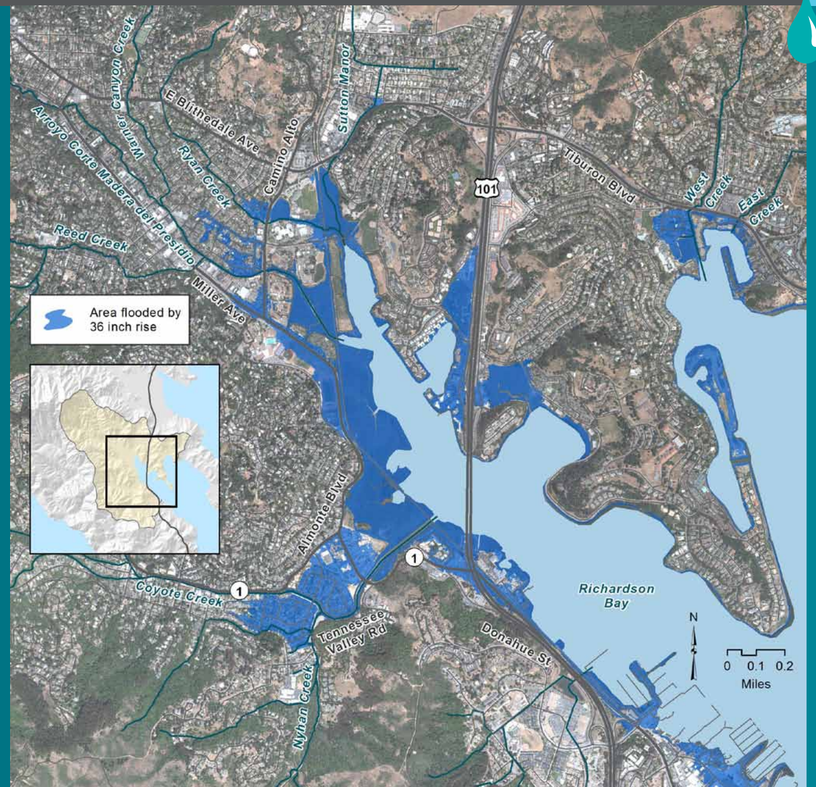
When water temperature increases, water expands and takes up more space than cold water. As the planet warms, the water in the ocean warms, expands, and elevates sea levels. The changing climate has also melted parts of the ice caps at the North and South Poles. As this ice melts and flows into the ocean, it increases the amount of water in the ocean and raises sea levels even more. Sea levels in San Francisco Bay have risen seven inches over the past century.

Predictions of future sea level rise vary from 12 inches by 2030 to 60 inches by 2100. The Bay Conservation and Development Commission (BCDC) recommends using 36 inches of sea level rise for planning purposes.

Rising sea levels increase the upstream extent of tidal flooding, worsen creek overflow due to backwater effects of elevated high tides, and create larger, stronger waves which erode the shoreline and destroy sensitive marshes. Coastal flooding will have a large impact on cities and habitat.



A 36-inch increase in sea levels will greatly impact people’s lives throughout Southern Marin. Daily high tides will inundate major thoroughfares, schools, retirement communities, private homes, shopping areas, bike paths, and stormwater detention ponds. Valuable marsh and mudflat habitat will be permanently flooded. Infrastructure will need to be armored, abandoned, or relocated. Shorelines will be eroded by increased wave erosion, threatening even more infrastructure.





Reducing Flood Risk

With an understanding of how and why flooding occurs, we can take a closer look at how to reduce flood risk.





How can we protect ourselves from flooding?

There are many ways to reduce flood risk. Generally, multiple strategies are employed simultaneously. Possible approaches depend on the type of flooding, the physical setting, cost-benefit considerations, available funding, legal and permitting implications, and the support of the local community.

Away from the Channels

Hold Back Stormwater

Stormwater detention in basins or vaults captures stormwater before it enters the creek and releases it slowly to reduce downstream flooding. Finding the space for stormwater detention facilities can be difficult and expensive in urban areas.



PHOTO: A. VOLKENING

Stormwater Bypass

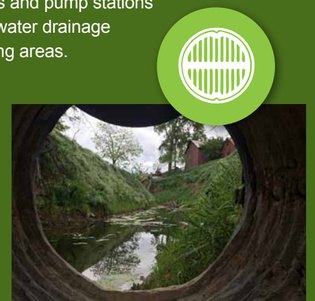
Stormwater pipes or channels bypass water from flood prone areas to a location downstream. New pumps and/or tide gates may be required depending on where the bypass flood waters are discharged.



Pipe Stormwater Underground

Conveying stormwater in underground pipes creates space for streets, homes, and other urban features. Well-maintained pipes may quickly move water downstream but underground infrastructure can be difficult to inspect and troubleshoot. Over time, land settles and pipes age, clog, and break. Downstream tides or flooding limit how fast water is able to exit the drainage pipe, so larger pipes do not necessarily improve drainage. Many stormwater pipes are located on private property.

Regular inspections, pipe flushing, repair, and eventual replacement of old or failed pipes are all necessary to reduce the risk of stormwater overflow. Tide gates and pump stations can improve stormwater drainage efficiency in low-lying areas.



Raise or Flood-Proof Buildings out of the Floodplain

Structure elevation is a reliable flood risk reduction strategy. It can be expensive and must be weighed against the expected damage and frequency of flooding to get a true picture of the costs and benefits. While it may raise a building above floods, it does not necessarily improve access from that building to nearby roads and resources that may be underwater or cut off by flooding.



PHOTO: EP_JHU

How can we protect ourselves from flooding?

In and Along the Channels

Creek Maintenance

Vegetation trimming and targeted sediment removal within creeks and channels can help reduce flood risk, although the benefits can be short-lived. Creek maintenance is typically performed annually. Excessive vegetation or sediment removal can harm wildlife, water quality, and bank stability.



Increase Creek Flow Capacity

By replacing bridges or utility crossings, increasing the size of culverts, or widening the creek channel, we can increase the amount of water that can flow in a channel during floods. It can also provide space for habitat and promote bank stability. It is expensive because creek widening is constrained by buildings, roads, and property lines.



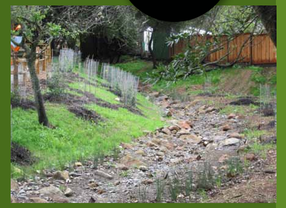
Stabilize Channels

Stabilizing creek banks and channel bottoms reduces erosion, stabilizes habitat, and protects infrastructure. This activity includes vegetating eroding slopes with native plants and sometimes re-grading bank slopes. Depending upon the location of infrastructure, the strategic placement of rocks, wood and/or installation of an engineered structure may be required to stabilize the creek banks.



Habitat Enhancement and Restoration

Habitat enhancement and restoration to improve habitat for flora and fauna while reducing flood risk. Projects that remove obstructions to flow or allow flood waters to be absorbed by wetlands can reduce flood risk and improve critical habitat. Closer to the bay, strategic wetland restoration can absorb floodwaters and reduce the impact from storm-related waves.



Levees and Floodwalls

Levees and floodwalls constructed alongside the creek or bay confine floodwaters. While effective, levees and floodwalls must be contiguous throughout the area of flooding, require space and material, and may require pump stations and drainage pipes to move water over or through them and into creeks.

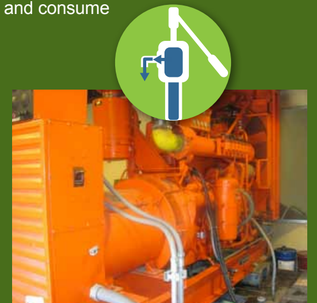


How can we protect ourselves from flooding?

Near the Mouth of the Channels

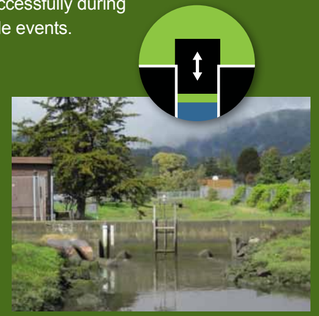
Pump Stormwater from Low-lying Areas to Creeks

In the baylands, the District operates eight pump stations to move water out of low-elevation neighborhoods constructed on former marshlands. Rainfall from these areas drains to a point lower than the adjacent levees or creeks. Large pumps move ponded water into adjacent creeks where it can drain to the bay. Opportunities may exist to increase pumping capacity at currently-operated pump stations. Pumps are effective at protecting low-lying areas but they are expensive, require regular maintenance, and consume a lot of energy.



Block tides

Adjustable tide gates can extend across channels or attach to outfalls of stormdrain pipes that drain to creeks and channels. They are designed to keep tidal waters out of the stormdrain system during high tides and protect low-lying areas. They are prone to being stuck open by debris and require regular maintenance. Larger gates are manually operated increasing the burden to deploy them successfully during forecasted high tide events.



	Away from the Channels				In and Along the Channels					Near the Mouth of the Channels	
	Hold Back Stormwater	Stormwater Bypass	Pipe Stormwater Underground	Raise Buildings	Creek Maintenance	Increase Creek Flow Capacity	Stabilize Channels	Levees and Floodwalls	Habitat Restoration	Pump Stormwater	Block Tides
Costs											
Requires Right-of-Way	✓	✓	✓					✓	✓		
Requires Ongoing Maintenance		✓	✓		✓			✓		✓	✓
Benefits											
Environmentally Sustainable	✓			✓	✓	✓	✓	✓	✓		
Responsive to Sea Level Rise				✓					✓		
Improves Habitat						✓	✓		✓		
Improves Water Quality						✓	✓		✓		
Can be Implemented by Home Owners	✓[1]			✓					✓		

1. Small-scale retention on individual parcels

Who is responsible for flood risk reduction?

Everyone has a role to play. The "Whole Community" approach to flood risk reduction requires communities and government agencies to work together to understand, assess, and identify flood risk reduction needs and solutions. The collaboration and shared understanding creates communities more resilient to flooding and better able to adapt and respond when floods occur.

The Marin County Flood Control and Water Conservation District (District) maintains 3.6 miles of channels (17% of the total channel length) and related flood control infrastructure in the Southern Marin Watershed. Maintenance activities include regular servicing of eight pump stations, multiple tide gates, miles of levees and drainage ditches, and an annual vegetation maintenance program. Work is limited to areas where the District has permission to perform maintenance – on its own lands or where it has acquired easements.

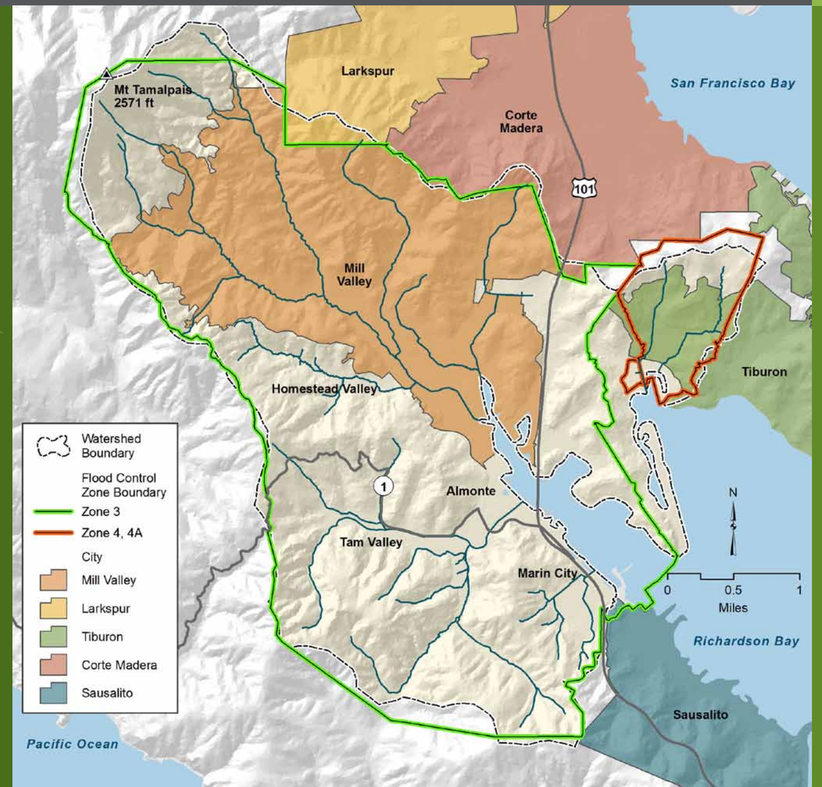
Two "Flood Control Zones" partner with municipalities and other agencies to provide flood risk reduction in Southern Marin. The District Board of Supervisors established Flood Control Zone 3 in 1956 and Flood Control Zone 4 in 1957.

Each zone has an advisory board of residents who are appointed by the District Board of Supervisors. The zones have authority to construct, operate, and maintain stormwater basins, levees, pumping stations, culverts, drainage ways, and creeks.

Property and special taxes (if approved by a majority of voters) support work in Zones 3 and 4. All revenues in the District are collected through the zones and must be spent in the zone providing the funding. The annual work program is coordinated by the zone engineer and the budget for the work program is reviewed annually by the advisory board prior to being adopted by the District Board of Supervisors.

Within the Mill Valley city limits, the City and Zone 3 share some responsibilities for reducing flood risk. The City of Mill Valley operates one pump station, numerous tide gates, and partners with Zone 3 to maintain some of the creeks. Roadways and underlying drains are regularly inspected and maintained by the City.

Within Tiburon town limits, the Town and Zone 4 share some responsibilities for flood protection. Roadways and underlying stormdrains within the public right of way are regularly inspected and, in incorporated areas, are maintained by the Town. Many of these stormdrains convey flow into stormwater pump stations which are operated and maintained by Zone 4.



Flood control zone map with subwatersheds and city/town boundaries



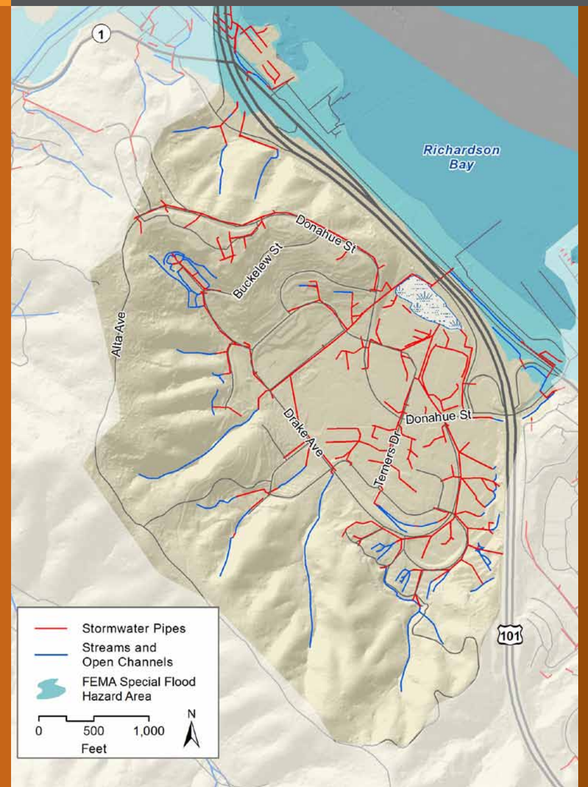
What Can Be Done in Your Watershed?

What causes flooding and what can reduce flood risk varies between subwatersheds in Southern Marin.

Marin City Watershed

Watershed Facts

Size: 0.6 square miles
Population: 2,754
Creek Length:
2.4 miles
% of Creek Maintained by District: 0%



The Marin City watershed is the southernmost sub-watershed and consists mostly of the unincorporated community of Marin City.

Before the Second World War, the small, bowl-shaped watershed was home to a dairy farm. During World War II, Marin City was developed to house workers for the nearby shipyards.

The National Park Service owns most of the upper watershed. The lower watershed is a mix of housing and commercial development.

Small channels drain the steep hillsides into a densely populated valley floor. As the channels meet the developed areas, they enter underground stormdrain pipes which converge in a small marsh (Marin City Pond) between the Gateway Center and Highway 101. Water levels in the pond can be manipulated by a manually controlled tide gate that drains into Richardson Bay. A second tide gate on the southeast side of the marsh controls drainage between the marsh and the Highway 101 off-ramp.

Challenges

Valley Floor

Creek overflow: Trash racks in small channels collect debris and help reduce blockage of downstream pipes. However, debris caught by the trash racks can block flow and flood the surrounding area. The channel, trash rack, and stormwater drain lie outside of the public right-of-way. The lack of regular debris clearing, inspection, and maintenance, and the dumping of debris in the channels all exacerbate flooding.



Baylands

Isolated ponding: The lands in the lower watershed are former tidal marshes and have subsided. This impairs drainage, creates depressions, and causes localized ponding. The old bay shoreline which extended to Drake Avenue has been filled repeatedly, but the former bay mud beneath homes and the shopping center continues to subside.

Tidal inundation: The Marin City Pond collects water from stormwater pipes and the drainage to the bay can be limited by high tides.

Marin City Watershed

Goals

- Reduce stormwater ponding on roadways
- Improve water quality at Marin City Pond
- Reduce frequency of stormwater flooding
- Increase public safety and emergency access



Possible improvements

1 Valley Floor

Creek maintenance

- Regularly inspect and clean the channels upstream and the stormdrains downstream of the trash rack

Pipe stormwater underground

- Assess stormdrains to determine existing capacity
- Replace storm drain pipes based on the findings of the assessment

2 Baylands

Pipe stormwater underground

- Inspect and clean the stormdrains and water quality control device to determine condition
- Identify possible pipe replacement needs
- Replace pipes based on the findings of the inspection

Pump stormwater

- Design and construct a new stormwater pump station

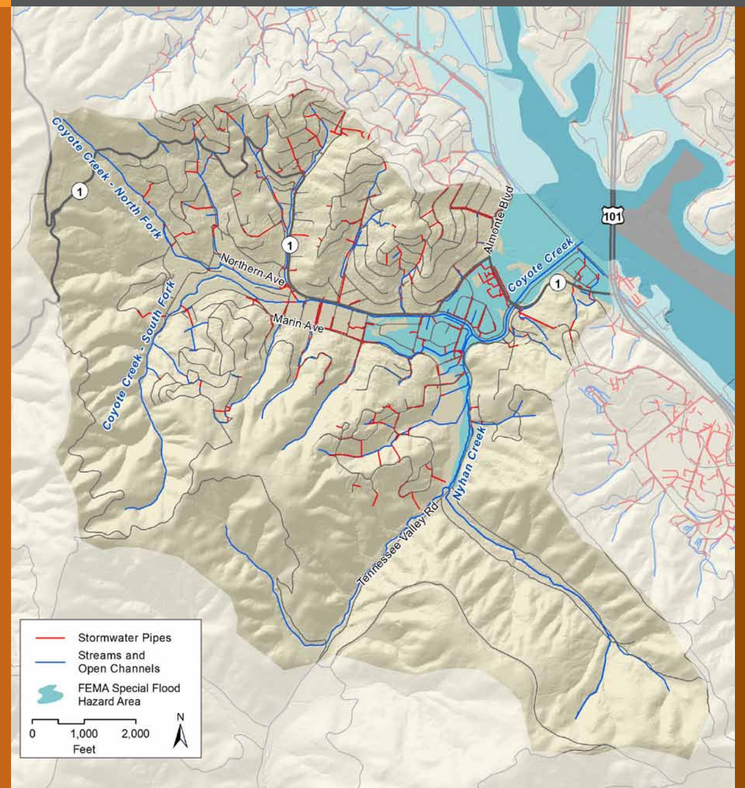
Habitat restoration



Coyote Creek Watershed

Watershed Facts

Size: 3.6 square miles
Population: 6,787
Creek Length: 14 miles
% of Creek Maintained by District: 11%
Creeks:
Coyote Creek,
Nyhan Creek,
Oakwood Valley Creek
Flood Control Facilities:
Coyote Creek Flood Control Channel
Coyote Creek Levees
Cardinal Road Pump Station
Crest Marin Pump Station
Shoreline Pump Station



Coyote and Nyhan Creeks capture and convey stormwater runoff from the steep upper watershed and valley floor, and join a half mile from the bay in a flat lowland that was formerly tidal marsh.

The National Park Service owns much of the uplands. On the valley floor, the 2-acre Tennessee Valley Marsh next to the Tamalpais Valley Elementary School is the largest freshwater marsh in the Southern Marin Watershed. In the baylands is the 106-acre Bothin Marsh Open Space Preserve - home to several sensitive species including Ridgway's rail and the hirsute Point Reyes bird's beak plant.

In an effort to reduce frequent flooding, the U.S. Army Corps of Engineers completed the Coyote Creek Flood Control Project in the 1960s. The project involved the construction of a concrete channel and earthen levee and was handed over to the District for ongoing operation and maintenance.

Challenges

Valley Floor

Much of the low-lying area of Tam Valley was developed by filling tidal marshes and creeks. Stormwater runoff was collected in a series of stormdrains and discharged directly to the creek. Flap gates on the end of the stormdrain pipes helped prevent high creek flows and tides from flowing back up the stormdrain system and into the nearby neighborhoods. In the 1960s, the Coyote Creek Flood Control Project helped reduce the occurrence of creek overflow and tidal inundation in Tam Valley. In the 1970s and 1980s, the addition of stormwater pump stations and floodwalls also helped reduce flood risk.

Isolated ponding: As Tam Valley's low-lying areas continued to subside, the effectiveness of the drainage system decreased. Depressions filled with stormwater and caused localized ponding. To address this, three pump stations were constructed between 1977 and 1985 and subsequently upgraded. Continued maintenance is needed to ensure that the pump stations continue to function as subsidence continues in the valley.

Creek overflow: The flood control facilities require frequent maintenance to address continued settlement of the levees, aging culverts and floodwalls, impeding vegetation, unauthorized encroachments, and sediment accumulation.

Baylands

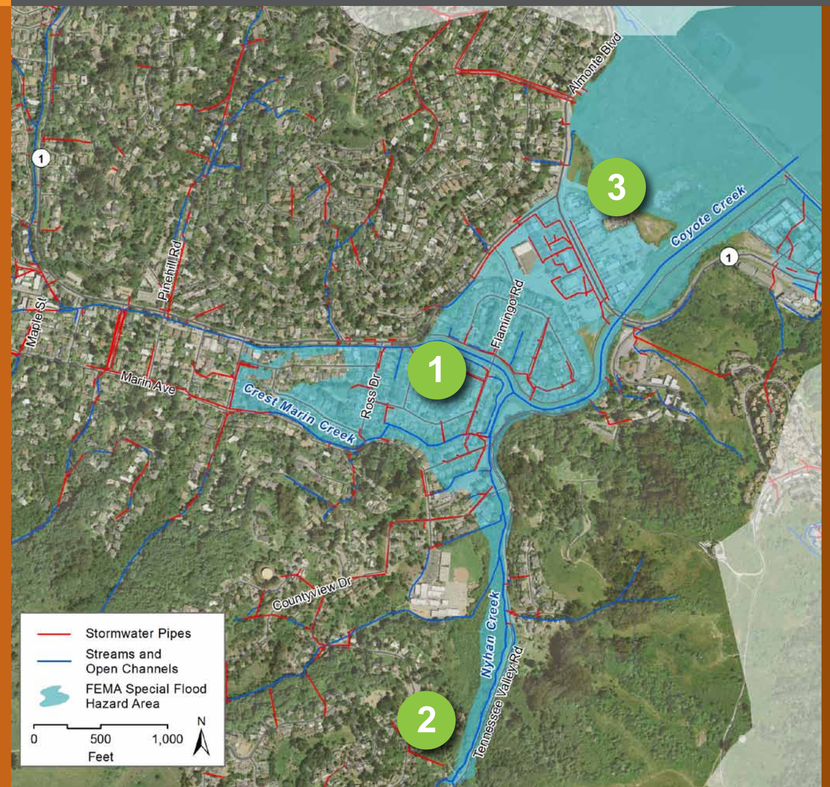
Tidal inundation: High tides regularly flood the area east of Shoreline Highway. Originally, a portion of the Coyote Creek Flood Control Project extended downstream past Shoreline Highway, but the development of the lands behind the levees was never realized and the majority of the levee was not maintained to its original design elevation. Tidal flooding impacts several businesses and leads to closure of the Shoreline Highway, CalTrans' Manzanita Park-and-Ride lot, and the Mill Valley-Sausalito Pathway.



Coyote Creek Watershed

Goals

- Reduce the risk of stormdrain overflow and stormwater ponding in Tamalpais Valley
- Reduce the risk of creek overflow
- Reduce risk of tidal flooding
- Enhance and restore tidal and freshwater marsh and creek habitat



Possible improvements

1 Valley Floor

Pump stormwater (create new and/or increase capacity of existing)

Levees and floodwalls (create new and/or increase height of existing)

Creek maintenance

2

Habitat restoration at Tennessee Valley marsh

3 Baylands

Habitat restoration

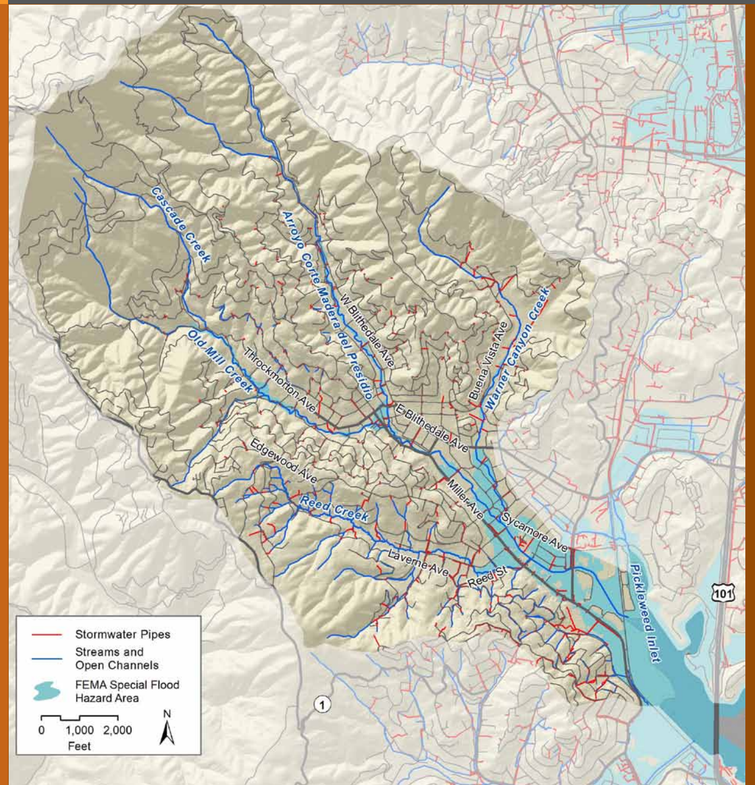
Levees and floodwalls



Arroyo Corte Madera del Presidio Watershed

Watershed Facts

Size: 6.0 square miles
Population: 13,305
Creek Length:
29 miles
% of Creek Maintained by District: 4%
Creeks:
Arroyo Corte Madera del Presidio
Cascade Creek
Old Mill Creek
Warner Canyon Creek
Reed Creek
Flood Control Facilities:
Sycamore Pump Station



The Arroyo Corte Madera del Presidio subwatershed drains from the summit of Mount Tamalpais to Pickleweed Inlet on the Richardson Bay. In Spanish, the name means *the creek where wood is cut for the Presidio.* In 1836, the first saw mill began operating. By the late 1800s, the area had developed first as a summer retreat and later as a town with bridges, dams, local water supply, and houses along the creeks.

Today, Arroyo Corte Madera del Presidio, Cascade, Old Mill, Reed, and Warner Canyon Creeks drain the mostly forested uplands. Along the urbanized valley floor, buildings, roads, and infrastructure confine the creek to a narrow channel. Tidal marshes, which once extended well past Camino Alto are now limited to the perimeter of Pickleweed Inlet.

Challenges

Uplands

Creek overflow: Drainages in the upper watershed generally consist of steep, open channels with culverts placed at roadway crossings. Culverts on private property or protected public lands may not receive regular maintenance to ensure that water can pass freely through them.



In addition to the flood problems, Arroyo Corte Madera del Presidio has a number of fish barriers preventing upsteam passage for steelhead trout to their spawning grounds.

Valley Floor

Creek overflow: Arroyo Corte Madera del Presidio has flooded homes and businesses several times over the past century. The creek can spill over its banks at relatively low flows.

Stormwater overflow: Results from undersized stormdrains, differential settlement of inlets and pipes, high tides, and debris-choked pipes.

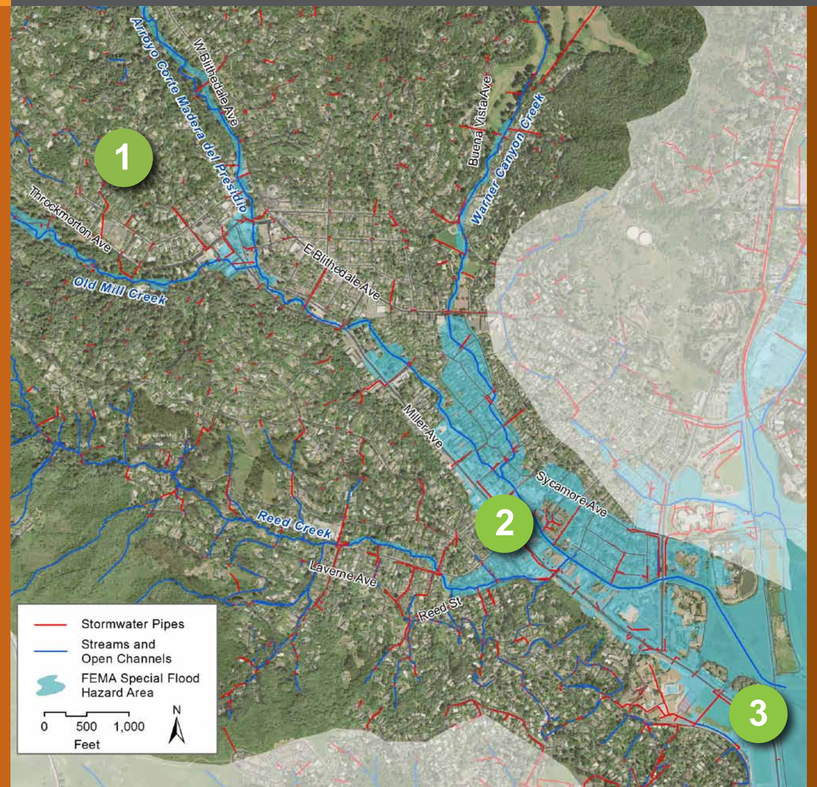
Tidal inundation: Extreme high tides can inundate low-lying areas near the shoreline. These parks, wastewater treatment facilities, commercial developments, roads, sewer, water and electrical utilities that serve all residents of the watershed may require protection, adaptation, and/or relocation.

Isolated ponding: Occurs in areas lacking stormdrains.

Arroyo Corte Madera del Presidio Watershed

Goals

- Reduce the frequency and severity of storm-drain overflow and stormwater ponding
- Reduce the frequency and severity of creek overflow within the upper Arroyo Corte Madera del Presidio Watershed, Cascade Creek, Old Mill Creek, Reed Creek, and Warner Canyon Creek sub-watersheds
- Reduce frequency and severity of creek overflow within the valley floor
- Reduce frequency and severity of direct tidal inundation



Possible improvements

1 Uplands

- Increase creek flow capacity
- Raise/flood-proof buildings out of floodplain
- Stabilize channel
- Habitat restoration

2 Valley Floor

- Pipe stormwater underground
- Levees and floodwalls
- Increase creek flow capacity
- Hold back stormwater
- Stormwater bypass
- Stabilize channel
- Raise/flood-proof buildings out of floodplain
- Habitat restoration – fish passage

3 Baylands

- Levees and floodwalls
- Pipe stormwater underground
- Habitat restoration

Watershed-wide

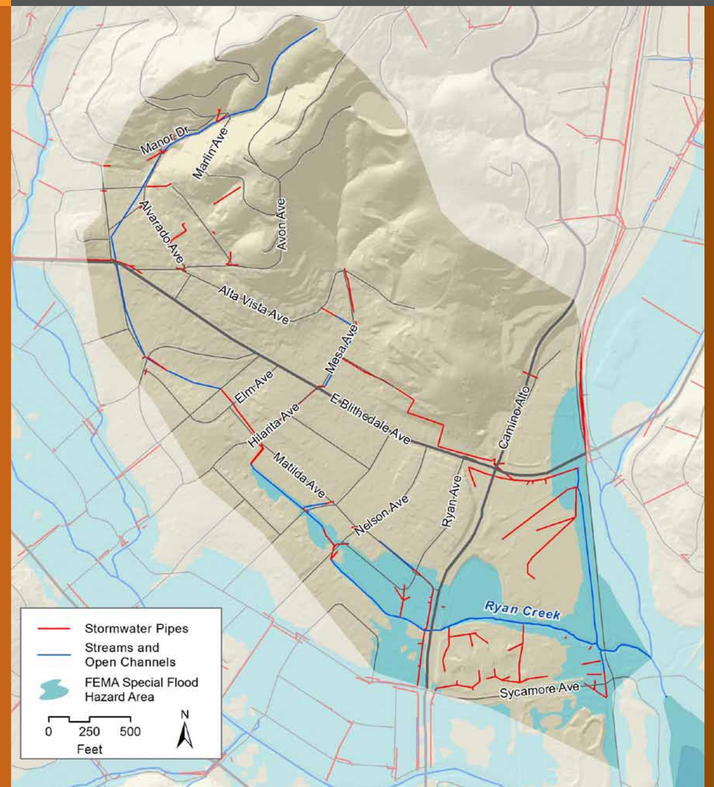
- Creek maintenance
- Pump stormwater



Ryan Creek Watershed

Watershed Facts

Size: 0.31 square miles
Population: 1,391
Creek Length:
1.3 miles
% of Creek Maintained by District: 1%
Creeks:
Ryan Creek
Flood Control Facilities:
Ryan Creek Pump Station



Ryan Creek only flows after storms and is practically unrecognizable as it moves through a series of ditches, culverts, and pipes in the neighborhood south of Blithedale Avenue and east of Camino Alto. Downstream of Nelson Avenue, Ryan Creek conveys flows in an open channel which is interrupted by short culverted sections at Camino Alto and two pathways at the Mill Valley Middle School. At the edge of the school, stormwater enters the intake of the Ryan Creek Pump Station where it is pumped into Richardson Bay. A concrete tidal barrier wall at the pump station equipped with a manually operated tide gate regulates tides within the creek.

Challenges

Valley Floor

Isolated ponding: The lack of extensive stormdrains to move stormwater results in ponding and, during intense rainfall, uncontrolled runoff flowing down gutters and streets.

Baylands

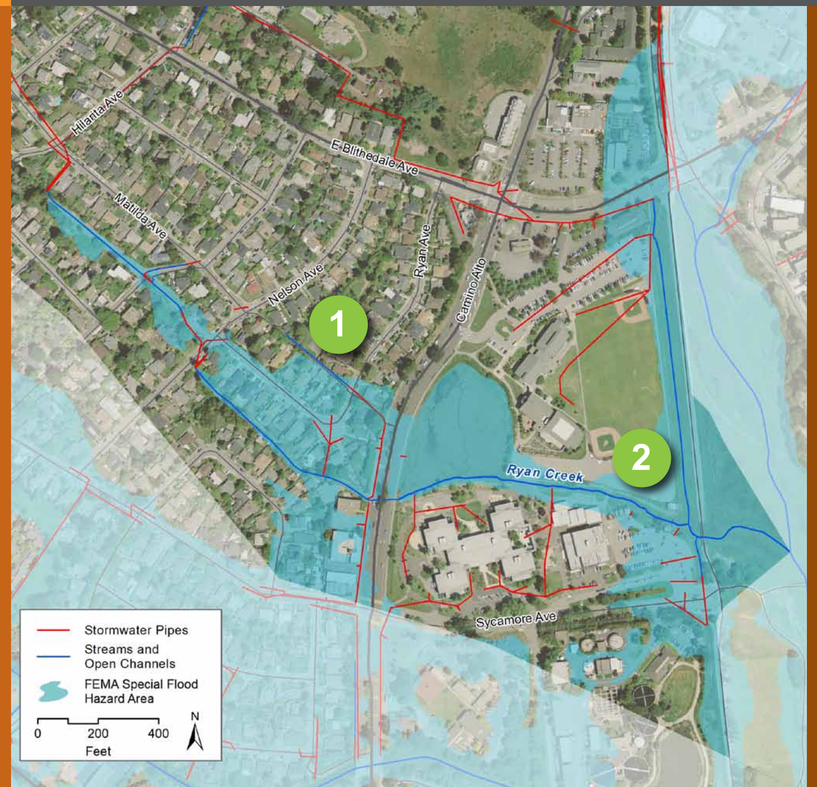
Tidal inundation: Some stormdrain outfalls in tidally influenced portions of the creek are not equipped with tide gates. Low-lying areas upstream of these outfalls may be susceptible to tidal flooding.



Ryan Creek Watershed

Goals

- Reduce the frequency and severity of storm-drain overflow and stormwater ponding
- Reduce the frequency and severity of direct tidal inundation



Possible improvements

1 Valley Floor

- Pipe stormwater underground
- Levees and floodwalls
- Habitat restoration

2 Baylands

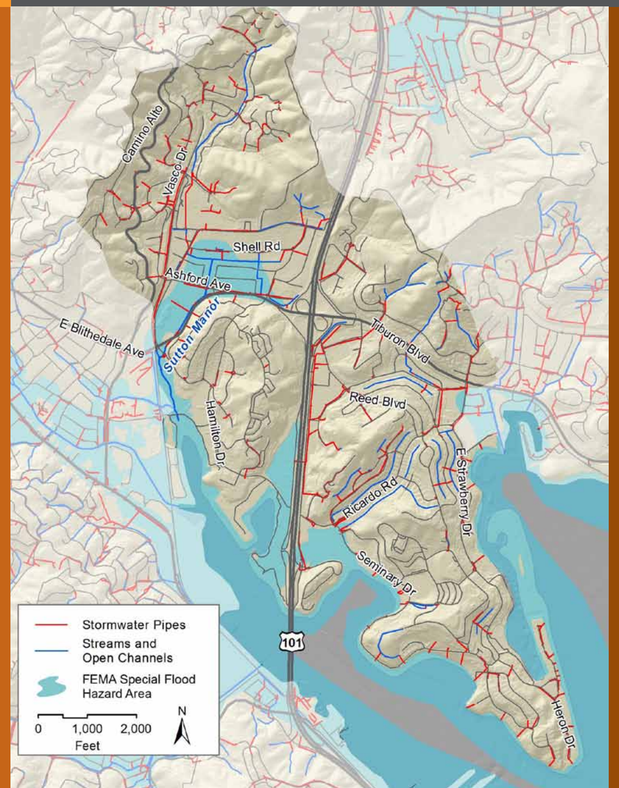
- Pipe stormwater underground
- Block tides
- Habitat restoration



Sutton Manor/Alto/Strawberry Watershed

Watershed Facts

Size: 2.5 square miles
Population: 8,452
Creek Length:
3.7 miles
% of Creek Maintained by District: 3%
Creeks:
Sutton Manor
Flood Control Facilities:
Seminary Marsh Channel
Seminary Drive Pump Station



The Sutton Manor/Alto/Strawberry Watershed includes the Sutton Manor Creek Watershed and lands on the Strawberry Peninsula that drain directly through very small drainages into Richardson Bay.

The small Sutton Creek Watershed includes Horse Hill Open Space Preserve, the Edna Maguire School, houses, and commercial properties.

In addition to the street drainage system, major drainage facilities include a series of earthen- and concrete-lined open channels, pipes, culverts, and a wetland retention facility. Flows upstream of Ashford Avenue concentrate in a T-shaped ditch (known as the T-ditch), then flow into a concrete-lined channel that discharges into a marsh adjacent to Hauke Park.

Challenges

Valley Floor

Stormwater overflow: The majority of the residential development in the watershed had been completed when significant flooding occurred in January 1970. The existing stormdrain system was undersized and overwhelmed by the amount of storm runoff. Storm flows not captured by the system overflowed into yards and homes. Improvements were made in the following years to retain and redistribute runoff but flooding persists.

Isolated ponding: Occurs in areas lacking stormdrains.

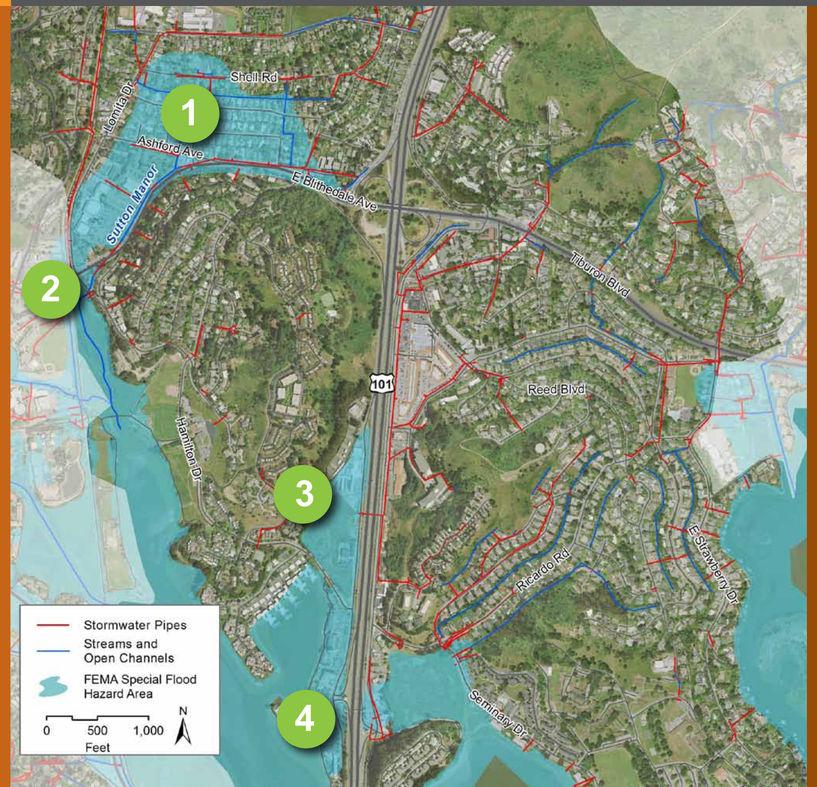
Baylands

Tidal inundation: Extreme high tides can inundate roadways, trails, and parking lots along the Richardson Bay shoreline. These parks, wastewater treatment facilities, commercial developments, roads, sewer, water and electrical utilities that serve all residents of the watershed may require flood protection, and/or relocation.

Sutton Manor/Alto/Strawberry Watershed

Goals

- Reduce frequency and severity of stormdrain overflow, channel overtopping, and stormwater ponding
- Reduce frequency and severity of direct tidal inundation



Possible improvements

1 Valley Floor

- Pipe stormwater underground (stormwater bypasses)
- Levees and floodwalls

2

- Pipe stormwater underground
- Levees and floodwalls
- Habitat restoration

3 Baylands

- Pump stormwater
- Habitat restoration

4

- Pipe stormwater underground

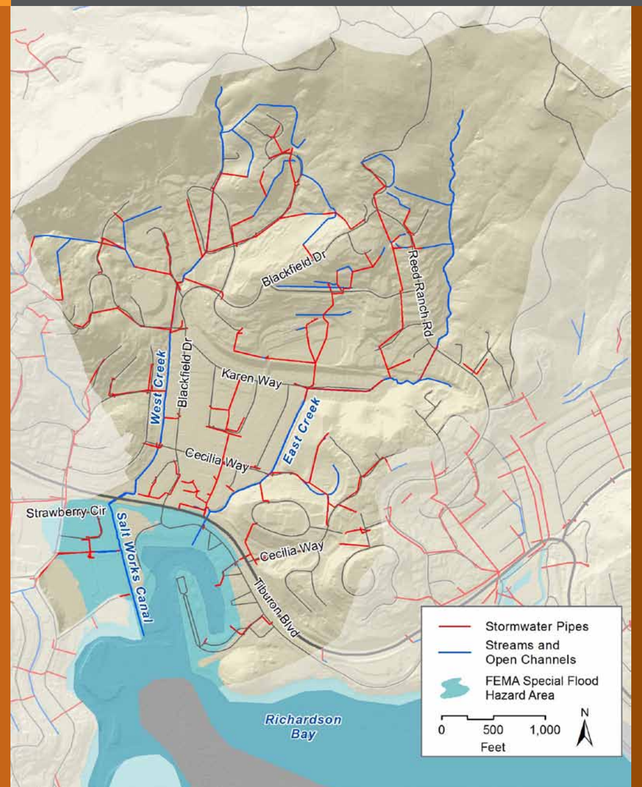




Bel Aire Watershed

Watershed Facts

Size: 0.78 square miles
Population: 2,095
Creek Length:
2.7 miles
% of Creek Maintained by District: 30%
Creeks:
West Creek
East Creek
Flood Control Facilities:
Strawberry Marsh Channel
Salt Works Canal
Strawberry Circle Pump Station
Pamela Court Pump Station
Cove Pump Station



The uplands of the Bel Aire watershed lie within the Ring Mountain Open Space Preserve. East and West Creeks drain the southern flank of the ridge through a residential neighborhood in the City of Tiburon. In the baylands, three stormwater pump stations (Cove, Pamela Court, and Strawberry) handle stormwater. Each pump station receives water for a separate stormwater collection system and helps keep stormdrains from backing up and overflowing.

Challenges

Valley Floor

Creek overflow: During large storm events, West Creek has historically overflowed into streets, backyards, and homes, and flooding has been reported on parcels fronting on Blackfield Drive. In 2006, water-inflated flood barrier bags served as temporary flood protection in advance of a large storm. On East Creek and along Karen Way, homes and landscaping encroach upon the creek reducing the creek's capacity where the District holds contiguous easements. Many private encroachments, such as landscaping improvements and small structures have been constructed in the easement and may impede channel flow.

Stormwater overflow: Underground stormdrain pipes that collect water from Blackfield Drive have backed up during high water conditions and may benefit from a tide gate.

Isolated ponding: Water also ponds along East Strawberry Drive between Tiburon Boulevard and Ricardo Lane.

Baylands

Tidal inundation: The tide gate east of the Strawberry Pump Station requires frequent maintenance to keep tidal flows from the channel. Existing berms and floodwalls have been constructed downstream of Tiburon Boulevard, but could overtop during extreme high tide events.

Stormwater overflow: Significant flooding due to stormwater overflow has occurred at the Cove Pump Station as recent as December 2014.

Bel Aire Watershed

Goals

- Reduce frequency and severity of creek overflow
- Reduce frequency and severity of stormdrain overflow and stormwater ponding across the Bel Aire watershed
- Reduce frequency and severity of tidal flooding, both in the near-term and in the future given projected sea level rise
- Increase public awareness of flooding issues



Possible improvements

1 Valley Floor

- Levees and floodwalls
- Increase creek flow capacity
- Raise/flood-proof buildings out of floodplain
- Habitat restoration

2

- Levees and floodwalls
- Increase creek flow capacity
- Raise/flood-proof buildings out of floodplain

3 Baylands

- Pipe stormwater underground
- Pump stormwater
- Levees and floodwalls
- Habitat restoration





What can we do about sea level rise in Southern Marin?

A 36-inch increase in sea levels will greatly impact people's lives throughout Southern Marin. Daily high tides will inundate major thoroughfares, schools, retirement communities, private homes, shopping areas, bike paths, and stormwater detention ponds. Valuable marsh and mudflat habitat will be permanently flooded. Infrastructure will need to be armored, abandoned, or relocated. Shorelines will be eroded by increased wave erosion, threatening even more infrastructure.



Unlike many of the strategies to address flooding described earlier in this document, adaptations to sea level rise are still in the early phases of evaluation. *The Richardson Bay Shoreline Study: Evaluation of Sea Level Rise Impacts and Adaptation Alternatives* investigates strategies that may help address the many risks associated with sea level rise. The extent of the problem requires collective action at the local, state, and federal levels of government.

Hard Engineering Adaptation Tools

Hard engineering alternatives refer to barriers that work to prevent high tides from flooding inland. These include floodwalls and levees, large tidal gates, rip-rap (to armor shorelines against increased wave erosion), and pump stations. These alternatives can be effective against sea level rise; however, they are expensive, barriers must be continuous, and can have a negative impact on aesthetics and habitat.

Soft Engineering Adaptation Tools

Soft engineering tools attempt to work more with natural processes to achieve engineering goals while also providing other benefits such as habitat. Wetland enhancement involves placing fill in marshes to keep pace with sea level rise and attenuate wave erosion. Horizontal levees are broad levees with gradual slopes that allow for extensive habitat on either side. Beach construction restores coarse-grained beaches along the shoreline to inhibit wave erosion.

Existing



Horizontal Levee



Implementing a flood risk reduction project

There are many steps between identifying a problem and implementing a flood risk reduction project. Given the interconnectedness of watersheds, a careful and deliberate process ensures that projects are designed and implemented correctly.

Funding is needed to construct new projects and maintain flood infrastructure. Working near or in water (creeks and wetlands) can add time to the design and permit process. Projects need dedicated funding for the life of the project; from design and permitting to construction and then maintenance. Funding for projects that provide multiple benefits, reduce flood risk, and improve habitat are attractive to grant funding agencies.

Funding can also come from the Flood Control Zone, but the amount of money held in reserve by each zone varies. Most of the reserves are used to maintain existing infrastructure and respond to emergencies. New funding within the zone can be raised with a ballot measure as the zones do not have ratepayers like other utilities. All zones are funded by annual revenues from *ad valorem* property taxes which vary considerably from one zone to another. The amount of revenue received from *ad valorem* property taxes in a particular zone is based on the total assessed value of property within the zone and the zone's share of property taxes which was in effect at the time Proposition 13 became effective.





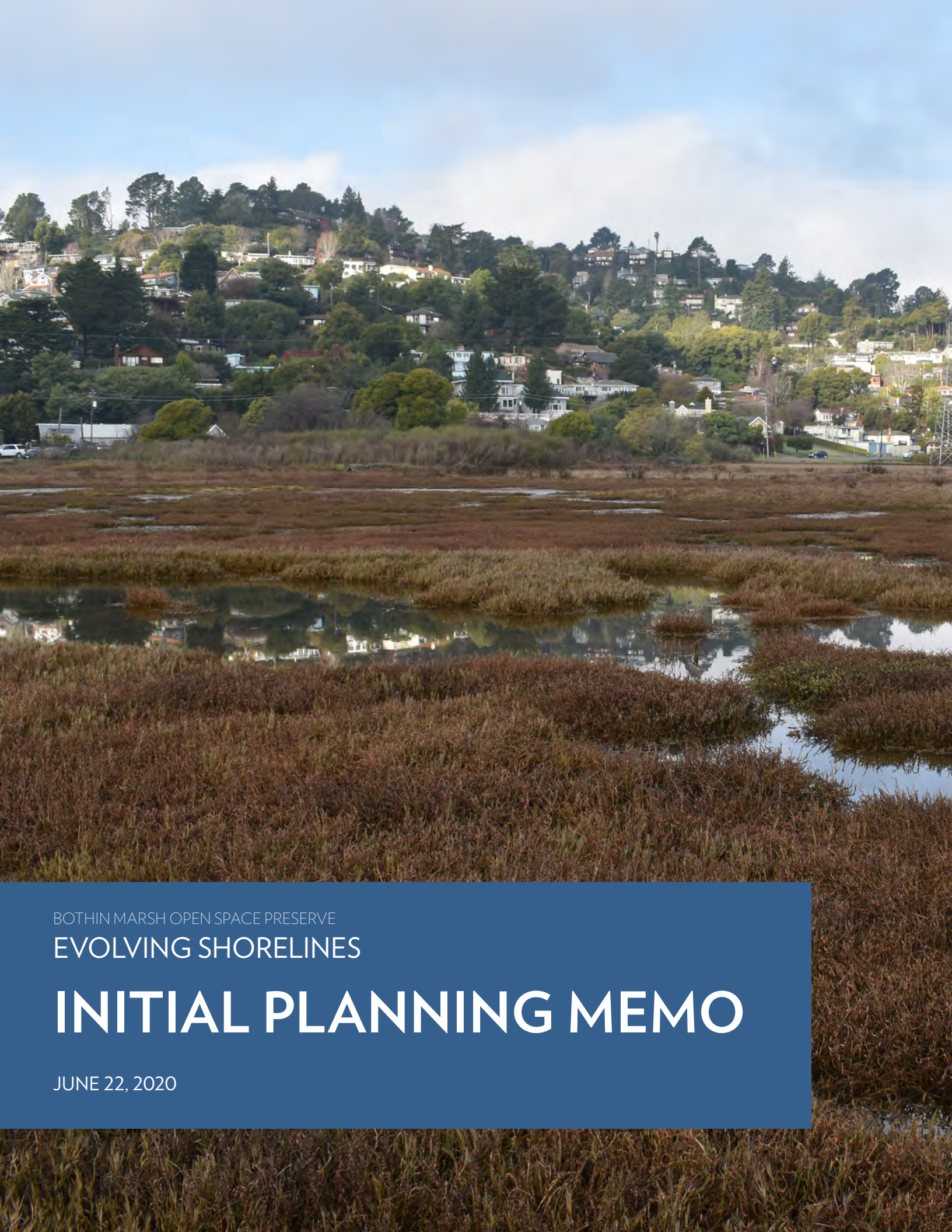
PHOTO: CHRISTIAN ARBALLO

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APPENDIX C

Bothin Marsh Memo



BOTHIN MARSH OPEN SPACE PRESERVE

EVOLVING SHORELINES

INITIAL PLANNING MEMO

JUNE 22, 2020

ACKNOWLEDGEMENTS

PROJECT TEAM

WRT is a team of planners, urban designers, architects, and landscape architects based in San Francisco and Philadelphia. Through our collective approach, we serve the communities we work with by designing places that enhance the natural and social environment.

ESA is a 100% employee-owned environmental consulting firm. We plan, design, permit, mitigate, and restore—for projects across our communities, infrastructure systems, open spaces, and wildlands.

WRT and ESA are joined by technical partners:

Peter R. Baye, Ph.D.,

GHD,

Hultgren Tillis,

and Arup.

One Tam brings together inspired community members, California State Parks, Marin County Parks, Marin Municipal Water District, National Park Service with the nonprofit Golden Gate National Parks Conservancy to leverage skills and resources to support the long-term stewardship of Mt. Tam.

Sea level rise adaptation work at Bothin Marsh is primarily funded by Measure A. The conceptual design of the Evolving Shorelines project is partially funded by the California State Coastal Conservancy and the Marin Community Foundation through the Advancing Nature-Based Adaptation Solutions grant program. This program seeks to support nature-based approaches that address the risks and impacts of climate change and sea level rise to protect the Marin County bay and coastal shorelines and natural resources.

ONE TAM

Rob LaPorte, Golden Gate National Parks Conservancy

Veronica Pearson, Marin County Parks



BACKGROUND

Bothin Marsh Open Space Preserve is a well-loved county park located along the northwestern shore of Richardson Bay near the town of Mill Valley in Marin County, California. The Preserve is home to more than 70 acres of tidal marsh habitats and features one of the most popular segments of the Mill Valley-Sausalito Mulit-Use Path. Both the habitats and the trail face challenges due to coastal erosion and rising sea levels. In 2018 and 2019, One Tam partners from the Golden Gate National Parks Conservancy and Marin County Parks collaborated with community members to develop a vision for how the park will evolve and adapt to these challenges. The Evolving Shorelines Project is the next step towards making the community's vision a reality. The Conceptual Design Phase of the Evolving Shorelines Project aims to develop and evaluate potential project alternatives and will recommend a preferred alternative for detailed design and implementation.

Purpose

This memorandum, currently in draft, has been developed to support Conceptual Design of the Evolving Shorelines Project. The Project Team will review and synthesize prior studies, collect new field data, and prepare analysis to better understand existing conditions at the Preserve. The Project Team will then solicit input from the Science and Technical Advisory Committee (STAC) and stakeholders to develop a "menu" of potential project measures for improving conditions at the Preserve. These measures will then be further developed in the upcoming Alternatives Development and Evaluation stages of conceptual design.

This draft memorandum is intended to provide a brief summary of historic and existing conditions at the Preserve, to highlight key physical processes affecting the habitats and trails, and to introduce potential project measures that have been identified for future development. The Project Team hopes that this document will provide a starting point for understanding conditions at the Preserve and will help facilitate information sharing, discussions, and solicitation of feedback related to project opportunities and constraints, potential project measures, and the development and evaluation of design alternatives.

Note on Preliminary Nature of Document Materials

This document has been developed to support ongoing deliberation and planning efforts. Some of the materials presented herein include technical results and design concepts that are preliminary, and that may be refined and revised during future project planning and design. Portions of this document will be revised and further developed , and may be incorporated into final project deliverables and released for public distribution.

In particular, this document presents brief descriptions of several potential project measures that have been identified by the Project Team for consideration during the upcoming Alternatives Evaluation project stage. The Project Team expects that these preliminary measures will be updated and revised in response to feedback received from the STAC, project stakeholders, as well as the findings of ongoing technical studies. During Alternatives Evaluation, the revised measures will be developed in greater detail and will be evaluated for feasibility and to characterize anticipated benefits and impacts.

Bothin Marsh.

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3 POTENTIAL DESIGN ELEMENTS

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1. VISION, GOALS & OBJECTIVES

PROJECT VISION

Project Overview

Bothin Marsh at first glance appears to be a natural and ecologically functioning marsh. Managers, scientists, and regulators understand the more complete story of its fragile and degraded health. In addition to at-risk natural resources, the well-used recreational trail, known as the Mill Valley-Sausalito Multi-Use Path (Bay Trail), is also compromised. The present-day effects of tidal flooding cause the trail to flood around 30 times a year. This, in addition to inadequate trail width, are critical challenges in the Preserve today. Looking ahead to the next several decades, there will be an exacerbation of these conditions if no action is taken– from an increasingly submerged marsh to complete loss of trail connectivity.

The challenge ahead is to weave together the enhancement and preservation of the tidal wetland with improvements to the trail network so that they are resilient in a future that includes sea level rise (SLR) while the trail continues to provide a carbon-free transportation route and recreational experience of the marsh.

Critical design elements need to include the ability to capture and retain sediment on site; provide a habitat 'bridge' and migration to future suitable habitat for special status species to remain in the Preserve; and incorporate a process for evaluating resilient investments.

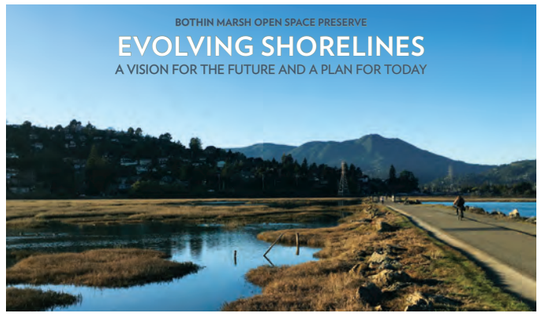
Importantly, this project is an opportunity for continued learning and ongoing stewardship. Work by Watson and Byrne (2012) indicates that Bothin Marsh is one of the few marshes in San Francisco Bay that has displayed signs of submergence over the past decades. Comparison of historic vegetation transect surveys at Bothin Marsh demonstrates a shift from pickleweed to cordgrass dominance, a leading indicator of ongoing submergence. It is understood the marsh is at risk of total submergence by the end of the century due to rising sea-levels.

However, there is an opportunity now to implement innovative nature-based sea level rise adaptations and to monitor the response over time to inform applications across the larger Bay Area region. Marsh restoration also provides a level of protection for the community while a larger adaptation strategy is developed to address projected SLR by 2100.

Building on the Evolving Shorelines Vision Document

The project vision and shared community values for Bothin Marsh are identified in the **Evolving Shorelines: A Vision for the Future and a Plan for Today** document prepared by One Tam in collaboration with local and regional stakeholders.

This conceptual design phase will build off of the community vision with Marin County Parks and Golden Gate National Parks Conservancy taking the lead in continuing stakeholder and community engagement in the design process, and sharing new found knowledge.



The Bothin Marsh Open Space Preserve needs to be a place where...

- *We use innovative approaches to meet the challenges of climate change so that Bothin Marsh can continue to evolve and support all life that depends upon it.*
- *Residents and visitors enjoy year-round recreation and travel using Bothin's trails for carbon-free transportation.*
- *And we embrace our responsibility to take care of our shared open spaces for benefit of current and future generations.*

- Evolving Shorelines:
A Vision for the Future and a Plan for Today

PROJECT GOALS AND OBJECTIVES

Project Goals and Objectives

The project goals and objectives for the Evolving Shorelines Project have been developed by One Tam, drawing on community input from the Visioning Phase (stakeholder workshops, working group, and community engagement) and scientific and technical input from Collins, Baye, Collins (2018) (Chapter 5: Local Priorities and Strategies For Environmental Management Response to Sea Level Rise). The goals and objectives are a working draft through the conceptual design process and will be finalized at the end of the phase.

Project Phasing

The current effort, Conceptual Design of the Evolving Shorelines Project at Bothin Marsh, will identify immediate (Phase 1) and near-term (Phase 2) design solutions. Mid- and long-term planning horizons will be discussed and considered at a high level in an effort to make the immediate and near-term phases consistent with potential later phases, as possible. All design options will be evaluated as part of a long-term vision for adaptation as sea level continues to rise. Phasing takes into account the planning timeline for when actions such as design, planning, permitting, and funding need to be initiated well ahead of anticipated rising sea levels.

Goal 1. Manage the shoreline for the health and safety of the community.

- Objective 1A. Create a resilient, safe, and well-connected shoreline trail network.
- Objective 1B. Enhance access to a carbon-free transportation system.
- Objective 1C. Reduce the risk of tidal flooding utilizing nature-based strategies.

Goal 2. Restore the shoreline ecosystem's ability to adapt to sea level rise.

- Objective 2A. Improve the resilience of the marsh habitats against risks from sea level rise and climate change.
- Objective 2B. Maintain biodiversity within the marsh.
- Objective 2C. Enhance and expand the distribution, abundance, and quality of high tidal marsh habitat.
- Objective 2D. Create space for different marsh habitats to shift and migrate with sea level rise.
- Objective 2E. To the extent feasible, increase resilience through the restoration of natural processes.

Goal 3. Demonstrate leadership and innovation in developing solutions to adapt to the impacts of climate change and sea level rise.

- Objective 3A. Use Bothin Marsh as a living laboratory to test innovative nature-based approaches to sea level rise adaptation that will benefit the local community and inform strategies for the broader region.
- Objective 3B. Identify adaptation pathways that anticipate changing climate and sea levels and that balance near-term and long-term outcomes.







Photos from One Tam, 2019. Counter-clockwise from top: One Tam-led scavenger hunt; Typical King Tide; Bothin Marsh community engagement event

CHALLENGES FACING THE BOTHIN MARSH OPEN SPACE PRESERVE

ANTICIPATED ENVIRONMENTAL CHANGES

- Climate Change
- Marsh Submergence
- Loss of Biodiversity
- Shoreline Erosion
- Trail Flooding
- Infrastructure Degradation

SITE SPECIFIC OPPORTUNITIES

- Legacy fills provide a platform supporting existing tidal marsh habitats and public access trails. This landscape offers special opportunities for public shoreline access and habitat preservation in a regionally important area.
- Bothin Marsh currently supports exceptional high marsh plant diversity, including the largest population of Point Reyes bird's-beak in SF Bay.
- The project could improve resilience of these habitats through increasing sediment delivery. The adjacent creek channels are a potential source of fluvial sediment to build up mudflats and marshes and keep up with sea level rise.
- This project offers the opportunity to demonstrate nature-based adaptation strategies that integrate public shoreline access and the preservation and enhancement of shoreline and tidal marsh habitats.



Marsh Submergence



Erosion



Trail Flooding

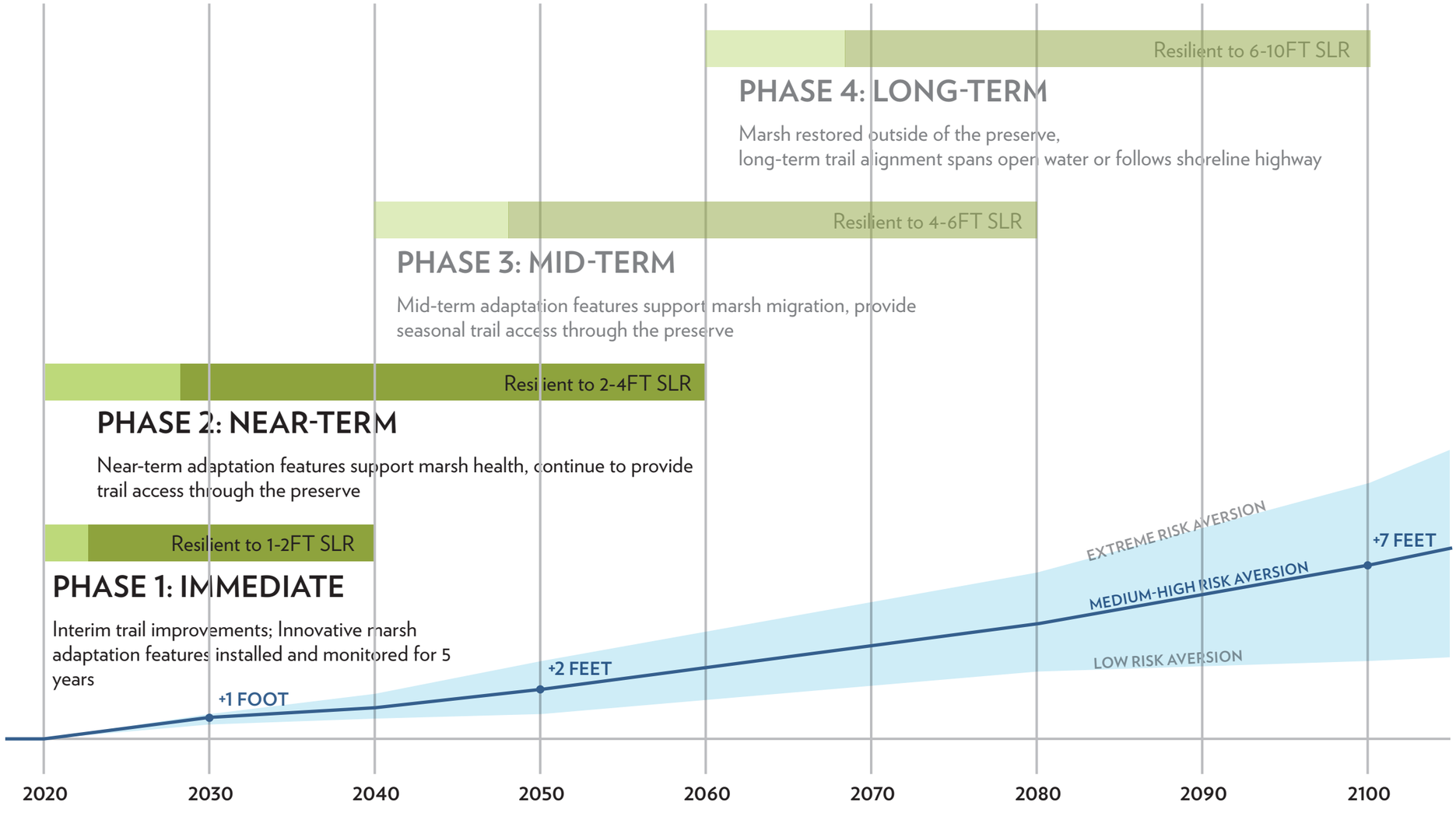


Evidence of Artificial Fill in Bothin Marsh Today



Enlargement of Trail Conditions

PLANNING HORIZONS & CONCEPTUAL PHASING



Sources:
SLR Scenarios based on OPC's State of California Sea-Level Rise Guidance, 2018, Table 1: Projected Sea-Level Rise (in feet) for San Francisco.

Planning Horizons & Conceptual Phasing

Phase 1 - Immediate

(Current project): Interim improvements and smaller-scale actions that can be implemented quickly (in ~2 years) and provide an immediate benefit in terms of increased resilience and/or learning for future phases. This includes, for example, trail resurfacing and bridge repairs to maintain use of the existing trail, and small-scale and innovative marsh adaptation measures such as marsh mounds and tidal channel improvements. The SLR resilience of Phase 1 measures will vary, though are generally intended to provide resilience to the marsh over the shorter term, +1-2ft SLR (~2040)

Phase 2 - Near-term

(Current project): Near-term adaptation measures that require a longer lead time than Phase 1. For example, significant in-place trail improvements and realignment of lower Coyote Creek. Phase 1 includes measures implementable within the Preserve; measures outside the Preserve boundaries would be explored for the mid-term. Phase 2 Implements measures that are resilient through +2-4ft SLR (~2060)

Phase 3 - Mid-term

Major trail re-alignment and landscape transition. Phase 3 measures that are resilient through +4-6ft SLR (~2080)

Phase 4 - Long-term

Marsh restored outside of the Preserve. Longterm trail alignment +10 ft either as a future bridge or along Shoreline Highway. Phase 4 Implements measures that are resilient through +6-10ft SLR (~2100)

2. EXISTING CONDITIONS

BOTHIN MARSH:
HISTORIC CHANGES AND TODAY



View of Arroyo Corte Madera del Presidio from the Bay Trail

A walk along the Bay Trail through Bothin Marsh offers picturesque views of the Richardson Bay shoreline and tidal marshes. A visitor might not realize that the Preserve and its extensive tidal marsh habitats and coastal habitats have been strongly influenced by human interventions.

Chapter 3 of L.Collins et al., 2018 presents a detailed history of north Richardson Bay, and a few events that contribute to significant landscape changes are highlighted below and illustrated on the next page.



BOTHIN MARSH: EXISTING CONDITIONS
BIRD'S EYE PERSPECTIVE



BOTHIN MARSH:
HISTORIC CHANGES AND TODAY

Pre-1851 – Historic Baylands

Shell middens dating from over 5,000 years old to recent centuries confirm that Richardson Bay has been occupied and influenced by paleoindians and Coast Miwok communities throughout the late Holocene prehistoric period (Moratto, 1984; Anderson and Morratto, 1996). The likely environment of Richardson Bay included tidal wetlands which are depicted based off of what is known from the 1851 U.S. Coast Survey map which provides the best record of the historic Baylands extents. Under the mapped historic conditions, the area that is now the Preserve is mostly inter-tidal mudflat and the mouth of Coyote Creek is nearly a quarter-mile farther inland than its present day location. A narrow band of tidal marsh ("Almonte Marsh") existed along the west side of North Bothin Marsh. Extensive tidal marsh areas are mapped along the mouths of both Coyote Creek and Arroyo Corte Madera del Presidio. Europeans arrived in San Francisco Bay the late 1700s, and the growing influence of Europeans over the subsequent years led to significant changes in land uses and development.

1850-1924: Roads and Railroads

Early European development of present day Tam Valley skirted the perimeter of the historical Coyote Creek Marsh along steep hillsides. The first railroad bridge constructed across Richardson Bay in the 1870s bypassed the Coyote Creek embayment, following a route similar to present day Highway 101. In the 1880s a second track was installed running on a wooden trestle along the current Bay Trail alignment. Also around this time, State Route 1 (SR1) was established along an earthen levee that cut across the marshes and floodplain of Coyote Creek. These early transportation corridors have left a lasting mark on the landscape, and are still in active use today.

1924-1942 – Fill and Build

The timber railroad trestle is replaced with an earth embankment with a single, wide bridge at the mouth of Coyote Creek. This embankment blocks wave energy from Richardson Bay, and sediment from Coyote Creek begins to accumulate in the sheltered area west of the embankment (the area that is now South Bothin Marsh). Artificial fill is placed near SR1 to support commercial development. Berms are constructed across portions of North Bothin Marsh and fill is placed in the diked area to the west to support planned development.

1942-1968 – Channelize the Creeks, Block the Tides (and more fill)

Both Coyote Creek and Arroyo Corte Madera del Presidio are re-routed into new engineered channels.

The straightening of Coyote Creek into an US Army Corps flood control channel dramatically alters the hydrology of South Bothin Marsh. The original long bridge at the mouth of Coyote Creek is removed and replaced with an earthen embankment, and a new tidal flap gate is constructed farther south, establishing the mouth of Coyote Creek in its present location. A flood control levee was constructed along the entire north side to prevent tidal access to South Bothin Marsh. After the embankment and berm construction, the marsh is completely disconnected from the tides and stormwater drainage is provided by a single culvert with a tide gate that is located near the location of the current south marsh bridge.

During this time period there is also a major effort to place fill in North Bothin Marsh to support planned development. A new set of containment berms is built along the marsh edge, and fill is placed, significantly increasing the size of North Bothin Marsh.

Construction begins on a third set of berms farther out into the bay, and deep channels are dredged to allow barges to deliver dredge material. However, after decades of fill placement, the development plans were abandoned and while a significant amount of fill material had been placed, no structures had been built on the shoreline that would become North and South Bothin Marsh (other than the bridges, railroad/trail and power lines).

1968 - 1982 – Preservation and Public Access

Around 1970, the railroad line is decommissioned, and in 1975 the Trust for Public Land purchases the Bothin Marsh area from the railroad. In 1981 the Marin County Parks and Open Space District acquire the property, leading to the establishment of the Bothin Marsh Open Space Preserve and the opening of the Mill Valley/Sausalito Multi-Use Path (Bay Trail). Under County ownership, additional fill placement is halted and the dikes around North Bothin Marsh were allowed to gradually degrade. Small gaps and breaches in the North Marsh perimeter berm gradually grew in size.

Present Day - Tidal Action and Erosion

Tidal flows were re-introduced to South Marsh in 1987 when the tide gate was replaced by a 26-foot long pedestrian bridge. However, the bridge is not large enough to provide full tidal prism to the South Marsh. This undersized bridge continues to constrict tidal flows into and out of South Marsh.

Over subsequent decades, the berms around North Bothin Marsh have not significantly eroded and no new breaches have appeared. The channel at the original levee breach has enlarged, which increased the tidal prism and concomitantly increased sediment supply and subsequent marsh elevation. Wave-induced erosion has occurred along the edges of the fringing salt marshes east of the trail, and along the south-facing shoreline of North Marsh. Erosion has also been observed along the banks of Coyote Creek and Arroyo Corte Madera del Presidio. Vertical slumping marsh scarps and exposed rocky fill now occur in areas along each creek channel that were formerly cordgrass and pickleweed marshes. Small nick-points and vegetated swales have been observed along the north bank of Coyote Creek where high ebb tides flow from the marsh into the creek. These nick-points and swales could evolve into full channel connections over time, however their growth has been slowed by the coarse constructed levee fill and dense marsh vegetation.

Bothin Community Context

Today, the Bothin Marsh Open Space Preserve is surrounded by an urbanized environment and is heavily used by the public who travel through the marsh daily. The trail has become a popular recreational and commuter route for pedestrians and bicyclists. However, the relatively low elevation of the trail means that it is prone to flooding during high tides and storm events.

The Preserve is surrounded by a wide range of land ownership. To the west and upstream of Coyote Creek is the unincorporated community of Tam Valley and Marin County Flood Control District property. To the south, the Bay Trail remains owned by the County. It passes through a range of adjacent properties owned by Caltrans, County of Marin, and private lands. The Bay Trail traverses lands owned and managed by the City of Mill Valley to the north.

North Richardson Bay is bordered by the City of Mill Valley on the north, and several unincorporated neighborhoods including Marin City to the south, Tam Valley and Almonte to the west, and Strawberry to the east. This mosaic of landownership and management influences the planning and management of the Preserve.

The trail is enjoyed by a wide range of users who cycle, walk, and jog along the route at varying paces. Students use the trail as a route to school. The trail is also used by those who enjoy communing with nature and observing wildlife. The close proximity of varying user groups has lead to a number of collisions. Current trail guidance by regional agencies recommends a wider trail to better separate cyclists and pedestrians which may reduce the potential for future collisions. For example, the Bay Trail Design Guidelines recommend a minimum of 12 feet of paved clearance for a multi-use trail, whereas the existing width accommodates 10 feet typically.

The marsh is highly visible to the public. Views are afforded to many nearby residences around the surrounding hillsides and from Highway 101. Recent planning for Miller Avenue conducted by the City of Mill Valley highlights the unique visual asset of the marsh. Views across the natural landscape are celebrated as part of the local community character.

Looking to the Future – Resilience, Adaptation, Challenges and Change

Bothin Marsh is a constructed landscape that was created through extensive fill placement on historic mudflat and open water areas. This has resulted in a marsh landscape that is largely divorced from the geomorphic processes that support tidal marsh formation under natural conditions. Nonetheless, the existing marsh is biodiverse and provides high value habitat for resident and migratory species, provides important ecological services to the community, and the Preserve supports a highly valued recreational and commuter trail that is enhanced by proximity to the Bay and marsh habitats.

Left unmanaged, the "natural" trajectory for the landscape will generally be a slow transition towards the area's original mudflat and open-water morphology. The marshes will slowly be submerged by rising tides and the trail will flood with greater frequency. Yet there are numerous opportunities for interventions over the coming decades that can improve resilience and prolong the life of these important ecological and recreation resources. As time passes, the Preserve will face increasing stress from rising sea levels, coastal erosion, upland stream flooding, changes in sediment and climate change. Some management strategies that could provide great benefits in the near-term will grow less effective over time, meanwhile new tools and management strategies may emerge. The Evolving Shorelines Project aims to identify and implement management strategies that will allow the Preserve managers and community at large to navigate these evolving challenges over the coming decades, including the following fundamental challenges facing the Preserve:

Marsh Submergence

Tidal marshes accumulate sediment over time, allowing the marshes to increase in elevation as sea-levels rise. But there are limits to how fast a marsh can accrete based on the amount of sediment that is available. Bothin Marsh receives very little sediment due to human intervention, and as sea-levels rise the marsh will be submerged with greater frequency, resulting in a gradual conversion from high marsh to low marsh to mudflat and open water habitats. These habitat shifts will impact the rare, threatened and endangered species found within the Preserve. There is the potential to restore hydrological connections and processes to reconnect sediment supply to the marsh. This, in addition to artificial sediment placement techniques, will be evaluated as a potential design element to help reduce the rate of marsh submergence over time.

Shoreline and Creek Bank Erosion

While Richardson Bay is somewhat sheltered from waves compared to other areas of San Francisco Bay, high wind-wave events that do reach the area often erode salt marsh edges along the bay. There are indications of ongoing erosion along many of the shorelines and channel banks at Bothin Marsh, including vertical marsh scarps and formation of lag-covered flats along the edges of former fill placement areas.

Trail Flooding

The Bay Trail segment at Bothin Marsh is at a relatively low elevation and is subject to periodic tidal flooding. The risk of flooding will increase with rising sea-levels. Trail flooding disrupts recreational and commuter uses of the trail, and also degrades the trail surface and embankments, increasing the frequency of required re-surfacing and other maintenance. The Bay Trail segment continuing south to Marin City and Sausalito, outside of the Preserve boundaries, also faces similar flooding challenges which need to be addressed to maintain a viable regional trail corridor.

Infrastructure Maintenance

The existing trail and bridges were constructed several decades ago and these structures are approaching the end of their design life. It is necessary to retrofit or replace many of these structures over the coming years and decades in order to provide safe continued public access.

Climate Change

The Preserve will experience many other challenges due to climate change, including changes in streamflow and watershed sediment supply (potentially exacerbated by increased risk of wildfire), altered oceanographic conditions, and changed patterns of precipitation and temperature. Some of these changes will be gradual over time, while others will be experienced as extreme events, however all of these changes will place new stresses on the Preserve and its habitats and infrastructure.

The next few pages provide a more detailed look at the existing conditions at Bothin Marsh, and the key physical processes that shape the marsh landscape.

Citations:

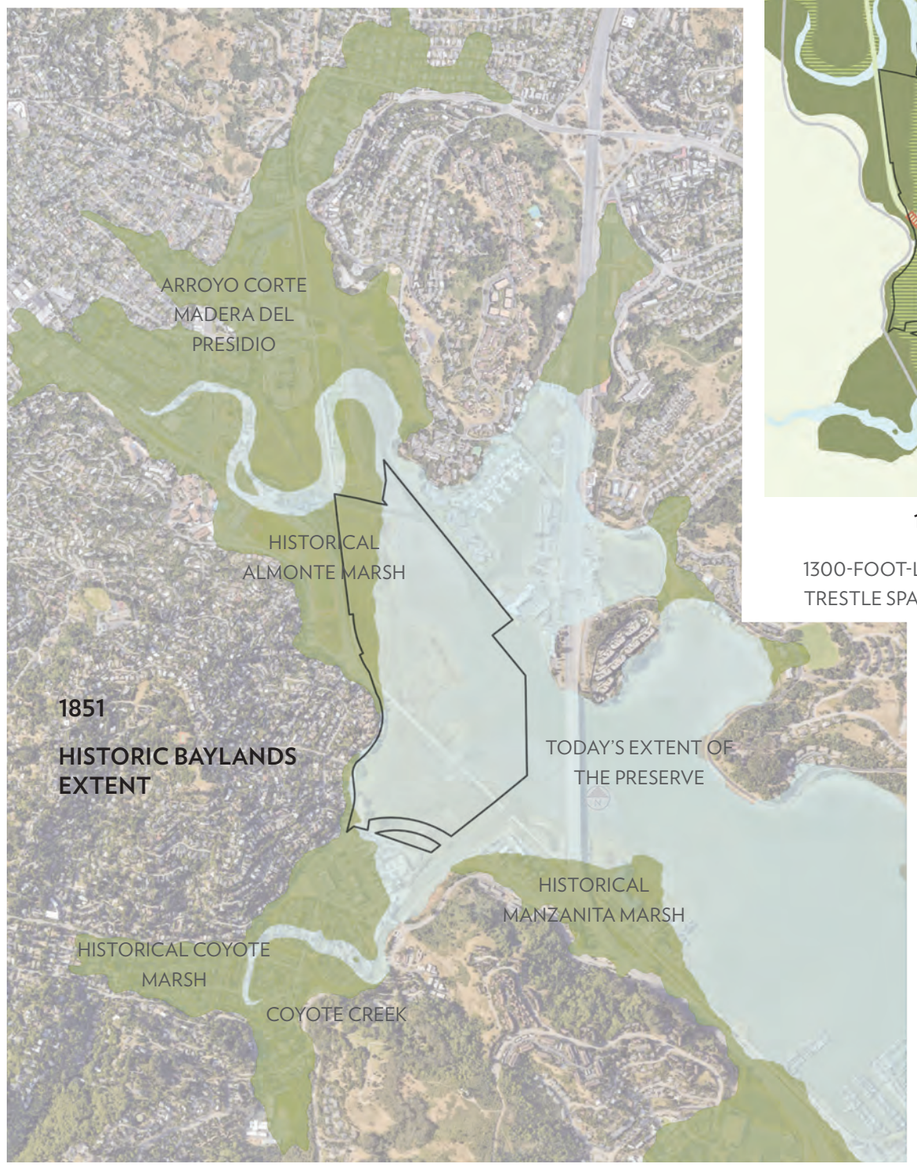
Anderson, M.K. and Moratto, M.J. 1996. Native American Land-use Practices and Ecologica Impacts. In Sierra Nevada Ecosystem Project: Final Report to Congress. Vol. 2, pp. 187-206. University of California, Centers for Water and Wildland Resources, Davis. January 1996.

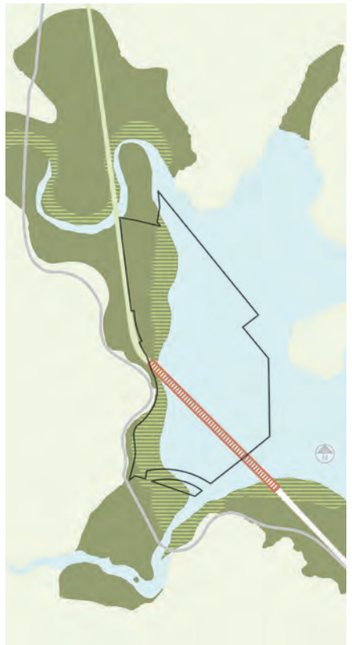
Collins, L., Baye, P., and Collins, J. 2018. Bothin Marsh Geomorphology, Ecology, and Conservation Options. Prepared for the Marin County Open Space District, San Rafael CA.

Moratto, Michael J. 1984. California Archaeology. Academic Press.

Nelson, N. 1909. Shellmounds of the San Francisco Bay Region. The University Press, Berkeley. December 1909.

HISTORY OF BOTHIN MARSH





1924

1300-FOOT-LONG RAILROAD TRESTLE SPANS OPEN WATER



1946

RAILROAD BERM BUILT,

EXTENSIVE FILL, SHORT BRIDGE OVER COYOTE CREEK



1968

COYOTE CREEK CHANNELIZED,

NEW BRIDGE OVER THE CHANNEL,

OLD BRIDGE REMOVED AND TIDAL INFLUENCE BLOCKED IN SOUTH BOTHIN



TODAY (SINCE 1987)

NEW BRIDGE RESTORES TIDAL INFLUENCE IN SOUTH BOTHIN MARSH

HISTORIC BAYLANDS EXTENT 1851

NEW BAYLANDS EXTENT

Sources:
Historical maps collected by the team, including: 1851 U.S. Coast Survey, San Francisco Bay, T-00334, NOAA; 1924 (need source); 1946 Aerial Photo, Mill Valley Library History Room; 1968 San Rafael 7.5-minute Quadrangle, USGS; 1987 Aerial Pohoto, USGS via Google Earth.

LAND OWNERSHIP

EXISTING CONDITIONS: LAND OWNERSHIP

- Stakeholders near the Preserve include:
  - » Caltrans,
  - » PG&E Utility Easement,
  - » City of Mill Valley,
  - » Marin County Flood Control District,
  - » Sewer Agency of Southern Marin (SASM)
  - » Tamalpais High School
  - » in addition to local landowners, businesses and residents



INFRASTRUCTURE

EXISTING CONDITIONS: INFRASTRUCTURE

- Bay Trail is subjected to inundation during peak high tide and storm events.
- Bay Trail embankment is susceptible to erosion from waves.
- Existing asphalt trail surface suffering from mechanical / tidal weathering and base coarse upheaval due to swelling from constant water inundation.
- Portions of Bay Trail constructed on bay mud and likely still undergoing some settlement.
- Subsurface conditions along the trail embankment consist of fill, bay mud crust, bay mud, and alluvium. Bottom of bay mud depths range from 32 to 83 feet below the existing grade of the trail.
- Bay Trail, Bridges 1, 2, and 3, and connecting offsite trails, like the McGlashan Pathway, will need to be upgraded and replaced in near-term SLR scenarios.
- Bridge pile lengths are unknown, and pile capacities are unknown.
- There is no data currently available for the observed telecom manholes along the Bay Trail alignment.
- Observed culverts may be blocked - unclear drainage patterns.
- Major PG&E transmission line and associated boardwalk at risk of future inundation.
- Sanitary sewer pipelines along Almonte Blvd may be impacted by future fill placement.
- The Coyote Creek Flood Control Channel is maintained by the County.

Description

The major infrastructure in the Preserve consists of the Bay trail and its embankment, three bridges, the levees along Coyote Creek, the PG&E transmission line, the observed telecom lines potentially under the existing trail alignment, and the stormwater and sanitary sewer pipelines and drains that run along Miller Ave and Almonte Blvd. All of this infrastructure rests on layers of landfill and bay mud. The site has a history of flooding and stormwater drainage issues along Miller Ave, Hwy 1, and the Manzanita and Pohono Park and Ride locations.

Sources:
Miller Pacific Geotech Report June 6, 2017;

SF Bay Trail
Bridge
Tide Gate
Stormwater Structure
Stormwater Pump Station
Stormwater Pipeline
Sanitary Sewer Pipeline
Power Line
Transmission Line
Transmission Tower
Aboveground Telecom Line
Underground Telecom Line



INFRASTRUCTURE

EXISTING CONDITIONS: TRAIL SURFACES

The trail conditions summary below was provided in the NCE field review and short term recommendations report for the Mill Valley - Sausalito Path (2019). The County plans to move forward with trail resurfacing improvements in the immediate future which will result in a minimal elevation increase to the trail. The following information was provided in the report:

Key Issues

The trail is frequently impacted / underwater from King Tides and the surface is showing significant deterioration.

The variable and often closely spaced (< 30 ft.) thermal cracking leads to a rough surface for bicycle riders, particularly at areas of uplift and damaged/ spalled cracks.

The trail was observed to consist of at least two lifts of asphalt concrete (AC), with the top lift being approximately 1 to 1.25 inches thick. It is understood that the lower lift(s) of unknown thickness is the original paved trail and the existing surface lift was placed later.

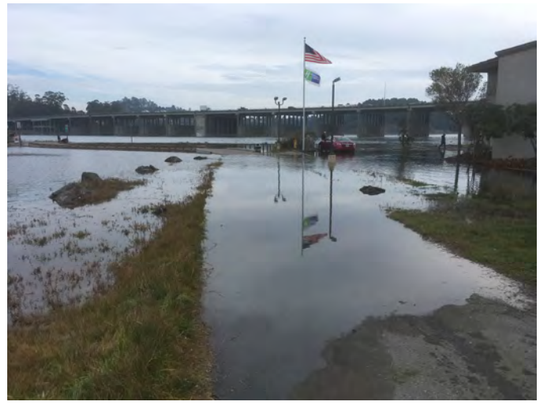
The trail appears to be performing well from a pavement structural standpoint having been built on top of a former rail bed. The distress appears to be concentrated at the trail edge and is likely in part caused by lack of proper edge confinement.

However, the trail shows significant environmental distresses, likely a result of aging, oxidation, and potential stripping of asphalt from tidal wave submersion. The trail exhibits high severity weathering over the vast majority of the trail. This weathering leaves the AC surface with a loss of much of the finer portions of the AC mix. Any further deterioration of the trail would result in aggregate raveling and rock pockets.

The trail also shows consistent thermal cracking of varying spacing and severity over much of the length of the trail. In some areas there is significant enough uplift to affect cyclist ride quality and walkers for trip hazards. The image on the right shows a typical thermal crack and also some more severe thermal cracks that have been patched.

The top lift (surface) for most of the upper AC layer from Almonte Blvd south was highly weathered and of uniform appearance and aggregate type, likely a 3/8 inch nominal maximum size AC mix as shown in the image to the right.

Source: NCE, Miller-Sausalito Trail Report, November 12, 2019



EDGE WEAR AT AREAS WITH KING TIDES



THERMAL CRACKING



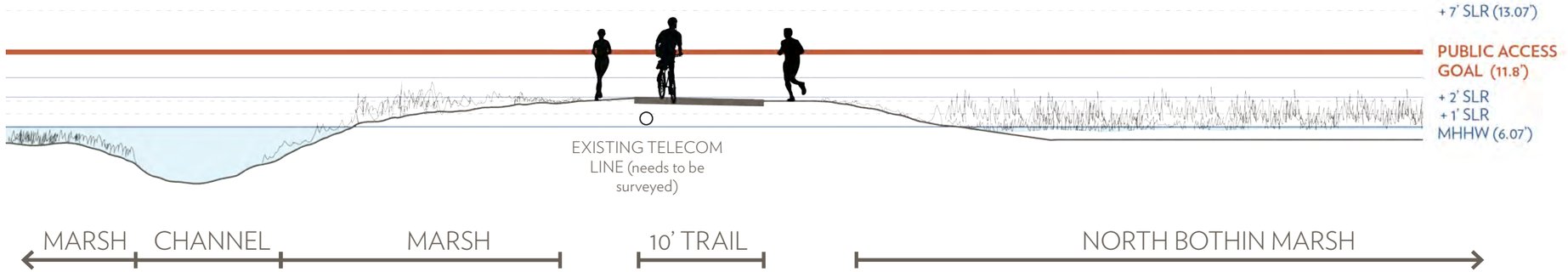
HIGH SEVERITY WEATHERING

Top photo taken by ONE TAM, middle and bottom photo taken by NCE.

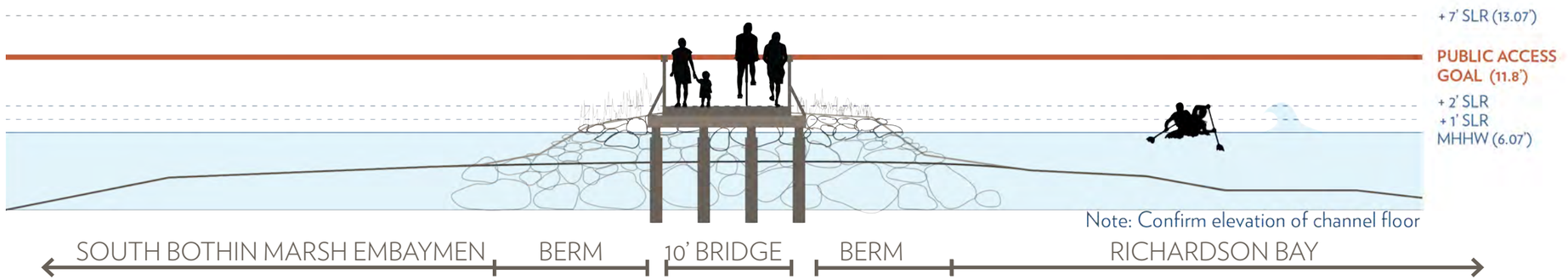
EXISTING TRAIL ALIGNMENT CROSS SECTIONS

EXISTING CONDITIONS + SLR SCENARIOS

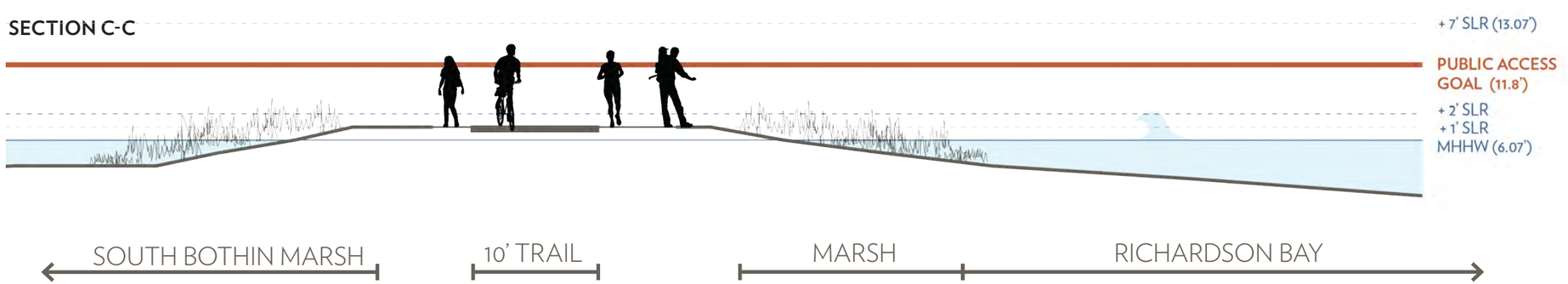
SECTION A-A



SECTION B-B



SECTION C-C

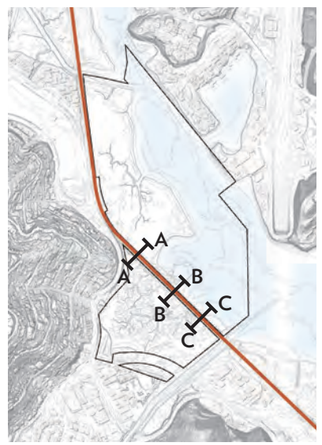


EXISTING CONDITIONS

The paved portion of the existing trail is generally ten feet across with shoulder widths that vary between two and four feet. The embankment and trail elevations generally vary approximately between 7 and 8 feet NAVD, which is just above MHHW.

The trail embankment protects South Bothin Marsh from wave action and additional erosion. On the other hand, the muted tidal prism caused by the undersized openings along the embankment increases erosion and marsh submergence.

KEY PLAN



Sources:

Elevations based on 2019 LiDAR; Tidal datums based on CLE Study; Flood Evelvations based on FEMA 2017 Flood Insurance Study

INFRASTRUCTURE

EXISTING CONDITIONS: BRIDGES

Bridge 1

Bridge 1 is a 105-ft long multi-span timber bridge, was constructed in 1960s for the flood control channel, built on the same alignment as the 1900s railway bridge. Much of the superstructure and substructure are the original construction for railroad loading and has considerably more capacity than required for the demands imposed by a pedestrian bridge. However, the steel hardware and fasteners are in need of replacement. There is a significant risk of the bridge being unseated during a seismic event or the superstructure being damaged by floating debris. The abutments for Bridges 1 are in very poor condition and in need of replacement.

Bridge 2

Bridge 2 is a 26-ft long multi-span timber bridge, built in the late 1970s to replace the tide gate that was installed as part of the flood control project in 1965. The tide gate lets freshwater flow out and prevented tides from flowing into the marsh. During flood events, the top of deck is below high-water elevation and the entire bridge can be completely submerged. The steel hardware and fasteners are severely corroded and in need of replacement. The abutments for Bridges 2 are in very poor condition and in need of replacement.

Bridge 3

Bridge 3 is a 96-ft long multi-span timber bridge that was constructed in 1981. Bridge 3 was erected much higher than Bridges 1 and 2, and there is a small freeboard between the flood water elevation and bottom of soffit, so the timber superstructure is not submerged. Thus, the timber framing is in serviceable condition, with minor to moderate corrosion at the steel hardware and fasteners that could be serviced or replaced. The abutments for Bridge 3 are above the high-water elevation and is in a serviceable condition.



BRIDGE 1 -
COYOTE CREEK



BRIDGE 2 -
SOUTH BOTHIN MARSH CHANNEL



BRIDGE 3 -
ARROYO CORTE MADERA DEL PRESIDIO

Photos taken November 2019 and January 2020.

MOBILITY

EXISTING CONDITIONS: MOBILITY

- Access to the Preserve is primarily from Almonte Blvd and Miller Ave.
- Bay trail serves as an important Safe Routes to Schools connection and provides an important carbon-free commute option for the community.
- Parking options are limited to on-street parking along Miller Ave and Almonte Blvd, in addition to the nearby Park and Ride areas and the Mill Valley Community Center.
- Bay Trail is a critical link in the active transportation network for the larger region.

MOTOR VEHICLE USE

1. Avg. # of two way, daily trips on Almonte/Miller | 2014 | **19,322**
2. Avg. # of cars, Hwy. 1, two-way peak hour | 2016 | **4,800**
3. Avg. # of cars, Hwy. 1, one way N/E peak hour | 2016 | **2,950**

Sources: 1. City of Mill Valley 2014 Traffic Counts, 2. & 3. CalTrans

TRAIL COUNTER

1. Peak # of cyclists, 8-10AM weekdays | 2017 | **99**
2. Avg. # of cyclists, weekends | 2017 | **1,796**
3. Avg. # of pedestrians, daily | 2017 | **803**

**The trail counter was located along the Mill Valley-Sausalito Path at the Sycamore Roundabout (located off the map on the north side of the Preserve).*

Description

Bothin Marsh is accessible to the region via Shoreline Highway and Highway 101. The Mill Valley - Sausalito Pathway (Bay Trail) provides major access for cyclists and pedestrians, with peak use on the weekends. The Preserve is also accessible via the McGlashan Pathway on the southwest side.

There is no parking provided on site, though parking areas can be found on nearby streets and along the trail, including the Park and Ride lots and the Mill Valley Community Center.

Marin County Transit has bus stops along Almonte Blvd. The Muir Woods Shuttle operates from the Manzanita Park and Ride lot as well.



USER EXPERIENCE

EXISTING CONDITIONS: USER EXPERIENCE

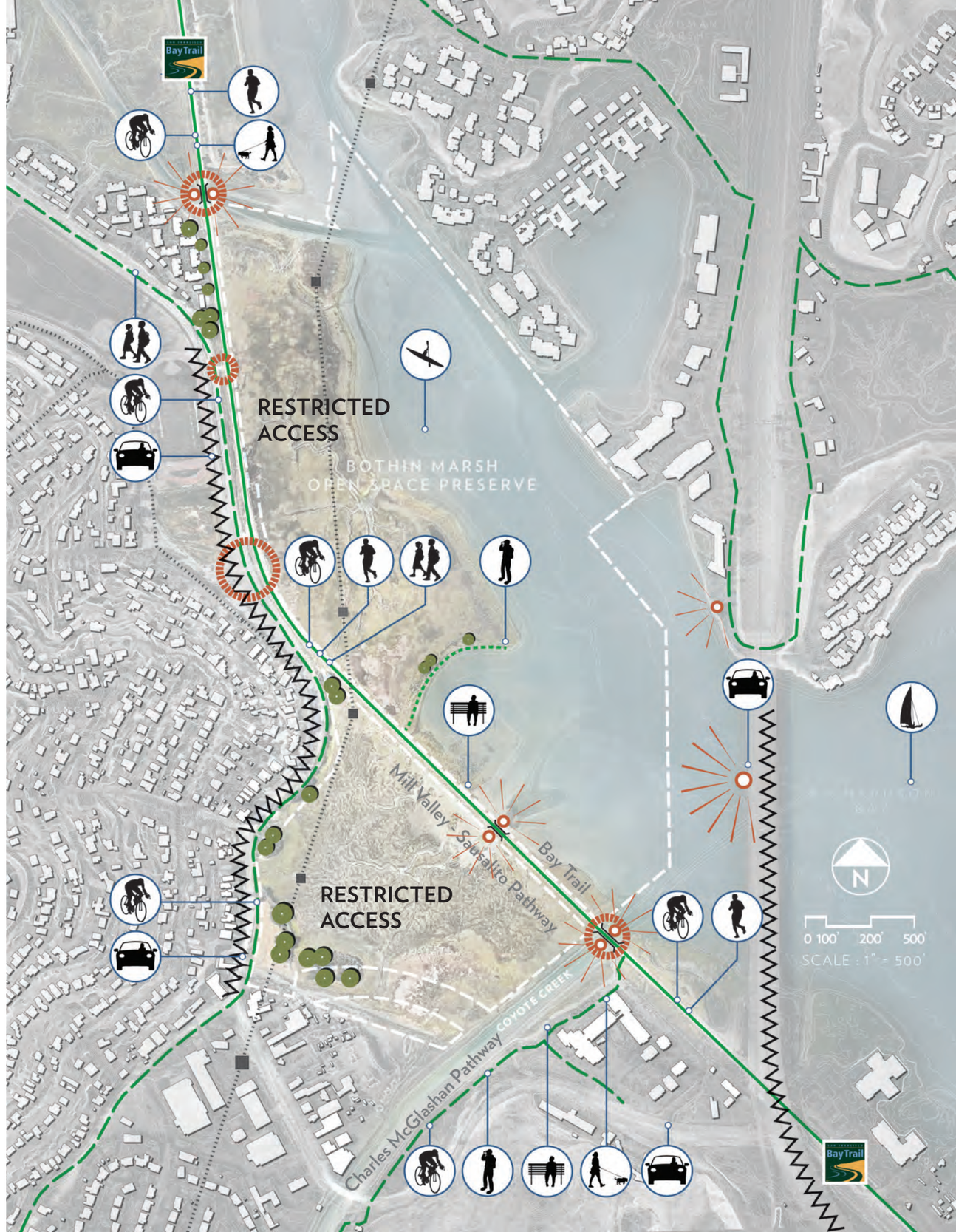
- User experience patterns highlight active vs inactive areas of the Preserve. Many users overlap along the trail, while access to the marsh areas is generally discouraged.
- Drivers experience the marsh from key vantage points along Highway 101 and Miller Avenue.
- Kayakers have access to areas in North Bothin Marsh that are otherwise unreachable by pedestrians. San Francisco Bay Water Trail Trailhead and boat launch at Bayfront Park.
- Birders and naturalists use the central trail to view more isolated habitat areas
- The Preserve is impacted by urban noise.

Description

The Preserve and its trails offer various users the ability to feel immersed in the wetland ecosystem, while also offering a direct route for students and commuters to travel between communities. The Bay Trail offers views across the marsh and the opportunity to protect diverse species and their habitats by limiting disturbance in some areas.

As sea levels rise, the experience along the trail will change as nature-based adaptation strategies are implemented, marsh habitats migrate upland, and the water experience along the trail expands.

- SF Bay Trail
- Off-Site Bike Trail
- Walking Trail
- Site Access Point
- Activity on Trail
- Noise Pollution
- Non-Vehicular Bridge
- Notable View
- Tree
- Power Line
- Transmission Tower



TIDAL HYDROLOGY

EXISTING CONDITIONS: HYDROLOGY

FLOOD ELEVATION	ELEVATION (FT NAVD)	SOURCE
500 - YEAR STILLWATER ELEVATION	11.5	FEMA. Flood Insurance Study, Marin County, California and Incorporated Areas. 2017. FIS # 06041CV001D
100 - YEAR STILLWATER ELEVATION	9.8	
50 - YEAR STILLWATER ELEVATION	9.3	
10 - YEAR STILLWATER ELEVATION	8.3	

Measured water levels at Bothin Marsh

The Project Team installed three temporary tide gages (Solinst "Leveloggers") at the Bothin Marsh Preserve to measure water levels within the north and south marsh basins, and at the mouth of coyote Creek. A barometric pressure gage (Solinst "Barologger") was also installed at the site so that the gage measurements can be corrected to account for variations in atmospheric pressure.

The gages were installed on December 9, 2019. On January 8, 2020 the gages were serviced and one month of data was downloaded in order to allow for preliminary analysis. The gages were then reinstalled at their original locations. The gages were recovered on May 25, 2020 and more than 5 months of measured water level data was downloaded and analyzed.



TIDAL HYDROLOGY

TIDAL DATUMS AT BOTHIN MARSH PRESERVE

TIDAL DATUM	NORTH BOTHIN MARSH	SOUTH BOTHIN MARSH	COYOTE CREEK BRIDGE (ESA 2020)	COYOTE CREEK BRIDGE (CLE 2018)	NOAA SF GOLDEN GATE (9414290)
MHHW	5.86	5.89	5.88	6.07	5.9
MHW	5.25	5.29	5.27	5.45	5.29
MSL	3.46	3.41	3.23	-	3.18
MTL	3.71	3.6	3.37	-	3.24
MLW	2.17	1.91	1.46	1.32	1.19
MLLW	1.82	1.38	.69	1.0	.06

Note: All values are feet, NAVD88

Measured water levels at Bothin Marsh compared to NOAA SF tide gage

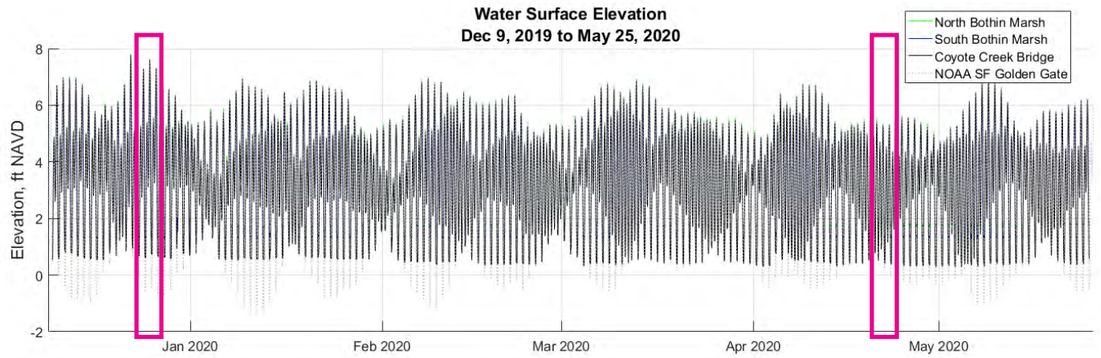
The temporary tide gages were compared to the NOAA tide gage at San Francisco (gage # 9414290). This NOAA gage is located approximately 5.9 miles south of the Bothin Marsh Preserve.

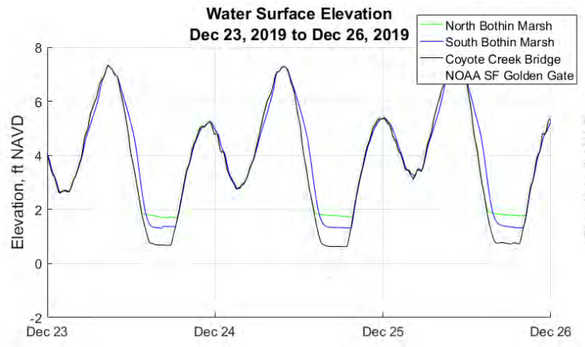
Tidal datums were calculated for all three gages, and the results were compared to tidal datums previously calculated by CLE for the mouth of Coyote Creek, and datums calculated by NOAA for the San Francisco tide gage.

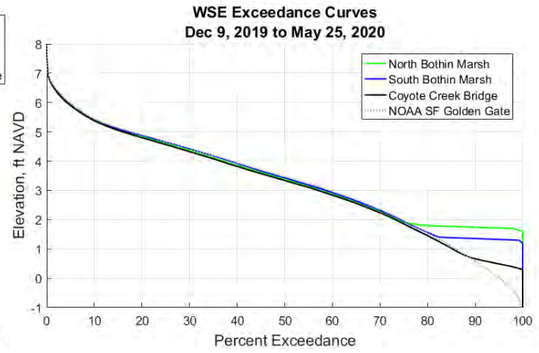
The water level data were used to calculated percent exceedance curves for the three gage locations. These curves show the percentage of time that the water level exceeded a given value for each gage location.

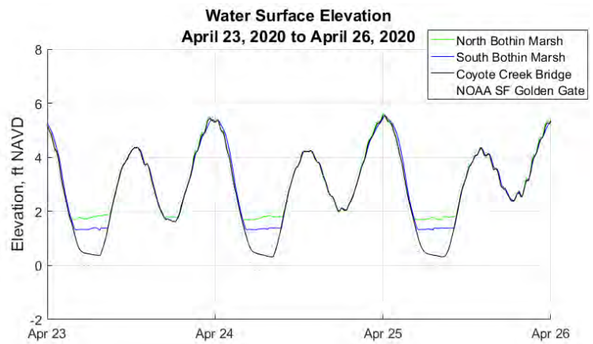
The water level data reveal the following trends:

- High tide elevations at all three gage locations are nearly identical, and are very similar to the high tide elevation at the NOAA gage.
- Low tide elevations measured in the two marsh locations are elevated relative to the low tide elevation in the open Bay or at Coyote Creek due to the higher elevation of the channel bed at the marsh gages. The channels where the two marsh gages were installed go dry during the lowest tides, and this is the reason for the higher calculated MTL, MSL, MLW and MLLW datums in the marshes (compared to Coyote Creek and Golden Gate).
- Rising and falling tides in South Bothin Marsh are delayed slightly relative to the tides at the Coyote Creek Bridge and in North Bothin Marsh. This lag is attributed to the constricted channel size at Bridge #2. The duration of the delay varies depending on the height of the tide.
- The percent exceedance curves show that areas in South Bothin Marsh that are at low to mid-marsh elevations (4 to 5 ft NAVD) are inundated more frequently (approximately 2% of a day /30 minutes per day longer on average) compared to areas of the same elevation in North Bothin Marsh or along the Richardson Bay shoreline. Tidal marsh vegetation is sensitive to inundation frequency and duration, and the longer duration of inundation in South Bothin Marsh reduces the productivity of existing tidal marsh vegetation and limits the expansion of vegetation into unvegetated areas.









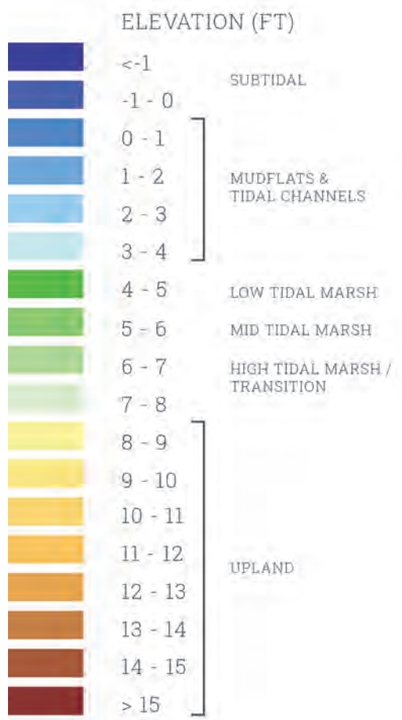
TOPOGRAPHY

EXISTING CONDITIONS

The topography at Bothin Marsh has been strongly influenced by construction and fill placement over the past 150 years.

The topography at North Bothin Marsh was largely established as the result of the construction of containment berms around the perimeter of the site, hydraulic placement of fill material within the site interior, and breaching and limited re-connection with Richardson Bay and Arroyo Corte Madera del Presidio. The North Marsh displays very little topographic relief. Elevations in the interior of North Bothin Marsh vary from 5 ft to 7 ft NAVD, and the berms around the perimeter of the marsh rise to approximately 8 ft NAVD. The Bay Trail embankment runs along the east boundary of the North Marsh, ranging in elevation between 8 and 10 ft NAVD. A small area of remnant historic Almonte Marsh exists along the bayward toe of the Bay Trail embankment, identifiable as a band of high marsh at slightly higher elevations than the majority of the marsh interior.

The topography at South Bothin Marsh has been influenced by the railroad/Bay Trail embankment and the several phases of re-alignment and diversions of the Coyote Creek channel. Typical elevation of marshes within the interior of South Bothin Marsh is 4.5 to 6ft NAVD. Deep scour pools exist on both sides of the Bridge 2 tidal channel due to the high velocity flows under the bridge during rising and falling tides. The Bay Trail embankment separates South Bothin Marsh from Richardson Bay, ranging in elevation between 7-8 feet NAVD. Higher elevation upland/transition areas exist along the west perimeter of South Bothin Marsh, adjacent to Almonte Blvd and Tam Junction. Several debris mounds are found in the southwest corner of the Preserve. These mounds are remnants of various mid-20th century fills related to channel dredging, bridge construction, and bay filling before modern Bay fill regulation. The mounds contain a mix of soil as well as concrete, rebar and other debris.



Source: 2018 Marin County LiDAR



SEDIMENT AND EROSION

EXISTING CONDITIONS

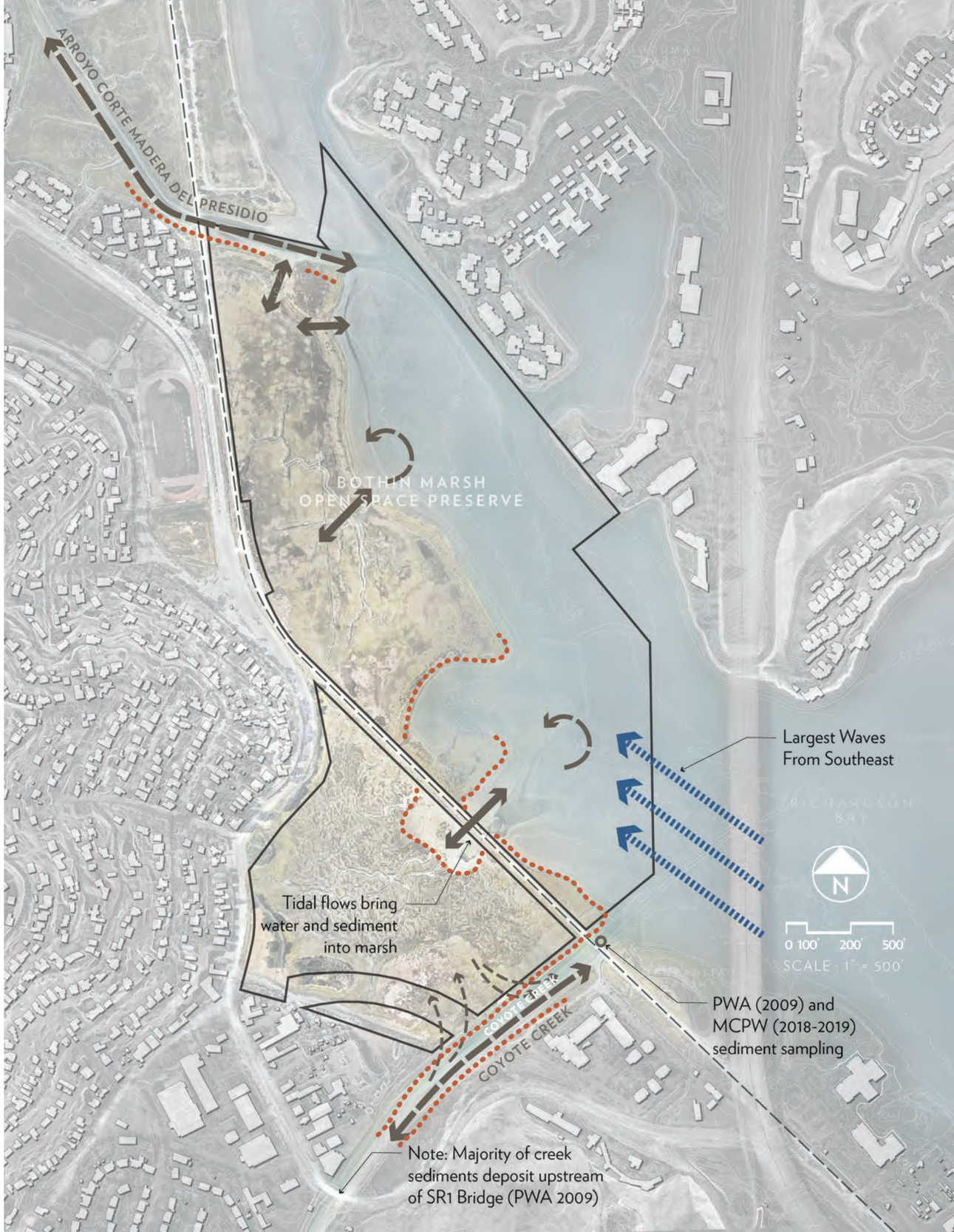
Sediment is an essential resource for the formation and sustenance of tidal marshes and mudflats. These landforms exist where there is an equilibrium between sediment deposition from creeks and the estuary, and erosion due to waves and currents. If the amount of sediment available increases, new marshes and mudflats are formed. However, areas of marsh and mudflat may be lost if the sediment supply decreases, or if hydrologic conditions change leading to increased erosion. It will be important to understand the balance of sediment and erosion at Bothin Marsh under existing and future conditions, and to understand how proposed project measures might increase the resilience of tidal marsh habitats by increasing sediment delivery, sediment capture, and reducing erosion. Outcomes and findings from prior studies evaluating these processes are summarized below.

Bothin Marsh receives very low amounts of estuarine sediment. The geology and hydrologic conditions in Richardson Bay are such that only a small amount of sediment from the San Francisco Bay and Delta reach north Richardson Bay and Bothin Marsh (Collin, L. et al., 2018).

Creeks may provide a significant additional source of fine sediment (silt, clay) in north Richardson Bay during wet years. Depositional channel bars consisting of mixed coarser sediment (sand, gravel) and fine sediment are evident in upstream reaches of Coyote Creek and Arroyo Corte Madera del Presidio below the head of tide. Coarser sediment is not recently evident in lower reaches of the creeks near the Bothin Preserve.

The average annual total sediment yields from nearby creek watersheds have been estimated based on regional regressions:

- Coyote Creek: 1854 tons/year (from SFEI 2017)
- Arroyo Corte Madera del Presidio: 5900 tons/year (based on SFEI 2017 estimates for Coyote Creek, scaled to match ACMdP drainage area)
- The amount of sediment that is delivered from the creek mouths to nearby tidal marshes and mudflats will be less than the total watershed yield because some of the watershed sediment yield is trapped in upstream depositional channel segments, and some of the sediment yield is flushed out to deep water areas of the Bay. The fraction of total watershed sediment yield that deposits on the marshes and mudflats is a topic of ongoing analysis.



Sources: SFEI 2017; PWA 2009; Stralberg, et al. 2011

SEDIMENT AND EROSION

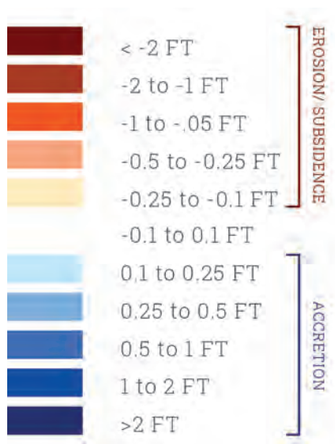
- Landforms that separate the marshes from nearby creek mouths, such as artificial levees and embankments, reduce the amount of sediment from the creeks that deposits on the marshes. The North Bothin Marsh tidal channel network is reasonably well-connected to the mouth of ACMdP , however the South Bothin Marsh tidal channel network is disconnected from the mouth of Coyote Creek by a remnant berm along the north bank of the creek and the Bay Trail embankment.

Comparison of LiDAR surveys in 2009 (CA Coastal Conservancy) and 2019 (Marin County) do not show signs of progradation of deltaic tidal marsh or mudflat at the Coyote Creek canal or Arroyo Corte Madera del Presidio mouth. Both creek channels express across the mudflats and connect with the main Richardson Bay thalweg. The LiDAR datasets show signs of deposition in the former dredged channels near North Bothin marsh, slight erosion/ subsidence on the shallow wave-exposed mudflats, and show evidence of shoreline erosion along the bay-facing edge of the berms around the perimeter of North Bothin Marsh. The LiDAR data shows a mix of accretion and erosion/subsidence within the tidal marshes. The trail and perimeter berms show evidence of slight subsidence, but are within the margin of error of the surveys.

LiDAR surveys have less accuracy in vegetated areas, and the observed elevation changes in the vegetated tidal marsh areas are within the margin of error of the LiDAR datasets.

Re-suspension of sediments from mudflats during large wave conditions can cause temporary increases in suspended sediment concentrations and may cause episodic pulses of sediment delivery to marshes. PWA (2009) observed visible areas of higher turbidity offshore in Richardson Bay relative to outflow of Coyote Creek during windy conditions while monitoring sediment at Coyote Creek.

TOPOGRAPHIC CHANGE 2009-2019



This map shows the observed change in ground elevation between 2009 and 2019 based on available LiDAR datasets (CA Coastal Conservancy 2009; Marin County 2019). The mapped elevation changes are subject to the limitations and uncertainties inherent in LiDAR-based topographic surveys, and may exhibit errors and distortions due to vegetation, standing water, and built infrastructure.



SEDIMENT AND EROSION

Typical suspended sediment concentrations in Richardson Bay are around 20-40mg/L on average (PWA 2009). The average rate of deposition in dredged channels near Sausalito significantly exceeds the deposition rate expected under typical conditions; observed accretion rates in dredged channels near Sausalito indicate that the deep-water portions of Richardson Bay experience an average suspended sediment concentration of 120mg/L (PWA 1983). This suggests that rare events that cause temporary periods of high suspended sediment concentrations, such as periods of high streamflow and large wave conditions, play an outsized role in sediment transport processes in Richardson Bay.

The magnitude of sediment delivered to marshes during large wave and large streamflow events has not been well quantified and is a topic of ongoing research. Streamflow and wave events might not deliver sediment to marshes as frequently as to the deep-water areas, because marshes are only inundated during high tides.

Order of magnitude estimates based on regional average vegetation growth rates suggest that organic productivity can have a significant contribution to marsh accretion. In areas with low estuarine sediment supplies, organic productivity can outpace mineral sediment deposition in vegetated marsh areas (Stralberg, et al. 2011). Vegetation productivity and organic accretion rates have not been directly measured at Bothin Marsh and should be studied further.

Based on regional average marsh accretion rates, the tidal marshes in North Richardson Bay are not expected to keep pace with sea-level rise through the end of century (2100) and will convert to mudflats or open water unless the sediment supply to the marshes is increased (Stralberg, et al. 2011).

Edge erosion has been observed along southeast-facing shorelines and along the banks of the creeks. Episodic bank erosion can occur during large storm events, and may also be an indication of a long-term sediment deficit resulting in sustained shoreline erosion. Continued monitoring and observations are recommended.



Eroding vegetation and mudflats in South Bothin Marsh, 2019.

Estimated Average Annual Sediment Delivery Required to Keep Pace with SLR

SCENARIO	SEA-LEVEL RISE RATE		SOUTH MARSH (24 ACRES)	NORTH MARSH (26.4 ACRES)
HISTORIC SLR	0.0064 ft/ yr	(2mm/ yr)	248 CY/ yr	273
IMMEDIATE FUTURE	0.02 ft/ yr	(6mm/ yr)	774	852
NEAR TERM (MID-CENTURY)	0.04 ft/ yr	(12mm/ yr)	1549	1704
MID TERM	0.08 ft/ yr	(24mm/ yr)	3098	3407
LONG TERM (END OF CENTURY)	0.12 ft/ yr	(36mm/ yr)	4646	5111

EXISTING ECOLOGICAL RESOURCES

KNOWN SPECIAL STATUS SPECIES

The following is a short list of special status species known to occupy Bothin Marsh. There are numerous additional species with the potential to occupy the marsh or that may be affected by changes to the marsh, see Collins et al. (2018) for complete list.

CALIFORNIA RIDGEWAY'S RAIL (*Rallus obsoletus*). FE, SE

- Critical Habitat Features: Small tidal channels and adjacent berms

CALIFORNIA BLACK RAIL (*Laterallus jamaicensis coturniculus*). FSOC, ST

- Critical Habitat Features: Secluded high marsh and transition zones (away from trail)

NORTH COAST OR POINT REYES BIRD'S-BEAK (*Chloropyron maritimum subsp. palustre* also listed as *Cordylanthus maritimus ssp. palustris*) FSOC, CNPSR

- Critical Habitat Features: High marsh and transition-zone habitats with high soil salinity

NOTE ON SALT MARSH HARVEST MOUSE:

- Past identification of salt marsh harvest mouse (*Reithrodontomys raviventris*; FE,SE) occurrence at Bothin Marsh has been corrected as tidal marsh populations of western harvest mouse (*Reithodontomys megalotis*) based on new genetic analysis (V. Pearson, pers. Comm. 2017). No salt marsh harvest mice are known to occur at Bothin Marsh and vicinity.

ECOGEOMORPHIC UNITS

The Bothin Marsh Preserve contains a diverse range of habitats that are influenced by specific geomorphic, hydrologic, and ecologic processes affecting different areas of the Preserve. Collins et al. (2018) applied an "ecogeomorphic unit"-based framework to account for the interactions between these processes in shaping the extents and functions of existing habitats within the Preserve. Detailed mapping of existing ecogeomorphic units present within the Preserve can be found in Chapter 4 of the Collins et al. (2018) report and a brief annotated summary of that mapping is provided in the Appendix of this document.

The basic ecogeomorphic units of Bothin Marsh are dynamic landforms associated with major distinct vegetation and habitat types. The units include variable forms of high salt marsh (flooded only during higher spring tides), playa-like high salt marsh pans, terrestrial transition zones (gradients between above-tide lands and high salt marsh), salt marsh plains, low intertidal salt marsh, tidal channels and banks, and various types of saline pools within the marsh. Marsh wildlife utilize interconnected combinations of these features, and plant distributions correspond with them in different positions within the Bothin Marsh landscape.

Sources: SFEI 2017; PWA 2009; Stralberg, et al. 2011



CALIFORNIA RIDGEWAY RAIL

Image Credit : Peter Baye



POINT REYES BIRD'S-BEAK

Image Credit : Peter Baye



CALIFORNIA BLACK RAIL

Image Credit : UC Division of Agriculture and Natural Resources, photo taken by Laurie Hal

ABBREVIATIONS

PAST IDENTIFICATION OF SALT MARSH HARVEST MOUSE (REITHRODONTOMYS RAVIVENTRIS; FE,SE) OCCURRENCE AT BOTHIN MARSH

PREDICTED SEA-LEVEL RISE IMPACTS ON BOTHIN MARSH



TODAY (SINCE 2019)

- Subtidal (<MLLW)
- Mudflat (MLLW-MSL)
- Low-Mid Tidal Marsh (MSL-MHHW)
- High Tidal Marsh (MHHW-HAT)
- 10-Year Coastal Flood
- 100-Year Coastal Flood



2030 +1' SEA LEVEL RISE

IMMEDIATE



2050 +2' SEA LEVEL RISE

NEAR-TERM



2100 +7' SEA LEVEL RISE

LONG-TERM

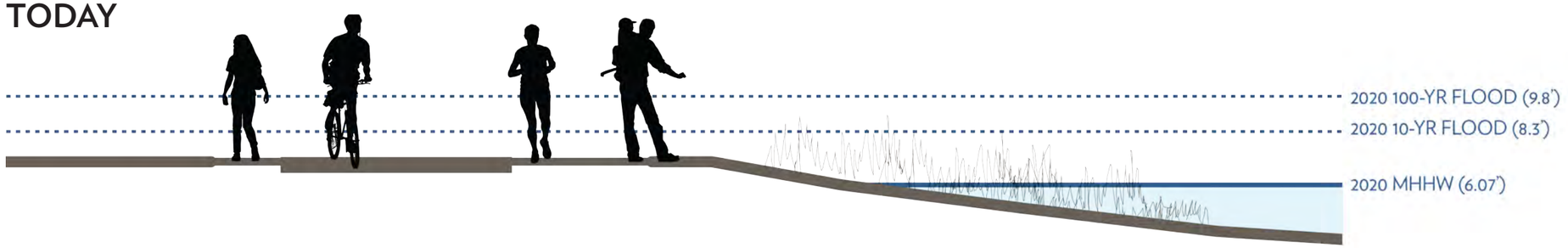
The inundation extents shown provide only a rough estimate of the inundation extents that may occur during the indicated flood events. These maps have been developed to inform project planning and may contain errors or inaccuracies. Key processes affecting actual inundation extents have been neglected in this simplified mapping.

Sources:
Elevations based on 2019 LiDAR; Tidal daturms based on CLE Study; Flood elevations based on FEMA 2017 Flood Insurance Study;
SLR Scenarios based on OPC's State of California Sea-Level Rise Guidance, 2018, Table 1: Projected Sea-Level Rise (in feet) for San Francisco, assuming Medium-High Risk Aversion in the High Emissions scenario for 2030, 2050, and 2100.

PREDICTED SEA-LEVEL RISE IMPACTS

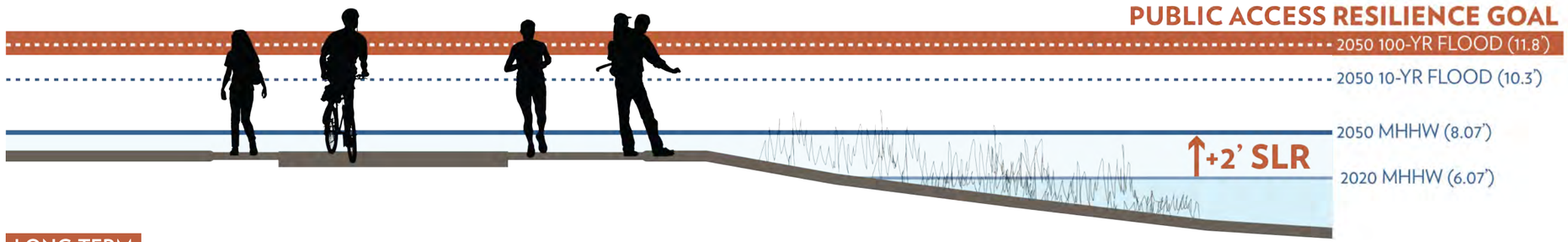
EXISTING TRAIL CONDITIONS + SLR SCENARIOS

TODAY



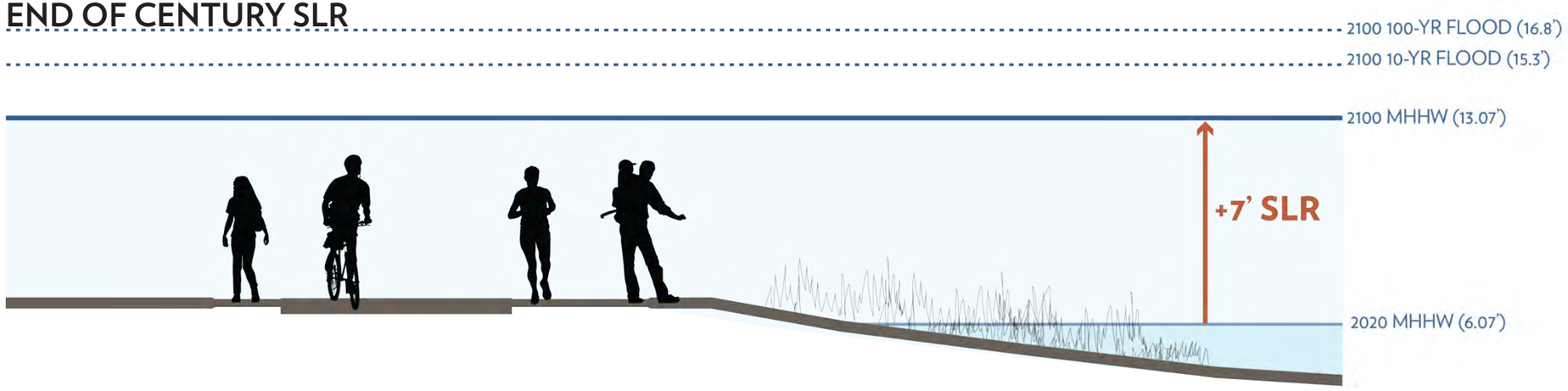
NEAR-TERM

MID-CENTURY SLR



LONG-TERM

END OF CENTURY SLR



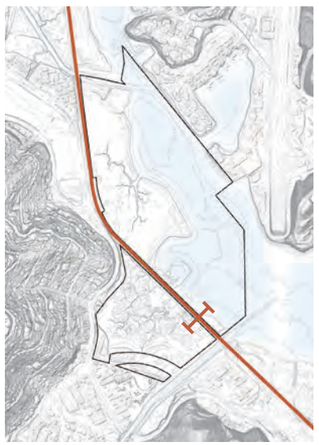
EXISTING TRAIL CONDITIONS & SLR SCENARIOS

The existing trail ranges from approximately 7 to 8 feet NAVD in elevation, just above MHHW and below 10-year flood levels. The poor trail surface conditions are a result of frequent trail overtopping throughout the year.

The "near-term" planning horizon for this project assumes the mid-century sea level to be about 2 feet above today's conditions. As is indicated in the sections to the left, BCDC recommends that public access to the shoreline be resilient to the mid-century sea-level rise and 100-year flood levels. To achieve this resilience goal the elevation of the trail ought to exceed 11.8 feet NAVD.

The "long-term" planning horizon for this project assumes end-of-century sea level to be about 7 feet above today's condition. This scenario is shown here for reference, but the proposed conceptual design of this project will not address this condition because it will require land use and policy changes well beyond the Preserves boundaries.

KEY PLAN



Sources:
Elevations based on 2019 LiDAR; Tidal datums based on CLE Study;
Flood Evelvations based on FEMA 2017 Flood Insurance Study; SLR Scenarios based on OPC's State of California Sea-Level Rise Guidance, 2018

3. POTENTIAL DESIGN ELEMENTS

POTENTIAL DESIGN ELEMENTS

INTRODUCTION: MENU OF POTENTIAL DESIGN ELEMENTS

This section presents a "menu" of potential design elements that have been identified for improving public access, ecological functions and sea-level rise resilience at Bothin Marsh. The collection of potential elements includes elements identified in prior planning studies and community workshops (CC&B; Leventhal and Baye, Evolving Shorelines), regional planning efforts, and workshops between the project team and the STAC. More detailed information regarding the Science and Technical Advisory Committee (STAC), including membership, meeting notes and presentation slides, can be found in the Appendix.

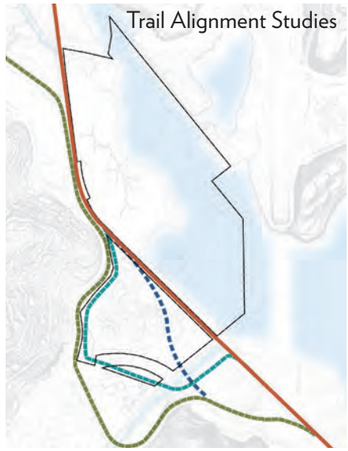
The pages that follow provide brief descriptions of the potential design elements and summaries of the opportunities, constraints, and uncertainties associated with each. The project has also developed preliminary recommendations for how each potential element might be incorporated into potential design alternatives. Each of the potential design elements aligns with one or more of the project planning horizons (Immediate, Near-term, Mid-term, and Long-term) as defined on pages 16-17 of this report and is identified with a label in the upper left-hand corner of the page.

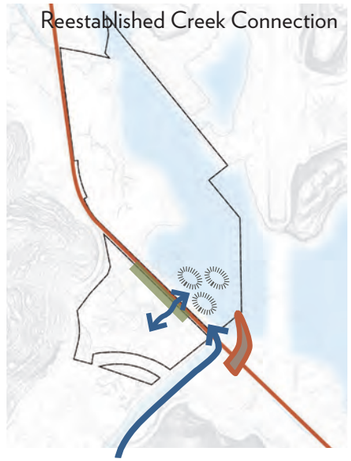
During future planning phases, these design elements will be assembled and combined into project alternatives for more detailed evaluation and comparison. The project alternatives will represent a range of potential approaches and prioritizations of the multiple project goals and objectives.

These alternatives will be evaluated and a preferred alternative will be selected, establishing the design approach that will be advanced to a detailed conceptual level of design and subsequent design phases.

MENU OF POTENTIAL DESIGN ELEMENTS

- Trail Alignment Studies
- Reestablished Creek Connection
- Tidal Marsh Drainage & Circulation
- High Marsh Mounds
- Oyster Reef / Eelgrass
- Hydraulic "Thin-lift" Sediment Placement
- Ecotone Slope
- Coarse Beaches
- Other Strategies

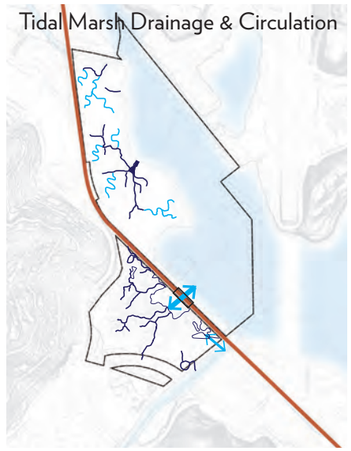






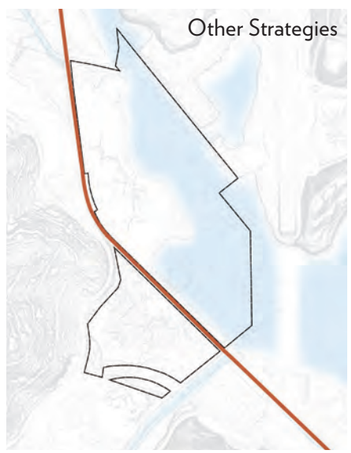












NEAR-TERM
LONG-TERM

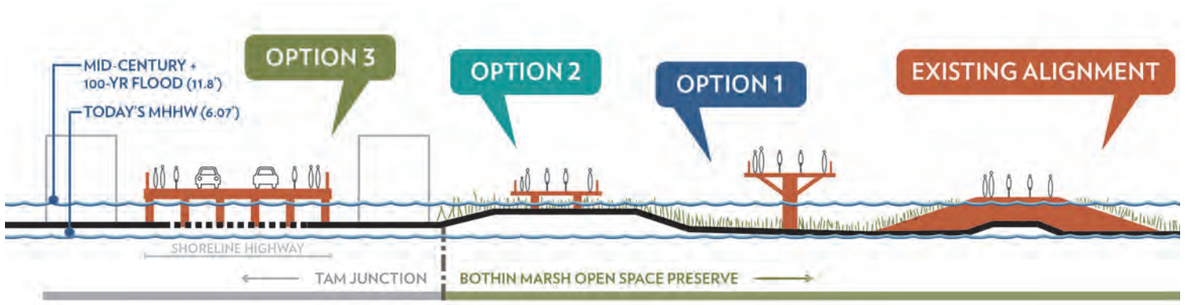
TRAIL ALIGNMENT STUDIES

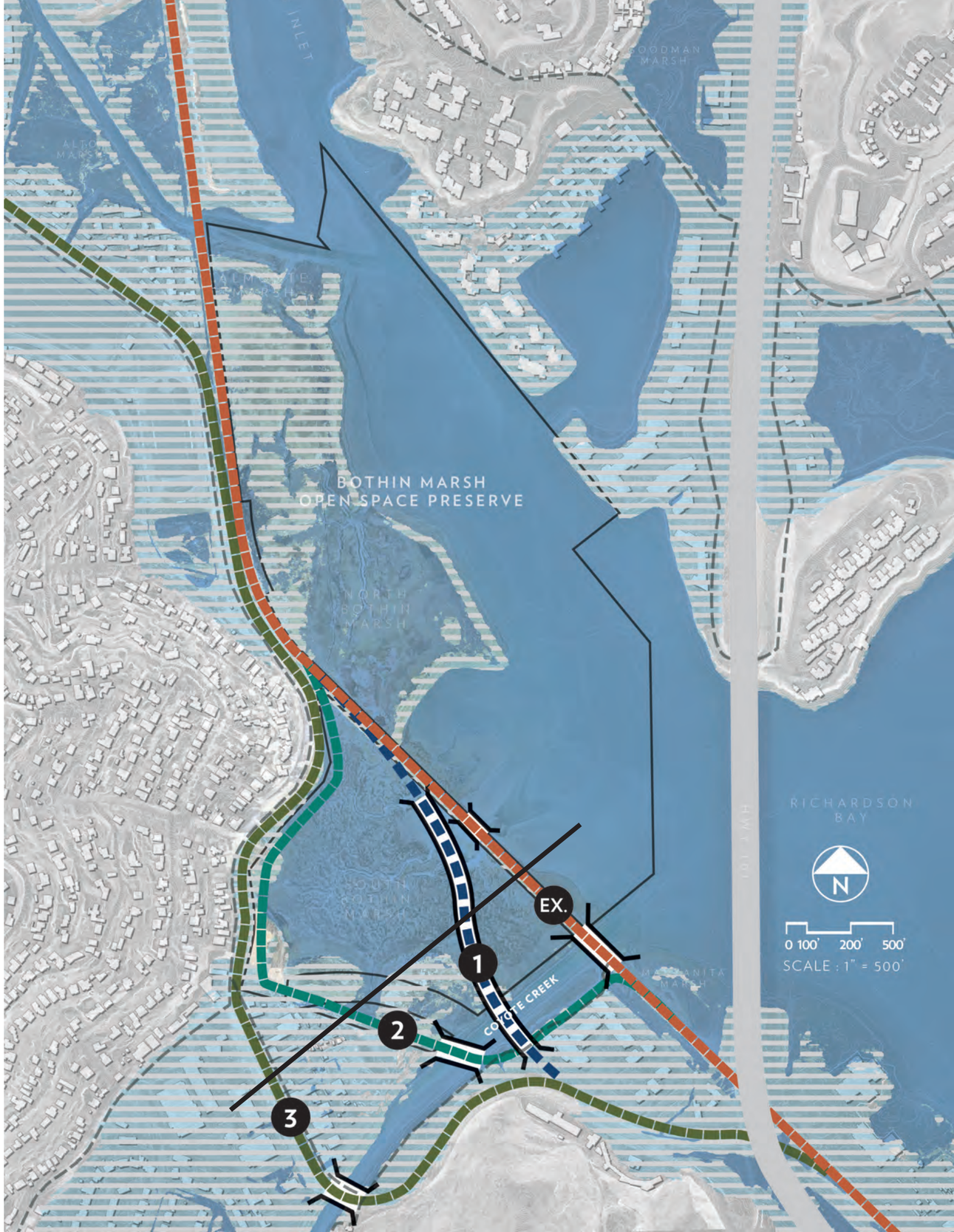
ALIGNMENT STUDIES

- There are several limitations to keeping the existing Mill Valley-Sausalito Pathway alignment through the Bothin Marsh Open Space Preserve. In order to address concerns related to present-day flooding, trail user conflicts, ecological concerns, and the future impacts of sea-level rise across the shoreline, the following potential trail alignments are being explored and represent high-level conceptual alternatives. The existing alignment, Option 1, and Option 2 are shown in greater detail on the following pages.
- The trail alignment along Option 3 is not shown in detail in this study because the alignment is outside of the preserve, but it is likely that sea-level rise impacts will require a complete street redesign of Almonte Blvd and Highway 1/Shoreline Highway. The project team recommends that this alignment remain in consideration as a long-term trail alignment as the region begins planning for mid-century and end-of-century sea-level rise adaptations.

TRAIL WIDTH STUDIES

- The existing trail width is understood to be inadequate based on the high number of users and number of collisions recorded over time. This study illustrates options that follow Bay Trail Guidelines for shared-use trails, and also explores separated-use trail alternatives.



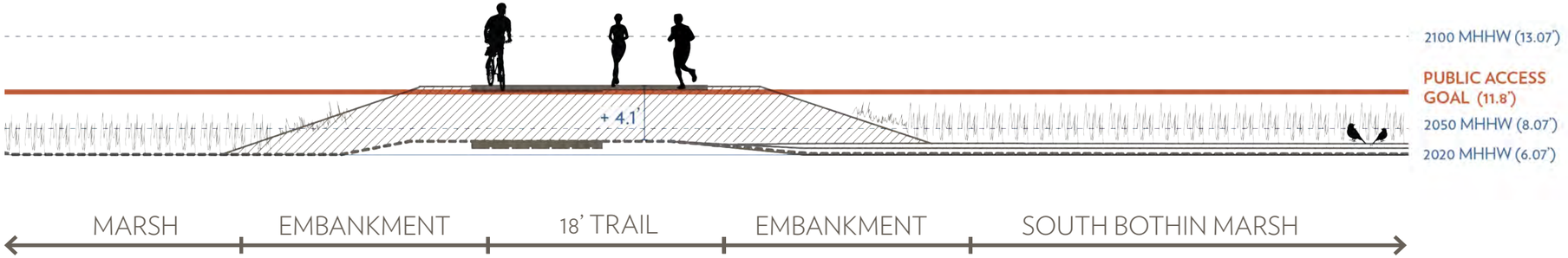


TRAIL ALIGNMENT: EXISTING

ENLARGED EMBANKMENT AND BRIDGES

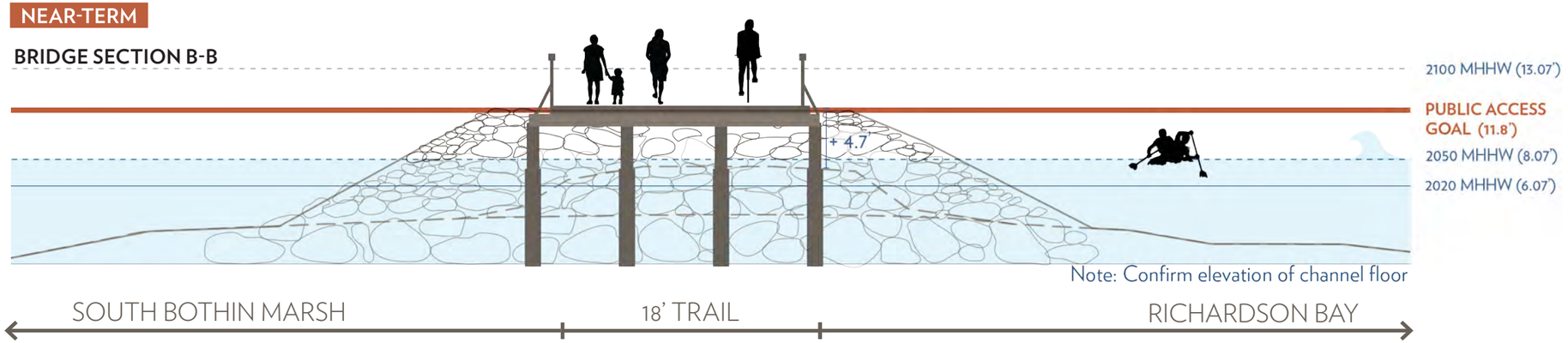
NEAR-TERM

EMBANKMENT SECTION C-C



NEAR-TERM

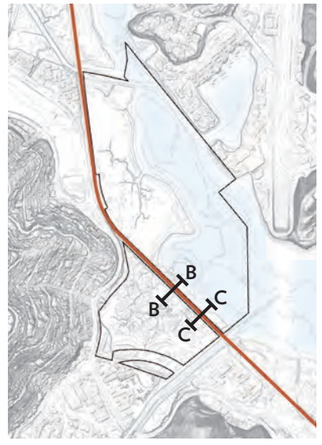
BRIDGE SECTION B-B



EXISTING TRAIL ALIGNMENT

- Trail redesign could build upon the existing foundation as sea levels rise, or elevate it on a causeway
- Existing embankment would continue to protect habitat from high wave energy
- The trail embankment would require 1 or more bridges to convey creek and tidal flows. These bridges would likely need to be longer in length than the existing structures to avoid adverse flooding and ecological impacts
- Raising the trail on a larger embankment would require significant fill and would impact tidal drainage
- Fill placement could impact existing telecom line
- An elevated trail along this alignment should be planned in coordination with the regional approach to active transportation improvements.

KEY PLAN



Sources:

Elevations based on 2019 LiDAR; Tidal datums based on CLE Study;

Flood Evelvations based on FEMA 2017 Flood Insurance Study

TRAIL ALIGNMENT: OPTION 1

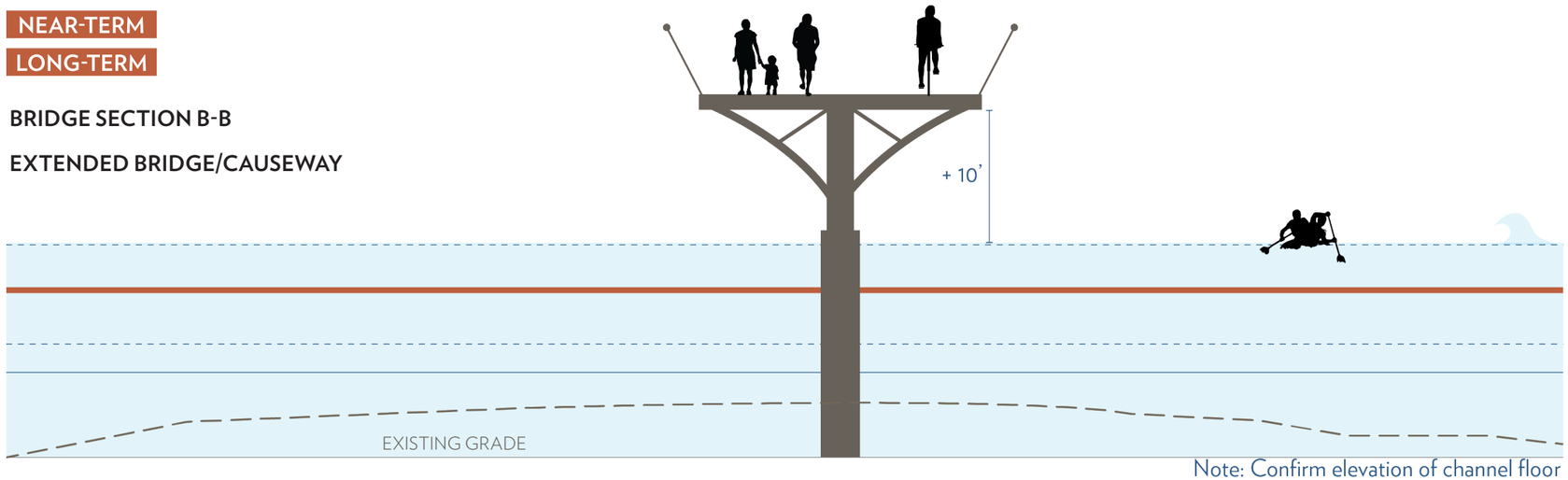
CAUSEWAY CONNECTING HIGH ELEVATIONS

NEAR-TERM

LONG-TERM

BRIDGE SECTION B-B

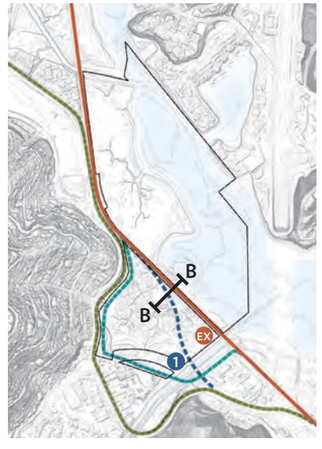
EXTENDED BRIDGE/CAUSEWAY



OPTION 1 - CAUSEWAY

- Would require a new long-span bridge or causeway over South Bothin Marsh and Coyote Creek
- An elevated bridge/trail along this alignment would connect high elevation areas through long-term sea level rise scenarios
- The specific footprint and alignment of this option would need further study in the alternatives phase.
- In this option, the trail along the existing alignment could be abandoned and the embankment could be modfied to enhance ecological and hydrologic connectivity between Richardson Bay and South Bothin Marsh.

KEY PLAN



Sources:

Elevations based on 2019 LiDAR; Tidal datums based on CLE Study;

Flood Evelvations based on FEMA 2017 Flood Insurance Study

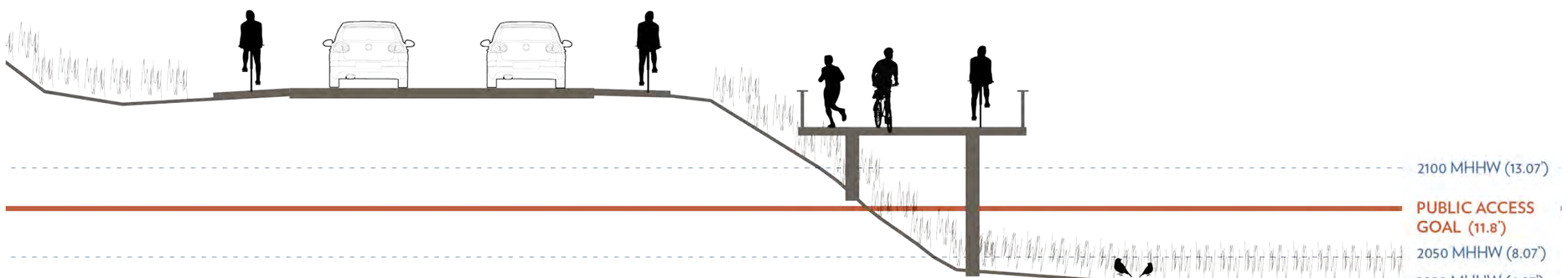
TRAIL ALIGNMENT: OPTION 2

ALONG THE EDGE OF THE PRESERVE

NEAR-TERM

WITHIN PRESERVE NEAR ALMONTE BLVD.

SECTION D-D

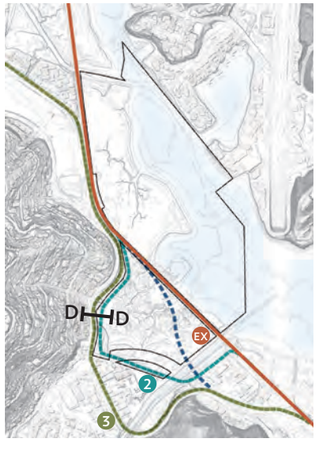




OPTION 2 - WITHIN THE PRESERVE

- Trail stays within the Preserve, along an embankment on the high elevation perimeter through long-term sea level rise scenarios
- Could be integrated into an ecotone levee strategy and provide some flood protection to adjacent land uses.
- Would require significant fill and would affect drainage conditions
- Could impact PG&E transmission towers
- Would require a new bridge over Coyote Creek connecting down to the McGlashen Trail
- In this option, the trail along the existing alignment could be abandoned and the embankment could be modfied to enhance ecological and hydrologic connectivity between Richardson Bay and South Bothin Marsh.

KEY PLAN



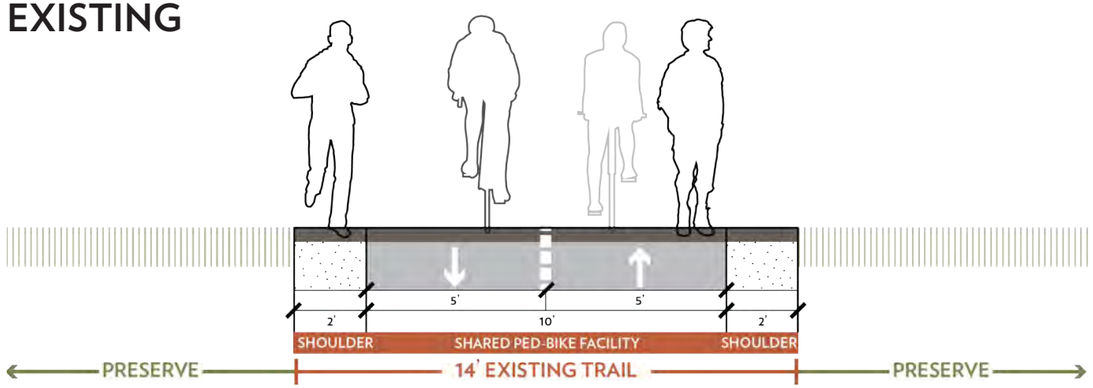
Sources:

Elevations based on 2019 LiDAR; Tidal datums based on CLE Study;

Flood Evelvations based on FEMA 2017 Flood Insurance Study

TRAIL WIDTH OPTIONS

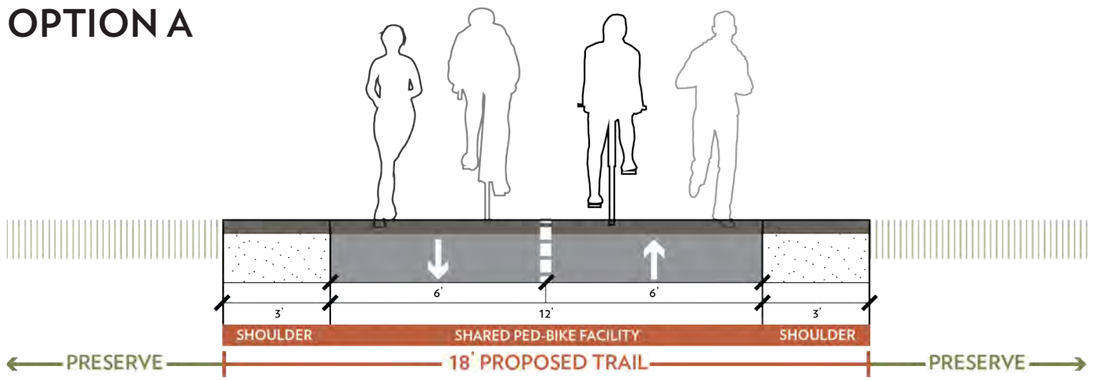
EXISTING



EXISTING TRAIL WIDTHS

The existing trail consists of a 10-foot wide paved path with 2-foot shoulders providing 14' of clearance overall. The existing trail is heavily used and has a history of dangerous collisions.

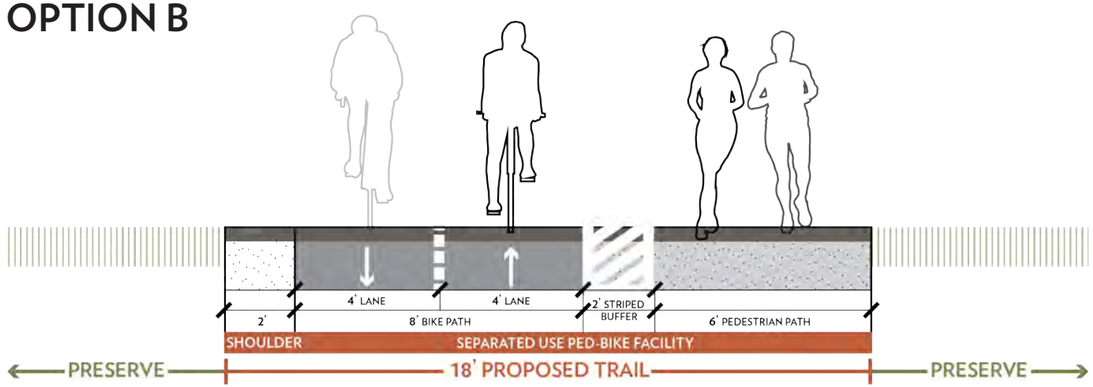
OPTION A



OPTION A : BAY TRAIL DESIGN STANDARD

The 2016 Bay Trail Design Guidelines and Toolkit recommends that typical trail segments provide a minimum of 18' of clearance overall, with at least 12' of paved surface for a shared-use facility. In this case, the shoulders are 3' wide.

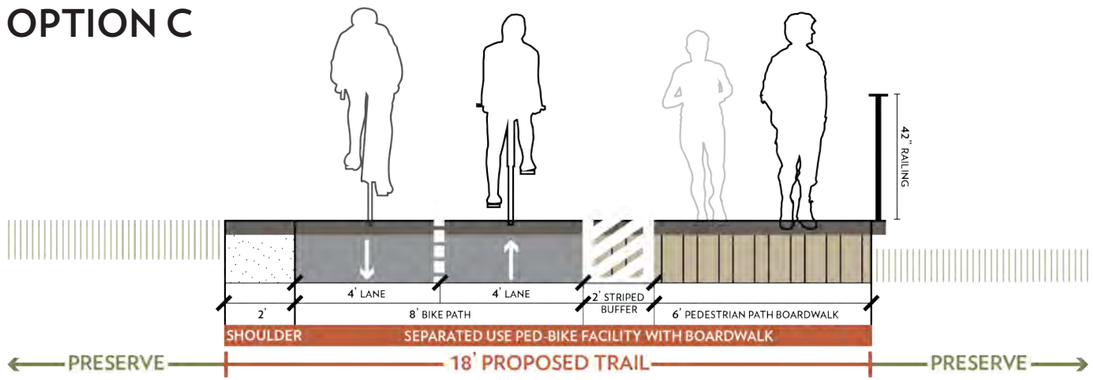
OPTION B



OPTION B: SEPARATED USE

Another option for the trail is a separated-use facility. Within the same 18'-wide clearance recommended by the Bay Trail Guidelines, this option provides a two-way 8' bike path with 2' shoulders and a 6' dedicated pedestrian path. The 2' striped shoulder provides a safe, curbless buffer that provides separation, but still encourages bikers to maintain safe speeds.

OPTION C



OPTION C: SEPARATED USE WITH BOARDWALK

Option 3 provides the same widths for the separated-use facility but includes a boardwalk and railing component for the areas of the trail where there may be an opportunity to elevate the structure above the marsh.

NEAR-TERM

MID-TERM

REESTABLISHED CREEK CONNECTION



NO ACTION



1. WIDEN BRIDGE



2. REDIRECT CREEK MOUTH TO OFFSHORE MUDFLATS



3. LOWER BERM ALONG NORTH COYOTE CREEK



4. SMALL TIDAL CHANNELS BETWEEN CREEK AND MARSH



5. BIFURCATED COYOTE CREEK CHANNEL



6. FULLY DIVERT CREEK THROUGH SOUTH BOTHIN MARSH



OTHER?

NEAR-TERM

MID-TERM

REESTABLISHED CREEK CONNECTION

Two creeks border the Bothin Marsh Preserve, Coyote Creek and Arroyo Corte Madera del Presidio. The creeks convey sediment from their upland watersheds into the Bay. Under historic conditions the sediment from creeks deposited in alluvial fans along the upland edge of the bay-fringing tidal marshes, helping to help build and sustain mudflats and tidal marsh habitats. Prior flood protection and reclamation projects have altered the alignments of both creek channels, and now these channels bypass the marshes along the Bay's edge and convey the majority of their stream flow and sediment load directly into Richardson Bay.

Prior studies at Bothin Marsh have identified the potential for benefits to the Preserve's tidal marsh habitats by improving the connection between Coyote Creek and the tidal marshes in South Bothin Marsh (Collins et al., 2018). There are a wide range of potential measures that aim to improve the connection between the creek and marsh and enhance sediment delivery to the tidal marsh habitats, improving the resilience of those habitats to sea level rise. These measures cover a wide range of potential scales ranging from the excavation of small connecting channels to the complete re-alignment of the creek channel. The relative benefits and impacts anticipated for these different measures will need to be carefully evaluated and considered. The long-term evolution of a stream delta in a confined, small tidal marsh may be similar to other examples from the Central Coast region, such as Pine Gulch Creek in Bolinas Lagoon, and Los Osos Creek in Morro Bay, and others. These have generated tidal marsh landforms and dynamics that do not correspond with ecological objectives for Bothin Marsh (relatively planar high salt marsh with no significant development of tidal channels or channel banks, frequent flood disturbance, poor high tide cover), not associated with maintenance or enhancement of rail or bird's-beak habitats. Marsh areas near new creek connections would be periodically disturbed due to sediment deposition during flood events. These periodic deposition events may be detrimental to existing birds beak populations and may fill existing tidal channels that provide rail habitat. Fluvial sediment deposits on former marsh plain can create foraging habitat for shore birds, and over the long term can increase marsh resilience to sea-level rise.

Potential options for re-establishing connections between Coyote Creek and South Bothin Marsh include:

Widening Bridge #2 to increase connection between offshore mudflats and South Bothin Marsh. Potentially modify offshore mudflats and shallows with flow diversion features (e.g. tidal marsh islands or peninsulas) to encourage deltaic deposition on nearby shallow mudflats rather than in the deeper parts of Richardson Bay. Sediments deposited on the mudflats would be available as a source of sediment to the tidal marsh, reducing export of sediment from North Richardson Bay. Wave break features (e.g. reefs) could be incorporated to increase sediment trapping. (Option 1 & 2)

Excavating small channels connecting between the creek and the marsh interior. The size and location of the connecting channels could vary, and the channels may enlarge on their own over time. (Option 3 & 4)

Creating a second creek channel - a distributary channel - through the marsh interior. The current Coyote Creek channel would remain in place. A new bridge would be constructed across the second creek channel. (Option 5)

Fully diverting the creek into a new channel through the marsh interior. Fill would be placed to block the existing creek outlet, and a new channel would be excavated through the existing marsh habitats and discharging to Richardson Bay at Bridge #2. This option has the potential to increase sediment delivery and trapping in the tidal marsh, but also would have extensive impacts to existing marsh habitats. (Option 6)

The outlet of Arroyo Corte Madera del Presidio is relatively well connected to North Bothin Marsh via existing tidal channels, and no significant opportunities to improve connections between that creek and North Bothin Marsh have been identified.

Options 1 and 2 promote indirect sediment delivery from creek to mudflats to marsh whereas Options 3 through 6 promote direct sediment delivery from creek to marsh.

OPPORTUNITIES

- Increase delivery of fluvial sediments to North and South Bothin Marsh.
- Improve tidal drainage in South Bothin Marsh via lower Coyote Creek to support more robust vegetation growth (see also Tidal Marsh Drainage and Circulation below).
- Increase ecological connections and opportunities for wildlife movement between creek channels and tidal marshes.

CONSTRAINTS AND CONSIDERATIONS

- Creek re-connection would require earthwork in sensitive existing habitats, including habitats occupied by rare/special status species, and result in long-term conversion from one habitat type (e.g., high marsh) to another (e.g., shallow open water channel). Temporary and permanent impacts to habitats must be considered.
- The design measures must cause no adverse flood impacts to upstream infrastructure or communities
- Any configuration would need to consider the need for ongoing maintenance dredging in the Coyote Creek channel to maintain flood capacity. Reconfiguration of the creek mouth could potentially increase the environmental impacts or cost of dredging. The lower reaches of Coyote Creek have not historically required frequent maintenance dredging; however, the upper reaches of the creek are periodically dredged to maintain flood conveyance capacity. The project should consider opportunities for beneficial re-use of dredged sediments, and should avoid creek configurations that would increase need for future maintenance dredging.

UNCERTAINTIES

- The extent to which creek reconnection will result in increased marsh sedimentation and resilience. This uncertainty makes it difficult to weigh the potential benefits of reconnection with the readily-quantified drawbacks of direct marsh loss with channel excavation.
- The average sediment yield of the adjacent creeks and the fraction of that sediment that is likely to deposit on the tidal marshes (rather than deposit in upstream channels or flush to the Bay) is challenging to measure or estimate with great certainty. Diversion of sediment

NEAR-TERM

MID-TERM

REESTABLISHED CREEK CONNECTION

from existing creek channel into South Bothin Marsh may alter the sediment budget for offshore mudflats and marshes along the Bay edge, potentially aggravating ongoing shoreline erosion.

- The fraction of creeks sediment yield that is likely to travel as suspended load (and could potentially deposit on tidal marshes), or as bed load (and would be unlikley to deposit on tidal marshes).
- The effects of creek connections on the morphological evolution and ecological functions of the tidal marsh habitats in South Bothin Marsh are uncertain. While some increased deposition at South Bothin Marsh would be beneficial, significant sediment deposition could transform the channel-adjacent marsh to a higher, poorly drained and relatively unvegetated deltaic plain. This type of deltaic plain can be seen at the mouth of Wildcat Creek in Richmond and in other systems. Deltaic plain, if it were to occur, would provide high tide shorebird roosting habitat, but would result in a loss of the small tidal channels critical for rails. Large seasonal sediment pulses would create conditions too disturbed for Point Reyes birds beak to persist. Processes that shape the long term habitat outcome are complex and difficult to predict with certainty.

ADDITIONAL STUDIES

- Marin County and Anchor QEA are conducting a parallel project to evaluate potential impacts to flooding and sediment transport processes from reconnecting Coyote Creek to South Bothin Marsh. The outcomes of this study will be informative for the Evolving Shorelines Project.
- Any creek re-connection must be carefully evaluated for flood performance, potential ecological benefits associated with increased sediment supply, and potential ecological impacts associated with habitat type conversions.

LINKAGES WITH OTHER DESIGN ELEMENTS

- The creek connection measures will need to be developed in coordination with any changes to the Bay Trail, with particular attention to the bridges.

PHASING CONSIDERATIONS

- It is likely that many of the uncertainties related to the Creek Connection measures will not be fully resolved in the course of this phase of the project. The STAC suggested that simplified analyses can still be informative and useful to guide prioritization and decision making.





Existing conditions along Coyote Creek, photos taken by project team in 2019.

IMMEDIATE

NEAR-TERM

TIDAL MARSH DRAINAGE AND CIRCULATION

Tidal marshes are strongly influenced by the patterns of drainage and circulation with the rising and falling tides. Increased tide range and improved low tidal drainage provides benefits for salt marsh vegetation productivity, which in turn benefits species living and foraging in the marsh, and increases marsh accretion rates and SLR resilience. Good low tide drainage is important to avoid stressing emergent vegetation and inhibiting plant growth. Tidal circulation is important for exchange of sediment, nutrients and biota in and out of the marsh.

Some areas of the Bothin Marsh Preserve experience poor drainage and circulation compared to healthy tidal marshes. North Bothin Marsh has fewer tidal channels compared to natural tidal marshes, and demonstrates habitat changes indicative of poor drainage of and circulation to the marsh interior, including vegetation die-offs and conversion of vegetated marsh to tidal ponds during recent drought years (ca. 2011-2016). South Bothin Marsh experiences delayed and incomplete low tide drainage due to the small size of the channel at Bridge #2, which is the primary connection between South Bothin Marsh and Richardson Bay. While channel excavation would cause near-term habitat impacts and longterm conversions, it seems likely that drainage improvements can be implemented at select appropriate locations and at appropriate scales to achieve a more balanced distribution of marsh micro-habitats, to increase abundance of specific micro-habitats, and to achieve net habitat diversity benefits.

OPPORTUNITIES

- Establish full low tide drainage in South Bothin Marsh by increasing the depth and width of the Bridge #2 channel and/or by creating new tidal connection channels between the marsh and the Coyote Creek channel.
- Improve interior tidal drainage and circulation in North Bothin Marsh by excavating new tidal marsh channels connecting to poorly drained areas. In addition to providing tidal circulation and drainage benefits, small tidal channels provide foraging areas and movement corridors for fish, birds and other marsh species (including Ridgway's rail).



IMMEDIATE

NEAR-TERM

TIDAL MARSH DRAINAGE AND CIRCULATION

CONSTRAINTS AND CONSIDERATIONS

- Temporary impacts associated with construction access and excavation within existing tidal marsh areas (expected to be limited in extent and duration).
- Permanent, small-scale impacts associated with habitat conversions (eg. conversion from vegetated tidal marsh to tidal channel/open water).
- Certain species benefit from poor marsh drainage, for example certain bird species forage in tidal ponds that form in poorly drained marsh areas. These species could be adversely impacted by drainage improvements.
- Drainage and circulation patterns may change with future sediment deposition or erosion, with sea level rise, due to changes in the tidal prism and due to increased erosion and/or overtopping of the perimeter berms. The project design should anticipate and be compatible with such changes, to extent feasible.
- The new tidal channels would likely be constructed in the interior of the tidal marsh, in close proximity to portions of the site used by Ridgway's rail and California black rail. There is a need to evaluate tradeoffs between habitat type conversions and outcomes for wildlife (eg. marsh pool to marsh plain conversion). Elements should be located to avoid or minimize conflicts with sensitive habitats and rare/special status species.

UNCERTAINTIES

- Some benefits of new channels may be temporary and relative project benefits may be reduced over time as sea-levels rise, for example, the benefits associated with increases in tidal flushing of the marsh plain and reduction in salt concentration (Watson and Byrne 2009).

LINKAGES BETWEEN DESIGN ELEMENTS

- Consider synergies been tidal channel excavation and marsh mound construction. Tidal channels can be constructed with adjacent high tide habitats (marsh mounds) to create adjacent forage and refuge habitats for rails and small mammals.
- Creek connections and Thin-lift sediment placement project elements could alter tidal drainage and circulation patterns. These design elements will need to be coordinated.



Salt pans have formed in North Bothin Marsh in recent years due to poor tidal drainage. Vegetation die-back occurs in poorly drained areas subject to extended periods of inundation, and die back can be exacerbated by elevated salinities that occur during periods of drought. Image Credit: P. Baye

IMMEDIATE

NEAR-TERM

HIGH MARSH MOUNDS

The Bothin Marsh Preserve currently has very little high-tide refuge habitat. These areas are locations where animals living in the marsh can find shelter during higher tides when the majority of the marsh is underwater. Currently, many of the existing refuge areas are near trails and roads, leading to wildlife-recreation conflicts.

High marsh mounds are constructed features that mimic naturally occurring channel-adjacent mounds. High marsh mounds are relatively low-relief mounds constructed on the tidal marsh plain that support plant species with canopies that rise above the high tides. The ground elevation of a marsh mound is slightly above the surrounding marshplain and below the highest tides. Keeping the ground elevation below the highest tides reduces the potential for colonization by undesirable upland vegetation and avoids conversion of jurisdictional wetlands to uplands. Mounds just need to be high enough to support taller high-marsh vegetation (I.e. gumplant).

These features have been implemented and have shown benefits for enhancing habitat diversity in other parts of San Francisco Bay (M. Latta pers. Comm). Marsh mounds can be co-located with new tidal channel creation, reusing excavated channel material to construct adjacent mounds. Other potential sources of fill are the adjacent marshplain and imported fill.

Marsh mounds can be constructed using manual labor to minimize construction-related impacts.

Marsh mounds are likely to provide significant near-term ecological benefits, but like all tidal marsh habitats, marsh mounds are vulnerable to drowning and submergence with rising sea-levels.

The scale of marsh mounds (size of individual mounds, and number and density of mounds) can be adjusted to balance benefits from increased habitat diversity versus the impacts to existing habitats.



IMMEDIATE

NEAR-TERM

HIGH MARSH MOUNDS

OPPORTUNITIES

- Marsh mounds provide high-tide refuge areas for birds and terrestrial marsh species. Mounds could increase habitat diversity and heterogeneity by supporting a greater variety of plant species in the marsh interior.

CONSTRAINTS AND CONSIDERATIONS

- Requires fill placement in existing sensitive habitats, causing short-term impacts to these habitats.

INTEGRATION OF ELEMENTS

- Identified synergies with tidal channel excavation. Channel excavation can be source of fill material for mound construction.
- Marsh mounds require relatively small lead time and investment to construct and could provide immediate ecological enhancements. Mounds could be installed as a permanent enhancement feature, or could be temporary features providing interim benefits before measures requiring longer lead time such as thin-lift sediment placement and creek connections can be constructed.



Low Tide, Muzzi Marsh, Corte Madera



High Tide, Muzzi Marsh, Corte Madera

IMMEDIATE
NEAR-TERM

OYSTER REEF / EELGRASS

Artificial oyster reefs and eelgrass plantings are potential elements that aim to increase the ecological diversity of the shallow subtidal habitats offshore of a tidal marsh. The extents of oyster and eelgrass habitat in San Francisco Bay has significantly decreased over the past centuries due to artificial fill and increased turbidity and sediment deposition resulting from hydraulic mining operations and other upland land use changes.

There have been several recent demonstration projects in San Francisco Bay testing approaches for creating new native oyster habitats and eel grass beds. These demonstration projects are also testing the effectiveness of these habitats for dissipating wave energy and reducing coastal erosion.

These habitats are sensitive to coastal conditions, and only are appropriate within a limited range of depths, salinities, and wave exposure.

OPPORTUNITIES

- These features could increase diversity of nearshore aquatic habitats.
- Native Olympia oysters occur on rip-rap (at existing bridge abutments) at lower intertidal elevation ranges, suggesting potential habitat suitability for this species.
- Potential to provide wave energy dissipation and increase sediment trapping on mudflat.

CONSTRAINTS

- Native oyster survival is best at the lowest inter-tidal elevations. Mudflats off shore of Bothin Marsh may be too high to support productive oyster reefs. Offshore areas at suitable elevations may be too far from the shoreline to provide wave attenuation benefits. Near-shore reefs would provide greater wave attenuation benefits. Such reefs would not support native oysters, but could provide benefits for other marine organisms.
- Oyster reefs and eelgrass beds are most productive under conditions with relatively low turbidity, but most objectives for marsh resilience favor higher turbidity conditions to encourage sediment deposition.



IMMEDIATE
NEAR-TERM

OYSTER REEF / EELGRASS

- Native oysters can experience high mortality during periods of freshwater or brackish conditions. Freshwater flows from Coyote Creek and Arroyo Corte Madera del Presidio can cause low-salinity conditions in the local embayment during periods of prolonged high discharges.
- Marine-based access for construction/ installation may be challenging due to shallow bathymetry in north Richardson Bay.

UNCERTAINTIES

- Unclear how to resolve conflicting sediment needs for these aquatic habitat features compared to healthy tidal marshes.
- There have been no studies of native oyster recruitment/survival in this part of Richardson Bay. Conditions in the Bothin Preserve may be different from conditions at prior oyster reef projects in San Francisco Bay. The non-native Atlantic oyster drills may impact any pilot project to establish native oysters.
- The non-native Atlantic oyster drills may impact any pilot project to establish native oysters.

INTEGRATION OF ELEMENTS

- Bridge abutments and other engineered rock slope protection may provide persistent local sub-habitats for native oysters. These hard substrate features should be designed with attention to suitability for oysters and other desired benthic species.



Giant Marsh Living Shoreline Project

IMMEDIATE MID-TERM
NEAR-TERM LONG-TERM

HYDRAULIC "THIN-LIFT" SEDIMENT PLACEMENT

Hydraulic sediment placement uses pumps and hoses to deliver sediment to a tidal marsh or mudflat more rapidly than would occur under natural conditions. A sediment-rich slurry is pumped and discharged onto the marsh or mudflat, and water-to-sediment ratio of the slurry can be controlled to allow the sediment to flow and deposit in a manner similar to natural deposition during a large streamflow event. Hydraulic sediment placement can create landforms that mimic natural alluvial depositional fans.

"Thin-lift" sediment placement refers to the use of hydraulic placement methods to deposit sediment on an existing vegetated tidal marsh in a controlled manner that avoids burying the existing vegetation. Under a "thin-lift" approach, the depth of sediment placement during a given year is limited to a few inches, so that the existing vegetation can grow through and above the newly placed sediment. In this way, sediment can be placed on an existing marsh while avoiding the creation of large unvegetated areas and subsequent temporary habitat loss.

The San Francisco Bay NERR is testing thin-lift sediment placement on small-scale test plots at the neighboring Manzanita Marsh, (located ¼ mile southeast of the Preserve) as part of a nation-wide study. Outcomes from the NERR study could inform future pilot projects.

OPPORTUNITIES

- Engineered sediment placement can raise ground elevations and improve sea-level rise resilience in both inter-tidal and adjacent transitional and upland areas.
- Proposed hydraulic dredging on Coyote Creek could provide a local source to supply hydraulic slurry sediment placement at Bothin Marsh.
- Hydraulic sediment placement can mimic natural sediment deposition processes, resulting in landforms that are suitable for native tidal marsh vegetation communities.
- Hydraulic sediment placement can be performed gradually in "thin-lifts" that avoids burial of existing marsh vegetation (burial depth can be limited to below the canopy height of perennial salt marsh vegetation). This allows the existing habitats to recover faster for thin-lift projects compared to traditional, thicker fill placement methods that burry and kill the majority of the existing vegetation in the fill placement area.



IMMEDIATE MID-TERM
NEAR-TERM LONG-TERM

THIN-LIFT SEDIMENT PLACEMENT

CONSTRAINTS AND CONSIDERATIONS

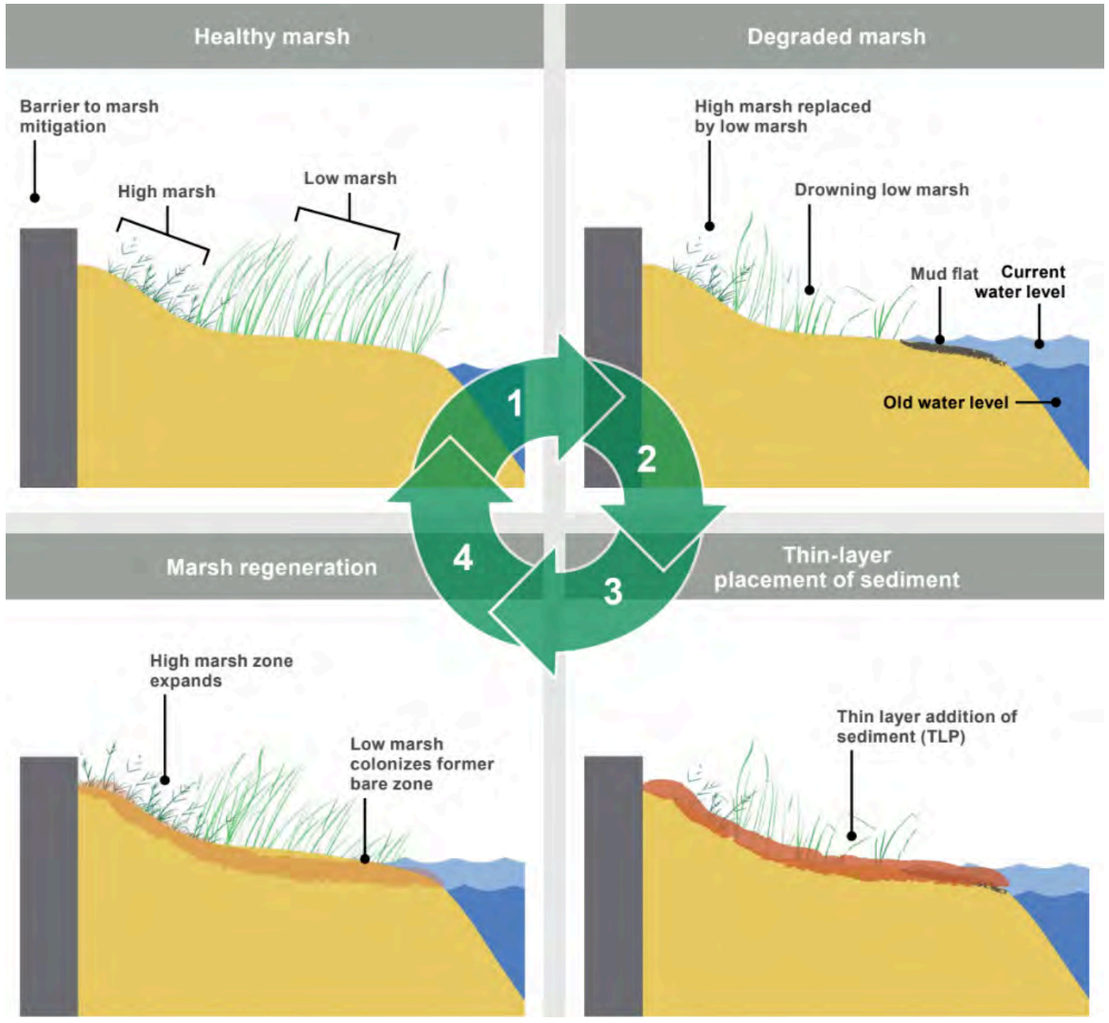
- Sediment placement can be staggered in both time and space to minimize near-term impacts to habitats. Application of sediment in staggered patches (alternating placement and preserved areas) may facilitate recovery and recolonization of sediment-disturbed patches and can preserve non-impacted habitats near impacted areas in order to maintain stable populations of sensitive species.
- There are no examples of thin-lift placement on a large scale in an existing tidal marsh in San Francisco Bay. The project would likely be considered a "Pilot Project" and would require extensive monitoring and adaptive management.

UNCERTAINTIES

- There is limited information on methods and best practices for thin-lift sediment placement to minimize impacts/maximize long-term benefits.
- Need to identify reliable, long term sediment supply and funding sources to allow for repeated lifts over several years or decades.
- Need to better understand risk of placed material eroding/washing to Bay. What trapping efficiency would be acceptable? Are there potential impacts (or benefits) to downstream/offshore areas?

INTEGRATION OF ELEMENTS

- Design elements that restore natural sediment delivery processes, such as creek re-connection, should be considered first. If natural-processes approaches are found to be unable to provide sufficient benefits to marsh resilience, then engineered sediment placement options, including thin-lift placement, should be considered. Thin-lift placement is particularly valuable as this method can increase the resilience of high marsh and marsh to upland ecotone transition habitat types that are more difficult or impossible to support via natural estuarine or fluvial deposition.



Source: National Estuarine Research Reserve Association

IMMEDIATE MID-TERM
NEAR-TERM LONG-TERM

ECOTONE SLOPE

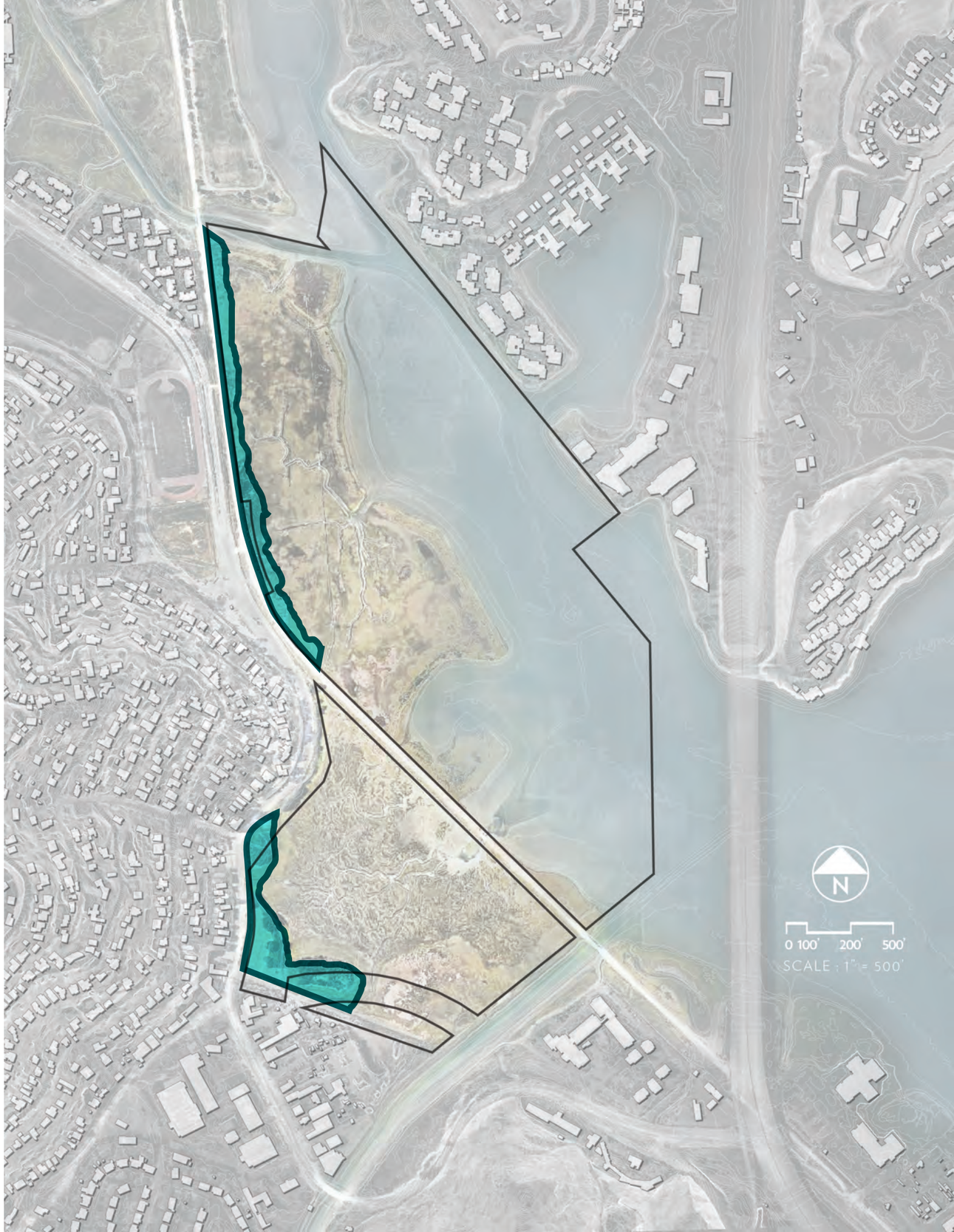
An "ecotone" refers to a transition between two habitat types or biological communities. Ecotones are found around the edges of tidal marshes where the landscape transitions from marsh habitats to upland habitats. Tidal marsh ecotones provide essential services for rails and terrestrial animals by providing safe refuges during high tides when the tidal marshes are submerged. An ecotone slope can be constructed along the Bay-facing side of an engineered levee or embankment in order to create a wider band of transition zone and high marsh habitat than would be provided by a typical engineered fill slope.

Ecotone slopes can support valuable marsh to upland transition-zone habitats in the near term, and provide space for tidal marshes to transgress with rising sea-levels. There are few existing ecotone slopes at the Preserve and little terrestrial space to create them, since most of the higher perimeter of the marsh has been developed. To avoid impacts to existing high-value habitats, ecotone slopes are best constructed where poor-quality transition zones exist (weed uplands, rubble).

Low-value, weedy lowland terrestrial fills suitable for grading into wide ecotone slopes exist at the west end of South Bothin Marsh. Ecotone slopes can be created here with minimal impacts to existing high-value habitats. Some of these areas are outside of the County-owned Preserve, and so are not included in the current planning study.

In North Bothin Marsh, much of the available area for ecotone slope creation is high-value, high-diversity high salt marsh occupied by special-status plants (bird's-beak). The project will want to avoid extensive fill over these areas, yet without any fill these high-value habitats are vulnerable to loss with sea-level rise. Ecotone slope creation at North Bothin could be phased as a series of smaller thin-lift sediment fans. This would avoid extensive fill and allow vegetation and wildlife recruitment to the fill areas from adjacent undisturbed areas. Fans could continue to be created in a phased approach, over time, improving overall marsh resilience.

Constructed ecotone slopes can be designed to incorporate subsurface application of treated wastewater as a source of irrigation water to support native brackish wetland vegetation. Filtering of treated wastewater through an ecotone slope also provides water quality treatment benefits. Water quality treatment wetlands could incorporate lessons learned from the Oro Loma "Horizontal Levee" pilot project.



IMMEDIATE MID-TERM
NEAR-TERM LONG-TERM

ECOTONE SLOPE

OPPORTUNITIES

- Create ecotone slopes in low-value, weedy terrestrial fills or, in higher-value salt marsh areas, use a phased approach to add resilience while minimizing impacts.
- Opportunities for ecotone slope creation exist in areas where new upland fill placement may be otherwise unavoidable; for example, adjacent to potential new trail embankments.
- Integration of treated wastewater into an ecotone slope could be explored in coordination with nearby wastewater treatment facilities in Mill Valley.

CONSTRAINTS AND CONSIDERATIONS

- There is little terrestrial space for ecotone slope creation at most of the Bothin Marsh Preserve.
- Ecotone slopes require more fill and have a larger footprint compared to traditional steep-sloped embankments. Several regulatory policies for fill placement in tidal wetlands and waters encourage projects to minimize fill volume and footprint to the extent feasible.
- Single-event construction of ecotone slopes in existing high tidal marsh would likely have excessive near-term adverse ecological impacts unless located in existing upland or degraded areas. Create ecotone slopes opportunistically in areas where impacts are already unavoidable (e.g., for trail improvements) or where fill can be justified given anticipated long-term benefits.

UNCERTAINTIES

- The nearby Mill Valley Sewage Treatment Plant is a potential source of treated wastewater, but the feasibility of treated wastewater delivery to North Bothin Marsh across Arroyo Corte Madera del Presidio is currently unknown.

PROJECT PHASING

- Consider use of methods like gradual construction by staggered/phased thin-lift sediment deposition in pace with sea-level rise, and to minimize ecological impacts.



China Camp valley grassland ecotone with prehistoric tidal salt marsh. Species include Pickleweed in the tidal marsh, Baltic rush and creeping wildrye in the moist transition zone, with scattered coyote brush, poison oak, California rose. Peter Baye, 2008.



Horizontal Levee Project at Oro Loma Sanitary District, ESA, 2019.

IMMEDIATE
NEAR-TERM

COARSE BEACHES

The fine-grained estuarine sediments (clays and silts) present at the site offer very little resistance against wave-induced erosion on wave-exposed shorelines, such as those along the southeast-facing shorelines of Bothin Marsh. Coarse sediment beaches, made of materials such as shell, sand, or gravel, can provide protection against marsh edge erosion. Coarse sediment beaches can adjust to a cross section geometry that is stable under higher estuarine wave energy. The highest elevation portions of the beach can support tidal marsh vegetation, and these salt marsh beach berms can provide valuable habitat and wave attenuation benefits.

Coarse sand and gravel beaches are usually depositional during periods of high, steep waves that otherwise erode marshes and fine sand, allowing them to migrate landward and build to higher elevations with rising sea-levels where their sediment supply is sustained. While not present within the immediate project area, pocket beaches historically occurred in west-facing Richardson Bay shorelines near the location of Bothin Marsh.

Aramburu Island and Sanctuary Beach provide local reference sites, and ongoing monitoring at these locations could help resolve uncertainties.

The rate of sediment loss can be reduced by using appropriate sediment sizes and by incorporating structural features like rock headlands, and rock or wood groyne structures. Periodic maintenance and nourishment may be advisable to replace beach material that is transported to offshore or downdrift areas.

OPPORTUNITIES

- Some bay-edge salt marsh and levee scarps that exhibit long-term indicators of net erosion could be converted to beach-edged marshes that develop high salt marsh berms like natural levees, with associated habitat benefits.
- While not at risk of erosion, the rocky, compacted fill of the Bay Trail (old railroad) embankment is a potentially receptive shore for coarse beaches like those that historically occurred in the vicinity. The old railroad embankment is likely to be retained even if the trail is relocated, its large boulders are difficult to remove and the embankment provides wave attenuation and sediment trapping benefits for South Bothin Marsh. Creation of a coarse beach along the eastern slope of the embankment would provide beach berm habitat. This would be particularly valuable if the trail is realigned, as the created habitat would be more secluded from human disturbance.
- Coarse sand and gravel beaches rise with sea level if supplied with sufficient sediment.



IMMEDIATE

NEAR-TERM

COARSE BEACHES

CONSTRAINTS

- Depending on the shoreline geometry and wave climate, beaches may gradually lose coarse sediment due to longshore or offshore transport.

UNCERTAINTIES

- Still learning about the ecological function of constructed beaches.
- Need to identify suitable source of coarse sediment.
- Period maintenance is likely to be required and ability to source material and maintenance costs are unknown.
- Future funding source for maintenance.
- Need to better understand coastal erosion rates and offshore/nearshore wave conditions. The NERR's Richardson Bay sonde data might be useful if wind, wave, or turbidity data is measured. Otherwise it is not apparent whether wind speed/direction data exists in the vicinity (Crissy Field is closest known long-term wind gage).

ADDITIONAL STUDIES

- Evaluate shoreline erosion rates along the Preserve coastline, and identify areas of greatest concern where ongoing erosion is most likely to cause loss of marsh habitats (e.g. rapid erosion of exposed tidal marsh, or erosion leading to imminent loss of high marsh providing high tide refuge habitats).

INTEGRATION OF ELEMENTS

- If the Bay Trail is relocated from its present alignment, the existing trail embankment could be reconfigured to support a new coarse beach.



Coarse beach at Aramburu Island, ESA, 2013.

OTHER STRATEGIES

This section describes additional potential strategies that were identified in collaboration with the STAC to be considered for incorporation into the project alternatives.

POTENTIAL STRATEGIES

- Vegetation management should be considered as an integral component of all measures, since all measures involve actions that result in bare disturbed substrate subject to new colonization by estuarine marsh plants. Passive, spontaneous colonization of disturbed, bare sediment by the local estuarine flora is influenced by high "seed rain" by only a few dominant native species and non-native weeds, which by itself may not maintain the characteristic high native species diversity of Bothin Marsh that has accrued over decades. The seed rain at Bothin Marsh is loaded with wetland weeds from outside the Preserve, but only small loads of seed from the some of the less prevalent native species. Vegetation management can vary in scope and scale. A minimal approach might be limited to repairing areas affected by construction. A larger scale approach could include targeted or broad removal of invasive weeds, and landscape-scale seeding or planting of uncommon, rare and/or high value native plants.
- Consider planned trail flooding for the Bay Trail. One option might be to establish an alternate trail alignment at higher elevation, but leave the existing trail in place. Acknowledge that the existing trail won't always be accessible, but will still provide value during lower tides. This is similar to seasonal trail restrictions used at other Bay trails. Meanwhile, the new alignment would be accessible at all tide levels. Plan for eventual abandonment of the existing trail at the end of its useful life.



4. REFERENCES

LIST OF REFERENCES

Anderson, M., and Michael Moratto. "Native American Land-Use Practices and Ecological Impacts." *University of California, Davis, Centers for Water and Wildland Resources 2* (January 1, 1996): 187–206.

SFEI & SPUR. *San Francisco Bay Shoreline Adaptation Atlas: Working with Nature to Plan for Sea Level Rise Using Operational Landscape Units*. Publication #915, San Francisco Estuary Institute, Richmond, CA. 2019.

Collins, Laurel, Peter Baye, and Joshua Collins. "Bothin Marsh Geomorphology, Ecology, And Conservation Options," 2018. https://www.onetam.org/sites/default/files/pdfs/BothinMarshGeomorphologyEcologyandConservationOptions.pdf.

Latta, Marilyn. "RE: Bothin STAC Meeting #1" Email, 2020.

Leventhal, R. and Baye, P. "Coyote Creek to Bothin Marsh Dredge Sediment Reuse Feasibility Study". January 30, 2017.

Miller Pacific Engineering Group. "Foundation Report Mill Valley-Sausalito Path Bridge Planning Project. Federal Project No. 5927(051) Caltrans District 4, Mill Valley, CA." Project 1665.031. Report prepared for California Infrastructure Consultancy. June 6, 2017.

Moratto, Michael J., and David Allen Fredrickson. *California Archaeology.* Academic Press, 1984.

NCE. "Mill Valley-Sausalito Trail Maintenance Recommendations." November 12, 2019.

Nelson, Nels C. *Shellmounds of the San Francisco Bay Region*. Berkeley: The University press, 1909. https://catalog.hathitrust.org/Record/100170034.

One Tam. "Evolving Shorelines: Vision For The Future." Accessed June 18, 2020. https://www.onetam.org/sites/default/files/pdfs/Evolving%20Shorelines_VisionForTheFuture_BothinMarsh_FINAL_WEB.pdf.

Philip Williams & Associates (PWA). "Reassessment of Coyote Creek Channel Management Requirements". Report prepared for Marin County Flood Control and Water Conservation District. January 10, 2005.

PWA. "Feasibility Study: Lower Coyote Creek Flood Management and Marsh Enhancement Project". Report prepared for Marin County Flood Control and Water Conservation District. September 1, 2009.

San Francisco Estuary Institute-Aquatic Science Center. "Changing Channels: Regional Information for Developing Multi-benefit Flood Control Channels at the Bay Interface". A SFEI-ASC Resilient Landscape Program report developed in cooperation with the Flood Control 2.0 Regional Science Advisors, Publication #801, San Francisco Estuary Institute-Aquatic Science Center, Richmond, CA. 2017.

Stralberg, Diana, Matthew Brennan, John C. Callaway, Julian K. Wood, Lisa M. Schile, Dennis Jongsomjit, Maggi Kelly, V. Thomas Parker, and Stephen Crooks. "Evaluating Tidal Marsh Sustainability in the Face of Sea-Level Rise: A Hybrid Modeling Approach Applied to San Francisco Bay." *PLOS ONE* 6, no. 11 (November 16, 2011): e27388. https://doi.org/10.1371/journal.pone.0027388.

Watson, Elizabeth Burke, and Roger Byrne. "Abundance and Diversity of Tidal Marsh Plants along the Salinity Gradient of the San Francisco Estuary: Implications for Global Change Ecology." *Plant Ecology* 205, no. 1 (2009): 113–28.

Watson, Elizabeth, and Roger Byrne. "Recent (1975-2004) Vegetation Change in the San Francisco Estuary, California, Tidal Marshes." *Journal of Coastal Research* 28 (January 1, 2012): 51–63. https://doi.org/10.2307/41331989.

APPENDIX D

Data Sources

APPENDIX E

CCTV Maps and Repair Costs

A Tradition of Stewardship
A Commitment to Service

Planning, Building & Environmental Services

1195 Third Street, Suite 210
Napa, CA 94559
www.countyofnapa.org

David Morrison
Director

December 23, 2020

George Monteverdi
Monteverdi Consulting
P. O. Box 6079
Napa, CA 94581

Via email: george@monteverdiconsulting.com

Re: P19-00097 and P19-00098; Duckhorn Vineyards Major Modification and Variance
1000 Lodi Lane; APN 022-130-010
Application Status Letter #3

Dear Mr. Monteverdi:

Thank you for your November 24, 2020, response to comments and resubmittal related to the referenced Major Modification and Variance. Staff has determined that the additional information listed below is needed to enable the County to continue with the review of your application.

PROJECT REVIEW STATUS BY DIVISION			
DIVISION	**REVIEW STATUS**	**REVIEWERS NAME**	**CONTACT INFO**
PLANNING	SEE COMMENTS	EMILY HEDGE	(707) 259-8226
BUILDING	NO COMMENTS	STACIE GUTIERREZ	(707) 299-1337
ENGINEERING	SEE COMMENTS	DANIEL HORNETT	(707) 299-1358
ENV HEALTH	NO COMMENTS	KIM WITHROW	(707) 251-1075
FIRE DEPARTMENT	NO COMMENTS	ADAM MONE	(707) 299-1466
PUBLIC WORKS	SEE COMMENTS	AHSAN KAZMI	(707) 259-8370

Planning Division

Please clarify or provide the following information:

1. Previous Comment #4 - Hospitality Areas – Use Permit Modification #98122-MOD, identified that the area used for Public tastings was limited to 1,000 square feet and required signage restricting the areas. Please show on the plans, the areas that will be used for public tastings. While this area can be relocated, it cannot be expanded beyond the 1,000 square feet and must be clearly identified.

   Response to Applicant Resubmittal – Based on discussion with County Counsel, per County Code Section 18.16.020.I, because the winery was authorized to conduct public visitation, the winery can continue the permitted visitation levels, provided that the winery does not expand the extent of the use or the structure(s) containing the uses. Additional hospitality areas can be

added through the use permit process, but those areas must be used in a way that complies with the current regulations which require visitation to occur by appointment. As noted in the original comment #4, the area used for public visitation is limited to the previously identified total square footage, however, that could be relocated or redesigned. Additionally, you could request to revise your visitation to remove public visitation. If all visitation is by appointment there does not need to be a separation of spaces for visitation types.

2. Previous Comment # 10. Does the winery currently have any sources of amplified outdoor music, i.e. outdoor speakers? If so, does the winery intend to continue using them?

   Response to Applicant Resubmittal – Staff is reviewing the project history. Continued or expanded use of outdoor speakers may require a noise analysis to be included in the CEQA document. It should be noted that the WDO restricted allowance of amplified music as a mitigation measure and the restriction was subsequently adopted by the Board of Supervisors as a standard condition of approval for winery projects.

3. Previous Comment # 15.Traffic MOA

   Response to Applicant Resubmittal – Submit the Traffic Impact Study to the Planning Division and staff will route it to Public Works Division for review.

4. Previous Comment # 16. Supplemental reports note that the water system will be improved to serve the western property. Provide information on the necessary infrastructure improvements, how the system will reach the adjacent property, and any work in the creek setback. See Environmental Health Division comments.

   Response to Applicant Resubmittal - Please provide additional information regarding the proposed construction process of the directional bores going under the Napa River so staff can determine whether or not this issue would be subject to our Conservation Regulations and therefore require a Use Permit Exception. This information will also be used in the environmental analysis of the project. With this information, please provide any documentation that you have had with State or local resource agencies concerning special permits required (e.g., Department of Fish and Wildlife, Regional Water Quality Control Board, Army Corp of Engineers). These agencies will be provided a copy of the environmental document for review and comment.

5. Previous Comment # 21. Previous Conditions of Approval. Please review the previous permit conditions and request any you would like removed or that conflict with the current proposal.

   Response to Applicant Resubmittal – See response #1 above.

6. Previous Comment # 23. Variance Application P19-00098. Based on review of the winery's project history, a Variance is necessary to approve the expansion of the Estate House within the 600-foot winery setback.

Response to Applicant Resubmittal – The updated Variance application has been reviewed and staff has determined that additional justification is necessary in order to support the request.

Special Circumstances and Hardship - Staff acknowledges that the road setback and flood zones do represent special circumstances that make the Eastern property difficult to develop and remodel. However, a major component of the project includes new development on the Western property, therefore the claim that including the development on that property is a hardship is difficult for staff to support. As noted in the Variance application packet, profit motive, practical difficulty, and operational efficiencies have value and are desirable from a planning perspective, but these factors are legally irrelevant when considering a variance application.

Parity and Preservation of Property Rights - The property already has a winery on it and is proposing to expand the winery on the other side of the property. Not permitting the expansion on the Eastern property does not restrict the winery from further modifying their overall development. While the winery itself and nearby wineries may have been granted variances in the past, the application packet also notes that it is not a valid legal argument that a neighboring property received a variance in the past.

Building Division

1. No comments.

Engineering Services

1. Note that the proposed improvements to the Estate House will likely trigger the Substantial Improvement provisions of Napa County Code Chapter 16.04.680. The substantial improvement determination will require that the entire structure be made to be compliant with the conditions of Chapter 16. Per a floodproofing certificate provided to this office in 2016, the estate house was floodproofed to the elevation 243.1' NAVD88 based on a Base Flood Elevation of 241.9' NAVD88. This BFE was determined using best available County data at the time. The memo provided by Schaaf & Wheeler determines a flood elevation at the estate house of 242.2. Therefore, floodproofing must be provided to at least 243.2' NAVD. A new floodproofing certificate and Elevation Certificate for the entire structure will be required at final of the building permits.

Environmental Health

1. No comments.

Fire Marshal's Office

1. No comments.

Public Works

1. Submit the Traffic Impact Study to the Planning Division to be routed to Public Works for review.

Please be aware that this is an identification of information known to be necessary at this time to continue processing of your application. Further review of your project may necessitate the request for additional information, including supplemental reports in the event County staff determines that submitted reports have been prepared in a manner inconsistent with County protocol or otherwise inadequate for the purposes of application processing and evaluation under the California Environmental Quality Act (CEQA).

Thank you in advance for providing the above material. Please insure that all revised plans, reports, or other resubmitted documents are clearly marked "revised" and dated. When you are ready to submit a full resubmittal responding to all comments and requests for additional information, please contact me for instructions on use of the Napa County File Sharing website.

Please be advised that failure to provide the responsive information requested above, within 120 days of the date of this letter, shall cause the application to be deemed "abandoned" in accordance with Section 401(b)(2) of Napa County's Local Procedures for Implementing the California Environmental Quality Act, unless the Planning Director grants a request for an extension to that deadline as also provided in the Procedures. Once an application is deemed abandoned, County staff will do no further work on the proposed project without submission of a new application and payment of new fees.

You must be in compliance with the scope of your current entitlements at all times. While your application is in process you are not authorized to anything beyond your current entitlements. You should not begin the activities requested under this application until you receive approval.

If you have any questions about this letter or other matters relating to your application, please feel free to contact me at (707) 259-8226 or by e-mail at Emily.Hedge@CountyofNapa.org.

Sincerely,

Emily Hedge

Emily Hedge
Planner III

CC: Matt Dexter via email: mdexter@duckhorn.com

APPENDIX F

Cove Hydrology Tech Memo

Schaaf & Wheeler
CONSULTING CIVIL ENGINEERS
30 years of excellence, commitment and value

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DRAFT MEMORANDUM

TO:	Roger Leventhal, PE	DATE:	November 11, 2015
FROM:	Dan Schaaf, PE	JOB#:	MARN.01.15
SUBJECT:	Development of a Design Storm Hydrologic Model		

Purpose

A design storm hydrologic model is used to estimate peak discharge and volume of runoff during different frequency storm events (e.g. the 100-year design storm or the 10-year design storm). It should be noted that a design storm is a hypothetical storm and is not an actual rainfall event. Therefore, this type of model cannot be used to replicate a specific event in time. Once calibrated, a design storm hydrologic model can be used to study the effect of changing land use or cover on peak discharge and/or volume, and analyzing the effects of the change in storage on downstream discharges and volumes of runoff. It is important to note that a design storm hydrologic mode only provides an estimate with an inherent error. The model is not a perfect representation of the hydrology of the watershed. It is best if the error can be established for the hydrologic model so that those using the model can plan factors of safety into designs. Common errors of hydrologic models range in the plus or minus 20% to the plus or minus 30% or greater range.

The design storm hydrologic model is composed of three basic parameters – a design storm, rainfall runoff procedure, and runoff response. These parameters do not include the combining and hydraulic routing of individual hydrographs in a downstream direction in any large watershed.

Design Storm

The first basic parameter of the design storm hydrologic model is the design storm itself. It is best to use a statistically based balance storm with the pattern based on an actual rain storm event. The statistics for each duration in the design storm must be determined. A design storm will have no zeros in it. That is, there will not be periods of no rain. This is not possible with a continuous statistical curve of rainfall for various durations. An intensity-duration-frequency curve (IDF curve) is a good graphical representation of this because there are no gaps in an IDF curve.

The duration of the design storm should take into account historic rainfall patterns, available statistics, watershed size and future applications of the hydrology. Most watersheds in Marin County have times of concentrations much less than 24-hours. Urbanized areas can have times of concentration less than 15 minutes while tidal cycles are roughly 12 hours. Longer duration storm events allow for the analysis of storage facilities such as reservoirs, detention basins and pump station wet wells. A 24-hour rainfall duration is appropriate for nearly all drainage and flood control applications in Marin County. This mirrors the design storm duration of Santa Clara County, Yolo County, Alameda County, and Contra Costa County.

The design storm must be able to be transposed to various parts of the watershed. There are several methods for transposing rainfall. The Mean Annual Precipitation (MAP) is often used to transpose the

storm over various watersheds if MAP data is readily available. If this is the case then the rainfall statistics must be related to the MAP. Unfortunately, NOAA does not provide a MAP. In many cases the depth of rain for any duration will vary as a function of MAP. For shorter durations this relationship may not hold. This relationship must be investigated.

If the NOAA Atlas 14 statistics are used, there still needs to be a way of determining the appropriate rainfall for any watershed area. The most common and simplistic way is to find the centroid of the watershed and determine the statistics from NOAA Atlas 14. But, depending upon where the centroid is located, the value at the centroid may not equal the average of the rainfall over the watershed. For example, in steeper terrain the upper part of the watershed may have far more rainfall than the lower part of the watershed. It is possible to use GIS data from NOAA to average the depth over an area, but this has to be done for every duration (e.g. 5-min, 15-min, 30-min, 1-hour, etc.). Some methodology must be developed to accurately determine the average rainfall over any given watershed.

The spacing of the time steps in the design storm is also a factor for consideration. Generally, the rainfall time spacing must be in the range of one-third to one-fifth of the time of concentration or the lag time. If only large watersheds are to be considered with a time of concentration of about 2 hours, then a design storm broken into 15-minute intervals is sufficient. However, if very small watersheds with times of concentrations of 30 minutes or less are to be considered then the design storm must be broken into 5-minute intervals. Some thought must be given to how the model is to be used.

Another consideration for the design storm is the Area Reduction Factor (ARF). This factor takes into account the improbability of having the same frequency storm over larger and larger areas. The U.S. Army Corps of Engineers (USACE) in past work have often determined an ARF for watersheds in which they have developed standard project floods. NOAA also has an area reduction factor; however, it appears somewhat biased toward rainstorms in the middle of the country rather than on the West Coast. Generally, area reduction factors come into play when drainage areas exceed approximately 50 square miles. It is also true that some hydrologic models do not include area reduction factors, even with areas up to 300 to 400 square miles. The area reduction factor is a consideration for development of the design storm.

Rainfall-Runoff Procedure

The second basic parameter in the design storm hydrologic model is the rainfall-runoff procedure. There are many procedures used in practice. One that was mentioned in the January 22, 2014 memo was a loss rate function that included an initial loss followed by constant loss rate. This is a fairly standard loss rate function. Another typical loss rate function is based on the Soil Conservation Service Curve Number and Antecedent Moisture Condition system (now National Resource Conservation Service, or NRCS). There are many other loss rate functions however; the initial and constant loss rate and the SCS procedure are the most common.

The parameters for the loss rate function should be based on physical parameters such as soil type and land cover. Generally, a literature search of nearby hydrologic models will provide a starting point to relate loss rate parameters to land use, land cover and impervious surface. The impervious surface parameter can be estimated based on land cover type or GIS information. However, care must be taken to know whether the impervious surface is total impervious surface or directly connected impervious surface. Most hydrologic modeling software such as HEC-HMS requires the input of directly connected

impervious area not total impervious area. The procedure must be developed to estimate the parameter to be used in the loss rate calculations.

Runoff Response

The third basic parameter in the design storm hydrologic model is the runoff response. Usually this means a unit hydrograph. Some unit hydrographs are one-parameter graphs. An example is the SCS shaped unit hydrograph. The only input parameter is lag. Other unit hydrographs are two-parameter graphs. The Snyder Unit Hydrograph uses lag and a peaking factor. The Clark Unit Hydrograph uses time of concentration and a storage parameter. While the time parameter – lag or time of concentration – is based on physical parameters such as slope, length of watershed main stream, and roughness; the second parameter has little or no physical meaning. The basic way to determine the second factor is to reconstitute a variety of storm events and calibrate the second factor to match the gauged hydrograph. The best estimate of the second parameter is then related to physical parameters as best as possible. In some cases any fit of physical parameters to the second unit hydrograph parameter has shown so much scatter that, at least in the case of the state of Iowa, the second parameter is simply fixed once and for all. If this is done the Clark and Snyder unit hydrographs essentially becomes a one-parameter hydrograph based on some type of response time for the watershed to drain to the point in question.

Calibration

The actual calibration of the design storm hydrologic model takes place in two steps. The first step involves reconstituting runoff hydrographs from a variety of actual storm events. This type of reconstitution is sometimes aided by the use of radar rainfall. The most important parameter to determine during these reconstitutions is the lag or time of concentration. Once it looks like the timing of the peaks is approximately correct the lag time may be assumed to be sufficiently accurate to continue.

The second step in the calibration is to locate nearby stream gages with long-term records (ideally 30 years or more of record). These watersheds need to be able to have a log-Pearson Type III statistical analysis done on the stream gauge records for instantaneous peak discharge as well as for volume of discharge for various durations. The gauged must be in compliance with Bulletin 17B guidelines. These guidelines will eliminate streams on which there are large storage facilities, streams that are subject to the effects of urbanization, and streams that have greatly modified conveyance systems.

Once the statistics are complete for each of the gauge records, the hydrologic model is applied to each watershed. The watershed is taken as a whole and is not subdivided into pieces because this calibration is for hydrologic parameters not hydraulic parameters for the interior drainage. The usual procedure is to vary the loss rates based on physical parameters such as soil type so that the peak discharge matches the peak discharge from the gauged statistics. The time of concentration or lag parameter has already been calibrated and is thus not changed at this time, only the loss rate. This is done for all of the gauged watersheds. Of course it is not possible to precisely hit the gauged discharges with a model at every storm. This will necessarily lead to an estimate of the standard error of estimate of the design storm hydrologic model. If such calibration is done on only one gauge record statistics it is not possible to estimate the standard error. It is best to have at least three stream gauge records and their corresponding statistics so that a better estimate of this standard error can be determined. It should be noted that when calibrating loss rates, it can be expected that loss rates will vary with return period (e.g. losses for the 2-year storm event will differ to those of the 100-year storm event).

Conclusion

Development and the calibration of a design storm hydrologic model is a somewhat time-consuming, exciting and often frustrating assignment. However, if good data are used the results can be very useful for future planning in project design. The best results include an estimate of the standard error of the hydrologic model.

APPENDIX G

Modeling Files (electronic)

APPENDIX H

Task Force Meeting Notes

Flood Management
&
Drainage Task Force

Location: Mill Valley City Hall, Council Chambers
Date: November 5, 2019
Time: 1pm – 2:30pm

Meeting #1 Summary

Attendees: Robin Lee, Emily Straley, Andrew Poster, Stephanie Moulton-Peters, John McCauley, Garry Lion, Jim Revoir, Nona Dennis, Matt Cramer, Hugh Kuhn, Jim McCann

1) TASK FORCE GOAL

a) The goal of the Task Force is to assist the City in bringing choices to the community with regard to drainage improvements and flood management strategies, estimated costs and funding options in conjunction with the development of a Master Plan.

2) WHAT WILL THE MASTER PLAN REPORT INCLUDE

a) Analysis looks at pipes draining into the creeks and the creek system flowing through Mill Valley City limits. Areas outside the City limits that drain to City systems is analyzed although improvements outside City limits will not be considered.

b) Modeling of the Creek results using Stetson Engineers models. While they are no longer involved in the project, their models and reports were used as the starting point for the master plan.

c) The creek has not been surveyed and it's understood that the creek bed is dynamic and the invert elevation and capacity changes over time due to sedimentation and scour. The model represents a snapshot of the creek and is used to develop conceptual projects. Detailed design is not part of the Master Plan but will be required as projects are developed and the model can be refined at that time.

d) Discussion on climate change impacts due to sea level rise and due to precipitation changes.

e) Range of projects to achieve a determined level of service and the associated costs of the projects. The list of projects will also be prioritized based on urgency, costs, environmental impacts, and number of properties protected by each project.

f) The Master Plan will identify projects and associated costs that the City could use to develop a fee. This process needs to be timed correctly to not interfere with Zone 3 fee measures.

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3) TYPES OF PROJECTS TO CONSIDER

a) Retention/detention will be considered as improvements. Retention means storing water with no outlet, it drains through infiltration and evaporation. Detention is storing water with a metered outlet to the drainage system to reduce peak flow rates. The hydrologic and hydraulic model is an unsteady 2D model capable of analyzing the impact of storage.

b) Storing water and infiltrating water will be considered when developing CIPs.

c) Mill Valley has 61 miles of street and 15.7 miles of storm drain pipe. The streets can be used to convey stormwater if there is curb and gutter. Many streets do not currently have curb and gutter so stormwater runs off into private property.

4) TECHNICAL BACKGROUND

a) Flood Zone 3, which Mill Valley is a part of, is funded by a parcel tax. The City has a funding opportunity but needs this master plan to determine what projects should be built.

b) The "Southern Marin Watershed Guide: Planning for Floods" can be found here: https://www.marinwatersheds.org/resources/publications-reports/southern-marin-watershed-guide-planning-floods-0

c) Mill Valley does not currently have explicit standards for level of service. Pipes in the Bay Area are typically sized to convey the 10-year storm event with the 100-yr conveyed in the creeks. Next meeting S&W will bring some results to further this discussion and determine a level of service.

d) A series of solutions that have been vetted to make sure they are acceptable aesthetically, environmentally, and financially could be developed before presenting to community.

e) Mill Valley currently has a 30' creek setback for new development, but there is not a way to remove private structures that encroach on the creek. Perhaps this gets back to the recommendations for what residents can do to protect themselves from flooding when the City does not have jurisdiction.

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5) OPEN DISCUSSION

a) What is the main problem we're trying to fix? It's possible that water is coming down from the hills too fast? Once the problem is understood then projects can be developed.

b) A discussion of what property owners can do to help address flooding? Such as building walls along the creek with a pump station to drain backyards or other suggestions.

c) Perhaps the level of service can be set by figuring out how much money can be acceptably requested from residents which can be determined through a survey. It's possible that a tax or fee for flood preventions can be combined with a fire tax or fee.

d) Focus areas should include Sycamore Park Neighborhood, Upper Miller Avenue, Lower Miller Avenue, Bayfront, Alto Sutton Manor Neighborhood, and Tam Park.

e) Perhaps residential flooding can be addressed through policies such as providing sandbags or giving homeowners information on flood proofing/dry proofing. Subsidies could be used to encourage implementation.

f) Master plan should include a section on what maintenance activities help prevent flooding, such as sediment removal.

g) Green infrastructure, such as underground detention in parks, should be considered. May be possible to partner with other entities such as schools. It's a touchy subject so will need to be fully vetted before presenting to the community.

h) Can fire and floods be considered together? Or model the floods like FireSafe Marin.

6) NEXT STEPS

a) Schaaf & Wheeler (S&W) will review the Coyote Creek study that the flood control district is currently completing to make sure we're using similar climate change forecasts.

b) Flood Zone 3 requested that any funding or ballot measures be coordinated so there aren't duplicated efforts and competing funding requests.

c) The Committee requested S&W to model 2-year, 10-year, 25-year, and 100-year storm events and send out results prior to the next meeting. However, following the meeting, S&W and staff reviewed the request and as S&W are scoped to model a single level of service and develop a

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capital improvement program with associated costs based on those results. In order to keep this project moving forward without requiring Council action and a budget adjustment for added scope, S&W will develop thematic maps to show flood impacts from different storm events. The group will then discuss options and how to select level of service.

d) S&W will prepare discussion points and analysis results to get a better understanding of private property impacts.

e) The frequency of recent storms, such as 2005 and 2017, will be determined and presented with photos so that an understanding of level or service can be gained.

f) A list of projects previously developed and considered will be made.

g) S&W will tour the Sycamore and surrounding areas, during a rain event or high tide/low tides. S&W has visited the area with City maintenance staff during dry weather and low tide.

h) Next task force meeting to be held in February prior to a community meeting.

Flood Management
&
Drainage Task Force

Location: Mill Valley City Hall, Council Chambers
Date: February 13, 2020
Time: 10am – noon

Meeting #2 Summary

Attendees: Andrew Poster, Hannah Lee, Robin Lee, Emily Straley, Chuy Beltran, Tony Boyd, Jim Revoir, Richard Rider, Roger Leventhal, Hugh Kuhn, Matt Cramer, Gary Lion, John McCauley, Tricia Ossa, Stephanie Moulton-Peters, Linn Walsh

1) TASK FORCE GOAL

a) The goal of the Task Force is to assist the City in bringing choices to the community with regard to drainage improvements and flood management strategies, estimated costs and funding options in conjunction with the development of a Master Plan. The focus of the Study is on the City owned infrastructure.

2) FLOOD THREATS INCLUDED INTO THE MASTER PLAN

a) Piped infrastructure – undersized pipes

b) Creek System – undersized creek systems – focus is on ACMDP and Warner Creek that were the basis of the Stetson Study

c) Bay Tides – historical tides are used in conjunction with the Creek model

d) Sea Level Rise – County Reports and regional efforts are reviewed, and results and improvements presented.

3) SUMMARY OF PIPE MODEL ANALYSIS AND RESULTS

a) **Pipes** were analyzed under "Creek Full" and "Creek Empty" scenarios. The Creek Empty scenario model was used to identify undersized pipes that increasing the pipe size would alleviate the flood threat. The Creek Full scenario was used to identify pipes that need the Creek to be fixed in order to alleviate those pipe threats.

b) There is just over one mile of pipes to be improved under the 10-year model run. This would come at an estimated cost of approximately **$3M (includes design, permitting, and construction contingencies)**.

c) Suggest that in addition to pipe improvements, the Master Plan discuss areas that should have flap gates installed or improve flap gates performance. Schaaf & Wheeler will work with Tony and team to develop a database of flap gate locations to draft a plan.

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d) Consultant also did some CCTV inspections and has identified pipes that require maintenance or improvements due to condition. These projects will also be a part of the Master Plan.

4) SUMMARY OF CREEK MODEL ANALYSIS AND RESULTS

a) **Creek** model was run with and without bridges for a 10yr event to analyze the capacity of the channel alone and then bridge constrictions. Creek model was also run without Warner Creek to simulate upstream detention on the golf course.

b) Both the ACMDP and Warner Creek have less than 10-year capacity. The overflows from Warner travel down Sycamore Street and the overflows from ACMDP travel down Miller Avenue.

c) Removing Warner reduces flooding along Sycamore, but not the flooding from ACMDP.

d) Spill volumes for a 10yr event are very large, on the order of 100-ft of water on a football field. Upstream detention in the form of rain barrels is not enough (100+ per parcel).

e) Stetson Report includes **$20-30M** of infrastructure improvements to meet a 10-year level of protection. This estimate does not include land acquisition costs which are challenging to determine, but are expected to be very high.

5) SUMMARY OF BAY TIDES AND SEA LEVEL RISE

a) The County has conducted studies on sea level rise in the Bay and identified vulnerable structures impacted by future sea level rise.

The Richardson Bay report shows projects that Mill Valley could construct to protect just Mill Valley or regional projects such as large tide gates under highway 101 that would protect all the communities around Richardson Bay.

6) SUMMARY OF SUGGESTED IMPROVEMENTS

a) There is not one project that solves all the flood threats in the City. There are areas of only one flood threat, however, in the low lying neighborhoods closer to the bay, there are pipe, creek, and tidal issues that could only feasibly solved by combining multiple projects.

b) Improvements need to be conducted in a manner that makes sense such as increasing creek capacity prior to increasing pump into the creek.

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c) Building walls needs to be done holistically throughout the entire reach of the creek sections with limited capacities and not at just sporadically some locations otherwise conditions could worsen elsewhere.

d) Designing to 100-year level of protection is beyond engineering capabilities and funding. Instead, the Master Plan may have to look at more programmatic alternative such as better sand bag programs, more educational materials for those living on and owning the creek, searching for ways to maintain the Creek such as beginning the permitting process to clear the creek of debris and silt built up over the years (aka "the D word")

e) PIPES (in order of priority)

i) Maintain and repair and/or replace pipes in poor condition

ii) Upsize pipes that are undersized in the Empty Creek Model

iii) Raise curbs in order to convey overflows in streets without impacting structures

iv) Add/repair flap gates

v) Add pipes and catch basins where infrastructure is needed

vi) City to provide ongoing drainage support to the localized drainage problems that are regularly reported. Perhaps more can be recorded and obtained at Community Meeting. For localized drainage issues that are private responsibility the City will coordinate with County Program for private pipe assistance or develop own program.

vii) Increase capacity at Sycamore and/or Ryan pump stations- this needs to be done in conjunction with increasing Creek capacity. The City is currently performing a condition assessment on the Sycamore Pump Station.

f) CREEKS

i) Improvements such as flood walls aren't feasible unless the City acquires land to build and maintain walls. Instead, solutions and improvements should focus on projects that can be constructed within the City right of way and owned property.

ii) The construction of Miller Avenue set aside an area for construction of a bypass, this will be further analyzed and appears to be more viable option than dams.

iii) Consider educational program for residents that own and have property that is along the Creek

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iv) Areas of the Creek impacts by tides also need to consider tidal barriers to hold back high tides

v) Consider the use of the floodplain and use streets as conveyances for spills out of the Creek. City already owns, much less expensive then underground culverts.

g) RICHARSON BAY

i) Sea level rise impacts are in the future, thus the City could consider supporting the regional projects rather than constructing improvements on their own, but the Task Force has concerns on the timing/funding of regional solutions.

7) MEETING TAKE AWAYS

a) The Task Force seems to generally agree that the Master Plan should aim for a 10-year level of service, or protection against the storm event that has a 10% chance of occurring each year.

b) It is worth studying the Miller Avenue bypass

c) The Master Plan should somehow mention the private pipes and the problems that they can create while also explaining the City's role in maintaining the larger infrastructure in the public right of way

d) Projects should be assessed and address the following goals:

i) Visual

ii) Environmental

iii) Costs

e) Community Meeting will need to present focused list of projects

f) Willow is the former edge of the Marsh. Might be worth presenting an image at the Community Meeting to show where the Bay once was

g) While it is understood that dredging the Creek is a permitting challenge to overcome, actions should get underway now to start the process so that ultimately the channel capacity can be increased

h) Confirmed that Mater Plan can go straight to City Council and does not need to go to any Board/Commissions

Flood Management & Drainage Task Force

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8) NEXT STEPS

a) Schaaf & Wheeler will analyze:

i) Creek model with no tidal boundary

ii) Miller Ave Bypass in more detail

iii) Upstream dam potential storage to see if worth investigating more

iv) Develop improvement list to review with Task Force and for presenting to Community Meeting

v) Develop DRAFT Community Agenda and Presentation Outline to share with the Task Force

b) Next Task Force Meeting late March/early April

c) Community Meeting April/May

d) Draft Master Plan send to Task Force – June/July

e) Task Force Meeting and Financial Planning – end of June

f) Present Draft to Flood Zone 3 Advisory Board – July/August

g) Present Draft to City Council – Aug/Sept

h) Finalize Master Plan – Oct/Nov

i) Financial firm start work on financing options and strategies

Flood Management
&
Drainage Task Force

Location: webcast
Date: March 26, 2020
Time: 9am – 11:30am

Meeting #3 Summary

Attendees: Andrew Poster, Robin Lee, Emily Straley, Tony Boyd, Richard Rider, Roger Leventhal, Hugh Kuhn, Matt Cramer, Gary Lion, John McCauley, Stephanie Moulton-Peters, Linn Walsh

1) TASK FORCE GOAL

a) The goal of the Task Force is to assist the City in bringing choices to the community with regard to drainage improvements AND flood management strategies, estimated costs and funding options in conjunction with the development of a Master Plan. The focus of the Study is on the City owned infrastructure.

2) HISTORICAL MAP OF MILL VALLEY

a) This slide was not highlighted during the presentation but is in the PDF that was sent out. It shows how the Bay used to exists all the way into the Sycamore neighborhood.

b) It was discussed at Meeting #2 that this should be provided at the Community Meeting

3) CREEK SYSTEM IMPROVEMENT PROJECTS

a) **Dams**

i) Grove Park – 9.2 acre-ft

ii) Old Mill Park – 13.5 acre-ft

iii) The group discussed the idea of multiple smaller dams such as those that were used historically for fishing. But the group agreed that those will be full when the storm peak comes through and water will just overflow the dams.

iv) Ultimately the task force decided to move away from dams as an option because the costs are high, the environmental impact is high, and the benefit is low.

b) **Partial Bypass on ACMdP near Willow**

i) This was the selected alternative in the Stetson Report over the full bypass to the Marsh.

ii) The partial bypass puts water back into the channel just downstream of La Goma Street

iii) While the partial bypass does improve flooding, it does not improve the Sycamore neighborhood.

c) **Full Bypass down Miller Ave to Marsh near Mt Tam High School**

i) This alternative improves the flooding significantly more than the partial bypass because it does not have the overflows re-enter into the Creek

ii) Stetson Report suggested a 4.5ft by 10ft culvert but upon further modeling it was determined that a 4.5ft by 20ft culvert solves the majority of the flooding along Miller Ave

iii) This alternative assumes that there would be a pump at the outfall into the Marsh to allow peak flows during high tides to enter into the Bay

iv) Unit costs for construction the box culvert are around $2,000 per liner foot. The box culvert needs to travel approximately 4,300 ft for a price tag of $8.5M.

v) The pump station would need to convey a peak flow rate of 600cfs for an approximate cost of $12M.

vi) Price tag of culvert plus pump station alone is close to $20M. Schaaf & Wheeler will work to detail out the entire cost for this project to present to Task Force at next meeting.

d) **Warner Creek Bypass**

i) Stetson Report recommended a 4.5ft diameter pipe to run down East Blithdale to the Marsh.

ii) This bypass pipe reduces the flooding in the Sycamore neighborhood significantly when paired with the ACMdP bypass pipe down Miller Ave.

iii) The unit pipe cost is approximately $750 per linear foot and the pipe needs to travel approximately 4,700 feet to the Marsh for an estimated construction cost of $4.7M

iv) Pump station conveying peak flow rate of 60cfs would be on the order of $1.2

v) Total for the Warner bypass is in the $6M just for the culvert and pump.

vi) It should be noted here that the Warner Bypass needs to be done in conjunction with the Miller bypass because the Warner bypass is to prevent overflows into the Sycamore neighborhood and the Miller Bypass prevents spills down Miller Ave and reduces the water surface elevation in ACMDP which helps Warner drain better.

4) **SEA LEVEL RISE STRATEGIES**

a) Recommendation is to include both the Mill Valley only protection (levees, horizontal levees, etc) and regional projects (large tide gates) into the plan.

b) The idea is that having projects mentioned in Master Plan will strengthen both.

c) City will look for grant opportunities for the horizontal levee approaches or ecotone slopes.

d) More details can be located here on horizontal levee and habitat enhancing flood protection work that the County is doing

e) https://www.marincounty.org/-/media/files/departments/cd/planning/slr/baywave/vulnerability-assessment-final/demo-projects-booklet-ada-final.pdf?la=en

5) **RAISING HOMES**

a) Marin County received a grant to raise 16 smaller homes throughout the County

b) Based on the grant receive (no actual costs yet), it is estimated the cost to raise a home is about $230,000. This price appears to be on the high end and could potentially be reduced perhaps if multiple homes contracted with same contractor to do the work in a similar timeframe.

c) The grant application stated that these costs did not include all the restoration to connect utilities and access to the home.

d) Any raising of homes would be to the height of 1-ft above the mapped BFE (base flood elevation) plus SLR (sea level rise) which could be anywhere from an additional 1 foot to 3 feet (use 1.5’ for now).

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e) Each house will differ based on BFE (which can be identified on the link below) but will be somewhere around height to raise home = BFE +1' + 1.5' – existing house elevation

f) https://msc.fema.gov/portal/home

g) For example- houses in the BFE 11ft Zone along Plymouth would need to be at elevation 13.5ft (NAVD datum)

h) Based on Google Earth, it appears as though the ground is around 10-ft elevation. So those houses would need to be elevated 3.5ft

i) During the 05/06 storm even it appears as though roughly 140 properties reported damage. However, it should be noted that damage may have been a car or just in the garage. This number is much higher than the FEMA claims as only those with flood insurance could make FEMA claims.

j) From GIS exercise there are 976 building footprints within the FEMA 100-year flood zones. Not all of these are residential, and are inclusive of detached garages. There are roughly 930 residential parcels within the FEMA mapped flood zones.

6) The idea of raising homes was presented again for a comparison of the cost of raising homes to the larger capital improvement projects like the large bypass culverts. For comparison:

   i) 25 year protection - 60 homes would be $13.6M

   ii) 10 year protection - 14 homes would be $3.2M

7) **DRAINAGE IMPROVEMENTS – the "low hanging fruit"**

a) There are numerous projects that the City would start implementing such as:

   i) Upsizing pipes that are creating local drainage issues throughout the City

      (1) Modeling results show 17 pipe projects that could be implemented now.

      (2) Upsizing these pipes removes water from the streets and conveys the water through pipes. These improvement projects should not change the Creek modeling results.

ii) Standard maintenance program to replace corrugated metal pipes (CMP) that are corroded.

iii) Repairing pipes that have holes, cracks, defects, etc and CCTV more pipes each year to replace failing pipes before they cause sinkholes

iv) Cleaning pipes that have buildup of sediments and debris that can limit hydraulic capacity of pipes. The model assumes pipes are clean so any sediment and debris buildup could be causing drainage issues that would not be identified in a mode

v) Raising street curbs to contain water in the street and direct it to the nearest drain inlet

(1) This was presented in both low lying neighborhoods such as the Sycamore neighborhood and in the hillside streets where there are no curbs

(2) It was mentioned that raising curbs within the Sycamore neighborhood would not solve the flooding problems because there is just too much water

vi) Repairing and adding flap gates to prevent the Creek backflowing into neighborhoods

(1) The City already has 5 flap gates, of which 3 don't operate properly so could be replaced by different product such as the Check Mate or moved upstream in system so they are not impacted by sediment.

(2) https://www.redvalve.com/tideflex/tideflex-products/checkmate-inline-check-valve

(3) There are also locations in the Sycamore neighborhood stretch of the ACMdP that need flap gates because the Creek is backing up into the neighborhood, based on MarinMap it appears as though roughly 5-6 outfalls could use flap gates. Schaaf & Wheeler intends to walk the creek post COVID to identify locations for additional flap gates.

8) **FURTHER RESEARCH AND ANALYSIS**

a) More detailed cost information on the proposed full bypass and Warner Creek bypass

b) What benefit does the bypass have on larger storms like the 25-year event

c) More research into dredging

i) Timeline

ii) Increase in capacity

iii) Costs

d) Is there a way to divert flow from Warner Creek to ACMdP above Willow so that the Warner bypass is not necessary and Miller bypass solves both flooding issues

e) Community Meeting will need to present focused list of projects

f) What is the cost to raise curbs

g) What is the cost for flap gates

i) Need to identify how many locations require

ii) Need to identify potential replacement for ones that are not working

9) **MEETING TAKE AWAYS**

a) There is not one project that solves all the flood threats in the City. There are areas of only one flood threat, however, in the low lying neighborhoods closer to the bay, there are pipe, creek, and tidal issues that could only feasibly solved by combining multiple projects

b) The costs of the bypass pipes will be in the multiple millions, if not hundred millions

c) For comparison, similar sized jurisdiction of Moraga went for a storm drain fee on a $26M capital improvement plan. The average fee was about $120 a parcel. During polling it appeared as though the community was willing to pay, but the measure did not pass by a narrow margin.

d) In general, storm drain and flooding measures are hard to pass throughout the state. Novato did not pass Measure E which was a parcel tax to help pay for flood control projects. It was an annual fee of $47, which would raise $1.1M annually for a total of $19.8M over the course of 18 years.

e) Perhaps the Sycamore neighborhood needs a “surgical approach” by stopping the incoming flow entering the neighborhood and pumping out water to the Bay.

Location: webcast
Date: March 26, 2020
Time: 9am – 11:30am

f) Dams are not worth researching further, but will be presented to the community to show they were considered and why they were removed.

g) Dredging is worth including and understanding how much more capacity can be achieved from dredging.

h) Focus on storm flooding and not SLR

i) Consider breaking the study into two parts – one that focuses on the City's storm drain infrastructure (pipes, manholes, pump stations, flap gates, etc) and another part that focuses are the larger flood threats from the Creeks and the Bay. The two studies would be:

   i) Storm Drain Master Plan – this report could be finished by end of 2020

   ii) Flood Mitigation Strategies – this effort will take longer and require more meetings and discussions

10) **UPDATED SCHEDULE OF PROJECT**

a) Next Task Force Meeting late May – likely webcast depending on current shelter in place recommendations

b) Community Meeting late June if allowed, more likely will be held in Fall to avoid summer

c) Draft Master Plan send to Task Force – August/September

d) Task Force Meeting and Financial Planning – late September

e) Present Draft to Flood Zone 3 Advisory Board – October

f) Present Draft to City Council – November

g) Finalize Master Plan – December

h) Financial firm start work on financing options and strategies in 2021

Flood Management
&
Drainage Task Force

Location: webcast
Date: May 13, 2020
Time: 1pm – 3:00pm

Meeting #4 Summary

Attendees: Andrew Poster, Robin Lee, Emily Straley, Tony Boyd, Richard Rider, Roger Leventhal, Hugh Kuhn, Matt Cramer, Gary Lion, John McCauley, Tricia Ossa, Stephanie Moulton-Peters, Apryl Uncapher, Linn Walsh

1) HOUSEKEEPING

a) The Task Force elected John McCauley as Chair.

2) HISTORICAL MAP OF MILL VALLEY

a) These maps were presented to show the historical location of the Bay and marshes. Some of the areas that the Task Force is looking to protect from floods historically were located in the Bay or a salt marsh. These maps should be presented in community meetings to set the stage for how difficult it is to engineer a project to protect some of these areas.

3) OVERALL MEETING SUMMARY

a) Stetson studied the Creek from 2008 – 2017 and developed solutions that were too expensive for the City to pursue. In 2017, the City hired Schaaf & Wheeler hoping for a fresh set of eyes and to attempt to identify a simple solution that would be environmentally sound and more feasible in terms of costs. Schaaf & Wheeler has come to the same conclusions as Stetson; that the flooding issues are complex, caused by multiple sources, and there is no silver bullet that can mitigate all the issues within a reasonable budget. In addition, the Creek system itself is so undersized that most solutions require the City to buy easements and residents to give up all or portions of their backyards, which isn't something the Task Force expressed interest in pursuing.

b) Instead, the Task Force will be looking more into the "surgical approach" which will start at the end of the Creek with resolving small issues such as not functioning flap gates, dealing with high tides, and possibly dredging. Slowly, the work can proceed upstream. Issues higher up in the creek and watershed cannot be resolved until downstream

capacity limitations are resolved as sending more water downstream can remove flooding in one place and induce flooding elsewhere.

c) Task Force voted to separate the flood management and storm drain master plan (SDMP) into two separate reports in an effort to expedite budgeting and implementation of drainage repairs. However, upon receiving further input and ensuing discussions with the Chair and staff, it was decided that it is in the City's best interest to keep the two topics in a single Master Plan and Flood Mitigation Report as initially envisioned, in order to present both types of projects to Flood Zone 3 for consideration of comprehensive funding of addressing Mill Valley's flooding issues.

d) An outline of the proposed Community meeting and Report will be shared with Task Force members for soliciting their input mid June.

4) **DREDGING**

a) Justin Semion from WRA presented a summary of the process, timeline (Work only allowed between Sept 1 through Nov 30 and it takes about 2.5 to 3 years to receive approval to proceed. , environmental considerations, and costs to dredging (expected to be $3Million for the first year in Mill Valley, not including transporting and placement of the spoils/fill, which is often the most expensive part. The project would need to be repeated approx. every 5 – 10 years).

b) The increase in capacity is minimal as compared to the larger bypass systems presented. However, there could be some smaller benefits such as improved flap gate performance with dredging. Perhaps dredging is more of a maintenance procedure that is included into the SDMP.

5) **CREEK SYSTEM BYPASSES**

a) Two bypass solutions have been presented that address the <u>10-year storm event</u>

i) Warner Creek bypass 4.5-ft culvert down Blithedale - $10M – $12.5M

ii) ACMdP – 20' x 4.5' culvert down Miller - $36M - $45M

b) It was identified that if Warner Creek could be diverted into ACMdP near Fern Street, the Blithedale bypass (the culvert removing overflows from Warner Creek) would not be

needed, but the Miller bypass would still be required. Additionally, the Miller Bypass must be completed first, because the ACMDP does not have capacity at Willow Street to accept more flows from Warner Creek. No costs were presented for this alternative as it does require purchasing an easement between two parcels, or possibly the City acquiring both parcels.

6) **RAISING HOUSES**

a) While this flood mitigation strategy appeared unrealistic during the first meetings, based on the large costs for the bypasses which solve only the 10-year storm event, more research has been put into raising homes.

b) Schaaf & Wheeler presented a phased approach to raising the homes that were damaged during the 05/06 storm event, which has been deemed similar in nature to the 100-year storm event.

c) Homes would need to be raised about 2-3 feet to meet FEMA standards, and then some sort of Sea Level Rise (SLR) factor should be included as well.

d) The total for all three phases of raising homes was presented to show a comparison to the large bypass systems. All homes could be raised for less money than the Miller bypass alone.

e) Raising homes would address the 100-year storm event and rising tides, where are the large bypass culverts only solve the 10-year storm event and does not protect homes from rising tides.

f) Could be significant savings to homeowners in the floodplain as they would no longer be required to have flood insurance policies, savings on the order of $2-3k annually.

g) While raising homes would not be something the City would pay for, it is something that could be implemented by an Assessment District and a program that the City could support in ways such as providing no-cost permits to complete the work and staff assistance locating contractors and suggested SLR height to include into design.

h) It should be noted that some of the homes in the Sycamore neighborhood have already been raised above the floodplain. Any significant improvement requires homes in the

floodplain to elevate one foot above the mapped 100-year water surface elevation. But FEMA does not require any SLR height additions.

i) Raising homes may introduce other concerns or opportunities with the City's Planning process, in terms of maximum heights, volumes, etc. issues that would need to be considered and addressed.

7) **CITY BACKLOG OF STORM DRAIN WORK (to be included into SDMP)**

a) City currently has $0 set aside for storm drain maintenance projects. This is compared to annual funding of $1.8 for sewer maintenance projects.

b) As typical with most agencies, residents pay a sewer use fee, but do not pay separate fees for storm drains. Storm drains are not considered a utility and are hard to secure funding for due to Prop 218 requirements.

c) Novato and Moraga recently voted down stormwater fee measures, while the cities of Berkeley and Alameda passed stormwater fee measures.

d) City has the following backlog of work that could become the basis for the SDMP:

i)	Detailed Mapping of infrastructure	$150k
ii)	Upsizing undersized pipes	$7.5M
iii)	Repair/Replace/Rehab	$350k
iv)	Replace CMP	$8.5M
v)	Flap Gates	$75k

vi) Ongoing annual programs TBD

(1) Nuisance Drainage Issues

(2) Raising/Adding curbs

(3) Ongoing inspection and maintenance

8) **FURTHER RESEARCH AND ANALYSIS**

a) None Identified

Location: webcast
Date: May 13, 2020
Time: 1pm – 3:00pm

9) **NEXT STEPS**

a) Outline Community Meeting presentation for Task Force members to review and provide input

b) Draft Report outline for Task Force members to review

APPENDIX I

Storm Drain CIP Summary Sheets

A. Project ID: 1 | **B. Project Name: Camino Alto**

C. Project Location: Blithedale Ave. and Camino Alto

D. Priority: High

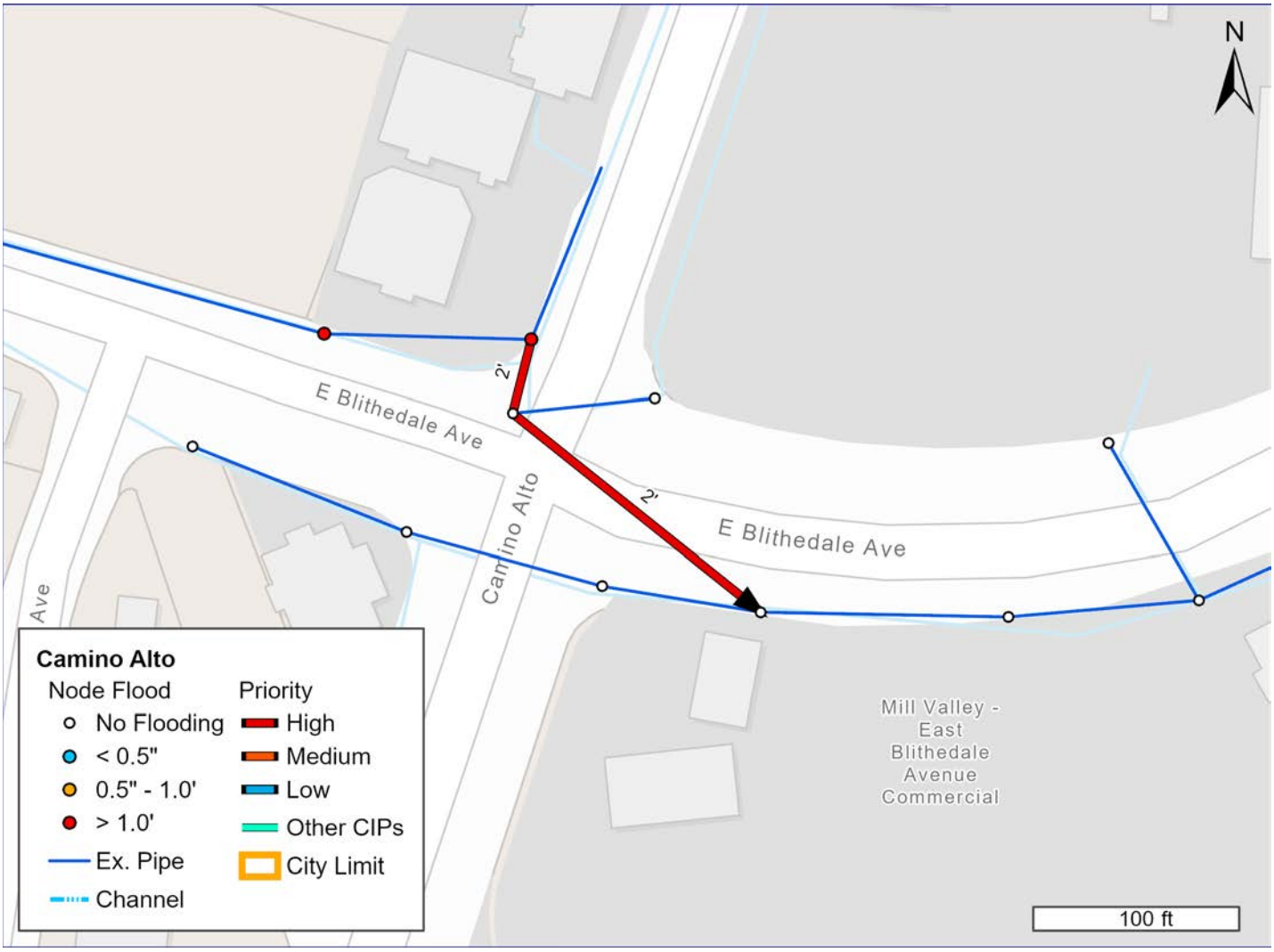
E. Type: Capacity

F. Project Description: Significant flooding occurs at the north-west corner of Blithedale Ave. and Camino Alto. Upsizing the pipes that cross under Blithedale will mitigate the flooding.

CIP Pipe Diameter (in)	Length (ft)
24	154
24	37

G. Special Considerations: N/A

H. Alternatives: N/A



A. Project ID: 1 | **B. Project Name: Camino Alto**

C. Project Location: Blithedale Ave. and Camino Alto

D. Priority: High

E. Project Cost:

MAJOR ITEMS	DIAM. (in)	DEPTH (ft)	QTY.	UNIT	UNIT COST	COST
BASELINE CONSTRUCTION COST						
Pipe Construction						
CIP Pipe	24	3	190	LF	$350	$67,050
Structures						
Manholes						$40,970
SUBTOTAL						**$108,010**
Mobilization/Demobilization					10%	$10,800
Traffic Control					5%	$5,400
Contingency					40%	$43,200
CONSTRUCTION COST TOTAL						**$167,420**
Engineering/Inspection					20%	$33,484
CIP TOTAL						**$200,000**

A. Project ID: 2 | **B. Project Name: Hill**

C. Project Location: Hill St. between Mountain View Ave. and Miller Ave.

D. Priority: High

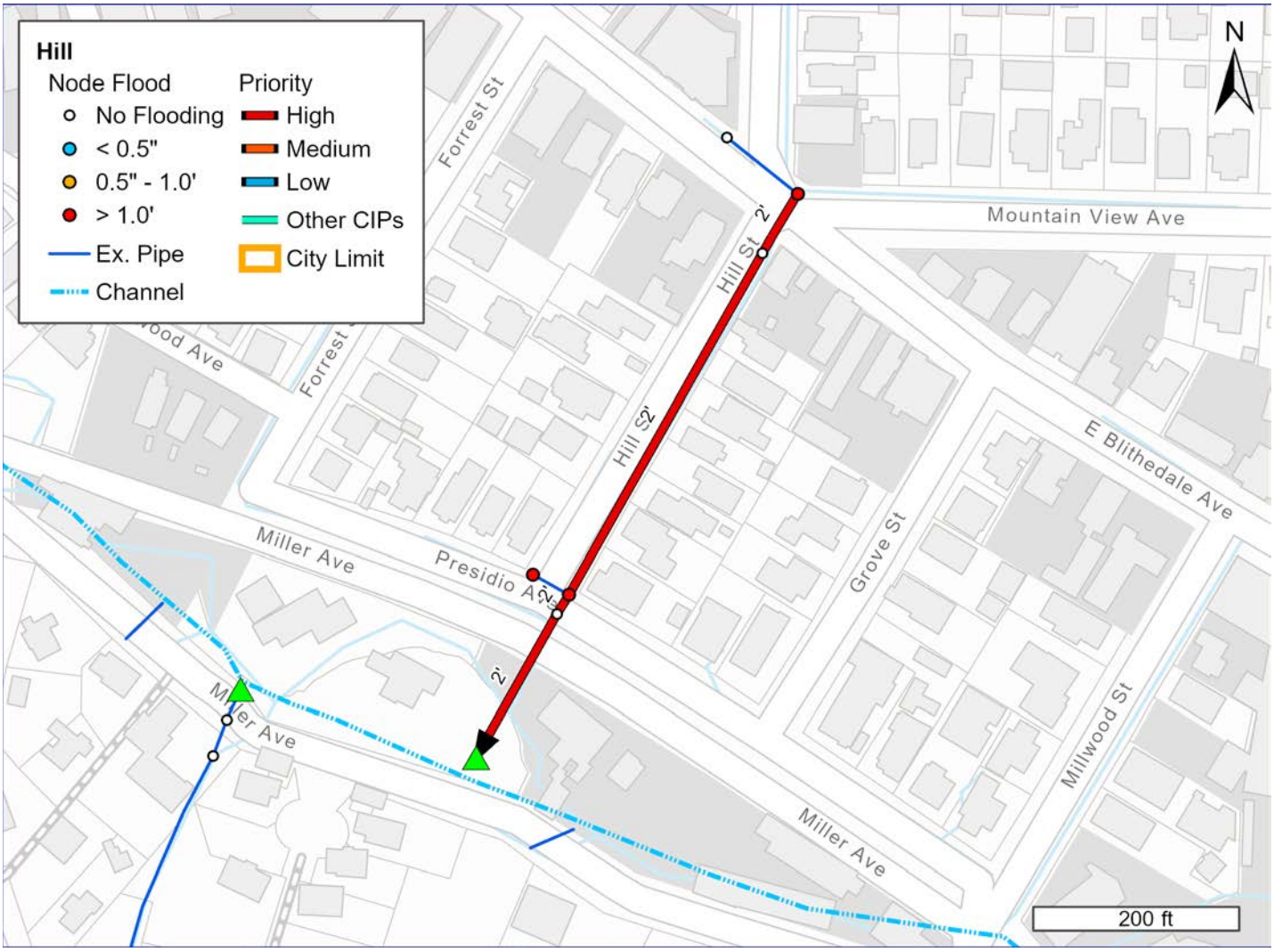
E. Type: Capacity

F. Project Description: Significant flooding occurs along Hill St. at Mountain View Ave. and Presidio Ave. Upsizing the pipe in Hill St. to the outfall will mitigate this flooding.

CIP Pipe Diameter (in)	Length (ft)
24	67
24	381
24	22
24	160

G. Special Considerations: N/A

H. Alternatives: N/A



A. Project ID: 2 | **B. Project Name: Hill**

C. Project Location: Hill St. between Mountain View Ave. and Miller Ave.

D. Priority: High

E. Project Cost:

MAJOR ITEMS	DIAM. (in)	DEPTH (ft)	QTY.	UNIT	UNIT COST	COST
BASELINE CONSTRUCTION COST						
Pipe Construction						
CIP Pipe	24	3	630	LF	$350	$220,730
Structures						
Manholes						$68,280
SUBTOTAL						**$289,010**
Mobilization/Demobilization					10%	$28,900
Traffic Control					5%	$14,450
Contingency					40%	$115,600
CONSTRUCTION COST TOTAL						**$447,960**
Engineering/Inspection					20%	$89,590
CIP TOTAL						**$540,000**

A. Project ID: 3 | **B. Project Name: Sycamore 1**

C. Project Location: Sycamore Ave. and Pump Station

D. Priority: High

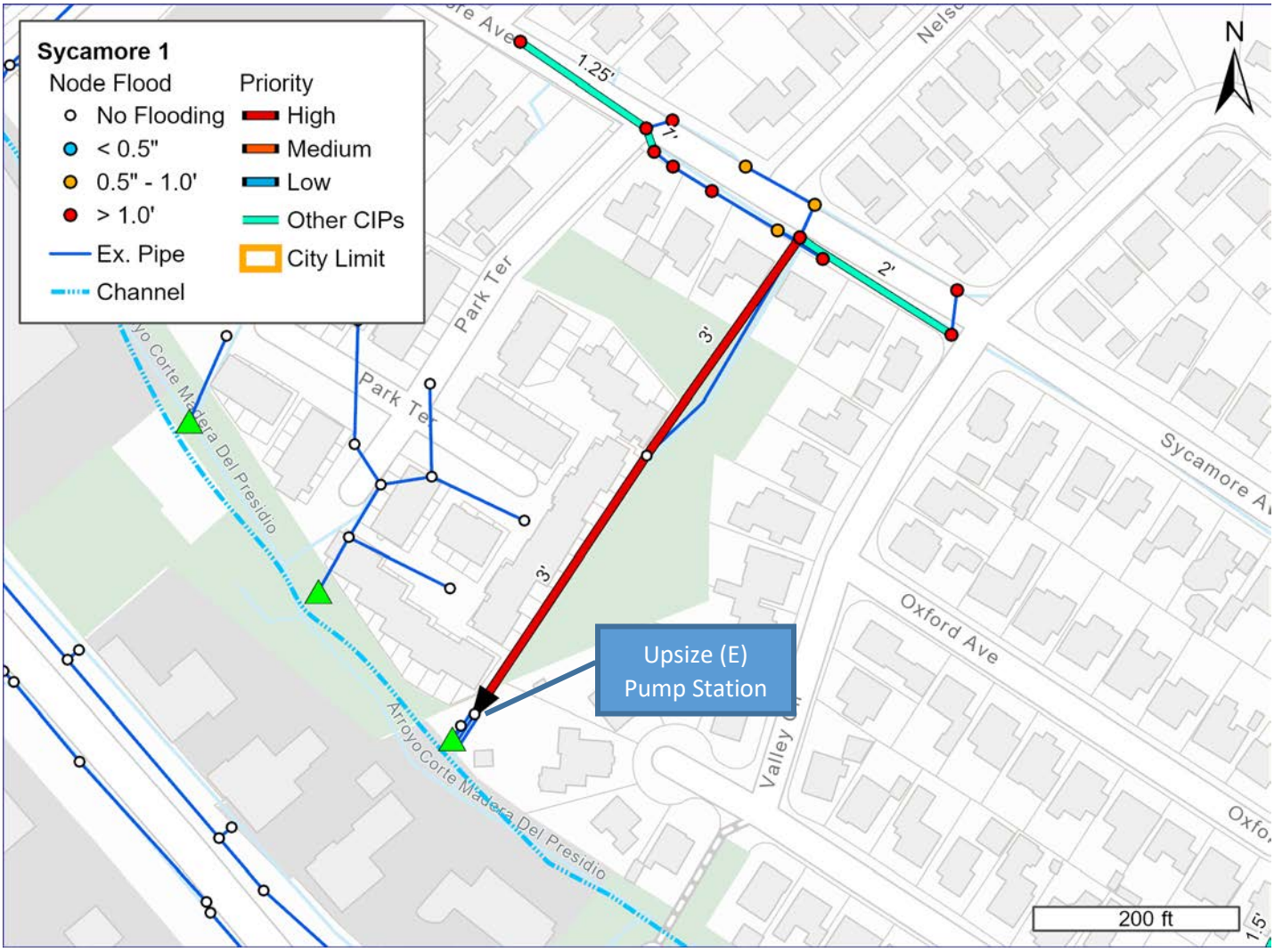
E. Type: Capacity

F. Project Description: Significant flooding occurs in the Sycamore neighborhood. Upsizing the existing pump station and the pipe that conveys water from Sycamore Ave. to the pump station will mitigate this flooding. This improvement should be constructed before other Sycamore area improvements.

CIP Pipe Diameter (in)	Length (ft)
36	301
36	258
Pump Station	NA

G. Special Considerations: N/A

H. Alternatives: N/A



A. Project ID: 3 | **B. Project Name: Sycamore 1**

C. Project Location: Sycamore Ave. and Pump Station

D. Priority: High

E. Project Cost:

MAJOR ITEMS	DIAM. (in)	DEPTH (ft)	QTY.	UNIT	UNIT COST	COST
BASELINE CONSTRUCTION COST						
Pipe Construction						
CIP Pipe	36	3	560	LF	$516	$288,884
Structures						
Manholes						$42,684
Pump Station						
Pump Station Upgrade						$1,000,000
SUBTOTAL						**$1,331,568**
Mobilization/Demobilization					10%	$133,157
Traffic Control					5%	$66,578
Contingency					40%	$532,627
CONSTRUCTION COST TOTAL						**$2,063,930**
Engineering/Inspection					20%	$412,786
CIP TOTAL						**$2,480,000**

A. Project ID: 4

B. Project Name: Blithedale

C. Project Location: Blithedale Ave. between Alta Vista Ave. and outfall

D. Priority: Medium

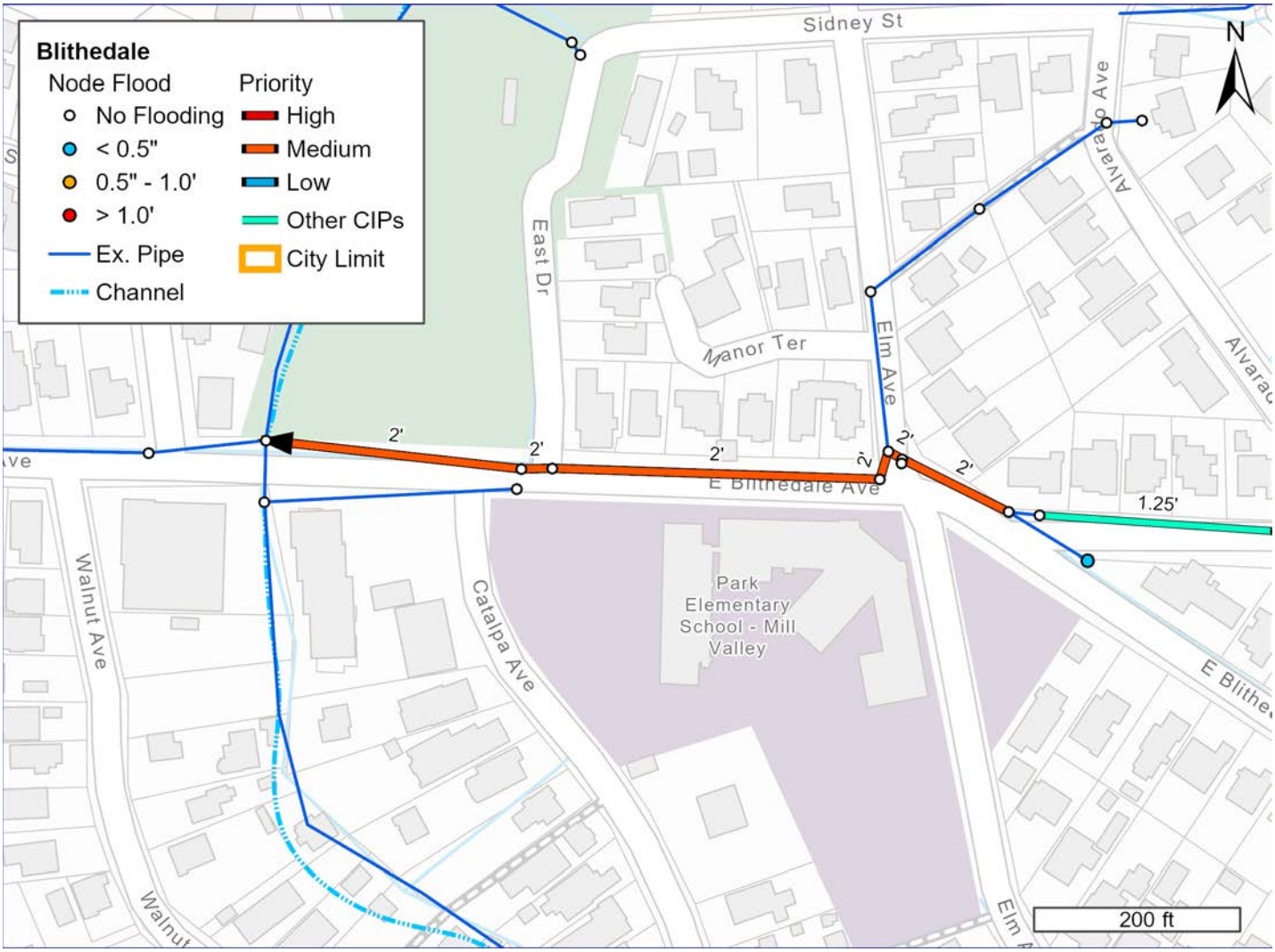
E. Type: Capacity

F. Project Description: Flooding occurs upstream of this improvement due to undersized pipes. This improvement will mitigate this flooding and should be constructed before upstream improvements.

CIP Pipe Diameter (in)	Length (ft)
24	30
24	250
24	28
24	318
24	115
24	16

G. Special Considerations: N/A

H. Alternatives: N/A



A. Project ID: 4 | **B. Project Name: Blithedale**

C. Project Location: Blithedale Ave. between Alta Vista Ave. and outfall

D. Priority: Medium

E. Project Cost:

MAJOR ITEMS	DIAM. (in)	DEPTH (ft)	QTY.	UNIT	UNIT COST	COST
BASELINE CONSTRUCTION COST						
Pipe Construction						
CIP Pipe	24	3	760	LF	$350	$265,250
Structures						
Manholes						$95,590
SUBTOTAL						**$360,840**
Mobilization/Demobilization					10%	$36,080
Traffic Control					5%	$18,040
Contingency					40%	$144,330
CONSTRUCTION COST TOTAL						**$559,290**
Engineering/Inspection					20%	$111,860
CIP TOTAL						**$670,000**

A. Project ID: 5

B. Project Name: Commercial

C. Project Location: Blithedale Ave. and commercial driveway

D. Priority: Medium

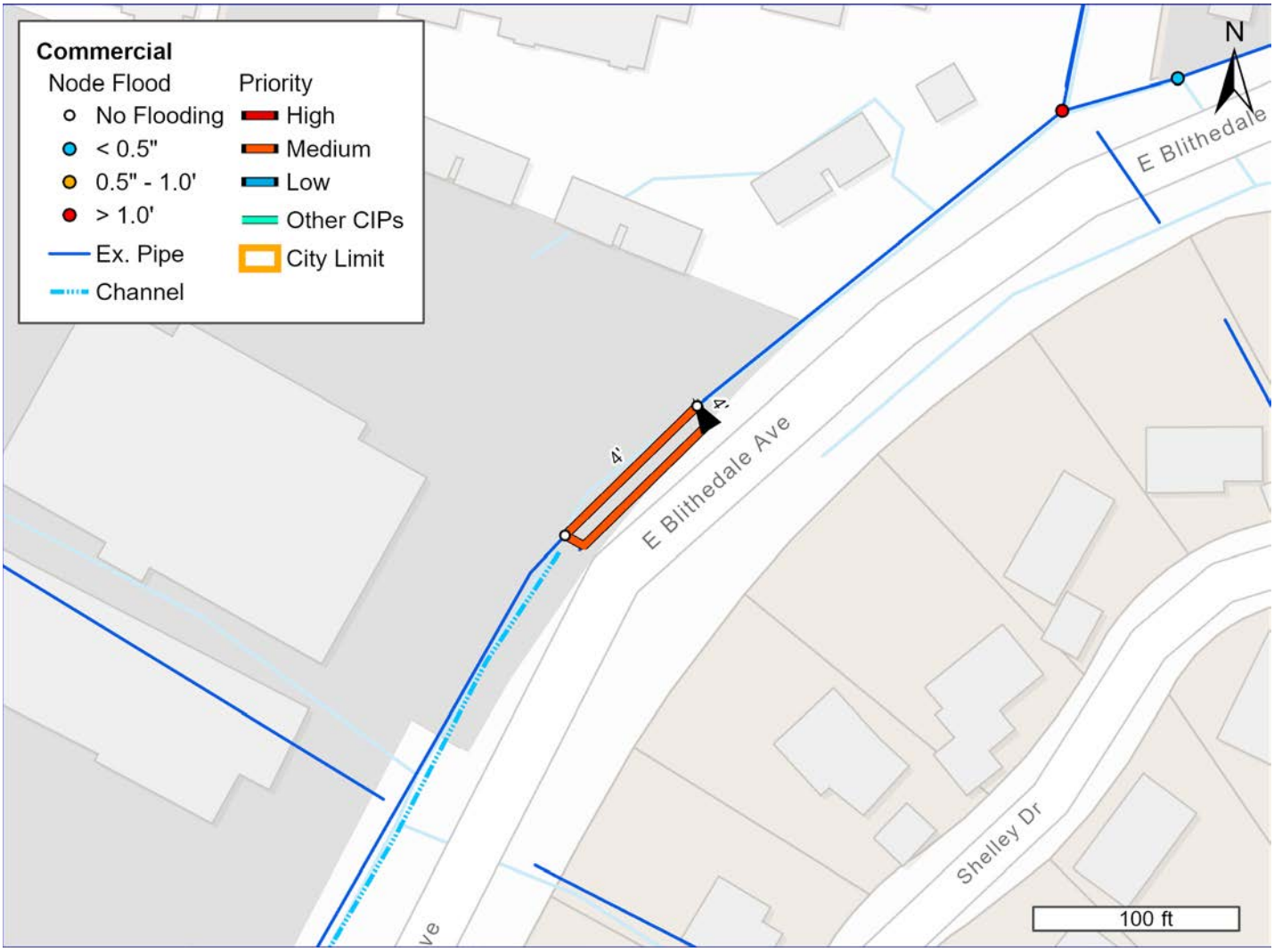
E. Type: Capacity

F. Project Description: The culvert under the driveway from Blithedale Ave. to the commercial development are undersized causing upstream flooding. Upsizing the culverts will mitigate this flooding.

CIP Pipe Diameter (in)	Length (ft)
48	90
48	105

G. Special Considerations: N/A

H. Alternatives: N/A



A. Project ID: 5 | **B. Project Name: Commercial**

C. Project Location: Blithedale Ave. and commercial driveway

D. Priority: Medium

E. Project Cost:

MAJOR ITEMS	DIAM. (in)	DEPTH (ft)	QTY.	UNIT	UNIT COST	COST
BASELINE CONSTRUCTION COST						
Pipe Construction						
CIP Pipe	48	3	195	LF	$690	$135,280
Structures						
Manholes						$44,400
SUBTOTAL						**179,690**
Mobilization/Demobilization					10%	$17,970
Traffic Control					5%	$8,980
Contingency					40%	$71,870
CONSTRUCTION COST TOTAL						**$278,510**
Engineering/Inspection					20%	$55,700
CIP TOTAL						**$330,000**

A. Project ID: 6 | **B. Project Name: Lomita**

C. Project Location: Lomita Dr. from the Elementary School to Shell Rd.

D. Priority: Medium

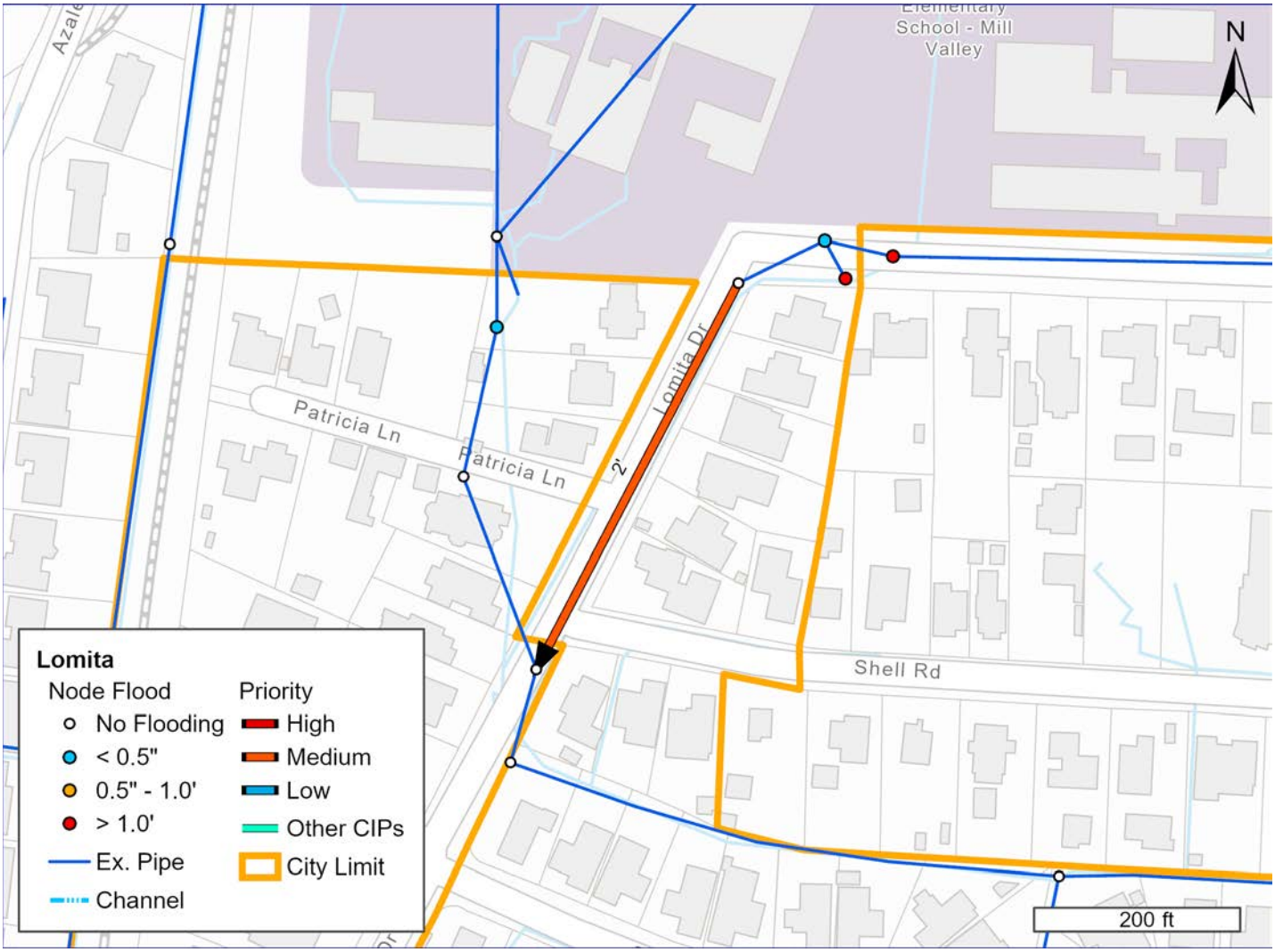
E. Type: Capacity

F. Project Description: Significant flooding occurs at the Elementary School at Lomita Dr. Upsizing the pipe in Lomita Dr. to Shell Rd. will mitigate this flooding.

CIP Pipe Diameter (in)	Length (ft)
24	423

G. Special Considerations: N/A

H. Alternatives: N/A



A. Project ID: 6 | **B. Project Name: Lomita**

C. Project Location: Lomita Dr. from the Elementary School to Shell Rd.

D. Priority: Medium

E. Project Cost:

MAJOR ITEMS	DIAM. (in)	DEPTH (ft)	QTY.	UNIT	UNIT COST	COST
BASELINE CONSTRUCTION COST						
Pipe Construction						
CIP Pipe	24	3	423	LF	$350	$148,200
Structures						
Manholes						$27,310
SUBTOTAL						**$175,510**
Mobilization/Demobilization					10%	$17,550
Traffic Control					5%	$8,780
Contingency					40%	$70,200
CONSTRUCTION COST TOTAL						**$272,040**
Engineering/Inspection					20%	$54,510
CIP TOTAL						**$330,000**

A. Project ID: 7 | **B. Project Name: Madrona**

C. Project Location: Madrona St. from Lovell Ave. to Mill Creek outfall

D. Priority: Medium

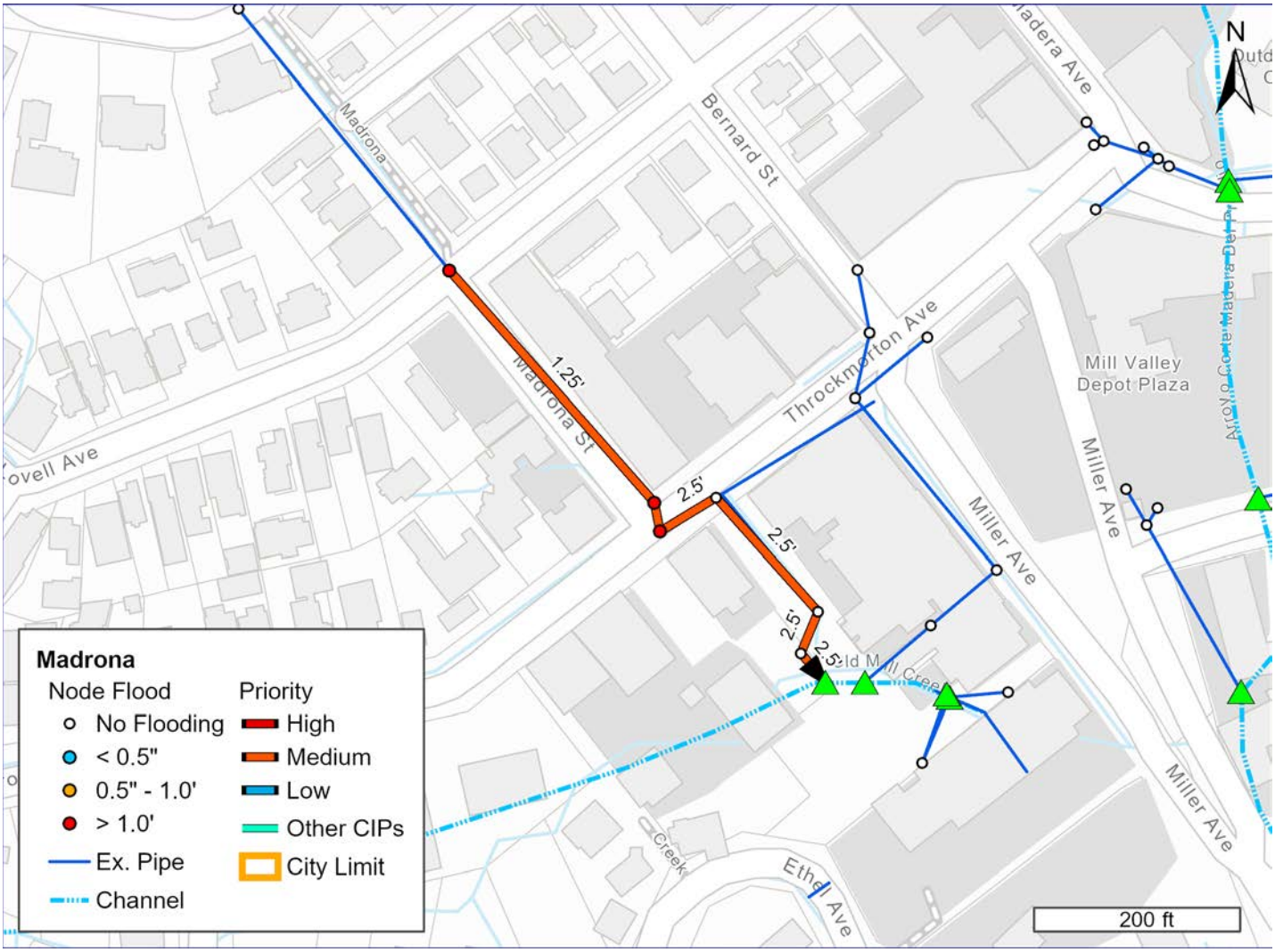
E. Type: Capacity

F. Project Description: Flooding occurs along Madrona St. at Lovell Ave. and Throckmorton Ave. Upsizing the pipe in Madrona St. from Lovell Ave. to the outfall at Mill Creek will mitigate this flooding.

CIP Pipe Diameter (in)	Length (ft)
15	300
30	64
30	149
30	44
30	37
18	29

G. Special Considerations: N/A

H. Alternatives: N/A



A. Project ID: 7

B. Project Name: Madrona

C. Project Location: Madrona St. from Lovell Ave. to Mill Creek outfall

D. Priority: Medium

E. Project Cost:

MAJOR ITEMS	DIAM. (in)	DEPTH (ft)	QTY.	UNIT	UNIT COST	COST
BASELINE CONSTRUCTION COST						
Pipe Construction						**$217,380**
CIP Pipe	15	3	300	LF	$260	$78,470
CIP Pipe	18	3	39	LF	$280	$8,130
CIP Pipe	30	3	294	LF	$450	$130,790
Structures						
Manholes						$95,590
SUBTOTAL						**$312,970**
Mobilization/Demobilization					10%	$31,300
Traffic Control					5%	$15,650
Contingency					40%	$125,190
CONSTRUCTION COST TOTAL						**$485,100**
Engineering/Inspection					20%	$97,020
CIP TOTAL						**$580,000**

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

C. Project Location: Park Ave. to creek outfall

D. Priority: Medium

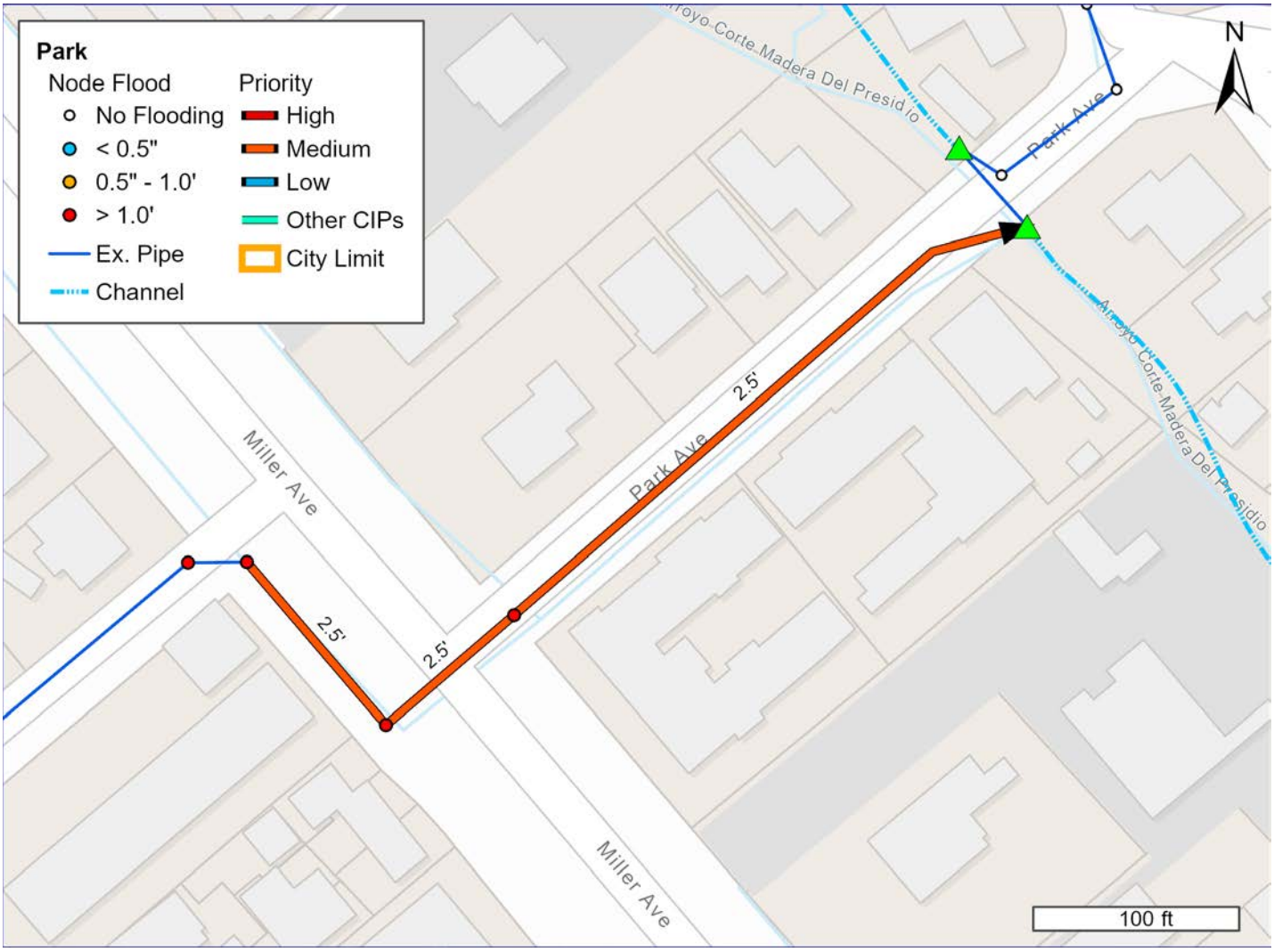
E. Type: Capacity

F. Project Description: Flooding occurs at Park Ave. and Miller Ave. Upsizing the pipe in Park Ave. from Miller Ave. to the outfall at Arroyo Corte Madera Del Presidio Creek will mitigate this flooding.

CIP Pipe Diameter (in)	Length (ft)
30	104
30	82
30	316

G. Special Considerations: N/A

H. Alternatives: N/A



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

C. Project Location: Park Ave. to creek outfall

D. Priority: High

E. Project Cost:

MAJOR ITEMS	DIAM. (in)	DEPTH (ft)	QTY.	UNIT	UNIT COST	COST
BASELINE CONSTRUCTION COST						
Pipe Construction						
CIP Pipe	30	3	503	LF	$450	$224,640
Structures						
Manholes						$55,770
SUBTOTAL						**$280,400**
Mobilization/Demobilization					10%	$28,040
Traffic Control					5%	$14,020
Contingency					40%	$112,160
CONSTRUCTION COST TOTAL						**$434,620**
Engineering/Inspection					20%	$86,920
CIP TOTAL						**$520,000**

A. Project ID: 9 | **B. Project Name: Sycamore 2**

C. Project Location: Sycamore Ave. from Amicita Ave. to Park Terrace

D. Priority: Medium

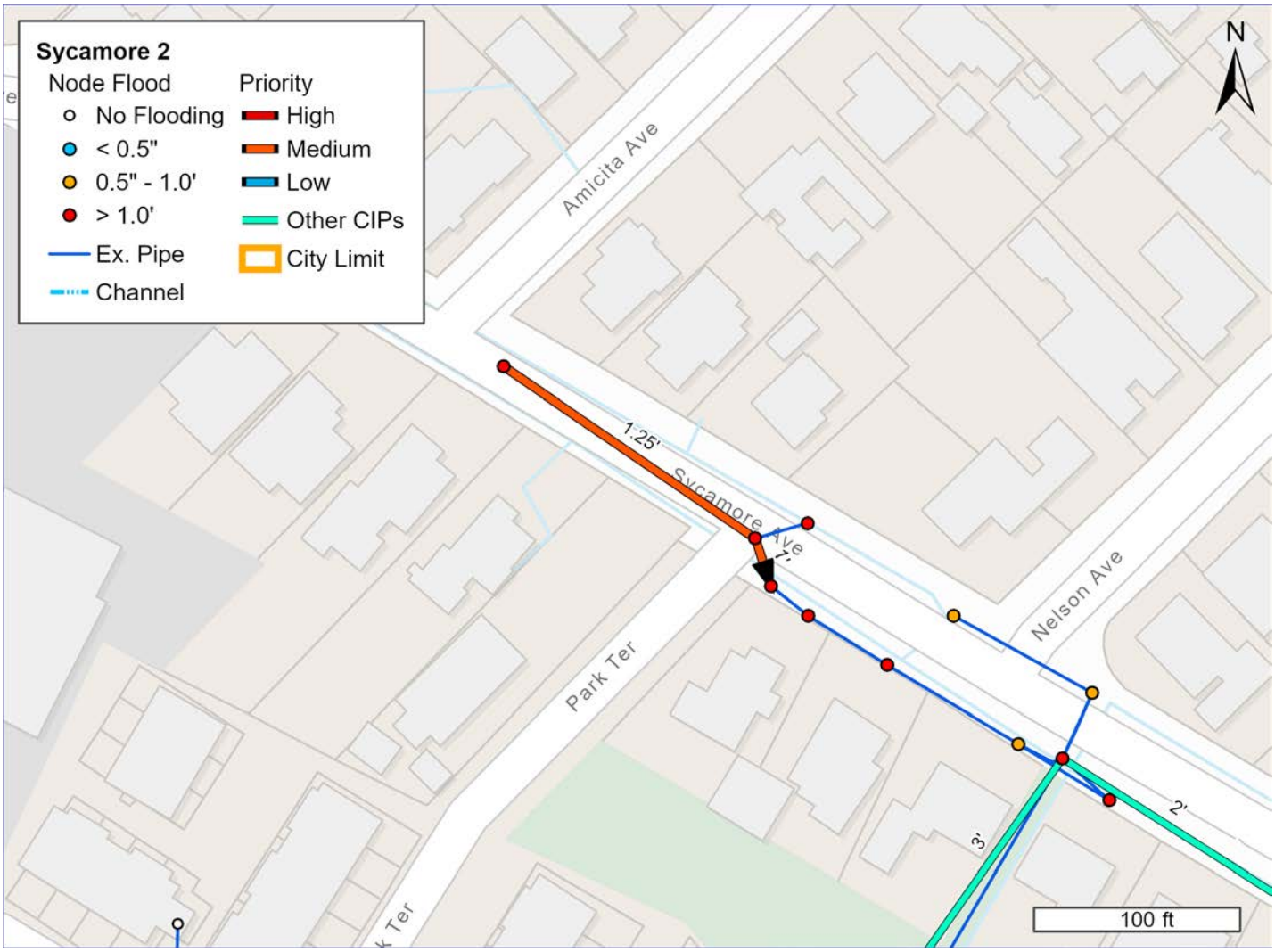
E. Type: Capacity

F. Project Description: Significant flooding occurs in the Sycamore neighborhood. Upsizing the pipe in Sycamore Ave. from Amicita Ave. to Park Ter. will help mitigate this flooding. This improvement should be constructed after the Sycamore 1 improvement.

CIP Pipe Diameter (in)	Length (ft)
15	148
12	24

G. Special Considerations: N/A

H. Alternatives: N/A



A. Project ID: 9 | **B. Project Name: Sycamore 2**

C. Project Location: Sycamore Ave. from Amicita Ave. to Park Terrace

D. Priority: Medium

E. Project Cost:

MAJOR ITEMS	DIAM. (in)	DEPTH (ft)	QTY.	UNIT	UNIT COST	COST
BASELINE CONSTRUCTION COST						
Pipe Construction						**$44,225**
CIP Pipe	12	3	24	LF	$230	$5,599
CIP Pipe	15	3	148	LF	$261	$38,626
Structures						
Manholes						$39,533
SUBTOTAL						**$83,758**
Mobilization/Demobilization					10%	$8,376
Traffic Control					5%	$4,188
Contingency					40%	$33,503
CONSTRUCTION COST TOTAL						**$129,825**
Engineering/Inspection					20%	$25,965
CIP TOTAL						**$160,000**

A. Project ID: 10 | **B. Project Name: Sycamore 3**

C. Project Location: Sycamore Ave. from Valley Cir. to Nelson Ave.

D. Priority: Medium

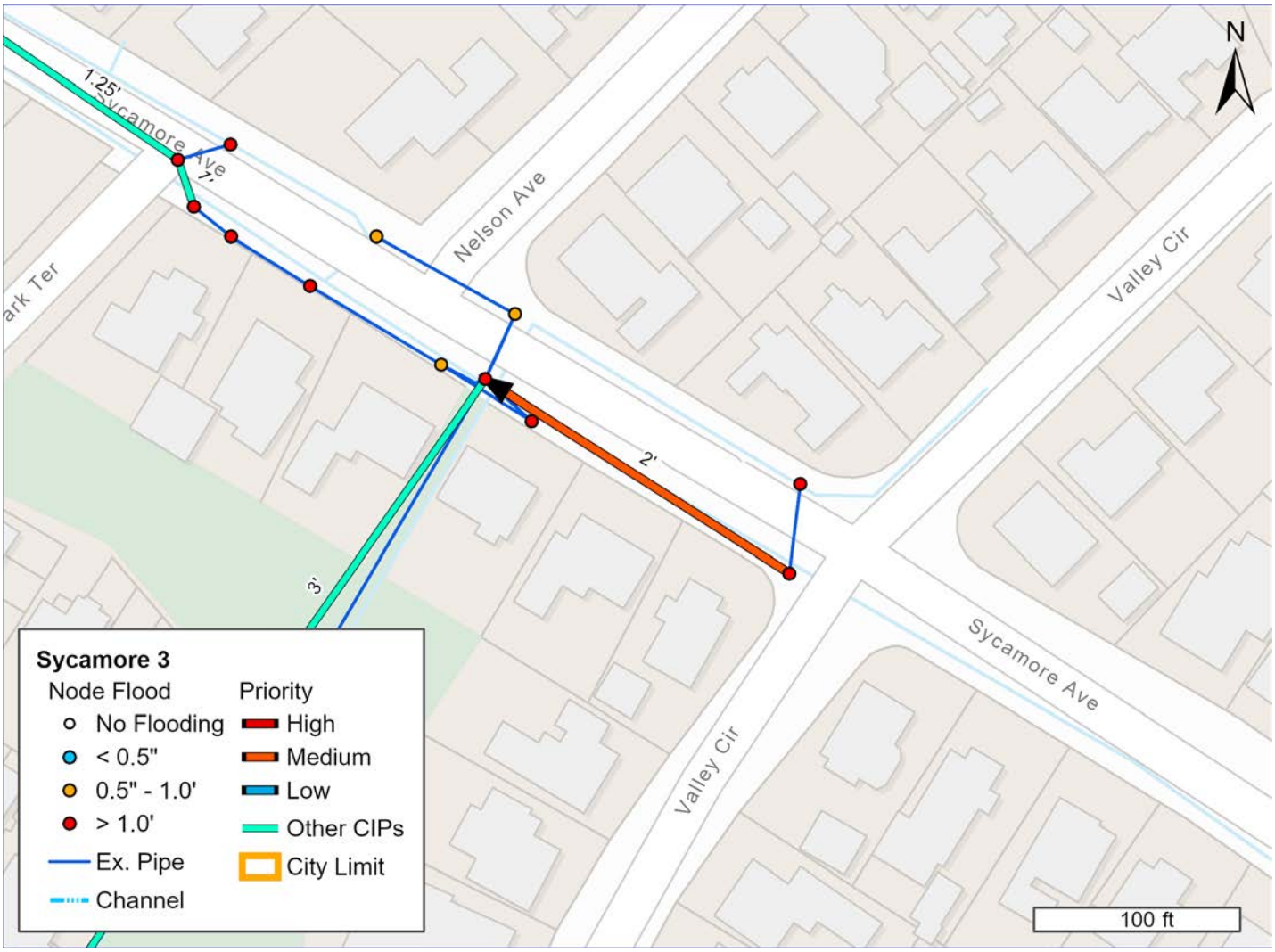
E. Type: Capacity

F. Project Description: Significant flooding occurs in the Sycamore neighborhood. Upsizing the pipe in Sycamore Ave. from Valley Cir. to Nelson Ave. Will help mitigate this flooding. This improvement should be constructed after the Sycamore 1 improvement.

CIP Pipe Diameter (in)	Length (ft)
24	175

G. Special Considerations: N/A

H. Alternatives: N/A



A. Project ID: 10 | **B. Project Name: Sycamore 3**

C. Project Location: Sycamore Ave. from Valley Cir. to Nelson Ave.

D. Priority: High

E. Project Cost:

MAJOR ITEMS	DIAM. (in)	DEPTH (ft)	QTY.	UNIT	UNIT COST	COST
BASELINE CONSTRUCTION COST						
Pipe Construction						
CIP Pipe	24	3	175	LF	$350	$61,301
Structures						
Manholes						$27,310
SUBTOTAL						**$88,612**
Mobilization/Demobilization					10%	$8,861
Traffic Control					5%	$4,431
Contingency					40%	$35,445
CONSTRUCTION COST TOTAL						**$137,348**
Engineering/Inspection					20%	$27,470
CIP TOTAL						**$160,000**

A. Project ID: 11 | **B. Project Name: Alta Vista**

C. Project Location: Alta Vista Ave. between Alvarado Ave. and Blithedale Ave.

D. Priority: Low

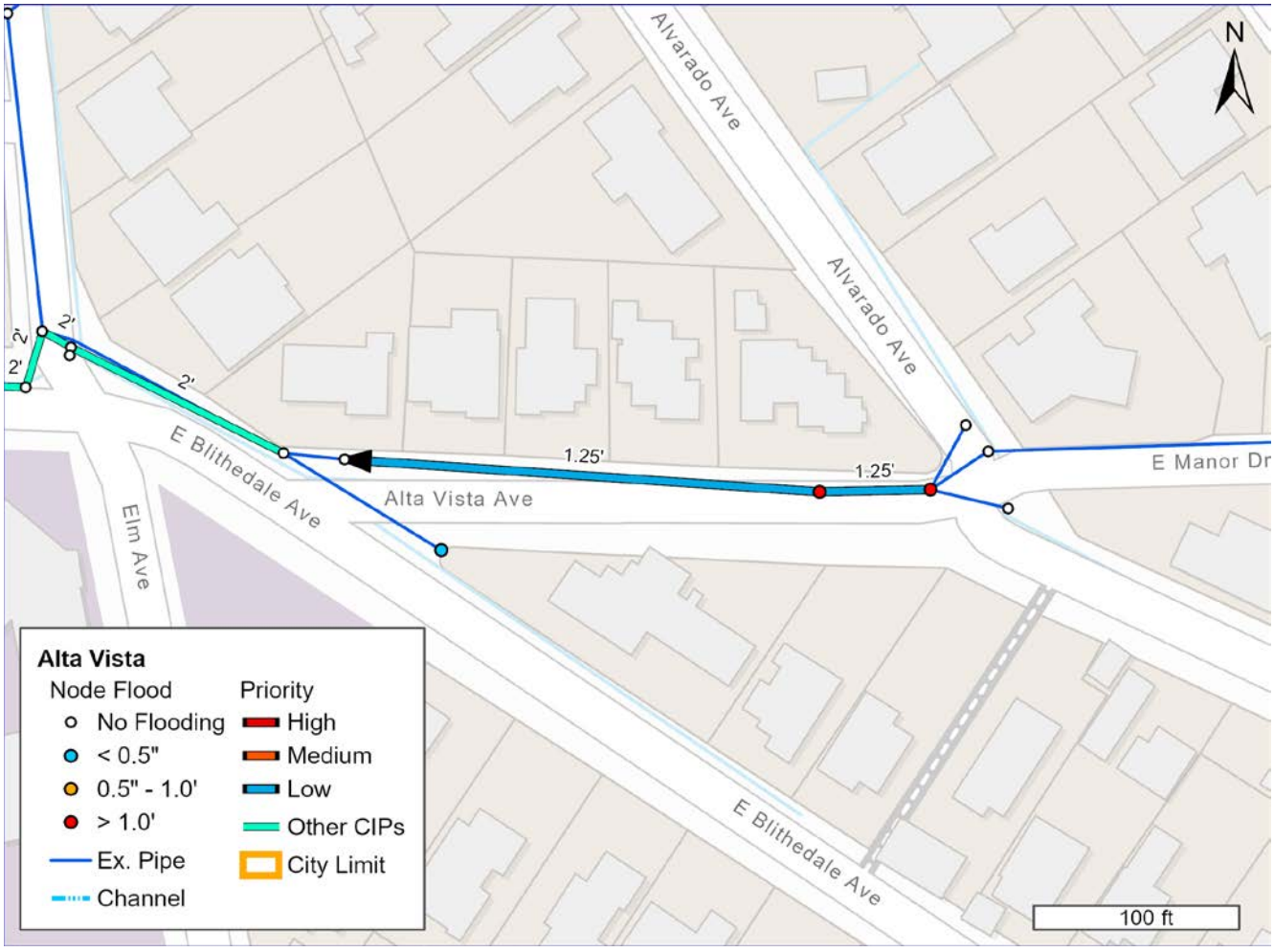
E. Type: Capacity

F. Project Description: The undersized pipe in Alta Vista Ave. causes water to travel overland toward Blighedale Ave. Upsizing the pipe in Alta Vista Ave. will mitigate overland flow.

CIP Pipe Diameter (in)	Length (ft)
15	53
15	231

G. Special Considerations: N/A

H. Alternatives: N/A



A. Project ID: 11 | **B. Project Name: Alta Vista**

C. Project Location: Alta Vista Ave. between Alvarado Ave. and Blithedale Ave.

D. Priority: Low

E. Project Cost:

MAJOR ITEMS	DIAM. (in)	DEPTH (ft)	QTY.	UNIT	UNIT COST	COST
BASELINE CONSTRUCTION COST						
Pipe Construction						
CIP Pipe	15	3	285	LF	$260	$74,400
Structures						
Manholes						$39,700
SUBTOTAL						**$114,100**
Mobilization/Demobilization					10%	$11,410
Traffic Control					5%	$5,700
Contingency					40%	$45,640
CONSTRUCTION COST TOTAL						**$176,860**
Engineering/Inspection					20%	$35,370
CIP TOTAL						**$210,000**

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

C. Project Location: Matilda Ave. from Elm Ave. to Ryan Creek outfall

D. Priority: Low

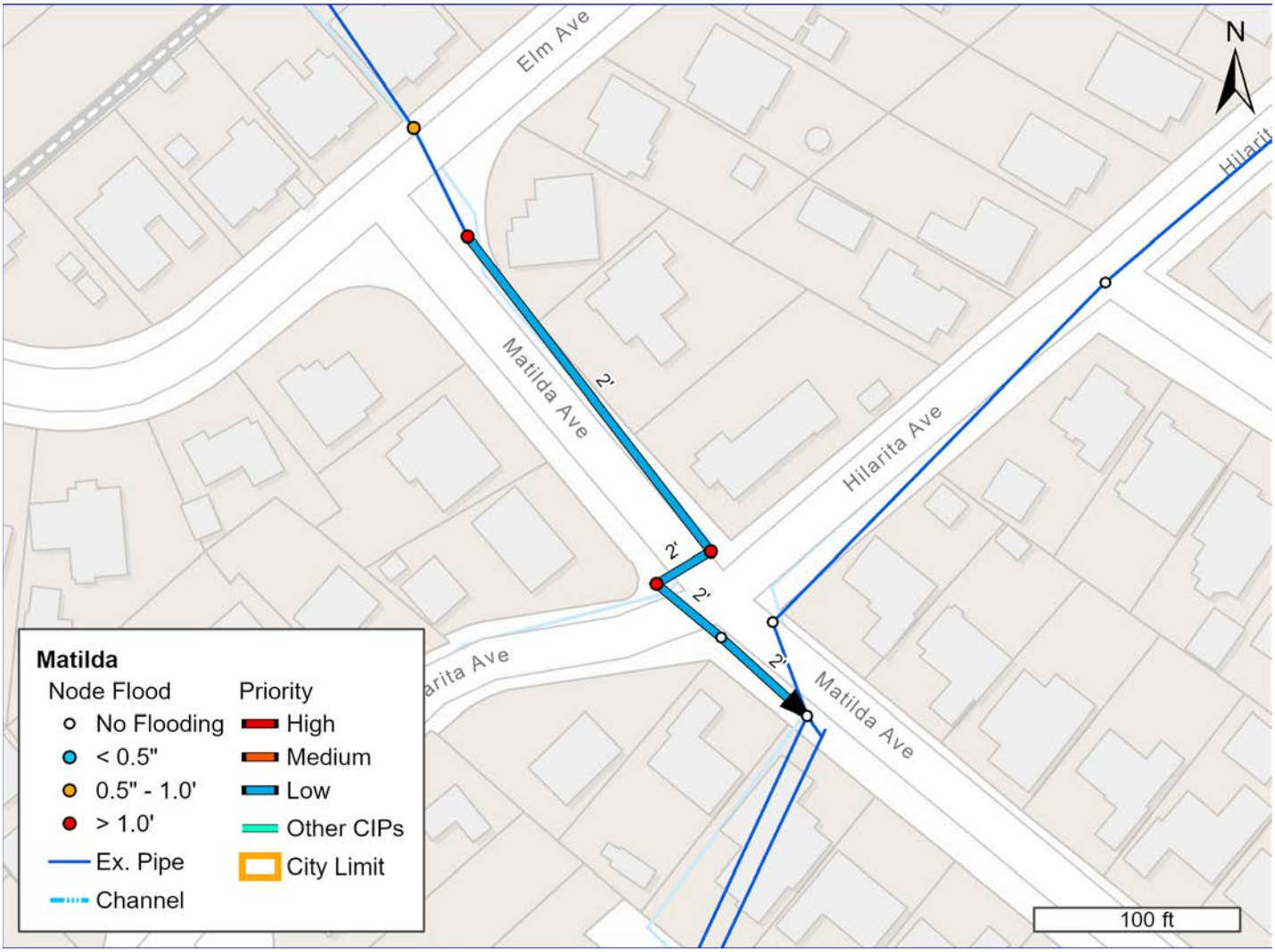
E. Type: Capacity

F. Project Description: Flooding occurs along Matilda Ave. between Elm Ave. and Hilarita Ave. Upsizing the pipe in Matilda Ave. from Elm Ave. to the outfall at Ryan Creek will mitigate this flooding.

CIP Pipe Diameter (in)	Length (ft)
24	193
24	31
24	41
24	56

G. Special Considerations: N/A

H. Alternatives: N/A



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

C. Project Location: Matilda Ave. from Elm Ave. to Ryan Creek outfall

D. Priority: Low

E. Project Cost:

MAJOR ITEMS	DIAM. (in)	DEPTH (ft)	QTY.	UNIT	UNIT COST	COST
BASELINE CONSTRUCTION COST						
Pipe Construction						
CIP Pipe	24	3	321	LF	$350	$112,370
Structures						
Manholes						$68,280
SUBTOTAL						**$180,640**
Mobilization/Demobilization					10%	$18,060
Traffic Control					5%	$9,030
Contingency					40%	$72,260
CONSTRUCTION COST TOTAL						**$280,000**
Engineering/Inspection					20%	$56,000
CIP TOTAL						**$336,000**

A. Project ID: 13 | **B. Project Name: Oxford**

C. Project Location: Oxford Ave. and Plymouth Ave.

D. Priority: Low

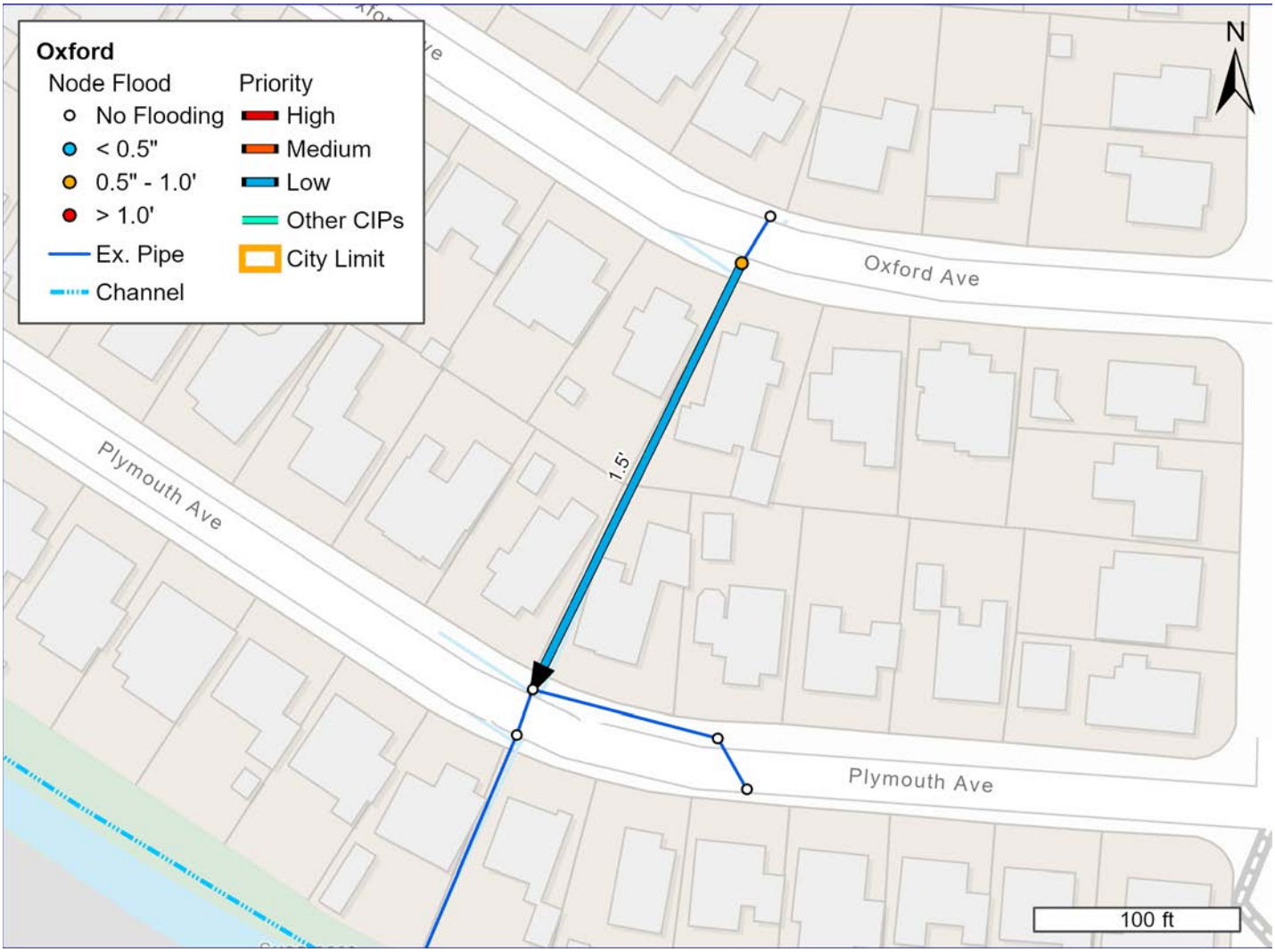
E. Type: Capacity

F. Project Description: Flooding occurs at Oxford Ave. just west of Surrey Ave. Upsizing the pipe between Oxford Ave. and Plymouth Ave. will mitigate this flooding.

CIP Pipe Diameter (in)	Length (ft)
18	230

G. Special Considerations: N/A

H. Alternatives: N/A



A. Project ID: 13 | **B. Project Name: Oxford**

C. Project Location: Oxford Ave. and Plymouth Ave.

D. Priority: Low

E. Project Cost:

MAJOR ITEMS	DIAM. (in)	DEPTH (ft)	QTY.	UNIT	UNIT COST	COST
BASELINE CONSTRUCTION COST						
Pipe Construction						
CIP Pipe	18	3	230	LF	$280	$65,330
Structures						
Manholes						$26,740
SUBTOTAL						**$92,060**
Mobilization/Demobilization					10%	$9,210
Traffic Control					5%	$4,600
Contingency					40%	$36,830
CONSTRUCTION COST TOTAL						**$142,700**
Engineering/Inspection					20%	$28,540
CIP TOTAL						**$170,000**

A. Project ID: 14 | **B. Project Name: Sycamore 4**

C. Project Location: Sycamore Ave. from Surrey Ave. to Camino Alto

D. Priority: Low

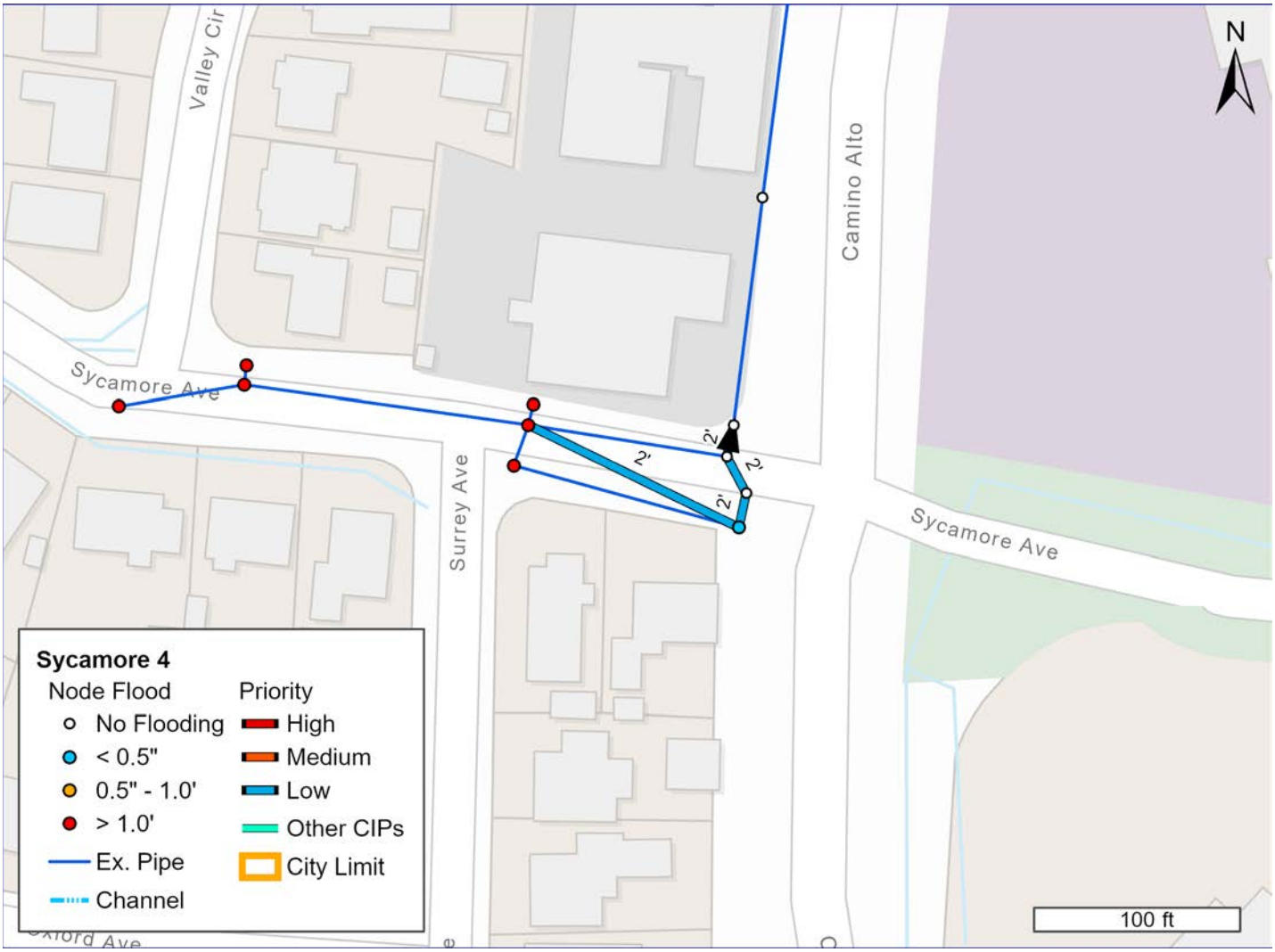
E. Type: Capacity

F. Project Description: Flooding occurs along Sycamore Ave. between Valley Cir. and Camino Alto. Upsizing the pipe in Sycamore Ave. between Surrey Ave. and Camino Alto will mitigate this flooding.

CIP Pipe Diameter (in)	Length (ft)
24	114
24	16
24	17
24	20

G. Special Considerations: N/A

H. Alternatives: N/A



A. Project ID: 14 | **B. Project Name: Sycamore 4**

C. Project Location: Sycamore Ave. from Surrey Ave. to Camino Alto

D. Priority: Low

E. Project Cost:

MAJOR ITEMS	DIAM. (in)	DEPTH (ft)	QTY.	UNIT	UNIT COST	COST
BASELINE CONSTRUCTION COST						
Pipe Construction						
CIP Pipe	24	3	167	LF	$350	$58,403
Structures						
Manholes						$68,276
SUBTOTAL						**$126,678**
Mobilization/Demobilization					10%	$12,668
Traffic Control					5%	$6,334
Contingency					40%	$50,671
CONSTRUCTION COST TOTAL						**$196,351**
Engineering/Inspection					20%	$39,270
CIP TOTAL						**$240,000**

A. Project ID: 15 | **B. Project Name: Willow**

C. Project Location: Willow St. from Miller Ave. to creek outfall

D. Priority: Low

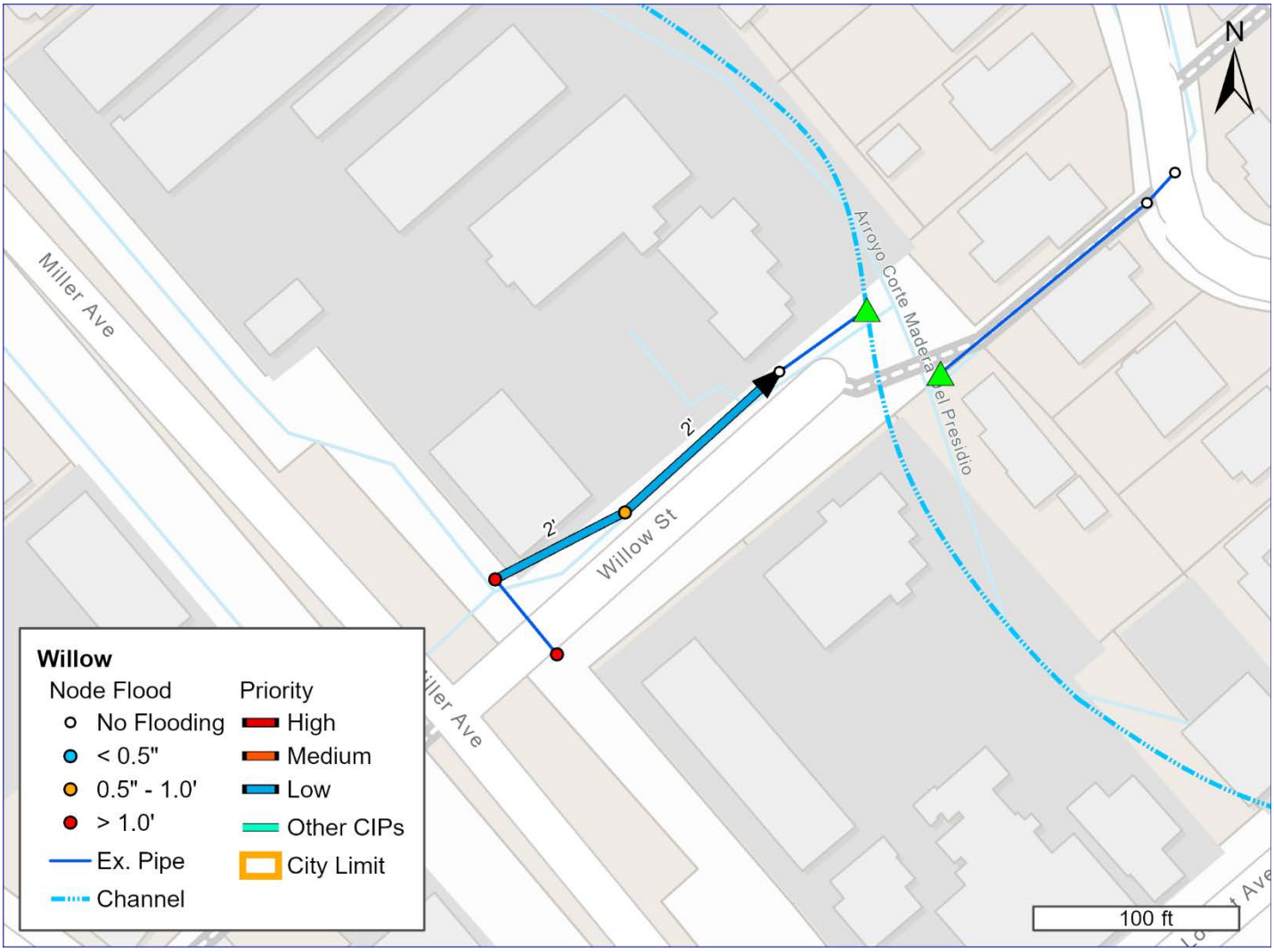
E. Type: Capacity

F. Project Description: Flooding occurs at Miller Ave. and Willow St. Upsizing the pipe in Willow St. will mitigate this flooding.

CIP Pipe Diameter (in)	Length (ft)
24	101
24	71

G. Special Considerations: N/A

H. Alternatives: N/A



A. Project ID: 15 | **B. Project Name: Willow**

C. Project Location: Willow St. from Miller Ave. to creek outfall

D. Priority: High

E. Project Cost:

MAJOR ITEMS	DIAM. (in)	DEPTH (ft)	QTY.	UNIT	UNIT COST	COST
BASELINE CONSTRUCTION COST						
Pipe Construction						
CIP Pipe	24	3	172	LF	$350	$60,349
Structures						
Manholes						$40,965
SUBTOTAL						**$101,315**
Mobilization/Demobilization					10%	$10,131
Traffic Control					5%	$5,066
Contingency					40%	$40,526
CONSTRUCTION COST TOTAL						**$157,038**
Engineering/Inspection					20%	$31,408
CIP TOTAL						**$190,000**

APPENDIX J

Marin Shoreline Sea Level Rise Vulnerability Assessment
Executive Summary

Marin Shoreline Sea Level Rise Vulnerability Assessment



Bay Waterfront Adaptation & Vulnerability Evaluation

Prepared by BVB Consulting LLC for Marin County Department of Public Works

June 2017 | County of Marin, CA | marinslr.org

Marin Shoreline Sea Level Rise Vulnerability Assessment

Bay Waterfront Adaptation & Vulnerability Evaluation (BayWAVE)

With special thanks to the California State Coastal Conservancy's Climate Ready Grant Program

Prepared by BVB Consulting for Marin County Department of Public Works

June 2017| County of Marin, CA | marinslr.org

Cover Photo: Manzanita Parks & Ride, December 2, 2014. Almonte. Marin County Department of Public Works

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Jim McCann, Mill Valley City Manager
John Moe, PE, PLS, Ross, Moe Engineering, Inc.
Mary Neilan, Belvedere City Manager
Barbara Salzman, Marin Audubon Society
Elise Semonian, San Anselmo Planning Director
Neal Toft, Larkspur Planning and Building Director
Garret Toy, Fairfax City Manager

Additional Advisors

Federal Emergency Management Agency (FEMA)
State Coastal Conservancy

List of Acronyms

BayWAVE	Bay Waterfront Adaptation and Vulnerability Evaluation
MHHW	Mean Higher High Water
GGBHTD	Golden Gate Bridge, Highway and Transportation District
GGT	Golden Gate Transit
GGF	Golden Gate Ferry
C-SMART	Collaboration: Sea-Level Marin Adaptation Response Team
OWTS	On-site Wastewater Treatment System
CDA	Community Development Agency
DPW	Department of Public Works
NMWD	North Marin Water District
MMWD	Marin Municipal Water District
PG&E	Pacific Gas and Electric
SASM	Sewerage Agency of Southern Marin
NSD	Novato Sanitary District
USFWS	United States Fish and Wildlife Service
CADFW	California Department of Fish and Wildlife
LGVSD	Las Gallinas Valley Sanitary District
CMSA	Central Marin Sanitation Agency
LHMP	Local Hazard Mitigation Plan

EXECUTIVE SUMMARY

Executive Summary

Sea level in the San Francisco Bay Area has risen eight inches in the past century, and could rise up to 70 inches by the end of the century.[1, 2] Marin's bay shoreline is vulnerable to sea level rise and intensifying storm patterns. The third National Climate Assessment cites strong evidence that the cost of doing nothing exceeds the costs associated with adapting to sea level rise by 4 to 10 times.[3] Therefore, it is critical the County of Marin, incorporated jurisdictions, and special districts plan and prepare for the impacts of sea level rise to ensure a resilient county for present and future generations.

The County of Marin Department of Public Works and Community Development Agency are the project leads for the Bay Waterfront Adaptation & Vulnerability Evaluation (BayWAVE) program. The program began in September 2015 with funding from County of Marin and additional financial support from the California Coastal Conservancy.

Several committees support the BayWAVE process. The Executive Steering Committee consists of County of Marin and local jurisdiction representatives. The Technical Advisory Committee includes staff from local, state, and federal agencies. Lastly, the Policy Committee includes elected officials from the participating jurisdictions. These committees serve as the beginning of the program's goals to establish an efficient shared learning process and community messaging, and create a collaborative environment for preparing for sea level rise for all shoreline communities, and others inland, that could face the impacts of sea level rise in the coming decades. This effort may also support these communities in collaborating with and benefiting from the larger Bay Area region efforts underway.

The Vulnerability Assessment is an initial effort to identify the risks and exposure from sea level rise. Future tasks could include development of an adaptation report and may occur at different jurisdictions: local municipalities, service districts, and County of Marin could update general plans, master plans, capital improvement plans, hazard mitigation plans, and other relevant plans and procedures in the near future. While this effort focuses on sea level rise, Marin County experiences flooding from creeks, tides, and stormwater. Planning for solutions should evaluate the combined impacts of flooding to best prepare for a range of conditions.

This effort is part of an ongoing scientific and public process to understand and prepare for sea level rise along the shoreline This Vulnerability Assessment seeks to provide context and estimates of the physical and fiscal impacts across the County of Marin's bayside shoreline over the coming decades. These data highlight the complexity of the potential impacts and the need for concerted and individual actions in the face of rising tides. The data can be used to prioritize efforts, seek funding, and shape policy and development discussions that will guide the plans mentioned above.

This document presents asset profiles describing the potential consequences of a no-action, or business as usual political environment, especially for existing development. Asset profiles present potential consequences for parcels and buildings, transportation networks, utilities, working lands, natural resources, recreational assets, emergency services, and cultural resources. Vulnerable assets are also presented by jurisdiction in community profiles to enable local professionals, officials, and residents to engage is local discussions and relate to their neighbors. The following exposed and vulnerable communities have community profiles and make up the 85,840 acre study area shown in Map 1.

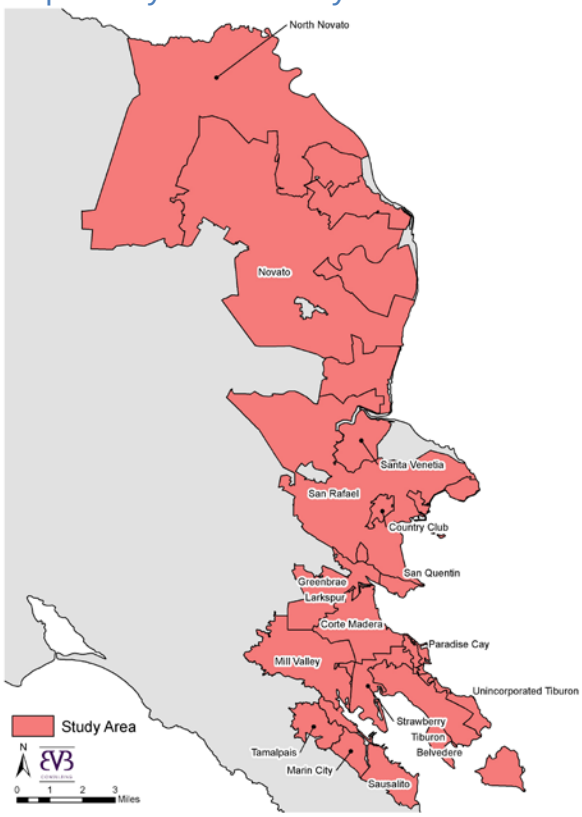
[1] Sea-Level Rise for the Coasts of California, Oregon and Washington: Past, Present and Future. National Research Council (NRC), 2012.

[2] Rising sea levels of 1.8 meter in worst-case scenario, researchers calculate. Science Daily Online News. University of Copenhagen. Oct. 14, 2014. http://www.sciencedaily.com/releases/2014/10/141014085902.htm Original published in the journal Environmental Research Letters.

[3] Moser, S. C., M. A. Davidson, P. Kirshen, P. Mulvaney, J. F. Murley, J. E. Neumann, L. Petes, and D. Reed, 2014: Ch. 25: *Coastal Zone Development and Ecosystems. Climate Change Impacts in the United States: The Third National Climate Assessment*, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., US Global Change Research Program, , 579-618. doi:10.7930/J0MS3QNW. http://nca2014.globalchange.gov/report/regions/coasts

EXECUTIVE SUMMARY

Map 1. BayWAVE Study Area



- Municipalities
  - Belvedere
  - Corte Madera
  - Larkspur
  - Mill Valley
  - Novato
  - San Rafael
  - Sausalito
  - Tiburon
- Unincorporated Jurisdictions
  - Almonte
  - Bayside Acres
  - Bel Marin Keys
  - Black Point
  - California Park
  - Country Club
  - Greenbrae
  - Kentfield
  - Marin City
  - North Novato
  - Paradise Cay
  - Point San Pedro
  - San Quentin
  - Santa Venetia
  - St. Vincent's
  - Strawberry
  - Tamalpais Valley
  - Unincorporated Tiburon
  - Waldo Point Harbor

Each profile details key issues and geographic locations. Asset profiles include economic, environmental, equity, and management considerations related to sea level rise vulnerability. Each profile can be read independently of the others, enabling asset managers to focus on their professional area, and community members, elected officials, and others to read the analysis for a community as a whole.

Methods

Table 1 shows the range of sea level rise projections for California adopted by the National Research Council in 2012. Given the uncertainty in the magnitude and timing of future sea level rise, this Assessment uses a scenario based approach to assess a range of potential sea level rise impacts. The scenarios selected for this Vulnerability Assessment are derived from the United States Geological Survey (USGS) Coastal Storm Modeling System (CoSMoS) that combines global climate and wave models with projected sea level rise to identify areas that could be flooded across 10 different sea levels (ranging from 0 to 200 inches) and 4 storm severities (none, annual, 20-, 100-year storm surges) to total 40 possible combinations. All of these scenarios are viewable on the Our Coast Our Future (OCOF) Flood Map website.

One limitation of the model and every sea level rise model available at this time is the failure to combine sea level rise, stormwater drainage, and creeks. The model displays the impacts of flooding from the bay overtopping the shoreline edge and flooding low-lying areas. However, in Marin areas experience the impacts of high tides that coincide with storms, which result in water coming from the hills and the bay. Additionally, underground or low-lying drainage pipes and channels allow water to flood areas where the shoreline edge is sufficiently elevated to prevent direct overtopping. These vulnerabilities are described in the text, but tables and maps show sea level rise as presented in the CoSMoS model.

EXECUTIVE SUMMARY

The findings of this assessment are based on three sea levels and each sea level combined with a 100-year storm surge as shown in Table 2. Scenarios 1 and 2 represent the near-term, and correspond to the 2030 NRC projected sea level range. Scenarios 3 and 4 represent the medium-term and are within the 2050 NRC range. Scenarios 5 and 6 represent the long-term and correspond to the 2100 NRC range. Figure 3 presents another view of the BayWAVE scenario where the red lengths represent tidal flooding in sea level rise scenarios 1, 3, and 5, and the blue lengths represent the addition storm surge water level associated with scenarios 2, 4, and 6. Together these bands show the potential flooding in the near-, medium-, and long-terms.

Vulnerability is based on an asset's exposure, sensitivity, and adaptive capacity to rising bay waters and storm surge threats. If an exposed asset is moderately or highly sensitive to sea level rise impacts, with low to no adaptive capacity, the asset is considered vulnerable. Vulnerable assets may be vulnerable to flooding and/or increased rates of subsidence over the coming decades. Extensive geographic mapping was conducted overlapping layers of assets from MarinMap and sea level rise extent and flood depth layers to determine exposure. To ascertain sensitivity and adaptive capacity, the project team interviewed 115 asset managers, for example, the heads of public works departments, using the *BayWAVE Asset Vulnerability Assessment Tool* to assess more than 350 built and natural resource assets. The interview results were combined with the geographic data to develop the Vulnerability Assessment.

Table 1. Sea Level Rise Projections for San Francisco, CA Region

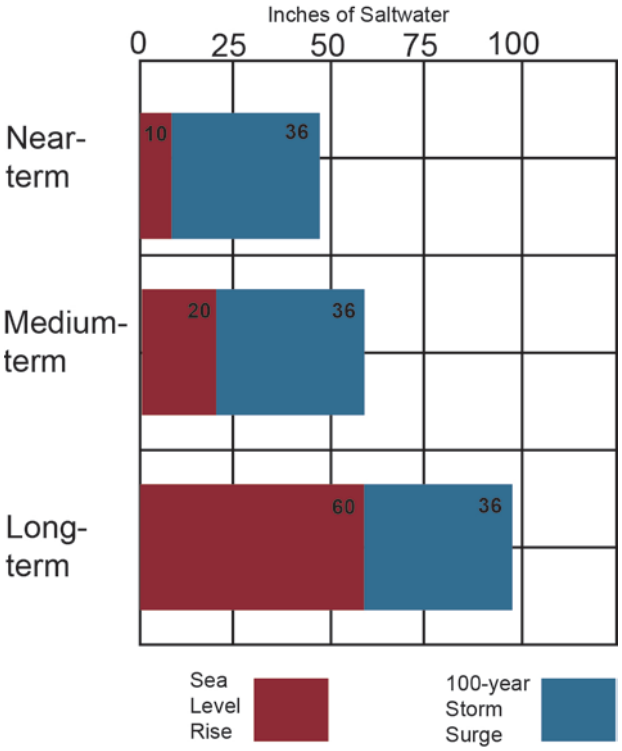
Time Period	Projected Range
by 2030	1.6 – 11.8 inches
by 2050	4.7 – 24 inches
by 2100	16.6 – 65.8 inches

Source: NRC 2012

Table 2. BayWAVE Sea Level Rise Scenarios

Scenario 1	10 inches
Scenario 2	10 inches+100-year storm surge
Scenario 3	20 inches
Scenario 4	20 inches+100-year storm surge
Scenario 5	60 inches
Scenario 6	60 inches+100-year storm surge

Figure 3. BayWAVE Scenarios Associated Water Levels



15-year Expectations

Sea level rise flooding could reduce useable living space and adversely affect tourism, transportation, and natural attractions and resources within 15 years. The first threats are to buildings, roads, and original utility systems along the shoreline. Disruptive flooding to the road and utility networks could have regional ripple effects for extended periods of time. In the near-term, San Rafael and Southern Marin shoreline communities are most at risk to tidal and storm surge flooding.

EXECUTIVE SUMMARY

In this near-term timeframe, tidal flooding at 10 inches of sea level rise (MHHW) could reach 5,000 acres, 1,300 parcels, and 700 buildings, potentially impacting tens of thousands of residents, employees, and visitors. Regular tidal flooding could adversely impact San Rafael east of US Highway 101, bayfront Belvedere and Tiburon, Greenbrae Boardwalk, Waldo Point, and Paradise Cay.

With an additional 100-year storm surge, the previously impacted acres, parcels, and buildings could face tidal and storm surge flooding. An additional 3,000 acres, 2,500 parcels, and 3,800 buildings could anticipate storm surge flooding. These figures amount to six percent of parcels and buildings in the study area. Storm surge flooding, could impact North Novato at Gnoss Field, Black Point on the Petaluma River, lower Santa Venetia, Belvedere around the lagoon, bayfront Corte Madera, bayfront Mill Valley, Marinship in Sausalito, Tamalpais, and Almonte, in addition to the communities vulnerable to tidal flooding.

Eight miles of road could expect tidal flooding. Many of these flooded areas already experience seasonal and king tide flooding. These are:

- Manzanita, Almonte
- Miller Avenue in Mill Valley,
- the Marinship area in Sausalito,
- US Highway 101 in Marin City, Corte Madera, Larkspur, and
- State Route 37 in Novato.

This is expected to worsen in severity and become increasingly frequent. Tidal flooding would reach the Canal area of San Rafael, spreading to I-580. Several roads in Santa Venetia, Tamalpais, Belvedere, Mill Valley, Marin Lagoon of San Rafael, and bayfront Corte Madera and Larkspur would begin to experience seasonal, king tide, and storm surge flooding more frequently.

Water travel infrastructure could be compromised at ferry facilities in Larkspur, Tiburon, and Sausalito preventing commuters from traveling to work. Even if the facilities are able to handle near-term higher tides, providing safe parking and access to ferry users could prove challenging. Samller public and private and marinas and boat launches along the bay in Sausalito, Mill Valley, Strawberry, Tiburon, Belvedere, Bel Marin Keys, and Black Point could be flooded out and unusable. Storm surges can be powerful enough to damage and sink boats. This is especially a corncen for residential boats.

Southern Marin Fire Protection and Sausalito Police Deparmtent boats are included in the boats harbored in marinas vulnerable to sea level rise. The Castro Fire Station in San Rafael is vulnerable to tidal flooding in the near-term and the California Highway Partrol offices in Corte Madera could expect storm surge flooding in this time period. Most concerning, however; is the potential inability of emergency professionals and vehicles to access people in or through flooded areas.

In addition, the marshlands that buffer the shoreline communites from high tides and storm surges could begin to experience transitions in habitat, especially those in Southern Marin where they are typically bordered by urban development. Consequently, the waters here would get deeper and flood out the existing habitat, shifting high marsh to low marsh, low marsh to mud flat, and mud flats to open water. Without adequate light of shallow water, eelgrass beds would shrink. Collectively, these habitat shifts could have significant impacts on vulnerable specieis such as the salt marsh harvest mouse, Ridgway's Rail, or the long-fin smelt.

IMPACTS AT-A-GLANCE: SCENARIO 2

<table>
<tr><td>5,000 acres flooded @ MHHW</td><td>200,000+ residents plus commuting employees</td></tr>
<tr><td>8,000 acres flooded @ MHHW +100-year storm surge</td><td>2,000 agricultural acres
(mostly ranch)</td></tr>
<tr><td>4,500 homes, businesses, & institutions</td><td rowspan="3">Property Owners
County of Marin
Municipalities
Caltrans
Sanitary Districts
Water Districts
Fire Districts
Sausalito Police Department
CHP
SMART
GGBHTD
MTA
PG&E
AT&T
CADFW</td></tr>
<tr><td>30 miles of wet road,
3 ferry landings,
5 marinas,
4 boat launches</td></tr>
<tr><td>Beaches
Tidal Marshes
Eelgrass beds
Wetlands</td></tr>
</table>

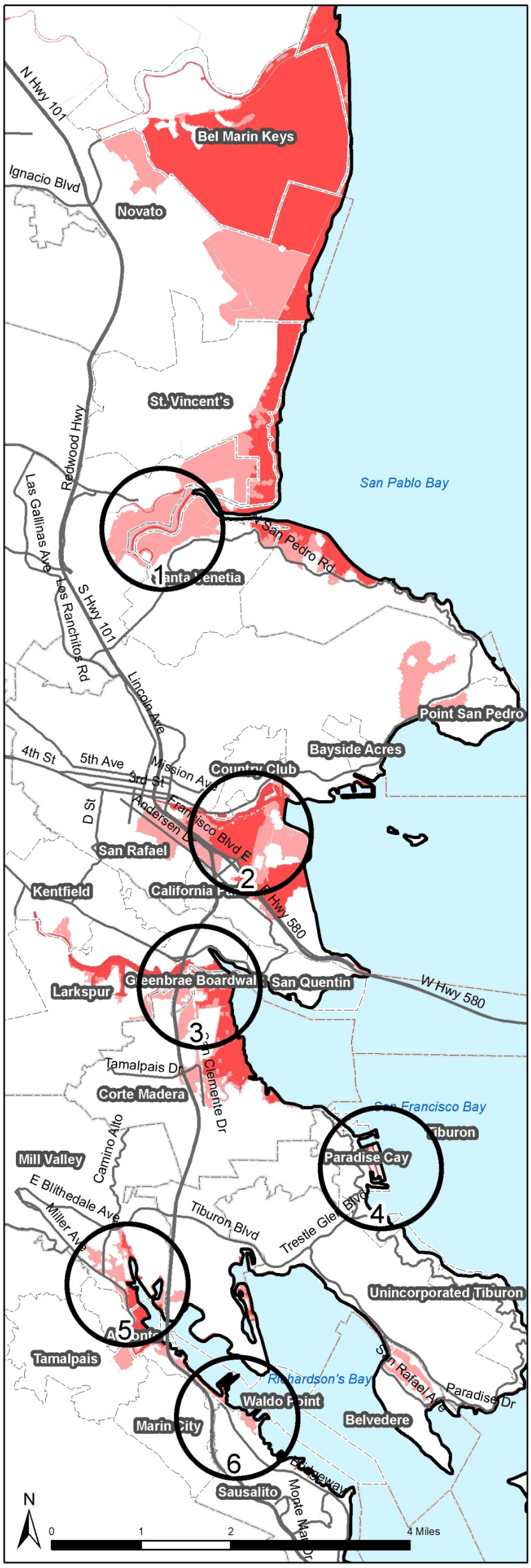
Map 131. Fifteen-year Expectation: Near-term Vulnerable Assets

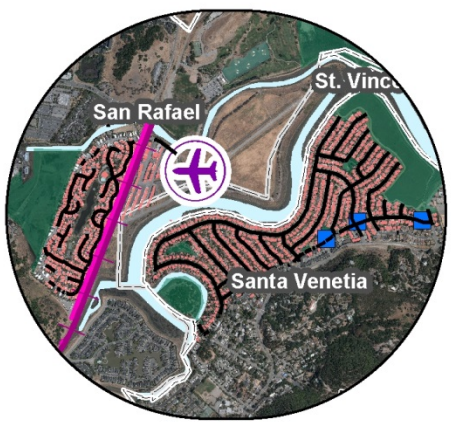
NEAR TERM

Scenario 1:
10 in. Sea Level Rise

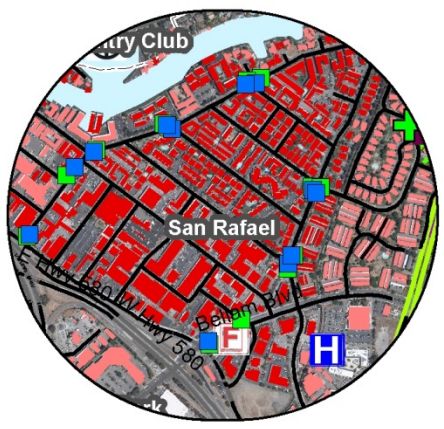
Scenario 2:
10 in. Sea Level Rise
+ 100-year storm surge

In 15 years, high tides could threaten Marin's shoreline buildings, roads, and original utility systems. Damage and breakdowns in road and utility networks would impact the entire County, especially Southern Marin. Tidal flooding (red) could reach 5,000 acres, 1,300 parcels, 700 buildings, and 8 miles of road in San Rafael east of State Route 101, bayfront Belvedere and Tiburon, Greenbrae Boardwalk, Waldo Point, and Paradise Cay. A 100-year storm surge (pink) would flood these areas with storm surge flooding, and flood an additional 3,000 acres, 2,500 parcels, 3,800 buildings, and 20 miles of road in North Novato, Black Point on the Petaluma River, lower Santa Venetia, Belvedere Lagoon, bayfront Corte Madera and Mill Valley, Marinship in Sausalito, Marin Lagoon in San Rafael, Tamalpais, and Almonte. Flooded ferry facilities would prevent commuters and visitors from traveling across the Bay. Boating facilities in Sausalito, Mill Valley, Strawberry, Tiburon, Belvedere, San Rafael, Bel Marin Keys, and Black Point may be inaccessible. This is especially a concern for marinas with residential boats and Southern Marin Fire and Sausalito Police boats. The Castro St. Fire Station in San Rafael is vulnerable to tidal flooding, though all emergency professionals would be denied vehicular access to people in vulnerable areas Southern Marin marshlands would shift high marsh to low marsh to mud flat, and eelgrass beds could shrink under deeper darker waters. These habitat shifts would have significant repercussions for plant, insect, fish, and animal species.

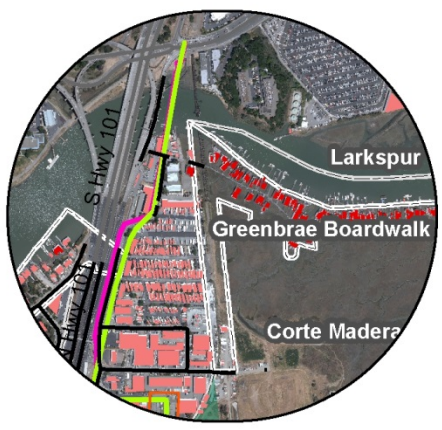




1: Santa Venetia



2: Canal Area



3: Greenbrae Boardwalk/ Larkspur



4: Paradise Cay



5: Mill Valley



6: Waldo Point Harbor

Vulnerable Assets

Vulnerable Buildings
- Scen. 1: 10" Sea Level Rise (SLR)
- Scen. 2: 10" SLR+Storm Surge
- Park
- Vulnerable Road
- Marin Transit Stop
- Golden Gate Transit Stop
- Park & Ride
- SMART Track
- Ferry
- Airport
- Public Boat Launch
- Marina
- School
- Medical Facility
- Law Enforcement
- Emergency Shelter
- Fire Station
- District Office
- Gas Pipe
- Electrical Tranmission Tower
- Substation
- PG&E Property
- Transmission Lines

Sea Level Rise Scenarios
- Scen 1: 10" SLR
- Scen 2: 10"SLR+Storm Surge

Location Indicators
- Unincorporated
- Municipality
- Road
- Bay

Disclaimer: Vulnerability Assessment maps, tables, etc. can be used as a resource to help identify potential hazardous areas and vulnerable assets. Marin County, and data providers here in, make no warranties of the accuracy or completeness of maps and data. Maps are representational and subject to future revision. Local site conditions must be examined. Commercial use is prohibited.

EVB CONSULTING Date: 2/18/2017 CoSMoS

EXECUTIVE SUMMARY

IMPACTS AT-A-GLANCE: SCENARIO 4

6,700 acres flooded @ MHHW	200,000+ residents plus commuting employees
13,500 acres flooded @ MHHW +100-year storm surge	2,000 agricultural acres (mostly ranch)
5,600 homes, businesses, & institutions	Property Owners County of Marin Municipalities Caltrans Sanitary Districts Water Districts Fire Districts Sausalito Police Department CHP SMART GGBHTD MTA PG&E AT&T CA DFW
62 miles of wet road, 3 ferry landings, 5 marinas, 4 boat launches	
Beaches Tidal Marshes Creeks Eelgrass beds Ponds Wetlands	



King tides preview future water levels. Mill Valley. 10:41 a.m., Nov. 25, 2015. Credit: Light Hawk Aerial

Mid Century Expectations

In this medium-term timeframe, tidal flooding at 20 inches of sea level rise (MHHW) could reach nearly 7,000 acres, 3,000 parcels, and 2,000 buildings, potentially impacting even more residents, employees, and visitors than in the near-term. Regular high tide tidal flooding could adversely impact the same locations tidally flooded in the near-term, though more severely.

With an additional 100-year storm surge, the previously impacted acres, parcels, and buildings could face tidal and storm surge flooding, and an additional 7,000 acres, 2,200 parcels, and 3,600 buildings could anticipate storm surge flooding. These figures amount to eight percent of parcels and seven percent of buildings in the study area. Most levees south of Novato are not designed to withstand this level of flooding and could be overtopped. Storm surge flooding would impact the same locations as in near-term scenario 2, 10 inches with a 100-year storm surge, and extends further inland beyond the marshy areas of Mill Valley, Strawberry, San Rafael, St. Vincent's, and North Novato.

Eighteen miles of roadway, ten more miles than in the near-term, could expect tidal flooding. Many of the impacted roads are the same as those impacted in the near-term, though much greater lengths could anticipate tidal flooding and flooding depths would increase. Storm surge flooding could reach a total of 44 additional miles of roadway. Water travel could experience similar outcomes as in the near-term, though the highest high tides and storms surges would cause even more damage than weathered twenty years earlier.

With respect to utilities, pipelines under vulnerable roads, and lateral pipes to vulnerable properties, would become squeezed between rising groundwater and the confining roadway. This could cause pipes to bend and break, and could even damage roadways. In the medium-term, impacts to the North Marin Water District service area would impact water service in Bel Marin Keys and unincorporated Novato. In fact, Bel Marin Keys already experiences seasonal saltwater contamination. Vulnerable substations, electrical transmission towers and lines, and underground natural gas pipelines along the shoreline would be compromised by flooding and subsidence. Disruptions or failures in this network could also have far reaching impacts in transportation, sanitary

service, stormwater management facilities, food storage, communications, and general public safety.

This twenty inch increase in sea level would continue to shrink Southern Marin, Tiburon Peninsula, and Pt. San Pedro marsh and tidal habitats. Complimentary recreational trails, parks, althetic facilities would experience reductions in capacity with increases in maintainance costs.



Mill Valley-Sausalito Path. Credit: J. Poskazner



Historic Flood on US Highway 101 and fronting marshes. Larkspur. Credit: Marin DPW

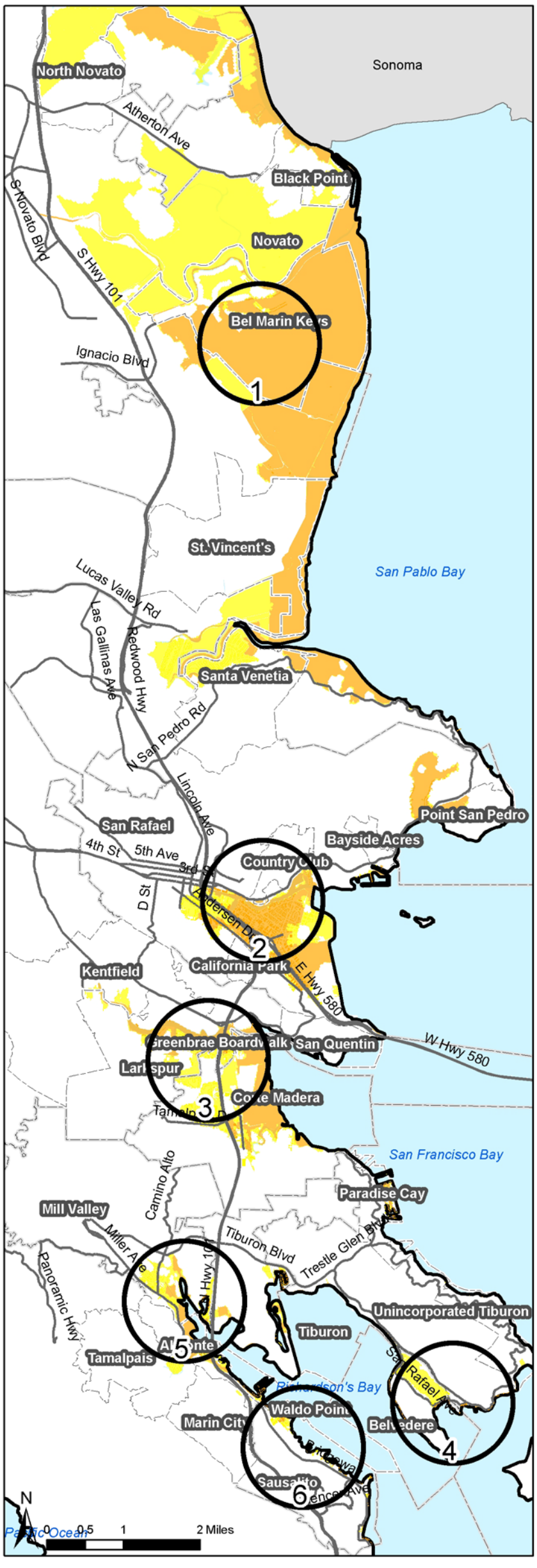
Map 132. Mid-century Expectation: Medium-term Vulnerable Assets

MEDIUM TERM

Scenario 3:
20 in. Sea Level Rise

Scenario 4:
20 in. Sea Level Rise
+ 100-year storm surge

Tidal flooding could reach 7,000 acres, 3,000 parcels, 2,000 buildings, and 18 miles of roadway in the same locations impacted in the near-term, though more severely. With a 100-year storm surge, the area vulnerable to tidal flooding would also experience storm surge flooding. An additional 7,000 acres, 2,200 parcels (8%), 3,600 buildings (7%), and 40 miles of roadway could anticipate storm surge flooding. Most levees south of Novato are not designed to withstand this level of flooding and would be overtopped. Storm surge flooding would extend further inland beyond the marshy areas of Mill Valley, Strawberry, San Rafael, St. Vincent's, and North Novato. Water travel could experience similar outcomes as in the near-term, though the highest high tides and storms surges would cause even more damage than weathered twenty years earlier. Pipelines beneath flooded roads could become squeezed between rising groundwater and the roadway, cause pipes to bend and break, and even damage roadways, this is true for sanitary, stormwater, and potable water pipes. PG&E substations, electrical transmission towers and lines, and natural gas pipelines could be bent or broken by flooding, subsidence, and erosion, with far reaching impacts on utilities, buildings, and transportation. This ten inch increase in sea level would continue to shrink trapped beach and marsh habitats in Southern Marin. Shoreline parks and pathways would flood often.





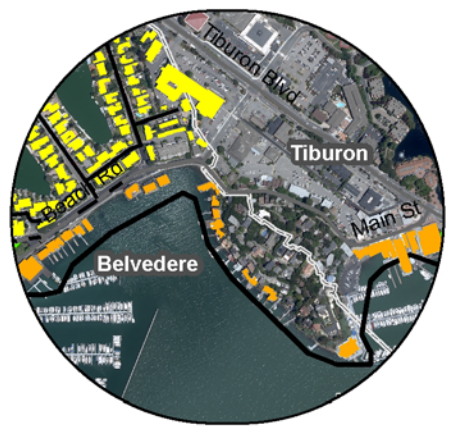
1: Southern Bel Marin Keys



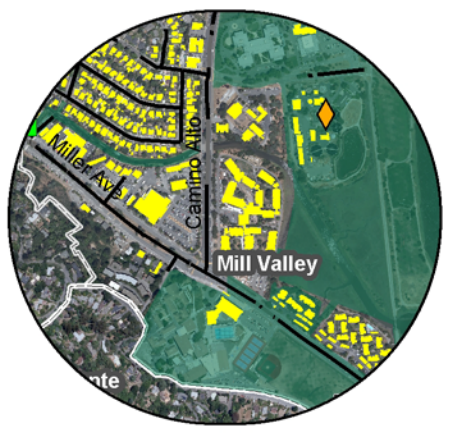
2: U.S. Hwy. 101
@ Interstate 580



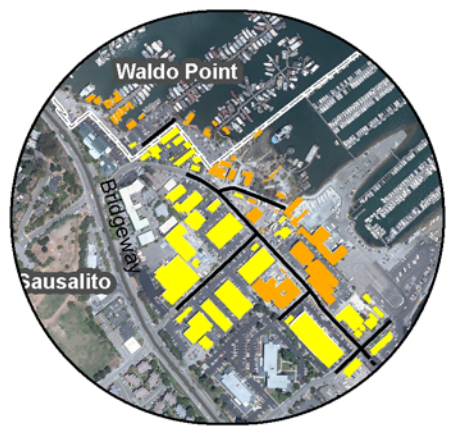
3: Riviera Circle



4: Tiburon/Belvedere



5: Mill Valley



6: Marinship

Vulnerable Assets

- Scen. 3: 20" Sea Level Rise
- Buildings Vulnerable to Storm Surge
- @20"+Storm Surge
- Park
- SMART Track
- Marin Transit Stop
- Golden Gate Transit Stop
- Park & Ride
- Ferry
- Airport
- Boat Launch
- Marina
- School
- Medical Facility
- Law Enforcement
- Emergency Shelter
- Fire Station
- District Office
- Gas Pipe
- Electrical Tranmission Tower
- Substation
- Transmission Lines

Sea Level Rise (SLR) Sceanrios

- Scen 3: 20" SLR
- Scen 4: 20"SLR+Storm Surge

Location Indicators

- Unincorporated
- Municipality
- Road
- Bay

Disclaimer: Vulnerability Assessment maps, tables, etc. can be used as a resource to help identify potential hazardous areas and vulnerable assets. Marin County, and data providers here in, make no warranties of the accuracy or completeness of maps and data. Maps are representational and subject to future revision. Local site conditions must be examined. Commercial use is prohibited.

EVB CONSULTING

Date: 4/1/2017

OCOF CoSMoS

IMPACTS AT-A-GLANCE: SCENARIO 6

16,300 acres flooded @ MHHW	200,000+ residents plus commuting employees
18,000 acres flooded @ MHHW +100-year storm surge	4,150 agricultural acres (mostly ranch)
12,100 homes, businesses, & institutions	Property Owners County of Marin Municipalities Caltrans Sanitary Districts Water Districts Fire Districts Sausalito & Central Marin Police Departments CHP SMART GGBHTD MTA PG&E AT&T CADFW
$15.6 billion in assessed property value[4]	
200 miles of wet road, 3 ferry landings, 5 marinas, 4 boat launches	
Beaches Tidal Marshes Creeks Eelgrass beds Ponds Wetlands	



Kappas Marina. April 2016. Credit: Richardson's Bay Floating Homes Association.

[4] 2016 dollars

End of Century Expectations

In this long-term timeframe, tidal flooding at 60 inches of sea level rise (MHHW) could reach nearly 7,000 acres, 8,000 parcels, and 9,000 buildings, potentially impacting hundreds of thousands of residents, employees, and visitors. These figures amount to 13 percent of parcels and 12 percent of buildings in the study area. Regular tidal flooding could adversely impact the same locations impacted in the near- and medium-terms and significant portions of what would have previously only flooded from the 100-year storm surge. The additional areas that would tidally flood at 60 inches of sea level rise are:

- Tamalpais Valley,
- Mill Valley from the Richardson's Bay shoreline up to and beyond Camino Alto between Miller and East Blithedale Avenues,
- Mill Valley and Strawberry fronting US Highway 101 between Seminary Drive and Tiburon Boulevard,
- Santa Venetia north of N. San Pedro Boulevard,
- Cove Neighborhood, Tiburon,
- Belvedere Lagoon neighborhood,
- Paradise Cay
- Mariner Cove, Marina Village, Madera Gardens, and major retail centers lining US Highway 101,
- Riviera Circle, Creekside, and Heatherwood neighborhoods, Larkspur,
- Interstate 580 and westward towards Andersen Drive in San Rafael and the community of California Park,
- Marin Lagoon and Peacock Gap neighborhoods, San Rafael,
- Bel Marin Keys northern and southern lagoon areas,
- Hamilton, Vintage Oaks, and pockets of development east of US Highway 101 at Rowland Boulevard and State Route 37 in Novato, and,
- North Novato at US Highway 101 and Binford Road.

In long-term scenario 6, storm surge flooding could occur on nearly 13,500 acres hosting 12,600 parcels with 12,000 buildings, potentially impacting 200,000 residents, thousands of employees, and several million visitors. These figures amount to nearly one-fifth of parcels and more than 15 percent of the buildings in the study area. Area that could anticipate storm surge flooding are:

- Sausalito west of Bridgeway,
- Marin City neighborhood,
- Mill Valley east of East Blithedale Avenue at Alto Shopping Center,
- Las Gallinas and North San Pedro Boulevard, east of US Highway 101, San Rafael,
- Bayside Acres,
- Country Club, and
- Kentfield.

Tidal and storm surge flooding could cause significant economic losses. Minor storm impacts alone could account for $61 million[5] in property damages. The market value of vulnerable single-family homes could exceed $20 billion in 2016 dollars. The assessed value, typically less than market value, for all the vulnerable parcels in the study area is $15.6 billion.[6] By the end of the century, these figures could be even higher.

One-hundred miles of public and private roadways, or five percent of all road miles in the study area, could be vulnerable to tidal exposure. Roads could degrade more quickly, or if flood waters are deep enough, become impassable. Lane miles could be more than double this figure. An additional 30 miles of roadway could be vulnerable at 60 inches of sea level rise and a 100-year storm surge. Moreover, several park and rides, several hundred bus stops, and bus transit and SMART rail routes could flood. The San Rafael Transit Center, where the SMART train and nearly all local and regional buses stop, could expect tidal flooding at MHHW and storm surge flooding in the long-term. Breakdowns in the transportation network would have major impacts on the economy and daily life functions. In addition, significant safety hazards could cause injury or loss of life.

Flooding at the SASM and Novato Sanitary Wastewater Treatment Plants is a significant vulnerability that could arise, potentially disrupting hundreds of thousands of people. By this time, much of the low-lying shoreline sanitary sewer and stormwater infrastructure could be flooded out.

By the end of the century, sea level rise could have direct impacts to Tiburon Fire Station No. 1, Corte Madera Station No. 13, and Novato Atherton Avenue Fire Station. A few emergency shelters in Southern Marin communities could be vulnerable to tidal flooding, and several more could expect storm surge flooding and may not be available when needed most. By this time, the Central Marin Police Department could have to wade through saltwater surrounding the site to reach Larkspur and Corte Madera residents in need.

Southern Marin marshes may no longer exist by the end of the century, destroying the habitat of several shoreline birds and mammals. Northern Marin marshes would become increasingly tidally influenced, with tide water reaching US Highway 101 in Bel Marin Keys and North Novato up the Petaluma River. Typically freshwater marshes west of US Highway 101, for example, Sutton Marsh, could also expect damaging salinity impacts. Tidal marsh lands may increase in Northern Marin if they are not prevented from migrating inland.

In the long-term scenario, approximately 1,358 acres on 30 agricultural parcels could be vulnerable to sea level rise and storm conditions. Another 3,000 acres are public agency lands near Bel Marin Keys, Hamilton Field, and the Novato Sanitary District that are leased for agricultural use. Higher high tides could push brackish conditions inland, reducing grazing, manure spreading, and cultivation area. Moreover, reduced vehicular access on Highways 37, 101, and other major roads could disrupt product distribution.

Finally, all of these assets contain or contribute to the well-being of the region's cultural, archeological, and historic resources that constitute each community's sense of place. This is especially a concern for Sausalito, Tiburon, and Novato.



China Camp Historic pier. December 2016 King Tide. Credit: Ron Rothbart

[5] 2016 dollars
[6] 2016 dollars

EXECUTIVE SUMMARY

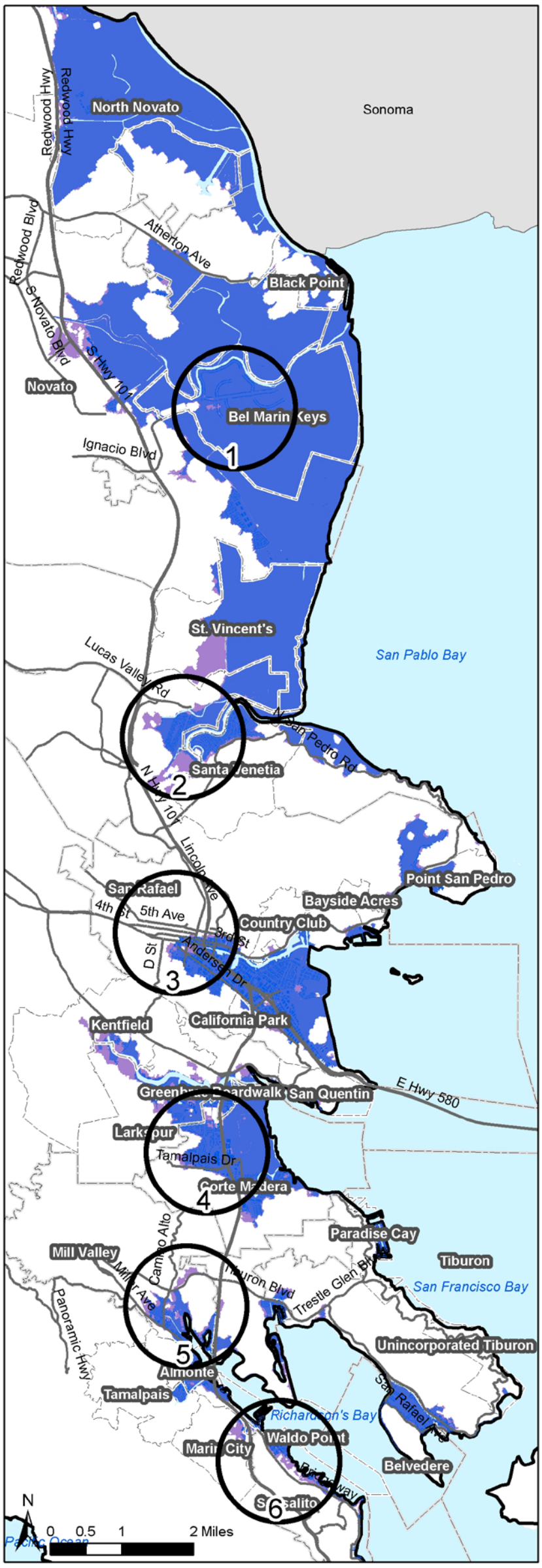
Map 133. End of Century Expectations: Long-term Vulnerable Assets

LONG TERM

Scenario 5:
60 in. Sea Level Rise

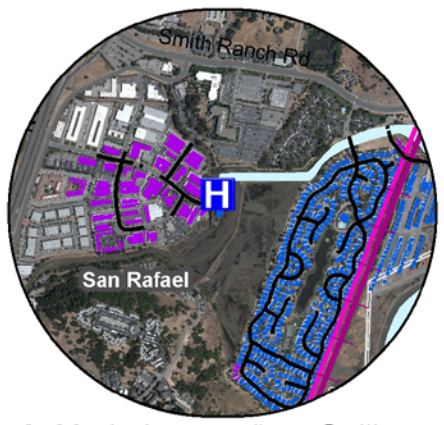
Scenario 6:
60 in. Sea Level Rise
+ 100-year storm surge

By 2100, tidal flooding could reach nearly 7,000 acres, 8,000 parcels (13%), 9,000 buildings (12%), and 100 miles of road. Higher high tides could adversely impact the locations flooded in medium-terms, and significant portions of the areas that previously suffered storm surge flooding. Tidal flooding would reach beyond the State Routes 101and 580 in low-lying areas, into Southern Marin's narrow valleys and creek sides, and over every levee in Marin County. A 100-year storm surge could flood these areas, and an additional 6,500 acres, 4,600 parcels (20% total), 3,000 buildings (15% total), and 30 miles of road, extending to Sausalito west of Bridgeway, Marin City housing, Mill Valley's Alto Shopping Center, Las Gallinas and N. San Pedro Blvd. in San Rafael, Bayside Acres, Country Club, and Kentfield. Minor building damage could amount to $61 million (2016 dollars). Vulnerable single family homes exceed $20 billion in market value (2016 dollars). Several park and rides, hundreds of bus stops, and bus routes, and SMART rail track, including the San Rafael Transit Center, could experience flooding. Disruptive flooding at the SASM and NSD wastewater treatment plants and pump stations would affect tens of thousands of people. Storm surges could flood Tiburon Fire Station No. 1, Corte Madera Fire Station No. 13, and Novato Atherton Ave. Fire Station. A few emergency shelters in Southern Marin flood at high tide, and many more could be closed during a storm. The Central Marin Police Department may have to navigate deep water to reach Larkspur and Corte Madera shoreline residents. In Southern Marin, mud flats and water would dominate existing marshes. In the north, tidal marshes could expand.

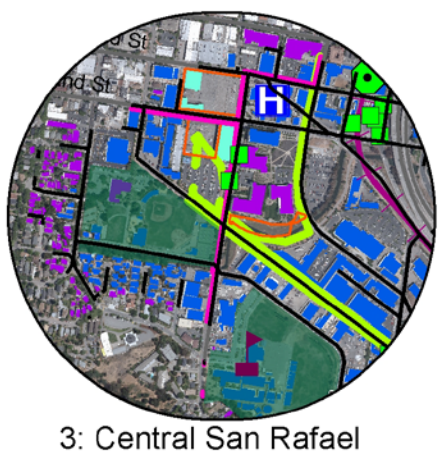




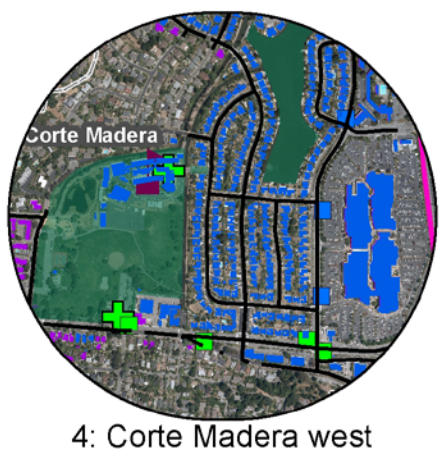
1: Bel Marin Keys



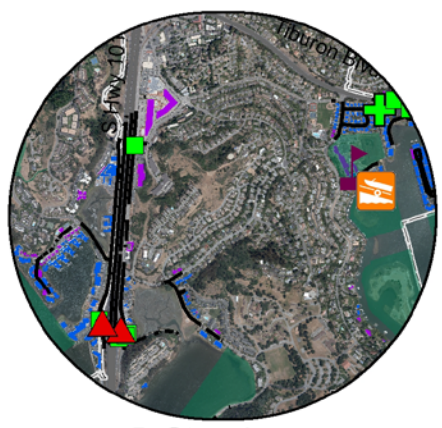
2: Marin Lagoon/Las Gallinas



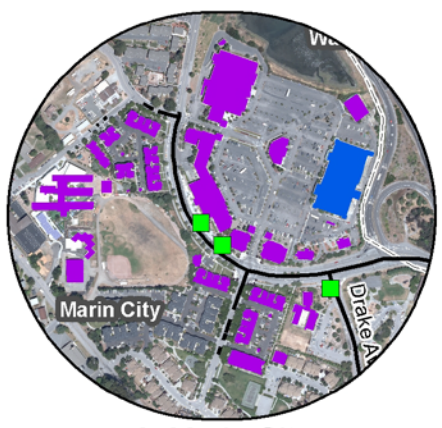
3: Central San Rafael



4: Corte Madera west of U.S. Hwy. 101



5: Strawberry



6: Marin City

Vulnerable Assets

Vulnerable Buildings
- @60" Sea Level Rise
- @ 100-Year Storm Surge
- Park
- Park & Ride
- Marin Transit Stop
- Golden Gate Transit Stop
- Public Boat Launch

- SMART Station
- SMART Track
- School
- Medical Facility
- Emergency Shelter
- Gas Pipe
- Transmission Lines

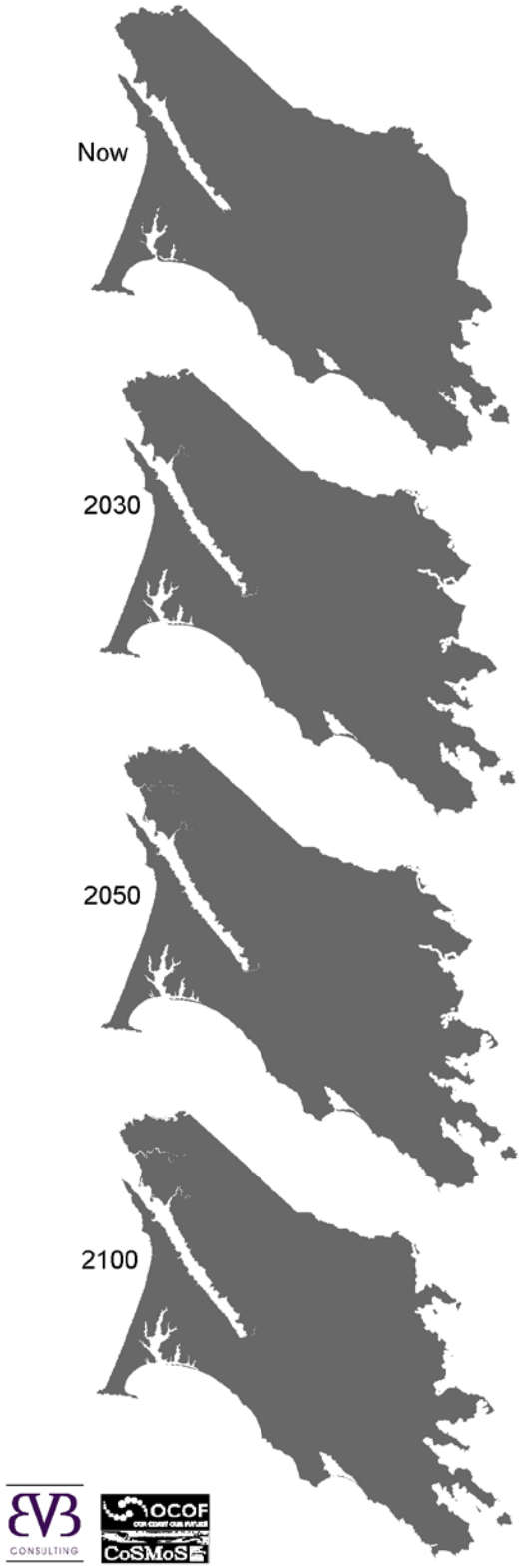
Sea Level Rise (SLR) Scenarios
- Scen 5: 60" SLR
- Scen 6: 60"SLR+Storm Surge

Location Indicators
- Unincorporated
- Municipality
- Road
- Bay

Disclaimer: Vulnerability Assessment maps, tables, etc. can be used as a resource to help identify potential hazardous areas and vulnerable assets. Marin County, and data providers here in, make no warranties of the accuracy or completeness of maps and data. Maps are representational and subject to future revision. Local site conditions must be examined. Commercial use is prohibited.

EVB CONSULTING Date: 4/1/2017 OCOF CoSMoS

Figure 6. Estimated Decreases in Marin County Land Area due to Sea Level Rise



A significant degree of uncertainty exists as to how soon these increases in sea level could occur because future carbon emissions are an unknown. However, even if global citizens stabilize carbon emissions, sea level rise would likely continue. Moreover, even if the growing global population reduces carbon emissions to levels where atmospheric concentrations decline, the decline will be slow and sea levels would still likely continue to rise for decades, and hundreds of years could pass before the sea level stabilizes or drops.[7,8] If emissions continue to increase, the rate of sea level rise is also likely to increase and these assets could be vulnerable sooner than this assessment presents. Because of this uncertainty, this assessment is the first step in an iterative process that will need to be updated as additional science becomes available and adaptation efforts are implemented. The sea level rise preparation process will require consistent monitoring and evaluation to improve modeling assumptions and ensure preparation efforts are effective and efficient.

Hamilton Wetlands and Aramburu Wildlife Preserve were recently enhanced, and wetland restoration is in planning for Bothin Marsh, McInnis Park, and Novato's baylands. Nonprofits are also working to include: Marin Audubon Society project in Corte Madera, and the Coastal Conservancy's Bel Marin Keys restoration project once funds are secured.

Combined with potential losses in West Marin due to potential sea level rise, the impacts to Marin County will be significant across all asset categories. The image to the left combines estimates for land area that would be lost at MHHW across the near-term, 2030, the medium-term, 2050, and the long-term, 2100 scenarios applied to Western and Eastern Marin.

[7] IPCC Fourth Assessment Report: Climate Change 2007. Climate Change 2007: Working Group I: The Physical Science Basis. 10.7.2 Climate Change Commitment to Year 3000 and Beyond to Equilibrium. https://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch10s10-7-2.html

[8] IPCC Fourth Assessment Report: Climate Change 2007. Climate Change 2007: Working Group I: The Physical Science Basis. 10.7.4 Commitment to Sea Level Rise. https://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch10s10-7-4.html

EXECUTIVE SUMMARY

With this vulnerability assessment, Marin County professionals, officials, residents, employees, and other Bay Area communities can gain an understanding of the potential fallout from higher high tides in a no action scenario. With this comprehensive view of the potential issues, Marin County communities can approach preparing for this shared concern with greater efficiency and collaboration.



Tiburon's Main Street buildings are from the early 1900s, and are adjacent to the ferry terminal. Credit: Marin CDA



Low lying properties in Black Point. Credit: Marin CDA

INTRODUCTION

Introduction

Climate change is affecting natural and built systems around the world, including the California coast. In the past century, average global temperature has increased about 1.4°F, and average global sea level has increased 7 to 8 inches.[9] Sea level at the San Francisco tide gauge has risen 8 inches over the past century, and the National Research Council (NRC) projects that by 2100, sea level in California south of Cape Mendocino may rise 66 inches.[10] The two major causes of global sea level rise are thermal expansion of warming oceans and the melting of land-based glaciers and polar ice caps.[11]



View of Almonte from Shoreline Highway. Dec. 2014. Credit: Marin DPW

While Marin's shoreline already experiences regular erosion, flooding, and significant storm events, sea level rise will exacerbate these natural processes, leading to significant social, environmental, and economic impacts. The third National Climate Assessment cites strong evidence that the cost of doing nothing exceeds the costs associated with adapting to sea level rise by 4 to 10 times.[12] Therefore, it is critical the County of Marin, municipalities, and special districts plan and prepare for the impacts of sea level rise to ensure a resilient county for present and future generations.

This publication presents the Bay Waterfront Adaptation and Vulnerability Evaluation (BayWAVE) for Marin's San Francisco, Richardson's, and San Pablo Bay communities' built and natural assets. This effort is part of an ongoing scientific, collaborative, and public process to understand and prepare for sea level rise along the Marin shoreline. This Vulnerability Assessment seeks to provide context and estimates of the physical and fiscal impacts to shoreline over the coming decades. This analysis highlights the complexity of the potential impacts and the need for both concerted and individual actions in the face of rising tides. The data presented can be used to prioritize efforts, seek funding, and shape policy and development discussions.

The County of Marin Department of Public Works is the project lead for the Bay Waterfront Adaptation & Vulnerability Evaluation (BayWAVE) program. The program began in September 2015 with funding from County of Marin and additional financial support from the California State Coastal Conservancy. Several multi-jurisdictional committees guide the BayWAVE process. The Executive Steering Committee consists of County of Marin and local jurisdiction representatives to guide staff and provide direction at critical milestones. The Policy Committee is made up of elected officials from each city and the County of Marin. The Technical Advisory

[9] Heberger, M., Cooley, H., Moore, E. and Herrera, P. 2012 The Pacific Institute. *The Impacts of Sea Level Rise on the San Francisco Bay.* California Energy Commission. Publication number: CEC-500-2012-014.

[10] *Sea-Level Rise for the Coasts of California, Oregon and Washington: Past, Present and Future.* National Research Council (NRC), 2012.

[11] Heberger, M., Cooley, H., Moore, E. and Herrera, P. 2012 The Pacific Institute. *The Impacts of Sea Level Rise on the San Francisco Bay.* California Energy Commission. Publication number: CEC-500-2012-014.

[12] Moser, S. C., M. A. Davidson, P. Kirshen, P. Mulvaney, J. F. Murley, J. E. Neumann, L. Petes, and D. Reed, 2014: Ch. 25: *Coastal Zone Development and Ecosystems. Climate Change Impacts in the United States: The Third National Climate Assessment*, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., US Global Change Research Program, , 579-618. doi:10.7930/J0MS3QNW. http://nca2014.globalchange.gov/report/regions/coasts

INTRODUCTION

Committee includes staff from local, state, and federal agencies. These committees are essential in achieving the BayWAVE goals to establish an efficient shared learning process and messaging platform, and create a collaborative environment to prepare for sea level rise. See the Acknowledgements for a complete list of committee participants.

This Vulnerability Assessment is advisory and not a regulatory document or legal standard of review for action the County of Marin, municipalities or other involved special governments may take. Such actions are subject to the applicable requirements in each jurisdiction's governing documents and applicable state and local regulations.

The County of Marin, municipalities, and special jurisdictions participating in this assessment have engaged in sea level rise planning and climate action for several years. For example, Marin's Countywide Plan (2007) addresses sea level rise in two policies: EH-3.k Anticipate Climate Change Impacts, Including Sea Level Rise and C-EH-22 Sea Level Rise and Marin's Coast. Other local efforts include sea level rise white papers for San Rafael and Novato, the Here.Now.Us project started by Marin County Supervisor Kate Sears for Southern Marin, the Department of Public Works *Richardson's Bay Shoreline Study*, Novato, Southern Marin, and Gallinas Watershed Program's demonstration projects, and the Collaboration: Sea-level Marin Adaptation Response Team (C-SMART) Program for the West Marin coastline.

This assessment follows extensive efforts throughout the nation, state, and region to understand the science of sea level rise and the impacts it could have. The San Francisco Bay Conservation and Development Commission (BCDC) established the Adapting to Rising Tides program, which includes adaptation planning guidance, and local to regional case studies, and previously published *Living with a Rising Bay: Vulnerability and Adaptation in San Francisco Bay and on the Shoreline* and *Innovative Wetland Adaptation Techniques.* Most recently, BCDC released a Levee Overtopping Study that determines the water levels required to spill over the tops of levees into the areas the aim to protect. Pacific Gas & Electric (PG&E) also released a climate change vulnerability assessment for the Bay Area. In addition, the California Energy Commission (CEC) released *Impacts of Predicted Sea-Level Rise and Extreme Storm Events on the Transportation Infrastructure in the San Francisco Bay Region*. Finally, released two years ago with special attention to climate change impacts is the Baylands Ecosystem Habitat Goals Science Update 2015.

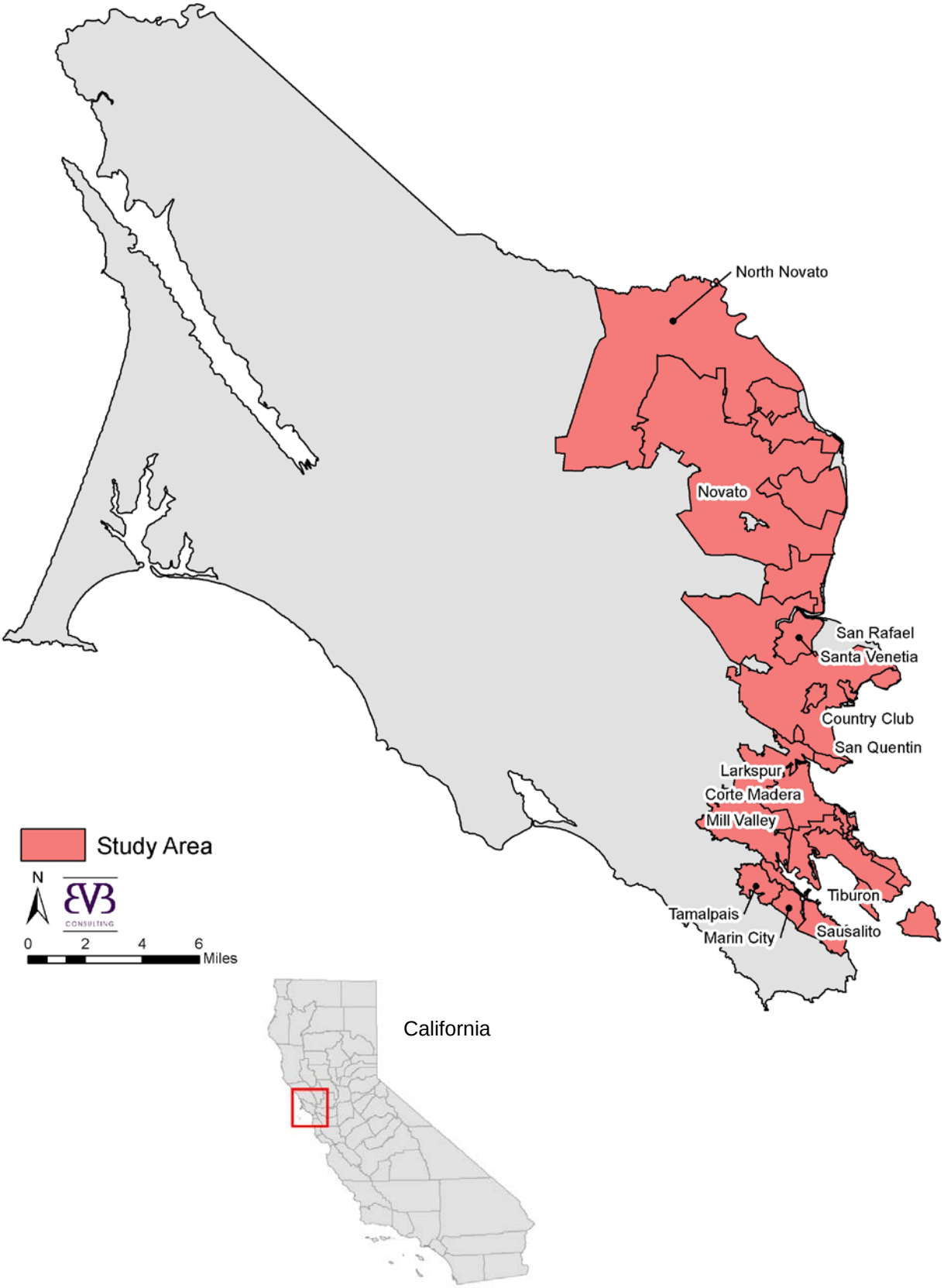
In an effort to dovetail with these studies, goals, and regulations, this assessment applies and presents the best available sea level rise and storm surge science to Marin's shoreline to generate an understanding of Marin's potential future.

This Assessment examines lands on the Marin County bay shoreline from the Golden Gate Bridge to the Petaluma River (see Map 1). The study area is approximately 85,840 acres and comprises of the entire jurisdiction for each municipality and unincorporated community vulnerable to sea level rise under the BayWAVE scenarios. Communities exposed to sea level rise are:

- Municipalities
  - Belvedere
  - Corte Madera
  - Larkspur
  - Mill Valley
  - Novato
  - San Rafael
  - Sausalito
  - Tiburon
- Unincorporated Jurisdictions
  - Almonte
  - Bayside Acres
  - Bel Marin Keys
  - Black Point
  - California Park
  - Country Club
  - Greenbrae
  - Kentfield
  - Marin City
  - North Novato
  - Paradise Cay
  - Point San Pedro
  - San Quentin
  - Santa Venetia
  - St. Vincent's
  - Strawberry
  - Tamalpais Valley
  - Unincorporated Tiburon
  - Waldo Point Harbor.

INTRODUCTION

Map 1. BayWAVE Study Area



v

INTRODUCTION



Tiburon revetment looking to Corinthian Marina and Tiburon Ferry Terminal, 2016. Credit: BVB Consulting LLC

The locations in the study area most likely to experience sea level rise and storm surge impacts in this century are low lying areas in Marin's shoreline communities, especially east of US Highway 101. However, the dry unexposed portions of every community in the study, Tamalpais Valley, Strawberry, Da Silva Island, Mill Valley, Belvedere Island, Tiburon uplands, Sausalito, and San Rafael, could be indirectly impacted. Similarly, East Marin communities outside of the study area, such as Fairfax, San Anselmo, Ross, Alto, Lucas Valley, and others could be vulnerable to transportation network and utility impacts.[13] Note that while in Marin County, the Marin Headlands and Fort Baker are Federal property and not the focus of this assessment. The Federal Parks assessment is at http://www.nature.nps.gov/geology/coastal/coastal_assets_report.cfm.

This assessment is organized into five major sections: (1) methods, (2) asset profiles, and (3) municipality profile, and (4) the Conclusion. The methods section details the background science and research methods used in the BayWAVE process. Asset profiles highlight the vulnerable features bayside residents, employees, and visitors depend on, such as buildings, roads, drinking water, septic, and others. The municipality profiles detail all asset vulnerabilities for each exposed municipality. The Unincorporated Marin profile also provides the same analysis for areas within County of Marin jurisdiction. Each profile details key issues and geographic locations. Asset Profiles highlight initial economic, environmental, equity, and management considerations related to sea level rise vulnerability. Each profile can be read independently, enabling asset managers to focus on a professional area, and community members, elected officials, and others to read about their community as a whole. The conclusion summarizes the impacts by time-period or onset of near-, medium-, and long-term impacts across all asset types and communities.

Key findings include:

- Southern Marin would likely suffer the worst flooding impacts, and could experience these impacts in the near-term.
- Increasingly compromised access to and from the Manzanita Interchange of US Highway 101 and 1 could affect hundreds of thousands of residents, employees, and visitors.
- Reductions in useable space for living, tourism, transportation, and natural resources could impact approximately 12,750 properties, more than 12,000 buildings, and 100 miles in roads.
- Based FEMA HAZUS damage estimates, waves, wind, and temporary flooding during storms could account for $60 million to $6 billion (2016 dollars) in building damages.
- Impacts to wastewater treatment in the Sausalito, Tamalpais, Almonte, Alto, Mill Valley, Novato, and Bel Marin Keys could affect tens of thousands of residents.
- Physical and economic impacts will be felt differently across the various income and age groups, causing social and economic inequities.
- In California, tidelands (land below the mean high water mark) and submerged lands are under public trust. As the sea level rises, thousands of private properties, if still in use, could be subject to the Public Trust Doctrine, become Waters of the State, and be required to pay a leasing fee.
- The most vulnerable habitats are shoreline beaches and marshes south of St. Vincent's.
- Areas that are not exposed to rising bay waters under the BayWAVE scenarios can still be vulnerable to sea level rise when the wastewater treatment plant, ports, and major roadways become compromised under flooding conditions.
- Marin is not self-contained and could feel impacts from across the Bay region, such as the Port of Oakland, which receives imports and exports for the entire Bay Area, or transportation network in San Francisco and the East Bay that,

[13] http://cal-adapt.org/sealevel/ Cal Adapt Sea Level Rise Threatened Areas Map

when flooded, would disrupt commuting, and regional and global travel.

- Sea level rise is one of several climate change impacts residents will likely face. Combined with typical hazards that already exist (e.g. liquefaction and ground shaking near fault lines, erodible soils, and heavy rainfall), Marin is more vulnerable than this assessment can describe.

This assessment is the first step in an ongoing iterative process. The sea level rise preparation process will require consistent monitoring and evaluation to improve modeling assumptions and ensure preparation efforts are effective and efficient. With this vulnerability assessment, Marin County professionals, officials, residents, employees, and other Bay area communities can gain an understanding of the potential fallout from higher high tides in a no action scenario. With this comprehensive view of the potential issues, Marin County communities can approach preparing for this shared concern with greater efficiency and collaboration.

Marin Flood History

Understanding past floods can inform future vulnerabilities. Marin is no stranger to damaging floods. Major floods occurred in 1952, 1955-1958, 1967, 1969 and 1970. In later years, portions of Corte Madera, Larkspur, Greenbrae, Mill Valley, Ross, San Anselmo, San Rafael and Novato flooded in the winters of 1982/1983, 1986, 1997/1998, and 2005/2006, during El Niño events. Recent media attention has focused on the king tides that flood Southern Marin.



Ross Business District during the 1925 flood.
Credit: Marin History Museum

February 10th 1925 More than seven inches of rain fell in the Ross Valley, overflowing creeks, and flooding streets. Extensive damage occurred to homes and infrastructure in San Anselmo, Ross and Kentfield.[14]



Credit: Independent Journal

1956-58 Corte Madera Creek experienced major flooding that prompted a large Army Corps of Engineers flood control project. Due to continuous flooding, the Kentfield Fire Department tied a rowboat to the Laurel/Sir Francis Drake sign for use.[15]



Credit: San Anselmo Historical Museum

January 1982 The 'Great Storm of 1982,' dumped sixteen inches of rain that killed four residents, destroyed 35 Marin homes, and damaged 2,900 more, totaling $80 million in damages.[16, 17]

December 1969
Independent-Journal



I.J. 12/31/69 p.1 WEATHER

Marin County Is Declared Disaster Area

I-J Special Report

SAN FRANCISCO — Marin County today was declared a disaster area by the Small Business Administration, Rep. William S. Mailliard, R-Sixth District, reported.

The declaration, one day after an official of the SBA toured the county to inspect homes and businesses damaged by the recent floods, means that property owners will be eligible for low-interest SBA loans to repair damages, and that the county will be eligible for flood relief grants.

The SBA based its declaration on an estimate by the county that damage by flood water and landslide damage totaled $400,000. Four homes suffered major damage, the SBA said, and minor damage was reported at 190 homes, five apartment buildings and 18 businesses.

The county estimated damages at $250,000 to private property and $150,000 to public property.

[14] San Anselmo Historical Museum. 2015. *San Anselmo's Long History of Flooding.* http://sananselmohistory.org/articles/flooding/. Accessed 1/29/16
[15] Source Unknown
[16] Blodgett J.C., and Edwin H. Chin. 1989. *Flood of January 1982 in the San Francisco Bay Area, California.*
[17] Marin Independent Journal. 2011. *Highlights of Marin's History, from 1850-2010*

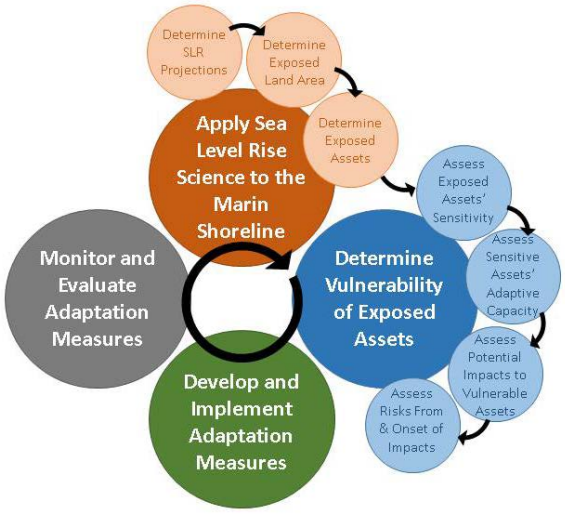
METHODS

Methodology

The BayWAVE Vulnerability Assessment process (see Figure 1) is guided by CalAdapt[18] through the following phases of analysis:

- Phase 1: Exposure: Assess potential changes in water level from sea level rise, storm events, and geomorphic change to determine the built and natural assets that could be exposed to saltwater.
- Phase 2: Sensitivity: Assess the degree of damage or disruption tidal and storm surge flooding could cause on the exposed assets.
- Phase 3: Adaptive Capacity: Assess each asset's adaptive capacity, or ability to respond successfully, to flooding, without human intervention
- Phase 4: Potential Impacts: Evaluate the potential consequences to the assets and larger context, assuming no intervention actions.
- Phase 5: Risk & Onset: Describe the certainty and timing of impacts.

Figure 1. BayWAVE Process



[18] CA Emergency Management Agency, CA Natural Resource Agency. *California Climate Adaptation Planning Guide (APG).* July 2012. http://resources.ca.gov/docs/climate/01APG_Planning_for_Adaptive_Communities.pdf

Modeling Methods

Sea level rise estimates used in this analysis are from the USGS Coastal Storm Modeling Systems (CoSMoS) and are viewable online through the Our Coast Our Future (OCOF) Flood Map tool. OCOF was developed through a partnership of several notable institutions and agencies, and represents the best available sea level rise and storm science.

OCOF uses the USGS's Digital Elevation Model (DEM) constructed for the region (http://topotools.cr.usgs.gov/topobathy_viewer/) with 2-meter horizontal grid resolution based on North American Vertical Datum of 1988 (NAVD88) elevations, and USGS's numerical modeling system called Coastal Storm Modeling System (CoSMoS) to produce a combination of 40 different sea level rise and storms scenarios. CoSMoS scales down global and regional climate and wave models to produce local hazard projections.[19]

High quality elevation data incorporated in the DEM was used to create maps of mean higher high water (MHHW) tidal elevation, and provides the option to add storm surges of different magnitudes. Mean higher high water is the average of the higher high water level of each tidal day observed over the National Tidal Datum Epoch.[20,21] Each day has two high tides, one typically higher than the other. The higher values are used for this analysis. Some days the higher high tide will be lower or higher than other days, however, several days of flooding a month, several months a year, or even once every year would be problematic depending on the resource being examined.

Note, also because the analysis uses high tide, properties near the inland extent of properties exposed to MHHW may not flood at low tides. On

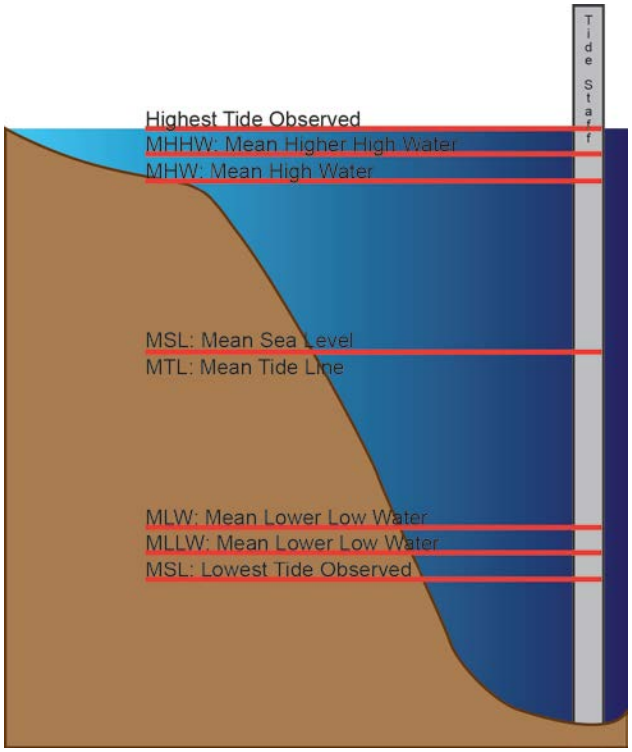
[19] Ballard, G., Barnard, P.L., Erikson, L., Fitzgibbon, M., Higgason, K., Psaros, M., Veloz, S., Wood, J. 2014. Our Coast Our Future (OCOF). [web application]. Petaluma, California. www.pointblue.org/ocof. (Accessed: Date August 2014]).

[20] National Tidal Datum Epoch is the specific 19-year period adopted by the National Ocean Service as the official time segment over which tide observations are taken and reduced to obtain mean values (e.g., mean lower low water, etc.) for tidal data.

[21] NOAA/National Ocean Service. *Tidal Datums*. Access Oct. 19, 2015. Last updated: 10/15/2013. Center for Operational Oceanographic Products and Services. https://tidesandcurrents.noaa.gov/datum_options.html.

the other hand, these properties, and properties just beyond the inland extent of scenario 6, the most-severe scenario examined in this report, could experience flooding from the highest high tides, especially in combination with storms and/or king tides.

Figure 2. Tidal Datum Comparing MHHW to Mean Sea Level and Low Water Levels



Source: National Oceanic and Atmospheric Administration. Credit: BVB Consulting LLC



King tides preview future water levels. Mill Valley. 10:41 a.m., Nov. 25, 2015. Credit: LightHawk

CoSMoS accounts for wave run-up and set-up, storm surge of the ocean, seasonal effects, tides, levees, river discharge, and wind from the San Francisco Bay. Note that this tool only accounts for bay water levels and does not assess fresh stormwater flooding upstream or changes in the shoreline (geomorphology) as erosion continues. Thus, storms used in this analysis include bay storm surge only, not additional freshwater creek flooding upstream. In addition, this analysis does not account for the ability of pump stations to drain flooded areas.

Table 1 shows the range of sea level rise projections for California adopted by the National Research Council in 2012. Given the uncertainty in the magnitude and timing of future sea level rise, this analysis uses a scenario based approach to assess a range of potential sea level rise and storm surge exposure. The six USGS CoSMoS scenarios selected for the BayWAVE Vulnerability Assessment in Table 2 align with the NRC 2012 estimates as follows:

- Scenarios 1 and 2 represent the near-term projection anticipated by 2030.
- Scenarios 3 and 4 represent the medium-term projection anticipated by 2050.
- Scenarios 5 and 6 represent the long-term projection anticipated by 2100.

Table 1. Sea Level Rise Projections for San Francisco, CA Region

Time Period	Projected Range
by 2030	1.6 – 11.8 inches
by 2050	4.7 – 24 inches
by 2100	16.6 – 65.8 inches

Source: NRC 2012

Table 2. BayWAVE Sea Level Rise & Storms Scenarios

Sea Level Rise Scenario		Term
1	10 inches	Near
2	10 inches+100-year storm	
3	20 inches	Medium
4	20 inches+100-year storm	
5	60 inches	Long
6	60 inches+100-year storm	

Figure 3. BayWAVE Scenarios Associated Water Levels

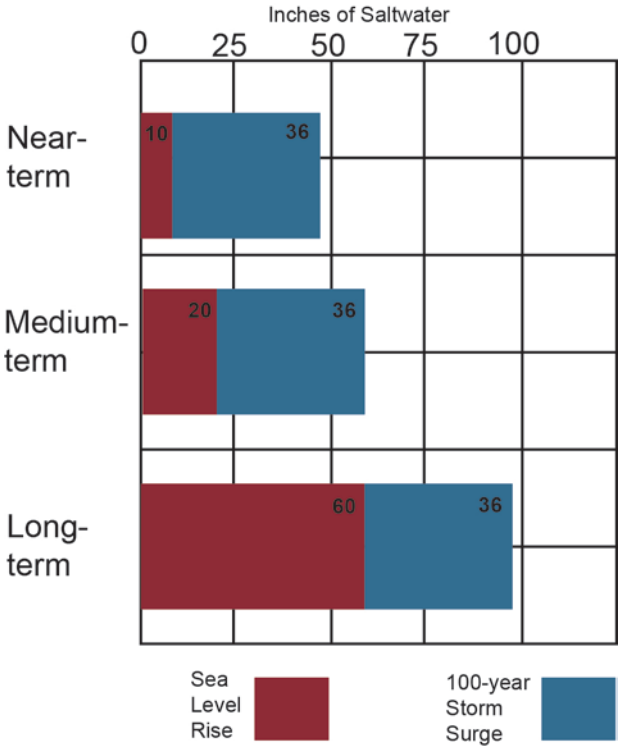


Figure 3 presents another view of the BayWAVE scenarios where the red lengths represent tidal flooding in sea level rise scenarios 1, 3, and 5, and the blue lengths represent the additional storm surge water level associated with scenarios 2, 4, and 6. Together these bands show the potential flooding in the near-, medium-, and long-terms.

The odd numbered scenarios illustrate sea level rise only. Even numbered scenarios illustrate sea levels and incorporate the storm flooding from a future based 100-year storm surge. The scenarios include storm surges because storm surges have the potential to cause catastrophic damage. The CoSMoS model uses research and predictions for future storm patterns to create the future storm typology used in the BayWAVE scenarios. Future storms are anticipated to come from a southerly direction, as opposed to historic storms, which tend to come from the north. For more information on how storms were modeled see references on the OCOF website.

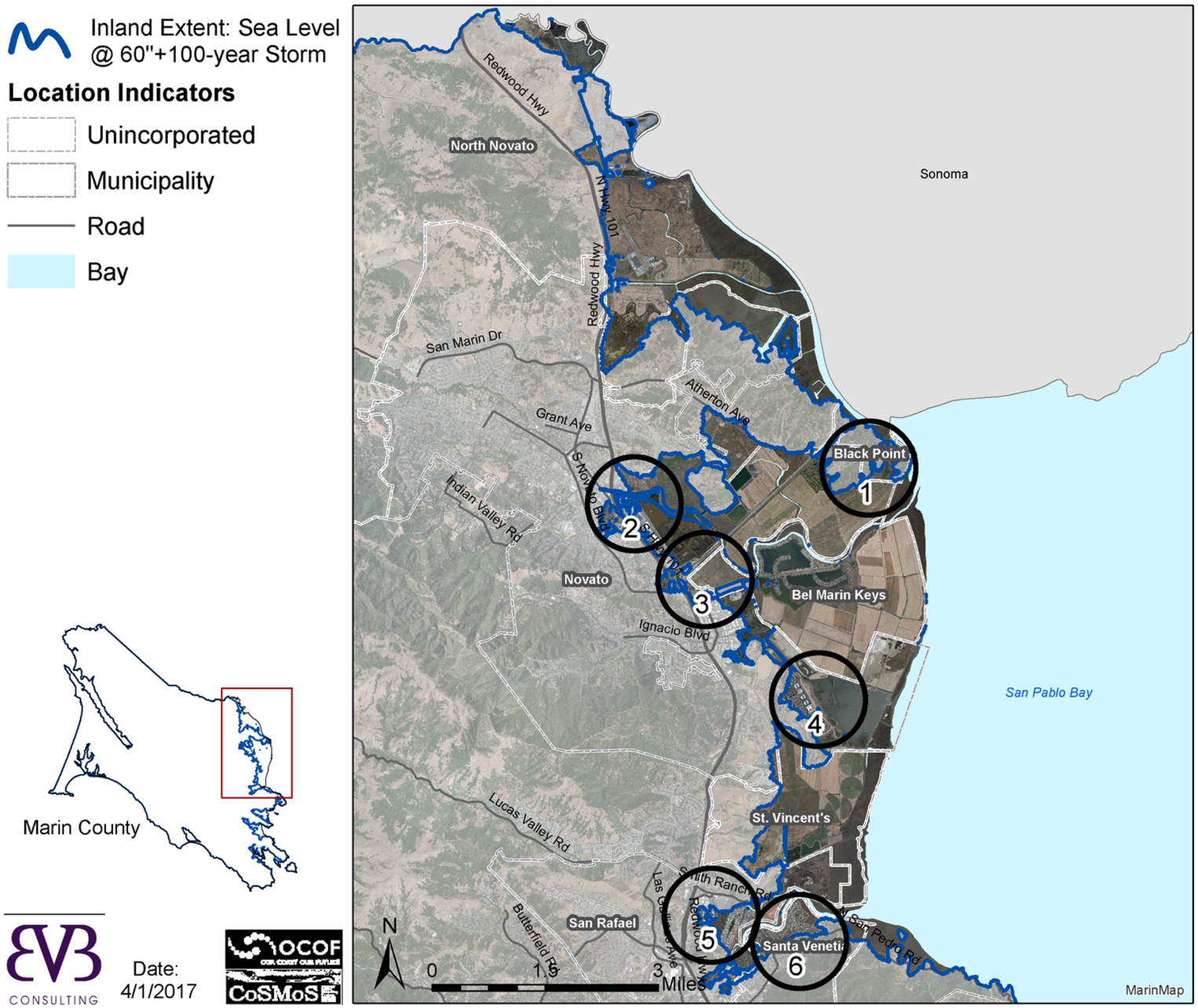
A 100-year storm surge has one percent chance of happening in any storm in a given year. Within a 30-year mortgage, a 100-year storm has a nearly 30 percent chance of occurring. Note that, as climate change continues, the 100-year storm surge level of flooding may occur more frequently, increasing the annual risk of this level storm occurring from a 100-year storm surge to a 50-year storm surge, for example. In addition, there are more frequent storm surges, and less frequent storm surges such as the, 200-year, 400-year, annual, or 5-year storm surges. Less frequent larger storms would result in more severe flooding than presented in this report,[22] whereas, smaller storm surges would produce less severe flooding.

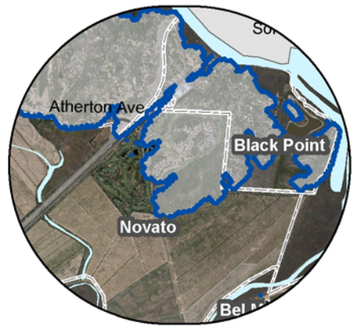
Maps 2 and 3, on the following pages, show the furthest inland extent of scenario 6. Maps 4 and 5 show scenarios 1, 3, and 5, and Maps 6 and 7 show scenarios 2, 4, and 6. The shoreline is typically mapped in two maps: (1) the northern study area, north of Pt. San Pedro, and (2) the southern study area, south of Pt. San Pedro, halves of the study area. The call out circle maps show zoomed in images of locations that may be difficult to se. The circles do not indicate these do not indicate that there areas are more vulnerable than areas not depicted in the circular maps.

[22] W. Eisenstein, M. Kondolf, and J. Cain. *ReEnvisioning the Delta: Alternative Futures for the Heart of California.* Department of Landscape Architecture and Environmental Planning. University of California, Berkeley. University of California Publishing Services. IURD report # WP-2007-01. http://landscape.ced.berkeley.edu/~delta

METHODS

Map 2. Northern Study Area Inland Extend of Scenario 6





1: Black Point/Green Point



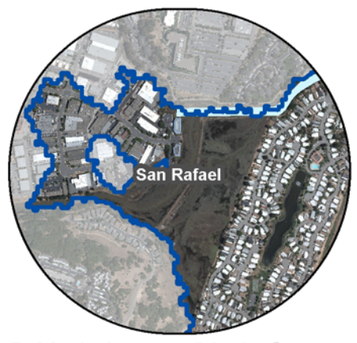
2: U.S. Hwy.101 @ Rowland Blvd.



3: U.S. Hwy. 101 @ Bel Marin Keys Blvd.



4: Hamilton



5: Marin Lagoon/Marin Commons



6: Santa Venetia

Date: 4/1/2017

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Map 3. Southern Study Area Inland Extent of Scenario 6

Inland Extent: Sea Level @ 60"+100-year Storm

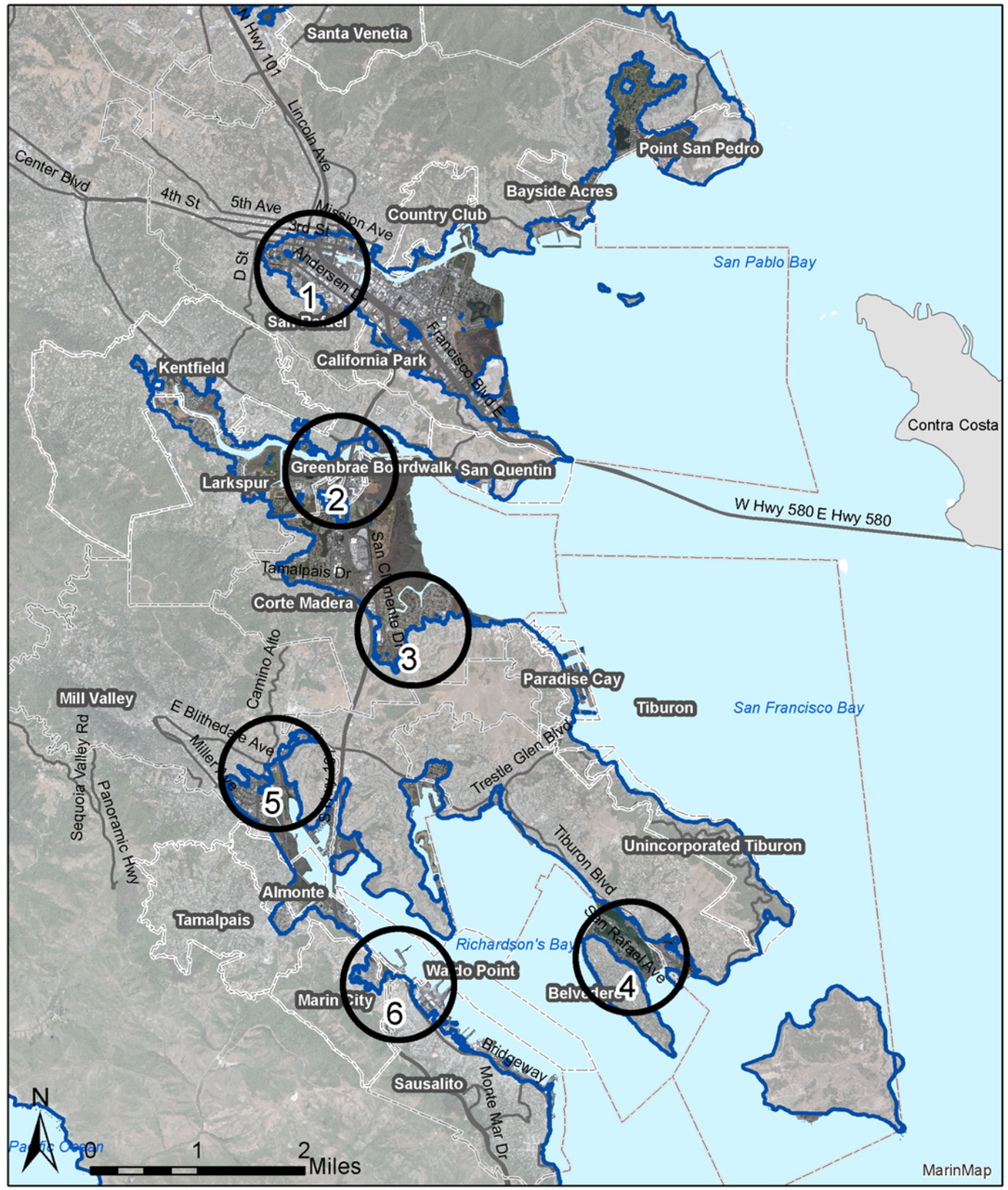
Location Indicators

Unincorporated

Municipality

Road

Bay





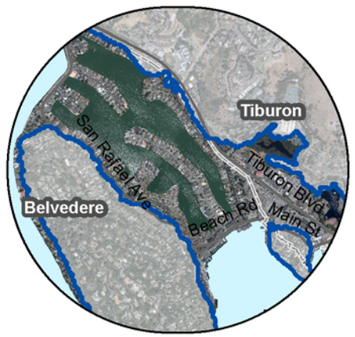
1:Downtown San Rafael



2: Greenbrae/Larkspur



3: Corte Madera



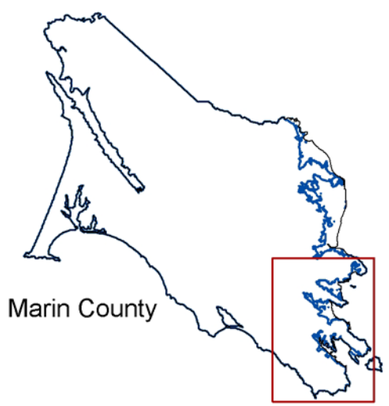
4: Belvedere/Tiburon



5: Mill Valley



6: Waldo Pt. Harbor



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Date: 1/7/2017

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METHODS

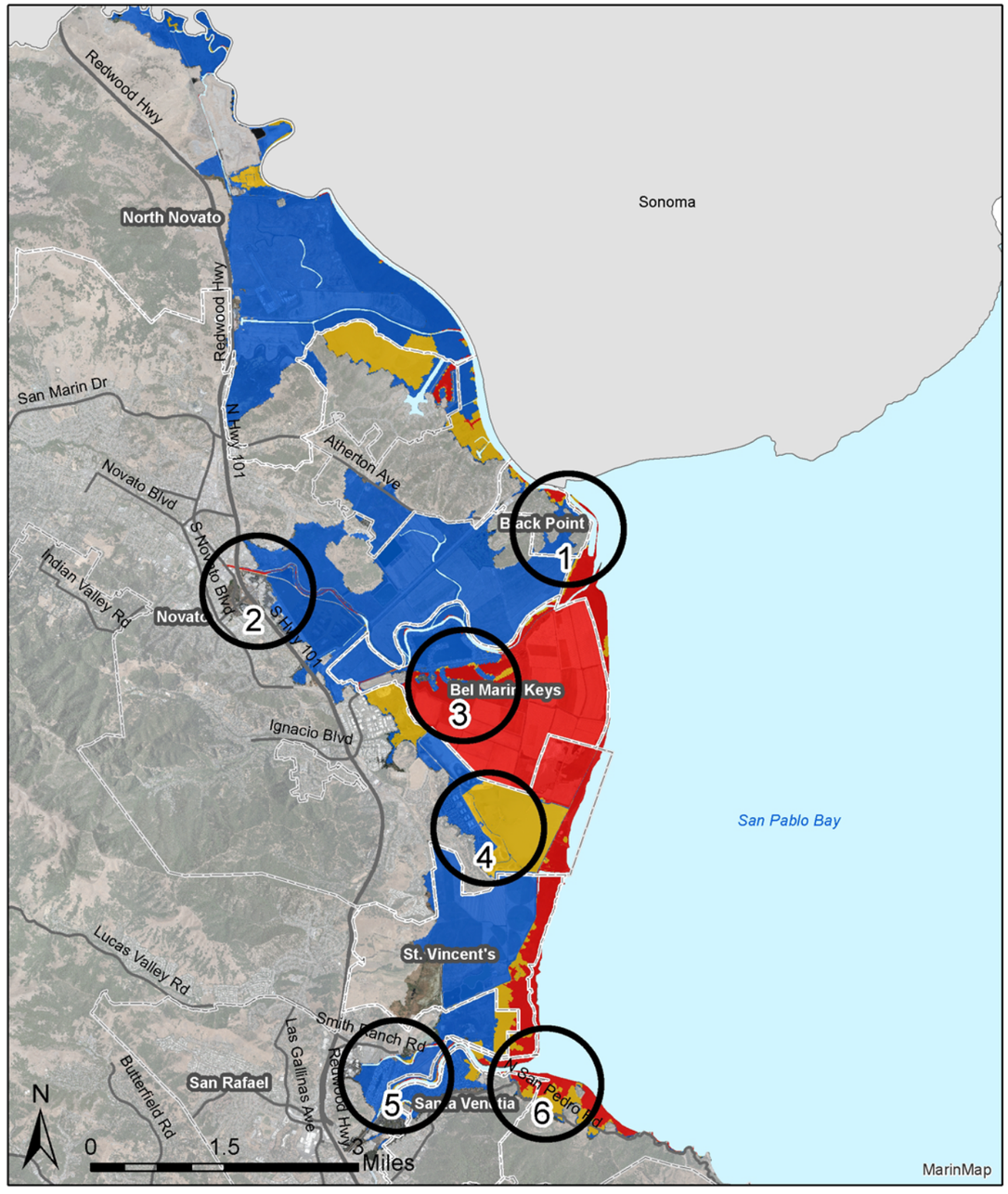
Map 4. Northern Study Area Sea Level Rise Scenarios

BayWAVE Sea Level Rise (SLR) Scenarios

- Scen 1: 10" SLR
- Scen 3: 20" SLR
- Scen 5: 60" SLR

Location Indicators

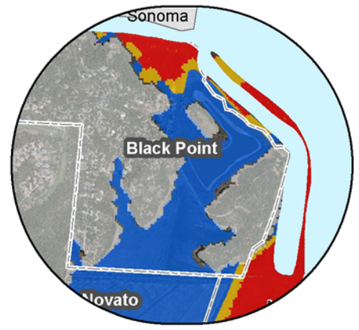
- Unincorporated
- Municipality
- Road
- Bay





CONSULTING

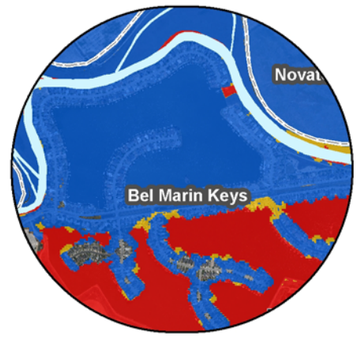
Date: 4/1/2017



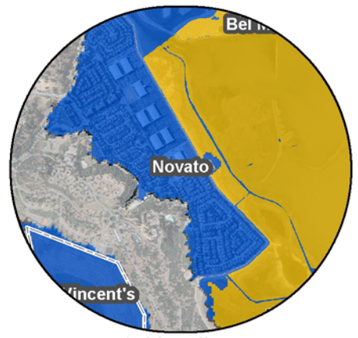
1: Black Point/Green Point



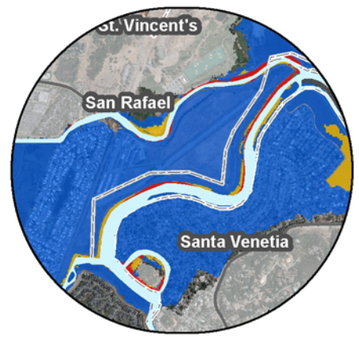
2: U.S. Hwy. 101 @ Rowland Blvd.



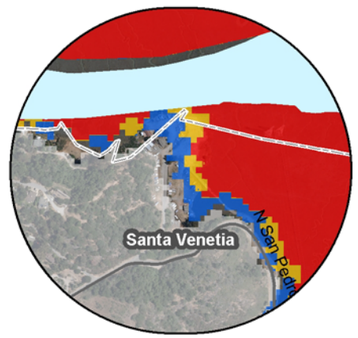
3: Bel Marin Keys



4: Hamilton



5: Santa Venetia/ Marin Lagoon



6: Buck's Landing

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METHODS

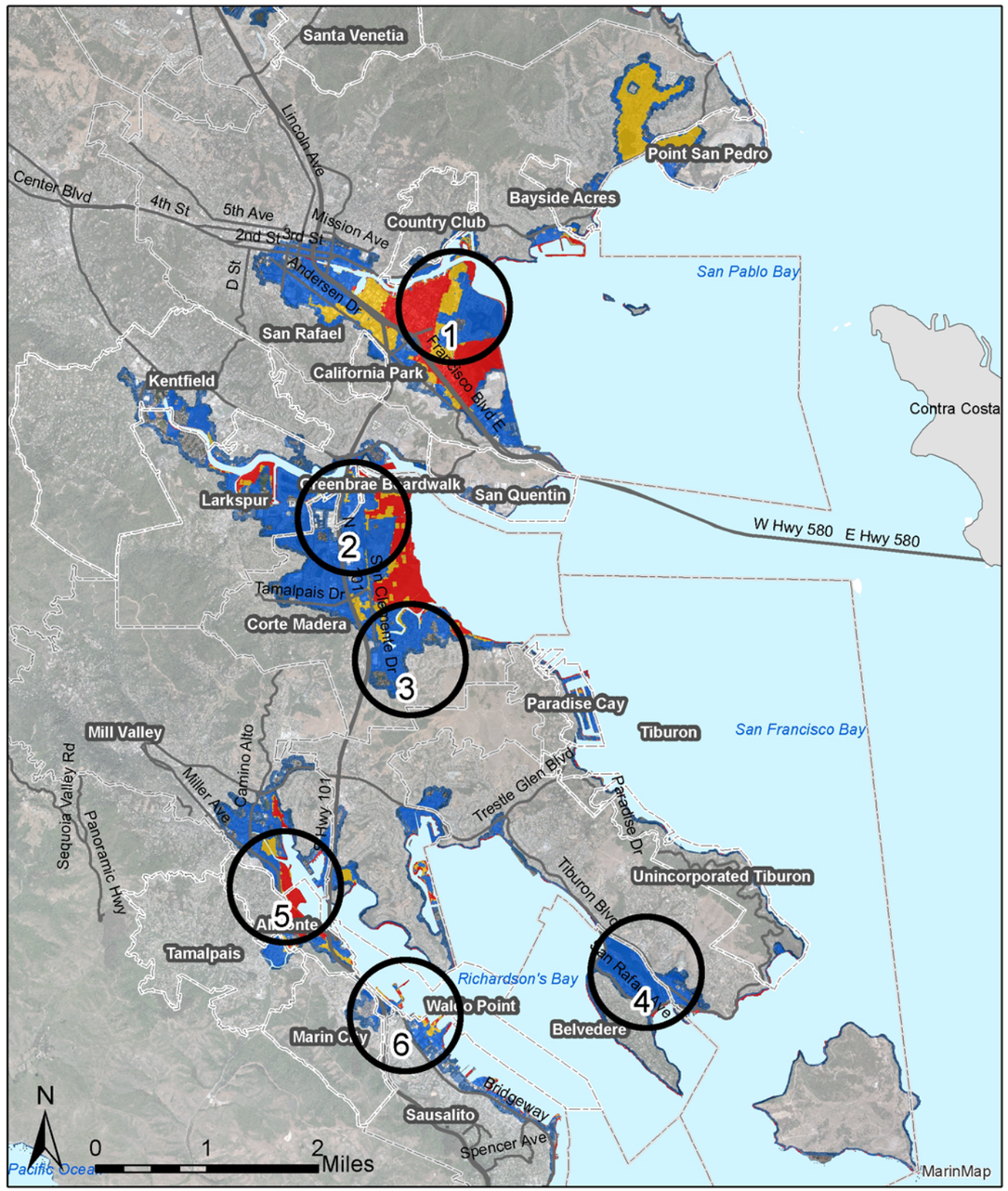
Map 5. Southern Study Area Sea Level Rise Scenarios

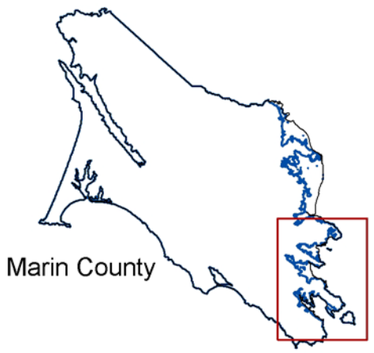
BayWAVE Sea Level Rise (SLR) Scenarios

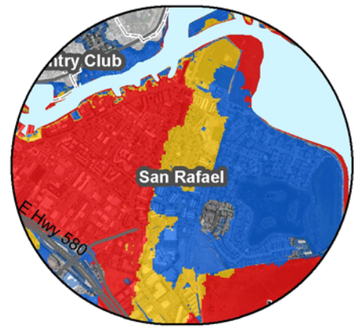
- Scen 1: 10" SLR
- Scen 3: 20" SLR
- Scen 5: 60" SLR

Location Indicators

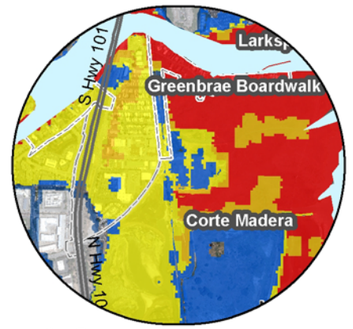
- Unincorporated
- Municipality
- Road
- Bay



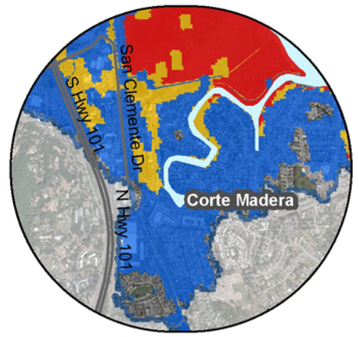




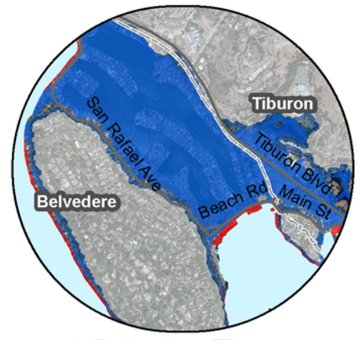
1: Canal Neighborhood



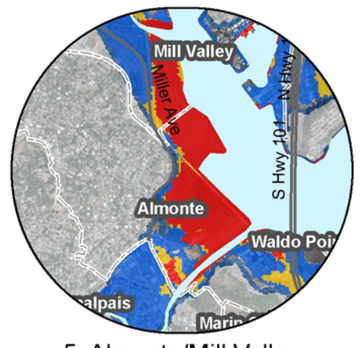
2: Greenbrae Boardwalk/ Larkspur/Corte Madera



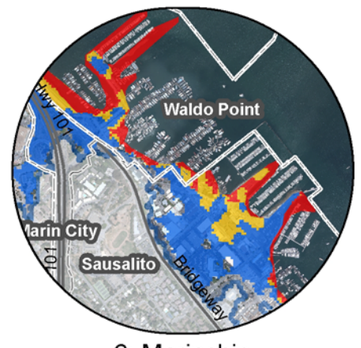
3: Corte Madera



4: Belvedere/Tiburon



5: Almonte/Mill Valley



6: Marinship

Date: 1/7/2017

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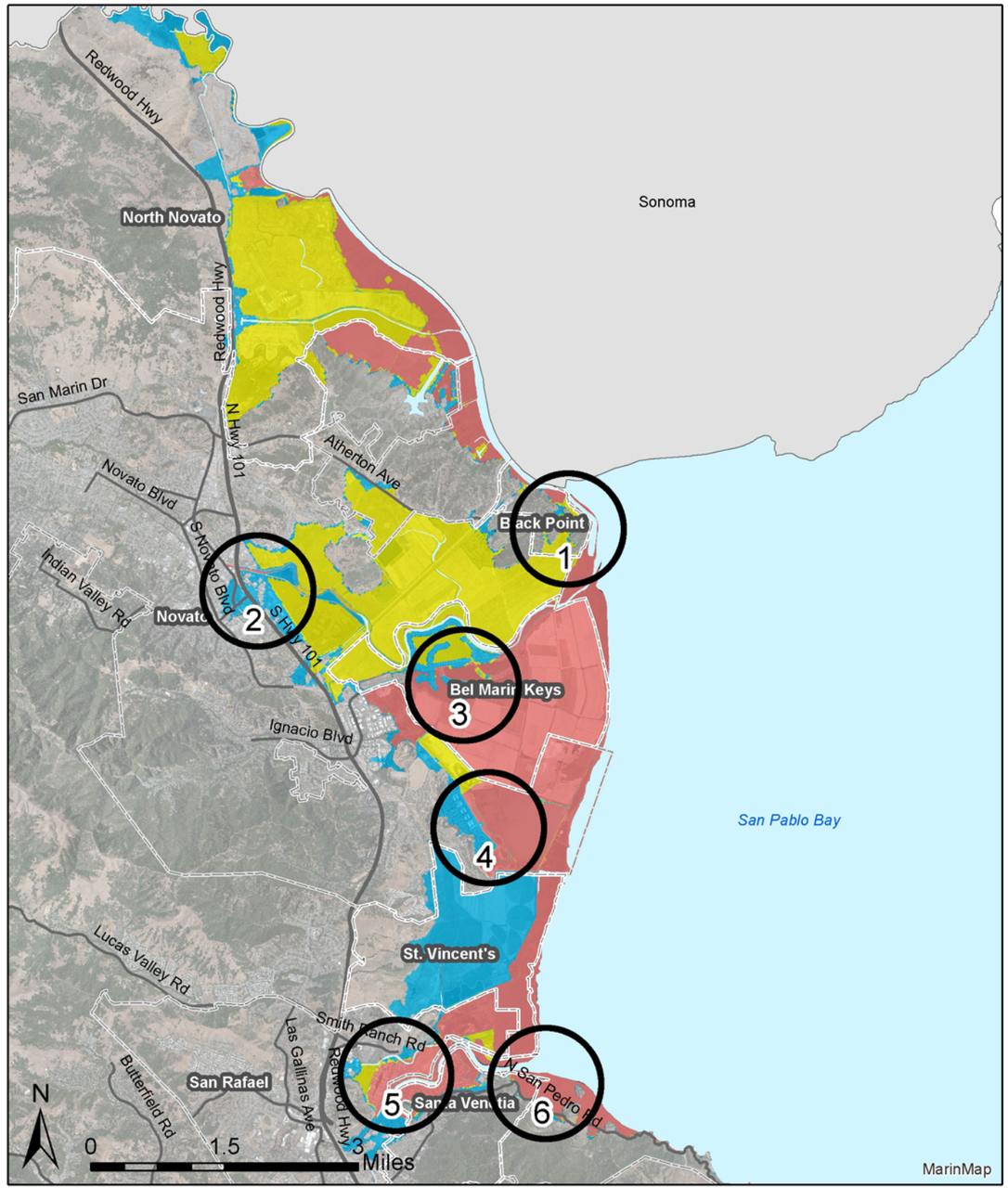
Map 6. Northern Study Area Sea Level Rise and 100-year Storm Surge Scenarios

BayWAVE Sea Level Rise (SLR) & 100-year Storm Surge Scenarios

- Scen 2: 10"SLR+Storm Surge
- Scen 4: 20"SLR+Storm Surge
- Scen 6: 60"SLR+Storm Surge

Location Indicators

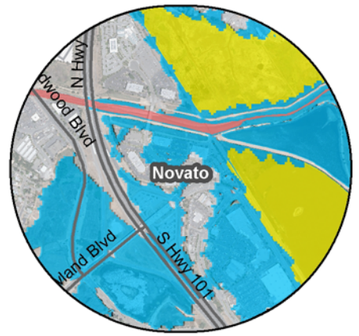
- Unincorporated
- Municipality
- Road
- Bay



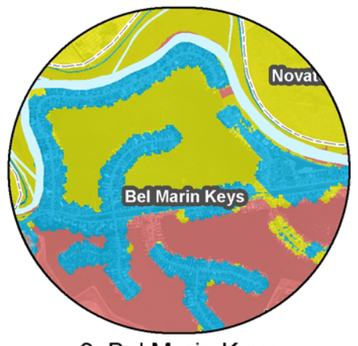




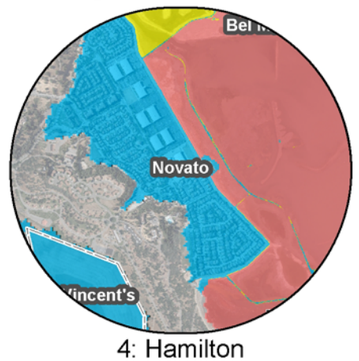
1: Black Point/Green Point



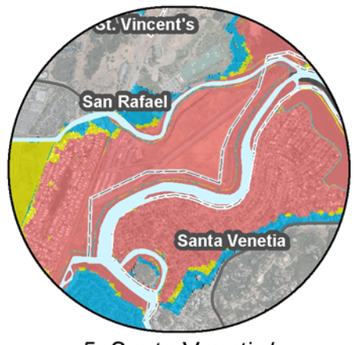
2: U.S. Hwy. 101 @ Rowland Blvd.



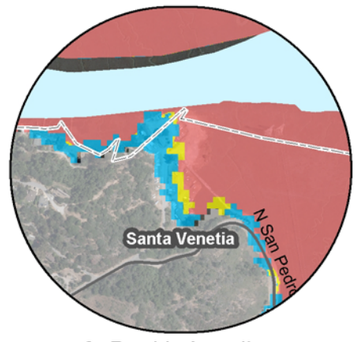
3: Bel Marin Keys



4: Hamilton



5: Santa Venetia/ Marin Lagoon



6: Buck's Landing

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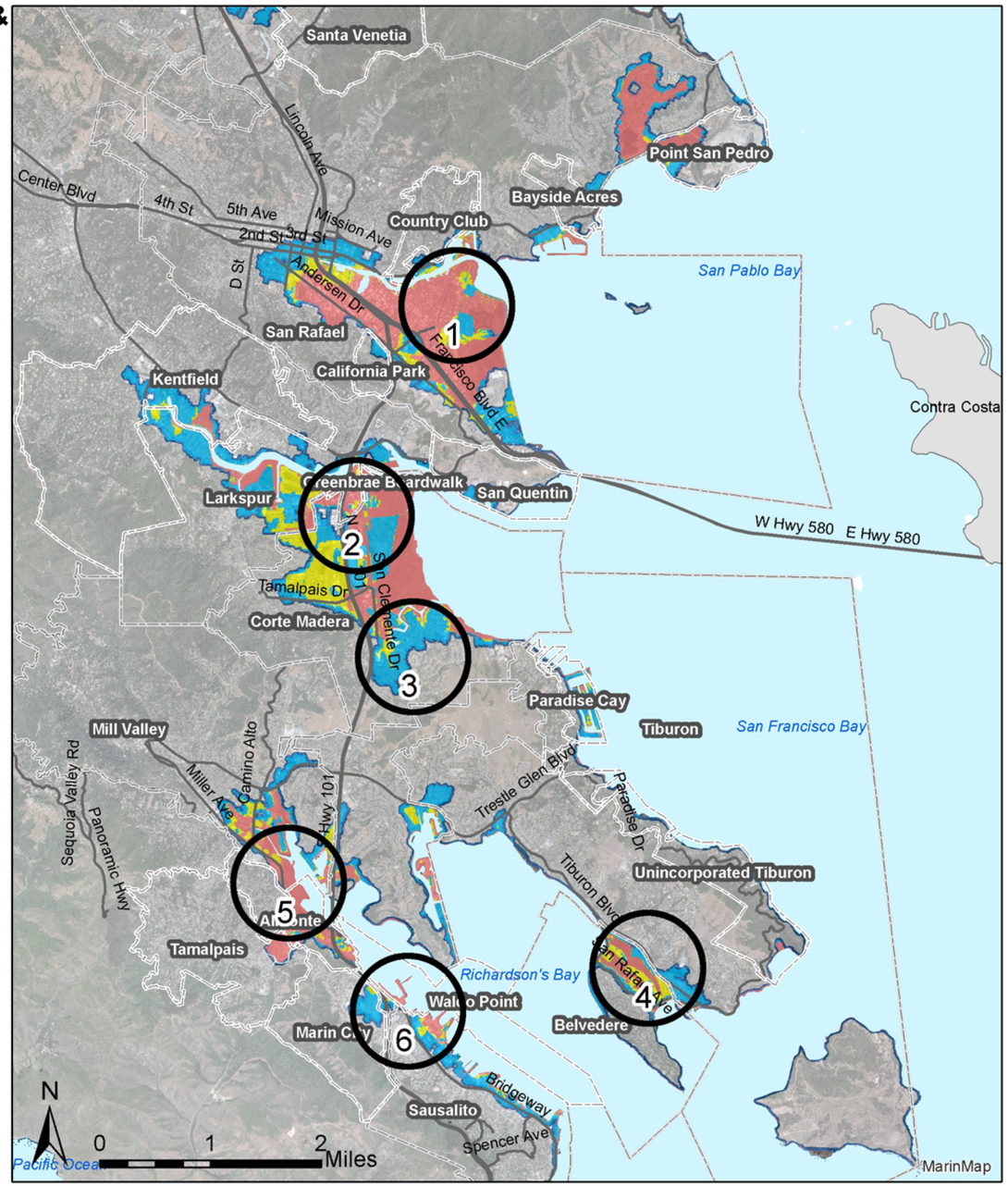
Map 7. Southern Study Area Sea Level Rise and 100-year Storm Surge Scenarios

BayWAVE Sea Level Rise (SLR) & 100-year Storm Surge Scenarios

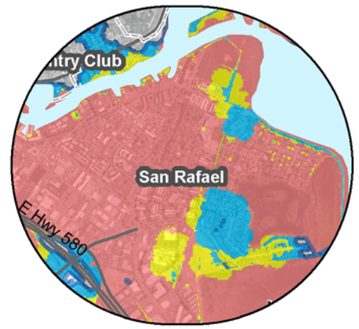
- Scen 2: 10"SLR+Storm Surge
- Scen 4: 20"SLR+Storm Surge
- Scen 6: 60"SLR+Storm Surge

Location Indicators

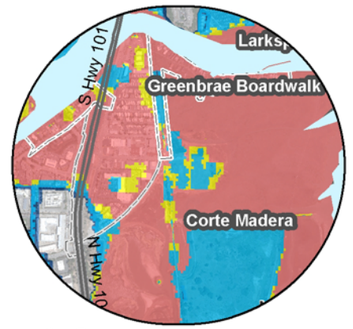
- Unincorporated
- Municipality
- Road
- Bay



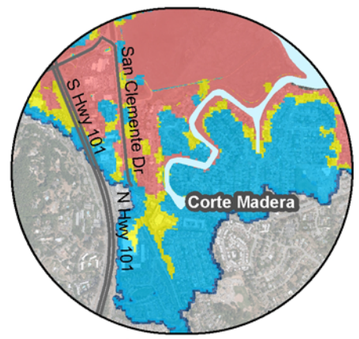




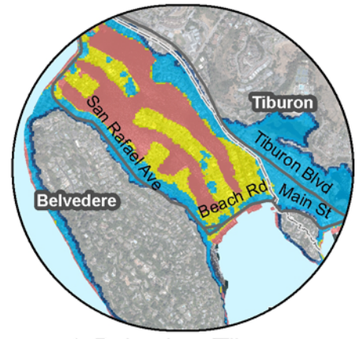
1: Canal Neighborhood



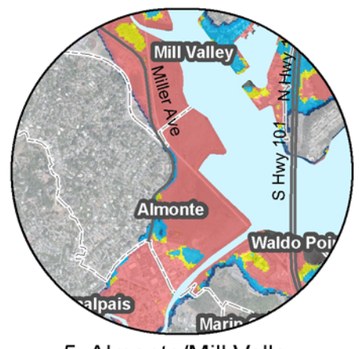
2: Greenbrae Boardwalk/ Larkspur/Corte Madera



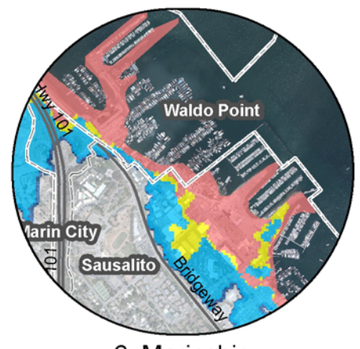
3: Corte Madera



4: Belvedere/Tiburon



5: Almonte/Mill Valley



6: Marinship

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According to the San Francisco Bay Conservation and Development Commission's *A Sea Level Rise Strategy for the San Francisco Bay Region* noted that it is particularly difficult to develop a strategy for dealing with sea level rise when the temperature increase scenarios yield a tenfold difference between the lowest and highest potential increases in the San Francisco Bay water level over the next 100 years.[23]

This high degree of uncertainty, due differing assumptions in carbon emissions, in sea level rise modeling results in a range of onset predictions. Variances between the predictions increase further out in time. This uncertainty is heightened by the non-linear growth rate of sea level rise.[24,25] Because of this variation, the BayWAVE scenarios do not focus on years, rather a framework of near-, medium-, and long-term scenarios. The OCOF tool enables the user to view the year a sea level projection could be met across the various published sea level estimates on the OCOF website.

Regardless, even if the world stabilizes carbon emissions, sea level rise will continue. Even if the global population reduces carbon emissions to levels where atmospheric concentrations decline, the decline will be slow, sea levels could continue to rise for decades, and hundreds of years could pass before sea level stabilizes or drops.[26,27]

Known Issues

The USGS acknowledges local modeling issues at the Petaluma River where dense vegetation leads to a false elevation reading and thus, under-predicts the potential flooding extent. Maximum flood potential indicates more probable flooding extents in these locations. In addition, the 100-year storm scenario flooding extents in the vicinity of Petaluma River and Novato may be under-predicted. The modeling team manually adjusted parameters to show more probable flooding behavior. Local professionals also suspect that water absorbed by the marshes at China Camp State Park may yield less flooding than the model estimates.

In addition, several sites underwent, or are currently undergoing, elevation increases after the baseline imagery was taken in 2010. Thus, the model and maps may overestimate flooding. These projects are shown on Maps 8 and 9 and include:

- Waldo Point Harbor: Filled and elevated parking and entrance area.
- Rose Garden Neighborhood, Larkspur: This recently completed development was elevated to meet FEMA and County flood prevention requirements.
- Aramburu Island, Strawberry: This man-made barrier island off Harbor Point in Strawberry was improved in 2012 and offers enhanced protection from wave impacts during storms.
- Hospice and base of Cal Park Hill: Recent construction may have elevated the site above 2010 elevations. This could result is less than flooding than estimated in this assessment.
- The Strand and Loch Lomond Marina, San Rafael: This project is near completion. The sites were filled with sediment and elevated to meet FEMA standards.
- Redwood Landfill: Roughly two feet in height was added to the external and internal levees after 2010.

Another issue arises with the Belvedere and Bel Marin Keys Lagoons. These lagoons are managed with tide gates that can close during high tides. The model treats these gates as open. So long as the tide gates and levees are not over topped, closing these protective devices could reduce flooding to properties on the lagoons in the near- and medium-terms.

Finally, note that the model does not take planned projects into consideration and assumes no action taken to prepare of adapt for sea level rise. Several projects along the shoreline are planned that could also help to reduce sea level rise flooding threats. These projects will be presented in the BayWAVE sea level rise early action report, the counterpart to this Assessment.

[23] San Francisco Bay Conservation and Development Commission. Revised September 2008. *A Sea Level Rise Strategy for the San Francisco Bay Region*

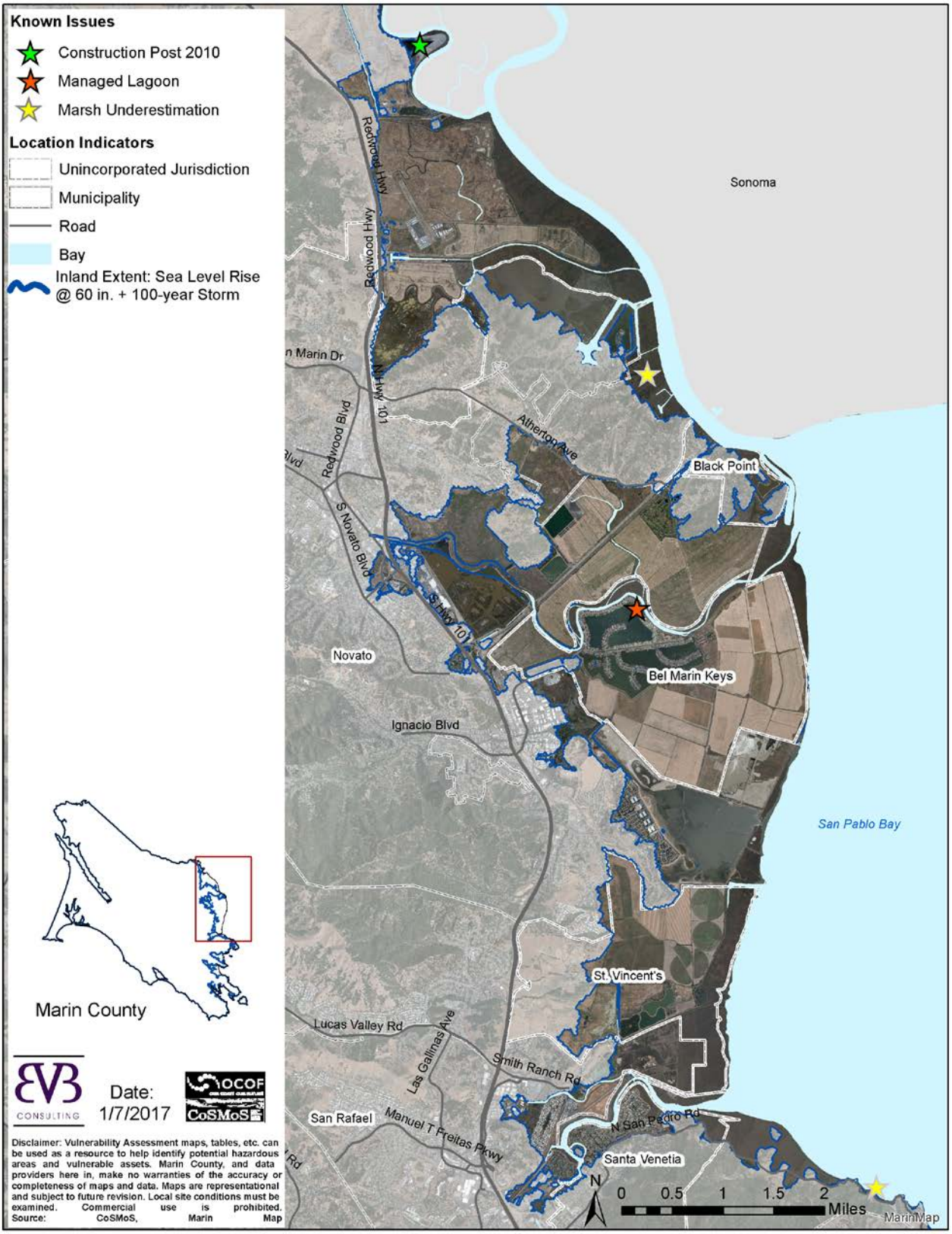
[24] P. Barnard. C-SMART Kick-off Meeting July 2014. htttp://walrus.wr.usgs.gov/coastal_processes/cosmos/

[25] Annual mean Sea Level Rise, San Francisco Tidal Gage. Wwwlpsmsl.org/data/obtaining/stations/10.php

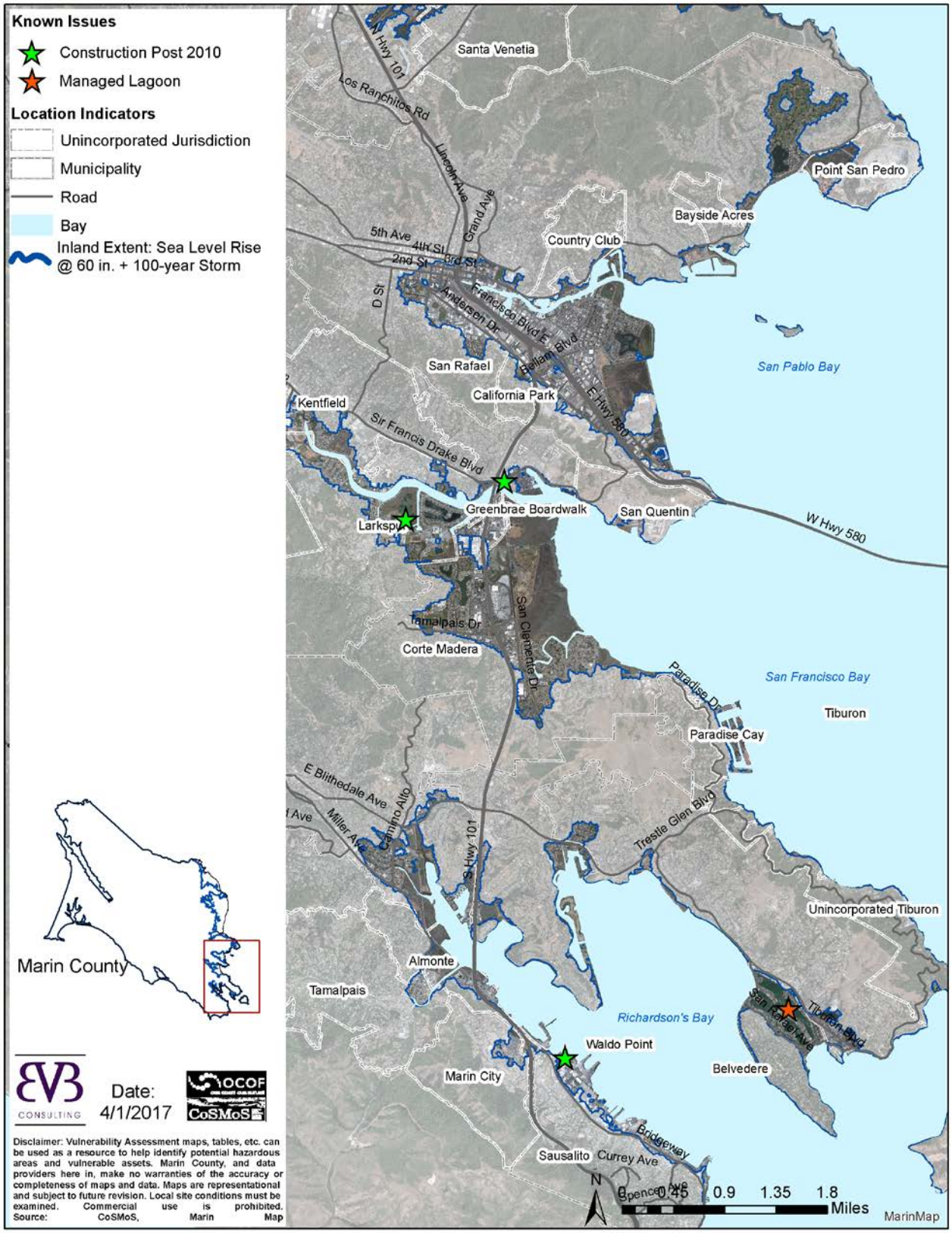
[26] IPCC Fourth Assessment Report: Climate Change 2007. Climate Change 2007: Working Group I: The Physical Science Basis. 10.7.2 Climate Change Commitment to Year 3000 and Beyond to Equilibrium. https://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch10s10-7-2.html

[27] IPCC Fourth Assessment Report: Climate Change 2007. Climate Change 2007: Working Group I: The Physical Science Basis. 10.7.4 Commitment to Sea Level Rise. https://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch10s10-7-4.html

Map 8. Northern Study Area Known Issues with CoSMoS Model



Map 9. Southern Study Area Known Issues with CoSMoS Model



METHODS

Sea Level Rise Maps & FEMA

Several shoreline communities already grapple with stormwater and storm surge flooding on a near yearly basis and qualify for federal flooding insurance under the Federal Emergency Management Agency (FEMA). FEMA maps flood prone area in maps called Flood Insurance Rate Maps (FIRMs). These maps, while related to flooding, do not consider future potential sea level rise flooding. As the sea level rises, FIRMS would need to be updated to represent the new existing conditions. Other major differences between FIRMs and the sea level rise maps in this assessment are:

- FIRMs are based on *historic and current* trends and assumptions. CoSMoS sea level rise maps are based on modeling of potential *future* conditions.
- FIRMS address bay surge and stormwater creek flooding. CoSMoS does not address stormwater creek flooding, and
- FIRMS can incorporate policy decisions to exclude the role of non-FEMA certified protective shoreline armoring. CoSMoS is based solely on elevation, such that any shoreline armoring that contributes to elevation is accounted for.

Assessment Methods

As described in CalAdapt, vulnerability is based on an asset's exposure, sensitivity, and adaptive capacity to rising tides and bay surge threats. Such that, if an exposed asset is moderately or highly sensitive to sea level rise impacts, with low to no adaptive capacity, the asset is vulnerable.

Assets were identified using existing MarinMap geographic data layers for roads, trails, parks, public facilities, utility districts, buildings, and parcels, and Department of Fish and Wildlife sources for wildlife species, habitats, fishing piers, marinas, access points, and ports. The Technical Advisory Committee supplemented these data sources with additional assets. Note that not all vulnerable assets are mapped due to data conflicts or unavailable geographic data. This does not imply that an asset is not vulnerable. This is especially true for utiltiy assets. The data layers generated span several years, and changes to the built environment may have occurred since the data was last updated. Where idetified, these areas were manually adjusted to reflect known current conditions. For example, based on aerial imagery, Niel Cumings Elementray school appears to be one large building, however, upon site visit, it becomes clear the site has four buildings connected by awnings. Improving the data comprehensively was not within the scope of this analysis, thus buildings numbers may be slightly off in some locations.

Phase 1: Exposure

To determine what could be exposed to sea level rise at MHHW and/or a100-year storm surge, the six BayWAVE scenarios, identified asset locations, and aerial imagery were overlaid in ArcGIS, a geographic statistical computer program. Assets intersecting sea level rise and storm scenarios were identified as exposed, and further assessed for sensitivity and adaptive capacity to determine if the asset is vulnerable to:

- Extreme event flooding during the annual highest high tides and/or storm surges that cause nuisance flooding,
- Inundation at,-at least, one high tide a day, several days a month, that results in chronic flooding,
- Erosion and geomorphic evolution from higher high tides and extreme storm events,
- Wave run up and high winds in extreme storm events,
- Saltwater intrusion,
- Rising water table, and/or
- Habitat shifts (applicable to natural resources).

In addition to geographic extent, CoSMoS GIS layers illustrating potential flood depth at MHHW were spatially joined with each vulnerable asset yielding average depths for scenarios 1, 3, and 5. Flood depth was calculated by converting GIS vector data to raster data to break the flood depth layer into thousands of cells, each with an assigned flood value. For roads, a high and low value was calculated on the line segment. Bridges are not quantitatively accounted for in this assessment. For buildings, cells underlying the building footprint were averaged to one flood depth at MHHW for scenarios 1, 3, and 5 for each building. Note that flood depth data is not available for all vulnerable areas and assets, especially those that exist in the bay beyond mean sea level and already subject to tidal influences. The data presented in this Assessment is

for what is available and may not directly compare with data presented under exposure.

Flood depth figures are displayed in the onset and depth tables in each profile. In these tables, roads were assigned high and low values along the exposed segments for each scenario. Exposed road mileage provided is road miles, not lane miles. Lane mileage would more than double the mileage figures presented in this assessment. Where buildings are presented as a neighborhood group, a maximum average flood depth is provided. Where data is available, additional analysis summarizes how many buildings in each community could flood by one-foot flood depth intervals for scenarios 1, 3, and 5.

Phases 2 & 3: Sensitivity & Adaptive Capacity

The project team interviewed more than 100 asset managers, such as fire chiefs, city planners, transportation agency staff, using the Asset Vulnerability Assessment Tool, available in Appendix A, to assess built and natural resource assets. The tool is designed based on previous pre- and post- disaster assessments conducted in the Bay Area, Southern California, New Orleans, New York City, and guidance from State of California and the US EPA.[28,29,30,31,32,33,34]

Several public agency professionals were interviewed due to a high number of public assets in the exposed areas. Homeowners' association representatives were invited to be interviewed; however, home owners or non-public property owners were not individually interviewed. A list of interviews can be found in Appendix A

Asset managers were interviewed in person or by phone to answer two primary questions:

1. How ***sensitive*** is the asset to each exposure or threat?[35]
2. And if sensitive, what is the ***adaptive capacity***, or the asset's ability to maintain its function without further intervention (human action)?[36, 37,38, 39]

Any asset deemed moderately or highly sensitive to flooding or storm damage, with low to no adaptive capacity is considered vulnerable. Other questions about previous disruptions and the nature of potential disruptions were discussed to provide context to the qualitative statements. The interview results were combined with geographic data to develop this Vulnerability Assessment.

Additional analysis was conducted to determine the potential monetary losses from storm damages to buildings in scenario 6. Scenario 6 is chosen because it is the worst case scenario selected for assessment. This method applies damage levels to all vulnerable buildings in scenario 6 based on the FEMA HAZUS model intervals for yellow, minor damage of $5,000-17,000; orange, damage of $17,001+; and red, destroyed, post-disaster inspection tags.[40,41] Information on the real estate website Zillow was used to estimate median market value of single-family homes in February 2016.

[28] US EPA. Being Prepared for Climate Change: A Workbook for Developing Risk-Based Adaptation Plans. August 2014.
[29] CURRV-Tijuana River Valley - http://trnerr.org/currv/
[30] Bay Conservation & Development Commission: Adapting to Rising Tides. Hayward Resilience Study. 2014.
[31] City and County of San Francisco Sea Level Rise Committee. Guidance for incorporating Sea Level Rise into Capital Planning in San Francisco: Assessing Vulnerability and Risk to Support Adaptation. September 2014.
[32] http://mitigationguide.org/task-5/steps-to-conduct-a-risk-assessment-2/3-analyze-risk/
[33] California Emergency Management Agency, California Emergency Natural Resource Agency. California Climate Adaptation Planning Guide (APG). July 2012. http://resources.ca.gov/docs/climate/01APG_Planning_for_Adaptive_Communities.pdf
[34] Department of Transportation, Federal Highway Administration, Office of Environment and Planning, Mike Culp, IFC International, *Literature Review: Climate Change Vulnerability Assessment, Risk Assessment, and Adaptation Approaches.* http://www.fhwa.dot.gov/environment/climate_change/adaptation/publications_and_tools/vulnerability_assessment/index.cfm#Toc236233837
[35] Guidance for Incorporating Sea Level Rise into Capital Planning in San Francisco. September 22, 2014. Appendix 5. OneSF Checklist
[36] Center for Science in the Earth System (CSES), University of Washington, *Conduct a Climate Resiliency Study*, Chapter 8. Conduct a Climate Change Vulnerability Assessment. http://cses.washington.edu/db/pdf/snoveretalgb574ch8.pdf
[37] Department of Transportation, Federal Highway Administration, Office of Environment and Planning, Mike Culp, IFC International, *Literature Review: Climate Change Vulnerability Assessment, Risk Assessment, and Adaptation Approaches.* http://www.fhwa.dot.gov/environment/climate_change/adaptation/publications_and_tools/vulnerability_assessment/index.cfm#Toc236233837
[38] California Energy Commission Public Interest Environmental Research Program. Adapting to Sea Level Rise: A Guide for California's Coastal Communities. 2012.
[39] Bay Conservation & Development Commission: Adapting to Rising Tides. Hayward Resilience Study. 2014.
[40] Federal Emergency management Agency (FEMA) Website. Hazus. Last updated July 8, 2015. http://www.fema.gov/hazus.
[41] 2016 dollars

The vulnerabilities found in the assessment process are summarized in Asset, Municipal, and Unincorporated Marin Profiles.

Phase 4: Risk & Onset

Risk & onset assess when and how likely impacts will occur to prioritize actions, though this alone may not be adequate criteria for decision-making. Onset is determined by the scenario an asset is exposed under. The scenario indicates a "no later than" timeline, as opposed to a "not until after" timeline, thus onset could occur before the snap shot in time represented by each scenario. Because of this, this assessment uses near-, medium-, and long-term labeling corresponding with the NRC ranges for before 2030, 2050, and 2100 respectively in Table 1.

All vulnerable assets are at risk of flooding and/or increasing rates of subsidence. Two types of flooding could occur, tidal flooding at MHHW or seasonal storm flooding. All assets that experience tidal flooding will also experience storm surge flooding. Tidal flooding at the average higher high tide could flood an asset once a day, several days a month. Each day has two high tides, thus it is possible that some properties could flood twice a day. Land that is flooded at this frequency is not useable for land based development. Storms surge flooding analyzed in this assessment is a 100-year storm surge, such that this storm surge has a 1 percent chance of occurring each year.

Other Considerations Methods

As adaptation planning moves forward, more detailed study and assessment across each of the 3 E's: economy, environment, and equity, will be critical. Moreover, the California Coastal Commission's Sea Level Rise Policy Guidance calls for assessing these, legal consequences, and the cumulative and secondary consequences of the vulnerabilities.[42] The "Other Considerations" section in each asset profile begins to identify issues and opportunities for each "E," and management. These sections are informed through literature review, asset manager interviews, and policy discussions with professional staff.

Economic: Highlights costs of damage, or preparation, and the cost burden to residents. Potential economic issues and opportunities were determined using several geographic and tabular data sources maintained by the County of Marin, US Census, and Zillow. Note that population and monetary figures are based on current or historic values. Generally, both populations and property values are projected to grow, thus, this assessment underestimates the number of people and value of property that would be vulnerable in the future.

Environmental: Highlights how disruption to buildings, roads, septic systems, and other assets could have secondary impacts on the environment and wildlife. Environmental impacts were gathered from asset managers and literature review.

Equity: Highlights the disparity in cost burden across populations of different social and economic means, and how the social fabric of communities may shift. Several storms impacting the south (i.e. Hurricane Katrina, Hurricane Audrey) have "shown that natural disasters can cause the greatest harm to low-income communities and communities of color."[43] Populations that may be at higher risk include, low-income, limited English speaking, children, and those with limited mobility or sensory abilities.

Management: Highlights political and management issues that will need to be considered when planning for sea level rise to ensure the public health, safety, and welfare of East Marin residents.

To gain a better idea of these secondary consequences, asset managers were asked several questions about the nature of the damage or disruption that could happen, levels of risk, persons impacted, and if environmental, economic, equity, or political issues could arise. Potential secondary impacts include:[44, 45]

[42] *California Coastal Commission Sea Level Rise Policy Guidance: Interpretive Guidelines for addressing Sea Level Rise in Local Coastal Programs and Coastal Development.* August 12, 2015. http://www.coastal.ca.gov/climate/slrguidance.html

[43] The Impacts of Sea-Level Rise on the California Coast. California Climate Change Center. Heberger, M., Cooley, H., et. al. The Pacific Institute. CEC-500-2009-024-F. May 2009

[44] Delaware Coastal Programs, *Sea Level Rise Adaptation*. http://www.dnrec.delaware.gov/coastal/Pages/SeaLevelRiseAdaptation.aspx

[45] City and County of San Francisco Sea Level Rise Committee. *Guidance for incorporating Sea Level Rise into Capital Planning in San Francisco: Assessing Vulnerability and Risk to Support Adaptation.* September 2014.

- Contaminant releases from industrial sites or storage tanks,
- Loss of habitat from increased erosion,
- Loss of jobs and revenue streams,
- Loss of community or sense of place,
- Increased need for government services or intervention, and
- Potential injury and loss of life.

Though the methods for this countywide assessment are robust, some areas may be represented as more vulnerable or less vulnerable than available information suggests. Some locations can only be represented accurately with onsite inspections of ground-level conditions. For example, the homes on Greenbrae Boardwalk, in unincorporated Marin and on Boardwalk One, in the City of Larkspur are raised on piers above tidal marshes. Utilities run to homes above the marsh plain along raised, wooden boardwalks. These communities already live with water and are accustomed to high tides surrounding their homes. In theory, these buildings and associated utilities can be adapted with minimal expense compared to on-land buildings (although they would still be impacted by the flooding in surrounding neighborhoods and streets). Understanding the full vulnerability of these communities requires, at a minimum, onsite inspections of utilities and base floor elevations for each home; analysis that is beyond the scope of this report. The report uses the best available GIS data to analyze vulnerability. The data does not account for raised floor elevations. The County is committed to regularly updating its assessments in response to new sea level rise projections and the availability of new and better data.

Collectively these methods determine what is vulnerable to sea level rise on the Marin shoreline and at what levels of sea level rise impacts could be felt by. This analysis can be a useful in assessing asset and community sea level rise vulnerabilities, and developing adaptation strategies and policies well suited for this unique and valuable bay region.