# Appendix J

Site-Specific Coastal Hazards Analysis Technical Memorandum

# Technical Memorandum

**March 4, 2025**

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| **Project Name** | Sandpiper Golf Course Renovations | | |
| **Subject** | Site-Specific Coastal Hazards Analysis | | |

## 1. Introduction

The objective of this site-specific coastal hazards analysis is to identify potential current and future site-specific hazard zones for the Sandpiper Golf Course renovation project (Project). The proposed golf course renovations require supporting studies to acquire permits and approvals from the City of Goleta and other jurisdictions. This report addresses items 72 (Site Specific Hazard Study) and 74 (Coastal Hazards Report/Bluff Erosion Study/Control Plan, and Wave Uprush Study) listed in the notice of incomplete application letter from the City, dated January 13, 2023. The future effects of sea level rise will be incorporated into each of these hazard evaluations with the exception of tsunami hazards. This report does not include an evaluation of liquefaction or seismic hazards.

The proposed renovations and improvements are listed below and described in more detail in the Project Description prepared by Suzanne Elledge Planning & Permitting Services, Inc dated November 21, 2022 (Suzanne Elledge, 2022). Several of the Project components are shown in Figure 1:

- Construct a clubhouse
- Redesign and improve the 18-hole course
- Repurpose Barnsdall Gas Station as a coffee shop
- Replace and upgrade the existing comfort station
- Replace and upgrade the existing maintenance facilities
- Improvements along Hollister Avenue
  - Entry points,
  - New public trail
  - Underground electrical lines
  - Relocate bus station
  - Curb and sidewalk improvements


*Figure 1. Sandpiper Golf Course Site Map (relevant course holes are called out)*

# 2. Coastal Setting

The Project site shoreline is characterized by narrow sandy beaches backed by coastal bluffs ranging in elevation from 70 ft to 90 ft (NAVD88) (Figure 2). The bluffs extend the entire project area except for Bell Canyon Wash, situated adjacent to the northern side of the Sandpiper Golf Course. The Bell Canyon Wash is fronted by narrow sandy beach. The bluffs along the western segment of the Project are fronted by rock shoreline protection (RSP) which line an access road to abandoned oil facilities. Bluffs along the eastern segment are fronted by incontiguous remnants of a timber pile bulkhead.

Shoreline change along a beach can primarily be attributed to the availability and seasonal movement of sediment. Sediment generally moves within the boundaries of a littoral cell before sediment is lost to offshore features such as canyons. Sediment transport is largely affected by the wave climate, which tends to follow seasonal patterns for the Project area.

The Project area in Goleta is located near the center of the Santa Barbara littoral cell along a southwest facing shoreline exposed to the wave climate of the Santa Barbara Channel. Point Conception to the northwest and the Channel Islands to the south create a narrow swell window that shelters much of the south facing coast of Santa Barbara County from extreme wave events (City of Goleta, 2015). The predominant west-northwest direction of waves in the Santa Barbara Channel drive an almost unidirectional longshore sediment transport from west to east in which beaches narrow during the winter and spring (November to April) and widen during the summer and fall (May to October) (City of Goleta, 2015).

The sand on Goleta's beaches move along the coast of southern Santa Barbara and Ventura Counties to the Point Mugu submarine canyon at the southern end of the littoral cell (City of Goleta, 2015). Goleta's shoreline oscillates based on occurrences of large erosional wave events, sediment deposition following flood events, and periods of accretion during extended periods of time with reduced wave energy (Revell and Griggs, 2006; Revell, 2007; Barnard et al., 2009).

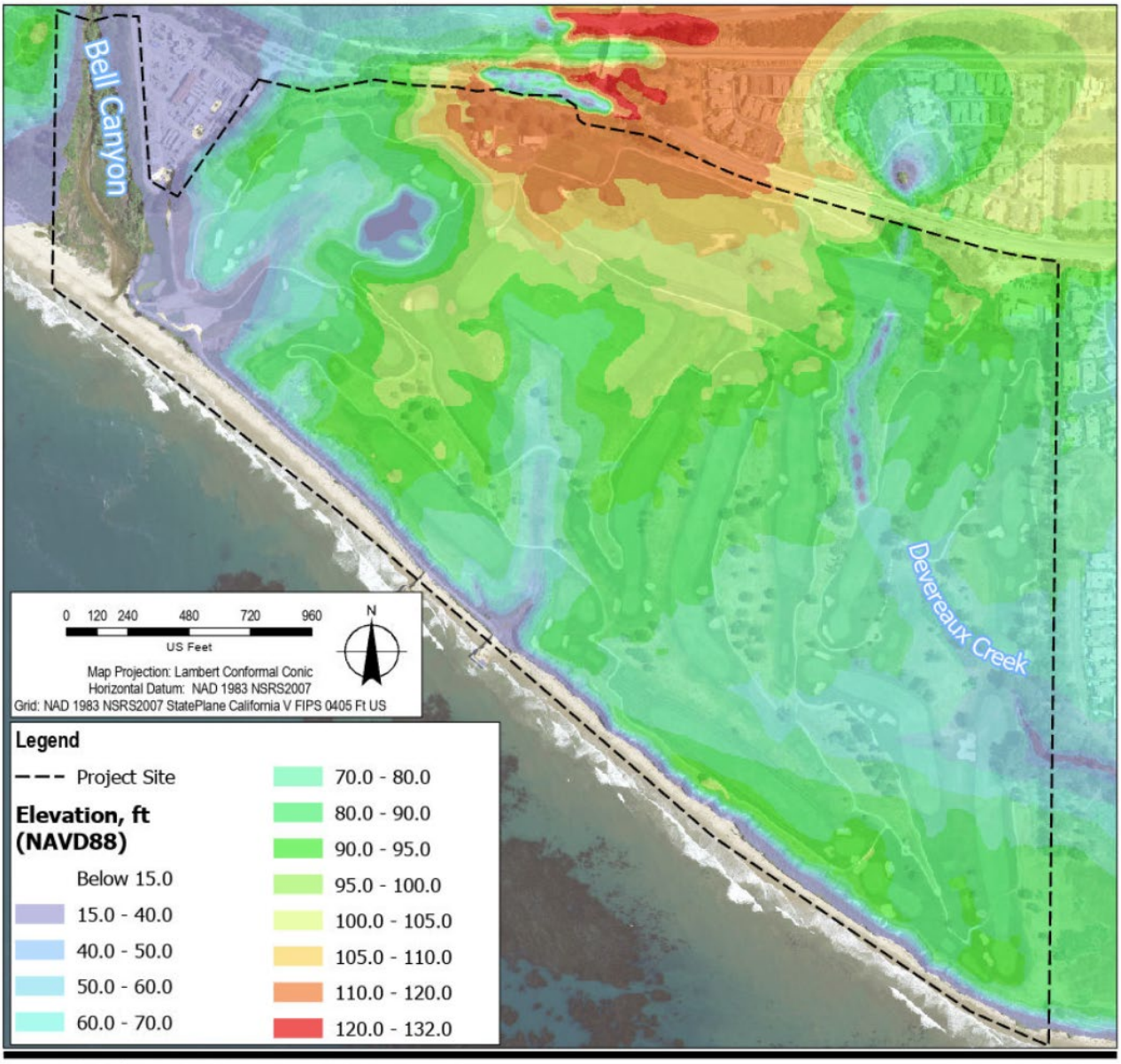


*Figure 2. Site Topography*

### 2.1.1 Water Levels

The tides in southern California are mixed semi-diurnal, meaning there are two unequal low and high tides each lunar day, which is approximately 25-hours. The National Oceanic and Atmospheric Administration (NOAA) operates tide stations globally and the nearest station to the Project site is located in Santa Barbara (Station 9411340), approximately 13 miles southeast. This station has a data repository as far back as 1974 and is representative of high-water levels at the project site. The tidal datums for a range of open ocean water levels are shown in Table 1 for this station.

*Table 1. Datums for Santa Barbara Tide Gauge (NOAA Station 9411340)*

| Datum | Elevation, ft NAVD88 |
|---|---|
| Highest Observed Tide (12/13/2012) | 7.52 |
| Highest Astronomical Tide (HAT) | 7.23 |
| Mean Higher High Water (MHHW) | 5.26 |
| Mean High Water (MHW) | 4.51 |
| Mean Sea Level (MSL) | 2.65 |
| NAVD88 | 0.00 |
| Mean Low Water (MLW) | 0.84 |
| Mean Lower Low Water (MLLW) | -0.13 |
| Lowest Astronomical Tide (LAT) | -2.18 |
| Lowest Observed Tide (12/17/1933) | -3.00 |

# 3. Sea Level Rise

Sea level rise (SLR) projections are provided for 12 active tide gauges along the coast of California in the Ocean Protection Council's (OPC) State of California Sea-Level Rise Guidance 2018 Update. The 2018 update to the California Coastal Commission (CCC) Sea Level Rise Policy Guidance refers to these as the "best available science" on SLR projections in California. These projections are recommended by the CCC for planning, permitting and other coastal management decisions.

It is important to consider risk tolerance, risk aversion and design life when evaluating SLR scenarios and the effects of SLR on various coastal hazards. The OPC defines risk tolerance as "the level of comfort associated with the consequences of SLR and associated hazards in project planning and design." Whereas risk aversion is defined as the strong inclination to avoid taking risks in the face of uncertainty (OPC, 2018). SLR projections are presented with various occurrence probabilities that correspond to risk aversion scenarios. The selection of a risk aversion SLR scenario should depend on an evaluation of the assets and infrastructure that are potentially affected by SLR. The risk aversion categories applicable to the Project include:

- **Low risk aversion**: Refers to the upper limit of the "likely range" (66% probability) SLR projections and is intended for project elements with higher adaptability, meaning projects would suffer little to no damage or disruption if SLR exceeded this projection.
- **Medium-high risk aversion**: Refers to the 1-in-200 chance (0.5% probability) and is intended for project elements which would suffer greater consequences (damage and disruption) if SLR exceeded this projection.

The SLR projections for the Santa Barbara tide gauge are presented below in Table 2 for a range of probabilistic scenarios and time horizons. This analysis will evaluate 0.8 feet, 1.6 feet, 3.3 feet, and 6.6 feet of SLR based on available hazard data. These projections align with the OPC (2018) medium-high risk aversion projections, although the probability of a SLR scenario will vary with the projected timing. For instance, there is an extremely low probability ~0.5% that SLR will exceed 6.6 feet before 2100 and a higher probability (17%) that SLR will exceed 3.1 feet by 2100.

*Table 2. SLR Projections for Santa Barbara, CA (OPC, 2018)*

| Time Horizon | Likely Range | | Moderate Risk Aversion | Medium-High Risk Aversion |
|---|---|---|---|---|
| | 66% Chance SLR is in between… | | 5% probability SLR meets or exceeds | 0.5% probability SLR meets or exceeds |
| 2030 | 0.2 | 0.4 | 0.5 | 0.7 |
| 2050 | 0.4 | 1.0 | 1.2 | 1.8 |
| 2070 | 0.7 | 1.7 | 2.1 | 3.3 |
| 2100 | 1.2 | 3.1 | 4.1 | 6.6 |

The extreme risk aversion scenario is not specifically considered in this Study because there is no critical infrastructure or other risk-averse development proposed. The extreme risk aversion scenario refers to the 'worst-case scenario' and is geared towards projects with little to no adaptive capacity and if SLR were to exceed this projection, would pose a significant threat to public health / safety and the environment. This scenario ranges from 1.0 ft of SLR by 2030, to 9.8 ft of SLR by 2100 for the Santa Barbara tide gauge. Unlike the probabilistic scenarios shown in Table 2, there is not a defined probability with the extreme risk aversion category.

Additionally, recent updates to SLR projections indicate this extreme scenario (H++) is less plausible that previously thought. A joint agency SLR study was published by NOAA in February of 2022, Global and Regional Sea Level Rise Scenarios for the United States: Updated Mean Projections and Extreme Water Level Probabilities Along the U.S. Coastline (Sweet et al., 2022). The updated projections reflect input from a large team of scientists from a variety of government agencies and academic institutions. Specifically, this joint agency effort builds upon the work provided in the OPC (2018) SLR projections provided above. A larger observational database and improvements in modelling led to a better understanding of the drivers of SLR and more realistic timing of the higher SLR scenarios than in Sweet et al., 2017. A significant outcome of the NOAA (2022) study is the exclusion of the extreme risk aversion scenario (H++) from SLR projections this century.

The removal of the H++ scenario was based on an improved understanding of the timing of possible large future ice sheet loss contributions. In summary, the uncertain physical processes that drive SLR (i.e., ice sheet loss) are noted by Sweet at al. (2022) as less plausible in the decades leading up to 2100. Given the proposed development is not extremely risk-averse and to remain consistent with the work undertaken by Sweet at al. (2022), the extreme risk aversion scenario (i.e. SLR greater than 6.6 feet) was not evaluated in this analysis.

# 4. Coastal Hazards

The coastline of the Sandpiper Golf Course is exposed to a variety of hazards including coastal flooding, shoreline and bluff erosion, groundwater emergence and tsunamis. This section will provide a general overview of each hazard evaluated in this analysis as well as hazard maps for each SLR scenario.

## 4.1 Coastal Flooding

### 4.1.1 Extreme Water Levels

Ocean water levels typically vary within predictable astronomical tide ranges. However, sea level anomalies may occur that increase water levels above the predicted tides. These anomalies may occur with El Nino Southern Oscillation or large storm events and can result in elevated water levels and temporarily increased potential for coastal flooding of low-lying areas.

Extreme water levels (EWL) are provided by NOAA's Center for Operational Oceanographic Products and Services (NOAA CO-OPS) for annual occurrence probabilities of 1%, 10%, 50% and 99%. Each probability corresponds to an annual return period of 100-years, 10-years, 2-years, and 1-year. The nearest station to the Project site is located in Rincon Island (Station 9411270), approximately 27 miles southeast. This station has a data repository as far back as 1962 and is representative of extreme water levels at the project site. The EWL's at the Rincon Island tide station (Sta. ID 9411270) are shown in Table 3.

*Table 3. Extreme Water Levels for Rincon Island (Sta. 9411270)*

| Annual Exceedance Probability | Return Period (years) | Elevation, ft NAVD88 |
|---|---|---|
| 1% | 100 | 8.2 |
| 10% | 10 | 7.9 |
| 50% | 2 | 7.6 |
| 99% | 1 | 7.1 |

When assessing potential scenarios with SLR, it is important to consider SLR with normal tide cycles as well as extreme events. This relates to the frequency and occurrence probability of a given scenario, as a MHHW+SLR will be more likely and representative of typical "non-storm" conditions. Whereas an extreme (100-yr) event with SLR has lower occurrence probability and will be episodic. The high end of normal tide cycles are represented by MHHW, which is 5.26-ft (NAVD88) for the Project site, although spring tides which occur twice per lunar month result in peak water levels a foot or more above MHHW. When combined with the 1.8 feet of SLR (2050 medium high SLR scenario), the typical "non-storm" water levels could reach 7.2-feet (NAVD88).

### 4.1.2 Fluvial Flooding

The Project area is located southward of Bell Canyon with Devereaux Creek intersecting the northeast section of the site. Fluvial (riverine) flow primarily results from upstream precipitation and runoff in the watershed and extreme events can lead to flooding within the floodplain. Devereaux Creek exists along the elevated bluff zone, leading outside of the project site to the Devereaux Creek Tributary. The Federal Emergency Management Agency (FEMA) defines flood hazards zones and base flood elevations (BFE), which represents the water surface elevation corresponding to a 1% annual occurrence probability, otherwise known as a 100-year flood.

Fluvial flooding will result from high river flows triggered by an extreme rainfall event. It is unlikely that sea level rise will have a significant influence on extreme fluvial hazards, given that both Bell Canyon and Devereaux Creek have relatively steep water surface profile gradients adjacent to the Project site, an indication these creeks are not sensitive to downstream water levels. Floodplain impacts would be

anticipated in situations where ocean water levels are closer to equal to or greater than the BFE, which would result in water backing up within the floodplain.

The FEMA flood hazard zone for a 100-year event is shown below in Figure 3 and Figure 4. The area's characterization is split between Zone VE and Zone AE, meaning that the BFE has been estimated for these flood zones. Zone VE represents coastal areas with a 1% or greater chance of flooding and an additional hazard associated with storm waves. Zone VE was contained to the coastline of Sandpiper Golf Course with a BFE ranging from 16 ft to 18 ft. Bell Canyon Wash is designated as a Zone AE/Regulatory Floodway with a BFE ranging from 8 ft to 22.1 ft. Devereaux Creek is designated as a Zone AE/Regulatory Floodway with a BFE ranging from 49 ft to 92 ft. Within the Project Area, the 100-year flood zones are contained within both Bell Canyon Wash and Devereaux Creek.

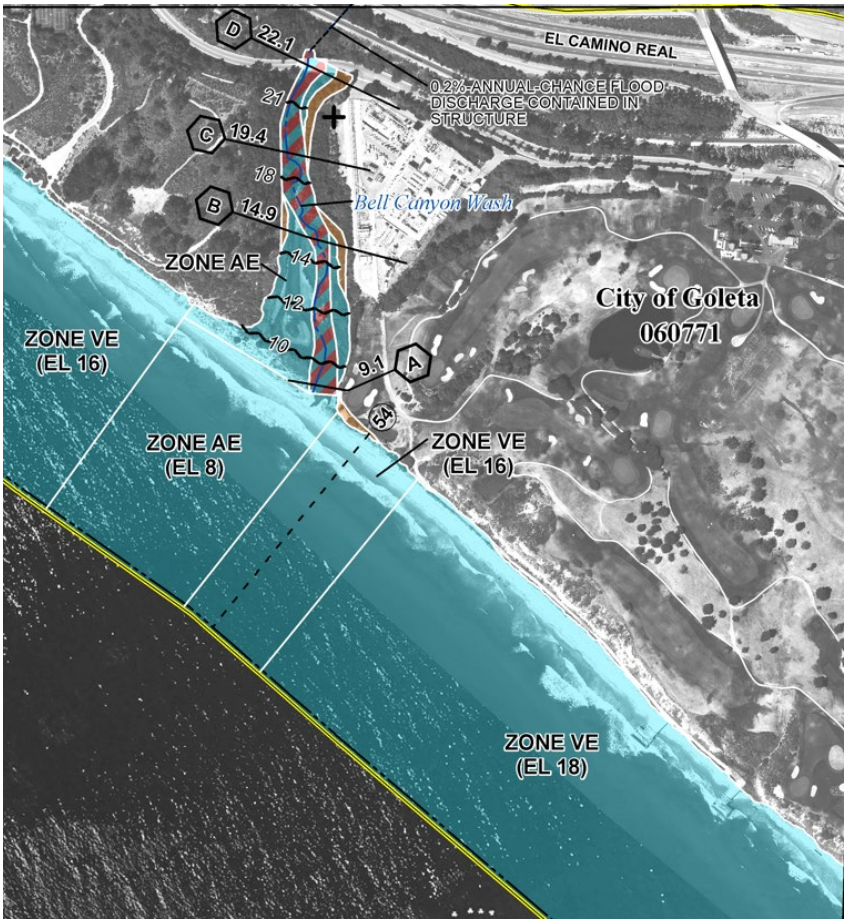


*Figure 3. FEMA Flood Insurance Rate Map #06083C1341H (Effective Map Date: 9/28/2018).*

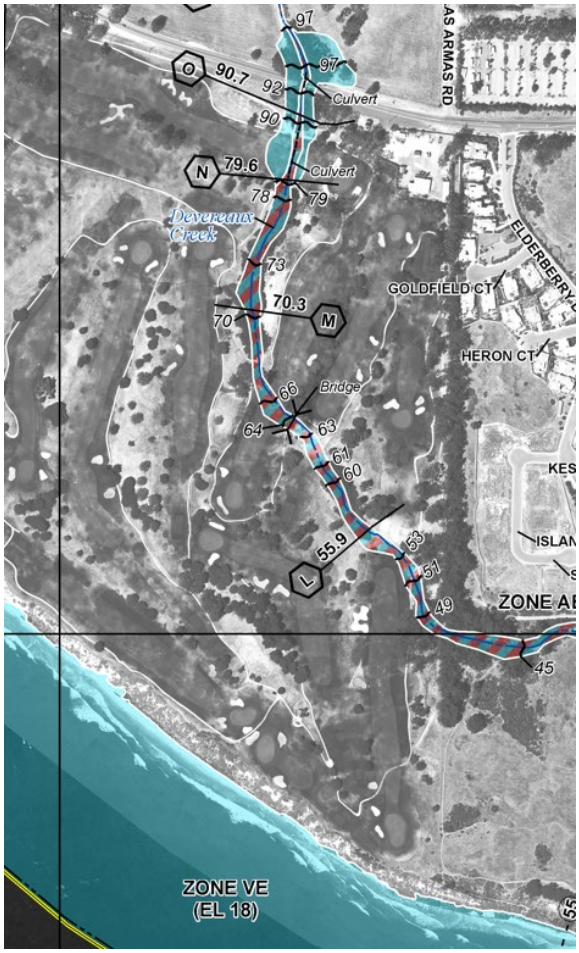


*Figure 4. FEMA Flood Insurance Rate Map #06083C1342H (Effective Map Date: 9/28/2018).*

The disparity between Zone VE along the bluff-lined section of the Project Area (BFE of 18 ft) and Zone AE at Bell Canyon Wash (BFE at 8 ft) is likely due to the difference in wave runup along the bluff face. Still water levels (SWL) indicate the water levels above the normal tidal level but do not include waves. Total water levels (TWL) indicate the water level with an aggregation of tides, surge, and wave runup. Zone AE fronting Bell Canyon indicates that the FEMA BFE is not accounting for wave action, and the BFE of 8 feet corresponds relatively well to the NOAA EWL of 8.2 feet. The remaining Project area coastline is represented by Zone VE, indicating that the BFE does account for wave action and should be considered a TWL.

The majority of the Project Area is not exposed to flooding under a 100-year fluvial event. Only course holes #1 and #2 are intersected by Devereaux Creek are expected to experience flooding. As mentioned above, it is unlikely that SLR will significantly affect the floodplain for Bell Canyon or Devereaux Creek. The proposed development does not occur within the 100-year flood hazard zone. Bell Canyon Wash's entrance has a BFE of 9.1 ft while the closest course hole is at an elevation of approximately 15 ft to 20 ft (NAVD88). Even a 500-year flood zone is contained within Bell Canyon Wash as shown by the orange areas in Figure 3. Devereaux Creek crosses Hollister Avenue via a culvert, resulting in a wider floodplain in the vicinity of Hollister Avenue. Based on the FEMA flood mapping, some portions of the golf course could be exposed to flooding in an extreme event.

## 4.2 Coastal Flooding Hazards

The U.S. Geological Survey (USGS) provides predictions of coastal flooding with SLR through the Coastal Storm Modeling System (CoSMoS). The CoSMoS flood projections account for SLR as well as SLR coupled with storms, the intensity of which is designated by storm frequency (i.e., 100-year storm). Along the shoreline, the landward extent of flooding includes the effects of wave action under storm conditions (high surf, long period). As waves approach the shoreline and break, there is a temporary increase in the still water level which then increases the total extent of flooding. Thus, the CoSMoS results represent extreme water levels, including wave exposure at the shoreline.

The CoSMoS results are provided for increments of 25 cm, from no SLR (0 cm) to 3 meters (9.8 feet), and an extreme scenario of 5 meters (16.4 feet). Thus, the CoSMoS scenarios slightly differ from the OPC (2018) projections, however there is still general alignment in the selected scenarios. The relevant CoSMoS SLR scenarios are shown relative to the OPC (2018) SLR projections below in Figure 5. These increments of CoSMoS align with the medium-high (0.5% probability) projections for 2030 through 2100 as shown below in Figure 5.

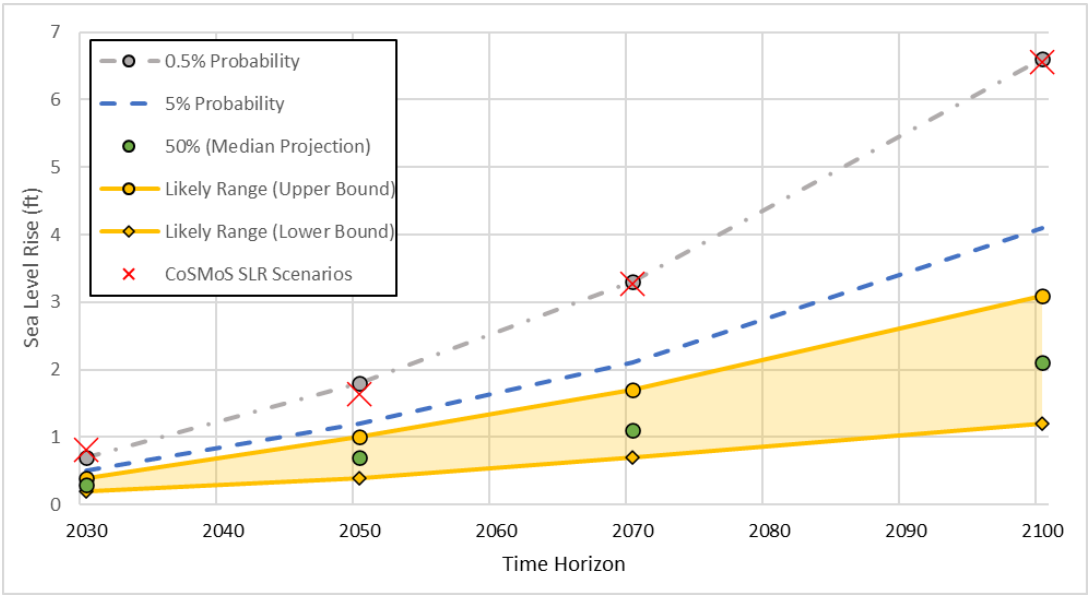


*Figure 5. SLR Projections for Santa Barbra, CA (OPC, 2018)*

The USGS CoSMoS flood hazards are shown below in Figure 6 for SLR scenarios of 1.6 ft, 3.3 ft, and 6.6 ft. This flooding layer represents a 100-year storm coupled with SLR, which is estimated by NOAA at the Santa Barbara gauge to be 8.2 feet (NAVD88), although the NOAA and CoSMoS 100-year water surface elevations likely differ. The results for 1.6 and 3.3 feet of SLR are very similar and predict that flooding would be generally limited to the extents of Bell Canyon Wash and the shoreline along the Project Area. At the northwest course hole (hole #11), the CoSMoS results depict some coastal flooding across the southernmost portion of the hole under an extreme event combined with 3.3 ft of SLR. The CoSMoS results suggest that the entire hole will be subject to coastal flooding with an extreme event combined with 6.6 ft of SLR. However, based on a review of the range of CoSMoS flood projections, the threshold for flooding at this location is likely 5.7 feet of SLR coupled with an extreme event.

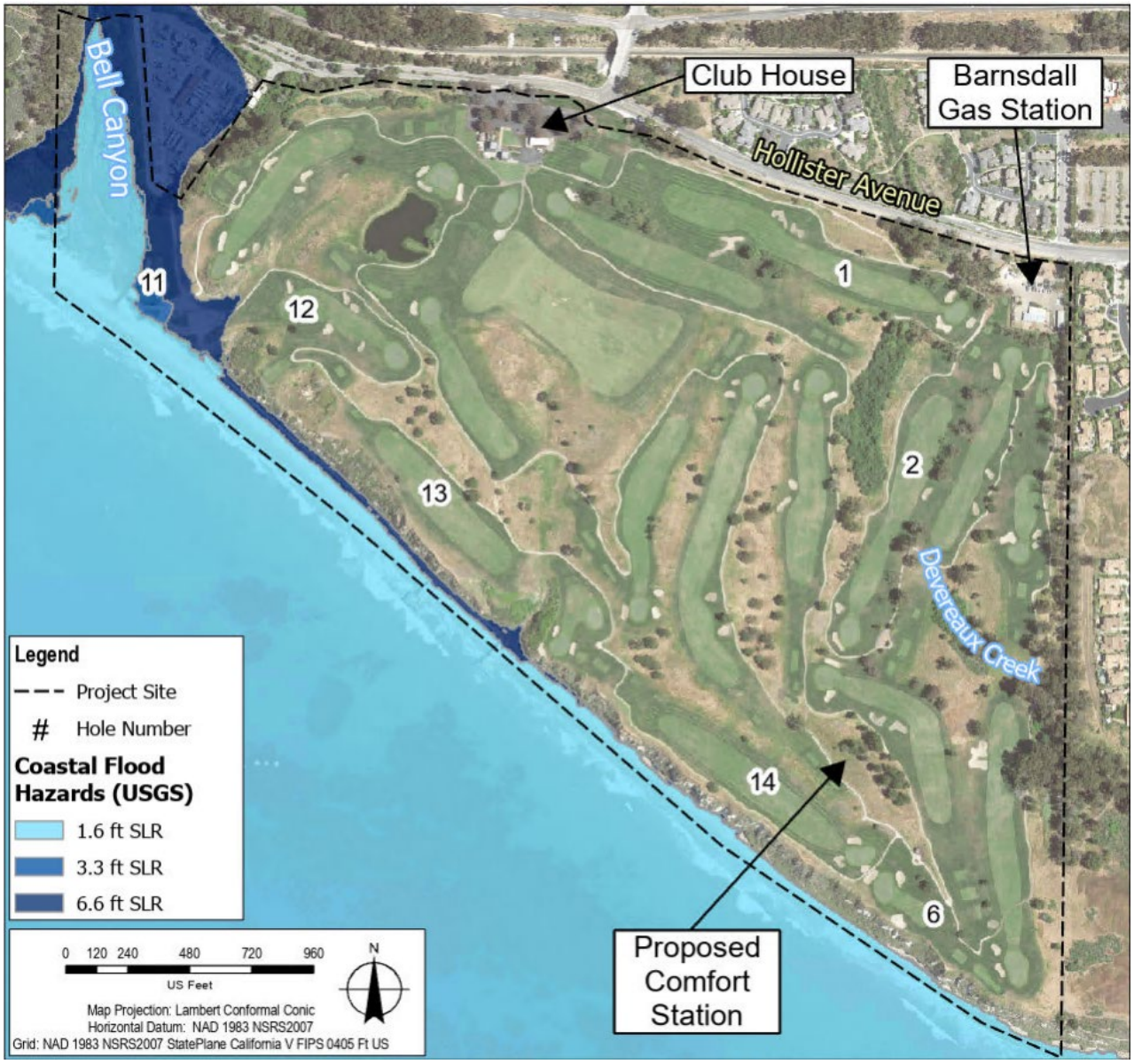


*Figure 6. USGS CoSMoS Flood Hazards (100-year event)*

Based on the CoSMoS results, the Project Area is not exposed to coastal flooding with 6.6 ft of SLR, except for the aforementioned northwest course hole. Coastal flooding is limited to Bell Canyon Wash with most of the Project Area elevated well above existing and future wave uprush limits. Due to Devereaux Creek's elevated location on the bluff top and outflow to a neighbouring delta, the CoSMoS results do not depict any coastal flooding occurring under the projected scenarios.

Coastal flood hazards were also examined in the City of Goleta Coastal Hazards Vulnerability Assessment (VA) (2015). This hazard assessment was based on available SLR projections, which have since been superseded. The study assessed SLR projections of 0.8 ft by 2030, 2.3 ft by 2060, and 5.0 ft by 2100. Comparative to the 2018 OPC guidance, the 2030, 2060, and 2100 SLR projections differentiated by 0.1 ft, 0.2 ft, and 1.6 ft, respectively. This assessment depicts the flood zone with 5.0 feet of SLR atop the bluff, however the model used to assess coastal flooding for this VA did not appear to take into account the elevated surface of the Project Area. The projected coastal hazard displayed coastal flooding taking place along the entire southwestern edge of the golf course. The bluff elevations of 70 ft to 90 ft should be well above the 100-year storm TWL's, even when coupled with SLR. Besides this, the projected flooding of the Bell Canyon Wash in this VA corresponds well with the CoSMoS results at this location.

## 4.3 Shoreline Erosion

Erosion is a dynamic process that results from a sediment deficit in combination with hydrodynamic forces acting at the shoreline. Eroded sediment is transported in the longshore or cross-shore direction as the mean sea level (MSL) shoreline moves landward. Depending on the setting, this process may be spontaneous and event based, or chronic and continuous. Forces such as wave exposure and wave action at the shoreline are significant drivers in this process, however physical elements such as grain size also dictate the stability of the shoreline.

It is generally accepted that SLR will result in accelerated erosion rates. Projected shoreline evolution with SLR was modeled by the USGS with CoSMoS. CoSMoS results are provided for multiple scenarios that represent coastal management techniques such as “hold the line vs let it go,” which generally determines a landward non-erodible boundary in the model. Beach nourishment can also be a specified scenario for the CoSMoS shoreline retreat, as the availability of sand is very influential on the rate of shoreline retreat. The “Let it go, no nourishment” scenario considers an erodible shoreline and no future beach nourishment activities. Thus, this scenario will have the greatest rates of shoreline retreat and can be considered the most conservative scenario. The CoSMoS shoreline projections are shown below in Figure 7 for the “Let it go, no nourishment” scenario for up to 6.6 feet of SLR.


*Figure 7. USGS CoSMoS Shoreline Erosion Projections*

The shoreline retreat projections shown in Figure 7 for 6.6 feet of SLR should only be considered for the Bell Canyon Wash mouth as the remaining shoreline is backed by coastal bluffs, which will retreat at different rates than that of the shoreline. There is only one segment of this shoreline which are not backed by coastal bluffs, being Bell Canyon Wash. Elsewhere, we anticipate that bluff erosion will be the dominant process at higher SLR scenario (i.e. 3.3 and 6.6 feet) and is described in the following section. While shoreline retreat is not expected to hold a direct threat to the site in most scenarios, it may influence the process of bluff erosion.

The CoSMoS projections suggest that the sandy shoreline through the entire Project area will be eroded to the bluff toe with 1.6 feet of SLR. For the Bell Canyon Wash area, the results suggest that course hole # 11 is vulnerable to shoreline retreat with SLR projections exceeding 3.3 feet. At 3.3 feet of SLR, shoreline erosion may begin to impact the bluff stability and corresponding bluff retreat rates provide a more representative hazard zone. In the near term (up to 1.6 feet SLR), the existing RSP may provide some protection against wave attack along the bluff toe. Although, the effectiveness of this protection under present-day and future scenarios is difficult to determine without more information regarding the condition of the RSP.

## 4.4 Bluff Retreat

Coastal bluff erosion is a process that is largely connected to the oceanographic forces (i.e., waves and tides) acting on the shoreline. Bluff erosion is typically measured over long time periods to estimate average retreat rates. However, the bluff erosion process is often episodic and event based. One of the driving forces in bluff erosion is wave action, in which a beach acts as the primary buffer to dissipate wave energy as it approaches the bluff toe. The stability of the shoreline is linked to stability of the bluff, in that erosion of the shoreline will allow for increased wave attack at the bluff toe. And as the sea level rises, waves will approach the bluff more frequently and accelerate retreat rates. However, there are other driving forces to consider such as earthquakes, groundwater conditions, and precipitation. Predicting the impacts of each of these factors is complicated, and models and projections that incorporate each of these factors are not readily available for analysis.

The USGS CoSMoS projections use numerical models alongside factors such as historic retreat rates, nearshore slope, coastal cliff height and mean annual wave power. The USGS CoSMoS bluff retreat projections are shown below in Figure 8. The results indicate that existing course holes #6, #12, #13, and #14 are exposed to bluff erosion. For 1.6 ft SLR, the bluff retreat in the Project Area is approximately 5 to 65 ft from bluff edge. For 3.3 ft of SLR, the bluff retreat in the Project Area is approximately 20 to 85 ft from the existing bluff edge. For 6.6 ft of SLR, the bluff retreat in the Project Area is approximately 35 to 115 feet from the existing bluff edge. Based on CoSMoS projections, the estimated rate of bluff erosion is approximately 0.63 to 2.0 ft per year. This rate corresponds well with the estimated retreat rates along the bluff crest of 0.3 to 2.1 ft per year found through the analysis of LiDAR data from 1997 to 2018 (Padre Associates, 2021).

It should be noted that bluff retreat can be spontaneous and influenced by site specific factors such as geology of the underlying material. In some coastal California areas, bluff geology is known to vary widely across a relatively small area and thus the retreat rates also vary. Because of this, there is a degree of uncertainty associated with bluff retreat projections, and the uncertainty bands for CoSMoS can range +/- 15 to 25 feet for the scenarios examined in this Study.

Only the course holes directly adjacent to the existing bluff edge are exposed to these potential bluff erosion zones. The project description acknowledges this potential hazard but notes there is ample room on the property to accommodate alterations to the course in response to bluff retreat. There are no proposed structural developments within any of the projected bluff retreat hazard zones. The proposed comfort station structure is approximately 350 ft from the edge of the existing bluff and the Clubhouse is at least 1,000 ft or more from the blufftop. Given the large setback from the bluff edge, the proposed onsite structural developments would not be exposed to future bluff erosion for the scenarios considered in this study.


*Figure 8. USGS CoSMoS Bluff Retreat Projections*

Bluff erosion was also examined in the 2015 City of Goleta's Coastal Hazards VA, which calculated the historic long-term cliff erosion rates based on multiple shorelines from USGS (Hapke and Reid, 2007) and a 2010 cliff edge derived from recent LIDAR data. This rate ranged between 0 inches/year and 11.4 inches/year (City of Goleta, 2015). The toe or base of the sea cliffs in this area are largely protected by the remnants of oil and gas infrastructure, namely a timber seawall that was backfilled and has protected the toe of the cliffs from wave attack (City of Goleta, 2015). The Assessment's projection of the cliff erosion hazard zones under the 2030 and 2060 projections generally corresponded with the CoSMoS results. Although, the hazard zones under the 2100 projections are presented as more conservative than the CoSMoS results, extending much further back from the existing bluff edge. This could be due to the usage of a model that accelerates historic erosion rates based on the increase in duration of wave attack at various elevations on the cliff (City of Goleta, 2015).

## 4.5 Groundwater Emergence

Coastal groundwater levels can increase with SLR where shallow groundwater floats on underlying seawater, resulting in shoaling where groundwater moves closer to the surface or emergence where flooding of the surface occurs. The USGS conducted numerical modeling to project coastal areas which may be vulnerable to elevated groundwater levels driven by SLR (Befus et al. 2020). These simulations accounted for a range of horizontal hydraulic conductivity scenarios (i.e., 0.1, 1, and 10 m/day) under two model versions. The hydraulic conductivity scenarios represent the assumed permeability and depth of the existing water table for any specific site. For example, 0.1 m/day means a less permeable and shallower water table, 1 m/day signifies a moderately permeable and moderately deep water table, and 10 m/day denotes a more permeable and deeper water table. The first model version attempts to simulate loss via natural drainage by removing groundwater that reaches the land surface. The second model simulates the "worst-case" scenario where SLR simply raises the present day groundwater level, retaining the groundwater that reaches the land surface. The results of these models are provided for increments of 25 cm, from no SLR (0 cm) to 2 meters (6.6 feet), and further elevated scenarios of 2.5 m (8.2 feet), 3 m (9.8 feet), and 5 m (16.4 feet). Thus, similar to CoSMoS's difference from OPC (2018) projections, there is still general alignment in the selected scenarios.

Due to the lack of existing data for this site's geological conditions, the most conservative model conditions were selected for this analysis. This included the usage of a low hydraulic conductivity scenario that is less permeable and contains a shallower water table, alongside the second model's linear "worst-case" simulations. These conditions utilized the highest current groundwater levels and raised them by the amount of SLR without accounting for natural drainage. The results of this model provided the most conservative scenario for the shoaling and emergence of groundwater at the Project site.

Based on these conservative groundwater scenarios, groundwater emergence is only projected along the lower lying Bell Canyon Wash fluvial channel. Within the Bell Canyon Wash, this groundwater emergence is projected to occur at 1.6 ft of SLR and through 3.3 ft of SLR as shown in Figure 9 and Figure 10. With SLR projections greater than 3.3 ft, tidal influence is expected to dominate the lower lying portions of the Wash as can be seen in Figure 11. These groundwater emergence projections suggest that the Project site along bluffs is significantly elevated over the water table, as the bluffs range in elevation from 70 ft to 90 ft (NAVD88). Thus, the Project Site is not exposed to groundwater emergence hazards with SLR.

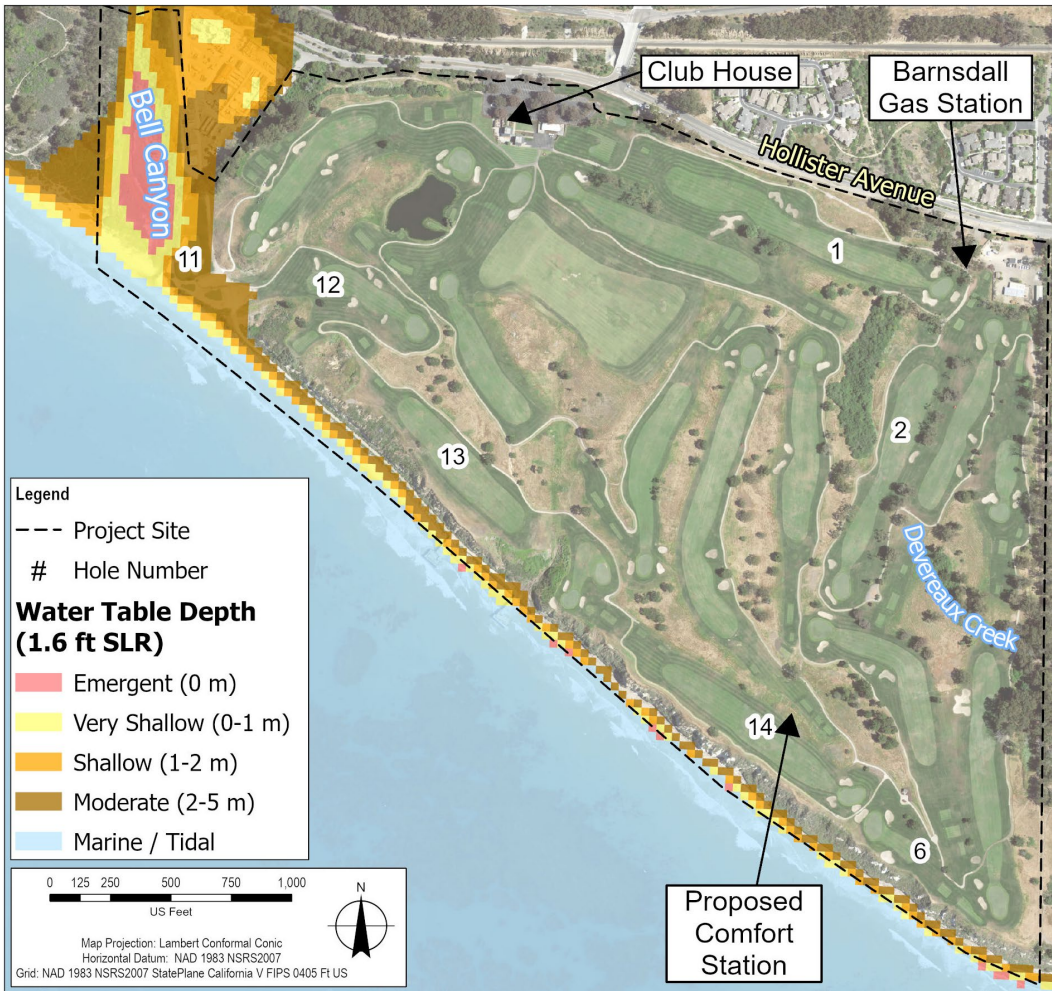


*Figure 9. USGS Groundwater Depth and Emergence Projections for 1.6 ft of SLR*

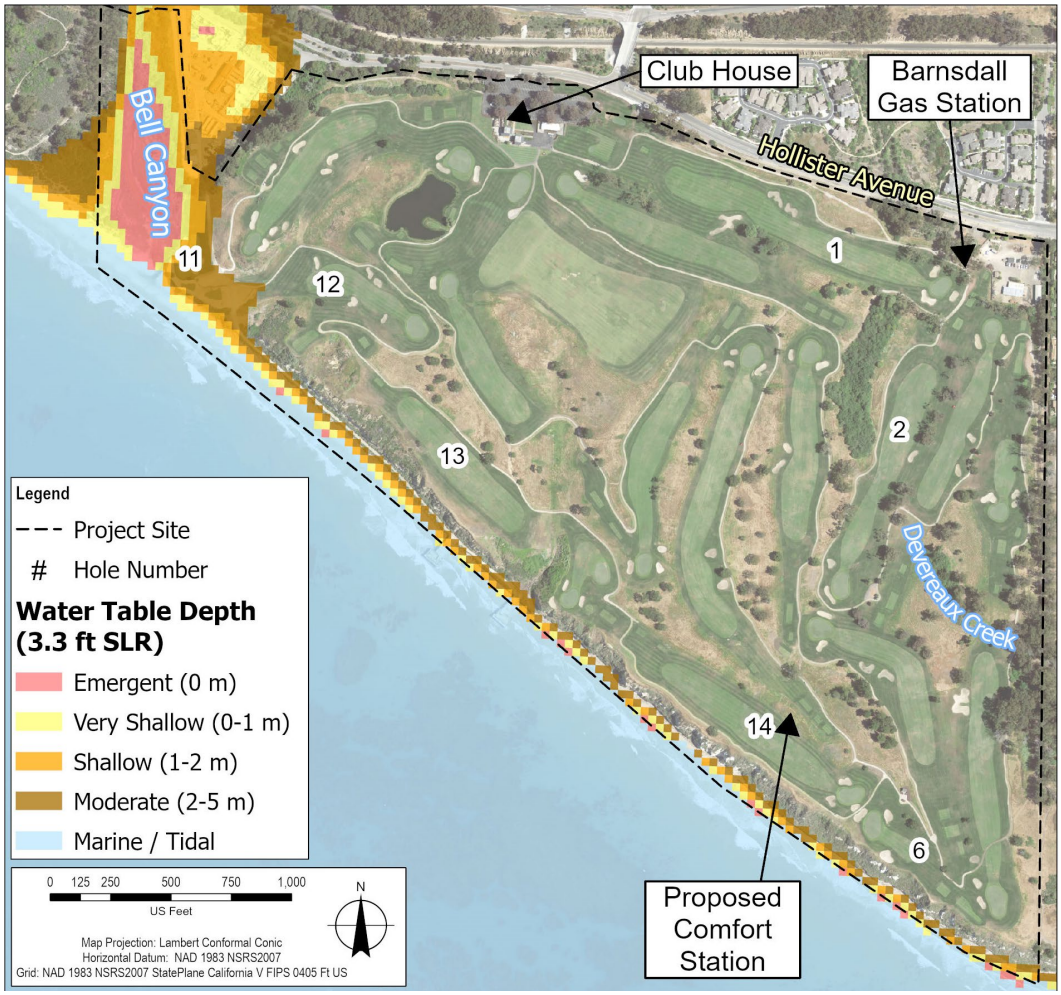


*Figure 10. USGS Groundwater Depth and Emergence Projections for 3.3 ft of SLR*

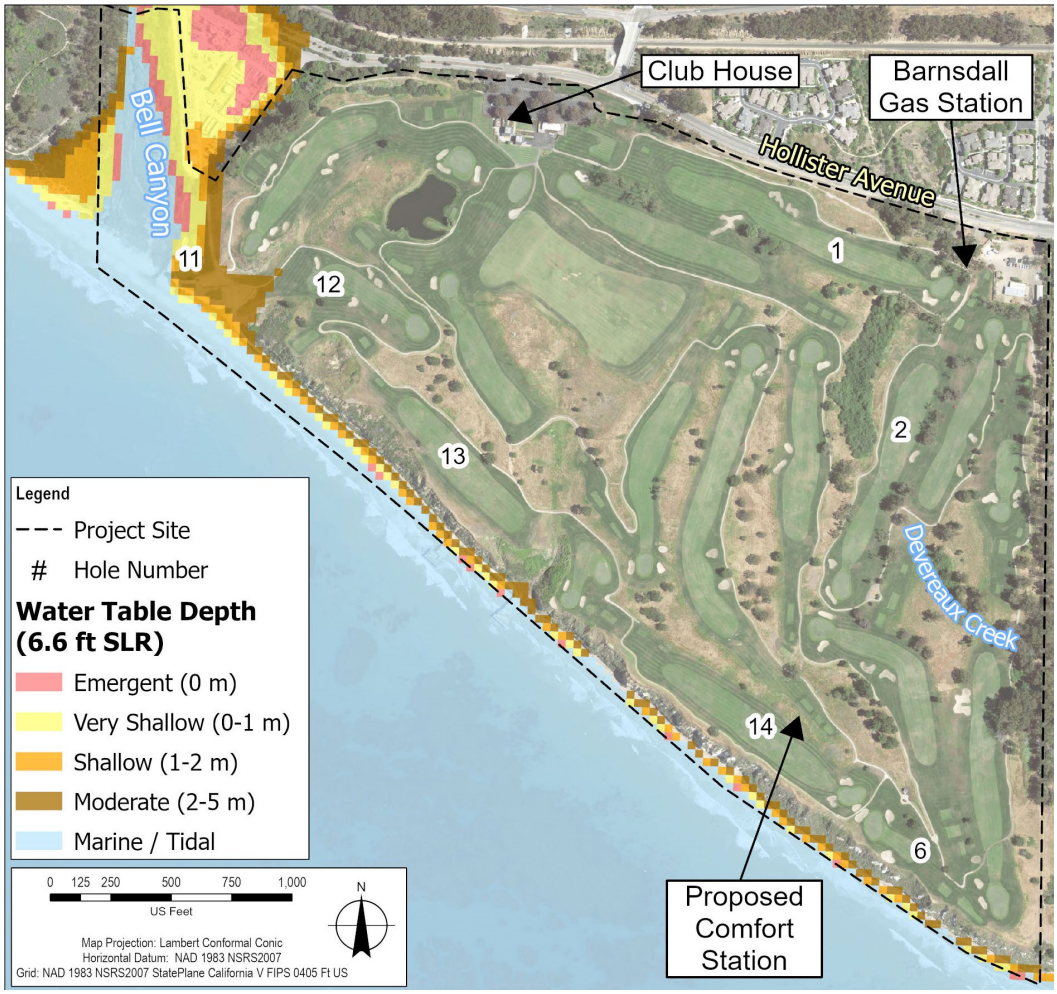


*Figure 11. USGS Groundwater Depth and Emergence Projections for 6.6 ft of SLR*

## 4.6 Tsunami Hazards

Tsunami hazards were evaluated at the project site using the American Society of Civil Engineers Standard 7-16 “Minimum Design Loads and Associated Criteria for Buildings and Other Structures” (ASCE 7-16) which has been adopted by state and local building codes. Chapter 6 of ASCE 7-16 includes design provisions for evaluating “Tsunami Loads and Effects” on buildings and other structures that fall within Risk Categories II, III, and IV. The Project area is considered to be Category I, referring to building and structures that represent low risk to human life in the event of a failure. Although the design criteria varies for each risk category, the methods for estimating depth and velocity from the tsunami event are the same.

ASCE 7-16 provides two options for evaluating depth and velocity of tsunami hazards within the MCT design zone. The energy grade line analysis (EGLA) method uses the runup elevation at the inundation limit to develop a profile of maximum flow depth and velocity between that point and the coastline. The second method of analysis involves the use of a site-specific numerical model to simulate the propagation of the tsunami waveform across the project site. The ASCE also provides geocoded reference points of runup and associated inundation limits along the Pacific west coast in the ASCE Tsunami Hazard Tool (ASCE Tsunami Design Geodatabase Version 2022-1.0). It should be noted that this hazard tool does not consider the effects of SLR on tsunamis.

The Tsunami Hazard Tool provides points along the shoreline which describe the wave runup associated with the tsunami. These wave runup points describe the runup elevation limits of the tsunami inundation. At the Project Site, the results of the tool show that the tsunami inundation is limited by the elevation of the bluff edge, which primarily ranges in elevation from 70 to 90 feet (Figure 12). The tsunami runup elevations along the shoreline range from 17 to 22 feet, thus the Project Site and associated components are not particularly vulnerable tsunami hazards.

The tsunami hazard zone as delineated by the hazard tool shows a flood zone similar to that of the coastal flood hazards, meaning that the lower lying Bell Canyon area is subject to tsunami runup and contains slightly higher runup elevations as the gradient landward from the shoreline is more gradual than that of the adjacent coastline. These lower grades allow for wave runup to travel further inland. However, there are no Project components being proposed in the Bell Canyon Wash area, and the remaining runup hazard zone is outside of the Project area.


*Figure 12. ASCE 7-16 Tsunami Hazard Tool displaying tsunami runup limits (blue shaded polygon and orange points)*

As mentioned above, the tsunami hazard tool does not incorporate SLR into the tsunami runup elevation calculations. However, given the gradient differential between the runup elevations and the average elevations of the Project area (atop the bluff), SLR is not expected to greatly alter the existing runup elevations. That is, even if runup elevations are enhanced by SLR, it is likely that there will still be enough elevation difference between the runup values and the Project area (Figure 13).

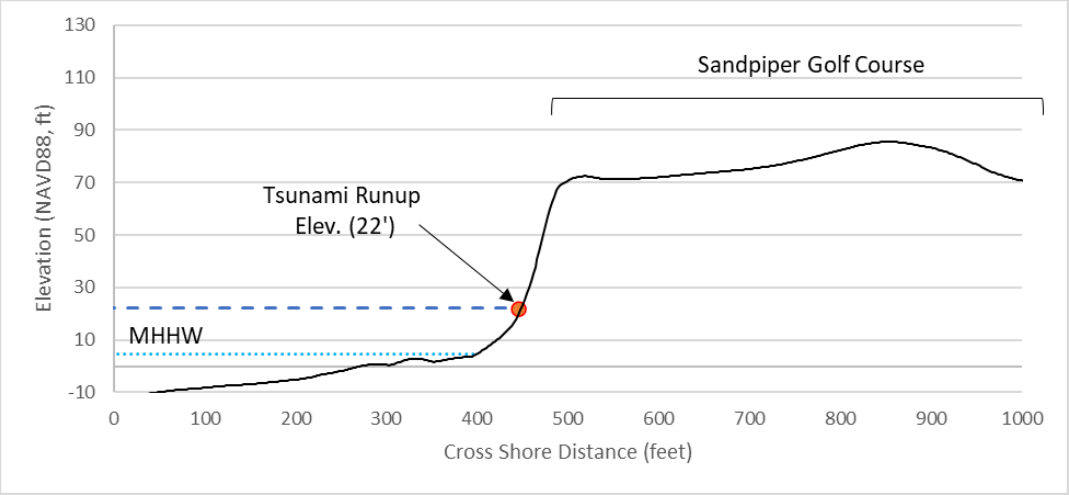


*Figure 13. Tsunami runup elevation plotted along cross shore transect through project area*

# 5. Summary

This Study examined coastal hazards for a range of probabilistic SLR scenarios, specifically coastal flooding, shoreline erosion, bluff retreat, and tsunami inundation. This Study considered SLR projections of 1.6 feet, 3.3 feet, and 6.6 feet, which correspond to the OPC (2018) medium high risk aversion scenario projections through 2100. Based on the available hazard projection data, the key conclusions are as follows:

- The major project elements (Clubhouse, upgraded comfort station, and re-purposed gas station) are not located within any coastal hazard zones. The nearest proposed Project element is the comfort station, which is well outside (over 200 feet landward) of the future bluff hazard zones.
- Fluvial flooding of Bell Canyon Wash is not expected to directly impact the Project Area. Golf course holes #1 and #2 could be exposed to fluvial flooding via Devereaux Creek in a 100-year event. SLR is not expected to influence fluvial flooding due to the large energy differential between creek water surface profiles and ocean water levels.
- Golf course hole #11, adjacent to Bell Canyon Wash, is exposed to partial coastal flooding for an extreme event coupled with 3.3 feet of SLR, with more substantial flooding expected at this hole for higher SLR scenarios (i.e. above flood threshold estimated at 5.7 feet of SLR). It is important to note that erosion will likely be a concern before this flood threshold is reached.
- The sandy beach may be completely eroded to the bluff toe with 1.6 feet of SLR, and the Bell Canyon Wash area may be most affected by shoreline erosion. Course hole #11 is also exposed to shoreline erosion with 3.3 feet of SLR.
- The bluff-adjacent course holes #6, #12, #13, and #14 are exposed to bluff retreat, particularly for SLR scenarios of 3.3 feet or higher. However, these features have sufficient adaptive capacity to remain functional while accommodating bluff retreat. In the unlikely event that bluff retreat affects the course of play, there is ample room within the golf course to accommodate alterations to the course in response to bluff retreat.
- The golf course is not anticipated to be exposed to groundwater emergence as it is only expected to occur along the existing Bell Canyon Wash.

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