GEOTECHNICAL REPORT

SR 99 HOV LANES PROJECT
FEDERAL WAY, WASHINGTON

CivilTech

GEOTECHNICAL REPORT

SR 99 HOV LANES PROJECT
FEDERAL WAY, WASHINGTON

SUBMITTED TO

ENTRANCO, INC.

AND

WASHINGTON STATE DEPARTMENT OF TRANSPORTATION

PREPARED BY

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January 23, 2002

Mr. D. Chris Fowler, P.E.
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10900 N.E. 8th Street, Suite 300
Bellevue, WA 98004

RE: Preliminary Geotechnical Report
SR 99 HOV Lanes Project
Federal Way, Washington

Dear Mr. Fowler:

We are pleased to submit herewith our preliminary geotechnical report for the above referenced project. Included herein is a description of the subsurface conditions and a summary of our recommendations for the design and construction of this project.

We appreciate the opportunity to be of service on this project. If you have any questions or need additional information, please contact our office.

Sincerely,
CivilTech Corporation

James Su, Ph.D., P.E.
Principal

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INTRODUCTION

This report presents the results of our geotechnical engineering exploration performed for the proposed State Route (SR) 99, South 284th St. to South 272nd St. - HOV Lanes project located in Federal Way, Washington. The general location and vicinity of the site are shown on the Location Map, Figure 1.

This report summarizes subsurface conditions and preliminary geotechnical recommendations resulting from our field exploration, laboratory testing, and engineering analyses. The information and recommendations provided here are intended for the design of the SR 99 HOV Lanes project. The findings and recommendations presented are subject to the limitations noted at the end of this report.

PROJECT BACKGROUND

The proposed SR 99 HOV Lanes project will consist of improvements to SR 99 from approximately S. 284th Street to S. 272nd Street. Fourteen-foot HOV lanes will be added in each direction, along with curb, gutter, planter strip, and 8-foot sidewalks. The resulting road widening will require that retaining walls be constructed at proposed changes in grade. Alternatively, cut and fill slopes may be constructed at some locations.

In addition to the road widening, a stormwater treatment and underground detention facility is planned to collect drainage runoff. Details of the facility and its location have not yet been finalized.

PURPOSE AND SCOPE

The purpose of our geotechnical engineering exploration for the proposed SR 99 HOV Lanes project is to obtain an overview of the subsurface conditions at the project site. The geologic and subsurface information obtained was used to develop geotechnical engineering recommendations pertinent to the design of the project, including final recommendations for cut and fill slopes and preliminary recommendations for retaining walls. The scope of our work for this project included the following tasks and work efforts:

1. Collection and review of readily available geotechnical and geologic information for the project corridor, including information provided by WSDOT related to the proposed project.
2. Coordination of the field exploration with WSDOT.
3. Logging of the borings by a field engineer from our firm.
4. Field and laboratory testing of selected samples to aid in classifying the materials and evaluating their engineering properties.
5. Engineering analysis of the field and laboratory data to develop geotechnical engineering recommendations pertinent to the proposed design.

6. Preparation of this geotechnical report summarizing our work on the project and presenting our findings and preliminary geotechnical recommendations.
7. Quality assurance of our work on the project by a principal engineer of our firm.
8. Miscellaneous work efforts, such as drafting, word processing, and clerical support.

Detailed descriptions of the field exploration by CivilTech and logs of borings are presented in Appendix A of this report. Laboratory test results are presented in Appendix B.

GEOLOGY

Regional Geology

The project site is located near the southern end of the Puget Sound lowland. The surface geology of the Puget Sound Lowland is primarily the result of Quaternary Period glaciation. During this time, glacial ice repeatedly advanced into the region from the north, modifying the landscape by scour and deposition. The most recent episode of this glaciation occurred about 15,000 years ago when the Vashon stade of the Fraser continental ice sheet moved into the region.

The Vashon glacial deposits are characterized by their common soil types, glacial till and outwash. In general, the till is characterized by a heterogeneous mixture of clay, silt, sand, gravel, cobbles, and boulders that were deposited at the base of the glacial ice and were subsequently highly over-consolidated. The outwash consists of sand and gravel deposited in a fluvial environment in front of the glacier as it advanced or retreated. Outwash deposited in front of an advancing glacier is generally over-consolidated due to being overridden and is designated as advance outwash. Outwash deposited as the glacier retreated is normally consolidated and designated as recessional outwash.

During glaciation, as the area was repeatedly overridden, the till and outwash soils were inter-deposited. The surface expression of the till left by the melting of the glacier is commonly characterized by a smooth, rolling plain or slope. The advanced outwash soils were common to areas of ice stagnation and were deposited by melt waters in advance of the glacier, creating well-drained bench lands.

Site Geology

Site geology conditions are inferred from review of geologic maps, site reconnaissance, subsurface explorations performed for this study, subsurface explorations completed by others in the site vicinity and information provided by others.

Based on a geologic map of the Poverty Bay quadrangle by Waldron (1961), glacial till soils comprise the area of the SR 99 alignment at the site and the predominant soil in the site vicinity. The mapped unit is described as generally nonsorted and nonstratified, but includes crudely stratified beds and lenses of silt, sand, and gravel. The mapped unit

includes a gravel layer up to 20 feet thick in some places, which overlies the till. The glacial till is oxidized near the surface to a loose condition.

Recessional outwash deposits are mapped in a low area in the northern portion of the site east of the SR 99 alignment. They are described as glaciofluvial and glaciolacustrine in origin and are composed of sand and gravel deposits, generally less than 15 feet thick.

A glaciolacustrine deposit, composed chiefly of sand, is mapped on a terrace at the base of the slope west of the southern portion of the site. This unit is believed to have been deposited in temporary lakes marginal to glacial ice in the Puget Sound trough.

Soils encountered in our borings are generally consistent with the glacial till unit mapped in the area by Waldron (1961) and described above. A weathered till was observed near the surface in most of our borings which is consistent with the oxidized till layer described by Waldron. Advance outwash sand and gravel soils were encountered at depth in our borings and are described as common in the area, but reportedly were not mapped as a separate unit due to limited exposures.

The near-surface soils at the project site were modified and covered locally with fill soils to support development.

SITE CONDITIONS

Surface Conditions

The proposed project extends along the alignment of SR 99 a distance of roughly 0.8 mile from S. 272nd Street in the north to S. 284th Street in the south. The topography in the northern portion of the site is generally level to gently sloping with elevations ranging from 317 feet at S. 272nd Street to 342 feet at S. 279th Street. The topography in the southern portion of the site slopes downward moderately to the north and relatively steeply to the west. Elevations in this area range from approximately 342 feet at S. 279th Street to 400 feet at S. 284th Street. Slopes along the eastern side of SR 99 were cut to a relatively steep inclination to allow the construction of the roadway.

The northern portion of the site, north of S. 279th Street, is developed and supports a number of stores, restaurants, small businesses, and a King County Auction site. The southern portion of the site is partially developed along its eastern side. Several apartment buildings are located in this area. Rockery walls have been constructed along the cut slopes at some of the driveway entrances to these apartment buildings.

Our site reconnaissance and an underground utility locate by others identified several utilities in the area. Fiber-optic conduit is located along the west shoulder of SR 99 from roughly S. 279th Street to the southern end of the site. Overhead lines were observed to run along both the east and west sides of SR 99. Sewer and gas lines are also present in some areas.

The undeveloped slopes east and west of SR 99 in the southern portion of the site are vegetated with mixed deciduous and coniferous trees with a moderate to dense brush understory.

Subsurface Conditions

The subsurface conditions were explored by drilling and sampling 8 borings, designated as B-1-01 through B-8-01, to depths of about 25 to 51 feet below the existing ground surface. The borings were located as close as practical to the anticipated retaining wall locations. Five borings (B-1-01, B-4-01, B-5-01, B-7-01 and B-8-01) were drilled on the western side of SR 99 to depths ranging from 29.5 to 51.5 feet below the ground surface to evaluate conditions for fill walls. Three borings (B-2-01, B-3-01 and B-6-01) were drilled on the eastern side of SR 99 to depths ranging from 25.5 to 26.5 feet to evaluate soil conditions for cut walls. The approximate locations of the borings are shown on the Site and Exploration Plan, Figures 2a and 2b. Detailed descriptions of the materials encountered in the borings are presented on the logs of borings, Plates A-1 through A-12 in Appendix A. Results of the laboratory tests performed on selected soil samples are presented in Appendix B. The geologic cross sections A-A' and B-B' are shown in Figures 3 and 4.

Additional information regarding the subsurface conditions was obtained from borings previously completed in the vicinity of the site by others. These studies are listed in the References section of this report. At the northern end of the site, soil conditions along S. 272nd Street were investigated by King County Department of Public Works (1972). WSDOT (1974) performed several shallow test holes and borings along SR 99 from S. 272nd Street to approximately 550 feet south of S. 272nd Street to investigate the pavement section and subgrade conditions for proposed channelization to add left and right turn lanes. WSDOT (1976) completed one shallow (1.5-foot deep) core sample and one shallow (0.5-foot deep) soil sample between S. 272nd Street and S. 279th Street as part of a resurfacing project on SR 99. WSDOT (1986) completed borings for cantilever signal foundations at the intersections of SR-99 and S. 260th Street and S. 288th Street.

Soil Conditions

Based on information from the borings, subsurface conditions are characterized by glacial till and other glacially derived soils. Glacial soils encountered are generally very dense and include glacial till and advance outwash sand and gravel. The glacial till soils are oxidized and loosened near the surface to a weathered till which was observed in most borings to vary from approximately 2 to 6 feet in thickness. The weathered till is characterized by relatively lower densities and shear strengths. Advance outwash soils were observed in four of our borings below or within the glacial till soils, consisting of very dense sand and gravel with variable silt content.

Groundwater Conditions

At the time of drilling, groundwater was recorded in five of our borings at depths ranging from 14.5 to 44 feet. These depths correspond to elevations ranging from 310 to 370 feet.

The water levels were generally allowed to dissipate overnight or over the weekend in the open boreholes before recording the water level. However, in light of the impermeable nature of the soils these levels may represent the residual water from the mud rotary drilling operation rather than actual groundwater. In addition, in light of the variation in recorded groundwater level and the raised topography of the area, any groundwater present most likely represents water perched atop zones of relatively impermeable soil and does not represent the regional groundwater table. It should be noted that groundwater levels may fluctuate depending on rainfall, season of the year, construction activities, and site utilization.

SEISMICITY

Seismic Tectonics

The project is located in an active seismic region of the Pacific Northwest. The main tectonic feature in the Pacific Northwest is the Cascadia subduction zone where the Juan de Fuca oceanic plate is being subducted under the North American continental plate. This subduction is mainly responsible for the seismic and volcanic activity in the region. The large recent historic earthquakes include the 1949 Olympia (M=7.1), 1965 SeaTac (M=6.5), 2001 Nisqually (M=6.7), and 1918 (M=7.0) and 1946 (M=7.3) Vancouver Island earthquakes.

In addition to the large historic earthquakes, recent geologic investigations in the coastal areas of Washington and Oregon have uncovered evidence of the occurrence of several large subduction earthquakes. The latest event occurred about 300 years ago.

There is other evidence supporting the possible occurrence of a great subduction-zone earthquake in the Pacific Northwest. This evidence is based on the similarity between the seismotectonic environments in the Pacific Northwest and in other subduction zones around the world where great historic earthquakes have occurred.

Seismic Source Zones

Three seismic source zones in the region have the potential to produce earthquakes capable of generating strong ground motions at the site. These source zones include the interplate and intraplate segments of the Cascadia subduction zone and the Puget Trough. The interplate segment of the Cascadia subduction zone is the portion of the plate where the Juan de Fuca and North American plates are in contact. This contact region lies approximately between the offshore trench and the middle of the coast ranges. This region is assumed to be capable of generating large earthquakes (M>8½).

The intraplate segment of the Cascadia subduction zone is the portion of the Juan de Fuca plate that is underneath the North America plate. This plate segment dips gradually to the east from the middle of the coast ranges, where the top of the plate is approximately 30 km deep, to the western edge of the Cascade Range. The 1949 Olympia and 1965 SeaTac earthquakes are recent events associated with the intraplate fault mechanism, located about 30 to 70 km beneath Puget Sound.

The Puget Trough seismic zone is located at relatively shallow elevation beneath Puget Sound (up to 30 km) and includes the Seattle, Whidbey Island, and Rattlesnake faults. This zone has relatively high seismic activity and a crustal earthquake can occur almost anywhere in the area. Although the largest known earthquake in this zone was M<6, the Puget Trough is considered capable of generating larger earthquakes (M 6½ to 7½).

CONCLUSIONS AND RECOMMENDATIONS

General

Construction of the SR 99 HOV Lanes project will extend along both sides of the highway from S. 272nd Street to S. 284th Street. For purposes of discussion, major areas of construction include those areas east and west of SR 99.

East of SR 99

According to our field explorations east of SR 99, subsurface conditions in that area are characterized by mainly glacial till consisting of dense to very dense silty sands and sandy gravel with advance outwash soils locally.

Construction of the northbound HOV lane will require SR 99 to expand eastward. As a result, a portion of the current slope will be cut back and portions of the parking areas of the nearby residences will be demolished for the expansion of the highway. According to the surveying data we have, slope cuts of as much as 20 feet may be necessary. We recommend soil nail walls to be used for retaining the slopes east of SR 99 based on the topography, subsurface conditions, and feasibility, as well as technical and economic reasons.

In order to protect the existing developments and roadways in the site, the slopes east of SR 99 will be retained by at least five soil nail walls, each of varying height and length. Details regarding the location and the height of each soil nail wall are listed in Table 1.

West of SR-99

The results of our field exploration west of SR 99 indicate that the site is underlain by mainly glacial till soils to depths of about 5 to 50 feet. Advance outwash soils up to 20 feet thick occur within, or below the glacial till in some areas. In addition, layers of silt or sandy silt, varying from 2 to 10 feet thick, occur locally within the glacial till.

Construction of the southbound HOV lane will involve a 40-ft westward expansion of SR 99. As a result, a fill slope supported by retaining walls will be required along portions of the western side of the highway between S. 279th Street and S. 284th Street. Either cantilever concrete retaining walls or mechanically stabilized earth (MSE) retaining walls would be appropriate in those areas. Based on the subsurface conditions, slope stability, and loading conditions, we anticipate that cantilever concrete walls would be recommended for the lower walls, and mechanically stabilized earth (MSE) wall would be

recommended for the higher walls. Details about these two retaining wall types are presented in the Retaining Walls section.

Table 1

Preliminary Design Criteria for Retaining Walls

Wall Location/ Approximate Station	Approx. Max. Wall Height[1] Cut/Fill	Anticipated Subgrade Soil Conditions/ Representative Explorations/ Recommended Explorations	Recommended: Wall Type Allow. Bear. Cap. Embedment[2]
SR 99 NB RT STA 29+30 ~ 35+75	13 ft Cut	**Soil Cond.:** 2.5 ft of medium dense, gravelly, silty SAND (Weathered Till) over very dense silty, gravelly SAND (Glacial Till). Up to 0.5 ft of sod/topsoil near the surface in most places. **Representative Explor. :** B-2-01, B-3-01 **Recommended Explor.:** Minimum of 2 test pits for evaluating the standup time of the soil.	Soil Nail Wall Not Applicable
SR-99 NB RT STA 27+65 ~ 28+30 STA 21+65 ~ 27+35 STA 19+60 ~ 21+35 STA 15+70 ~ 19+20 STA 12+60 ~ 15+40	7 ft 11 ft 12 ft 9 ft 12 ft Cut	**Soil Cond.:** ~20 ft of very dense gravelly, silty SAND (glacial till) over very dense SAND and GRAVEL (advance outwash). Up to 2.5 ft of sod over topsoil near the surface in most places. **Representative Explor. :** B-6-01 **Recommended Explor.:** Minimum of 2 test pits for evaluating the standup time of the soil.	Soil Nail Wall Not Applicable
SR-99 SB LT STA 56+00 ~ 58+50	4 ft Fill	**Soil Cond.:** Assume medium dense. Confirm at time of construction.	MSE/Reinf. Conc. 4000 psf for 2-ft or more embedment
SR-99 SB LT STA 41+75 ~ 44+80	7 ft Fill	**Soil Cond.:** Assume medium dense. Confirm at time of construction.	MSE/Reinf. Conc. 4000 psf for 2-ft or more embedment

[1] Exposed wall height, i.e. top of wall to finish ground

[2] Embedment refers to depth below existing native grade

Table 1 (cont.)

Preliminary Design Criteria for Retaining Walls

Wall Location/ Approximate Station	Approx. Max. Wall Height[1] Cut/Fill	Anticipated Subgrade Soil Conditions/ Representative Explorations/ Recommended Explorations	Recommended: Wall Type Allow. Bear. Cap. Embedment[2]
SR-99 SB LT STA 26+00 ~ 32+95	16 ft Fill	**Soil Cond.:** ~4 ft of loose to medium dense, silty sand with some gravel (weathered till) over 3-10 ft of dense to very dense glacial till grading locally to very dense advance outwash. **Representative Explor. :** B-4-01, B-5-01 Note: Bearing capacity increases with depth due to loose to medium dense soils near surface.	MSE/Reinf. Conc. 4000 psf for 2-ft. embedment 8000 psf for 4-ft. embedment
SR-99 SB LT STA 12+70 ~ 26+00	16 ft Fill	**Soil Cond.:** 6-7 ft of medium dense to dense, gravelly, silty SAND (weathered till) over a very dense, gravelly, silty SAND (glacial till) or a very dense, SAND and GRAVEL (advance outwash). Up to 8 ft of very dense, SAND And SILT occurs locally within the glacial till or advance outwash. **Representative Explor. :** B-7-01, B-8-01 Note: Bearing capacity increases with depth due to loose to medium dense soils near surface.	MSE/Reinf. Conc. 4000 psf for 2-ft. embedment 8000 psf for 4-ft. embedment

[1] Exposed wall height, i.e. top of wall to finish ground

[2] Embedment refers to depth below existing native grade

Seismic Design Considerations

Ground Acceleration and Site Response

In accordance with the USGS 1996 National Seismic Hazard Map and Washington State Department of Transportation's *Bridge Design Manual*, a peak firm-ground acceleration (PGA) of 0.3 g is recommended for the seismic design. The recommended PGA is based on expected ground motion at the project site that has a 10 percent probability of being exceeded in 50 years (i.e., the ground motion with an average return period of 475 years). The USGS estimated peak firm-ground acceleration values by conducting probability studies for the three major earthquake mechanisms affecting the Puget Sound Area.

Site Coefficient

We have evaluated the soil conditions in the areas of the proposed HOV lanes for seismic design purposes in accordance with the criteria established in 1996 *AASHTO Standard Specifications for Highway Bridges*. Based on the conditions encountered in borings completed along both sides of SR 99 between S. 279th Street and S. 284th Street, the soils in this area can be classified as Soil Profile Type I. A site coefficient of 1.0 is recommended for seismic design in this area.

Liquefaction Potential

Seismically induced liquefaction typically occurs in loose, saturated, sandy and silty materials. Soil liquefaction is a condition where saturated cohesionless soils located near the ground surface undergo a substantial loss of strength due to the build-up of excess pore water pressures resulting from cyclic stress applications induced by earthquakes. Soils most susceptible to liquefaction are loose, uniformly graded, fine-grained sands and loose silts with little cohesion. It is generally acknowledged that liquefaction will not occur if the deposit is greater than about 50 feet below the ground surface. In deeper deposits, the greater overburden pressure is generally sufficient to prevent liquefaction from occurring. Based on the dense nature of the soils encountered at depth in our borings and the low degree of saturation of the relatively loose soils at shallower depth, the potential for liquefaction for the overall project is relatively low.

Retaining Walls

Construction of the new HOV lanes will require retaining walls to support changes in grade along widened portions of SR 99 between S. 279th Street and S. 284th Street. On the western side of SR 99, retaining walls will be required to support the road fill materials and prevent them from being eroded. Along the eastern side of SR 99, retaining walls will be necessary to support the steep cuts. Based on the cut or fill conditions and wide range of wall heights and locations relative to right-of-way, three types of retaining walls are recommended. Design criteria and recommended wall types for each wall location are presented in Table 1. General recommendations for mechanically stabilized earth (MSE), reinforced concrete, and soil nail walls are presented in the following sections. For all wall types, the geotechnical engineer should evaluate the global stability conditions based on the final design configuration of the wall system. Preliminary global stability was evaluated based on the soil conditions encountered and wall geometry with a width to height ratio of 70 percent to identify any potential design problems. Based on this preliminary evaluation, the walls appear stable and the soils encountered do not appear to be subject to deep-seated rotational failures.

Recommendations for bearing pressures for AASHTO load groups I and VII are presented in Table 2, below for the retaining walls.

Table 2 *Recommended Bearing Pressure for Retaining Walls* [1]		
AASHTO LOAD GROUP	I	VII
Allowable Bearing Capacity (medium dense soils)	4,000	5,300
Allowable Bearing Capacity (dense to very dense soils)	8,000	10,600
Acceleration Coefficient (g)	N/A	0.30

[1]See Table 1 for preliminary design criteria and embedment requirements. Values assume 2H:1V sloped conditions.

Mechanically Stabilized Earth Walls

Mechanically stabilized earth (MSE) walls are recommended to confine the new fills on the west side of SR 99. In general, a MSE wall is often a cost-effective method for support of fill soils. Design of such a wall system must be based on site-specific conditions and geotechnical parameters. Pre-cast concrete members (panels or blocks) are widely used as facing elements. Principal advantages of MSE walls include relatively low unit cost and tolerance of relatively large differential settlements.

MSE walls consist of alternating layers of backfill soil and reinforcing material with facing elements. Commonly used reinforcing elements include steel strips, wire meshes, and various geosynthetic products such as geogrid and geotextile sheets. The vertical spacing of the reinforcing elements is typically on the order of 1 to 3 feet, depending on the reinforcing material specified and other parameters. If geosynthetic products are selected, long-term creep characteristics should be taken into consideration in product selection.

Many MSE wall systems are available as proprietary wall systems. WSDOT has preapproved five proprietary structural earth wall systems for roadway projects. They are "ARES" of Tensar Earth Technologies, "MSE" of SSL, LLC, "Reinforced Earth" of Reinforced Earth Company, "Retained Earth" of L.B. Foster Company, and "Reinforced Soil" of Hilfiker Retaining Walls. These wall systems have been preapproved for heights up to 30 feet and soil surcharge slopes above the wall, provided such slopes are 2H:1V or flatter.

Design of the MSE wall will need to consider both external and internal stability of the wall structure. In evaluating external stability, the MSE wall structure must satisfy four stability conditions: (1) bearing failure, (2) translational sliding, (3) overturning stability, and (4) overall slope stability. We recommend the design parameters summarized in Table 3 be used in design of MSE walls. To achieve the values shown in the table, the backfill

soil and the retained soil should be compacted to meet the requirements of WSDOT *Standard Specifications* (latest edition) Section 2-03.3(14)C Method C. Preliminary recommendations for allowable bearing pressures are presented in Tables 1 and 2.

Table 3

Recommended Design Parameters for MSE Walls[1]

Soil Properties	Backfill Soil		Retained Soil	Foundation Soil
	Gravel Borrow [2]	Gravel Backfill for Walls [3]	Compacted Fill	On-Site Very Dense Soil
Density (pcf)	125	128	125	130
Friction Angle (degrees)	36	38	35	38
Cohesion (psf)	0	0	0	0

[1]See Table 1 for preliminary design criteria

[2]WSDOT 9-03.14(1).

[3]WSDOT 9-03.12(2).

MSE walls should be placed on a level foundation compacted to the specified requirements. Any loose and soft soils encountered at the foundation level should be removed and replaced with compacted granular fill. The base of the wall should not be less than 70 percent of the wall height or a minimum of 6 feet, whichever is greater, and should be extended where needed to meet global stability requirements. The uppermost reinforcing layer should be placed no lower than 2 feet below the top of the wall. The MSE walls should be embedded a minimum of 10 percent of the wall height, or to the depths indicated in Tables 1 and 2 for specific bearing capacities, whichever is greater. For MSE walls located on the slopes, we recommend that a minimum set-back distance of 4 feet be maintained, measured horizontally from the bottom of wall to the face of the slope, assuming a 2H:1V (horizontal:vertical) slope angle.

MSE walls should be designed for a minimum factor of safety of 1.5 against sliding and pullout of reinforcing elements and 2.0 against overturning. If proprietary wall systems are used, the wall supplier is responsible to design the wall for adequate internal stability. However, we recommend that proprietary wall system designs be reviewed by a qualified geotechnical engineer to verify that valid assumptions were made relative to material properties and other factors. The geotechnical engineer should evaluate the global slope stability of the embankment based on the final design configuration of the wall system.

Global stability should have a minimum static factor of safety of 1.3 per AASHTO Standard Specifications for Highway Bridges, Section 5.2.2.3 since the slope is not supporting a critical structure. Under seismic conditions, global stability should have a minimum factor of safety of 1.1.

We assume the walls will be subjected to the influence of surcharge loading (such as traffic loading) within a horizontal distance equal to the height of the wall. Accordingly, the walls should be designed for the additional horizontal pressure using an appropriate design method. A common practice is to assume a surcharge loading equivalent to 2 feet of additional fill to simulate traffic loading; we consider this method appropriate for typical situations. Where large surcharge loads such as from heavy trucks, cranes, or other construction equipment are anticipated in close proximity to the retaining walls, this loading condition should be specified and the walls designed to accommodate the additional lateral pressures resulting from these concentrated loads. The assumed surcharge loading should be added to the entire wall height.

The above estimates assume removal of the near surface loose or soft soils, if encountered, and replacement with Gravel Borrow per Section 9-03.14(1) or Foundation Material Class A per Section 9-03.17 of the *Standard Specifications*. We recommend that depths and lateral limits of over-excavation be determined in the field by a qualified geotechnical engineer during construction. Materials used as fill for supporting MSE walls should be properly compacted and should meet the specifications for Gravel Borrow or Foundation Material listed above.

Cantilever Concrete Retaining Walls

Cantilever concrete retaining walls are another option for supporting the westward widening of SR 99. Cantilever concrete retaining walls are readily installed without specialized equipment and are usually economical to construct up to heights of 10 to 15 feet, but are allowed by WSDOT to heights up to 35 feet.

The principal disadvantage of conventional concrete walls is that a relatively large area must be available behind the wall for excavation of the temporary back cut when the wall is used to support cut slopes. In addition, such rigid walls have relatively low tolerance for differential settlement, and therefore they are not appropriate for areas where significant settlement is expected.

The concrete retaining walls should be designed to resist lateral earth pressures due to the adjacent soil and surcharge effects. The lateral earth pressures against concrete retaining walls depend upon the inclination of the back-slope, degree of wall restraint, type of backfill, method of backfill placement, degree of backfill compaction, drainage provisions, and magnitude and location of any surcharge loads. It is anticipated that concrete retaining walls will be unrestrained, or free to rotate at the top.

These walls will meet the WSDOT design criteria for Standard Walls as referred to by the WSDOT Standard Plans. The computer program RETWAL can be used for analysis as recommended in the WSDOT *Bridge Design Manual*.

Surcharge stresses due to area surcharges, line loads, and point loads within a horizontal distance equal to the depth of the wall should be considered in the design. Standard loads recommended in the WSDOT *Bridge Design Manual* should be applied as part of this analysis based on wall heights and backslopes.

Backfills behind retaining walls should meet the requirements for Gravel Backfill for Walls as specified in Section 9-03.12(2) of the Standard Specifications for Road, Bridge, and Municipal Construction by WSDOT and APWA. The backfill should be moisture-conditioned to near the optimum moisture and compacted to between 90 and 95 percent relative compaction. To prevent construction damage to the wall, over-compaction of the wall backfill should be avoided.

Lateral loads acting on the structure supported by a shallow foundation system may be resisted by passive earth pressure developed against the embedded near-vertical faces of the foundation system and by frictional resistance developed between the bottom of the foundation and the supporting subgrade soils. For footings bearing on the very dense outwash/glacial till, a frictional coefficient of 0.8 may be used to evaluate sliding resistance developed between the cast in place concrete and the native soil.

The passive pressure at the toe of the retaining wall should not be considered in evaluating resistance to lateral loading unless the backfill at the toe of the wall is properly placed and adequately compacted. Where the toe of the wall is cast directly against undisturbed glacial soils or properly compacted fill materials, lateral loads may be evaluated in design using passive pressures recommended in the WSDOT *Bridge Design Manual.* In addition, the retaining wall should be set back from the slope a sufficient distance to provide a minimum embedment of 2 feet below the lowest adjacent finish grades. A minimum set-back distance of 4 feet is recommended, measured horizontally from the bottom of the wall to the face of the slope, assuming a 2H:1V (horizontal:vertical) slope angle. The set back should also provide the embedments below existing native grade recommended in Table 1 to provide the required bearing capacity. Unless covered by pavements or slabs, the passive resistance in the upper 12 inches of soil should be neglected.

Recommendations for allowable bearing pressures are presented in Tables 1 and 2. Based on these allowable bearing pressures, we estimate settlements to be less than the maximum allowable settlement of 1 inch, which is recommended to support the walls for overall stability.

Dynamic lateral earth pressures due to seismic loading may be estimated using the Mononobe-Okabe method for level backfill. The Mononobe-Okabe method is presented in Figure 9.4.3-3 of the *Bridge Design Manual* (July 1996). Fifty percent of the peak ground acceleration is recommended in this method.

Retaining walls should be well drained to reduce the build-up of hydrostatic pressures. If drainage is not used behind the retaining walls, hydraulic pressure should be considered in the design. A typical drainage system would consist of a 1- to 2-foot-wide zone of permeable material immediately adjacent to the wall with a perforated pipe at the base of the wall discharging to a suitable drainage facility. Weep holes should be incorporated into

the wall at approximately 12-foot centers, to provide additional drainage. A filter fabric should be placed between the drainage material and the compacted backfill material. The filter fabric should be nonwoven and should meet moderate survivability properties and Class A drainage filtration properties listed in Tables 1 and 2 of the *Standard Specifications*, Section 9-33.2 Geotextile Properties. As an alternative, a prefabricated geocomposite drainage product, such as MiraDrain, may be used instead of the drainage material with filter fabric. The prefabricated drainage product should also be hydraulically connected to a drainpipe at the base of the wall.

Soil Nail Walls

Soil nail walls are recommended where cuts into the existing slope east of SR 99 are required for widening the highway. Soil nail wall design parameters are presented in Table 4 based on soil conditions anticipated.

The soil nail process involves "top-down" excavation, starting with a vertical cut, typically 4 to 6 feet high, depending on the horizontal nail spacing, which is normally 5 to 6 feet. The soil conditions anticipated at the proposed soil nail wall locations are mainly glacial till that consisted of very dense, silty sand and gravel. Layers of very dense advance outwash sand and gravel with some cobbles and scattered boulders are expected to be embedded within the glacial till, especially in the southern portion of the site. Both glacial till and advance outwash are suitable soil types for installing soil nail walls, but the gravel and cobbles embedded in these soils may create difficulty when drilling the nail holes. In addition, scattered boulders may present obstructions to the drilling. Additional test pits are recommended in different areas of the site to evaluate the stand-up time for the cut.

Table 4 *Soil Nail Wall Design Parameters*				
Soil Type	**Friction Angle (degree)**	**Cohesion (ksf)**	**Unit Weight (pcf)**	**Allowable Nail Adhesion (ksf) FS = 2**
Dense to Very Dense SAND and GRAVEL	38	0 ksf	130 pcf	2 ksf

We recommend that factors of safety and seismic loadings, which are in general accordance with the recommendations of the FHWA manual be used in the design of the soil nail walls as follows:

Overall stability:	FS = 1.5 (static) and 1.1 (seismic)
Soil friction:	FS = 1.35
Soil cohesion:	FS = 1.35
Soil-grout adhesion:	FS = 2.0
Nail tendon:	FS = 1.82
Punching shear:	FS = 1.5
Facing flexure:	FS = 1.5

Contractor qualifications, installation, testing requirements and material properties are detailed in the WSDOT Special Provisions and should be followed.

Construction Considerations

We envision that earthwork for the proposed project will generally consist of cuts of 5 to 20 feet in the proposed northbound HOV lane location and fills for the southbound HOV lane up to 20 feet relative to the existing ground surface to achieve the design grade. In general, all grading work should conform to Division 2 of WSDOT's *Standard Specifications for Road, Bridge, and Municipal Construction* (2000), sections 2 and 9.

We recommend that earthwork be observed by a qualified geotechnical engineer. It is important that the earthwork be observed to evaluate whether any undesirable/unsuitable materials are encountered during the excavation and scarification process, and whether the exposed soil conditions are similar to those encountered in our exploration. The following subsections provide general guidelines for design of site grading and earthwork.

Dewatering Considerations

The excavations for the shallow foundations may encounter seepage from perched groundwater accumulated above the relatively impermeable underlying glacial soils. We anticipate that seepage and infiltration through these soils will be moderate and will dissipate over time. The amount of seepage should also be expected to fluctuate, depending on the time of year construction is performed. An internal system of sumpholes and pumps will likely be adequate to temporarily dewater these excavations during construction.

Cut and Fill Slopes

Based on the materials encountered from our field exploration, the cut slopes may be designed with a slope ratio of 1.5H:1V. Permanent fill slopes should be designed 2H:1V or flatter. Fills placed on existing slopes having slope ratios steeper than 5H:1V should be keyed and benched into the firm and stable materials to enhance the stability of the new embankment fill against sliding. The filling operations should start at the lowest point and continue up in level horizontal compacted layers in accordance with the above recommendations for fill placement. Fill slopes should be constructed by over-filling past the design limits of the slope and cutting back to the design slope to provide adequate compaction at the edges of the slope.

Drainage and Erosion Control

Most soil types are subject to erosion when the vegetative cover is removed and the soils are exposed to the elements. We recommend that any grading activity which might accompany the proposed construction be performed on a limited basis and during the drier summer and early fall months. The ground surface in the construction area should be protected from erosion. During construction, all exposed slopes should be protected from runoff by berms or swales. The swales should be routed to existing drainage facilities to divert runoff from the bare soil slope. Straw bales staked in the swales, perpendicular to the swales' center lines, may be used to reduce water velocities to minimize erosion.

After completion of construction, the exposed cut and fill slopes within the project area should be compacted, spread with topsoil, planted with a deep rooted vegetation cover and covered with staked jute netting, Excelsior Mat, or other erosion control fabric if necessary. All erosion control measures should conform to Section 8-01 of WSDOT's *Standard Specifications for Road, Bridge, and Municipal Construction* (latest edition) and the site-specific recommendations contained in this report. Vegetation should be established as soon after construction as possible to provide long-term erosion protection of the slopes. Prior to establishing vegetation, silt fences and straw bales staked along contours and slopes are recommended to reduce erosion. The slopes should be periodically monitored until vegetation has become fully established.

LIMITATIONS

This report has been prepared for the exclusive use of Entranco and WSDOT and their consultants for specific application to the proposed SR 99, S. 284th Street to S. 272nd Street HOV lanes project in accordance with generally accepted geotechnical engineering principles and practices. No other warranty, expressed or implied, is made.

The analyses and recommendations submitted in this report are based, in part, upon the subsurface information obtained from borings. The boring logs indicate subsurface conditions only at the specific locations and at the time of excavation. Variations of subsoil conditions between the locations and with the passage of time may occur. The nature and extent of these variations may not become evident until construction is underway. If variations then appear evident, it will be necessary to reevaluate the recommendations provided in this report.

Respectfully submitted,

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(y:\geotech\2001\21022 SR99\Report\21022_SR99HOVLanesFinalReport.doc)

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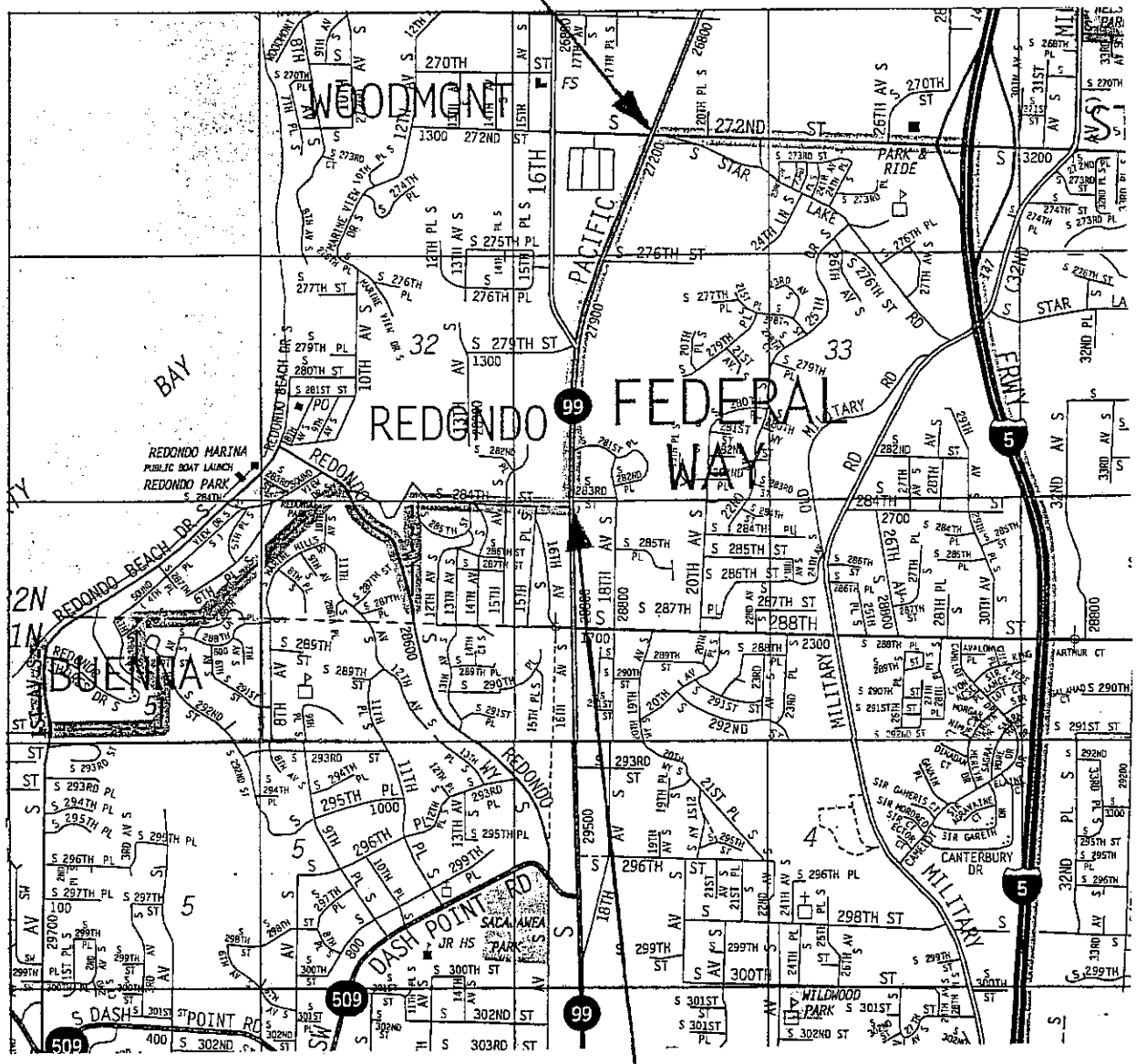
FIGURES

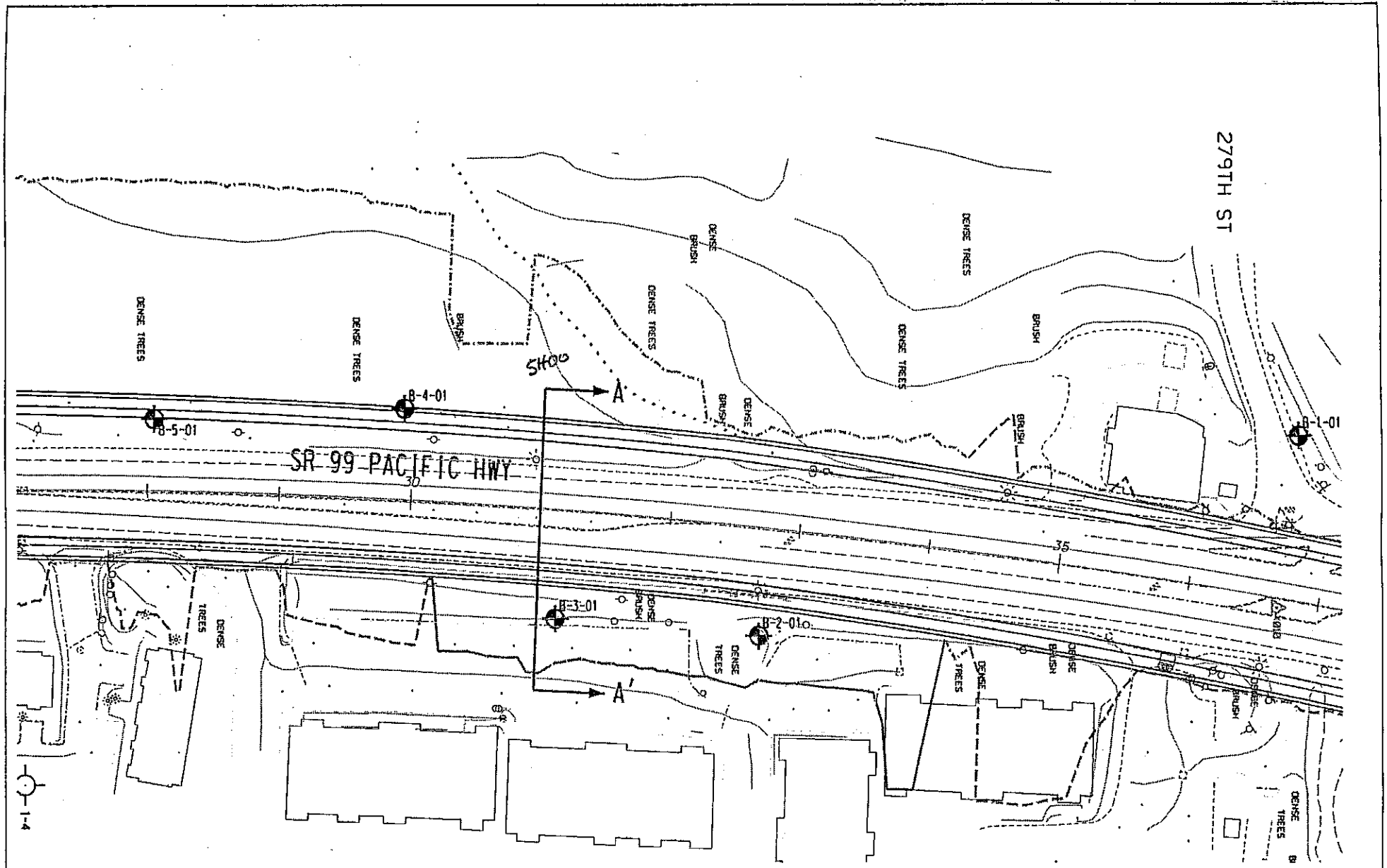
NORTHERN PROJECT LIMITS



SOUTHERN PROJECT LIMITS

N

CIVILTECH CORPORATION	LOCATION MAP	JOB NO. 21022
	SR-99 HOV LANES PROJECT FEDERAL WAY, WASHINGTON	SHT. NO. FIGURE 1



B-1-01 APPROXIMATE BORING LOCATION

0' 100' 200'

N

CIVILTECH CORPORATION

SITE AND EXPLORATION PLAN

SR99 HOV LANES
FEDERAL WAY, WASHINGTON

JOB NO. 21022

SHEET NO. FIGURE 2a

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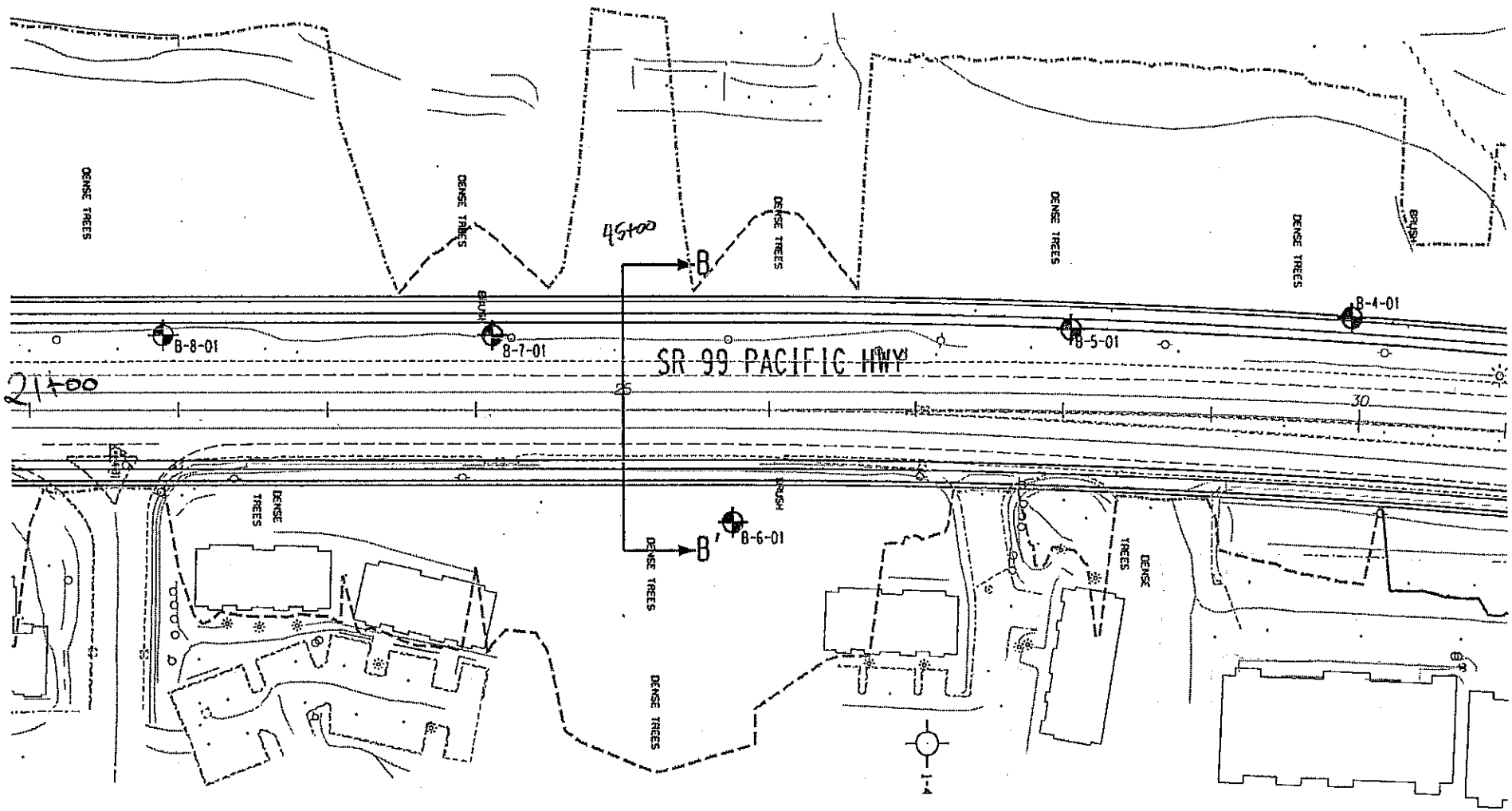

B-1-01 APPROXIMATE BORING LOCATION

0' 100' 200'

N

CIVILTECH CORPORATION

SITE AND EXPLORATION PLAN

SR99 HOV LANES
FEDERAL WAY, WASHINGTON

JOB NO. 21022

SHEET NO. FIGURE 2b

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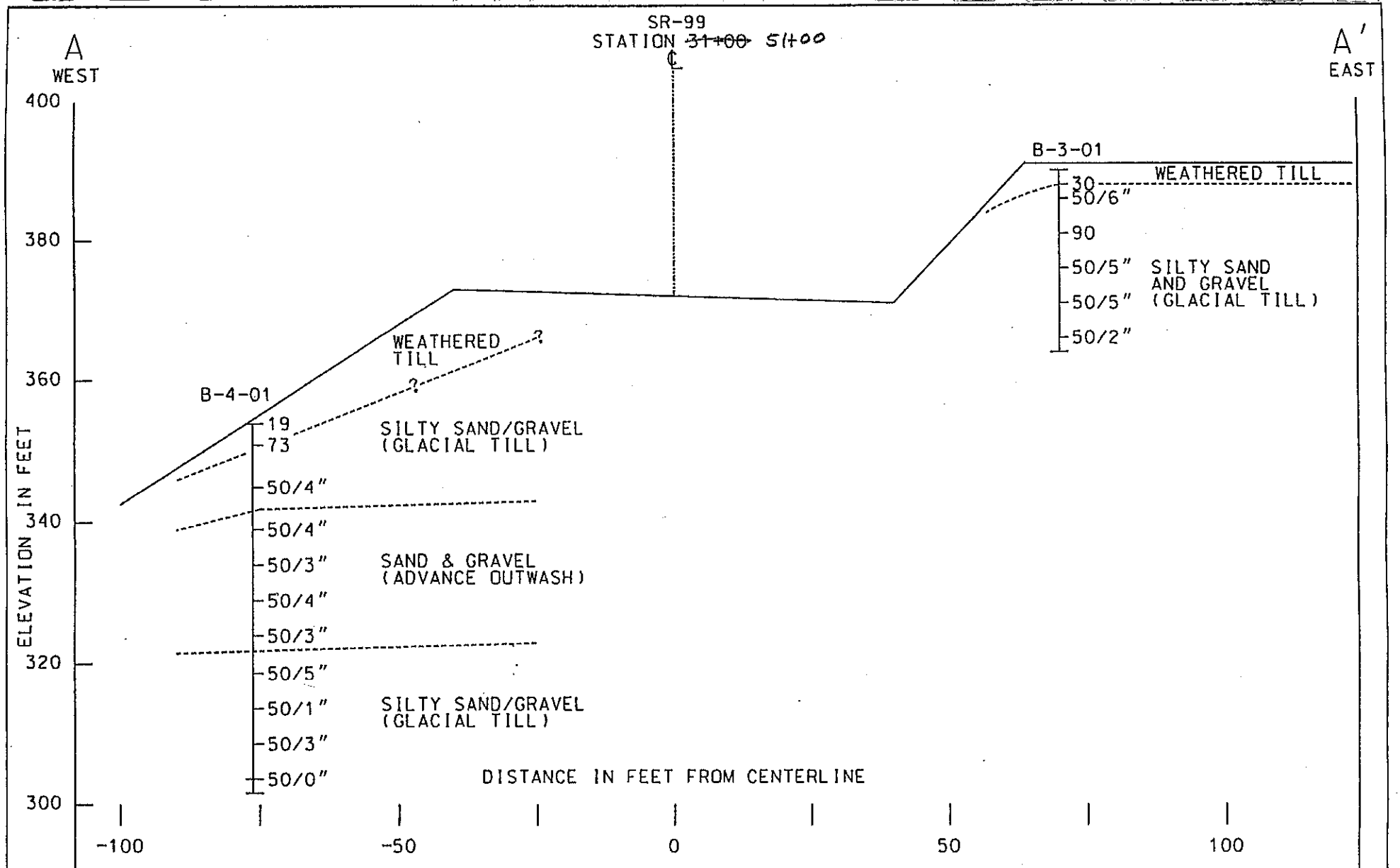

CIVILTECH CORPORATION

GEOLOGIC CROSS SECTION

SR99 HOV LANES
FEDERAL WAY, WASHINGTON

JOB NO. 21022

SHEET NO. FIGURE 3

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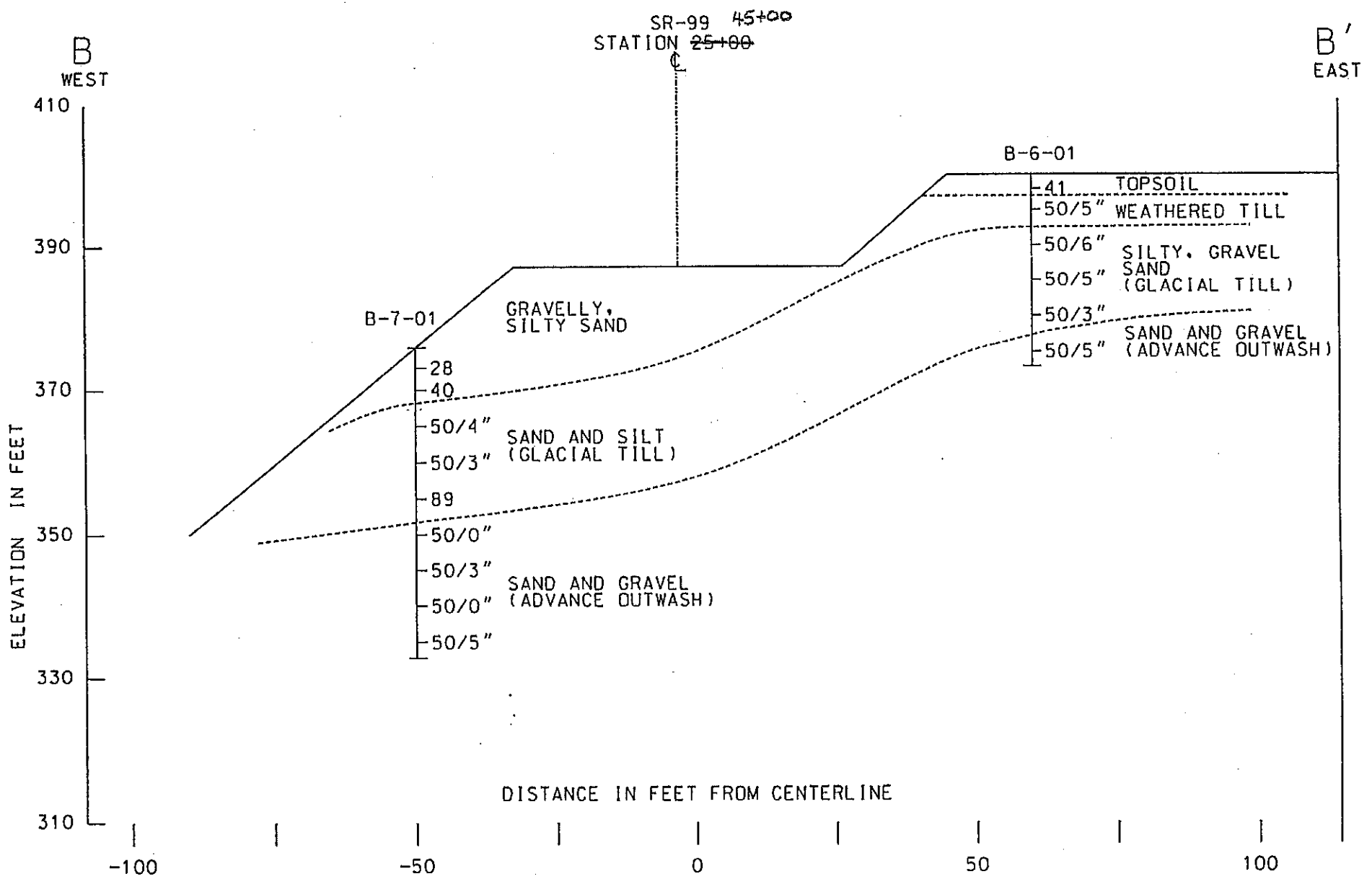

CIVILTECH CORPORATION

GEOLOGIC CROSS SECTION

SR99 HOV LANES
FEDERAL WAY, WASHINGTON

JOB NO. 21022

SHEET NO. FIGURE 4

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APPENDIX A - FIELD EXPLORATION

The subsurface conditions at the site were explored by drilling and sampling of eight borings to depths ranging from about 25.5 to 51.5 feet below the existing ground surface at the approximate locations shown on the Site and Exploration Plan, Figure 2.

The borings were drilled using track- and trailer-mounted drill rigs equipped with mud rotary drilling equipment by a WSDOT drill crew. The borings were backfilled with cuttings and bentonite chips after completion of drilling.

Soil samples were obtained from the drilled borings in accordance with ASTM Standard Method D 1586-84, Penetration Test and Split-Barrel Sampling of Soils, by driving a 2-inch O.D. standard split-spoon sampler with a 140-pound hammer free-falling 30 inches. The blow counts needed to advance the sampler the last 12 inches of an 18-inch drive are shown on the boring logs at the approximate sample depths.

The materials encountered in the borings were classified by visual and textural examination in the field by our engineer, who monitored the drilling operation on a near-continuous basis in general accordance with ASTM Standard Practice D-2488-84, Description and Identification of Soils (Visual-Manual Procedure). These classifications were further reviewed visually and by testing in the laboratory. Graphic presentation of the materials encountered are provided on the boring logs, Plates A-1 through A-12. The key to the symbols and notations is shown on Plates A-13 and A-14.

B-1-01

SR-99 HOV -- S. 272nd to S. 284th St.
Federal Way, Washington

Drill Rig: CME 45 Skid/Mud Rotary
Sampling: SPT
Logged By: KHO
Total Depth: 29.5 feet

Date Started: 06/26/2001
Date Completed: 06/27/2001
Elevation: 342 feet
Groundwater: 14.5' BGS ATD 06/27/01

Description	Graphic Log	Depth	Sample Type	SPT N-Value	MC (%)	Remarks
Surface: 6 inches sod/topsoil		0				
Medium dense, moist, dark brown, gravelly, silty SAND (SM)				12	11.8	
Loose, damp, tan gray, gravelly, silty SAND (SM) (Weathered Till)				5	8.2	29% fines
		5				
Medium dense, moist, tan gray, silty, gravelly SAND (SM) (Weathered Till)				26	12.3	23% fines (see sieve analysis)
		10				
Very dense, moist, tan gray, silty, gravelly SAND (SM) (Advance Outwash)						Drilled through two 6" to 8" cobbles
			06/27/01	51	11.8	13% fines
		15				Perched groundwater
Increasing gravel, decreasing silt						Drilled through 3" to 8" cobbles
				50/4"		
		20				
Increasing silt, decreasing gravel				50/4"	8.0	15% fines
		25				
Becomes moist to wet, and grayish brown				50/4"	8.8	
Boring completed at depth of 29.5 feet		30				
		35				

CIVILTECH CORPORATION

Project No. 21022

Plate A-1

SuperLog V2.8 CivilTech Software, USA www.civiltech.com File: Y:\Geotech\2001\21022 SR99\Boring Logs\SR99_Aug15.log Date: 1/23/02

B-2-01

SR-99 HOV -- S. 272nd to S. 284th St.
Federal Way, Washington

Drill Rig: CME 45 Skid/Mud Rotary
Sampling: SPT
Logged By: MAW
Total Depth: 25.5 feet

Date Started: 8/7/01
Date Completed: 8/7/01
Elevation: 385 feet
Groundwater: N/E ATD

Description	Graphic Log	Depth	Sample Type	SPT N-Value	MC (%)	Remarks
Surface: 6 inches sod/topsoil		0				
Medium dense, moist, grayish-brown, gravelly, silty SAND (SM) (Weathered Till)				49	14.0	
Very dense, moist, tan-gray, gravelly SAND (SM) And Silt with some cobbles (Glacial Till)		5		70	11.1	
		10		50/4"	12.8	48% fines
Very dense, moist, tan-gray, silty SAND (SM) And Gravel (Glacial Till)		15		50/5"	8.9	30% fines
		20		50/5"	10.0	26% fines (see sieve analysis)
		25		90	10.9	
Boring completed at depth of 25.5 feet		30				
		35				

CIVILTECH CORPORATION

Project No. 21022

Plate A-2

B-3-01

SR-99 HOV -- S. 272nd to S. 284th St.
Federal Way, Washington

Drill Rig: CME 45 Skid/Mud Rotary
Sampling: SPT
Logged By: MAW
Total Depth: 25.5 feet

Date Started: 8/8/01
Date Completed: 8/8/01
Elevation: 390 feet
Groundwater: N/E ATD

Description	Graphic Log	Depth	Sample Type	SPT N-Value	MC (%)	Remarks
Surface: 6 inches sod/topsoil Medium dense, moist, grayish-brown, gravelly, silty SAND (SM) with trace organics (Weathered Till)		0		30	16.4	
Very dense, moist, brownish gray, silty, SAND (SM) And Gravel with some cobbles (Glacial Till)		5		50/6"	13.9	17% fines (see sieve analysis)
Increasing silt		10		90	12.3	39% fines
Becomes gray		15		50/5"	9.1	28% fines
		20		50/5"		
		25		50/2"		Blowcount Overstated, Pounding On Rock
Boring completed at depth of 25.5 feet		30				
		35				

CIVILTECH CORPORATION

Project No. 21022

Plate A-3

B-4-01

SR-99 HOV -- S. 272nd to S. 284th St.
Federal Way, Washington

Drill Rig: CME 45 Skid/Core Barrel
Sampling: SPT
Logged By: KHO
Total Depth: 51.5 feet

Date Started: 07/02/2001
Date Completed: 07/09/2001
Elevation: 354 feet
Groundwater: 43.7' ATD BGS

Description	Graphic Log	Depth	Sample Type	SPT N-Value	MC (%)	Remarks
Surface: 8-12 inches sod/topsoil		0				
Medium dense, moist to damp, tan gray, fine SAND (SM) And Silt with some gravel (Weathered Till) Becomes gravelly				19	13.2	35% fines
Very dense, moist, tan, silty SAND (SM) And Gravel (Glacial Till)		5		73	11.2	17% fines (see sieve analysis) At 6'-6.5': Starting to drill into hard materials
Very dense, moist, tan gray, silty, gravelly SAND (SM) with some cobbles (Glacial Till)		10		50/4"	10.5	13% fines At 11'-11.5': Difficult drilling
Very dense, moist, tan gray, silty GRAVEL (GM) And Sand (Advance Outwash)		15		50/4"	9.1	15% fines (see sieve analysis)
Very dense, moist, tan gray, gravelly, silty SAND (SM) (Advance Outwash)		20		50/3"	13.7	11% fines
		25		50/4"	9.5	11% fines
		30		50/3"		No Recovery
Very dense, moist, tan, silty SAND (SM) And Gravel (Glacial Till)		35				

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CIVILTECH CORPORATION

Project No. 21022

Plate A-4

B-4-01

SR-99 HOV -- S. 272nd to S. 284th St.
Federal Way, Washington

Drill Rig: CME 45 Skid/Core Barrel
Sampling: SPT
Logged By: KHO
Total Depth: 51.5 feet

Date Started: 07/02/2001
Date Completed: 07/09/2001
Elevation: 354 feet
Groundwater: 43.7' ATD BGS

Description	Graphic Log	Depth	Sample Type	SPT N-Value	MC (%)	Remarks
Very dense, moist, tan, silty SAND (SM) And Gravel (Glacial Till)		35		50/5"	5.3	
		40		50/1"		No Recovery
Hard, moist, light brown, clayey SILT (ML)		07/09/01				Perched Groundwater
		45		50/3"		
Very dense, moist, tan, silty SAND (SM) And Gravel (Glacial Till)		50		50/0"		No Recovery
Boring completed at depth of 51.5 feet		55				
		60				
		65				
		70				

CIVILTECH CORPORATION

Project No. 21022

Plate A-5

SuperLog V2.8 CivilTech Software, USA www.civiltech.com File: Y:\Geotech\2001\21022 SR99\Boring Logs\SR99_Aug15.log Date: 1/23/02

B-5-01

SR-99 HOV -- S. 272nd to S. 284th St.
Federal Way, Washington

Drill Rig: CME 45 Skid/Core Barrel
Sampling: SPT
Logged By: KHO/MAW
Total Depth: 46.5 feet

Date Started: 07/10/2001
Date Completed: 07/16/2001
Elevation: 365 feet
Groundwater: 30' ATD BGS

Description	Graphic Log	Depth	Sample Type	SPT N-Value	MC (%)	Remarks
Surface: 6-9 inches sod/topsoil		0				
Loose, moist to damp, dark brown, gravelly, silty SAND (SM)				8		
Hard, moist, tan gray, gravelly, clayey SILT (ML) And Sand		5		79	8.8	22% fines (see sieve analysis)
Very dense, moist, tan gray, SAND (SW) And Gravel with some silt						
Very dense, moist to wet, light brown, silty SAND (SM) with some gravel (Glacial Till)		10		50/3"		25% fines
Very dense, wet, tan gray, GRAVEL (GW) And Sand with some silt (Glacial Till)		15		50/5"	10.2	12% fines (see sieve analysis)
		20		50/4"		No Recovery
		25		50/2"		No Recovery: Pounding on rock
Becomes rusty brown		30	07/16/01	50/5"		Perched Groundwater No Recovery
		35				

CIVILTECH CORPORATION

Project No. 21022

Plate A-6

SuperLog V2.8 CivilTech Software, USA www.civiltech.com File: Y:\Geotech\2001\21022 SR99\Boring Logs\SR99_Aug15.log Date: 1/23/02

B-5-01

SR-99 HOV -- S. 272nd to S. 284th St.
Federal Way, Washington

Drill Rig: CME 45 Skid/Core Barrel
Sampling: SPT
Logged By: KHO/MAW
Total Depth: 46.5 feet

Date Started: 07/10/2001
Date Completed: 07/16/2001
Elevation: 365 feet
Groundwater: 30' ATD BGS

Description	Graphic Log	Depth	Sample Type	SPT N-Value	MC (%)	Remarks
Very dense, wet, tan gray, GRAVEL (GW) And Sand with some silt (Glacial Till)		35		50/5"	16.1	13% fines
Very dense, moist, tan gray, gravelly SAND (SW) with some silt (Glacial Till)		40		50/5"	16.2	10% fines
		45		50/1"		No Recovery
Boring completed at depth of 46.5 feet		50				
		55				
		60				
		65				
		70				

CIVILTECH CORPORATION

Project No. 21022

Plate A-7

SuperLog V2.8 CivilTech Software, USA www.civiltech.com File: Y:\Geotech\2001\21022 SR99\Boring Logs\SR99_Aug15.log Date: 1/8/02

B-6-01

SR-99 HOV -- S. 272nd to S. 284th St.
Federal Way, Washington

Drill Rig: CME 45 Skid/Core Barrel
Sampling: SPT
Logged By: KHO
Total Depth: 26.5 feet

Date Started: 08/13/2001
Date Completed: 08/14/2001
Elevation: 398 feet
Groundwater: 15' ATD BGS

Description	Graphic Log	Depth	Sample Type	SPT N-Value	MC (%)	Remarks
Surface: Damp, brown, sod over topsoil		0				
				41	6.3	
Very dense, damp, light brown, gravelly, silty SAND (SM) with trace cobbles (Weathered Till) Becomes moist, grayish brown		5		50/5"	9.2	30% fines
Very dense, moist, tan, gravelly, silty SAND (SM) (Glacial Till)						Cobble between 8.5'-9'
		10		50/6"	13.3	24% fines
Becomes moist to wet, gray, decreasing gravel						
Decreasing silt		15	08/14/01	50/5"		Perched Groundwater
Very dense, moist to wet, tan gray, silty SAND (SM) And Gravel (Glacial Till) Increasing gravel and sand grain size		20		50/3"	9.0	20% fines (see sieve analysis)
Very dense, moist to wet, tan gray, silty, medium to coarse SAND (SP) And Gravel (Advance Outwash)		25		50/5"	8.3	
Boring completed at depth of 26.5 feet		30				
		35				

CIVILTECH CORPORATION

Project No. 21022

Plate A-8

SuperLog V2.8 CivilTech Software, USA www.civiltech.com File: Y:\Geotech\200\121022 SR99\Boring Logs\SR99_Aug15.log Date: 1/23/02

B-7-01

SR-99 HOV -- S. 272nd to S. 284th St.
Federal Way, Washington

Drill Rig: CME 45 Skid/Core Barrel
Sampling: SPT
Logged By: KHO
Total Depth: 41.5 feet

Date Started: 07/17/2001
Date Completed: 07/17/2001
Elevation: 375 feet
Groundwater: N/A

Description	Graphic Log	Depth	Sample Type	SPT N-Value	MC (%)	Remarks
Surface: Damp, dark brown, sod over topsoil		0				
Medium dense, damp to moist, brown, gravelly, silty SAND (SM)				28	9.1	13% fines
Becomes dense and cobbly		5		40		No Recovery
Dense to very dense, moist to damp, tan gray, fine SAND (SM) And Silt with some gravel (Glacial Till)						
3" of decayed wood log		10		50/4"	25.3	Blowcount overstated on wood; 31% fines (see sieve analysis)
		15		50/3"		No recovery
Very dense, moist, tan gray, silty, gravelly SAND (SM) (Glacial Till)						
Decreasing gravel		20		89	11.6	15% fines (see sieve analysis)
Very dense, damp to moist, brownish gray, SAND (SM) And Gravel with some silt and cobbles (Advance Outwash)		25		50/0"	7.8	
		30		50/3"	5.6	9% fines
		35				

CIVILTECH CORPORATION

Project No. 21022

Plate A-9

B-7-01

SR-99 HOV -- S. 272nd to S. 284th St.
Federal Way, Washington

Drill Rig: CME 45 Skid/Core Barrel
Sampling: SPT
Logged By: KHO
Total Depth: 41.5 feet

Date Started: 07/17/2001
Date Completed: 07/17/2001
Elevation: 375 feet
Groundwater: N/A

Description	Graphic Log	Depth	Sample Type	SPT N-Value	MC (%)	Remarks
Very dense, damp to moist, brownish gray, SAND (SM) And Gravel with some silt and cobbles (Advance Outwash)		35		50/0"		No recovery
		40		50/5"		No recovery
Boring completed at depth of 41.5 feet		45				
		50				
		55				
		60				
		65				
		70				

CIVILTECH CORPORATION

Project No. 21022

Plate A-10

B-8-01

SR-99 HOV -- S. 272nd to S. 284th St.
Federal Way, Washington

Drill Rig: CME 45 Skid/Core Barrel
Sampling: SPT
Logged By: KHO
Total Depth: 41.5 feet

Date Started: 07/18/2001
Date Completed: 07/24/2001
Elevation: 387 feet
Groundwater: 17' ATD BGS 7/23/01

Description	Graphic Log	Depth	Sample Type	SPT N-Value	MC (%)	Remarks
Surface: 6-12 inches, damp, dark brown, Sod or Topsoil (TP)		0				
Medium dense, moist, dark brown, SAND (SW) And Gravel with some silt				13	9.7	8% fines (see sieve analysis)
Becomes dense, decreasing gravel		5		45	7.9	
Very dense, moist, tan gray, silty SAND (SM) And GRAVEL (GW)		10		65	14.5	34% fines
Hard, damp to moist, tan gray, sandy SILT (ML)						
Very dense, moist to wet, tan gray, gravelly, silty SAND (SM)		15		50/5"	12.9	24% fines
Becomes saturated			07/23/01			Perched Groundwater
Very dense, wet to moist, tan gray, gravelly SAND (SM) And Silt (Glacial Till)		20		50/3"	13.2	40% fines
		25		50/3"		No Recovery: Rock in sampler
		30		50/0"		No Recovery
				50/0"		No Recovery: Drilled into 2 big boulders from 30.5' to 34.5'
Very dense, damp to moist, rusty brown, silty, fine SAND (SM) with trace to some gravel		35				

CIVILTECH CORPORATION

Project No. 21022

Plate A-11

SuperLog V2.8 CivilTech Software, USA www.civiltech.com File: Y:\Geotech\2001\21022 SR99\Boring Logs\SR99_Aug15.log Date: 1/23/02

B-8-01

SR-99 HOV -- S. 272nd to S. 284th St.
Federal Way, Washington

Drill Rig: CME 45 Skid/Core Barrel
Sampling: SPT
Logged By: KHO
Total Depth: 41.5 feet

Date Started: 07/18/2001
Date Completed: 07/24/2001
Elevation: 387 feet
Groundwater: 17' ATD BGS 7/23/01

Description	Graphic Log	Depth	Sample Type	SPT N-Value	MC (%)	Remarks
Very dense, damp to moist, rusty brown, silty, fine SAND (SM) with trace to some gravel Become some cobbles		35		62	23.2	21% fines
		40		50/1"		No Recovery: Sampler hit on rock
Boring completed at depth of 41.5 feet		45				
		50				
		55				
		60				
		65				
		70				

CIVILTECH CORPORATION

Project No. 21022

Plate A-12

KEY:

■ Indicates 3-inch OD Dames & Moore Sample.

◪ Indicates 2-inch OD Split Spoon Sample (SPT).

☒ Indicates Disturbed Sample.

I Indicates No Recovery.

□ Indicates Bag Sample.

⧅ Indicates Shelby Tube Sample.

COMPONENT DEFINITIONS

COMPONENT	SIZE RANGE
Boulders	Larger than 12 in
Cobbles	3 in to 12 in
Gravel	3 in to No 4 (4.5mm)
Coarse gravel	3 in to 3/4 in
Fine gravel	3/4 in to No 4 (4.5mm)
Sand	No. 4 (4.5mm) to No. 200 (0.074mm)
Coarse sand	No. 4 (4.5 mm) to No. 10 (2.0 mm)
Medium sand	No. 10 (2.0 mm) to No. 40 (0.42 mm)
Fine sand	No. 40 (0.42 mm) to No. 200 (0.074 mm)
Silt and Clay	Smaller than No. 200 (0.074 mm)

COMPONENT PROPORTIONS

DESCRIPTIVE TERMS	RANGE OF PROPORTION
Trace or little	1 - 5%
Some	6 - 12%
Clayey,-silty, sandy, gravelly	13 - 30%
And	31 - 50%

MOISTURE CONTENT

DRY	Absence of moisture, dusty, dry to the touch.
DAMP	Some perceptible moisture; below optimum
MOIST	No visible water; near optimum moisture content
WET	Visible free water, usually soil is below water table.

RELATIVE DENSITY OR CONSISTENCY VERSUS SPT N -VALUE

COHESIONLESS SOILS			COHESIVE SOILS		
Density	N (blows/ft)	Approximate Relative Density (%)	Consistency	N (blows/ft)	Approximate Undrained Shear Strength (psf)
Very Loose	0 to 4	0 - 15	Very Soft	0 to 2	< 250
Loose	5 to 10	16 - 35	Soft	3 to 4	250 - 500
Medium Dense	11 to 30	36 - 65	Medium Stiff	5 to 8	501 - 1000
Dense	31 to 50	66 - 85	Stiff	9 to 15	1001 - 2000
Very Dense	over 50	86 - 100	Very Stiff	16 to 30	2001 - 4000
			Hard	over 30	> 4000

MAJOR DIVISION			GRAPHIC SYMBOL	LETTER SYMBOL	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
				GP	POORLY-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
	MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES
MORE THAN 50% OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE	SAND AND SANDY SOILS	CLEAN SAND (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
				SP	POORLY-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
	MORE THAN 50% OF COARSE FRACTION PASSING NO. 4 SIEVE	SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, SAND-SILT MIXTURES
				SC	CLAYEY SANDS, SAND-CLAY MIXTURES
FINE GRAINED SOILS	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
MORE THAN 50% OF MATERIAL IS SMALLER THAN NO. 200 SIEVE SIZE	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
				OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

NOTE: DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS

UNIFIED SOIL CLASSIFICATION SYSTEM

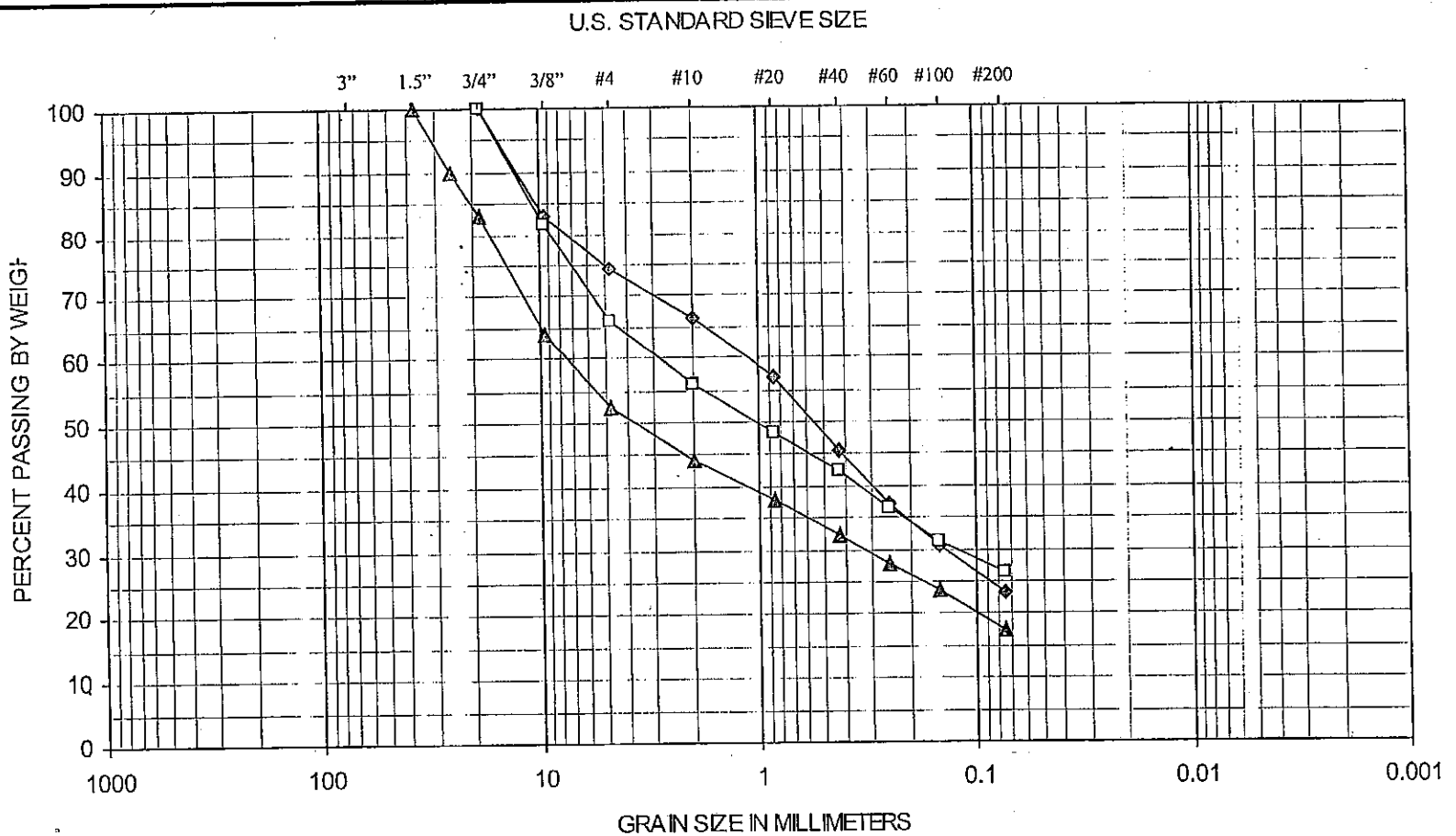
APPENDIX B - LABORATORY TESTS

Moisture content (ASTM D 2216) determinations were performed on selected soil samples as an aid in the classification and evaluation of soil properties. The results of these tests are presented on the logs of borings at the appropriate sample depths.

Twenty-one #200 wash tests (ASTM D 1554) were performed on selected soil samples to quantify the percentage passing #200 sieve to aid in soil classification. The results of these tests are presented on the logs of borings at the appropriate sample depths.

Eleven sieve analysis tests (ASTM C 136) were performed on selected soil samples to evaluate the gradation characteristics of the soils and to aid in soil classification. Results of the tests are presented on Plates B-1 through B-3.

Y:\Geotech\2001\21022\Lab\sieve



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SYMBOL	EXPLORATION NUMBER	DEPTH (ft)	SOIL CLASSIFICATION
◆	BH-1-01 S3	8.0'-9.5'	Silty, gravelly SAND (SM)
□	BH-2-01 S5	19.0'-20.5'	Silty SAND And fine Gravel (SM-GP)
▲	BH-3-01 S2	4.0'-5.5'	Silty GRAVEL And Sand (GM-SM)

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SIEVE ANALYSIS RESULTS

SR-99 HOV -- S.272nd TO S.284th ST.
Federal Way, WA Job No. 21022

PLATE B-1

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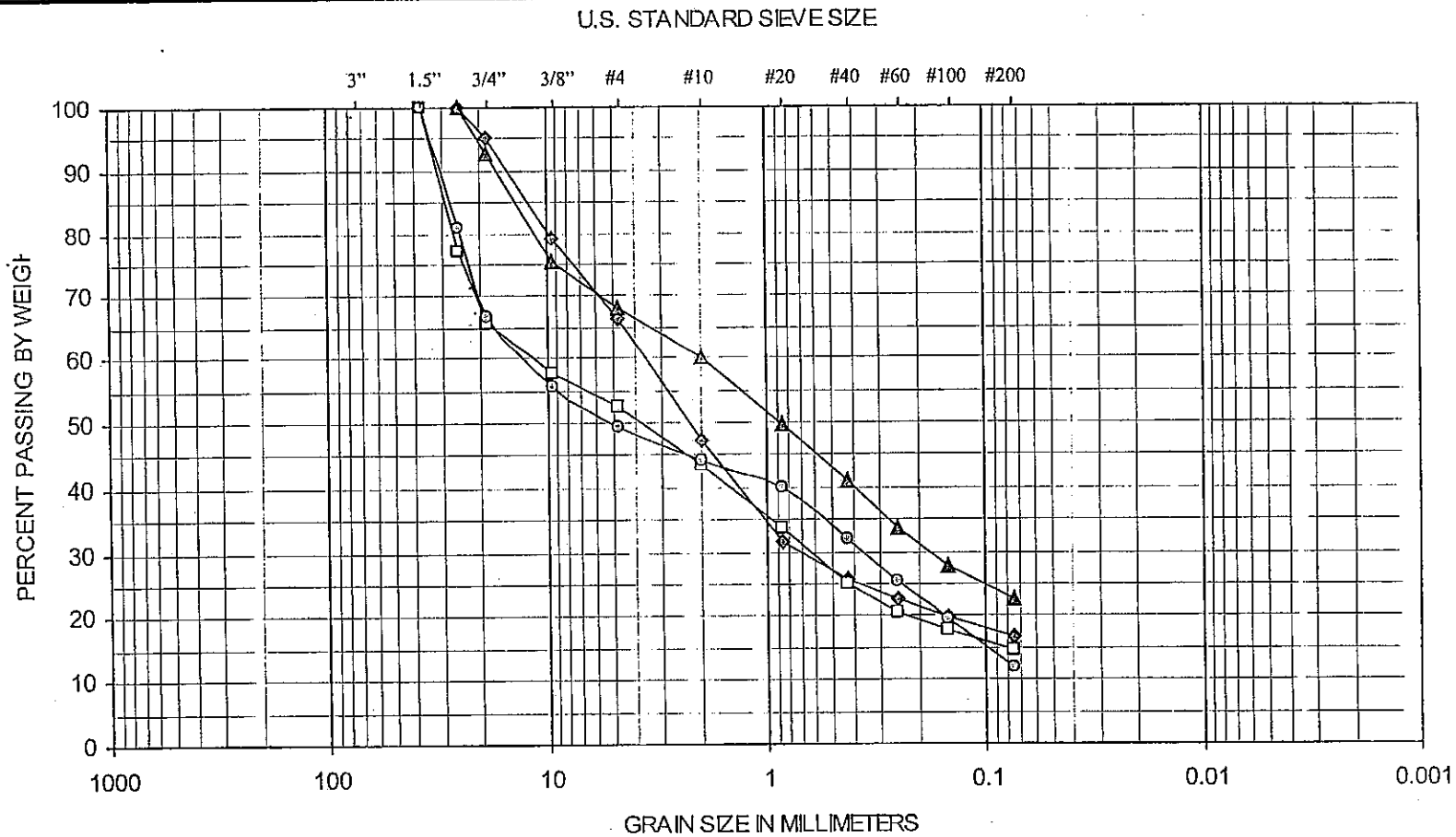

*COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SYMBOL	EXPLORATION NUMBER	DEPTH (ft)	SOIL CLASSIFICATION
◆	BH-4-01 S2	5.0'-6.5'	Silty, gravelly SAND (SM)
□	BH-4-01 S4	15.0'-16.5'	Silty SAND And fine Gravel (SM-GM)
▲	BH-5-01-S2	5.0'-6.5'	Silty GRAVEL And Sand (GM-SM)
⊗	BH-5-01 S4	16.0'-17.5'	GRAVEL And Sand with some silt (GW-SW)

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SR-99 HOV -- S.272nd TO S.284th ST.
Federal Way, WA Job No. 21022

SIEVE ANALYSIS RESULTS

PLATE B-2

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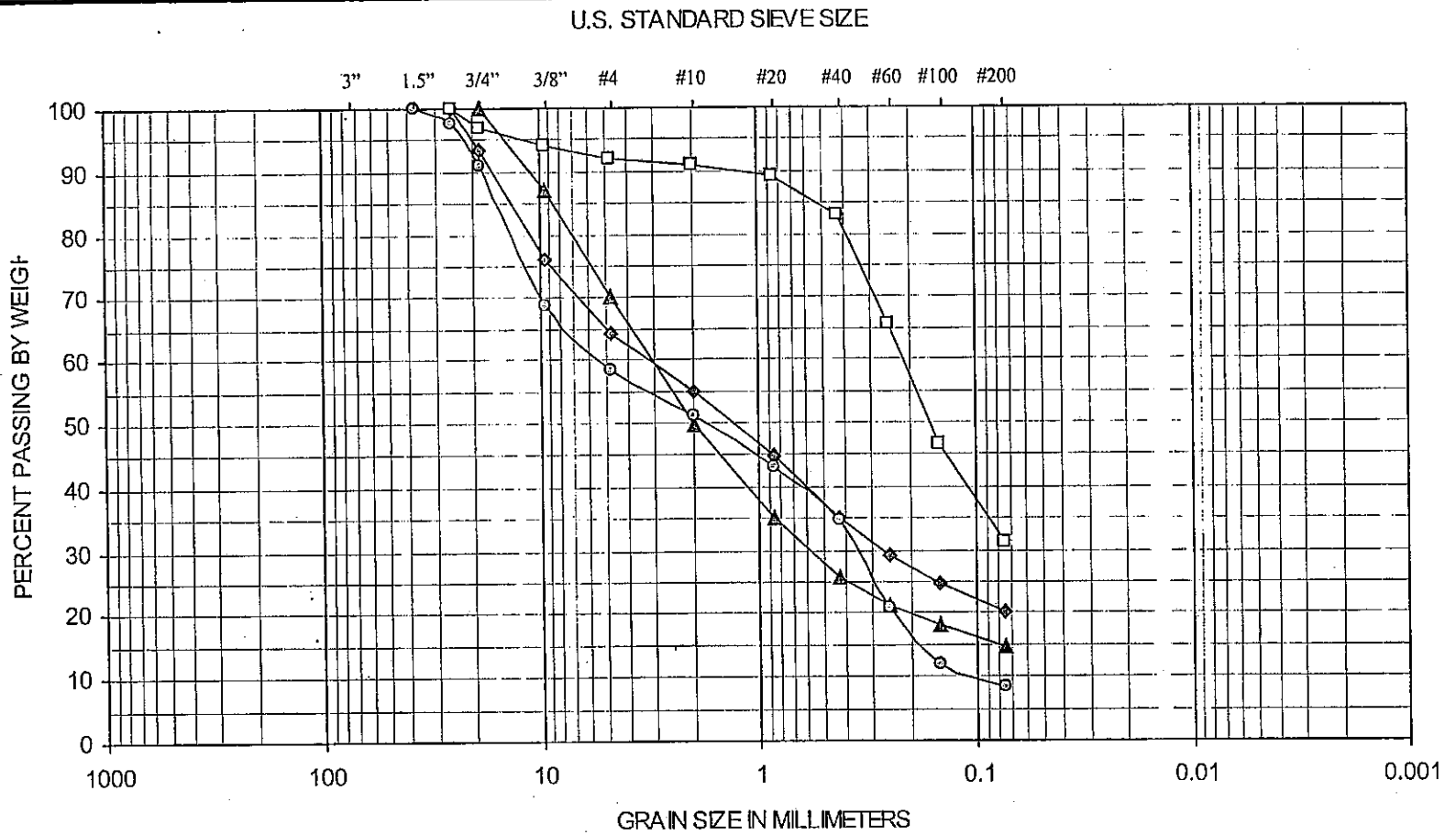

COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SYMBOL	EXPLORATION NUMBER	DEPTH (ft)	SOIL CLASSIFICATION
◆	BH-6-01 S5	20.0'-21.5'	Silty SAND And Gravel (SM-GM)
□	BH-7-01 S3	10.0'-11.5'	SAND And Silt with some gravel (SM-ML)
▲	BH-7-01 S5	20.0'-21.5'	Silty, gravelly SAND (SM)
⊙	BH-8-01 S1	2.0'-3.5'	SAND And Gravel with some silt (SW-GW)

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SR-99 HOV -- S.272nd TO S.284th ST.
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SIEVE ANALYSIS RESULTS

PLATE B-3