Addendum 1

Comparison of CHVRA, CoSMoS, and FEMA for Beach Erosion, Bluff Erosion, and Coastal Storm Flood Hazards

EXECUTIVE SUMMARY

This addendum to the Del Mar Coastal Hazards, Vulnerability, and Risk Assessment (CHVRA, ESA 2016) provides a comparison of beach erosion, bluff erosion, and coastal flood risk assessments performed for the CHVRA to the U.S. Geological Survey's latest Coastal Storm Modeling System 3.0 results (CoSMoS 3.0 Phase 2, USGS 2017) and the Federal Emergency Management Agency (FEMA 2017) Flood Insurance Study (FIS) and Flood Insurance Rate Map (FIRM). The conclusion and recommendations of this comparison are as follows:

Beach Erosion

The beach erosion and shoreline projections in the CHVRA and most recent CoSMoS results generally agree. Both the CHVRA and CoSMoS results project the potential for the loss of the Del Mar Beach with about 2.6 feet of sea-level rise (SLR), which is projected to occur by about 2060 in the high SLR scenario used for the CHVRA.[1] ESA concludes that:

- The CHVRA shoreline erosion projections are appropriate for the purposes of adaptation planning and coastal policy development.

- CoSMoS projections should not be used in place of the CHVRA results without a comparison to CHVRA results and an independent, third-party review by a qualified coastal engineer and/or geologist.

Bluff Erosion

The latest CoSMoS Phase 2 bluff erosion projections show less erosion than the previously released CoSMoS Phase 1 results. The CHVRA bluff erosion projections were based on the previously released CoSMoS Phase 1 results and the CHVRA, therefore, projects more bluff erosion than the latest CoSMoS results. ESA further assessed and compared the bluff erosion projections from the CHVRA and CoSMoS Phase 1 and 2 and concluded that the CoSMoS Phase 2 results may under-predict future erosion with SLR. Based on this review, ESA recommends:

- An independent bluff erosion analysis to provide additional information for the basis of refining the City's coastal bluff overlay.

- If the City does not choose to do an independent analysis, ESA recommends using the CHVRA bluff erosion projections (which are based on the CoSMoS Phase 1 results) to inform the coastal bluff overlay. ESA also recommends the option for the City to sub-divide the overlay into subareas with different levels of risk (e.g., one or more transitional subareas) based on both the CHVRA/CoSMoS Phase 1 results and the CoSMoS Phase 2 results.

ESA does not recommend using the CHVRA's bluff erosion projection without increased SLR, which ESA and Dr. Adam Young performed solely for the purpose of comparison to the CoSMoS

[1] The high SLR scenario used in the CHVRA projects 5.5 feet of SLR in 2100.

results. Note that the bluff erosion projections from the CHVRA and CoSMoS do not consider existing bluff armoring or stabilization measures because the existing armoring and stabilization may not limit or prevent bluff erosion over the long-term. Also note that the bluff erosion hazard and vulnerability assessments from the CHVRA and CoSMoS assume that the bluffs would erode past the railroad; this approach provides the baseline “no action” scenario for the purposes of adaptation planning and policy development.

Flooding

The flood hazards from the CHVRA and the most recent CoSMoS release both consider SLR and generally agree. The updated FEMA flood maps do not consider SLR and show a limited coastal flood risk compared to the CHVRA, which does include SLR. Note that while the CHVRA, CoSMoS, and FEMA use different methods to assess coastal flooding, all consider the existing seawalls and revetments and all show that beachfront properties are currently vulnerable to coastal flooding. Based on ESA’s analysis and comparison, ESA concludes that the CHVRA coastal flooding and wave hazard maps and analysis are the best available and most appropriate mapping for the purposes of the City’s adaptation planning and coastal policy development.

1 INTRODUCTION

This addendum to the Del Mar Coastal Hazards, Vulnerability, and Risk Assessment (CHVRA, ESA 2016) provides a comparison of beach erosion, bluff erosion, and coastal flood risk assessments performed for the CHVRA to the latest U.S. Geological Survey Coastal Storm Modeling System 3.0 results (CoSMoS, USGS 2017) and the Federal Emergency Management Agency (FEMA, 2017) Flood Insurance Study (FIS) and Flood Insurance Rate Map (FIRM). The CHVRA was prepared in 2016 when only partial initial CoSMoS results were available and before the updated FEMA FIS and FIRM were available. This addendum to the CHVRA compares the results of the CHVRA to the latest CoSMoS results and FEMA products. The conclusion of this comparison (Section 5) is that CHVRA results are appropriate for SLR adaptation planning and informing policy development.

The CHVRA analyzed the increase in coastal hazard exposure and vulnerability with SLR in the City of Del Mar for the following four hazards:

1. Beach Erosion (Section 4.1 in CHVRA)
2. Coastal Flooding (Sections 4.3 and 5.1 in CHVRA)
3. Bluff Erosion (Sections 4.2 and 5.2 in CHVRA)
4. River Flooding (Sections 4.4 and 5.3 in CHVRA)

At the time that the CHVRA was prepared and completed in 2016, only the following partial initial results for CoSMoS 3.0 were available (published November 15, 2015).

1. Beach erosion: Initial CoSMoS results included beach erosion or shoreline positions in 2100 under CoSMoS' "hold the line and continued nourishment" scenario. ESA therefore performed a supplemental analysis of beach erosion from 2030 to 2100 for the CHVRA.
2. Coastal flooding: Initial CoSMoS results included coastal flood extents, but these flood extents excluded the contribution of wave runup and beach erosion. For the CHVRA, ESA therefore performed an independent wave runup analysis and coastal flood hazard assessment.
3. Bluff erosion: Initial CoSMoS results included bluff erosion (also referred to as cliff retreat rates) and positions in 2100. ESA applied the CoSMoS cliff retreat rates and interpolated cliff positions from the CoSMoS results for the CHRVA.

4. River flooding: CoSMoS results include only extreme coastal flooding with inclusion of the coincident river discharge and flooding estimated to occur during an extreme coastal flood event. ESA assessed extreme San Dieguito River flooding for the CHVRA. CHVRA results for extreme river flooding are not compared to CoSMoS results because the CHRVRA considers extreme river flood hazards, whereas CoSMoS does not.

Since publication of the CHVRA, additional CoSMoS erosion and flooding data have become available through the USGS. This addendum compares the results of the CHVRA and the latest CoSMoS results (CoSMoS 3.0, Phase 2, published October 2016) for beach erosion, bluff erosion, and coastal flooding. Compared to the initial CoSMoS release, the latest CoSMoS results show different hazard extents than the initial outputs and provide additional results and scenarios. Sections 2.2, 3.2, and 4.2 of this addendum provide overviews of the updated CoSMoS modeling, and sections 2.3, 3.3, and 4.4 compare the results of the CHVRA with the updated CoSMoS shoreline and flood modeling within the City of Del Mar.

At the time that the CHVRA was prepared and completed in 2016, the available and effective FEMA FIS and FIRM were based on analyses performed in the 1980s (see CHVRA Section 4.4.2). FEMA subsequently released an updated FIS for San Diego County and FIRMs, including for the City, in April 2016. The FEMA update includes new analyses and mapping of current extreme coastal flood hazards. FEMA does not consider or analyze future flood hazards with SLR or coastal erosion. This addendum compares the updated FEMA and CHVRA results for current extreme coastal flood hazards. FEMA did not update or include new analyses of extreme river hazards for the San Dieguito River. The CHRVA results for extreme river flood hazards are based on the prior FEMA results and mapping of river flood hazards, which FEMA has not updated. A comparison of CHRVA and FEMA river flood hazards results is therefore not necessary or included in this addendum. For information on how the river flooding hazards were evaluated, refer to CHVRA Sections 4.4 and 5.3.

2 COMPARISON OF BEACH EROSION ASSESSMENT

The following sections summarize the beach erosion assessment methods used in the CHVRA (Section 2.1) and CoSMoS (Section 2.2) and compare the results (Section 2.3).

2.1 CHVRA

As described further in CHVRA Section 4.1, ESA calculated future beach widths for a range of SLR curves (CCC 2015) using the Bruun rule, assuming no background erosion (0 feet/year). A representative mean starting beach width was estimated to be approximately 95 feet in 2010 and was used as the baseline for this analysis. The width of 95 feet was calculated as an approximate annual mean beach width at Mean High Water along a representative North Beach profile (Profile SIOB). The annual mean was calculated across surveys taken from January 2011 and January 2016, as shown in Figure 26 in Section 4-1 of the CHVRA. A beach width analysis was also conducted for Profile SIOB using only winter beach profiles and only summer beach profiles.

Figure 27 and Table 2 in the CHVRA show the beach widths over time under existing conditions and three future SLR scenarios. Under the high SLR scenario, ESA's analysis shows beach widths reaching zero as early as 2060. For the mid SLR scenario, ESA's analysis shows beach loss by 2090. Note that Figure 27 and Table 2 represent average beach widths, which is typically 25 feet greater than winter beach widths and 25 feet less than summer beach widths.

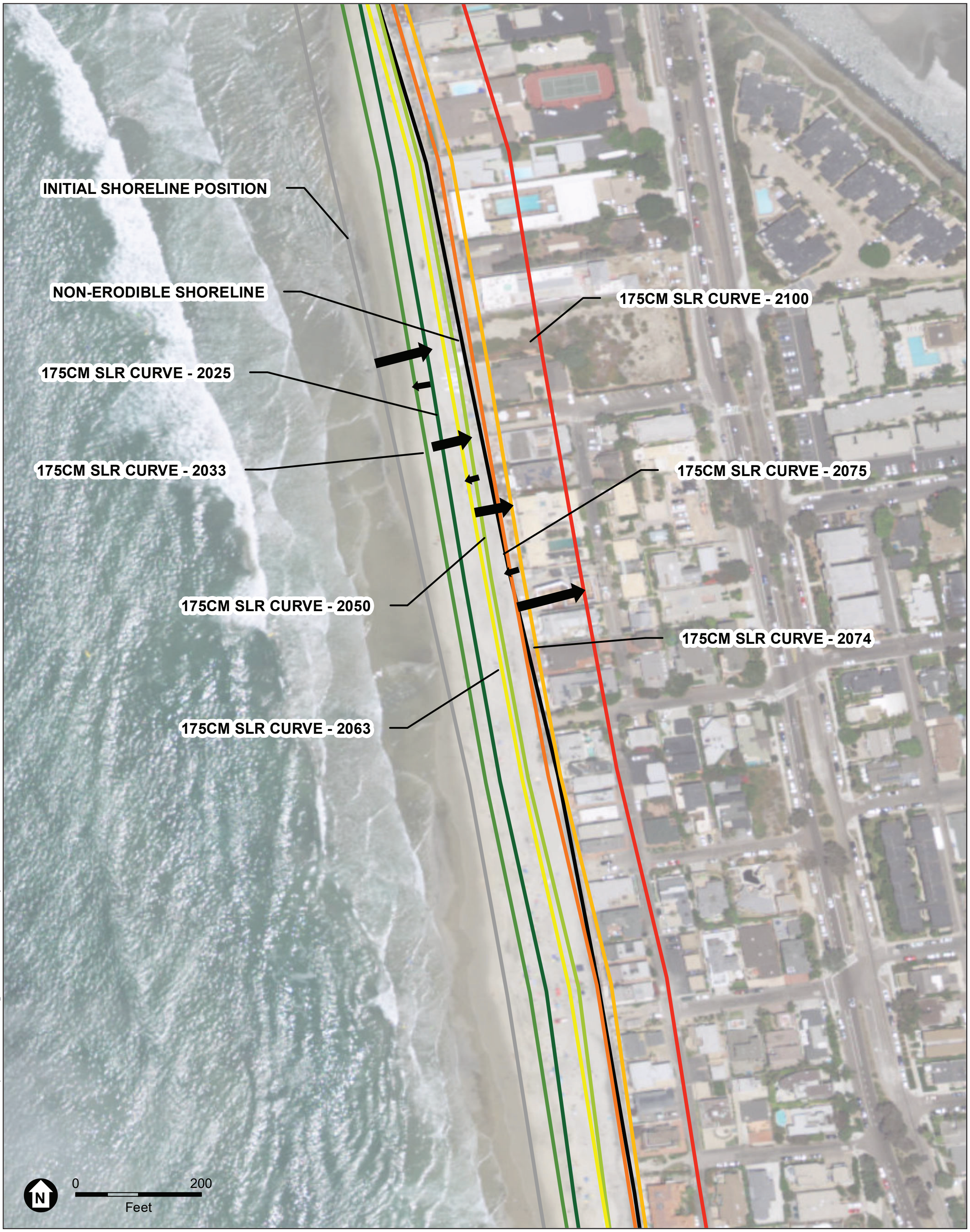
2.2 CoSMoS

Figure 1 below shows the results of the most recent CoSMoS 3.0 shoreline erosion projections for various SLR amounts. CoSMoS uses past shoreline position data to estimate the historic "background" rate of shoreline. This background rate is then included in the projection model, which assumes a Bruun-type geomorphic response to SLR and incorporates historical trends in shoreline position, longshore transport, and cross shore transport to provide a line indicating the inland extent of shoreline erosion. The CoSMoS shoreline erosion model evaluates the beach width on January 1 of each simulation year under two management scenarios ("hold-the-line" and "let it go") and two nourishment scenarios ("nourishment" and "no nourishment"). The model is then run to simulate historic erosion, and if the model results show a shoreline position that is farther seaward than past shoreline position data, the model estimates the amount of beach nourishment (or other sand sources/sinks) that would have needed to occur for the model to match past shoreline position data. For the beach nourishment model scenarios, the model includes this estimate of past beach nourishment as part of the shoreline erosion projections. For the "no beach nourishment" model scenarios, the model does not include this adjustment. Note that for Del Mar beach, the CoSMoS results for their "nourishment" and "no nourishment" scenarios are the same because CoSMoS uses historic shoreline transect data from 1995 to present, which show erosion. Therefore, there is no nourishment term in CoSMoS for the Del Mar shoreline transects and no difference between the "nourishment" and "no nourishment" CoSMoS results for Del Mar (Sean Vitousek, USGS, pers. comm., April 12, 2017).

Figure 1 shows the CoSMoS results for the "let it go" scenario, in which shoreline erosion is not stopped at the existing developed edge. The CoSMoS shoreline erosion projections for the Del Mar beach shoreline appear to indicate oscillation between erosion and accretion over time as shown by the black arrows between successive shoreline positions in Figure 1. This is because the CoSMoS model simulates shoreline position on a daily or similar time step based on simulated ocean conditions and the results are output for January 1 of each year. In certain model output years (2033, 2063, and 2075), the model output shoreline shows positions on January 1 that are seaward of the shoreline position output for the preceding output year. This is due to the CoSMoS method of simulating daily and annual variations in the shoreline position (Sean Vitousek, USGS, pers. comm., April 12, 2017). The CoSMoS results do show overall progressive erosion over time as discussed further in following section.

2.3 Comparison

To compare the CHVRA and CoSMoS shoreline erosion projections, ESA measured the beach widths derived from the CoSMoS shoreline projections over time for 175 cm (5.7 ft) of SLR in 2100 (shown in Figure 1). **Figure 2** compares beach widths based on the CoSMoS results with the CHVRA's beach width projections with 5.5 ft of SLR in 2100. To ensure consistency, the beach widths were measured at the same location as the representative transect used for ESA's shoreline position analysis (SIOB). As shown in Figure 2 below, the shoreline projections from the CHVRA and CoSMoS generally agree, as they are both primarily based on application of the Bruun Rule. The CoSMoS shoreline outputs showed three positions (2033, 2063 and 2075) that showed shoreline accretion due to the fact that the CoSMoS results output shoreline position on January 1 as discussed in the above section. When these outputs for years when wider beach widths are simulated by CoSMoS on January 1 are excluded, the ESA CHVRA and CoSMoS beach widths are in close agreement as shown in Figure 2. This is because the CHVRA and CoSMoS shoreline projections are both based on the Bruun rule and the fact that future projected shoreline erosion projected with SLR based on the Bruun rule dominates the future projections more so than other coastal processes simulated by CoSMoS. Both the CHVRA and CoSMoS results project the potential for the loss of the Del Mar beach by about 2060 in the SLR scenario with about 5.5 ft of SLR in 2100. The CHVRA did not project the potential shoreline position landward of existing development, whereas CoSMoS results for the "let it go" scenario show the potential for shoreline erosion into developed areas after about 2060.



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SOURCE: USGS, 2015

Del Mar Vulnerability Assessment

Figure 1
CoSMoS 3.0 Phase 2 Shoreline Projections Over Time with 175 cm (5.7 ft) of SLR in 2100

ESA

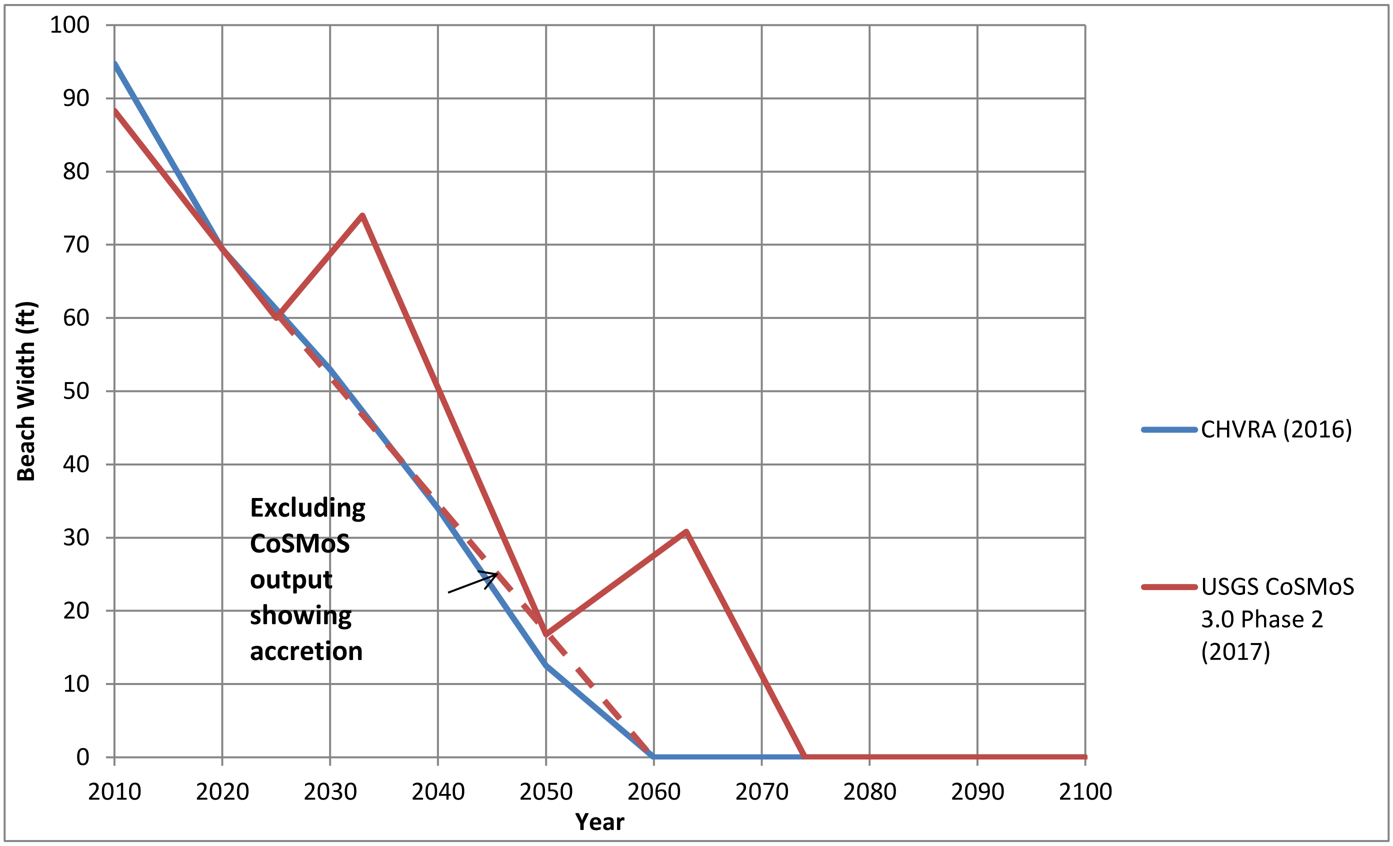


Figure 2. ***CHVRA and CoSMoS Beach Width Comparison with approximately 5.5 ft of SLR for Transect SIOB***

3 COMPARISON OF BLUFF EROSION ASSESSMENT

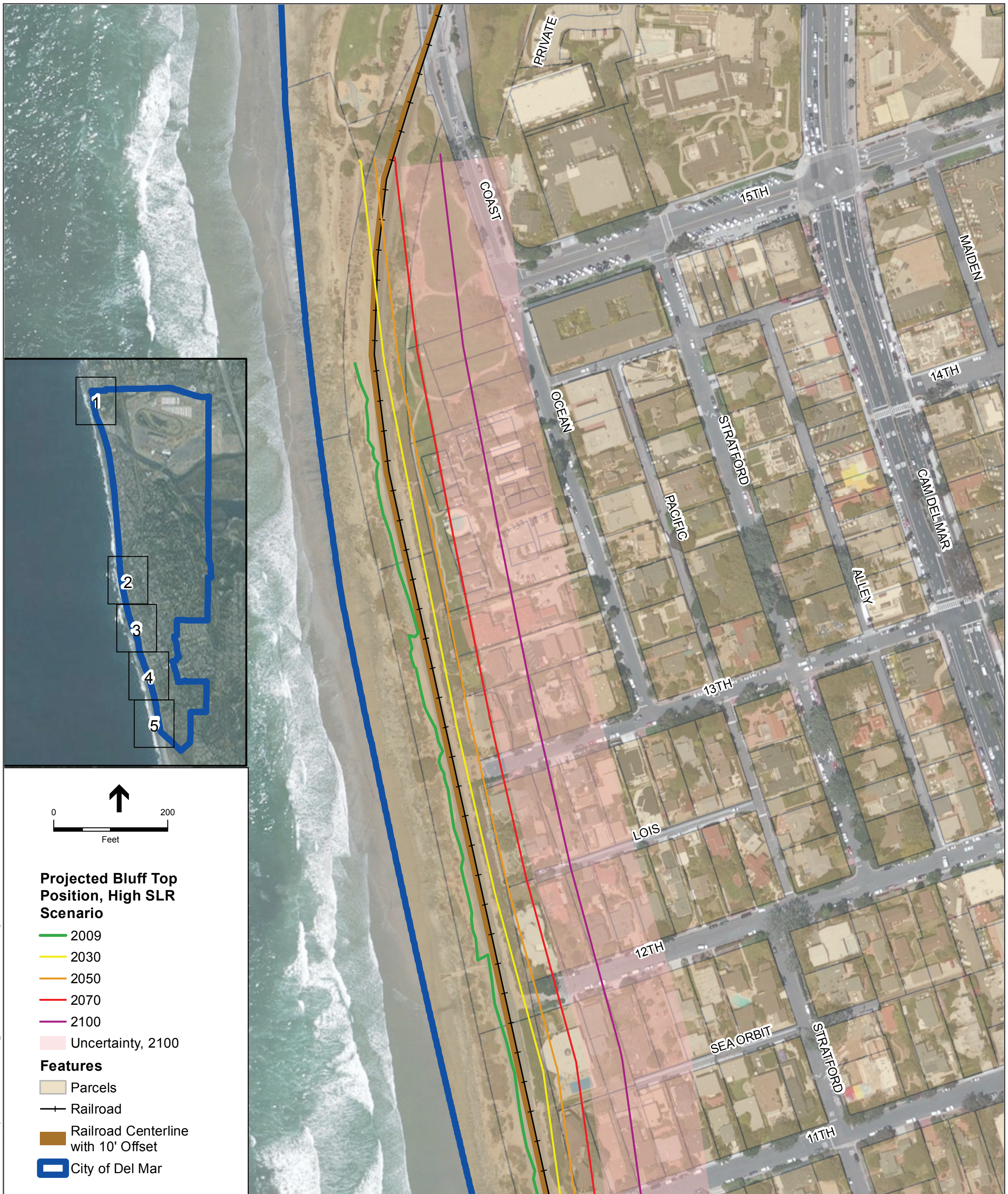
The following section summarizes the bluff erosion hazard assessment methods used in CHVRA (Section 3.1), and CoSMoS (Section 3.2). Section 3.2 also discusses the differences in bluff erosion projections between the initial 2015 CoSMoS 3.0 release and the subsequent 2016 CoSMoS 3.0 Phase 2. Section 3.3 compares the results of both the CHVRA and both CoSMoS projections, and discusses potential implications for the City of Del Mar.

3.1 CHVRA

Section 4.2 of the CHVRA provides a full description of the bluff retreat analysis performed as part of the CHVRA; this section includes a brief summary of the methods. The future acceleration of cliff retreat rates and future cliff top positions with SLR were assessed for the CHVRA using results from the initial USGS CoSMoS 3.0 cliff retreat projections. Additionally, an analysis of historic cliff retreat for the Del Mar bluffs was performed for the CHVRA as a check of CoSMoS. At the time of CHVRA publication, CoSMoS provided bluff edge projections for 1.0 m (3.3 ft), 1.5 m (4.9 ft), and 2.0 m (6.6 ft) SLR. ESA used the CoSMoS 1.0 m cliff retreat rate and position for the mid-SLR scenario for the CHVRA assessment. For the high SLR scenario, ESA interpolated the cliff retreat rates and positions between the CoSMoS 1.5 m and 2.0 m SLR scenario to estimate bluff erosion with 5.5 ft (1.68 m) of SLR in 2100.

Starting with the 2100 cliff top positions based on CoSMoS 3.0 Phase 1, ESA projected backwards in time using the CoSMoS 3.0 cliff retreat rates to estimate cliff top positions in 2070, 2050, and 2030. Rather than assuming a constant retreat rate over time, ESA developed retreat rate curves where the retreat rate increases over time due to accelerating rates of SLR. The increase in retreat rates was assumed to be proportional to the increase in the rate of SLR based on the National Research Council (NRC 2012) SLR curves. The average retreat rate along the south Del Mar bluffs from CoSMoS was used to project the 2030, 2050, and 2070 cliff top projections for the South Beach and South Bluffs Districts. The average rate along the North Bluffs was used for the North Bluffs projections. **Figure 3** below shows one panel of cliff top position projections from the CHVRA; Figures 30 – 30.5 in the CHVRA provide the bluff projection positions for all of Del Mar.

Additionally, as a check, ESA evaluated potential future cliff top positions at decadal intervals from 2020-2100 using the estimated mean Del Mar long-term historical cliff retreat rate between 1934 and 2009 of 0.52 ft/yr, shown in **Figure 4** below. Future cliff line positions were generated by buffering the 2009 digitized cliff line for the specified retreat distance. Actual future retreat is expected to be greater than this projection of the historic bluff erosion rate because increased SLR is expected to increase the rate and extent of bluff erosion. Figures A1-A7 in Appendix A of the CHVRA provide these projection maps for the entire City.



Note : Projected bluff top position for 2100 is interpolated from CoSMoS 3.0 results with 1.5 m SLR and 2.0 m SLR. Positions for 2030 – 2070 are interpolated based on CoSMoS 3.0 erosion rates. Positions in 2010 (north) and 2009 (south) are based on LiDAR elevation data.

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SOURCE: SanGIS 2016, USGS 2015

Figure 3
High SLR Bluff Projections from the CHVRA

ESA

Note: Projections are based on the average long term historical cliff top edge retreat rate between 1934 and 2009. Actual future retreat would vary from the average rate and projections. The alongshore variation from the mean historical cliff retreat between 1934 and 2009 is approximately 25 ft (two standard deviations). This provides a measure of how much greater (or less) the retreat could be than the average projected retreat shown.

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SOURCE: USGS 2016

Figure 4
Bluff Retreat Projections for Historic Rates of Retreat without Increased SLR

ESA

3.2 CoSMoS 3.0 Phase 1 and Phase 2

After publication of the CHVRA, the USGS released updated CoSMoS 3.0 Phase 2 results that superseded the initial CoSMoS 3.0 Phase 1 results. CoSMoS 3.0 Phase 2 included an updated set of bluff projections for the same SLR scenarios used for Phase 1 (1.0, 1.5, and 2.0 m SLR), as well as additional SLR scenarios (0.25, 0.5, 0.75, 1.25, 1.75, and 5.0 m SLR). According to the USGS, the bluff retreat modeling approach was refined significantly between the Phase 1 and Phase 2 release dates. The Phase 1 modeling approach used a single model, whereas the Phase 2 methods used a suite of projections from multiple models (Patrick Limber, USGS, pers. comm., 2018). As a result, the USGS significantly reduced the CoSMoS bluff erosion projections between the Phase 1 and Phase 2 releases. **Figure 5-1** through **Figure 5-8** below show the bluff erosion projections for the 1.0, 1.5, and 2.0 m SLR scenarios for both CoSMoS Phase 1 and Phase 2.

In addition to the difference in model ensemble, the historical retreat rates used for the modeling and projected bluffs differed between the Phase 1 and Phase 2 releases. For the 2015 projections, CoSMoS used the historic rates from the USGS National Assessment of Shoreline Change (Hapke and Reid 2007), which were developed from bluff edge positions between the mid 1930s and 1998. In the Phase 2 modeling, the USGS incorporated a more recent bluff end position from 2010, which generally lowered the historic rates calculated at each transect. **Table 1** below shows and compares the historic rates used in the bluff projection modeling for Phase 1 and Phase 2. In general, the Phase 2 historic rates were lower than the corresponding Phase 1 rates. The bluff erosion models are sensitive to background historical rates at each transect, and as a result both the projected bluff erosion rates and cliff edge location are generally lower, or more seaward, for the Phase 2 projections (Patrick Limber, USGS, pers. comm., 2018).

Note that CoSMoS applies the erosion rate estimated at each model transect location and projects bluff erosion at individual transects. The projected bluff top erosion line from CoSMoS is a straight line interpolation that connects the projected bluff top at each transect.

TABLE 1
HISTORIC AND PROJECTED BLUFF EROSION RATES

Transect ID	Phase 1	Phase 2	Difference	Phase 1	Phase 2	Difference	Phase 1	Phase 2	Difference
	Projected Bluff Erosion Rates (m/yr)								
	Historic Rate (m/yr)			1 m			2 m		
596	0.250	0.185	0.065	0.500	0.268	0.232	0.780	0.401	0.379
597	0.220	0.165	0.055	0.450	0.249	0.201	0.730	0.370	0.360
598	0.210	0.181	0.029	0.410	0.239	0.171	0.690	0.362	0.328
599	0.180	0.161	0.019	0.360	0.230	0.130	0.600	0.347	0.253
600	0.150	0.121	0.029	0.280	0.187	0.093	0.470	0.290	0.180
601	0.130	0.094	0.036	0.250	0.149	0.101	0.400	0.244	0.156
602	0.130	0.117	0.013	0.250	0.197	0.053	0.410	0.289	0.121
603	0.150	0.144	0.006	0.280	0.210	0.070	0.450	0.316	0.134
604	0.160	0.133	0.027	0.310	0.205	0.105	0.490	0.309	0.181
605	0.160	0.120	0.040	0.330	0.185	0.145	0.520	0.241	0.279
606	0.180	0.141	0.039	0.360	0.189	0.171	0.570	0.265	0.305
607	0.220	0.178	0.042	0.400	0.246	0.154	0.640	0.356	0.284
608	0.240	0.232	0.008	0.430	0.313	0.117	0.680	0.452	0.228
609	0.230	0.214	0.016	0.420	0.317	0.103	0.660	0.453	0.207
610	0.200	0.167	0.033	0.390	0.235	0.155	0.620	0.318	0.302
611	0.180	0.182	-0.002	0.380	0.291	0.089	0.600	0.403	0.197
612	0.180	0.142	0.038	0.380	0.199	0.181	0.620	0.293	0.327
613	0.180	0.178	0.002	0.390	0.268	0.122	0.650	0.390	0.260
614	0.180	0.160	0.020	0.400	0.225	0.175	0.670	0.314	0.356
615	0.180	0.151	0.029	0.400	0.209	0.191	0.640	0.304	0.336
616	0.170	0.166	0.004	0.380	0.222	0.158	0.600	0.311	0.289
617	0.170	0.154	0.016	0.360	0.253	0.107	0.570	0.353	0.217
618	0.170	0.153	0.017	0.360	0.233	0.127	0.570	0.334	0.236
619	0.170	0.153	0.017	0.350	0.218	0.132	0.580	0.218	0.362
Average (m/yr)	**0.183**	**0.158**		**0.368**	**0.231**		**0.592**	**0.331**	
Average (ft/yr)	**0.6**	**0.5**		**1.2**	**0.8**		**1.9**	**1.1**	

3.3 Comparison

The CHVRA was based on and is consistent with the initial USGS CoSMoS 3.0 Phase 1 results that were available at that time. The CoSMoS Phase 1 results projected an increase in erosion over the historic rate of erosion projected by ESA for the CHVRA, which is consistent with the expectation that erosion will increase with increasing rates of SLR. The updated CoSMoS 3.0 Phase 2 results projected less erosion than the Phase 1 results. The Phase 1 model projections that ESA used as the basis for the CHVRA are outside of the outer range of uncertainty from the CoSMoS 3.0 Phase 2 results (Figure 5). Therefore, CoSMoS Phase 2 results appear to suggest that the Phase 1 results over-predict projected erosion.

To further assess this change in the CoSMoS model results for this addendum, ESA compared the CoSMoS Phase 2 bluff erosion projections with 1.0 m SLR to the CHVRA's projection of the historic erosion rate (performed previously by ESA and Dr. Adam Young as described in Section 3.2), which is shown in **Figure 6-1** through **Figure 6-8.** ESA's comparison shows that the CoSMoS Phase 2 bluff erosion projections with 1.0 m SLR range from approximately 60 ft landward (at CoSMoS transect 609) to approximately 22 ft seaward (between CoSMoS transects 606 and 605) of the CHVRA's projection of the historic rate of erosion. CoSMoS Phase 2 bluff projections with 1.0 m of SLR are less than the CHVRA's projection of the historic rate of erosion at a number of locations south of 6th St (various locations interpolated between CoSMoS transects 607 and 599 and at transects 605 and 601). This indicates that the CoSMoS Phase 2 projections may underestimate future bluff erosion, since it is expected that future erosion rates will be higher than historic rates due to the projected increase in SLR.

CoSMoS Phase 2 and the CHVRA use similar historic rates of erosion (average historic erosion rates along the Del Mar southern bluffs of 0.5 ft/yr for both). The CoSMoS Phase 2 projections of limited erosion beyond or less erosion than the CHRVA historic erosion rate projection can be attributed to differences in modeling methodology. CoSMoS Phase 2 applies a suite of models to project the increase in the historic rate due to SLR at a particular transect. The CHVRA applies an average rate of historic erosion along the entire Del Mar southern bluffs. ESA's opinion is that CHVRA's approach of applying a spatially averaged rate of erosion to a representative section of bluff is an accepted practice of accounting for spatial and temporal variability in bluff erosion that is scientifically supported. For example, locations along a bluff that have not historically eroded as fast as adjacent locations could actually erode more rapidly in the future due to the long time scale and episodic nature of bluff erosion (Young et al. 2018).

Figure 7-1 through **7-8** compare the following bluff erosion projections for 2100 for the purposes of informing the City's planning and policy decisions and providing a basis for ESA's recommendations below:

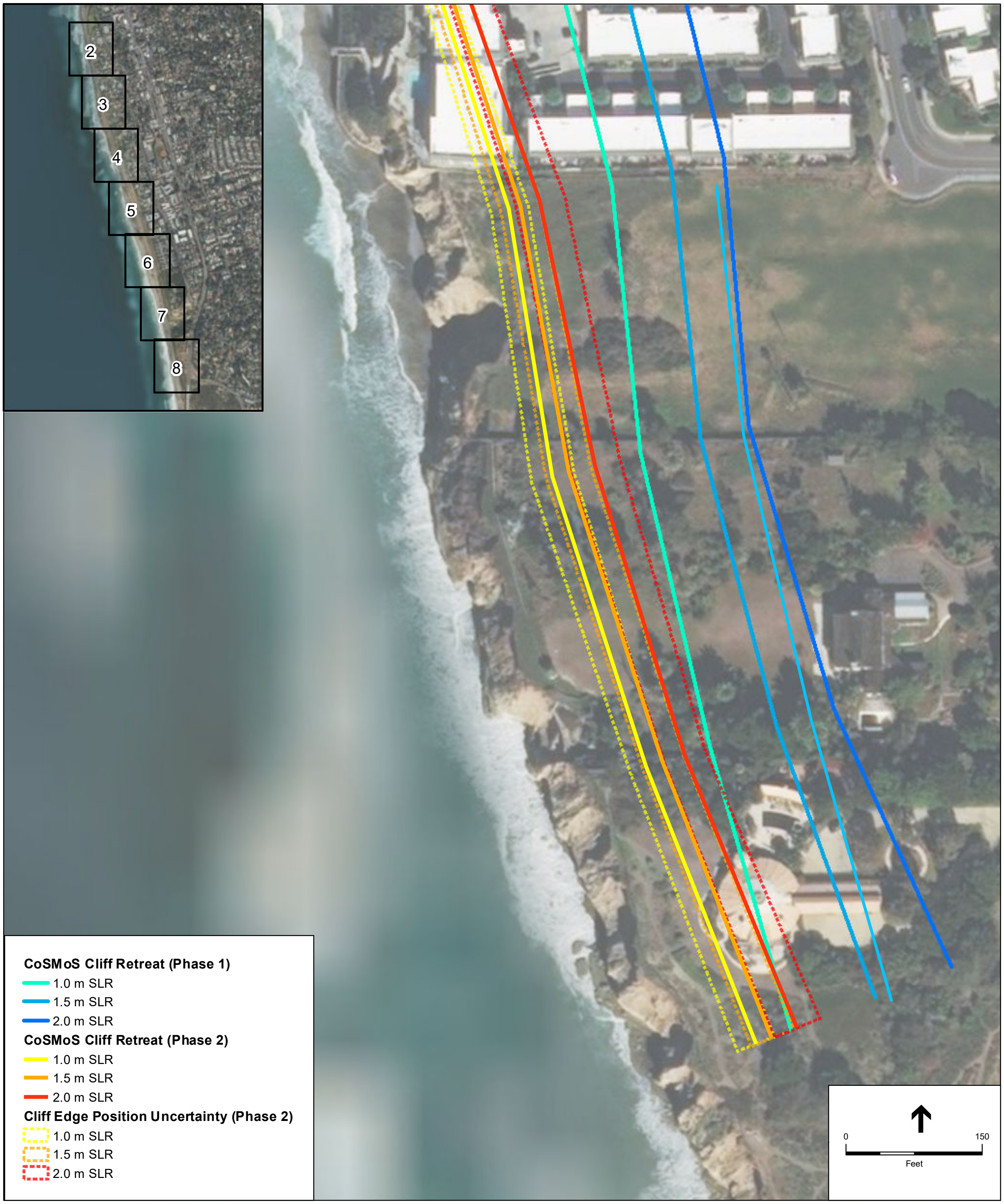
1. CHVRA bluff erosion projection with 5.5 ft of SLR in 2100 (high SLR scenario), based on CoSMoS 3.0 Phase 1.

2. CoSMoS 3.0 Phase 2 bluff erosion projection with 5.7 ft of SLR in 2100 (high SLR scenario). The outer or landward uncertainty limit of the CoSMoS 3.0 Phase 2 model results is shown, rather than the average model projection.

3. CHVRA projection of bluff erosion in 2100 without increased SLR performed by ESA and Dr. Adam Young. Note that this projection is only shown for comparison to the model projections above. As discussed further below, ESA does not recommend using this bluff erosion projection without increased SLR as a representation of future bluff erosion.

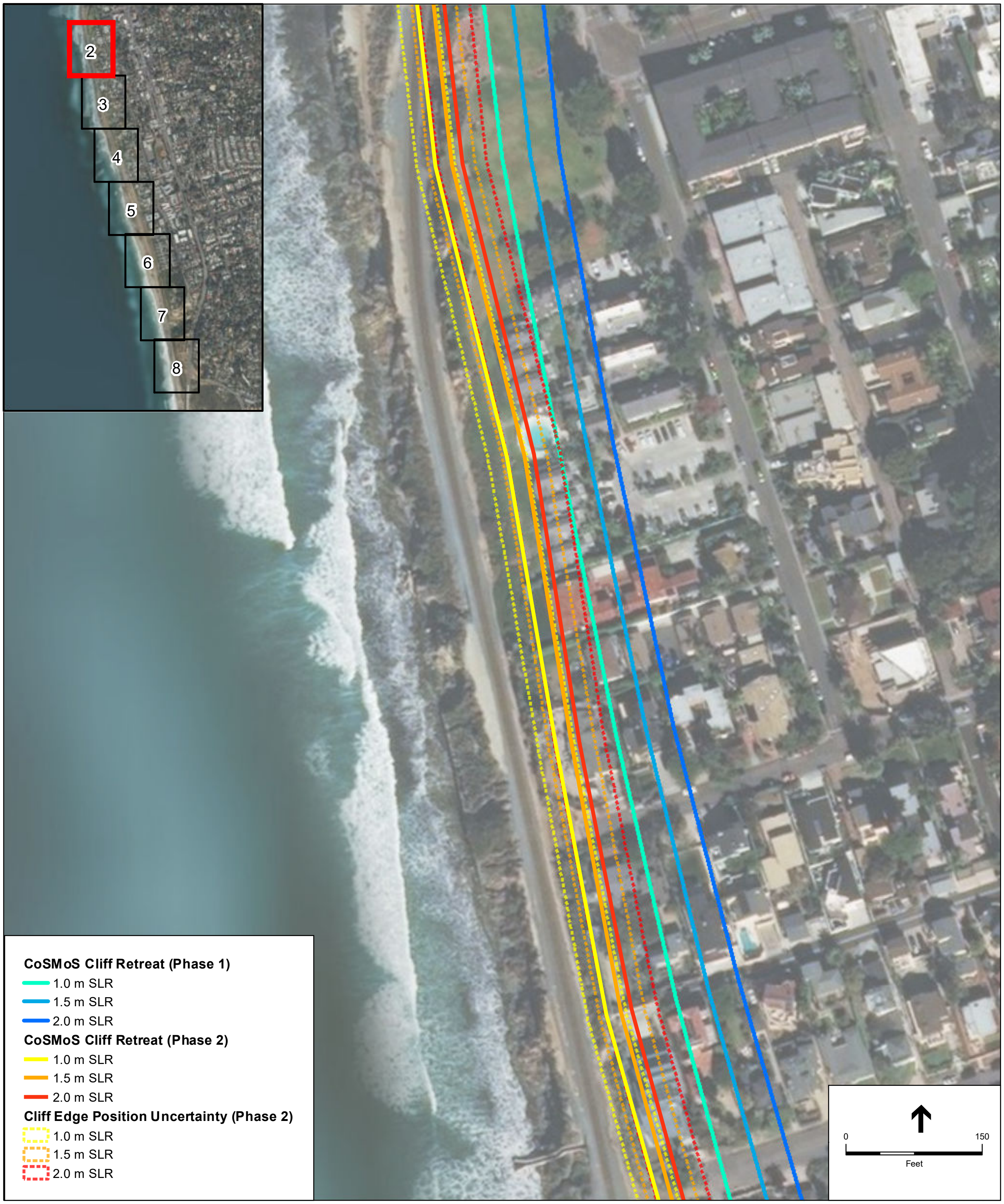
At this time, ESA does not recommend updating the CHVRA's projection of future bluff erosion with SLR (item 1 above, which is based on CoSMoS Phase 1 results) with the CoSMoS Phase 2 results (item 2) because ESA's comparison of the different models indicates that the CoSMoS Phase 2 results may under-predict future erosion with SLR. ESA recommends that ESA and Dr. Adam Young perform an independent, site-specific analysis with modeling of projected future bluff erosion with SLR for the Del Mar bluffs. Note that modeling independent from CoSMoS was not included in the City's work program for the CHVRA because the work program was based on using CoSMoS. ESA does not recommend using CoSMoS Phase 2 results to update bluff erosion overlay zones for the Local Coastal Program (LCP) Amendment or other planning purposes at this time. An independent bluff erosion analysis as recommended above would provide additional information for the basis of refining the LCP and planning. If an independent analysis is not performed, an alternative approach to refining the bluff erosion hazard overlay zone would be to sub-divide the bluff erosion hazard overlay zone into subareas with different levels of risk. If the City chooses to take this approach, ESA recommends using the CHVRA (i.e., CoSMoS 3.0 Phase 1) and the outer/landward uncertainty of the CoSMoS 3.0 Phase 2 model projections for the high sea-level rise scenario in 2100 (items 1 and 2 above). ESA does not recommend using the bluff erosion projection without increased SLR in 2100 (item 3 above), which ESA has included for comparison only.

Note that the bluff erosion projections from the CHVRA and CoSMoS do not consider existing bluff armoring or stabilization measures because the existing armoring and stabilization may not limit or prevent bluff erosion over the long-term. Also note that the bluff erosion hazard and vulnerability assessments from the CHVRA and CoSMoS assume that the bluffs would erode past the railroad; this approach provides the baseline “no action” scenario for the purposes of adaptation planning and policy development.



SOURCE: USGS 2015

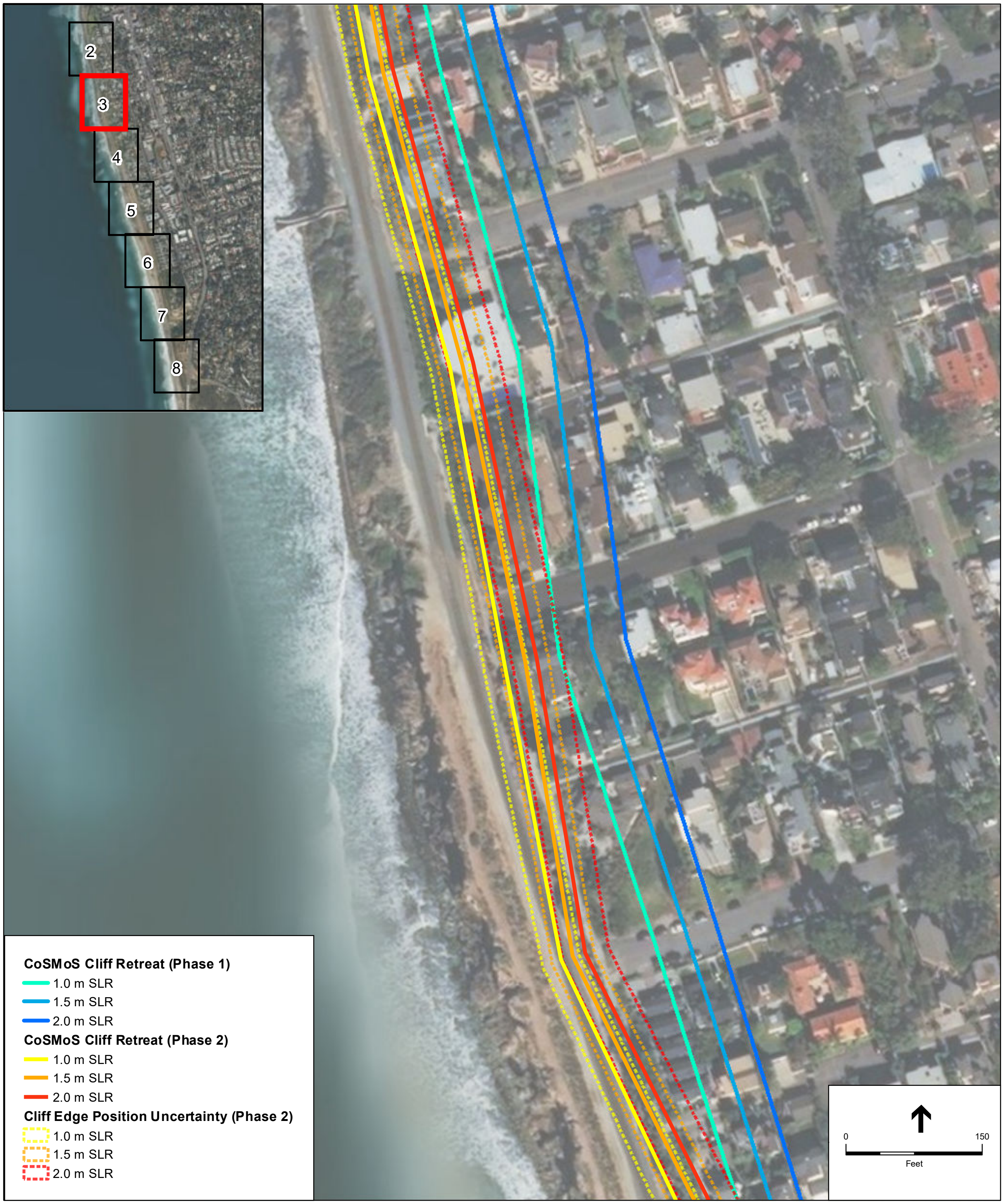
Figure 5-1
Bluff Retreat Comparison between CoSMoS 3.0 Phase 1 and Phase 2



SOURCE: USGS 2015

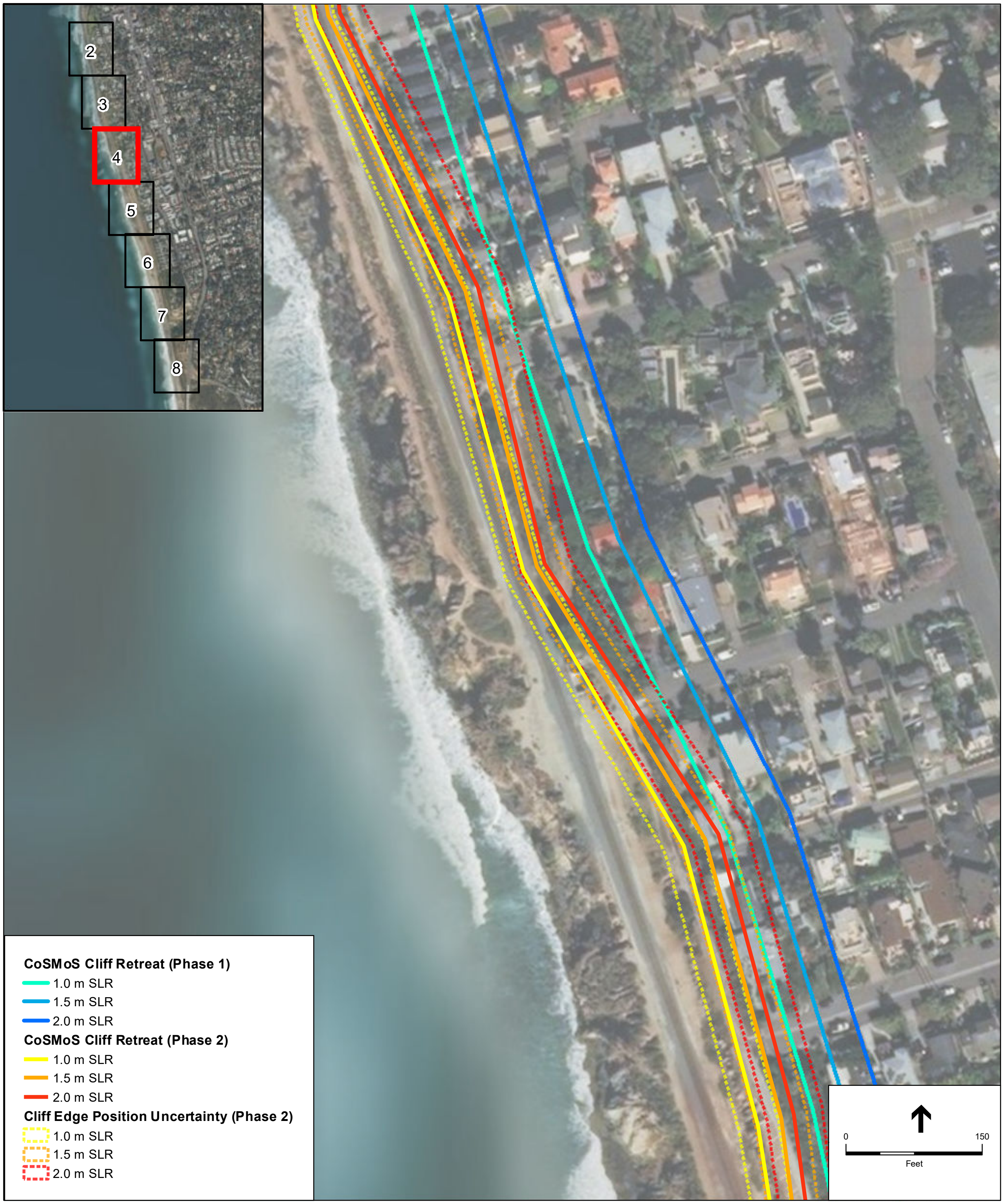
Figure 5-2

Bluff Retreat Comparison between CoSMoS 3.0 Phase 1 and Phase 2



SOURCE: USGS 2015

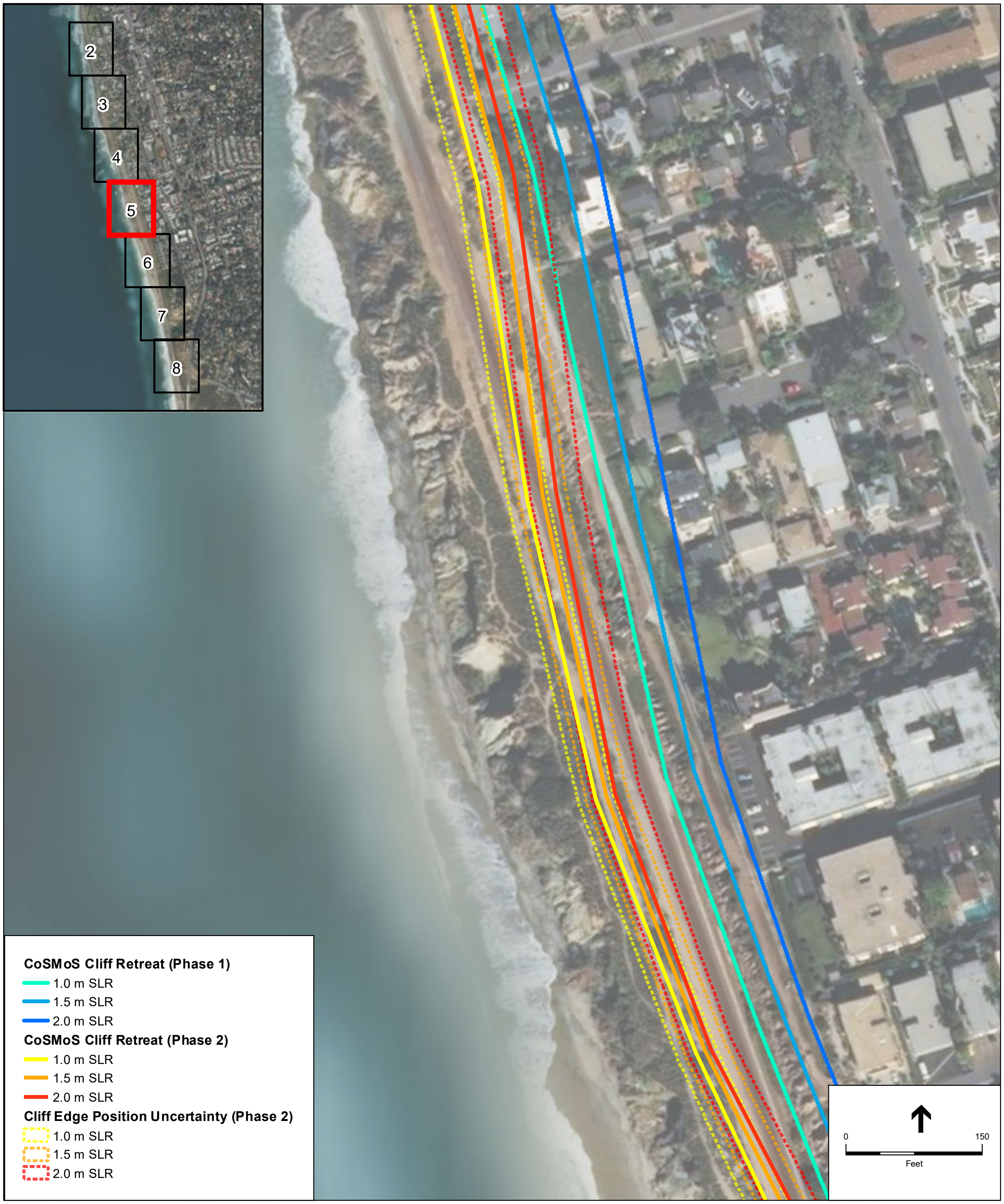
Figure 5-3
Bluff Retreat Comparison between CoSMoS 3.0 Phase 1 and Phase 2



SOURCE: USGS 2015

Figure 5-4

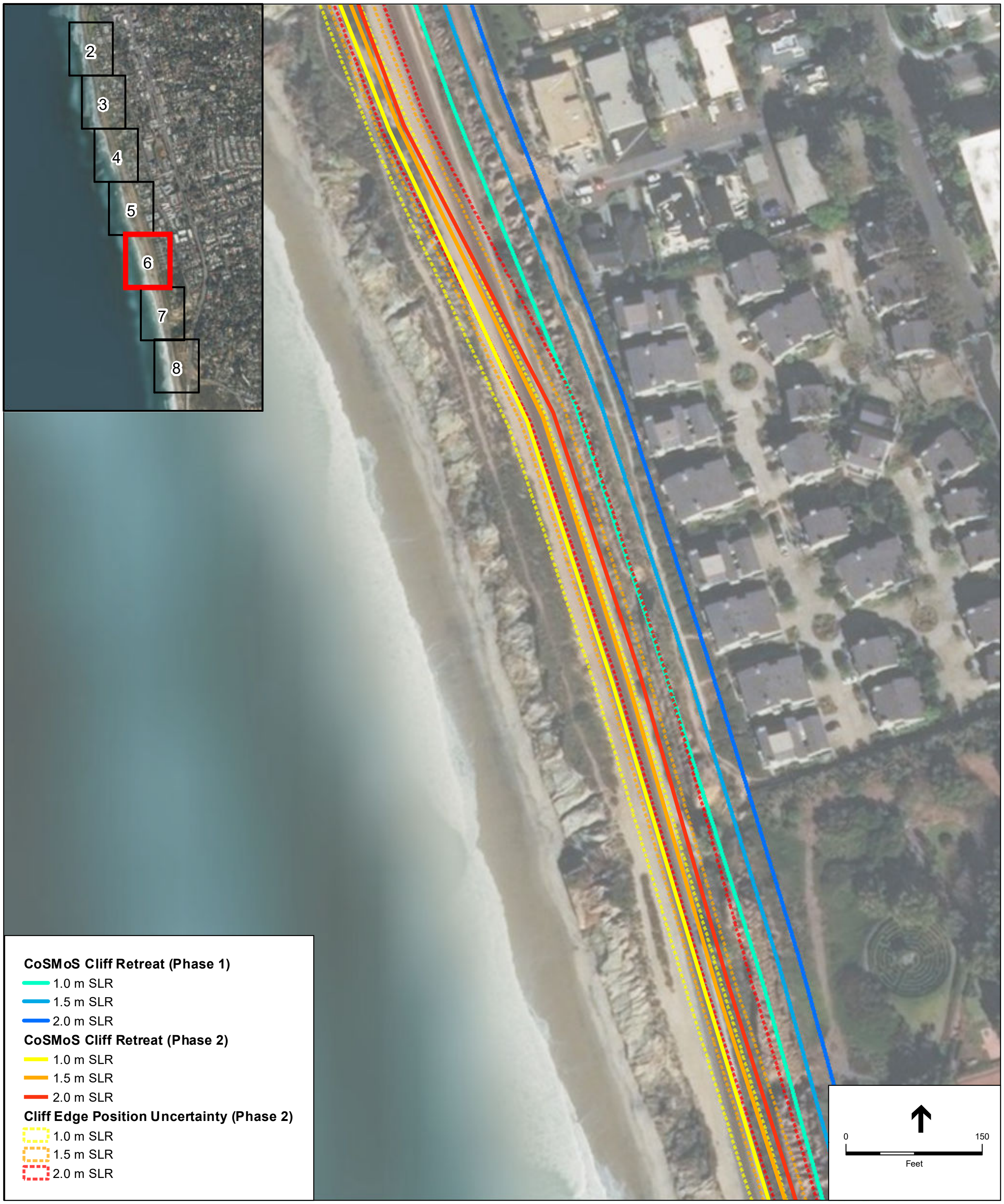
Bluff Retreat Comparison between CoSMoS 3.0 Phase 1 and Phase 2



SOURCE: USGS 2015

Figure 5-5

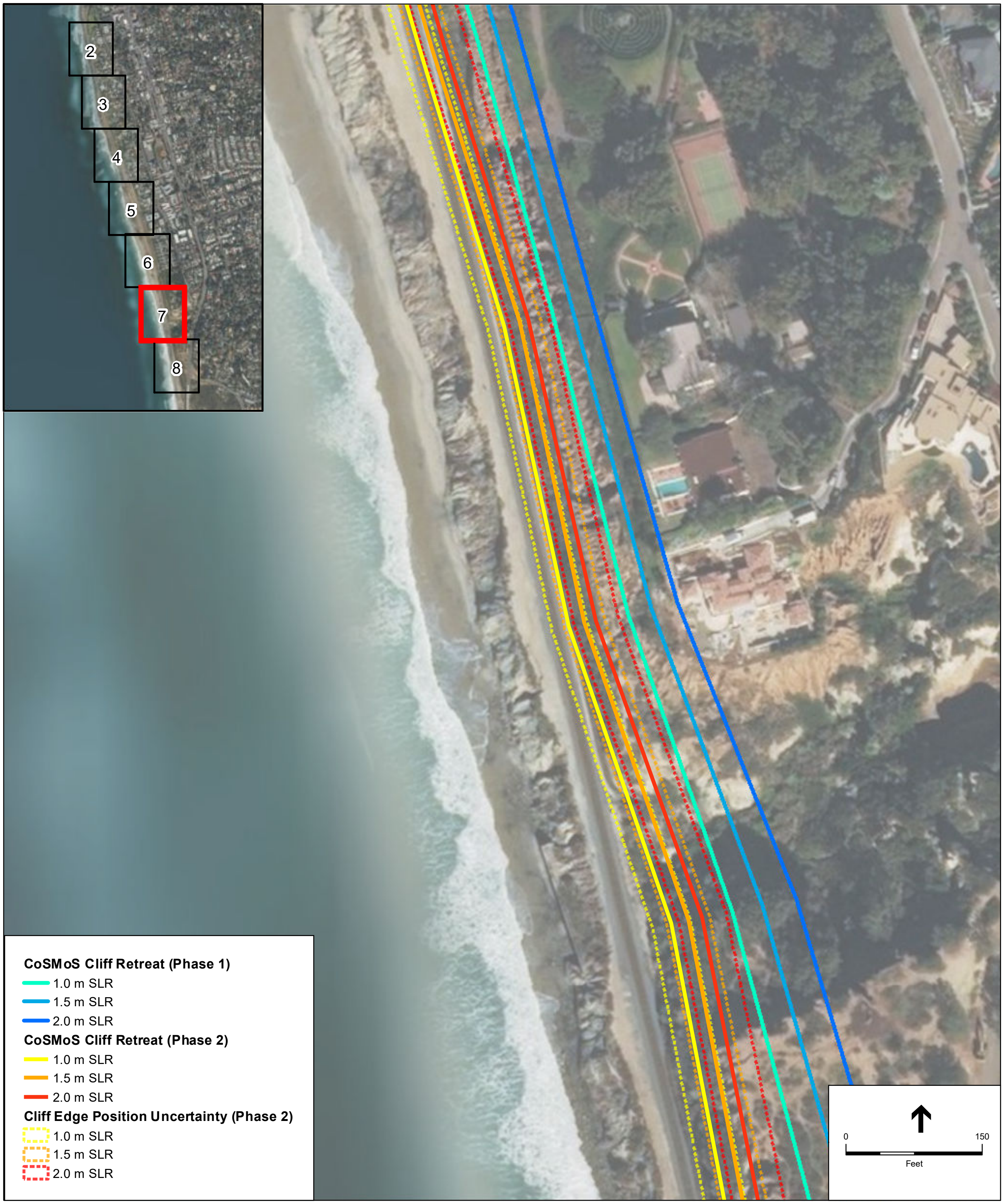
Bluff Retreat Comparison between CoSMoS 3.0 Phase 1 and Phase 2



SOURCE: USGS 2015

Figure 5-6

Bluff Retreat Comparison between CoSMoS 3.0 Phase 1 and Phase 2



SOURCE: USGS 2015

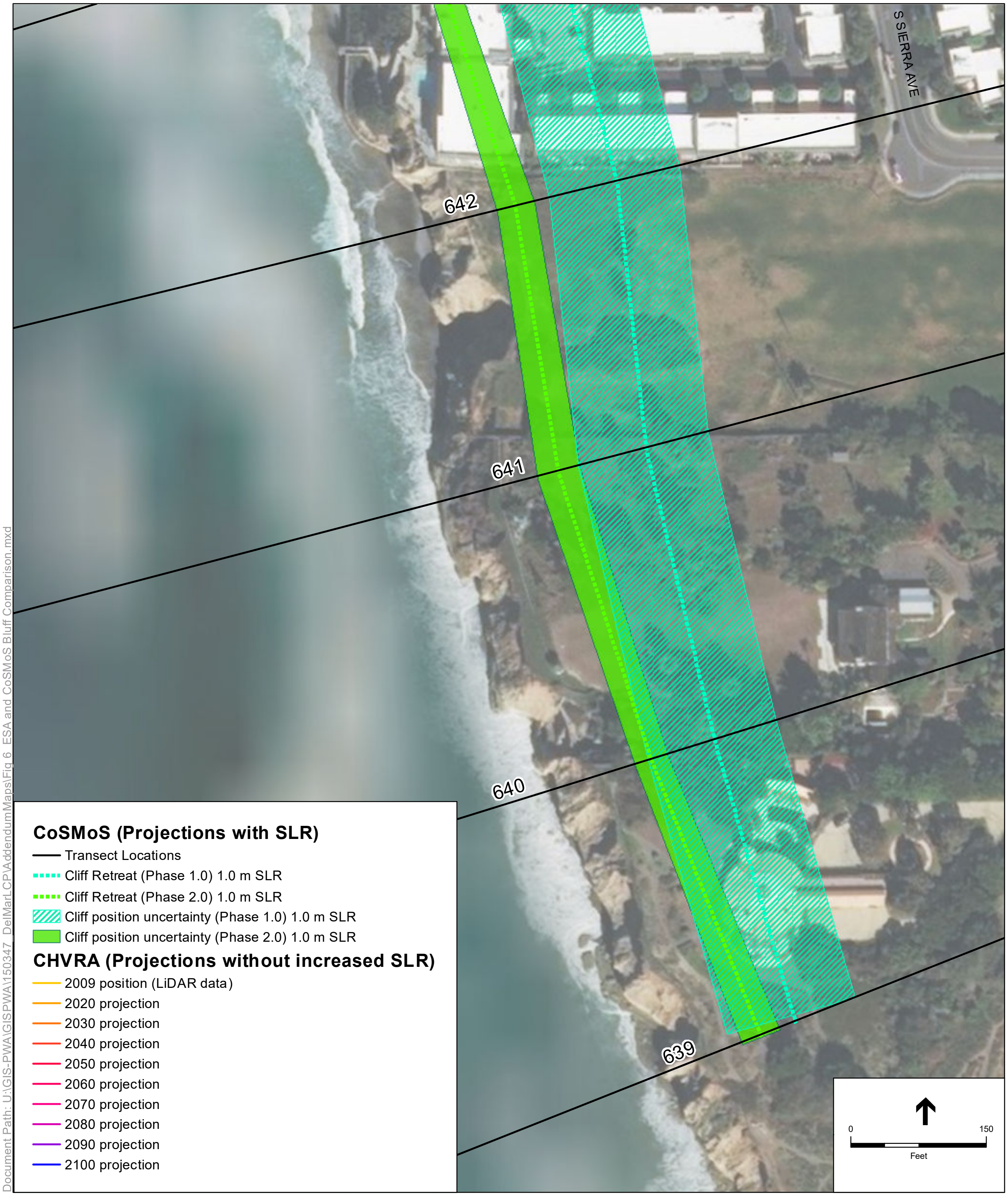
Figure 5-7

Bluff Retreat Comparison between CoSMoS 3.0 Phase 1 and Phase 2

SOURCE: USGS 2015

Figure 5-8

Bluff Retreat Comparison between CoSMoS 3.0 Phase 1 and Phase 2



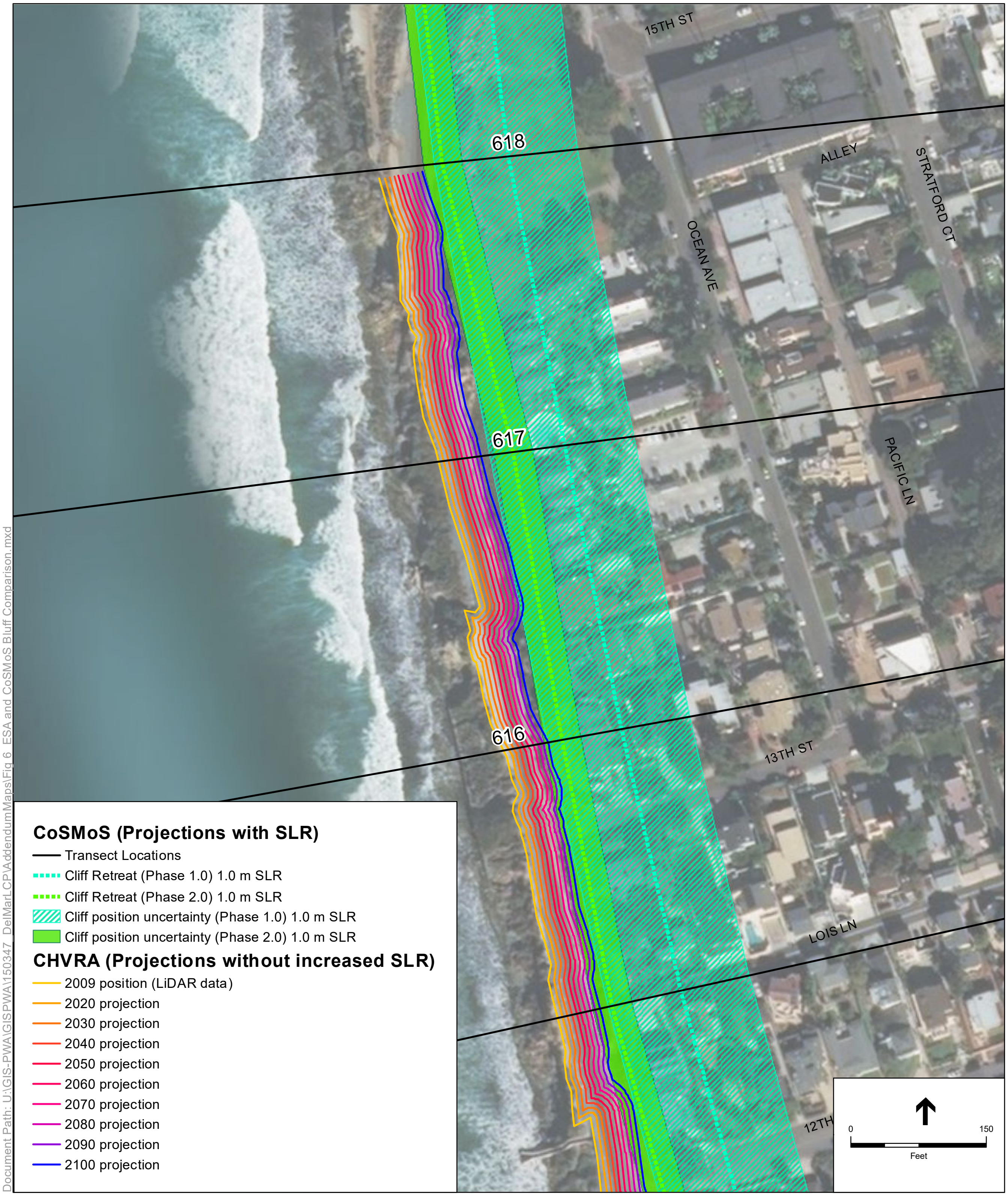
Document Path: U:\GIS-PWA\GIS\PWA\150347_DelMarLCP\AddendumMaps\Fig 6_ESA and CoSMoS Bluff Comparison.mxd

SOURCE: USGS 2016

Note: Projections are based on the average long term historical cliff top edge retreat rate between 1934 and 2009. Actual future retreat would vary from the average rate and projections. The alongshore variation from the mean historical cliff retreat between 1934 and 2009 is approximately 25 ft (two standard deviations). This provides a measure of how much greater (or less) the retreat could be than the average projected retreat shown.

Figure 6- 1

Comparison of Bluff Retreat Projections without Increased SLR from CHVRA and Projections with SLR from CoSMoS Phase 1 and Phase 2



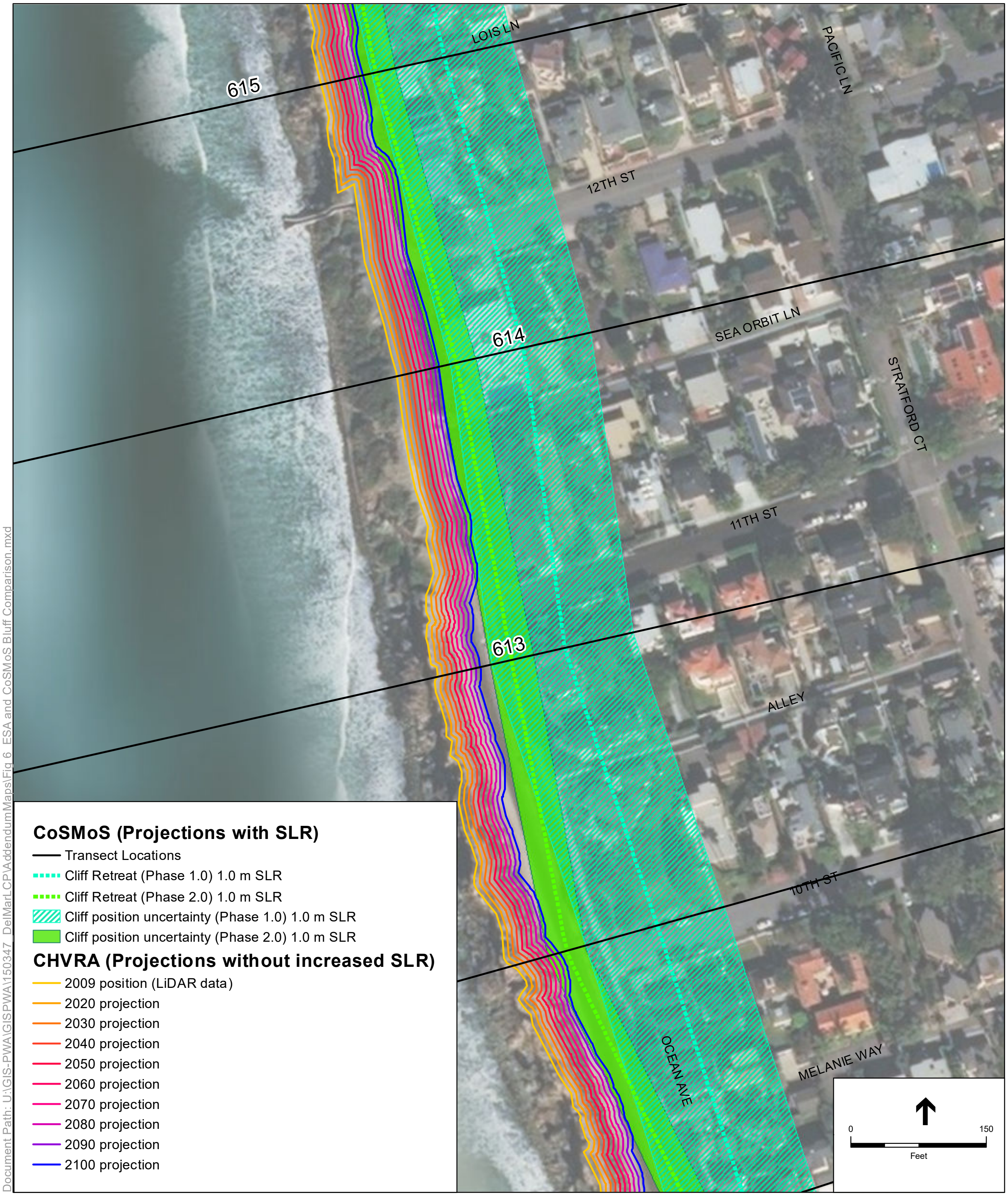
Document Path: U:\GIS-PWA\GISPWA\150347_DelMarLCP\AddendumMaps\Fig 6_ESA and CoSMoS Bluff Comparison.mxd

SOURCE: USGS 2016

Note: Projections are based on the average long term historical cliff top edge retreat rate between 1934 and 2009. Actual future retreat would vary from the average rate and projections. The alongshore variation from the mean historical cliff retreat between 1934 and 2009 is approximately 25 ft (two standard deviations). This provides a measure of how much greater (or less) the retreat could be than the average projected retreat shown.

Figure 6- 2

Comparison of Bluff Retreat Projections without Increased SLR from CHVRA and Projections with SLR from CoSMoS Phase 1 and Phase 2



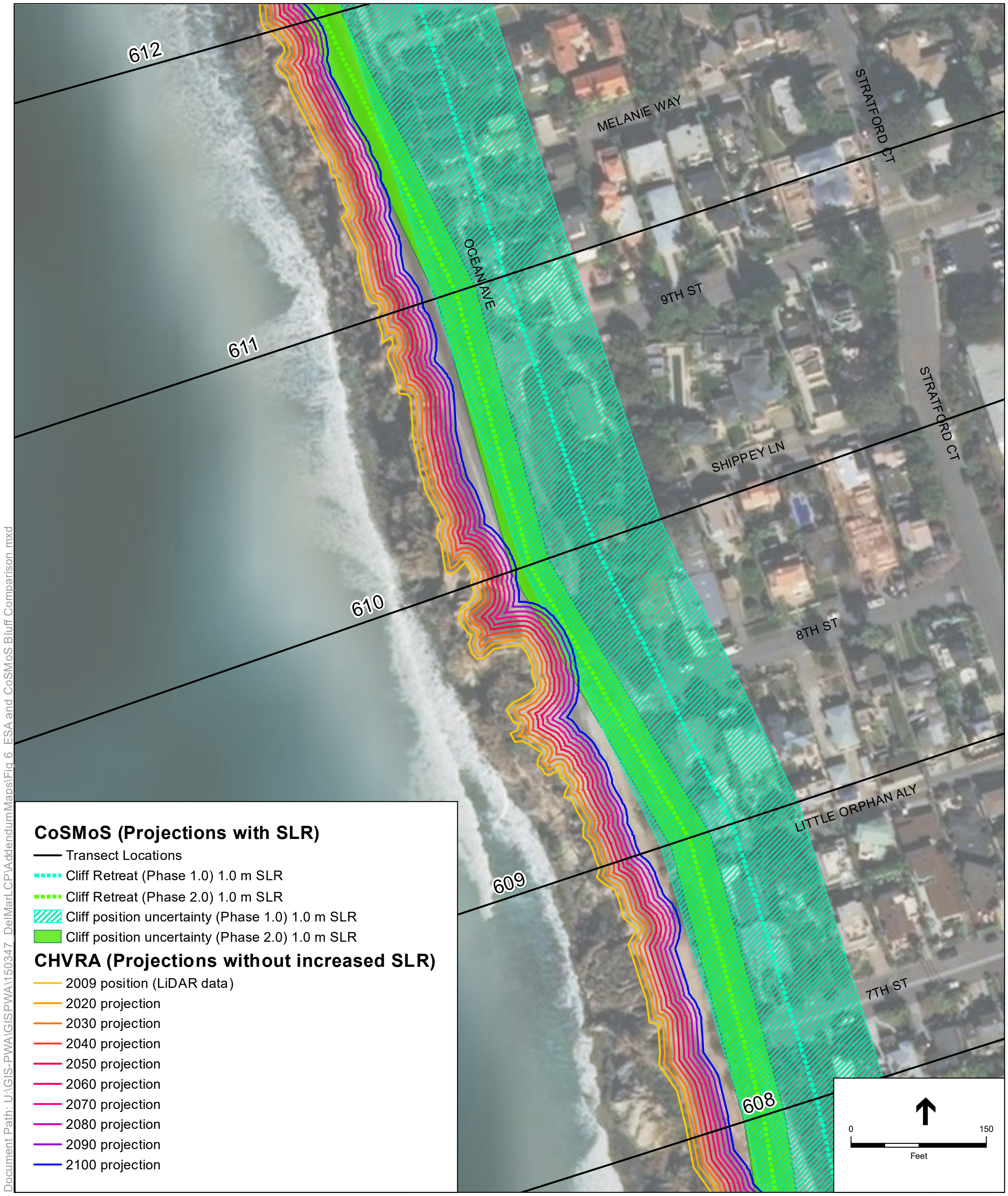
Document Path: U:\GIS-PWA\GISPWA\150347_DelMarLCP\AddendumMaps\Fig 6_ESA and CoSMoS Bluff Comparison.mxd

SOURCE: USGS 2016

Note: Projections are based on the average long term historical cliff top edge retreat rate between 1934 and 2009. Actual future retreat would vary from the average rate and projections. The alongshore variation from the mean historical cliff retreat between 1934 and 2009 is approximately 25 ft (two standard deviations). This provides a measure of how much greater (or less) the retreat could be than the average projected retreat shown.

Figure 6- 3

Comparison of Bluff Retreat Projections without Increased SLR from CHVRA and Projections with SLR from CoSMoS Phase 1 and Phase 2



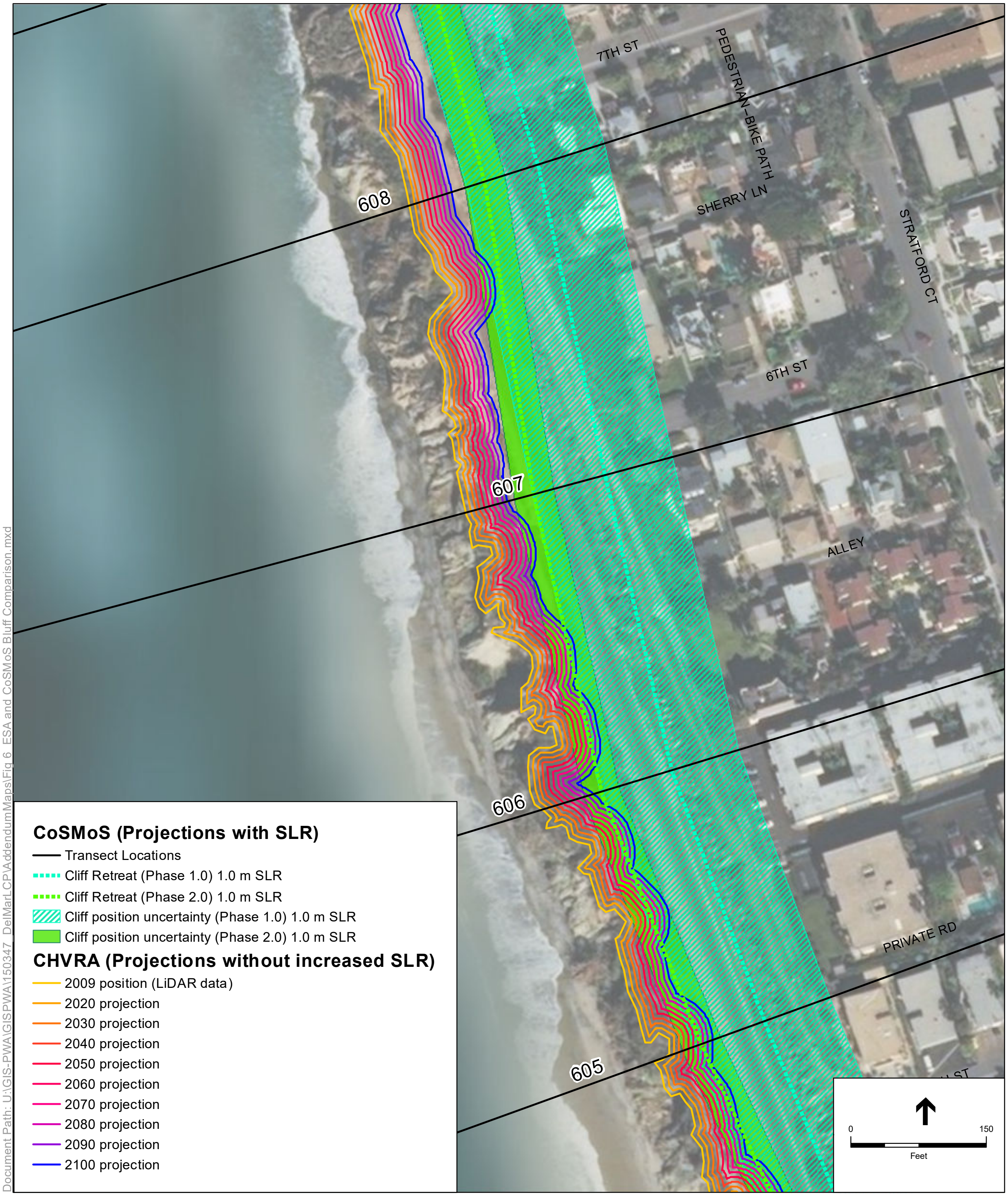
Del Mar Vulnerability Assessment

SOURCE: USGS 2016

Note: Projections are based on the average long term historical cliff top edge retreat rate between 1934 and 2009. Actual future retreat would vary from the average rate and projections. The alongshore variation from the mean historical cliff retreat between 1934 and 2009 is approximately 25 ft (two standard deviations). This provides a measure of how much greater (or less) the retreat could be than the average projected retreat shown.

Figure 6- 4

Comparison of Bluff Retreat Projections without Increased SLR from CHVRA and Projections with SLR from CoSMoS Phase 1 and Phase 2

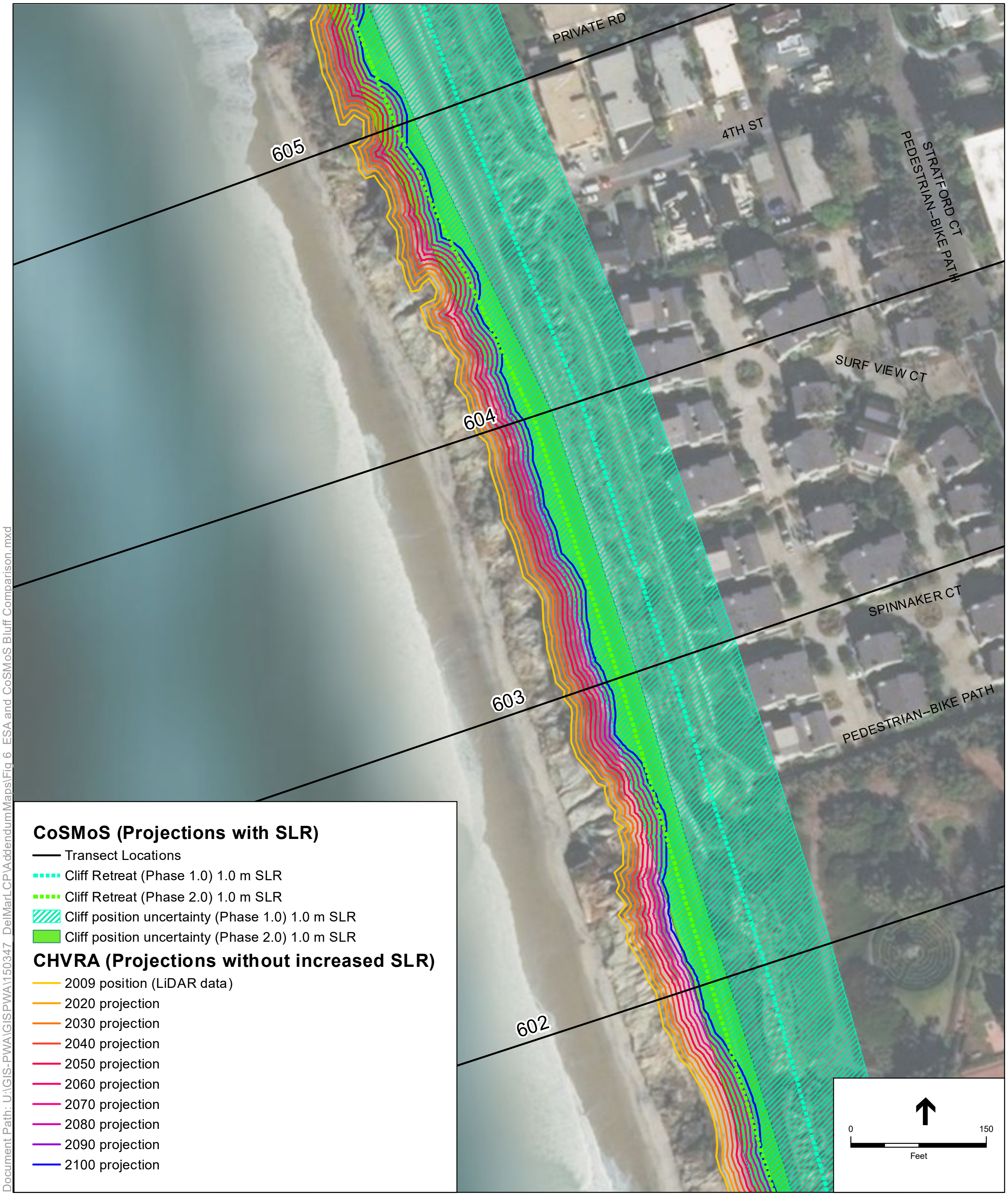


SOURCE: USGS 2016

Note: Projections are based on the average long term historical cliff top edge retreat rate between 1934 and 2009. Actual future retreat would vary from the average rate and projections. The alongshore variation from the mean historical cliff retreat between 1934 and 2009 is approximately 25 ft (two standard deviations). This provides a measure of how much greater (or less) the retreat could be than the average projected retreat shown.

Figure 6- 5

Comparison of Bluff Retreat Projections without Increased SLR from CHVRA and Projections with SLR from CoSMoS Phase 1 and Phase 2

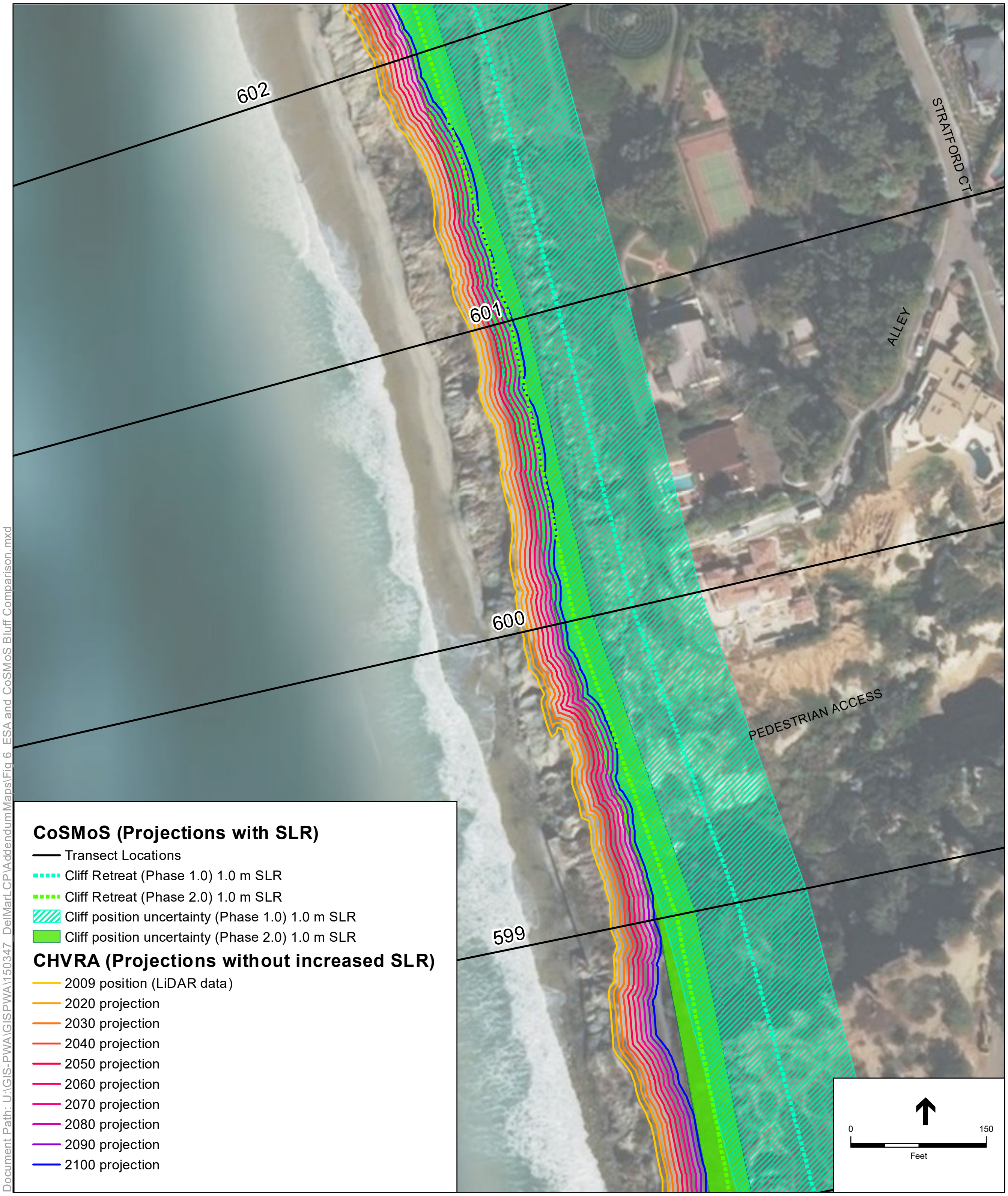


SOURCE: USGS 2016

Note: Projections are based on the average long term historical cliff top edge retreat rate between 1934 and 2009. Actual future retreat would vary from the average rate and projections. The alongshore variation from the mean historical cliff retreat between 1934 and 2009 is approximately 25 ft (two standard deviations). This provides a measure of how much greater (or less) the retreat could be than the average projected retreat shown.

Figure 6- 6

Comparison of Bluff Retreat Projections without Increased SLR from CHVRA and Projections with SLR from CoSMoS Phase 1 and Phase 2



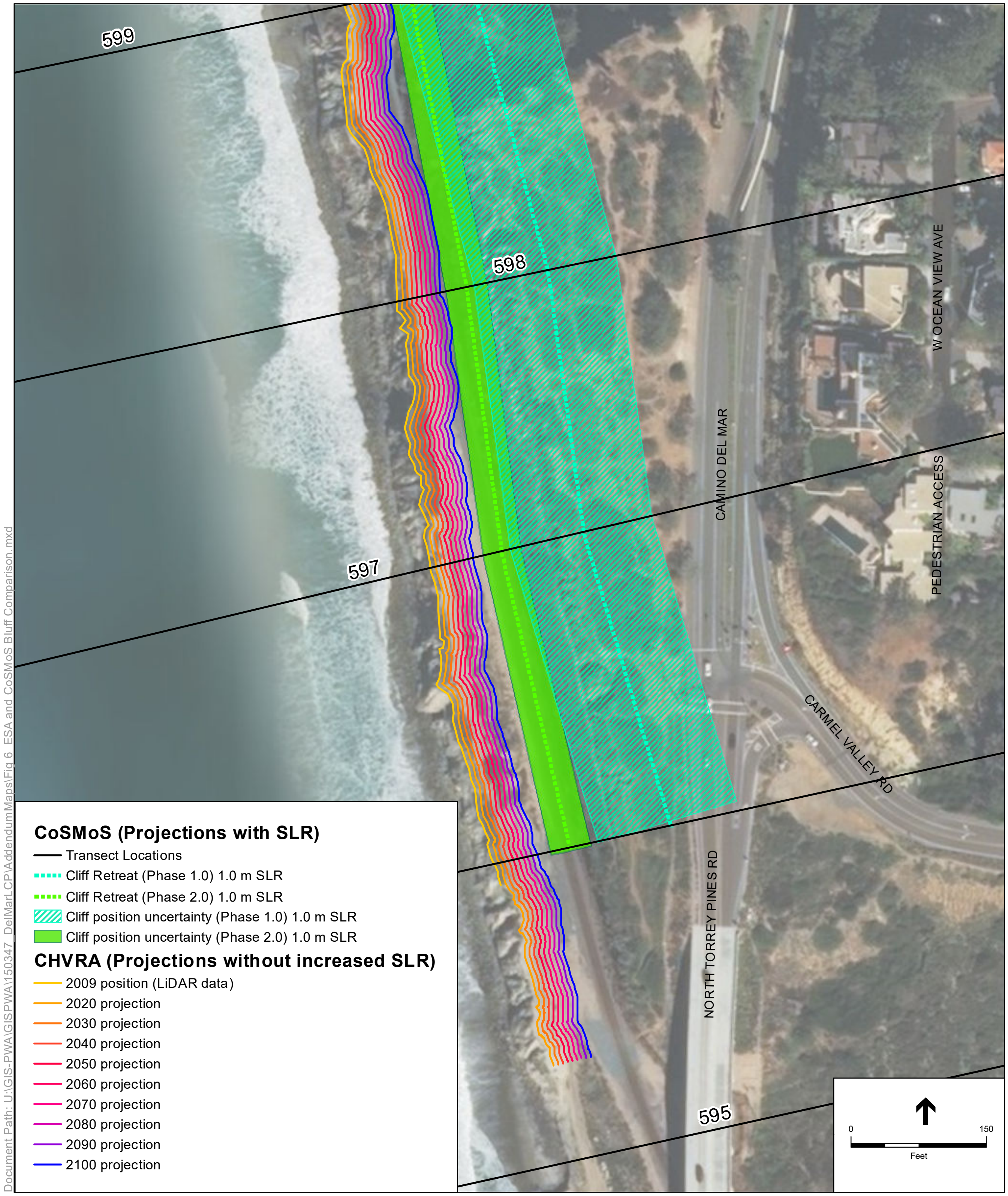
Document Path: U:\GIS-PWA\GISPWA\150347_DelMarLCP\AddendumMaps\Fig 6_ESA and CoSMoS Bluff Comparison.mxd

SOURCE: USGS 2016

Note: Projections are based on the average long term historical cliff top edge retreat rate between 1934 and 2009. Actual future retreat would vary from the average rate and projections. The alongshore variation from the mean historical cliff retreat between 1934 and 2009 is approximately 25 ft (two standard deviations). This provides a measure of how much greater (or less) the retreat could be than the average projected retreat shown.

Figure 6- 7

Comparison of Bluff Retreat Projections without Increased SLR from CHVRA and Projections with SLR from CoSMoS Phase 1 and Phase 2



SOURCE: USGS 2016

Note: Projections are based on the average long term historical cliff top edge retreat rate between 1934 and 2009. Actual future retreat would vary from the average rate and projections. The alongshore variation from the mean historical cliff retreat between 1934 and 2009 is approximately 25 ft (two standard deviations). This provides a measure of how much greater (or less) the retreat could be than the average projected retreat shown.

Figure 6- 8

Comparison of Bluff Retreat Projections without Increased SLR from CHVRA and Projections with SLR from CoSMoS Phase 1 and Phase 2

SOURCE: USGS 2016
Note: ESA does not recommend using the bluff erosion projection in 2100 without increased SLR, which ESA has included for comparison only.

Figure 7- 1
Bluff Erosion Hazard Risk Zones

Figure 7- 2
Bluff Erosion Hazard Risk Zones

SOURCE: USGS 2016
Note: ESA does not recommend using the bluff erosion projection in 2100 without increased SLR, which ESA has included for comparison only.

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Del Mar Vulnerability Assessment

Figure 7- 3
Bluff Erosion Hazard Risk Zones

SOURCE: USGS 2016
Note: ESA does not recommend using the bluff erosion projection in 2100 without increased SLR, which ESA has included for comparison only.

Document Path: U:\GIS-PWA\GISPWA\150347_DelMarLCP\AddendumMaps\Fig 7 Bluff Overlay Hazard Zones_v2.mxd

SOURCE: USGS 2016
Note: ESA does not recommend using the bluff erosion projection in 2100 without increased SLR, which ESA has included for comparison only.

Figure 7-4
Bluff Erosion Hazard Risk Zones

Document Path: U:\GIS-PWA\GIS\PWA\150347_DelMarLCP\AddendumMaps\Fig 7 Bluff Overlay Hazard Zones_v2.mxd

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Figure 7- 5

Bluff Erosion Hazard Risk Zones

SOURCE: USGS 2016

Note: ESA does not recommend using the bluff erosion projection in 2100 without increased SLR, which ESA has included for comparison only.

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Figure 7- 6

Bluff Erosion Hazard Risk Zones

SOURCE: USGS 2016

Note: ESA does not recommend using the bluff erosion projection in 2100 without increased SLR, which ESA has included for comparison only.

SOURCE: USGS 2016

Note: ESA does not recommend using the bluff erosion projection in 2100 without increased SLR, which ESA has included for comparison only.

Figure 7- 7
Bluff Erosion Hazard Risk Zones

Figure 7- 8
Bluff Erosion Hazard Risk Zones

SOURCE: USGS 2016
Note: ESA does not recommend using the bluff erosion projection in 2100 without increased SLR, which ESA has included for comparison only.

4 COMPARISON OF COASTAL FLOOD HAZARD ASSESSMENT

The following sections summarize the coastal flood hazard assessment methods used in the CHVRA (Section 4.1), CoSMoS (Section 4.2), and FEMA FIS and FIRM (section 4.3). Section 4.4 provides a comparison of the results.

4.1 CHVRA

To determine existing flood extents and depths, ESA calculated Total Water Level (TWL) from 2001 to 2015 and the 1983 and 1998 coastal storm events using measured tide level and wave data (see CHVRA Section 2.6). ESA used a TAW (Technische Adviescommissie voor de Waterkeringen) equation (FEMA 2005) to determine total water levels (the maximum elevation of the water surface) and wave runup (the vertical extent of wave wash) in Del Mar. ESA performed an extreme value analysis of the maximum annual TWL from 2001 to 2015 to estimate the annual chance of occurrence (or return period) of extreme TWLs during coastal storms. To determine future extreme TWLs with SLR, ESA increased measured tide levels by adding the projected amount of SLR, applying beach erosion estimates, re-calculating TWLs for the period from 2001 to 2015, and performing an extreme value analysis on the TWL simulated for this period with SLR. ESA performed this TWL analysis for a mid SLR scenario with 1 ft of SLR in 2050 and 3.1 ft in 2100. ESA then plotted the TWL calculated for the 1983 extreme coastal storm event and a 2015 storm event on the TWL extreme value distributions to estimate the increase in the annual chance of occurrence of these types of coastal storm event with SLR. The results (**Figure 8**) show how coastal flood events are projected to occur more frequently (i.e., have a greater chance of occurring) in the future with SLR as discussed in CHVRA Section 5.1. Note that the future coastal flooding projections account for beach erosion. Sections 2.6.1, 4.3, and 6 in the CHVRA provide more details on the coastal flood hazard mapping and SLR projections.

In addition to the TAW method, ESA performed a more detailed analysis of the inland extent of coastal flood waters for the 1983 storm event using X-beach, a 1-D numerical model. The analysis determined peak wave height, average period, hourly still water level, water elevation, and velocity. ESA used FEMA guidelines to create three existing hazard zones based on wave height (wave heights > 3 ft = VE, wave heights between 3 and 1.5 feet = Coastal VA, and wave heights between 1.5 and 1 feet = VA). ESA also determined an alternative VE hazard zone based on a momentum-force index of 200 ft^3/second. ESA used the 1983 storm event to represent an extreme coastal flooding event. In addition to 1983, ESA also mapped a significant coastal flood event that occurred in 2016. To represent this, ESA mapped the extent of flooding as the zone 10 ft landward of the seawalls.

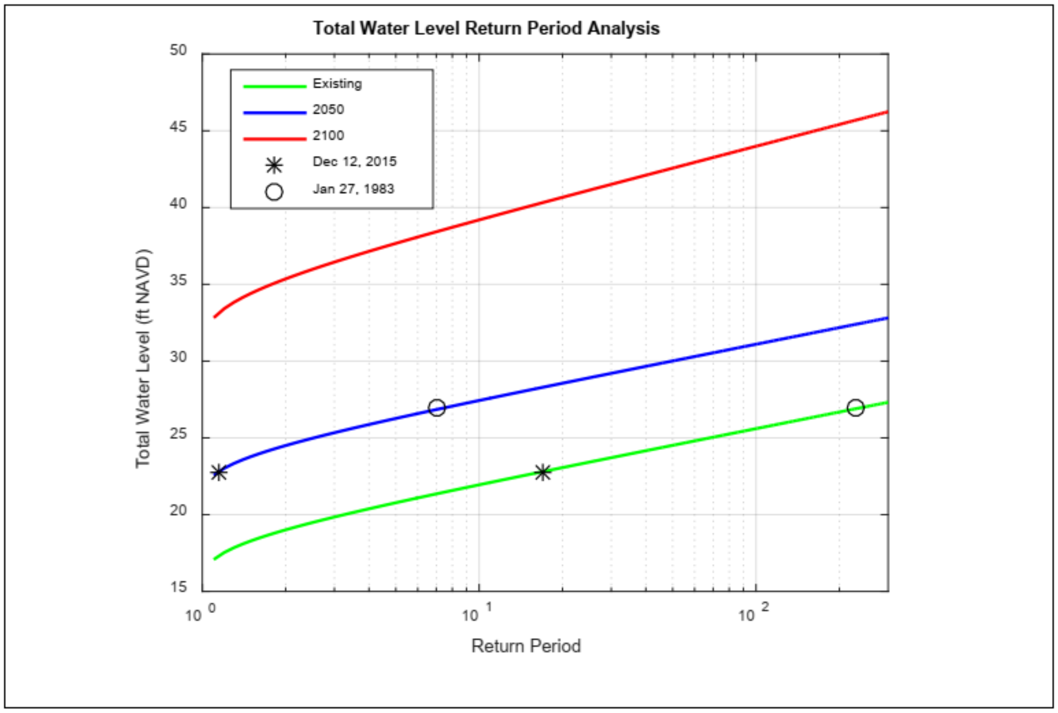

Figure 8. CHVRA Extreme Value Analysis of Total Water Level - Existing and Future Conditions with Sea-Level Rise

4.2 CoSMoS

The CoSMoS coastal flood modeling uses a set of nested models at different scales to determine flooding extents for various storm events under current and future conditions. The model is based on a global climate mode (winds and waves), a Tier 1, large-scale wave growth and propagation model, a Tier II, downscaled, regional wave model, and a Tier III Xbeach cross shore (wave breaking, wave setup, and wave rump) model. CoSMoS determined the flood depth and extent by intersecting the maximum sustained two-minute water level (effectively the still water level plus wave setup) with the eroded shoreline profile for each scenario, as detailed in **Figure 9** below. More detailed information on the CoSMoS flood mapping methodology is available in the CoSMoS 3.0 Phase 2 Southern California Bight Summary document (Erickson et al. 2017) available through the USGS CoSMoS website. CoSMoS results to not provide wave runup or TWL elevations or extents; however, the maximum extent of wave runup on the modeled transects is available as point data. ESA requested this maximum wave runup extent point data from the USGS for Del Mar, which the USGS provided.

CoSMoS modeling and flood mapping include flooding due to the estimated river discharge coincident with the extreme coastal storm. For Del Mar and the San Dieguito River, CoSMoS incudes an estimated 20-year discharge for the San Dieguito River coincident with the 100-year coastal storm event. **Figures 10-12** show the CoSMoS coastal storm flooding inundation extent (still water level and wave setup) and maximum wave runup location points for the 1-year, 20-year, and 100-year storm events.

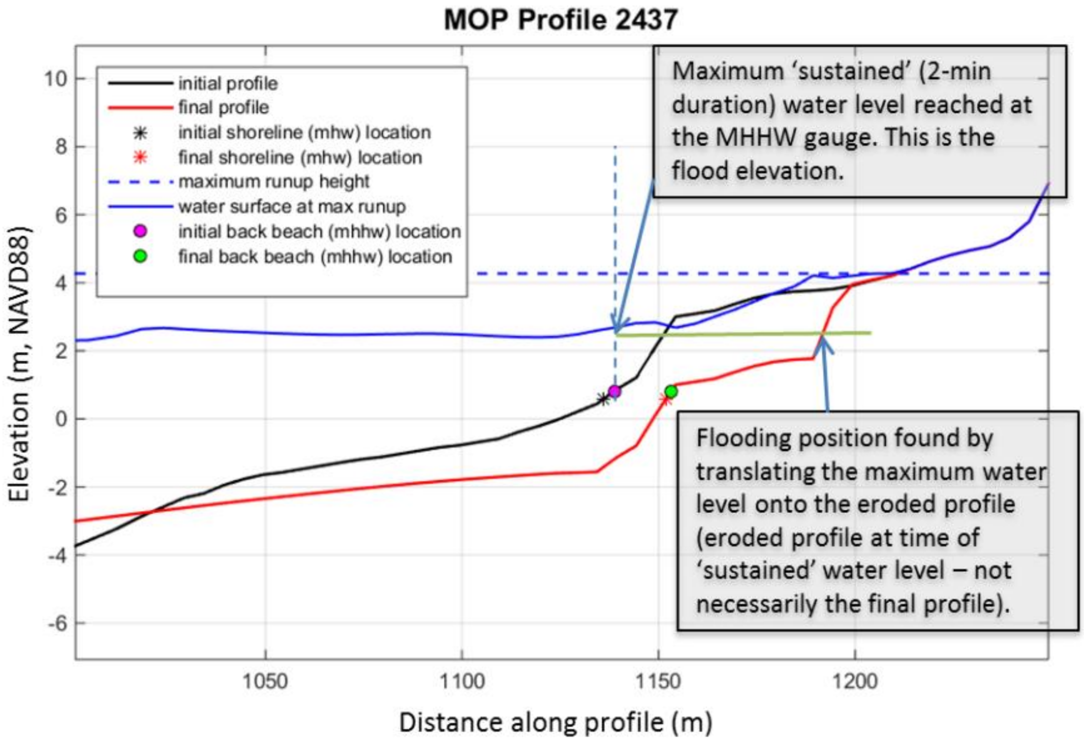

Figure 9. CoSMoS Flood Extent and Depth Diagram

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SOURCE: FEMA FIRM

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Figure 10
CoSMoS 1-year (100% Annual-Chance-of-Occurrence)
Coastal Flooding for Existing Conditions (0 cm SLR), 50 cm (1.6 ft) of SLR,
100 cm (3.3 ft) of SLR, and 175 cm (5.7 ft) of SLR

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SOURCE: FEMA FIRM

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Figure 11
CoSMoS 20-year (5% Annual-Chance-of-Occurrence) Coastal Flooding for Existing Conditions (0 cm SLR), 50 cm (1.6 ft) of SLR, 100 cm (3.3 ft) of SLR, and 175 cm (5.7 ft) of SLR

ESA

SOURCE: FEMA FIRM

Figure 12
CoSMoS 100-year (1% Annual-Chance-of-Occurrence)
Coastal Flooding for Existing Conditions (0 cm SLR), 50 cm (1.6 ft) of SLR,
100 cm (3.3 ft) of SLR, and 175 cm (5.7 ft) of SLR

4.3 FEMA

FEMA provided updated coastal flood maps, estimated flood water levels, and flood extents for the 100-year and 500-year flood as part of the FEMA Flood Insurance Study (FIS) and Flood Insurance Rate Maps. FEMA methods consider a range of potential flood mechanisms, including waves and wave runup, storm surge still water elevations, and wave overtopping. FEMA does not consider future projected SLR or coastal erosion. The updated FEMA maps are intended to estimate the current flood hazards for the purposes of the FEMA flood insurance program. The methods used by FEMA for Del Mar are generally described in the FIS (FEMA 2016). A detailed review of the methods and calculations used by FEMA is beyond the scope of this addendum. FEMA methods are similar to the methods used by ESA to estimate extreme TWLs and flood extents. For coastal structures that are not FEMA certified, FEMA methods (as specified in FEMA's 2005 Coastal Flood Analysis and Mapping for the Pacific Coast of the United States (FEMA 2005)) call for analyzing wave runup and flooding for scenario in which the non-certified coastal structure fails due to storm damage. ESA's understanding of the updated FEMA flood maps is that the analysis and mapping do not consider a failed structure scenario. **Figure 13** shows the FEMA flood zones for the 1% (100-year) and 0.2% (500-year) floods.

4.4 Comparison

4.4.1 CHVRA and CoSMoS Comparison

Table 2 compares the extreme coastal flood events used for the CHVRA (1983 storm event) and the CoSMoS 100-year event. The water levels, storm surge, wave height and period, and annual chance of occurrence of the extreme events used for the CHRVRA and CoSMoS are similar.

Figures 14 and **15** below show the ESA flood and wave hazards overlaid on the CoSMoS flood outputs. Figure 14 shows the CoSMoS 100-year flood event compared to ESA's extreme coastal flooding storm extent based on the 1983 flood. For current conditions (CoSMoS flood extent for 0 cm SLR shown in blue in Figure 14), CoSMoS shows flooding of the area bounded by Camino Del Mar, 23rd Street, Grand Avenue, and Ocean Front in North Beach. CoSMoS does not map the rest of North Beach as flooded by the 100-year event under current conditions, apparently because the "sustained" water level (i.e., still water level and wave setup) does not inundate this area; however, CoSMoS maximum wave runup point data (blue dots in Figure 14) show that modeled wave runup extends beyond the railroad during the 100-year event. In comparison, ESA's mapping of the coastal flood inundation hazard (hatched white area in Figure 14) is not as far landward as the CoSMoS inundation area in the southern portion of North Beach. ESA applied the coastal flood inundation hazard to the northern portion of North Beach, which extends east of Camino Del Mar to about Sandy Lane. CoSMoS does not show this area as inundated by the 100-year coastal storm event (based on the 2-minute average runup); however, CoSMoS does show that the maximum wave runup reaches farther inland than the CHVRA flood inundation hazard zone. Also, note that much of North Beach is at risk of 100-year San Dieguito River flooding per FEMA mapping, which is not included in CoSMoS, but is included in the CHVRA. The CHVRA maps a coastal wave hazard zone (i.e., zone with wave heights greater than 3 ft shown as white hatched area with a different direction cross-hatching seaward of the inundation hazard zone). CoSMoS does not provide mapping of the wave hazard zone.

Figure 15 shows the CoSMoS 20-year (5% chance) coastal flood inundation and extent with the CHVRA significant coastal flooding hazard, derived from the 2016 storm event and estimated to have a 5% to 10% annual chance of occurrence. Similar to the more extreme coastal flood comparison discussed above, the CHVRA coastal flood zone is slightly landward of the CoSMoS 20-year coastal flood inundation zone; however, CoSMoS shows maximum wave runup beyond the CHVRA significant coastal flood hazard zone.

The CoSMoS results show how the extent of the 100-year coastal flood event will increase with SLR. Since North Beach is already subject to both coastal and river flooding, the CHVRA focuses on assessing how the frequency of flooding will increase with SLR. In summary, CoSMoS and the CHVRA use different approaches and methods; however, the coastal flood hazards shown by CoSMoS and the CHVRA are generally similar in that they both show that there is a risk of extreme coastal flooding in North Beach under current conditions, which is projected to increase with SLR. The CHVRA provides additional information and mapping of the wave hazard zone, which is pertinent for adaptation planning and policy development.

TABLE 2
COASTAL FLOOD EVENT COMPARISON – CHVRA AND COSMOS

	Del Mar CHVRA: 1983 storm	CoSMoS: 2 representative 1% (100-year) storms
SWL (ft NAVD)	6.9	~7.1-7.3
Storm surge (ft)	0.4	0.6 - 0.8
Predicted tide (ft NAVD)	6.6	~ 6.5
Wave height (ft)	24	20 – 22
Tp (s)	18	16 – 18
Annual chance of occurrence	Less than 1%	1%

Source: CHVRA, USGS CoSMoS (2017)

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SOURCE: FEMA FIRM

Figure 13
FEMA Coastal Flooding Map

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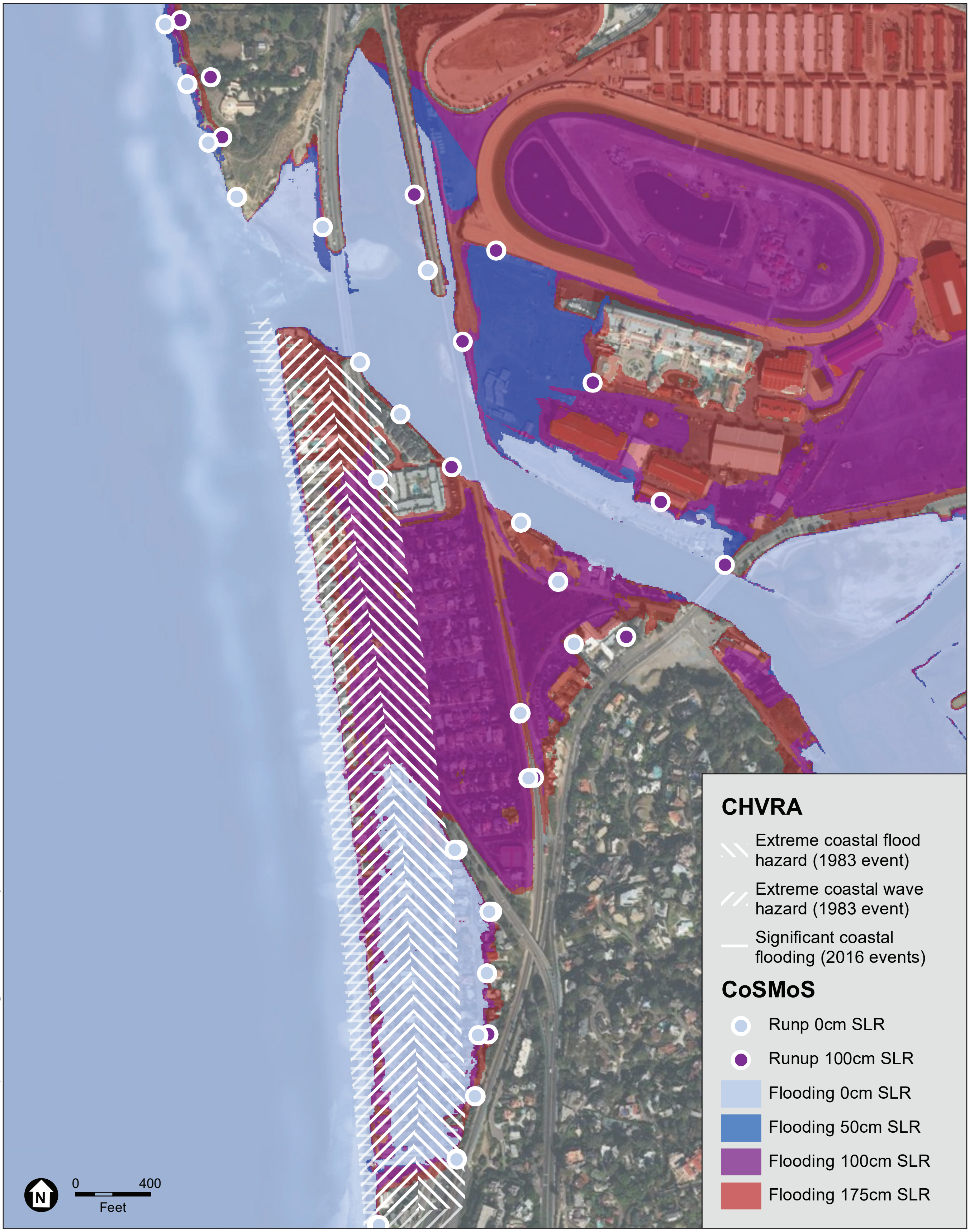

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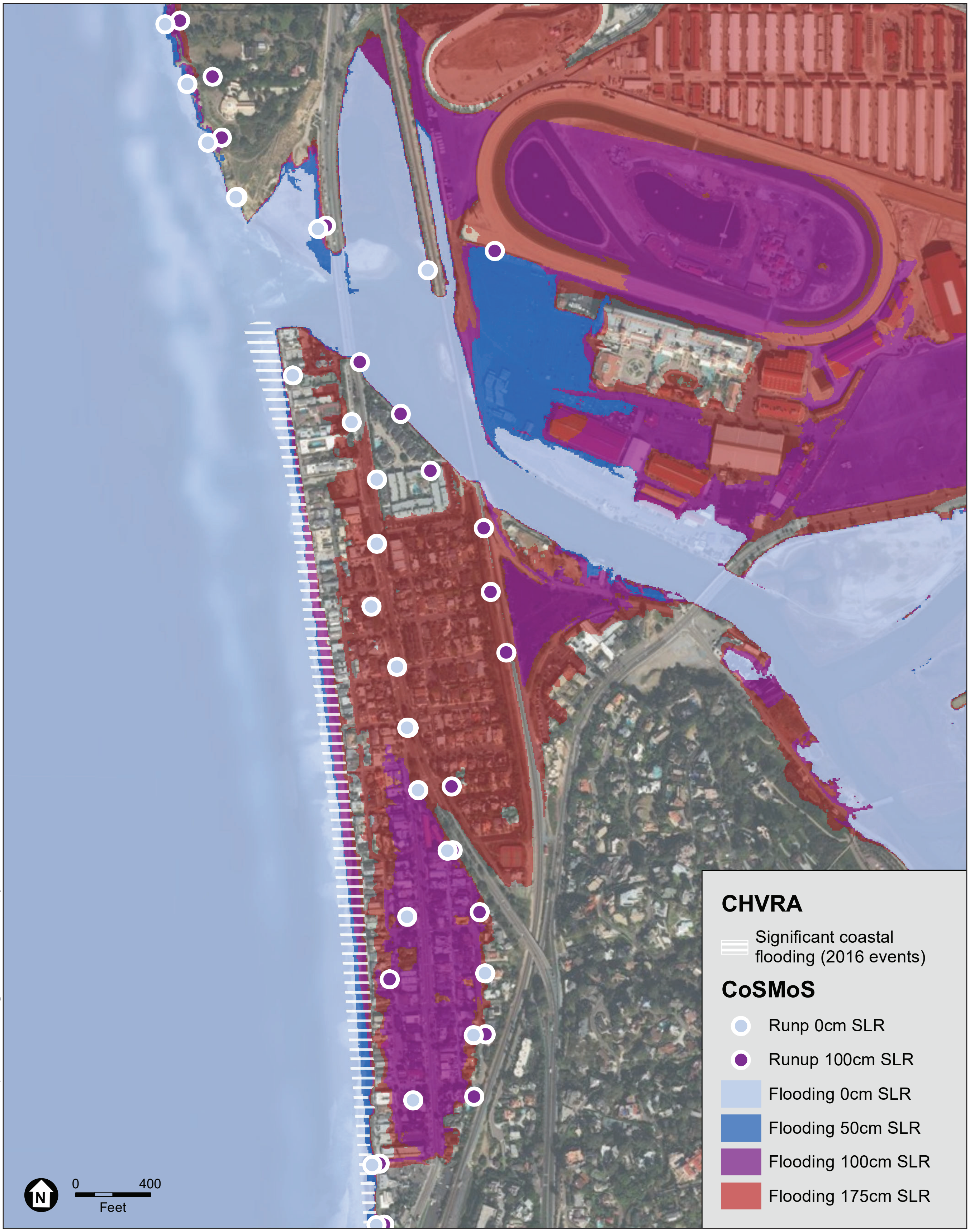
SOURCE: CHVRA 2016, USGS 2017

Figure 14
Comparison of Extreme Coastal Flood Hazard Map for CHVRA (1983 Storm Event) and CoSMoS (100-Year Storm Event)



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SOURCE: CHVRA 2016, USGS 2017

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Figure 15
ESA CHVRA and CoSMoS 5% Chance (20-Year) Coastal Flooding

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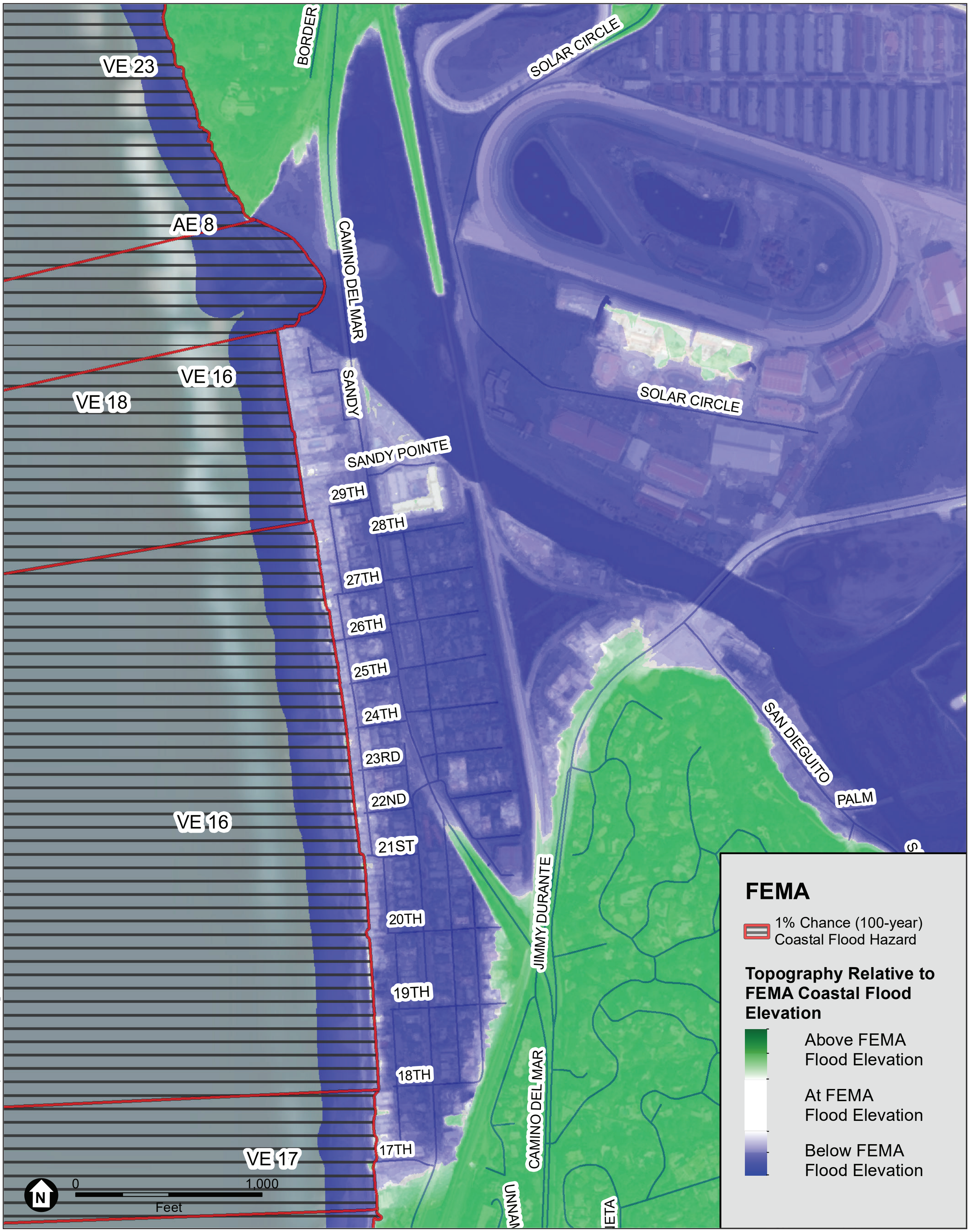
4.4.2 CHVRA and FEMA Comparison

Figures 16-18 compare the CHVRA hazard mapping and FEMA flood hazard mapping. Figure 16 overlays the FEMA coastal flood zone on the existing topography. Areas below the FEMA coastal flood elevations are shown in blue, areas above the flood elevation are shown in green, and areas that are at or near the flood elevations are shown in white. As seen in Figure 16, the FEMA 1% chance (100-year) coastal flood hazard zone (black hatching), stops within a short distance landward of the existing sea walls in North Beach at a narrow strip of high ground that is at or near the flood elevations. The areas landward of the flood zone and this strip of high ground is below the coastal flood elevation.

Figures 17 compares the 100-year coastal flood zone identified by FEMA with the significant (2016) storm flood extents used in the CHVRA (shown with white hatching). Both the FEMA 1% chance coastal flood zone and the significant coastal flood zone from the CHVRA, which is estimated to have a 5% to 10% annual-chance-of-occurrence, are limited in extent by the existing sea walls and, therefore, coincide. Figure 18 shows the FEMA 100-year coastal flood zone with the CHVRA extreme coastal flood zone (white hatching), as well as the CoSMoS 100-year maximum wave runup point data for current conditions (pink dots). The CHRVA's extreme coastal flood zone was defined by the 1983 storm event, which is estimated to have a 0.5% annual-chance-of-occurrence (i.e., 200-year event), is mapped beyond the existing sea walls and the FEMA coastal flood zone. CoSMoS results also show wave runup well beyond the existing sea walls for CoSMoS' 100-year event. In summary, the FEMA coastal flood hazard zone represents a coastal flood condition that is limited to and does not extend landward of the existing sea walls, whereas the CHVRA uses a coastal flood hazard zone that represents conditions that occurred during the 1983 coastal storm event, in which coastal structures failed and flooding extended beyond the structures.



SOURCE: CHVRA 2016, USGS 2017, FEMA 2017

Figure 16
FEMA 1% Chance Coastal Flood Hazard Zone and Topography Relative to FEMA Coastal Flood Elevation

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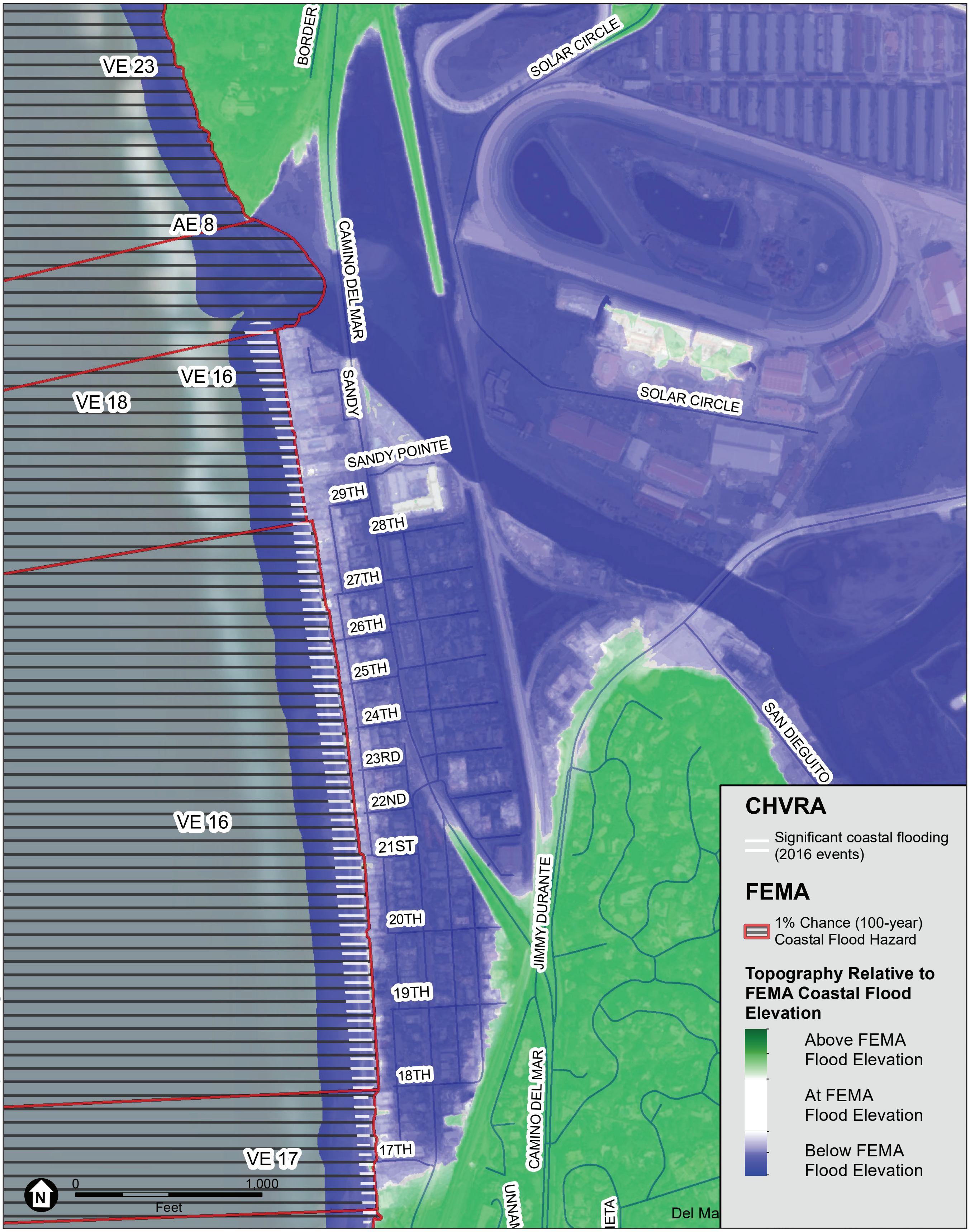

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SOURCE: CHVRA 2016, USGS 2017, FEMA 2017

Del Mar Vulnerability Assessment

Figure 17
Comparison of FEMA 1% Chance Coastal Flood Hazard Zone and Del Mar CHVRA Significant Coastal Flood Hazard Zone (Defined by a 5% to 10% Chance Storm Event That Occurred in 2016)

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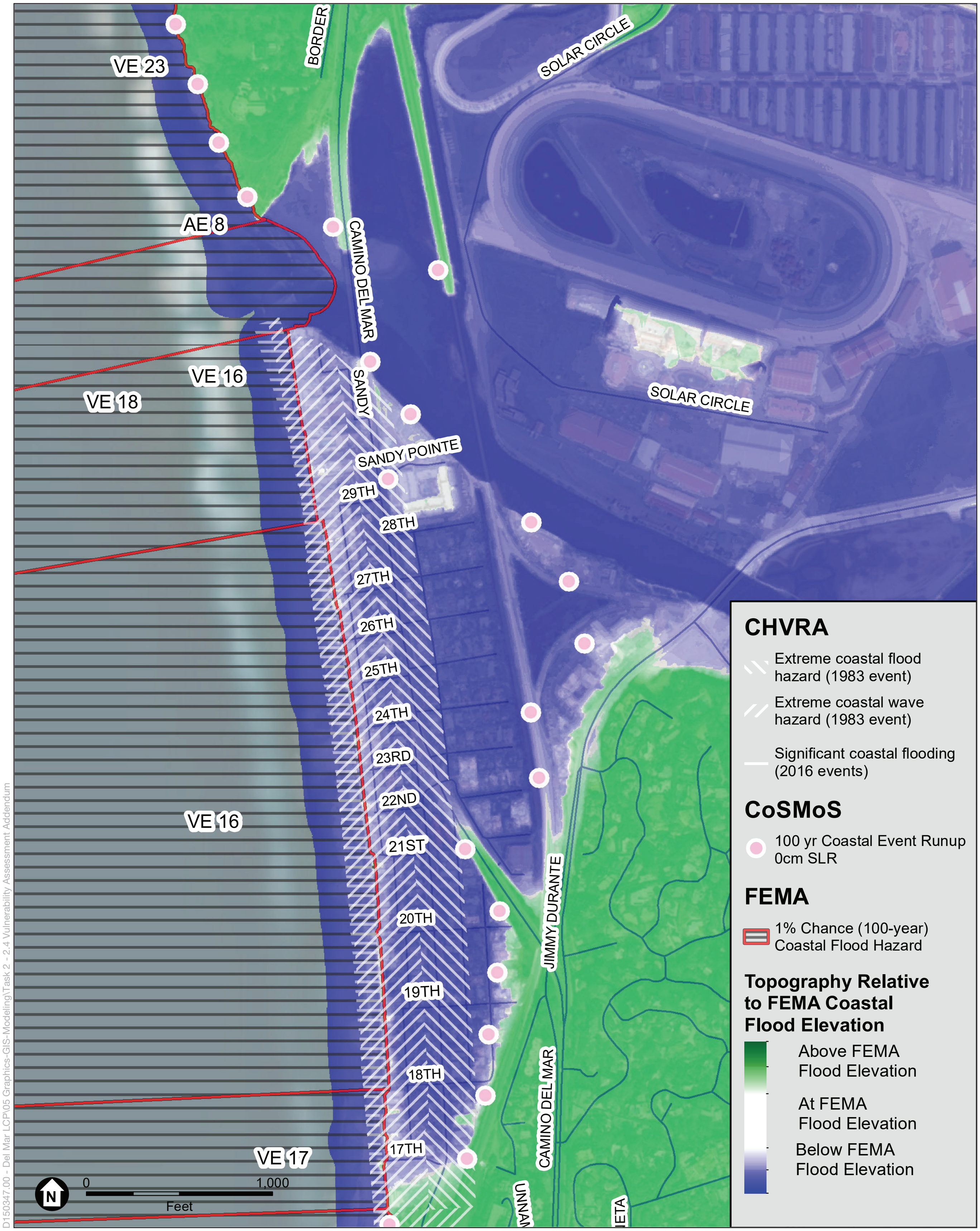

SOURCE: CHVRA 2016, USGS 2017, FEMA 2017

Figure 18
Comparison of FEMA 1% Chance Coastal Flood Hazard Zone, Del Mar CHVRA Extreme Coastal Flood Hazard Zone, and CoSMoS Current Conditions Maximum Wave Runup for 100-year Coastal Storm Event

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5 CONCLUSIONS

ESA analyzed and assessed coastal hazards, vulnerabilities, and risks for the CHVRA including beach and bluff erosion and coastal and San Dieguito River flooding for the purpose of informing adaptation planning and coastal policy for the City of Del Mar. The updated final CoSMoS results for beach erosion and coastal flooding, which were released after completion of the CHVRA, are generally consistent with the CHVRA's results. The updated FEMA flood maps, also released after completion of the CHRVA, do not consider SLR and show a coastal flood risk that is limited to the existing sea walls for the purposes of the FEMA flood insurance program. In contrast, both the CHVRA and CoSMoS show coastal wave hazards landward of the existing sea walls for current and future conditions with SLR. The comparisons performed for this addendum and general agreement between the results of the CHVRA and CoSMoS support that the CHVRA coastal flood zones are appropriate for the purposes of adaptation planning and coastal policy development.

ESA recommends that the CHVRA results and hazard mapping be used for the purposes of City adaptation planning and policy. The CHVRA includes information and mapping of coastal wave hazard zones based on flooding and storm damage that occurred in Del Mar during the 1983 storm event, whereas CoSMoS does not provide wave hazard zone mapping and FEMA maps do not reflect this risk or address future SLR. The CHVRA coastal flooding and wave hazard mapping are therefore the best available and most appropriate mapping for the purposes of adaptation planning and policy. Note that while the CHVRA, CoSMoS, and FEMA use different methods to assess coastal flooding, all consider the existing seawalls and revetments and all show that beachfront properties are currently vulnerable to coastal flooding.

For beach erosion hazards, the CHVRA is generally consistent with CoSMoS. Note that CoSMoS beach erosion or shoreline projections should not be used independently of the CHVRA results because CoSMoS results for certain intermediate years (e.g., 2033, 2066, and 2075) under-predict the potential erosion as discussed in Section 2.3 above. Results from CoSMoS or other analyses of beach erosion or flooding should not be applied in place of CHVRA results without a comparison to CHVRA results and an independent third-party review by a qualified coastal engineer and/or geologist, such as ESA.

As discussed in Section 3.3 ESA does not recommend updating the CHVRA's projection of future bluff erosion with SLR (which is based on CoSMoS Phase 1 results) with the CoSMoS Phase 2 results because ESA's comparison of the different models indicates that the CoSMoS Phase 2 results may under-predict future erosion with SLR. ESA recommends that ESA and Dr. Adam Young perform an independent, site-specific analysis with modeling of projected future bluff erosion with SLR for the Del Mar bluffs. Note that modeling independent from CoSMoS was not included in the City's work program for the CHVRA because the work program was based on using CoSMoS. ESA does not recommend using CoSMoS Phase 2 results to update bluff erosion overlay zones for the Local Coastal Program (LCP) Amendment or other planning purposes at this time. An independent bluff erosion analysis as recommended above would provide additional information for the basis of refining the LCP and planning. If an independent analysis is not performed, an alternative approach to refining the bluff erosion hazard overlay zone would be to sub-divide the bluff erosion hazard overlay zone into subareas with different levels of risk. If the City chooses to take this approach, ESA recommends using the CHVRA (i.e., CoSMoS 3.0 Phase 1) and the outer/landward uncertainty of the CoSMoS 3.0 Phase 2 model projections for the high sea-level rise scenario in 2100 (items 1 and 2 above). ESA does not recommend using the bluff erosion projection without increased SLR in 2100, which ESA has included for comparison only.

Note that the bluff erosion projections from the CHVRA and CoSMoS do not consider existing bluff armoring or stabilization measures because the existing armoring and stabilization may not limit or prevent bluff erosion over the long-term. Also note that the bluff erosion hazard and vulnerability assessments from the CHVRA and CoSMoS assume that the bluffs would erode past the railroad; this approach provides the baseline “no action” scenario for the purposes of adaptation planning and policy development.

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