98-08

Earth Consultants International

FAULT TRENCHING INVESTIGATION, NEWPORT-BANNING PROPERTY, ORANGE COUNTY, CALIFORNIA

November 25, 1997
Project No. 978100-019

Prepared for:

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Earth Consultants International

December 18, 1997

To: **Leighton and Associates, Inc.**
17781 Cowan, Suite 200
Irvine, California 92614

Attention: **Ms. Rosalind Munro**

Subject: Final Report, Fault Trenching Investigation, Newport-Banning Property, Cities of Newport Beach and Costa Mesa and Unincorporated Orange County, California
(Leighton and Associates Project No. 1970011-001)

We are pleased to present the attached report, dated November 25, 1997, which summarizes the results of a fault trenching and field mapping study we conducted at the Newport-Banning Property in Orange County, California. The primary objective of this study was to assess whether splays of the Newport-Inglewood fault system extend across the site, with emphasis on three areas: 1) the eastern portion of the site, south of the West 17th Street entrance, 2) the prominent point on the west side of the mesa, and 3) the proposed school location at the base of the bluffs, in the central portion of the site.

The results of our study indicate that in the eastern portion of the site, south of the filtration plant, the site is underlain by a fault that appears to have moved once during the Holocene. According to State of California Alquist-Priolo Act guidelines, this fault is active. The lateral extent and continuity of this fault have not been determined, so if this area is to be developed, additional studies need to be conducted to locate the fault across this portion of the site.

In the areas trenched or mapped in the western portion of the mesa, and in the area where the school is proposed, there are no active faults. Several faults were mapped in this area, but none extended upwards into and through soils that are significantly more than 11,000 years old — the Alquist-Priolo Act-defined threshold for active faults for residential developments.

There are various sections of the site where the absence of faulting has not been conclusively shown by trench excavations, despite the extensive trenching, either by us, or by EarthTech (1986). At your request, we have prepared and submitted to you, under separate cover, a work plan schedule outlining the geological work that would be necessary to evaluate whether active faults underlie these areas. We have no data suggestive of active faults through these untrenched areas, but it cannot be totally precluded.

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Thank you for the opportunity to work with you on this project. If you have any questions regarding our report, please do not hesitate to contact the undersigned at your convenience.

Respectfully submitted,

EARTH CONSULTANTS INTERNATIONAL, INC.

Tania Gonzalez, CEG 1859
Project Consultant

Eldon Gath, CEG 1292
Principal Consultant

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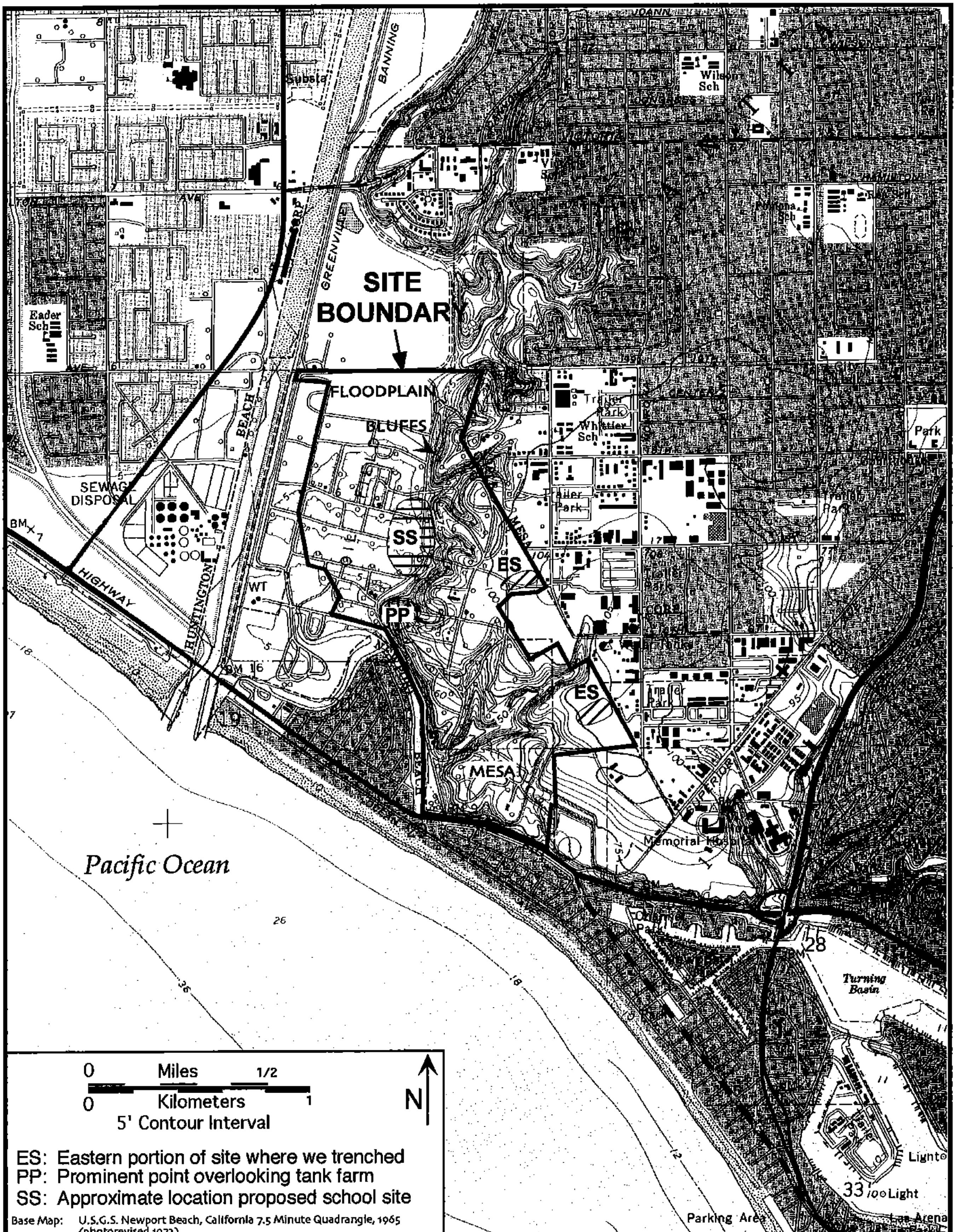
1.0 INTRODUCTION

This report presents the results of a fault trenching and field mapping study conducted by Earth Consultants International (ECI), under contract to Leighton and Associates, Inc. (Leighton), at the Newport-Banning property in and northwest of the city of Newport Beach, California (Figure 1). The study was designed to evaluate the potential for active faults to underlie portions of the site, in accordance with the guidelines established by the California Division of Mines and Geology (1996) for evaluating the hazard of surface fault rupture. The study was designed to complement the fault data previously obtained by Woodward-Clyde Consultants (1985), The Earth Technology Corporation (EarthTech, 1986), and Converse Consultants (Converse, 1994) at or immediately adjacent to the site.

Although the site is not located within a State-defined Alquist-Priolo Earthquake Fault Study Zone, several splays of the active Newport-Inglewood fault zone have been mapped across the site and in the site vicinity. Faults that break the ground surface during an earthquake can do considerable damage to structures built across them. Therefore, fault studies are typically designed to evaluate whether a fault is active — that is, whether it has moved in the last about 11,000 years (the State-established threshold for an active fault when planning schools and residential subdivisions). If a fault is deemed active, school structures cannot be placed within 50 feet of the trace of the fault (Section 39002 of the California Education Code; Title 24, California Code of Regulations). Other structures for human occupancy cannot be placed over the trace of the fault and must be set back from the fault and associated ground fractures, but the setback distance can be less than 50 feet (Alquist-Priolo Act, 1972 as described in Hart, 1994). Since structural setbacks from a fault have a significant impact on the design, fault studies are critical in the early planning stages of a development.

The purpose and scope of work conducted for this study evolved and expanded over the course of the project. The consulting services we conducted were described in our proposals dated May 28, July 23, and August 22, 1997.

The trench locations, geologic contacts and other geologic data obtained during this study are shown on the topographic base map, at a scale of 1"=200', provided to us in digital format by Fuscoe Engineering (Plate 1).



Earth Consultants International	Date: 11/25/97 Project: 978100-019	**Site Location Map Newport/Banning Property**	**Figure 1**

1.1 Purpose of the Study

The purpose of this study was to evaluate the hazard of surface fault rupture at specific locations in the Newport-Banning property.

Specifically, we were to:

1) assess whether the West Mesa fault extends into and across the southeastern portion of the site;

2) evaluate, if possible, the recency of activity of a set of faults mapped in the west-central portion of the site, in the area of the prominent point that overlooks the tank farm;

3) obtain soils and structural data for the site, with emphasis on those areas of the bluff that appear to have been cleared of vegetation since EarthTech mapped the site in 1986; and

4) determine whether splays of the Newport-Inglewood fault system extend across the proposed school site at the base of the bluffs. Since no school structures can be located within 50 feet of an active fault, this study needed to be conducted prior to finalizing the selection of the school site. A preliminary report addressing the issue of faulting in the area of the proposed school site was issued under separate cover on September 3, 1997. The data presented in our preliminary report has been incorporated into this report.

1.2 Scope of Work

The following tasks were completed for this study:

1) Reviewed available published and unpublished geologic reports and maps of the site and vicinity, with emphasis on the Newport-Inglewood fault zone (the references are listed in Appendix A).

2) Reviewed historic aerial photographs and topographic maps for landforms indicative of active faulting (the photos reviewed are listed in Appendix A).

3) Excavated, shored, cleaned, logged, photographed and backfilled a trench south of the West 17th Street entrance (T-1), to assess whether the West Mesa fault extends with a northwesterly trend through the eastern portion of the site.

4) Excavated, shored, cleaned, logged, photographed and backfilled a trench (T-2) on the mesa where Converse (1994) previously excavated two trenches, to assess whether the West Mesa fault extends with a south to southeasterly trend through the southeastern portion of the site.

5) Excavated, shored, cleaned, logged, photographed and backfilled a series of trenches (T-3 series) on the bluff overseeing the tank farm, to evaluate, if possible, the recency of activity of the faults previously mapped by EarthTech (1986) in this area.

6) Field mapped the bluffs and road-cuts around the mesa, concentrating on those portions of the bluff that had been cleared of vegetation since EarthTech conducted their 1986 study. Ultimately, we field reviewed over 9,200 lineal feet of bluff; approximately 4,400 feet were mapped in detail.

7) Excavated, shored, cleaned, logged, photographed and backfilled a series of trenches (T-4 through T-14 series), to obtain geologic data necessary to assess whether faults extend across the proposed school location at the base of the bluffs, in the central portion of the site.

8) Analyzed soil samples collected from one of the trenches for particle size distribution and bulk density.

9) Analyzed the data obtained from the field phase of the study.

10) Prepared a preliminary letter report (dated September 3, 1997), and this final report summarizing our findings, conclusions and recommendations. This final report includes the geologic map of the site (Plate 1) showing the trench locations, and the drafted trench logs (Plates 2 through 13).

1.3 Site Location and Description

The Newport-Banning property is located immediately north of Pacific Coast Highway, between Superior Avenue to the east, and the Santa Ana River to the west (Figure 1). The site's northern boundary is defined by the westward projection of West 19th Street. The property can be divided into two areas, a lowland area in the floodplain of the Santa Ana River, and an elevated area on West Newport Mesa. Elevations in the lowland area range from about 2 feet above mean sea level along its southwestern corner to 9 feet above mean sea level near the northwestern corner of the site. Elevations in the mesa area range from approximately 50 feet near the southeastern corner of the site, to 105 feet along the northeastern corner. Surface drainage is to the west and south. The lowland and mesa surfaces are separated by a bluff face that generally provides good exposures of the sediments comprising the mesa.

The mesa portion of the site can be divided into two distinct terrace surfaces based on topography and elevation. The terrace surfaces are separated by a low (20-foot high) rise that can be observed locally in the southern portion of the mesa. The lower surface (Qtm_1 in the geologic map) lies between 50 and 70 feet elevation, with a rise of 8 to 10 feet per 1,000 feet lateral distance. The higher surface (Qtm_2) ranges from 90 to 105 feet in elevation within the site. The Qtm_2 surface slopes more steeply, with a rise of between 16 to 20 feet per 1,000 feet lateral. In some areas, the terrace surfaces have been incised by drainages, forming relatively deep canyons. The canyon walls are steep where they cut resistant materials and have lower grades in the more friable deposits. The drainages feed into the Santa Ana River floodplain or south into man-made culverts along Pacific Coast Highway. In many locations along the mesa margins, where the incised drainages are no longer confined, small alluvial fans have formed as sediments are deposited at the mouth of these canyons.

Review of aerial photographs of the site and vicinity show that the natural topography has been modified extensively, both by natural processes, and by man (Figure 2). The bluffs on the western and northwestern portions of the site, adjacent to the Santa Ana River, appear to have been cut back (reducing the mesa's surface), by as much as 100 feet locally between 1927 and 1980 — the time period covered by the stereoscopic aerial photographs reviewed. A good portion of this erosion appears to have occurred between 1938 and 1939 as a result of extensive flooding in the area. During the first week of March, 1938, Orange County received more than 8 inches of rainfall. Breached levees along the Santa Ana River inundated the majority of the floodplain in the vicinity of the site (Troxell et al., 1942). Photographs taken after this flood show a large blanket of sediments deposited in the western portion of the site. It also appears that the bluff face was quarried for sand and gravel used to construct flood control berms and levees. Between 1931 and 1938, a channel south of the site, across Pacific Coast Highway, was artificially infilled. The soils used to fill the channel may have been quarried, in part, from the bluff faces to the north, within the site.

The top of the mesa was used for agriculture in the late 1920s and 1930s, and since 1943, the property has been in use as a producing oil field (Banning area of the West Newport Oil Field). As a result of farming and oil-production activities, such as grading of well pads, abandonment of wells, and excavations of sumps, the topsoil has been removed or eroded off in many areas on top of the mesa. Therefore at many locations, there are no soils left that can be used to evaluate the age of faulting. It is also plausible that small-scale landforms that could have provided evidence as to the location and activity of the faults across the mesa have been destroyed. Quarrying of soil materials generally has been restricted to areas along the base of bluffs. However, in the 1960s, a deep road cut was excavated along the eastern side of the site, reportedly for a possible extension of Balboa Boulevard. This road cut provides several good exposures of the near-surface sediments in this portion of the site. On the other hand, a section of bluff face in the southwestern portion of the mesa was covered with gunite, possibly in an attempt to control erosion at this location.

The site is presently occupied by several active oil wells, and associated pipelines, tanks, roads, and other structures. It is our understanding that the oil field operator is in the process of abandoning many of the oil wells in the field. Therefore, several abandoned oil wells are also present, marked by 4 to 5-foot lengths of orange PVC piping. Sections of abandoned well casing are stacked at various locations onsite. Uncontrolled fills occur locally throughout the mesa, especially along roads, drilling pad excavations, and where sumps and oil well cellars have been excavated as part of the oil wells abandonment process. The fills encountered in our trenches were generally no more than 5 feet thick, but thicker fills may occur in areas where we did not trench.

Vegetation at the site, on the mesa, consists primarily of grasses, coastal sage scrub community, cacti (prickly pear), and wild berries. The only major stands of trees onsite occur in the lowlands.

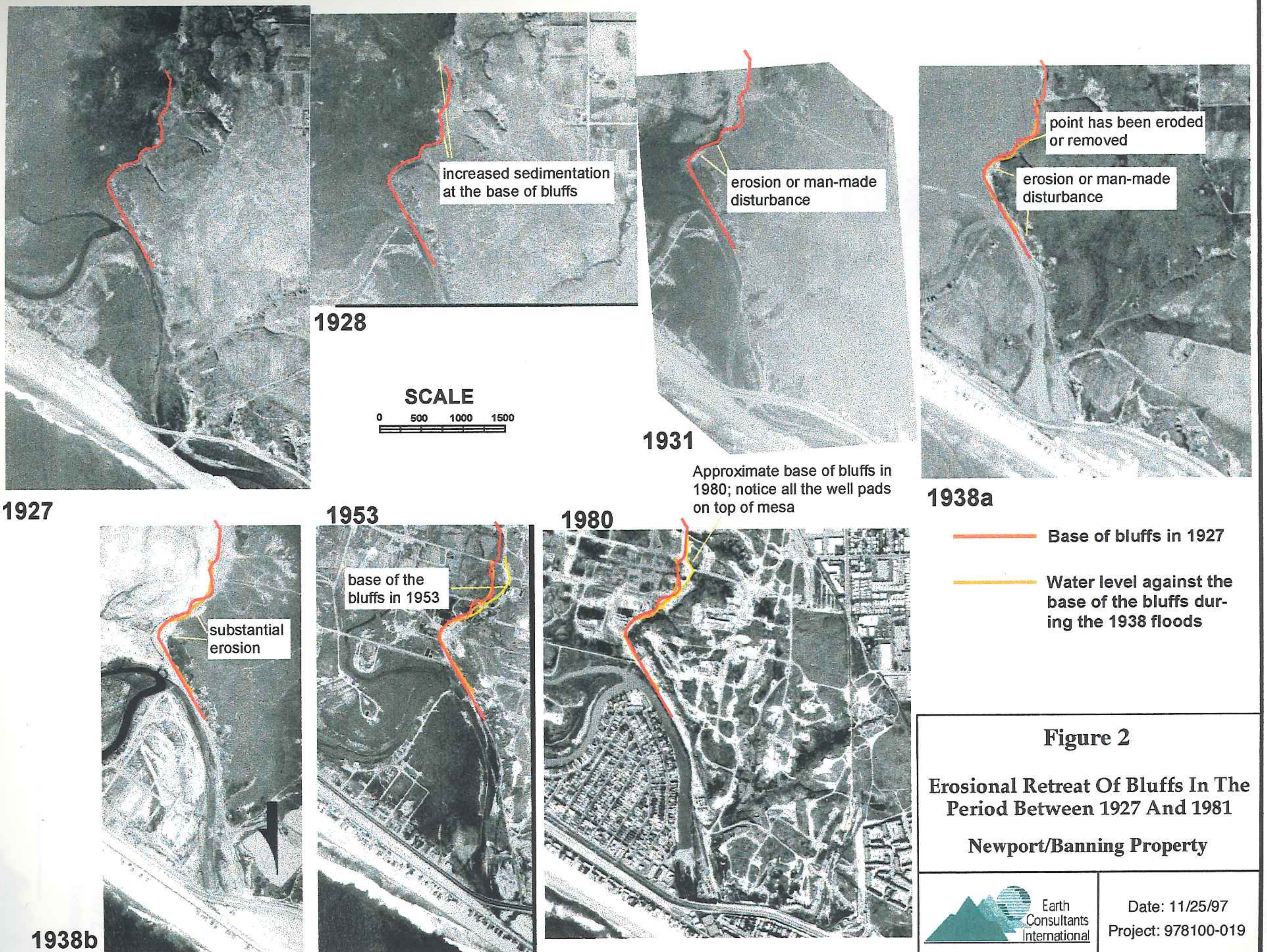


Figure 2

Erosional Retreat Of Bluffs In The Period Between 1927 And 1981

Newport/Banning Property

Earth Consultants International

Date: 11/25/97
Project: 978100-019

2.0 BACKGROUND ANALYSIS

2.1 Regional Geologic Setting

The site is located in the southwesternmost portion of the Los Angeles Basin, in the Peninsular Ranges physiographic and tectonic province. This province is characterized by a prevailing northwesterly orientation of structural geologic features, such as the Whittier, Newport-Inglewood and Palos Verdes faults. The Los Angeles Basin itself is a northwest-trending lowland plain approximately 50 miles long and 20 miles wide. The Basin is bounded by the Santa Monica Mountains to the northwest; the low-lying Elysian and Repetto Hills to the north; the Puente Hills, Peralta Hills, and San Joaquin Hills to the east and southeast; and the Pacific Ocean to the southwest. The lowland surface of the Los Angeles Basin slopes gently southward and westward to the Pacific Ocean. This sloping plain is interrupted by the Newport-Inglewood structural zone, which extends from Newport Mesa, where the site is located, northwesterly to Beverly Hills. This line of low discontinuous hills and ridges are the surface expression of the Newport-Inglewood Fault Zone (NIFZ).

The Los Angeles Basin began to form about 7 million years ago, in late Miocene time, as the San Andreas fault shifted eastward to its present position. For the next 5 million years, the basin subsided along major faults that displayed a normal sense of displacement, including the NIFZ (Wright, 1991), and was rapidly filled with sediments eroded from highlands to the north, northeast and east. Between 5 and 2 million years ago, the NIFZ began its present right-lateral movement. In the Pleistocene epoch (the last 2 million years) the region was warped gently upward forming the present shoreline and topography (Yerkes et al., 1965; Wright, 1991).

2.2 Newport-Inglewood Fault Zone (NIFZ)

The NIFZ is one of several northwest-trending right-lateral strike-slip fault zones that form the boundary between the North American and Pacific Plates. The NIFZ consists of a series of en-echelon fault segments that extend from Santa Monica south to Newport Beach and offshore, where it lines up with a deep submarine canyon. To the southeast, the offshore segment of the NIFZ joins the Rose Canyon fault, which extends southeasterly to San Diego and the international border.

Folding and faulting of the sedimentary rocks underneath the hills along the NIFZ formed traps for petroleum. Since the beginning of this century, most of these hills have been drilled for oil, making the Los Angeles Basin one of the most oil-productive regions in the world. The oil reserves along the NIFZ are estimated to yield nearly 3.2 billion barrels of oil over the lifetime of the oil fields.

The slip rate of the NIFZ has not been well constrained. Woodward-Clyde Consultants (1979) calculated a slip rate of 0.5 mm/yr for the southern onshore segment of the NIFZ. Fischer and Mills (1991) estimated that the offshore segment of the NIFZ between San Mateo Point and Newport Beach (the segment immediately south of the site) moves at a rate of between 1.3 and 3.5 mm/yr, with surface rupturing earthquakes occurring every 200 to 800 years. More recent studies suggest that the minimum slip rate on the onshore segment of the NIFZ is 0.34 to 0.55 mm/yr (Grant et al., 1997). However, if the NIFZ is structurally related to the Rose Canyon fault, then the NIFZ may have a maximum slip rate of nearly 2 mm/yr (Lindvall and Rockwell, 1995). Grant et al.'s (1997), and Shlemon et al.'s (1995) studies have shown that the onshore segment of the NIFZ has had three, and possibly five, ground rupturing earthquakes in the last 11,700 (± 700) years. The last significant earthquake on this fault was the M 6.3 1933 Long Beach earthquake, which is not known to have ruptured the surface.

2.3 Local Faulting

Because of intensive oil exploration at the site, much is known about the upper 1/2-mile of crust in the area. Oil is produced primarily from three zones (referred to as zones A, B and C) in the Puente Formation of Miocene age. Corwin (1947) used oil well data to produce cross-sections and structural contour maps of the West Newport oil field area that defined the major faults at the top of the "B zone," an oil-producing sand 900 to 2,200 feet below the ground surface. More recently, the West Newport Oil Company prepared a map showing the faults interpreted at the top of the "A zone," approximately 300 to 1,650 feet below the ground surface. Both maps show that the Banning area of the West Newport oil field is a north- to northwest-plunging block that has been uplifted and rotated along a series of northwest-trending faults. The southernmost of these, which Corwin (1947) calls the Inglewood fault, is a significant trap to oil, as indicated by the fact that most wells in the area produce from bedrock on the northwest side of the fault. The eastern boundary to the oil-producing block is a north- to northeast- trending fault Corwin refers to as the Banning fault, that terminates on the south against the Newport-Inglewood fault.

The first studies to identify faults at or near the surface in the site area were reportedly conducted jointly by Woodward-Clyde Consultants and the West Newport Oil Company in 1981 and 1985. The report describing the 1981 study was not available for our review, although some of the results were published in the magazine *California Geology* (Guptill and Heath, 1981). The 1985 study was summarized by EarthTech (1986). According to EarthTech (1986), several faults were identified by Woodward-Clyde and the West Newport Oil Company, who excavated more than 2,500 lineal feet of trenches on the mesa. However, the 1981 and 1985 studies did not resolve the length and width of the fault zones, nor the latest age of movement on the faults identified. To answer some of these questions, EarthTech trenched and cleared 21 additional exposures in 1986. Also as part of their 1986 study, EarthTech projected from the subsurface upward to near the ground surface the two most significant faults interpreted by the West Newport Oil Company from oil well data. These two splays, referred to as the North Branch (Corwin's Inglewood fault) and North Branch Splay faults were inferred to trend northwesterly through the site (Figure 3). EarthTech concluded that the faults investigated were not active under Alquist-Priolo criteria.

More recently, Converse Consultants (1994), while conducting a geologic study and grading for a filtration water plant immediately east of the site, exposed a fault that was interpreted to have moved within the last approximately 11,000 years. At that time, the school site planned as part of the development of the Newport-Banning property was proposed to be located next to the filtration plant. T[redacted]ve fau[redacted] the[redacted]. The site at the base of the bluffs, north of the inferred trace of the North Branch Splay fault, was then selected.

Other more regional studies of the Newport-Inglewood fault system have been conducted in the last few years. In 1995, Shlemon et al. studied four splays of the North Branch fault at the water filtration plant immediately west-northwest of the Newport Mesa, across the Santa Ana River (Shlemon et al., 1995). Their data suggests that five surface rupturing events have occurred during the Holocene on this fault zone, trending southeasterly towards the West Newport Oil Field. In 1997, Grant et al. published a study of the North Branch fault in Huntington Beach and concluded that this fault has generated three, and possibly five, surface-rupturing earthquakes in approximately the last 11,700 years (Grant et al., 1997). Given these recent paleoseismic studies of the Newport-Inglewood fault, it seemed prudent to conduct a detailed study of the proposed school site and portions of the mesa to assess whether near-surface faults capable of breaking the ground surface during an earthquake underlie these specific areas.

3.0 METHODOLOGY

3.1 Aerial Photo Analysis

In addition to reviewing existing reports, several vintage aerial photographs from 1927, 1928, 1931, 1938, 1953 and 1980 were reviewed to look for landforms that would be indicative of faulting. The canyons and gullies draining the top of the bluffs were reviewed carefully to evaluate whether they might be controlled by faulting. Canyons and gullies roughly perpendicular to the average orientation of the fault zone (trending approximately 30 to 40 degrees to the northwest) were reviewed to determine whether they have been offset or deflected in such a manner that it would suggest the presence of a strike-slip fault. Other features that we looked for in the photographs included vegetation lineaments (alignments of similar types of plants, or enhanced plant growth along a discrete zone suggestive of a fault line); strong tonal contrast lineations (color or textural contrasts that could be indicative of different types of bedrock or soil materials across a fault); and linear troughs (depressions) or scarps that could be aligned parallel to, or adjacent to a fault trace. Breaks in slope at the margin between terrace levels of different age were also mapped from the photographs.

The aerial photographs were also reviewed to determine the locations along the bluff face where significant erosion occurred between 1927 and 1980. Where slope retreat has clearly occurred, we tried to estimate the amount (Figure 2). The aerial photographs also helped us interpret the historical land use at the site and in the vicinity.

3.2 Field Mapping

As discussed previously, the mesa portion of the site rises abruptly 50 to 100 feet above the floodplain of the Santa Ana River. Where not covered by vegetation, gunite, or slope-wash debris, the bluffs expose the sediments comprising the mesa. Some of the larger drainages have cut fairly deep canyons in the mesa, also exposing the sediments. Therefore, by mapping the bluffs and canyons, we could obtain valuable data from which we can interpret the stratigraphy and structure of the area. Ideally, this technique is fairly non-invasive and very cost-effective, since there is no need for trenching. Unfortunately, large areas of the bluffs are covered with vegetation and slope-wash debris, so our field mapping efforts were limited.

3.3 Trenching and Other Excavations

In the flat-lying areas in the central and eastern portion of the site, where there are no canyons or bluffs that can be mapped, trenching was necessary to evaluate the potential for faulting. Trenching was also necessary adjacent to those sections of the bluffs that were covered by vegetation, colluvium, or gunite.

Trenching within the school site proper would not have provided us with the data necessary to confidently evaluate the potential for surface faulting in the area. Most of the proposed school site is underlain by recently deposited (less than 11,000 years old) stream sediments of the Santa Ana River. Furthermore, ground water reportedly occurs within 6 feet of the ground surface, which would have made trenching very dangerous, if not impossible. To assess whether faults underlie the school area, we tried to map or trench near the base of the bluffs. However, trenching at these locations was severely limited by the extensive stands of coastal sage on the bluff slopes, and the extensive network of pipelines and utilities associated with oil production activities. Ultimately, we excavated several long trenches along the top or near the top of the bluffs, where we anticipated to expose sediments of sufficient age to estimate the age of last movement if faults were encountered. Although every effort was made to obtain complete coverage of the school area, some small sections of the bluff could not be trenched, due primarily to pipeline locations.

A total of twenty-six, 3-foot wide trench segments (T-1, T-2, T-3a, T-3b, T-3c, T-3d, T-4, T-5, T-6, T-7, T-8a, T-8b, T-9a, T-9b, T-9c, T-10, T-11a, T-11b, T-11c, T-12, T-13a, T-13b, T-13c, T-14a, T-14b, T-14c) were excavated for this study, amounting to nearly 2,400 lineal feet of trenching. The trenches were excavated using a rubber-tire backhoe capable of digging to a depth of about 14 feet.

All trenches were shored and/or benched in accordance with Cal-OSHA guidelines, with the exception of trench T-7, which was not entered or logged because its walls were unstable and it exposed very young sediments. At least one wall of every trench or exposure (except T-7) was scraped to remove clay smears and gouge marks left by the backhoe. Sandier areas were brushed lightly or blown with a leaf blower to accentuate the presence of finely laminated units. A level line was established using string and nails along the length of each trench. Using spray paint, we marked stations at 5-foot intervals directly on the trench wall, adjacent to the level line. To prepare a graphic log of the trench, we measured from this level line to stratigraphic units, the top and bottom of the trench, and any other pertinent features. Laterally continuous, discrete sedimentary beds and channels, and animal burrows (krotovinas) were flagged or etched, then plotted on the log at a scale of 1 inch equals 5 feet. Utility lines that extended across the trench were also located and identified as to the size and type of pipe.

After cleaning and logging, the trenches were photographed with 35-mm print film. Most of the trench locations were surveyed by Fuscoe Engineers. The last two trench series excavated (T-13 and T-14 sets) were surveyed by us with tape and Brunton compass, using existing oil wells and other structures as reference points.

3.4 Soil Analysis

Soil profile analysis was the primary dating technique employed because materials useful to date the sediments exposed in the trenches and bluffs (such as charcoal) were not readily available at the site. Soil profile dating is a relative dating technique that is based on the fact that as soils mature, they generally develop distinct characteristics, including deeper and redder profiles. An experienced soils researcher can, upon comparing an undated soil with similar soils from the region that have been dated using absolute methods, estimate the age of the soil, and therefore, the minimum age of the geomorphic surface upon which the soil formed.

Six representative profiles from four trenches (T-1, T-2, T-9a, and T-3c) were described in detail (Table C-1), and supplemental soil descriptions were recorded for deposits exposed in the rest of the trenches. To minimize the possible effect of erosion, the soil profiles described were collected from stable positions on the terrace surfaces. The soil profiles were described according to the characteristics and nomenclature set forth by the Soil Survey Staff (1975, 1992) and Birkeland (1984). Colors of the soil horizons and parent materials were generally, but not always, described using the Munsell Soil Color Chart (1954). If the Munsell Chart was used, the Munsell color notation follows the color name in the description.

Four of these profiles were used as representative samples of the degree and character of soil development on the Qtm_2 terrace surface. In addition to the field descriptions, samples were collected for laboratory analyses. Samples from two of the soil profiles collected (T-2, profiles 1 and 2) were submitted to the Quaternary Research Laboratory at San Diego State University. These samples were analyzed to measure their weight percentages of sand, silt, and clay, and their dry density (using the paraffin-clod method).

Soil development index (SDI) values were calculated for these soils based on their field descriptions using a modified version of the Harden (1982) index, and the maximum horizon index (MHI) of Ponti (1985). Both SDI and MHI values have been shown to be useful relative indicators of age when comparing soils developed in similar parent materials under similar climatic conditions. The laboratory data were used to calculate the secondary clay mass (PSCM) for each soil profile — PSCM is a soil component that increases with age. Age estimates for the deposits were made by comparing the SDI, MHI and PSCM values obtained at the site with those of dated regional soils developed under similar conditions (Charts A through C, Appendix C).

4.0 FINDINGS

4.1 Stratigraphy

At least four stratigraphic units crop out or occur in the shallow subsurface at the site. Three of these units occur in the elevated area of the site, and are exposed along the bluffs. These units have been interpreted as the marine San Pedro Formation, and two shallow, near-shore marine terrace sediments herein referred to as the Qtm_1 and Qtm_2 deposits. These terrace sediments overlie the San Pedro Formation, and probably reflect two different periods of shoaling of the Los Angeles basin in Pleistocene time. The terrace sediments are overlain locally by younger colluvial deposits and artificial fill. The fourth unit consists of alluvial (stream) sediments of the Santa Ana River floodplain. This unit occurs in the lowland portions of the site. The units are further described below:

4.1.1 San Pedro Formation (map symbol Qsp):

This is the oldest stratigraphic unit exposed at the site. The sediments in this unit are lithologically similar to sediments in other parts of the Los Angeles Basin that have been mapped as the San Pedro Formation. Previous investigators at the site, including EarthTech (1986) and Converse (1994) have assigned these sediments to the San Pedro Formation. We have continued to use the San Pedro nomenclature in this report, although there are no age data to confirm this interpretation.

The deposits consist primarily of light gray to reddish-yellow (iron-oxide stained) friable, fine- to coarse-grained sandstone with frequent thin beds of well-rounded pebbles, siltstone and clay. Where these interbeds are present, the bedding structure is generally well-developed. Internal structure within the sandstone layers ranges from massive to laminated and cross-laminated, with scattered small channel structures. This unit also contains a lesser amount of silty very fine-grained sandstone. The gravelly sand is locally overlain by thin layers of fine sand, silt and clay that are thought to represent shallow marine, lagoonal, and tidal flat deposits.

These deposits often exhibit features such as distorted, tubular bodies of sand or gravel, and irregular wedges or lenses that cross-cut bedding. Similar features have been described in the literature as liquefaction features (Bonilla and Leinkaemper, 1991). Locally along the bluffs where this unit is exposed, we observed truncated fractures and faults that appear to be related to paleo-liquefaction processes and/or submarine slumping. Bedding and fractures in this unit are often enhanced by liesegang banding, a type of iron-oxide staining that generally occurs in sediments that have been previously saturated.

4.1.2 Older Marine Terrace Deposits (map symbol Qtm_2):

Two distinct geomorphic terrace surfaces have been mapped onsite. Each of these surfaces consists of an abrasion platform that was cut into the underlying, older units during a high sea level stand. Then, as the sea level fell, shallow marine sediments were deposited on top of the newly created platform. The sediments deposited on the higher, and older marine terrace at the site are labeled herein as Qtm_2 marine terrace deposits. These sediments were exposed in most of the trenches we excavated for this study.

The Qtm_2 terrace sediments consist predominantly of a light grayish brown to yellowish brown, fine-grained sand with scattered gravel and uncommon lenses of coarse sand and gravel. This unit is generally well-sorted, massive and very friable, similar to beach sand. At the contact between this unit and the underlying San Pedro Formation, we generally saw a layer of sandy gravel that often contained shells and shell fragments. The contact between this unit and the underlying San Pedro Formation is not conformable; the San Pedro gravelly sand beds typically dip 10 to 15 degrees more than the beds of the terrace deposits.

A thick, strongly developed argillic soil has formed in these terrace sediments. The soil profile developed in these deposits is locally more than 10 feet thick (see Section 4.2).

EarthTech (1986) correlated the units and surfaces on the mesa with the world-wide, marine oxygen-isotope stages first defined by Shackleton and Opdyke (1973), and tentatively assigned this terrace surface to the Stage-7 interglacial (which is dated at about 210,000 years ago). The sediments deposited on this terrace surface were referred to in EarthTech's (1986) report as Stage-7 sediments.

4.1.3 Younger Marine Terrace Deposits (map symbol Qtm_1):

Qtm_1 sediments were not exposed in any of the trenches we excavated for this study. However, we did observe these deposits while mapping near the southeastern corner of the site. EarthTech (1986) described the Qtm_1 deposits as generally massively bedded and poorly cemented sand and silt. The deposits reportedly include a basal clay bed interpreted to represent deposition in a tidal flat setting. A strongly developed soil has also formed in the Qtm_1 deposits. EarthTech (1986) tentatively assigned this lowest terrace surface to the oxygen-isotope Stage 5 interglacial (dated at between 80,000 and 120,000 years ago), and referred to the sediments on the terrace as Stage-5 sediments.

4.1.4 Colluvium (map symbol Qcol):

Colluvium consists of surficial deposits that have accumulated in drainage swales and at the toes of slopes as a result of slopewash and shallow slumping. Holocene-age colluvial sediments were encountered in the trenches excavated on the flanks and near the base of the bluffs, and in trenches excavated across canyons draining the bluffs (trenches T-6, T-7, and T-12). The colluvium observed at the site typically consists of dark yellowish brown to grayish brown sandy clay to sandy loam, with many pinhole pores, poor soil structure, and no clay films on ped faces. These deposits are typically more homogeneous and massively bedded then the marine terrace deposits or the San Pedro sediments. Where exposed, the colluvium was more than 12 feet deep.

4.1.5 **Alluvium (map symbol Qal):**

Holocene-age alluvial deposits were not exposed in the trenches excavated for this study. However, from previous work conducted at the site by Leighton (1997), and in the site vicinity by Shlemon et al. (1995), we know that these sediments typically consist of a thick sequence of sand interbedded with layers of silt, clay, and gravel. Peat layers or charcoal fragments have also been reported within the alluvial deposits. The Holocene section near the central axis of the Santa Ana River immediately north of the subject site is approximately 100 feet (30 meters) thick (Shlemon et al., 1995).

4.2 Soils

To evaluate the age of latest fault movement in the mesa portion of the site, it was necessary that we develop an understanding of the age of the soils developed in the marine terrace sediments, since the soils are the youngest deposits that are either faulted, or that overlie (unbroken) the faults observed. Estimating the age of the soils would also allow us to obtain a minimum age for the deposits in which the soils have developed (the Qtm_2 sediments), since soils only develop in relatively stable geomorphic surfaces where little to no erosion or sedimentation are occurring.

Most of the trenches in this study were excavated to a sufficient depth to expose the soil profile and some of the underlying parent deposits. In undisturbed areas on the mesa, a near-surface A soil horizon was observed, which locally has been reworked by man. An eluviated, or leached, E soil horizon was also observed in some areas of the mesa. This horizon, if present, typically occurs between a blanket of artificial fill or reworked A soil horizon, and the underlying, clay-rich Bt soil horizon. The E horizon is generally 4 to 12 inches (10 to 30 cm) thick, and appears to have formed recently, the product of percolating water flowing horizontally at the contact with, or in the upper portion of the relatively impermeable Bt horizon. Scattered remnant chunks of Bt soil observed in some areas within the E horizon suggest that portions of this horizon may be forming at the expense of the argillic horizon.

These upper horizons (the A and E, where present) are considered to have formed in the Holocene, the result of active geologic and climatic processes. In fact, genetically, both of these soil horizons are actively forming today in response to modern soil-forming factors such as climate, and biologic activity (plants and animals — including man).

The trenches excavated at the top of the mesa, and along the upper portions of the bluffs exposed a 5- to 10-foot thick soil profile with a well-developed, composite argillic (Bt) horizon 3 to 7 feet thick. These argillic soils are reddened, and have common to continuous moderately thick, and few thick clay films. In many trenches, the clay-plugged argillic horizons were underlain by a series of banded, laminar Bt horizons.

The laminar Bt horizons are sub-horizontal, wavy to irregular clay-rich soil bands or lamellae that are believed to be a product of deep weathering of the sandy sediments. The lamellae are thought to form relatively early in the pedogenic (soil-forming) process by deep moisture percolation and unsaturated, horizontal flow in the vadose zone. As the surface soil develops, or as pedogenic lamellae form, the depth of percolation is retarded. In the near surface, the lamellae grow together forming the thick argillic horizons described above. Although the lamellae are not primary stratigraphy, they often appear to mimic stratigraphy by bedding control over unsaturated flow. Once the lamellae form they produce excellent, high precision indicators of tectonic displacements due to their brittle nature, and a sharp color and textural contrast with the nearly cohesionless sands of the parent material.

The argillic horizons exposed at the site are significantly different from their parent materials (the Qtm_2 deposits) in clay content, color, structure, and other characteristics. This indicates that substantial weathering and illuviation of the fine grain mineral fraction have occurred within these soils. Although the numerical analyses conducted for this study indicate that the soil profiles described are significantly different from each other, at the 95 percent confidence level, all of the argillic soils described are Pleistocene in age (Charts A through C in Appendix C). Our age estimates for these soils, although highly variable, support an age estimate for the Qtm_2 deposits of approximately 200,000 years, which agrees with EarthTech's (1986) designation of these deposits as Stage-7 sediments.

4.3 Faulting

4.3.1 Faults in the San Pedro Formation:

While mapping the bluffs, we observed several faults and fractures within sediments assigned to the San Pedro Formation. These fractures and faults are often enhanced by liesegang banding, a yellow-orange staining that results from the cyclical oxidation and reduction of iron under saturated conditions. Many of the fractures are also associated with convoluted bedding that suggest soft-sediment deformation. For example, adjacent to the proposed school site, a fault was exposed in the cut slope behind trench T-5b. The fault had approximately 8 inches of vertical separation within the San Pedro Formation. However, trench T-5b (which was excavated at the base of this cut slope to confirm this feature) exposed no faulting, but rather, folding of the sediments, showing that these sediments underwent substantial soft-sediment deformation early in their depositional history, when they were still under water. Furthermore, these faults and fractures do not extend upward into the overlying marine terrace deposits. Based on these observations, we conclude that these secondary faults in the San Pedro Formation predate deposition of the marine terrace sediments, are at least 200,000 years old, and are therefore now inactive.

4.3.2 Fault in the Southeastern and Southern Portions of the Site:

Trench T-2, excavated in the southeastern portion of the site, exposed a fault zone approximately 5-feet wide between stations 3+75 and 3+80 (see Plate 3). The zone consists of four near-vertical fault strands lined with secondary clay and several minor fractures heavily stained with manganese oxide. The main strands affect both the primary stratigraphic units and the soil horizons. Although the lowermost stratigraphic layers exposed in the trench appear to "drape" across the fault zone, total vertical separation (down to the southwest) of 12 to 18 inches (30-45 cm) was measured at the top of a well-defined, laminated sandy silt layer. Several of the upward diverging traces within the fault zone were followed upwards through the Bt soil horizon, and into the near-surface E horizon. Infilling between some of the fault traces at the level of the Bt horizon consist of porous, friable soil of mixed lithologies. The top of the Bt soil horizon is broken across some of the traces, and the E and AE soil horizons thicken across the zone. The trend of the fault zone, measured across the floor of the trench, is N50W.

The fault zone was traced into the E soil horizon, a deposit we interpret to be late Holocene in age, therefore surface fault rupture at his locality has occurred once in the last 11,000 years (and possibly within the last 2,000 to 4,000 years). Under the Alquist-Priolo criteria, this fault is considered an active structure. Older, pre-Holocene rupture events could not be interpreted from this exposure. This fault break probably formed during a large earthquake on the main Newport-Inglewood fault.

A similar fault zone was discovered by Converse (1994) during grading for the water reservoir to the northeast of our trench T-2 location. This fault zone, which they called the West Mesa fault, also appears to have ruptured only once during the Holocene. Stratigraphic units across the more recently active traces also show approximately 12 inches of vertical separation. However, the West Mesa fault has a more northerly strike (N5W to N15W) than the fault exposed in our trench T-2 (N55W). Furthermore, Converse (1994) trenched approximately 300 feet to the north of our trench T-2 location, approximately halfway between the southernmost exposure of the West Mesa fault and our fault exposure, and did not find any faults. Therefore, it is unclear how these two faults are related structurally. However, given the overlap between our trench T-2 and Converse's (1994) trenches T-1 and T-4, the West Mesa fault appears not to continue southward into the Newport-Banning property.

To evaluate whether the West Mesa fault extends northwestward along the eastern boundary of the site, we excavated trench T-1. No faults or fractures were exposed in this trench, suggesting that the West Mesa fault maintains its northerly trend and does not underlie the site in the area south of the West 17th Street entrance.

As part of our review of the existing data, we examined all of EarthTech's (1986) trench logs. EarthTech (1986) concluded that none of the faults investigated were active; however, using their data, we could not reach a similar conclusion for a narrow zone of faulting in the southern portion of the site. Specifically, we found that several of the faults EarthTech mapped in this area were shown as extending upwards to either the surface, or into the near-surface soils. Furthermore, the most significant of these fault strands (based on the amount of vertical separation measured in the exposures) appears to be laterally continuous, extending from at least trench T-86-13 on the north, to trench T-86-20 at the southern boundary of the site. Our interpretation of the near-surface trace of this fault is shown on our Plate 1. In addition to the trench logs mentioned above, other trench logs from the EarthTech report which show evidence for this fault are T-86-15, T-86-16, T-86-18, and T86-19. Each of these logs is discussed in more detail below.

EarthTech's logs for trenches T-86-13 and T-86-15 record several north-northwest trending fault strands that extend upward to the base of deposits interpreted to be historical in age. The faulted deposits immediately below the historical sediments are interpreted to be 200,000 to 300,000 years old. Therefore, given the lack of Holocene-age deposits, the possibility of Holocene faulting at these locations cannot be precluded.

In trench T-86-16, EarthTech documented four fault strands that displace strata assigned to the unit we refer to as Qtm_2. Two of these strands extend upwards into fluvial sediments that EarthTech interpreted as historical. These "historical" sediments thicken considerably across the fault zone, and are possibly involved in the faulting, as they infill fissures between faulted and rotated blocks of the underlying sediments. Thickening of these deposits across the area suggests recurrent faulting and/or folding while the sediments were being deposited. If EarthTech interpreted the age of these deposits correctly, this is an active fault.

In trench T-86-18, EarthTech exposed four north-northwest trending faults that displaced sediments probably correlative with our Qtm_1 deposits. Although the faults were not traced upwards into the overlying pedogenic horizons, combined, the faults had nearly 5 feet (1.5 m) of vertical separation. In trench T-86-19, three fault strands are shown to extend upwards to the base of what can be interpreted to be a Pleistocene argillic horizon (based on its columnar texture). A fourth strand was traced farther upward, to the base of a younger soil horizon that based on their soil descriptions, could be Holocene in age. As in trench T-86-16, the soil profile in this trench also thickens across the fault zone, which could suggest recurrent faulting while the sediments were being deposited.

In trench T-86-20, two of three fault strands are shown to extend upward to nearly the top of the pedogenic horizons. The fault zone in this area appears to have been extensively bioturbated. One of the infilled animal burrows (krotovina) shown on the log may have been faulted. Since krotovina are generally Holocene features (older krotovina are typically not discernible in exposures because the organic materials have been completely oxidized), if the krotovina was faulted it would strongly suggest active faulting.

In plan view, the fault trace interpreted from these exposures trends approximately N5W to N12W, and dips steeply to the west, similar to the West Mesa Fault. These interpretations are based solely on our review of EarthTech's published trench logs. Their conclusions, on the other hand, were reached by review of the actual field relationships exposed in their trenches. Considering the potentially significant impacts to planning an active fault zone could pose, it seems appropriate to exhume one or two of EarthTech's trenches.

4.3.3 **Faulting in the West-Central Portion of the Site:**

Several faults were mapped in the sediments assigned to the San Pedro Formation exposed along the bluffs on the prominent point overseeing the tank farm. Some of these faults could be traced through the San Pedro Formation and into the overlying marine terrace sediments. To determine whether these faults extended upward to near the ground surface, we excavated a series of trenches at the top of the mesa. The trenches were located along the edges of the oil well pad at this location, in an effort to expose undisturbed soils that would allow us to evaluate the recency of activity of the faults exposed, if any. Nevertheless, artificial fill associated with the abandonment of several oil wells was exposed in portions of trenches T-3a, T-3b and T-3c.

Although we cannot unequivocally preclude faulting in this area, in those sections of trenches T-3a, T-3b and T-3c where we did expose native soils, no faults or fractures were observed. In addition, projection of the soil horizons across the fill portions of the trenches does not show significant changes in the elevation of these units that might suggest faulting.

A narrow zone of faulting was exposed near the southeastern end of trench T-3d. On the north wall of the trench, which was extensively bioturbated, the zone consisted of at least three traces. One of the strands appeared to extend upward to the base of the Btk_2 soil horizon. However, on the opposite (south) trench wall, where there was less bioturbation, the fault splays could not be traced to the base of the argillic horizon. The soil layers exposed in the southeastern end of the trench, especially in the north wall, also seemed to rise to the south. The displacements observed were significantly less in the opposite trench wall, and the fault strands could not be traced upward through the argillic soil horizon. Due to the differences in the amount of displacement across a short zone (approximately 3' trench width) and the unaffected appearance of the argillic horizon, we interpret that movement on the faults exposed in trench T-3d occurred prior to the Holocene and have since been inactive.

4.3.4 **Faulting Adjacent to the School Site:**

As described previously, to evaluate the potential for faults to underlie the proposed school site, we cleared two cut-slopes and excavated several trenches on the bluffs to the east and south of the site.

Adjacent to the eastern boundary of the proposed school site, a fault was exposed on the cut-slope behind trench T-5b. The fault had approximately 8 inches of vertical separation within the San Pedro Formation. However, trench T-5b (which was excavated at the base of the cut-slope to confirm this feature) exposed no faulting, but rather, folding of the sediments, suggesting that the San Pedro sands underwent substantial soft-sediment deformation early in their depositional history, when they were still underwater.

Several low-angle faults were also exposed in the western portion of trench T-4. The faults observed had less than 6 inches (15 cm) of apparent displacement. These faults broke the argillic lamellae in the lowest soil horizon exposed, and attenuated upwards, so higher lamellae were folded, and the highest lamellae were not affected. The overlying argillic soil horizons also were not broken. Some of the faults were lined with pedogenic clay similar in color and thickness to the lamellae. The displacements must have occurred after the lower lamellae formed because some of the lams were fractured or slightly offset. This suggests that the higher lamellae formed after the last faulting event. Since we believe that the lamellae formed before the surface soil horizons effectively sealed off deep moisture infiltration, the last episode of faulting on this portion of the Newport Mesa predates the development of the pronounced argillic horizon which is Pleistocene in age. Therefore, the faults observed in this area are considered inactive by Alquist-Priolo definitions.

5.0 CONCLUSIONS AND RECOMMENDATIONS

A substantial amount of data regarding the potential for surface faulting have been obtained at the Newport-Banning property and immediate vicinity over the course of several investigations conducted since 1981. We have reviewed all of the readily available reports prepared by previous investigators, and at your request, conducted a detailed field investigation to evaluate the potential for surface faulting at specific locations on the site. Based on an analysis of these data, we conclude the following:

- Several of the most-recently active faults of the Newport-Inglewood fault system have been identified at the water treatment plant across from the Santa Ana River, to the northwest of the site (Law/Crandall, 1994; Shlemon et al., 1995). Projecting these faults to the south, across the river, and toward the site, places ~~them along the southwestern boundary of the Newport-Banning site, and farther to the west, offsite.~~ These studies, and a similar study conducted by Grant et al. (1997) in the Bolsa Chica area of Huntington Beach, indicate that three, and possibly as many as five surface fault rupturing events have occurred during the Holocene on the Newport-Inglewood fault system. Therefore, this fault system should be considered a likely source for future earthquakes that would generate strong ground motions at the site.

- Several older faults associated with the Newport-Inglewood fault system occur onsite. The most prominent set of faults extends across the point overlooking the tank farm. Our trenching studies at this location support EarthTech's (1986) findings that the faults in this area do not extend upward into soils that are Pleistocene in age. These faults are considered inactive under the State's Alquist-Priolo criteria, and therefore pose a lower risk of seismic activity. ~~No structural setbacks from these faults are considered necessary.~~

- No faults were observed in the trenches excavated to evaluate the potential for surface fault rupture at the proposed school site. Although we were not able to trench along the entire section of bluff overseeing the school site, the areas left untrenched are areally minor. ~~Therefore, we conclude that the risk of surface fault rupture through the proposed school site is low.~~ Furthermore, the inferred "North Branch Splay" fault (EarthTech, 1986), which was arbitrarily selected to form the southern boundary of the school site, was not observed in the trenches excavated for this study. Therefore, the southern boundary of the school site could be moved farther south, should the project require it.

- Two secondary but recently active faults have been identified near or in the eastern portion of the site. The first of these was observed and reported by Converse Consultants (1994) during their geotechnical evaluation of the water treatment facility at the western terminus of West 16th Street. ~~They referred to this fault as the West Mesa fault.~~ We trenched south of Converse's location, and exposed a fault that we determined has moved at least once during the Holocene. This second fault does not seem to project toward and tie in with the West Mesa fault (see Plate 1). Other recently active faults associated with the two faults that have been observed may occur in this area of the site. These faults are not considered to be seismogenic (i.e., they are not likely to generate an earthquake), but they probably move co-seismically with earthquakes on the main Newport-Inglewood fault. Nevertheless, under California's Alquist-Priolo Act, ~~these faults are active, and a building setback from them is recommended.~~ ~~Furthermore, the lateral continuity and general trend of the fault exposed in our trench T-2 need to be better constrained.~~ The most efficient way to do this is by excavating a series of short trenches along the projected trend of the fault, starting near the known location, and progressing outward, both to the north and south, of trench T-2.

- ~~EarthTech (1986) consultants mapped several faults in the southern portion of the site. We have reviewed EarthTech's (1986) logs of these fault exposures, and believe that there is a narrow zone of faulting that has not been conclusively shown to be inactive.~~ The fault that we have interpreted from EarthTech's data trends N5W to N12W, and dips steeply to the west. This fault is shown on our Plate 1. ~~The recency of activity of this fault should be assessed to determine whether building setbacks will be required.~~ Furthermore, this fault and the West Mesa fault could be part of a right-stepping, en-echelon system of faults. Additional studies in the southeastern portion of the site may be warranted to evaluate the structural relation, if any, between the faults identified in this area (including the fault in Trench T-2 of this study).

- Our investigative program was set up to intercept primarily the northwest-trending faults of the primary Newport-Inglewood system. There are north-south trending secondary faults, such as the West Mesa fault, and the fault interpreted from EarthTech's data, that are active or potentially active. ~~These are short, discontinuous, generally minor features, and it is very likely that more north-south trending faults are present within the site.~~

5.1 Degree of Confidence In and Limitations of Data and Conclusions

In the area of the prominent point, and in the area investigated for the school site, there were a few small "windows" between our trenches where overlap was not possible due to pipelines or thick artificial fill. However, these gaps were only tens of feet wide, compared to the approximately 6,800 lineal feet of trenches and bluffs surveyed. No indications of faulting, such as vertical displacement of the terrace deposits, thickening or displacement of the overlying soil horizons, fractures, or geomorphic effects, were found to indicate that a fault trace might trend through any of these gaps.

As discussed in previous sections, we used the degree of soil development to estimate the age of the terrace deposits and the recency of faulting. This is a relative age-dating technique that relies on correlating the strength of soil development of undated soils with that of soils whose ages have been determined through absolute dating techniques. The independently dated soils (the control population) are used to statistically calculate the estimated mean ages for indexed measures of soil development. Then by comparing the developmental index values of the Newport-Banning soils to the indexed values of the control population, we can estimate the mean age of the Newport-Banning soils. As with any other form of measure, the mean estimations of age have associated margins of error. Therefore, we have listed the upper and lower boundaries of the 95 percent confidence interval for each age prediction.

Although this soil dating technique only provides relative age control, the degree of soil development we observed at this site, and the age distributions at the 95 percent confidence intervals in our statistical analyses, are such that we are comfortable in our assessment of the faults we have called inactive.

5.2 Other Potential Seismic Risks

Recent research suggests that the Newport-Inglewood fault poses a relatively lower earthquake risk to the Los Angeles basin than previously thought. Nevertheless, the fault does have the potential of generating future earthquakes. Therefore, although the hazard of surface fault rupture in most areas of the site is relatively low, a near-field earthquake on this fault would generate strong ground motions at the site that are likely to be considerably larger than the minimum values used in standard Uniform Building Code design. This should be considered in the design of both the school structures, and the residential structures proposed at the top of the bluffs. ~~Additionally, the alluvial soils underlying the school site will likely pose additional earthquake design considerations, specifically, seismically induced liquefaction and amplification of seismically generated ground motions.~~ However, both constraints have engineering solutions.

Recent and on-going studies of this part of Orange County by Southern California Earthquake Center-funded researchers suggest that the Newport Mesa is the northward extension of the San Joaquin Hills (SJH). The SJH, and therefore, the area where the Newport-Banning site is located, are being uplifted by movement on a blind thrust fault that underlies the area. Although these studies are too preliminary to quantify the seismic risk posed by this blind thrust fault, in general, the fault is thought capable of generating earthquakes similar in magnitude to the 1994 Northridge earthquake.

APPENDIX A
REFERENCES and
AERIAL PHOTOGRAPHS REVIEWED

APPENDIX A
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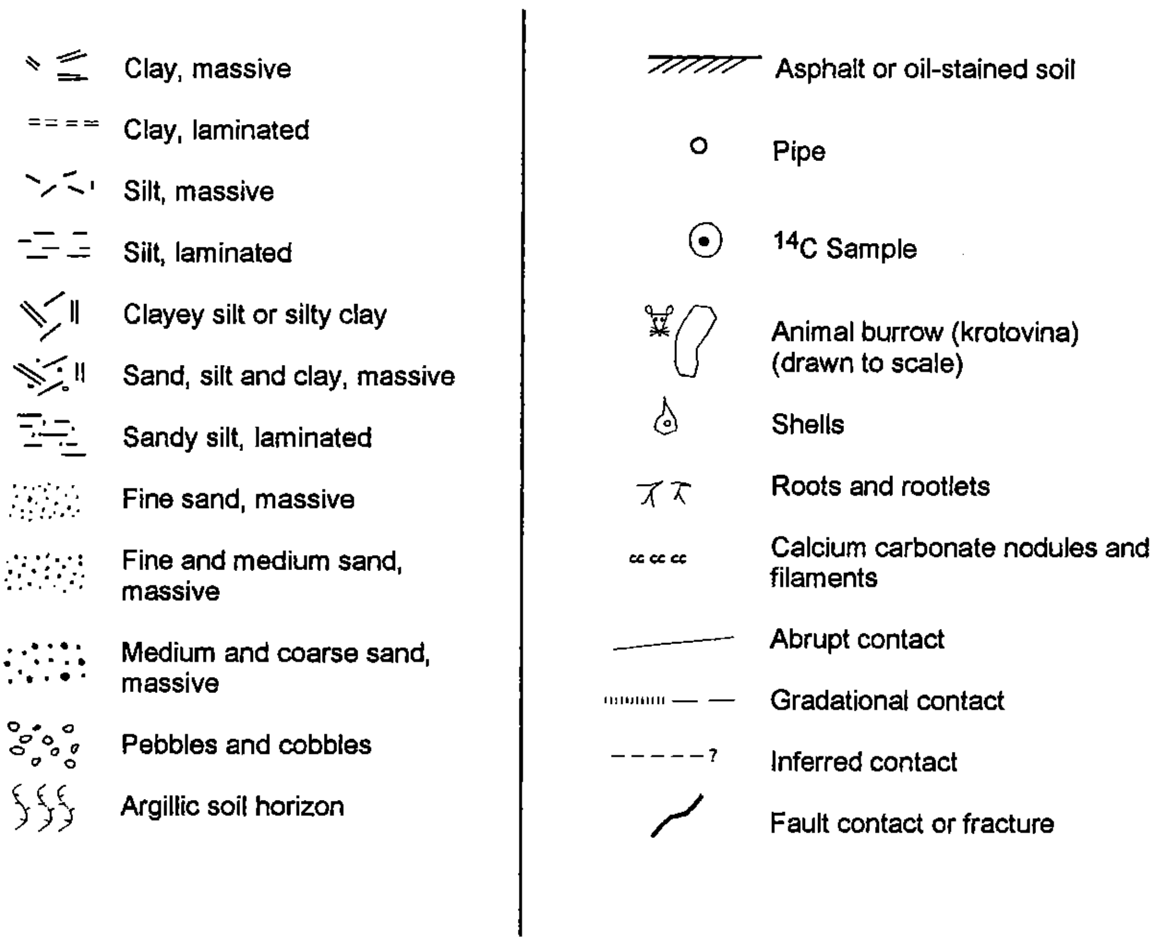
Aerial Photographs Reviewed

Date	Flight No.	Frame No.	Source	Scale
1927	113	764, 717	Fairchild Collection	1:18,000
10/28	C278	B-8, B-9, B-10	Fairchild Collection	1:24,000
5/22/31	1590	34, 35	Fairchild Collection	1:18,000
1938	5029	35, 61, 48,	Fairchild Collection	1:25,000
5/23/38	AXK-29	68, 69, 70, 76 -79	USDA	1:20,000
6/2/53	AXK-6K	54, 55, 56, 66,70	USDA	1:20,000
2/26/80	80033	174, 176, 177	American Aerial Survey	1:24,000

APPENDIX B
TRENCH DESCRIPTIONS

Figure B-1
Key To Symbols
Used In The Trench Logs



Trench Descriptions

The trenches excavated for this study are described below. Specifics regarding faulting as observed in some of these trenches are described in more detail in the main portion of the report.

T-1

Trench T-1 was begun at the east property line, south of the West 17th Street entrance, and extended in a S70W to West direction for 378 feet. The trench was in general 9 to 11 feet deep along its entire length. The bottom of the trench exposed sandy to silty parent material. A thick soil profile has developed in these sediments, including several argillic subhorizons, and sands with distinctive clayey lamellae that strengthen and weaken laterally. Each of the stratigraphic units in this trench showed some degree of gradual lateral variation in grain size, which was interpreted to reflect facies changes in the depositional environment. Throughout the length of this trench, the sedimentary units and soil profile were observed to be continuous and flat-lying, with no evidence of shearing, fracturing, or offset.

T-2

Trench T-2 was located more than 1,800 feet south of Trench T-1. This trench was also begun against the fence along the eastern boundary to the site, and was extended in a S55W to S60W direction for 397 feet. The sediments exposed in this trench were very similar to the sediments in T-1, with sandy to silty layers at the bottom. A thick soil profile has also developed in these sediments. A narrow zone of faulting, including several manganese oxide-stained fractures, was exposed between Stations 3+75 and 3+80. A gray, thinly laminated sandy silt layer was deformed, and down-dropped (to the west) about 12 to 18 inches across several of the fault strands. The main fault strands could be traced upward through the argillic horizon, and into the E soil horizon, which thickened significantly across the zone. The base of the argillic horizon was broken, indicating that the most recent event occurred after formation of this soil layer.

T-3 a,b, c, and d

The third series of trenches was located on a bluff overlooking the floodplain of the Santa Ana River, directly above the tank farm. This portion of the site has been altered significantly by oil field operations. T-3a was oriented N55E, and was 24 feet long. Because artificial fill was exposed from Station 0+14 on to the northeast, we stopped excavation of T-3a, and stepped farther to the east, where we excavated trench T-3b. Trench T-3b was 69 feet long, oriented N65W, and also exposed predominantly artificial fill. The longest trench in this portion of the site, T-3c, was 104 feet long and about ten feet deep. Its orientation ranged from N42W to N60W. Several thick argillic subhorizons overlie the sand and sandy silt layers at the bottom. Every one of these trenches exposed a distinctive gleyed unit with moderate to large (up to 5 cm) calcium carbonate nodules. The gleyed unit overlies a sand bed with clay lamellae that strengthen and weaken laterally. No evidence for faulting or shearing was observed in these three trenches.

Trench T-3d was 55 feet long and 6 to 8 feet deep. This trench, oriented N75W, was a continuation of T-3c. Evidence for faulting was exposed in the eastern end of this trench. Several clay-lined fractures were observed to displace the primary stratigraphy and affect soil development up to the base of the argillic horizon. The underlying BC horizon was intensely bioturbated, especially on the north wall. The sand beds at the bottom of the trench rose in elevation, from a depth of 6 feet at Station 0+35, to nearly the ground surface near Station 0+50.

T-4

Trench T-4 was begun as a cut-face exposure with a shallow trench excavated at its base. The height of exposure, including the trench at the base, was 10 to 11 feet. As the orientation of the exposure changed from N68W to E-W (to avoid cutting across a road and to avoid live gas lines), the trench was deepened to 10 feet, and the cut-face was no longer present. The total length of the exposure, including the trench and cut-face, was 165 feet. This excavation exposed sandy beach deposits overprinted by soil development, and a distinctive sand bed with clay lamellae near its base. At least three faults were observed near the west end of the exposure, confined to the sand bed with clayey lamellae. A distinctive, coarse sand unit was vertically offset approximately 6 inches by one of the faults. Nevertheless, the faults did not extend upward to the base of the more developed argillic horizon, and the clay lamellae near the top of the unit were not affected by faulting. These observations indicated that the most recent faulting event impacting these sediments occurred prior to the formation of the Pleistocene-age argillic soil horizon.

T-5a, b

Trenches T-5a and T-5b were excavated below and parallel to a large cut-face that extended on both sides of a drainage beside the main road on the property. The cut-face exposed most of the soil profile, therefore, the trenches at the base were fairly shallow, going only as deep as necessary to expose the unaltered sandy parent material. T-5a was 100 feet long, oriented N35E to N27E, and was 3 to 9 feet deep. This trench was deepened in several places to investigate linear clay-filled fractures. At depth, these features became less apparent, less linear, or disappeared altogether. Also, we could not correlate these features on both trench walls. Two of the units near the bottom of this trench appear to be dipping slightly. The first, at the northern end of the trench, is a sand that grades to a silty sand above. The contact is gradational, and no evidence of shearing was observed in this area to suggest that the contact was caused by faulting. Dipping of the primary stratigraphy (to the south) was also indicated by a line of cobbles in the deeper portion of the trench.

Trench T-5b, located approximately 35 feet north of T-5a exposed friable, well-sorted fine sand and silt beds. This trench was oriented N5E to N-S, was 72 feet long, and less than 5 feet deep in most places. There were several pockets of shell rich sand. The bedding showed evidence for folding and/or soft sediment deformation. No evidence of faulting or shearing was observed in this exposure.

T-6 and T-7

Trenches T-6 and T-7 were excavated to the northeast of T-5a and T-5b, closer to the floodplain. Their locations were selected with help from oil field personnel and the project's biologist to avoid pipelines and stands of coastal sage, respectively. Trench T-6 exposed several layers of artificial fill, including oil-stained sand, underlain by colluvium, and midden material. The colluvium was more than 14 feet deep at this location. The trench was excavated in two phases. There was no evidence for faulting or shearing, but the colluvium exposed was too young to conclude that no Holocene faults extend through this area.

Trench T-7, just below T-6, was less than 100 feet long, and was not logged due to severe potential for collapse. Visual inspection from the surface, however, showed alternating layers of fine sand and silt, several inches thick. There appeared to be no evidence for shearing or offset of the sediments.

T-8a,b and c

These trenches, and the T-9 series, were located on top of the bluffs, behind the diesel tanks. The trenches were excavated in segments to avoid various gas lines and abandoned wells. Trench T-8a, oriented N68E, was 51 feet long and ranged from 3 to 7 feet deep. Trench T-8b was oriented N5E, and was 50 feet long and 5 to 9 feet deep. The last 10 feet of trench exposed artificial fill from top to bottom. Trench T-8c, oriented N70E, cut across the access road, and was 34 feet long and 8 feet deep. Sediments and soil development in all of the trenches near the diesel tanks were similar, with several argillic subhorizons overlying fining-upward sequences of laminated sand and silt.

T-9a and b

Trench T-9a was oriented N10E, and was 100 feet long and 10 feet deep. This trench exposed several feet of artificial fill overlying soil developed in sandy parent material. The lowermost sand unit was continuous across all of the T-8 and T-9 trenches, and the thin clayey siltstone overlying it was continuous northward from station 0+70 in T-9a (i.e., it was observed in all the trenches north of T-9a in this area). All of the units appeared to be continuous and unbroken, with only gradual lateral variations in grain size and soil development. No shearing or faulting were observed in any of the T-8 or T-9 trenches.

T-10a and b

Trenches T-10a and T-10b were located on the hill slope just south of the diesel tanks, and were a continuation of trenches T-8 and T-9. Trench T-10a was also oriented N10E, and was 85 feet long and 8 to 11 feet deep. Due to the geomorphology of this particular portion of the site, there was more lateral variation in both grain size and soil development. The argillic horizon, for example, thickened considerably down-slope. Such changes were gradational, with no observable shears or strong planar features suggestive of faulting.

Trench T-10b was excavated next to an 8-inch utility line. This trench consisted of two small trenches, each less than 10 feet long and 10 feet deep, separated by a 12- inch pipe. These trenches exposed artificial fill and oil stained sand to a depth of 5 to 6 feet, overlying well-laminated gray siltstone and fine sandstone. Several continuous 1- to 2-inch thick beds were observed in both trenches, with no evidence for shearing or faulting.

T-11a, b and c

The T-11 trench series was also located on a hill-slope. These trenches were located north of the diesel tanks, and segmented in order to avoid numerous active gas and oil lines. T-11a was located farthest down hill and was terminated as close as possible to the main road. The trench was 30 feet long and about 10 feet deep. T-11b was 8-1/2 feet up-slope from T-11a, and was 10 feet long and less than 10 feet deep. The longest trench in this series, T-11c, was oriented N10E, and was 110 feet long. This trench had a 4- to 5- foot high bench at the surface, with an

8 to 11-foot deep trench below the bench. Trenches T-11a, T-11b and the lowermost portion of T-11c were dominated by soil development in colluvium, and did not expose unaltered parent material. The characteristic laminated sand unit observed in other trenches at the top of the bluffs was first observed near Station 0+20 in T-11c; from this location it was exposed in the remaining, uphill portion of this trench. The trench was unstable between Stations 0+90 to 1+05. Beyond Station 1+05, we observed a clay-lined fracture that could be discerned in both trench walls. The fracture was oriented N80W, and dipped 41 degrees to the south. The fracture did not offset the primary stratigraphic layers or soil horizons.

T-12

Trench T-12 was located between T-10a and T-4. It was positioned very carefully to avoid several power and gas lines and a pump access road. This trench was 25 feet long and 11 feet deep. Due to its location, more or less in the center of a drainage, this trench exposed colluvium with some incipient soil development. No shears or faults were observed in this exposure.

T-13a, b and c

This series of trenches was excavated across the main access road connecting the mesa surface and the floodplain below. Orientation of these trenches ranged from N5E to N55W. The trenches were excavated in segments to avoid several pipelines. T-13a was 70 feet long and 5 to 6 feet deep. The trench exposed from top to bottom artificial fill and a thin layer of asphalt, an argillic soil horizon and sandy parent material. T-13b was 82 feet long and 6 to 11 feet deep. T-13c was 94 feet long, with a 12-inch steel pipe at Station 0+35. The trench was excavated with a bend about Station 0+42 to avoid trenching through backfill from an abandoned well. Stratigraphy and soil development were consistent throughout the trench, with only minor lateral variations. There was no evidence for faulting or shearing.

T-14a,b and c

This series of trenches was located above the T-5, T-6 and T-7 series. The trenches were excavated to expose sediments older than those exposed in T-6 and T-7, and confirm that no active faults extend through this section of the site. T-14a was 100 feet long and 9 feet deep (except where it had collapsed). T-14b was approximately 35 feet north of T-14a; a large fiberglass line reportedly extends across the section untrenched. T-14c was excavated parallel to, and next to the section of T-14a that had collapsed. These trenches exposed marine terrace deposits that have been modified in their upper 7 to 8 feet by soil development. There was no evidence for faulting or shearing.

APPENDIX C
SOIL DESCRIPTIONS

APPENDIX C
Soil Descriptions

Soil Stratigraphy

The soils present at this site consists of a stratigraphic sequence of soil horizons each having a different set of characteristics. The A horizon, unless removed or buried beneath artificial fill, is the surface horizon. Locally present below the A horizon is an E horizon (zone of leached material). Stratigraphically below the A and/or E horizon lies a series of Bt or argillic horizons (differentiated based on individual sub-horizon characteristics). Below the weathering profile, there are relatively unaltered sediments of the C horizon(s).

A horizon

Where present, the intact A horizon ranges from approximately 22 to 90 cm in thickness. Its color is in the range of 10YR5/4 to 10YR3.5/4 when dry. Consistence is generally soft to slightly hard when dry, and non-sticky to slightly sticky and non-plastic to slightly plastic when wet. The texture of A horizon material is loamy fine to medium sand and sandy loam. The soil structure is generally massive breaking to moderately developed blocky peds. Pore space is greater within the A horizon then that of any of the subsurface soil horizons. No clay films were observed within this horizon.

E horizon

The E horizon (zone of eluviation) is indicative of leaching of organics and the fine or soluble mineral fractions within the soil profile. Where present in the soil profile, the E horizon is relatively thin (10-20cm), and may be either weakly developed or have characteristics of the overlying A or underlying B horizons. The color of the E horizon is lighter in value than other soil horizons (generally 10YR4.5-5/x when dry). The consistence is slightly hard when dry, and commonly fragic when damp. Wet consistence is non-sticky and non-plastic to slightly plastic. The texture ranges from sandy loam to loam. Structure is massive breaking to moderately developed blocky peds. The E horizon material shows either no signs of secondary clay films or incipient clay films.

Bt horizon

The Bt or argillic horizons display significant accumulation of secondary clays and soluble minerals. The Bt is generally redder than the unaltered sediments and other soil horizons. Hues of 10YR to 7.5YR are common. The accumulation of pedogenic clays is reflected in the sandy clay loam to clay texture. The structure within these horizons ranges from moderate to strong blocky to prismatic peds. The consistence of the Bt horizon material is generally hard to extremely hard when dry, and sticky and plastic when wet. Oriented films of pedogenic clay were observed coating ped faces, lining pores, and forming bridges between grains. The Bt horizons are temporally diagnostic in that the amount of pedogenic materials accumulated within them control the strength of developed attributes for the entire soil profile.

C horizon

The C horizon is best described as having the properties of the unaltered sediments that the soil profile has developed in. The color is generally 10YR to 2.5Y in hue.

Structure is that of the parent material. The consistence and textures are also that inherent to the geologic unit. Where locally present, the Cox horizon is similar to the unaltered sediments but may be slightly redder due to oxidation on the surfaces of the individual particles.

In addition to the principal horizons described above, the soils at this locality commonly contain intermediate horizons. These intermediate horizons may have characteristics of two of the principal horizons and may be stratigraphically between them, or take their place within the profile.

Soil Development

The thickness and degree of soil development within surficial geologic deposits is a good relative indicator of duration of exposure and weathering. The Newport Mesa soils display 1.4 to 2.8-meter thick profiles with a composite argillic thickness of 1.0 to 2.2 meters. The marked difference between the characteristics of the argillic horizons and that of the original parent material (unaltered sediments) indicate that substantial illuviation and transformation of the fine-grain mineral fraction has occurred within these soils. To compare the degree of development of the undated Newport Mesa soils to that of dated marine terrace soils developed under similar conditions, we calculated the soil development index (SDI) values and maximum horizon index (MHI) values for six Newport Mesa soils.

The SDI is a depth-dependent value that we therefore normalized to a common depth of 300 cm for comparative purposes. The normalized SDI values for the Newport Mesa soils (Chart B) range from 100 to 154. Because this range in SDI values did not support our interpretation that these soils, which are on the same geomorphic surface, are of similar age, we evaluated the SDI values from other dated soils used as controls. Our review indicated that the variability in these values appears to be a function of the thickness of the composite Bt horizon. We propose that soils developed in coarser sand lithofacies have thicker argillic horizons and therefore higher SDI values, while those soils with argillic horizons developed in less-permeable, finer-grained deposits, have thinner zones of accumulated pedogenic clay, which calculates into lower SDI values. However, the variability of the SDI values within the undated soils group is irrelevant with respect to age estimate errors imposed by the variability in the dated soils group. The estimates for the undated Newport Mesa soils therefore generally fall into a wide range of values. However, based on the SDI values for this suite of soils, at the 95 percent confidence level, predicted ages for these soils fall well within the Pleistocene epoch.

The MHI value is independent of the thickness of the specific horizon or that of the total soil profile. However, differences in lithologies can affect the apparent strength of soil development in materials of similar age. As in the case of age estimations based on SDI values, there are large margins of error for predicted ages, but at the 95 percent confidence level all the Newport Mesa soils examined indicate that the deposits forming the Qtm_2 terrace are late Pleistocene in age.

To summarize, the strength of soil development within the Qtm_2 deposits is characterized by several properties, the foremost being the thick clay-rich argillic horizons present in all of the soil profiles observed. Using field descriptions from the representative profiles, we estimated index values for the degree of development of some of these soils. When comparing the different index values to the soil development models of well-dated soils formed under similar conditions (Charts A through C) several observations can be made: 1) there is a large variability in the degree of development of similar age soils in both the dated and undated sample populations, 2) age predictions at the 95 percent confidence level reflect these large margins of error, 3) age estimates vary depending on the type of development index used (MHI vs. SDI vs. PSCM), and 4) at the 95 percent confidence level, all representative soils from the Qtm_2 deposits plot well within the Pleistocene epoch.

Table C-1
Soil Profile Descriptions
Newport/Banning

	PEDON	HORIZOI	DEPTH (cm)	COLOR d;m	TEXTURI	STRUCTURE	CONSIST d;m	CLAY FILMS	BOUNDARY	SDI	H.I.	NOTES
ID	T-1 Profile 1	asphalt	0-5	Truncated surface								
Date	7/14/97		5									
Locatior	Trench 1 @ 75' S. wall	E/Btj	5-50	10YR5/4d; 3/4m	LS-SL	3mabk	sh; so-ss, po-ps	1npf*	c, s-w	15.50	0.34	Slightly fragic, Slight effervescence
P.M.	Mt sands & silty sands		45	0.20	0.30	0.83	0.57	0.17				*C.F. locally in lower part of horizon
Landfori	Marine terrace tread	2Bt1	50-145	10YR5/6d; 10YR-7.5YR3/4m	fSC-SCL	3mabk-pr	h-vh; s, p	3mk-kpf, 3mk&2kpo, 2-3mkbr	g, w	65.31	0.69	2n-mkpo mangans
Surface	Qmt77		95	0.33	0.70	0.92	1.37	0.82				
Age		2Bt2	145-195	10YR5/5d; 3.5/4m	fSC	3m-cabk	h-vh; s, p	1-2npf, 3kpo, 1nbr	g, w	31.82	0.64	2mkpo mangans & sm noduals
Source	ECI MSB		50	0.25	0.80	0.83	1.27	0.67				
Veg.	grasses	3Bt3	195-240+	10YR5/5 damp; 4/4m	CL	2cabk	fi; vs, vp	2-3npf, 2mkpo,		26.50	0.59	1npo mangans
note	truncated profile		45	0.20	0.80	0.67	1.33	0.53				
									SDI @ 240cm =	139.13		
		Bt thickness	190.00						SDI @ 250cm =	145.02		
									SDI @ 300cm =	154.02		
									SDI @ 350cm =	158.52		

	PEDON	HORIZOI	DEPTH (cm)	COLOR d;m	TEXTURI	STRUCTURE	CONSIST d;m	CLAY FILMS	BOUNDARY	SDI	H.I.	NOTES
ID	T-1 Profile 2	EB	0-64	10YR3.5/4m	vfSL	m-1f-mabk	fi; ss, ps	1-2stpf	a, s	23.29	0.36	
Date	7/14/97		64	0.20	0.40	0.42	0.83	0.33				
Locatior	Trench 1 @ 2+90' S. wall	2Bt1	64-140	10-7.5YR3/4m	SC	3mabk-fpr	eh; vs, vp	3-4mkbr, 3mk&1kpf, 3mk&2kpo	g, w	60.80	0.80	Carb in few pores and on few pedface
P.M.	Mt sands & silty sands		76	0.25	0.80	0.92	2.00	0.83				Slight effervescence
Landfori	Marine terrace tread	2Bt2	140-165	10YR4/6d; 4/4m	fSCL	3mabk	vh; s-vs, p	3-4n&2mkpf, 3kpo, 2mkbr	c, s-w	16.94	0.68	weak to moderate effervescence (loca
Surface	Qmt77		25	0.30	0.60	0.83	1.55	0.78				
Age		3Btg	165-190	10YR5/4 &2.5Y5/4m*	CL	m-2f-mabk	fi; vs, vp	3n&1mkpf, 4npo	c, w	14.58	0.58	*mottles are2-5cm & 4-10cm apart
Source	ECI MSB & TKG		25	0.10	0.80	0.50	1.50	0.60				Weak effervescence
Veg.	grasses	3Bt3	190-224	10YR4/4m	CL	m-3f-mabk	fr; vs, vp	3npf, 3-4mkpo	c,w	20.40	0.60	
note	truncated profile		34	0.20	0.80	0.67	1.30	0.63				
		4Bt(lam)	224-284+	10-7.5YR5.5/6d; 4/4m	SCL-SL	2mabk	h-vh; ss, ps-p	3mk&1kpo, 3-4mk&3nbr		8.33	0.56	Clay rich Lams 20-25% of horizon
			15	0.35	0.50	0.67	1.12	0.70				
				10-7.5YR5.5/5d; 10YR4/4m	fS	m-2msbk	so; so, po	3stgr		8.31	0.18	Clay poor zones 75-80% of horizon
			45	0.28	0.00	0.33	0.20	0.30				
									SDI @ 284cm =	152.66		
									SDI @ 250cm =	144.26		
		Bt thickness	220.00						SDI @ 300cm =	156.02		
									SDI @ 350cm =	163.02		

	PEDON	HORIZOI	DEPTH (cm)	COLOR d;m	TEXTURI	STRUCTURE	CONSIST d;m	CLAY FILMS	BOUNDARY	SDI	H.I.	NOTES
ID	T- 2 Profile 1	AE	0-28	10YR5/4d; 3/3.5m	fSL	m-2m-cabk	sh; so, po-ps	n.o.	c, s-w	7.27	0.26	
Date	7/18/97		28	0.18	0.40	0.50	0.48	0.00				
Locatior	Trench 2 @ 32' S. wall	Bt1	28-160	10YR5/6d; 3.5/4m	SC	3mabk	vh; s, p	3mk&2kpf, 3kpo	c, w	96.07	0.73	
P.M.	Mt sands & silty sands		132	0.30	0.80	0.83	1.47	0.97				
Landfori	Marine terrace tread	Bt2	160-196	10YR5/6d; 3.5/4m	SC-SCL	2-3mabk	h; ss-s, p	3n&1mkbr, 2npf, 2mkpo	a, i	21.60	0.60	
Surface	Qmt77		36	0.30	0.70	0.75	1.18	0.67				
Age		2BC1	196-226	10YR4.5/3m	vfSL	m-1-2fabk	fr; ss, ps	2npf*, 2mkpo*	a, s	8.35	0.28	*Locally as pipes
Source	ECI MSB		30	0.10	0.40	0.50	0.63	0.25				
Veg.	grasses	3BC2	226-262	10YR4.5/5d; 4/4m	SL-LS	m-1mabk	sh; so-ss, po	v1npf*	a, s	8.78	0.24	*Locally as pipes
note	truncated upper profile??		36	0.25	0.30	0.42	0.48	0.13				
		4C1	262-287	10YR5/4m	fSL	m-2msbk-abk	sh; so, po	n.o.	a, s	3.40	0.14	
			25	0.20	0.00	0.42	0.20	0.00				
		5C2	287-330+	10YR5/3m	SiS & C	m-2m-cabk(m)	fr-fi; ss, ps	n.o.		2.87	0.07	
			43	0.10	0.00	0.30	0.00	0.00				
									SDI @ 330cm =	148.34		
									SDI @ 250cm =	138.17		
		Bt thickness	168.00						SDI @ 300cm =	146.34		
									SDI @ 350cm =	151.68		

Table C-1
Soil Profile Descriptions
Newport/Banning

	PEDON	HORIZOI	DEPTH (cm)	COLOR d;m	TEXTURI	STRUCTURE	CONSIST d;m	CLAY FILMS	BOUNDAR\	SDI	H.I.	NOTES
ID	T-2 Profile 2	AE	0-40	10YR5/4d; 3.5/3m	vfLS	2m&fsbk	sh; so, po-ps	n.o.	c, s	8.89	0.22	Common worm casts; no effervescenc
Date	7/18/97		40	0.15	0.20	0.50	0.48	0.00				
Locatior	Trench 2 @ 325' S. wall	Bt1	40-112	10-7.5YR4/4d; 3/4m	SC	3mabk-pr	vh; vs, vp	3mk&2kpf, 3-4kbr, 3mkpo	c-g, w	56.00	0.78	Slight effervescence
P.M.	Mt sands & silty sands		72	0.25	0.80	0.92	1.80	0.90				
Landfori	Marine terrace tread	Bt2	112-132	10-7.5YR4/5d; 10YR4/4m	SC-SCL	m-2mabk	h; s-vs, p	3n&1kpf, 3mkbr, 1mk&1kpo	a, s	12.31	0.62	Slight effervescence
Surface	Qmt??		20	0.28	0.70	0.50	1.35	0.87				
Age		2Bt3	132-153	10YR4/4m; 2.5Y6/4(mottles)	CL	3fabk	vh-eh; s, vp	4mkpo, 3-4mkpf, 3kbr	a, s	16.04	0.76	Common 2-4 cm mottles,
Source	ECI MSB		21	0.10	0.80	0.83	1.93	0.92				Some primary clay
Veg.	grasses	3Bt4	153-174	10YR4/6d; 4/4m	SCL	m-2f-mabk	fr; ss, ps	2mkpf, 2n&1mkpo, 3n&1mkbr	a, s	9.57	0.46	
note	truncated upper profile??		21	0.20	0.60	0.50	0.63	0.80				
		4Bt5	174-224	2.5Y-10YR5/6d; 10YR4/4m	fLS	m-2f-msbk	so; so, po	1npf, 2-3npo	a, s	11.60	0.23	
			50	0.23	0.20	0.33	0.20	0.43				
		5C	224-280+	2.5Y5/4m	SiC	bedded-3fabk	fr-fi; vs, vp	stpo		1.24	0.02	Primary clay
			56	0.00	0.00	0.00	0.00	0.13				
									SDI @ 280cm =	115.64		
		Bt thickness	184.00						SDI @ 250cm =	114.98		
									SDI @ 300cm =	116.09		
									SDI @ 350cm =	117.20		

	PEDON	HORIZOI	DEPTH (cm)	COLOR d;m	TEXTURI	STRUCTURE	CONSIST d;m	CLAY FILMS	BOUNDAR\	SDI	H.I.	NOTES
ID	T-3c Profile 1	Fill	0-74	Fill of Sand, locally sluried								
Date	7/28/97		74									
Locatior	Trench 3c @ 26' N. wall	A	74-99	10YR3.5/4(damp); 3/2m	LS-SL	m-2mabk*	so; ss, po	n.o.	a-c, s	4.93	0.20	*Damp & compacted, no effervescenc
P.M.	Mt sands & silty sands		25	0.10	0.30	0.42	0.37					
Landfori	Marine terrace tread	Bt1	99-165	7.5YR3.5/4m	C	3mpr	eh; vs, vp	3kpf, 4mk-kpo, 3mkbr	c, w	56.47	0.86	Some pressure faces on peds
Surface	Qmt??		66	0.30	1.00	1.00	2.00	0.83				
Age		Bt2	165-194	10YR4/3.5m	SC	3mabk	fr; s, p	3mkpf, 3mkpo, 2mkbr	c, w	17.00	0.59	
Source	ECI MSB		29	0.15	0.80	0.83	0.97	0.77				
Veg.	removed	2Btk	194-213	10YR4.5/4m	fSC	3mabk	fr; s, p	1-2npf, 2npo	c, w	10.03	0.53	Common to many 1-3 cm Carb noduals
note			19	0.20	0.75	0.83	0.97	0.42				
		2C	213-270+	2.5Y-10YR4/4m	fLS	2-3mabk	fr; so-ss, ps	n.o.		13.30	0.23	
			57	0.10	0.00	0.75	0.55	0.00				
									SDI @ 270cm =	101.72		
		Bt thickness	114.00						SDI @ 250cm =	97.06		
									SDI @ 300cm =	108.72		
									SDI @ 350cm =	120.39		

	PEDON	HORIZOI	DEPTH (cm)	COLOR d;m	TEXTURI	STRUCTURE	CONSIST d;m	CLAY FILMS	BOUNDAR\	SDI	H.I.	NOTES
ID	T-9a Profile 1	Fill	0-25									
Date	8/11/97		25									
Locatior	Trench 9a @ 11' W. wall	Fill2	25-97									
P.M.	Mt sands & silty sands		72									
Landfori	Marine terrace tread	A	97-138	10YR4/3(slight damp); 3/2m	SL	m-2mabk	so; so, ps	n.o.	c, s	10.36	0.25	
Surface	Qmt??		41	0.05	0.60	0.50	0.37	0.00				
Age		E	138-148	10YR4.5/3d; 3/2.5m	L-SL	m-2mabk	sh; so, po-ps	n.o.	a-c, s	2.60	0.26	
Source	ECI MSB		10	0.08	0.50	0.50	0.48	0.00				
Veg.	removed	Bt1	148-191	7.5YR3.5/4(s. damp); 7.5YR3.5/4m	SC	3mabk-pr	vh; vs, ps	3-4mkpf, 3kpo	c, w	32.37	0.75	
note			43	0.30	0.80	0.92	1.80	0.70				
		Bt2	191-248	7.5-10YR4/5d; 7.5YR3.5/4m	SC	2mabk	vh; s, p	1k&2-3mkpf, 1k&3mkpo	g, s	38.55	0.68	
			57	0.33	0.80	0.83	1.47	0.63				
		2BC	248-298	2.5Y-10YR6/6d; 10YR4/4m	L	m-2cabk	sh-h; so, ps	n.o.	a-c, s	17.01	0.34	
			50	0.28	0.60	0.50	0.67	0.00				
		2C	298-316+	2.5Y5/4m	fSL	bedded-2-3fabk	sh-h; po, ps	n.o.		0.00	0.00	Common Carb in pores & as filaments
			18	0.00	0.00	0.00	0.00	0.00				
									SDI @ 316cm =	100.90		
									SDI @ 250cm =	83.88		
		Bt thickness	100.00						SDI @ 300cm =	100.90		
									SDI @ 350cm =	100.90		

Table C-2

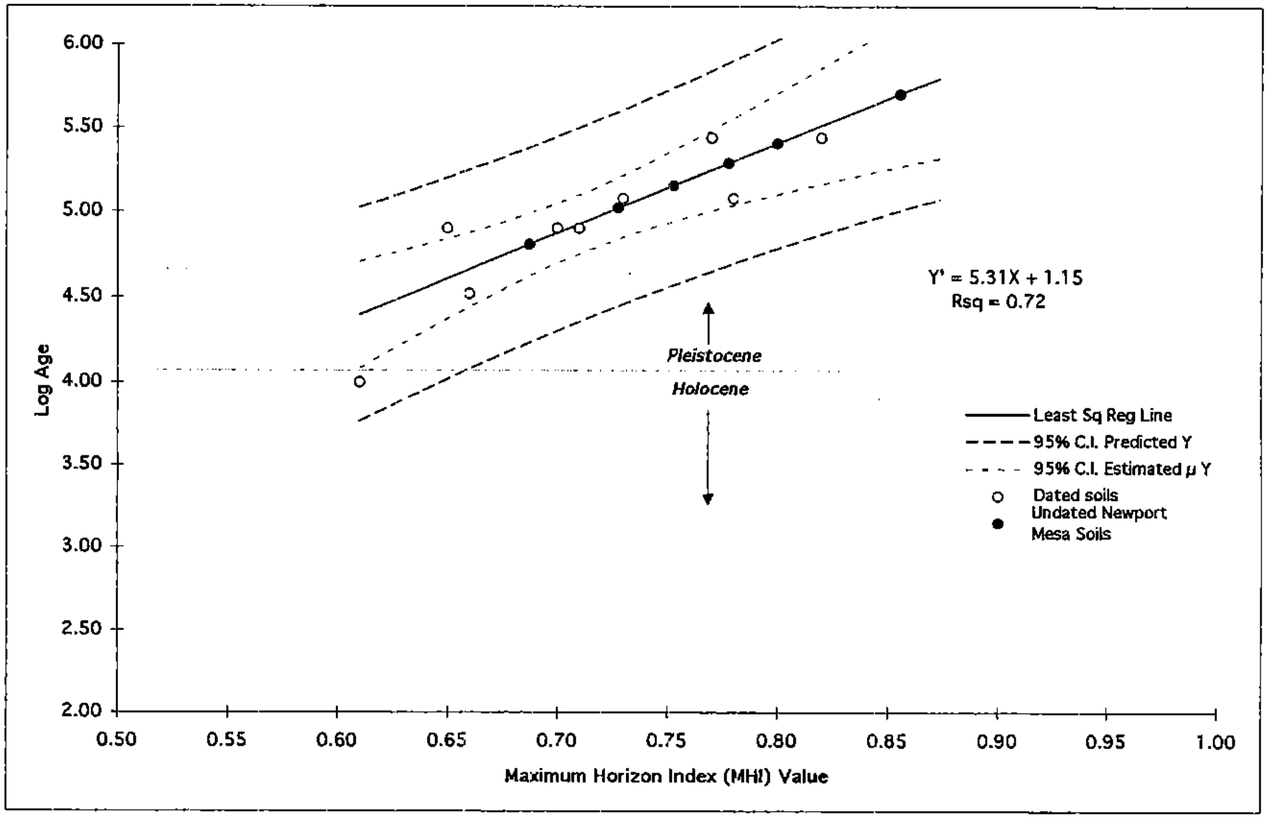
Laboratory Results for Particle Size Distribution and Bulk Density, Trench T-2

Labratory Results for Particle Size Distribution and Bulk Density

Sample T-2 Profile 1	% Sand	% Silt	% Clay	Bulk Density (g/cc)
AE 0-28	56.10	22.56	21.33	1.73
BTI 28-98	53.52	29.23	17.25	1.99
BTI 98-160	53.63	23.66	22.71	2.05
BT2 160-196	65.99	14.69	19.32	1.97
2BC 196-226	35.44	51.33	13.22	1.81
3BC 226-262	75.90	12.16	11.94	1.84
4C 262-287	67.90	21.52	10.58	1.78
5C 287-330+	27.96	57.10	14.93	1.51

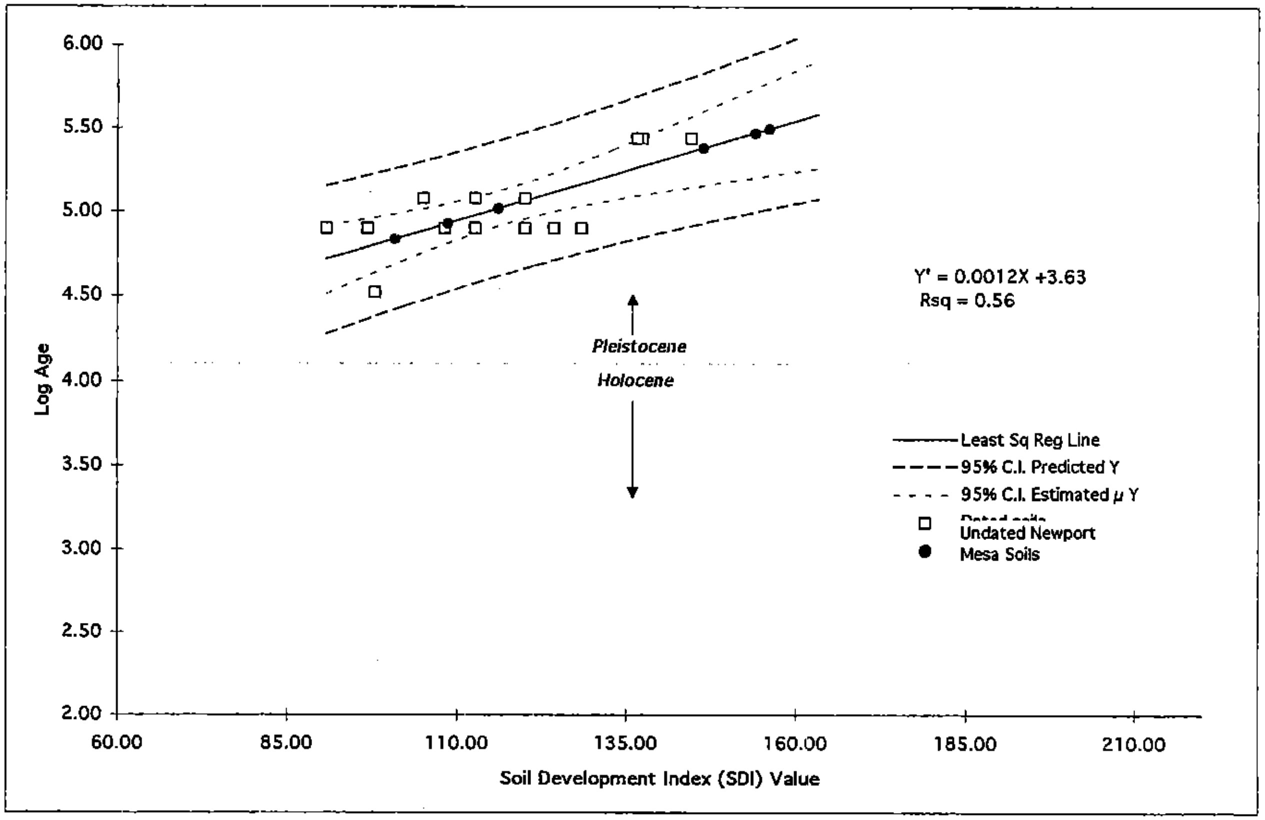
Sample T-2 Profile 2	% Sand	% Silt	% Clay	Bulk Density
AE 0-40	49.61	40.26	10.13	1.54
BTI 40-112	47.67	23.68	28.65	2.04
BT2 112-132	65.03	16.18	18.78	1.99
2BT3 132-152	38.45	34.52	27.04	2.04
3BT4 153-174	65.44	20.01	14.55	1.85
4BC 174-224	62.99	25.40	11.62	1.79
5C 224-280+	13.72	62.25	24.03	1.56

Chart A
Maximum Horizon Index Values



Profile	MHI	Log Age	Max Error in μ of Y	Min Error in μ of Y	Max Error in Y pop.	Min Error in Y pop.	Age (yrs)	95% Predicted Age C.I. Max	95% Predicted Age C.I. Min
T-1 Profile 1	0.69	4.81	4.99	4.63	5.38	4.23	64,258	240,415	17,175
T-1 Profile 2	0.80	5.41	5.71	5.10	6.03	4.78	254,782	1,066,713	60,854
T- 2 Profile 1	0.73	5.02	5.20	4.84	5.59	4.45	105,223	393,516	28,136
T- 2 Profile 2	0.78	5.29	5.54	5.03	5.89	4.69	194,087	773,637	48,692
T- 3c Profile 1	0.86	5.70	6.13	5.27	6.40	5.01	503,033	2,493,409	101,485
T- 9a Profile 1	0.75	5.16	5.16	5.16	5.70	4.61	142,907	499,896	40,853

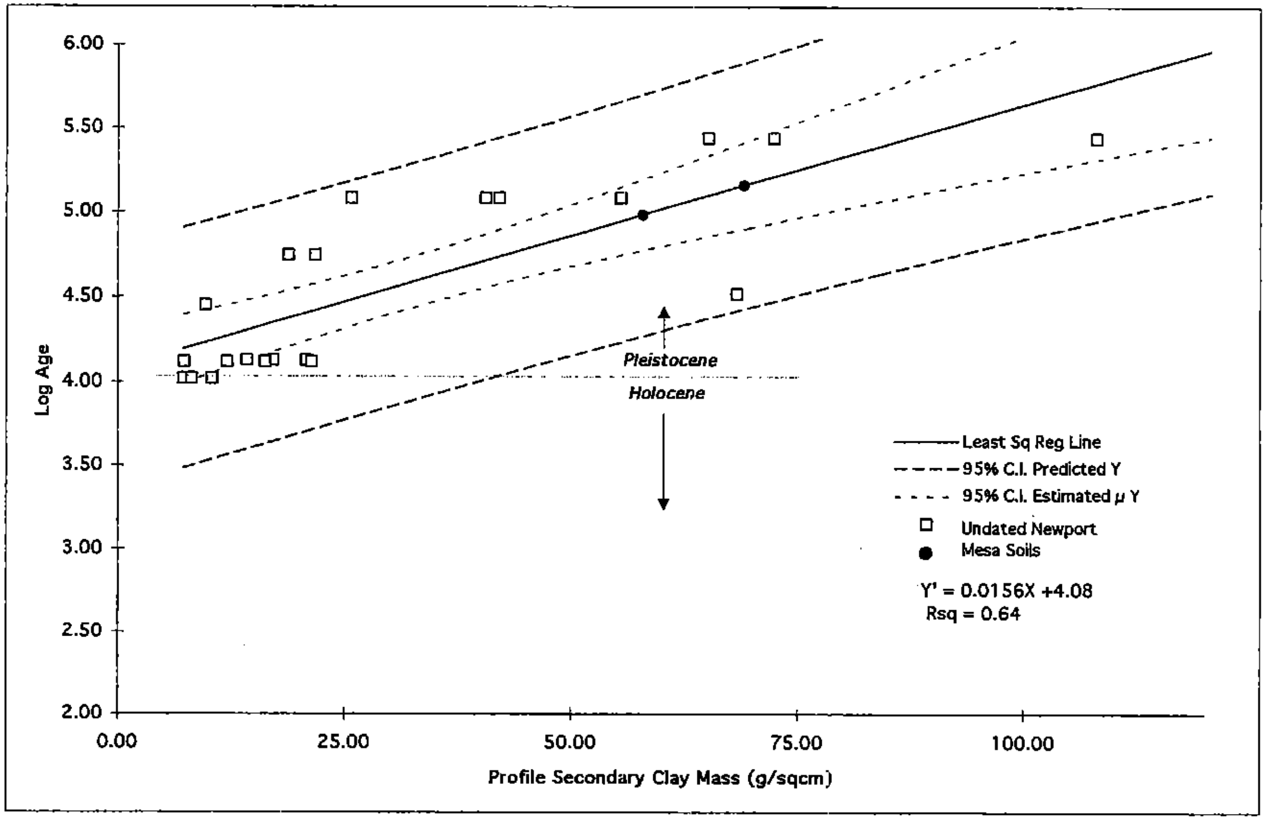
Chart B
Soil Development Index Values



Normalized
Depth nd = 300 cm

Profile	SDI	Log Age	Max Error in μ of Y	Min Error in μ of Y	Max Error in Y pop.	Min Error in Y pop.	Age (yrs)	95% Predicted Age C.I. Max	95% Predicted Age C.I. Min
T-1 Profile 1	154.02	5.47	5.74	5.20	5.95	5.00	297,379	886,561	99,750
T-1 Profile 2	156.02	5.50	5.78	5.22	5.98	5.02	314,236	952,182	103,703
T- 2 Profile 1	146.34	5.38	5.60	5.16	5.83	4.93	240,687	678,231	85,414
T- 2 Profile 2	116.09	5.02	5.12	4.91	5.42	4.61	104,597	265,749	41,169
T- 3c Profile 1	108.72	4.93	5.05	4.81	5.34	4.52	85,387	218,716	33,335
T- 9a Profile 1	100.90	4.84	4.84	4.84	5.23	4.45	68,833	169,428	27,964

Chart C
Profile Secondary Clay Mass Values



Normalized
Depth nd = 300 cm

Profile	PSCM	Log Age	Max Error in μ of Y	Min Error in μ of Y	Max Error in Y pop.	Min Error in Y pop.	Age (yrs)	95% Predicted Age C.I. Max	95% Predicted Age C.I. Min
T-2 Profile 1	57.93	4.99	4.99	4.99	5.67	4.30	96,636	466,377	20,024
T-2 Profile 2	69.10	5.16	5.16	5.16	5.84	4.48	144,387	696,825	29,918