TerraCosta
Consulting Group

Geotechnical Engineering
Coastal Engineering
Maritime Engineering

Project No. 2086
August 8, 2019

Mr. Gene Matter, Assistant Director
Transportation & Storm Water Department
CITY OF SAN DIEGO
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TEXT CLARIFICATION
COASTAL EROSION ASSESSMENT AND
CAVE SOLUTION FEASIBILITY ANALYSIS
COAST BOULEVARD AND COOK'S CRACK SEA CAVE
SAN DIEGO, CALIFORNIA

Dear Mr. Matter:

During our meeting with City Staff today specific to the stability of the Cook's Crack Sea Cave, we made a presentation summarizing the results of our June 17, 2019, Coastal Erosion Assessment report for the Cook's Crack sea cave. In the Conclusions section of our report, we stated, "It is our opinion that within a few years, there is a high probability of collapse of additional supporting roof rock resulting in the formation of voids or sinkholes under Coast Boulevard, causing damage to the street and utilities that overlie the Cook's Crack Sea Cave and/or injury or death due to a vehicle or pedestrian falling into a sinkhole. Based on our studies, the most feasible alternative would be to seal and infill the sea cave."

As we discussed today during our presentation, and as shown on Photo 3 of our June 17 report, this possibly 5,000-pound block that has become dislodged within the adjacent fault joints, along with both the groundwater and overlying terrace deposits that are now falling from the roof, creates a very unstable condition, and this block could in fact, collapse at any time. Moreover, any seismic tremor, or even a break of the City's water main that runs over the roof of the sea cave, could cause an imminent and catastrophic collapse. We have attached Photo 3 from our June 17, 2019, report to remind the reader that this overhanging block, although temporarily wedged into the parallel joint sets associated with this fault, could fall out at any time, thereby completely removing support for the overlying loose and friable terrace deposits. The relatively substantial seepage exposed in the sidewalls of the cave (visible in Photo 3) is an additional cause for concern, as the seepage, along with the failure of the block, could trigger an immediate and catastrophic collapse, resulting in a rather large linear sinkhole into which a vehicle or pedestrian could fall, possibly resulting in serious injury.

The words used in our June 17 report, namely, "within a few years," was a measured description of the urgency to stabilize the site, and should not have been construed to suggest that there is **not** a very real concern that this collapse could occur at any time, and particularly after a small seismic tremor or waterline break.

If you would like to discuss this issue further, please feel free to give me a call. After normal business hours, I can be reached on my cell phone at (619) 540-9257.

Very truly yours,

TERRACOSTA CONSULTING GROUP, INC.

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R.C.E. 23792, R.G.E. 245

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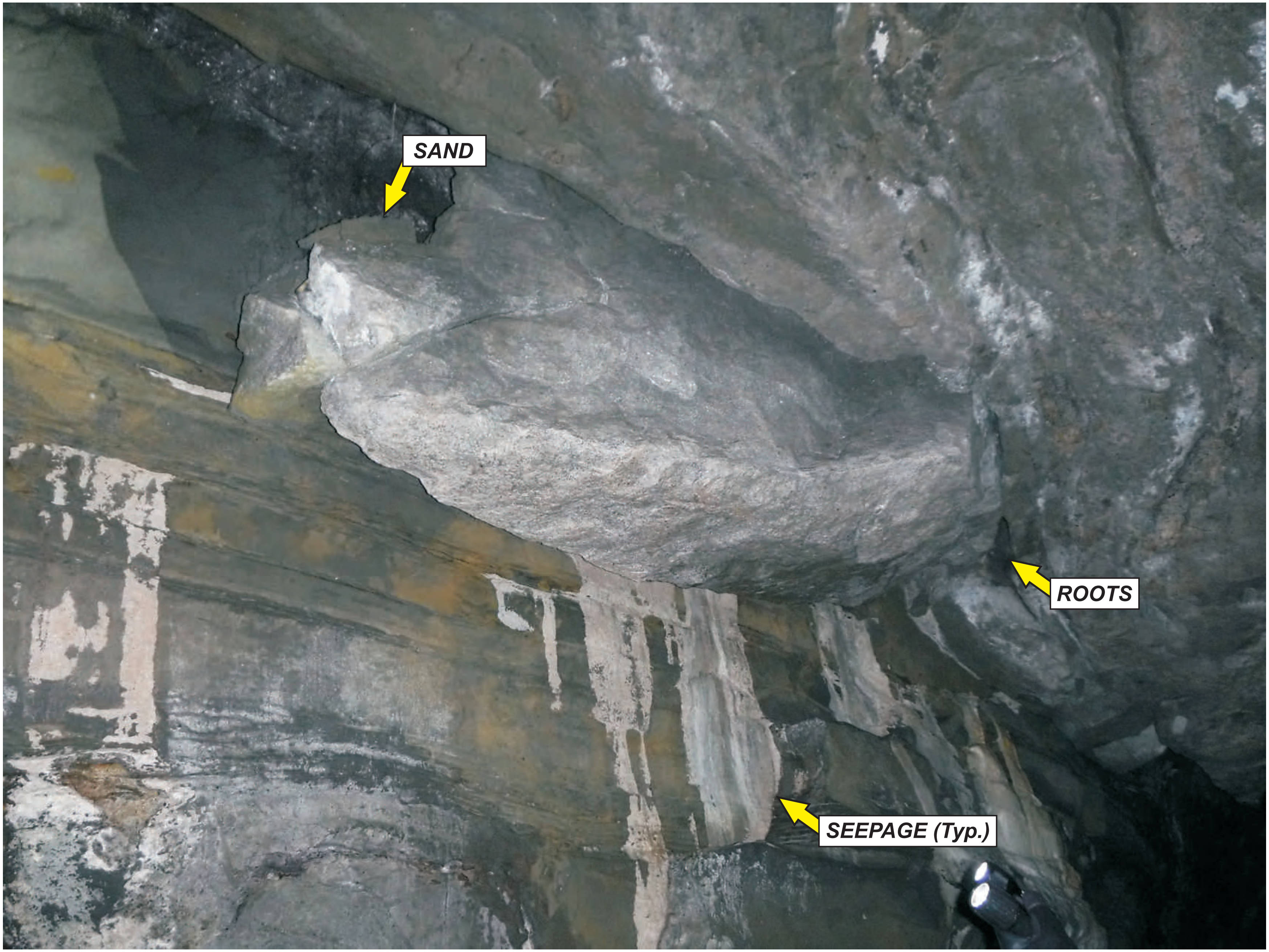

DATE OF PHOTO: MARCH 5, 2019

TERRACOSTA CONSULTING GROUP 3890 Murphy Canyon Road, Suite 200 San Diego, California 92123 (858) 573-6900	PROJECT NO.: **2086B**	PROJECT NAME: **COOK'S CRACK SEA CAVE**	PHOTO NO.: **3**

COASTAL EROSION ASSESSMENT AND CAVE SOLUTION FEASIBILITY ANALYSIS
COAST BOULEVARD AND COOK'S CRACK SEA CAVE
SAN DIEGO, CALIFORNIA

Prepared for
TETRA TECH
San Diego, California

Prepared by
TERRACOSTA CONSULTING GROUP, INC.
San Diego, California

Project No. 2086B
June 17, 2019

TerraCosta
Consulting Group

Geotechnical Engineering
Coastal Engineering
Maritime Engineering

Project No. 2086B
June 17, 2019

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COASTAL EROSION ASSESSMENT AND
CAVE SOLUTION FEASIBILITY ANALYSIS
COAST BOULEVARD AND COOK'S CRACK SEA CAVE
SAN DIEGO, CALIFORNIA

Dear Mr. Taylor:

TerraCosta Consulting Group, Inc. (TerraCosta) is pleased to present the accompanying report, which provides a summary of our most recent survey of Cook's Crack and our assessment of coastal erosion and alternatives to stabilization of the Cook's Crack Sea Cave extending under Coast Boulevard in the La Jolla area of San Diego, California.

We appreciate the opportunity to work with you on this project and trust this information meets your current needs. If you have any questions or require additional information, please give us a call.

Very truly yours,

TERRACOSTA CONSULTING GROUP, INC.

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COASTAL EROSION ASSESSMENT AND
CAVE SOLUTION FEASIBILITY ANALYSIS
COAST BOULEVARD AND COOK'S CRACK SEA CAVE
SAN DIEGO, CALIFORNIA

1 INTRODUCTION

It has been reported that in 1996, City of San Diego geologists first entered the Cook's Crack Sea Cave to evaluate the limits and general stability of the cave. As we understand, at that time, they recommended filling the sea cave with concrete to stabilize it. However, the City elected to not infill the cave due to environmental concerns. In 2002, the City commissioned TerraCosta, in concert with RBF, to complete a comprehensive study to measure the limits of the cave and perform an engineering assessment of the stability of the cave. The results of that assessment are discussed in our report titled, "Coastal Bluff Stability Study, Coast Boulevard Between Prospect Street and South Casa Beach (including La Jolla Cove and Children's Pool Beach), La Jolla, California," dated December 12, 2002.

During a more recent evaluation of the street drainage facilities on Coast Boulevard by City Staff, High Severity Divided Slab Distress of the concrete pavement panels was observed, which raised concern over the stability of the sea cave below. Based on their assessment of the surface conditions and their concerns, the City retained TerraCosta to complete an update geotechnical survey and evaluation of the Cook's Crack Sea Cave. The results of that study are presented in our report titled, "Geotechnical Survey and Evaluation, Cook's Crack Sea Cave, San Diego, California," dated June 28, 2018 (Appendix A).

During the tidal low of -0.5 foot MLLW on March 5, 2019, Messrs. Walter Crampton and Gregory Spaulding with TerraCosta accessed Cook's Crack by boat and swam into the sea cave to conduct a low tide survey. An additional safety swimmer provided survey control. Additional measurements and photographs were taken, and a geophysical survey performed, to attempt to locate proposed construction-period access shaft locations.

This report presents a summary of TerraCosta's March 5, 2019, survey and recent assessment of the coastal erosion and stability of the Cook's Crack Sea Cave located in the La Jolla area of San Diego, California (Figures 1 and 2, Photo 1). The Cook's Crack Sea Cave was formed along a northeast/southwest-trending fault by marine erosion, and ranges from approximately 3 feet in width near its mouth, to approximately 55 feet at its maximum width, and extends back a distance of approximately 150 feet under Coast Boulevard.

During our 2002, 2018, and 2019 studies, Walter Crampton and Gregory Spaulding from TerraCosta entered the cave to evaluate its condition, take measurements, and make observations and notes of changes that had occurred since our initial study in 2002. In general, both the 2018 and 2019 mapping of the sea cave indicated that additional small block failures have occurred since 2002. In addition, evidence of groundwater seepage along the fault, localized collapse of roof rock, and the apparent migration of sand from the overlying terrace deposits were observed, suggesting the likelihood of lost ground and the reduction of support by the roof rock. Moreover, between the 2018 and 2019 surveys, we noticed the additional accumulation of salts originating from groundwater seepage through the fault, along with the migration of additional sand from the overlying terrace deposits down through the fault.

The March 5, 2019, survey was also intended to better define the geometry and sea floor elevations near the mouth of the cave to help address potential constructability issues for sealing off the mouth of the cave. Figures 3 and 4 indicate the elevations and dimensions recorded during the 2019 survey.

2 SCOPE OF WORK

Based on our 2018 study, the City of San Diego requested that TerraCosta, as a subcontractor to Tetra Tech, complete a "Coastal Erosion Assessment and Coastal Cave Solution Feasibility Analysis" for the bluffs around Coast Boulevard and the Cook's Crack Sea Cave, expanding on our June 2018 report (Appendix A). Our current scope of work included the following:

1. Evaluate current and future impacts of coastal erosion to City infrastructure, expanding on our June 20, 2018, report to determine the current rate of erosion and future impacts due to cave and bluff erosion and sea level rise.

2. Complete a low-tide survey of the cave, addressing the geometry and sea floor elevation at the mouth of the cave.

3. Determine feasibility of proposed solutions (costs, permits, utilities, impacts, etc.) to address the feasibility of both temporary and long-term solutions, including addressing the cost of construction and permitting through the various regulatory agencies. This task was also performed to identify utilities that may be impacted and the feasibility of modifying, replacing, or rerouting utilities to reduce future impacts to those improvements.

4. Preparation of this report summarizing the results of our current study, including conclusions, recommendations, and concept-level design drawings addressing the various alternatives, including methods to prevent or reduce piping of the sandy overlying terrace soils, building a reinforced roadway section, sealing the mouth of the cave opening, and/or infilling the sea cave with an erodible concrete mixture, and address potential impacts on the coastal bluff and bluff-top improvements over the long term.

3 GEOTECHNICAL CONDITIONS

Our appended June 2018 report generally describes the changes that have occurred over the last 16+ years. Observations made during that study indicated that while additional block failures had occurred, our engineering analysis revealed that overall stability of the sea cave has not substantially changed and our calculations exhibited factors of safety against collapse ranging from 1.32 to 1.89. However, our 2019 observations indicated that groundwater seepage and widening of the major through-going fracture (fault), localized collapse of a block from the roof (Photos 2 and 3), and the apparent migration of sand from the overlying terrace deposits have occurred, likely resulting in more lost ground supporting the overlying roadway and utilities, as well as the loss of intimate contact between the two primary blocks that support the roof of the cave. Recent construction activities and the related heavy traffic may have contributed to the movement of this block and migration of sand into the fracture.

Although the numerical approach to developing the factor of safety (refer to our 2002 report for details) would still suggest a factor of safety ranging from 1.32 to 1.80, it is the widening of the joint and the downdropped block and associated (and progressive) loss of the overlying terrace deposits that would suggest, at a qualitative level, that the stability of the roof rock is now a concern and we would now discount our previous factor of safety calculations.

3.1 Current Rates of Erosion

Based on a comparison of the mapping between our 2002 and 2018 studies, the sea cave has expanded laterally (widened) 5+ feet throughout the base of the cave (Figure 3). While the annualized erosion rate along the coastline within the Point Loma Formation is on the order of 0.2 foot per year, the annualized erosion rate widening the cave appears to be on the order of 0.3 foot per year, possibly because both sides are eroding at or near equal rates. As indicated above, while numerically the small widening of the base of the sea cave does not have a significant impact on the reduction in tensile strength, which holds the roof rock blocks in place, the fact that the major through-going fracture is widening, with an associated apparent increase in lost ground and notably additional block falls within the cave proper, is a more troubling indicator than the annualized rate of erosion and corresponding cave growth. The interior of the sea cave appears less stable and, although subjective, this is a more important indicator than the annualized rate of erosion.

4 FUTURE IMPACTS DUE TO SEA LEVEL RISE AND BLUFF EROSION

Any proposed stabilization measures would be reviewed by the California Coastal Commission and the U.S. Army Corps of Engineers, both of whom have jurisdiction within the bottom portion of the sea cave. Moreover, these agencies require an assessment of sea level rise as part of any proposed stabilization effort, and the Coastal Commission Sea Level Rise Policy Guidance Document now also requires incorporation of the State of California's Sea-Level Rise Guidance presented in the Ocean Protection Council's (OPC) 2018 Update. While we have presented future impacts due to sea level rise and bluff erosion in the following paragraphs, it is our opinion that the existing wave environment, even in the absence of any significant sea level rise, has finally destabilized the roof rock within Cook's Crack to the point where immediate stabilization measures should be undertaken as soon as permits allow to avoid the consequences of a larger roof rock collapse, and the associated collapse of the overlying terrace deposits, the results of which would create a linear fissure crossing Coast Boulevard; a fissure that could be large enough for a vehicle to fall into.

4.1 Coastal Environment

The site is located along the northern boundary of the Mission Bay Littoral Cell and the southern boundary of the Oceanside Littoral Cell. The site is characterized by a rocky sea cliff-bounded shoreline with a few small sandy pocket beaches (U.S. Army Corps of Engineers [USACE], 1991). The Mission Bay littoral cell is an area of sand movement along the coast bounded by Point La Jolla to the north and Point Loma to the south, a distance of approximately 13.5 miles. The Oceanside Littoral Cell extends about 52 miles northward to Dana Point. Under natural conditions, a littoral cell is supplied with sediment by rivers and streams that empty into the ocean within its limits. The sandy material brought to the coast by fluvial action is then incorporated into the beach sands and transported south (in most areas) along the coast by wave action. This longshore transport of sand from the Oceanside Littoral Cell is ultimately intercepted by the La Jolla Submarine Canyon, where it is diverted offshore and lost to the nearshore environment. Because this site is located on the margin of these two littoral cells, there is no significant source of sand and the local beaches are comprised primarily of gravel, cobble, and boulder conglomerate.

4.2 Wave Climate

Waves provide nearly all of the energy input that drives shoreline processes along the California coast. As illustrated in Figure 5 (below), incoming waves along the southern California coast fall into three main categories: Longer period northern and southern hemisphere swell, and locally short-period generated seas. North hemisphere swell from the North Pacific Ocean dominate the winter wave conditions off California, while southern hemisphere swell is more important in the summer. Short-period seas are produced by storms sweeping through the area. The offshore islands, shallow banks, submarine canyons and generally complex bathymetry offshore of southern California greatly complicate the wave climate at the coast (Figure 6, below).

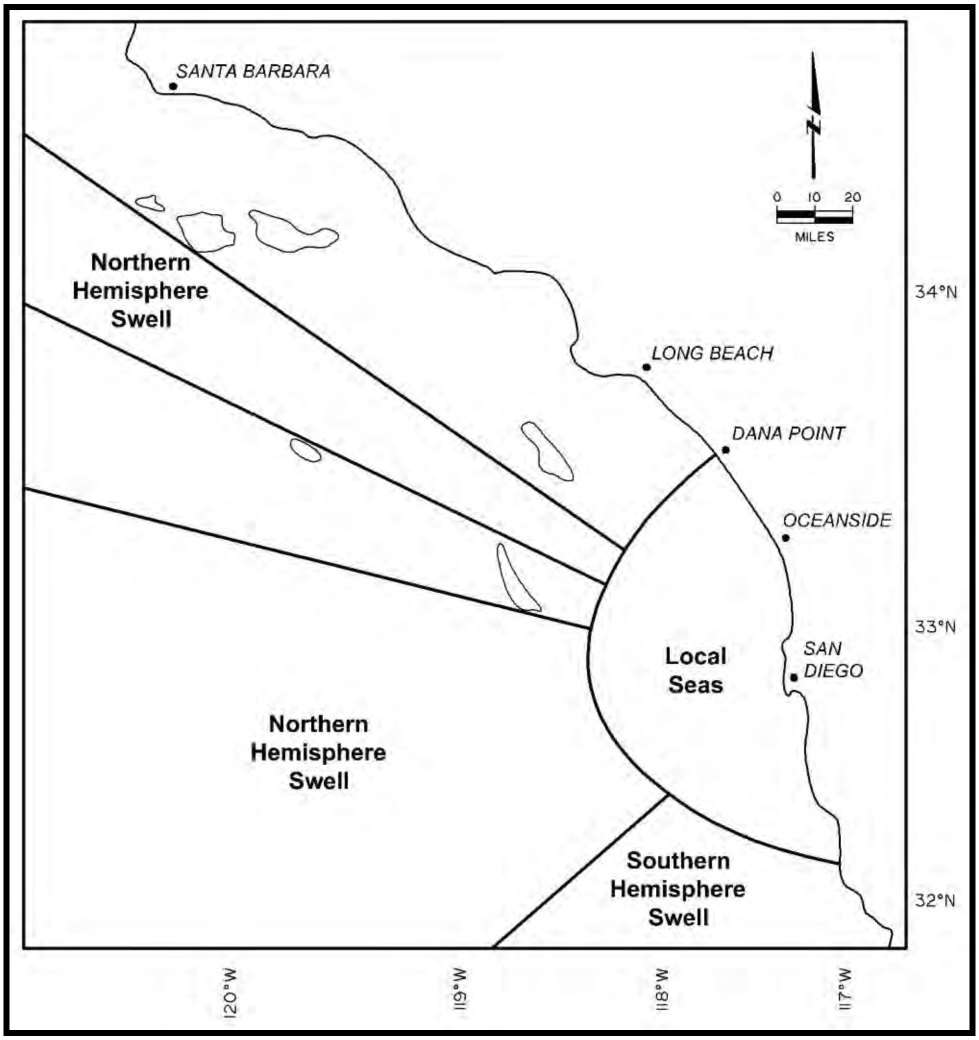


Figure 5. Map Showing Generalized Wave Exposure for Southern California.

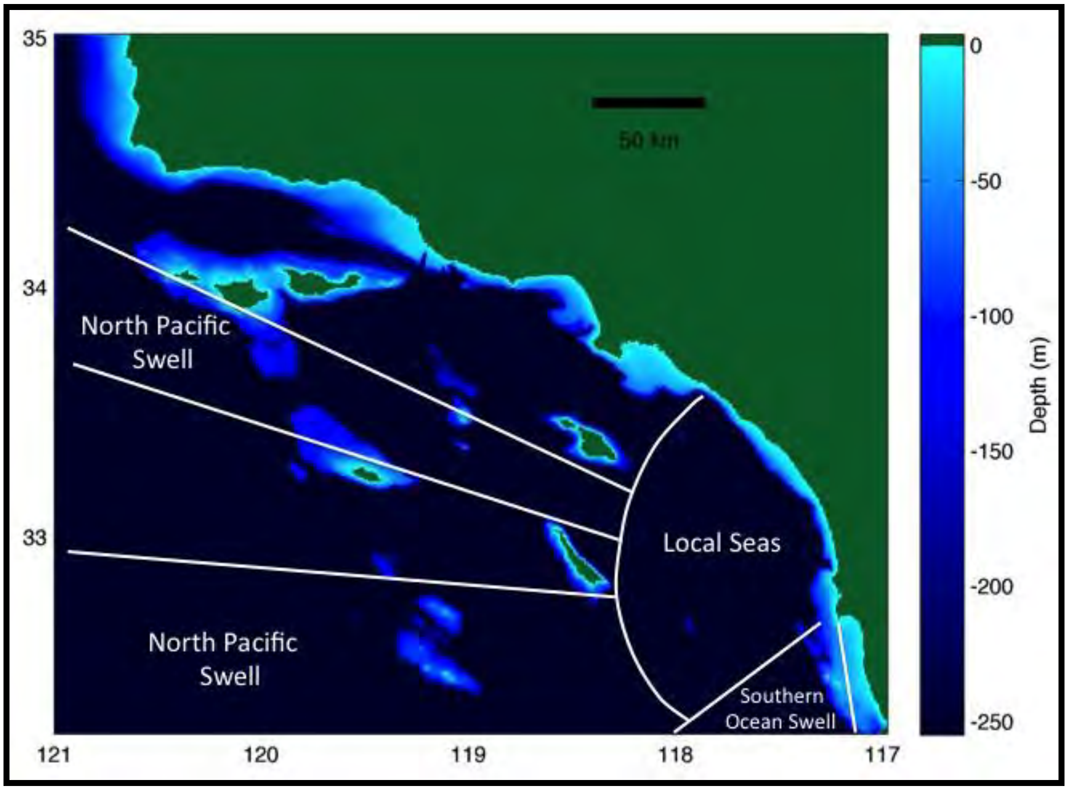


Figure 6. Map Showing Generalized Bathymetry in the Southern California Bight and Wave Exposure Windows at Oceanside.

Coastal orientation, and the islands and banks greatly influence the swell propagating toward shore by partially sheltering southern California, including La Jolla, especially from directions north of west. Figure 6 (above) shows the approximate directions from which incoming swell is blocked by the islands. The coastline fronting the subject site actually faces to the northeast and is somewhat sheltered from the southern hemisphere swell. Storm originating from the North Pacific and locally generated seas from winds out of the northwest reach the site. However, due to the effects of bathymetry and island shadowing, the wave height at the shoreline is sensitive to relatively small changes in the incoming direction of the deep ocean waves.

While waves along the San Diego County shoreline generally range in height from 2 to 5 feet, deep water waves off the coast have been recorded with deep water significant wave heights approaching 10 meters (33 feet).

4.3 Short-Term Sea Level Change

The effect of waves on the coast is highly dependent on the sea level during the wave episode. Large waves at low sea level cause limited erosion, since they break well offshore. When episodes of large waves combine with short-term high sea level from tides and other factors, rapid retreat may occur along vulnerable coastlines.

4.3.1 *Tides*

Tides are caused by the gravitational pull of astronomical bodies; primarily the moon, sun, and planets. Tides along the San Diego coast have a semi-diurnal inequality. On an annual average basis, the lowest tide is about -2.2 feet MLLW and the highest tide is about +7.8 feet, MLLW.

4.3.2 *El Niño*

Large-scale, Pacific Ocean-wide warming periods occur episodically and are related to the El Niño phenomenon. These meteorological anomalies are characterized by low atmospheric pressures and persistent onshore winds. During these events, average sea levels in southern California can rise up to 0.5 foot above normal. Tidal data indicates that six episodes (1914, 1930 through 1931, 1941, 1957 through 1959, 1982 through 1983, and 1997 through 1998 - mild El Niño-type conditions were also reported in 1988 and 1992) have occurred since 1905. Further analysis suggests that these events have an average return period of 14 years, with 0.2-foot tidal departures lasting for two to three years.

The added probability of experiencing more severe winter storms during El Niño periods increases the likelihood of coincident storm waves and higher storm surge. The record water level of 8.35 feet, MLLW, observed in San Diego Bay in January 1983, includes an estimated 0.8 foot of surge and seasonal level rise (Flick and Cayan, 1984), which set the stage for the wave-induced flooding and erosion that marked that winter season.

4.4 Sea Level Rise

Past and possible future changes in mean sea level (MSL) are of interest in design and planning for all coastal cities, as well as for any engineering activities on the coast. Global mean sea level rose at least 300 feet, and perhaps as much as 400 feet, during the past 18,000 years or so (CLIMAP, 1976). Sea level, both globally and along California, rose approximately 0.7 foot over the past century, as shown in Figure 7 (below). Furthermore, evidence suggests that the rate of global mean sea level rise has accelerated since the mid-1800s, or even earlier (Church and White, 2006; Jevrejeva, et al., 2008), and that it has now reached a rate of about 1 foot per century over the past decade or so (Nerem, et al., 2006).

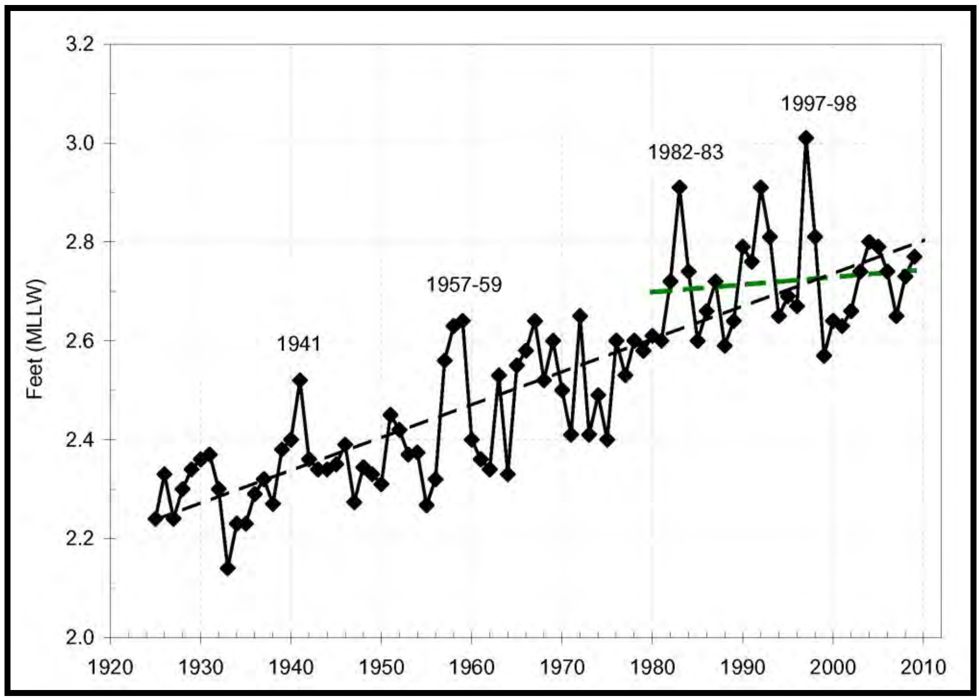


Figure 7. Annual Average Sea Level History at La Jolla, 1925-2007. Broken Line Shows Linear Trend of 0.7 Feet/Century Rise.

Figure 7 is a plot of the annual mean sea levels measured at the La Jolla tide gauge starting in 1925. The linear trend indicates the approximate 0.7 foot per century sea level rise. Also noticeable are the enhanced sea levels during the El Niño episodes of 1941, 1957-59, 1982-83, and 1997-98 (respectively labeled).

A notable feature of the sea level history at La Jolla is the leveling-off of sea level rise since about 1980 (Figure 7, above). The green broken line shows a much reduced trend of about 0.15 foot per century between 1980 and 2009, or about 4.5 times smaller than the overall trend of 0.67 foot per century. A similar reduction in the rate of sea level rise has been noted at San Francisco, which has a similar overall appearance as the La Jolla record, but is a much longer record extending back to 1856.

Figure 8 (below) shows the global distribution of the rate of sea level change for the period of 1993-2012 (University of Colorado, 2012). Note that warm colors (yellow-orange-red) show areas of sea level rise (positive rates), while cool colors (green- blue) indicate falling sea level (negative rates) over the record. Inspection of the North Pacific reveals that sea levels in the western Pacific, especially in the lower latitudes, have risen at a rate of 3-9 mm/year (equivalent to 30-90 cm per century, or about 1-3 feet per century). Conversely, sea levels in the eastern Pacific, extending from Central America north to Washington State, have fallen at a rate of 0-3 mm per year (0-30 cm per century, or 0-1 foot per century). This may explain the coastal tide gauge observations (La Jolla sea level history; Figure 7, above) described above.

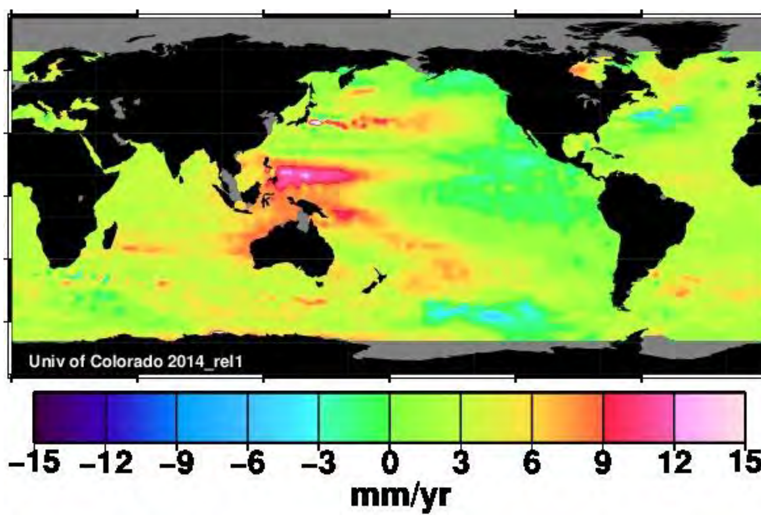
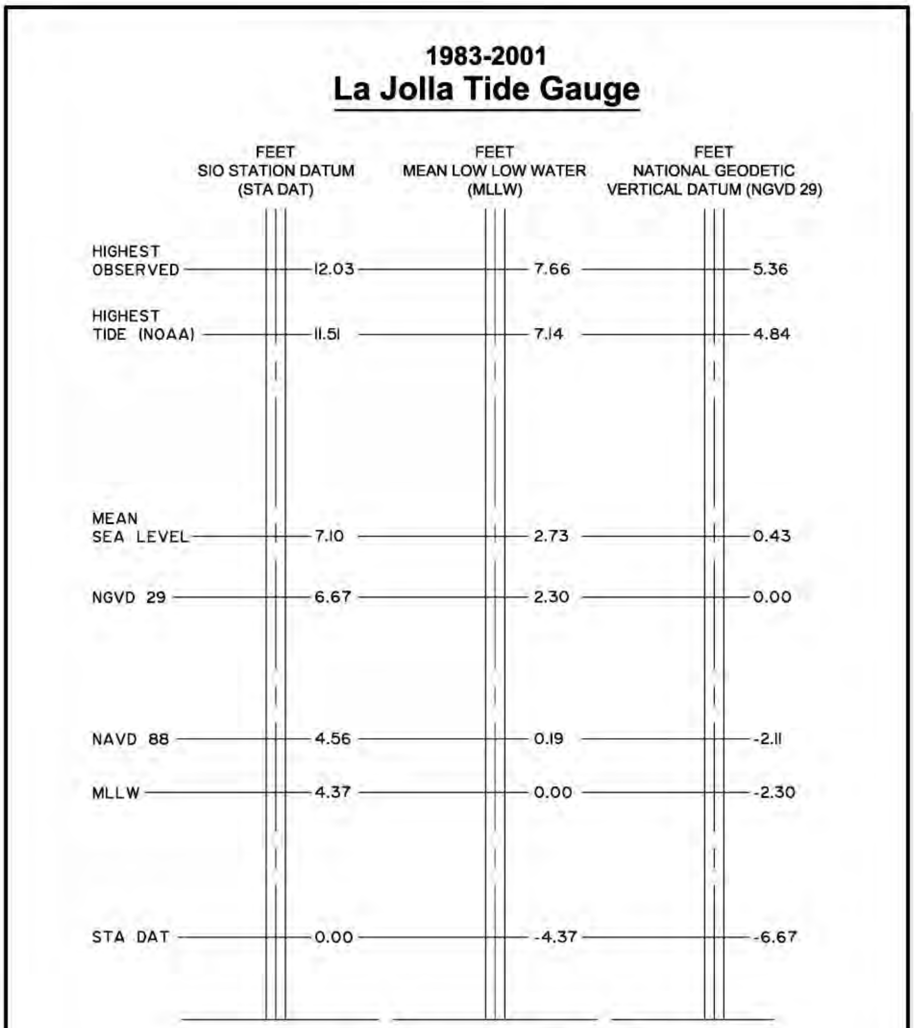


Figure 8. Global Sea Level Change Rates 1993-2012 as derived from satellite altimetry measurements, following University of Colorado (2012).

While the cause of these regional differences undoubtedly lies in the large-scale circulation of the Pacific Ocean and the overlying atmosphere, no detailed explanation is known. However, these observations could be a cause for some concern. If the conditions driving sea level up in the western Pacific and down in the eastern Pacific were to relax or even reverse, sea level along the coast of California could begin to increase at a much higher rate than what has been observed over the past several decades. Future global sea level rise scenarios could further increase the rate of sea level rise.

4.5 Water Levels

Past water elevations are based on the tide gauge data from La Jolla, which has been collected at Scripps Institution of Oceanography (SIO) Pier since 1924. These data are applicable to the San Diego region open-ocean coastline. The tidal and geodetic reference relationships at La Jolla are illustrated in Figure 9 (below).



Tidal and geodetic datum relationships for the latest (1938-2001) tidal epoch at La Jolla (Scripps Pier). These are applicable to the open-coast of the San Diego region.

Figure 9. Sea Level Datum.

Tide gauges measure total water level outside the breaker zone, which includes contributions from the tide, as well as storm surges and other factors that raise sea level over the short and long term, including the effects of El Niño. All non-tide sea level influences measured by the tide gauges are termed "non-tide residuals, or "NTR." Importantly, tide gauges do not include the effects of waves or wave-driven runup. At the shoreline and on beaches, wave-driven runup is a crucial component of the design water elevation and must be determined by means other than tide gauge data. Alternatively, as the back beach becomes flooded during high tide and low beach sand level events, the standard runup formulations may not apply, and other factors, including local shallow-water depth-limited waves, must be considered.

When considering the effects of future sea level rise, the National Academy of Sciences (NAS, 2012) presents a possible global, west-coast, and state-wide future Mean Sea Level Rise (MSLR) for California, Oregon, and Washington (Figure 10, dots) and its range (Figure 10, bars). These are based on the IPCC (2007) mid-range Green House Gas emissions scenarios for the ocean steric (warming) expansion component added to the results of new research projecting the likely contributions of future ice-melt. The resulting projected *global* MSLR relative to 2000 ranged from 0.08-0.23 m (0.26-0.75 ft) by 2030; 0.18-0.48 m (0.59-1.6 ft) by 2050; and 0.50-1.4 m (1.6-4.6 ft) by 2100 (Figure 10, red bars). The global estimates were adjusted for vertical crustal movement (uplift north of Cape Mendocino and down-drop in the south) resulting in the orange bars, also shown in Figure 10 (below). The State of California (2013) used these results of NAS (2012) shown as the updated MSLR guidance in Table 1 (below).

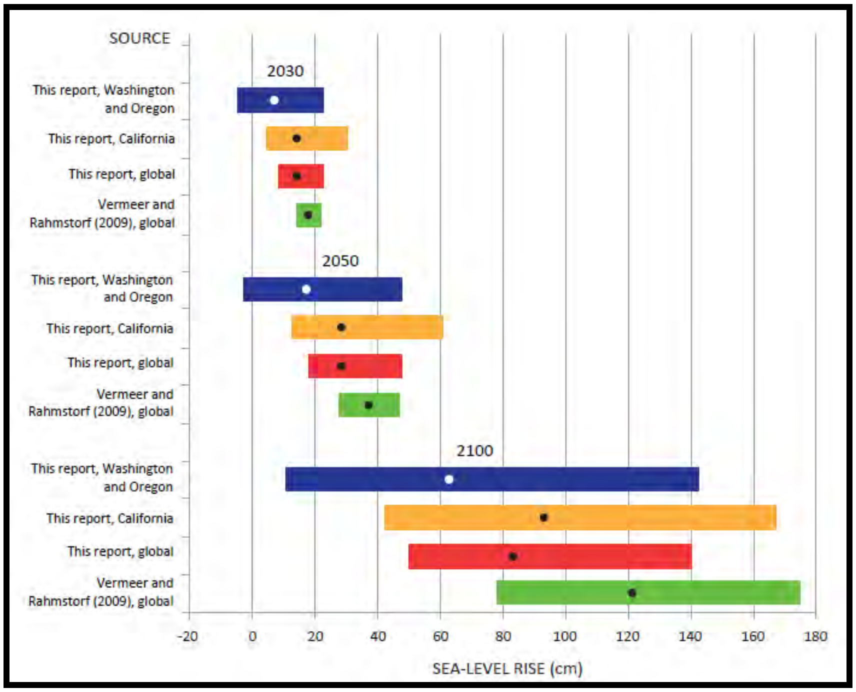


Figure 10. NAS (2012) summary of global, Washington, Oregon, and California (south of Cape Mendocino) MSLR projections for 2030, 2050, and 2100 relative to 2000.

Table 1. Updated MSLR Guidance from State of California (2013)

Time Period	North of Cape Mendocino[3]	South of Cape Mendocino
2000 - 2030	-4 to 23 cm (-0.13 to 0.75 ft)	4 to 30 cm (0.13 to 0.98 ft)
2000 – 2050	-3 to 48 cm (-0.1 to 1.57 ft)	12 to 61 cm (0.39 to 2.0 ft)
2000 – 2100	10 to 143 cm (0.3 to 4.69 ft)	42 to 167 cm (1.38 to 5.48 ft)

5 BLUFF EROSION

This section of coastline is characterized by steep coastal bluffs comprised of relatively erosion-resistant Cretaceous-age strata (Point Loma Formation) at the base of the bluff and a less resistant upper bluff (terrace deposits). A cliff section forms the base of the bluff to below sea level along this reach of the coast. The bluff in the project area is located in a medium to high energy wave environment subject to continuous direct wave impact.

5.1 Lower Bluff Erosion

Review of historical photographs dating back to the 1970s does not reveal a great deal of long-term lower bluff erosion in the general area of this site. Based on our review of historical photographs, we estimate that on the order of 5 to at most 10 feet of erosion has occurred in the last 45+ years. Younger Eocene-age formations to the north, Solana Beach for example, exhibit erosion rates on the order of 0.4 foot per year. The older Point Loma Formation would be expected to have a lower erosion rate, possibly on the order of 2 to 3 inches (0.17 to 0.25 foot) per year.

5.2 Empirical and Analytical Techniques of Erosion Rate Assessment

The scientific community has been actively engaged in developing numerical models to assess rates of shoreline erosion. Numerical models attempt to address both the landward retreat of the sea cliff and the development of the shore platform. In this simplest expression, predictive cliff-erosion models take the following form (Sunamura, 1977):

$$dx / dt \propto \ln\left(\frac{f_w}{f_r}\right)$$

where *dx/dt* is the horizontal rate of erosion, f_w is the wave force, and f_r is the rock resistance. Similar equations have been developed to describe platform development.

Of particular interest in numerical modeling is the fact that a minimum or critical wave height capable of causing erosion exists, below which, for a given rock lithology, no erosion would occur. Additionally, the rate of erosion increases in logarithmic proportion to increase in wave force, which is substantially less than a linear increase in wave energy. Importantly, however, these numerical models describe the mechanical erosion of intact rock of assumed uniform lithology, and do not account for the accelerated erosion caused by the hydrodynamic component of wave forces that occurs in fractured rock.

When using the preceding equation, and when comparing the site conditions with San Diego's North County Tertiary cliff-forming sediments, the wave force (f_w) is likely lower for the subject site than the open coast along North County San Diego. The erosion resistance of the rock (f_r) is also stronger for the older late Cretaceous sediments than for the younger Eocene sediments. This suggests both a more severe storm wave to initiate erosion of the sea cliff, and a corresponding reduction in marine erosion for a given design wave event for the late Cretaceous sediments than from the North County Eocene sediments. Thus, one would again conclude that, in the absence of more data, the annualized average erosion rate for the site would be on the order of 2 to 3 inches (0.17 to 0.25 foot) per year, given the more well-defined erosion rate of the younger Eocene sediments of 4.8 inches (0.4 foot) per year.

5.2.1 *SLR Impact on Bluff Erosion*

The OPC's Sea-Level Rise Guidance Update requires that one consider the Medium-High Risk Aversion sea level rise of 7.1 feet by the year 2100, which has a 0.5 percent probability of sea level rise by the year 2100. The OPC further requires that any proposed project also develop adaptive strategies for the H++ scenario with an estimated 10.2 feet of sea level rise by the year 2100.

As indicated in the previous section, the rate of marine erosion is a function of the wave force, f_w, divided by the rock resistance, f_r, with any sea level rise increasing the available wave energy, and hence the wave force, f_w, assailing the coastal bluff. While the increased rate of coastal erosion associated with any sea level rise can be calculated, suffice to say, and in keeping with the OPC's Sea Level Rise Guidance documents, any measurable sea level rise will increase the rate of sea cave growth, imparting more wave energy into the sea cave, further reducing roof rock stability.

While we appreciate the OPC requirements for evaluating future projects, as indicated previously, even in the absence of any sea level rise, the sea cave under Coast Boulevard will eventually collapse with the highest section of roof rock extending across the entire travelway of Coast Boulevard. Any sea level rise only reduces the time until a collapse will occur.

6 FEASIBILITY OF PROPOSED SOLUTIONS AND ALTERNATIVES

As part of this study, we have been tasked with addressing the feasibility of both temporary and long-term solutions, addressing the cost of construction and permitting through the various regulatory agencies. This task also includes identifying utilities that may be impacted and the feasibility of modifying, replacing, or rerouting utilities to reduce future impacts to those improvements.

6.1 No Project

As we understand, the City is currently in the process of designing and replacing the storm drain system in the vicinity of the Cook's Crack Sea Cave. As previously discussed, it is our opinion that the recent construction activity may have aggravated and potentially accelerated the migration of sand entering the cave through the fracture (fault). As indicated above it is also our opinion that the sea cave roof rock has an unacceptably low current static factor of safety against failure and collapse of the sea cave. Moreover, with the site being located in such close proximity to the Rose Canyon Fault, the probability of a seismically induced collapse is also greatly increased. Due to the high probability of a collapse occurring, whether triggered by a seismic event, water line break, or construction activity, it is our opinion that public safety outweighs the option of doing nothing.

6.2 Chemical Grouting of Terrace Deposits

As discussed in our 2018 report, a temporary solution to reduce or prevent the migration of sand into the cave, resulting in lost ground and support for the overlying roadway and utilities, may involve chemically grouting the overlying terrace deposits to strengthen the soils and aid in preventing piping of the sandier terrace deposits. Grouting would be completed on a grid pattern using either a microfine cement or silicate grout, which would solidify the sandier materials within the terrace deposits. This alternative should only be considered as a temporary solution. The cost of chemical grouting is estimated to be on the order of $200,000 to $250,000.

This alternative essentially slows the erosion process by creating a more solidified soil mass that is less susceptible to soil piping and lost ground by creating a more stabilized upper terrace section, which comprises the upper 15± feet of the geologic section. However, this alternative cannot provide the assurances of an engineered structure, such as the bridge alternative described below, and thus the recommendation that this alternative be considered temporary, possibly limited to no more than 10 years.

6.3 Construct a Bridge

Constructing a bridge over the sea cave, and allowing the sea cave to continue to erode and collapse over time, would require the construction of an approximately 100-foot-long by 60-foot-wide bridge or substantial structural roadway section to span the sea cave. This alternative would also require relocation and support of the utilities within the bridge's or structural section. We estimate the cost of construction such a bridge to be on the order of \$2 to \$3 million.

6.4 Sea Cave Infill

A common solution for mitigating the potential for collapse of a sea cave is to infill the cavity with concrete. This option would require construction of a bulkhead at the entrance to the sea cave, drilling access adits through the top of the cave to allow workers to enter and prep the cave, and pumping a concrete mix into the cave to provide support against collapse. The concrete mix would consist of a non-reinforced lean (sand-cement) mix designed to erode as the face of the bluff erodes in the future. As shown on Figure 2, a new storm drain pipe can be installed in the northerly adit to replace the existing questionable storm drain that currently overlies the Cook's Crack Sea Cave. The total volume of low strength concrete fill is estimated to be approximately 2,500 cubic yards, with a total anticipated construction cost on the order of \$1.5 to \$2 million. In our opinion, the sea cave infill is the only option that positively stabilizes both Coast Boulevard and the numerous utilities in and adjacent to Coast Boulevard.

7 ANTICIPATED CONSTRUCTION APPROACH

As indicated on Photo 1, the Cook's Crack Sea Cave is located on a cliffed section of the La Jolla shoreline, with the bathymetry immediately fronting the sea cave, although somewhat variable, around -3 feet MLLW. Photo 4, taken during our survey during a tidal low with the water level at about -0.2 foot MLLW, shows an indentation into the cliffed shore face of about 9 feet prior to actually entering the 4½-foot-wide mouth of the sea cave that is still not visible in Photo 4. The width of this indentation is also about 9 feet, and provides perspective for the anticipated construction approach, which initially includes placing ten to twelve 4-ton rock within the outer indentation to reduce wave energy and create a safer working environment. Notably, and while Photos 1 and 4 show a rather calm sea state, this area is, much of the time, awash in surf and very dangerous. Moreover, and specific to Photo 4, six hours before this photo was taken, the water surface was 5 feet higher than that shown in Photo 4. Additionally, and when entering the narrow mouth of the sea cave, the floor of the sea cave drops about 2 feet in an environment, absent the temporary rock protection, that is very dangerous and unacceptable for construction crews.

Concurrently with placement of the rock, the contractor would drill two 4-foot-diameter vertical shafts for construction access to the sea cave, with the two ends of the high relief sea cave more or less coinciding with the outer edges of both the northerly and southerly travelways adjacent the Coast Boulevard travelway. The southerly proposed vertical shaft location may conflict with numerous utilities in the area, and it may ultimately be necessary to extend the more southerly construction access shaft slightly into the Coast Boulevard travelway. City Staff and Tetra Tech should weight the options for the best locations of the construction shafts. Notably, and as indicated on Figure 2, the northerly construction shaft also appears to be located atop the 12-inch RCP storm drain that also discharges into the Cook's Crack Sea Cave. However, in discussions with Tetra Tech Staff, it was agreed that this location is likely still viable, recognizing that Tetra Tech will likely make improvements to the discharge pipe of this storm drain.

Prior to advancing the vertical construction shafts, the contractor shall be required to pre-drill the proposed shaft locations with a 4- to 6-inch-diameter test boring, into which the contractor would place a camera, enabling a suitable visual assessment of the exact 4-foot shaft location. The intent is to not intercept the fracture (fault), which would potentially create a less stable condition in the roof rock. Although the central portion of the sea cave is quite large and the roof rock relatively wide, the actual best locations for the construction shafts are somewhat limited in extent, with the exploratory camera survey considered important to optimally locate the two 4-foot-diameter construction access shafts.

Both construction shafts can be easily drilled during night shifts to avoid impacts to vehicular traffic along Coast Boulevard, and the area secured, with most of the actual construction having only limited impacts on vehicular traffic.

Once the shafts are drilled and safe access to the sea cave provided, we anticipate that the contractor would initially set lights into the ceiling to facilitate construction, then plug the mouth of the sea cave.

As indicated on Figure 4, the face of the concrete plug would coincide with the approximate back of the depressed area along the sea cliff, as shown on Photo 4, with the actual completed plug not even visible from the perspective of Photo 2. We propose that the plug be filled utilizing concrete-filled 2 cubic yard geobags, for which we are recommending GT1000MB geobags (product literature provided in Appendix B). The front face of the geobags would be positioned to coalign with the back of the indentation within the coastline, then backfilled with a non-reinforced erodible concrete mix consisting of two sacks of cement with 200 pounds of fly ash per cubic yard of erodible concrete. We have utilized this mix design to fill-in several sea caves, and the mix provides both a pumpable and low strength mix that should roughly approximate the strength of the Point Loma formational shelf rock.

The bottom of the narrow sea cave contains boulders along its floor. As an option, the contractor could attempt to remove some of the boulders, or simply place the non-reinforced concrete geobags and, after placement, attempt to grout some of the voids from the back of the geobag barrier to further reduce the flow of tidal waters through the interstices of the underlying cobbles and boulders. We have arbitrarily set the top of the concrete-filled geobags at +10 feet MSL, which is a little more than 16 feet above the bottom of the narrow cave opening in order to provide additional light and air into the interior of the sea cave.

After the mouth of the sea cave is stabilized, the interior of the sea cave would then need to be prepped. Although we recommend that the entire sea cave be filled with the erodible concrete mix, it is critically important that a sufficient volume of the low strength concrete fill be founded directly on the competent formational bedrock that underlies the transient sands within the sea cave. Minimally, we recommend that 30 percent of the floor of the sea cave be cleaned, exposing the underlying Point Loma formational bedrock. While sand and debris can be locally piled within the cave bottom, the 30 percent bedrock exposure must be uniformly distributed across the bottom of the cave to ensure relatively uniform bearing of the low strength concrete fill. We anticipate that the cleaning of the bottom of the sea cave will require some effort by the contractor. However, this cleaning must be carefully performed in a good workmanlike manner in order to ensure the subsequent intimate contact of the concrete fill extending up the sloping sidewalls of the cave up to its roof rock, and then ultimately up into the concrete construction access shafts.

We anticipate that the contractor would fill the cave in relatively horizontal lifts, and after the tops of the geobags have been reached, the exposed seaward face of the open jointed roof of the Cook's Crack Sea Cave (see Photo 1) would then be architecturally shaped to blend in with the surrounding formational bedrock to recreate the architectural appearance of the faulted roof rock. Once the cave is filled, the ten to twelve 4-ton rocks could be lifted back out of the mouth of the cave, returning the cliffed section to that shown in Photo 4.

7.1 Permitting

The various regulatory agencies that will provide review and oversight for any project requiring construction would likely be the City of San Diego's Environmental Department and the California Coastal Commission. Because the site is located adjacent the La Jolla Marine Sanctuary Underwater Park, and the bottom of the cave is situated below the Mean High Tide Line, the California State Lands Commission, U.S. Army Corps of Engineers, the Regional Water Quality Control Board, and the U.S. Fish & Wildlife would also provide additional input and oversight of the project.

8 CONCLUSIONS AND RECOMMENDATIONS

As discussed in our June 2018 report, based on the results of our mapping, observations, and engineering analyses, it is our opinion that within a few years, there is a high probability of collapse of additional supporting roof rock resulting in the formation of voids or sinkholes under Coast Boulevard, causing damage to the street and utilities that overlie the Cook's Crack Sea Cave and/or injury or death due to a vehicle or pedestrian falling into a sinkhole. Based on our studies, the most feasible alternative would be to seal and infill the sea cave.

In addition, prior to infilling the sea cave, we recommend that should a moderate to strong earthquake impact the area, or a waterline break occur, the sea cave be inspected as soon as possible and evaluated for any additional collapse or loss of supporting roof rock.

9 LIMITATIONS

The data provided in this report were collected from our field observations and mapping of Cook's Crack Sea Cave, previously published reports and maps, and our general knowledge of geologic and geotechnical conditions in the area. No subsurface exploration or laboratory testing were performed for this report. This report was not prepared for any specific repair option. Therefore, it may not satisfy the requirements of regulatory agencies or reviewers if submitted, and additional site-specific investigation may be required. This report is not valid after two years after its issue date.

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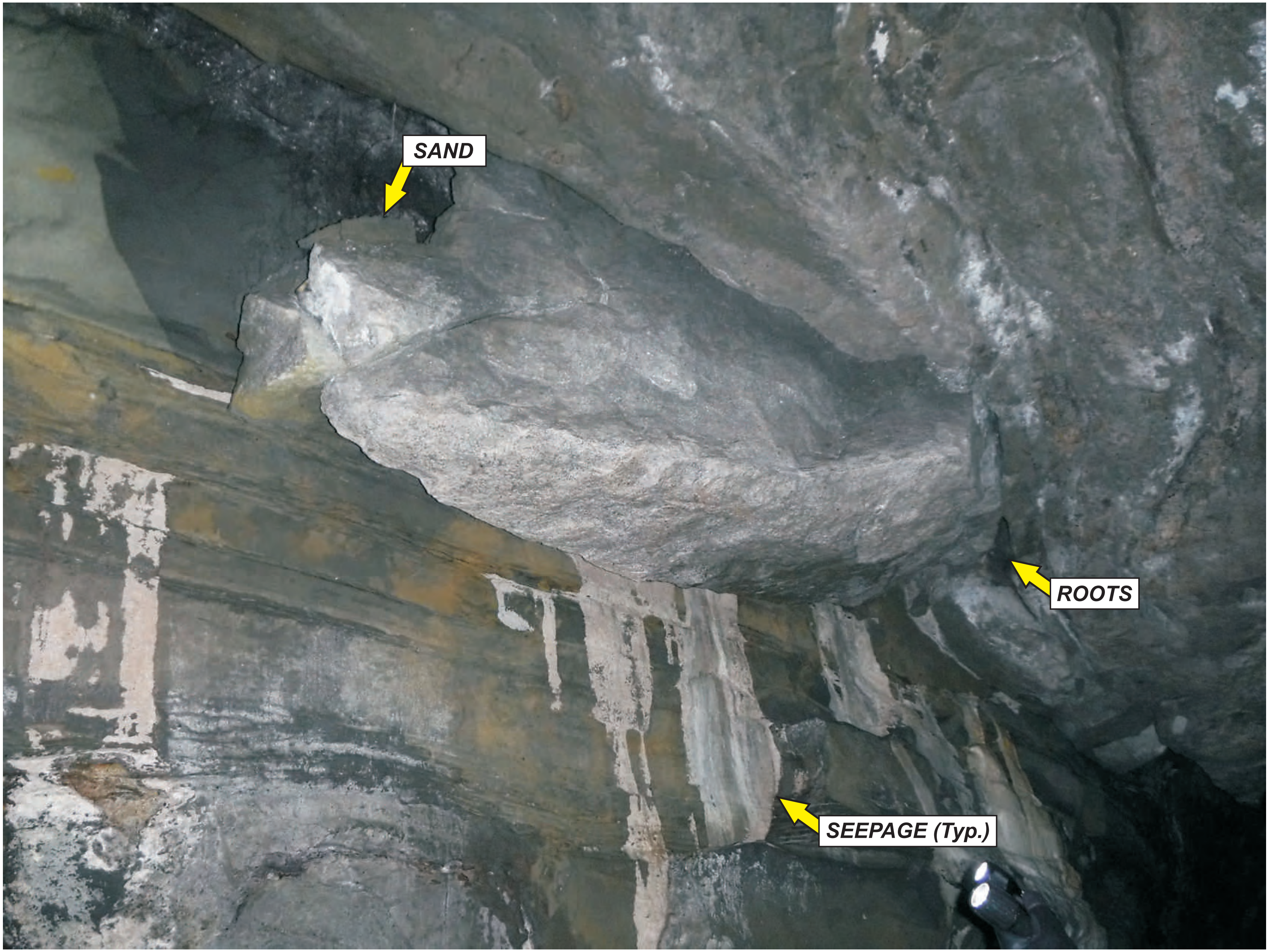
TERRACOSTA CONSULTING GROUP 3890 Murphy Canyon Road, Suite 200 San Diego, California 92123 (858) 573-6900	PROJECT NO.: **2086B**	PROJECT NAME: **COOK'S CRACK SEA CAVE**	PHOTO NO.: **1**

DATE OF PHOTO: MARCH 5, 2019

TerraCosta Consulting Group **TERRACOSTA CONSULTING GROUP** 3890 Murphy Canyon Road, Suite 200 San Diego, California 92123 (858) 573-6900	PROJECT NO.: **2086B**	PROJECT NAME: **COOK'S CRACK SEA CAVE**	PHOTO NO.: **2**

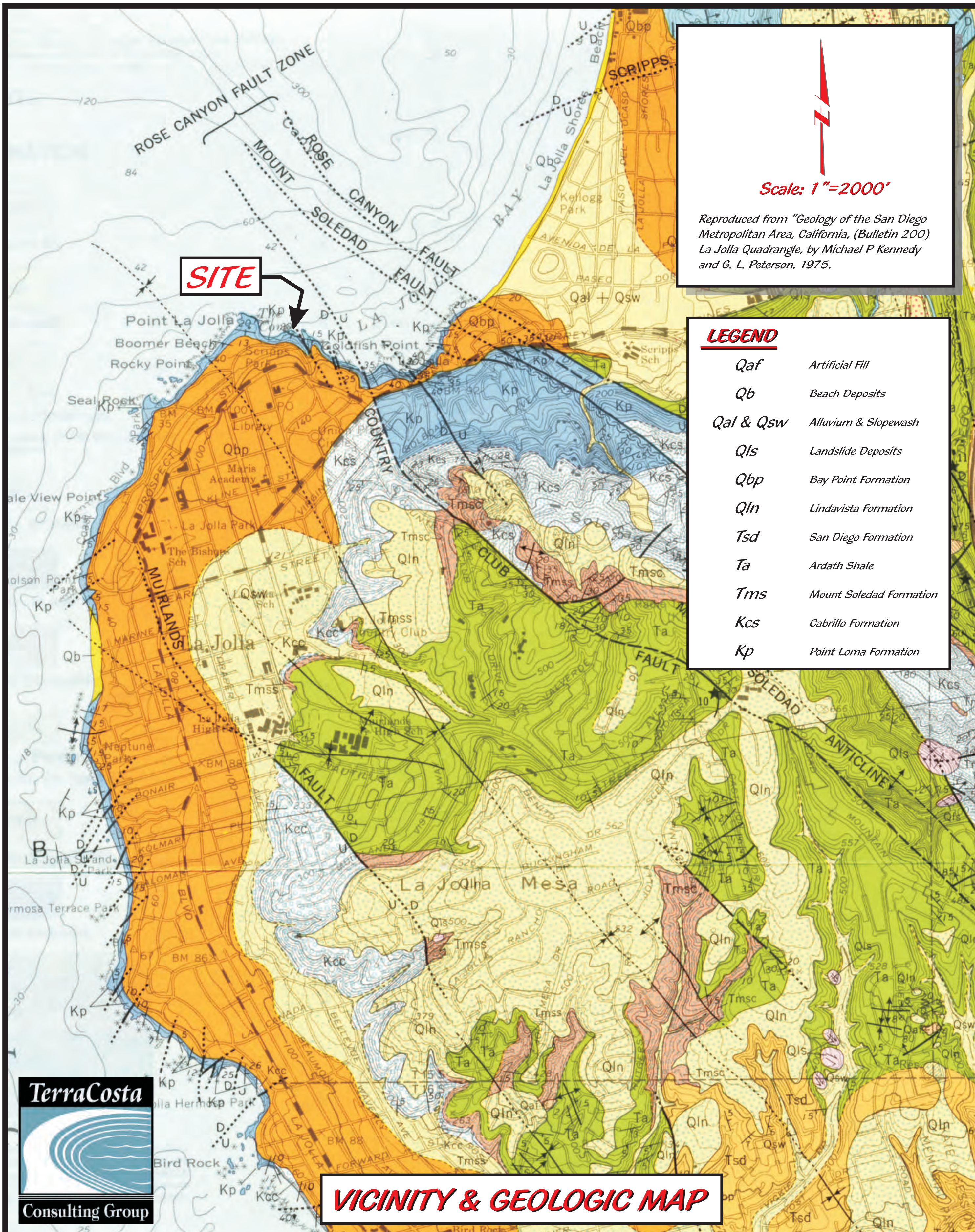


DATE OF PHOTO: MARCH 5, 2019

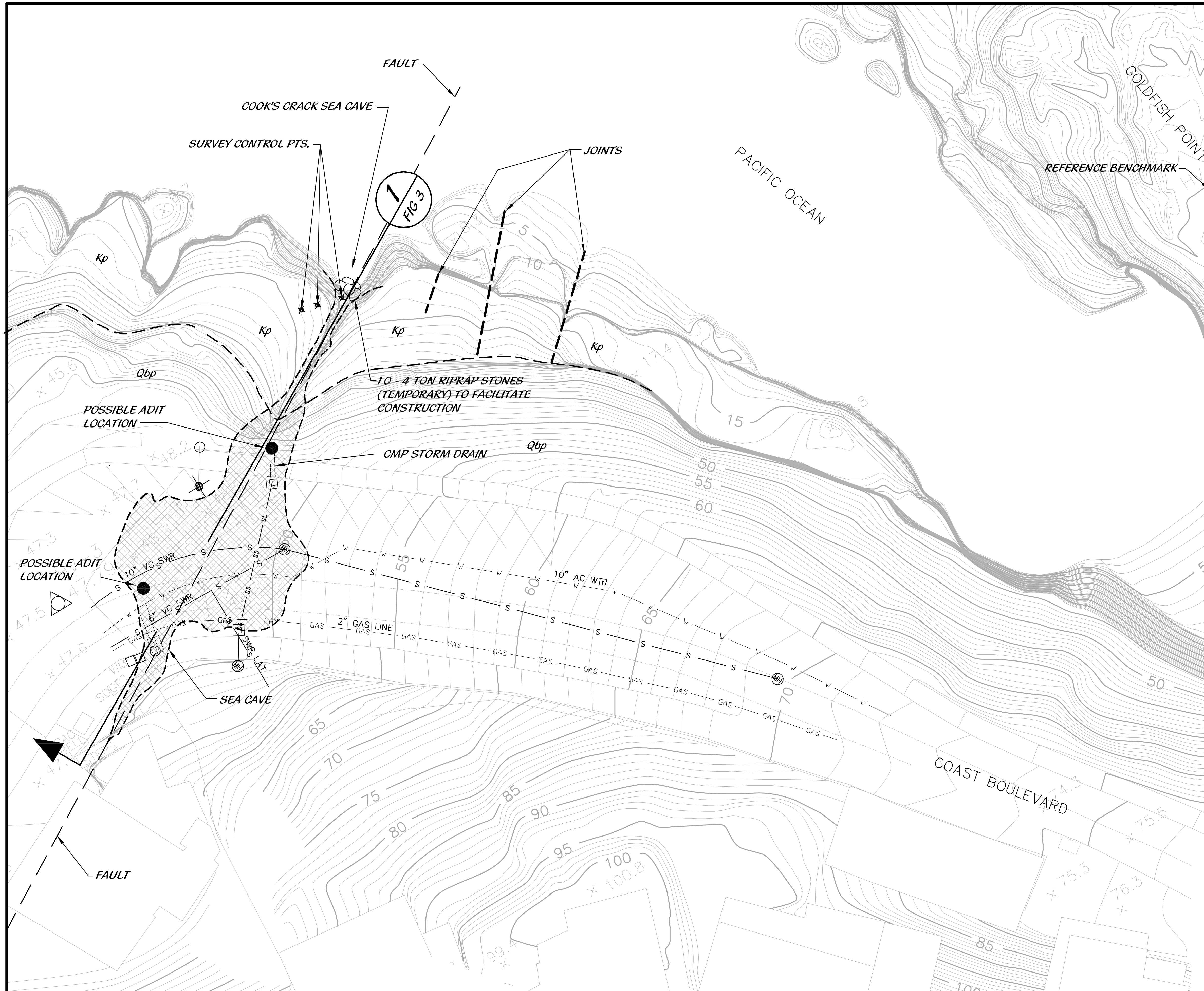
TerraCosta Consulting Group	**TERRACOSTA CONSULTING GROUP** 3890 Murphy Canyon Road, Suite 200 San Diego, California 92123 (858) 573-6900	PROJECT NO.: **2086B**	PROJECT NAME: **COOK'S CRACK SEA CAVE**	PHOTO NO.: **3**

DATE OF PHOTO: MARCH 5, 2019

TerraCosta Consulting Group	PROJECT NO.:	PROJECT NAME:	PHOTO NO.:
TERRACOSTA CONSULTING GROUP 3890 Murphy Canyon Road, Suite 200 San Diego, California 92123 (858) 573-6900	**2086B**	**COOK'S CRACK SEA CAVE**	**4**



VICINITY & GEOLOGIC MAP



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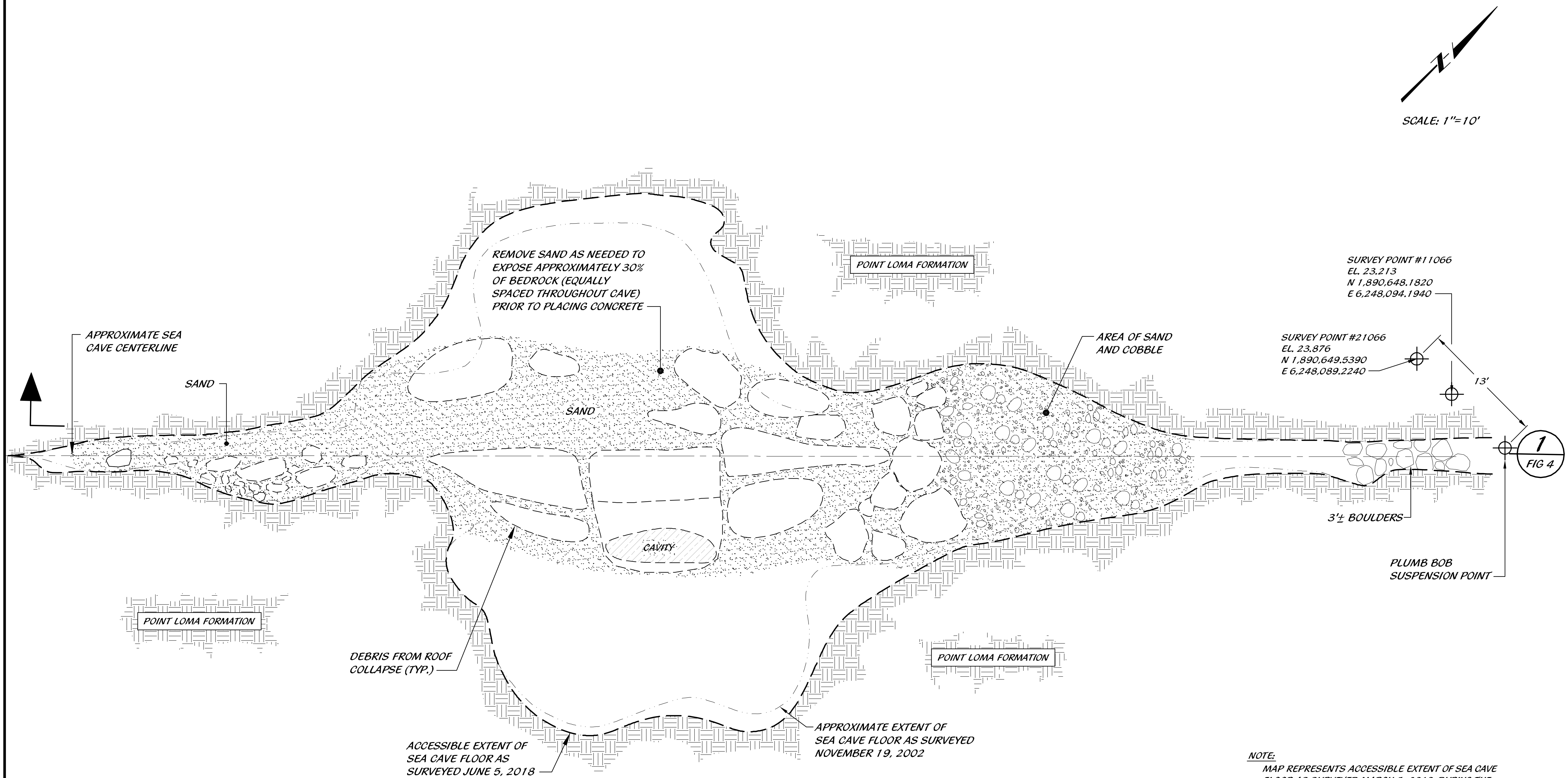
ENGINEERS AND GEOLOGISTS
3890 MURPHY CANYON ROAD, SUITE 200 SAN DIEGO, CA 92123 (858) 573-6900

FIGURE NUMBER	2
PROJECT NAME	COOK'S CRACK SEA CAVE
PROJECT NUMBER	2086B

SITE PLAN

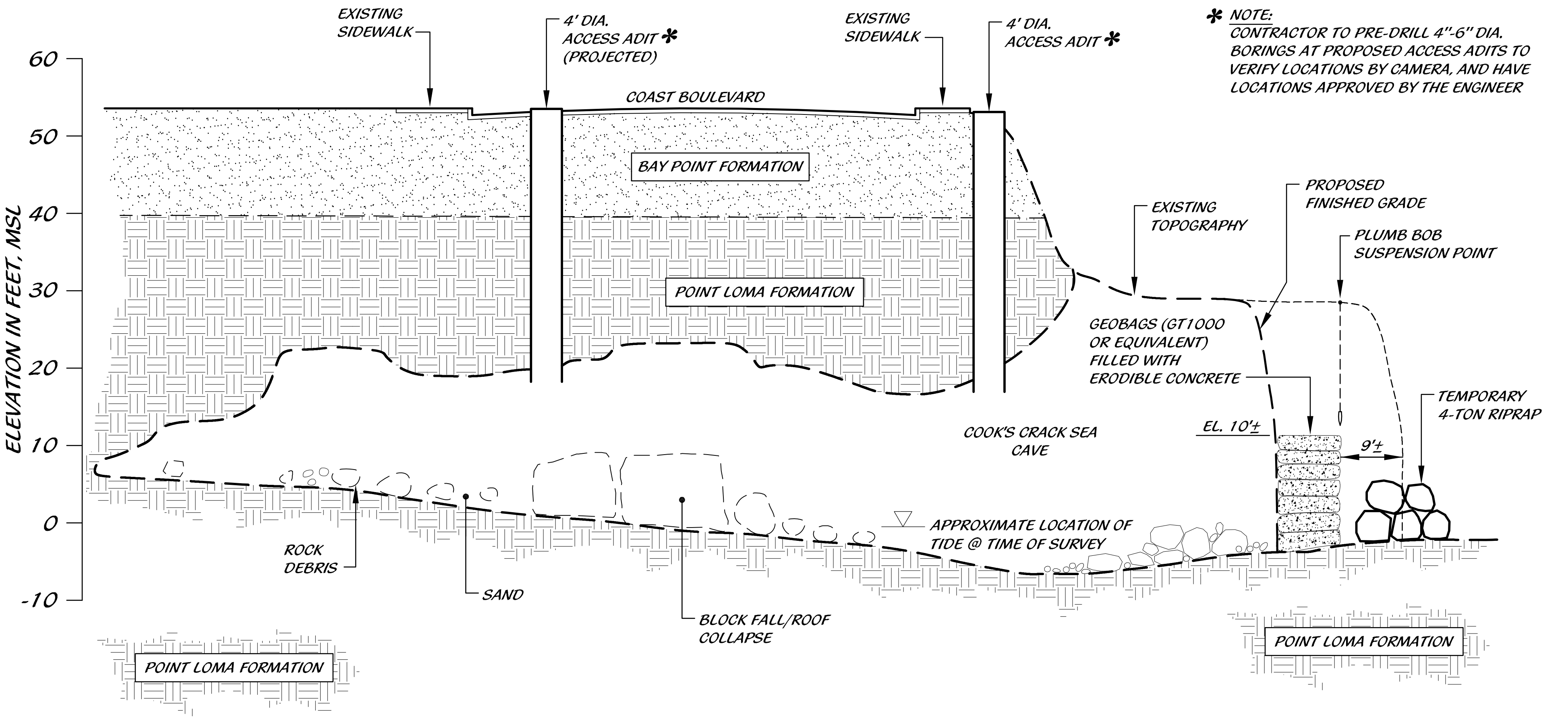


NOTE:
MAP REPRESENTS ACCESSIBLE EXTENT OF SEA CAVE FLOOR AS SURVEYED MARCH 5, 2019, DURING THE TIDAL LOW OF -0.4 MLLW (APPROX. 3:00 p.m.)

PLAN VIEW

SCALE: 1"=10'

TerraCosta Consulting Group	TERRACOSTA CONSULTING GROUP ENGINEERS AND GEOLOGISTS 3890 MURPHY CANYON ROAD, SUITE 200 SAN DIEGO, CA 92123 (858) 573-6900	FIGURE NUMBER 3
	PROJECT NAME COOK'S CRACK SEA CAVE	PROJECT NUMBER 2086B
	PLAN VIEW OF SEA CAVE	



CROSS SECTION

SCALE: 1"=20'

1

--

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FIGURE NUMBER	4
PROJECT NAME	COOK'S CRACK SEA CAVE
PROJECT NUMBER	2086B

CROSS SECTION

APPENDIX A

GEOTECHNICAL SURVEY AND EVALUATION
COOK'S CRACK SEA CAVE
JUNE 28, 2018
BY TERRACOSTA

TerraCosta
Consulting Group

GEOTECHNICAL SURVEY & EVALUATION
COOK'S CRACK SEA CAVE
SAN DIEGO, CALIFORNIA

Prepared for
CITY OF SAN DIEGO
San Diego, California

Prepared by
TERRACOSTA CONSULTING GROUP, INC.
San Diego, California

Project No. 2086A
June 28, 2018

TerraCosta Consulting Group
Geotechnical Engineering
Coastal Engineering
Maritime Engineering

Project No. 2086A
June 28, 2018

Mr. Joshua Lahmann, P.E., Senior Civil Engineer
CITY OF SAN DIEGO
Transportation & Stormwater Street Division
2781 Caminito Chollas, M.S. 44
San Diego, California 92105

GEOTECHNICAL SURVEY & EVALUATION
COOK'S CRACK SEA CAVE
SAN DIEGO, CALIFORNIA

Dear Mr. Lahmann:

TerraCosta Consulting Group, Inc. (TerraCosta) is pleased to present the accompanying report, which provides a summary of our geotechnical survey and mapping of the current limits of the Cook's Crack Sea Cave, and provides the results of our evaluation of stability of the sea cave extending under Coast Boulevard in the La Jolla area of San Diego, California.

We appreciate the opportunity to work with you on this project and trust this information meets your current needs. If you have any questions or require additional information, please give us a call.

Very truly yours,

TERRACOSTA CONSULTING GROUP, INC.

Gregory A. Spaulding, Project Geologist
P.G. 5892, C.E.G. 1863

Walter F. Crampton, Principal Engineer
R.C.E. 23792, R.G.E. 245, D.CE

GAS/WFC/jg
Attachments

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GEOTECHNICAL SURVEY & EVALUATION
COOK'S CRACK SEA CAVE
SAN DIEGO, CALIFORNIA

1 INTRODUCTION

This report presents a summary of TerraCosta's mapping and engineering analysis of the stability of the Cook's Crack Sea Cave extending under Coast Boulevard in the La Jolla area of San Diego, California (Figures 1 and 2, Photo 1). The City of San Diego has noted that portions of the roadway along South Coast Boulevard in the area of the sea cave are showing signs of extensive cracking, raising concerns as to the stability of the underlying soil and rock. In an earlier study, presented in our report titled, "Coastal Bluff Stability Study, Coast Boulevard Between Prospect Street and South Casa Beach (including La Jolla Cove and Children's Pool Beach), La Jolla, California," dated December 12, 2002, it was determined that although stable under the conditions in 2002, it was reasonable to conclude that at some time in the future, the Cook's Crack Sea Cave would collapse. That collapse mechanism would likely be in the form of a down-dropped block resulting in lost ground and/or settlement. It is important to note that in that study, the stability of the roof rock was based on static conditions with no additional growth of the sea cave. It is also important to note that seismic loading increases both the dead weight of the overhanging block and, depending upon the direction of seismic forces, stability of the roof rock is substantially reduced.

2 SCOPE OF WORK

Because of the distress observed in the pavements in the area overlying the Cook's Crack Sea Cave, concerns were raised over the stability of the sea cave and potential for collapse of the roof rock impacting the overlying Coast Boulevard improvements. Based on our understanding of the City of San Diego's current needs, we completed the following scope of work.

2.1 Survey Mapping

Survey mapping of the Cook's Crack Sea Cave was completed on June 5, 2018. Work was completed by setting survey control on the bluffs near the mouth of the sea cave (at the locations indicated on Figure 3) to provide a baseline for mapping. Survey mapping was completed by a geotechnical engineer and geologist from TerraCosta, assisted by two swimmers to help maintain survey control. During survey operations, a safety boat was stationed offshore from the sea cave to assist with ingress and egress of the cave.

2.2 Engineering Analysis

After mapping of the sea cave and geotechnical site conditions, and collection of data during the mapping process, an analysis of the stability of the sea cave in its current condition was completed, including calculating the factor of safety of overhanging blocks and estimating the thickness of the remaining supportive roof material. The results of our engineering analysis indicated that there has been no significant change in the stability of the principal overhanging blocks. It should be noted that minor block falls have occurred, as discussed below in Section 5.

3 SUMMARY OF GEOTECHNICAL CONDITIONS

3.1 Geologic Setting

Point La Jolla is a significant promontory formed by northerly movement of the land mass westerly of the Rose Canyon fault. The Rose Canyon Fault is part of the San Andreas fault system, which is the boundary between the Pacific Plate and the North American Plate. The Pacific Plate moves northerly in relation to the North American Plate at a rate of 5 to 6 cm per year. Within Southern California, that rate of movement is spread across numerous strike-slip faults across an approximately 100-mile-wide zone. Locally, it is estimated that the Rose Canyon fault zone is responsible for approximately 2 mm per year of movement within that zone. During the initial formation of the Rose Canyon Fault, a series of minor faults formed as the result of strain within the crust near the Rose Canyon Fault. While these minor faults are considered inactive, they have locally weakened the bedrock, allowing for the increase in erosion and the formation of sea caves and coves, as can be seen along San Diego's coastline. Some of these features can be seen on Photo 1.

3.2 Soil and Geologic Units

The two geologic formations present in the general coastal area of Cook's Crack Sea Cave are the 70- to 80-million-year old Point Loma Formation and the approximately 120,000-year-old Quaternary-age Bay Point Formation. Locally, overburden soils consisting of alluvium and colluvium, have also been deposited. The following paragraphs describe these units from oldest to youngest.

Point Loma Formation (Kp): The Cretaceous-age Point Loma Formation is an approximately 900-foot-thick sedimentary rock unit that discontinuously crops out along the coastline between northern Baja California to as far north as Carlsbad (Kennedy, 1975). Along this reach of the coastline, it forms the lower, more resistant parts of the sea cliff. Based on our review of geologic mapping by Kennedy, bedding within the Point Loma Formation dips (locally) approximately 20 degrees to the south within the area of the Cook's Crack Sea Cave. The Point Loma Formation consists of well-indurated marine sediments deposited offshore within a deep-water environment, which are represented by thinly bedded siltstone and fine sandstone. The Point Loma Formation is depicted by a narrow strip of blue along the coastline, and is identified as Kp, on the Geologic Map (Figure 1).

Bay Point Formation (Qbp): The Pleistocene-age Bay Point Formation forms the upper coastal bluff terrace deposits. The Bay Point Formation is restricted in age to between 80,000 and 120,000 years and is deposited on a wave-cut platform formed on the Point Loma Formation during the last interglacial period when worldwide sea level was approximately 20 feet higher. These deposits generally consist of marine and non-marine silty to clayey sandstones and hard sandy clays that form the moderate slopes on the coastal terraces, and are exposed in the bluffs in the project area. Geologic evidence indicates that, since deposition of the Bay Point Formation, Point La Jolla has locally been uplifted upwards of 23 feet near Goldfish Point east of Cook's Crack at a rate of about 0.2 inch per 100 years. The Bay Point Formation is designated in orange and identified as Qbp on Figure 1.

Alluvial and Colluvial Deposits (not mapped): Geologically recent alluvial and colluvial soils and the topsoils developed on them are present over most of the terrace in the area and on the slopes above and to the south and east of the project site.

Typically less than 2 feet in thickness, these soils consist of porous, loose to medium dense, silty to clayey sands with occasional gravel.

Artificial Fill (not mapped): Artificial fill soils, consisting predominantly of silty to clayey sands with gravel, commonly exist as the result of the development of numerous bluff-top improvements. These moderately to poorly compacted fills are commonly locally derived and generally range up to a few feet in thickness. Fill also exists as soil backfill of utility trenches.

3.3 Geologic Structure

Tectonic forces associated with movement along the Rose Canyon fault zone and strain, which pre-dates the Rose Canyon fault zone (Fischer and Mills, 1991; Greene and Kennedy, 1981), have resulted in the formation of minor faults and joints locally within the Point Loma Formation bedrock. Crustal warping associated with tectonic activity has gently tilted the bedding and shore platform on the order of 20 degrees to the south (locally). These long-continued tectonic stresses have resulted in literally thousands of visible joints, fractures, and shear zones ranging from micro to large scale.

3.4 Groundwater

A contributor to the erosion of coastal bluffs is the flow of groundwater along the contact between the relatively pervious, moderately consolidated coastal terrace deposits and the well-indurated, less pervious, Cretaceous formations that form the lower sea cliffs. During our mapping and reconnaissance, localized seepage was observed in both fractures and sea caves. The groundwater typically migrates through the permeable terrace deposits, where it eventually encounters and enters the joints and fractures within the Point Loma Formation where, over time, it partially dissolves the cementing agents within the rock, further weakening the rock along the joint or fracture, thus locally increasing the rock's susceptibility to erosion and aiding in the formation of sea caves.

Generally, the sources of groundwater are natural groundwater migration from highland areas to the east of the project site, and infiltration by rainfall, irrigation water, and leakage of utilities.

4 ANALYSIS OF CAVE STABILITY

Our current survey indicates that as expected, the sea cave has widened approximately 6 to 8 feet (Figure 3) and continues to advance southerly under the sidewalk on the southerly side of Coast Boulevard, as shown on Figure 2. Figures 2 through 8 illustrate the current limits of the sea cave. Photos 2 through 8 are of the interior of the sea cave. It should also be noted that there is evidence of the widening of the fault, allowing the down-dropping of a smaller block, as illustrated on Figure 8 and discussed below in Section 5.

As discussed above, an analysis of the Cook's Crack Sea Cave was completed in 2002. That study found that, at that time, the sea cave was relatively stable against failure and collapse, with calculations exhibiting factors of safety against collapse ranging from 1.32 to 1.89. Our recent analysis of block and wedge failure of the current conditions revealed that there has been no substantial change in the overall stability of the sea cave.

5 OBSERVATIONS AND SITE CONDITIONS

Observations made during our current mapping of the sea cave indicated that additional block failures have occurred since 2002, which appear to have locally weakened the roof of the sea cave. In addition, there is evidence that groundwater seepage, widening of a major through-going fracture (fault), localized collapse of a block from the roof, and the apparent migration of sand from the overlying terrace deposits have occurred (Photos 5, 5a, 6, and 6a). Figure 8 illustrates the basic problem with the dropping of the approximately 19-foot-long, 2-foot-wide block by approximately 3 feet, which has resulted in some lost ground and the loss of intimate contact that one time existed between the southeasterly face of the northwesterly overhanging block where it lays against the faulted face of the formation on the left side of the crack. Recent construction activities and related heavy traffic may have contributed to the movement of this block and migration of sand into the fracture.

6 CONCLUSIONS AND RECOMMENDATIONS

Based on the results of our mapping, observations, and engineering analysis, it is our opinion that within a few years, there is a high probability of collapse of portions of the sea cave and/or the formation of voids under Coast Boulevard by downward migration of Bay Point

Formation soils through widening fractures into the sea cave. This mechanism is exhibited in Figure 8, with sands from the overlying terrace deposits now migrating through this underlying fracture. This lost ground will progressively worsen with time. Based on our recent observations, we recommend that the roadway over the sea cave be closely monitored for signs of settlement, and that the sea cave be inspected again in the next five years. It is also our opinion that a structural solution is necessary to prevent a future catastrophic failure.

Given the increased probability of a collapse and/or voids developing along Coast Boulevard, we recommend that the following solutions be considered.

6.1 **Stabilization Options**

6.1.1 *Sea Cave Infill*

A common solution for mitigating the potential for collapse of a sea cave is to infill the cavity with concrete. This would likely entail drilling a series of access holes through the top of the cave roof and pumping a concrete mix into the sea cave to provide support against collapse. The concrete mix should consist of a lean (sand-cement) mix pumped into the outer portion of the cave that will erode as the face of the bluff erodes in the future, with a stronger more fluid mix to completely fill all of the voids within the interior of the cave.

6.1.2 *Chemical Grouting of Terrace Deposits*

A temporary solution would involve chemically grouting the terrace deposits to strengthen the soils and aid in preventing the piping of the overlying terrace deposit soils into the developing cracks along the fault trace. Grouting would be completed on a grid pattern and consist of either a micro-fine cement or silicate type grout to solidify the sandier materials within the terrace deposits.

6.1.3 *Construct a Bridge*

This option would consist of constructing a bridge over the sea cave, allowing the sea cave to collapse over time. This solution would require relocation of utilities to prevent the loss and interruption of utilities as the sea cave collapses. This solution does not prevent the propagation and advancement of the sea cave, which would eventually affect the properties adjacent to Coast Boulevard.

7 LIMITATIONS

The data provided in this report were collected from our field observations and mapping of Cook's Crack Sea Cave, previously published reports and maps, and our general knowledge of geologic and geotechnical conditions in the area. No subsurface exploration or laboratory testing were performed for this report. This report was not prepared for any specific repair option. Therefore, it may not satisfy the requirements of regulatory agencies or reviewers if submitted, and additional site-specific investigation may be required. This report is not valid after two years after its issue date.

REFERENCES

1. Fischer, P.J., and G.I. Mills, 1991, "The Offshore Newport-Inglewood - Rose Canyon Fault Zone, California: Structure, Segmentation and Tectonics," in P.L. Abbott and W.J. Elliott (eds.), Environmental Perils - San Diego Region, published by San Diego Association of Geologists, pp. 17-36.

2. Greene, H.G., and M.P. Kennedy, 1981, Review of Offshore Seismic Reflection Profiles in the Vicinity of the Christianitos Fault, San Onofre, California, unpublished U.S. Geological Survey Document prepared for the Nuclear Regulatory Commission.

3. Kennedy, M.P., 1975, Geology of the San Diego Metropolitan Area, California: Section A - Western San Diego Metropolitan Area (Del Mar, La Jolla, Point Loma 72 minute quadrangles); and Section B - Eastern San Diego Metropolitan Area (La Mesa, Poway, and SW 3 Escondido 72 minute quadrangles), California Department of Conservation, Division of Mines and Geology, Bulletin 200.

4. TerraCosta Consulting Group, Inc., December 12, 2002, Coastal Bluff Stability Study, Coast Boulevard Between Prospect Street and South Casa Beach (including La Jolla Cove and Children's Pool Beach), La Jolla, California.

TerraCosta Consulting Group **TERRACOSTA CONSULTING GROUP** 3890 Murphy Canyon Road, Suite 200 San Diego, California 92123 (858) 573-6900	PROJECT NO.: **2086A**	PROJECT NAME: **COOK'S CRACK SEA CAVE**	PHOTO NO.: **1**

PHOTO 2: NOTE LARGE CONCRETION IS GONE, AND WALLS HAVE ERODED BACK AND WIDENED.

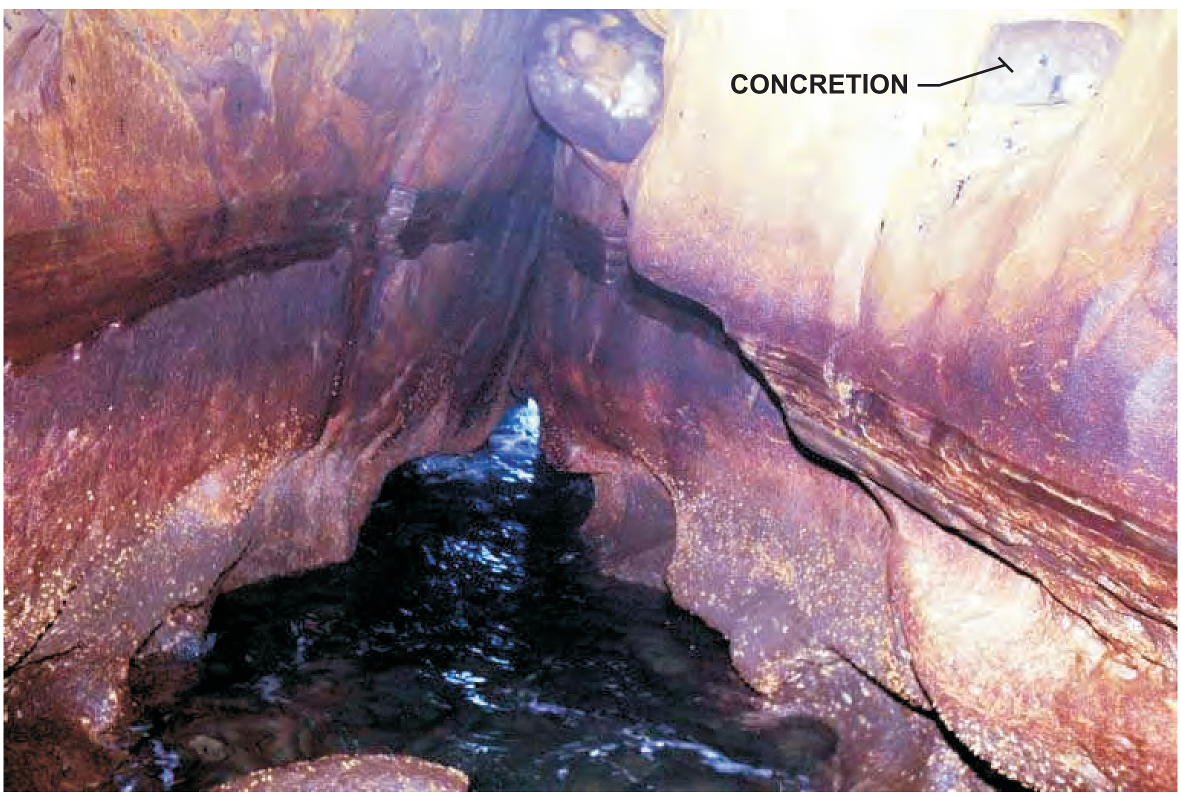

PHOTO 2A: (2002) LOOKING OUT. NOTE EXISTING CONCRETION AT UPPER EDGE OF PHOTO.

TerraCosta Consulting Group	PROJECT NO.:	PROJECT NAME:	PHOTO NOS.:
TERRACOSTA CONSULTING GROUP 3890 Murphy Canyon Road, Suite 200 San Diego, California 92123 (858) 573-6900	**2086A**	**COOK'S CRACK SEA CAVE**	**2 & 2A**

PHOTO 3: MAIN BLOCK SEEN IN 2002 SURVEY STILL MOSTLY INTACT. A CAVITY HAS DEVELOPED, UNDERMINING THE SOUTHERLY SIDE OF THE BLOCK.

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PHOTO 4: TAKEN IN 2002.

PHOTO 4A:
NOTE SAND LEVEL HAS DROPPED 1.5 TO 5 FEET.

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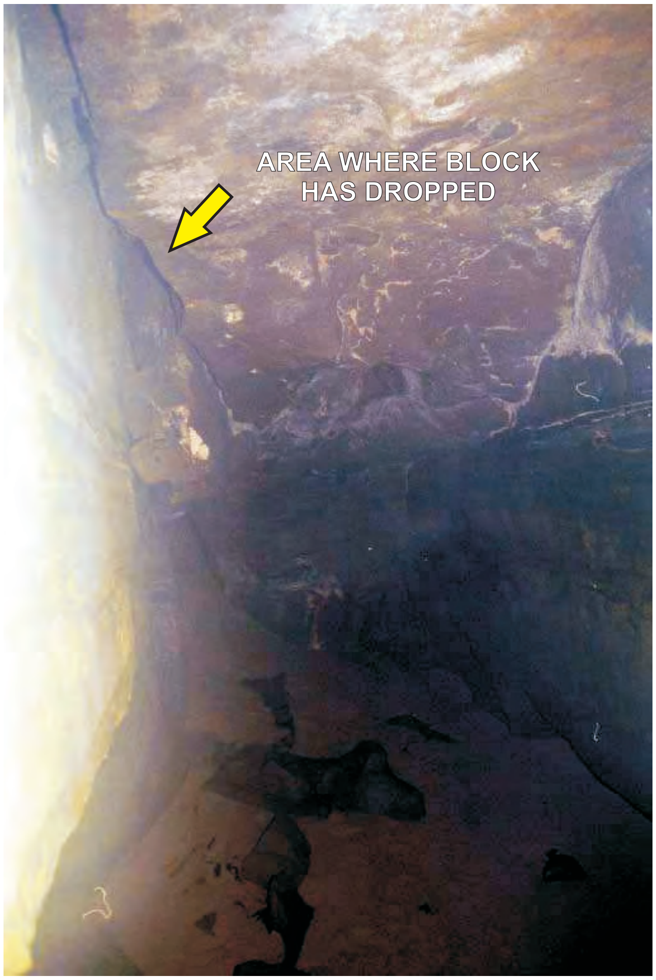

PHOTO 5: (2002) NOTE AREA PRIOR TO RECENT ROOF BLOCK FAILURE.

PHOTO 5A: NOTE APPARENT RECENT ROCK DEBRIS (ARROW).

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PHOTO 6: ARROW INDICATES DOWN DROPPED BLOCK. NOTE SAND ON TOP OF BLOCK.

PHOTO 6A: NOTE SAND PIPING FROM OVERLYING TERRACE DEPOSITS (ARROW).

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PHOTO 7: SOUTHWEST CAVE EXTENSION

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PHOTO 8: NORTHWEST CAVE EXTENSION

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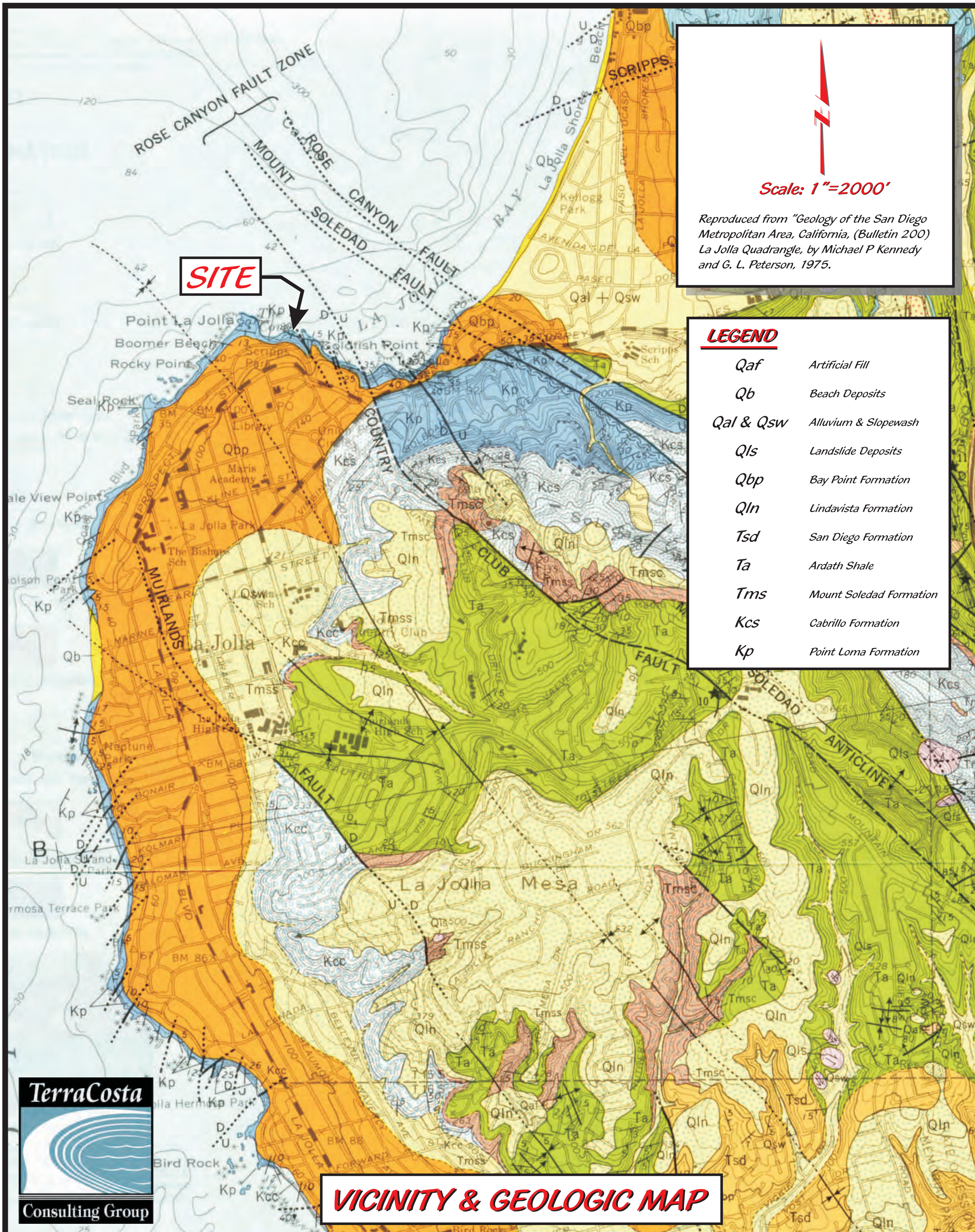

Project Name: Cook's Crack Sea Cave Project No.: 2086A Figure No.: 1

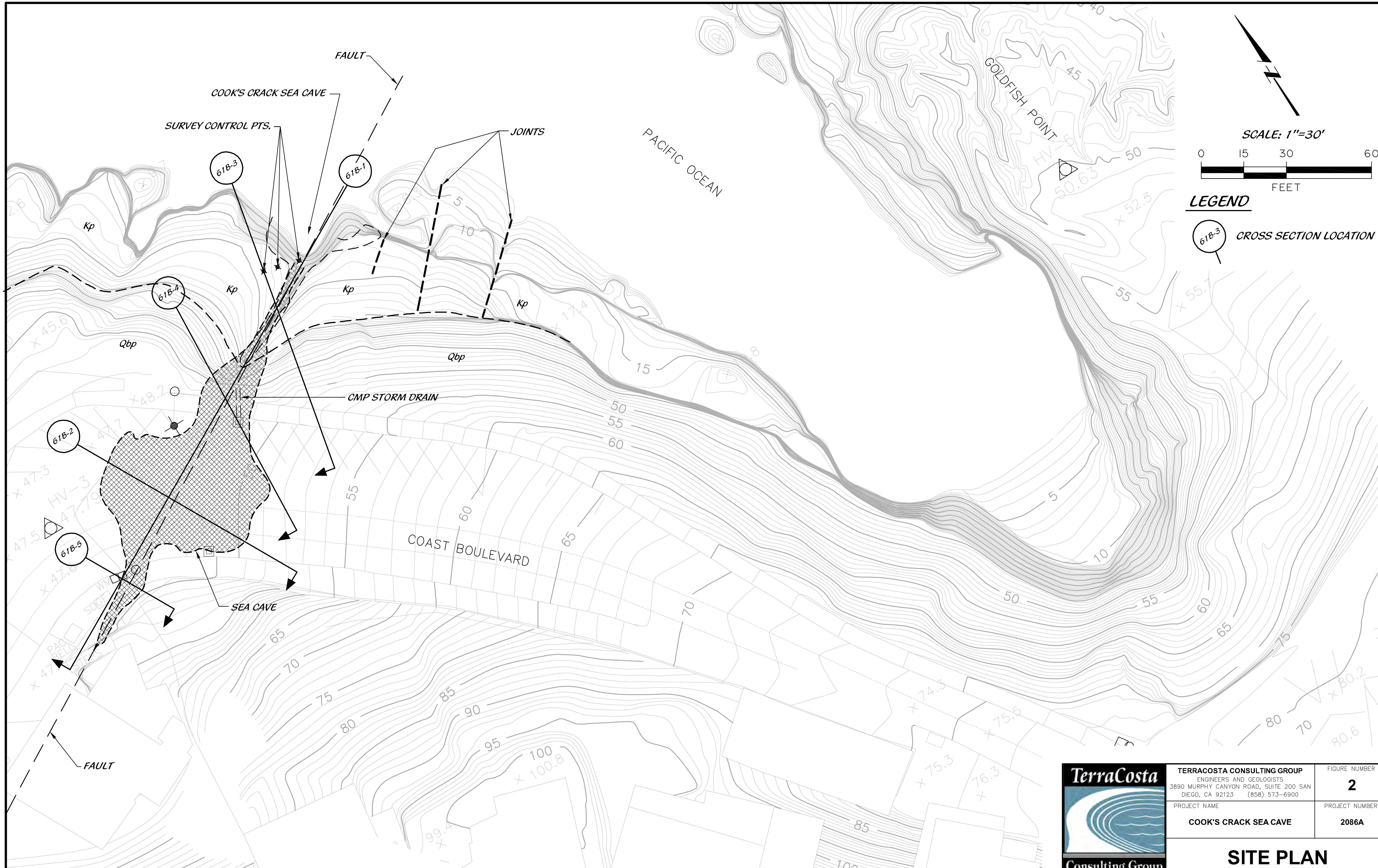

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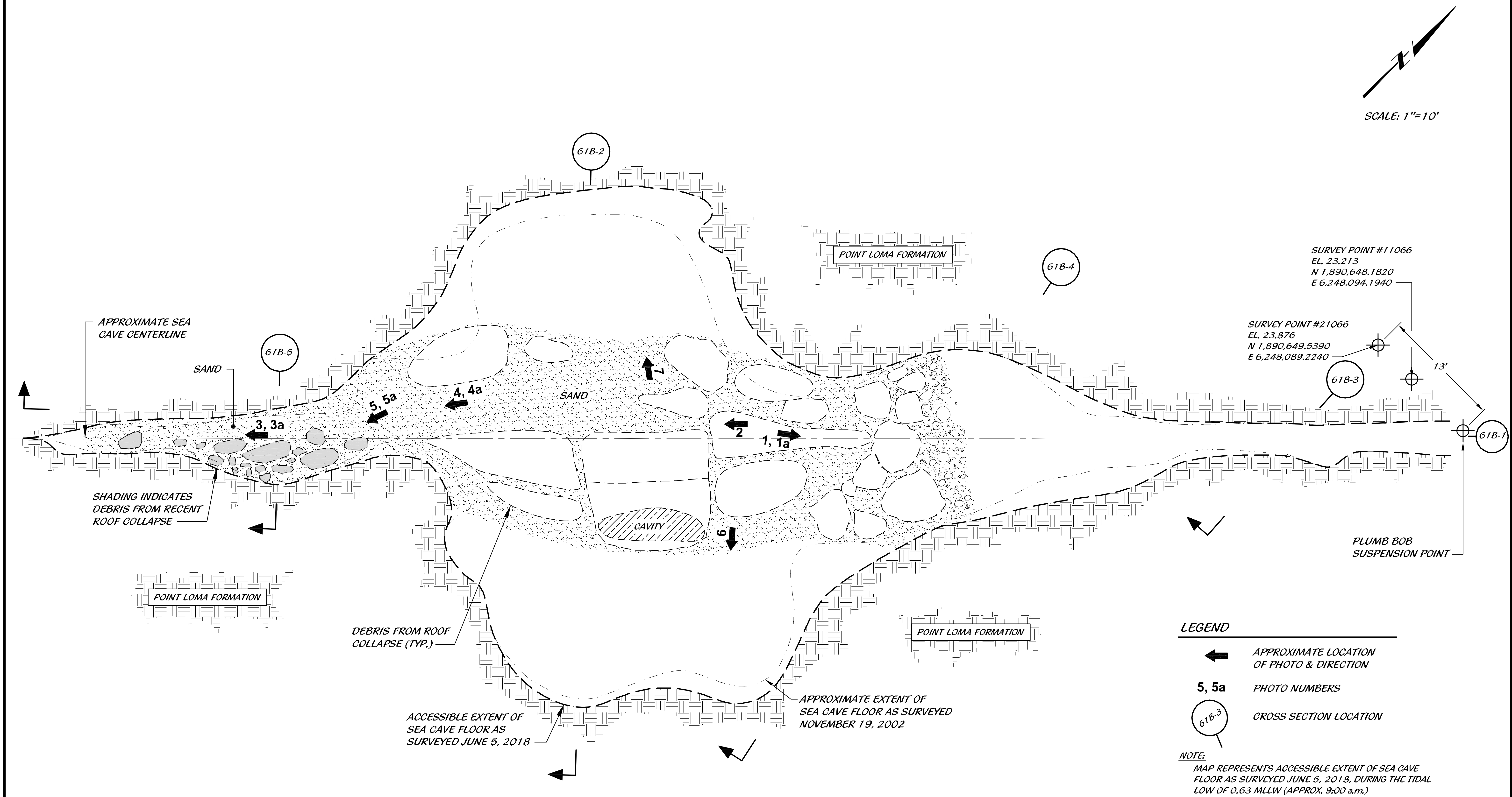
FIGURE NUMBER 2

PROJECT NAME: COOK'S CRACK SEA CAVE

PROJECT NUMBER: 2086A

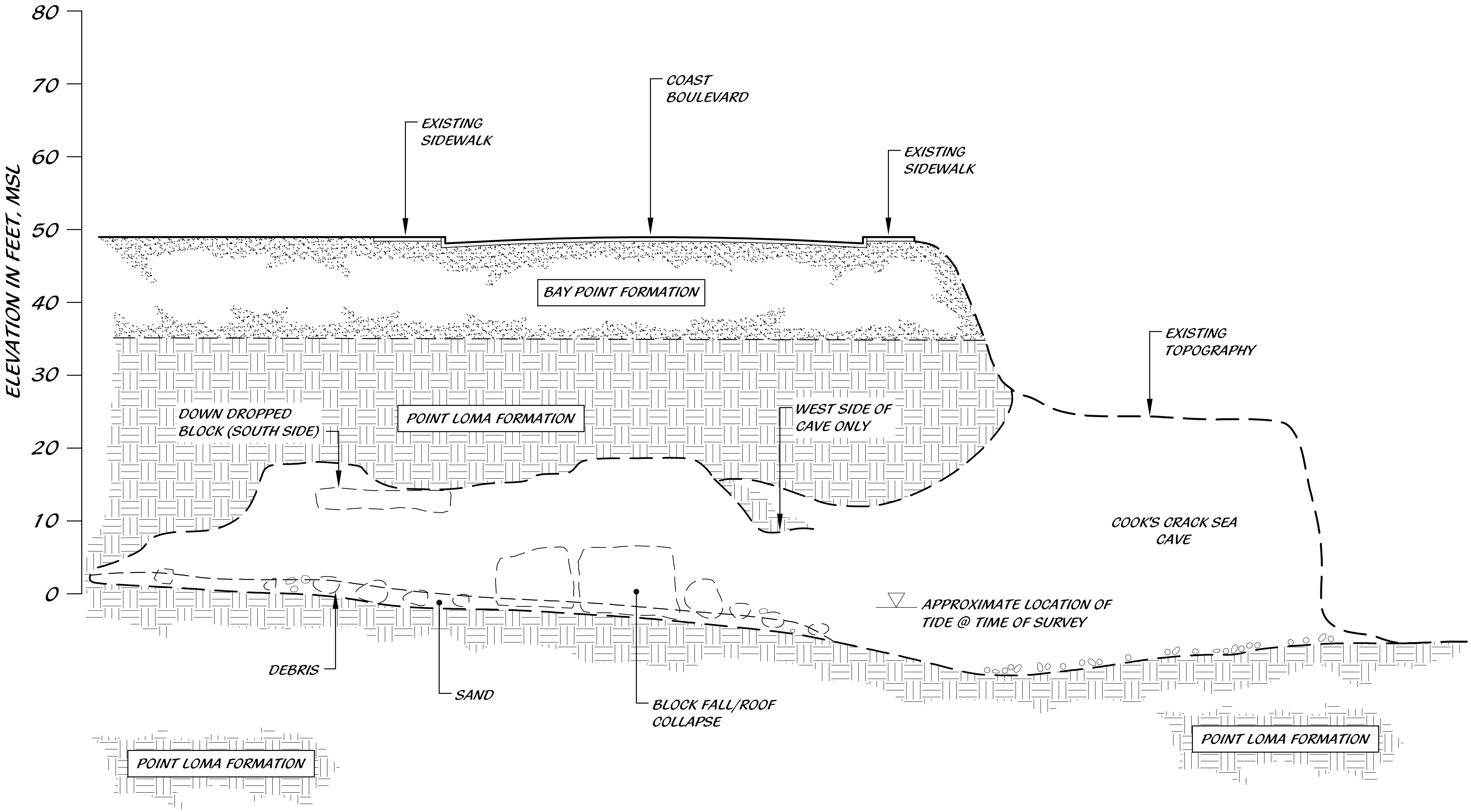
SITE PLAN



PLAN VIEW

SCALE: 1"=10'

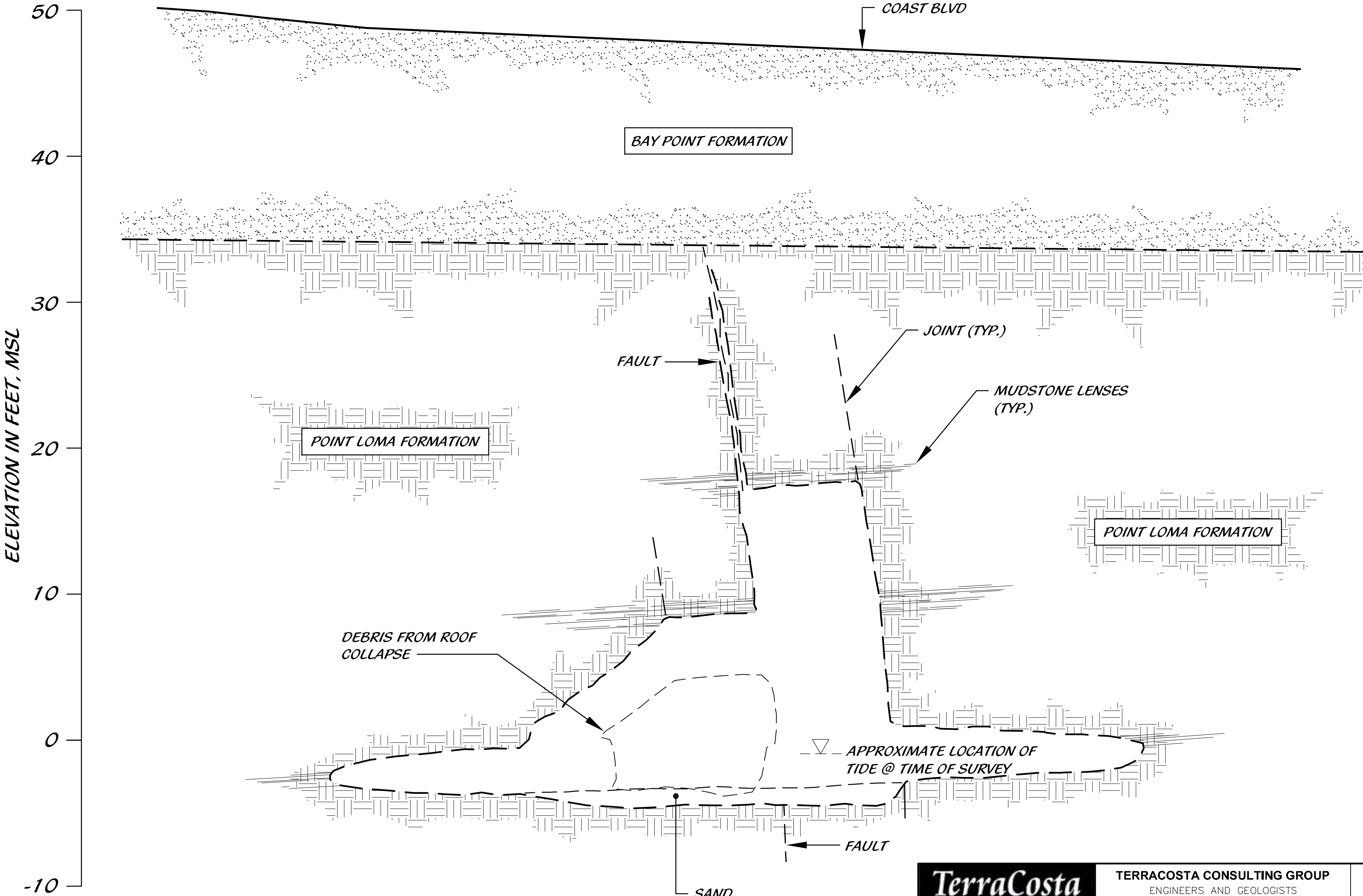
TerraCosta Consulting Group	TERRACOSTA CONSULTING GROUP ENGINEERS AND GEOLOGISTS 3890 MURPHY CANYON ROAD, SUITE 200 SAN DIEGO, CA 92123 (858) 573-6900	FIGURE NUMBER 3
	PROJECT NAME COOK'S CRACK SEA CAVE	PROJECT NUMBER 2086A
	PLAN VIEW OF SEA CAVE	



CROSS SECTION 61B-1

SCALE: 1"=20'

TerraCosta Consulting Group	TERRACOSTA CONSULTING GROUP ENGINEERS AND GEOLOGISTS 3890 MURPHY CANYON ROAD, SUITE 200 SAN DIEGO, CA 92123 (858) 573-6900	FIGURE NUMBER 4
	PROJECT NAME COOK'S CRACK SEA CAVE	PROJECT NUMBER 2086A
	CROSS SECTION 61B-1	



CROSS SECTION

61B-2

SCALE: 1"=10'

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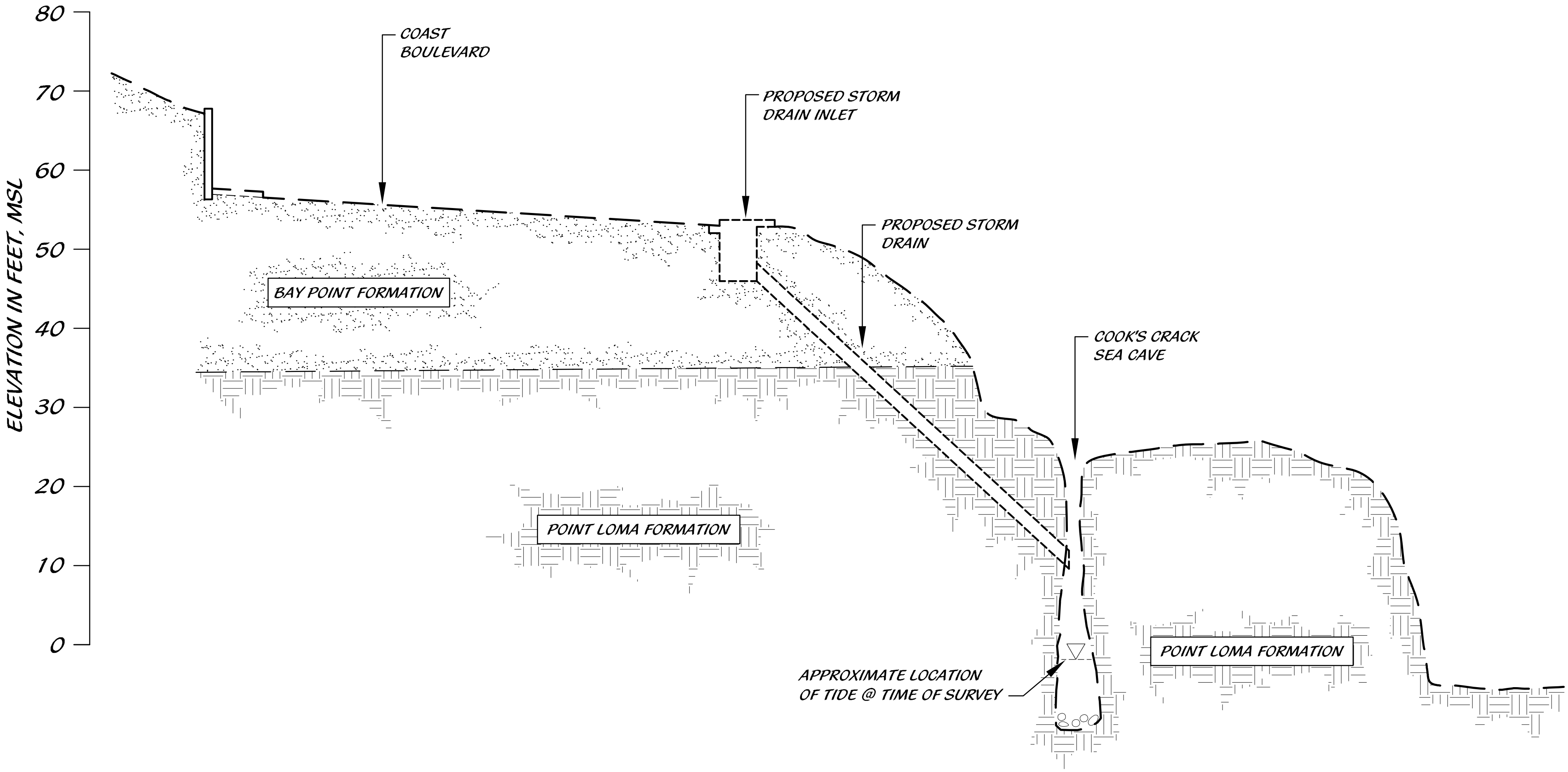
	PROJECT NAME **COOK'S CRACK SEA CAVE**	PROJECT NUMBER **2086A**
	CROSS SECTION 61B-2	



CROSS SECTION

61B-3

SCALE: 1"=20'

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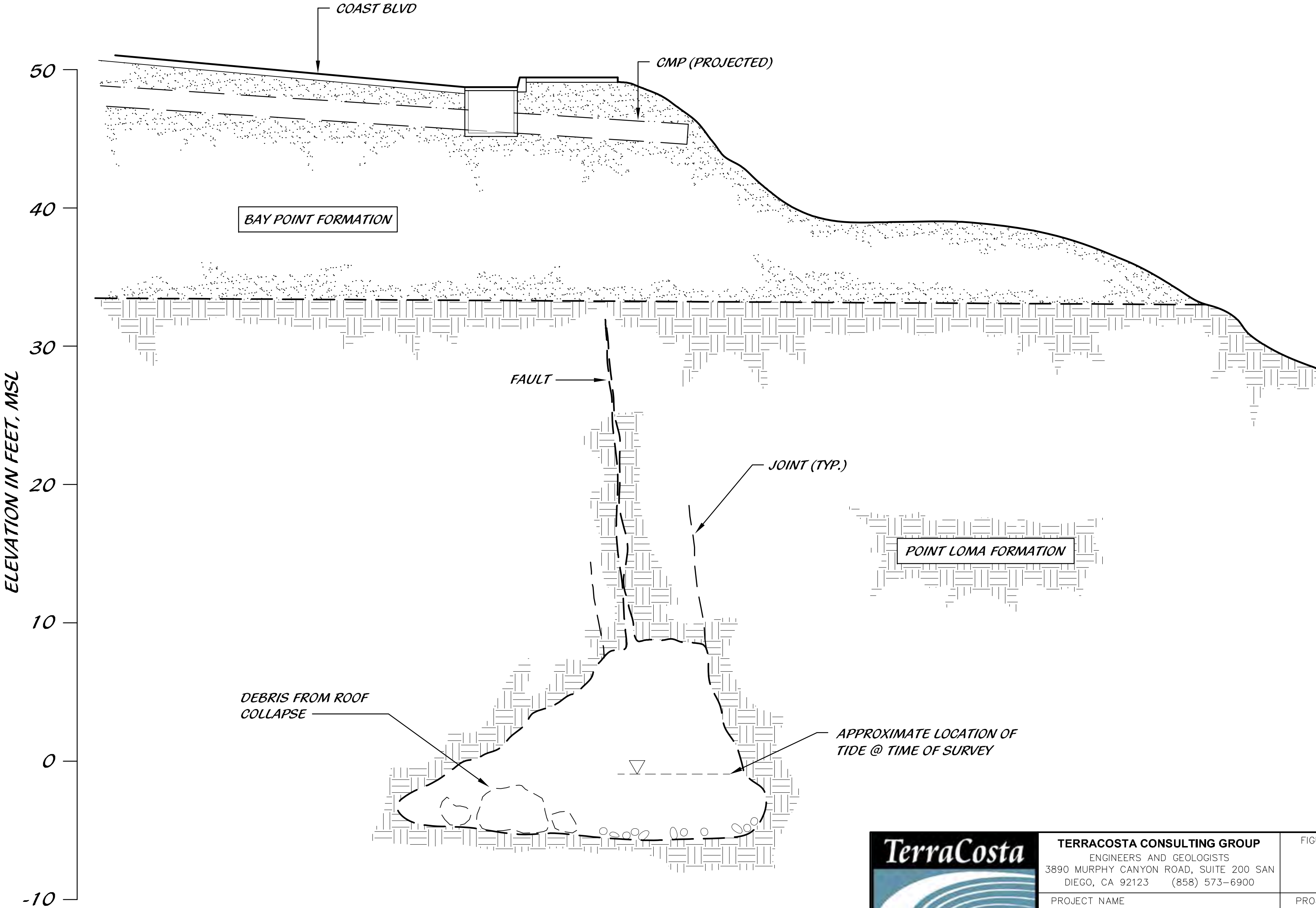
FIGURE NUMBER	PROJECT NAME	PROJECT NUMBER
6	COOK'S CRACK SEA CAVE	2086A

CROSS SECTION 61B-3



CROSS SECTION

61B-4

SCALE: 1"=10'

TERRACOSTA CONSULTING GROUP ENGINEERS AND GEOLOGISTS 3890 MURPHY CANYON ROAD, SUITE 200 SAN DIEGO, CA 92123 (858) 573-6900	FIGURE NUMBER 7
PROJECT NAME COOK'S CRACK SEA CAVE	PROJECT NUMBER 2086A

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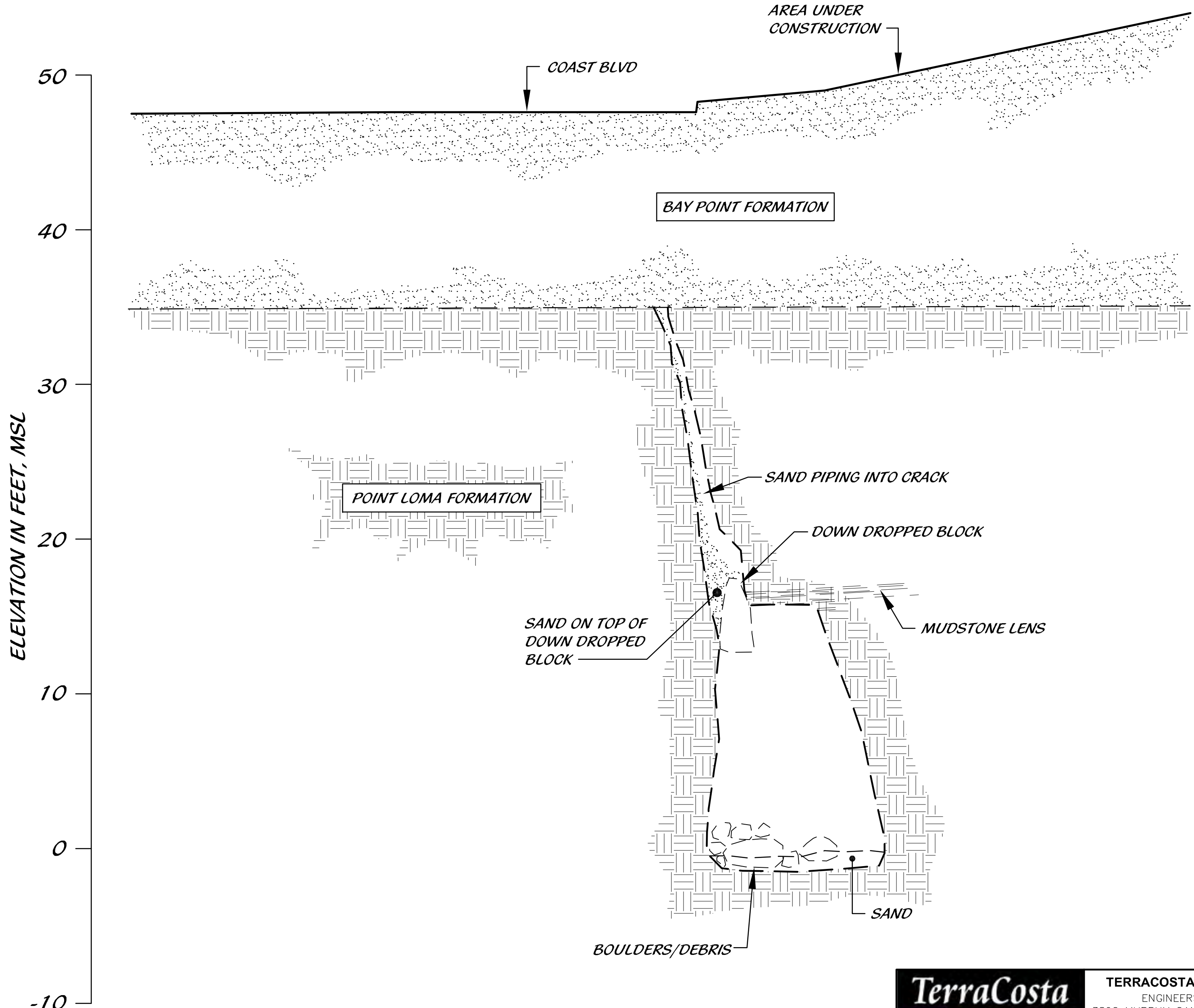
CROSS SECTION 61B-4



CROSS SECTION 61B-5

SCALE: 1"=10'

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FIGURE NUMBER	**8**
PROJECT NAME	**COOK'S CRACK SEA CAVE**
PROJECT NUMBER	**2086A**

CROSS SECTION 61B-5

APPENDIX B

GT1000MB PRODUCT LITERATURE

TerraCosta Consulting Group

TenCate Geotube

GT1000MB (Sand-color GT1000 Marine/Beach)

GT1000MB is composed of high-tenacity polypropylene multifilament yarns, which are woven into a stable network such that the yarns retain their relative position. GT1000MB is inert to biological degradation and resistant to naturally encountered chemicals, alkalis, and acids.

Mechanical Properties	Test Method	Unit	Minimum Average Roll Value	
			Machine Direction	Cross Direction
Wide Width Tensile Strength (at ultimate)	ASTM D4595	lbs/in (kN/m)	1026 (180)	1026 (180)
Wide Width Tensile Elongation	ASTM D4595	%	20	10
Factory Seam Strength[1]	ASTM D4884	lbs/in (kN/m)	582 (102)	
Apparent Opening Size (AOS)	ASTM D4751	U.S. Sieve # (mm)	30 (0.60)	
Water Flow Rate	ASTM D4491	gpm/ft^2 (l/min/m^2)	20 (813)	
Mass/Unit Area[1]	ASTM D5261	oz/yd^2 (g/m^2)	28 (949)	
UV Resistance (% strength retained after 500 hrs)	ASTM D4355	%	70	

[1]Factory Seam Strength and Mass/Unit Area are Typical Values

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