SHANNON & WILSON, INC.

GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

Mark Biever Copy
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PHASE 2 GEOTECHNICAL REPORT
SUNRISE BEACH ROAD NW LANDSLIDE
THURSTON COUNTY DEPARTMENT OF ROADS & TRANSPORTATION SERVICES
THURSTON COUNTY, WASHINGTON

1.0 INTRODUCTION

1.1 Purpose

This letter report presents our findings, conclusions, and engineering recommendations regarding a landslide that has affected private properties and the public roadway in the 4800 to 5000 blocks of Sunrise Beach Road NW in Thurston County, Washington, as shown on the Vicinity Map (Figure 1) and Site Plan (Figure 2). The purpose of this work is to provide an evaluation of the causes of landsliding, provide recommendations to increase the stability of the hillside, and formulate additional recommendations for monitoring of future remedial measures and instrumentation of the hillside

1.2 Scope of Work

The scope of our services included:

1. Drilling and soil sampling of five borings with truck-mounted equipment and three hand borings with portable equipment.
2. Installation of inclinometer casings in four of the borings.
3. Installation of groundwater level monitoring devices.
4. Additional geologic reconnaissance.
5. Establishing and monitoring of 17 ground surface points.
6. Perform a ground survey of a topographic profile from the top of the bluff to the beach.
7. Monitoring of the groundwater levels in monitoring wells and water wells.
8. Monitoring of ground movements in the inclinometer casings.
9. Preparation of geologic profiles.
10. Perform slope stability analyses.
11. Excavation and logging of three test pits.
12. Preparation of this geotechnical report.
13. Presentation of the results of the report to the Board of County Commissioners.
14. Presentation of the results of the report to the public.

1.3 Authorization

Phase 2 work was authorized by Mr. Dale Rancour, County Engineer for the Thurston County Department of Roads & Transportation Services, on March 31, 1999. This authorization was Amendment No. 1 for geologic and geotechnical consulting services.

2.0 EXPLORATION AND TESTING PROGRAM

2.1 Field Explorations

The site was explored with five borings, designated B-1 through B-5; three hand borings, designated HB-1 through HB-3; three test pits, designated TP-1 through TP-3; three deep groundwater monitoring wells, designated DM-1 through DM-3; and two shallow groundwater monitoring wells, designated SM-1 and SM-2. Using a Ground Positioning System (GPS), surveyors from Thurston County Department of Roads & Transportation Services determined the locations of the explorations. The locations are shown on Figure 3, Subsurface Exploration Plan. The logs of the borings and groundwater monitoring wells are presented on Figures A-2 through A-11 in Appendix A.

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A geologist from our firm was present throughout the field exploration program to observe the drilling, collect representative soil samples for subsequent laboratory testing, and to prepare descriptive field logs of the borings and monitoring wells. Each soil sample was classified according to the Unified Soil Classification System presented on the Soil Classification and Log Key (Figure A-1).

Borings were performed at three locations along Sunrise Beach Road NW (B-1 through B-3), above the beach on the Fenton property (B-4), at the top of the bluff (B-5), above the beach on the Lawrence property (HB-1) and Chorba property (HB-2), and along the unimproved road on the Fields property (HB-3). A truck-mounted B-61 drill rig operated by Holocene Drilling of Pacific, Washington, was used to drill all the borings and groundwater monitoring wells except boring B-4 between March 29 and April 20, 1999. Gregory Drilling, Inc., of Renton, Washington, drilled boring B-4 on April 21 and 22, 1999, with a track-mounted CME-185 drill rig due to difficult access. All the borings were drilled using the mud rotary method.

The truck-mounted borings ranged from 90.8 to 198.5 feet deep. Deep groundwater monitoring wells were installed within 50 feet of the roadway borings and designated DM-1 through DM-3 to correspond with the adjacent boring number designation. The depth of each deep monitoring well closely matched that of the nearby boring. The two shallow groundwater monitoring wells, designated SM-2 and SM-3, to correspond with the adjacent boring and deep well numbers, were installed to 34 and 27.5 feet deep, respectively.

Disturbed samples were taken in conjunction with Standard Penetration Tests (SPTs). All retrieved samples were classified by our field representative, placed in airtight containers, and transported to the Shannon & Wilson, Inc., laboratory in Seattle for further classification and testing. SPTs were performed in general accordance with American Society for Testing and Materials (ASTM) Designation: D 1586, Standard Method for Penetration Test and Split-Barrel Sampling of Soils. The tests were performed at approximately 5-foot intervals in borings B-1 through B-5, except where closer intervals were required to determine specific geologic conditions, such as slide zones. At these locations, the sample interval was reduced to 2.5-feet. In general, soil sampling was not performed for the borings drilled to install the groundwater monitoring wells.

The SPT consists of driving a 2-inch outside-diameter (O.D.), split-spoon sampler a total distance of 18 inches into the bottom of the boring with a 140-pound hammer falling 30 inches. The number of blows required to drive the sampler 18 inches in 6-inch increments is recorded. The number of blows required for the last 12 inches of penetration is termed the Standard Penetration Resistance (N-value). These values provide a means for evaluating the relative density or compactness of cohesionless (granular) soils and relative consistency or stiffness of cohesive soils. When penetration resistances exceeded 50 blows for 6 inches or less of penetration, the test was terminated. The resistance values and resulting penetrations were recorded by our field representative and are plotted on the respective boring logs.

The hand borings, designated HB-1 through HB-3, were accomplished by Shannon & Wilson, Inc., personnel and the logs are presented as Figures A-5 through A-7. The test pits, designated TP-1 through TP-3, were excavated by Thurston County Department of Roads & Transportation Services in April 27, 1999. The logs of the explorations are presented as Figures A-9 through A-11.

The hand borings were accomplished with a 4-inch-diameter hand auger. Samples were obtained continuously by driving a 1.5-inch O.D., split-spoon sampler a distance of 18 inches with a 40-pound weight falling a distance of 18 inches. The number of blows for the last two 6-inch increments of penetration were recorded. Each of these blow counts are designated as the Porter Penetration Resistance. It is our experience that the Porter Penetration Resistance in blows per

6-inch increment closely approximates the Standard Penetration Test N-value in blows per foot. These values provide a means for evaluating the relative density of cohesionless (granular) soils and the consistency (stiffness) of cohesive soils. The test pit excavations were observed by an experienced geologist from Shannon & Wilson, Inc., who visually classified the exposed soils and their characteristics.

2.2 Laboratory Testing

Laboratory tests were performed on selected samples retrieved from the borings to evaluate the basic index and engineering properties of the soil. The tests included natural water contents, Atterberg limits determinations, and grain size analyses. All testing was conducted at our Seattle laboratory in general accordance with ASTM procedures. The water contents and Atterberg limits are indicated on the exploration logs. The results of the grain size analyses are shown on Figures B-1 through B-2. Plots of the Atterberg limits are shown on the Plasticity Charts, Figures B-3 through B-4.

2.3 Instrumentation

An inclinometer casing was installed in the boreholes following completion at borings B-1 throughout B-4. An inclinometer casing provides a method to monitor lateral slope movements through the depth of the boring. Readings taken periodically are compared to initial readings. Changes in the position of the casing correspond to lateral movements of the ground. Plots of the inclinometer data are presented on Figures C-1 through C-4. Interpretation of the data is presented in Section 4.5.

In borings B-2 and B-4, a vibrating wire transducer was attached to the inclinometer casing and installed at the bottom of the borehole. This instrument measures the groundwater pressure at the location of the instrument by quantifying the hydrostatic pressure present at that depth. These two instruments were installed into the sandy gravel of the deep aquifer found at about elevation minus 60 feet.

Three deep groundwater monitoring wells and two shallow wells with standard slotted well screens were also installed. The purpose of these wells was to determine the groundwater level and monitor any changes in the level due to precipitation or tides. Plots of the groundwater levels and further discussion of the significance of the groundwater level on landsliding are presented in Section 4.4.

2.4 Survey Monitoring

Seventeen ground surface monitoring points were installed and monitored by surveyors from SCA Engineers of Lacey, Washington, under subcontract to Shannon & Wilson, Inc. They used high-precision GPS units to establish and weekly monitor the horizontal and vertical position of the points. The results of the readings are presented in Appendix D of this report.

3.0 SITE DESCRIPTION

3.1 General

The landslide is located along Sunrise Beach Road NW, on the west side of Eld Inlet, as shown on Figure 1. It encompasses an area about 1,700 feet wide from north to south, and about 350 feet long from east to west, as indicated on the Site Plan, Figure 2. The paved road, about 18 feet wide, is located on a bench at about elevation 45 to 54 feet. The road is highest on the two ends and has two locally low spots in the vicinity of the Lawrence and Christensen properties. Approximately 20 residences are located between the roadway and Eld Inlet in the area that experienced slope movements.

The toe of the slope, along Eld Inlet, is continuously protected by bulkheads of various ages, designs and construction. The slope up to the west from the beach to the top of the bluff ranges from about 40 to 50 percent overall; however, some benches on the slope are level (Sunrise Beach Road NW) and other portions of the slope are as steep as 100 percent. The slope from the top of the seawall to the eastern edge of the road ranges from 35 to 40 percent. The slope from the western edge of the road to the top of the bluff ranges from 45 to 55 percent. A relatively level plateau extends westward from the top of the bluff. Two logging roads traverse the slope to the top of the bluff: the southern road is partially overgrown but still graded and the northern road is mostly obliterated.

The slope west of Sunrise Beach Road NW is mostly forested with medium-diameter evergreen trees, but at the south end of the slide area, the trees have been harvested. We understand that the septic effluent for these residences is pumped to the level plateau west of the top of the bluff. All but two of the residences that appear to be located within the slide scarps are on the east side of the roadway. The exceptions are a small cabin and the Martin residence.

We understand that there are about ten domestic water wells that serve these residences. Several wells serve two or more residences. Most are located at the level of the roadway, but at least two are located west of the top of the bluff and several are located on the slope or lower bench east of the roadway.

Springs are abundant, but scattered on this hillside. The most prolific emerge from just below or just above the seawall, at the locations indicated on the Site Plan, Figure 2. All of these springs were flowing during our first visits in early March 1999 through our most recent visit on April 27, 1999.

The other springs that were flowing in March but are no longer flowing are on the Lawrence and Whitener properties, at roadway level, and an open well on the public right-of-way, west of the Christensen property. A spring on the Fields property continues to flow, but at a much reduced rate than it did in early March.

3.2 Landslide Features

As indicated on Figure 2, the scarps outlining the landslide extend from the Lindskog property on the south, where the scarp has damaged the asphalt surface of the roadway (1 1/2 inches vertical displacement), to the Johnson property on the north. Earth cracks on the slope to the west of the area of damaged pavement indicated that the southern end of the landslide mass could eventually extend farther south, toward the Cratsenberg residence; however, no roadway or residential distress was ever observed in that area.

The headscarp, 1 to 3 feet high, follows the top of the bluff in some locations, but in other locations, it is as much as 60 feet east of the top of this steep slope. At the southern end of the top of the bluff, two swales were observed; most likely remnants of previous landsliding activity. Although no earth cracks were observed beneath the Johnson residence, Mr. Johnson's anecdote regarding the subtle shaking of this residence may indicate recent periods of landsliding movements. The toe of the landslide is defined by a bulge of soft, disturbed glacial clay on the beach in some places; however, in other places the toe appears to be above the seawall. This clay contains fragments of hard clay and numerous whole clam shells in its matrix. The maximum amount of uplift appeared to be about 4 inches. The upheaved clay is particularly notable at the Johnson, Christensen, Solberg, Moore, Whitener, Lawrence, Alberti and Estes properties.

Secondary scarps have developed throughout the hillside. On the steep slope west of the road, these scarps were as high as 2 feet. A down-dropped block has occurred on the Martin property and just west of the road. Numerous cracks have developed on two portions of the road: the

Fields, Hurst, Questi, Chorba and Graham properties at the north and the Lawrence and Whitener properties in the middle portion of the site, as shown on Figure 2. A linear depression extends across the Lawrence, Whitener and Moore properties about 5 to 20 feet west of the top of the seawall.

Many of the structures have suffered some damage, some the result of backtilting of the ground surface and some from the pushing of earth into them or tension cracks pulling them apart. The only seawall damage observed is the reopening of a vertical crack in the wall on the Moore property. Sewage effluent pipes have reportedly been broken in at least six places by landslide movements.

The Questi and Chorba residences have suffered significant structural damage owing to both backtilting and lateral stress. The Whitener residence has been undermined on its east side by slumping. The Lawrence residence has been partly backtilted and partly pushed from west to east.

An alternative hypothesis for the northern outline of the landslide is that the north end of the deep-seated slump traverses to the beach through the Fields and Henning properties, and that the ground movements on the Johnson property are separate; related to a previous small-scale slump, reportedly caused by placement of fill on the north edge of the steep Johnson slope. The small slump could have reactivated this year, causing upheaval of clay on the beach.

4.0 GEOLOGIC CONDITIONS

4.1 Regional Geology

The soils in the subject area are a legacy of at least two glacial incursions into the southern end of the Puget Lowland. Based on published geologic maps, water well logs, soil exposures noted during our site visits, and the recent subsurface explorations, most of the stratigraphy is typical of the sediments deposited during the Vashon Stade of the Fraser Glaciation between about 13,000 and 15,000 years ago. This group of sediments is underlain by deposits of previous glaciations and nonglacial deposits.

The Vashon sediments are comprised of till, glacial outwash and glacial lake deposits. Nonglacial materials are represented by silt and fine sand with traces of organics, and previous glaciations are represented by glaciomarine drift and outwash sand and gravel.

4.2 Geologic Units

The geologic conditions at the site were evaluated based on the soils encountered in our subsurface explorations and exposures observed during the reconnaissance. Our interpretation of the distribution of geologic units across the site is illustrated by a composite geologic profile on Figure 4. More detailed conditions, based on the exploration results, are shown on the generalized subsurface profiles (Figures 5 through 7).

On the geologic profiles, the soil strata have been delineated according to geologic units. The following is a list the geologic units encountered within the Sunrise Beach Road landslide area and from youngest to oldest.

- Vashon (glacial)
  - Recessional Lacustrine Deposits (Qvrl)
  - Recessional Outwash (Qvro)
  - Lodgement Till (Qvt)
  - Advance Outwash (Qva)
  - Glaciolacustrine Deposits (Qvgl)

- Pre-Vashon (nonglacial)
  - Lacustrine Deposits
  - Fluvial Deposits

- Pre-Vashon (glacial)
  - Glaciomarine Drift (Qpgm)
  - Outwash (Qpgo)

Recessional Lacustrine Deposits (Qvrl). This glaciolucustrine sediment was deposited in depressions in quiet water as the glacial ice retreated from and wasted in the Puget Lowland. This unit is a soft to very stiff unit and composed of silt and clay with some fine sand.

Recessional Outwash (Qvro). This is a glaciofluvial sediment and was deposited as glacial ice retreated from and wasted in the Puget lowland. This loose to medium dense unit is composed of sand or silty sand and can be locally gravelly.

Lodgement Till (Qvt). This unit was deposited along the base of the advancing glacial ice sheet and was consequently overridden by the ice. The unit is a generally homogeneous, very dense mixture of gravelly, silty sand or gravelly, sandy silt and is generally impervious to water infiltration.

Advance Outwash (Qva). These glaciofluvial sediments were deposited as the glacial ice advanced through the Puget Lowland and are typically found as stratified sand, gravelly sand and sandy gravel. The unit was overridden by the advancing ice and is very dense.

Glaciolacustrine Deposits (Qvgl). This is a fine-grained soil unit, the result of deposition of rock flour into quiet water in proglacial lakes in the Puget Lowland. The unit is composed of clayey silt, silty clay, and fine sand. The deposit is generally very stiff to hard and can be thinly laminated.

Nonglacial Lacustrine Deposits (Qpnl). These fine-grained lake sediments were deposited during an interglacial interval prior to the Vashon Stade. They consist of hard, gray, and gray-green, sandy, clayey silt, trace of organics and iron-oxide staining.

Nonglacial Fluvial Deposits (Qpnf). These granular river or stream sediments were deposited during an interglacial interval prior to the Vashon Stade. They consist of very dense, silty sand, trace of fine organics, and iron-oxide staining.

Glaciomarine Drift (Qpgm). This unit is a till-like deposit with a clayey matrix deposited in lakes or marine water by icebergs, floating ice, and gravity currents. It is generally a heterogeneous and variable mixture of clay, silt, sand, and gravel and is very dense due to glacial overconsolidation.

Outwash (Qpgo). This unit is a glaciofluvial sediment deposited as the glacial ice advanced or retreated through the Puget Lowland. It consists of very dense sand, and sandy gravel. The deep groundwater monitoring wells and the vibrating wire transducers are installed into this unit.

4.3 Subsurface Site Conditions

In general, most of the near surface soils (upper 40 feet) between the road and the seawall consist of Vashon recessional deposits of gravelly sand (Qvro) and silt and clay (Qvrl). These soils were deposited on a terrace locally eroded into the underlying hard clay/silt layer (Qvgl). Such recessional deposition is typically chaotic, changing grain-size over very short distances. Such is the case at this site. The recessional deposits were not found at the top of the bluff in B-5 during the reconnaissance of the slope or in test pit TP-3. The upper portion of the site is locally capped with lodgement till (Qvt) and underlain in turn by 86 feet of advance outwash (Qva), 89 feet of glaciolacustrine deposits (Qvgl), and relatively thin layers of nonglacial deposits (Qpnl and Qpnf), glaciomarine deposits (Qpgm), and older outwash (Qpgo), as illustrated on Figure 4.

The transition from the glacially overridden deposits on the steep hillside west of the road to the normally consolidated deposits beneath and east of the road is poorly understood, but is thought to be very complex three-dimensionally; best illustrated on Figure 7. It appears that the recessional deposits may be interrupted by sharp ridges of hard clay. The zones of heavy seepage along the beach/seawall may indicate the locations of these gullies that are infilled with loose sand or medium stiff clay.

Boring B-5, located on the Lawrence property about 195 feet west of the top of the bluff, is located outside the observed landslide area and was drilled 198.5 feet deep. The sequence of all the geologic units listed above is present at this location with the exception of the recessional glacial deposits. Figure 5 presents a cross section of the soils encountered along a profile drawn between B-5, B-3, and HB-1. Boring B-5 encountered thick deposits of gravelly sand (Qva) and clay and silt (Qvgl) of 86 and 89 feet, respectively, underlying a 10-foot-thick sandy gravel cap of lodgement till (Qvt). A thin layer of glaciomarine drift (Qpgm) was found below the silt and clay and overlying the deep sand and gravel outwash (Qpgo). A deep groundwater monitoring well (DM-5) was installed into the deep outwash unit in this boring.

Figure 6 presents an interpretation of the soils encountered in the northern portion of the study area, based on borings B-1 and HB-3. The slope between the roadway and the seawall is underlain by very loose to medium dense and medium stiff recessional deposits (Qvro and Qvrl). These relatively weak layers are underlain by a thick stratum of very stiff to hard clay and silt. At depth, the clay is underlain by layers of silty, clayey, sandy gravel (Qpgm) and sandy gravel (Qpgo).

Figure 7 presents a cross-section showing our interpretation of the subsurface conditions from south to north along the road. The elevation of the road ranges from 54 feet at B-1 to 45 feet at B-3. Two swales are included in the area explored along the road, with the shallow groundwater monitoring wells placed in the lowest points of these swales.

Recessional lacustrine (Qvrl) and recessional outwash (Qvro) deposits were found at the ground surface and to as deep as 40 feet along the road alignment. Soft to medium stiff, clayey silt (Qvrl) was found to extend to 20 feet deep in boring B-2. Below 16 feet of recessional sand (Qvro), boring B-1 contained a 5-foot-thick layer of recessional silty clay (Qvrl). A large unit of hard clayey silt and silty clay (Qvgl) was found below the recessional lacustrine deposits and ranged from 55 to 84 feet thick. A thin layer of glaciomarine drift (Qpgm) was found between the glaciolacustrine deposits (Qvgl) and the sandy gravel (Qpgo).

At the south end of the site, 35 feet of recessional outwash sand (Qvro) was encountered at the ground surface in boring B-3. This unit was underlain by hard clay and silt (Qvgl) 55 feet thick. Glaciomarine drift (Qpgm) and outwash sandy gravel (Qpgo) were also located at the bottom of this boring. The presence of hard clay (Qvgl) at a depth of 1.5 feet in test pit TP-3 in close horizontal proximity to thick deposits of loose recessional granular sediment demonstrates to the irregularities in the top of the hard clay layer.

4.4 Site Hydrogeology

There are two significant aquifers in the Sunrise Beach Road NW landslide study area. The principal aquifer of the area is the deep coarse-grained pre-Vashon outwash aquifer. The top of this aquifer ranges from elevation –50 feet to –65 feet in the study area. Water levels in the coarse-grained unit in the vicinity of Sunrise Beach Road NW are typically at about elevation 16 to 20 feet. Because the piezometric levels are above the top of the aquifer, the groundwater is under confined (pressure head) conditions. Based on water levels measured at observation wells located along the road (DM-1, DM-2, and DM-3), about 75 to 85 feet of excess pressure exists at the base of the overlying clay confining unit. The aquifer is likely recharged from infiltration of precipitation in the upland areas of the peninsula. Groundwater flow in this unit is from the western upland areas eastward toward, and presumably discharging to, Eld Inlet. Based on groundwater level measurements, the average groundwater gradient in the unit is about 0.03 to 0.07 feet per foot to the east (S 65° E). Figure 8 presents the groundwater contours for the deep aquifer and groundwater level measurements recorded at low tide on April 26, 1999. The discharge characteristics of the aquifer to the inlet are not clearly understood. Eld Inlet is reportedly only about 10 feet deep. Given the hydrostratigraphy observed in the vicinity of the slide area, it would appear that either the clay extends beneath the inlet, or Holocene fill in the channel has partially isolated the aquifer from direct discharge to the bay. Analysis of grain-size data from soil samples collected during subsurface explorations indicates that the hydraulic conductivity of the unit may range between $1x10^{-3}$ to $5x10^{-2}$ cm/s, however, specific capacity data from wells in the project vicinity suggest that hydraulic conductivities may be as high as 1 cm/s. These values indicate that the unit is pervious and capable of transmitting large quantities of groundwater.

The upper aquifer lies in the recessional and advance outwash deposits overlying the clay, and is under water table conditions. Groundwater flow through this aquifer is complex and is not completely understood given the water levels measured and field observations of seepage at various times of this study. The recessional outwash aquifer lies in the immediate vicinity of the road. This aquifer is recharged by groundwater flow from the advance outwash aquifer to the west, which appears to be truncated at or just west of the road (Figure 4). This aquifer is also likely recharged by precipitation, shallow groundwater (interflow) discharge from the slopes above the road, and from discharge from the septic drain fields installed at the top of the bluff. Groundwater levels and directions of flow are difficult to describe precisely because they are governed not only by swales or channels that likely exist in the top of the hard clay, but by recessional clay deposits sporadically distributed in the aquifer. Groundwater levels measured in shallow wells installed for the project in the recessional outwash aquifer (SM-2 and SM-3) varied between elevations 26 and 28 feet (about 14 to 17 feet below ground surface). However, springs on the hillside observed during the Phase 1 reconnaissance and observations of shallow test pit explorations performed on April 27, 1999 indicate that groundwater may also be at or near the elevation of the road (about elevation 40 to 50 feet). These data suggest channelization and damming of groundwater flow through the recessional outwash that is controlled by the presence of the clay deposits or low permeability outwash deposits. Groundwater discharge from the recessional outwash aquifer is through seeps and springs, at or just above beach level. Based on grain-size analyses of the soils, the hydraulic conductivity of these soils may be on the order of 1×10^{-2} to 1×10^{-1} cm/s. Groundwater elevations measured in the upper and lower aquifer indicate a downward hydraulic gradient during the period of the study.

Groundwater levels in the deep aquifer fluctuate vertically more than 8 feet due to tidal fluctuations. The piezometric level fluctuations shown in Figure 9 show a strong tidal efficiency for the observation wells and vibrating wire piezometers installed between the shoreline and the road. Only about a 10 to 20 minute delay was observed between peaks in the aquifer and tidal levels. Water level fluctuations due to tidal fluctuations measured at DM-5 are significantly less. The measured responses suggest either that the aquifer has a lower hydraulic conductivity at DM-5 than that at the other monitoring wells, or that the aquifer is partially truncated between DM-5 and the remaining wells located along Sunrise Beach Road NW. No water level fluctuations were observed in the upper aquifer due to tidal responses.

The water level measurements show that the piezometric surface at DM-5 slowly lowered about 0.3 feet over the 4-day measurement period (Figure 9). In comparison, measurements at the domestic water supply wells completed in the lower aquifer show about a 2-foot increase in head between the measurements collected on March 17, 1999, and April 26, 1999 (see below) at the same tidal elevation. The magnitude of water level fluctuations in the upper aquifer are not known, however, the Martin (Moore) property has an old domestic well reportedly screened in the upper unconfined aquifer that reportedly occasionally dries in the summer. Though this does not necessarily indicate that the aquifer dries completely during the summer, it suggests that significant drops in water levels may occur during drier seasons. Additional groundwater measurements at these wells are necessary to determine the antecedent, or water level trends with time, and in particular, how water levels in both the shallow and deep aquifers respond to precipitation events.

WATER LEVEL ELEVATIONS OF DOMESTIC WELLS AT LOW TIDE

Well Name	Low Tide Water Level Elevation (feet) on 3/17/99	Low Tide Water Level Elevation (feet) on 4/26/99
Cratzenberg	18.7	20.5
Lawrence	19.3	21.4
Graham	13.5	15.4
Questi	17.5	20.0

Note: 1) Domestic wells are completed in the deep aquifer.
2) Domestic well elevations are approximate.

4.5 Inclinometers

Four inclinometer casings were installed at selected boring locations shown on Figure 3. Casing depths along the roadway (Casings B-1 through B-3) ranged from approximately 99 to 116.5 feet below ground surface. Casing B-4 was installed to a depth of approximately 86 feet below ground surface.

Several sets of data have been obtained since installation of the casings. The plots of these data sets are presented in Appendix C, Figures C-1 through C-4. As shown on the plots, the current sets of data (obtained April 27, 1999) indicate negligible horizontal displacement in the primary anticipated direction of movement (A-axis) since initial readings were obtained. The inclinometer casing has four internal grooves along the length of the casing (placed at 90-degree intervals). During installation, the casing is oriented such that the plane through a set of grooves (opposite each other) is in line with anticipated direction of movement (or downslope, for this project). This plane is known as the A-axis.

As shown on some of the B-axis plots, fluctuations among the data sets are observed. These fluctuations are common along this axis, as these displacements are in a plane perpendicular to the direction of the inclinometer probe. The inclinometer probe tracks along the casing's A-axis grooves.

Overall, the accuracy of the inclinometer system is approximately 0.1-inch per 100 feet of casing. As shown on the attached plots, most of the fluctuations observed are within the accuracy of the system.

5.0 ENGINEERING STUDIES

5.1 Slide Mechanism

The hillside in the vicinity of the project site has a history of sliding as evidenced by signs of old headscarps and disturbed subsoils encountered in the field explorations. It should be noted that highly disturbed soils were only noted near the top of the silty clay (Qvgl) layer in borings B-1 and B-2. Other thin (1/6- to 1/8-inch-thick) layers of slickensided clay exist throughout the Qvgl unit of all the borings. It is our opinion that the recent sliding is probably occurring in the previously disturbed soils. Reactivation of old slide masses could be initiated by many factors. The significant factors contributing to the present slide appear to be prolonged heavy rain and low strength soils. Precipitation for the winter months has been significantly above normal in three of the past four winters, as summarized on Table 1 (Winter Precipitation 1995/96 through 1998/99). In addition, precipitation in the past winter has exceeded the normal by a record amount. Because major landslides are typically initiated or reactivated by a long-term rise in the groundwater table, it is not unexpected that this landslide reactivated in 1999. No human factors have been identified that could have caused this landslide. In addition, although observed only in boring B-2 where medium stiff, clayey silt (Qvrl) was encountered in the upper 20 feet immediately below the roadway, it is our opinion that the presence of less permeable soils in the lower portion of the slide area contribute to the buildup of piezometric levels in the sand and gravel (Qva) located above and west of the Sunrise Beach roadway. In our opinion, this elevation of piezometric levels probably triggered the major slides that extend from the top of the bluff to the seawall.

Additional slide scarps appear to extend from the Sunrise Beach roadway to the seawall or immediately above the seawall in the vicinity of the Lawrence/Whitener and Graham/Chorba/Questi/Hurst properties. These slides exist in areas where there is reduced toe support (the distance between the roadway and the seawall is reduced at the Lawrence/Whitener properties), and in locations where the existing hillside east of the roadway slopes more steeply to the beach than at other locations. In our opinion, the slide surface along Profile B-B' intersects the ground surface above the seawall, near the toe of the existing steep slope immediately east of the roadway, as shown on Figure 11.

The following information describes our present interpretation of the current sliding activities:

- Observed movement is probably occurring in previously disturbed materials.
- The bottoms of the assumed slide planes are located near the top of the clayey silt soils (Qvgl and Qvrl), as indicated on Figures 10 and 11.
- The sliding occurred after a period of winter-long heavy rain. Movements appeared to slow to negligible levels and even possibly stop after the precipitation levels decreased. No movement within the accuracy of the instruments has been detected in the slope inclinometers or on the ground surface monitoring points.
- No signs of movement are evident west of the top of the bluff.

Based on the available information, it is our opinion that the main factors which apparently triggered the current sliding include the following: (1) the rise in groundwater level in the relatively permeable advance and recessional outwash strata encountered above and below the roadway level, (2) the low permeability of localized fine-grained strata along the lower portion of the slide area, which apparently blocks downhill drainage in selected areas and permits water pressure buildup, and (3) the low shear strength of the disturbed silt/clay beds.

5.2 Stability Analyses

In order to evaluate potential mitigation measures for the area, engineering analyses were accomplished to evaluate the existing landslide conditions. Two typical cross-sections located along the Alberti/Lawrence (Profile A-A') and Chorba (Profile B-B') properties were studied. The profiles extend from the beach to the top of the bluff. These profiles were chosen based on available subsurface information and the presence of cracks or slide scarps located at both the top of the bluff and along Sunrise Beach Road NW.

For each study section, existing failure surfaces (Slide Planes A and B) were evaluated based on observations of the existing landslide features and the results of the subsurface explorations, as shown on Figures 10 and 11. Note that a third failure surface (C) was assumed for Profile A-A'. This surface was not used to back-calculate the shear strength of the subsoils, and there is no evidence that an actual failure surface exists at this depth. This failure surface was studied to evaluate the potential for deep-seated slide movements, assuming that the low residual shear strengths determined from the back-calculations exist at this depth. Ideally, the results of inclinometer measurements would be used to confirm the depth of the assumed failure surface at the inclinometer location. As indicated in Section 4.5, however, it appears that no ground movements within the accuracy of the inclinometer probe have occurred at the inclinometer locations since the initial readings were collected.

Groundwater levels were assumed for each study section based on the results of the groundwater measurements collected from the observation wells and piezometers installed in the borings completed for the project. For Profile B-B', it was assumed that the groundwater level ponded behind the wall that supports the Chorba residence. It should be emphasized that subsurface conditions were generalized for the analyses based on limited exploration data.

Stability analyses were performed for the assumed existing failure surfaces (A and B) of each study profile using the UTEXAS2 computer program (Wright, 1986) and employing Spencer's Method of analysis (Spencer, 1967). This method estimates the factor-of-safety (FS) of a slope by satisfying both forces and moments in static equilibrium equations.

Using the assumed existing slide planes (A and B) and groundwater conditions described above, we back-calculated the shear strength parameters along the slide plane that would result in an FS equal to about 1.0. Based on our back-calculated analyses, we estimate the shear strength parameters along the slide plane to be:

BACK-CALCULATED MATERIAL PROPERTIES

Material	Assumed Total Unit Weight (pcf)	Shear Strength	
		Friction Angle (degrees)	Cohesion (psf)
Loose Sand and Gravel (Qvro)	120	32	0
Stiff clayey Silt/silty Clay (Qvrl/Qvgl)	120	21-22	0

The friction angle estimated for the clay was sensitive to the assumed groundwater level, stratigraphy, ground surface topography, and failure surface geometry. As a result, a range of values for a back-calculated FS equal to about 1.0 was estimated for the clay. These parameters are reasonable for disturbed clay and also fit published relationships of residual angles of internal friction versus plasticity index which is about 20 for the clayey silt and silty clay soil (see Figures B-3 and B-4) encountered at the site (Boris, 1985; and Deere, 1974).

5.3 Remedial Measures for Existing Slides

There are a number of techniques to increase the stability of a slide, including regrading, buttressing, pile reinforcement, and groundwater dewatering. Considering that the rise in the groundwater table was apparently the main cause of this slide, we evaluated means to increase stability by lowering the groundwater table. Other remedial methods do not appear to be practical, or environmentally or economically feasible at this time.

Using the above back-calculated strength parameters for assumed existing slide surfaces A and B, we evaluated the effect of lowering the groundwater level of the upper aquifer on the stability of the slope. In our stability analyses, we generally assumed a uniform groundwater drawdown throughout the analyzed cross-section. The lowest water level was controlled by the high tide level, which is located about 2 to 3 feet below the top of the existing seawalls. Results of this evaluation are summarized below:

RESULTS OF STABILITY STUDIES

Subsurface Profile	Assumed Failure Surface	Assumed Uniform Groundwater Level Drawdown of Upper Aquifer (ft)	Estimated Factor of Safety
A-A'	A	5	1.08
	B		1.07
	A	10	1.14
	B		1.11
	C		1.07
	A	15	1.19
	B		1.15
	C		1.10
B-B'	A	7 (to top of clay)	1.20
	B		1.14

As indicated, uniform drawdowns of the upper groundwater level equal to about 7 to 15 feet increase the FS of the assumed failure surfaces by about 7 to 20 percent. As anticipated, the greater increases in FS occur for the smaller assumed failure surfaces (surface A for both Profiles A-A' and B-B'). In this regard, the analyses and stability of the slope along failure surface A appear to be more sensitive to the groundwater level in the slope. If higher groundwater levels occur, it is our opinion that these failure surfaces could therefore be more readily reactivated.

The results of the stability analyses for surface C of Profile A-A' indicate that there is a risk that deeper-seated movements could occur. The risk of occurrence of these deeper seated movements is dependent on the piezometric levels of the lower aquifer and the mobilization of residual strength parameters of the silty clay encountered at greater depths. It is recommended that the impacts of the deeper aquifer be further evaluated by the performance of a pumping test, as discussed in Section 6.3.

It should be noted that even a 15 percent increase in slope stability is a low value. In our opinion, however, this slight increase indicates a positive increase above the existing stability condition. Further conclusions regarding the FS should be made following the additional recommended field work, studies, and discussions with Thurston County personnel regarding the level of acceptable risk.

As indicated above, the analyses assume a uniform drawdown in groundwater level. Depending on the effectiveness of the actual drainage measures installed, the stability analyses should be re-evaluated to reflect the achieved groundwater levels. It should also be noted that the above analyses only considered groundwater pressures based on the upper aquifer, which is appropriate considering that the measured piezometric levels of the deeper aquifer are generally lower than the upper groundwater levels. Depending upon the depth of the assumed failure surface and the piezometric levels of the deeper aquifer relative to the upper groundwater levels, however, the piezometric levels of the deeper aquifer may have to be considered in the stability analyses. This should be further evaluated based on the results of the recommended pumping test.

In our opinion, lowering groundwater levels along the slope could be accomplished by installing trench drains and horizontal drains. A trench drain could be installed along the roadway (Figure 12) to intercept springs or seepage before they reach the slide area and infiltrate into the subsoils on the slope. The interceptor trench should extend to a depth of 20 feet. Water intercepted by the trench should be collected in a pipe and carried downslope to the beach. To prevent collected water from leaking into the sand-infilled gullies notched into the top of the hard clay, both a perforated and a tightline pipe should be installed in the interceptor trench. In areas where the sand (Qvro)/clay (Qvgl) contact is below the base of the trench, a 3- to 5-foot-high dam of lean concrete should be constructed in the bottom of the trench to collect the groundwater collected upgradient into the tightline. The effectiveness of the proposed trench and collection system depends on the soil and groundwater conditions in the vicinity of the roadway. In order to further evaluate the subsurface conditions in this area, it is recommended that additional shallow auger borings be drilled along the roadway, as discussed in Section 6.2.

In addition to the trench drain, it is recommended that horizontal drains also be installed, as shown on Figure 12. The effectiveness of the horizontal drains depends on the presence of granular deposits in the area to be drained. Subsurface conditions, as revealed by field explorations, indicate that the soils in local areas may be more impervious than the clean sand and gravel that appears to be dominant. To evaluate the effectiveness of the recommended horizontal drains, it is recommended that a test section of horizontal drains be installed. We recommend that the test section consist of a fan of five 200- to 250-foot-long drains installed at a maximum horizontal spacing of 5 to 15 degrees and at a slope angle that parallels the top of the clay. The test section should be installed in one of the preliminary locations west of the roadway, as shown on Figure 12. Based on the results of the borings, the recommended trench drains and the horizontal drain test section, the number and location of horizontal drains required to lower the groundwater level along the hillside would then be finalized. Preliminary anticipated locations of the horizontal drains located above and below the roadway are shown on Figure 12. These locations were selected based on access considerations, the anticipated subsurface conditions at the site, and the presence of seepage and springs that currently or previously existed along the beach and immediately west of the roadway.

If it is required to lower the piezometric level of the deeper aquifer, deep pumping wells would be required. The necessity for these wells and the required spacing would depend on the results of the recommended pumping test.

6.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the results of our observations, explorations, and engineering analyses, lowering the groundwater table would increase the stability of the slope. We recommend that this be accomplished by initially installing a 20-foot-deep trench drain along Sunrise Beach Road NW. In addition, it is recommended that horizontal drains also be installed west of the roadway to lower the groundwater level in areas where seepage and springs were observed. If sufficient drawdown of the groundwater cannot be achieved with the trench drain and horizontal drains installed west of the roadway, other options, such as installing horizontal drains from immediately above the seawall, should be implemented.

The following additional recommendations are provided in the order in which they should be implemented.

6.1 Instrumentation Monitoring

It is recommended that the observation wells, vibrating wire piezometers, slope inclinometers, and ground surface monitoring points installed at the site continue to be monitored and the data evaluated. A long-term groundwater level monitoring program would identify current and seasonal groundwater level fluctuations in both aquifers and in the clay. Determining the seasonal water level fluctuations in the upper aquifer is necessary to provide an indication of the pressure distribution in the clay. This information could also be used to evaluate the dewatering requirements for installation of the trench drain. Long-term monitoring of the deep aquifer should also be performed to provide an indication of current and long-term seasonal fluctuations and their impact on a potential deep-seated slide. The results of this monitoring would be used to confirm and/or revise our conclusions and recommendations.

6.2 Perform Additional Shallow Borings Along the Roadway

As indicated in Section 4.3, the subsurface conditions along the roadway vary significantly within relatively short distances. To further evaluate the subsurface conditions and the feasibility of installing a trench drain along the roadway, as shown on Figure 12, it is recommended that additional shallow borings be drilled about every 200 feet along the road. The borings should extend to the top of the stiff to hard, silty clay unit (Qvgl). Hollow-stem auger drilling techniques could be utilized. Observation wells should be installed in the borings to monitor groundwater levels. Gradation analyses should also be performed on samples of sand retrieved from the borings to evaluate the suitability of reusing this material as trench backfill.

6.3 Perform a Pumping Test

We recommend performing a pumping test in the vicinity of boring DM-2. The pumping test would be performed to evaluate the hydraulic characteristics of the deep aquifer in preparation for design of a dewatering or pressure relief groundwater control system. The test would also be used to evaluate the ability to reduce the pore pressures in the clay from deep pumping and provide information to help assess the potential for a deep-seated slide in the clay. Based on the results of this test, we will re-evaluate the results of the stability studies. This test would utilize observation wells installed at borings DM-2, DM-3, DB-4, and DM-5 for drawdown data collection during the test. Additional site installations would consist of drilling a pumping (dewatering) well to a depth of about 125 feet, and drilling an additional boring near SM-2 to install two vibrating wire piezometers in the clay. These would be used to monitor the drainage of the clay during the test.

6.4 Install Trench Drains Along the Roadway

As shown on Figure 12, we recommend installing a trench drain along the Sunrise Beach roadway. The purpose of the trench drain would be to lower groundwater levels and to intercept seepage along the slope west of the roadway. A perforated subdrain and tightline pipe should be placed at the base of the trench to collect groundwater and properly dispose of it at the beach. The trench should extend as deep as possible. Based on our experience, trench depths greater than about 20 feet are typically not practical assuming conventional excavating and trench-box shoring techniques are utilized.

It is our opinion that a dewatering system would be required to lower the groundwater level of the upper aquifer prior to installing the trench drain. Additional dewatering considerations would be developed based on the results of the recommended borings performed along the roadway.

6.5 Install Horizontal Drains West of the Roadway

As shown on Figure 12, we recommend installing horizontal drains at the base of the hillside located west of the roadway. Initially, the drains should be installed in areas where springs and seepage were observed along the toe of the slope. Depending upon the depth of the groundwater lowering observed in the monitoring wells installed in the shallow borings drilled along the roadway (Section 6.2) after the trench drain and horizontal drains are installed, additional horizontal drain locations west of the roadway could be considered.

6.6 Install Horizontal Drains at Seawall

Depending upon the effectiveness of the trench drain and the horizontal drains installed along the upper slope, additional horizontal drains may be required near the beach, immediately above the seawall. The location and extent of these drains would depend upon the subsurface conditions encountered and the results of groundwater level monitoring.

6.7 Design and Install a Deep Dewatering or Pressure Relief System

Depending upon the results of the continued monitoring and the recommended pump test (Sections 6.1 and 6.3, respectively), as well as the level of risk acceptable to the County and local residents; a deep dewatering and/or pressure relief system may be required to lower the piezometric levels in the deep aquifer. This would be further evaluated based on the monitoring and test results, as well as the results of additional stability analyses.

7.0 ESTIMATED COSTS AND LEVEL OF RISK

The estimated costs to implement the above recommendations (Section 6.0) are summarized on Table 2. The unit costs are based on our experience, as well as discussions with contractors who perform this type of work. These unit costs should be considered approximate at this time. Other than the recommended trench drain, quantities of the other mitigation measures largely depend on the subsurface conditions encountered in additional explorations and the depths to which the groundwater levels are lowered as the work proceeds. As a result, the estimated total cost to mitigate the slide is very approximate at this time.

The level of risk of future instabilities along the hillside is also dependent upon the subsurface conditions and the depth that the groundwater levels are actually lowered as a result of drainage installations. The results of our analyses indicate that the stability of the hillside is very sensitive to both groundwater levels and the assumed strength of the subsoils. FS increases of 15 to 20 percent are marginal and do not guarantee that future instabilities could not occur along the hillside. In particular, the stability of the steep slope that extends from the roadway to the beach in the vicinity of the Graham/Chorba/Questi/Hurst properties may not be sufficiently increased by only installing drainage improvements, as it appears that the existing groundwater levels in this area (boring B-1) are currently relatively low. Considering that the cracks in the roadway have appeared to widen since our involvement in the project, the existing FS of the slope in this area may currently be less than 1.0. As a result, it is our opinion that minor groundwater fluctuations and/or removal of existing structures near the toe of the slope could result in greater slope movements in this area.

Furthermore, assuming that remedial measures are successfully implemented to mitigate the current slope movements, the potential for deep-seated movements still exists, as discussed in Section 5.2.

There is always a risk of landsliding on steep hillsides in the Puget Sound area that owners must be prepared to take. Although drainage and other earth-stabilizing measures can be implemented, the risks of damage to properties and dewatering facilities cannot be completely eliminated. In addition to natural factors (soil and groundwater), other factors that may affect the stability of the hillside are excavations, fills, leaking or broken utility lines, improper drainage, lack of maintenance of drainage facilities or vegetative cover, unwise actions by adjacent owners, or similar events or unknown conditions that may cause sliding.

8.0 LIMITATIONS

The analyses, conclusions, and recommendations presented in this report are based on observed site conditions as they presently exist and on information that we reviewed regarding the history of the area and the subsurface information obtained from the borings and test pits. If conditions described in this report change, we should be advised immediately so we can review those conditions and reconsider our conclusions and recommendations.

This report was prepared for the use of the Thurston County Department of Roads & Transportation Services. It should be made available to contractors involved in remedial measures for factual data and not as a warranty of subsurface conditions, such as those interpreted from the boring logs or as presented in the discussions on subsurface conditions included in this report.

The scope of our services did not include any environmental assessment or evaluation regarding the presence or absence of wetlands or hazardous or toxic materials in the soil, surface water, groundwater, or air, on or below or around the site. Shannon & Wilson, Inc., has prepared the attached Appendix E, "Important Information About Your Geotechnical Report," to assist you and others in understanding the use and limitations of our reports.

SHANNON & WILSON, INC.

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WILLIAM T. LAPRADE
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ENGINEERING GEOLOGIST

4/30/99

GERARD J. BUECHEL
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22136
REGISTERED PROFESSIONAL ENGINEER
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4/30/99

William T. Laprade, C.E.G.
Vice President

Gerard J. Buechel, P.E.
Vice President

BMR:WTL:GJB/lkd

TABLE 1

WINTER PRECIPITATION (INCHES)
1995/96 THROUGH 1998/99

	October	November	December	January	February	March	6-month Total	Deviation from 30-year Normal	4-month Total	Deviation From 30-year Normal
30-year normal	4.31	8.05	8.12	8.10	5.77	4.95	39.3	--	30.04	--
1995-1996	5.2	13.56	7.69	7.22	11.07	2.65	47.39	+8.09	39.54	+9.50
1996-1997	5.46	6.25	11.4	9.22	5.03	11.79	49.15	+9.85	31.90	+1.86
1997-1998	8.18	6.07	5.50	10.43	5.04	5.71	40.93	+1.63	27.04	-3.00
1998-1999	3.41	15.28	12.99	12.25	15.50	6.95	66.38	+27.63	56.02	+25.98

6-month total = October through May
4-month total = November through February

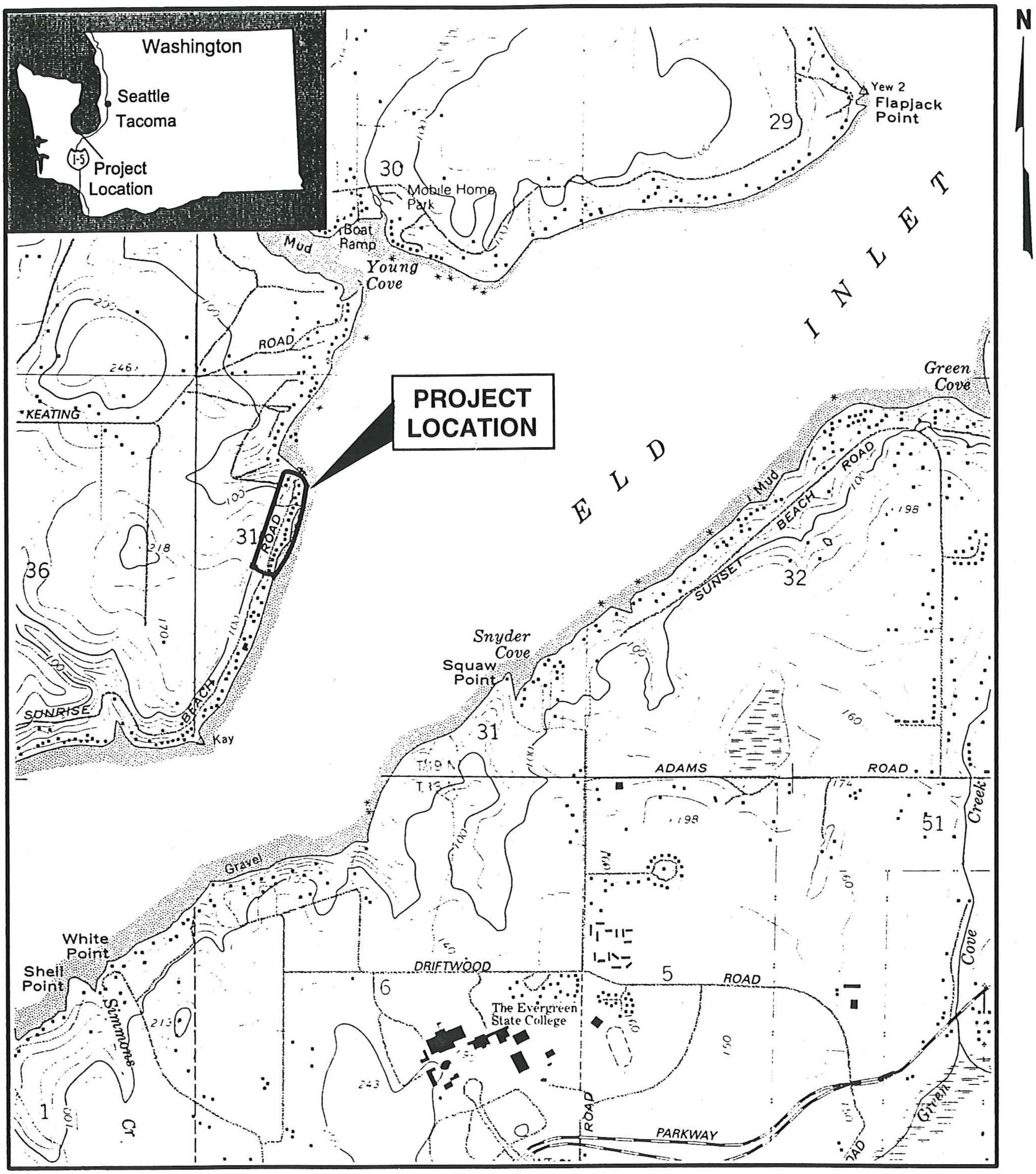
Note: Precipitation data was recorded at the Olympia Airport Station.

TABLE 2

COST ESTIMATE FOR ADDITIONAL ENGINEERING SERVICES AND REMEDIAL CONSTRUCTION

Item	Description	S&W	Subcontract	Total
6.1	**Instrumentation Monitoring**			
	Inclinometer Readings	$9,900		
	1 every 6 weeks for 1 year			
	Water Level Readings	$16,500		
	1 every 3 weeks for 1 year			
	Ground Surface Monitoring		$12,000	
	1 reading every month for 1 year			
6.2	**Perform Additional Shallow Borings Along Roadway**			
	Drill Subcontract		$6,000	
	8 borings approx. 240 ft total			
	Monitor borings and prepare logs and profiles	$6,300		
6.3	**Perform a Pumping Test**			
	Subcontract		$34,000	
	Monitor and Analyze Pump Test	$21,100		
	Re-evaluate Slope Stability	$7,700		
6.4	**Install Trench Drains Along Roadway(1)**			
	Subcontract			
	20 ft deep, 1,700 lf @ $300/ft		$513,000	
	Temporary dewatering wells @ 30 ft on center @ $3,000 ea		$140,000	
	Construction Monitoring	$39,000		
6.5	**Install Horizontal Drains West of Roadway(1)**			
	Subcontract		$76,000	
	4 arrays of 5 drains each			
	Construction Monitoring	$14,800		
6.6	**Install Horizontal Drains at Seawall(1)**			
	Subcontract		$118,800	
	3 arrays of 5 drains each			
	Construction Monitoring	$14,800		
6.7	**Design and Install a Deep Dewatering or Pressure Relief System**			
	Subcontract		$103,500	
	4 wells @ 300 ft on center			
	Monitor Well Installation	$21,000		
6.8	**Project Management (10%)**	$15,100		
	Subtotal	$166,200	$1,003,300	
	Contingency (10%)	$16,600	$100,330	
	Subtotal	$182,800	$1,103,630	
	Total			**$1,286,430**

(1) Assumes the County will develop plans, specifications, and contract documents, and procure low bid contractor.



NOTE

Map adapted from 1:24,000 USGS topographic map of Tumwater, Washington quandrangle, dated 1959, revised 1994.

Thurston County, Washington
Sunrise Beach Road NW Landslide

VICINITY MAP

April 1999 W-8615-02

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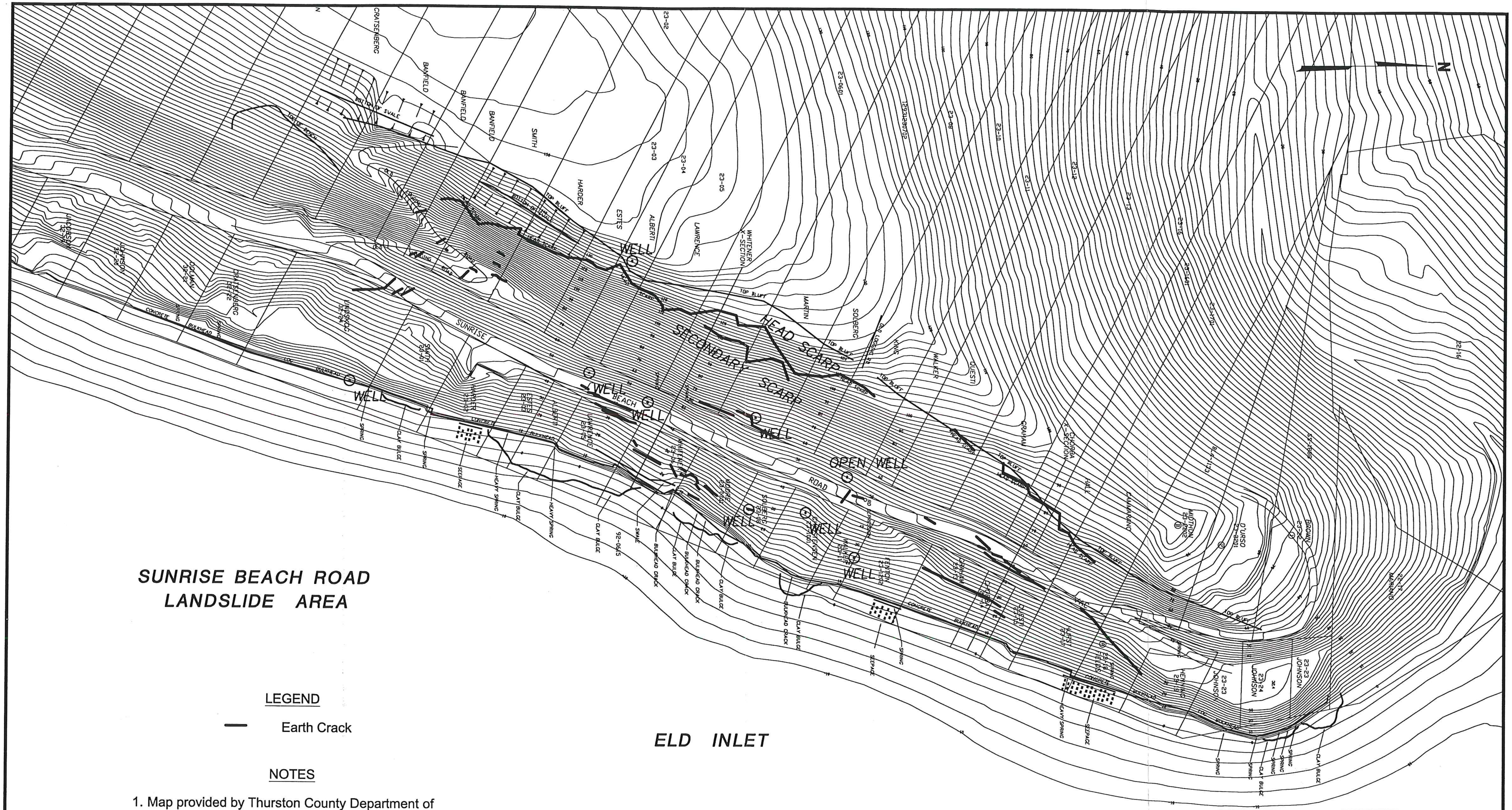
FIG. 1



LEGEND

▬ Earth Crack

NOTES

1. Map provided by Thurston County Department of Roads and Transportation Services.
2. Data Collected by Thurston County using Trimble PRO-XR GPS with sub-meter accuracy horizontally.
3. Wells are privately owned water supply wells.
4. Topography is based on aerial photographic survey.

0 150 300
Scale in Feet

Thurston County, Washington
Sunrise Beach Road NW Landslide

SITE PLAN

April 1999 W-8615-02

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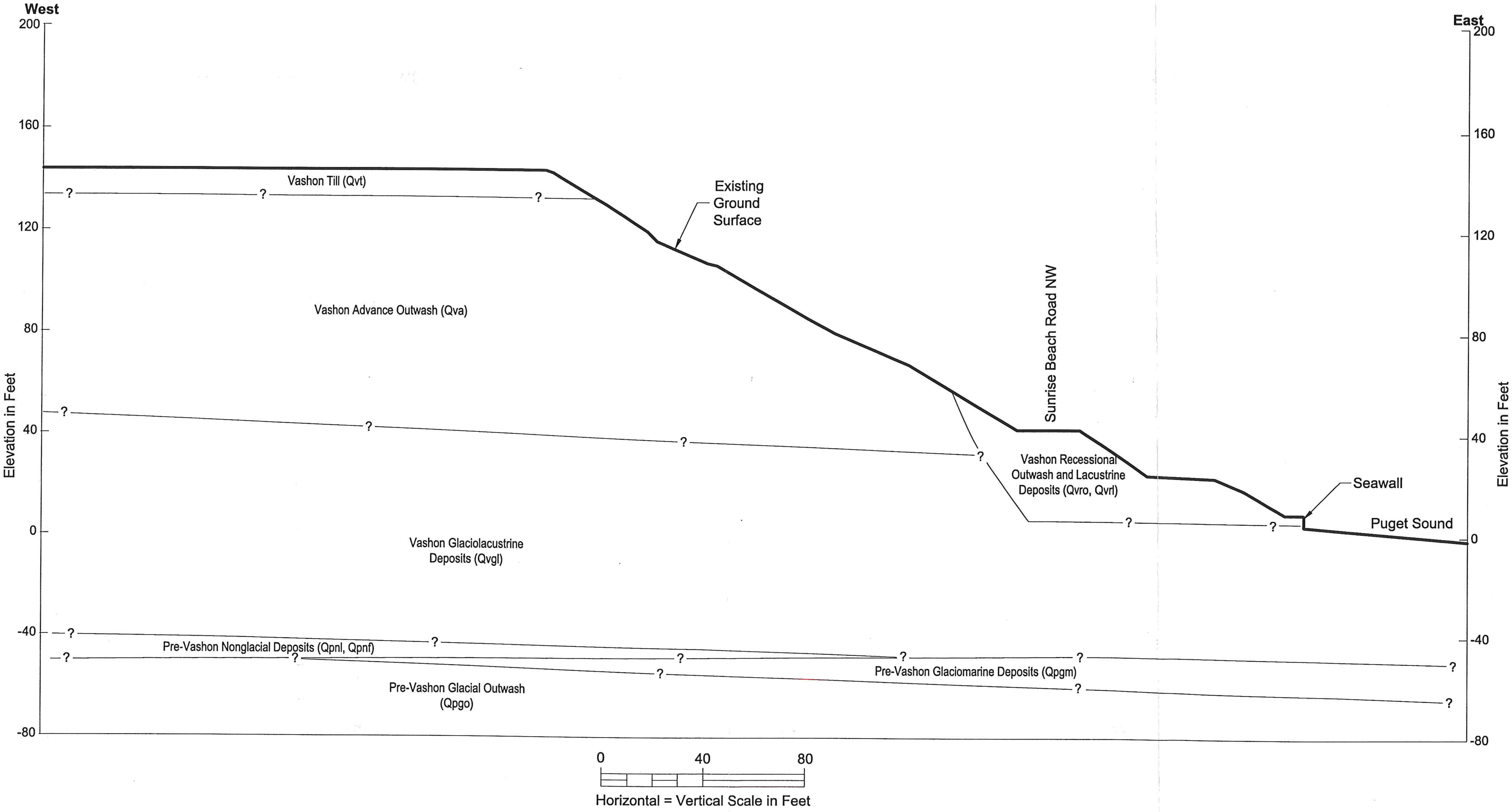
FIG. 2

File: W-8615-02 Fig. 2 Date: 4/29/99



NOTES

1. Ground surface profile adapted from profile created by Thurston County Department of Roads and Transportation.
2. See Section 4.2 for descriptions of geologic units.

Thurston County, Washington
Sunrise Beach Road NW Landslide

GENERALIZED COMPOSITE OF GEOLOGIC PROFILE

April 1999
W-8615-02

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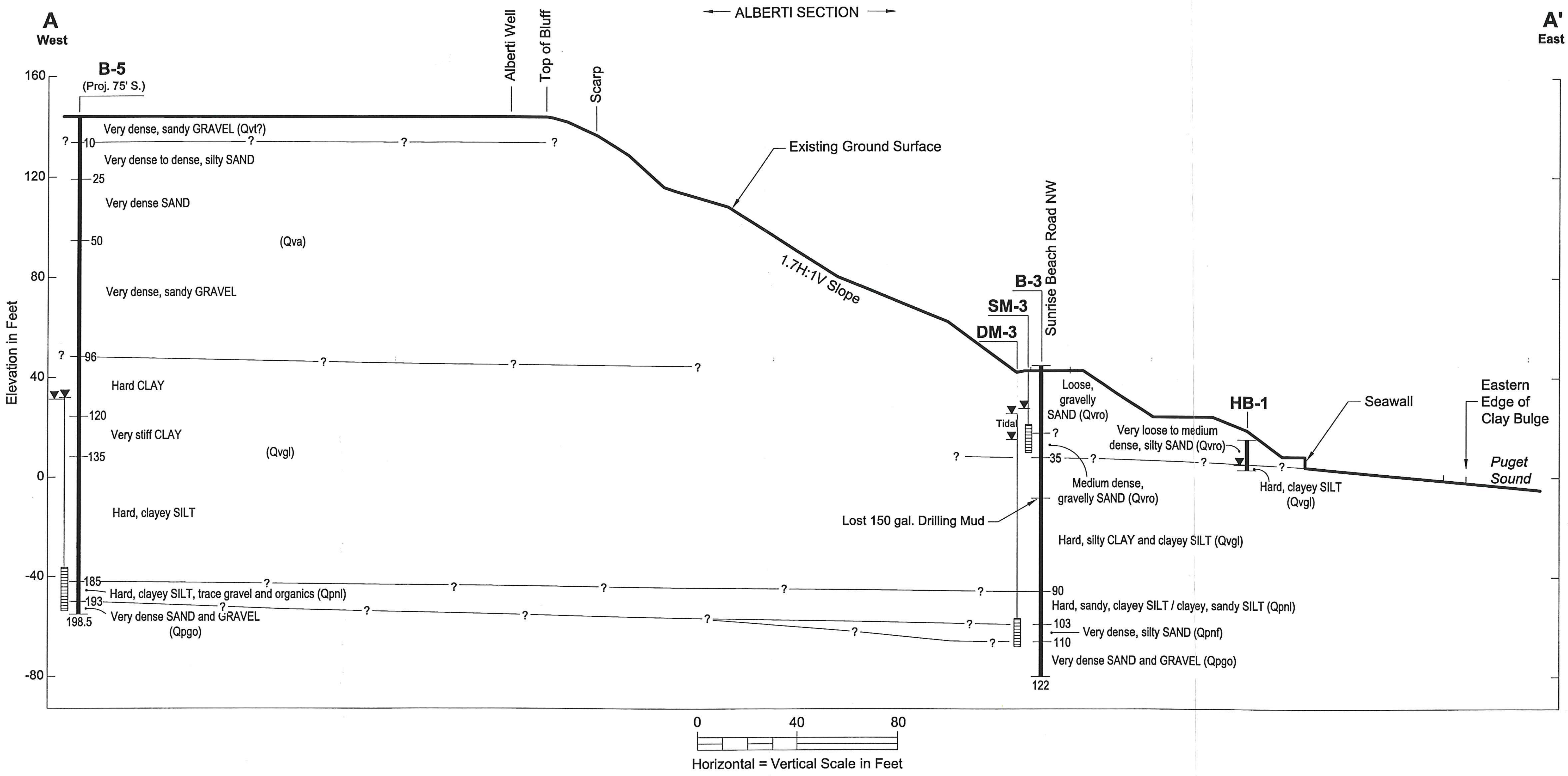
FIG. 4

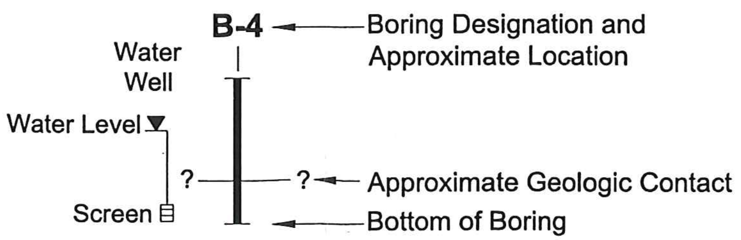
File: W-8615-02 Fig. 4.dwg Date: 4/30/99



NOTES

1. Ground surface profile adapted from profile created by Thurston County Department of Roads and Transportation.
2. The geology shown is derived from borings conducted by Shannon & Wilson, Inc. for this study. Elevations and geologic contacts should be considered approximate. Variations between the profile and actual conditions may exist.

LEGEND



Thurston County, Washington
Sunrise Beach Road NW Landslide

GENERALIZED SUBSURFACE PROFILE A-A'

April 1999 W-8615-02

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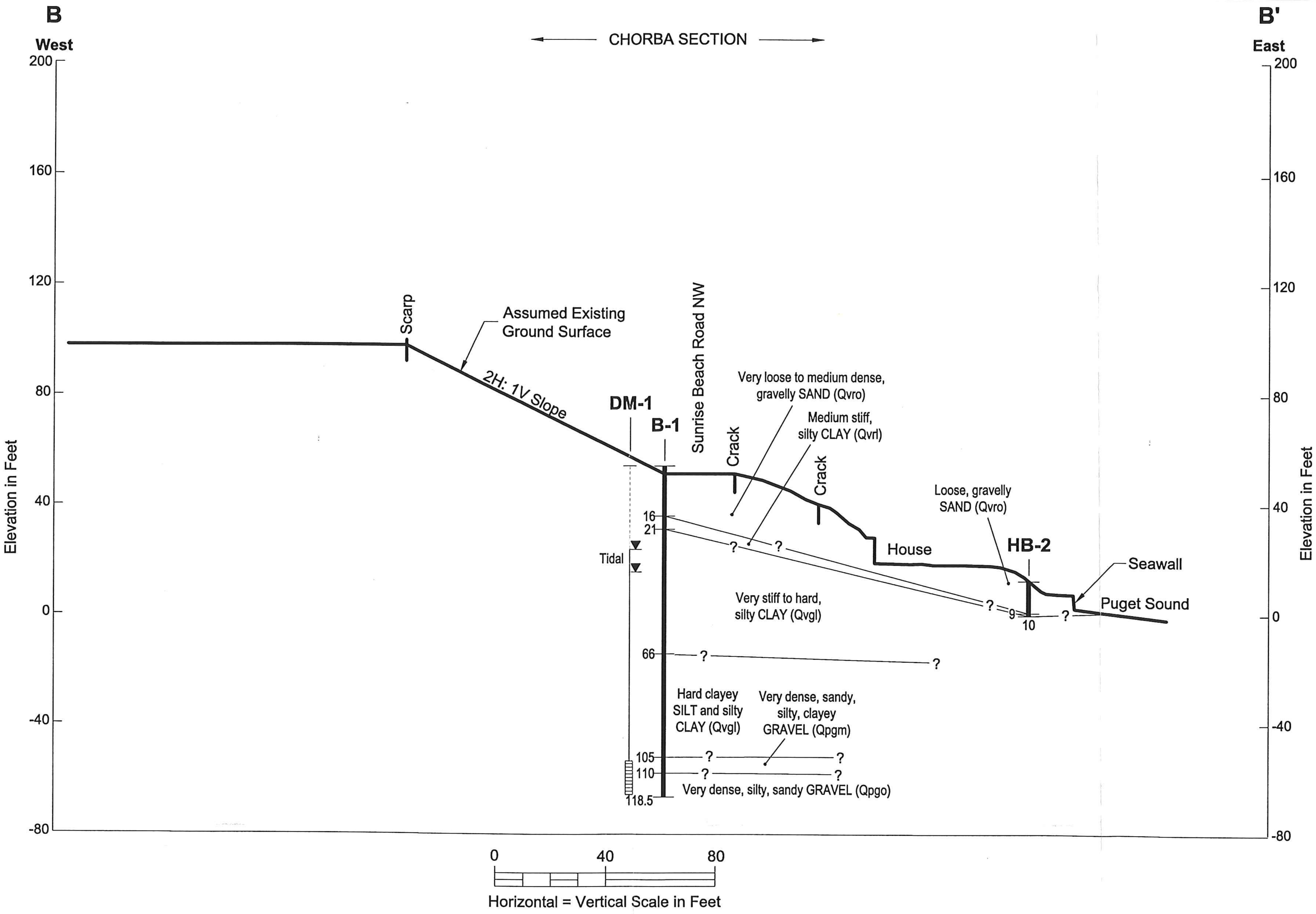
FIG. 5

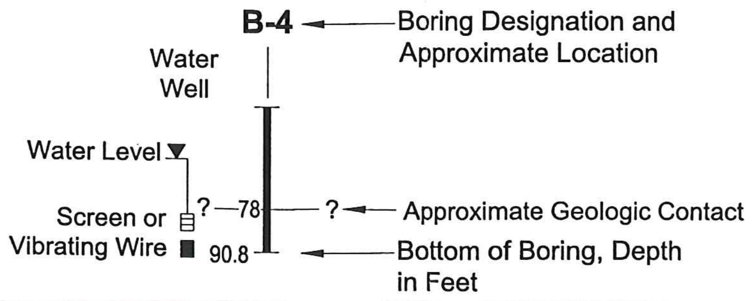
File: W-8615-02 Fig. 5.dwg Date: 4/30/99



NOTES

1. Ground surface profile adapted from profile created by Thurston County Department of Roads and Transportation.
2. The geology shown is derived from borings conducted by Shannon & Wilson, Inc. for this study. Elevations and geologic contacts should be considered approximate. Variations between the profile and actual conditions may exist.

LEGEND



Sunrise Beach Road NW Landslide
Thurston County, Washington

GENERALIZED SUBSURFACE PROFILE B-B'

April 1999 W-8615-02

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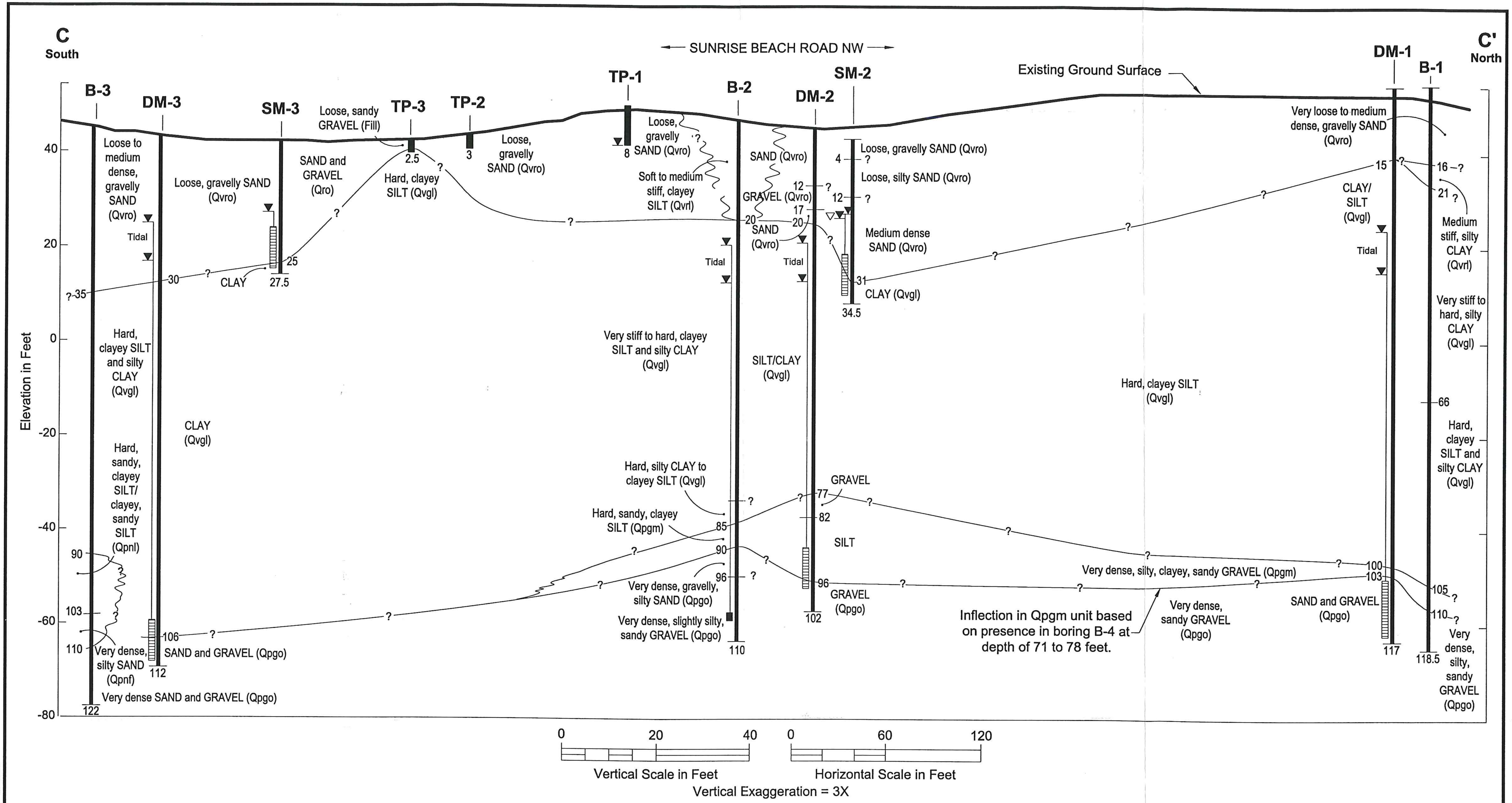
FIG. 6

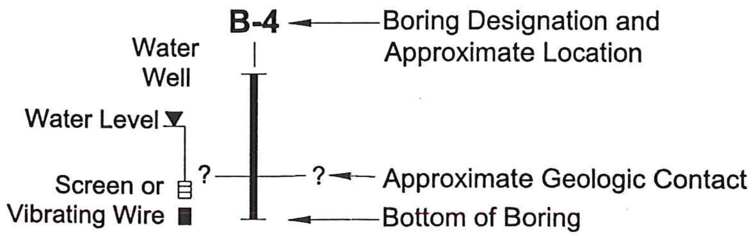
File: W-8615-02 Fig. 6.dwg Date: 4/30/99



NOTES

1. Ground surface profile adapted from profile created by Thurston County Department of Roads and Transportation.
2. The geology shown is derived from borings conducted by Shannon & Wilson, Inc. for this study. Elevations and geologic contacts should be considered approximate. Variations between the profile and actual conditions may exist.

LEGEND



Thurston County, Washington
Sunrise Beach Road NW Landslide

GENERALIZED SUBSURFACE PROFILE C-C'

April 1999
W-8615-02

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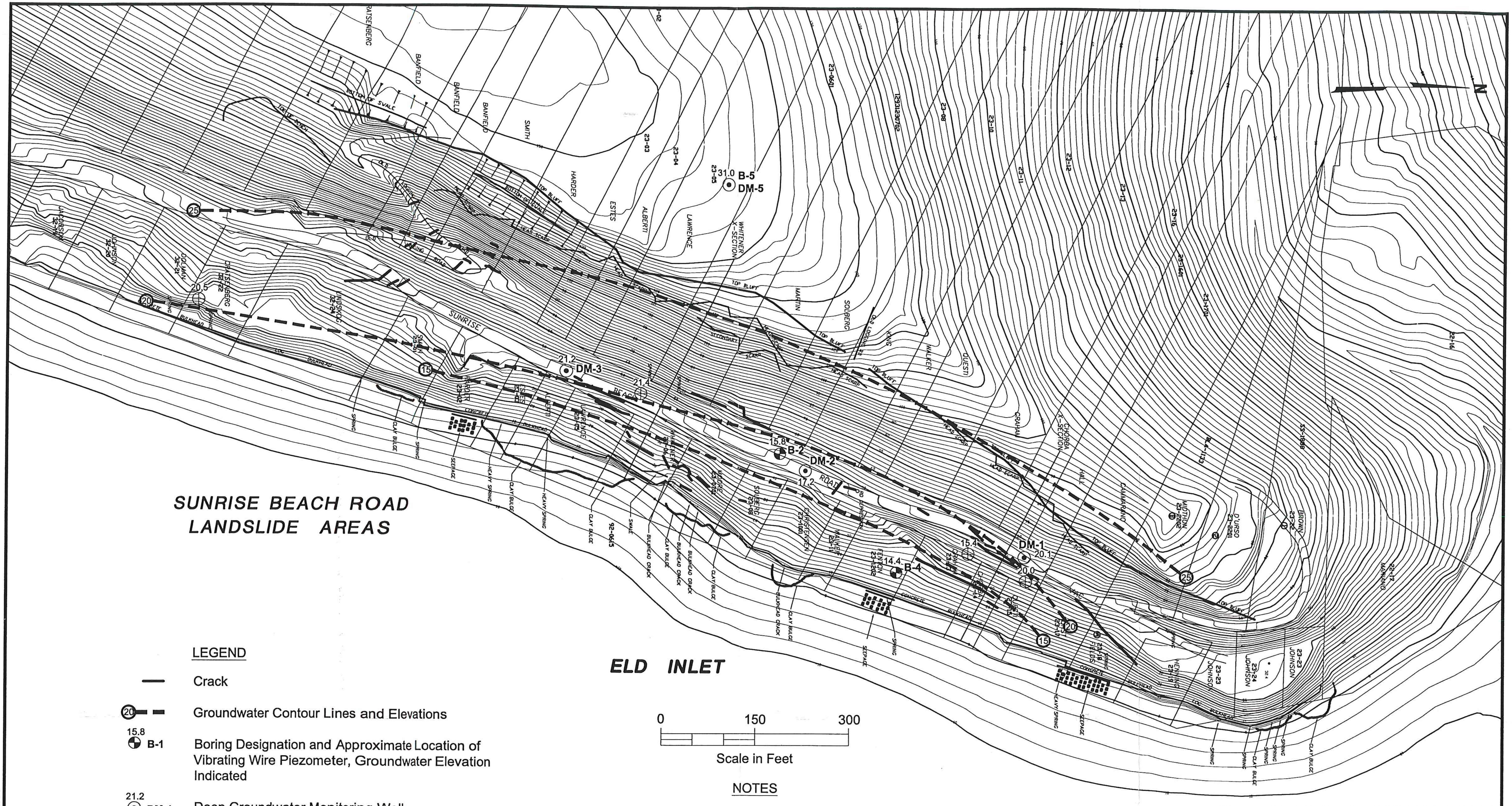
FIG. 7

File: W-8615-02 Fig. 7.dwg Date: 4/29/99



LEGEND

Crack

Groundwater Contour Lines and Elevations

15.8 B-1 Boring Designation and Approximate Location of Vibrating Wire Piezometer, Groundwater Elevation Indicated

21.2 DM-1 Deep Groundwater Monitoring Well Groundwater Elevation Indicated

20.5 Domestic Water Supply Well Groundwater Elevation Indicated

NOTES

1. Map provided by Thurston County Department of Roads and Transportation Services.
2. Data Collected by Thurston County using Trimble PRO-XR GPS with sub-meter accuracy horizontally.
3. Domestic well elevations are approximate.

Sunrise Beach Road NW Landslide
Thurston County, Washington

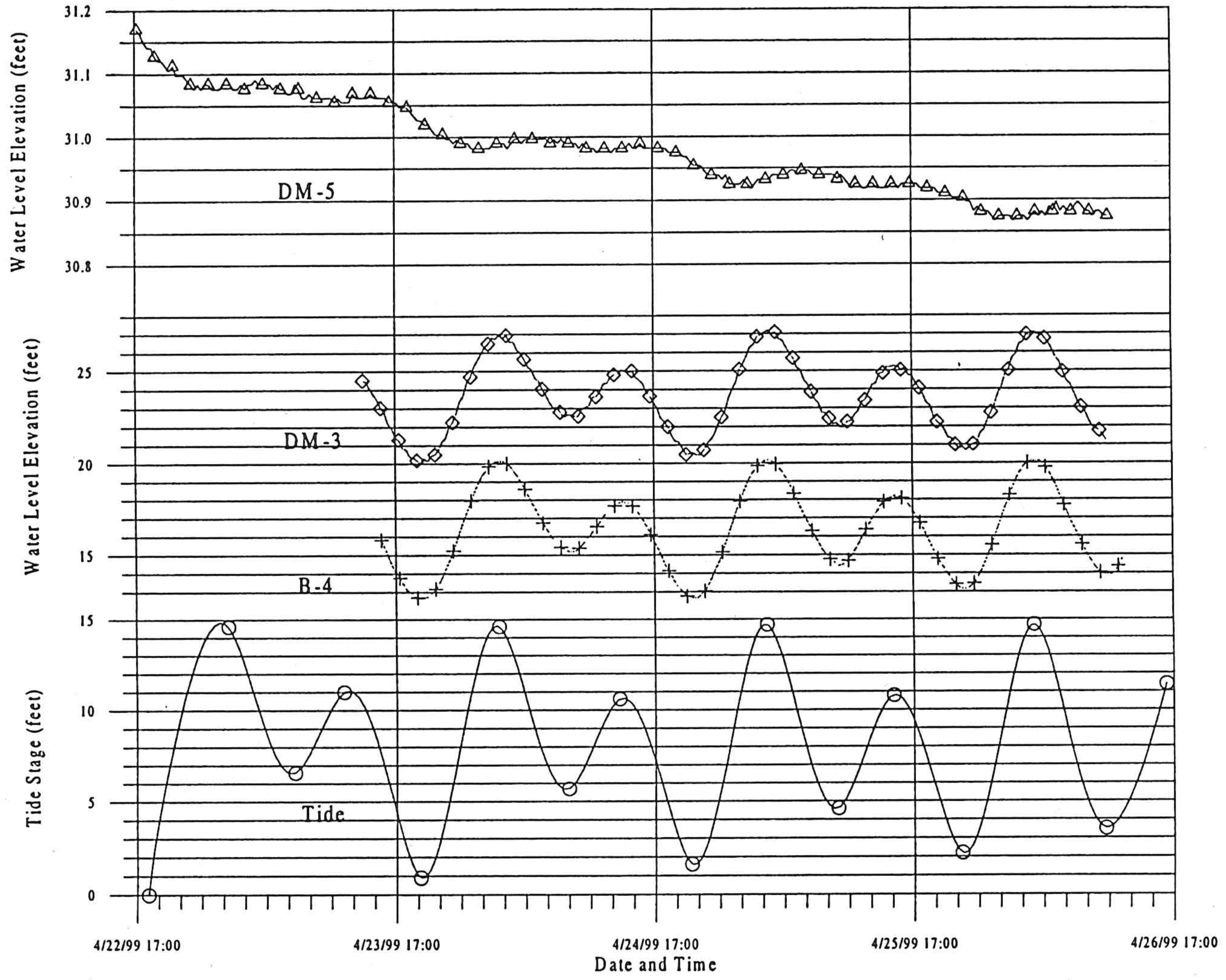
GROUNDWATER ELEVATION CONTOURS IN THE DEEP AQUIFER AT LOW TIDE ON 4/26/99

April 1999 W-8615-02

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. 8

File: W-8615-02 Fig. 8 Date: 4/29/99



NOTES

1. DM-5 uses a different scale.
2. Tide stage is not equal to elevation.
3. Every fifth measurement is plotted for B-4, DM-3, and DM-5.
4. High and low tide stages are plotted (taken from Olympia tide table).

Thurston County, Washington
Sunrise Beach Road NW Landslide

WATER LEVEL RESPONSES IN MONITORING WELLS DUE TO TIDAL FLUCTUATIONS

April 1999
W-8615-02

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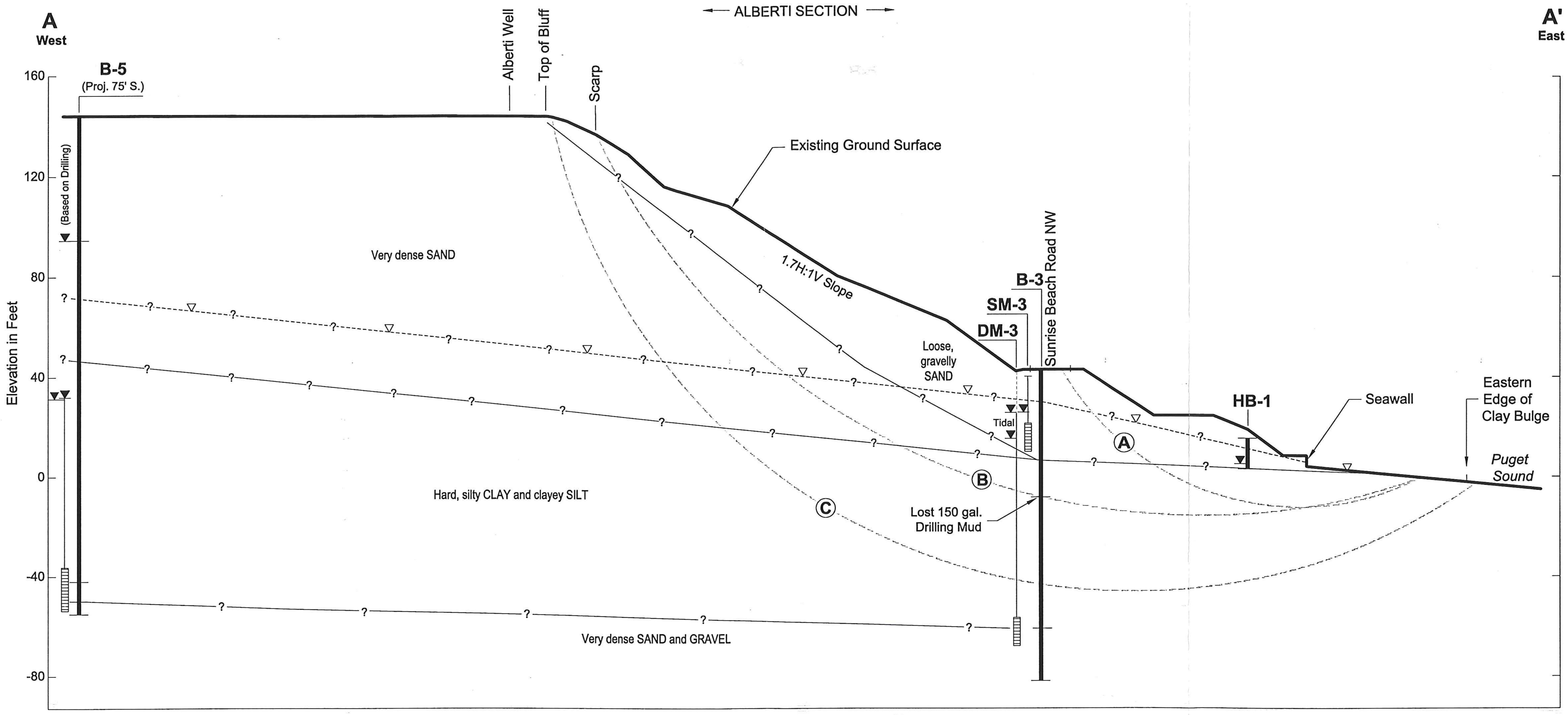
FIG. 9

FIG. 9



0 40 80

Scale in Feet

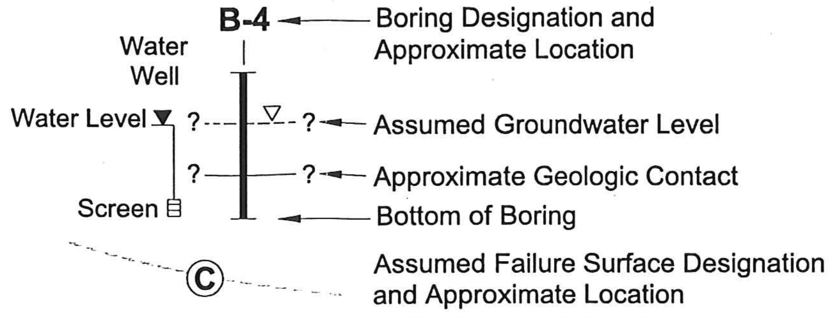
NOTES

1. Ground surface profile adapted from profile created by Thurston County Department of Roads and Transportation, supplemented by field surveys performed for this project.

2. The assumed existing failure surfaces (A and B) shown were utilized in our engineering studies. Assumed failure surface C was studied to evaluate the potential for deep-seated slides.

3. The assumed stratigraphy and groundwater levels are derived from borings conducted by Shannon & Wilson, Inc. for this study. Elevations and geologic contacts should be considered approximate. Variations between the profile and actual conditions may exist.

LEGEND



- Boring Designation and Approximate Location
- Assumed Groundwater Level
- Approximate Geologic Contact
- Bottom of Boring
- Assumed Failure Surface Designation and Approximate Location

Thurston County, Washington
Sunrise Beach Road NW Landslide

ASSUMED FAILURE SURFACES
PROFILE A-A'

April 1999 W-8615-02

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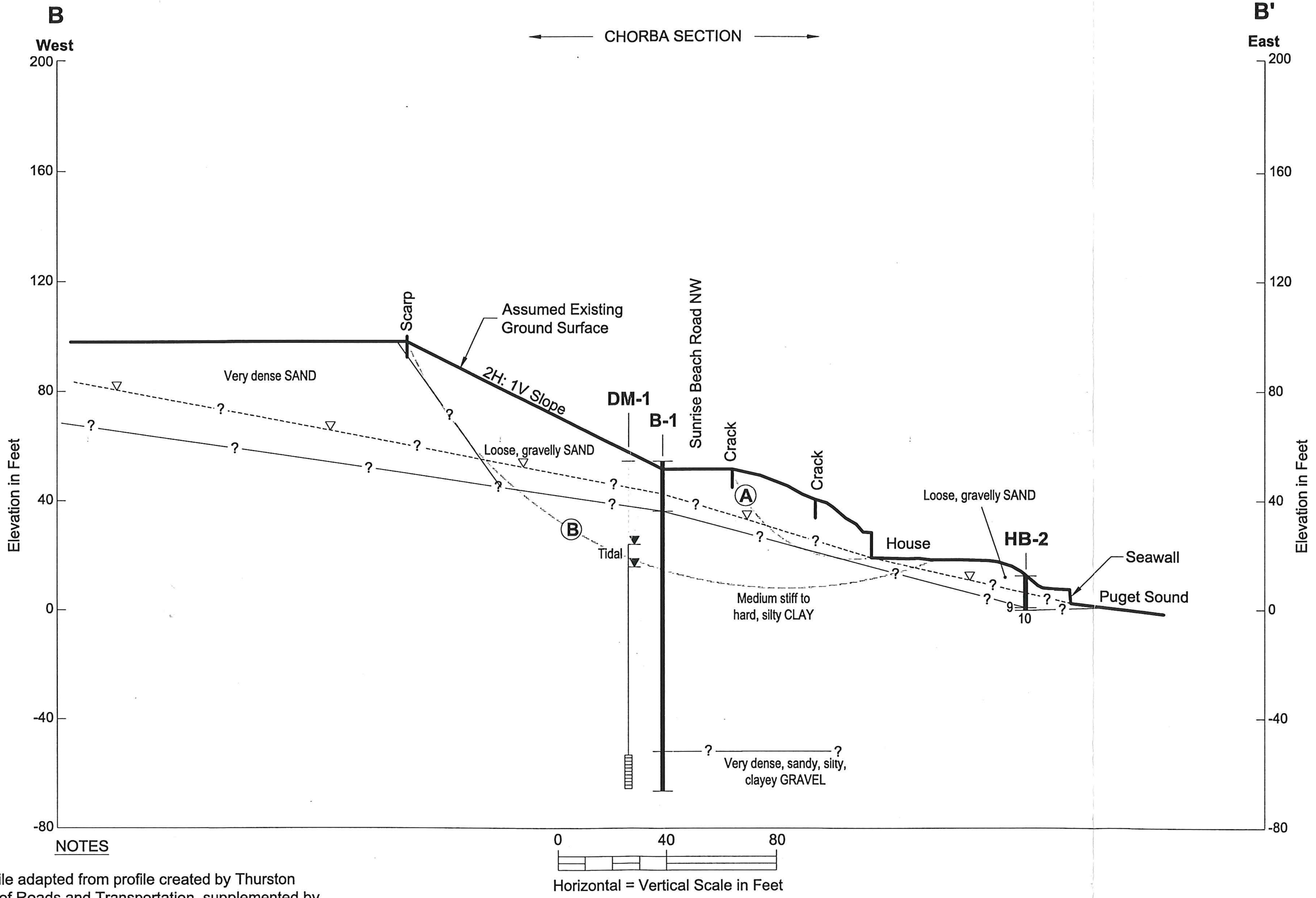
FIG. 10

File: W-8615-02 Fig. 10.dwg Date: 4/30/99



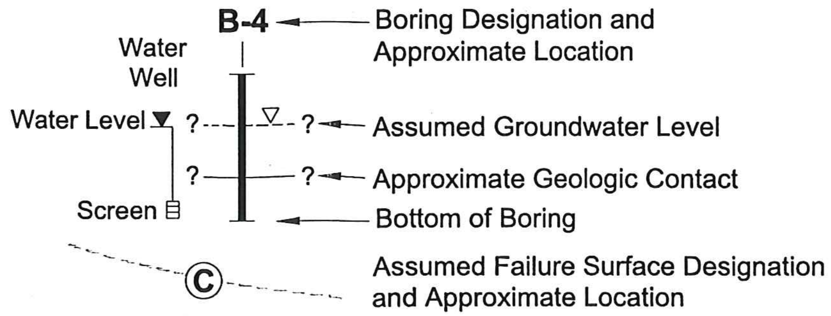
NOTES

1. Ground surface profile adapted from profile created by Thurston County Department of Roads and Transportation, supplemented by field surveys performed for this project.

2. The assumed existing failure surfaces (A and B) shown were utilized in our engineering studies. Assumed failure surface C was studied to evaluate the potential for deep-seated slides.

3. The assumed stratigraphy and groundwater levels are derived from borings conducted by Shannon & Wilson, Inc. for this study. Elevations and geologic contacts should be considered approximate. Variations between the profile and actual conditions may exist.

LEGEND



Sunrise Beach Road NW Landslide
Thurston County, Washington

ASSUMED FAILURE SURFACES
PROFILE B-B'

April 1999 W-8615-02

SHANNON & WILSON, INC.
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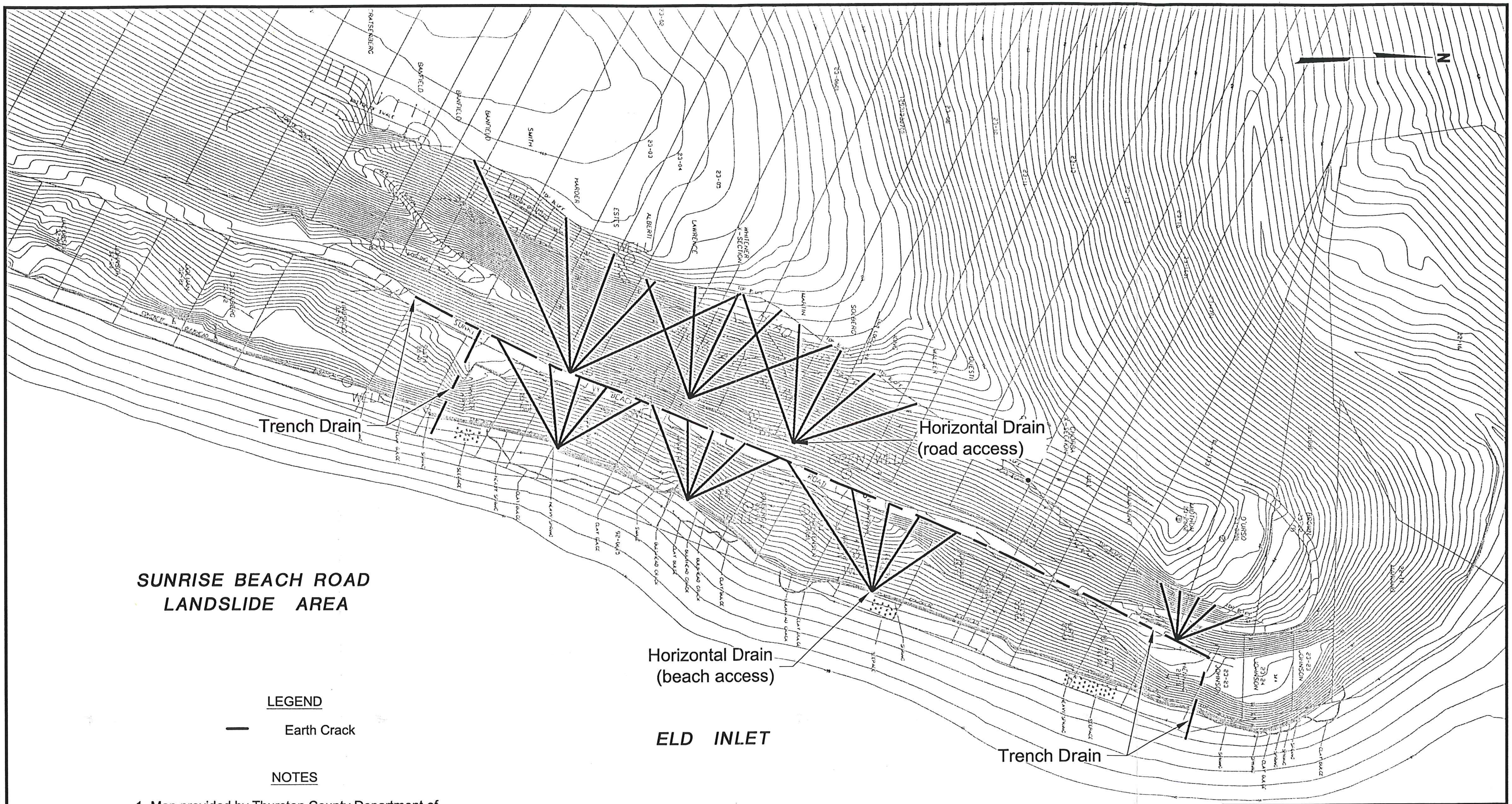
FIG. 11

File: W-8615-02 Fig. 6.dwg Date: 4/30/99



NOTES

1. Map provided by Thurston County Department of Roads and Transportation Services.
2. Data Collected by Thurston County using Trimble PRO-XR GPS with sub-meter accuracy horizontally.
3. Layout of remedial measures is preliminary, actual locations will depend on additional subsurface information and analysis.

0 150 300

Scale in Feet

Thurston County, Washington
Sunrise Beach Road NW Landslide

PROPOSED REMEDIATION MEASURES

April 1999 W-8615-02

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. 12

File: W-8615-02 Fig. 12 Date: 4/30/99

APPENDIX A

FIELD EXPLORATIONS

APPENDIX A

FIELD EXPLORATIONS

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Key Rev. 1 7-12-96

Shannon & Wilson, Inc. (S&W), uses a soil classification system modified from the Unified Soil Classification System (USCS). Elements of the USCS and other definitions are provided on this and the following page. Soil descriptions are based on visual-manual procedures (ASTM D 2488-93) unless otherwise noted.

S&W CLASSIFICATION OF SOIL CONSTITUENTS

- MAJOR constituents compose more than 50 percent, by weight, of the soil. Major constituents are capitalized (SAND).
- Minor constituents compose 12 to 50 percent of the soil and precede the major constituents (silty SAND). Minor constituents preceded by "slightly" compose 5 to 12 percent of the soil (slightly silty SAND).
- Trace constituents compose 0 to 5 percent of the soil (slightly silty SAND, trace of gravel).

MOISTURE CONTENT DEFINITIONS

Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, from below water table

ABBREVIATIONS

ATD	At Time of Drilling
Elev.	Elevation
ft	feet
HSA	Hollow Stem Auger
ID	Inside Diameter
in	inches
lbs	pounds
Mon.	Monument cover
N	Blows for last two 6-inch increments
NA	Not Applicable or Not Available
OD	Outside Diameter
OVA	Organic Vapor Analyzer
PID	Photoionization Detector
ppm	parts per million
PVC	Polyvinyl Chloride
SS	Split Spoon sampler
SPT	Standard Penetration Test
USC	Unified Soil Classification
WLI	Water Level Indicator

GRAIN SIZE DEFINITIONS

DESCRIPTION	SIEVE SIZE
FINES	< #200 (0.08 mm)
SAND* • Fine • Medium • Coarse	 • #200 - #40 (0.4 mm) • #40 - #10 (2 mm) • #10 - #4 (5 mm)
GRAVEL* • Fine • Coarse	 • #4 - 3/4 inch • 3/4 - 3 inches
COBBLES	3 - 12 inches
BOULDERS	> 12 inches

* Unless otherwise noted, sand and gravel, when present, range from fine to coarse in grain size.

RELATIVE DENSITY / CONSISTENCY

COARSE-GRAINED SOILS		FINE-GRAINED/COHESIVE SOILS	
N, SPT, BLOWS/FT.	RELATIVE DENSITY	N, SPT, BLOWS/FT.	RELATIVE CONSISTENCY
0 - 4	Very loose	<2	Very soft
4 - 10	Loose	2 - 4	Soft
10 - 30	Medium dense	4 - 8	Medium stiff
30 - 50	Dense	8 - 15	Stiff
Over 50	Very dense	15 - 30	Very stiff
		Over 30	Hard

WELL AND OTHER SYMBOLS

⬚	Cement/Concrete	■	Asphalt or PVC Cap
▨	Bentonite Grout	○	Cobbles
▩	Bentonite Seal	▦	Fill
▧	Slough	∴	Ash
⁘	Silica Sand	▩	Bedrock
⁘	2" I.D. PVC Screen (0.020-inch Slot)	●	Gravel

Thurston County, Washington
Sunrise Beach Road NW Landslide

SOIL CLASSIFICATION AND LOG KEY

April 1999 W-8615-02

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-1
Sheet 1 of 2

Key Rev. 1 7-12-96

UNIFIED SOIL CLASSIFICATION SYSTEM
(From ASTM D 2488-93 & 2487-93)

MAJOR DIVISIONS			GROUP/GRAPHIC SYMBOL②		TYPICAL DESCRIPTION
Coarse-Grained Soils *(more than 50% retained on No. 200 sieve)* *[Use Dual Symbols for 5 - 12% Fines (i.e. GP-GM)]*①	Gravels *(more than 50% of coarse fraction retained on No. 4 sieve)*	Clean Gravels① *(less than 5% fines)*	GW	○	Well-Graded Gravels, Gravel-Sand Mixtures, Little or No Fines
			GP	●	Poorly Graded Gravels, Gravel-Sand Mixtures, Little or No Fines
		Gravels with① Fines *(more than 12% fines)*	GM	⦙	Silty Gravels, Gravel-Sand-Silt Mixtures
			GC	▨	Clayey Gravels, Gravel-Sand-Clay Mixtures
	Sands *(50% or more of coarse fraction passes the No. 4 sieve)*	Clean Sands① *(less than 5% fines)*	SW	⁘	Well-Graded Sands, Gravelly Sands, Little or No Fines
			SP	⁚	Poorly Graded Sand, Gravelly Sands, Little or No Fines
		Sands with① Fines*(more than 12% fines)*	SM	⦙	Silty Sands, Sand-Silt Mixtures
			SC	▧	Clayey Sands, Sand-Clay Mixtures
Fine-Grained Soils *(50% or more passes the No. 200 sieve)*	Silts and Clays *(liquid limit less than 50)*	Inorganic	ML	▥	Inorganic Silts of Low to Medium Plasticity, Rock Flour, or Clayey Silts with Slight Plasticity
			CL	▨	Inorganic Clays of Low to Medium Plasticity, Gravelly Clays, Sandy Clays, Silty Clays, Lean Clays
		Organic	OL	☰	Organic Silts and Organic Silty Clays of Low Plasticity
	Silts and Clays *(liquid limit 50 or more)*	Inorganic	CH	▨	Inorganic Clays of Medium to High Plasticity, Sandy Fat Clay, Gravelly Fat Clay
			MH	▥	Inorganic Silts, Micaceous or Diatomaceous Fine Sands or Silty Soils, Elastic Silt
		Organic	OH	▧	Organic Clays of Medium to High Plasticity, Organic Silts
Highly Organic Soils	Primarily organic matter, dark in color, and organic odor		PT	≋	Peat, Humus, Swamp Soils with High Organic Content (See D 4427-92)

NOTES

1. Dual symbols (symbols separated by a hyphen, i.e., SP-SM, slightly silty fine SAND) are used for soils with between 5% and 12% fines or when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart.

2. Borderline symbols (symbols separated by a slash, i.e., CL/ML, silty CLAY/clayey SILT; GW/SW, sandy GRAVEL/gravelly SAND) indicated that the soil may fall into one of two possible basic groups.

Thurston County, Washington
Sunrise Beach road NW Landslide

SOIL CLASSIFICATION AND LOG KEY

April 1999 W-8615-02

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-1
Sheet 2 of 2

SOIL DESCRIPTION

Surface Elevation: Approx. 54.0 Ft.

Very loose to medium dense, brown, slightly gravelly, fine to coarse SAND, trace silt; moist; (Qvro) SW.

Medium stiff, brown, silty CLAY; wet; massive to laminated, iron-oxide stains, slightly diced; (Qvrl) CH.

Very stiff to hard, gray, slightly silty CLAY; moist; massive to faintly laminated, 1/4- to 1/2-inch-thick seams of dark gray clay with slickensided diced texture (dry) at 6- to 12-inch intervals; (Qvgl) CH.

Hard, clayey SILT and silty CLAY; moist; massive (Qvgl) ML and CL.
1/2-inch blocky and slickensided lens at 68 feet.

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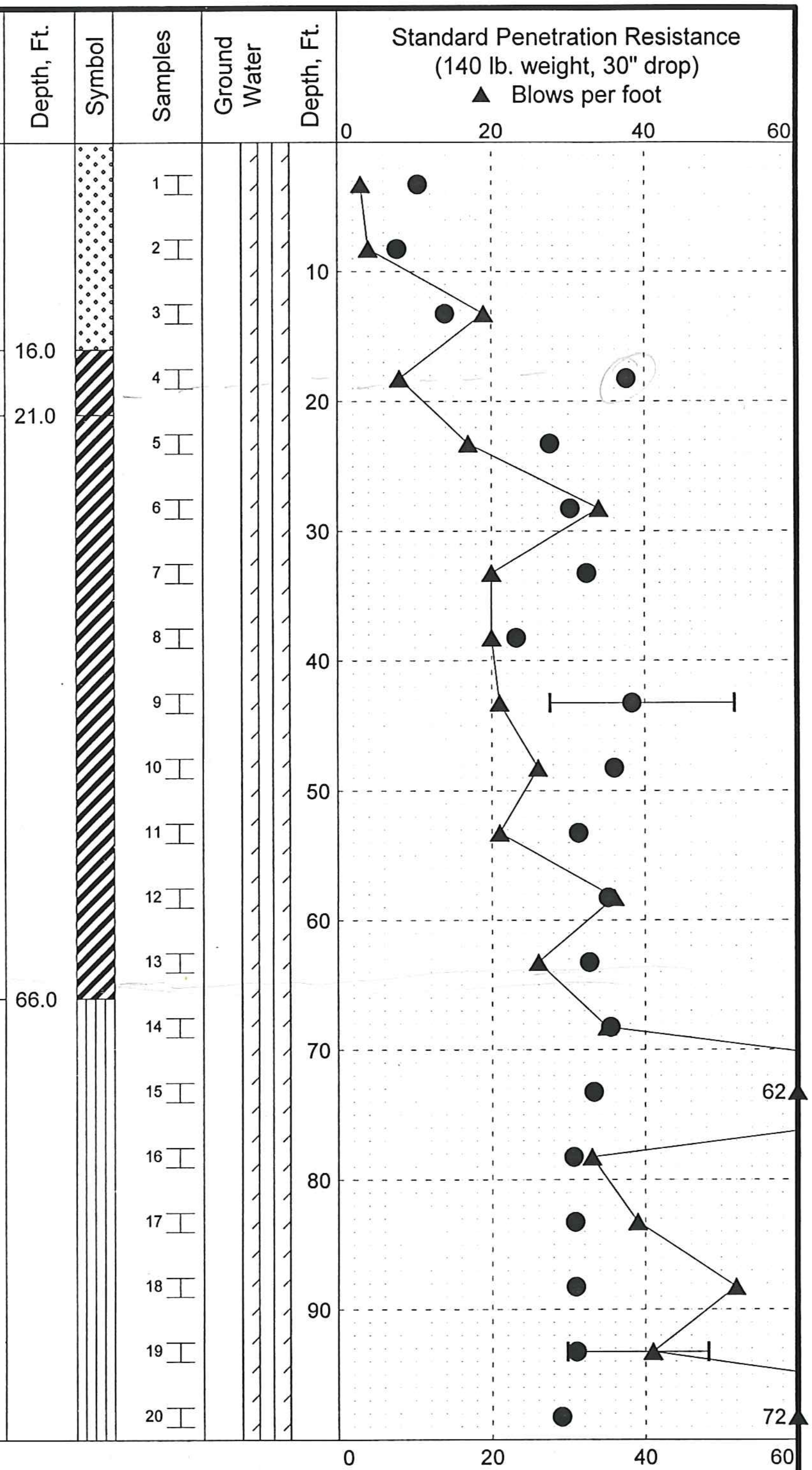


● % Water Content

Plastic Limit |—●—| Liquid Limit
Natural Water Content

LEGEND

*	Sample Not Recovered	◫	Surface Seal
⌶	2-inch O.D. Split Spoon Sample	◫	Annular Sealant
Ⅱ	3-inch O.D. Shelby Tube Sample	◫	Piezometer Screen
G	Grab Sample	◫	Grout
		▼	Ground Water Level ATD
		▽	Highest Ground Water Level
		▽	Lowest Ground Water Level

NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials.
3. Groundwater level, if indicated above, is for the date specified and may vary.
4. Refer to KEY for explanation of "Symbols" and definitions.
5. USCS designation is based on visual-manual classification and selected laboratory index testing.

Thurston County, Washington
Sunrise Beach Road NW Landslide

LOG OF BORING B-1

April 1999
W-8615-02

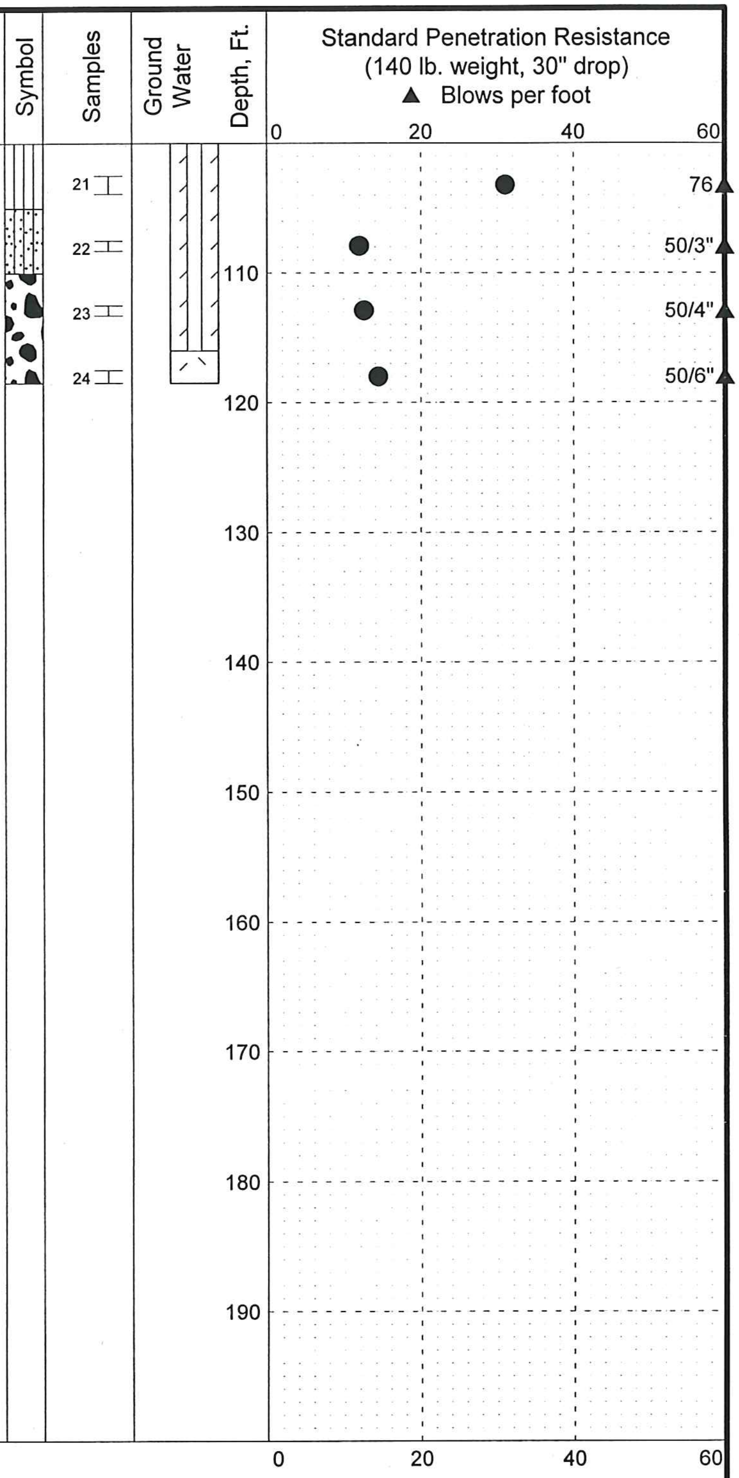
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-2
Sheet 1 of 2

SOIL DESCRIPTION Surface Elevation: Approx. 54.0 Ft.	Depth, Ft.
Disturbed soil and hard chunks in softer matrix at 103 feet.	105.0
Very dense, brown, fine sandy, silty, clayey GRAVEL; moist; with iron staining; (Qpgm) SM/GC.	110.0
Very dense, brown, silty, fine to coarse sandy GRAVEL and gravelly SAND: wet; with iron-oxide staining; (Qpgo) GW-SM.	118.5

BOTTOM OF BORING
COMPLETED 3/30/99

Note: Inclinometer casing installed to 116.5 feet deep.



● % Water Content

Plastic Limit ├─●─┤ Liquid Limit
Natural Water Content

LEGEND

- * Sample Not Recovered
- Ⅰ 2-inch O.D. Split Spoon Sample
- Ⅱ 3-inch O.D. Shelby Tube Sample
- G Grab Sample
- Surface Seal
- Annular Sealant
- Piezometer Screen
- Grout
- ▼ Ground Water Level ATD
- ▽ Highest Ground Water Level
- ▽ Lowest Ground Water Level

NOTES

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2. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials.
3. Groundwater level, if indicated above, is for the date specified and may vary.
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Thurston County, Washington
Sunrise Beach Road NW Landslide

LOG OF BORING B-1

April 1999
W-8615-02

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-2
Sheet 2 of 2

SOIL DESCRIPTION Surface Elevation: Approx. 47.0 Ft.	Depth, Ft.
Soft to medium stiff, brown and gray at 16 feet; clayey SILT; moist; laminated with diced disturbed appearance at 8 to 9 feet and at 17.5 to 19 feet with slickensides at 18 feet; (Qvrl) ML.	20.0
Very stiff to hard, gray, silty CLAY to clayey SILT; moist; massive with scattered seams of dark gray slickensides at 12- to 18-inch intervals, becomes clayey silt with depth, slightly moister; (Qvgl) ML/CL.	80.0
Hard, gray, silty CLAY and clayey SILT; moist; with seam of medium sand, wet, and a seam of fractured disturbed laminations at 83 feet; (Qvgl) CL/ML.	85.0 90.0
Hard, gray, slightly coarse sandy (pebbly), fine sandy, clayey SILT; moist to wet; (Qpgm) ML.	96.0
Very dense, brown, slightly fine gravelly, slightly silty, fine SAND with fine sandy SILT	

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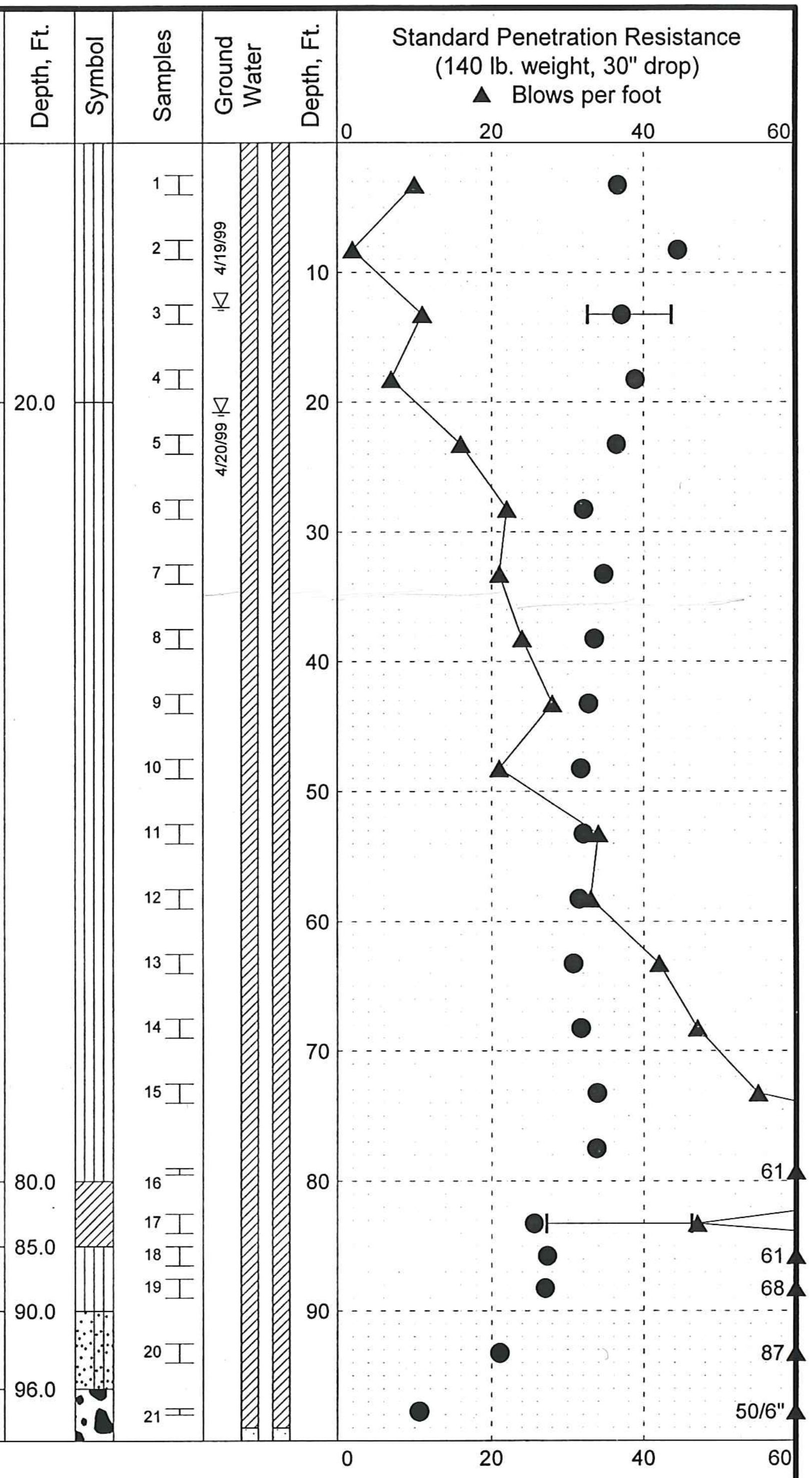

● % Water Content

Plastic Limit ├─●─┤ Liquid Limit
Natural Water Content

Log: BMR Rev: Typ: PEC

MASTER LOG HL W8615-02.GPJ SHAN WIL.GDT 4/29/99

LEGEND

- * Sample Not Recovered
- 工 2-inch O.D. Split Spoon Sample
- 工 3-inch O.D. Shelby Tube Sample
- ▨ Surface Seal
- ▭ Annular Sealant
- ▭ Piezometer Screen
- ▭ Grout
- ▼ Ground Water Level ATD
- ▽ Highest Ground Water Level
- ▽ Lowest Ground Water Level

NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials.
3. Groundwater level, if indicated above, is for the date specified and may vary.
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5. USCS designation is based on visual-manual classification and selected laboratory index testing.

Thurston County, Washington
Sunrise Beach Road NW Landslide

LOG OF BORING B-2

April 1999 W-8615-02

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-3
Sheet 1 of 2

SOIL DESCRIPTION

Surface Elevation: Approx. 47.0 Ft.

layers; wet; with iron-staining; (Qpgo) SP-SM.

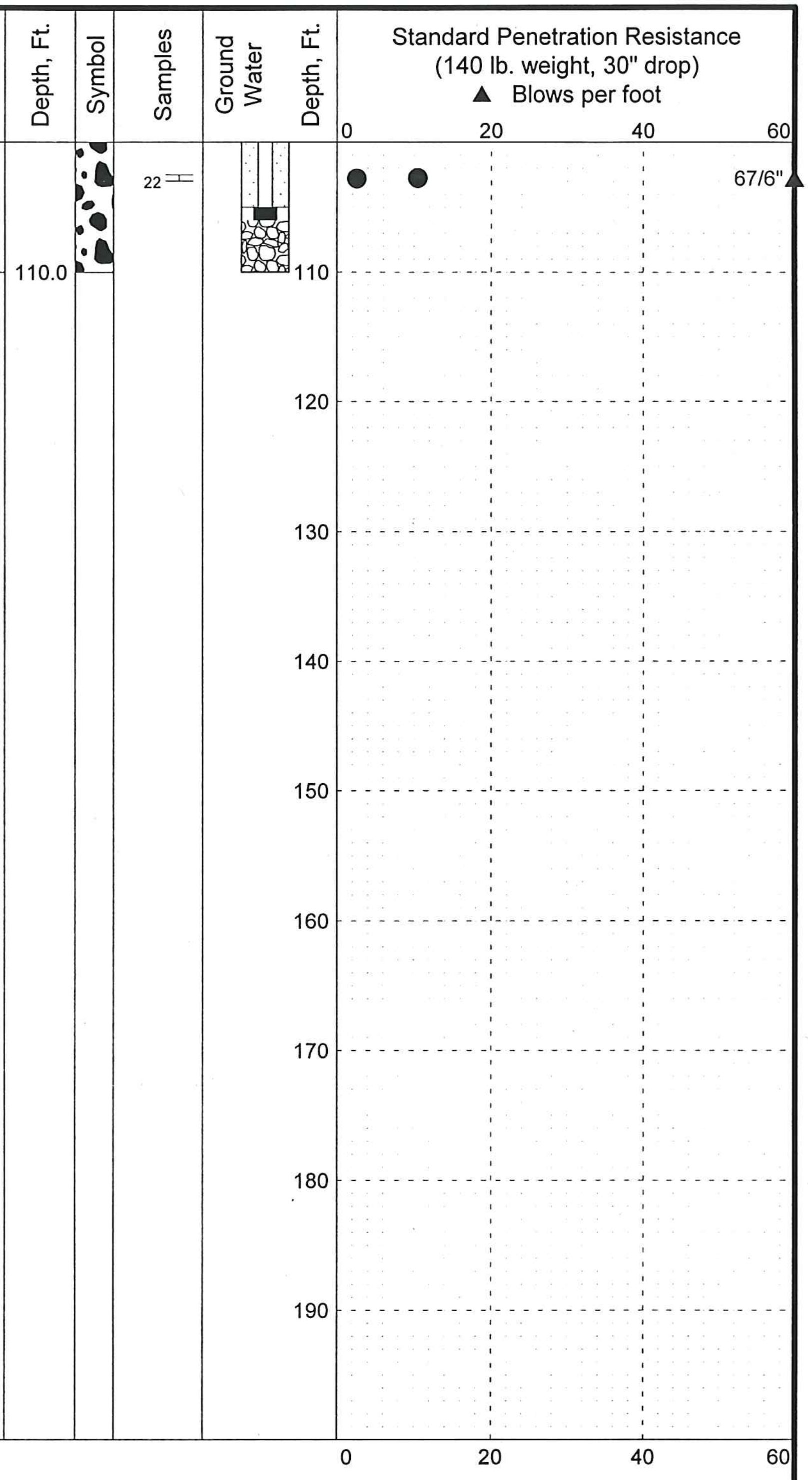
Very dense, brown, slightly silty, sandy, fine to coarse GRAVEL; wet; slight iron-staining; (Qpgo) GW-GP.

BOTTOM OF BORING
COMPLETED 4/5/99

Notes:

(1) Inclinometer casing installed to 99 feet deep.

(2) Vibrating wire pressure transducer installed at 105 feet.



● % Water Content

Plastic Limit ├─●─┤ Liquid Limit
Natural Water Content

LEGEND

*	Sample Not Recovered	▨	Surface Seal
⌶	2-inch O.D. Split Spoon Sample	▯	Annular Sealant
Ⅱ	3-inch O.D. Shelby Tube Sample	▦	Piezometer Screen
		▯	Grout
		▼	Ground Water Level ATD
		▽	Highest Ground Water Level
		▽	Lowest Ground Water Level

NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials.
3. Groundwater level, if indicated above, is for the date specified and may vary.
4. Refer to KEY for explanation of "Symbols" and definitions.
5. USCS designation is based on visual-manual classification and selected laboratory index testing.

Thurston County, Washington
Sunrise Beach Road NW Landslide

LOG OF BORING B-2

April 1999 W-8615-02

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-3
Sheet 2 of 2

SOIL DESCRIPTION

Surface Elevation: Approx. 45.0 Ft.

Depth, Ft.	Soil Description
	Loose, brown, slightly to gravelly, fine to coarse SAND; moist; (Qvro) SW.
25.0	Medium dense, brown, gravelly SAND, trace silt; moist; wet at 30 feet; (Qvro) SW.
35.0	Very stiff to hard, gray, silty CLAY; moist to wet; with scattered dark gray laminated clay seams; (Qvgl) CL. Lost 150 gallons of drilling mud at 50 feet.
65.0	Hard, gray, silty CLAY to clayey SILT; moist; massive to faintly laminated, with slightly disturbed texture at 82 to 84 feet; (Qvgl) CL-ML.
90.0	Hard, gray and gray-green, slightly sandy, clayey SILT; moist; with scattered coarse sand; (Qpnl) ML.
96.0	

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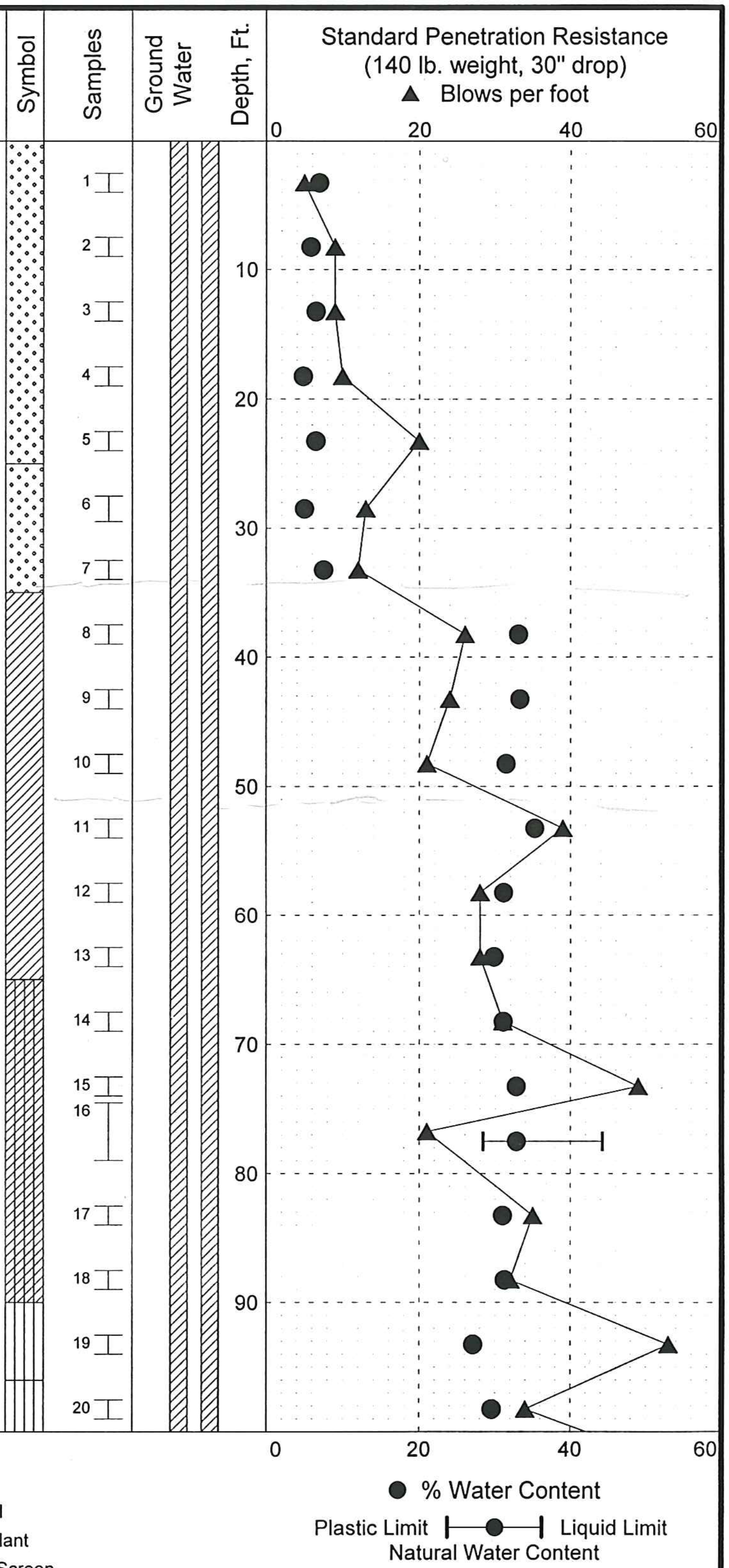


LEGEND

*	Sample Not Recovered		Surface Seal
Ⅰ	2-inch O.D. Split Spoon Sample		Annular Sealant
Ⅱ	3-inch O.D. Shelby Tube Sample		Piezometer Screen
G	Grab Sample		Grout
		▼	Ground Water Level ATD
		▽	Highest Ground Water Level
		▽	Lowest Ground Water Level

NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials.
3. Groundwater level, if indicated above, is for the date specified and may vary.
4. Refer to KEY for explanation of "Symbols" and definitions.
5. USCS designation is based on visual-manual classification and selected laboratory index testing.

Thurston County, Washington
Sunrise Beach Road NW Landslide

LOG OF BORING B-3

April 1999
W-8615-02

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

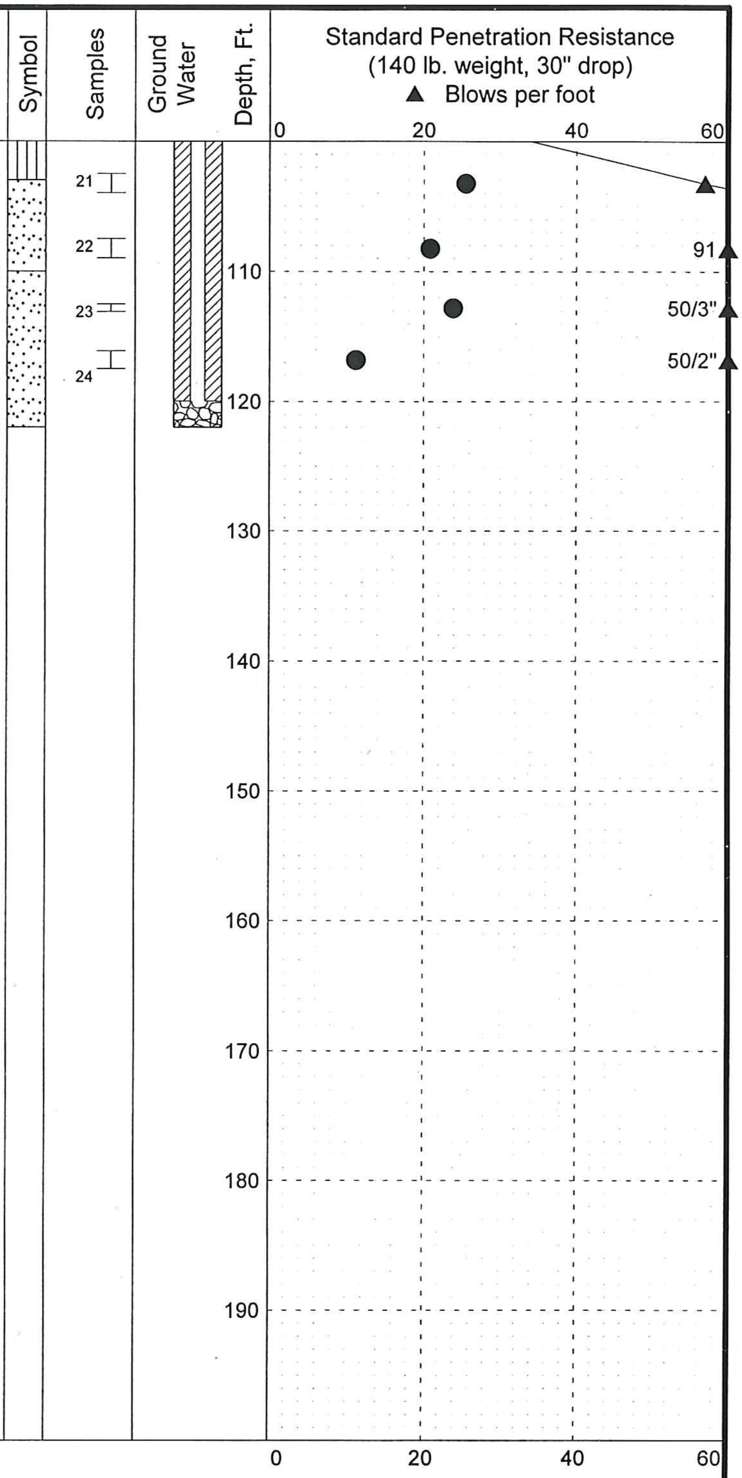
FIG. A-4
Sheet 1 of 2

MASTER LOG HL W8615-02.GPJ SHAN WIL.GDT 4/29/99 Log: BMR Rev: Typ: PEC

SOIL DESCRIPTION Surface Elevation: Approx. 45.0 Ft.	Depth, Ft.
Hard, gray, clayey, sandy SILT; moist; (Qpnl) ML.	103.0
Very dense, gray becoming brown, silty, fine SAND; wet; massive to laminated with iron staining, trace fine organics; (Qpnf) SP.	110.0
Very dense, brown, fine gravelly, fine SAND; wet; becomes brown, fine to coarse sandy gravel; wet; alternate sand/gravel layers; (Qpgo) SP-GP.	122.0

BOTTOM OF BORING
COMPLETED 4/8/99

Note: Inclinometer casing installed to 120 feet deep.



● % Water Content

Plastic Limit ├─●─┤ Liquid Limit
Natural Water Content

LEGEND

- * Sample Not Recovered
- 𝙸 2-inch O.D. Split Spoon Sample
- II 3-inch O.D. Shelby Tube Sample
- G Grab Sample

- Surface Seal
- Annular Sealant
- Piezometer Screen
- Grout
- ▼ Ground Water Level ATD
- ▽ Highest Ground Water Level
- ▽ Lowest Ground Water Level

NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials.
3. Groundwater level, if indicated above, is for the date specified and may vary.
4. Refer to KEY for explanation of "Symbols" and definitions.
5. USCS designation is based on visual-manual classification and selected laboratory index testing.

Thurston County, Washington
Sunrise Beach Road NW Landslide

LOG OF BORING B-3

April 1999 W-8615-02

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-4
Sheet 2 of 2

SOIL DESCRIPTION Surface Elevation: Approx. 26.0 Ft.	Depth, Ft.
Loose, brown, gravelly fine to medium SAND; moist; (Qvro) SP.	8.0
Stiff, brown, clayey SILT; moist to wet; laminated with trace of organics; slightly dessicated; (Qvrl) ML.	17.0
Soft to medium stiff, brown, clayey SILT; wet; laminated with very disturbed diced, broken texture (Slide Zone); (Qvrl) ML.	22.0
Stiff to very stiff, brown, clayey SILT; moist to wet; laminated with seams of dark gray clay, slightly disturbed at 35 feet; (Qvrl) ML.	38.0
Hard, gray, clayey SILT; moist; massive; (Qvgl) ML.	71.0
Dense, gray, slightly silty, fine SAND; wet; (Qvgl) SP.	71.1
Very dense, brown, silty, clayey, sandy, fine GRAVEL; moist; (Till-like) (Qpgm) GP.	78.0
Very dense, brown, fine to coarse sandy GRAVEL; wet; (Qpgo) GP.	90.4
Very dense, brown, silty, sandy fine GRAVEL; moist; (Till-like) (Qpgo) GM.	90.8

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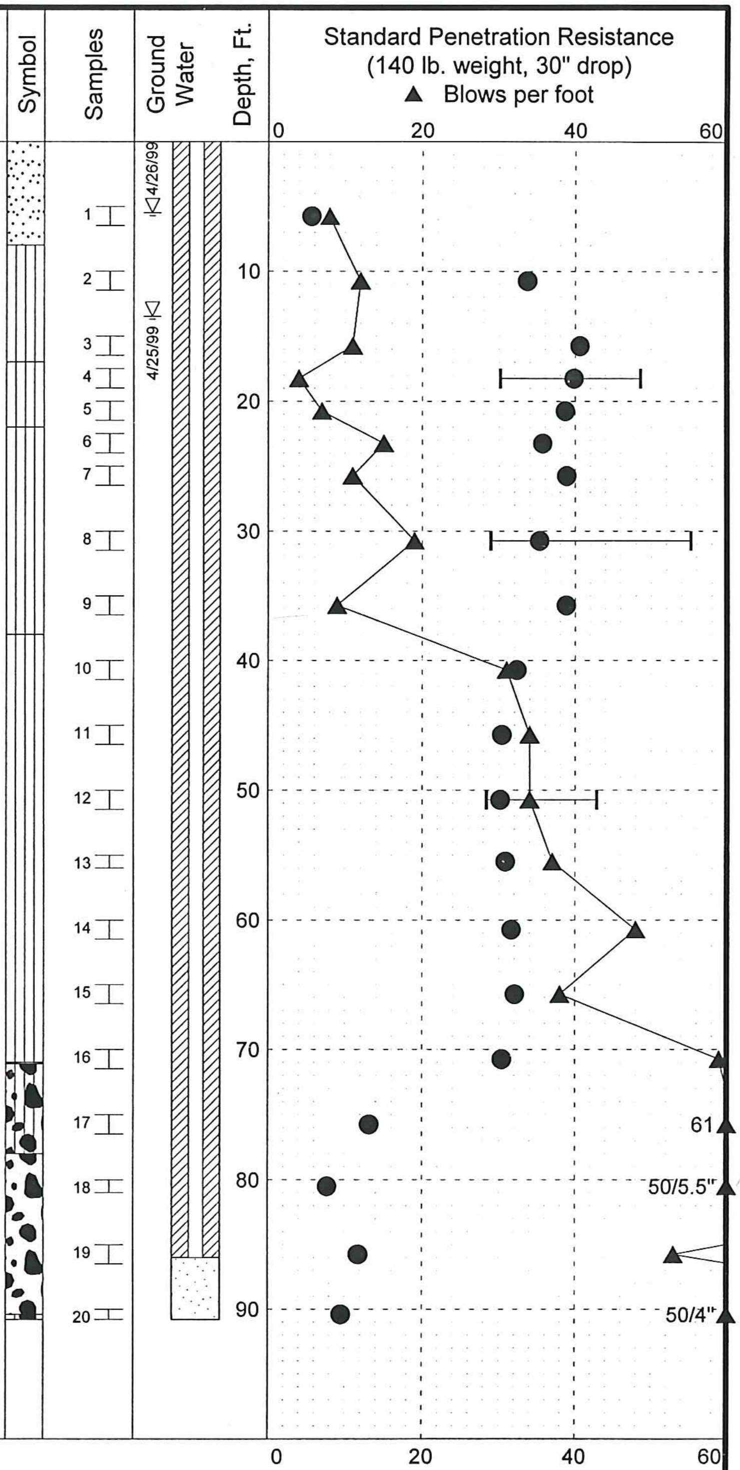


● % Water Content

Plastic Limit ├─●─┤ Liquid Limit
Natural Water Content

LEGEND

*	Sample Not Recovered		Surface Seal
Ⅰ	2-inch O.D. Split Spoon Sample		Annular Sealant
Ⅱ	3-inch O.D. Shelby Tube Sample		Piezometer Screen
			Grout
		▼	Ground Water Level ATD
		▽	Highest Ground Water Level
		▽	Lowest Ground Water Level

NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials.
3. Groundwater level, if indicated above, is for the date specified and may vary.
4. Refer to KEY for explanation of "Symbols" and definitions.
5. USCS designation is based on visual-manual classification and selected laboratory index testing.

Thurston County, Washington
Sunrise Beach Road NW Landslide

LOG OF BORING B-4

April 1999
W-8615-02

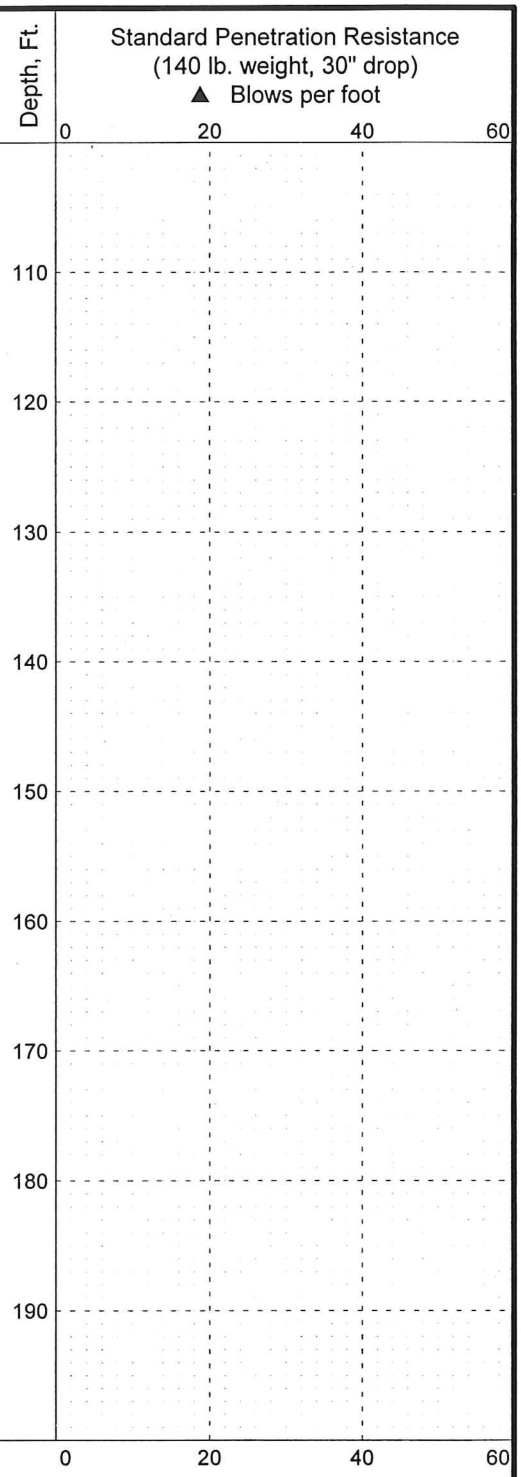
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-5
Sheet 1 of 2

MASTER LOG HL W8615-02.GPJ SHAN WIL.GDT 4/29/99

Log: BMR Rev: Typ: LKD

SOIL DESCRIPTION Surface Elevation: Approx. 26.0 Ft.	Depth, Ft.	Symbol	Samples	Ground Water	Depth, Ft.
BOTTOM OF BORING COMPLETED 4/21/99 Notes: (1) Inclinometer casing installed to 86 feet deep. (2) Vibrating wire pressure transducer at 93 feet.					



LEGEND

- * Sample Not Recovered
- I 2-inch O.D. Split Spoon Sample
- II 3-inch O.D. Shelby Tube Sample
- ▨ Surface Seal
- ☐ Annular Sealant
- ▦ Piezometer Screen
- ☐ Grout
- ▼ Ground Water Level ATD
- ▽ Highest Ground Water Level
- ▽ Lowest Ground Water Level

NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials.
3. Groundwater level, if indicated above, is for the date specified and may vary.
4. Refer to KEY for explanation of "Symbols" and definitions.
5. USCS designation is based on visual-manual classification and selected laboratory index testing.

Thurston County, Washington
Sunrise Beach Road NW Landslide

LOG OF BORING B-4

April 1999 W-8615-02

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-5
Sheet 2 of 2

MASTER LOG HL W8615-02.GPJ SHAN WIL.GDT 4/29/99 Log: BMR Rev: Typ: LKD

SOIL DESCRIPTION Surface Elevation: Approx. 143.0 Ft.	Depth, Ft.
Very dense, brown, sandy GRAVEL; moist; (Qvt?) GW-SP.	10.0
Very dense to dense, brown, slightly silty to silty, fine to medium SAND; moist; laminated; (Qva) SM.	25.0
Very dense, brown, fine to medium becoming fine SAND; moist; wet at 45 feet, trace of fine gravel; (Qva) SP.	50.0
Very dense, brown, fine to coarse sandy GRAVEL, interbedded with very dense, brown, silty SAND; wet; (Qva) GW-SP.	96.0

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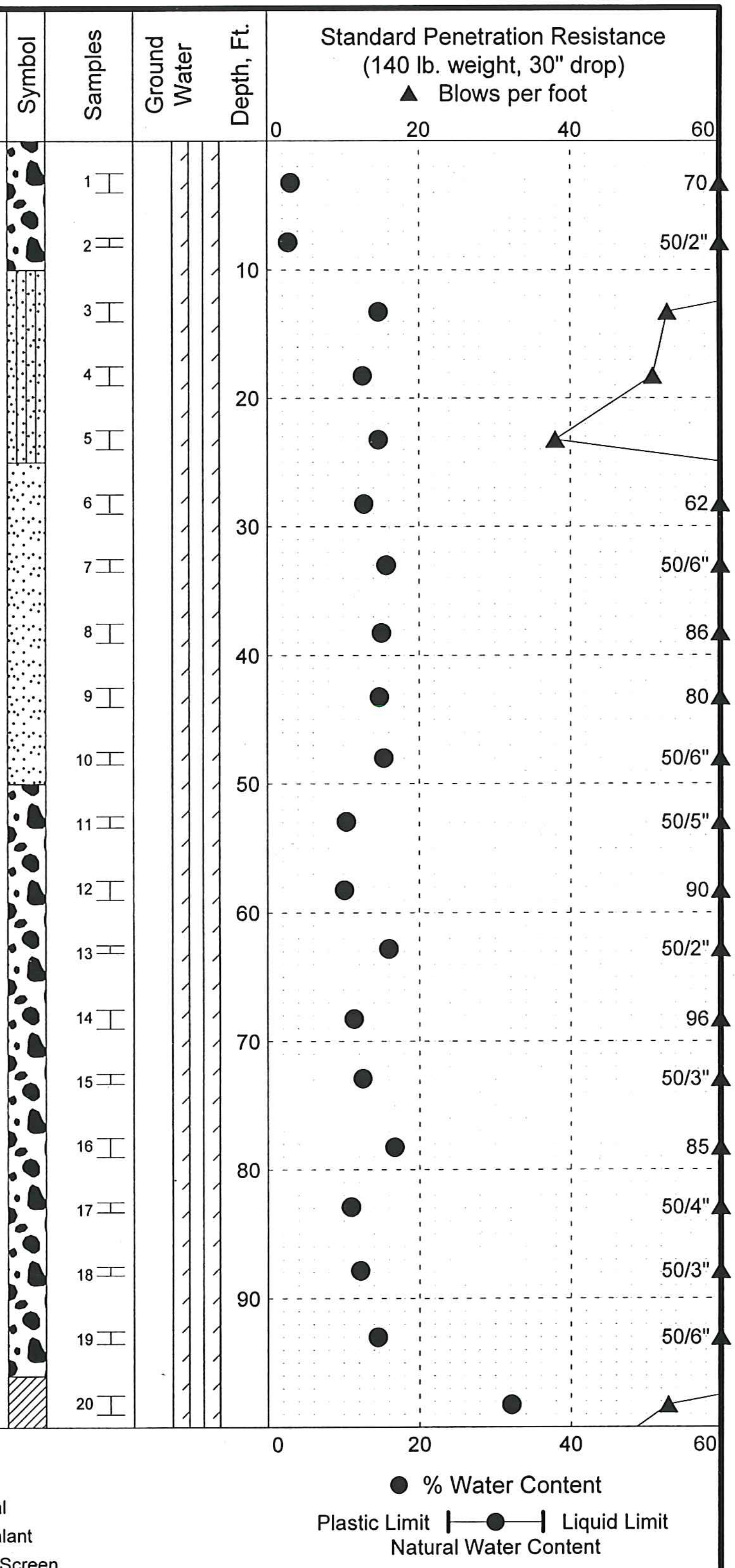


LEGEND

- * Sample Not Recovered
- ⌶ 2-inch O.D. Split Spoon Sample
- II 3-inch O.D. Shelby Tube Sample
- ▨ Surface Seal
- ☐ Annular Sealant
- ▦ Piezometer Screen
- ☐ Grout
- ▼ Ground Water Level ATD
- ▽ Highest Ground Water Level
- ▽ Lowest Ground Water Level

NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials.
3. Groundwater level, if indicated above, is for the date specified and may vary.
4. Refer to KEY for explanation of "Symbols" and definitions.
5. USCS designation is based on visual-manual classification and selected laboratory index testing.

Thurston County, Washington
Sunrise Beach Road NW Landslide

LOG OF BORING B-5

April 1999 W-8615-02

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-6
Sheet 1 of 3

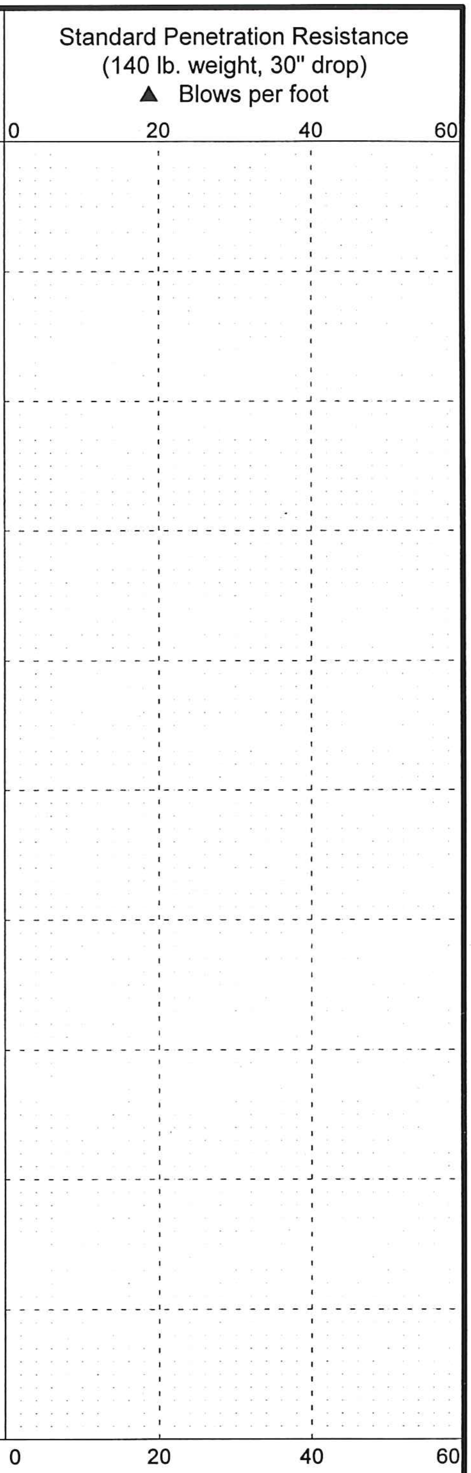
SOIL DESCRIPTION

Surface Elevation: Approx. 143.0 Ft.

Depth, Ft. | Symbol | Samples | Ground Water | Depth, Ft.

BOTTOM OF BORING
COMPLETED 4/15/99

Deep groundwater well DM-5 installed to 198 feet deep.



● % Water Content

Plastic Limit ├─●─┤ Liquid Limit
Natural Water Content

LEGEND

*	Sample Not Recovered	▨	Surface Seal
⌶	2-inch O.D. Split Spoon Sample	▥	Annular Sealant
Ⅱ	3-inch O.D. Shelby Tube Sample	▦	Piezometer Screen
		▭	Grout
		▼	Ground Water Level ATD
		▽	Highest Ground Water Level
		▽	Lowest Ground Water Level

NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials.
3. Groundwater level, if indicated above, is for the date specified and may vary.
4. Refer to KEY for explanation of "Symbols" and definitions.
5. USCS designation is based on visual-manual classification and selected laboratory index testing.

Thurston County, Washington
Sunrise Beach Road NW Landslide

LOG OF BORING B-5

April 1999 W-8615-02

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

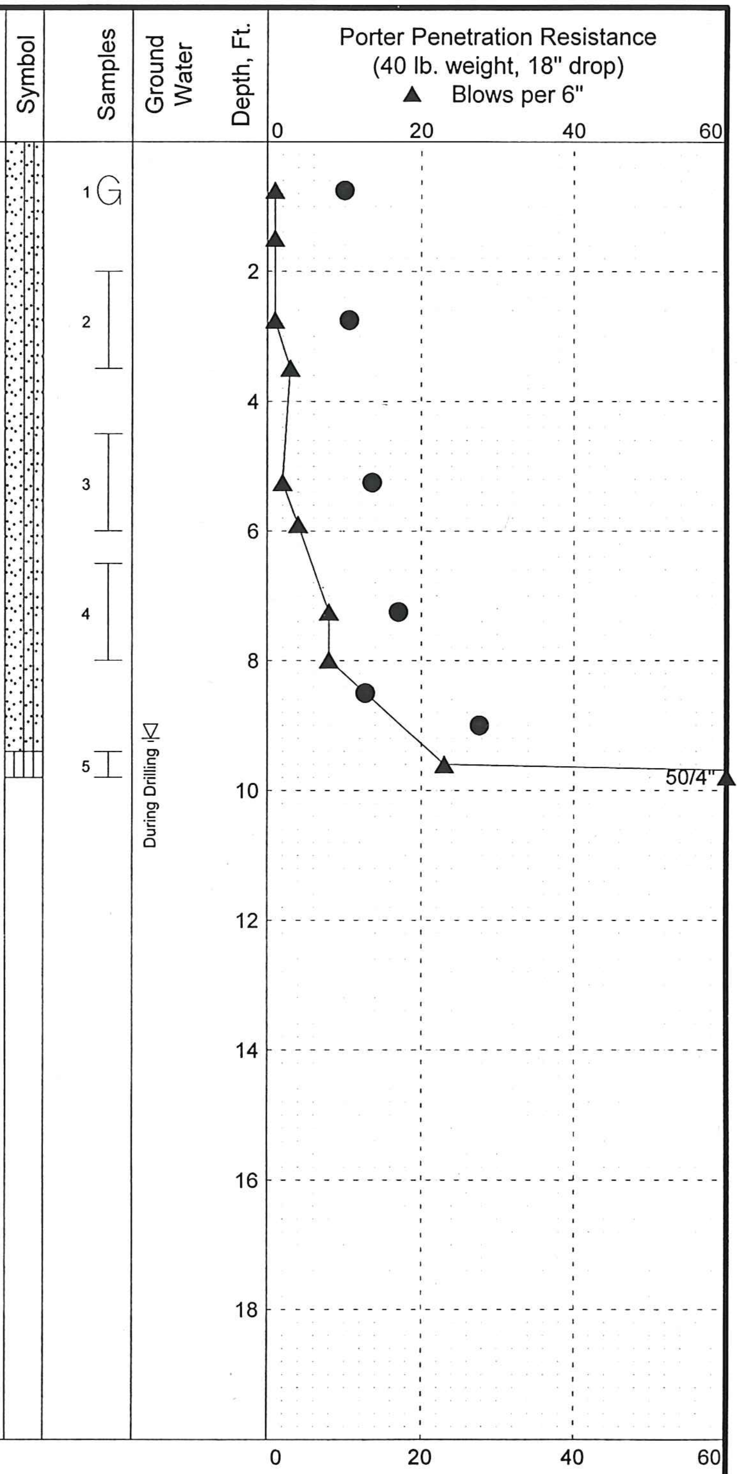
FIG. A-6
Sheet 3 of 3

MASTER LOG HL W8615-02.GPJ SHAN WIL.GDT 4/29/99 Log: BMR Rev: Typ: PEC

SOIL DESCRIPTION

Surface Elevation: Approx. 15.0 Ft.

SOIL DESCRIPTION	Depth, Ft.
Very loose to medium dense, brown, slightly silty to silty, fine to medium SAND; moist; wet at 9.2 feet; (Qvro) SP-SM.	
Hard, brown, clayey SILT; moist; massive with slight iron-staining, slightly disturbed at 9.4 feet; sand/silt contact; (Qvrl) ML.	9.4
BOTTOM OF BORING COMPLETED 4/23/99	9.8



LEGEND

* Sample Not Recovered

⌶ 1.5-inch O.D. Split Spoon Sample

G Grab Sample from Cuttings

∇ Ground Water Level ATD

NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
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3. Groundwater level, if indicated above, is for the date specified and may vary.
4. Refer to KEY for explanation of "Symbols" and definitions.
5. USCS designation is based on visual-manual classification and selected laboratory index testing.

Thurston County, Washington
Sunrise Beach Road NW Landslide

LOG OF HAND BORING HB-1

April 1999 W-8615-02

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-7

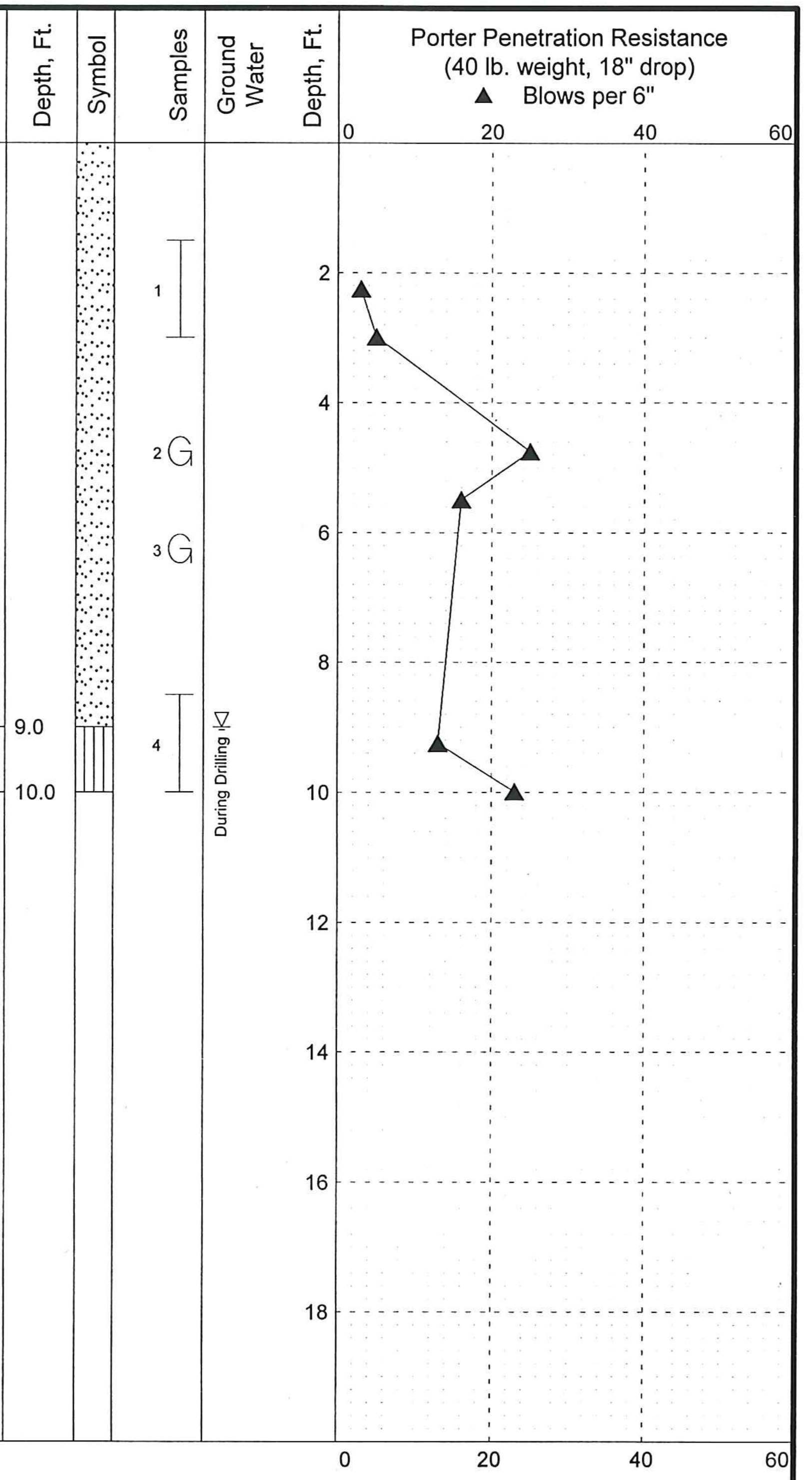
SOIL DESCRIPTION

Surface Elevation: Approx. 11.0 Ft.

Loose to medium dense, brown, slightly silty, gravelly, fine to medium SAND; moist; (Qvro) SP.

Stiff to very stiff, brown, clayey SILT; moist; (Qvrl) ML.

BOTTOM OF BORING
COMPLETED 4/27/99



● % Water Content

Plastic Limit ├─●─┤ Liquid Limit
Natural Water Content

LEGEND

* Sample Not Recovered

⌶ 1.5-inch O.D. Split Spoon Sample

G Grab Sample from Cuttings

∇ Ground Water Level ATD

NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials.
3. Groundwater level, if indicated above, is for the date specified and may vary.
4. Refer to KEY for explanation of "Symbols" and definitions.
5. USCS designation is based on visual-manual classification and selected laboratory index testing.

Thurston County, Washington
Sunrise Beach Road NW Landslide

LOG OF HAND BORING HB-2

April 1999 W-8615-02

SHANNON & WILSON, INC.
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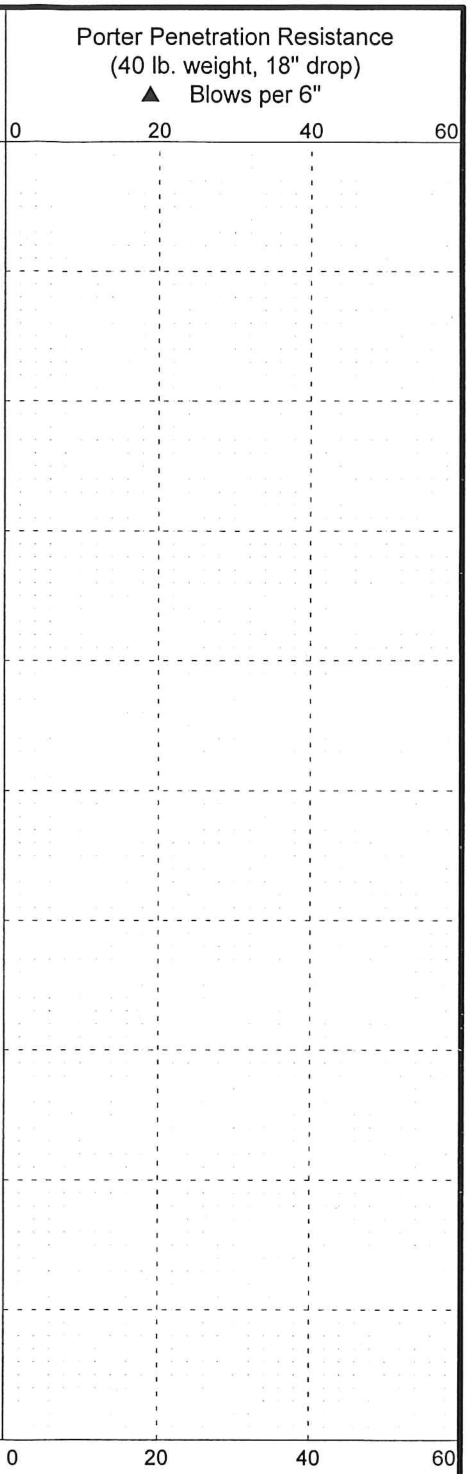
FIG. A-8

HAND BORING LOG W8615-02.GPJ SHAN WIL.GDT 4/29/99 Log: BMR Rev: Typ: LKD

SOIL DESCRIPTION Surface Elevation: Approx. 42.0 Ft.	Depth, Ft.	Symbol	Samples	Ground Water	Depth, Ft.
Very loose, brown, gravelly, fine to medium SAND; wet; (Qvro) SW.			1 G	∇ During Drilling	
Very stiff, brown, clayey SILT; moist; (Qvrl) ML.	3.1 3.3		2 G		

BOTTOM OF BORING
COMPLETED 4/27/99



● % Water Content

Plastic Limit ├──●──┤ Liquid Limit
Natural Water Content

LEGEND

- * Sample Not Recovered
- ⌶ 1.5-inch O.D. Split Spoon Sample
- G Grab Sample from Cuttings
- ∇ Ground Water Level ATD

NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials.
3. Groundwater level, if indicated above, is for the date specified and may vary.
4. Refer to KEY for explanation of "Symbols" and definitions.
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Thurston County, Washington
Sunrise Beach Road NW Landslide

LOG OF HAND BORING HB-3

April 1999 W-8615-02

SHANNON & WILSON, INC.
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FIG. A-9

HAND BORING LOG W8615-02.GPJ SHAN WIL.GDT 4/29/99 Log: BMR Rev: Typ: LKD

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

LOG OF TEST PIT TP-1

JOB NO: W-8615-02 DATE: 4/27/99 LOCATION: Martin Property
PROJECT: Sunrise Beach Road NW, Thurston County

SOIL DESCRIPTION	Ground Water	% Water Content	Samples	Depth, Ft.
① Loose, red-brown, silty, gravelly SAND; moist; trace clay and scattered roots; SP. (Qvro)				0
② Loose, brown, gravelly, fine to coarse SAND; moist; wet at 8'; sidewalls caving; SW. (Qvro)				2
			S-1	
				4
				6
	▽			8
				10
				12

Sketch of North Pit Side

Surface Elevation: 50'

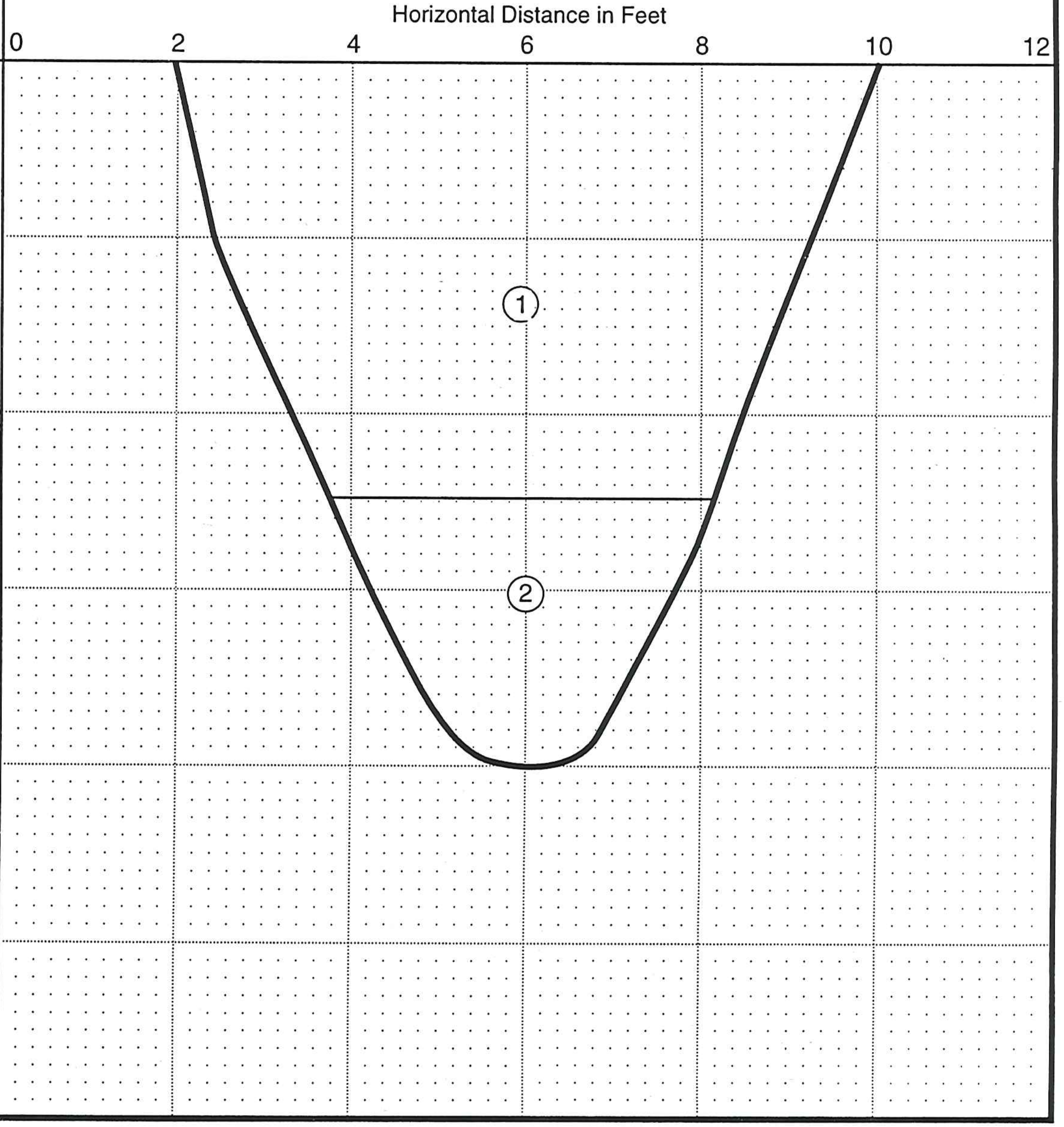


FIG. A-10

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

LOG OF TEST PIT TP-2

JOB NO: W-8615-02 DATE: 4/27/99 LOCATION: Whitener Property
PROJECT: Sunrise Beach Road NW, Thurston County

SOIL DESCRIPTION	Ground Water	% Water Content	Samples	Depth, Ft.
① Loose, silty, gravelly SAND; moist; SM. (Qvro)				0
② Loose, brown, gravelly, fine to coarse SAND; wet. (Qvro)	∇			
				2
				4
				6
				8
				10
				12

Sketch of North Pit Side Surface Elevation: 44'

Horizontal Distance in Feet

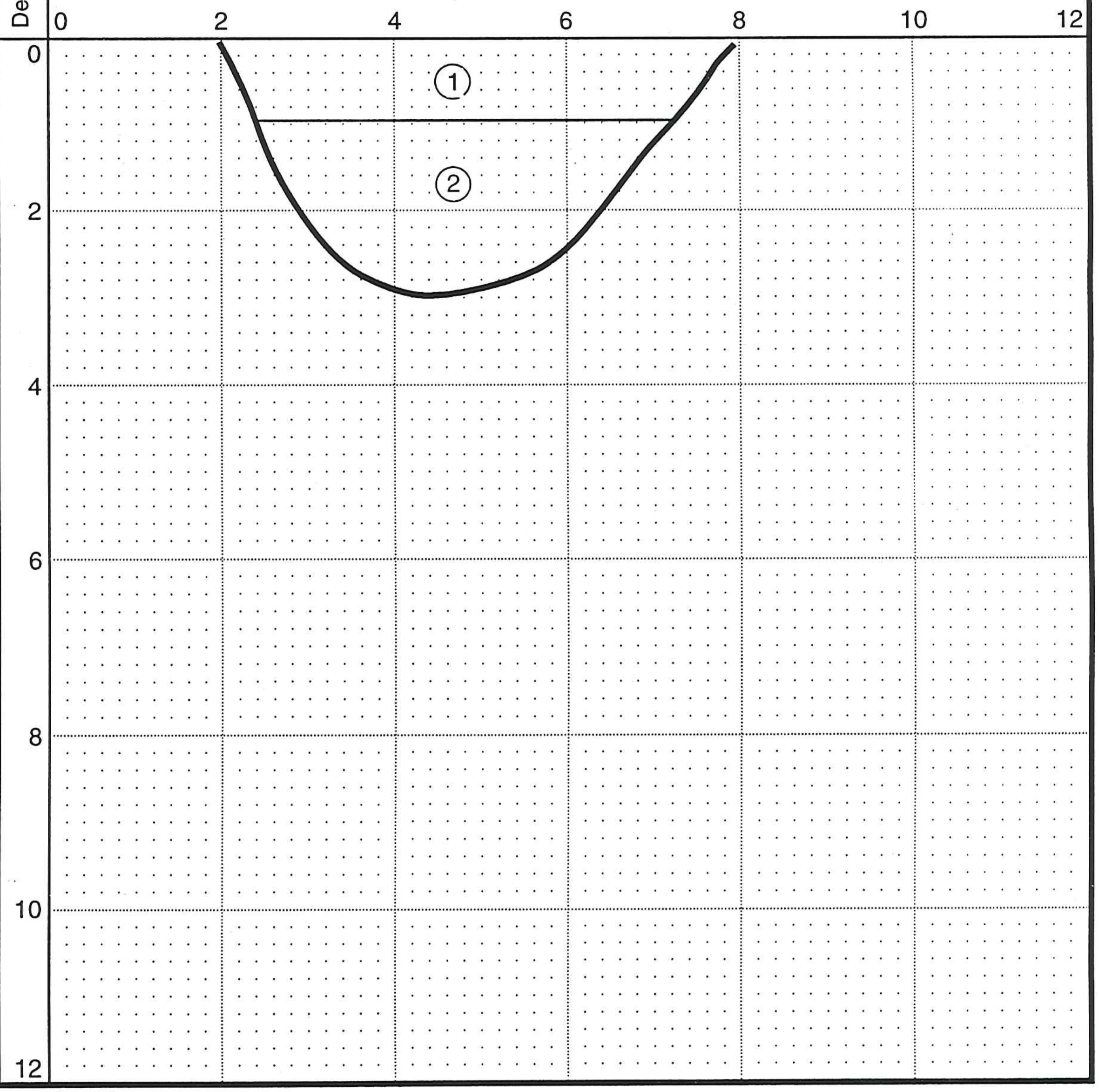


FIG. A-11

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

LOG OF TEST PIT TP-3

JOB NO: W-8615-02 DATE: 4/27/99 LOCATION: Whitener Property (Middle)

PROJECT: Sunrise Beach Road NW, Thurston County

SOIL DESCRIPTION	Ground Water	% Water Content	Samples
① Loose, brown, silty, sandy GRAVEL; moist; (Fill). (Qvro) ② Hard, brown, slightly clayey SILT; moist; laminated with greasy partings. (Qvgl)	No Groundwater Observed		

Sketch of West Pit Side

Surface Elevation: 42'

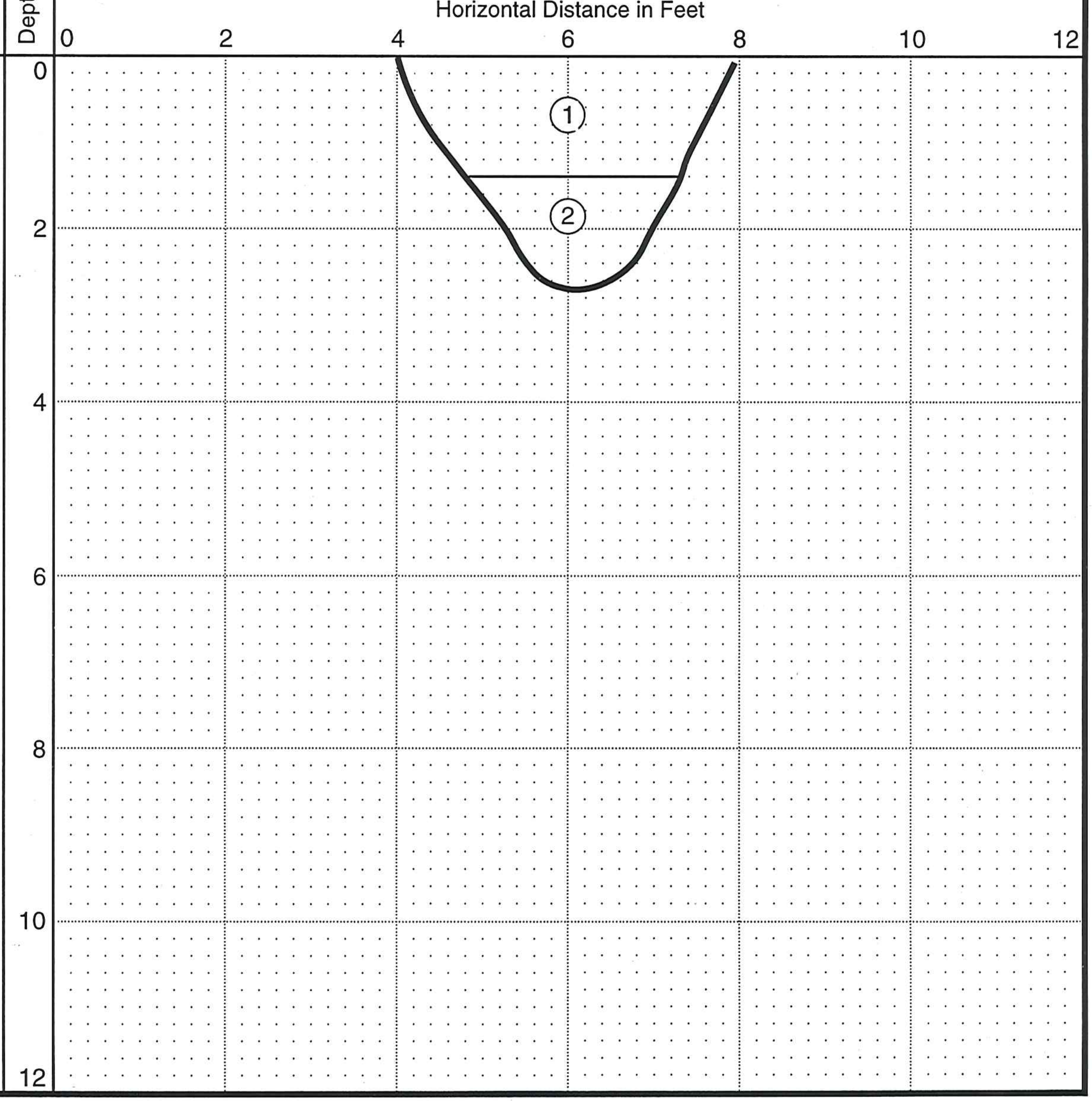


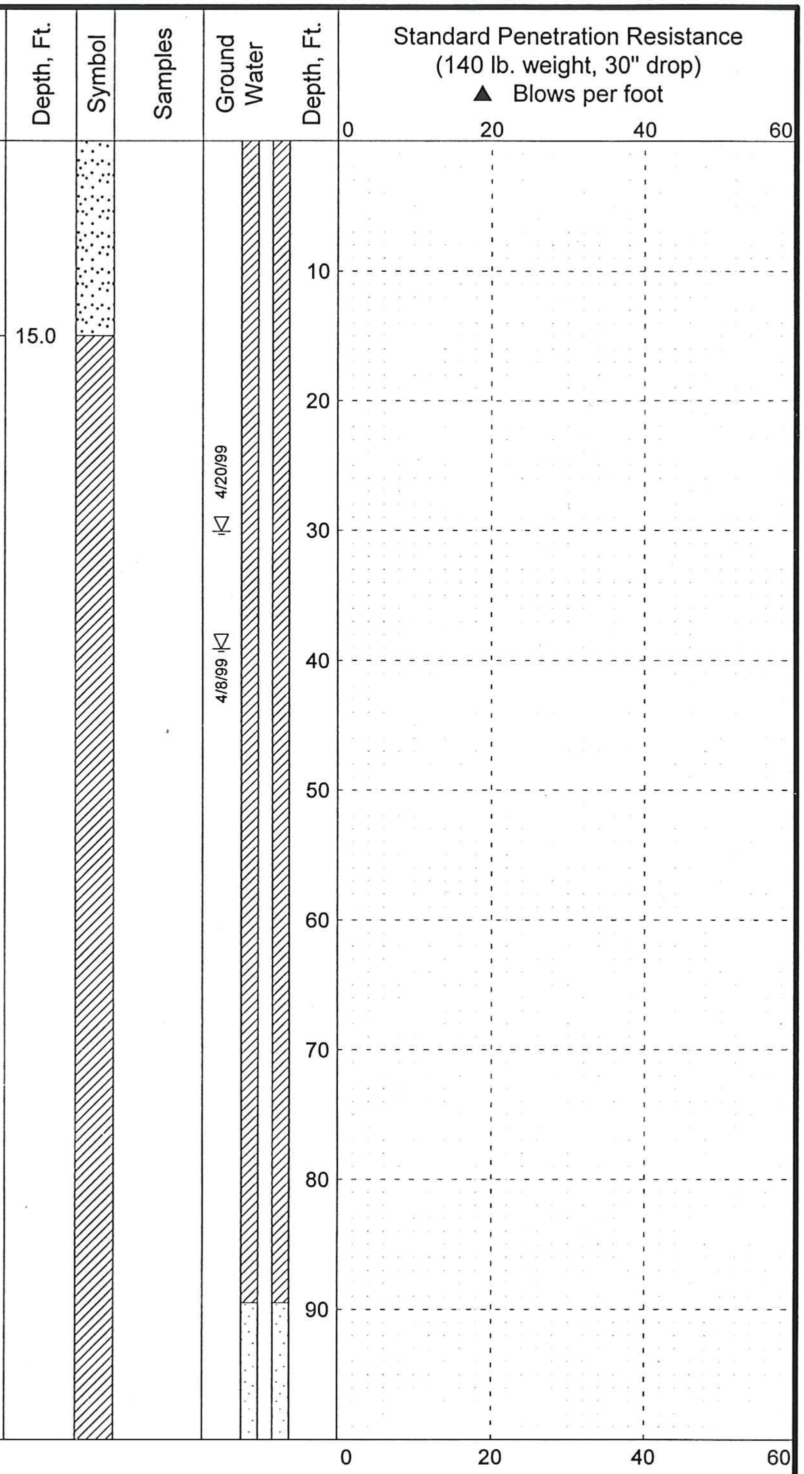
FIG. A-12

SOIL DESCRIPTION

Surface Elevation: Approx. 54.0 Ft.

Gravelly SAND; SP.

Silty CLAY/clayey SILT; CL/ML.



CONTINUED NEXT PAGE

● % Water Content

Plastic Limit |—●—| Liquid Limit
Natural Water Content

LEGEND

- * Sample Not Recovered
- Ɪ 2-inch O.D. Split Spoon Sample
- ꟷꟷ 3-inch O.D. Shelby Tube Sample

- ▨ Surface Seal
- ☐ Annular Sealant
- ⊞ Piezometer Screen
- ☐ Grout
- ▼ Ground Water Level ATD
- ▽ Highest Ground Water Level
- ▽ Lowest Ground Water Level

NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials.
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Thurston County, Washington
Sunrise Beach Road NW Landslide

LOG OF BORING DM-1

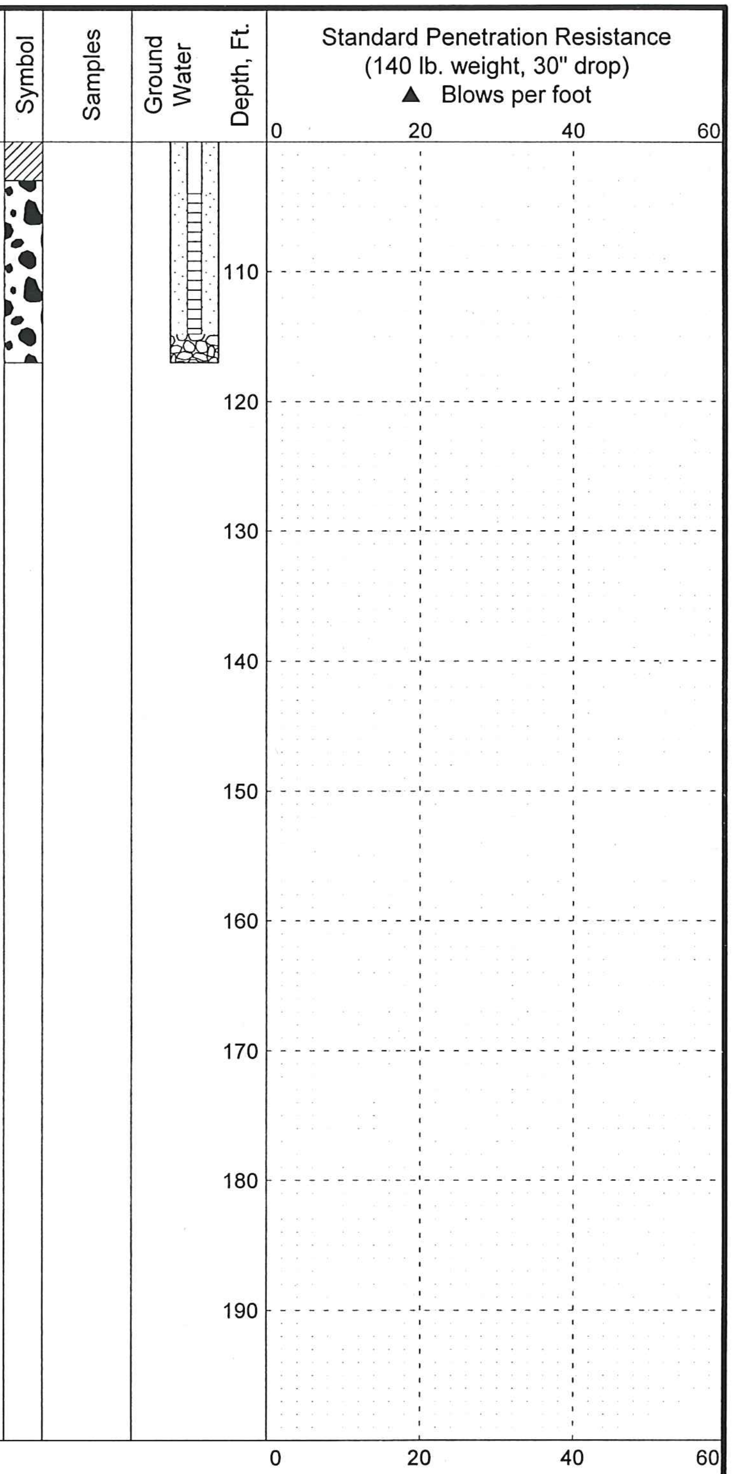
April 1999 W-8615-02

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-13
Sheet 1 of 2

SOIL DESCRIPTION Surface Elevation: Approx. 54.0 Ft.	Depth, Ft.
Gravelly CLAY; CL.	100.0
Sand and gravel; GW.	103.0
BOTTOM OF BORING COMPLETED 4/1/99	117.0

No soil samples were retrieved in this drill hole (deep monitoring well). Soil descriptions are based on drill cuttings only.



LEGEND

- * Sample Not Recovered
- ⌶ 2-inch O.D. Split Spoon Sample
- Ⅱ 3-inch O.D. Shelby Tube Sample
- Surface Seal
- Annular Sealant
- Piezometer Screen
- Grout
- ▼ Ground Water Level ATD
- ▽ Highest Ground Water Level
- ▽ Lowest Ground Water Level

NOTES

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Thurston County, Washington
Sunrise Beach Road NW Landslide

LOG OF BORING DM-1

April 1999
W-8615-02

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-13
Sheet 2 of 2

Surface Elevation: Approx. 45.0 Ft.

SOIL DESCRIPTION	Depth, Ft.
SAND; SP.	12.0
GRAVEL; GP.	17.0
SAND; SP.	20.0
Clayey SILT/silty CLAY; ML/CL.	77.0
GRAVEL; GP.	82.0
SILT; ML.	96.0
GRAVEL; GW.	

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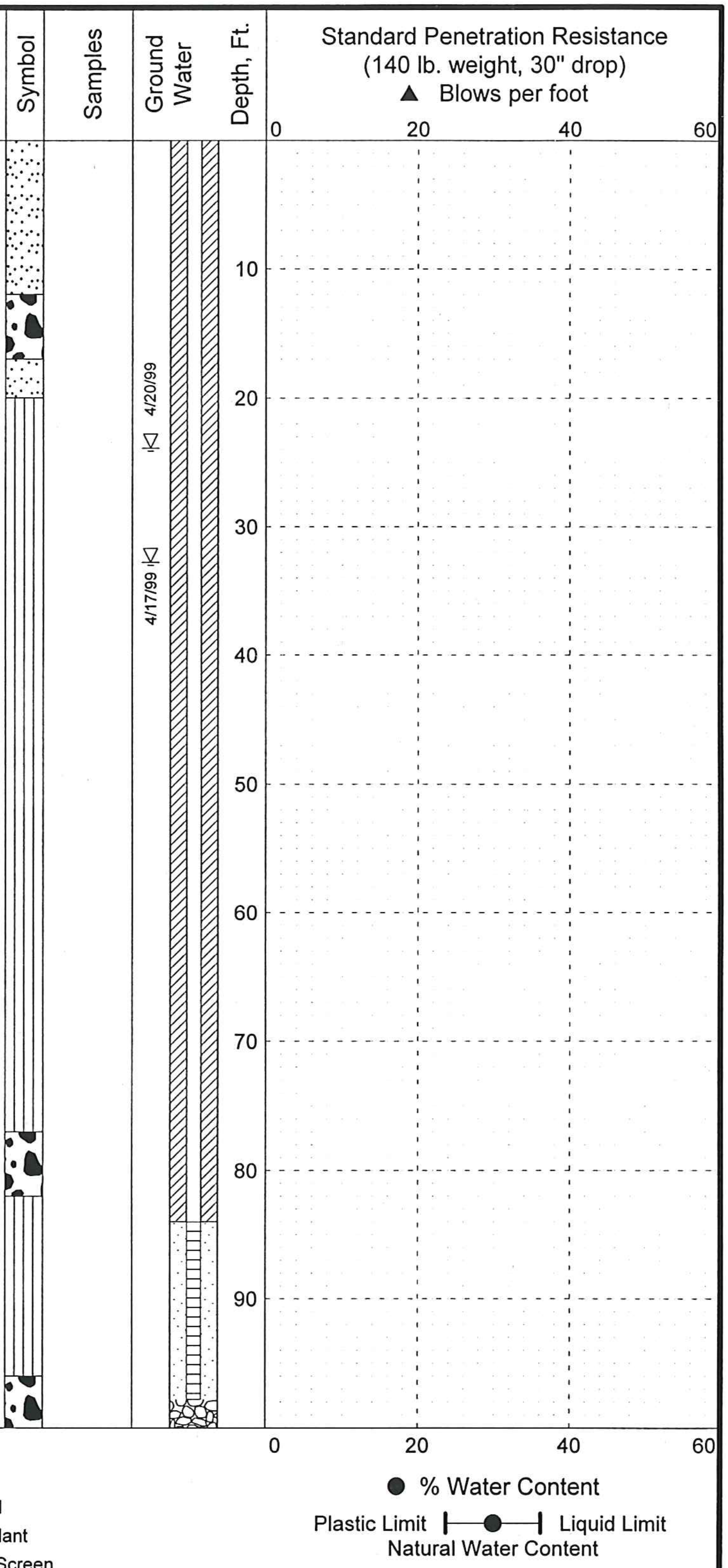

LEGEND

- * Sample Not Recovered
- 2-inch O.D. Split Spoon Sample
- 3-inch O.D. Shelby Tube Sample
- Surface Seal
- Annular Sealant
- Piezometer Screen
- Grout
- ▼ Ground Water Level ATD
- ▽ Highest Ground Water Level
- ▽ Lowest Ground Water Level

NOTES

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Thurston County, Washington
Sunrise Beach Road NW Landslide

LOG OF BORING DM-2

April 1999 W-8615-02

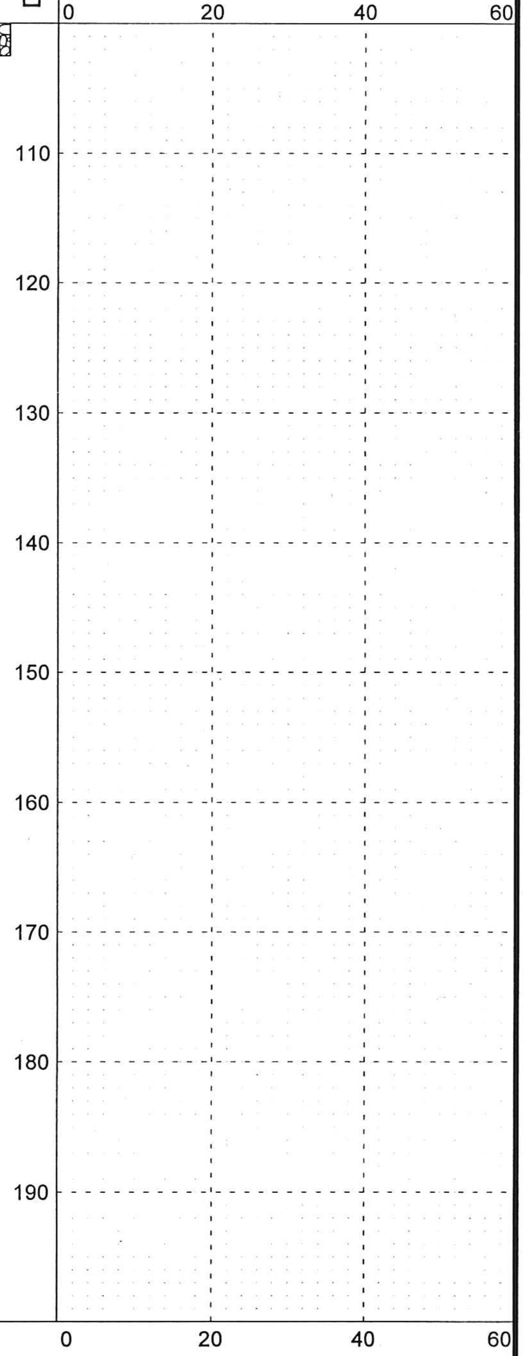
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-14
Sheet 1 of 2

MASTER LOG HL W8615-02.GPJ SHAN WIL.GDT 4/29/99 Log: BMR Rev: Typ: PEC

SOIL DESCRIPTION Surface Elevation: Approx. 45.0 Ft.	Depth, Ft.	Symbol	Samples	Ground Water	Depth, Ft.	Standard Penetration Resistance (140 lb. weight, 30" drop) ▲ Blows per foot
BOTTOM OF BORING COMPLETED 4/18/99	102.0					

Note: No soil samples were retrieved in this drill hole (deep monitoring well). Soil descriptions are based on drill cuttings only.



● % Water Content

Plastic Limit |—●—| Liquid Limit
Natural Water Content

LEGEND

* Sample Not Recovered
2-inch O.D. Split Spoon Sample
3-inch O.D. Shelby Tube Sample

Surface Seal
Annular Sealant
Piezometer Screen
Grout
▼ Ground Water Level ATD
▽ Highest Ground Water Level
▽ Lowest Ground Water Level

NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials.
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4. Refer to KEY for explanation of "Symbols" and definitions.
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Thurston County, Washington
Sunrise Beach Road NW Landslide

LOG OF BORING DM-2

April 1999
W-8615-02

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-14
Sheet 2 of 2

MASTER LOG HL W8615-02.GPJ SHAN WIL.GDT 4/29/99 Log: BMR Rev: Typ: PEC

SOIL DESCRIPTION

Surface Elevation: Approx. 43.0 Ft.

Loose, brown, gravelly SAND; moist; SW.

Very stiff, brown to gray, silty CLAY; moist; laminated with dark gray seam at 34 feet; CL.

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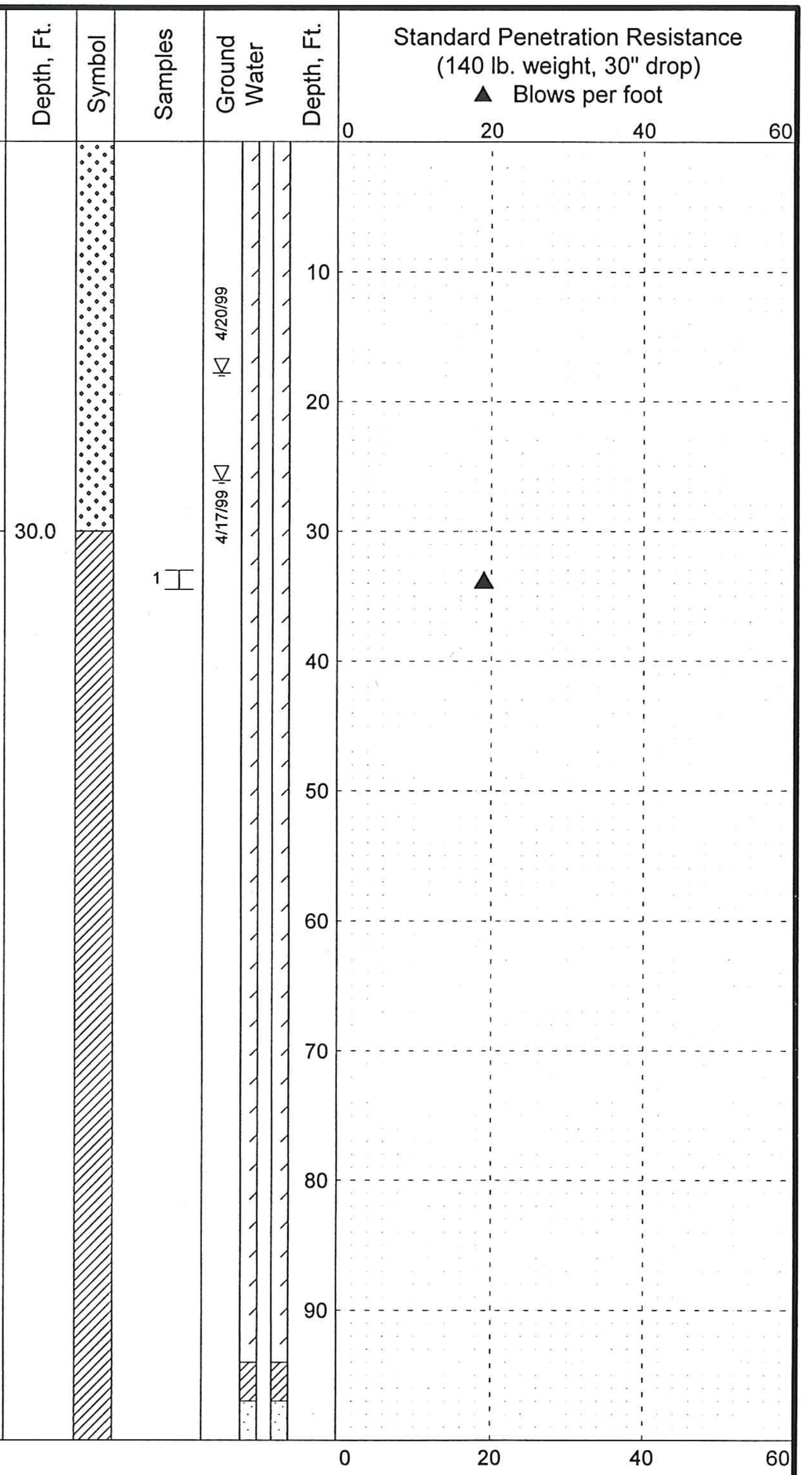

● % Water Content

Plastic Limit ├──●──┤ Liquid Limit
Natural Water Content

LEGEND

* Sample Not Recovered
⌶ 2-inch O.D. Split Spoon Sample
⌶⌶ 3-inch O.D. Shelby Tube Sample

▨ Surface Seal
☐ Annular Sealant
☐ Piezometer Screen
☐ Grout
▼ Ground Water Level ATD
▽ Highest Ground Water Level
▽ Lowest Ground Water Level

NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials.
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Thurston County, Washington
Sunrise Beach Road NW Landslide

LOG OF BORING DM-3

April 1999 W-8615-02

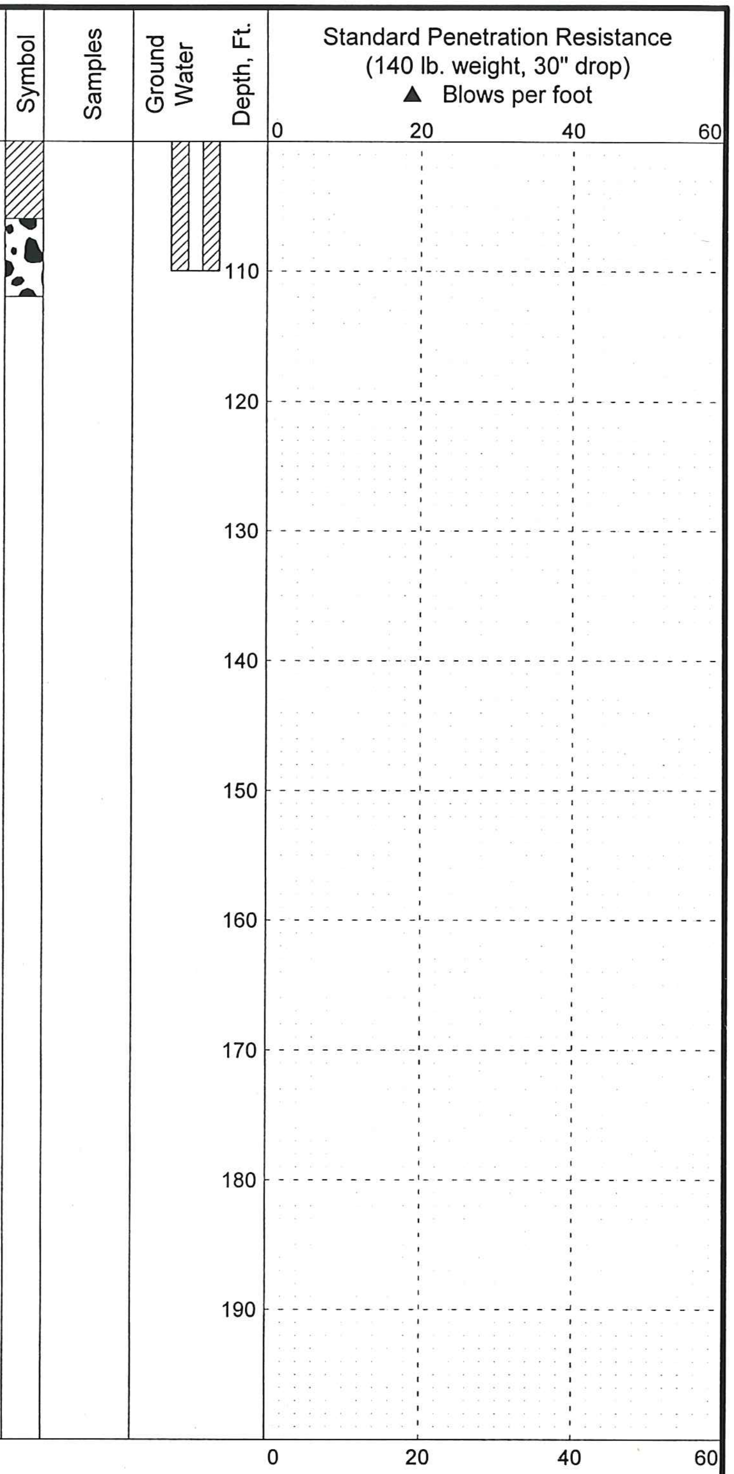
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-15
Sheet 1 of 2

MASTER LOG HL W8615-02.GPJ SHAN WIL.GDT 4/29/99 Log: BMR Rev: Typ: LKD

SOIL DESCRIPTION Surface Elevation: Approx. 43.0 Ft.	Depth, Ft.
Very dense SAND and GRAVEL; caving at 112 feet; GW.	106.0
BOTTOM OF BORING COMPLETED 4/12/99	112.0

Note: No soil samples were retrieved in this drill hole (deep monitoring well). Soil descriptions are based on drill cuttings only.



LEGEND

* Sample Not Recovered
Ⅰ 2-inch O.D. Split Spoon Sample
Ⅱ 3-inch O.D. Shelby Tube Sample

Surface Seal
Annular Sealant
Piezometer Screen
Grout
▼ Ground Water Level ATD
▽ Highest Ground Water Level
▽ Lowest Ground Water Level

NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
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3. Groundwater level, if indicated above, is for the date specified and may vary.
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Thurston County, Washington
Sunrise Beach Road NW Landslide

LOG OF BORING DM-3

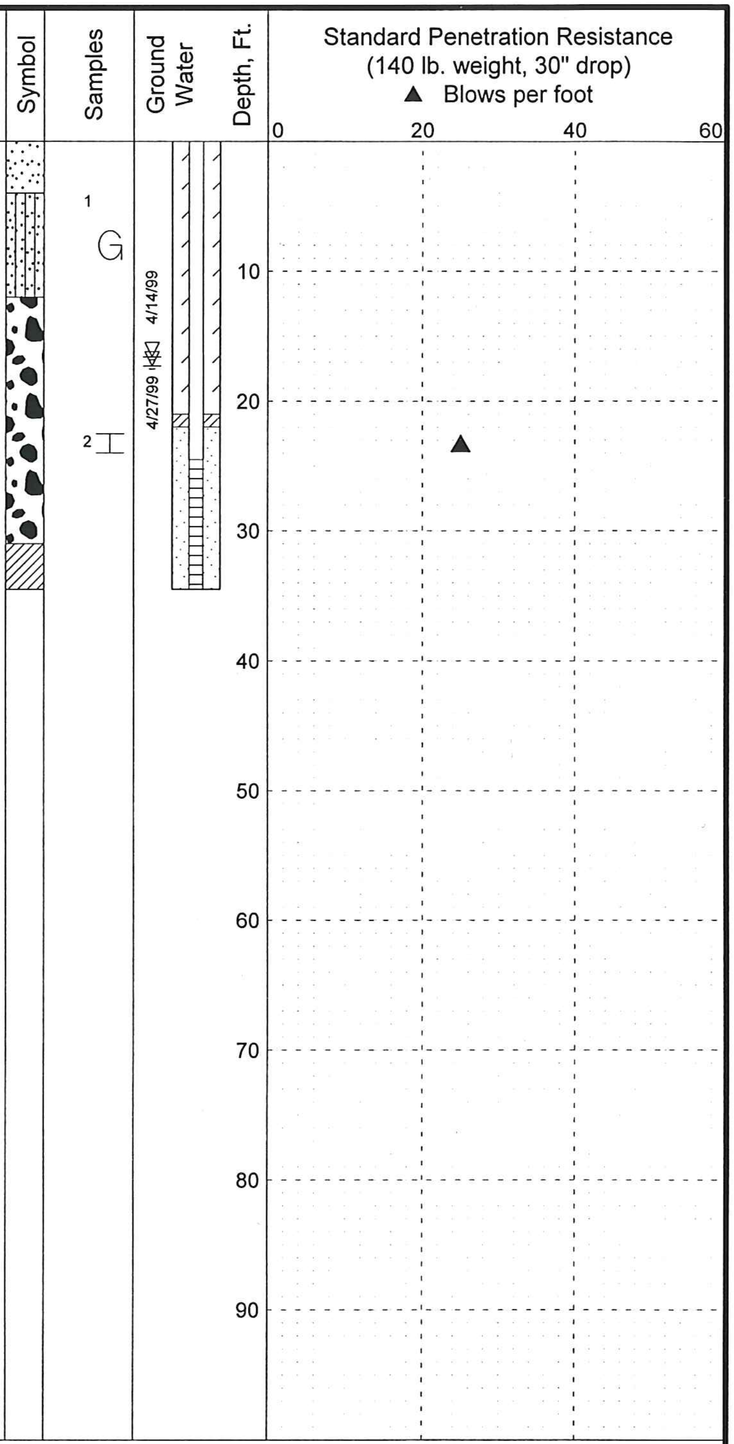
April 1999 W-8615-02

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-15
Sheet 2 of 2

MASTER LOG HL W8615-02.GPJ SHAN WIL.GDT 4/29/99 Log: BMR Rev: Typ: LKD

SOIL DESCRIPTION Surface Elevation: Approx. 43.0 Ft.	Depth, Ft.
Loose, brown, gravelly SAND; moist; SP.	
Loose, brown, silty fine SAND; becomes less silty at approximately 12 feet; more gravels; SM.	4.0
Medium dense, brown, fine to coarse sandy GRAVEL; wet; GW.	12.0
Gray-brown, silty CLAY; moist; CL.	31.0
BOTTOM OF BORING COMPLETED 4/14/99	34.5



0 20 40 60

● % Water Content

Plastic Limit ├──●──┤ Liquid Limit
Natural Water Content

LEGEND

*	Sample Not Recovered	▨	Surface Seal
⌶	2-inch O.D. Split Spoon Sample	☐	Annular Sealant
Ⅱ	3-inch O.D. Shelby Tube Sample	☐	Piezometer Screen
G	Grab Sample	☐	Grout
		▼	Ground Water Level ATD
		▽	Highest Ground Water Level
		▽	Lowest Ground Water Level

NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials.
3. Groundwater level, if indicated above, is for the date specified and may vary.
4. Refer to KEY for explanation of "Symbols" and definitions.
5. USCS designation is based on visual-manual classification and selected laboratory index testing.

MASTER LOG HL W8615-02.GPJ SHAN WIL.GDT 4/29/99 Log: BMR Rev: Typ: LKD

Thurston County, Washington
Sunrise Beach Road NW Landslide

LOG OF BORING SM-2

April 1999 W-8615-02

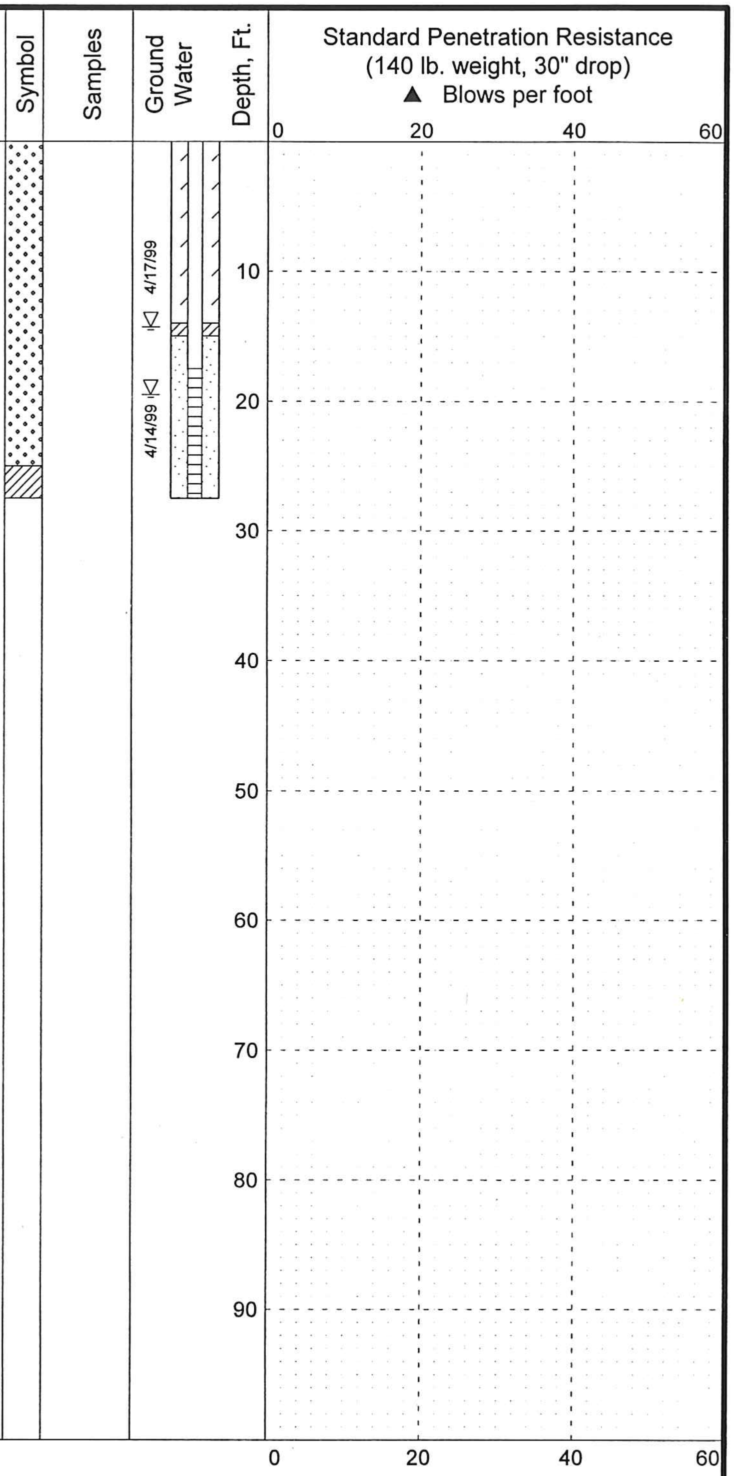
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-16

SOIL DESCRIPTION

Surface Elevation: Approx. 42.0 Ft.

SOIL DESCRIPTION	Depth, Ft.
Loose, brown, gravelly, fine to coarse SAND; moist; SW.	
Gray, silty CLAY; moist (on tip of rods); CL.	25.0
BOTTOM OF BORING COMPLETED 4/13/99	27.5



0 20 40 60

● % Water Content

Plastic Limit |—●—| Liquid Limit

Natural Water Content

LEGEND

- * Sample Not Recovered
- ⌶ 2-inch O.D. Split Spoon Sample
- Ⅱ 3-inch O.D. Shelby Tube Sample
- ▨ Surface Seal
- ▭ Annular Sealant
- ▦ Piezometer Screen
- ▭ Grout
- ▼ Ground Water Level ATD
- ▽ Highest Ground Water Level
- ▽ Lowest Ground Water Level

NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials.
3. Groundwater level, if indicated above, is for the date specified and may vary.
4. Refer to KEY for explanation of "Symbols" and definitions.
5. USCS designation is based on visual-manual classification and selected laboratory index testing.

Thurston County, Washington
Sunrise Beach Road NW Landslide

LOG OF BORING SM-3

April 1999 W-8615-02

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FIG. A-17

APPENDIX B

LABORATORY TEST RESULTS

APPENDIX B

LABORATORY TEST RESULTS

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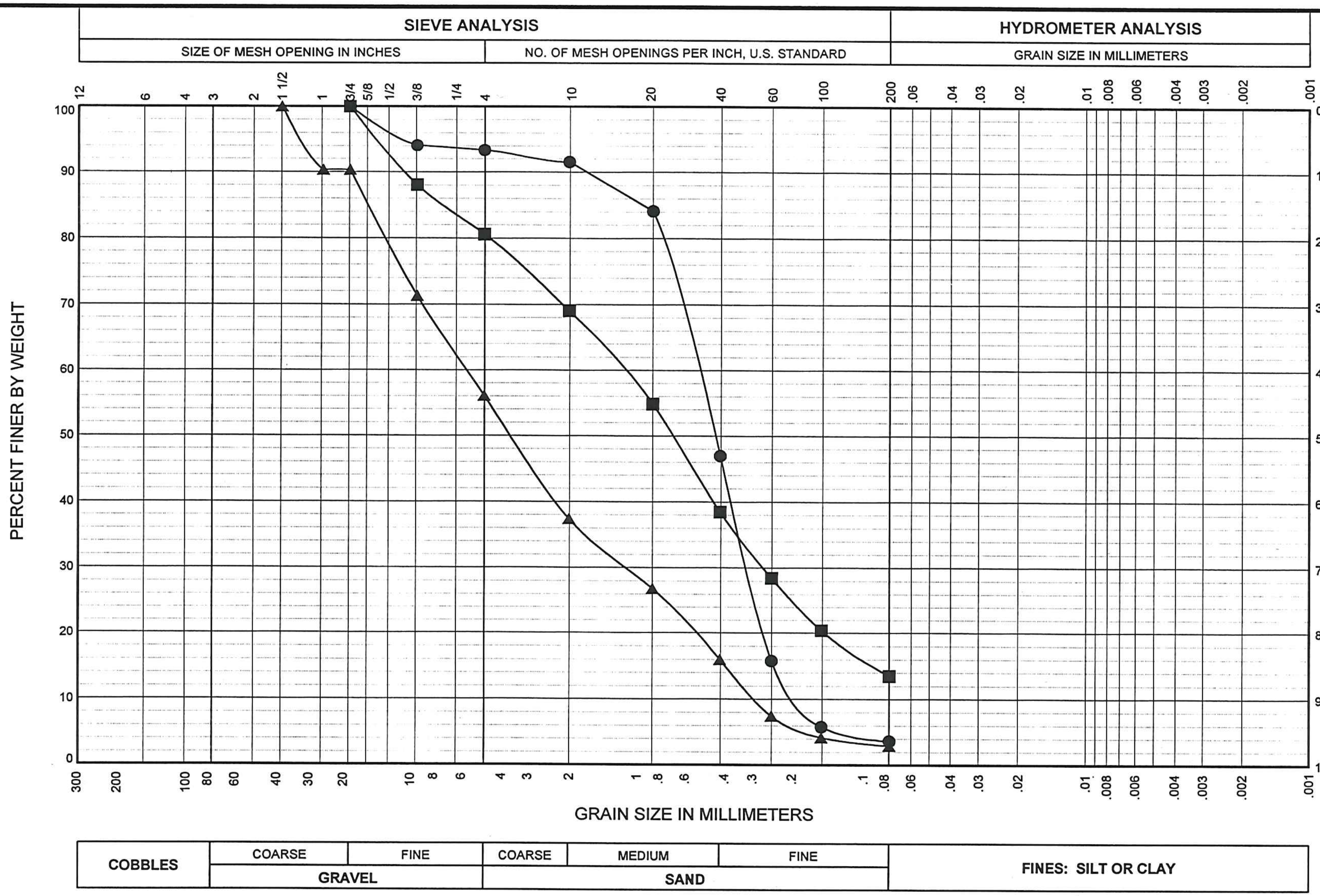
B-1 Grain Size Distribution Curves
B-2 Grain Size Distribution Curves
B-3 Atterberg Limit Plots
B-4 Atterberg Limit Plots



BORING AND SAMPLE NO.	DEPTH (feet)	U.S.C.S. CODE	SAMPLE DESCRIPTION	FINES %	NAT. W.C. %	LL %	PL %	PI %
● B-1, S-2	7.5	SP	Brown, slightly gravelly SAND, trace of silt; (Qvro)	3.7	7.7			
■ B-1, S-24	117.5	SM	Brown, silty gravelly SAND; (Qpqo)	13.5	14.4			
▲ B-3, S-6	27.5	SW	Brown, gravelly SAND, trace of silt; (Qvro)	3.0	5.0			

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GRAIN SIZE DISTRIBUTION

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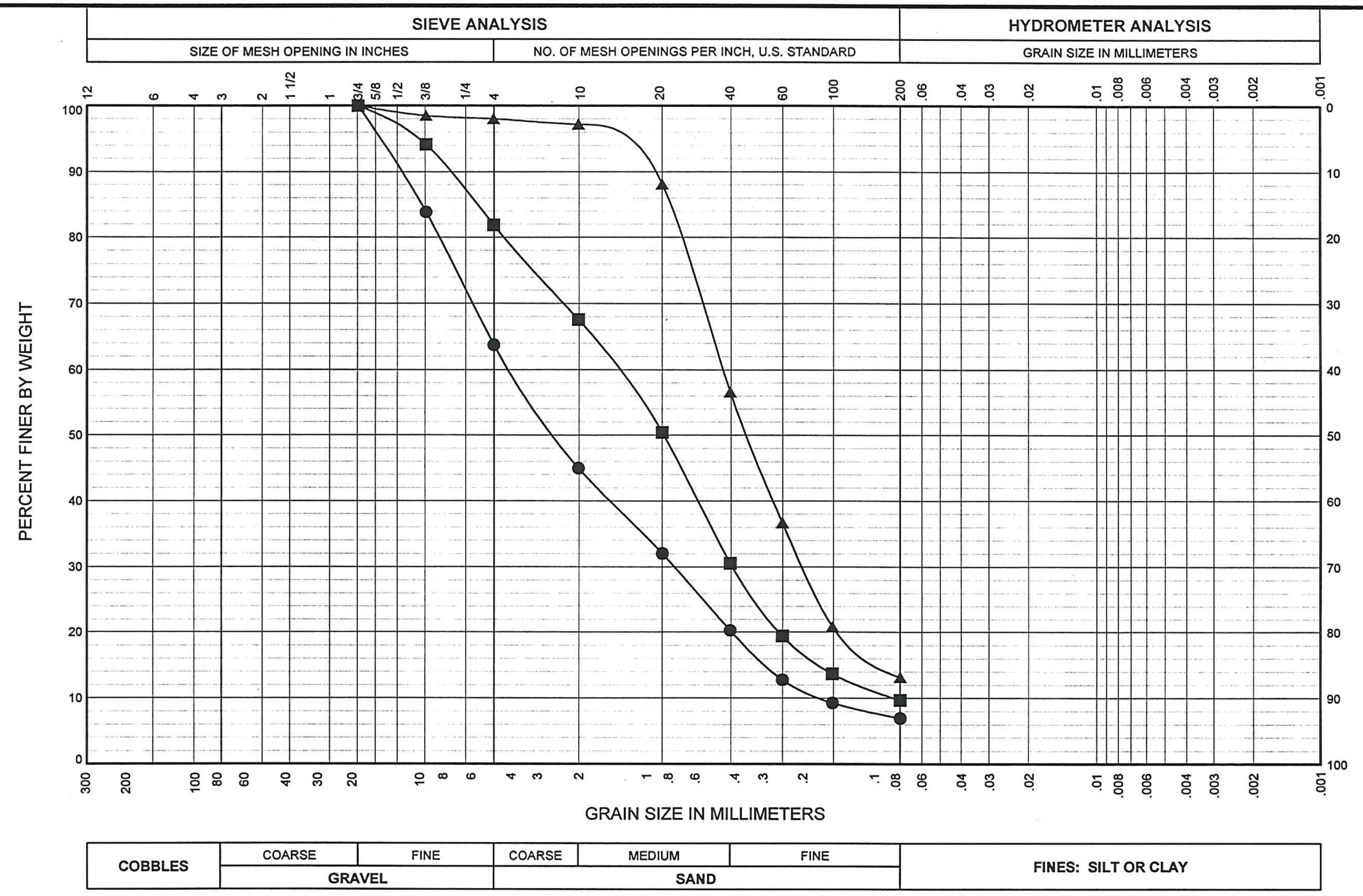
FIG. B-1

GSAMAIN2 W8615-02.GPJ SHAN_WIL.GDT 4/29/99



BORING AND SAMPLE NO.	DEPTH (feet)	U.S.C.S. CODE	SAMPLE DESCRIPTION	FINES %	NAT. W.C. %	LL %	PL %	PI %
● B-4, S-19	85.0	SP-SM	Brown, slightly silty, gravelly SAND; (Qpgo)	7.0	11.7			
■ B-5, S-14	67.5	SW-SM	Brown, slightly silty, gravelly SAND; (Qva)	9.7	11.4			
▲ B-5, S-16	77.5	SM	Brown, silty SAND, trace of gravel; (Qva)	13.2	16.7			

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Sunrise Beach Road NW Landslide

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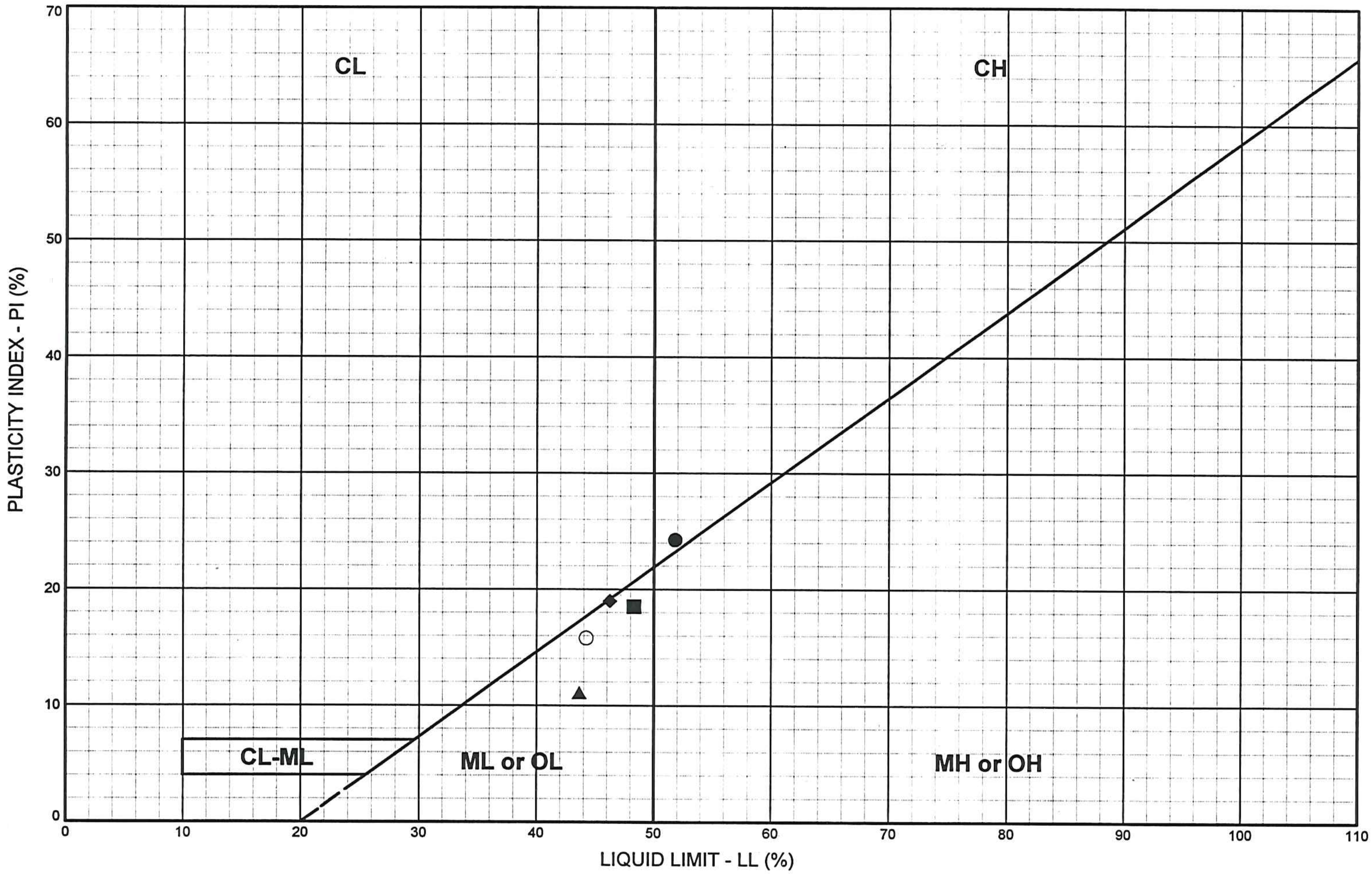
FIG. B-2

FIG. B-2



LEGEND

CL:	Low plasticity inorganic clays; sandy and silty clays
CH:	High plasticity inorganic clays
ML or OL:	Inorganic and organic silts and clayey silts of low plasticity
MH or OH:	Inorganic and organic silts and clayey silts of high plasticity
CL-ML:	Silty clays and clayey silts

BORING AND SAMPLE NO.	DEPTH (feet)	U.S.C.S. CODE	SOIL CLASSIFICATION	LL %	PL %	PI %	NAT. W.C. %	PASS. #200, %
● B-1, S-9	42.5	CH	Gray, silty CLAY; (Qvgl)	52	28	24	38.3	
■ B-1, S-19	92.5	ML	Gray, clayey SILT; (Qvgl)	48	30	18	31.0	
▲ B-2, S-3	12.5	ML	Brown, clayey SILT; (Qvrl)	44	33	11	37.1	
◆ B-2, S-17	82.5	CL	Gray, sandy, silty CLAY; disturbed; (Qvgl)	46	27	19	25.6	
○ B-3, S-16	77.5	ML	Gray, clayey SILT; (Qvgl)	44	28	16	32.8	

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PLASTICITY CHART

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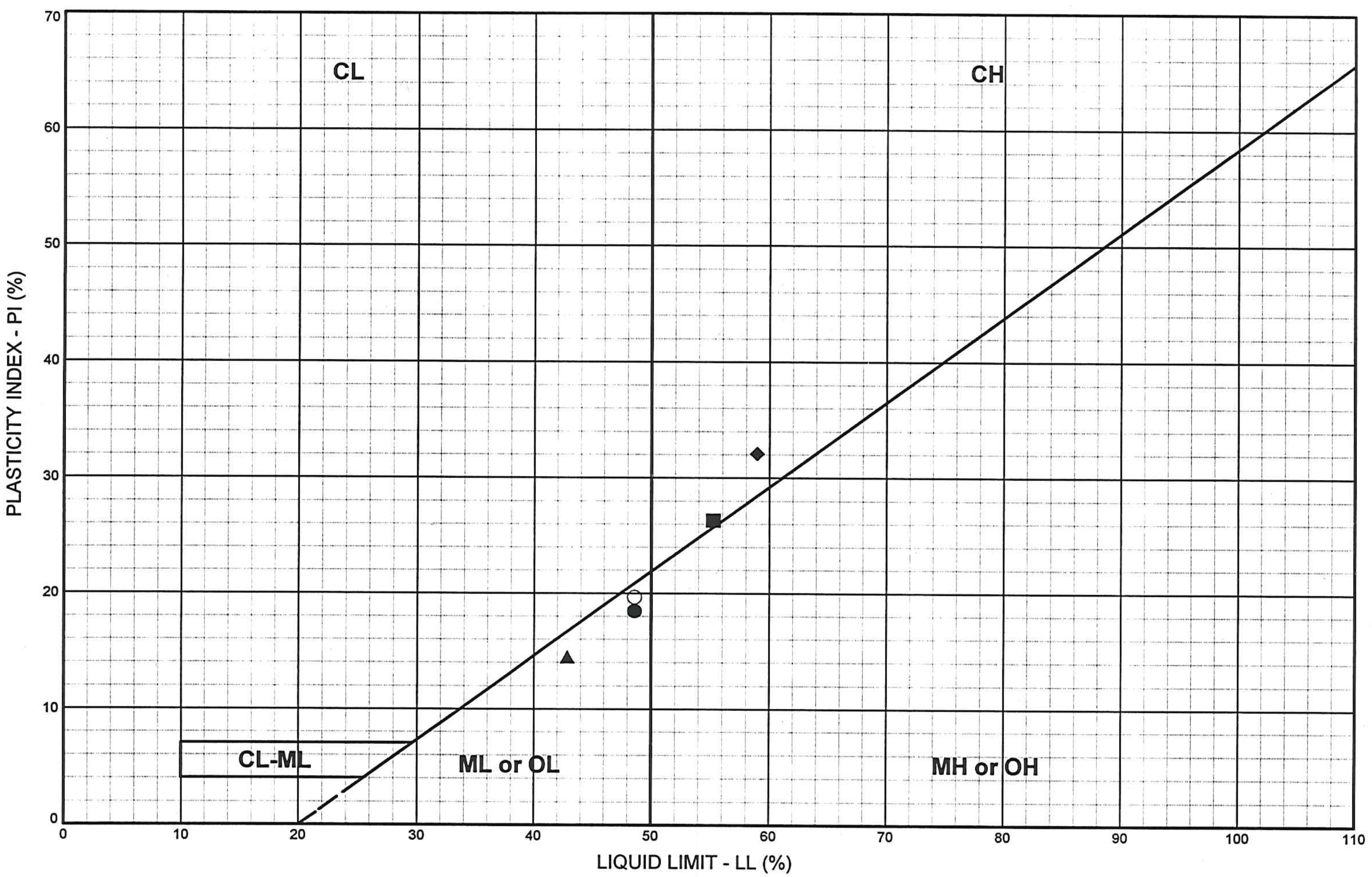
FIG. B-3



LEGEND

CL: Low plasticity inorganic clays; sandy and silty clays

CH: High plasticity inorganic clays

ML or OL: Inorganic and organic silts and clayey silts of low plasticity

MH or OH: Inorganic and organic silts and clayey silts of high plasticity

CL-ML: Silty clays and clayey silts

BORING AND SAMPLE NO.	DEPTH (feet)	U.S.C.S. CODE	SOIL CLASSIFICATION	LL %	PL %	PI %	NAT. W.C. %	PASS. #200, %
● B-4, S-4	17.5	ML	Brown, clayey SILT; (Qvrl, slide zone)	49	30	19	39.8	
■ B-4, S-8	30.0	CH	Brown, silty CLAY; (Qvrl)	55	29	26	35.3	
▲ B-4, S-12	50.0	ML	Gray, clayey SILT; (Qvgl)	43	28	15	30.2	
◆ B-5, S-26	127.5	CH	Gray, silty CLAY; (Qvgl)	59	27	32	26.3	
○ B-5, S-35	172.5	ML	Gray, clayey SILT; (Qvgl)	49	29	20	33.5	

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Sunrise Beach Road NW Landslide

PLASTICITY CHART

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FIG. B-4

APPENDIX C

SLOPE INCLINOMETER PLOTS

APPENDIX C

SLOPE INCLINOMETER PLOTS

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C-2 Inclinometer Casing B-2
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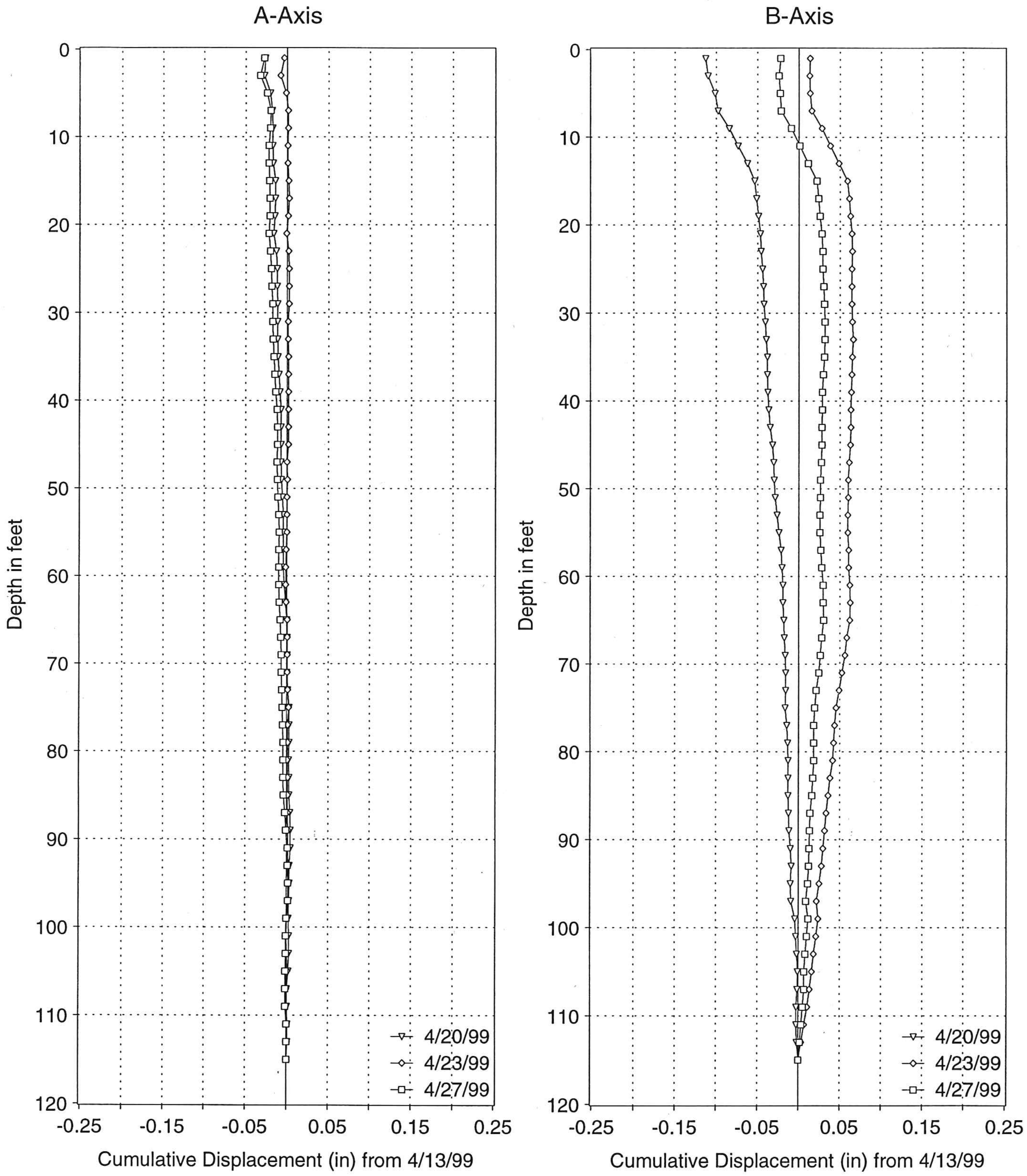
C-4 Inclinometer Casing B-4



Inclinometer Casing B-1

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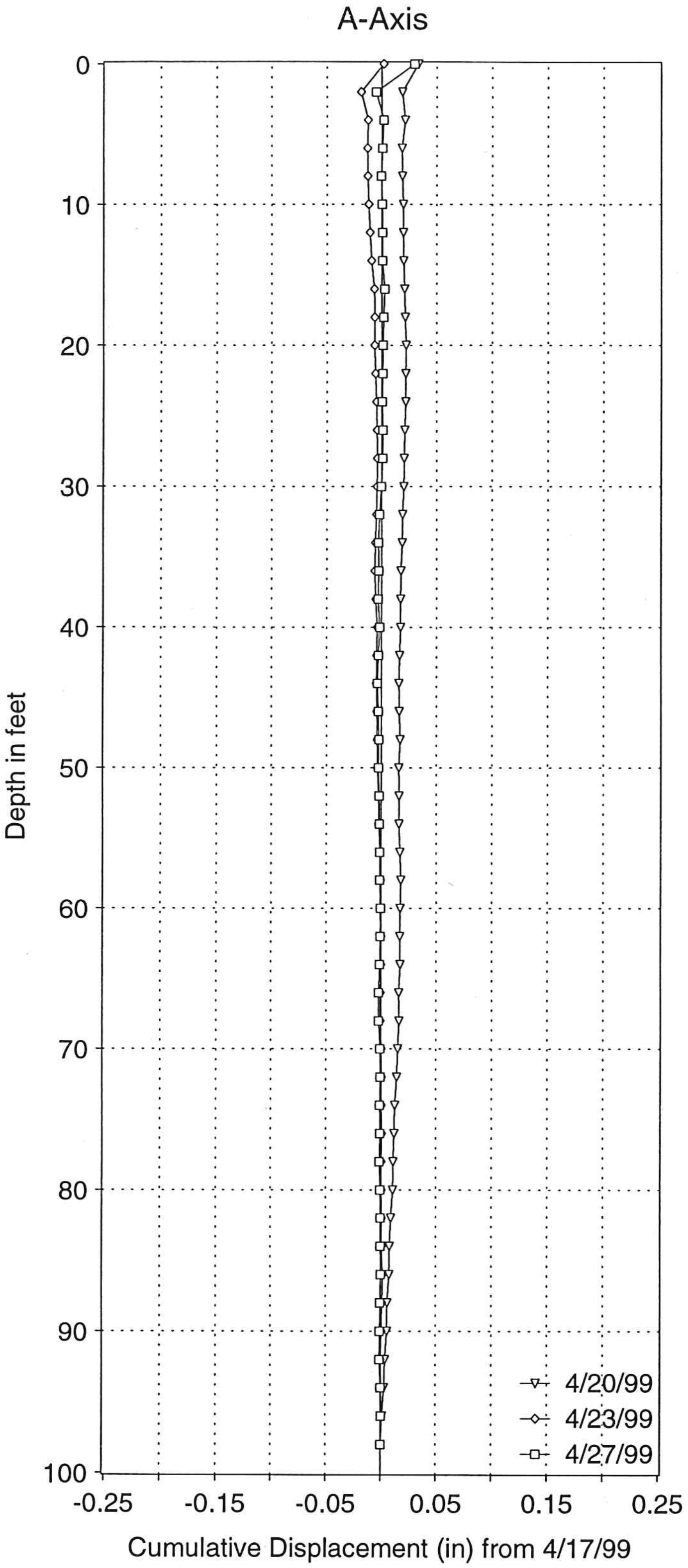
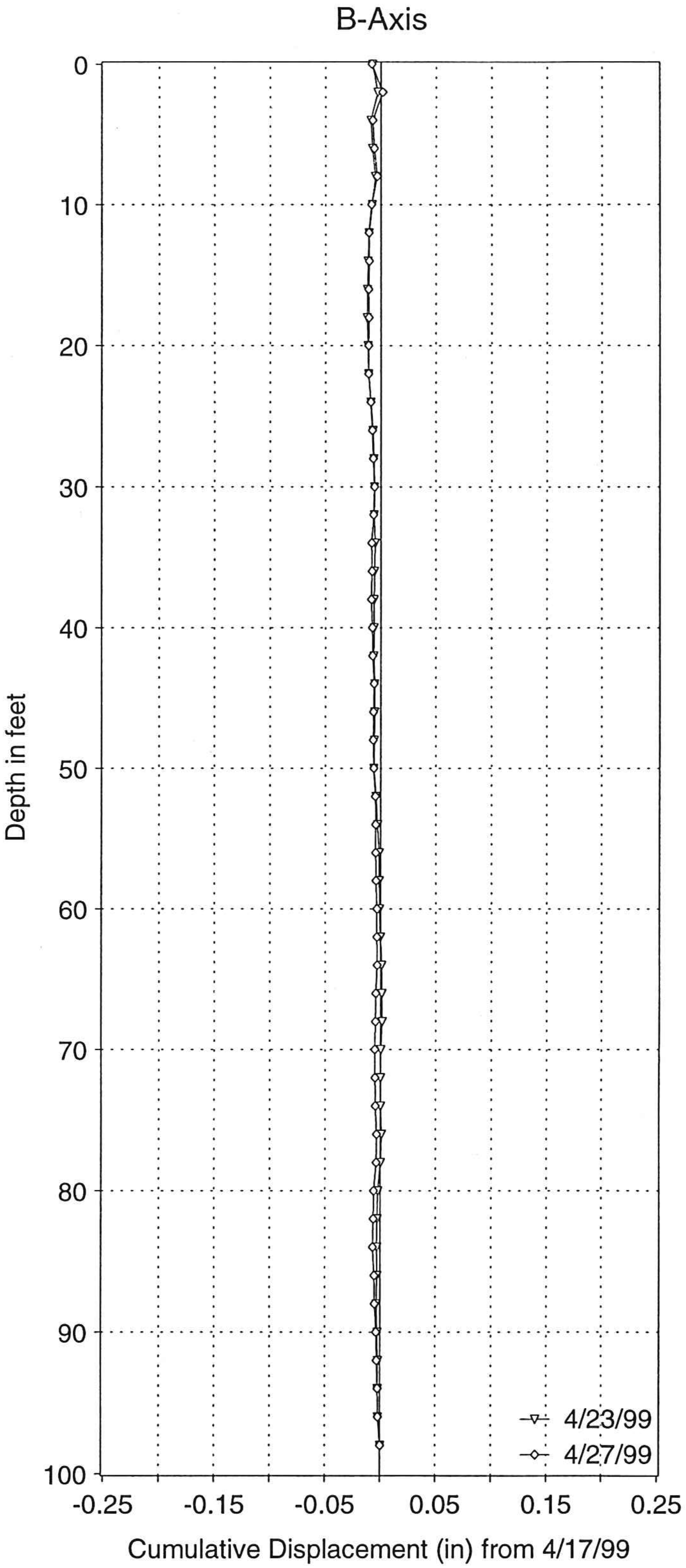
Fig. C-1





Inclinometer Casing B-2

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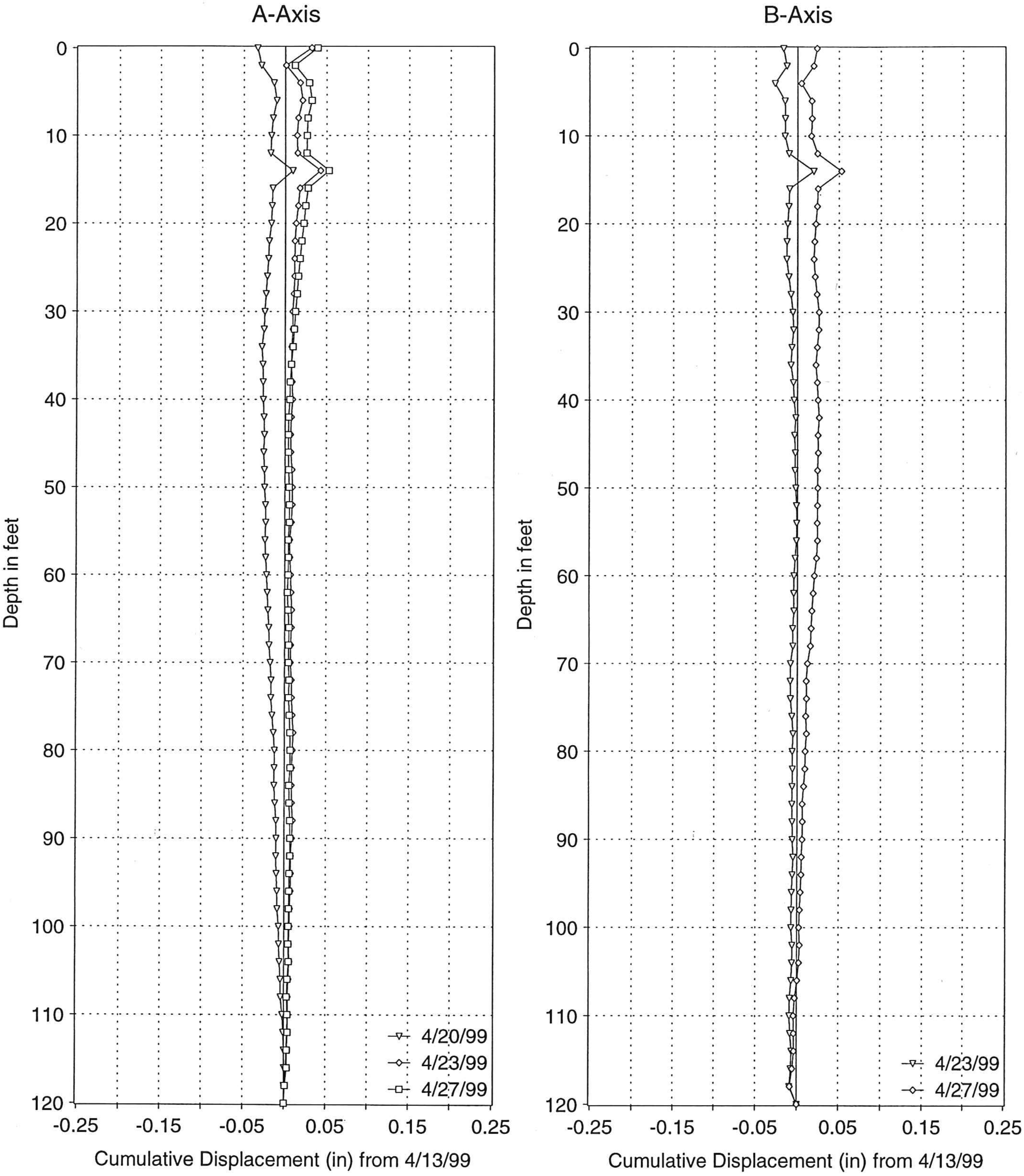
Fig. C-2



Inclinometer Casing B-3

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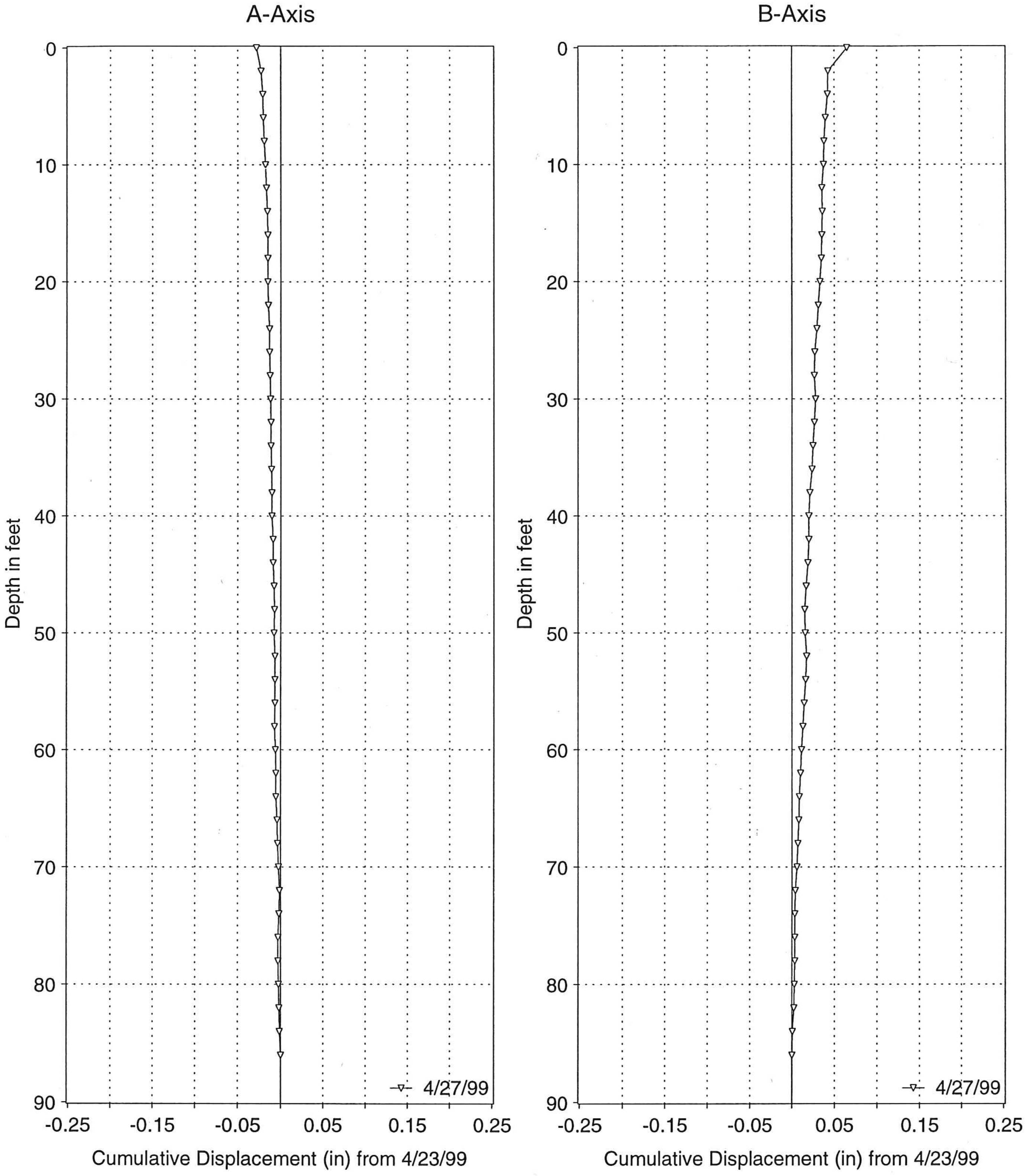
W-8615-02

Fig. C-3



Inclinometer Casing B-4

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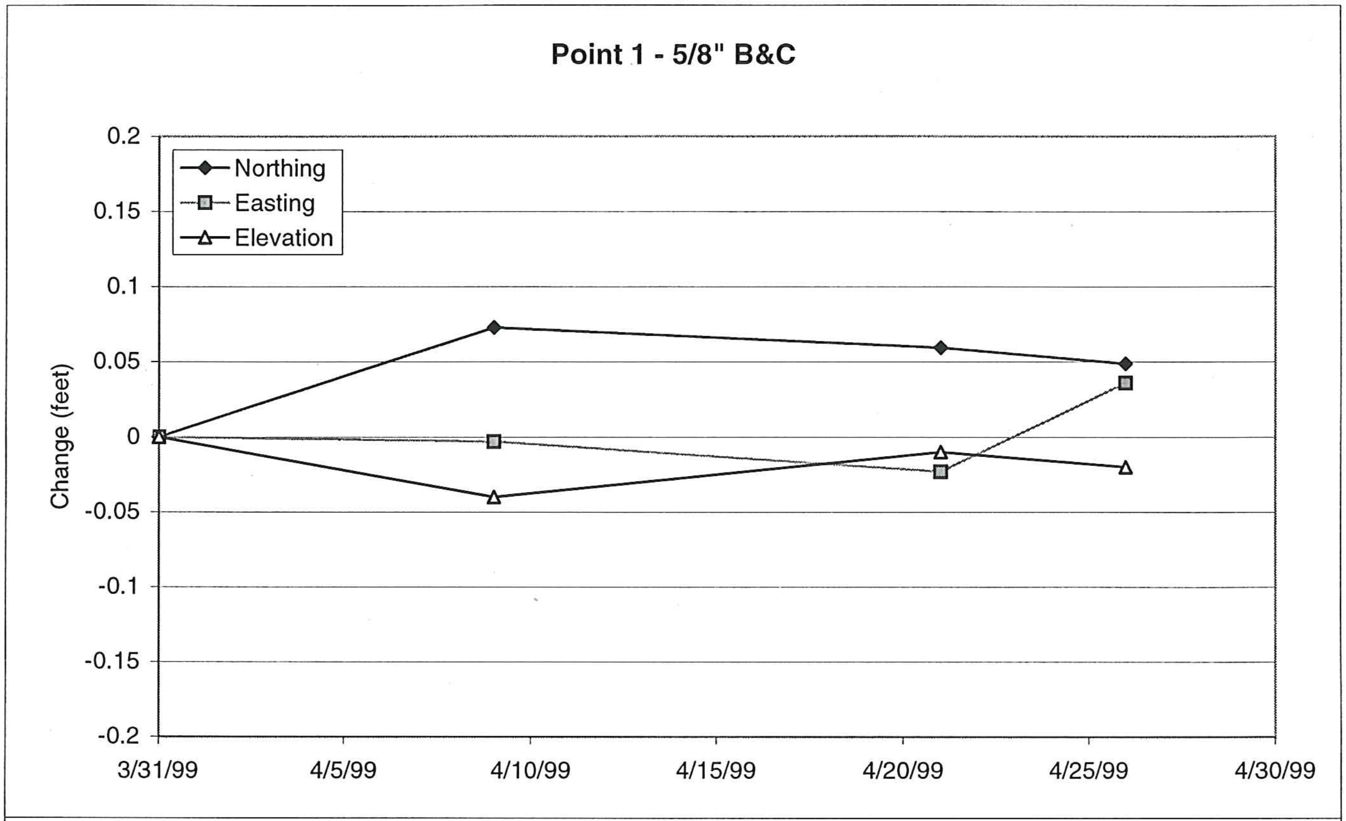
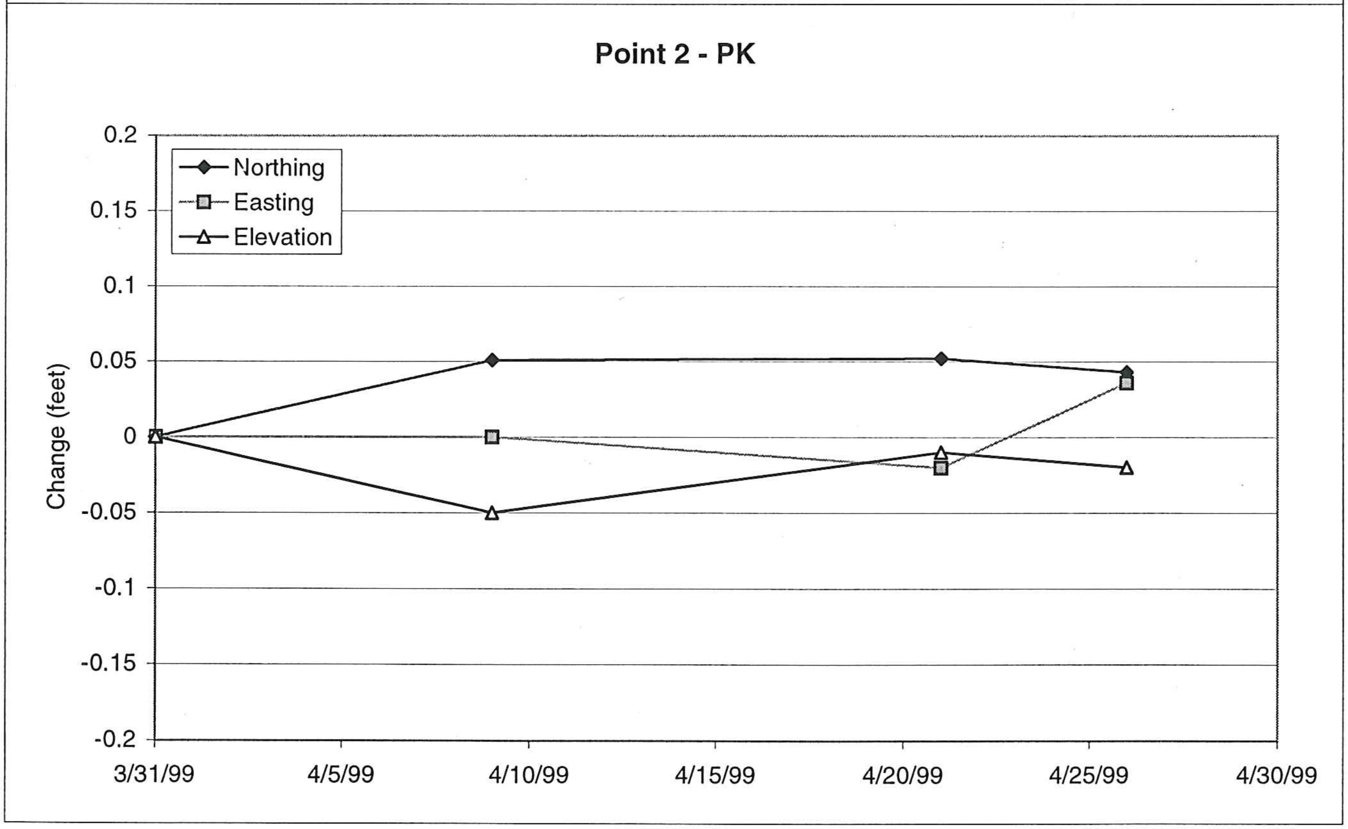
Fig. C-4

APPENDIX D

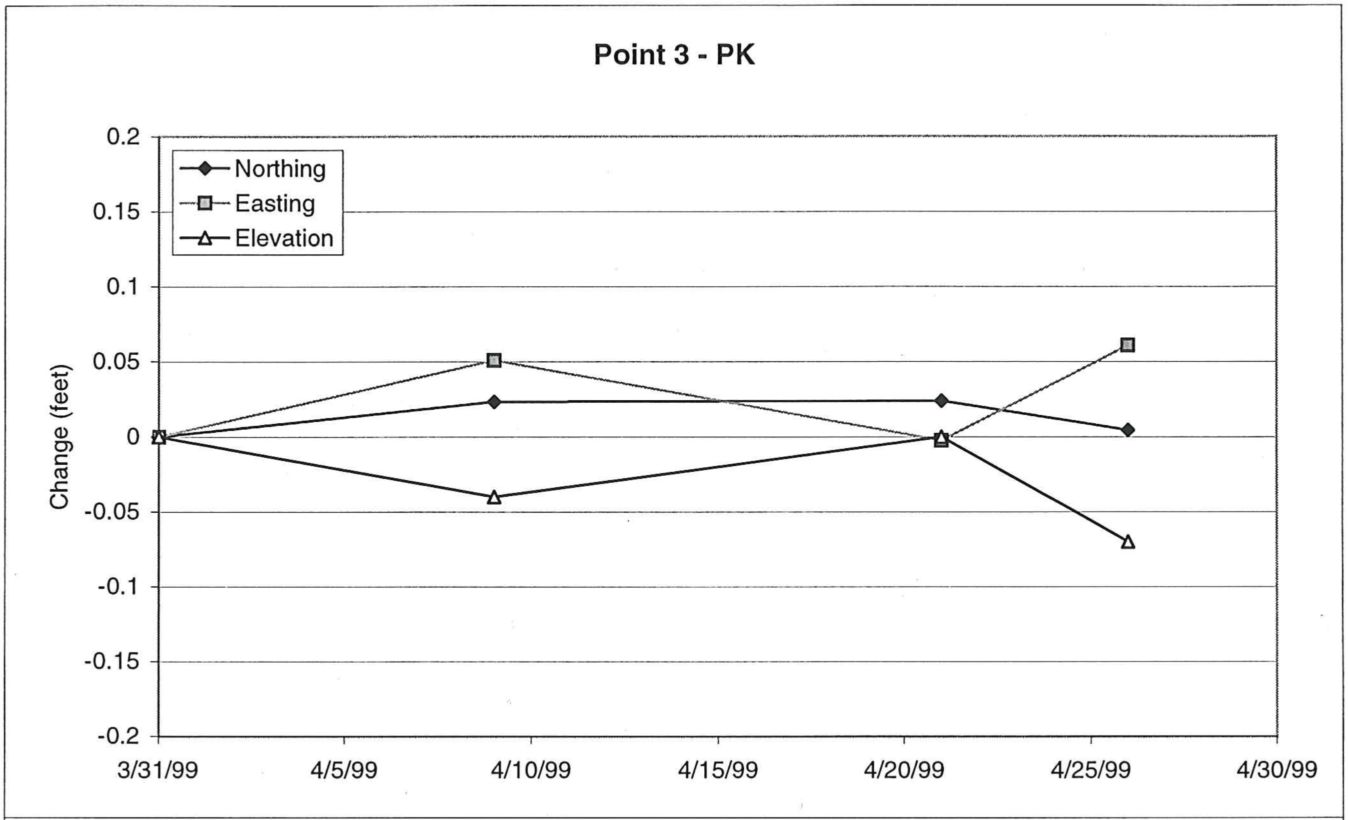
SURVEY MONITORING PLOTS



Point 1 - 5/8" B&C



Point 2 - PK


Point 3 - PK
Northing
Easting
Elevation
Change (feet)
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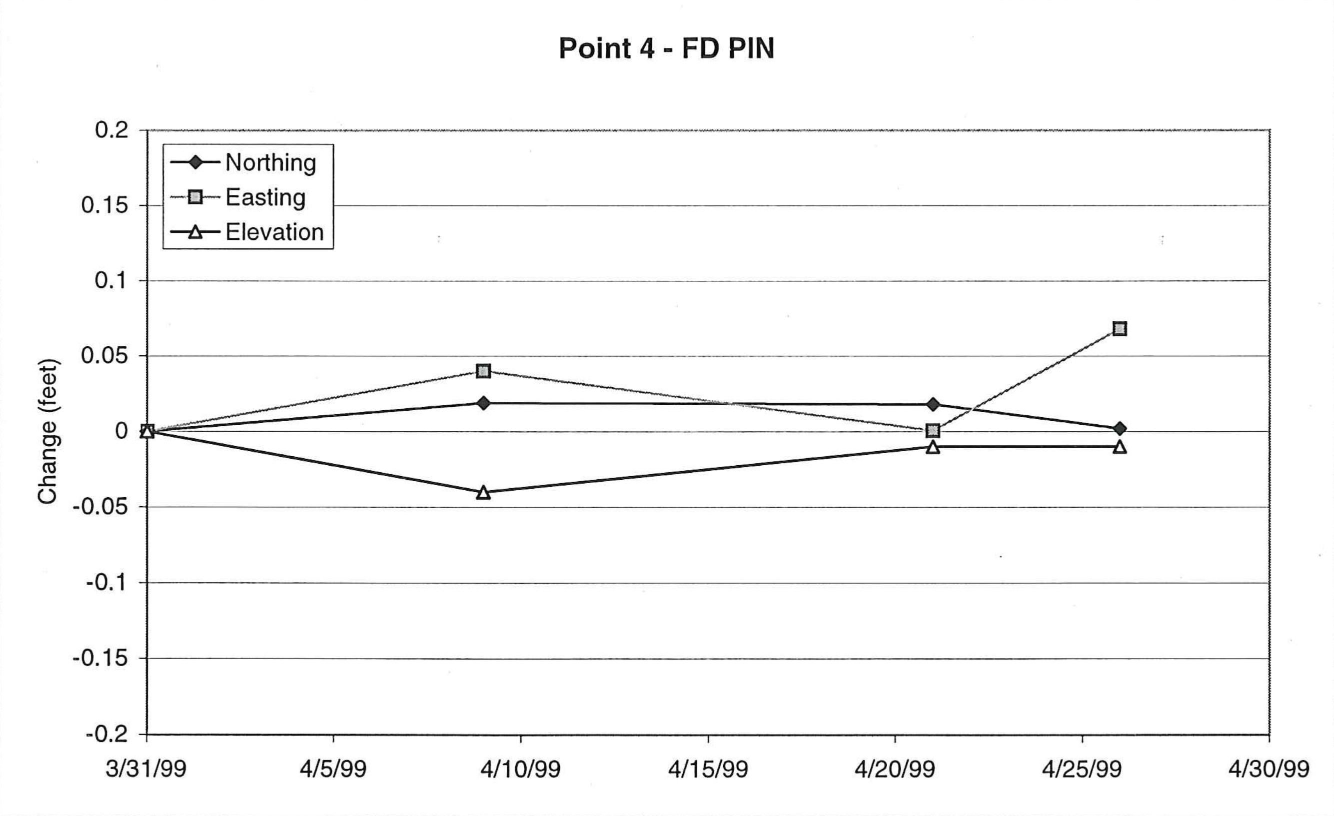
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
3/31/99
4/5/99
4/10/99
4/15/99
4/20/99
4/25/99
4/30/99


Point 4 - FD PIN
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Easting
Elevation
Change (feet)
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0
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-0.1
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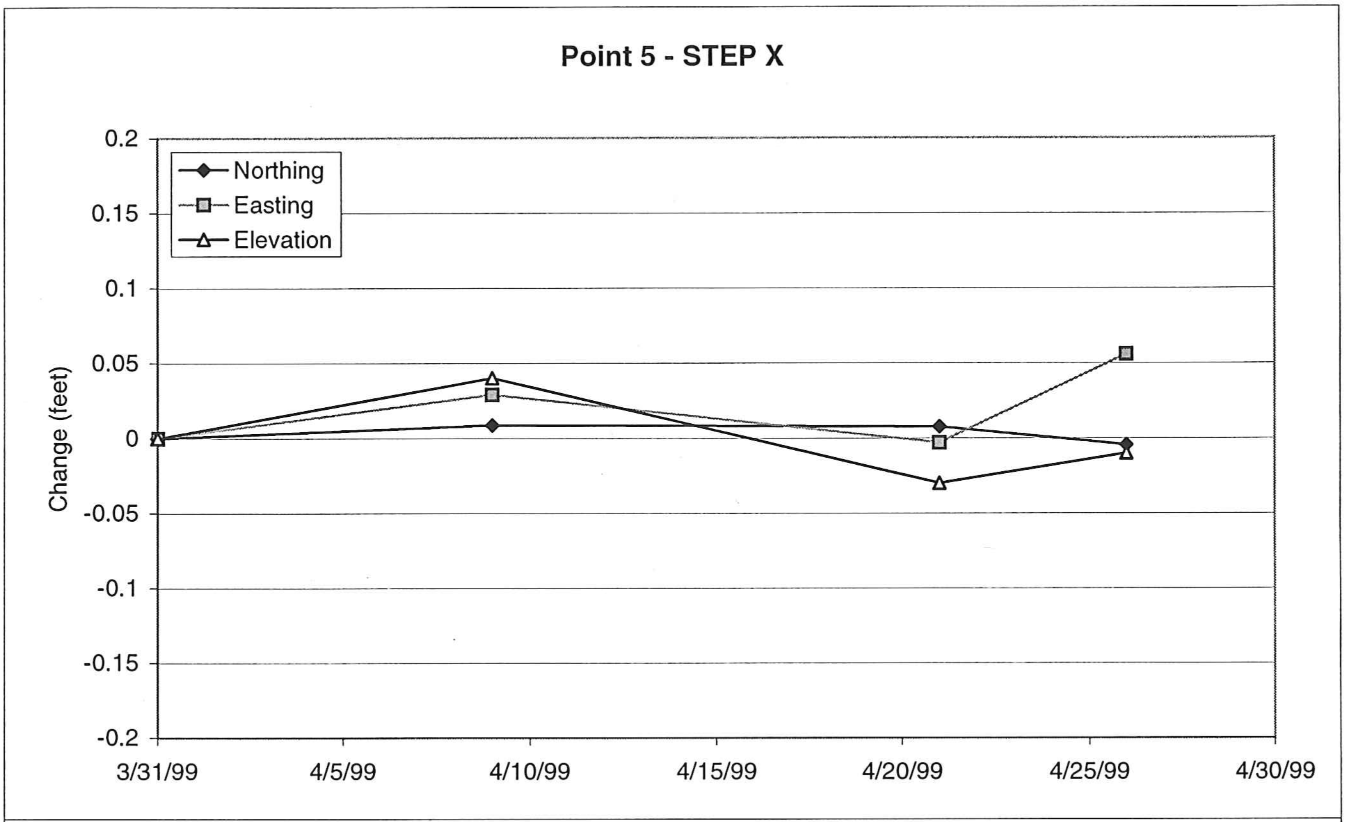
-0.2
3/31/99
4/5/99
4/10/99
4/15/99
4/20/99
4/25/99
4/30/99


Point 5 - STEP X
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Easting
Elevation
Change (feet)
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-0.1
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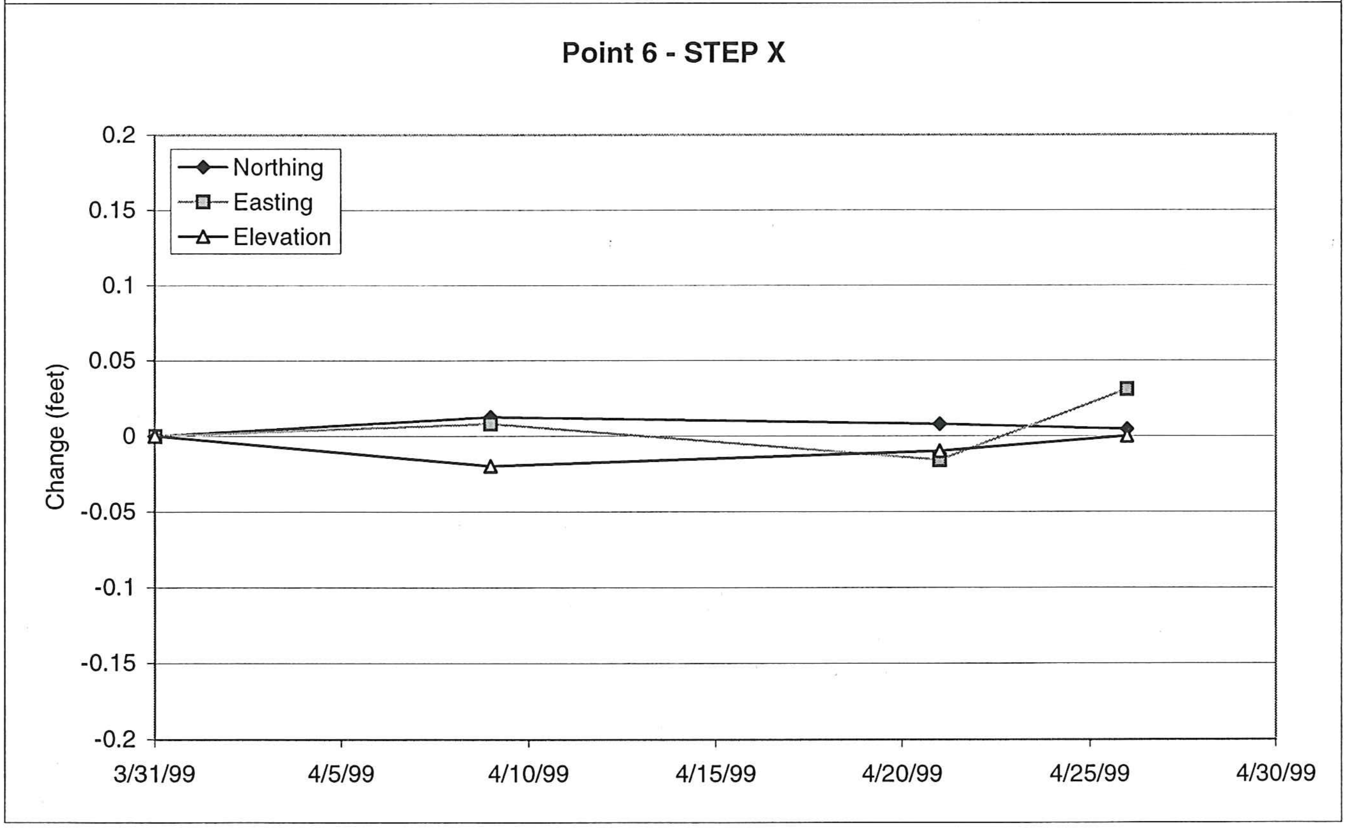
-0.2
3/31/99
4/5/99
4/10/99
4/15/99
4/20/99
4/25/99
4/30/99


Point 6 - STEP X
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Easting
Elevation
Change (feet)
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-0.1
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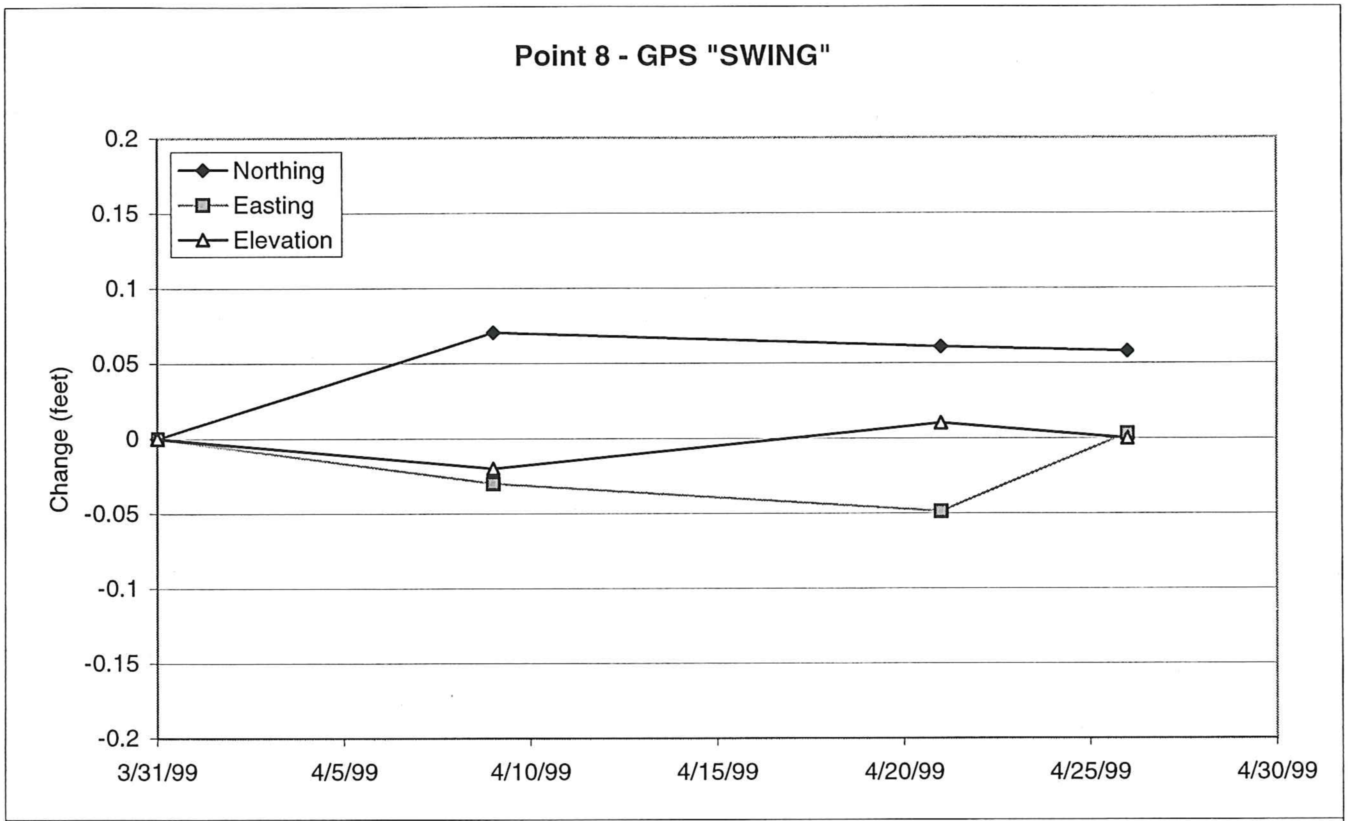
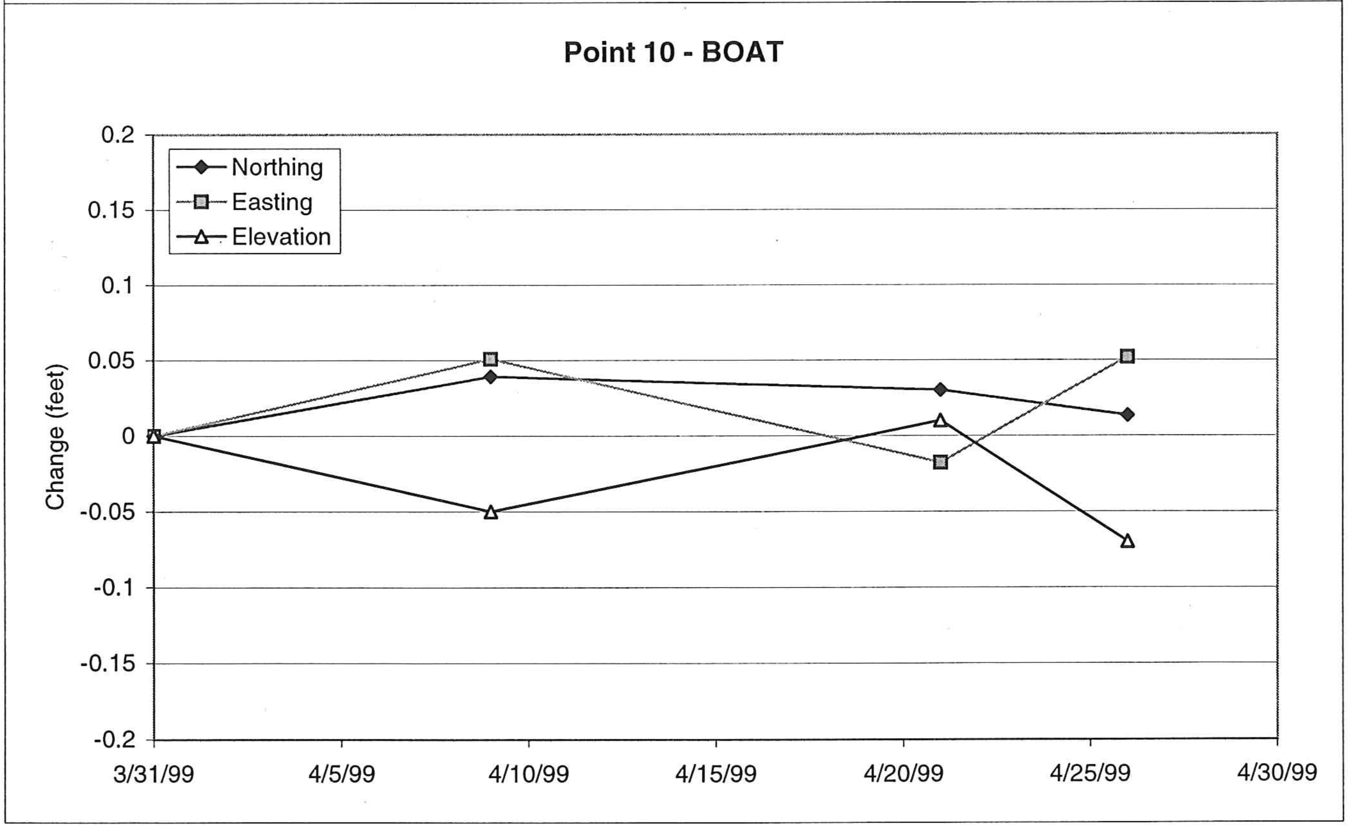
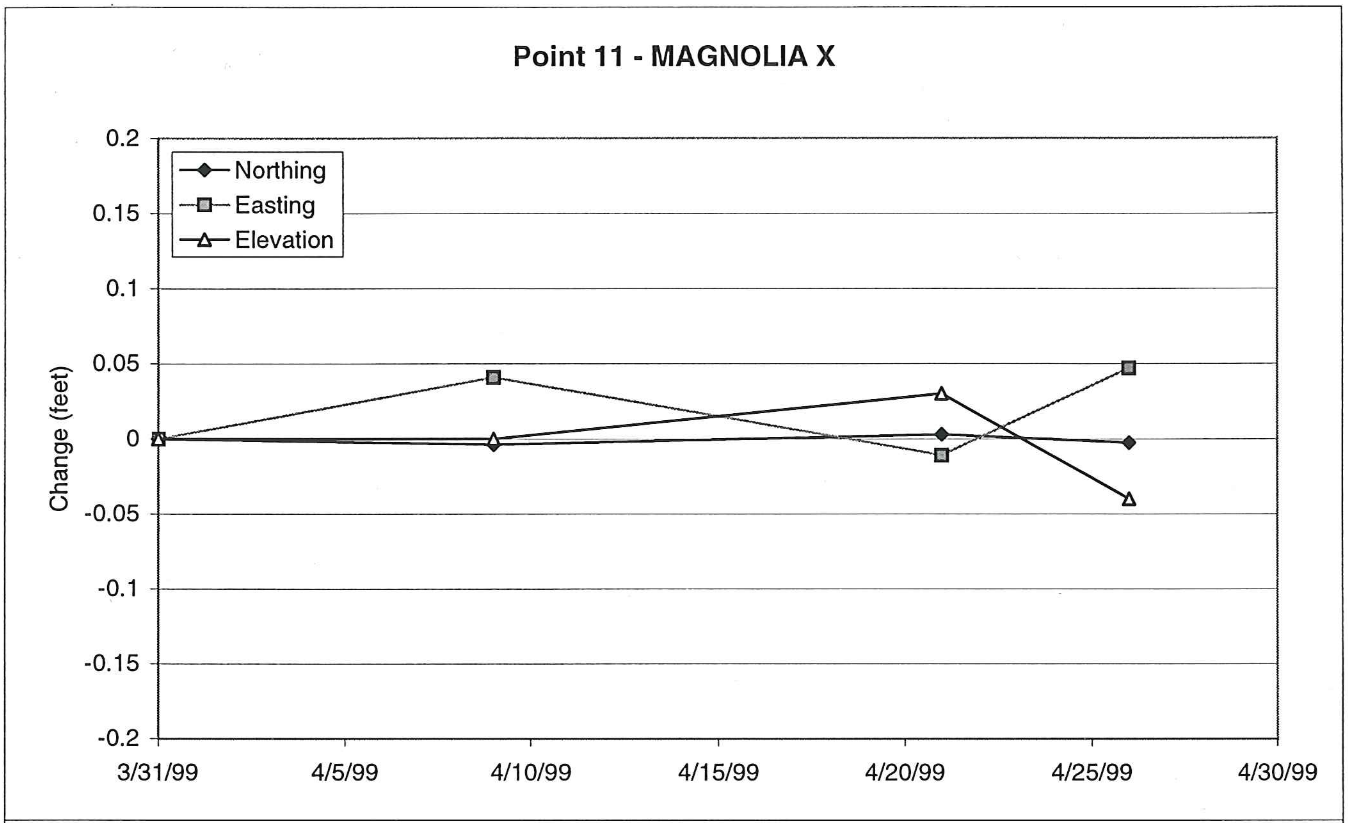
3/31/99
4/5/99
4/10/99
4/15/99
4/20/99
4/25/99
4/30/99



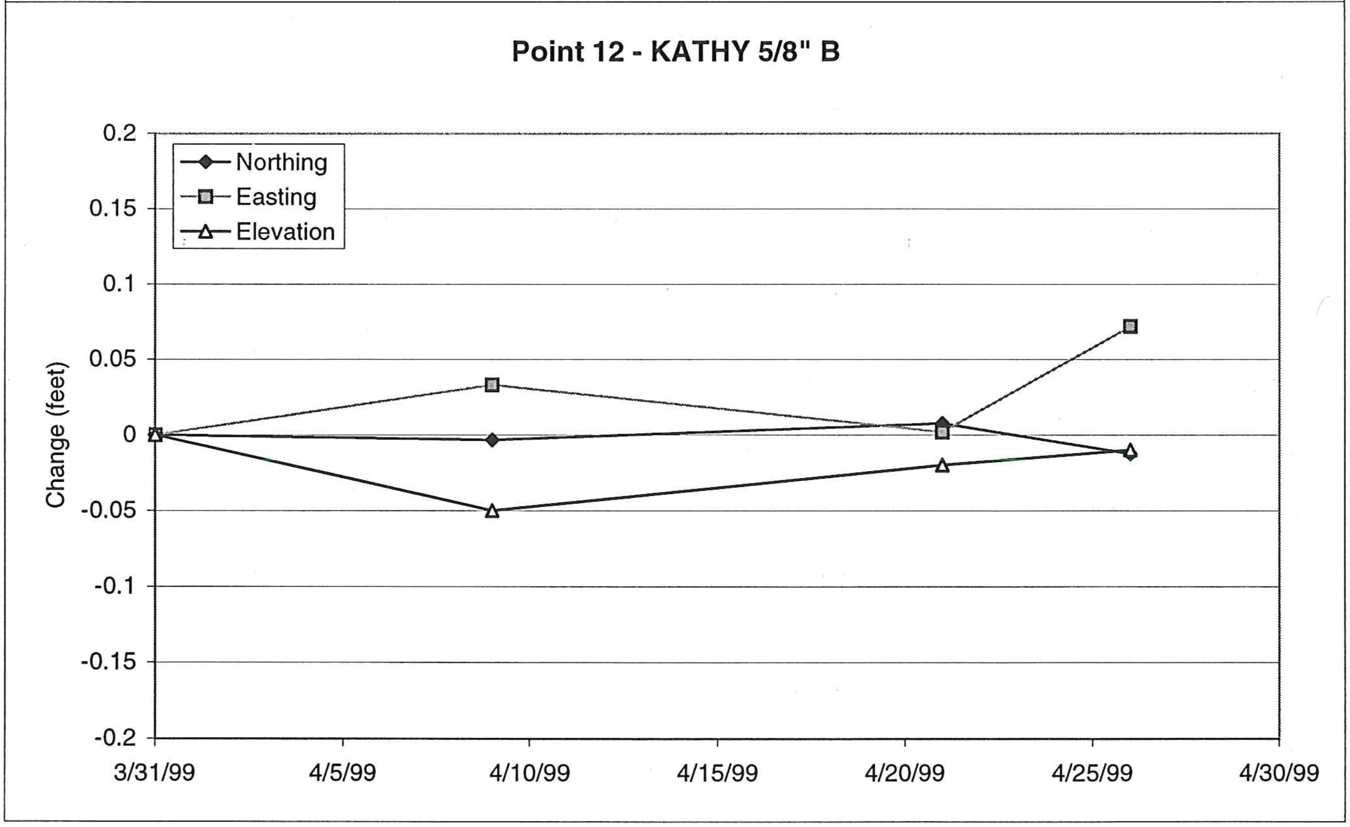
Point 8 - GPS "SWING"



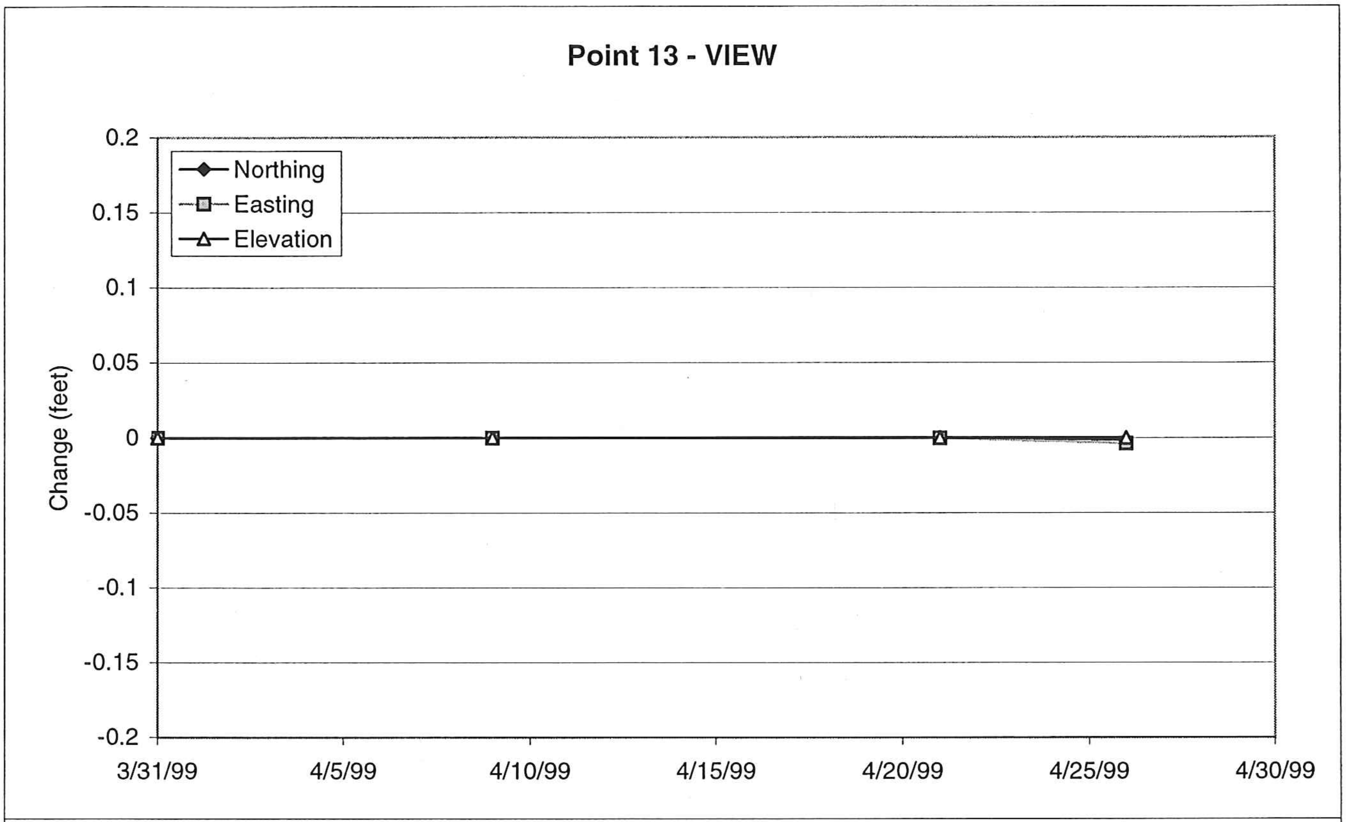
Point 10 - BOAT



Point 11 - MAGNOLIA X



Point 12 - KATHY 5/8" B


Point 13 - VIEW
Northing
Easting
Elevation
Change (feet)
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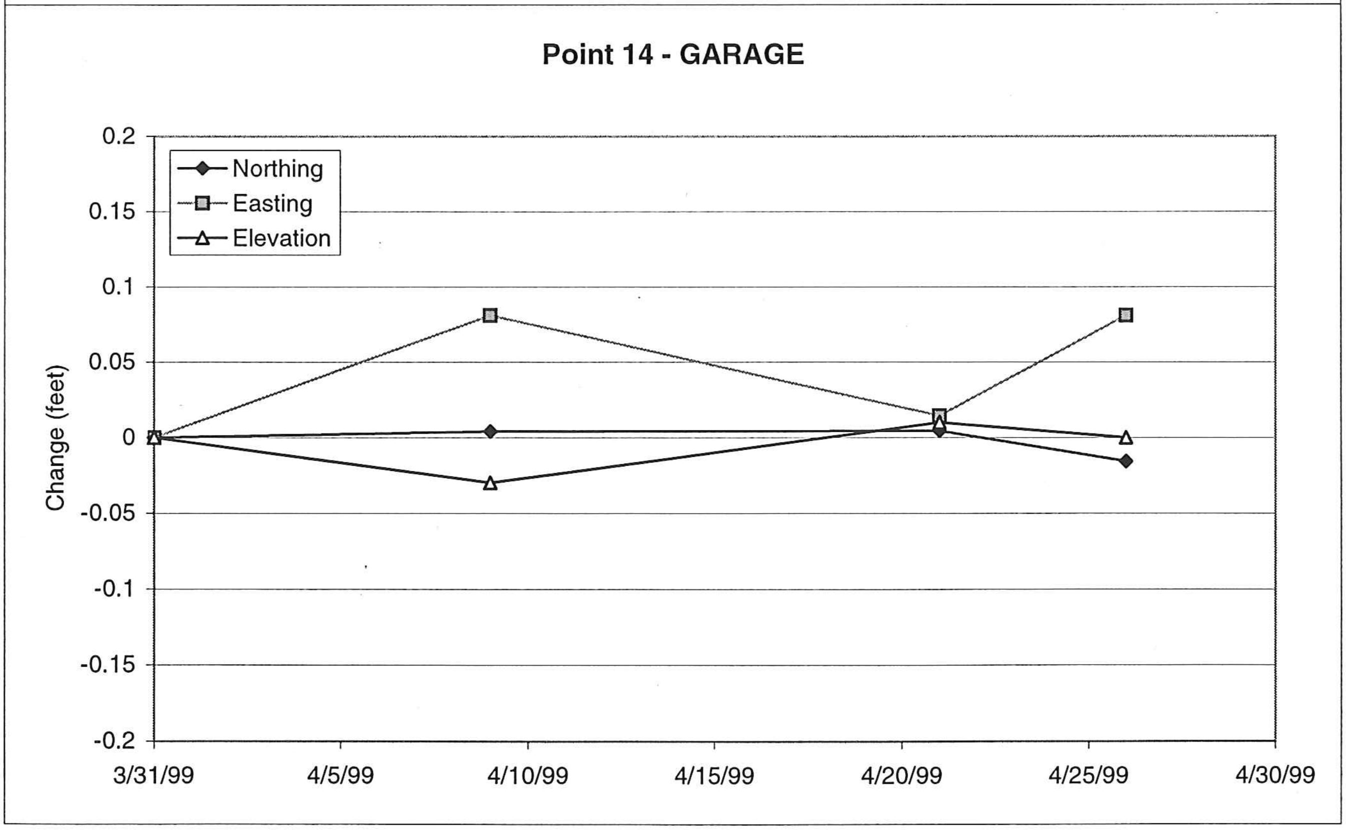
4/10/99
4/15/99
4/20/99
4/25/99
4/30/99


Point 14 - GARAGE
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Easting
Elevation
Change (feet)
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0.1
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4/20/99
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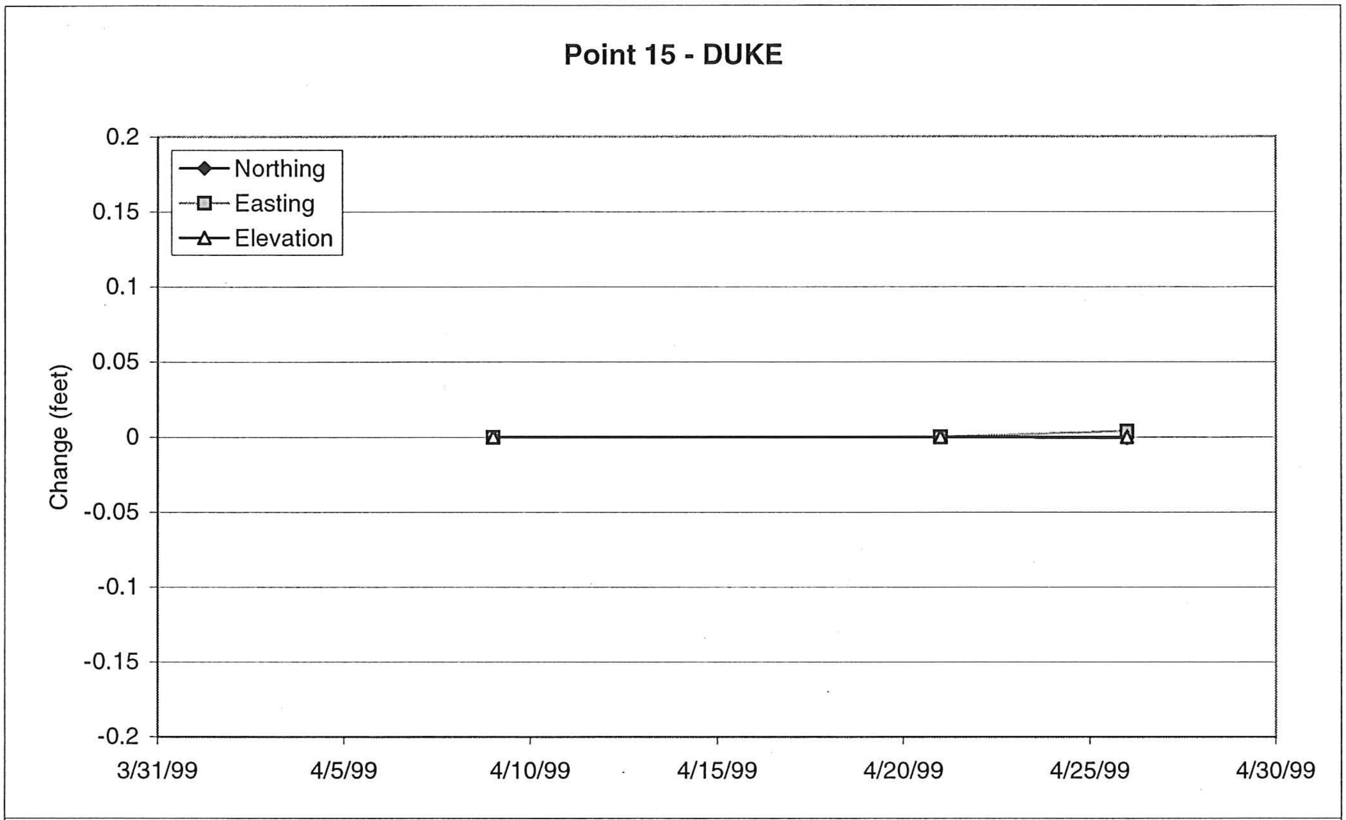
Point 15 - DUKE
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Elevation
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4/20/99
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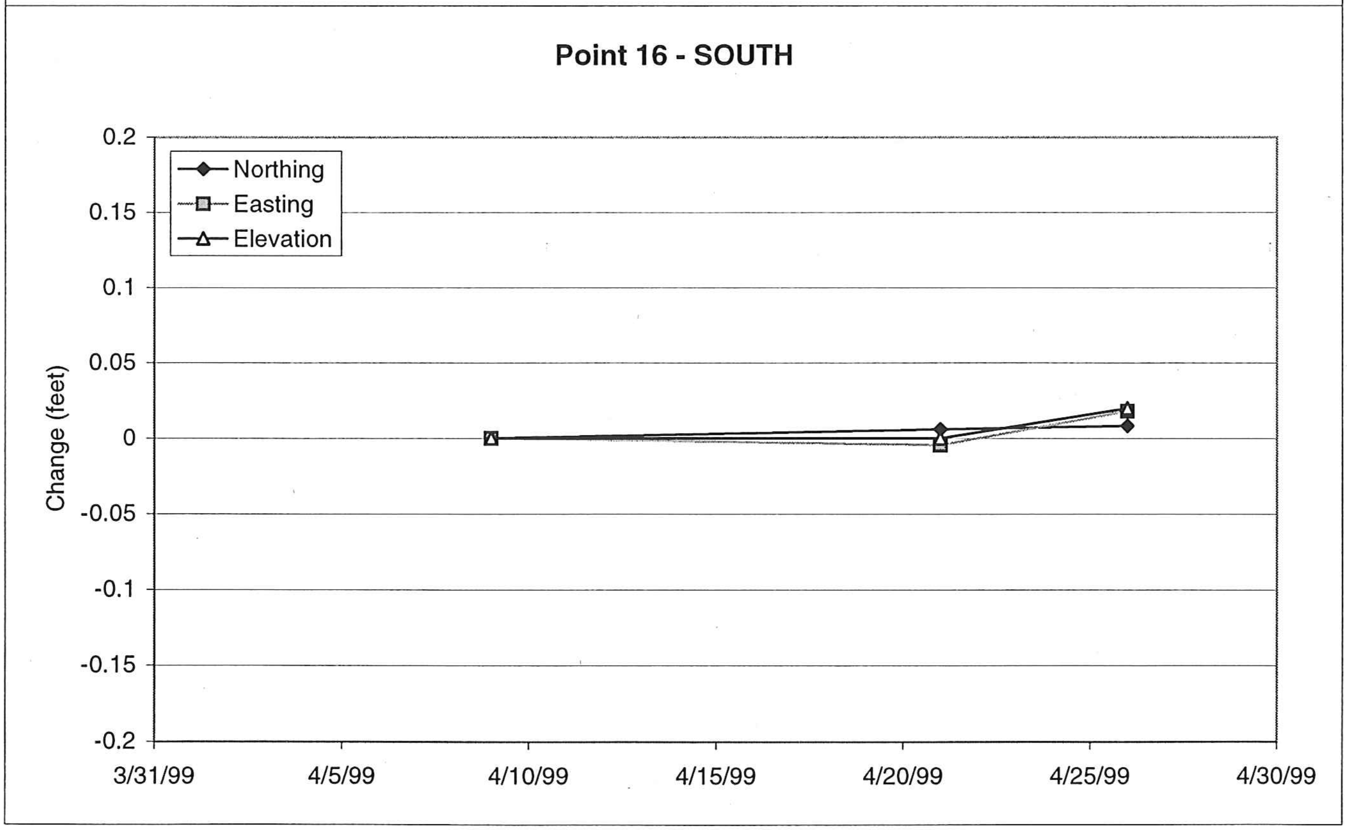
4/30/99


Point 16 - SOUTH
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Easting
Elevation
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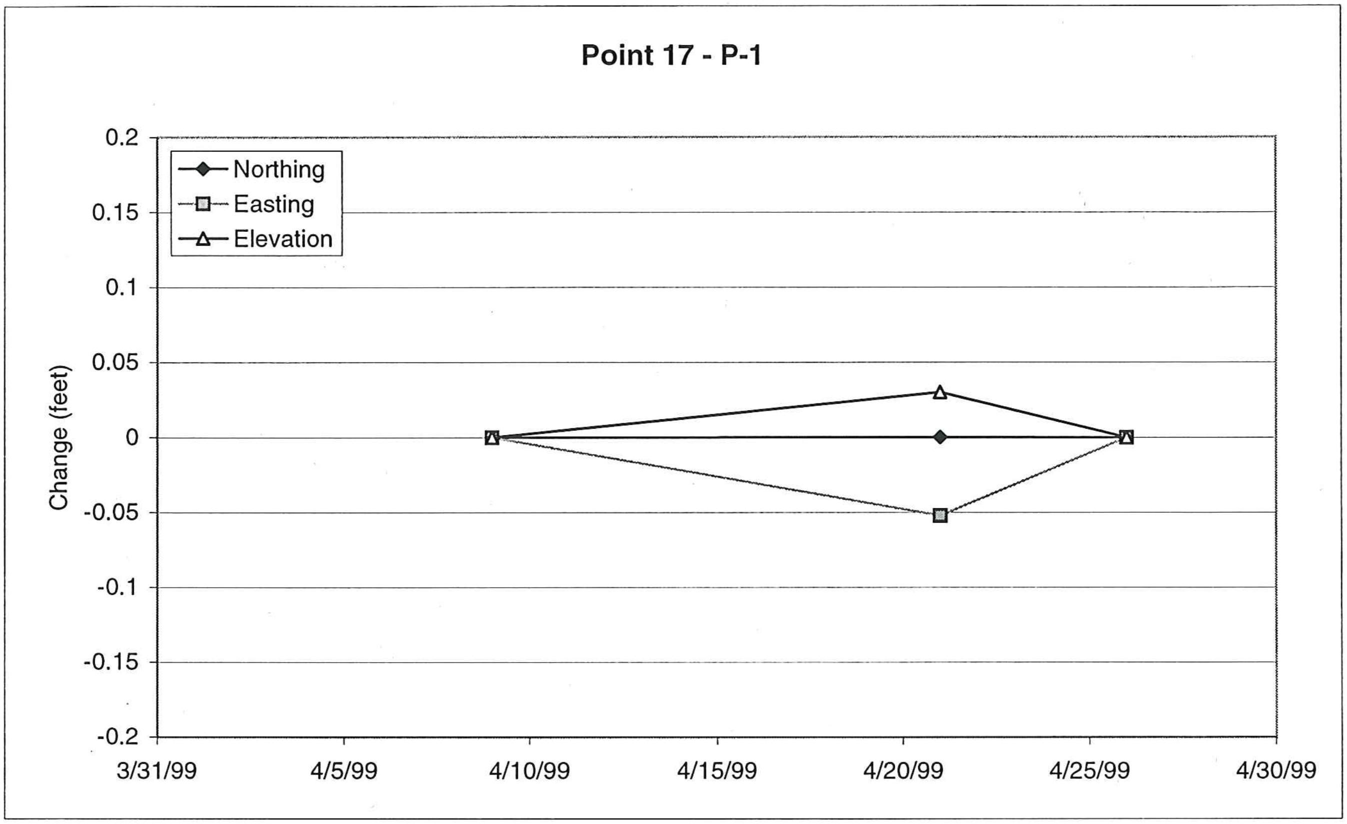
4/15/99
4/20/99
4/25/99
4/30/99


Point 17 - P-1
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Easting
Elevation
Change (feet)
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0
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-0.1
-0.15
-0.2
3/31/99
4/5/99
4/10/99
4/15/99
4/20/99
4/25/99
4/30/99

APPENDIX E

IMPORTANT INFORMATION ABOUT YOUR GEOTECHNICAL REPORT

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

W-8615-02
Attachment to Report Page 1 of 2

Dated: April 30, 1999
To: Thurston County Dept. of Roads & Transportation Services

Important Information About Your Geotechnical/Environmental Report

CONSULTING SERVICES ARE PERFORMED FOR SPECIFIC PURPOSES AND FOR SPECIFIC CLIENTS.

Consultants prepare reports to meet the specific needs of specific individuals. A report prepared for a civil engineer may not be adequate for a construction contractor or even another civil engineer. Unless indicated otherwise, your consultant prepared your report expressly for you and expressly for the purposes you indicated. No one other than you should apply this report for its intended purpose without first conferring with the consultant. No party should apply this report for any purpose other than that originally contemplated without first conferring with the consultant.

THE CONSULTANT'S REPORT IS BASED ON PROJECT-SPECIFIC FACTORS.

A geotechnical/environmental report is based on a subsurface exploration plan designed to consider a unique set of project-specific factors. Depending on the project, these may include: the general nature of the structure and property involved; its size and configuration; its historical use and practice; the location of the structure on the site and its orientation; other improvements such as access roads, parking lots, and underground utilities; and the additional risk created by scope-of-service limitations imposed by the client. To help avoid costly problems, ask the consultant to evaluate how any factors that change subsequent to the date of the report may affect the recommendations. Unless your consultant indicates otherwise, your report should not be used: (1) when the nature of the proposed project is changed (for example, if an office building will be erected instead of a parking garage, or if a refrigerated warehouse will be built instead of an unrefrigerated one, or chemicals are discovered on or near the site); (2) when the size, elevation, or configuration of the proposed project is altered; (3) when the location or orientation of the proposed project is modified; (4) when there is a change of ownership; or (5) for application to an adjacent site. Consultants cannot accept responsibility for problems that may occur if they are not consulted after factors which were considered in the development of the report have changed.

SUBSURFACE CONDITIONS CAN CHANGE.

Subsurface conditions may be affected as a result of natural processes or human activity. Because a geotechnical/environmental report is based on conditions that existed at the time of subsurface exploration, construction decisions should not be based on a report whose adequacy may have been affected by time. Ask the consultant to advise if additional tests are desirable before construction starts; for example, groundwater conditions commonly vary seasonally.

Construction operations at or adjacent to the site and natural events such as floods, earthquakes, or groundwater fluctuations may also affect subsurface conditions and, thus, the continuing adequacy of a geotechnical/environmental report. The consultant should be kept apprised of any such events, and should be consulted to determine if additional tests are necessary.

MOST RECOMMENDATIONS ARE PROFESSIONAL JUDGMENTS.

Site exploration and testing identifies actual surface and subsurface conditions only at those points where samples are taken. The data were extrapolated by your consultant, who then applied judgment to render an opinion about overall subsurface conditions. The actual interface between materials may be far more gradual or abrupt than your report indicates. Actual conditions in areas not sampled may differ from those predicted in your report. While nothing can be done to prevent such situations, you and your consultant can work together to help reduce their impacts. Retaining your consultant to observe subsurface construction operations can be particularly beneficial in this respect.

A REPORT'S CONCLUSIONS ARE PRELIMINARY.

The conclusions contained in your consultant's report are preliminary because they must be based on the assumption that conditions revealed through selective exploratory sampling are indicative of actual conditions throughout a site. Actual subsurface conditions can be discerned only during earthwork; therefore, you should retain your consultant to observe actual conditions and to provide conclusions. Only the consultant who prepared the report is fully familiar with the background information needed to determine whether or not the report's recommendations based on those conclusions are valid and whether or not the contractor is abiding by applicable recommendations. The consultant who developed your report cannot assume responsibility or liability for the adequacy of the report's recommendations if another party is retained to observe construction.

THE CONSULTANT'S REPORT IS SUBJECT TO MISINTERPRETATION.

Costly problems can occur when other design professionals develop their plans based on misinterpretation of a geotechnical/environmental report. To help avoid these problems, the consultant should be retained to work with other project design professionals to explain relevant geotechnical, geological, hydrogeological, and environmental findings, and to review the adequacy of their plans and specifications relative to these issues.

BORING LOGS AND/OR MONITORING WELL DATA SHOULD NOT BE SEPARATED FROM THE REPORT.

Final boring logs developed by the consultant are based upon interpretation of field logs (assembled by site personnel), field test results, and laboratory and/or office evaluation of field samples and data. Only final boring logs and data are customarily included in geotechnical/environmental reports. These final logs should not, under any circumstances, be redrawn for inclusion in architectural or other design drawings, because drafters may commit errors or omissions in the transfer process.

To reduce the likelihood of boring log or monitoring well misinterpretation, contractors should be given ready access to the complete geotechnical engineering/environmental report prepared or authorized for their use. If access is provided only to the report prepared for you, you should advise contractors of the report's limitations, assuming that a contractor was not one of the specific persons for whom the report was prepared, and that developing construction cost estimates was not one of the specific purposes for which it was prepared. While a contractor may gain important knowledge from a report prepared for another party, the contractor should discuss the report with your consultant and perform the additional or alternative work believed necessary to obtain the data specifically appropriate for construction cost estimating purposes. Some clients hold the mistaken impression that simply disclaiming responsibility for the accuracy of subsurface information always insulates them from attendant liability. Providing the best available information to contractors helps prevent costly construction problems and the adversarial attitudes that aggravate them to a disproportionate scale.

READ RESPONSIBILITY CLAUSES CLOSELY.

Because geotechnical/environmental engineering is based extensively on judgment and opinion, it is far less exact than other design disciplines. This situation has resulted in wholly unwarranted claims being lodged against consultants. To help prevent this problem, consultants have developed a number of clauses for use in their contracts, reports and other documents. These responsibility clauses are not exculpatory clauses designed to transfer the consultant's liabilities to other parties; rather, they are definitive clauses that identify where the consultant's responsibilities begin and end. Their use helps all parties involved recognize their individual responsibilities and take appropriate action. Some of these definitive clauses are likely to appear in your report, and you are encouraged to read them closely. Your consultant will be pleased to give full and frank answers to your questions.

The preceding paragraphs are based on information provided by the
ASFE/Association of Engineering Firms Practicing in the Geosciences, Silver Spring, Maryland