Oakland / Alameda Resilience Study

Potential Climate Impacts and Climate Scenarios

Potential Climate Impacts

There are five impacts associated with sea level rise and storm events that will be considered in this study:

More frequent floods

- Extreme high Bay water levels will occur more often, leading to more frequent flooding in flood-prone areas that could cause disruptions of emergency services and access to power, water, food, and medical care.

More extensive, longer-duration flooding

- Higher Bay water levels especially during storm events will flood larger areas for longer periods of time. Along with many other potential impacts this may result in the increased mobilization of pollutants if contaminated lands such as closed landfills are subjected to prolonged inundation.

Permanent inundation

- Sea level rise will cause areas not currently exposed to the tide to be inundated, resulting in the need to either protect or move people and infrastructure, and the loss of trails, beaches, vistas, and other shoreline recreation areas.

Shoreline erosion and overtopping

- Higher Bay water levels will cause changes in tidal and wave energy, leading to increased shoreline erosion and the potential that levees and other types of shoreline protection will be overtopped.

Elevated groundwater and increased salinity intrusion

- As the Bay rises, groundwater levels and salinity intrusion will increase, affecting water supplies along the shoreline, damaging below or at-grade infrastructure, requiring additional pumping and costly maintenance and repairs of stormwater and flood control facilities, and increasing the risk of earthquake induced liquefaction.

Climate Scenarios

The Oakland / Alameda Resilience Study will evaluate near-term and long-term impacts for a range of sea level rise projections from 12 to 96 inches. This range was selected based on the best available science[1], the range of elevations of the Alameda County shoreline, and the water levels that are most likely to overtop the current shoreline.

Two sea level rise projections and three Bay water levels within this range were used to determine exposure of assets in ART subregional assessment of vulnerability and risk. These six future climate scenarios are described in Table 1.

Table 1. Future climate scenarios used in the ART subregional project.

Sea Level Rise	Bay Water Level / Condition		
	"Daily" high tide	Storm event	Storm event with wind waves
16 inches	Mean higher high water (MHHW)*	100-year Stillwater (SWEL)	100-year SWEL plus wind driven waves
55 inches			

* MHHW = the average of the higher of the two daily high tides over a tidal epoch (19 years)

A study of sea level rise commissioned by the Alameda County Water Conservation and Flood Control District (ACWCFCD) as a follow up to the ART subregional project will result in a series of six inundation maps (see Table 2) that can be used to understand a wider range of sea level rise, storm event, and Bay water level scenarios. These inundation maps will also be used in the Oakland / Alameda Resilience Study to refine the understanding of vulnerability and risk, and to develop potential implementation timeframes for various adaptation actions.

The ACWCFCD inundation maps will be used to evaluate exposure to six Bay water levels that represent a wide range of possible futures and events (see Table 3). For example, a future Bay water level of 36 inches above mean higher high water (MHHW)[2] can represent the new "daily" high tide with 36 inches of sea level rise, and can also represent the existing 50-year tide level with no sea level rise, a 1-year tide level (e.g., the King Tide) with 24 inches of sea level rise, or a 2-year tide level with 18 inches of sea level rise.

[1] The Coastal and Ocean Working Group of the California Climate Action Team (CO-CAT) updated the *State of California Sea-Level Rise Guidance Document* in March 2013 to include the scientific findings of the National Research Council (NRC) *Sea-Level Rise for the Coasts of California, Oregon, and Washington* study released June 2012

[2] Mean higher high water (MHHW) is the average of the higher of the two daily high tides over a 19 year tidal epoch

Table 2. ACWCFCD inundation map scenarios

Map	Map Scenario (inches above MHHW NAVD88)
1	12
2	24
3	36
4	48
5	72
6	96

Table 3. Sea level rise and extreme tide level combinations represented by ACWCFCD inundation maps

	Sea Level Rise (inches)										
Map	0	6	12	18	24	30	36	42	48	54	60
1	1-yr		MHHW								
2	5-yr 10-yr	2-yr	1-yr		MHHW						
3	25-yr 50-yr	10-yr 25-yr	5-yr 10-yr	2-yr	1-yr		MHHW				
4		100-yr	25-yr 50-yr	10-yr 25-yr	5-yr 10-yr	2-yr	1-yr		MHHW		
5						100-yr	25-yr 50-yr	10-yr 25-yr	5-yr 10-yr	2-yr	1-yr
6										100-yr	25-yr 50-yr

Extreme tides are the maximum high tide level that has occurred over a specific return period that correlates to a probability of occurring. For example a 100-year tide has a return period of 100 years and therefore a 1% chance of occurring in any given year. Tide levels used in the ACWCFCD study are based on model results leveraged from the FEMA's San Francisco Bay Area Coastal Study[3]. For the Alameda County shoreline, the extreme tide levels above MHHW are as follows: 1-year = 12 inches; 2-year = 19 inches; 5-year = 23 inches; 10-year = 27 inches; 25-year = 33 inches; 50-year = 37 inches; 100-year = 42 inches.

[3] http://www.r9map.org/Pages/San-Francisco-Coastal-Bay-Study.aspx

ANNEX

Best Available Science on Sea Level Rise

The Coastal and Ocean Working Group of the California Climate Action Team (CO-CAT) updated the *State of California Sea-Level Rise Guidance Document* in March 2013 to include the scientific findings of the National Research Council (NRC) *Sea-Level Rise for the Coasts of California, Oregon, and Washington* study released June 2012.

The guidance includes recommendations for incorporating sea level rise projections into planning and decision making for projects in California. It also provides recommendations for how to consider risk tolerance, timeframes, economic considerations, adaptive capacities, legal requirements and other relevant factors. Because there is significant uncertainty in how much sea level will rise, the CO-CAT guidance presents ranges for three planning time periods: 2030, 2050 and 2100 (Table 4). The range in projected values increases over time due to the increasing uncertainty in how much sea level will eventually rise.

Table 4. Range of sea level rise projections for California South of Cape Mendocino, using 2000 as a baseline (NRC 2012)

	Sea Level Rise (inches)	
Year	**Low**	**High**
2010	1	4
2020	1	8
2030	**2**	**12**
2040	3	18
2050	**5**	**24**
2060	7	32
2070	10	41
2080	12	49
2090	14	57
2100	**17**	**66**

*based on the June 2012 NRC report on sea level rise and the Our Coast Our Future Sea Level Rise Helper (http://data.prbo.org/cadc/tools/sealevelrise/compare/)

Translating Sea Level Rise Projections to Inundation Maps

Sea level rise is often visualized using inundation maps. These maps can assist in determining under what conditions assets will exposed, how far reaching the consequences may be, and how to prioritize adaptation actions for implementation. To best understanding these key factors it is helpful to evaluate a wide range of possible futures; however this can result in a large number of maps to be created, analyzed and interpreted.

When investigating level rise in the San Francisco Bay or elsewhere, this evaluation can be simplified through the selection of future water levels that represent various combinations of projected sea level rise and potential extreme tide levels. For example, a future Bay water level of 36 inches above mean higher high water (MHHW)[4] can represent the new "daily" high tide

[4] Mean higher high water (MHHW) is calculated as the average of the higher of the two daily high tides over a 19 year tidal epoch

with 36 inches of sea level rise, and can also represents the existing 50-year tide level with no sea level rise, a 1-year tide level (e.g., the King Tide) with 24 inches of sea level rise, or a 2-year tide level with 18 inches of sea level rise.

The relationship of future water level to projected sea level rise and potential extreme tide level for the Alameda County shoreline is presented in Table 5. This matrix represents the increase above existing MHHW that would occur from 6 to 60 inches of sea level rise with tide levels of a 1, 2, 5, 10, 25, 50 or 100 year return period event. The existing water levels (e.g., 0" sea level rise) are based on an understanding of current tides levels along the Alameda County shoreline[5].

Because of the uncertainties in the underlying elevation and water level data, each inundation map can be used to understand water levels within a +/- 3 inch range. This means that the inundation map for 24 inches of sea level rise above MHHW could be used to understand exposure to future water levels between 21 to 27 inches.

Table 5. Water levels and the sea level rise and extreme tide level scenario they represent. Color coding indicates which inundation map (see Table Map Key) can be used to visualize each scenario.

		Extreme Tide Level						
Sea Level Rise	**Water Level above MHHW**	**1-yr**	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
+0	0	12	19	23	27	33	37	42
+6	6	18	25	29	33	39	43	48
+12	12	24	31	35	39	45	49	54
+18	18	30	37	41	45	51	55	60
+24	24	36	43	47	51	57	61	66
+30	30	42	49	53	57	63	67	72
+36	36	48	55	59	63	69	73	78
+42	42	54	61	65	69	75	79	84
+48	48	60	67	71	75	81	85	90
+54	54	66	73	77	81	87	91	96
+60	60	72	79	83	87	93	97	102

** All values in inches above MHHW (NAVD88)

Table Map Key

Color Code	**Map Number**	**Map Scenario** (inches above MHHW)	**Map Interpretation** (+/-3 inches existing or future water levels)
	Map 1	12	9 to 15
	Map 2	24	21 to 27
	Map 3	36	33 to 39
	Map 4	48	45 to 51
	Map 5	72	69 to 75
	Map 6	96	93 to 99

[5] http://www.r9map.org/Pages/San-Francisco-Coastal-Bay-Study.aspx