APPENDIX G

APPENDIX G

GEOTECHNICAL ENGINEERING INVESTIGATION

G-1: Engineering Geology Assessment Report
G-2: Fault Investigation Report

G-1: ENGINEERING GEOLOGY ASSESSMENT REPORT

ENGINEERING GEOLOGY ASSESSMENT REPORT

PROPOSED POWER PLANT LOCATIONS FOR TESLA SUBSTATION AREA, MIDWAY QUADRANGLE ALAMEDA COUNTY, CALIFORNIA

GEOCON
GEOTECHNICAL & ENVIRONMENTAL CONSULTANTS

PREPARED FOR

FPL ENERGY
JUNO BEACH, FLORIDA

GEOCON PROJECT NO. E8062-06-01

APRIL 2001

Project No. E8062-06-01
April 27, 2001

Mr. Tim Rossknecht
FPL Energy
700 Universe Blvd.
Juno Beach, FL 33408-2683

Subject: PROPOSED POWER PLANT LOCATIONS
FOR TESLA SUBSTATION AREA
MIDWAY QUADRANGLE
ALAMEDA COUNTY, CALIFORNIA
ENGINEERING GEOLOGY ASSESSMENT REPORT

Dear Mr. Rossknecht:

In accordance with our proposal No. LE-01-026 dated March 20, 2001; we performed an Engineering Geology Assessment of three alternative sites for the proposed FPL Energy Tesla Power Generation Facility in Alameda County, California. The accompanying report provides initial geological findings and recommendations for a detailed geological and geotechnical investigation.

The geologically related characteristics considered for this study were tectonics, liquefaction, subsidence, slope stability, soil and rock properties, resources, hydrology, and physiography. The factors were addressed at the assessment level, and will require additional investigation to make a determination of effects sufficient for submission to the California Energy Commission as part of an Application for Certification.

The primary geologic concerns for the project are potentially active faulting, and strong ground motion shaking. Based on our preliminary review, the most favorable geologic conditions are encountered on the Tesla South site, with greater restrictions encountered at the Tesla North and Tesla West sites.

If you have any questions regarding this report, or if we may be of further service, please contact the undersigned at your convenience.

Sincerely,

GEOCON CONSULTANTS, INC.

REGISTERED PROFESSIONAL ENGINEER ERIC J. SWENSON No. G.E. 2474 Exp. 12/31/02 GEOTECHNICAL STATE OF CALIFORNIA

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ENGINEERING GEOLOGY ASSESSMENT REPORT

EXECUTIVE SUMMARY

This report was prepared for FPL Energy of Juno Beach, Florida, and contains a summary of the geology and geotechnical issues for a seven and one half square mile area surrounding the existing Tesla Substation in eastern Alameda County, California. The study was conducted to help determine the feasibility of constructing a gas-fired power generation facility in the hills west of Tracy, California. The primary objectives of the study were to determine what site(s) in the study area are suitable for facility construction, and what geological and geotechnical factors are present that can influence facility design, construction, and operation. The geologically related characteristics considered for this study were tectonics, liquefaction, subsidence, slope stability, soil and rock properties, resources, hydrology, and physiography. The factors were addressed at the assessment level, and will require additional investigation to make a determination of effects sufficient for submission to the California Energy Commission as part of an Application for Certification. Liquefaction potential and soil corrosivity were not analyzed during this study, but will need to be addressed prior to final facility design. The factors identified in the initial study that most effect facility design, construction, and operation are tectonic factors related to faulting and seismicity in the area.

Three sites designated as Tesla North, Tesla South, and Tesla West were evaluated. The primary geologic concerns for the sites are potentially active faulting, and strong ground motion shaking. Based on our preliminary review, the most favorable geologic conditions are encountered on the Tesla South site, with greater restrictions encountered at the Tesla North and Tesla West sites.

1.0 INTRODUCTION

1.1 Purpose

FPL Energy (FPL) of Juno Beach, Florida is investigating the feasibility of constructing a gas-fired power generation facility adjacent to the existing Tesla Substation in eastern Alameda County, California (Regional Map - Figure 1 and Study Area Locations - Figure 2). As a part of their feasibility study, FPL has contracted with Geocon Consultants, Inc. to perform an engineering geology assessment of the proposed power plant locations. This report presents the findings from the engineering geology assessment of three potential power plant sites in the Tesla Substation Area. The findings and recommendations presented herein are assessment level only, and are based on a literature review and a preliminary site reconnaissance. The information presented in this report is not represented to be complete for purposes of filing a submission for regulatory review to the California Energy Commission (CEC) as part of an Application for Certification (AFC). In order to fulfill the CEC requirements for an AFC, a comprehensive geological and geotechnical investigation will be necessary.

Three sites were identified by FPL as potential generating facility locations. Geocon reviewed the August 2000 CEC Publication P800-00-07, *Rules of Practice and Procedure & Power Plant Certification Regulations* (CEC Certification Regulations) and discussed the general geological and geotechnical factors considered for power plant certification with Mr. Robert Anderson, Engineering Geologist with the CEC. The contents of this report are set forth in such a manner that it can form the outline for the geological and geotechnical portions of the AFC.

The three alternative sites were evaluated for potential geotechnical constraints associated with the local and regional geology. Geological and related concerns fall into eight major categories:

- Tectonics
- Liquefaction
- Subsidence
- Slope Stability
- Soil and Rock Properties
- Resources
- Hydrology
- Physiography

The eight categories include fourteen geologic and geotechnical factors that must be considered as part of the AFC. All of the fourteen factors are mentioned in this report. However, liquefaction potential and soil corrosivity were not analyzed during this initial study. Additional fieldwork will be necessary to fully assess several of the factors in this report. The additional work will be addressed in the appropriate sections of this report. The eight characteristics and fourteen factors that should be evaluated for the AFC are shown in Table 1.

1.2 Applicable Laws, Ordinances, Regulations, and Standards (LORS)

Several LORS are applicable to the proposed project that specify actions required to assess geological and geotechnical factors related to the design, permitting, construction, operation, and closure of the proposed facility. The CEC is granted the exclusive authority to certify AFCs under the California Public Resources Code (CPRC), Section 25500 *et seq.* As a part of the project certification process, the CEC will verify that geological and geotechnical issues are adequately addressed in the AFC and that the information presented is adequate to comply with federal, state, and local LORS.

The master governing regulations for the project are Title 20, California Code of Regulations (CCR), Chapter 1, Subsections 1001 to 1003, Chapter 2, Subsections 1101 to 1236, Chapter 5, Subsections 1701 to 2012, Chapter 6, Subsections 2305, 2306, and 2307, and Chapter 7, Subsections 2501 to 2557 as contained in CEC Certification Regulations. CEC Certification Regulations details the areas of geologic and related concern that need to be addressed, and the basic requirements for how to address them.

No Federal LORS were identified that are applicable to the geological and geotechnical issues addressed herein. CPRC Section 21000 *et seq.* and 14 CCR, Section 15000 *et seq.* cover the California Environmental Quality Act (CEQA) aspects of the geological and geotechnical issues of the project. The CEC is the lead agency responsible for implementing and administering CEQA for power plant projects.

The *1997 Uniform Building Code* (UBC97) and the *1998 California Building Code* (CBC98) govern the geological and geotechnical information needed for project design and construction. The Alameda County Building Department will be the agency administering the requirements of the UBC and CBC.

Geotechnical testing is governed by standards set forth by the American Society for Testing and Materials (ASTM).

1.3 Site Description

Three sites, Tesla North, Tesla West, and Tesla South, were identified as potential power generation facility locations by FPL. The sites are all accessed off of Midway Road, in an unincorporated portion of Alameda County, California. The three sites are located in Sections 29, 30, 31, and 32, Township 2 South, Range 4 East, and Sections 5 and 6, Township 3 South, Range 4 East, Mount Diablo Base and Meridian, in the Midway Topographic Quadrangle, California. The boundaries of the three sites are shown on Figure 2.

The sites have rolling topography, and straddle a topographic basin that is bordered on the south and west by hills reaching to elevations in excess of 2,000 feet, and to the north and east by low hills averaging 400 to 500 feet in elevation. The major natural features in the area are low rolling hills, bluffs, and the drainage of Patterson Run.

The sites are generally open and vegetated with grass, except that scattered trees occur along Patterson Run. Land uses in the area include livestock grazing, wind-based electrical power generation, and electric power distribution. Midway Road runs through and along the northeastern portion of the Tesla North site. The Tesla North site is bordered on its north and east sides by a Union Pacific Railroad track right-of-way that is reported as abandoned. The Tesla West site is bordered on its south side by an active rail line that is shown as operated by the Union Pacific Railroad. Patterson Pass Road runs through the Tesla West site. The Union Pacific Railroad line runs through the central portion of the Tesla South site.

2.0 REGIONAL GEOLOGY

2.1 Regional Geologic Setting

The three sites studied for the proposed FPL power generation facility are located in the foothills of the eastern Diablo Range. The area is located on the boundary of the Diablo Range of the Coast Range Geomorphic province to the west and the San Joaquin Valley of the Great Valley Geomorphic province to the east. The Diablo Range trends northwest, subparallel to the rift valley of the San Andreas Fault, and consist of a series of folds which most likely occurred in the middle to upper Miocene during transgression of the Cierbo seas. The study area is surrounded by the rolling hills of the Diablo Range foothills, with several small or seasonal creeks running throughout. Bedrock on the site is Miocene marine rock of the San Pablo Group, which form resistant bluffs in the Tesla North site. Quaternary alluvial deposits from erosion of the San Pablo group are present in the valleys.

The study area is highly deformed, with beds dipping up to 30 degrees. The Altamont Anticline, the largest fold in the area, is the closest fold of interest, with the sites sitting on its eastern flank. The axis of the fold has a northwestern trend of forty degrees west of north, much like all the features of the area, and a plunge to the southeast. Downflank on both limbs of the fold, high angle faults parallel the trend of the fold. The Midway Fault that runs along the northern boundary of the Tesla North site is one example of these northwest trending high angle faults. Geomorphic evidence and the occurrence of a magnitude 3.5 earthquake near the fault trace suggest that the Midway Fault is active. Several other faults in the area have resulted in large seismic events. The Coast Range-Central Valley thrust system, which includes the Green Valley Fault and the Greenville Fault less than 6 miles away, have produced magnitude 6.0 earthquakes in historic time.

To the east of this study area lies the northwest portion of the San Joaquin Valley. This valley is a northwesterly trending structural basin that is filled with approximately 30,000 feet of quaternary alluvial sediments. San Joaquin valley sediments are derived from erosion of the Sierra Nevada Mountains and the Coast Ranges. A Regional Geologic Map of the study area is presented as Figure 3.

2.2 Tectonic Setting

The San Francisco Bay area is characterized by regular seismic shaking and potential ground rupture. The area lies at the boundary of the North American and Pacific plates, an active predominately strike-slip plate boundary. The San Andreas Fault takes up the main motion along this boundary, though the area of deformation ranges across to the Central Valley.

Many large magnitude earthquakes have been reported in the region during the past 2000 years. The largest of these was the 1906 Richter magnitude 8.0 earthquake of San Francisco, which was caused by movement on the San Andreas Fault. The surface rupture from the 1906 earthquake was 270 miles long, and extended from Shelter Cove to San Juan Bautista. Fault movement for the 1906 quake had a right lateral displacement of approximately 20 feet with three feet of vertical displacement. This historic quake resulted in the destruction of San Francisco. More recently the 1989 magnitude 7.1 Loma Prieta earthquake caused a surface rupture of about 22 miles on the San Andreas Fault. This quake caused a right lateral slip of about 6-1/2 feet, and resulted in damage totaling six to seven billion dollars. Closer to the site, smaller magnitude earthquakes have occurred on the Hayward, Calaveras, Green Valley and Greenville faults. Although the majority of the events occurred before the turn of the 20th century, recent events have occurred on the Calaveras Fault (1984 Magnitude 6.1 and 1979 Magnitude 5.9) and the Greenville Fault (1980 Magnitude 5.6).

Two additional faults are worth mentioning here. These two faults have visual traces that intersect the study area. The Midway Fault, an active to potentially active fault runs across the site at the north end of the Tesla North site. This fault's last movement has been dated as late Quaternary by Jennings (1994). The second fault, a smaller, previously unnamed fault, herein called the West Site Fault, was discovered in a railroad cut on the south border of Tesla West site. The age or possible seismicity of the West Site Fault has not yet been established.

Future ground shaking could occur on any of the active or potentially active faults in the area. Active faults are defined as faults that have historic or Holocene movement, while potentially active faults have movement that has taken place in the Quaternary. A listing of the active faults within a 63-mile radius of the study area is contained in Table 2.

2.3 Site Stratigraphy and Geology

The study area is predominantly rolling pastureland with short grasses and naturalized wild oats. The three sites are generally open and free of obstructions that would interfere with geologic work. The best rock outcrop exposures are found in the railroad cuts within and bordering the three sites.

Rocks at the surface of the area are predominantly upper Miocene Neroly Formation (the youngest member of the San Pablo Group) shale, siltstone, and sandstone. However, Pliocene age rocks of the Tulare Formation are reported on the east side of the Midway Fault. A Site Geologic Map of the area is shown in Figure 4. Regionally, the Midway quadrangle plays host to a variety of rock types typical of the California Coast Ranges. A generalized stratigraphic section typical of the Midway Quadrangle is shown on Figure 5. The youngest named stratigraphic units identified in this study are the shales of the Upper Neroly Formation. These shales are estimated to be close to 2000 feet thick, although the top of the shales are usually covered with alluvium so a complete thickness cannot be established. Below these shales, is the more commonly seen section of the Neroly Formation, the blue sandstones and, at the base of this section, andesitic conglomerates. This member ranges in thickness from 50 to 700 feet in thickness depending on location. The source area for these beds is primarily the Sierra Nevada Mountains during a period of andesitic eruptions.

In fresh cuts and outcrops, the Neroly is a series of light brownish gray (10YR6/2) to very pale brown (10YR8/2), cross-bedded, sandstones, siltstones and pebbly sandstones. The sands vary from poorly to well sorted, but are generally subangular to subrounded. Outcrops of the Neroly Formation weather to grayish brown (10YR5/2), with a somewhat rounded to blocky outcrop appearance. The outcrops within approximately one-half mile of the Midway Fault are highly jointed, with three distinct joint sets. Topography in the Neroly terrain is generally rolling, with minimal gully formation, and generally symmetrical broad valleys. Generally speaking, the Neroly forms apparently stable, moderate slopes with grades averaging from 10 to 15 percent. However, north of a previously undocumented fault that we call the "West Site Fault", the Neroly tends to act as a resistant cap with a distinct tendency to form steep bluffs on the hill and ridge caps. The location of the West Site Fault is shown in Figure 4. The average thickness of the colluvium formed from weathering of the Neroly is not known in the study area, but is estimated at five to ten feet. Neroly rocks appear to be moderately hard and ripability is expected to be low to moderate. Prior to construction, a geotechnical investigation should be performed on the chosen site to determine soil and rock properties.

Below the Neroly Formation, lies the second member of the San Pablo Group, the Cierbo Formation. Although the Cierbo has not been identified on the study sites, it has been mapped by others, in the area. The Cierbo, a transgressive formation, is the unit most often involved in the folding and faulting of the area. It consists of sandstone, white to buff in color, and is formed predominately of quartz. The source area for this member is from the granites of the Sierra Nevada. Nowhere is there found a good stratigraphic section of the Cierbo and therefore no measurement of the thickness can be established, but it appears to have a maximum thickness of 500 feet. The contact between the Cierbo and the Neroly Formations can be either conformable or unconformable, depending on location.

Below the Cierbo, lie several formations that are exposed in the Midway Quadrangle but were not observed in the study sites. Most notably are the white sands and dark brown shales of the Tesla Formation and below that the massive sandstones, silty shales and conglomerates of the Panoche Formation. These two members make up over 12,000 feet of the remaining stratigraphic column. Basement rocks are believed to belong to the Franciscan mélange.

3.0 GEOLOGICAL AND GEOTECHNICAL CONSIDERATIONS

3.1 Tectonics

The proposed project sites are in a region of known faulting and seismicity. Several significant historically activity faults are present within 62.5 miles (100 kilometers) of the area. The significant faults are shown on the regional geologic map, Figure 3, and are summarized in Table 2. The fault that is likely to have the most influence on the site with regards to ground accelerations is the Greenville Fault, approximately 6 miles west of the study area. Although the Midway Fault runs along the northern boundary of the Tesla North site, geomorphic and historic evidence suggests that it poses a low seismic risk.

Geocon's preliminary investigation included a limited study of aerial photos of the area. The purpose of the aerial photo study was to identify large-scale features such as lineaments (linear features caused by natural processes) suggestive of faulting and seismicity. As expected, the major regional features trend northwest, including most of the mapped structures and faults in the area. However, a second less distinct lineament trend was also noticed. The second trend crosses and is roughly perpendicular to the primary trend. Most of the watercourses in the region follow this secondary trend, as do many of the topographic features and the West Site Fault. No definitive tectonic features were identified within the three sites on the aerial photos.

3.1.1 Faulting

Faulting was observed in outcrop or shown on existing geologic maps on two of the three sites. The trace of the northeast trending Midway Fault is shown on the 1:24,000 Regional Geologic Map for the area (Figure 3), and runs across the Tesla North site, along the eastern side of the property. The Midway Fault is a northwest trending fault, with a trace length of approximately 6 miles. Information in a State of California Department of Water Resources report titled *Reevaluation of Seismic Hazards for Clifton Court Forebay Bethany Dams and Reservoir Patterson Reservoir Del Valle Dam and Lake Del Valle* (DWR Clifton report), states that the age of the Midway Fault cannot be determined more definitely than post Miocene, although geomorphic features such as sag ponds suggest recent surface displacements. The DWR Clifton report, the geomorphic evidence, and the occurrence of a magnitude 3.5 earthquake near the Midway Fault suggest that the fault is still active. The primary hazard associated with the Midway Fault is ground rupture. Facilities damage due to surface rupture can be minimized by locating structures at least 50 feet from the fault zone, and constructing cables and pipelines to cross the fault perpendicular to the fault trend.

An unnamed and previously undocumented northwest trending West Site Fault was observed in the railroad cut on the south side of the Tesla West site as noted on the 1:24,000 Site Geologic Map for the area (Figure 4). The limited exposure of the West Site Fault did not lend itself to a determination of the age of seismicity. However, the apparent fault trace lines up with possible fault related surface features in the form of linear topographic depressions to the northeast and southwest of the cut in the railroad embankment. A subtle, apparently fault related depression extends southeast from the railroad cut. However, the depression may be the result of increased erosion along the fault, rather than actual movement. It is not known whether the West Site Fault extends northeast into the Tesla North site.

In order to characterize the Midway and West Site faults in sufficient detail to fulfill the requirements of an AFC, additional study will be necessary. The additional study will probably require the excavation of two trenches across each of the fault traces. The purpose of the trenching will be to better define the fault traces, determine the age of faulting, and estimate the amount of displacement on the faults during past seismic events.

No evidence of recent faulting was observed in the Tesla South site.

3.1.2 Seismicity

The 14 faults listed in Table 2 are within 63 miles of the area and are considered active. Six of the faults are considered type "A" faults, those with slip rates in excess of five millimeters per year (mm/yr) and capable of producing an earthquake with a moment magnitude (M) of 7.0 or greater. The type "A" faults are the north segment of the Calavares, the north and south branches of the Hayward, the north and peninsula segments of the San Andreas, and the San Gregorio. Of the type "A" faults the north segment of the Calaveras, and the north and south segments of the Hayward are expected to have the most effect on the site. The only type "B" faults that may have a strong effect on the site are the Greenville and Concord-Green Valley faults. Type "B" faults are those with slip rates greater than 2 mm/yr and M greater than 6.5, that do not qualify as a type "A" fault. The three sites are considered susceptible to seismicity and seismic damage due to activity on the faults. The Greenville Fault, at five to six miles west of the three sites is the fault considered most likely to cause seismically induced damage on the sites.

For purposes of this initial report, Geocon only performed a probabilistic seismic assessment. The probabilistic assessment was based on data from the California Division of Mines and Geology (CDMG) Open-file Report 96-08, *Probabilistic Seismic Hazard Assessment for the State of California* (DMG OFR96-08), the DWR Clifton report, the International Conference of Building Officials (ICBO) *Maps of Known Active Fault Near-Source Zones in California and Adjacent Portions of Nevada* (ICBO California Fault Zone Maps) and Interpolation from the DMG's 1999 *Seismic Shaking Hazards Maps of California*, Map Sheet 48 (MS48). The site accelerations due to an earthquake on the individual faults within 63 miles of the area were derived using the Boore, Joyner, Fumal attenuation relationship for peak horizontal acceleration for North American earthquakes. The calculated peak acceleration on the Greenville Fault is 0.47 g, the Calaveras Fault gave a calculated peak acceleration of 0.17 g. and the north and south segments of the Hayward Fault each contributed a 0.15 g acceleration on the site. The calculated peak acceleration agrees with the peak acceleration derived from MS48 that shows a 10% probability in 50 years of an earthquake causing ground accelerations in the area exceeding 0.4 to 0.5 g.

It is recommended that a deterministic seismic hazard assessment be performed for the site. The deterministic assessment uses site-specific information derived form borings and geotechnical testing to calculate accelerations. The advantage of the deterministic approach is that the acceleration values derived from it are generally lower than the probabilistic values, and thus do not result in conservative design calculations. An elastic response spectrum for the site should also be prepared by a geotechnical engineer for the structural engineer's design calculations.

3.2 Liquefaction

Liquefaction occurs when the induced pore pressure of water in a poorly consolidated soil, exceeds the overburden pressure. The most common cause of increased pore pressure is due to seismic shaking. Liquefiable soils are usually made up of loose, fine sands or silts, located at soil depths of less than 100 feet. Liquefaction features were not observed in the field. However, areas where liquefiable soils may be present were observed on both the Tesla North and Tesla West sites. The liquefaction potential (a measure of a soils susceptibility to liquefaction) is determined from a combination of soil description and the blow count obtained while driving a standard sample collection tube. A drilling program will need to be conducted, in order to assess the liquefaction potential of the sites.

3.3 Subsidence

Subsidence is sinking or settlement of the ground surface due to any of several processes. Subsidence in California generally occurs due to collapse of underground cavities such as abandoned mines, groundwater or petroleum withdrawal, desiccation and decomposition of buried organic matter, and hydrocompaction. Hydrocompaction is a process that results in volume decrease and density increase that occurs when moisture-deficient soils are wetted for the first time after burial. No subsidence features were observed on any of the three sites during the site reconnaissance. However, without geotechnical testing and evaluation, the subsidence potential cannot be adequately assessed.

3.4 Slope Stability

The natural slopes within the three sites appear to be stable. No slumps, slides, rock falls, or evidence of soil creep was observed in the field or on the aerial photos of the sites. Stability calculations were not performed for the soils in the study areas, so maximum stable slopes could not be determined. The geotechnical investigation for final design and construction should include testing in order to calculate the maximum stable slopes for the area soils.

3.5 Soil and Rock Properties

3.5.1 Expansive Soils

No evidence of highly expansive soils was noted during a limited literature search, or observed in the field. However, given the nature of the soils on site, they may have some expansion potential. Geotechnical testing will be necessary to assess the expansion potential of the soils on the site.

3.5.2 Corrosive Soils

Corrosive potential of the soils has not been determined. However, other professionals familiar with the area have verbally indicated that corrosive soils are present in the general area. Geotechnical testing will be necessary to assess the corrosive potential of the sites.

3.5.3 Hazardous Geologic Substances

No hazardous geological substances (Naturally occurring asbestos, mercury containing rocks, etc.) were noted during a limited literature search, and were not observed in the field. Since the primary rock units observed on the site are marine sandstones of the San Pablo Group, hazardous geologic substances are not likely to be encountered. The closest identified potential host rocks for hazardous geologic substances are potentially asbestos bearing rocks, approximately 13 miles south of the site.

3.6 Resources

3.6.1 Paleontological Resources

No vertebrate paleontological resources were reported from the study sites during a limited literature search, and none were observed in the field. Numerous invertebrate species have been reported in the San Pablo Group, but they were not readily apparent in the outcrop exposures examined. However, vertebrate fossils have been found within the Neroly Formation. The vertebrate fossils found were several horses teeth located in the sandstone member of the lower Neroly, which is not located at the surface in the study sites. A comprehensive paleontological resource assessment as per the Society of Vertebrate Paleontologists Guidelines will be necessary for the AFC.

3.6.2 Geological Resources

No significant mineral resources (mineral deposits, oil and gas, sand and gravel deposits, etc.) were noted on the sites. A review of *California Oil and Gas Fields –Northern California* did not reveal any oil or gas fields in the immediate vicinity. The closest fields are the Tracy and Union Island gas fields, approximately 10 miles east of the area. No on-site evidence of minerals exploration was discovered either in the field or during a literature search. There is no active sand and gravel mining on the sites. Potential sand and gravel resources may be available on the sites, but the quality and economic potential for these resources does not appear to be high.

3.7 Hydrology

3.7.1 Surface Water

The surface water on the sites flows in a generally east or northeast direction, toward the San Joaquin Valley. Semi-permanent bodies of surface water were observed on the Tesla North and Tesla West sites. A seasonal stream, Patterson Run drains the Tesla North and Tesla West sites. An unnamed ephemeral drainage flows through the Tesla South site. Patterson Run has an approximate average channel width of 15 to 25 feet and an average channel depth of approximately 3 to 7 feet in the site areas. A stock pond was noted at the western end of the Tesla West site. Based on the site geology, topography, and local vegetation patterns, the stock pond appears to be located over a spring that provides the water to fill and maintain it. No other springs were observed on any of the three sites. No surface water was observed on the Tesla South site.

3.7.2 Flooding

Geocon checked the Alameda County Federal Emergency Management Agency (FEMA) Flood Zone designation for the area. The sites are located within FEMA Flood Zone 7 as listed in the FEMA Digital Q3 Flood Data, FIPS Code 06001 located on CD Q3CD1. The sites are not located within either a 100 or 500-year flood zone. However, very localized short-term flooding may occur on the Tesla West and Tesla North sites due to a heavy rain in the catchment area for Patterson Run. As part of the AFC, it will be necessary to perform flood and runoff modeling and analysis using the United States Army Corps of Engineer's HEC-HMS or a similar model.

3.7.3 Runoff

The steepest topography on the three sites occurs on the Tesla West site, where low bluffs and rolling hills are found. Rolling to steeply rolling hills are found on the Tesla North and Tesla South sites. Due to the combination of steep topography and a natural water course on the site, potential off-site effects from on-site activities are greatest on the Tesla North and Tesla West sites. As part of the AFC, it will be necessary to perform flood and runoff modeling and analysis using the United States Army Corps of Engineer's HEC or a similar model.

3.8 Physiography

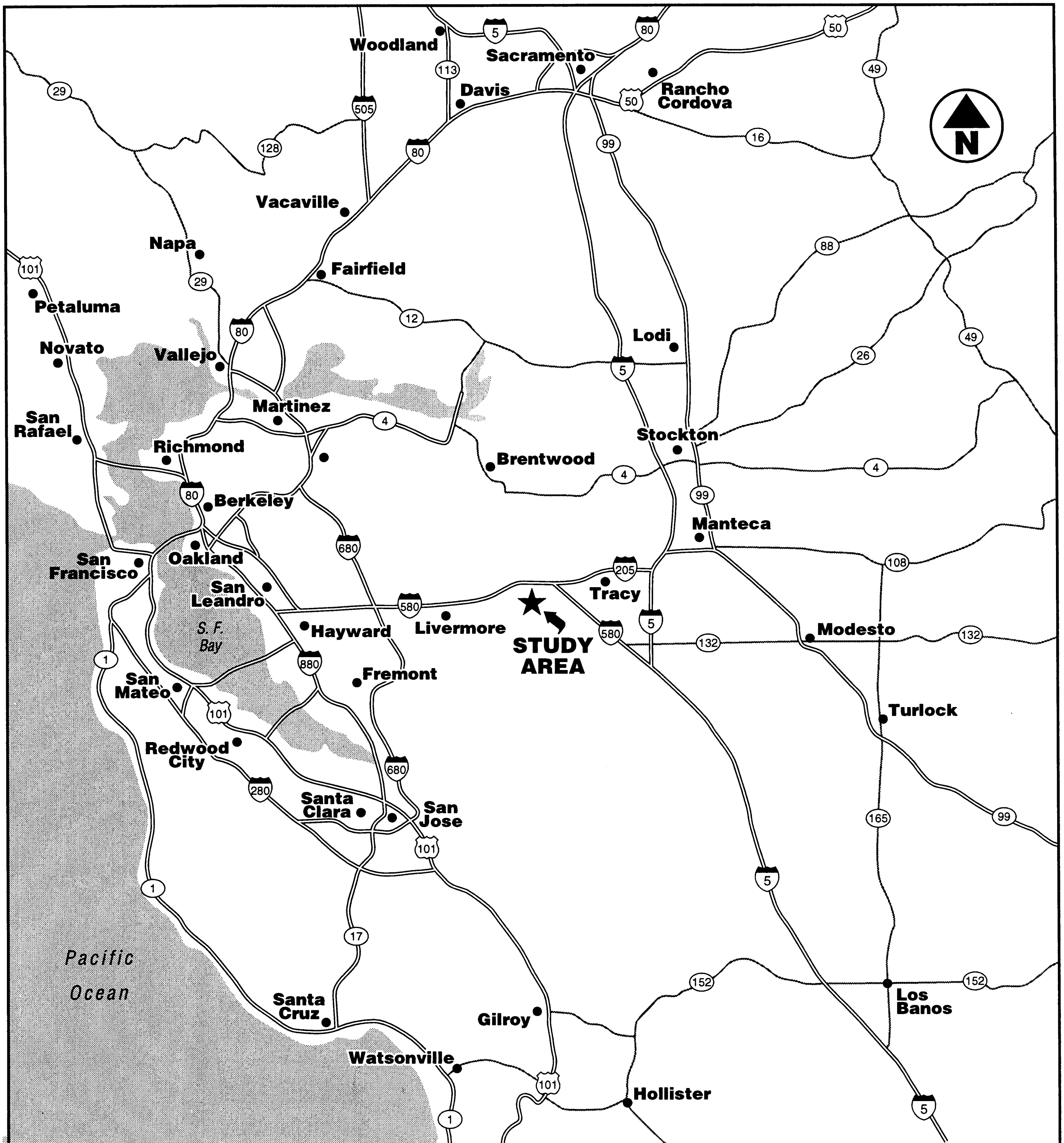
The general topography of the sites is rolling, with sandstone-capped bluffs present in the Tesla West site. The steepest topography on the three sites occurs on the Tesla West site. Low bluffs and rolling hills bounding tilted rolling valleys are found across the Tesla West site. The Tesla North and Tesla South sites are not as steep as the Tesla West site. The topography on the northern and southern sites is characterized by sequences of gently to steeply rolling hills and valleys. The sites straddle a topographic basin that is bordered on the south and west by hills reaching to elevations in excess of 2,000 feet, and to the north and east by low hills averaging 400 to 500 feet in elevation. Based on topographic data on the Midway United States Geological Survey topographic map, the elevations within the three sites range from approximately 390 to 580 feet in the Tesla South site, 380 to 540 feet in the Tesla West site, and 360 to 460 feet in the Tesla North site. The best building sites from a topographic standpoint are found on the northern and southern sites.

4.0 CONCLUSIONS

Faulting and seismicity issues have the greatest geological influence on facility design within the project area. The overall seismic hazard is comparable on all three sites, but faulting is more of an issue on the Tesla North and Tesla West sites. Flash flooding and runoff are also higher concerns on the Tesla North and Tesla West sites, since the catchment area for Patterson Creek is much larger than that for the unnamed drainage on the Tesla South site.

In order to assess the geology of the sites at a level adequate for an AFC, all areas need to be addressed in more depth and additional work will be necessary. The additional work should include borings to assess site geology, soil bearing capacities, liquefaction potential, and site specific properties for deterministic seismic hazard analysis. Trenching will be necessary to adequately assess faulting. A paleontological resource evaluation, using the guidelines of the Society of Vertebrate Paleontologists is required for the AFC. Flood and runoff modeling should also be incorporated into the report.

Using the data gathered to date, each of the three sites was ranked from 1 to 3 from least to most likely to be adversely effected by the various geologic factors, as they relate to construction of the proposed power generation facility. The site rankings based on various geologic and physiographic factors is presented in Table 1. Based on the work performed for this initial assessment, the Tesla South site has the fewest geologic related risks. If other factors out-weigh the geologic considerations, the Tesla North site appears to be the next most desirable location. From the geologic standpoint, the Tesla West site is the least desirable of the three sites for situating the proposed power generation facility.



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Scale in Miles

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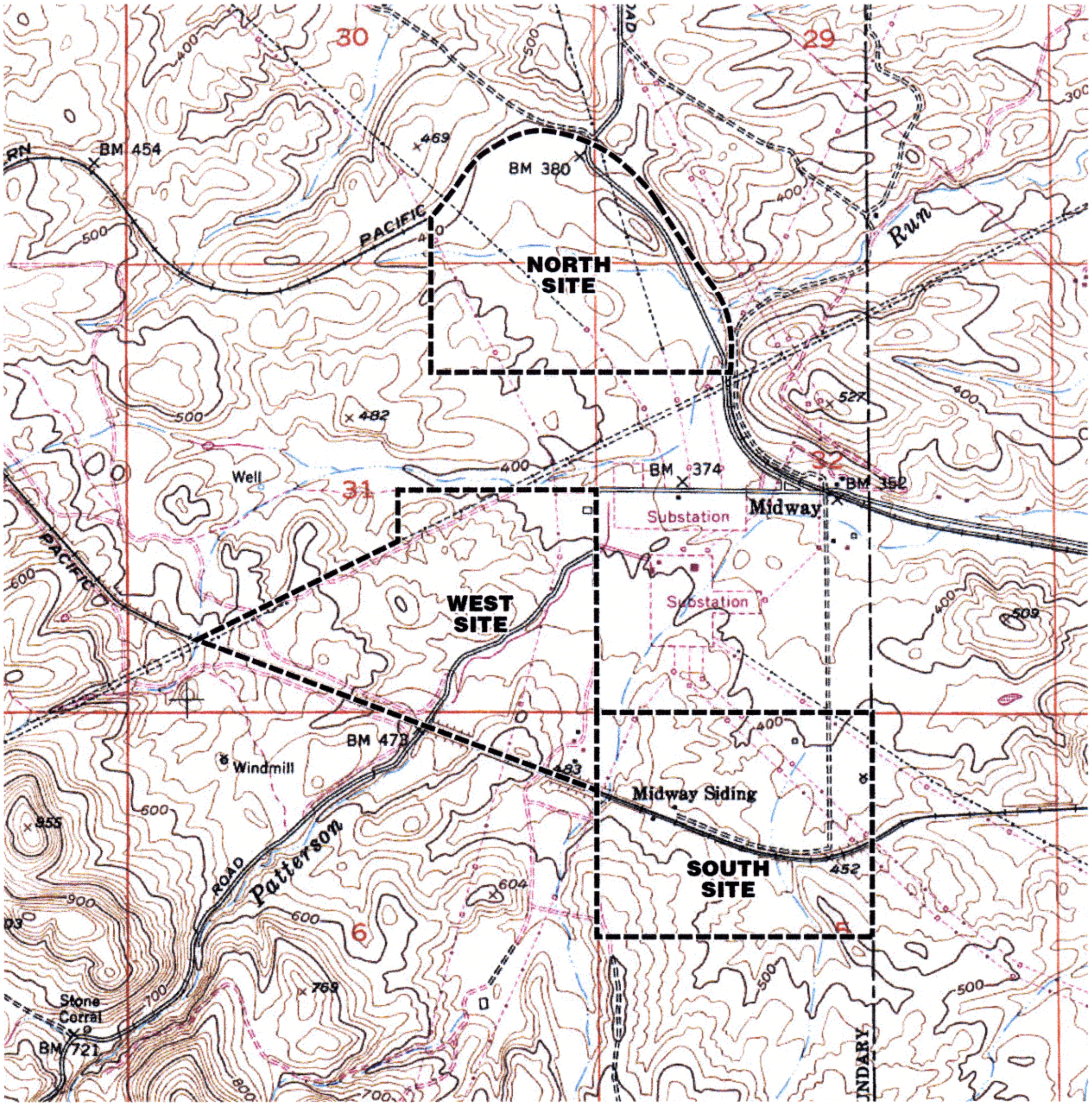
Tesla Site Investigation

Alameda County, California

REGIONAL MAP SHOWING LOCATION OF GENERAL STUDY AREA

E8062-06-01	April 2001	Figure 1



0 2,000 Ft.

Scale: 1:24,000

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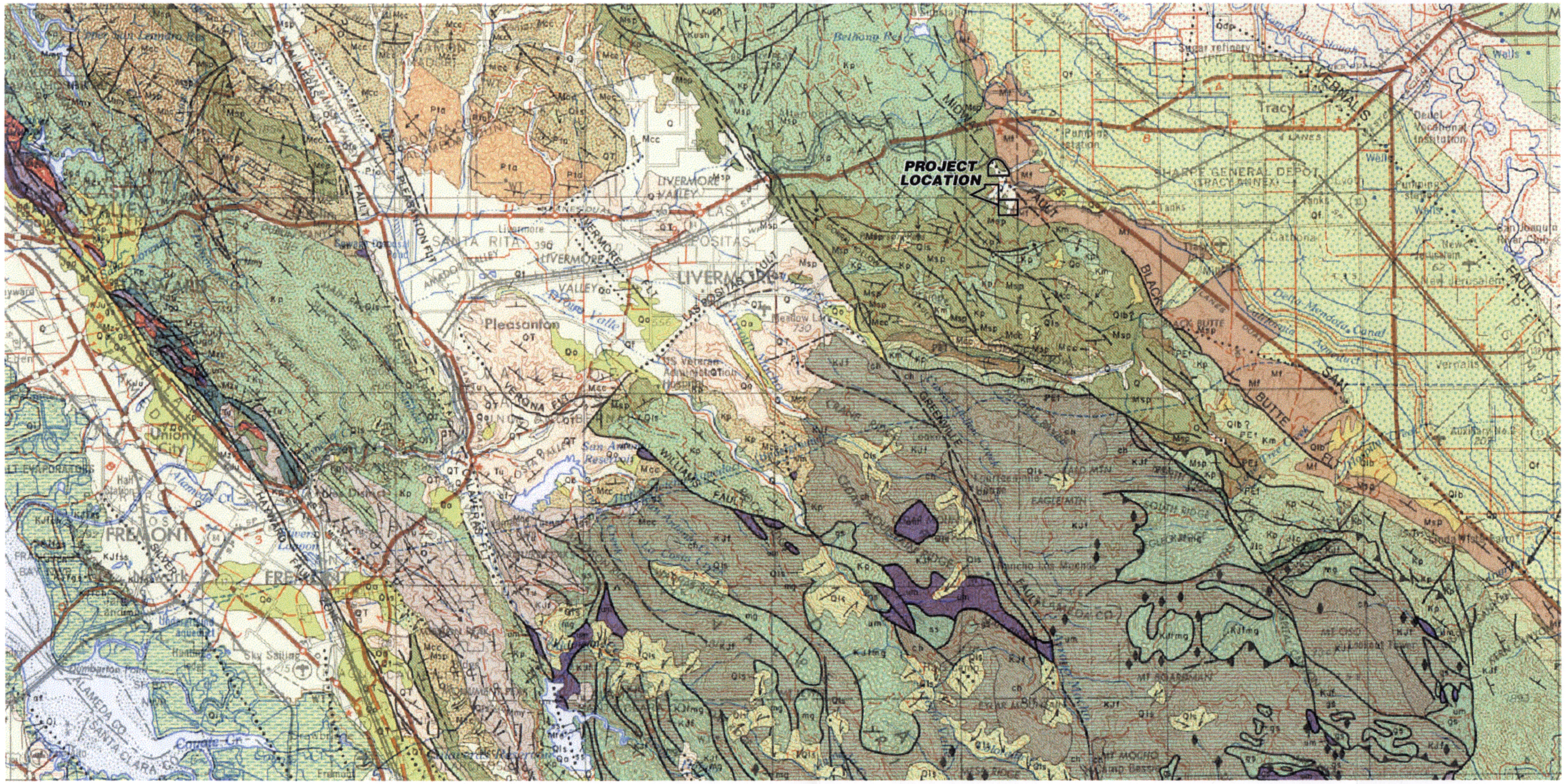
Tesla Site Investigation

Alameda County,
California

STUDY AREA LOCATIONS

E8062-06-01	April 2001	Figure 2



N

0 5 Miles

Scale: 1:250,000

LEGEND (Refer to Stratigraphic Column, Figure 5 for Unit Ages):

- Q — Alluvium
- Qf — Alluvial Fan Deposits
- Qls — Landslide Deposits
- Qo — Older Alluvium
- Qlb — Los Banos Alluvium
- Pta — Tassajara Foundation (Nonmarine)
- Mcc — Contra Costa Group (Nonmarine)
- Msp — San Pablo Group (Marine Sandstone)
- Mf — Fanglomerate
- Kp — Panoche Formation (Marine Sandstone & Shale)
- KJf — Franciscan Complex:
  - mg — Metagraywacke
  - um — Serpentinized Ultramafic Rock

- Fault (Dashed Where Approximate, Dotted Where Concealed)
- Thrust Fault-Barbs on the Upper Plate (Dashed Where Approximate, Dotted Where Concealed)
- Anticlinal Fold
- Synclinal Fold

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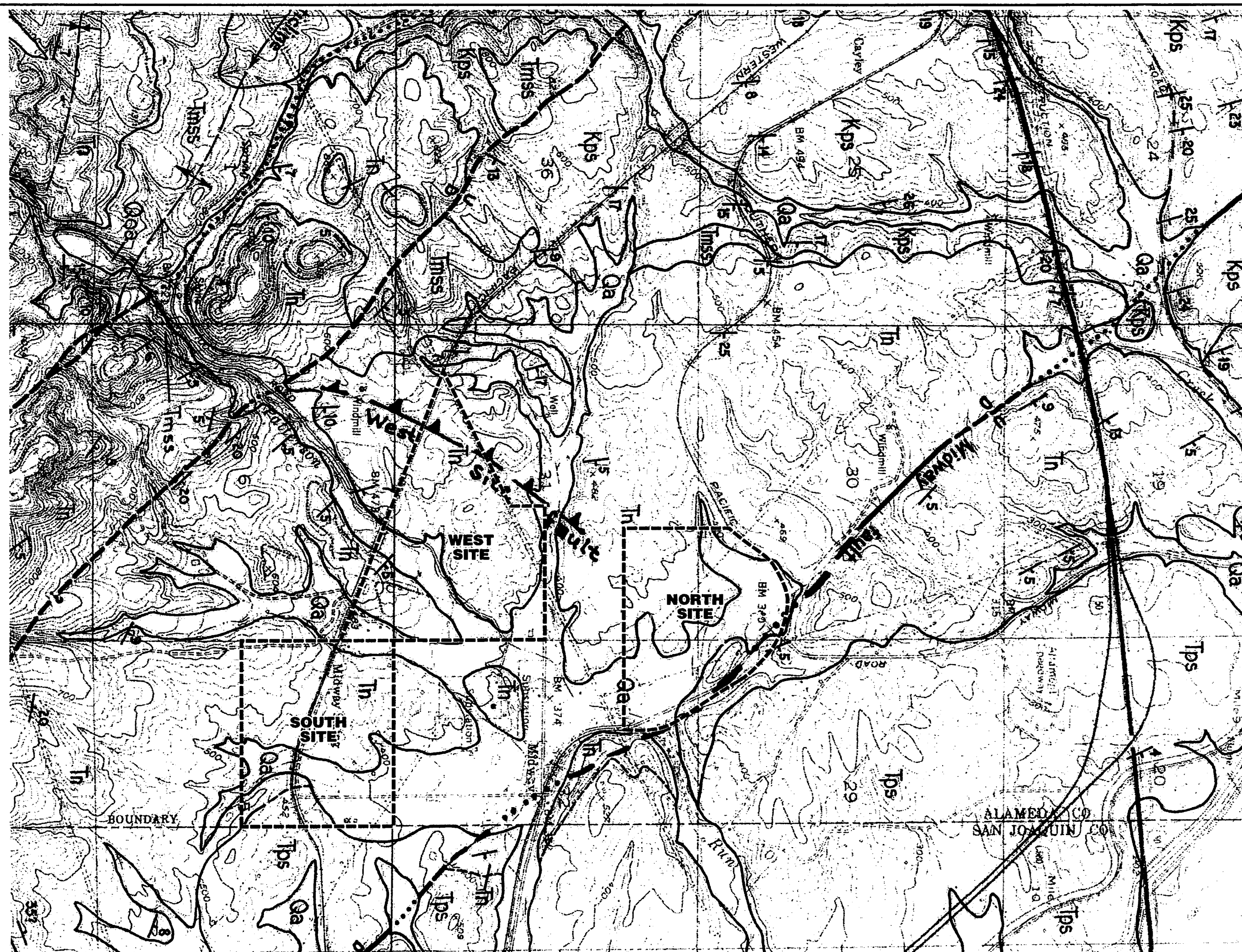
REGIONAL GEOLOGIC MAP OF THE EAST SAN FRANCISCO BAY AREA

E8062-06-01	April 2001	Figure 3



LEGEND (Refer to Stratigraphic Column, Figure 5 for Unit Ages):

Qa	Alluvium
Qoa	Older Alluvium
Tps	Tulare and Non-Marine Sedimentary Rocks
Tn	Nerly Formation
Tmss	Cierbo Formation
Kps	San Pablo Group - Undifferentiated
Kp	Panoche Formation
20	Strike and Dip

U D ? Fault (Dashed Where Approximate, Dotted Where Concealed)

? Thrust Fault-Barbs on the Upper Plate (Dashed Where Approximate, Dotted Where Concealed)

Anticlinal Fold

Synclinal Fold

0 — 2,000 Ft.

Scale: 1:24,000

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SITE GEOLOGIC MAP

E8062-06-01 | April 2001 | Figure 4

ERA	AGE	Formation	Column	Thickness (feet)	Description
Cenozoic	Quarternary	Alluvium and landslide debris	Qa Qls	?	Gravels, sands, silts, clays
		Older Alluvium	Qoa		
	Pliocene	Tulare and non-marine sedimentary rocks	Q1 Tps	100+ 4000	Continental deposits of gravels, sands, clays
	Upper Miocene	San Pablo Group – Neroly – Upper	Tn_{sh}	2000+	Shales, blue sandstones, tuffs
		San Pablo Group – Neroly – Lower	Tn_{ss}	50-700	Blue sandstone, andesitic conglomerate, tuffs
		San Pablo Group – Cierbo	Tm_{ss}	100-500	Granular white sands, tan sands, tuffs, conglomerate, and coal
	Middle Eocene	San Pablo Group – Tesla	Tt_s	2,000	Marine units - Tan sands, white sands, and clays Brackish water units - Tan sands, dark brown fissile shales, and coal.
Mesozoic	Upper Cretaceous	Morano	K_m	550	Upper-most unit is localized tan sandstone, siliceous, argillaceous, and sandy shales with calcareous concretions and interbedded sandstones.
		Panoche	K_{pg}	10,000+	Massive sandstone with abundant concretions, argillaceous and silty shales, conglomerates.
	Cretaceous and Jurassic	Franciscan Assemblage	KJf	15,000?	Melange - Chaotic mixture of sandstones, shales, cherts, conglomerates, and pillow basalts. Glaucophane schist, serpentine, diabase, and diorite-gabbros are common.

Conformable Contact (dashed where gradational)

Unconformable Contact

Fault Contact

Figure 5 - Generalized Stratigraphic Column of the Tesla Area

Proposed Tesla Power Plant Site Alternatives

TABLE 1 - Site Rankings Based on Various Geologic and Physiographic Factors

Characteristic	Factor	Tesla North	Tesla West	Tesla South	Notes
Tectonic	Apparent Faulting	2	3	1	
	Seismicity	1	1	1	Preliminary data indicates that probable peak ground accelerations are the same for all three sites.
Liquefaction	Liquefaction	0	0	0	Areas of liquefiable soils may be present, drilling and testing will be necessary to properly assess the hazard.
Subsidence	Subsidence	1	1	1	No evidence of subsidence was noted during a limited literature search, or observed in the field.
Slope Stability	Slope Stability	1	1	1	No slope failures were observed in the field.
Soil and Rock Properties	Expansive Soils	0	0	0	No evidence of highly expansive soils was noted during a limited literature search, or observed in the field.
	Corrosion	0	0	0	Corrosive potential of the soils has not been determined.
	Hazardous Geological Substances	0	0	0	Hazardous geological substances (naturally occurring asbestos, mercury containing rocks, etc.) were not noted during a limited literature search, and were not observed in the field.
Resources	Paleontological Resources	0	0	0	No paleontological resources were noted during a limited literature search, and were not observed in the field.
	Geological Resources	0	0	0	No significant geological resources were noted on the sites.
Hydrology	Surface Water	2	3	1	
	Flooding	3	2	1	
	Runoff	2	3	1	
Physiography	Physiography	1	2	1	
	Cumulative Score	13	16	8	
	Ranking	**2**	**3**	**1**	

Notes: A higher score for any particular factor indicates a higher risk. If two or three of the sites have an equal risk, they are assigned an equal risk score. A rating of zero indicates that either no data is available, or there is no evidence of an adverse effect noted in the literature or observed within the limited scope of the work performed in the preparation of this report.

TABLE 2 - List of Known Active Faults Within 100 Kilometers

Fault Name	Fault Type (1)	Fault Geometry	Distance from Sites (Approx) Km (Miles)	Fault Length Km	Slip Rate (Approx.) mm/yr	M_{max}	R. I. Years	Estimated Duration of Shaking (2) seconds	(3) Peak Horizontal Acceleration at Tesla Site g
Greenville (4)	B	rl-ss	9 (6)	73	2	7.2	521	15	0.47
Calaveras (north)	A	rl-ss	29 (18)	52	6	6.8	146	14	0.17
Hayward (north)	A	rl-ss	39 (24)	43	9	6.9	167	15	0.15
Hayward (south)	A	rl-ss	40 (25)	43	9	6.9	167	15	0.15
Calaveras (south)	B	rl-ss	40 (25)	106	15	6.2	33	9	0.10
Concord-Green Valley	B	rl-ss	40 (25)	66	6	6.9	176	15	0.15
Hayward (southeast)	B	rt-r-o	43 (27)	66	3	6.4	220	10	0.11
Monte Vista-Shannon	B	r45, E	49 (31)	41	0.4	6.8	2410	14	0.12
San Andreas (Peninsula)	A	rl-ss	68 (43)	88	17	7.1	400	17	0.11
West Napa	B	rl-ss	76 (47)	30	1	6.5	701	11	0.07
Rogers Creek	B	rl-ss	77 (48)	63	9	7.0	222	16	0.09
San Gregorio	A	rl-ss	83 (52)	129	5	7.3	400	19	0.10
San Andreas (North Coast)	A	rl-ss	91 (57)	322	24	7.6	n/a	24	0.11
Hunting Creek-Berryessa	B	rl-ss	95 (59)	60	6	6.9	194	15	0.07

(1) From UBC97, Table 16-U
(2) Bracketed duration of shaking (duration of shaking in excess of 0.05g) - approximate times for soil.
(3) Site acceleration derived using *Boore, Joyner, Fumal* attenuation relationship for peak horizontal acceleration for North American Earthquakes.
(4) Mmax for the Greenville Fault is based on the Association of Bay Area Governments 1999 Earthquake Hazard Map for the Entire Bay Area, Scenario: Greenville Fault.

Km - Kilometer
mm/yr - millimeters per year
M_{max} - maximum magnitude
R. I. - Recurrence Interval

ss - strike slip
r45, E - reverse fault dipping 45 degrees east
o - oblique
rl - right lateral

g - acceleration due to gravity

APPENDIX A

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G-2: FAULT INVESTIGATION REPORT

TESLA POWER PLANT
FAULT INVESTIGATION REPORT

ALAMEDA COUNTY, CALIFORNIA

GEOCON

GEOTECHNICAL & ENVIRONMENTAL CONSULTANTS

PREPARED FOR
FPL ENERGY
JUNO BEACH, FLORIDA

PREPARED BY

GEOCON CONSULTANTS, INC.
2356 RESEARCH DRIVE
LIVERMORE, CALIFORNIA

AUGUST 2001

TABLE OF CONTENTS

EXECUTIVE SUMMARY

This report was prepared for FPL Energy of Juno Beach, Florida, and contains results of a study of the Midway Fault in the Southeast Quarter of the Southeast Quarter, Section 30, Township 2 South, Range 4 East, Mount Diablo Base and Meridian, in the Midway Topographic Quadrangle, Alameda County, California. The study was conducted to help determine whether a potential geohazard exists due to fault movement and seismicity on the Midway Fault. The study data will be used in siting and design of a proposed 1140 megawatt, gas-fired power generation facility (the Site) located adjacent to the fault, in the hills west of Tracy, California. The primary objectives of the study were to determine the location and the activity of the Midway Fault as previously mapped at the Site. The techniques used to gather information were a review of past work, air photo analysis, mapping of the surface geology in the area, a gamma-ray spectroscopy geophysical survey, and subsurface investigation by trenching.

Past mapping based on air photo observation by Thomas Dibblee with the United States Geological Survey indicated that the Midway Fault cuts directly across the proposed power plant location. Field mapping and observation by Geocon Consultants, Inc. personnel indicated that the Midway Fault runs through the northeast corner of the Site. Geocon performed a portable gamma-ray spectrometer survey perpendicular to and across both the Dibblee trace and the Geocon trace of the Midway Fault. Gamma-ray anomalies were identified at both potential fault locations. A trench excavated along the geophysical line encountered the Geocon fault trace trending through the northeast corner of the Site. At the Dibblee fault location, the trench cut a stratigraphic boundary at approximately twelve feet below ground surface. The boundary marked a change from the Neroly Formation sandstones and siltstones common in the area to a greenish clay to silty clay. No direct evidence of faulting was observed in the trench where it crossed Dibblee's interpreted fault trace.

In 1979, the California Department of Water Resources (DWR) prepared seismic hazards assessments for several sites in eastern Alameda County. DWR identified several possible sag ponds, and the apparent epicentral location of a small (magnitude 3.5) earthquake on the Midway Fault. DWR's assessment of the Midway Fault was that "The geomorphic evidence and the occurrence of a magnitude 3.5 earthquake near the fault suggest the fault may be active." Geocon personnel did not observe any obviously recent fault related surface features in the project area. Surface soils in the fault trench were not obviously displaced. Geocon subcontracted Certified Professional Soil Scientist Dr. Glenn Borchardt to perform age dating of the soils cut by the trench. Geocon's staff observed and recorded structural and stratigraphic features in the trench. Based on Dr. Borchardt's work, and the geologic features observed in the trench, the last significant movement (greater than five centimeters per episode) on the fault was pre-Holocene (more than 10,000 year ago), but not pre-Pleistocene (more than 2,000,000 years ago). Geocon tentatively places the age of last significant movement between 10,000 and 40,000 years ago, and therefore considers the fault to be potentially active.

Dibblee mapped the fault as a normal fault, with the upthrown side to the east, but features observed in air photos and in the trench are more consistent with those that occur in a dominantly strike-slip fault. The direction of movement could not be determined in the trench, but based on air photo interpretation, the Midway Fault appears to have a right-lateral sense of movement, which is consistent with other strike-slip faults in the region. The degree of movement from any single event could not be determined from the data gathered during this study, but any Holocene movement that may have occurred is believed to be less than five centimeters per episode. Based on the regional geology, the Midway Fault is interpreted to be a fault that's movement is sympathetic to movement on the major faults in the region, rather than being a causative fault.

The primary hazard posed by the fault is that of surface rupture. Based on statistical relationships established by Bonilla et al (1984), the maximum potential displacement on the fault is one to three feet. Data derived by Wesnousky (1986) give an estimated maximum moment magnitude of 6.3 for the Midway Fault. However, the maximum strong ground motions anticipated at the Site are expected to occur due to seismicity from the more distant Greenville Fault. Given the available information, Geocon recommends that a 50-foot setback from the fault and associated shear zone be established for the construction of critical and occupied structures. Pipelines, cables, and similar infrastructure should cross the fault perpendicular to the fault trace to minimize damage.

1.0 INTRODUCTION

1.1 Project Description

FPL Energy of Juno Beach, Florida, proposes to build a 1140 megawatt, gas-fired power generation facility (the Site) approximately one-half mile north of Pacific Gas and Electric Corporation's (PG&E) Tesla substation, in the hills west of Tracy, California. Figure 1 is a regional map showing the location of the Site. The project will include several gas-fired turbines, a switchyard, support structures, pipelines to bring gas and water to the facility, electrical lines to take power to the Tesla substation, and related infrastructure. Figure 2 depicts the location of the Site and proposed support infrastructure. A second 100-acre property has recently been acquired north of the subject property; this investigation does not address geologic concerns of that property. As a part of their feasibility study, FPL contracted with Geocon Consultants, Inc. to perform an in-depth fault investigation of the Site. The choice of the Site was based in part on the findings of a geologic assessment report prepared by Geocon (2001) of three possible parcels. This report presents geologic findings from the field and fault trench investigation performed for the proposed power generation facility at the Site.

1.2 Site Description

FPL proposes to construct the proposed power generation facility in the Southeast Quarter of the Southeast Quarter, Section 30, Township 2 South, Range 4 East, Mount Diablo Base and Meridian, in the Midway Topographic Quadrangle, Alameda County, California. The parcel of land selected for the development of the FPL facility is located north of the PG&E Tesla Substation.

The Site is located in a topographic basin with gently rolling topography bordered on the east by low hills averaging 400 to 500 feet in elevation. The major natural features in the area are low rolling hills and bluffs to the east of the Site and the drainage of Patterson Run approximately one-half mile south of the Site.

The Site is open and vegetated with short grass. A well, connected to a windmill and stock tank, is located adjacent to livestock pens along the eastern boundary of the Site. Land uses in the area include livestock grazing, wind-based electrical power generation, and electric power distribution. Midway Road runs along the eastern boundary of the Site. The Site is bordered on its north and west sides by an abandoned Union Pacific Railroad right-of-way.

1.3 Scope of Services

The scope of services covered by this report are the determination of the location of the Midway Fault, the approximate age of faulting, and the nature of movement on the Midway Fault. The techniques used to gather information included a review of past work, air photo analysis, geologic mapping, a gamma-ray spectroscopy geophysical survey, and subsurface investigation by trenching across the mapped fault traces. In order to gain information on the nature of the Midway Fault at the Site, Geocon performed the following services:

- Reviewed published geologic maps, aerial photographs, and other literature pertaining to the Site to aid in evaluating the presence of faulting.
- Excavated one exploratory trench across the Midway Fault in the northeast portion of the Site to locate the identified potential faults. The trench was excavated beginning in the northeast corner of the Site and continued approximately 500 feet to the southwest. The depth of the trench was approximately 10 feet. The trench sidewalls were cleaned of loose and smeared soil. Following cleaning, the trench sidewalls were logged and mapped by a Geocon Certified Engineering Geologist (CEG). Soil layers were traced for horizontal continuity and any vertical lineations or shears in the soil.
- Geocon contracted with Dr. Glenn Borchardt, PhD. to perform a pedochronological study on the Site. Dr. Borchardt is a soil scientist who specializes in pedochronology (dating of soils) for fault studies. Dr. Borchardt has worked on numerous projects for the United States Geological Survey (USGS) and other governmental and academic institutions.
- McGill Martin Self, Inc. surveyed the surface fault trace, logging stations along the fault trench and geophysical survey stations.
- Following excavation and logging, the trench was backfilled with the excavated spoils.

The data gathered was used in the preparation of this report presenting the findings and conclusions of the investigation. The report contains the following:

- A geologic map showing the location of the fault, geophysical survey line, and trench.
- A log of the trench excavated at the Site.
- A discussion of the background literature and aerial photography review.
- A discussion of faulting at the Site.
- Recommendations for structural setback zones.

2.0 LITERATURE REVIEW

2.1 Regional Studies

Several studies have been conducted on the regional geology of the Midway Quadrangle that encompasses the Site. The main regional studies dealing with the Site area have been those of Dibblee (1980), Wagner, et al (1990), and Sowers, et al (1993). Other studies have dealt with features or areas outside of, but either similar to, or affecting the site. Related regional studies that have findings significant to the Site are those of the California Division of Mines and Geology (CDMG) (Open-file Report 81-8), the California Department of Water Resources (DWR) (1979), and Lawrence Livermore (1991). The Midway Fault was among the faults evaluated by Wesnousky in his 1986 article on seismic hazards in California.

Dibblee's work placed the Midway Fault trending northwest, approximately 430 feet west of the intersection of Midway Road and the Union Pacific Railroad right-of-way. Geocon mapped the fault trace 380 feet east of Dibblee's interpreted location, and with the same northwest trend. The Dibblee interpreted fault position was based on a rapid aerial photo evaluation with minimal field checking of the data. Wagner, et al (1990) and Sowers, et al (1993) mapped the fault location based on Dibblee's earlier interpretation of the Midway Fault location. Previous estimates of the age of faulting on the Midway Fault were based on the work of the DWR (1979) and Jennings (1991) These studies placed the age of last significant movement on the Midway Fault at Late Quaternary (Jennings, 1994) to post Miocene and possibly still active (DWR, 1979). Work by Dibblee (1980), Wagner, et al (1990), and Sowers, et al (1993) was used as a starting point for mapping the surface geology of the Site. Stratigraphic interpretations were based on the Lawrence Livermore (1991) study south of the area, and information from the Mount Diablo (Mount Diablo Interpretive Association, 1996) and Bethany Dam (DWR, 1991) areas to the north.

2.2 Site Specific Studies

Geocon was unable to find any prior site-specific geological studies for the Site. Specific references checked include the DWR, CDMG, USGS, the California Department of Transportation, and PG&E.

Geocon contacted PG&E regarding a geologic or geotechnical study for the Tesla substation located one-half mile south of the Site. Jim Gamble from PG&E's Geosciences Department, informed Geocon that PG&E performed borings for the installation of specific equipment and facilities on the substation, but had not done any area-wide studies (phone conversation with David Bieber on July 26, 2001).

A Bibliography and References section is presented in Appendix A.

3.0 SITE INVESTIGATION METHODS

3.1 Air Photo Review

Geocon obtained and reviewed three sets of aerial photo stereo pairs for the Site and surrounding areas, dated 1966 (approximately 1:30,200 scale), 1968 (approximately 1:35,600 scale), and 1990 (approximately 1:36,000 scale). The specific photo references are contained in Table 1. The purpose of the Geocon air photo review was to identify geomorphic expressions of active faulting. Indications of active faulting may include variations in soil color, vegetation color and shading. These variations may show up as photo lineaments; distinct variations on either side of a linear feature. Active or recent faulting can also be expressed as topographic saddles, linear ridges, offset linear features such as rivers, roads, and railroads, lines of springs, and sag ponds. A Geocon CEG conducted the air photo review. Anomalies identified in the aerial photographs were checked in the field to determine whether they were fault related, associated with other natural processes, or the result of human activity.

3.2 Field Mapping

Field mapping was carried out over a period of three days. The objectives of mapping were to locate surface exposures of the fault, identify fault related geomorphic features, measure structural attitudes of bedding and other features, and to observe lithology of outcrops in the area. A Geocon CEG, assisted by a Geocon staff geologist, performed the field mapping.

3.3 Geophysical Survey

Geocon performed a gamma-ray spectrometer (GRS) geophysical survey across the Site. Geocon's California Registered Geophysicist supervised the geophysical survey. The survey was performed to aid in locating the trace of the Midway Fault across the Site and to determine if multiple fault traces were located on the Site. GRS surveying permits rapid, nondestructive qualitative identification and, with calibration, quantitative measurement of radio nuclides ^{40}K, ^{214}Bi and ^{208}Tl, the major geological sources of gamma rays. These radioactive decay products of potassium, uranium and thorium are found in most geological materials. A portable GRS-410 spectrometer was used to detect radio nuclide anomalies. Anomalies detected with the spectrometer correspond to structural and compositional differences in bedrock deposits. Geocon's use of this technique on other sites and research from Japan has shown that variation in the ratio of equivalent potassium/thorium ($^{214}Bi/^{208}Tl$) is indicative of changes in subsurface geology.

3.4 Fault Trench Study

Geocon excavated a trench using an excavator with a 30-inch wide bucket to an average depth of 10 feet below ground surface (bgs). A 30-inch wide bench, approximately 18 to 24 inches high, was excavated on both sides of the trench to minimize sloughing of surface material into the trench. Hydraulic speed shores were placed every 8 feet along the length of the trench to protect against the collapse of the sidewalls. The ends of the trench were sloped approximately 3:1 to allow egress by any wildlife that might have entered into the trench. Egress for personnel working in the trench was provided via ladders placed within 25 feet of the work area. After the trench was excavated, Geocon personnel removed the smeared material from the walls to allow for viewing of the trench walls. The trench was excavated through both the Geocon and Dibblee traces of the Midway Fault. A trench log legend is presented on Figure 3. The detailed trench logs are presented on Figures 3A through 3C.

4.0 DISCUSSION

4.1 Regional and Local Geology

4.1.1 Regional Geology and Tectonics

The Site of the proposed FPL power generation facility is located in the foothills of the eastern Diablo Range. The area is located on the boundary of the Diablo Range of the Coast Range Geomorphic province to the west and the San Joaquin Valley of the Great Valley Geomorphic province to the east. The Diablo Range trends northwest, subparallel to the rift valley of the San Andreas Fault, and consists of a series of folds of possible middle to upper Miocene age. Bedrock at the Site is Miocene marine rock of the San Pablo Group, which forms resistant bluffs to the west of the Site. Quaternary alluvial deposits derived from erosion of the San Pablo group are present in the valleys. East of the site area lies the northwest portion of the San Joaquin Valley. A Regional Geologic Map of the study area is presented as Figure 4.

The Site is located on the eastern flank of the Altamont Anticline, which is the largest fold in the region and closest major tectonic feature. The fold axis has a northwestern trend of forty degrees west of north, much like all the features of the area, and plunges to the southeast. Down-flank on both limbs of the fold, high angle faults parallel the trend of the fold. The Midway Fault along the northeast boundary of the Site is one example of these northwest trending high angle faults. Geomorphic evidence and the occurrence of a magnitude 3.5 earthquake near the fault trace suggest that the Midway Fault is active (DWR, 1979). Movement on several other faults in the area have resulted in large seismic events. The Coast Range-Central Valley Thrust System, which includes the Green Valley Fault and the Greenville Fault less than 6 miles away, have produced magnitude 6.0 earthquakes in historic time.

East of this study area lies the northwest portion of the San Joaquin Valley. This valley is a northwesterly trending structural basin filled with approximately 30,000 feet of Quaternary alluvial sediments. San Joaquin Valley sediments are derived from erosion of the Sierra Nevada Mountains and Coast Ranges.

4.1.2 Regional Seismicity

Regular seismic activity and potential surface rupture characterize the San Francisco Bay area. The area lies at the boundary of the North American and Pacific plates, an active, predominately strike-slip plate boundary. The San Andreas Fault accommodates the main motion along this boundary, though the area of deformation ranges across to the Central Valley.

Many large magnitude earthquakes have been reported in the region during the past 200 years. The largest of these was the 1906 San Francisco earthquake (Richter magnitude 8.0), caused by movement on the San Andreas Fault. The surface rupture from the 1906 earthquake was 270 miles long and extended from Shelter Cove to San Juan Bautista. Fault movement for the 1906 quake had a right lateral displacement of approximately 20 feet with three feet of vertical displacement. This historic quake resulted in the destruction of San Francisco. More recently, the 1989 magnitude 7.1 Loma Prieta earthquake caused a surface rupture of about 22 miles on the San Andreas Fault. This earthquake had a right lateral slip of about 6-1/2 feet, and resulted in damage totaling six to seven billion dollars.

The seismicity of the study area is predominantly generated by active faults located east and west of the Site. The Coast Range – Central Valley (CRCV) Thrust System is located approximately one and one half miles east of the Site, and the Greenville Fault is located approximately six miles west of the Site. The CRCV Thrust System is at the boundary between the Great Valley and Coast Range geomorphic provinces and is approximately 300 miles long. Two significant historical seismic events have been tied to the CRCV Thrust System; specifically a 6.7 Richter magnitude event near Coalinga in 1983 and a 7.0 Richter magnitude event near Winters in 1892. The Greenville fault is a right-lateral strike-slip fault associated with the San Andreas Fault System. In 1980, a Richter magnitude 5.8 seismic event occurred on the Greenville Fault. The epicenter of the event was located approximately six miles west of the Site, near Livermore. Although both the CRCV Thrust System and the Greenville Fault have the capacity to generate major seismic events, seismicity in the region is dominated by earthquakes on the Greenville Fault because it has a much higher recurrence interval than does the CRCV Thrust System.

The Midway Fault, an active to potentially active fault, runs across the Site near the northeast boundary. The last movement on the Midway Fault has been dated as late Quaternary by Jennings (1994). According to the DWR 1979 seismic hazards evaluation for Bethany Reservoir, two earthquakes have been detected near the trace of the Midway Fault since 1900. The larger of the two was a 3.5 Richter magnitude event. The DWR assigned a maximum credible earthquake (MCE) magnitude of 5.0 and a maximum probable earthquake (MPE) magnitude of 3.5 to the Midway Fault. Wesnousky's 1986 data show the Midway Fault to be an approximately 7 miles long, Pleistocene age reverse fault with a slip rate of between 0.004 and 0.02 inches per year, an average recurrence interval of 2,651 years, and a maximum potential moment magnitude (MPM) of 6.3. It should be noted that MCE, MPE, and MPM are not equivalent values. The MPM is a theoretical maximum earthquake that a given fault can generate, whereas the MCE is the largest earthquake that a fault can generate given the actual regional tectonics and geology, and the MPE is the largest earthquake that the fault is likely to generate.

Future ground shaking could occur on any of the active or potentially active faults in the area. Active faults are defined as faults having historic or Holocene movement (within the last 10,000 years). Potentially active faults have movement that has taken place in the Quaternary (within the last two million years).

4.1.3 Site Geology

The study area is surrounded by rolling hills of the Diablo Range foothills, with several small seasonal creeks running throughout. The Site is predominantly rolling pastureland with short grasses and naturalized wild oats. The Site is open and free of obstructions that would interfere with geologic work. The best rock outcrop exposures are found in the railroad cuts bordering the Site.

Bedrock on the site is Miocene marine rock of the San Pablo Group, which forms resistant bluffs west of the Site. Frequent outcrops of the San Pablo Group are visible in the road and railway cuts surrounding the Site. Quaternary alluvial deposits from erosion of the San Pablo group are present in the valleys. Rocks at the surface of the area are predominantly upper Miocene Neroly Formation (the youngest member of the San Pablo Group) shale, siltstone, and sandstone. However, Pliocene age rocks of the Tulare Formation are reported on the east side of the Midway Fault. A Geologic Map of the Site area is shown in Figure 5. Regionally, the Midway Quadrangle hosts a variety of rock types typical of the California Coast Ranges. A generalized stratigraphic column typical of the Midway Quadrangle is shown on Figure 6. The youngest stratigraphic units identified in this study are the shales of the Upper Neroly Formation. These shales are estimated to be close to 2,000 feet thick, although the top of the shales are usually covered with alluvium so a complete thickness cannot be established. Below these shales are the more commonly seen blue sandstones of the Neroly Formation at the base of which are andesitic conglomerates. This member ranges in thickness from 50 to 700 feet depending on location. The source area for these beds is primarily the Sierra Nevada Mountains during a period of andesitic eruptions.

Below the Neroly Formation, lies the second member of the San Pablo Group, the Cierbo Formation. Although the Cierbo has not been identified on the Site, others have mapped it in the area (Dibblee, 1980). The Cierbo is the unit most often involved in the folding and faulting of the area. It consists of sandstone, white to buff in color, and is formed predominately of quartz. The source area for this member is from the granites of the Sierra Nevada. A good stratigraphic section of the Cierbo has not been found and therefore no measurement of the thickness can be established, though it appears to have a maximum thickness of 500 feet. The contact between the Cierbo and the Neroly Formations can be either conformable or unconformable, depending on location.

Below the Cierbo lie several formations that are exposed in the Midway Quadrangle but were not observed on the Site. Most notably are the white sands and dark brown shales of the Tesla Formation. Below these are the massive sandstones, silty shales and conglomerates of the Panoche Formation. These two members make up over 12,000 feet of the remaining stratigraphic column. Basement rocks are believed to belong to the Franciscan mélange.

4.1.3.1 Bedrock Geology

Bedrock at the Site appears to be entirely made up of units within the Neroly Formation. Bedrock is covered by less than three feet of soil on that portion of the Site lying east of the Midway Fault, The bedrock east of the Midway Fault is a yellowish gray (5Y 7/2), very fine grained, subangular, well sorted, hard, dense, slightly calcareous sandstone with blocky jointing, abundant iron staining (orange), manganese staining (black), and pale pink clay coatings (5RP 8/2) in shears. A zone of intensely sheared bedrock extends 30 feet west from the fault trace. Just east of the Site, observations of Neroly outcrops exhibit lithologies common to the lower portion of the Upper Neroly. The exposed rock units include interbedded units of the classic Neroly "blue sandstone", siltstone, and andesitic conglomerates.

On the west side of the Midway Fault, the bedrock in the study area dips gently to the east. Depth to bedrock ranges from less than one foot on the western edge of the Site to 12 feet or more along the fault. The bedrock underlying the Site west of the Midway Fault is moderate to dark yellowish orange (10YR 6/6), subangular, well sorted, poorly graded, calcareous, moderately dense, very fined grained sand to silty sand with some silt and trace clay. Starting approximately 400 feet west of the Midway Fault at a depth of approximately 12 feet bgs, a pale olive (10Y 6/2) clay, with calcareous lime stringers, abundant iron veining, and abundant silt was found to unconformably underlie the sandstone. The observed location of the pale olive clay subcrop corresponds with an anomaly observed using the gamma-ray spectroscopy geophysical survey method. Rare pea-sized rip-up clasts of pale olive clay were observed in the sandstone overlying the pale olive clay, in hand samples taken from an outcrop in the railroad easement on the north side of the Site. Filled burrows (*Crotavina*) that resemble those of *Callianassa*, a characteristic Tertiary age marine crustacean, were also observed in the sandstone in the railroad outcrop. In addition to the *Callianassa* burrows, a piece of petrified redwood bark was found in the stockpile from the fault investigation trench excavated across the Site. Since the bark was not found in place, its stratigraphic position cannot be determined.

4.1.3.2 Soil Deposits

A relatively thin layer of colluvial and alluvial material, ranging from one-half to ten feet thick, overlies bedrock at the Site. The top approximately two feet of soil represent the active or "A" soil horizon, also called the zone of leaching by soil scientists. The "A" horizon soils are dark, humic, surficial soils in the zone of active leaching. The "A" zone soil extends across the Site and is interpreted by Dr. Glen Borchardt to be of Holocene age. Dr. Borchardt's Pedochronological Report for the Midway Fault, Tracy, California is contained in Appendix B of this report. In general, "A" horizon soils overlie a zone of deposition of the material leached from the "A" horizon called the "B" horizon. The deepest soil horizon on a site is called the "C" horizon, which is the bedrock on the Site. Soils on the Site can be roughly divided into three groupings based primarily on their relationship to the Midway Fault zone, and secondarily to their topographic position. The three soil groupings are:

- A "shallow profile" soil occurs in areas where the depth to bedrock is less than two feet. Soil in the shallow profile is dark organic rich soil of the "A" horizon sitting directly on top of the bedrock. Shallow profile soils occur on elevated topography on the east and west edges of the Site. The Midway Fault separates the shallow profile soils from the shear zone soils. The change from the shallow to the deep profile on the west side of the Site is a transitional change.

- The "shear zone" soil is an "A" horizon as already described, underlain by a relatively unaltered "B" soil over highly sheared and altered generally greenish "B" fault gouge soils. The fault gouge in the shear zone appears to be a mixture of material derived from the Neroly east of the fault and from weathered Neroly soils west of the fault. The gouge material is highly altered to clay with rinds of calcite, pink clay, and gypsum in joints and on the shear faces. The gouge is predominantly olive green and slickensides are present on individual shear and joint faces. There does not appear to be a dominant orientation to the slickensides. The shear zone soils are over 10 feet thick, and occupy a band approximately 40 feet wide along the west side of the Midway Fault. The boundary between the shear zone soils and the deep profile soils is a shear. The shear zone soils underlie the slope on the east side of the Site, within approximately 100 feet of Midway Road.

- A "deep profile" soil exists where there is development of distinct "A" and "B" soil horizons over the "C" horizon. The deep profile soil includes approximately two feet of well developed "A" soils over light to medium brown "B" zone soils, all lying on the "C" soil zone bedrock. They are the dominant soils on the Site occurring in topographic lows. The deep profile soils have an apparent maximum thickness of 12 feet where in contact with shear zone soils. To the west the deep profile soils thin and gradationally transition to shallow profile soils.

Figure 7 shows the stratigraphic columns and a geologic cross-section for surface and near-surface deposits across the Site.

4.1.3.3 Groundwater

An active wind powered agricultural well is located on the Site, south of the fault trench and just west of the surface trace of the Midway Fault. A second well lies on or adjacent to the fault one-half mile north of the Site. Free groundwater was not encountered in the fault investigation trench. However, the clay units in the shear zone stayed moist throughout the ten days that the trench was open, despite temperatures in excess of one hundred degrees Fahrenheit. Well logs for the surrounding area, indicate that the static groundwater level west of the Midway Fault lies at a depth of 25 to 30 feet bgs, while the single well log found east of the Midway Fault reports a static water level of 85 feet bgs. The times and conditions under which water level observations were made varied from well to well. Fluctuations in the level of groundwater may occur due to variations in rainfall, temperature, and other factors. The seasonal fluctuation of the groundwater level in this area is not known.

4.1.3.4 Structure

During the field mapping, Geocon's field geologists located the surface trace of the Midway Fault cutting across Midway Road on the eastern edge of the Site. The surface trace of the fault has a bearing of approximately north 44 degrees west. The bearing and location agree with Geocon's interpreted location as presented in the April 2001 Engineering Geology Assessment Report.

Geocon did not observe any definitive geomorphic evidence of recent movement on the Midway Fault within one mile of the Site. Directly east of the Site, a series of gentle topographic depressions were noted along the fault trace on the east side of Midway Road, between the road and the abandoned railroad grade. The depressions may be old sag ponds or an artifact of road and railroad construction. No definitive fault scarps were observed along the fault trace in the study area. There are several breaks in slope on the hillsides that may be fault related north and south of the study area.

Several outcrops were investigated on and adjacent to the Site. Strike and dip of bedding planes were measured at the outcrops on both sides of the Midway Fault. With the exception of one outcrop sitting within ten feet of the Midway Fault, all observed bedding planes dip gently to the east. Strikes in the area are generally in a northerly direction and dips are generally less than 15 degrees. Shearing and jointing was not generally pronounced in the outcrops except in an outcrop just north of the center of Section 31, one-half mile west of the Site. Geocon examined outcrops exposed in the railroad cuts approximately one mile west of the Site. In a railroad cut southwest of the Site, Geocon observed a fault for which no references were found. Geocon unofficially named the fault the West Site Fault. The West Site Fault appears to be a high angle reverse fault, upthrown on the north side. The apparent strike on the West Site Fault is north 35 degrees east, roughly perpendicular to other faults in the region. The limited exposure of the West Site Fault did not lend itself to a determination of the age of seismicity. However, the apparent fault trace lines up with possible fault related surface features in the form of linear topographic depressions to the northeast and southwest of the railroad cut. A subtle, apparently fault related depression extends southwest from the railroad cut. However, the depression may be the result of increased erosion along the fault, rather than actual movement. It is not known if the West Site Fault extends northeast into the Site.

The jointed and sheared outcrop is adjacent to the interpreted eastward extension of the West Site Fault identified in Geocon's previous study. Geocon also noted that north of the West Site Fault, the Neroly sandstone tends to form low flat-topped bluffs, while south of it the hills have a rounded profile.

The Midway Fault that runs along the northern boundary of the Site, is an example of the northwest trending high angle faults common to the region. Stratigraphic beds are locally dipping approximately 5 to 25 degrees east on the west side of the Midway Fault and between 5 and 13 degrees east on the east side of the Midway Fault. The Midway Fault was mapped by Dibblee (1980) trending 40 degrees west of north, approximately 315 feet west of USGS benchmark 380. In the preliminary field investigation performed by Geocon, the Midway Fault was mapped trending 43 degrees west of north, approximately 50 feet east of the USGS benchmark 380. Both the Dibblee interpreted location and the fault trace revealed in the trench are shown on the Site Geologic Map, Figure 5.

4.2 Fault Investigation

4.2.1 Air Photo Review

The three sets of air photos were examined to evaluate the topography of the Site and to evaluate geomorphic evidence of faulting in the area over the 24-year time frame that separates the earliest and latest photo sets.

Flight Line AV-710-22-32&33, March 22, 1966

The topography surrounding the Site is rolling with low to moderately steep northwest trending hills surrounding the Site. Numerous small east-northeast trending stream valleys bisect the hills. The Site occupies a topographic low between two linear hills. A narrow, relatively straight valley trending northwest was observed approximately 2-1/2 miles southeast of the Site. Plowed fields and heavily grazed lands show up as darker areas on the photos. Lightly grazed lands and areas where the Neroly bedrock is at or very near the surface show up as very light colored lands. The California Aqueduct, Delta-Mendota Canal, local roads, railroads, and the Tesla substation are all clearly identifiable on both photos. High-voltage power lines and the wind-powered well on the Site are also discernable. The visible vegetation is almost all grassland except for a few trees along drainages such as Patterson Run, and around occupied dwellings. Outcrops of bedrock are visible along many of the hillsides, and all appear to dip gently to the east.

Expression of the Midway Fault is generally subtle in the photo. A subtle linear color difference is visible northwest of the Site. The color difference extends southeast and is coincident with a series of saddles and breaks in topographic slope that are all in line with each other. A subtle variation in color is visible on either side of the known trace of the Midway Fault at the Site, with the soils on the east side of the fault being slightly lighter in shading. Patterson Run and several unnamed drainages are right laterally offset south of the Site. The inflection points of the offsets are all in line, and the drainages are offset approximately the same amount. A subtle linear color difference is visible south of the junction of Midway Road and Patterson Pass Road along a break in slope. The color change lines up with the previously mentioned northwest trending valley approximately 2-1/2 miles southeast of the Site.

A subtle, northeast trending photo lineament visible southwest of the Site is coincident with the projected trace of the West Site Fault. A faint, straight, broken, dark line extending approximately one-half mile northeast from the railroad cut where the West Site Fault was discovered distinguishes the feature. The lineament crosses the power lines and is not coincident with any observed man-made features in the area. The lineament has a total length of about one-half mile, was not discernable south of the railroad tracks.

Flight Line AV-844-27-28&29, May 2, 1968

There were no obvious topographic changes between the 1966 and 1968 photo pairs. The 1968 photo pair covers a slightly more northerly flight path than the 1966. North of the area described in the 1966 photos, the rolling topography continues with low to moderately steep northwest trending hills. Numerous small east-northeast trending stream valleys bisect the hills. The variations in shading observed in the 1966 photos are also apparent in the 1968 photos, but the photos overall are not as dark. In addition to the landmarks observed in the

1966 photos, Highway 580 is clearly identifiable on the north edge of the photos. No significant changes in vegetation patterns were noted between the 1968 and the earlier photo.

The expression of the Midway Fault is generally subtle in the photo. Based on the presence of a narrow, northwest trending valley and a subtle variation in color shading on either side of the valley, the Midway Fault apparently crosses Highway 580 at Grant Line Road. As noted in the 1966 photo, the subtle color difference extends southeast and is coincident with a series of saddles and breaks in topographic slope that are all in line with each other, and extend to the northeast portion of the Site. A subtle variation in color is visible on either side of the known trace of the Midway Fault on the Site, with the soils on the east side of the fault being slightly lighter in shading. The variation in shading south of Patterson Pass Road was not as visible in these photos due to disturbance of the area by agricultural practices.

The lineament coincident with the West Site Fault noted in the 1966 photos was not observed in these photos.

Flight Line K-AV-3817-15-6&7, May 4, 1990

The Site remained relatively unchanged from 1966 to 1990, except for the construction of numerous wind power generating turbines on adjacent properties. The area covered by the 1990 photos is almost identical to that covered by the 1968 photos. There were no obvious topographic changes between the 1968 and 1990 photo pairs. The variations in shading observed in the 1966 and 1968 photos are more apparent in the 1990 photos, since the earlier pairs are black and white, and the 1990 pair is in color. With the exception of irrigated fields several miles east of the site, and riparian vegetation, the landscape showed up in varying shades of light to medium brown. In addition to the landmarks observed in the 1966 and 1968 photos, the wind turbines in the area are clearly identifiable. No significant changes in vegetation patterns were noted between the 1990 and the earlier photos.

As with the 1966 and 1968 photos, expression of the Midway Fault is generally subtle. Unlike the previous photos, however, no evidence of the Midway Fault on the Site was observed in the 1990 photos. The variation in shading along the interpreted Midway Fault trace south of Patterson Pass Road was more visible in these photos than in the previous photos due to variation in both shading and color. The lineament coincident with the West Site Fault noted in the 1966 photos was not observed in these photos.

The interpreted Midway Fault trace from the air photo interpretation is shown on the Site Geologic Map, Figure 5, and crosses the extreme northeast corner of the Site. The fault crosses Midway Road approximately 350 feet from the north end of the abandoned railroad right-of-way, continues south between the railroad right-of-way and Midway Road, crosses the railroad at Patterson Run, and continues southwest at an azimuth of approximately 52 degrees. Where the Midway Fault crosses Patterson Run, the creek makes an approximately 25 degree bend to the right. Two other unnamed drainages south of Patterson Run, are also cut by the fault, and bend the same way. Approximately 2-1/2 miles south of the Site, the fault appears to form a linear valley.

Air photo investigation of the West Site Fault south of where it was first noted in the railroad grade was inconclusive. However, the interpreted trace of the West Site Fault runs near or through a wind-powered well, and up the valley where Patterson Pass Road runs, approximately one and one-half mile to the southwest of the Tesla substation. No air photo evidence of the West Site Fault was seen on the Site. No significant fault related features were seen on the air photos except those of the Midway Fault.

4.2.2 Geophysical Survey

Prior to running the GRS survey, Geocon laid out an 800-foot long survey line parallel to and across the suspected fault trace. The GRS survey line is shown on the Site Geologic Map, Figure 5. GRS readings were taken at stations located 100 feet apart on the line, and the resultant equivalent potassium/thorium ration was plotted. Two GRS anomalies were detected along the GRS survey line, one approximately at Geocon's interpreted location, and a second at approximately Dibblee's interpreted fault location. The anomalies are approximately 310 feet apart. Since the GRS survey stations were located 100 feet apart, the position accuracy for the GRS data peaks is about plus or minus 50 feet. The GRS survey data is included in this report as Appendix C. Geocon excavated a fault investigation trench across both anomalies to determine the anomaly source.

4.2.3 Fault Trench Study

In order to determine the actual location of the Midway Fault on the Site and the age of last movement, Geocon excavated a trench on the eastern portion of the Site. The approximate trace of the Midway Fault on the Site was located based on the fault trend observed in the road cut along Midway Road. The location of the trench was placed so as to extend through both GRS anomalies, the Geocon mapped fault trace, and through Dibblee's mapped fault trace. Geocon excavated a trench starting 20 feet west of Midway Road (Station 4+30) extending 430 feet to the west (Station 0+00). After Geocon excavated the initial trench, the regulatory geologist overseeing the site for the California Energy Commission requested that the trench be excavated an additional 70 feet westward (0+00 to 0-70). The fault trench was placed at approximate 15-foot offset and parallel to Geocon's GRS line as shown on the Site Geologic Map, Figure 5. The completed trench location extended approximately 100 feet beyond Dibblee's mapped fault trace.

The three soil profiles previously described were all observed in the fault trench. The soils in the trench from Station 0-70 to approximately 3+69, west of the shear zone, were all deep profile soils. These soils range in depth from nine feet deep on the west end of the trench to over twelve feet deep in the east-central portion of the trench. The shear zone soils observed in the fault trench in the Midway Fault shear zone extended from approximately Station 3+68 to 4+03, and fall into two broad categories; relatively unaltered soil, and highly sheared and altered fault gouge. Shallow profile soils were observed in the trench east of the Midway Fault from approximately Station 4+03 to 4+30. The shallow profile soils in the trench average one foot thick and are dominantly "A" horizon soils lying directly on top of the bedrock.

West of the Midway Fault Shear Zone

West of the Midway Fault shear zone, from approximately Station 0-70 to 3+69, five distinct soil zones characterize the soil/bedrock stratigraphy. The uppermost zone is the "A" soil horizon, which has a fairly consistent composition across the length of the trench, and averages about two feet thick. The "A" horizon soil is grayish brown clayey silt, with vertical jointing. Due to extensive ground squirrel activity, the "A" horizon is highly burrowed.

The soil zones below the "A" horizon are the various B1 and B2 units that make up the B1-2k zone. The B1-2k zone is distinguishable from the "A" horizon by the presence of calcium and by blocky jointing. The B1-2k zone is a calcareous, dark yellowish brown, clayey silt (10YR 4/2) with mottled very pale orange (10YR 8/2) iron staining, and contains some intermixed sand. As the soils are traced to the west, the B1-2k zone divides into two separate distinguishable units, a B1k zone and a B2k zone at approximately Station 3+25. The appearance of the calcite within the units is the primary characteristic distinguishing B1 from the B2 horizons. Within the B1 horizon, the calcite deposits are filamentous, whereas those in the B2 horizon are more nodular. The soil horizons under the B1-2k zone and above the weathered bedrock all merge into a single B4k unit in the area of Station 3+50, just west of the shear zone. Units that merge into B4k are apparently derived from erosion of the Neroly and redeposited by alluvial and colluvial processes. The soils are generally fine-grained sands with common pebble bands representing old soil surfaces. Scattered chert nodules up to 4 inches in diameter are present in various subunits within this zone. Several channels were observed in the middle and upper units that merge into B4k. No distinct bedding features were observed between bounding pebble layers or channel deposits. Features generally differentiating the units that merge into B4k are color, ped shape, and morphology of the visible calcite. Some variation in grain size is apparent across the units, but they are generally coarse silts to fine sands. Little or no void spaces were observed in the units, and the extensive calcite cementation appears to effectively fill the intergranular spaces in the units.

The boundary between the B1-2 zone and the underlying B3 zone is marked by a distinct change in the soil color. Whereas the "A" and B1-2 zones are uniformly gray brown, the zone immediately underlying them varies in color from pale pink through varying shades of light orange and brown. The B3 zone includes the various B3 units and merges with the underlying B4 zone at approximately Station 3+55. The soils within the B3 zone are sandy-silts to silty-sands, are highly calcareous, and generally exhibit blocky jointing. Pebbles are rare in the B3 zone except in one small channel incised into the top surface. *Crotavina* (trace fossil burrows) are scarce below the base of the B3 zone. The calcite in the B3 zone generally acts as a joint lining and gives the units a mottled appearance. Two small fragments of carbonaceous material were recovered from the B3 zone.

The B4 zone lies under the B3 zone and contains the various B4 units. The transition between the B3 and B4 zones is marked by a gradational change across a span of approximately one foot. The main units within the B4 zone are sandy-silts and silty-sands that are very hard and dense. One of the primary features distinguishing B4 from the B3 zone is the hardness of B4. B4 tends to be tightly calcite cemented and contains common thin bands of chert pebbles. Occasional rare chert clasts up to four inches in diameter were observed in the B4 zone. Several channels were observed, at Stations 0+30, 0+90, 1+00, 1+20, 1+90, 2+10, and 3+20, either within or at the top of the B4 zone. The channel deposits are generally coarser grained than the surrounding material and are not as well cemented.

The B4 zone sits on top of apparent bedrock on the site, referred to as the C zone. The top of the C zone was deeper than the bottom of the trench in the eastern half from Station 2+92 up to the Midway Fault. The C zone from about Station 2+92, west of the fault to about Station 0-22 is moderately hard, lightly calcite cemented, massive, fine-grained, pale orange sandstone. At Station 0-22, the pale orange sandstone is truncated against and laps up onto a pale olive, calcareous, silty-clay. A pebble layer marking the transition between the sand and clay is indicative of an erosional contact. A pebble line is generally present at the transition between the B4 and C zones above the pale olive silty-clay. The location of the pale olive silty-clay corresponds with the second GRS anomaly and with Dibblee's interpreted fault location.

Midway Fault Shear Zone

In the area where the trench crossed the eastern mapped trace of the Midway Fault, from Station 3+68 to 4+03, Geocon found a 35 foot wide shear zone on the west side of the Midway Fault. Rocks on the east side of the fault are highly sheared, but have relatively little alteration. The main bounding shear on the east side of the shear zone at Station 4+03 is the main trace of the Midway Fault. The eastern shear separates relatively undeformed Neroly Sandstone on the east from moderate to highly deformed Neroly Sandstone on the west, and dips at an angle of 69 degrees west. The easternmost shear displaces the B soil horizons, and may displace the lower part of the "A" horizon. Due the high degree of burrowing in the "A" horizon, it was not possible to determine whether faulting had displaced surface soils.

The shear zone soils observed in the fault trench in the Midway Fault shear zone extended from approximately Station 3+68 to 4+03, and fall into two broad categories; relatively unaltered soil and highly sheared and altered fault gouge. The relatively unaltered soil includes an "A" horizon like that on the east side of the Midway Fault and a B1-2k horizon that differs from the B1-2k west of the shear zone in that it is moderately to highly sheared. Highly altered and sheared fault gouge lies below the sheared B1-2k soil. The fault gouge in the shear zone appears to be a mixture of material derived from the Neroly on the east side of the fault and the weathered Neroly derived soils on the west side of the fault. The gouge material is highly altered to clay with rinds of calcite, pink clay, and gypsum in joints and on the faces of the shears. The gouge is predominantly olive green and slickensides are present on individual shear and joint faces. There does not appear to be a dominant orientation to the slickensides.

Five dominant shear blocks were observed in the overall shear zone on the west side of the fault. The first shear block (SB_1), from approximately Station 4+00 to 4+02, is an inclined wedge shaped block that is about 15 inches wide at 10 feet bgs, and pinches out at 4 feet bgs between bounding shears. The material in SB_1 is an olive green clayey sand and contains manganese coatings on joint faces, but is still recognizable as Neroly with lithology similar to the unaltered material east of the fault. The shear on the east side of SB_1 dips 64 degrees west, is approximately one-half inch wide, and is filled with a limonitic material.

The second shear block (SB_2), from approximately Station 3+97 to 4+03, is about 5-1/2 feet wide and is bounded on the west by a major shear dipping 79 degrees west. Numerous small, closely spaced, sub-parallel shears that extend up into, but not all the way across the 2Bj soil horizon are present within SB_2. The bounding shear on the east side of SB_2 dips at an angle of 49 degrees east and merges with the main bounding shear on the east side of the shear zone, at a depth of about four feet bgs. Below five feet bgs, the material in SB_2 is an olive green silty clay gouge, with pink clay films on joint faces. Unlike the upper B soil horizons observed along the rest of the trench there were no calcite nodules or stringers visible in the upper B soil horizon of SB_2.

All of the observed shears within SB_1 and SB_2 dip to the west. The shears in the third shear block (SB_3), from approximately Station 3+82 to 3+97, appear to start at the base of the "A" soil horizon and dip to the east. The dips of the shears in SB_3 increase with depth. Within SB_3, rocks are highly altered and deformed and boudinage structure was observed. The shears act as a path for water to leach salts from the soil. The soil in SB_3 is waxy, grayish-olive, blocky clay that was still moist after ten days of exposure in 100 degree Fahrenheit temperatures. Visible calcite was observed within the clay, and pink clay films were visible on joint faces. Below 5 feet bgs, patches of gypsum crystals were observed as linings on joint faces. The bounding shear on the west side of SB_3 is truncated by the B1-2k soil horizon.

Shear block four (SB_4), from approximately Station 3+77 to 3+82, is bounded on both sides by eastward dipping, sub-parallel shears, and is bounded on the top by an erosional surface at the base of the B1-2k soil horizon. SB_4 is divided approximately in half into upper (SB_{4A}) and lower (SB_{4B}) blocks by a shear with an apparent strike bearing 72 degrees and an apparent dip of 41 degrees north. The material within SB_4 is made up of blocks of pale olive, fine-grained sandstone in a matrix of pale olive, silty clay. Pale red-purple clay films were observed on joint faces within this shear block.

The western most shear block (SB_5), from approximately Station 3+69 to 3+77 appears to be the least recently deformed. It is bounded on both sides by eastward dipping, sub-parallel shears, and is bounded on the top by an erosional surface at the base of the B1-2k soil horizon. The soil horizon bounding the top of SB_5 is thicker than that over the other four shear blocks, due apparently to an extensive array of *Crotavina* that has displaced the deeper soils. The material within SB_5 is a light, olive gray to pale olive, mottled, silty clay with chaotic blocky jointing. The joint faces are coated with a calcite film that is overlaid in turn by pale pink clay films.

East of the Midway Fault Shear Zone

The soil profile east of the Midway Fault, from Station 4+03 to 4+31, is relatively thin. Approximately four inches to two feet of "A" horizon soil is present over the top of the bedrock. The bedrock east of the fault is yellowish gray, very fine-grained sandstone. Adjacent to the fault the sandstone is highly sheared, but shearing decreases significantly as the distance from the fault increases. There does not appear to be any dominant shear planes east of the Midway Fault.

5.0 SUMMARY OF FINDINGS

Geomorphic features observed in the air photos, conditions encountered in the fault investigation trench, and the results of geologic mapping indicate that the Midway Fault is a strike-slip fault. Dibblee mapped the fault as a normal fault, upthrown to the east, while Wesnousky listed it as a reverse fault, but features observed in the trench are more consistent with those that occur in a dominantly strike-slip fault. Shears observed in the fault trench dipped both east and west and there was no observed vertical warping of bedding adjacent to the shears. Hence, the lack of evidence showing vertical displacement suggests that movement on the fault is strike-slip rather than normal or reverse. The lateral direction of movement could not be determined in the trench, but based on changes in stream alignment as they cross the Midway Fault, it is interpreted to be a right-lateral strike-slip fault. The interpreted sense of movement is consistent with other strike-slip faults in the region. The degree of movement from any single event could not be determined from the data gathered during this study, but any Holocene movement that may have occurred is believed to be less than five centimeters per episode. Based on the regional geology, the Midway Fault is interpreted to be a fault with movement sympathetic to movement on the major faults in the region, rather than being a causative fault.

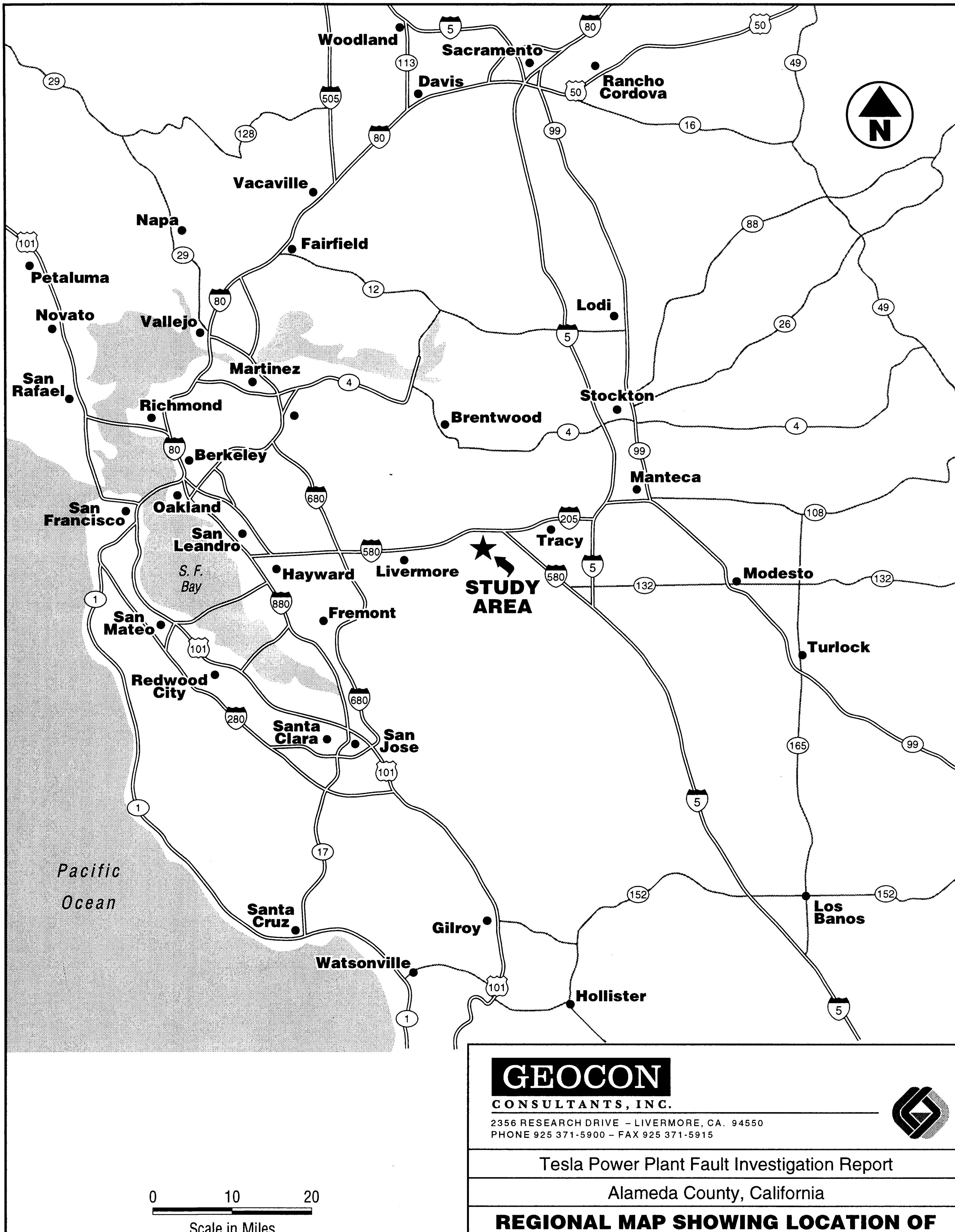
Based on the geomorphic evidence observed in the fault trench, and the paleochronological analysis completed by Dr. Borchardt, the last significant movement on the Midway Fault occurred in late Quaternary or possibly very early Holocene time. This interpretation is based on the lack of obvious seismic related disturbance in the "A" soil horizon, absence of obvious fault related surfaces around the Site, and the presence of calcite and clay films on the shear faces in the subcrop. According to Dr. Borchardt's work, and the geologic features observed in the trench, the last significant movement (greater than five centimeters per episode) on the fault was pre-Holocene (more than 10,000 year ago), but not pre-Pleistocene (more than 2,000,000 years ago). Geocon tentatively places the age of last significant movement at between 10,000 and 40,000 years ago, and therefore considers the fault to be potentially active since no evidence of Holocene movement was observed, but evidence of Quaternary movement was seen.

6.0 RECOMMENDATIONS

Our literature, air photo, and field investigation studies indicate that a significant fault, the Midway Fault, is located along the northeast side of the Site. The fault location is shown on the Site Geologic Map, Figure 5. Geocon was unable to place an age on the most recent significant movement on the fault. However, based on the pedochronological studies of Dr. Borchardt, as well as the shear zone exposures and possible historic seismicity, Geocon believes that the Midway Fault is potentially active. For purpose of the construction of a critical facility such as a power plant, Geocon recommends the establishment of a structural exclusion zone along the Midway Fault.

Based on statistical relationships established by Bonilla et al, the maximum potential displacement on the Midway Fault is one to three feet. The maximum strong ground motions on the Site are expected to occur due to seismicity on the more distant Greenville Fault. Given the available information, Geocon recommends that a 50-foot setback from the Midway Fault and associated shear zone be established for the construction of critical and occupied structures. The shear zone extends westward 35 feet from the main trace of the Midway Fault. The recommended setback extends 50 feet west from the shear zone edge and 50 feet east from the main trace of the Midway Fault. The total structural exclusion zone then is 135 feet wide, paralleling the Midway Fault. The recommended setback zone is shown on the Site Diagram with Proposed Development, Figure 2. Pipelines, cables, and similar infrastructure should cross the fault perpendicular to the fault trace to minimize damage.

As a part of the design phase for the construction of the Tesla power plant, Geocon recommends that deterministic seismic analysis be performed on the Midway Fault, and the other faults affecting the site. The deterministic analysis will better define the amount and nature of movement on the faults, as well as provide data on maximum probable site accelerations.



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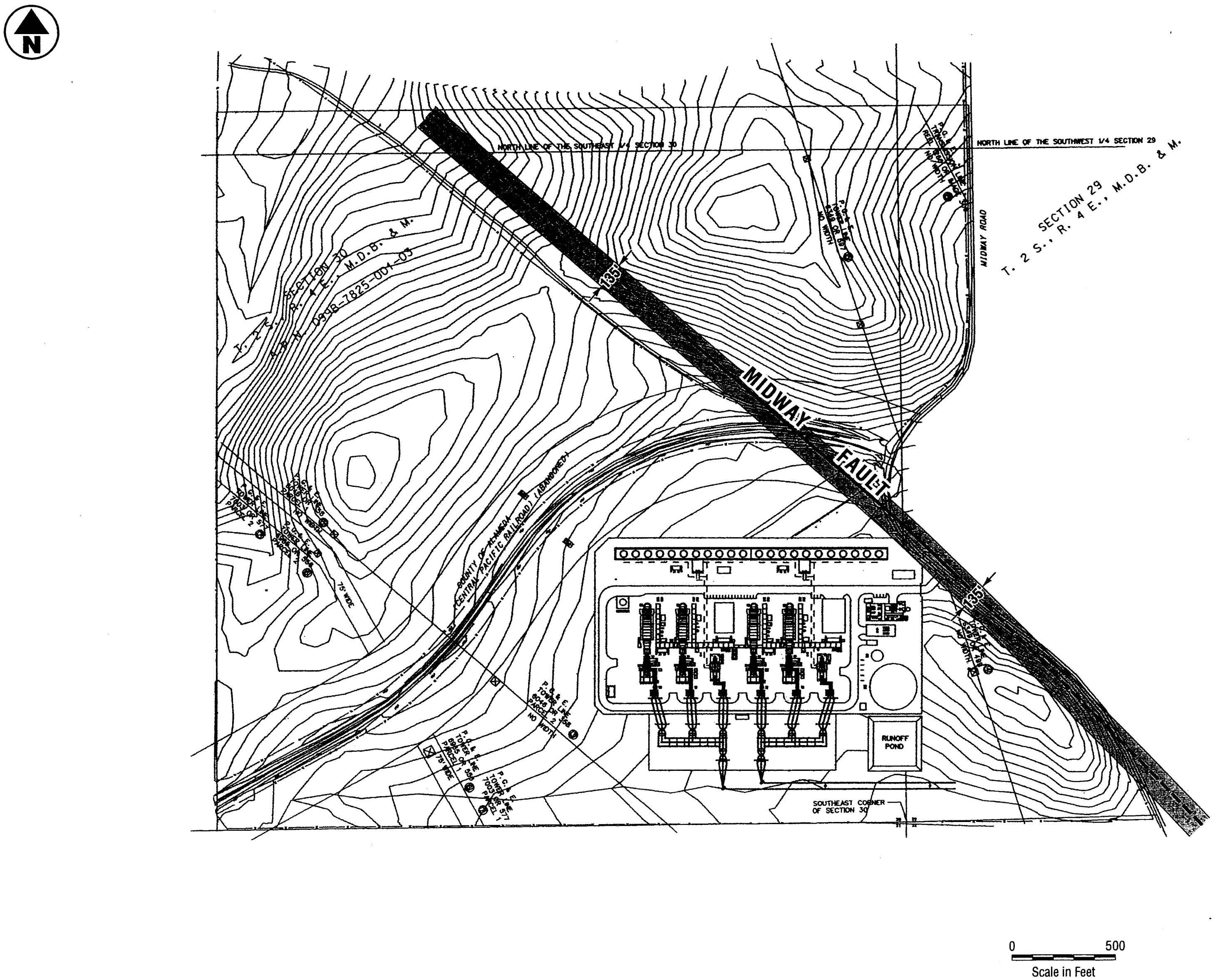
REGIONAL MAP SHOWING LOCATION OF GENERAL STUDY AREA

E8062-06-01	August 2001	Figure 1



LEGEND:

Setback Zone

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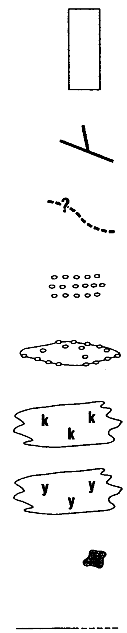
SITE DIAGRAM WITH PROPOSED DEVELOPMENT

E8062-06-02	August 2001	Figure 2

Midway Fault Trench Units, Colors, and Textural Descriptions

Unit Descriptor	Unified Soils Classification	Textural Description	Munsell Color
A	CL-OH	Clayey silt	grayish brown (5YR 3/2)
A_2	CL-OH	Clayey silt	pale brown (5YR 5/2)
CBtjk	SP-SM	Dense, calcareous sandstone, very fine grained	yellowish gray (5Y 7/2)
CBkj	SP-SM	Dense, calcareous sandstone, very fine grained	yellowish gray (5Y 7/2)
Bkj	ML	Calcareous sandy silt	pale yellowish brown (10YR 6/2)
2CBtk	ML-CL	Calcareous silty clay	pale olive (10Y 6/2)
2CBk	ML	Calcareous clayey sand, fine grained.	grayish olive (10Y 4/2)
B1-2k	CL-OL	Calcareous clayey sandy silt	dark yellowish brown (10YR 4/2)
2Bk	CL-OL	Calcareous clayey sandy silt	pale yellowish brown (10YR 6/2)
2Btj	CL	Waxy blocky clay	grayish olive (10Y 4/2)
2Bky	CL	Calcareous and gypsiferous waxy clay	grayish olive (10Y 4/2)
SB_1	.....	*See descriptions for 2CBtk*	....
SB_2	.....	*See descriptions for 2CBtk and 2CBk*	....
SB_3	.....	*See descriptions for 2Btj and 2Bky*	....
SB_4	ML and CL	Blocks of calcareous very fine grained sandstone in a non-calcareous silty clay matrix	pale olive (10YR 6/2)
SB_5	CL	Silty clay	light olive gray (5YR5/2) and pale olive mottled(10YR 6/2)
$B4k_{1-2}$	ML	Calcareous sandy silt with occassional pebble layers	pale pink (5RP 8/2) and grayish orange (10YR 7/4) mottled
B1k	CL-OL	Calcareous clayey silty sand with filimentous calcite	grayish brown (5YR 3/2)
B2k	CL-OL	Calcareous clayey silty sand with nodular calcite	grayish brown (5YR 3/2)
B3k	CL-OL	Calcareous clayey silty sand with patchy and nodular calcite	grayish orange (10YR 7/4) to pale yellowish brown (10YR 6/2)
Bcd_1	SM-SC	Silty clayey sand, fine to medium grained	very pale orange (10YR 8/2) to pale yellowish brown (10YR 6/2) mottled
Bcd_2	SM	Silty pebbly sand, fine to medium grained	grayish orange (10YR 7/4)
$B4k_1$	ML	Calcareous sandy silt	very pale orange (10YR 8/2)
$B4k_2$	SM	Calcareous silty sand	mottled v. pale orange (10YR 8/2) to dark yellowish orange (10YR 6/6)
$B4_1$	ML-SW	Sand, very fine grained	grayish orange (10YR 7/4)
$B4_2$	SM	Silty sand	light brown (5YR 6/4)
B4k	SM	Calcareous silty sand, fine grained	mottled v. pale orange (10YR 8/2) to dark yellowish orange (10YR 6/6)
$B2k_a$	SM-SC	Calcareous clayey silty sand	grayish brown (5YR 3/2)
$B2k_b$	SM-SC	Calcareous pebbly clayey silty sand	grayish brown (5YR 3/2)
$B3k_a$	ML	Calcareous sandy clayey silt	pale yellowish brown (10YR 6/2)
$B3k_b$	SM-SC	Calcareous silty clayey sand	mod. yellowish brown (10YR 5/4)
Ck	CL	Calcareous waxy clay	pale olive (10Y 6/2)



Stationing & Elevations Measured in Feet

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LEGEND

E8062-06-02	August 2001	Figure 3

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TRENCH LOG 1

E8062-06-01	August 2001	Figure 3A

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TRENCH LOG 2

E8062-06-01	August 2001	Figure 3B

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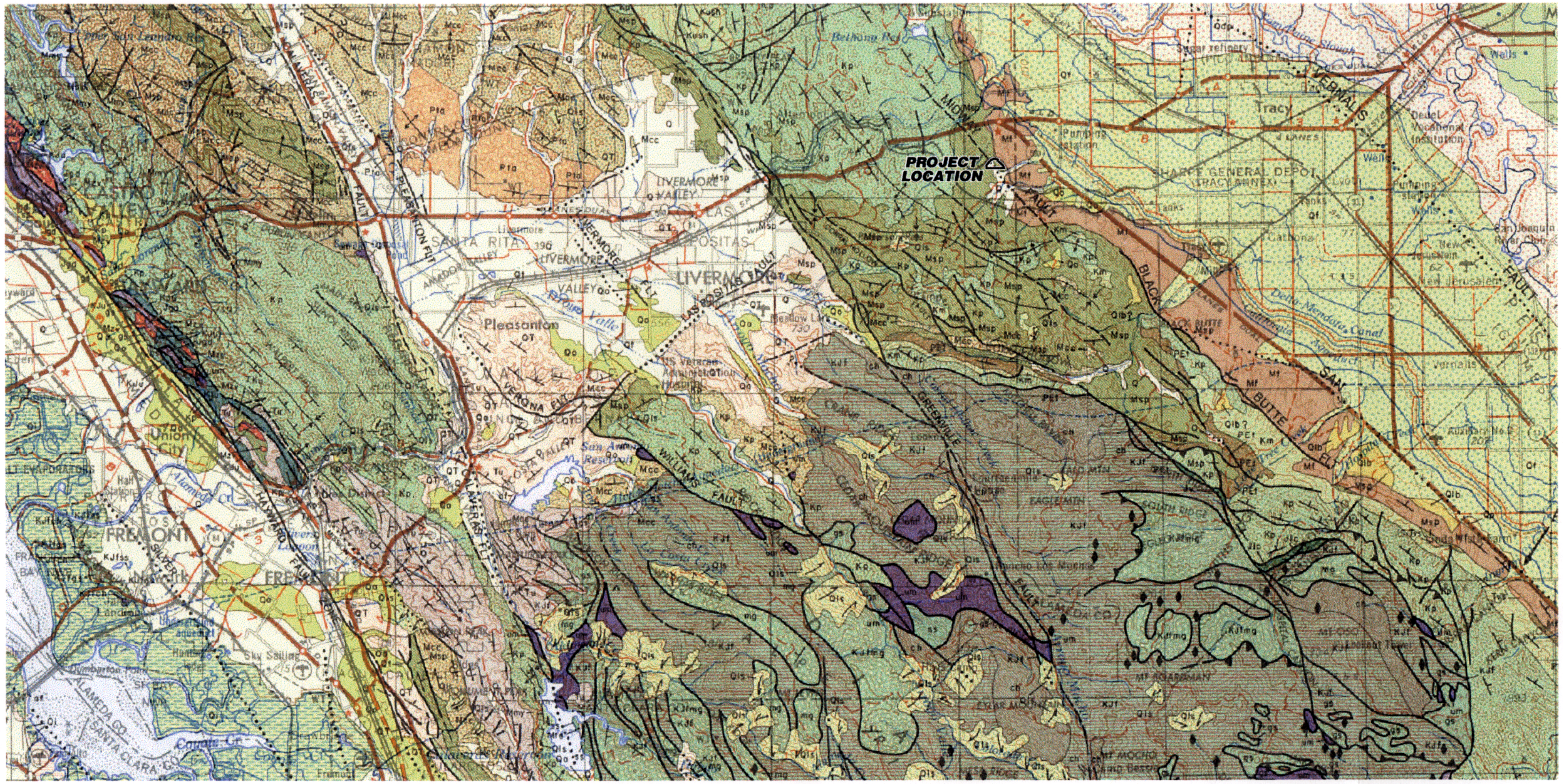
TRENCH LOG 3

E8062-06-01	August 2001	Figure 3C



N

0 5 Miles

Scale: 1:250,000

LEGEND (Refer to Stratigraphic Column, Figure 5 for Unit Ages):

- Q — Alluvium
- Qf — Alluvial Fan Deposits
- Qls — Landslide Deposits
- Qo — Older Alluvium
- Qlb — Los Banos Alluvium
- Pta — Tassajara Foundation (Nonmarine)
- Mcc — Contra Costa Group (Nonmarine)
- Msp — San Pablo Group (Marine Sandstone)
- Mf — Fanglomerate
- Kp — Panoche Formation (Marine Sandstone & Shale)
- KJf — Franciscan Complex:
  - mg — Metagraywacke
  - um — Serpentinized Ultramafic Rock

- Fault (Dashed Where Approximate, Dotted Where Concealed)
- Thrust Fault-Barbs on the Upper Plate (Dashed Where Approximate, Dotted Where Concealed)
- Anticlinal Fold
- Synclinal Fold

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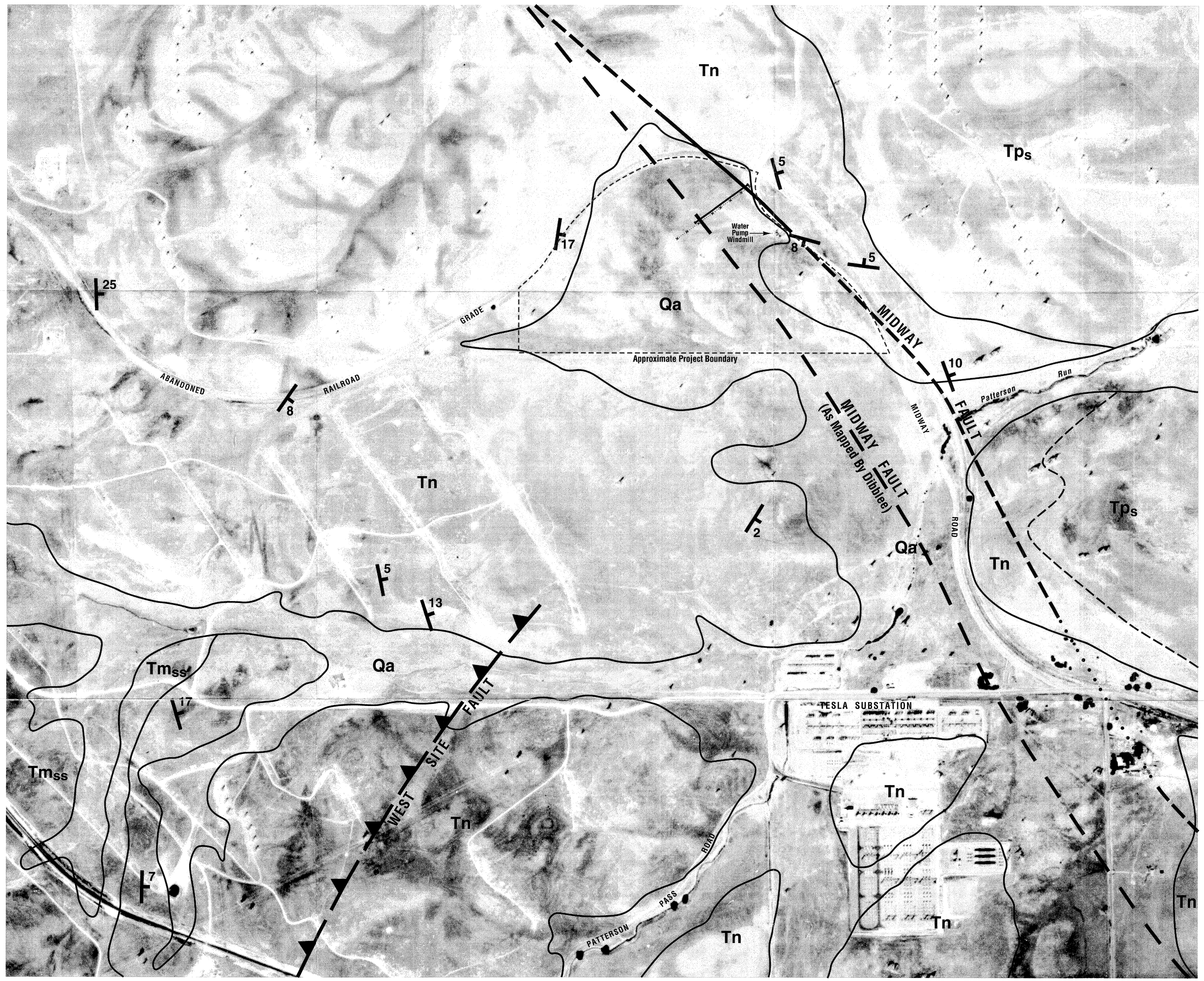
REGIONAL GEOLOGIC MAP OF THE EAST SAN FRANCISCO BAY AREA

E8062-06-02	August 2001	Figure 4



N

LEGEND:

Qa	Alluvium: Unconsolidated Gravel, Sand, Silt, and Clay
Tps	Tulare Formation: Continental Deposits of Gravels, Sands, Clays
Tn	Neroly Sandstone: Blue Sandstone With Minor Clay Shale Siltstone, Tuff and Conglomerate. Predominantly Marine
Tmss	Cierbo Sandstone: Granular White Sands, Tan Sands, Tuffs, Conglomerate, and Coal
	Geologic Contact
	Fault (Solid Where Known, Dashed Where Approximate & Dotted Where Concealed)
	Dibblee's Interpreted Fault Location
	Thrust Fault (Teeth Indicate Overthrust Side)
	Trench
	Gamma-Ray Spectroscopy Survey Points
5	Inclined Bedding Plane Strike and Dip

0 500
Scale in Feet

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SITE GEOLOGIC MAP

E8062-06-01	August 2001	Figure 5

ERA	AGE	Formation	Column	Thickness (feet)	Description
Cenozoic	Quarternary	Alluvium and landslide debris	Qa Qls	?	Gravels, sands, silts, clays
		Older Alluvium	Qoa		
	Pliocene	Tulare and non-marine sedimentary rocks	Q1 Tps	100+ 4000	Continental deposits of gravels, sands, clays
	Upper Miocene	San Pablo Group – Neroly – Upper	Tn_{sh}	2000+	Shales, blue sandstones, tuffs
		San Pablo Group – Neroly – Lower	Tn_{ss}	50-700	Blue sandstone, andesitic conglomerate, tuffs
		San Pablo Group – Cierbo	Tm_{ss}	100-500	Granular white sands, tan sands, tuffs, conglomerate, and coal
	Middle Eocene	San Pablo Group – Tesla	Tt_s	2,000	Marine units - Tan sands, white sands, and clays Brackish water units - Tan sands, dark brown fissile shales, and coal.
Mesozoic	Upper Cretaceous	Morano	K_m	550	Upper-most unit is localized tan sandstone, siliceous, argillaceous, and sandy shales with calcareous concretions and interbedded sandstones.
		Panoche	K_{pg}	10,000+	Massive sandstone with abundant concretions, argillaceous and silty shales, conglomerates.
	Cretaceous and Jurassic	Franciscan Assemblage	KJf	15,000?	Melange - Chaotic mixture of sandstones, shales, cherts, conglomerates, and pillow basalts. Glaucophane schist, serpentine, diabase, and diorite-gabbros are common.

LEGEND:

- - - - - ——— Conformable Contact (Dashed Where Gradational)

~~~~~ Unconformable Contact

–·–·–·– Fault Contact

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GENERALIZED STRATIGRAPHIC COLUMN OF THE MIDWAY AREA

E8062-06-01	August 2001	Figure 6
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Midway Fault Trench Units, Colors, and Textural Descriptions

Unit Descriptor	Unified Soils Classification	Textural Description	Munsell Color
A	CL-OH	Clayey silt	grayish brown (5YR 3/2)
A_2	CL-OH	Clayey silt	pale brown (5YR 5/2)
CBtjk	SP-SM	Dense, calcareous sandstone, very fine grained	yellowish gray (5Y 7/2)
CBkj	SP-SM	Dense, calcareous sandstone, very fine grained	yellowish gray (5Y 7/2)
Bkj	ML	Calcareous sandy silt	pale yellowish brown (10YR 6/2)
2CBtk	ML-CL	Calcareous silty clay	pale olive (10Y 6/2)
2CBk	ML	Calcareous clayey sand, fine grained.	grayish olive (10Y 4/2)
B1-2k	CL-OL	Calcareous clayey sandy silt	dark yellowish brown (10YR 4/2)
2Bk	CL-OL	Calcareous clayey sandy silt	pale yellowish brown (10YR 6/2)
2Btj	CL	Waxy blocky clay	grayish olive (10Y 4/2)
2Bky	CL	Calcareous and gypsiferous waxy clay	grayish olive (10Y 4/2)
SB_1	.....	*See descriptions for 2CBtk*	....
SB_2	.....	*See descriptions for 2CBtk and 2CBk*	....
SB_3	.....	*See descriptions for 2Btj and 2Bky*	....
SB_4	ML and CL	Blocks of calcareous very fine grained sandstone in a non-calcareous silty clay matrix	pale olive (10YR 6/2)
SB_5	CL	Silty clay	light olive gray (5YR5/2) and pale olive mottled(10YR 6/2)
$B4k_{1-2}$	ML	Calcareous sandy silt with occassional pebble layers	pale pink (5RP 8/2) and grayish orange (10YR 7/4) mottled
B1k	CL-OL	Calcareous clayey silty sand with filimentous calcite	grayish brown (5YR 3/2)
B2k	CL-OL	Calcareous clayey silty sand with nodular calcite	grayish brown (5YR 3/2)
B3k	CL-OL	Calcareous clayey silty sand with patchy and nodular calcite	grayish orange (10YR 7/4) to pale yellowish brown (10YR 6/2)
Bcd_1	SM-SC	Silty clayey sand, fine to medium grained	very pale orange (10YR 8/2) to pale yellowish brown (10YR 6/2) mottled
Bcd_2	SM	Silty pebbly sand, fine to medium grained	grayish orange (10YR 7/4)
$B4k_1$	ML	Calcareous sandy silt	very pale orange (10YR 8/2)
$B4k_2$	SM	Calcareous silty sand	mottled v. pale orange (10YR 8/2) to dark yellowish orange (10YR 6/6)
$B4_1$	ML-SW	Sand, very fine grained	grayish orange (10YR 7/4)
$B4_2$	SM	Silty sand	light brown (5YR 6/4)
B4k	SM	Calcareous silty sand, fine grained	mottled v. pale orange (10YR 8/2) to dark yellowish orange (10YR 6/6)
$B2k_a$	SM-SC	Calcareous clayey silty sand	grayish brown (5YR 3/2)
$B2k_b$	SM-SC	Calcareous pebbly clayey silty sand	grayish brown (5YR 3/2)
$B3k_a$	ML	Calcareous sandy clayey silt	pale yellowish brown (10YR 6/2)
$B3k_b$	SM-SC	Calcareous silty clayey sand	mod. yellowish brown (10YR 5/4)
Ck	CL	Calcareous waxy clay	pale olive (10Y 6/2)

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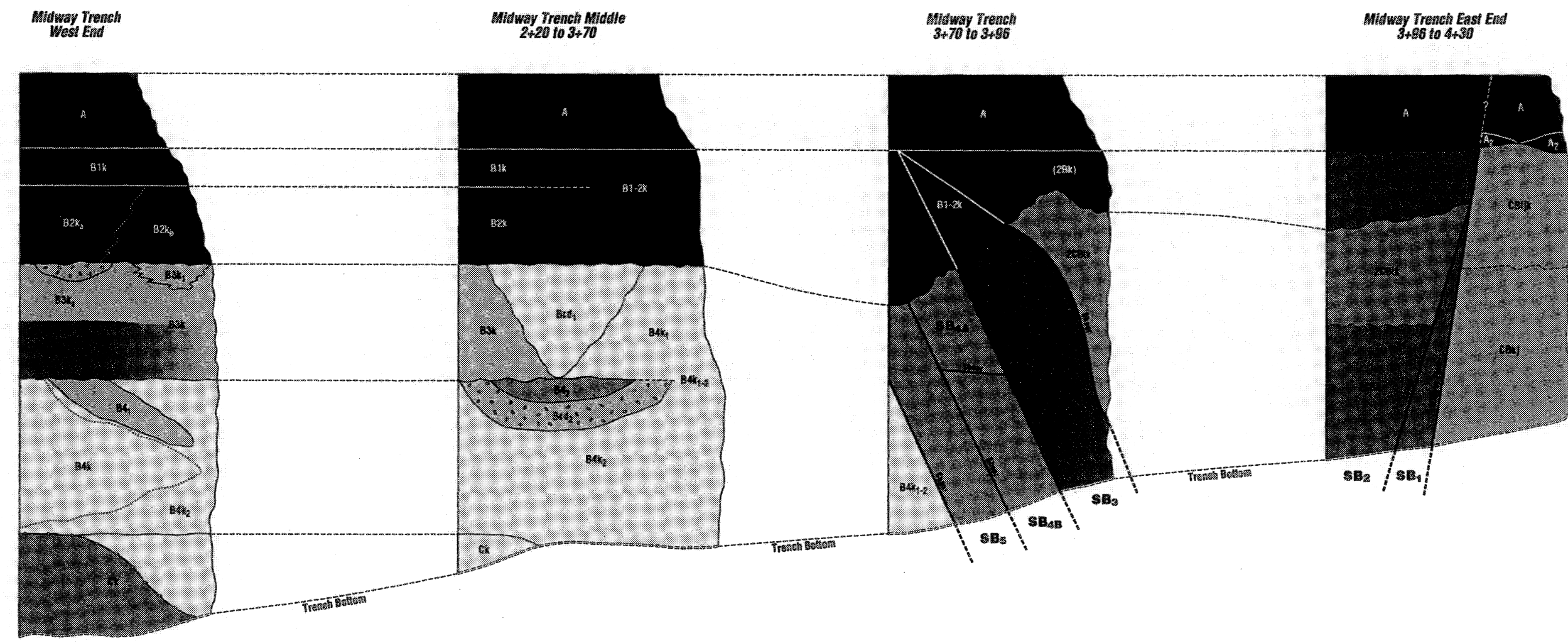
LEGEND

E8062-06-01	August 2001	Figure 7



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Stratigraphic Columns & Geologic Cross-Section For Surface And Near-Surface Site Deposits

E8062-06-02	August 2001	Figure 7

TABLE 1

AIR PHOTO REFERENCES

DATE	SCALE	FLIGHT LINE	FORMAT
March 22, 1966	1:35,600	AV-710-22-32&33	Black and White
May 2, 1968	1:30,200	AV-844-27-28&29	Black and White
May 4, 1990	1:36,000	K-AV-3817-15-6&7	Color

1. All photos were obtained from Pacific Aerial Surveys in Oakland, California.

APPENDIX A

APPENDIX A

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APPENDIX B

PEDOCHRONOLOGICAL REPORT FOR THE MIDWAY FAULT, TRACY, CALIFORNIA

Geocon Project No. E8062-06-02

July 3, 2001

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INTRODUCTION

An assessment of seismic risk due to fault rupture can be aided greatly by the techniques of pedochronology (Borchardt, 1992, 1998), soil dating. This is because the youngest geological unit overlying fault traces is generally a soil horizon. The age and relative activity of faulting often can be estimated by evaluating the age and relative tectonic disturbance of overlying soil units.

Soil horizons exhibit a wide range of physical, chemical, and mineralogical properties that evolve at varying rates. Soil scientists use various terms to describe these properties. A black, highly organic "A" horizon, for example, may form within a few centuries, while a dark brown, clayey "Bt" horizon may take as much as 40,000 years to form. Certain soil properties are invariably absent in young soils. For instance, soils developed in granitic alluvium of the San Joaquin Valley do not have Munsell hues redder than 10YR until they are at least 100,000 years old (Birkeland, 1999; Harden, 1982). Still other properties, such as the movement and deposition of clay-size particles and the precipitation of calcium carbonate at extraordinary depths, indicate soil formation during a climate much wetter than at present. In the absence of a radiometric age date for the material from which a particular soil formed, an estimate of its age must take into account all the known properties of the soil and the landscape and climate in which it evolved.

METHOD

The first step in studying a soil is the compilation of the data necessary for describing it (Birkeland, 1999; Borchardt, 1993). At minimum, this requires a Munsell color chart, hand lens, acid bottle, and pH kit or meter. The second step may involve the collection of samples of each horizon for laboratory analysis of particle size. This is done to check the textural classifications made in the field and to evaluate the genetic relationships between horizons and between different soils in the landscape. When warranted, the clay mineralogy and chemistry of the soil is also analyzed in order to provide additional information on the changes undergone by the initial material from which the soil weathered. The last step is the comparison of this accumulated soil data with that for soils having developed under similar conditions. Such information is scattered in soil survey reports (e.g., Welch, and others, 1966), soil science journals, and consulting reports. In a particular locality, there is seldom enough comparative data available for this purpose. That is why, at the very least, the study of one soil profile always makes the evaluation of the next that much easier.

RESULTS OF THIS EVALUATION

The Midway fault has been mapped across this property crossing normal to Trench T-1 at about station 0'. No evidence for faulting was seen in that area, which consists of an alluvial plain represented by Soil Profile No. 1 (Table 1, log in main report). A broad sheared gouge zone, however, was clearly evident at the eastern end of the trench between the alluvial plain and the hill front (from station 347' to 407').

The contact between the alluvium and the gouge zone dips 70E, while minor shears within the alluvium dip to the west. The lower part of the alluvium appears to be offset, while evidence from the upper part is equivocal. Of the hundreds of shears within the gouge, no single shear stands out as the most active or most recent. The zone between stations 397' and 403', however, seemed to lack the Bk horizon development seen throughout the remainder of the trench. Soil profiles therefore were taken on either side and within this zone to evaluate that development.

ALLUVIUM

Soil Profile No. 1, taken through the midsection of a very fine sandy channel fill, appears generally representative of soil development on the alluvial plain west of the gouge zone.

Soil Profile No. 1

Eight soil horizons were identified within this section, which includes a modern soil and two paleosols (Table 1).

The modern soil has a 60-cm thick A horizon that is a very dark grayish brown clay, with the base of the horizon forming a clear wavy boundary with the underlying Bk/A horizon. Large areas of this underlying horizon consist of A-horizon material that exists as krotovinas, filled burrows previously excavated by ground squirrels. The Bk portion of the horizon is grayish brown clay with common fine to medium white mottles due to calcite in filaments and nodules. The pH of the soil increases from 6.8 in the surface to 8.1 in the subsurface (Table 1), which reflects the formation of pedogenic calcite below the zone leached by acid rainfall.

The next horizon (Btkjb1) appears to be the former 30-cm thick A horizon of a silty clay loam paleosol. It has common thin faint brown clay films on yellowish brown peds, indicating that B-horizon characteristics have been overprinted upon it. There is some pedogenic calcite, but it exists as filaments and small nodules that probably formed as leakage from the modern soil above. The underlying 52-cm thick Btkb1 horizon is a brown, heavy silty clay loam with strong prismatic structure uninterrupted by burrowing. The prisms have thin coatings of calcite, which obviously precipitated subsequent to ped formation—possibly at the same time that the clay films were being deposited in the Btkjb1 above. These relationships could be produced by either a drying climate or by continuing alluvial deposition that led to the burial of this paleosol.

The underlying 2CBkb1 and 3CBkb1 horizons developed in an upward fining sequence with very fine sand at its base and silty clay loam at its top. In this sequence the very fine sand comprises the channel fill and the silty clay loam comprises the overbank deposit. The abrupt smooth boundary at the base of the 3CBkb1 horizon at the 240-cm (8'-) depth was clearly the thalweg of a channel that cut through the second paleosol.

The lower portion of the second paleosol is represented by the 4B2kb2 horizon, which is yellowish brown clayey very fine sand. The 4B1kb2 horizon, not seen in this profile, exists to the west and east, where the sides of the channel rise to meet the surface that existed before the cutting took place. The 4B2kb2 has calcite nodules to 3 cm in diameter—a dimension considerably greater than those found in the modern soil above. Like paleosol b1, the basal horizon of paleosol b2 is very fine sand.

FAULT SCARP

As mentioned, the soils developed in and around the fault scarp were measured, sampled, and described as Soil Profile Nos. 2, 3, and 4 (Table 2). No. 2 overlies greenish gray clay gouge at the base of the scarp. No. 4 is in the Neroly Formation above the scarp. No. 3 is in the light gray silty clay gouge in the area between the two. There is no evidence for buried paleosols in any of these three profiles, each having developed *in situ* from the local colluvium and the underlying fault gouge or bedrock.

Soil Profile No. 2

The A horizon of this soil is dark grayish brown silty clay with a few calcite coatings on peds. The pH of the horizon is 8.0, which is especially high for a surface soil. The conductivity is relatively low (Table 2). The next horizon is a Bk/A, which is a Bk clay horizon developed in the greenish gray gouge mixed with A horizon material through krotovina development. Calcite nodules in the horizon tend to be about 1 cm in diameter. The next horizon is a Btj, which is a weakly developed Bt horizon containing a few thin clay films on ped faces. It has only a few calcite nodules, compared to the horizon above. The next is a 66-cm thick By horizon containing fine crystalline coatings of gypsum on ped surfaces. There is a very small amount of calcite in the horizon and, as expected, the gypsum has produced an extremely high conductivity (Table 2). The C horizon, which exists below the 237-cm depth, consists of vertically oriented boudinaged clasts of calcitic claystone in a matrix of greenish gray gouge.

Soil Profile No. 3

The A1 horizon of this soil is similar to the A horizon at the base of the scarp except for its lower pH and higher conductivity (Table 2). A second silty clay A horizon exists between 55 and 90 cm, with the softness of the parent material allowing much deeper krotovina development than elsewhere. This is probably because the texture of the parent material here is silty clay instead of clay, which is especially hard to excavate. Additionally, the area around this profile is immediately west of the unsheared, relatively hard bedrock at the top of the scarp. This horizon has calcite nodules to 5 mm, but there are not enough to classify it as a Bk. The Bkj horizon from 90-120 cm has nodules to 1 cm, but the calcite development overall is weak. The next horizon, CBtk, is a silty clay that is light gray due to thin calcite coatings on joints and shears. The horizon has prominent red vertically oriented streaks due to thin clay films coating joints and shears. Although many of these clay films coat prominent shears, none of them have slickensides. None of the vertically oriented clay films on the shears have been disrupted by subsequent horizontal, oblique, or vertical displacement.

Soil Profile No. 4

The 60-cm thick A horizon in this profile also is silty clay, but it is slightly lighter in color than the others. This is probably due to bioturbation involving material from the white CBtjk beneath it. The white color is from the existence of a nearly complete coating of pedogenic calcite on joints. The rare yellowish brown is from iron oxide coatings and the faint reddish brown is from rare clay films in joints. The CBkj horizon contains fewer calcite coatings and the matrix exhibits no effervescence (Table 2).

Being on a fault scarp, the A horizons of the three profiles were first considered to be dominantly colluvial. If that were the case, however, the properties of the three A horizons would be identical due to extensive mixing as the materials moved slowly down hill. This indeed is not the case, as shown by the inverse relationship between soil conductivity and soil pH among these horizons (Fig. 1). Conductivity is a measure of the soluble salt content of the soil, while pH values greater than 7 (neutral) tend to reflect the amount of carbonate in the soil. The By horizon in Soil Profile No. 2 had an extremely high conductivity, but the A horizon above it had a relatively low conductivity (Table 2). The CBtjk horizon in Soil Profile No. 4 had an extremely low conductivity, which seems to suggest that soluble salts either move laterally instead of vertically in that soil or that the unsheared rock cannot retard its rapid movement.

DISCUSSION

AGE OF THE ALLUVIUM

The modern soil in Soil Profile No. 1 has features typical of soils that have developed since 10 ka (10,000 calendar years). It is grayish brown and contains calcite filaments and fine nodules. The underlying paleosols (fossil soils) have features more typical of soils developed during the late Pleistocene. Indeed, the strong prismatic structure and clay films in the Btkb1 horizon of the upper paleosol must have formed as a result of extensive shrink-swell activity when seasonal moisture and clay suspensions penetrated to that depth. The precipitation of pedogenic calcite on the prismatic ped surfaces could only have occurred during a subsequent period in which moisture penetration was not as great. There are two possible reasons for a rise in the depth of seasonal leaching: either the climate became drier, or material was deposited on the surface. In the first instance, the depth of leaching would have reached 182 cm during the wet period and only 60 cm during the present dry period. In the second instance, the depth of leaching would have been 82 cm when the prismatic structure was forming in the Btkb1 horizon and 60 cm after 100 cm of clayey alluvium (present A and Bk/A horizons) had been added to the surface. Both scenarios imply a drying climate, such as occurred during the Pleistocene-Holocene transition at 10 ka.

Paleosol b2 has many 3-cm diameter calcite nodules much like those at the bottom of paleosol b1 (Table 1). This implies that there was little change in the climate before and after the incision of the channel, an observation supported by the fact that both the bottom of the channel and the bottom of the b2 are very fine sand in texture. The facies as well as the pedogenic processes remained unchanged during the b2 to b1 transition.

Both the b1 and the b2 paleosols had calcareous horizons that were over 60 cm thick and both developed nodules to 3 cm in diameter. The great thickness of the complete calcareous zone (245 cm) in this soil profile reflects its Pleistocene age. The relative lack of krotovinas that can be associated with the surfaces of these paleosols probably indicates that the present dry climate provides for better ground squirrel habitat than did the wet Pleistocene climate. The time of origination of paleosol b2 could be as great as 40 ka (Table 1).

AGE OF FAULT ACTIVITY

As mentioned, the contact between the alluvium (estimated at 40 ka) and the fault gouge dips to the east at about 70° (see log in main report). A depositional contact would have a westerly dip commensurate with the degree of erosion having taken place before 40 ka. This obviously means that there has been movement along the Midway fault since 40 ka. The sense of movement appears to be almost entirely strike-slip. There are no indications of post-fault erosion along the fault contact and there are no colluvial wedges, multiple paleosols, or overthickened soils near the contact. Thus, no ongoing vertical movement is indicated.

The vertical orientation of the boudins of calcareous claystone in Soil Profile No. 2 indicates that the fault zone formed within a torsional regime like those commonly found along strike-slip faults. The extensive vertically oriented shear fabric at depth likewise indicates strike-slip faulting. The near-surface, easterly dip of some of this fabric just west of Soil Profile No. 2 appears typical of flower-like structures common along faults that have undergone horizontal movement that was influenced by the release of confining pressure very near the surface of the earth. This feature implies that the most recent movement along the fault has occurred east of those easterly dipping shears. On the other hand, the easterly dip may have been produced via downslope creep on this west-facing slope.

The soils developed across the scarp appear to be residual, that is, they have formed primarily from the underlying parent materials. Colluvial contributions from the adjacent slope appear to be surprisingly minor. The A horizons are by no means homogenous across the scarp (Fig. 2). Each of the soil profiles studied there reveals important information about the recency of fault activity.

In Soil Profile No. 2 the tops of the Bk and By horizons are at 65 and 188 cm, respectively (Table 2). These depths correspond to mean annual precipitation (MAP) values of 29 to 36 cm (Fig. 2). The MAP at Tracy is 28 cm (11"), so these leaching depths are commensurate with modern conditions. There is some evidence that these leaching depths once were lower. There are a few thin clay films on ped faces beneath the Bk/A horizon (Table 2).

The presence of calcite and the accompanying high pH generally causes clay suspensions to flocculate. In a similar situation at San Ramon, I estimated that about a thousand years had passed before the climate became arid enough to precipitate pedogenic calcite above the Bt horizon there (Borchardt, 1997). I reasoned that if the dry period began at 10 ka, as it did at Union City (Borchardt and Lienkaemper, 1999), then the t_o age for the soil would be 11 ka. A charcoal sample from the alluvium beneath the San Ramon soil yielded an age of 10.9 ka. Other permissible evidence for a drying climate in Soil Profile No. 2 includes the presence of small amounts of pedogenic calcite in the Btj and By horizons. High conductivity was associated with the visible evidence of gypsum in the By horizon (Table 2). The conductivity also was high in the horizon below, indicating that a By horizon was just starting to form there when the 10-ka dry period caused the gypsum precipitation depth to rise above 237 cm. Had the wet period been much longer than 1 ky, we would expect there to be more clay films, calcite, and visible gypsum at the lower depths.

Soil Profile No. 3 is representative of the gouge zone as it abuts the unsheared bedrock of the Neroly Formation. It has two A horizons, each with traces of pedogenic calcite. The A2 and Bkj horizons are at the same elevation as the Bk/A horizon in Soil Profile No. 2. The A2 has much less visible calcite, but the Bkj also has nodules to 1 cm in diameter. The calcite in No. 3 has penetrated to greater depths than in No. 2. While most of the calcite in No. 2 was confined to the upper 122 cm, the calcite in No. 3 was found throughout the exposure—to at least 300 cm (Table 2). This greater depth of calcite leaching is probably due to this part of the gouge zone being slightly coarser (silty clay) than that at No. 2 (clay). The conductivity is relatively low in No. 3, showing that the clay contents were not high enough to prevent gypsum from leaching through the profile.

The prominent red (10R8/1md) clay films in the CBtk horizon of No. 3 seem to be the counterparts of the greenish gray clay films in the Btj horizon of No. 2. In each case the clay films exist beneath horizons with considerable calcite, possibly indicating that they formed during an earlier wet period. Some calcite has precipitated on the films, giving them a pinkish cast in many places. Why the clay films are red in No. 3, but greenish gray in No. 2 remains somewhat of a puzzle. The solution appears similar to that for the famous red and black complex involving good vs. poor drainage (Borchardt, 1989, p. 689). The low chromas reflect relatively poor drainage in the smectitic clay of No. 2 and the high chromas reflect relatively good drainage in the kaolinitic (?) silty clay of No. 3.

Soil Profile No. 4, like No. 3, is in silty clay bedrock, but it remains unsheared. The horizon of major calcite accumulation (CBtjk, 60-150 cm) is mostly white with a few mottles due to iron oxides and rare faint reddish brown clay films (Table 2). There is some calcite at lower depths, but it has an olive color more like that of the original Neroly Formation.

CONCLUSIONS

Soils at this site are estimated to be between 11,000 and 40,000 years old. The 40 ka alluvium appears to be in strike-slip fault contact with a 60' wide gouge zone in the Neroly

Formation. Nevertheless, the 11,000-year old soils developed across the fault scarp show no clear evidence of having been disturbed by fault movement since 11 ka. Small amounts (<5 cm) of movement may have occurred since 11 ka without affecting the measured soil boundaries. However, there are no slickensides or other physical disturbances evident on clay films that coat major shears. There are no fault-related features such as multiple paleosols, colluvial wedges, or overthickened soils that would indicate apparent vertical movement. Thus the Midway fault, as represented by the gouge zone at the eastern end of Trench T-1, must be considered inactive by the State's current criteria for high-occupancy buildings.

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Table 1. Description of profile representative of the soil development at station 112' in trench T-1 excavated across the Midway fault trace near Tracy, California. Abbreviations and definitions are given in USDA-Natural Resources Conservation Service publications (Soil Survey Staff, 1993, 1998, 1999).

Described by Glenn Borchardt on June 22, 2001 at latitude 37° 43.530' and longitude 121° 34.152' at station 112' in the north wall of Trench T-1 at an elevation of 374.6' (via level survey from 380' bench mark) (~404' via GPS). The site is on an alluvial plain about 100' east of the trace of the Dibblee trace of the Midway fault. Mediterranean climate. Vegetation is grassland. Slope 0°. Well drained, with the soil dry throughout. The soil is neutral in the surface, becoming moderately to strongly alkaline is the subsurface. Current water table >3 m. Soil mapped as Linne clay loam (Welch, and others, 1966).

Horizon Depth, cm Description

Soil Profile No. 1 (station 112')

A 0-60 Dark grayish brown (10YR4/2m, 5/2d) clay; medium to coarse strong subangular blocky structure; very sticky and very plastic when wet, firm when moist, and very hard when dry; many fine roots; many fine continuous random tubular pores; many worm casts; few rounded chert clasts to 2 cm; clear wavy boundary; pH 6.8; conductivity 480 uS.

Bk/A 60-100 Grayish brown (10YR5/2m, 6/3d) clay with common fine to medium prominent white (10YR8/1md) mottles due to calcite filaments and nodules; medium to coarse strong subangular blocky structure; very sticky and very plastic when wet, very friable when moist, and very hard when dry; few fine roots; common fine continuous random tubular pores; violent effervescence; common krotovinas to 12 cm; gradual wavy boundary; pH 8.1; conductivity 770 uS.

* ESTIMATED AGE: t_o = 10 ka
t_b = **0** ka
t_d = 10 ky

Btkjb1 100-130 Yellowish brown (10YR5/4m, 6/4d) silty clay loam with few fine to medium prominent white (10YR8/1md) mottles due to calcite filaments and nodules and common fine faint brown (7.5YR5/4md) mottles due to common thin clay films coating pores and ped faces; massive to medium to coarse strong angular blocky structure; very sticky and very plastic when wet, very friable when moist, and very hard when dry; very few fine roots; common fine to medium continuous random tubular pores; slight to strong effervescence; clear wavy boundary; pH 8.0; conductivity 970 uS (probably a former A horizon).

Btkb1 130-182 Brown (10YR5/3m, 5/3d) heavy silty clay loam with many fine prominent white (10YR8/1md) mottles due to calcite coating ped faces and many fine faint brown (7.5YR5/4md) mottles due to many thin clay films coating pores, ped faces, and few thin clay films coating exped pores on calcite coats; medium strong prismatic structure; very sticky and very plastic when wet, very friable when moist, and hard when dry; many fine continuous vertical tubular pores; slight to strong effervescence; diffuse smooth boundary; pH 8.2; conductivity 1390 uS.

2CBkb1 182-211 Very pale brown (10YR7/3m, 8/2d) silty clay loam with many medium prominent white (10YR8/1md) mottles due to many calcite nodules to 2 cm; medium moderate subangular structure; sticky and plastic when wet, very friable when moist, and very hard when dry; common fine continuous vertical tubular pores; few thin clay films lining pores; violent effervescence; abrupt wavy boundary; pH 8.1; conductivity 1260 uS.

3CBkb1 211-240 Light gray (10YR7/2m, 8/2d) very fine sand with many medium prominent white (10YR8/1md) mottles due to many calcite nodules to 3 cm; massive to medium moderate subangular structure; nonsticky and nonplastic when wet, very friable when moist, and very hard when dry; common fine continuous vertical to random tubular pores; violent effervescence; abrupt smooth boundary; pH 8.5; conductivity 720 uS.

ESTIMATED AGE: t_o = 30 ka
t_b = 10 ka
t_d = 20 ky

4B2kb2 240-269 Yellowish brown (10YR5/4m, 6/4d) clayey very fine sand with many medium prominent white (10YR8/1md) mottles due to many calcite nodules to 3 cm and filaments on ped faces and coats lining pores; massive to medium moderate subangular structure; sticky and plastic when wet, very friable when moist, and very hard when dry; many fine continuous random tubular pores; violent effervescence; abrupt wavy boundary; pH 8.4; conductivity 740 uS.

5CBkb2 269-305+ Very pale brown (10YR7/3m, 8/2d) very fine sand with few fine to medium prominent white (10YR8/1md) mottles due to coats lining pores; massive structure; nonsticky and nonplastic when wet, very friable when moist, and hard when dry; few fine continuous random tubular pores; violent effervescence; pH 8.4; conductivity 640 uS.

ESTIMATED AGE: t_o = 40 ka
t_b = 30 ka
t_d = 10 ky

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*Pedochronological estimates based on available information. All ages should be considered subject to $\pm$50% variation unless otherwise indicated (Borchardt, 1992).
t_o = date when soil formation or aggradation began, ka
t_b = date when soil or strata was buried, ka
t_d = duration of soil development or aggradation, ky

Table 2. Descriptions of profiles representative of soil development across the Midway fault trace near Tracy, California. Abbreviations and definitions are given in USDA-Natural Resources Conservation Service publications (Soil Survey Staff, 1993, 1998, 1999).

Described by Glenn Borchardt on June 22, 2001 at latitude 37° 43.558' and longitude 121° 34.108' to 34.103' at stations 390', 400', and 410' in the north wall of Trench T-1 at an elevation of 385.9' (via level survey from 380' bench mark) (~396' via GPS). The site is on a footslope formed by the trace the Midway fault. Mediterranean climate. Vegetation is grassland. Slope 3°. Aspect SW (trench is oriented N52E). Well drained, with the soil dry throughout. The pH of the surface soil ranges from mildly alkaline above the scarp to moderately alkaline below it. The subsoil is moderately alkaline. Current water table >3 m. Soil mapped as Linne clay loam (Welch, and others, 1966).

Horizon Depth, cm Description

Soil Profile No. 2 (station 390') [BASE OF SCARP]

A 0-65 Dark grayish brown (10YR4/2m, 7/1d) silty clay with few medium faint white (10YR8/1md) calcite coats on peds; fine to very coarse strong granular structure; sticky and plastic when wet, very friable when moist, and very hard when dry; many fine roots; many fine to medium continuous random tubular pores; violent effervescence; abrupt smooth boundary; pH 8.0; conductivity 200 uS.

Bk/A 65-122 Light olive gray (5Y6/2m, 7/2d) clay and grayish brown (10YR5/2m, 7/1d) silty clay with common medium prominent white (10YR8/1md) calcite nodules to 1 cm and coatings on ped faces; fine to medium strong subangular structure; sticky and plastic when wet, very friable when moist, and very hard when dry; few fine roots; many fine continuous random tubular pores; violent effervescence; abrupt wavy boundary; pH 8.4; conductivity 520 uS.

Btj 122-188 Greenish gray (5GY5/1m, 7/1d) clay with few fine prominent white (10YR8/1md) calcite nodules; medium strong subangular to angular blocky structure; sticky and plastic when wet, very friable when moist, and very hard when dry; few thin clay films on ped faces; violent effervescence of nodules; abrupt wavy boundary; pH 8.4; conductivity 960 uS.

By 188-237 Greenish gray (5GY5/1m, 7/1d) clay with many coarse prominent white (10YR8/1md) mottles due to gypsum coatings on ped faces; massive to medium strong subangular to angular blocky structure; sticky and plastic when wet, very friable when moist, and very hard when dry; very slight effervescence of coatings; abrupt wavy boundary; pH 7.7; conductivity >9999 uS.

C/Ck 237-320+ Greenish gray (5GY5/1m, 7/1d) clay with many very coarse prominent white (5Y8/2md) vertically oriented boudinaged clasts of calcareous claystone; massive to medium strong subangular to angular blocky structure (matrix) and massive structure (claystone); sticky and plastic when wet, very friable when moist, and very hard when dry (matrix) and nonsticky and nonplastic, very friable when moist, and soft when dry (matrix); violent effervescence of claystone; pH 8.0 (matrix), 8.4 (claystone); conductivity >9999 uS (matrix), 250 uS (claystone).

ESTIMATED AGE: t_o = 11 ka
t_b = 0 ka
t_d = 11 ky

Soil Profile No. 3 (station 400') [MIDDLE OF SCARP]

A1 0-55 Dark grayish brown (10YR4/2m, 6/2d) silty clay with few fine faint white (10YR8/1md) mottles due to calcite coatings in pores and on peds; few clasts of siltstone-very fine sandstone from the Neroly Formation upslope; fine to very coarse strong granular structure; very sticky and very plastic when wet, very friable when moist, and slightly hard to hard when dry; common fine roots; many fine to medium continuous random tubular pores; violent effervescence; diffuse smooth boundary; pH 7.8; conductivity 440 uS.

A2 55-90 Dark grayish brown (10YR4/2m, 6/2d) silty clay with few medium faint white (10YR8/1md) mottles due to calcite coatings in pores and on peds with nodules to 5 mm; fine to very coarse strong granular structure; very sticky and very plastic when wet, very friable when moist, and slightly hard when dry; few fine roots; many fine to medium continuous random tubular pores; violent effervescence; diffuse smooth boundary; pH 8.0; conductivity 350 uS.

Bkj 90-120 Dark grayish brown (10YR4/2m, 6/2d) silty clay with few medium faint white (10YR8/1md) mottles due to calcite coatings in pores and on peds with nodules to 1 cm; fine to very coarse strong granular structure; very sticky and very plastic when wet, very friable when moist, and slightly hard when dry; many fine continuous random tubular pores; violent effervescence; abrupt wavy boundary; pH 8.0; conductivity 370 uS.

CBtk 120-230 Light gray (5Y7/2m, 8/2d) silty clay with common medium faint white (10YR8/1md) mottles due to calcite coatings on shears and in joints and few coarse red (10R4/6m, 6/3d) mottles due to thin clay films coating shears and ped faces; no slickensides on clay films in shears; vertically oriented clay films not disrupted by shearing; massive to medium weak subangular structure; sticky and plastic when wet, very friable when moist, and slightly hard to very hard when dry; strong effervescence; abrupt wavy boundary; pH 8.3; conductivity 60 uS.

CBk 230-300+ Light gray (5Y7/2m, 8/2d) silty clay with common medium faint white (10YR8/1md) mottles due to calcite coatings on shears and in joints and common fine distinct black mangans and few fine to medium yellowish red (5YR6/8md) mottles due to iron oxides in vertically oriented streaks; massive structure; violent effervescence; pH 8.5; conductivity 280 uS.

ESTIMATED AGE: t_o = 11 ka
t_b = 0 ka
t_d = 11 ky

Soil Profile No. 4 (station 410') [TOP OF SCARP]

A 0-60 Grayish brown (10YR5/2m, 6/2d) silty clay with few fine faint white (10YR8/1md) mottles due to calcite coatings in pores and on peds; fine to medium strong granular structure; very sticky and very plastic when wet, very friable when moist, and slightly hard when dry; many fine roots; many fine to medium continuous random tubular pores; slight effervescence; abrupt wavy boundary; pH 7.5; conductivity 750 uS.

CBtjk 60-150 White (10YR8/2m, 8/1d) silty clay with few coarse prominent yellowish brown (10YR6/8md) mottles due to iron oxides and few coarse faint reddish brown (5YR5/3m, 7/3d) mottles due to thin clay films coating joints; massive to medium weak subangular blocky structure; few fine continuous random tubular exped pores; violent effervescence due to thin to medium thick calcite coatings on joints; diffuse wavy boundary; pH 8.5; conductivity 30 uS.

CBkj 150-285 Olive (5Y5/3m, 7/3d) silty clay with few fine prominent yellowish brown (10YR6/8md) mottles due to iron oxides and few fine distinct black mottles due to mangans coating joints; massive to medium weak subangular blocky structure; few fine continuous random tubular exped pores; violent effervescence of calcite coatings on joints, but no effervescence of matrix; pH 8.5; conductivity 430 uS.

ESTIMATED AGE: t_o = 11 ka
t_b = 0 ka
t_d = 11 ky

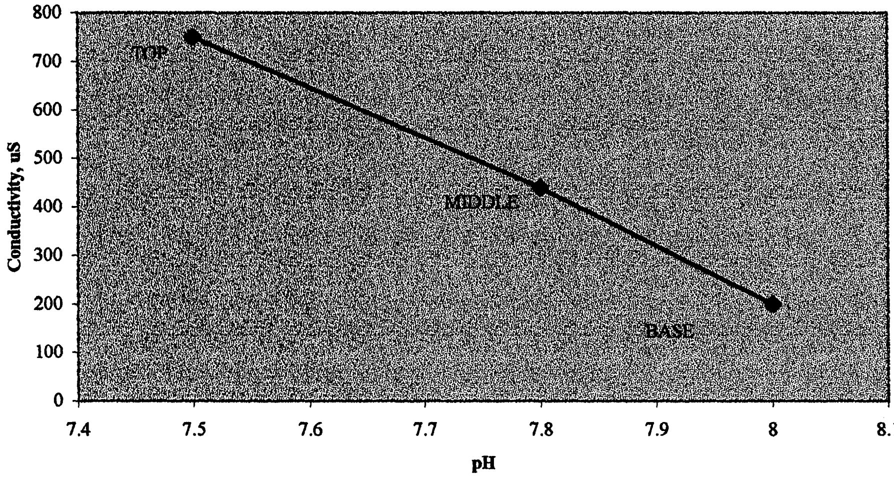


Fig. 1. Relationship between conductivity and pH in the A horizons of Soil Profile Nos. 4, 3, and 2 at the top, middle, and base of the scarp of the Midway fault.

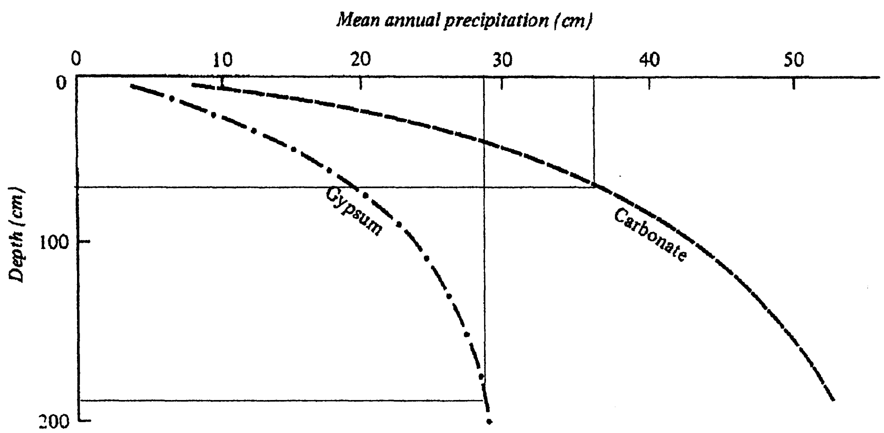


Fig. 2. Relationship between depth to top of pedogenic salt accumulation and mean annual precipitation (MAP) in modern soils of southern Israel (Dan and Yaalon, 1982) (as modified in Birkeland, 1999, p. 203). Data from Soil Profile No. 2 are plotted to yield MAP estimates ranging between 29 and 36 cm. MAP at Tracy is 28 cm (Welch, and others, 1966).

GLOSSARY

AGE. Elapsed time in calendar years. Because the cosmic production of C-14 has varied during the Quaternary, radiocarbon years (expressed as ky B.P.) must be corrected by using tree-ring and other data. Abbreviations used for corrected ages are: ka (kilo anno or years in thousands) or Ma (millions of years). Abbreviations used for intervals are: yr (years), ky (thousands of years). radiocarbon ages = yr B.P. Calibrated ages are calculated from process assumptions, relative ages fit in a sequence, and correlated ages refer to matching units. (See also yr B.P., HOLOCENE, PLEISTOCENE, QUATERNARY, PEDOCHRONOLOGY).

AGGRADATION. A modification of the earth's surface in the direction of uniformity of grade by deposition.

ALKALI (SODIC) SOIL. A soil having so high a degree of alkalinity (pH 8.5 or higher), or so high a percentage of exchangeable sodium (15 % or more of the total exchangeable bases), or both, that plant growth is restricted.

ALKALINE SOIL. Any soil that has a pH greater than 7.3. (See Reaction, Soil.)

ANGULAR ORPHANS. Angular fragments separated from weathered, well-rounded cobbles in colluvium derived from conglomerate.

ARGILLAN. (See Clay Film.)

ARGILLIC HORIZON. A horizon containing clay either translocated from above or formed in place through pedogenesis.

ALLUVIATION. The process of building up of sediments by a stream at places where stream velocity is decreased. The coarsest particles settle first and the finest particles settle last.

ANOXIC. (See also GLEYED SOIL). A soil having a low redox potential.

AQUICLUDE. A saturated body of sediment or rock that is incapable of transmitting significant quantities of water under ordinary hydraulic gradients.

AQUITARD. A body of rock or sediment that retards but does not prevent the flow of water to or from an adjacent aquifer. It does not readily yield water to wells or springs but may serve as a storage unit for groundwater.

ATTERBERG LIMITS. The moisture content at which a soil passes from a semi-solid to a plastic state (plastic limit, PL) and from a plastic to a liquid state (liquid limit, LL). The plasticity index (PI) is the numerical difference between the LL and the PL.

BEDROCK. The solid rock that underlies the soil and other unconsolidated material or that is exposed at the surface.

BISEQUUM. Two soils in vertical sequence, each soil containing an eluvial horizon and its underlying B horizon.

BOUDIN, BOUDINAGE. a French word for sausage, describes the way that layers of rock break up under extension. Imagine the hand, fingers together, flat on the table, encased in soft clay and being squeezed from above, as being like a layer of rock. As the spreading clay moves the fingers (sausages) apart, the most mobile rock fractions are drawn or squeezed into the developing gaps.

BURIED SOIL. A developed soil that was once exposed but is now overlain by a more recently formed soil.

CALCAREOUS SOIL. A soil containing enough calcium carbonate (commonly with magnesium carbonate) to effervesce (fizz) visibly when treated with cold, dilute hydrochloric acid. A soil having measurable amounts of calcium carbonate or magnesium carbonate.

CATENA. A sequence of soils of about the same age, derived from similar parent material and occurring under similar climatic conditions, but having different characteristics due to variation in relief and drainage. (See also Toposequence.)

CEC. Cation exchange capacity. The amount of negative charge balanced by positively charged ions (cations) that are exchangeable by other cations in solution (meq/100 g soil = cmol(+)/kg soil).

CLAY. As a soil separate, the mineral soil particles are less than 0.002 mm in diameter. As a soil textural class, soil material that is 40 percent or more clay, less than 45 percent sand, and less than 40 percent silt.

CLAY FILM. A coating of oriented clay on the surface of a sand grain, pebble, soil aggregate, or ped. Clay films also line pores or root channels and bridge sand grains. Frequency classification is based on the percent of the ped faces and/or pores that contain films: very few--<5%; few--5-25%; common--25-50%; many--50-90%; and continuous--90-100%. Thickness classification is based on visibility of sand grains: thin--very fine sand grains standout; moderately thick--very fine sand grains impart microrelief to film; thick--fine sand grains enveloped by clay and films visible without magnification. Synonyms: clay skin, clay coat, argillan, illuviation cutan.

COBBLE. Rounded or partially rounded fragments of rock ranging from 7.5 to 25 cm in diameter.

COLLUVIUM. Any loose mass of soil or rock fragments that moves downslope largely by the force of gravity. Usually it is thicker at the base of the slope.

COLLUVIUM-FILLED SWALE. The prefailure topography of the source area of a debris flow.

COMPARATIVE PEDOLOGY. The comparison of soils, particularly through examination of features known to evolve through time.

CONCRETIONS. Grains, pellets, or nodules of various sizes, shapes, and colors consisting of concentrated compounds or cemented soil grains. The composition of most concretions is unlike that of the surrounding soil. Calcium carbonate and iron oxide are common compounds in concretions.

CONDUCTIVITY. The ability of a soil solution to conduct electricity, generally expressed as the reciprocal of the electrical resistivity. Electrical conductance is the reciprocal of the resistance (1/R = 1/ohm = ohm^{-1} = mho [reverse of ohm] = siemens = S), while electrical conductivity is the reciprocal of the electrical resistivity (EC = 1/r = 1/ohm-cm = mho/cm = S/cm or mmho/cm = dS/m). EC, expressed as uS/cm, is equivalent to the ppm of salt in solution when multiplied by 0.640. Pure rain water has an EC of 0, standard 0.01 N KCl is 1411.8 uS at 25C, and the growth of salt-sensitive crops is restricted in soils having saturation extracts with an EC greater than 2,000 uS/cm. Measurements in soils are usually performed on 1:1 suspensions containing one part by weight of soil and one part by weight of distilled water.

CONSISTENCE, SOIL. The feel of the soil and the ease with which a lump can be crushed by the fingers. Terms commonly used to describe consistence are --

Loose.--Noncoherent when dry or moist; does not hold together in a mass.

Friable.--When moist, crushes easily under gentle pressure between thumb and forefinger and can be pressed together into a lump.

Firm.--When moist, crushes under moderate pressure between thumb and forefinger, but resistance is distinctly noticeable.

Plastic.--When wet, readily deformed by moderate pressure but can be pressed into a lump; will form a "wire" when rolled between thumb and forefinger.

Sticky.--When wet, adheres to other material, and tends to stretch somewhat and pull apart, rather than to pull free from other material.

Hard.--When dry, moderately resistant to pressure; can be broken with difficulty between thumb and forefinger.

Soft.--When dry, breaks into powder or individual grains under very slight pressure.

Cemented.--Hard and brittle; little affected by moistening.

CTPOT. Easily remembered acronym for climate, topography, parent material, organisms, and time; the five factors of soil formation.

CUMULIC. A soil horizon that has undergone aggradation coincident with its active devopment.

CUTAN. (See Clay Film.)

DEBRIS FLOW. Incoherent or broken masses of rock, soil, and other debris that move downslope in a manner similar to a viscous fluid.

DEBRIS SLOPE. A constant slope with debris on it from the free face above.

DEGRADATION. A modification of the earth's surface by erosion.

ELUVIATION. The removal of soluble material and solid particles, mostly clay and humus, from a soil horizon by percolating water.

EOLIAN. Deposits laid down by the wind, landforms eroded by the wind, or structures such as ripple marks made by the wind.

FIRST-ORDER DRAINAGE. The most upstream, field-discernible concavity that conducts water and sediments to lower parts of a watershed.

FLOOD PLAIN. A nearly level alluvial plain that borders a stream and is subject to flooding unless protected artificially.

FOSSIL FISSURE. A buried rectilinear chamber associated with extension due to ground movement. The chamber must be oriented along the strike of the shear and must have vertical and horizontal dimensions greater than its width. It must show no evidence of faunal activity and its walls may have silt or clay coatings indicative of frequent temporary saturation with ground water. May be mistaken for an animal burrow. Also known as a paleofissure.

FRIABILITY. Term for the ease with which soil crumbles. A friable soil is one that crumbles easily.

GENESIS, SOIL. The mode of origin of the soil. Refers especially to the processes or soil-forming factors responsible for the formation of the solum (A and B horizons) from the unconsolidated parent material.

GEOMORPHIC. Pertaining to the form of the surface features of the earth. Specifically, geomorphology is the analysis of landforms and their mode of origin.

GLEYED SOIL. A soil having one or more neutral gray horizons as a result of water logging and lack of oxygen. The term "gleyed" also designates gray horizons and horizons having yellow and gray mottles as a result of intermittent water logging.

GRAVEL. Rounded or angular fragments of rock 2 to 75 mm in diameter. Soil textures with >15% gravel have the prefix "gravelly" and those with >90% gravel have the suffix "gravel."

HIGHSTAND. The highest elevation reached by the ocean during an interglacial period.

HOLOCENE. The most recent epoch of geologic time, extending from 10 ka to the present.

HORIZON, SOIL. A layer of soil, approximately parallel to the surface, that has distinct characteristics produced by soil-forming processes. These are the major soil horizons:

O horizon.--The layer of organic matter on the surface of a mineral soil. This layer consists of decaying plant residues.

A horizon.--The mineral horizon at the surface or just below an O horizon. This horizon is the one in which living organisms are most active and therefore is marked by the accumulation of humus. The horizon may have lost one or more of soluble salts, clay, and sesquioxides (iron and aluminum oxides).

B horizon.--The mineral horizon below an A horizon. The B horizon is in part a layer of change from the overlying A to the underlying C horizon. The B horizon also has distinctive characteristics caused (1) by accumulation of clay, sesquioxides, humus, or some combination of these; (2) by prismatic or blocky structure; (3) by redder or stronger colors than the A horizon; or (4) by some combination of these.

C horizon.--The relatively unweathered material immediately beneath the solum. Included are sediment, saprolite, organic matter, and bedrock excavatable with a spade. In most soils this material is presumed to be like that from which the overlying horizons were formed. If the material is known to be different from that in the solum, a number precedes the letter C.

R layer.--Consolidated rock not excavatable with a spade. It may contain a few cracks filled with roots or clay or oxides. The rock usually underlies a C horizon but may be immediately beneath an A or B horizon.

These lower-case letters may be appended:

-a Mostly decomposed organic matter; rubbed fiber content is than 17%.

-b Buried soil horizon. If more than one buried soil exists, this letter is followed by an Arabic number indicating the sequence.

-c Concretions or nodules cemented by iron, aluminum, manganese, or titanium.

-d Dense horizon physically restricting root penetration.

-e Intermediately decomposed organic matter; rubbed fiber content is between 17 and 40%.

-f Frozen horizon cemented by permanent ice.

-g Gleyed horizon in which iron has been removed during soil formation or saturation with stagnant water has preserved a reduced state. Strong gleying is indicated by chromas of one or less, and hues bluer than 10Y. Bg is used for a horizon with pedogenic features in addition to gleying, while Cg is not.

-h Humus. Illuvial accumulation of amorphous organic matter-sesquioxide complexes that either coat grains, form pellets, or form sufficient coatings and pore fillings to cement the horizon.

-i Least decomposed organic matter; rubbed fiber content is greater than 40%.

-j Used in combination with another horizon designation (e.g., Btj, Ej) to denote incipient development of that feature.

-k Carbonates. Illuvial accumulation of alkaline earth carbonates, mainly calcium carbonate; the properties do not meet those for the K horizon.

-l Unused as of 1992.

-m Cemented. Horizon that is more than 90% cemented. Denote cementing material (zm, soluble salts; ym, gypsum; km, carbonate; sm, iron; kqm, carbonate and silica)

-n Sodium. Accumulation of exchangeable sodium.

-o Oxides. Residual accumulation of sesquioxides.

-p Plowed or otherwise disturbed by *Homo sapiens* or domesticated animals.

-q Silica (secondary) accumulation.

-r Rock weathered in place. Saprolite.

-s Sesquioxides. Illuvial accumulation of sesquioxides with color value and chroma greater than three.

-ss Slickensides

-t Accumulation of silicate clay that has either formed in place or has been translocated from above. Only used with B horizons.

-u Unweathered.

-v Plinthite. Iron-rich, reddish material that hardens irreversibly when dried.

-w Development of color (redder hue or higher chroma relative to C) or structure with little or no apparent illuvial accumulation of material.

-x Fragipan. Subsurface horizon characterized by a bulk density greater than that of the overlying soil, hard to very hard consistence, brittleness, and seemingly cemented when dry.

-y Gypsum. Accumulation of gypsum.

-z Salts. Accumulation of salts more soluble than gypsum.

HUMUS. The well-decomposed, more or less stable part of the organic matter in mineral soils.

ILLUVIATION. The deposition by percolating water of solid particles, mostly clay or humus, within a soil horizon.

INTERFLUVE. The land lying between streams.

ISOCHRONOUS BOUNDARY. A gradational boundary between two sedimentary units indicating that they are approximately the same age. Opposed to a nonisochronous boundary, which by its abruptness indicates that it delineates units having significant age differences.

KROTOVINA. An animal burrow filled with soil.

LEACHING. The removal of soluble material from soil or other material by percolating water.

LOWSTAND. The lowest elevation reached by the ocean during a glacial period.

MANGAN. A thin coating of manganese oxide (cutan) on the surface of a sand grain, pebble, soil aggregate, or ped. Mangans also line pores or root channels and bridge sand grains.

MORPHOLOGY, SOIL. The physical make-up of the soil, including the texture, structure, porosity, consistence, color, and other physical, mineral, and biological properties of the various horizons, and the thickness and arrangement of those horizons in the soil profile.

MOTTLING, SOIL. Irregularly marked with spots of different colors that vary in number and size. Mottling in soils usually indicates poor aeration and lack of drainage. Descriptive terms are as follows: abundance--few, common, and many; size--fine, medium, and coarse; and contrast--faint, distinct and prominent. The size measurements are these: fine, less than 5 mm in diameter along the greatest dimension; medium, from 5 to 15 mm, and coarse, more than 15 mm.

MRT (MEAN RESIDENCE TIME.) The average age of the carbon atoms within a soil horizon. Under ideal reducing conditions, the humus in a soil will have a C-14 age that is half the true age of the soil. In oxic soils humus is typically destroyed as fast as it is produced, generally yielding MRT ages no older than 300-1000 years, regardless of the true age of the soil.

MUNSELL COLOR NOTATION. Scientific description of color determined by comparing soil to a Munsell Soil Color Chart (Available from Macbeth Division of Kollmorgen Corp., 2441 N. Calvert St., Baltimore, MD 21218). For example, dark yellowish brown is denoted as 10YR3/4m in which the 10YR refers to the hue or proportions of yellow and red, 3 refers to value or lightness (0 is black and 10 is white), 4 refers to chroma (0 is pure black and white and 20 is the pure color), and m refers to the moist condition rather than the dry (d) condition.

OVERBANK DEPOSIT. Fine-grained alluvial sediments deposited from floodwaters outside of the fluvial channel.

OXIC. A soil having a high redox potential. Such soils typically are well drained, seldom being waterlogged or lacking in oxygen. Rubification in such soils tends to increase with age.

PALEOSEISMOLOGY. The study of prehistoric earthquakes through the examination of soils, sediments, and rocks.

PALEOSOL. A soil that formed on a landscape in the past with distinctive morphological features resulting from a soil-forming environment that no longer exists at the site. The former pedogenic process was either altered because of external environmental change or interrupted by burial.

PALINSPASTIC RECONSTRUCTION. Diagrammatic reconstruction used to obtain a picture of what geologic and/or soil units looked like before their tectonic deformation.

PARENT MATERIAL. The great variety of unconsolidated organic and mineral material in which soil forms. Consolidated bedrock is not yet parent material by this concept.

PED. An individual natural soil aggregate, such as a granule, a prism, or a block.

PEDOCHRONOLOGY. The study of pedogenesis with regard to the determination of when soil formation began, how long it occurred, and when it stopped. Also known as soil dating. Two ages and the calculated duration are important:

t_o = age when soil formation or aggradation began, ka
t_b = age when the soil or stratum was buried, ka
t_d = duration of soil development or aggradation, ky

Pedochronological estimates are based on available information. All ages should be considered subject to $\pm$50% variation unless otherwise indicated.

PEDOCHRONOPALEOSEISMOLOGY. The study of prehistoric earthquakes by using pedochronology.

PEDOLOGY. The study of the process through which rocks, sediments, and their constituent minerals are transformed into soils and their constituent minerals at or near the surface of the earth.

PEDOGENESIS. The process through which rocks, sediments, and their constituent minerals are transformed into soils and their constituent minerals at or near the surface of the earth.

PERCOLATION. The downward movement of water through the soil.

pH VALUE. The negative log of the hydrogen ion concentration. Measurements in soils are usually performed on 1:1 suspensions containing one part by weight of soil and one part by weight of distilled water. A soil with a pH of 7.0 is precisely neutral in reaction because it is neither acid nor alkaline. An acid or "sour" soil is one that gives an acid reaction; an alkaline soil is one that gives an alkaline reaction. In words, the degrees of acidity or alkalinity are expressed as:

Extremely acid------- <4.5
Very strongly acid--- 4.5 to 5.0
Strongly acid-------- 5.1 to 5.5
Medium acid---------- 5.6 to 6.0
Slightly acid-------- 6.1 to 6.5
Neutral-------------- 6.6 to 7.3
Mildly alkaline------ 7.4 to 7.8
Moderately alkaline-- 7.9 to 8.4
Strongly alkaline---- 8.5 to 9.0
Very strongly alkaline >9.0

Used if significant:
Very slightly acid--- 6.6 to 6.9
Very mildly alkaline- 7.1 to 7.3

PHREATIC SURFACE. (See Water Table.)

PLANATION. The process of erosion whereby a portion of the surface of the Earth is reduced to a fundamentally even, flat, or level surface by a meandering stream, waves, currents, glaciers, or wind.

PLEISTOCENE. An epoch of geologic time extending from 10 ka to 1.8 Ma; it includes the last Ice Age.

PROFILE, SOIL. A vertical section of the soil through all its horizons and extending into the parent material.

QUATERNARY. A period of geologic time that includes the past 1.8 Ma. It consists of two epochs--the Pleistocene and Holocene.

PROGRADATION. The building outward toward the sea of a shoreline or coastline by nearshore deposition.

RELICT SOIL. A surface soil that was partly formed under climatic conditions significantly different from the present.

RUBIFICATION. The reddening of soils through the release and precipitation of iron as an oxide during weathering. Munsell hues and chromas of well-drained soils generally increase with soil age.

SALINE SOIL. A soil that contains soluble salts in amounts that impair the growth of crop plants but that does not contain excess exchangeable sodium.

SAND. Individual rock or mineral fragments in a soil that range in diameter from 0.05 to 2.0 mm. Most sand grains consist of quartz, but they may be of any mineral composition. The textural class name of any soil that contains 85 percent or more sand and not more than 10 percent clay.

SECONDARY FAULT. A minor fault that bifurcates from or is associated with a primary fault. Movement on a secondary fault never occurs independently of movement on the primary, seismogenic fault.

SHORELINE ANGLE. The line formed by the intersection of the wave-cut platform and the sea cliff. It approximates the position of sea level at the time the platform was formed.

SILT. Individual mineral particles in a soil that range in diameter from the upper limit of clay (0.002 mm) to the lower limit of very find sand (0.05 mm.) Soil of the silt textural class is 80 percent or more silt and less than 12 percent clay.

SLICKENSIDES. Polished and grooved surfaces produced by one mass sliding past another. In soils, slickensides may form along a fault plane; at the bases of slip surfaces on steep slopes; on faces of blocks, prisms, and columns; and in swelling clayey soils, where there is marked change in moisture content.

SLIP RATE. The rate at which the geologic materials on the two sides of a fault move past each other over geologic time. The slip rate is expressed in mm/yr, and the applicable duration is stated. Faults having slip rates less than 0.01 mm/yr are generally considered inactive, while faults with Holocene slip rates greater than 0.1 mm/yr generally display tectonic geomorphology.

SMECTITE. A fine, platy, aluminosilicate clay mineral that expands and contracts with the absorption and loss of water. It has a high cation-exchange capacity and is plastic and sticky when moist.

SOIL. A natural, three-dimensional body at the earth's surface that is capable of supporting plants and has properties resulting from the integrated effect of climate and living matter acting on earthy parent material, as conditioned by relief over periods of time.

SOIL SEISMOLOGIST. Soil scientist who studies the effects of earthquakes on soils.

SOIL TECTONICS. The study of the interactions between soil formation and tectonism.

SOIL TONGUE. That portion of a soil horizon extending into a lower horizon.

SOLUM. Combined A and B horizons. Also called the true soil. If a soil lacks a B horizon, the A horizon alone is the solum.

STONE LINE. A thin, buried, planar layer of stones, cobbles, or bedrock fragments. Stone lines of geological origin may have been deposited upon a former land surface. The fragments are more often pebbles or cobbles than stones. A stone line generally overlies material that was subject to weathering, soil formation, and erosion before deposition of the overlying material. Many stone lines seem to be buried erosion pavements, originally formed by running water on the land surface and concurrently covered by surficial sediment

STRATH TERRACE. A gently sloping terrace surface bearing little evidence of aggradation.

STRUCTURE, SOIL. The arrangement of primary soil particles into compound particles or aggregates that are separated from adjoining aggregates. The principal forms of soil structure are--platy (laminated), prismatic (vertical axis of aggregates longer than horizontal), columnar (prisms with rounded tops), blocky (angular or subangular), and granular. Structureless soils are either single grained (each grain by itself, as in dune sand) or massive (the particles adhering without any regular cleavage, as in many hardpans).

SUBSIDIARY FAULT. A branch fault that extends a substantial distance from the main fault zone.

TECTOTURBATION. Soil disturbance resulting from tectonic movement.

TEXTURE, SOIL. Particle size classification of a soil, generally given in terms of the USDA system which uses the term "loam" for a soil having equal properties of sand, silt, and clay. The basic textural classes, in order of their increasing proportions of fine particles are sand, loamy sand, sandy loam, loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sand clay, silty clay, and clay. The sand, loamy sand, and sandy loam classes may be further divided by specifying "coarse," "fine," or "very fine."

TOPOSEQUENCE. A sequence of kinds of soil in relation to position on a slope. (See also Catena.)

TRANSLOCATION. The physical movement of soil particles, particularly fine clay, from one soil horizon to another under the influence of gravity.

UNIFIED SOIL CLASSIFICATION SYSTEM. The particle size classification system used by the U.S. Army Corps of Engineers and the Bureau of Reclamation. Like the ASTM and AASHO systems, the sand/silt boundary is at 80 um instead of 50 um used by the USDA and

FAA. Unlike all other systems the gravel/sand boundary is at 4 mm instead of 2 mm and the silt/clay boundary is determined by using Atterberg limits.

VERTISOL. A soil with at least 30% clay, usually smectite, that fosters pronounced changes in volume with change in moisture. Cracks greater than 1 cm wide appear at a depth of 50 cm during the dry season each year. One of the ten USDA soil orders.

WATER TABLE. The upper limit of the soil or underlying rock material that is wholly saturated with water. Also called the phreatic surface.

WAVE-CUT PLATFORM. The relatively smooth, slightly seaward-dipping surface formed along the coast by the action of waves generally accompanied by abrasive materials.

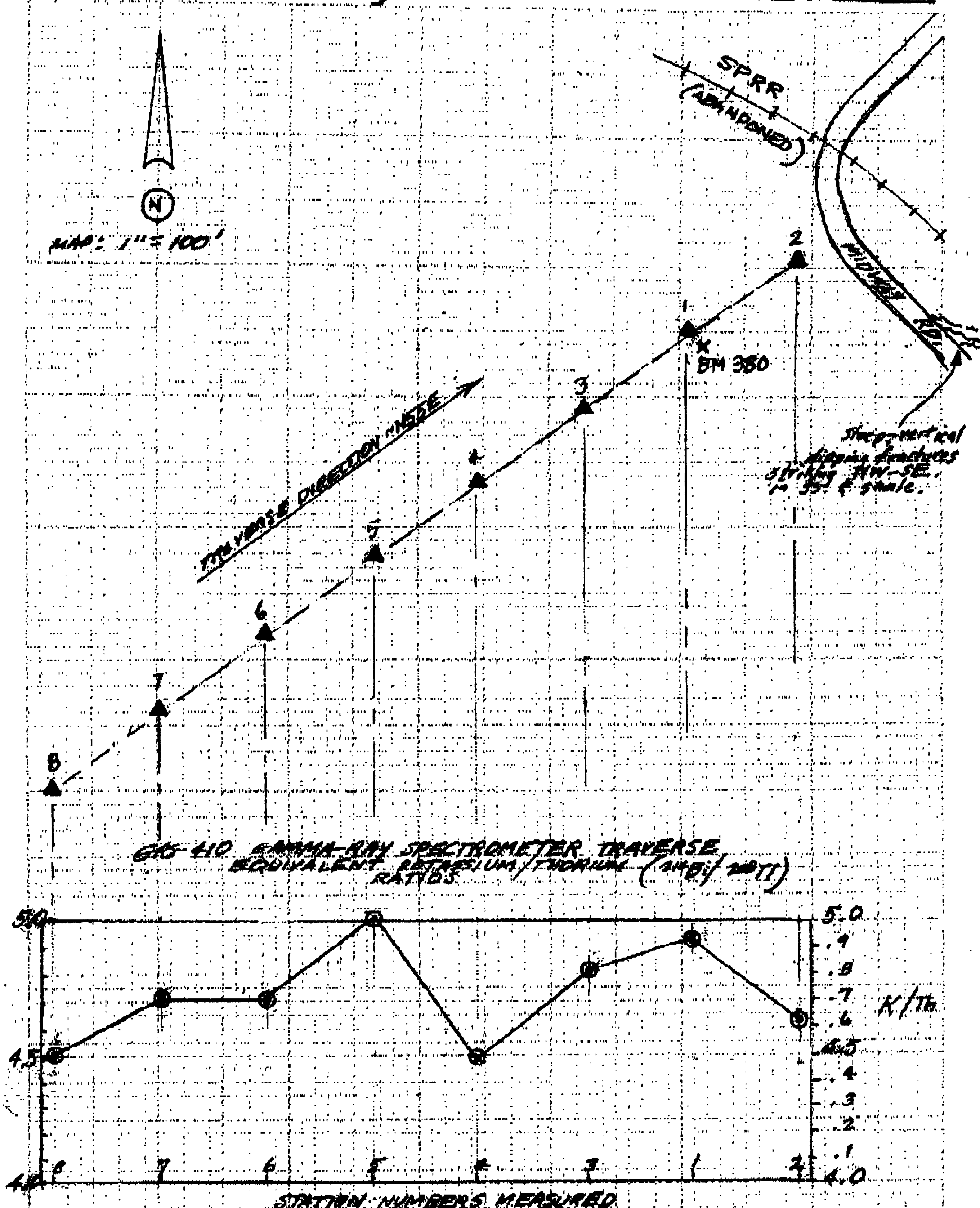
WEATHERING. All physical and chemical changes produced in rocks or other deposits at or near the earth's surface by atmospheric agents. These changes result in disintegration and decomposition of the material.

yr B.P. Uncorrected radiocarbon age expressed in years before present, calculated from 1950. Calendar-corrected ages are expressed in ka, or, if warranted, as A.D. or B.C.

APPENDIX C

PROJECT NAME Tesla Power Plant
Fault Investigation

PROJECT NO
BY G. Copeland DATE 5/23/01
SHEET 2 OF 2



GEOCON INCORPORATED

BY ____ DATE ____
BY ____ DATE ____
BY ____ DATE ____
CHECKED BY ____ DATE ____

GRS-410 Gamma Ray Spectrometer Field Sheet

TESLA POWER PLANT, George C. Copenhaver

Date: 5/31/01

Time: 1550

Station No. & location: 1 approx. 25' NW of BM 280

Counting Period: 4 min

Reading:	Total Count	Potassium	Uranium	Thorium
ground in vehicle	18600	1037	289	210

Backgrd. (Absolute bkg. is obtained over

ground:

in vehicle:

Corrected: K/Th ratio ; 4.94

Calculations:

Th(ppm)= (C - Cbg) / Th(sens)

U(ppm)= [(Cu - Cubg] - a(Cth - Cthbg)]

K(%)= [(Ck - Ckbg) - b(Cu - Cubg) - g(Cth - Cthbg)] / K(sens)

Stripping Constants:

Alpha(a) = 0.62
Beta(b) = 0.68
Gamma (g) = 0.83

Sensitivity Constants:

Thorium = 7.5 cpm/ppm
Uranium = 20.5 cpm/ppm
Potassium = 154 cpm/ %

Content: K(%) : U(ppm) Th(ppm)

Geology: Colluvium over Neroly Fm. ss. + shales

GRS-410 Gamma Ray Spectrometer Field Sheet

George C. Copenhaver

Date: 5/21/01
Time: 1555
Station No. & location: 2 N.E. end of line, approx. 30' w. of Midway Rd.

Counting Period: 4

Reading:	Total Count	Potassium	Uranium	Thorium
ground				
in vehicle	17630	960	242	205

Backgrd.
ground:
in vehicle:

Corrected: K/Th ratio: 4.63

Calculations:

Th(ppm)= (C - Cbg) / Th(sens)

U(ppm)= [(Cu - Cubg] - a(Cth - Cthbg)]

K(%)= [(Ck - Ckbg) - b(Cu - Cubg) - g(Cth - Cthbg)] / K(sens)

Stripping Constants:

Alpha(a) = 0.62
Beta(b) = 0.68
Gamma (g) = 0.83

Sensitivity Constants:

Thorium = 7.5 cpm/ppm
Uranium = 20.5 cpm/ppm
Potassium = 154 cpm/ %

Content: K(%) : U(ppm) Th(ppm)

Geology: Colluvium over Neroly Fm. ss. + shales

GRS-410 Gamma Ray Spectrometer Field Sheet

George C. Copenhaver

Date: 5/21/01
Time:..........
Station No. & location: 4 ~100' sw of Sta. 3

Counting Period:............

Reading:	Total Count	Potassium	Uranium	Thorium
ground				
in vehicle	17180	911	281	203

Backgrd.
ground:
in vehicle:

Corrected: K/Th ratio: 4.49

Calculations:

Th(ppm)= (C - Cbg) / Th(sens)

U(ppm)= [(Cu - Cubg] - a(Cth - Cthbg)]

K(%)= [(Ck - Ckbg) - b(Cu - Cubg) - g(Cth - Cthbg)] / K(sens)

Stripping Constants:

Alpha(a) = 0.62
Beta(b) = 0.68
Gamma (g) = 0.83

Sensitivity Constants:

Thorium = 7.5 cpm/ppm
Uranium = 20.5 cpm/ppm
Potassium = 154 cpm/ %

Content: K(%) : U(ppm) Th(ppm)

Geology:

GRS-410 Gamma Ray Spectrometer Field Sheet

George C. Copenhaver

Date: 5/21/01
Time: 1600 hrs.
Station No. & location: 3 ~100' W. of Sta. 1

Counting Period: 4 min.

Reading:	Total Count	Potassium	Uranium	Thorium
ground				
in vehicle	18090	101.7	268	211

Backgrd.
ground:
in vehicle:

Corrected: K/Th ratio: 4.82

Calculations:

Th(ppm)= (C - Cbg) / Th(sens)

U(ppm)= [(Cu - Cubg] - a(Cth - Cthbg)]

K(%)= [(Ck - Ckbg) - b(Cu - Cubg) - g(Cth - Cthbg)] / K(sens)

Stripping Constants:

Alpha(a) = 0.62
Beta(b) = 0.68
Gamma (g) = 0.83

Sensitivity Constants:

Thorium = 7.5 cpm/ppm
Uranium = 20.5 cpm/ppm
Potassium = 154 cpm/ %

Content: K(%) : U(ppm) Th(ppm)

Geology:

GRS-410 Gamma Ray Spectrometer Field Sheet

George C. Copenhaver

Date: 5/21/01
Time:
Station No. & location: 5 ~100' SW of Sta. 4

Counting Period: 4

Reading:	Total Count	Potassium	Uranium	Thorium
ground				
in vehicle	16810	915	245	182

Backgrd.
ground:
in vehicle:

Corrected: K/Th ratio: 5.03

Calculations:

Th(ppm)= (C - Cbg) / Th(sens)

U(ppm)= [(Cu - Cubg] - a(Cth - Cthbg)]

K(%)= [(Ck - Ckbg) - b(Cu - Cubg) - g(Cth - Cthbg)] / K(sens)

Stripping Constants:

Alpha(a) = 0.62
Beta(b) = 0.68
Gamma (g) = 0.83

Sensitivity Constants:

Thorium = 7.5 cpm/ppm
Uranium = 20.5 cpm/ppm
Potassium = 154 cpm/ %

Content: K(%) : U(ppm) Th(ppm)

Geology:

GRS-410 Gamma Ray Spectrometer Field Sheet

George C. Copenhaver

Date: 5/21/01
Time: 15:20 hrs.
Station No. & location: 6 ~100' SW of Sta. 5

Counting Period: 4 min.

Reading:	Total Count	Potassium	Uranium	Thorium
ground				
in vehicle	17040	905	243	192

Backgrd.
ground:
in vehicle:
Corrected: K/Th ratio: 4.71

Calculations:

Th(ppm)= (C - Cbg) / Th(sens)

U(ppm)= [(Cu - Cubg] - a(Cth - Cthbg)]

K(%)= [(Ck - Ckbg) - b(Cu - Cubg) - g(Cth - Cthbg)] / K(sens)

Stripping Constants:

Alpha(a) = 0.62
Beta(b) = 0.68
Gamma (g) = 0.83

Sensitivity Constants:

Thorium = 7.5 cpm/ppm
Uranium = 20.5 cpm/ppm
Potassium = 154 cpm/ %

Content: K(%) : U(ppm) Th(ppm)

Geology:

GRS-410 Gamma Ray Spectrometer Field Sheet

George C. Copenhaver

Date: 5/21/01
Time: 1625
Station No. & location: 7 ~100' SW of Sta. 6
Counting Period: 4 min.

Reading:	Total Count	Potassium	Uranium	Thorium
ground				
in vehicle	17110	880	244	205

Backgrd.
ground:
in vehicle:

Corrected: K/Th ratio: 4.71

Calculations:

Th(ppm)= (C - Cbg) / Th(sens)

U(ppm)= [(Cu - Cubg] - a(Cth - Cthbg)]

K(%)= [(Ck - Ckbg) - b(Cu - Cubg) - g(Cth - Cthbg)] / K(sens)

Stripping Constants:

Alpha(a) = 0.62
Beta(b) = 0.68
Gamma (g) = 0.83

Sensitivity Constants:

Thorium = 7.5 cpm/ppm
Uranium = 20.5 cpm/ppm
Potassium = 154 cpm/ %

Content: K(%) : U(ppm) Th(ppm)

Geology:

GRS-410 Gamma Ray Spectrometer Field Sheet

George C. Copenhaver

Date: 5/21/01
Time: 1:35
Station No. & location: 8 approx. 100' SW of Sta. 7

Counting Period: 4 min.

Reading:	Total Count	Potassium	Uranium	Thorium
ground				
in vehicle	16440	892	219	196

Backgrd.
ground:
in vehicle:

Corrected: K/Th Ratio: 4.50

Calculations:

Th(ppm)= (C - Cbg) / Th(sens)

U(ppm)= [(Cu - Cubg] - a(Cth - Cthbg)]

K(%)= [(Ck - Ckbg) - b(Cu - Cubg) - g(Cth - Cthbg)] / K(sens)

Stripping Constants:
Alpha(a) = 0.62
Beta(b) = 0.68
Gamma (g) = 0.83

Sensitivity Constants:
Thorium = 7.5 cpm/ppm
Uranium = 20.5 cpm/ppm
Potassium = 154 cpm/ %

Content: K(%) : U(ppm) Th(ppm)

Geology:

GRS-410 Gamma Ray Spectrometer Field Sheet

George C. Copenhaver

Date: 5/21/01
Time:.........
Station No. & location: ...9........ WPRR Cut in "Tesla West" property block

Counting Period:............

Reading:	Total Count	Potassium	Uranium	Thorium
ground				
in vehicle				
+3' (in harness)	19660	1131	467	185

Backgrd.
ground:.......
in vehicle:.......

Corrected: .... K/Th ratio: 6.14 ....
(U/Th is 2.52, compared to as low as 1.12 in "Tesla North" block traverse)

Calculations:

Th(ppm)= (C - Cbg) / Th(sens)

U(ppm)= [(Cu - Cubg] - a(Cth - Cthbg)]

K(%)= [(Ck - Ckbg) - b(Cu - Cubg) - g(Cth - Cthbg)] / K(sens)

Stripping Constants:

Alpha(a) = 0.62
Beta(b) = 0.68
Gamma (g) = 0.83

Sensitivity Constants:

Thorium = 7.5 cpm/ppm
Uranium = 20.5 cpm/ppm
Potassium = 154 cpm/ %

Content: K(%) : U(ppm) Th(ppm)

Geology: San Pablo Group (Neroly Fm.); Exposed fault gouge + parallel secondary shears, displacing N-S striking, 5-10°E interbedded calc. shales and sandstones. In a 20-30' cut.