STAFF REPORT
SAUSALITO CITY COUNCIL

AGENDA TITLE:
Conceptual Drainage Study Gate 5 Road – Report of Findings

RECOMMENDED ACTION:
Accept report, authorize staff to begin actions to correct flooding caused by land subsidence and sea-level rise.

SUMMARY

The Gate 5 Road area of the Marinship is subject to seasonal and storm related tidal flooding. This flooding appears to be the result of subsidence (settling) of artificial fill placed at the time of the construction of the Marinship. The condition negatively impacts public and private properties in the area. Despite private floodproofing efforts the condition is worsening. An analysis performed in 2009 by Towill, Inc. under contract with the City identified areas of the Marinship where ground surface elevations had decreased (subsided) as much as four feet between 1968 and 2007 (see attached Figure).

In an effort to rigorously evaluate the situation, on January 29, 2009, the City authorized West Yost Associates to prepare a concept level drainage study.

The study:

1) estimated runoff quantities and routed flows through the City storm drains tributary to the outfall near Gate 5 Road and Coloma, and
2) predicted water surface elevations during storm events and high tides.
3) performed a conceptual assessment and planning level cost estimates for possible solutions.

A final draft of the report was recently completed.

Staff recommends Council action to:

1. Invite public comment
2. Accept the study as complete
3. Direct staff to include work scope and budget in the 2011/2012 Capital Improvement Fund Budget to construct facilities to limit tidal backflows.

BACKGROUND

Portions of the Marinship have been experiencing flooding as a result of subsiding land fill and rising tides. On a frequent basis portions of Gate 5 Road and Coloma are inundated with sea water. During periods of intense rain the flood pool enlarges and the road has been impassible for periods of time (45 minutes to 6 hours in duration).

In response to community demands to address the problem West Yost Associates prepared a proposal for a Conceptual Drainage Study. The objective is to develop recommendation for improvements to control the impacts of this flooding.

West Yost has completed their assessment and has prepared a report documenting their findings and solution alternatives exploration.

ISSUES

This study highlights probable worst case scenarios of high tides and significant storms. The report also documents current conditions where tide pools form along portions of Gate 5 Road, Heath Way, Coloma Street in good weather and high tides. Figure 3.3 shows the extent of flooding during a 100 year storm event and 100 year high tides. A computer model has been prepared that animates the flood conditions in the affected watershed along the storm drain system. Flooding will extend from the Clipper Yacht Harbor outlet to Olima including some of the MLK park lands. It is a land management condition that is generally considered unacceptable.

Tidal Flooding on Gate 5 Road has been a concern for many years. It threatens the viability of some of the current land uses. An effort was started to install culvert flap gates. That effort was halted as physical conditions made that option problematic. More information was needed on the rainfall runoff standpoint to help determine if the discharge operations would be compatible with flap gate mechanics. On the private property side, Clipper Yacht Harbor, graced with a sizeable land area, filled their property to restore ground elevations to manageable elevations, though these efforts may not be enough if sea level rise predictions are accurate. Other properties, more constrained by structures consuming lot area, have responded by floodproofing their property - constructing walls to restrain floodwaters and installing drain systems with pumps to push floodwaters out to Gate 5 Road, where water will flow out to Richardson's Bay. There has not been a coordinated unified response to the problem.

The report discusses eight project scenarios as follows:

No.	Description	Costs
1	Duck Bill Flap Gate at Coloma Street Drain	$319,000
2	Pressurized flow of Coloma Street Drain	$1,217,000

3	Pressured flow of Coloma drain + Redirection of N. Gate 5 Road flows	$160,000
4	Flap Gate/Duck Bill Valve on the Coloma Street Drain and a Pump Station	$15,328,000
5	Flap Gate/Duck Bill Valve on the Coloma Street Drain, Pump Station, and Detention Basin in the Martin Luther King Junior Park	$9,332,000
6	Raising Gate 5 Road and/or Parking Lots (cost of improvements 3, 5, and 6 included for a complete system)	$22,389,000
7	Levee and Floodwall (cost of improvements 3, 5, and 7 included for a complete system)	$27,971,000
8	Flood Proofing Individual Structures (cost is per acre)	$1,040,000

The report discusses these projects in greater detail. You are encouraged to refer to the report if you have questions or need to understand in greater detail. The above improvements are engineering realm remedies with the presumption of publically coordinated project development and implementation.

Solving the flooding problem may be best managed through implementing multiple projects over time.

Due to the nature of some projects, Sausalito will likely need to coordinate with property owners, Army Corps of Engineers, Bay Conservation and Development Commission, and several other federal and state agencies.

The value of some scenarios suggests that a solution will require bond funding which is outside of the scope of the report. Property owners along Gate 5 Road and Coloma have been unable or unwilling to collectively address the problem. The nature of the challenge suggests that solution may be addressed by the City intervening either directly by implementing capital improvement projects or to facilitate formation of an improvement district. The City may also be able to assist the area indirectly by facilitating processes to create private non-profit or public special districts to address flood hazard abatement. There may also be other administrative structures which haven't been explored.

The Marinship area is a regional economic magnet. To ignore the matter could result in important businesses leaving the City for higher ground. Business operators will make these conclusions after experiencing one or more repetitive loss events.

FISCAL IMPACT

The Concept Study itself has no impact to the general fund. The topic within the study, solving a regional flooding problem, has the potential of having considerable impacts to the General Fund and other Funds.

Doing nothing, as is discussed in the report, may also have considerable impacts from potential claims as well as revenue losses if viable businesses leave the area for higher ground.

OPTIONS

1. Consider funding one or more capital projects in the coming budget cycle.
2. Consider funding a project to consider forming a hazard abatement district.
3. Provide staff direction on further study
4. Continue item, provide staff questions to respond to.
5. Do nothing

STAFF RECOMMENDATIONS

Adopt a Motion:

1. Accept the study as complete
2. Direct staff to include work scope and budget in the 2011/2012 Capital Improvement Fund Budget to construct facilities to limit tidal backflows. Project 3 (pressurized flow and partial redirection of storm drainage), top priority. Project 1 (Duck Bill flap gates at outfall), second priority.

ATTACHMENTS

Conceptual Drainage Study Gate 5 Road – Report of Findings, West Yost Associates
Ground Elevation Difference 1968-2007 Figure, Towill, Inc.

PREPARED BY:

Todd Teachout, City Engineer

REVIEWED BY (Department Head):

Jonathon Goldman, Director of Public Works

SUBMITTED BY:

Adam W. Politzer
City Manager

Gate 5 Road Area
Conceptual Drainage Study

Prepared for

City of Sausalito

April 2011

REGISTERED PROFESSIONAL ENGINEER
DOUGLAS T. MOORE
4-19-11
No. 58122
Expires 6-30-12
CIVIL
STATE OF CALIFORNIA

WEST YOST
ASSOCIATES
Consulting Engineers

454-00-09-03

TABLE OF CONTENTS

CHAPTER 1. PURPOSE, GOALS AND OBJECTIVES, AND IMPLEMENTATION PROCESS 1-1

1.1 PURPOSE 1-1

1.2 GOALS AND OBJECTIVES 1-1

1.3 IMPLEMENTATION PROCESS 1-1

CHAPTER 2. SUMMARY OF COLLECTED DATA 2-1

2.1 RECORD DRAWINGS 2-1

2.2 CALTRANS DOCUMENTS 2-1

2.3 MARIN COUNTY TOPOGRAPHIC MAPPING 2-2

2.4 FEMA FLOOD INSURANCE RATE MAPS 2-2

2.5 100-YEAR TIDE DATA 2-2

2.6 FUTURE SEA LEVEL RISE 2-2

2.7 SAUSALITO FLOOD STUDY 2-2

2.8 STORM DRAIN MAPPING 2-3

2.9 RAINFALL DATA 2-3

2.10 INFILTRATION RATES 2-3

2.11 INFORMATION FROM CITY STAFF 2-3

CHAPTER 3. XP-SWMM MODEL DEVELOPMENT AND EXISTING CONDITIONS RESULTS 3-1

3.1 HYDROLOGIC MODEL INPUT 3-1

Rainfall 3-1

Infiltration 3-1

Subshed Data 3-1

3.2 HYDROLOGIC MODEL RESULTS 3-1

3.3 HYDRAULIC MODEL INPUT 3-2

3.4 HYDRAULIC MODEL RESULTS 3-2

CHAPTER 4. CONCEPTUAL EVALUATION OF POTENTIAL FLOOD CONTROL IMPROVEMENTS 4-1

4.1 FLOOD CONTROL IMPROVEMENT DESCRIPTIONS AND PERFORMANCE 4-1

Improvement 1 – Duck Bill Flap Gate on the Coloma Street Drain 4-1

Improvement 2 – Pressurized Flow of the Coloma Street Drain 4-2

Improvement 3 – Pressurized Flow and Redirection of the North Branch of the Gate 5 Road Drain 4-2

Improvement 4 – Flap Gate/Duck Bill Valve on the Coloma Street Drain and a Pump Station 4-5

Improvement 5 – Flap Gate/Duck Bill Valve on the Coloma Street Drain, Pump Station, and Detention Basin in the Martin Luther King Junior Park 4-6

Improvement 6 – Raising Gate 5 Road and/or Parking Lots 4-7

Improvement 7 – Levee and Floodwall 4-8

Improvement 8 – Flood Proofing Individual Structures 4-9

4.2 COMPARISON OF IMPROVEMENTS PROJECTS 4-9

4.3 TAKE NO ACTION APPROACH 4-11

CHAPTER 5. REVIEW OF CITY POLICIES AND REGULATIONS 5-1

5.1 TITLE 8 BUILDING AND CONSTRUCTION, CHAPTER 8.48 FLOOD PLAIN MANAGEMENT 5-1

5.2 TITLE 11 ENVIRONMENTAL PROTECTION, CHAPTER 11.08 RESIDENTIAL DEVELOPMENT REVIEW 5-2

5.3 TITLE 11 ENVIRONMENTAL PROTECTION, CHAPTER 11.17 URBAN RUNOFF POLLUTION PROVENTION 5-3

5.4 TITLE 11 ENVIRONMENTAL PROTECTION, CHAPTER 11.18 REGULATORY FEE FOR CLEAN STORMWATER ACTIVITIES 5-3

CHAPTER 6. CONCLUSIONS AND RECOMMENDATIONS 6-1

6.1 SUMMARY CONCLUSIONS 6-1

6.2 RECOMMENDATIONS 6-2

List of Tables

Table 3-1. 100-Year Design Duration-Depth Data 3-3

Table 3-2. Subshed Data and Peak Runoff Results 3-4

Table 3-3. Hydraulic Model Node Input Data And Results 3-5

Table 3-4. Hydraulic Model Link Input Data & Results 3-6

Table 4-1. Comparison Level Improvement Cost Estimates 4-3

Table 4-2. Comparison of Improvements 4-10

List of Figures

Figure 1-1. Watershed Map 1-3
Figure 2-1. Watershed Map 2-4
Figure 2-2. 100-Year Tidal Flooding in the Year 2100 2-5
Figure 3-1. 100-Year Design Storm Hyetograph 3-7
Figure 3-2. Richardson Bay Design Tide Level 3-8
Figure 3-3. 100-Year Storm Freeboard 3-9

CHAPTER 1. PURPOSE, GOALS AND OBJECTIVES, AND IMPLEMENTATION PROCESS

1.1 PURPOSE

The long term purposes for preparing this Conceptual Drainage Study (CDS), and the subsequent project design and construction are to:

- Eliminate the routine (e.g. every few years) street and parking lot flooding that occurs in the low, flatter areas of the Gate 5 Road area. The Gate 5 Road watershed area is shown on Figure 1-1.
- Provide flood protection to the Gate 5 Road area from a 1 percent (100-year) storm event.

1.2 GOALS AND OBJECTIVES

The first step toward achieving these purposes is to prepare this CDS. The goals/objectives of this CDS are:

- Develop computer models that reasonably simulate the 1 percent storm event flooding.
- Use the computer models to conceptually develop an improvement project that provides the needed flood protection (the flood protection project, FPP).
- Evaluate the FPP at a conceptual level.
- Prepare construction and capital cost estimates for the FPP.
- Prepare a CDS summarizing these evaluations, the FPP, and the FPP cost estimate. The CDS can then serve as the basis for submittal of applications for grants or loans for the detailed design and construction of the FPP.

1.3 IMPLEMENTATION PROCESS

To achieve the goals/objectives of this CDS, the following steps need to be completed:

1. Collection and review relevant reports and other data.
2. Develop a 1 percent storm event XP-SWMM model of the Gate 5 Road area storm drain system.
3. Use the model to document the extent and causes of the flooding during the 1 percent storm event.
4. Develop a conceptual 1 percent storm event FPP.
5. Size the conceptual project facilities (storm drains, detention basins, pump station, *etc.*) using the XP-SWMM model.
6. Prepare a cost estimate for the FPP.

7. Summarize the conclusions and required next steps leading to design and construction of the FPP.
8. Summarize these evaluations in the CDS.

Subsequent to completion of this CDS, the following additional steps will be required:

9. Prepare a CEQA review of the FPP and receive City Council certification of the CEQA document.
10. Prepare grant/loan applications based on the CDS and secure the required funding.
11. Prepare detailed design and specifications for the FPP.
12. Seek bids for construction of the FPP.
13. Contract with a construction firm to build the FPP.
14. Construct the FPP.
15. Operate and maintain the FPP.

Figure 1-1. Watershed Map

CHAPTER 2. SUMMARY OF COLLECTED DATA

The following documentation and information were used in developing the XP-SWMM model for this report.

2.1 RECORD DRAWINGS

The following record drawings were received from the City of Sausalito (City). The information used from these record drawings is listed below:

- Whiskey Springs Project, dated 1977, no datum identified. Data used includes information on the 24-inch drain in Bridgeway Boulevard from Harbor Drive to Coloma Street and junction structure at southwest corner of Bridgeway Boulevard and Coloma Street.
- Whiskey Springs Improvement Plan, Coloma Street, dated 3/22/78, no datum given. Data used includes size and elevations of the Coloma Street 54-inch to 42-inch drain.
- Buena Vista Heights, dated November 1958, no datum identified. Data used includes information on the Lincoln-Driver 12, 15, and 21-inch drains. This drawing had pipe sizes and ground elevations from contours, but no invert data was available.
- 802 Butte Street Condo Improvement Plans, dated May 1996, elevations referenced to Benchmark #8 at 51.65 feet MSL. Data used included runoff flow patterns for subshed boundaries.
- Varda Landing Storm Drain Improvement Project, dated 11/30/98, elevations based on benchmark #2 at 10.97 feet. Data used includes drain sizes and materials, elevation of non-surveyed but connected drains.
- Marinship Storm Drain Improvement Plans, dated May 7, 1974 (hand drawn 1976), datum is Mean Sea Level. Data used includes 83" x 53"eliptical RCP size and elevations.
- Improvement Plans of Gate Five Road Assessment District, printed March 26, 1980, with an elevation datum of C&GS benchmark L108 at 10.778 feet. Data used includes storm drain sizes in Gate Five Road.

2.2 CALTRANS DOCUMENTS

Information about the culverts under Highway 101 through the Sausalito area was requested from Caltrans. Caltrans provided abundant reports, drawings, and other documents going back to the 1950s. This data was reviewed and it was determined that the culvert under Highway 101 in the Coloma Street watershed is a 30-inch RCP that was sized to convey a 10-year peak flow of 38 cubic feet per second (cfs) and a 100-year flow of 53 cfs.

2.3 MARIN COUNTY TOPOGRAPHIC MAPPING

The County of Marin Community Development Agency / GIS Division generated a 1.5-foot-Z accurate TIN, and created a 1-foot-XY gridded DEM from the TIN. West Yost used ArcGIS Spatial Analyst to generate a 2-foot contour layer from the County-provided DEM. The vertical datum for this data is NAVD88 feet, and the horizontal datum is California HARN Zone 3 US survey feet.

2.4 FEMA FLOOD INSURANCE RATE MAPS

The Flood Insurance Rate Maps for Sausalito (dated May 4, 2009) were obtained and reviewed. The 100-year base flood elevation in the bay was identified in 9.0 feet NAVD. The 100-year and 500-year flood plains are shown on Figure 2-1 (all figures and tables are presented at the end of each chapter).

2.5 100-YEAR TIDE DATA

The 100-year high tide elevation was obtained from the San Francisco Bay Tidal Stage vs. Frequency Study, dated October 1984, by the US Army Corps of Engineers, San Francisco District. This 100-year tide elevation for Sausalito was listed as 5.9 feet NGVD, which is equivalent to 8.66 feet NAVD of 1988.

2.6 FUTURE SEA LEVEL RISE

The San Francisco Bay Conservation and Development Commission has estimated that sea level will rise 55 inches by the end of the century (the year 2100). If this occurs, and this sea level rise is added to the FEMA 100-year high tide (9.00 feet NAVD), the resulting 100-year high tide will be 13.6 feet NAVD. Figure 2-2 shows the area that would be flooded by tidal flooding during a high tide at elevation 13.6 feet NAVD. A tide of 13.6 feet NAVD would flood much of the Gate 5 Road area from the Bay westward to Bridgeway Boulevard and the lower areas of Martin Luther King Jr. Park. Along Gate 5 Road, the flooding depths would be up to 6 to 8 feet.

2.7 SAUSALITO FLOOD STUDY

The Sausalito Flood Study was prepared by Philip Williams and Associates, Ltd (dated November 6, 2002). Data used from this study includes:

- Wave Run Up - A wave run up of 1 to 2 feet was estimated depending on the alternative evaluated. For this project, a wave run up of 2 feet was used.
- Settlement - This report used a future settlement depth of 0.83 feet over the next 20 years. Also, recent work by Towill, Inc. indicated that the lower part of the Coloma Street Watershed (northeast of Bridgeway Road) has settled by 1 to 2 feet from 1968 to 2007. So for this study an anticipated future settlement of 0.83 feet was used.
- Consolidation of the Bay Muds under a levee equal to 20 percent of the levee height was identified, and this value was also used in this study.

- Sea Level Rise - A sea level rise of 1 foot was estimated to occur from 1980 to 2020. However, in the White Slough Section 205 Flood Control Report (December 2001) by the US Army Corps of Engineers, the expected sea level rise was estimated at 0.6 feet for the year 2090. A value of 0.6 feet was used in this study, however, as discussed above sea level rise could be much greater than 0.6 feet.

2.8 STORM DRAIN MAPPING

Storm drain mapping, including drains, drain inlets, maintenance holes, culverts, inlets and outlets were provided by the City. This mapping included name/numbering of the storm drain facilities and that naming/numbering has been used in this report. The storm drains are shown on Figure 2-1.

2.9 RAINFALL DATA

Rainfall Data was originally obtained from two sources, including the California Department of Water Resources (DWR) Climate Data web site and the Solano County Water Agency's (SCWA) Hydrology Manual. Data from the DWR website included the preliminary rainfall data from the Marin City gage with a mean annual precipitation of 20.6 inches per year and duration depth frequency data for this gage. However, for this study, a 100-year, 4-day rain distribution was taken from the SCWA Hydrology Manual for Vallejo (across the Bay) for a mean annual precipitation of 22 inches per year because the SCWA Hydrology manual data has been refined to produce nested design storms.

The 100-year, 1 hour rain depths for the DWR data is 1.62 inches, and this value from the SCWA manual is 1.49 inches. These two data sources agree to within 8 percent of each other which supports the use of this approach. Also, after the modeling for this study was completed, rainfall duration-depth-frequency data was obtained from Marin County for the Mill Valley rain gage, and that data agrees closely with the data for Solano County (see the discussion of rainfall in Chapter 3).

2.10 INFILTRATION RATES

Based on the NRCS Web Soil Survey, the soil groups in the Coloma Street watershed include the Cronkhite-Barnabe Complex – 30 to 50 percent slopes, Los Osos-Urban Land-Bonnydoon Complex – 15 to 30 percent slopes, and Urban Land-Xerorthents Complex – 0 to 9 percent slopes, and small areas of other soils. This area appears to include mostly Hydrologic Group C soils.

2.11 INFORMATION FROM CITY STAFF

The approximate areas of routine flooding were identified by City staff and are shown on Figure 2-1. City staff also identified storm drain outlets that appear to have heavy sediment loads (see Figure 2-1).

Figure 2-1. Watershed Map

[redacted]

[redacted]

[redacted]

Figure 2-2. 100-Year Tidal Flooding in the Year 2100

[redacted]

[redacted]

[redacted]

CHAPTER 3. XP-SWMM MODEL DEVELOPMENT AND EXISTING CONDITIONS RESULTS

The modeling for this report was done using the XP-SWMM model software. This modeling software uses a hydrologic layer to simulate the rainfall to runoff process and a hydraulic layer to simulate the flow in the storm drain system and the resulting water surface elevations. The development of the existing conditions model is described below.

3.1 HYDROLOGIC MODEL INPUT

The hydrologic model layer of the XP-SWMM simulates the rainfall to runoff process. The data for this model layer are presented below.

Rainfall

The 100-year, 4-day storm rainfall duration-depth data is presented in Table 3-1, and the resulting hyetograph is presented in Figure 3-1. As shown, the 100-year storm has a peak rainfall intensity of 4.10 inches per hour. This rainfall intensity occurs for a 10 minute duration.

After the modeling had been completed for this study, rainfall duration-depth-frequency data was obtained for the Mill Valley rain gage in Marin County. This data is also shown in Table 3-1. As shown, for the durations up to of 1 hour, the Mill Valley rain data agree closely with the rain data used in the XP-SWMM model, which verifies that the rain data used is valid for this study.

Infiltration

The soils in this watershed are mostly Hydrologic Group C soils and consequently the following infiltration capacities have been used in this study.

- Initial infiltration rate = 1.0 inch per hour
- Constant infiltration rate = 0.11 inch per hour

Subshed Data

The Coloma Street watershed was divided into 17 subsheds. The subsheds are shown on Figure 2-1 and the model input data for each subshed are presented in Table 3-2.

3.2 HYDROLOGIC MODEL RESULTS

The hydrologic model produces runoff hydrographs that are used as input to the hydraulic model. The peak runoff rates for each of the subsheds are presented in Table 3-2 for the 100-year storm. The unit runoff rates (cfs per acre) are also presented in Table 3-2. As shown, the unit runoff rates range from 1.68 cfs to 3.36 cfs per acre. These runoff rates are generally consistent with typical runoff rates from small subsheds in urban residential and commercial areas. The lowest value is from subshed A (upstream of Highway 101), which is the largest subshed and is completely undeveloped. Consequently this shed should produce the lowest unit runoff rate.

3.3 HYDRAULIC MODEL INPUT

The hydraulic model simulates the flows and resulting water levels in the storm drain system and flood flow in the streets. Drain inlets and maintenance holes are modeled as nodes. Pipes and street sections are modeled as links. This model layer uses the runoff hydrographs as flow input at 17 of the model nodes, then routes the flows through the system, and determines the resulting water elevation at each node.

The locations of the nodes are shown on Figure 2-1 (and Figure 3-3), and the node data are presented in Table 3-3. The data for the links representing the pipes and street sections are presented in Table 3-4. The links are located by their upstream and downstream node names. The streets are represented as shallow trapezoidal channel sections, and the diameter (height) for the trapezoidal street sections was set to 0. This value tells the model to not limit the depth of flow in the trapezoidal street section.

The hydraulic model also requires a downstream boundary condition, or the tide level in Richardson Bay. The Richardson Bay tide level used in this study is presented in Figure 3-2. As shown, the maximum tide (9.26 feet NAVD) is assumed to occur at the end of the second day of the 100-year, 4-day design storm. The timing of the maximum tide coincides with the timing of the peak of the 100-year, 4-day design storm. This tide represents a 100-year tide with an additional 0.6 feet for future sea level rise. The high tides prior to and after the peak high tide are about 1.5 feet lower than the peak tide, but still represent unusually high tides.

3.4 HYDRAULIC MODEL RESULTS

The output from the hydraulic model are the flows in the links (pipes and street sections) and the resulting water levels at the nodes (drain inlets and maintenance holes). The maximum water levels and resulting freeboard (positive numbers) or flooding depths (negative numbers) at each node are presented in Table 3-3. The maximum flow in each link are presented in Table 3-4.

The 100-year model results are presented graphically in Figure 3-3. As shown, there is significant flooding in the lower areas of the watershed adjacent to Richardson Bay. This modeled flooding agrees well with FEMA flooding shown in Figure 2-1. The flooding northeast of Bridgeway Boulevard near the Bay is primarily due to tidal flooding. The shallower flooding southwest of the Bridgeway Boulevard occurs primarily because the storm drains lack capacity to convey the 100-year storm flows.

Since this model appears to reasonably reproduce the FEMA flooding, the model can be used for planning the future FPP.

Table 3-1. 100-Year Design Storm Duration-Depth Data

Duration	Rain Depth from SCWA Hydrology Manual Used In the XP-SWMM Model (in)	Rain Depth from the Mill Valley Rain Gage Used for Comparison With SWCA Data (in)
5 min	0.51	0.50
10 min	0.69	0.65
15 min	0.82	0.81
30 min	1.11	1.10
1 hour	1.49	1.54
2 hour	2.01	2.25
3 hour	2.39	2.82
6 hour	3.22	4.04
12 hour	4.33	5.52
1 day	5.83	7.02
2 day	7.86	
3 day	8.58	
4 day	9.40	

Table 3-2. Subshed Data and Peak Runoff Results

Subshed Number	Subshed Area (Acres)	Land Use	Impervious Percent	Hydrologic Soil Group	Ground Slope (ft/ft)	Width (ft)	Tributary Node	Peak Runoff (cfs)	Unit Runoff (cfs/ac)
104	17.80	Commercial/Park	30	C	0.04	304	MH104	29.8	1.68
106	6.54	Apartments/Office	70	C	0.03	317	MH105	22.0	3.36
302	10.67	Residential/Hills	40	C	0.17	238	CB302	27.9	2.62
361	5.56	School/Hills	50	C	0.25	168	CB362	17.9	3.22
365	4.00	Office/Commercial	80	C	0.01	145	CB365	11.4	2.84
371	5.37	Office/Commercial	80	C	0.01	156	CB371	14.1	2.63
373	5.27	Office/Commercial	80	C	0.01	153	CB373	13.8	2.63
379	4.78	Office/Commercial	80	C	0.01	278	CB379	15.6	3.26
384	2.48	Office/Commercial	80	C	0.01	180	CB384	8.5	3.44
386	2.62	Office/Commercial	80	C	0.01	190	CB386	9.0	3.44
388	5.92	Office/Commercial	80	C	0.01	286	CB388	18.4	3.11
73	15.50	Residential/Hills	40	C	0.16	450	MH73	42.8	2.76
75A	3.75	Residential/Hills	40	C	0.07	195	MH75		
75B	5.27	Residential/Hills	40	C	0.15	113	MH75	24.2	2.68
77	5.69	Residential/Hills	40	C	0.16	127	MH77	14.8	2.60
80	0.80	Residential/Hills	40	C	0.10	65	MH80	2.6	3.26
A	36.39	Open Space Hills	2	C	0.17	997	Shed A	57.3	1.57

Table 3-3. Hydraulic Model Node Input Data and Node Results (Water Surface Elevation and Freeboard)

Name	Ground Elevation (ft)	Invert Elevation (ft)	Max Water Elevation (ft)	Freeboard (ft) (Negative values are flooding Positive values are freeboard)
Shed A	186.0	180.0	181.5	4.5
SR 101	185.0	170.0	170.3	14.7
CB302	49.5	44.5	49.3	0.2
MH77	47.5	42.5	45.1	2.4
MH80	35.4	30.4	35.4	0.0
MH73	28.8	22.8	25.0	3.8
MH74	14.0	8.0	12.2	1.8
MH75	10.6	6.2	11.0	-0.5
MH104	8.4	3.9	10.5	-2.1
MH105	12.4	3.4	10.3	2.1
MH107	11.3	3.0	10.1	1.2
CB371	10.4	2.8	9.9	0.5
CB373	8.4	2.4	9.5	-1.1
CB379	6.8	4.7	9.3	-2.5
CB382	7.0	4.1	9.3	-2.2
CB384	6.5	2.9	9.3	-2.7
CB386	5.5	2.0	9.3	-3.8
CB362	14.0	7.5	14.1	-0.1
CB363	14.0	7.1	14.1	-0.1
CB365	14.0	6.2	13.9	0.1
CB394	7.6	4.7	9.3	-1.7
CB389	7.7	2.5	9.3	-1.6
CB388	7.2	1.3	9.3	-2.1
Bay	6.0	0.5	9.2	-3.2

Table 3-4. Hydraulic Model Link Input Data and Link Results (Peak Flow)

Link Name	Upstream Node Name	Downstream Node Name	Length ft	Diameter (Height) ft	Shape	Upstream Invert Elevation ft	Downstream Invert Elevation ft	Roughness Factor (n)	Max Flow cfs
CB302-A	CB302	MH77	120	2.00	Circular	44.5	42.5	0.015	45.1
CB362-A	CB362	CB363	79	2.00	Circular	7.5	7.1	0.015	15.1
CB362-B	CB362	CB363	100	0.00	Trapezoidal	13.2	13.5	0.020	1.1
CB363-A	CB363	CB365	267	2.00	Circular	7.1	6.2	0.015	15.0
CB363-B	CB363	CB365	267	0.00	Trapezoidal	13.5	13.5	0.020	0.0
CB365-A	CB365	CB394	278	2.00	Circular	6.2	4.7	0.015	21.4
CB365-B	CB365	CB394	278	0.00	Trapezoidal	13.5	7.1	0.020	0.0
CB371-A	CB371	CB373	187	6.92	Horizontal Elipse	2.8	2.4	0.015	130.8
CB371-B	CB371	CB373	187	0.00	Trapezoidal	9.9	7.9	0.020	0.0
CB373-A	CB373	CB388	489	6.92	Horizontal Elipse	2.4	1.3	0.015	69.6
CB373-B	CB373	CB388	489	0.00	Trapezoidal	7.9	6.7	0.020	72.0
CB379-A	CB379	CB382	139	1.00	Circular	4.7	4.1	0.015	1.2
CB379-B	CB379	CB382	139	0.00	Trapezoidal	6.3	6.8	0.020	15.9
CB382-A	CB382	CB384	234	1.25	Circular	4.1	2.9	0.015	2.5
CB382-B	CB382	CB384	234	0.00	Trapezoidal	6.5	6.0	0.020	19.9
CB384-A	CB384	CB386	214	1.50	Circular	2.9	2.0	0.015	4.1
CB384-B	CB384	CB386	214	0.00	Trapezoidal	6.0	5.0	0.020	33.0
CB386-A	CB386	CB388	223	1.50	Circular	2.0	1.3	0.015	7.9
CB386-B	CB386	CB388	223	0.00	Trapezoidal	5.0	6.7	0.020	63.4
CB388-A	CB388	Bay	333	6.92	Horizontal Elipse	1.3	0.5	0.015	44.0
CB388-B	CB388	Bay	333	0.00	Trapezoidal	6.7	5.5	0.02	182.5
CB389-A	CB389	CB388	283	2.00	Circular	2.5	1.3	0.015	3.4
CB389-B	CB389	CB388	283	0.00	Trapezoidal	7.2	6.7	0.020	20.9
CB394-A	CB394	CB389	234	2.00	Circular	4.7	2.5	0.015	2.9
CB394-B	CB394	CB389	234	0.00	Trapezoidal	7.1	7.2	0.020	20.3
MH104-A	MH104	MH105	64	4.50	Circular	3.9	3.4	0.015	110.5
MH104-B	MH104	MH105	64	0.00	Trapezoidal	7.9	11.9	0.020	0.0
MH105-A	MH105	MH107	126	6.92	Horizontal Elipse	3.4	3.0	0.015	120.5
MH105-B	MH105	MH107	126	0.00	Trapezoidal	12.1	11.0	0.020	0.0
MH107-A	MH107	CB371	133	6.92	Horizontal Elipse	3.0	2.8	0.015	120.7
MH107-B	MH107	CB371	133	0.16	Trapezoidal	10.8	9.9	0.020	0.0
MH73-A	MH73	MH74	413	3.00	Circular	22.8	8.0	0.015	92.9
MH73-B	MH73	MH74	414	0.00	Trapezoidal	28.3	13.5	0.020	0.0
MH74-A	MH74	MH75	100	3.50	Circular	8.0	6.2	0.015	92.8
MH74-B	MH74	MH75	100	0.00	Trapezoidal	13.5	10.1	0.020	0.0
MH75-A	MH75	MH104	361	3.50	Circular	6.2	4.9	0.015	47.7
MH75-B	MH75	MH104	361	0.00	Trapezoidal	10.1	7.9	0.014	72.3
MH77-A	MH77	MH80	172	2.00	Circular	42.5	30.4	0.015	49.2
MH80-A	MH80	MH73	162	2.00	Circular	30.4	22.8	0.015	50.4
Shed A-A	Shed A	SR 101	250	2.50	Circular	180.0	170.0	0.015	56.9
SR 101-A	SR 101	CB302	578	0.00	Trapezoidal	170.0	47.5	0.045	56.7

Figure 3-1. 100-Year Design Storm Hyetograph

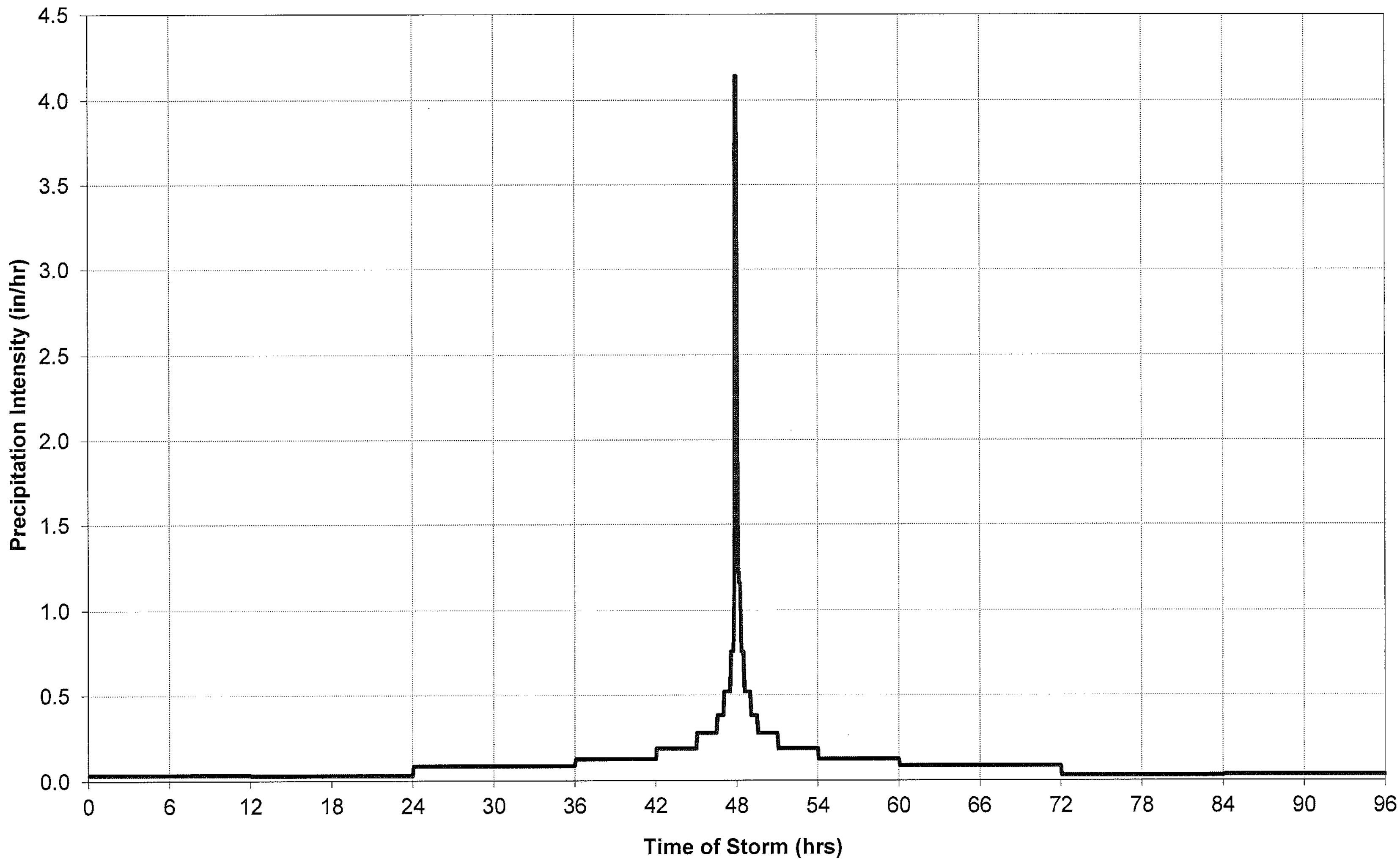
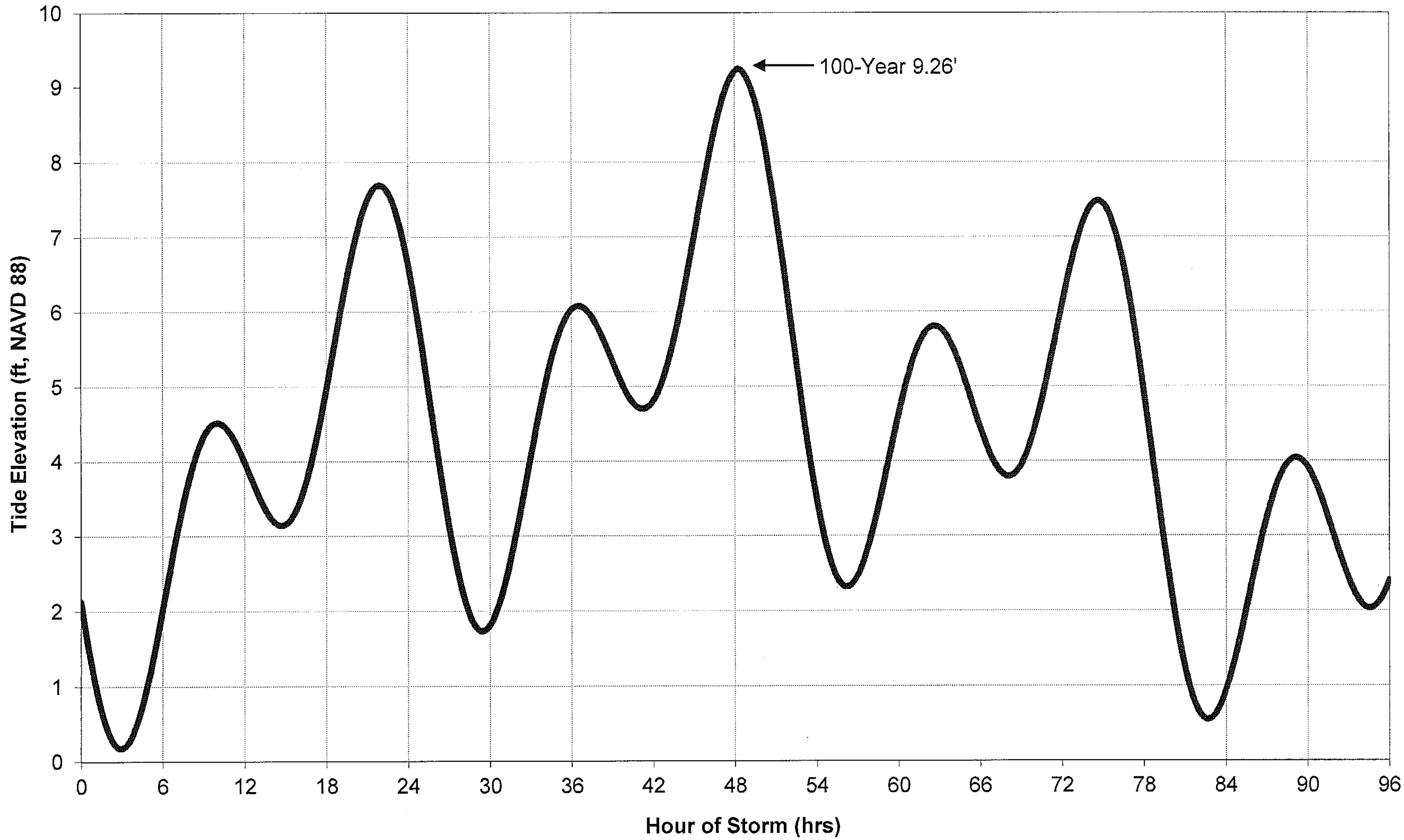
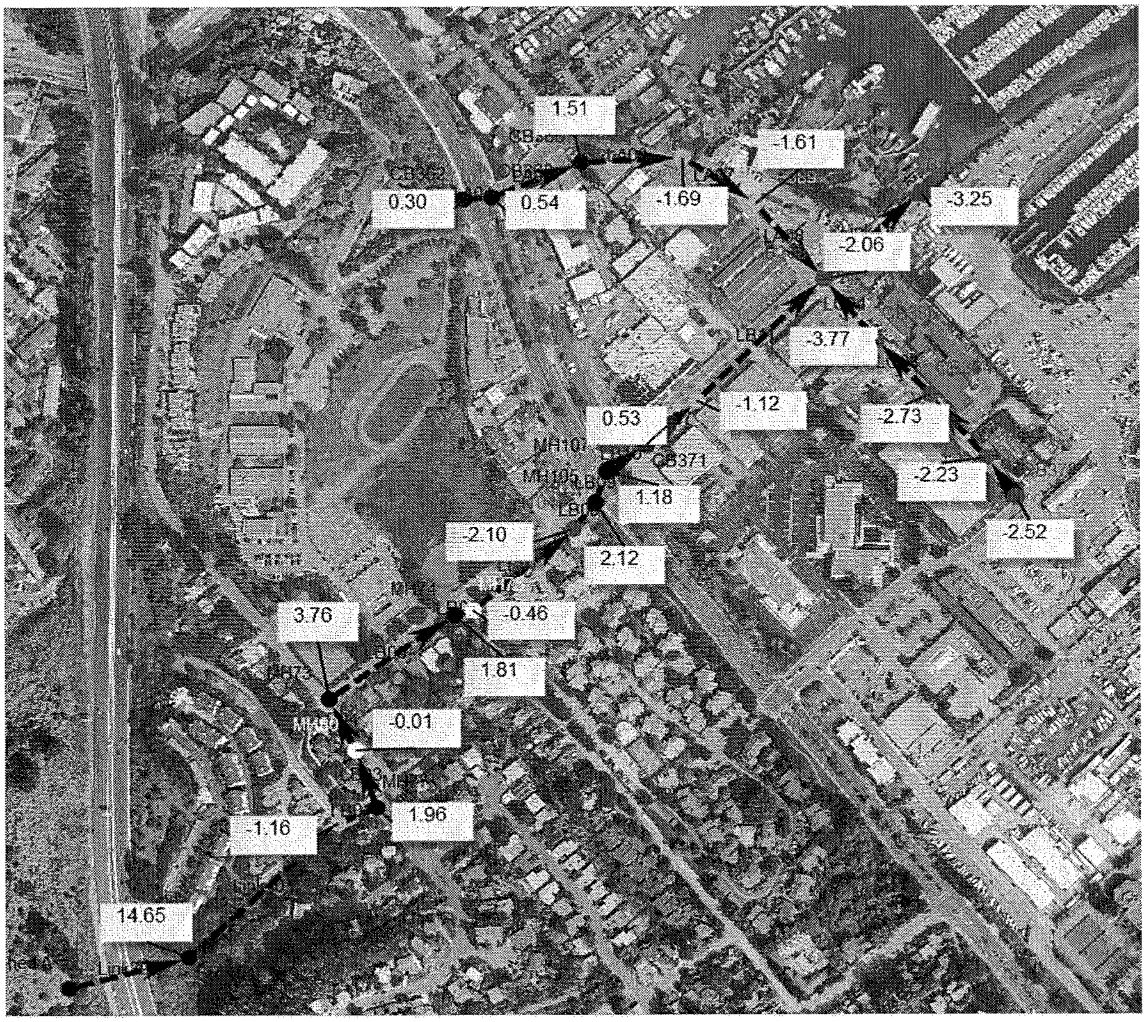


Figure 3-2. Richardson Bay Design Tide Level





Node Freeboard - Flooding Depth Legend

Flooding depth is greater than 2.0 feet

Flooding depth is 1.0 to 2.0 feet

Flooding depth is less than 1.0 feet

No flooding

Figure 3-3. 100-Year Storm Freeboard (Flooding).

Note: Freeboard depths are positive numbers, and Flooding depths are negative numbers.

CHAPTER 4. CONCEPTUAL EVALUATION OF POTENTIAL FLOOD CONTROL IMPROVEMENTS

This chapter describes and compares several potential sets of flood control improvements. The improvement projects would provide a wide range of flood control benefits.

4.1 FLOOD CONTROL IMPROVEMENT DESCRIPTIONS AND PERFORMANCE

Provided below are brief descriptions of the flood control improvements that could be implemented to reduce flooding in the Gate 5 Road Area.

In the discussion below, the term "Normal High Tides" means high tides that are not high enough to result in Bay water flowing over the ground surface and into the Gate 5 Road Area. However, these normal high tides could result in Bay water back-flowing up the storm drains and pooling in the low spots of the Gate 5 Road Area. The term "Near 100-Year High Tides" means tides that are high enough to flow over the ground surface and into the Gate 5 Road Area.

Improvement 1 – Duck Bill Flap Gate on the Coloma Street Drain

The goal of this improvement project is to eliminate tidal backflow up the 83" x 53" oval drain in Coloma Street. This existing drain discharges into a segment of open channel with vertical sheet pile sides. Standard flap gates are not available to fit this drain because it is an oval drain. Consequently, this improvement includes constructing a headwall with the 72-inch duck bill flap gate in the channel segment. The sheet piles forming the side of the channel would be built up to elevation 13.0 feet NAVD. The top of the new headwall would also be at 13.0 feet NAVD and would be connected to the sheet piles.

The performance of this improvement project is summarized below:

- Dry Weather, Normal High Tides: This improvement would prevent back flow of Bay water up the Coloma Street drain and would eliminate the ponding of tide water in the lows areas served by this drain.
- Dry Weather, Near 100-Year High Tides: This improvement would prevent back flow of tide water up the Coloma Street drain. However, in near 100-year high tides, Bay water would flow over the ground surface to these areas and consequently, flooding would still occur.
- Wet Weather Normal High Tides: During wet weather, runoff would still accumulate behind the tide gate to the same elevation as the tide level, so during normal high tides, this improvement would not provide significant reduction of flooding. In fact, this improvement would raise the water level slightly because of the head requirement needed to push open the duck bill flap gate.
- Wet Weather Near 100-Year High Tides: During wet weather, runoff would accumulate behind the tide gate to the same elevation as the tide level, and Bay water would flow over the ground surface to these areas. Consequently flooding would still occur.

The estimated cost for this improvement is about $319,000, as summarized in Table 4-1.

Improvement 2 – Pressurized Flow of the Coloma Street Drain

The goal of this improvement project is to allow the Coloma Street Drain to operate under pressure from Olima Street down to the outlet at the Bay. It would include sealing all of the maintenance holes along this drain so they could withstand 10 feet of head. Also, the drain inlets along this drain would be disconnected and reconnected to two new smaller drains (24 to 30 inches) that would parallel the existing drain and discharge to the Bay through flap gated outlets. This improvement would enable about 96 cfs of storm runoff to flow under pressure out to the Bay during a 100-year storm event.

The performance of this improvement project is summarized below:

- Dry Weather, Normal High Tides: This improvement would prevent Bay water from surcharging out of the drain system and consequently would eliminate the ponding of the Bay water in the low areas served by this drain.
- Dry Weather, Near 100-Year High Tides: In near 100-year high tides Bay water would flow over the ground surface to these areas and consequently flooding would still occur.
- Wet Weather Normal High Tides: During wet weather, this improvement would help force as much as 96 cfs into the Bay from upstream of Olima Street, some of which would otherwise surcharge out of the Coloma Street drain and pond on the ground surface. The runoff from the low areas would still accumulate behind the tide gate to the same elevation as the tide level, so during normal high tides, this improvement would provide some reduction of flooding, but the reduction might be minimal.
- Wet Weather Near 100-Year High Tides: During wet weather, this improvement would help force as much as 96 cfs into the Bay from upstream of Olima Street, some of which would otherwise surcharge out of the Coloma Street drain and pond on the ground surface. However, in near 100-year high tides, Bay water would still flow over the ground and into the Gate 5 Road Area. Consequently flooding would still occur.

Additional modeling would be needed to more accurately quantify the benefit that could be achieved with this improvement.

The estimated cost for this improvement is about $1.2 million as summarized in Table 4-1.

Improvement 3 – Pressurized Flow and Redirection of the North Branch of the Gate 5 Road Drain

The goal of this improvement project is to redirect the upstream segment of the north branch of the Gate 5 Road drain directly to the Bay. This improvement project includes about 260 feet of new 24-inch drain from near the north end of Gate 5 Road out to the Bay. The ground surface served by the upper reach of this drain is higher than the 100-year tide, so this drain could surcharge without causing runoff to flow out of the storm drain at intersections downstream. This improvement would enable about 15 cfs of storm runoff to flow under pressure out to the Bay during a 100-year storm event.

Table 4-1. Development and Comparison of Improvements Cost Estimates

Item	Unit of Measure	Cost, dollars	Quantity	Item Cost, dollars
Improvement 1 - Duck Bill Flap Gate on the Coloma Street Drain				
Headwall	each	40,000	1	40,000
Sheet Pile Extension	lump sum	50,000	1	50,000
72-Inch Duck Bill Flap Gate	each	106,000	1	106,000
Mobilization/demobilization (at 5 percent)				10,000
Construction Contingency (at 20 percent)				39,000
Estimated Construction Cost				245,000
Land/Easement	acre			
Engineering, CM/Insp, CEQA, City Admin (Note 1, at 30 percent)				73,500
Estimated Capital Cost				319,000
Improvement 2 - Pressurized Flow of the Coloma Street Drain				
Disconnect DI's and reconnect to new drains	each	2,000	12	24,000
Seal Maintenance Holes	each	1,000	8	8,000
24-Inch Storm Drain	ft	144	1,080	155,520
30-Inch Storm Drain	ft	180	2,520	453,600
Maintenance Holes	each	6,000	4	24,000
Duck Bill Flap Gate	each	22,000	2	44,000
Headwalls	each	20,000	2	40,000
Mobilization/demobilization (at 5 percent)				37,000
Construction Contingency (at 20 percent)				150,000
Estimated Construction Cost				936,000
Land/Easements	acre			0
Engineering, CM/Insp, CEQA, City Admin (Note 1, at 30 percent)				281,000
Estimated Capital Cost				1,217,000
Improvement 3 - Pressurized Flow and Redirection of the North Branch of the Gate 5 Road Drain				
24-inch drain	ft	260	144	37,440
Maintenance Holes	acre	6,000	1	6,000
Headwall	each	20,000	1	20,000
Mobilization/demobilization (at 5 percent)				3,000
Construction Contingency (at 20 percent)				13,000
Estimated Construction Cost				79,000
Land/Easement	acre	500,000	0.11	57,392
Engineering, CM/Insp, CEQA, City Admin (Note 1, at 30 percent)				24,000
Estimated Capital Cost				160,000
Improvement 4 - Flap Gate/Duck Bill Valve on the Coloma Street Drain and a Pump Station				
Pump Station (firm capacity = 195 cfs, total capacity = 260 cfs)	cfs	35,000	260	9,100,000
84-Inch Duck Bill Flap Gate	each	135,000	1	135,000
Mobilization/demobilization (at 5 percent)				462,000
Construction Contingency (at 20 percent)				1,847,000
Estimated Construction Cost				11,544,000
Land/Easements	acre	1,000,000	0.32	321,000
Engineering, CM/Insp, CEQA, City Admin (Note 1, at 30 percent)				3,463,200
Estimated Capital Cost				15,328,200
the Martin Luther King Junior Park				
Excavation	CY	25	26,222	655,551
Hydroseed Basin	acre	5,000	3	15,000
Inlet/Outlet Structures	lump sum	60,000	1	60,000
Pump Station (firm capacity = 105 cfs, total capacity = 135 cfs)	cfs	35,000	135	4,725,000
72-Inch Duck Bill Flap Gate	each	106,000	1	106,000
Mobilization/demobilization (at 5 percent)				278,000
Construction Contingency (at 20 percent)				1,112,000
Estimated Construction Cost				6,952,000
Land/Easements	acre	1,000,000	0.29	293,848
Engineering, CM/Insp, CEQA, City Admin (Note 1, at 30 percent)				2,086,000
Estimated Capital Cost				9,332,000

Item	Unit of Measure	Cost, dollars	Quantity	Item Cost, dollars
Improvement 6 - Raising Gate 5 Road and/or Parking Lots				
Fill	CY	30	55,000	1,650,000
Repave Road and driveways	sf	20	100,000	2,000,000
Estimating Contingency (at 50 percent of above)				1,825,000
Mobilization/demobilization (at 5 percent)				274,000
Construction Contingency (at 20 percent)				1,095,000
Estimated Construction Cost				6,844,000
Land/Easements (for basin)	acre	1,000,000	4.0	4,000,000
Engineering, CM/Insp, CEQA, City Admin (Note 1, at 30 percent)				2,053,000
Estimated Capital Cost				12,897,000
Improvement 7 - Levee and Floodwall				
Concrete	CY	1,200	1,800.0	2,160,000
Stop Log Access Structures	Each	100,000	10	1,000,000
Fill	CY	30	26,000	780,000
Repave Road and driveways	sf	20	100,000	2,000,000
Estimating Contingency (at 50 percent of above)				2,970,000
Mobilization/demobilization (at 5 percent)				445,500
Construction Contingency (at 20 percent)				1,782,000
Estimated Construction Cost				11,137,500
Land/Easements (for basin)	acre	1,000,000	4.0	4,000,000
Engineering, CM/Insp, CEQA, City Admin (Note 1, at 30 percent)				3,341,300
Estimated Capital Cost				18,478,800
Improvement 8 – Flood Proofing Individual Structures				
Pumping	cfs	100,000	3.0	300,000
400 feet of Floodwall	CY	1,200	200	240,000
Miscellaneous	LS	100,000	1.0	100,000
Mobilization/demobilization (at 5 percent)				32,000
Construction Contingency (at 20 percent)				128,000
Estimated Construction Cost				800,000
Engineering, CM/Insp, CEQA, City Admin (Note 1, at 30 percent)				240,000
Estimated Capital Cost				1,040,000

Notes:

1. Soft Costs include:
   - Engineering (conceptual and detailed design) at 12 percent of the construction cost
   - Construction period engineering services at 3 percent of the construction cost
   - CEQA environmental review and mitigation at 4 percent of the construction cost
   - Construction management and inspection at 6 percent of the construction cost
   - City administration (both during design and construction) at 5 percent
2. Costs are for April 2011 ENRCCI 20 City Average 8,677.

The performance of this improvement project is summarized below:

- Dry Weather, Normal High Tides: By itself, this improvement would not prevent Bay water from surcharging out of the drain system in the lower Gate 5 Road area, and little benefit would occur from this improvement.
- Dry Weather, Near 100-Year High Tides: By itself, this improvement would not prevent Bay water from surcharging out of the drain system or flowing over the ground surface in the lower Gate 5 Road area, and little benefit would occur from this improvement.
- Wet Weather Normal High Tides: Without a flap gate on the Coloma Street Drain, this improvement would not provide significant benefit. However, with the Coloma Street Drain flap gate, this improvement would help force as much as 15 cfs into the Bay from upstream of this drain, some of which would otherwise add to the flooding in the lower Gate 5 Road Areas.
- Wet Weather Near 100-Year High Tides: Without a flap gate on the Coloma Street Drain, this improvement would not provide significant benefit. However, with the Coloma Street Drain flap gate, this improvement would help force as much as 15 cfs into the Bay from upstream segment of this drain, some of which would otherwise add to the flooding along the Gate 5 Road and Coloma Street drains. However, in near 100-year high tides, Bay water would still flow over the ground and into the Gate 5 Road Area. Consequently flooding would still occur.

By itself, this improvement provides very limited benefits. However, if coupled with one of the pump station alternatives below, it could help reduce the required pumping capacity.

The estimated cost for this improvement is about $160,000 as summarized in Table 4-1.

Improvement 4 – Flap Gate/Duck Bill Valve on the Coloma Street Drain and a Pump Station

The goal of this improvement is to prevent back flow of Bay water up the Coloma Street Drain and to pump runoff out of the area. The flap gate system would be installed on the pump station wet well and would allow gravity discharge of the runoff when the tides are low. The pump station would have four 65 cfs pumps, a firm capacity of 195 cfs, a total capacity of 260 cfs, and would discharge to the Bay.

The performance of this improvement is summarized below:

- Dry Weather, Normal High Tides: This improvement would prevent back flow of Bay water up the Coloma Street Drain and would eliminate the ponding of tide water in the lows areas served by this drain.
- Dry Weather, Near 100-Year High Tides: This improvement would prevent back flow of tide water up the Coloma Street Drain. However, in near 100-year high tides, Bay water would flow over the ground surface to these areas and consequently flooding would still occur.

- Wet Weather Normal High Tides: During wet weather, the runoff would be pumped out of the lower Gate 5 Road Area, so during normal high tides, this improvement would eliminate flooding in the Gate 5 Road Area.
- Wet Weather Near 100-Year High Tides: During wet weather, and near 100-year high tides, Bay water would flow over the ground surface to the low areas. This surface flow from the Bay would likely overwhelm the pump station and flooding would continue to occur.

The estimated cost for this improvement is about $15.3 million, as summarized in Table 4-1.

If this improvement was combined with improvements 2 and 3, the required pumping capacity could be reduced significantly. Modeling of this improvement configuration would be required to fully evaluate the required pump station capacity and system performance.

Improvement 5 – Flap Gate/Duck Bill Valve on the Coloma Street Drain, Pump Station, and Detention Basin in the Martin Luther King Junior Park

The goal of this improvement is to prevent back flow of Bay water up the Coloma Street Drain and to detain and pump runoff out of the area. The flap gate system would be installed on the pump station wet well and would allow gravity discharge of the runoff when the tides are low. The detention basin would have storage capacity of about 13 ac-ft, which would be located within the softball field at Martin Luther King Junior Park. This basin would reduce the required firm pumping capacity from 195 cfs to about 105 cfs.

The performance of this improvement project is summarized below:

- Dry Weather, Normal High Tides: This improvement would prevent back flow of Bay water up the Coloma Street Drain and would eliminate the ponding of tide water in the lows areas served by this drain.
- Dry Weather, Near 100-Year High Tides: This improvement would prevent back flow of tide water up the Coloma Street Drain. However, in near 100-year high tides, Bay water would flow over the ground surface to these areas and consequently flooding would still occur.
- Wet Weather Normal High Tides: During wet weather, the runoff would be pumped out of the lower Gate 5 Road Area, so during normal high tides, this improvement would eliminate flooding in the Gate 5 Road Area.
- Wet Weather Near 100-Year High Tides: During wet weather, and near 100-year high tides, Bay water would flow over the ground surface to the low areas. This surface flow from the Bay would likely overwhelm the detention basin and pump station and flooding would continue to occur.

The estimated cost for this improvement project is about $9.3 million, as summarized in Table 4-1.

If this improvement was combined with improvements 2 and 3, the required detention basin volume and/or pumping capacity could be reduced significantly.

Modeling of this improvement project configuration would be required to fully evaluate the required detention basin volume and pump station capacity.

Improvement 6 – Raising Gate 5 Road and/or Parking Lots

The goal of this improvement is to eliminate the flow of Bay water over the ground surface into the Gate 5 Road Area even in 100-year high tides. This improvement includes raising about 1,800 feet of Gate 5 Road to about elevation 13 feet NAVD, or by about 5 to 8 feet (essentially becoming a levee). To provide significant benefit, this improvement would need to be coupled with improvements 1, 2, 4 or 5. This improvement would severely impact vehicle access from Gate 5 Road to the parking lots and driveways along Gate 5 Road and would create driving hazards. It would require encroachment of the raised road onto numerous private properties. It would also have significant visual impacts. It is unclear if this improvement could be successfully implemented.

The performance of this improvement project is summarized below:

- Dry Weather, Normal High Tides: This improvement project would prevent back flow of Bay water up the Coloma Street drain and would eliminate the ponding of tide water in the lows areas served by this drain.
- Dry Weather, Near 100-Year High Tides: This improvement would prevent back flow of tide water up the Coloma Street drain. It would also provide flood protection for Gate 5 Road and the parcels west of Gate 5 Road. It would not eliminate tidal flooding of the properties east of Gate 5 Road.
- Wet Weather Normal High Tides: During wet weather, the runoff would be pumped out of the area west of Gate 5 Road (pumping is part of improvement 4 or 5), so during normal high tides, this improvement would eliminate flooding west of Gate 5 Road. East of Gate 5 Road the tidal flooding would continue.
- Wet Weather Near 100-Year High Tides: During wet weather and near 100-year high tides, the runoff would be pumped out of the area west of Gate 5 Road, so this improvement would eliminate flooding west of Gate 5 Road. East of Gate 5 Road the tidal flooding would continue

The estimated cost for this improvement is about $12.9 million, as summarized in Table 4-1. This cost is only for improvement 6. Because of the complexity and uncertainty of this improvement, a 50% estimating contingency has been included in the construction cost estimate for this improvement.

It may be possible to raise some parking areas east of Gate 5 Road southeast of Coloma Street rather than the Road itself. If so, this would expand the area that gains flood protection from this improvement project.

Improvement 7 – Levee and Floodwall

The goal of this improvement is to eliminate the flow of Bay water over the ground surface into the Gate 5 Road Area even in 100-year high tides. This improvement includes constructing about 3,000 feet of levee and floodwall where possible and as high as possible (up to 8 feet high, up to elevation 13.0 feet NAVD), while not impacting vehicle access. The levee and floodwall would run from near the north end to the south end of Gate 5 Road. A floodwall would be constructed on top of the levee (or in place of the levee) to achieve the full design freeboard and complete the full connectivity of the levee-floodwall system. The floodwall would have access ways at driveways or walkways. The access ways would be fit with stop log structures, which are slots into which the stop logs can be inserted to seal the wall. The stop logs are often made of aluminum or steel and are grooved to fit to each other. They usually have seals abound the ends that help provide the water tight seal to the flood wall slots. This improvement would require manual installation of the stop logs prior to high tide events, potentially during storm events. Additionally, once installed, the stop logs would prevent access through the access way.

This improvement project would also have significant visual impacts. Installation of the stop logs during high tides or storm events would represent a potential safety hazard for pedestrians attempting to leave the docks behind the wall. It is unclear if this improvement project could be successfully implemented.

To provide significant benefit, this improvement project would need to be coupled with improvements 1, 2, 4 or 5.

The performance of this improvement project is summarized below:

- Dry Weather, Normal High Tides: This improvement would prevent back flow of Bay water up the Coloma Street drain and would eliminate the ponding of tide water in the lows areas served by this drain.
- Dry Weather, Near 100-Year High Tides: This improvement would prevent back flow of tide water and thereby would eliminate flooding of the full Gate 5 Road Area.
- Wet Weather Normal High Tides: During wet weather, the runoff would be pumped out of the area west of the levee/floodwall, so during normal high tides, this improvement would eliminate flooding of the full Gate 5 Road Area.
- Wet Weather Near 100-Year High Tides: During wet weather and near 100-year high tides, the runoff would be pumped out of the Gate 5 Road Area, so this improvement would eliminate flooding of the full Gate 5 Road Area.

The estimated cost for this improvement is about $18.5 million, as summarized in Table 4-1. This cost is only for improvement 7. Because of the complexity and uncertainty of this improvement, a 50% estimating contingency has been included in the construction cost estimate for this improvement.

Improvement 8 – Flood Proofing Individual Structures

This improvement includes providing flood protection to individual structures. The flood protection would include installation of small pumps (about 3 cfs per acre of tributary area) and other improvements to restrict Bay water or runoff from flowing onto the individual parcel. The particular system of flood proofing would have to be developed on a parcel by parcel basis. The costs could vary greatly by individual parcel. Flood proofing would likely be used on only a few parcels that couldn't be protected by any of the improvements described above.

The estimated cost presented in Table 4-1 is an approximation of flood proofing for a single 1 acre parcel. The actual costs for any specific parcels could be significantly higher or lower.

4.2 COMPARISON OF IMPROVEMENTS PROJECTS

A comparison of these improvement projects is presented in Table 4-2.

The costs of the individual improvement projects are summarized in Table 4-1. As shown, these costs range from $160,000 to as much as $18.5 million for the individual projects.

To achieve full 100-year protection for the entire Gate 5 Road Area would require the combination of improvements 3, 5, and 7, at a total cost of $28 million (as shown in Table 4-2 for improvement 7). This set of improvements would be very difficult to construct and would cause many severe impacts. A combination of improvements 3, 5, and 6 would cost $22.4 million, but would only provide full protection for the area west of Gate 5 Road (see improvement project 6 in Table 4-2).

A combination of improvement projects 1, 2, 3, and raising of some of the lowest areas along the Bay front to reduce the flow of Bay water over the ground into the Gate 5 Road Area would represent a set of improvements that could be implemented for about $2 million. The ground raising would have to be planned using accurate topographic mapping of the lower Gate 5 Road Area along the Bay. The goal would be to identify what areas could be provided with some level of increased protection from high tides flowing over the ground surface, but 100-year protection would not be expected. Also, the detention basin from improvement project 5 could be included for an additional cost of approximately $1.2 million, and could significantly improve the overall performance. It is recommended that this set of improvements be further evaluated with the XP-SWMM model.

There could be other combinations of these improvements that would perform better and at lower costs than the combinations of the improvements described above. For example, a combination of Improvements 2, 3, and 5 and downsizing of the detention basin and pump station could perform better and cost less than improvement 5 by its self. The use of combinations of improvements should be evaluated in future studies.

Annual operations and maintenance costs have not been estimated for these improvement projects. These costs can be significant and should be evaluated in future studies.

Table 4-2. Comparison of Improvements

Improvement Project	Flood Reduction: Dry Weather, Normal High Tides	Flood Reduction: Dry Weather, Near 100-Year High Tides	Flood Reduction: Wet Weather Normal High Tides	Flood Reduction: Wet Weather Near 100-Year High Tides	Full System Cost, $	Construction Complexity	Impacts
Improvement 1 - Duck Bill Flap Gate on the Coloma Street Drain	Yes	No	No	No	319,000	Moderate	Low
Improvement 2 - Pressurized flow of the Coloma Street Drain	Yes	No	Some	No	1,217,000	Moderate	Low
Improvement 3 - Pressurized Flow and Redirection of the North Branch of the Gate 5 Road Drain	No	No	No	No	160,000	Low	Low
Improvement 4 - Flap Gate/Duck Bill Valve on the Coloma Street Drain and a Pump Station	Yes	Some	Yes	No	15,328,000	High	Moderate
Improvement 5 - Flap Gate/Duck Bill Valve on the Coloma Street Drain, Pump Station, and Detention Basin in the Martin Luther King Junior Park	Yes	Some	Yes	No	9,332,000	Moderate	Moderate
Improvement 6 - Raising Gate 5 Road and/or Parking Lots (cost of improvements 3, 5, and 6 included for a complete system)	Yes	Yes (west of Gate 5 Road only)	Yes	Yes (west of Gate 5 Road only)	22,389,000	High	High
Improvement 7 - Levee and Floodwall (cost of improvements 3, 5, and 7 included for a complete system)	Yes	Yes	Yes	Yes	27,971,000	High	High
Improvement 8 – Flood Proofing Individual Structures (cost is per acre)	Yes	Yes	Yes	Yes	1,040,000	Moderate	Moderate

4.3 TAKE NO ACTION APPROACH

Although not recommended, another approach is to take no action related to the flooding in the Gate 5 Road Area. If no action is taken over the long term, then the Gate 5 Road flooding will get worse than what occurs now because:

- Ground settlement of this area is expected to result in lowering of the ground by about 0.8 feet over the next 20 years.
- Sea level is expected to rise. There is a wide range of sea level rise predicted over the next century. The BCDC has predicted a 16-inch rise by the mid-century and a 55 inch rise by the end of this century. However, for this study a sea level rise of only 0.6 feet was assumed.

Figure 2-2 shows the extent of 100-year tidal flooding that would occur with a 55-inch rise in sea level. This figure, however, did not account for continued ground settlement, which could add another 1 foot to the depth of flooding. With the continued settlement, sections of Bridgeway Boulevard would also be flooded. Figure 2-2 also did not account for wave run up (which could add 1 to 2 feet of increased water levels) or storm related flooding.

There is no immediate cost associated with taking no action, but over time the risk of significant flood damage occurring in the Gate 5 Road Area will increase. At some time in the future, a tide/storm event will occur that will cause significant flooding and result in major property damage. Additionally this level of future flooding would put city residents at significant risk of harm and loss of life. The cost of repairing that damage could exceed the cost of even the most expensive improvements discussed above. As sea level rises, flooding that causes damage will occur more frequently, resulting in repetitive flood damage costs; whereas the capital cost of providing flood protection is a one-time cost. However, there would be annual operation and maintenance costs associated with the improvements.

CHAPTER 5. REVIEW OF CITY POLICIES AND REGULATIONS

This chapter presents a review of the City policies and regulations related to providing flood control improvements for the Gate 5 Road Area. The following documents were reviewed:

- Title 8 Buildings and Construction, Chapter 8.48 Floodplain Management
- Title 11 Environmental Protection, Chapter 11.08 Residential Development Review
- Title 11 Environmental Protection, Chapter 11.17 Urban Runoff Pollution Prevention
- Title 11 Environmental Protection, Chapter 11.18 Regulatory Fee for Clean Stormwater Activities

The review comments presented below provide suggested revisions to these documents.

5.1 TITLE 8 BUILDING AND CONSTRUCTION, CHAPTER 8.48 FLOOD PLAIN MANAGEMENT

Section 8.48.041 should include a requirement for the applicant to submit the FEMA base flood water surface elevation at the development site.

Section 8.48.043 A3 allows development at sites that are "reasonably safe from flooding." It is suggested that developments should only be approved if the finished floor elevation is at least 1 foot above the base flood elevation (100-year flood elevation).

Section 8.48.043 A4. For areas where a base flood elevation has been determined, but a floodway has not been designated, this section allows development to result in an increase in the base flood elevation of up to 1 foot. An increase of the base flood elevation of 1 foot could result in many more buildings or structures flooding after development. It is suggested that this criterion be revised to allow no increase in the base flood elevation. Additionally, no increase in the base flood elevation should be allowed in any area, regardless of whether base flood elevations have been determined.

Section 8.48.043 B. This section should start as a new paragraph, rather than a continuation of the previous paragraph. Also, for areas without base flood elevations established by FEMA, this section places the responsibility of obtaining other base flood information on the floodplain administrator. This text should be revised to place this responsibility on the party proposing the development, with review and approval by the floodplain administrator.

Section 8.48.043 C. It appears that words are missing from this section and consequently its meaning is unclear.

Section 8.48.051 C1. This section requires that the lowest floor be elevated to or above the base flood elevation. It does not require any freeboard. It is suggested that this section be revised to require finished floors (and flood proofing improvements) be raised to at least 1 foot above the base flood elevation.

Section 8.48.053. This section should require subdivisions be designed to have all finished floor elevations at least 1 foot above the base flood elevation after the subdivision is constructed. It will be necessary for the developer to determine the base flood elevation after construction of the development project.

Section 8.48.053 E. This section requires a subdivision to provide adequate drainage. This section should be revised to require storm drain systems to be designed to convey the 10-year storm with at least 1 foot of freeboard (e.g. water levels 1 foot below the drain inlet grate elevations).

Section 8.48.054. This section requires that the lowest floor of manufactured homes be elevated to or above the base flood elevation. It does not require any freeboard. It is suggested that this section be revised to require finished floors (and flood proofing improvements) be raised to at least 1 foot above the base flood elevation.

Section 8.48.055. This section prohibits encroachments into floodways if they cause any increase in the base flood elevation (the 100-year storm). This section should be revised to prohibit any increase in the water level from any storm that results in less than 1 foot of freeboard to the top of bank of the floodway or within 1 foot of causing property damage.

Section 8.48.056 A. This section requires that the structural members of the lowest floor be elevated to or above the base flood elevation for structures within coastal high hazard areas. It does not require any freeboard. It is suggested that this section be revised to require the structural members of the lowest finished floors be raised to at least 1 foot above the base flood elevation plus wave run up.

Section 8.48.056 B. This section requires that new construction to be located on the land side of the mean high tide elevation. Even with this requirement, it is likely that the structure will be completely surrounded by water during a 100-year high tide. It is suggested that this section be revised to require an access way that is at least 1 foot above the base flood elevation plus wave run up.

Lastly, global climate change is expected to result in significant sea level rise. This document refers to tide levels in several sections. It is suggested that this document be revised to require all new development to also allow for sea level rise in addition to the 1 foot of freeboard discussed above. The amount of sea level rise to be used should be determined through a literature review of relevant, current studies. The amount of anticipated sea level rise may have to be updated every 5 to 10 years to remain valid.

5.2 TITLE 11 ENVIRONMENTAL PROTECTION, CHAPTER 11.08 RESIDENTIAL DEVELOPMENT REVIEW

Section 11.08.130 identifies criteria for determining the number of units that can be approved each year. It includes a criterion for the availability of utilities and public services.

A criterion could be added that clearly requires new development to have 100-year or 200-year flood protection.

5.3 TITLE 11 ENVIRONMENTAL PROTECTION, CHAPTER 11.17 URBAN RUNOFF POLLUTION PROVENTION

Section 11.17 was reviewed, but no suggested revisions were identified.

5.4 TITLE 11 ENVIRONMENTAL PROTECTION, CHAPTER 11.18 REGULATORY FEE FOR CLEAN STORMWATER ACTIVITIES

Section 11.18 was reviewed, and no suggestions related to flood control issues or requirements were identified; however, several other comments are provided below.

It is noted that section 11.18.020 allows funds collected under the Clean Stormwater Activities program to be used for maintenance and repair of storm drain facilities and for capital improvements for the storm drain system. Thus, it appears that the Clean Stormwater Fund could be used for improvements to eliminate flooding of the Gate 5 Road Area.

Section 11.18.030 F should be reworded. It appears that an RU is supposed to be the impervious area of an average residential lot, in which case it should be calculated by multiplying the lot size times the runoff factor (0.4). However, the text actually says to multiply the impervious area of the lot by the runoff factor. The equation that should further explain this is "7,500 Sq Ft x 4 – 3,000 ft." It appears that this equation should probably be "7,500 Sq Ft x 0.4 = 3,000 Sq Ft."

Section 11.18.050 C includes a table of runoff factors. These factors appear to be equivalent to the C values used in the Rational Method for calculating runoff. For Vacant Land, the value in this table is set to 1.0. It is unclear why vacant land (with no pavement or impervious areas) would have the highest runoff factor of all land use categories. If these are equivalent to C values, vacant land should probably be in the range of 0.1 to 0.3 depending on soil types, slope, or other conditions.

CHAPTER 6. CONCLUSIONS AND RECOMMENDATIONS

This chapter presents a summary of the work performed and the conclusions and recommendations for the next steps related to this CDS.

6.1 SUMMARY CONCLUSIONS

Conclusions are summarized below:

- An XP-SWMM computer model of the Gate 5 Road watershed storm drain system was developed to determine the causes of flooding.
- The 100-year high tide is 8.66 feet NAVD. The FEMA 100-year water surface elevation in the Bay is 9.00 feet NAVD. These tide levels result in street flooding along Gate 5 Road even when no storm occurs.
- The XP-SWMM model was used to simulate the 100-year storm with a 100-year tide. In this condition, flooding with depths over 3 feet would occur along the Gate 5 Road. Flooding along Coloma Street upstream of Bridgeway Road would occur with depths up to 2 feet.
- The XP-SWMM model was used to simulate the 100-year storm with low tides. In this condition, flooding with depths over 1.4 feet would occur along the Gate 5 Road. Flooding along Coloma Street upstream (west) of Bridgeway Road would occur with depths up to 1.2 feet.
- Flooding in the Gate 5 Road area can occur from:
  - Inadequate storm drain capacity to convey the 100-year storm flows.
  - Flow of Bay water up the storm drain, out the drain inlets, and onto the streets.
  - Flow of Bay water westward over the streets.
- The San Francisco Bay Conservation and Development Commission has estimated that the sea level will rise 55 inches by the end of the century (the year 2100). If this occurs, and this sea level rise is added to the FEMA 100-year high tide (9.00 feet NAVD), the resulting 100-year high tide will be 13.6 feet NAVD. A tide at 13.6 feet would flood the area east of Bridgeway Boulevard. Along Gate 5 Road, flooding depths of up to 6 to 8 feet would occur.
- A wide range of improvement projects were evaluated. The performance of the improvement projects ranged from:
  - Providing minimal reduction of flooding only during normal high tides during dry weather. The costs for these improvements ranged from $160,000 to $1.2 million.

- Providing 100-year flood protection for most of the area (but not all of the area) even during the 100-year storm with a 100-year tide. The costs for these improvements ranged from $22 million to $28 million.

- Combinations of the improvements could perform better and cost less than the individual improvement projects.
- Although not recommended, taking no action now would result in no immediate expenditure of construction/capital costs; but, it will ultimately lead to repetitive, very expensive flood damage costs.
- Several City policies and regulations were reviewed, and revisions to improve flood protection were suggested.

6.2 RECOMMENDATIONS

Recommendations are provided below:

- Conduct a literature review to determine an appropriate level of sea level rise and the time frame in which it will occur. Prepare City-wide maps of tidal flooding for two or three different levels of sea level rise.
- Further develop and evaluate three sets of improvements that provide a range of level of flood protection from reduction of dry weather tidal flooding only to full protection from the 100-year storm and tide. Evaluate and size these improvements with the XP-SWMM model.
- Perform a study similar to this one for the Nevada - Spring Street watersheds.
- Conduct workshops with City residents and leaders to explain the current situation, potential solutions, potential community impacts associated with the improvements, and the consequences of taking no action.
- Adopt the changes to the City policies and regulations suggested in Chapter 5.
- Develop short term and long term plans for resolving current and future flooding problems.