Preliminary Feasibility Study for South San Francisco Bay Shoreline

Economic Impact Areas 1 to 10

Appendix III: Coastal Storm Damage Risk Analysis

Final Report

Prepared For:
Santa Clara Valley Water District

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Table of Contents

1.0 INTRODUCTION 1
1.1 Purpose 1
1.2 Guidance & References 1
1.3 The Study Area 2
1.4 Other Reports on Coastal Flood Risk in the Study Area 2
1.5 Contents of the Report 3
2.0 RISK ASSESSMENT OVERVIEW 4
2.1 Defining and Understanding Flood Risk 4
2.2 Categories of Flood Damage 5
2.3 Methods & Models Used 7
2.4 Evaluating Project Economic Justification 8
2.5 The Consideration of Future Sea-Level Rise 8
3.0 VALUE AT RISK IN THE STUDY AREA 9
3.1 Property in the Coastal Flood Zone 9
3.2 Coastal Zone 1: EIAs 1 to 3 13
3.3 Coastal Zone 2: EIAs 4 & 5 15
3.4 Coastal Zone 3: EIA 6 & 7 15
3.5 Coastal Zone 4: EIAs 8 & 9 16
3.6 Coastal Zone 5: EIA 10 17
3.7 Summary of Structure and Content Values 17
3.8 Regional Water Quality/Pollution Control Plants 18
3.9 Palo Alto Airport 21
3.10 Highways 101 & 237 21
4.0 EXISTING & FUTURE WITHOUT-PROJECT FLOOD RISK 22
4.1 Direct Flood Damage 22
4.2 Limits and Simplifying Assumptions 24
4.3 HEC-FDA Model Results: Direct Flood Damage to Structures and Contents 24
5.0 WITH-PROJECT RISK REDUCTION 27
5.1 Description of the Coastal Levee Project 27
5.2 Flood Damages Reduced and Residual Risk 27
6.0 POTENTIAL ECONOMIC JUSTIFICATION 29
7.0 SUMMARY & CONCLUSIONS 35

8.0 REFERENCES 37
9.0 APPENDIX 39
  9.1 Structure & Content Valuation Methodology 39
  9.2 Depth-Damage Relationship for Structures & Contents 40

List of Tables

Table 1. List of Study Area EIAs 9
Table 2. Preliminarily Estimated Levee Construction Cost for Low SLR Projection 28
Table 3. Preliminarily Estimated Levee Construction Cost for Intermediate SLR Projection 28
Table 4. Preliminarily Estimated Levee Construction Cost for high SLR Projection 29
Table 5. Preliminarily Estimated Benefit-Cost Analysis in EIA 1 30
Table 6. Preliminarily Estimated Benefit-Cost Analysis in EIA 2 & EIA 3 30
Table 7. Preliminarily Estimated Benefit-Cost Analysis in EIA 4 31
Table 8. Preliminarily Estimated Benefit-Cost Analysis in EIA 5 31
Table 9. Preliminarily Estimated Benefit-Cost Analysis in EIA 6 32
Table 10. Preliminarily Estimated Benefit-Cost Analysis in EIA 7 32
Table 11. Preliminarily Estimated Benefit-Cost Analysis in EIA 8 33
Table 12. Preliminarily Estimated Benefit-Cost Analysis in EIA 9 33
Table 13. Preliminarily Estimated Benefit-Cost Analysis in EIA 10 34
Table 14. Summary of Preliminary Project Costs & Benefits with 3.125% Discount Rate 34
Table 15. Summary of Preliminary Project Costs & Benefits with 7.0% Discount Rate 35
Table 16. CSVRs Used in the Analysis 40
Table 17. Non-Residential Contents Depth-Damage Curves, Short Duration Saltwater 43

List of Figures

Figure 1. Critical Infrastructure & General Land Use in the Study Area 1
Figure 2. Characterizing Flood Risk – 4 Key Questions 4
Figure 3. Flood Damage Categories 6
Figure 4. Delineation of Study Area Coastal Modeling Zones & EIAs 10
Figure 5. 1% ACE Event Flood Map, Year Zero (Existing Conditions) 11
Figure 6. 1% ACE Event Flood Map, Year 50, Sea-Level Rise Curve III 12
Figure 7. Representative Residential Structures in EIAs 1-3 13
Figure 8. Estimated Number and Value of Structures and Contents in the Study Area, by EIA and Type 14
Figure 9. Representative Commercial and Industrial Structures in EIAs 4 and 5 15
Figure 10. Representative Commercial and Industrial Structures in EIAs 7, 8, and 9 16
Figure 11. Estimated Depreciated Replacement Value of Parcel Improvements 17
Figure 12. Ground Elevations of Developed Parcels 18
Figure 13. Aerial View of the Palo Alto RWQCP 20

Figure 14. Aerial View of Sunnyvale WPCP 21
Figure 15. Example Coastal Hydro-economic Model..23
Figure 16. Existing Expected Annual Damage, and Future Equivalent Annual Damage..................25
Figure 17. Direct Flood Damage Estimate - 1% ACE Event, Year 0 (current conditions)................25
Figure 18. Direct Flood Damage Estimate - 1% ACE Event, Year 50, SLR Curve II........................26
Figure 19. Direct Flood Damage Estimate - 1% ACE Event, Year 2067, SLR Curve III...................26
Figure 20. Levee Alignment - With-Project Analysis..27
Figure 21. Residential Depth-Damage Curves, Short Duration Salt Water......................................41
Figure 22. Commercial Depth-Damage Curves, Short Duration Saltwater 42
Figure 23. Residential Contents Depth-Damage Curves, Short Duration Saltwater.........................42

1.0 INTRODUCTION

1.1 Purpose

The purpose of this report is to document the methodology and results of the preliminary economic analysis conducted to quantify the coastal flood risk in the area known as the South San Francisco Bay Shoreline. The study area is located in Santa Clara County, CA, and extends across approximately 9 miles of shoreline from San Francisquito Creek south to the Guadalupe River as shown in Figure 1. This preliminary analysis is intended to be the foundation upon which a more detailed and comprehensive flood damage analysis, alternatives analysis, and benefit-cost analysis can be developed.

Figure 1. Critical Infrastructure & General Land Use in the Study Area

1.2 Guidance & References

The flood damage analysis is intended to be consistent with the policies and procedures for economic analyses of the U.S. Army Corps of Engineers. The principal guidance referenced for this analysis comes from the U. S. Army Corps of Engineers *Planning Guidance Notebook*

(Engineering Regulation 1105-2-100) (U.S. Army Corps of Engineers, 2000), with specific guidance from Appendix D – Economic and Social Considerations. Additional guidance on various topics came from the following documents:

Risk-based Analysis: *USACE ER 1165-2- 101, Risk Analysis for Flood Damage Reduction Studies* (U.S. Army Corps of Engineers, 2006).

Prices, Discount Rate, and Period of Analysis: USACE FY16 *Economic Guidance Memorandum (EGM) 16-01*. All benefits and costs are expressed in average annual terms at 2016 price levels. The project benefit-cost ratio is calculated using the fiscal year 2016 federal discount rate of 3.125%, as well as the rate of 7%. The period of analysis is 50 years.

Structure and Contents Stage-Damage Relationships: The short-duration saltwater curves used in this analysis were developed by the USACE New Orleans District for the Donaldsonville to the Gulf Feasibility Evaluation (Gulf Engineers and Consultants, Inc., 2006).

1.3 The Study Area

The study area spans the cities of Palo Alto, Mountain View, Sunnyvale, and Santa Clara, all of which are located in Santa Clara County, California. According to the latest data from the U.S Census Bureau, the population in the study area is racially diverse and fast growing, and has a household income that is more than 50% greater than the average household in California.

Within the cities of Palo Alto, Mountain View, and Sunnyvale, the top three industries by number of employees are manufacturing, professional and scientific services, and information (US Census 2014). The area also includes significant and critical public infrastructure – the Palo Alto Regional Water Quality Control Plant (RWQCP), the Sunnyvale Water Pollution Control Plant (WPCP), the Palo Alto Airport, and Highway 101. It is important to note that coastal flood damages estimated in this report do not include direct or indirect impacts to public infrastructure such as roads and utilities. Estimating these impacts is beyond the scope of this preliminary analysis, which should be considered and described in more detail in the subsequent analysis, as appropriate.

While most of the properties in the study area are residential, there are many commercial and industrial properties in the floodplain, and a large percentage of the property value at risk is associated with these commercial and industrial structures. These properties include many high tech companies such as Google, Yahoo, Intuit, and Sun Microsystems that are part of the larger Silicon Valley information technology industry. The NASA Ames Research Center and the Moffett Federal Airfield are also in the study area. Figure 1 is an aerial of the study area with the location of the critical infrastructure and general land use identified.

1.4 Other Reports on Coastal Flood Risk in the Study Area

Interest and concern over the impact of climate change and sea-level rise in the San Francisco Bay Area has continued to increase over the last many years. The U.S. Army Corps of Engineers, local governmental agencies, and non-profits have produced a significant volume of useful and informative information.

The U.S. Army Corps of Engineers completed a draft report in 2010 that attempted to describe the without-project coastal flood risk from the bay within Santa Clara County – an area that includes all of the study area for this preliminary analysis. The preliminary results of that 2010 report found that there was a significant future coastal flood risk in the study area. Some of the data developed for that report – such as baseline structure inventory data – has been used here but updated as necessary.

The U.S. Army Corps of Engineers San Francisco District completed an approved feasibility report in 2015 for a project that will reduce coastal flood risk in the community of Alviso, which is part of the City of San Jose, and located adjacent to the study area.

The Impacts of Sea-Level Rise on the California Coast (Pacific Institute, 2009) estimates that in Santa Clara County there are currently around 13,000 people vulnerable to a "100-year flood[1]" event along the San Francisco Bay, and that with sea-level rise that number may more than double by 2100. The report estimates that for the County there are currently 10 miles of highway, 110 miles of roads, and 6 miles of railways that are vulnerable to the 100-year flood event. The report also estimates that the replacement value of buildings and contents in Santa Clara County vulnerable to a 1% annual chance of exceedance (ACE) flood event at the bay is currently $3.7 billion, and that with 1.4 meters of sea-level rise that value would be just less than $8 billion.

The Santa Clara County Office of Sustainability and their consultant, AECOM, are in the process of developing a decision-support tool to "evaluate potential climate change impacts and community/regional strategies." The effort is called "Silicon Valley 2.0", and, according to its website, "The Silicon Valley 2.0 Project was developed by the County of Santa Clara Office of Sustainability in order to respond to a gap in regional climate adaptation planning, and the need for an implementation playbook rather than, simply, a plan. In addition, authors of the project focused on the question of what tool would best serve decision-makers and those who influence and consult them where significant commitments and long-term strategies are needed."

1.5 Contents of the Report

Section 2 defines flood risk, identifies the primary damage categories typically evaluated, and provides a brief overview of the methodology used to estimate flood damages and overall flood risk.

Section 3 describes the structures and infrastructure that are located in the floodplain, and, where appropriate, describes the total value of the assets that are exposed to flood risk due to their location.

Section 4 describes the without-project flood risk, which was calculated within the HEC-FDA v.1.2.5a computer program. The damages are described in event-based terms as well as in expected annual damages and equivalent annual damages.

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[1] This is a flood that has an estimated 1% chance of occurring in any given year (over the long term about once every hundred years). Such a flood or storm event will be referred to in this report as the "1% annual chance of exceedance event "or "1% ACE event."

Section 5 reports the estimated economic benefits of a single with-project alternative: a coastal levee with a crest elevation of approximately 15 feet (NAVD88). The estimate of the remaining (or residual) flood risk with the project in place is described as well.

Section 6 summarizes the results and describes the potential economic justification of a protective coastal levee with a crest elevation of approximately 15 feet.

Section 7 concludes and discusses some of the important next steps for a more detailed and complete flood risk assessment.

Section 8 contains the bibliography.

Section 9 includes selected supporting documentation.

2.0 RISK ASSESSMENT OVERVIEW

2.1 Defining and Understanding Flood Risk

Flood damage is one component of flood risk. Understanding the risk of something undesirable happening (in this case a flood event) requires an understanding of the likelihood of the event happening as well as the potential magnitude of the impacts. The purpose of characterizing coastal flood risk is to support decisions related to reducing the risk to people and property in the floodplain. Figure 2 shows four questions that are critical to answer when evaluating flood risk.

Question 1	• What can go wrong?
Question 2	• How can it happen?
Question 3	• How likely is it to happen?
Question 4	• What are the consequences?

Figure 2. Characterizing Flood Risk – 4 Key Questions

Questions 1 and 2 can be answered without a significant level of analysis. What can go wrong in the study area is that coastal water can inundate developed properties and put people and property at risk of injury or damage. A coastal flood event in the study area can happen by either an overtopping or breaching of the existing levees that are currently the only line of defense keeping bay water from reaching the homes, businesses, people, and infrastructure in the interior of the floodplain. Coastal waters could also contribute to flooding in the area by raising the stage of the various creeks in the study area where they flow into the bay.

Questions 3 and 4 above, however, require detailed and thorough analyses to answer, and are the focus of the risk analysis described in this report. The question of likelihood has been addressed by a detailed but preliminary coastal engineering analysis, which serves as a primary input to this risk assessment that will combine likelihood and consequence estimates to provide a preliminary understanding of the coastal flood risk in the area.

In order to fully understand risk from coastal storms and flooding, the likelihood and consequences of the wide range of possible flood events must be analyzed. Knowing the consequences of a single large, low annual probability flood event is not enough information – you must also understand the consequences of more likely (smaller) storm and flood events. Many reports and studies focus on the consequences of a single, large storm event; most often they estimate the damage to homes and businesses from the 1% ACE storm event. Such estimates are useful information, but do not provide enough information to determine whether and to what extent an investment in risk reduction measures is warranted from an economic standpoint. Only by integrating the estimated damages across a broad spectrum of event probabilities, and by considering changes over time, can a clear enough depiction of the flood risk be developed so that a well-informed investment decision can be made.

This analysis does consider a wide range of event probabilities, and any change in flood risk due to rising sea level over the next fifty years (the standard period of analysis for a federal project). The flood risk and the risk reduction benefits are expressed in what are known as "equivalent annual damages," which are average annual values that consider the range of event probabilities and their consequences, as well as any changes in the risk over the fifty-year period of analysis. As is described below in Section 2.4, for comparison's sake the total estimated project cost will also be described in average annual terms.

2.2 Categories of Flood Damage

For this report, the estimation of the consequences of coastal flooding will be primarily focused on what the USACE calls National Economic Development (NED) impacts (U.S. Army Corps of Engineers, 2000). Furthermore, the focus is specifically on "tangible", "direct" damages from flooding. These terms are defined below.

The USACE Planning Guidance Notebook (PGN) defines NED impacts as follows:

Contributions to NED are increases in the net value of the national output of goods and services, expressed in monetary units. Contributions to NED are the direct net benefits that accrue in the planning area and the rest of the Nation. Contributions to NED include increases in the net value of those goods and services that are marketed, and also of those that may not be marketed.

In the NED definition above, marketed goods and services are those that are bought and sold, while non-marketed goods are not. An example of a non-marketed good is the value of the time spent cleaning up a flooded house in the aftermath of a flood event. Non-marketed goods can be further classified as tangible and intangible, a distinction that is explained below.

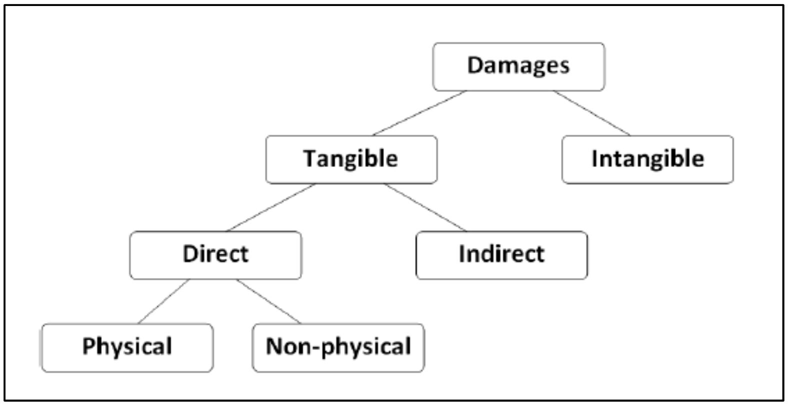


Figure 3. Flood Damage Categories

The Institute for Water Resources (Institute for Water Resources, 2013) categorizes flood damage as shown above. **Intangible** damages consist of things such as emotional distress that cannot be readily quantified. **Tangible** damages can be either direct or indirect in nature. **Direct** damages are the damages that result from the action of floodwater on structures and property. Direct damage can either be **physical** or **non-physical**. The types of direct damages typically evaluated in detail for USACE flood damage analyses are listed below with the corresponding damage category in parentheses.

- Structure and Content Damages (Physical Damage)
- Damage to the Water Pollution/Quality Control Plants (Physical Damage)
- Cost to Temporarily Displaced Residents (Non-Physical)
- Automobile Damages (Physical)
- Transportation Delay and Detour Costs (Non-Physical)

Damage is indirect if it is associated with a disruption to economic activities caused by flooding – for example impacts to manufacturers that are supplied by a flooded business.

Indirect economic impacts from a flood event are defined here as the losses resulting from the consequences of physical destruction (rather than the physical destruction itself). From a purely economic perspective, floods and other natural disasters can result in both positive and negative indirect impacts (National Research Council, 1999).

The short-term indirect economic losses from flooding could include:

- Induced losses in sales, wages, and/or profits due to loss of function. The inability to operate may derive from either direct physical damage to commercial structures or from infrastructure failure.
- Losses to firms forward-linked or backward linked in production to businesses closed as a result of direct physical damage or infrastructure failure. Slowdowns or shutdowns are induced by reductions in demands for inputs and supplies of outputs from damaged firms.
- Spending reductions from the income losses triggered by firm closures or cutbacks – so-called multiplier or ripple effects. Employees of the firms experiencing reduced production and sales suffer income losses and subsequently curtail their own expenditures, initiating a new round of firm cutbacks.

The short-term indirect economic gains from flooding could include:

- Changes in future production, employment, and income and/or changes in these flows outside the damaged area. Current production outside the immediate area of impact or future production within the affected region may compensate for initial disaster-induced losses.
- Income gains outside the impact area to owners of commodities inflated in price by disaster-induced reconstruction are particularly likely to generate these windfall profits outside the region.
- Positive economic stimuli of jobs and production generated from cleaning up and rebuilding and the multiplier effect of those increases.

On the whole, measured over the entire economy the *indirect* gains and losses may cancel out and the net effect could be zero. On both an individual level as well as an overall social level however, the impact of a flood event is unambiguously negative: Injuries and deaths can occur, people's lives are disrupted, personal belongings are destroyed, financial and emotional hardship is suffered by many – especially the uninsured, and friends and families can be displaced from their homes and community. Also, if flood damage disrupted service at the two water treatment plants in the area, the release of raw sewage into the bay could cause significant environmental and economic impacts. An analysis of the indirect impacts of flooding is beyond the scope of this preliminary flood risk analysis.

2.3 Methods & Models Used

The damage to structures, contents, automobiles, and the cost of residential displacement are all estimated within the computer program HEC-FDA v.1.2.5a (FDA). The FDA program estimates flood damage by applying a hydro-economic model, which is explained in detail in Chapter 4.

Due to the uncertainty regarding the rate of future sea-level rise, and in accordance with USACE policy, the flood damage analysis considers three different sea-level rise scenarios. The sea-level rise scenarios considered are those specified in USACE Engineering Circular (EC) 1165-2-212 (U.S. Army Corps of Engineers, 2011). The details of these scenarios are specified in the EC and on the Corps' climate change adaptation website (U.S. Army Corps of Engineers, 2014).

The FDA models were built with data for each structure, under each sea-level rise scenario, and for each of the eight standard exceedance probabilities – 50%, 20%, 10%, 4%, 2%, 1%, .4% and .2% events. This report uses exceedance probabilities to describe flood events. The exceedance probability is the reciprocal of what is often referred to as the "return period." The return period (or recurrence interval) of an annual maximum flood event has a return period of X years if its magnitude is equaled or exceeded once, on the average, every X years. As an example, a 1% return period (1/100) means that there is a 1% probability of an occurrence in any one year. FDA uses Monte Carlo simulation to calculate a stage-damage relationship with uncertainty, and the program then annualizes the probability-weighted damages to calculate what is termed the "equivalent annual damage" for each scenario considered. The model can also be used to describe the damages associated with a particular probability storm event, and it produces various statistics that are useful to understanding the coastal flood risk associated with storms in the area.

For this preliminary analysis, the coastal modeling was completed for the base year (Year Zero), and a single future year (Year 50). The base year is the year 2017, and the future year is 2067. The FDA modeling was completed for these two years for each of the three sea-level rise scenarios. For the calculation of the equivalent annual damage, the FDA models each assume a linear relationship between the Year Zero and Year 50 expected annual damage results.

Finally, for this analysis no removal or relocation of structures from the floodplain was assumed under the without-project future scenario. In the aftermath of a flood event, property owners may decide to relocate, or may not be able to rebuild in the floodplain. This gradual or sudden evacuation of the floodplain would reduce the number and value of properties exposed to future flooding in the area. This would be an important consideration of a more detailed benefit-cost analysis of a coastal flood damage project. This consideration requires detailed temporal flood modeling that is not part of the scope of this preliminary study.

2.4 Evaluating Project Economic Justification

Because future sea-level rise means that the risk associated with coastal flooding in the study area is constantly changing over time, the increase in expected annual flood damage in future years must be discounted to present value terms and annualized in order to compare the damages (and damages reduced) to the annualized cost of one or more potential projects. The estimate of the reduction in expected annual flood damage from the implementation or construction of a project can be compared to the annualized cost of the project to determine whether the project is economically justified. From a net benefits perspective, if the annualized dollar value of the reduction in future flood damage exceeds the annualized total cost of the project (including maintenance, mitigation, etc.), then the project has net economic benefits and is economically justified. The comparison of benefits and costs can also be done to compare several project alternatives, and the most efficient project can be identified. Importantly, when a benefit-cost analysis is conducted from a federal perspective (for example when federal cost-sharing exists), the relevant economic impacts are only those that represent a net change for the nation. Transfers of wealth or spending between regions of the country do not have an impact on national economic development.

2.5 The Consideration of Future Sea-Level Rise

Relative sea level in the San Francisco Bay is expected to continue to rise through the foreseeable future. How fast sea level will rise, and by how much ultimately, is unknowable. Because of this uncertainty, the U.S. Army Corps of Engineers requires that feasibility studies consider multiple scenarios of sea-level rise (U.S. Army Corps of Engineers, 2011). In addition to the existing condition (risk given today's sea level), studies must consider a low, intermediate, and high sea-level rise scenario. The low scenario corresponds to an extrapolation of the historic rate of sea-level rise, while the intermediate and high rates are based on modifications to curves developed by the National Research Council.

This flood risk analysis considers the three sea-level rise scenarios to an equal extent. The coastal hydrodynamic modeling was completed for Year Zero (2017) and Year 50 (2067). The fifty-year period of analysis is consistent with USACE planning principles and procedures as described in the USACE PGN (U.S. Army Corps of Engineers, 2000). Coastal and economic modeling of the intervening years was not within the scope of this preliminary analysis, but should be considered for future additional coastal flood risk analyses.

3.0 VALUE AT RISK IN THE STUDY AREA

For this report the study area is divided into 10 areas termed Economic Impact Areas, or EIAs. The location of the EIAs is defined by the area between the numerous creeks within the study area. An exception to this is EIAs 6 and 7, which were separated based on the border between the NASA Ames and Moffett Federal Airfield property and the area east of this property but west of the Sunnyvale East creek. This was done because of the specialized nature of the facilities on the federal property and because it is a large area owned by the Federal Government. As described further below, for purposes of the coastal modeling and flood damage analysis, the EIAs have been combined into five areas termed "coastal modeling zones." Table 1 and Figure 4 describe and display the location of each of the coastal zones and the EIAs within them.

Table 1. List of Study Area EIAs

Coastal Modeling Zone	EIA	Located Between…
1	1	San Francisquito Creek & Matadero Creek
	2	Matadero Creek & Barron Creek
	3	Barron Creek & Adobe Creek
2	4	Adobe Creek & Permanente Creek
	5	Permanente Creek & Stevens Creek
3	6	Stevens Creek & Sunnyvale West Creek- NASA Only
	7	Stevens Creek & Sunnyvale West Creek - Non-NASA
4	8	Sunnyvale West Creek & Sunnyvale East Creek
	9	Sunnyvale East Creek & Calabazas Creek
5	10	Calabazas Creek & Guadalupe Creek

Figure 5 and Figure 6 show the floodplains for the 1% ACE event under the Year 0 conditions (current), and the Year 50 under sea-level rise scenario 3. The maps show the increase in the depth and extent of the coastal floodplain when considering future sea-level rise. Compared to Year Zero, peak depths in the floodplain are, on average, between two and three feet greater under high sea-level rise scenario (Curve III) at Year 50.

3.1 Property in the Coastal Flood Zone

The kinds of structures in the study area can be broadly classified based on the type of activity that occurs there. Accurately classifying the structures exposed to flood risk is important because the type of structure is an important determinant of the depreciated replacement value (DRV) of the structure and the assumptions about the value of the contents. For example, a warehouse and an office building of the same size will have different replacement costs due to factors such as the number of interior walls and the need for building aesthetics. The structures in the study area are classified as residential, commercial, industrial, or public. Residential structure types include single-family (SFR), multi-family (MFR), and manufactured housing (MH). Commercial (Com) structures include small and large-scale retail or service operations that serve the local or regional residential areas. Industrial (Ind) structures are those devoted to warehousing, distribution, research and business support services, and offices. The baseline inventory of structures and contents in the floodplain used for this report was provided by the Corps of Engineers as developed for their 2010 without-project feasibility study in the area. Minor updating has been done to the structure valuations to account for the increased cost of construction between 2010 and 2016. Finally, while many of the commercial and industrial structures in the floodplain are multiple stories high, the DRV estimated for this analysis applies only to the first floor of these buildings since the flood depths are not expected to reach beyond the first floor of these buildings.

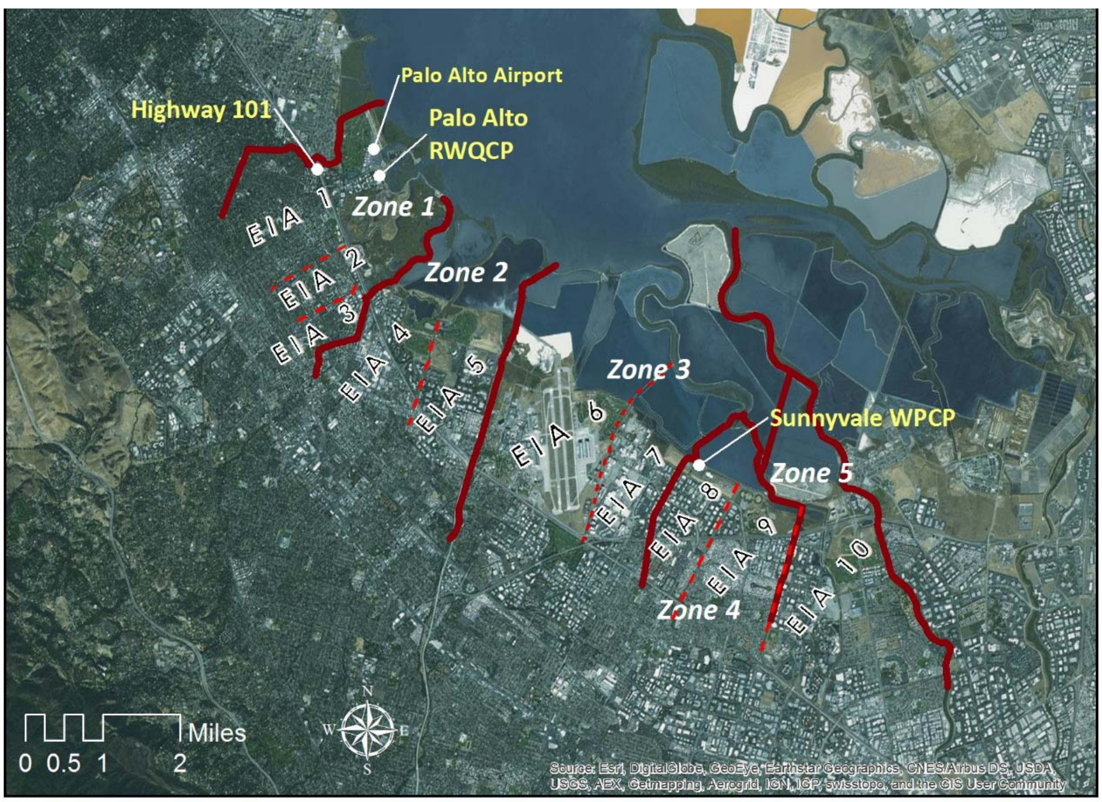


Figure 4. Delineation of Study Area Coastal Modeling Zones & EIAs

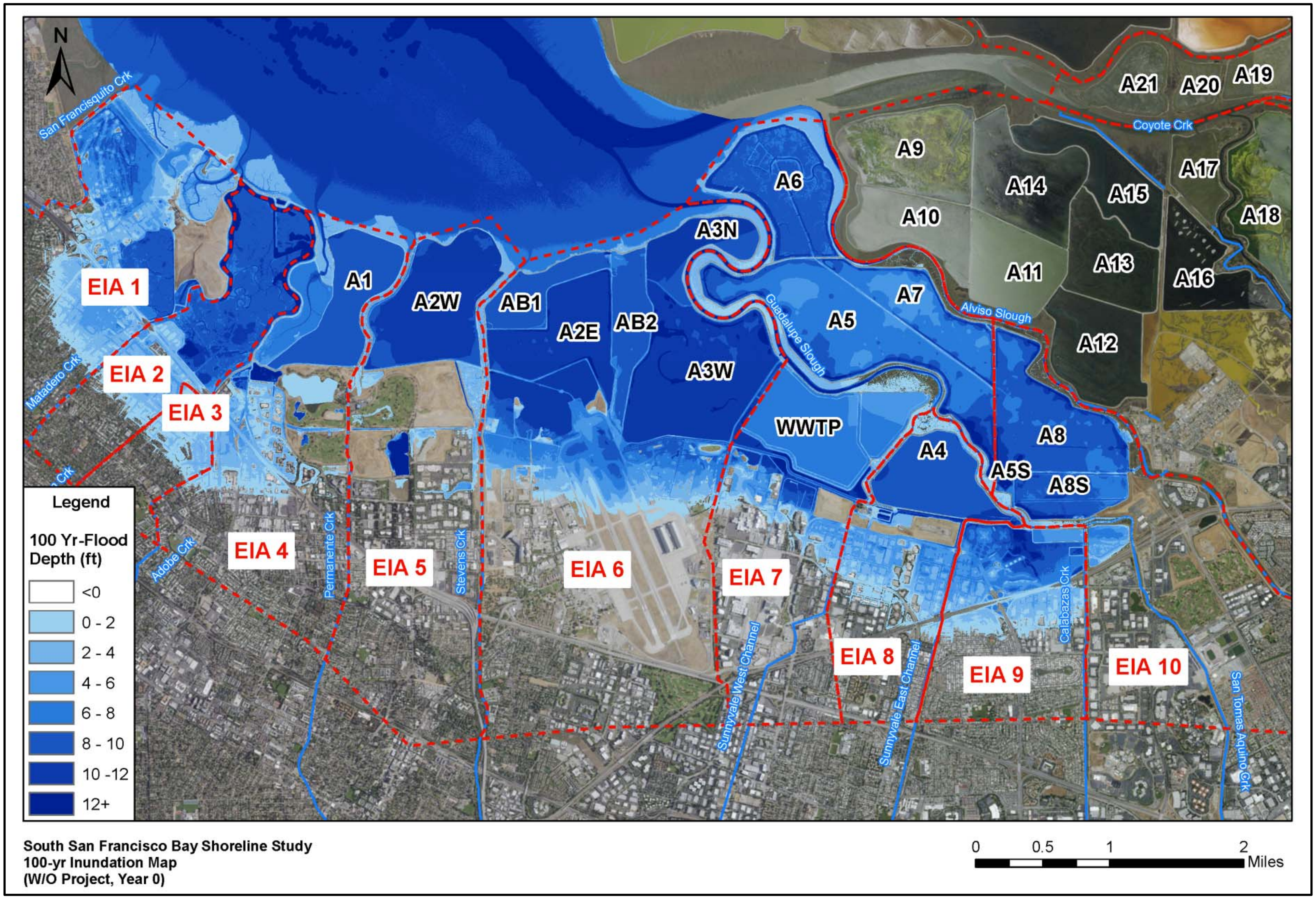
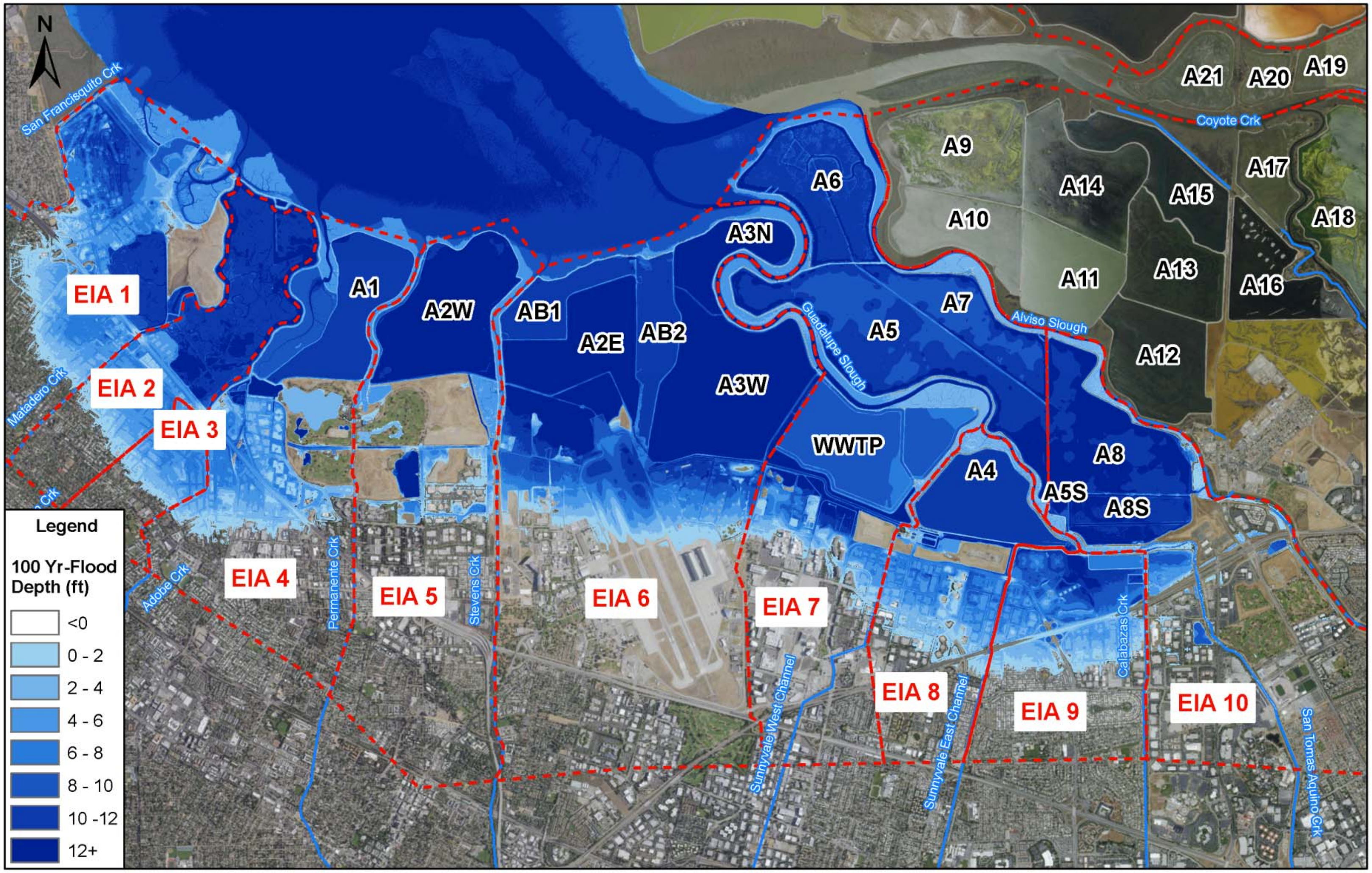


Figure 5. 1% ACE Event Flood Map, Year Zero (Existing Conditions)



South San Francisco Bay Shoreline Study
100-yr Inundation Map
(W/O Project, Year 50, Curve III)

Figure 6. 1% ACE Event Flood Map, Year 50, Sea-Level Rise Curve III

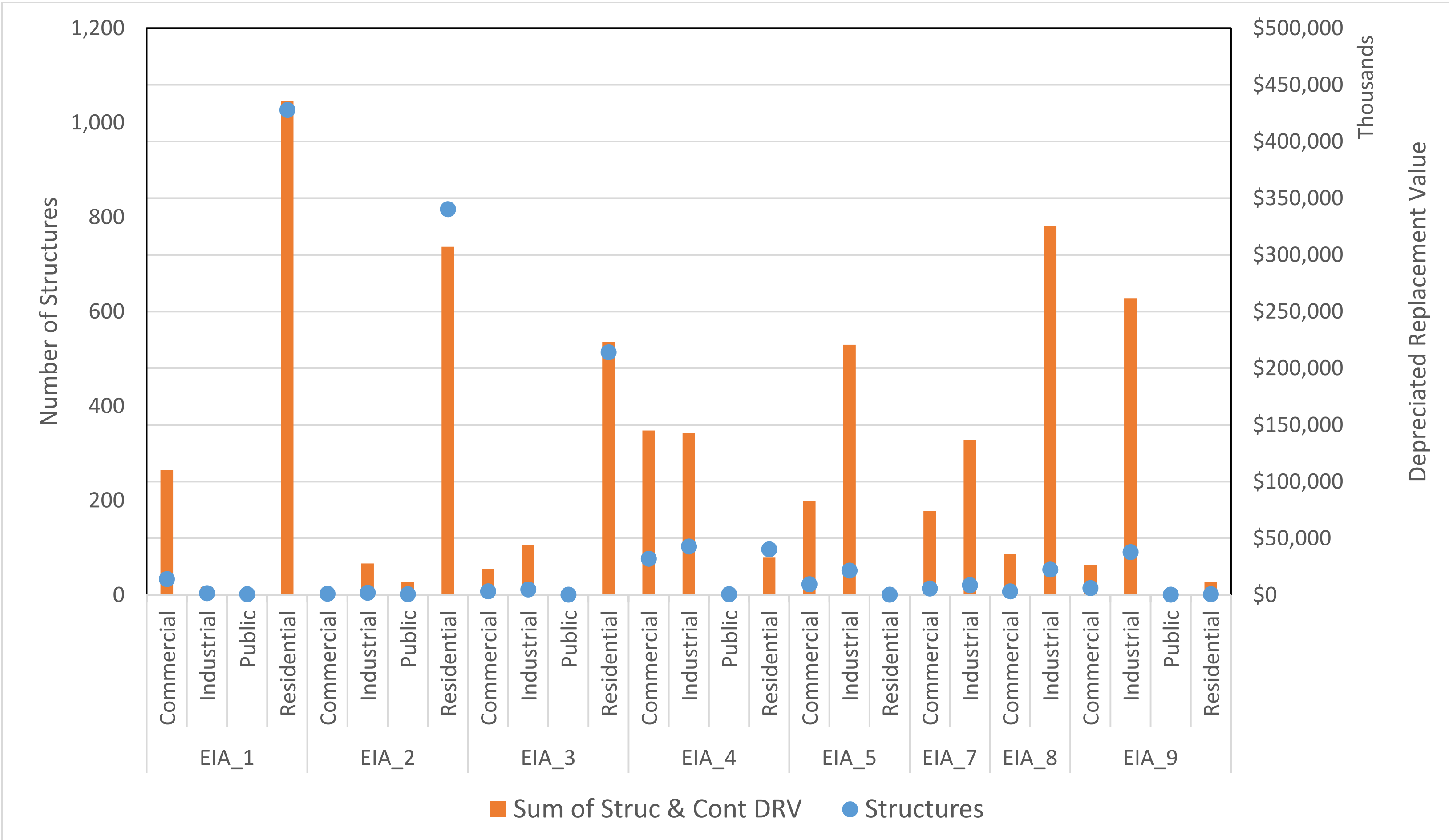
3.2 Coastal Zone 1: EIAs 1 to 3

The typical structure features in EIAs to 3 is illustrated in Figure 7. EIA 1 is primarily a residential area, and over 97% of the structures at risk from flooding are single-family and multi-family residences. There are more than 1,000 residential parcels (mostly single family homes), and approximately 50 non-residential parcels with structures for commercial and industrial use. There is estimated to be total of $550 million in structures and contents exposed to flood risk.

Figure 8 shows the breakdown of the depreciated replacement value by structure type exposed to the 0.2% (500 year) coastal storm event in EIA 1 under the high sea-level rise scenario (SLR Curve III) in Year 50. This represents the full extent of the structures included in this coastal flood risk analysis. The procedure followed for estimating the value of all structures and contents in the study area is further described in detail in the Section 8.

Figure 7. Representative Residential Structures in EIAs 1-3

Importantly, the Palo Alto Airport and the Palo Alto Water Quality Control Plant are also located in this EIA. Highway 101 runs through this and the adjacent EIAs, and is one of the most trafficked stretches of highway in the region with approximately than 350,000 trips per day on average.



Note: Structures are within the extent of the 500-year ACE flood event at Year 50 under SLR scenario III.

Figure 8. Estimated Number and Value of Structures and Contents in the Study Area, by EIA and Type

EIAs 2 and 3 are also almost completely residential, with a handful of commercial and industrial structures located near Highway 101. As indicated in Figure 8, there are approximately 800 structures in EIA 2, with a DRV of over $350 million, and 530 structures in EIA 3, with a total DRV of $290 million.

3.3 Coastal Zone 2: EIAs 4 & 5

EIA 4 is primarily commercial and industrial structures, and includes many IT and Aerospace companies such as Oracle and Space Systems Loral, which designs and manufactures satellites. 90% of the exposed structure and content value is associated with non-residential structures. There are approximately 300 buildings exposed to flood risk, with an estimated DRV of $325 million as shown in Figure 8. EIA 5 contains a mix of high-tech companies from the pharmaceutical, biotechnology, and IT industries. There are approximately 75 buildings in the floodplain, with a DRV of $300 million. Figure 9 shows the general structure features in EIAs 4 and 5.

Figure 9. Representative Commercial and Industrial Structures in EIAs 4 and 5

3.4 Coastal Zone 3: EIA 6 & 7

EIA 6 is NASA Ames and Moffett Field. Many of the structures on the NASA property contain specialized, non-standard contents such as lab equipment, supercomputing equipment, compressors, and aircraft parts. However, there are not a large number of structures in the largest floodplain modeled for this analysis, and those that are generally do not have a very high structure or content value according to NASA's very detailed structure and content inventory.

For this reason, flood damage to NASA structures and contents was not estimated for this analysis. The 2010 without-project flood damage analysis completed by the Corps of Engineers estimated the overall flood risk in this EIA to be low relative to the other EIAs (less than $400k in equivalent annual damage).

EIA 7 is exclusively commercial and industrial structures as illustrated in Figure 10, and includes several companies in the Aerospace and Defense Industries such as Lockheed Martin, and IT companies such as Yahoo. There are approximately 35 large office, commercial, and industrial structures that are subject to coastal flood risk, with an estimated total DRV of $210 million as presented in Figure 8.

Figure 10. Representative Commercial and Industrial Structures in EIAs 7, 8, and 9

3.5 Coastal Zone 4: EIAs 8 & 9

EIA 8 is also exclusively commercial and industrial (see Figure 10), and contains a mix of office space, research and manufacturing facilities for industries including IT, electronics, and others, and includes such companies as Fujitsu Components America, Infinera Corporation, and Texas

Instruments. There are approximately 60 structures that are exposed to flood risk, with an estimated DRV of $361 million. The area also includes the Sunnyvale Water Pollution Control Plant. More details on this facility are included further below.

EIA 9 includes a mix of industrial, commercial, and residential structures (manufactured housing units), as shown in Figure 10. Some of the companies include Honeywell, Contec Microelectronics, Venturi Wireless, Communication Systems Inc., and FedEx. In total, there are an estimated 110 structures in the floodplain with a DRV of $300 million (see Figure 8).

3.6 Coastal Zone 5: EIA 10

According to the coastal floodplain modeling, all flooding of EIA 10 under base year and future conditions is confined to a low area north of Highway 237. No structures or vital infrastructure in this EIA are at risk from coastal flooding according to the preliminary modeling.

3.7 Summary of Structure and Content Values

Figure 11 displays the distribution of estimated depreciated replacement value of structures in the study area. The values are based on the estimates at the parcel level. It is important to remember that this value does not include the value of land, which is not considered in the flood damage analysis.

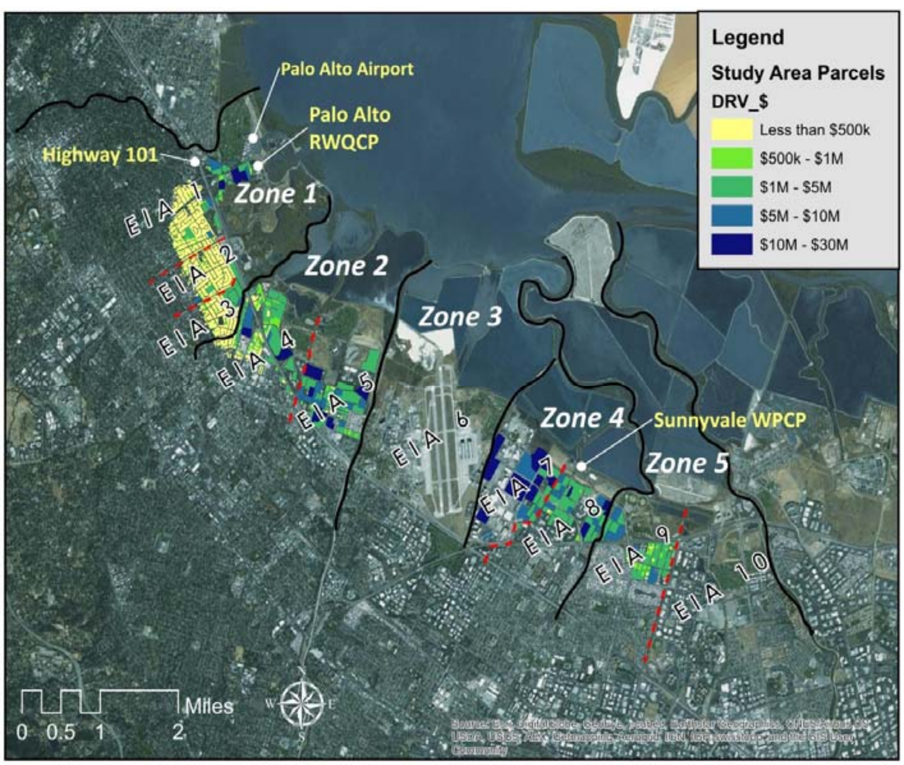


Figure 11.Estimated Depreciated Replacement Value of Parcel Improvements

The elevation of structures and their contents is obviously an important determinant of flood risk. Figure 12 displays the distribution of ground elevations of parcels in the study area. The figure does not include adjustment for the elevation of the finished floor of the structure above the ground. Knowing both the elevation of the structure and the elevation of the finished floor are important to the damage analysis because flood damage can occur at flood elevations between the ground and the finished floor. The residential structures in the area are typically elevated 1 to 3 feet, while the commercial and industrial buildings are typically elevated between zero and 1 foot. Along with the other structure characteristics such as ground elevation, DRV, and use type, the first floor elevation is part of the structure database in the HEC-FDA model.

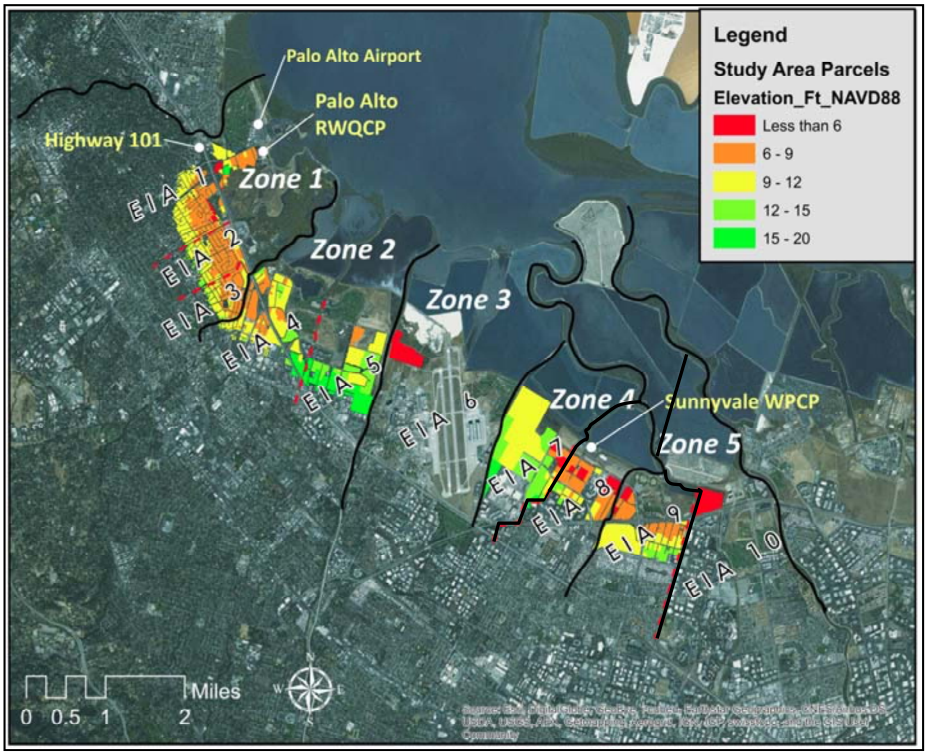


Figure 12. Ground Elevations of Developed Parcels

3.8 Regional Water Quality/Pollution Control Plants

The most critical and valuable public service and infrastructure in the study area that is at risk from a coastal flood event is water treatment service provided by two facilities – The Palo Alto Water Quality Control Plant (PAWQCP) and the Sunnyvale Water Pollution Control Plant (SWPCP). These two sewage treatment facilities process wastewater conveyed from individual businesses, residences, and other community facilities via a system of pipes. Each of the two plants has a daily treatment capacity of approximately 30 million gallons per day (gpd). Both facilities are located within the coastal floodplain.

The fact that these facilities are at a low elevation and in a floodplain is typical of wastewater treatment facilities. According to the Federal Emergency Management Agency (Federal

Emergency Management Agency, 2006), flow to water treatment facilities is typically gravity flow because it is more economical and easy to maintain. As a result, sewage conveyance and treatment systems are typically in low-lying areas. Treated sewage is also generally released into water bodies, so these treatment facilities are often in the floodplain, making them more vulnerable to damage from flooding.

As with water treatment systems, sewage treatment requires electricity for pumping and processing. When electrical power service is interrupted, treatment facilities must depend on generators to remain functional. These facilities require human intervention and a fuel source. Breaks in the conveyance system as a result of a major storm event can lead to environmental contamination, as well as the spread of disease, as humans come in contact with unprocessed sewage materials. Also, when sanitary and stormwater sewer systems are combined, the system can become overwhelmed during a major precipitation or flooding event, which can result in an overflow release of untreated sewage at either overflow points designed as part of combined sewer systems or at the treatment plant itself. Similarly, when there is infiltration of stormwater into the sanitary sewer system via cracks in pipes, manholes, or illegal connections, the system might also be pushed beyond capacity, leading to an overflow release at the treatment plant. Overwhelming the system might also lead to sewer backups, which can damage the interior of buildings and pose health risks.

The impact to water treatment services during Hurricane Katrina serve as a recent example of the impact of a loss of treatment capability. According to FEMA (Federal Emergency Management Agency, 2006) sewage treatment plants, sewage lift stations, and other system components were heavily impacted by the hurricane. As with the water systems, areas farther inland than originally thought vulnerable were impacted. A wastewater treatment plant in Diamondhead, Hancock County, Mississippi, with ground elevations of roughly 6 feet, had saltwater flooding up to 20+ feet. The saltwater flooding caused destruction of many system components, including pumps and electrical panels, and resulted in hundreds of thousands of dollars in damages. Furthermore, the system did not operate up to capacity, resulting in raw sewage bypassing the treatment facility and traveling directly into nearby rivers and streams. Multiple lift stations were similarly damaged when their pump systems and electrical panels were destroyed by the saltwater.

The Palo Alto plant, shown in Figure 13, is owned and operated by the City of Palo Alto for the cities and communities of Los Altos, Los Altos Hills, Mountain View, Palo Alto, Stanford University and the East Palo Alto Sanitary District. According to its website, “the plant is an advanced treatment facility that uses gravity settling, biological treatment with microorganisms and dual media filtration to remove unwanted organic materials and toxins from the approximately 22 million gallons a day of wastewater generated by the service area’s 220,000 residents. The plant’s treated effluent meets all of the stringent requirements for discharge to the sensitive South San Francisco Bay” (City of Palo Alto, 2014). According to the *Long Range Facilities Plan for the Regional Water Quality Control Plant* that was completed in 2012, there are between $300M and $400M in recommended investments over the next fifty years. The 2012 report does not reference any specific plans to reduce the risk from future sea-level rise other than coordination with the U.S. Army Corps of Engineers and others conducting feasibility studies to address the issue in the region.

Source: City of Palo Alto

Figure 13. Aerial View of the Palo Alto RWQCP

The Sunnyvale plant, shown in Figure 14 was originally constructed in 1956, and utilizes primary, secondary and tertiary treatment processes to treat the wastewater. The plant has a capacity of approximately 30 million gallons per day. The plant is owned by the City of Sunnyvale, and is funded through an enterprise fund that relies on user fees.

The replacement values of the plants have not been estimated, but, based on estimates obtained for the San Jose Santa Clara Water Pollution Control Plant (U.S. Army Corps of Engineers, 2010), the costs are likely to be measured in the hundreds of millions of dollars. The continuous operation of each of these plants is obviously critical to the environment, human health, and prosperity of the serviced communities as well as to the larger San Francisco Bay region.

A coastal storm event that inundated the plants would have enormous direct and indirect costs. Not only would the inundation cause damage to the facilities themselves, but a flood event that resulted in a disruption of service would mean an inability to treat raw sewage and a lack of availability of recycled water to local customers who depend on it for the cooling of machinery during industrial processes. These customers include local power providers. In general, large flood events which result in plant shutdown will lead to potential sewage overflows in the communities served by the plant, degradation of the Bay environment, and a shutdown of recycled water customers. According to interviews of plant officials conducted by the Corps of Engineers in 2010 (U.S. Army Corps of Engineers, 2010), a 1-2 foot flood event on plant property is expected to result in direct damage to mechanical and electrical equipment of between $20M and $50M at each plant. No estimate was made for this report of the direct or indirect damage to the treatment plants from coastal flooding.

Source: Bing Maps, 2014

Figure 14. Aerial View of Sunnyvale WPCP

3.9 Palo Alto Airport

The Palo Alto Airport of Santa Clara County is located in EIA 1, sits on the edge of the bay, and is at low elevation. The Airport property spans 102 acres and has one asphalt paved runway. The public airport has a control tower and multiple airplane repair shops, and is home to more than 200 small airplanes.

Detailed statistics on the types, sizes, and values of the planes were unfortunately not available at the time of writing. A representative of a maintenance company that works at the airport explained that significant flooding damage would begin once flood waters reached the fuselage (body) of the airplane. If water reached the engine, it would have to be removed, dissembled, and cleaned at a significant cost (U.S. Army Corps of Engineers, 2010). Neither the direct nor indirect damage to this facility and the planes was estimated for this preliminary report.

3.10 Highways 101 & 237

Highways 101 and 237 are major traffic arteries in the Bay Area. Either or both could be impacted by a significant coastal storm event that resulted in flooding from the bay.

The stretch of Highway 101 that runs through the study area is known as the Bayshore Freeway. According to CALTRANS data from 2013, approximately 350,000 trips per day are made along the highway between San Jose and East Palo Alto, which are just south and north of the study area, respectively. Approximately 95% of these trips are by passenger vehicles, and about 5% by commercial trucks. A coastal flood event that overtopped the highway would adversely affect not only users of the highway but also the traffic in the greater bay region as a result of drivers being forced to take alternate routes around the affected stretch of highway. The location of the highway most vulnerable to coastal flooding is in EIAs 1 through 4.

The stretch of Highway 237 that runs through the study area sees approximately 250,000 trips per day – a large percentage of which are traveling to or from the nearby junction with Highway 101. The location of the highway most vulnerable to coastal flooding is in EIA 9.

Travel delays increase the cost of moving goods and people, disrupt supply chains, and cost commuters and vacationers alike valuable time. Estimating the total cost to businesses of a highway closure is very challenging (Hu, 2008), and is not typically done for flood damage analyses such as this. However, there is a framework established for estimating the personal value (cost) of a travel delay to affected drivers and passengers. IWR Report 91-R-12 '*Value of Time Saved for Use in Corps Planning Studies'* (Institute for Water Resources, 1991) lays out a straightforward method for estimating the opportunity cost of a traffic delay. The value of the delay is a function of the duration of the delay, the income of the traveler, and the trip purpose.

4.0 EXISTING & FUTURE WITHOUT-PROJECT FLOOD RISK

4.1 Direct Flood Damage

The HEC-FDA program uses a hydro-economic model to estimate expected annual damages without and with flood damage reduction measures in place. The model combines characteristics of the flooding and of the development in the floodplain to characterize the flood risk from an economic perspective. The typical hydro-economic model has four component parts: the stage-discharge curve, the stage-damage curve, the discharge-exceedance frequency curve, and the damage-exceedance frequency curve. Because this is a coastal flood risk analysis, there are no discharges as there are for analyses of flooding from rivers and creeks. The relevant relationships of a coastal hydro-economic model are exceedance probability-stage, stage-damage, and exceedance probability-damage. Figure 15 shows how these three relationships are related.

This figure is purely for illustrative purposes and does not use data from the study area. The figure shows how the relationships are linked in the hydro-economic model. The coastal modeling estimates the annual likelihood of a range of stages or water surface elevations (top graph). For the developed area within the interior of the floodplain, data on elevation, the depreciated replacement value of structures and contents, and the relationship between water depth and damage for each structure type are the primary inputs to the determination of the aggregate stage-damage relationship (middle graph). Because each of these two relationships has stage as one component, stage can then be used to derive the relationship between annual exceedance probability and damage. The integration of this curve results in the probability-weighted estimate of expected annual flood damage.

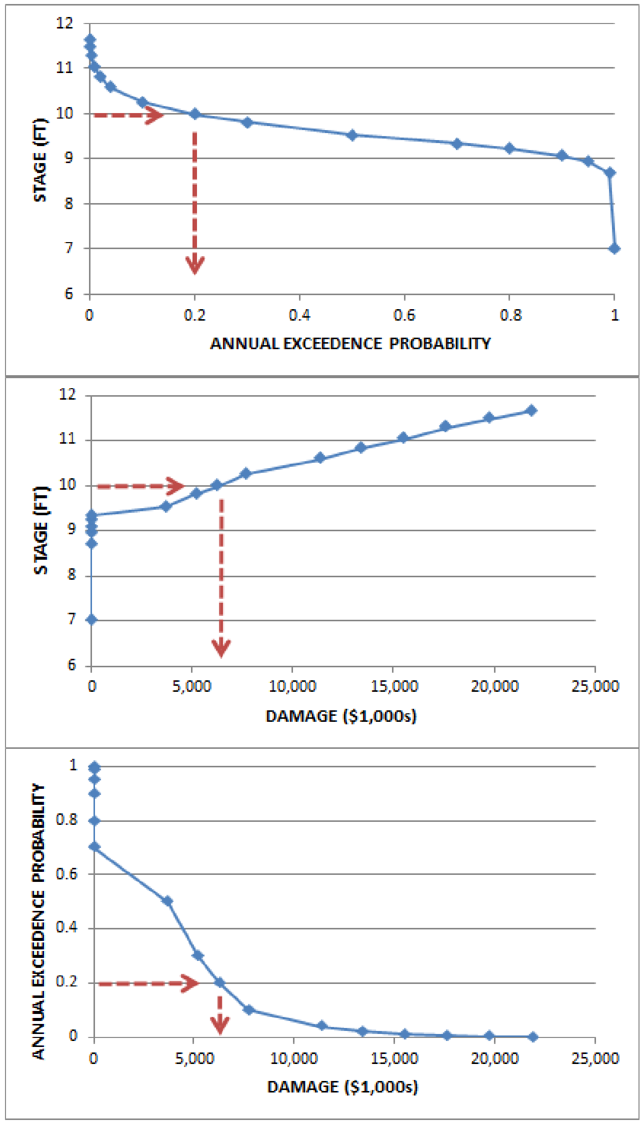


Figure 15. Example Coastal Hydro-economic Model

As described in Section 2, the modeling of flood damage was completed within the HEC-FDA program. The exceedance probability-stage relationship for each sea-level rise scenario was modeled outside of the FDA model and provided for use as the primary engineering input. Data for the beginning (2017) and end (2067) of the fifty-year period of analysis were provided from the storm-induced water surface elevation analysis.

The three FDA models are equivalent except for the water surface profiles that differ by sea-level rise scenario. While the extent of the floodplain changes under the various scenarios, the FDA models all contain the same base structure inventory.

The primary inputs to the FDA models include a structure inventory (structure type, value, first floor elevation, etc.), a water surface profile for each structure (stage and probability), a specification of the depth-damage relationship for each structure type, and a specification of the content-to-structure value ratio for each structure type. Uncertainty is included in each of these variables.

The water surface profile data consists of water elevations for eight different flood events – ranging from the 50% ACE event to the 0.2% ACE event. Each parcel in the structure inventory is assigned a unique cross section number, and the depth of flooding at each parcel or each of the ACE events was determined in a GIS by overlaying the floodplains on a parcel shapefile. The water elevation was taken at the centroid of each parcel, which is the geographic center of mass of each parcel shape. All structures on a particular parcel were assigned the same water surface profile data.

The uncertainty in the water surface profile data was estimated in the FDA models using what is known as the "graphical method." More on the graphical method can be found in the HEC-FDA user's manual.

4.2 Limits and Simplifying Assumptions

1. Exceedance-probability stage data was only provided for the beginning and end of the period of analysis. This means that the equivalent annual damage value is estimated assuming a linear relationship between Year 0 and Year 50 of the analysis. Because the actual relationship between the two points is expected to be concave, the linear interpolation means, all else equal, that the equivalent annual damage is somewhat overstated.

2. No structure and content value or damage surveys were conducted for this study area. The report uses depth-damage relationships and content value ratios developed as part of other more detailed feasibility studies (U.S. Army Corps of Engineers, 2010).

3. Because there are no depth-damage relationships available for multi-story commercial structures, this report uses the relationships developed for single-story structures and calculates the structure value of just the first floor by dividing the total value by the number of stories.

4.3 HEC-FDA Model Results: Direct Flood Damage to Structures and Contents

According to the HEC-FDA modeling, the coastal flood risk in the study area is significant. The Expected Annual Damage for the entire study area in 2017 (current conditions) is $17 million. With future sea-level rise over the next fifty years, the Expected Annual Damage will increase over time. According to the HEC-FDA modeling, under the three future sea-level rise scenarios (Curves I, II, and III), when combining the 2017 and the 2067 Expected Annual Damage estimates into an equivalent annual damage value over the 50 year period of analysis (discount the increase at 2016 Federal water resources discount rate of 3.125%), the average annual damage is estimated to be $21 million, $27 million, and $46 million under sea-level rise scenarios I, II and III, respectively. Figure 16 depicts these results graphically.

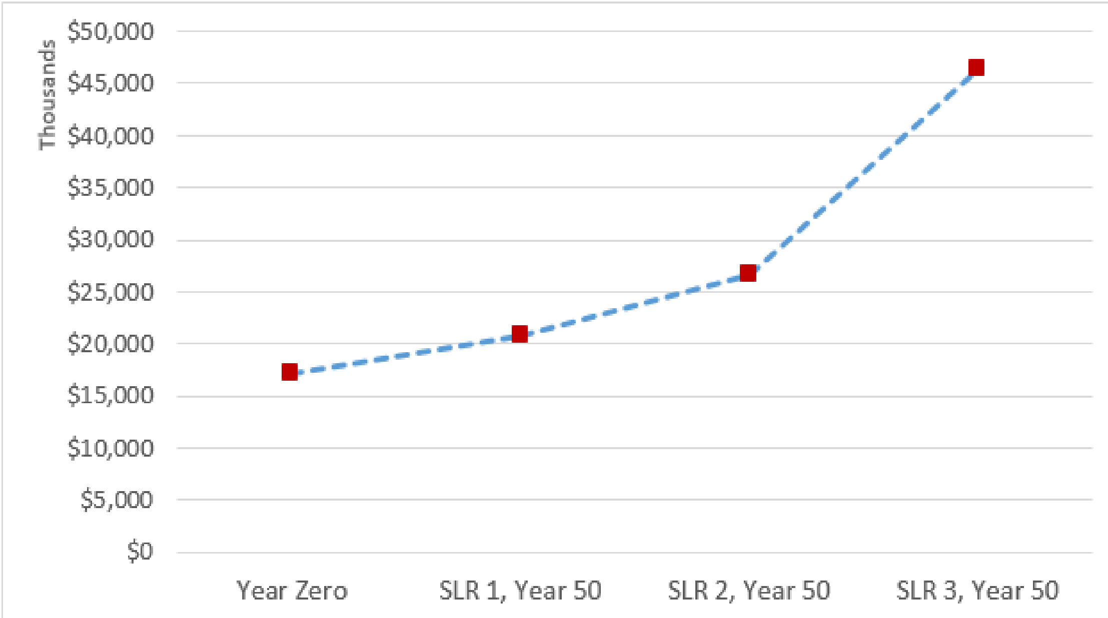


Figure 16. Existing Expected Annual Damage, and Future Equivalent Annual Damage (50 Years, 3.125%)

The HEC-FDA model estimates damages for a wide range of storm event probabilities as well as the expected and equivalent damage values. Figure 17 to Figure 19 show the damage estimates for the 1% ACE event by EIA and structure type. Under current conditions, a 1% ACE event is estimated to cause approximately $300 million in direct flood damage to structures and contents in the floodplain. At Year 50, under sea-level rise scenario 3 the same probability event is estimated to cause $765 million in damage.

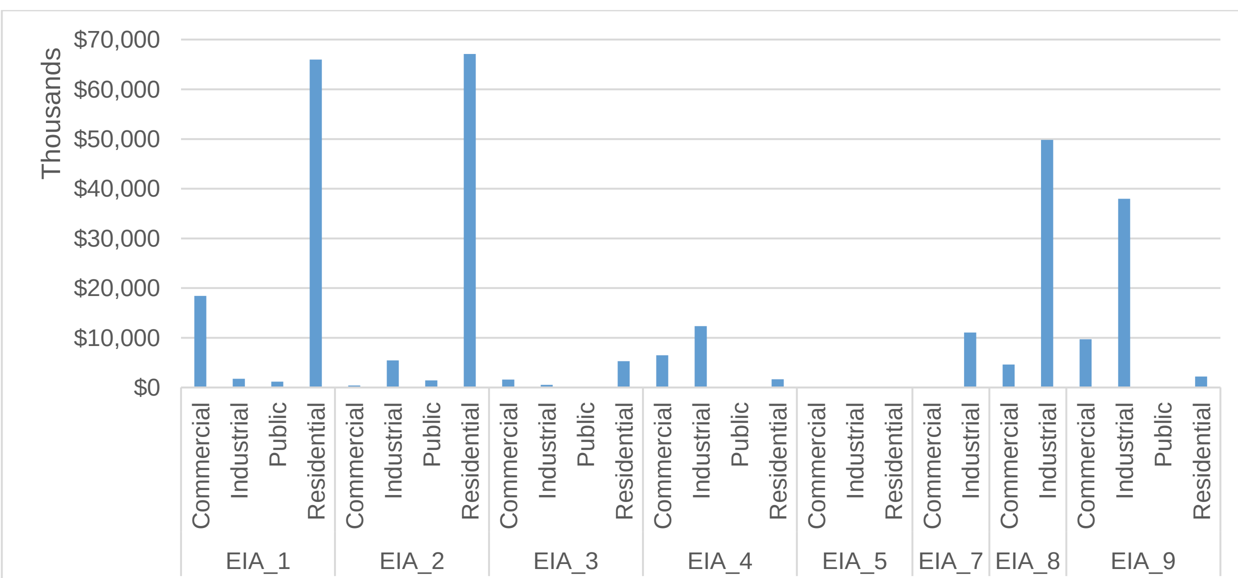


Figure 17. Direct Flood Damage Estimate - 1% ACE Event, Year 0 (current conditions)

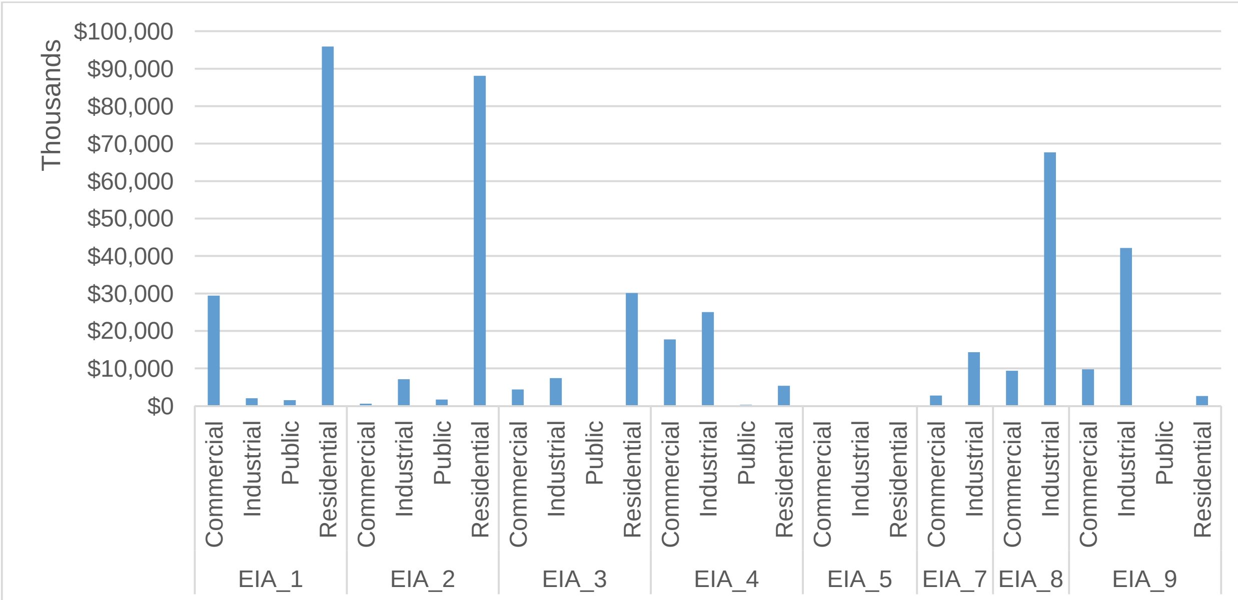


Figure 18. Direct Flood Damage Estimate - 1% ACE Event, Year 50, SLR Curve II

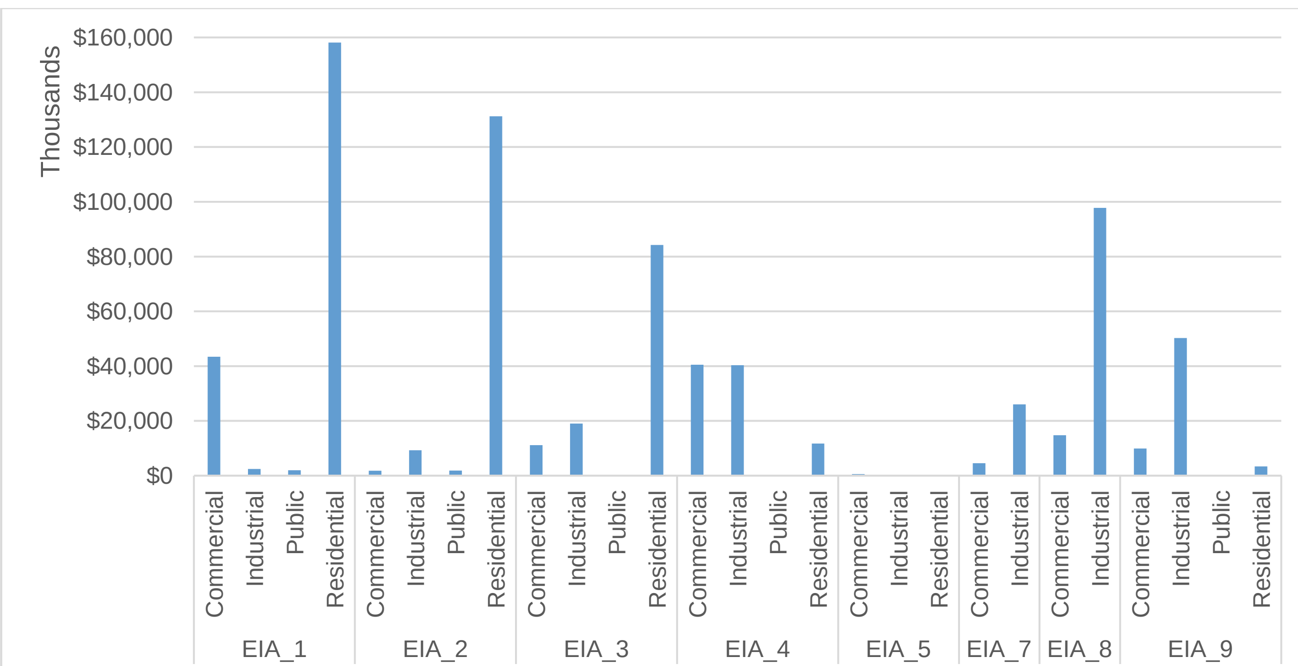


Figure 19. Direct Flood Damage Estimate - 1% ACE Event, Year 2067, SLR Curve III

5.0 WITH-PROJECT RISK REDUCTION

5.1 Description of the Coastal Levee Project

This analysis evaluates a single levee alignment and three different heights. The entire length of the protective levee is approximately 14 miles with different crest elevations depending on which future SLR projection is considered. Figure 20 shows the alignment of a potential levee to reduce the risk from coastal flooding in the study area, while Table 2 to Table 4 present the preliminary cost estimates for constructing the proposed protective levees extending from EIA 1 to EIA 10 under the three SLR scenarios.

5.2 Flood Damages Reduced and Residual Risk

Outside of complete floodplain evacuation, no flood risk management project can completely eliminate the flooding risk. However, a well-designed levee can significantly decrease the flood risk to a community, and responsible floodplain land management and well-conceived emergency response plans can reduce the risk further.

According to the project performance statistics produced by the HEC-FDA models developed for this analysis, all else equal, a 15' levee would virtually eliminate the risk of flood damage from an overtopping coastal flood event. The project performance statistics predict that with a 15' levee in place, the probability of even a single overtopping event over the 50 year period of analysis is less than 1%. The annual likelihood is much lower still. These performance statistics assume that the levee would not fail until overtopped by coastal waters.

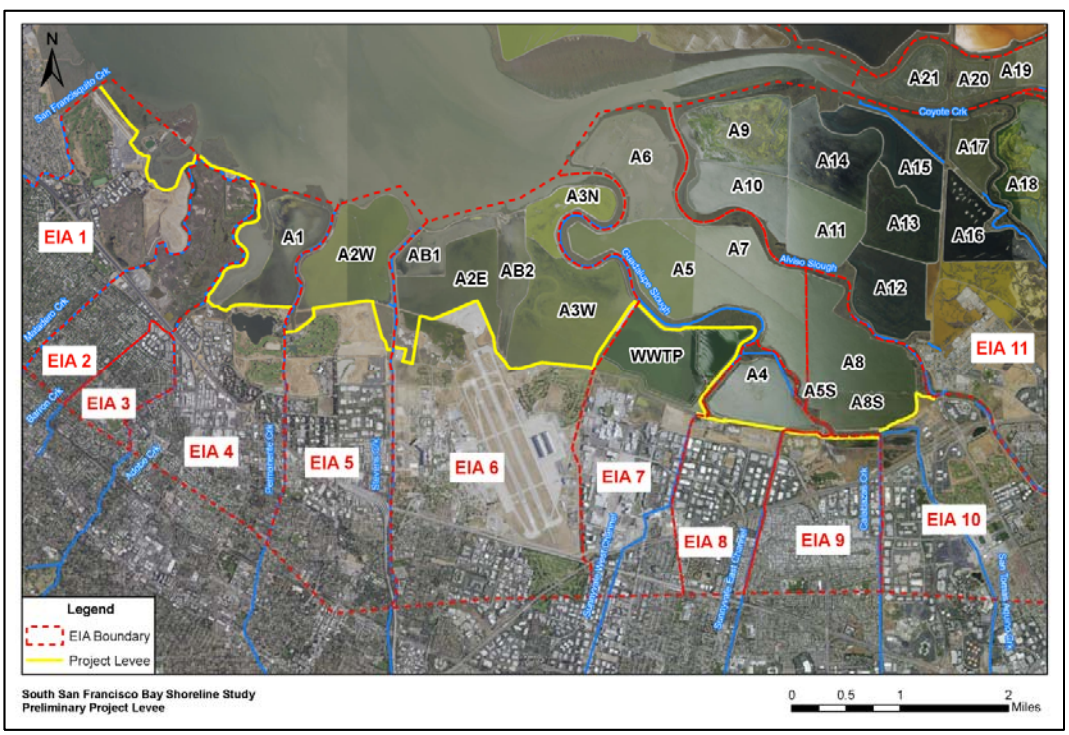


Figure 20. Levee Alignment - With-Project Analysis

Table 2. Preliminarily Estimated Levee Construction Cost for Low SLR Projection

EIA	Proposed Levee Length (ft)	Crest Elevation (ft, NAVD88)	Required Levee Length (ft)	Unit Cost ($/lf)	Subtotal ($)
1	9,408	13.0	9,408	970	9,125,800
2	10,595	13.0	10,595	970	10,277,200
3	-	-	-	-	-
4	4,355	13.0	1,358	970	1,317,300
5	7,638	13.0	1,369	970	1,327,900
6	14,776	12.8	14,776	920	13,593,900
7	15,968	13.1	15,968	1,000	15,968,000
8	4,359	13.1	4,359	1,000	4,359,000
9	4,613	14.7	4,613	1,420	6,550,500
10	3,957	13.1	577	1,000	577,000
				Total	$ 63,097,000
				Including 25% Contingency	$ 78,871,000

Table 3. Preliminarily Estimated Levee Construction Cost for Intermediate SLR Projection

EIA	Proposed Levee Length (ft)	Crest Elevation (ft, NAVD88)	Required Levee Length (ft)	Unit Cost ($/lf)	Subtotal ($)
1	9,408	13.5	9,408	1,100	10,348,800
2	10,595	13.5	10,595	1,100	11,654,500
3	-	-	-		
4	4,355	13.5	1,358	1,100	1,493,800
5	7,638	13.5	1,369	1,100	1,505,900
6	14,776	13.3	14,776	1,050	15,514,800
7	15,968	13.5	15,968	1,100	17,564,800
8	4,359	13.4	4,359	1,080	4,707,700
9	4,613	14.7	4,613	1,420	6,550,500
10	3,957	13.6	577	1,130	652,000
				Total	$ 69,993,000
				Including 25% Contingency	$ 87,491,000

Table 4. Preliminarily Estimated Levee Construction Cost for high SLR Projection

EIA	Proposed Levee Length	Crest Elevation	Required Levee Length	Unit Cost	Subtotal
	(ft)	(ft, NAVD88)	(ft)	($/lf)	($)
1	9,408	15.0	9,408	1,500	14,112,000
2	10,595	15.0	10,595	1,500	15,892,500
3	-	-	-	-	-
4	4,355	15.0	1,358	1,500	2,037,000
5	7,638	15.0	1,369	1,500	2,053,500
6	14,776	15.1	14,776	1,520	22,459,000
7	15,968	15.1	15,968	1,520	24,271,400
8	4,359	15.3	4,359	1,580	6,887,200
9	4,613	15.2	4,613	1,550	7,150,200
10	3,957	15.2	577	1,550	894,400
				Total	$95,758,000
				Including 25% Contingency	$119,698,000

6.0 POTENTIAL ECONOMIC JUSTIFICATION

Given the magnitude of the equivalent annual damages estimated in the study area, a project that reduced or effectively eliminated coastal flood risk in the study area would have significant economic benefits. Whether the project has overall economic net benefits depends on the comparison of the annualized project costs and the reduction in equivalent annual flood damage.

A pre-screening review of the damage scenarios indicates that the flood damages occur under both 2-year and 5-year return WSE conditions, which cannot be validated in the field. The reason is due primarily to the adopted levee failure criterion that results in a high probability of existing levee failure, and consequently high WSEs with frequent flood damage (i.e., every 2 years or 5 years). Therefore, to more realistically reflect what has been observed in the past, the flood damage resulting from events more frequent than the 10-year event (10% ACE) were removed from the risk assessment. In other words, damages are truncated at the 10-year event for all scenarios. It is expected to result in a more realistic risk and damage assessment. It is plausible, however, that under the high SLR scenario flood damage may occur as a result of these more frequent events. This would mean that the future equivalent annual damage estimate under this SLR scenario may be underestimated. Underestimating future flood risk would mean that the derived benefit-cost ratio of the levee project would also be underestimated.

The estimated benefit and cost ratios for individual EIAs are presented in Table 5 to Table 13, based on a discount rate of 3.125%. It is noted that EIA 2 and EIA 3 are combined since no protective levee is proposed in EIA 3 and both EIAs are in the jurisdiction of the City Of Palo Alto. Also, the flooding damage displayed for EIA 6 is based on the 2010 USACE analysis of the study area. That report estimated flood risk in EIA 6 to be low, and those estimates were not updated for this report. Finally, it is important to note that indirect and direct impacts to public infrastructure in the study area were not included in this analysis. These estimates would require a detailed site-specific analysis. This level of detail was beyond the scope of this preliminary evaluation, but should be included in subsequent, more detailed flood risk evaluations as appropriate.

Table 5. Preliminarily Estimated Benefit-Cost Analysis in EIA 1

Analyzed Condition	SLR Scenario		
	Low	Intermediate	High
Without-Project Conditions	*Equivalent Annual Flood Damage (in 1,000)*		
	$4,734	$5,327	$7,179
With-Project Condition (Protective Levee in Place)	*Equivalent Annual Flood Damage (in 1,000)*		
	$0	$0	$0
Equivalent Annual Damage Reduced	$4,734	$5,327	$7,179
Project Costs (in 1,000)			
Construction Cost	$9,216	$10,349	$14,112
Interest During 48-month Construction	$130	$147	$201
Average Annual Cost (Sum of Construction Cost & Interest)	$368	$418	$570
Net Benefits and Benefit-Cost Ratio			
Annual Net Benefits in 1,000 (EAD Reduced - Average Annual Cost)	$4,366	$4,909	$6,609
Benefit-to-Cost Ratio (EAD Reduced / Average Annual Cost)	12.9	12.8	12.6

Notes: 1) 50-year period of analysis, 2) The assumed interest rate is 3.125%,
3) Construction cost excludes real estate & maintenance, &
4) Some municipal infrastructures are not valued in this analysis.

Table 6. Preliminarily Estimated Benefit-Cost Analysis in EIA 2 & EIA 3

Analyzed Condition	SLR Scenario		
	Low	Intermediate	High
Without-Project Conditions	*Equivalent Annual Flood Damage (in 1,000)*		
	$6,548	$7,416	$10,454
With-Project Condition (Protective Levee in Place)	*Equivalent Annual Flood Damage (in 1,000)*		
	$0	$0	$0
Equivalent Annual Damage Reduced	$6,548	$7,416	$10,454
Project Costs (in 1,000)			
Construction Cost	$10,277	$11,655	$15,893
Interest During 48-month Construction	$146	$166	$226
Average Annual Cost (Sum of Construction Cost & Interest)	$415	$470	$641
Net Benefits and Benefit-Cost Ratio			
Annual Net Benefits in 1,000 (EAD Reduced - Average Annual Cost)	$6,133	$6,946	$9,813
Benefit-to-Cost Ratio (EAD Reduced / Average Annual Cost)	15.8	15.8	16.3

Notes: 1) 50-year period of analysis, 2) The assumed interest rate is 3.125%,
3) Construction cost excludes real estate & maintenance, &
4) Some municipal infrastructures are not valued in this analysis.

Table 7. Preliminarily Estimated Benefit-Cost Analysis in EIA 4

Analyzed Condition	SLR Scenario		
	Low	Intermediate	High
Without-Project Conditions	*Equivalent Annual Flood Damage (in 1,000)*		
	$1,309	$1,660	$2,827
With-Project Condition (Protective Levee in Place)	*Equivalent Annual Flood Damage (in 1,000)*		
	$0	$0	$0
Equivalent Annual Damage Reduced	$1,309	$1,660	$2,827
Project Costs (in 1,000)			
Construction Cost	$1,317	$1,494	$2,037
Interest During 48-month Construction	$19	$21	$29
Average Annual Cost (Sum of Construction Cost & Interest)	$53	$60	$82
Net Benefits and Benefit-Cost Ratio			
Annual Net Benefits in 1,000 (EAD Reduced - Average Annual Cost)	$1,256	$1,600	$2,745
Benefit-to-Cost Ratio (EAD Reduced / Average Annual Cost)	24.6	27.5	34.4

Notes: 1) 50-year period of analysis, 2) The assumed interest rate is 3.125%,
3) Construction cost excludes real estate & maintenance, &
4) Some municipal infrastructures are not valued in this analysis.

Table 8. Preliminarily Estimated Benefit-Cost Analysis in EIA 5

Analyzed Condition	SLR Scenario		
	Low	Intermediate	High
Without-Project Conditions	*Equivalent Annual Flood Damage (in 1,000)*		
	$0	$0	$9
With-Project Condition (Protective Levee in Place)	*Equivalent Annual Flood Damage (in 1,000)*		
	$0	$0	$0
Equivalent Annual Damage Reduced	$0	$0	$9
Project Costs (in 1,000)			
Construction Cost	$1,328	$1,506	$2,054
Interest During 48-month Construction	$19	$21	$29
Average Annual Cost (Sum of Construction Cost & Interest)	$54	$61	$83
Net Benefits and Benefit-Cost Ratio			
Annual Net Benefits in 1,000 (EAD Reduced - Average Annual Cost)	-$54	-$61	-$74
Benefit-to-Cost Ratio (EAD Reduced / Average Annual Cost)	0.00	0.00	0.11

Notes: 1) 50-year period of analysis, 2) The assumed interest rate is 3.125%,
3) Construction cost excludes real estate & maintenance, &
4) Some municipal infrastructures are not valued in this analysis.

Table 9. Preliminarily Estimated Benefit-Cost Analysis in EIA 6

Analyzed Condition	SLR Scenario		
	Low	Intermediate	High
Without-Project Conditions	*Equivalent Annual Flood Damage (in 1,000)*		
	$301	$307	$363
With-Project Condition (Protective Levee in Place)	*Equivalent Annual Flood Damage (in 1,000)*		
	$0	$0	$0
Equivalent Annual Damage Reduced	$301	$307	$363
Project Costs (in 1,000)			
Construction Cost	$13,594	$15,515	$22,459
Interest During 48-month Construction	$193	$221	$320
Average Annual Cost (Sum of Construction Cost & Interest)	$549	$626	$906
Net Benefits and Benefit-Cost Ratio			
Annual Net Benefits in 1,000 (EAD Reduced - Average Annual Cost)	-$248	-$319	-$543
Benefit-to-Cost Ratio (EAD Reduced / Average Annual Cost)	0.5	0.5	0.4

Notes: 1) 50-year period of analysis, 2) The assumed interest rate is 3.125%,
3) Construction cost excludes real estate & maintenance, &
4) Some municipal infrastructures are not valued in this analysis.

Table 10. Preliminarily Estimated Benefit-Cost Analysis in EIA 7

Analyzed Condition	SLR Scenario		
	Low	Intermediate	High
Without-Project Conditions	*Equivalent Annual Flood Damage (in 1,000)*		
	$613	$692	$957
With-Project Condition (Protective Levee in Place)	*Equivalent Annual Flood Damage (in 1,000)*		
	$0	$0	$0
Equivalent Annual Damage Reduced	$613	$692	$957
Project Costs (in 1,000)			
Construction Cost	$15,968	$17,565	$24,271
Interest During 48-month Construction	$193	$250	$346
Average Annual Cost (sum of Construction Cost & Interest)	$644	$709	$980
Net Benefits and Benefit-Cost Ratio			
Annual Net Benefits in 1,000 (EAD Reduced - Average Annual Cost)	-$31	-$17	-$23
Benefit-to-Cost Ratio (EAD Reduced / Average Annual Cost)	0.95	0.98	0.98

Notes: 1) 50-year period of analysis, 2) The assumed interest rate is 3.125%,
3) Construction cost excludes real estate & maintenance, &
4) Some municipal infrastructures are not valued in this analysis.

Table 11. Preliminarily Estimated Benefit-Cost Analysis in EIA 8

Analyzed Condition	SLR Scenario		
	Low	Intermediate	High
Without-Project Conditions	*Equivalent Annual Flood Damage (in 1,000)*		
	$2,758	$3,020	$3,780
With-Project Condition (Protective Levee in Place)	*Equivalent Annual Flood Damage (in 1,000)*		
	$0	$0	$0
Equivalent Annual Damage Reduced	$2,758	$3,020	$3,780
Project Costs (in 1,000)			
Construction Cost	$4,359	$4,708	$6,887
Interest During 48-month Construction	$62	$67	$98
Average Annual Cost (Sum of Construction Cost & Interest)	$176	$190	$278
Net Benefits and Benefit-Cost Ratio			
Annual Net Benefits in 1,000 (EAD Reduced - Average Annual Cost)	$2,582	$2,830	$3,502
Benefit-to-Cost Ratio (EAD Reduced / Average Annual Cost)	15.7	15.9	13.6

Notes: 1) 50-year period of analysis, 2) The assumed interest rate is 3.125%,
3) Construction cost excludes real estate & maintenance, &
4) Some municipal infrastructures are not valued in this analysis.

Table 12. Preliminarily Estimated Benefit-Cost Analysis in EIA 9

Analyzed Condition	SLR Scenario		
	Low	Intermediate	High
Without-Project Conditions	*Equivalent Annual Flood Damage (in 1,000)*		
	$2,577	$2,634	$2,914
With-Project Condition (Protective Levee in Place)	*Equivalent Annual Flood Damage (in 1,000)*		
	$0	$0	$0
Equivalent Annual Damage Reduced	$2,577	$2,634	$2,914
Project Costs (in 1,000)			
Construction Cost	$6,551	$6,551	$7,150
Interest During 48-month Construction	$93	$93	$102
Average Annual Cost (Sum of Construction Cost & Interest)	$264	$264	$289
Net Benefits and Benefit-Cost Ratio			
Annual Net Benefits in 1,000 (EAD Reduced - Average Annual Cost)	$2,313	$2,370	$2,625
Benefit-to-Cost Ratio (EAD Reduced / Average Annual Cost)	9.7	10.0	10.1

Notes: 1) 50-year period of analysis, 2) The assumed interest rate is 3.125%,
3) Construction cost excludes real estate & maintenance, &
4) Some municipal infrastructures are not valued in this analysis.

Table 13. Preliminarily Estimated Benefit-Cost Analysis in EIA 10

Analyzed Condition	SLR Scenario		
	Low	Intermediate	High
Without-Project Conditions	*Equivalent Annual Flood Damage (in 1,000)*		
	$0	$0	$0
With-Project Condition (Protective Levee in Place)	*Equivalent Annual Flood Damage (in 1,000)*		
	$0	$0	$0
Equivalent Annual Damage Reduced	$0	$0	$0
Project Costs (in 1,000)			
Construction Cost	$577	$652	$894
Interest During 48-month Construction	$8	$9	$13
Average Annual Cost (Sum of Construction Cost & Interest)	$23	$26	$36
Net Benefits and Benefit-Cost Ratio			
Annual Net Benefits in 1,000 (EAD Reduced - Average Annual Cost)	-$23	-26	-36
Benefit-to-Cost Ratio (EAD Reduced / Average Annual Cost)	0.0	0.0	0.0

Notes: 1) 50-year period of analysis, 2) The assumed interest rate is 3.125%,
3) Construction cost excludes real estate & maintenance, &
4) Some municipal infrastructures are not valued in this analysis.

Table 14 summarizes the combined results of ten EIAs from this preliminary analysis. For comparison, a summarized table of BCR for another discount rate of 7% is also presented in Table 15. Both rates are used by the Federal government to evaluate and compare project economic justification.

Table 14. Summary of Preliminary Project Costs & Benefits with 3.125% Discount Rate

Analyzed Condition	SLR Scenario		
	Low	Intermediate	High
Without-Project Conditions	*Equivalent Annual Flood Damage (in 1,000)*		
	$20,763	$26,669	$46,372
With-Project Condition (Protective Levee in Place)	*Equivalent Annual Flood Damage (in 1,000)*		
	$0	$0	$0
Equivalent Annual Damage Reduced	$20,763	$26,669	$46,372
Project Costs (in 1,000)			
Construction Cost	$78,871	$87,491	$120,000
Interest During 48-month Construction	$1,123	$1,246	$7,534
Average Annual Cost (sum of Construction Cost & interest)	$3,183	$3,531	$5,075
Net Benefits and Benefit-Cost Ratio			
Annual Net Benefits in 1,000 (EAD Reduced - Average Annual Cost)	$17,580	$23,138	$41,297
Benefit-to-Cost Ratio (EAD Reduced / Average Annual Cost)	6.5	7.6	9.1

Table 15. Summary of Preliminary Project Costs & Benefits with 7.0% Discount Rate

All dollars in thousands; 50 year period of analysis; 7% interest rate. Construction cost does not include real estate, mitigation, or maintenance.	SLR Scenario		
	Low	Intermediate	High
Without-Project			
Equivalent Annual Flood Damage	$18,118	$19,629	$24,666
With-Project			
Equivalent Annual Flood Damage Remaining	$0	$0	$0
Equivalent Annual Flood Damage Reduced	$18,118	$19,629	$24,666
Project Costs			
Construction Cost	$78,871	$9,5907	$120,000
Interest During 48-Month Construction	$2,500	$2,773	$17,420
Average Annual Cost (Sum of Construction Cost & Interest)	$5,896	$6,541	$9,957
Net Benefits and Benefit-Cost Ratio			
Annual Net Benefits (EAD Reduced - Average Annual Cost)	$12,222	$13,088	$14,709
Benefit-to-Cost Ratio (EAD Reduced / Average Annual Cost)	3.1	3.0	2.5

At this preliminary stage of the risk assessment and alternatives analysis, given the magnitude of the possible reduction in flood damages, it appears more likely than not that a $120 million project that essentially eliminates the risk of coastal flooding over the fifty year period of analysis would have a BCR above unity. A more detailed feasibility study is needed to determine with more certainty the net benefits and the BCR of the project.

7.0 SUMMARY & CONCLUSIONS

The economic analysis that was performed herein was based on the methods and models applicable to the coastal flood risk assessment. The approach is consistent with the planning policies and procedures of the U.S. Army Corps of Engineers as described in the *Planning Guidance Notebook* or PGN (USACE, 2000). The economic impacts are all associated with categories of damage that the USACE considers part of the National Economic Development (NED) account. It is noted that vehicle damage, displacement cost, and transportation delays, which typically constitute a small percentage of the total flood damage estimated in the project area were not included in the analysis.

Within the extent of the impacted floodplain analyzed for this study, there are approximately 3,000 residential, commercial, industrial, and public structures with an estimated depreciated replacement value of $2.7 billion, including structures and their contents within the first floor. The damage estimate does not include either of the two water pollution control plants (i.e., PAWQCP and SWPCP) in the study area. Future, more detailed flood risk assessments should include a more thorough description of the exposure of the water pollution control plants, and should attempt to quantify the flood risk for inclusion in the benefit-cost ratio.

The economic damages were modeled using the HEC-FDA computer program that was developed by the USACE for use in flood risk management feasibility studies. The key simplification of the model developed for this analysis assumes no human intervention to protect the on-site structures in the floodplain over the 50-year analyzed period. Residents and businesses would intuitively be expected to take action to reduce their flood risk after experiencing significant or repeated flooding events. They may decide to relocate out of the study floodplain, or not be allowed to rebuild. In addition, a forecasting future change of land use in a floodplain is highly uncertain and complex, and is not considered in this economic analysis. The flood risk analysis considers three different rates of future sea-level rise between a base year (2017, or “Year 0”) and at a single future year (2067, or “Year 50”). The fifty-year period of analysis is a standard planning horizon used by USACE.

A large, low annual probability storm event (for example a 1% annual chance of exceedance storm) that breached the existing levees under today’s conditions is estimated to cause approximately $300 million in structure and content damage in the floodplain. In 50 years and with a sea-level rise consistent with the USACE high projection, a low annual probability (i.e., 1% occurrence) is estimated to cause as much as $765 million in structure and content damage. These estimates only include direct damage associated with structures and contents. A flood event that caused a disruption in water treatment services at either or both of the plants (i.e., PAWQCP & SWPCP) in the area would potentially result in very significant but as of yet unquantified environmental and economic impacts. The equivalent annual damage under a without-project future scenario between the years 2017 and 2067 is estimated to be between $17 million and $46 million (see Figure 16) depending on the sea-level rise scenario.

The project alternatives analyzed under the with-project condition are engineered levees, based on a 2-foot freeboard criterion, with crest elevations that vary based on each of the three SLR projections. The levees all extend between San Francisquito Creek to the west and the Guadalupe River to the east. The preliminarily estimated construction cost, excluding real estate, mitigation, maintenance, or interest during construction, ranges from approximately $79 million for the low SLR scenario, $87 million for the intermediate scenario, and $120 million for the high scenario. While no project eliminates all risk, the likelihood of any significant coastal flood damage over the period of analysis in the study area with an engineered levee in place is estimated to be extremely low. For example, with the project in place to protect from the high SLR scenario, the likelihood of having even one overtopping event at any time during the 50-year analyzed period scenario is less than one percent (1%). The likelihood in any given year of having an overtopping event is even less likely.

Given the magnitude of the equivalent annual damages estimated in the study area, a project that reduced or effectively eliminated coastal flood risk in the study area would have significant economic benefits. The results from this preliminary analysis indicate that, upon more detailed investigation, each of the alternatives analyzed would very likely have a benefit-cost ratio (BCR) greater than unity.

A more detailed feasibility study is needed to determine, with more certainty, the net benefits and the BCR of the projects. Additional analyses required for the comprehensive phase of this feasibility study to consider and incorporate economic factors that are important to the benefit-cost analysis are:

- Additional intervening years in addition to Year 0 and Year 50 need to be evaluated to more accurately quantify the change of flood risk over time under different SLR rates.
- Additional categories of project cost, including real estate, mitigation, and maintenance (following the completion of an EIR/EIS);
- Changes in land use in the floodplain that may occur in the face of significant or repetitive coastal flooding;
- Damages to the water treatment plants in the study area;
- Transportation delay costs and any damages to roads and highways in the floodplain; and
- Damages to vehicles and the displacement cost incurred by residents whose homes have been flooded.

8.0 REFERENCES

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9.0 APPENDIX

9.1 Structure & Content Valuation Methodology

The parcels identified as within the .2% ACE floodplain were matched to parcel data from the Santa Clara County Assessor's Office. The vast majority of the residential structures inventoried fit into the Class D category, which are buildings characterized by combustible construction. The exterior walls may be made up of closely spaced wood or steel studs, as in the case of a typical frame house, with an exterior covering of wood siding, shingles, stucco, brick, stone veneer, or other materials. Most of the commercial and industrial buildings are characterized by cement block construction.

The estimate of structure value was based on the Depreciated Replacement Value (DRV) method, which is akin to an insured value that considers depreciation of the asset (Institute for Water Resources, 1995). The DRV method requires visits to the structures themselves in order to attain the necessary information, which includes foundation height, structure type, quality of construction, and current structure condition. Base per-square-foot construction cost estimates for the Santa Clara County area for each structure type were taken from the Marshall & Swift Real Estate Valuation Service. This value was then adjusted by a depreciation factor and multiplied by the total square footage to estimate the DRV. If the square footage was not available within the real estate records for a particular property, square footage estimates were made from aerial photography measurements using the Google Earth application. Structure inventory fieldwork (primarily windshield surveys) found that the residential structures were generally of good construction quality and in good condition, while the commercial structures were of average construction quality and in good condition.

California's Proposition 13 restricts the annual increase in assessed valuation (and thus property taxes) to a maximum of 2% between sales or significant improvements. Since the average annual increase in both the market value and the construction cost of properties in the area has exceeded 2% since the inception of Proposition 13 in 1978, the assessed value generally cannot be relied upon to be an accurate measure of market value or replacement value. Using the assessed value of improvements in the study area would underestimate the total value at risk from coastal flooding.

The valuation of the contents of the residential, commercial, and public structures is obviously fraught with uncertainty. The Institute for Water Resources (IWR) and many USACE districts have developed estimates of what is known as the Content to Structure Value Ratio (CSVR) for buildings of different use. The ratio is the total value of a structure's contents relative to the replacement value of the structure. The results of the various expert panel elicitations show that results can vary tremendously for the same structure type – especially for non-residential structures. For example, a 2011 report from IWR (Institute for Water Resources, 2011) estimates the CSVR for grocery stores to be .75, while a 2006 report completed for a Corps study (Gulf Engineers and Consultants, Inc., 2006) in Louisiana estimates the CSVR for this type of business to be 1.58. The 2006 report includes results from both an expert panel elicitation as well as detailed owner/operator interviews, and the report notes that the most accurate CSVR data is likely to come from the owners and operators of the businesses and structures. This seems like a reasonable conclusion and for that reason this preliminary flood damage analysis will use the data from the 2006 GEC report on CSVRs, as presented in Table 16. This data was used in the 2010 Corps Study (U.S. Army Corps of Engineers, 2010).

Table 16. CSVRs Used in the Analysis

Structure Use	CSVR	
	Mean	St. Dev
Eating and Recreation	0.7	0.39
Groceries and Gas	1.58	0.69
Multi-Family Housing	0.14	0.09
Professional Business	0.43	0.46
Public and Semi-Public	0.14	0.05
Repair and Home Use	1.22	1.23
Retail and Personal Services	1.29	1.23
Warehouse and Contractor Services	0.85	0.38

Source: GEC, Inc. (Gulf Engineers and Consultants, Inc., 2006)

9.2 Depth-Damage Relationship for Structures & Contents

Flooding can cause significant damage to structures of all types. Water can cause a structure's structural components to shift or warp – including the studs and foundation. Water can also damage the wiring, gas lines, and septic system. For high water, ceilings may sag under the weight of trapped water or soggy drywall, wet floorboards can bend and buckle, and the roof may leak or break altogether. Flooding in a basement can be especially dangerous; if the water is removed too quickly, pressure from the soaked earth outside can push inward and crack the foundation walls. Most of the structures in this analysis are wood frame, and this type of structure will suffer greater exterior damages than those made of brick or masonry. In all types of residential housing, though, flooding will most likely destroy the interior walls. Soaked wallboard becomes so weak that it must be replaced, as do most kinds of wall insulation, and any plywood in the walls is likely to swell and peel apart. Water can also dissolve the mortar in a chimney, which creates leaks and thus a risk of carbon monoxide poisoning once the heat comes back on.

Also, floods often deposit dirt and microorganisms throughout the house. Silt and sediment can create short circuits in the electrical system as residue collects in walls and in the spaces behind each switch box and outlet. Appliances, furnaces, and lighting fixtures also fill with mud, making them dangerous to use. Anything that gets soaked through with water may contain sewage contaminants or provide a substrate for mold. Most upholstered items must be thrown away, as well as carpets and bedding.

Damages to structures, contents, and vehicles were determined based on depth of flooding relative to the structure's first floor elevation. The depth-damage relationships assign loss as a percentage of value for each parcel or structure. The deeper the relative depth, the greater the percentage of value damaged. The sources of the relationships were different depending on structure type.

In this study, the damage from flooding is exacerbated because of the corrosive effects of saltwater. A 1997 report by Gulf Engineers and Consultants for the USACE New Orleans District describes the effect of saltwater on structures and contents.

According to the panel of experts, saltwater causes more damages and quicker damages than freshwater. Saltwater is more corrosive on metal items. Contents that remain in saltwater for over one day will eventually begin to rust unless the items can be washed, but that is not cost-effective.

Saltwater also damages wood quicker than freshwater. Salt causes discoloration and markings on content items due to the salinity of the water. According to the expert panel, to the human eye everything appears to be okay when the water is going down. Saltwater damages those little unnoticeable things such as screws that hold on wiring, toggle switches inside mechanisms, all of these things appear to be fine until they are examined months later. Saltwater does not necessarily have to touch the items to cause damage. For example, if saltwater gets close to an item it will still have the corrosive effect. The atmosphere is concentrated with salt. Therefore, when it evaporates the salt does not stay down. The salt becomes part of the mist or the moisture in the room.

Saltwater damages light fixtures, door hinges, and other various contents. With evaporation, the salt becomes more concentrated. Eventually paint will start to flake off, recliners will not close, recliners will begin to squeak, mechanisms fail and salt line residuals will be left on the contents.

The short-duration saltwater curves used in this analysis were developed by the New Orleans District for the Donaldsonville to the Gulf Feasibility Evaluation (Gulf Engineers and Consultants, Inc., 2006). The depth-damage relationships for the primary structure types and their contents are shown in Figure 21 to Figure 23 and Table 17.

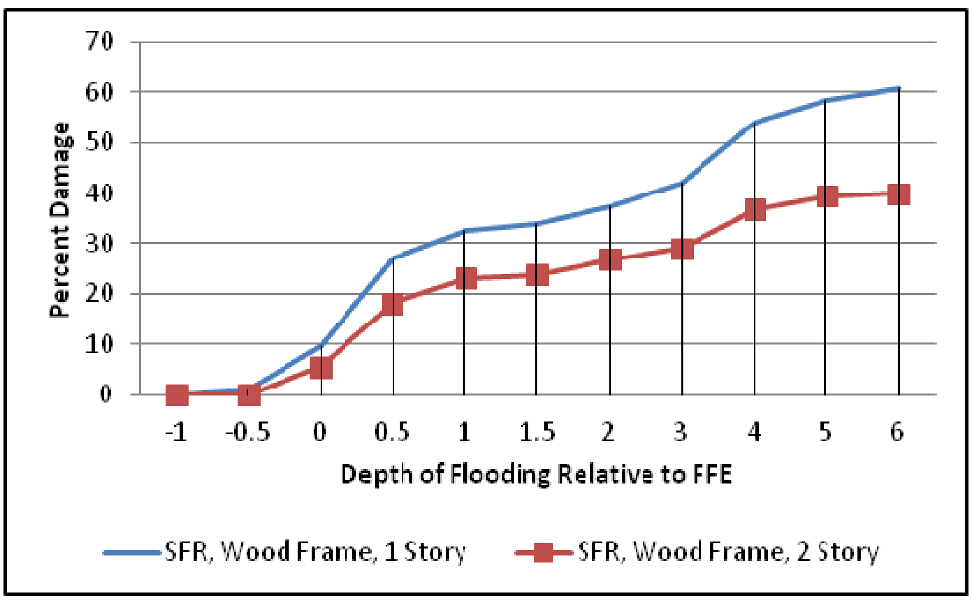

Figure 21. Residential Depth-Damage Curves, Short Duration Salt Water

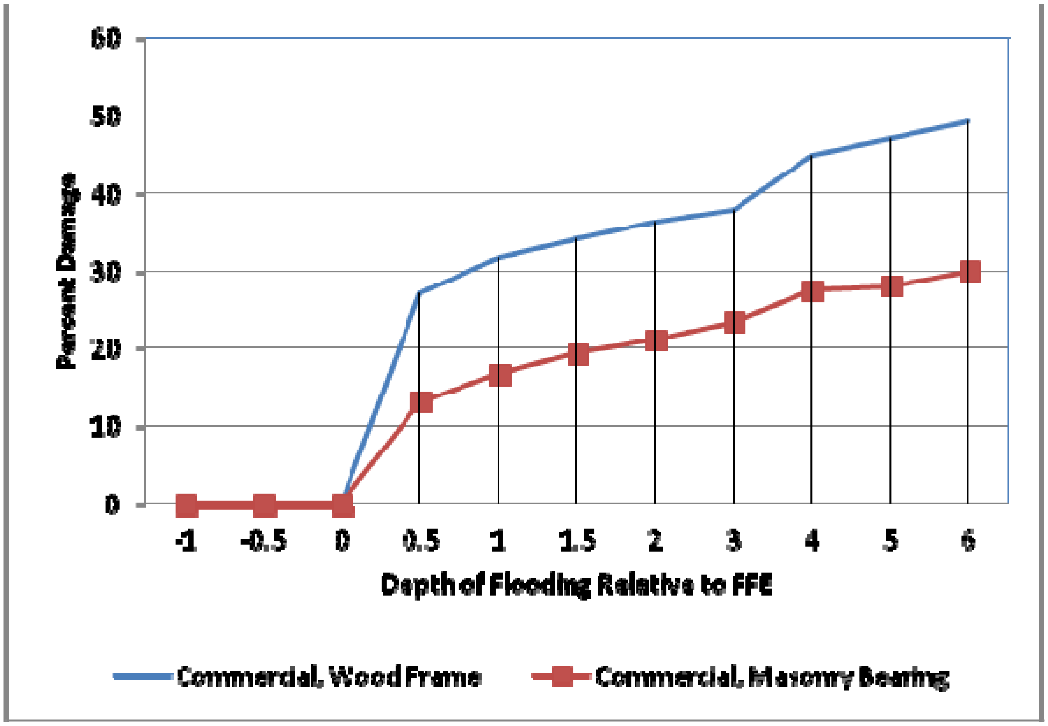

Figure 22: Commercial Depth-Damage Curves, Short Duration Saltwater

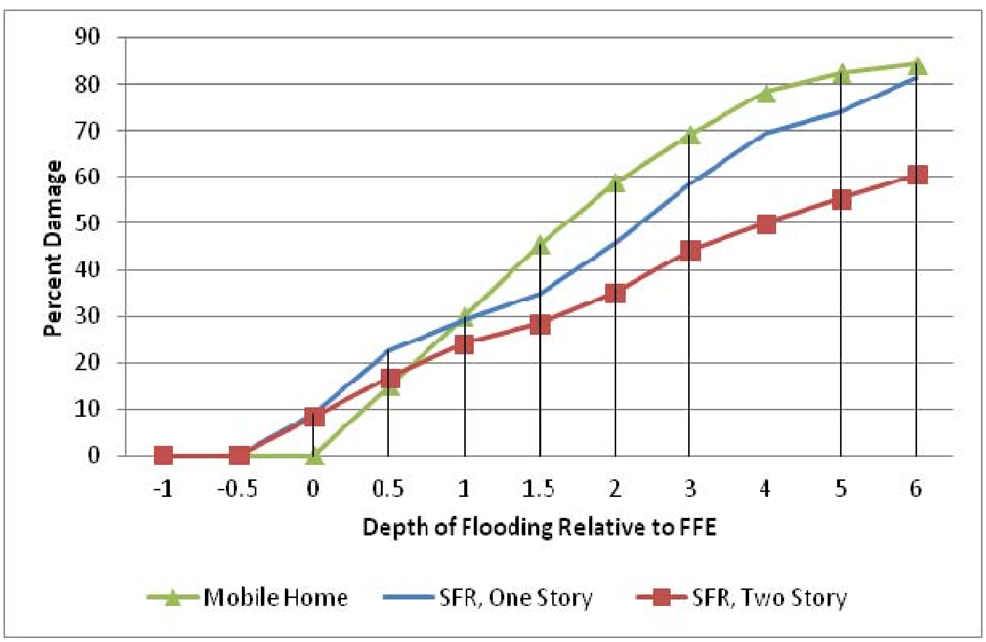

Figure 23. Residential Contents Depth-Damage Curves, Short Duration Saltwater

Table 17. Non-Residential Contents Depth-Damage Curves, Short Duration Saltwater

Depth (ft)	Eating and Recreation	Groceries and Gas Stations	Professional Businesses	Public and Semi-Public	Repairs and Home Use	Retail	Warehouse and Contractor Services	Multi-Family Residences
-1	0%	0%	0%	0%	0%	0%	0%	0%
-0.5	0%	0%	0%	0%	0%	0%	0%	0%
0	0%	12%	0%	0%	0%	0%	0%	0%
0.5	31%	31%	11%	1%	17%	55%	8%	15%
1	34%	42%	15%	2%	24%	66%	12%	20%
1.5	60%	74%	19%	2%	33%	77%	16%	22%
2	65%	92%	23%	2%	34%	88%	19%	28%
3	84%	100%	68%	90%	64%	90%	27%	45%
4	91%	100%	87%	100%	66%	92%	34%	49%
5	93%	100%	87%	100%	68%	94%	42%	49%
6	93%	100%	99%	100%	73%	100%	49%	49%