APPENDIX G
Coastal Hazard and Wave Runup Analysis

GeoSoils, Inc.

Geotechnical • Geologic • Coastal • Environmental

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January 26, 2023 WO S8538

Mr. Matthew Segal, AIA
3000 Upas St. #104
San Diego, CA 92104

SUBJECT: Coastal Hazard and Wave Runup Analysis, 6110 Camino de la Costa, La Jolla, San Diego County, California.

Dear Mr. Segal:

GeoSoils Inc. (GSI) is pleased to provide this coastal hazard analysis for the proposed new residence at the subject property in La Jolla. The purpose of this analysis is to provide the City of San Diego and the California Coastal Commission (CCC) the necessary hazard information typically requested for coastal development. The site is on top of a coastal bluff that is fronted by a bed rock shoreline. The proposed project is to remove the existing improvements, construct a new residence, and other improvements. The new residence will be setback about 25 feet from the top of the bluff at about elevation +25 feet to +27 feet NGVD29. Our scope of work includes a review of the CCC Sea-Level Rise (SLR) Guidance (updated November 2018), a review of the National Oceanographic and Atmospheric Administration (NOAA) latest SLR science (NOAA, 2022), a review of the site elevations, a review of the proposed residence plans, a site inspection, and preparation of this letter report. This report constitutes an investigation of the wave and water level conditions expected at the site as a result of extreme storm and wave action over the next 75 years. It also provides conclusions and recommendations regarding the susceptibility of the proposed development to wave attack and erosion. The analysis uses design storm conditions typical of the January 18-19, 1988, the winter of 1982-83, and recent January 2023 type storm waves and king tide conditions.

SITE INSPECTION

The shoreline fronting the site was inspected by GSI personnel in January 2023. In addition, the bluff and shoreline in this area of La Jolla have been observed periodically by the undersigned for the last four decades while working on bluff top residential development projects nearby. There were no signs of recent bluff top erosion at the site or on the adjacent properties. There were signs of some historical marine erosion at the base of the bluff nearby to the west in the form of blocks of failed bedrock. The site is in an area of bluff/shoreline that is composed of a very erosion resistant bedrock material that is fronted by a broad bedrock shore platform. The shore platform and erosion resistant bedrock provide significant protection to the site from waves and erosion. Figure 1 is an aerial photograph of the site taken in February 2022 downloaded from GoogleEarth.

Figure 1. Subject site, bedrock shoreline and broad shore platform in 2022.

Site elevations were taken from a topographic map prepared by San Diego Land Surveying & Engineering, Inc. dated 2/14/23, using MSL (NGVD29) as the vertical datum. Preliminary project plans prepared by Jonathan Segal, FAIA, were reviewed. Site geology was investigated by Christian Wheeler Engineering (CWE). The top of the bluff was determined by CWE along with the historical bluff erosion rate (CWE, 2022). The shoreline is primary large rounded bedrock that overly and fronts the erosion resistant broad shore platform.

HAZARD ANALYSIS

There are three different potential oceanographic hazards identified at this site: bluff erosion, flooding, and waves (extreme waves and tsunami). For ease of review, each of these hazards will be analyzed and discussed separately, followed by a summary of the analysis, including conclusions and recommendations.

Bluff Erosion Hazard

The typical coastal-bluff profile is divided into three zones: the shore platform; a lower near-vertical cliff surface termed the sea cliff (about 60 degrees or greater); and an upper bluff slope generally ranging in inclination between about 20 and 50 degrees (measured from the horizontal). The upper bluff typically transitions into a relatively flat-lying coastal terrace. The bluff edge is the boundary between the upper bluff and coastal terrace. Offshore from the sea cliff is an area of indefinite extent termed the near-shore zone. The bedrock surface in the near-shore zone, which extends out to sea from the base of the sea cliff, is the shore platform. Prior to the development of La Jolla the steep topography resulted in subaerial erosion determining the location of the top of the bluff. After development, with landscaping and drainage control the top of the bluff is essentially stabilized. The impact of marine erosion is minimal due to the broad shore platform and the dissipation of wave energy by the bedrock.

The bluff and shoreline in front of the site have been observed on several occasions in the past four decades during work on adjacent sites. Sea cave or arch collapse occurs sporadically but typically these are very local failures do not extend up to the top of the bluff. One of the best was to estimate shoreline and bluff erosion is by comparing historical aerial photographs. Figure 2 is a vertical aerial photograph of the site taken in 1952 downloaded with permission from the University of Santa Barbara Aerial Photograph website (Flight C 18080, Frame 4-7). Figure 1, on page 2, is a 2022 vertical aerial photograph of the same area as shown in Figure 2. These images can be used to compare changes in the bluff edge, the bluff face, and the shoreline position over the 70 year period between the time the photographs were taken. Because the individual houses have not moved measurements of the images can be approximately scaled, and can be compared. The shoreline bedrock fingers, the small cove below the property, the location of the existing residence relative to the bedrock, and apparent bluff top have not changed significantly over the previous 70 years.

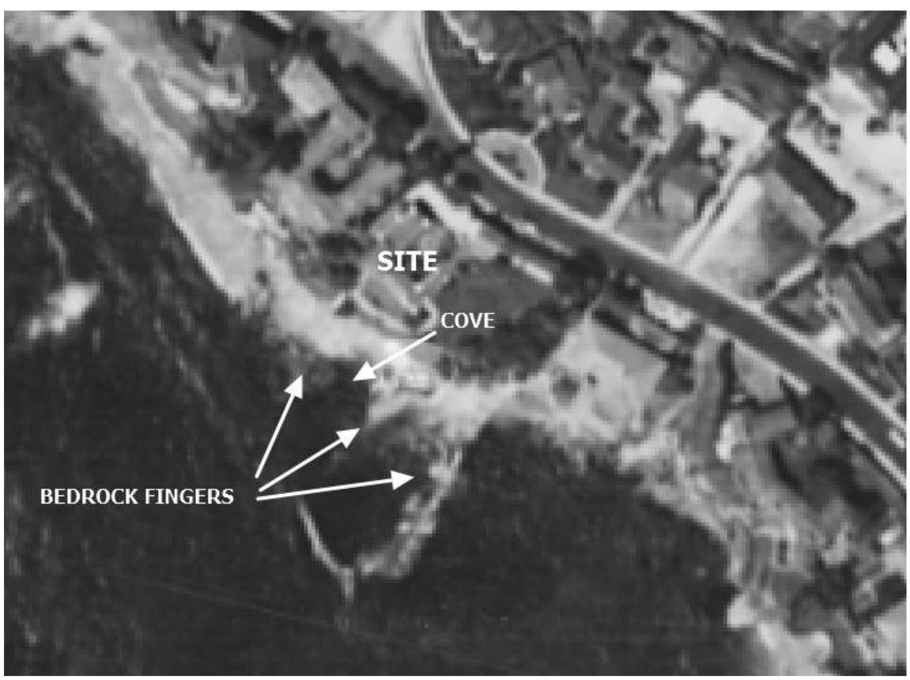


Figure 2. Subject site and shoreline features in November 1952.

The project geotechnical consultant, CWE, using a more comprehensive historical aerial photograph analysis, determined a historic bluff erosion rate of 0.03 ft/y. This rate is consistent with the minimal erosion that can been seen looking at the oblique aerial photographs from the California Coastal Records (https://www.californiacoastline.org/) project images. The potential for SLR to impact the rate of bluff erosion is discussed later on in this report.

FLOODING HAZARD

The historical water levels (tides) in the La Jolla area are well documented. The National Oceanographic and Atmospheric (NOAA) National Ocean Survey tidal data station closest to the project site is at the Scripps Institution of Oceanography La Jolla Pier Station. The current (last tidal epoch) tidal datum elevations in feet are as follows:

MEAN HIGHER HIGH WATER (MHHW)	= 3.03
MEAN HIGH WATER (MHW)	= 2.30
MEAN TIDE LEVEL (MTL)	= 0.45
MEAN SEA LEVEL (MSL)	= 0.43
NGVD29	= 0.00
MEAN LOW WATER (MLW)	=-1.39
MEAN LOWER LOW WATER (MLLW)	=-2.30

The maximum historical water elevation at the site including El Niño effects is ~+5.3 feet NGVD29. The proposed residence is behind and above the top of the bluff at ~+25 feet NGVD29. As a result, the proposed development is located at an elevation that would not expose it to flooding.

Sea Level Rise

The 2018 Coastal Commission Sea Level Rise Guidance (CCCSLRG) requires the use of the “best available science” with regards to sea level rise (SLR) projections. The CCCSLRG is based upon the California Ocean Protection Council (COPC) update to the State’s Sea-Level Rise Guidance in March 2018. These COPC estimates are based upon a 2014 report entitled “Probabilistic 21st and 22nd century sea-level projections at a global network of tide-gauge sites” by Kopp, et al., 2014. The Kopp et al. paper used 2009 to 2012 SLR modeling by climate scientists for the probability analysis, which means the “best available science” used by the CCC is over 10 years old. There is more current “best available science” (measurements, models and projections) provided by NOAA (NOAA, 2022).

NOAA has been measuring SLR globally, and specifically in La Jolla. The NOAA La Jolla SLR rate is 2.04 mm/yr as shown in Figure 3. The rate can be used to calculate a sea level rise of 46.9mm (0.154ft) over the last 23 years (2000 through December 2022). If the La Jolla rates do not change significantly in the next 7 years (which is likely), the amount of La Jolla SLR to the year 2030 will be about 0.20 feet.

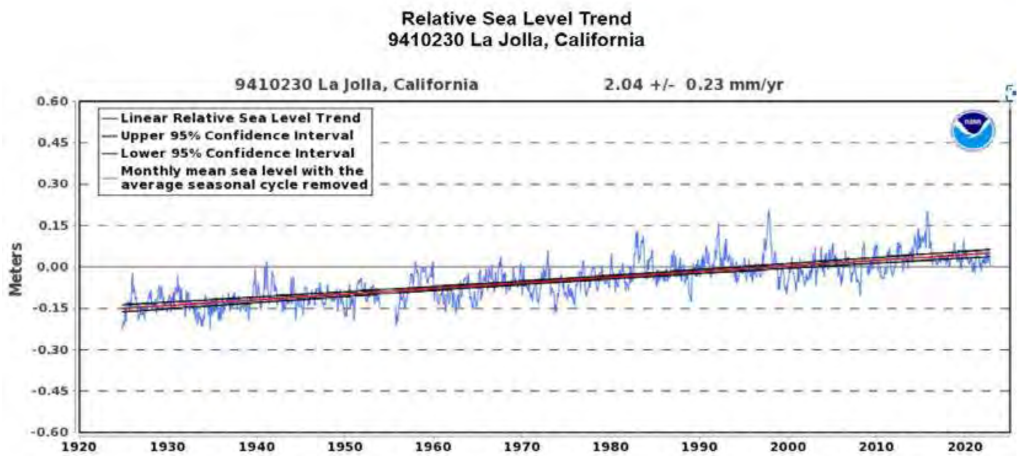
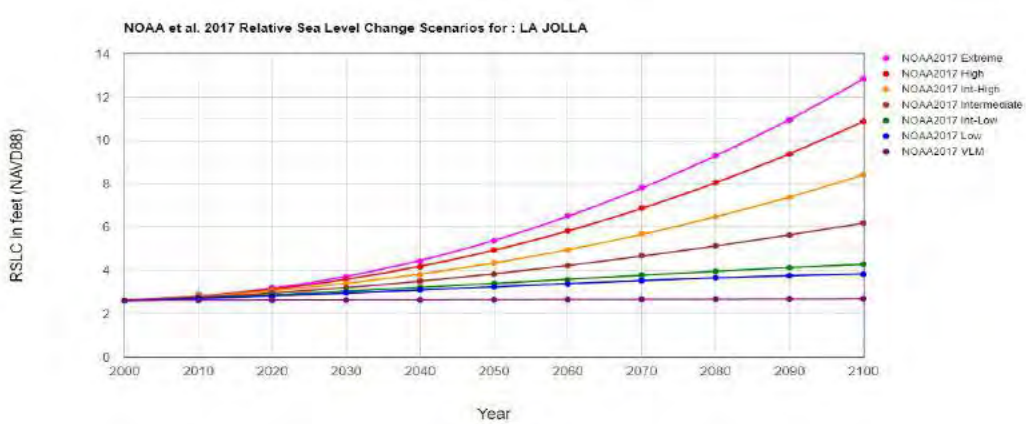


Figure 3. Latest measure SLR at La Jolla from NOAA.

NOAA also provides plots of the most current SLR model projections (best available science) over time starting in the year 2000. Figure 4, is the model projections taken from NOAA, which is more current SLR science and better SLR science than the 2018 COPC Guidance. To determine which model is accurately predicting SLR, the data for La Jolla can be either plotted onto the curves or estimated from the table below the curves. The model that is most accurate now should be considered the "best available science" SLR model for the project, at this time.



La Jolla SLR
Scenarios for LA JOLLA
NOAA2017 VLM: 0.00072 feet/yr
All values are expressed in feet

Year	NOAA2017 VLM	NOAA2017 Low	NOAA2017 Int-Low	NOAA2017 Intermediate	NOAA2017 Int-High	NOAA2017 High	NOAA2017 Extreme
2000	2.61	2.61	2.61	2.61	2.61	2.61	2.61
2010	2.62	2.71	2.71	2.78	2.84	2.87	2.87
2020	2.63	2.81	2.87	2.97	3.07	3.14	3.20
2030	2.63	2.97	3.07	3.20	3.40	3.56	3.70
2040	2.64	3.10	3.20	3.50	3.79	4.15	4.42
2050	2.65	3.24	3.40	3.83	4.35	4.94	5.37
2060	2.66	3.37	3.56	4.22	4.94	5.83	6.52
2070	2.66	3.53	3.79	4.68	5.70	6.88	7.83
2080	2.67	3.66	3.96	5.14	6.48	8.06	9.31
2090	2.68	3.76	4.12	5.63	7.37	9.37	10.95
2100	2.68	3.83	4.29	6.19	8.42	10.88	12.85

Figure 4. NOAA 2022 SLR projections for La Jolla.

Recognizing that in the year 2000 the SLR zero line is 2.61 feet, and using the current La Jolla SLR data (trends), La Jolla SLR should be (2.61 + 0.20 feet) 2.81 feet in the year 2030. Looking at the table in Figure 4 for the year 2030 (~7 years from now) reveals that La Jolla SLR is tracking below the NOAA 2017 Low SLR model curve. The Low SLR model predicts a SLR rise total in the year 2100 of about 1.22 feet.

The CCCSLRG document recommends that a project designer determine the range of SLR using the “best available science.” The California Ocean Protection Council (COPC) update included SLR estimates and probabilities for La Jolla, the closest SLR estimates. Table I provides the March 2018 COPC data (from the Kopp, et al., 2014 report) with the SLR adopted estimates (in feet), and the probabilities of those estimate to meet or exceed the 1991-2009 mean, based upon the outdated best available science. The 2022 NOAA SLR information provided above is more current than the CCCSLRG (2018 COPC). The 2022 NOAA SLR science/data is the “best available science” for SLR prediction and is required to be used by the CCC.

Table I

		Probabilistic Projections (in feet) (based on Kopp et al. 2014)					H++ scenario (Sweet et al. 2017) *Single scenario
		MEDIAN	LIKELY RANGE		1-IN-20 CHANCE	1-IN-200 CHANCE	
		50% probability sea-level rise meets or exceeds...	66% probability sea-level rise is between...		5% probability sea-level rise meets or exceeds...	0.5% probability sea-level rise meets or exceeds...	
				Low Risk Aversion		Medium - High Risk Aversion	Extreme Risk Aversion
High emissions	2030	0.5	0.4 -	0.6	0.7	0.9	1.1
	2040	0.7	0.5 -	0.9	1.0	1.3	1.8
	2050	0.9	0.7 -	1.2	1.4	2.0	2.8
Low emissions	2060	1.0	0.7 -	1.3	1.7	2.5	
High emissions	2060	1.2	0.9 -	1.6	1.9	2.7	3.9
Low emissions	2070	1.2	0.9 -	1.6	2.0	3.1	
High emissions	2070	1.5	1.1 -	2.0	2.5	3.6	5.2
Low emissions	2080	1.4	1.0 -	1.9	2.4	4.0	
High emissions	2080	1.9	1.3 -	2.5	3.1	4.6	6.7
Low emissions	2090	1.6	1.0 -	2.2	2.9	4.8	
High emissions	2090	2.2	1.6 -	3.0	3.8	5.7	8.3
Low emissions	2100	1.7	1.1 -	2.5	3.3	5.8	
High emissions	2100	2.6	1.8 -	3.6	4.6	7.1	10.2

In contrast to the measured SLR at La Jolla, the model the CCC is recommending to be analyzed (2018 COPC) is the high emissions scenario and the 0.5% probability shown in Table I. For the year 2030 the CCC recommended SLR is 0.9 feet, which is over 4 times greater than the 0.20 feet that is being measured. Over the 75-year life of the development this results in a very significant difference between what the SLR the CCC suggests based upon older science and what SLR is currently occurring. The current best available science using measured SLR data shows that the La Jolla SLR trend is tracking more closely to the likely range than the low probability 0.5% range. There is no current SLR science/measurements that supports the CCCSLRG (2018 COPC) 0.5% probability use. There is current/best science that supports the use of a much lower SLR estimate over the life of the development.

Table I illustrates that SLR in the year 2100 could be any where between 1.7 feet to 7.1 feet (or higher). The likely range for the most onerous RCP is 1.8 feet to 3.6 feet, with a 5% probability that SLR meets or exceeds 4.6 feet. Typically, the CCC recognizes that a new single family residence design life is 75 years.

WAVE RUNUP

As waves encounter the shore platform, rocky beach and bluff in front of the site, the wave runup rushes up the bluff. Based upon the mature vegetation pattern, there is no visible evidence that wave runup has impacted the bluff above elevation ~+20 feet NGVD29. Historically, marine caused bluff erosion is negligible along this section of shoreline. However, in the future with SLR, wave runup, spray, and splash may reach higher up the bluff during extreme events. Wave runup is defined as the vertical height above the still water level to which a wave will rise on a structure of infinite height (bluff). Wave runup on the beach/slope is calculated using the USACOE Automated Coastal Engineering System, ACES. ACES is an interactive computer based design and analysis system in the field of coastal engineering. The methods to calculate runup and overtopping implemented within this ACES application are discussed in greater detail in Chapter 7 of the Shore Protection Manual (1984) and the Coastal Engineering Manual. The input variables for the ACES wave runup are based upon the fact that the maximum wave runup occurs when the design wave is breaking at the toe of the bluff. This requires a depth limited determination of the design breaker height. The design SLR, using the high emissions 0.5% corresponds to about 6 feet in the year 2100.

The maximum design water depth is the maximum historical water elevation plus the amount of SLR less the design scour elevation . The design scour is 0.0 feet NGVD29. The design breaker height is then 78% of the water depth. The design wave height is 8.8 feet [(5.3+ 6)0.78)]. The runup on the irregular bedrock bluff will be modeled using a rough slope model. The wave period data for the analysis will be taken from Coastal Data Information Program (CDIP) at Scripps Institution of Oceanography. The CDIP Station is the deepwater station, Mission Bay West (#220), to the south of the site. The design period is 15 seconds which is a dominant wave period in the CDIP data. The nearshore slope was taken from the NOAA nautical chart and is 1/80 (vertical/horizontal) and the runup zone average slope is 1/1 (v/h) based upon the site topography (slope from scour elevation to mid bluff). The ACES output is in the table below. The limit of the wave runup is the design water elevation of +11.3 feet NGVD29 + 8.5 feet of runup or elevation +19.8 feet NGVD29. In the maximum SLR case over the 75 year life, the wave runup does not exceed to the top the bluff at +25 feet NGVD29.

ACES	Mode: Single Case	Functional Area: Wave – Structure Interaction
Application: Wave Runup and Overtopping on Impermeable Structures		

Item		Unit	Value
Incident Wave Height	Hi:	ft	8.800
Wave Period	T:	sec	15.000
COTAN of Nearshore Slope	COT(ø):		80.000
Water Depth at Structure Toe	ds:	ft	11.300
COTAN of Structure Slope	COT(θ):		1.000
Structure Height Above Toe	hs:	ft	25.000
Rough Slope Coefficient	a:		0.956
Rough Slope Coefficient	b:		0.900
Wave Runup	R:	ft	8.520
Deepwater Wave Height	H0:	ft	6.106
Relative Height	ds/H0:		1.851
Wave Steepness	H0/(gT^2):		0.001

Rough Slope Runup

6110 Camino de la Costa

Wave Runup 6 FT SLR

Tsunami Runup

The site is adjacent to the Pacific Ocean, which would allow for both near field (Channel Island faults) and far field (Alaska and Japan faults) generated tsunami to approach the site. The State of California (2009) shows that the site is just within the limit of a tsunami inundation zone. However, the limit of the tsunami zone does not reach the location of the proposed residence as shown in Figure 5. It should be advised that the site is mapped within the limits of the California Office of Emergency Services tsunami innundation map, La Jolla Quadrangle (State of California 2009). The tsunami inundation maps are very specific as to their use. Their use is for evacuation planning only. The limitation on the use of these maps is clearly stated in the **PURPOSE OF THIS MAP** on every quadrangle of California coastline. In addition, the following two paragraphs were taken from the CalOES Local Planning Guidance on Tsunami Response concerning the use of the tsunami inundation maps.

> *In order to avoid the conflict over tsunami origin, inundation projections are based on worst-case scenarios. Since the inundation projections are intended for emergency and evacuation planning, flooding is based on the highest projection of inundation regardless of the tsunami origin. As such, projections are not an assessment of the probability of reaching the projected height (probabilistic hazard assessment) but only a planning tool.*
>
> *Inundation projections and resulting planning maps are to be used for emergency planning purposes only. They are not based on a specific earthquake and tsunami. Areas actually inundated by a specific tsunami can vary from those predicted. The inundation maps are not a prediction of the performance, in an earthquake or tsunami, of any structure within or outside of the projected inundation area.*

Figure 5. CalOES site tsunami map on Google Earth overlay.

The community of La Jolla and the City of San Diego have developed a tsunami alert and evacuation plan. This plan recommends that coastal communities within the potential areas of inundation upgrade their tsunami education programs. The City of San Diego has posted signs throughout the community showing tsunami evacuation routes, tsunami evacuation center locations, and the limits of the tsunami hazard zones.

FUTURE BLUFF EROSION WITH SLR

The California Coastal Commission (CCC) observes the simplified numerical models (Young, et al., 2014) as tools for assessing the long-term retreat of coastal bluffs relative to current SLR projections. These simplified models build upon and generally follow the core principles of the Soft Cliff and Platform Erosion (SCAPE). The simplified model produces a dynamic equilibrium profile of an eroded shoreline, similar to the SCAPE model, whereby the erosion rate is a function of the velocity of cliff retreat. More specifically, the model initially shows a direct relationship between erosion and SLR, but for higher rates of SLR, the erosion rates begin to diminish as the equilibrium erosion profile steepens.

The simplified numerical model (“SCAPE”) equation is defined as:

$$R_2=R_1(S_2/S_1)^m$$

Where: R_2 = Future retreat rate
R_1 = Historical retreat rate
S_1 = Historical rate of sea level rise
S_2 = Future rate of sea level rise
m =Site-specific response parameter

The parameter “m” is dependent on the feedbacks between the shore profile geometry and erosion. An instant or linear feedback (m=1) represents an eroding shoreline where the erosion rate and SLR rate increase linearly. Potential examples of eroding shorelines exhibiting an instant response are dominated by sediment flux gradients and include coasts with bluffs and cliffs with high sediment yields. A negative feedback or nonlinear system (0<m<1) include eroding shorelines with negative feedbacks, such as high earth material strengths (like this site) or a protective beach that reduce erosion. Potential examples of negative feedback systems are shorelines dominated by wave-driven erosion, such as rocky shore platforms and coastal bluffs adjacent to low volume beaches. A no feedback system (m=0) include eroding shorelines where the magnitude of erosion is independent of SLR. Potential examples of no feedback systems include shorelines comprised of hard rock without shore platforms, shorelines dominated by bioerosion, or shorelines subjected to low wave energy.

Presence of a Protective Beach and Shore Platform

The shoreline along the toe of the coastal bluff, fronting the site, is generally composed of Point Loma Formation with sporadic cobbles and failed, boulder-sized fragments of Point Loma Formation. These shoreline deposits are more concentrated seaward of the bluff toe, forming a shingle rampart. This quasi-revetment/seawall helps dissipate in-coming wave energy before it can impact the coastal bluff, and will equilibrate in step with SLR over the 75-year design life of the proposed residential structure. The broad shore platform attenuates in-coming wave energy prior to impacting the coastal bluff, also limiting runup.

Most of the time, the site conditions are similar to a conditionally decoupled profile model (CDPM) curve BB:0 (see Figure 6, which is Figure 12 of Young, et al., 2014). Curve BB:0, which is below the m= 0.5 (or ½) curve of the simplified numerical equation, and closer to m=0, near the 2 meter SLR endpoint (when the design 6 feet of SLR will have occurred). Given the proximity to the BB:0 (m=0) line and the aforementioned geologic and bathymetric factors that limit marine-induced bluff erosion, we judge that m = 0.1 (or 1/10) appears appropriate for the coastal bluff adjacent to the site.

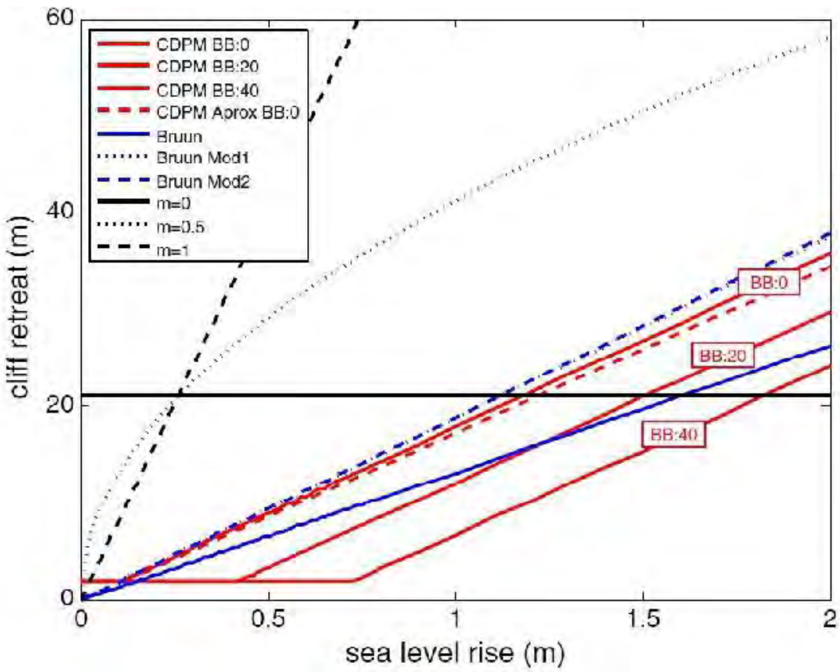


Fig. 12. Comparison of the conditionally decoupled profile model (CDPM) with 0, 20, and 40 m beach buffers (BB) and original Bruun, modified Bruun (Bruun Mod1 and Mod2), no feedback ($m = 0$), approximate SCAPE ($m = 0.5$), and linear extrapolation ($m = 1$). Exponent m models are based on historical cliff and MSLR, while others are sediment balance based.

Figure 6 - Sea Level Rise (meters) and Cliff Retreat (meters)

Future Bluff Retreat Summary

The calculated long-term rate of future bluff retreat using the simplified numerical model equation is presented below, based on the aforementioned three curvilinear sections and:

- Historical rate based on the site photography is 0.03 ft/yr = R_1 (CWE, 2022).
- Avg SLR rate over 90 years (1932 to 2022), based on NOAA (Gloss Station Handbook Scripps Pier, La Jolla) is 2.04 mm/yr = 0.08 inch/yr x 1 ft/12 in = 0.0067 ft/yr = S1
- Future SLR rate (2097), under *medium-high risk aversion scenario* = 6 ft/75 yrs = 0.08 ft/yr=S_2
- m=1/10

Solving the equation yields R_2 = 0.038 ft/yr in the year 2097. While the increase in retreat rate will occur exponentially like SLR in the later years of the development, one can conservatively say the retreat rate is the average of the historic retreat rate and the future retreat rate at the end of the life of the development. The average retreat rate is 0.03 ft/y, which over the life of the development would account for less than 3 feet of bluff retreat.

CONCLUSIONS

- The proposed development is safe from coastal hazards including over 6 feet of SLR. The elevation of the development prevents site flooding from the ocean and wave runup in consideration of the 0.5% SLR (CCCSLRG, 2018). Finally, the site is well setback from the impact of shoreline erosion in consideration of SLR.

- No protective devices will be necessary to protect the proposed development from any existing or anticipated future coastal hazards over the life.

RECOMMENDATIONS

Based upon the analysis and discussion herein, the proposed development is reasonably safe from coastal hazards for the next 75 years including shoreline movement, erosion, wave runup, and flooding with future SLR. The proposed development will neither create nor contribute significantly to erosion, geologic instability, or destruction of the site or adjacent area. There are no recommendations necessary for shore protection. The final plans should be reviewed by this office for conformance with our report.

The opportunity to be of service is sincerely appreciated. If you should have any questions, please do not hesitate to contact our office.

Respectfully submitted,

GeoSoils Inc.

GeoSoils Inc.
David W. Skelly MS, PE

REFERENCES

California Coastal Commission Sea Level Rise Guidance Science Update, November 2018.

Christian Wheeler, Engineering, 2022, “Report of Preliminary Geotechnical Investigation, Proposed Single Family Residence, 6110 Camino de la Costa, La Jolla California,” dated July 15.

Emery, K.O. and Kuhn, G.G., 1982, Sea cliffs: their processes, profiles, and classification: Geological Society of America Bulletin, v. 93, no 7.

Kopp, Robert E., Radley M. Horton Christopher M. Little Jerry X. Mitrovica Michael Oppenheimer D. J. Rasmussen Benjamin H. Strauss Claudia Tebaldi Radley M. Horton Christopher M. Little Jerry X. Mitrovica Michael Oppenheimer D. J. Rasmussen Benjamin H. Strauss Claudia Tebaldi “Probabilistic 21st and 22nd century sea-level projections at a global network of tide-gauge sites” First published: 13 June 2014.

State of California, 2009, County of San Diego, Tsunami Inundation Map for Emergency Planning, La Jolla Quadrangle, 1:24,000 scale, dated June 1.

NOAA, 2022, Web Site, Maps http://anchor.ncd.noaa.gov/states/ca.htm Tidal Datums http://www.opsd.nos.noaa.gov/cgi-bin/websql/ftp/query_new.pl

NOAA 2022, Sea Level Rise Report email link. https://oceanservice.noaa.gov/hazards/sealevelrise/sealevelrise-tech-report.html

USACOE, 1984, Shore Protection Manual.

USACOE, 1988, CCSTWS report #88-6 "Historic Wave and Water Level Data Report San Diego Region.”

USACOE, 1991, CCSTWS “State of the Coast Report San Diego Region.”

USACOE, 2004, Coastal Engineering Manual.

Young, A.P., R.E. Flick, W.C. O'Reilly, D.B. Chadwick, W.F. Crampton,, and Helly, J.J., 2014, Estimating Cliff Retreat in Southern California Considering Sea Level Rise Using a Sand Balance Approach. Marine Geology, 348, p. 5-26.