SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
GEOTECHNICAL EXPLORATION
Santa Cruz County, California

VOLUME I

WILLIAM COTTON AND ASSOCIATES
Geotechnical Consultants

SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
GEOTECHNICAL EXPLORATION

Santa Cruz County, California

VOLUME I

for

U.S. Army Corps of Engineers
211 Main Street
San Francisco, California

by

William Cotton and Associates, Inc.
330 Village Lane
Los Gatos, California 95030

September 30, 1990

William Cotton
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October 31, 1990
G1409F

Mr. Arijs A. Rakstins
U.S. Army Corps of Engineers
San Francisco District
211 Main Street
San Francisco, California 94105-1905

SUBJECT: **Final Report, Volumes I and II of II**
RE: Schultheis Road and Villa Del Monte Areas
Geotechnical Exploration, Santa Cruz County, California

Dear Mr. Rakstins:

With this letter, we are presenting Volumes I and II of II of our final report regarding the work we performed as part of our contract with the U.S. Army Corps of Engineers (COE) for the Schultheis Road and Villa Del Monte Areas Geotechnical Exploration project. This work was performed under our contract DACW07-90-C-9706 (including modification No. P00001) with the COE. This report is being submitted in order to provide data for your analyses.

If you have any questions regarding this report or any aspect of our investigation, please call.

Very truly yours,

WILLIAM COTTON AND ASSOCIATES, INC.

Dale R. Marcum
Project Engineer

Patrick O. Shires
Project Manager
Principal Geotechnical Engineer
GE 770

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SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS

GEOTECHNICAL EXPLORATION

Santa Cruz County, California

Table of Contents

VOLUME I

Table of Contents (Cont.)

Table of Contents (Cont.)

SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
GEOTECHNICAL EXPLORATION
Santa Cruz County, California

VOLUME I

William Cotton and Associates

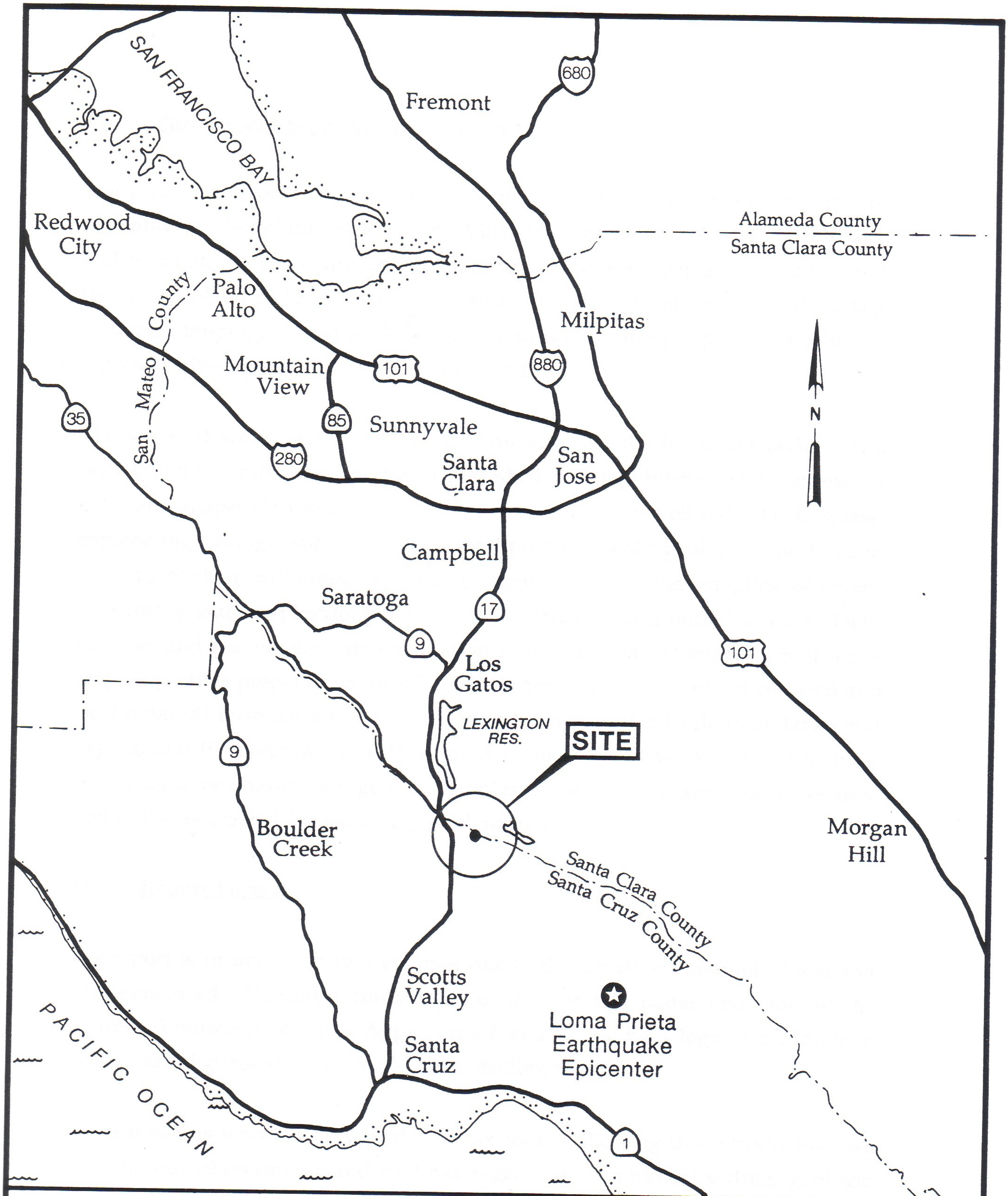
SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
GEOTECHNICAL EXPLORATION
Santa Cruz County, California

1.0 INTRODUCTION

This report describes the findings, conclusions, and recommendations of our geotechnical exploration of the Schultheis Road and Villa Del Monte landslide areas (see Figure 1, Location Map). We conducted this investigation in accordance with the U. S. Army Corps of Engineers (COE) contract DACW07-90-C-9706 and Modification No. P00001.

1.1 Project Description

Many areas in the Santa Cruz Mountains experienced significant ground deformation as a result of the Loma Prieta earthquake of October 17, 1989. The earthquake distress area was mapped by staff from the California Division of Mines and Geology, U. S. Geological Survey, County of Santa Cruz, various agencies and private consulting firms. This mapping resulted in the identification of areas which had been impacted by coseismic ground cracking and fissuring. Because areas of earthquake ground deformation appeared to correspond to previously mapped areas of regional landsliding, concern was raised that the previously mapped landslides had reactivated as a result of the Loma Prieta earthquake. This concern was heightened by the potential for additional movement as a result of aftershocks or increased groundwater levels during the approaching winter season. Because of the extent, magnitude, and type of ground deformation in the Schultheis Road region and the Villa Del Monte residential subdivision, these two areas were selected for initial study by the COE as advised by a Technical Advisory Group (TAG) of experts. As part of the broad study to address slope stability concerns, William Cotton and Associates (WCA) was retained by the COE to install subsurface monitoring instrumentation and to characterize the geologic site conditions.



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MILES

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SITE LOCATION MAP

SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
SANTA CRUZ COUNTY, CALIFORNIA

GEO/ENG. BY	SCALE	PROJECT NO.
JW	1"=6 Miles	G1409
APPROVED BY	DATE	FIGURE NO.
BOS	9/30/90	1

1.2 Purpose and Scope of Investigation

The primary purpose of our work was to install subsurface monitoring instrumentation in the Schultheis Road and Villa Del Monte areas. As part of this task, and in an attempt to characterize and interpret general geologic conditions and the depth of landsliding in the two areas, we also performed limited surface geologic mapping, logged geologic data from the drilling program and collected representative samples of subsurface materials.

The scope of work performed by our firm included the following tasks: (1) a review and compilation of pertinent published and unpublished geologic reports, data, and maps; (2) research and review of local water well data; (3) localized engineering geologic surface mapping and profiling of the geologic conditions in portions of the study areas; (4) drilling, logging and selected sampling of seventeen rotary wash exploratory borings; (5) installation and initialization of inclinometer and piezometer instrumentation in the borings; (6) evaluation of topographic profiles prepared by Towill, Inc.; (7) geologic analysis of the research and field data; (8) formulation of geologic interpretation of landslide boundaries and depths, and (9) preparation of this report. Our scope of work **did not** include comprehensive engineering geologic studies, slope stability analyses, or evaluation of the associated landslide and earthquake risk.

1.3 Report Format

The report is presented in two volumes due to the significant amount of text and data generated. Volume I contains all of the text and plates and most of the figures. Volume II contains Appendices F and G, the field logs of exploratory drilling and figures showing exploratory drilling rates.

The text of this report is presented in 11 sections. Following this introduction, we describe our observations and findings regarding the physical setting, geologic setting, surficial distress, water well data, subsurface exploration, monitoring instrumentation, probable landslide parameters, conclusions and recommendations, limitations, and references used. Figures (i.e., page-size illustrations) referred to in the text follow the page of text wherein they are first referenced.

Appendices A through G provide, sample summary and testing recommendations, water well data, representative inclinometer and piezometer plots, information pertaining to preparation of the Geotechnical Exploration Map and Engineering Geologic Cross Sections, field logs of exploratory drilling, and exploratory drilling rates.

Oversize plates are located in pockets at the back of Volume I of the report. The Geotechnical Exploration Map (Plate 1) presents a large-scale portrayal of the two study areas. The following information is presented on the Geotechnical Exploration Map: roads, regional topography, boring/instrumentation locations, approximate water well locations, survey transect locations, ground cracks, topographic lineaments, and interpreted landslide boundaries. Generalized engineering geologic cross sections prepared along the survey transect lines provided by Towill, Inc. are included as Plates 2, 3, 4, and 5.

2.0 PHYSICAL SETTING

2.1 Location

The Schultheis Road and Villa Del Monte areas are located in the Summit Road area of the Santa Cruz Mountains between the communities of Los Gatos and Santa Cruz in the southern San Francisco Bay Area (Figure 1). The areas are located approximately 1-1/2 to 2 miles east of State Highway 17 and south of Summit Road. Both areas are located within the northeastern portion of Santa Cruz County. Aerial photographs of the Schultheis Road and Villa Del Monte areas are included as Figures 2 and 3, respectively. These photographs illustrate the location of survey lines and exploratory borings with respect to residential structures, roads and vegetative cover.

The "**Schultheis Road Area**" is an arbitrarily designated (for the purposes of this report) geographic area of about 200 acres that is roughly bounded on the northeast by Summit Road and on the southwest by Burns Creek. Access to the central portion of the area is via Old Santa Cruz Highway and Schultheis Road (spelled "Schultheis" on County Maps, but spelled "Schulties" on the County street sign).

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AERIAL PHOTOGRAPH OF
SCHULTHEIS ROAD AREA
SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
SANTA CRUZ COUNTY, CALIFORNIA

GEO/ENG. BY	SCALE	PROJECT NO.
MT	Not To Scale	G1409
APPROVED BY	DATE	FIGURE NO.
GCS.	9/30/90	2

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AERIAL PHOTOGRAPH OF
VILLA DEL MONTE AREA
SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
SANTA CRUZ COUNTY, CALIFORNIA

GEO/ENG. BY	SCALE	PROJECT NO.
MT	Not To Scale	G1409
APPROVED BY	DATE	FIGURE NO.
	9/30/90	3

The area is sparsely developed and characterized by older, ranch-style homes on large, generally several acres or more, redwood-forested properties.

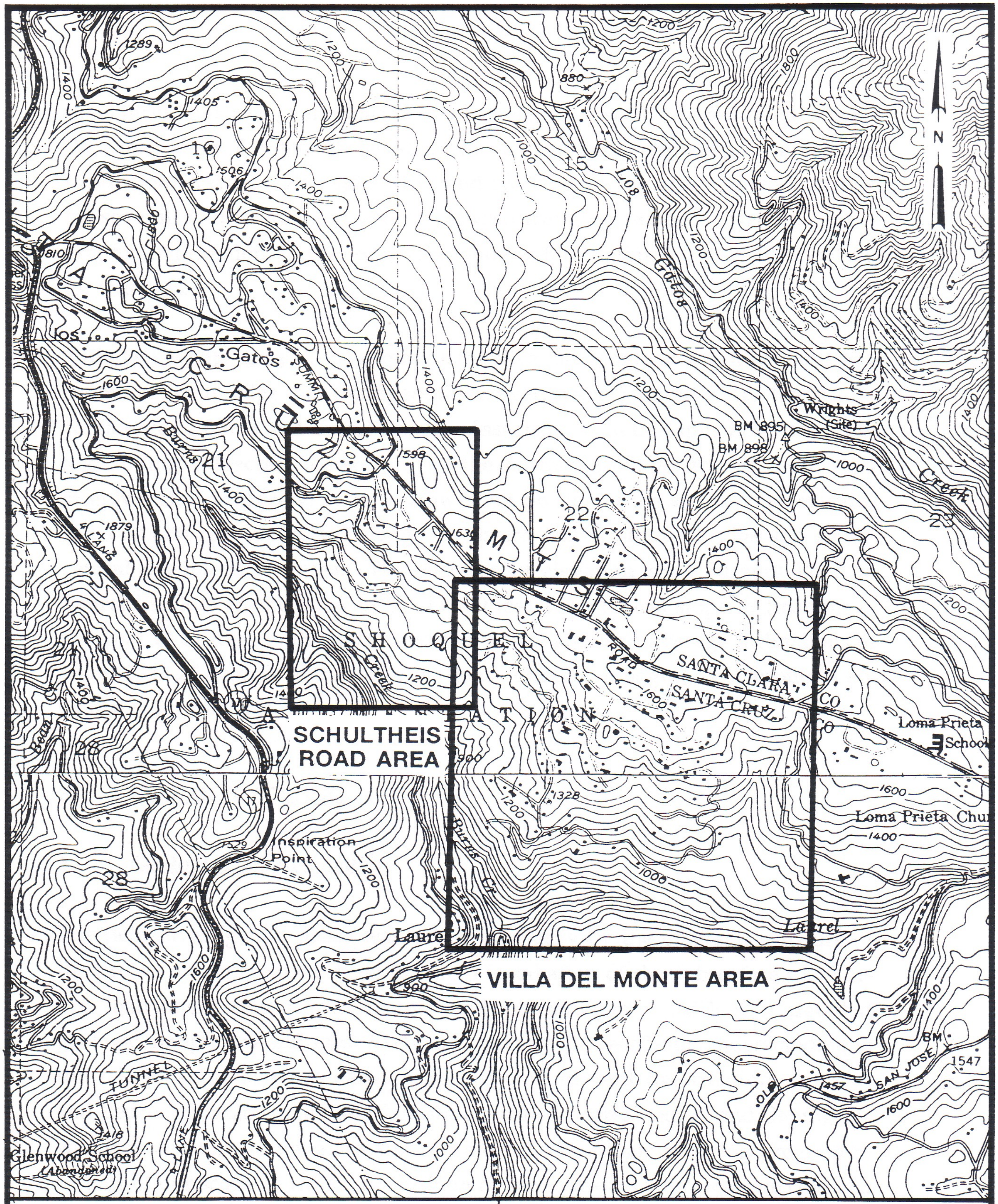
The "**Villa Del Monte Area**" is a residential subdivision that is bounded on the north by Summit Road, on the south by Laurel Creek, and on the southwest by Burns Creek. The area is roughly 300 acres in size and is characterized by moderate to large-size homes on one-half to one acre lots. Access to the subdivision from Summit Road is via Sunset Drive and Del Monte Way. Other roadways in the subdivision include Deerfield Road, Evergreen Lane, Sky View Terrace, Sky View Court, Cove Lane Road, Troy Road, Bel Air Court, and Tree View Trail.

2.2 Topography

The Schultheis Road and Villa Del Monte Areas are located in the Summit Ridge region of the central Santa Cruz Mountains. The Santa Cruz Mountains, which are part of the California Coast Ranges geomorphic province, extend approximately 85 miles northwestward from the Pajaro River in the south to near South San Francisco in the north. The mountain range is rugged and steep, and overall relief of the ridgecrests varies from about 1,500 to greater than 3,700 feet above sea level.

In general, Summit Ridge and the surrounding vicinity display a predominantly northwest-trending series of ridges and valleys which are of moderate to high relief. The terrain is characterized by broad, rolling uplands with gentle, rounded ridgecrests and steep hillsides with narrow, deeply incised stream canyons (Figure 4). Typically, the ridgecrests are relatively open and free of dense vegetation, whereas the hillsides are heavily forested with second- and third-growth redwood trees and dense undergrowth. The Schultheis Road and Villa Del Monte areas are situated along the southwest-facing flank of Summit Ridge south of Summit Road.

Schultheis Road Area - Topography in the Schultheis Road area is typical of most hillsides along Summit Ridge. In this area, the elevation change from Summit Road downslope to Burns Creek is approximately 550 feet and the typical hillslope inclination varies from 15 to 20 degrees. However, local topographic condi-



0 2000 4000

FEET

Contour Interval = 40 feet

Reference:
U.S.G.S. 7.5 Minute Topographic Series, Los Gatos and Laurel Quadrangles (1953 and 1955, respectively).

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REGIONAL TOPOGRAPHY

SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
SANTA CRUZ COUNTY, CALIFORNIA

GEO/ENG. BY	SCALE	PROJECT NO.
WC	1"=2000'	G1409
APPROVED BY	DATE	FIGURE NO.
BPS	9/30/90	4

tions include extreme variations in slope angle, from relatively flat-lying benches (less than about 5 degrees inclination) to very steep (35 degrees to near-vertical inclination) scarps, ravine side-walls, and creekbanks. Drainage is characterized by several southward- and southwestward-trending ravines. Detailed topographic information, in the form of a topographic contour map, is not available for this area.

Villa Del Monte Area - Topography in the Villa Del Monte area is influenced by a prominent spur ridge that trends southwestward from Summit Ridge toward the confluence of Burns and Laurel Creeks. Associated with this spur ridge are broad and rolling ridgecrest topography in the north-central portion of the area, a steeply inclined ridgeline in the southwestern portion of the area, and steep-sided canyons and ravines incised along the eastern and western margins and south-central portion of the area. The decrease in elevation from Summit Road to Laurel Creek is on the order of 800 to 900 feet, with typical slope inclinations of less that 10 degrees in the upland portion of the area and average inclinations of about 20 to 25 degrees in the lower portions. Detailed topographic mapping is not available for this area.

3.0 GEOLOGIC SETTING

3.1 Geologic Data Acquisition

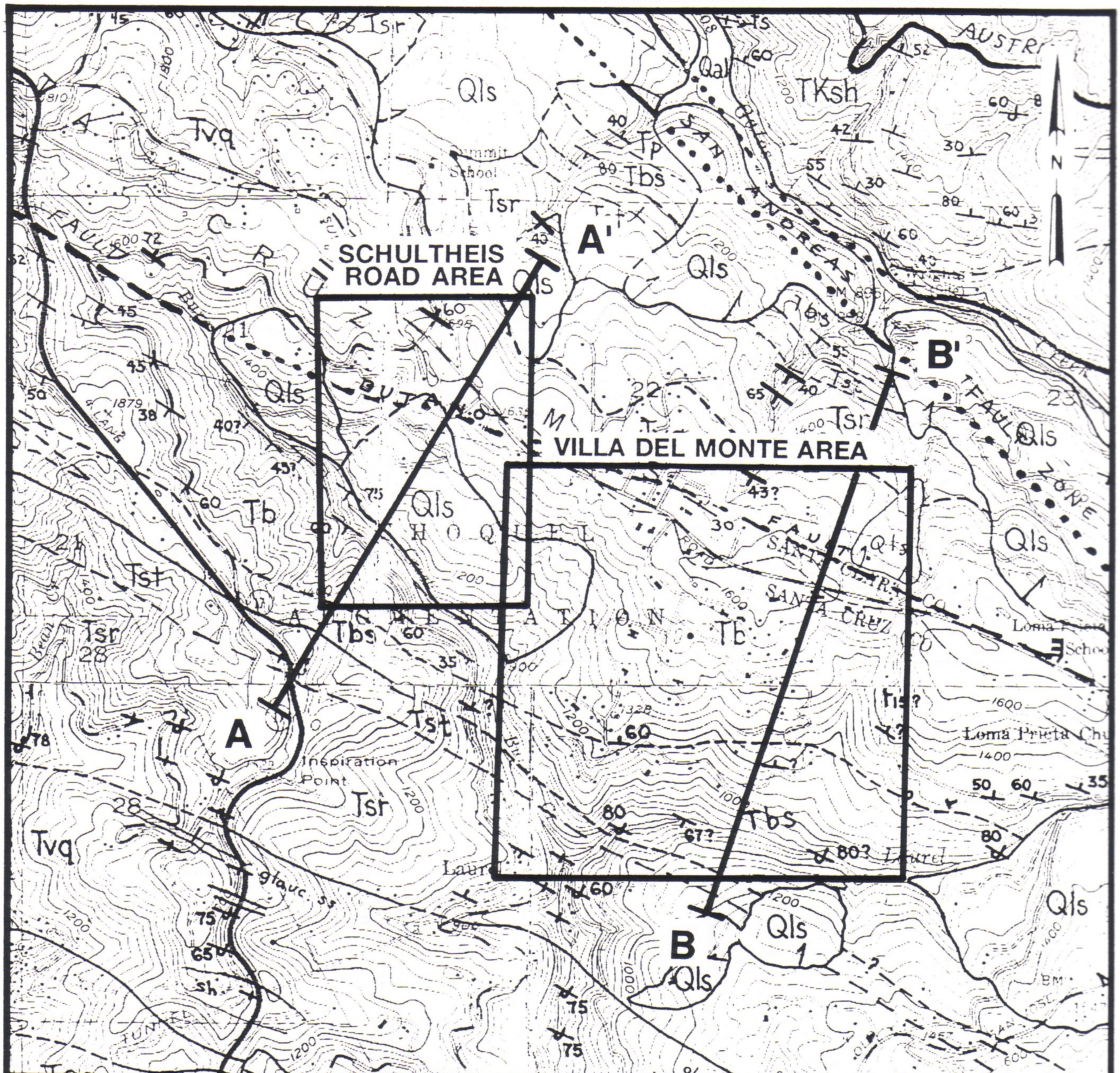
The field investigation phase was driven primarily by the emergency nature of the project and consequent need for rapid installation of the subsurface monitoring instrumentation (inclinometers and piezometers). Although detailed geologic mapping would most likely have greatly increased our understanding of the relationships between earthquake-triggered ground deformation, surficial and bedrock characteristics and landslide geometry (areal extent and depth), the emergency status did not allow time for a detailed geologic mapping program to be part of our scope of work. Acquisition of geologic data was therefore confined to: 1) review of existing regional geologic maps; 2) review and compilation of the CDMG/USGS/Santa Cruz County ground crack maps; 3) limited and generalized geomorphic mapping (at a scale of 1 inch = 2000 feet); 4) detailed geomorphic mapping of two, localized zones in the Schultheis Road area (at scales of 1 inch = 5 and 10 feet); 5) reconnaissance of portions of survey transect line nos. 3, 6 and 8; 6) logging of cuttings and samples during drilling operations; and 7) inspections of core X-rays and extruded core samples.

3.2 Earth Materials

The central Santa Cruz Mountains are characterized by a thick, highly deformed section of Tertiary sedimentary rocks (Figures 5 and 6). The Tertiary bedrock section consists predominantly of marine clastic sedimentary rocks which have an estimated thickness of about 25,000 feet (Clark, 1981). These rocks have been strongly folded and locally overturned into a series of northwest-southeast trending anticlines and synclines. The Tertiary rocks overlie older granitic and metamorphic rocks which are referred to as the Salinian Block basement-rock complex.

As portrayed on regional geologic maps, the Summit Ridge region is underlain by steeply inclined (i.e., 30 to 60 degrees) sedimentary bedrock of the Butano Formation and Vaqueros Formation (Dibblee and Brabb, 1978; Dibblee and others, 1978; and Clark and others, 1989). These two bedrock formations are separated by the Butano fault, which extends roughly east-west across the Schultheis Road area and trends just north of the Villa Del Monte area. The Vaqueros Formation is present north of the Butano fault and the Butano Formation is present south of the fault. The regional portrayal of geologic structure in the vicinity of the Summit Ridge area indicates that intact Butano Formation strata are inclined toward the south, whereas intact Vaqueros Formation strata appear to be folded into a southeast-plunging syncline that is truncated by the Butano fault. As shown on Figure 6, the Vaqueros Formation strata are inclined toward the north in the vicinity of the Schultheis Road area and are inclined toward the south in the Villa Del Monte area.

As mapped on a regional scale, large, deep-seated landslide deposits overlie the Vaqueros and Butano bedrock in a broad zone extending downslope from Summit Ridge to Los Gatos, Burns, and Laurel Creeks (Figure 7). Approximately 40% to 50% of the south slope of Summit Ridge (between Highway 17 and



EXPLANATION

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EARTH MATERIALS:

Qls	Landslide Deposits
Tvq	Vaqueros Formation
Tb, Tbs	Butano Formation
Tst, Tsr	San Lorenzo Formation

MAP SYMBOLS:

- Strike and dip of bedding
- Strike and dip of overturned bedding
- Contact, dashed where uncertain
- Fault, dashed where uncertain, dotted where concealed

A ⊢—⊣ A' Location of Regional Geologic Cross Section (see Figure 6)

References:
Dibblee and Brabb (1978), Dibblee and others (1978), and Clark and others (1989).

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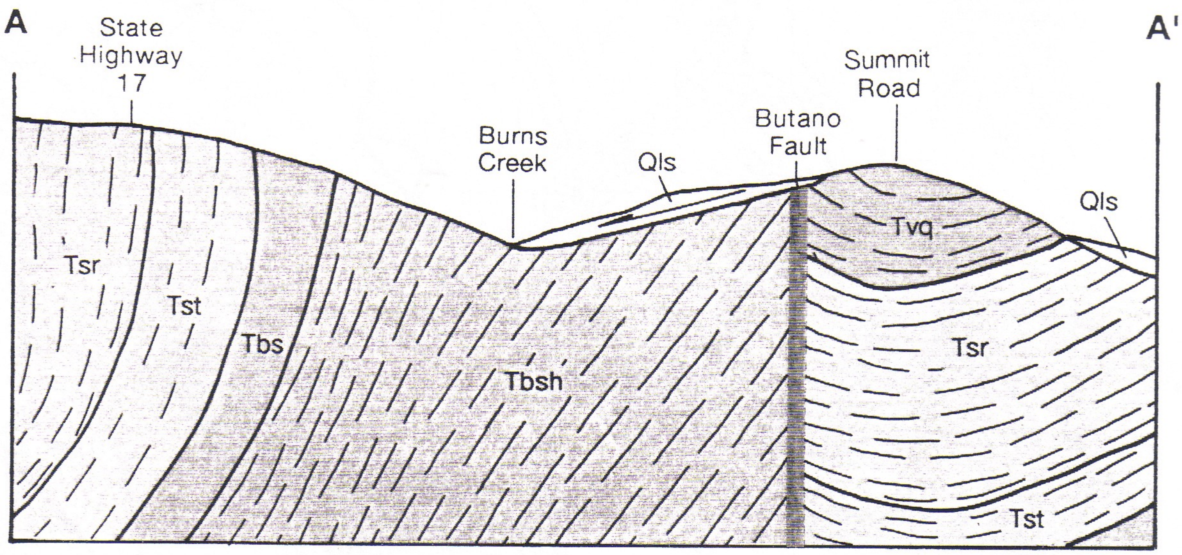
REGIONAL GEOLOGIC MAP

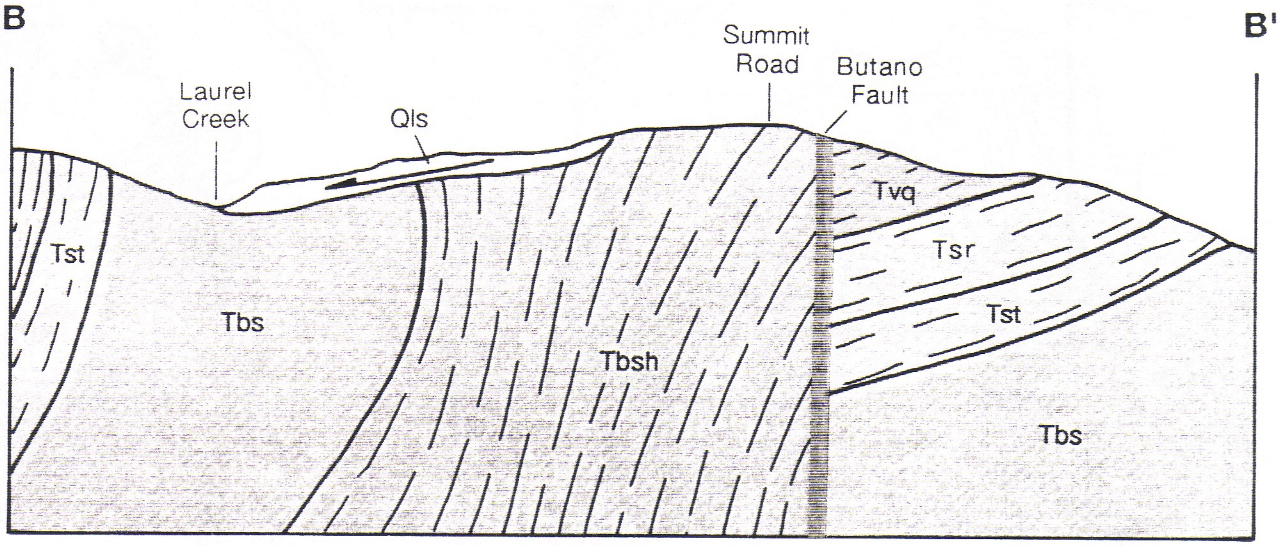
SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
SANTA CRUZ COUNTY, CALIFORNIA

GEO/ENG. BY	SCALE	PROJECT NO
WC	1"=2000'	G1409
APPROVED BY	DATE	FIGURE NO
BOS	9/30/90	5

SCHULTHEIS ROAD AREA



VILLA DEL MONTE AREA



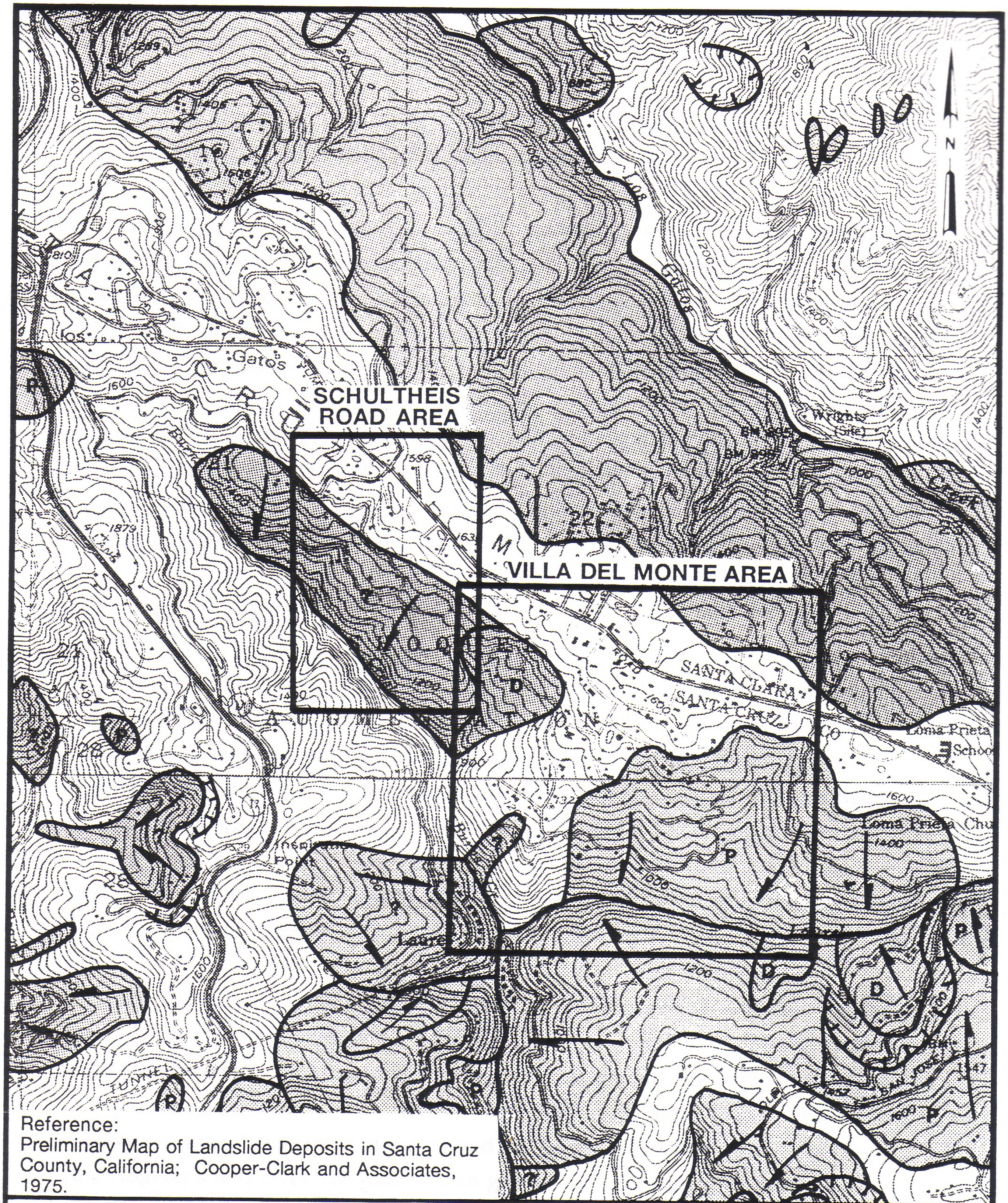
EXPLANATION

Qls	Landslide Deposits	Tb, Tbs	Butano Formation
Tvq	Vaqueros Formation	Tst, Tsr	San Lorenzo Formation

WC William Cotton and Associates

REGIONAL GEOLOGIC CROSS SECTIONS
A-A' AND B-B'
SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
SANTA CRUZ COUNTY, CALIFORNIA

GEO/ENG. BY	SCALE	PROJECT NO.
BC/WC	Not To Scale	G1409
APPROVED BY	DATE	FIGURE NO.
BOS	9/30/90	6



Reference:
Preliminary Map of Landslide Deposits in Santa Cruz County, California; Cooper-Clark and Associates, 1975.

0 2000 4000

FEET

EXPLANATION

Landslide Deposits: 'D' indicates definite landslides; 'P', probable landslides; '?', questionable landslides. Arrows indicate direction of movement; hachures indicate inferred main scarp.

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REGIONAL LANDSLIDE MAP

SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
SANTA CRUZ COUNTY, CALIFORNIA

GEO/ENG. BY	SCALE	PROJECT NO.
WC	1"=2000'	G1409
APPROVED BY	DATE	FIGURE NO.
QOS	9/30/90	7

Soquel-San Jose Road) has been mapped as being underlain by landslide deposits (Cooper-Clark and Associates, 1975 and Brabb and Dibblee, 1978).

Both the Butano and Vaqueros bedrock materials and the ancient landslide deposits are overlain by unconsolidated surficial accumulations of regolith. "Regolith" consists of highly weathered and fractured soil and rock materials, derived from underlying bedrock units of the Butano and Vaqueros formations, that have been subjected to physical and chemical weathering processes aided by cyclic changes in groundwater levels, seismic shaking and downslope creep processes. "Colluvium" generally represents the upper portion of regolith and consists primarily of unconsolidated surficial materials derived from weathered bedrock and soil. Colluvium has evolved from weathering and slow downslope transport via soil creep and other slope movement processes.

3.3 Geomorphology

Figure 8 represents our interpretation of large geomorphic features on the crest and flanks of Summit Ridge. The primary sources of the geomorphic interpretation were 1939 stereoscopic aerial photographs (with an approximate scale of 1 inch = 1,666 feet) and U. S. Geological Survey topographic quadrangle maps. Large landforms are portrayed better on the 1939 aerial photographs than more recent aerial photographs because of their smaller scale and the relative lack of vegetation. The increased vegetative cover on post-1939 aerial photographs obscures geomorphic features.

Summit Ridge geomorphology is characterized by widespread landslide terrane and strong ridgetop lineaments. In general, the geomorphology of the ancient landslide terrane is characterized by "stepped" topography, including very steep scarps, flatlying topographic benches, and steep basal slopes along the creek canyons. Several sequences of scarps and flat-lying benches are present between the ridgetops and creek canyons. Fresh ground fissures throughout the ancient landslide terrane indicate that portions of these large landslide complexes experienced deformation and local downslope displacement as a result of the Loma Prieta earthquake.

Topographic lineaments, such as linear alignments of swales, depressions and steep-sided ridges, are present along the crest of Summit Ridge and locally extend into the adjacent hillsides. Topographic lineaments in the Summit Ridge area have formed primarily by repeated ground breaks due to earthquakes. These lineaments have been mapped by previous investigators and are portrayed on the Geotechnical Exploration Map (Plate 1, pocket).

3.4 Hillslope Processes

Hillslope processes, including rock creep, soil creep and landsliding, are natural mechanisms of regolith development and hillside degradation. The regolith material described in Section 3.2 represents formerly intact bedrock material that has been deformed and disrupted due to hillslope processes that have been active over a long period of time.

Landslide movement can be initiated by any event or process that disrupts, or adversely affects, the equilibrium of a previously stable hillside. In many cases, the hillside in question may be only marginally stable before some triggering event causes failure. Triggering events for landsliding include strong ground shaking from an earthquake or high pore pressures from a period of intense rainfall. In a general sense, landsliding has been occurring along the flanks of Summit Ridge since the early stages of development of the canyons along which Burns, Laurel and Los Gatos creeks flow. The primary regional factors leading to deep-seated hillside instability in the Summit Ridge area are weak and fractured earth materials, variable (but generally shallow) groundwater conditions, steep slopes, erosional undercutting by adjacent creeks, and periodic earthquake shaking.

The ancient landslide masses underlying the Schultheis Road and Villa Del Monte areas are, in general, founded in lithologically weak earth materials. The landslide materials were derived from fractured, folded and faulted Tertiary sedimentary rocks that have been subjected to periods of intense rainfall, groundwater fluctuations, and strong earthquake shaking. These materials (primarily fine-grained, thinly bedded and highly fractured shale and claystone rock) contain numerous shears, fractures and other discontinuities that are able to collect, transmit, and store water from various sources (e.g., rainfall, runoff, and groundwater). Saturation of the landslide materials reduces their resistance to shearing, thereby further weakening the hillslope. Permeable portions of the landslide material may become saturated during wet periods, and form zones of weakness which can fail suddenly during intense storms. Subsurface flow also contributes to saturation of the hillsides. Groundwater saturation may be exacerbated by the presence of ridgetop depressions, which tend to collect and store surface runoff, thereby allowing water that might otherwise flow overland to infiltrate and flow along subsurface discontinuities. Groundwater affects slope stability adversely because it lowers the shear strength of critical materials and creates high pore pressures that lower the resistance to downslope movement.

Hillslope steepness is another factor affecting slope instability. In general, the steeper the gradient (within the same slope materials), the less stable the slope. Long-term creek erosion, in addition to steepening the adjacent hillside, also tends to remove material that provides lateral support to the hillside and therefore results in increased instability events.

"Rock creep" is defined as slow, downslope movement of an upper zone of bedrock produced by gravity-induced shear stresses. The gravitational stresses result in permanent deformation of the bedrock structure to produce a zone of fractured and disrupted bedrock overlain by a mantle of surficial slope materials that can vary in thickness from several inches to tens of feet.

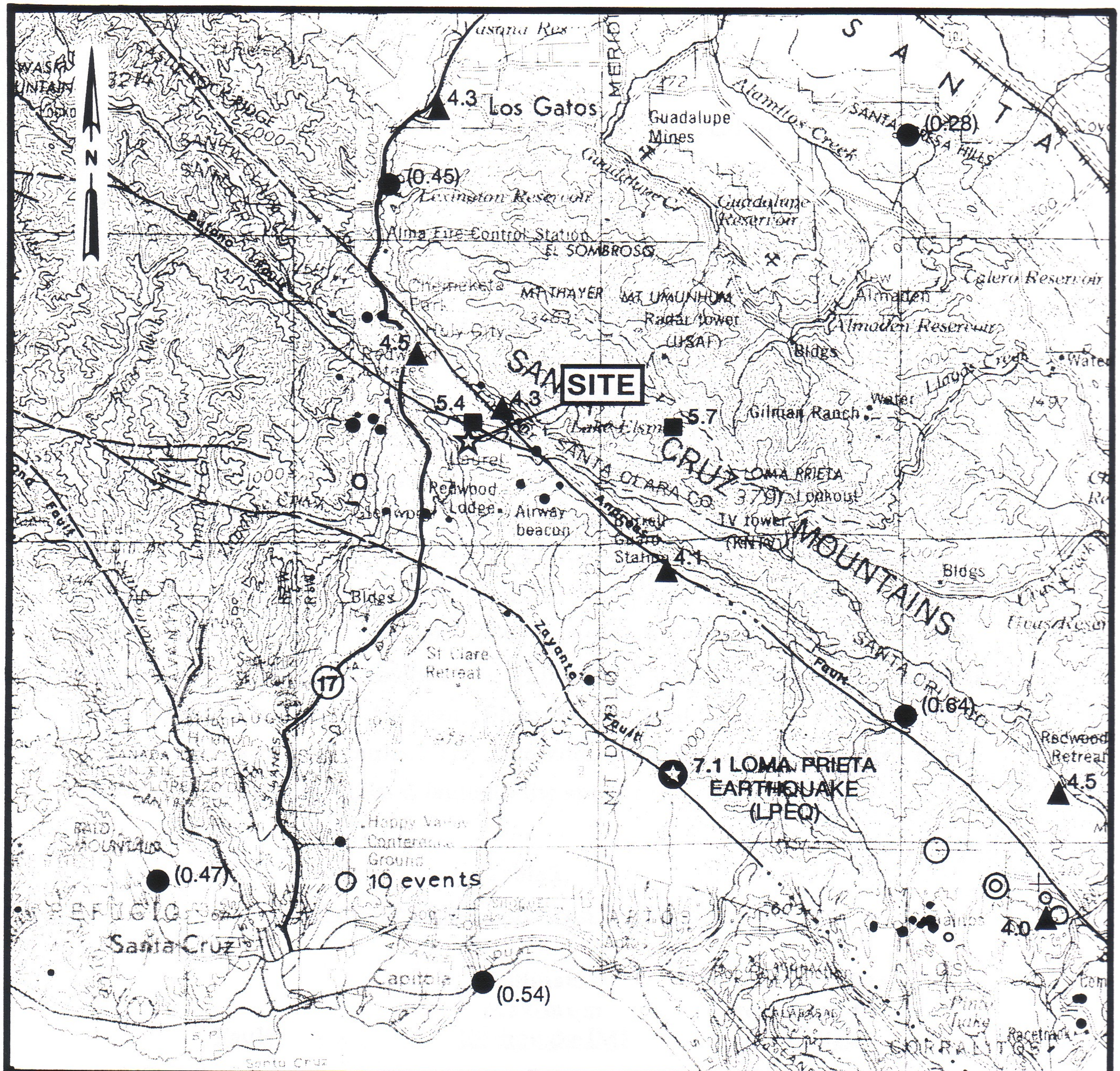
Field observations at a post-earthquake roadcut along State Highway 17 near the Summit Road intersection (approximately 1-1/2 miles west of the Schultheis Road area) demonstrates that rock creep plays a strong role in deforming the upper zone of earth materials on the hillslopes flanking Summit Ridge. The Highway 17 roadcut exposes near-vertical Vaqueros Formation bedrock materials at the crest of Summit Ridge. However, the upper 10 to 20 feet of bedrock exposed at the northern and southern ends of the roadcut are deformed in a downslope direction. We did not observe any rock outcrops on the hillside between Summit Road and Burns Creek that were inplace or undisturbed. Given the amount of rock creep occurring near the crest of Summit Ridge, the disturbed nature of isolated exposures on the south flank of Summit Ridge, and the destabilizing effects of steeper gradients and more deeply weathered rock on the hillslopes, it is reasonable to conclude that the thickness of rock creep increases in the downslope directions. Furthermore, on the basis of rock exposures in the Schultheis Road and Villa Del Monte areas, rock creep has resulted in local reversal of bedrock inclination.

The regolith materials and the underlying landslide deposits in the Schultheis Road and Villa Del Monte areas represent bedrock material that has been deformed due to rock creep processes. It is probable that rock creep plays a significant role in controlling the depth of landsliding along the flanks of Summit Ridge. We believe that the basal rupture surfaces, or shear surfaces, that separate the landslide masses from underlying intact bedrock may coincide with the depth of significant rock creep. We have incorporated the affects of rock creep into our interpretation of subsurface conditions on the Engineering Geologic Cross Sections (Plates 2 through 5, pocket).

3.5 Faulting and Seismicity

The Schultheis Road and Villa Del Monte areas are located less than one mile from the mapped main trace (i.e., probable 1906 surface rupture) of the San Andreas fault, and are considered, in a broad sense, to be within the San Andreas fault zone (SAFZ). The SAFZ is a wide zone of right-lateral strike-slip faults that forms the major crustal boundary along which vast regions of the earth's crust (known as the Pacific and North American plates) are moving past one another. This fault zone has dominated the tectonic history of western California for the past 12 to 15 million years and, together with related fault systems, has helped to create the rugged relief of the Santa Cruz Mountains.

Because of the proximity to the SAFZ, the Summit Ridge region, including the Schultheis Road and Villa Del Monte areas, is situated in a highly seismic area. This was demonstrated dramatically on October 17, 1989, during the Magnitude 7.1 Loma Prieta earthquake. Seismologic data indicate that the Loma Prieta earthquake was a result of slip along an approximately 25-mile-long segment of the San Andreas fault in the Santa Cruz Mountains that ruptured the earth's crust from a depth of about 3 miles to 11 miles below the ground surface (U. S.



EXPLANATION

Earthquake Magnitudes

●●●○○	<4.0 (Oct. 1926-Nov. 1972)
▲	4.0-5.5 (Dec. 1972-Oct. 1989)
■	5.5-6.5 (Dec. 1972-Oct. 1989)
✪	>6.5 (Oct. 1926-Oct. 1989)

(0.47)
● Strong motion instrumentation stations with LPEQ ground acceleration (peak horizontal ground acceleration, g)

References:
1) 1926-1972 events: Greene and others (1973).
2) 1973-1989 events: National Earthquake Information Center (1990).

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REGIONAL SEISMICITY MAP

SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
SANTA CRUZ COUNTY, CALIFORNIA

GEO/ENG. BY	SCALE	PROJECT NO.
JL	1"=3.3 Miles	G1409
APPROVED BY	DATE	FIGURE NO.
RCS	9/30/90	9

Geological Survey, 1989). No continuous or unequivocal surface rupture was observed along the trace of the San Andreas fault. The Schultheis Road and Villa Del Monte areas are located about 8 miles northwest of the Loma Prieta earthquake epicenter, near the northwest end of the rupture zone.

The Loma Prieta earthquake and associated aftershocks occurred along a segment of the San Andreas fault that had experienced comparatively little seismicity during the previous half century. Background seismicity in the area is depicted on Figure 9. Although the recurrence interval for moderate- to large-magnitude earthquakes on this segment of the San Andreas fault is not known with precision, seismic activity will certainly continue to occur and will periodically generate significant ground shaking in the region. Significant fault rupture, and associated ground deformation, occurred along the Santa Cruz Mountains segment of the SAFZ in 1865 and 1906. Other faults that are likely to produce future earthquakes with potentially significant ground shaking in the Summit Ridge area include the Sargent, Shannon-Berrocal, Zayante-Vergales, San Gregorio and Hayward faults. The following table provides a summary of the relationship of these significant faults to the study area:

Table 1

Earthquake Magnitudes and Fault Distances

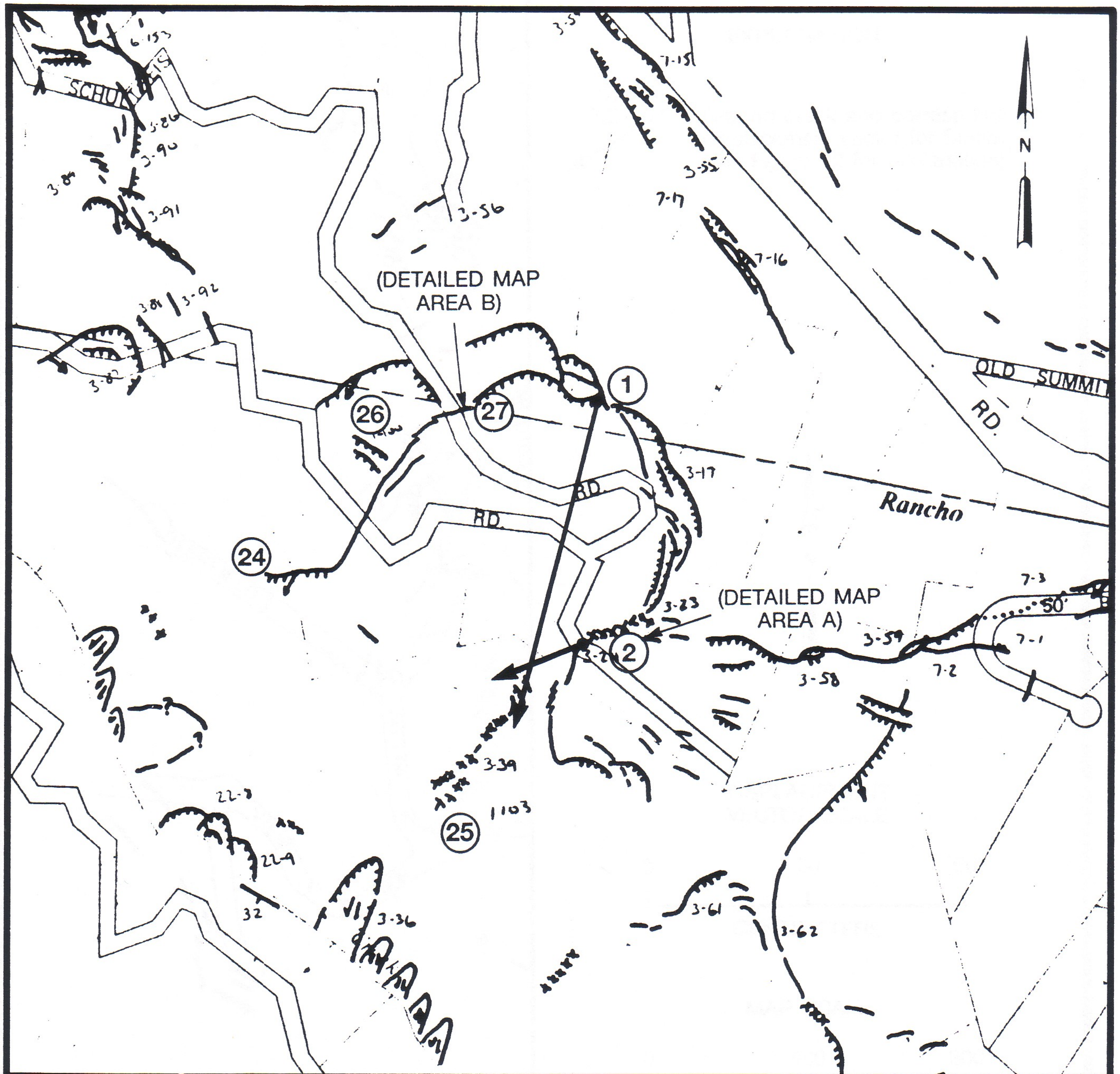
Fault	Estimated Maximum Earthquake [M]	Approximate Distance from Fault to Site (miles)
San Andreas	7.8	0.7
Shannon-Berrocal	7.1	6.5
Sargent	7.1	1.5
Zayante-Vergales	7.1	2.5
San Gregorio-Hosgri	7.7	17
Hayward-Evergreen	6.7	17

These faults are all considered to be active or potentially active because they display evidence of movement within Quaternary time (i.e., the last 2 to 3 million years). The estimated maximum earthquakes (i.e., Moment Magnitude [M]) were developed by Wesnousky (1986) based on assumed fault rupture lengths and slip rate data.

4.0 SURFICIAL DISTRESS

Within hours of the Loma Prieta event, geologists and representatives from various public and private agencies were investigating and documenting the surficial distress caused by the earthquake in the Summit Ridge area. These agencies included the U. S. Geological Survey (USGS), the California Division of Mines and Geology (CDMG), the County of Santa Cruz, the U.S. Army Corps of Engineers, the University of California at Santa Cruz, Leighton and Associates, Weber and Associates, Dames and Moore, the Hebrew University in Israel, and the New Zealand Geological Survey. The information gathered by these groups was compiled as a preliminary map on the County of Santa Cruz Cadastral Base Maps (scale: 1 inch = 400 feet) by the CDMG and the USGS (Spittler and Harp, in press). The cracks mapped in the Schultheis Road and Villa Del Monte areas have been included on the Geotechnical Exploration Map (Plate 1, pocket). Our firm independently mapped cracks for several weeks following the earthquake.

The documentation consisted of the mapping of ground cracks as well as information regarding relative movement of the ground on either side of the cracks. Detailed measurements of relative displacement across a collection of cracks in the Schultheis Road area (Keefer and Jibson, unpublished data; Spittler and Harp, unpublished data; and our field work) and the Villa Del Monte area (Harp et al, unpublished data) were used to calculate the horizontal displacement vectors shown on Figures 10 and 11. The recorded measurements across the fissures are listed in Figure 12. The cracks were filled by the San Jose Conservation Corps and by homeowners as an emergency measure to mitigate the potential for surface water to enter the cracks and potentially destabilize adjacent areas. Consequently, not all of the features could be fully documented before they were filled. Most of the major cracks in the Schultheis Road and Villa Del Monte areas had been filled or obscured by grading and road repair operations prior to the initiation of our subsurface exploration program. However, in both study areas, a well-defined pattern of ground cracks was observed and mapped and is interpreted to represent partial reactivation of ancient landslide masses. In other areas, the cracks are not well defined and, therefore, their relationship to landslide processes is not clear.



DISPLACEMENT VECTOR SCALE

0 — 100 — 200

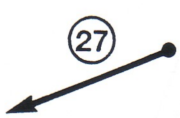
CENTIMETERS

MAP SCALE

0 — 400 — 800

FEET

EXPLANATION



Ground crack and corresponding displacement vector for Station 27 (see Figure 12 for explanation).

3 - 36 Note on ground crack recorded by California Division of Mines and Geology.

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HORIZONTAL DISPLACEMENT VECTORS
SCHULTHEIS ROAD

SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
SANTA CRUZ COUNTY, CALIFORNIA

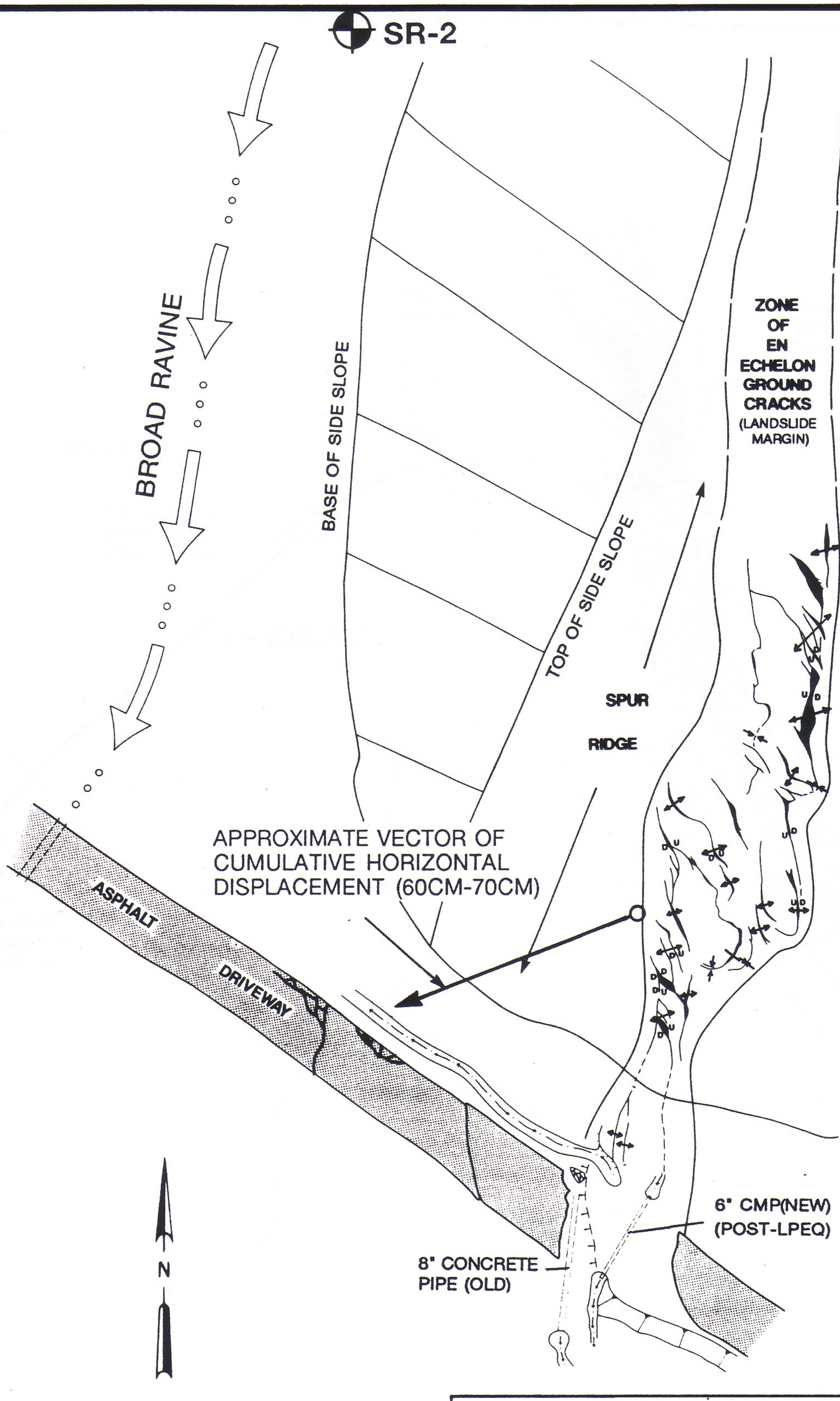
GEO/ENG. BY	SCALE	PROJECT NO.
DRM	1"=100cm/400'	G1409
APPROVED BY	DATE	FIGURE NO.
BOS	9/30/90	10

4.1 Schultheis Road Area

A set of extensive, well-defined linear and arcuate cracks in the Schultheis Road area define a crack system of approximately 900 feet (275 meters) in width. A profile along the predominant direction of movement (S15°W) was constructed along the upper portion of this crack system to document the horizontal and vertical displacements across 13 tensional cracks (Keefer and Jibson, unpublished data). The cumulative horizontal, vertical and total vector displacement magnitudes for this set of cracks were 7.1 feet (2.2 meters), 3.7 feet (1.1 meters) and 8.0 feet (2.4 meters), respectively. Portions of the southeast (Detailed Map Area A) and northwest (Detailed Map Area B) lateral margins were mapped and the resulting data are presented as Figures 13 and 14, respectively. The locations of the detailed areas are shown on Plate 1 (pocket).

A series of right-stepping, *en echelon* tensional cracks were mapped along the southeast margin of the crack system (Detailed Map Area A, Figure 13). The cumulative horizontal, vertical and total vector displacement magnitudes measured in the S68°W direction were 2.0 feet (0.6 meters), 3.3 feet (1.0 meters) and 3.9 feet (1.2 meters), respectively. The predominant sense of vertical movement was downslope to the southwest. A paved driveway in this area was laterally offset approximately 2.4 feet (0.7 meters) measured in approximately the S34°W direction. The ground crack along the northwest margin of the landslide was oriented in a southwest direction across Schultheis Road (Detailed Map Area B, Figure 14). The road had been patched prior to the initiation of our mapping program; therefore, the amount of horizontal or downslope displacement could not be determined with a high degree of accuracy. The relative vertical displacement was measured at approximately 1 to 2 feet (0.3 to 0.6 meters), downslope and to the southeast. No evidence of compressional cracking was observed in the lower downslope portions of this system.

The upper, arcuate tensional cracks in this system are near a well-defined break-in-slope (Plate 2, pocket), and the cracks along the eastern margins of the system are aligned along the orientation of a spur ridge (Plate 1 and Figure 13). Both of these physiographic features are interpreted to have been formed due to past



Note: Original map at 1"=5' scale.

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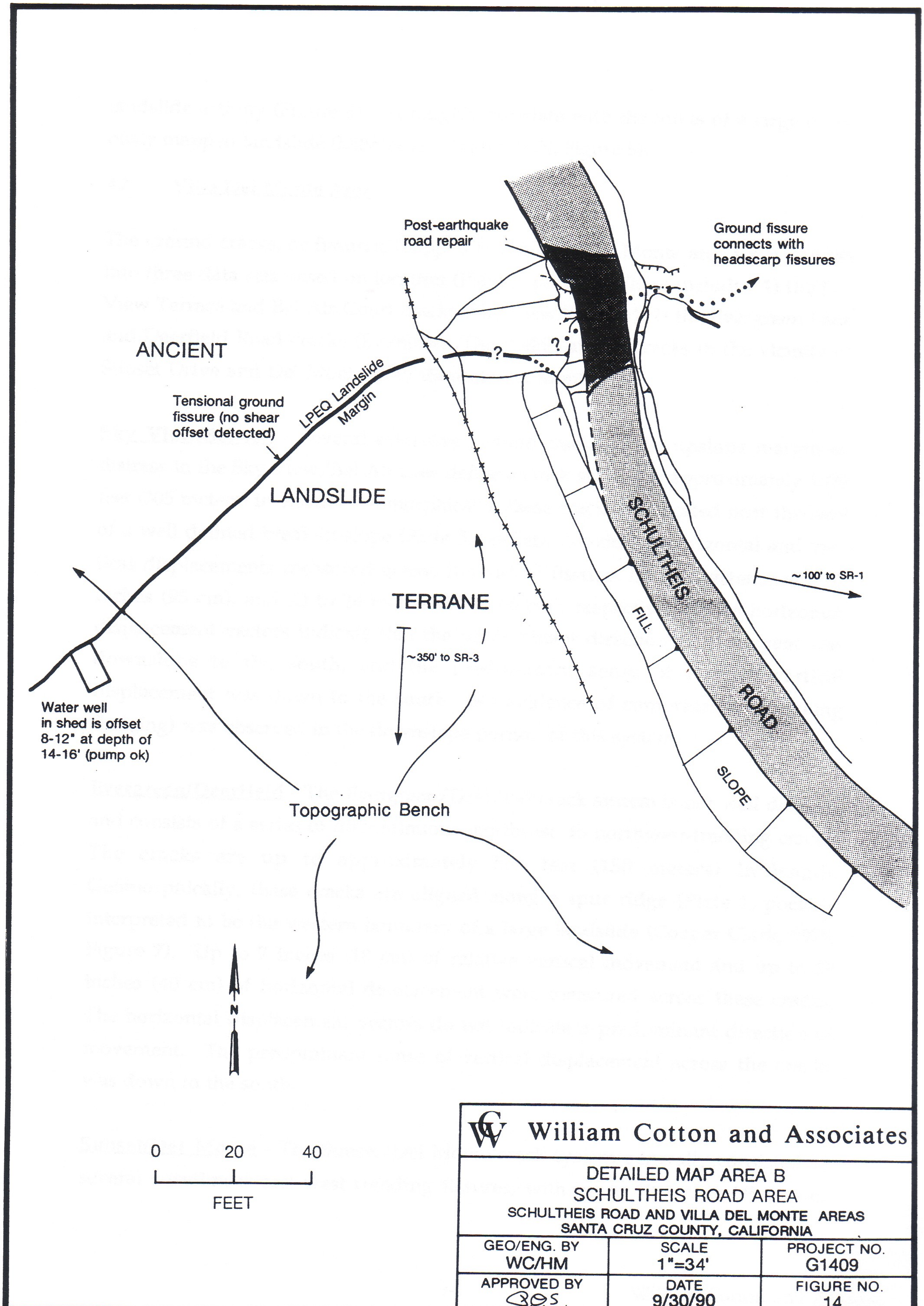
DETAILED MAP AREA A
SCHULTHEIS ROAD AREA

SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
SANTA CRUZ COUNTY, CALIFORNIA

GEO/ENG. BY	SCALE	PROJECT NO.
WC/DRM	1"=24'	G1409
APPROVED BY	DATE	FIGURE NO.
BOS	9/30/90	13



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DETAILED MAP AREA B
SCHULTHEIS ROAD AREA
SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
SANTA CRUZ COUNTY, CALIFORNIA

GEO/ENG. BY	SCALE	PROJECT NO.
WC/HM	1"=34'	G1409
APPROVED BY	DATE	FIGURE NO.
BOS.	9/30/90	14

landslide activity (Figure 8) and roughly correlate with the limits of a large previously mapped landslide (Dibblee and Brabb, 1978, Figure 5).

4.2 Villa Del Monte Area

The ground cracks, or fissures, mapped in the Villa Del Monte area were divided into three data sets based on location (Plate 1, pocket). These include: 1) the Sky View Terrace and Bel Air Court cracks (Sky View/Bel Air); 2) the Evergreen Lane and Deerfield Road cracks (Evergreen/Deerfield); and 3) cracks in the vicinity of Sunset Drive and Del Monte Way (Sunset/Del Monte).

Sky View/Bel Air - Several extensive arcuate cracks at the upslope margin of distress in the Sky View/Bel Air area define a crack system of approximately 1000 feet (305 meters) in width. Geomorphically, these cracks are located near the base of a well defined break-in-slope (Plate 5, pocket). Maximum horizontal and vertical displacements measured across individual fissures in this system were 37 inches (95 cm), and 20 to 24 inches (50 to 60 cm), respectively. The horizontal displacement vectors indicate that the predominant direction of movement was downslope to the south, and the predominant sense of relative vertical displacement was down to the south. No evidence of compressional cracking (bulging) was observed in the downslope portion of this system.

Evergreen/Deerfield - The Evergreen/Deerfield crack system is not well defined, and consists of a series of discontinuous, northeast- to northwest-trending cracks. The cracks are up to approximately 500 feet (150 meters) in length. Geomorphically, these cracks are aligned along a spur ridge (Plate 1, pocket), interpreted to be the western boundary of a large landslide (Cooper Clark, 1975, Figure 7). Up to 7 inches (18 cm) of relative vertical movement and up to 16 inches (40 cm) of horizontal displacement were measured across these cracks. The horizontal displacement vectors do not indicate a predominant direction of movement. The predominant sense of vertical displacement across the cracks was down to the south.

Sunset/Del Monte - The Sunset/Del Monte crack system generally consisted of several curvilinear east-west trending fissures, with up to 18 inches (45 cm) of relative horizontal displacement, and up to 12 inches (30 cm) of relative vertical displacement. These cracks are aligned along a strong break in slope (Plate 4, pocket) that geomorphically that had been previously interpreted as the result of landsliding (Cooper Clark, 1975, Figure 7). Although the horizontal displacement vectors do not indicate a predominant direction of movement, the predominant sense of vertical movement was down to the south. In addition, our observations indicate a curvilinear crack which crossed Sunset Drive (Plate 1, pocket) and displayed right lateral horizontal displacement, and vertical down-drop to the south. This sense of horizontal and vertical displacement would be consistent with the movement of a large landslide which encompasses the Villa Del Monte area.

4.3 Discussion

The fissuring which occurred in the Summit Ridge area as a result of the Loma Prieta earthquake was widespread and varied in nature. Geologic mapping and subsurface exploration performed by our firm and other investigators along the crest of Summit Ridge indicates that most of the fissures which occurred on the ridge are linear in pattern and are related to pre-existing topographic features such as ridge-top depressions, linear topographic furrows, and subdued scarps. It is our opinion that these cracks are the result of coseismic secondary faulting along weak layers in the underlying bedrock structures in response to the seismic energy released by the Loma Prieta earthquake. The fissures that have been investigated in detail in the subsurface (i.e., by trenching) show clear evidence of (1) fault displacement of young geologic deposits (Holocene age) that form the surface cover of the ridge, and (2) a relationship to coseismic offsets in the underlying bedrock. From these observations it can be concluded that the fissures at the ridge crest are the result of normal fault displacement in the bedrock and that repeated episodes of faulting in the geologic past have resulted in multiple offsets in the Holocene (i.e., last 11,000 years) strata and tectonically deformed geomorphology characteristic of young rift topography.

The cracks in the Schultheis Road and Villa Del Monte areas (located on the south slope of Summit Ridge) exhibit different patterns than those studied along the ridge crest, which is indicative of a different causative mechanism. The well-defined arcuate pattern of tensional cracks in the upslope areas, the sense of shear displacement along the lateral margins, the relationship of the cracks to ancient landslide deposits, and the magnitude and sense of relative horizontal and vertical displacements documented for both the Schultheis Road and Sky View/Bel Air areas, indicate that the crack systems in these areas are the result of landsliding. The probable extent of landsliding shown on Plate 1 is based on the location and style of ground cracks, regional geomorphology, and extrapolated subsurface data. As shown graphically in Figure 15, the well-developed cracks and displacements in the headscarp (tensional) regions and the *en echelon* and shear cracking along the lateral margins are indicators of landslide masses which have experienced failure. As described by Fleming and Johnson (1989), these modes of surface deformation can indicate complete landslide movement at depth. Visible bulging and cracking in the toe (compressional) area does not generally occur until the landslide mass has undergone a large magnitude of shearing. The apparent absence of deformation in the toe regions suggests that shearing of the basal rupture surfaces (to date) has, probably been less than several feet. Based on the observed surface deformation and comparison to other studies, a large portion, if not all, of the basal shear surfaces in the Schultheis Road and Sky View/Bel Air areas probably ruptured.

The crack systems in the Deerfield/Evergreen and the Sunset/Del Monte areas are not represented by continuous arcuate headscarp (tensional) or lateral (shear) margins, and there is not a predominant sense of horizontal movement across the cracks in these systems. The downdrop to the south across most of these features, however, and the sense of shear across Sunset Drive are consistent with movement indicative of large-scale landsliding. These areas are located within the limits of mapped large-scale ancient landsliding, and the cracks correlate with well-defined geomorphic features indicative of past landsliding. Therefore, it is likely that these crack patterns are the result of large, deep-seated landsliding in the very early stages of renewed movement. The Deerfield/Evergreen and Sunset/Del Monte crack systems could be the result of individual landslides, or more likely are the result of larger incipient reactivation of a landslide which encompasses all three crack systems in the Villa Del Monte area (Plate 1). The basal rupture surface of this probable deep landslide either extends below most of the water wells in the area, or there has not been sufficient shear displacement of the basal rupture surface to interrupt the useful service of the apparently "undamaged" wells.

5.0 WATER WELL DATA

An effort was made by the County of Santa Cruz to collect information from existing water wells in the Schultheis Road and Villa Del Monte areas prior to the initiation of our subsurface exploration program. The purpose of this research was twofold: 1) to gather information regarding the physical condition of the wells in the hope of gaining a preliminary idea of the depths of likely landslide displacement; and 2) to document the water levels in the wells to help estimate water pressures prior to the earthquake. We intended to use the data regarding the depths or zones of distress to help plan the locations of the subsurface borings and to target specific sampling intervals. Because the main purpose of the exploratory boring program was the installation of instrumentation to monitor the movement and water pressures in these areas, the emergency nature of this portion of the study dictated that the subsurface program be initiated as quickly as possible. In addition, difficulties were encountered in obtaining the water well data. Consequently, not all of the information regarding the physical condition of the wells was available for analysis during the subsurface exploration program.

The water well data received from the County of Santa Cruz consists of a list of damaged wells, wells with water level information, and a summary of all wells inventoried in the Santa Cruz Mountains. For this report, the data from the Villa Del Monte and Schultheis Road areas was extracted and tabulated by location and well status. This summary, and the untabulated data received from the County of Santa Cruz, is presented in Appendix B. It should be noted that the comments regarding well status listed in our tabulated data were taken from the County of Santa Cruz list of damaged wells. Several of the comments in the County damaged well list are not consistent with those in the county well summary. The collected information generally consists of the depth of the well and a qualitative report by the owner regarding the operating condition of the casing and pumping equipment. The reports which included a description of the well status, but not the depth of the well and/or depth of distress (if any), were not included in our tabulated summary. These wells are listed in the County of Santa Cruz data compilation. The information regarding water level data is sparse in both study areas. This data is also included in Appendix B. An important finding of our well compilation task is that the majority of the wells were reported to be in working condition after the earthquake.

The majority of data collected in the Schultheis Road and Villa Del Monte areas regarding undamaged wells were qualitative reports volunteered to the County of Santa Cruz by the homeowners. It is not known if any of the undamaged wells were "sounded" by lowering a measuring tape down the casing. This data should be interpreted carefully. For example, if an undamaged well was reported to be 200 feet deep, but the pump was located only 100 feet below the ground surface, the casing could have been sheared by landslide movement anywhere between 100 to 200 feet below ground surface, and the well would remain operational (i.e, apparently "undamaged"). In addition, of the 14 wells reported to be damaged, only 5 were known to have been "sounded". In some cases, no specific indication of the cause of the distress is given, and factors responsible for the problems are subject to interpretation. Several of the wells, however, were reported to have "shearing" or "pinching" of the well casings at specific depths. A higher degree of confidence should be given to these wells with respect to possible depths of landsliding.

The wells for which information was obtained are approximately located on the Geotechnical Exploration Map (Plate 1, pocket) and water well information is presented on the Engineering Geologic Cross Sections (Plates 2 through 5, pocket). Elevations and precise locations for these water wells are not known. Consequently, the projected locations of water well information onto the engineering geologic cross sections are approximate.

5.1 Schultheis Road Area

Six reports of well status were received from this area. Three of these wells reportedly experienced problems at depths varying from 14 to 114 feet. The motor shaft for well number 141, located near the eastern lateral margin of the landslide, was reported to have been bent at a right angle at a depth of 97 feet.

Boring SR-2 was subsequently located near this well and a sampling interval was scheduled to bracket this depth of distress.

Information regarding water levels both before and after the earthquake were obtained from two wells. The water level for well number 141 (discussed above) was reported at 19 feet below ground surface prior to, and after, the earthquake. The water level for well number 17, located approximately 200 feet southwest of well number 141, was reported to have dropped from 35 feet below the ground surface before the earthquake to over 60 feet in depth after the event.

5.2 Villa Del Monte Area

Reports regarding well status and depths were received for a total of 62 wells in this area. Problems after the earthquake were reported for a total of eleven wells, most of which are located near the top of Summit Ridge. These reports generally consist of qualitative and quantitative statements by the owners concerning the collapsed conditions of the well casings and/or the depth of distress or obstructions. The depths of distress varied from 16 to 161 feet below the ground surface. Several of these wells were checked by the County of Santa Cruz by lowering a measuring tape down the holes.

Water level information was reported for eight wells in this study area. Only one report was received regarding water level data prior to, and after, the earthquake. The water level in this well (number 60) remained at 70 to 75 feet below the ground surface after the earthquake. For the remaining wells, we received either reported water levels 11 to 17 years prior to the earthquake and several months afterwards, or only the water levels several months after the earthquake.

6.0 SUBSURFACE EXPLORATION

Locations for subsurface exploration were selected by the TAG in consultation with our firm in the Schultheis Road and Villa Del Monte areas to investigate apparent large-scale landsliding observed during the initial crack-mapping program conducted in these areas. The locations of the borings were determined to some extent by the previously surveyed transect lines. The purpose of the borings was threefold: 1) to allow the installation of downhole instrumentation (inclinometers and piezometers) to monitor potential future movements and pore water pressures, 2) to acquire representative soil and rock samples for laboratory testing, and 3) to provide some degree of characterization of the subsurface geologic conditions in the study areas. The detailed logs of the borings are presented in Appendix F (Volume II), and data regarding drilling dates, total depths and the type of drilling rig used are included in Table 2 (page 21). Borings SB-1A and SR-1A were drilled adjacent to borings SB-1 and SR-1 at the request of the TAG. The purpose of these borings was to install conventional Casagrande-type piezometers to verify the accuracy and method of installation of the strain-gauge type piezometers which had been installed in SB-1 and SR-1 (as discussed in more detail in Section 7.0 of this report).

All borings were drilled with rotary wash drill rigs provided by Pitcher Drilling Company of Palo Alto and All Terrain Drilling of Roseville. The rotary wash set-up consists of a drilling bit attached to a series of hollow drill rods. Fluid is pumped through the drill rods to the drilling bit where it enters the borehole. The fluid picks up the soil and rock pieces (cuttings) loosened by the bit and travels up the borehole to the surface where it is collected into a large tub. A series of baffles in the tub allows the cuttings to settle out of the fluid. The fluid is then sucked into a pump and the process is repeated. If the soil or rock is characterized by open fractures, the drilling fluid can enter the host material and not be returned to the surface. This phenomenon is termed "losing circulation" and is noted on the boring logs as indicative of highly fractured rock typically encountered in landslide masses. The borings on this project were advanced using drag bits or carbide- or diamond-impregnated tricone rock drilling bits. Bentonite drilling fluid was utilized to help cool the drill bits, stabilize the boring sidewalls and to remove cuttings from the borings. Upon reaching the surface,

TABLE 2
BOREHOLE AND INSTRUMENT DATA

BORING	DATE BEGIN	DATE FINISH	TOTAL DEPTH	DRILLER/ METH.	PIEZOMETER DEPTHS	INCLIN. DEPTH	INCLIN. INSTALL DATE	INCLIN. READING 1	INCLIN. READING 2	INCLIN. READING 3	INCLIN. READING 4	INCLIN. READING 5	INCLIN. READING 6
SR-1	12/18	12/22	203	P/RW	39.5,79.5,198	200	12/28/89	1/8/90	1/18/90	4/20/90	5/9/90	5/22/90	
SR-1A	12/29	1/2	82.5	P/RW	40,80	NA	NA	NA	NA	NA	NA	NA	NA
SR-2	1/3	1/5	153.5	P/RW	69.5,99.5,149.5	150	1/5/90	1/9/90	1/18/90	4/20/90	5/10/90	5/21/90	5/21/90
SR-3	1/8	1/12	248 *	P/RW	59.5, 169.5, (175), 249	250	3/5/90	3/19/90	4/20/90	5/7/90	5/22/90		
SR-4	1/29	3/13	250	P/RW	66, 116, (116), 176	244	3/15/90	3/19/90	4/20/90	5/7/90	5/22/90		
SB-1	12/21	12/30	204	P/RW	38, 90, 130	200	12/29/89	1/9/90	1/18/90	4/24/90	5/7/90	5/23/90	
SB-1A	1/2	3/1	100	P/RW	37.7,89.7	NA	NA	NA	NA	NA	NA	NA	NA
SB-2	1/2	1/10	292	AT/RW	69.5, 149.5, (150),289	290	3/5/90	3/13/90	4/24/90	5/9/90	5/23/90		
SB-3	1/10	1/18	303	AT/RW	69.5,139.5 (138),219.5	300	3/1/90	3/13/90	4/18/90	5/7/90	5/24/90		
SB-4	1/11	1/12	155	P/RW	35,69.5,149.5	150	2/23/90	3/1/90	3/6/90	4/18/90	5/9/90	5/24/90	
SB-4A	1/15	1/15	20	P/RW	NA	NA	NA	NA	NA	NA	NA	NA	NA
DM-1	1/29	1/31	141	AT/RW	39.5, 61, (61), 139.5	140	3/7/90	3/14/90	4/23/90	5/7/90	5/22/90		
DM-2	1/15	1/23	205	P/RW	69.5,119.5,199.5	200	2/21/90	2/27/90	3/6/90	4/24/90	5/9/90	5/24/90	
DM-3	1/30	3/9	250	P/RW	60,120, (121), 250	250	3/12/90	3/14/90	4/25/90	5/7/90	5/22/90		
DM-4	1/18	1/26	253	AT/RW	70, 130, 250	250	1/26/90	2/14/90	2/22/90	4/24/90	4/25/90	5/9/90	5/24/90
SD-1	1/4	1/10	203	P/RW	38.8,95,198.8	200	1/10/90	1/12/90	1/20/90	4/25/90	5/9/90	5/24/90	
ED-1	1/17	1/24	208	P/RW	49.5, 94.5, 199	200	1/26/90	2/1/90	2/26/90	3/7/90	4/25/90	5/7/90	5/23/90
ED-2	1/23	1/30	202	P/RW	55,109.5,199.5	200	2/27/90	3/8/90	3/14/90	4/25/90	5/7/90	5/24/90	

*-Reamed to 250+ Feet to Install Inclinometer
(121)-Casagrande Piezometer Depth
P-Pitcher Drilling Co.
AT-All Terrain Drilling Co.
RW-Rotary Wash

samples of the cuttings were captured in a screen by an engineering geologist, visually classified and logged.

The actual drilling process (rate of advancement) was timed to determine the rate of drilling. The drilling rate can be influenced by many factors, including the type of drilling bit, the condition of the bit, the pressure exerted on the drill rod, and the revolution speed of the bit. It is also, however, indicative of the relative physical condition of the rocks and consequently provides an additional source of subsurface data. In general, when the drilling rate becomes faster, the material being drilled is softer or more fractured (or both) than the overlying material. The drilling rates have been tabulated for each boring and computer generated plots of the rate versus depth (along with a graphical representation of rock type) are presented in Appendix G.

Decisions regarding the locations of samples retrieved during the subsurface exploration program were based on a number of factors. In order to characterize the lithology and physical condition of all rock and soil types encountered in the study areas, a decision to sample was generally made when the cuttings or drilling rates indicated that a change in material or physical condition had been encountered. Because landslide basal rupture surfaces are often associated with fractured or very soft rock, sampling was often attempted when circulation problems were encountered or when drilling rates increased significantly. Continuous sampling intervals were also targeted at potential rupture surfaces identified on preliminary geomorphic cross sections developed prior to drilling.

Two types of sampling methods were available on the drill rigs provided by Pitcher Drilling Company. The Pitcher Barrel sampler can retrieve "undisturbed" Shelby tube samples approximately 30 inches in length. The Shelby tube (3 feet in length and 3 inches OD by 2-7/8 inches ID) is slowly pushed into the earth materials while the barrel rotates around it, relieving the friction along the outside of the liner. This sampling technique was designed for soil or soft rock and, because of the high quality of samples which can be obtained for laboratory testing, was used during this project whenever field conditions allowed. When the rock became too hard to use this technique, rock core barrels were used to obtain samples. The rock core samplers provided by Pitcher were

NX (2-1/8 inches ID) and HW (Christianson Diamond Products NQ version, 2-2/5 inches ID) sized, tip- and side-circulating barrels with diamond or carbide bits. The rock core barrels are attached to the drill rod and are advanced by pushing on the drill rod while the entire barrel rotates and cuts around the sample. When the barrel is lifted out of the hole, a core catching device secures the disturbed sample inside the barrel.

The sampling methods available on the All Terrain drill rigs were the Pitcher Barrel sampler and a 94mm wireline punch, drill, and core system. The latter system employs a core barrel (94.2 mm OD, 65.07 mm ID) which can be lowered by wires through the hollow drill stem to the bottom of the hole. The coring process is similar to that previously described, yet when the core run has been completed, the barrel (with disturbed samples inside) can be disengaged and retrieved using the cables. This eliminates the need to pull all of the drill rod out of the hole after each core interval. The bits which were used were soil sample bits and diamond surface set, or impregnated, rock bits.

The samples obtained by rock core barrels were logged and classified in detail in the field and were stored in labeled core boxes. Representative Pitcher Barrel samples were also extruded in the field and logged in detail in order to characterize the physical condition of the material during drilling. These disturbed samples, if still relatively intact, were then trimmed and placed carefully back into the tubes. Both the extruded and unextruded Pitcher Barrel samples were sealed at both ends with wax, capped and taped, and transported to our laboratory for safekeeping. The extruded samples which were not replaced into the Shelby tubes were stored in core boxes. X-rays taken of the tube samples were studied in an effort to obtain information regarding lithologic contacts or shearing surfaces. Interpretations made from analysis of the X-rays are indicated on the boring logs.

6.1 Schultheis Road Area

In the Schultheis Road area, a total of five (5) borings were drilled to depths of 82.5 to 250.0 feet beneath the ground surface in the locations shown on Plate 1 (pocket). Two borings (SR-1 and SR-1A) were drilled near the upper margin of significant ground cracking. One boring (SR-2) was drilled near a well that had been distressed at a measured depth. One boring (SR-3) was drilled near the center of the significant crack zone, and one (SR-4) was drilled near the toe of the crack zone. All borings except for SR-2 were drilled near survey transect Line 3 (Plate 2, pocket).

6.2 Villa Del Monte Area

In the Villa Del Monte area, a total of twelve (12) borings were drilled to depths of 100.0 to 303.0 feet beneath the ground surface (Plate 1, pocket). Five borings were drilled in the Sky View/Bel Air area, one (SB-4) above the zone of significant ground-cracking, two (SB-1 and SB-1A) near the upper margin of the significant crack zone, one (SB-3) near the center of the crack zone, and one (SB-2) near the toe of the crack zone. All of these borings were located close to survey transect Line 8 (Plate 5, pocket). A shallow boring, SB-4A, was drilled to 20 feet adjacent to SB-4 in order to sample a soft zone of rock identified during the drilling of SB-4.

Two borings were drilled in the Evergreen/Deerfield area. One boring (ED-1) was located near the upper margin of the crack system, and one (ED-2) was located near the toe of the crack system.

Four borings were excavated in the Sunset/Del Monte area. One boring (DM-1) was drilled upslope of the significant ground cracking, two (DM-2 and DM-3) were located in the center of the crack system, and one (DM-4) was excavated near the toe of this area. All of these borings were located adjacent to survey transect Line 7 (Plate 4, in pocket).

7.0 MONITORING INSTRUMENTS

Two types of instrumentation were selected by the TAG for installation in the exploratory borings, and are described in general below. These include inclinometer casing (for measuring the depth and amount of landslide movement) and self-recording, multi-staged piezometers (for measuring subsurface pore water pressures). The interested reader is referred to Dunnicliff (1988) for a further discussion of the technical aspects of these instruments.

Surface monuments (quadrilaterals) have been installed and monitored by TAG member Gary Griggs of the University of California at Santa Cruz and are not discussed in this report.

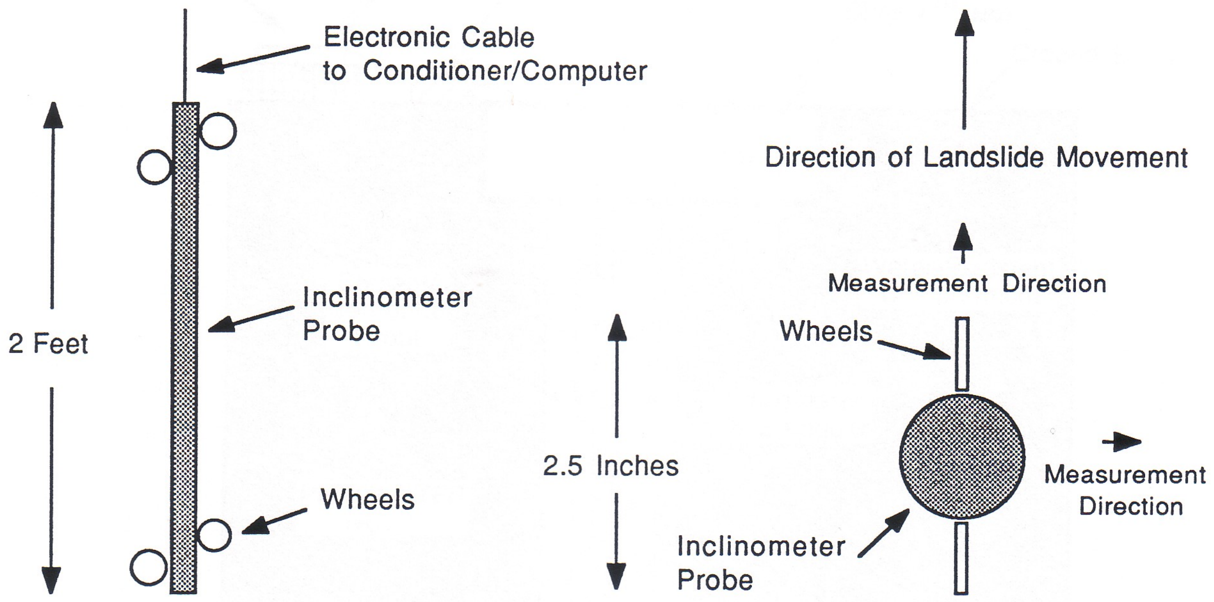
7.1 Inclinometers

The type of inclinometer casing selected for installation was a SINCO™ 2.75-inch O.D. CPI quadri-grooved ABS casing with self-aligned O-ring sealed couplings. The instrument used to monitor verticality (deflections) in the casings was a SINCO™ Digitilt Sensor with a sensitivity of one part in 10,000. The margin of system error established by the manufacturer is 0.25 inches of horizontal deflection per 100 vertical feet. This sensor is a waterproof biaxial (two perpendicular servo-accelerometers) digital inclinometer probe with a 24-inch wheel spacing. The sensor was connected to an ISIS™ conditioner and automatic data collector managed by a Packard Bell™ laptop computer (IBM™ AT compatible).

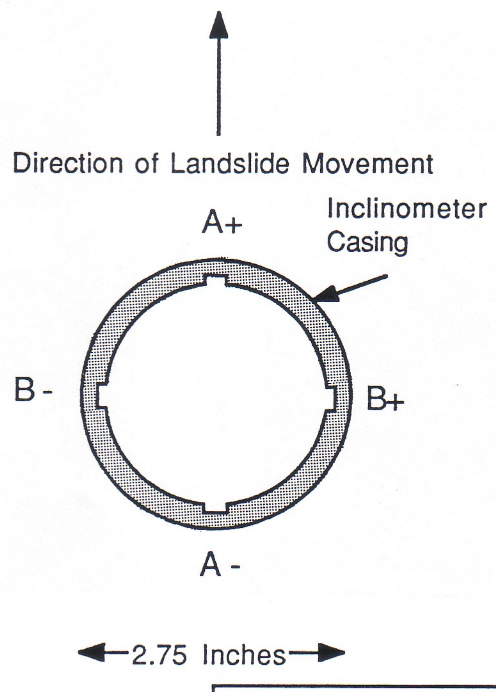
The CPI inclinometer casings are manufactured in 10 foot sections and contain four interior grooves opposed at 90°. The casing sections were connected with couplings (such that the grooves were aligned) and lowered to the bottom of the borehole. The casing was then rotated until a set of grooves (opposed at 180°) were oriented downslope toward the suspected azimuth of landslide movement (Figure 16). This direction is defined as the "A+" direction, and the azimuth located at 90° to A+ is defined as the "B+" direction. The annulus between the casing and the borehole was then grouted with 5% bentonite (clay) to Portland cement mix pumped through a grout tube taped to the bottom of the casing such that the grout filled the hole from the bottom up to the top.

The inclinometer is monitored by lowering the probe to the bottom of the casing (Figure 17). The wheels of the probe are opposed at 180°, and fit into the grooves oriented downslope (Figure 16). The probe measures the angle that the casing deviates from vertical in the A+ and B+ directions, and transmits this information electronically to the conditioner/computer. The computer then plots the horizontal deflection graphically on the screen, and writes the data to a magnetic file (diskette) for later analysis. The probe is then raised 2 feet (the length of the

Inclinometer Probe Detail



Inclinometer Casing Detail



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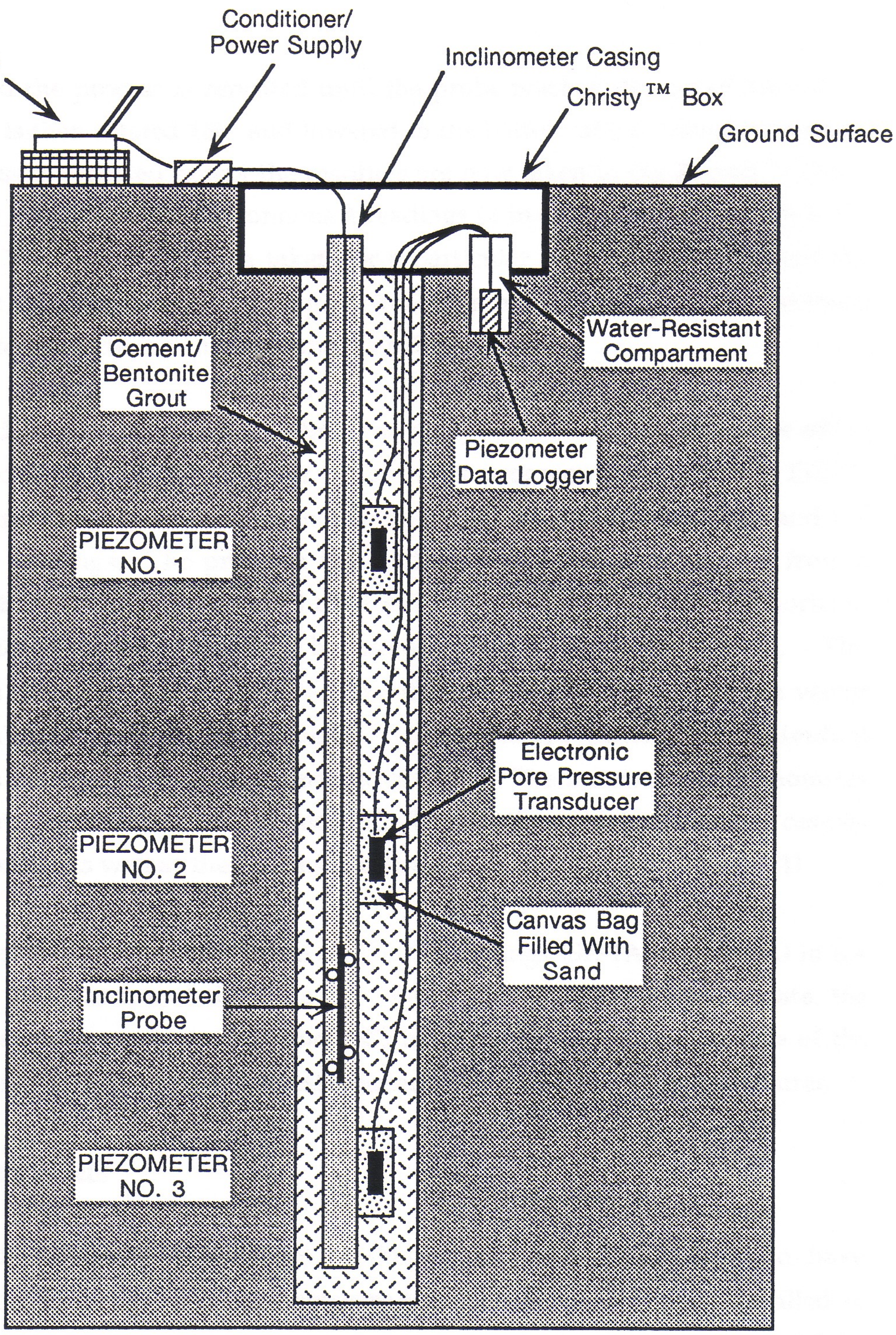
INCLINOMETER SYSTEM DETAILS

SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
SANTA CRUZ COUNTY, CALIFORNIA

GEO/ENG. BY	SCALE	PROJECT NO.
DRM	Not To Scale	G1409
APPROVED BY	DATE	FIGURE NO.
B.O.S.	9/30/90	16



William Cotton and Associates

SCHEMATIC DIAGRAM OF BOREHOLE INSTRUMENTATION

SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
SANTA CRUZ COUNTY, CALIFORNIA

GEO/ENG. BY	SCALE	PROJECT NO.
POS	Not To Scale	G1409
APPROVED BY	DATE	FIGURE NO.
WCS.	9/30/90	17

probe), and the process is repeated until the probe reaches the top of the casing. The probe is then rotated 180° and lowered to the bottom of the casing once again. This process is repeated except the readings are now taken in the A- and B- directions. The resulting data file contains 4 readings (2 in each plane) for every 2 feet of depth. The first set of data taken for a particular inclinometer is termed the "initial" or "base" reading. Subsequent readings are acquired at time intervals sufficient to characterize the movement of the landslide.

After the data acquisition is complete, the computer is transported to the office and connected to a graphics plotter. A software program, written by the ISIS™ manufacturer, averages the difference between the A+ and A- readings, and the B+ and B- readings. The program then subtracts the initial reading set from a subsequent set (chosen by the user) to produce a graph which shows the horizontal deflection versus depth which has occurred since the initial reading. The deflections in the A+ and in the B+ directions are plotted, as well as the vector sum (resultant) of these components. The resultant bearing of individual deflections are also plotted as a function of depth. The most recent inclinometer plots to date are included in Appendix C. The depth of the inclinometer casings for each boring, as well as the reading dates, are included in Table 2 (page 21).

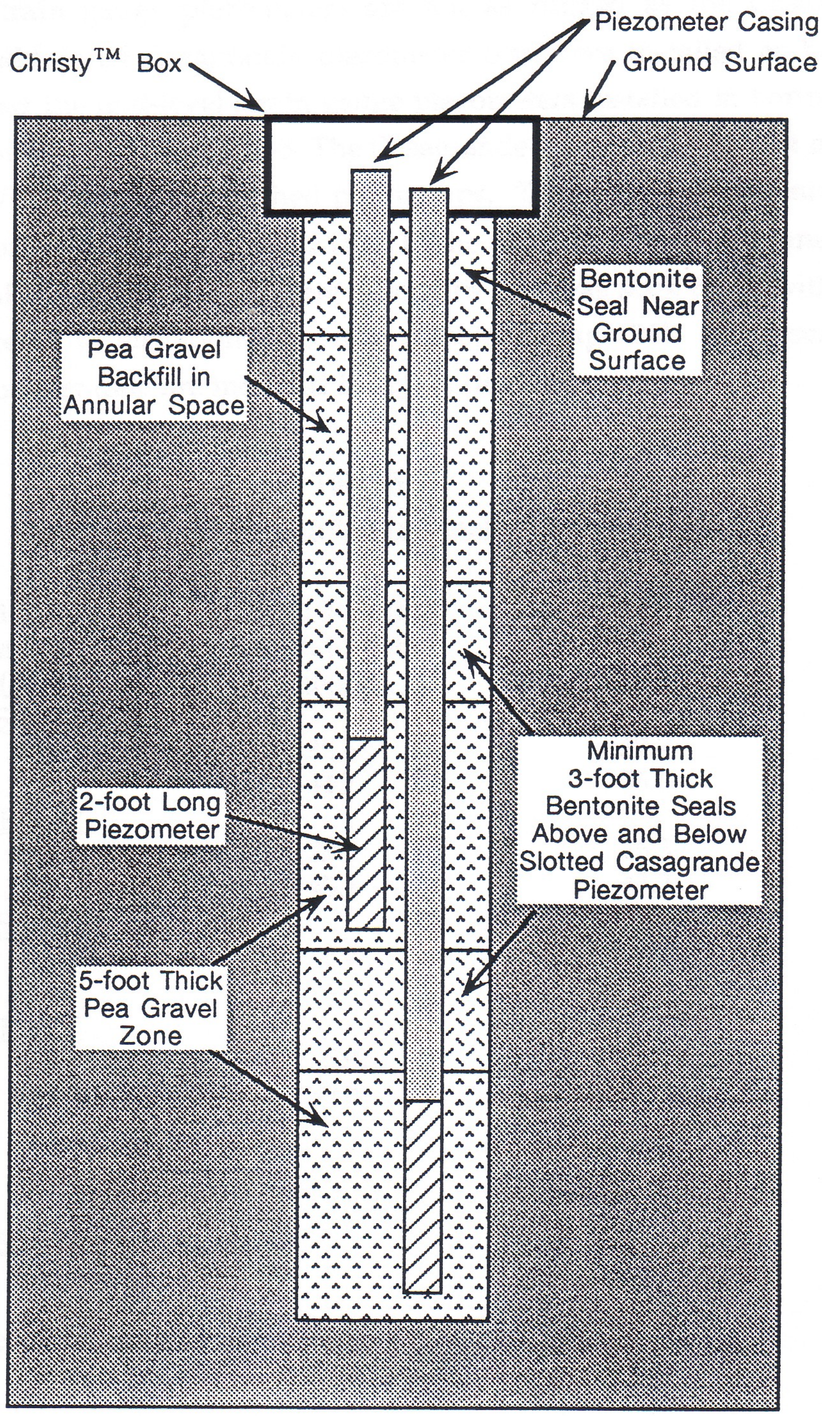
Inclinometer casing was installed in all but two borings (SR-1A and SB-1A) in the Schultheis Road area and the Villa Del Monte area, respectively. To date, the inclinometer measurements (Appendix C) have not shown offsets outside of the margin of the system error limits established by the instrument manufacturer.

7.2 Piezometers

Because of the emergency nature of this project, the TAG elected to have electronic strain gauge type pore pressure transducers (piezometers) installed so that automatic continuous monitoring of groundwater pressures could be provided. The type of piezometer selected was the Thor™ Model DPXE electronic pressure transducer with a 100 psi range and 1.5 times overrange capacity. In simplistic terms, this type of instrument calculates strain (deflection) by measuring a change in electrical resistance. The strain is then correlated with pressure to produce measurements of groundwater pressure. These piezometers were installed by placing the instruments into canvas socks filled with sand, and securing the socks onto the exterior sides of the inclinometer casings (Figure 17). Three strain gauge piezometers were installed at pre-determined elevations in all of the borings except SR-1A and SB-1A. The piezometer tip elevations were selected in order to characterize the groundwater pressure regimes along the length of the casings, and to provide pore pressure data in the vicinity of suspected basal shear surfaces. The piezometers were tied into Thor™ Model SDEE-03A, 3-channel dataloggers with 64K EPROM memory. The dataloggers were programmed and data was downloaded using a Packard Bell™ (IBM™ AT compatible) laptop computer.

Computer generated graphs showing the relationships between time, piezometer readings and rainfall were plotted for analysis. The charts were produced by a macro program written for this project by our firm in the Microsoft™ Excel for Windows spreadsheet and database program. Representative results from this plotting program are included in Appendix D. These plots were made by combining all available data files and by deleting spurious data.

Casagrande type piezometers were installed at two, staged levels in boring SR-1A and SB-1A in order to monitor the performance of strain gauge type piezometers at the same levels in the adjacent borings SR-1 and SB-1 (Figure 18). A comparison of readings between these two instruments is presented in Table 3 (page 28). The strain gauge piezometer installed at a depth of 90 feet in SB-1 has not functioned since installation. In general, the SR-1 and SR-1A instruments located at approximately 80 feet, and the SB-1 and SB-1A instruments located at approximately 40 feet, show good correlation. The readings from the SR-1 and SR-1A piezometers at approximately 40 feet below ground surface differ consistently by approximately 10 feet of water pressure. Since the Casagrande piezometer backfill consists of pea gravel isolated by only a three-foot bentonite clay plug, it is likely that these piezometers could have higher water levels due to the potentially greater amount of fractured rock that these tips are probably exposed to. The difference might also be attributed to differences in the local ground water regime due to subsurface disruptions caused by dip of bedding or nearby coseismic fissures or landsliding.



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SCHEMATIC CASAGRANDE PIEZOMETER DETAIL

SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
SANTA CRUZ COUNTY, CALIFORNIA

GEO/ENG. BY	SCALE	PROJECT NO.
DRM	Not To Scale	G1409
APPROVED BY	DATE	FIGURE NO.
[signature]	9/30/90	18

Because the strain gauge piezometers are not as rugged as the Casagrande piezometers, additional Casagrande piezometer tips were installed as back-up instruments near the mid-level strain gauge piezometers installed in borings SR-3, SR-4, SB-2, SB-3, DM-1, and DM-3. The Casagrande piezometers consist of open standpipes (PVC pipes) with attached porous tips. The ground water enters the pipe via the porous tip, and the water level in the pipes is measured by mechanical or electrical means. The tips were placed in a canvas sock filled with sand and were lowered to elevations shown on Table 2 (page 21). Representative results of piezometer data are included in Appendix D of this report.

Table 3

Strain Gauge/Casagrande Piezometer Comparisons

Boring No./ Piezo. Depths (feet)	1/4/90 Reading Depth to Water (feet)	9/20/90 Reading Depth to Water (feet)
SR-1/		
39.5	35.6	37.7
79.5	44.7	46.5
SR-1A/		
38.0	25.1	26.3
77.2	45.2	43.3
SB-1/		
38.0	5.4	8.24
90.0	–	–
SB-1A/		
37.0	5.0	6.9
89.7	39.8	57.9

8.0 LANDSLIDE PARAMETERS

8.1 Surface and Subsurface Geometry

Ancient landslide complexes were identified as part of our interpretation of geomorphic features in the study areas. These complexes consist of numerous, individual landslides that have formed over a long period of geologic time (see Section 3.4). Many of the individual landslides represent reactivation of portions of ancient deep-seated landslides. Our interpretation of the areal extent of earthquake-triggered landsliding is illustrated on the Geotechnical Exploration Map (Plate 1, pocket). This interpretation is based on stereoscopic evaluation of pairs of aerial photographs, review of regional geologic maps and ground crack maps, limited field mapping, and geomorphic profiling of selected portions of the areas. The subsurface dimensions of individual landslides are based on our interpretation of geomorphology and subsurface exploration (primarily drilling observations, sample descriptions and drilling rates). These interpretations are illustrated graphically on the Engineering Geologic Cross Sections (Plates 2 through 5, pocket). Detailed geomorphic mapping and detailed geologic exploration were beyond the scope of our authorized investigation.

8.2 Groundwater

Groundwater information was obtained by monitoring piezometers and reviewing information from domestic water wells.

At this time, it appears that the local groundwater regime can be characterized by a complex system of perched subsurface water zones. A relatively shallow groundwater zone appears to be associated with the upper, deeply weathered regolith layer (typically 20 to 50 feet in depth). Deeper groundwater zones are present within the underlying geologic materials. Many of these zones do not appear to be hydraulically connected; however, subsurface flow (and consequent interconnectivity) between various zones could be occurring too slowly to be detected by the available data. Only the shallowest groundwater zone has shown a significant response to local rainfall. However, we note that a long lag time between rainfall and subsurface response and a general lack of several significant rainfall events since the installation of the piezometers would not yet allow determination of a clear response pattern. Additional monitoring over a period of significant rainfall events is needed to more fully characterize the groundwater regime.

8.3 Recommendations for Laboratory Testing

The objectives of the laboratory testing program are to provide data to be used in determining geotechnical parameters for slope stability analysis of the landslides present in the two subject areas. Based on meetings with the TAG, we understand the analysis method that will be employed for the landslides may involve, but will not necessarily be limited to, a combination of a conventional limit equilibrium analysis, a pseudostatic analysis, a cumulative deformation analysis and possibly finite element or other state-of-the art modeling.

The laboratory testing program will need to be comprehensive enough to provide the parameters important for such analyses. These parameters include, but may not be limited to:

- index properties of soil-like materials, including detailed sample description, moisture/density, grain size (macro and micro), and Atterberg limits,
- density (dry, moist, and saturated) properties of all representative soil and rock materials, but primarily those comprising the slide mass,
- shear strength properties of representative materials, including most importantly those of any landslide rupture surface materials, but also the strength bounds of the various materials that make up the landslide mass and the underlying intact bedrock,
- porosity or permeability properties that may provide clues to groundwater conditions, and
- dynamic properties (cyclic shear strength, bulk and shear modulus, and Poisson's ratio).

Based on our analysis of the boring logs, the landslide mass material above a possible slide surface could be composed of one or more of the following geologic units:

- Colluvium: This material consists of surficial soils that have evolved as a result of weathering and downslope creep processes.

- Regolith: This material consists of highly weathered and fractured bedrock materials derived from the underlying Butano Formation that has been subjected to cyclic changes in groundwater levels, seismic shaking and downslope creep processes. This unit contains angular, weathered gravel to boulder sized rock fragments with varying amounts of soil matrix.

- Butano Sandstone: This unit is predominantly medium gray to dark gray sandstone that is composed of very fine to medium grained quartz sand. Bedding is generally massive and was not often recognizable in the samples. In general, this unit was the most competent material encountered during the drilling operations.

- Butano Shale: This unit is predominantly dark yellow brown shale that is composed of clay to silt sized particles. The unit was often described as having fissile bedding. In general, this unit was the most fractured material encountered during the drilling operations and samples often contained a high percentage of clay matrix.

- Butano Siltstone: This unit varies in color from gray to dark yellow brown and is composed of mainly silt sized particles. The bedding of this unit was often described as fissile. In general, this unit was intermediate with respect to the sandstone and shale in degree of fracturing.

In order to characterize the basal sliding surface, we gathered data from the following sources: Exploratory drilling logs, drilling rates, inclinometer readings, limited geologic mapping, surface distress maps and water well data. Although the acquired data has not conclusively established a basal rupture surface, we were able to define probable slide zones which warrant detailed analysis. Because the actual basal rupture surfaces remain in question, it will be important to provide a broad data base of strength testing in order to evaluate other potential slide surfaces.

Based on logging of the samples, the materials underlying the landslides can be characterized as: 1) colluvial materials; 2) essentially intact rock with little fracturing; 3) highly fractured or crushed rock with varying percentages of clay matrix and; 4) Rock or soil with clay shears or gouge material. Because the landslides were activated under rapid, undrained loading conditions, total stress strength parameters for these materials should be determined. For those samples with clearly defined clay or gouge seams, this can be accomplished by consolidated undrained direct shear tests. For the intact specimens, existing discontinuities or fabricated discontinuities (a saw cut) might also be tested with a direct shear apparatus. More massive samples without clearly defined discontinuities might be tested with consolidated-undrained triaxial tests with pore pressure measurements. Consolidation pressures should bracket the range of depths to be represented by the particular test. All strength testing should be performed at strains sufficient to achieve the residual or ultimate strength of the materials.

We anticipate that only a few samples will provide appropriate specimens for intact slide plane testing. It would be prudent to test remolded samples from interstitial clay materials collected from bag or core box samples.

Each geologic unit within the slide mass needs to be characterized by determining appropriate descriptions, moisture contents, and dry, moist, and saturated unit weights. This can be accomplished by testing the moisture/density relationships of representative samples of each engineering geologic unit in the moist (field moisture content), saturated and dry states. In order to provide a statistically valid assessment of representative densities, these tests should be conducted on as many samples within the slide mass as practical.

A spreadsheet listing of samples obtained during the exploration program is included as Appendix A. Based on our observations during drilling and examination of the boring logs and x-rays, particular samples are suggested for testing. Some of the samples were extruded for logging purposes and carefully returned to the sample tubes. Although these samples have been subjected to various degrees of disturbance, they may still provide useful parameters and properties for the analysis. Those that have not been extruded will provide the best strength parameters and index testing results and should be used for the bulk of the testing program.

8.4 Seismic Loading

Seismic loading parameters, in terms of ground acceleration or velocity, can be estimated by reviewing earthquake records recorded by seismographs during the Loma Prieta earthquake, and by using appropriate attenuation relationships developed by several investigators. Data from most of the strong motion recorders in the San Francisco Bay Area included peak ground accelerations in three directions, two horizontal and one vertical. Peak horizontal ground acceleration (PHGA) refers to the higher of the two horizontal accelerations. Mean peak horizontal ground acceleration (MPHGA) is the average of peak ground accelerations from two orthogonal horizontal directions.

The level of ground acceleration at any site is influenced by a number of factors including: 1) earthquake magnitude, 2) distance of the site from the source of energy released, 3) geologic characteristics of earth materials along the wave transmission path, 4) source mechanism and rupture propagation mechanisms of the earthquake, 5) wave interference effects, 6) local soil conditions, and 7) topographic amplification. A maximum horizontal ground acceleration of 0.64g was measured at the Corralitos Strong Motion Instrumentation Station (Figure 9). The Corralitos Station is approximately 3.5 miles from the Loma Prieta earthquake epicenter and represents the strongest natural ground shaking recorded during the earthquake. A maximum horizontal ground acceleration of 0.45g was measured at the left abutment of Lexington Dam, located approximately 14 miles from the Loma Prieta earthquake epicenter (Shakal, et al, 1989).

Considering pertinent site parameters, new strong ground motion records collected after the Loma Prieta earthquake, the proximity of the San Andreas fault, and attenuation relationships prepared by Seed and Idriss (1982) and Krinitzsky, et al (1988), we estimate that the Schultheis Road and Villa Del Monte areas probably experienced mean peak horizontal ground accelerations (MPHGA) on the order of 0.4g to 0.5g. However, based on accounts of thrown stone boulders in the site vicinity, it is possible that topographic amplification could have increased local shaking along the crest of Summit Ridge to PHGA greater than 0.6g.

8.5 Landslide Failure Modes

In our opinion, the large landslides observed in the Schultheis Road and Villa Del Monte areas appear to have similar failure mechanisms and appear to be deep-seated features that are related to areas of ancient landsliding and rock creep. The mode of failure appears to be primarily translational with some rotational component. We believe the landslide basal rupture surfaces are most probably represented by a zone that may coincide with the depth of significant rock creep.

The pattern of surface ground cracking suggests that at least portions of ancient landslides were re-activated as a result of seismic shaking. In the Schultheis Road area and Sky View/Bel Air portion of the Villa Del Monte area, well-defined landslides appear to have experienced complete shearing along their basal surfaces. However, it appears that other portions of the Villa Del Monte area may not have completely sheared along one or more basal rupture surface(s) in response to the recent earthquake. A lack of surface cracks portraying continuous shear or strike-slip movement along the probable lateral margins of the Villa Del Monte complex supports this preliminary opinion. Domestic water well data throughout the area suggest that, although coseismic movement occurred in the headward regions of the landslides (expressed by surface ground cracking), subsurface rupture surfaces either experienced a relatively small amount of shear displacement or did not fully shear during the earthquake motion. Continued monitoring and modeling may provide a basis for determining whether renewed movement or continued movement of these landslides will occur in the future.

In areas where well-defined tension cracks formed at the head of landslide deposits and discontinuous, and somewhat less well-defined, *en echelon* cracks formed along the lateral margins of the landslides, it is concluded that the landslide moved enough to displace the basal shear surface.

9.0 CONCLUSIONS AND RECOMMENDATIONS

The following section of our report describes the conclusions and recommendations of our geotechnical exploration of the Schultheis Road and Villa Del Monte landslide areas.

9.1 Conclusions

1. Ground cracking, relative displacements across the cracks and the relationship of these fissures to geomorphic features in the vicinity of the Schultheis Road and Villa Del Monte areas indicates that landsliding took place in these regions in response to the Loma Prieta earthquake. Deformation locally indicates that either incipient landsliding (the initial phase of slope failure) or more complete landslide failure (complete shearing along a basal surface between the landslide mass and the underlying intact rock) has occurred.

2. The Schultheis Road area and the Sky View/Bel Air portion of the Villa Del Monte area are judged to be discrete landslides that experienced reactivation in response to the Loma Prieta earthquake. The basal rupture surfaces for these landslides probably sheared completely as a result of the earthquake. However, it is not yet clear how much movement occurred along the basal rupture surfaces in these areas. Other portions of the Villa Del Monte area have also experienced landslide-related ground cracking; however, the extent and degree of landslide movement is not well-defined. We believe the data collected to date indicates that the Villa Del Monte area may be

underlain by either a single, large landslide or an inter-related landslide complex.

3. Since installation in 1990, the inclinometers have not shown any offsets within the Schultheis Road or Villa Del Monte areas outside the limits of the system accuracy established by the instrument manufacturer.

9.2 Recommendations

In order to characterize the extent and depth of landsliding, we have compiled all the data made available to us during this exploration program. The ancient and active landslides in the Schultheis Road and Villa Del Monte areas, however, are very complex, and the following recommendations are presented to better characterize these areas.

1. Thorough mapping of geomorphic features and surface geology would increase the level of understanding of the areas and maximize the amount of information acquired to date by more accurately defining specific landslide boundaries. Such mapping should be performed on a detailed topographic base map of the two areas. The information compiled on our Geotechnical Exploration Map should be transferred to the detailed topographic base map.

2. As the transects supplied by Towill, Inc. were not constructed along a single azimuth, the projected topography does not represent actual conditions along a straight cross section. Analyses of slope stability should take this into consideration. New topographic profiles along the most critical slope of the landslide should be constructed and used as a basis for any slope stability analysis.

3. The locations of the basal rupture surfaces were chosen by carefully analyzing all the data available to us during our geotechnical exploration. As the landslides have not displaced the inclinometers, however, the depths of the basal rupture surfaces are necessarily interpretive. The existing water wells could provide a valuable source of data with respect to the depth of landsliding. A number of strategically situated water wells should be selected for

further study. The wells should be sounded, and if possible, viewed by TV camera to check the condition of the casings. In addition, a suite of downhole geophysical techniques could be employed on selected water wells and the existing inclinometers. These could include P and S wave downhole seismic surveys, natural (passive) gamma ray and inductive resistivity logging (non-conductive casings only, e.g. ABS inclinometer and PVC well casings).

4. Several large-diameter borings should be excavated near the headscarp regions of the landslides to provide further information regarding the depth and inclination of basal rupture surfaces. In addition, oriented hand samples could be obtained directly from the slide surfaces. Subsequent laboratory testing of these samples would further characterize the strength of the sheared materials.

5. To further refine the limits and depths of landsliding, an attempt should be made to collect all available geologic, geotechnical and geophysical information gathered by other workers in the explored areas since the earthquake.

6. Monitoring of surface monuments (quadrilaterals), inclinometers, and piezometers should continue for a period of at least a few years (including a period of normal, or above normal, rainfall activity) to detect future deformation.

10.0 LIMITATIONS

Our services consist of professional opinions and recommendations made in accordance with generally accepted engineering geology and geotechnical engineering principles and practices. No warranty, expressed or implied, or merchantability of fitness, is made or intended in connection with our work, by the proposal for consulting or other services, or by the furnishing of oral or written reports or findings.

Subsurface exploration was performed on an emergency basis without sufficient lead time for careful planning of boring locations, depths and sampling intervals.

Accurate information from existing water wells was difficult to obtain and much of the expression of distress was covered over shortly after the Loma Prieta earthquake.

Boring logs represent our interpretation of subsurface conditions based on visual observation of drill bit cuttings and sampled intervals. Our firm was not responsible for determining survey transect line locations and orientations or for determining boring locations. Our scope of work **did not** include comprehensive engineering geologic studies, slope stability analyses, or evaluation of the associated landslide and earthquake risk.

It should be emphasized that subsurface conditions in ancient landslide terrane are extremely complex. While the recognition of landsliding can be determined from the available data, interpretations of the depths of landsliding are based on widely scattered information. Although the cross sections represent our best estimate of subsurface conditions, the subsurface extent and character of landsliding is likely to be more irregular and more complicated than portrayed. Additional surface and subsurface information could significantly alter our interpretation.

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11.2 Stereoscopic Aerial Photographs

Date	Scale	Flight/Frame	Type
11/01/89	1" ≈ 500'	894481/4-19,20,21 & 5-20,21,22	Color
8/26/89	1" ≈ 500'	GSLPEQ/6-11,12,13,14 & 7-10,11,12	B & W
8/1/39	1" ≈ 1666'	CIV-286/ 87, 88, 89, 90	B & W

APPENDIX A

Sample Summary and Testing Recommendations

APPENDIX A

Sample Summary and Testing Suggestions

SAMPLE DEPTH(FT)		LENGTH (FT)	RUN (FT)	TYPE	TUBE NOT EXTRUDED	TUBE EXTRUDED	CORE BOX	BAG	COMMENTS	POSSIBLE LAB TEST	X-RAY
SR-1											
10	11	1	2.5	PB	SR-1/S-1					SEE NOTE 6	X
20	21.7	1.7	2	PB	SR-1/S-2					SEE NOTE 2	X
30	32	2	2.5	PB	SR-1/S-3					SEE NOTE 1	X
40	41.8	1.8	2.5	PB	SR-1/S-4					SEE NOTE 1	X
50	50.7	0.7	2.5	PB	SR-1/S-5						X
52.5	53.3	0.8	0.8	PB					DIST.,NOT RETAINED		
57	60.5	3.5	4.4	NX			SR-1/BOX1				
61.4	61.4	0	2.2	NX					NO RECOVERY		
64	67	3	5	NQ			SR-1/BOX1				
69	73.5	4.5	5	NQ			SR-1/BOX2				
100	104.7	4.7	5	NQ			SR-1/BOX3				
150	153	3	3	NQ			SR-1/BOX4				
200	202.5	2.5	3	NQ			SR-1/BOX5				
SR-1A											
40	41.3	1.3	1.5	PB	SR-1A/S-1					SEE NOTE 3	X
41.5	43	1.5	1.5	PB	SR-1A/S-2					SEE NOTE 1	X
43	44.5	1.5	1.5	PB	SR-1A/S-3					SEE NOTE 1	X
44.5	46	1.5	1.5	PB	SR-1A/S-4					SEE NOTE 1	X
46	47.25	1.25	1.5	PB	SR-1A/S-5					SEE NOTE 1	X
47.5	48.25	0.75	0.75	PB	SR-1A/S-6					SEE NOTE 1	X
SR-2											
70	70.2	0.2	1.5	PB				SR-2/B-1			
71.5	73	1.5	1.5	PB		SR-2/S-1 DIST.					X
73	73.2	0.2	0.2	PB				SR-2/B-2			
73.2	73.7	0.5	1.5	PB				SR-2/B-3			
73.7	74.2	0.5						SR-2/B-4			
74.7	76	1.3	2	PB		SR-2/S-2					X
76.7	78	1.3	1.5	PB		SR-2/S-3					X
78.2	79.9	1.7	1.8	PB		SR-2/S-4				TRIAXIAL	X
80	80.6	0.6	2	PB				SR-2/B-5			
80.6	81.3	0.7						SR-2/B-6			
81.3	81.9	0.6						SR-2/B-7			
82	83.5	1.5	1.5	PB		SR-2/S-5					X
83.5	84.5	1	1	PB		SR-2/S-6					X
84.5	85.3	0.8	1.7	PB				SR-2/B-8			
86.2	87.2	1	1.5	PB		SR-2/S-7			DIRECT SHEAR	TRIAXIAL	X
87.7	88.3	0.6	1.6	PB				SR-2/B-9			
88.3	88.8	0.5						SR-2/B-10			
89.3	90.5	1.2	1.5	PB		SR-2/S-8			DIRECT SHEAR	DIRECT SHEAR	X
90.8	91.5	0.7	1.5	PB				SR-2/B-11			
91.5	92.2	0.7						SR-2/B-12			
92.3	92.9	0.6	1.2	PB				SR-2/B-13			
92.9	93.3	0.4						SR-2/B-14			
93.5	94.6	1.1	1.5	PB		SR-2/S-9					X
95	95.5	0.5	1.5	PB				SR-2/B-15			
95.5	96	0.5						SR-2/B-16			
96.5	97	0.5	1.5	PB		SR-2/S-10				DIRECT SHEAR	X
98	98.9	0.9	1.5	PB		SR-2/S-11					X
99.5	100.4	0.9	1.8	PB		SR-2/S-12				DIRECT SHEAR	X
101.3	102	0.7	1.5	PB		SR-2/S-13					X
102.8	103.6	0.8	1.3	PB		SR-2/S-14					X
104.1	104.9	0.8	0.9	PB				SR-2/B-17			
153	153.4	0.4	0.5	PB				SR-2/B-18			
SR-3											
70	70.3	0.3	1.2	PB				SR-3/B-1			
70.3	70.9	0.6						SR-3/B-2			
71.2	71.8	0.6	1.5	PB			SR-3/BOX1				
72.7	73	0.3	0.4	PB			SR-3/BOX1				
73.1	73.8	0.7	1.6	PB			SR-3/BOX1				
74.7	75.3	0.6	1.4	PB			SR-3/BOX1				
76.1	76.6	0.5	1.5	PB				SR-3/B-3			
76.6	76.9	0.3					SR-3/BOX1				
77.6	78.5	0.9	1.1	PB	SR-3/S-1				COULDNT EXTRUDE	SEE NOTE 7	X
78.5	78.7	0.2			SR-3/S-2						
93.5	94.1	0.6	0.6	PB	SR-3/S-3				COULDNT EXTRUDE		X
97.5	97.9	0.4	0.5	PB	SR-3/S-4				COULDNT EXTRUDE		X
103	103.8	0.8	0.8	PB	SR-3/S-5				COULDNT EXTRUDE		X
103.8	104.5	0.7	0.7	PB			SR-3/BOX2				
104.5	105	0.5	0.5	PB			SR-3/BOX2				

SAMPLE DEPTH(FT)		LENGTH (FT)	RUN (FT)	TYPE	TUBE NOT EXTRUDED	TUBE EXTRUDED	CORE BOX	BAG	COMMENTS	POSSIBLE LAB TEST	X-RAY
105	105.3	0.3	0.3	PB			SR-3/BOX2				
122.5	124	1.5	1.5	PB		SR-3/S-6					X
124	125.5	1.5	1.5	PB		SR-3/S-7				DIRECT SHEAR	X
125.5	126.5	1	1	PB		SR-3/S-8					X
126.5	127	0.5	1.5	PB			SR-3/BOX2				
128	128.5	0.5	1.5	PB		SR-3/S-9					X
128.5	129.4	0.9					SR-3/BOX2				
129.5	130.4	0.9	1.5	PB			SR-3/BOX2				
131	131.7	0.7	1.8	PB			SR-3/BOX2				
132.8	133.5	0.7	0.9	PB		SR-3/S-10					
150	151.2	1.2	1.5	PB		SR-3/S-11					X
168	168.6	0.6	0.8	PB		SR-3/S-12					X
180	181.2	1.2	1.5	PB		SR-3/S-13				TRIAXIAL	X
SR-4											
27	28.5	1.5	1.5	PB			SR-4/BOX1				
64.5	65.5	1	1.8	NX			SR-4/BOX1				
80	80.4	0.4	0.4	PB			SR-4/BOX1				
101.5	102	0.5	0.9	PB				SR-4/B-1			
102	102.4	0.4						SR-4/B-2			
DM-1											
20	22	2	2	C(SS)			DM-1/BOX1				
38.5	40.5	2	3.5	C			DM-1/BOX1				
40.5	40.9	0.4							NOT RETAINED		
60	61.7	1.7	4	C			DM-1/BOX1				
64	66	2	2	C			DM-1/BOX1				
70	72	2	2	C			DM-1/BOX1				
82	83	1	2	C			DM-1/BOX2				
84	84	0	10	C					NO RECOVERY		
94	94	0	2	C					NO RECOVERY		
96	96	0	2	C					NO RECOVERY		
98	99.4	1.4	2	C			DM-1/BOX2				
100	101.1	1.1	4	C			DM-1/BOX2				
104	106	2	2	C			DM-1/BOX2				
106	108	2	5	C					NOT RETAINED		
108	110	2					DM-1/BOX2				
113	117	4	8	C					NOT RETAINED		
119	121.6	2.6	5	C					NOT RETAINED		
124	126.5	2.5	6	C					NOT RETAINED		
130	130.2	0.2	1	C					NOT RETAINED		
131	133	2	2	C			DM-1/BOX3				
133.7	135	1.3	2	C			DM-1/BOX3				
135	136.2	1.2	2	C			DM-1/BOX3				
137	139	2	2	C			DM-1/BOX3				
139	141	2	2	C			DM-1/BOX3				
DM-2											
20	20.5	0.5	1.3	PB			DM-2/BOX1	DM-2/B-1			
30	30.4	0.4	1.5	PB			DM-2/BOX1	DM-2/B-2			
30.4	30.8	0.4					DM-2/BOX1	DM-2/B-3			
50	50.5	0.5	2	PB			DM-2/BOX1	DM-3/B-4			
50.5	51	0.5					DM-2/BOX1	DM-3/B-5			
51	51.5	0.5					DM-2/BOX1	DM-3/B-6			
52	52.4	0.4	1.2	PB			DM-2/BOX1	DM-3/B-7			
71.5	72.2	0.7	0.9	PB			DM-2/BOX1	DM-3/B-8			
90	90.4	0.4	1	PB			DM-2/BOX1	DM-2/B-9			
90.4	91	0.6					DM-2/BOX1	DM-2/B-10			
91	91.4	0.4	1.2	PB			DM-2/BOX1	DM-2/B-11			
91.4	91.8	0.4					DM-2/BOX1	DM-2/B-12			
93	93.6	0.6	1	NX			DM-2/BOX1	DM-2/B-13			
94	97	3	3	NX			DM-2/BOX2				
97	98.3	1.3	5	NX			DM-2/BOX2				
102	104	2	2.2	NX			DM-2/BOX2				
105	107	2	2	NX			DM-2/BOX2				
107	108.8	1.8	3	NX			DM-2/BOX3				
110	111.5	1.5	1.8	NX			DM-2/BOX3				
111.8	113.3	1.5	3	NX			DM-2/BOX3				
115	115.4	0.4	1	PB			DM-2/BOX3	DM-2/B-14			
115.4	115.9	0.5					DM-2/BOX3	DM-2/B-15			
146	147.7	1.7	3	NX			DM-2/BOX3				
149	151.5	2.5	3	NX			DM-2/BOX4				
152	156	4	5	NX			DM-2/BOX4				
157	161.2	4.2	5	NX			DM-2/BOX4				
174	174.3	0.3	0.5	PB			DM-2/BOX5				
196	200.5	4.5	5	NX			DM-2/BOX5				

SAMPLE DEPTH(FT)		LENGTH (FT)	RUN (FT)	TYPE	TUBE NOT EXTRUDED	TUBE EXTRUDED	CORE BOX	BAG	COMMENTS	POSSIBLE LAB TEST	X-RAY
DM-3											
20	20.3	0.3	0.8	PB			DM-3/BOX1	DM-3/B-1			
30	31.3	1.3	3	NX			DM-3/BOX1				
40	40.8	0.8	4.3	NX			DM-3/BOX1				
50	55	5	5	NX			DM-3/BOX1				
70	71.5	1.5	6	NX			DM-3/BOX1				
76	76	0	1	NX					NO RECOVERY		
90	93	3	4	NX			DM-3/BOX2				
DM-4											
20	22	2	2	C(SS)			DM-4/BOX1				
30	32	2	2	C(SS)			DM-4/BOX1				
40	40.9	0.9	2	C(SS)			DM-4/BOX1				
50	51.7	1.7	2	C(SS)			DM-4/BOX1				
60	61.7	1.7	2	C(SS)			DM-4/BOX1				
70	70	0	1	C(SS)					NO RECOVERY		
80	81.5	1.5	2	C			DM-4/BOX2				
82	84.8	2.8	3	C			DM-4/BOX2				
85	87	2	2	C			DM-4/BOX2				
87	89	2	2	C			DM-4/BOX2				
89	89.3	0.3	4	C			DM-4/BOX2				
93	93.7	0.7	2	C					NOT RETAINED		
130	131.2	1.2	2	C			DM-4/BOX3				
132	134.5	2.5	4	C			DM-4/BOX3				
136	137.4	1.4	2	C			DM-4/BOX3				
138	139.5	1.5	2	C			DM-4/BOX3				
140	142	2	2	C			DM-4/BOX4				
142	143.7	1.7	2	C			DM-4/BOX4				
144	146	2	2	C			DM-4/BOX4				
146	147.4	1.4	2	C			DM-4/BOX4				
148	149.9	1.9	2	C			DM-4/BOX4				
150	152	2	2	C			DM-4/BOX5				
152	154	2	2	C			DM-4/BOX5				
154	155.6	1.6	2	C			DM-4/BOX5				
156	157.8	1.8	2	C			DM-4/BOX5				
158	162	4	4	C			DM-4/BOX6				
162	164	2	2	C			DM-4/BOX6				
164	166	2	2	C			DM-4/BOX6				
166	168	2	2	C			DM-4/BOX6				
168	170	2	2	C			DM-4/BOX6				
170	172	2	2	C			DM-4/BOX7				
172	176	4	4	C			DM-4/BOX7				
176	180	4	4	C			DM-4/BOX7				
180	185	5	5	C			DM-4/BOX8				
185	189.5	4.5	4.5	C			DM-4/BOX8				
189.5	190	0.5	2.5	C			DM-4/BOX8				
190	192	2					DM-4/BOX9				
192	194	2	2	C			DM-4/BOX9				
194	196	2	2	C			DM-4/BOX9				
196	198	2	2	C			DM-4/BOX9				
198	200	2	2	C			DM-4/BOX9				
200	202	2	2	C			DM-4/BOX10				
202	204	2	5	C			DM-4/BOX10				
207	208	1	1	C			DM-4/BOX10				
208	209.8	1.8	2	C			DM-4/BOX10				
210	212	2	2	C			DM-4/BOX11				
212	214	2	2	C			DM-4/BOX11				
214	215.7	1.7	2	C			DM-4/BOX11				
216	217.7	1.7	2	C			DM-4/BOX11				
218	219.7	1.7	2	C			DM-4/BOX11				
220	220.7	0.7	1	C			DM-4/BOX12				
221	224	3	3	C			DM-4/BOX12				
224	228	4	4	C			DM-4/BOX12				
228	229.3	1.3	1.3	C			DM-4/BOX12				
229.3	230	0.7	2.7	C			DM-4/BOX12				
230	231.8	1.8					DM-4/BOX13				
232	233	1	1	C			DM-4/BOX13				
233	235	2	2	C			DM-4/BOX13				
235	237	2	2	C			DM-4/BOX13				
237	239.8	2.8	3	C			DM-4/BOX13				
SB-1											
10	12.3	2.3	2.5	PB		SB-1/S-1					X
12.5	14.5	2	2.5	PB		SB-1/S-2					X
15	15.7	0.7	2	PB				SB-1/S-3/B-1			
15.7	16.4	0.7						SB-1/S-3/B-2			

SAMPLE		LENGTH	RUN		TUBE	TUBE				POSSIBLE	
DEPTH(FT)		(FT)	(FT)	TYPE	NOT EXTRUDED	EXTRUDED	CORE BOX	BAG	COMMENTS	LAB TEST	X-RAY
17	17.6	0.6	1.5	PB				SB-1/S-4/B-1			
17.6	18.2	0.6						SB-1/S-4/B-2			
18.5	19.9	1.4	2	PB	SB-1/S-5					SEE NOTE 1	X
20.5	21.8	1.3	1.5	PB	SB-1/S-6					SEE NOTE 1	X
22	23.5	1.5	1.5	PB	SB-1/S-7					SEE NOTE 1	X
23.5	24.25	0.75	2	PB				SB-1/S-8/B-1			
24.25	25	0.75						SB-1/S-8/B-2			
25.5	26.2	0.7	1.5	PB				SB-1/S-9/B-1			
26.2	26.9	0.7						SB-1/S-10/B-2			
27	28.4	1.4	1.5	PB	SB-1/S-10					SEE NOTE 1	X
28.5	29.7	1.2	1.5	PB	SB-1/S-11					SEE NOTE 1	X
30	31.4	1.4	1.5	PB	SB-1/S-12					SEE NOTE 1	X
31.5	32.5	1	1.5	PB	SB-1/S-13					SEE NOTE 1	X
33	34.4	1.4	1.5	PB	SB-1/S-14					SEE NOTE 1	X
34.5	36	1.5	1.5	PB	SB-1/S-15					SEE NOTE 1	X
36	37.7	1.7	2	PB	SB-1/S-16					SEE NOTE 1	X
38	39.2	1.2	1.5	PB	SB-1/S-17					SEE NOTE 1	X
39.5	41	1.5	1.5	PB	SB-1/S-18					SEE NOTE 1	X
41	41.8	0.8	1.5	PB	SB-1/S-19					SEE NOTE 1	
42.5	43.7	1.2	1.5	PB		SB-1/S-20				SEE NOTE 4	
44	44.7	0.7	1.5	PB				SB-1/S-21/B-1			
44.8	45.5	0.7						SB-1/S-21/B-2			
45.5	46.4	0.9	1	PB				SB-1/S-22/B-1			
46.5	46.8	0.3	2	PB					NOT RETAINED		
46.8	47.4	0.6						SB-1/S-23/B-1			
47.4	48.1	0.7						SB-1/S-23/B-2			
48.5	49.1	0.6	1	PB	SB-1/S-24					SEE NOTE 5	
50	50.6	0.6	1.5	PB	SB-1/S-25					SEE NOTE 5	X
51.5	52.3	0.8	1.5	PB	SB-1/S-26					SEE NOTE 5	X
53	53.4	0.4	1.5	PB				SB-1/S-27/B-1			
53.4	53.85	0.45						SB-1/S-27/B-2			
54.5	54.9	0.4	1.5	PB				SB-1/S-28/B-1			
54.9	55.3	0.4						SB-1/S-28/B-2			
56	56.3	0.3	1.5	PB				SB-1/S-29/B-1			
56.3	56.8	0.5						SB-1/S-29/B-2			
57.5	57.85	0.35	1	PB	SB-1/S-30						X
58.5	59.2	0.7	1.5	PB	SB-1/S-31					SEE NOTE 8	X
60	61	1	1.5	PB	SB-1/S-32						
61.5	62.8	1.3	1.5	PB	SB-1/S-33						X
63	64.2	1.2	1.5	PB	SB-1/S-34						X
64.5	65	0.5	1.5	PB	SB-1/S-35						
66	66.7	0.7	1.5	PB	SB-1/S-36					SEE NOTE 9	X
67.5	68.2	0.7	1	PB	SB-1/S-37						X
68.5	69.1	0.6	1	PB				SB-1/S-38/B-1			
70	75	5	5	NX			SB-1/BOX1				
75	78.3	3.3	3.5	NX			SB-1/BOX1				
80	80.9	0.9	1	NX			SB-1/BOX2				
100	100.7	0.7	1	NX			SB-1/BOX2				
SB-1A											
87	87.65	0.65	1.5	PB		SB-1A/S-1				DIRECT SHEAR	X
88.5	89.7	1.2	1.5	PB		SB-1A/S-2				TRIAXIAL	X
90	90.7	0.7	1.5	PB		SB-1A/S-3				TRIAXIAL	X
91.25	91.8	0.55	1.5	PB				SB-1A/B-5			
91.8	92.35	0.55						SB-1A/B-6			
92.5	93.4	0.9	1	PB				SB-1A/B-1			
93.5	94	0.5	1	PB				SB-1A/B-2			
94	94.5	0.5						SB-1A/B-3			
SB-2											
31	33	2	3	PB	SB-2/S-1					SEE NOTE 10	X
34	34.5	0.5	0.5	C				SB-2/B-1			
34.5	35.3	0.8	1.5	C				SB-2/B-2			
36	37.9	1.9	2	C			SB-2/BOX1				
41	42.3	1.3	1.3	PB	SB-2/S-2						X
51	53.3	2.3	2.5	PB	SB-2/S-3					SEE NOTE 10	X
60	61.9	1.9	2	C			SB-2/BOX1				
62	62.3	0.3	3	C					NOT RETAINED		
65	66.7	1.7	1.7	C			SB-2/BOX1				
66.7	67.9	1.2	1.2	C			SB-2/BOX1				
68	68.9	0.9	1	C			SB-2/BOX2				
69	74.5	5.5	6	C			SB-2/BOX2				
75	77	2	6	C			SB-2/BOX2				
77	81	4					SB-2/BOX3				
81	85	4	4	C			SB-2/BOX3				
85	86.5	1.5	5	C			SB-2/BOX3				

SAMPLE		LENGTH	RUN		TUBE	TUBE				POSSIBLE	
DEPTH(FT)		(FT)	(FT)	TYPE	NOT EXTRUDED	EXTRUDED	CORE BOX	BAG	COMMENTS	LAB TEST	X-RAY
86.5	88.6	2.1					SB-2/BOX4				
90	95	5	5	C			SB-2/BOX4				
95	98	3	5	C			SB-2/BOX4				
98	100	2					SB-2/BOX5				
100	105	5	5	C			SB-2/BOX5				
105	107.8	2.8	3	C			SB-2/BOX5				
145	145.2	0.2	2	C(SS)					NOT RETAINED		
160	164.4	4.4	5	C			SB-2/BOX6				
165	167.3	2.3	2.3	C			SB-2/BOX6				
167.3	170	2.7	4	C			SB-2/BOX6				
170	171.3	1.3					SB-2/BOX7				
171.3	173	1.7	1.7	C			SB-2/BOX7				
173	175	2	2	C			SB-2/BOX7				
175	177	2	2	C			SB-2/BOX7				
177	179	2	2	C			SB-2/BOX7?				
179	184	5	5	C			SB-2/BOX8?				
242	244	2	3	C			SB-2/BOX8?				
SB-3											
20	22	2	2	C(SS)			SB-3/BOX1				
30	32	2	2	C(SS)			SB-3/BOX1				
40	41.5	1.5	2	C(SS)	CLEAR PLASTIC TUBE		SB-3/BOX1				
50	52	2	2	C(SS)			SB-3/BOX1				
60	60.2	0.2	0.2	C(SS)					NOT RETAINED		
64	66	2	6	C(SS)			SB-3/BOX1				
70	72	2	4	C			SB-3/BOX2				
75	76	1	2	C			SB-3/BOX2				
76	78	2	2	C			SB-3/BOX2				
78	78	0	2	C					NO RECOVERY		
80	80.2	0.2	2	C					NOT RETAINED		
82	82	0	2	C					NO RECOVERY		
84	85.5	1.5	2	C			SB-3/BOX2				
86	86.4	0.4	2	C					NOT RETAINED		
88	88.7	0.7	0.7	C(SS)			SB-3/BOX2				
88.7	88.9	0.2	1.3	C(SS)					NOT RETAINED		
90	90	0	1	C(SS)					NO RECOVERY		
91	93.5	2.5	3	C			SB-3/BOX3				
94	97	3	6	C			SB-3/BOX3				
140	140	0	3	C					NO RECOVERY		
143	144	1	2	C			SB-3/BOX4				
145	148	3	3	C			SB-3/BOX4				
148	151.8	3.8	4	C			SB-3/BOX4				
190	191.4	1.4	2	C			SB-3/BOX5				
192	193.6	1.6	1.8	C			SB-3/BOX5				
193.8	197	3.2	3.2	C			SB-3/BOX5				
197	200	3	3	C			SB-3/BOX5				
230	231	1	1.2	C			SB-3/BOX6				
231.2	231.9	0.7	85	C			SB-3/BOX6				
232	233.9	1.9	2	C			SB-3/BOX6				
234	238	4	4	C			SB-3/BOX6				
238	240	2	2	C			SB-3/BOX6				
SB-4											
50	50.5	0.5	1.2	PB			SB-4/B-1				
100	100.5	0.5	0.9	PB			SB-4/B-2				
100.5	100.9	0.4					SB-4/B-3				
150.5	150.9	0.4	0.9	PB			SB-4/B-4				
150.9	151.3	0.4					SB-4/B-5				
SB-4A											
6.5	7	0.5	2.5	PB			SB-4A/B-1				
9	10.4	1.4	2	PB	SB-4A/S-1					SEE NOTE 1	X
15	16.2	1.2	2	PB	SB-4A/S-2					SEE NOTE 1	X
17	18.5	1.5	1.5	PB	SB-4A/S-3					SEE NOTE 1	X
18.5	19.5	1	1.5	PB	SB-4A/S-4					SEE NOTE 1	X
ED-1											
31.5	32.9	1.4	1.5	PB		ED-1/S-1				DIRECT SHEAR	X
33	34	1	1.5	PB		ED-1/S-2					X
34.5	35.2	0.7	1.5	PB			ED-1/BOX1	ED-1/B-1			
36	36.6	0.6	1.5	PB			ED-1/BOX1	ED-1/B-2			
37.5	38.6	1.1	1.5	PB			ED-1/BOX1				
39	40.4	1.4	1.5	PB			ED-1/BOX1				
55	55.1	0.1	1.5	PB			ED-1/BOX2	ED-1/B-3			
56.5	56.5	0	1.5	PB					NO RECOVERY		
58	58.5	0.5	1.5	PB			ED-1/BOX2	ED-1/B-4			

SAMPLE DEPTH(FT)		LENGTH (FT)	RUN (FT)	TYPE	TUBE NOT EXTRUDED	TUBE EXTRUDED	CORE BOX	BAG	COMMENTS	POSSIBLE LAB TEST	X-RAY
58.5	59	0.5					ED-1/BOX2	ED-1/B-5			
59	59.5	0.5					ED-1/BOX2	ED-1/B-6			
59.5	61	1.5	1.5	PB			ED-1/BOX2				
61	62.3	1.3	1.5	PB		ED-1/S-3				TRIAXIAL	X
62.5	64	1.5	1.5	PB			ED-1/BOX2				
64	65.8	1.8	1.8	PB			ED-1/BOX3				
65.8	66.9	1.1	1.2	PB			ED-1/BOX3				
80	81.4	1.4	2.5	PB			ED-1/BOX3				
130	130.7	0.7	0.7	PB				ED-1/B-6			
163	163.5	0.5	0.5	PB		ED-1/S-4				DIRECT SHEAR	X
196	196.5	0.5	0.5	PB		ED-1/S-5					X
ED-2											
40	40.8	0.8	1.8	PB			ED-2/BOX1	ED-2/B-1			
40.8	41.7	0.9					ED-2/BOX1	ED-2/B-2			
41.7	43	1.3	2	PB	ED-2/S-1					SEE NOTE 1	X
60	61.1	1.1	1.5	PB		ED-2/S-2					
61.1	61.5	0.4					ED-2/BOX1	ED-2/B-3			
80	80.6	0.6	0.8	PB			ED-2/BOX1	ED-2/B-4			
102	105.5	3.5	5	NX			ED-2/BOX1				
112	112.8	0.8	1	PB	ED-2/S-3						
132	134.7	2.7	3	NX			ED-2/BOX2				
135	135	0	3	NX					NO RECOVERY		
138	141.5	3.5	3.5	NX			ED-2/BOX2				
141.5	143.6	2.1	3.8	NX			ED-2/BOX2				
145.3	149.8	4.5	4.7	NX			ED-2/BOX2				
196	197.7	1.7	2	NX			ED-2/BOX3				
SD-1											
40	41.1	1.1	1.5	PB		SD-1/S-1					X
41.5	43	1.5	2	PB		SD-1/S-2				DIRECT SHEAR	X
43	43.5	0.5					SD-1/BOX1	SD-1/B-5			
43.5	44	0.5	2	PB		SD-1/S-3				DIRECT SHEAR	X
44	44.2	0.2							NOT RETAINED		
44.2	44.6	0.4				SD-1/S-4					
44.6	44.8	0.2							NOT RETAINED		
44.8	45.5	0.7					SD-1/BOX1	SD-1/B-6			
45.6	46.4	0.8	1.4	PB			SD-1/BOX1	SD-1/B-1			
46.4	46.9	0.5					SD-1/BOX1	SD-1/B-2			
46.9	47.5	0.6	1.4	PB			SD-1/BOX1	SD-1/B-3			
47.5	48.3	0.8		PB			SD-1/BOX1	SD-1/B-4			
48.3	49.1	0.8	2	PB			SD-1/BOX1	SD-1/B-7			
49.1	49.8	0.7					SD-1/BOX1	SD-1/B-8			
71.1	71.8	0.7	2	PB			SD-1/BOX1	SD-1/B-9			
71.8	72.5	0.7					SD-1/BOX1	SD-1/B-10			
72.5	72.8	0.3							NOT RETAINED		
73	73.6	0.6	1.3	PB			SD-1/BOX1	SD-1/B-11			
73.6	74.1	0.5					SD-1/BOX1	SD-1/B-12			
81	81.6	0.6	1.5	PB			SD-1/BOX2	SD-1/B-13			
81.6	82.2	0.6					SD-1/BOX2	SD-1/B-14			
82.5	82.9	0.4	1	PB			SD-1/BOX2	SD-1/B-15			
83	83.5	0.5					SD-1/BOX2	SD-1/B-16			
90	90.5	0.5	0.5	PB			SD-1/BOX2	SD-1/B-17			
90.5	91	0.5	0.7	PB			SD-1/BOX2	SD-1/B-18			
91.2	91.75	0.55	1.4	PB			SD-1/BOX2	SD-1/B-19			
91.75	92.3	0.55					SD-1/BOX2	SD-1/B-20			
92.8	93.4	0.6	2	PB			SD-1/BOX2	SD-1/B-21			
93.4	94	0.6					SD-1/BOX2	SD-1/B-22			
94	94.6	0.6					SD-1/BOX2	SD-1/B-23			
94.6	95.3	0.7	1.4	PB			SD-1/BOX2	SD-1/B-24			
95.3	96	0.7					SD-1/BOX2	SD-1/B-25			
96	96.7	0.7	1	PB			SD-1/BOX2	SD-1/B-26			
97	97.6	0.6	1.2	PB			SD-1/BOX3	SD-1/B-27			
97.6	98.2	0.6					SD-1/BOX3	SD-1/B-28			
98.2	99.4	1.2	1.2	PB			SD-1/BOX3				
150	152	2	2	NX			SD-1/BOX3				
	TOTAL	550.75	824								
	R(%)=	67									

NOTES	THE NOTES ON UNEXTRUDED SAMPLES ARE FROM THE BORING LOGS AND FROM ANALYSIS OF X-RAYS		
1	REGOLITH OR WEATHERED BEDROCK, MAY CONTAIN SHEARS OR MAY BE SOFT ENOUGH FOR ROCK MASS STRENGTH TEST		
2	REGOLITH, MAY HAVE A SANDSTONE/SILTSTONE CONTACT		
3	LOGS SHOW SANDSTONE/SILTSTONE CONTACT, X-RAY SHOWS THIN FEATURE AT 45° AT 41 FEET.		
4	EXTRUDED SAMPLE CONTAINS CONTACT (SOFT ZONE) BETWEEN REGOLITH AND WEATHERED ROCK		
5	MAY CONTAIN SOFT ROCK		
6	MAY BE SOFT OR WEATHERED ROCK, X-RAYS SHOWS BLOTCHY DARK BAND NEAR MIDDLE OF TUBE		
7	X-RAYS SHOW DARK FEATURE IN MIDDLE OF SAMPLE DIPPING 10°-15°		
8	X-RAYS SHOW TONAL CHANGE, SHALE/SANDSTONE CONTACT ?		
9	BORING LOGS SHOW SHALE/SILTSTONE CONTACT, X-RAYS SHOW AN INDISTINCT TONAL CHANGE DIPPING 50°		
10	X-RAYS SHOWED SEVERAL WEDGE SHAPED TONAL FEATURES (SHEARS)		

APPENDIX B
Water Well Data

APPENDIX B
WATER WELL DATA

SCHULTHEIS ROAD AREA

WELLS REPORTED TO BE UNAFFECTED BY EARTHQUAKE

Well #	Parcel #	Owner	Well Depth
12	96-121-03	Aldana	150
14	96-121-19	Nutt	260
17	96-121-31	Pence	100

WELLS REPORTED TO BE DISTRESSED BY EARTHQUAKE

Well #	Parcel #	Owner	Well Depth	Possible Depth of Distress	Comments
15	96-121-06	Bertschinger	114	88	Casing squeezed down to ≈4" & punched hole in pump pipe.
141	96-121-21	Roumimper	105	97	Severe shaking, pump motor broken off pump, motor shaft bent at 90°.
218	96-121-17	Piazzo	50	14-16	Offset of 8-12" in 30" casing. Well pumping OK.

WELLS WITH WATER LEVEL INFORMATION

Well #	Parcel #	Owner	Well Depth	WL Prior/Date	WL After/Date	Comments
17	96-121-31	Pence	100	35 (undated)	60 (undated)	Also 95' (12/13/89)
141	96-121-21	Roumimper	105	19 (undated)	19 (undated)	Pump motor broke off due to severe shaking.
240	96-121-15	Wells	?	≈25 (undated)	≈25 (undated)	

VILLA DEL MONTE AREA

WELLS REPORTED TO BE UNAFFECTED BY EARTHQUAKE

Well #	Parcel #	Owner	Well Depth
19	96-131-30	Thompson	150
20	96-131-31	Jordan	200
21	96-281-05	Mitchell	240
22	96-281-06	Wilson	211
23	96-283-09	Bull	81
24	96-283-10	Ellis	165
26	96-311-44	Rexford	330
29	96-311-55	Jones	280

53	96-291-02	Broadbent	210
54	96-291-11	Biro	120
56	96-291-18	Gerhardt	210
57	96-291-19	Harrington	540
58	96-292-06	Christiani	240
59	96-292-07	Tunnicliffe	185
60	96-292-10	Browning	180
61	96-292-13	Fahrenholz	180
63	96-292-15	Riding	140
65	96-292-17	Wade	145
69	96-281-01	Carrington	230
70	96-281-09	Howell	200
72	96-281-13	Jarmann	98
73	96-281-15	Hillyard	130
76	96-281-19	Davis	200
77	96-282-01	Hernandez	70
79	96-282-04	Day	70
80	96-282-08	Anderson	140
84	96-283-11	Herbst	180
91	96-311-39	Heiman	80
92	96-311-42	Edwards	200
93	96-311-79	Casale	160
94	96-311-72	Ferrier	305
100	96-331-02	Murphy	250
101	96-332-04	Bergen	625
102	96-332-11	Szabo	260
103	96-334-03	Weldon	420
105	96-333-12	Gallagher	210
106	96-333-05	Cochran	280
108	96-333-13	Plavidal	220
109	96-302-38	Almond	340
110	96-302-44	Erfurth	225
112	96-282-02	Conkle	80
114	96-293-01	Pearce-Percy	30-50
115	96-311-51	Simmons	70
119	96-131-13	Kay	200
120	96-131-17	Dewey	220
122	96-131-28	Tershy	183
124	96-131-32	Rumasuglia	160
126	96-131-35	Gray	190
128	96-292-32	Hausle	135
129	96-302-12	Davis	98
130	96-282-06	Pefferle	125

WELLS REPORTED TO BE DISTRESSED BY EARTHQUAKE

Well #	Parcel #	Owner	Well Depth	Possible Depth of Distress	Comments
71	96-281-10	Lind	230	60	Collapsed casing, sounded by S.C.C.
74	96-281-17	Osborne	80	75	Collapsed casing, sounded by S.C.C.
75	96-281-18	Dwyer	260	17	Collapsed casing, sounded by S.C.C.
78	96-282-03	Adams	185	90	Sheared at 90'. Recovered 90' of pipe.
83	96-283-05	Johnson	240	100	Obstruction at 100'. Well pumping OK.
85	96-301-01	Lee	108	82	Partial collapse - 3" pinch-down
88	96-302-01	Schmidt	60	16	Cave in at 16'. Well pumping OK.
89	96-302-11	Earle	225	161	Collapsed casing; recovered 161' of pipe.
95	96-311-67/70	Taylor	280	17	Casing bent & broken at 17'. Tried to pull pump, but unsuccessful.
104	96-334-06	Malefyt	275	53	Collapsed casing.
125	96-131-33	Thompson	100	55	Installed pump in back-up well, hit obstruction at ≈55'.

WELLS WITH WATER LEVEL INFORMATION

Well #	Parcel #	Owner	Well Depth	WL Prior/Date	WL After/Date	Comments
26	96-311-44	Rexford	330	-	105' (undated)	Water at 81' after March 1990 rains.
60	96-292-10	Browning	180	70-75 (undated)	70-75 (undated)	
71	96-281-10	Lind	230	-	59.5 (undated)	Well collapsed at 70'
72	96-281-13	Jarman	98	-	42 (3/7/90	
75	96-281-18	Dwyer	250	-	17' (undated)	Damaged well at 17'; rusty water at 17'.
85	96-301-01	Lee	108	70-80 (1979)	30' (undated)	Casing neck-down from 6" to 3"
100	96-331-02	Murphy	250	90 (1973)	227 (12/19/89	Well went dry after several months.
104	96-334-06	Malefyt	275	38 (8/1/77)	41 (1/3/90)	Well partially collapsed at 53'.

Water Well Data
County of Santa Cruz

William Cotton and Associates

DAMAGED WELLS 8/6/90

Well No.	Well Depth (ft)	Probl Depth (ft)	Remarks	Owner
Villa Del Monte				
89	225	161	Collapsed Casing. Recovered 161' of pipe.	Earle
83	240	100	Obstruction at 100'. Well pumping OK.	Johnson
78	185	90	Sheared at 90'. Recovered 90' of pipe.	Adams
85	108	82	Partial collapse - 3" pinch-down, 3" pump pulled up past obstruction, reset at 80'. Well pumping OK	Lee
74	80	75	Collapsed casing.	Osborne
71	230	60	Collapsed casing.	Lind
104	275	53	Collapsed casing.	Malefyt
75	260	17	Collapsed casing.	Dwyer
88	60	16	Cave in at 16'. Well pumping OK	Schmidt
95	280	17	Casing bent & broken at 17'. Tried to pull pump, but unsuccessful	Taylor
100	250		Well went dry after Earthquake	Murphy
27	360	≈90?	Damaged at ≈90', not confirmed	Ruel
66	245	?	2 wells, pumps not working, tried to pull pumps, couldn't. Not confirmed.	Hewitt
82	240	?	Well damaged ?	Buehler
87	260	?	Well damaged ?	Reichert
233		?	Well damaged	Wahlenmeir
234		?	Well damaged ?	Sengstack
97	275	?	Pump stopped 1 month after Earthquake. Installed sensor, pumped but then turned off. Tried to pull pump but was tight and couldn't pull.	Paul

Well No.	Well Depth (ft)	Probl Depth (ft)	Remarks	Owner
Schultheis, Summit & Old Santa Cruz Hwy				
141	105	97	Severe shaking, pump motor broken off pump, motor shaft bent at 90°. Pump pulled, repaired and reset at 87'. Pump working OK.	Roumimper
140	420	47	Uplift of well head tore pump pipe from well, lost down hole.	Andrews
15	114	88	Casing squeezed down to ≈4" and punched hole in pump pipe. Replaced pump and pipe, reset pump at 87'. Well pumping OK.	Bertschinger
171	400	75	Well damaged at 75'	Hubbard
220		75	2 wells damaged at 75'	Rush
222	80	70	Damaged at 70'	Childers
225		60	Damaged at 60'	Worrell
125	100	55?	Pump stopped on 3/90, couldn't pull pump. Installed pump in backup well, hit obstruc tion at 55'. Was able to lower pump past obstruction and set pump at 72'. Probable collapsed casing in damaged well at ≈55'.	Thompson
218	50	14-16	Offset of 8-12" in 30" casing Well pumping OK.	Piazza
Jarvis Road				
142	465	300'	Pumped 1000 gallons of water after earth-quake, then the pump stopped. Tried to pull pump, moved about 20'. Found obstruction at 300'. Believe casing broke and gravel invaded well.	Crawford
Hutchinson Road				
144	280	58	Kink in casing at 58'. Couldn't pull pump.	Isaak

DAMAGED WELLS (cont.)

Well No.	Well Depth (ft)	Probl Depth (ft)	Remarks	Owner
Redwood Lodge Road, Soquel-San Jose, Miller Cut-off				
159	110	≈90	Well went dry after 6 weeks. Couldn't pull pump, pipe broke at ≈90'. Casing partially offset.	Downey
38	385	≈100	Well collapsed. ≈100' of PVC pipe recovered.	Iadiano
152	300	?	Well collapsed.	Victorine
170	140	?	Well quit pumping.. 8' diameter well caved in.	Rizzuto
153	410	?	Well damaged	McQuillin

DAMAGED WELLS (cont.)

In the Villa Del Monte area, 18 wells were reported damaged. Of these, 12 were confirmed; 5 wells with collapsed casings ranged in depth from 17 to 161 feet, 1 partially collapsed well casing but the pump was pulled and reset at 80 feet, just 2 feet above the 3" pinch down of the casing, 1 well reported sheared at 90 feet (probably a collapsed casing), 1 large diameter shallow well was caved in but is still pumping okay, 1 well with bent and broken casing at 17 feet, 1 well with an obstruction at 100 feet, but the well is still pumping okay, 1 well with damage (probable collapse) at 90 feet, but the status was not confirmed by the owner, 1 well which went dry right after the earthquake, 2 wells on one property and 1 on another where the pumps stopped pumping but the pumps and water pipe could not be pulled, and 4 wells which were reported damaged but never were able to confirm the damage or at what depth.

In the Malefyt well, the pump still ran electrically after the earthquake but the pump could not be pulled, therefore, the well casing was probably nearly completely collapsed.

There were one or more damaged wells in each of the 4 potential landslide areas in the Villa Del Monte area of concern.

The Schultheis Road area of concern in the Summit area had 8 damaged wells although 3 of the wells were either not damaged enough to be destroyed or were able to be repaired so that the 3 wells are currently pumping okay. One of these wells experienced severe shaking and the pump motor broke off from the pump shaft and the shaft was bent at 90 degrees. The second well's casing was collapsed down to approximately 4 inches and a hole was punched into the pump pipe but the pump was pulled, checked and reset a foot above the 88 foot damaged area. The third well had a 30 inch casing which was offset 8-12 inches at a depth of 14-16 feet but the well is still pumping okay.

Of the 5 destroyed wells, 1 was lost when the pump and water pipe was broken loose from the well head and plummeted down the hole. Four wells on the Old Santa Cruz Highway were destroyed with damage at depths of 65 to 75 feet. The fifth well stopped pumping 5 months after the earthquake but the pump could not be pulled. Another pump was installed on a well on the adjacent property but encountered an obstruction at 55 feet depth although the pump was able to be lowered past the obstruction and set at the 72 foot level. Therefore, the original well was probably partially collapsed at the 55 foot depth.

The one 465 foot well on the Jarvis Road pumped 1000 gallons of water after the earthquake and then stopped. The pump could not be pulled but the obstruction or broken casing was found at a depth of 300 feet.

The destroyed well on Hutchinson Road had a partial collapse (kink) in the casing at 58 feet but the pump couldn't be retrieved.

In the Redwood Lodge Road area, 5 wells were destroyed. Three wells were collapsed, at 100 feet, the other 2 at unknown depths and 2 other wells quit pumping, one - 6 weeks after the earthquake; both of these wells probably had collapsed casings.

POSSIBLE VIDEO PROBES

STRUCTURE	WELL #	PROBLEM DEPTH	OWNER	REMARKS
DM-1	83	100	Johnson	Obstruction at 100', well pumping OK.
DM-4	104	53	Malefyt	Casing collapse
DM-4/ED-1	100	DRY	Murphy	Water dropped in well after earthquake. Well went dry.
ED-2	89	161	Earle	Collapsed well casing, 161' casing recovered.
ED-2	85	82	Lee	Partial collapse, 3" pinch-down. Pump pulled, reset at 80'.
SB-1	97	-	Paul	Pump stopped 1 month after earthquake. Couldn't pull pipe, installed sensor but it turned off first time use.
SB-2	95	17	Taylor	Casing bent & broken at 17'
SB-3	27	90?	Ruel	Probable collapsed casing at ≈90', unconfirmed
SB-4	78	90	Adams	Casing collapsed at 90', 90' pipe recovered
SD-1	71	60	Lind	Collapsed casing
SD-1	74	80	Osborne	Collapsed casing
SD-1	75	17	Dwyer	Collapsed casing
SD-1	88	16	Schmidt	Cave in at 16', well pumping OK
SR-2	141	97	Roumimper	Severe shaking in well, pump motor broken & shaft bent to 90 degrees. Pump motor replaced. Pump reset at 87' and working OK.

Well	Owner	Remarks
17	Bruce Pence	prior to quake 35', post quake 60', 12/13/89 95' SWL
26	Elliot Rexford	post quake 105', after rain in March 81'
60	Brent Browning	before and after quake, same 70-75'
71	Fredrick Lind	well collapsed at 70', water at 59.5' - Brumbaugh
72	Adolf Jarman	SWL 42' on 3/7/90 - Brumbaugh measured
75	Daniel Dwyer	damaged well at 17', rusty water at 17' - checked by Brumbaugh, 1/11/90
83	Alden Johnson	Johnson used plumb bob and encountered obstruction at 100' after the quake
85	Harold Lee	casing neck-down from 6": to 3", pump pulled and reset at 80' (2' above 82' obstruction), 1979 - SWL 70-80' after quake - 30' per Lee.
100	James Murphy	7/19/73 - SWL 90', water dropped after quake, 12/19/89 measured 227', later water dropped to 231'. Well went dry after several months.
104	Thomas Malefyt	well partially collapsed at 53', SWL 41' per Malefyt phone call on 1/3/90. Well completion on 8/1/77 SWL 38'.
109	Anthony Almond	no water levels available but less water since the quake per Almond. Insurance Inclinometer on property.
141	Bob Roumimper	pump motor broken off due to severe shaking during the earthquake. Pump repaired and reinstalled. Roumimper reported SWL at 19' - same as before quake.
139	Fletcher Downey	8/16/68 SWL 100'. Post quake - well pumped for 6 weeks, then ran out of water. Recovered 90' of well pipe, no water at 110', only muck - 31" diameter well offset at 90' per Downey.
188	Bill Denues	July 1990 - well went dry.

SANTA CRUZ WELL HISTORIES SUMMARY 7/21/90

1.	95-011-06	23264 Schulties,Rd., Los Gatos 200' well	- Charles Griswold
2.	95-011-14	1103 Old San Jose Road, Soquel 210' well	- Salvatore Ciraulo
3.	95-011-16	Schulties Spring	- Clarence Nieland
4.	95-011-17 OK	23633 Schulties Rd., Los Gatos Pump from spring	- Jeanette Walton
5.	95-011-18	23405 Schulties Rd., Los Gatos 100' well	- Carl Engelbrecht
6.	95-011-19	23505 Schulties Rd., Los Gatos 176' well	- Richard Hickman
7.	95-012-01 OK	Woodwardia (23555 Hwy 17), Los Gatos 140' well	- Mauro Folena
8.	95-012-02	Woodwardia (23500 Hwy 17) 340' well	- Gregorio Gonzalez
9.	95-012-05	22990 Hwy 17, Los Gatos 300' well	- Mary Gacinich
10.	95-012-06	22970 Santa Cruz Hwy, Los Gatos 340' well	- Eivind Taaje
11.	95-021-09 OK	23995 Schulties Rd., Los Gatos 410' well	- Douglas Smucker
12.	96-121-03 OK	22850 Summit Rd., Los Gatos 150' well	- Ron & Jackie Aldana
13.	96-121-04 NC	22890 Summit Rd., Los Gatos 350' well	- Fred Wool
14.	96-121-19 OK	22912 Summit Rd., Los Gatos 260' well, 2nd well not checked since quake	- Jim Nutt
15.	86-121-06 T Pumping OK	22930 Summit Rd., Los Gatos 114' well Earthquake damage -pump pulled, hole in pump pipe at 88'. Casing partially crimped at 88'. New pump and pipe installed but wouldn't pass 88' mark, set pump at 87' and	- George Bertschinger

is working OK.

16.	95-011-05 OK	Next to 23300 Schulties, Los Gatos Spring.	- Tony Piazza
17.	96-121-31	23270 Schulties Rd., Los Gatos 100' well	- Bruce & Arlene Pence
18.	96-121-27	22870 Old Santa Cruz Hwy 140' well	- Fred Rothweiler
19.	96-131-30 OK	23120 Summit Rd (Bunny Ranch Rd.) LG 150' well	- Trent Thompson
20.	96-131-31 OK	23144 Bunny Ranch Rd. off Summit, LG 200' well	- Wm. Jordan
21.	96-281-05 OK	23005 Del Monte Way 240' well	- Edward Mitchell
22.	96-281-06 OK	23440 Summit Rd., Los Gatos 211' well	- Lawrence Wilson
23.	06-283-09 OK	23490 Sunset Drive 81' well	- Charles Bull
24.	96-283-10 OK	23492 Sunset Drive 165' well	- Charles Ellis
25.	96-292-27 NC	23498 Skyview Terrace 105' well. Belongs to Water Co., pumped motor burned out prior to quake.	- Theodore Faley
26.	96-311-44 OK	Skyview Terrace, Los Gatos 330' well 1'	- Elliot Rexford
27	96-311-85 T	Bell Air Court, off Skyview, Los Gatos 360' well. Tried to pull pump, couldn't.	- Dusty Ruel
28.	96-311-59 A	23490 Bel Air Court, Los Gatos Well - No data. Well covered over for 3-5 years.	- Ralph Adams
29.	96-311-55 OK	23575 Skyview Terrace, Los Gatos 280' well	- Royce Jones
30.	96-251-06	24500 Miller Hill Road, Los Gatos 320' well	- Christopher Beach
31.	96-231-08	25030 Old San Jose Road, Los Gatos	- Eric Hagedorn

		283' well.	
32.	97-081-27	25150 Old San Jose Rd., Los Gatos 245' well	- Kerry Smith
33.	97-031-08 OK	24945 Soquel-San Jose Rd., Los Gatos 200' well	- Victor Grabeel
34.	97-051-19	Next to 25105 Soquel Rd., Los Gatos 280' well	- John Bates
35.	97-041-07 OK	Soquel-San Jose Rd., Los Gatos 320' well	- Don Good
36.	97-041-08 OK	Old San Jose Road, Los Gatos 370' well	- David Fullagar
37.	97-041-20 OK	Old San Jose Road, Los Gatos 150' well	- Bernard Bohlin
38.	97-071-14 T	15930 Redwood Lodge Road, Los Gatos 385' well - Well collapsed, recovered 100' pipe, scuff marks on pipe.	- Frank Iadiano
39.	97-071-16 NC	15960 Redwood Lodge Road, Los Gatos 420' well	- Dave Taban-Nejad
40.	97-071-20 OK	16000 Redwood Lodge Road, Los Gatos 360' well	- Aubrey Keich
41.	96-221-66	34591 Miller Cut-off 300 well	- Jim Murray
42.	96-261-02	24705 Miller Hill Road, Los Gatos 240' well	- Ron Parker
43.	96-261-12	24995 Miller Cut-Off, Los Gatos Well serves 3 parcels (96-261-13,14 & 12) 150' well	- John Harkness
44.	96-271-04	24740 Miller Hill Road, Los Gatos 100' well	- Wayne Worthington
45.	96-271-07	24600 Miller Hill Road, Los Gatos 250' well	- Andre Kobel
46.	96-271-09	24600 Miller Hill Road, Los Gatos 200' well	- Ray Persico

47.	96-271-11	24614 Miller Rd., Los Gatos 400' well	- Dan Duc
48.	97-091-05	Stetson Rd., Los Gatos 105' well	- Dr. Stanley Skillicorn
49.	97-091-22	24780 Miller Hill Rd. (Longview Dr.) 150' well	- Gerald McCutchen
50.	97-091-21	24777 Miller Hill (Longview Dr.) 160' well, 2nd well 300'	- Victor Longa
51.	97-091-27	Oceanview off Skyland 520' well	- David Wiemken
52.	97-091-28	24775 Miller Hill Rd., Los Gatos 220' well	- Chris Springer
53.	96-291-02 OK	23414 Sunset Dr., Los Gatos 210' well	- K. Broadbent
54.	96-291-11 OK	23043 Evergreen & Deerfield, Los Gatos 120' well	- Anthony Biro
55.	96-291-14 A	23430 Sunset, Los Gatos 55' well, hasn't used well in 35 years, abandoned	- Sterner
56.	96-291-18 OK	23418 Sunset Drive 210' well	- John Gerhardt
57.	96-291-19 OK	23416 Sunset Dr., Los Gatos 540' well	- Tim Harrington
58.	96-292-06 OK	23054 Evergreen Ln., Los Gatos 240' well	- Larry Christiani
59.	96-292-07 OK	23056 Evergreen Ln., Los Gatos 185' well	- John Tunnicliffe
60.	96-292-10 OK	23062 Evergreen Ln., Los Gatos 180' well	- Brent Browning
61.	96-292-13 OK	23061 Evergreen Ln., Los Gatos 180' well	- Thomas Fahrenholz
62.	96-292-14 OK	23059 Evergreen Ln., Los Gatos Well	- Stephen Nemeth

63.	96-292-15 OK	23055 Evergreen Ln., Los Gatos 140' well	- Kenneth Riding
64.	96-292-16 OK	23051 Evergreen Ln., Los Gatos Well	- Jane Trujillo
65.	96-292-17 OK	23430 Deerfield Rd., Los Gatos 145' well	- Jack Wade
66.	96-292-29 T ?	23462 Skyview Terrace, Los Gatos 245' well	- Wm. Hewitt Jr.
67.	96-292-33 OK	23650 Skyview Terrace, Los Gatos Well, serves Parcels 96-292-34, 96-311-68 & 69	- James Graebner
68.	96-292-34 OK	23048 Del Monte Way Well	- Larry Falcinello
69.	96-281-01 OK	23416 Summit, Los Gatos 230' well	- Rebecca Carrington
70.	96-281-09 OK	23449 Sunset Dr., Los Gatos 200' well	- Thomas Howell
71.	96-281-10 T	23441 Sunset Dr., Los Gatos 230' well Problem at 60', tried to pull pump, only moved 2'	- Frederick Lind
72.	96-281-13 OK	23426 Summit, Los Gatos 98' well	- Adolf Jarmann
73.	96-281-15 OK	23415 Sunset Dr., Los Gatos 130' well, 2 other wells OK	- Duane Hillyard
74.	96-281-17 T	23433 Sunset Dr., Los Gatos 80' well Trouble at 75'	- Robert Osborne
75.	96-281-18 T	23435 Sunset Dr., Los Gatos 250' well Trouble at 17', rusty water at 17'	- Daniel Dwyer
76.	96-281-19 OK	23428 Summit, Los Gatos 200' well	- Thomas Davis
77.	96-282-01 OK	Summit & Del Monte Way, Los Gatos 70' well	- Luis Hernandez

78.	96-282-03 T	23484 Summit, Los Gatos 185' well Well sheared at 90', recovered 90' of pump pipe	- Dr. Jerod Adams
79.	96-282-04 OK	23486 Summit Dr., Los Gatos 70' well	- Kenton Day
80.	96-282-08 OK	23475 Sunset Dr., Los Gatos 140' well	- Kenneth Anderson
81.	96-283-13 OK	Sunset Dr., Los Gatos 2 wells	- Ed Bush
82.	96-283-03 T ?	23454 Sunset Dr., Los Gatos 240' well	- Roland Buehler
83.	96-283-05 T Pumping OK	23476 Sunset Dr., Los Gatos 240' well Obstruction at 100' but well pumping OK	- Alden Johnson
84.	96-283-11 OK	23494 Sunset Dr., Los Gatos 180' well and 2nd well 76'	- Carl Herbst
85.	96-301-01 T	23240 Deerfield, Los Gatos 108' well Well cave-in 7', & well casing neck-down or obstruction at 82'. Pump pulled up & worked past neck/obstruction (Casing ID 6", Pipe OD ~ 3"). Lowered pump to neck-down, acted like a shelf, reset pump 2' above neck-down at 80'. Now pumping at 80' - more water now than before Quake.	- Harold Lee
86.	96-301-04 OK	23390 Deerfield, Los Gatos Well	- Eugene Leman
87.	96-301-06 T ?	23382 Deerfield, Los Gatos 260' well. Well also serves 96-301-04	- Reichert
88.	96-302-01 T Pumping OK	23423 Deerfield, Los Gatos 60' well Cave in 16', but pump below & pumping OK, could have occurred prior to earthquake.	- Dieter Schmidt
89.	96-302-11 T	23309 Deerfield, Los Gatos 350' well Well sheared or collapsed at 160'. Tried to pull pump, pump snug, pulled 160' pipe, rope broke & still in well.	- Tom Earle
90.	96-311-25	23476 Bel Air Court, Los Gatos	- Paul Breen

	OK	Well	
91.	96-311-39 OK	23547 Sky View Terrace, Los Gatos 80' well	- Eric Heiman
92.	96-311-42 OK	23525 Sky View Terrace, Los Gatos 200' well	- Mary Ellen Edwards
93.	96-311-79 OK	Sky View Terrace, Los Gatos 160' well	- Casale
94.	96-311-72 OK	23533 Sky View Terrace, Los Gatos 315' well	- Ferrier
95.	96-311-67/70 T	23545 Tree View Trail, Los Gatos Well Pipe bent & broken at 17'. Tried to pull pump, couldn't.	- Priscilla Taylor
96.	96-311-71 OK	23500 Tree View Trail, Los Gatos Well	- Broadbent
97.	96-311-83 T ?	23507 Sky View Terrace, Los Gatos 275' well. Well serves Parcel 96-311-33 also. Well quit 1 month after quake, installed sensor, quit also. Tried to pull pump, couldn't, pipe tight.	- Randolph Paul
98.	96-311-78 NC	23535 Sky View Terrace, Los Gatos 200' well	- James Francy
99.	96-331-01	23634 Skyview Terrace, Los Gatos 250' well	- Donald Kelley
100.	96-331-02 T	23632 Skyview Terrace, Los Gatos 250' well Water dropped after quake, then went dry after several months.	- James Murphy
101.	96-332-04 OK	23616 Skyview Terrace, Los Gatos 625' well	- Mike Bergen
102.	96-332-11 OK	23584 Skyview Terrace, Los Gatos 260' well	- Robert Szabo
103.	96-334-03 2 OK	23613 Skyview Terrace, Los Gatos 420' well & 2nd well	- Ed Weldon
104.	96-334-06 T	23599 Skyview Terrace, Los Gatos 275' well Well pipe broken at 53' but electrically still connected	- Thomas Malefyt

105.	96-333-12 OK	23635 Skyview Terrace, Los Gatos 210' well. Well shared with 96-333-13.	- Peter Gallagher
106.	96-333-05 OK	23652 Skyview Terrace, Los Gatos 280' well	- Wilson Cochran
107.	96-333-06	23650 Skyview Terrace, Los Gatos 160' well	- Michael D'Addio
108.	96-333-13 OK	23637 Skyview Terrace, Los Gatos 220' well	- Richard Plavidal
109.	96-302-38 OK	23346 Deerfield Dr., Los Gatos 340' well Pump weak, less water since the earthquake	- Almond
110.	96-302-44 OK	23415 Deerfield, Los Gatos 225' well	- Bill Erfurth
111.	96-302-41 2 OK	23343 Deerfield, Los Gatos 2 wells - both OK	- Bridgeman
112.	96-282-02 OK	23480 Summit Rd., Los Gatos 80' well	- Conkle
113.	96-293-05 OK	23441 Skyview, Los Gatos Well	- Bravo
114.	96-293-01 OK	23415 Sunset Dr., Los Gatos 30 - 50' well	- Pearce-Percy
115.	96-311-51 OK	Skyview Dr., Los Gatos 70' 30" diameter well	- Simmons
116.	96-111-01 OK	23021 Old Santa Cruz Highway, Los Gatos 190' well	- Dick Gabler
117.	96-131-27	23116 Summit Road, Los Gatos 160' well	- Richard Barton
118.	95-021-21	Schulties Road, Los Gatos 220' well	- Bob Hickman
119.	96-131-13 OK	23080 Summit 200' well	- Ronald Kay
120.	96-131-17 OK	23060 Summit Road, Los Gatos 220' well	- Charles Dewey

121.	96-131-22	23136 Summit 100' well	- Donna Hines
122.	96-131-28 OK	23120 Summit (Bunny Ranch Rd.) 183' well	- Russell Tershy
123.	96-131-29	23128 Summit 270' well	- Jerry Brown
124.	96-131-32 OK	23122 Summit 160' well	- John Rumasuglia
125.	96-131-33 T	23124 Summit 200' well. Well serves 96-131-33 (well) & 96-131-34. Pumped for 5 months, then quit, couldn't pull pump. Obstruction at 55'.	- Trent Thompson
126.	96-131-35 OK	23064 Summit 190 ' well 1	- Glen Gray
127.	96-281-14	Sunset Drive, Los Gatos 200' well	- Central Cal Mort.
128.	96-292-32 OK	23444 Sunset Dr., Los Gatos 135' well	- Steven Hausle
129.	96-302-12 OK	23383 Deerfield Rd., Los Gatos 98' well	- Mark Davis
130.	96-282-06 OK	23485 Sunset Dr., Los Gatos 125' well	- Pefferle
131.	96-283-12 OK	23496 Sunset Dr., Los Gatos Well	- Nava
132.	96-251-02	24530 Miller Hill Rd., Los Gatos Well	- Bruno Broseghini
133.	96-251-03	24550 Miller Hill Rd., Los Gatos 210' well	- Kathy Frutchey
134.	97-041-13 OK	16155 Redwood Lodge Rd., Los Gatos 650' well	- Parviz Mahdavi
135.	97-041-14 OK	16195 Redwood Lodge Rd., Los Gatos 303' well. Less water since earthquake.	- Luke Rizzuto
136.	97-041-15	16161 Redwood Lodge Rd., Los Gatos	- Bob Baker

		405' well	
137.	97-041-16 OK	16167 Redwood Lodge Rd., Los Gatos 600' well	- Stanley Voyles
138.	97-041-17 OK	16151 Redwood Lodge Rd., Los Gatos 498' well	- Dan Netzley
139.	97-051-17	25119 Soquel-San Jose Rd., Los Gatos 127' well	- Robert Goodenought
140.	96-111-06 T	23020 Old Santa Cruz Highway, Los Gatos 420' well Casing bent to NW at 47', well head pulled off, pipe & pump dropped down hole.	Tony Andrews
141.	96-121-21 T Pumping OK	23250 Schulties Rd., Los Gatos 105' well. Supplies water to Parcel 96-121-20. Pump pulled. Pump motor had been broken from pump at 97' and remained in hole, shaft was bent at 45 degree angle. Pump repaired & reset at 87'. Well pumping OK.	- Bob Roumimper
142.	95-181-04 T	8191 Jarvis Road, Santa Cruz 465' well. Problem at 300'. Pumped 1000 gals after earthquake after storage tank fixed and pump stopped. Tried to pull pump, only moved 20'. Lowered rope into well & found damaged well area, then pulled out. Tied socket wrench to rope & lowered. Destroyed 10' past damaged area. Tried to retrieve rope & wrench but couldn't. Believe that plastic casing is broken and gravel has invaded the well and buried the pump. Also think that casing is bent to south because stones dropped into the well hit the side of the casing.	- Bruce Crawford
143.	96-361-04	22820 Hutchinson Rd., Los Gatos 250' well	- Steve Yazen
144.	96-361-08 T	22831 Hutchinson Rd., Los Gatos 280' well Found kink in casing at 58'. Pump at 260', tried to pull pump out past kink, but couldn't. Electrical wiring was torn off but was dry.	- Merlyn Isaak
145.	96-361-21	22540 Hutchinson Rd., Los Gatos 324' well	- Jacob Bomerin
146.	96-361-22	22060 Hutchinson Rd., Los Gatos Well	- Steve Sweeters
147.	97-031-37 OK	24985 Soquel San Jose Rd., Los Gatos 240' well	- Larry Lopp

148.	97-031-12 OK	16205 Redwood Lodge Rd., Los Gatos 400' well	- Walter Carlos
149.	97-031-17 OK	16089 Redwood Lodge Rd., Los Gatos 300' well	- Wm. Von Rotz
150.	97-031-20	16095 Redwood Lodge Rd., Los Gatos 360' well 4 wells serve 97-031-20 & -19	- Michael Lindsay
151.	97-031-26	Redwood Lodge Rd., Los Gatos 200' well	- Jim Young
152.	97-031-27 T	16099 Redwood Lodge Rd., Los Gatos 300' well Well collapsed	- George Victorine
153.	97-031-30	Redwood Lodge Rd., Los Gatos 200' well	- Kevin McQuillin
154.	97-031-31	16081 Redwood Lodge Rd., Los Gatos 120' well	- Robert Friday
155.	97-031-38	16101 Redwood Lodge Rd., Los Gatos 210' well	- Michael Teresa
156.	97-061-08 OK	16214 Redwood Lodge Rd., Los Gatos 297' well	- Jack Roberts
157.	97-061-20	16200 Redwood Lodge Rd., Los Gatos 400' well	- Marilyn Waiton
158.	97-061-21	16210 Redwood Lodge Rd., Los Gatos 425' well	- Richard Henderson
159.	97-061-30 T	16040 Redwood Lodge Rd., Los Gatos ~ 110' well Post Quake - Pumped water for 6 weeks, then no water. Tried to pull pump but black poly draw pipe broke at ~ 90'. No water at 110', only muck. 30" well offset at 90'?	- Fletcher Downey
160.	97-061-32	25256 Terrace Grove, Los Gatos 225' well	- Frank Schonig
161.	97-061-37	25240 Terrace Grove, Los Gatos 380' well	- Lee Findley
162.	97-061-39	25237 Terrace Grove, Los Gatos	- Robert Stille

220' well

163. 97-071-18 25119 Soquel San Jose Rd., Los Gatos - Evelyn Lim
300' well

164. 97-081-07 15645 Stetson Rd., Los Gatos - John Luckhardt
300' well

165. 97-081-23 15441 Stetson Rd., Los Gatos - Dan Starick
350' well

166. 97-081-24 24778 Miller Hill Rd., Los Gatos - Scott Skillicorn
303' well

167. 97-091-15 15377 Stetson Rd., Los Gatos - Jenny Cox
164' well

168. 97-271-16 24610 Miller Hill Rd., Los Gatos - Gerhardt Schlecht
201' well

169. 97-271-18 24600 Miller Hill Rd., Los Gatos - Gerhardt Schlecht
OK
320' well, plus 3 other wells. Wells serve 96-271-18 & -19

170. 97-041-22 16195 Redwood Lodge Rd., Los Gatos - Violet Rizutto
T
140' & 24' wells
Deep well quit & shallow 8' diameter well collapsed

171. 96-061-07 17800 Old Summit Rd., Los Gatos - Scott Hubbard
T
400' well
Collapsed well at 75'

172. 96-061-11 17774 Old Summit Rd., Los Gatos - Reza Almineih
OK
150' well

173. 96-091-03 17430 Old Summit Rd., Los Gatos - Gordon Emerson
OK
300' well

174. 96-091-05 22616 Summit Rd., Los Gatos - Joseph Howard
OK
137' well

175. 96-091-08 22654 Summit Rd., Los Gatos - Sol Saks
OK
100' well

176. 96-091-12 22889 Summit Rd., Los Gatos - Roger Caron
240' well

177. 96-091-13 17430 Summit Rd., Los Gatos - Mark Kritz
OK
210' well

178.	96-091-20 OK	22666 Summit Rd., Los Gatos 205' well	- Bill Roster
179.	96-091-23 OK	22682 Summit Rd., Los Gatos 90' well	- Robert Stefan
180.	96-091-24 OK	22666 Summit Rd., Los Gatos ~ 250' well New well to supplement existing well - poor yielder	- Earl Way
181.	96-151-01 OK	23490 Summit Rd., Los Gatos 260' well	- David Bouley
182.	96-151-02 OK	23520 Summit Rd., Los Gatos 175' well. Moved to 2nd well	- Paul Timason
183.	96-151-08 T	23540 Summit Rd., Los Gatos 120' well Pump stopped, well ran out of water	- Bill Denues
184.	96-151-10 OK	23580 New Summit Rd., Los Gatos 320' well	- Guy Denues
185.	96-151-11 OK	23584 Summit Rd., Los Gatos 400' well More water since the earthquake.	- Eberhard Ehrich
186.	96-151-13	23700 Morrell Rd., Los Gatos Well #1 76', Well #2 84', Well #3 340'	- Louis Klindt
187.	96-151-14	23800 Morrell Rd., Los Gatos Well	- Tom O'Neill
188.	96-151-15 OK	23610 Morrell Rd., Los Gatos 200' well	- Louise Merrill
189.	96-151-16 OK	23620 Morrell Rd., Los Gatos Well. Not adequate water - has always gotten water from 96-151-15.	- Carroll Diaz
190.	96-151-25	23800 Summit Rd., Los Gatos 322' well	- Loma Prieta Joint School District
191.	96-161-10 OK	23900 Summit Rd., Los Gatos 285' well	- Ramond Haworth
192.	96-161-12	23557 Morrell Rd., Los Gatos 140' well	- Andrew Silverman

193.	96-161-33 OK	23914 Summit Rd., Los Gatos 200' well	- Lynn Care
194.	96-161-34 OK	23920 Summit Rd., Los Gatos Well. Better water since earthquake	- Wm. McKown
195.	96-161-35 OK	23946 Summit Rd., Los Gatos - Mt. Bible Church of Loma Prieta 100' well	
196.	96-161-43 OK	23940 Summit Rd., Los Gatos 300' well	- Ken Self
197.	96-161-39 OK	24060 Summit Rd., Los Gatos 320' well	- David Moulton
198.	96-161-40 OK	24040 Summit Rd., Los Gatos 230' well	- Greg Vasche
199.	96-161-41 OK	24010 Summit Rd., Los Gatos 260' well	- Robert Stanton
200.	96-161-44 OK	23940 Summit Rd., Los Gatos 250' well	- Ed Mitchell Jr.
201.	96-171-08	24205 Summit Rd., Los Gatos 175' well	- Gordon Athearn
202.	96-171-15	24389 Loma Prieta Ave., Los Gatos 180' well	- Howard Waage
203.	96-171-16	24201 Loma Prieta Ave., Los Gatos 200' well	- Richard Spranzo
204.	96-171-32	24261 Loma Prieta, Los Gatos 300' well	- Hazel Smith
205.	96-171-34	24325 Loma Prieta, Los Gatos 102' well	- Harry Schoenfeld
206.	96-171-36 OK	24333 Loma Prieta, Los Gatos 240' well	- Kathy Gorham
207.	96-171-38 OK	24355 Loma Prieta, Los Gatos 130' well	- Jon Long
208.	96-171-42 NC	24383 Loma Prieta, Los Gatos 325' well	- Robert Thompson

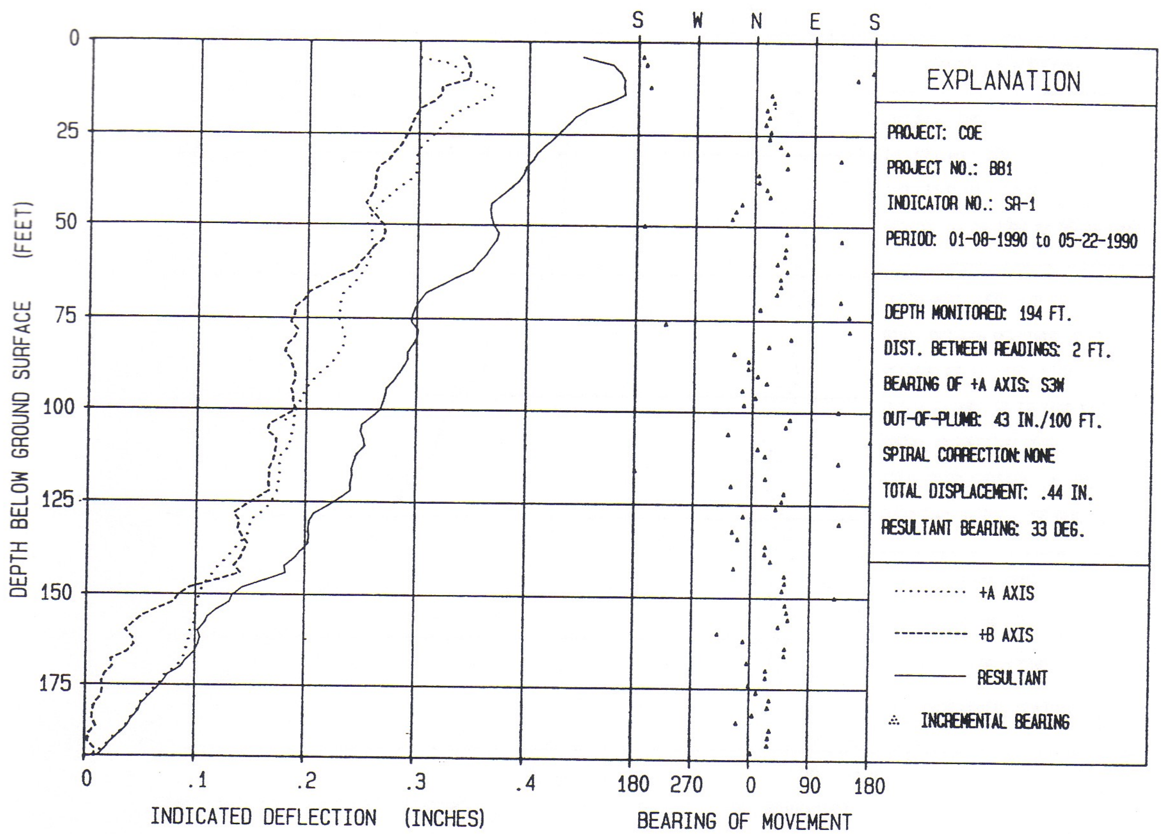
209.	96-171-44 NC	24177 Loma Prieta, Los Gatos Well House down from earthquake	- Charles Jackson
210.	96-171-46	24193 Summit Dr., Los Gatos 255', 320' & 72' wells	- Don Jeske
211.	96-171-49	24181 Loma Prieta, Los Gatos 80' well	- Lewis Rollins
212.	96-201-08	24571 Soquel San Jose Rd., Los Gatos 80' well. Well shared with Parcel 96-201-17..	- Hendrikus Van der Pyl
213.	96-201-15	24569 Old San Jose Rd., Los Gatos Well	- Michael Thomas
214.	96-201-19	24181 Soquel San Jose Rd., Los Gatos 150' well. Well serves Parcels 96-201-18, -31, & -32.	- Barnes Parker
215.	96-201-28	24567 Old Soquel Rd., Los Gatos Well	- Orvell Kanady
216.	96-201-29	24190 Summit Rd., Los Gatos 255' well	- Alan Clark
217.	96-161-37 OK	23960 Summit Dr., Los Gatos 217' Nearly dry, pumping from spring.	- Eric Isacson
218.	96-121-17 T Pumping OK	23300 Schulthies Rd., Los Gatos 50' well Offset 8-12" in 30" well at 14-16'. Well pumping OK.	- Tony Piazzo
219.	96-061-10 OK	17788 Old Summit Rd., Los Gatos 280' well. Checked OK 5/90.	- John Ray
220.	96-061-05 T	17770 Old Summit Rd., Los Gatos 2 wells. Both damaged at 75'.	- William Rush
221.	96-061-08 NC	17776 Old Summit Rd., Los Gatos 100' well House destroyed, awaiting County disposition	- Peter Blacklock
222.	96-061-02 T	17750 Old Summit Rd., Los Gatos 85' well Well damaged at 70', reset pump at 30', but not enough water.	- Winston Childers
223.	96-081-03 OK	17650 Old Summit Rd., Los Gatos 258' well	- Jeffery White

224.	96-081-06 OK	17550 Old Summit Rd., Los Gatos Well	- Raymond Hebert
225.	96-081-18 T	17546 Old Summit Rd., Los Gatos 280' well Well damaged at 60'. Pump wire & casing not broken but squeezed. Redrill - dry hole 7/90.	- Burton Worrell
226.	96-081-10	23400 Old Santa Cruz Hwy., Los Gatos 245' well	- Lucinda Martin
227.	96-081-14	23394 Old Santa Cruz Hwy. Los Gatos 255' well	- Norman Evans
228.	96-081-15 OK	23378 Old Santa Cruz Hwy., Los Gatos 85' well	- Robert Holms
229.	96-081-16 OK	23149 Old Santa Cruz Hwy., Los Gatos Well in 1971	- Paul Gray
230.	96-081-09	23376 Old Santa Cruz Hwy, Los Gatos 200' well	- Jerry Koopman
231.	96-081-20 A	23175 Old Santa Cruz Hwy, Los Gatos Well abandoned. 2/3 interest in 96-081-18	- Diana Eglash
232.	96-292-20 OK	23454 Sky View Terrace, Los Gatos Well	- Doug Henderson
233.	96-301-05 T ?	23386 Deerfield Rd., Los Gatos Well. Minimal well, never for drinking	- Wayne Wahlenmier
234.	96-302-14. T ?	23361 Deerfield Rd., Los Gatos 420' well	- Edward Sengstack
235.	96-302-15 OK	23353 Deerfield Rd., Los Gatos 200 - 300' well & second well	- John Schlosser
236.	96-302-20 NC	23335 Deerfield Rd., Los Gatos Well House razed after Earthquake.	- Gary Clark
237.	96-302-21, 22 OK	23340 Deerfield Rd., Los Gatos 365' well	- John Morlan
238.	96-302-46 OK	23409 Deerfield Rd., Los Gatos Well	- Charles Lyons

239. 96-333-01 Sky View Terrace, Los Gatos - Ted Anderson
Well

APPENDIX C

Representative Inclinometer Data



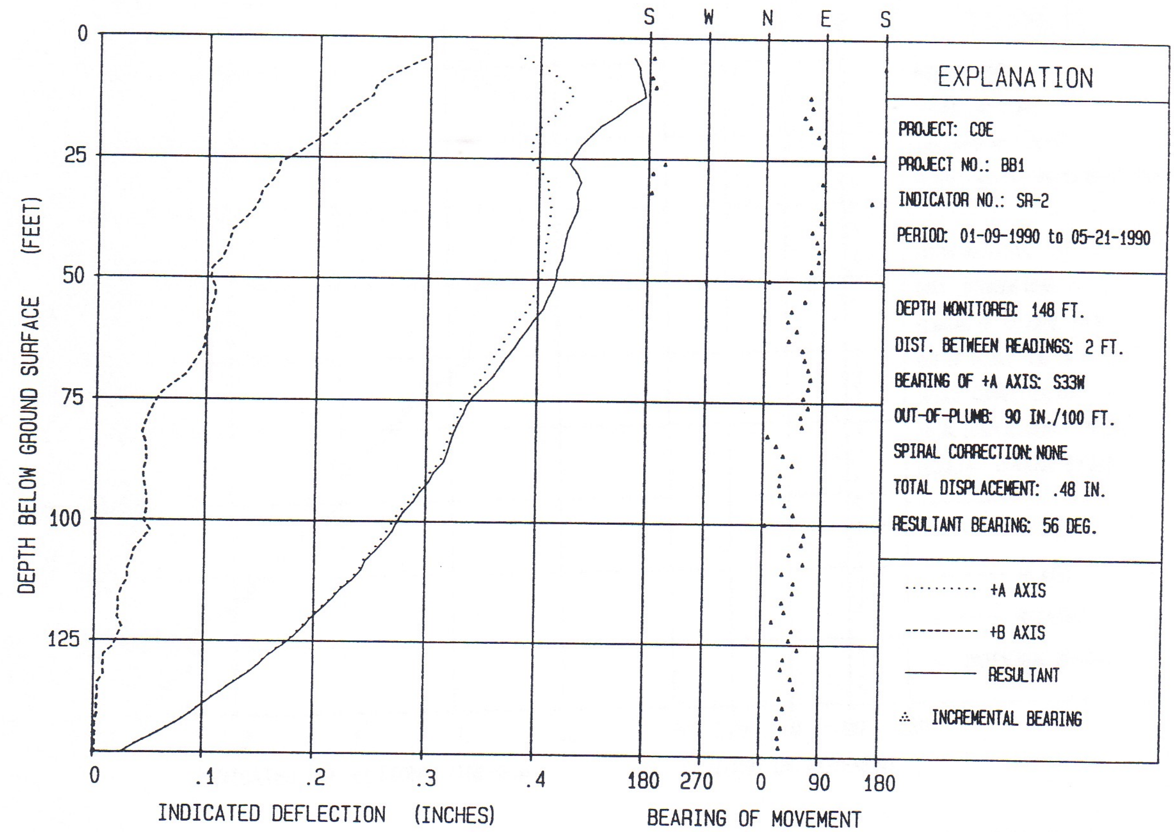
SR-1

William Cotton and Associates

INCLINOMETER SURVEY DATA, SR-1

SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
SANTA CRUZ COUNTY, CALIFORNIA

GEO/ENG. BY	SCALE	PROJECT NO.
DRM	As Shown	G1409
APPROVED BY	DATE	FIGURE NO.
[signature]	9/30/90	C-1



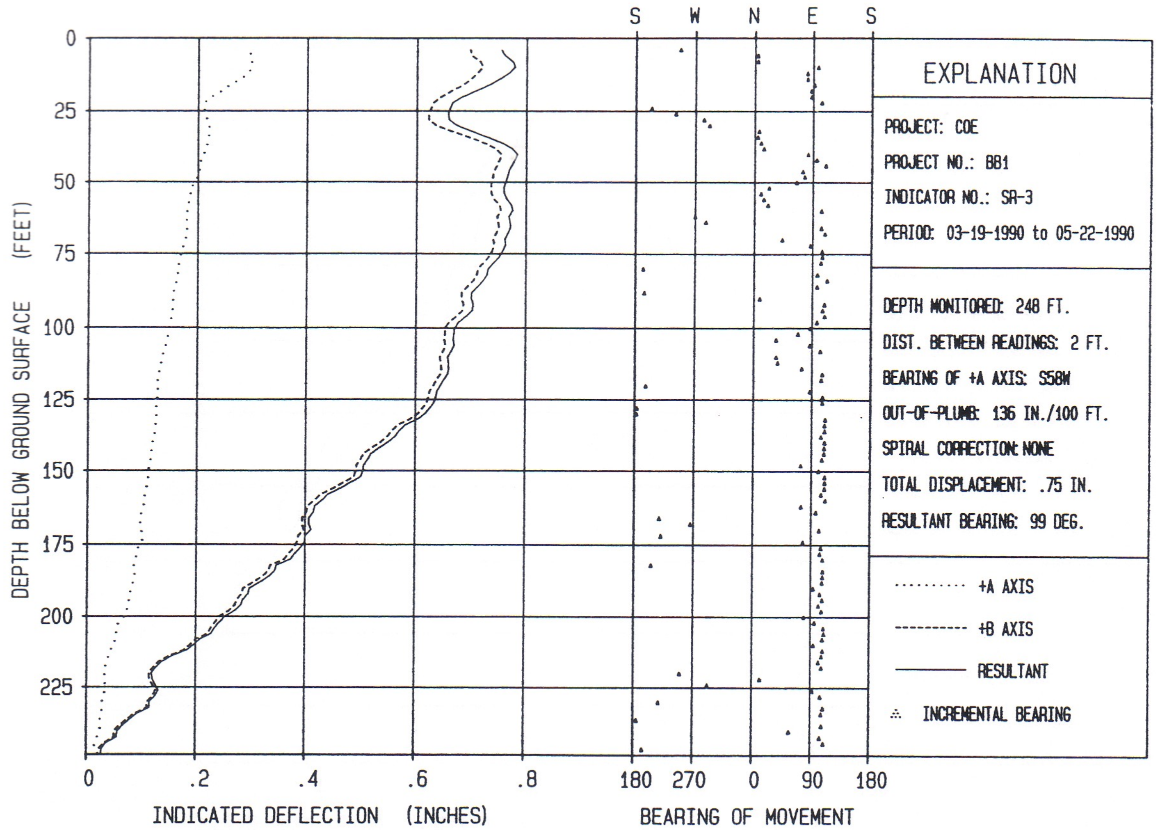
SR-2

William Cotton and Associates

INCLINOMETER SURVEY DATA, SR-2

SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
SANTA CRUZ COUNTY, CALIFORNIA

GEO/ENG. BY	SCALE	PROJECT NO.
DRM	As Shown	G1409
APPROVED BY	DATE	FIGURE NO.
BOS.	9/30/90	C-2



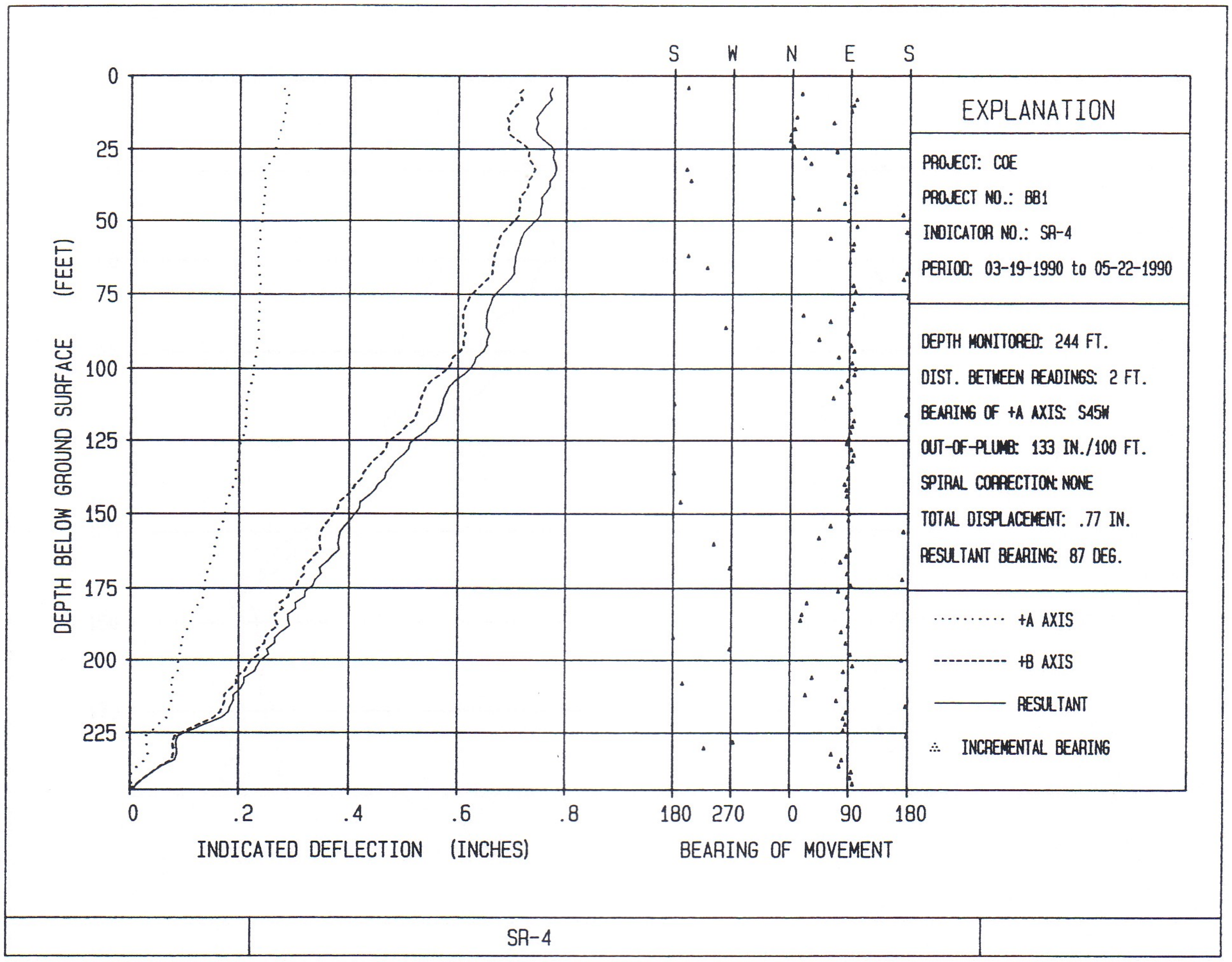
SR-3

William Cotton and Associates

INCLINOMETER SURVEY DATA, SR-3

SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
SANTA CRUZ COUNTY, CALIFORNIA

GEO/ENG. BY	SCALE	PROJECT NO.
DRM	As Shown	G1409
APPROVED BY	DATE	FIGURE NO.
RO.S.	9/30/90	C-3

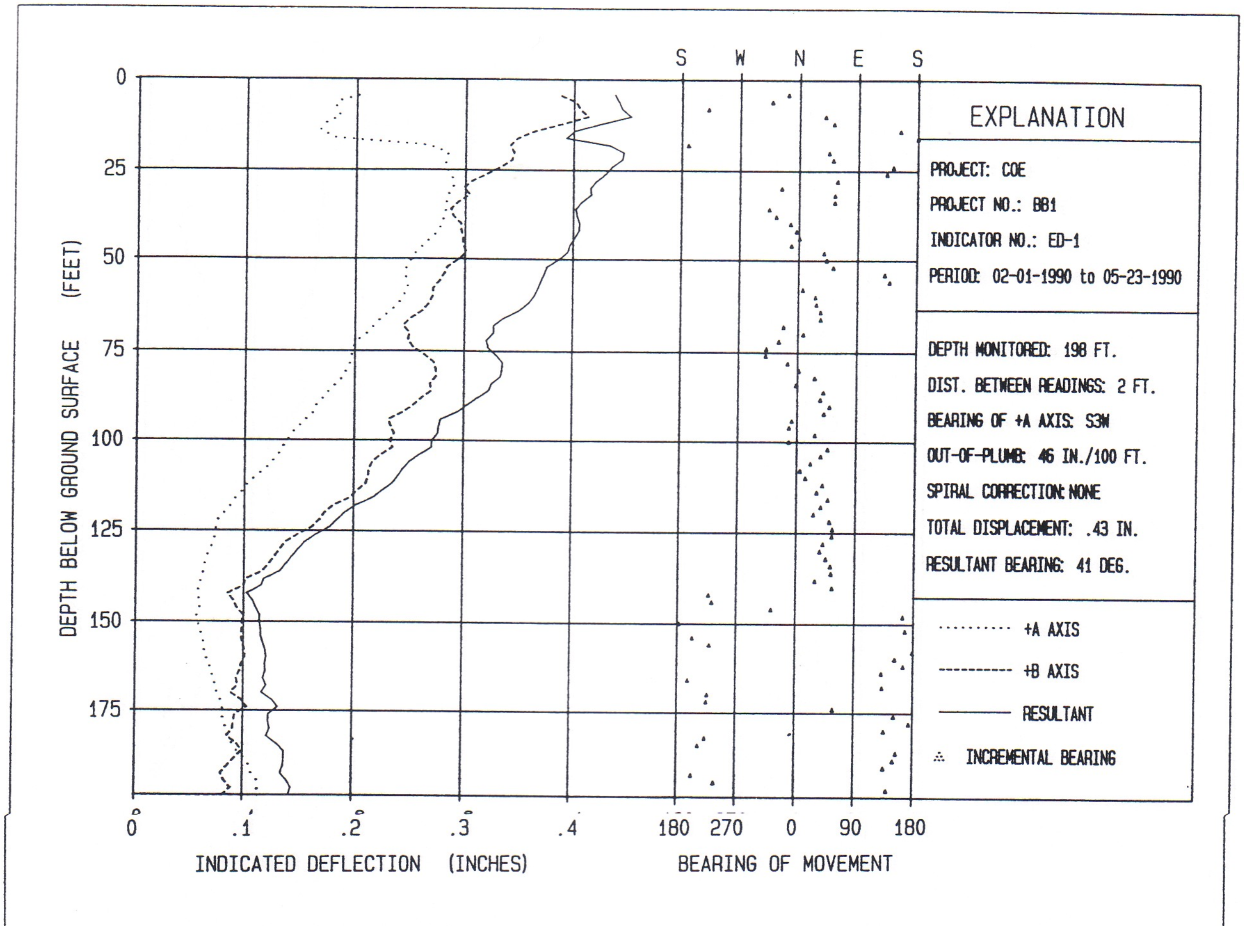


William Cotton and Associates

INCLINOMETER SURVEY DATA, SR-4

SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
SANTA CRUZ COUNTY, CALIFORNIA

GEO/ENG. BY	SCALE	PROJECT NO.
DRM	As Shown	G1409
APPROVED BY	DATE	FIGURE NO.
R.O.S.	9/30/90	C-4



ED-1

William Cotton and Associates		
INCLINOMETER SURVEY DATA, ED-1		
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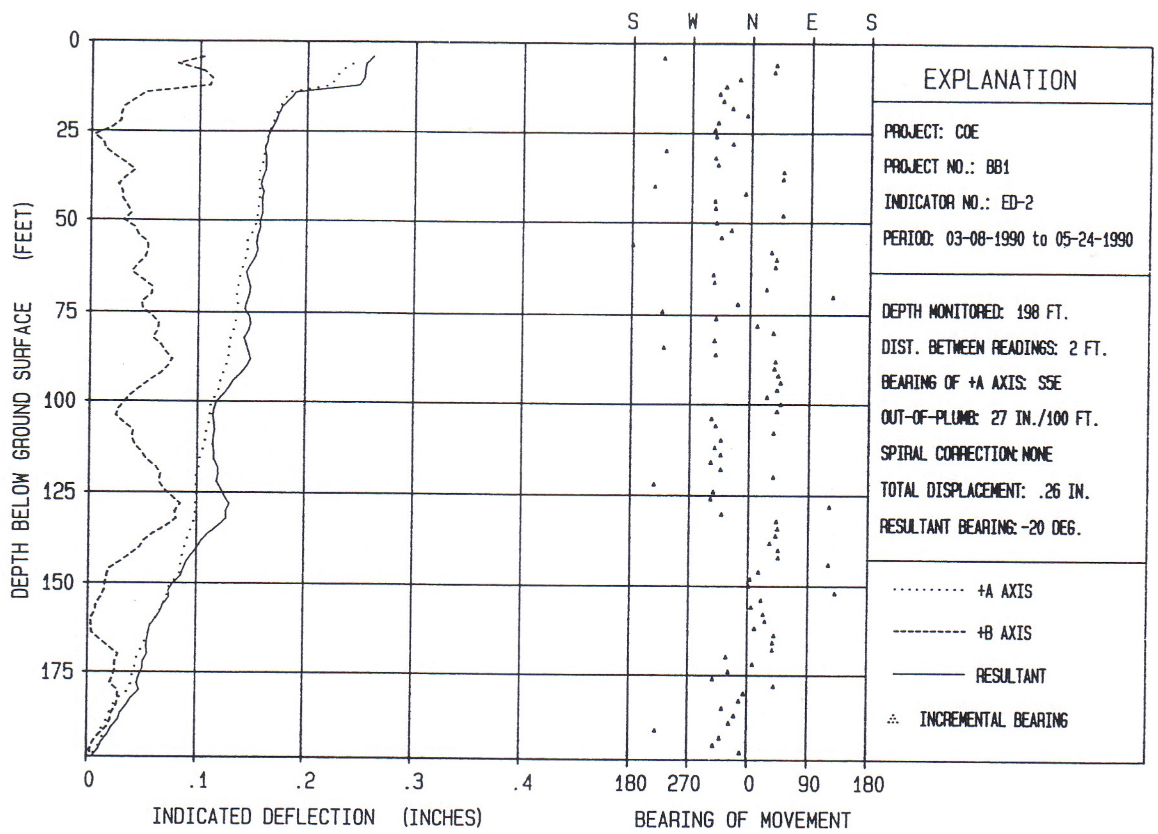
GEO/ENG. BY DRM	SCALE As Shown	PROJECT NO. G1409
APPROVED BY [signature]	DATE 9/30/90	FIGURE NO. C-5



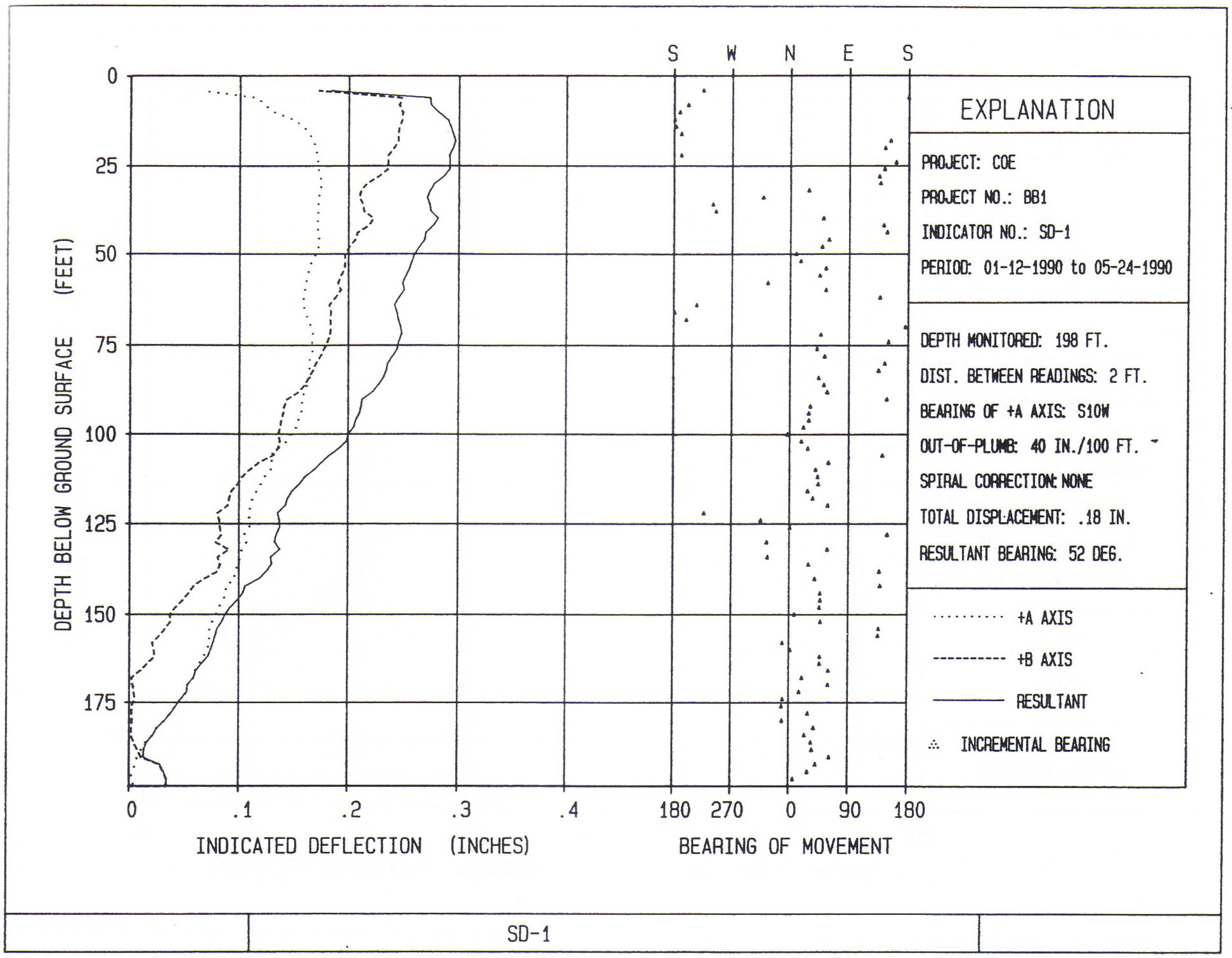
ED-2

William Cotton and Associates

INCLINOMETER SURVEY DATA, ED-2

SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
SANTA CRUZ COUNTY, CALIFORNIA

GEO/ENG. BY	SCALE	PROJECT NO.
DRM	As Shown	G1409
APPROVED BY	DATE	FIGURE NO.
QOS	9/30/90	C-6



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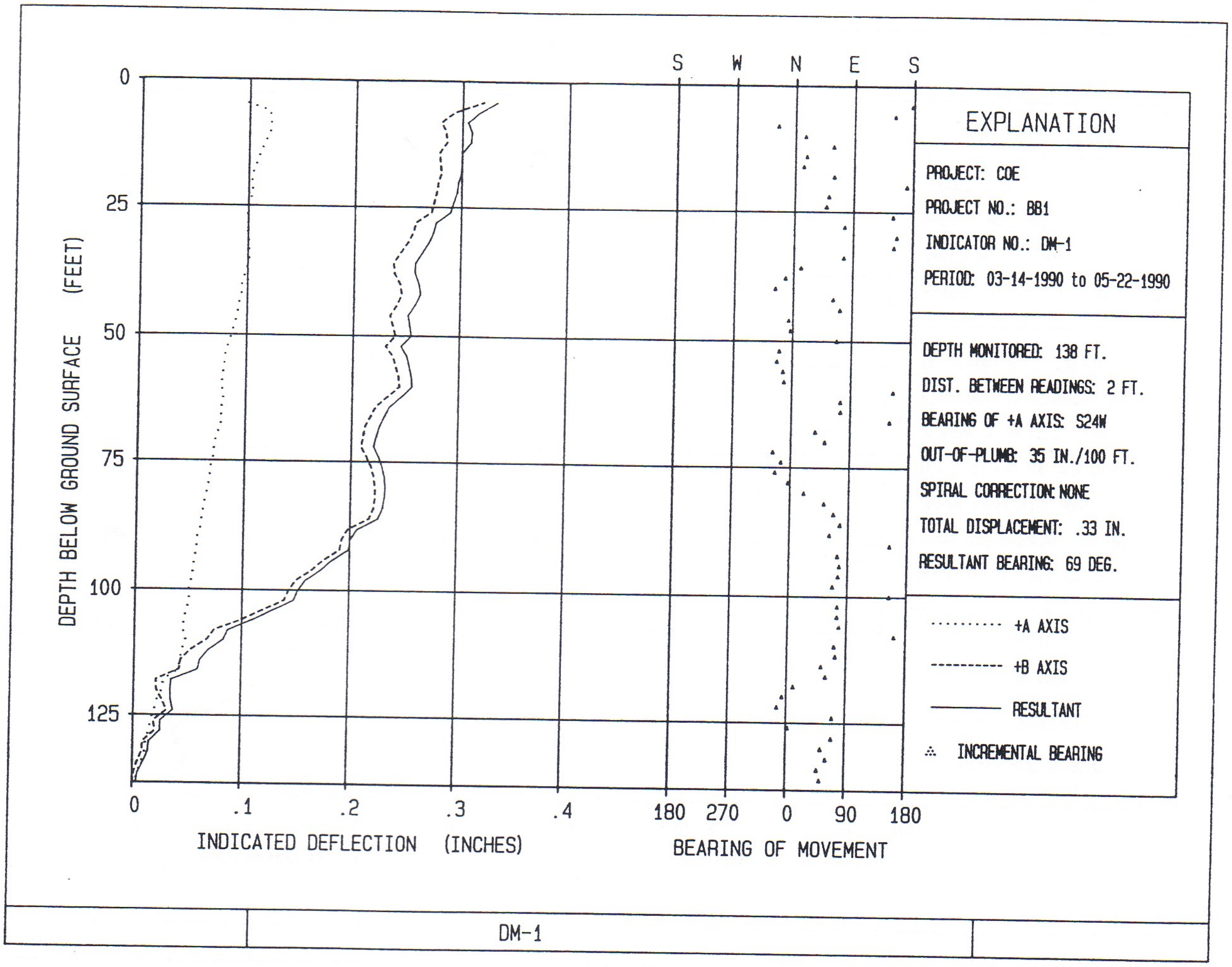
INCLINOMETER SURVEY DATA, SD-1

SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
SANTA CRUZ COUNTY, CALIFORNIA

GEO/ENG. BY	SCALE	PROJECT NO.
DRM	As Shown	G1409
APPROVED BY	DATE	FIGURE NO.
(signature)	9/30/90	C-7



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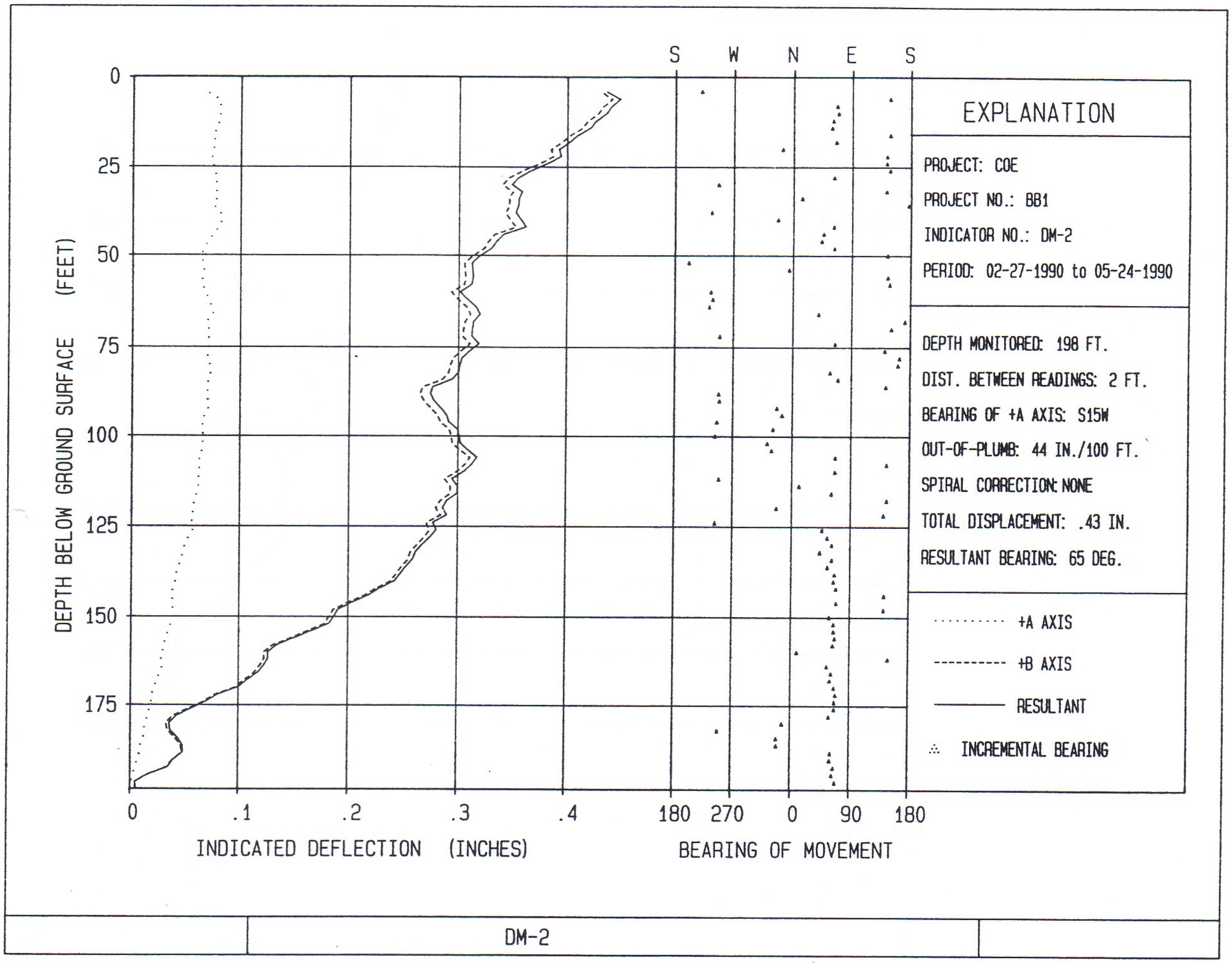
INCLINOMETER SURVEY DATA, DM-1

SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
SANTA CRUZ COUNTY, CALIFORNIA

GEO/ENG. BY	SCALE	PROJECT NO.
DRM	As Shown	G1409
APPROVED BY	DATE	FIGURE NO.
RDS.	9/30/90	C-8



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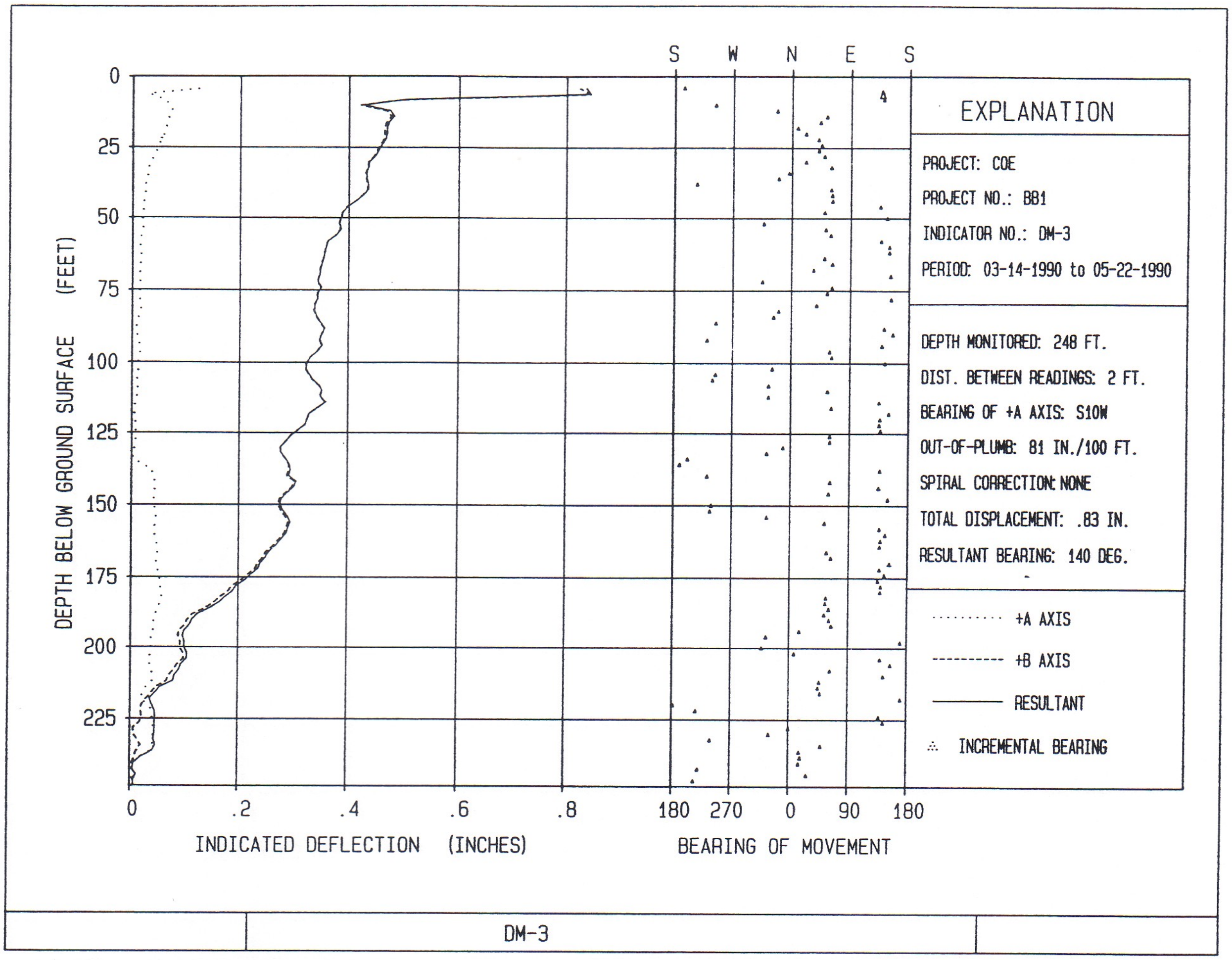
APPROVED BY	DATE 9/30/90	FIGURE NO. C-9



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INCLINOMETER SURVEY DATA, DM-3

SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
SANTA CRUZ COUNTY, CALIFORNIA

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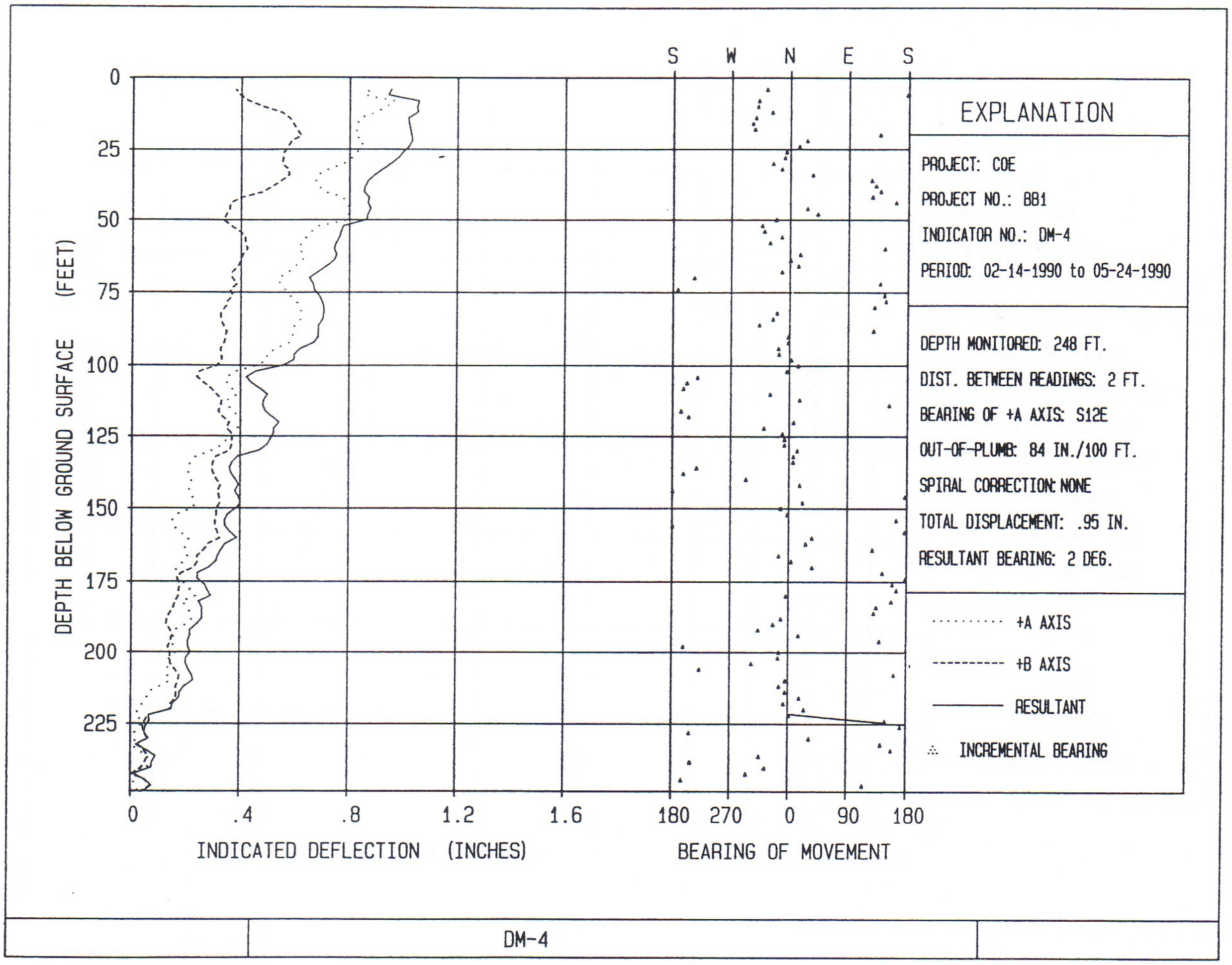
DRM	As Shown	G1409
APPROVED BY	DATE	FIGURE NO.
[signature]	9/30/90	C-10



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INCLINOMETER SURVEY DATA, DM-4

SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
SANTA CRUZ COUNTY, CALIFORNIA

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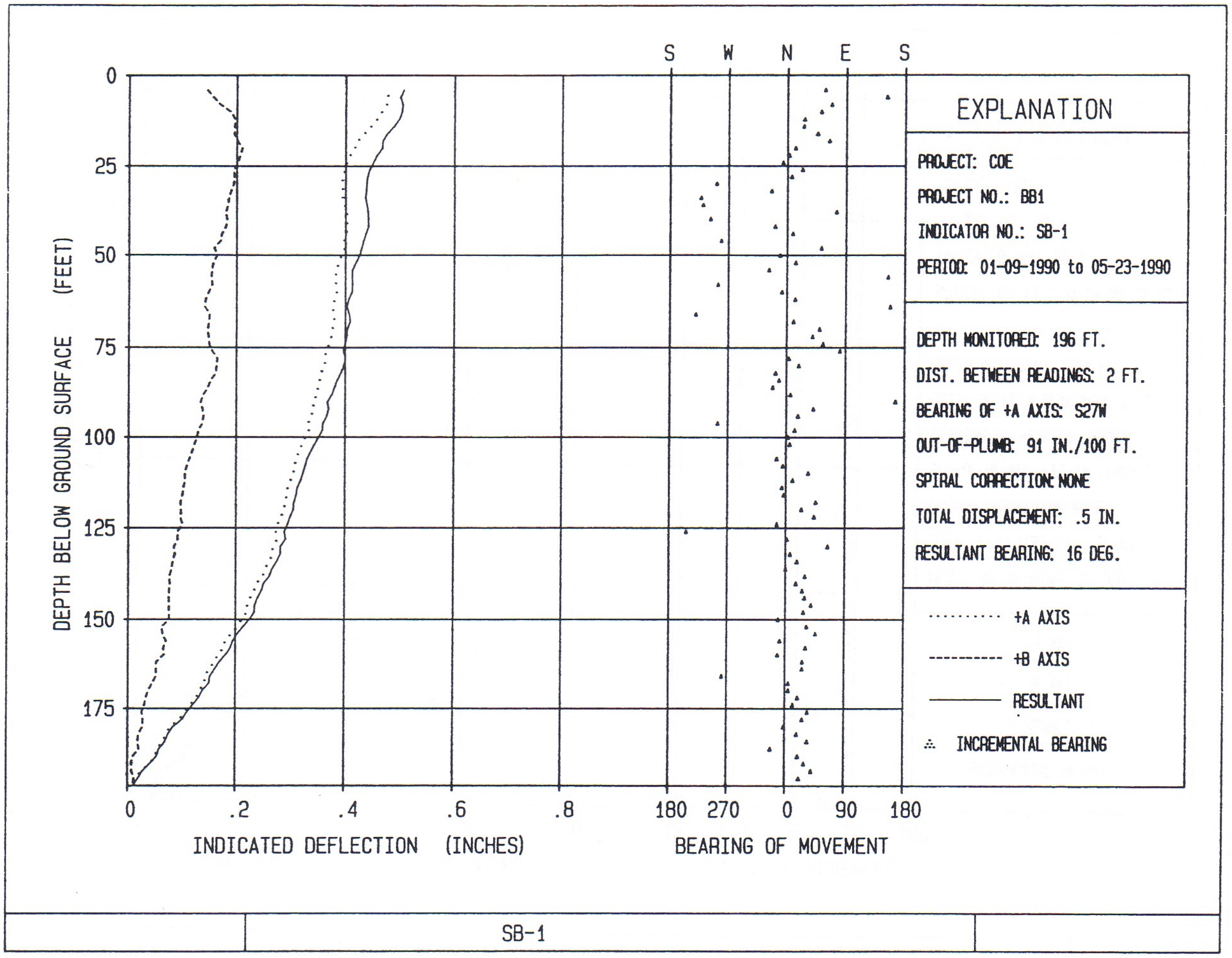
DRM	As Shown	G1409
APPROVED BY	DATE	FIGURE NO.
[signature]	9/30/90	C-11



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INCLINOMETER SURVEY DATA, SB-1

SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
SANTA CRUZ COUNTY, CALIFORNIA

GEO/ENG. BY	SCALE	PROJECT NO.
DRM	As Shown	G1409
APPROVED BY	DATE	FIGURE NO.
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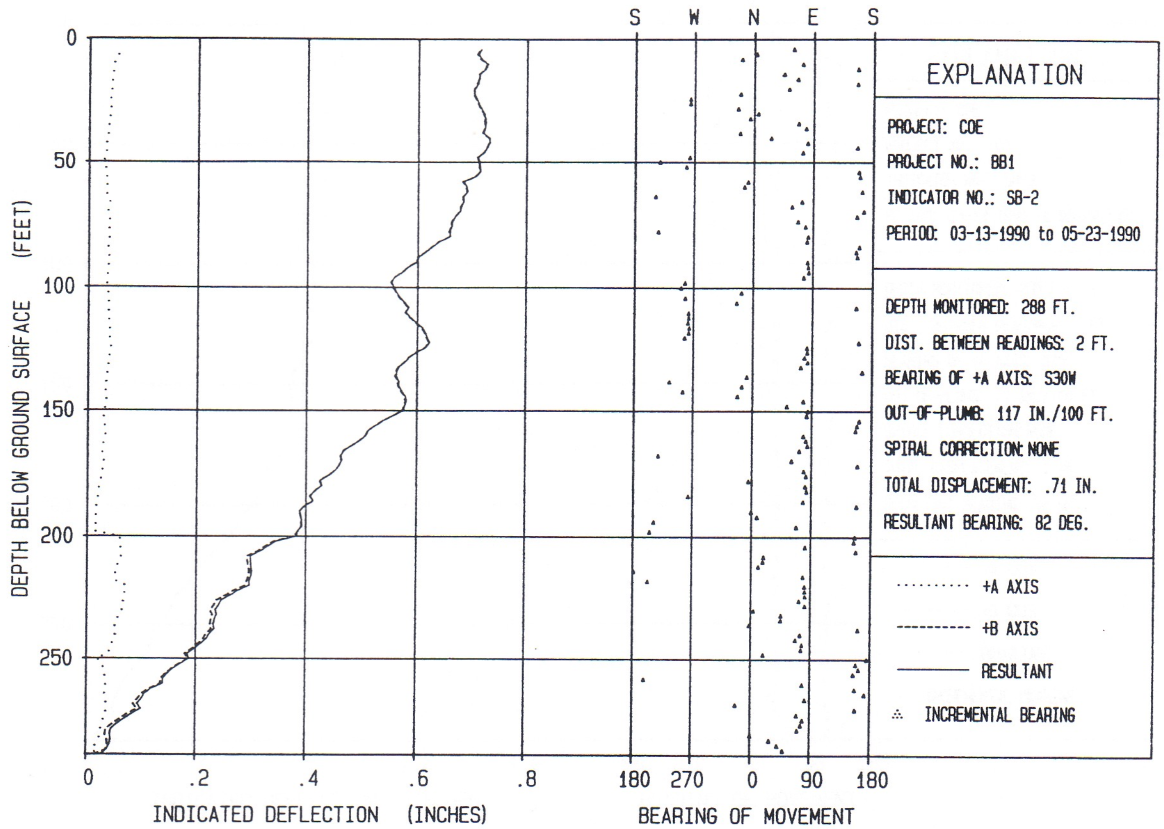

SB-2

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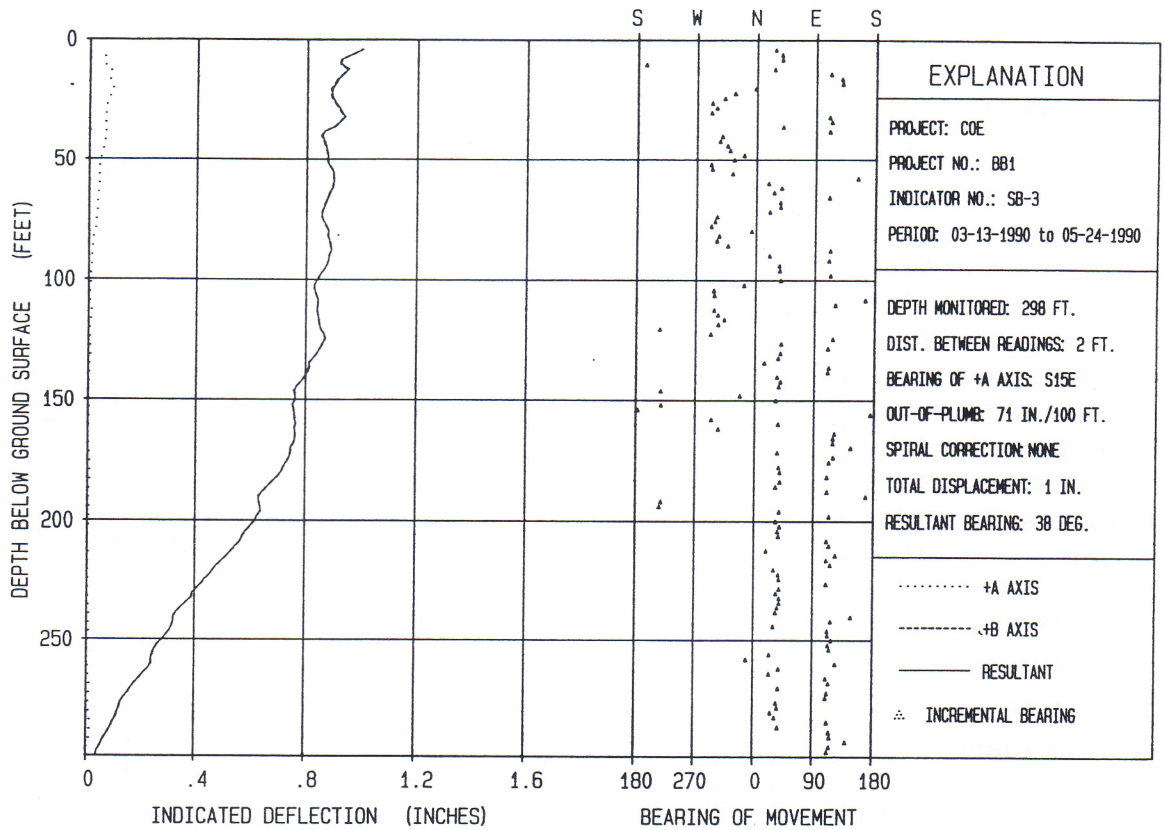
INCLINOMETER SURVEY DATA, SB-2

SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
SANTA CRUZ COUNTY, CALIFORNIA

GEO/ENG. BY	SCALE	PROJECT NO.
DRM	As Shown	G1409
APPROVED BY	DATE	FIGURE NO.
[signature]	9/30/90	C-13



SB-3

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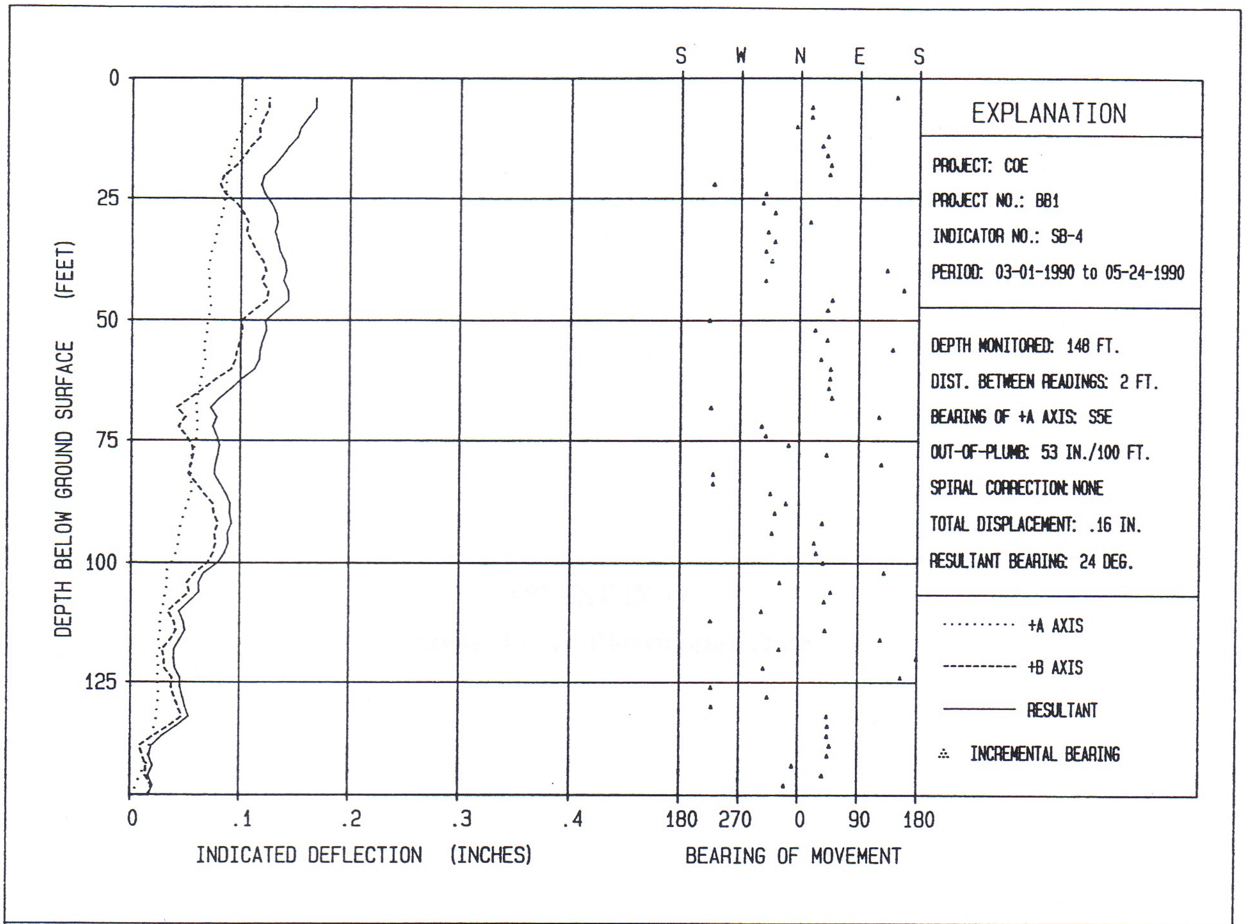
INCLINOMETER SURVEY DATA, SB-3

SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
SANTA CRUZ COUNTY, CALIFORNIA

GEO/ENG. BY	SCALE	PROJECT NO.
DRM	As Shown	G1409
APPROVED BY	DATE	FIGURE NO.
J.C.S.	9/30/90	C-14



SB-4

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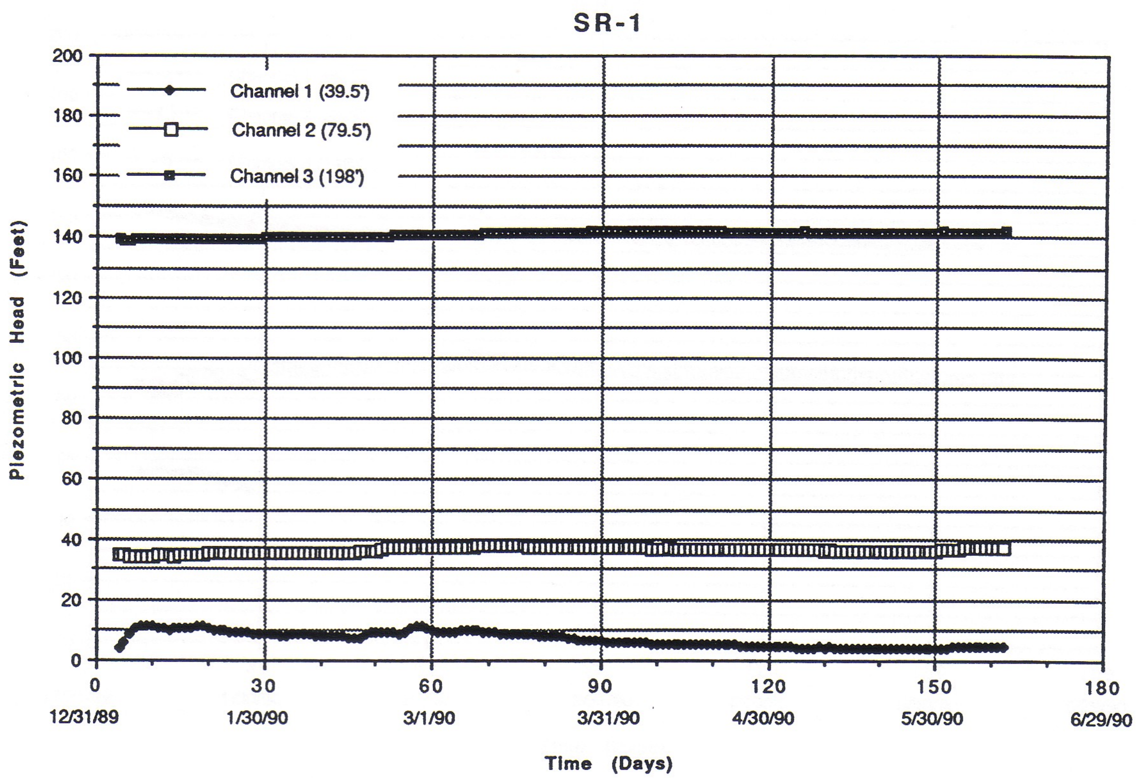
INCLINOMETER SURVEY DATA, SB-4

SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
SANTA CRUZ COUNTY, CALIFORNIA

GEO/ENG. BY	SCALE	PROJECT NO.
DRM	As Shown	G1409
APPROVED BY	DATE	FIGURE NO.
BOS.	9/30/90	C-15

APPENDIX D

Representative Piezometer Data



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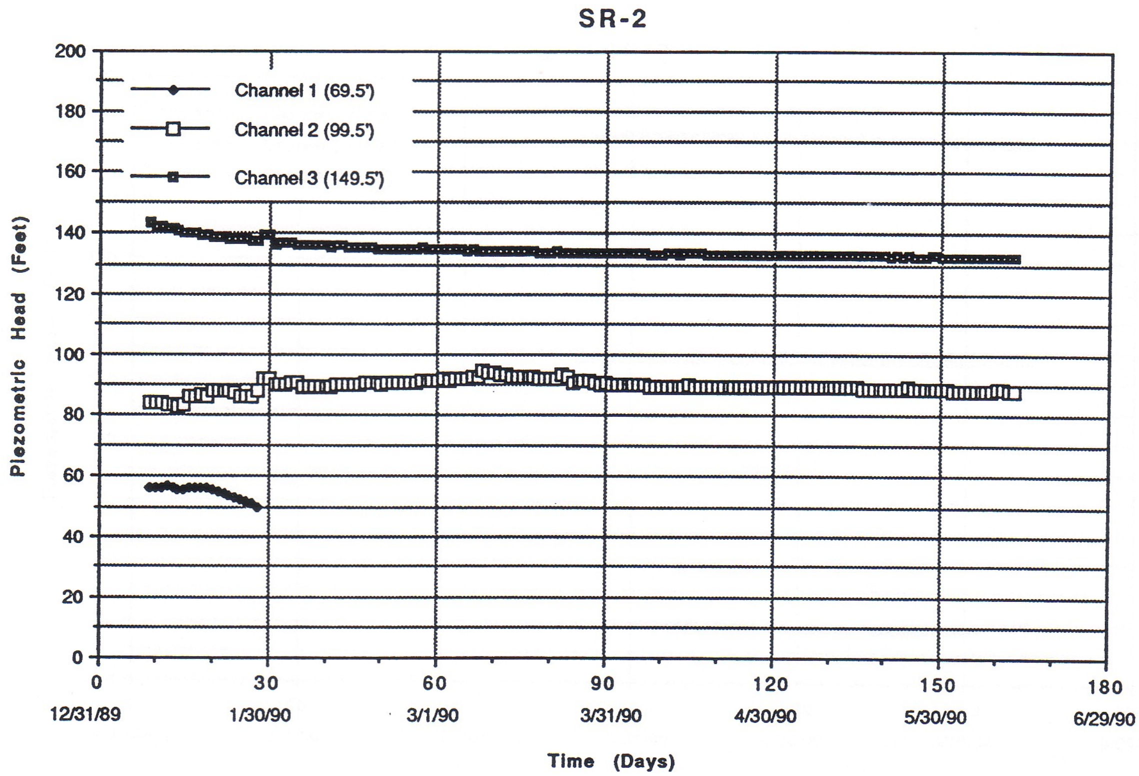
PIEZOMETER DATA, SR-1

SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
SANTA CRUZ COUNTY, CALIFORNIA

GEO/ENG. BY	SCALE	PROJECT NO.
DRM		G1409
APPROVED BY	DATE	FIGURE NO.
B.O.S.	9/30/90	D-1



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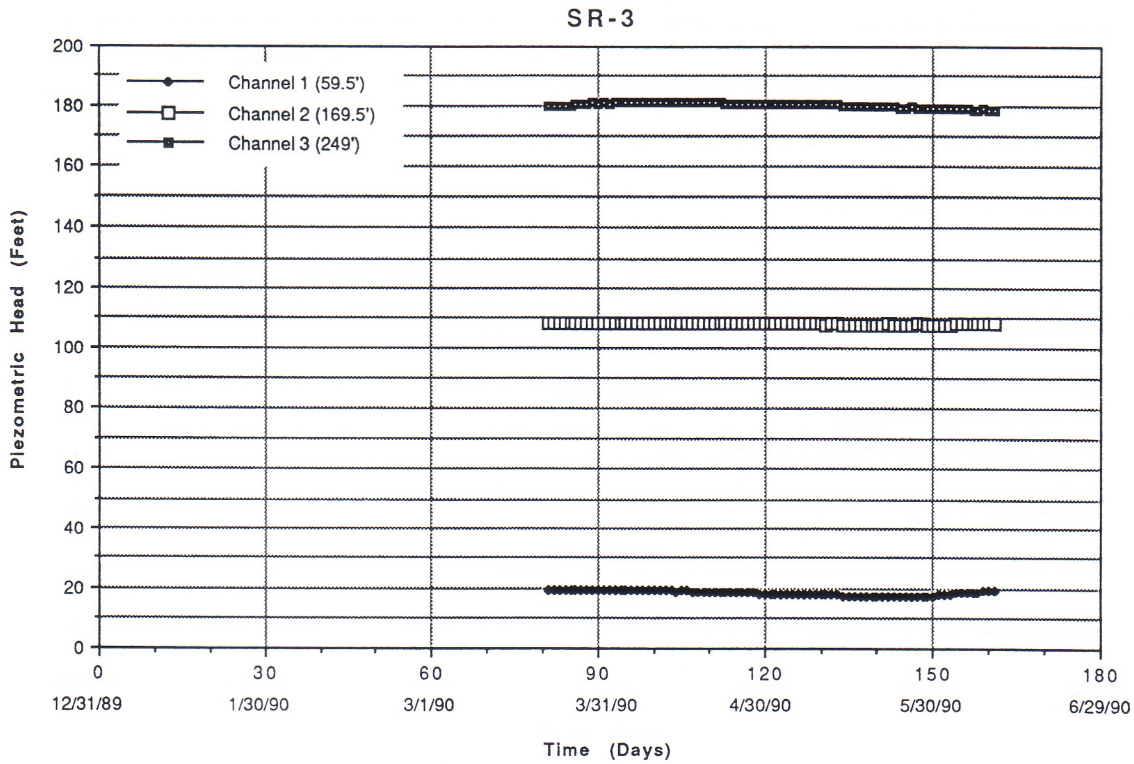
PIEZOMETER DATA, SR-2

SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
SANTA CRUZ COUNTY, CALIFORNIA

GEO/ENG. BY	SCALE	PROJECT NO.
DRM		G1409
APPROVED BY	DATE	FIGURE NO.
B.O.S.	9/30/90	D-2



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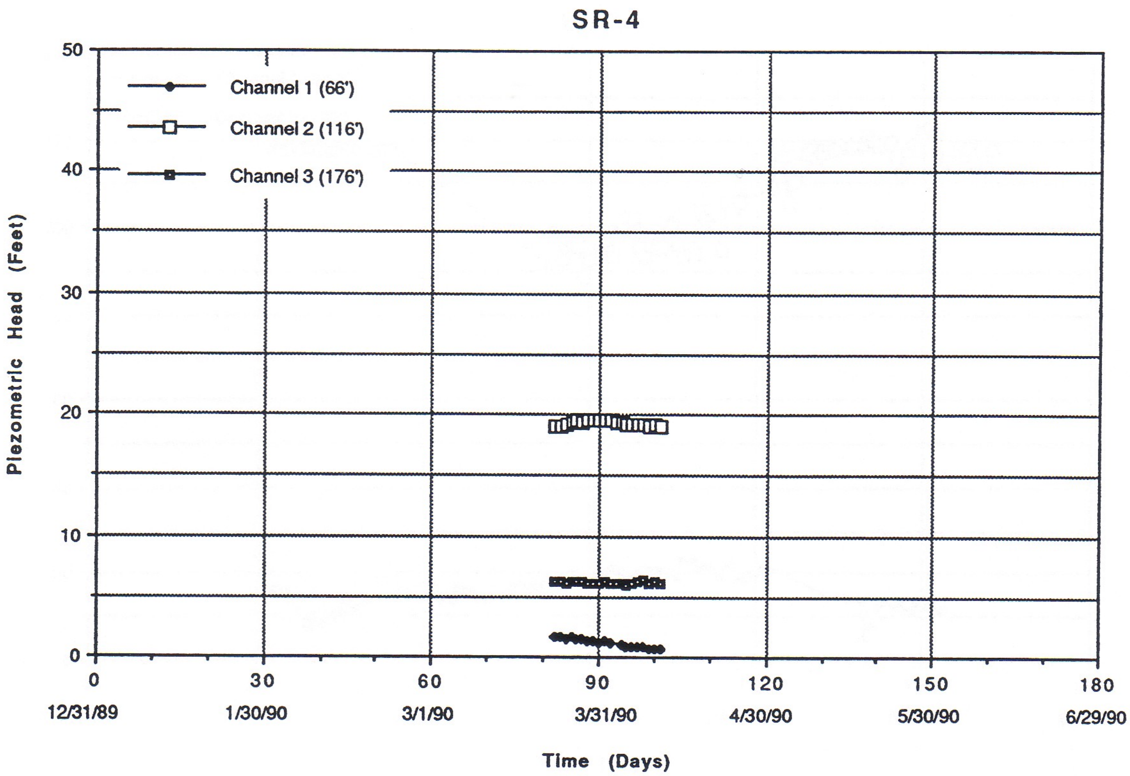
PIEZOMETER DATA, SR-3

SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
SANTA CRUZ COUNTY, CALIFORNIA

GEO/ENG. BY	SCALE	PROJECT NO.
DRM		G1409
APPROVED BY	DATE	FIGURE NO.
ROS.	9/30/90	D-3



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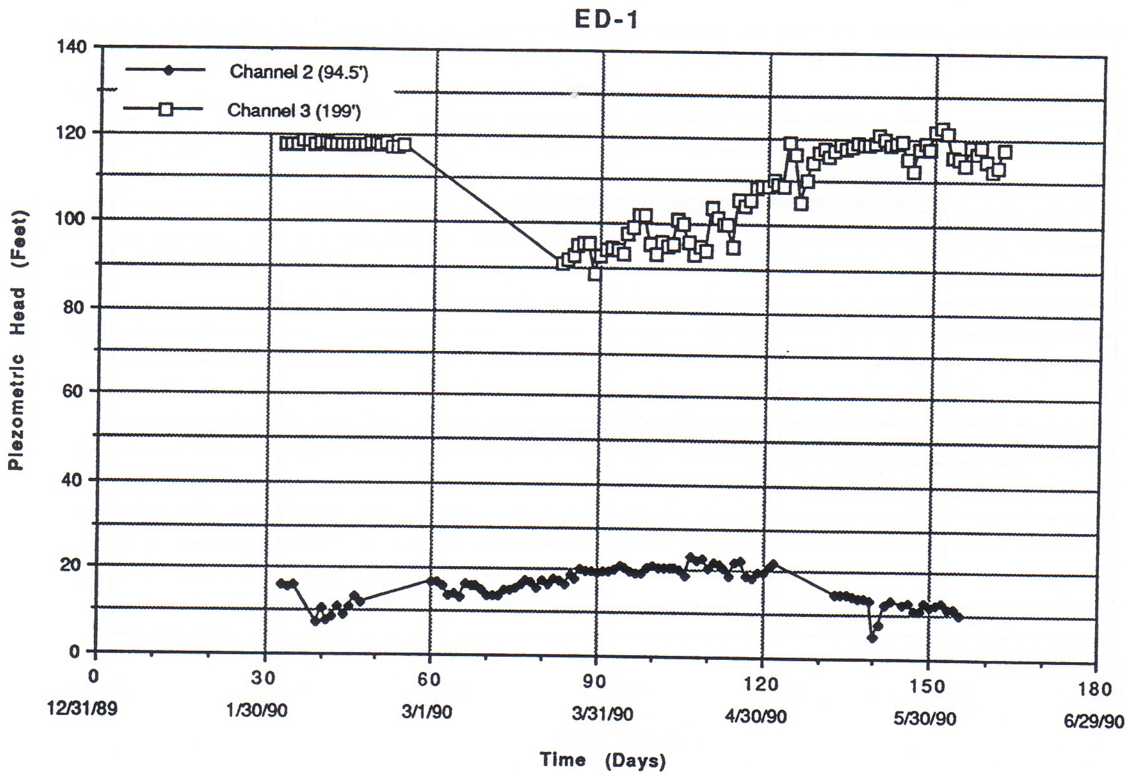
PIEZOMETER DATA, SR-4 SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS SANTA CRUZ COUNTY, CALIFORNIA		
GEO/ENG. BY DRM	SCALE	PROJECT NO. G1409
APPROVED BY ROS.	DATE 9/30/90	FIGURE NO. D-4



William Cotton and Associates		
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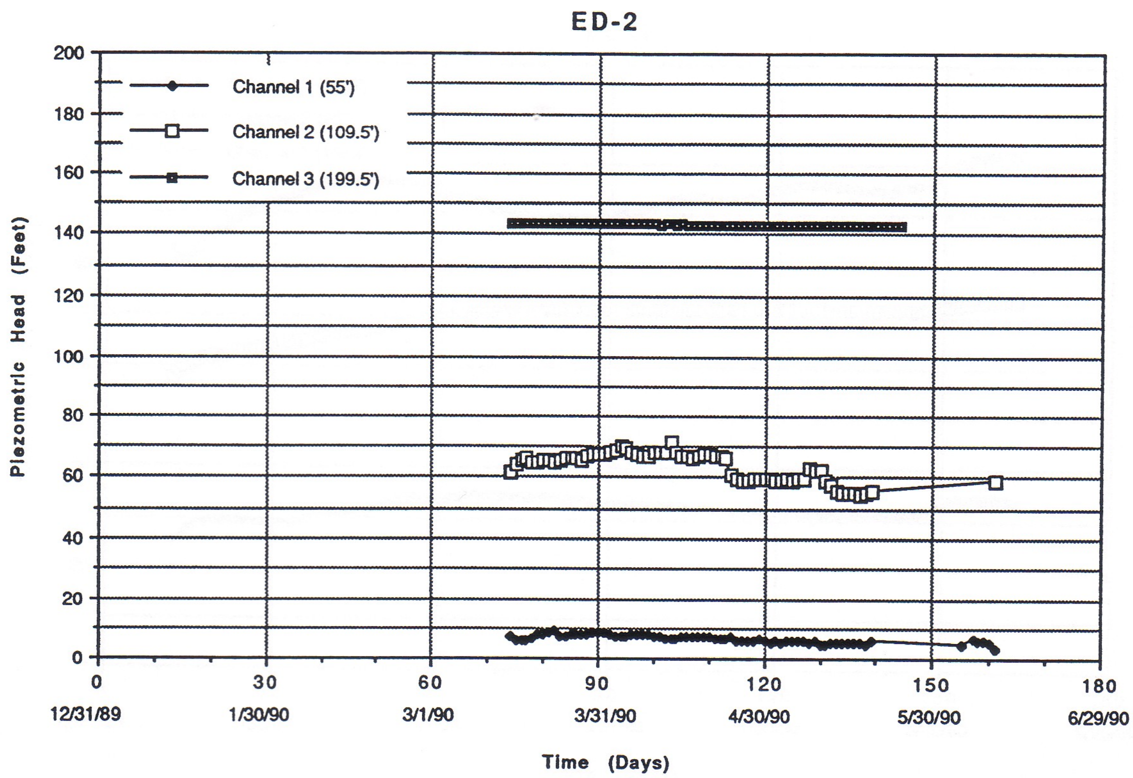
GEO/ENG. BY DRM	SCALE	PROJECT NO. G1409
APPROVED BY Q.O.S.	DATE 9/30/90	FIGURE NO. D-5



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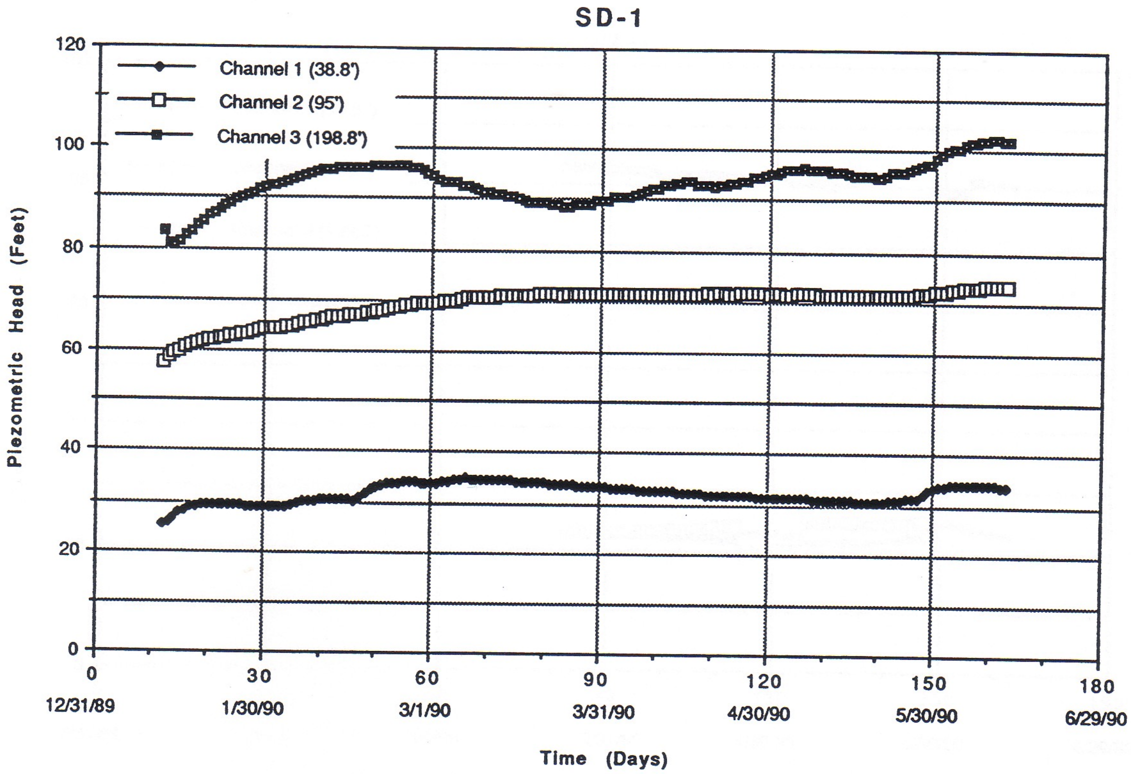
PIEZOMETER DATA, ED-2

SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
SANTA CRUZ COUNTY, CALIFORNIA

GEO/ENG. BY	SCALE	PROJECT NO.
DRM		G1409
APPROVED BY	DATE	FIGURE NO.
W.O.S.	9/30/90	D-6



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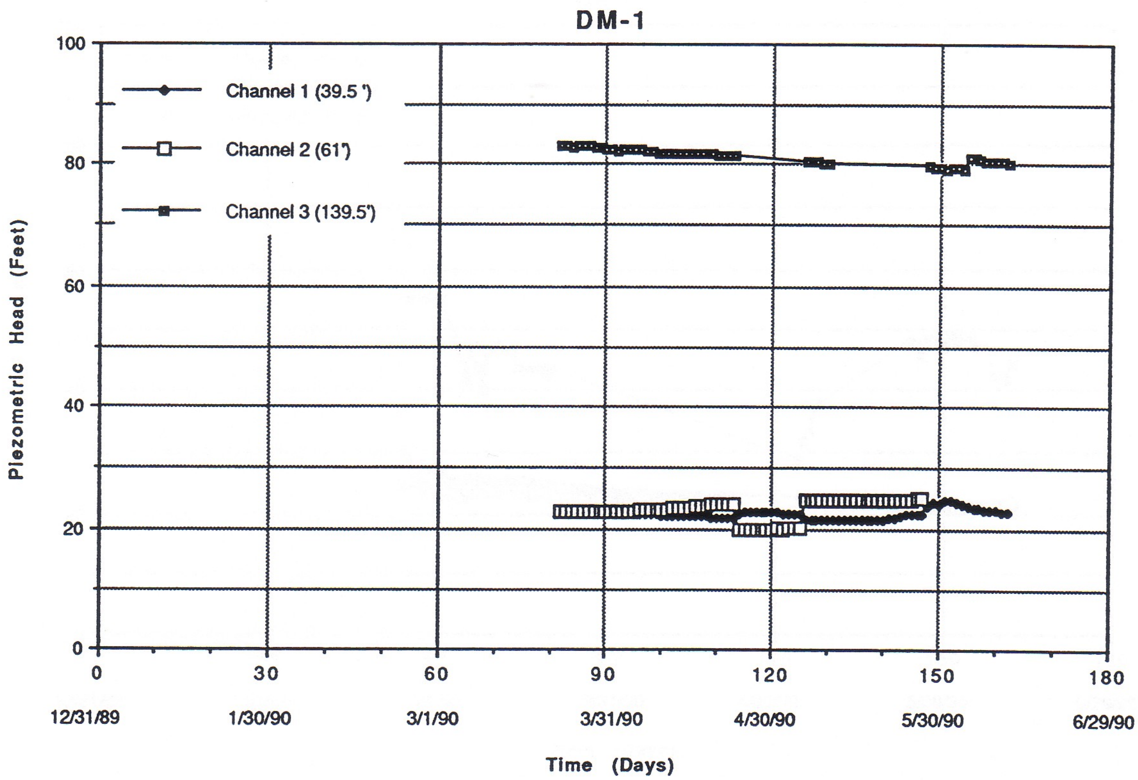
PIEZOMETER DATA, SD-1

SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
SANTA CRUZ COUNTY, CALIFORNIA

GEO/ENG. BY	SCALE	PROJECT NO.
DRM		G1409
APPROVED BY	DATE	FIGURE NO.
W.O.S.	9/30/90	D-7



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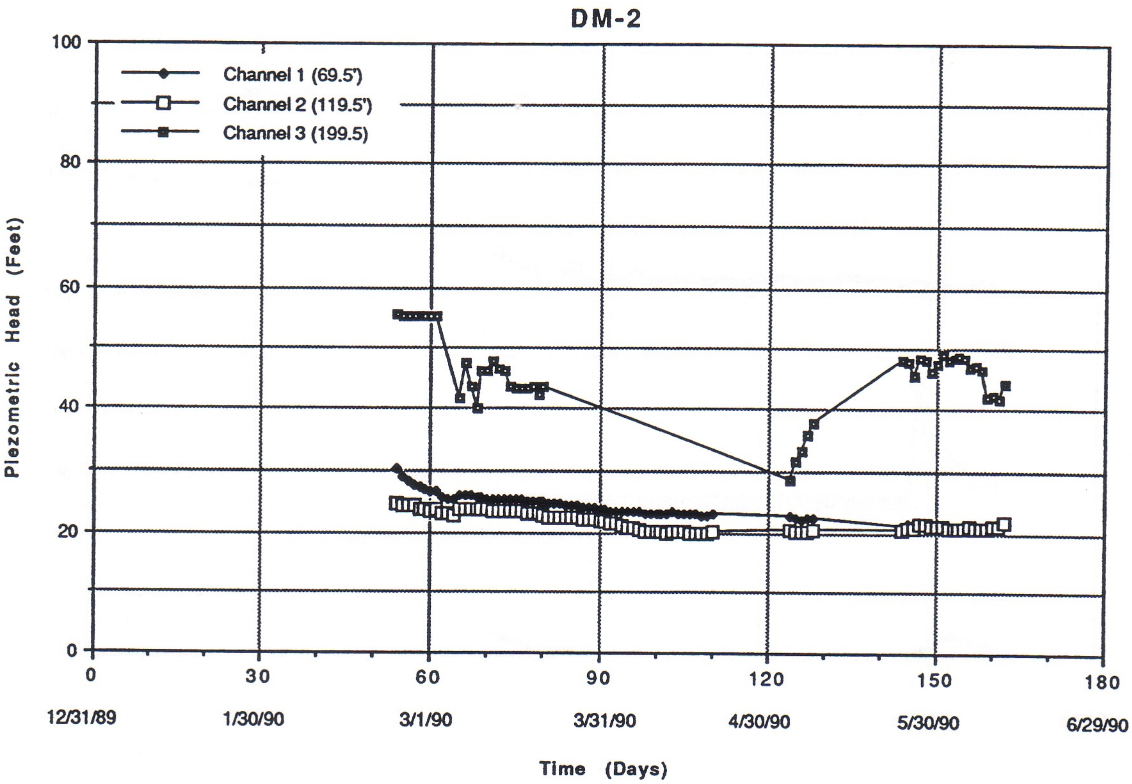
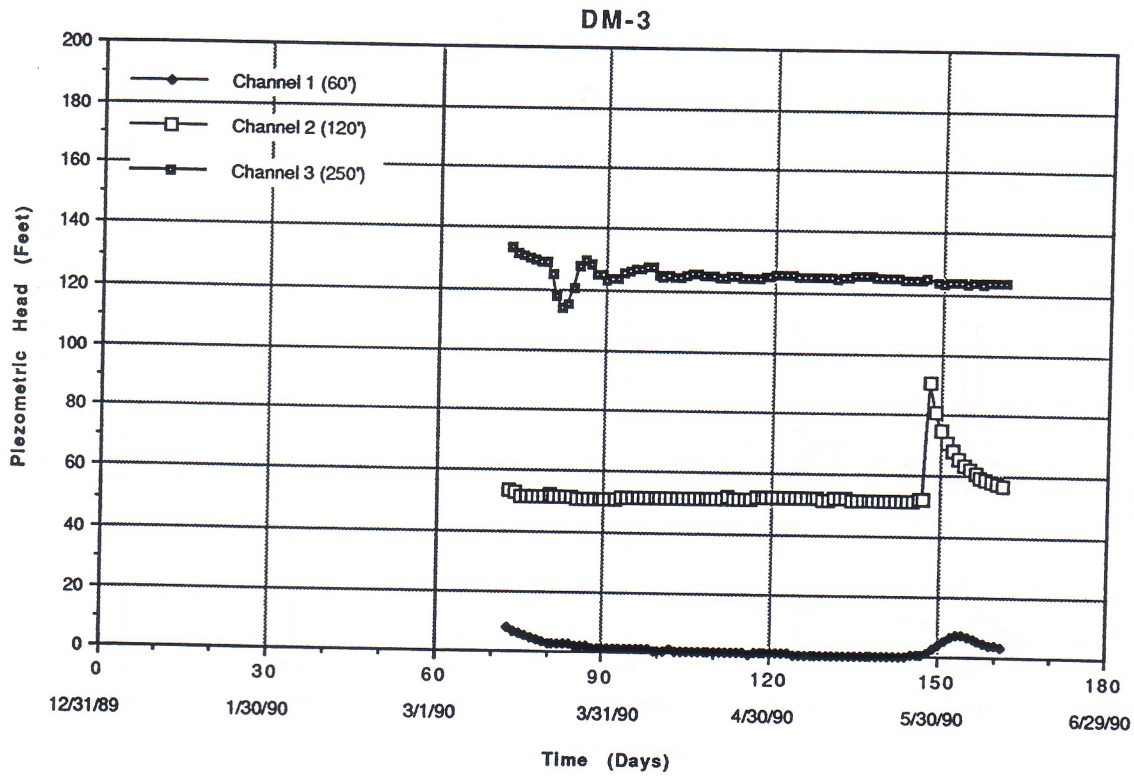
PIEZOMETER DATA, DM-1

SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
SANTA CRUZ COUNTY, CALIFORNIA

GEO/ENG. BY	SCALE	PROJECT NO.
DRM		G1409
APPROVED BY	DATE	FIGURE NO.
Q.O.S.	9/30/90	D-8



William Cotton and Associates		
PIEZOMETER DATA, DM-2 SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS SANTA CRUZ COUNTY, CALIFORNIA		
GEO/ENG. BY DRM	SCALE	PROJECT NO. G1409
APPROVED BY BOS.	DATE 9/30/90	FIGURE NO. D-9

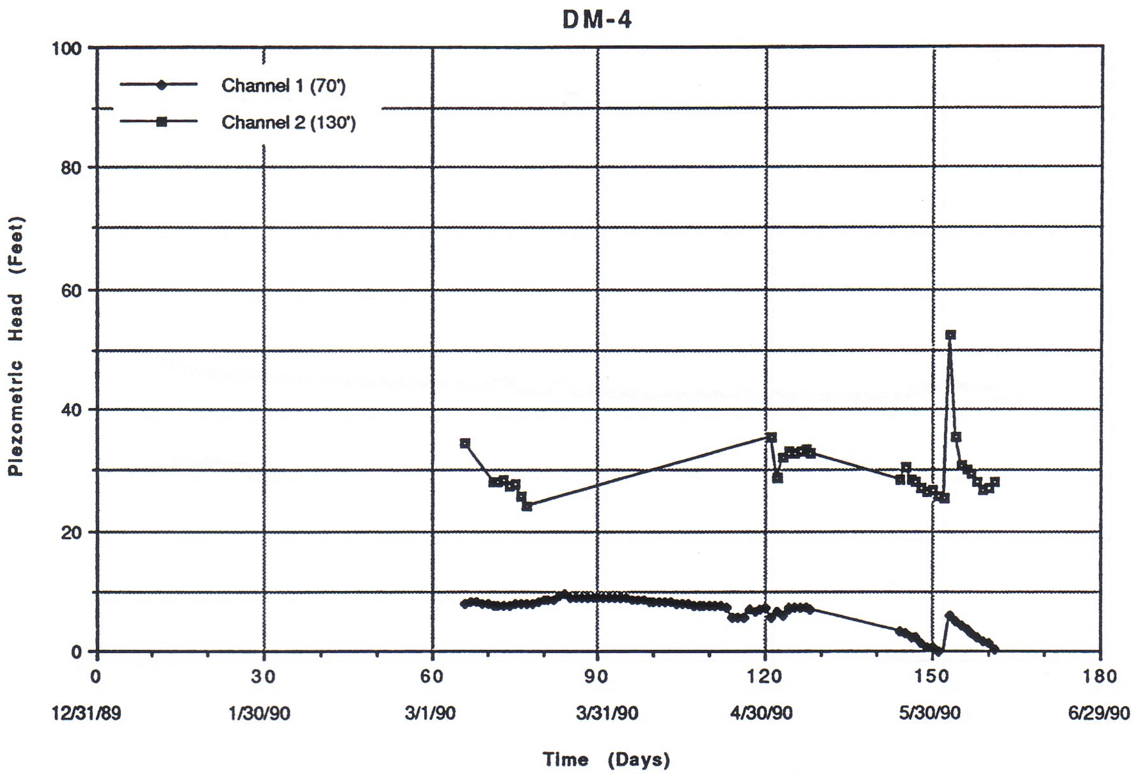


William Cotton and Associates

PIEZOMETER DATA, DM-3

SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
SANTA CRUZ COUNTY, CALIFORNIA

GEO/ENG. BY	SCALE	PROJECT NO.
DRM		G1409
APPROVED BY	DATE	FIGURE NO.
QOS.	9/30/90	D-10

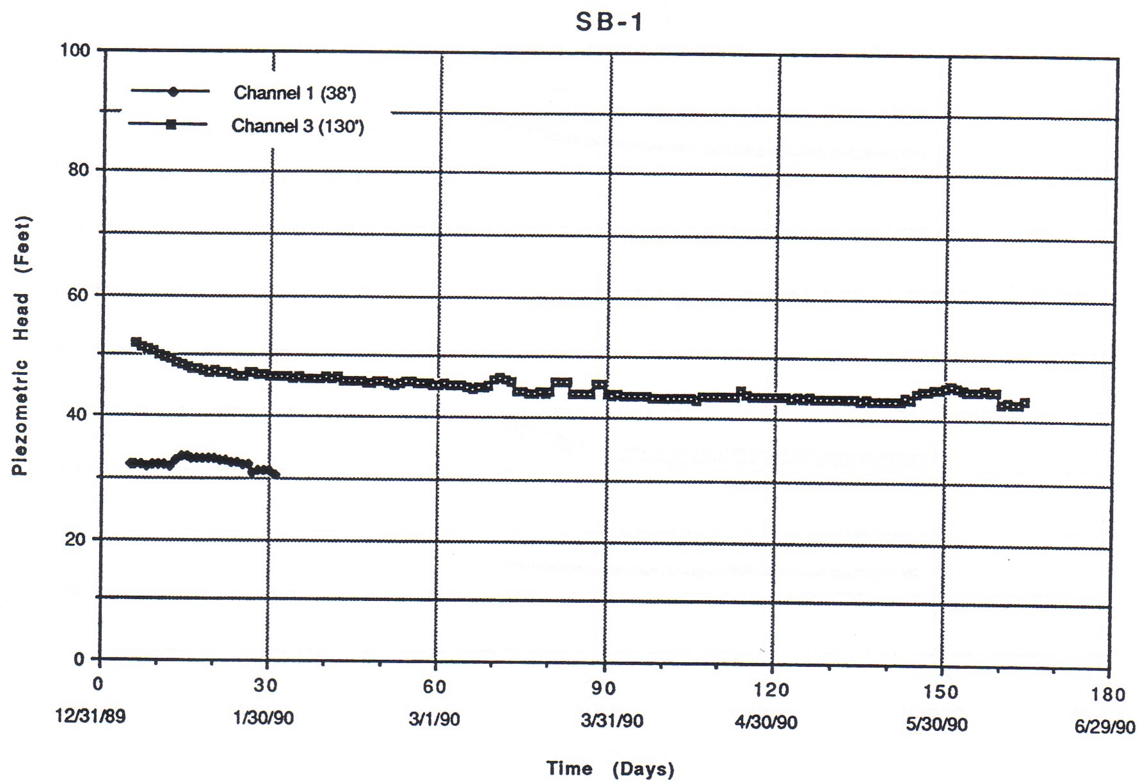


William Cotton and Associates

PIEZOMETER DATA, DM-4

SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
SANTA CRUZ COUNTY, CALIFORNIA

GEO/ENG. BY	SCALE	PROJECT NO.
DRM		G1409
APPROVED BY	DATE	FIGURE NO.
C.O.S.	9/30/90	D-11



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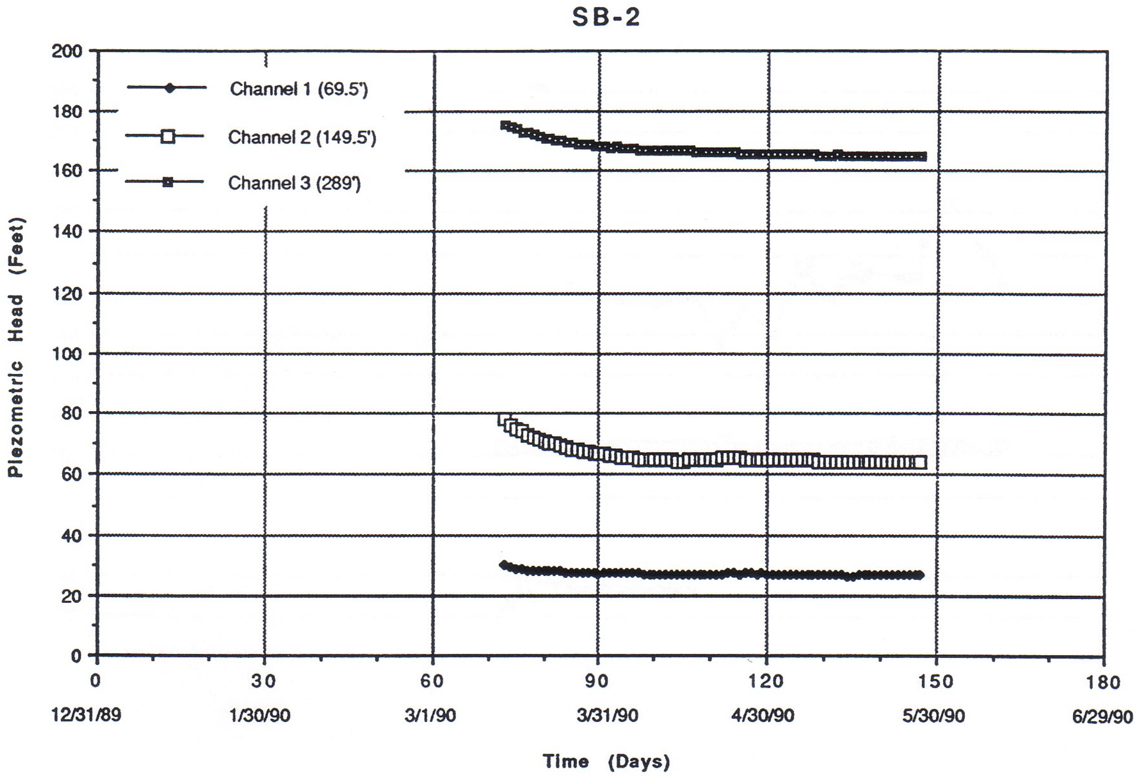
PIEZOMETER DATA, SB-1

SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
SANTA CRUZ COUNTY, CALIFORNIA

GEO/ENG. BY	SCALE	PROJECT NO.
DRM		G1409
APPROVED BY	DATE	FIGURE NO.
RGS	9/30/90	D-12

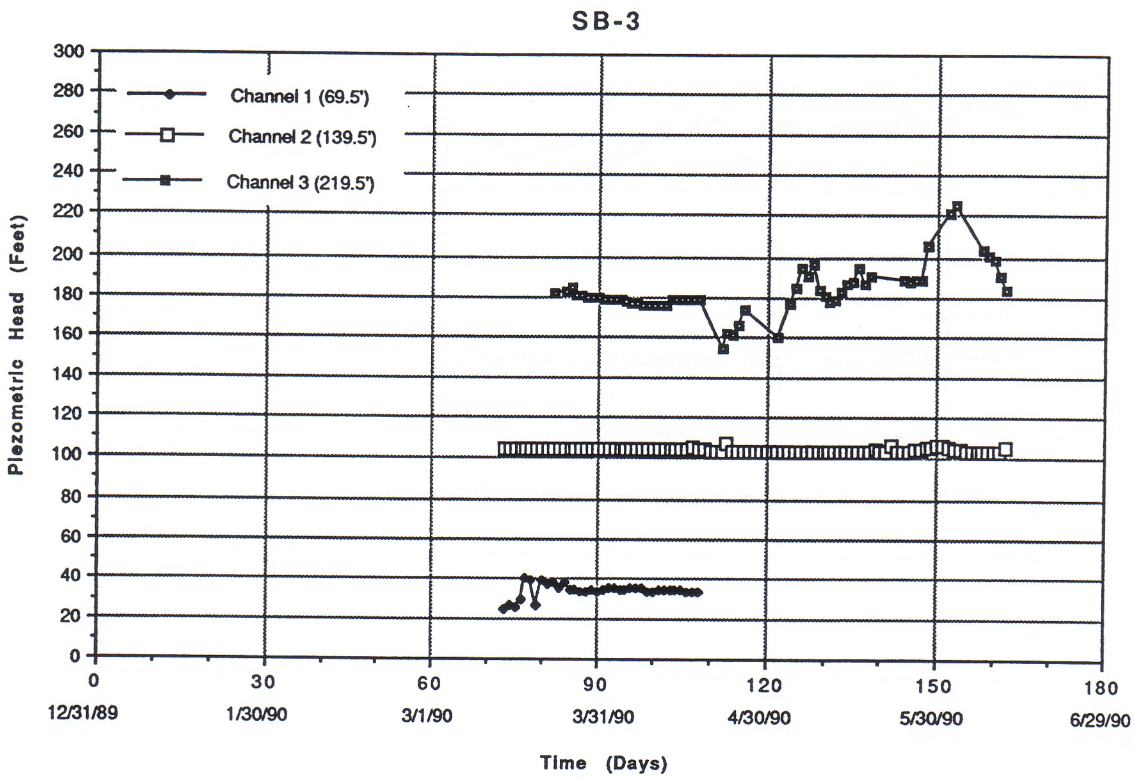


William Cotton and Associates

PIEZOMETER DATA, SB-2

SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
SANTA CRUZ COUNTY, CALIFORNIA

GEO/ENG. BY	SCALE	PROJECT NO.
DRM		G1409
APPROVED BY	DATE	FIGURE NO.
BOS.	9/30/90	D-13

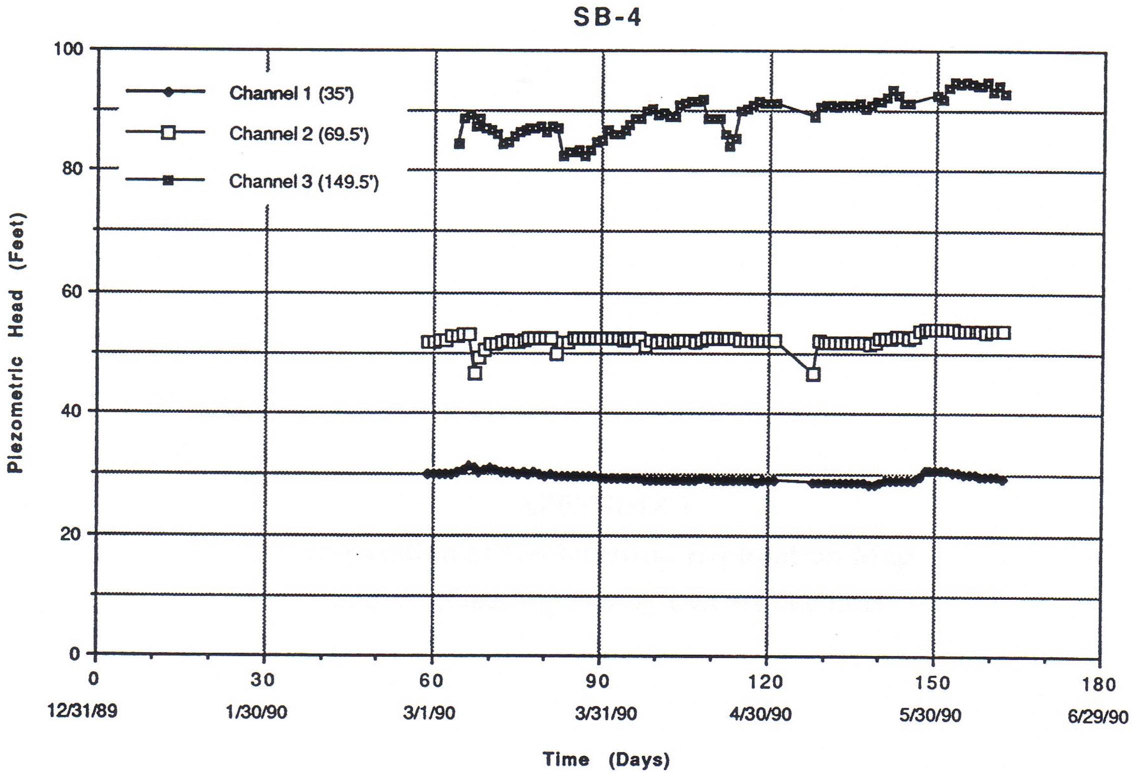


William Cotton and Associates

PIEZOMETER DATA, SB-3

SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
SANTA CRUZ COUNTY, CALIFORNIA

GEO/ENG. BY	SCALE	PROJECT NO.
DRM		G1409
APPROVED BY	DATE	FIGURE NO.
B.O.S.	9/30/90	D-14



William Cotton and Associates

PIEZOMETER DATA, SB-4

SCHULTHEIS ROAD AND VILLA DEL MONTE AREAS
SANTA CRUZ COUNTY, CALIFORNIA

GEO/ENG. BY	SCALE	PROJECT NO.
DRM		G1409
APPROVED BY	DATE	FIGURE NO.
[illegible]	9/30/90	D-15

APPENDIX E

Preparation of Geotechnical Exploration Map and Engineering Geologic Cross Sections

APPENDIX E
Preparation of Geotechnical Exploration Map and Engineering Geologic Cross Sections

The 200-scale Geotechnical Exploration Map (Plate 1, pocket) and 100-scale Engineering Geologic Cross Sections (Plates 2, 3, 4, and 5, pocket) represent an attempt to depict detailed conditions in the Schultheis Road and Villa Del Monte areas. However, a detailed Engineering Geologic Map was not prepared for this landslide exploration project. Rather, the various data depicted on the Geotechnical Exploration Map and Engineering Geologic Cross Sections were compiled from several sources which were not all consistent with one another. Consequently, the relative locations, in horizontal and vertical directions, between various information shown on these graphics may not represent actual relationships. We have provided this appendix to describe how the data on these graphics were assimilated so that the user can understand the level of confidence we believe can be applied to the various data sets.

<u>Geotechnical Exploration Map</u> - Information presented on the Geotechnical Exploration Map includes: roads, regional topography, boring (and instrumentation) locations, approximate water well locations, survey transect locations, ground cracks, topographic lineaments, and interpreted landslide boundaries. The sources of information used to interpret these features are listed below:

Information	Sources of Information
• roads	Santa Cruz County Cadastral Maps (400 scale).
• topography	U. S. Geological Survey 7.5 minute quadrangles (2000 scale).
• boring locations	survey coordinates provided by Towill, Inc. on August 17, 1990.
• water well locations	map provided by Santa Cruz County (100 scale).
• transect locations	plots of transects on County cadastral base and U. S. Geological Survey quadrangles (1 inch = 400 feet and 1 inch = 1000 feet) provided by Towill, Inc. on August 9, 1990.

- ground cracks — County cadastral base provided by T. Spittler and E. Harp on August 20, 1990 (1 inch = 400 feet).
- topographic lineaments — Special Studies Zone (Alquist-Priolo) map and Santa Cruz County Fault Map (2000-scale).
- landslide boundaries — WCA interpretation from geomorphology (U.S.G.S. topography), ground cracks, and subsurface information on the basis of final plots of boring and transect locations (see text of this report).

The County cadastral map and the U. S. Geological Survey Los Gatos and Laurel topographic quadrangles were photographically enlarged to 1 inch = 200 feet scale. Most of the above information was then assimilated and compiled onto the enlarged versions of either the County cadastral map or topographic map. For example, transect and boring locations were re-plotted on the enlarged topographic map, and ground cracks were re-plotted onto the enlarged cadastral map.

In previous analyses, and for our preliminary report dated June 1990, the two maps described above were merged to create a single base map by overlying and matching, as accurately as possible, roads portrayed on the two maps. Roads in the upland portion of the Villa Del Monte area are relatively free from tree cover and could be observed on aerial photographs. Consequently, the exposed roads shown on the U. S. Geological Survey quadrangles matched relatively well with the County cadastral map. However, Schultheis Road is in a heavily forested area and the location of Schultheis Road on the U. S. Geological Survey quadrangle is significantly different than the location on the County cadastral map. Consequently, the originally compiled map in the Schultheis Road area did not accurately portray the actual relationship between topography and roads.

For this report, we used the two transect plots and boring coordinates received (on August 9, and August 17, 1990) from Towill, Inc., to produce a new Geotechnical Exploration Map. The new version was created in a slightly different manner that helps remove some of the inaccuracies inherent with the previous method. Rather than using mapped road locations to merge the cadastral and topographic maps, we were able to use Towill's transect locations, which are now plotted on both the cadastral map (400-scale) and the enlarged version of the U. S. Geological Survey topographic map (1000-scale). In addition, we were able to plot boring locations and compare them directly with topography and transect locations. Topographic lineaments, water wells, and interpreted landslide boundaries were then plotted onto the final compilation.

We have observed horizontal errors of as much as 120 feet on portions of the map (for example, where landslide cracks mapped along the creeks on the County Cadastral Map do not match well with the U. S. Geological Survey topography). However, in our opinion, the overall accuracy of the Geotechnical Exploration Map is likely to be on the order of ± 30 feet.

Engineering Geologic Cross Sections - Cross sections were prepared at a scale of 1 inch = 100 feet using surface profiles provided by Towill, Inc. We were supplied with two sets of profiles, one set at 1 inch = 400 feet and another at a vertical-exaggerated scale of 1 inch = 200 feet (horizontal) and 1 inch = 50 feet (vertical). Although the exaggerated profiles show some crack locations that were not noted on the small (1 inch = 400 feet) profiles, we would have had to re-plot individual points along the profile in order to construct a non-exaggerated section. Therefore, because of time constraints, we chose to photographically enlarge the 1 inch = 400 feet profiles to our cross section scale of 1 inch = 100 feet. Some distortion results from the photo-enlargement process. Consequently, at a scale of 1 inch = 100 feet, the overall horizontal distance of the cross sections are approximately 11 to 18 feet longer than Towill's calculations indicate that they should be. We consider this difference to be relatively minor in light of other discrepancies described below.

There is a difference between lengths measured from the profiles and lengths measured from plotted (i.e., map view) profiles received from Towill. Two of the profiles, transect Line Nos. 6 and 7, are significantly longer (172 and 127 feet, respectively) than their mapped lengths as plotted by Towill on the County cadastral base. We do not know the reason for this apparent discrepancy.

There are also differences in the locations of physical features, such as Burns and Laurel Creeks, between their plotted locations on base maps and profiles. For example, the horizontal locations of creeks on transect line nos. 3 and 6 are approximately 300 and 80 feet, respectively, off from the mapped locations of the creeks. We believe these differences are a function of regional topography in the redwood-forested hillside area and serve to illustrate the inaccuracies associated with using regional topographic maps to portray detailed site conditions. As we have previously stated, the lack of an accurate topographic base map, with suitable ground control, prevented a detailed analysis of geomorphic features.

Borings and water wells were projected into the cross sections along a perpendicular alignment to the nearest section. Borings were plotted using the corresponding elevation provided for each boring by Towill. We note that some borings have been projected long distances (as much as 670 feet) into the nearest cross section; consequently, information from these distant borings (i.e., projected greater than approximately 100 feet) should not be used to interpret subsurface conditions along that specific cross section. However, we believe the information for all borings should be considered, in a general sense, in the interpretation of the subsurface conditions. Consequently, the information from all borings are shown on the nearest cross section to each boring. This information can be transferred to additional cross sections, if such sections are constructed in the future.

Water well data have also been projected onto the cross sections; however, the locations of individual water wells are not well established and the elevations of water wells are currently unknown. We estimate the mapped location of each water well to be within approximately 100 feet of its actual location. The cross sections only portray water wells that are located less than approximately 200 feet from the section. For interpretive purposes, the tops of the projected water wells were plotted at the ground surface profile.

<u>Interpretation of Landslide Depths</u> - Interpretations of the depths of landsliding shown on the engineering geologic cross sections are from our evaluation of, in descending order of importance: geomorphology, ground crack locations, rock quality data (e.g., fractures, shears, etc.), variations in drilling rate, lithology, and, to a lesser extent, reports of water well damage.

We were initially concerned that the relatively low percentage of sampling in the borings and lack of supporting exploration techniques (e.g., downhole geophysics, logging of large-diameter borings) would not allow much resolution of specific subsurface conditions. In addition, many borings were projected long distances into the cross sections. Consequently, early attempts at interpretation were based more upon surface information (geomorphology and ground cracks) than subsurface information.

However, where borings are located near the cross section alignments, the subsurface information generally agrees well with preliminary interpretations based on surface data. This apparently good correlation gives us confidence that the subsurface data is useful and can be incorporated into the landslide interpretation process despite the lack of samples. Because of the lack of continuous sampling and the low density of subsurface information, we have shown the base of landsliding to be within an approximate 50-foot-thick zone.