

## Appendix D: Regional Geologic Report

Gilpin Geosciences, Inc

Earthquake & Engineering Geology

November 1, 2007

4644.01

Dr. Ramin Golesorkhi, G.E.  
Treadwell & Rollo, Inc.  
555 Montgomery Street, Suite 1300  
San Francisco, California 94111

**Re: Engineering Geologic Evaluation  
Vista Grande Basin Alternatives  
Thornton State Beach/Fort Funston  
Daly City/San Francisco, California**

Dear Dr. Golesorkhi,

## **INTRODUCTION**

We are pleased to present our Engineering Geologic Evaluation for the Vista Grande Basin Alternatives located between Westlake District and Fort Funston, in Daly City and San Francisco, California, as shown on Figure 1, Location and Landslide Map. The objective of our evaluation was to perform a preliminary geological reconnaissance of the site to characterize the foundation conditions along the various alternative improvement alignments. A primary task was to research the Bay Area libraries and archive resources to locate any documents addressing the site vicinity. We present our findings in this letter report.

The Vista Grande Drainage Basin Alternatives Analysis Project has been undertaken by the City of Daly City to address storm-related flooding in the Vista Grande Watershed Drainage Basin, specifically the downstream area around the Vista Grande canal and tunnel at Lake Merced Boulevard and John Muir Drive. The underground system in this area conveys storm flows generated within the basin to Lake Merced Boulevard and then north to the Vista Grande canal, where it is discharged via a tunnel and outfall structure into the Pacific Ocean near Fort Funston.

Of the seven initial alternatives, Alternatives 1 through 3 present new pipes or tunnel along the existing Vista Grande tunnel alignment (North alignment). Alternatives 4 through 7 present new pipes or tunnels along an alignment south of the County Line (South alignment) in addition to using the existing Vista

Grande Tunnel for either partial or backup capacity. Based on these alternatives we have considered the geological conditions in the general vicinity of Lake Merced and extending south to John Daly Boulevard, however, we have focused on the two alignments for the proposed pipe or tunnel structures: (1) Northern alignment along the existing Vista Grande tunnel; and (2) Southern alignment proposed along a route that extends from the southeastern corner of the Olympic Club, beneath Westlake Village to the ocean shoreline.

## **BACKGROUND**

The Vista Grande Tunnel, that lies along the Northern alignment (Figure1) was constructed between May 1895 and sometime in 1896. If a complete record of the geological conditions encountered during this excavation were kept they must have been lost during the 1906 fires. Marliave (1945; 1947) prepared a geologic report for the City of San Francisco regarding a proposed new sewer tunnel. He recovered a pencil profile along the Vista Grande tunnel from the files of the Spring Valley Water Company. The profile shows some geologic information with a record of progress during the driving of the tunnel. Marliave notes that this tunnel has performed very well considering the equipment used to construct the brick and mortar lined structure, and its age. Since it has survived the 1906 earthquake event he suggests that it must be driven through “fairly sound” ground.

Marliave infers that the principal source of trouble driving the tunnel was groundwater. Laying of bricks is very difficult in the presence of running ground. The groundwater was probably confined to sandy strata, however he notes the presence of the vertical shaft along the alignment, approximately 900 feet from the west portal, where the tunnel likely encountered a fault “where the water was trapped on top of a blue clay stratum evidently cause considerable trouble”. There was a nine-month hiatus in the tunnel advancement at the shaft station. A second significant geologic structure, a syncline or fault, was encountered at 1700 feet from the east portal, though little water was reported. These faults and folds are likely associated with the Serra fault, shown on Figure 1, and discussed further in the following Geology Section.

Marliave noted water was reported between 1348 feet and 1516 feet in from the east end, and considerable water was noted at station 1950.

Marliave took the Vista Grande construction documents and plotted them at a natural scale, however there is not enough information to depict the geologic structure of the formations. He suggests “the evidence seems to point to some folding of the beds and probably the crossing of two faults. He also noted two 6-inch diameter drain pipes exposed below the tunnel invert at the west portal. One of these was flowing at the time of his visit.

In contrast to the sound nature of the existing Vista Grande tunnel alignment, there is information from the vicinity of the Southern alignment (Figure 1) that was developed as a drainage tunnel by California Department of Transportation in association with the Olympic Club. In an earlier report for the same San Francisco proposed tunnel project, Marliave (1945) considered a southern alignment for the proposed sewer tunnel. The southern alignment was described as passing just south of the Olympic Golf Club clubhouse and was entirely outside of San Francisco County. He describes the serious landslide issues along the bluff on this alignment that have been exacerbated by three significant northwest trending faults.

In 1928 the State constructed a drainage tunnel to mitigate landslide impact to the Skyline Drive corridor. The tunnel extended from slightly above sea level for 486.5 feet. Marliave (1945) describes the tunnel as having caved and filled with slide debris. At the time of his report he describes an attempt to reopen the drainage tunnel. "It was cleaned out and retimbered for 170 feet in from the portal, but at this place wet running muck filled the tunnel and kept coming in so that the crew were unable to cope with it".

## **REGIONAL AND SITE GEOLOGY**

The site is located in the Coast Ranges geomorphic province that is characterized by northwest-southeast trending valleys and ridges. These are controlled by folds and faults that resulted from the collision of the Farallon and North American plates and subsequent shearing along the San Andreas fault. Bedrock of the Franciscan Complex underlies most of this terrain and is characterized by a diverse assemblage of greenstone, sandstone, shale, chert, and melange, with lesser amounts of conglomerate, calc-silicate rock, schist and other metamorphic rocks.

The Merced Formation crops out in a broad trough that is partially exposed along the coastal bluffs of the site vicinity. It is of Plio-Pleistocene age (5 million to 10,000 years ago) and is characterized by sands and fine grained deposits deposited in nearshore ocean environments with some units representing deposition onshore as dune fields. It is mapped as filling a northwest-southeast trending fault-bounded basin that is exposed along the sea cliffs from Mussel Rock on the south to the north end of Lake Merced a distance of approximately 3.8 miles. The Merced Formation is overlain by the Late Pleistocene age (80,000 to 125,000 years ago) Colma Formation composed of sandy nearshore and beach deposits. Recent dune sand and localized fill overlie the Colma Formation in the site vicinity. We show a geologic map of the site vicinity on Figure 2.

Several investigators have mapped the Merced Formation deposits cropping out in the bluffs in the site vicinity. Hall (1966; 1967) and Clifton and Hunter (1987) mapped the Merced Formation in detail to understand the age range and rapid changes in depositional environments preserved in the deposits outcropping along the Fort Funston/Thornton Beach coastal bluffs.

Strike and dip of bedding within the Merced Formation sand and mud units varies along the coastal bluffs north of Fort Funston from N14°W, 8°NE dip to N46°W, 44°NE dip and south of the Thornton Beach landslide complex from N33°W, 40°NE dip to N64°W, 75°NE dip. There is some suggestion based on a review of orientations of a shallowing dip along the section of the coastal bluff associated with the complex landsliding.

As shown on the Regional Geologic Map, Figure 2, and the Fort Funston Site Geology Map, Figure 4, the site is blanketed by recent Dune Sand up to a few feet in thickness. The underlying Colma Formation at the site vary in thickness from about 25 feet to 40 feet, is moderately cemented to uncemented, and contains varying amounts of clay and silt.

The bluff top areas in the site vicinity have a long history of shallow and deep-seated landsliding. Since the proposed tunnel outlet would be at the base of the bluff slope stability is a primary concern for the design and construction of the tunnel. The landslide events that have occurred in the vicinity are compiled in Table 1 (Appendix) and include offsite areas of the Olympic Club, Thornton State Beach, and along the washed out Thornton Beach Road. The area from the southern edge of Fort Funston south to Thornton Beach includes a large rotational landslide, however depositional units of the Colma and underlying Merced Formation could be mapped on the coastal bluffs. The largest of these landslides is the Thornton Beach landslide shown in Figures 1 and 2.

Evidence of deep-seated landsliding in the vicinity of Thornton State Beach is based on dramatic topographic and historic movement data. The toe of the bluff along much of the area forms the eastern edge of a large linear depression resulting from oceanward movement of a large coherent block of Merced Formation material. This depression or graben extends from just south of John Daly Boulevard north to the southern end of the Fort Funston facilities. Since formation of the depression or graben erosion and shallow landsliding of the bounding slopes have partly filled the depression. The bluff forms the headscarp of the landslide that may extend to depths of approximately 140 feet below sea level.

Bonilla (1960) mapped landslide deposits and described the Thornton Beach landslide complex and estimated the depth of the landslide basal slip surface at approximately 140 feet below sea level based on the geometry of the blocks involved and detailed surface mapping of a volcanic tuff unit near the top of the Merced Formation. We show Bonilla's interpretation on Figure 3; the location of the section is shown on Figure 1.

Although the age of this landslide is not known, it is estimated to have originated around 400 years ago based on a study of the slope stability and assumed local bluff retreat rates (Liebhart, M.D., 2002). The slide topography is shown on the earliest U.S. Coast and Geodetic topographic map of the area published in 1869.

The 1957 Daly City earthquake triggered a number of landslides along the coastal bluffs between Pacifica and Lake Merced, damaging the coast highway (State Route 1), which formerly ran along the coastal bluffs to the south of the Thornton State Beach. The highway was abandoned in 1958 because of on-going landsliding; however, a portion of the highway was repaired and used as a beach access (Thornton Beach Road). The landsliding and erosion eventually also forced closure of the road. Since then, the heavy rains of 1982-83 and reported road drainage problems appear to have started a cycle of cliff erosion that has undermined and washed out the Beach Road and buried the parking lot that was situated in the depression.

The 1989 Loma Prieta earthquake caused shaking that triggered a very large block failure in the coastal bluff approximately 2 miles south of Thornton Beach (Sitar, 1991). Because of this long history of slope instability potential liquefaction and earthquake-induced landslide hazards have been mapped along the coastal bluffs, as shown on Figure 7 (California Geological Survey, 2000), and should be considered during subsequent design phases.

The Serra fault has been mapped in the general vicinity of the site (Kennedy, 2002;2004). Its northern-most surface extent is shown on Figure 1. The Serra fault is the northernmost fault in the Foothills thrust system, a zone of northwest striking thrust faults adjacent to and northeast of the Peninsula Segment of the San Andreas fault. The thrust faults generally dip southwest towards the San Andreas fault and probably merge with it at depth. The Serra fault is mapped as a blind feature in the site vicinity (is not exposed at the surface but buried beneath young surficial deposits). Kennedy (2002; 2004) has shown that folding in the Merced Formation units is compatible with thrusting on the Serra fault. The Serra fault is probably not seismogenic (capable of generating an earthquake) however, it is subject to displacements during large earthquake events on the San Andreas fault. Recent investigations along the Serra fault trace south of the site (Kennedy and Hitchcock, 2004) have determined that the fault appears to have been active in the Holocene (11,000 to Recent). Faults interpreted by Marliave (1945;1947) in the Vista Grande tunnel section construction documents may be related to the Serra fault and have estimated total offset of up to 40 feet.

### **Groundwater Conditions**

Lake Merced and the general site vicinity lies within the Westside Basin which encompasses about 9,450 acres of western San Francisco and northwestern San Mateo County (Yates et al., 1990). The groundwater levels in the site vicinity have been declining over the decade of the 1980-1990's (Yates et al., 1990; Phillips et al., 1993). The USGS studies (Yates et al., 1990; Phillips et al., 1993) conclude that the declines in ground water are the result of pumping for irrigation (Olympic and San Francisco Golf Clubs) and potable water supply (Daly City). Water levels in these wells ranged from -155 feet to 83 feet Elevation ((NGVD 1929:Phillips et al., 1993). Although these studies rely on wells extending to depths from 51 feet to 1,500 feet below ground surface, regional groundwater table could fluctuate significantly along the proposed tunnel alignments in the presence of impermeable barriers such as the faulting noted by

Marliave (1945; 1947) during the construction of the Vista Grande Tunnel in the 1940's. Groundwater conditions along any future tunnel route should be confirmed by groundwater monitoring wells that sample the appropriate depths proposed for the tunnel alignment.

## **SITE CONDITIONS**

### **Southern Alignment**

There are two bluff sites that are the focus of our geologic evaluation. The west end of the Southern alignment is located at the base of the coastal bluffs at the western projection of John Daly Boulevard. This site is located within the Thornton Beach Landslide complex, approximately 1.6 miles north of the intersection of the San Andreas fault trace with the coastline just north of Mussel Rock. The bluff top at the site is characterized by a gently undulating to nearly level surface at approx. elevation 220 feet. The coastal bluff is 120 feet high.

The crest of the coastal bluff forms the east slope of the large depression or graben formed by the oceanward movement of a large coherent block of Merced Formation material. This graben extends from just south of John Daly Boulevard north to Fort Funston. Since the formation of this graben, erosion and shallow landsliding of the bounding slopes have partly filled this depression. In particular, the heavy rains of 1982-83 and 1997-98 are part of a cycle of cliff erosion that has resulted in undermining and eventual washing out of the Daly Boulevard extension.

We identified a prominent shear offsetting the Merced Formation sandstones and siltstones and extending upward through the Colma Formation to the root mat of the ground cover mapping within the eroded gully southwest of John Daly Boulevard. The shear is oriented approximately N20°W and dips 60° southwest. A seep was exposed associated with this shear on the south wall of the gully. The northwest projection of this shear was traced along the slope west of the site and corresponds to several debris slide scars that were active in 1983 aerial photographs

### **Northern Alignment**

The ocean bluff at the Northern Alignment is the second site that is the focus of our geologic evaluation. The bluff is approximately 160 feet high at the existing Vista Grande outfall shown on Figures 4, 5, and 6. We mapped the Recent Dune Sand and Colma Formation overlying the Merced sandstone units at the top of the bluff. At the beach level, a prominent nose of bedrock appears to be protected from wave erosion by the presence of the tunnel outfalls.

There are numerous active and dormant shallow debris and slump landslides on the face of the bluffs as shown on the Fort Funston Site Geology map and cross sections. The debris slides are generally less than 10 feet deep, and involve only the loose recent

material blanketing the slope, weathered blocks of the bedrock, and organic debris, Figure 6. A much larger slope failure is characterized by translational movement of large blocks of the bluff that appear to be destabilized along preexisting bedrock geologic structures. These failure planes may have been old faults that appear to have offset the Rockland Ash unit prominently exposed on the bluff. The age of the Rockland Ash is in dispute but falls in the range of 610,000 to 370,000 years old (Sarna Wojcicki, 2000). Based on our mapping it is difficult to identify the amount of recent displacement of the block that may be related to gravitational or landslide movement. Regardless of origin, the planes present weak discontinuities that pose significant slope stability concerns in the design of any new tunnel outlets in the bluff.

## SEISMICITY

The seismicity in the Daly City area is related to activity on the San Andreas system of active faults. The faults in this system are characterized by right lateral, strike-slip movements that are predominantly horizontal. The major active faults in the area are the San Andreas, Hayward, and San Gregario faults. These and other active<sup>1</sup> or potentially active<sup>2</sup> faults of the region are shown on Figure 3. For selective active faults the distance from the site and estimated maximum credible event are summarized in Table 2.

**TABLE 2**  
**Regional Faults and Seismicity**

<b>Fault Segment</b>	<b>Approx. Distance from fault (km)</b>	<b>Direction from Site</b>	<b>Mean Characteristic Moment Magnitude</b>
San Andreas - 1906 Rupture	1.1	Southwest	7.9
San Andreas – Peninsula	11	Southeast	7.2
San Gregorio	12	Southwest	7.4
South Hayward	24	Southeast	6.7
Northern Hayward	18	Northeast	6.9
Northern Calaveras	30	East	6.9
Southern Calaveras	42	Southeast	6.5

<sup>1</sup> Active faults are defined as those exhibiting either surface ruptures, topographic features created by faulting, surface displacements of Holocene age (younger than 11,000 years old), tectonic creep along fault traces, and/or close proximity to linear concentrations or trends of earthquake epicenters.

<sup>2</sup> Potentially active faults are those that show evidence or displacement of surficial deposits of Quaternary age (less than 2 million years old).

Three major earthquakes have been recorded on the San Andreas fault since 1800. In 1838, an earthquake occurred with an estimated intensity of about VII on the Modified Mercalli Intensity Scale, as shown on Figure 8, corresponding to a Magnitude of about 7. The San Francisco Earthquake of 18 April 1906 caused the most significant damage in history of the Bay Area in terms of loss of lives and property damage. This earthquake surface rupture along the San Andreas extended approximately 270 miles in length and recorded displacements of up to 21 feet. The Magnitude 8.3 event was felt 350 miles away in Oregon, Nevada and Los Angeles. The epicenter of the 1906 event is estimated to be offshore the Golden Gate and the San Francisco Shoreline within a few miles of the site.

Another smaller, but notable, earthquake on the San Andreas fault occurred on 22 March 1957. The epicenter of the Daly City magnitude 5.4 earthquake was near Mussel Rock, about two miles south of the site. Although this was a relatively small earthquake of short duration (about five seconds of strong shaking), it caused liquefaction-induced landslides along the banks of lake Merced and slope failures along California Route 1, south of the site.

In 1836 an earthquake with a estimated intensity of IX occurred in the vicinity of San Juan Bautista, probably on the San Andreas fault. An earthquake occurred in 1838 on the southern peninsula segment of the San Andreas fault (Topozada, T.R., and Borchardt, G., 1998).

In 1868, an earthquake with an estimated maximum intensity of X occurred along the Hayward fault. This earthquake is believed to have had a magnitude of 7 or greater. In 1861, an earthquake of unknown magnitude, estimated at 6.5 was reported on the Calaveras fault.

## **CONCLUSIONS AND RECOMMENDATIONS**

We believe that the Northern alignment presents the only feasible alternatives for the proposed tunnel or pipe improvements (Alternatives 1-3; Jacobs Associates 2007). Based on historic landslide impacts to existing developments and the estimated depth of the failure plane, the Southern alignment is not considered feasible alignment to route tunnels or pipes.

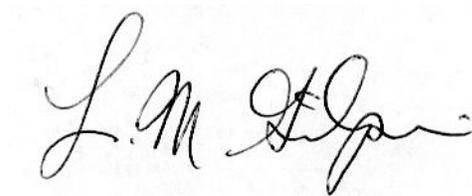
The Northern alignment appears to be feasible based on our geologic reconnaissance and document review. The strongest argument for this is the performance of the existing Vista Grande tunnel. The western end of the tunnel should take into account the block failure in the bluff at the existing tunnel portals. We estimate potential movement of this block along existing faults and slide planes for a distance of at least 140 feet from the western portal. We do not see any significant geologic hazards impacting the location of the eastern portal of any tunnel or pipe improvements.

We believe that the site is subject to very strong to violent ground shaking and that localized ground rupture similar to ground cracking along the bluff top in the 1906 earthquake, as well as earthquake-induced landsliding is possible. Although sympathetic movement of the Serra fault during a large event on the San Andreas is possible it did not appear to significantly impact the existing Vista Grande tunnel in 1906.

Erosion and shallow sliding will continue to cause the bluff top to retreat. Published retreat rates (Griggs and Savoy, 1979) associated with the coastline adjacent to the site varies from 10 to 13 inches a year; this probably occurs catastrophically during seasons of heavy precipitation and weather. We understand that reports from GGNRA staff representatives that during the 1997-1999 winter seasons the Fort Funston bluffs experienced over 19 feet of retreat (Liebhardt, 2002).

Thank you for the opportunity to provide assistance with this project. Please call us if you have any questions regarding this report.

Sincerely,  
GILPIN GEOSCIENCES, INC.



Lou M. Gilpin, Ph.D., C.E.G.  
Engineering Geologist 1518

#### References

List of Aerial Photograph

#### Attachments:

##### FIGURES

Figure 1	Site Location and Landslide Map
Figure 2	Regional Geology Map
Figure 3	Cross Section C-C' (Bonilla, 1960)
Figure 4	Fort Funston Site Geology Map

FIGURES (continued)

Figure 5	Cross Section A-A'
Figure 6	Cross Section B-B'
Figure 7	Seismic Hazards Map
Figure 8	Modified Mercalli Intensity Scale

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### **List of Aerial Photographs**

<u>Date</u>	<u>Photo Number</u>	<u>Scale</u>	<u>Source</u>
3/10/05	KAV 9010-64-1, 2	1:10,000	Pacific Aerial Surveys
8/17/01	AV 7091-02-13,14,15,16,17	1:6,600	Pacific Aerial Surveys
8/15/00	AV 6600-02-6,7,8,9,10	1:12,000	Pacific Aerial Surveys
6/23/97	AV 5434-2-10,11,12,13	1:12,000	Pacific Aerial Surveys
9/7/95	AV 4916-02-7,8,9,10,11	1:12,000	Pacific Aerial Surveys
6/10/94	AV 4661-01-7,8,9,10	1:12,000	Pacific Aerial Surveys
8/27/93	AV 4515-02-8,9,10,11	1:12,000	Pacific Aerial Surveys
7/2/91	AV 4075-02-9,10,11	1:12,000	Pacific Aerial Surveys
6/19/89	AV 3556-01-6,7,8,9	1:12,000	Pacific Aerial Surveys
10/14/85	AV 2670-01-8,9,10,11,12	1:12,000	Pacific Aerial Surveys
5/6/83	AV 2265-01-8,9,10,11	1:12,000	Pacific Aerial Surveys
5/27/77	AV 1356-01-7,8,9	1:12,000	Pacific Aerial Surveys
4/28/75	AV 1188-01-8,9,10,11	1:12,000	Pacific Aerial Surveys

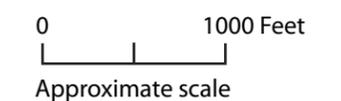
5/11/72	AV 1045-02-12,13,14,15	1:12,000	Pacific Aerial Surveys
10/29/69	AV 993-02-8,9,10,11	1:12,000	Pacific Aerial Surveys
4/23/58	AV 279-01-10,11,12	1:7,200	Pacific Aerial Surveys
5/10/55	AV 170-02-11,12,13,14	1:10,000	Pacific Aerial Surveys
6/29/50	AV 35-01-19,20,21,22	1:6,000	Pacific Aerial Surveys
7/28/48	AV 17-02-10,11,12	1:7,600	Pacific Aerial Surveys
3/21/38	AV 8-01-8,9,10,11	1:20,000	Pacific Aerial Surveys
1935	AV 248-06-11,12	1:16,500	Pacific Aerial Surveys

## FIGURES



**EXPLANATION**

<b>QIs</b>	<b>Geologic Units</b>	<b>Key</b>
	Landslide Deposit	— · — · Geologic Contact

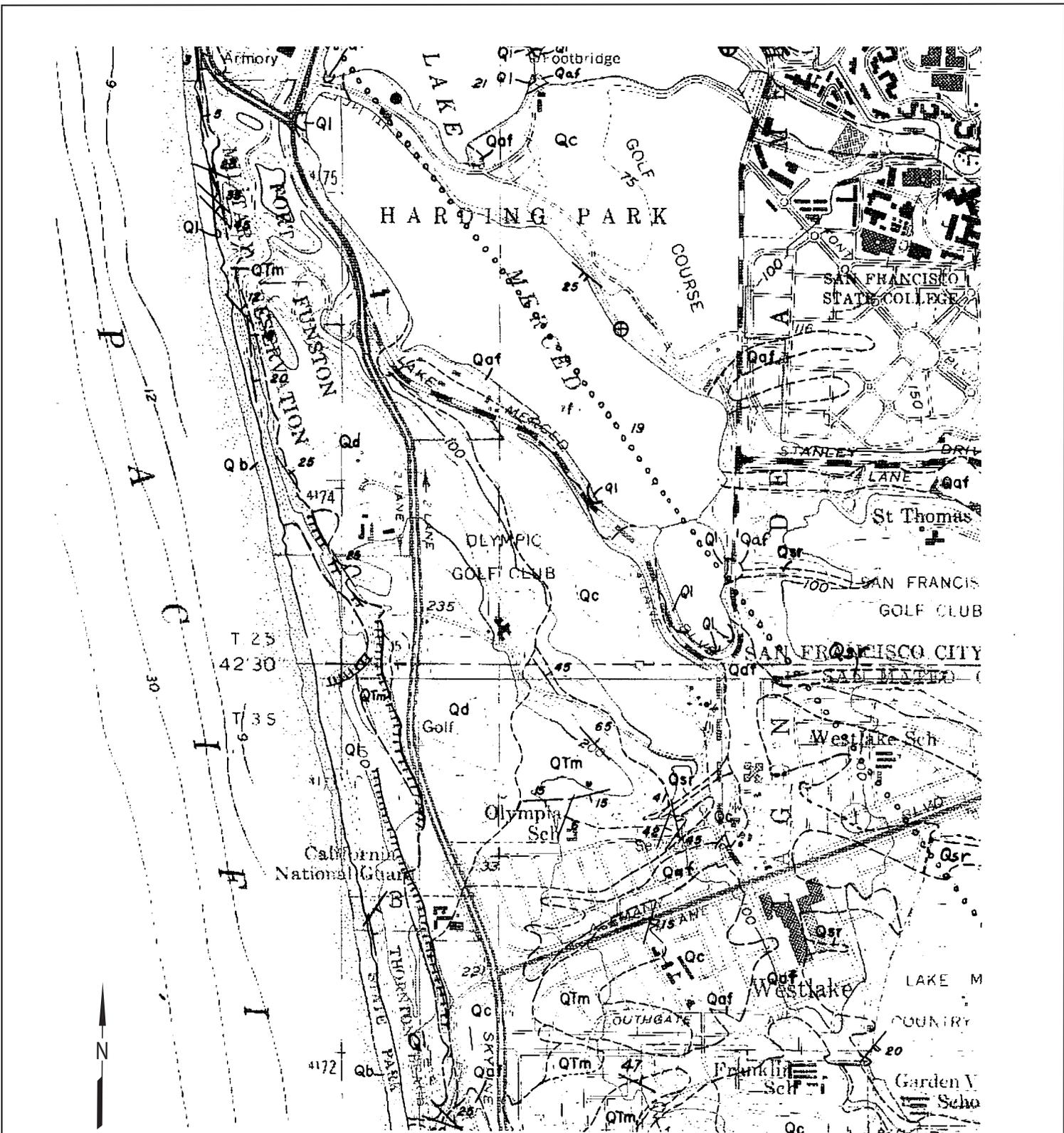


- Notes: 1. Reference: Jacob Associates, 2007.  
 2. See Figure 3 for Cross Section.

**LOCATION AND LANDSLIDE MAP**

**Vista Grande Basin Alternatives**  
 San Francisco, California

Date 10/30/07	Project No. 4644.01	Figure 1
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0 1500 Feet  
Approximate scale

**EXPLANATION**

Geologic Units		Key	
Qa	Artificial Fill	---	Geologic Contact
Qb	Beach Deposit		Scarp
Ql	Landslide Deposit	.....	Fault
Qd	Dune Sand		
Qsr	Slope and Ravine Fill		
Qc	Colma Formation		
QTm	Merced Formation		

Notes: 1. Geologic Reference: Bonilla, 1970.

<b>REGIONAL GEOLOGY MAP</b>		
Vista Grande Basin Alternatives San Francisco, California		
Date 07/30/07	Project No. 4644.01	Figure 2
<b>Gilpin Geosciences, Inc.</b> Earthquake & Engineering Geology Consultants		

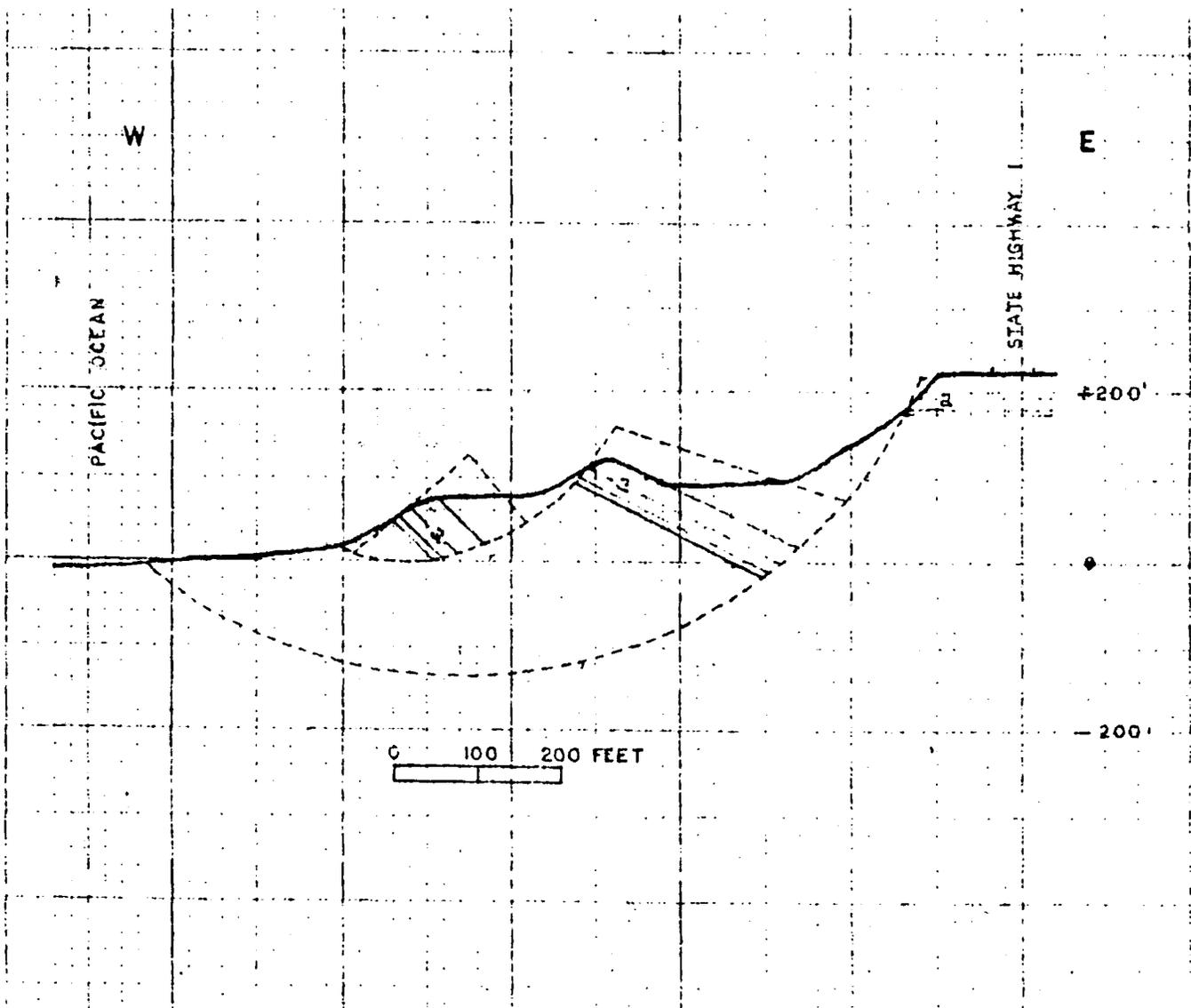


Figure 6. COMPARISON OF CALCULATED AND OBSERVED FEATURES OF SLIDE 13D

Solid lines show profile, bedding, and position of displaced topographic surfaces as determined from surface exposures; dashed lines show calculated positions of rupture surfaces and topographic surfaces. Ash bed indicated by letter "a".

- Notes: 1. Geologic Reference: Bonilla, 1960.  
 2. See Location and Landslide Map (Figure 1) for Cross Section location.

**SCHEMATIC CROSS SECTION OF LANDSLIDE**

Vista Grande Basin Alternatives  
 San Francisco, California

Date 07/30/07

Project No. 4644.01

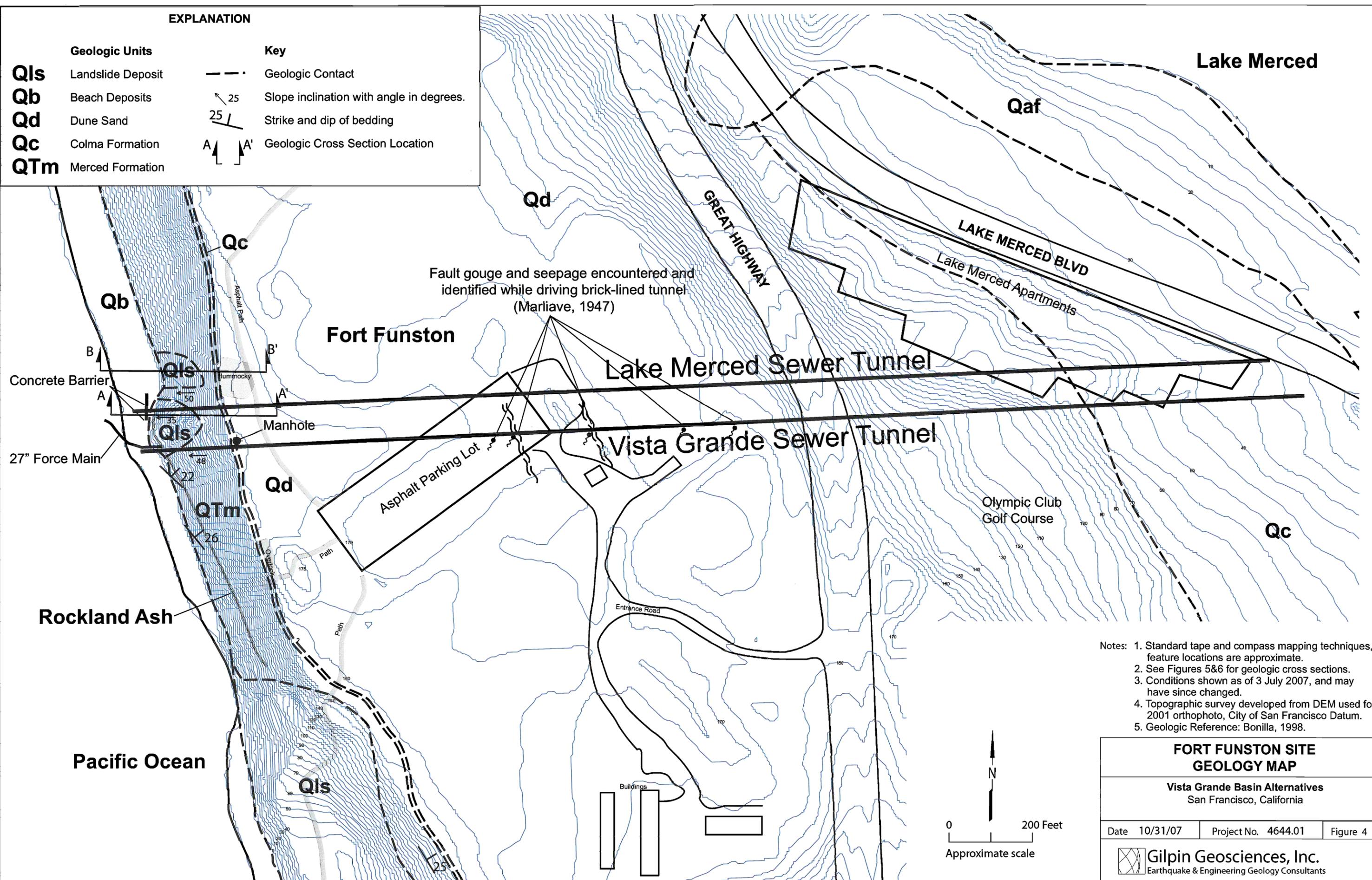
Figure 3



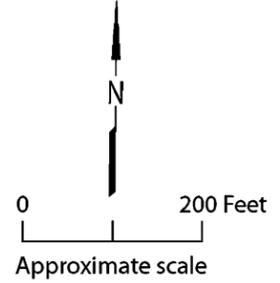
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**EXPLANATION**

<b>Geologic Units</b>	<b>Key</b>
<b>Qls</b> Landslide Deposit	--- Geologic Contact
<b>Qb</b> Beach Deposits	↘ 25 Slope inclination with angle in degrees.
<b>Qd</b> Dune Sand	↘ 25 Strike and dip of bedding
<b>Qc</b> Colma Formation	A ↑ A' Geologic Cross Section Location
<b>QTm</b> Merced Formation	



- Notes:
1. Standard tape and compass mapping techniques, feature locations are approximate.
  2. See Figures 5&6 for geologic cross sections.
  3. Conditions shown as of 3 July 2007, and may have since changed.
  4. Topographic survey developed from DEM used for 2001 orthophoto, City of San Francisco Datum.
  5. Geologic Reference: Bonilla, 1998.

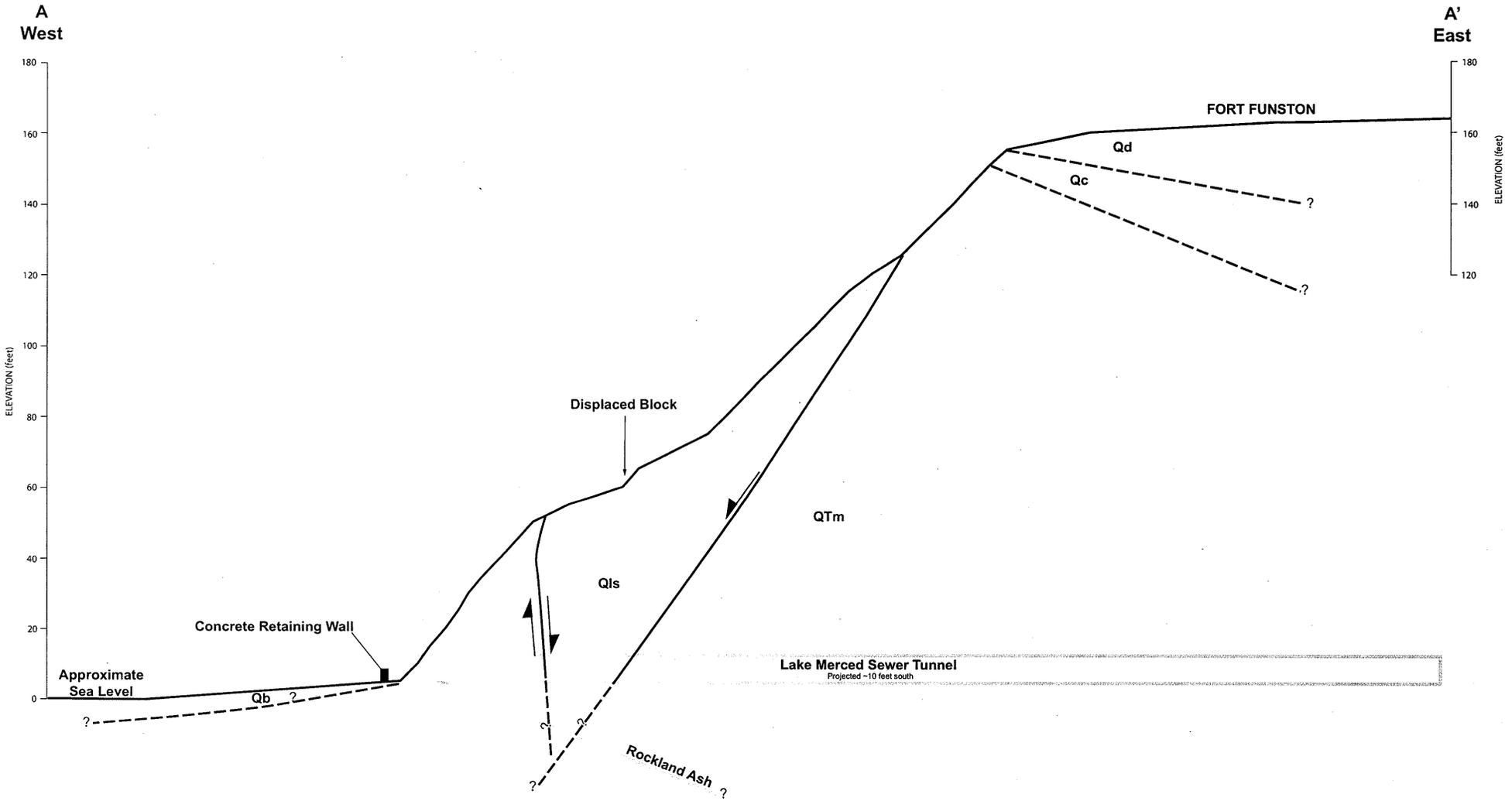


**FORT FUNSTON SITE  
GEOLOGY MAP**

**Vista Grande Basin Alternatives**  
San Francisco, California

Date 10/31/07	Project No. 4644.01	Figure 4
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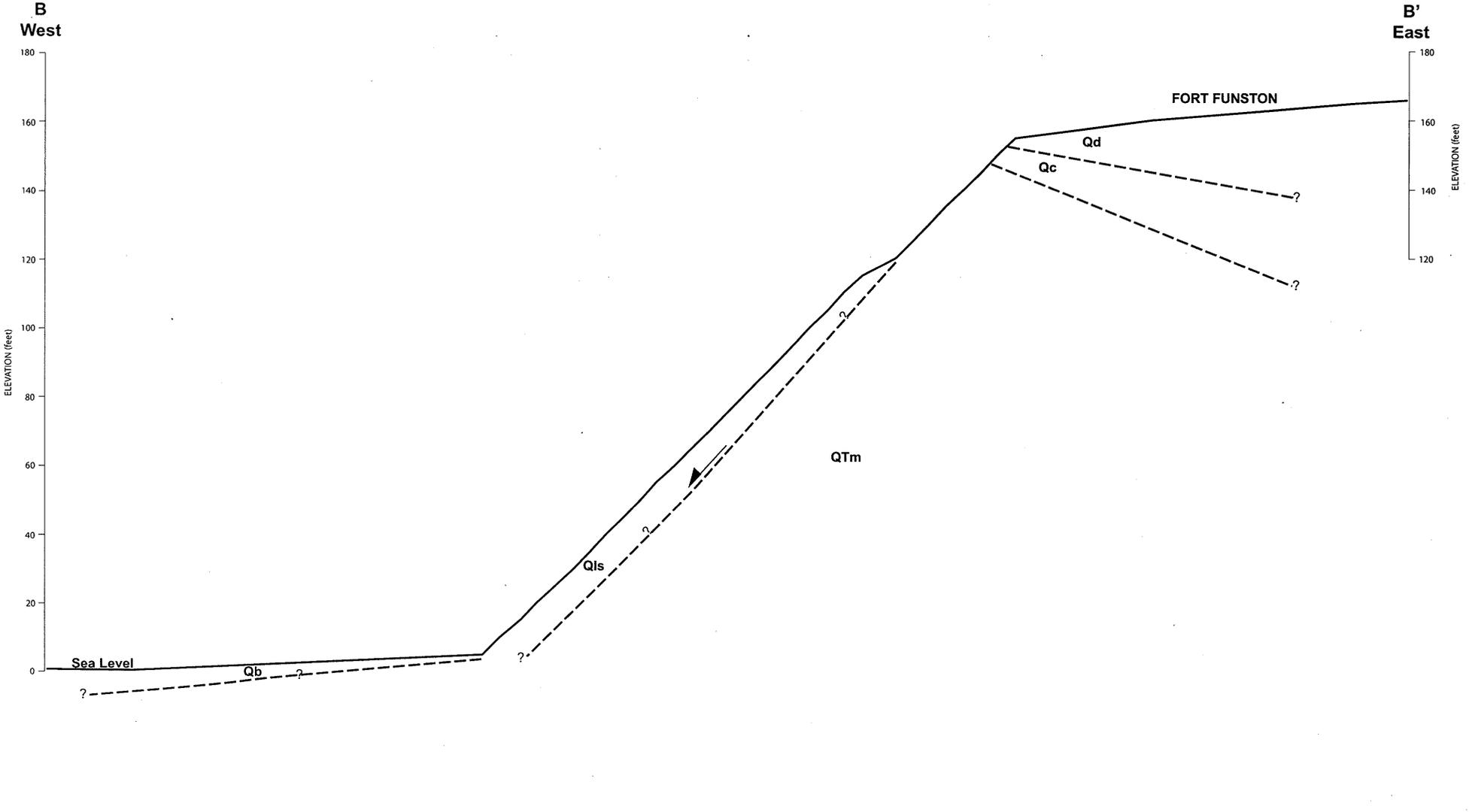


- Notes:
1. Geologic interpretation based on limited subsurface exploration, actual conditions may vary.
  2. Line of section shown on Plan (Figure 4).
  3. No vertical exaggeration (Horizontal=Vertical).
  4. Elevations in feet, SFGD datum.

**EXPLANATION**

<b>Qls</b>	Landslide Deposits
<b>Qb</b>	Beach Deposits
<b>Qd</b>	Dune Sand
<b>Qc</b>	Colma Formation
<b>QTm</b>	Merced Formation

CROSS SECTION A-A'		
Vista Grande Drainage Basin San Francisco, California		SCALE <b>5</b>
JOB NUMBER 4644.01	DATE 7/30/07	
<b>Gilpin Geosciences, Inc.</b> Earthquake & Engineering Geology Consultants		

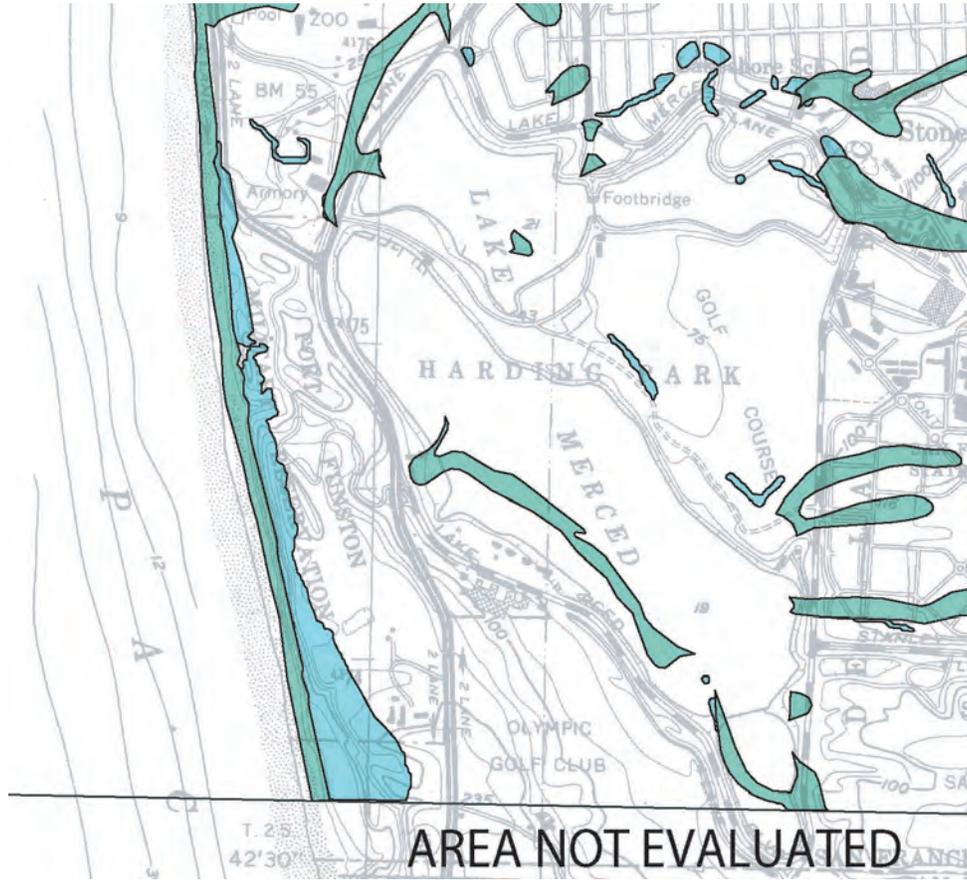


**EXPLANATION**

- Qls** Landslide Deposits
- Qb** Beach Deposits
- Qd** Dune Sand
- Qc** Colma Formation
- QTm** Merced Formation

- Notes:
1. Geologic interpretation based on limited subsurface exploration, actual conditions may vary.
  2. Line of section shown on Plan (Figure 4).
  3. No vertical exaggeration (Horizontal=Vertical).
  4. Elevations in feet, SFCD datum.

<b>CROSS SECTION B-B'</b>		<b>FIGURE</b> <b>6</b>
Vista Grande Drainage Basin San Francisco, California		
JOB NUMBER 4644.01	DATE 7/30/07	
<b>Gilpin Geosciences, Inc.</b> <small>Earthquake &amp; Engineering Geology Consultants</small>		



**MAP EXPLANATION**

Zones of Required Investigation:

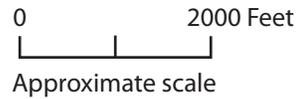


**Liquefaction**

Areas where historic occurrence of liquefaction, or local geological, geotechnical and groundwater conditions indicate a potential for permanent ground displacements such that mitigation as defined in Public Resources Code Section 2693(c) would be required.

**Earthquake-Induced Landslides**

Areas where previous occurrence of landslide movement, or local topographic, geological, geotechnical and subsurface water conditions indicate a potential for permanent ground displacements such that mitigation as defined in Public Resources Code Section 2693(c) would be required.



DATA AND METHODOLOGY USED TO DEVELOP THIS MAP ARE PRESENTED IN THE FOLLOWING:

Seismic Hazard Evaluation of the City and County of San Francisco, California:  
California Division of Mines and Geology, Open-File Report 2000-009.

For additional information on seismic hazards in this map area, the rationale used for zoning, and additional references consulted, refer to DMG's World Wide Web site (<http://www.consrv.ca.gov/dmg/>).

**SEISMIC HAZARDS MAP**

**Vista Grande Basin Alternatives**  
San Francisco, California

Date 07/30/07	Project No. 4644.01	Figure 7
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