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PHASE I KARST AND SLOPE STABILITY HAZARDS INVESTIGATION

Peace United Church - Envision Housing
Proposed Housing Development
900 High Street
Santa Cruz, California

Job #2018011-G-SC
2 July 2018

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Envision I, LLC
Attention: Alyssa Willett
Chief Financial Analyst, Envision Housing
740 Front Street, Suite 345B
Santa Cruz, CA 95060

Re: Phase I karst and slope stability hazards investigation
Proposed apartment housing
900 High Street
Santa Cruz, CA 95060
County of Santa Cruz APN 001-022-40

Dear Ms. Willett:

This report presents the results of our Phase I karst and slope stability hazards investigation for the proposed apartment housing project, located in karst terrane on the Peace United Church campus at 900 High Street, Santa Cruz, California. The project has advanced to the conceptual design status and we have attempted to integrate our analysis with that work, completed on 4/12/2018.

FINDINGS

In our opinion, the potential is low to moderate for the karst-related hazard of ground subsidence to occur within the lifetime of the proposed developments within the identified doline centered on boring B2 (see Plates 1 and 2). This hazard potential corresponds to a greater than “ordinary risk” as defined in Appendix B of this report and should be mitigated to lower it to an “ordinary risk”.

The balance of the site is subject to a low potential for karst-related ground subsidence corresponding to an “ordinary risk”, provided our recommendations for grading, drainage and irrigation are followed.

If an “ordinary risk” level is unacceptable to the developer and the property owners, then the geologic hazards identified should be mitigated to reduce the corresponding risks even further to an acceptable level.

The site is located in an area of high seismic activity and will be subject to strong seismic shaking in the future.

Most of the historically reactivated dolines and sinkholes have been triggered by unnaturally high contributions of storm water or domestic water into the subsurface, due to poor control, construction and maintenance of the water utilities. Given the dissolution zone at the marble surface across the entire site, as well as the existing doline on the lower parking lot site, it should be assumed that adding water to the subsurface in an unnatural fashion at the site may trigger the formation of sinkhole.

RECOMMENDATIONS

1. The project geotechnical engineer should analyze the blanket of denser soils that overlie the marble bedrock in the area centered on boring B2, flagged as a doline of concern (shaded orange polygons on Plate 1), taking our prescribed maximum doline width into account. The geotechnical engineer should determine if the density and thickness of this surficial "blanket" is sufficient to buffer any structures from damage caused by the potential stoping or settlement of the relatively softer soils below. Mitigation of this condition should be proposed if warranted. Mitigation schemes could potentially include proper foundation design, ground improvement under the foundation, or subsurface changes made to the soft soil zones.

2. Because of the high degree of variability of soil conditions over short intervals encountered throughout the study area, we recommend that all structures for the lower parking lot area be designed to span zones of subsidence or soil collapse of a prescriptive minimum of thirty feet. We recognize that this may be economically prohibitive for residential construction. The minimum prescriptive subsidence zone value can be potentially reduced by drilling on a denser grid under the proposed structures in order to reduce the uncertainty of the marble surface between the current spacing of the borings.

   We recommend a gridded drilling program be pursued for the upper meadow quadplex development prior to any foundation design being pursued. The drilling grid should be laid out to allow for borings to be completed under the proposed residential footprint. One or more borings should be advanced near the steep quarry wall that lies to the east of the site in order to characterize the thickness and character of the marine terrace deposits that overlie the marble bedrock. All borings advanced on the upper meadow site should be drilled to refusal on the underlying marble bedrock.

3. We recommend that all of the storm water generated for this project be disposed in the City of Santa Cruz storm drains. Attenuating the storm flows by detaining the water in

impervious structures is geologically acceptable, as long as the water is NOT allowed to infiltrate the soil.

4. Landscape watering for the project should NOT saturate the subgrade in an unnatural fashion. The natural distribution and application rate of rainfall should be emulated for landscaping irrigation, in order to avoid saturating the subgrade and triggering a doline collapse.

5. Seismic shaking values for any structures designed on the property should at least adhere to the minimum prescriptive design values outlined in the 2016 California Building Code. The seismic shaking values should be developed by the Project Geotechnical Engineer of Record as part of their soils report for the design of proposed structures.

6. Any soft soil zones exposed in the foundation footings or soil changes encountered during excavation should be investigated in the field at the time of construction by the project geotechnical engineer and the project geologist.

7. We recommend that Zinn Geology be retained to inspect all cuts made during grading for the project in order to identify unanticipated potential karst hazards.

8. We recommend that our firm be provided the opportunity for a review of the final design and specifications in order that our recommendations may be properly interpreted and implemented in the design and specification. If our firm is not accorded the privilege of making the recommended review we can assume no responsibility for misinterpretation of our recommendations.

Sincerely,
ZINN GEOLOGY

Erik N. Zinn
Principal Geologist
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NOTE: Plate and figures must accompany text of report in order for report to be considered complete.

INTRODUCTION

This report presents the results of preliminary geological investigation report for the proposed residential housing project located north of Peace United Church at 900 High Street, Santa Cruz, California (Figure 1 and Plate 1). The purpose of our investigation was to investigate the geological hazards that might pose elevated risks to the housing development. The primary focus of the investigation was to evaluate the geologic conditions underlying the site, focusing on the identification of potentially hazardous karst features that could possibly contribute to settlement or collapse of soil under the building sites and infrastructure, and if necessary recommend mitigation measures to lower the risk posed to the structures. We also investigated the potential for the steep wall from the abandoned marble quarry east of the development to fail and impinge upon the proposed developments.

The currently proposed development depicted on the conceptual plans dated 4/12/2018 will consist of 8 to 10 three-story town homes on the lower dirt parking lot, as well as 12 quadplexes on the upper meadow site. We focused solely on the three-story town homes for this investigation at the request of the client, although we have attempted to extrapolate findings and recommendations in a preliminary fashion from the data procured for this project.

SCOPE OF INVESTIGATION

Work performed during this study included:

1. Discussion of the proposed scope of work with the project geotechnical engineer, Becky Dees of Dees & Associates [DA].
2. Multiple meetings, teleconferences and email correspondence with the design team.
3. A review of geologic literature pertinent to the site, including the logs of exploratory borings advanced by former consultants for the surrounding area.
4. Field mapping of surface exposures and outcrops at the site and in the general vicinity.
5. Observation of select small-diameter exploratory borings advanced by DA.
6. Construction of interpretive geologic cross-sections and a geological map of the site.
7. Presentation of our preliminary findings and recommendations in this report.

Please refer to the DA geotechnical engineering report to view the boring logs generated for their investigation.

REGIONAL GEOLOGY

The site is situated on the western flank of the Santa Cruz Mountains, in the central portion of the Coast Ranges Physiographic Province of California. The Coast Ranges Province consists of a series of coastal mountain chains paralleling the pronounced northwest-southeast structural grain of central California geology. The structural grain is controlled by a complex of active faults and faults with pre-Holocene activity, that form the San Andreas fault system. Southwest of the San Andreas fault, the Coast Ranges including the Santa Cruz Mountains are underlain by a large, northwest-trending, fault-bounded, elongate prism of granitic and metamorphic basement rocks, collectively known as the Salinian Block. The Salinian Block is separated from contrasting basement rock types to the northeast and the southwest by the San Andreas and the Sur-Nacimiento fault systems, respectively (Figure 2). Overlying the granitic and metamorphic basement rocks is a sequence of dominantly marine sediments of Tertiary age and non-marine sediments of Pliocene to Pleistocene age. The Tertiary and younger rocks occur only as thin, scattered patches of deposits that overlie the exposed metamorphic and granitic basement complex in the vicinity of the site.

Throughout the late Cenozoic Era (approximately the past 25 million years), central California has been dominated by tectonic forces associated with lateral or “transform” motion between the North American and Pacific crustal plates, producing a complex system of northwest-trending faults (the San Andreas Fault system) (Figure 3). These faults show horizontal displacements measured in tens to hundreds of miles. Uplift, deformation, erosion, and subsequent re-deposition of sedimentary rocks have been driven primarily by the northwest-directed, horizontal (strike-slip) movement of the plates and the associated southwest to northeast-oriented compressive stress. The region continues to be characterized by moderate to high rates of tectonic and seismic activity.

The site is underlain by metamorphosed sedimentary rocks, consisting of marble and schist, that are locally cut by veins of intruding granitic rock. These rocks cap the massive granitic intrusion that forms the core of Ben Lomond Mountain. The original horizontally layered sequence of meta-sedimentary rocks has been disrupted by folding and faulting of the section, but the original layering is still reflected in the distribution of the different rock types. On the nearby University of California at Santa Cruz campus, beds of the schist and marble appear generally to be steeply inclined and inter-fingering. The Ben Lomond fault borders the university campus to the east and northeast as mapped by Stanley and McCaffrey (1983), although it should be noted that the fault’s southerly terminus was mapped several miles north of the site near the town of Felton by Clark (1981).

The granitic intrusion, metamorphism, and much of the folding and faulting that accompanied uplift of the rock mass to the earth’s surface are ancient occurrences, several tens of million years to greater than one hundred million years old. The recent geologic history of the area (the last 500,000 years) is characterized by gentle regional uplift, now occurring at a rate of about 0.4 mm per year, and gradual reduction of the earth's surface by stream erosion, dissolution of marble by groundwater, and episodes of sea cliff erosion during high sea-level stands.

REGIONAL FAULTING AND SEISMICITY

Central California's system of faults has had a complex history of movement over the past 15 to20 million years. Many of these faults are either active or are considered potentially active (Hall et al., 1974; Buchanan-Banks et al, 1978) and may be expected to produce moderate to strong seismic shaking on the site. These faults include the San Andreas, San Gregorio, Zayante-Vergeles, Monterey Bay-Tularcitos, Butano and Ben Lomond faults. These faults are discussed in following sections of this report and graphically depicted on Figures 2 and 3.

San Andreas Fault

The San Andreas fault is active and represents the major seismic hazard in northern California(Working Group on Northern California Earthquake Potential [NCEP], 1996). The main trace of the San Andreas fault trends northwest-southeast and extends over 700 miles from the Gulf of California through the Coast Ranges to Point Arena, where the fault extends offshore.

Geologic evidence suggests that the San Andreas fault has experienced right-lateral, strike-slip movement throughout the latter portion of Cenozoic time (the past 20 to 30 million years), with cumulative offset of hundreds of miles. Surface rupture during historical earthquakes, fault creep, and historical seismicity confirm that the San Andreas fault and its branches, the Hayward, Calaveras, and San Gregorio faults, are all active today.

Historical earthquakes along the San Andreas fault and its branches have caused significant seismic shaking in the Monterey Bay area. The two largest historical earthquakes on the San Andreas to affect the area were the moment magnitude (M_w) 7.9 San Francisco earthquake of 18April 1906 (actually centered near Olema) and the M_w 6.9 Loma Prieta earthquake of 17 October1989. The San Francisco earthquake caused severe seismic shaking and structural damage to many buildings in the Monterey Bay area. The Loma Prieta earthquake appears to have caused more intense seismic shaking than the 1906 event in localized areas of the Santa Cruz Mountains, even though its regional effects were not as extensive. There were also significant earthquakes in northern California along or near the San Andreas fault in 1838, 1865 and possibly 1890 (Sykes and Nishenko, 1984; NCEP, 1996).

Geologists have recognized that the San Andreas fault system can be divided into segments with"characteristic" earthquakes of different magnitudes and recurrence intervals (Working Group on California Earthquake Probabilities [WG], 1988 and 1990). A study by NCEP in 1996 has redefined the segments and the characteristic earthquakes for the San Andreas fault system in northern and central California. Two "locked" overlapping segments of the San Andreas fault system represent the greatest potential hazard to the site.

The first segment is defined by the rupture that occurred from Cape Mendocino to San Juan Bautista along the San Andreas fault during the great M_w 7.9 earthquake of 1906. The NCEP(1996) has hypothesized that this "1906 rupture" segment experiences earthquakes with comparable magnitudes at intervals of about two hundred years.

The second segment is defined by the rupture zone of the M_w 6.9 Loma Prieta earthquake. Although it is uncertain whether this "Santa Cruz Mountains" segment has a characteristic earthquake independent of great San Andreas fault earthquakes, the NCEP (1996) has assumed an “idealized” earthquake of M_w 7.0 with the same right-lateral slip as the 1989 Loma Prieta earthquake but having an independent segment recurrence interval of 138 years and a multi-segment recurrence interval of 400 years.

The 2002 WG (2003) segmentation model is largely similar to that adopted by NCEP in 1996,although they have added far more complexity to the model, and have reduced the forecasted magnitudes for the different segments. The 2002 California probabilistic seismic hazard maps issued by the California Geological Survey (Cao et al., 2003) appear to have largely adopted the earthquake magnitudes issued by the 2002 WG. The most significant change in modeling the San Andreas Fault Zone by Cao et al. (2003) is the elimination of a singular listing of the penultimate event, the 1906 Mw 7.9 earthquake (although such an event can be derived by looking at the aggregate probability of the individual segments rupturing together, as they did in 1906).

In spite of the increasing complexity of the models addressing different size earthquakes with different recurrence intervals on the sundry segments of this fault, it is undeniable that the 1906 M_w 7.9 earthquake still eclipses all the other events which have occurred on the San Andreas fault in this region. Keeping this in mind, it is important that any seismic analyses performed for development on the site take the 1906 event into account where warranted, particularly since the empirical evidence presented by field researchers indicates the 1906 event recurs every several centuries.

San Gregorio Fault

The San Gregorio fault, as mapped by Greene (1977), Weber and Lajoie (1974), and Weber et al. (1995) skirts the coastline of Santa Cruz County northward from Monterey Bay, and trends onshore at Point Año Nuevo. Northward from Año Nuevo, it passes offshore again, to connect with the San Andreas fault near Bolinas. Southward from Monterey Bay, it may trend onshore north of Big Sur (Greene, 1977) to connect with the Palo Colorado fault, or continue southward through Point Sur to connect with the Hosgri fault in south-central California. Based on these two proposed correlations, the San Gregorio fault zone has a length of at least 100 miles and possibly as much as 250 miles.

The landward extension of the San Gregorio fault at Point Año Nuevo shows evidence of late Pleistocene (Buchanan-Banks et al., 1978) and Holocene displacement (Weber and Cotton, 1981). Although stratigraphic offsets indicate a history of horizontal and vertical displacements, the San Gregorio is considered predominantly right-lateral strike slip by most researchers (Greene, 1977; Weber and Lajoie, 1974; and Graham and Dickinson, 1978).

In addition to stratigraphic evidence for Holocene activity, the historical seismicity in the region is partially attributed to the San Gregorio fault (Greene, 1977). Due to inaccuracies of epicenter locations, even the magnitude 6+ earthquakes of 1926, tentatively assigned to the Monterey Bay fault zone, may have actually occurred on the San Gregorio fault (Greene, 1977).

The NCEP (1996) has divided the San Gregorio fault into the "San Gregorio" and "San Gregorio, Sur Region" segments. The segmentation boundary is located west of the Monterey Bay, where the fault appears to have a right step-over. The San Gregorio fault has been assigned a slip rate that results in a M_w 7.3 earthquake with a recurrence interval of 400 years. This is based on the preliminary results of a paleoseismic investigation at Seal Cove by Lettis and Associates (see NCEP, 1996) and on regional mapping by Weber et al. (1995). The Sur Region segment has been assigned a slip rate that results in a M_w 7.0 earthquake with an effective recurrence interval of 400 years (coinciding with the recurrence interval for the other segment). The Sur Region earthquake was derived from an assumed slip rate similar to that of the Hosgri fault.

2002 WG and Cao et al. (2003) have adopted a model similar to the NCEP (1996), essentially renaming the San Gregorio segment the “San Gregorio North” segment, and downgrading the forecasted earthquake on this segment to a Mw 7.2, and renaming the San Gregorio, Sur Region segment the San Gregorio South segment, retaining the forecasted earthquake of Mw 7.0.

Zayante-Vergeles Fault

The Zayante fault lies west of the San Andreas fault and trends about 50 miles northwest from the Watsonville lowlands into the Santa Cruz Mountains. The southern extension of the Zayante fault, known as the Vergeles fault, merges with the San Andreas fault south of San Juan Bautista.
The Zayante-Vergeles fault has a long, well-documented history of vertical movement (Clark and Reitman, 1973), probably accompanied by right-lateral, strike-slip movement (Hall et al., 1974;Ross and Brabb, 1973). Stratigraphic and geomorphic evidence indicates the Zayante-Vergeles fault has undergone late Pleistocene and Holocene movement and is potentially active(Buchanan-Banks et al., 1978; Coppersmith, 1979).

Some historical seismicity may be related to the Zayante-Vergeles fault (Griggs, 1973). For instance, the Zayante-Vergeles fault may have undergone sympathetic fault movement during the1906 earthquake centered on the San Andreas fault, although this evidence is equivocal(Coppersmith, 1979). Seismic records strongly suggest that a section of the Zayante-Vergeles fault approximately 3 miles long underwent sympathetic movement in the 1989 earthquake. The earthquake hypocenters tentatively correlated to the Zayante-Vergeles fault occurred at a depth of 5 miles; no instances of surface rupture on the fault have been reported.

In summary, the Zayante-Vergeles fault should be considered potentially active. The NCEP (1996)considers it capable of generating a magnitude 6.8 earthquake with an effective recurrence interval of 10,000 years. Alternatively, Cao et al. (2003) considers this fault capable of generating a maximum earthquake of M_w 7.0, with no stated recurrence interval.

Monterey Bay - Tularcitos Fault Zone

The Monterey Bay-Tularcitos fault zone is 6 to 9 miles wide, about 25 miles long, and consists of many en échelon faults identified during shipboard seismic reflection surveys (Greene, 1977). The fault zone trends northwest-southeast and intersects the coast in the vicinity of Seaside and Ford Ord. At this point, several onshore fault traces have been tentatively correlated with offshore traces in the heart of the Monterey Bay-Tularcitos fault zone (Greene, 1977; Clark et al., 1974; Burkland and Associates, 1975). These onshore faults are, from southwest to northeast, the Tularcitos-Navy, Berwick Canyon, Chupines, Seaside, and Ord Terrace faults. Only the larger of these faults, the Tularcitos-Navy and Chupines, are shown on Figures 2 and 3. It must be emphasized that these correlations between onshore and offshore portions of the Monterey Bay-Tularcitos fault zone are only tentative; for example, no concrete geologic evidence for connecting the Navy and Tularcitos faults under the Carmel Valley alluvium has been observed, nor has a direct connection between these two faults and any offshore trace been found.

Outcrop evidence indicates a variety of strike-slip and dip-slip movement associated with onshore and offshore traces. Earthquake studies suggest the Monterey Bay-Tularcitos fault zone is predominantly right-lateral, strike-slip in character (Greene, 1977). Stratigraphically, both offshore and onshore fault traces in this zone have displaced Quaternary beds and, therefore, are considered potentially active (Buchanan-Banks et al., 1978). One offshore trace, which aligns with the trend of the Navy fault, has displaced Holocene beds and is therefore active by definition (Buchanan-Banks et al., 1978).

Seismically, the Monterey Bay-Tularcitos fault zone may be historically active. The largest historical earthquakes *tentatively* located in the Monterey Bay-Tularcitos fault zone are two events, estimated at 6.2 on the Richter Scale, in October 1926 (Greene, 1977). Because of possible inaccuracies in locating the epicenters of these earthquakes, it is possible that they actually occurred on the nearby San Gregorio fault zone (Greene, 1977). Another earthquake in April 1890 might be attributed to the Monterey Bay-Tularcitos fault zone (Burkland and Associates, 1975).

The NCEP (1996) has assigned an earthquake of M_w 7.1 with an effective recurrence interval of 2,600 years to the Monterey Bay-Tularcitos fault zone, based on Holocene offshore offsets. Petersen et al. (1996) have a similar earthquake magnitude, but for a recurrence interval of 2,841 years. Their earthquake is based on a composite slip rate of 0.5 millimeters per year (after Rosenberg and Clark, 1995).

Cao et al. (2003) has developed a model for the Monterey Bay fault zone that combines slip rates of the different segments, resulting in a composite slip rate of 0.5 mm per year and a forecasted earthquake of Mw 7.3, with no stated recurrence interval. The Cao et al. (2003) model adopted implicitly assumes that all the assessed segments in the Monterey Bay fault zone each have an independent slip rate of 0.1 mm per year (based upon the one slip rate developed by Rosenberg and Clark, 1995 for the Tularcitos segment), and essentially assigns the composite slip rate to the Tularcitos trace of the Monterey Bay fault zone.

Butano Fault

The northwest-trending Butano fault is an approximately 20-mile-long system of discontinuous bedrock faults that merges with the San Andreas fault at its southern end (Figures 2 and 3). Pliocene stratigraphic offsets are known, and questionable geomorphic evidence raises the possibility of Quaternary activity (Buchanan-Banks et. al., 1978; Hall et al., 1974). Some historic seismicity in the area is possibly related to the Butano fault (Griggs, 1973). Based largely on its position relative to the other faults in the area, the Butano fault is considered capable of magnitude 6.4 earthquake, with a recurrence interval similar to that formerly assumed of the Zayante-Vergles fault (about 6,000 years; Hall et al., 1974). Neither Cao et al. (2003) nor the 2002 WGCEP have assigned any predicted or modeled future seismicity to this fault.

Ben Lomond Fault

The northwest-trending Ben Lomond fault is a bedrock fault with a long geologic history of vertical movement in the Tertiary Period. The fault follows the San Lorenzo River valley for its12-mile mapped trace, and appears to join the Zayante-Vergles fault at its northwest end (Figures 2 and 3).The youngest beds known to be offset by the fault are older than 7 million years (Hall et al., 1974). Stanley and McCaffrey (1983) projected the Ben Lomond fault to a location in the modern sea cliff along West Cliff Drive in Santa Cruz based on a Bouguer gravity anomaly and identified a small vertical step (about one inch) across the fault in an 85,000 year old wave cut platform. They interpreted this small step as evidence for Pleistocene activity. The sense of vertical displacement, however, is opposite to that indicated by stratigraphic and structural relationships along the fault, and the fault does not offset the terrace sediments overlying the wave cut platform. In essence, this evidence presented for Pleistocene activity argues against any significant late Pleistocene movement on the fault. This activity assessment is consistent with stratigraphic evidence which indicates that the majority of motion on the fault took place in Miocene and Pliocene time.

Although the activity of the Ben Lomond fault is questionable, it does join or branch off of the potentially active Zayante-Vergles fault. Hall et al. (1974) consider the Ben Lomond fault capable of a magnitude 5.5 earthquake. Alternatively, neither Cao et al. (2003) or 2002 WGCEP specifically addressed this fault as a source for moderate to large magnitude earthquakes.

KARST DEVELOPMENT

The dissolution of the marble by groundwater has created an extensive system of cavities in the area, with local areas of karst topography. This type of landscape is rare in California but is common to many areas underlain by marble or limestone in the eastern United States. The solution process is slow, taking place over thousands of years.

In general, the solution cavities consist of highly irregular, interconnected caverns and channels through the marble bedrock. Where they intersect the ground surface, they form pits, called sinkholes or dolines, which may gradually fill by infiltration of fine-grained sediments from the surface or by collapse of the adjacent rock walls or roof into the cavity (Figures 5 and 6).

The site is located in an area where karst formation began between about 200,000 and 300,000 years ago, based on the approximate ages of the tow marine terrace sequences cut into the marble bedrock in this area. Most of these dolines in this region have been filled and their physical expression at the ground surface almost completely obliterated by erosion and deposition since their initial formation.

Solution-cavity distribution is not random, but commonly follows zones of concentrated groundwater flow, such as along pre-existing fractures or faults in the bedrock. For this reason, although the solution cavities are irregularly shaped, they tend to be arranged along roughly linear trends (Figure 5) . Previous geologic mapping on the nearby university campus (Johnson and Associates, 1987; Weber and Associates, 1993) has identified a system of intersecting fault or fracture surfaces that shows a strong correlation with the locations of sinkholes. The karst system on the campus appears to fit a "network" pattern as described by Palmer (1991) and the karst system that underlies the site is presumably similar.

Prior subsurface investigations on the nearby university campus have shown a distinct pattern of blow counts from exploratory borings advanced in dolines. The blow counts routinely decrease markedly as the marble surface is approached. This observation suggests that there may be widespread solution at the top of the marble, which could result in stoping of the doline fill, weathered schist or other materials immediately above the contact (Figures 6 and 7).

Our interpretation of the geometry of the dolines and the “intact” marble surface is constrained by the mechanical limitations of the drilling equipment used for the field exploration. The drill rigs used by the project geotechnical engineer for this investigation were a 6-inch diameter, hydraulically operated, continuous flight auger, mounted on a truck. "Intact" marble for this project is mostly defined by refusal for the 6-inch diameter auger. It is possible that the auger may have encountered refusal in some borings on a large piece of marble rubble instead of the assumed intact marble (Figure 6). Nevertheless, the results obtained from the equipment used for this project, combined with consistent assumptions, allow for reasonable conclusions to be drawn about the relative geometry of the "intact" marble surface. Obtaining the absolute geometry of the marble surface, however, may prove economically prohibitive.

We have also attempted to portray the elevation of intact marble bedrock in the proposed development area footprint by utilizing the boring data generated from the exploration program by DA (see Plate 1). We have attempted to utilize the same criteria as stated above for ascertaining what constitutes intact marble. In many cases we relied upon our specialized geologic expertise that we have gained from working in the karst terrain on the nearby university campus for the last 27 years to interpret the existing data.

SITE GEOLOGY

The site is located near the back edge of the second-emergent marine terrace, near its intersection with the higher the third-emergent marine terrace, both of which are part of the uplifted marine terrace sequence in the Santa Cruz area that has been carved into the underlying metamorphic and igneous bedrock complex. The gently sloping ground slated for upper and lower development sites are remnant marine terrace surfaces that are approximately 200,000 and 300,000 years old. A blanket of marine terrace deposits consisting of predominantly mixed sand and clay with some silt and gravel covers the entire site with the thickness generally varying between 5 ½ and 10 feet on the lower site and possibly as thick as about 30 feet on the upper meadow site. The marine terrace deposits overlie one and possibly two uplifted, south-sloping fossil wave-cut platforms that were beveled into the underlying metamorphic bedrock complex.

The underlying metamorphic bedrock at the site is mostly marble bedrock with some granitic intrusions. The entire metamorphic-igneous package has been intensely folded and faulted and subsequently weathered. Weathering in the marble bedrock is displayed as karst in the form of dolines or sinkholes, which represent locations where the marble bedrock has been dissolved and removed by acidic water flowing along the ground surface or through fractures. This dissolution process is slow and typically takes place over hundreds of thousands of years, leaving complicated, irregular surfaces, creating underground channels or caverns that capture surface water, leaving few or no surface streams. Where these zones of solution and collapse intersect the ground surface, they form closed depressions or pits, called sinkholes or dolines. These depressions may be gradually filled by infiltration of sediments from the surface, or by collapse of the walls of the doline (similar to landsliding) into the cavity. There is a tendency for dissolution to take place preferentially along existing breaks in the rock, such as fractures and faults, that provide a conduit for water flow. Solution cavity distribution is not random, but commonly follows zones of concentrated groundwater flow in the bedrock such as along pre-existing fractures or faults. For this reason, although they are irregularly shaped, the solution cavities often tend to be arranged along roughly linear trends.

Infilled dolines can present a hazard to the buildings, utilities and infrastructure, because they have been backfilled with bedrock and soil that have washed, crept or collapsed into the void in the marble. The poorly consolidated doline fill presents a potential settlement hazard, which is further exacerbated by the an almost complete lack of settlement potential from the surrounding intact crystalline marble bedrock. Depending upon the loads placed on the soil by a foundation, such conditions could lead to structural failure. In addition to cavern collapse and subsidence of soils into voids, there is wide spread dissolution of the marble surface below the overlying deposits. This dissolution creates areas of weak or soft soils in a zone that directly overlies the marble surface. These zones are composed of marble fragments in a matrix of silt, sand, and clay. The marble fragments may or may not be in point-to-point contact and the soil matrix is generally soft and poorly consolidated. Caverns or large voids are not present in these soft zones, and the zones are usually not associated with evidence for doline formation or collapse. Such zones may have inadequate bearing strength and may present hazards to construction unless recognized and mitigated where warranted.

The lower site is clearly cut by at least infilled dolines as evidenced by the boring log data and our marble bedrock contour analysis (see Plates 1 and 2). This doline may present an elevated risk to the southwestern corner of the proposed residential development centered on boring B2. This doline appears to be relatively shallow and filled with very soft soil and marble rubble. We have depicted the ground surface projection of the doline on Plate 1 as an orange-shaded polygon and in cross section on Plate 2.

The surficial deposits appear to be almost uniformly composed of mixed relatively dense sand and stiff clay derived from colluvium and marine terrace deposits deposited on the site in the late Pleistocene. The samples recovered near the contact of marble bedrock and marine terrace deposits to be marine terrace deposits, but they were so deeply weathered we could not differentiate them from doline fill deposits, particularly in the vicinity of the existing doline.

It is important to note that no regionally persistent groundwater was encountered on the site. Groundwater is typically needed to create an environment for accelerated dissolution of the marble and possible stoping of doline fill.

The lower site appears to be sitting on an old existing compound cut fill pad formed for the parking lot, with the fill being several feet at its thickest at the crest along the southern margin of the dirt parking lot. It is unknown as to whether the fill was properly compacted and engineered at the time it was constructed.

We have conservatively projected the marble bedrock surface encountered to the north, underneath the upper meadow site for the quadplexes. It is likely that the a much thicker sequence of marine terrace deposits (30'?) overlies the marble at the upper meadow site and that the marble may be cut by heretofore undiscovered infilled dolines at depth.

Marble Contour Map

Plate 1 depicts our preliminary interpretation of the marble surface underlying the proposed development area, based on the exploratory boring data. As noted above, Plate 1 shows that the buried surface of the marble is a gently south-sloping plateau cut by one doline. This morphology is characteristic of solution cavities and solution fissures in karst terrane. The configuration of the marble surface in the proposed development area is clearly influenced by solution, but may also be controlled in part by pre-existing folding or faulting of the bedrock.

It should be noted that our interpretation of the marble surface portrayed on Plate 1 is influenced by the spacing of the exploratory borings. Kriging contouring methods with anisotropy weighting (roughly along north-south and east-west axes) were employed to create the marble surface contours. The apparent smoothness of the contours is a function of the number of data points. The marble surface may be much more complex than portrayed on Plate 1, considering the irregularity of karst terrane, as well as in cut slopes that this author has observed for other buildings constructed on the nearby university campus.

As noted earlier, the site appears to be underlain by a marble plateau cut by a doline in the marble bedrock. The current development plan calls for residential structures to be placed over this doline, creating an elevated risk for those structures with respect to the hazards of differential settlement and doline collapse. The existing doline is relatively shallow and filled with marble rubble and relatively soft soil. We did not observe any obvious evidence of voids within the soil that has filled the doline.

It does not appear that grading for the proposed development has been designed yet. The marble bedrock appears to be very near the ground surface across some of the site, which means that the proposed excavations and foundations may encounter marble bedrock (see Plates 1 and 2). It is important for the design team to keep track of the depth of the marble when developing foundation and grading options in order to lessen the chance that structures or infrastructure will be straddling a marble bedrock pinnacle and the doline filled with soil and rubble. Avoiding that circumstance of a disparity in bearing capacity between the marble bedrock and surficial deposits under building foundations is important, because that could lead to issues with differential settlement of the foundation.

Placement of fill in the karst terrane is also important because the loads imposed by artificial fill on to the underlying native soil can be large depending upon the thickness and distribution of the fill.

The configuration of the marble surface portrayed on our geologic cross sections (Plate 2) do not always exactly match the marble surface portrayed on Plate 1. The marble surface contours were simply used as a general guideline for the profile constructions. The karst geometry was conservatively interpreted on the profiles; hence, the marble surface shown on the profiles varies slightly from the configuration portrayed on Plate 1. The marble contour map is intended to be used as an overview of gross marble surface configuration; it is not possible to portray all the nuances of the marble surface that may be present in the complex karst terrain that underlies all of the building sites.

The reader may also note that we did not attempt to construct marble bedrock contours in the upper meadow area slated for the development of the quadplexes. That is because that area is bereft of the drilling data needed to construct that type of map.

GEOLOGIC HAZARDS

This section address the following hazards and attendant risks: karst development, seismic shaking, surface fault ground rupture and landsliding. We have specifically focused on the residential structures at the site with respect to those hazards. We have identified areas of concern for infrastructure components such as storm water disposal where warranted, but in general we have not focused on other infrastructure components such as roads and sidewalks. This is because it would be economically prohibitive to mitigate the risks to components like sidewalks and roadways for hazards such as karst development and seismic shaking, because of the ubiquity of those hazards across the site. It will be extremely expensive to attempt to mitigate the impacts due to those hazards for the portions of the development that are not absolutely essential to the operation of the development and whose failure will not create life-safety issues.

Karst-Related Hazards

The potential karst-related hazards to the proposed development site concern the presence of the doline and zones of soft soil within the development footprint. The marine terrace surface that occupies the lower parking lot site is approximately 200,000 years old and as such, represents a geological condition that is as close one can get to geological stasis. The fact that this surface may only be cut by one buried doline in the development area indicates that some form of karst formation equilibrium has been achieved with respect to the rainfall, groundwater movement, dissolution and seismic shaking over the past 200,000 years since the terrace surface was abandoned by the retreating ocean. It also indicates that the doline identified at the site has not catastrophically collapsed during the current climatic sea-level rise regime that began 18,000 years when the climate transitioned from a glacial minima to the current glacial maximum cycle. This is further supported by the fact that every instance of the reactivation of dolines in this region has been triggered by unnatural addition of water to the surface and subsurface via disposal of collected storm water.

A doline of concern, containing marble rubble and relatively soft soil was encountered in the development area, centered on boring B2 (see orange-shaded polygon on Plate 1). Hazards associated with the soft sediment zone within this doline includes subsidence of the ground surface due to settlement of doline fill on top of marble bedrock and stoping of materials into any cavities that were not detected during this investigation. We consider the potential to be low to moderate for the blanket of sediments within the identified doline of concern to settle or stope into the doline, inducing subsidence of the ground surface. This hazard potential corresponds to a greater than "ordinary risk" as defined in Appendix B of this report and should be mitigated to lower it to an "ordinary risk".

The balance of the site is subject to a low potential for karst-related ground subsidence corresponding to an "ordinary risk", provided our recommendations for grading, drainage and irrigation are followed.

As noted above historically reactivated dolines and sinkholes within the karst terrane in this region have been triggered by unnaturally high contributions of storm water or domestic water into the subsurface, due to poor storm water control, construction and maintenance of the water utilities. A number of historically reactivated sinkholes on the nearby university campus are examples of that finding. Given the dissolution zone at the marble surface across the entire site, as well as the existing dolines scattered across the site, it should be assumed that adding water to the subsurface in an unnatural fashion at the site may trigger the formation of sinkhole in the vicinity of the water disposal.

Given the above observation regarding the formation and accelerated development of sinkholes in the presence of added water, it may also be prudent to consider adding flexible connections to the domestic water supply lines where they enter structures. If flexible connections are used at the interface with the rigid structures, it may provide enough time for the owners to shut off the water connection prior to pipe or connection rupturing, which in turn will lessen the extent and impacts of the sinkhole on the structure if that occurs.

Seismic Shaking Hazard

Seismic shaking at the site will be intense during the next major earthquake along local fault systems. Seismic shaking values for any structures designed on the property should at least adhere to the minimum prescriptive design values outlined in the 2016 California Residential Code. The seismic shaking values should be developed by the Project Geotechnical Engineer of Record as part of their soils report for the design of proposed structures.

Fault Surface Rupture Hazard

No active or potentially active faults have been identified on the site, even though the site lies within one of the most seismically active areas of the western United States. The closest mapped large fault is the Ben Lomond fault, which trends north-south beyond the site. As discussed in the preceding sections, this fault is not considered to be an active fault by most researchers, where an active fault is defined as a fault that has experienced movement resulting in surface ground rupture during the Holocene epoch –(the past 11,000 years of earth history).

The underlying metamorphic bedrock is, however, cut by a series of north-south and east-west trending faults on the nearby university campus. These faults are discernable only: 1) because of secondary development of erosional valleys and depressions due to weathering of sheared rock along the faults, or 2) because the faults juxtapose dissimilar rock types across narrow zones.

None of the faults observed in the metamorphic bedrock are considered to be active, for the following reasons:

1. The nearest large fault zone, the Ben Lomond fault that lies along the east side of the UCSC campus is not active.

2. The geomorphic features developed along the faults within the metamorphic bedrock are all related to long periods of erosion along "weak zones" in the rock. There are no geomorphic features indicative of recent fault activity.

3. The large, roughly north-south trending faults on the nearby university campus do not offset the Santa Margarita Sandstone (age 5-6 million years). These faults offset the east-west trending faults, indicating that the east-west trending faults are also inactive.

4. The east-west and north-south orientations for the faults are not consistent with the type of fault movement anticipated to occur in the present day stress regime associated with the San Andreas fault system.

Therefore, surface ground rupture due to movement along active faults is not a hazard at the development site, resulting in an "ordinary risk" to the development, as defined in Appendix B of our report.

Landsliding Hazard

In general, the granitic and metamorphic rocks that underlie campus are hard, stable slope forming materials. The relative lack of large landslides in that type of bedrock , despite some very steep slopes, attests to this character of the bedrock, in contrast to other portions of the Santa Cruz Mountains, principally areas underlain by Tertiary sedimentary rocks, which are characterized by numerous large, older landslides.

The marine terrace surface at the development site has been stable for roughly 200,000 years and shows no signs of having shed landslides on the gentler slopes at the site, in spite of the high rate of seismicity and much greater amounts of rainfall it had to have experienced during the Pleistocene. Landsliding on those slopes is not a hazard at the development site, resulting in an "ordinary risk" to the development, as defined in Appendix B of our report.

The steep wall of the abandoned marble quarry that abuts both development sites on the eastern edge of the property has been in place for roughly 100 years and shows no signs of catastrophic failure. It does appear, however, that the steep wall has shed smaller landslides emanating out of the marine terrace deposits, causing the westward retreat of the marine terrace deposits the top of the slope transition that also marks the top of the steep wall. We scrutinized the marble bedrock exposed in the same quarry wall for evidence of spalling, fracturing and jointing. We did note one location that was cut by faulting and granitic intrusion in the marble, resulting in a weak zone that did fail, probably during the quarrying operations. A “notch” or “slot” has developed in the marble at that location, resulting in localized retreat of the overlying marine terrace deposits. It appears that a debris flow bowl has developed within the marine terrace deposits above the marble bedrock notch. A stand of eucalyptus trees (circa 1982?) has grown in the bowl indicating that landsliding has not occurred in the bowl for 35+ years, which may mean that the marine terrace deposits have achieved equilibrium within the bowl.

Given the above observations, we have attempted construct a geologically-derived top-of-slope development setback west of and behind the steep quarry wall along the eastern edge of the subject property. The construction of this line conservatively assumes that over the long term the marble face will retreat five feet and the overlying marine terrace deposits will lay back to an angle of 35 degrees. This results in a setback line of approximately 20 feet from the top of the quarry face for the lower development, rising to an approximately 60 ft setback from the top of the quarry face. The variable setback is due to northward thickening of the marine terrace deposits. It should also be noted that setback line for the upper meadow site will need to be refined after a program of geotechnical engineering drilling has been completed for the upper meadow site.

FINDINGS

In our opinion, the potential is low to moderate for the karst-related hazard of ground subsidence to occur within the lifetime of the proposed developments within the identified doline centered on boring B2 (see Plates 1 and2). This hazard potential corresponds to a greater than “ordinary risk” as defined in Appendix B of this report and should be mitigated to lower it to an “ordinary risk”.

The balance of the site is subject to a low potential for karst-related ground subsidence corresponding to an “ordinary risk”, provided our recommendations for grading, drainage and irrigation are followed.

If an “ordinary risk” level is unacceptable to the developer and the property owners, then the geologic hazards identified should be mitigated to reduce the corresponding risks even further to an acceptable level.

The site is located in an area of high seismic activity and will be subject to strong seismic shaking in the future.

Most of the historically reactivated dolines and sinkholes have been triggered by unnaturally high contributions of storm water or domestic water into the subsurface, due to poor control, construction and maintenance of the water utilities. Given the dissolution zone at the marble surface across the entire site, as well as the existing doline on the lower parking lot site, it should be assumed that adding water to the subsurface in an unnatural fashion at the site may trigger the formation of sinkhole.

RECOMMENDATIONS

1. The project geotechnical engineer should analyze the blanket of denser soils that overlie the marble bedrock in the area centered on boring B2, flagged as a doline of concern (shaded orange polygons on Plate 1), taking our prescribed maximum doline width into account. The geotechnical engineer should determine if the density and thickness of this surficial "blanket" is sufficient to buffer any structures from damage caused by the potential stoping or settlement of the relatively softer soils below. Mitigation of this condition should be proposed if warranted. Mitigation schemes could potentially include proper foundation design, ground improvement under the foundation, or subsurface changes made to the soft soil zones.

2. Because of the high degree of variability of soil conditions over short intervals encountered throughout the study area, we recommend that all structures for the lower parking lot area be designed to span zones of subsidence or soil collapse of a prescriptive minimum of thirty feet. We recognize that this may be economically prohibitive for residential construction. The minimum prescriptive subsidence zone value can be potentially reduced by drilling on a denser grid under the proposed structures in order to reduce the uncertainty of the marble surface between the current spacing of the borings.

   We recommend a gridded drilling program be pursued for the upper meadow quadplex development prior to any foundation design being pursued. The drilling grid should be laid out to allow for borings to be completed under the proposed residential footprint. One or more borings should be advanced near the steep quarry wall that lies to the east of the site in order to characterize the thickness and character of the marine terrace deposits that overlie the marble bedrock. All borings advanced on the upper meadow site should be drilled to refusal on the underlying marble bedrock.

3. We recommend that all of the storm water generated for this project be disposed in the City of Santa Cruz storm drains. Attenuating the storm flows by detaining the water in impervious structures is geologically acceptable, as long as the water is NOT allowed to infiltrate the soil.

4. Landscape watering for the project should NOT saturate the subgrade in an unnatural fashion. The natural distribution and application rate of rainfall should be emulated for

landscaping irrigation, in order to avoid saturating the subgrade and triggering a doline collapse.

5. Seismic shaking values for any structures designed on the property should at least adhere to the minimum prescriptive design values outlined in the 2016 California Building Code. The seismic shaking values should be developed by the Project Geotechnical Engineer of Record as part of their soils report for the design of proposed structures.

6. Any soft soil zones exposed in the foundation footings or soil changes encountered during excavation should be investigated in the field at the time of construction by the project geotechnical engineer and the project geologist.

7. We recommend that Zinn Geology be retained to inspect all cuts made during grading for the project in order to identify unanticipated potential karst hazards.

8. We recommend that our firm be provided the opportunity for a review of the final design and specifications in order that our recommendations may be properly interpreted and implemented in the design and specification. If our firm is not accorded the privilege of making the recommended review we can assume no responsibility for misinterpretation of our recommendations.

INVESTIGATION LIMITATIONS

1. The conclusions and recommendations noted in this report are based on probability and in no way imply the site will not possibly be subjected to ground failure or seismic shaking so intense that structures will be severely damaged or destroyed. The report does suggest that building structures at the subject site, in compliance with the recommendations noted in this report, is an acceptable risk.

2. This report is issued with the understanding that it is the duty and responsibility of the owner or his representative or agent to ensure that the recommendations contained in this report are brought to the attention of the architect and engineer for the project, incorporated into the plans and specifications, and that the necessary steps are taken to see that the contractor and subcontractors carry out such recommendations in the field.

3. If any unexpected variations in soil conditions or if any undesirable conditions are encountered during construction or if the proposed construction will differ from that planned at the present time, Zinn Geology should be notified so that supplemental recommendations can be given.

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APPENDIX A

FIGURES

BASE MAP: Felton Quadrangle, California - Santa Cruz Co., 7.5-Minute Series, United States Geological Survey, 2015, Scale: 1" = 2,000', and Santa Cruz Quadrangle, California - Santa Cruz Co., 7.5-Minute Series, United States Geological Survey, 2015, Scale: 1" = 2,000 '; maps are available to the public at: https://carto.nationalmap.gov

N
W E
S

SCALE 1:24,000

1000 0 1000 2000 feet

ZINN GEOLOGY

Topographic Index Map

Peace United Church - Envison Housing

900 High Street

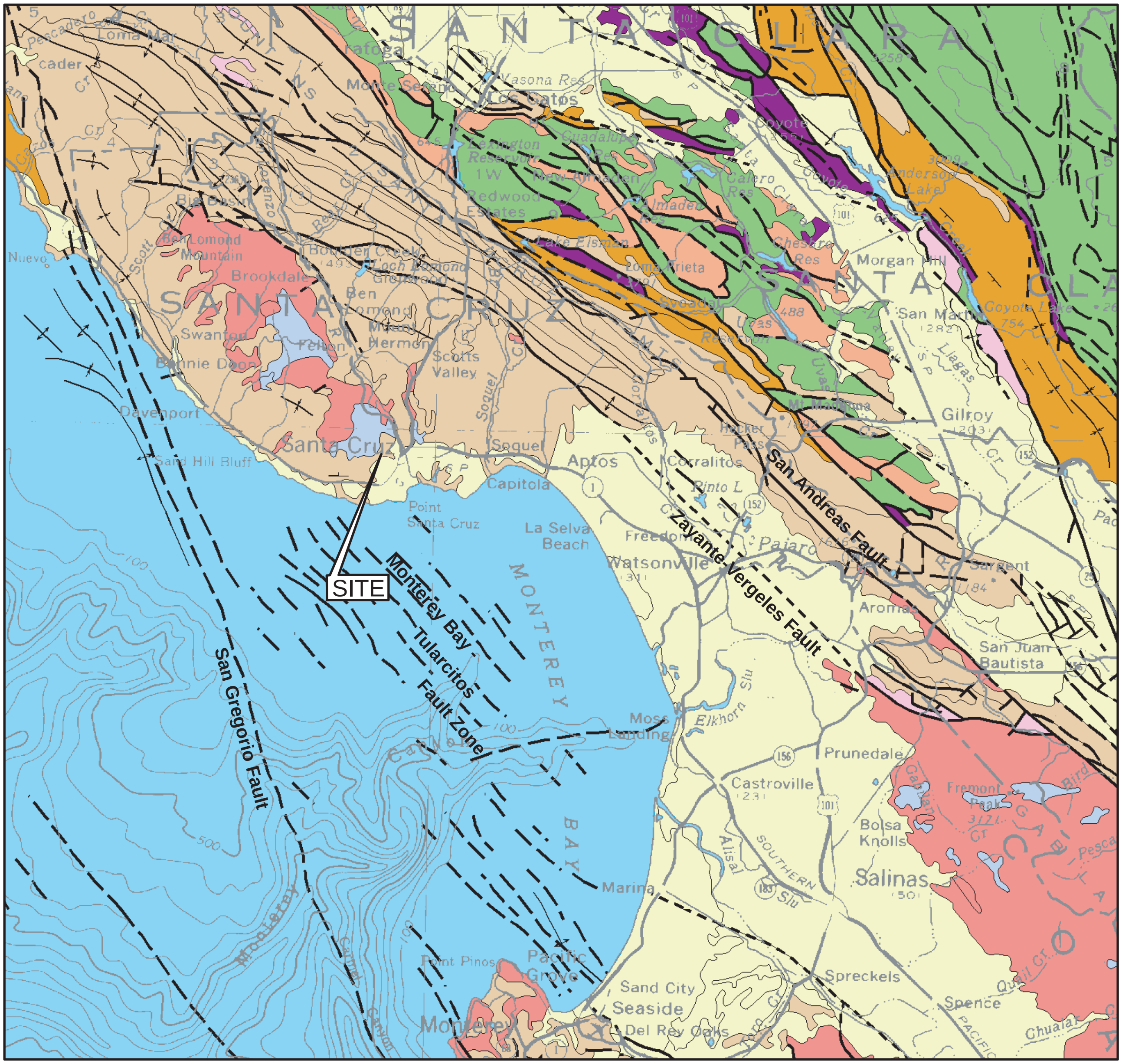
Santa Cruz, California

FIGURE #

1

JOB #

2018011-G-SC



Reference: Jennings, C.W., 1977, Geologic Map of California: California Department of Conservation, Division of Mines and Geology, scale 1:750,000.

Digital Data: Saucedo, G.J., Bedford, D.R., Raines, G.L., Miller, R.J., and Wentworth, C.M., 2000, GIS Data for the Geologic Map of California: California Department of Conservation, Division of Mines and Geology, CD-ROM 2000-007, ver. 2.0.

EXPLANATION

Geologic Units

- 🟨 Quaternary Deposits
- 🟨 Quaternary Volcanics
- 🟫 Tertiary Sedimentary Rocks
- 🟪 Tertiary Volcanic Rocks
- 🟧 Pre-Tertiary Sedimentary Rocks
- 🟧 Pre-Tertiary Volcanic Rocks
- 🟥 Grantic Intrusive Rocks
- 🟩 Franciscan Complex
- 🟪 Ultramafic Rocks
- 🟦 Pre-Tertiary Metamorphic Rock
- 🟦 Pre-Cambrian Metamorphic and Igneous Rocks

Symbols

- ╲ contact
- ╲ fault, certain
- ╲ fault,approx. located
- ⋱ fault, concealed or inferred
- ✕ anticline
- ✕ monocline
- ✕ syncline

SCALE 1:500,000

10 Miles 0

ZINN GEOLOGY

Regional Geologic Map

Peace United Church - Envison Housing

900 High Street

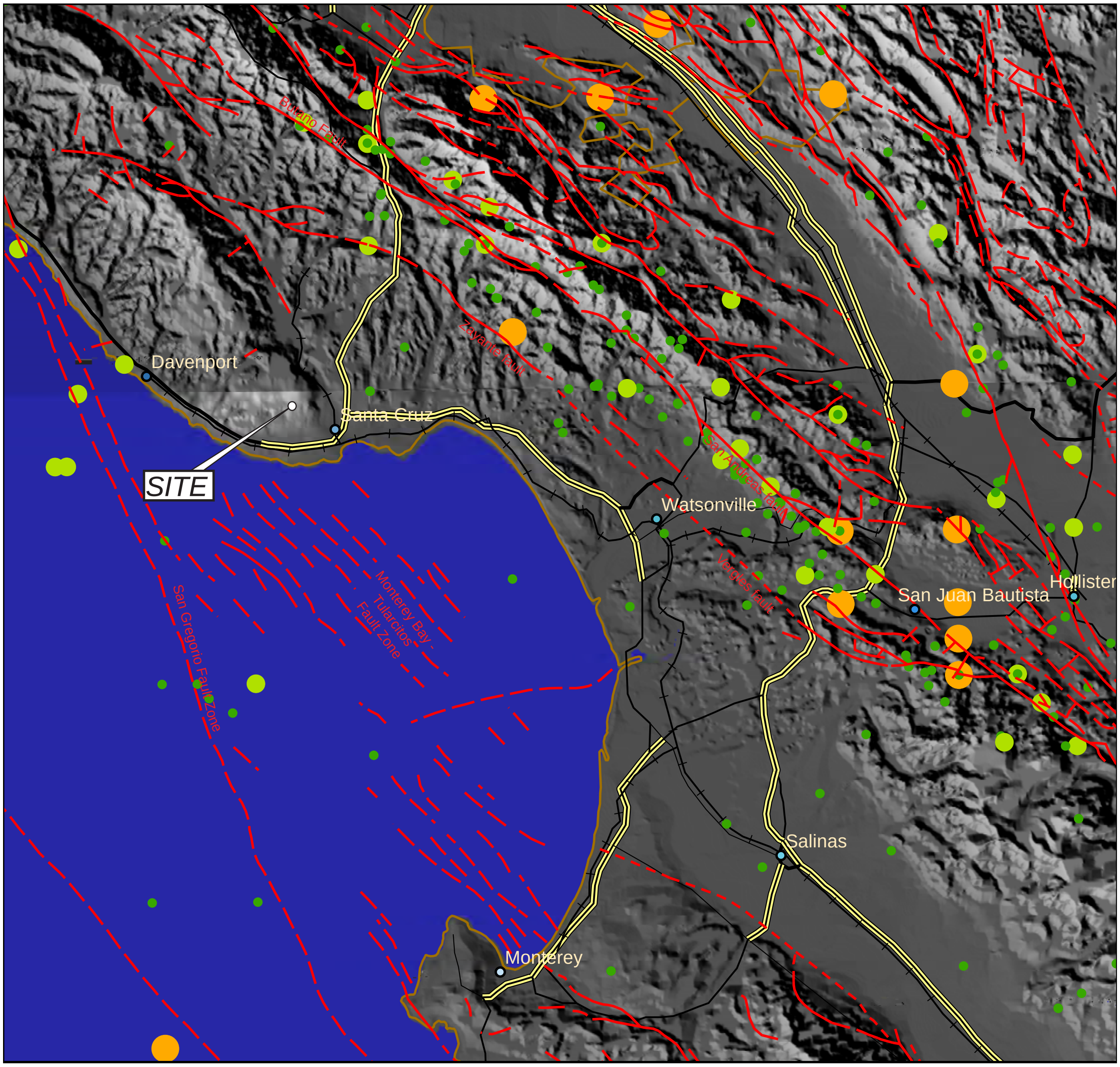
Santa Cruz, California

FIGURE #

2

JOB #

2018011-G-SC



Seismicity Information: Magnitude 4 and greater earthquakes, compiled from various sources, 1769 to 2000; available at www.consrv.cagov/CGS/rghm/quakes/cgs2000_fnl.txt
Fault Information: Jennings, C.W., 1977, Geologic map of California: California Department of Conservation, Division of Mines and Geology, scale 1:750,000

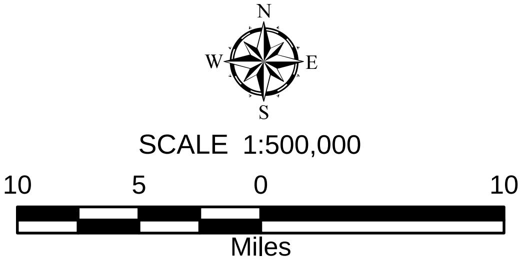
EXPLANATION

Symbols

— fault, certain
— — fault,approx. located
- - - - fault, concealed or inferred

Earthquake Magnitude

● 4.0 to 4.99
● 5.0 to 5.99
● 6.0 to 6.99
● 7.0 +



ZINN GEOLOGY

Regional Seismicity Map

Peace United Church - Envison Housing
900 High Street
Santa Cruz, California

FIGURE #
3
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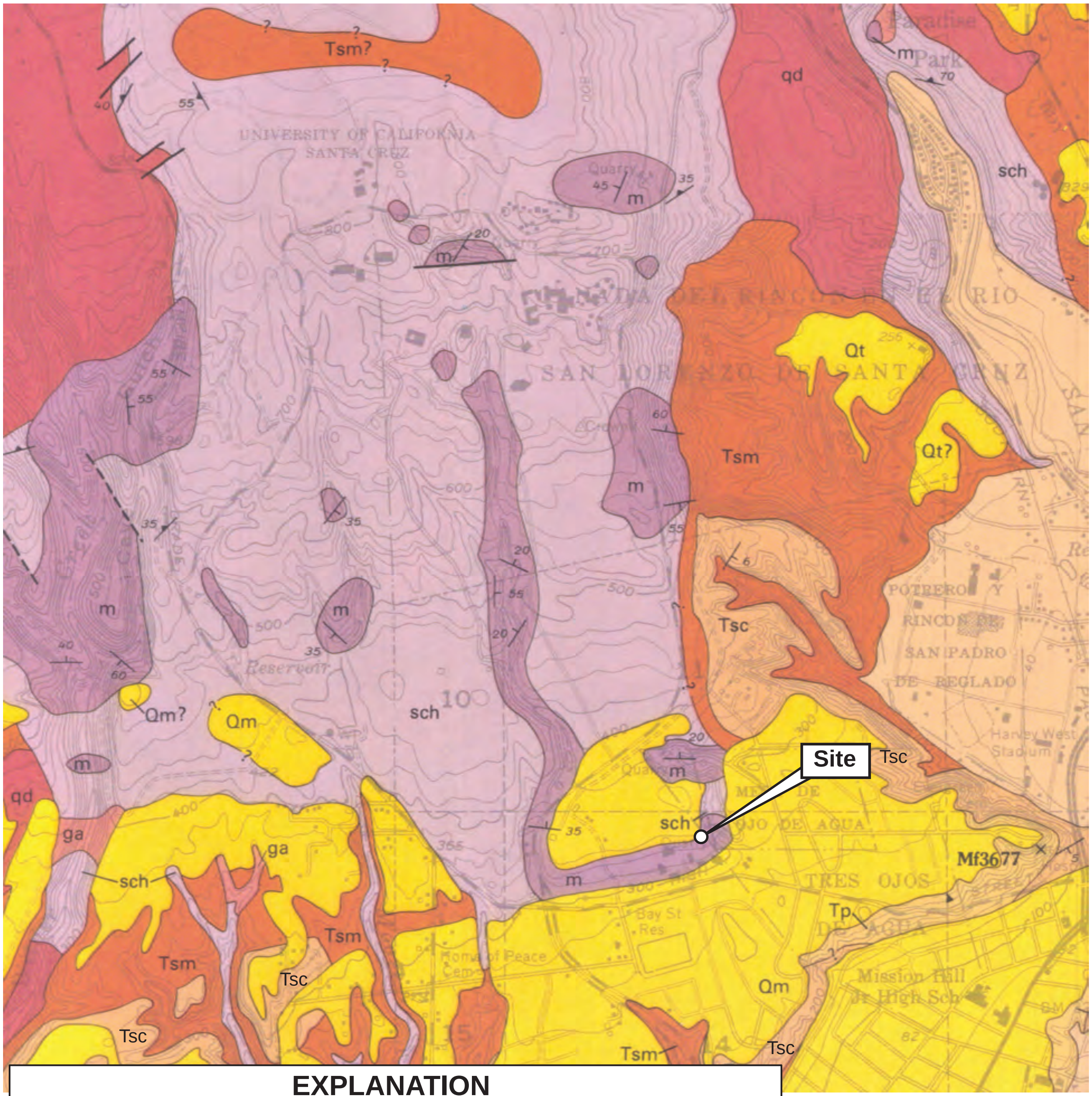
2018011-G-SC



EXPLANATION

Qal	Alluvium
Qt	River terrace deposits
Qm	Marine terrace deposits
Tsc	Santa Cruz Mudstone
Tsm	Santa Margarita Sandstone
qd	quartz diorite
sch	schist
m	marble

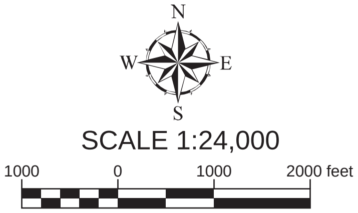
Earth materials contact

45 Bedding attitude

55 Foliation attitude

Fault

Base Map: Plate 2 from "Stratigraphy, Paleontology, and Geology of the Central Santa Cruz Mountains, California Coast Ranges," by J.C. Clark, 1981, U.S. Geological Survey Professional Paper 1168, scale: 1"=2000'.

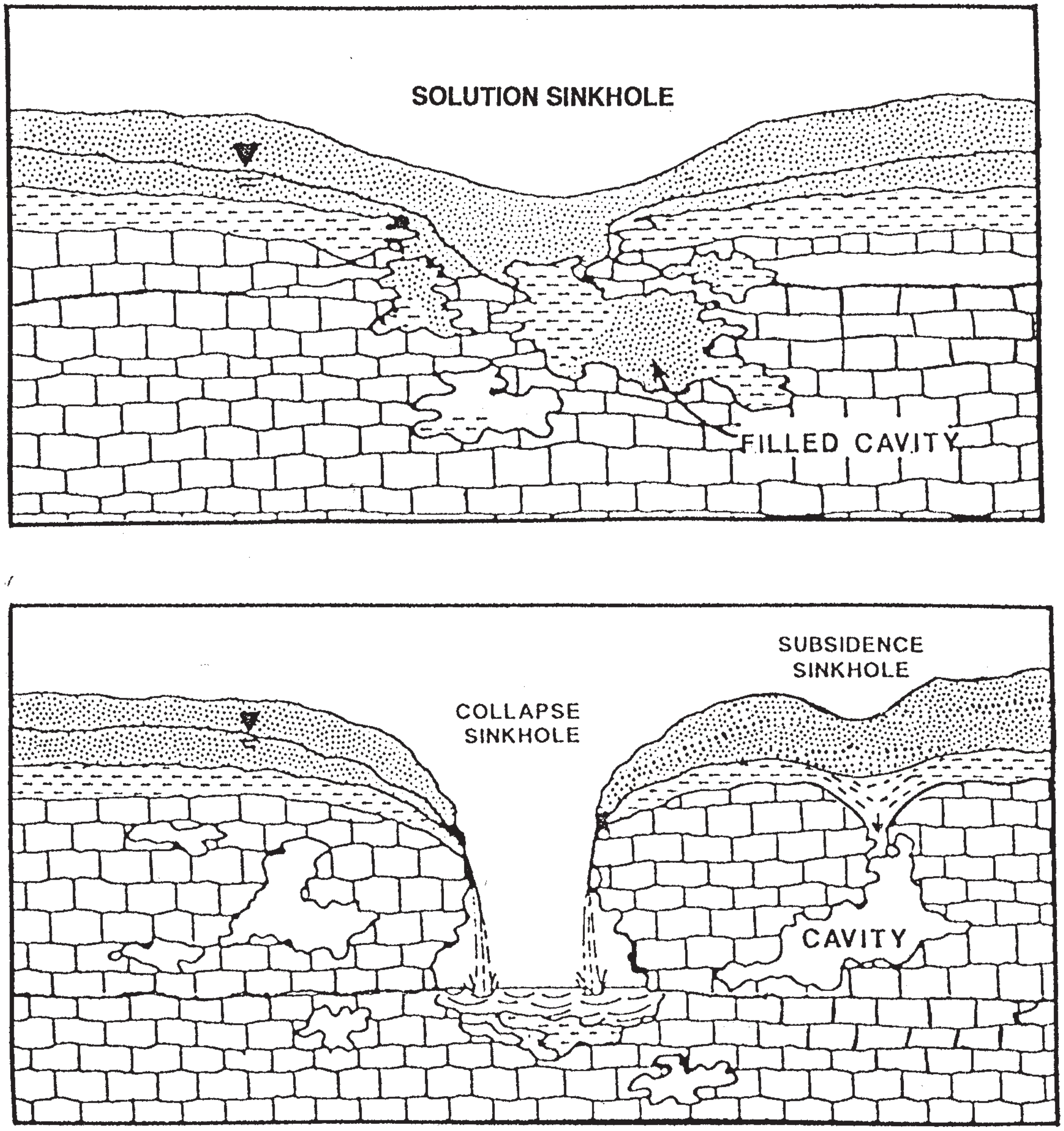


ZINN GEOLOGY

LOCAL GEOLOGIC MAP

Peace United Church - Envison Housing
900 High Street
Santa Cruz, California

FIGURE #
4
JOB #
2018011-G-SC



Modified after Destephen and Wargo, 1992

ZINN GEOLOGY

Sinkhole Formation Processes
Peace United Church - Envison Housing
900 High Street
Santa Cruz, California

FIGURE #
5
JOB #
2018011-G-SC

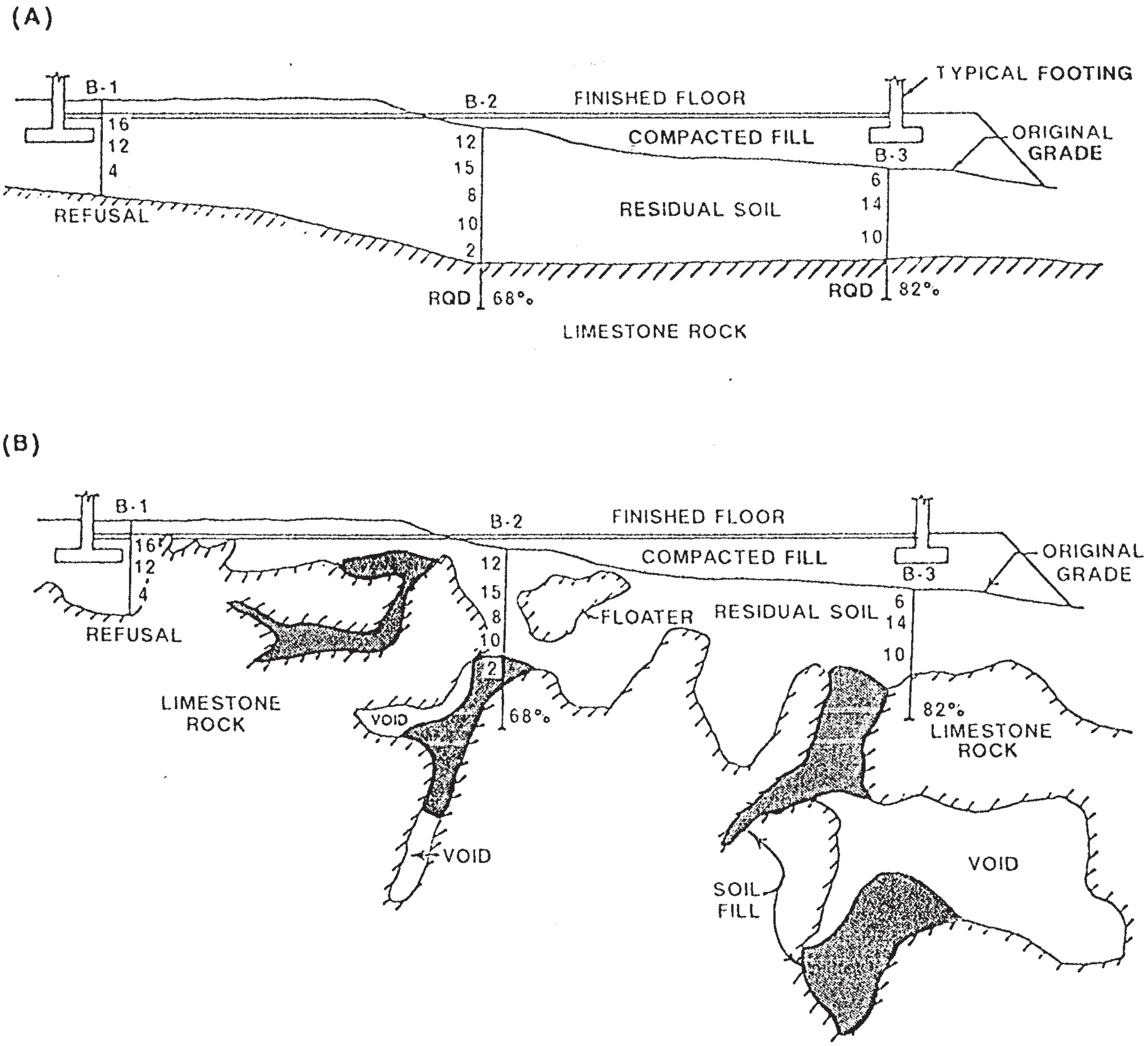


Figure A represents a possible geologic interpretation of subsurface conditions assuming there are no karst conditions. Figure B represents possible subsurface conditions using the same test boring data as in figure A and assuming karst conditions.

Modified after Destephen and Wargo, 1992

ZINN GEOLOGY

Geologic Interpretation In Karst Terrane
Peace United Church - Envison Housing
900 High Street
Santa Cruz, California

FIGURE #
6
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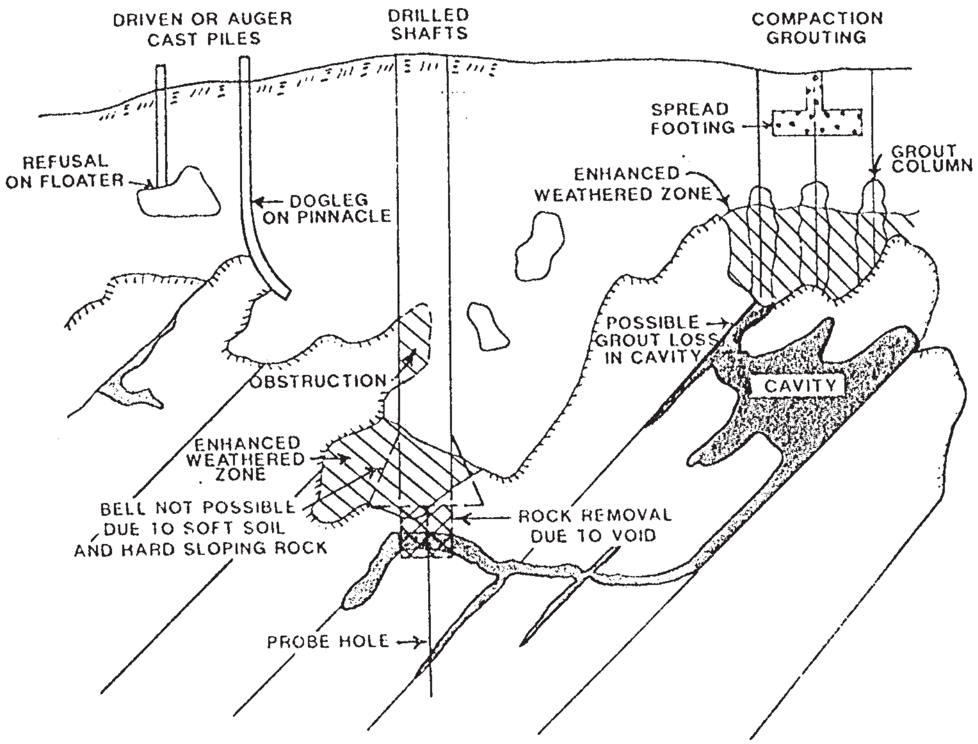

Modified after Destephen and Wargo, 1992

ZINN GEOLOGY

Foundation Difficulties In Karst
Peace United Church - Envison Housing
900 High Street
Santa Cruz, California

FIGURE #
7
JOB #
2018011-G-SC

APPENDIX B

SCALE OF ACCEPTABLE RISKS FROM GEOLOGIC HAZARDS

SCALE OF ACCEPTABLE RISKS FROM SEISMIC GEOLOGIC HAZARDS

Risk Level	Structure Types	Extra Project Cost Probably Required to Reduce Risk to an Acceptable Level
Extremely low[1]	Structures whose continued functioning is critical, or whose failure might be catastrophic: nuclear reactors, large dams, power intake systems, plants manufacturing or storing explosives or toxic materials.	No set percentage (whatever is required for maximum attainable safety).
Slightly higher than under "Extremely low" level.[1]	Structures whose use is critically needed after a disaster: important utility centers; hospitals; fire, police and emergency communication facilities; fire station; and critical transportation elements such as bridges and overpasses; also dams.	5 to 25 percent of project cost.[2]
Lowest possible risk to occupants of the structure.[3]	Structures of high occupancy, or whose use after a disaster would be particularly convenient: schools, churches, theaters, large hotels, and other high rise buildings housing large numbers of people, other places normally attracting large concentrations of people, civic buildings such as fire stations, secondary utility structures, extremely large commercial enterprises, most roads, alternative or non-critical bridges and overpasses.	5 to 15 percent of project cost.[4]
An "ordinary" level of risk to occupants of the structure.[3,5]	The vast majority of structures: most commercial and industrial buildings, small hotels and apartment buildings, and single family residences.	1 to 2 percent of project cost, in most cases (2 to 10 percent of project cost in a minority of cases).[4]

1 Failure of a single structure may affect substantial populations.

2 These additional percentages are based on the assumptions that the base cost is the total cost of the building or other facility when ready for occupancy. In addition, it is assumed that the structure would have been designed and built in accordance with current California practice. Moreover, the estimated additional cost presumes that structures in this acceptable risk category are to embody sufficient safety to remain functional following an earthquake.

3 Failure of a single structure would affect primarily only the occupants.

4 These additional percentages are based on the assumption that the base cost is the total cost of the building or facility when ready for occupancy. In addition, it is assumed that the structures would have been designed and built in accordance with current California practice. Moreover the estimated additional cost presumes that structures in this acceptable-risk category are to be sufficiently safe to give reasonable assurance of preventing injury or loss of life during and following an earthquake, but otherwise not necessarily to remain functional.

5 "Ordinary risk": Resist minor earthquakes without damage: resist moderate earthquakes without structural damage, but with some non-structural damage; resist major earthquakes of the intensity or severity of the strongest experienced in California, without collapse, but with some structural damage as well as non-structural damage. In most structures it is expected that structural damage, even in a major earthquake, could be limited to repairable damage. (Structural Engineers Association of California)

Source: *Meeting the Earthquake,* Joint Committee on Seismic Safety of the California Legislature, Jan. 1974, p.9.

SCALE OF ACCEPTABLE RISKS FROM NON-SEISMIC GEOLOGIC HAZARDS[6]

Risk Level	Structure Type	Risk Characteristics
Extremely low risk	Structures whose continued functioning is critical, or whose failure might be catastrophic: nuclear reactors, large dams, power intake systems, plants manufacturing or storing explosives or toxic materials.	1. Failure affects substantial populations, risk nearly equals nearly zero.
Very low risk	Structures whose use is critically needed after a disaster: important utility centers; hospitals; fire, police and emergency communication facilities; fire station; and critical transportation elements such as bridges and overpasses; also dams.	1. Failure affects substantial populations. Risk slightly higher than 1 above.
Low risk	Structures of high occupancy, or whose use after a disaster would be particularly convenient: schools, churches, theaters, large hotels, and other high rise buildings housing large numbers of people, other places normally attracting large concentrations of people, civic buildings such as fire stations, secondary utility structures, extremely large commercial enterprises, most roads, alternative or non-critical bridges and overpasses.	1. Failure of a single structure would affect primarily only the occupants.
"Ordinary" risk	The vast majority of structures: most commercial and industrial buildings, small hotels and apartment buildings, and single family residences.	1. Failure only affects owners /occupants of a structure rather than a substantial population. 2. No significant potential for loss of life or serious physical injury. 3. Risk level is similar or comparable to other ordinary risks (including seismic risks) to citizens of coastal California. 4. No collapse of structures; structural damage limited to repairable damage in most cases. This degree of damage is unlikely as a result of storms with a repeat time of 50 years or less.
Moderate risk	Fences, driveways, non-habitable structures, detached retaining walls, sanitary landfills, recreation areas and open space.	1. Structure is not occupied or occupied infrequently. 2. Low probability of physical injury. 3. Moderate probability of collapse.

[6] Non-seismic geologic hazards include flooding, landslides, erosion, wave runup and sinkhole collapse

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GEOLOGIC SITE MAP

Peace United Church - Envison Housing
900 High Street
Santa Cruz, California

Date: 2 July 2018	Revised:
Job #2018011-G-SC	
Scale: 1"=10'	**Plate 1**
Drawn by: ENZ/enz	

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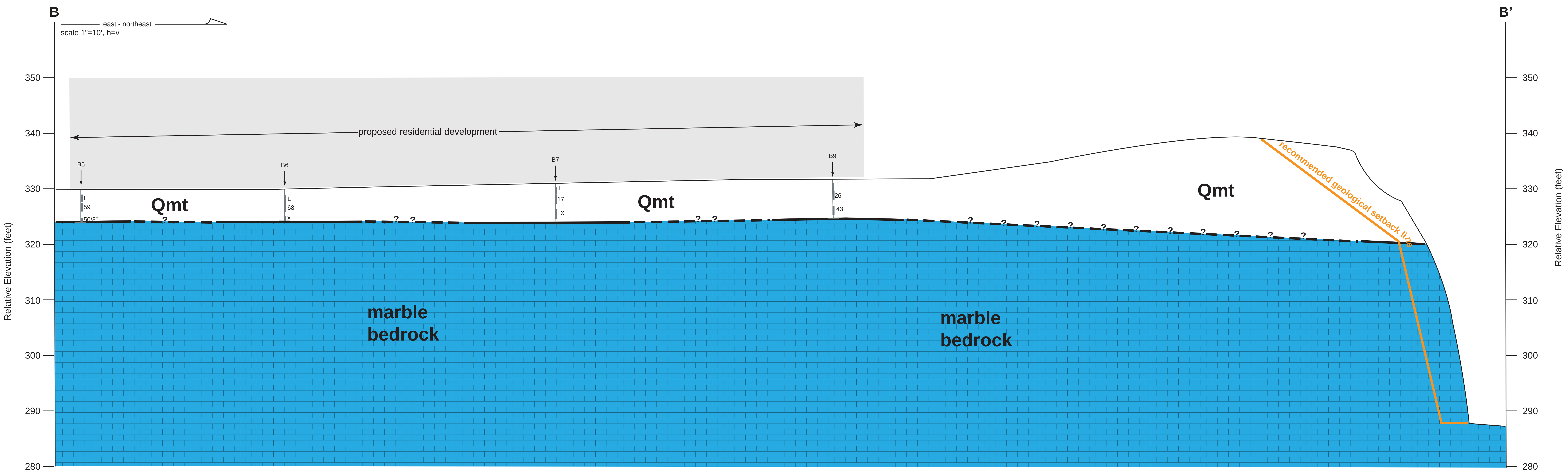
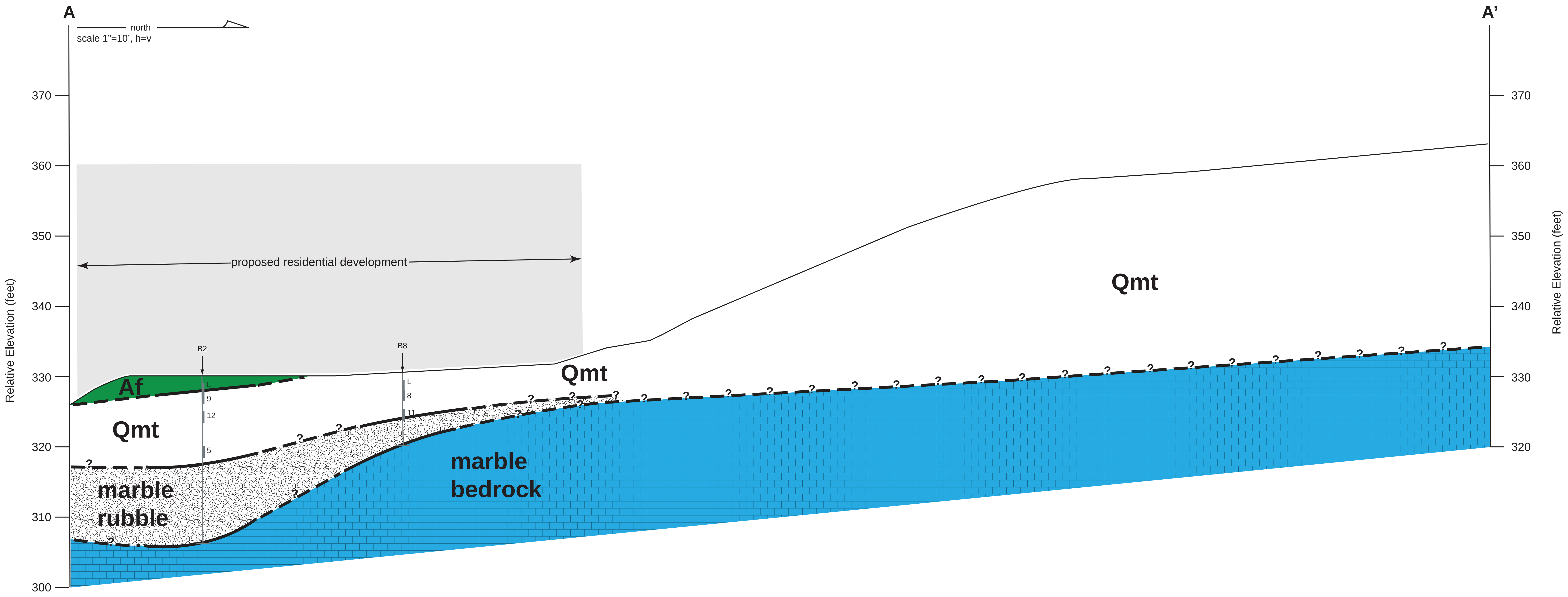
EXPLANATION

B10 330 12 318	Small-diameter borings advanced for this project; the elevation of the boring, the depth below the ground surface at which intact marble bedrock was encountered and the elevation at which intact marble bedrock was encountered is beside the boring symbol.
670	Intact marble bedrock surface elevation contours; five-foot contour interval; hachures point downslope within closed depressions in bedrock.
🟧	Dolines containing relatively soft soil that pose a risk to the proposed development due to settlement or collapse
B├─┤B'	Line of geologic cross section; see Plate 2 for cross sections
Qmt/mar	Marine terrace deposits underlain by marble bedrock

BASE MAP: Excerpted from a digital copy of A00 titled *"Envision Housing - Peace United Church-Site Plan"* , by David Baker Architects, dated 12 April 2018, intended publication scale: 1"=100'.





SYMBOLS

?	Interpreted contact between earth material units; queried where uncertain
B-10 49	Exploratory boring advanced by Dees & Associates; Small filled rectangles indicate where samples were taken; integers next to rectangles are blow counts for that sample, normalized to a Terzaghi sampler.

EARTH MATERIALS

Af	Artificial fill
Qmt	Marine terrace deposits
Marble rubble	Marble rubble - angular gravel to boulder sized fragments of marble that have collapsed into doline
Marble	Intact marble bedrock

NOTES

1. Marble rubble are shown only on cross section.

2. The configuration of the marble surface portrayed on our geologic profile does not exactly match the marble surface portrayed on Geologic Site Map (Plate 1). The marble surface contour map was used as a general guideline for the profile constructions. The karst geometry is conservatively interpreted on the profile; hence, the marble surface shown on the profile varies slightly from the configuration portrayed on Plate 1.

3. Final location and foundation depth of proposed buildings has not been decided upon as of the publication of this report. Buildings shown on this cross are schematic and are intended only to aid the reader in understanding where the building might approximately lie upon the existing ground surface with respect to the underlying geologic structure.

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GEOLOGIC CROSS SECTIONS
Peace United Church - Envison Housing
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Date: 2 July 2018   Revised:

Job #2018011-G-SC

Scale: 1"=10', h=v

Drawn by: ENZ/enz

Plate 1