LAW/CRANDALL, INC.

geotechnical, environmental & construction materials consultants

REPORT OF
PRELIMINARY GEOTECHNICAL INVESTIGATION
METRO PASADENA LINE
UNION STATION TO THE BROADWAY BRIDGE

FOR

PARSONS BRINCKERHOFF/
DANIEL, MANN, JOHNSON & MENDENHALL

(L92045.AE1)

JUNE 24, 1992

LAW/CRANDALL, INC. ▲ geotechnical, environmental & construction materials consultants
200 Citadel Drive, Los Angeles, California 90040-1554, Phone (213) 889-5300, Fax (213) 721-6700
Los Angeles ▲ Anaheim ▲ Los Alamitos ▲ Marina del Rey ▲ Riverside ▲ San Diego

[illegible]

77

June 24, 1992

Parsons Brinckerhoff/
Daniel, Mann, Johnson & Mendenhall
707 Wilshire Boulevard, Suite 2900
Los Angeles, California 90017

Client Ref. #R05CA 100
(L92045.AE1)

Attention: Mr. Erik Collett
Project Manager

Ladies/Gentlemen:

We are pleased to submit our "Report of Preliminary Geotechnical Investigation, Metro Pasadena Line, Union Station to the Broadway Bridge, for Parsons Brinckerhoff/Daniel, Mann, Johnson & Mendenhall." The scope of our work was performed in general accordance with our proposal of February 25, 1992, which was authorized by Ms. Stevie Tabb of Parsons Brinckerhoff/Daniel, Mann, Johnson & Mendenhall on February 25, 1992. A draft report covering our concurrent Phase I environmental site assessment was submitted on May 21, 1992.

The accompanying report presents the details of our investigation and preliminary recommendations for your use in design.

We appreciate the opportunity to provide this service for you. Please call if you have any questions or need further information.

Respectfully submitted,

LAW/CRANDALL, INC.

Jake Kharraz
Principal Engineer

Registered Professional Engineer
Jake Kharraz
No. 2087
Exp. 9-30-95
Geotechnical
State of California

Paul Elliott

Paul Elliott, C.E.G. 1435
Senior Engineering Geologist

Paul Elliott
#1435
Certified Engineering Geologist
State of California

Monte E Ray

Monte E. Ray, C.E.G. 918
Principal Engineering Geologist

Registered Geologist
Monte E. Ray
No. 918
Certified Engineering Geologist
State of California

Marshall Lew

Marshall Lew, Ph.D.
Project Manager
Vice President

Registered Professional Engineer
Marshall Lew
No. 522
Exp. 3-31-96
Geotechnical
State of California

aef/act
(20 copies submitted)

TABLE OF CONTENTS

Text — Page No.

1.0 Introduction 1
  1.1 General 1
  1.2 Purpose of Investigation 1
  1.3 Scope of Work 2
  1.4 Report Structure 2
  1.5 Limitations and Basis for Recommendations 3

2.0 Project Description 4

3.0 Project Geology 6
  3.1 Physical Setting 6
  3.2 Geologic Materials 6
  3.3 Ground Water 8
  3.4 Geologic Structure 13
  3.5 Geologic Hazards 13

4.0 Field Exploration and Laboratory Testing 20
  4.1 Field Exploration Program 20
  4.2 Laboratory Testing 20

5.0 Subsurface Conditions 21

6.0 Conclusions and Preliminary Recommendations 22
  6.1 Feasibility 22
  6.2 Foundations 22
  6.3 Walls Below Grade 25
  6.4 Tracks On Grade 25
  6.5 Grading 25
  6.6 Slope Stability 26

Appendix A - Explorations and Laboratory Tests
Appendix B - Chain of Custody and Laboratory Tests
Appendix C - Geologic and Seismic Data

TABLE OF CONTENTS (Continued)

Tables	Page No.
1. Summary of Soil Analysis (Hydrocarbons)	12
2. Summary of Ground Water Analyses for Title 22 Metals	12
C-1 Criteria for Classification of Faults with Regard to Seismic Activity	C-2
C-2 Major Named Faults Considered to be Active in Southern California	C-3
C-3 Major Named Faults Considered to be Potentially Active in Southern California	C-4
Computer Printout of Earthquakes (After Appendix C)	

Plates	Plate No.
Plan and Profile	1.1 – 1.4
Geologic Map	2
Regional Geology	3
Regional Seismicity	4
Recurrence Curve	5
Log of Boring	A-1.1 – A1.10
Unified Soil Classification System	A-2
Direct Shear Test Data	A-3.1
Triaxial Shear Tst Data	A-3.2
Consolidation Test Data	A-4.1 – A-4.4
Compaction Test Data	A-5
Mechanical Analysis	A-6.1 – A-6.3
Monitoring Well Construction Details	A-7.1 and A-7.2

REPORT OF

PRELIMINARY GEOTECHNICAL INVESTIGATION

METRO PASADENA LINE

UNION STATION TO THE BROADWAY BRIDGE

FOR

PARSONS BRINCKERHOFF/

DANIEL, MANN, JOHNSON & MENDENHALL

SECTION 1.0
INTRODUCTION

1.1 GENERAL

This report presents the findings, conclusions, and recommendations of a preliminary geotechnical investigation performed to assist in the preliminary design of the proposed Metro Pasadena Line. The preliminary geotechnical investigation and related work discussed in this report covers the Metro Pasadena Line starting at Union Station and extending to the Broadway Bridge at the Los Angeles River. The Metro Pasadena Rail Line will have an aerial structure from Union Station to the Chinatown Station, and into the Southern Pacific (SP) Cornfield Property. The alignment will be at grade along the base of a slope to the Broadway Bridge. A yard and shops area will be located in the northern portion of the SP Cornfield Property. The locations of proposed alignment and our exploration borings are shown on Plates 1.1 through 1.4, Plan and Profile.

1.2 PURPOSE OF INVESTIGATION

The investigation was authorized to evaluate the geotechnical conditions along the alignment with regard to their possible effects on the planned construction. More specifically, the investigation included the following objectives:

- To evaluate the existing surface and subsurface conditions, including the soil and ground water conditions, along the proposed alignment.
- To define the geologic environment and evaluate geologic/seismic hazards that may affect the project.
- To evaluate environmental conditions that may impact the project.
- To provide preliminary design recommendations.

1.3 SCOPE OF WORK

The scope of work for this geotechnical investigation included the following major tasks:

- Review of existing available geotechnical information
- Geologic and seismic studies
- Environmental Assessment
- Field explorations
- Laboratory testing
- Engineering analyses
- Preparation of geotechnical report

1.4 REPORT STRUCTURE

The report has been divided into six basic sections, and three appendices.

Section 1, Introduction: purpose, scope, report structure, and limitations.

Section 2, Project Description: structural features of project.

Section 3, Project Geology: geologic and seismic information and evaluation.

Section 4, Field Explorations and Laboratory Tests: field and laboratory work and prior studies used in our analyses.

Section 5, Subsurface Conditions: subsurface conditions along the alignment and in the yard and shops area.

Section 6, Conclusions and Recommendations: conclusions and preliminary design parameters for foundations and walls below grade, and preliminary recommendations for tracks-on-grade and grading.

Appendix A - Field Explorations and Laboratory Tests
Appendix B - Chain-of-Custody and Laboratory Analytical Results
Appendix C - Geologic and Seismic Data

1.5 LIMITATIONS AND BASIS FOR RECOMMENDATIONS

Our professional services have been performed using that degree of care and skill ordinarily exercised, under similar circumstances, by reputable geotechnical engineers practicing in this or similar localities. No other warranty, expressed or implied, is made as to the professional advice included in this report. This report has been prepared for Parsons Brinckerhoff/Daniel, Mann, Johnson & Mendenhall as part of their evaluation of the proposed Metro Pasadena Line. The report has not been prepared for use by other parties, and may not contain sufficient information for purposes of other parties or other uses.

The recommendations provided in this report are preliminary and are based upon our understanding of the described project information and on our interpretation of the data collected during the subsurface exploration. We have made our recommendations based upon experience with similar subsurface conditions under similar loading conditions. The recommendations apply to the specific project discussed in this report; therefore, any change in the alignment or project features should be provided to us so that we may review our conclusions and recommendations and make any necessary modifications.

SECTION 2.0
PROJECT DESCRIPTION

The first phase of the proposed Metro Pasadena Line begins at Union Station to the south and ends at the Broadway Bridge to the north, a distance of about 1.5 miles.

The alignment begins at Platform No. 1 at Union Station and extends north on the east side of the Terminal Annex Post Office. Next, the alignment diverges off the existing rail track and crosses the existing asphalt paved parking lot behind the Terminal Annex building. The alignment continues within the parking lot paralleling the south side of the Vignes Street until reaching the intersection with Main Street. At the southeast corner of Main and Vignes Streets, the alignment intersects the northern portion of an abandoned building at 1081 North Vignes Street. From there, the proposed alignment crosses Main Street in a northwesterly direction, crossing an existing parking lot until it meets Alameda Street. The alignment then parallels Alameda Street near the eastern curb line and eventually crosses over to Spring Street and into the westerly edge of the SP Cornfield Property. After that, the alignment proceeds northerly, eventually paralleling the base of a steep embankment that separates the SP Cornfield Property from Broadway. This portion of the alignment ends at the Broadway Bridge.

The Metro Pasadena Line will have an aerial structure from the Union Station area to the Chinatown Station, and into the SP Cornfield Property. The alignment will be at grade along the base of the slope to the Broadway Bridge. There will be two stations, one located at Union Station and the other in Chinatown at the intersection of College and Alameda Streets. Retaining walls and abutments will be required where the structure alignment ascends from and descends to the at-grade track bed.

A yard and shops area will be located in the northern portion of the SP Cornfield Property.

Topography of the alignment reflects the flat valley terrain along the west side of the Los Angeles Narrows and varies in elevation from about 290 at the south end to about 310 at the north end.

SECTION 3.0
PROJECT GEOLOGY

3.1 PHYSICAL SETTING

The proposed alignment will be located within the Los Angeles Basin at the northerly end of the Peninsular Ranges geomorphic province. This geomorphic province is characterized by northwest trending fold belts and fault zones. The alignment is located southeast of the Elysian Park Hills and west of the Los Angeles River.

The major geologic structural feature in the area is the Elysian Park Fold and Thrust Belt, which is reflected at the surface by the nearby Elysian Park Hills. The alignment is located entirely within this fold and thrust belt.

The relationship of the rail transit alignment to local and regional geologic features is shown on Plate 2, Geologic Map, and Plate 3, Regional Geology. The alignment is shown in relation to geomorphic provinces, major fault zones, and earthquake epicenters on Plate 4, Regional Seismicity.

3.2 GEOLOGIC MATERIALS

3.2.1 General

The proposed alignment is underlain by geologic units consisting of sedimentary bedrock of the Puente Formation, older and younger alluvial deposits, and artificial fill. The areal extent of the geologic materials in the vicinity of the alignment is shown on Plate 2.

3.2.2 Puente Formation, Sandstone Member (Tpss)

Marine sedimentary bedrock of the late Miocene age Puente Formation is exposed along the flanks of the Elysian Park Hills adjacent to the northerly end of the alignment.

The Puente Formation in this area has been defined and mapped by Lamar (1970) as the siltstone and sandstone members of the Puente Formation. Adjacent to the alignment, these materials consist of light brown massive to thickly bedded sandstone with minor grey and brown interbeds of siltstone and shale. This sandstone member is generally moderately to well cemented and moderately hard. The Puente Formation was encountered in Borings 1, 3 and 7 through 10 at depths of 63, 51, 34½, 8, 17, and 9½, respectively.

3.2.3 Older Alluvial Deposits (Qalo)

The older alluvium underlies the younger alluvium and is exposed in the slope adjacent to the northerly portion of the alignment. These materials form a dissected alluvial terrace on either side of the Los Angeles River channel. The older alluvial materials were observed in Borings 3 through 9, and consist primarily of brown to grayish brown clayey silt and silty sand with gravel.

3.2.4 Younger Alluvial Deposits (Qal)

The younger alluvium has been deposited within the drainages which have dissected the older alluvium. These deposits are Holocene in age and directly underlie most of the alignment. The younger alluvium was observed in Borings 1 through 6, and 10. These materials consist of silt, silty sand, sand, and gravelly sand.

3.2.5 Artificial Fill (af)

Portions of the alignment are locally underlain by artificial fill. Fill was observed in Borings 1 and 4 through 10, ranging from 3 to 14½ feet in depth. These materials consist of silt, fine to coarse-grained sand and silty sand with some gravel and cobbles. Pieces of brick, asphaltic paving, glass, and metal debris were locally encountered in the fill.

3.3 GROUND WATER

3.3.1 General

The proposed transit alignment is located within the Central Hydrologic Subarea of the Coastal Plain of the Los Angeles County Hydrologic Subunit. Holocene age continental alluvial deposits of the Gaspur aquifer underlie most of the proposed alignment. The Gaspur aquifer is approximately 50 to 100 feet thick in the project area and is underlain by older alluvium and marine sedimentary rocks of the Miocene age Puente Formation. The Puente Formation bedrock is considered non-waterbearing. Water within this formation typically occurs as seepage along joints, bedding or coarse grained layers within the rock.

3.3.2 Ground Water Occurrence

The occurrence of ground water along the proposed alignment has been evaluated using regional ground water data and by direct measurement of water levels encountered in our current exploratory borings. Previous data include water level measurements by Los Angeles County Department of Public Works (LACDPW) (1934 to 1988), regional water level information from the U. S. Geological Survey (1977), water level information from Levine•Fricke (1989 to 1991), and water level measurements from previous exploratory borings drilled in the vicinity of the alignment by us and by others.

Water level measurements by the LACDPW indicate the depth to ground water in the area has historically been about 30 to 40 feet beneath the ground surface in the vicinity of the proposed alignment. These records also indicate that ground water levels reported by LACDPW are generally more shallow near the northern terminus of the alignment than near the southern terminus of the alignment. The highest recorded water levels in the area over the past 58 years were at a depth of about 24 feet in 1980 in Well No. 2772D and 26 feet in 1938 in Well No. 2774F situated 0.4 mile north and 0.4 mile east of the alignment, respectively.

Regional data compiled by the U. S. Geological Survey (Yerkes et al., 1977) indicate ground water levels in 1977 ranged from a depth of 23 feet beneath the northern part of the alignment to a depth of about 40 feet beneath the southern part of the alignment. These ground water levels are consistent with LACDPW data that indicate water levels are generally deeper beneath the southern terminus of the alignment relative to the water levels beneath the northern terminus.

Ground water levels were measured in monitoring wells installed during a previous investigation by Levine•Fricke near the southern terminus of the alignment. These wells indicate a rise in the water level of about 6 feet, from 43 to 37 feet below ground surface (approximate water surface elevations of 242 to 248 feet above sea level) during a 17-month (December 1989 to April 1991) monitoring period (Levine•Fricke, 1989, 1991). The rise in the water level noted in the monitoring wells is probably attributable to a cessation of temporary construction dewatering in the area and, to some degree, to the influence of heavy rains in March 1991. Dewatering was conducted between August 1988 and June 1990 during construction of the Metro Red Line Tunnel, which extends beneath the southern part of the alignment. These ground water levels are consistent with regional ground water levels compiled by the U.S. Geological Survey (1977) that indicate the depth to water near the southern terminus of the alignment is about 40 feet.

A review of logs of borings drilled for previous projects (1983 to 1991) near the southern terminus of the alignment indicate that ground water occurred at a depth of about 30 to 33½ feet below the ground surface, which corresponds to water surface elevations of between 244 and 250 feet above sea level.

3.3.3 Current Water Level Measurements

Data from our current exploratory borings indicate that ground water beneath the alignment is generally confined to the Holocene age alluvial deposits; only minor seepage was encountered in the Pleistocene age alluvial deposits and the Miocene age Puente

Formation bedrock. The depth to ground water encountered in our exploratory borings ranged from 16½ feet in Boring 10 to 40 feet in Boring 1. These depths correspond to water surface elevations of 253 to 292½ feet above mean sea level.

Borings 8 and 10 encountered shallow bedrock at depths of 8 and 9½ feet beneath the existing ground surface, respectively. Since the bedrock is considered non waterbearing, the water encountered in these borings is believed to represent a perched condition.

Borings 7 and 9 were drilled on top of the bluff adjacent to Broadway Street. These borings were drilled for slope stability evaluation purposes and are elevated approximately 40 feet above the proposed alignment. Seepage encountered in these borings is also believed to represent perched water conditions. Ground water was not encountered in Boring 5 drilled to a total depth of 30 feet below the existing ground surface, corresponding to an elevation of 270 feet.

Ground water monitoring wells (piezometers) were constructed in Borings 1, 3 and 10 drilled to a depth of 100 feet. The wells were constructed by installing 2-inch diamter PVC well casing in each of the three borings. Detailed descriptions of the piezometer installations are presented on the boring logs, and the details of the well construction are presented on Plates A-7.1 and A-7.2 of Appendix A.

Ground water levels were measured in the wells on May 5 and 25, 1992; the measurements are tabulated below.

Boring	Depth of Water Level (feet)	
	May 5, 1992	May 25, 1992
1	not measured	40
3	21½	21½
10	16½	16½

As previously indicated, the ground water level in Boring 10 is believed to represent a perched water condition within the bedrock materials beneath the northern portion of the alignment.

About 5 inches of floating oil was noted in the monitoring well installed in Boring 3 on May 25, 1992 during our second ground water measurement. Oil was not observed during our initial measurement on May 5, 1992. It appears that naturally occurring petroleum may have seeped into the monitoring well from oil bearing strata in the vicinity of the well.

3.3.4 Water Quality

Water quality data collected during the exploration program are summarized in Table 1, Summary of Soil Analysis (Hydrocarbons), and Table 2, Summary of Ground Water Analyses for Title 22 metals (hazardous metals listed in Title 22 of the California Administrative Code). Chain-of-Custody documents and analytical results are presented in Appendix B.

As shown, the sample from Boring 3 had a concentration of benzene (a volatile aromatic hydrocarbon) of 1.0 (μg/L), which is at the California Department of Health Services' Maximum Contaminant Level (MCL) for this compound. Trace concentrations of toluene (0.7μg/L) and total xylene isomers (1.4 μg/L) were detected from the ground water sample obtained from Boring 10; neither of these concentrations exceed the MCL for these compounds. Additionally, no elevated concentrations of petroleum hydrocarbons or Title 22 metals were detected in either sample.

Table 1
Summary of Soil Analysis (Hydrocarbons)

Well Number	Total Fuel Hydrocarbons (8015) (mg/kg)	Petroleum Hydrocarbons (418.1) (mg/kg)	Benzene (8020) (μg/kg)	Ethyl-benzene (8020) (μg/kg)	Toluene (8020) (μg/kg)	Total Xylene Isomers (8020) (μg/kg)
Boring 3	<100	0.2	1.0	<0.5	<0.5	<1.0
Boring 10	<100	<0.2	<0.5	<0.5	0.7	1.4
California State MCL	None	None	1.0 μg/L	680 μg/L	100 μg/L	1,750 μg/L

NOTES: 1.(<) indicates concentration below indicated detection limit.
2.(mg/kg) milligrams per kilogram; (μg/kg) micrograms per kilogram.
3.(8015), (418.1), (8020) = EPA Methods of Analysis

Table 2
Summary of Ground Water for Title 22 Metals

	Boring 3	Boring 10	MCL
Arsenic	<0.002	0.002	0.05
Antimony	0.06	<0.06	---
Barium	0.93	0.098	1.0
Cadmium	<.001	<0.001	0.01
Chromium	<0.005	<0.005	0.05
Cobalt	0.13	<0.04	---
Copper	<0.02	<0.02	---
Lead	0.005	0.016	0.05
Mercury	<0.0005	<0.0005	0.002
Molybdenum	<0.04	<0.4	---
Nickel	0.07	<0.04	---
Selenium	<0.005	<0.005	0.01
Silver	<0.01	<0.01	0.05
Thallium	<0.4	<0.4	---
Vanadium	<0.04	<0.04	---
Zinc	.29	0.05	---

NOTES: All concentrations in milligrams per liter (mg/L).
< = less than
--- = not detected
MCL = Maximum Contaminant Level

3.4 GEOLOGIC STRUCTURE

The site lies within the Elysian Park Fold and Thrust Belt defined by Hauksson (1990). The feature consists of a sequence of northwest trending folds and faults. The geologic structure in the vicinity of the proposed alignment is shown on Plate 2.

Along the northerly portion of the alignment, bedrock is exposed within the slopes, adjacent to the alignment. Within this area bedding is generally consistent, striking north 60 degrees west to east-west with dips of 45 to 55 degrees to the south and southwest.

A northeast-trending potentially active, high angle normal fault is postulated to traverse the proposed alignment in the vicinity of the Broadway Street Bridge, Bulletin 104 (1961). However, no evidence for the presence of this fault was found during our field investigation. Geologic mapping in the vicinity of the inferred fault trace and exploratory borings drilled on either side of the inferred fault trace provided no evidence for the existence of this fault. This fault is not shown in more recent work by Lamar (1970).

Additionally, an unnamed inactive fault mapped by Lamar (1970) trends southeasterly towards the alignment near Lei Min Way and North Broadway in Chinatown.

3.5 GEOLOGIC HAZARDS

3.5.1 General

The geologic hazards along the alignment are essentially limited to those caused by earthquakes. The major cause of damage from earthquakes is the result of shaking from earthquake waves. Damage due to actual displacement or fault movement beneath a structure is much less frequent.

3.5.2 Seismic Hazards

Surface Rupture

The numerous faults in Southern California include active, potentially active, and inactive faults. Detailed information concerning the faults is presented in Appendix C.

No known active or potentially active faults with evidence of surface rupture pass beneath the alignment, nor is the alignment located within an established Alquist-Priolo Special Studies Zone for fault rupture hazard. In our opinion, there is little probability of surface fault rupture occurring beneath the proposed alignment.

The closest active fault to the alignment is the Raymond fault, about 3.3 miles to the north-northeast. The Raymond fault is a high-angle reverse fault that thrusts basement rocks north of the fault over alluvial sediments south of the fault. Other nearby major active fault zones that could cause significant ground shaking along the alignment include the Newport-Inglewood fault zone about 8.5 miles to the west-southwest. The active San Andreas fault zone, along which the largest historic earthquakes in California have occurred, is located about 33.5 miles northeast of the alignment at the nearest point. The alignment is within the postulated limits of the Elysian Park Fold and Thrust Belt, a series of deep buried thrust faults that do not extend to the ground surface.

The closest potentially active fault to the site is the Santa Monica-Hollywood fault zone approximately 3.8 miles north-northwest of the alignment. The potentially active Eagle Rock - San Rafael fault zone is located 5 miles north of the alignment, and the Verdugo fault is located approximately 5.2 miles north. Other potentially active faults relatively near the alignment include the Overland and Charnock faults. A northeast trending unnamed potentially active fault has been postulated to traverse the proposed alignment in the vicinity of the Broadway Street Bridge (Yerkes et al., 1977).

Ground Shaking

Ground shaking is caused largely by waves generated by earthquakes. The intensity of the ground shaking generally depends on distance from the causative fault and the response of the individual geologic unit underlying the site. Generally, the younger and less consolidated the deposit, the greater the intensity of ground shaking within the unit.

A database search of regional seismicity as compiled by the California Institute of Technology was performed. The epicenters of earthquakes with magnitude equal to or greater than 4.0 within a radius of 100 kilometers (62 miles) of the alignment are shown in a table at the end of Appendix C; other pertinent information regarding these earthquakes is also shown in this printout.

The database search indicates that 326 earthquakes of Richter magnitude 4.0 and greater have been recorded within 100 kilometers (62 miles) from the center of the alignment during the period from 1932 to 1991. The earthquake recurrence curve based on that information is presented on Plate 5, Recurrence Curve.

Liquefaction and Seismically-Induced Settlement

The evaluation of the liquefaction potential of the soils along the alignment involved the estimation of the potential loss of shear strength during earthquakes of saturated cohesionless soils that may affect the project. The significant factors that may affect liquefaction include the soil types, particle size and gradation, water level, relative density, confining pressure, intensity of shaking, and duration of shaking. Studies indicate that the liquefaction potential is the greatest where the ground water level is shallow and loose, fine sands occur within a depth of 40 to 50 feet. The liquefaction potential increases as the ground acceleration and duration of shaking increase.

As noted in our exploratory borings, the alignment is generally underlain by dense and firm silty sand and sand, with gravel. The silty sand and sand are underlain by consolidated sandstone and siltstone of the Puente Formation. Standard penetration tests conducted during our site exploration indicate the sandy deposits have relative densities greater than 80%; therefore, the possibility of liquefaction occurring beneath the site is judged to be low.

Seismically induced differential settlement is also not considered a potential problem.

3.5.3 Non-Seismic Hazards

Slope Stability

The ground surface within the southerly half of the alignment slopes gently to the east. This portion of the alignment is not located within a slope stability study area as designated by the City of Los Angeles Seismic Safety Plan (1975). Therefore, the potential for slope stability problems or lurching (movement at right angles to a steep slope during strong ground shaking) in the southerly half of the alignment is considered very low.

The northerly half of the alignment is located within a City of Los Angeles Slope Stability Study Area. An east-facing slope occurs adjacent to and along the westerly edge of the alignment north of the intersection of the alignment with Spring Street. The slope varies from about 25 to 45 feet high with a gradient varying from about 1½:1 (horizontal to vertical) with some localized zones as steep as 1:1. The slope is underlain by older alluvial materials throughout most of the northerly portion of the alignment. However, artificial fill locally underlies portions of the slope and the sandstone bedrock underlies the slope near the Broadway Bridge.

The older alluvial materials exposed in the slope face are horizontally stratified. These materials lack any well-defined planar features or discontinuities (such as bedding or joints) which could act as planes of weakness. This condition is considered favorable for gross stability from a geologic standpoint. However, the slope is prone to surficial instability as evidenced by surficial sloughing and erosion. Such surficial instability is not considered a serious problem and can be mitigated by proper design and construction during development.

The bedrock materials in the vicinity of the alignment dip 45 to 55 degrees to the south and southwest toward the slope face. Because the dips are steep, the bedding is not unsupported and is therefore favorable with respect to the gross (deep-seated) stability of the slopes.

Based on our preliminary investigation and stability calculations, the slope adjacent to the northerly portion of the alignment exhibit factors-of-safety of about 1.5 with respect to gross stability. However, there is a potential for surficial failures and lurching. Additionally, the northerly portion of the alignment is not within the path of any known landslides.

Flooding, Tsunamis, and Seiches

The alignment extends across a "Zone C" flood hazard area, as designated by the Federal Insurance Administration. "Zone C" refers to areas of minimal flood hazard.

The alignment is at elevations of about 290 to 310 feet above mean sea level and is located about 14 miles east-northeast of the Pacific Ocean. Earthquake-generated sea waves, called tsunamis, are not a potential problem at this site.

According to the revised draft of the County of Los Angeles Seismic Safety Element (1990), the alignment is located within an inundation area as a result of earthquake-induced failure and seiches (oscillating waves that form in an enclosed body of water) from Sepulveda Dam, Hansen Dam, or the Elysian Reservoir Dam.

These dams, as wells as other dams in California, is continually monitored by various governmental agencies (such as the Army Corps of Engineers and the California Division of Safety of Dams) to guard against the threat of dam failure. The possibility of dam failures during an earthquake has been addressed by the California Division of Mines and Geology in the earthquake planning scenarios for a magnitude 8.3 earthquake on the San Andreas fault (Davis, et al., 1982) and a magnitude 7.0 earthquake on the Newport-Inglewood fault (Toppozada, et al., 1988). As stated in both reports, Catastrophic failure of a major dam as a result of the scenario earthquake is regarded as unlikely. Current design and construction practices, and ongoing programs of review, modification, or total reconstruction of existing dams are intended to ensure that all dams are capable of withstanding the Maximum Credible Earthquake (MCE) for the site.

Subsidence and Oil Wells

The Los Angeles City Oil Field is located within approximately 100 feet of the alignment. Additionally, the Union Station Oil Field and the Los Angeles Downtown Oil Field are located 0.5 mile north and 2 miles northeast of the alignment, respectively. Subsidence associated with petroleum production has been identified in some of the oil fields in the Los Angeles Basin; however, subsidence has not been identified in the Los Angeles City Oil Field, the Union Station Oil Field, or the Los Angeles Downtown Oil Field. Consequently, the potential for future subsidence within the three nearby oil fields is considered low.

Several known oil wells are located along the proposed alignment. These wells consist of Texaco Inc. "Southern Pacific Corehole 1," Ventura Oil Company "Freight Depot Number 1," Ventura Oil Company "Number 1," and Paul F. McKenzie "T-2". Texaco Inc. "Southern Pacific Corehole 1" is located approximately 50 feet north of the alignment near North Broadway and Solano Avenue. Ventura Oil Company "Freight Depot Number 1" is also located near Solano Avenue and North Broadway, approximately 100 feet south of the alignment. Ventura Oil Company "No. 1" is located approximately 100 feet west of the alignment near College Street and North Broadway. Paul F. McKenzie "T-2" is located approximately 150 feet west of the alignment near College Street and North Broadway. The rail alignment may encroach into the area of the "Freight Depot" wells; therefore, any oil wells encountered during construction will need to be properly abandoned in accordance with the current requirements of the California Division of Oil and Gas.

Methane Gas

Because oil wells are located within and in close proximity to the proposed alignment, there is a potential for methane and other volatile gases to occur beneath the site.

SECTION 4.0
FIELD EXPLORATION AND LABORATORY TESTING

4.1 FIELD EXPLORATION PROGRAM

The alignment was explored by drilling ten borings. Soil samples were obtained and logged by a certified engineering geologist. The locations of the borings are shown on Plates 1.1 through 1.4. The borings were drilled to depths of 30 to 100 feet below the existing grade. Piezometers were installed in three of the borings to permit water level measurements and sampling. Further details of the explorations and logs of the borings are presented in Appendix A.

4.2 LABORATORY TESTING

Each soil sample was first visually observed in the laboratory to verify the sample description and classification assigned by the field personnel. A laboratory testing program was then developed that would provide the soil parameters required in performing various engineering analyses.

The following tests were performed: moisture content and dry density determination, direct shear, triaxial shear, consolidation, compaction, Atterberg limits, and grain size distribution. The test procedures and results are presented in Appendix A.

Chemical tests were performed on water samples obtained from the piezometers to determine the presence and concentrations of chemical compounds and possible contaminants. The Chain-of-Custody documents and test results are presented in Appendix B.

Soil samples recovered from the borings and remaining after laboratory testing are stored at the laboratory of the Los Angeles Office of Law/Crandall, Inc. located at 200 Citadel Drive, Los Angeles, California 90040.

SECTION 5.0
SUBSURFACE CONDITIONS

Fill soils, 3 to about 14 feet in depth were encountered in eight of the borings. Deeper fill may occur along the alignment between boring locations. The fill soils, which consist primarily of silty sand, silt, sand, and gravel, are not uniformly well compacted and contains some debris.

The underlying overburden natural soils are younger and older alluvium deposits consisting of silt, silty sand, sand, and gravel. Varying amounts of cobbles and boulders were encountered in the sandy deposits. Bedrock of Puente Formation, consisting of interbedded siltstone and sandstone, was encountered in six of the borings at depths ranging from 8 to 63 feet below the existing grade. Except for the upper few feet, the overburden natural soils are generally firm and dense. The underlying bedrock is firm to very firm.

Water was measured at depths ranging from about 16½ to 40 feet.

Soil samples from our borings were monitored for the possible presence of Volatile Organic Compounds (VOCs). The samples were monitored in the field and in our laboratory using Gastector Model 1238 and Foxboro Model Century 126GC. In general, the majority of the samples monitored did not register any elevated organic vapor analyzer (OVA) readings. However, high OVA levels were detected in Borings 6 and 8. The results of the OVA readings are shown on borings logs in Appendix A.

SECTION 6.0
CONCLUSIONS AND PRELIMINARY RECOMMENDATIONS

6.1 FEASIBILITY

Based on our preliminary subsurface exploration and laboratory testing program, a review of available geotechnical information, and preliminary analyses, it is our opinion that it is geotechnically feasible to construct the first phase of the Rail Transit Project that extends between Union Station and the Broadway Bridge near the Los Angeles River.

The locations and structural features of the proposed Metro Pasadena Line, including the proposed bridge abutments bridge piers, and yard and shop buildings have not been established at this time, and the conclusions and recommendations presented below are preliminary and necessarily general in nature. Additional studies along the alignment will be required to provide detailed recommendations prior to preparing final plans for the project.

6.2 FOUNDATIONS

6.2.1 Spread Footings (Compacted Fill and/or Natural Soils):

There are existing fill deposits along the alignment. Also, the upper soils will be disturbed by removal of existing structures, asphaltic paving and utilities. Except the upper few feet, the natural soils beneath the site are generally firm and dense.

With proper grading, including excavation and compaction of all existing fill, typical one- or two-story structures, including minor free standing walls and retaining walls, could be supported on shallow spread footings. For preliminary design, it may be assumed that footings established on compacted fill or the underlying natural soils, at a depth of at least 2 feet beneath the adjacent grade or floor slab, may be designed to impose a net dead plus live load pressure of 2,500 pounds per square foot.

6.2.2 Spread Footings (Natural Soils)

For support of heavy or multi-story structures, including major retaining walls, spread footings should extend into the underlying undisturbed firm and dense natural soils. It may be assumed that spread footings established in the firm and dense natural soils may be designed to impose a dead plus live load pressure of 5,000 pounds per square foot. Such footings should extend at least 1 foot into the firm and dense soils and at least 2 feet below the lowest adjacent grade or floor level. Deep spread footings will be required where the depth of fill is great. All footing excavations should be inspected to confirm the presence of firm and dense soils at the design footing depth.

6.2.3 Drilled Piling

The aerial structures, including the bridge abutments and piers, may be supported on drilled cast-in-place concrete piling. Drilled piling will result in reduced settlement and will provide good foundation for resistance of seismic loads and other lateral forces. Either group piles or single large-diameter concrete piles may be used. The larger piles may be used for support of the heavier columns of the aerial structures, bridge abutments, and bridge piers, and the smaller size piles could be used to support the lighter columns.

For preliminary estimating, it may be assumed that a 6-foot-diameter drilled pile 70 feet in length would develop a downward capacity of about 1,600 kips. This capacity is based on penetration into the upper alluvial soils. Where the bedrock is at a depth of 30 feet or less below the finished grade, the capacity may be increased to 1,900 kips. The upward capacity may be assumed to be equal to one-half the downward capacity. The capacities of other sizes of piles may be assumed to be proportional to the diameter.

The proposed segment is located within areas mantled by younger and/or older alluvium deposits underlain by bedrock of Puente Formation. There are significant amounts of sand and gravel within the alluvium deposits. It should be anticipated that significant caving and sloughing may occur during excavation of the large-diameter drilled piles above the ground water table and below the water unless positive steps are taken to support the sides of the hole. Special techniques will likely be needed to satisfactorily install the piles. Casing and/or drilling mud has been used for the Metro Green Line construction in El Segundo. Casing and/or drilling mud may or may not be required, depending on the field conditions.

Only competent drilling contractors with demonstrated experience in the installation of drilled cast-in-place large-diameter piles using drilling mud and casing in similar circumstances should be considered for the pile work.

6.2.4 Driven Piling

Some of the minor and lighter columns of the aerial structures, bridge piers, and bridge abutments may be supported on driven prestressed concrete piles; batter piles may be used to increase the lateral capacities of the piles.

For preliminary estimating, it may be assumed that a 14-inch-square prestressed concrete pile driven 40 feet into the upper alluvial soils would develop a downward capacity of about 250 kips. Where the bedrock is at a shallow depth, it may be assumed that a 14-inch-square prestressed concrete pile, at least 25 feet long, would develop a downward capacity of about 250 kips if driven at least 10 feet into the bedrock. The upward capacity may be assumed to be equal to one-half the downward capacity.The capacities of other sizes of piles may be assumed to be proportional to the width.

Hard driving may be encountered within the sandy soils and underlying bedrock, and predrilling may be required. Prior to ordering production piles, we recommend that indicator piles be driven to evaluate the driving resistance. The installation of the piling should be observed by a qualified geotechnical engineer so that modifications in the driving criteria and the pile lengths can be made if required.

6.3 WALLS BELOW GRADE

For the design of the abutment and retaining walls, where the backfill is level and properly drained, it may be assumed that the soils will exert a lateral earth pressure equal to that developed by a fluid with a density of 30 pounds per cubic foot for walls up to 15 feet high. For walls greater than 15 feet high, an equivalent fluid pressure of 40 pounds per cubic foot may be used. In addition, a lateral surcharge pressure should be included in the design for any traffic surcharge. An appropriate uniform lateral pressure equal to one-third of the anticipated traffic surcharge within 10 feet of the abutment walls should be included in the wall design. Before final planning and design of the project proceeds, additional studies should be performed to provide detailed information for walls below grade.

The above recommended values are for properly drained soils; weep holes should be provided to relieve hydrostatic pressures due to water.

6.4 TRACKS ON GRADE

With proper grading, tracks on grade may be supported by the conventional system consisting of ties, ballast, and sub-ballast established on firm natural soils or properly compacted fill.

6.5 GRADING

6.5.2 General Earthwork

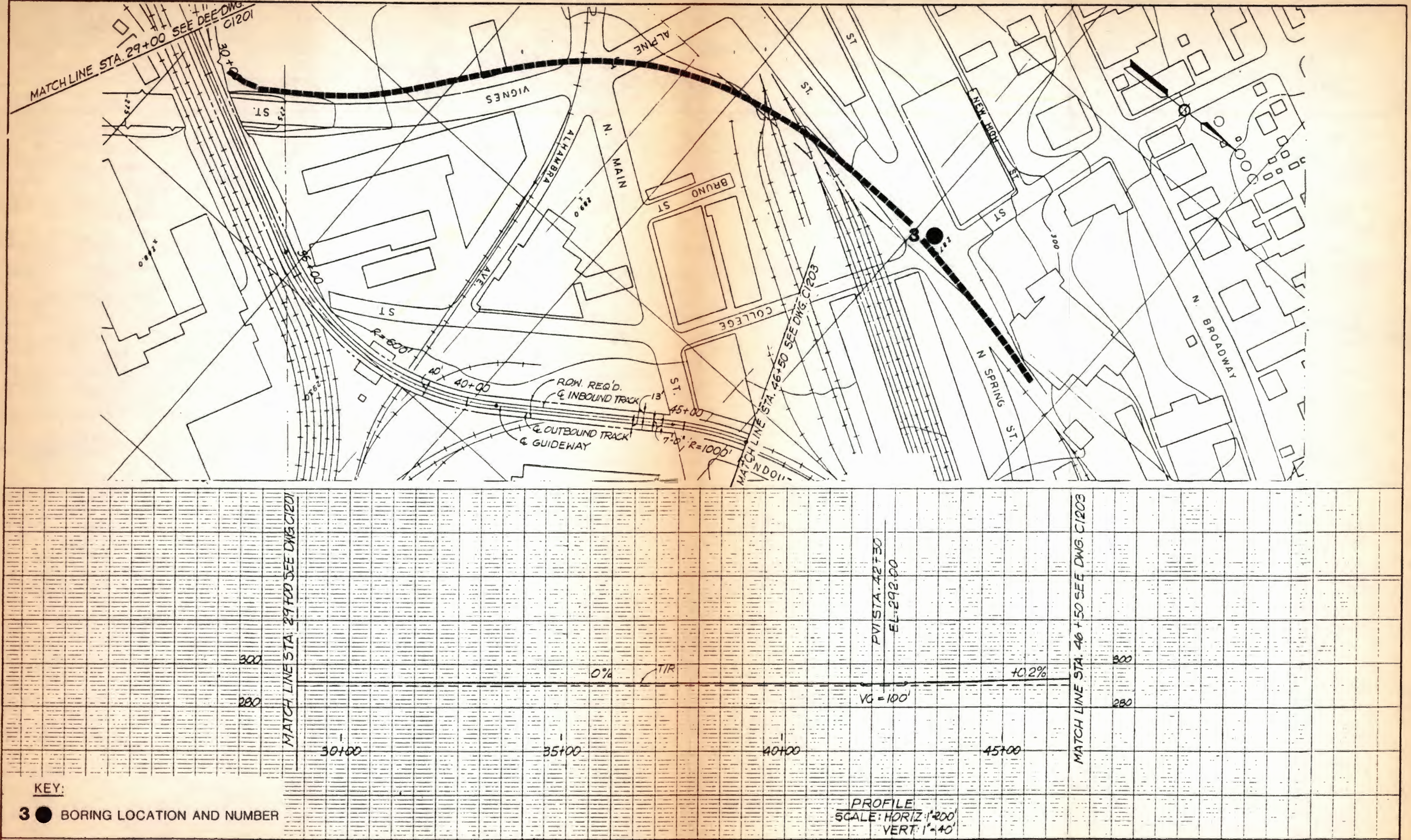
To provide support for shallow spread footings and slabs and tracks on grade, all existing fill should be excavated and replaced as properly compacted fill. Where possible, the excavation of the fill should extend at least 4 feet beyond the footings, slabs and tracks in plan.

All required fill should be compacted to 90% of the maximum density obtained by the ASTM Designation D1557-78 method of compaction. The on site soils, less debris and organic matter within existing fill deposits, would be suitable for use in compacted fills.

6.6 SLOPE STABILITY

As the alignment enters the SP Cornfield Property and proceeds northerly, the alignment parallels the base of a steep embankment that separates the SP Cornfield Property from Broadway. The embankment has an average slope of 1½:1 (horizontal to vertical). The maximum slope height is approximately 44 feet. The slope is composed of artificial fill material, alluvial material and Puente Formation. Stability analyses were performed to evaluate the potential for failure of the slopes. The results indicate that the slope is generally stable. The slope was evaluated using the computer program TSTAB, which uses Bishop's Simplified Method for analysis of circular slip surfaces. The factor-of-safety under static conditions was found to be about 1.5. Where possible, we recommend that the slopes be cut back at 2:1 (horizontal to vertical). The slopes should be protected from erosion, and surficial sloughing. A 5-foot slough wall with at least 3 feet of free board should be constructed at the toe of the slope. Periodic clean-up should be performed to remove slough material accumulated behind the slough wall.

-oOo-



KEY:

3 ● BORING LOCATION AND NUMBER

PROPOSED METRO PASADENA LINE

Designed by

Drawn by Juliana Miranda

Checked by

Approved by

LOS ANGELES COUNTY TRANSPORTATION COMMISSION

PASADENA - LOS ANGELES ROUTE REFINEMENT STUDY

LACTC

LAW/CRANDALL, INC.

Submitted:

IN ASSOCIATION WITH:
ANIL VERMA ASSOCIATES
ACOUSTICAL ANALYSIS ASSOCIATES
DKS ASSOCIATES
MICHAEL BRANDMAN ASSOCIATES, INC.
PGH WONG ENGINEERING, INC.
RALPH STONE AND COMPANY, INC.

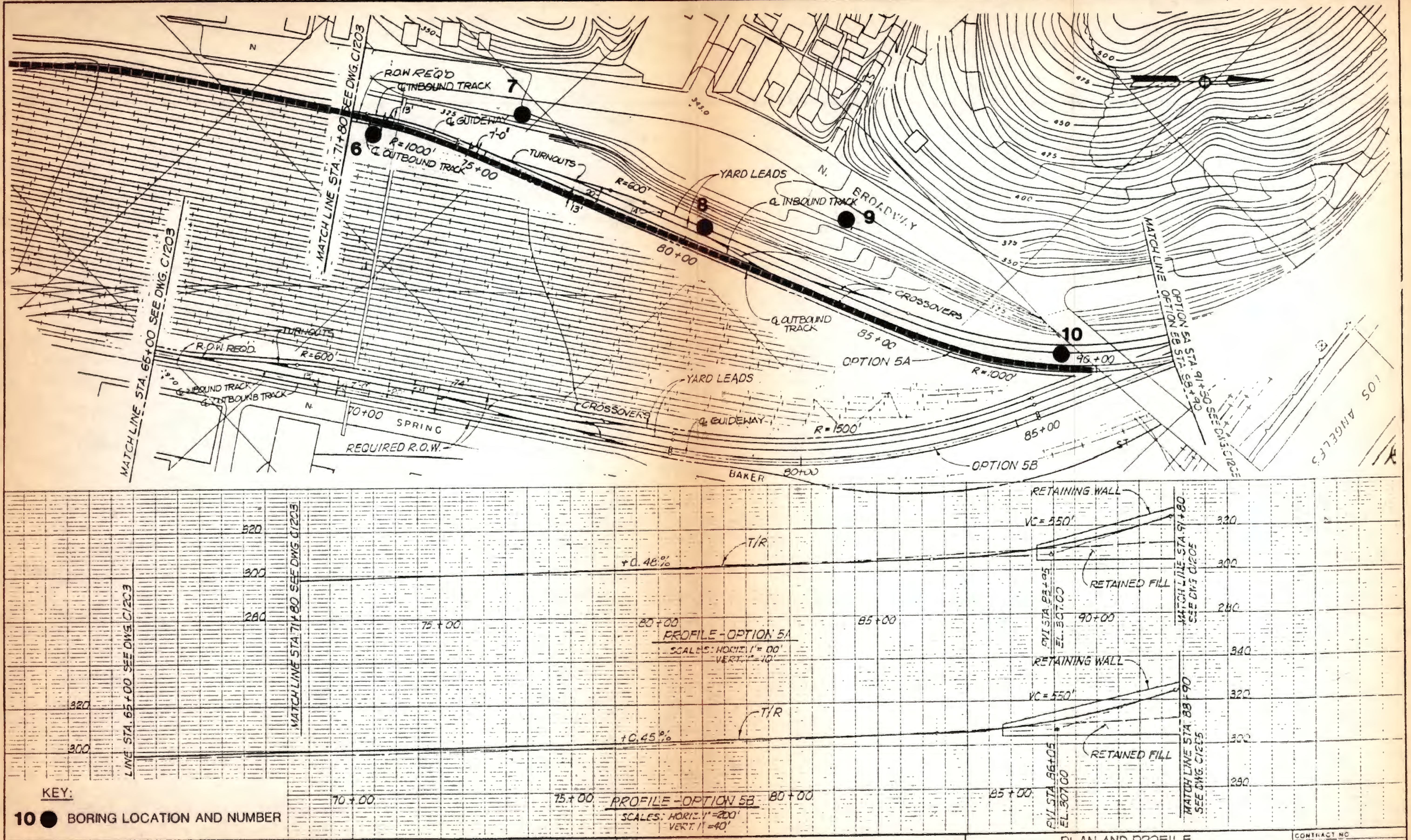
PLAN AND PROFILE
DOWNTOWN CONNECTIONS
TO HIGHLAND PARK ALTENATIVE
UNION STATION - NO SUBWAY OPTION
STA. 29+00 TO STA. 46+50

CONTRACT NO

DRAWING NO.

SCALE 1"=200'

DATE 5-15-92



KEY:

10 ● BORING LOCATION AND NUMBER

L92045.AEF1

PROPOSED METRO PASADENA LINE

Designed by

Drawn by Juliana Miranda

Checked by

Approved by

LOS ANGELES COUNTY TRANSPORTATION COMMISSION

PASADENA - LOS ANGELES ROUTE REFINEMENT STUDY

LACTC

LAW/CRANDALL, INC.

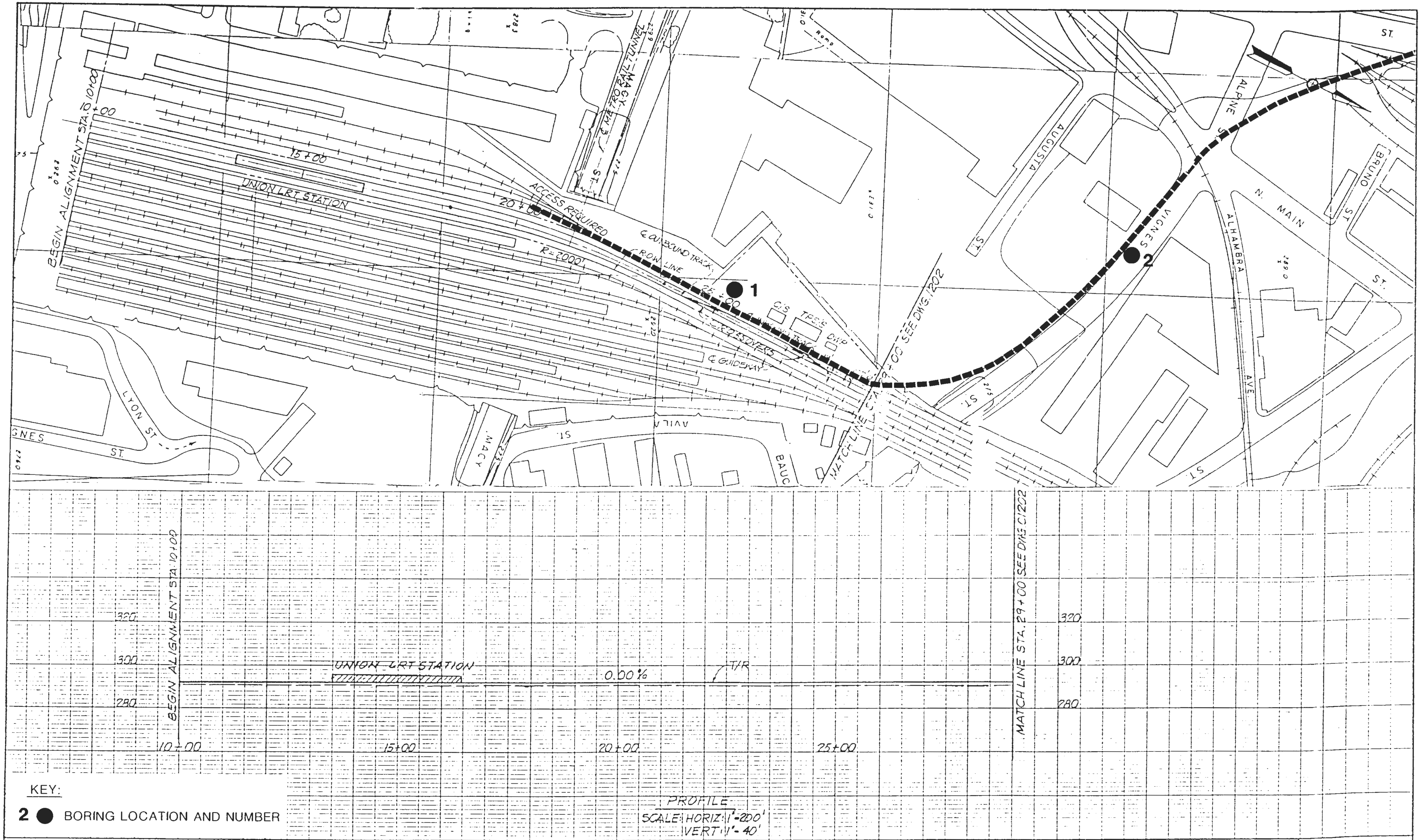
Submitted:

IN ASSOCIATION WITH:
ANIL VERMA ASSOCIATES
ACOUSTICAL ANALYSIS ASSOCIATES
DKS ASSOCIATES
MICHAEL BRANDMAN ASSOCIATES, INC.
PGH WONG ENGINEERING, INC
RALPH STONE AND COMPANY, INC

PLAN AND PROFILE
DOWNTOWN CONNECTIONS
TO HIGHLAND PARK ALTENATIVE
UNION STATION - NO SUBWAY OPTION
OPTION 5A: STA. 71+80 TO STA. 91+80
OPTION 5B: STA 65+00 TO STA. 88+90

CONTRACT NO
DRAWING NO
SCALE 1"=200'
DATE 5-15-92
SHEET NUMBER

PLATE 1.4



PROPOSED METRO PASADENA LINE

Designed by
Drawn by Juliana Miranda
Checked by MS
Approved by

LOS ANGELES COUNTY TRANSPORTATION COMMISSION
PASADENA-LOS ANGELES ROUTE REFINEMENT STUDY
LACTC

LAW/CRANDALL, INC.
Submitted:

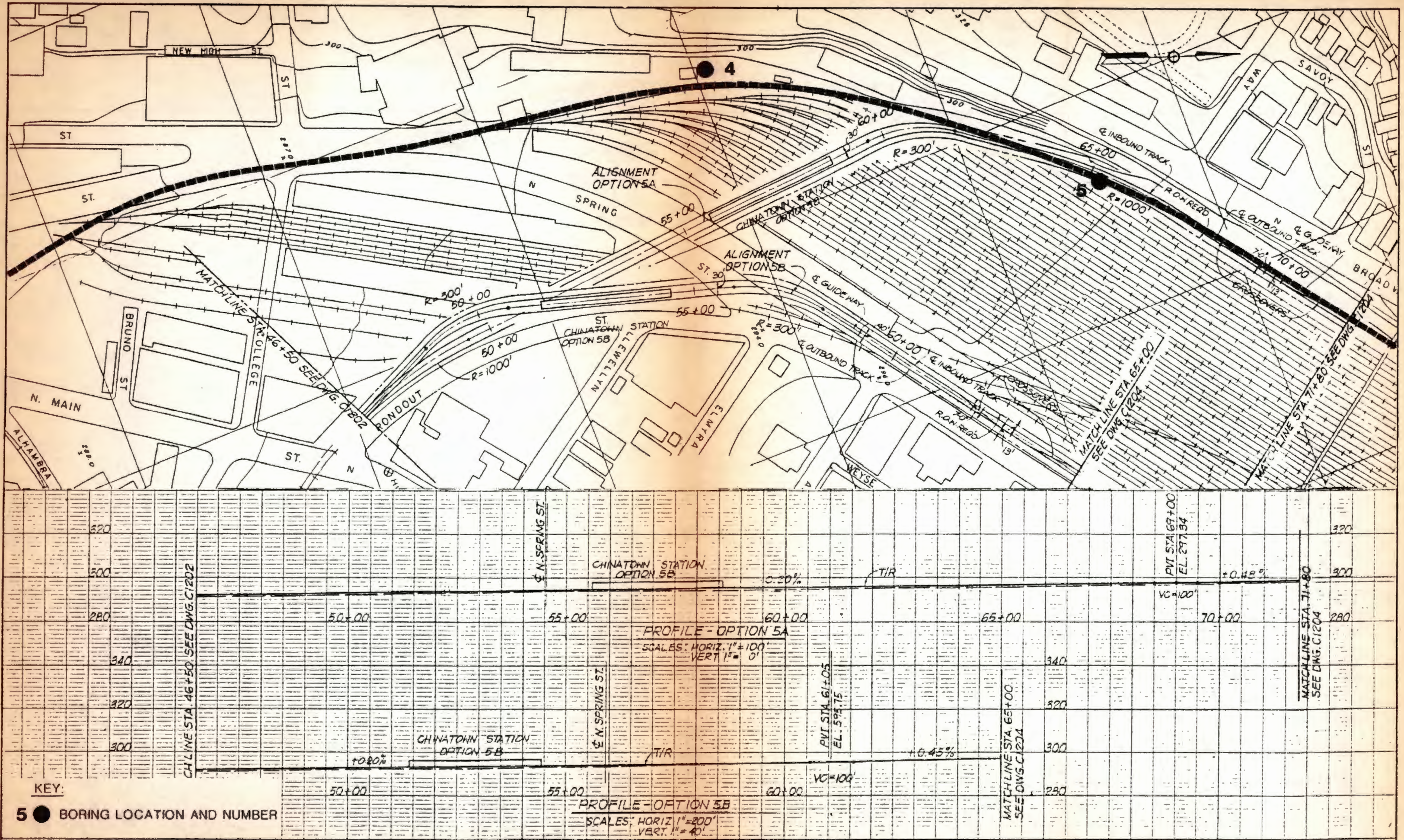
IN ASSOCIATION WITH:
ANIL VERMA ASSOCIATES
ACOUSTICAL ANALYSIS ASSOCIATES
DKS ASSOCIATES
MICHAEL BRANDMAN ASSOCIATES, INC.
PGH WONG ENGINEERING, INC
RALPH STONE AND COMPANY, INC.

PLAN AND PROFILE
DOWNTOWN CONNECTIONS
TO HIGHLAND PARK ALTENATIVE
UNION STATION-NO SUBWAY OPTION
STA. 10+00 TO STA. 29+00

CONTRACT NO
DRAWING NO
SCALE 1"=200'
DATE 5-15-92
SHEET NUMBER

PLATE 1.1

L92045.AEF1



PROPOSED METRO PASADENA LINE

Designed by

Drawn by Juliana Miranda

Checked by MS

Approved by

LOS ANGELES COUNTY TRANSPORTATION COMMISSION
PASADENA - LOS ANGELES ROUTE REFINEMENT STUDY

LACTC

LAW/CRANDALL, INC.

Submitted:

IN ASSOCIATION WITH:
ANIL VERMA ASSOCIATES
ACOUSTICAL ANALYSIS ASSOCIATES
DKS ASSOCIATES
MICHAEL BRANDMAN ASSOCIATES, INC.
POH WONG ENGINEERING, INC.
RALPH STONE AND COMPANY, INC.

PLAN AND PROFILE
DOWNTOWN CONNECTIONS
TO HIGHLAND PARK ALTENATIVE
UNION STATION-NO SUBWAY OPTION
OPTION 5A: STA. 46+50 TO STA. 71+80
OPTION 5B: STA. 46+50 TO STA. 65+00

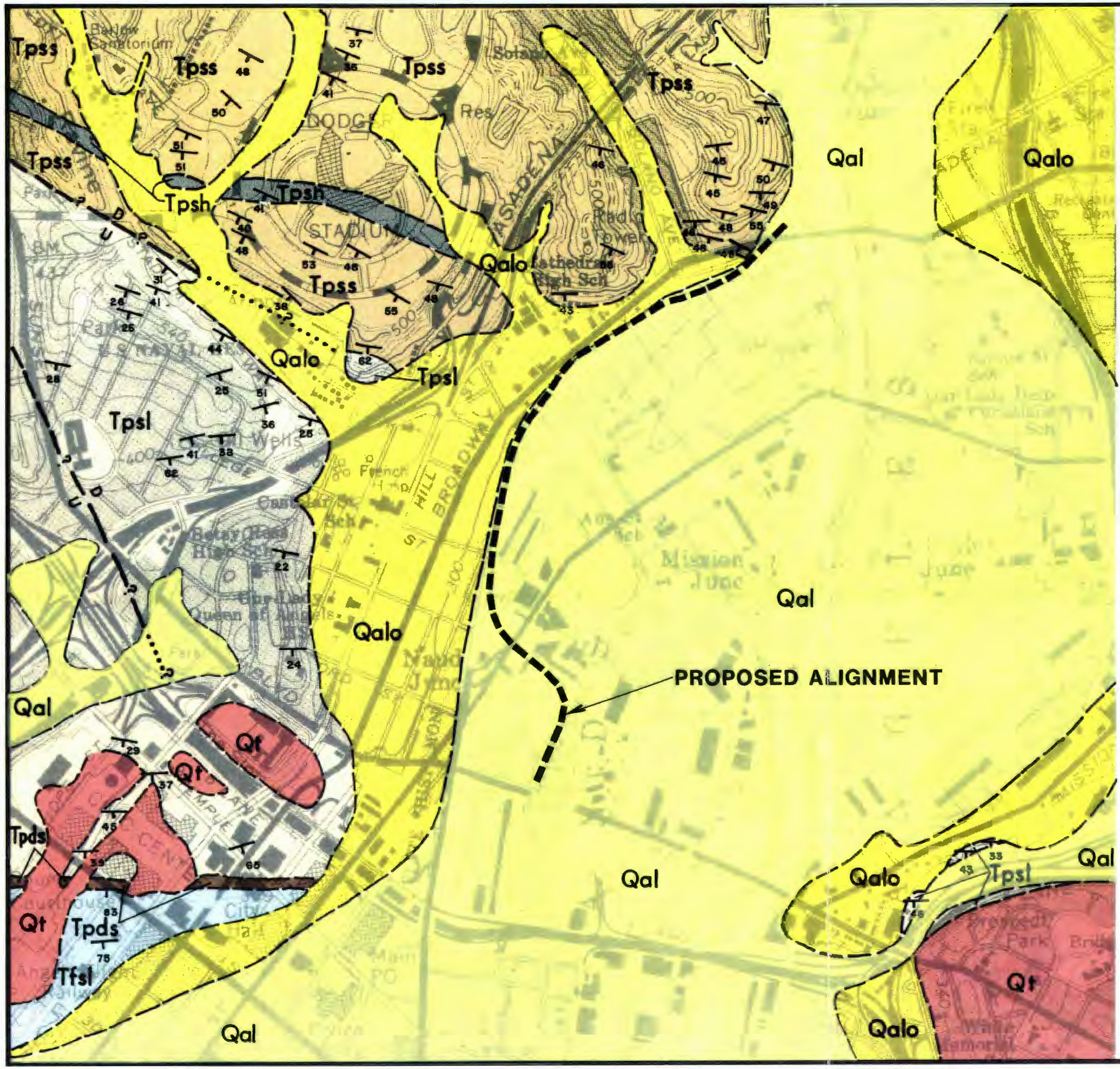
CONTRACT NO
DRAWING NO

SCALE 1"= 200'
DATE 5-15-92

SHEET NUMBER

PLATE 1.3

JOB 04 REF DATE 3/ DR. JULIA C.E. F CHK'D. PE



REFERENCES:

U.S.G.S. 7.5' LOS ANGELES QUADRANGLE 1966, PHOTOREVISED 1981.

GEOLOGIC MAP OF THE ELYSIAN PARK-REPETTO HILLS AREA, LOS ANGELES COUNTY, CALIFORNIA, LAMAR 1970 C.D.M.G. SPECIAL REPORT 101.

EXPLANATION:

Qal	YOUNGER ALLUVIUM
Qalo	OLDER ALLUVIUM
Qt	TERRACE DEPOSITS
Tfsl	FERNANDO FORMATION, siltstone
Tpsl Tpsh Tpds Tpss	PUENTE FORMATION, Tpsl: siltstone, Tpsh: shale, Tpds: diatomaceous shale, Tpss: sandstone
— —	CONTACT, dashed where approximately located , queried where inferred
—— —— ?…	FAULT, dashed where approximately located, querried where inferred or hypothetical, dotted where concealed . U: up-thrown side, D: down-thrown side
33	STRIKE AND DIP OF BEDDING

N

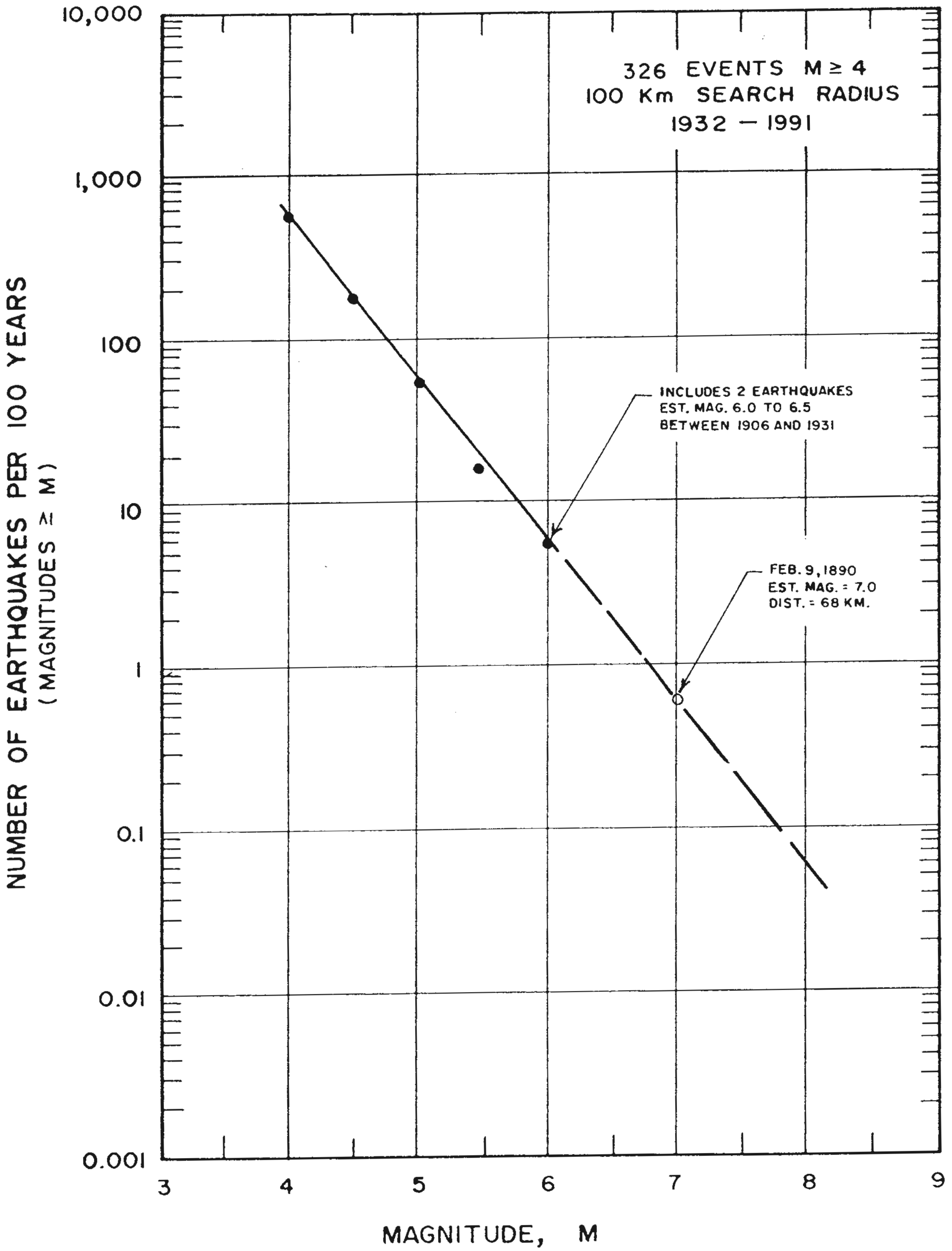
GEOLOGIC MAP

SCALE 1" = 1000'

LAW/CRANDALL, INC.

PLATE 2

JOB L92045.AEFI DATE 3-9-92 W.P. n.h. O.E. ЧK CHKD



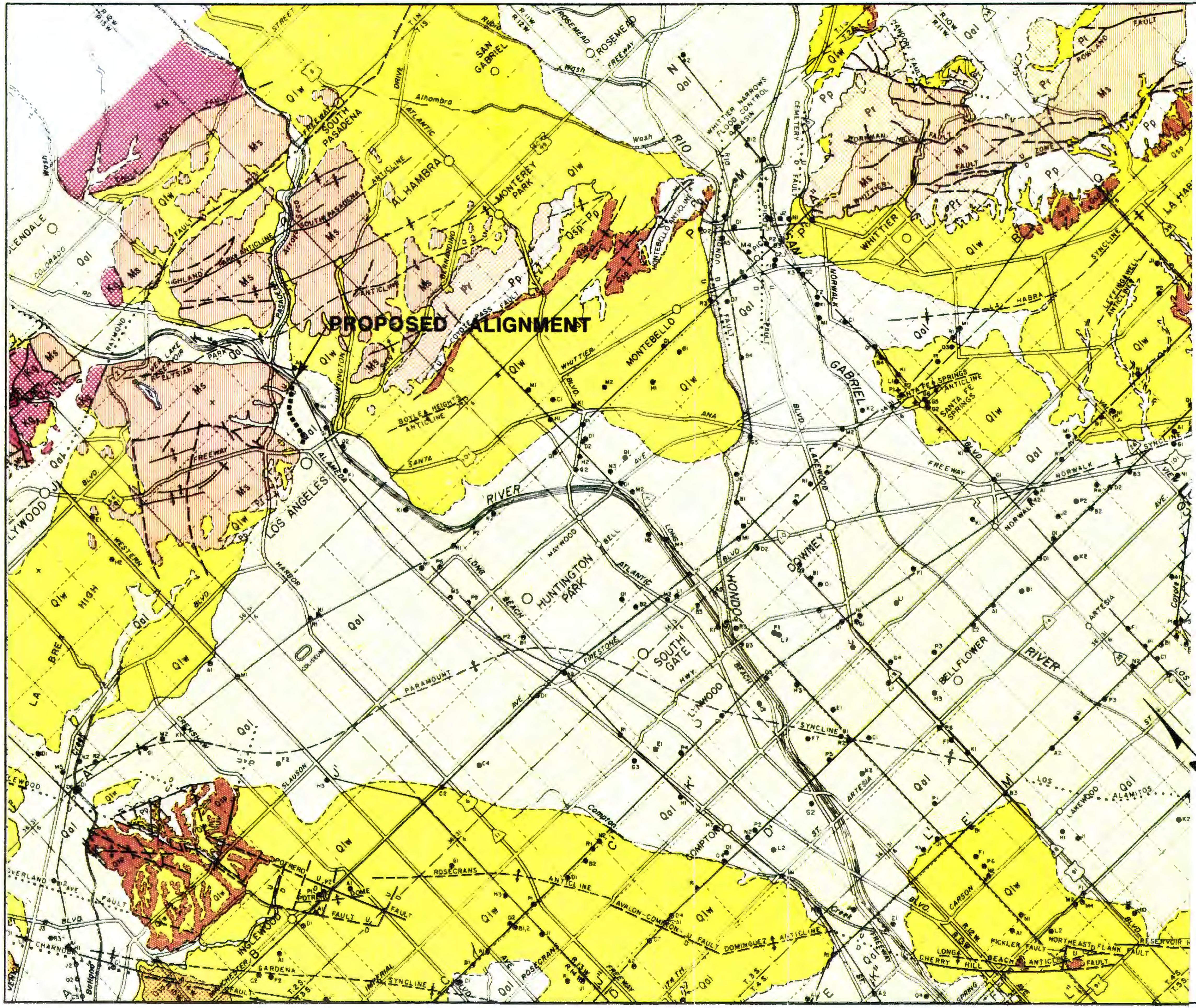
RECURRENCE CURVE

○ REPRESENTS SINGLE EVENT, AND THEREFORE HAS BEEN DISCOUNTED IN PREDICTION.

LAW/CRANDALL, INC.

PLATE 5

JOB [illegible] AE DATE 3/[illegible]/12 DR. JULIANA O.E. [illegible] CHKD. [illegible]



LEGEND

SEDIMENTARY ROCKS

QUATERNARY	RECENT		Qal	ALLUVIUM GRAVEL, SAND SILT, AND CLAY
			Qsr	ACTIVE DUNE SAND WHITE OR GREYISH, WELL SORTED SAND
	PLEISTOCENE	UPPER	Qso	OLDER DUNE SAND FINE TO MEDIUM SAND WITH SILT, AND GRAVEL LENSES
			Qlw	LAKEWOOD FORMATION (INCLUDES "TERRACE DEPOSITS "PALOS VERDES SAND," AND "UNNAMED UPPER PLEISTOCENE DEPOSITS") MARINE AND CONTINENTAL GRAVEL, SAND SANDY SILT SILT, AND CLAY WITH SHALE PEBBLES
		LOWER	Qsp	SAN PEDRO FORMATION (INCLUDES "LA HABRA CONGLOMERATE" AND PART OF "SAUGUS FORMATION MARINE AND CONTINENTAL GRAVEL, SAND, SANDY SILT, SILT, AND CLAY
			Qsp-Pp	UNDIFFERENTIATED SAN PEDRO FORMATION AND OR PICO FORMATION MARINE, PARTIALLY CONSOLIDATED GRAVEL SAND SILT AND CLAY
TERTIARY	PLIOCENE		Pp	PICO FORMATION MARINE SAND, SILT, AND CLAY INTERBEDDED WITH GRAVEL
			Pr	REPETTO FORMATION MARINE SILTSTONE WITH LAYERS OF SANDSTONE AND CONGLOMERATE
	MIOCENE		Ms	(SANTA MONICA MOUNTAINS) MODELO FORMATION MARINE CONGLOMERATIC SANDSTONE, SANDSTONE, AND SHALE TOPANGA FORMATION MARINE CONGLOMERATE, SANDSTONE AND SHALE (PALOS VERDES HILLS) MONTEREY FORMATION MUDSTONE, DIATOMITE, AND SHALE ELYSIAN HILLS, REPETTO HILLS AND PUENTE HILLS PUENTE FORMATION MARINE SILTSTONE, SANDSTONE SHALE CONGLOMERATE, LIMESTONE, AND TUFF
	OLIGOCENE(?)		Φ	VAQUEROS AND SESPE FORMATIONS CONTINENTAL RED CONGLOMERATE AND SANDSTONE
	EOCENE		E	MARTINEZ FORMATION MARINE CONGLOMERATE, SANDSTONE SANDY SHALE AND SHALE
	PALEOCENE(?)		E-K	UNDIVIDED MARTINEZ AND CHICO FORMATIONS
CRETACEOUS	UPPER		Ks	CHICO FORMATION UPPER MARINE MEMBER-HARD CONGLOMERATE SANDSTONE AND SHALE LOWER CONTINENTAL MEMBER-RED CONGLOMERATE AND SANDSTONE

IGNEOUS AND METAMORPHIC ROCKS

TERTIARY	MIOCENE	Mv	MIDDLE MIOCENE VOLCANIC ROCKS VOLCANIC FLOWS, BRECCIAS, TUFFS, AND INTRUSIVES CHIEFLY BASALTIC AND ANDESITIC WITH OCCASIONAL ACID ROCKS GENERALLY ASSOCIATED WITH TOPANGA, MODELO, OR PUENTE FORMATIONS
CRETACEOUS	UPPER	Kg	(SANTA MONICA MOUNTAINS) INTRUSIVES OF GRANITE AND GRANODIORITE
JURASSIC		J	(PALOS VERDES HILLS) CATALINA SCHIST COMPARED WITH FRANCISCAN FORMATION OF THE COAST RANGES VARIED TYPES OF SCHISTOSE ROCKS
TRIASSIC		ћ	SANTA MONICA SLATE GREY TO BLACK SLATE, SPOTTED SLATE, MICA SCHIST WITH QUARTZ VEINS

$\overset{U}{\underset{D}{—}}$ — —	FAULT (DASHED WHERE APPROXIMATLY LOCATED; U- UPTHROWN SIDE; D-DOWNTHROWN SIDE)
·······$\overset{U}{\underset{D}{·}}$·······	CONCEALED FAULT
—↕— — —	ANTICLINE (DASHED WHERE APPROXIMATLY LOCATED.
—✝— — —	SYNCLINE (DASHED WHERE APPROXIMATLY LOCATED.
———	CONTACT (DASHED WHERE APPROXIMATLY LOCATED.
● A5	WELLS USED IN PREPARATION OF GEOLOGIC SECTIONS.
A——A'	LINE LOCATION OF GEOLOGIC SECTIONS SHOWN ON PLATES 6A THROUGH 6G

REFERENCE:
AREAL GEOLOGY MAP BY STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES SOUTHERN CALIFORNIA DISTRICT.

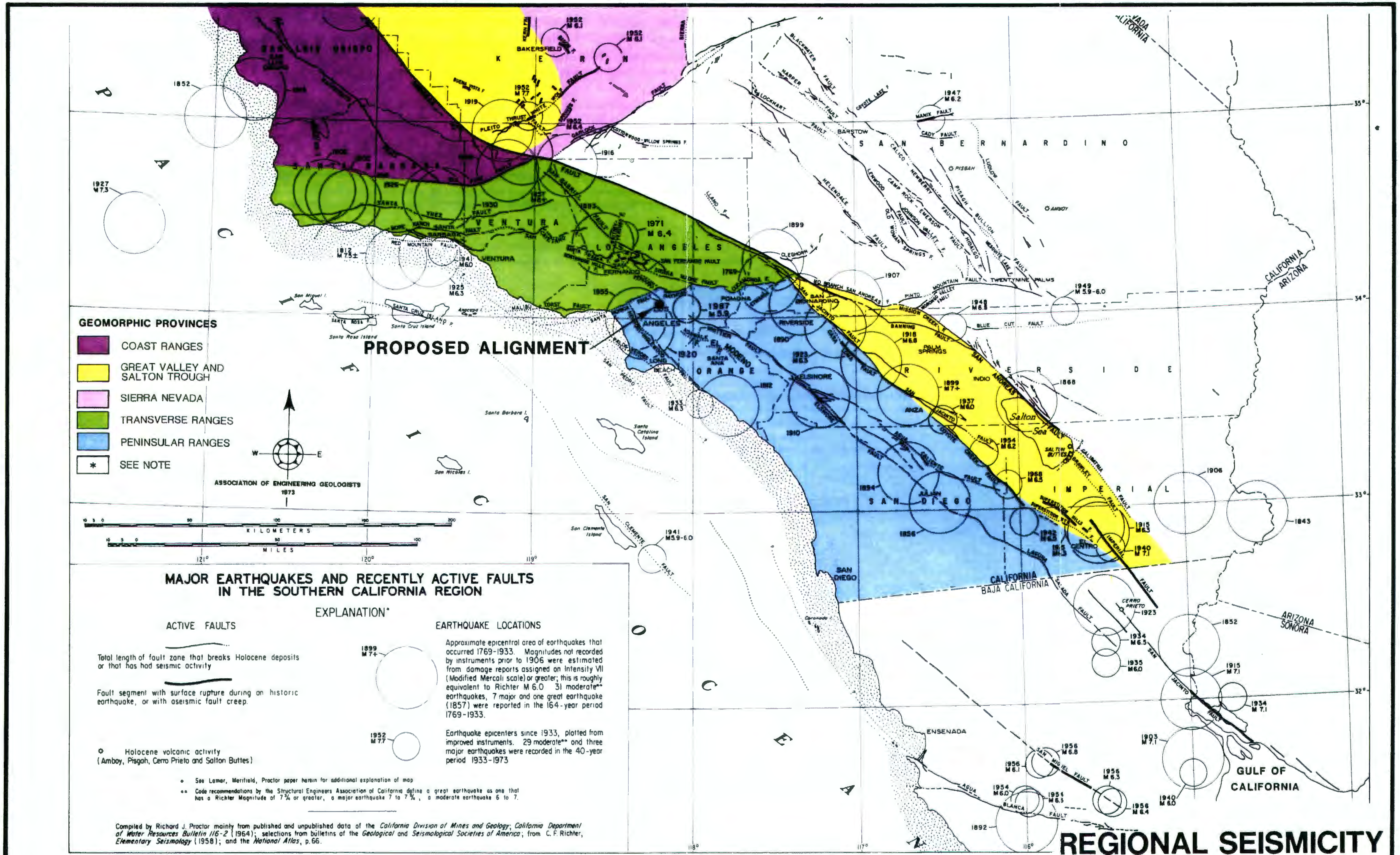
REGIONAL GEOLOGY

SCALE OF MILES

1 0 1 2 3

LAW/CRANDALL, INC.

JOB [illegible]-AEF DATE [illegible]/6/[illegible] DR. Juliana O.E. [illegible] CHKD.



GEOMORPHIC PROVINCES

- 🟪 COAST RANGES
- 🟨 GREAT VALLEY AND SALTON TROUGH
- 🟪 SIERRA NEVADA
- 🟩 TRANSVERSE RANGES
- 🟦 PENINSULAR RANGES
- * SEE NOTE

MAJOR EARTHQUAKES AND RECENTLY ACTIVE FAULTS IN THE SOUTHERN CALIFORNIA REGION

EXPLANATION*

ACTIVE FAULTS

Total length of fault zone that breaks Holocene deposits or that has had seismic activity

Fault segment with surface rupture during an historic earthquake, or with aseismic fault creep.

✪ Holocene volcanic activity (Amboy, Pisgah, Cerro Prieto and Salton Buttes)

EARTHQUAKE LOCATIONS

1899 M 7+

Approximate epicentral area of earthquakes that occurred 1769-1933. Magnitudes not recorded by instruments prior to 1906 were estimated from damage reports assigned on Intensity VII (Modified Mercali scale) or greater; this is roughly equivalent to Richter M 6.0 31 moderate** earthquakes, 7 major and one great earthquake (1857) were reported in the 164-year period 1769-1933.

1952 M 7.7

Earthquake epicenters since 1933, plotted from improved instruments. 29 moderate** and three major earthquakes were recorded in the 40-year period 1933-1973

* See Lamar, Merifield, Proctor paper herein for additional explanation of map

** Code recommendations by the Structural Engineers Association of California define a great earthquake as one that has a Richter Magnitude of 7¾ or greater, a major earthquake 7 to 7¾, a moderate earthquake 6 to 7.

Compiled by Richard J. Proctor mainly from published and unpublished data of the *California Division of Mines and Geology*; *California Department of Water Resources Bulletin 116-2* (1964); selections from bulletins of the *Geological* and *Seismological Societies of America*; from C. F. Richter, *Elementary Seismology* (1958); and the *National Atlas*, p. 66.

* NOTE

Uncolored areas include from North to South, Great Basin and Mojave Desert Provinces, Nevada, Arizona, Baja California, and Pacific Ocean to West.

REGIONAL SEISMICITY

(GEOMORPHIC PROVINCES INCLUDED)

LAW/CRANDALL, INC.

PLATE 4

APPENDIX A

APPENDIX A
FIELD EXPLORATIONS AND LABORATORY TESTS

EXPLORATIONS

Borings

The soil conditions along the alignment were explored by drilling ten borings at the locations shown on Plates 1.1 through 1.4.

The borings were drilled to depths of 30 to 100 feet below the existing grade using 20- and 24-inch-diameter bucket-type drilling equipment and/or 5-inch-diameter rotary wash-type equipment. Caving of the bucket boring walls occurred during drilling, as indicated on the boring logs; casing or drilling mud was not used to extend the bucket borings to the depths drilled. Drilling mud was used with the rotary wash-type equipment to prevent caving.

After completion of drilling, piezometers (PVC pipe with the lower portion perforated) were installed in Borings 1, 3, and 10 to permit future water level measurements and sampling. Detailed descriptions of the piezometer installations are presented on the boring logs, and details of the well construction are presented on Plates A-7.1 and A-7.2.

Soil Sampling

The soils encountered were logged by a certified engineering geologist, and undisturbed samples were obtained for laboratory inspection and testing. The logs of the borings are presented on Plates A-1.1 through A-1.10; the depths at which relatively undisturbed samples were obtained are indicated to the left of the boring logs. The energy required to drive the sampler 12 inches is indicated on the logs. The soils are classified in accordance with the Unified Soil Classification System described on Plate A-2.

OVA Monitoring

The boring samples were monitored with an organic vapor analyzer (OVA). The results are shown on the boring logs.

Water Sampling

Ground water samples were obtained on May 5, 1992 from two of the three monitoring wells (piezometers). Prior to sampling, each well was developed by pumping approximately 55 gallons of ground water using a submersible pump. To minimize cross-contamination, the pumping system was purged with a soap (TSP brand) solution, followed by a distilled water rinse/purge. Each of the samples was obtained using a clean disposable bailer, placed in laboratory-supplied containers, labeled, placed in a chilled ice chest, and delivered to Brown and Caldwell Analytical Laboratory for chemical analyses.

LABORATORY TESTS

Moisture and Density Determinations

The field moisture content and dry density of the soils encountered were determined by performing tests on the samples. The field moisture tests were performed in accordance with ASTM Designation D2216-80. The results of the tests are shown to the left of the boring logs.

Atterberg Limits

To further aid in classifying the soils, Atterberg limit tests to determine the liquid limit and plasticity index of the soils were performed on selected samples. The tests were performed in accordance with ASTM Designation D4318-84. The results of the tests are presented on the boring logs.

Direct Shear Tests

Direct shear tests were performed on selected undisturbed samples to determine the strength of the soils. The tests were performed on samples at field moisture content and on samples that had been placed under a nominal surcharge and soaked for at least 12 hours. The samples were tested at various surcharge pressures. The tests were performed in accordance with ASTM Designation D3080-72. The yield-point values determined from the direct shear tests are presented on Plate A-3.1, Direct Shear Test Data.

Triaxial Shear Tests

To provide additional information on the strength of the rock, triaxial shear tests were performed on three samples. The samples were tested at field moisture content. The tests were performed in accordance with ASTM Designation D4767-88. The results of the tests are presented on Plate A-3.2, Triaxial Shear Test Data.

Consolidation Tests

Confined consolidation tests were performed on eight relatively undisturbed samples to determine the compressibility of the soils. Water was added to one of the samples during the tests to illustrate the effect of moisture on the compressibility. The other samples were tested at field moisture content. The tests were performed in accordance with ASTM Designation D2435-80. The results of the tests are presented on Plates A-4.1 through A-4.4, Consolidation Test Data.

Compaction Tests

The optimum moisture content and maximum dry density of the soils were determined by performing compaction tests on samples from two of the borings. The tests were performed in accordance with the ASTM Designation D1557-78 method of compaction. The results of the tests are presented on Plate A-5, Compaction Test Data.

Mechanical Analyses

To determine the particle size distribution of the soils and to aid in classifying the soils, mechanical analyses were performed on nine samples. The tests were performed in accordance with ASTM Designation D422-63. The results of the mechanical analyses are presented on Plate A-6.1 through A-6.3, Particle Size Distribution.

Water Quality Analyses

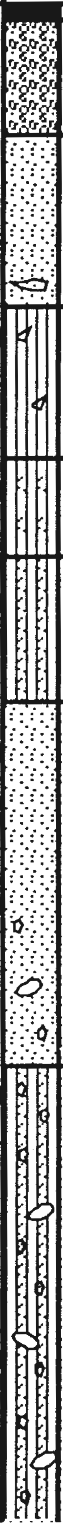
The ground water samples were analyzed for total fuel and volatile aromatic hydrocarbons by EPA Methods 8015 and 8020, respectively. The samples were also analyzed for petroleum hydrocarbons (EPA Method 418.1), semi volatile organics (EPA Method 8270), halogenated volatile hydrocarbons (EPA Method 8010), and Title 22 metals. The Chain-of-Custody documents and the analytical results are presented in Appendix B.

-o0o-

BORING 1

Coordinates
N-4,133,660
E-4,217,025

DATE DRILLED:	May 18, 1992
EQUIPMENT USED:	5" - Diameter Rotary Wash
TIME DRILLED:	Start: 6:30 am; Finish: 3:30 pm
ELEVATION	293 *



ELEVATION	DEPTH (ft.)	OVA (ppm)	"N" VALUE STD.PEN.TEST	MOISTURE (% of dry wt.)	DRY DENSITY (lbs./cu. ft.)	DRIVE ENERGY (ft.-kips/ft.)	SAMPLE LOC.		
									6" Asphaltic Paving
								GP	ARTIFICIAL FILL FILL - GRAVEL (Rail Road Ballast)
290									
								SW	SAND - well graded, lenses of Clayey Silt, grey and brown
	5								
									Some pieces of wood, strong odor
285								ML	CLAYEY SILT - some Siltstone fragments, some Sand, brown
				22.9	104	13	■		
	10								
280				17.1	103	6	■	ML SM	SANDY SILT and SILTY SAND - fine, grey
	15							SM	YOUNGER ALLUVIUM (Qal) SILTY SAND - fine, grey
				16.2	103	3	■		
275									
								SP	SAND - fine to medium, grey
				10.3	105	8	■		
	20								
270									
				12.1	120	21	■		Some Gravel and Cobbles
	25								
265								SM	SILTY SAND - fine to coarse, about 15% Gravel, some Cobbles, grey
				9.6	119	29	■		
	30								
			50 (5" pen)						
260									
	35								
				10.3	110	29	■		Fine to medium Sand
255									
	40		80						

* Elevations refer to datum of Plan and Profile Drawings provided by the Rail Construction Corporation.

(CONTINUED ON FOLLOWING PLATE)

Note : The log of subsurface conditions shown hereon applies only at the specific boring location and at the date indicated. It is not warranted to be representative of subsurface conditions at other locations and times.

JOB L92045.AEF-1 DATE 5/12/92 F.T. TC DR. lk O.E. MS MS CHKD DM

LOG OF BORING

LAW/CRANDALL, INC.

BORING 1 (Continued)

DATE DRILLED: May 18, 1992
EQUIPMENT USED: 5" - Diameter Rotary Wash
TIME DRILLED: Start: 6:20 am; Finish: 3:30 pm

ELEVATION	DEPTH (ft.)	OVA (ppm)	"N" VALUE STD.PEN.TEST	MOISTURE (% of dry wt.)	DRY DENSITY (lbs./cu. ft.)	DRIVE ENERGY (ft.-kips/ft.)	SAMPLE LOC.
250							
	45						
245							
	50			11.7	123	29	■
240							
	55			12.9	125	27	■
235							
	60			32.5	92	19	■
230							
	65			24.0	106	53	■
225							
	70			28.9	96	53	■
220							
	75			30.8	90	27	■
215							
	80			25.0	99	22	■

SW SAND - well graded, some Gravel, grey

SM SILTY SAND - fine to coarse, about 20% Gravel, few Cobbles, grey

Fine to medium Sand

ML SANDY SILT - grey

Thin layers of Silty Sand

PUENTE FORMATION (Tpss)
SILTSTONE with INTERBEDDED SANDSTONE - well bedded, poorly cemented, grey

(CONTINUED ON FOLLOWING PLATE)

Note : The log of subsurface conditions shown hereon applies only at the specific boring location and at the date indicated. It is not warranted to be representative of subsurface conditions at other locations and times.

JOB L92045.AEF-1 DATE 5/12/92 F.T. TC DR. lk O.E. MS MB CHKD DM

LOG OF BORING

LAW/CRANDALL, INC.

BORING 1 (Continued)

DATE DRILLED: May 18, 1992
EQUIPMENT USED: 5" - Diameter Rotary Wash
TIME DRILLED: Start: 6:30 am; Finish: 3:30 pm

ELEVATION	DEPTH (ft.)	OVA (ppm)	"N" VALUE STD.PEN.TEST	MOISTURE (% of dry wt.)	DRY DENSITY (lbs./cu. ft.)	DRIVE ENERGY (ft.-kips/ft.)	SAMPLE LOC.
210							
	85			29.1	93	18	■
205							
	90			32.9	86	15	■
200							
	95			25.4	100	24	■
195							
	100			24.7	94	19	■

NOTE: Drilling mud used in drilling process. To obtain future water level measurements and sampling, installed 2"- diameter PVC pipe to a depth of 100'. Pipe perforated between depths of 40' and 100'. Backfilled with Sand to within 38' of ground surface. Bentonite plug placed between depths of 35' and 38' and was grouted with cement above 35'. Water level measured in the well at a depth of 40' on 5/27/92.

Note : The log of subsurface conditions shown hereon applies only at the specific boring location and at the date indicated. It is not warranted to be representative of subsurface conditions at other locations and times.

JOB L92045.AEF-1 DATE 5/12/92 F.T. TC DR. lk O.E. MS MS CHKD DM

LOG OF BORING

LAW/CRANDALL, INC.

PLATE A - 1.1c

BORING 2

Coordinates
N-4,134,525
E-4,216,940

DATE DRILLED: April 25, 1992
EQUIPMENT USED: 5" - Diameter Rotary Wash
TIME DRILLED: Start: 6:00 am; Finish: 2:00 pm
ELEVATION 287

ELEVATION	DEPTH (ft.)	OVA (ppm)	"N" VALUE STD.PEN.TEST	MOISTURE (% of dry wt.)	DRY DENSITY (lbs./cu. ft.)	DRIVE ENERGY (ft.-kips/ft.)	SAMPLE LOC.		
									4" Asphaltic Paving - 8" Concrete Slab - 6" Base Course
285								ML	YOUNGER ALLUVIUM (Qal)
				19.1	48	2	■		SANDY SILT - lenses of Silty Sand, greyish brown
				31.8	90	3	■		
	5							SM	SILTY SAND - fine, grey
				12.0	111	3	■	SP	SAND - fine to medium, some Gravel, grey
280									
				15.8	108	12	■		
	10								
								SW	SAND - well graded, some Gravel and Cobbles, light brownish grey
275									
			46						
	15							GW	GRAVEL - well graded, grey
				2.3	98	8	■		
270									
								SW GW	SAND and GRAVEL - well graded, grey
			9						
	20								
				7.1	105	18	■		
265									
			100 (4" pen)						
	25								
260									
				11.1	129	58	■		
	30								
			80 (5" pen)						Layer of Sandy Clay
255									
								SP	SAND - fine, some Gravel, grey
				28.6	96	23	■		
	35							SM	SILTY SAND - fine to medium, some Clay and Gravel, grey
250			39						
								GP SM	GRAVEL and SILTY SAND - fine to coarse, grey
				17.9	113	30	■		
	40								

(CONTINUED ON FOLLOWING PLATE)

Note : The log of subsurface conditions shown hereon applies only at the specific boring location and at the date indicated. It is not warranted to be representative of subsurface conditions at other locations and times.

JOB L92045.AEF-1 DATE 5/12/92 F.T. TC DR. lk O.E. MS MS CHKD DN

LOG OF BORING

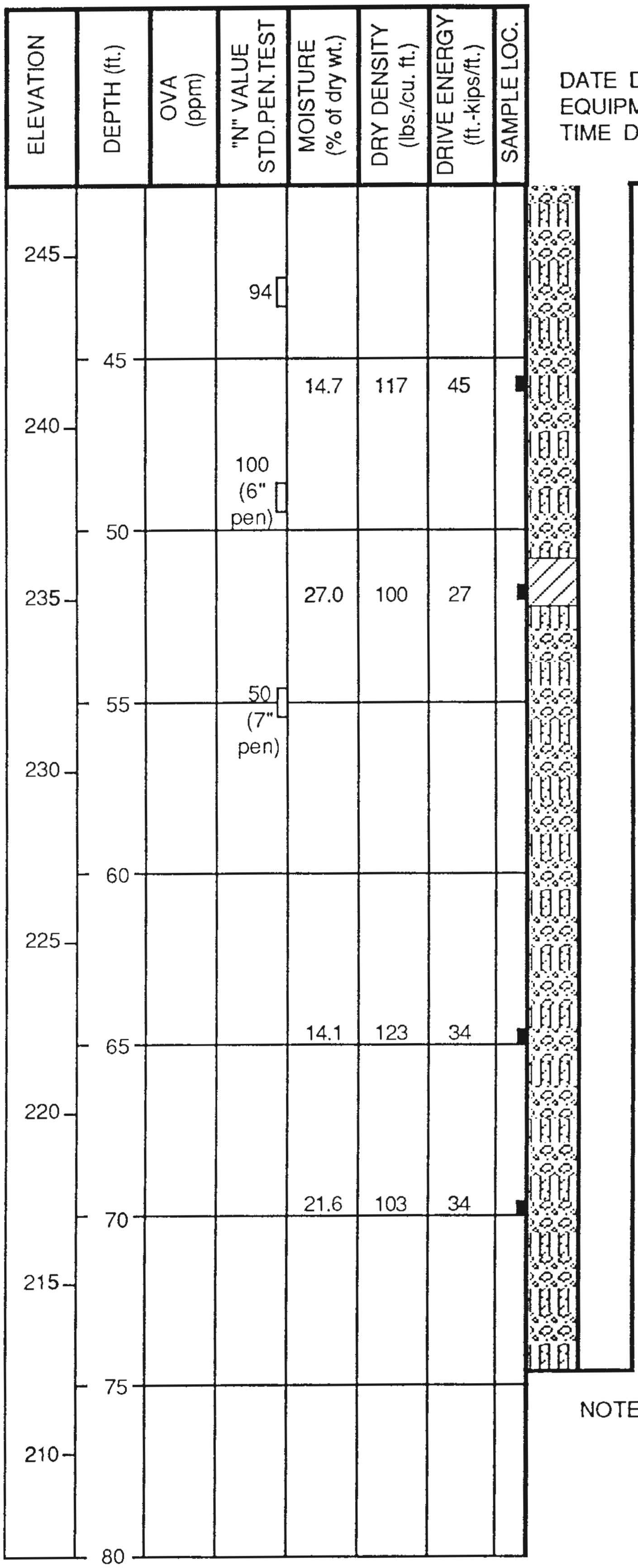
LAW/CRANDALL, INC.

JOB L92045.AEF-1 DATE 5/12/92 F.T. TC DR. lk O.E. MS MS CHKD DM

Note : The log of subsurface conditions shown hereon applies only at the specific boring location and at the date indicated. It is not warranted to be representative of subsurface conditions at other locations and times.

BORING 2 (Continued)

DATE DRILLED:	April 25, 1992
EQUIPMENT USED:	5" - Diameter Rotary Wash
TIME DRILLED:	Start: 6:00 am; Finish: 2:00 pm



Layer of Silty Clay

Fine to medium

NOTE: Drilling mud used in drilling process. Water level not established.

LOG OF BORING

L A W / C R A N D A L L , I N C.

BORING 3

Coordinates
N-4,135,275
E-4,216,425

DATE DRILLED: April 16, 1992
EQUIPMENT USED: 5" - Diameter Rotary Wash
TIME DRILLED: Start: 7:30 am; Finish: 1:00 pm
ELEVATION 288

ELEVATION	DEPTH (ft.)	OVA (ppm)	"N" VALUE STD.PEN.TEST	MOISTURE (% of dry wt.)	DRY DENSITY (lbs./cu. ft.)	DRIVE ENERGY (ft.-kips/ft.)	SAMPLE LOC.		
									1-1/2" Asphaltic Paving - Bricks to a depth of 1-1/2'
								SP	YOUNGER ALLUVIUM (Qal)
285				4.2	100	8	■		SAND - fine, light brownish grey
				7.7	103	11	■		
	5								
				11.8	105	6	■		Some coarse Sand, about 15% Gravel
280									
				30.2	91	2	■		
	10								
								ML	CLAYEY SILT - some Sand, dark brown
								SP	SAND - fine to medium, light brownish grey
275			57						
	15								
				12.4	116	18	■		Lenses of Sandy Silt, bluish grey
270									
			58						
	20								
				14.5	112	18	■		Fine to coarse Sand, bluish grey
265								MH	SILT - bluish grey
	25		12						(LL = 52%; PI = 12%)
260									
	30								
			16						
255									Layer of Sand
				23.4	103	14	■		
		22							
	35								
								SP	SAND - fine, traces of tar, greyish brown
			54						
250									
								ML	OLDER ALLUVIUM (Qalo)
		31		31.9	92	4	■		CLAYEY SILT - some Sand, grey
	40								(LL = 41%; PI = 9%)

Note : The log of subsurface conditions shown hereon applies only at the specific boring location and at the date indicated. It is not warranted to be representative of subsurface conditions at other locations and times.

JOB L92045.AEF-1 DATE 5/12/92 F.T. LS DR. lk O.E. MS MS CHKD Dm

(CONTINUED ON FOLLOWING PLATE)

LOG OF BORING

LAW/CRANDALL, INC.

BORING 3 (Continued)

DATE DRILLED: April 16, 1992
EQUIPMENT USED: 5" - Diameter Rotary Wash
TIME DRILLED: Start: 7:30 am; Finish: 1:00 pm

ELEVATION	DEPTH (ft.)	OVA (ppm)	"N" VALUE STD.PEN.TEST	MOISTURE (% of dry wt.)	DRY DENSITY (lbs./cu. ft.)	DRIVE ENERGY (ft.-kips/ft.)	SAMPLE LOC.
245			58 ☐				
	45	15		27.0	95	28	■
240			50 ☐				
	50						
235							
	55		69 ☐				
230							
	60	18		23.2	99	35	■
225							
	65			25.2	100	35	■
220							
	70			22.9	101	42	■
215							
	75			22.9	103	38	■
210							
	80	70		19.5	103	42	■

SP SAND - fine, bluish grey

ML SANDY SILT - thin layers of Silty Sand, bluish grey

PUENTE FORMATION (Tpsl)
SILTSTONE with minor INTERBEDDED
SANDSTONE - fine to medium, poorly bedded, poorly to moderately cemented, dark grey

(CONTINUED ON FOLLOWING PLATE)

Note : The log of subsurface conditions shown hereon applies only at the specific boring location and at the date indicated. It is not warranted to be representative of subsurface conditions at other locations and times.

JOB L92045.AEF-1 DATE 5/12/92 F.T. LS DR. lk O.E. MS MS CHKD DM

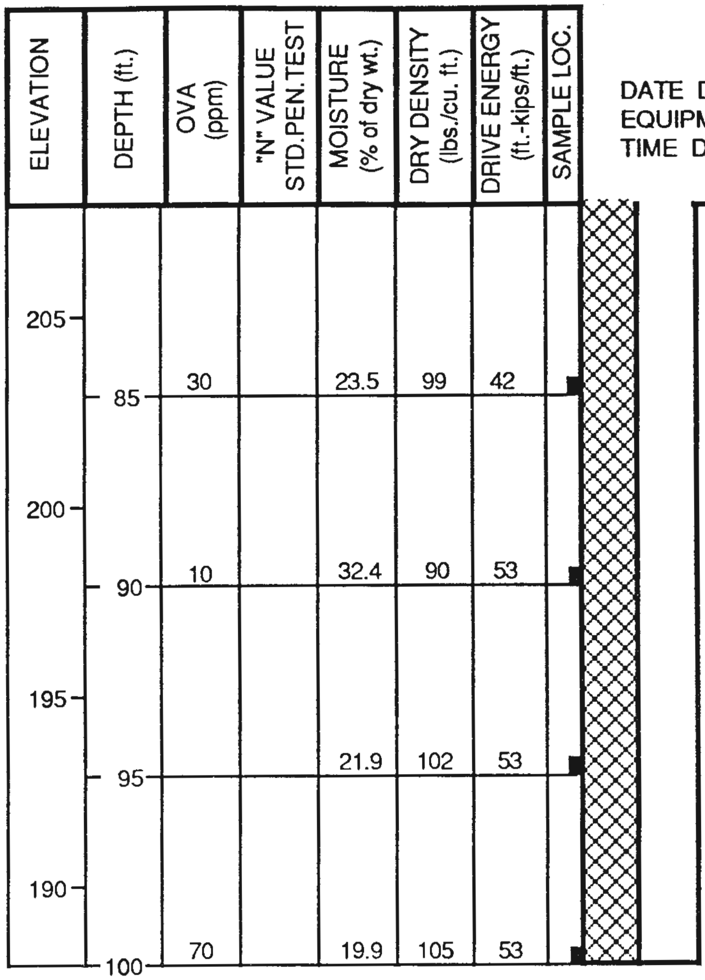
LOG OF BORING

LAW/CRANDALL, INC.

PLATE A - 1.3b

BORING 3 (Continued)

DATE DRILLED: April 16, 1992
EQUIPMENT USED: 5" - Diameter Rotary Wash
TIME DRILLED: Start: 7:30 am; Finish: 1:00 pm



ELEVATION	DEPTH (ft.)	OVA (ppm)	"N" VALUE STD.PEN.TEST	MOISTURE (% of dry wt.)	DRY DENSITY (lbs./cu. ft.)	DRIVE ENERGY (ft.-kips/ft.)	SAMPLE LOC.
	85	30		23.5	99	42	■
	90	10		32.4	90	53	■
	95			21.9	102	53	■
	100	70		19.9	105	53	■

NOTE: Drilling mud used in drilling process. To obtain future water level measurements and sampling, installed 2"- diameter PVC pipe to a depth of 100'. Pipe perforated between depths of 20' and 100'. Backfilled with Sand to within 20' of ground surface. A bentonite plug was placed between depths of16' and 20' and was grouted with cement above 16'. Top is capped. Water level measured in the well at a depth of 21-1/2' on 5/5/92.

Note : The log of subsurface conditions shown hereon applies only at the specific boring location and at the date indicated. It is not warranted to be representative of subsurface conditions at other locations and times.

JOB L92045.AEF-1 DATE 5/12/92 F.T. LS DR. lk O.E. MS MS CHKD DM

LOG OF BORING

LAW/CRANDALL, INC.

PLATE A - 1.3c

JOB L92045.AEF-1 DATE 5/12/92 F.T. LS DR. lk O.E. MS CHKD DM

Note : The log of subsurface conditions shown hereon applies only at the specific boring location and at the date indicated. It is not warranted to be representative of subsurface conditions at other locations and times.

BORING 4

Coordinates
N-4,136,525
E-4,216,630

DATE DRILLED: April 14 & 16, 1992
EQUIPMENT USED: 5" - Diameter Rotary Wash
20" - Diameter Bucket
TIME DRILLED: Start: 8:00 am; Finish: 11:00 am (RW)
Start: 8:00 am; Finish: 9:50 am (B)
ELEVATION 295

ELEVATION	DEPTH (ft.)	OVA (ppm)	"N" VALUE STD.PEN.TEST	MOISTURE (% of dry wt.)	DRY DENSITY (lbs./cu. ft.)	DRIVE ENERGY (ft.-kips/ft.)	SAMPLE LOC.
				15.1	99	4	■
				13.0	112	5	■
290	5						
				12.0	102	8	■
				8.9	95	10	■
285	10						
				11.0	100	12	■
			55 (5" pen) □				
280	15						
				10.3	122	28	■
			80 □				
275	20						
				32.5	91	8	■
270	25						
			29 □				
				13.1	118	35	■
265	30						
			46 □				
260	35			16.7	115	16	■
			85 □				
255	40						

	3" Asphaltic Paving
ML SM	ARTIFICIAL FILL SANDY SILT and SILTY SAND - fine to medium, brownish grey
SP SM	YOUNGER ALLUVIUM (Qal) SAND and SILTY SAND - fine, light brownish grey
SP	SAND - fine to coarse, about 10% Gravel, light browish grey About 15% Gravel Thin layer of fine Sand
ML	OLDER ALLUVIUM (Qalo) SANDY SILT - some Clay, lenses of Sand, greenish grey and brown
SP	SAND - fine to medium, light greyish brown Some coarse Sand
SW	SAND - well graded, about 20% Gravel, light bluish grey Thin layer of Sandy Silt Lenses of Sandy Silt

(CONTINUED ON FOLLOWING PLATE)

LOG OF BORING

LAW/CRANDALL, INC.

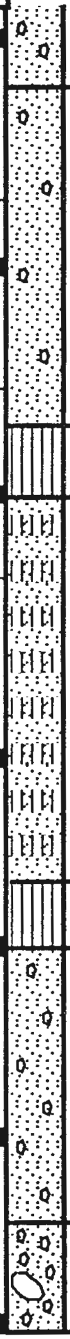
JOB L92045.AEF-1 DATE 5/12/92 F.T. LS DR. lk O.E. MS MS CHKD DM

Note : The log of subsurface conditions shown hereon applies only at the specific boring location and at the date indicated.
It is not warranted to be representative of subsurface conditions at other locations and times.

BORING 4 (Continued)

DATE DRILLED: April 14 & 16, 1992
EQUIPMENT USED: 5" - Diameter Rotary Wash
20" - Diameter Bucket
TIME DRILLED: Start: 8:00 am; Finish: 11:00 am (RW)
Start: 8:00 am; Finish: 9:50 am (B)

ELEVATION	DEPTH (ft.)	OVA (ppm)	"N" VALUE STD.PEN.TEST	MOISTURE (% of dry wt.)	DRY DENSITY (lbs./cu. ft.)	DRIVE ENERGY (ft.-kips/ft.)	SAMPLE LOC.		
				12.7	116	32	■		
								SP	SAND - fine, some Gravel, grey
									Thin layer of Sandy Silt
			48						
250	45								
				21.4	104	28	■		
			60						
245	50								
								ML	SANDY SILT - bluish grey
				14.1	112	25	■		
								SP SM	SAND and SILTY SAND - fine to medium, bluish grey
240	55								
			62						
				15.4	113	32	■		Grey
235	60								
								ML	CLAYEY SILT - bluish grey
				22.7	99	21	■		
230	65							SP	SAND - fine to medium, about 15% Gravel, bluish grey
				17.8	110	15	■		
225	70								
								SW	SAND - well graded, about 20% Gravel, bluish grey
									10" Cobble
				12.7	120	50	■		
220	75								



NOTE: Drilling mud used in drilling process. Mud removed to a depth of 40' after completion of drilling. Water level measured at 33-1/2' 30 minutes after removal of mud. To obtain water level measurement, a bucket boring was drilled adjacent to the rotary wash. Water level measured in the bucket boring at a depth of 32' 20 minutes after completion of drilling.

LOG OF BORING

LAW/CRANDALL, INC.

BORING 5

Coordinates
N-4,137,280
E-4,217,210

DATE DRILLED: April 16, 1992
EQUIPMENT USED: 24" - Diameter Bucket
TIME DRILLED: Start: 10:00 am; Finish: 2:15 pm
ELEVATION 300

ELEVATION	DEPTH (ft.)	OVA (ppm)	"N" VALUE STD.PEN.TEST	MOISTURE (% of dry wt.)	DRY DENSITY (lbs./cu. ft.)	DRIVE ENERGY (ft.-kips/ft.)	SAMPLE LOC.
				9.7	118	5	■
				11.5	121	12	■
295	5						
				4.5	113	12	■
290	10						
				12.8	104	20	■
				6.8	107	25	■
285	15						
				3.8	113	27	■
280	20						
				5.2	122	34	■
275	25						
				9.4	110	34	■
270	30						

SM

3" Asphaltic Paving

APTIFICIAL FILL

SILTY SAND - fine to coarse, about 30% Gravel, pieces of brick and asphaltic paving, dark brown

SM

YOUNGER ALLUVIUM (Qal)

SILTY SAND - fine to medium, light brown

SP
SM

SAND and SILTY SAND - fine to coarse, about 10% Gravel and Cobbles (to 8" in size), light brownish grey

Some Boulders (to12" in size)

About 30% Gravel and Cobbles

About 20% Gravel and Cobbles

SM

OLDER ALLUVIUM (Qalo)

SILTY SAND - fine to medium, about 30% Gravel and Cobbles (to 6" in size), light grey

NOTE: Water not encountered. Caving from 5' to 9' (to 3-1/2' in diameter).

Note : The log of subsurface conditions shown hereon applies only at the specific boring location and at the date indicated. It is not warranted to be representative of subsurface conditions at other locations and times.

JOB L92045.AEF-1 DATE 5/12/92 F.T. GMC/SJ DR. lk O.E. MS MS CHKD DM

LOG OF BORING

LAW/CRANDALL, INC.

PLATE A - 1.5

BORING 6

Coordinates
N-4,137,695
E-4,217,760

DATE DRILLED: April 17, 1992
EQUIPMENT USED: 20" - Diameter Bucket
TIME DRILLED: Start: 8:20 am; Finish: 10:25 am
ELEVATION 301

ELEVATION	DEPTH (ft.)	OVA (ppm)	"N" VALUE STD.PEN.TEST	MOISTURE (% of dry wt.)	DRY DENSITY (lbs./cu. ft.)	DRIVE ENERGY (ft.-kips/ft.)	SAMPLE LOC.
300							
				7.3	111	8	■
				4.0	92	3	■
	5						
295				14.4	98	< 1	■
				3.1	112	12	■
	10						
290				4.9	118	17	■
	15						
285		10		12.9	102	8	■
	20						
280				5.6	118	34	■
	25						
275				3.8	122	20	■
	30	>1000		32.6	96	14	■

3" Asphaltic Paving

SM **ARTIFICIAL FILL**
SILTY SAND - fine to coarse, pieces of glass, about 20% Gravel and Cobbles, dark brown

SM **YOUNGER ALLUVIUM (Qal)**
SILTY SAND - fine, light brownish grey

Strong gasoline odor

Fine to medium Sand, about 30% Gravel and Cobbles

Less Gravel and Cobbles

More Gravel and Cobbles

Slight gasoline odor
Layer of Sand

SW **OLDER ALLUVIUM (Qalo)**
SAND - well graded, about 30% Gravel, slight gasoline odor, grey
Strong gasoline odor, greenish grey

Grey

Cemented layer

ML CLAYEY SILT - strong gasoline odor, dark grey

NOTE: Water level measured at a depth of 29' after completion of drilling. Caving from 27' to 29' (to 2-1/2' in diameter).

Note : The log of subsurface conditions shown hereon applies only at the specific boring location and at the date indicated. It is not warranted to be representative of subsurface conditions at other locations and times.

JOB L92045.AEF-1 DATE 5/12/92 F.T. GMC/SJ DR. lk O.E. MS CHKD DM

LOG OF BORING

LAW/CRANDALL, INC.

JOB L92045.AEF-1 DATE 5/12/92 F.T. SEJ/LS DR. lk O.E. MS MS CHKD DM

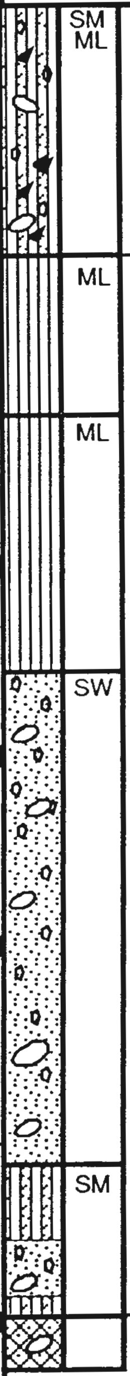
Note : The log of subsurface conditions shown hereon applies only at the specific boring location and at the date indicated. It is not warranted to be representative of subsurface conditions at other locations and times.

BORING 7

Coordinates
N-4,137,975
E-4,217,965

DATE DRILLED:	April 15, 1992
EQUIPMENT USED:	24" - Diameter Bucket
TIME DRILLED:	Start: 1:33 pm; Finish: 4:48 pm
ELEVATION 342	

ELEVATION	DEPTH (ft.)	OVA (ppm)	"N" VALUE STD.PEN.TEST	MOISTURE (% of dry wt.)	DRY DENSITY (lbs./cu. ft.)	DRIVE ENERGY (ft.-kips/ft.)	SAMPLE LOC.
340				7.8	119	7	■
				8.5	115	5	■
	5			16.0	109	5	■
335				14.0	109	3	■
	10			11.9	107	1	■
330							
	15			15.6	112	7	■
325							
	20			3.1	125	15	■
320							
	25			5.7	114	15	■
315							
	30						
310							
	35			19.3	107	34	■
305							
	40						



SM ML

ARTIFICIAL FILL
SILTY SAND and SANDY SILT - about 20% Gravel and Cobbles, pieces of brick, dark brown

More pieces of brick

ML

OLDER ALLUVIUM (Qalo)
SANDY SILT - brown

ML

CLAYEY SILT - some Sand, brown

NOTE: Slight water seepage encountered at a depth of 32-1/2'. 1" of water at the bottom of the boring 10 minutes after completion of drilling. Caving below 17' (to 4' in diameter).

SW

SAND - well graded, some Silt, about 30% Gravel and Cobbles, light greyish brown

Some Cobbles (to 6" in size)

Few Cobbles and Boulders (to 13" in size)

SM

SILTY SAND - fine, reddish brown

Layer of well graded Sand, some Gravel and Cobbles

PUENTE FORMATION (Tpss)
SANDSTONE - fine to medium grained, scattered Cobbles, poorly bedded, moderately cemented, bluish grey

(BORING TERMINATED AT A DEPTH OF 36' DUE TO DIFFICULT DRILLING THROUGH CEMENTED LAYER)

LOG OF BORING

LAW/CRANDALL, INC.

PLATE A - 1.7

BORING 8

Coordinates
N-4,138,100
E-4,218,430

DATE DRILLED: April 14, 1992
EQUIPMENT USED: 20" - Diameter Bucket
TIME DRILLED: Start: 11:00 am; Finish: 2:20 pm
ELEVATION 305

ELEVATION	DEPTH (ft.)	OVA (ppm)	"N" VALUE STD.PEN.TEST	MOISTURE (% of dry wt.)	DRY DENSITY (lbs./cu. ft.)	DRIVE ENERGY (ft.-kips/ft.)	SAMPLE LOC.
				10.9	118	6	■
				2.1	94	6	■
300	5						
				4.4	94	< 1	■
		175		16.8	112	10	■
295	10						
				22.8	103	5	■
				18.2	109	8	■
290	15						
				18.9	106	14	■
285	20						
				17.0	113	19	■
280	25						
				13.7	103	19	■
275	30						
				15.7	113	56	■
270	35						
265	40	25		8.8	111	24	■

SM
2" Asphaltic Paving

ARTIFICIAL FILL
SILTY SAND - fine, about 20% Gravel, dark brown

SW
OLDER ALUVIUM (Qalo)
SAND - well graded, about 10% Gravel, light greyish brown

SP
SAND - fine, some Gravel and Cobbles, strong gasoline odor, dark grey

PUENTE FORMATION (Tpss)
INTERBEDDED SANDSTONE and SILTSTONE - fine to medium grained, poorly bedded, poorly to moderately cemented. light bluish grey
Strong H_2S odor

SILTY SANDSTONE - fine to medium grained, poorly bedded to massive, poorly to moderately cemented, light grey
Strong H_2S odor
Light brown and light grey

Siltstone layers, grey
Dark brown, strong gasoline odor and stains

Moderately to well cemented

NOTE: Water seepage encountered at depths of 14', 19' and 34'. Water level measured at a depth of 38' after completion of drilling and at 36' 20 minutes later. Patchy caving at 19'.

Note : The log of subsurface conditions shown hereon applies only at the specific boring location and at the date indicated. It is not warranted to be representative of subsurface conditions at other locations and times.

JOB L92045.AEF-1 DATE 5/12/92 F.T. GMC/SJ DR. lk O.E. MS MB CHKD DM

LOG OF BORING

LAW/CRANDALL, INC.

PLATE A - 1.8

JOB L92045.AEF-1 DATE 5/12/92 F.T. GMC DR. lk O.E. MS *MS* CHKD *DM*

Note : The log of subsurface conditions shown hereon applies only at the specific boring location and at the date indicated. It is not warranted to be representative of subsurface conditions at other locations and times.

BORING 9

Coordinates
N-4,138,345
E-4,218,650

DATE DRILLED: April 15, 1992
EQUIPMENT USED: 24" - Diameter Bucket
TIME DRILLED: Start: 7:35 am; Finish: 1:25 pm
ELEVATION 346

ELEVATION	DEPTH (ft.)	OVA (ppm)	"N" VALUE STD.PEN.TEST	MOISTURE (% of dry wt.)	DRY DENSITY (lbs./cu. ft.)	DRIVE ENERGY (ft.-kips/ft.)	SAMPLE LOC.
345							
				5.9	110	5	■
				5.8	115	8	■
	5						
340							
				3.9	108	5	■
				21.0	97	5	■
	10						
335							
				12.6	111	3	■
	15						
330							
				15.3	107	12	■
	20						
325							
				26.4	98	19	■
	25						
320							
				15.6	112	24	■
	30						
315							
				17.5	112	20	■
	35						
310							
				19.6	104	29	■
	40						

SM
ML

ARTIFICIAL FILL

SILTY SAND and SANDY SILT - fine to coarse, about 20% Gravel and Cobbles (to 6" in size), about 10% debris (including pieces of glass, brick, and concrete), brown

More debris, large Cobbles (to 10" in size)

Some Sandstone fragments

SW

OLDER ALLUVIUM (Qalo)

SAND - well graded, about 20% Gravel, brown and grey

CL

SILTY CLAY - brown

PUENTE FORMATION (Tpss)

SANDSTONE - medium to coarse grained, poorly bedded, poorly cemented, yellowish brown

Bedding: N84W, 64SW

Light grey to yellowish brown

INTERBEDDED SANDSTONE and SILTSTONE - well beddded, poorly to moderately cemented, light grey and brown

SANDSTONE - medium to coarse grained, poorly bedded, moderately cemented, yellowish brown and grey

Bedding: N72W, 56SW

Fine to medium grained, dark bluish grey

(CONTINUED ON FOLLOWING PLATE)

LOG OF BORING

LAW/CRANDALL, INC.

JOB L92045.AEF-1 DATE 5/12/92 F.T. GMC DR. lk O.E. MS MB CHKD DM

Note : The log of subsurface conditions shown hereon applies only at the specific boring location and at the date indicated. It is not warranted to be representative of subsurface conditions at other locations and times.

BORING 9

DATE DRILLED: April 15, 1992
EQUIPMENT USED: 24" - Diameter Bucket
TIME DRILLED: Start: 7:35 am; Finish: 1:25 pm

ELEVATION	DEPTH (ft.)	OVA (ppm)	"N" VALUE STD.PEN.TEST	MOISTURE (% of dry wt.)	DRY DENSITY (lbs./cu. ft.)	DRIVE ENERGY (ft.-kips/ft.)	SAMPLE LOC.
305							
	45			16.6	113	20	■
300							
	50			20.5	106	24	■
295							
	55						

Medium to coarse grained

Fine to medium grained

NOTE: Water level encountered at a depth of 41' after completion of drilling and at 32' 2 hours later. No caving. Downhole logged.

LOG OF BORING

LAW/CRANDALL, INC.

Note : The log of subsurface conditions shown hereon applies only at the specific boring location and at the date indicated. It is not warranted to be representative of subsurface conditions at other locations and times.

JOB L92045.AEF-1 DATE 5/12/92 F.T. TC DR. lk O.E. MS MJ CHKD DM

BORING 10

DATE DRILLED:	April 14 & 15, 1992
EQUIPMENT USED:	24" - Diameter Bucket to 30' 5" - Diameter Rotary Wash to 100'
TIME DRILLED:	Start: 7:30 am; Finish: 10:40 am (B) Start: 6:45 am; Finish: 11:50 am (RW)
ELEVATION	309

Coordinates
N-4,138,480
E-4,219,200

ELEVATION	DEPTH (ft.)	OVA (ppm)	"N" VALUE STD.PEN.TEST	MOISTURE (% of dry wt.)	DRY DENSITY (lbs./cu. ft.)	DRIVE ENERGY (ft.-kips/ft.)	SAMPLE LOC.
				4.3	118	5	■
305				2.6	103	5	■
	5						
				2.3	117	5	■
				2.6	109	8	■
300							
	10			14.8	107	24	■
295				28.6	92	11	■
	15						
290				24.1	101	16	■
	20						
285				18.7	111	24	■
	25						
280							
	30						
275				17.4	115	50	■
	35						
270				24.5	100	25	■
	40						

SM

ARTIFICIAL FILL
SILTY SAND - fine, some Gravel, brown

SW

YOUNGER ALLUVIUM (Qal)
SAND - well graded, about 40% Gravel and Cobbles (to 6" in size), light brown

PUENTE FORMATION (Tpss)
SANDSTONE - fine grained, poorly bedded, poorly cemented, yellow brown

SILTSTONE - some fine Sand, massive, poorly cemented, bluish grey

SANDSTONE with INTERBEDDED SILTSTONE - well bedded, poorly cemented, fine grained, light bluish grey,

Petroliferous Sandstone, dark brown
Scattered Cobbles to 4"

Moderately cemented

(BUCKET BORING TERMINATED AT A DEPTH OF 30' DUE TO DIFFICULT DRILLING THROUGH HARD CEMENTED LAYERS)

SILTSTONE with minor INTERBEDDED SANDSTONE - fine grained, moderately bedded, poorly cemented, bluish grey

(CONTINUED ON FOLLOWING PLATE)

LOG OF BORING

LAW/CRANDALL, INC.

BORING 10 (Continued)

DATE DRILLED: April 14 & 15, 1992
EQUIPMENT USED: 24" - Diameter Bucket to 30'
5" - Diameter Rotary Wash to 100'
TIME DRILLED: Start: 7:30 am; Finish: 10:40 am (B)
Start: 6:45 am; Finish: 11:50 am (RW)

ELEVATION	DEPTH (ft.)	OVA (ppm)	"N" VALUE STD.PEN.TEST	MOISTURE (% of dry wt.)	DRY DENSITY (lbs./cu. ft.)	DRIVE ENERGY (ft.-kips/ft.)	SAMPLE LOC.	
265								
	45			21.3	108	47	■	
260								
	50			21.8	104	42	■	
								SANDSTONE with minor INTERBEDDED SILTSTONE - fine grained, poorly bedded, moderately cemented, bluish grey and dark brown
255								
	55			15.6	117	63	■	
250								
	60			19.9	108	42	■	
245								Well cemented layer, 6" thick
	65			19.0	106	126	■	
240								
	70			19.4	111	126	■	
235								
	75			22.8	104	101	■	
230								
	80			15.8	117	158	■	

(CONTINUED ON FOLLOWING PLATE)

LOG OF BORING

LAW/CRANDALL, INC.

PLATE A - 1.10b

Note : The log of subsurface conditions shown hereon applies only at the specific boring location and at the date indicated. It is not warranted to be representative of subsurface conditions at other locations and times.

JOB L92045.AEF-1 DATE 5/12/92 F.T. TC DR. lk O.E. MS MS CHKD JB DM

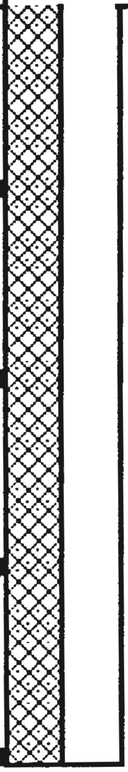
JOB L92045.AEF-1 DATE 5/12/92 F.T. TC DR. lk O.E. MS MS CHKD DM

Note : The log of subsurface conditions shown hereon applies only at the specific boring location and at the date indicated. It is not warranted to be representative of subsurface conditions at other locations and times.

BORING 10

DATE DRILLED: April 14 & 15, 1992
EQUIPMENT USED: 24" - Diameter Bucket to 30'
5" - Diameter Rotary Wash to 100'
TIME DRILLED: Start: 7:30 am; Finish: 10:40 am (B)
Start: 6:45 am; Finish: 11:50 am (RW)

ELEVATION	DEPTH (ft.)	OVA (ppm)	"N" VALUE STD.PEN.TEST	MOISTURE (% of dry wt.)	DRY DENSITY (lbs./cu. ft.)	DRIVE ENERGY (ft.-kips/ft.)	SAMPLE LOC.
225				22.6	105	84	■
	85						
220				17.7	108	158	■
	90						
215				17.0	113	105	■
	95						
210				17.5	112	158	■
	100						



Well cemented layer, 6" thick

NOTE: BUCKET BORING:

Slight water seepage encountered at 28'. About 6" of water at the bottom of boring 30 minutes after completion of drilling. Caring from 4' to 9' (to 3' in diameter).

ROTARY WASH BORING:

Drilling mud used in drilling process. To obtain future water level measurements and sampling, installed 2" - diameter PVC pipe to a depth of 100'. Pipe perforated between depths of 20' and 100'. Backfilled with Sand to within 20' of ground surface. Bentonite plug was placed between 16' and 20' and was grouted with cement above 16'. Water level measured in the well at 16-1/2' on 5/5/92.

LOG OF BORING

LAW/CRANDALL, INC.

PLATE A - 1.10c

MAJOR DIVISIONS			GROUP SYMBOLS	TYPICAL NAMES
COARSE GRAINED SOILS (More than 50% of material is LARGER than No. 200 sieve size)	GRAVELS (More than 50% of coarse fraction is LARGER than the No. 4 sieve size)	CLEAN GRAVELS (Little or no fines)	GW	Well graded gravels, gravel-sand mixtures, little or no fines.
			GP	Poorly graded gravels or gravel-sand mixtures, little or no fines.
		GRAVELS WITH FINES (Appreciable amt. of fines)	GM	Silty gravels, gravel-sand-silt mixtures.
			GC	Clayey gravels, gravel-sand-clay mixtures.
	SANDS (More than 50% of coarse fraction is SMALLER than the No. 4 sieve size)	CLEAN SANDS (Little or no fines)	SW	Well graded sands, gravelly sands, little or no fines.
			SP	Poorly graded sands or gravelly sands, little or no fines.
		SANDS WITH FINES (Appreciable amt. of fines)	SM	Silty sands, sand-silt mixtures.
			SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS (More than 50% of material is SMALLER than No. 200 sieve size)	SILTS AND CLAYS (Liquid limit LESS than 50)		ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
			OL	Organic silts and organic silty clays of low plasticity.
	SILTS AND CLAYS (Liquid limit GREATER than 50)		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
			CH	Inorganic clays of high plasticity, fat clays.
			OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS			Pt	Peat and other highly organic soils.

BOUNDARY CLASSIFICATIONS: Soils possessing characteristics of two groups are designated by combinations of group symbols.

PARTICLE SIZE LIMITS

SILT OR CLAY	SAND			GRAVEL		COBBLES	BOULDERS
	FINE	MEDIUM	COARSE	FINE	COARSE		

NO. 200 NO. 40 NO. 10 NO. 4 3/4 in. 3 in. (12 in.)

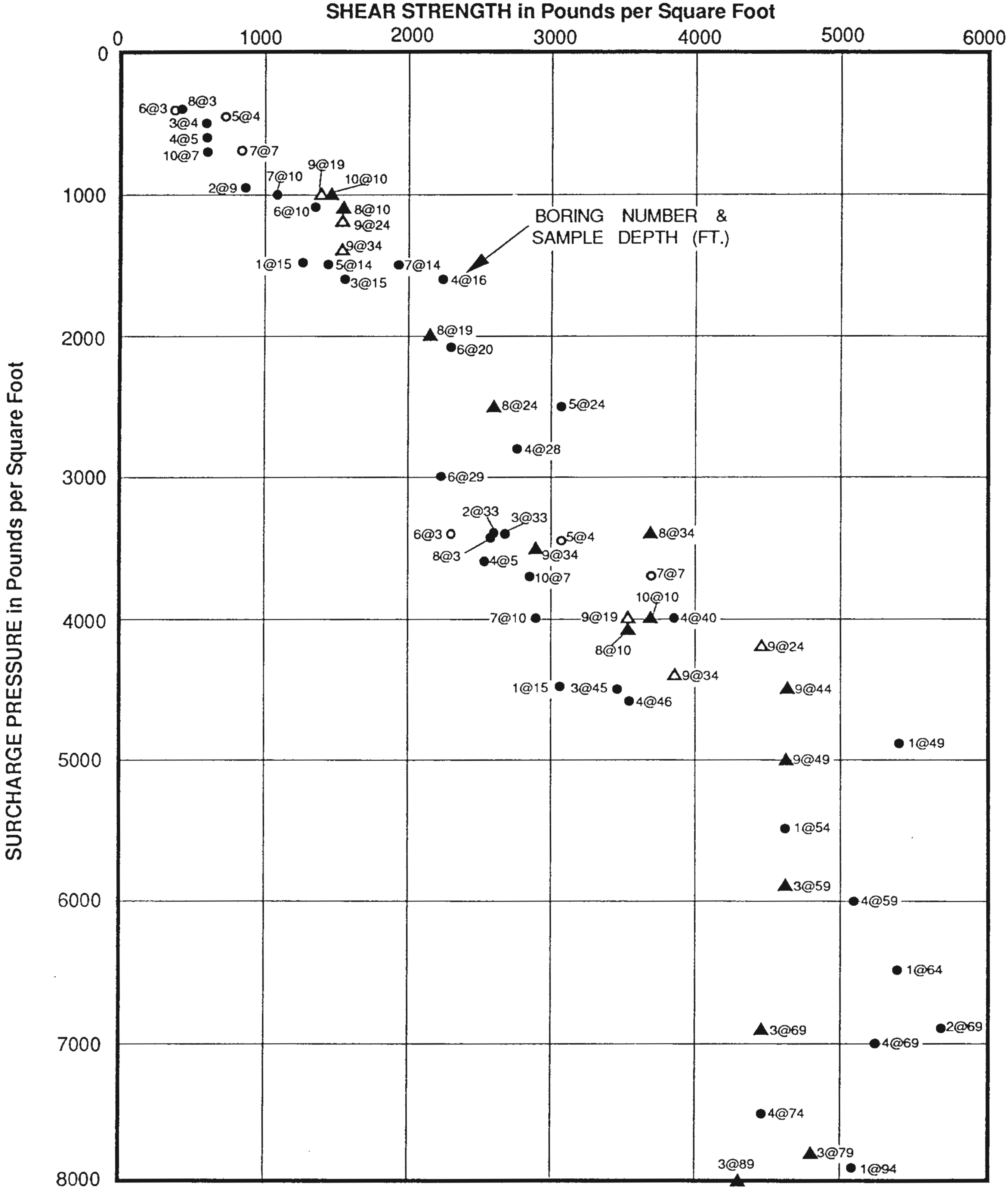
U. S. STANDARD SIEVE SIZE

UNIFIED SOIL CLASSIFICATION SYSTEM

Reference :
The Unified Soil Classification System, Corps of Engineers, U.S. Army Technical Memorandum No. 3-357, Vol. I, March, 1953. (Revised April, 1960)

LAW/CRANDALL, INC.

PLATE A-2



KEY:

▲ ● Samples tested at field moisture content

△ ○ Samples tested after soaking to a moisture content near saturation

○ Overburden natural soils

△ Bedrock

DIRECT SHEAR TEST DATA

LAW/CRANDALL, INC.

PLATE A-3.1

JOB L92045.AEF-1

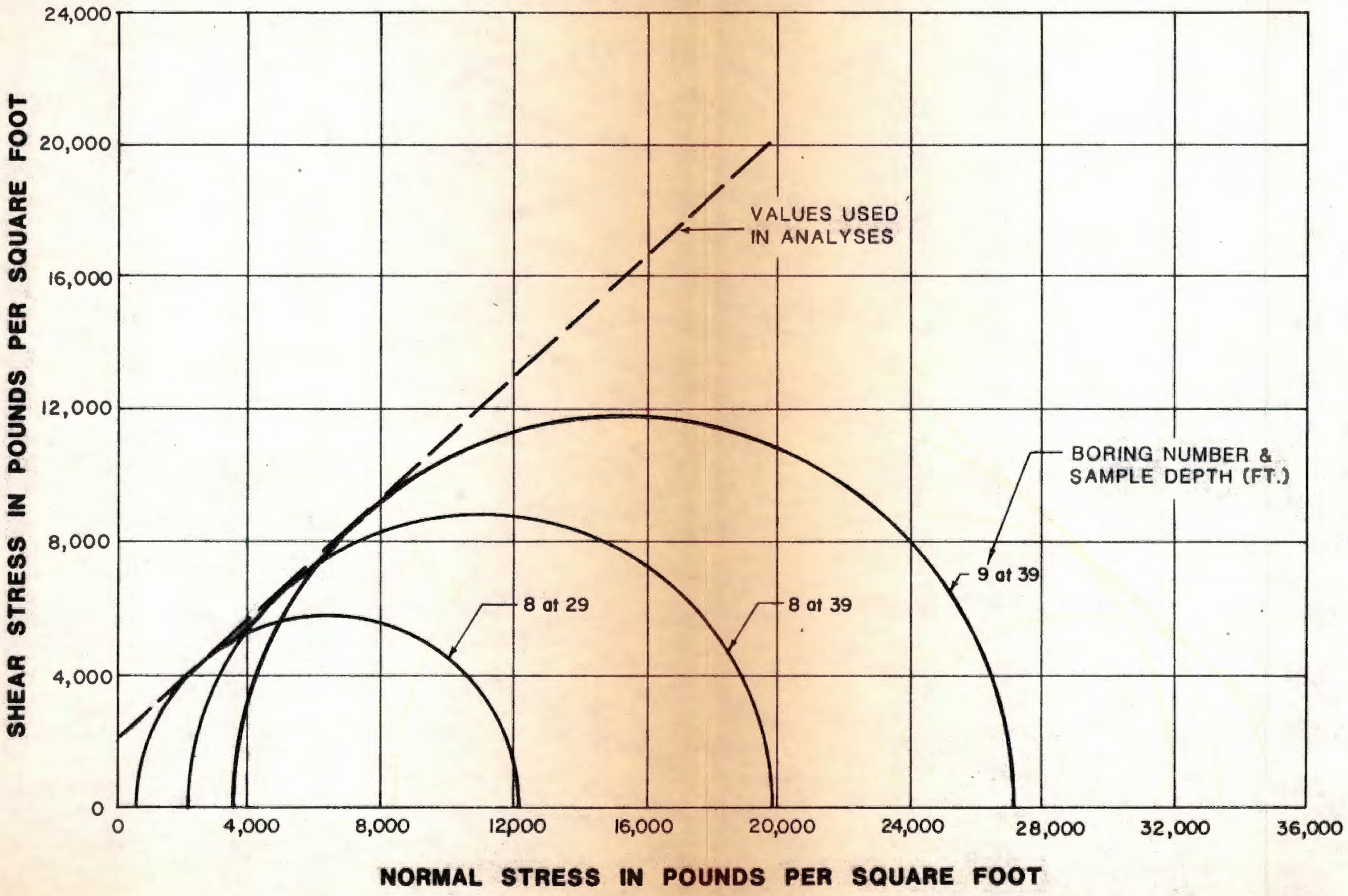
DATE 5/4/92

DR ph

O.E.

MS

CHKD. DM



<u>NOTES:</u>

1-TESTS WERE PERFORMED ON BEDROCK

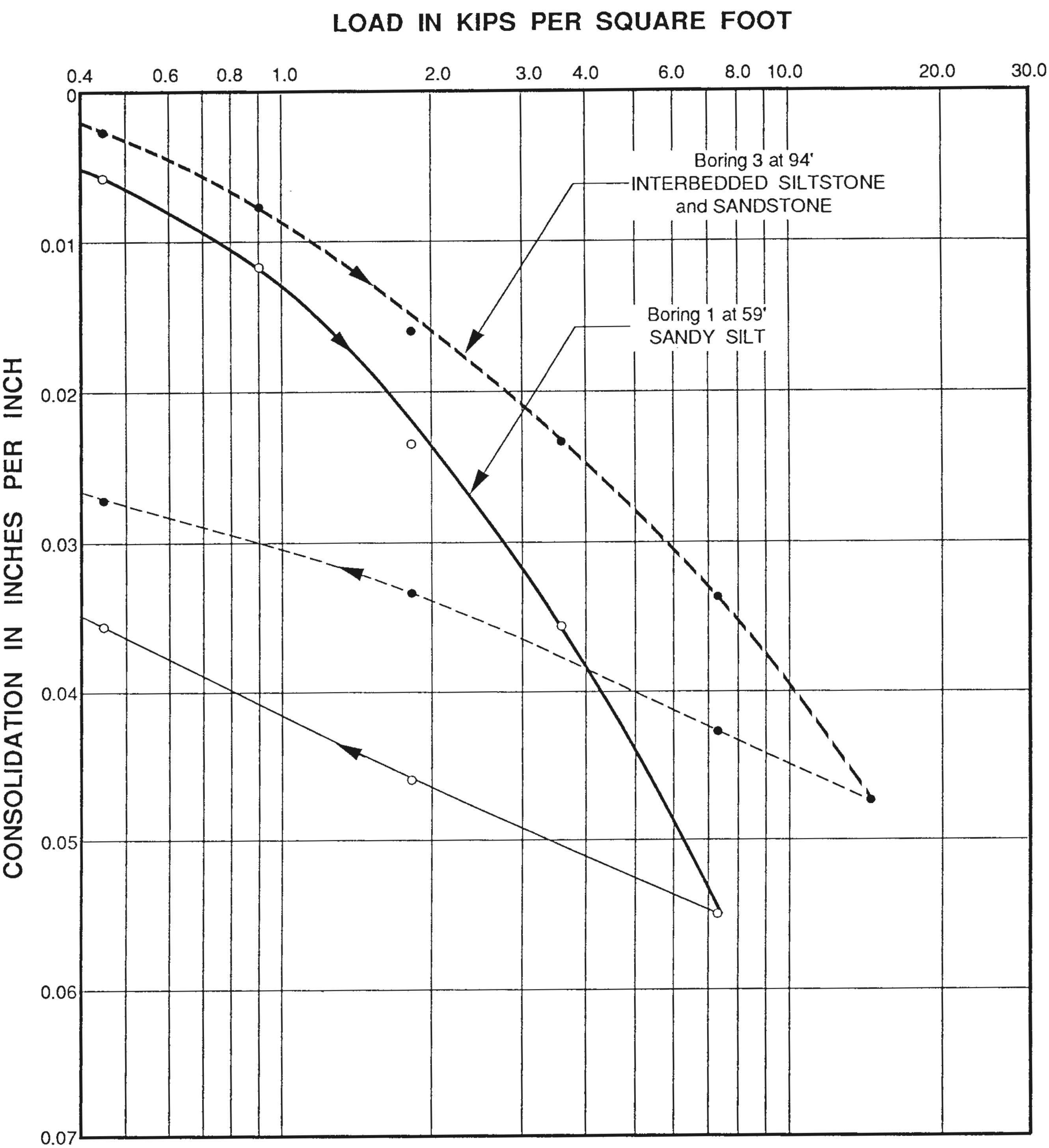
2-SAMPLES TESTED AT FIELD MOISTURE CONTENT

TRIAXIAL SHEAR TEST DATA

LAW/CRANDALL, INC.

FORM 137-A

JOB L92045AEF-1 DATE 5/14/92 DR. lk O.E. MS MS CHKD DM

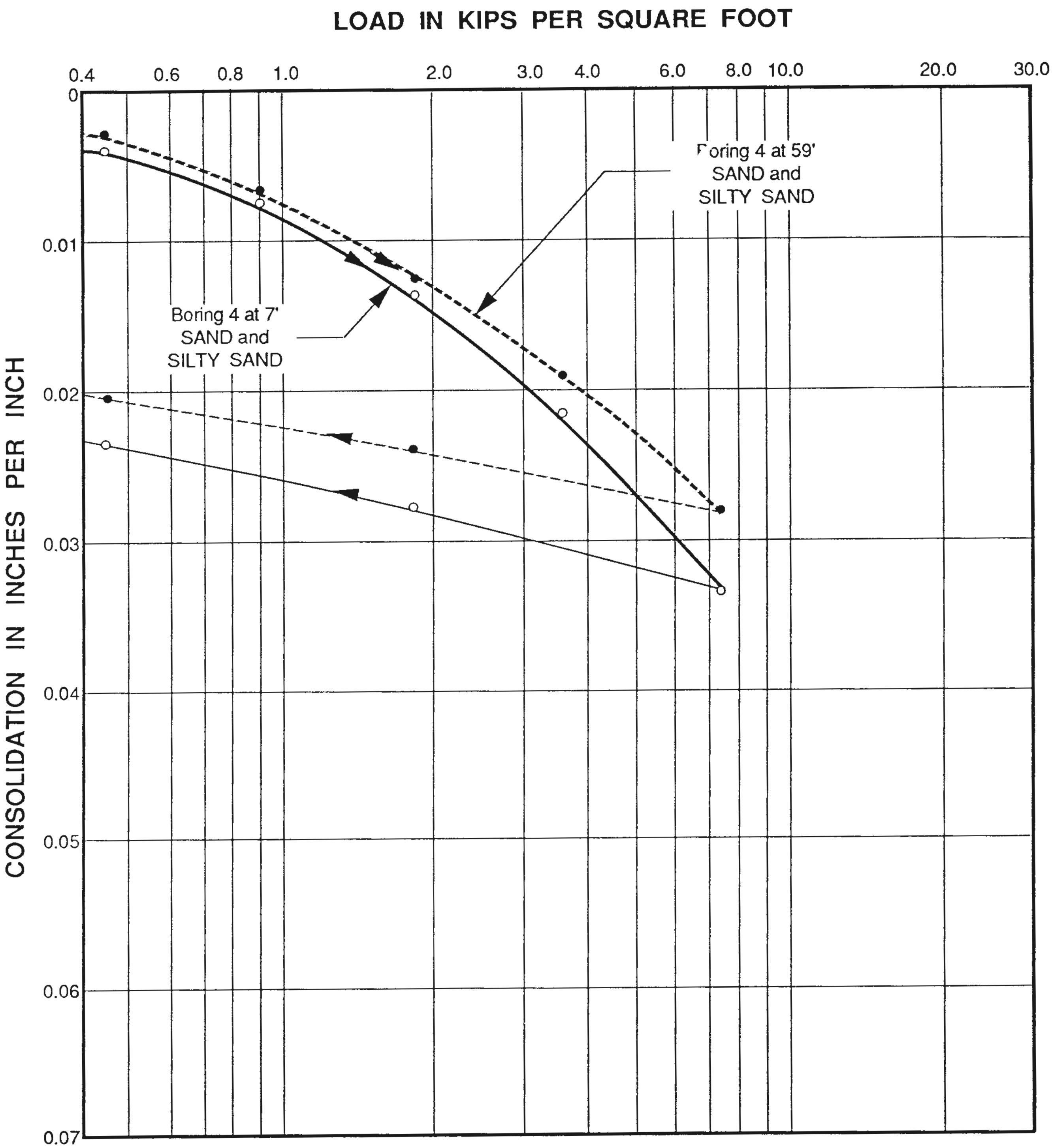


NOTE: Samples tested at field moisture content.

CONSOLIDATION TEST DATA

LAW/CRANDALL, INC.

JOB L92045AEF-1
DATE 5/14/92
DR. lk
O.E. MS
CHKD DM

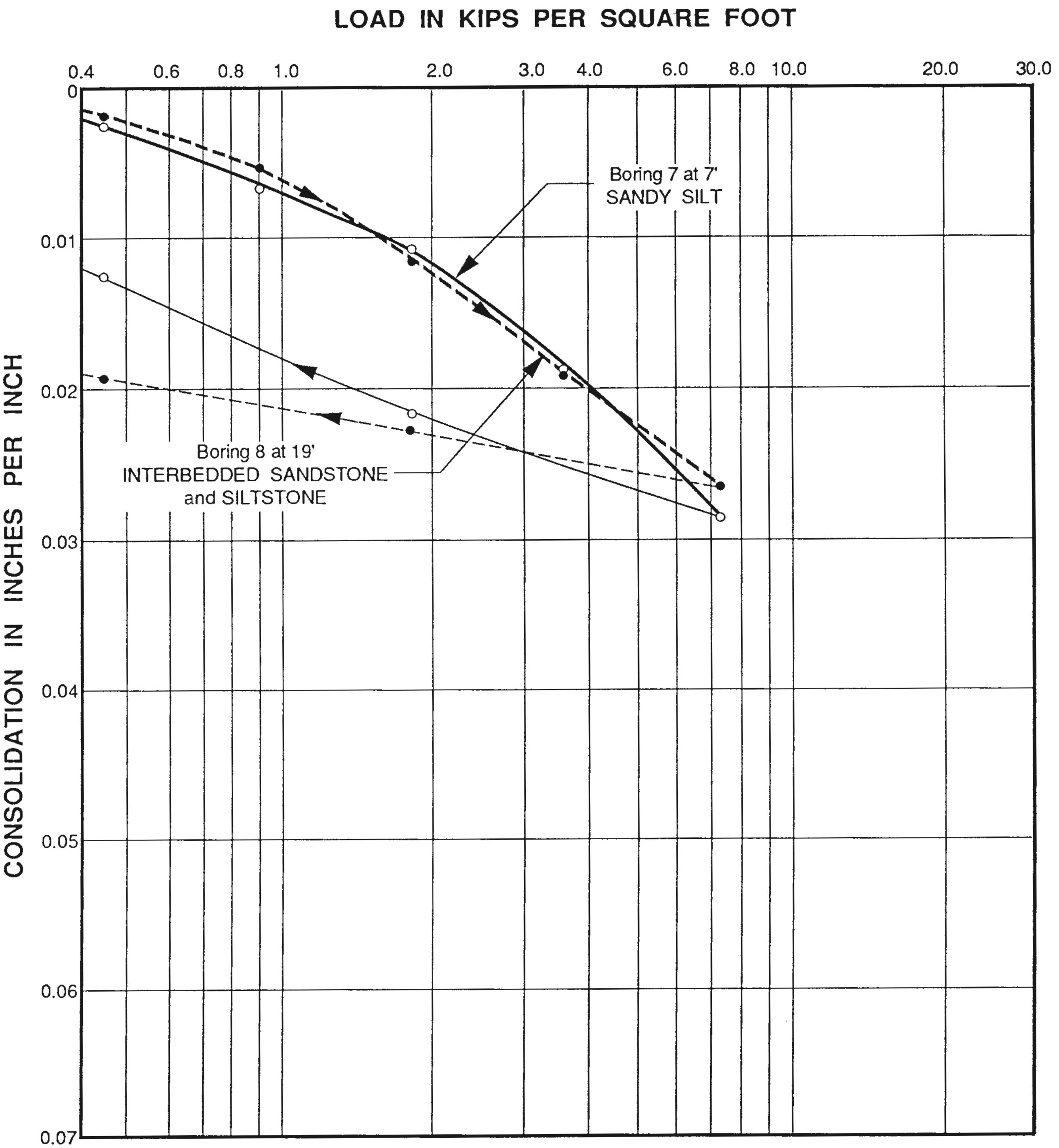


NOTE: Samples tested at field moisture content.

CONSOLIDATION TEST DATA

LAW/CRANDALL, INC.

JOB L92045AEF-1 DATE 5/14/92 DR. lk O.E. MS MS CHKD DM

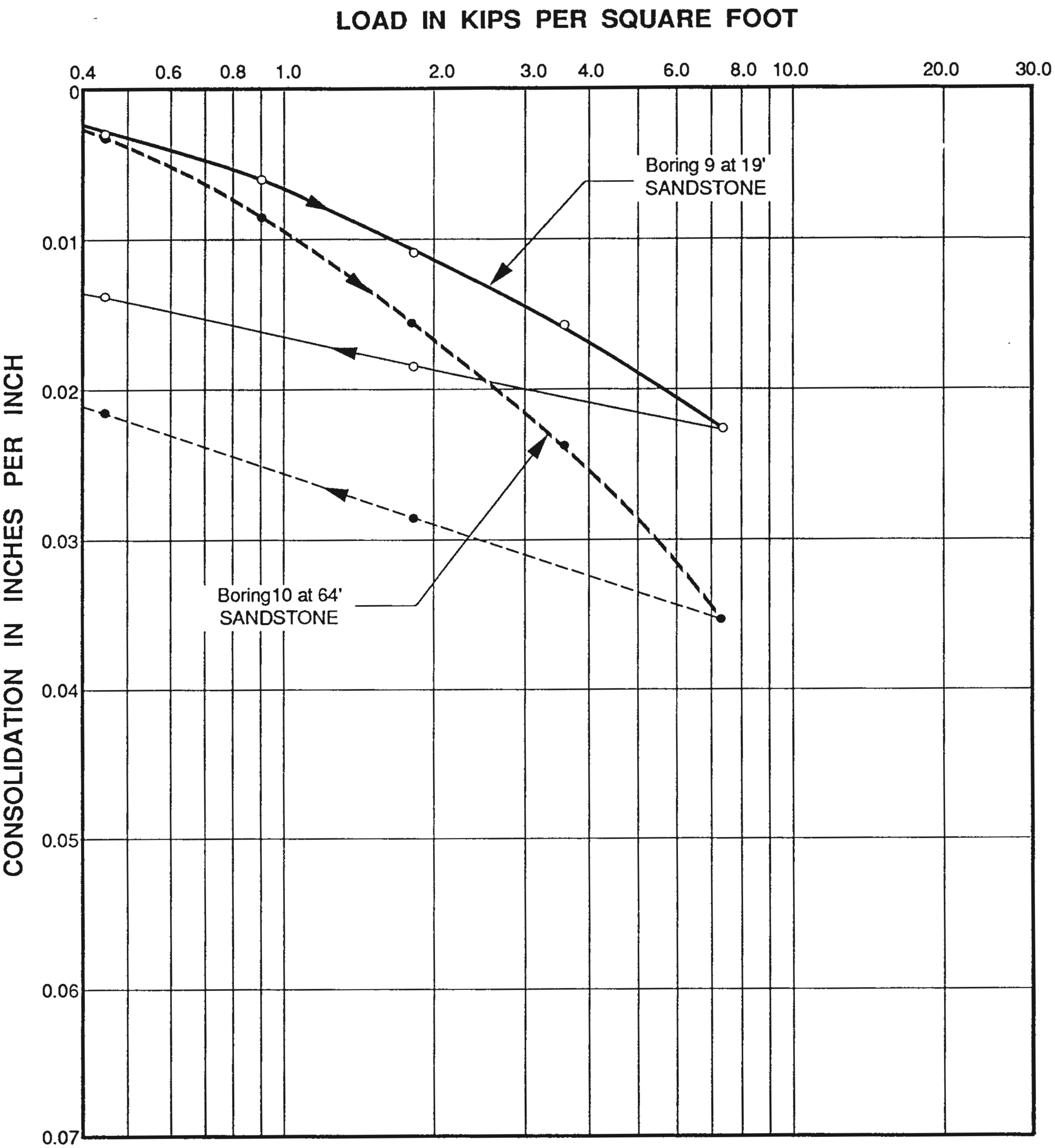


NOTE: Water added to sample from Boring 7 after consolidation under a load of 3.6 kips per square foot. The other sample tested at field moisture content.

CONSOLIDATION TEST DATA

LAW/CRANDALL, INC.

JOB L92045AEF-1 DATE 5/14/92 DR. lk O.E. MS CHKD DM



NOTE: Samples tested at field moisture content.

CONSOLIDATION TEST DATA

LAW/CRANDALL, INC.

PLATE A-4.4

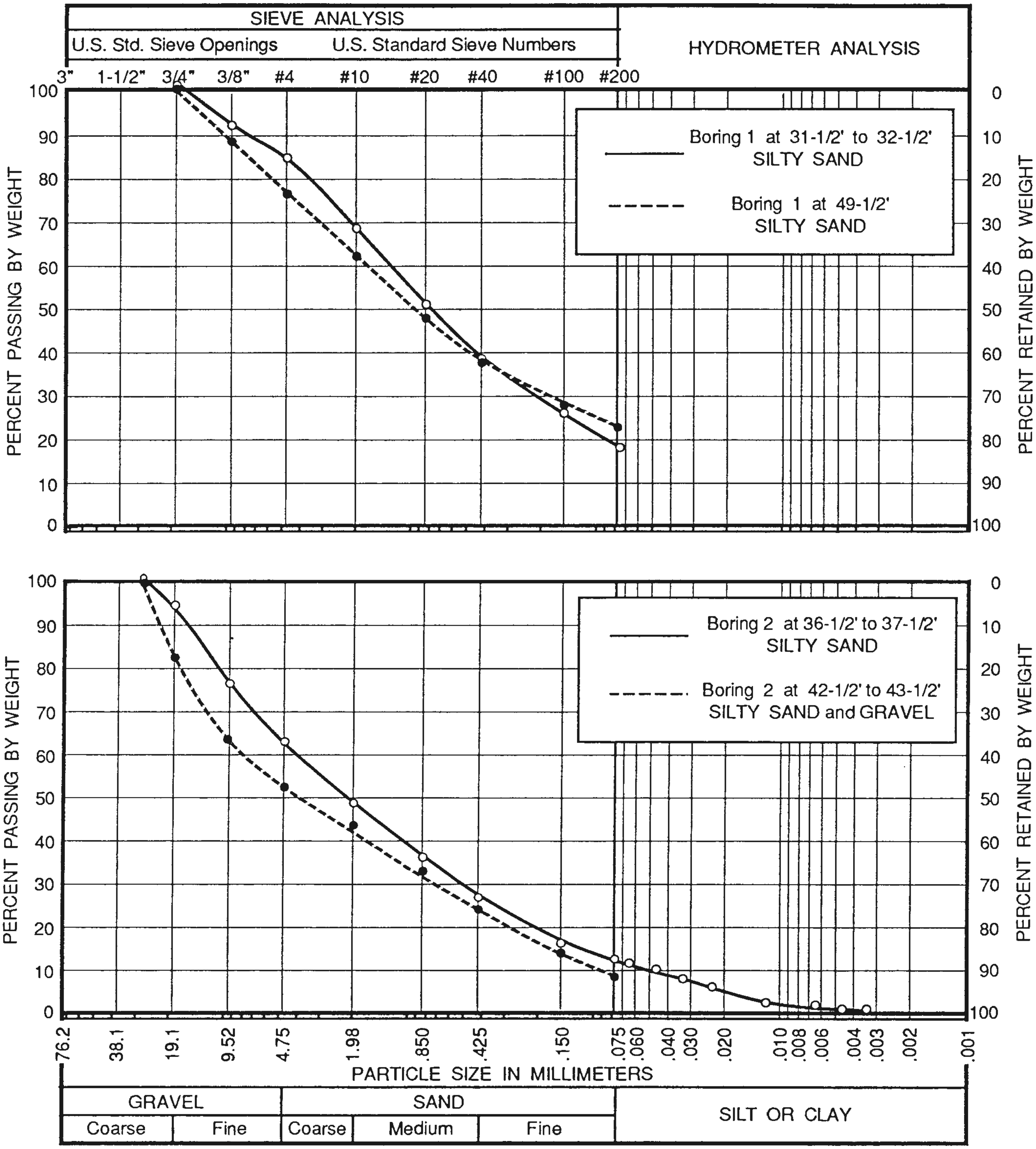
BORING NUMBER AND SAMPLE DEPTH :	7 at 1' to 5'	9 at 0' to 5'
SOIL TYPE :	FILL - SILTY SAND and SANDY SILT	FILL - SILTY SAND and SANDY SILT
MAXIMUM DRY DENSITY : (lbs./cu. ft.)	133	132
OPTIMUM MOISTURE CONTENT : (% of dry wt.)	9	8

TEST METHOD : ASTM Designation D1557 - 78

COMPACTION TEST DATA

JOB L92045.AEF-1 DATE 5/26/92 DR. lk O.E. MS CHKD DM

JOB L92045.AEF-1
DATE 5/14/92
D.R. lk
O.E.
MS
CHKD DM

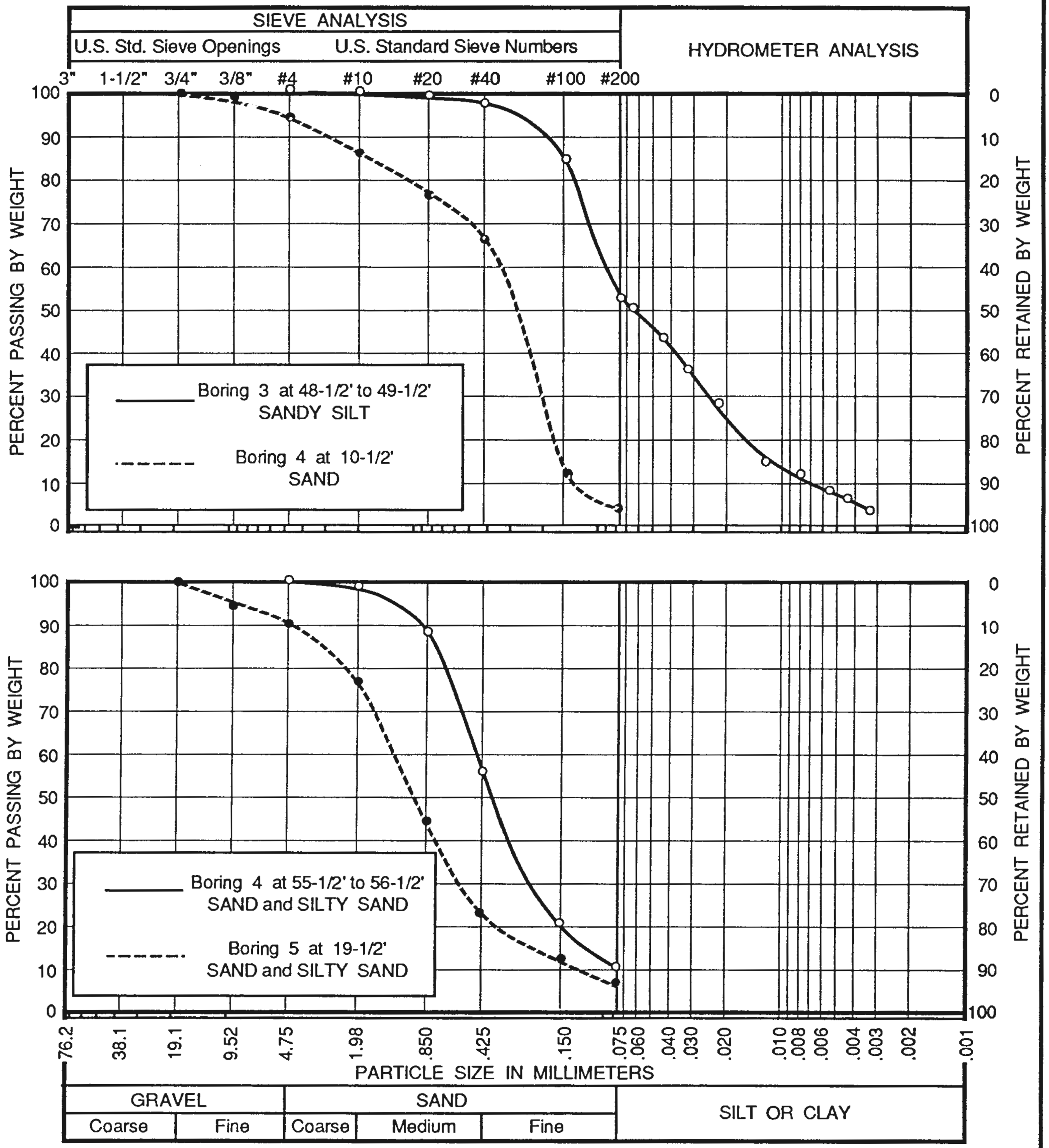


PARTICLE SIZE DISTRIBUTION

LAW/CRANDALL, INC.

PLATE A-6.1

JOB L92045.AEF-1 DATE 5/14/92 D.R. lk O.E. MS MWS CHKD DM

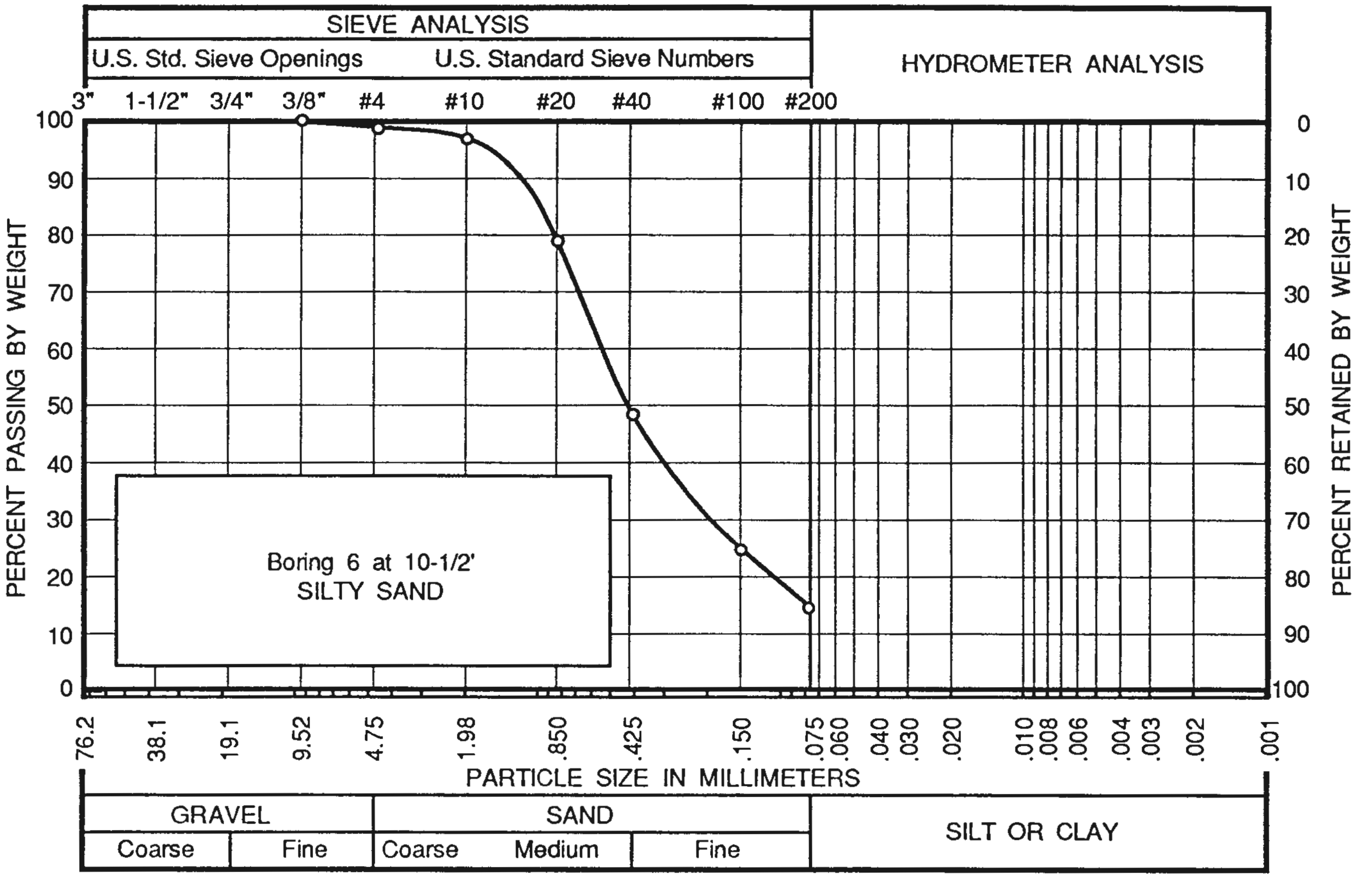


PARTICLE SIZE DISTRIBUTION

LAW/CRANDALL, INC.

PLATE A - 6.2

JOB L92045.AEF-1 DATE 5/14/92 D.R. lk O.E. MS CHKD. DM

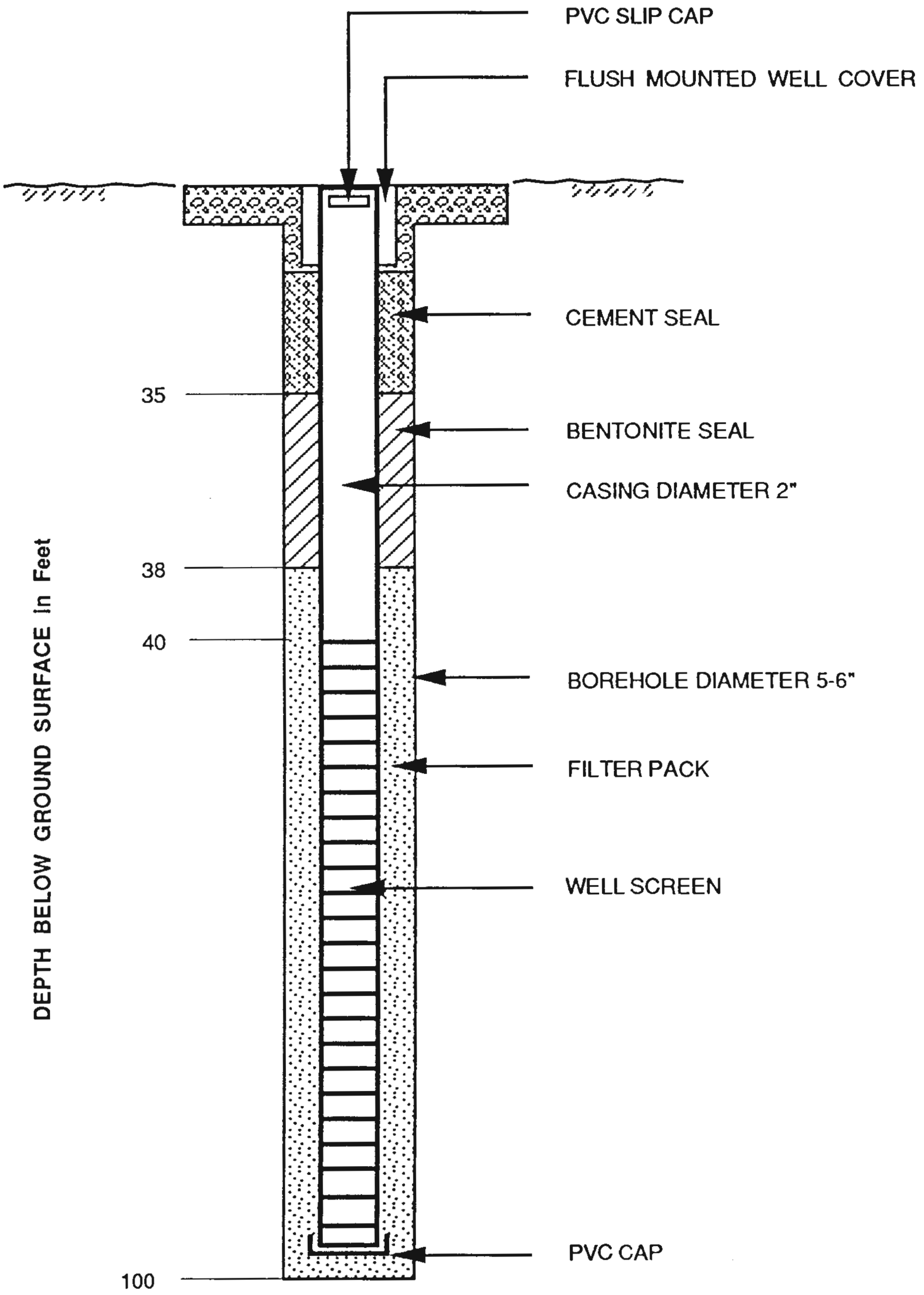


PARTICLE SIZE DISTRIBUTION

LAW/CRANDALL, INC.

PLATE A-6.3

JOB L92045.AEF1 DATE 5/22/92 W.P. ph S.G. BM CHKD

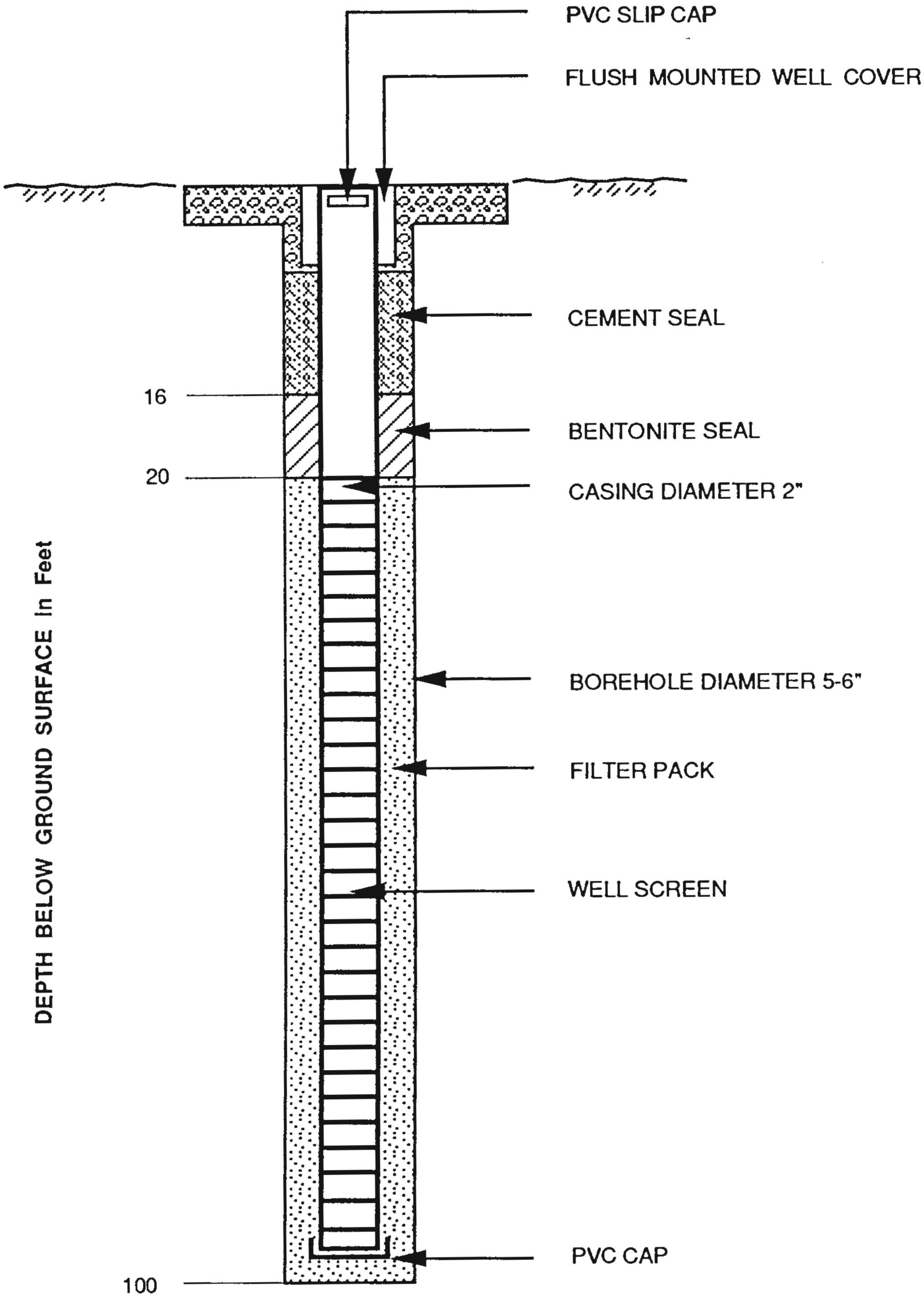


NOT TO SCALE

MONITORING WELL CONSTRUCTION DETAILS
BORING 1

LAW/CRANDALL, INC.

JOB L92045.AEF1 DATE 5/22/92 W.P. ph S.G. BM CHKD



NOT TO SCALE

MONITORING WELL CONSTRUCTION DETAILS BORINGS 3 and 10

LAW/CRANDALL, INC.

PLATE A-7.2

APPENDIX B

B C Analytical

801 Western Avenue
Glendale, CA 91201
818/247-5737
Fax: 818/247-9797

ANALYTICAL REPORT

LOG NO: G92-05-050

Received: 05 MAY 92
Mailed : 19 MAY 92

Mr. Bill Mitchell
Law/Crandall, Inc.
200 Citadel Drive
Los Angeles, California 90040

Project: L92045.AEFO

REPORT OF ANALYTICAL RESULTS

LOG NO	SAMPLE DESCRIPTION, GROUND WATER SAMPLES	DATE SAMPLED
05-050-1	B-3	05 MAY 92
05-050-2	B-10	05 MAY 92

PARAMETER	05-050-1	05-050-2
Nitric Acid Digestion with HCl, Date	05/06/92	05/06/92
Nitric Acid Digestion, Date	05/06/92	05/06/92
Arsenic by Graphite Furnace, mg/L	<0.002	0.002
Antimony, mg/L	<0.06	<0.06
Barium, mg/L	0.093	0.098
Beryllium, mg/L	0.029	<0.002
Cadmium by Graphite Furnace, mg/L	<0.001	<0.001
Chromium by Graphite Furnace, mg/L	<0.005	<0.005
Cobalt, mg/L	0.13	<0.04
Copper, mg/L	<0.02	<0.02
Lead by Graphite Furnace, mg/L	0.005	0.016
Mercury, mg/L	<0.0005	<0.0005
Molybdenum, mg/L	<0.04	<0.04
Nickel, mg/L	0.07	<0.04
Selenium by Graphite Furnace, mg/L	<0.005	<0.005
Silver, mg/L	<0.01	<0.01
Thallium, mg/L	<0.4	<0.4
Vanadium, mg/L	<0.04	<0.04
Zinc, mg/L	0.29	0.05
Petroleum Hydrocarbons (418.1), mg/L	0.2	<0.2

LOG NO: G92-05-050

Received: 05 MAY 92
Mailed : 19 MAY 92

Mr. Bill Mitchell
Law/Crandall, Inc.
200 Citadel Drive
Los Angeles, California 90040

Project: L92045.AEFO

REPORT OF ANALYTICAL RESULTS

LOG NO	SAMPLE DESCRIPTION, GROUND WATER SAMPLES	DATE SAMPLED
05-050-1	B-3	05 MAY 92
05-050-2	B-10	05 MAY 92

PARAMETER	05-050-1	05-050-2
EPA Method 8270		
Date Analyzed	05/13/92	05/13/92
Date Extracted	05/08/92	05/08/92
Dilution Factor, Times	1	1
1,2,4-Trichlorobenzene, ug/L	<5	<5
1,2-Dichlorobenzene, ug/L	<5	<5
1,2-Diphenylhydrazine, ug/L	<5	<5
1,3-Dichlorobenzene, ug/L	<5	<5
1,4-Dichlorobenzene, ug/L	<5	<5
2,4,5-Trichlorophenol, ug/L	<20	<20
2,4,6-Trichlorophenol, ug/L	<5	<5
2,4-Dichlorophenol, ug/L	<10	<10
2,4-Dimethylphenol, ug/L	<10	<10
2,4-Dinitrophenol, ug/L	<30	<30
2,4-Dinitrotoluene, ug/L	<5	<5
2,6-Dinitrotoluene, ug/L	<5	<5
2-Chloronaphthalene, ug/L	<20	<20
2-Chlorophenol, ug/L	<10	<10
2-Methyl-4,6-dinitrophenol, ug/L	<20	<20
2-Methylnaphthalene, ug/L	<20	<20
2-Methylphenol (o-Cresol), ug/L	<5	<5
2-Nitroaniline, ug/L	<50	<50
2-Nitrophenol, ug/L	<10	<10
3,3'-Dichlorobenzidine, ug/L	<10	<10
3-Nitroaniline, ug/L	<10	<10
4-Bromophenylphenylether, ug/L	<5	<5
4-Chloro-3-methylphenol, ug/L	<5	<5

LOG NO: G92-05-050

Received: 05 MAY 92
Mailed : 19 MAY 92

Mr. Bill Mitchell
Law/Crandall, Inc.
200 Citadel Drive
Los Angeles, California 90040

Project: L92045.AEFO

REPORT OF ANALYTICAL RESULTS

LOG NO	SAMPLE DESCRIPTION, GROUND WATER SAMPLES	DATE SAMPLED
05-050-1	B-3	05 MAY 92
05-050-2	B-10	05 MAY 92

PARAMETER	05-050-1	05-050-2	
4-Chloroaniline, ug/L	<10	<10	
4-Chlorophenylphenylether, ug/L	<5	<5	
4-Methylphenol (p-Cresol), ug/L	<5	<5	
4-Nitroaniline, ug/L	<20	<20	
4-Nitrophenol, ug/L	<20	<20	
Acenaphthene, ug/L	<5	<5	
Acenaphthylene, ug/L	<5	<5	
Aniline, ug/L	<10	<10	
Anthracene, ug/L	<5	<5	
Benzidine, ug/L	<200	<200	
Benzo(a)anthracene, ug/L	<5	<5	
Benzo(a)pyrene, ug/L	<5	<5	
Benzo(b)fluoranthene, ug/L	<5	<5	
Benzo(g,h,i)perylene, ug/L	<5	<5	
Benzo(k)fluoranthene, ug/L	<5	<5	
Benzyl Alcohol, ug/L	<5	<5	
Benzoic acid, ug/L	<50	<50	
Butylbenzylphthalate, ug/L	<5	<5	
Chrysene, ug/L	<5	<5	
Di-n-octylphthalate, ug/L	<5	<5	
Dibenzo(a,h)anthracene, ug/L	<5	<5	
Dibenzofuran, ug/L	<5	<5	
Dibutylphthalate, ug/L	<10	<10	
Diethylphthalate, ug/L	<10	<10	
Dimethylphthalate, ug/L	<10	<10	
Fluoranthene, ug/L	<5	<5	
Fluorene, ug/L	<5	<5	

LOG NO: G92-05-050

Received: 05 MAY 92
Mailed : 19 MAY 92

Mr. Bill Mitchell
Law/Crandall, Inc.
200 Citadel Drive
Los Angeles, California 90040

Project: L92045.AEFO

REPORT OF ANALYTICAL RESULTS

LOG NO	SAMPLE DESCRIPTION, GROUND WATER SAMPLES	DATE SAMPLED
05-050-1	B-3	05 MAY 92
05-050-2	B-10	05 MAY 92

PARAMETER	05-050-1	05-050-2
Hexachlorobenzene, ug/L	<5	<5
Hexachlorobutadiene, ug/L	<5	<5
Hexachlorocyclopentadiene, ug/L	<5	<5
Hexachloroethane, ug/L	<5	<5
Indeno(1,2,3-c,d)pyrene, ug/L	<10	<10
Isophorone, ug/L	<5	<5
N-Nitrosodimethylamine, ug/L	<5	<5
N-Nitrosodiphenylamine, ug/L	<5	<5
N-Nitrosodi-n-propylamine, ug/L	<20	<20
Nitrobenzene, ug/L	<5	<5
Naphthalene, ug/L	<5	<5
Phenanthrene, ug/L	<5	<5
Phenol, ug/L	<10	<10
Pentachlorophenol, ug/L	<10	<10
Pyrene, ug/L	<10	<10
Bis(2-chloroethoxy)methane, ug/L	<10	<10
Bis(2-chloroethyl)ether, ug/L	<10	<10
Bis(2-chloroisopropyl)ether, ug/L	<10	<10
Bis(2-ethylhexyl)phthalate, ug/L	<10	<10

B C Analytical

801 Western Avenue
Glendale, CA 91201
818/247-5737
Fax: 818/247-9797

LOG NO: G92-05-050

Received: 05 MAY 92
Mailed : 19 MAY 92

Mr. Bill Mitchell
Law/Crandall, Inc.
200 Citadel Drive
Los Angeles, California 90040

Project: L92045.AEFO

REPORT OF ANALYTICAL RESULTS

LOG NO	SAMPLE DESCRIPTION, GROUND WATER SAMPLES	DATE SAMPLED
05-050-1	B-3	05 MAY 92
05-050-2	B-10	05 MAY 92

PARAMETER	05-050-1	05-050-2
TPH - Volatile Hydrocarbons		
Date Analyzed	05/08/92	05/07/92
Dilution Factor, Times	1	1
TPH-Volatile Hydrocarbons, ug/L	<100	<100
Other TPH - Volatile Hydrocarbons	---	---

B C Analytical

801 Western Avenue
Glendale, CA 91201
818/247-5737
Fax: 818/247-9797

LOG NO: G92-05-050

Received: 05 MAY 92
Mailed : 19 MAY 92

Mr. Bill Mitchell
Law/Crandall, Inc.
200 Citadel Drive
Los Angeles, California 90040

Project: L92045.AEFO

REPORT OF ANALYTICAL RESULTS

LOG NO	SAMPLE DESCRIPTION, GROUND WATER SAMPLES	DATE SAMPLED
05-050-1	B-3	05 MAY 92
05-050-2	B-10	05 MAY 92

PARAMETER	05-050-1	05-050-2
EPA Method 8010		
Date Analyzed	05/08/92	05/08/92
Date Confirmed	05/08/92	05/08/92
Dilution Factor, Times	1	1
1,1,1-Trichloroethane, ug/L	<0.5	<0.5
1,1,2,2-Tetrachloroethane, ug/L	<0.5	<0.5
1,1,2-Trichloroethane, ug/L	<0.5	<0.5
1,1-Dichloroethane, ug/L	<0.5	<0.5
1,1-Dichloroethene, ug/L	<0.5	<0.5
1,2-Dichloroethane, ug/L	<0.5	<0.5
1,2-Dichlorobenzene, ug/L	<0.5	<0.5
1,2-Dichloropropane, ug/L	<0.5	<0.5
1,3-Dichlorobenzene, ug/L	<0.5	<0.5
1,4-Dichlorobenzene, ug/L	<0.5	<0.5
2-Chloroethylvinylether, ug/L	<0.5	<0.5
Bromodichloromethane, ug/L	<0.5	<0.5
Bromomethane, ug/L	<0.5	<0.5
Bromoform, ug/L	<0.5	<0.5
Chlorobenzene, ug/L	<0.5	<0.5
Carbon Tetrachloride, ug/L	<0.5	<0.5
Chloroethane, ug/L	<0.5	<0.5
Chloroform, ug/L	<0.5	<0.5
Chloromethane, ug/L	<0.5	<0.5
Dibromochloromethane, ug/L	<0.5	<0.5
Dichlorodifluoromethane, ug/L	<3	<3
Freon 113, ug/L	<1	<1
Methylene chloride, ug/L	<0.5	<0.5

LOG NO: G92-05-050

Received: 05 MAY 92
Mailed : 19 MAY 92

Mr. Bill Mitchell
Law/Crandall, Inc.
200 Citadel Drive
Los Angeles, California 90040

Project: L92045.AEFO

REPORT OF ANALYTICAL RESULTS

LOG NO	SAMPLE DESCRIPTION, GROUND WATER SAMPLES	DATE SAMPLED
05-050-1	B-3	05 MAY 92
05-050-2	B-10	05 MAY 92

PARAMETER	05-050-1	05-050-2
Trichloroethene, ug/L	<0.5	<0.5
Trichlorofluoromethane, ug/L	<0.5	<0.5
Tetrachloroethene, ug/L	<0.5	<0.5
Vinyl chloride, ug/L	<0.5	<0.5
cis-1,2-Dichloroethene, ug/L	<0.5	<0.5
cis-1,3-Dichloropropene, ug/L	<0.5	<0.5
trans-1,2-Dichloroethene, ug/L	<0.5	<0.5
trans-1,3-Dichloropropene, ug/L	<0.5	<0.5
EPA Method 8020		
Date Analyzed	05/08/92	05/08/92
Date Confirmed	05/08/92	05/08/92
Dilution Factor, Times	1	1
1,2-Dichlorobenzene, ug/L	<0.5	<0.5
1,3-Dichlorobenzene, ug/L	<0.5	<0.5
1,4-Dichlorobenzene, ug/L	<0.5	<0.5
Benzene, ug/L	1.0	<0.5
Chlorobenzene, ug/L	<0.5	<0.5
Ethylbenzene, ug/L	<0.5	<0.5
Toluene, ug/L	<0.5	0.7
Total Xylene Isomers, ug/L	<1	1.4

B C Analytical

801 Western Avenue
Glendale, CA 91201
818/247-5737
Fax: 818/247-9797

LOG NO: G92-05-050

Received: 05 MAY 92
Mailed : 19 MAY 92

Mr. Bill Mitchell
Law/Crandall, Inc.
200 Citadel Drive
Los Angeles, California 90040

Project: L92045.AEFO

REPORT OF ANALYTICAL RESULTS

Jane Freemyer

Jane Freemyer, Client Services Manager

CHAIN OF CUSTODY RECORD

BCA Log Number

Client name: Law Crandall Inc	Project or PO#: LG2045. AFFO
Address:	Phone #:
City, State, Zip:	Report attention: Bill Mitchell

Sampled by: Mike Eagen

Analyses required

Lab Sample number	Date sampled	Time sampled	Type* See key below	Sample description	Number of containers	418.1	8015 (gasol)	8010 8020	8270 Title 22	metals			Hazardous sample Special handling required	Remarks
	5/5/92		GW	B-3	11	X	X	X	X					
	5/5/92		GW	B-10	11	X	X	X	X					

	Signature	Print Name	Company	Date	Time
Relinquished by	Bill Mitchell	Bill Mitchell	Law Crandall Inc	5/5/92	3 pm
Received by	Steve Wy	Steven Wong	LCI	5/5/92	1500
Relinquished by					
Received by					
Relinquished by					
Received by Laboratory					

B C ANALYTICAL

☐ 1255 Powell Street, Emeryville, CA 94608 (415) 428-2300
☐ 801 Western Avenue, Glendale, CA 91201 (818) 247-5737
☐ 1200 Pacifico Avenue, Anaheim, CA 92805 (714) 978-0113

Note: Samples are discarded 30 days after results are reported unless other arrangements are made. Hazardous samples will be returned to client or disposed of at client's expense.

Disposal arrangements: ____________________

*KEY: AQ—Aqueous NA—Nonaqueous SL—Sludge GW—Groundwater SO—Soil OT—Other PE—Petroleum

APPENDIX C

APPENDIX C
GEOLOGIC AND SEISMIC DATA

GENERAL

The geologic-seismic studies included a field reconnaissance along the alignment, as well as office analysis of published and unpublished literature pertinent to the study area. The seismic Safety Plan for the City of Los Angeles (1975) was reviewed as part of our literature analysis.

This Appendix presents additional background information regarding faults and seismicity.

FAULTS

The numerous faults in Southern California include active, potentially active, and inactive faults. The criteria for these major groups, as modified from the Association of Engineering Geologists (1973), are presented in Table C-1. Table C-2 presents a listing of active faults in Southern California with the distance in miles between the alignment and the nearest point on the fault, and the maximum credible earthquake for the fault. Table C-3 provides a similar listing for potentially active faults. No faults or fault-associated features were observed on the site during the field reconnaissance. The site is not within an established Alquist-Priolo Special Studies Zone for fault rupture hazard or a City of Los Angeles Fault Rupture Study Area.

TABLE C-1

CRITERIA FOR CLASSIFICATION OF FAULTS WITH REGARD TO SEISMIC ACTIVITY
(After D.B. Slemmons, 1979)

Activity Classification and Definition	Criteria		
	Historic	Geologic	Seismologic
Active - a tectonic fault with a history of strong earthquakes or surface faulting, or a fault with a short recurrence interval relative to the life of the planned project. The recurrence interval used to define activity rate may vary according to the consequence of activity.	(1) Surface faulting and associated strong earthquakes. (2) Tectonic fault creep or geodetic evidence of fault displacement or deformation.	(1) Geologically young deposits cut by the fault. (2) Youthful geomorphological features that are characteristic of geologically young displacements along the trace fault. (3) Ground water barriers in geologically young or unconsolidated deposits.	Earthquake epicenter can be assigned with confidence to the fault.
Potentially Active - a tectonic fault without historic surface offset, but with a recurrence interval that could be sufficiently short to be significant to the particular project.	No reliable report of historic surface faulting.	(1) Geomorphic features that are characteristic of active faults, but with subdued, eroded, and discontinuous form. (2) Faults not known to cut or displace youngest alluvial deposits, but offset older Quaternary deposits. (3) Water barriers in older deposits. (4) Geological setting in which the geometry in relation to active or potentially active faults suggests similar degree of activity.	Alignment of some earthquake epicenters along or near fault, but assigned locations have low degree of confidence in location.
Activity Uncertain - a fault with insufficient evidence to define past activity or recurrence interval. The following classifications can be used until the results of additional studies provide definitive evidence.	Available information is insufficient to provide criteria that are sufficiently definitive to establish fault activity. This lack of information may be due to the inactivity of the fault or to lack of investigations needed to provide definitive criteria.		
Tentatively Active - predominant evidence suggests that the fault may be active even though its recurrence interval is very long or poorly defined.	Available information suggests evidence of fault activity, but evidence is not definitive.		
Tentatively Inactive - predominant evidence suggests that the fault is not active.	Available information suggests evidence of fault inactivity, but evidence is not definitive.		
Inactive - a fault along which it can be demonstrated that surface faulting has not occurred in the recent past, and that the requirement interval is long enough not to be of significance to the particular project.	No historic activity.	Geomorphic features characteristic of active fault zones are not present and geological evidence is available to indicate that the fault has not moved in the recent past and recurrence is not likely during a time period considered significant to the site. Should indicate age of last movement: Holocene, Pleistocene, Quaternary, Tertiary, etc.	Not recognized as source of earthquakes.

TABLE C-2

MAJOR NAMED FAULTS CONSIDERED TO BE ACTIVE (a) IN SOUTHERN CALIFORNIA

Fault (in alphabetical order)	Maximum Credible Earthquake			Closest Distance From Alignment (Miles)	Direction From Alignment
Big Pine	7.5	(b)	SS	63	NW
Calico-Newberry	7.25	(b)	SS	92	NE
Cucamonga	6.5	(b)	RO	33	ENE
Elsinore	7.5	(b)	SS	45	ESE
Elysian Park Structure	6.75	(c)	RO	0	--
Garlock	7.75	(b)	SS	59	NNW
Helendale	7.5	(b)	SS	70	NE
Malibu Coast	7.0	(a)	RO	17	W
More Ranch	7.5	(b)	SS	90	WNW
Newport-Inglewood	7.0	(b)	SS	8.5	WSW
Raymond	6.9	(a)	RO	3.3	NNE
San Andreas	8.25	(b)	SS	33	NE
San Cayetano	7.0	(a)	RO	36	NW
San Fernando	6.5	(b)	RO	15	NNW
San Gabriel	7.5	(a)	SS	14	NNE
San Jacinto	7.5	(b)	SS	38	NE
Sierra Madre	7.5	(a)	RO	10	NE
White Wolf	7.75	(b)	RO	77	NW
Whittier	7.0	(a)	SS	12	WSW

(a)	Slemmons, 1979
(b)	Greensfelder, C.D.M.G. Map Sheet 23, 1974.
(c)	Mark, 1977
SS	Strike Slip
NO	Normal Oblique
RO	Reverse Oblique

TABLE C-3

MAJOR NAMED FAULTS CONSIDERED TO BE POTENTIALLY ACTIVE (a) IN SOUTHERN CALIFORNIA

Fault (in alphabetical order)	Maximum Credible Earthquake			Closest Distance From Alignment (Miles)	Direction From Alignment
Charnock	6.5	(a)	SS	12	WSW
Chino	7.1	(a)	NO	26	E
Duarte	6.7	(a)	RO	14	NE
Eagle Rock - San Rafael	6.6	(a)	RO	5	N
Northridge Hills	6.5	(b)	SS	18	NW
Norwalk	6.7	(a)	RO	16	SE
Oakridge	7.5	(b)	RO	36	NW
Overland	6.0	(a)	SS	10	WSW
Palos Verdes	7.0	(b)	SS	19	SW
San Jose	6.9	(a)	RO	21	E
Santa Cruz Island	7.1	(a)	RO	68	W
Santa Monica-Hollywood	6.9	(a)	RO	3.8	NNW
Santa Susana	6.5	(b)	RO	23	NW
Santa Ynez	7.5	(b)	SS	52	NW
Sierra Nevada (Southern Branch)	8.25	(b)	NO	84	N
Verdugo	7.4	(a)	RO	5.2	N

(a)	Slemmons, 1979
(b)	Greensfelder, C.D.M.G. Map Sheet 23, 1974
(c)	Mark, 1977
SS	Strike Slip
NO	Normal Oblique
RO	Reverse Oblique

Active Faults

Raymond Fault: The closest active fault with evidence of surface rupture to the alignment is the Raymond fault, about 3.3 miles to the north-northeast. The Raymond fault is a high-angle reverse fault that thrusts basement rocks north of the fault over alluvial sediments south of the fault. It has long been recognized as a ground water barrier in the Pasadena/San Marino area, and numerous geomorphic features along its length (such as fault scarps, sag ponds, springs, and pressure ridges) attest to the fault's activity during the Holocene epoch (last 11,000 years). Eight earthquake events have been recognized to have occurred along the Raymond fault within the last 36,000 years, (Crook et al., 1987). The most recent fault movement, based on radiocarbon ages from materials collected in an excavation exposing the fault, occurred sometime between 2,160 ± 105 and 1,630 ± 100 years before present (Crandall and Associates, 1978; Crook et al., 1987).

Newport-Inglewood Fault Zone: The active Newport-Inglewood fault zone is about 8.5 miles to the west-southwest of the alignment. This fault zone is composed of a series of discontinuous northwest-trending en echelon faults (including the nearby Potrero and Inglewood faults), extending from the southern edge of the Santa Monica Mountains southeastward to the area offshore of Newport Beach. This zone, commonly referred to as the Newport-Inglewood uplift or zone of deformation, is reflected at the surface by a line of geomorphically young anticlinal hills and mesas formed by the folding and faulting of a thick sequence of Pleistocene and Tertiary sedimentary rocks (Barrows, 1974). At depth, the fault zone is considered a complex fault system that serves as the boundary between Catalina Schist basement to the west and granitic basement to the east. According to Wissler (1943), the Newport-Inglewood fault zone has been a deformational zone since Miocene time. Stratigraphic evidence indicates recurrent movement during Late Tertiary and Quaternary time. The 1933 Long Beach earthquake has been attributed to movement on the Newport-Inglewood fault zone.

San Andreas Fault Zone: The San Andreas fault zone, California's most prominent structural feature, trends in a general northwest direction for almost the entire length of the state. The southern segment, the closest to the alignment, is approximately 280 miles long, and extends from the Mexican border to the Transverse Ranges west of Tejon Pass. The San Andreas fault zone is approximately 33 miles northeast of the alignment at the nearest point. Wallace (1968) estimated the recurrence interval for a magnitude 8.0 earthquake along the total length of the fault to be between 50 and 200 years. More recent data by Sieh (1984) indicates an average earthquake recurrence interval of 140 to 200 years for the local segment of the San Andreas fault. The last major earthquake along the San Andreas fault zone in Southern California was the 1857 Fort Tejon earthquake.

Elysian Park Structure: The 1987 Whittier Narrows earthquake (magnitude 5.9) has been attributed to subsurface thrust faults, which are reflected at the earth's surface by a west-northwest trending anticline known as the Elysian Park Anticline (Lamar, 1970), or the Elysian Park Fold and Thrust Belt (Hauksson, 1990). The axial trace of this fold structure extends approximately 12 miles through the Elysian Park-Repetto Hills from about Silverlake on the west to the Whittier Narrows on the east. The alignment lies within the boundaries of Elysian Park Fold and Thrust Belt as defined by Hauksson (1990). The subsurface faults that create the structure are not exposed at the surface, and do not present a potential surface rupture hazard; however, as demonstrated by the 1987 earthquake and two smaller earthquakes on June 12, 1989, the faults are a source for future seismic activity. As such, the structure should be considered an "active" feature capable of generating future earthquakes. Based on an approximate length of the axial trace of 12 miles, we have assigned a maximum credible earthquake of magnitude 6.75, using Mark's fault length versus magnitude relationship (1977).

Potentially Active Faults

Santa Monica-Hollywood Fault Zone: The closest potentially active Santa Monica-Hollywood fault zone is approximately 3.8 miles north-northwest of the alignment (Converse Davis and Associates, 1972). The Santa Monica and Hollywood faults are two distinctly separate structural features. The Hollywood fault lies at the base of the Santa Monica Mountains, approximately 4,000 feet north of the Santa Monica fault. It is separated from the Santa Monica fault to the south by the Hollywood syncline. The two faults are generally poorly defined in the near surface and have been located based on water well, oil well, geophysical data, and recent trenching by Crook et al. (1983). All evidence to date indicates that the Santa Monica fault has not moved within the Holocene epoch. Converse et al. (1981) suggest the Hollywood fault may be active, based on data gathered during investigation for the Metro Red Line Rail Project. These opinions, however, have not been positively verified. Neither the Santa Monica nor Hollywood faults have been zoned as active under the Alquist-Priolo Special Studies Zone program. Currently, the Santa Monica-Hollywood fault zone is considered potentially active. Some geologists believe the fault zone is structurally aligned with, and may be contiguous with, the Raymond, Benedict Canyon, and Malibu Coast faults, which are of similar age, trend, and displacement (Weber et al., 1980).

Eagle Rock - San Rafael Fault Zone: The potentially active Eagle Rock - San Rafael fault zone is located 5 miles north of the alignment. This fault trends northwesterly through the San Rafael Hills and is approximately 6 miles in length. Based on geomorphic evidence, Weber (1980) describes the Eagle Rock - San Rafael fault zone as a late Quaternary feature.

Verdugo Fault: The Verdugo fault is located approximately 5.2 miles north of the alignment. This fault forms a partial barrier to ground water movement by having offset upper Pleistocene deposits. The fault, however, has no known affect on Holocene deposits. The main trace of the fault extends beneath the alluvium along a line projected from the southwesterly flank of the Verdugo Mountains to the southerly side of the Pacoima Hills.

Overland Fault: The Overland fault is located about 10 miles west-southwest of the alignment. The Overland fault trends northwest and lies between the Charnock and Newport-Inglewood fault zones. The fault extends from the northwest flank of the Baldwin Hills to Santa Monica Boulevard in the vicinity of Overland Avenue. Displacement on the fault is believed to be vertical, with an offset of about 30 feet. Water levels in the Pleistocene age sediments indicate the fault is an effective barrier to ground water movement and that Pleistocene materials have been offset.

Charnock Fault: The potentially active Charnock fault is located 12 miles west-southwest of the alignment at its closest point. The Charnock fault trends northwest-southeast, subparallel to the trend of the Newport-Inglewood fault zone and the Overland fault. Differential water levels occur in the San Pedro Formation across the fault and, therefore, it is concluded that the fault has experienced some movement during early Pleistocene time (approximately 500,000 to 2 million years ago).

Unnamed Fault: A northeast trending unnamed potentially active fault has been postulated to traverse the proposed alignment in the vicinity of the Broadway Bridge (Yerkes et al., 1977). The location of this fault is based on information interpreted from well logs and is shown on Plate 4, Regional Seismicity. Geologic mapping in the vicinity of the fault provides no evidence for the presence of this fault. Based on our exploratory borings, we see no evidence suggesting faulting of the subsurface materials within the 100-foot explored depth. Based on the lack of evidence for the existence of this fault and the fact the fault is not within an Alquist-Priolo Special Studies Zone, it is our opinion that the fault will not adversely impact the alignment during the anticipated design life of the project.

Inactive Faults

Several northwest-southeast trending faults have been mapped by Lamar (1970) in the vicinity of the proposed alignment. These faults are considered inactive and should not adversely affect the alignment.

SEISMICITY

The seismicity of the region surrounding the project was determined from a search of a data base of earthquakes. The data base of earthquakes includes those with a Richter magnitude greater than 4.0, within a radius of 100 kilometers (62 miles) from the center of the alignment, compiled by the California Institute of Technology for the period 1932 to 1991, and those earthquakes for the period 1812 to 1931 compiled by Richter and the U.S. National Oceanic and Atmospheric Administration (NOAA). The database printout of the earthquakes is presented at the end of this Appendix.

The information listed for each earthquake found in the database listing includes data and time in Greenwich Civil Time (GCT), location of the epicenter in latitude and longitude, quality of epicentral determination (Q), depth in kilometers, and magnitude. Where a depth of 0.0 is given, the solution was based on an assumed 16-kilometer focal depth. The explanation of the letter code for the quality factor of the data is presented on the first page of the listing.

Four earthquakes of moderate magnitude have occurred in the metropolitan Los Angeles area within the last 60 years. The earliest of these events was the magnitude 6.3 Long Beach earthquake that occurred on March 11, 1933 (GCT). The epicenter of this earthquake was located about 35 miles south-southeast of the alignment.

The epicenter of the magnitude 6.4, February 9, 1971 San Fernando earthquake was about 25 miles northwest of the alignment. Surface rupture occurred on the several fault segments of the San Fernando fault zone.

The epicenter of the October 1, 1987 Whittier Narrows earthquake was situated about 8.7 miles east of the alignment. This magnitude 5.9 earthquake was followed by numerous aftershocks, including a magnitude 5.3 quake on October 4, 1987.

The June 28, 1991 Sierra Madre earthquake was situated about 19 miles northeast of the alignment. Preliminary data indicate that the earthquake registered a magnitude of 5.8.

The location of the alignment in relation to known active and potentially active faults indicates that the alignment is not exposed to greater than normal seismic risk relative to other areas within the Coastal Plain of Los Angeles County.

BIBLIOGRAPHY

Association of Engineering Geologists, 1973, "Geology and Earthquake Hazards Planners Guide to the Seismic Safety Element," Special Publication.

Association of Engineering Geologists, 1973 "Geology, Seismicity, and Environmental Impact," Special Publication.

Barrows, A.G., 1974, "A Review of the Geology and Earthquake History of the Newport-Inglewood Structural Zone, Southern California," California Division of Mines and Geology Special Report 114.

Bolt, B.A., 1973, "Duration of Strong Ground Motion," in Proceedings, Fifth World Conference on Earthquake Engineering.

California Division of Oil and Gas, 1974, "California Oil and Gas Fields, Vol. II - South Central Coastal and Offshore California" Report No. TR12.

California Division of Oil and Gas, 1986, "Boyle Heights, Los Angeles Downtown and Union Station Oil Fields," Map No. 119.

California Division of Oil and Gas, 1987, "Regional Wildcat Map," No. W1-5.

California Division of Oil and Gas, 1988, "Los Angeles City Oil Field," Map No. 116.

California Department of Water Resources, Bulletin 104, 1961, "Planned Utilization of the Ground Water Basins of the Coastal Plain of Los Angeles County," Appendix A, Ground Water Geology.

California Department of Water Resources, Bulletin 116-2, 1964, "Crustal Strain and Fault Movement Investigation."

California Department of Water Resources, 1988, Water Level Data for Southern California on Microfiche.

Converse Consultants, Earth Science Associates, Geo-Resource Consultants, 1981, "Geotechnical Investigation Report, Volume I; Volume II -- Appendices 1 and 2," for Southern California Rapid Transit Metro Rail Project.

Converse Davis and Associates, 1972, "Ground Water Investigation Vicinity of Forest Lawn, Glendale-Los Angeles, California," CDA Project 70-044-EH, Report April 4, 1972, Drawings 1 and 2.

Crandall, LeRoy and Associates, 1978, "Report of Geologic Studies Related to Raymond Fault Identification, San Marino High School, San Marino, California," for the San Marino Unified School District, E-77186.

Crandall, LeRoy and Associates, 1983, "Report of Geotechnical Investigation, Proposed Central Maintenance Facility, Macy and Vignes Streets, Los Angeles, California," for the Southern California Rapid Transit District, ADE-83009.

Crandall, LeRoy and Associates, 1990, "Report of Geotechnical Investigation, Proposed Lippobank Tower and Oriental Marketplace, Hill Street Between Ord and Alpine Streets, Los Angeles, California," for Hip Hing Holdings, Limited, L90255.ADEB.

Crook, R., Proctor, R.J., and Lindvall, E.I., 1983, "Seismicity of the Santa Monica and Hollywood Faults Determined by Trenching," Technical Report to the U.S. Geological Survey, Contract No. 14-08-001-20253, p. 26.

Crook, R., Jr., Allen, C.R., Kamb, R. Bayne, C.M., and Proctor, R.J., 1987, "Quaternary Geology and Seismic Hazard of the Sierra Madre and Associated Faults, Western San Gabriel Mountains," in U.S. Geological Survey Professional Paper 1339, Ch. 2, pp. 27-63.

Fall, E.W., Rzonca, G.F., and Spellman, H.A., Shleman, R.J., 1987, "Late Quaternary Faulting, Malibu Coast Fault Zone, Malibu, California (abstract)," Association of Engineering Geologists Annual Meeting, October 8-13, Atlanta, Georgia, Abstracts and Program, p. 38.

Greensfelder, R.W., 1974, "Maximum Credible Rock Acceleration from Earthquakes in California," California Division of Mines and Geology Map Sheet 23.

Haukkson, E., 1990, "Earthquakes, Faulting, and Stress in the Los Angeles Basin," Journal of Geophysical Research, Vol. 95, No. 1310, Pages 15,365-15,934.

Jennings, Charles W., et. al., 1975, "Fault Map of California with Locations of Volcanoes, Thermal Springs and Thermal Wells, California Division of Mines and Geology.

Lamar, D.L., 1970, "Geology of the Elysian Park-Repetto Hills Area, Los Angeles County, California," California Division of Mines and Geology Special Report 101.

Law/Crandall, Inc., 1991, "Draft Report of Geotechnical Investigation, Proposed Metro Plaza, Macy Street and Vignes Street, Los Angeles, California, for the Catellus Development Corporation," (LC L91291.ADEO).

Levine•Fricke, 1989a, "Preliminary Environmental and Geotechnical Assessment of Los Angeles Union Passenger Terminal, Los Angeles, California," for the Catellus Development Corporation, Job No. L•F 1646.

Levine•Fricke, 1989b, "Phase I Soil and Ground Water Investigation, Los Angeles Union Passenger Terminal, Los Angeles Union Passenger Terminal, Los Angeles, California," for the Catellus Development Corporation, Job No. L•F 1977.

Levine•Fricke, 1990, "Environmental Assessment, Los Angeles Union Passenger Terminal, Los Angeles, California," for the Catellus Development Corporation, Job No. L•F 1977.

Levine•Fricke, 1991a, "Phase II Soil and Ground Water Investigation, Los Angeles Union Passenger Terminal, Los Angeles, California," for the Catellus Development Corporation, Job No. L•F 1977.

Levine•Fricke, 1991, "Addition to the Phase II Soil and Ground Water Investigation Report, Los Angeles Union Passenger Terminal, Los Angeles, California," for the Catellus Development Corporation, Job No. L•F 1977.

Los Angeles, City of, Seismic Safety Plan (1975).

Los Angeles, County of, 1975, Draft revision 1990, "Seismic Safety Element."

Mark, R.K., 1977, "Application of Linear Statistical Models of Earthquake Magnitude Versus Fault Length in Estimating Maximum Expectable Earthquakes," Geology, Vol. 5, pp. 464-466.

Poland, J.F., Garrett & Sinnott, 1959, "Geology, Hydrology, and Chemical Character of Ground Waters in the Torrance-Santa Monica Area, California," U.S. Geological Survey Water Supply Paper 1461.

Sieh, K.E., 1984, "Lateral Offsets and Revised Dates of Large Prehistoric Earthquakes at Pallett Creek, California," Journal of Geophysical Research, Vol. 9, pp. 7641-7670.

Slemmons, D.B., 1979, "Evaluation of Geomorphic Features of Active Faults for Engineering Design and Siting Studies," Association of Engineering Geologists Short Course.

Wallace, R.E., 1968, "Notes on Stream Channels Offset by San Andreas Fault, Southern Coast Ranges, California," in Dickerson, U.R., and Grantz, A., editors, Proceedings of Conference of Geologic Problems on San Andreas Fault System, Stanford University Publications, Geological Sciences, Vol. IX, p. 6-21.

Weber, F.H., Bennett, J.H., Chapman, R.H., Chase, G.W., and Saul, R.B., 1980, "Earthquake Hazards Associated with the Verdugo-Eagle Rock and Benedict Canyon Fault Zones, Los Angeles County, California," California Division of Mines and Geology Open File Report 80-10LA.

Wissler, S.G., 1943, "Stratigraphic Formations of the Producing Zone of the Los Angeles Basin Oil Fields," California Division of Mines Bulletin 118, Part 2, pp. 210-234.

Yerkes, R.F., McCulloch, T.H., Schoellhamer, J.E., and Vedder, J.G., 1965, "Geology of the Los Angeles Basin, California," U.S. Geological Survey Professional Paper 420-A.

Yerkes, R.F., Tinsley, J.C., and Williams, K.M., 1977, "Los Angeles Area Geologic Aspects of Tunneling," U.S. Geological Survey, Map MF-866.

Zielbauer, E.J., Kues, H.A., Burnham, W.L., and Keene, A.G., 1962, "Coastal Basin Barrier and Replenishment Investigation, Dominguez Gap Barrier and Replenishment Investigation," unpublished report by the Los Angeles County Flood Control District.

-o0o-

LIST OF HISTORIC EARTHQUAKES OF MAGNITUDE 4.0 OR GREATER WITHIN 100 KM OF THE SITE
(CAL TECH DATA 1932-1991)

DATE	TIME	LATITUDE	LONGITUDE	Q	DIST	DEPTH	MAGNITUDE
11-01-1932	04:45:00	34.00 N	117.25 W	E	91	.0	4.0
03-11-1933	01:54:08	33.62 N	117.97 W	A	56	.0	6.3
03-11-1933	02:04:00	33.75 N	118.08 W	C	38	.0	4.9
03-11-1933	02:05:00	33.75 N	118.08 W	C	38	.0	4.3
03-11-1933	02:09:00	33.75 N	118.08 W	C	38	.0	5.0
03-11-1933	02:10:00	33.75 N	118.08 W	C	38	.0	4.6
03-11-1933	02:11:00	33.75 N	118.08 W	C	38	.0	4.4
03-11-1933	02:16:00	33.75 N	118.08 W	C	38	.0	4.8
03-11-1933	02:17:00	33.60 N	118.00 W	E	56	.0	4.5
03-11-1933	02:22:00	33.75 N	118.08 W	C	38	.0	4.0
03-11-1933	02:27:00	33.75 N	118.08 W	C	38	.0	4.6
03-11-1933	02:30:00	33.75 N	118.08 W	C	38	.0	5.1
03-11-1933	02:31:00	33.60 N	118.00 W	E	56	.0	4.4
03-11-1933	02:52:00	33.75 N	118.08 W	C	38	.0	4.0
03-11-1933	02:57:00	33.75 N	118.08 W	C	38	.0	4.2
03-11-1933	02:58:00	33.75 N	118.08 W	C	38	.0	4.0
03-11-1933	02:59:00	33.75 N	118.08 W	C	38	.0	4.6
03-11-1933	03:05:00	33.75 N	118.08 W	C	38	.0	4.2
03-11-1933	03:09:00	33.75 N	118.08 W	C	38	.0	4.4
03-11-1933	03:11:00	33.75 N	118.08 W	C	38	.0	4.2
03-11-1933	03:23:00	33.75 N	118.08 W	C	38	.0	5.0
03-11-1933	03:36:00	33.75 N	118.08 W	C	38	.0	4.0
03-11-1933	03:39:00	33.75 N	118.08 W	C	38	.0	4.0
03-11-1933	03:47:00	33.75 N	118.08 W	C	38	.0	4.1
03-11-1933	04:36:00	33.75 N	118.08 W	C	38	.0	4.6
03-11-1933	04:39:00	33.75 N	118.08 W	C	38	.0	4.9
03-11-1933	04:40:00	33.75 N	118.08 W	C	38	.0	4.7
03-11-1933	05:10:22	33.70 N	118.07 W	C	44	.0	5.1
03-11-1933	05:13:00	33.75 N	118.08 W	C	38	.0	4.7
03-11-1933	05:15:00	33.75 N	118.08 W	C	38	.0	4.0
03-11-1933	05:18:04	33.57 N	117.98 W	C	60	.0	5.2
03-11-1933	05:21:00	33.75 N	118.08 W	C	38	.0	4.4
03-11-1933	05:24:00	33.75 N	118.08 W	C	38	.0	4.2
03-11-1933	05:53:00	33.75 N	118.08 W	C	38	.0	4.0
03-11-1933	05:55:00	33.75 N	118.08 W	C	38	.0	4.0

NOTE: Q IS A FACTOR RELATING THE QUALITY OF EPICENTRAL DETERMINATION

A = SPECIALLY INVESTIGATED
B = EPICENTER PROBABLY WITHIN 5 KM, ORIGIN TIME TO NEAREST SECOND
C = EPICENTER PROBABLY WITHIN 15 KM, ORIGIN TIME TO A FEW SECONDS
D = EPICENTER NOT KNOWN WITHIN 15 KM, ROUGH LOCATION
E = EPICENTER ROUGHLY LOCATED, ACCURACY LESS THAN "D"
P = PRELIMINARY

DATE	TIME	LATITUDE	LONGITUDE	Q	DIST	DEPTH	MAGNITUDE
03-11-1933	06:11:00	33.75 N	118.08 W	C	38	.0	4.4
03-11-1933	06:18:00	33.75 N	118.08 W	C	38	.0	4.2
03-11-1933	06:29:00	33.85 N	118.27 W	C	25	.0	4.4
03-11-1933	06:35:00	33.75 N	118.08 W	C	38	.0	4.2
03-11-1933	06:58:03	33.68 N	118.05 W	C	46	.0	5.5
03-11-1933	07:51:00	33.75 N	118.08 W	C	38	.0	4.2
03-11-1933	07:59:00	33.75 N	118.08 W	C	38	.0	4.1
03-11-1933	08:08:00	33.75 N	118.08 W	C	38	.0	4.5
03-11-1933	08:32:00	33.75 N	118.08 W	C	38	.0	4.2
03-11-1933	08:37:00	33.75 N	118.08 W	C	38	.0	4.0
03-11-1933	08:54:57	33.70 N	118.07 W	C	44	.0	5.1
03-11-1933	09:10:00	33.75 N	118.08 W	C	38	.0	5.1
03-11-1933	09:11:00	33.75 N	118.08 W	C	38	.0	4.4
03-11-1933	09:26:00	33.75 N	118.08 W	C	38	.0	4.1
03-11-1933	10:25:00	33.75 N	118.08 W	C	38	.0	4.0
03-11-1933	10:45:00	33.75 N	118.08 W	C	38	.0	4.0
03-11-1933	11:00:00	33.75 N	118.08 W	C	38	.0	4.0
03-11-1933	11:04:00	33.75 N	118.13 W	C	37	.0	4.6
03-11-1933	11:29:00	33.75 N	118.08 W	C	38	.0	4.0
03-11-1933	11:38:00	33.75 N	118.08 W	C	38	.0	4.0
03-11-1933	11:41:00	33.75 N	118.08 W	C	38	.0	4.2
03-11-1933	11:47:00	33.75 N	118.08 W	C	38	.0	4.4
03-11-1933	12:50:00	33.68 N	118.05 W	C	46	.0	4.4
03-11-1933	13:50:00	33.73 N	118.10 W	C	40	.0	4.4
03-11-1933	13:57:00	33.75 N	118.08 W	C	38	.0	4.0
03-11-1933	14:25:00	33.85 N	118.27 W	C	25	.0	5.0
03-11-1933	14:47:00	33.73 N	118.10 W	C	40	.0	4.4
03-11-1933	14:57:00	33.88 N	118.32 W	C	23	.0	4.9
03-11-1933	15:09:00	33.73 N	118.10 W	C	40	.0	4.4
03-11-1933	15:47:00	33.75 N	118.08 W	C	38	.0	4.0
03-11-1933	16:53:00	33.75 N	118.08 W	C	38	.0	4.8
03-11-1933	19:44:00	33.75 N	118.08 W	C	38	.0	4.0
03-11-1933	19:56:00	33.75 N	118.08 W	C	38	.0	4.2
03-11-1933	22:00:00	33.75 N	118.08 W	C	38	.0	4.4
03-11-1933	22:31:00	33.75 N	118.08 W	C	38	.0	4.4
03-11-1933	22:32:00	33.75 N	118.08 W	C	38	.0	4.1
03-11-1933	22:40:00	33.75 N	118.08 W	C	38	.0	4.4
03-11-1933	23:05:00	33.75 N	118.08 W	C	38	.0	4.2
03-12-1933	00:27:00	33.75 N	118.08 W	C	38	.0	4.4
03-12-1933	00:34:00	33.75 N	118.08 W	C	38	.0	4.0
03-12-1933	04:48:00	33.75 N	118.08 W	C	38	.0	4.0
03-12-1933	05:46:00	33.75 N	118.08 W	C	38	.0	4.4
03-12-1933	06:01:00	33.75 N	118.08 W	C	38	.0	4.2
03-12-1933	06:16:00	33.75 N	118.08 W	C	38	.0	4.6
03-12-1933	07:40:00	33.75 N	118.08 W	C	38	.0	4.2

DATE	TIME	LATITUDE	LONGITUDE	Q	DIST	DEPTH	MAGNITUDE
03-12-1933	08:35:00	33.75 N	118.08 W	C	38	.0	4.2
03-12-1933	15:02:00	33.75 N	118.08 W	C	38	.0	4.2
03-12-1933	16:51:00	33.75 N	118.08 W	C	38	.0	4.0
03-12-1933	17:38:00	33.75 N	118.08 W	C	38	.0	4.5
03-12-1933	18:25:00	33.75 N	118.08 W	C	38	.0	4.1
03-12-1933	21:28:00	33.75 N	118.08 W	C	38	.0	4.1
03-12-1933	23:54:00	33.75 N	118.08 W	C	38	.0	4.5
03-13-1933	03:43:00	33.75 N	118.08 W	C	38	.0	4.1
03-13-1933	04:32:00	33.75 N	118.08 W	C	38	.0	4.7
03-13-1933	06:17:00	33.75 N	118.08 W	C	38	.0	4.0
03-13-1933	13:18:28	33.75 N	118.08 W	C	38	.0	5.3
03-13-1933	15:32:00	33.75 N	118.08 W	C	38	.0	4.1
03-13-1933	19:29:00	33.75 N	118.08 W	C	38	.0	4.2
03-14-1933	00:36:00	33.75 N	118.08 W	C	38	.0	4.2
03-14-1933	12:19:00	33.75 N	118.08 W	C	38	.0	4.5
03-14-1933	19:01:50	33.62 N	118.02 W	C	54	.0	5.1
03-14-1933	22:42:00	33.75 N	118.08 W	C	38	.0	4.1
03-15-1933	02:08:00	33.75 N	118.08 W	C	38	.0	4.1
03-15-1933	04:32:00	33.75 N	118.08 W	C	38	.0	4.1
03-15-1933	05:40:00	33.75 N	118.08 W	C	38	.0	4.2
03-15-1933	11:13:32	33.62 N	118.02 W	C	54	.0	4.9
03-16-1933	14:56:00	33.75 N	118.08 W	C	38	.0	4.0
03-16-1933	15:29:00	33.75 N	118.08 W	C	38	.0	4.2
03-16-1933	15:30:00	33.75 N	118.08 W	C	38	.0	4.1
03-17-1933	16:51:00	33.75 N	118.08 W	C	38	.0	4.1
03-18-1933	20:52:00	33.75 N	118.08 W	C	38	.0	4.2
03-19-1933	21:23:00	33.75 N	118.08 W	C	38	.0	4.2
03-20-1933	13:58:00	33.75 N	118.08 W	C	38	.0	4.1
03-21-1933	03:26:00	33.75 N	118.08 W	C	38	.0	4.1
03-23-1933	08:40:00	33.75 N	118.08 W	C	38	.0	4.1
03-23-1933	18:31:00	33.75 N	118.08 W	C	38	.0	4.1
03-25-1933	13:46:00	33.75 N	118.08 W	C	38	.0	4.1
03-30-1933	12:25:00	33.75 N	118.08 W	C	38	.0	4.4
03-31-1933	10:49:00	33.75 N	118.08 W	C	38	.0	4.1
04-01-1933	06:42:00	33.75 N	118.08 W	C	38	.0	4.2
04-02-1933	08:00:00	33.75 N	118.08 W	C	38	.0	4.0
04-02-1933	15:36:00	33.75 N	118.08 W	C	38	.0	4.0
05-16-1933	20:58:55	33.75 N	118.17 W	C	36	.0	4.0
08-04-1933	04:17:48	33.75 N	118.18 W	C	36	.0	4.0
10-02-1933	09:10:18	33.78 N	118.13 W	A	34	.0	5.4
10-02-1933	13:26:01	33.62 N	118.02 W	C	54	.0	4.0
10-25-1933	07:00:46	33.95 N	118.13 W	C	16	.0	4.3
11-13-1933	21:28:00	33.87 N	118.20 W	C	22	.0	4.0
11-20-1933	10:32:00	33.78 N	118.13 W	B	34	.0	4.0
01-09-1934	14:10:00	34.10 N	117.68 W	A	51	.0	4.5

DATE	TIME	LATITUDE	LONGITUDE	Q	DIST	DEPTH	MAGNITUDE
01-18-1934	02:14:00	34.10 N	117.68 W	A	51	.0	4.0
01-20-1934	21:17:00	33.62 N	118.12 W	B	51	.0	4.5
04-17-1934	18:33:00	33.57 N	117.98 W	C	60	.0	4.0
10-17-1934	09:38:00	33.63 N	118.40 W	B	51	.0	4.0
11-16-1934	21:26:00	33.75 N	118.00 W	B	42	.0	4.0
06-11-1935	18:10:00	34.72 N	118.97 W	B	99	.0	4.0
06-19-1935	11:17:00	33.72 N	117.52 W	B	76	.0	4.0
07-13-1935	10:54:17	34.20 N	117.90 W	A	34	.0	4.7
09-03-1935	06:47:00	34.03 N	117.32 W	B	84	.0	4.5
12-25-1935	17:15:00	33.60 N	118.02 W	B	56	.0	4.5
02-23-1936	22:20:43	34.13 N	117.34 W	A	83	.0	4.5
02-26-1936	09:33:28	34.14 N	117.34 W	A	83	.0	4.0
08-22-1936	05:21:00	33.77 N	117.82 W	B	51	.0	4.0
10-29-1936	22:35:36	34.38 N	118.62 W	C	50	.0	4.0
01-15-1937	18:35:47	33.56 N	118.06 W	B	59	.0	4.0
03-19-1937	01:23:38	34.11 N	117.43 W	A	74	.0	4.0
07-07-1937	11:12:00	33.57 N	117.98 W	B	60	.0	4.0
09-01-1937	13:48:08	34.21 N	117.53 W	A	67	.0	4.5
09-01-1937	16:35:34	34.18 N	117.55 W	A	64	.0	4.5
05-21-1938	09:44:00	33.62 N	118.03 W	B	53	.0	4.0
05-31-1938	08:34:55	33.70 N	117.51 W	B	78	.0	5.5
07-05-1938	18:06:56	33.68 N	117.55 W	A	76	.0	4.5
08-06-1938	22:00:56	33.72 N	117.51 W	B	77	.0	4.0
08-31-1938	03:18:14	33.76 N	118.25 W	A	34	.0	4.5
11-29-1938	19:21:16	33.90 N	118.43 W	A	26	.0	4.0
12-07-1938	03:38:00	34.00 N	118.42 W	B	19	.0	4.0
12-27-1938	10:09:29	34.13 N	117.52 W	B	66	.0	4.0
04-03-1939	02:50:45	34.04 N	117.23 W	A	93	.0	4.0
11-04-1939	21:41:00	33.77 N	118.12 W	B	35	.0	4.0
11-07-1939	18:52:08	34.00 N	117.28 W	A	88	.0	4.7
12-27-1939	19:28:49	33.78 N	118.20 W	A	32	.0	4.7
01-13-1940	07:49:07	33.78 N	118.13 W	B	34	.0	4.0
02-08-1940	16:56:17	33.70 N	118.07 W	B	44	.0	4.0
02-11-1940	19:24:10	33.98 N	118.30 W	B	12	.0	4.0
04-18-1940	18:43:44	34.03 N	117.35 W	A	82	.0	4.4
05-18-1940	09:15:12	34.60 N	118.90 W	C	85	.0	4.0
06-05-1940	08:27:27	33.83 N	117.40 W	B	81	.0	4.0
07-20-1940	04:01:13	33.70 N	118.07 W	B	44	.0	4.0
10-11-1940	05:57:12	33.77 N	118.45 W	A	39	.0	4.7
10-12-1940	00:24:00	33.78 N	118.42 W	B	37	.0	4.0
10-14-1940	20:51:11	33.78 N	118.42 W	B	37	.0	4.0
11-01-1940	07:25:03	33.78 N	118.42 W	B	37	.0	4.0
11-01-1940	20:00:46	33.63 N	118.20 W	B	49	.0	4.0
11-02-1940	02:58:26	33.78 N	118.42 W	B	37	.0	4.0
01-30-1941	01:34:47	33.97 N	118.05 W	A	20	.0	4.1

DATE	TIME	LATITUDE	LONGITUDE	Q	DIST	DEPTH	MAGNITUDE
03-22-1941	08:22:40	33.52 N	118.10 W	B	62	.0	4.0
03-25-1941	23:43:41	34.22 N	117.47 W	B	72	.0	4.0
04-11-1941	01:20:24	33.95 N	117.58 W	B	62	.0	4.0
10-22-1941	06:57:19	33.82 N	118.22 W	A	28	.0	4.9
11-14-1941	08:41:36	33.78 N	118.25 W	A	32	.0	5.4
04-16-1942	07:28:33	33.37 N	118.15 W	C	78	.0	4.0
09-03-1942	14:06:01	34.48 N	118.98 W	C	83	.0	4.5
09-04-1942	06:34:33	34.48 N	118.98 W	C	83	.0	4.5
04-06-1943	22:36:24	34.68 N	119.00 W	C	98	.0	4.0
10-24-1943	00:29:21	33.93 N	117.37 W	C	81	.0	4.0
06-19-1944	00:03:33	33.87 N	118.22 W	B	22	.0	4.5
06-19-1944	03:06:07	33.87 N	118.22 W	C	22	.0	4.4
02-24-1946	06:07:52	34.40 N	117.80 W	C	54	.0	4.1
06-01-1946	11:06:31	34.42 N	118.83 W	C	67	.0	4.1
03-01-1948	08:12:13	34.17 N	117.53 W	B	66	.0	4.7
04-16-1948	22:26:24	34.02 N	118.97 W	B	68	.0	4.7
10-03-1948	02:46:28	34.18 N	117.58 W	A	62	.0	4.0
01-11-1950	21:41:35	33.94 N	118.20 W	A	15	.0	4.1
01-24-1950	21:56:59	34.67 N	118.83 W	C	86	.0	4.0
02-26-1950	00:06:22	34.62 N	119.08 W	C	99	.0	4.7
09-22-1951	08:22:39	34.12 N	117.34 W	A	83	.0	4.3
02-17-1952	12:36:58	34.00 N	117.27 W	A	89	.0	4.5
08-23-1952	10:09:07	34.52 N	118.20 W	A	50	.0	5.0
10-26-1954	16:22:26	33.73 N	117.47 W	B	80	.0	4.1
11-17-1954	23:03:51	34.50 N	119.12 W	B	95	.0	4.4
05-15-1955	17:03:26	34.12 N	117.48 W	A	70	.0	4.0
05-29-1955	16:43:35	33.99 N	119.06 W	B	77	.0	4.1
01-03-1956	00:25:49	33.72 N	117.50 W	B	78	.0	4.7
02-07-1956	02:16:57	34.53 N	118.64 W	B	63	.0	4.2
02-07-1956	03:16:39	34.59 N	118.61 W	A	67	.0	4.6
03-25-1956	03:32:02	33.60 N	119.10 W	A	96	.0	4.2
03-18-1957	18:56:28	34.12 N	119.22 W	B	91	.0	4.7
06-28-1960	20:00:48	34.12 N	117.47 W	A	71	.0	4.1
10-04-1961	02:21:32	33.85 N	117.75 W	B	51	.0	4.1
10-20-1961	19:49:51	33.65 N	117.99 W	B	52	.0	4.3
10-20-1961	20:07:14	33.66 N	117.98 W	B	51	.0	4.0
10-20-1961	21:42:41	33.67 N	117.98 W	B	50	.0	4.0
10-20-1961	22:35:34	33.67 N	118.01 W	B	49	.0	4.1
11-20-1961	08:53:35	33.68 N	117.99 W	B	49	.0	4.0
09-14-1963	03:51:16	33.54 N	118.34 W	B	60	.0	4.2
08-30-1964	22:57:37	34.27 N	118.44 W	B	29	.0	4.0
01-01-1965	08:04:18	34.14 N	117.52 W	B	66	.0	4.4
04-15-1965	20:08:33	34.13 N	117.43 W	B	74	.0	4.5
07-16-1965	07:46:22	34.48 N	118.52 W	B	53	.0	4.0
01-08-1967	07:37:30	33.63 N	118.47 W	B	53	.0	4.0

DATE	TIME	LATITUDE	LONGITUDE	Q	DIST	DEPTH	MAGNITUDE
01-08-1967	07:38:05	33.66 N	118.41 W	C	48	.0	4.0
06-15-1967	04:58:06	34.00 N	117.97 W	B	25	.0	4.1
02-28-1969	04:56:12	34.57 N	118.11 W	A	57	.0	4.3
05-05-1969	16:02:10	34.30 N	117.57 W	B	66	.0	4.4
10-27-1969	13:16:02	33.55 N	117.81 W	B	70	.0	4.5
09-12-1970	14:10:11	34.27 N	117.52 W	A	69	.0	4.1
09-12-1970	14:30:53	34.27 N	117.54 W	A	68	.0	5.4
09-13-1970	04:47:49	34.28 N	117.55 W	A	67	.0	4.4
02-09-1971	14:00:42	34.41 N	118.40 W	B	41	.0	6.4
02-09-1971	14:01:08	34.41 N	118.40 W	D	41	.0	5.8
02-09-1971	14:01:33	34.41 N	118.40 W	D	41	.0	4.2
02-09-1971	14:01:40	34.41 N	118.40 W	D	41	.0	4.1
02-09-1971	14:01:50	34.41 N	118.40 W	D	41	.0	4.5
02-09-1971	14:01:54	34.41 N	118.40 W	D	41	.0	4.2
02-09-1971	14:01:59	34.41 N	118.40 W	D	41	.0	4.1
02-09-1971	14:02:03	34.41 N	118.40 W	D	41	.0	4.1
02-09-1971	14:02:30	34.41 N	118.40 W	D	41	.0	4.3
02-09-1971	14:02:31	34.41 N	118.40 W	D	41	.0	4.7
02-09-1971	14:02:44	34.41 N	118.40 W	D	41	.0	5.8
02-09-1971	14:03:25	34.41 N	118.40 W	D	41	.0	4.4
02-09-1971	14:03:46	34.41 N	118.40 W	D	41	.0	4.1
02-09-1971	14:04:07	34.41 N	118.40 W	D	41	.0	4.1
02-09-1971	14:04:34	34.41 N	118.40 W	C	41	.0	4.2
02-09-1971	14:04:39	34.41 N	118.40 W	D	41	.0	4.1
02-09-1971	14:04:44	34.41 N	118.40 W	D	41	.0	4.1
02-09-1971	14:04:46	34.41 N	118.40 W	D	41	.0	4.2
02-09-1971	14:05:41	34.41 N	118.40 W	D	41	.0	4.1
02-09-1971	14:05:50	34.41 N	118.40 W	D	41	.0	4.1
02-09-1971	14:07:10	34.41 N	118.40 W	D	41	.0	4.0
02-09-1971	14:07:30	34.41 N	118.40 W	D	41	.0	4.0
02-09-1971	14:07:45	34.41 N	118.40 W	D	41	.0	4.5
02-09-1971	14:08:04	34.41 N	118.40 W	D	41	.0	4.0
02-09-1971	14:08:07	34.41 N	118.40 W	D	41	.0	4.2
02-09-1971	14:08:38	34.41 N	118.40 W	D	41	.0	4.5
02-09-1971	14:08:53	34.41 N	118.40 W	D	41	.0	4.6
02-09-1971	14:10:21	34.36 N	118.31 W	B	33	.0	4.7
02-09-1971	14:10:28	34.41 N	118.40 W	D	41	.0	5.3
02-09-1971	14:16:13	34.34 N	118.33 W	C	31	.0	4.1
02-09-1971	14:19:50	34.36 N	118.41 W	B	36	.0	4.0
02-09-1971	14:34:36	34.34 N	118.64 W	C	48	.0	4.9
02-09-1971	14:39:18	34.39 N	118.36 W	C	37	.0	4.0
02-09-1971	14:40:17	34.43 N	118.40 W	C	43	.0	4.1
02-09-1971	14:43:47	34.31 N	118.45 W	B	33	.0	5.2
02-09-1971	15:58:21	34.33 N	118.33 W	B	30	.0	4.8
02-09-1971	16:19:26	34.46 N	118.43 W	B	47	.0	4.2

DATE	TIME	LATITUDE	LONGITUDE	Q	DIST	DEPTH	MAGNITUDE
02-10-1971	03:12:12	34.37 N	118.30 W	B	34	.0	4.0
02-10-1971	05:06:36	34.41 N	118.33 W	A	39	.0	4.3
02-10-1971	05:18:07	34.43 N	118.41 W	A	43	.0	4.5
02-10-1971	11:31:35	34.38 N	118.45 W	A	40	.0	4.2
02-10-1971	13:49:54	34.40 N	118.42 W	A	40	.0	4.3
02-10-1971	14:35:27	34.36 N	118.49 W	A	40	.0	4.2
02-10-1971	17:38:55	34.40 N	118.37 W	A	39	.0	4.2
02-10-1971	18:54:42	34.45 N	118.44 W	A	46	.0	4.2
02-21-1971	05:50:53	34.40 N	118.44 W	A	41	.0	4.7
02-21-1971	07:15:12	34.39 N	118.43 W	A	40	.0	4.5
03-07-1971	01:33:41	34.35 N	118.46 W	A	37	.0	4.5
03-25-1971	22:54:10	34.36 N	118.47 W	A	39	.0	4.2
03-30-1971	08:54:43	34.30 N	118.46 W	A	33	.0	4.1
03-31-1971	14:52:23	34.29 N	118.51 W	A	35	.0	4.6
04-01-1971	15:03:04	34.43 N	118.41 W	A	43	.0	4.1
04-02-1971	05:40:25	34.28 N	118.53 W	A	36	.0	4.0
04-15-1971	11:14:32	34.26 N	118.58 W	B	38	.0	4.2
04-25-1971	14:48:07	34.37 N	118.31 W	B	34	.0	4.0
06-21-1971	16:01:08	34.27 N	118.53 W	B	35	.0	4.0
06-22-1971	10:41:19	33.75 N	117.48 W	B	78	.0	4.2
07-27-1972	00:31:17	34.78 N	118.90 W	A	100	.0	4.4
02-21-1973	14:45:57	34.06 N	119.03 W	B	74	.0	5.9
03-09-1974	00:54:32	34.40 N	118.47 W	C	43	.0	4.7
08-14-1974	14:45:55	34.43 N	118.37 W	A	42	.0	4.2
01-01-1976	17:20:13	33.96 N	117.89 W	A	34	.0	4.2
04-08-1976	15:21:38	34.35 N	118.66 W	A	50	.0	4.6
08-12-1977	02:19:26	34.38 N	118.46 W	B	40	.0	4.5
09-24-1977	21:28:24	34.46 N	118.41 W	C	46	.0	4.2
05-23-1978	09:16:51	33.91 N	119.17 W	C	88	.0	4.0
01-01-1979	23:14:39	33.94 N	118.68 W	B	44	.0	5.0
10-17-1979	20:52:37	33.93 N	118.67 W	C	43	.0	4.2
10-19-1979	12:22:38	34.21 N	117.53 W	B	67	.0	4.1
09-04-1981	15:50:50	33.67 N	119.11 W	C	92	5.0	5.3
10-23-1981	17:28:17	33.63 N	119.02 W	C	88	12.0	4.6
10-23-1981	19:15:52	33.64 N	119.06 W	C	90	6.2	4.6
04-13-1982	11:02:12	34.05 N	118.96 W	A	67	16.6	4.0
05-25-1982	13:44:30	33.54 N	118.21 W	A	59	13.7	4.1
01-08-1983	07:19:30	34.14 N	117.45 W	A	73	4.6	4.1
06-12-1984	00:27:52	34.54 N	118.99 W	A	87	11.7	4.1
10-26-1984	17:20:44	34.02 N	118.99 W	A	70	13.3	4.6
10-02-1985	23:44:12	34.02 N	117.24 W	A	92	15.2	4.8
10-01-1987	14:42:20	34.06 N	118.08 W	A	14	9.5	5.9
10-01-1987	14:45:41	34.05 N	118.10 W	A	12	13.5	4.7
10-01-1987	14:48:03	34.08 N	118.09 W	A	13	11.7	4.1
10-01-1987	14:49:06	34.06 N	118.10 W	A	12	11.7	4.7

DATE	TIME	LATITUDE	LONGITUDE	Q	DIST	DEPTH	MAGNITUDE
10-01-1987	15:12:32	34.05 N	118.09 W	A	13	10.8	4.7
10-04-1987	10:59:38	34.07 N	118.10 W	A	12	8.3	5.3
10-24-1987	23:58:33	33.68 N	119.06 W	A	88	12.2	4.1
02-11-1988	15:25:56	34.08 N	118.05 W	A	17	12.5	4.7
06-26-1988	15:04:58	34.14 N	117.71 W	A	49	7.9	4.7
11-20-1988	05:39:29	33.51 N	118.07 W	C	64	6.0	4.5
12-03-1988	11:38:26	34.15 N	118.13 W	A	13	13.3	4.9
01-19-1989	06:53:29	33.92 N	118.63 W	A	40	11.9	5.0
02-18-1989	07:17:05	34.01 N	117.74 W	A	46	3.3	4.1
04-07-1989	20:07:30	33.62 N	117.90 W	A	59	12.8	4.5
06-12-1989	16:57:18	34.03 N	118.18 W	A	7	15.6	4.4
06-12-1989	17:22:25	34.02 N	118.18 W	A	7	15.5	4.1
12-28-1989	09:41:08	34.19 N	117.39 W	A	79	14.6	4.5
02-28-1990	23:43:37	34.14 N	117.70 W	A	50	5.3	5.2
03-01-1990	00:34:57	34.13 N	117.70 W	A	50	4.4	4.0
03-01-1990	03:23:03	34.15 N	117.72 W	A	48	11.4	4.7
03-02-1990	17:26:25	34.14 N	117.69 W	A	51	5.6	4.7
04-17-1990	22:32:27	34.11 N	117.72 W	A	48	3.6	4.8
06-28-1991	14:43:55	34.26 N	118.00 W	A	30	10.5	5.4
06-28-1991	17:00:56	34.25 N	117.99 W	A	30	9.5	4.3
07-05-1991	17:41:57	34.50 N	118.56 W	A	56	10.9	4.1

SEARCH OF EARTHQUAKE DATA FILE 1

SITE: LACTC, Pasadena Rail Transit, L92045.AEF1

COORDINATES OF SITE	34.07 N 118.23 W
DISTANCE PER DEGREE	110.9 KM-N 92.3 KM-W
MAGNITUDE LIMITS	4.0 - 8.5
TEMPORAL LIMITS	1932 - 1991
SEARCH RADIUS (KM)	100
NUMBER OF YEARS OF DATA	60
NUMBER OF EARTHQUAKES IN FILE	3140
NUMBER OF EARTHQUAKES IN AREA	326

LAW/CRANDALL, INC.

LIST OF HISTORIC EARTHQUAKES OF MAGNITUDE 6.0 OR GREATER WITHIN 100 KM OF THE SITE
(RICHTER DATA 1906-1931)

DATE	TIME	LATITUDE	LONGITUDE	Q	DIST	DEPTH	MAGNITUDE
05-15-1910	15:47:00	33.70 N	117.40 W	D	87	.0	6.0
07-23-1923	07:30:26	34.00 N	117.25 W	D	91	.0	6.3

SEARCH OF EARTHQUAKE DATA FILE 2

SITE: LACTC, Pasadena Rail Transit, L92045.AEF1

COORDINATES OF SITE	34.07 N 118.23 W
DISTANCE PER DEGREE	110.9 KM-N 92.3 KM-W
MAGNITUDE LIMITS	6.0 - 8.5
TEMPORAL LIMITS	1906 - 1931
SEARCH RADIUS (KM)	100
NUMBER OF YEARS OF DATA	26
NUMBER OF EARTHQUAKES IN FILE	35
NUMBER OF EARTHQUAKES IN AREA	2

LAW/CRANDALL, INC.

```
           LIST OF HISTORIC EARTHQUAKES OF MAGNITUDE 7.0 OR
                 GREATER WITHIN 100 KM OF THE SITE
                    (NOAA/CDMG DATA 1812-1905)

    DATE        TIME     LATITUDE  LONGITUDE   Q  DIST  DEPTH  MAGNITUDE


 02-09-1890  04:06:00   34.00 N  117.50  W   D   68     .0       7.0




    S E A R C H   O F   E A R T H Q U A K E   D A T A   F I L E  3




     SITE:  LACTC, Pasadena Rail Transit, L92045.AEF1

          COORDINATES OF SITE  ..........  34.07 N  118.23 W

          DISTANCE PER DEGREE  .....  110.9 KM-N   92.3 KM-W

          MAGNITUDE LIMITS  ......................  7.0 - 8.5

          TEMPORAL LIMITS  ....................  1812 - 1905

          SEARCH RADIUS (KM)  ........................   100

          NUMBER OF YEARS OF DATA  ..................    94

          NUMBER OF EARTHQUAKES IN FILE  ............     9

          NUMBER OF EARTHQUAKES IN AREA  ............     1




                      L A W / C R A N D A L L , I N C .
```

SUMMARY OF EARTHQUAKE SEARCH

* * *

NUMBER OF HISTORIC EARTHQUAKES WITHIN 100 KM RADIUS OF SITE

MAGNITUDE RANGE	NUMBER
4.0 - 4.5	218
4.5 - 5.0	78
5.0 - 5.5	22
5.5 - 6.0	6
6.0 - 6.5	4
6.5 - 7.0	0
7.0 - 7.5	1
7.5 - 8.0	0
8.0 - 8.5	0

* * *

```
C O M P U T A T I O N   O F   R E C U R R E N C E   C U R V E

                      L O G   N  =  A  -  B M


                             * * *


      BIN     MAGNITUDE        RANGE           NO/YR (N)

       1        4.00       4.00 - 8.50        5.45

       2        4.50       4.50 - 8.50        1.82

       3        5.00       5.00 - 8.50        .519

       4        5.50       5.50 - 8.50        .152

       5        6.00       6.00 - 8.50        .521E-01

       6        6.50       6.50 - 8.50        .556E-02 NU

       7        7.00       7.00 - 8.50        .556E-02 NU

       8        7.50       7.50 - 8.50        .000

       9        8.00       8.00 - 8.50        .000


        A = 1.140      B =  .5649       (NORMALIZED)
        A = 4.840      B = 1.0235     SIGMA =    .254E-01


                             * * *



               L A W / C R A N D A L L , I N C .
```

```
            C O M P U T A T I O N   O F   D E S I G N   M A G N I T U D E

                               C O N S T A N T   A R E A


                                         * * *


                                TABLE OF DESIGN MAGNITUDES


    RISK          RETURN PERIOD (YEARS)              DESIGN MAGNITUDE

                                    DESIGN LIFE (YEARS)
                   25      50      75      100       25      50      75      100


    .01  ..      2487    4974    7462    9949  ..  7.92    8.12    8.21    8.27

    .05  ..       487     974    1462    1949  ..  7.33    7.60    7.74    7.84

    .10  ..       237     474     711     949  ..  7.04    7.32    7.48    7.59

    .20  ..       112     224     336     448  ..  6.72    7.01    7.18    7.29

    .30  ..        70     140     210     280  ..  6.53    6.82    6.99    7.10

    .50  ..        36      72     108     144  ..  6.25    6.54    6.71    6.83

    .70  ..        20      41      62      83  ..  6.01    6.31    6.48    6.60

    .90  ..        10      21      32      43  ..  5.74    6.03    6.20    6.33

                         MMIN =    4.00     MMAX =  8.50
                         MU =      5.57     BETA = 2.357


                                         * * *


                          L A W / C R A N D A L L , I N C .
```