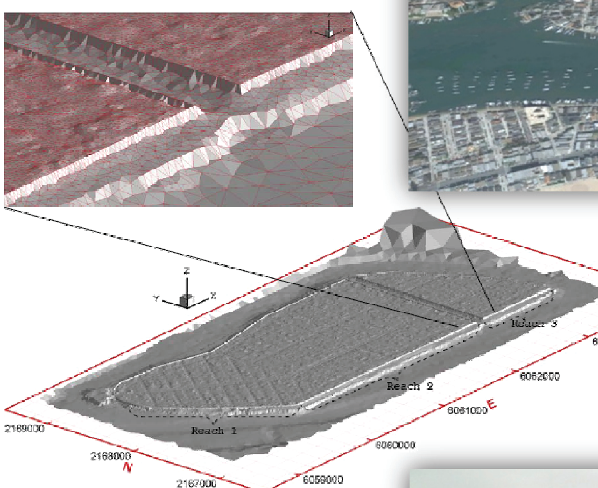
ASSESSMENT OF SEAWALL STRUCTURAL INTEGRITY AND POTENTIAL FOR SEAWALL OVER-TOPPING

for Balboa Island and Little Balboa Island

MAIN REPORT



Prepared for
City of Newport Beach

Prepared by
Everest International Consultants, Inc.

In association with
Flow Simulation, LLC
URS Corporation

April 2011

EVEREST

ASSESSMENT OF SEAWALL STRUCTURAL INTEGRITY AND POTENTIAL FOR SEAWALL OVER-TOPPING FOR BALBOA ISLAND AND LITTLE BALBOA ISLAND

MAIN REPORT

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ACRONYMS AND ABBREVIATIONS

ADA	Americans with Disabilities Act
BFE	Base Flood Elevation
BIIA	Balboa Island Improvement Association
CEQA	California Environmental Quality Act
CO-CAT	Coastal and Ocean Working Group of the California Climate Action Team
EIR	Environmental Impact Report
EO	Executive Order
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
ft	foot/feet
in	inch(es)
IPCC	Intergovernmental Panel on Climate Change
LiDAR	Light Detection and Ranging
MLLW	mean lower low water
MSL	mean sea level
NA	not applicable
NAS	National Academy of Sciences
NAVD88	North American Vertical Datum 1988
NGDC	National Geophysical Data Center
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NRC	National Research Council
NTDE	National Tidal Datum Epoch
OPC	Ocean Protection Council
OPR	Office of Planning and Research
SCCOOS	Southern California Coastal Ocean Observing System
SFHA	Special Flood Hazard Area
SSO	sanitary sewer overflow
USACE	U.S. Army Corps of Engineers
UV	ultraviolet

1 INTRODUCTION

The City of Newport Beach (City) has been dealing with localized flooding for years, even before global warming and the associated sea level rise issue became widely understood. Due to lower-than-optimum seawall and land mass heights around the Newport Harbor (Harbor) and Newport Bay (Bay) and the preponderance of privately owned seawalls, gangways, docks and other infrastructures that are outside the City's direct control, flooding of city streets and walkways has occurred on Balboa Peninsula, Balboa Island and other areas in the City when high water levels occur. The challenge of flood control is compounded by City storm drain lines that empty by gravity into the Bay and therefore do not provide flood relief when the Bay water level is high. Furthermore, City and privately owned storm drains can provide a conduit for water to enter the boundary of the various land masses when drain valves or plugs malfunction or are not properly used. To a lesser extent, distress in the form of concrete cracks and construction joints allows water to breach the protection of these walls and contributes to localized flooding.

The Balboa Island and the Little Balboa Island are two adjacent islands in the Newport Bay separated by a channel – the Grand Canal. These two islands are also collectively known as the Balboa Island. Balboa Island was formed by building up a Bay sand bar and tidal marsh in the early 20th Century. Since its inception the island has been plagued by flooding, which forced initial investors and residents to construct a mix of concrete and timber seawalls along the waterfront. In exchange for property taxes from Balboa Island property owners, the City took the first steps of constructing a proper seawall by designing and building a concrete seawall along much of the Grand Canal in 1929. A seawall for the remainder of the island was designed in 1935 and constructed in 1938 as part of the National Recovery Act.

Under normal present-day conditions, wave overtopping and flooding occur in Balboa Island during high tide and high wave events, causing damage to residences, businesses, vehicles, public infrastructure and the environment. Home damage includes, but is not limited to, loss of personal property and effects, cosmetic and structural damage, and mold growth. Businesses are prone to the same damage as homes as well as loss of inventory and business interruptions. Interiors of vehicles and possibly their mechanical parts may be damaged. Additionally, fuel tanks, home natural gas connections, and vehicles may leak petrochemical products into the environment. Sewers and storm drains are the most susceptible public utilities. When streets become flooded, water infiltrates the sewer system, which then causes sewage to spill out in an event called a "sanitary sewer overflow" (SSO). People and the environment are thereby exposed to raw sewage. An example of an SSO is shown in Figure 1.1. During high water events, the City closes the storm drain outlets to the Bay to prevent sea water from flowing backwards through the storm water outlets and inundating Balboa Island. Figure 1.2 shows a picture of City personnel pumping out water that was collected at the storm drain outlet junction structure located at a bay-front street in a high water and high wave event in December 22, 2010.

Figure 1.1 Example of a Sanitary Sewer Overflow

Figure 1.2 City Personnel Pumping Flood Water Back into the Bay

Additional photos from this event depicting wave overtopping and flooding of the Balboa Island seawall and the resulting damage are shown in Figures 1.3 to 1.7. As shown in Figure 1.3 and 1.4, water overtopped the seawall at Turquoise and South Bay Front flooding the boardwalk. Flood waters spilled into adjacent streets as seen in Figure 1.5 and some businesses were inundated as shown in Figure 1.6. After the tide ebbed and the flood waters drained, the boardwalk was covered with sand and debris as shown in Figure 1.7, clogging the boardwalk drainage system.

In an effort to prevent potential damages to property and residences around the Harbor due to flood waters associated with storms and sea level rise, the City has retained Everest International Consultants, Inc. to conduct an assessment of the potential flood impacts to Balboa Island and Little Balboa Island. This assessment includes:

1) Predicting flood water overtopping and resulting inundation due to sea level rise and storm events over the next 100 years,
2) Assessing the condition of the seawalls and remaining useful life of the seawalls,
3) Assessing options to extend or replace the seawalls,
4) Providing recommendation for flood hazard mitigation measures, and
5) Developing cost and phasing for seawall retrofit.

Balboa Island represents approximately 11% of the entire seawall waterfront in the City. Built over 70 years ago, the Islands' seawall is the oldest within the City inventory. Around the harbor, it is loosely estimated that over 80% of the seawalls in the City are privately owned, with the remaining 20% being publically-owned by the City, County, or the State. Since the Balboa Island and Little Balboa Island have public boardwalks around the entire waterfront, and all the seawalls around the islands are publically-owned and reasonably accessible, these seawalls provide an excellent pilot study opportunity for the City to assess flood risk and seawall condition in the Harbor.

This report highlights the major findings of the seawall and residence elevation surveys (Chapter 2); flood and wave overtopping modeling results for existing and future sea level rise scenarios (Chapter 3), seawall condition assessment (Chapter 4); and flood hazard mitigation alternatives and recommendations for seawall improvement phasing (Chapter 5). Recommendations for coping with sea level rise for Balboa Island are provided in Chapter 6.

Figure 1.3 Waves Splashing over the Balboa Island Seawall at Turquoise and South Bay Front

Figure 1.4 Bay Waters Overtopping the Seawall

Figure 1.5 Street Flooding

Figure 1.6 Flooded Businesses

Figure 1.7 Accumulated Sand and Debris, Post-Storm

Details of the Study are provided in three technical appendices. Appendix A – *Balboa Island and Little Balboa Island Elevation Survey* provides a detailed summary of the methodology and control points used for the survey, as well as maps and spreadsheets of the survey results. The results of Appendix A are used to define the seawall and residences elevations for the flood inundation and wave overtopping modeling summarized in Appendix B – *Balboa Island and Little Balboa Island Flood Inundation Modeling*. Lastly, Appendix C – *Condition Assessment Study and Report: Balboa Island Seawalls* provides detailed findings of the seawall assessment and recommendations for seawall modifications and other alternatives to address the potential flood risk due to sea level rise identified in Appendix B.

2 SEAWALL AND RESIDENCE ELEVATION SURVEYS

2.1 Overview

Topographic surveys were conducted on Balboa Island and Little Balboa Island on April 26 and 27, May 3 and 18, and June 6, 2010. The surveys provide top of seawall, boardwalk, and mudline elevations around the boardwalk; as well as first floor elevations of some houses around the boardwalk and three streets that transect the islands – Pearl, Coral and Crystal Avenues. In addition, topographic surveys were also conducted for the Balboa Island Ferry Boat Landing and its surroundings, as well as the three bridges on the Island. The bridges are:

1) Marine Avenue Bridge, which links the Balboa Island to the mainland,
2) The Park Avenue Bridge, which spans the Grand Canal and connects Balboa Island and Little Balboa Island; and
3) The Collins Island Bridge, which extends Park Avenue on Balboa Island over a small channel onto Collins Island.

The main objective for the topographic survey is to provide accurate top of seawall elevations, as well as identify low points at the Ferry Boat Landing and the three bridges to be used for simulating flood inundation during high tides. The mudline elevations along the outside of the seawall were also measured and are used for estimating wave overtopping of the seawalls during high tide. A summary of the flood inundation modeling is provided in Chapter 3 with the details documented in Appendix B. In addition, the survey data are useful for the development of inundation solutions for the two islands described in Chapter 5 and in more details in Appendix C.

The survey was conducted by a team of two California licensed civil engineers. Three existing Orange County benchmarks were used for determining elevations. Elevations were read through a KJ-24 Automatic Level along either closed or open oriented traverses starting at one of the benchmarks and ending at either the same (closed traverse) or different benchmark (open traverse). This method allowed for error distribution between the survey points along the traverse. The rod has 1/100 foot increments. Vertical accuracy of elevations read through the automatic level is ± 0.01 feet.

A brief summary of the seawall and residential house survey data are presented in the following sections. Details of these data, as well as survey results for the ferry boat landing and bridges are provided in Appendix A.

2.2 Datum

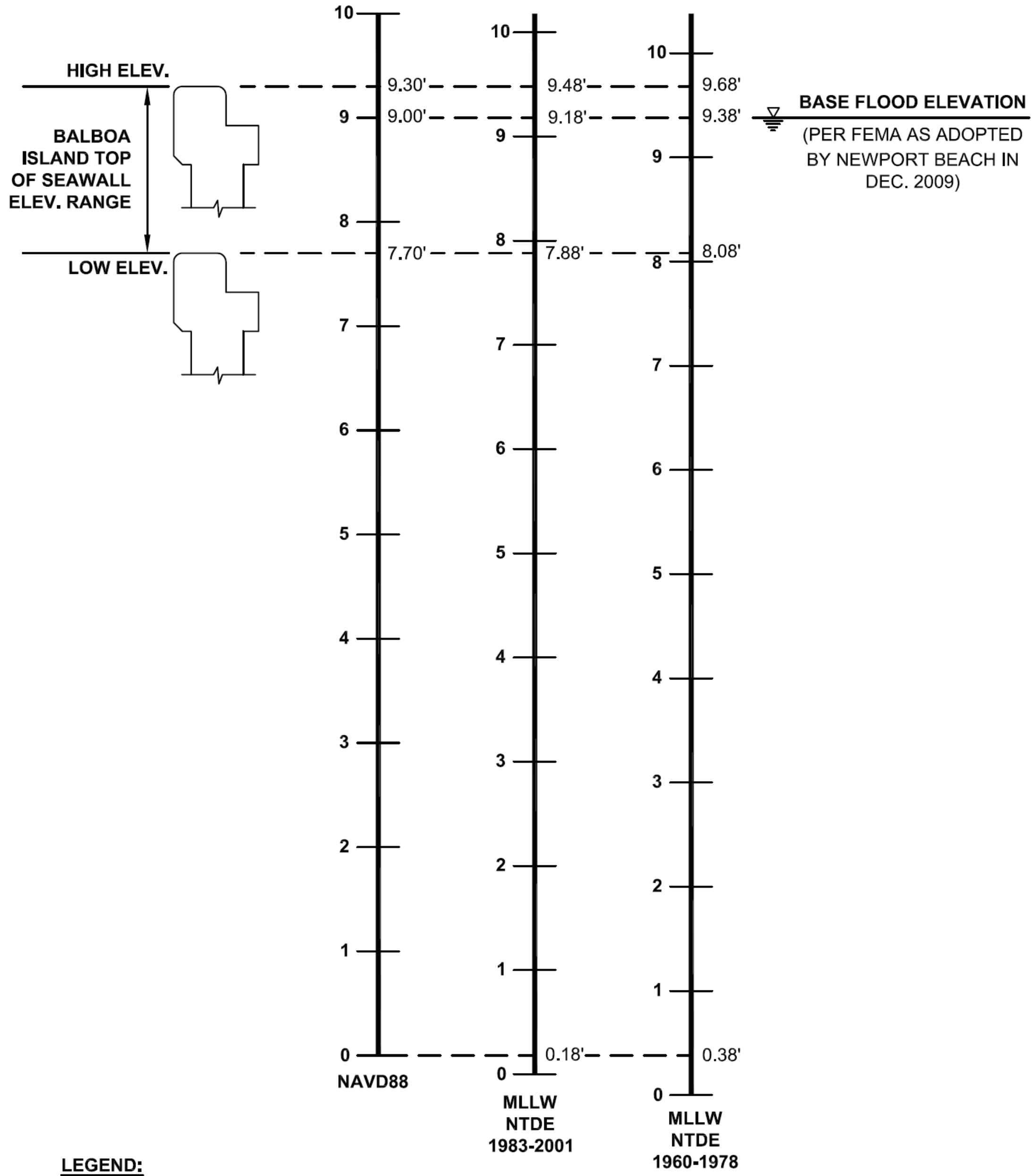
All elevation measurements are recorded in feet and the vertical datum used in the survey is the North American Vertical Datum of 1988 (NAVD88). NAVD88 is used as the primary datum for this report because it is a fixed datum that does not change over time or vary from city to city. However, since most maritime elevations in southern California are referenced to the mean lower low water (MLLW) datum, it is also used in this report. When elevation is reported, it is reported in NAVD88 with the equivalent MLLW shown in parentheses.

The National Oceanic and Atmospheric Administration (NOAA) is responsible for developing the various vertical (elevation) datums that are used by the public. The MLLW developed by NOAA's National Ocean Service (NOS) is a tidal datum, which is based on the National Tidal Datum Epoch (NTDE, i.e. a recent 19-year period over which tide data is collected and computed to determine average values used for tidal datums). A 19-year period is used because this relates to the length of a lunar cycle, and the moon is the primary gravitational influence on tide height. Tides on the west coast of the United States have a mixed semi-diurnal pattern with two uneven high tides and two uneven low tides per day. MLLW is the average of the lower of the two daily low tides over a tidal epoch. As sea levels change, so do the elevations of the high and low tides relative to a geodetic datum such as NAVD88. Therefore, MLLW is a "relative" datum, and it can change with each NTDE. For example, the current NTDE (1983 to 2001) has a MLLW datum that is 0.2 feet higher than the previous NTDE (1960 to 1978) for the Harbor. In addition, since MLLW is a tidal datum, it is only fixed locally (e.g., MLLW in the Harbor is different than MLLW in San Francisco Bay).

For the Harbor, 0.0 feet NAVD88 is equal to 0.18 feet MLLW under the most recent NTDE (1983 – 2001). Figure 2.1 shows graphically how the NAVD88 is related to the two most recent MLLW datums. In the figure, the high and low Balboa seawall elevations determined from the survey discussed in this Chapter, as well as the Balboa Island's Base Flood Elevation (BFE) are shown. Details of the BFE are provided in Section 2.4.

2.3 Seawall and Boardwalk Measurements

The survey data for the seawall and boardwalk are summarized in Figure 2.2. In the figure, locations of the Orange County benchmarks used for vertical control and the three transects (Pearl Avenue, Coral Avenue, and Crystal Avenue) through the two islands are marked. In addition, the figure also shows the horizontal stationing and top of seawall elevations around the boardwalk. These elevations are shown in both feet relative to NAVD88 and MLLW (NTDE 1983-2001), hereafter simply as MLLW.



LEGEND:

NTDE = NATIONAL TIDAL DATUM EPOCH
(A 19 YEAR PERIOD OVER WHICH TIDAL DATA IS COLLECTED AND REDUCED TO OBTAIN MEAN (AVERAGE) VALUES FOR TIDAL DATUMS)

MLLW = MEAN LOWER LOW WATER
(RELATIVE DATUM BASED ON NTDE DATA)

NAVD88 = NORTH AMERICAN VERTICAL DATUM 1988
(GEODETIC VERTICAL DATUM USING A SINGLE FIXED REFERENCE POINT)

Figure 2.1 Comparison of Different Tidal Datums

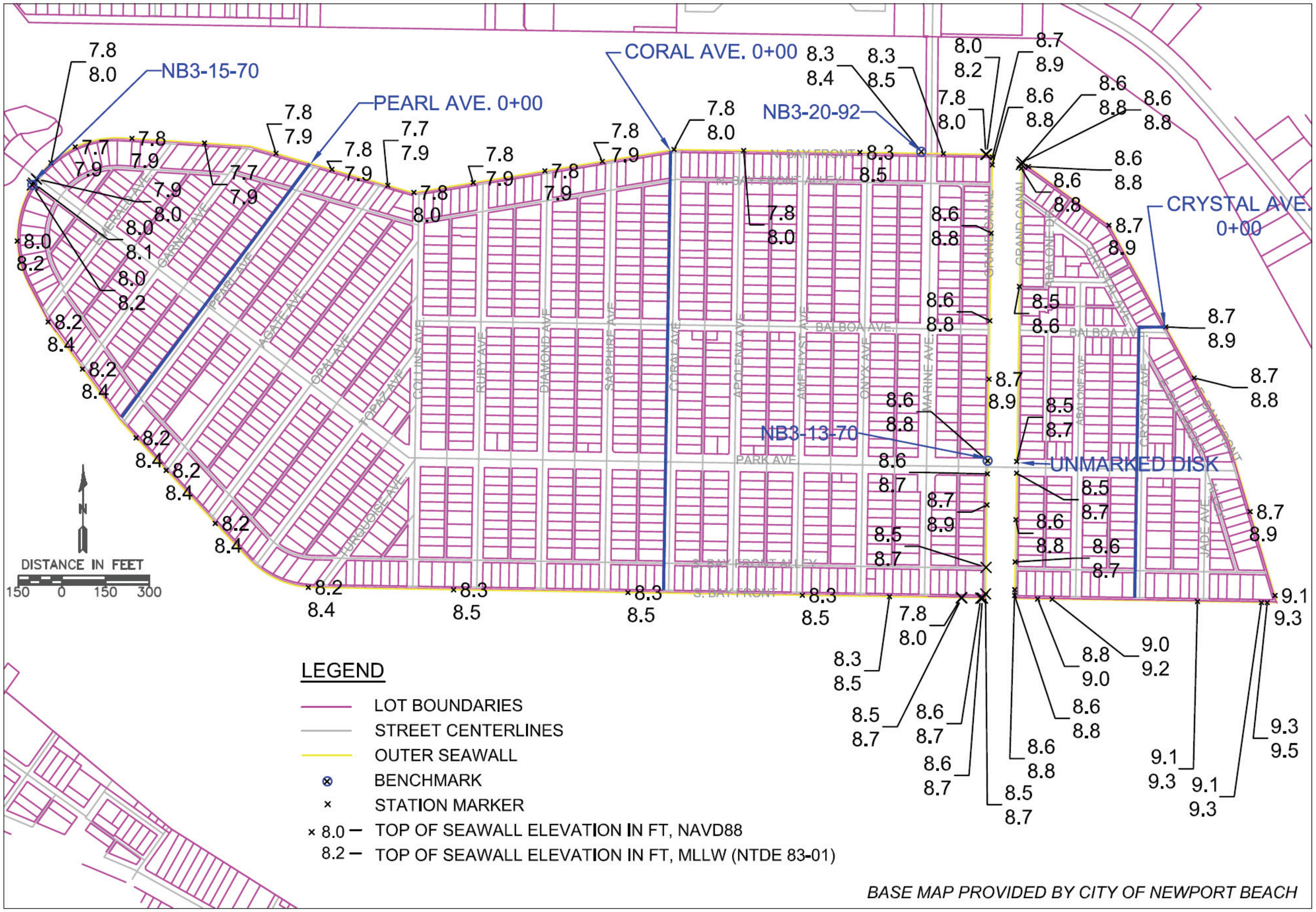


Figure 2.2 Top of Seawall Survey Results

The top of seawall elevations were found to vary between 7.6 and 8.7 feet NAVD88 (7.8 and 8.9 feet MLLW) on Balboa Island and between 8.5 and 9.3 feet NAVD88 (8.7 and 9.5 feet MLLW) on Little Balboa Island. Mudline elevations vary between approximately 1 foot below the top of seawall elevation in locations where the beach sand has been replenished and/or managed, to approximately 7 feet below the seawall elevation, where beach sands have eroded over time.

The boardwalk elevation along the Balboa Island seawall ranges between 5.0 and 7.3 feet NAVD88 (5.2 and 7.5 ft MLLW) with an average elevation of approximately 6.2 feet NAVD88 (6.4 feet MLLW). The low of 5.0 feet NAVD88 (5.2 feet MLLW) is an aberration in the data since most elevation data points fell between 5.5 and 6.7 feet NAVD88 (5.7 and 6.9 feet MLLW). The boardwalk around Little Balboa Island is between 6.2 and 6.8 feet NAVD88 (6.4 and 7.0 feet MLLW) with an average elevation of approximately 6.5 feet NAVD88 (6.7 feet MLLW). The sidewalk elevations, taken along three streets traversing the interior of the Island, averaged between 6 and 7 feet NAVD88 (6.2 and 7.2 feet MLLW) with extremes of 5.7 feet NAVD88 (5.9 feet MLLW) and 7.2 feet NAVD88 (7.4 feet MLLW).

2.4 House First Floor Elevations

In order to assess flooding of houses, residential first floor elevations were measured for ninety one houses along Pearl, Coral, and Crystal Avenues. The first-floor elevations correspond to the threshold upon which flood water would penetrate the living space of the building and potentially cause significant water damage. For the 91 surveyed parcels, the first floor elevations range from 6.2 feet NAVD88 (6.4 feet MLLW) to 11.6 feet NAVD88 (11.8 feet MLLW), with a median of 8.2 feet NAVD88 (8.4 feet MLLW), i.e. half of the first floor elevations are below 8.2 feet NAVD88 (8.4 feet MLLW). Details about the survey and the use of the surveyed data for flood modeling are provided in Appendix B.

The Federal Emergency Management Agency (FEMA) develops Flood Insurance Rate Maps (FIRMs) to determine the Base Flood Elevation (BFE) in an area and set flood insurance rates accordingly. Balboa Island is in a Special Flood Hazard Area (SFHA) called Zone A, which means the general land elevation is below the BFE. Per FEMA, the lowest floor elevation of structures in an SFHA must be above the BFE. The lowest floor is defined by FEMA as the lowest floor of an enclosed space including the basement area. This requirement is usually applied only to habitable space, so flood-resistant or unfinished areas used for parking, storage, or building access are typically exempted. For Balboa Island, the BFE is 9.0 feet NAVD88 (9.18 MLLW). On December 3, 2009, the City of Newport Beach adopted this BFE as the minimum top of slab elevation for habitable space for new construction on Balboa Island. For the 91 houses that were surveyed, approximately 85% of the houses have first floor elevation below the BFE.

3 FLOOD INUNDATION MODELING

3.1 Overview

A hydraulic model was developed and applied to Newport Bay to simulate tidal flow in the bay and inundation of Balboa and Little Balboa Islands resulting from extreme water levels and wave overtopping of the seawalls. The model was used to map present-day and future flood zones on the two islands based on actual and projected tide data[1] accounting for sea level rise and proposed improvements. Overtopping may occur from a combination of high Bay water levels and waves that either splash or flow over seawalls. Moreover, flood water is predicted to spread across the land in accordance with local topography.

A total of 17 different scenarios were simulated to map present-day and future flood zones and account for both sea level rise and potential infrastructure improvements. A brief summary of the flood inundation modeling methodology, the data used for model setup, model scenarios and model results are provided in the following sections. Details of the flood inundation modeling can be found in Appendix B.

3.2 Flood Modeling Methodology

Hydraulic modeling of Bay tide dynamics, overtopping of seawalls, and flood inundation was completed using the BreZo computer model developed by Dr. Brett Sanders at the University of California, Irvine. BreZo is a state-of-the-art, multi-dimensional flood inundation model based on the full shallow-water equations. BreZo is applied to the model domain, which encompasses all of Newport Bay and surrounding terrain and extends offshore as shown in Figure 3.1. An offshore boundary condition is specified to simulate the rise and fall of the ocean tide, which acts as the forcing for the hydraulic response of the Bay. A variable-resolution computational mesh was developed for this study. The mesh was locally refined on Balboa and Little Balboa islands for flood mapping precision. An intermediate resolution was used within the embayment, and a coarser resolution was used offshore. The locally refined mesh used for Balboa Island and Little Balboa Island is shown in Figure 3.1.

Several datasets were relied upon to implement BreZo including topographic and bathymetric data, seawall elevation data, ocean tide height data (including mean sea level trends), and wave-driven overtopping rates. These are briefly described in the following sections.

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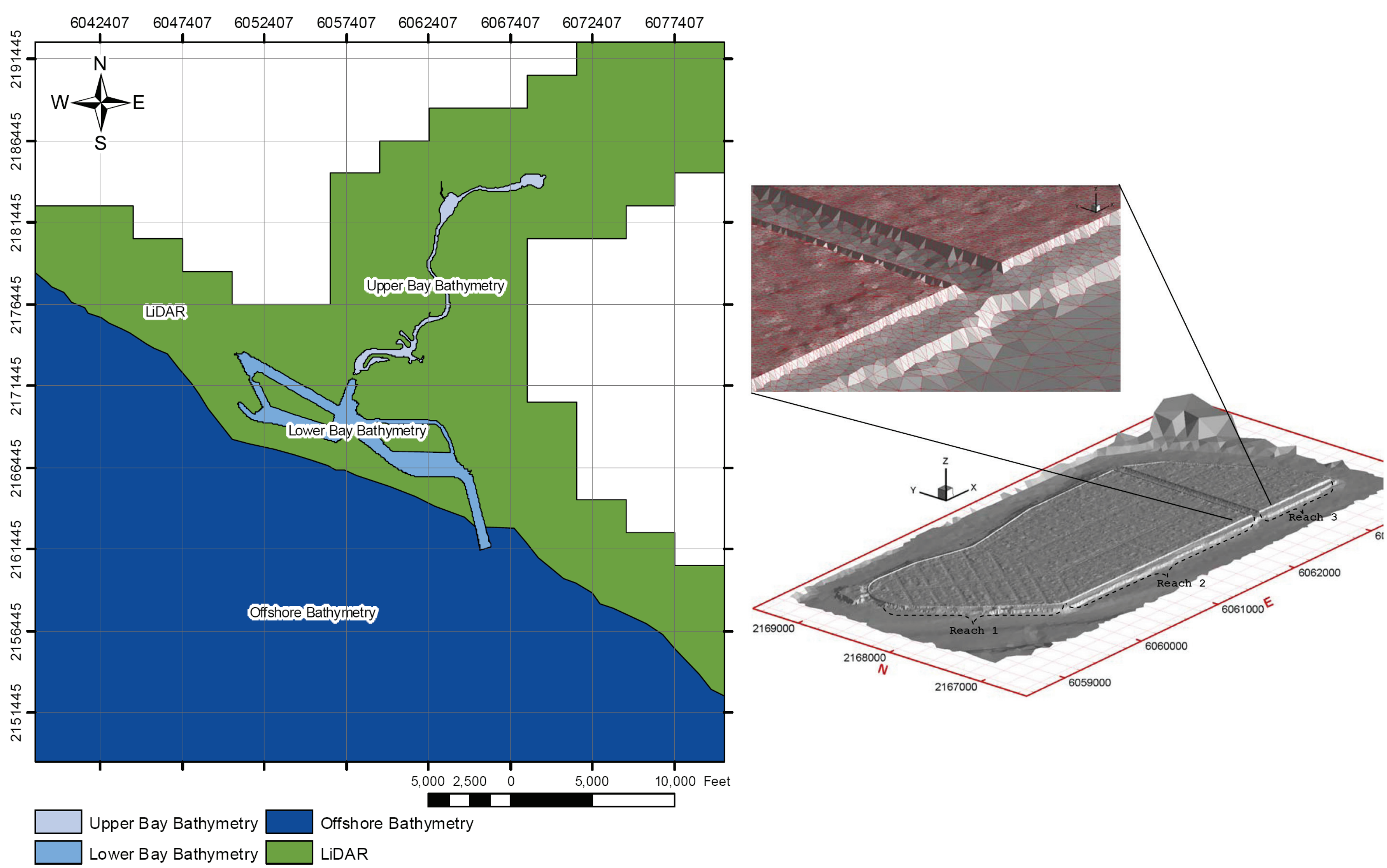
[1] Tide data used in this study is based on the NOAA gage for Los Angeles, the measured tide includes the astronomical tide and other factors affecting water level such as storm surge.



(a) Domain of hydraulic model encompasses all shaded areas, and the ocean tide boundary condition is applied on the southern boundary.

(b) Computational mesh of Balboa and Little Balboa Island region. Reach 1, 2 and 3 are subject to wave-driven overtopping.

Figure 3.1 Flood Modeling of the Newport Harbor Area

3.2.1 Topographic and Bathymetric Data

Several sources of data were obtained and organized to provide a seamless terrain map that synthesizes available topographic (above sea level) and bathymetric (below sea level) ground elevation data in the vicinity of Newport Harbor. The data sources include the following:

1) Light Detection and Ranging (LiDAR) topography data collected by Merrick for the City of Newport Beach.
2) Upper Bay bathymetry resulting from a multi-beam survey by an unknown contractor for the U.S. Army Corps of Engineers, Los Angeles District.
3) Lower Bay bathymetry data resulting from a multi-beam survey by an unknown contractor for the U.S. Army Corps of Engineers, Los Angeles District.
4) Offshore bathymetry data from the National Geophysical Data Center (NGDC) 3 Arc-Second Coastal Relief Model accessed from the Southern California Coastal Ocean Observing System (SCCOOS) website.

3.2.2 Seawall Elevation Data

Balboa and Little Balboa Islands are encircled by concrete seawalls that provide protection from flooding during periods of high tides and waves. Because elevations of the seawall represent a threshold for overtopping, it is critically important that they are surveyed with 0.1 ft accuracy or less. As described in Chapter 2, the seawall elevations used for setting up the BreZo Model were surveyed for this study with a vertical accuracy of approximately 0.01 ft. Additional detail is provided in Appendix A.

3.2.3 Wave-driven Overtopping Rates

Waves are an important driver of embayment flooding when the water level approaches the crest of the seawall. Wave action provides the necessary energy for water to rise up above the water level and spill over the barrier. Wave overtopping rates were calculated using the ACES program developed by the U.S. Army Corps of Engineers (Veri-Tech, Inc., 2009). The parameters controlling the onset of wave overtopping and the overtopping rate include structure type, structural slope, beach slope, water depth (hence the need for mudline elevations), and wave characteristics (height and period). Based on these parameters for Balboa and Little Balboa Islands, wave overtoppings were calculated for three different reaches (see Figure 3.1). Reach 1 and 2 correspond to the southwest and south sides of Balboa Island, respectively, and Reach 3 corresponds to the south side of Little Balboa Island. Waves along the northern and eastern shore of the island were considered to be small, and hence, not included in the inundation modeling.

Two major wave sources were considered for this study:

1. Wind waves - these are locally generated waves within the harbor caused by local winds, normally having short wave periods of typically less than 8 seconds, and are often referred to as "sea", and

2. Ocean swell – these are waves generated from far away storm activities that have travelled a long distance to reach southern California coastline, typically with wave periods of 10 to 20 seconds. These waves travel into the Harbor through the harbor mouth.

Details of the wave analyses for wave overtopping simulations are provided in Appendix B.

3.3 Extreme High Tides and Sea Level Rise Projections

Extreme high tide scenarios are needed to support hydraulic modeling of coastal flooding and plan for sea level rise. Flooding occurs as tide heights rise above protective sea walls, and lasts from minutes to hours depending on the duration of overtopping and the required time to drain the flood water. For this study, two extreme high tide scenarios with 1%[2] and 10% probability of occurrence for both present and future sea level rise conditions are used. The two tide scenarios, in combination with different wave and seawall conditions, form the 17 flood modeling scenarios. These flood modeling scenarios and the results are discussed in Section 3.4.

The development of the extreme high tides for present and with future sea level rise consists of the following three steps:

1. Analyses of historical through present tide data to develop change in high tides relative to mean sea level,

2. Projection of future mean sea level rise, and

3. Projection of future extreme high tides by combining the trend of high tides (historical to present) (Step 1) and the projection of future sea level rise (Step 2).

A brief summary of these three steps are provide here, details are provided in Appendix B.

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[2] A 1% probability of occurrence means that there is a 1 in 100 chance that an event equal or larger will occur during the year.

Step 1: Analyses of Historical Extreme High Tide Data

Over 80 years of hourly tide measurements at Los Angeles (NOAA Station ID: 9410660) were analyzed for this study. Newport Bay data were not used because only a short time-history of measurements was available. Using the hourly record, the mean and maximum value of the tide height from each year was computed, and a linear model was least-squares fit to each of the time series. These tide heights and trends are shown in Figure 3.2. These trend lines show that the annual maximum high tide is rising slightly faster than mean sea level. Figure 3.2 also shows that the maximum tide heights exhibit considerable inter-annual variability on the order of 1 foot. For this study, this variability is treated by considering the extreme tide height to be a random variable and probability analysis was performed to obtain the 1% and 10% extreme high tide trends shown in Figure 3.2. Details on the probability analysis are provided in Appendix B.

Based on the analyses of the historical data, mean sea level for 2010 is 2.65 feet NAVD88 (2.83 feet MLLW), and the 10% and 1% probability of occurrence extreme tide heights for 2010 are 7.41 and 7.71 feet NAVD88 (7.59 and 7.89 feet MLLW), respectively.

Step 2: Projection of Mean Sea Level

The U.S. Army Corps of Engineers (USACE) and many California State agencies have issued guidelines to provide guidance for incorporating sea level rise for Federal or State projects. The following is a brief summary of these recently issued guidelines.

<u>U. S. Army Corps of Engineers (USACE) Guidance</u>: The USACE issued an Engineer Circular titled, “Water Resource Policies and Authorities Incorporating Sea-level Change Considerations in Civil Works Programs” on July 1, 2009. The circular provides USACE guidance for incorporating the potential direct and indirect physical effects of projected future sea level change in the engineering, planning, design, and management of USACE projects. The guidance states that potential sea level change must be considered in every USACE coastal activity as far inland as the extent of estimated tidal influence. USACE recommends a multiple scenario approach to address uncertainty and help develop better risk-informed alternatives. Planning studies and engineering designs should consider alternatives that are developed and assessed for the entire range of possible future rates of sea level change. The alternatives should be evaluated using “low”, “intermediate”, and “high” rates of future sea level change for both “with” and “without” project conditions. The historic rate of sea level change should be used as the “low” rate. The “intermediate” rate of local mean sea level change should be estimated using the modified Curve I from the National Research Council (NRC) 1987 report titled “Responding to Changes in Sea Level: Engineering Implications”. The “high” rate of local sea level change should be estimated using the modified Curve III from the 1987 NRC report.

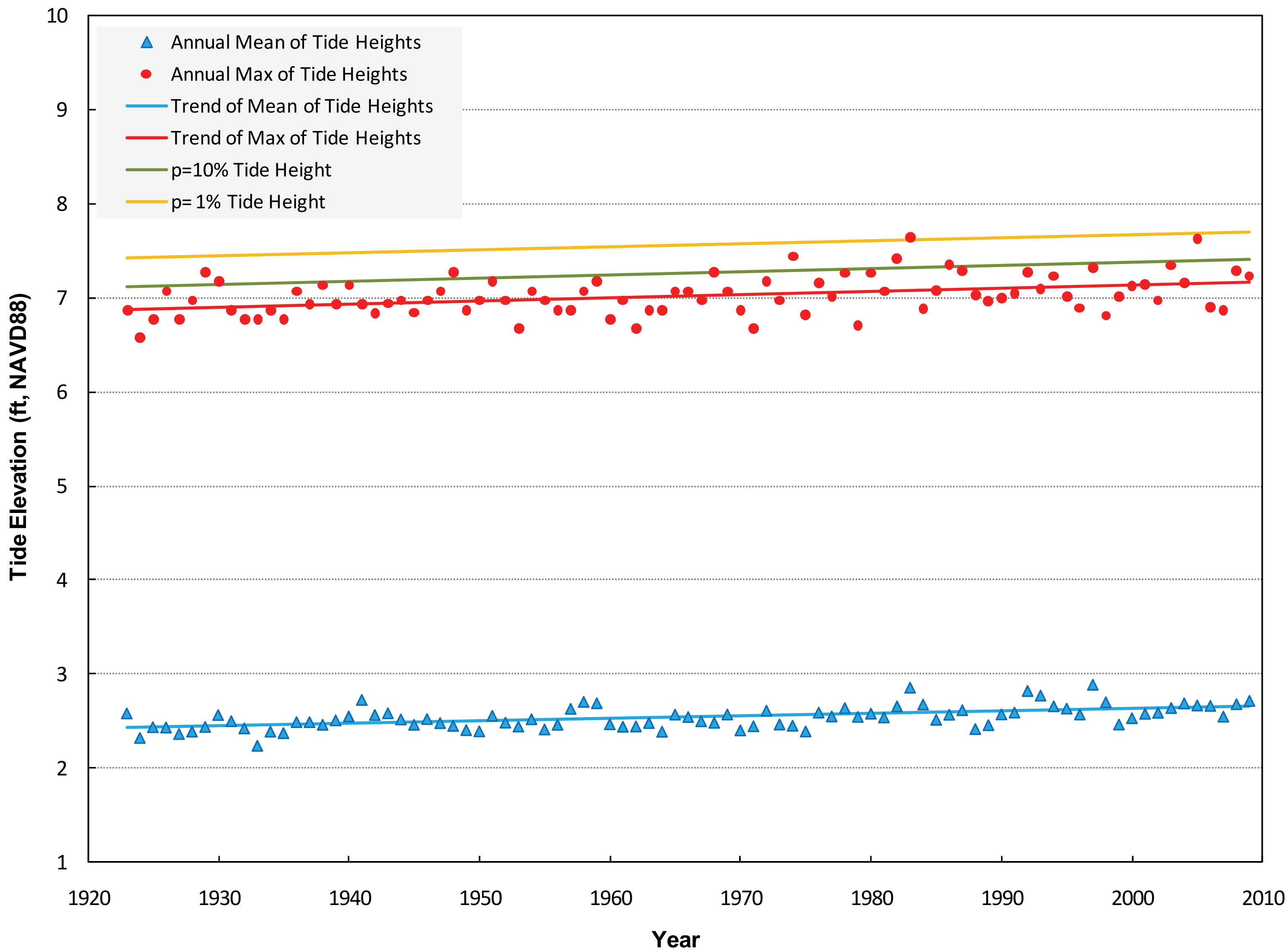

Figure 3.2 Mean and Annual Maximum Tide Elevations, and Trends of Mean, Maximum, 10% and 1% Annual Exceedance-Probability Tide Heights, Los Angeles, 1923 – 2009

<u>*State of California: Executive Order S-13-08*</u>: On November 14, 2008, Governor Arnold Schwarzenegger issued Executive Order (EO) S-13-08 (Office of the Governor, 2008) to enhance the State's management of potential climate effects from sea level rise, increased temperatures, shifting precipitation and extreme weather events. There are directives for four key actions in the EO including:

- initiate California's first statewide climate change adaptation strategy that will assess the state's expected climate change impacts, identify where California is most vulnerable and recommend climate adaptation policies by early 2009;
- request the National Academy of Sciences (NAS) establish an expert panel to report on sea level rise impacts in California to inform state planning and development efforts;
- issue interim guidance to state agencies for how to plan for sea level rise in designated coastal and floodplain areas for new projects; and
- initiate a report on critical existing and planned infrastructure projects vulnerable to sea level rise.

The Sea Level Rise Assessment Report is required to be completed by the NAS by December 1, 2010. The EO directs that, prior to release of the final Sea Level Rise Assessment Report from the NAS, all State agencies that are planning construction projects in areas vulnerable to future sea level rise shall, for the purposes of planning, consider a range of sea level rise scenarios for the years 2050 and 2100 in order to assess project vulnerability and, to the extent feasible, reduce expected risks and increase resiliency to sea level rise. The EO also directs the Governor’s Office of Planning and Research (OPR) to provide State land-use planning guidance related to sea level rise and other climate change impacts by May 30, 2009. That guidance has not been released by OPR as of this writing.

<u>*California State Coastal Conservancy*</u>: The California State Coastal Conservancy Board adopted the *Climate Change Policy* on June 4, 2009. The *Climate Change Policy* describes the concerns about the effects of global warming on coastal, marine, and near-coast resources within the Conservancy’s jurisdiction. The *Policy* recommends prior to the completion of the NAS report on sea level rise, consistent with Executive Order S-13-08, the Conservancy will consider the following sea level rise scenarios in assessing project vulnerability and, to the extent feasible, reducing expected risks and increasing resiliency to sea level rise:

- 16 inches by 2050 (1.3 ft)

- 55 inches by 2100 (4.6 ft) [3]

<u>*California Natural Resources Agency*</u>: The California Natural Resources Agency had issued draft guidance on sea level rise in response to Executive Order S-13-08 in a document entitled *2009 California Climate Adaptation Strategy* (released August 3, 2009). The report provides a summary of the latest science on how climate change could impact the State and provides recommendations on how to manage against those threats in seven sector areas. The sectors include: Public Health; Biodiversity and Habitat; Ocean and Coastal Resources; Water Management; Agriculture; Forestry; and Transportation and Energy Infrastructure. The most pertinent recommendation is to comply with the CEQA Guidelines, which will be done in the Environmental Impact Report (EIR) for this project.

<u>*California Ocean Protection Council*</u>: On November 9, 2010, the *Resolution of the California Ocean Protection Council on Sea-Level Rise, Draft* was released for public comment. The guidance document was created by the Sea-Level Rise Task Force of the Coastal and Ocean Working Group of the California Climate Action Team (CO-CAT), including staff from fifteen different agencies which reached agreement on the recommendations in the guidance document:

The guidance advises to use sea level rise values from Vermeer and Rahmstorf (2009) as a starting place and select sea level rise values based on agency and context-specific considerations of risk tolerance and adaptive capacity. These values are summarized below in Table 3.1.

Table 3.1 Sea Level Rise Projections Using 2000 as the Baseline

YEAR	RANGE OF SEA LEVEL RISE (IN)
2030	5 – 8
2050	10 – 17
2070	17 – 32
2100	31 – 69

[3] Based on the reference material quoted in the Coastal Conservancy Climate Change Policy, these sea level rise values use Year 2000 as the base year.

For this study, future mean sea levels are estimated by applying the NRC III methodology recommended by the Corps (USACE 2009) since it is likely that the City may seek support from USACE for funding to implement major flood protection projects. Figure 3.3 shows how sea level rise predicted by the USACE / NRC III methodology compares with sea level rise projections by Vermeer and Rahmstorf (2009) (recommended by OPC) that correspond to low (B1), medium (A2) and high (A1FI) future carbon emission scenarios developed by the Intergovernmental Panel on Climate Change (IPCC). Vermeer and Rahmstorf (2009) considered output from 19 climate models and a range of carbon cycling scenarios to characterize the uncertainty in their projections, and this is reflected by the vertical spread of each projection. Figure 3.3 shows that the USACE / NRC III sea level rise projection closely tracks the upper limit of the medium emission scenario (A2) and the mean of the high emission scenario (A1FI). Figure 3.3 also shows that current estimates of sea level rise are considerably greater than those of a few years ago when the IPCC Assessment Report 4 (AR4) was published. In Figure 3.3, the Coastal Conservancy recommended sea level rise for 2050 and 2100 are also shown. It can be seen that the Coastal Conservancy recommended values are similar to the values based on USACE/NRC III methodology.

Step 3: Projections of Future Extreme Tides

Figure 3.4 and Table 3.2 show projections of future tide heights assuming that the future extreme tides will follow the USACE/NRC III sea level rise trend. As shown in Figure 3.4, projections point to a rapid increase of sea level over the coming decades, compared to the historical rate of rise. The projections also show that the difference between the 10% and 1% extreme tide events is very important in the near future, but less important in the long term compared to sea level rise.

Table 3.2 Sea Level and Annual Maximum Tide Height Projections Through 2100

YEAR	MEAN SEA LEVEL (FT, NAVD88)	10% TIDE HEIGHT (FT, NAVD88)	1% TIDE HEIGHT (FT, NAVD88)	PROJECTED SEA LEVEL RISE (FT)*
2010	2.65	7.41	7.71	-
2025	3.05	7.81	8.11	0.40
2050	4.03	8.79	9.09	1.38
2100	7.25	12.01	12.31	4.60

* equals change in mean sea level from 2010.

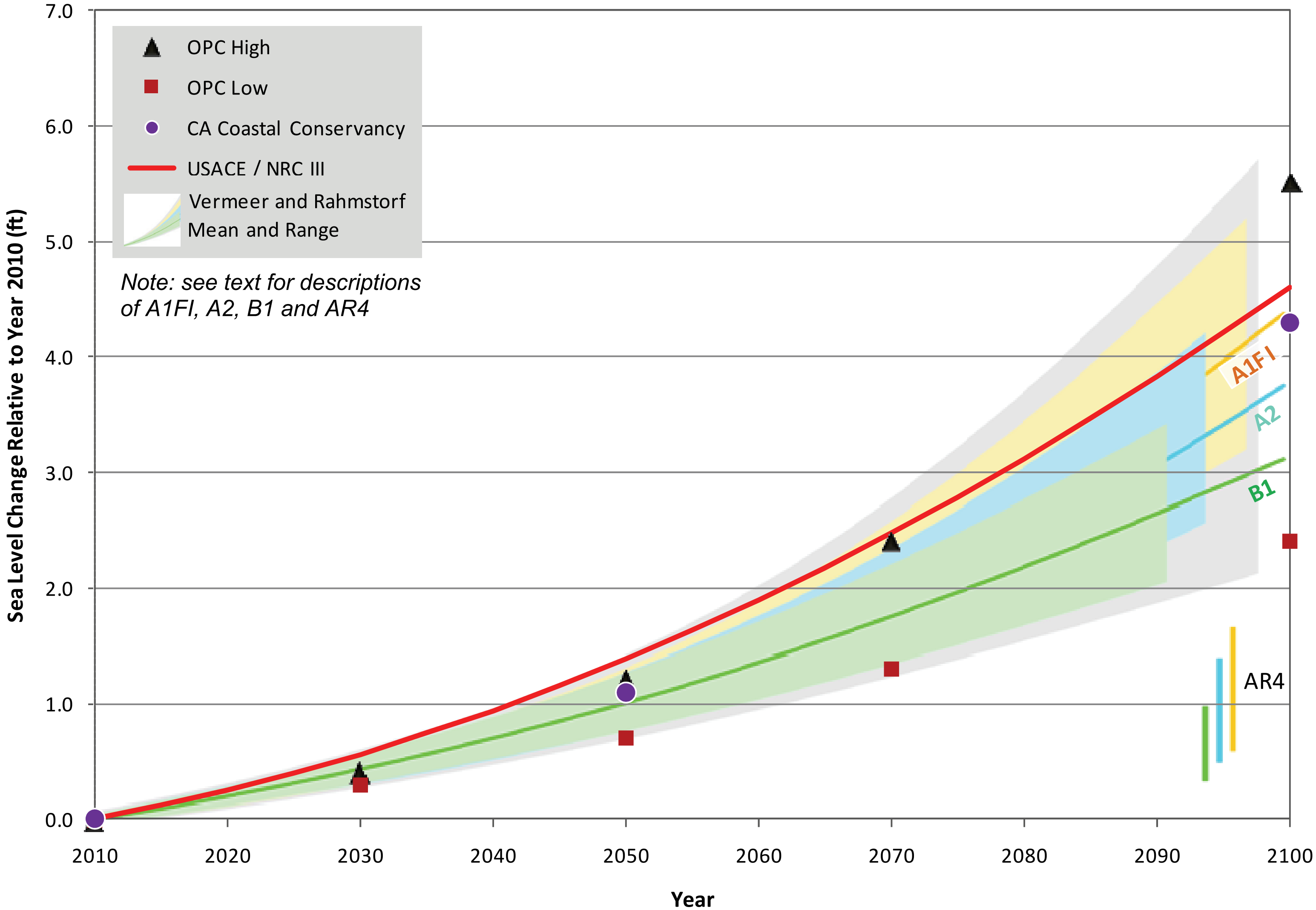

Figure 3.3 Comparison of USACE/NRC III Projections of Sea Level Rise with Vermeer and Rahmstorf (2009), (Adopted from Vermeer and Rahmstorf 2009) and OPC and California State Coastal Conservancy Recommendations

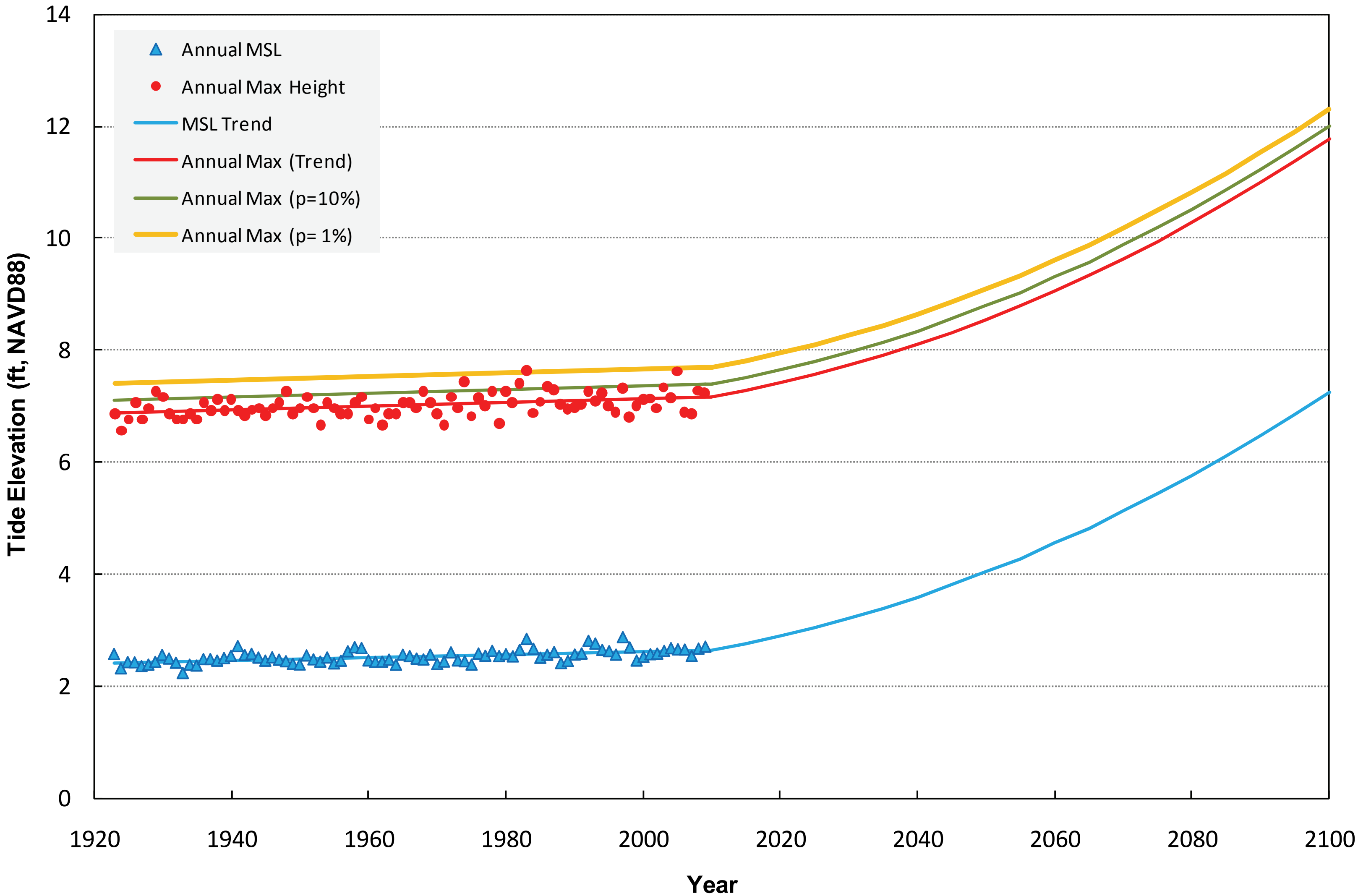

Figure 3.4 Projections of Mean Sea Level and Extreme Tide Heights Through 2100

3.4 Flood Inundation Model Scenarios

The BreZo Model was used to simulate existing and future (with sea level rise) flood inundations of Balboa Island and Little Balboa Island. A total of seventeen scenarios representing different seawall conditions, sea level rise and the corresponding high tides and wave conditions, were simulated. Each scenario is characterized by: (a) the year and corresponding rise of mean sea level, (b) the tide height that is superimposed upon mean sea level to represent the total ocean height, (c) a wave condition that may contribute to seawall overtopping, and (d) flood defense infrastructure which may be improved to mitigate future flooding. These model scenarios are summarized in Table 3.3.

Three different seawall conditions were modeled: 1) existing, 2) a sandbagging scenario that would add 6 inches to the existing seawall height and shore up low points, and 3) a proposed new seawall with top of seawall at +9.8 ft NAVD88 (+10 ft MLLW). The sandbagging scenario was proposed based on the potential sea level rise conditions and model results discussed in the next section such that it would be effective in minimizing flooding at the two islands for possibly the next 20 to 25 years. Details about the proposed new seawall are provided in Chapter 5.

In addition to the present mean sea level and high tide conditions, sea level rise and the corresponding high tide conditions for Year 2025, 2050 and 2100 were simulated. For flood inundation, it is the water level during high tides (on top of the rise in sea level in the future) together with wave overtopping that governs the severity of flooding. Hence, the 17 flood model scenarios include a combination of tide height and wave (wind wave or ocean swell) conditions. Two different tide heights with annual exceedance probabilities of 10% and 1% were simulated. These 10% and 1% exceedance tide heights for present (2010) and Year 2025, 2050 and 2100 are shown in Table 3.2.

Table 3.3 Flood Inundation Modeling Scenarios

Scenario	Seawall Condition	Year	Sea Level Rise From 2010	Tide Height (Annual Exceedance Probability)	Wave Scenario
1	Existing Conditions	2010	NA	10%	No Waves
2	Existing Conditions	2010	NA	10%	Wind Waves
3	Existing Conditions	2010	NA	10%	Ocean Swell
4	Existing Conditions	2010	NA	1%	Wind Waves
5	Existing Conditions	2025	0.40 ft	10%	Wind Waves
6	Existing Conditions	2025	0.40 ft	10%	Ocean Swell
7	Existing Conditions	2025	0.40 ft	1%	Wind Waves
8	Existing Conditions	2050	1.38 ft	10%	No Waves
9	Existing Conditions	2050	1.38 ft	1%	No Waves
10	Existing Conditions	2100	4.60 ft	10%	No Waves
11	Sandbagging (+0.5 ft)	2010	NA	1%	Wind Waves
12	Sandbagging (+0.5 ft)	2025	0.40 ft	1%	Wind Waves
13	10 ft (MLLW) seawall	2010	NA	1%	Wind Waves
14	10 ft (MLLW) seawall	2025	0.40 ft	1%	Wind Waves
15	10 ft (MLLW) seawall	2050	1.38 ft	1%	Wind Waves
16	10 ft (MLLW) seawall	2050	1.38 ft	10%	Wind Waves
17	10 ft (MLLW) seawall	2100	4.60 ft	1%	Wind Waves

3.5 Flood Inundation Model Results

The flood model results were used to estimate the number of parcels and the number of buildings on Balboa Island and Little Balboa Island that may be subject to flooding under each of the 17 model scenarios. A summary of model results are shown in Table 3.4. A total of 1,410 parcels were identified on the two islands, and the building impact assessment assumes one building per parcel with the first floor height characterized by the statistical distribution described in Section 2.3. Potential damage is assumed when the local flood water height predicted by the model exceeds the first floor height. In the table, the average flood depth within the predicted flood zone is also shown.

Table 3.4 Average Flood Depth, Parcel and Building Impacts Associated with Each Model Scenario

Scenario	Year	Tide Height (Annual Exceedance Probability)	Wave Scenario	Average * Flood Depth (ft)	Impacted** Parcels (number)	Parcels Impacted (%)	Impacted*** Buildings (number)	Impacted Buildings (%)	Flood Extent Figure Number
Existing Condition Scenarios									
1	2010	10%	No Waves	0.26	61	4.0	3 ± 2	0.2	Figure 3.5
2	2010	10%	Wind Waves	0.26	61	4.3	3 ± 2	0.2	Figure 3.6
3	2010	10%	Ocean Swell	0.29	514	36.5	24 ± 5	1.7	Figure 3.7
4	2010	1%	Wind Waves	0.36	324	23.0	22 ± 4	1.5	Figure 3.8
5	2025	10%	Wind Waves	0.48	681	48.3	66 ± 7	4.7	Figure 3.9
6	2025	10%	Ocean Swell	0.79	1,176	83.4	235 ± 13	16.6	Figure 3.10
7	2025	1%	Wind Waves	1.16	1,179	83.6	420 ± 14	29.8	Figure 3.11
8	2050	10%	No Waves	1.84	1,410	100.0	894 ± 17	63.4	Figure 3.12
9	2050	1%	No Waves	2.15	1,410	100.0	1047 ± 15	74.3	Figure 3.13
10	2100	10%	No Waves	5.02	1,410	100.0	1410 ± 1	100.0	Figure 3.14
Sandbagging Scenarios									
11	2010	1%	Wind Waves	0.03	0	0.0	0	0.0	Figure 3.15
12	2025	1%	Wind Waves	0.12	12	0.9	0-1	<0.1	Figure 3.16
10-foot Seawall Scenarios									
13	2010	1%	Wind Waves	0	0	0.0	0	0.0	Figure 3.17
14	2025	1%	Wind Waves	0	0	0.0	0	0.0	Figure 3.18
15	2050	1%	Wind Waves	0	0	0.0	0	0.0	Figure 3.19
16	2050	10%	Wind Waves	0	0	0.0	0	0.0	Figure 3.20
17	2100	1%	Wind Waves	5.30	1,410	100.0	1410 ± 1	100.0	Figure 3.21

* *Average flood depth within the predicted flood zone.*

** *An Impacted Parcel implies some fraction of the parcel is flooded.*

*** *An Impacted Building implies that the predicted flood depth exceeds a statistical estimate for the foundation height. Again note that actual first floor heights for individual houses were not used in the model.*

In addition to estimating the number of impacted parcels and buildings, the flood model results were also used to generate graphics to illustrate the flood extent and flood depth associated with each modeling scenario. These graphics are shown in Figures 3.5 through 3.21 for model Scenarios 1 through 17, respectively. Even though the model results were used only to quantify the number of parcels and buildings that may be impacted under each model scenario, the graphics showing flood extent and flood depth can be used to qualitatively describe where other damages (e.g. cars parked on a flooded street likely to be damaged) may occur.

A brief description of the flood model simulation findings are provided in the following section based on the results shown in Table 3.2, and the graphics showing the flood extent.

3.5.1 Existing Condition Scenarios

Scenarios 1 through 10 reveal the flood risk of existing conditions in response to tide height, sea level rise, and wave height effects. Scenarios 1 to 4 (see Figures 3.5 to 3.8) show that the present day (2010) flood risk mainly involves flooded streets. Scenarios 3 and 4 also show a small fraction (1%) of the buildings in Balboa Island being impacted. Scenario 3 shows that ocean swell has the potential to overtop the southern boundary of Balboa Island when combined with a 10% exceedance-probability tide. Flood water that overtops the southern seawall generally spreads north, but Park Avenue also acts to spread flood water east and west. The lowest elevations are on the west side of the island, so street flooding tends to progress in this direction.

Scenario 4 shows that flooding may commence on the southwest and northwest edges of Balboa Island from a 1% exceedance probability tide and wind waves. The number of impacted parcels is smaller compared to Scenario 3, but the estimated impact to buildings is roughly equal. This is attributed to lower elevations on the west end of the island. This scenario causes water to pond more and spread less compared to Scenario 3.

Ocean swell (Scenario 3, see Figure 3.7) is predicted to have a stronger effect on flooding than wind waves (Scenario 4, see Figure 8), mainly because swell-induced overtopping is initiated at lower tide heights than wind-wave overtopping. Additionally, flood modeling indicates that Little Balboa Island is presently well protected from tide and wave-driven flooding. This is attributed to a higher seawall compared to Balboa Island.

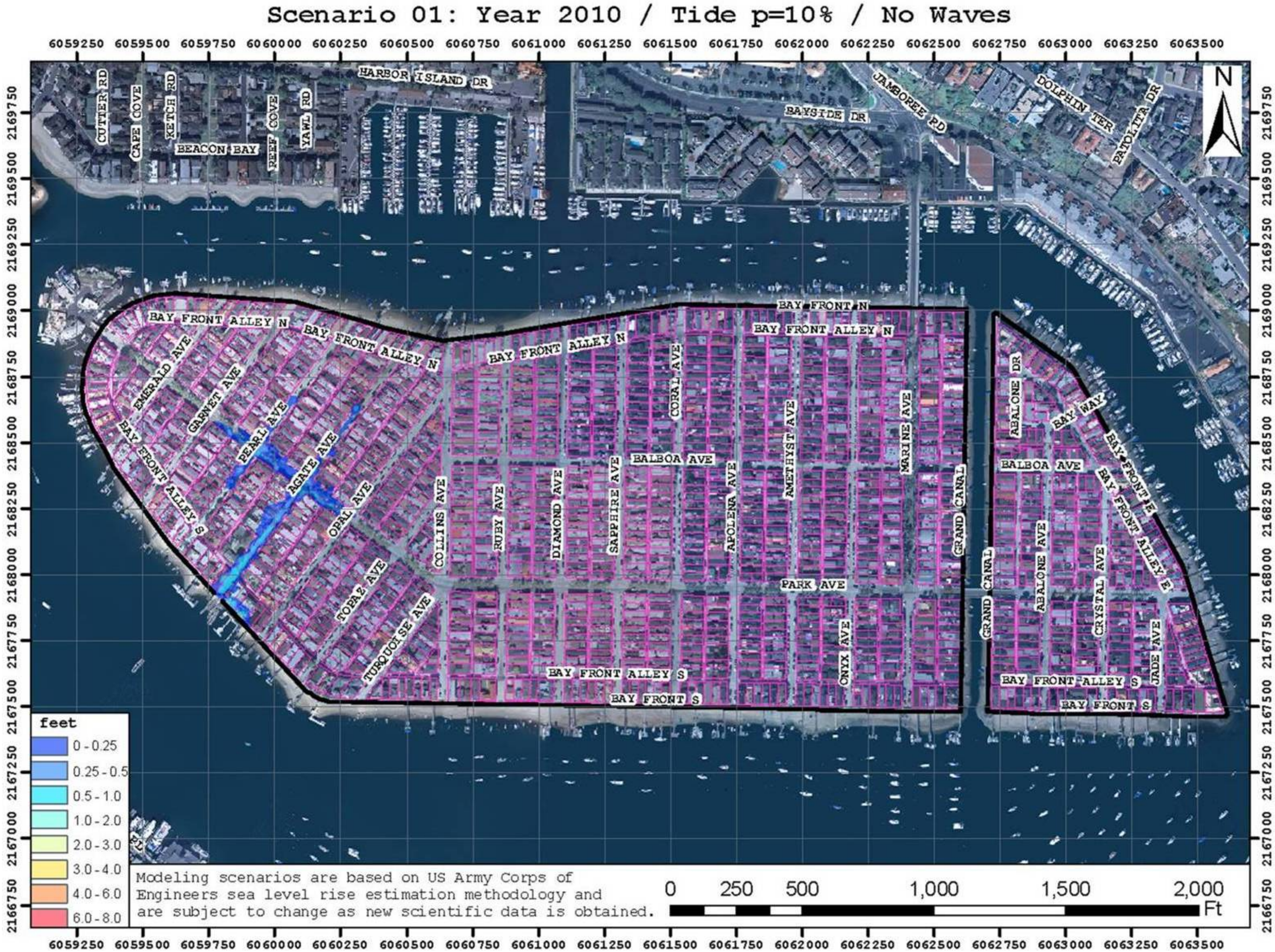

Figure 3.5 Model Prediction of Flood Extent and Flood Depth for Scenario 1

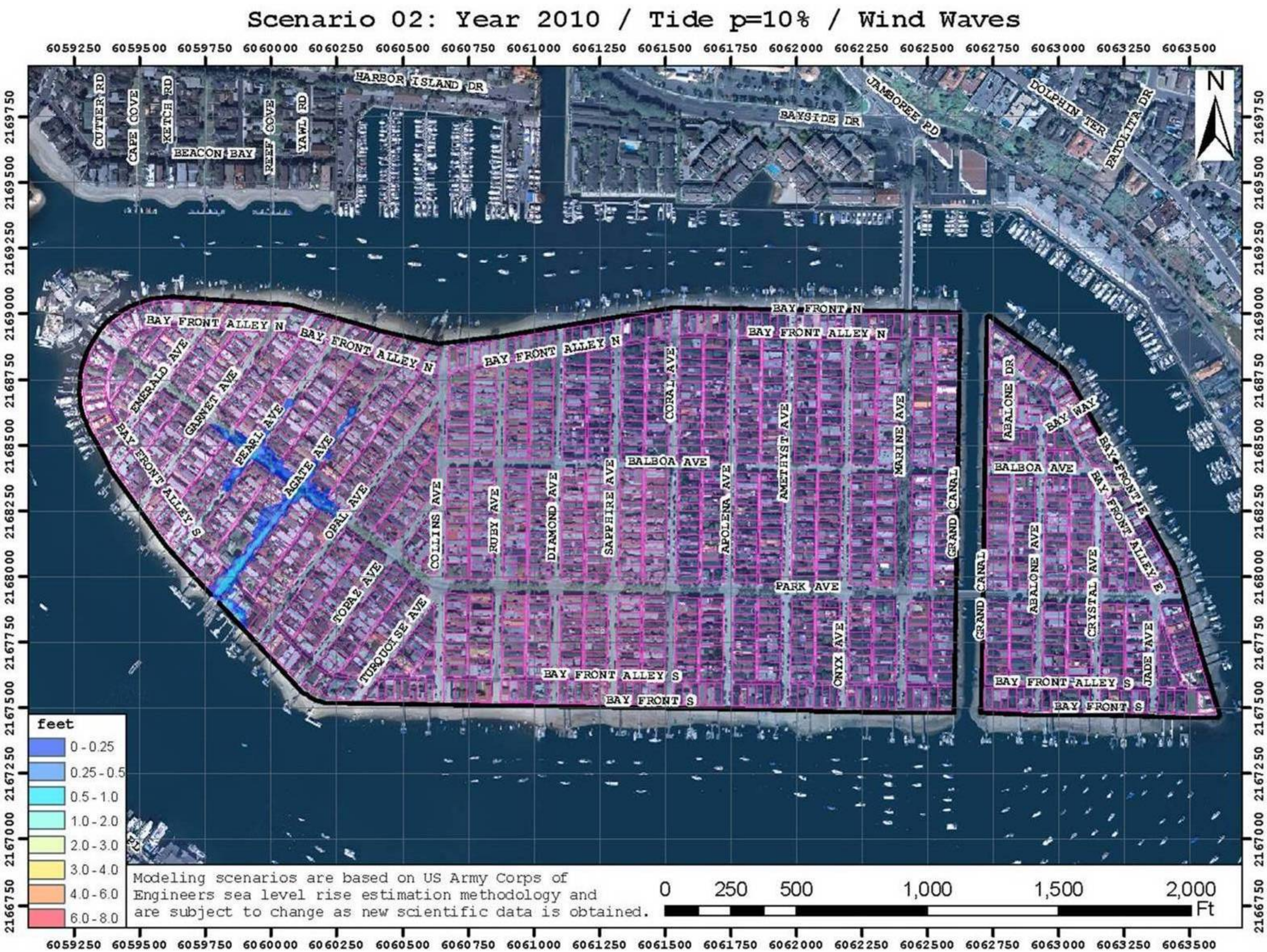

Figure 3.6 Model Prediction of Flood Extent and Flood Depth for Scenario 2

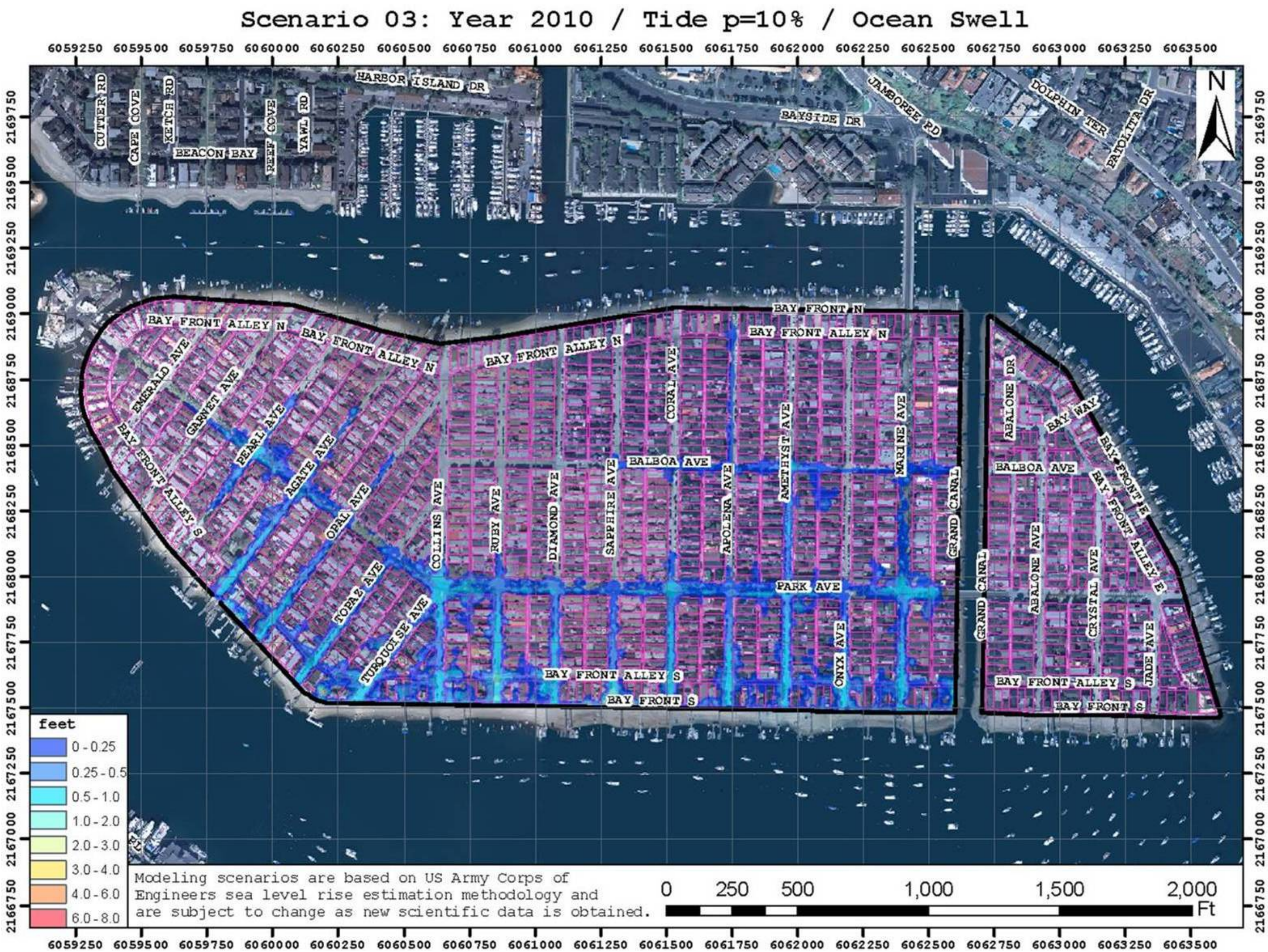

Figure 3.7 Model Prediction of Flood Extent and Flood Depth for Scenario 3

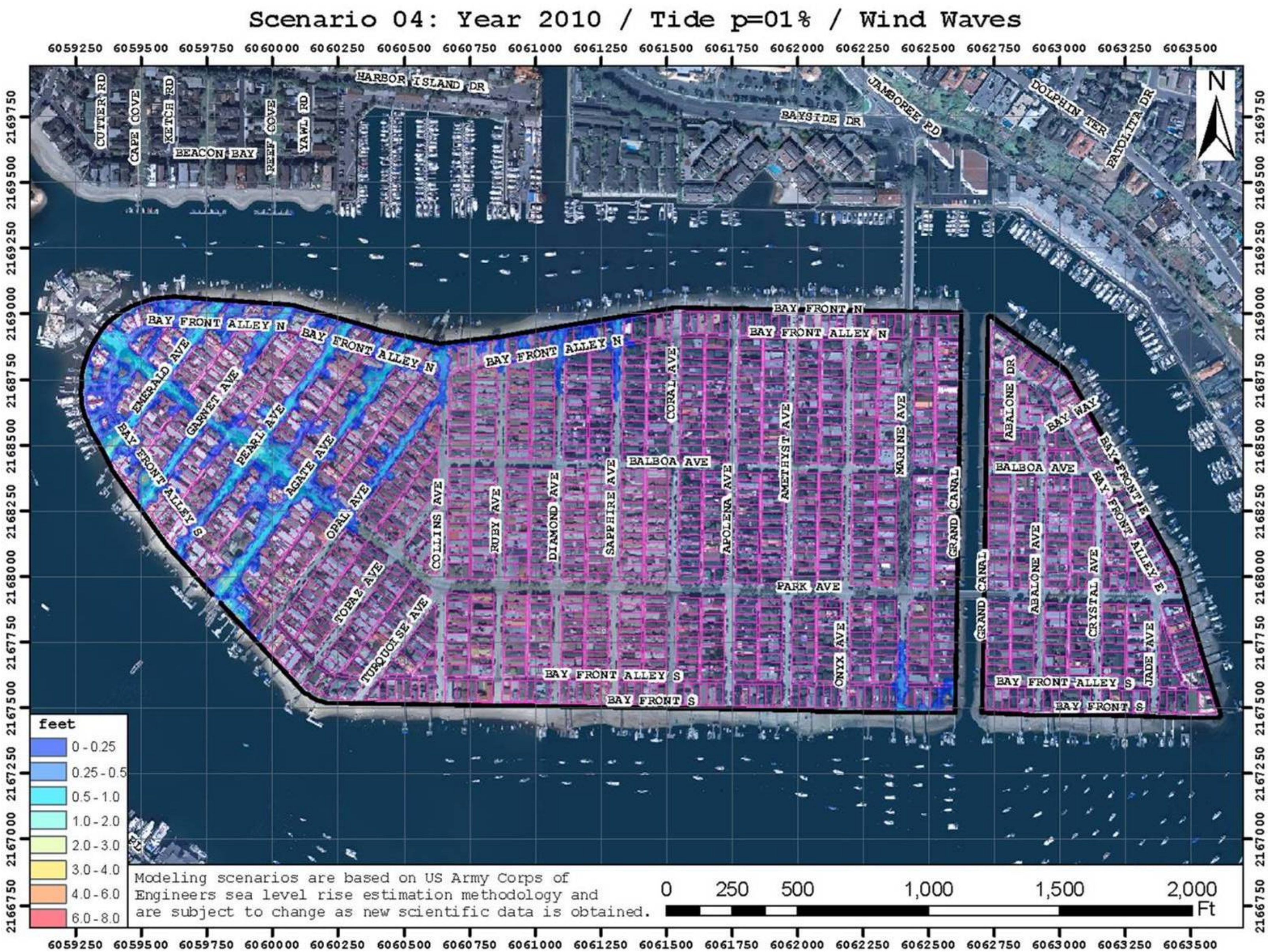

Figure 3.8 Model Prediction of Flood Extent and Flood Depth for Scenario 4

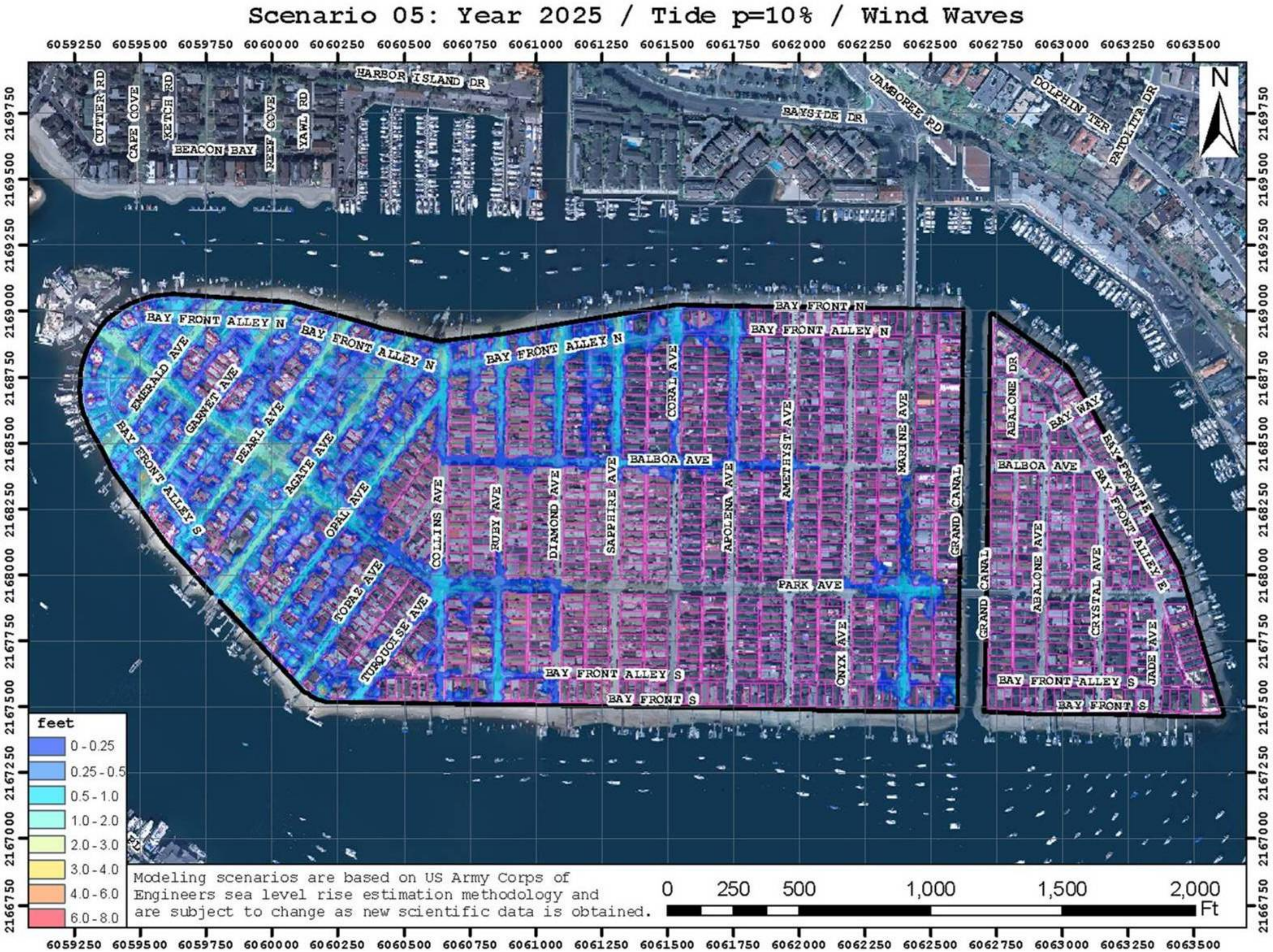

Figure 3.9 Model Prediction of Flood Extent and Flood Depth for Scenario 5

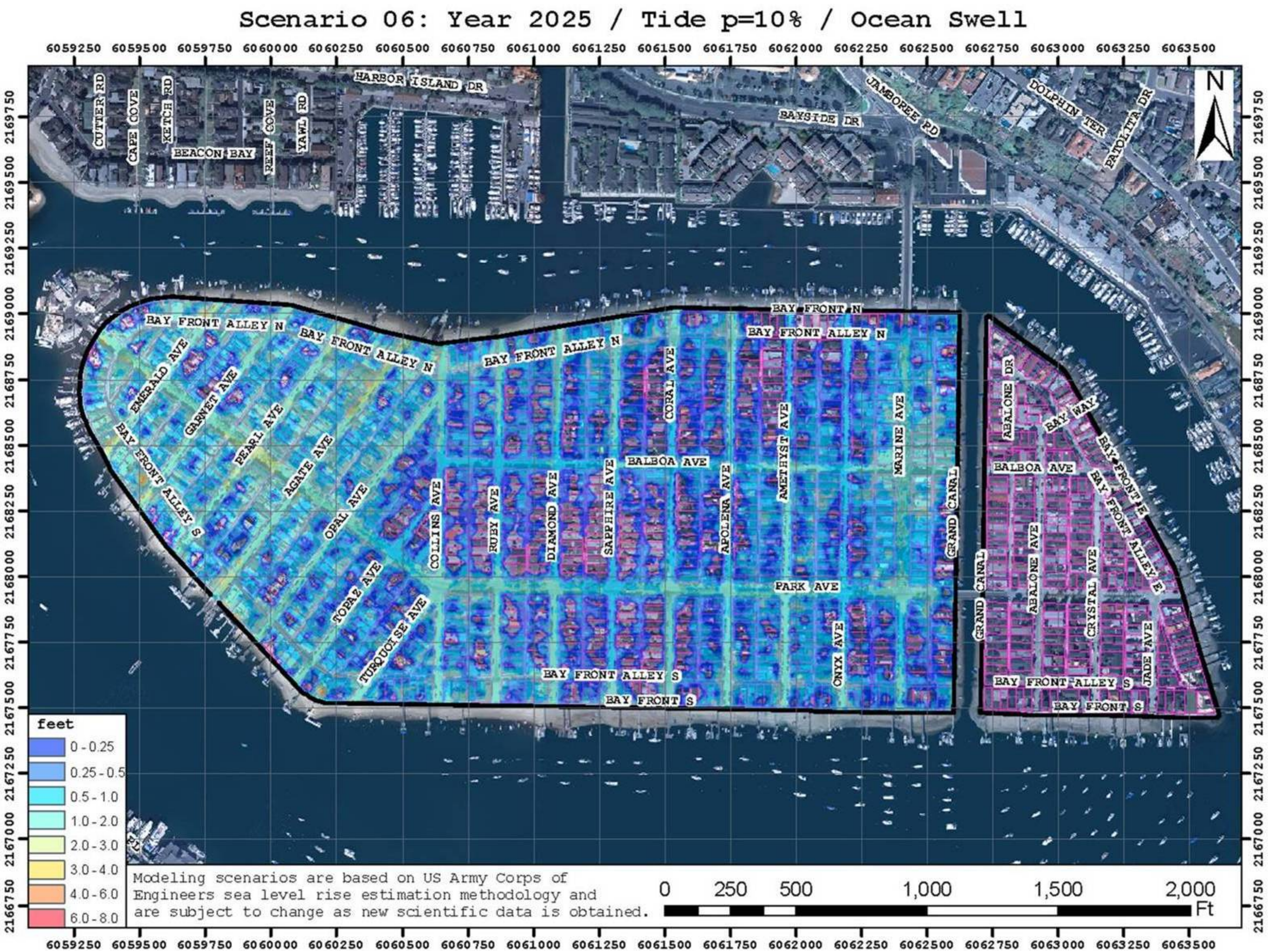

Figure 3.10 Model Prediction of Flood Extent and Flood Depth for Scenario 6

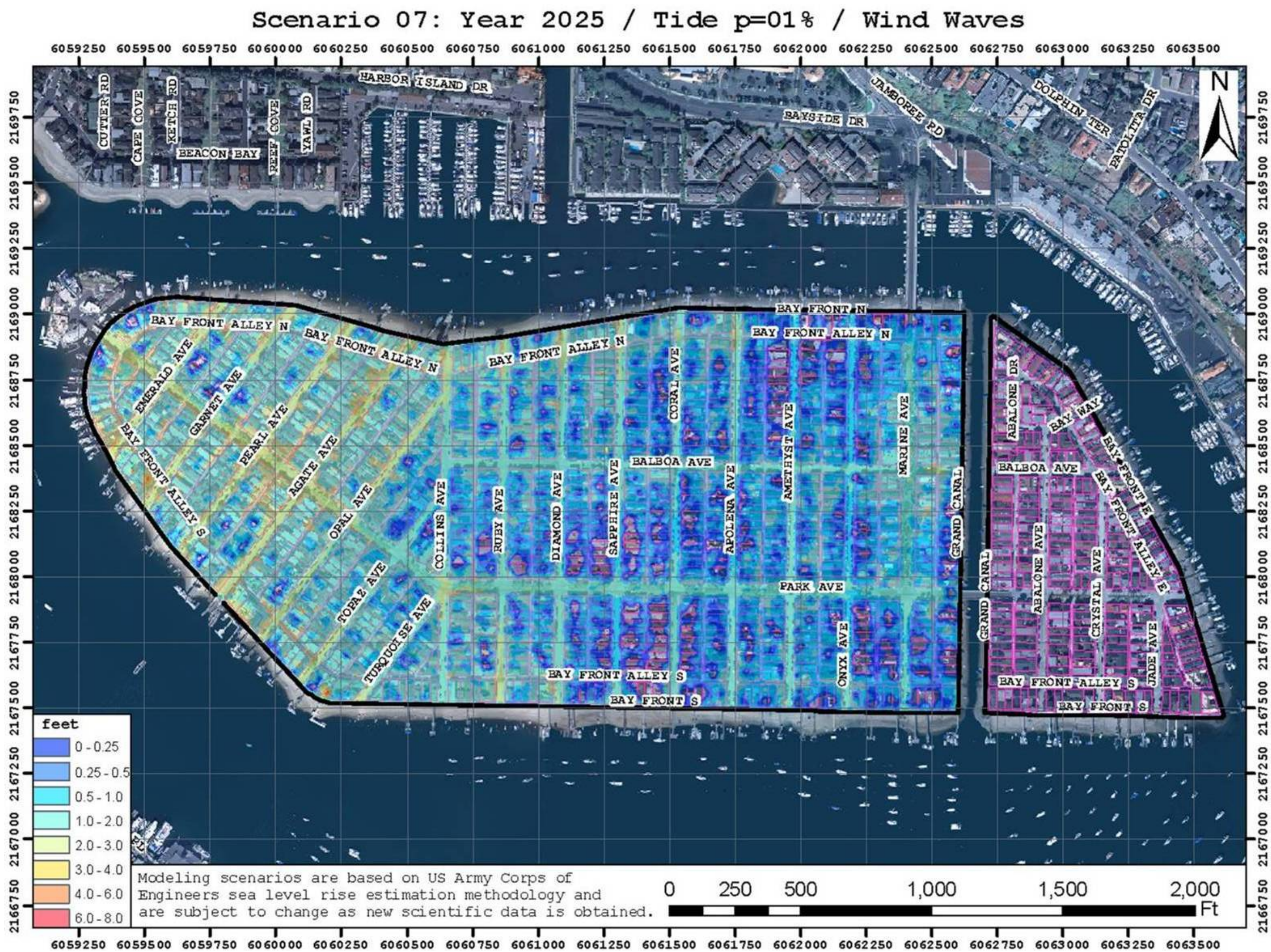

Figure 3.11 Model Prediction of Flood Extent and Flood Depth for Scenario 7

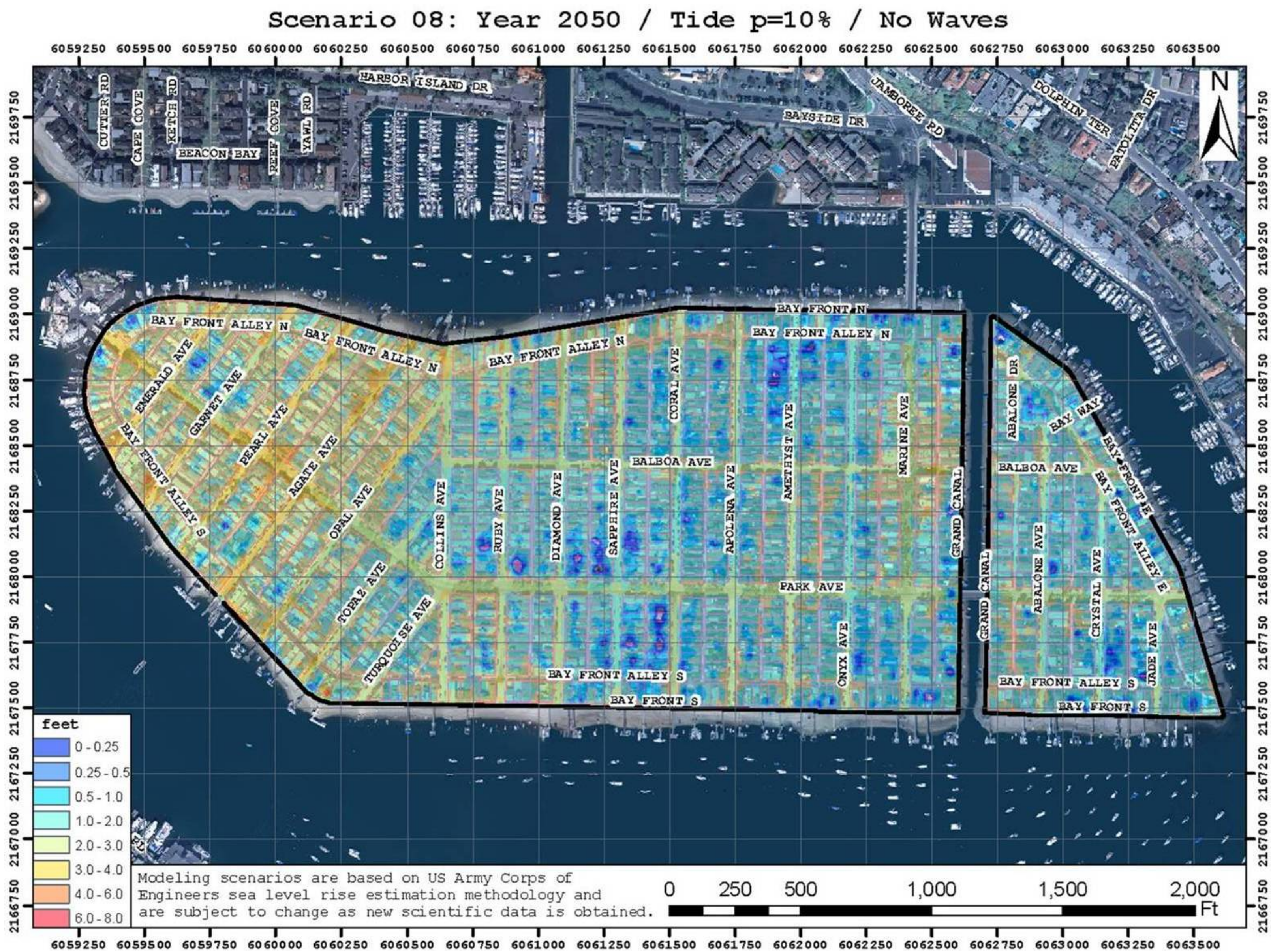

Figure 3.12 Model Prediction of Flood Extent and Flood Depth for Scenario 8

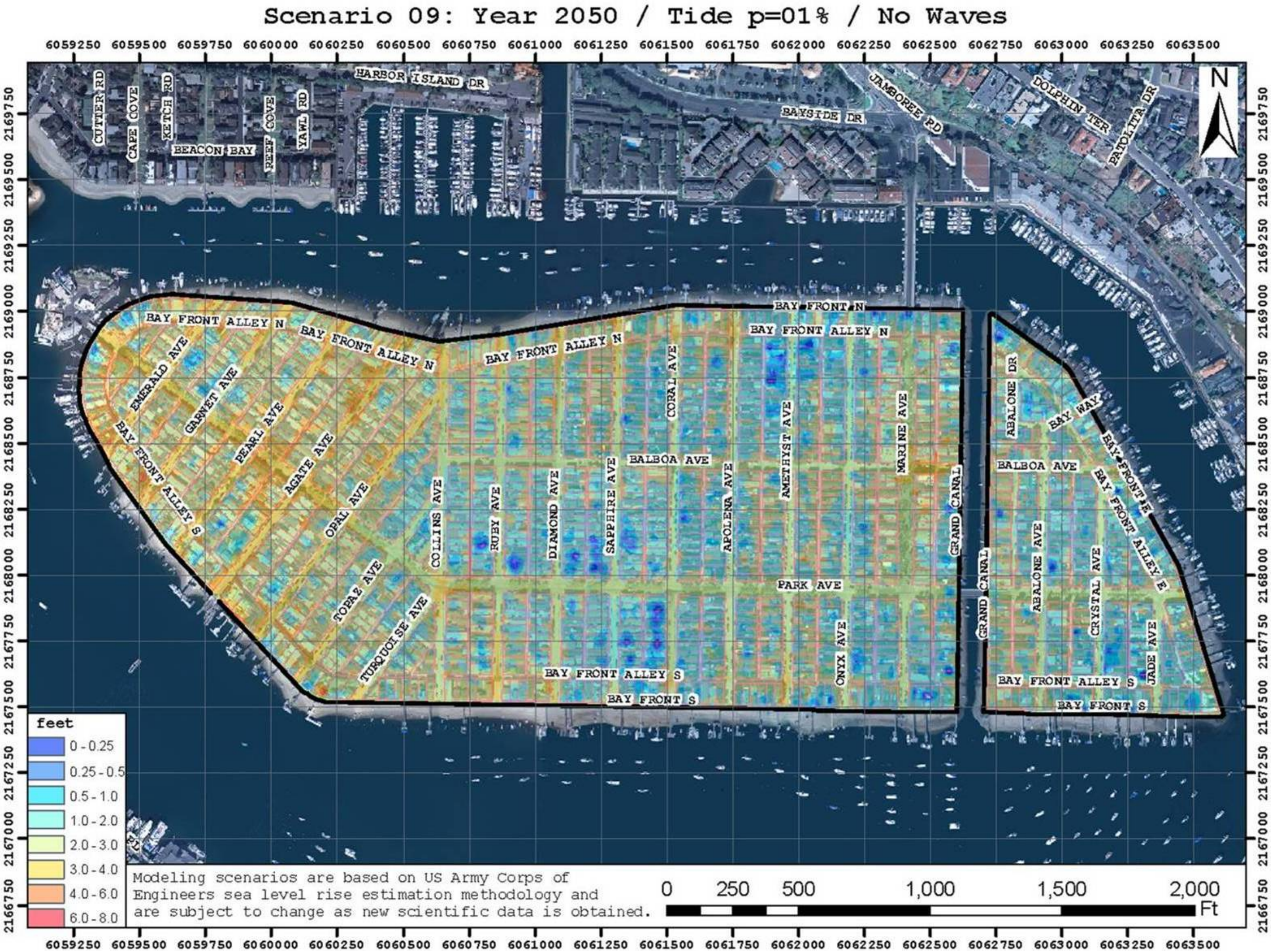

Figure 3.13 Model Prediction of Flood Extent and Flood Depth for Scenario 9

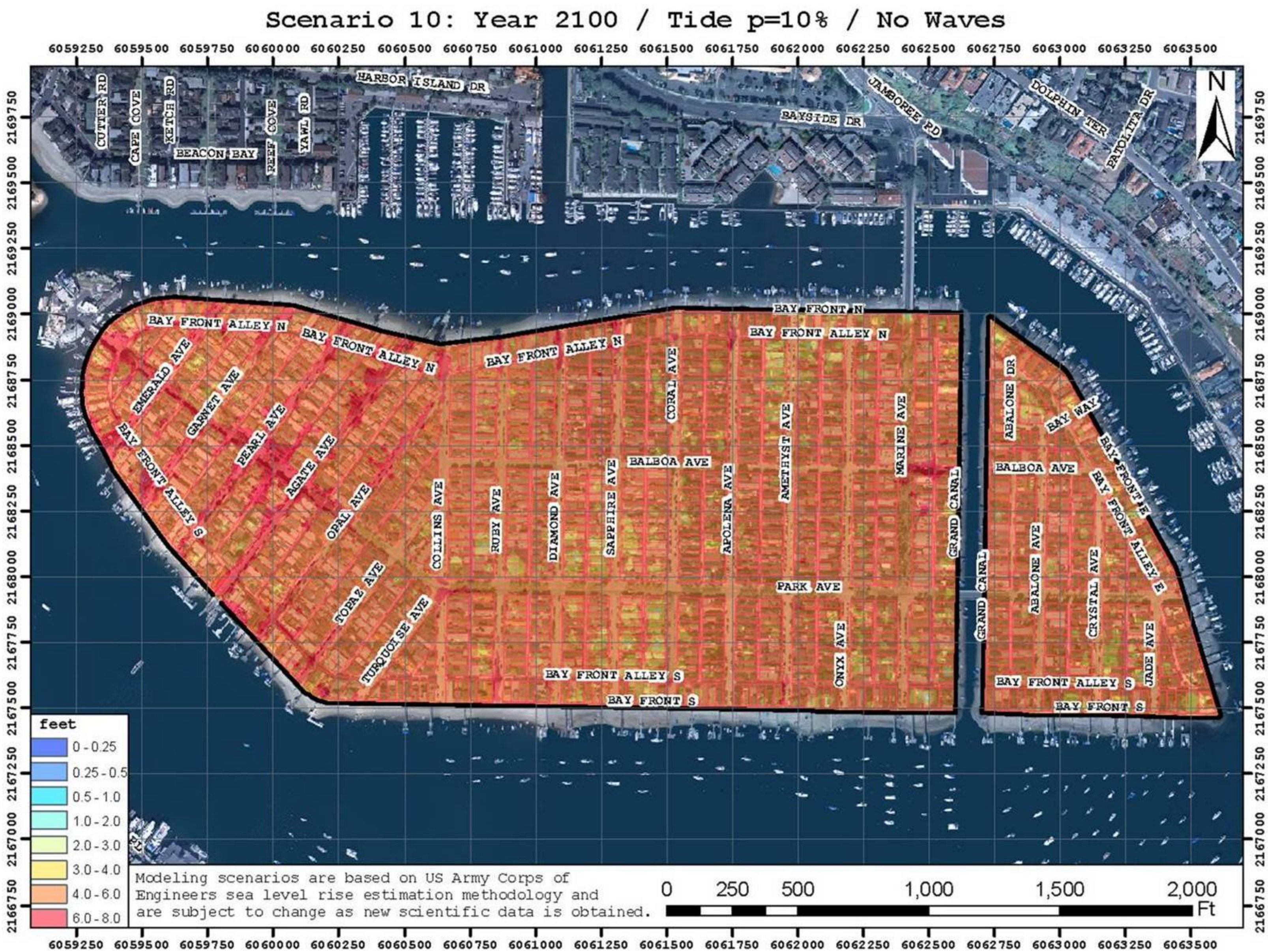

Figure 3.14 Model Prediction of Flood Extent and Flood Depth for Scenario 10

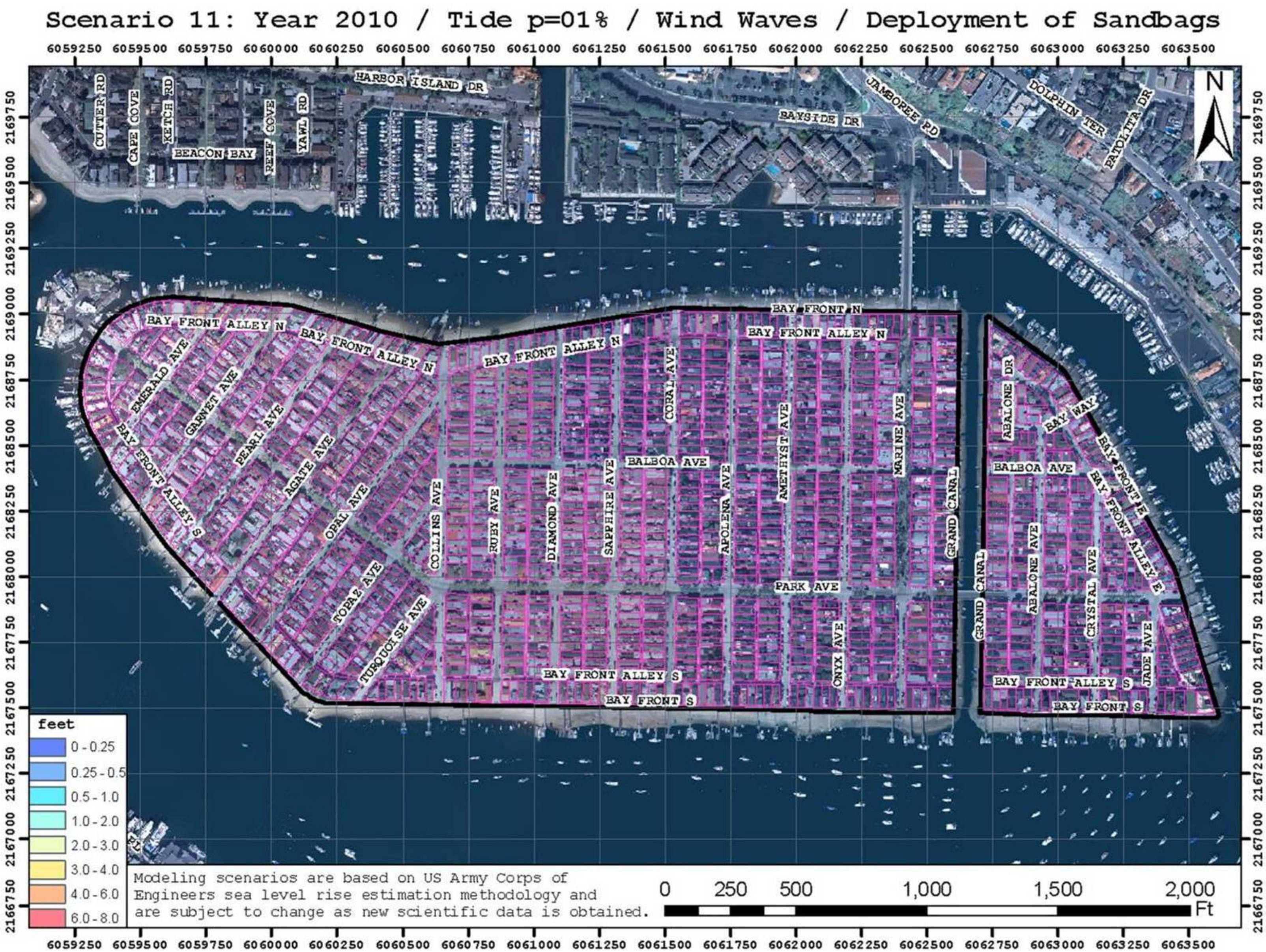

Figure 3.15 Model Prediction of Flood Extent and Flood Depth for Scenario 11

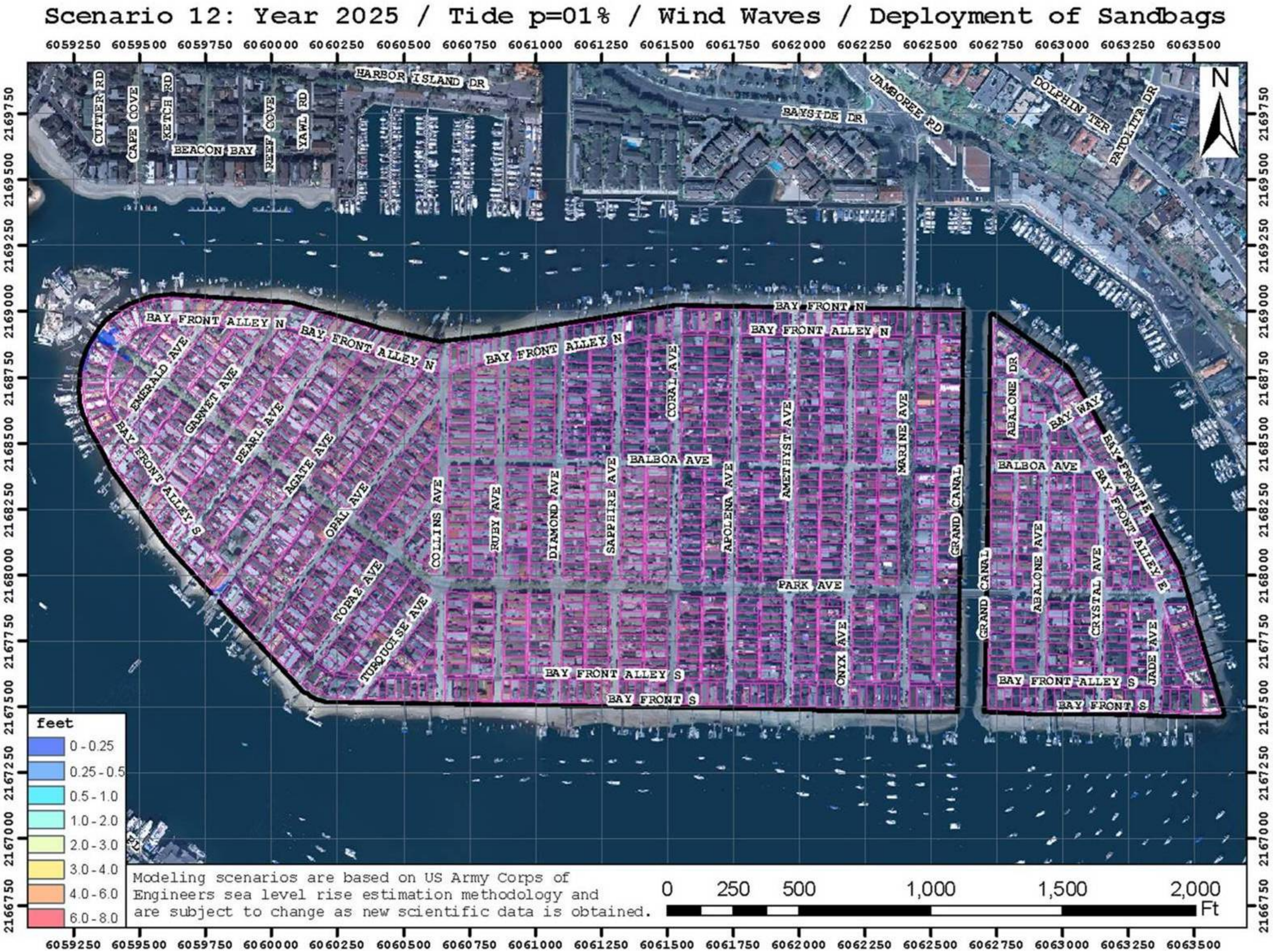

Figure 3.16 Model Prediction of Flood Extent and Flood Depth for Scenario 12

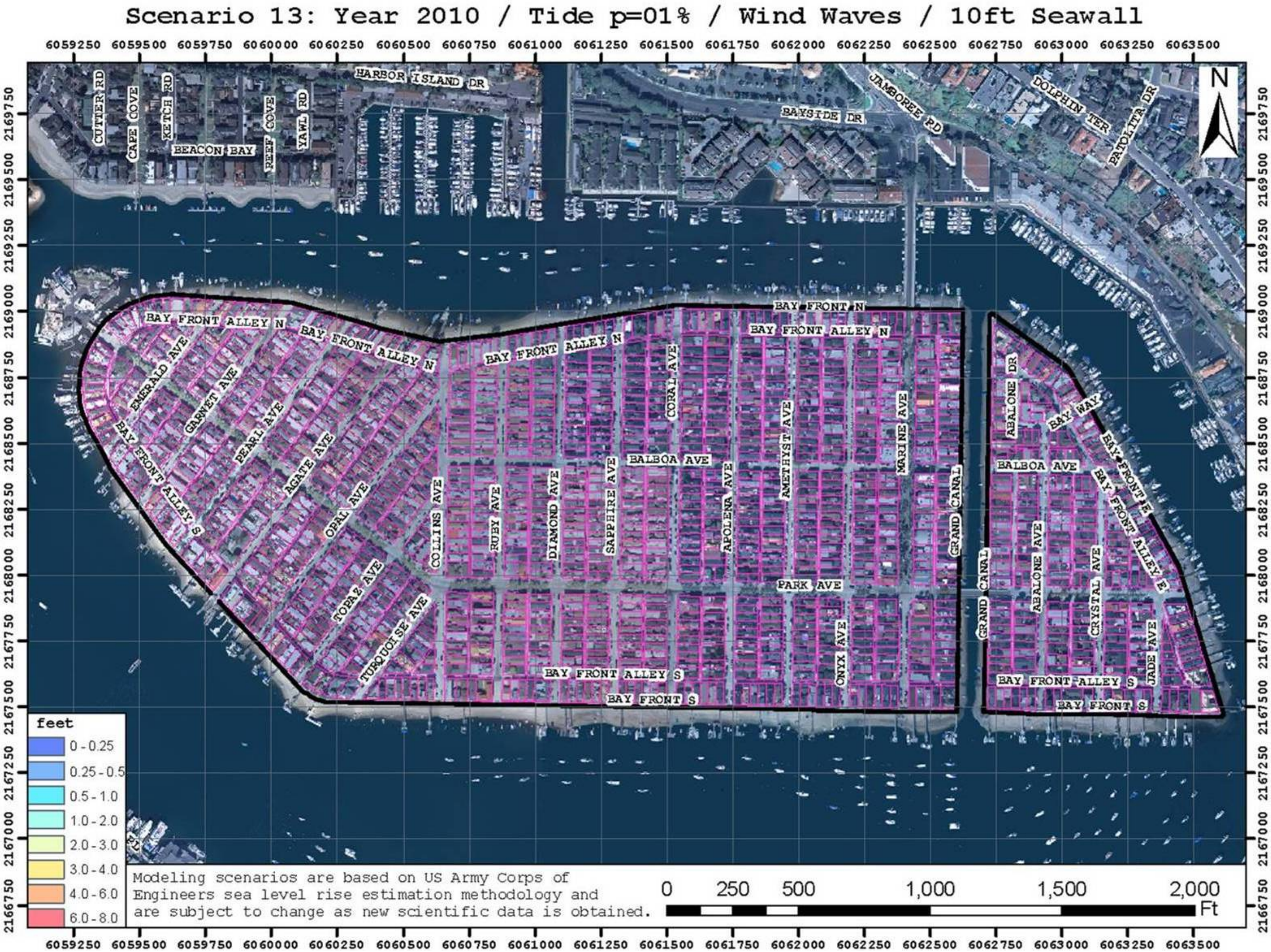

Figure 3.17 Model Prediction of Flood Extent and Flood Depth for Scenario 13

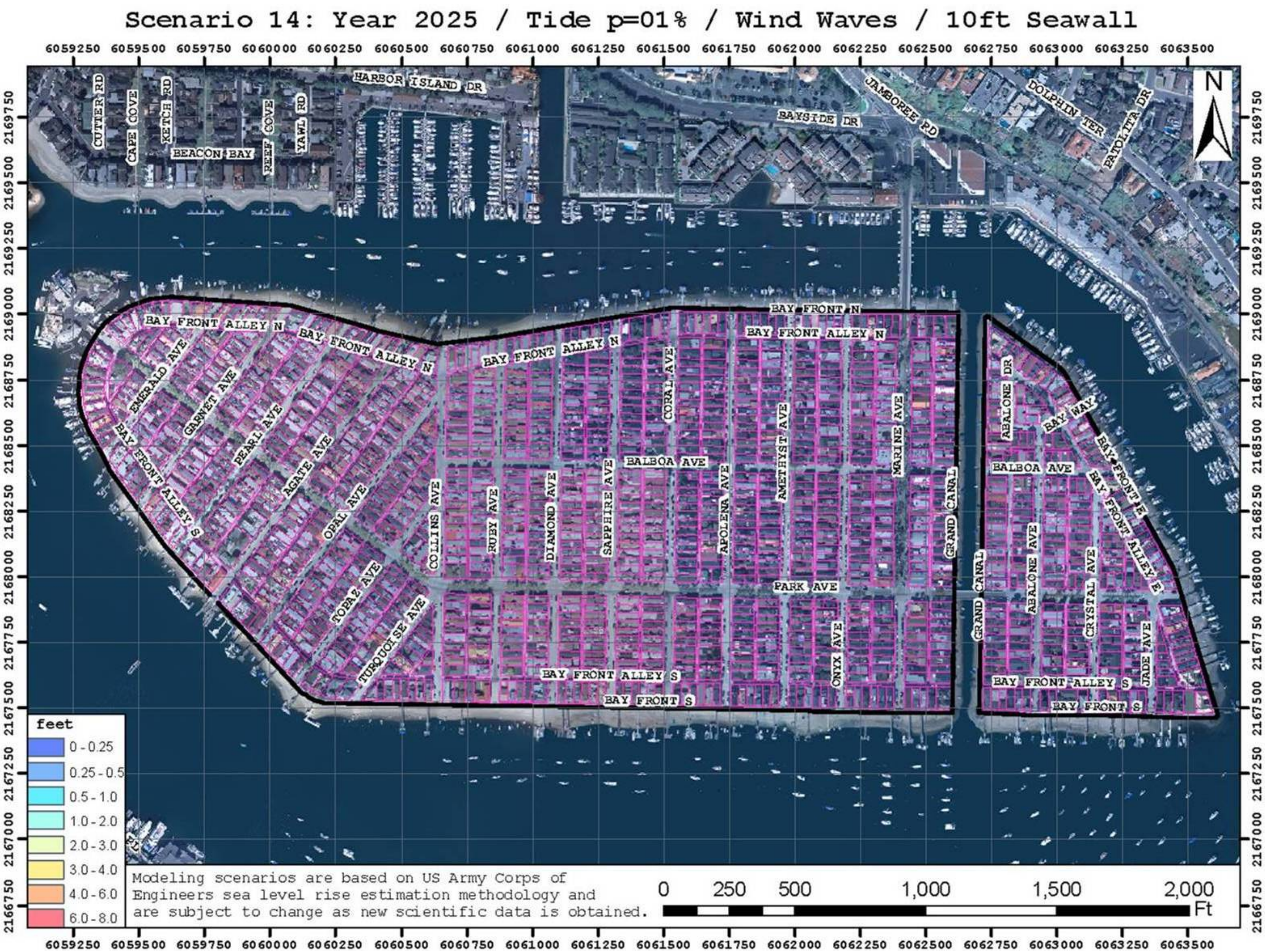

Figure 3.18 Model Prediction of Flood Extent and Flood Depth for Scenario 14

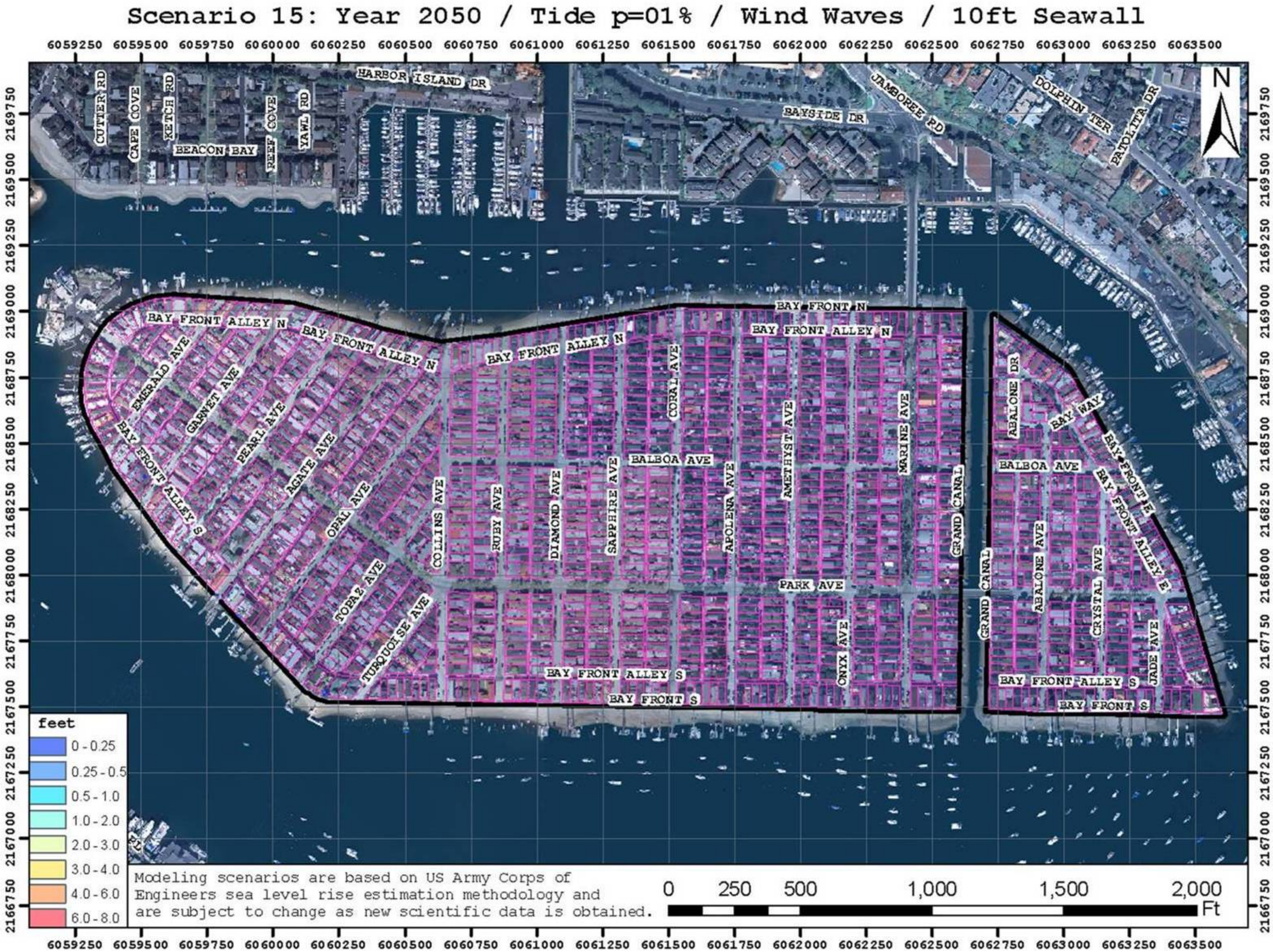

Figure 3.19 Model Prediction of Flood Extent and Flood Depth for Scenario 15

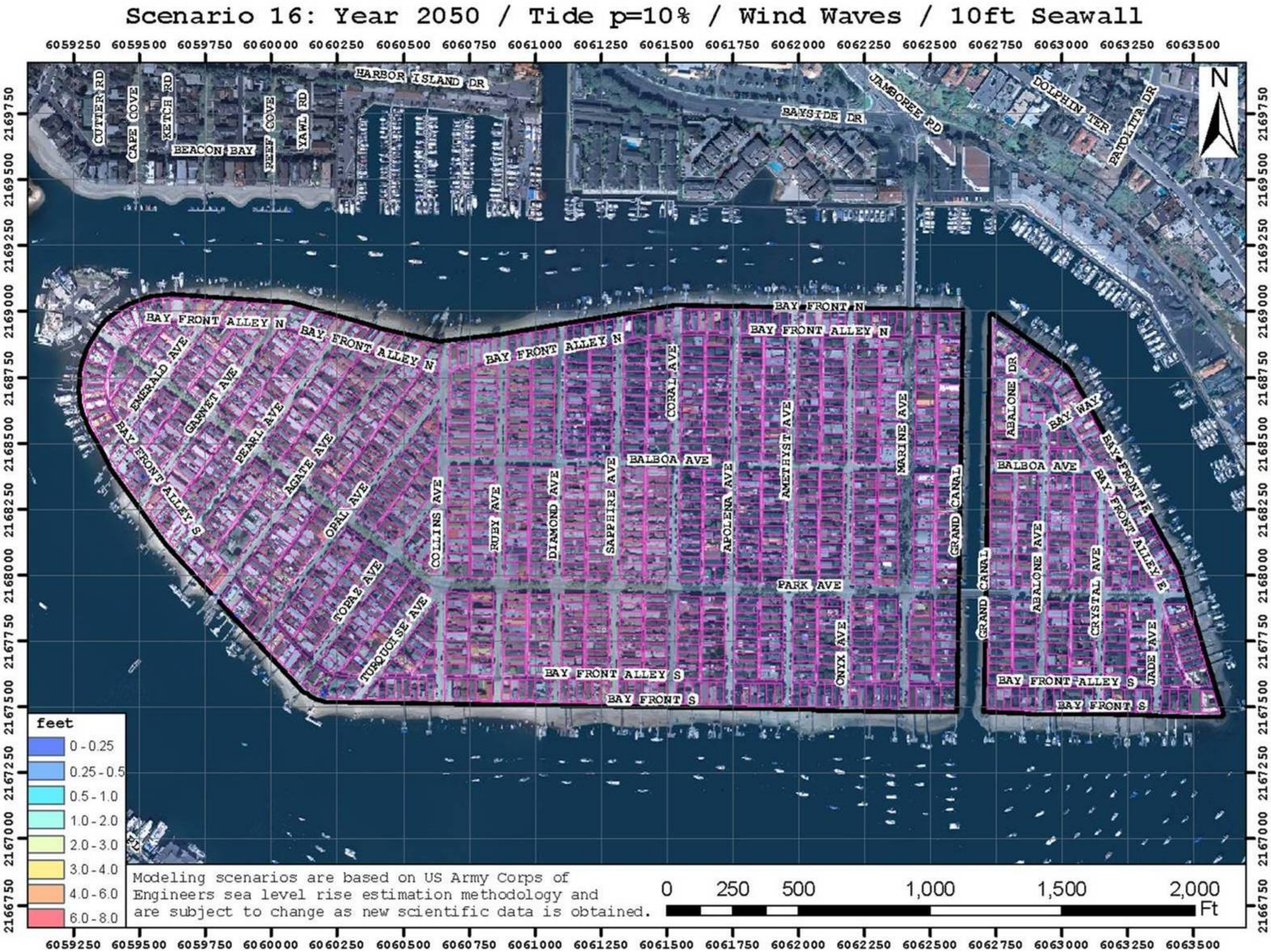

Figure 3.20 Model Prediction of Flood Extent and Flood Depth for Scenario 16

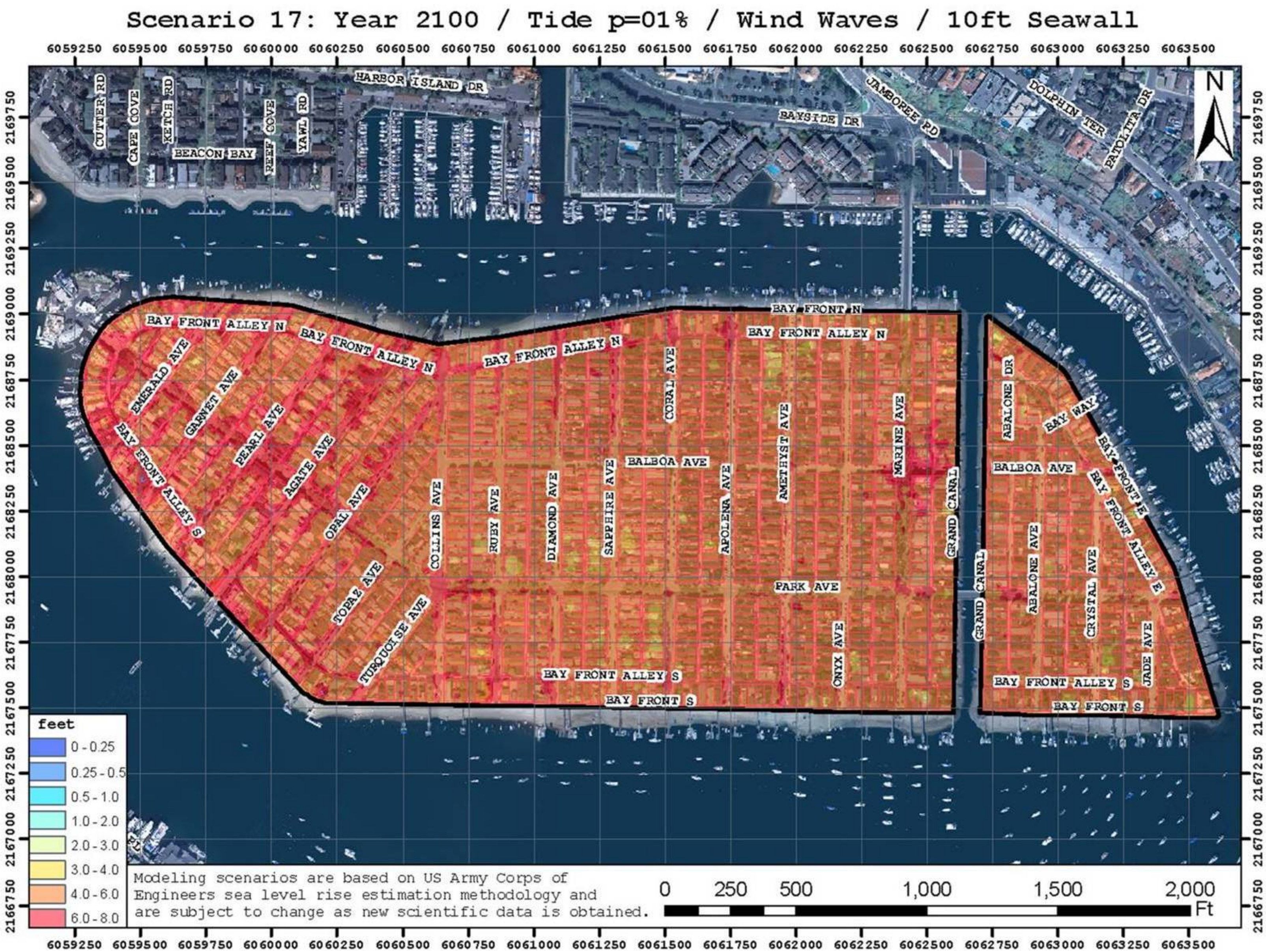

Figure 3.21 Model Prediction of Flood Extent and Flood Depth for Scenario 17

Scenarios 5 through 7 (see Figures 3.9 through 3.11) results indicate that by 2025, a majority of the parcels on Balboa Island will be at risk of flooding and impact to over 400 buildings is possible. Scenario 5 (Figure 3.9) shows overtopping of the southwest and northwest seawalls, and ponding west of Collins Avenue. Flood water depths exceeding 2 feet are predicted for Park Avenue near Pearl Avenue. Scenario 5 also shows overtopping along the southern seawall at Marine Avenue, and the spread of water north to Balboa Avenue with depths exceeding 0.5 feet.

Scenario 6 (Figure 3.10) shows more widespread flooding of Balboa Island than Scenario 5, which is attributed to wave overtopping all along the southern boundary of Balboa Island (South Bay Front). As in Scenario 4, flood water is predicted to progress north across the island and to gradually spread west towards lower topography. Depths exceeding 2 feet are predicted for Park Avenue, near Pearl Avenue, and depths exceeding 1 foot are predicted for Marine Avenue.

Scenario 7 (Figure 3.11) shows widespread flooding on Balboa Island from overtopping along the southwest, south, and northern seawalls. Depths exceeding 3 feet are predicted for Park Avenue, near Pearl Avenue, and depths exceeding 1.5 feet are predicted for Marine Avenue. Comparing Scenarios 6 and 7, Table 3.4 shows that the number of impacted parcels is about the same in both scenarios, however almost twice the number of buildings is impacted in Scenario 7. This difference can be attributed to the deeper flood depth predictions for Scenario 7. As shown in Table 3.4, the average flood depth for Scenario 7 is 1.16 feet compared to 0.79 feet for Scenario 6.

Flooding of Little Balboa Island is not predicted in Scenarios 5 through 7, suggesting a low risk of tide and wave-driven flooding through 2025.

Scenarios 8 and 9 (Figures 3.12 and 3.13) reveal the flood risk through 2050, and Scenario 10 reveals the flood risk predicted for 2100. The 2050 scenarios, even in the absence of waves, show complete flooding of both islands with impacts to most of the buildings. By 2100, all of the buildings will be at risk of impact based on Scenario 10 (Figure 3.14) results.

3.5.2 Sandbagging Scenarios

Scenarios 11 (Figure 3.15) shows no significant flood impacts to either island from 1% exceedance-probability tides and wind waves for Year 2010, and Scenario 12 (Figure 3.16) shows only a small flood zone near the bridge to Collins Island and an impact of 0 to 1 buildings for Year 2025. These results suggest that if the existing seawall were sandbagged to provide an additional six inches of flood protection, the flood risk to Balboa and Little Balboa Islands will be minimal through 2025.

3.5.3 10-foot (MLLW) Seawall Scenarios

Scenarios 13 through16 (Figures 3.17 through 3.20) shows no flooding from the combined effects of a 1% exceedance-probability tide and wind waves through 2050, assuming a new 9.8 ft NAVD88 (10 feet MLLW) seawall encircles both islands. However, Scenario 17 (Figure 3.21) shows complete inundation of the island from a 1 in 100 year (1%) event for Year 2100. A 1 in 10 year (10%) tide was not modeled, but total flooding can also be expected based on tide height data. Considering sea level projections shown in Figure 3.4, a 10 ft MLLW seawall is not likely to offer protection far beyond year 2050. Sea level rise projections are subject to change as new climate change data becomes available, so all flood risk projections for the future should be re-examined as better data becomes available.

4 SEAWALL CONDITION ASSESSMENT

4.1 Overview

This chapter provides a summary of existing seawall conditions and assessment of the useable life of the seawall based on site observations and review of available documents, reports and drawings. Detail of the assessment is provided in Appendix C. The review of older drawings and reports provide the historical background, as well as types and modifications of the seawalls on Balboa and Little Balboa Islands. Site observation included visual observations of the conditions of the current seawalls, and cataloguing of obstructions, modifications, utility lines, storm drains, and gangways and platforms as they relate to the seawalls. In addition to assessing the conditions of the seawall, special attention was given to the Balboa Island Ferry Boat Landing and its surroundings and the three bridges on the islands. If an extension or reconstruction of the existing seawalls are to be performed, these four locations would need to be modified to prevent them from acting as openings in an otherwise solid seawall protection around the islands.

4.2 Document Review

4.2.1 Record Drawings

Design drawings from 1929 and 1935 were reviewed. Drawings show that in 1929 over 60% of the walls along the Grand Canal, as well as the returns along the north beach of Balboa Island and the south beaches of both Balboa and Little Balboa Island, were replaced. These walls used a concrete soldier pile and concrete panel design in which soldier piles were driven to a depth of approximately -3.0 feet MLLW[4] along the length of the Grand Canal and to approximately -8.0 feet MLLW[5] at the corners as measured in 1929 and in accordance with City Drawing No. STD-115-L. The concrete wall panels span between the soldier piles. This particular wall relies on tie-backs comprised of 1-inch-diameter steel tie-rods attached to 9-foot-long by 10-inch-diameter timber pile deadmen (approximately 8.0 to 8.5 feet back from the face of the outside seawall) and a structural cap to counteract the overturning moment. The tie-rods are shown to be placed at every other soldier pile at 22 feet on-center.

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[4] MLLW is used in the Drawing No. STD-115-L but there is no information on the referenced tidal epoch. For the rest of the report, MLLW is referenced to NTDE 1983-2001.

[5] See footnote No. 4

Although the design drawings for the remaining and majority of the seawalls around Balboa Island were dated 1935, construction was not performed until 1938 as part of the National Recovery Act. These seawalls replaced older substandard walls and tied into the existing seawalls along the Grand Canal and along a 500-foot-long section on the western tip of Balboa Island. The new seawalls, as designed and constructed, used a concrete soldier pile and concrete panel design similar to the seawalls built along the Grand Canal in 1929. Soldier piles were driven to a depth of approximately -5.0 feet MLLW[6] as measured in 1938 and in accordance with City Drawing No. STD-115-L. However, the new design placed a tie-back at each soldier pile at 11.67 feet on-center, and according to the design, these tie-backs provide all the resistance to counteract overturning. These tie-backs are comprised of 1¼-inch-diameter steel tie-rods attached to 10-foot-long by 12-inch-diameter timber pile deadmen (approximately 8.0 to 8.5 feet back from the face of the outside seawall). The cap does not have a structural connection to the solider piles or to the concrete panels and relates to an architectural finish to the seawall structure. Since extending the cap is one of the major considerations to be assessed to mitigate flooding, the fact that there is either no, or a substandard connection, between the cap and the wall below for the majority of the Balboa seawall is considered significant.

It is assumed that the aforementioned 500-foot-long section at the western end of Balboa Island predates the 1935 seawall design drawings since the cap of this 500-foot-long seawall was slated to be replaced in said drawings. The 500-foot-long section of wall on the west end of Balboa Island is a sheet pile design similar to the wall surrounding Collins Island and is believed to have been constructed in the late 1920's or early 1930's. This design consists of interconnecting vertical concrete sheet piles and a structural concrete cap with tie-backs extending some distance behind the seawall. This section of seawall was upgraded with a rock revetment as a result of the findings in a 1985 report discussed later in this section.

Both sets of drawings show "square" symbols next to the rebar dimensions indicating that the rebar used was of the square, dimpled type, as opposed to deformed round bars currently used in modern construction. The distances between rebar and the outside face of concrete as shown on the drawings is narrow compared to a modern standard of 3.0 inches for construction in the marine environment. Furthermore, neither drawing construction notes nor specifications were available identifying concrete and/or rebar material type and strength. Based on common practice of design and construction in the late 1920's and 1930's, it is assumed that the existing seawall concrete is of lower strength compared to modern concrete mix designs.

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[6] See footnote No. 4

4.2.2 Reports and Studies

Cash & Associates (now part of URS) provided condition survey reports for the Balboa seawall to the City in 1985 and 2005. The 1985 report included a description of the unearthing of tie-rods at the west end of Balboa Island and at various locations around Little Balboa and discussion of opinions regarding seawall stability. Work performed for the 2005 report consisted of a visual inspection of the wall for signs of obvious distress as well as suggested repairs.

In all cases where tie-rods were uncovered, the rods did not have a corrosion protection system (coatings or wrappings) and all rods showed evidence of at least 50% loss of cross-sectional area, with several rods completely severed. Preliminary calculations noted that the walls around Balboa Island would be stable without tie-rods for gravity loads, if the exposed height of support (i.e., the difference in elevation between top of boardwalk and top of mudline) was no greater than 5 feet.

The 1985 Report prompted the City to stabilize the toe of the seawall at four critical locations around the Island by constructing rock revetments as shown in Figure 4.1. Observations also noted a separate seawall stabilization project performed along the seawall east of the Balboa Island Ferry Boat Landing. Earth anchors were installed, as shown in Figure 4.2, and a submerged concrete block revetment was placed at the toe of the seawall.

Figure 4.1 Rock Revetment Stabilization at Western End of Balboa Island

Figure 4.2 Earth Anchors and Concrete Block Revetment (Submerged) at Balboa Island Ferry Boat Landing

The City also responded by pursuing a repair and maintenance program. Most of the noted distresses in the seawall cap and soldier piles were repaired. An example of a typical repair is shown in Figure 4.3.

Figure 4.3 Use of Elastomeric Filler to Seal Cracks to Prevent Seawater Intrusion

4.3 Site Observation

In addition to the seawall and boardwalk elevation surveys described in Chapter 2, a visual survey of Balboa Island was conducted on May 25, and June 6, 2010 to assess the condition of the seawall and to examine Balboa Island Ferry Boat Landing and three bridges of concern. The findings are presented in the following section.

4.3.1 Seawall Cap Visual Survey

During the visual survey of the seawall, seawall cap extensions were observed in the Little Balboa Island. The extension raises the top of wall elevation by between 6 and 12 inches depending on location around Little Balboa. An example of this cap extension is shown in Figure 4.4. Although this extension provides a defense against high water events, the limited remaining useful life and the existing condition of the underlying seawall make further extensions questionable.

Figure 4.4 Little Balboa Seawall Cap Extension

The visual survey also found universal distresses in the cap, specifically multiple cracks, coinciding with the locations of the soldier piles. The development of these cracks at the specific locations of the soldier piles is likely due to a reduced structural cross-section and a concentration of load ultimately relating to concrete stress. Despite a concentration of cracks at the soldier piles, cracking also can be found at many locations along the concrete cap including the structural cap along the Grand Canal. Coupled with similar cracks found on the exposed portions of the soldier piles and panels, the evidence portends to universal distress throughout the seawall. The shot-creted piles and panels along the Grand Canal walls (see Figure 4.5) are of particular concern because the condition of the original concrete is hidden by the shot-crete repairs. Despite repairs to cracks over the years, cracks are still prevalent in the seawall cap (see Figures 4.6 and 4.7).

Figure 4.5 Shot-crete on Grand Canal Seawall

Figure 4.6 Typical Crack and Spall Repairs

Figure 4.7 Crack Repairs with Corroding Rebar

Another common and continuous distress point along the seawall is parallel to and approximately 2 to 4 inches above the boardwalk. As part of the drainage mitigation project performed in the 1980's, the boardwalk was lowered several inches from its original design elevation in order to facilitate drainage away from private properties. This placed the boardwalk below the bottom of the existing cap and it is assumed a patch was done to fill the gap between the boardwalk and the cap. Therefore, the continuous crack appears to be non-structural and related to the patchwork as shown in Figure 4.8. This assumption should be confirmed as part of a subsequent study.

Figure 4.8 Sidewalk Separation from Seawall

In addition to visual observations, we utilized what is known as a "chain-drag" test by impacting the concrete with a heavy metal object to detect holidays (voids caused by concrete chemical reactions or rebar corrosion) and de-laminations in the structure. A hollow sound, typically associated with de-laminations and holidays was heard throughout the cap on both islands, but were particularly evident along the portion of the Grand Canal seawall constructed in 1929. Weathering, settling, and seismic events coupled with porous concrete elements have allowed seawater to seep into the seawall and corrode the rebar within. As the rebar corrodes, the rust expands putting pressure on the concrete from within causing voids and separation, or de-lamination of the concrete from the rebar, thus weakening the structure. These actions lead to cracks and breaking off of chunks of concrete, known as spalling.

Although many major cracks and spalls have been repaired over the past several years by the City, the "chain-drag" test found additional locations needing repair. The results were noted in the field survey, and should be confirmed as part of a subsequent investigation through the use of more invasive testing procedures.

Storm drain outlets that drain through the seawall and into the Bay (see Figure 4.9) have existed for decades at the street ends of Balboa Island, based on the 1935 record drawings and the recent visual survey. In the 1980's as part of the boardwalk reconstruction, a storm water drainage system with 4- to 6-inch diameter drains was constructed landward of and parallel to the seawall. These drains connect to the City's storm drain system outlets at the street ends and were designed to keep water from ponding along the seawall and from spilling onto private property.

This drainage system would not have functioned without the installation of gate valves at all storm water outlets on Balboa Island, as shown in Figures 4.10 and 4.11. These valves are closed during high water events to prevent seawater from flooding low lying spots on the Island. Prior to the valve installation, the storm drain outlets were a major source of flooding during high water events.

Figure 4.9 Storm Drain Outlet Through Seawall

Figure 4.10 Hand-Operated Gate Valve in Storm Drain Manhole

Figure 4.11 Actuated Gate Valve in Storm Drain Vault

4.3.2 Bridges and Ferry Boat Landing

In addition to the visual survey and measurements of the Balboa Island seawall, special attention was given to the Balboa Island Ferry Boat Landing and its surroundings and the three bridges on the Island - the Marine Avenue Bridge, the Park Avenue Bridge, and the Collins Island Bridge. If an extension or reconstruction of the existing seawall is to be performed, these four areas need to be modified to prevent them from acting as openings in an otherwise solid seawall fortification around the Island. Any openings in the bridges that would allow seawater to seep onto the roadway should be sealed, and waterproofing should be performed on surfaces exposed to rising sea level. Any reconstruction or modification of the existing bridges should include modifications to ensure a waterproof structure. The goal is to allow water to escape but not to enter the fortified Island.

<u>Bridges</u>

The Marine and Park Avenue bridges have solid concrete parapet (side) walls that tie into the existing seawall (see Figure 4.12) and have peak roadway elevations about the current Base Flood Elevation of 9.0 feet NAVD88 (9.18 feet MLLW). The Collins Island Bridge cuts through the seawall, has an open metal rail wall (see Figure 4.13) and a peak roadway elevation of approximately 7.3 feet NAVD88 (7.5 feet MLLW), which is below BFE. This bridge will require thorough waterproofing as well as solid concrete parapet (side) walls sealed to the seawall to prevent it from becoming a source of flooding. The seawalls on Collins Island will need to be retrofitted or replaced in concert with Balboa Island, to prevent flooding of that island and to prevent seawater from flanking the Balboa Island barriers.

Figure 4.12 Park Avenue Bridge Interface at Big Balboa Seawall

Figure 4.13 Collins Island Bridge Interface at Seawall Abutment

<u>*Balboa Island Ferry Boat Landing*</u>

The approach to the Balboa Island Ferry Boat Landing also breaches the seawall, as shown in Figure 4.14, allowing a path for water to enter the Island. In addition, the Ferry Boat Launch Ramp is particularly low in its current configuration as shown in Figure 4.15. The approach elevation is 6.6 feet NAVD88 (6.8 feet MLLW) at the seawall opening and 7.0 feet NAVD88 (7.2 feet MLLW) at the ramp leading to the ferry boat dock. During high water events, the launch ramp must be shut-down until water recedes.

Figure 4.14 Balboa Island Ferry Boat Landing Approach

Figure 4.15 Balboa Island Ferry Boat Landing as Viewed from Side

If the dock and launch ramp are left in their basic current location, a major effort would be required to raise the launch ramp and the approach street, Agate Avenue. This would impact adjacent buildings and the intersecting boardwalk. Two options of raising the launch ramps are provided in Chapter 5.

4.4 Predicted Lifespan and Remaining Useful Life of Existing Seawalls

The lifespan of structural concrete depends on many factors including the design, construction, quality control and environmental conditions of the structure. Based on a review of the construction documents and an understanding of design and construction practices in the 1920's and 1930's, the lifespan of a reinforced concrete structure would be judged by today's standards, to have a realistic lifespan of between 75 to 100 years.

The condition of the Balboa seawall is somewhat better than the condition of the Little Balboa seawall. Little Balboa, which is aligned with the main channel and harbor entrance, is particularly susceptible to ocean swells. The long fetch also allows for larger wind waves to impact Little Balboa seawalls during storm events. Balboa is somewhat more sheltered and has a shorter fetch, except for its exposed western tip.

The sections of seawall supporting greater gravity loads due to erosion and dredging (i.e., greater exposed seawall height) and exposed to greater wave and swell activity are expected to have a lifespan closer to the lower end of the range, or between 75 and 90 years. Those sections of the seawall protected by beaches and fronting calmer waters are expected to have a lifespan closer to the upper end of the range, or between 85 and 100 years. Since the seawalls are in a corrosive marine environment, none are expected to have a lifespan exceeding much more than 100 years.

In summary, since most of the seawalls on Balboa and Little Balboa Islands were constructed in the 1920s and 1930s, it is estimated that the remaining useful life of the seawalls is between 10 and 25 years, depending on location.

5 PROPOSED SEAWALL REPAIR AND REPLACEMENT ALTERNATIVES AND INUNDATION SOLUTIONS

5.1 Seawall

Given the existing seawall's condition and remaining useful life and an understanding of construction techniques used in the late 1920's and 1930's, major seawall retrofit does not appear to be a feasible option. Installation of earth anchors and rock revetments may provide an increase in overturning resistance and toe support, respectively. However, for most of the seawalls, the primary concern is degradation of the concrete and rebar within the structure. Therefore, the following sections provide interim short-term alternatives to prevent flooding of Balboa Island and long-term seawall replacement and extension options.

5.1.1 Cap Replacement/Extension Alternatives

In the interim, prior to full replacement of the Island seawalls, the Balboa Island seawalls may be extended by an incremental amount of 6 to 8 inches to prevent overtopping from waves during high water levels. Based on the existing seawall age, predicted lifespan, condition, and design, two alternatives were developed for increasing the height of the existing seawall.

Alternative 1: Replace the existing cap with a taller cap that is mechanically attached to the soldier piles and concrete panels using dowels.

Alternative 2: Extend the existing cap to a calculated height that will not undermine the seawall or seawall cap structural integrity. This extension may consist of either:

- Option 1 – Mechanically connecting a reinforced concrete extension to the existing seawall cap using dowels,
- Option 2 – Deploying polypropylene sandbags on the seawall cap and other floodwater entry points (i.e., bridges and ferry boat landing) during high water events, or
- Option 3 – Placing geotextile (Longard) bags or tubes on the seawall cap and other floodwater entry points until the seawalls are replaced.

If a mechanical extension (Alternative 2, Option 1) of the seawall cap is chosen, there is precedent for an extension of up to 8 inches, since the Little Balboa seawall was previously extended by this amount. This extension is referred to as a mechanical extension because it utilizes rebar dowels to mechanically connect the new extension to the existing cap. First, the top surface of the existing cap would be roughened. Then, the existing cap would be drilled at distances and to depths to be determined pending tests of the existing cap and a decision on the final extension height. Rebar dowels would epoxy-set in these holes. A reinforced concrete extension would then be built on top of the existing cap incorporating the rebar dowels. The roughened surface of the existing cap would allow for the new concrete to better bind with the original concrete. Any extension beyond 6 to 8 inches may compromise the structural integrity of the Balboa Island seawall cap. For this reason, any mechanical extension of the already-extended Little Balboa seawall should include demolition of the existing extension and reconstruction of a new extension.

The other two extension alternative options use sandbags to extend the protective height of the seawall. Sandbags are provided as options since the Balboa Island seawalls are nearing the end of the useful life and are recommended for replacement between 10 and 25 years. In addition, sandbags are commonly used to protect against flooding in all kinds of weather and water conditions. Typical sandbags (Alternative 2, Option 2) consist of 2-foot-long polypropylene bags filled with sand and tied at one end. Although these bags may be left in place for extended durations, they are primarily designed to be deployed when needed. Two stacks of sandbags will extend the seawall by about 6 inches, providing adequate flood protection for Balboa Island for the next 10 to 25 years based on the flood modeling results described in Chapter 3.

The other sandbag-type option (Alternative 2, Option 3) consists of geotextile (Longard) bags or tubes. An example of using geotextile bags for flood protection is shown in Figure 5.1. These geotextile bags are made of thicker and stronger material than the traditional polypropylene sandbag (Alternative 2, Option 2). These bags can be left in place until the seawalls are replaced, and given their thickness, only one bag will be needed to meet the required height. Just like any other plastic material, ultraviolet (UV) degradation is a concern. The use of UV inhibitors in the geotextile material or the placement of a protective tarp overtop the geotextile bags may be sufficient to shield the bags from UV light.

Figure 5.1 Geotextile Sandbags Used as a Seawall Along a Beach

5.1.2 New Seawall Options

To increase the seawall height beyond a 6- to 8-inch extension, the seawall will have to be replaced. Two conceptual options for replacement of the seawall were developed. The two options differ in the seawall design but share a similar implementation plan with the five phases graphically illustrated in Figure 5.2.

Phase 1: Short-term augmentation of the seawall by 6 to 8 inches as discussed in the last section.

Phase 2: Begin replacement of the existing seawalls between 10 to 25 years of baseline year 2010. This initial phase will consist of a seawall constructed to 9.8 feet NAVD88 (10 feet MLLW), which would place the new wall 0.8 foot above the current Base Flood Elevation height of 9.0 feet NAVD88 (9.2 feet MLLW) for Balboa Island.

Phase 3: If necessary, extend the seawalls by an additional several feet up to an elevation of 14.0 feet NAVD88 (14.2 feet MLLW) within 40 to 50 years from baseline year 2010, or as required by rising sea levels.

Phase 4: If necessary, construct a deep well groundwater dewatering system to protect the Island from subsequent high water tables associated with high water levels. If sea levels rise as predicted, then dewatering will be required within 40 to 50 years of baseline year 2010.

Phase 5: Establish appropriate minimum lowest floor elevation in accordance with the federal Base Flood Elevation (BFE). The City must continue to adhere to this requirement since Balboa Island is in a Flood Insurance Rate Map (FIRM) Zone A, which is considered a Special Flood Hazard Area. If sea levels rise as predicted, then the BFE may be higher in year 2100 compared to the current BFE of 9.0 feet NAVD88 (9.2 feet MLLW).

The implementation of Phases 3 and 4, which are common to both options, are discussed in Section 5.4. The two seawall replacement options outlined below include the seawall replacement and the future cap extension.

Replacement Option 1 - "H" Piles with Reinforced Concrete Wall (Lag) Panels

Install steel "H" soldier piles at approximately 10 feet on center. Insert prestressed reinforced concrete wall (lag) panels (similar to the existing wall) in a tongue-and-groove fashion in the space between soldier piles. Cast a reinforced concrete structural cap, designed to be extended in the future if and when required, on top of this assembly. This conceptual option is shown in Figure 5.3. An example of this kind of reinforced concrete wall is shown in Figure 5.4.

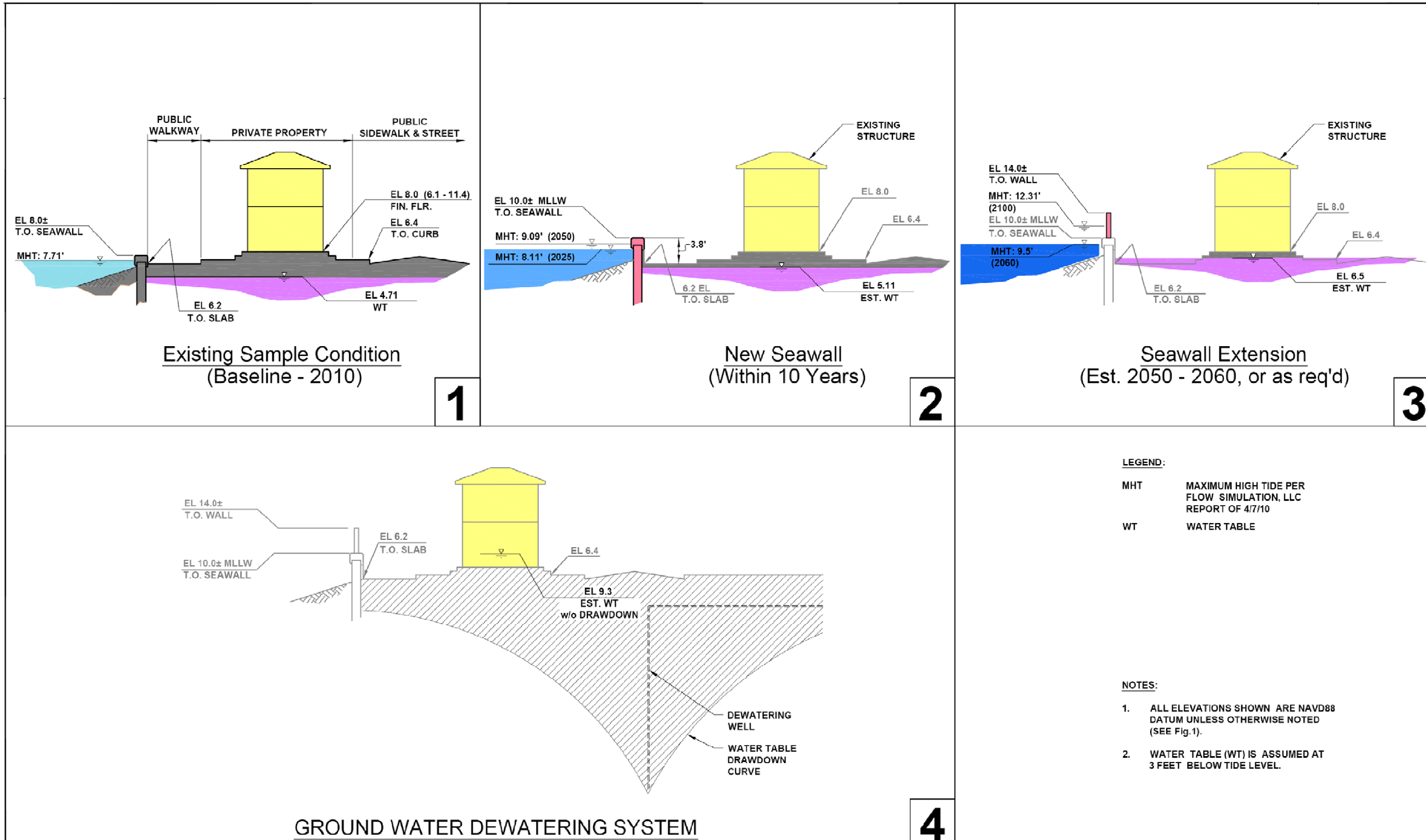


Figure 5.2 Conceptual Seawall Replacement Implementation Plan

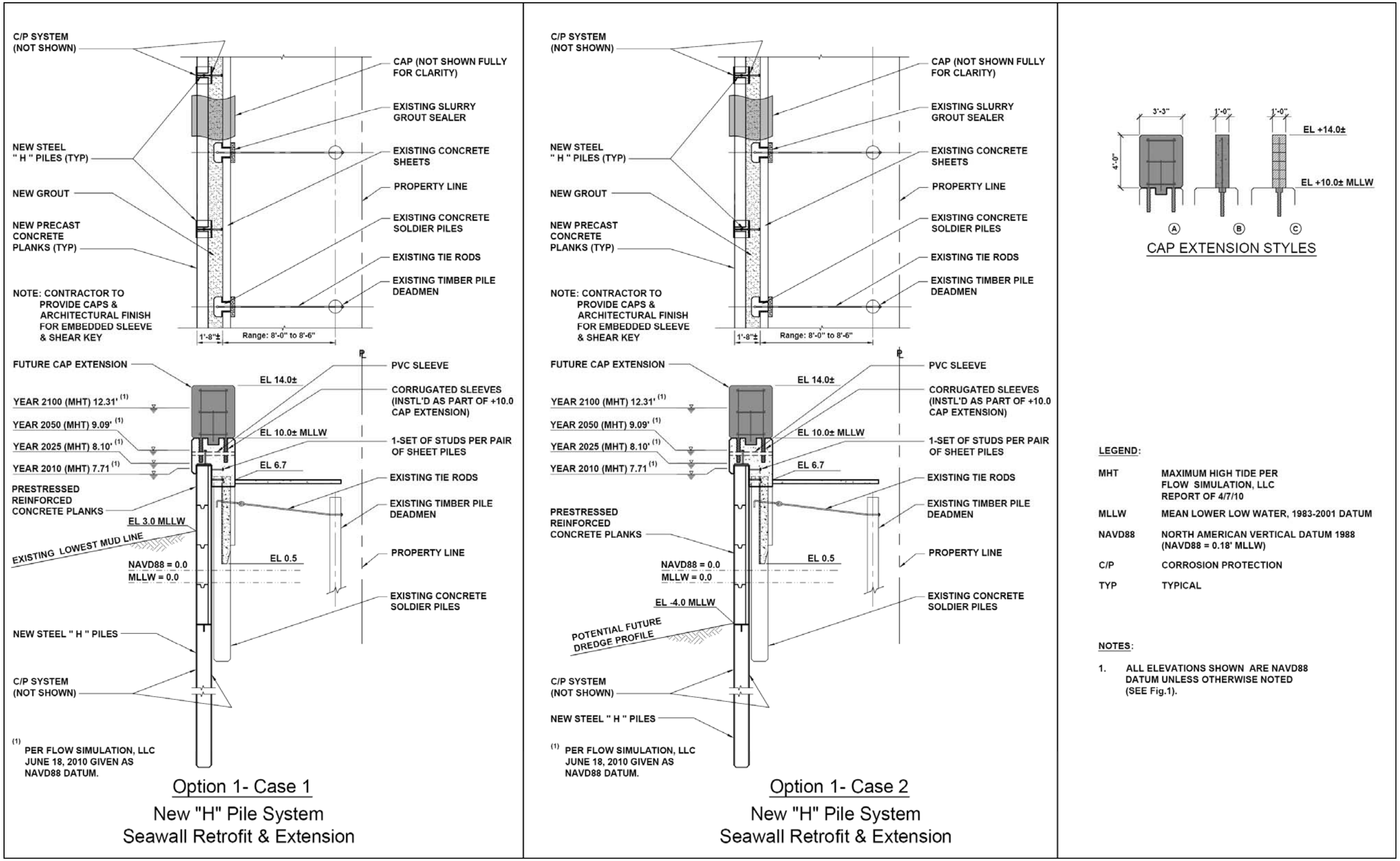
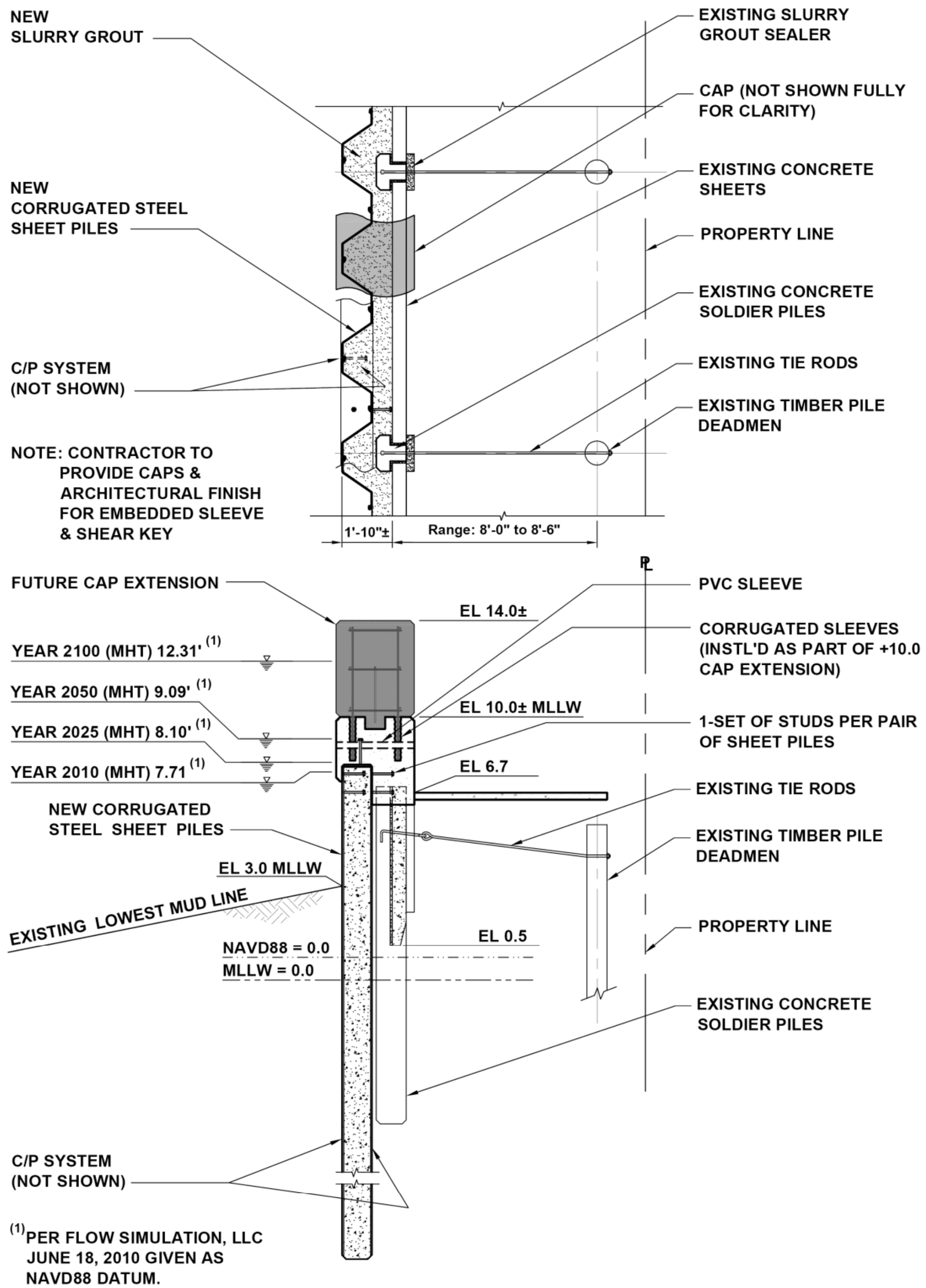


Figure 5.3 New "H" Pile System Seawall Retrofit and Extension

Figure 5.4 Construction of Retaining Wall Using H-piles and Concrete Wall (Lag) Panels

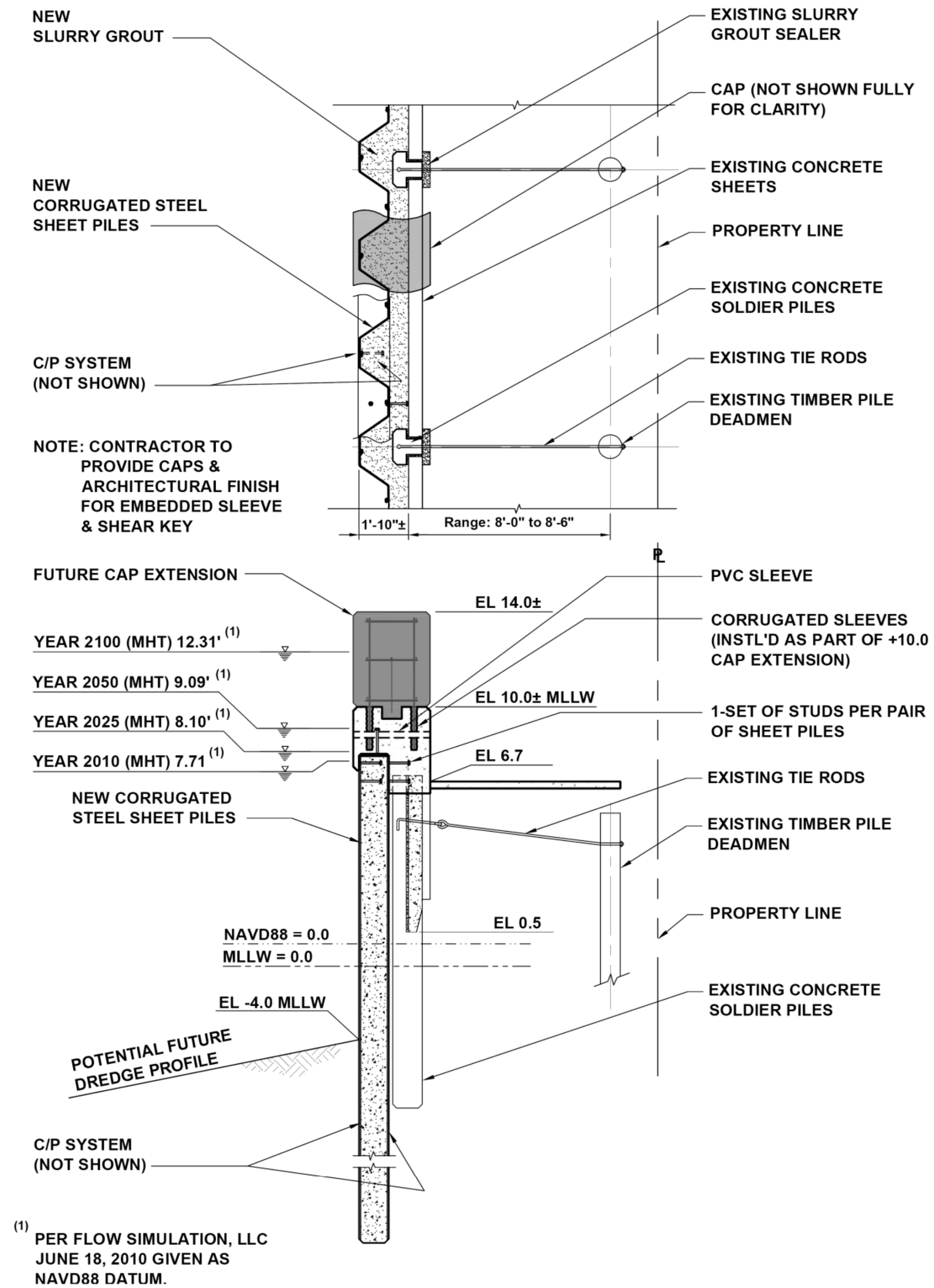
Replacement Option 2 - Continuously-driven Steel Sheet Piles

Install continuous steel sheet piles. Cast a reinforced concrete structural cap, designed to be extended in the future if and when required, on top of this assembly. This conceptual option is shown in Figure 5.5 and a picture for this kind of seawall is shown Figure 5.6. Both options are based on installing the new seawall waterside of the existing wall, and then grouting the void between the two walls for a seal. Both State and Federal permitting agencies typically do not promote projects that contain impacts to tidal wetlands. Taking into account the entire length of the Balboa Island seawall and the offset between the face of the existing seawalls and the face of the proposed seawall, approximately 0.5 acre of tidelands would be lost. For either of the proposed seawall replacement options, discussions will be necessary with State and Federal permitting agencies to illustrate the impracticality of other alternatives which carry more risks to utility lines and private properties as well as higher construction costs.



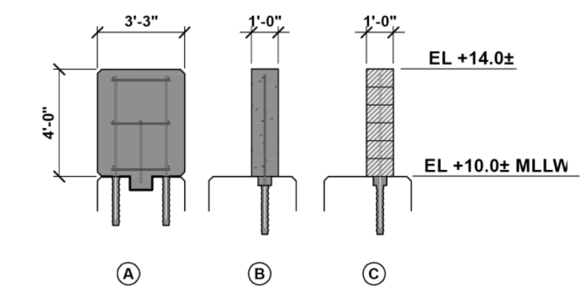
Option 2- Case 1

New Steel Sheet Pile System
Seawall Retrofit & Extension



Option 2- Case 2

New Steel Sheet Pile System
Seawall Retrofit & Extension



CAP EXTENSION STYLES

LEGEND:

MHT	MAXIMUM HIGH TIDE PER FLOW SIMULATION, LLC REPORT OF 4/7/10
MLLW	MEAN LOWER LOW WATER, 1983-2001 DATUM
NAVD88	NORTH AMERICAN VERTICAL DATUM 1988 (NAVD88 = 0.18' MLLW)
C/P	CORROSION PROTECTION
TYP	TYPICAL

NOTES:

1. ALL ELEVATIONS SHOWN ARE NAVD88 DATUM UNLESS OTHERWISE NOTED (SEE Fig.1).

Figure 5.5 New Steel Sheet Pile System Seawall Retrofit and Extension

Figure 5.6 Steel Sheet Pile Bulkhead

Both replacement seawall designs are also cantilevered, meaning they do not require tie-rods, deadmen, or earth anchors to be drilled into the earth behind the wall. The ability to cantilever the seawall is a function of the depth of seawall embedment, of the exposed height of the wall (difference between top of boardwalk on the landside and top of mudline on the waterside), and of the type of structure desired. With cathodic protection and a rigorous maintenance and repair schedule, both replacement options have a lifespan of up to 150 years.

It is assumed that either seawall option selected will be designed to one of two mudline conditions depending on the location on the Island and based on anticipated City and community desires. The majority of the rebuilt seawall (approximately 9,200 feet of shoreline) would be designed using a mudline elevation of 3.0 feet NAVD88 (3.2 feet MLLW) allowing continuing use of existing beaches around Balboa Island. The remaining 4,000 feet would have a rebuilt seawall designed with a mudline elevation of approximately 4.0 feet NAVD88 (4.2 feet MLLW) to allow for dredging for boat berthing and navigation.

5.2 Balboa Island Ferry Boat Landing

With the replacement of the seawalls on Balboa Island, the dock and launch ramp at the Balboa Island Ferry Landing would also need to be modified. If the dock and launch ramp are left in their basic current location, a major effort would be required to raise the launch ramp and the approach street, Agate Avenue. Two options for raising the launch ramp were developed; they are shown in Figure 5.7. As shown in the figure, both options would impact adjacent buildings and the intersecting boardwalk.

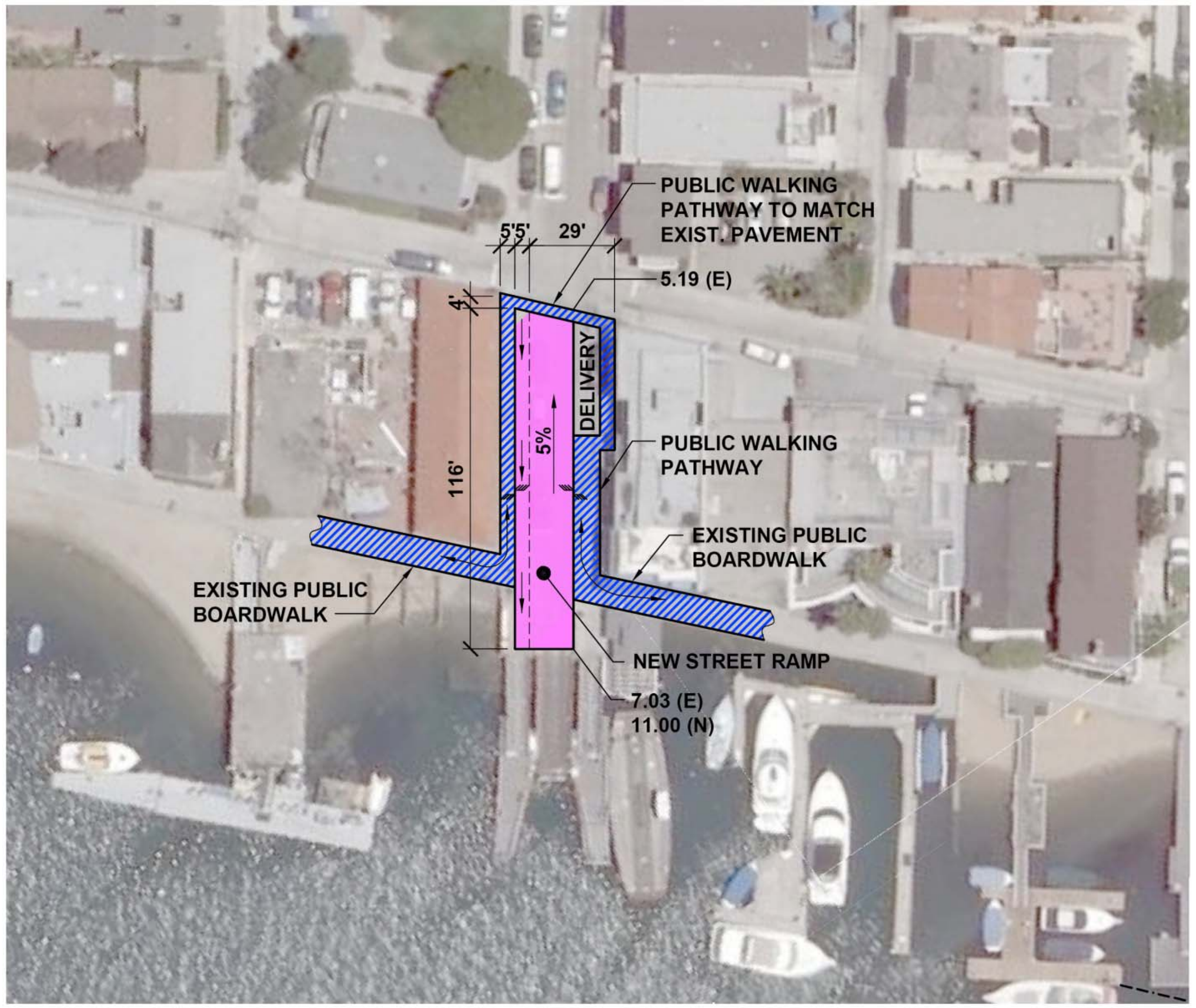
<u>Option 1</u> blocks the boardwalk at the intersection with the proposed ferry boat landing approach ramp. Pedestrians have to travel an additional 200 feet around the approach ramp to get from one side of the boardwalk to the other side. This option only allows one-way traffic from the ferry to the intersection of the approach ramp and alleyway. Existing grade-level sidewalk and delivery access are maintained on Agate Avenue.

<u>Option 2</u> allows continuous boardwalk access by constructing 5% grade ramps on either side of the approach ramp. These ramps are ADA-compliant and do not require handrails. However, the ramps do extend beyond the Agate Avenue right-of-way and impact access to six waterfront properties. The proposed approach ramp and adjacent sidewalks are widened to the full right-of-way width allowing for two-way traffic on Agate but blocking access to two structures on Agate.

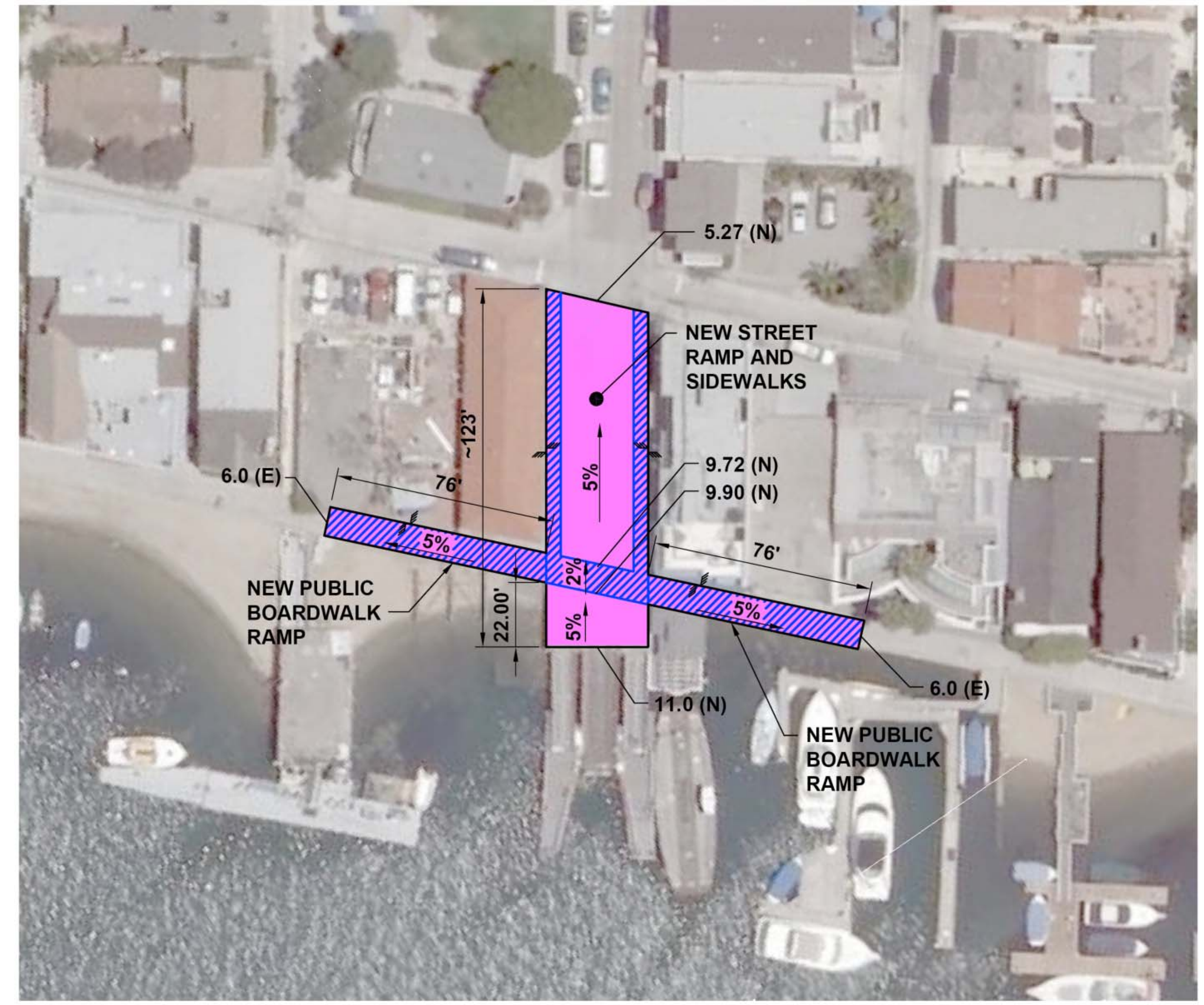
It is hard to envision raising the launch ramp without requiring the reconstruction of the two buildings on either side of Agate Avenue adjacent to the launch ramp, one of which, the J.A. Beek Building, may be considered a historic structure. Despite the impacts to surrounding properties and pedestrian access, Options 1 and 2 are land-based and only require the ferry launch ramp and float to be raised in concert with the new approach ramp. Additionally, these options do not impact existing navigation in the main channel.

An option to shift the launch ramp further into the main channel so that existing properties can remain unchanged was also developed. This proposed option (Option 3) is shown in Figure 5.8. To account for the effect of sea level rise to the Balboa Peninsula and to show the full extent of anticipated channel width reduction, a similar redevelopment of the ferry landing and launch ramp on the Balboa Peninsula side of the channel will be required. After some assessment of navigational clearances, which included incursions on both sides of the channel, the proposal appears feasible, although additional study would be necessary as well as discussions with the City Harbor Resources Department, the U.S. Coast Guard, California Coastal Commission, California Fish & Game, and the U.S. Army Corps of Engineers. Such a shift would likely require a similar extension of the adjacent fuel dock to prevent any reduction to ingress and egress into this facility. These changes would affect the existing pierhead lines.

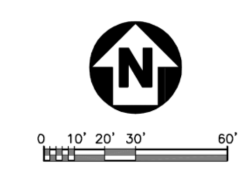
Any reconstruction of this facility, regardless of the type, will take time. The facility could be inactive for nine months or more during construction of a new approach and launch ramp including installation, testing, and activation of all utility and mechanical systems. Furthermore, if this channel-ward approach were taken, a similar structure should be required on the Balboa Peninsula.



Option 1
Street Approach Ramp with Diverted Walking Path
@ 8% : ELEV. 14.0



Option 2
Street Approach & Boardwalk Ramps
@ 8% : ELEV. 12.5



Datum: NAVD 88

Figure 5.7 Two Options to Raise the Launch Ramp at Balboa Island Ferry Landing

Figure 5.8 Balboa Island Ferry Modification

5.3 Solutions for Groundwater-Caused Inundation of Balboa Island and Little Balboa Island

Based on the sea level rise scenarios discussed in Chapter 3, the mean sea level (MSL) could be as high as 7.3 feet NAVD88 (7.5 feet MLLW) by 2100. This water level is higher than many of the finished floor elevations of buildings in the Balboa Island. Therefore if sea levels rise as modeled, widespread flooding is predicted by 2100 as groundwater percolates through finished surfaces onto Balboa Island streets. Assuming that the water table lags the tide by approximately 3 feet adjacent to the seawall, it can be assumed that flooding may become a common occurrence between the interval Years 2050 and 2100 as the predicted high water level (with one percent probability of occurrence) increases from 9.1 feet to 12.3 feet NAVD88 (9.3 to 12.5 feet MLLW). If the predicted high water level and MSL occur, then a deep well groundwater dewatering system, coupled with seawall reconstruction, most likely would be necessary to prevent widespread flooding with current Island ground elevations.

The risks and benefits associated with a groundwater dewatering system should be assessed in further detail. The primary benefit is that existing infrastructure, except for the seawall (which is proposed to be reconstructed) and piers, may remain in their current state. However, operations of such a system may be high over time and disposal of groundwater may be problematic. Regional Water Quality Control Board does not allow direct discharge into Newport Bay. Additional pump redundancy and power backup will be required to prevent any failure of the system, which would likely result in extensive flooding and damage. Therefore, it is recommended that other long-term solutions be investigated. As part of any chosen solution, the City should continue adopting revisions to the Base Flood Elevation for Balboa Island as determined by FEMA. The Base Flood Elevation is likely to increase in the future to account for sea level rise.

Residents of Balboa Island have lived with the risk of floods since it was first constructed. Ever since then, individual residents, the Balboa Island Improvement Association (BIIA), and the City have investigated various solutions to flooding of Balboa Island during high water events. With the potential introduction of groundwater induced flooding, the risks of flooding and associated measures to combat these conditions become more complex.

5.4 Conceptual Costs

A conceptual level costs for each of the recommended flood inundation mitigation components are summarized in the following. These costs are based on 1st quarter 2011 construction costs with no escalation. These values should be adjusted for inflation and material and labor cost increases (i.e., contingency) if these values are projected to some future date. Details of the cost estimates can be found in Appendix C.

5.4.1 Short-term Seawall Extension Alternatives

Alternative 1: Cap Replacement

The cost to replace the existing seawall cap is estimated to be between $625 and $725 per lineal foot for a total cost of between $8.25 and $9.57 million. This estimate includes costs of design, permitting, and construction management and inspection.

Alternative 2: Cap Extension

The estimated construction cost to extend the existing seawall cap using a doweled-in concrete extension (Option 1) is between $250 and $300 per linear foot for a total cost of between $3.30 and $3.63 million. This estimate includes costs of design, permitting, and construction management and inspection.

For the use of polypropylene sandbags (Option 2), the estimated cost is between $170 and $190 per linear foot for a total cost of between $2.26 and $2.52 million over twenty years. This estimate includes operation and maintenance costs and assumes the sandbags need to be replaced once every five years.

For the use of geotextile (Longard) bags/tubes (Option 3), the estimated cost is between $130 and $160 per linear foot for a total cost of between $1.72 and $2.11 million over twenty years. This estimate includes projected maintenance items such as repair of damaged bags, replacement of lost or destroyed bags, and upkeep of UV-protection measures.

5.4.2 New Seawall

Seawall Replacement Option 1 consists of steel “H” piles with concrete panels placed between the piles to form a panel wall. The major cost components include demolition of the existing boardwalk, construction of a new boardwalk and drainage system, construction of the seawall and cap to 9.8 feet NAVD88 (10 feet MLLW), and cathodic protection of the steel “H” piles. The seawall, including all piles, panels, the seawall cap, and all associated costs such as corrosion protection and design, costs between $3,800 and $4,000 per lineal foot. The total construction cost is estimated to be between $50.2 and $52.8 million.

Seawall Replacement Option 2 consists of continuous steel sheet piles with a grout seal pumped between the existing seawall and this new seawall. Installation of the seawall sheet piles and cap, including all associated costs such as corrosion protection and design, is estimated to cost between $4,100 and $4,300 per lineal foot with a total construction cost of between $54.1 and $56.8 million.

Potential Cap Extension: Extending the seawall cap several feet up to 14.0 feet NAVD88 (14.2 feet MLLW) if needed as sea level rise in the future as modeled is estimated to cost between $400 to $500 per lineal foot for a total between $5.3 and $6.6 million.

The new seawall including the extended cap (14.0 feet NAVD88, 14.2 feet MLLW) and all associated soft costs is estimated to cost between $55.5 and $59.4 million for Option 1 and between $59.4 and $63.4 million for Option 2.

5.4.3 Balboa Island Ferry Boat Landing

Three options were presented in Section 5.2 to retrofit the Balboa Island Ferry Boat Landing. Options 1 and 2 are similar in that they propose to retrofit the existing Ferry Boat Landing approach structure and construct an approach ramp on Agate Avenue. These two options differ in how pedestrians cross the interface between the Ferry Boat Landing and the boardwalk. However, given the similarities and differing impacts of adjacent structures, the anticipated cost of these two retrofit options is estimated to be between $3.5 and $5.0 million. This includes the cost for retrofitting the existing restroom and mechanical building serving the Ferry Boat.

Option 3 calls for both the Balboa Island Ferry Boat Landing and the fuel dock to be moved further into the Main Channel. In addition, the fixed structures such as the restroom building and approach structure for the ferry boat landing and the tackle and supply shop for the fuel dock will need to be raised. The cost associated with the ferry boat landing is approximately $2.0 and $3.0 million. The cost associated with the fuel dock is approximately between $1.5 and $2.0 million. These costs includes all demolition, new bulkheads as needed, fill behind new bulkheads as needed, reconstruction of approach structures and fixed piers and gangways, and construction of new wharves and buildings as needed. It is assumed that the owners of both facilities will bear the cost of raising existing or driving new guidepiles and providing all new connections for their respective floating docks.

5.4.4 Retrofitting Bridges

The cost to waterproof and retrofit the Island bridges is estimated to be $250,000 to $350,000 per bridge. Although the Collins Island Bridge requires additional work such as construction of solid wall parapets, its cost is similar to the other bridges since it is relatively short. If any bridge is reconstructed in the near future, savings may be found by incorporating the long-term planning measures in the design.

5.4.5 Long-term Solutions

The cost of measures associated with installation of deep groundwater dewatering wells and pump stations cannot be determined at this time since the number of wells and pump stations are dependent on a through geotechnical report and soil permeability testing program. Additionally, the costs associated with meeting revisions to the Base Flood Elevation (BFE) cannot be calculated since the ultimate BFE is unknown as is the integration of associated costs into the typical structure design, permitting, and construction process.

5.4.6 Total Estimated Cost

A summary of the conceptual cost estimates is provided in Table 5.1. Assuming the proposed seawall is eventually extended to a final height of 14.0 feet NAVD88 (14.2 feet MLLW), the total projected cost of the short-term protection measures and long-term Balboa Island seawall replacement and fortification is anticipated to be between $61.5 and $79.0 million.

Table 5.1 Estimated Conceptual Construction Costs

MITIGATION COMPONENT	UNIT PRICE ($/LF) [1]	CONCEPTUAL COST [2]
Interim Seawall Height Extension		
Alt. 1: New Seawall Cap	$625 - $725	$8.25 - $9.57 million
Alt. 2: Existing Seawall Cap Extension		
Option 1: Mechanical Extension	$250 - $300	$3.30 - $3.63 million
Option 2: Polypropylene Sandbags	$170 - $190	$2.26 - $2.52 million
Option 3: Geotextile Bags/Tubes	$130 - $160	$1.72 - $2.12 million
New Seawall		
Option 1: Steel H-Piles w/ Conc. Panels	$3,800 - $4,000	$50.20 - $52.80 million
Option 2: Steel Sheet Piles	$4,100 - $4,300	$54.10 - $56.80 million
Subsequent Seawall Extension: 3 – 4 feet (When/If Required)	$400 - $500	$5.30 - $6.60 million
Ferry Landing and Bridges		
Ferry Boat Landing and Fuel Dock Retrofit (All 3 Options)		$3.50 -$5.00 million
Bridge Retrofit (3 bridges)	$250,000 - $350,000 per bridge	$0.75 - $1.05 million
Total Estimated Program Cost [3]		**$61.47 - $79.02 million**

1 *All prices provided as $ per lineal foot, LF, unless noted otherwise. Range in unit prices includes design, permitting, and construction costs as described in the preceding paragraphs.*

2 *Engineer's Conceptual Cost Estimate is based on 1st quarter 2011 construction costs with no escalation.*

3 *Assumes the proposed seawall is extended to a final height of 14.0 feet NAVD88 (14.18 feet MLLW NTDE 83-01).*

5.5 Funding Mechanisms

Given the scope of the proposed seawall project, the City of Newport Beach is likely to issue bonds to fund the project. The formation of a Special Assessment District likely will be needed to pay off these bonds. Formation of these assessment districts are governed by Propositions 13 and 218. Prior to the formation of an assessment district, Proposition 218, which is now incorporated as Section 4, Article XIII D of the California Constitution, requires a report detailing 1) the total project cost, 2) how the total cost was calculated, 3) the individual project cost to each parcel, 4) the parcels of record within the assessment district, 5) the duration of the assessment, and 6) the reasons for the assessment. In addition, Proposition 13 prevents the calculation of an assessment calculated as a percentage of the property value. In other words, assessment districts must base their fees on either 1) parcel area, 2) relative benefit, or 3) a flat rate.

There are a few assessment district mechanisms that may apply to the seawall project. These are:

1) Geological Hazard Abatement District
2) Seismic Safety Assessment District
3) Reclamation District
4) Facilities Benefit Assessment District

A Geological Hazard Abatement District and/or a Seismic Safety Assessment District may be formed since the seawalls were not designed to handle seismic loads and rising sea level will erode the land in front of the seawall. Given that Balboa Island is subject to flooding and is below the Base Flood Elevation, formation of a Reclamation District may be another option. Finally, since the seawall is a public facility, a Facilities Benefit Assessment may be used to repay the bonds. These Special Assessment Districts are easier to approve if they are brought to the City as a petition from the residents as this appears to be the least legally challenging avenue.

The City may consider seeking assistance from the U.S. Army Corps of Engineers (USACE) in addressing the flooding problems at Balboa Island. The USACE has five core missions, they are: commercial navigation, flood damage reduction, hurricane and storm damage reduction, ecosystem restoration, and comprehensive watershed planning. This project is most likely to fall under the flood damage reduction and the hurricane and storm damage reduction missions.

Section 103 of the 1962 River and Harbor Act (Hurricane and Storm Reduction Program) authorizes the Corps of Engineers to study, design, and construct small coastal storm damage reduction projects in partnership with non-federal government agencies, such as cities. Hurricane and storm damage reduction projects are not limited to any particular type of improvement. The maximum federal cost for planning, design, and construction of any one project is $5,000,000. Final design and construction costs are 65% Federal and 35% non-federal.

The USACE Floodplain Management Services (FPMS) Program's authority stems from Section 206 of the 1960 Flood Control Act (PL 86-645). Goals of the program include: 1) improving the capabilities to collaboratively deliver and sustain flood damage reduction and flood hazard mitigation services to the nation, and 2) identifying and assessing flood hazards posed by aging flood damage reduction infrastructure. Upon request, program services may be provided to state, regional, and local governments, and other non-federal public agencies without charge.

6 RECOMMENDATIONS

The existing seawalls at Balboa and Little Balboa Islands are between 72 and 83 years old and are near their expected useful lifespan of 75 to 100 years. They are showing extensive signs of distress and over the next 25 years, these walls will exhibit advanced deterioration which will be quite costly to repair. Furthermore, they are frequently being overtopped during extreme tide and high wave events. Therefore, instead of continually spending large sums of money for significant repairs for the seawalls with estimated remaining usable life of between 10 to 25 years, we recommend the City to begin implementing a plan to replace the existing seawalls with higher ones, as well as other mitigation solutions to address potential flood inundation of the two islands due to projected future sea level rise. Our recommendations include the following:

1. Begin replacement of the existing seawall within 10 years from baseline year 2010. This initial stage will consist of a perimeter seawall constructed to 9.8 feet NAVD88 (10 ft MLLW) which would place the new wall 0.8 feet about the current Base Flood Elevation of 9.0 feet NAVD88 (9.18 feet MLLW). In the interim, augment the exiting seawalls by 6 to 8 inches either by adding a cap extension, or by being prepared to deploy sandbags around the Balboa and Little Balboa Islands. A cap extension would be more aesthetically pleasing but would cost more than deploying sandbags.

2. When necessary, extend the seawall by an additional 3 to 4 feet during a timeframe spanning Years 2050 and 2060 (i.e., 40 to 50 years from baseline year 2010).

3. When necessary, construct a deep well groundwater dewatering system to protect the islands from subsequent high water tables associated with highest extreme water levels. If sea levels rise as predicted, this would need to be done during a timeframe spanning Years 2050 and 2060 (i.e., 40 to 50 years from baseline Year 2010).

4. Establish appropriate minimum lowest floor elevation in accordance with the federal Base Flood Elevation (BFE). The City of Newport Beach must continue to adhere to this requirement since Balboa Island is in a Flood Insurance Rate Map (FIRM) Zone A, which is considered a Special Flood Hazard Area. If sea levels rise as predicted, then in the future, the BFE may be higher than the current BFE of 9.0 feet NAVD88 (9.18 feet MLLW).

5. Start planning for reconstruction of the Ferry Boat Landing infrastructure. This study recommends two options for raising the launch ramps and one solution of moving the approach ramp further into the main channel. Any of these options will take time to implement, and the facility could be inactive for nine months or more during construction. The City may want to further investigate other alternatives.

6. The City should develop and implement a community awareness program. Inclusion of Collins Island and its residents in the Balboa Island seawall process is critical to the success of any Balboa Island mitigation measure, since Collins Island needs to raise their seawalls in concert with the Balboa Island program.

7. The City should undertake opportunities to coordinate with other Federal, State and County agencies to draw upon as a large pool of expertise that will be needed to address the complex and unprecedented issues associated with sea level issue. The City may be able to utilize the resources of other agencies which may have been working on addressing regional sea level rise impacts. In addition, the City should start investigating potential funding sources from other agencies that may help the City to develop a regional plan to mitigate sea level rise impacts.

The recommendations on replacement of existing seawalls, interim extension of the seawall cap and the deep well groundwater dewatering system were analyzed based on the current projection of future sea level rise. Recommendations could change when there is better certainty in the projected sea level rise. Hence, we recommend the City periodically revisit mitigation.

7 REFERENCES

U.S. Army Corps of Engineers. 2009. Water Resources Policies and Authorities Incorporating Sea-Level Change Considerations in Civil Works Programs.

Veri-Tech, Inc. 2009. Coastal Engineering Design and Analysis System (CEDAS) 4.03. http://www.veritechnic.com/products/cedas/index.php.

Vermeer, M and Rahmstorf, S. 2009. Global Sea Level Linked to Global Temperature. Proceedings of the National Academy of Sciences, 106(51), 21527–21532.