14 October 2025 Project No. 2381.2

City of Capitola, Public Works
Attention: Jessica Kahn, Public Works Director
420 Capitola Ave
Capitola, California 95010
Phone: (831) 475-7300
jkahn@ci.capitola.ca.us

Re: Updated limited geological investigation of coastal bluff failure
Grand Avenue footpath between Oakland and Central Avenues
Capitola, California 95010

REFERENCES

"Re: Limited geological investigation of coastal bluff failure - Grand Avenue footpath near intersection with Oakland Avenue and Saxon Avenue - Capitola, California 95010", unpublished consultant letter by Pacific Crest Engineering, dated 9 June 2023

"Re: Limited geological investigation of coastal bluff failure - Grand Avenue near intersection with Oakland Avenue and Hollister Avenue - Capitola, California 95010", unpublished consultant letter by Zinn Geology, dated 15 May 2017

Dear Jessica:

This letter presents the results of our updated limited geological investigation of the ongoing bluff failures that have undermined portions of the footpath along Grand Avenue between its intersection with Oakland Avenue and Central Avenues (see Plate 1). Our work and this letter build upon the work completed previously in this area by Zinn Geology (2017) and Pacific Crest Engineering (2023). The reader should refer to those letters for a detailed discussion about the ongoing geological processes driving the configuration of the coastal bluff and its retreat.

Over the long term, the bluff below the footpath has been episodically retreating as the soil and bedrock exposed on the bluff face erodes and fails in the form of shallow landslides, debris flows and rock falls, mostly in response to intense storms, wave erosion and earthquakes. The most recent shallow landslides that have caused the top of the bluff to retreat and undermine the footpath this winter appear to have been driven by a combination of a large slab toppling failures of the Purisima Formation bedrock face of the bluff, saturation of the marine terrace deposits soil that caps the underlying Purisima Formation bedrock, as well as erosion of the Marine Terrace Deposits where a culvert flows out of the face of the bluff.

The overall long term failure process for the coastal bluff at this location is a two-part process. The Purisima Formation bedrock exposed in the lower bluff is eroded and notched at the base by waves until the notch intersects a nearly vertical bluff-parallel joint set, at which point a slab of bedrock slides downward or topples, typically from top to bottom for the exposed slab. The bedrock topple process also takes the overlying cap of marine terrace deposits along with it leaving a very steeply dipping to nearly vertical scar in the bluff face that freshly exposes both the bedrock and marine terrace deposits. At that point, the wave scour process begins anew at the base of the bluff, eventually carving another notch into the bedrock. The marine terrace deposits concurrently begin to erode and slide in a piecemeal fashion as they seek the angle of repose of about 38 degrees for the sand and gravels that compose that majority of the formation. This process continues unabated until the bedrock topples again in the future, resetting the entire retreat process geometry and clock.

For this current work we have mapped the position of the top of the bluff using a combined data set of our own drone flight and a surveyed base map prepared and provided by Bowman and Williams. The base map also shows the location of the current fence line and property lines.

The bluff is in various states of failure between Central and Oakland Avenues. Portions of the bluff have recently failed from top to bottom in response to intense storms of the past winters coinciding with El Nino Climatic events. In some locations, the bedrock exposed in the bluff is dilated and appears to be primed for toppling. Deep notches within the bedrock at the base of the bluff and sea caves have been observed during our field reconnaissance in this area in past years.

We also reviewed a geological report for the Depot Hill Geological Hazard Abatement District, prepared on 12 April 2000 by Rogers Johnson and Associates. The report documents a past calculated long term bluff retreat rate of about 1.0 feet per year at that time. The authors also cautioned the reader that the bluff had been severely undercut at that point, implying that a large failure of the bluff was imminent. This process described by them isn't a one time event – as noted above this is an ongoing cyclical process that is constantly driving the face of the bluff landward.

As noted at the beginning of this letter, the fate of the bluff and the retreat is always tied to what is happening at the base of the bluff with respect to notching and formation of sea caves. We noted two distinct conditions with respect to that observation for the area studied:

1. Various portions of the bluff failures between Central and Oakland Avenues that have occurred in the last several winters appear to have been triggered by toppling of undercut bedrock.

2. Some of landslides that have occurred in the last several winters between Central and Oakland Avenues appear to have been within the marine terrace deposits only.

3. Although no landsliding occurred this past winter in some locations between Central and Oakland Avenues (see heavily vegetated areas on bluff face on Plate 1), the bedrock is primed to topple at those locations due to being notched at the base.

Most of the marine terrace deposits in this area are over steepened and will likely lay back to an average angle of about 38 degrees. This may come about in one to three rainy seasons. A conservative analysis would assume that we will have back-to-back wet seasons for the next several years, which may lay back the marine terrace deposits to the angle of repose. A more liberal analysis would assume that we will enter a drought period of three to five years, followed by wet year. Using those ranges implies that the top of the bluff may retreat significantly within one to six years.

A review of the most recent El Nino status by NOAA (which can be accessed here: https://www.cpc.ncep.noaa.gov/products/analysis_monitoring/lanina/enso_evolution-status-fcsts-web.pdf) stipulates that "La Niña conditions are present and favored to persist through December 2025 -February 2026, with a transition to ENSO-neutral likely in January-March 2026 (55% chance).*" Although La Nina climatic conditions typically results in lower than average precipitation and relatively smaller storm waves, there is always a chance that large coastal storm waves might impact central California even during a La Nina climatic cycle.

We have used two methods of projecting the future top of bluff retreat for this study. The first method is a simple long range bluff retreat method generated by measuring the difference in time and position of the bluff between the set of stereopair aerial photographs and the current bluff position. The only set of high resolution historical stereopair aerial photos we could procure on short notice were the 1956 set. We measured a variable retreat rate of 0.33 feet per year to 0.66 feet per year for the study area between 1956 and 2025. We used these retreat rates to calculate and plot the projected bluff top position 10 years from now (represented by the purple line on Plate 1).

We also drew transects at select locations in the area of interest and plotted the projected top of bluff assuming the Marine Terrace Deposits will lay back to the angle of repose of about 38 degrees (Represented by the pink line on both the transects and map; see Plate 1) in response to rainfall and earthquakes. Using just this analysis pushes the top of the bluff back between 12 ½ to 22 feet from the current position. In our opinion this line represents the retreat that could happen in one to six years, taking future storms into consideration. **We have not factored in the collapse of the undercut portion of the bluff bedrock or the landsliding and subsequent retreat that would occur in the event of a large magnitude earthquake. If either of those processes are factored in and occur within that time period of one to six years, the amount of bluff retreat may be even greater.**

It is of interest to note that the two methods result in a consistent difference in projected bluff top retreat configuration. The aerial photo method plotting the predicted position of the bluff ten years from now is consistently less than the pure physical model method of using the

angle of repose of the Marine Terrace Deposits with a stipulated life of one to six years. The shorter-lived angle of repose line actually lies consistently inland of the historical aerial photograph derived line. The angle of repose method might be overly conservative and the aerial photo analysis might be overly liberal, which may mean that reality lies between the two extremes. We have created a plate that depicts the area that lies between the two retreat lines and have labeled that area as a "Zone Of Short Term (1-10 Years) Blufftop Retreat" (red stippled polygon on Plate 3).

DISCUSSION OF FUTURE FOOTPATH CONFIGURATION

The objective of this study was to provide the City with an overview of the feasibility of mitigating the risk to the footpath with respect to the hazard of short-term bluff retreat. In discussions with City staff, we learned that the narrowest the path could be is four feet with a two-foot seaward buffer, resulting in an overall width of six feet.

Turning to Plate 1, it should be noted that the **existing** footpath is impinged upon at several locations by both of the bluff top retreat method lines, with the angle of repose method line even impinging upon a property line at one location.

Given that observation we have plotted a **hypothetical** six-foot-wide relocated footpath right up against the current seaward property lines along Grand Avenue in the study area (see Plate 1). This reflects the most extreme landward position that the footpath can be located without being pushed onto private property. As can be noted from the map, this hypothetical repositioning will result in a short-term life of mostly one to ten years, depending upon which retreat method line is used.

There is one issue toward the downcoast end of the study area, near the intersection of Oakland and Grand Avenues. At that location the angle of repose method retreat line impinges upon the hypothetical repositioning of the footpath. This implies that even if the footpath is pushed landward and snugged up against the property at that corner, it may be undermined and threatened in less than decade.

The author of this letter has discussed at length in the past, as well as participated in a past City designated committee, about exploring the possibility of armoring the entire bluff face with seawalls, retaining walls, rock bolts or even constructing jetties or groins in an attempt to arrest the ongoing retreat of the entire bluff. Such an armoring or protection effort is likely to cost a great amount of money (in excess of tens of millions of dollars) and will take years to design, permit and construct. **Protecting the entire bluff is therefore not feasible for a short-term solution.**

There are also different methods of erosion control that might slow down the retreat of the blanket of Marine Terrace Deposits, such as planting woody vegetation or vines that will combat rain drop impact, runoff and provide some evapotranspiration at the saturated contact between the Marine Terrace Deposits soil and the Purisima Formation bedrock.

This will retard the rate at which the Marine Terrace Deposits lay back to the angle of repose but ultimately will be subsumed by the bottom-up process of bluff retreat as the bedrock bluff face fails.

FINDINGS

1. An effective life of a decade or less can likely be achieved via reconfiguring and repositioning the footpath into a four-foot-wide path with a two-foot buffer and then placing that configuration adjacent to the seaward property line of the residences along Grand Avenue (see Plate 1 for the hypothetical layout).
2. Placing erosion control on the portion of the bluff face where the Marine Terrace Deposits are exposed may attenuate the retreat of just the Marine Terrace Deposits. Ultimately though, any erosion control placed on the upper bluff face will be subsumed by the bottom-up process of bluff retreat as the bedrock bluff face fails.
3. Freezing the bluff face in its current position could be achieved through armoring the entire bluff with seawalls, retaining walls, or rock bolts. Constructing jetties or groins at the base of the bluff could capture sand and slow the overall rate of retreat too. Such an effort is likely to cost a great amount of money (in excess of tens of millions of dollars) and will take years to design, permit and construct. **Protecting the entire bluff is therefore not feasible for a short-term solution.**

RECOMMENDATIONS

1. If the longest lifetime of a relocated footpath is desired, the City should relocate the footpath as far inland as possible, with the inland side of the path abutting the property lines of the residences (see Plate 1 for this hypothetical layout).
2. An engineered grading and drainage plan should be prepared as part of the proposed footpath location. Care should be taken to avoid ponding water near the top of the bluff to avoid triggering large landslides and no collected storm water should be allowed to flow over the top of the bluff.
3. The effective life of the footpath should be considered when contemplating short term and long-term expenditures for keeping the footpath open. Long-term solutions, such as protecting the entire bluff from erosion will be very expensive and will require extensive studies, design work and may entail a difficult permitting process.

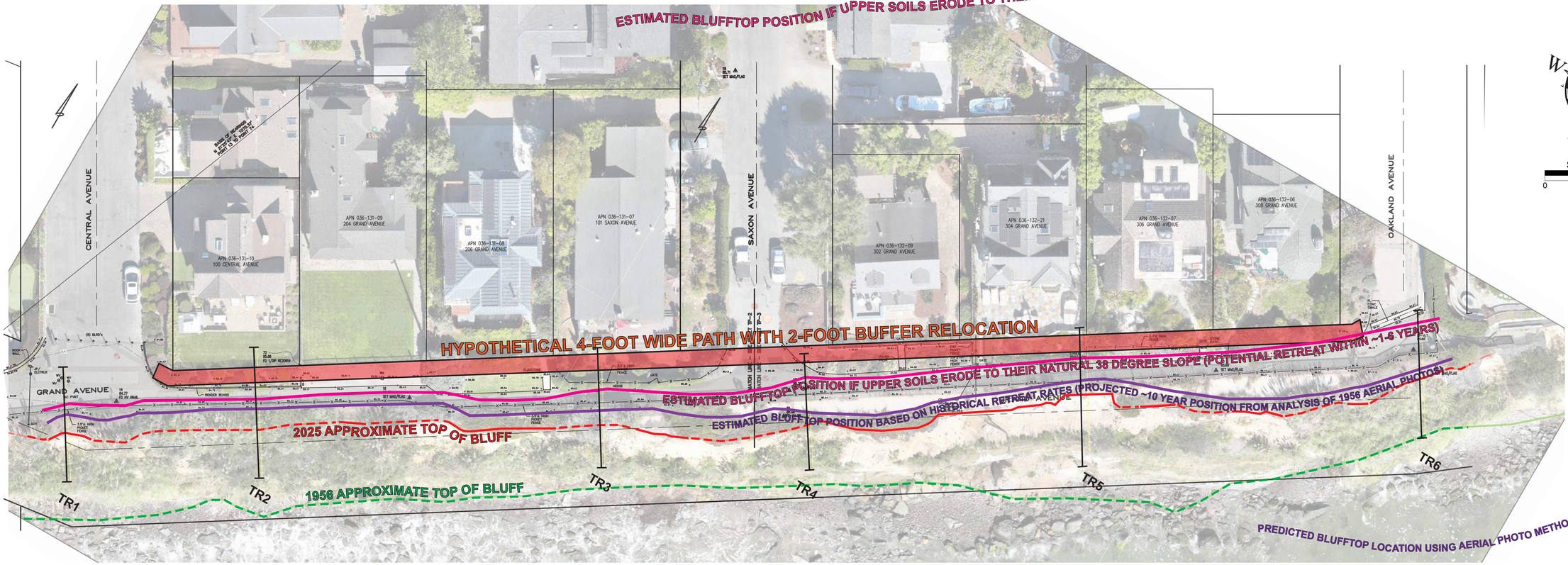
This concludes our geological letter regarding the impacts of landsliding and bluff top retreat for the Grand Avenue footpath between the intersections of Central and Oakland Avenues. Please do not hesitate to contact us if you have any questions about this letter or our work or need further assistance.

Sincerely,

PACIFIC CREST ENGINEERING INC.

Erik N. Zinn
Principal Geologist
P.G. #6854, C.E.G. #2139

Attachments: Plate 1 – Site Plan & Geologic Transects
Plate 2 – Site Plan Without Aerial Photo & Geologic Transects
Plate 3 – Site Plan Showing Zone of Short Term Blufftop Retreat



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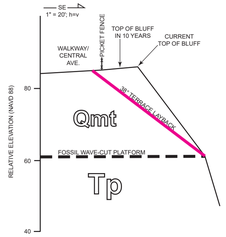

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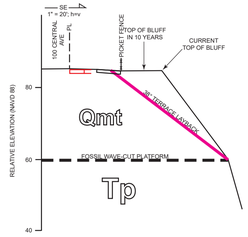

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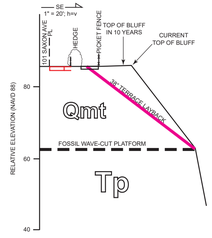

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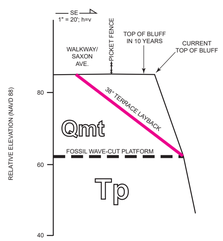

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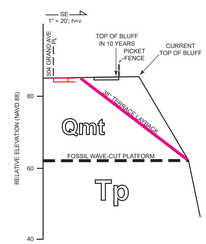

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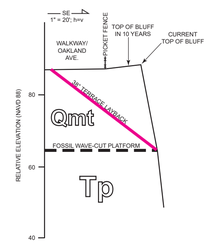

Transect Note: Elevations and distances were measured using a hybrid of: Bowman & Williams; Topographic Map of a Portion of the Capitola Grand Avenue Pathway, Sheets TP-2 and TP-3; dated 10-06-2025; original scale: 1"=10'; & 3-D reconstruction of a 2-D photogrammetry drone flight using DJI Terra and ArcGIS Pro.

TRANSECT EXPLANATION

EARTH MATERIALS

Qmt Marine Terrace Deposits

Tp Purisima Formation Bedrock

SYMBOLS

Existing footpath

Hypothetical footpath relcoation placed directly adjacent to residential properties (includes 2-foot buffer from seaward edge of path)

Earth materials contact - dashed where approximate

SITE PLAN EXPLANATION

SYMBOLS

Estimated blufftop position if upper soils (Marine Terrace Deposits) erode to their natural 38 degree slope (potential retreat within ~1-6 years)

Estimated blufftop position based on historical retreat rates (projected ~10 year position from analysis of 1956 aerial photos)

TR6

Transect line and location

Hypothetical footpath relcoation placed directly adjacent to residential properties (includes 2-foot buffer from seaward edge of path)

Base Map: Bowman & Williams; Topographic Map of a Portion of the Capitola Grand Avenue Pathway, Sheets TP-2 and TP-3; dated 10-06-2025; original scale: 1"=10'; Imagery provided by Pacific Crest Engineering for 9/25/2025 drone flight

PROFESSIONAL GEOLOGIST
ERIK N. ZINN
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ERIK N. ZINN
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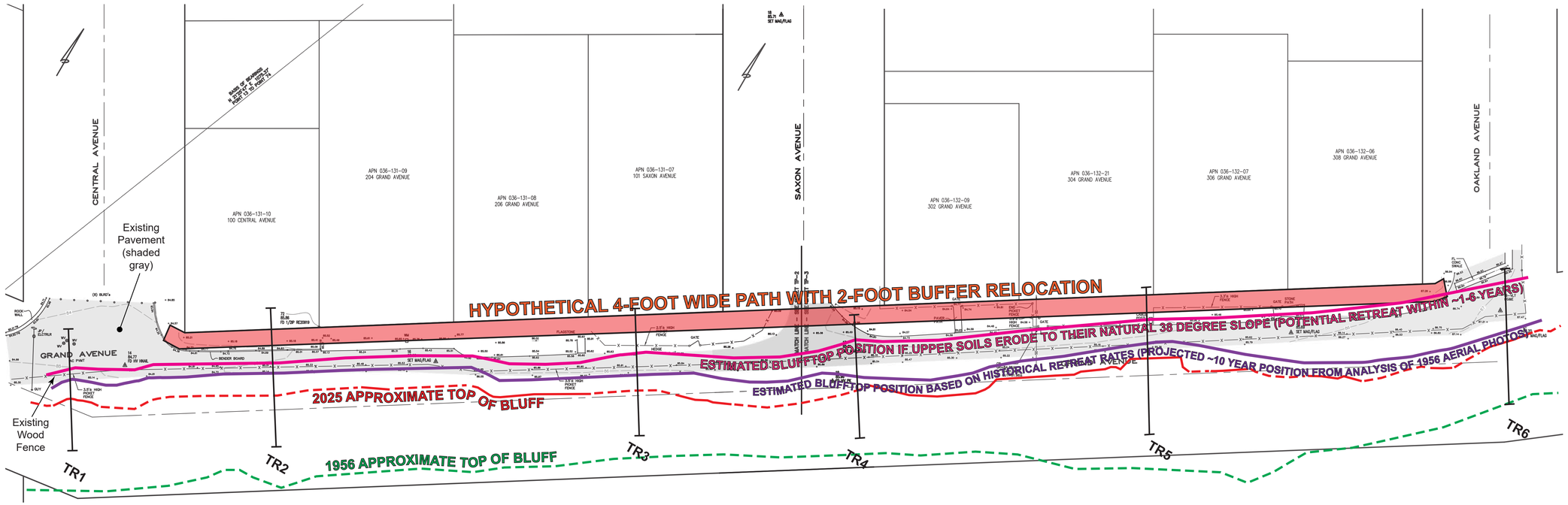
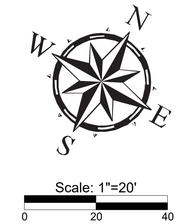
Pacific Crest
ENGINEERING INC

Site Plan & Geologic Transects
Grand Avenue Footpath Bluff Retreat Hazard & Risk Assessment
Capitola, California

Date: 10 October 2025	Revised: 14 October 2025
Job #2381.2	
Scale: 1"=20'	**Plate 1**
Drawn by: MP/ENZ/mp	





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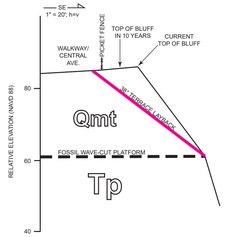

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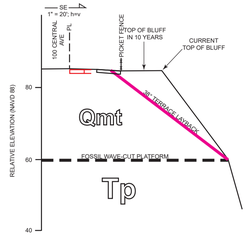

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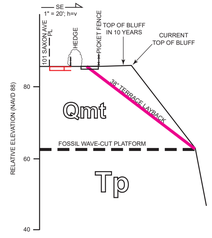

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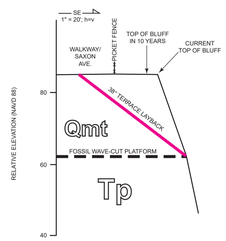

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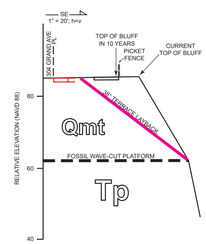

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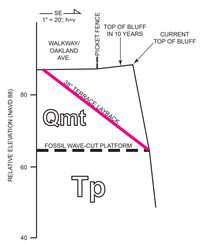

TRANSECT EXPLANATION

EARTH MATERIALS

Qmt Marine Terrace Deposits

Tp Purisima Formation Bedrock

SYMBOLS

Existing footpath

Hypothetical footpath relcoation placed directly adjacent to residential properties (includes 2-foot buffer from seaward edge of path)

Earth materials contact - dashed where approximate

Transect Note: Elevations and distances were measured using a hybrid of: Bowman & Williams; Topographic Map of a Portion of the Capitola Grand Avenue Pathway, Sheets TP-2 and TP-3; dated 10-06-2025; original scale: 1"=10'; & 3-D reconstruction of a 2-D photogrammetry drone flight using DJI Terra and ArcGIS Pro.

SITE PLAN EXPLANATION

SYMBOLS

Intersection of 38-degree angle of repose Marine Terrace Deposits line with ground surface - see see transects on this plate for derivation of the line

Projected top of bluff in 10 years using long term bluff retreat calculations derived from analysis of 1956 stereopair aerial photographs

TR6

Transect line and location

Hypothetical footpath relcoation placed directly adjacent to residential properties (includes 2-foot buffer from seaward edge of path)

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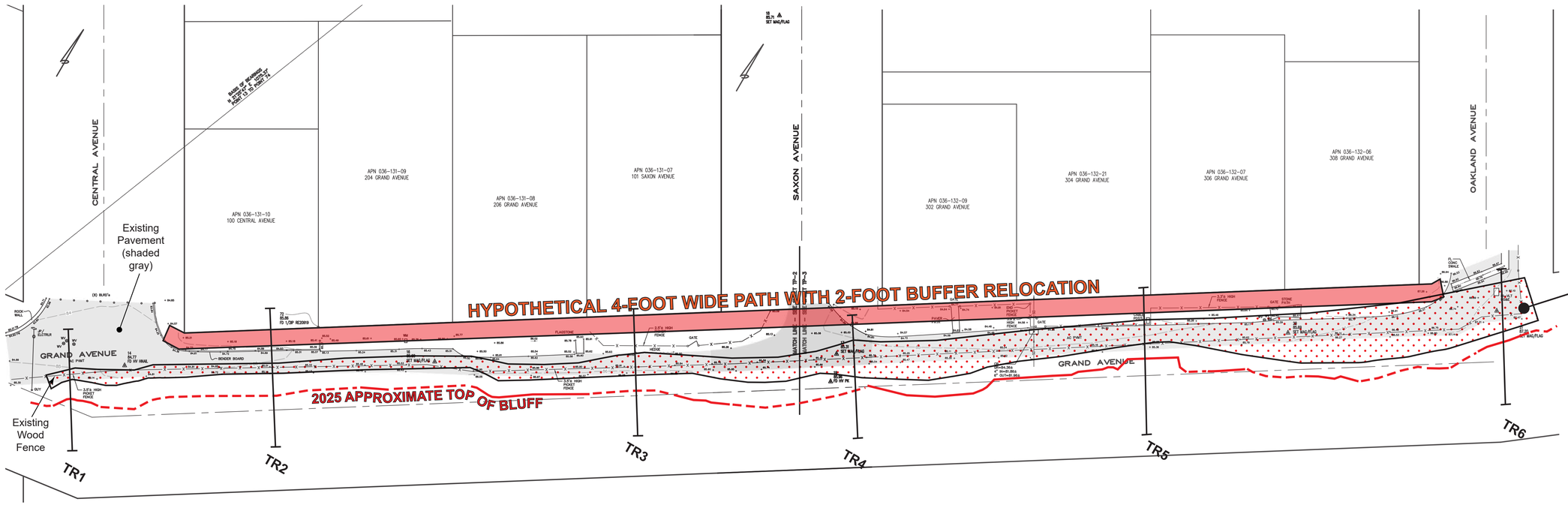
Pacific Crest
ENGINEERING INC

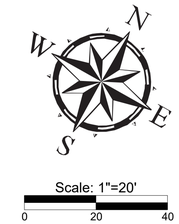
Site Plan Without Aerial Photo & Geologic Transects

Grand Avenue Footpath Bluff Retreat Hazard & Risk Assessment

Capitola, California

Date: 14 October 2025	Revised:
Job #2381.2	
Scale: 1"=20'	**Plate 2**
Drawn by: MP/ENZ/mp	





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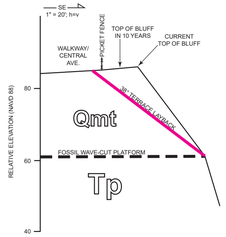

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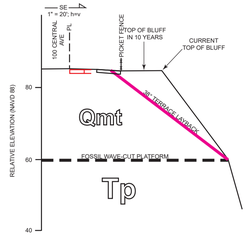

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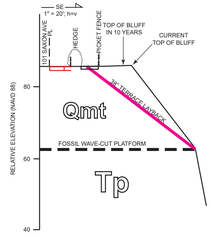

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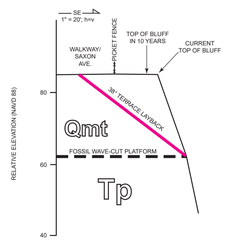

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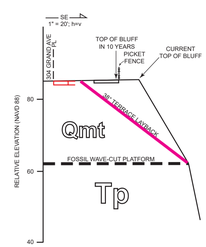

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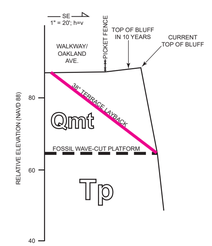

TRANSECT EXPLANATION

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Tp Purisima Formation Bedrock

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SITE PLAN EXPLANATION

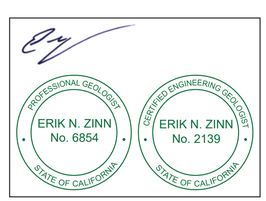
SYMBOLS

Zone of short term (1-10 years) blufftop retreat

TR6 Transect line and location

Hypothetical footpath relcoation placed directly adjacent to residential properties (includes 2-foot buffer from seaward edge of path)

Base Map: Bowman & Williams; Topographic Map of a Portion of the Capitola Grand Avenue Pathway, Sheets TP-2 and TP-3; dated 10-06-2025; original scale: 1"=10'



Pacific Crest
ENGINEERING INC

Site Plan Showing Zone Of Short Term Blufftop Retreat

Grand Avenue Footpath Bluff Retreat Hazard & Risk Assessment

Capitola, California

Date: 14 October 2025	Revised:
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Scale: 1"=20'	**Plate 3**
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