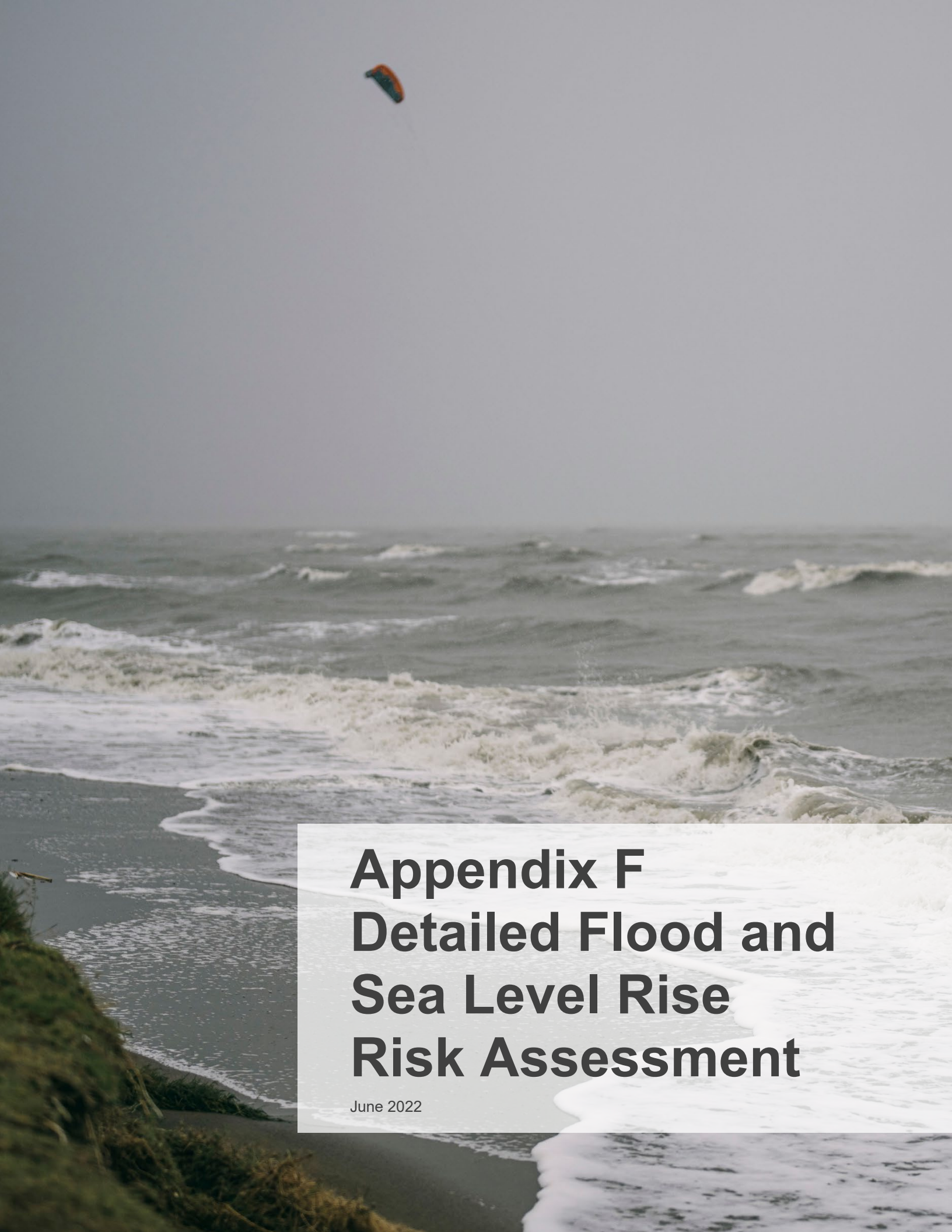

Appendix F Detailed Flood and Sea Level Rise Risk Assessment

June 2022

This appendix provides detailed assessment of how existing and future people, economy, buildings and infrastructure may be impacted by flooding and sea level rise in Alameda.

The People of Alameda

According to the United States Geological Survey (USGS) Hazard Exposure Reporting and Analytics (HERA) Tool (usgs.gov/apps/hera/floodTool.php) over 10,000 Alameda residents can be affected by the flood hazard resulting from a 100-year coastal storm event under a "maximum" hazard scenario (**Figure F-1**). Of those, approximately 1,700 are age 65 and older and 561 are under 5 years old. Additional populations and household types are shown in the table below for various flooding scenarios.

Many studies have shown that socially disadvantaged groups such as persons of color, low income residents and persons with disabilities are disproportionately impacted by natural disasters. These populations may have more difficulty evacuating in the event of a flood and more difficulty recovering after an event. Persons with disabilities may also be reliant on electricity for medical equipment and refrigeration of medication that can be lost during floods and winter storms. A 2016 study found that disadvantaged populations are more likely to live in housing that may be damaged in an earthquake and less able to prepare, respond and recover from a flood.[1]

Table F-1 People of Alameda Affected by Depth of Flooding

Population	No. of People Affected at 100-yr Flood Event	No. of People Affected at 39.5-in Sea Level Rise	No. of People Affected at 100-yr Flood Event + 39.5-in Sea Level Rise
Total Residents	10,241	15,394	28,015
Over Age 65	1,758	2,625	4,632
Under Age 5	561	865	1,579
Hispanic or Latino	908	1,472	2,572
Asian	3,721	5,230	10,317
Black or African American	635	1,434	2,411
Institutionalized (group quarters)	118	145	546
Household Type	**No. of Households Affected at 100-yr Flood Event**	**No. of Households Affected at 39.5-in Sea Level Rise**	**No. of Households Affected at 100-yr Flood Event + 39.5-in Sea Level Rise**
Owner-Occupied	2,518	3,500	6,629
Renter-Occupied	1,668	2,721	4,643

[1] ABAG and BCDC, 2015, *Stronger Housing, Safer Communities*, www.adaptingtorisingtides.org/project/stronger-housing-safer-communities-strategies-for-seismic-and-flood-risks/.

Alameda Economy

The USGS HERA Tool also shows economic assets that are affected by the 100-year flood hazard under a “maximum” hazard scenario. Employee data shown was determined from the Infogroup Employer Database and reflect employee counts as of March 1, 2020. Businesses are described and grouped according to the North American Industry Classification System (NAICS). Parcel boundaries and their values (tax year 2019) are from the Homeland Infrastructure Foundation-Level Data (HIFLD) repository.

Table F-2. Economy of Alameda Affected by Depth of Flooding

Types of Employees Affected	No. of Employees Affected in 100-year Flood Event	No. of Employees Affected at 39.5-in Sea Level Rise	No. of Employees Affected at 100-yr Flood Event + 39.5-in Sea Level Rise
Total Employees	2,394	5,961	10,310
Government and Critical Facilities	404	919	2,573
Manufacturing	140	391	763
Natural Resources	3	3	5
Services	740	2,285	3,961
Trade	1,107	2,363	3,008
Parcel Values	**Improved Parcel Value in 100-year Flood Event**	**Improved Parcel Value at 39.5-in Sea Level Rise**	**Improved Parcel Value at 100-yr Flood Event + 39.5-in Sea Level Rise**
Both Improved and Land Values	$1.7 Billion	$2.6 Billion	$5.3 Billion
Improved Parcels	$1.2 Billion	$1.8 Billion	$3.6 Billion
Land	$575.0 Million	$857.6 Million	$1.7 Billion
Building Replacement Value	**Building Replacement Value in 100-year Flood Event**	**Building Replacement Value at 39.5-in Sea Level Rise**	**Building Replacement Value at 100-yr Flood Event + 39.5-in Sea Level Rise**
Total Value Across All Uses	$1.4 Billion	$2,348,021,412	$4.0 Billion
Residential Use	$1.2 Billion	$1.8 Billion	$3.2 Billion
Commercial Use	$186.6 Million	$393.9 Million	$578.4 Million
Educational Use	$10.5 Million	$22.3 Million	$32.9 Million
Governmental Use	$13.0 Million	$42.6 Million	$56.7 Million
Industrial Use	$25.4 Million	$63.5 Million	$85.4 Million

Buildings

Buildings constructed in Alameda are not generally designed to withstand projected levels of flooding or saltwater exposure, yet Alameda's buildings are vulnerable to flooding from sea level rise, storm surge, major rainfall events, and other sources of flooding - such as water main breaks and groundwater intrusion.

All buildings are vulnerable to flooding, especially if they are slab-on-grade or have basements. Damage consists of direct damage by water, and later damage by mold. Additionally, all building contents below the flood line are vulnerable to flooding. If the flooding is relatively shallow, then carpet, sheetrock and paneling can be removed and replaced and mold abated. The building can then be returned to its former level of service. After flooding, many buildings lose function temporarily until they are deemed safe or are rebuilt. Depending upon the building, this loss of service may include emergency services, sheltering and gathering, commerce, education, medical care, daycare, elder care, government, and recreation. Short term and long-term recovery of the City depends upon quick restoration of these services.

Coastal Flood Vulnerable Buildings

Over 1,100 Alameda buildings are mapped within the current 100-year flood zone. The majority of buildings are privately owned homes, followed by commercial and industrial properties. There are however a handful of City-owned buildings as well (most City buildings are located away from the shoreline on higher ground and therefore not within the flood zone), This also holds true for future total water level scenarios involving sea level rise.

City-owned and privately-owned buildings vulnerable to coastal flooding at the current 100-year flood event, a future 36-inch sea level rise scenario, and a combined 100-year + 36-inch sea level rise scenario are listed in **Table F-3 and F-4** below. The depths of flooding listed were calculated by finding the approximate ground elevation at each location from City GIS contour data and then subtracting it from the total water level anticipated at each scenario.

City-Owned Buildings

There are eight City-owned buildings vulnerable to flooding at the 100-year flood event. On the main island these include the Fleet Vehicle Service Center on Grand Avenue, the O'Club building at Alameda Point, Alameda Point Gym, and Encinal Jr. Sr. High School (southern portion of property is in flood zone, buildings are not). All of these facilities are expected to have less than 1 ft of flooding at the 100-year flood event, and negligible flooding at a 36-inch sea level rise scenario. Additional City-owned properties are listed below these four that will be affected by the 100-year + 36-inch sea level rise scenario. These include City Hall West, Otis School, the Animal Shelter, and Alameda Community Learning Center. All main island buildings listed will have 1 ft or greater of flooding at the 100-year + 36-inch sea level rise scenario.

On Bay Farm Island, properties vulnerable to the 100-year event include the Chuck Corica Golf Course clubhouse building, the small building within Godfrey Park south of the golf course, the eastern-most building on the Earhart School property, and Bay Farm Island Library (library property is in flood zone, building is not). Of these four, only the clubhouse building and the Godfrey Park building may see significant flood depth at the 100-year event due to their low-lying ground elevation. A similar trend is predicted for the 36-inch sea level rise scenario. However, all four Bay Farm properties will be affected by

the 100-year + 36-inch sea level rise scenario and will experience 1 ft or greater of flooding at the 100-year + 36-inch sea level rise scenario.

Table F-3 City-Owned Coastal Flood Vulnerable Buildings and Depths of Flooding

City Building	Approx. Ground Elevation at Building (NAVD88)	Approx. Depth of Flooding at 100-yr Flood Event (Total Water Level = 10ft NAVD88)	Approx. Depth of Flooding at 36-in Sea Level Rise (Total Water Level = ~ 9.5ft NAVD88)	Approx. Depth of Flooding at 100-yr Flood Event + 36-in Sea Level Rise (Total Water Level = 13ft NAVD88)
Main Island:				
Fleet Vehicle Service Center	10 ft	Less than 1 ft	n/a	3 ft
O'Club (Alameda Point)	10 ft	Less than 1 ft	n/a	3 ft
Gym (Alameda Point)	10 ft	Less than 1 ft	n/a	3 ft
Encinal Jr. Sr. High School	11 ft	n/a	n/a	2 ft
City Hall West	12 ft	n/a	n/a	1 ft
Otis School	10 ft	n/a	n/a	3 ft
Animal Shelter	11 ft	n/a	n/a	2 ft
Alameda Community Learning Center	11 ft	n/a	n/a	2 ft
Bay Farm Island:				
Golf Course Clubhouse	2 ft	8 ft	7.5 ft	11 ft
Godfrey Park Building	5 ft	5 ft	4.5 ft	8 ft
Earhart School (One Building Only)	9.5 ft	Less than 1 ft	n/a	3.5 ft
Earhart School (Remainder of Property)	12 ft	n/a	n/a	1 ft
Bay Farm Island Library	11 ft	n/a	n/a	2 ft

Privately-Owned Buildings

Over 1,000 privately-owned buildings are considered vulnerable at these scenarios, split between the main island and Bay Farm Island. On the main island a mixture of building types are impacted in the northern shoreline flooding area, with a 100-year flood depth limited to 3 ft or less and a 36 in sea level rise event flood depth of 2.5 ft or less, due to land elevations in the 7 to 10 ft NAVD88 range. Along the eastern shoreline, the majority of affected private buildings are single-family homes in the Liberty Avenue and Fernside Boulevard neighborhoods that have a land elevation of 8 to 10 ft NAVD88 and therefore can expect 2 ft and 1.5 ft of flooding depth for the 100-year and 36 in sea level rise event respectively. The developed properties within Alameda Point's flooding area are largely similar in elevation to the eastern shoreline area and therefore can expect depths of 2 ft and 1.5 ft or less, respectively, for the 100-year

and 36 in sea level rise event, for the mixture of commercial, industrial, and residential properties impacted.

On Bay Farm Island, the lowest elevations in the City occur here, as low as 2 ft NAVD88 - and as such there is also the potential for the largest depth of flooding. In the Island and Maitland Drive areas, populated by mostly single family homes, a depth of flooding ranging between 0 to 8 ft, and 0 to 7.5 ft respectively for the 100-year event and 36 in sea level rise event is expected, depending on the exact elevation at a given home address. Along Lagoon System 1 North, where ground elevations are higher and the area is populated by single family homes and townhouses, flooding is expected to be 2 ft and 1.5 ft or less, respectively, for the 100-year and 36 in sea level rise events.

All locations listed are vulnerable to significant flooding from the 100-year + 36-inch sea level rise event, depths of which are shown in the far-right column.

Table F-4. Privately-Owned Coastal Flood Vulnerable Buildings and Depths of Flooding

Building Location within Given Flood Event	Majority Building Type	Approx. Range of Ground Elevations within Area (NAVD88)	Approx. Depth of Flooding Range at 100-yr Flood Event (Total Water Level = 10ft NAVD88)	Approx. Depth of Flooding Range at 36-in Sea Level Rise (Total Water Level = ~ 9.5ft NAVD88)	Approx. Depth of Flooding Range at 100-yr Flood Event + 36-in Sea Level Rise (Total Water Level = 13ft NAVD88)
Main Island:					
Northern Shoreline	Mixed	7 to 10 ft	0 to 3 ft	2.5 ft or Less	3 ft to 6 ft
Eastern Shoreline	Single Family Homes	8 to 10 ft	0 to 2 ft	1.5 ft or Less	3 ft to 5 ft
Alameda Point	Mixed	8 to 10 ft	0 to 2 ft	1.5 ft or Less	3 ft to 5 ft
Bay Farm Island:					
Island & Maitland Drive Areas	Single Family Homes	2 ft to 10 ft	0 to 8 ft	0 to 7.5 ft	3 ft to 11 ft
Lagoon System 1 North	Single Family & Townhouses	8 ft to 10 ft	0 to 2 ft	1.5 ft or Less	3 ft to 5 ft

Overland Flood Vulnerable Buildings

Overland flooding can occur due to various causes (rainfall, water main breaks, groundwater, etc.) and can happen anywhere, since all of Alameda is susceptible to these sources in one form or another. Therefore, all buildings within Alameda, public and private, are considered vulnerable to overland flooding in some form. The depth of flooding due to any of these causes would in all likelihood be less than what would occur due to a coastal flooding event, but exact conditions would depend on the individual event.

Critical Services

Alameda's critical services—fire, police, emergency medical services (EMS), schools, hospitals—are vulnerable to flooding from sea level rise, storm surge, and major rainfall events, primarily due to access issues created by flood events and the resulting inability to provide services. Disruption directly to Alameda's critical facilities or the transportation system on which they rely can exacerbate climate impacts because the public depends on these services most during emergencies. Schools are especially important to disadvantaged and vulnerable communities because they rely on these services for child care and meals. Critical services must have systems in place to communicate with the public, avoid becoming overtaxed, and keep their staff safe as they care for the public.

As shown in the above table of City-owned buildings vulnerable to flooding, there are no fire, police, EMS, or hospital facilities within the 100-year coastal flood zone in Alameda. However, there are two schools that are affected: Earhart School and Otis School. Otis School sits at the Base Flood Elevation and will not have flooding at the 100-year event or 36-inch sea level rise scenario. Earhart School on Bay Farm Island has one of the buildings on their campus that lies on the edge of the flood zone which passes through the property. This building will see less than 1ft of flooding at the 100-year event because topographically it is slightly lower than the Base Flood Elevation, and no flooding at the 36-inch sea level rise scenario. Both however will have significant depth of flooding at the combined flood/sea level rise scenario.

As detailed in the Transportation section below, all 3 major roadways that provide egress from Bay Farm Island to the main island and Oakland (via Doolittle Drive) will experience flooding to a different degree due to their varying elevations. This will make access by critical services nearly impossible in the event of a 100-year flood or events of greater depth due to impassible roadways.

Land Use

The broad types of land use in Alameda include residential, mixed-use, business, wildlife habitat, public parks/open space, public/institutional, commercial maritime/marinas, federal facilities, and general/maritime industry. On the main island, low and medium-density residential use stretches from the eastern shoreline to Main Street on the west side, while business and mixed-use occupies the northern shoreline and open space/public parks line the southern shores. On Alameda Point, mixed use, wildlife habitat, and open space are the largest uses. Low and medium-density residential dominates the developed area of Bay Farm Island, while the Chuck Corica Golf Course is the largest open space.

Table F-5 below shows the land uses most affected by the 100-year flood event or 36-inches of sea level rise.

Table F-5 Land Uses Most Affected by 100-Year Flood Event

Area of Island Impacted by 100-Year Flood Event or 36-Inches of Sea Level Rise	Land Uses Most Affected
Main Island:	
Northern Shoreline	#1: Business #2: Mixed-Use #3: Medium-Density Residential
Eastern Shoreline	Low-Density Residential
Alameda Point	#1: Mixed-Use #2: Wildlife Habitat #3: Open Space
Bay Farm Island:	
Island & Maitland Drive Areas	#1: Low-Density Residential #2: Medium-Density Residential
Lagoon System 1 North	#1: Low-Density Residential #2: Medium-Density Residential
Chuck Corica Golf Course	Open Space

Given Alameda's exposure to a wide range of climate hazards, most notably sea level rise and storm surge flooding, existing and future land use planning needs to incorporate adaptation strategies to keep residents and businesses out of harm's way. This involves important decisions about how to modify existing land use, where development opportunities still exist, and how to design new development and redevelopment that can adapt to future climate conditions. Land use policies are an important avenue to creating a resilient Alameda.

Utilities

Stormwater and Sewer Systems

Stormwater

The closed-system stormwater network located in the lower elevations of Alameda's main island is composed of catch basins, manholes, and pipes and receives watershed drainage from the upper elevations of the island. Approximately 20% of the closed stormwater system is within the area impacted by either the current 100-year flood zone or a 36-inch sea level rise scenario.

Additionally, there are five stormwater pump stations located in the current 100-year flood zone: on the main island these include the Main Street, Webster Street, Northside, and Central/Eastshore stations, and on Bay Farm Island, Golf Course station is the only station. At the time of this writing, design of new elevated control panels for all but Northside is complete and preparing for bid. Panels are planned to be constructed at Elevation 13 ft NAVD88, which is above the elevation of the 100-year flood event plus 36-inches of sea level rise scenario (see far-right column). **Table F-6** shows the depth of flooding expected at the pump stations at different scenarios.

While the Golf Course station shows significant flooding potential at all scenarios due to its low-lying elevation, the extensive regrading of the golf course over the last few years has created a landscape of mounds that would in all likelihood alter the flood patterns experienced there. As discussed previously the FEMA FIRMs do not reflect the golf course grading on the FIRMs since the work is not FEMA accredited. Note that Golf Course station is one of the 4 stations mentioned above that will receive the new control panels elevated to 13 ft NAVD88.

Table F-6. Stormwater Pump Station Depths of Flooding

Stormwater Pump Station	Approx. Ground Elevation at Station (NAVD88)	Approx. Depth of Flooding at 100-year Flood Event (Total Water Level = 10ft NAVD88)	Approx. Depth of Flooding at 36-in Sea Level Rise (Total Water Level = ~ 9.5ft NAVD88)	Approx. Depth of Flooding at 100-yr Flood Event + 36-in Sea Level Rise (Total Water Level = 13ft NAVD88)
Main Street	9 ft	1 ft	0.5 ft	4 ft
Webster Street	9 ft	1 ft	0.5 ft	4 ft
Northside	9.5 ft	0.5 ft	n/a	3.5 ft
Central/Eastshore	9.5 ft	0.5 ft	n/a	3.5 ft
Bay Farm Island				
Golf Course	1 ft	9 ft	8.5 ft	12 ft

The City must address stormwater system vulnerabilities and deficiencies identified during previous storm drain (Storm Drain Master Plan, 2008) and sea level rise modeling. Given the criticality of addressing the stormwater system, it is highlighted as a priority asset.

Sewer

Floods can damage Alameda's sanitary sewer system, particularly pump stations. Old, cracking pipe can also be infiltrated with rainwater or rising groundwater. This water then must be conveyed to the treatment plant, increasing the likelihood of partially treated effluent being discharged directly into the Bay. As part of a Federal Consent decree, the City of Alameda is replacing 2.6 miles of sanitary sewer main a year and making other improvements to reduce infiltration to the system.

Table F-7. City-Owned Stormwater and Wastewater Utilities Affected by Flooding

Utility	Quantity	Approx. % Exposed to Current 100-year Flood, Total Water Level = 10ft NAVD88	Approx. % Exposed to 36-in Sea Level Rise, Total Water Level = ~ 9.5ft NAVD88
Stormwater			
Storm Pipes and Cross Culverts	90 miles	20%	Less than 20%
Storm Manholes	2,058 each	20%	Less than 20%
Other Storm Structures (ex. Catch basins, outlets)	401 each	20%	Less than 20%
Storm Pump Stations	11 each	45%	45%
Storm Outfalls	227 each	100%	100%
Wastewater			
Sewer Mains	142 miles		
Sewer Manholes	3,122 each		
Sewer Pump Stations	42 each		

Drinking Water System

The linear footage of the drinking water system affected by the 100-year flood event is similar to that of the roadway network (see **Table F-9**, Transportation section) since EBMUD pipelines largely lie within city roadways. Floods have minimal consequences for water pipelines.

Electric System

The vulnerability assessment reviewed AMP electrical facilities and found none to be at immediate high risk of exposure to sea level rise or storm-event flooding. The greatest risks to the energy system are liquefaction and other impacts to buried infrastructure rather than flooding. Addressing flooding due to overtopping of the shoreline will provide some degree of protection of critical energy system infrastructure over the longer term but will not increase the resilience of buried infrastructure to seismic hazards such as liquefaction and groundwater rise.

One component of the electric system that might be affected indirectly by sea level rise and directly by earthquake is the Cartwright Substation at Alameda Point. The Cartwright Substation is a critical component of the existing electric system and is intended to remain in service. The substation provides local electric distribution to Alameda Point and portions of the surrounding areas to the east.

Increases in sea level will result in increased groundwater levels. Water enters the basement level of the Cartwright Substation through underground conduits and other penetrations. A sump pump is used intermittently to prevent the basement from flooding. Increased levels of groundwater will make it harder to prevent flooding of the substation's basement which could lead to damage of electrical equipment on the main level.

Table F-8. Electrical Utilities

Utility	Amount	% Exposed to Current 100-yr Flood	% Exposed to 36-in Sea Level Rise
Alameda Municipal Power Overhead Distribution	86 pole miles	10	5
Alameda Municipal Underground Distribution	194 circuit miles	35	15
Alameda Municipal Power Overhead Transmission	6.8 pole miles	10	5
Alameda Municipal Power Underground Transmission	1.9 circuit miles	5	2

Natural Gas System

The linear footage of the natural gas system affected by the 100-year flood event is similar to that of the roadway network (see **Table F-9**, Transportation section) since natural gas pipelines largely lie within city roadways. Floods have minimal consequences for water pipelines. PG&E has completed a vulnerability assessment that included the natural gas system but was not specific to Alameda. This assessment lays the foundation for PG&E to identify strategies to address key threats, but the City has limited control over the natural gas infrastructure within Alameda.

Communications and Technology Systems

Building 2 on Alameda Point (telecom switch station) is a critical facility for AT&T telecommunications infrastructure on Alameda Point. The vulnerability assessment concluded that this facility is not directly exposed to sea level rise and flooding but may be vulnerable to rising temperatures because it lacks an internal climate control system. The Alameda Point MIP includes flood protection systems that could protect Building 2 and other telecom assets on Alameda Point, but it does not cover internal adaptations for specific buildings.

Transportation

Flooding of various areas and neighborhoods of Alameda has already been discussed. However, the routes needed to provide egress for these properties are also affected. **Table F-9** shows the major roadways and approximate linear footage of each within the current 100-year flood zone. This is similar to the total linear footage affected by a 36-inch sea level rise scenario as well, since the total water elevations for each are only 0.5 ft different. Major roadway exposure is quantified at approximately 32,700 linear feet. There are many side streets also affected that are not included in this estimate.

All major roadways within the 100-year flood zone are anticipated to flood at least 1 ft deep (less than 1 ft of floodwaters can render a road unpassable by vehicles). **Table F-10** shows the approximate maximal depth of flooding for each roadway. On the northern end of the main island, State Route 260 descends as it enters the Webster and Posey Tube Portals separately to pass under the Bay. At the top of the descent the elevations are approximately 10 ft and 9 ft NAVD88 respectively (note that the depth of flooding that will be ultimately reached within each tube at a given event will vary depending on the elevation that floodwaters reach on land as well as the duration of the flood event). On the east end, Fernside

Boulevard has approximately 1 ft depth of flooding at the 100-year event. And on Alameda Point, Main Street will see 3 ft of flooding at its lowest point.

The risk assessment section discussed Bay Farm Island's particular vulnerability to flooding given its interconnected flood zone and multiple routes of egress that are affected. The 3 major roadways that provide egress from Bay Farm Island to the main island, and from Bay Farm Island to Oakland via Doolittle Drive are: Harbor Bay Parkway, Island Drive, and Doolittle Drive. Each will experience flooding to a different degree along their length due to varying elevations. At the 100-year event Harbor Bay Parkway will experience a 10 ft depth of flooding at its lowest point and Island Drive will experience 5 ft at its lowest, both definitely impassible. Doolittle Drive and Robert Davey Jr. Drive are on relatively higher ground and will experience 1 ft of flooding at their low points, on the verge of being passable. It is unknown how the grading changes on the golf course over the last few years will affect flooding on the surrounding streets during an actual event.

Table F-9. Length of Major City Roadways within 100-year Flood Zone

Major Roadways Impacted by Flooding (and Area of City) at 100-yr Flood Event	**Approx. Linear Footage (LF) Affected at Current 100-yr Flood Event (Total Water Level = 10ft NAVD88)**
Main Island:	
SR 260/Webster St. Leading to Posey Tube Portal Descent (Northern Shoreline)	3,000 LF
SR 260/Webster St Loop Leading to Webster Tube Portal Descent (Northern Shoreline)	600 LF
Fernside Blvd. (Eastern Shoreline)	2,000 LF
Main Street (Alameda Point)	5,700 LF
Bay Farm Island:	
Doolittle Drive	1,800 LF
Harbor Bay Parkway	6,100 LF
Island Drive	4,600 LF
Maitland Drive	4,400 LF
Mecartney Road	2,500 LF
Robert Davey Jr. Drive	2,000 LF
Total Major Roadway Exposure:	**32,700 LF**

Table F-10. City Roadways and Maximum Depth of Flooding at Their Low Points

Major Roadways Impacted by Flooding (Area of City) at 100-yr Flood Event	Approx. Lowest Ground Elevation within Flood Zone (NAVD88)	Approx. Maximum Depth of Flooding at Current 100-yr Flood Event (Total Water Level = 10ft NAVD88)	Approx. Maximum Depth of Flooding at 36-in Sea Level Rise (Total Water Level = ~ 9.5ft NAVD88)	Approx. Maximum Depth of Flooding at Current 100-yr Flood Event + 36-in Sea Level Rise (Total Water Level = 13ft NAVD88)
Main Island:				
SR 260/Webster St. at Beginning of Posey Tube Portal Descent (Northern Shoreline)	8 ft	2 ft	1.5 ft	5 ft
SR 260/Webster St Loop at Beginning of Webster Tube Portal Descent (Northern Shoreline)	9 ft	1 ft	0.5 ft	4 ft
Fernside Blvd. (Eastern Shoreline)	9 ft	1 ft	0.5 ft	4 ft
Main Street (Alameda Point)	7 ft	3 ft	2.5 ft	6 ft
Bay Farm Island:				
Doolittle Drive	9 ft	1 ft	0.5 ft	4 ft
Harbor Bay Parkway	0 ft	10 ft	9.5 ft	13 ft
Island Drive	5 ft	5 ft	4.5 ft	8 ft
Maitland Drive	3 ft	7 ft	6.5 ft	10 ft
Mecartney Road	6 ft	4 ft	3.5 ft	7 ft
Robert Davey Jr. Drive	9 ft	1 ft	0.5 ft	4 ft

Shoreline, Natural, and Recreation Areas

Alameda has a total of 23.6 miles of shoreline (excluding Coast Guard Island) consisting of both engineered shorelines (primarily seawalls or levees and associated riprap and other armoring) and natural shoreline. These shorelines attenuate waves and mitigate the impacts of storm events, and will also do so under future sea level rise conditions. In many areas, including the full perimeter of Bay Farm Island, they provide a protective distance between ocean waters and residential homes. They also provide a public access area for the public to enjoy the waterfront and is designated as the San Francisco Bay Trail for a large part of that.

Riprap is by far the most common type of shoreline used within the city. **Table F-11** illustrates the type and quantity of shorelines on Alameda's main island and Bay Farm Island.

Table F-11. Shoreline Types, Perimeter Mileage, and Percentage of Each within Alameda

Shoreline Type	Perimeter Mileage	Percentage of Overall Shoreline Protection
Main Island:		
Rip Rap Revetment	10.27	51.3%
Bulkhead	4.21	21.0%
Residential Seawalls or Natural Shoreline Berm	1.32	6.6%
Beach	2.52	12.7%
Alameda Point Piles (N.W. Corner)	0.13	0.6%
Rip Rap Revetment (Ballena Isle)	1.56	7.8%
TOTAL MILEAGE:	**20.01**	**100%**
Bay Farm Island:		
Rip Rap Revetment	2.75	77.0%
Natural Shoreline	0.75	21.0%
Seawall	0.07	2.0%
TOTAL MILEAGE:	**3.57**	**100%**

On the main island, 59% of shoreline protection consists of riprap, including Ballena Isle. The largest presence of riprap occurs along the Alameda Point shoreline and Ballena Isle shoreline where exposure to the Bay's wave effects is greatest. The Alameda Point shoreline is mainly within or adjacent to the 100-year VE Flood Zone (wave heights greater than or equal to 3 ft) that extends into the Bay, with a BFE = 12 ft NAVD88. Moving eastward along the southern shoreline, the BFE varies and reaches as high as 13 ft NAVD88 along the Ballena Isle perimeter and within crab cove, as the Zone designation shifts to AE (wave heights less than 3 ft). See **Figure F-1**.

Large diameter riprap is used along 77% of Bay Farm Island's shoreline in order to buffer it from the impacts of wave action since it is directly exposed to the Bay's wave effects from the south and west. As shown on **Figure F-2**, the southernmost portion of shoreline has the highest BFE within the City of Alameda, at 14 ft NAVD88 in elevation, and is in the VE Zone that extends out into the Bay. As you move northerly up the coastline and eastward, the BFE values decrease, and the flood zone changes from VE to AE as exposure to the Bay decreases.

Figure F-1. FEMA FIRM Showing VE and AE Flood Zones with Varying Base Flood Elevations and Wave Heights Around Alameda Point and the Southerly Shoreline of Alameda's Main Island

Figure F-2. FEMA FIRM Showing VE and AE Flood Zones with Varying Base Flood Elevations and Wave Heights Around Bay Farm Island's Shoreline

Although shoreline vulnerability depends on several factors including location and current stage of maintenance, all shorelines are vulnerable to flooding and erosion. There have been instances in the past when large storms disturbed the large-diameter riprap along the Bay Farm Island perimeter and replacement was needed. In 2006, large storms displaced the riprapped southern shoreline of Bay Farm Island near the airport and this area needed to be repaired.

When erosive issues are at play, the underlying berm fill material is eaten away and the integrity of the shoreline is compromised. With natural shoreline areas such as the northern shoreline of Bay Farm Island, the erosion is even more pronounced because there are not large boulders present to buffer the wave energy. In turn, the protective distance between homes and the waterfront is lessened and the potential for coastal flooding increased.

If erosion / flooding is relatively minimal in a riprap shoreline area, in most cases the shoreline can be restored using construction equipment and be replacing the riprap and regrading as needed. For natural shorelines such as the northern shoreline of Bay Farm Island, natural erosion-protection measures such as coconut fiber logs and erosion control matting secured with stakes have been used effectively in the past to repair eroded areas. The shoreline is then allowed to regrow to its former level of stability over time. Short term and long-term recovery of the shoreline may depend upon the speed of restoration.

Lowest Elevation Shoreline Areas

Thankfully, nearly all low points of the city's shoreline that are entry points for coastal flooding occur in AE Zones where the BFE is limited to 10 ft NAVD88, and therefore floodwaters would extend onto city land until they meet the ground contour at that same elevation. For this reason, nearly the entire city's land-based flooding has a BFE = 10 ft NAVD88.

The points of lowest elevation along the perimeter shoreline are the most vulnerable to coastal flooding because floodwaters would first enter here. The lowest elevation of shoreline on the main island is on Federal property, along the southern shoreline of Alameda Point, where it dips down as low as 7 ft NAVD88 in one area. Otherwise, the lowest elevations of shoreline on the main island are generally 9 ft NAVD88 or greater, as shown in Error! Reference source not found.. Both the northern shoreline and the eastern shoreline, primary overtopping location at Liberty Ave have concrete structures that extend higher in elevation than the shoreline behind them. The seawall along the northern shoreline has a top of wall elevation at approximately 10.5 ft NAVD88, and the concrete windrow has a top elevation at approximately 11 ft NAVD88. Despite the presence of these structures, the shorelines in these locations are still shown as coastal flood entry points on the FEMA FIRMs because the seawalls were not originally built to FEMA accreditation standards. This means that although they are currently in operation for flood prevention, FEMA does not consider them as barriers to the 100-year flood event and did not consider them when preparing the FIRMS. Consequently, the flood zone is shown as extending onto land to the 10 ft NAVD88 contour via the shoreline at both locations.

The Bay Farm Island perimeter shoreline has multiple points of entry for the 100-year flood event. The lowest locations are at the Lagoon System 1 North Outfall, Veterans Court, the model airplane field, and Doolittle Drive/SR 61. However, there are currently seawalls in two of these locations – the lagoon outfall and Veterans Court - that extend higher in elevation than the shoreline and provide some level of protection for these two shoreline areas. The seawall at the lagoon outfall has a top of wall elevation at approximately 11.5 ft NAVD88, and the seawall at Veterans Court has a top of wall elevation at approximately 9 ft NAVD88. In a similar fashion as described above for the northern and eastern shorelines, the shorelines at Veterans Court and the Lagoon System 1 North Outfall are still shown as coastal flood entry points on the FEMA FIRMs because the seawalls were not originally built to FEMA accreditation standards. Consequently, the flood zone is shown as extending onto land to the 10 ft NAVD88 contour via the shoreline at Veterans Court and the Lagoon System 1 North Outfall.

Error! Reference source not found. below shows the lowest perimeter shoreline locations and elevations, and how shorelines are affected by storm and anticipated sea level rise events, assuming no locations have effective floodwalls (as FEMA assumes on the FIRMs). It also summarizes the elevations of the unaccredited floodwalls/structures in Alameda for reference. Many of these shoreline locations are described in further detail in the description of Priority Coastal Inundation Locations in Chapter 5.

As shown in the table, the greatest depth of shoreline flooding in Alameda at the 100-year event theoretically occurs at Veterans Court, with 4 feet expected, assuming no seawall is present. However, the existing seawall does currently hold back tidal Bay waters on a daily basis and to a higher degree during king tide events, so practically speaking if the 100-year flood were to occur today and the wall functioned effectively, the flood depth over the top of the wall would be limited to 1 ft, because the top of the wall is at 9 ft NAVD88.

The tops of the other walls, along the northern and eastern shorelines as well as at the Lagoon System 1 North Outfall, are all higher than the 100-year base flood elevation, and therefore if they functioned effectively at the 100-year event then there would most likely be minimal flooding extending landward.

The table shows us that for the vast majority of the coastal flooding locations in Alameda, flooding is limited to 2 ft or less at the 100-year event along the shoreline, assuming no seawalls are present. For the 36-inch sea level rise scenario, flooding is even less. However, as described previously in the Buildings and Transportation sections flood depths will be greater in magnitude in areas of the city with low elevations as the flooding extends to those locations.

For a scenario of the 100-year flood event plus an additional 36-inches of sea level rise added on top of it for a total water elevation of 13 ft NAVD88, flood depths are substantial along the shoreline (far right column) assuming no seawalls are present.

Table F-12 Summary of Applicable Priority Coastal Flooding Locations

Shoreline Location	Flood Zone and BFE (NAVD88)	Type of Shoreline	Approx. Top Elevation of Unaccredited Seawall at Location, if Present (NAVD88)	Approx. Ground Elevation at Lowest Point (if Seawall is Present, then Behind/Landward of it) (NAVD88)	Approx. Depth of Flooding at Shoreline at Current 100-yr Flood Event Assuming No Seawall (Total Water Level = 10ft NAVD88)	Approx. Depth of Flooding at Shoreline at 36-in Sea Level Rise Assuming No Seawall (Total Water Level = ~ 9.5ft NAVD88)	Approx. Depth of Flooding at Shoreline at Current 100-yr Flood Event + 36-in Sea Level Rise Assuming No Seawall (Total Water Level = 13ft NAVD88)
Main Island:							
Crown Beach and Bird Sanctuary	AE, Varies between 11 & 12 ft	Beach/ Natural Shoreline	n/a	9.5 ft	0.5 ft	Less than 0.5 ft	3.5 ft
Eastern Shoreline Primary Overtopping Location At Liberty Ave	AE, 10 ft	Riprap and Concrete Windrow	11 ft	9 ft	1 ft	0.5 ft	4 ft
Northern Shoreline North of Tubes	AE, 10 ft	Concrete Seawall	10.5 ft	9.5	0.5 ft	Less than 0.5 ft	3.5 ft
Bay Farm Island Bridge Touchdown	AE, 10 ft	Riprap	n/a	9 ft	1 ft	0.5 ft	4 ft

Shoreline Location	Flood Zone and BFE (NAVD88)	Type of Shoreline	Approx. Top Elevation of Unaccredited Seawall at Location, if Present (NAVD88)	Approx. Ground Elevation at Lowest Point (if Seawall is Present, then Behind/Landward of it) (NAVD88)	Approx. Depth of Flooding at Shoreline at Current 100-yr Flood Event Assuming No Seawall (Total Water Level = 10ft NAVD88)	Approx. Depth of Flooding at Shoreline at 36-in Sea Level Rise Assuming No Seawall (Total Water Level = ~ 9.5ft NAVD88)	Approx. Depth of Flooding at Shoreline at Current 100-yr Flood Event + 36-in Sea Level Rise Assuming No Seawall (Total Water Level = 13ft NAVD88)
Alameda Point's Southern Shoreline on Federal Property	VE, 12 ft	Riprap	n/a	7 ft	3 ft	2.5	6 ft
Bay Farm Island:							
Lagoon System 1 North Outfall	AE, 10 ft	Concrete Seawall	11.5 ft	9.5 ft	0.5 ft	Less than 0.5 ft	3.5 ft
Veterans Court	AE, 10 ft	Concrete Seawall	9 ft	6 ft	4 ft	3.5 ft	7 ft
Model Airplane Field	AE, 10 ft	Natural Shoreline	n/a	8 ft	2 ft	1.5 ft	5 ft
Doolittle Drive / SR 61	AE, 10 ft	Riprap	n/a	8.5 ft	1.5 ft	1 ft	4.5 ft

Figure F-3. Seawall Along Northern Shoreline in Flood Zone

Figure F-4. Looking North Along Veterans Court Seawall at King Tide Event, January 2017

Figure F-5. Lagoon System 1 North Outfall Seawall at King Tide Event, January 2018

Figure F-6. Concrete Windrow at End of Liberty Avenue, East End

Contaminated Lands and Waste

The impact that sea level rise will have on contaminated sites is specific to the environmental conditions at each property. The types of contaminants and how they respond to changes in groundwater elevation, groundwater flow gradients, changes in geochemistry, and current site uses are just some of the parameters that would factor into how rising sea levels might impact these properties. Remedial action plans include pre-cleanup monitoring of environmental conditions to identify the contaminants that need to be addressed. Some remedial actions are short-term activities that include removing material from the property, while other remedial actions are more complex and can take decades to complete, such as pumping and treating contaminated groundwater. Remedial action plans also include implementing monitoring programs during and after remediation to verify the effectiveness of the remedial activity. These monitoring programs can assess the effect of changing environmental conditions on contaminants within a particular site. If, after the remedial action is complete, the property use is changed, or if the environmental conditions significantly change, the oversight agency can require additional environmental characterization of the property to verify that previous remedial activities are still effectively protecting human health and the environment.

Public Health and Welfare

Flooding can cause multiple public health impacts, such as mobilizing contaminants in soil (from hazardous waste sites), preventing access to safety, or preventing access to health care facilities due to flooded roads or public transit routes.