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W17c

6-21-0758 (Pollock)

November 16, 2022

EXHIBITS

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EXHIBIT NO. 1

APPLICATION NO.

6-21-0758

Vicinity Map

California Coastal Commission

EXHIBIT NO. 1

APPLICATION NO.
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Location Map

California Coastal Commission

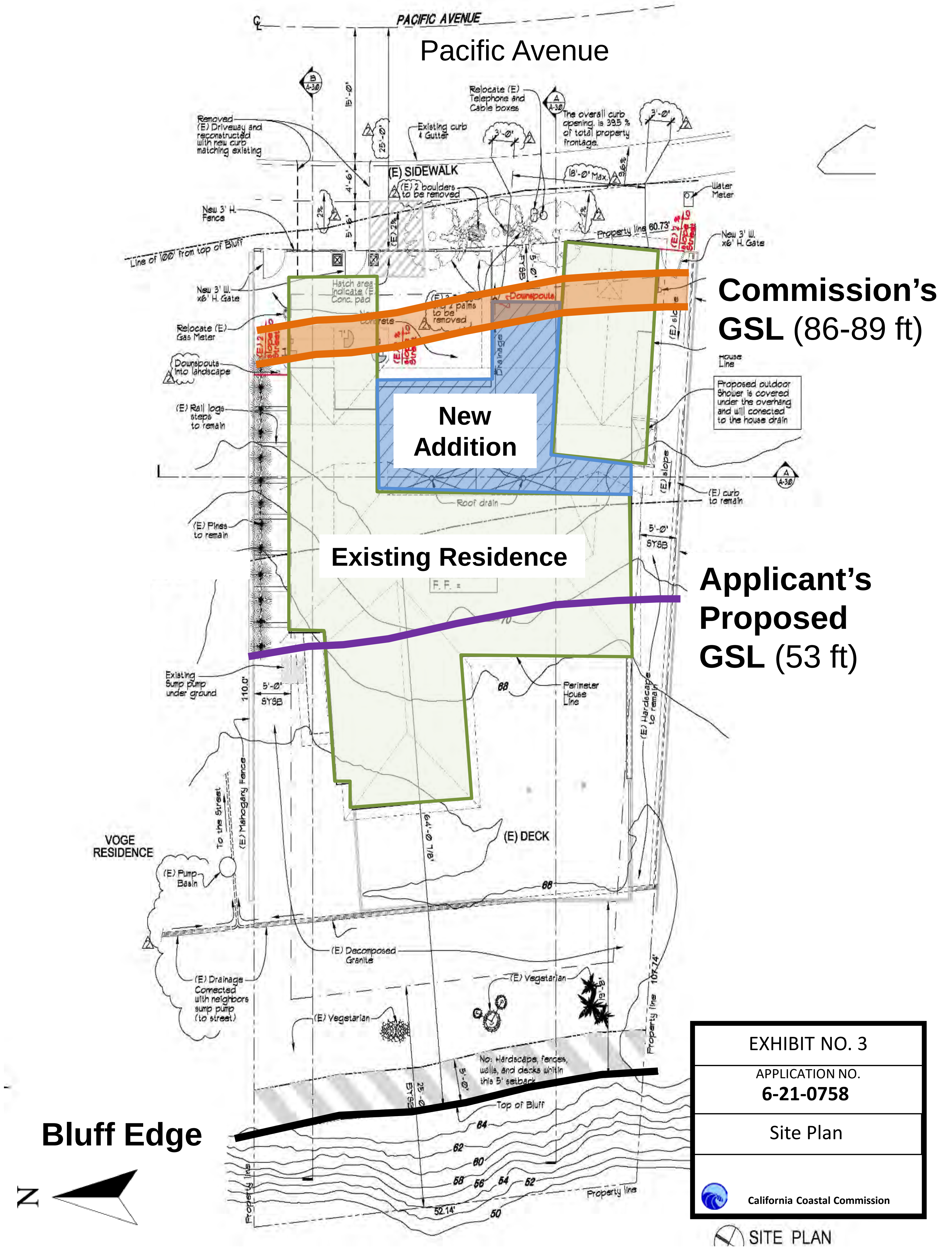


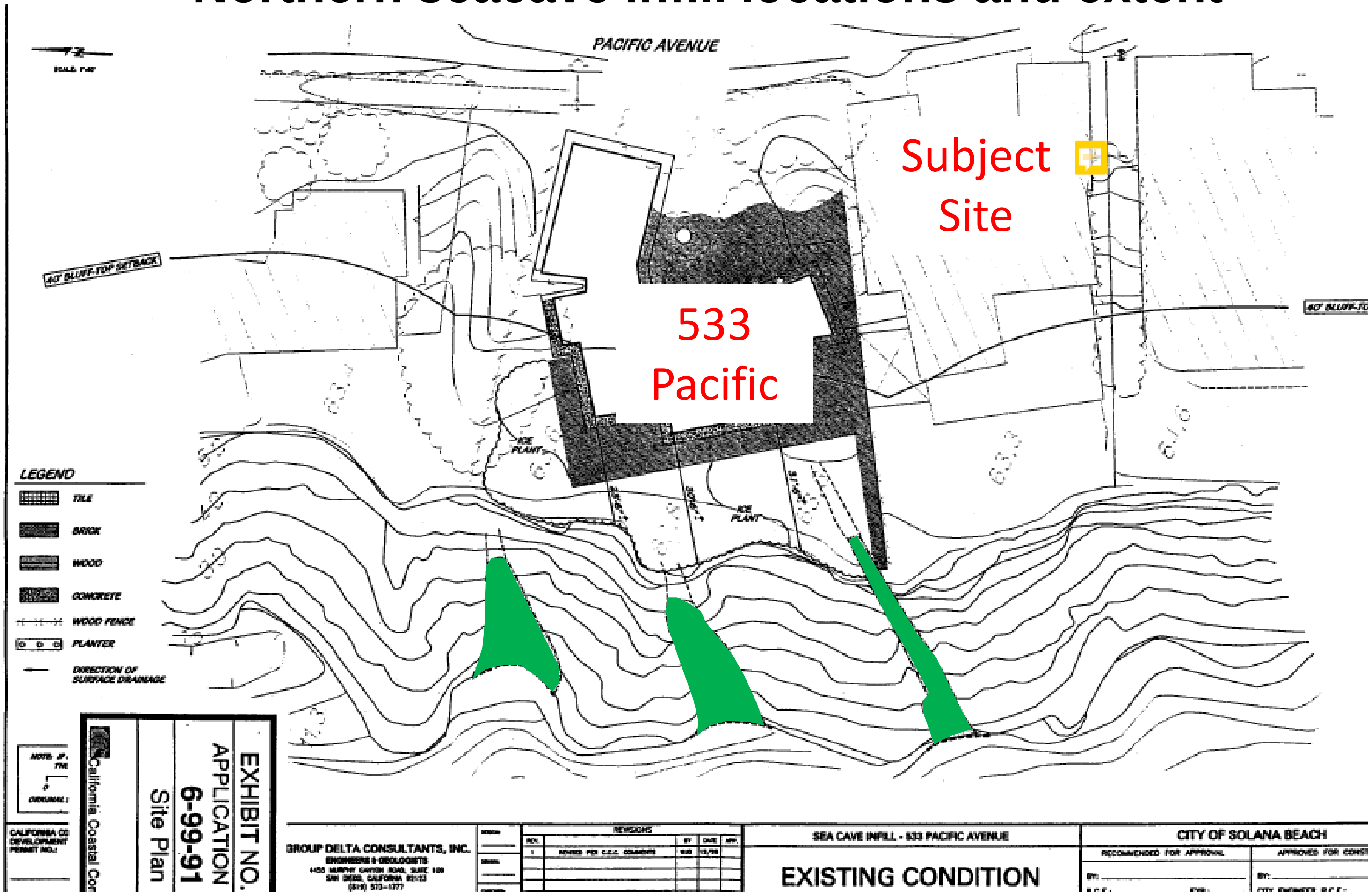
EXHIBIT NO. 3

APPLICATION NO.
6-21-0758

Site Plan

California Coastal Commission

Northern seacave infill locations and extent



Southern seacave infill locations and extent

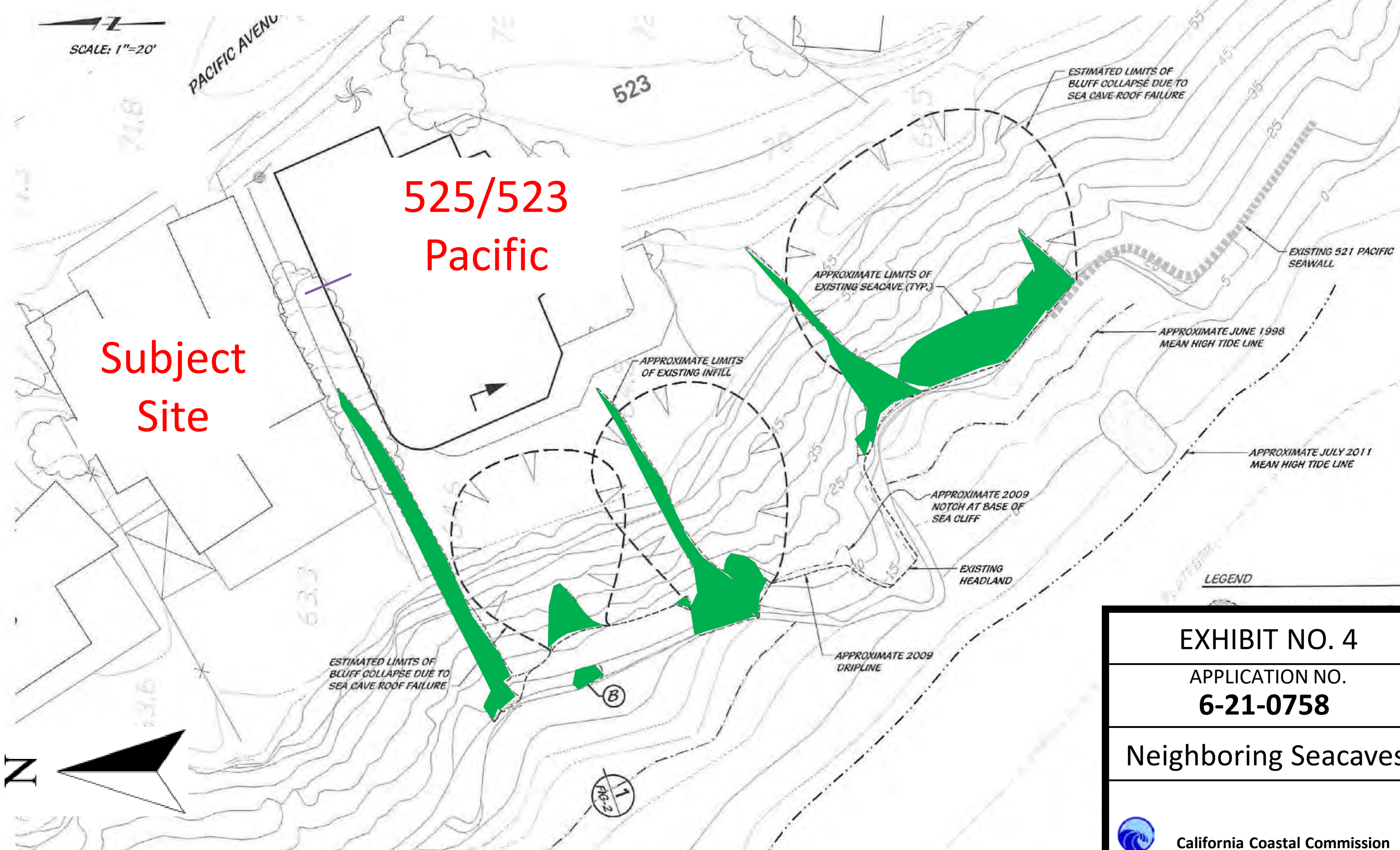


EXHIBIT NO. 4

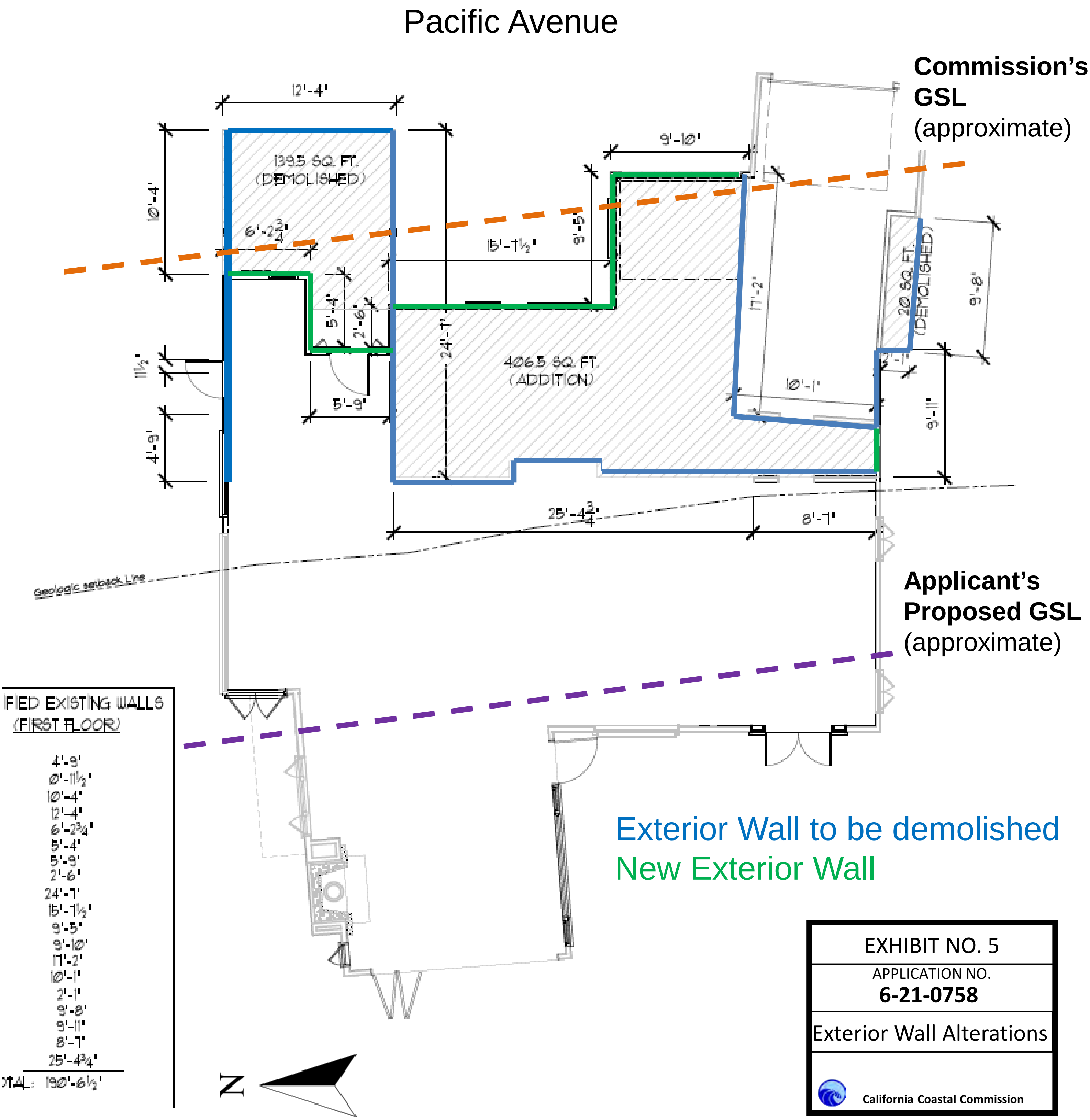
APPLICATION NO.

6-21-0758

Neighboring Seacaves

California Coastal Commission

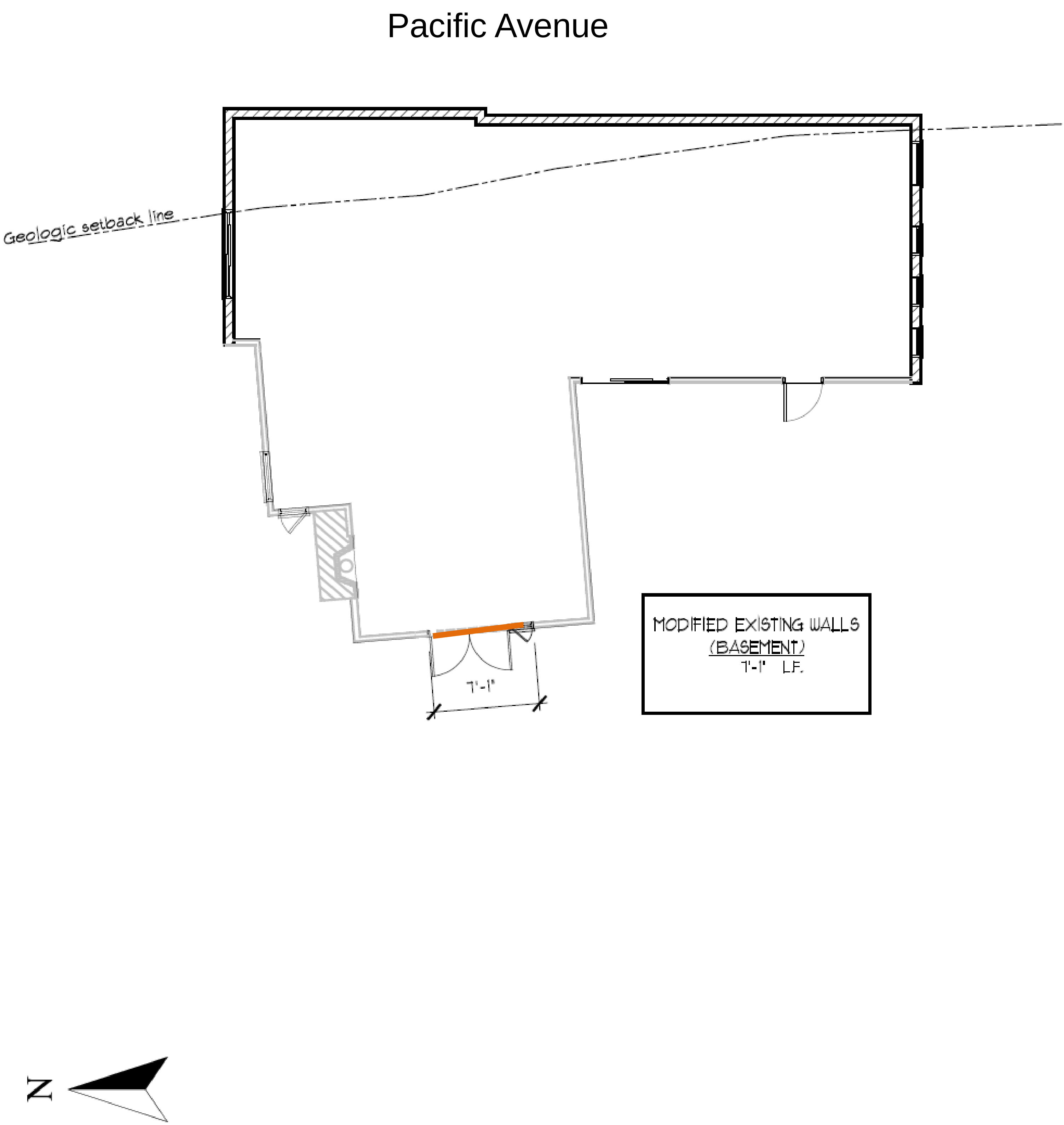
Proposed Exterior Wall Alterations – First Floor



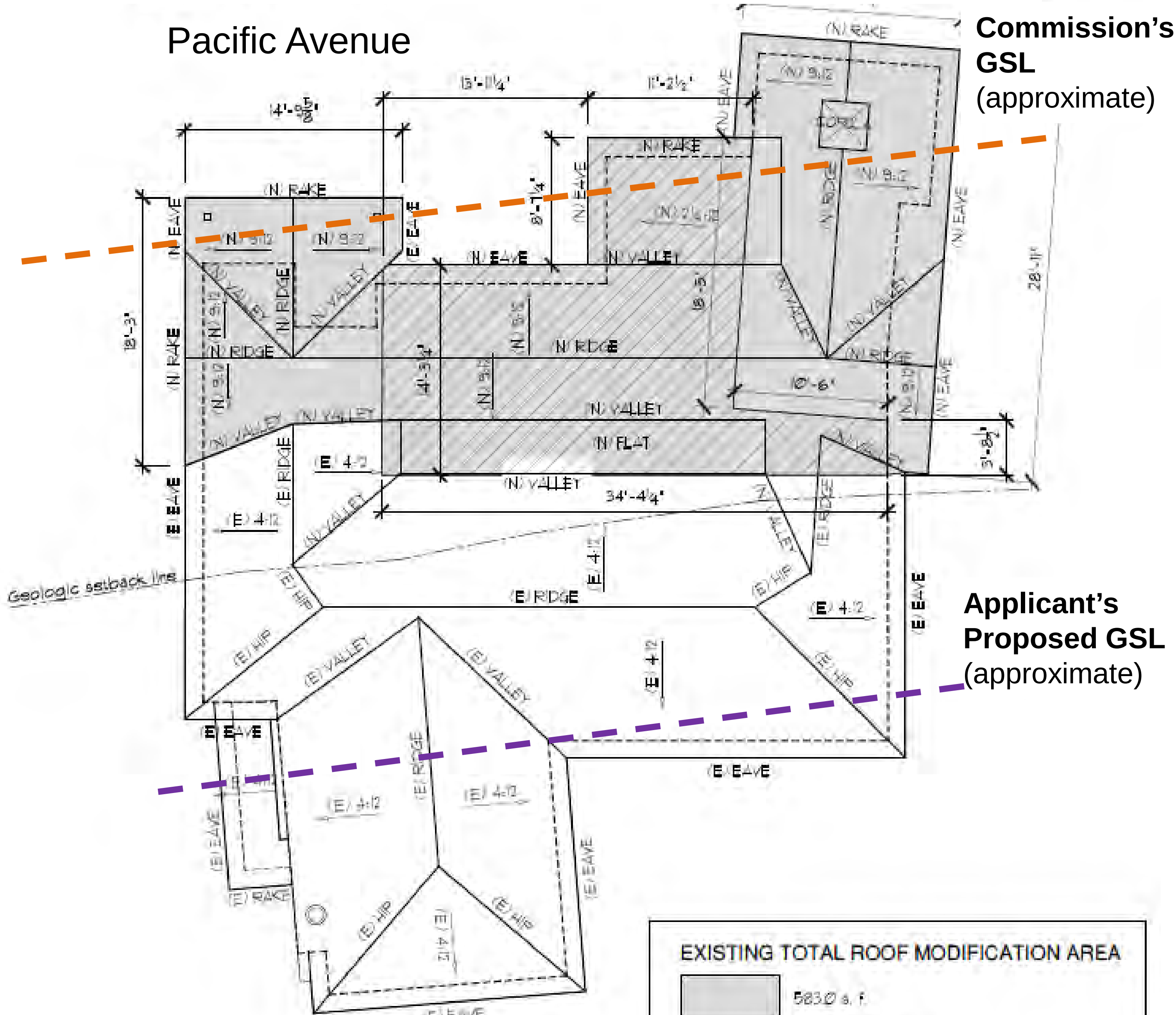
Exterior Wall to be demolished
New Exterior Wall

EXHIBIT NO. 5
APPLICATION NO.
6-21-0758
Exterior Wall Alterations
California Coastal Commission

Proposed Exterior Wall Alterations – Basement



Proposed Roof Alterations



EXISTING TOTAL ROOF MODIFICATION AREA

583.0 s. f.

TOTAL NEW ROOF AREA

473.4 s. f.

TOTAL modify 583.0 + new 473.4 = 1056.4 s. f.
1056.4 s. f. / (E) roof 2113.5 = 49.9 %

N

EXHIBIT NO. 6

APPLICATION NO.
6-21-0758

Roof Alterations

California Coastal Commission

Proposed Foundation Alterations – First Floor

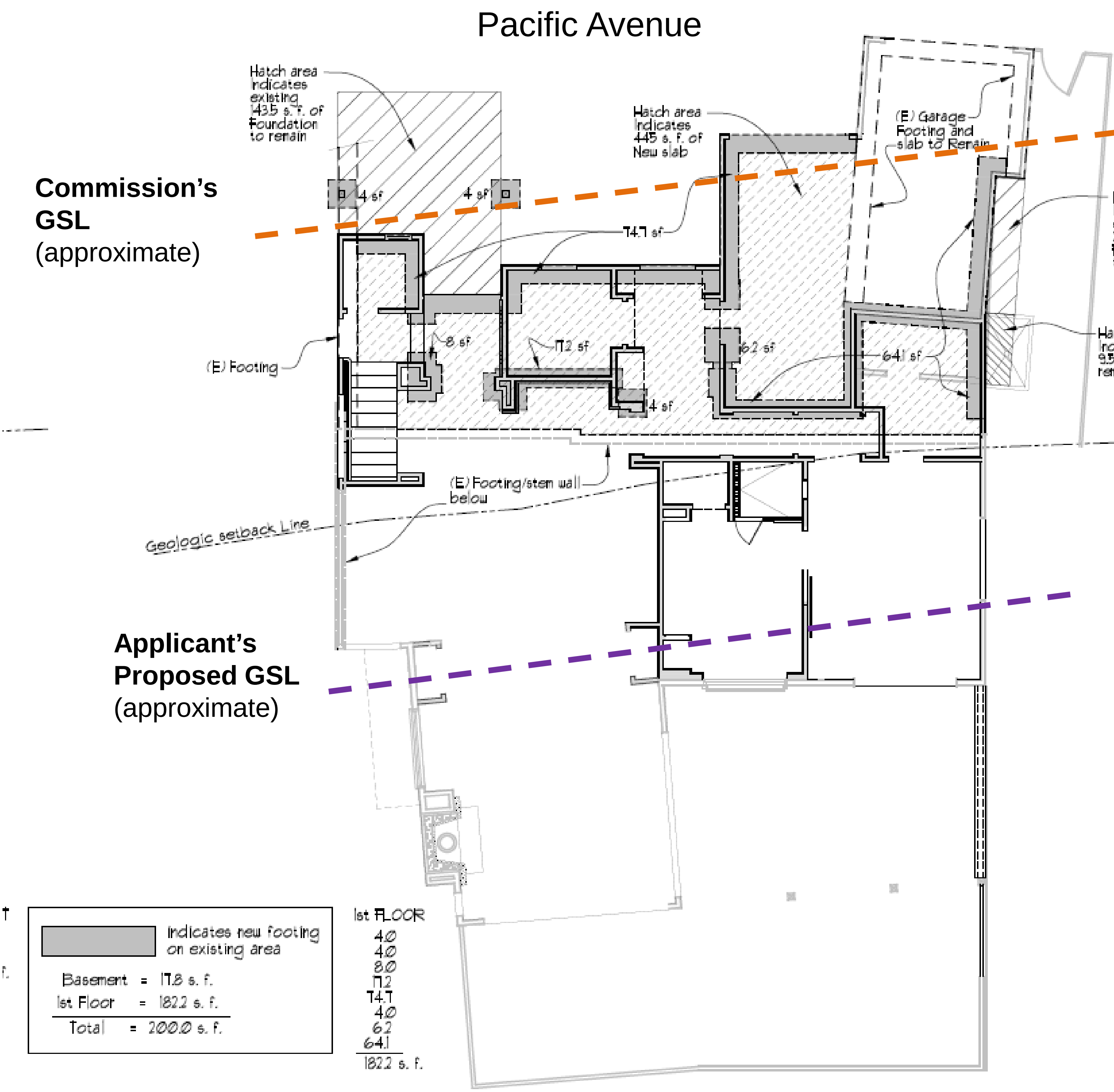


EXHIBIT NO. 7

APPLICATION NO.

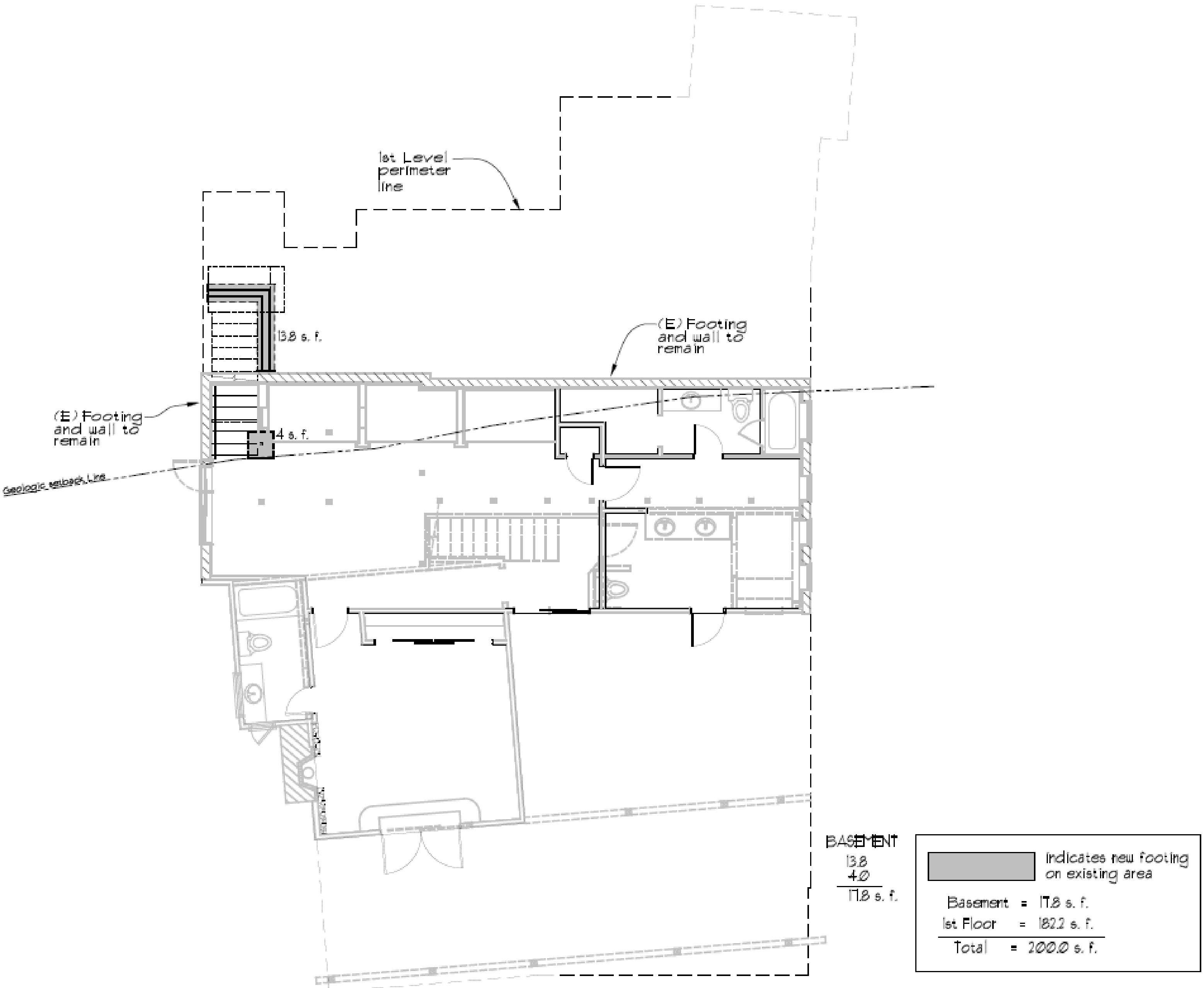
6-21-0758

Foundation Alterations

California Coastal Commission

Proposed Foundation Alterations – Basement

Pacific Avenue



STATE OF CALIFORNIA – CALIFORNIA NATURAL RESOURCES AGENCY GAVIN NEWSOM, *GOVERNOR*

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November 4, 2022

GEOTECHNICAL REVIEW MEMORANDUM

To: Kaitlin Carney, Coastal Program Analyst

From: Joseph Street, Ph.D. P.G., Staff Geologist *Joseph Street*

Re: 529 Pacific Ave., Solana Beach (Pollock Residence)
Coastal Development Permit Application No. 6-21-0758

Introduction

The proposed project involves the substantial remodel of an existing residence at 529 Pacific Ave., Solana Beach, and construction of a 406 square foot addition on the inland side of house. Project plans indicate that the addition would be set back a minimum of 64 feet from the edge of the approximately 65-foot-high coastal bluff. A plan view of the site is shown in **Exhibit 3**.

The purpose of this memo is to evaluate the total bluff top setback that would be needed to minimize geologic and coastal hazards to the proposed development, and to assure stability and structural integrity without reliance on existing or future shoreline or bluff protective devices, consistent with Coastal Act Section 30253 and the City of Solana Beach's certified coastal Land Use Plan (LUP). The City LUP requires that new bluff top development be "set back from the bluff edge a sufficient distance to ensure that it will not be in danger from erosion and that it will ensure stability" over a 75-year economic life. More specifically, Policy 4.25 requires the determination of a Geologic Setback Line (GSL) based on (1) a quantitative slope stability analysis demonstrating a minimum factor of safety against sliding of 1.5 (static) or 1.2 (pseudostatic, k = 0.15), and (2) a finding that the proposed location for the new development will *maintain* the minimum factors of safety for 75 years, factoring in the potential for bluff retreat as influenced by "continued and accelerated sea level rise, future increase in storm or El Niño events, the presence of clean sands and their potential effect on the pattern of erosion at the site, an analysis of the ongoing process of retreat of the subject segment of the shoreline, and any known site-specific conditions."

To this end, I have reviewed the following reports, submitted by the applicant, addressing geologic and coastal hazards conditions on the subject property:

1) GeoSoils, Inc. (GSI), 2019, "Preliminary Geotechnical Set Back Evaluation, Proposed Residential Addition, 529 Pacific Ave., Solana Beach, San Diego County, California, 92075, Assessor's Parcel Number (APN) 263-041-02-00", signed by J. P. Franklin (CEG) and D. W. Skelly (RCE), October 25, 2019.

2) GSI, 2022, "Geotechnical Update and Response to Review Comments, Propose Residential Remodel, 529 Pacific Avenue, Solana Beach, San Diego County, Ca

EXHIBIT NO. 8
APPLICATION NO.
6-21-0758
Geotechnical Review Memo from CCC's Geologist
California Coastal Commission

92075, Coastal Development Permit Application # 6-21-0758", signed by J. P. Franklin (CEG), D. W. Skelly (RCE), and R. B. Boehmer, March 11, 2022.

I have also reviewed project plans (Boka & Sneed Architects, June 3, 2019) and consulted several other sources (listed below) which provide additional geologic context and hazards information. I have also visited the project vicinity and observed the coastal bluffs in northern Solana Beach on several previous occasions.

Geologic Setting

As described in Refs. (1) and (2), the lower portion of the bluff consists of a steep seacliff composed of sedimentary bedrock belonging to the Tertiary-aged Delmar Formation and Torrey Sandstone. The lower bluff consists predominantly of fine- to medium-grained sandstone, with several thin, recessed beds of green-gray mudstone, and numerous joints. Ref. (2) indicates that active marine erosion is occurring at the bluff toe:

> Currently, marine erosion is causing localized wedge failures near the toe of the seacliff. The failures are generally occurring where northeast- and more northerly- to northwest-trending joints, and the mudstone beds intersect. The incipient sea caves resulting from these wedge failures are only a few feet wide and recessed a couple of feet relative to the adjacent seacliff face.

Above an elevation of 18 - 19 feet NAVD88, the bedrock is overlain by Quaternary-aged old paralic deposits ("marine terrace deposits") consisting largely of sand with smaller fractions of silt and clay and varying levels of cementation. The lowest subunit consists of a layer of friable sand ("clean sand") with very low cohesion and shear strength. Ref. (2) indicates the clean sand layer is approximately 5 feet thick at the site, but thicknesses of 10 – 12 feet have also been reported in the near vicinity.

Cycles of bluff retreat in Solana Beach are typically triggered by wave-driven notching and collapse of the lower bluff bedrock, followed by the exposure and failure of the much weaker clean sand layer immediately above the bedrock. Once exposed, the clean sand layer is extremely vulnerable to subaerial erosion (e.g., wind & runoff), leading in relatively quick succession to the progressive failure of the overlying terrace deposits. Many structures along the Solana Beach bluffs have required protection from this cycle of bluff failure through the construction of seawalls, usually designed to protect the bluff toe from marine erosion and encapsulate the clean sand lens, and/or upper bluff retention devices.

Previous studies (e.g., GDC 1998, GEI 2011, TerraCosta 2013; ACOE 2015) have described how the presence of lower bluff sea caves, formed by preferential erosion along zones of weakness (e.g., faults, joints), contributes to accelerated bluff retreat and instability in the Solana Beach bluffs. The bluffs immediately up- and downcoast of the subject site (at 523-525 and 533 Pacific Ave.) have experienced frequent and relatively rapid sea cave formation over the last few decades, necessitating the placement of shotcrete infills to slow erosion that threatened the neighboring residences (see **Exhibit 4**). GEI (2011) has documented the presence of a linear sea cave, now plugged with shotcrete, extending approximately 50 feet into the bluff along the 525 – 529 Pacific Ave. property line. Another long, plugged sea cave extends below the bluff face on the northern portion of the subject property toward the residence at 533 Pacific Ave (CCC 2000). With this exception, the portion of bluff beneath the subject property has so far remained free of large sea caves. Nonetheless, as discussed in more detail below, the tendency for the neighboring bluffs to experience sea cave formation (and thus accelerated retreat) under certain conditions must be considered in evaluating the long-term stability of the proposed development at 525 Pacific Ave.

Bluff Stability – Present Day

GSI (Refs. 1 and 2) provided quantitative slope analyses of the coastal bluff at the project site along three bluff cross-sections (A-A', B-B', C-C'), focusing on the potential for circular slope failures originating in the clean sand layer in the lower portion of the upper bluff old paralic deposits. This approach is warranted based on the low shear strength of the clean sands (near-zero cohesion) and numerous past observations in Solana Beach of bluff failures originating in this layer. The shear strength values used in the slope stability model provide a reasonable basis for the analysis and are similar to those used to characterize the bluff at nearby sites. Factors of safety (FS) against failure were evaluated using both Spencer's and the Modified Bishop methods, yielding similar results. GSI's analysis indicated that the modeled surfaces with a 1.5 factor of safety under static conditions daylighted on the bluff top 29 – 30 feet inland of the bluff edge. GSI's pseudostatic analysis (Ref. 2), which simulates bluff stability under strong seismic ground-shaking (k_h = 0.15), indicates that a 1.2 factor of safety is achieved approximately 31 – 34 feet landward of the bluff edge, depending on the cross-section evaluated. [1] The results of the analysis indicate that the slightly larger setback of <u>31 – 34 feet</u> (1.2 FS pseudostatic) is necessary to meet the LUP standards for present-day slope stability.

Future Bluff Retreat & Sea Level Rise

In addition to minimizing present-day geologic hazards, the Coastal Act and City LUP require that new development assure stability over a 75-year economic life. Today considerations of safety include future bluff erosion and retreat and the potential effects of sea level rise. Thus, the slope stability component of the GSL must be augmented by an additional setback necessary to account for the potential long-term retreat of the coastal bluff.

Three critical but uncertain factors influencing the potential for future bluff retreat at the project site include: (1) the status of the beach fronting the bluff at the project site, which historically has been closely linked to rates of bluff retreat; (2) the magnitude and rate of future sea level rise (SLR); and (3) the sensitivity of the bluff erosion response to sea level rise.

Historical Bluff Retreat & Status of the Beach

Recent history demonstrates that the coastal bluffs in Solana Beach are susceptible to significant erosion and retreat when subject to direct wave attack, and that the degree of bluff exposure to wave action is strongly influenced by the presence and width of the sandy beach at the toe of the coastal bluff. The frequency with which the base of the bluff is impacted by storm waves in the future will, to a large extent, determine how quickly the bluff retreats over the project life.

Historical bluff retreat rates along the Solana Beach shoreline have been estimated in several previous studies, often based on analysis of historical aerial photographs and topographic maps. For example, Benumoff and Griggs (1999) estimated bluff edge retreat rates ranging from 0.15 – 0.46 ft/yr (average 0.27 ft/yr; 1932 – 1994) for a 0.4-mile segment somewhat to the south of the project site. Data from the U.S. Geological Survey (USGS) includes bluff retreat rate estimates (spanning c.1930 – 2010) for ten bluff transects in the immediate project vicinity (Fletcher Cove to Circle Dr.) ranged from 0.18 – 0.34 ft/yr, with an average of 0.27 ft/yr (Barnard et al. 2018). GSI (Ref. 1) provided a historical retreat rate estimate of 0.19 ft/yr for the bluff at the subject site but elected to use a local average rate of 0.27 ft/yr in its future bluff retreat analysis (see below). However, such long-term, annualized bluff retreat rates tend to

[1] Cross-Section A-A': 34 feet; cross-section B-B': 32.5 feet; cross-section C-C': 31 feet.

obscure both the episodic nature of marine-driven bluff erosion and the larger historical pattern observed along the Solana Beach bluffs.

As described in previous studies (e.g., GDC 1998, TCG 2013, USACE 2015), the coastal bluffs in Solana Beach experienced relatively little retreat over much of the 20th century, prior to the 1980s. The fronting beaches experienced normal cyclical variation but were generally wide due to greater fluvial sand delivery and a series of sand placements associated with harbor construction and dredging within the broader Oceanside littoral cell. The presence of a moderate beach provided a buffer limiting the frequency with which waves directly impinged on the bluff. Since the late 1970s, however, the long-term depletion of the shoreline sand supply combined with a period of more severe coastal and weather conditions has resulted in the narrowing and, at times, loss of the protective beach. For example, during the intense storm season of 1997-98 (a major El Niño event), the already depleted beaches fronting the Solana Beach bluffs were stripped away and largely lost from the littoral system. Low sand levels persisted for the next fifteen years, with sustained increases in beach width and volume only occurring following the major beach replenishment carried out by SANDAG ("Regional Beach Sand Placement II", or RSBP II) in 2012.

The last few decades of stormier conditions and beach depletion in Solana Beach corresponded closely with a period of accelerated bluff erosion and retreat. As stated by TCG (2013), the "rate of marine erosion of the sea cliff has at least doubled, if not tripled, along the entire Solana Beach coast as a result of the loss of the sand beach." A detailed study of the north Solana Beach coast (Las Brisas to Cardiff Beach parking lot) following the 1997-98 El Niño described widespread erosion of the lower bluff, including the rapid formation and expansion of sea caves, severe basal notching of the seacliff triggering block falls in the overlying bluff, and high short-term rates of bluff retreat ranging from 0.5 to 1.25 ft/yr (1990 – 1998) (GDC 1998). The bluff at 529 Pacific Ave. is reported to have retreated four to six feet at the toe and up to four feet at the top between 1990 – 1998. High rates of sea cave expansion and bluff retreat (of up to 1 ft/yr) continued over the next decade in the immediate project vicinity, as documented for the neighboring bluffs at 523-525 and 533 Pacific Ave. (GEI 2011, TCG 2013). Using aerial photographs available from Google Earth, I have made spot estimates of more recent bluff edge retreat at 525, 529 and 533 Pacific Ave., with rates ranging from 0.05 – 0.5 ft/yr, for the 2013 – 2022 period. This exercise suggests that bluff retreat near the project site may have slowed following the RBSP II beach nourishment but has not ceased.

The recent experience in Solana Beach is a strong indication that rates of future bluff retreat at the project site will depend heavily on the presence and status of the sand beach. Given the on-going sand deficits within the Oceanside littoral cell and the likelihood that sea level rise will continue to promote shoreline retreat at an increasing pace, successfully maintaining a beach in north Solana Beach will likely require beach nourishment efforts on the scale of RBSP II, but sustained over decades. At present, the U. S. Army Corps of Engineers (USACE) is poised to begin implementation of a long-term sand replenishment program intended to rebuild and maintain the beaches of Encinitas and Solana Beach over the next 50 years. If the nourishment project performs as intended, it could limit or even reduce bluff retreat over the next several decades (USACE 2015). However, many uncertainties remain. Storms and vigorous wave action have quickly washed away previous large-scale nourishment efforts (e.g., SANDAG's RBSP I in 2001), and the USACE program could experience similar, rapid losses of sand. The nourishment program could be discontinued, for example if sand losses and renourishment costs are greater than expected, or if federal funding is discontinued. Even if sustained for decades, the program could then be abandoned in the face of mounting sea level rise, and the artificially maintained beach eroded relatively quickly. Another point of caution is that the proposed Solana Beach nourishment would not extend as far north as the project site, instead ending at Fletcher Cove. While migrating sand would likely augment the beach fronting the project site, it may benefit less than other locations where direct sand placement is occurring.

Future Sea Level Rise

Both the rate and magnitude of future sea level rise (SLR) are highly uncertain, depending on both future emissions and earth system processes (e.g., ice sheet dynamics) that are incompletely understood. In an effort to frame these uncertainties and provide guidance on addressing SLR for policy-makers in California, the *State of California Sea-Level Rise Guidance* (OPC 2018)[2] and its associated SLR science update (Griggs et al. 2017) provided a range of California-specific projections of future SLR, under several greenhouse gas emissions scenarios, within a quasi-probabilistic framework.[3] For example, under a high emissions pathway (RPC 8.5), the report estimates that, by 2100, SLR in northern San Diego County (represented by the La Jolla tide gauge) could exceed 2.6 feet under a 50% probability scenario (median model result), 4.6 feet under the 5% probability scenario (95th percentile model result), and 7.1 feet under the 0.5% probability result (>99th percentile result), by 2100.[4] Both the State Guidance and the Commission's *Sea-Level Rise Policy Guidance* (2018 update) recommend specific sea level rise projections for use in different types of planning and policy decisions, depending on factors such as adaptive capacity and risk tolerance. For "medium-high risk aversion" decisions like the siting of residential development, for which the consequences of being wrong (i.e., loss of life and property) are greater and the range of adaptation options is limited, the guidances recommend that the 1-in-200 chance (0.5% simulated probability) projections be addressed through siting, design, or future adaptive measures.

Future Bluff Retreat with Sea Level Rise

Rising sea level is expected to cause significant changes to the California coast, including the narrowing or loss of beaches where they are backed by less-erosive bluffs or artificial barriers to inland migration, such as shoreline armoring (Vitousek et al. 2017). In Solana Beach, the retreat of the shoreline and narrowing of beaches is likely to lead to increased wave attack at the base of coastal bluffs and, as seen during recent intervals with narrow or absent beaches, increased rates of bluff erosion. More generally, SLR shrinks the distance between the wave breaking point and bluff positions (the "coastal squeeze"), results in deeper water and reduced wave attenuation, and is expected to increase the frequency and effectiveness of wave attack, increasing bluff erosion (e.g., Limber et al. 2018). Other effects of climate change, such as possible changes in storm tracks, wave climate and the frequency of large El Niño events (e.g., NRC 2012; Wang et al. 2017), will also influence rates of bluff retreat. Nonetheless, the degree to which bluff retreat will respond to sea level rise remains highly uncertain and will necessarily be mediated by site-specific factors.

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[2] Available at https://www.opc.ca.gov/updating-californias-sea-level-rise-guidance/.

[3] Following the method of Kopp et al. (2014), the "probabilistic" projections provided in the *Rising Seas* and State Guidance reports reflect the probability that a given amount of SLR was predicted by the ensemble of climate models used to estimate future SLR (from processes such as thermal expansion, glacier and ice sheet mass balance, oceanographic conditions, etc.).

[4] The State is currently in the initial stages of preparing an updated SLR Guidance for 2023, which will likely rely on new regional SLR projections from NOAA (Sweet et al. 2022). Although the NOAA analysis framework differs from that of OPC (2018), the range in SLR projections considered is very similar.

In light of the many uncertainties related to the magnitude and rate of future SLR and the response of the coastal bluff, and the fate of the fronting beach at the project site, it is prudent to examine a number of plausible scenarios of bluff retreat using different assumptions about the effects of SLR and the effectiveness of erosion mitigation efforts like the proposed USACE project.

<u>Applicant's Analysis</u>

In my view, the long-term bluff retreat analysis provided by the applicant (GSI 2019, Ref. 1) presents an optimistic scenario of the potential for bluff retreat at the project site over the next 75 years, particularly given the higher-end SLR scenario (6.3 ft in 2094) considered. Specifically, the GSI analysis relies on two key, interrelated assumptions that are far from assured: (1) SLR will have only a minor influence on the rate of bluff retreat, and (2) the beach fronting the bluff will persist over the long-term and continue to provide some protection to the bluff, even in the face of large amounts of SLR.

Accordingly, GSI assumes that the locally observed, average historical bluff retreat rate of 0.27 ft/yr will remain unchanged for the first 37 years of the project life. For the middle 25 years, the retreat rate is assumed to increase by one-third, to 0.32 ft/yr. For the final 13 years of the 75-year period, the historical retreat rate is adjusted upward, to 0.43 ft/yr, using a simple equation ("SCAPE" equation, see below) that projects a future bluff retreat rate based on historical rates of bluff retreat and sea level rise, an estimated future sea level rise rate, and an exponential term governing the sensitivity of the bluff retreat response. In total, GSI projects 23.5 feet of bluff retreat over the next 75 years, which is equivalent to an average retreat rate of 0.32 ft/yr.

While the amount of SLR (6.3 feet) considered by GSI is similar to the higher-end projections contained in the 2018 State and Coastal Commission Sea-Level Rise Guidances, the amount of projected bluff retreat is relatively modest, and implies only a minor effect of SLR on rates of bluff retreat. GSI's total bluff retreat of 23.5 feet is only about three feet more than would be expected if the average *historical* bluff erosion rate persisted for the next 75 years, with no increase. Phrased differently, the applicant's analysis anticipates that over the next 75 years, the bluff retreat rate will increase by only about 16%, despite an average rate of sea level rise (0.084 ft/yr, 6.3 ft/75 yrs) that is an order of magnitude (>10 times) greater than the current rate (0.007 ft/yr, at La Jolla tide gauge).[5] While it is not expected that the rate of bluff retreat will keep pace with the expected acceleration in SLR (particularly under a high SLR scenario), an increase as modest as projected in the applicant's analysis is only credible if, as presented by GSL, coastal bluff erosion at the site is insensitive to sea level, and/or the fronting beach persists over the next 75 years and protects the base of the bluff from wave attack at least as effectively as in the past, despite large amounts of SLR.

The first assumption is highly tenuous based on the recent history of bluff erosion in Solana Beach, including the project vicinity. As discussed above, on multiple instances in recent decades and especially during the strong El Niño winter of 1997-98, high water levels combined with large storm waves resulted in sustained wave attack at the base of the bluff, causing significant notching and sea cave formation in the sea cliff bedrock, as well as block falls affecting the upper bluff. These conditions were exacerbated by the loss of sand from the beach, and persistent low sand levels on the beach throughout the 1990s and early 2000s left the bluff with little buffer against frequent wave attack. In the immediate project vicinity, the bluff experienced basal notching, rapid sea cave expanding, and

[5] For purposes of comparison, a recent modeling study by the U.S. Geological Survey projects that bluff retreat rates in southern California could increase more than two-fold (100-200%) relative to historical means under a sea level rise scenario with 6.6 feet of rise by 2100 (Limber et al. 2018).

elevated short-term retreat rates from approximately 1990 – 2012. Sea level rise represents an increase in the baseline still water level and is expected to increase the frequency of the high total water level events that have contributed to episodes of rapid bluff erosion in Solana Beach in the past.

Given the recent decades of depleted beach conditions in Solana Beach and the ongoing sand supply deficits in the Oceanside littoral cell, GSI's second assumption that a protective beach will be maintained in front of the bluff over the long-term is plausible only if the regional sand supply is significantly restored or, more likely, if major, sustained beach nourishment projects are carried out over the next 75 years. It appears increasingly likely that such efforts will be attempted, though their long-term success is not assured. The USACE's long-planned, 50-year beach nourishment program for Encinitas and Solana Beach has received congressional approval and is scheduled to begin in 2023. Thus, there is reason to hope that the beaches in the project vicinity can be restored and maintained, at least for a time, and that they will provide some degree of protection to the bluffs. Nonetheless, for the reasons noted above, the overall effectiveness of the USACE or other large-scale nourishment projects is not assured (particularly at the project site where the potential benefits to the beach would rely on sand migration rather than direct placement), and more precautionary scenarios for future bluff retreat should also be evaluated.

Precautionary Analysis

To this end, I have evaluated the potential for future bluff retreat at the project site assuming a range of high SLR conditions (~3 – 7 feet by 2100), but also assuming that the erosion of the coastal bluff is relatively susceptible to the effects of SLR, and without assuming the presence of a substantial fronting beach. I used two different approaches. First, I consulted future bluff retreat projections from the USGS Coastal Storm Modeling System (CoSMoS) 3.0 (Phase 2) cliff retreat dataset (Barnard et al. 2018; Limber et al. 2018), which includes projections of coastal bluff retreat along individual cross-shore transects for multiple sea level rise scenarios.[6] Second, I employed the simple equation ("SCAPE Equation") referenced and partially utilized by GSI (Ref. 1). This equation, derived from previous modeling studies, seeks to project a future bluff retreat rate (R_2) as a function of the historical retreat rate (R_1), historical sea level rise rate (S_1), and projected future sea level rise rate (S_2):

$$R_2 = R_1 (S_2 / S_1)^{0.5} \qquad \text{(SCAPE Equation)}^{7}$$

This equation is necessarily a simplification of the complex processes that govern the response of a coastal bluff to changing sea level, but has been shown to reproduce the projections of the full process-based model from which it is derived in simulations of "soft rock,"

[6] The CoSMoS cliff retreat projections integrate the output of eight numerical and statistical models which relate wave climate (wave height, period, frequency, impact intensity) to the erosion of bluff materials. Cliff retreat is modeled along hundreds of transects (~100 m spacing), based on the historical erosion rate, shore platform and cliff profile, and wave power derived from the broader CoSMoS model (Barnard et al. 2014). Model behavior also includes wave run-up, wave set-up that raises the water level during large wave events, and tidal levels. Historical retreat rate estimates for each cross-shore transect are based on the previous analysis of Hapke and Reid (2007), with cliff edge positions and retreat rate estimates updated to 2010. The CoSMoS cliff retreat projections, viewable in Google Earth, are publicly available at https://www.sciencebase.gov/catalog/item/57f4234de4b0bc0bec033f90.

[7] This equation is a "best fit" equation derived from the Soft Cliff and Platform Erosion (SCAPE) model of Walkden and Hall (2005) and Walkden and Dickson (2008), a process-based numerical model developed to simulate cliff retreat in response to sea level changes. The exponent term (m) governs the sensitivity with which bluff retreat responds to sea level rise; m = 0.5 is the value of the best-fit equation, but it can be adjusted to fit local conditions if warranted (Ashton et al. (2011).

low beach volume coasts under equilibrium conditions (Ashton et al. 2011). Although both approaches have limitations, and all projections of responses to sea level rise have a high level of uncertainty, both CoSMoS and the SCAPE equation provide useful information on the amounts and rates of bluff retreat that could result from rising sea levels in the future.

The frameworks outlined in the Commission's SLR Policy Guidance and the 2018 State Guidance recommend using the 0.5% probability sea level rise projection for the high emissions scenario for determining the possible hazards to new residential development. This means that sea level rise of up to about two meters should be considered for the possible future erosion that could occur at this site. Nonetheless, there is value in also examining the bluff retreat that could result under lower, more likely, but still potentially very damaging scenarios of future SLR. **Table 1** (below) provides CoSMoS projections of future bluff retreat at the project site for several amounts of future sea level rise. Similarly, **Table 2** provides estimates of future bluff retreat at the site calculated using the SCAPE equation, using on sea level rise scenarios and future sea level rise rates provided in the OPC (2018).

Table 1: CoSMoS Bluff Retreat Projections, Northern Solana Beach*

Projected Sea Level Rise	**Estimated SLR probability of Exceedance** (high emissions) (OPC 2018)	**Projected average bluff retreat rate,** 2010 – 2100 (median projections) (ft./yr.)	**Projected 75-year bluff retreat** (ft.)
100 cm (3.3 ft)	~25%	0.43	32
150 cm (4.9 ft)	~3%	0.59	44
200 cm (6.6 ft)	<1%	0.74	55

*Average of Transects 656 – 665 (Fletcher Cove to northern terminus of Solana Beach bluffs)

Table 2: Bluff Retreat Projections from SCAPE Equation -- OPC (2018) High Emissions Scenario
Historical Sea Level Rise Rate (S1) = 2.04 mm/yr (La Jolla tide gauge); Historical Bluff Retreat Rate (R1) = 0.27 ft/yr

Sea Level Rise Scenario, 2100 (OPC 2018)	**Estimated SLR probability of Exceedance** (OPC 2018)	***S2*** **Future SLR rate** 2080-2100 (mm/yr)	***R2*** **Future bluff retreat rate** 2080-2100 (ft./yr)	**Average bluff retreat rate** 2018 - 2100 (ft. /yr.)	**75-year bluff retreat** (ft.)
3.6 ft "low risk aversion"	17%	17	0.78	0.53	39
4.6 ft	5%	22	0.89	0.58	43
7.1 ft "medium- high risk aversion"	0.5%	28	1.17	0.72	54

These projections follow from a set of reasonable but precautionary assumptions, including large amounts of SLR (~3 – 7 feet) through 2100, a relatively sensitive bluff erosion response to rising sea level, and little effective protection provided by the fronting beach over the long-term. A range of other plausible scenarios, employing somewhat different assumptions, can obviously be formulated. For example, one such scenario, less conservative than that discussed above, but more precautionary than GSI's approach, could assume that future beach nourishment efforts meet with mixed success, partially forestalling the effects of SLR over multiple decades, if not for the full 75 years. As suggested in Ref .1, one simple approach for approximating the effects of a more substantial fronting beach is to reduce the exponent term (*m*) in the SCAPE Equation, which produces a more "damped" bluff retreat response to an increase in the rate of SLR. GSI's analysis used a value of *m* = 0.33 (instead of 0.5). If I repeat my prior analysis using the SCAPE Equation with an exponent (*m*) value of 0.33, the projected bluff retreat is reduced from 54 feet to 37 feet, and the calculated GSL is 68 – 71 feet from the bluff edge.

Conclusion

The magnitude of future bluff erosion and retreat at the project site over the next 75 years is difficult to project, in large part due to significant uncertainty in the amount and rate of future sea level rise, the response of coastal bluff erosion to the rising seas, and the future status of the fronting beach. The applicant's bluff retreat projection of 23.5 feet over 75 years appears to depend on SLR having little effect on the rate of bluff erosion, and/or the continued presence of a substantial beach at the site. My more precautionary analysis, described above, suggests that approximately 55 feet of bluff retreat could occur over 75 years with SLR similar to OPC (2018)'s "medium-high risk aversion" scenario. Added to the 31 – 34 ft blufftop setback needed to achieve 1.5 (static) and 1.2 (pseudostatic) factors of safety against bluff failure (under present conditions), this analysis results in a total setback (GSL) of 86 – 89 feet. I do note, however, that other somewhat less precautionary but still protective development setbacks can be justified at this site, particularly if accounting for future efforts to maintain the beaches locally and within the broader littoral cell. On the other hand, I would also argue that a precautionary approach is warranted at this site due to the extensive sea caves formation and rapid bluff erosion that has occurred in the recent past at the neighboring sites (523-525 and 533 Pacific Ave.), which led to the emplacement of shoreline protection. Even if bluff retreat proves to be less severe at the project site, higher rates of erosion on the neighboring bluffs, in the absence of shoreline protection, could still potentially pose a threat to the new development at the subject site in the future.

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